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STUDY OF OUTER SPACE BY REACTION DEVICES

K. E. Tsiolkovskiy

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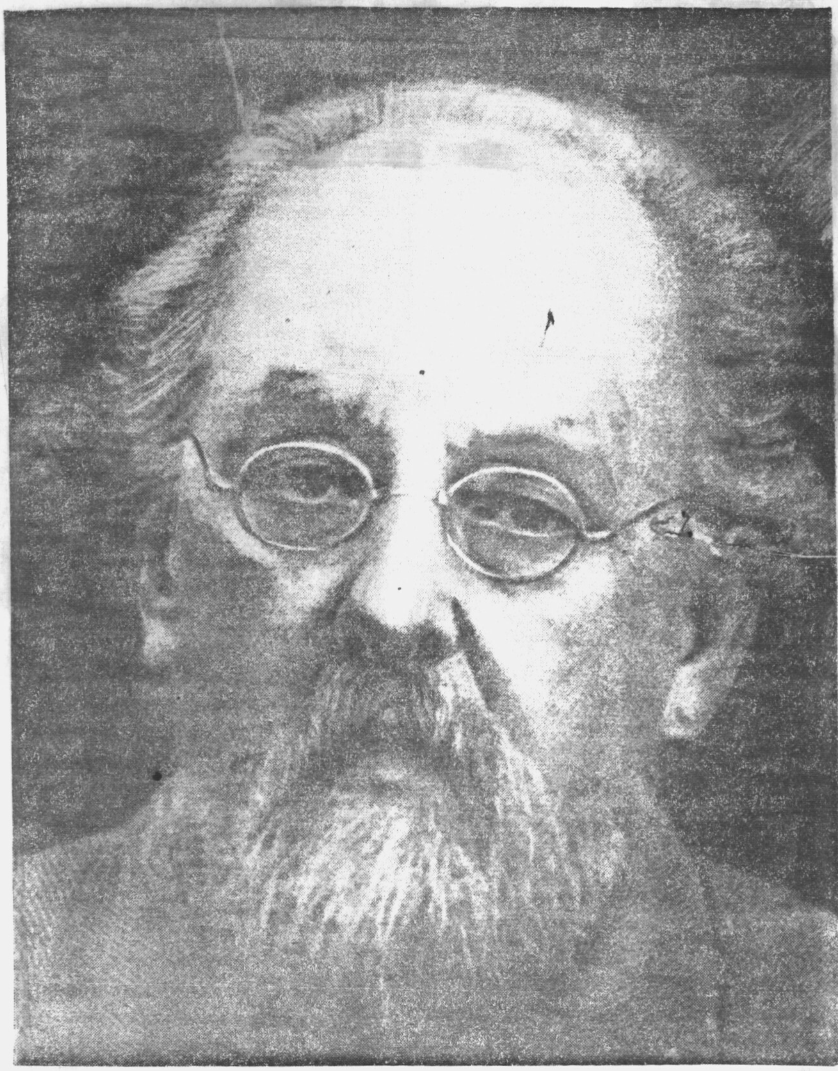

Константинъ Циолковскій

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Under the editorship of
M.K. TIKHONRAVO

In the present book have been collected, basic works of K.E. Tsiolkovskiy devoted to the problem of the conquest and utilization of cosmos, and recognized as classical. These works, a greater part of which was completed by K.E. Tsiolkovskiy in the Soviet times, have earned world-wide fame for our science and technology. They served as a starting point for the creation of, the first in the world, Soviet Artificial Earth Satellite, for the accomplishment of, the first in the world, flight of Soviet cosmonaut, opening a new era in the development of the mechanics of flying, and for other flights in the cosmic expanse.

In the works, included in the book, the basic theorems and conditions of jet propulsion, and technical conclusions from them have been expalined the methods of solving different technical problems are adduced and the aims of cosmic and interplanetary flights have been indicated. The book has been in demand by scientific workers, engineers and those studying in Universities. Table. 45. Illustrations 34.

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Works of K.E. Tsiolkovskiy on Rocket-Navigation and Inter-Planetary Information.

I dedicate all my labors on aviation, rocket-navigation and interplanetary information to the Party of Bolsheviks and Soviet Power —— the genuine leaders of the progress of human culture.

K.E. Tsiolkovskiy

The name of Konstantine Edwardovitch Tsiolkovskiy, one of the greatest Russian scientists has acquired world-wide reputation K.E. Tsiolkovskiy for the first time showed the way to the solution of complicated scientific problems —— the creation of jet aircraft, liquid fuel guided missile, metallic airship, accomplishment of interplanetary flights and a host of others. But of all the problems, with which K.E. Tsiolkovskiy busied himself, the central one was "Rocket". This subject for him was the "dearest" as he told the author of this article in February 1934 in the city of KALUGA.

Only recently humanity taken the first significant steps in the field of investigation of cosmic expanse. Already in the cosmos are flying satellite ships piloted by man.

Already devices created by human hands are being directed to the Moon; they have made it possible to peep on its landscape, as if we were ourselves on its surface. Already automatic stations are flying to Venus and Mars. Moreover, man has thrown on the Moon and Venus objects, made by his hands. Man has had a look on the side of the Moon, invisible from the Earth.

Humanity finds itself on the eve of the accomplishment of inter-bodies. And if in the beginning of the century it was possible to show and to prove (theoretically) work of K.E. Tsiolkovskiy, that the "Spaceship must be similar to the rocket" and that only on such a ship is it possible to accomplish flights between the other planets, then at the present time it has become a nearly realizable and clear even the common man. The credit here in the first instance goes to K. E. Tsiolkovskiy.

However, the calculations of designing of rocket flying vehicles and their trajectories are at present being implemented immeasurably more exactly, than they had been done in the times of K.E. Tsiolkovskiy. And if there are many conceptions in his works, ingeniously thought out, then naive ones are also met, specially where the matter concerns practical questions. From this, however, it should be incorrect to draw a conclusion, that the works of K.E. Tsiolkovskiy have only an historical value. In the first place they will remain classical, since the fundamental theorems of K.E. Tsiolkovskiy are stable; The young generations of workers on rocket and cosmic technology must also study these works. Secondly, in the works of K.E. Tsiolkovskiy for the first time were mentioned ideas, which gradually acquired the more and more importance.

Interplanetary voyages with K.E. Tsiolkovskiy were not the end in themselves but a means of settling a part of humanity in the solar system. "Many imagine spaceships with people travelling from planct to planet, gradual settlement on planets and the evolution from here of the advantages which the usual earthly colonies provide. The matter does not end here", wrote K.E. Tsiolkovskiy as early as in 1929. And further he drew a grandiose picture of the conquest by humanity, of space near the sun construction of cities and settlements in the very interplanetary space with energetics, based on the use of solar energy, and vital activity of man by a small, artificial force of gravity. Having settled in such colonies, people will obtain, according to the conception of K.E. Tsiolkovskiy, spaciousness limited by nothing for future progress of life. "Planet is a ship of reason, but it is not permissible to live permanently in a ship", he remarked.

From the total number of his works, K.E. Tsiolkovskiy devoted to the problem of flying with the help of different jet devices highly significant part. It can be said without exaggeration that amongst his works he gave first degree importance in this direction. Continuously one after the other, till very death of K. E. Tsiolkovskiy, articles, observations and calculations, devoted to all-round analysis of the possibilities and methods of interplanetary information kept pouring in.

The vastness of the problem and great importance of the result of its solution were for none so distinctly clear as for K. E. Tsiolkovskiy. None of the authors, engaged by the problem of interplanetary flights, went so far as Tsiolkovskiy, in the consideration of future social and economic results of the solution of this problem.

The problem of flight with the help of rockets in itself is extraordinarily vast K.E. Tsiolkovskiy worked it out in all its semi-jet plane with a life at a height of about 30 kilometers and ending with interplanetary rocket ship for voyage in interstellar speces. Among the works of K.E. Tsiolkovskiy the reader will find suggestions on the use of reactive exhaust from aircraft-engines, projects of powerful semi-reactive engines for aricraft, projects of air reactor engines for flights in stratosphere, sketches of rocket aircraft for flying out over the limits of stratosphere, consideration on the organization of interplanetary stations and, eventually, the suggestions about the future colossal settlements of people somewhere in the region of asteroids. All these subjects were considered on the basis of the results, obtained by him with the help of mathematical calculations details, beginning from stratospheric and with the use of the achievements in different fields of science and technology.

In this book are contained the main works of K. E. Tsiolkovskiy on rocket and cosmic technology. The works of K. E. Tsiolkovskiy on jet-propelled aviation are not included in it. These works will be obtained collected and published specially. They do not have direct relation to rocket technology. K.E. Tsiolkovskiy himself wrote, for example, in the article, "Jet air plane" "only about terrestrial transport and only hints at spatial; in the article, "New Aeroplane" he is pointing out the shortcomings of ordinary air planes, he indicates that aeroplanes, proposed by him, only "in future will serve for transition to stellar navigation"; eventually in the article "Stratoplane Semi-reactive" he writes, that it was hoped to attain the speed of 2 kilometers per second, which of course, was far from cosmic speed. For this reason despite the established practice to publish all works of K.E. Tsiolkovskiy on jet-propelled aviation along with the works on rockets and cosmic technology, we have divided them in two separate subjects.

The works of K.E. Tsiolkovskiy, contained in the present book may be divided into classical and traditional old scientific and popular scientific. The latter, however, possess a distinctive feature: they are popular in form, but sometimes hold deep, original technical ideas and cannot be excluded from the scientific legacy of K. E. Tsiolkovskiy. For this reason we have referred not only to those scientific articles, in which one or the other hypothesis is mathematically proved but also those in which projects, suppositions etc. have been included.

Works, in which K.E. Tsiolkovskiy propagated his technical ideas, occupy a specific position. Behind dry mathematical calculations of K.E. Tsiolkovski life was always found. He did not occupy himself with rockets simply for the sake of interest towards the new problem. We have already said, that K. E. Tsiolkovskiy dreamed about the resettlement of humanity in the entire solar system; he dreamed about possibly more complete use of solar energy, he dreamed of more comfortable life according to his opinion, in the environment without gravitational force, about cities in the interpalnetary space. Search for means of achievement of all this was started. Means was found by K.E. Tsiolkovskiy himself. This is the rocket. But how much labor and energy was necessary to invest to accomplish the interplanetary ship !

K.E. Tsiolkovskiy knew, that he "Will have to work still more, oh, oh, how much" (Remark in the letter of G. Obert to K. E. Tsiolkovskiy dated October 24 1929). But he was convinced, that interplanetary rocket would certainly be accomplished. And life confirmed this certainty. Therefore all articles of K.E. Tsiolkovskiy, devoted to the problem of interplanetary voyages arouse great interest, and are useful for the solution of great and variegated problem of rocket flying, as regards the technology to be used.

K.E. Tsiolkovskiy started work on the rocket problem, so to say, "officially" in 1903, when the first work on this subject under the title "Investigation of cosmic spaces by reactive devices" was published by him. Later the title of this work was changed by K.E. Tsiolkovskiy himself for "Rocket to cosmic space". But in fact the work of K.E. Tsiolkovskiy on rockets was seriously begun much earlier. He himself considered, that he had started his theoretical prospecting about the possibility of the use of rockets for cosmic voyages in the year 1896. In this year, having received the less enlightened booklet of A.P. Fedorov, "New principle of Air navigation" (St. Petersberg, 1896), Tsiolkovskiy began independent work. He writes, "To me it (i.e. book of Fedorov) appeared unclear, and in these conditions. I began calculations independently. This did not give me anything, all the same it prompted me towards serious work". (vide, "Investigation of outer spaces by reactive devices" 1926).

But K.E. Tsiolkovskiy had proposed to use the reactive principle for motion in interplanetary spaces much earlier. In the manuscripts, left behind after the death of Tsiolkovskiy, his work under the title, "Free space"*) relating to the year 1883, was discovered (it was started in February and finished in April 1883), from which it is clear, that even then K.E. Tsiolkovskiy knew abou the rocket principle of motion and thought of applying it to the motion in air-free and gravity-free space.

After this work Thirteen years had passed since the publication of the above-mentioned book of Fedorov and still it served for K.E. Tsiolkovskiy as a fillip for new investigations.

In the year 1896, K.E. Tsiolkovskiy wrote the groundwork of the story "Out of Earth"**). In the third

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*) This work of K.E. Tsiolkovskiy was published in the collection of works, Vol. II, Academy of Sciences, USSR, Moscow, 1954. "Free Space" is referred to by K.E. Tsiolkovskiysuch space in which either the force of gravity on the observed body totally does not or acts greatly feebly. (Editorial board).

**) More exact, first 10 chapter. About this see the preface "From the Publishers" in the book of K.E. Tsiolvoskiy "Out of Earth" 1920 and also "Air Resistance and fast train", 1927, in both the cases they Kalyga editions. (Editorial Board).

chapter of this story he points out towards the rocket as an a device for interplanetary voytages. The eighth chapter was directly called, "Two experiments with the rocket in the limits of the atmosphere", while the tenth —— "Preparation for the flight around the Earth".

The years 1896 - 1901 were spent by K.E. Tsiolkovskiy in conducting experiments and investigations on aerodynamics, construction of the first wind tunnel, in Russia, (1897) and experiments on the investigation of air resistance. In the beginning of 1903 he prepared for the press the first part of the work "Investigation of outer space by reactive devices".

In this chain of events we must note three dates: 1883, 1896 and 1903. To this (chain of events) is confined the whole argument about the priority of K.E. Tsiolkovskiy in the field of rockets, about which, in reality, K.E. Tsiolkovskiy himself wrote : "There is priority today and tomorrow it disappears" (vide his article "From air plane to stellar plane "); "Never had I pretended for the complete solution of the question" (vide "Investigation of outer space by reactive devices" 1926) But undoubtedly, K.E. Tsiolkovskiy first of all gave not only the concept of the use of rockets, but also substantiated the prospects of its application for interplanetary flights.

After 1903 the following work of K.E. Tsiolkovskiy on rockets appeared in 1910. Further in 1911 - 1912, part II was published by him, while in 1914, addendum to parts I and II, Investigation of outer space by reactive devices". After that follows the interval 10 years. And only after the October Revolution K. E. Tsiolkovskiy continues the future processing of his concepts in the field of rocket flying. Since 1924 his manuscript "Cosmic ship" has been preserved. Further, the articles of K.E. Tsiolkovskiy follow one after an other, while since the year 1926 he wrote several articles every year. The productivity of the work of K.E. Tsiolkovskiy is amazing. It is necessary to take into consideration that here we are speaking about his works, devoted only to rockets. But did he not write similar works on air navigation, astrophysics, geology and geo-chemistry, philosophy and on other branches of science.

It is necessary to say a few words about the relation of the works of K.E. Tsiolokovskiy to the old caste of diplomaed scientists of Czarist Russia. At that time K.E. Tsiolkovskiy remained an unknown self-taught inventor. Even the attempts of such great scientists, as Mendelef and Stoletov, to attract attention towards the concepts of the talented innovator crashed on bureaucratic indifference.

Nothing offended K.E. Tsiolkovskiy so much as the thought of the inopportuneness of his technical concepts. As regards this he once wrote a letter, in which he fulminated against the general narrow-mindedness and absence of foresight. Here is what he wrote:

"There are in fact, things and affairs inopportune, but they fail to discourage. At the very same time it is known, that all great beginnings proved themselves inopportune and although not forbidden, yet not finding sympathy, came to an end or had to struggle against discouragements big and make sacrifices. Thus, the railways proved to be inopportune. Commissions of reputed scientists and specialists not only found them inopportune, but even harmful and disastrous, for example, for health. The steamer was considered a toy by no less a person than the great Napoleon himself along with geniouses people, of his time.

Any invention, any original concept caused mockery, pursuit for harm and, at the best, inopportuneness. There was a majority of foolish concepts, and absurd discoveries and inventions and their percentage was gigantic, but past historical experience shows, that no scientists nor specialistts, nor the wise, were never known to differ much from the insignificant.

Imagine, that amongst us there appeared a person, so extraordinary as John Bruno, Galileo, Copernicus etc. None understands him, the small circle of students doubts him, but also sympathizing with him, can do nothing. Editorial boards of journalists do not accept his articles finding them unscientific and contradictory to the contemporary observations. Hexrequires wisdom of the encyclopaedic dictionaries, who would agree with the unknown man, attacking the universally accepted authorities.

We do not hear that which is silent and set, but that which thunders abroad. To criticize and to dismantle more thunderously in the press, is not in our power. For this it is necessary to be a genius, and we are ordinary people.

And what thunders ! Authority, thunders to whom it is allowed to make mistakes and to lie, thunders every-body, having links in the power of relationship capital, inherited might. How many impossible vulgarities were printed and are now being printed in the jounals. This is partly good. Canard crumbles by itself and must not hinder the expansion of ideas. But it is not good that the right of voice is possessed only be the mighty or the established authorities and the diplomaed scientists. They suppress the remaining ones as castes."*).

How from this letter differs that, which K.E. Tsiolkovskiy wrote before his death ! " Only October", —— he wrote —— brought recognition to the labors of the self-taught.".

After revolution K.E. Tsiolkovskiy, having abandoned the teaching profession, directed his total energy to the future promotion of his ideas, by publishing and populariza-tion of his works.

At the present time the scientific works of K.E. Tsiolkovskiy are highly valued and universally recognized.

The role of labors of K.E. Tsiolkovskiy in the development of rocket technology in our country cannot be but substatial. K.E. Tsiolkovskiy showed the most rational way and prospects of the development of this new aspect of technology and gave a lot of schemes of reactive devices, having practical importance.

This role was also recognized abroad. In the twenty years of our century, when the concept of K.E. Tsiolkovskiy began to penetrate in the beginning into Germany,

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*) **Text of letter is printed in accordance with the manuscript kept in archives of K.E. Tseot Kovskiy.**

then into France, many scientists having then conceived rocket technology, stopped to dispute the priority of K.E. Tsiolkovskiy. Many scientists and engineers became interested by the works of K. E. Tsiolkovskiy. Professor G. Obert in September 1929, wrote to K.E. Tsiolkovskiy : " I send you compliments, I hope, that you hope the fulfilment of your high aims —— Your have lit the light and we shall works, for the time being the greatest dream of humanity will not be realized. I am sending you my new book and I shall be very glad, if in exchange receive your latest works. (Extracts from this letter for the first time were made public as an appendix to the book of K.E. Tsiolkovskiy, "New Air plane" Kaluga*, 1929).

The concepts of K.E. Tsiolkovskiy were subjected to consideration on the pages of technical press, sometimes they were criticized. For example, the suggestions, of K.E. Tsiolkovskiy, to place rudder for steering the rocket in the stream of gas, escaping from the nozzle of the rocket engine, and in this way to obtain the possibility of steering rocket in air-free space or in the upper, highly rarefied layers of the atmosphere were subjected to critiism by the German engineer Lademann**) —— The article of Ledemann,

*) Further we shall designate all KALUGA editions of the works of K. E. Tsiolkovskiy by the letter "K".

**) ZFM, April 28, 1927.

in which he, in the meantine, had made a lot of observations and apropos of the work of K.E. Tsiokovskiy, "Investigation of outer space reactive devices", Kaluga, 1926 made criticism of K.E. Tsiolkovskiy, which was published by him simultaneously jointly with the work, "Cosmic Rocket —— Experimental preparation "Kaluga 1927. After 15 years, was proved the rightness of K.E. Tsiolkovskiy : in June 1942, successful launching of the German rocket A4, known afterwards under the name FAU-2, provided exactly with gas Vanes i.e. according to the method, suggested by K.E. Tsiolkovskiy. The vanes were made from graphite mass and were placed in the gas stream of the rocket engine. The rationality of such a device was fully justified during the experiment. It is known, that the rocket FAU-2 was employed by the Germans in the last war as a long-range missile.

During the second world war the rocket technology made a lot of success and if we compare its attainment with the ideas of K. E. Tsiolkovskiy we shall see, that in his work of the year 1903, he almost exactly foretold the type of the contemporary rocket with liquid fuel. K.E. Tsiolkovskiy at that time wrote about the automatically guiding orcket, using liquid oxygen in the capacity of an oxidizer, in the rocket, into the combustion chamber of which fuel is suppli d by pumps, . "The necessary automatic devices, guiding the movement of rocket and by the force of explosion according to a pre-contemplated plan", —— he wrote in his article in the year 1903. Of course , not all the statements of K.E. Tsiolkovskiy are convincing. Much he could not foresee, specially that, for which are required practical proofs and experience of work. For this reason, to all, that was written by him, one cannot refer without criticism.

The scientific heritage of K. E. Tsiolkovskiy, was left in the form of books, a large part of it was published by him through his own means, and the rest in the form of manuscripts.

Tha language of K. E. Tsiolkovskiy is simple, clear and precise. The text is basically divided in to small, numbered paragraphs, facilitating the references at separate places of the work, but along with this, making summaries in a somewhat dry and concise manner.

In the present edition the numbering of paragraphs has been retained in the same form, as it was given by K,E. Tsiolkovskiy himself. The gaps of several paragraphs appearing are consequences of the fact, that the author himself discarded several paragraphs, apparently, not having importance.

During editing, the style of writing of K.E. Tsiolkovskiy has been left unchanged. We have only a lot of inaccurate expressions in those works which were left after the death of K.E. Tsiolkovskiy, in draft form. Several abbreviations were unavoidable in view of the appearance of almost literal repetitions.

However,, we have not omitted the abbreviation of the earlier printed scientific works of K.E. Tsiolkovskiy. For this reason in the present collection of his articles it was not possible to avoid repetition completely, especially in the works serving the purposes of propagation of ideas of rocket technology. Such places, however, are not many.

K.E. Tsiolkovskiy's terminology is peculiar. We have left unchanged the term "reactive", but have changed, for example, "planetoid" to "asteroid", "aerolite" to "meteorite" etc. At some places, leaving the terminology of K.E. Tsiolkovskiy as such, we have given in our remarks contemporary terms, since it has been attempted to retain the works of K.E. Tsiolkovskiy in the form, in which they were written by himself.

Though the language of K.E. Tsiolkovskiy is very clear, this cannot be saidabout the mathematical side of his works: For alphabetic designations in formulae, he mainly employed the Russian alphabet and evidently, he was used to such designation. In any case, only one work on rockets, published in KALUGA, is known, with Latin designations. This is the second edition of the work "Rocket in cosmic space". Meanwhile, such a tracing of formulae, sharply differing from generally accepted in our country and the rest of the world, highly complicates their reading. Only in "Selected Works" of K.E. Tsiolkovskiy published by ONTI in the year 1934 in all 1500 Nos (rough drafts), the transcription of formulae was changed.

The second inconvenience, hampering, from our point of view, the drawing of inferences of K.E. Tsiolkovskiy, is the illustration of formulae by means of tables, adopted by him. In no one work of his K.E. Tsiolkivskiy has adopted the graphic illustration of function, to which the scientists and technologists of all the world are so much accustomed. He thought in images. For one proof or another he required approximate, roughly drawn character of any physical function, data etc. According to his opinion, small tables served for this purpose more simply.

Majority of mathematical calculations was required by K.E. Tsiolkovskiy for sketchy proof; if technical concept could be expressed like that. It is doubtful if the majority of mathematical inferences of K.E. Tsiolkovskiy will be used by engineers during the practical accomplishment of the corr sponding technical projects. A great majority of the calculations of K.E. Tsiolkovskiy are very approximate. But many : technical concepts, the proof of feasibility of which has been given by K.E. Tsiolkovskiy, undoubtedly, will be used.

In the present edition we have adopted the chronological order of distribution of works of K.E. Tsiolkovskiy. This edition is not the complete collection of the works of K.E. Tsiolkovskiy, but, in any case, almost all the most significant works on rockets, coming out during his life time, published as seprate books, as well as those having appeared in the form of articles in various journals and collection, are published in the present edition.

A few words about the publications of the works of K.E. Tsiolkovskiy. Till the year 1947, the dissemination of the works of K.E. Tsiolkovskiy was insignificantly small: it comprised several articles in the periodical press, Kaluga editions of K.E. Tsiolkovskiy himself and "Selected Works", published in 1934*) in a very restricted number of volumes (copies). About the second book of "Selected Works", devoted to rockets, which came out, as is known,

*) K.E. Tsiolkovskiy, Selected works, Book II Reactive Motion, "Gosmashmetizdat", 1934.

under the editorship of such a profound expert of the problem of rocket-navigation, as engineer F.A. Tsander, may be quoted as the best reference . To our regret, however, in this edition, mainly only those works of K.E. Tsiolkovskiy have been collected, which received from him materialistic processing, several fundamental statements of K.E. Tsiolkovskiy being suppressed. The text of "Selected Works " (1934) along with the printed works of K.E. Tsiolkovskiy were made use of by us. However, many with the printed works of K.E. Tsiolkovskiy were made use of by us. However, many vacant places have been filled in by the collection of the works of K.E. Tsiolkovskiy*).

In the year 1951 the Academy of Sciences of the USSR started to publish the collection of works of K.E. Tsiolkovskiy. The Academy of Sciences of the USSR has so far published several collectiones of the works of K.E. Tsiol ovskiy, including in the series "Classics of Science". Owing to this, at the present time the works of K.E. Tsiolkovskiy, mainly on rocket flying devices, are more or less widely knowh.

We shall now proceed to the consideration of separate works of K.E. Tsiolkovskiy, contained in this volume.

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*) K.E. Tsiolkovskiy, Collection of Works, Vol. II, Academy of Sciences of USSR, Moscow, 1954.

First of all our attention is attracted by a lot of articles which may be united with a general caption "Investigation of outer space with the halp of rocket devices". Here are found the earliest works of K.E. Tsiolkovskiy on rockets.

"Investigation of the outer space by reactive devices" —— the first published work of K.E. Tsiolkovskiy about rockets —— was for the first time printed in the journal "Scientific Review" No, 5, 1903, K.E. Tsiolkovskiy ofterwards called this work the first part of his study. In 1924 in Kaluga it was published as aseparate brochure under a new caption "Rocket in Cosmic Space".

The change of title as may be guessed, is explained by the fact, that in 1923 Obert's book "Die Rakete Zu den Planetenraumen" came out. Being almost a verbal translation of the title of this own book, K.E. Tsiolkovskiy took a view of protest against the fact, that the book of Obert was perceived as a new discovery whereas K.E. Tsiolkovskiy has enunciated the very same concept as early as the year 1903. For this reason in the edition of the year 1924, the article "Destiny of thinkers or twenty years in hiding" was placed in the form of a preface, in which he had complained of oblivion, impeding publicity of his works. This article has been omitted by us.

We are printing in the text the edition of the year 1924, the work of K.E. Tsiolkovskiy since 1903. The first edition (in the journal "Scientific Review") was prepared, according to the opinion of K.E. Tsiolkovskiy himself, extremely carelessly.

The work of K.E. Tsiolkovskiy "Investigation of outer space by reactive devices", without doubt, is one of his basic works on rockets. At the same time this work deserves to be called classical in this field. Acquaintance with it is necessary it everyone, interested not only in the problem of interplanetary flight but also with motion of the rocket in general.

In the term "reactive device", frequently appearing in K.E. Tsiolkovskiy's works, he includes all the flying mechanisms moving by the effect of thrust of rocket engines.

"Investigation of outer space by reactive devices" or shortly "Investigations of the year 1911" appeared in journal "Air Navigation Herald" in the year 1911 in numbers 19-22 and further in the year 1912 in No. 2-9. We are printing the first part of the article in the text of the journal, introducing many of the corrections and additions, which K.E. Tsiolkovskiy had made with his own hands in the printed text of the journal. "Investigation of the year 1911" was named as the second part of his great work by K.E. Tsiolkovskiy.

Later, on the publication of "Investigations of the year 1926" K.E. Tsiolkovskiy removed from the "Investigations of the year 1911 completely the preface and the chapters "The action of gravity on moving off from the planet" and "The velocity of flight and the time of flight ". "Investigations of the year 1926" is better known, more important, and vastly problem-embracing, and therefore the indicated preface and two chapters (the last two in abbreviated form) have been retained by us in the "Investigation of the year 1926" and in "Investigation of the year 1911" with the preface deleted. After this preface followed the extensive "Resumer of the work of the year 1903". We have deliberately abridged it, retaining only the main, fundametal positions, since this resume briefly states the contents of "Investigation of the year 1903". Further we follow the text, adopted in the collection of works of K.E. Tsiolkovskiy, volume II, a publication of the Academy of Sciences of the USSR, Moscow, 1954.

"Investigation of the outer space by reactive devices" (appendix to parts I and II, works of the very same name) published in the year 1914. —— We are re-printing the text from this edition, leaving out several initial pages, in which auspicious references by K.E. Tsiolkovskiy were contained regarding the specialists of that time about parts I and II of his works.

The article "Cosmic Ship" has be n printed according to the manuscripts of the year 1924*). The article was meant for publication by K.E. Tsiolkovskiy and was sent with this aim in July 1924 to the journal "Technology and Life". However, the editorial board returned it to the author without printing it. In the article is contained an interesting indication for the use of braking in the Earth's atmosphere of the interplanetary ship at the time of landing on the Earth. An analogous method was afterwards also suggested by Gomann in his work "Die Erreichbarkeit der Himmelskorper" in 1925.

The article "Investigation of outer space by reqctive devices "(or briefly "Investigation of the year 1926) was published by K.E. Tsiolkovskiy in the year 1926 in the city of KALUGA. On the jacket appeared the inscription "Re-publication of works of the years 1903 and 1911 with several changes and additions". But this does not accord with reality. It is also not wholly correct that a subsequentxof K.E. Tsiolskovskiy that "had to be confined by one new, by virtue of material conditions" is also not wholly correct. There is no doubt, that the this work is not a re-publication of works of the previous years, but at the same time there is no doubt belonged to that they

*) This article was written in two variants: we are printing in accordance with the first variant in such a way as it was for the first time ublished in the book "K.E. Tsiolokovskiy Works on rocket technology" OBORONG Publishing House 1947. The second variant, see in the Collected Works Volume 11, Academy of Sciences of USSR, 1954.

the year 1903 and specially those of 1911 were included in it. For this reason one must not wonder at the rarely appearing repetitions. The preface to this article, as has already been indicated, was written in the year 1911.

In the records of K.E. Tsiolkovskiy was found a manuscript, with the caption, "Album of cosmic voyages". The text of this, album has the date June 21, 1933; the drawings were done in the period October 1933 —— March 1934. The text is devoted mainly to the establishment of interplanetary stations. The drawing of the album have been done on the subject of the text. The album appears as material, was for the film "Cosmic trip" the scientific consultant of which had invited K.E. Tsiolkovskiy*) to prepare the drawing.

The drawings of the album (Numbering more than 100) are schematic. K.E. Tsiolkovskiy giving the sketches, suggested that animated cartoons could be made by him. The drawings, to a great extent, depict various effects of the absence of gravity. They do not attract much

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*) "Album of Cosmic Voyages" published in the capacity of an appendix in the book, "Manuscript Materials of K.E. Tsiolkovskiy", Works of the Archives of the Academy of Sciences of USSR, Imp 22, "Nauka" Publishing House, Moscow, 1966.

interest but some of them may serve as illustrations at different places from previous works of K.E. Tsiolkovskiy and that is why they have been preserved by us. The drawings 3,5,7,8 and 9 (enumeration of "Album") suit as illustrations to the article "Reactive Movement", drawings 11, 12 and 13 show different methods of return of the rocket in air-free space. Drawing 49 perhaps, pertains to the article "Csomic Ship" and only drawing No, 54 relates directly to the question about an interplanetary station. The inscriptions and drawings have been made by K.E. Tsiolkovskiy himself.

"Works about the cosmic rocket 1903-1927". In this article K.E. Tsiolkovskiy sums up the first results of his work in the field of rocket technology. We notice that the general program of practical work on the reactive movement, mentioned in this article is not to be recognized as accurate. Experiments with automobiles with the aim, with which K.E. Tsiolkovskiy examines them, are evidently not necessary if man can soon fly in aeroplane. The skill to control the machine at present is not the first rate problem. Until the accomplishment of flight by man in the rocket the difficult way of the creation of the rocket engine must be traversed.

"Aims of stellar Navigation". This work of K.E. Tsiolkovskiy is devoted to the sbuject regarding the future resettlement of humanity on the planets of the solar system. Earlier this article was related to scientific-cum-fantasy works of K.E. Tsiolkovskiy. However, this is completely unbelievable. Only the lack of understanding of the importance of the future rocket movement and the conquest of cosmos by man might lead to such a conclusion. We consider it necessary to include this work of K.E. Tsiolkovskiy in the collection of his works, devoted to the rocket and cosmic technology. The article is printed in the Kaluga edition of 1929.

"Reactive Movement". The article was written in May 1932, and was published in the journal "Into the Fight for Technology", No. 15-16, August 1932, under the caption "Theory of the reactive motion". The article is being printed by us with insignificant abbreviations of places, repeating literally the previous works of K.E. Tsiolkovskiy, and with certain corrections in the collection of works of K.E. Tsiolkovskiy*).

The idea regarding the folded device of the external surface of the rocket meant for flights into the cosmic

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*) K.E. Tsiolkovskiym Collected Works, vol II- Academy Sciences of the USSR, Moscow, 1954.

space, was expressed by K.E. Tsiolkovskiy even in 1925.

"Fuel for Rocket". The article was compiled by K.E. Tsiolkovskiy from two manuscripts. One of them is "Explosives and Fuel" (June 1932) *), while the other "Explosives for Stellar-Plane" (March 1933). To the article obtained in this way by K.E. Tsiolkovskiy, the name "Achievement of Stratosphere" was given. The article was contained in the collection "Reactive Movement", No. 2, 1936, under the caption "Fuel for the Rocket". It is also preserved by us. The manuscript of the year 1933 in the article begins with the section "Selection of Explosion Elements".

"Stellar-Plane with Machines preceding to it". This article was not published during the life of K.E. Tsiolkovskiy . We are printing it according to the text of "Selected Works" edition of the Academy of Sciences of the USSR , 1962. It is known that K.E. Tsiolkovskiy considered gradually possible, by means of increasing the velocity and designing modifications of an aeroplane and mainly its motors to pass on to a stellar-plane, i.e. to attain cosmic velocity. This article is devoted to a brief survey of this question.

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*) Data at the end of the manuscript was always considered by us as the data of finishing of the given work.

"Missiles, devising cosmic velocities on the earth or water". The article is being printed on the pattern of the manuscript, dated December 3-8, 1933.

K.E. Tsiolkovskiy devoted the last year of his life to the great work, "Basis of making gas machines, motors and flying devices", which he could, not complete. He started work on it towards the end of 1934. In this work he vastly made use of his previous labors. According to his idea, the work "Basis of making gas machines" must have comprised 12 chapters. He changed the captions and order of individual chapters several times.

For rocket technology the 10th chapter offers the greatest interest. This chapter bearing the caption "Greatest velocity of the rocket" was written in January 1935. The subject of this chapter is the particular method of attaining great velocities of flight. The basic principles of the method suggested by K.E. Tsiolkovskiy, were popularized by engineer Y.I. Perelmann*) . From the letter of K.E. Tsiolkovskiy to Perelmann, it follows that the idea of this method occurred to him in December 1934. This work is being published by us in the book, "Works on rocket technology" (Ministry of Defence Publishing House, 1947).

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*) Y. I. Perelmann, Tsiolkovskiy ONTI, 1937.

It is as if it were the finale of the creative work of K.E. Tsiolkovkskiy. The method of attaining cosmic velocities, about which there is mention in this book, consisting in pauring fuel from rocket to rocket during the gradual diminishing of the number of simultaneously flying rockets, prefably of component rocket too, is not rejected by K.E. Tsiolkovskiy. In the present case he suggests the use of the method of pouring not for ordinary liquid propelled rockets*) but for the rocket-planes.

We have already pointed out the fact that the present book is not the complete collection of works of K,E. Tsiolkovskiy on cosmonautics. What about the works not included in this book ?

In the first place they belong to a small portion of the manuscript, not having independent significance for rocket and cosmic technology.

Secondly, Out of the works of K.E. Tsiolkovskiy having been printed earlier on the problem of inter-planetary voyages, the following ware not included:

1- A small article "For the atmospheric land" printed along with the article, "New Aeroplane", Science", 1929, .

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*) As has been in the book of Y.I. Perelmaun, 1937.

2. The article "From aeroplane to stellar-plane" printed in the journal, "Sparks of Science". 1929, No. 2.

3. The article "For the Atmosphere", written by K.E. Tsiolkovskiy in March 1932 and published with some changes in the journal "Around the world", 1934, No. 1.

4. The article "Reactive Motion and its successes" written in March 1932 and published in the journal, "Aeroplane", 1932, No. 6.

5. The article "Stellar-Plane" published in the journal "Knowledge is Power", December 1932 No. 23-24.

6. Scientific news paper article "Can the Earth some day announce to the inhabitants of other planets about the existence on it of rational beings", printed in the "Kaluga Review" 1896 No. 68.

7. Popular Scientific Narrative "Out of the Earth", which was published in the journal "Nature and people" in the year 1918 (NO. 2-14), was published as a separate book in Kaluga in 1920 and found its way in the collection of works

of K.E. Tsiolkovskiy "Way to Stars", Academy of Sciences of the USSR, Msocow 1960.

8. Article "Reactive device, as means of flight in the vacuum and in the atmosphere", printed in the journal, "Air Navigator", 1910, No. 2. being a very brief account of the work, "Investigation of outer space by reactive devices" (1903).

9. Article "Application of reactive devices to the investigation of stratosphere", published in the newspaper Working Moscow" No. 51, dated 3 March 1935. The manuscript of this article was finalized on February 27, 1935. In the article, the idea of rocket is briefly dealt with.

Even during not particularly serious reading of the work of K.E. Tsiolkovskiy it becomes clear, that the author did not consider interplanetary flight of rocket as material without preliminary preparation, without overcoming the difficulties standing in the way and temporary set-backs. He suggested that aviation is the first stage on the road to cosmic flights and the wisdom to fly in the atomosphere is the first stage in the art of flying beyond the atmosphere. An air plane according to K.E. Tsiolkovskiy may be, in future, converted into a cosmic ship.

Gradual modification of the air plane into the interpanetary ship, according to K.E. Tsiolkovskiy is drawn up in the following way. In case of the aero-engine the waste of heat is made use of, reactive exhaust for the creation of thrust not with the help of a screw, but with the help of the reaction of waste product of mass. The cylinders of the engine at this stage are converted into the combustion chambers of the reaction engine. The engine, provided with a compressor (with the compression of gases, in the terminology of K.E. Tsiolkovskiy), is accommodated in a tube, where the products of cumbustion burn out and the process characteristic of the rocket aero-engine takes place. The air plane is converted into a semi-reactive strato plane, since the screws all the same are needed by it. The altitudes of flight are significantly heightened. Piston-engines may be changed by turbines.

Further, the content of oxygen in the oxidizer of fuel increases. On the stratoplane are located tanks with special oxidizers. The altitude of flight increases. still more. Finally, the use of oxygen is completely discarded and switch over tb some oxidizer, which is in the liquid state, is made. The stratoplane is converted into the rocket-plane, which, depending on the relative quantity of the fuel contained in it, may fly out of the limits of the atmosphere.

With the help of combination from several rocket-planes, in the form of either a component rocket or devices, moving the reserve of fuel from one to the other, may attain a speed of 8 kilimeters per second, and will become a stellite of the Earth. By means of delivery from the Earth of the required materials this satellite may be converted into a station, from which interplanetary ships will be directed in more distant cosmic voyages.

When all this has been acheived,, a time will come to organize "Colonies in Ether", as K.E. Tsiolkovskiy has called the interplanetary stattion cities.

Side by side with the above stated concepts K.E. Tsiolkovskiy did not rule out the possibility of direct flight of the rocket beyond the limits of the atmosphere into the cosmic space. In his works he has suggested the use of the inclined ascent of the rocket with its preliminary boost for this purpose. But such a way Tsiolkovskiy considered more difficult. The way through aviation from this point of view is the way of amassing experience with the object of possessing the art of flying beyond the atmosphere. Only by reading and studying the works of K.E. Tsiolkovskiy, is it possible to appraise the importance of his idea, having kept the beginning factually to the scientific relation to the rocket as a device for the movement of human beings into the cosmos.

M.K. Tikhonravov.

Moscow,

1967.

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RESEARCH OF OUTER SPACE BY REACTIVE DEVICES.

(The Rocket in Cosmic Space)

(1903)

Lift on air balloons; sizes, their weight, temperature and density of air.

I. Small aerostats with automatic vision devices, without human beings, till this time have ascended up to a height, not more than 22 kilometers.

The difficulties of ascent to a large height with the help of air balloons increase extraordinarily quickly with the increase of this height.

Suppose, we want, that the aerostat ascended to a height of 27 km and lifted a weight of 1 kg. Air at the height of 27 km has a density of about 1/50 of its density on the surface of the Earth (760 mm pressure and $0^{\circ}C$). It means that the balloon on such a height must occupy the volume 50 times more than below, at the level of the sea. It needs to inject into it not less than 2 M^3 of hydrogen, which at the altitude will occupy 100 M^3. At this stage the balloon lifts a weight of 1 kilogram i.e. it lifts the automatic device, and the balloon itself would weigh 1 kilogram or nearly that much. The surface of its jacket with a diameter of 5. 8 M constitutes not less than 103 M^2. Consequently each 1 M^2 of matter, taking into consideration its protecting gauze, must weigh 10 g.

A square meter of ordinary writing paper weighs 100 g; the weight of 1 M^2 cigarette paper constitutes 50 g. So that even the cigarette paper will be 5 times heavier than that material, which must be used in our aerostat. To use such material in the aerostat is impossible because the jacket, made from its, will burst and will violently release the gas.

The balloons of a larger size may have a thicker jacket. Thus, the balloon with fantastically large diameter of 58 M will have a jacket, 1 M^2 which weighs about 100 g, i.e. a bit heavier than the ordinary writing paper. It lifts 1000 kg of load, which is much too much for the recorder (self - recording device).

1903 Tenth Year

SCIENTIFIC REVIEW

Monthly

Scientific - cum - philosophical and Literary journal.

No. 5

M A Y

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St. Petersberg.

E.L. Porokhovshchikova Printing House,
3 - 5, Swimming Pool Street,

1903.

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OLD RUSSIAN VERSION

Research of outer space by reactive

Small aerostats with automatic vision devices, without human beings, till this time, have ascended up to a height of not more than 20 versts.

The difficulty of ascent to a height with the help or air balloons increases extraordinarily quickly with the increase of this height.

Suppose, we want that the aerostat rose to a height of 27 kilometers has a density of about 1/50 of its density of in normal conditions (760 mm pressure and 0°Centigrade). It means that the balloon on such a height must occupy a volume 50 times greater than below. At the very sea level, it allows, to inject into it not less than 2 meters of hydrogen, which at a height will occupy 100 cubic meters. At this stage the balloon will lift a load of 1 kg, i.e. will lift the automatic device and the balloon itself will weigh one kilogram or about that.

The surface of its jacket, at a diameter of 5. 8 meters, constitutes not less than 103 M^2. Consequently each square meter of material, taking into consideration its protecting gauze, must weigh to 10 gram, or square arshin will weigh about first one Zolotnik.

A square meter of this writing paper weighs 100 gram ; similarly a square meter of cigarette paper constitutes 50 g. So that even the cigarette paper will weigh 5 times heavier than that meterial, which must be used in our aerostat. Such a material in use for the aerostat, is not possible, because the jacket made from it will burst and will violently release gas.

The balloons of large sizes may have thicker jackets. Thus, the balloon with fanstastically large diameter of 58 meters.

<u>Page from the journal Scientific Review</u>
<u>Year 1903, No. 5.</u>

If one is restricted to the same, enormous sizes of the aerostat by the lifting force 1 kilograms, then it is possible to make the jacket two times heavier. In general, in such a case, although, the aerostat costs very dearly, its construction is not to be considered impossible. Itss volume at an altitude of 27 kilometers constitutes 100,000 M^3, the surface area of the jacket being 10, 300 M^2.

Meanwhile, what sorrowful results will an ascent to some 27 kilometers of altitudentail.

One has to say about the ascent of devices to a great height ! The sizes of aerostats must be still greater; but at this stage it should not be forgotten that with the increase of sizes of air balloons the forces tearing as under the jacket all the more and more take the overweight on the resistance of material.

The ascent of the devices beyond the limits of the atmosphere with the help of air balloon, of course, is totally inconceivable. From the observations on the falling stars it is seen, that these limits do not extend beyond 200 - 300 kilometers. Theoretically even the height of the atmosphere is calculated at 54 kilometers, taking into consideration, the basis of the lowering of temperature of air to 5°C for each kilometer of ascent, which is sufficiently close to reality, at least, for accessible layers of the atmosphere*.

A table of heights, temperature and density of air is adduced above, calculated by me on thus basis. From this it is seen, how equickly the difficulties of ascent grow with the height.

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*) Now it is known, that the lowering of temperature goes up to the limits of the troposphere, i.e. up to 11 kilometers (auther).

On altitudes from 11 to 25 kilometers the temperature is constant and is equal to - 56, 49°C (Editorial Board).

Altitude of the atmosphere in kilometers.	Temperature. °C	Density of air.	Altitude of the atmosphere in kilometers K.M.	Temperature. °C	Density of air.
0	0	1	30	-150	1: 116
6	-30	1:2	36	-180	1 :584
12	-60	1:4,32	42	-210	1 :3900
18	-90	1:10,6	48	-240	1 :28000
24	-120	1:30.5	54.5	-272	0

The denominator of the last column indicates the difficulty, which may be forced in the manufacture of the air balloon.

2. We now switch over to the other idea of flight to the altitude —— with the help of launched missiles.

In practice the initial velocity of motion of missiles does not exceed, 1200 M/sec. Such a missile launched vertically, rises up to an altitude of 73 km, if the flight is accomplished in air- free space. In air the altitude of lift will be much less and depends on the form and mass of the missile.

On a good form of the missile the altitude of lift may attain important values but to accomodate the vision devices inside the missile is impossible, because they will be smashed to pieces either during the return of the missile to the Earth, or during its very movement in the launching barrel. The danger in the channel on the motion of the missile is less, but this danger for the intactness of the devices is enormous. Let us suppose for simplicity, that the pressure of gases on the missile is even, on account of which the acceleration of its motion works out as W M/sec.^{2}. Then the same acceleration is obtained and all the objects in the missile are constrained to attain with it one motion. Due to this, inside the missile, there must develop a relative, apparent gravity, equal to $\frac{W}{g}$ where g is the acceleration of the Earth's pull on the surface of the Earth.

The length of the gun L will be expressed by the formula.

$$L = \frac{V^2}{2\ (W - g)},$$

from which

$$W = \frac{V^2}{2L} + g,$$

Where, V — is the velocity acquired by the missile on exit from the orifice.

From the formula it is evident that W, the increase of relative gravity in the missile, therefore, decreases with the increase of height of the gun [illegible] at the constant V, i.e. the longer the gun, less dangerous it is to the devices at the time of pushing out of the missile. But on a very long gun which is impracticable to work, the apparent gravity in the missile on the acceleration of its motion in the gun channel is so large that the tenderly built devices can hardly bear it without damage. It is even more impossible to send in it anything living in the missile, if need should arise.

3. Thus, we assume, that the built-up gun is roughly 300 meters high. Let it be located along the Eiffel Tower which as is known, possesses such a height and let the missile with an even pressure of gas receive, on exit from the orifice, a speed, sufficient for ascent beyond the limits of the atmosphere, for example, for an ascent up to 300 kilometers from the Earth's surface. Then we calculate the velocity V for this, by the formula.

$$V = \sqrt{2gh}.$$

On h = 300 kilometers we obtain V as about 2450 meters/sec. Out of the two last formulae, eliminating, we find

$$\frac{W}{g} = \frac{h}{L} + 1;$$

here, $\frac{W}{g}$ expresses the relative, or apparent gravity in the nucleus. According to the formula we find, that it is equal to 1001.

Therefore, the gravity of all devices in the missile must be increased 1000 times also, i.e. an object with weight of 1 kilogram experiences from the apparent gravity a pressure 1000. kilograms (force). Hardly, perhaps any physical device will bear a similar pressure. What type of a jerk thrust those bodies must experience in a small gun and during flight at an altitude, more than 300 kilometers !

So as not to lead anybody astray by words, "relative, or apparent gravity", I shall say, that here I mean force depending on the accelerating movement of the body (for example the missile); it appears either on uniform motion of the body, if only the motion is curvilinear and is called centrifugal force. Generally, it appears always on the body or in the body, if only on one body some force acts, disturbing the movement of the body by inertia. The relative gravity exists till the time, its generating force exists; as soon as the latter ceases to exist - the relative gravity disappears tracelessly. I name this force gravity, then only because its temporary effect is completely identical with the effect of the gravitational force. As each material particle is subject to gravity, so also the relative gravity is born in each particle of the body, contained in the missile; this takes place because the apparent gravity depends on inertia, to which all the material parts of the body are equally subject. Thus the devices inside the missile will be made 1001 times heavier. Even if on this terrible, through short - timed, (0. 24 sec) reinforcement of the relative gravity it succeeded in preserving them intact, all the same, many other impediments for the application of guns in the capacity of senders into the sky space, will be found.

First of all there is the difficulty of their construction even in the future. Further there is the enormous initial velocity of the missile; in fact, in the lower thick layers of the atmosphere, the velocity of the missile loses much on account of the resistance of the air; the loss of velocity will vigorously cut down the altitude of flight of the missile; after that it is difficult to attain even the pressure of gases on the missile at the time of its motion in the barrel, from which the force of gravity will be much more than we had calculated (1001); finally the safety of the return of the missile to the Earth is very doubtful.

Reactive Device —— " The Rocket"

4. But then one enormous increase of gravity is completely sufficient, so as to retain the conception of the use of guns for our work.

In their place or the aerostat in the capacity of a researcher of the atmospher I suggest the reactive device, i.e. of the type of rocket, but the rockets are grandiose and are built by a special method. The concept is not new, but the calculations connected with it, give so remarkable results, that to keep silent about them should have been impermissible.

It is not my business to further examine all aspects of work, as its practical aspect regarding the feasibility categorically does not allow it; but in the distant future, prospects can be seen through the fog, to such a degree enticing and important, that hardly anybody dreams about them at present.

We shall imagine such a missile: metallic oblong chamber (of the form of least resistance), provided with light, oxygen, obsorbers of carbon dioxide, miasmata and other animal secretions, meant not only for the preservation of different physical devices but also for human beings, controlling the chamber (we shall discuss the question more widely according to possibility). The chamber has a larger reserve of substances, which on their mixing immediately form explosive mass. These substances, accurately, and satisfactorily evenly exploiding at the fixed place for the purpose, flow in the form of hot gases in the tubes widening toward the end like the horn or the blowing musical instrument. These tubes are located along the small walls of the chamber, in the direction of its length. At one, narrow end of the tube the mixing of the explosive substances takes place: here the thickened and flaming gases are obtained. At the other, widened end of it, they, being vigorously rarefied and cooled, escape outside from the tube through the socket with enormous relative speed. It is understood, that such a missile, as a rocket, in known conditions, will be lifted to the altitude.

Automatic devices controlling the motion of the rocket (we shall often call our device thus) and the force of explosion for the plan contemplated earlier, are required.

<u>Schematic view of the rocket.</u> (fig. 1). Both the liquid gases are divided by a partition. The place of the mixing of gases and their explosion is visible. We also see the fund for pouring out vigorously rarefied and cooled vapors. The tube is surrounded by a casing with metallic fluid quickly circulating in it. We see rudder, serving to the control the motion of the rocket.

If the equally - functioning forces of explosion do not pass exactly through the center of inertia of the missile, the missile will rotate and consequently it will be useless. To obtain mathematical precision in this coincidence is absolutely impossible because as inertia cannot fluctuate on account of the movement of the contained substances, as well as the direction, in the tube of the differently functioning forces of pressure of gases cannot have an unchnged direction mathematically. We can still direct the

Figure. Keys: 1- Freely circulating Liquid, oxygen, at a very low temperature.
2. Liquid hydrocarbon.
3. People and devices for breathing, and others.

....

missile in air by the help of a rudder similar to the manner of a bird but what would you do in the air-free space, where ether will hardly offer any appreciable support.

The fact is that if the equivalent force, as far as possible is close to the center of inertia of the missile, then its rotation will be fairly slow. But the moment it begins, we transfer some mass inside the missile at the time of the transferance of the center of inertia resulting from it, does not force themissile, to tilt in the opposite direction. In this way keeping a watch on the missile and transferring inside it small mass we shall achieve the oscillation of the missile sometimes to one and sometimes to the other side, the usual direction of the effect of the explosive substances and the movement of the missile will not change.

Perhaps the manual control of motion of the missile will prove not only embarrassing, but practically impossible, In such a case, one mustswitch over to the automatic control.

The pull of the Earth cannot be fundamental here for adjustment, because in the missile there would only be relative gravity with the acceleration W, the direction of which coincides with the relative direction of the flying out explosive substances or directly opposite to the direction of the equivalent forces of their pressure. And since the direction changes with the turning of the missile and tube this gravity as a regulator guide is not suitable.

It is possible to use for this purpose a magnetic needle or the energy of solar rays, concentrated with the help of a double convex lens. Every time, the missile with the tube takes a turn, a small and clear image of the Sun changes its relative position on the missile, which may stimulate the expansion of gas pressure, electric current and the movement of mass, restoring the specific direction of the tube, on which the light spot falls on the neutral, so to say, the non - sensitive place of the mechanism.

The automatically slowly moving masses must be two. A small chamber with two quickly rotating circles in different planes may also serve as a basis for the direction regulator of the missile. The chamber has been suspended in such a way that the position or, more exactly, its direction does not depend on the direction of the tube. When the latter rotates, the chamber under the force of inertia, neglecting friction, retains the previous absolute direction (with respect to stars); this property is revealed to a high degree during the quick rotation of the chamber discs. Small, spring fastned to the chamber during the rotation of the tube convey a change of the relative position of the chamber in the missile, which may serve as a reason for the emergence of the current and the motion of the regulating masses.

Finally the turning of the end of the funnel may also serve as a means of preserving the specific direction of the missile. The double rudder, located outside the rocket close to the discharge end of the tube, may serve for the control of the rocket simplest of all. Avoidance of the rotation of the rocket around the longitudinal axis is made possible by the turning of the plate, located in the direction of movement of the gases and in their midst.

Advantages of the Rocket.

5. Before stating the theory of the rocket or of the reactive device, similar to it, I shall attempt to interest the reader in the advantages of the rocket over the gun - type missile:

a) Our apparatus compared with the gigantic gun is as simple as a feather; it is comparatively cheap and simply practicable;

b) The pressure of explosive substances, being sufficiently uniform, causes - evenly, accelerated motion of the rocket, which enhances the relative gravity; we can control according to our wish the magnitude of this temporary gravity i.e. regulating the force of explosion, we are in a position to make it arbitrarily more or less exceeding the usual terresterialgravity. If we assume, for the sak of simplicity, that the force of explosion decreases proportionately to the mass of the missile, added to the mass of the remaining unexploded explosive substances, the acceleration of the missile and consequently, the value of the relative gravity will be constant. Thus, in a rocket not only measuring devices but also men can be sent safely on occount of the apparent gravity, whereas in the gun-type missile, even in the presence of an enormous gun, with the magnitude of the Eiffel Tower, the relative gravity increases 1001 times on a lift at 300 kilometers; c) There are still more advantages of the rocket: its speed increases according to the desired progression and in the desired direction; it may be constatn and may be decrease of evenly, which will give possibility of safely landing it to the planet. All work in well regulatod explosion; d) On the start of ascent so long as the atmosphere is dense and the resistance of air to high velocity is large, the rocket moves comparatively slowly and due to this loses less on account of the resistance of the medium and is less heated up.

The speed of the rocket increases only slowly; but after that to the extent of lift altitude and rarefaction of the atmosphere it can artificially increase quickly; finally in the air-free space this growing speed may still be increased. In this way we shall spend minimum of work in overcoming the resistance of the air.

Rocket in a medium, free from gravity and the atmosphere. Correction of masses in the rocket.

6. In the beginning we shall examine the effect in the medium, free from gravity and the surrounding material i.e. the atmosphere. Last of all we shall take up to decipher only its resistance to the motion of the missile, but not the motion of the swifty exploding vapors. The influence of the atmosphere on the explosion is not quite clear; on the one hand, it is favorable because the explosive substances have in the surrounding material medium, some support, which they carry along detracts during their motion and in this way promotes the increase of velocity of the rocket; but on the other hand the very same atmosphere with its density and elasticity disturbs the expansion of gases farther than the known limits, which the explosive substances do not acquire with that velocity which they could have acquired, by exploding themselves in the vacuum. This, last effect is unfavorable, because the increase of

velocity of the rocket is proportional to the speed of thrown out products of explosion.

We shall designate the mass of the missile with all the contents, except the reserve of explosive substances, by M_1, complete mass of the latter by M_2; at last, the variable mass of explosive substances, having been left unexploded in the missile at the given moment by M.

In this way, the entire mass of the rocket at the start of explosion will be equal to $(M_1 + M_2)$; after some time it will be expressed by the variable value $(M_1 + M)$; and at the end of explosion —— by constant value M_1.

In order that the rocket acquired the highest speed, it is necessary, that the throwing out of the produts of explosion was performed in one direction in respect of stars. While for this it is necessary that the rocket did not rotate; and so that it did not rotate, it is necessary, that the equivalent force of the explosive forces, passing through the center of their pressure, passed at the same time also through the center of inertia of the entire combination of the flying masses. The question how to adhieve it in practice, we have already solved it partially.

Thus, assuming such a most advantageous throwing out of gases in one direction, we shall obtain the following differential equation on the basis of the constancy of the Theorem of Momentum Conservation.

8.

$$dV\ (M_1 + M) = V_1 dM.$$

9. Here dM indicates infinitely small waste of the explosive substances, escaping from the gun-type funnel with a constant velocity V_1 in respect of the rocket.

10. I want at offirm, that the relative velocity V_1 of the escaping elements in similar conditions of explosion is one and the same at all times of explosion on the basis of the Momentum Conservation Theorem: dV is the increase of Speed V are dV is obtained owing to throwing out of the element dM with a velocity V_1. By the determi ation of the last, we are in our places.

11. Dividing the variable values in the equation (8)* and integrating, we shall obtain.

12.
$$\frac{1}{V_1}\int dV = -\int \frac{dM}{M_1 + M} + C,$$

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*) Tables and formulas are designated by numbers of points of text (Editorial board).

or,

13.

$$\frac{V}{V_1} = - \ln (M_1 + M) + C.$$

Here C is a constant. When $M = M_2$, i.e. before explosion, V=0; on this basis we find

14.

$$C = + \ln (M_1 + M_2),$$

consequently,

15.

$$\frac{V}{V_1} = \ln \frac{M_1 + M_2}{M_1 + M} .$$

The greatest speed of the missile is obtained when M = 0, i.e. when the entire reserve of M_2 is exploded; then assuming in the previous equation M = 0 we shall obtain,

16.

$$\frac{V}{V_1} = \ln \left(1 + \frac{M_2}{M_1}\right).$$

17. From here we see, that the speed V of the missile grown unlimitedly with the increase of the quantity of M_2 of the explosive substances. It means storing them in different quantities, during different voyages, we shall acquire diverse final speeds. From equation (16) it is also seen that the speed of the rocket on the consumption of a definite reserve of explosive substances does not depend on the quickness or irregularity of explosion, if only the particles of the thrown out material moved with one and the same speed V_1 relative to the missile.

However, with the increase of the reserve of M_2 the velocity V of the rocket grows slower and slower even though limitlessly. Approximately it grows as a logarithm by the increase of quantity of the explosive reserves of M_2 (if M_2 is large in comparison with M_1, i.e. if the mass of the explosive substances is several times larger than the mass of the missile).

18. The future calculations will be interesting, when we shall find out V_1 i.e. the relative and final speeds of the exploded element. Since gas or vapor (steam) on abondonment of gun-type funnel gets highly rarefied and cooled (on sufficient length of tube), even turns into solid state - into spray, which rushes with terrible rapidity,

one can conclude that all combustion energy, or chemical combinations, on explosion turns in to the motion of the combustion products, or into kinetic energy. In fact, we shall imagine a certain quantity of gas, having dilated in vacuum, without any devices; it will expand in all directions and on account of this get cooled till the time it gets converted into drops of liquid or mist.

This mist turns into small crystals, not by expansion but by evaporation and radiation in the outer space.

Having expanded, the gas releases all its kinetic and partly potential energy, which is converted eventually into rapid motion of small crystals, directed in all directions since the gas expands freely in all directions. If it is obstructed in expansion in the reservoir with a tube, the tube will direct the movement of gaseous molecules in the fixed direction, by which we are also benifited in our purposes i.e. for the motion of —— the rocket.

One would think that the energy of the motion of molecules get, converted into kinetic motion till the time that the substances preserve their gaseous or vaporous condition. But this is not exactly the position. In fact, part of the substance might turn into the liquid state;

but at this stage energy is released (latent heat of vapor formation) which passes on material to the remaining vapor-forming part and retards its change, for a short time, to the liquid state.

We see a similar phenomenon in the vapor (steam) cylinder, when the vapor (steam) by its natural expansion, blocks its outlet from the steam boiler to cylinder. In this case, whatever the temperature of steam, part of it is converted into mist, i.e. liquid state, the other part continues to preserve vaporous state and to work, borrowing latent heat of steam condensed into the liquid.

Thus the molecular energy will be converted into kinetic at least to the liquid state. When all the mass is converted into drops, conversion into kinetic energy almost stops, because vapors of fluid and solid bodies on low temperatures possess too insignificant elasticity and their use in practice is embarrassing, since it would require enormously long tubes.

And still some insignificant part of the energy indicated by us, will be lost to us i.e. it will not be converted into kinetic energy owing to the friction on the tube and radiation of heat by heated a parts of the tube. However, the tube may be surrounded by a casing, in which some liquid (molten) metal circulates, It will give heat of the highly heated part of one end of to its other part cooled by means of vigourous rarefaction of vapors. In this way, this loss by radiation and heat conduction may be utilized or may be made very insignificant. In view of the shortness of explosion continuing in the last resort from 2 to 5 minutes loss from radiation and without any coutrivance is insignificant; circulation of metallic liquid in the casing, surrounding the tube, is necessary for an other purpose; for maintaining one and the same low temperature of tube i.e. for preserving its strength. Notwithstanding this it is possible, that a part of it will be melted, oxidized and washed away along with gases and vapors. Perhaps for avoiding this, the internal part of the tube will be lined with some special fireproof material : with carbon, tungsten or with something else. Although part of carbon at this tage will burn down, but the strength of the metallic tube, less heated, cannot suffer from it.

Gas-forming combustion product of carbon carbonic acid only reinfores the ascent of the rocket. A kind of cruicible material. Some mixture of substances may be used. In any case, it is not for me to decide these question, as others, pertaining to reactive devices.

In many cases I am compelled only to surmise or suppose. I am not at all deceived and excellently know, that not only the fact that I do not decide the question to its entirety, but to work 1000 times more than I had worked earlier on that which still remains. My aim is to stimulate interest in it, pointing to its great importance in future and to the possibility of its solution ....

At present time the conversion of hydrogen and oxygen into a liquid does not represent any particular difficulty. One can replace hydrogen by liquid or by hydrocarbons concentrated into liquid for example acetylene or naphtha, etc. These liquids must be separated by a partition. Their temperature is extremely low, therefore, it is useful to cover them either by casings with the circulating metal or directly the tubes themselves.

Experience will show, how to do better. Several metals become stronger by cooling : then such metals are necessary to use, for example copper. But I remember well, in some experiments on resistance, it appears, iron*)

*) In general the elongation of metals at very low temperatures, remarkably decreases, but the resistance to ruputure increases to a large degree. (Editorial Board).

in liquid air pointed out to the fact, that its viscosity at this low temperature increases almost by ten times. I do not guarantee for the truth of this, but these experiments in a way also the ordinary guns, before firing from them; while liquid air nowadays is such a common thing).

Liquid oxygen and hydrogen pumped out from their reservoirs and supplied in known ratio into the narrow beginning of the tube, connecting here a little, may give excellent explosive material. The water vapor obtained during the chemical combination of these liquids at ter-ribly high temperature will get expended, moving towards the end or the opening of the tube till the time it will cool down to such a degree that it will turn into liquid, the apparently non-existing thin mist in the direction of the length of the tube towards its outlet (funnel).

19. Hydrogen and oxygen in gaseous state, combining for the formation of 1 kilogram of water develop 3825 small calories. By the word "Calorie" we here understand the quantity of heat, required for heating up to 1°C one kilogram of water.

This quantity of (3825) with us will be a little less, if oxygen and hydrogen are in the liquid and not the gaseous state, to which pertains the number of calories given by us. In fact, liquids are required in the first instance to heat up, secondly, turn into the gaseous state, on which some energy is spent. In view of the insignificant magnitude of this energy in comparison with the chemical energy we shall abandon our quantity without any loss (this question has not completely been elaborated by Science, but we take hydrogen and oxygen only for an example).

Taking the mechanical equivalent of heat as 427 kilogram, M we find that 3825 calories correspond to the work at 1633 kg/km; this is sufficient for the uplift of the products of explosion i.e. 1 kilogram of the substance to an altitude of 1633 kilometers from the surface of the Earth's globe, assuming the force of gravity as constant. This work, converted into motion, corresponds to the energy of 1 kilogram of mass, moving with a velocity of 5700 M/sec. I do not know a single group of bodies which on their chemical combination should evolve for a unit of mass of the obtained product such an enormous quantity of energy. Besides several other substance, on combining do not form volatile products, which fact is wholly unsuitable forms. Thus, Silicon, burning in oxygen ($Si + O_2 = SiO_2$), releases enormous quantity of heat, namely, 3654 small calories for a unit mass of the obtained product (SiO_2) but, to out regret, bodies formed do not become easily volatile.

Having taken liquid oxygen and hydrogen for our material, most suitable for explosion I gave the quantity for the term of their mutual chemical energy coinciding with the unit of mass of the obtained product (H_2O), somewhat more virtual, since the combination taking place in the rocket, must be in liquid and not in gaseous state, and besides, that, at very low temperature.

I consider it relevant here to console the reader, that not only on this (3825 calories), but also on incomparably large energy we can hope in the future, when perhaps we find it possible to substantiate our still insufficiently worked out concepts. In fact, examining the quantum of energy, obtained from the chemical processes of different substances, we note in general, not without exception, of course, that the auantum of energy, spent on unit of mass of the products of combination, depends on atomic weights of the ordinary combining less the atomic weights of the bodies the more the heat they release bodies, at the time of their combination. Thus, during the formation of sulphur dioxide gas (SO_2) only 1250 calories are formed, while during the formation of Cupric Ocide (Cuo) only 546 calories; meanwhile as carbon on the formation of carbonic acid (Co_2) releases on the unit of its mass 2204 calories, hydrogen with oxygen, as we have seen, releases still more (3825 calories).

For the evaluation of these data in use for the idea put forward by me, I immediately recollect the magnitude of the atomic weights of the cited elements; Hydrogen - 1; Oxygen 16, Carbon - 12; Sulphur 32; Silicon 28; Copper - 63.

Of course, one can refer to many exceptions from this rule, but in general it holds. In reality, if we imagine a number of points, the abscissae of which express the sum (or product) of atomic weights of the combinning simple elements, while ordinates corresponding the energy of chemical combination then passing through the points (possibly closer to it) smooth curves, we shall see continuous decrease of the abscissae, which proves our view.

Therefore, if sometimes the so called simple bodies prove to be complicated and they are spread on new elements, then the atomic weights of the last must be less than those of the simple bodies, known to us.

The newly discovered elements as previously, must release incomparably larger quantity of energy on their combination, than the bodies, considered now conditionally simple and having comparatively large atomic weight.

The very existence of ether with its almost infinite elasticity and enormous speed of its atoms points to the infinitely small atomic weight of these atoms and limitless energy in case of their chemical combination.

20. However that may be for the time being for V_1 (see 15 and 19) we cannot accept more than 5700 M/sec. But with the pass age of time, who knows, perhaps, this number will increase several times ?.

Taking 5700 M/sec we may, according to formula (16) calculate not only the ratio of velocities $\frac{V}{V_1}$, but also absolute value of final (highest) velocity V of the rocket depending on the ratio $\frac{M_2}{M_1}$.

21. From formula (16) it is seen that the mass of rocket with all the passengers and all the devices M_1 may be arbitrarily large and the velocity V of the missile due to this is not at all lost, if only the reserve of explosive substances M_2 grew proportionately to the growth of the mass M_1 of the rocket.

In this way, all sorts of magnitudes of the missile with any number of travellers may acquire velocity of the disired magnitude. However, the growth of velocity of the rocket is accompanied, as we have seen, by incomparably quick growth of mass M_2 of explosive substances. Therefore, how much possible easy and is the growth of mass of the missile being uplifted in the void of the sky, so much embarrassing is t e increase of its velocity.

Velocities of flight depending on the consumption of fuel.

22. By equation (16) we shall obtain the following table.

$\frac{M_2}{M_1}$	$\frac{V}{V_1}$	Velocity V Meters/Sec.	$\frac{M_2}{M_1}$	$\frac{V}{V_1}$	Velocity V Meters/Sec.
0.1	0.095	543	7	2.079	11800
0.2	0.182	1 037	8	2.197	12500
0.3	0.262	1 493	9	2,303	13100
0.4	0.336	1 915	10	2.393	13650
0.5	0.405	2 308	19	2.996	17100
1	0.693	3 920	20	3.044	17330
2	1.098	6 260	30	3.434	19560
3	1.386	7 880	50	3.932	22400
4	1.609	9 170	100	4.615	26.280
5	1.792	10 100	193	5.268	30038
6	1.946	11 100	Infinite.	—	Infinite.

23. From the table we discover that the velocities acquired by the reactive method, are not far very small. Thus, in the presence of the mass of explosive substances, 193 - times exceeding the weight M_1 of the missile (rocket), its velocity at the end of the explosion and the consumption of the entire reserve M_2 is equal to the velocity of the motion of the Earth around the Sun. Do not think, that such an enormous mass of explosive material requires for its preservation enormous quantity of durable material for containers, holding explosive elements. In reality hydrogen and oxy en in the liquid state display high pressure only when the containers, holding them, are closed and when the gases themselves underthe influence of the comparatively warm surrounding bodies, are heated up. With us too these liquified gases must have free outflow into the tube (apart from their continuous intake there in liquid state), where they explode after combining chemically,

The continuous and quick flow of gases, corresponding to the evaporation of liquids, cools down these liquids till the moment that they with their own vapors do not produce any pressure whatsoever on the walls surrounding them. Thus, for preserving the elements of explosion a large mass of substances is not required in the containers.

24. When the reserve of explosive substances is

equal to the mass of the rocket ($\frac{M_2}{M_1} = 1$), the velocity of the latter is nearly twice more than that which is required for a stone or cannon missile, launched "by Selenites" from the surface of our Moon, so as permanently to separate from it and become a Satellite of the Earth, a second Moon.

This velocity (3920 meters / sec) is almost sufficient for permanent separation of the bodies, flung from the surface of Mars or Mercury.

If the ratio $\frac{M_2}{M_1}$ of the masses will be equal to three, then, on the consumption of the entire reserve, such a velocity of the missile will already be obtained which is only a little insufficient for the fact, that it could revolve around the Earth similarly to its Satellite, beyond the limits of the atmosphere.

On the ratio $\frac{M_2}{M_1}$, being equal to six, the velocity of the rocket is almost sufficient for its removal from the Earth and permanent revolution around the Sun in the capacity of an independent planet. In case of a large quantity of explosive reserve, achievement of the region of asteroids and even of heavy planets is possible.

25. From the table it is evident, that in case of a small reserve of explosive substances, the final velocity of the missile is still sufficient for practical purposes.

Thus, on a reserve, comprising only 0.1 of the weight of the rocket, the velocity is equal to 543 meters / second, which is sufficient for lifting of the rocket to 15 kilometers. Furthermore, from the table we observe, that during an insignificant reserve the velocity at the end of explosion is approximately proportional to the mass of the reserve (M_2); consequently in this case, the altitude of uplift is proportional to the square of this mass (M_2) of the reserve. Thus, on a reserve comprising half of the mass of rocket $\frac{M_2}{M_1} = 0.5$, the latter will fly far beyond the limits of the atmosphere.

COEFFICIENT OF USEFUL WORK (UTILIZATION) OF THE ROCKET ON ASCENT.

26. It is interesting to determine, what portion of the overall work of explosive substances i.e. their chemical energy is transmitted to the rocket.

The work of the explosive substances will be expressed by $\frac{V_1^2}{2g} M_2$, where g is the acceleration of the Earth's pull; the mechanical work of the rocket, having velocity V, will be expressed in those very units: $\frac{V_2}{2g} M_1$, or on the basis of formula (16).

$$\frac{V^2}{2g} M_1 = \frac{V_1^2}{2g} M_1 \left[\ln \left(1 + \frac{M_2}{M_1}\right)\right]^2$$

Dividing now the work of the rocket by the work of the explosive material,

$$\frac{M_1}{M_2}\left[\ln\left(1+\frac{M_2}{M_1}\right)\right]^2 .$$

According to this formula, we shall calculate the table of utilization of rocket energy of the explosive substances (see table).

$\frac{M_2}{M_1}$	Utilization.	$\frac{M_2}{M_1}$	Utilization	$\frac{M_2}{M_1}$	Utilization
0.1	0.090	4	0.65	19	0.47
0.2	0.165	5	0.64	20	0.46
0.3	0.223	6	0.63	30	0.39
0.4	0.282	7	0.62	50	0.31
0.5	0.328	8	0.60	100	0.21
1	0.480	9	0.59	193	0.144
2	0.600	10	0.58	Infinite	Nil.
3	0.64				

From the formula and table it is evident, that in the presence of very small quantities of explosive material its utilization is equal to $\frac{M_2}{M_1}$, i.e. the smaller the utilization the smaller is the relative quantity of explosive materials.*)

Furthermore, with the increase of the relative quantity of explosive substances utilization grows and approximately on quadrouplicate of their quantity (comparatively with the mass of the rocket) it attains the highest value (0.65).

The subsequent increase of the explosive substances even though slowly but continuously decreases their usefulness; when their quantity is infintely large, the usefulness is nil, and similarly so when it is infinitely small. From the table we also see, that on the change of ratio $\frac{M_2}{M_1}$, from 2 to 10. the utilization is more than half; this means that more than half of the potential energy of the explosive material in such a case is transmitted, in the form of kinetic energy, to the rocket. In general, from 1 to 20 it is highly large and close to 0.5.

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* In reality $(1 + x) = x - \frac{x^2}{2} + \frac{x^3}{3} - \frac{x^4}{4}$, therefore,

Approximately = $\frac{M_1}{M_2}\left[1n\left(1 + \frac{M_2}{M_1}\right)\right]^2 = \frac{M_1}{M_2}\,\frac{M_2^2}{M_1^2} = \frac{M_2}{M_1}$.

ROCKET UNDER THE INFLUENCE OF GRAVITY.

VERTICAL ASCENT.

27. We have found out that the velocity, acquired by the rocket in vacuum and in the absence of the force of gravity depends on the mass of the rocket, the mass of explosive substances and the energy of their chemical combination.

Now we shall analyze the effect of the permanent force of gravity on the vertical motion of the missile.

We see, that without the effect of gravity, gigantic velocities are acquired by the rocket and significant quantity of the energy of explosion is utilized. This will be true also for the medium of gravity, if the explosion is only monentary. But such an explosion is not suitable, for us because, upon this, a fatal jerk will be felt, which will take away neither the missile, nor things nor the people accommodated in it. Obviously we require a slow explosion; on a slow explosion, the useful effect decreases and even may be come nil.

Indeed, let the explosion, be so much weak that the acceleration of the rocket, taking place as a results of it, will be equal to the acceleration g of the Earth. Then the missile in the entire duration of explosion will stand in the air motionless without support.

Of course, it does not at this stage acquire any velocity and the utilization of explosive substances, notwithstanding their quality, will be equal to nil. Thus, it is extremely important to investigate the analytical effect of gravity on the missile.

Determination of the acquired velocity Review of the obtained numerical values. Altitude of the lift.

When the rocket moves in a medium free from the force of gravity, the time t, in the direction of which the entire reserve of explosive substances explodes, is given by .

28

$$t = \frac{V}{p} ,$$

where V is the velocity of the missile at the end of explosion, and p the constant acceleration, communicated to the rocket by the explosive materials in 1 second of time *).

*) It is assumed, that the mass of the rocket changes according to he exponential rule; then the acceleration p, conditioned by reactive force, will be constant (Editorial Board).

The force of explosion, i.e. the quantity of the substances, consumed during the explosion in a unit of time, in this simplest case of evenly accelerated motion of the missile, is not constant, it continuously decreases proportionately to the decrease of mass of the missile with the residue of unexploded materials.

29. Knowing p, or the acceleration in the medium without gravity, we can express the value of the apparent (temporary) gravity inside the rocket in the duration of its accelerating motion, or in the duration of the time of explosion.

Taking the force of gravity on the surface of the Earth for unit, we shall find out the value of temporary gravity in the missile, equal to $\frac{p}{g}$, where g is the terresterial acceleration; this formula shows as to how many times the pressure on the support of all things, accommodated in the rocket, is more than the pressure of those very things, lying on the table in our room in ordinary conditions. Highly important to know is the value of the relative gravity in the missile, because it stipulates intactness of the devices and the health of the persons set in motion on the way for the study of the unknown space.

30. During the effect of constant or variable gravity of any force the time, in the duration of which one and the same reserve of explosive material is consumed,

will be the same, as it is without the effect of gravity; it will be expressed by the formula (28) known to us, or by the following:

31.
$$t = \frac{V_2}{p - g},$$

where V_2 is the acceleration of rocket at the end of explosion in the medium of gravity with constant acceleration g. Here, of course, it is assumed that p and g are parallel and opposite ; p - g expresses the apparent acceleration of the missile (relative to the Earth), being the result of two opposing forces; the force of explosion and the force of gravity.

32. The effect of the latter on the missile in no way, whatsoever influences the relative gravity in it and it is expressed without any change by the formula (29) $\frac{p}{g}$. For example if p = 0, i.e. if there is no explosion then there is also no temporary gravity, because $\frac{p}{g} = 0$. This means, that if the explosion will stop and the missile with move in one or the other direction only under the influence of its own velocity and the force of gravity of the Sun, Earth and other stars and planets, then the observer accommodated in the missile himself will not have, apparently, the least weight and will not discover it with the help of the most sensitive spring balance, neither in any of the objects, found on

his person or in the rocket. Falling or getting up in it (rocket) under one's own momentum, even on the very surface of the Earth, the observer will experience not even the least gravity, until, of course, the missile meets some inpediment in the form, for example, of the atmosphereic resistances, water or hard ground.

33. If $p = g$ i.e. if the pressure of the exploding gases is equal to the gravity of the missile ($\frac{p}{g} = 1$), then the relative gravity will be equal to the Earth's. During the initial immobility, the missile in this case will remain stationary in the whole duration of explosion; if up to this time the missile had any velocity (upwards, lateral, downwards), then this velocity will remain as such without any change, unless the weight of the explosive material is consumed : here the body i.e. the rocket, is equilibrated and move s as if under its own momentum in the medium, free from gravity. On the basis of the formulae (28) and (31), we obtain

34.

$$V = V_2 \left(\frac{p}{p - g} \right) .$$

From there, knowing, what velocity V_2 the missile must have at the end of the explosion, we shall calculate V, according to which with the formula (16) we shall calculate the required quantity M_2 of the explosive substances.

From the equation (16) and (34) we shall obtain

35.

$$V_2 = V_1 \left(1 - \frac{g}{p}\right) \ln\left(\frac{M_2}{M_1} + 1\right).$$

36. From this formula, as from the previous one, it follows, that the velocity acquired by the rocket, is less during the effect of gravity, than without it (16). The velocity V_2 may be even nil, notwithstanding the abundance of the explosive reserve, if $\frac{p}{g} = 1$ i.e. if the acceleration communicated to the missile by the explosive material is equal to the acceleration of the earth's gravity, or the pressure of gases is equal and directly opposite to the effect of gravity [see the formulae(34) and (35)] .

In this case the rocket stands stationary for several minutes not in the least ascending; when the reserve is run out, it falls down like a stone.

37. The greater p is with respect to g, the greater is the velocity V_2 that the missile acquires on the given quantity of M_2 of the explosive substances (formula (35).

Therefore desiring to lift ourselves higher, it is necessary to make 'p' as big as possible, i.e. to produce explosions as actively as possible. However, at this stage it is necessary, in the first instance, to have more powerful objects and devices in the missile, because according to (32) time relative gravity in it will be greatly high and especially dangerous for the living observer, if such a one is sent in the rocket.

In every case, on the basis of the formula (35) in the limit.

$$V_2 = - V_1 \cdot \ln\left(\frac{M_2}{M_1} + 1\right),$$

i.e. if 'p' is infinitely large, or the explosion is momentary, then the velocity V_2 of the rocket in the medium of ravity is the same, which is in the medium without gravity.

According to formula (30) the time of explosion does not depend on the force of gravity, and only exceptionally on the quantum of $\frac{M_2}{M_1}$ of the explosive material and the rapidity of their explosion.

39. It is interesting determine this value. we shall substitute in the formula (28 V = 11, 100 meters / second (see table 22). and p = g = 9.8 meters / sec, then t = 1133 sec.

It means, that in a medium, free from gravity, the rocket should fly with uniformly accelerated motion in less than 19 minutes and this, with a quantity of explosive substances six times the mass of the projectile (see table 22).

In case the explosion is on the surface of our planet, the projectile should continue motionless during those very 19 minutes.

40. If $\frac{M_2}{M_1} = 1$, then according to table V = 3920 meters / second; therefore t = 400 sec or $6\,^2/_3$ minutes.

When $\frac{M_2}{M_1} = 0.1$, V = 543 meters/second, and t = 55.4 seconds, that is less than a minute. In the latter case, on the surface of the Earth, the projectile should stand motionless for $55\,^1/_2$ seconds.

From here we see that explosion on the surface of a planet or generally in a medium, not free from the force of gravity, may be completely without result if it takes place eventhough for a longer time, but with insufficient force; in fact, the projectile remains at its place and will not receive any transitional velocity, if it did not acquire the same earlier; on the contrary it may make a certain motion with uniform velocity. If this motion is upwards, the projectile will do some work. In case a horizontal velocity and motion is horizontal; there will be no work*) but then the projectile may serve the same purposes, as a locomotive, steamship or guided balloon. The movement of the projectile may serve these aims only for a duration of several minutes, as long as the explosion continues, but in such a short time it traverse considerable space, especially, if it moves on the atmosphere. However, we disclaim**), practical significance of the rocket for flying in air,

The time of standing of the apparatus in the medium of gravity is inversely proportional to 'g' i.e. to the force of this gravitation.

Thus, on the Moon the apparatus should stand motionless without support when $\frac{M_2}{M_1} = 6$, for a duration of two hours.

41. Let us substitute in formula (35) for a medium with gravity g/p = 10; $\frac{M_2}{M_1} = 6$, then we shall calculate V_2 = 9990 meters/second. The relative gravity according to the foreging conclusion will be equal to 10 i.e. a man weighing 70 kilograms during the entire time of explosion (about 2 minutes) will experience gravity

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*) If the work of resistance of the atmosphere is not taken into account (Edit).

**) It should not be forgotten that this phrase was written in the year 1903, that is before the beginning of the development of aviation. This conception of Tsiolkovskiy was due to the fact that the flying apparatus with the rocket has low c.u.m. (Coefficient of useful work or efficiency). (Editorial Board).

10 times greater than on the Earth, and will weigh 700 kilograms on the spring balance. A traveller can bear such a gravity without harm only by observing special precautions: by immersing himself in a special liquid, under special conditions.

On the basis of formula (28) we shall calculate the time of explosion, or the time of this increased gravity we shall get 113 seconds that is less than two minutes. This is very small and it appears for the first time amazing, as the projectile in the duration of such an infinitesimal interval of time can acquire a velocity, almost sufficient for going away from the Earth and for moving around the Sun, similar to a new planet.

We have found that V_2 = 9990 meters per second, that is a velocity, only a little less than the velocity V, acquired in a medium, free from the force of gravitation under those very conditions of explosion (see table 22).

But since the projectile rises to a still higher altitude at the time of explosion, it comes to mind, that the total work of the explosive substances does not at all decrease, as compared with them in a medium without gravity.

44. We shall analyze this question now.

Acceleration of projectile in a medium full of action of forces of gravity is expressed by $P_1 = p - g$.

At a distance from the surface of the Earth, not exceeding several hundered versts, we accept 'g' as constant and this will not leave after it a large error, even the errior will be on the more favorable side, than those calculated by us.

The height 'h' of the ascent of projectile in the time 't' —— of the action of explosion will be

45.

$$h = \frac{1}{2} p_1 t^2 = \frac{p - g}{2} t^2 .$$

Eliminating from here t, in accordance with the equation (31) we shall obtain.

46.

$$h = \frac{V_2^2}{2(p - g)} ,$$

Where V_2 is the velocity of the projectile in the medium of gravitation during the consumption of the entire explosive reserve.

Now we shall obtain from (34) and (46) eliminating V_2 :

47.

$$h = \frac{p - g}{2p^2} V^2 = \frac{V^2}{2p} \left(- 1 - \frac{g}{p} \right),$$

where V is the velocity, acquired by the rocket in a medium, free from gravitation.

Coefficient of Useful Work (Efficiency)

The useful work of a unit of mass of the explosive substances in a medium, free from gravitation will be expressed

48.

$$T = \frac{V^2}{2g} .$$

The work T_1 in a medium of gravitation will be expressed depending on the altitude of ascent of the projectile and its velocity at the end of explosion:

49.

$$T_1 = h + \frac{V_2^2}{2g} .$$

The ratio of this work to the previous one, is ideal and is given by

50.

$$\frac{T_1}{T} = \frac{2hg + V_2^2}{V_2} .$$

Having eliminated from here h and V by the use of the formulae (46) and (34), we shall obtain

51.

$$\frac{T_1}{T} = 1 - \frac{g}{p} ,$$

that is, the work in a medium of gravitation, obtained from the specified quantity of explosive substances M_2, is less, than in a medium free from gravitation: the difference $\frac{g}{p}$ is still smaller, the quicker the gases or the greater is p. For example, in case (41) the loss comprises only 1/10, while the utilization according to (51) is equal to 0.9. When p = g or when the projectile is in the air, not having even a constant velocity, the loss will be full, while utilization will be equal to nil. Such would be the utilization, if the projectile possesses constant horizontal velocity.

52. In para 41 we calculated V_2 = 9990 meters/second. Having employed the formula (46) to the case of 41, we find

h = 565 km; it means that in the duration of explosion the projectile travels farther beyond the limits of the atmosphere and still acquire the translational velocity of 9990 meters / sec.

We shall observe, that this velocity at 1110 meters/second is less than in a medium free from the forces of gravitation. This difference comprises exactly 1/10 of the velocity in a medium without gravity (table 22).

From her: it is evident that the loss in velocity submits to the very same law asthe loss of work (51), which, nevertheless, strictly follows also from the formula (54), transforming which, we get

$$V_2 = V \left(1 - \frac{g}{p}\right),$$

or,

$$V - V_2 = V \frac{g}{p} \quad ,$$

We find from (51)

56.

$$T = T_1 \left(\frac{p}{p - g}\right) ,$$

where T_1 is work, obtained by projectile from the explosive substances in a medium of gravitation with the accleration, equal to g.

In order that the projectile could complete all the required work, ascending to the altitude, overcoming the resistance of the atmosphere and acquiring the desired velocity required so that the sum of all work equalled T_1.

When we shall determine all these works, with the help of the formula (56) we shall calculate T. Knowing T, we shall find also V, that is the velocity in a medium, free from gravitation according to the formula.

$$T = M_1 \frac{V^2}{2g} .$$

Knowing now, V, we can calculate the required mass M_2 of the explosive substances according to formula (16).

In this way with the help of the foregoing we find

57.

$$M_2 = M_1 \left[e^{\sqrt{\frac{T_1 p}{T_2 (p-g)}}} - 1 \right] .$$

Calculating, we changed for brevity $M_1 \frac{V_1^2}{2g}$ by T_2 .

Thus, knowing the mass of the projectile M_1 with all the contents, excluding the explosive substances M_2 , mechanical work T_2 of the explosive substances for their mass, equal to the mass of the projectile M_1, the work T_1 which must be done by the projectile in its vertical ascent, acceleration by he force of explosion p, and the force of gravitation g, we may find out the quantity of the explosive substances M_2, necessary for the lifting of the mass M_1 of the projectile.

The ratio T_1/T_2 in the formula does not change, if M_1 is cancelled, so that T_1 and T_2 can be considered as mechanical work T_1, done by a unit mass of the projectile, and the mechanical work T_2, by a unit of explosive sunstances.

By 'g' may be meant in general, the sum of accelerations from the forces of gravity and the forces of resistance of the medium. But the force of gravitation gradually diminishes with the recession from the center of the Earth, in consequence of which, more quantum of mechanical work of explosive substances is utilized. On the other hand, the resistance of the atmosphere, being highly insignificant compared with the gravity of the projectile , reduces the utilization of energy of the explosive substances.

Furthermore, it can be seen, that the latter loss, continuing for a short time of flight through the air, is more than compensated by the surplus obtained from the reduction of attraction at considerable distances (500 km), where the action of explosive substances discontinues.

Thus we can **boldly** apply the formula (20) to the vertical flight, not-withstanding the complication from the changes of gravity and resistance of the atmosphere.

Medium of Gravity.
Vertical Return to the Earth.

59. Let us examine in the beginning the stoppage in a medium free from gravity, or momentary stoppage in a medium of gravity.

Let, the rocket for example acquire a velocity of 10,000 meters/second by the force of explosion of some (not all) quantity of gases. Now for stopping such very velocity is required, but in the opposite direction. Evidently, the quantity of the remaining explosive substances, in accordance with table 22, must be 5 times larger than the mass M_1 of the projectile. Consequently, the projectile must have at the end of the first part of explosion (for obtaining) translational velocity) reserve of the explosive substances, the mass of which will be expressed by $5\ M_1 = M_2$.

60. The entire mass along with the reserve will comprise $M_2 + M_1 = 5\,M_1 + M_1 = 6M_1$. The initial explosion must also impart to this mass $6M_1$ a velocity of 10,000 meters/second but for this is required a fresh quantity of explosive material which must likewise 5 times (see table 22) exceed the mass of the projectile with the mass of reserve for stopping, that is, we must increase 6M1,5 times; we shall get 30 M_1 which along with the reserve for stopping 5M1 comes to 35 M_1.

Having denoted the number from table 22, showing as to how many times the mass of explosive material is larger than the mass of the projectile, by $q = \frac{M_2}{M_1}$, the previous calculations, determining the mass of the entire explosive substance $\frac{M_3}{M_1}$ for acquiring a velocity and its suppression, we shall express thus :

61. $$\frac{M_3}{M_1} = q + (1 + q)\,q = q\,(2 + q),$$

or, by adding and substracting unity from the second part of the equation, we shall get

$$\frac{M_3}{M_1} = 1 + 2q + q^2 - 1 = (1 + q)^2 - 1,$$

thereby

62. $$\frac{M_3}{M_1} + 1 = (1 + q)^2.$$

The latter expression is easy to remember.

When q is very small, the quantity of explosive substance is approximately equal to 2q (because q^2 will be negligble), i.e. it is twice, what is needed to acquire velocity alone.

63. On the basis of the formulae obtained and table 22, we shall compile the following table.

From this table we see, how inadmissibly enormous is the reserve of explösive material which is needed, if we want to acquire a large velocity and then lose it.

In a medium without gravity.

V Meters per second.	$\frac{M_2}{M_1}$	$\frac{M_3}{M_1}$	V Meters per second.	$\frac{M_2}{M_1}$	$\frac{M_3}{M_1}$	V Meters per/sec.	$\frac{M_2}{M_1}$	$\frac{M_3}{M_1}$
543	0.1	0.21	9170	4	24	17 100	19	399
1037	0.2	0.44	10100	5	35	17 330	20	440
1493	0.3	0.69	11100	6	48	19 560	30	960
1915	0.4	0.96	11800	7	63	22 400	50	2600
2308	0.5	1.25	12500	8	80	26 280	100	10200
3920	1	3	13100	9	99	30 038	193	37248
6260	2	8	13650	10	120	Infinite.	-	Infinite
7880	3	15						

From (62) and (16) we have

$$\frac{M_3}{M_1} + 1 = e^{\frac{-2V}{V1}} ,$$

or

$$\frac{M_3}{M_1} = e^{\frac{-2V}{V_1}} - 1.$$

It will be noted that the ratio $-\frac{2V}{V_1}$ is positive because the velocities of the projectile and gases are in opposite directions and, consequently have different signs.

64. If we find outselves in a medium of gravitation, then in the simplest case of vertical motion the process of stopping and descent to the Earth will be as follows: When the rocket has ascended up to a certain altitude and has stopped, under the influence of the acquired velocity, then its fall towards the Earth starts.

When the projectile reaches the point at which the action of the explosive substances during the ascent has stopped, it will be subjected again to the action of the remainder of the explosive substances in that very direction and order. Evidently, at the end of their action and the consumption of the reserve, the rocket will stop at that very point on the surface of the Earth, from which the ascent had started. The method of ascent is strictly identical with the method of descent; the entire difference is only in the fact, that the velocity is reverse at each point of the journey.

Stopping in the gravitational field requires more work and more explosive substances, than in a medium, free from gravitation, and for this reason 'q' (in formulae (61) and (62)) must be greater.

Denoting this greater ratio by q_1, we find, on the basis of the foregoing,

65.

$$\frac{q}{q_1} = \frac{T_1}{T} = 1 - \frac{g}{p} ,$$

whence

$$q_1 = q \left(\frac{p}{p - g} \right) ;$$

substituting q_1 in place of q in equation (62), we obtain

66.

$$\frac{M_4}{M_1} = (1 + q_1)^2 - = \left(1 + \frac{pq}{p - g}\right)^2 - 1.$$

Here M_4 denotes the quantity or mass of explosive substances necessary for the lift of the rocket from a known point and return to that very point, to a total stop and during its flight is a medium of gravity.

67. On the basis of the last formula we can compile the following table, assuming, that $\frac{p}{g} = 10$, that is, that the pressure of the explosive material is 10 times more of the gravity of the rocket with the remainder of the explosive substances. In this table V expresses the work proper, $\frac{V^2}{2g}$, the very velocity will be less because part of this work was spent on the lift in a medium of gravitation.

For a Gravitational Field

V Meters/sec.	$\frac{M_2}{M_1}$	$\frac{M_4}{M_1}$	V Meters/sec.	$\frac{M_2}{M_1}$	$\frac{M_4}{M_1}$
543	0.1	0.235	7 880	3	17.78
1493	0.3	0.778	9 170	4	28.64
2308	0.5	1.420	10 100	5	41.98
3920	1.0	4.457	11 100	6	57.78
6260	2	9.383	11 800	7	76.05

Gravitational Medium. Inclined Ascent.

68. Although the vertical motion of the rocket would seen to be advantageous, because, by it, the atmosphere is traversed in a shorter time and the projectile ascends to a greater altitude, however, on the one hand, the work of traversing the atmosphere, compared with the total work of the explosive substances, is highly insignificant, on the other, in inclined motion, one can set up a permanent observatory, moving beyond the limits of the atmosphere for an indefinitely long time about the Earth, like its Moon. Besides, and this is an important thing-during the inclined flight incomparably greater part of the energy of explosion is utilized than during the vertical motion.

Let us first consider a particular case - the horizontal flight of the rocket.

If by R (fig. 2) we designate the value of the resultant of horizontal acceleration of the rocket, by p - the acceleration on account of the action of explosion and by g- the acceleration due to the force of gravity, then we have

69.

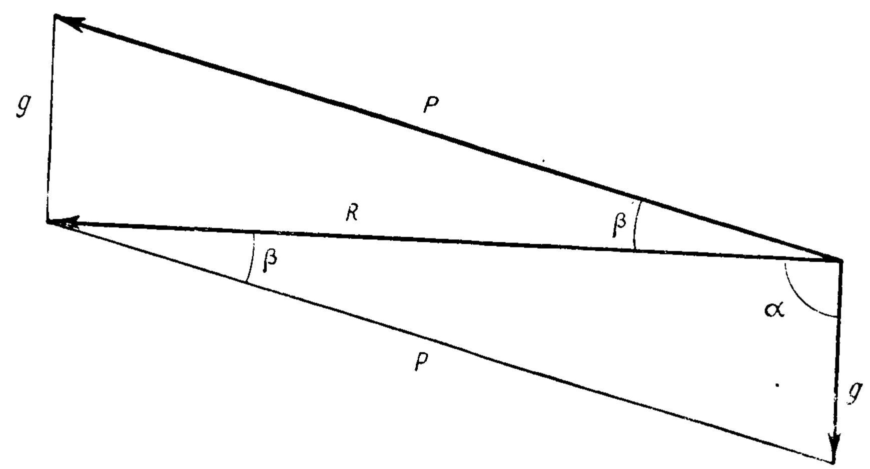


Figure 2.

....

70.

$$R = \sqrt{p^2 - g^2} .$$

The kinetic energy, obtained by the projectile in time t is, on the basis of the preceding formula equal to :

71.

$$\frac{R}{2}\, t^2 \left(\frac{R}{g}\right) = \frac{R^2}{2g}\, t^2 = \frac{p^2 - g^2}{2g}\, t^2 ,$$

Where t is the time of explosion. It is the total useful work acquired by the rocket. Indeed, the rocket does not rise in the least, if we take the direction of gravity, as constant (which in practice is true only for a small trajectory of the projectile). The work of the explosive substances, acquired by the rocket in a medium, free from gravity is equal to

72.

$$\frac{p}{2} t^2 \frac{p}{g} = \frac{p^2}{2g} t^2 .$$

Dividing the useful work (71) by the total work (72), we get the utilization for the horizontal flight of the rocket

73.

$$\left(\frac{p^2 - g^2}{2g} t \right) : \left(\frac{p^2}{2g} t \right) = 1 - \left(\frac{g}{p} \right)^2 .$$

The resistance of air, as before, has still not been taken into the calculation.

From the latter formula it is seen, that the loss of work as compared with the work in a medium, free from the force of gravitation, is expressed by $\left(\frac{g}{p} \right)^2$. From here it follows, that this loss is much less, than during the vertical motion. For example, when $\frac{g}{p} \equiv \frac{1}{10}$ the loss comprises $\frac{1}{100}$ i.e. 1 %, yet in vertical motion it was expressed by $\frac{g}{p}$ or equal to 1/10 i.e. 10%.

74. Here is a table, where β is the angle of inclination of acceleration p to the horizon.

Horizontal Motion of the Rocket.

$\frac{p}{g}$	$\left(\frac{g}{p}\right)^2$	$\frac{g}{p}$	$\beta°$	$\frac{p}{g}$	$\left(\frac{g}{p}\right)^2$	$\frac{g}{p}$	$\beta°$
1	1	1	90	5	1: 25	1 : 5	11.5
2	1:4	1:2	30	10	1: 100	1 ; 10	5.7
3	1 :9	1:3	19.5	100	1: 10000	1 : 100	0.57
4	1 :16	1:4	14.5				

Inclined Ascent. Work of Ascent with respect to the work in a medium without gravitation. Losses of work.

75. Let us now solve the question in general - during any inclination of the resultant R. Horizontality of trajectory (orbit) or of the resultant is not suitable

because in such a motion the projectile terribly increases its path in the atmosphere, and along with that the work of cleaving the air also increases.

Thus, we shall remember, that α , or the angle of inclination of the resultant to the vertical, is more than a right angle; we have

76.

$$R = \sqrt{p^2 + g^2 + 2pg \cos \gamma},$$

where $\gamma = \alpha + \beta$ (obtuse angle of parallelogram) in the diagram .

Further,

77.

$$\gamma = \alpha + \beta; \quad \sin \alpha : \sin \beta : \sin \gamma = p:g:R$$

78,

$$\cos a = \frac{R^2 + g^2 - p^2}{2Rg} \quad .$$

The kinetic work is expressed by formula (71), where R is determined accordin to equation (76). The vertical acceleration of the resultant R is equal to

79.

$$R_1 = \sin (a - 90^o) R = - \cos aR.$$

Hence, the work of lifting the projectile will be

80.

$$\frac{R_1}{2} t = \frac{-\cos\alpha}{2} Rt^2,$$

where t is the time of explosion of the entire reserve of explosive substances. The whole work, acquired by the projectile in a medium of gravitation (on the basis of 71 and 80) is :

81.

$$\frac{R^2}{2g} t^2 + \frac{-\cos\alpha}{2} Rt^2 = \frac{Rt^2}{2} \left(\frac{R}{g} - \cos\alpha \right).$$

Here, unit of work, is taken as the lifting of the projectile per unit of altitude in a medium with an acceleration 'g'. If $\alpha > 90^\circ$, for example in the case of lifting of the projectile, then Cos α is the positive quantity, and conversely.

Work in a medium, free from gravitation, will be equal, according to (72), to $\frac{p^2}{2g}$ t^2 (we should not forget, that the time of explosion does not depend on the forces of gravitation).

Taking the ratio of these two quantities of work we shall get the utilization of energy of the explosive substances compared with their utilization in a medium, devoid of gravity, namely

82.

$$\frac{Rt^2}{2}\left(\frac{R}{q}-\cos\alpha\right):\left(\frac{p^2}{2g}t^2\right)=\left(\frac{R}{p}\quad\frac{R}{p}-\frac{g}{p}\quad\cos\alpha\right).$$

Eliminating 'R' from here according to formula (76,) we find

83.

$$1+\frac{g^2}{p^2}+2\cos\gamma\frac{g}{p}-\cos\alpha\frac{g}{p}\quad\sqrt{1+\frac{g^2}{p^2}+2\cos\gamma\frac{g}{p}}.$$

Formulae (51) and (73), for example, constitute only the particular cases of this formula, which will be easily elucidated.

84. We shall immediately make use of the formula established. Suppose, that the rocket flies upwards at an angle of 14.5° to the horizon; the sign of this angle will be 0.25; this means that the resistance of the atmosphere increases four times as compared with its resistance

during vertical motion of the projectile, for its resistance is approximately inversely proportional to the sine of the angle of inclination ($\alpha - 90^{\circ}$) of the trajectory of the rocket to the horizon.

85. The angle $\alpha = 90 + 14\frac{1}{2} = 104\frac{1}{2}^{\circ}$; Cos α = 0.25 ; knowing α , we can find β . **Indeed, from (77) we find**

$$\sin \beta = \sin \alpha \frac{g}{p} \quad ;$$

Thus, if $\frac{g}{p} = 0.1$, then

$$\text{Sin}\, \beta = 0.0968; \; \beta = 5\frac{1}{2}^{\circ} \; ,$$

whence,

$$\gamma = 110^{\circ} \; ; \quad \cos \gamma = 0.342.$$

Now, according to formula (83) we calculate the utilization as 0.966. The loss comes out to 0.034, or about 1/20, more precisely 3.4 %.

This loss is less than one third than during vertical motion. This is not bad, if we lso take into account, that the resistance of the atmosphere and in case of inclined motion (14 1/2 %) in no case more than 1 % of the work of sending away the projectile from the Earth.

86. For different reasons we put forward the following table. The first column shows the incline of motion to the horizon, the last the loss of work; β is the deviation of the direction of pressure of the explosive substances from the line of actual motion (69).

Inclined Motion.

Degrees				Utilization	Loss.
$\alpha - 90$	α	β	$\gamma = \alpha + \beta$		
0	90	5 3/4	95 2/3	0.9900	1 : 100
2	92	5 2/3	97 2/3	0.9860	1 : 72
5	95	5 2/3	100 2/3	0.9800	1 : 53
10	100	5 2/3	105 2/3	0.9731	1 : 37
15	105	5 1/2	110 1/2	0.9651	1 : 29
20	110	5 1/3	115 1/3	0.9573	1 : 23.4
30	120	5	125	0.9426	1 : 17.4
40	130	4 1/3	134 1/3	0.9300	1 : 14.3
45	135	4	139	0.9246	1 : 13.3
90	180	0	180	0.9000	1 : 10

87. For very small angles of inclination ($\alpha - 90^\circ$), formula (83) may extraordinarily be simplified, having replaced and the trigonometric values by their arcs and having made other simplifications.

Then we shall get the following expressions for the loss of work.

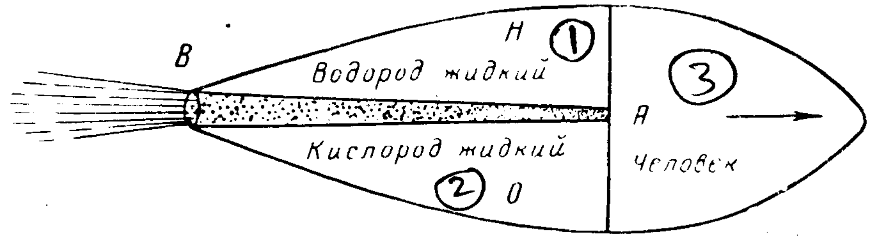
$$x^2 + \delta x\left(1 - \frac{x^2}{2}\right) + \delta^2 x^2 \left(x - \frac{\delta}{2}\right),$$

where δ denotes the angle of inclination of motion ($\alpha - 90^\circ$), expressed by the length of its arc, the radius of which is equal to unity, and x is the ratio g/p Dropping in the latter formula the infinitesimals of higher orders, we shall obtain, expression for the loss

$$x^2 + \delta x = \left(\frac{g}{p}\right) + \delta \frac{g}{p} \quad .$$

We can put $\delta = 0.002N$, where 0.02 is the part of the circle corresponding almost to one degree (1 1/7), while N is the number of these new degrees. Thus, the loss of work, will be expressed approximately.

$$\frac{g^2}{p^2} + 0.02 \frac{g}{p} N.$$



According to this formula it is easy to compile the following table, having substituted

$$\frac{g}{p} = 0.1.$$

N	0	0.5	1	2	3	4	5	6	10
Loss	$\frac{1}{100}$	$\frac{1}{91}$	$\frac{1}{83}$	$\frac{1}{70}$	$\frac{1}{60}$	$\frac{1}{55}$	$\frac{1}{50}$	$\frac{1}{45}$	$\frac{1}{33}$

From here we see, that even for large angles (upto 10°) the discrepancy between this table and the preceding one, (more exact) is small.

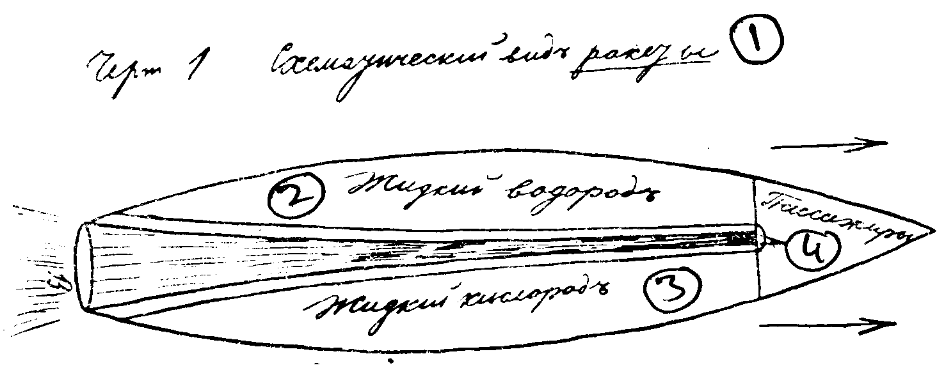


Figure I. Schematic appearance of rocket. Own hand drawing of K.E. Tsiolkovskiy relating to the period of preparation for the press. "Researches of the year 1903".

Keys: 1) Schematic Appearance of rocket. 2) Liquid Hydrogen 3) Liquid oxygen 4) Passengers.

We could have examined still much more: the work of gravitation, resistance of the atmospher; we have still not said anything at all about how a researcher may stay for a protracted period even: for an indefinitely long time in a medium, where there is no oxygen. We have not mentioned the heating of the projectile during its short-time flight in air, we even did not give a general picture of the flight and the attendant to it extremely interesting pehnomena (theoretical). We have hardly pointed out to the great perspectives in case of accomplishment of the task, for which we have only hazy sketches. Eventually, we could have traced out cosmic curves of motion of a rocket in celestial space.

Initially printed in the journal "Scientific Review" of the year 1903, No. 5 under the heading, "Investigation of Outer Spaces by Reactive (jet) Instruments" In the year 1924 the article was published as a separate brochure at KALUGA under a new heading "Rocket in Cosmic Space", K.E. Tsiolokovsky considered his work "Investigation of Outer Spaces by reactive (jet) Instruments" Part II ("Investigations of the years of 1911 - 1912 ".) as a continuation of this article. (Editorial Board).

Investigation of outer spaces by rocket devices
(1911).

Summary of work 1903.

Working on the theory of jet device since 1896, we arrived at the following conclusions.

The projectile has outwardly the appearance of a featherless bird, easily splitting air (fig. 1).

The larger part of the interior of the projectile is occupied by two substances in fluid state : hydrogen and oxygen. Both the fluids are separated by a partition and mix little by little. The remaining portion of the chamber, of small capacity, is meant for the accommodation of the observer and different varieties of apparatus, required for the preservation of his life, for scientific observations and for the control of the rocket.

Hydrogen and oxygen mixing in the narrow portion of the continuously widening tube, unite chemically and form water vapor at a terribly high temperature. It has enormous elasticity and escapes from a wide hole of the tube longitudinal axis of the chamber.

Turning of the end of funnel or the control before it serve as the simplest method of controls of rocket.

The energy of chemical combination of hydrogen with oxygen is enormous. A considerable part of it, precisely up to 0.65 (65%) is **transmitted** to the rocket, i.e., goes over to the energy of its motion. The remaining part (35%) goes to the movements of water vapor. Such a substantial part of energy of explosives is assimilated by the rocket in the medium, free from gravitation; in the medium of gravity such an assimilation may be only during momentary explosion, totally unsuitable in practical relationship. The slower the explosion is the longer it continues in the medium of gravity and the more powerful is the latter, and the less is the utilization of energy of explosives.

Popular - Scientific illustrated journal

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Investigation of outer spaces by reactive devices

Reactive device "Rocket" of K. Tsiolkovskiy.

Introduction:

For a long time I saw as all others, at the rocket from the point of view of amusement and small applications.

I do not remember well how it occurred to me to make the calculations relating to the rocket.

It seems to me that the first seeds of the idea were thrown by the dreamer Jules Verne. He pierced through the working of my mind in the known direction. Desires sprang up; behind the desires sprang up the activity of mind, which of course, could have led to nowhere if help had not been forthcoming from science.

Besides it seems to me - probably erroneous that - the principal idea and love, a permanent aspiration to be there - to the Sun, to the liberation from the chains of gravitation - were ingrained in me almost from my birth. At least, I perfectly remember that my favorite dream from very early childhood, even before books, was vague consciousness about a medium with gravity where movement in all directions is completely free, where one is better than a bird in the air. Where from did these desires come ? I hitherto cannot understand, there were no tables, and I vaguely believed and felt and desired precisely such a medium without a way of gravitation.

An old page, in my manuscripts, with final formulae relating to the reactive device has been dated August, 25 1898. Evidentally, I was engaged on them earlier. But it was not an insignificant flight of rocket which enchanted me, they were exact calculations. My calculations and conclusions were made public in 1903 (2) The present work is a development of that. But since printed work is less known to any one I have prepared a resume here and even its most important formulae.

God forgive me if I pretend to the solution of the question. In the beginning, inescapably go ...

From the Editor's office. 1) Below we reproduce the interesting work of one of the great theoreticians of air navigation in Russia. K.E. Tsiolkaskiy devoted to the question of the reactive devices and the flight in a medium beyond the atmosphere.

The author himself points to the grandeur of the idea developed by him, not only distant from realization, but still not being incarnated even in more or less concrete forms.

Mathematical calculations on which the author bases his future inferences give clear and critical view of theoretical feasibility of his ideas. But the difficulties which are unavoidable and enormous during that unusual and unknown interruption for us towards which the author aspires to penetrate in his investigations, permit us only mentally to follow the reasonings of the author.

In a letter of K.E. Tsiolkovskiy, in our knowledge, the author sees his work in this way:

I worked out several aspect of the question about the lifting into space with the help of the reactive device similar to the rocket.

The mathematical inferences based on the scientific data and verified many times point to the possibility with the help of such devices, to ascend into the celestial space (vacuum) may be to found settlements beyond the limits of the terrestrial atmosphere.

Probably hundreds of years will elapse, before the observations stated by me, find application and people are benefited by them so as to be settled not only on the face of Earth but on the entire universe. (However, the application to war affairs has already been started. Vide "Air Navigation Chronicle" No. 2 page 25, 1911.

Almost all the solar energy is lost at the present time, useless for humanity (the Earth receives two milliard times less, than the Sun emits). What is strange in the idea of utilizing this energy ! What is funny in the idea of making use of the surroundings globe of the Earth by the boundless space. At any rate- really it is erroneous to state similar ideas if they are bad for serious work.

2) Scientific Review No. 5, 1903.

K.E. Tsiolkovsky and his article.

In the present book it applies to the "Research of 1926".

In a medium without any gravity, utilization does not depend on time and order of explosion.

Owing to the accelerating motion of the rocket, an apparent (so long as the rocket is gathering acceleration), or temporary gravity develops inside it, which becomes larger as the explosion becomes faster, or greater is the pressure of vapors emerging from the pipe. This relative gravity, in its effect inside the rocket in no way differs from the natural gravity.

<u>Figure 1.</u>

1) Liquid Hydrogen.
2) Liquid Oxygen.
3) Human being.

....

The maximum utilization (65%), in a medium of gravity, as will as in a medium without gravity is obtained only when the quantity of explosive mixture exceeds the weight of the projectile, with all its contents, 4 times; on the contrary the utilization is less than 65%. For this ratio of the quantity of explosive substances to the weight of the projectile, the latter attains a velocity of up to 9 kilometers per second. The projectile can acquire an aribtarily greater or smaller velocity, but then less energy of the explosive material is utilized. This percentage of utilization is still smaller if the deviation of the relative quantity of explosive substances from number 4 is greater.

In case of a ratio of from 1 to 10 the utilization of energy is over 48%; the corresponding velocities in a medium without gravity range between 3.9 and 16. 9 kilometers per second. The latter velocity is more than sufficient for overcoming the attraction of the Sun and the Earth and the wandering of the rocket among the stars - on its launching in the direction of the annual revolution of the Earth.

In the calculations I took a ten-fold temporary gravity in the rocket but the magnitude of this gravity is in our hands and we can even make it a little but more than the terresterial gravity, particularly during inclined or horizontal ascent.

Let us imagine the absolutely impossible: we shall suppose, that for thousands or millions of kilometers, a marvellous vertical or inclined road has been built (for example, gear - operated) with cars, machines and all

K.E. Tsiolkovsky in 1910.

....

the accessories for a comfortable journey beyond the limits of the atmosphere. Ascending on it to a known altitude, we shall spend a definite amount of work. In performing the ascent with the help of some kind of engines, even the most developed for the contemporary state of technology we shall utilize not more than 10% of chemical energy of the fuel that we take with us to that height.

For ascent to such an altitude, but without stairs and hoisting machines, with the help of our projectile as we have seen, on reasonable consumption, not less than 50% of chemical energy of the union of hydrogen and oxygen is utilized. Thus, with the help of the imaginary vertical roads, at least 5 times more fuel, is consumed than in a reactive apparatus. This conclusion is correct only for ascent to an altitude not less than 700 vilometers, when a considerable part of the energy of explosive substances is utilized.

The result may be quite lamentable in case of low relative gravity and small ascent.

Such miserable reactive phenomena. We also usually observe on the Earth. That is why they could not encourage anyone to dreams and investigations. Only intelligence and science could point out towards the transformation of these phenomena in a stupendous, almost incomprehensible feelings..*)

Work of Gravitation on recession from a Planet.

By a very simple integration we can obtain the following expression for the work T, needed for sending the

*) These formulae are given in original from the article, "Investigation of outer spaces by reactive instruments 1903" "In order to avoid repetition, they have been ignored by us (Editors).

unit mass from the surface of a planet of radius r_1 to a height h :

$$T = \frac{g}{g_1} r_1 \left(1 - \frac{r_1}{r_1 + h}\right).$$

Here g denotes acceleration due to gravity on the surface of a given planet, while g_1 is the acceleration due to terresterial gravity on the surface of the Earth.

Let us suppose in this formula that h is equal to infinity. Then we shall determine the maximum work upon recession of unit mass from the surface of the planet, to infinity and shall get

$$T_1 = \frac{g}{g_1} r_1 .$$

Noting that $\frac{g}{g_1}$ is the ratio of the accelerations due to the force of gravity on the Earth, the work, needed for sending unit mass from the surface of the planet to an infinitely large distance, is equal to the work of lifting this very mass from the surface of the planetary, if we assume, that the force of gravity on it, does not decrease with the increasing distance from the surface of the planet.

From the last formula it is seen, that the limiting work T_1 is proportional to the force of gravity g_1 on the surface of the planet and to the magnitude of its radius.

For planets havings equal density i.e. for planets of one density, for example of the Earth, equal to 5.5, the force of gravity at the surface, as is known, is proportional to the radius of the planet and is expressed by the ratio of the radius of the planet r_1 to the radius of the Earth r_2.

Consequently $$\frac{g}{g_1} = \frac{r_1}{r_2}$$

and

$$T_1 = \frac{r_1}{r_2} \ r_1 = \frac{r_1^2}{r_2} \ .$$

It means, the limiting work T_1 decreases with extreme rapidity with the decrease of the radius r_1 of the planet, namely, as its surface.

Thus, if this work for the Earth ($r_1 = r_2$) is equal to r_2 , or 6 366 000 kg, m then for a planet with a diameter. ten times smaller, it is equal to 63 660 kg.m. (units of mass).

For the Earth, from a certain point of view, it is not very great. Indeed, if we consider the calorific value of petroleum at 10 000 calories, which is sufficiently correct then the energy of this combustion will be expressed as mechanical work to the time of 4270000 kg.m. per kilogram of combustible material.

It follows that for extreme recession of a unit mass from the surface of our planet, we require work, which is contained potentially, in one and a half weight units of petroleum. Thus, in application to a human being, weighing 70 kg, we shall obtain 105 kg of the quantity of petroleum.

Only the ability to make use of this powerful energy of chemical affinity is lacking.

It is now however, better understood, why the eight-fold quantity of the explosive material as compared with the weight of the projectile may help the latter overcome fully the force of the Earth's gravity.

According to Langley, a square meter, illuminated by the normal rays of Sun, gives in a minute 30 calories, or 12720 Kg. m. In order to obtain full work required for the control of 1 kg over the gravity of the Earth , it is necessary to make use of 1 square meter illuminated by the rays of the Sun, in 501 minutes, or eight and some incomplete hours.

All this is very small; but in comparison with the human endurace with the force of attraction, the latter will appear to us enormous.

Thus, let us suppose, that a man climbs to a height of 20 cm on a well - built staircase each second. Then the limiting work will be completed by him in 500 days of hard work if we allow him six hours daily for rest. In case of employing one horsepower for the lift, we reduce the work five times. In case 10 horsepower, only 10 days would be required, while during uninterrupted work - about a week.

In case of the work, which a flying aeroplane consumes, 70 horsepower is sufficient for one day.

For a majority of asteroids and for the Martian moons, this work of completely overcoming the gravity is amazingly small. Thus, the Martian moons are not more than 10 kilometers in diameter, if we take a terresterial density of 5½ for them, then the work T_1 will comprise not more than 16 kg-m. i.e. it corresponds to climbing on a birch tree 8 sajenes (1 sajene = 2.134 meters) in height. If on our Moon and on the Mars, there happened to be intelligent beings, control over the gravity for them would be much easier, than for the dwellers of the Earth.

Thus, for the Moon T_1 is 22 times less than for the Earth. On large asteriods and satellites of planets, conquest of the space, surrounding these celestial bodies, would be a trifle with the help of the reactive instruments described by me. For example, on the Vesta, T_1 is 1000 times less, than on the Earth. The diameter of Metis*) is about 100 versts, and T_1 is 15000 times less. But these are huge asteriods; the majority are 5 - 10 times smaller. For them T_1 is millions of times less, than for the Earth.

From the foregoing formulae we find for every planet

$$\frac{T}{T_1} = \frac{h}{h + r_1} = \frac{\frac{h}{r_1}}{1 + \frac{h}{r_1}} .$$

We have expressed here the work of lifting T for a height 'h' from the surface of planet of radius r_1 relative to the full maximum work T_1. According to this formulae we calculate

$$\frac{h}{r_1} = \frac{1}{10},\ \frac{1}{5},\ \frac{1}{4},\ \frac{1}{3},\ \frac{1}{2},\ 1,\ 2,\ 3,\ 9,\ 99,\ \text{Infinity}$$

$$\frac{T}{T_1} = \frac{1}{11},\ \frac{1}{6},\ \frac{1}{5},\ \frac{1}{4},\ \frac{1}{3},\ \frac{1}{2},\ \frac{2}{3},\ \frac{3}{4},\ \frac{9}{10},\ \frac{99}{100},\ 1$$

*) In the contemporary list, asteroids of Metis do not exist. Probably it is Metid but it is of more specified dimensions. (editors).

The first row indicates the ascent in planetary radii, the second-unity, For example, for moving out from the surface of the planet, for one radius it requires to complete half of the total work, while for moving out to infinity only twice as much.

Velocity required by a body for recession from a planet.

Since we have often mentioned velocities acquired by a rocket due to the action of explosive substances, it is interesting to know, what they should be, in order to overcome the resistance of gravitation.

We shall not give the ordinary calculations, with the help of which, these velocities are deremined and confine ourselves to the conclusions.

Thus, the velocity V_1 , required for the lifting of the rocket to a height "h" and obtaining after this velocity of the V, is as follows:

$$V_1 = \sqrt{V^2 + \frac{2gr_1h}{r_1 + h}} .$$

If here we put V = 0, i.e. if the body moves upwards until its stoppage by the force of gravity, we find

$$V_1 = \sqrt{\frac{2gr_1h}{r_1 + h}} .$$

When h is infinitely great, i.e. if the ascent is limitless, and the final velocity is zero, then the velocity required for that at the surface of the planet will be expressed by

$$V_1 = \sqrt{2gr_1} \quad .$$

By this formula we shall calculate for the Earth : V_1 = 11170 meters per second, or 5 times faster than the fastest cannon - ball at the time of its emergence from the nozzle.

For our Moon V_1 = 2373 meters per second, that is, this is close to the velocity of the cannon - ball and the molecules of hydrogen. For the planet Agata, which is 6 versts in diameter, and has a density, not greater than that of the Earth (5.5), V_1 is less than 5.7 meters per second; almost about the same velocity V_1 is found for the satellite of Mars also. On these bodies of the Solar system, it is sufficiently easy for one to run away, so as to be free for all times from the force of their gravitation and make oneself an independent planet.

For planets, having the same density as the Earth, we get where g_1 and r_2 , refer to the Earth.

$$V_1 = r_1 \sqrt{\frac{2g_1}{r_2}} \,,$$

From the formula it is seen, that the limiting landing velocity V_1 in this case is proportional to the radius r_1 of the given planet.

Thus, for the largest asteroid - Vesta, whose diameter is close to 400 kilometers, we find that $V_1 = 324$ meters per second. This means that even a rifle bullet leaves Vesta for good and becomes a meteorite, circling around the Sun.

The last formula is convenient for quick calculation of launching velocities on equally dense planets of different sizes. For instance, Metis, one of the large asteroids, has a diameter, about 4 times less, then Vesta, and the velocity for this reason, will be just as many times less, i.e. about 80 meters per second.

Eternal circling around the planet requires half the work, and velocity $\sqrt{2} = 1.41$ ... times smaller, than for moving off to infinity.

Duration of flight.

We shall not give here highly complicated formulae, determining the duration of flight of the projectile. All the more so because this problem is not new and has been solved, and we shall only repeat the known.

We shall make use of only one conclusion, which is extraordinarily simple and useful for solving the simplest problems regarding the time of motion of the rocket.

For the duration of fall t of an originally stationary body on the planet (or the Sun), concentrated in one point (for the same mass), we find

$$t = \frac{r_2}{r_1} \sqrt{\frac{r_2}{2g}} \left(\frac{r}{r_2} \sqrt{\frac{r_2}{r} - 1} + \arcsin \sqrt{\frac{r}{r_2}} \right).$$

Here r_2 denotes the distance, from which the body begins to fall; r is the course run through by the falling body; r_1 - is the radius of the planet and g is the acceleration due to the force of gravity on the surface of the planet.

The same formula of course, expresses, the time of ascent from r2 - r to r_2 when the body loses all t its velocity.

If we put $r = r_2$ i.e. if we find out time of fall to the center of a concentrated planet, then from the last formula we get

$$t = \frac{\pi}{2} \frac{r_2}{r_1} \sqrt{\frac{r_2}{2g}} .$$

Under ordinary conditions this formula also gives approximately the time of fall to the surface of the planet, or the time of ascent of the rocket from this surface to a full stoppage.

On the other hand, the time of a full round revolution of some body, for example projectile, around a planet (or the Sun) is as follows

$$t_1 = 2\pi \frac{r_2}{r_1} \sqrt{\frac{r_2}{g}} ,$$

where r_1 - is the radius of the planet with acceleration g at the surface and

r_2 - is the distance of the body from the center of the planet.

Comparing both the formulae, we get

$$\frac{t_1}{t} = 4\sqrt{2} = 5{,}657.$$

Consequently, the ratio of time of rotation of any satellite to the time of its central fall on the planet, concentrated to one point, is equal to 5.66.

Thus, in order to obtain the time of fall of some celestial body (for example our rocket) to the center (or approximately on the surface) around which it is rotating, the time of sidereal revolution of this body, along the circumference, must be divided by 5.66.

In this way we find that Moon will fall to the Earth in 4.8 days and nights and the Earth to the Sun in 64 1/4 days and nights.

On the contrary, a rocket launched from the Earth and stopping at the distance of the Moon should fly for a duration of 4.8 days and nights or about 5 days.

In the same way, a rocket launched from the Sun and stopping under the influence of powerful force of its (solar) gravitation and the insufficient velocity of the rocket at the distance of the Earth, would have consumed in its flight about 64 days and nights, or two months and over.

Resistance of the Atmosphere

Let us find out the work of cleaving the air by a rocket in case of its usual rectilinear, uniformly accelerated motion; we must also take into consideration the variable density d of the atmosphere at different altitudes.

It is equal (see my article "Aerostat and Aeroplane", 1905) to

$$d = d_1 \left(1 - \frac{d_1 h}{2\ (A + 1)\ f}\right)^{2A + 1} ,$$

where

$$A = \frac{d_1 \ MT_1 C}{f} .$$

In these formulae d_1 is the density of air at the sea level ($d_1 = 0.0013$); h - is the altitude of the projectile or the altitude of the part of the atmosphere under consideration; f - is the air pressure at the sea level per unit area ($f = 10.33$ tons / m^2) M is the mechanical equivalent of heat ($M = 427$ tons/ m): T_1 - is temperature of absolute zero ($T_1 = 273$); C - is the heat capacity of air at constant volume ($C = 0.\ 169$); $A = 2,441$ and the first formula takes the form of

$$d = d_1 \left(1 - \frac{h}{h_1}\right)^{\alpha} , \tag{2}$$

where $a = 2A+1 = 5.88$; $h_1 = 54,\ 540$ km and expresses the limiting theoretical altitude of the atmosphere on the adopted bases. In fact, if in the formula (1) $d = 0$, then

$$h = \frac{2\ (A + 1)\ f}{d_1}$$

denoting this altitude by h_1 we shall get formula (2).

Although this altitude of 54.5km is exceedingly small as in seen from the observation of the falling stars, it is without doubt, that the atmosphere above 54 km is so much rarefied, that its resistance may readily be neglected.

As a matter of fact, if we calculate the density of the air layer at this altitude, assumming the temperature to be constant, as at the sea level, and consequently, boundlessness of the atmosphere, then even in such a case we shall find $d/d1 = 0.001$, i.e. that at this altitude the air is rarefied 1000 times and, that means, that above 54 kilometers there is no more than a thousand (0.001) of the mass of the entire atmosphere.

But due to the lowered temperature, this remaining mass is incomparably small.

The differential of work of resistance T is expressed by

$$dT = F\,dh,$$

where F denotes the resistance of air to the movement of the projectile. It is equal to

$$F = \frac{KSdV^2}{2gU}.$$

Here K - is the coefficient which is equal to 1.4 according to Langley.

S - is the area of the maximum transverse cross-section of the projectile.

d - density of air at the place where at a given movement the rocket moves; d, of course, is a variable quantity, because with the increase of altitude, the density of air rapidly falls;

V - the velocity of projectile.

g - acceleration due to the Earth's gravity on the surface of the Earth ($g = 9.8$ meters/second^{2});

U - Utilization, or usefulness of the form of rocket; this number shows, how many times the resistance is reduced, owing to the bird-like form of the projectile, compared with the resistance of the area of its maximum transverse cross-section; U- is also a variable quantity which, as has been shown by numerous experiments increases with the increase of velocity V of the moving body: Incidentally, it is said that it increases with the increase of dimensions of the body. However, we shall take U as a constant quantity, since its dependence on velocity V is a very disputed question.

Further, since the resistance of the air in comparison with the pressure of explosive substances on the rocket is small (about 1% and less), the velocity V of the projectile may be taken as

$$V = \sqrt{2\,(p - g)\,h},$$

where $(p-g)$ is the true acceleration of the projectile. This situation, adding velocity, increases the work of the atmospheric resistance and consequently, equalizes the error on account of lowering the altitude of the atmosphere.

On the basis of formula (2) and the last three formulae we shall get

$$dT = b \left(1 - \frac{h}{h_1}\right)^{\alpha} hdh,$$

where,

$$b = \frac{Kd_1S\ (p - g)}{Ug} \quad \text{and } \alpha = 5.88.$$

Integrating by parts and determining the constant, we shall get

$$T = b\left\{\frac{h_1^2}{(a + 1)(a + 2)}\left[1 - \left(1 - \frac{h}{h_1}\right)^{a+2}\right] - \frac{h_1h}{a + 1}\left(1 + \frac{h}{h_1}\right)^{a+1}\right\}.$$

If here we put $h = h_1$, then we shall get the total work T_1 of the atmospheric resistance. Namely

$$T_1 = \frac{bh_1^2}{(a + 1)(a + 2)}$$

Let us put, K = 1.4; d = 0,0013; S = 2 M^2; p/g = 10; g = 9.8 meters/sec^2; U = 100, then b = 0.0003276; a = 5.88 and h_1 = 54540 M.

Then T_1 = 17975 ton - meters.

The work of one ton of explosive substances, on getting from hydrogen and oxygen one ton of water, is equal to 1600000 ton - meters. If a projectile with all the accessories and the passengers weighed one ton, while the explosive reserve constituted a six-fold quantity, or 6 tons then the rocket would be taking with it potential energy of 96,000,00 ton - meters. More than half of this energy is converted into mechanical work in the shape of rocket motion.

Consequently, the work of the atmospheric resistance in this case constitutes only about 1/300 that of gravitation. We may obtain the same, having compared directly the work of the atmosphere resistance (17975) with the total work of gravitation (6336000). We find it about 1/353).

I give here a table*, showing, (according to the conditions adopted by us) the time is seconds from the beginning of vertical flight, corresponding to the velocity of the rocket in meters, altitude of ascent in the same measures, the density of the surrounding air, having taken the density at the sea - level for unity and the unifrom lowering of temperature by 5°C at every kilometer.

The entire time of explosion with a six-fold quantity of the explosive substances lasts for 113 seconds, while at the end of this time the body acquires a velocity of 9990 meters per second and rises to an altitude of 575 kilometers; further ascent will be completed by inertia.

The work of the atmospheric resistance is extremely small while the less during vertical motion by the force of gravity does not represent such a small value ; namely the first loss is 35 times less than the second. For this reason it is advantageous to incline the path of motion (orbit) of the rockets in order to increase several times a comparatively small quality (i.e. resistance of the air) and to reduce at the same time the comparatively significant quantity, that is the loss of energy on account of the effect of gravity.

Its is not difficult to see, that work of atmospheric resistance is approximately proportional to the Cosec^2 (α - 90°) where (α - 90°) is the angle of dip of the trajectory of the projectile to the horizon.

Duration of ascent of rocket (seconds).	Velocity of ascent of rocket (meter/sec).	Altitude of ascent (meters).	Relative density of air.
0	0	0	1
1	90	45	-
2	180	180	-
3	270	405	-
5	450	1125	1:1, 13
7	630	2205	-
10	900	4500	1: 1.653
15	1350	10125	-
20	1800	18000	1:10.63
30	2700	40500	1: 2828
40	3600	72000	Close to zero.
50	4500	112500	Close to zero.
70	6300	220550	0
100	9000	450000	0
113	9900	574000	0

We are giving here a table, for the complition of which the preceding law has served as sufficiently dependable in case of some deflection from the horizontal flight*.

The first column shows the angle of slope of the trajectory to the horizon in degrees; the fourth - the sum of all losses, when the usefulness of the U form of the rocket is taken as 100.

Angle of slope of trajectory to the horizon. α -90°	loss		Total loss	Angle of slope of trajectory to the horizon. α -90°	loss		Total loss
	Due to the gravity**	Due to the atmosphere U = 100			Due to gravity**	Due to the atmosphere U = 100	
0	0.010	oo	—	20	0.045	0.0255	0.0205
2	0.014	2.47	2.48	30	0.057	0.0120	0.069
5	0.020	0.395	0.417	40	0.070	0;0073	0.0773
10	0.027	0.099	0.126	45	0.075	0.0059	0.0809
15	0.035	0.0477	0.0827	90	0.100	0.0030	0.1030

*) Table (see page 74) is cited in a corrected form by Tsiolkovsky himself. The correction was carried out by him before 1931 (Editors).

**) See table at para 86 of article "Investigations of the year 1903" (Editors).

In a medium without gravity with six - fold quantity of explosive substances (compared with the weight of the entire remaining substances), 0.63 of their entire latent energy is utilized.

Suppressing 8% of this figure in a worst case we shall find, that during inclined motion one can make use of 58% of the total chemical energy of the explosive material.

The work of the resistance of air may be decreased several times if the flight is to initiate from the top of a high mountain, -- or if the rocket has been lifted with the help of an airship to a specified altitude, the flight will begin rom there. Thus, the flight from an altitude of 5 km decreases the work of the resistance of air twice, while the flight from 10 - kilometers altitude four times.

Picture of Flight.

Relative Phenomena. Although it is before the journey in space, "How far it is", but let us suppose, that all is ready: devised, accomplished, experimented and we have already got ourselves accommodated in the rocket and are ready for the ascent and our friends are watching us.

We shall relate, the occurrences to the rocket, our acquaintances - the astronomers of Mars etc - to our planet Earth. All these phenomena will be relativ and not totally identical, because each type of phenomena will depend, meanwhile, on the form of motion of the body, to which the phenomena pertain.

Having started on the journey, we shall experience highly strange, perfectly miraculous unexpected feelings, the description of which we shall begin.

The signal has been given, the explosion has started, accompanied by deafening noise. The rocket has wavered and started on the journey. We feel we have become terribly heavy. Four poods (1 Pood = 16.38 kg) of my weight have turned into 40 poods . I fell on the floor, was injured seriously, and might even have been killed; it is too early for observations. There are media to bear such a terrible gravity, but, so to say, in packed up form or in a liquid (this will be discussed later).

Immersed in liquid we shall hardly be inclined for observations. Be that as it may, the gravity in rocket, has apparently increased 10 times. About this, we would be informed by spring balances or a dynamometer (a pound of gold hung on their spring, turns into 10 pounds), by accelerated oscillations of a pendulum (3 times more frequent), faster falling of bodies, diminishing the size of drops (their diameter decreases ten times), becoming heavier of all things and many other phenomena.

If the density of the Earth was increased ten times or if we found ourselves on a planet, where attraction is 10 times more than on the Earth then with nothing we would distinguish between the phenomena in the rocket and those on the planet with enhanced gravity. It could have been less in the rocket, but then the duration of explosion will be more, although the rocket will rise, with the same consumption of material for low altitude or will acquire less velocity. We are studying the case of vertical ascent, when the direction of relative gravity is the same as on the Earth. In case of inclined take off we could observe a change of direction of the relative gravity not more than 90°, while during the most advantageous take off, it is 75° - 80° as compared with its direction on the Earth at a given place.

If in such a case we looked out from the window of the rocket, then the Earth would appear to us almost as a vertical wall, going off from one side into the sky and into an abyss on the other.

The awful gravity being experienced by us will continue for 113 seconds or about two minutes, until explosion and its noise come to an end. Then, when dead silence sets in the gravity will disappear momentarily the same way as it had appeared. Now we have ascended beyond the limits of the atmosphere, to an altitude of 575 kilometers. Gravity has not only diminished it has vanished without traces; we we do not experience even the terresterial pull to which we were accustomed, as to air, but which for us is not so necessary as the latter 575 kilometers this is very little - this is almost on the surface of the Earth and the gravity must have diminished so insignificantly. And that is the actuality, But we have business with the relative phenomena and for them gravity does not exist.

The force of the Earth's pull acts on the rocket and the bodies accommodated in it equally. They are carried away by the same stream, by one and the same force and for the rocket as if there is no gravity.

In this we are convinced by many signs. All objects not fastened to the rocket have left their places and hang in the air not touching anything and if they at all touch, they do not exert pressure on each other or on the support. We ourselves as well do not touch the floor and adopt any position and direction: we can stand on the floor, on the ceiling and on the wall; we can stand perpendicularly and in an inclined way: we float in the middle of the rocket like fishes, but without any effort and without coming into contact with anything; not a single object exerts pressure on another if they are not pressed together.

Water does not pour out of the jug, the pendulum does not oscillate and hangs on one side. A huge mass, hung from the hook of a spring balance does not stretch the spring and it always shows zero. Lever scales are also rendered useless; their bean adopts any position irrespective and independent of the equality or inequality of weights in the pans. Gold cannot be sold by weight. The usual earthly methods of measuring mass cannot be employed here.

Oil is shaken out from the bottle with some effort (since the pressure or elasticity of the air that we breathe hinders), adopts the form of a vibrating sphere; after some minutes the vibration comes to an end and we have a liquid sphere of super exactness; we break it up into parts - we obtain a group of smaller spheres of different sizes. All this slides in different directions, spreads on the walls and wets them.

The mercury barometer has risen upwards and mercury had filled up the entire tube.

A double-knee syphon does not convey water.

An object dropped carefully from hands does not fall and a pushed object moves in a straight line and uniformly, until it strikes the wall or some object, so as to come in motion again although with a smaller velocity. Generally it rotates at the same time like a toy top. It is even difficult to push a body, without imparting rotation to it.

We feel nice and light, as if on the softest feather bed, but blood flows to the head; for the plethoric it is deletrious.

We are capable of observation and meditation. Notwithstanding the fact, that the powerful hand of the Earth with a fantastic force, is retarding constantly the ascent of the projectile, that is, the force of terresterial gravitation does not discontinue for a moment, we feel in the rocket the same, which we will feel on a planet whose force of gravity has vanished by some miracle or had been paralyzed by a centrifugal force.

All is so quite good and calm. We open the outer shutters of all windows and see through the thick glasses in all the six directions. We see two skies, two hemispheres, forming together one sphere, in the center of which, as if, we are accommodated. We are as if inside a ball consisting of two multi-colored halves. One half is black with stars and the Sun; the other is yellowish with many bright and dark spots and with vast spaces not so bright. This is the Earth, which we left a short while ago. It does not appear to us convex in the capacity of a sphere, but, on the contrary by the laws of perspective, it is concave, as a round balance - pan which we are looking at.

In the month of March we flew from the Equator at noon and that is why the Earth occupies almost half of the sky. If we had flown in the evening or morning we should have seen, that it covers one fourth of the sky in the form of a gigantic curved sickle; at midnight we would see only a circle or ring, brilliant by purple color of dawn and dividing the sky into two halves: one half is without stars, almost black, a bit reddish; the other is black as soot, dotted with numberless clusters of comparatively bright but not scintillating stars.

To the extent of recession from the surface of the Earth and ascent in altitude the ring becomes smaller and smaller, but at the same time brighter and brighter. The globe of the Earth in this form or in the form of a sickle, or the balance pan, appears to get smaller too, meanwhile as we see (absolutely) more and more of its surface. Now it appears to us in the form of an enormous dish, which, diminishing gradually, turns into a small saucer, further in the form of moon.

Up and down in the rocket, properly speaking, do not exist because there is no relative gravity, and a body left unsupported does not tend towards any wall of the rocket, but subjective sensations of up and down however remain. We feel up and down, only their places change with the change of direction of our body in the space. The side where there is our head, we recognize as 'up' and where there are feet- as 'down'. Thus if we turn out head towards our planet, it appears to be upwards and turning to it by our feet, we plunge it into an abyss, because it appears to be down. The picture is grandiose but at first terrifying; later you get accustomed to it and in reality you lose the conception of 'up' and 'down'.

Those observing us from the Earth saw the rocket roar and move from its place and fly upwards like a falling stone only in the opposite direction and 10 times more powerfully. The speed of the rocket grows, but to note it is difficult due to its quick motion. During the passage of one second, the rocket has already ascended an altitude of 45 meters, in 5 seconds - it is at an altitude of a verst, in 15 seconds - at 10 Versts, and we hardly see it in the form of a thin vertical dash, swifty rushing upwards. In half a minute it is already at an altitude of 40 kilometers, but we continue to see it freely, by the unaided eyes, because owing to its increasing speed it has become white hot (as a meteorite) and its protective refractory and non-oxidizable shell shines, like a star. For more than a minute this star-like flight continues; and thereafter all disappears little by little, because after crossing the atmosphere, the rocket does not come in contact with the friction of the air, gets cool and gradually disappears. Now it can be located only with the help of a telescope.

Heat did not penetrate to us, because we were **sitting** in the rocket and were protected from heating - by a low - heat-conductivity layer, and besides, we had a powerful source of cold: the evaporation of liquified gases. This protection was needed for one or two minutes.

The apparent absence of gravity in the projectile continues all the time, there is no explosion as long as the rocket does not revolve. It recedes from the Earth, moves at great distances from its planet, along one or the other curve, but there is **no gravity**; the rocket is whirling around the Sun, it is flying towards stars and is subject to strong and weak influences of all suns and planets, then gravity is not felt; all the phenomena, peculiar to a medium, devoid of gravity, are observed in and out of the rocket as before. This conclusion is not rigidly exact, but approximately it is dependable; the effect of its inexactitude is not only impossible to ascertain within the limits of rocket space, but even tens, hundreds and sometimes thousands of versts around it. Some small influence is still exerted by the force of attraction of the rocket itself, its people and objects which have been taken along with them.

But their interaction is very small and is discovered by the movement of stationary (relatively of course) bodies, only in the duration of hours. If the objects have even an insignificant movement - the effect of Newtonian gravitation cannot be discovered.

Around the Earth. It is possible, having restricted the explosion, to ascend only up to the desired altitude, then having lost almost all the velocity, so as not to fall back to the planet, we turn the rocket with the help of bodies, rotating inside it and carry out a new explosion in a direction, perpendicular to the original direction.

Relative gravity is again generated; only in this case we can confine ourselves to extremely small values; again, all the well-known phenomena in a medium of gravity, are repeated; again they will disappear and silence and peace will prevail but the rocket will e secured from falling down. It will acquire a velocity normal to the radius - victor, i.e. in a circle along the circumference like the moon, and will, similarly to the latter, eternally revolve around the Earth.

Now we can be completely satisfied since the rocket has acquired usual position; it became the Satellite of the Earth.

From the rocket is visible the enormous sphere of our planet as the moon in one of its phases. It is visible how the sphere rotates, how in several hours it shows its sides in succession. The closer it is to the rocket, the more immense it appears and the more concave stretched out on the horizon, its form is fantastic, the more brilliance it gives to its satellite (rocket), the faster the latter revolves around its mother - the Earth. This distance may be so small, that one circuit around it would take two hours and in several minutes we shall see different points of the Earth from various sides and at a close distance. This picture is to such an extent magnificient, tempting and endlessly diversified, that I heartly wish you to see it. In such a 2-hour circuit after every two hours, the rocket is obscured, as it plunges itself into the Earth's shadow and night. The latter (night continues less than an hour; after that the Sun shines for more than an hour so as to give way to darkness again.

If we wanted to make use of more quantity of light, i.e. a longer day, then we must either recede from the Earth, or revolve not in the direction of the Equator, but in the direction of the medidian, so that our path intersects the Poles of the Earth. In this case i.e. when the orbit of the rocket is normal to the rays of the Sun, even at a comparatively small distance from the planet we shall make use of a long day, lasting for a month and more; and the pictures of the Earth are still variegated, still charming and amazing, because the edges of the illuminated parts of the Earth will be visible in relief, which are fast moving. Specially good will be the view of the Poles.

We do not feel the motion of our own rocket, as we do not feel the rotation of the Earth (when we are on it) - and we have the idea that the planet itself is hurrying around us along with all the magic horizon: the rocket for our senses becomes the center of the universe, as sometimes the Earth was.

Curves of rocket movement and its velocity

In case of the vertical ascent of the rocket and the absence of the rotation of the Earth, the relative path of the rocket will be the simplest; this will be a straight line, more or less long, depending on the quantity of the explosive substances.

Such is the path of the rocket during its launching from the Poles of a rotating planet, ignoring the influence of other celestial bodies. When the quantity of explosive materials is 8 times more, the mass of the rocket, its path having its origin on the surface of the Earth, has no end in the other direction: it is infinite, and the rocket will never return to the Earth assuming, of course, that there are no celestial bodies and their gravitation.

In its application to the Earth, the least velocity, for recession from it, to infinity, is equal to 11170 meters/second, or more than 11 kilometers/second.

A little rotation of the planet, as we see in case of all average and small planets of the Solar System, beginning from the Earth, the straightness of path changes very little; namely the path of the rocket turns into a highly elongated ellipse in case of return of the projectile to the Earth and into a parabola or a hyperbola - in case of infinite recession.

Speaking about the trajectory of the rocket we did not have in view its comparatively short part corresponding to the time of explosion, which incidentally is also close to the straight line, if the direction of explosion does not change.

In the beginning, during the time of explosion, the movement of the rocket quickly accelerates. Later on the velocity changes more slowly - only under the influence of the force of gravitation, namely, during the ascent or recession from the center of the planet, the speed acquired by the projectile during the explosion, decreases; during approach or falling it increases.

During infinite recession in the course of endless time, the velocity of the projectile more and more approaches either zero, or to some constant value. In one as well in the other case, the rocket will never stop and will never return to the Earth, irrespective of the resistance of some and the attraction of the other celestial bodies.

But the vertical take off is not so advantageous, as the inclined. In the case of an initial (i.e. at the time of explosion) horizontal flight of the second order, tangential to the globe at the site of the take off. The focus of the curves will be located at the center of the Earth. In case of insufficient relative quantity of explosive substances (less than 3-4) the flight will not take place and the rocket will touch the Earth or will fall to the planet, as a horizontally fired ordinary cannon - ball.

If the velocity of the rocket due to the action of the explosive material is 2 time, less than the minimum velocity, which is needed for recession into infinity (11170 meters/second) the path of the rocket will be a circle coinciding with a large circleof the globe (with the Equator or the meridian). This case also does not have any application, because the rocket, flying uninterruptedly in the Earth's atmosphere, quickly loses all its velocity due to the resistance of air and quickly falls on the Earth. But if there had been no atmosphere, or if the rocket had started its flight from a mountain, with its top projecting beyond the limits of the ocean of air (atmosphere) then the path of the rocket, would, have been circular and eternal; it would as its moon never fall to the Earth, Obviously this too is impossible.

On the basis of what has been said, the speed required for circular motion will be calculated approximately at 8 kilometers / second or 7904 m/sec.

If we want to make use of the Earth's rotation and launch the rocket from the Equator in the direction of motion of equatorial points of the globe, the necessary velocity will be decreased by 465 meters/second (such is the maximum velocity of rotation of terresterial points) i.e. it will be equal to 7441 meters per second. The advantage as we see, is small. The required relative quantity of the explosive substances will be expressed by a number from 3 to 4 (if the weight of the rocket is taken as unity).

The work required for motion in a circle is exactly half of the minimum work for recession to infinity from the planet.

In case of any large increase in the velocity of the rocket, an ellipse, going out gradually beyond the limits of the atmosphere, is obtained. Further increase in velocity will stretch out the ellipse more and more, until it turns into a parabola; in such a case work and velocity needed by the projectile for resisting the force of gravitation, will be similar, as in the case of eternal recession in the direction of the radius of the planet (for the Earth 11.170 meters/sec).

For a still larger velocity, the path of the rocket will be a hyperbola. In all these cases, the rocket loses too much because of the resistance of the atmosphere, and therefore this rocket trajectory tangential to the Earth in practice will not be used.

We have been, that the most advantageous path of the rocket is inclined to the horizon by 20°C - 30°. In this case only 7 % of that energy is lost due to the action of gravity and resistance of the atmosphere, which the rocket acquires in airless space, free as well from gravity. The path of the rocket in this case would be the same i.e. one of the second degree curves (ellipse, parabola and hyperbola), but only the curve is not tangential to the surface of the Earth. If the quantity of the explosive material is not sufficient or altogether small describing a part of ellipse and having attained the maximum recession, the rocket returns to the Earth. Here it is necessary to explode a fresh quantity of substances, in order to slow down gradually and not be destroyed altogether. The total quantity of explosive reserve for ascent and safe return in case of a small recession from the Earth is twice as much as for one such ascent for greater ascents-it is three times larger, and for still greater, ascents four times and so on and so*).

*) See the formula (66) of the article "Researches of the year 1903", (Editors).

If we wanted to leave the rocket for ever in the airless space, having made it a permanent satellite of the Earth, then at the greatest recession from the Earth (in apogee), a certain small quantity of substances will have to be exploded anew for increasing the velocity of the projectile. When this point is close to the surface of the Earth, it is necessary for the rocket to have a velocity close to 8 km/sec, and the quantity of the entire explosive reserve will only 3-4 times exceed the wéight of the remaining mass of the projectile. Incidentally, it makes no difference how far away we have arranged our observational station, even at a distance of one million versts from the center of Earth, the quantity of explosive substances will be less than that needed for recession to infinity from the planet in a straight line or parabola. Namely, it is expressed by a number, less than 8.

It is possibble, of course, to convert a circular orbit into an elliptical one by a new explosion, while this latter, as has been described, again into a circular one with a larger radius. In this way we can arbitrarily change the magnitude of the radius of our circular motion, i.e. we can recede from the Earth or come closer to it as we wish.

If, having already a circular motion, we are to carry out a very weak explosion, but constant and in the direction of motion, then the rocket will move, during the entire period of explosion, along the spiral orbit, the equation of this orbit depends on the law of explosion.

The future trajectory of the rocket when the explosion comes to an end, will be some curve of the second order, for example a circle, which depends on us. During an explosion, retarding the motion of the projectile, the spiral will curl round inside the original circular orbit and the rocket will approach the Earth.

In case of spiral motion, almost perpendicular to the direction of the forces of gravity, almost similar percentage (up to 65%) of the energy of explosive substances is utilized, as also in a medium without gravity; then the same thing takes place in the process of turning of elliptical orbit into a circular one.

During an inclined take-off of the rocket on its elliptical path, the Moon will exert greater effect than in case of a stretched one and as the rocket comes closer to the Moon, which in its turn depends on the comparative quantity of the explosive material consumed and the relative position of the Moon and the rocket. It may happen - the motion of the rocket may be calculated in such a way, - that will leave its orbit totally under the influence of the attraction of Moon and will fall on the Moon.

The velocity of fall with not be less than 2373 meters/ second, i.e. about two times more than the speed of a launched cannon - ball. But the velocity is less than what it is during the fall on the Earth. The energy of dro ping on the latter is 22 times more, than that during the dropping on the Moon.

Having taken into consideration the velocity and rotation of the Moon and also the motion of rocket we can calculate also the little quantity of explosive substances, which is necessary for safe stoppage on the surface of the Moon. I can inform you that the entire quantity of the explosive reserve for a safe journey to our Moon in expressed by a number not more than 8. At a comparatively small distance from the Moon, the speed of rocket must be constantly decreased by means of an explosion. Everything must be calculated and controlled in such a way that at the moment of contact with the surface of the Moon soil, this relative speed equals zero. This problem is of course very delicate, but quite possible. The error in its solution may be corrected by a new explosion, only if there is a sufficient reserve of explosive substances.

In case of a miss, that is, if the rocket flies past in the neighbor hood of the Moon, but does not touch its surface, th rocket will not become a satellite of the moon, but, having approached it again recedes from it, revolving round the Earth describing a highly complicated curve, which passes sometimes close to the Earth and sometimes close to the Moon. There remains the possibility of falling either on the one or the other. At the moment of closest approach to the Moon, it is permissible to explode the explosive material in order to decelerate the motion of the rocket, and thus to become an eternal satellite of the Moon, the great grandson of the Sun. It is also possible, by different methods, to save this circular orbit and reach the Moon or recede from it.

According to the description of the flight, it is seen, that the rocket may become an eternal satellite of the Earth, moving around it, like the Moon. The distance of this artificial satellite, a little brother of the Moon, from the terrestrial surface may be arbitrarily small or large; its motion would be eternal, because the resistance of the ether is not noticed even for small density and small bodies, which are in the majority of cases mateorites, included most likely, in the make up of comets. If small bodies experienced resistance from the ether, (among other things), how could the rings of the Saturn, which according to astronomers consist of such small, solid bodies separated from one another, rushing around the Saturn with amazing rapidity have existed for millions of years.

Revolution around the Earth of a series of rockets with all their accessories for the existence of rational beings may serve as a base for the future expansion of mankind. People inhabiting a large number of rings around the Earth like the rings of the Saturn, could utilize 100 - 1000 times the reserve of solar energy, which is available to them on the surface of the Earth. But even by this, man will not be satisfied and from the conquered base may aspire to the conquest of the remaining Solar energy, which is two milliard (U.S. Billion) times that which the Earth receives. In that case eternal revolution around the Earth is necessary to be superseded by a similar kind of revolution around the Sun. For this purpose we shall have to recede still farther from the Earth and become an independent planet - satellite of the Sun, and a brother of the Earth. Precisely, a rocket with the help of an explosion will have to transmit a velocity in the direction of the motion of the Earth around the Sum, when the rocket moves with the maximum velocity relative to the Sun. The energy required for this, depends on the quantum of the distance, at which the rocket is from the Earth; the greater this distance is the less is the work; the total sum of energy, required for the circular motion around the Earth and for the subsequent almost complete recession from it, does not exceed that, which is required to recede from the Earth eternally, assuming that there is no Sun and other celestial bodies i.e. a seven-fold or eight-fold quantity of explosive substances (as compared with the remaining mass of the projectile).

On still more expenditure of energy the circle changes into a more or less elongated ellipse, the point of perihelion (smallest distance from the Sun) which is situated roughly at the distance of the Earth from the Sun.

In the first case, during the average expenditure of energy, the rocket, in the beginning, under the influence of a new thrust, will fly much faster, than needed for circular motion around the Earth and even the Sun. Later this velocity, due to the effect of terrestrial gravity (that of the Moon is neglected) decreases more and more and at the very end and at a significant distance from the Earth (roughly at 1000 times its diameter) will become equal to the velocity of the Earth around the Sun. The Earth and the rocket will align themselves in one and the same circle with the same velocity and therefore may not come across each other for hundreds of years. However, for such an equilibrium, there are few chances in the course of centuries, and the motion of the rocket, for maintaining considerable distance, is required to be decelerated, in order that like the Earth, other planets too, do not disturb this distance. Otherwise there exists the threat of falling on the Earth.

In the second case, when there is large expenditure of energy, and the path of the rocket is elliptical, chances of encountering the Earth are also not few, but it is possible to take advantage of the recession of the rocket in order to land on some "superior" planet: on the Mars or its satellite, on Vesta or on any other of the 500 small planets (planetoids, asteriods).

I do not speak about the access to the most massive and huge planets, which are the Jupiter, the Saturn and others, because for safe landing on them, such a enormous quantity of explosive substances is required that its launching for the time being, is not worth-while and should not be dreamt of. But it is easier to become their satellites, especially separately; it is easier to approach the rings of the Saturn and to have contact with it. The quantity of energy, required for approaching any planetary orbits (but not landing on the planet) depends on its distance from the Earth's orbit., the greater this distance is, then, as already explained, the greater would be the consumption of energy. But, howsoever great that recession may be, the required work will be less than that, which is required for infinite recession from the solar system and wandering amongst the stars. And this last work is not so enormous, as it appears in the beginning. In fact, it is not easy to overcome the more powerful attraction of the Sun, the mass of which is 324.000 times that of the Earth. But calculations show, that if we are flying the rocket at the moment of its fastest motion around the Sun or directly from the surface of the Earth at the favorable moment in a favorable direction then the velocity relative to the Earth, required for complete recession from it and the Sun, does not exceed 16.3 km/sec, which is accompanied by the consumption of explosive substances, relating to the mass of the rocket expressed by the number 20. In case of the most unfavorable launching of the rocket this velocity attained already is 76.3 kilometers/second, and the quantity of the explosive reserve must be stupendous as compared with the remaining mass of the rocket. The absolute velocity i.e, relative to the Sun when recession has been achieved, is one and the same, no matter-in what direction we fling the rocket. If the energy, needed for this, in a favorable case is about 25 times less, then this will depend on the fact that we then borrow it from the motion of the Earth, which must be decelerated for this, to a negligible value.

The circular path of the rocket around the Sun may be made elliptical after having increased or decreased the velocity of the projectile by means of an explosion.

On diminishing the velocity, the perihelion of the rocket will be less than the distance of the Earth from the Sun and then the rocket will be in a position to reach any lower planet: the Venus or the Mercury. Their masses are not so enormous and landing does not require such an unimaginable quantity of the explosive material, as a safe landing on the Jupiter, the Saturn or the Neptune. The energy of falling on the Mercury, as also on the Mars, is about 5 times less, than on our planet the energy of falling on the Venus comprises 0.82 of the energy of falling on the Earth. As far as asteroids and the major part of the planetary Satellites (moons) are concerned, the mass of the explosive reserve, spent for the sake of smooth landing on their surface, is simply negligible.

Theoretically, greater proximity to the Sun and even landing thereon in case of complete loss of velocity relative to the Sun, is possible. If the rocket is already revolving around the Sun, like the Earth, and at the same distance from it, then for decelerating the motion, it requires relative (reverse) velocity of about 30 Km/sec.

The quantity of th explosive material will be expressed by the number 200. The process of landing on the Sun will continue for 64 1/4 days (and nights), that is about 2 months.

From here it is evident, that landing on the fiery ocean of the Sun requires 10 times more of the explosive substance, than the fall from our sun and the approach to the new.

As around the Earth, the rocket can be put to any trajectory by n uninterrupted and extraordinarily weak explosion; it is permissible to compel it to describe one or the other path relative to the Sun, for example, along a spiral, and thus reach the desired planet, to come near or to recede from the Sun to fall on it or leaving it altogether, having become a comet. wandering for many thousands of years in blackness amongst the stars, until proximity to one of them, which will become for travellers or their generations a new Sun.

We shall observe, that in all cases of reducing the velocity of the rocket, the explosive material should be exploded in the direction of the Earth's motion; but the motion of the rocket relative to the Sun will remain as before, i.e. in the direction of the motion of our planet.

The plan of subsequent exploitation of solar energy will probably be as follows:

Man will launch its projectiles to one of the asteroids and will make it its base for its initial work. He will make use of the material of the small asteriod, decomposing it and carrying away the material up to the center for the building of his installations, consisting of the first ring around the Sun. This ring, will be overcrowded with rational beings, will consist of mobile parts similar to the ring of the Saturn.

Having taken apart and also utilized the tiny asteroids, intelligent beings will form still another series of rings, somewhere between the orbits of the Mars and the Jupiter, for out purposes in the cleared, i.e. the space free from asteroids.

For different technical and other requirements some rings may be located close to the Sun, between the orbits of "inferior" planets.

When the energy of the Sun is exhausted, intelligent beings will leave it, so as to go to another luminary, recently cooled but still in peak force. This may even take place earlier: part of the beings may desire another world or the inhabitation of deserts.

Perhaps, mankind in this way will swarm repeatedly. It is possible that it has swarmed once before and the present population is less than the previous one.

There is no need to deal with the surface of the Sun even when it is covered by a cold crust. There is even no need to be on the heavy planets, except to study them. It is difficult to reach them; to live on them means to bind ourselves with the chains of gravity, often stronger than the terrestrial, and to set up a multitude of obstacles, to cling ourselves to a small area, and live a miserable life in the mother's womb. Our planet is a cradle of intelligence but one cannot live in a cradle eternally.

MEANS OF SURVIVAL DURING FLIGHT.

Food and Respiration.

The first thing which is needed is oxygen for breathing; a large quantity of it is carried along for explosion; we could take more of its, so that it suffices for breathing for a known length of time.

Pure oxygen is hardly suitable for human beings even in a rearefied state as against the usual. Indeed, in such a case its pressure on the body will be insufficient and may result in haemorrhage from purely mechanical causes.

The most reliable to use is a mixture of oxygen with some gas which is harmless for breathing, e.g. nitrogen, or hydrogen, but not carbonic acid, which obstructs the liberation of carbon dioxide gas from the lungs and the skin of the living being thus poisoning him. By a mixture from 20% of oxygen and 80% nitrogen under a pressure from 1000 to 500 mm of mercury column it is easy to breathe. Nitrogen is preferable to hydrogen, because it does not present any danger of explosion.

It goes without saying, that the compartment for passengers must be hermetically sealed and sufficiently strong so as to maintain the pressure of gases not more than 1 kg/cm^2 on the walls of the room, when the latter will ascend into the rarefied layers of the atmosphere and beyond its limits. The elongated fish like or bird form of the rocket, is suitable for lightness of diffusion of air, promotes the preservation of gases as well as the strength of the rocket in general, withstanding ten fold weight in the course of explosion. The metallic material prevents the loss of the gas due to diffusion.

But it is not enough to have a mixture of oxygen and nitrogen; it is necessary to add oxygen, transforming into carbonic acid, and destroy or, more exactly eliminate the products of breathing carbonic acid, ammonia, surplus humidity and others. There are a number of substances, absorbing carbonic acid: vapors of water, ammonia etc. Therefore we also require reserve of these substances. Of course, if the journey is made in several minutes or hours, such reserves, with the addition of breakfast, cannot overburden the rocket. But it is a different story, if one has to journey for weeks and years or is never to come back, then we have to reject the indicated media.

For survival in the course of unspecified length of time without the atmosphere, planets may be made use of by the force of solar rays. As the terrestrial atmosphere is cleaned by plants with the help of the sun, so our artificial atmosphere can be revived. As on the Earth plants with their leaves and roots absorb the refuse and give food in exchange, in the same way plants by us [illegible] taken along during the journey, can work uninterruptedly for us. As all living things on the Earth exist with one and the same quantity of gases, liquids and solid bodies, which never decreases or increases (not taking into account the meteorites), so we can eternally live with the reserve of material taken by us. As on the surface of Earth there takes place an endless mechanical and chemical cycle of substances so in our little world it can also take place. From the scientific point of view, the possibility of the above mentioned cycle is undoubted; let us now see how far it is practicable for the future possibly a distant future.

According to Langley, one square meter of surface normal to the direction of the Sun's rays, receives in one minute the quantity of solar energy, expressible by thrity calories. This means, that one kilogram of water spread out on one square meter of surface illuminated by perpendicularly falling solar rays, will be heated up to 30°C in one minute if we ignore the losses of heat due to radiation thermal conduction etc,

Converting this thermal energy into mechanical energy, we shall obtain 12, 720 kg - m, In this way, in 24 hours we shall obtain 18,316,800 kg-m or 43.200 kilogram calories at the distance of the Earth from the Sun. (In a second, we shall obtain 0.5 kilogram calories or 212 Kg-m, i.e. a constant work of almost 3 horse-power).

According to Timiryazev, on physiological experiments with plants, upto 5% of solar energy, which will comprise 2160 kilogram - calories in 24 hours, stored in roots, leaves and fruits of plants, is utilized.

On the other hand, according to Lebon 1 kilogram of flour contains about twice that energy, so that 24 hours reserve of potential energy of a plant corresponds to 0.5 kilogram of flour, or almost a kilogram of breed.

That same gift of the Sun, utilized on one square meter of surface uninterruptedly illuminated by the Sun's rays, may be expressed by one of the following quantities: 4 kilograms of carrots, five kilograms of cabbage, 2/3 kg. of sugar, more than 0.5 kilogram of rice.

In the above-mentioned experiments the 5% economy was accumulated in all parts of the plant. In fruits, of course, it will be less. These experiments were conducted in possible favorable conditions, but our artificial atmosphere and plant mutrition may be in conditions still more favorable. According to Timiryazev, ground in good condition utilizes 1/5 i,e. about 1% of the Solar energy. From this it is evident that artificial conditions prove even 5 times more advantageous.

Let us turn to the direct indication of practice. A desyatina or approximately one hectare (10.000 m^2) gives an annual yield of up to 25000 poods of bananas which corresponds to 0.11 kilogram in a day per square meter of orchard area.

But there are clouds on the Earth; on the Earth there are the thick layers of air and vapors absorbing much eenrgy; on the Earth there is night and the inclined direction of the Sun's rays; the quantity of carbon dioxide in air is, similarly, as experiments show, unfavorable (the most favorable for plants according to Timiryazev, is 8% whereas in the air there is no more than a tenth of one per cent). Taking all this into consideration the one has to make at least ten-fold the gifts of the Sun and to make the productivity of one square meter in our artificial orchard not less than 1. 1 kilogram of bananas in a day. Bread-fruit tree, according to Humbolt, is almost as productive as bananas.

It follows from the foregoing, that one square meter of green house, turned towards solar light, is already sufficient for the feeding of one person*.

But who prevents us from taking along a greenhouse with a large surface in packed form, i.e. in a small volume! when the circular motion around the Earth or the Sun has settled, we assemble our hermetically sealed cylindrical boxes with various kinds of plants, embryos (seeds and suitable soil. The Sun's rays penetrate through the transparent covers of the greenhouse and prepare for us magnificant food with fabulous rapidity. The rays of the Sun

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* All these considerations of Tsiolkovsky were required by him for proving possibility of closed and autonomous (from the Earth) cycle of life in cosmic space,. The conditionality of calculation is justified by insufficient knowledge of the problem (Editors).

give us oxygen and simultaneously purify the soil and air of animal excretions. Neither objects nor people will feel gravity there, and therefore, the strength of vessels with plants will be designated only for withstanding the elasticity of the gases contained in them. The chief of them are: carbon dioxide and oxygen. Carbon dioxide gas in the Earth's atmosphere makes up not more than one or two thousands of its volume. Nitrogen and other gases also play a role in plant nutrition, but their density like the density of oxygen, which they (according to Timiryazev) consume 20 times less than carbon dioxide, may be extraordinarily small without harm for plants.

Thus, the atmosphere of our greenhouse may be so much rarefied, that the pressure of gases on their walls will be 1000 times less than the pressure of air at sea level.

From this it is evident, that not only will there be no struggle against gravity, but there would be almost no struggle against the elasticity of gases, so that for each passenger we can take, if required hundreds of meters of these narrow glass boxes with germinating vegetables and fruits.

There exists perfect possibility still on the Earth to work out and test media of respiration and nutrition of human beings in an insulated space.

Manuscript

It can be regularized when the living accommodations have been adjusted along the rays of the Sun. The longer it is, the lower temperature would be.

54. The soil is shaken down due to revolution farther from axis so that the rays slip along its surface and the plant planted on it will not be held at the very bottom of framework of soil. There would be no plants there and the energy of the Sun will be wasted in vain. However, in the presence of long cones, the slope of the surface and soil will not be great, it will remain at its place and the plants will be illuminated by slanting rays up to the very axis. We shall obtain a slight temperature and the advantage of solar rays.

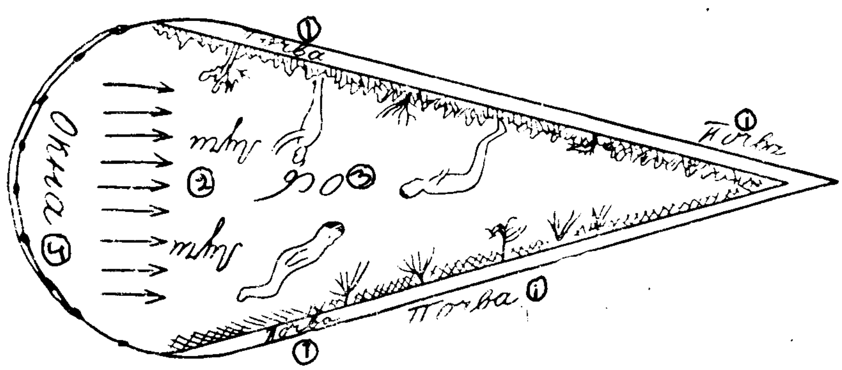

Figure. Greenhouse.
Drawing of K.E. Tsiolkovsky taken from the painting "Album of cosmic travel".

Key: (1) Soil (2) Rays (3) Axis (4) Windows.

....

It is possible to determine the smallest surface, illuminated by solar rays and sufficient for a person relative to his respiration and nutrition; it is possible to select and test plants suitable for this purpose. It is true, the conditions on the Earth are far from being such as in an the ethereal medium far off from the Planet, but then they can be made anyhow closer to our terrestrial ones. Thus, it is easy in a medium without gravity to arrange days and night; it requires only to give the greenhouses a slow rotational motion. Then light will alternate with darkness and the duration of this alternation is arbitrary. The motion will be eternal by inertia. In my opinion, the conditions there will be even much more favorable than on the Earth. In fact, the terrestrial plants suffer much more and even perish by reason of unfavorable variation of temperature during night or winter; and also due to bacteria, parasitic fungi, worms insects rodents and birds; due to insufficiency of moisture and the poverty of soil.

In the ethereal space there are no such enemies, because, all taken from the soil is returned to it, and because the variations of temperature depend on us, just as the duration of night; there will be no seasons, if the motion of the rocket is circular; there will be no harmful bacteria in a small greenhouse departments, because they may be destroyed by filling the compartments with lethal gas for undesirable beings and embryos, by raising the temperature or even simply by the uninterrupted light of the sun, killing the bacteria and malignant embryos, Moisture also cannot escape from hermetically sealed spaces.

Equipping on the Earth of experimental greenhouses especially well insulated from the external air and with favorably rarefied medium, is sufficiently difficult, because highly strong material and massive structures are required so as the withstand external pressure of the atmosphere, so as to withstand struggle against gravity. In experimental greenhouses we will first have to satisfy outselves with the pressure inside and outside them being the same and it means that only with the most favorable ratio of the mixture of gases, advantageous for the plants. The seem of internal pressures will be equal to one atmosphere wherease in the cohereal space, it is permissible to rarefy the gaseous mixture up to the most suitable degree. During terrestrial experiments the rays of light pass not only through the glass as in the ethereal space but also through thick layers of the atmosphere replete with water vapor, fogs and clouds making difficult the access of solar energy to the plants in its virgin condition. Actually, we are quite unacquainted with the true energy of the solar world, not having the true energy of the solar world, not having yet come into contact with the air. Possibly it is quite unusual in its chemical properties.

PROTECTION FROM ENHANCED GRAVITY.

In the very beginning of the flight when the explosive substances still continue to make noise, the relative gravity in the projectile, as we have seen, increases several times, may be ten fold.

The question is: it possible for a person to tolerate it for several minutes without harm to himself. This question can also be answered on the Earth, and at the same time the most favorable conditions can be worked out, in which this or even a greater gravity, not harmful for health can be tolerated by a person. I have been experimenting for a long time with different animals, subjecting them to the action of enhanced gravity on special centrifugal machines. I could not succeed in killing a single animal, and, of course, that was not my purpose, but I thought that could happen. I remember, that I increased, 300 times the weight of a brown cockroach, obtained from the kitchen, and the weight of a chicken 10 times; I did not find at that time that the experiment did them any harm.

To increase the apparent gravity in the preliminary experiments with man, the simplest of all is with the help of a centrifugal machine with vertical axis of rotation and with possibly large radius, i.e. possibly of large dimensions in the horizontal direction. The larger the distance from the axis of the experimental chamber with the human being, the better it is because the less the angular velocity of the device, the less the subjects under trial will be prove to dizziness.

Rotation brings particular harm to the body even in case of a small centrifugal force or in case of a small absolute velocity, if the angular velocity is great, i.e. when the radius of revolution is small. Everyone has the experienced this insignificant Farm, when still a child, somewhere in the garden, he turned round and round.

However, the rotation and, consequently the discomfort caused by it does not take place in case of an increase of gravity in a rectilinearly moving rocket. That a known slowing of rotation not only does not produce any painful sensations but is not even noticeable. We see from the phenomenon of the uninterrupted rotation of the Earth, to which we all have been subjected since the day of our birth; the same may be concluded when observing how long not only the children but also the grown ups can ride merry - go - rounds. Thus, I once saw on the merry-go-rounds two young girls, hired for attracting the public, by riding day and night on the Trojan horses.

For each experiment on the increase of gravity 2-10 minutes are sufficient i.e. as long as the explosion continues in the rocket.

I will not give here the known formulae from which one can conclude the following: By means of experiment it is possible to obtain artificial gravity of a desired force; the greater we desire to retard rotation, the greater must be the velocity of the chamber for obtaining the same gravity. For example, a radius of 100 meters at a velocity of 100 meters/second and a complete circuit in 6.3, seconds yield a tenfold force of gravity; if the radius is 10 times less than this, then for the same artificial gravity the number of revolutions or the angular velocity must be increased about three times; translational or absolute velocity will be just as many times less,

Doing experiments with a centrifugal machine or with the help of a rapid circular motion of a railway - car on inclined rails, we can find out the highest value of gravity which will not be harmful to health, which can maintain the subject for an indefinite time. If, contrary to expectations, we find from these experiments that a small, for example, doubled, gravity is the highest safe value, even then we cannot consider our case lost, first because a rocket may, in the course of inclined motion, advantageously utilize the work of the explosive substances even for such a small relative gravity inside it; secondly, because having immersed a person in water and performing the experiment of increase of gravity on such swimming subject, in favorable condition, we shall obtain incomparably more comforting results.

We shall explain: what is the matter?. We shall take a very strong open or closed vessel with liquid and shall immerse into it some delicately done figurine made of a very fragile material, but the density of which is equal to the density of the liquid in the vessel. Now let this figurine be so brittle and tender by itself, that is, outside the liquid, that it could not be dropped without breaking or even taken in one's hands without being dented or broken. Now, we shall take it with the vessel, in the liquid of which it is so well balanced, that it stands unmoved at that very place and in that position, in which we desire (as an oil drop in wine in Plato's experiment).

If the experiments on centrifugal machine are to be performed not with a person, but with such a tiny and delicate figurine, which outside the liquid hardly withstands its own gravity, then the results will be most brilliant; the figurine will remain intact and even motionless, notwithstanding any increase of relative gravity.

We can, even without the centrifugal machine, also strike the vessel with full force on the table, or can strike the vessel by a hammer; as long as the latter is intact and the liquid does not spill out of the vessel, our figurine will not be damaged, but as soon as the experiments are conducted without the liquid -, the entire effect vanishes; even the strong objects will break on sufficinetly fast rotation or on sufficiently strong blows. The same experiments with similar success can be easily performed with small fishes, immersed in water. From here it is evident, that the liquid, surrounding the body is of the same density, and apparently, eliminates the destructive effects of gravity, no matter how big it is. Accordingly if we take a liquid, the density of which is equal to the average density of a human being, and immerse the latter (man) in it, then in the experiments on the removal of enhanced gravity, we shall obtain, although partially, the same good results. I say "in parts" because all that has been said refers to bodies, all particles of which have one and the same density. The different organs of an animal at all, do not possess this property, particularly the density of its other organs. The bones, immersed in the liquid, will pull downwards in the direction of the relative gravity; while lighter parts will strive upwards: a tension will be set up between the different tissues, which may end in their tearing and even death of the organism, in case there is sufficient increase in gravity.

Thus, the maximum tolerable gravity without harmful effects to man is not unlimited even on immersing him in a proper liquid. This very limit, I think, is not less than 10 and may be determined for every subject only by experiment. Best of all is that during the experiment the person accommodated his body horizontally in a casing, approximately of the same shape an capacity, as the subject under test; then for filling the intermediate spaces with liquid, small quantity of the latter will be required, which is important in economic relationship on factual flight in rocket. Mouth, nose and ears must be tightly closed by a casing with a tube for free breathing.

That a person can, even without a liquid, withstand enormous gravity for amsmall fraction of a second, is undoubted. In fact, during a fall of a body from a height, it strikes the ground; so as to destroy the velocity acquired by the person during his fall, automatically imparts to the person through its own elasticity accelerated motion in the opposite direction. Here, through its own elasticity of the body of the living being also takes part, it is true, the elasticity of the body of the living being also takes part, especially inter - osseus elastic cartilages, - on a neat jump - similarly the force of muscles of bending legs. At this stage on apparent gravity must develop which is extremely great, because the duration of the impact is small and therefore the reverse accelerated motion at this moment is very great.

Nature itself in such cases and in cases of heavy blows by outside bodies does not ignore the property of liquids to destroy the destructive effect of the relative gravity and therefore carefully immerses all the delicate organs of the organism being in special liquids in tough natural vessels. Such is the brain, floating in a liquid, in the skull; such is also the embryo of the mammal, surrounded by liquid till its very birth. Even industry makes use of it for preserving delicate fruits, changing its liquid by a rough substitude - by friable substance; for example grape is covered by saw-or corkdust.

Struggle with the absence of gravity.

Now the explosion in the rocket is finished, and with this the terrifying gravity is no more. We safely come out of our casing, wipe from the body the remanents of the liquid and invest ourselves in dress. As if by way of reward for enchanced gravity, which we have just now withstood, we are now totally free from it.

The questions is: does not this absence of gravity fatally affect our health? Must not we here adopt some protective measures?.

At the time of fall or simply a jump on our planet, when still we have not touched its soil by our feet, we find ourselves in a medium, free gravity relative to our body, dress and objects around us. But this phenomenon lasts at most half a second. In this space of time parts of our body do not press upon one another, the coat does not weigh on our shoulders our watch does not pull our pocket and the eye-glasses on the nose do not press, to form on it a transverse diagram. During swimming on the Earth, the weight of our body is similarly almost paralyzed by the counter-action of water. Such an absence of weight may continue for an idefinitely long time, so long as water is suffciently warm. From this it is evident, that hardly any special experiments are necessary for proof of harmlessness of the medium , devoid of gravity. Possibly only for obese people, prove to apoplexy and the rush of blood towards the brain, such a medium will cause premature death, as lying and bathing untimely. Others are mortal, it is necessary to assume, that soon they will adapt to the new order of things. For the majority of the sick and the weak such a medium is directly beneficial.

The horizontal position also enhances blood pressure many times which draws closer this position to the absence of gravity. The lying position is not to be considered as injurious. For the weak and the sick it is beneficial while the healthy must moderate nutrition, so that lying did not prove harmful*.

Even if it were found, that people cannot live without gravity, it would be easy to create it artificially in a medium where it does not exist. For this purpose, only to mean's dwelling, even it be a rocket, a rotational motion will have to be imparted; then by means of a centrifugal force, an apparent gravity of the desired magnitude, is formed, depending on the dimensions of the dwelling and velocity of its rotation. Such a transformation of medium will not cost us anything, since the rotation of the body in airless space and in a medium free from gravitation will, without any contribution continue eternally. This gravity is particularly convenient, which can be made arbitrarily small or great and can always be eliminated and again restored; but like natural gravitation, it requires enhanced strength of dwellings and other objects, since it tends to destroy them: besides, the quick curvilinear motion harmfully affects the body.

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* The last three phrases represent the last insertion of Tsiolkovskiy (Editors).

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The action of enhanced gravity on plants has long since been tested but nothing special has been noticed; only by a change in its direction changes the direction of growth; namely, the stem points in a direction directly opposite to the direction of artificial gravity. It is interesting to know in what direction it will grow in case of its elimination; in all probability, its direction then will be a matter of chance and the influence of light.

Future of Reactive Devices.

In the first published work about eactive projectiles, we dreamed about the future still n t open and more elementary substances, the combination of which must be attended on the basis of the general data of ehemistry, by a more enormous release of energy, than the combination of the known simple bodies, for example, hydrogen with oxygen. Here, the volatile product of the combination must acquire a large velocity V_1 on exit from the reaction pipe.

According to formula (35)* it is evident that with the increase of V_1 ($\frac{M_2}{M_1}$) and V_2 - increase proportionately for the same relative consumption of the explosive material.

* See point 35 in the article "Investigations ofthe year 1903" (Editors).

It is thought, that radium, disintegrating continuously into more elementary matter, liberates from it particles of different masses, moving with amazing, unconceivable velocities, close to the velocity of light. For example, the helium atoms being released at this stage, move with a velocity of 30 - 100 thousands kilometers / second, the atoms of helium are four times heavier than the atoms of hydrogen; other little particles liberated by radium are 1000 times lighter than hydrogen, but they move with velocities of 150 - 250 thousand kilometers/second; the total mass of these particles (electrons) is considerably less than the mass of the atoms of helium. These velocities are 6 - 50 thousand times greater than the velocities of gases, flying out of the muzzle of our reaction pipe.

Therefore, it it were possible to accelerate sufficiently the disintegration of radium or other radio-active bodies, (such are probably all the bodies), then its use might give - in similar other conditions, see fornular (35) a velocity of the reactive device, by which access to the closest Sun (star) would come down to 10 - 40 years.

Then, a pinch of radium (see formula 16) would be sufficient, to enable the rocket weighing a ton, to break all relations with the solar system.

It is possible that future advancement of science will show, that all this, is far from reality but it is good that we can even now dream of it.

It may be, that with the help of electricity, it will be possible by and by, to impart tremendous velocity to the particles, being ejected from the reactive devices. And now, we know, that cathode rays in Crook's tube , like the rays of radium, are accompanied by a flux of electrons, the mass of each of which, as we have mentioned, is 4000 times less than the mass of an atom of helium, and whose velocity reaches 30 - 100 thousand km/sec, that is, it is 6-20 thousands times the velocity of the common combustion products, flying out from our reaction pipe.

Impossible Today Becomes Possible Tomorrow.

There was a time, and very recently, when the idea of the possibility of knowing the composition of celestial bodies was considered even by prominent scientists and thinkers as senseless. Now this time has passed. The idea about the possibility of a closer, and direct study of the universe, I think, at the present time will appear still wilder. To stand on the soil of asteroids, to lift a stone with your hand from the Moon, to set up moving stations in the ethereal space and form living rings around the Earth, the Moon, the Sun, to observe the Mars from a distance of several tens of versts, landing on its satellites or even on its very surface, - what apparently, may be more extravagant ! However, only from the moment of employment of reactive devices a new great era in astronomy will begin; the epoch of more careful study of the sky. The terrifying enormous force of gravitation - does it not frighten us more than it should?

A cannon ball, flying out with a velocity of 2 kilometers/second, does not appear to us amazing. Why at all should the projectile, flying at a speed of 16 kilometers/second and leaving the Solar system for ever into the deeps of the universe, overcoming the force of gravitation of the Earth and the Sun and all its systems - why should this plunge us in horror? Is there such a difference between the numbers 2 and 16? Is it not only that one is greater than the other 8 times?.

If a velocity of one unit is possible, then why is a velocity of 8 such units impossible? Are not all progressing, advancing with such rapidity that amazes our wits?. Was it very long ago that a ten versts any hour speed of was considered inconceivable and rendered our grandmothers wonder - struck? And now, automobiles are doing 100 - 200 verbts an hour i.e. 20 times quicker than they rode in the time of Newton. Was it so long ago as to appear strange to make use of any other force than the force of muscles, wind and water ? In one goes speaking on this subject there would be no end to it.

At the present time the advanced sections of mankind aspire to put their life more and more into artificial frames. Does not this represent progress? Struggle against inclement weather, with high and low temperature, with the force of gravity, beasts and harmful insects and bacteria - do not all these create around man a situation purely artificial? In the eternal space this artificiality is only proceeding towards its extreme limit, but then man will find himself in conditions, most favorable for him.

In course of centuries new conditions will create a new breed of beings and their surrounding artificiality will be weakened and , may gradually vanish. Did not ever the marine animals come out on the dry land and were gradually transformed into amphibians, and later on into terrestrial ones? The latter gave rise to aerial animals, i.e. flying ones, for example birds, insects and bats. Does not triumph over ethereal space? require triumph over air, Does not an aerial being transform into an ethereal one?

Then these beings will already be as if they are inborn natives of ether, pure solar rays and the infinite deeps of the cosmos.

Reactive Device will eliminate the calamities awaiting the Earth.

What does the globe of the Earth represent? It is a terribly glowing mass, solid inside due to the pressure of the upper layers, liquified molten close to the crust. Inside - it is all a small Sun, only on the outside packed and covered with the thin cold crust.

Chemical processes, all are still continuing deep inside her, the effect of water and the compression of the centeral mass must at times cause volcanic eruptions, and now still shocking the terrestrial layer.

Who can guarantee that in a thousand years the potential energy of the mass of the Earth's globe will not find itself, one one vicious day, with a force which will wipe out from the face of the Earth all life. The movement of the internal parts and their chemical combination accompanied by liberation of enormous quantity of heat and the increase of volume may serve as the cause of explosion. The fall of heavy elements accompanied by collection of elastic gases (helium and others) and elements can also serve as the cause. Here starts the cataclysm, destroying the organic world mechanically or through the rise of temperature of soil and air. Finally, the annihilation of higher animals may, at this stage, take place and the liberation in the atmosphere of gases harmful for respiration. The reactive device in such a case will save the seed of mankind.

The fall on the globe of the Earth of a meteorite several versts in diameter, is sufficient to kill people: and this may happen quite unexpectedly since such a meteorite, as a non - periodic comet, coming from the murky spaces of the stellar world, along a hyperbolic path, cannot be foreseen by the astronomers long before the catastrophe. Then people will perish because of earthquakes, rise of the temperature of the Earth and air and many other causes.

We see a star flare up, as if it is being born, so as again to be extinguished; this is a dark body, similar to the Earth, an extinct Sun outwardly struck by a catastrophe or due to the fall of gigantic bodies or, more quickly due to internal chemical or radio - active processes in the terribly hot inside of the celestial body.

The unexpected increase of its temperature must instantaneously annihilate all living beings, which succeeded in coming to life in the atmosphere of the planet in thousands of years of the silence of the Earth's crust.

The perishing of the Earth by coments is long awaited and not without reason, though the probability of this end is extraordinarily small; but all this might happen tomorrow or in trillions of years. It will be much more difficult for comets and other accidental, highly improbable but terrible and unexpected enemies of the living beings to annihilate by one stroke all creatures, which have been created, thanks to reactive devices in circular habitations around the Sun.

The population of the inhabitants of the Earth is uninterruptedly and sufficiently quickly increasing, notwithstanding a multitude of unfavorable conditions. For the last hundred years this growth has constituted not less than 1% per annum. If this percentage is taken as unchanging them within 1000 years the population of the Earth will increase by about 1000 times. Where will this human race be accommodated which the Earth's surface will not be in a position to feed.

The reactive devices will conquer for man limitless spaces and will provide solar energy, two milliards (2 thousand million) times more than that, which humanity has on the Earth.

But there is not one Sun, there are innumerable luminaries and therefore not only limitless space will be captured, but also limitless energy of rays of numberless suns, required for the life of creatures.

That it is possible to reach other Suns, it is evident from the following arguments: Suppose a reactive device moves uniformly only with a velocity of 30 kilometers/second, i.e. 10,000 times slower than light.

Such is the velocity of the Earth around the Sun, with such a velocity also move the meteorites from which it is evident, that this velocity is possible (without decrease) for small bodies as well. Since the rays of light from the nearest stars reach us several years, the reactive trams would reach them in several tens of thousands of years.

For the life of one man this length of tine, is of course, great but for the entire, mankind, it is similar as for the luminous life of our Sunh, it is negligible.

During the course of tens of thousands of years of journey towards another heavenly body, the human race, flying in artificial circumstances, will live by the reserves of potential energy, horrowed from our Sun.

If the transplantation of humanity is possible to another Sun, then why should our fears exist relating to luminous vitality of our new brilliant heavenly body? Let it become dark and be extinguished'. In the course of hundreds of millions of years of the glory and luster, man can make reserves of energy and will get transplanted with them towards a better seat of life.

The gloomy views of scientists about the inevitable end of all life on the Earth due to its cooling on account of the loss of Solar heat must not now have the qualities of unalterable truth.

The better part of humanity, in all probability, will never perish, but they will be transplanted from Sun to Sun to the extent of each one dying out. Through many decillions of years, we, may be, living on a Sun, which has still now not flard up, but exists only in the embryo, in the form of nebulous matter designed since centuries for high purposes.

If we now have the possibility to believe a little in infinitude of humanity, then what will happen in several thousand years, when our knowledge and reason will have grown.

Thus, there is no end to life, reason and perfection of humanity Its progress is eternal. And if it is so, then it is impossible to doubt the attainment of deathlessness.

Advance boldly forward great and small toilers of the human race, and know that not a little bit of your labors will vanish without a trace, but will bring you great fruit in infinity.

For the first time published in the journal "Air-Navigation Herald" in 1911 and 1912.

K. TSIOLKOVSKY

INVESTIGATION OF OUTER SPACE BY REACTIVE DEVICES.

(SUPPLEMENT TO THE 1st AND 2nd PARTS OF THE TREATISE OF THE SAME NAME).

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(Supplement for the year 1914).

I am seeking support for my efforts to be useful and that is why I am bringing forward all that is known to me, which may inspire faith in my works. It is hard to work all alone for many years in unfavorable conditions and not to see any opening and cooperation from anywhere.

From all the articles on "rocket" it is quite evident, that we are very far, with our contemporary technical facilities, from attaining the required velocity.

Here I would like to popularize my ideas, and make some elucidations relative to them and to refute the view on the rocket, as on something extremely distant from us.

Here are some of the theorems, that have been proved by me earlier.

Theorem No. 1 Let us suppose that the force of gravity does not diminish with the distance of a body from a planet. Suppose this body has been lifted to a height, equal to the radius of the planet: then it will perform work, equal to that, which is necessary for a full overcoming of the force of gravity of the planet.

For the Earth, for example, and for a ton of substance this work is equal to 6,366,000 ton-meters. If the projectile, as Esno Pelterie has stated, works for 24 minutes and weighs one ton, then it is not difficult to calculate that in one second its engine must give to the rocket work to the time of 4420 ton - meters or 58,800 horse power and not 400,000 as it is caculated by Esno Pelterie*.

According to my calculations, the explosion is faster and continues for about 110 seconds. In this way, in one second a projectile weighing one ton must liberate 57870 ton - meters which comes to 771,600 horsepower. All of course, will say: "Is it possible" ? A projectile weighing one ton and liberates a little less than a million horsepower !

The light engines generate at the present time not more than 1000 horse - power per ton of their weight.

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* See the article of K.E. Veigelin, "Priroda i. lydi" 1914, No. 4. Without doubt I have corrected a misprint here and not the mistake of Esno Pelterie.

But the point is, that here we are not speaking of the usual engines, but about the arrangements, resem ling a cannon.

Imagine yourself a cannon, with length of 10 meters flinging a one ton cannon ball with the velocity of 1 kilometer/second.

This is not far from reality. What work, is performed by the explosive substance and obtained by the cannon ball?. It is easier, to calculate that it comprises about 50,000 ton - meters and it is all in the course of a split second. The average speed of the cannon ball in the cannon is not less than 500 meters/second. Consequently, the space of 10 meters is covered by the cannon ball in 1/50 of a second. It means, that the work of the cannon in a second comprises 2,500,080 ton - meters or about 33,300,00 horse - power.

It is evident from here that the useful work of the artillery piece is 566 times more than the rocket of Esno Pelterie, and 43 times more than my reactive device.

Thus, quantitatively, there is nothing in cannon between the reactive projectile and ordinary motors.

Theorem 2. In a medium without gravity, the terminal speed of a rocket in the constant direction of explosion, does not depend on the force and order of explosion, but only on the quantity of explosive material, (relative to the mass of the "rocket"), its quality and the design of the explosive pipe.

Theorem 3. If the mass of the explosive substance is equal to the mass of the "rocket" almost half of the work of the explosive substance is communicated to the rocket.

This is easy to believe; all we have to do is to imagine two spheres similar in mass and a straightening spring between them. It will divide equally on expansdion between the spheres, the work contained in it.

If, for example, we have a cannon ball with a pipe and an equal mass of hydrogen at zero temperature emerging from it, the latent energy of hydrogen will be divided in two halves, with one half being communicated to the cannon ball. The velocity of hydrogen molecules, as is known, is about 2 kilometers per second. Therefore the cannon ball will acquire a velocity of about 1410 meters/second. But if we take into account the thermal capacity of hydrogen or the rotational motion of two atoms, from which each molecule of hydrogen is constituted then the cannon ball will acquire a velocity of about 2 kilometers / second.

After this it is not difficult to believe my calculations, according to which it follows that on chemical combination of hydrogen with oxygen the velocity of the newly formed molecules of water, escaping from the stationary pipe, comes to more than 5 kilometers/second. Consequently, the velocity acquired by a movable pipe of the same mass, is more than 3 1/2 kilometers / second. In fact, if the entire heat of combustion was transmitted to combination, that is to the water vapor, then its temperature would reach 10000°C (if there was no expansion of it); at this stage the velocity of the particles of vapor will be approximately six times more, than at 0°C (+ 273° absolute temperature).

The velocity molecules of water vapor at zero degree, as is known, is more than 1 kilometer / second, consequently, on the formation of vapor from oxygen and hydrogen is in progress, owing to chemical reaction the speed is upto 6 kilometers / second.

I am, of course, doing a rough and visual checking of my previous calculations.

Thus when the mass of detonating gas is equal to the mass of the "rocket" its velocity of 3 1/2 kilometers / second is highly natural and this number is very modest.

<u>Theorem 4</u>. When the mass of the rocket plus the mass of the explosive substances, carried by the reactive device, increases in geometrical progression, then the velocity on the "rocket" increases in arithmetical progression.

We shall velocity this law by the two rows of numbers:

Mass .... 2, 4, 8, 16, 32, 64, 128 ...

Velocity .... 1, 2, 3, 4, 5, 6, 7, ...

Let us suppose, for example, that the mass of the rocket and the explosive substances is 8 units.

I discard 4 units of the explosive substance and obtain a velocity which we shall take as unity.

Then I discard 2 units of the explosive material and obtain one more unit of velocity finally, I discard the last unit of the mass of the explosive substances and obtain one more unit of velocity total : 3 units of velocity.

From this theorem it is evident that the velocity is far from proportional to the mass of the explosive material, it grown very slowly, but without a limit.

There is the most advantageous relative quantity of the explosive substances on which their energy is used in the best way. This number is close to 4.

But the absolute velocities of the rocket, however, increase with more considerably the reserves of explosive materials. Here is the relative reserve of this material and corresponding velocities in kilometers per second:

Mass of explosive material 1, 3, 7, 31, 63, 127, 256.

Velocity ...... 3 1/2, 10 1/2, 14, 17 1/2, 21, 24 1/2.

Theorem 5. In a medium with gravity, for example, on the Earth during the vertical ascent of the rocket a part of the work of explosive substances is lost; the loss is the greater if the pressure of the escaping gases is closer to the weight of the latter.

If, for example, the rocket with all its contents weighs one ton and the pressure of the explosive substances on the projectile also constitutes one ton, then utilization is absent, or it is equal to zero, i.e. the explosion is without any effect, since the rocket stands at one place and no energy is communicate to it.

That is why in my projects, I take the pressure on the rocket 10 times more than the weight of the projectile, together with the weight of all its contents.

Esno Pelterie, taking the weight of the rocket at one ton, allots to the explosive substances the weight of one third of a ton. If the explosive substance) is radium, releasing its energy a million times faster than is actually the case, then interplanetary flights are assured.

I myself had once dreamed about radium. But recently I have carried out calculations, which have shown me, that if, we direct the particles (alpha and beta) emitted by radium in one direction in a parallel beam, then its weight decreases by approximately one millionth part of its own weight.

After this I discarded the idea of radium. All discoveries are possible and dreams can unexpectedly become realities, but I would like to stand on practical ground, as far as possible.

Esno Pelterie calculates that one third of a ton (20 poods) of the detonating gas can communicate to the rocket only 1/130 of the required work, needed for getting free from the force of gravity.

According to my calculations, rather a smaller part is communicated, namely only 1/540. The reason is not only that the relative quantity (1/3) of the explosive substances is insignificant, but mainly lies in the fact that the pressure of gases on the projectile according to

Esno Pelterie is accepted only at one tenth more than the weight of the rocket. This pressure is 100 times less than that taken by me.

On the basis of the last theorem (5) we have seen, that explosion in a medium of gravity may be even without any result, if the pressure of gases on the device is equal to its own weight.

As a matter of fact the relative quantity of the explosive substances (1/3) in case of Esno Pelterie is far from the most favorable one (4); therefore, in accordance with my tables, the projectile gathers velocity of not more than 1 1/2 kilometers/second and, , that too, only for the pressure of gases, as in my case. But since in his case this pressure is 9, the utilization will be 10 , and the velocity will be only about 0.5 kilometers /second. For overcoming terrestrial gravity, one requires to have a velocity of 11 kilometers/ second; Consequently, the velocity must be 22 times more, while energy, required for this, will be 484 times more.

I again repeat, that the errors detected by me in the report (paper) of Esno Pelterie, are, probably simple misprints, as it often happens; but I think, that it is not useless to correct them.

The successful construction of a rocket device, in my view, presents enormous difficulties and requires many years of preliminary work and theoretical and practical investigations; these difficulties however, are not so great, as those confronted by dreams about radium and about the as yet non-existing phenomena and bodies.

Is it possible to carry along the needed reserve of the explosive substances exceeding the weight of the rocket tens of times?

Let us suppose, that half of the elongated spindle shaped "rocket" is filled up with freely evaporating liquid explosive substances.

These substances find themselves under the influence of the enhanced relative gravity owing to the accelerated motion of the rocket, and, therefore, the walls of the latter experience greater pressure from the liquids, than during the stationary condition of the rocket on the Earth. Calculations show, that when the rocket is made of steel of dependable strength (6) and 10 meters long, with gravity exceeding that of the Earth 5 times, the weight of explosive substances may be 50 times more than the weight of the rocket together with the other contents. And this is in case of a common material with a large margin of strength. Theory also shows, that on the increase of dimensions of the rocket the relative reserve of the explosive substances decreases, and vice versa. Therefore, it is advantageous to give the rocket dimensions as small as possible, so that a length of 10 meters is fully sufficient.

Another important question is that of the temperature of the explosive substances.

Calculations show that on free (as in our explosion pipe) expansion of the products of combination of detonating gases their highest temperature must reach 8000°C.

But in practice even lime does not melt in a burning detonating gas. Consequently, the temperature is from far being so high. The cause lies in the phenomenon of dissociation.

When hydrogen and oxygen begin to combine chemically, the temperature increases so much that it prevents the larger part of molecules from taking to part in the chemical combination, since it is not possible at so high a temperature. Water begins to dissociate into hydrogen and oxygen even at 1000°C. Deville has found that the temperature of decomposition of water vapor is from 900 to 2500°C. Therefore, one may imagine that the maximum temperature of burning detonating gases does not exceed 2500°C.

The problem of the search of materials, withstanding such a temperature is not insurmountable. Here are some fusing temperatures of bodies, known to me: Nickel - 1500, Iron - 1700, Indium - 1760, Palladium - 1800, Platinum - 2100, Iridium - 2200, Osmium - 2500, Wolfram (Tungsten) - 3200 , Carbon does not melt even at 3500°C. On the one hand, the explosion pipe must be strongly cooled, and on the other - the investigators must search for substances which are strong and have high melting points.

Investigation must also be directed to finding out the substances most suitable for explosion. Of all the known chemical reactions the combination of hydrogen with oxygen yields the maximum quantity of heat.

How much heat is liberated per unit weight of the substances taken during their combination with oxygen, is given here: Hydrogen on the formation of water yields 34180 calories, and on the formation of vapor 28780 calories, coal on the formation of carbon dioxide gas, 8080 calories, and hydrocarbons, from 10000 to 13000 calories. But these figures are not important for us, as those which are expressed per unit mass of t e combustion products: only they give us an idea of the suitability of combustible materials for the rocket. In a unit mass of water vapor we find 3200 calories of carbon dioxide - 2200, and of petrol - 2370. Generally, hydrocarbons on combustion per unit of their mass yield a greater number than that of carbon, i.e. larger than 2200, but not reaching up to 3200.

but not reaching up to 3200. The more hydrogen is in the hydrocarbon the more advantageous it is for the "rocket". The materials giving nonvoltaile products, as, for example, calcium oxide or lime should not be considered.

One of the gases in the liquid form, preferably oxygen, is useful as a means of cooling the explosion pipe. Hydrogen in the liquid form may be replaced by liquid hydrocarbons or those which are easily condensed into liquid form. It is necessary to find out such compounds of hydrogen with carbon, as containing possibly more hydrogen, are formed from their elements with the absorption of heat as, for example, acetylene, which, unfortunately, contains less hydrogen. In the last resort turpentine and methane or marsh gas even better should serve the prupose; but this gas is not good because it condenses into liquid with difficulty.

There is no restriction on searching for similar compounds for oxygen also.

We must find out unstable compounds of oxygen with itself (like ozone) or with other bodies, which would give stable and volatile products on combination with the elements of hydrocarbons, with large release of heat.

If for the rocket, in place of hydrogen we were to use benzene or petrol, then for the occasion, when the mass of the explosive materials is equal to the mass of the "rocket" with its remaining contents, we should find the velocity of particles, flying out from the pipe to be only 4350 and not 5700 meters/second. And the velocity of the rocket would be only 3100 meters/second. Therefore now we should obtain the following table of masses of explosive material and rocket velocities.

Mass 1, 3, 7, 15, 31, 63, 127

Velocity kilometers/second .. 3, 6, 9, 12, 15, 18, 21.

These velocities are also sufficient for inter stellar voyages.

Hydrocarbons are advantageous because they yield very volatile products: water vapor and carbon dioxide; besides liquid hydrocarbons at ordinary temperature, do not absorb a considerable quantity of heat on their heating up, like liquid and very cold pure hydrogen.

The question of the weight of the explosion pipe; is important.. For this purpose it is necessary to know the pressure of gases inside it. This question is very complicated and requires a thorough mathematical exposition (which I am preparing for the press). Here we shall touch upon it very briefly.

We shall imagine the intake of the explosion pipe, where gases flow in a definite ratio and in liquid form (e.g. hydrogen and oxygen). Only a part of the atoms enter into chemical combination, because the temperature increasing up to 2500°C, hinders the combination of other atoms. Taking the density of the mixture of gases as unity, we shall find, that their elasticity, taking into consideration their high temperature, does not exceed 5000 atmospheres, or about 5000 kg/cm^2 of the surface of the pipe at the very time of its intake.

At the time of the motion of gases in the tube and their expansion, the temperature must decrease, but this will not happen for some time, since the lowered temperature will immediately provide the possibility for the chemical reaction to continue, which will again increase the temperature to 2500°C. And thus, to a certain degree of the expansion of gases, their temperature will remain constant, since it is maintained by the heat of combustion.

After the combination of all the atoms and the formation of water vapor, a quick lowering of temperature will begin. Calculation shows that with a six foldincrease of volume the absolute temperature falls twofold. On this basis we shall compile the following table of expansions and the corresponding absolute and ordinary temperatures (approximately).

Expansion	1	6	36	216	1296	7776
Absolute Temperature	2800	1400	700	350	175	87
Temperature °C.	+2500	+1100	+400	+50	-125	-213

From this it is evident, that on expnasion to about 200 times already almost the entire heat has been liberated, converting it into the work of forward motion of gases and the rocket. On subsequent expansion, the vapor is converted into liquid and even into the crystals of ice rushing out of the pipe with amazing swiftness.

Thus, such is the rough picture of the phenomena in the explosion pipe.

Let us suppose, for the sake of simplicity that it (the rocket) is cylindrical in shape and then find out its greatest thickness and the bottom area.

Let the weight of the rocket along with all its parts, and persons, besides the reserves of the explosive substances, be one ton. We shall then take 9 tons as the quantity of explosive substances.

We shall suppose the pressure on the rocket as 5 times more than its weight. The relative gravity of the rocket along with all the substances in it will be 5, i.e. 5 times the gravity on the Earth. The person must be in a lying position and immersed in a casing containing water. At the same time it is essential to guarantee for, the full safety of his body.

So, the pressure of gases on the rocket or on the bottom of the pipe comprises 50 T or 50,000 kilograms. And since the gases at the beginning of the pipe exert a pressure of 5000 kilograms per 1 c m ^{2} then the area of the bottom of the pipe will be 10 cm^2. The thickness of the walls of the pipe, using good steel and the usual safety (6), will be calculated as equal to 4.5 cm, the internal diameter being 3.6 cm. It means that the external diameter will be less than 13 cm, while the internal less than 4 cms.

The weight of one dicimeter of such a pipe will be about 10 kilograms and of one meter 100 kilograms, but one must not forget, that the weight of the pipe must fast diminish on removal from its origin, since the gases expand very fast and their pressure falls proportionately, not to speak of the lowering of temperature, which does not start immediately, but receding somewhat from the origin of the pipe.

However, it is evident that the pipe makes the larger part of the weight of rocket. Therefore, investigations must also be directed to the search for materials, very much harder than the common steel, which may not suit out pruposes, apart from its fusibility.

The determination of gross weight without higher mathematics is difficult. We leave this question for the more detailed treatise.

The explosive materials should, any method, be pressed into the tube; for this, enormous work is required, constituting one of the difficulties of the job. But, the eyes should not be closed. If the rocket weights 1 ton, and the explosive material - 9 tons, and acceleration of rocket is - 50 meters/sec^2, then the pressure on it (the pipe) during inclined (more advantageous) ascent will constitute about 50 tons. The initial elasicity of the gases and pressure on the bottom will be 50 tons. The pressure of the gases on 1 cm was taken by us as 5 tons, Now from this data we shall find, that for obtaining a velocity of 10 kilometers per second the explosion must continue for about 200 seconds; we must supply to the tube about 45 kilograms of the explosive material in a second.

The velocity of their flow, assuming their average density at unity, will be about 45 meters/second. The work of shoving of the explosive substance, when the pressure in the intake is enormous, will be 2250 ton meters in the course of one second, which will constitute 30,000 steam horses.

We have obtained the result which is unthinkable for engines in the present condition of technology. Therefore, pumping by common methods must be discarded. The simplest of all is to insert into the tube a known charge and to allow it to explode and volatilize. Thereafter in the absence of pressure another charge should be moved into the tube and so on. This must be done by a machine and with uncommon quickness too. Difficulties are also found here.

We shall observe that the useful work of the explosive substances in our projectile will not be less than 400,000 horse - power, which constitutes 13 times more work of injecting explosive material into the pipe. Cannot this material be injected by the work of the explosion itself, as the engineer Zhiffard injects water into the boiler by the force of the pressure of steam in it?

At the very intake of the pipe there must be a branch pipe through which the gases return to the intake and by dint of their quickness, suck in and inject the explosive material in a continuous jet into the very intake of the explosion pipe.

This would be feasible, without doubt, if structural materials suitable in refractoriness and strength were found.

If one takes into account the enormous force of pressure of gases on the rocket, reaching 5 tons and more per ton of the rocket, the problem of control of the rocket will not appear to be easy. By turning the exit end of the explosion pipe and changing the direction of the emerging gases, we produce lateral pressure and a change in the position of the rocket. But the total pressure on it is so great that before turning back the funnel (or the rudder in it), the rocket will have already received a powerful deviation or even overturned. Rockets and projectiles in general, designed for war purposes, are made to rotate for the sake of stability of the direction. They are given quick rotatory motion around the longitudinal axis. With our rocket this is not done because rotation causes centrifugal force, which is harmful to all living beings. But stability can be attained if two rapidly rotating bodies are installed in the rocket, the axes of rotation of which are perpendicular to one another. This will increase the weight of the rocket, which is not desirable.

Even in the minds of the educated people the pictures of the phenomena taking place in the rocket during its ascent, are very hazy. The description of science - fiction writers regarding these phenomena are either empty or unreliable.

The apparent gravity in the rocket depends on the acceleration it gets from the pressure of gases. Thus, if the acceleration of the rocket is 50 meters / second, the relative gravity in it will be 5 times more than the terrestrial one, since the accleration of the latter is 10 meters/per second^2. Therefore, at the time of explosion, there will be enhanced gravity in the rocket for 3-4 minutes; after the termination of explosion the gravity is destroyed, since the acceleration due to explosion will be zero. The accelerated gravity may easily be withstood, by getting into a strong casing of the form of a human being, containing very small quantity of water. Preliminary experiments must be conducted with the help of a large centrifugal machine, also generating relative gravity.

Similar experiments must be carried out in order to work out conditions, necessary for respiration and nutrition of the person, when the rocket is flying in a medium of airless space.

The above described picture gives an idea of the design of the reactive projectile for cosmic voyages.

The rear stern half of the rocket consists of two chambers, divided by a partition.

The first chamber contains freely evaporating liquid oxygen. It has a very low temperature and surrounds part of the explosion pipe and other instruments subjected to high temperature .

The other compartment contains hydrocarbons in liquid form. From the intake of the explosion pipe, two branches emerge with quickly rushing gases, which inject liquid elements of explosion into the intake, similar to a steam jet pump.

The freely evaporating liquid oxygen in gaseous and cold conditions flows around the intermediate space between the two shells of rockets and by this prevents the heating up of the interior of the rocket during its fast motion through the air.

The nose compartment i.e. the accommodation sealed from all sides includes:

1. Gases and vapor needed for respiration.

2. Devices for protecting living beings from five-fold or ten-fold forces of gravitation.

3. Food supplies.

4. Control devices, notwithstanding the lying position in water.

5. Substances, absorbing carbon dioxide gas

miasmae and generally all the harmful products of respiration.

Here, we shall perform rather rough calculations for comparison of artillery guns with the rocket pipe.

Though I have read about experiments with cannon balls which have attained velocities up to 1200 meters/second, yet in practice they are in the vacinity of 500 meters/second. In addition to it, not considering the resistance of the air, the cannon ball, moving vertically, rises to an altitude of 12 1/2 kilometers. On a flight at an angle of 45^o, it covers the maximum distance in the horizontal direction, namely 25 kilometers. In the first case the cannon ball flies for 100 seconds, in the second for 70 seconds.

When the velocity is 1000 meters/second the maximum ascent is 50 kilometers while the maximum horizontal displacement is 100 kilometers. The duration of the flight will be double.

With a 14-inche gun with length 10 meters and the weight of the projectile one ton, we shall find that the average pressure in the barrel comprises about 1250 kg/cm^2, or 1250 atmospheres. On a doubled velocity of the cannon ball, the average pressure reaches 5000 atmospheres. The maximum pressure is, of course, much larger. Consequently, in a cannon the pressure is close to the pressure taken by us in the rocket (5000 atmospheres).

Taking the mass of explosive substances at one ton in our gun, and the time of motion of the cannon ball in the barrel as 1/25 second (the final velocity is 500 meters/second) we shall find, that on an average, in a second 25 T of the explosive substance is consumed.

In our rocket only 45 kilograms of explosive substance is consumed, i.e. 555 times less. It is understood that the magnitude of the explosion pipe of the rocket is small.

In the explosion pipe of the rocket gas molecules are injected and not the heavy cannon balls. Naturally their velocity is much greater than the velocity of cannon balls which attain 5 km/sec. The velocity acquired by the rocket is of the same order. Hot gases transfer their work to the cannon ball to a small extent but only when they are in the barrel. Emerging from it, they still possess enormous elasticity and high temperature, which is proved by the sound and flash (light) at the time of gun fire. The gradually expanding explosion ipe of the rocket is so long that the temperature and elasticity of the gases emerging from the funnel (rudder) are completely destroyed. In this way the energy of the chemical reaction is consumed in the rocket almost without any residue.

The Spaceship (1924).

If on a body, pressure greater than its weight is exerted from below, then it will not only lift the body but will also continuously accelerate its motion. After some time it will receive a velocity, which may be sufficient for its eternal recession from the Earth and even from the Sun.

That is the basis for interplanetary and interstellar (intersolar) voyages. For recession of the projectile from the Earth and its straying the orbit of our planet, sufficient relative velocity (i.e. relative to the Earth, considering it to be stationary) of 11.2 kilometers / second, and for eternal recession from the Sun, sufficient relative velocity of 16.5 kilometers /second* are needed. In this case, it is necessary to make use of daily and particularly annual motion of the Earth, otherwise the required velocities will be rendered monstrous. For eternal flight around the Earth beyond the atmosphere, a velocity not less than 8 km/sec, is necessary. Then our projectile will be similar to a tiny moon.

What are the means existing, so as to apply pressure on the body, several times more than the weight of this body?

* All the figures and reasonings given here are based on calculations, contained in my works (Author).

First of all cannon comes to mind with explosive materials (powder, for example), with compressed gases, with superheated volatile liquids, electromagnetic force etc.

But here, not a few insurmountable impediments spring up. Let us suppose for the sake of simplicity, that the pressure of gases in the cannon is one and the same for the entire duration of explosion. Let the projectile (cannon ball) weigh one ton, while the pressure of gases on it be 2 tons. The acceleration will be twice the terrestrial and therefore the cannon ball will acquire an apparent relative gravity, twice that on Earth in other words, the pressure of gases on the cannon ball will be just as many times greater than its usual weight, as the apparent gravity in the cannon ball will be greater than the terrestrial gravity. At the same time, in order to obtain a sufficient velocity to overcome the terrestrial gravity, the cannon must have a length of approximately 3000 kilometers.

If the cannon is shorter, for example, with a length of 60 kilometers the pressure, required for acquiring sufficient velocity will be 100 times larger than the usual weight of the cannon ball with all its contents. In this case the weight of the bodies in it will increase 100 times. Such a gravity would be hardly withstood by a living being, even in the best protective medium.

When the cannon is 600 kilometers long the average apparent gravity increases 10 times. Even this gravity is hardly tolerable by man despite his being immersed in the liquid of the same density, as the average density of his body.

Let us explain the value of the liquid as a protective medium. Suppose that you are immersed in a liquid of the same density as the mean density of your body, and you are breathing through a small tube extending into the air. Your weight, seemingly vanishes, it is balanced by the pressure of the liquid, you neither go up not down. You are is equilibrium at any depth. Let the gravity now increase a million times. As before, you will be in equilibrium and will not feel the enhanced gravity. As before it seemingly does not exist for you. In fact, although the gravity of your body has increased one million times, and the pressure of the liquid has also increased just as many times. It menas, the equilibrium is not upset.

And so the liquid seemingly protects a person from destruction at any increase of gravity. Not in vain does nature take such precautionary measures, when it wishes to protect the tender bodies from the rough force of gravitation and jolts. For example, the embryos of animals develop in liquids, the brains of higher animals are also in analogical conditions.

But that would have been the case, if the body of a man, were fully uniform in density. This, unfortunately is not so. The bones are much denser than the muscles, while the muscles are denser than fat. On the increased force of gravity, a difference of pressure will appear, which, on a sufficiently large force of gravity, may destroy any organism. Only experience will determine the greatest relative gravity, which man may safely withstand for his health. Its ten-fold increase is considered possible, but then the cannon must have a length of 600 kilometers. In case of such a length, we have to arrange it inevitably in a horizontal position. Its cost is incredible and feasibility unlikely. Besides, the resistance of the air during horizontal flight and the enormous initial velocity would destroy the major part of the kinetic energy of the projectile and it would not reach its goal. Electromagnetic or other systems of cannon would inevitably yield the same lamentable results.

It is possible to acquire velocities still banking on air, as by air plane or a dirigible airship. But the velocities acquired by this method are much too far from what are needed. For example, the velocity of an air plane, i.e. 100 meters second (360 Km/hour) amounts to only 20th (less than 1%) of that required for overcoming the Earth's gravity completely.

It is difficult to expect that, an ordinary unmodified air plane could acquire cosmic velocity. The velocity of an air plane must be limited to 100-200 meters/second (360-720 kilometers/hour). But the air planes can be modified and can be put into motion by a different method without the help of air propellers, namely by the process of ejection of air by special complicated turbines. This method, apparently, provides an unlimited velocity and an unlimited quantity of material for ejection (oxygen, taken from the atmosphere). However, oxygen, at a considerable height (100-200 kilometers), in all probability, almost disappears giving place to hydrogen. Perhaps, it would be possible to make use of hydrogen as a fuel.

A still simpler method is to put airoplanes into action by the explosion of the earlier reserve explosive substances, but then the air plane turns into a gigantic rocket. This method is somewhat worse than the previous one. In fact, one has to store not only fuel but also oxygen, the weight of which is 8 times more that of the lightest fuel - hydrogen. Such a device as compared with the previous one is loaded with nine-fold reserve of the potential energy (in the form of explosive substances) Theoretically, at a certain, height, the explosive mixture of oxygen, nitrogen, and hydrogen must be found. It is true, this mixture is very rarefied but its pressure may be raised by means of complicated centrifugal pumps. Then the rocket may not have large reserves of fuel and easily acquire very great velocities in the rarefied layers of the air.

And finally, there is the third, the most tempting method of acquiring velocities . This is to transmit energy to the projectile from outside, from the Earth. The projectile itself need not store material part (i.e. weighable, in the form of explosive substances or fuel, or energy). The energy is transferred to the projectile from the planet in the form of parallel beam of electromagnetic rays with small length of short wave length. Such rays may be directed by parallel beam with the help of a large parabolic mirror towards the flying air plane and there perform work required for ejecting particles of air or the reserved "dead" material for obtaining cosmic velocity while still in the atmosphere.

This parallel beam of electrical or even light (Solar) rays must exert pressure, which also can give sufficient velocity to a projectile. In that case reserves are not needed for ejection.

The last method is seemingly most complete. In fact, on the Earth a power station could be built, almost of unlimited dimensions; The station transmits energy to a flying apparatus, which itself does not need any reserves of special energy. It will hold only passengers and what is necessary for their lives and its own continuation during the journey or during permanent residence in the ether. It would considerably simplify the problem of the inter-planetary communication.

The pressure of solar light at the distance of the Earth is not more than 0.0007 gram on one square meter. So as to produce a pressure of 10 tons (assuming that the projectile weighs only one ton), or 10 million grams, a mirror surface, not less than 16,000,000 square meters is needed. Then the rib (side) of a square parabolic reflector must be not less than 12.6 kilometers. It is not to be considered feasible, especially at the present time. Furthermore, beam of rays would instantaneously melt the most refractory material of the clestial ship. There is also the question as to how to direct the beam of energy onto the apparatus which is constantly changing its position. Such a method of obtaining velocities will pose a number of difficult problems, the solution of which, we shall leave to the future. But, the pressure of the solar light, the electromagnetic waves, electrons and helium particles (alpha - rays) may be applied to the projectiles, even today in the ether having succeeded already in conquering the gravity of the Earth and only needing further cosmic propulsion.

But all this is, for the time being, in the realm of fantasy.

At the present time it is advantageous at great heights in the atmosphere to make use of rarefied air for ejection, the pressure of which of course will have to be increased by complicated centrifugal compressors. When a velocity of about 8 kilometers/second is obtained then the projectile spirally comes out of the atmosphere completely and revolves around the Earth, as the Moon. In future it would be easy to obtain cosmic velocities.

We have, pointed out the magnitude of velocities required for overcoming the gravity of the Earth, the planets and the Sun, but we have not calculated the work, required for obtaining these velocities.

The simple integration shows that it is equal to that which is required by a projectile or some other body, so as to ascend to the distance of the Earth's radius, assuming that gravity is constant.

The work of gravitation is not infinite, but on the contrary, has a specified and not very substantial value.

If a body has a weight of one ton, then the entire work of gravitation of the Earth on infinite recession of this ton constitutes 6367000 ton meters. The latter value numerically expresses the radius of the Earth in meters.

Let us compare this energy with that, which is at the present time available to man. A ton of hydrogen, on burning in oxygen liberates 28780000 large calories, which correspond to 12300000 ton - meters.

It means that if this energy could be converted into mechanical work, then it would be almost twice larger than that, which is needed, so as to liberate completely one ton of fuel from the force of the Earth's attraction. Petrol gives up to 5560000 units of work i.e. the energy of petrol is slightly less that needed for complete recession of its mass from the Earth.

It is true, there is no oxygen in the ethereal space, and therefore we must take oxygen with us in the rocket device. Generally speaking, we must lift fuel oxygen and the ship itself with all its accessories persons.

A ton of a mixture, consisting of hydrogen and oxygen, forming water on chemical combination, liberates

1600000 ton-meters of work. This energy comprises only one fourth of that which is needed for a complete escape from the force of gravity of only the solitary product of combustion (i.e. water).

Petrol with oxygen gives 1,010,000 ton-meters per ton. This constitutes even less than one sixth of the required energy.

The energy of radium and other similar substances is enormous, but it is liberated so slowly, that it is absolutely unsuitable*. Thus, a ton of radium liberates, in a period of 2000 years, one U.S. billion ton - meters, which is a million times more than that released by coal, in the formation of one ton of its combustion products. One kilogram of radium yields about 130 calories in an hour, or 55640 gram-meters, which in a second will constitute about 15.5 kilogram-meters. Consequently, one kilogram of radium gives the continuous work of a workman in ideal employment. A ton of radium in these very conditions gives about 155 horsepower. It means, that in its weight radium is 5 times less productive, than aero-engines (they do not yield less than the same force for one kilogram of their weight).

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* At the time this article was written (1924) representations about the intra-atomic energy were insufficiently worked out and the possibilities of chain reactions were unknown (Editors).

There can be no question, that the needed quantity of radium cannot be found at present at our disposal, and that its cost is so stupendous that there does not exist even the radium engine and its ideal use is impossible.

But the use of electrons and ions is fully probable, i.e. cathode and anode or the canal rays (positive rays), particularly the last named.

The force of electricity is infinitely great and therefore may give mighty beams of ionized helium, which can be utilized for the clestial ship. But we shall leave off these dreams for the time being and shall return to our dull explosive substances.

It appears that the use of the most energetic explosive substances in the most ideal conditions, does not permit the overcoming even of their own gravity. But we shall now prove, that the explosive substances, taken in sufficient quantity, under specific conditions may transmit to celestial ships any velocity, and that in this way cosmic peregrination may be accomplished.

Let us suppose for a moment that there is no gravity. We have here two bodies of equal mass and between them there is a compressed spiral spring. The spring gets loose, and both the bodies, being stationary till that time, acquire equal velocity. We shall change one of the bodies by an equal mass of compressed gas, directed in its motion by a tube in one direction. We shall confine ourselves to a hollow sphere with a compressed gas or a superheated volatile liquid enclosed in it. The gas emerges in one direction, while the mass of the vessel- in the other. In place of the gas or vapor, for abtaining great velocities we may take an explosive substances.

The speed of emerging products of explosive substances may attain 5 Km/second in empty space when the length of the tube is sufficient. It means, that our rocket having a mass, equal to the mass of the exploding materials may acquire such a velocity.

Let us suppose, that the mass of the explosive substances is 3 times greater than the mass of the rocket. We shall take the mass of the rocket as unity. The mass of the explosive substances will then be equal to 3 or ($2^2-1 = 3$).

First we shall explode two units. The remaining two units of mass will receive a velocity of 5 Km/second. After this, we explode one more unit. We receive an increase of 5 Km/second. The projectile will receive a velocity of 10 Km/second. Now let us imagine, that the reserve of the explosive substance of the roc et is 7 units of the mass, i.e. $(2^3-1 = 7)$. We explode 4 units. The remaining four units receive a velocity of 5 Km/second. We explode another 2 units. The remaining units receive 5 Km/second more, i.e. in all 10 Km/second. Finally, the third time we explode one unit . The empty rocket of the mass being unity receives still more 5 Km/second, and it will have a total of 15 Km/second . The reserve of the explosive substances, as compared with the mass of the rocket, may be successively as : $2^4-1 = 15$; $2^5-1 = 31$; $2^6-1 = 63$; (2^n-1).

The corresponding velocities of the ship will be $5 \times 4 = 20$, $5 \times 5 = 25$; $(5 \times n)$ kilometers/second. . Obviously, the magnitude of velocity increases un limitedly whereas even for interstellar voyages, a velocity more than 16-17 Km/second is not required.

In a field of gravitation, part of the work of the explosive materials is wasted. This part is the smaller, the faster the explosion takes place. Thus, during an instantaneous explosion, there would be no loss of energy. There would also similarly be no loss in case the direction of the vector of reaction of gases is normal to the action of gravity (towards the vector) no matter what the speed of explosion is.

During an instantaneous explosion the relative gravity in the projectile will be infinitely great and therefore must kill all the living beings, who are in the clestial ship. In case of a horizontal direction of explosion, the rocket falls on the planet before acquiring the required velocity. At 8 kilometers/second, the centrifugal force becomes equal to the force of gravity and the projectile describes innumerable circles.

Moreover, during a horizontal flight, the traverse through the atmosphere increases many times. Because of this a considerable part of the work of explosive substances is literally squandered away on the air.

My calculations show that the most advantageous angle of elevation of the interplanetary ship is confined between 20 and 30°. At the same time the resistance of the atmosphere is not very great, and the relative gravity in the rocket is small, and the loss of energy of the explosive substancesdue to the force of gravitaty is small.

Thus, apparently, the projectile of any mass, can acquire a cosmic velocity with a comparatively small reserve of explosive substances.

It is necessary to use the most energetic explosive substances and to explode them in a very strong and small vessel, which we shall name explosion chamber, or the intake of the explosion pipe . The pressure of gases will be tested only by this chamber and its continuation - the explosion pipe, to which the production of explosion would be directed, gradually expanding and cooling by means of conversion of liberated thermal energy into kinetic energy.

The pipe and the explosion chamber have very small volume. Therefore their mass cannot be very great. It does not increase with the increase of the reserve of explosive substances. Vessels containing the explosive substances, do not experience any pressure, with the exception of that, which results from their enhanced, relative powderability. Such vessels, especially in case of multi-chambered (with partitions) arrangement and many explosion pipes, may weigh much less.

Continuous pumping of explosive materials into the explosion chamber is needed. Explosion in a medium with gravity must take place very rapidly, the quantity of the materials exploded in a second is great, and pressure is several thousand atmospheres. It is understood that the work of pumping is not small. We shall observe that in the capacity of the explosive substance prepared material, for example gun powder, dynamite etc. may be used, either two or several substances separated from one another, which should be mixed in the explosion chamber and on explosion yield gaseous products. The last named is practicable in all respects. In future we shall assume that in the rocket two or more substances, yielding gaseous products on reaction, will be used.

As my calculations show when a cosmic rocket is moving at an angle of 30° with the horizon, the gravity and resistance of the atmosphere absorb some energy. On rough calculations we shall neglect the mentioned before losses and take the acceleration of the rocket at 30 meters/second^2. The relative gravity in the rocket will be three times more than the Earth's. The table given below shows approximately the time in seconds from the beginning of the motion of the rocket, corresponding velocity in Km/second, the path traversed and the height of the ascent in kilometers. The fifth column indicates density of the atmosphere, or the force of terrestrial gravity.

Examining the table, we obtain the picture of motion of the rocket. Its motion continuously increases. In 15 seconds the velocity attained is 0.45 km/second, but the resistance of the atmosphere has already diminished twice, since the rocket has been raised to 5 kilometers, where the density of the air is twice that at the sea level. Still in 5 seconds the density decreases three times, the rocket attains a height of 9 kilometers at a velocity of 600 meters/second. The rocket has crossed the troposphere in 30 seconds from the start of the flight, it has attained a velocity of 0.9 kilometer/second, the resistance of the air is very weak, since the rocket has been brought to a height of 20 kilometers, where the density is 0.06, i.e. the air is 17 times rarer than it is below. Further the rocket flies through the stratosphere. This is the region of the falling stars (place of their burning up and destruction) and luminous clouds .

Approximately within a minute since the start of the motion, the rocket attains a height of 80 kilometers. Ascending higher than 80 kilometers, the rocket enters the mysterious region of the Aurora Borealis.

In 150 seconds or 2.5 minutes, the rocket enters the absolute vacuum, in the region of the luminous ether, where the velocity acquired by it becomes eternal as much as the motion of celestial bodies is eternal. First of all it is necessary to concentrate on the position of the small neighboring Moon of the Earth in the capacity of its satellite. From here it is not difficult to perform all future displacements and movements to the very exit from the Solar system and flight amid stars. The velocity

Time (seconds)	Velocity (Km/sec)	Distance (Km)	Height (Km).	Density of Air	Time (seconds)	Velocity (Km/sec)	Distance (km)	Height (km)	Force of gravity
0	0	0	0	1	260	7.8	3 101	1 550	0.66
1	0.03	0.046	0.023		270	8.1	3 340	1 670	
2	0.06	0.183	0.91		280	8.4	3 596	1 798	0.61
3	0.09	0.413	0.26		290	8.7	3 858	1 929	
5	0.15	1.15	0.57		300	9.0	4 130	2 065	
7	0.21	2.25	1.12		320	9.6	4 700	2 350	
10	0.30	4.6	2.3		350	10.5	5 620	2 810	0.50
15	0.45	10.3	5.1	0.5	370	11.1	6 184	3 100	0.45
20	0.6	18.3	9.1	0.3	380	11.4	6 235	3 117	
30	0.9	41.3	20.6	0.06	390	11.7	6 287	3 143	
40	1.2	73.4	36.7	0.006	400	12.0	7 339	3 669	0.41
50	1.5	115	57.5		420	12.6	7 980	3 990	0.38
60	1.8	165	82.5	0.000020	450	13.5	9 290	4 645	
70	2.1	225	112		470	14.1	10 140	5 070	0.31

Continuation ....

80	2.4	294	147		500	15.0	11 470	5 735	
90	2.7	371	185		520	15.6	12 460	6 230	0.26
100	3	459	230	0.000006	550	16.5	13 880	6 940	.
120	3.6	660	330		570	17.1	14 900	7 450	0.21
150	4.5	1030	515	0.000002	600	18.0	16 510	8 255	
170	5.1	1330	660		620	18.6	17 600	8 300	0.18
200	6	1830	915		650	19.5	19 380	9 690	
220	6.6	2220	1110		700	21.0	22 480	11 240	0.13
250	7.5	2870	1435						

of the rocket reaches 4.5 kilometers/second, and it is at a distance of 500 kilometers from the surface of the Earth.

But this velocity of the projectile is not enough, to make it a reliable satellite of the Earth. The rocket flies for 2 more minutes, making a total of 270 seconds from the start of the motion and by explosion attains a velocity of 8 kilometers per second and reaches a height of a 1700 kilometers.

Here the force of gravity of the Earth diminishes remarkably (about 35%) and the rocket should ascend considerably higher, if its path is always vertical. Let us suppose, that the explosion is continuing, then the table will show us its subsequent results. Calculations for subsequent explosions are given in the table; during the determination of height the diminishing of the force of gravity is not taken into account, as the point of importance is not the altitude of ascent but the acquired velocity. It provides the possibility, at the end of the explosion in 370 seconds, of receding completely from the Earth and flying in its annual orbit, in the capacity of its colleague, as a planet. In a subsequent explosion during 550 seconds (9 minutes) from the start of the flight, the vèlocity will not only be sufficient for reaching any planet (only the direction of the velocity of the rocket must coincide with the annual revolution of the Earth), but for completely overcoming the attraction of the Sun and wandering amid the other suns of the Milky Way.

Such an insignificant velocity overcomes the mighty solar attraction because the velocity is relative. The absolute velocity relative to the Sun is extremely great. We have made use of the work of the motion of the Earth and this has provided us with such a might itself losing a very negligible part of its velocity.

We calculated earlier in our publications that a celestial ship, for obtaining the initial cosmic velocity of 8 kilometers, (conditions of the rocket in the form of a small moon close to the Earth) must take reserve of the most energetic explosive substances, 4 times exceeding the weight of the rocket with its remaining contents.

If a rocket containing people and other things weighed one ton, then the consumption of the explosive substances should weigh 4 tons, or 400 kilograms, in the course of 270 seconds. The average, rate of their consumption in one second is 15 kilograms.

The pressure onthe cosmic rocket*, will be 3 times more than the weight of the rocket along with all the contents,

* Reaction of the gases emerging from the sun or the tractive effort of the rocket. (Editors).

including the unexploded materials. In this way, if the acceleration is constant, then in the beginning of the flight, when the rocket weighs 5 tons, the pressure comprises 15 tons (5x3). At the end of the explosion, when the material has been consumed and the rocket weighs one ton, the pressure is only 3 tons. It means, the consumption of the explosive substances in the beginning of the flight will be 5 times more, than at its end. If we took the mean consumption at 15 kilograms/second then the rocket in the beginning of the motion, would move more slowly while at the end, faster. This would be useful for reducing the losses due to resistance of the atmosphere.

This would similarly simplify the arrangement of the explosion pipe and the explosion chamber.

The work of the explosive material i.e. 4 tons of the substances, assuming the energy of chemical compound of hydrogen with oxygen, will be 5600,000 ton-meters. Consequently, in one second it liberates 20700 ton-meters, which corresponds to the work of 207000 metric forces. From this it is clear, that the work of explosion is enormous and cannot be compared with the capacity of common engines.

Meanwhile, the weight of the explosion pipe, which performs this gigantic work, is very insignificant: in all only a part of a ton.

Is it possible? Fully possible. We shall see the proof in the work of artillery guns. It is not difficult to calculate that the gun ejecting (firing) a ton of cast iron with an initial velocity of 1000 meters per second performs 50000 tons-meters of work, and this too, in the course of 1/50 second. It means that the work will amount to 2500,000 ton-meters in a second or 25 million metric forces. It is the additional work of the explosion pipe 121 times. If such a cannon weighs 20 tons, then our explosion pipe will weigh less than 200 kilograms, which is practicable (as my calculations show).

I shall give a description of the cosmic rocket as it was compiled by me in the year 1914.

The steering controls and be turns are similar to those of an air plane. They are located outside opposite the intakes of the explosion pipe. They function in the air and in vacuum. Their deflection, along with the deflection of the rocket in the atmosphere takes place due to the resistance of the air and the pressure of impetuously rushing gases. Similar is the rudder, but located separately may also serve as the regulator of rotation, i.e. it can compel the rocket to rotate in one or the other direction, gently or forcefully and stop the involuntary rotation of the rocket, taking place due to inaccurate explosion and the pressure of the air. Its function depends on the screw-shaped chamfering of the rudder plate, located along the flow of gases in the tube. The designation of course, is in the stoppage of any type of rotation of the rocket, fatal for people.

We shall describe the sensation of the travellers, being directe in the cosmic ship for wandering around the Earth similar to its Moon. It is presumed, that the rocket is well-organized and fulfils well its purpose.

In the rocket there are several casings of the form of human beings according to the number of travellers. People lie down in them in horizontal position with respect to the apparent velocity and are poured in with slight quantity of water. Hands are accommodated there is the liquid, but are free, so that they may control the levers of the devices also located in water. The devices adjust the direction of motion of the rocket, the composition of its air, temperature, humidity, explosion etc.

The travellers findthemselves in such a position for 270 seconds of the explosion and cannot observe much. Their gravity has been lowered very much by water.

Let us suppose, that the travellers are standing or are sitting in easy chairs, looking through the transparent windows and are silently observing the surroundings. Then in these 270 seconds or 4½ minutes, it is possible to notice something or the other.

An elevated locality has been selected in the mountains. A slope of the earth of 20 - 30 degrees to the horizon has been found. The locality has been levelled, and rails laid. The rocket stands on these rails. The height of locality is 5-6 kilometers, the density of air has been diminished twice; the railroad line has been laid for about 100 versts.

The rocket is on the rails in an inclined position the floor with screwed - on seats - is also likewise.. The travellers enter the rocket and are hermetically locked. The explosion has begun.

The rocket drives off on the rails, the travellers have felt the jolt, and the horizon, as it appears to them, turned around at 60°.

Gravity has increased to a little less than twice.

Pressure on the rocket is unchanged, but since the quantity of the explosive substances has decreased, the acceleration of the projectile has increased. Due to this the gravity continuously increases, from $1^{4/5}$ in the beginning of the trip to 9 at its end. It is clearly evident from the observation on the spring balance.

Hardly have two minutes elapsed when the rocket jumpes off the rails and becomes air-borne. The travellers can not notice its movement but it appears to them that the enormously disturbed horizon collapses with all the mountains, lakes and cities somewhere below and simultaneously it is getting farther.*

The travellers having reached a considerable distance from the Earth are getting towards obsolute vacuum but they have made a mistake: traces of the atmospheres are still manifest.

Therefore the rocket experiencing a small resistance describes a spiral with a very small pitch, which is bringing it near to the Earth continuously though very slowly. They have made such a large number of rounds that they even lost their count. All the same the return to the Earth is unavoidable. In the beginning the speed of the rocket had increased and the centrifugal force had counter - balanced the gravitation of the Earth notwithstanding the magnitude of this gravitation.

Later, the velocity of the cosmic ship started to recede by means of the enhanced resistance of the atmosphere. Then the travellers started to plan; having

* Further there is the description of various phenomena, being observed by the travellers in the rocket and in the surrounding atmosphere. Since it is a repetition (vide "Picture of Flight" page 76"), so we are ignoring it. (Editors).

raised the nose of the rocket upwards with the help of the rudder, which acted, like an airplane. They cannot only moderate the falling but even convert it into a lifting force, so long as the velocity has not yet been lost . But it is superflous, it can end in the loss of velocity and perishing of the rocket having been converted into a wingless airplane, They descend, but slowly, more coming closer to the earth.

In fact, the descent is more dangerous, than when in an airplane, since there are no wings in the rocket and required high velocity so as to counterbalance gravity by the resistance of air (on a almost inclined motion) and descends not abrupty, but almost horizontally. They fly into the sea in a slanting manner. The velocity is still great and they swim the respectable distance, before being stopped and been taken on board the steamer passing nearby.

Only the exact calculatio s can give answers to the question, relatin to the cosmic ship. Calculations will show as to the requirements, which must be met by explosive substances, properties of materials and mechanisms, suitable for flight and life in the ether.

Printed in the boo, "Works on Rocket Technology" State Defence Publishing House, 1947, where the article was for the time printed in accordance with the manuscript of the year 1924.

Investigation of Outer Spaces by reactive devices
(1926).

P R E F A C E.

The aspiration for the cosmic voyages was founded in me by the well known scientific fiction writer Jules Verne. He aroused my mind to work in this direction. Desires made their appearance. Behind the desires, the activity of brain sprang up. Of course, it could have led to nowhere, if assistance from science had not been forthcoming.

In my early youth I had already found a way to cosmic flights. This is the centrifugal force and the fast motion (see my "Dreams about the Earth and sky" 1895). The first counterbalances the gravity and brings it to zero. The second - lifts the bodies to skies and carries them farther, if velocity is increased. Calculation could point me out those, velocities are needed for escaping from the terrestrial gravity and having access to planets. But how to acquire them? This is the question which has been worrying me the whole life and only since the year 1896 it was definitely outlined by me, as to how it would be most feasible.

I have been seeing the rocket for long, as every one else, from the point of view of amusement and petty uses.

If even did not interest me in the capacity of a toy. But I looked it like many, who from times immemorial have viewed the rocket, as one of the methods of aerial navigation. Having dug deep in history, we find many inventors of this kind. Such are Kibalchich and Fedorov. Sometimes only the old drawings give us an indication of the desire of employing the rocket for aerial navigation.

In the year 1896, I ordered for the booklet of A.P. Fedorov, "New Principle of Aerial navigation" (St. Petersburg 1896). It appeared to me indistinct (since no calculations are given). And in such cases I undertake calculations independently abinitio. So it is the beginning of my theoretical calculations about the possibility of employing the reactive devices for cosmic voyages. None has thought before me about the booklet of Fedorov. It gave me nothing, but anyhow it pushed me towards serious work, as did the fallen apple to Newton towards the discovery of gravitation.

K. E. TSIOLKOVSKIY

BEYOND THE EARTH

NARRATIVES

EDITION
OF THE KALUGA SOCIETY FOR THE STUDY OF NATURE AND LOCAL LANDS.

KALUGA

4th SOVIET PRESS
1920.

K. TSIOLKOVSKY

INVESTIGATION OF OUTER SPACE BY REACTIVE DEVICES.

(Reprint of the works of 1903 and 1911 with some modifications and additions).

KALUGA

1926.

There is every likelihood that there exist still many more serious works about the rocket, not known to me, and published long ago. In this very year after having made many calculations I wrote the narrative "Beyond the Earth" which later found its way in the journal, "Priroda i Lyudi" (Nature and People") and was even published in the form of a separate book (1920).

The old page with final formulae, preserved by chance, has been marked with the data August 25 1898. But from the preceding it is evident, that I have busied. myself with the theory of the rocket since earlier than this time, namely since the year 1896.

I have never claimed for the complete solution of this problem. In the beginning, inevitably, appear the idea, fantasy and the tale. After them follow the scientific calculations. And eventually the idea is crowned with fulfilment. My works about the cosmic voyages relate to the middle phase of my creative work. More than anybody else , I understand a great deal about the idea being divided from its realization, since during life I have not only thought and calculated, but even experimented working with my hands as well.

However, it is impossible, not to be an idealist: concept precedes performance and fantasy - exact calculation.

"Here is what I wrote to M. PHILIP, editor, of "Scientific Treatise" before sending him my copy (published in the year 1903):" I worked out several aspects of ascent into space with the help of reactive device, similar to the rocket. Mathematical conclusion, based on scientific data and verified many times, point towards the possibility, with the help of such devices, to ascend into the celestial space and, perhaps to establish habitations beyond the limits of the Earth's atmosphere. Probably hundreds of years would have passed by before the concepts propounded by me would find application , and people benefited by them, so as to resettle not only on the face of the Earth, but also on the face of all the universe.

Almost all the energy of the Sun is lost to mankind at the present time because the Earth receives 2 (exactly 2.23) milliard (US billions) times less energy than the Sun emits.

What is strange in the idea to be benefited by this energy! what is strange in the concept to conquer limitless space" surrounding the Earth's globe".

Everybody knows, how unimaginably great, how limitless the universe is.

Everybody knows, that the entire Solar system with hundreds of its planets is a point in the Milky Way.

And the Milky Way itself is a point with respect to the ethereal island. The last-named is a point in the Universe.

Man has penetrated the Solar system, administering in it, as a house-wife in a home? Will the secrets of the Universe by covered? Not in the least! As the examination of some small stone or shell does not reveal more secrets of the ocean. Even if Man conquered another Sun, investigated the whole of the Milky Way, these milliards (US billions) of Suns, these hundreds of milliards (US billions) of planets - then and only then would we say the same. And the milliards (US billions) are - a point and they would not reveal all the secrets of sky.

Was it very long ago, when ascent in the air was considered a sacrilegious attempt and was punished by execution, and when reasoning about the rotation of the Earth was punished by burning ? Are really people doomed even to now indulge into mistakes of this very sort ?

My works printed earlier are very difficult to obtain. Therefore I just now connect my previous works with my latest achievements in my edition.

CELESTIAL SHIP MUST BE SIMILAR TO THE ROCKET.

The basis of working of every vehicle and ship is one and the same : it pushes away some mass in one direction, while it itself is moved away from it in the opposite direction. A steamer pushes away water, the dirigible airship and the airplane - air, man and horse the Earth's globe, reactive device, for example the rocket, Segner's wheels - not only air, but also these substances which are enclosed in them: powder - water etc. If the rocket is in the vacuum or in the ether, then in spite of everything it would acquire motion, since it has got reserve for pushing away ; powder or explosive substance, possessing simultaneously mass and energy.

Evidently, the device for motion in vacuum must be similar to the rocket i.e. it must possess not only energy, but also supporting mass in itself.

For a voyage beyond the atmosphere and every other material medium at an altitude of 300 kilometers and also still farther, between the planets and the suns a special device is needed, which we shall, only for the sake of brevity name the rocket.

We shall observe that the interstellar ether is a similar material medium, as is the air, but rarefied to such a degree that in no case can it serve as a support. Only conditionally it is not associated to matter. Even the celestial stones (bolides, meteorites, falling stars) with several grams of weight may move in it with awful velocities (upto 50 kilometers/second and more) not encountering any remarkable resistance. In a word, ether in respect of resistance to movement of bodies may be considered as vacuum. Also its currents in the form of radiant and electrical energies exert extraordinarily small pressure on bodies. Hence for the time being we shall ignore them.

An explosion not only can serve for the ascent from the planet, but also for landing on it, not only for gaining velocity but also for losing it. The projectile is in a position to recede from The Earth, wander between the planets, between the stars, visit the planets, their satellites, rings and other celestial bodies and return to the Earth, only if the energy held by the explosive material were sufficient. However, we shall see, that there exists the possibility to land on the planets having an atmosphere, without any expenditure of explosive material.

ESSENTIAL INFORMATION NEEDED FOR THE STUDY OF THE PROBLEM.

Work of gravitation on recession from the planet.

By a very simple integration we can obtain the following expression for the work T needed for recession of a unit mass from the surface of the planet of radius r_1 to an altitude h :

$$T = \frac{g}{g_1} r_1 \left(1 - \frac{r_1}{r_1 + h}\right.$$

Here g denotes the acceleration due to gravity on the surface of a given planet while g_1 is the acceleration due to Eeath's gravity on its surface .

Let us suppose that in this formula 'h' is equal to infinity. Then we shall find the maximum work on recession of the unit mass from the surface of the planet to infinity and shall obtain

$$T_1 = \frac{g}{g_1} r_1 .$$

Having observed that $\frac{g}{g_1}$ is gravity on the surface of the planet in relation to the gravity due to the Earth, we see, that work, required for the recession of a unit mass from the surface of the planet for an infinitely large distance, is equal to the work of lifting this very mass from the surface for one radius of the planet, if it is assumed, that the force of gravity on it does not diminish with the recession from the surface.

In this way, the force of gravitation of any planet is unlimited whatever the distance in space to which this force penetrates. However this force represents, it were a wall or a sphere of slight resistance enveloping the planet to the magnitude of its radius. Overcome this wall, pierce through his elusive (not sizeable) equiplanetary envelope - and the gravitation is overcome to the whole of its infinite extent.

From the last formula it is evident, that the overall work T_1 is proportional to the force of gravity on the surface of the planet and the magnitude of its radius.

For planets having equal density, i.e. for the planets of the same density, for example, as the Earth (5.5), the force of gravity on the surface, as is known, is proportional to the radius of the planet and is expressed by the ratio of the radius r_1 of the planet to the radius of the Earth (R):

$$\frac{g}{g_1} = \frac{r_1}{R}$$

and

$$T_1 = \frac{r_1}{R} r_1 = \frac{r_1^2}{R}.$$

It means that the overall work T_1 with extraordinary rapidity, decreases with the decrease of radius r_1 of the planet, precisely in the same as its surface decreases.

Thus, if this work for the Earth's globe ($r_1 = R$) is equal to R or 6,366,000 kilogram - meters, then for a planet with a diameter, 10 times less it will be equal to 63,660 kilogram-meters.

But for the Earth, from some point of view, it is not so great. In fact, if we are to consider the calorific value of petrol as 10.000 calories, which is sufficiently reliable, then the energy of this combustion will be expressed by the mechanical work of 4.240,000 kilogram - meters for one kilogram of the combustible material. It follws that for an overall recession of a unit mass from the surface of our planet, work is required, which is held potentially in 1 ½ mass units of petrol. Thus, in its application to a person, weighing 70 kilograms, we shall require 105 kilograms of petrol.

Only technology and skill are lacking to make use of this powerful energy of chemical affinity.

It becomes all the clearer why an eight-fold quantity of the explosive material, as compared with the weight of the projectile may help the latter to overcome fully the force of terrestrial gravitation.

According to Langley, one square meter of the surface, illuminated by normal rays of the Sun, yields in a minute, 30 calories or 12720 kilogram - meters. So as to obtain the entire work required for victory of one kilogram over the gravity of the Earth, one will have to utilize one square meter of the surface illuminated by the rays in 501 minutes, or a little more than 8 hours.

All this is very little, but in comparison of human force with the force of gravity, the latter appears to be enormous.

Thus, we shall suppose that a man climbs 20 cms in each second on a well-built staircase,. Then he will perform this work in 500 days of heavy labor, if we allow him 6 hours for each days rest. On employment of one horsepower for climbing we shall reduce the work 5 times. In case of 10 horsepower only 10 days would be required and in case of uninterrupted work - about a week.

For the work, which a flying airplane does (70 HP) one day is sufficient.

For the majority of asteroids and for the Martian moons this work of completely overcoming gravity is amazingly small. Thus the moons of the Mars are not more than 10 kilometers in diameter. If we take for them 5½ as the Earth's density, then the work T_1 will constitute not more than 4 kilogram-meters in height. If on our moon or on the Mars there appeared rational beings, conquest of gravity would be much easier for the inhabitants of Earth.

Thus, for the Moon T_1 is 22 times less, than for the Earth. On large asteroids and satellites of planets the conquest of gravity would be a trifle with the help of reactive devices described by me. For example, on the Vesta, T_1 is 1,000 times less than on the Earth, because the diameter of the Vesta is equal to 400 kilometers. The diameter of the Metis is about 107 kilometers, so T_1 - is 15,000 times less.

But these are enormous asteroids; the majority **of them are** 5- 10 times less. For them T_1 is million of times, less than for Earth.

From the previous formulae, we shall find for each planet

$$\frac{T}{T_1} = \frac{h}{h + r_1} = \frac{\frac{h}{r_1}}{1 + \frac{h}{r_1}} .$$

We have expressed the work of lifting T to an altitude h from the surface of the planet of radius r_1 relative to the total maximum work T_1. According to this formula we shall calculate,

$$\frac{h}{r_1} = \frac{1}{10}, \frac{1}{5}, \frac{1}{4}, \frac{1}{3}, \frac{1}{2}, 1, 2, 3, 9, 99, \text{infinitely}$$

$$\frac{T}{T_1} = \frac{1}{11}, , \frac{1}{6}, \frac{1}{5}, \frac{1}{4}, \frac{1}{3}, \frac{1}{2}, \frac{2}{3}, \frac{3}{4}, \frac{9}{10}, \frac{99}{100}, 1.$$

The first row shows the heights of ascent relative to the radius of the planet; the second - the corresponding work, taking the work of fully overcoming gravity as unity. For example, for recession from the surface of the planet of unit radius, half of the full work is to be performed, while for recession to infinity - only twice.

REQUIRED VELOCITIES.

It is interesting to know, the velocity acquired by the rocket due to the action of explosive substances to overcome the resistance of gravitation.

We shall not here carry out the calculations, with the help of which these velocities are determined but shall confine ourselves only to the conclusions .

Thus, the velocity V_1, needed for lifting the rocket to an altitude h and acquiring after this velocity V, is equal to

$$V_1 = \sqrt{V^2 + \frac{2g r_1 h}{r_1 + h}} .$$

Here if we put that V = 0, i.e. if the body moves upwards, till its stoppage from the force of gravity, then we shall find

$$V_1 = \sqrt{\frac{2g r_1 h}{r_1 + h}} .$$

When h is infinitely great, i.e. the ascent is infinite and the final velocity is zero, then the necessary velocity for it on the surface of the planet would be expressed by

$$V_1 = \sqrt{2g r_1} .$$

According to this formula, we shall calculate for the Earth V_1 = 11170 meters/second; which is 5 times faster than the fastest cannon ball on its emergence from the muzzle.

For our Moon V_1 = 2373 meters/second i.e. close to the velocity of the cannon ball and the speed of a hydrogen molecule. For the planet Agata, having 6.5 kilometers as diameter and density not larger than that of the Earth (5.5), V_1 is less than 5.7 meters/second; almost about the same velocity V_1 we shall find for the satellite of the Mars. On these bodies of the solar system it is sufficient to run away easily so as to free ourself for ever from the forces of their gravitation, and become independent satellites.

For planets, different in density from the Earth, we shall obtain

$$V_1 = r_1 \sqrt{\frac{2 g_1}{R}} ,$$

Where g_1 and R relate to the Earth's globe. From the formula it is evident, that the final velocity of launching, V_1, in this case is proportional to the radius r_1 of the given planet.

Thus, for the largest asteroid - the Vesta, the diameter of which is in the neighborhood of 400 kilometers, we shall find, that V_1 = 324 meters /second. This means that even a rifle bullet will leave Vesta and will become ameteorite circling the Sun.

The last formula is convenient for quick calculations of the velocities of launching on equally dense planets of different dimensions. For example, the Metis, one of the larger asteroids, has a diameter, about 4 times less than the Vesta and the velocity for it will be as many times less i,e, about 80 meters/second.

Eternal circling around the planet requires half the work and velocity $\sqrt{2}$ = 1.41 times less than for recession to infinity.

Duration of flight.

We shall not discuss here the highly complicated formulae, determining the duration of flight of the projectile, since this question is not new and has been solved, already we shall therefore only repeat what is already known.

We shall make use of only one conclusion extraordinarily simple and useful for the solution of the simplest problems about the time of motion of the rocket.

For the time 't' of fall of a body originally stationary on a planet (or the Sun), concentrated at one point (for the same mass), we shall find

$$t = \frac{r_2}{r_1} \sqrt{\frac{r_2}{2g}} \left(\frac{r}{r_2} \sqrt{\frac{r_2}{r_1}} - 1 + \text{arc sin} \sqrt{\frac{r}{r_1}} \right).$$

Here r_2 denotes the distance from which the body begins the fall; r is the magnitude of the fall; r_1 - the radius of the planet, and 'g' the acceleration due to gravity at this time on its surface.

The very same formula, of course, expresses the time of ascent from $(r_2 - r)$ to r_2 when the body loses all its velocity.

If we suppose, that $r = r_2$, that is, if we determine the time of fall to the center of the concentrated planet, then we shall get from the last formula,

$$t = \frac{\pi}{2} \frac{r_2}{r_1} \sqrt{\frac{r_2}{2g}} .$$

Under the usual conditions this formula also gives the approximate time of fall to the surface of the planet, or the time of ascent of the rocket from this surface to a stop.

On the other hand, the duration of complete revolution of some body, for example, a projectile around the planet or the Sun) is given by

$$t_1 = 2\pi \frac{r_2}{r_1} \sqrt{\frac{r_2}{g}} ,$$

where r_1 is the radius of the planet with acceleration 'g' on the surface, while r_2 is the distance of the body from the center.

Comparing both the formulae, we find

$$t_1 : t = 4 \sqrt{2} = 5.657.-$$

Consequently, the ratio of the time of revolution of some satellite to the time of its central fall on the planet, concentrated on one point, is equal to 5.66.

Thus, so as to obtain the time during which a celestial body (for example, our rocket) falls to the center (or approximately on the surface), around which it revolves, the time of sidereal revolution of this body along the orbit should be divided by 5.66.

In this way, we shall find, that the Moon will fall to the Earth in 4.8 days (and nights) while the Earth to the Sun in 64¼ days (and nights).

Conversely, a rocket, launched from the Earth and stopped at the distance of the Moon, would fly in the course of 4.8 days (and nights) or about 5 days.

Similarly a rocket, launched from the Sun and stopped by the influence of its powerful force of gravity and the insufficient velocity of the rocket itself, at the distance of the Earth, would require about 64 days or more than two months (and nights) of flight.

Work of Solar Gravitation

Let us determine the work of the Solar gravity when the rocket is launched from the Earth. Of course, it would be most suitable, if the projectile is launched in accordance with the annual revolution of the Earth around the sun. Here it is permissible similarily to take advantage by the rotation of our planet around its axis.

The work of the rocket consists of two functions. The first is the overcoming of the Earth's gravity, the second - the overcoming of the resistance of the atmosphere. For a unit mass, for example one ton, the first work is expressed by 6,366,000 ton - meters, or by a velocity of 11170 meters/second. If the rocket is launched in the direction of the annual revolution of the Earth, then it will recede from the Earth and will become a satellite of the

Sun, like the Earth. It will similarly have a velocity, let us suppose, (mean velocity) of 29.5 kilometers /seconds. In order for it now to recede completely from the Sun, it is necessary to increase the work of its annual revolution two times or a velocity of $\sqrt{2}$, i.e. to increase its velocity equal to 29.5 $(\sqrt{2} - 1)$= 12.21 kilometers second. The total work is expressed by a relative number $(11.17)^2 + (12.21)^2$, while the velocity, required for acquiring the total work, will be $\sqrt{11.17^2 + 12.21^2} = 16.55$ kilometers/second. As there is no second support at the rocket, it must immediately acquire this velocity, pushing itself away from the Earth. If we are to take advantage of the rotation of the equatorial points of the Earth, this velocity still decreases by 465 meters/second and will be 16085 meters/second i.e. about 16 kilometers / second. This velocity is more than sufficient for a flight to any planet of the Solar system. With the rocket it is possible to wander eternally amidst the stars (suns), never coming to a stop. Only it will be impossible to fly out or more exactly, to recede eternally from our Milky Way. If we should take it into our head to start the flight against the annual revolution of the Earth, then an enormous velocity and awful work would be required, so as to overcome the Solar gravitation. In fact, in the first instance, we recede from the Earth, but do not lose again our annual velocity of 29.5 kilometers/ second. On pushing away from the Earth in the opposite direction, so as to recede from the Sun, we must not only lose this velocity but acquire still more a velocity of 41.7 kilometers/second i.e. a total of 71.2 km/second, against the annual motion. The entire velocity, required for our work will be $\sqrt{71.2^2 + 11.2^2} = 72.1$. This velocity is 4½ times more, while the work required would be more than 20 times, and the quantity of the explosive substances unimaginably great. The launching of the projectile in the direction normal to the annual orbit of the Earth is less disadvantageous.

Resistance of the Atmosphere to the motion of projectile.

For the time being we shall show, that the resistance of the atmosphere is insignificant work in comparison with the work of gravitation. We shall subsequently discuss these problems throughly. Let the projectile have a perpendicular motion. If its velocity is 30 meters per second, it pierces 53 kilometers i.e. almost the entire atmosphere in 33 seconds. Besides, the maximum velocity is one kilometer per second. But, you know, this velocity is at an altitude, where there is almost no air. We can take the average velocity not more than 0.5 km/sec pressure at $4M^2$, the cross-section of the rocket will not exceed 100T in case of such a velocity, according to the known formulae. But as the rocket is very long, and has a good shape and moves very fast this pressure in the plane cross-section decreases at least 100 times. It means, it will not be more than one T. Our large rocket weighs not less than 10T. In this way it is 40 times more than that, which expresses the average resistance of the atmosphere. The total work of the projectile, or the work of gravitation, of course, will be a thousand times more than the work of resistance of the atmosphere. From this it is also evident that air must not have a noticeable effect on the velocity of the rocket.

AVAILABLE ENERGY.

We are giving a table, containing the data about the quantum of energy, liberated on the combustion of different substances, and attributed to one kilogram of the substance.

TABLE 1.

Combustion, own oxygen.	large calories	Work kg/m	Velocity met/sec	Ratio of work.
H_2 and O_2, water vapor is obtained	3200	$1.37 \cdot 10^6$	5180	1.455
Ditto, but water is obtained	3736	$1.6 \cdot 10^6$	5600	1.702
Ditto, but ice is obtained	3816	$1.63 \cdot 10^6$	5650	1.730

Continuation ....

Continuation ....

C and O_2, Co_2 is obtained. Petrol H_6 C_6 and O_2, H_2, and Co_2 is obtained.	2200 2370	$0,94.10^6$ $1.01.10^6$	4290 4450	1.000 1.078
Combustion. Oxygen from outside.	Large calories	Work kg/m	Velocity m/second	Ratio of work.
H_2 burns, H_2O is obtained C burns, CO_2 is obtained	28780 8080	$12,3.10^6$ $3.46.10^6$	15520 8240	13.08 3.673
Hydrocarbon burns, CO_2 and H_2O are obtained.	10000	$4.28.10^6$	9160	4.545
	13000	$5.56.10^6$	10440	5.909
Radium	$1.43.10^9$	$0.611.10^{12}$	$3.44.10^6$	$0.65.10^6$

We have seen that the work of gravitation of the Earth for one kilogram of mass constitutes $6.37\ 10^6$ kilogram - meters - or velocity at 11 kilometers/second. With this work we shall compare the energy, which may be at the disposal of man. The upper portion of the table relates to the occasion, when we fly in the vacuum and need our own, reserve of oxygen. In this case the energy of the explosive substances is at least 4 times that required for escape from gravitation, assuming the complete utilization of combustion. The corresponding velocity is about twice less. The lower portion of the table relates to the flight in the air, were we can borrow oxygen from the surrounding medium, and need not store it in the rocket. In such a case, the available energy will be about 2 times that required and the velocity too will be insignificant.

In general, it follows that the energy of the explosive substances is far from being sufficient for enabling these substances themselves to acquire a velocity that would free them from the terrestrial gravitation.

It is not difficult to prove primarily, that, in spite of this, the projectile may acquire any velocity-it costs only to store a little more of the explosive material. When the reserve is unity in relation to the weight of the empty projectile, evidently, the velocity will be close to 5 Km/second* because the pushing away masses are similar. On the relative reserve of 3 units, the velocity of the rocket will be already 10 kilometers/second. In fact., discarding two units of the explosive substances, we shall acquire the velocity (with surplus) at 5 kilometers/second. Exploding the residue we shall increase the velocity of the rocket still by 5 kilometers/second. We shall in all acquire a velocity of 10 kilometers/second. Thus, we shall prove easily, that in case the reserves of explosive substances are 7.15 and 31 we shall obtain the velocities of the ship. At 15.20 and 25 kilometers/second. Meanwhile even for freeing from the Solar gravitation velocities of 16-17 kilometers per second are sufficient.

Disintegration of atoms is a source of enormous energy, as is evident from the last column of the table. This energy is 400,000 times more than the most powerful chemical energy. Its shortcoming is that it is extremely costly, not readily available and outflows very slowly, although it may continue for thousands of years. Even if we added one kilogram of radium (quantity, still not available in the world), the energy released by it, would give only 15 kilogram meters/second, i.e. energy of an ordinaryworker. It means, such a motor with the same

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* See table 1. Combustion of air in oxygen (Author).

weight as that of an aviation motor, will be at least 7 times weaker than the latter. However, we do not yet have a radium motor, and also the cost of one kilogram of radium is not less than one milliard (US billion) Roubles*. But one should not to say that with the passage of time cheap and quick energy - releasing sources of energy will not be discovered.

Acquiring of Cosmic Velocities in General

We can acquire such a velocity also on the planet. After having acquired it we recede into the ethereal space, wander amidst planets, and even amidst stars. But if we do not have a reactive device there, our motion will be similar to the motion of a bolide i.e. it will not depend on our will. Consequently it is impossible to do without a rocket device.

Acquiring velocities on the Earth has great advantages, because, moving on its surface, we can acquire a continuous stream of energy, while not losing the reserve.

I shall examine again unrealizable means of acquiring cosmic velocities.

I. It is impossible to launch the projectile from a rotating wheel or a gigantic merry - go - round,

*) One should not for get, this was written in 1926 Editors.

since the speed on the circumference of the wheel, independent of its dimensions, cannot be more than 500 - 1000 meters/second, but this velocity is not cosmic. Even at this velocity, the wheel must tear asunder due to the centrifugal force. Besides not one of the organisms can withstand its action even if the diameter of the wheel were one kilometer.

2. A short cannon is impossible since the relative gravity in the projectile will throw the organisms into confusion. Even a cannon with a length 6 kilometers, is small. Should we put the projectile into motion by gas, explosive substances, or electromagnetic force or powder it is all the same.

3. A vertical cannon is also impracticable, since such a structure in case of a large height is not feasible.

4. The horizontal cannon is impracticable, independent of its length, since the projectile on flying out quickly loses all its velocity in the dense layer of air (table 2). From the eighth column of the table it is evident, that a rocket weighing 10 tons, with an area of the transverse cross -section as 4 M^2, on horizontal motion at 8 kilometers per second loses 20% of its kinetic energy. This is on flying 50 kilometers. But you know, on such a velocity, it moves in a circilinear way, but comes out from the atmosphere. Therefore, iw will lose

quickly all its velocity either earlier than it will fall on the Earth. On a velocity of 16 kilometers/second it will lose 80% of its energy. If the rocket has a small mass i.e. without the resence of explosive substances, for example, a mass of 1 ton, then at a velocity of 4 kilometers/second it will readily lose half of its energy. The massiveness of the projectile very much facilitates its flight. From the tenth column of the table is is evident, that the cannon on the highest mountains is tolerable, since the cannon ball even on a velocity of 12 kilometers per second loses only 13.6% of its energy.

5. Acquiring of cosmic velocity on mall circular paths is impossible, since the centrifugal force destroys the organism, although the well fixed path on the soil will not be destroyed.

6. Impracticable is also the acquiring of cosmic velocity on the immense paths, situated horizontally along the equator, because the resistance of the air, as in the previous case, consumes the entire velocity. The wheels for the moving cosmic vehicle (for relieving offriction) are not suitable.

Gaseous and especially elextromagnetic cannons, with length not less than 60 kilometers, located in a slanting manner on the mountains, so that the muzzle juts out

TABLE 2.

All rockets are 10 T. Area of the transverse cross-section 4 M^2. Utilization of form 100%. Specific gravity of air is 0.0013 of the specific gravity of water. Resistance of air and work are at the constant velocity of the projectile.

1. Velocities kilometers second.	4	6	8	10	12	16	17
2. Pressure of air* on the surface 4M^2 for T. P = 0.0001 cm^2 x 4.	6400	14400	25600	40000	576000	102400	115600
3. Pressure on the rocket on utilization by 100°, T.	64	144	256	400	576	1024	1156*
4. Work of the rocket on forward push for 10 kilometers, thousand Ton Meters.	640	1440	2560	4000	5760	10240	11560

5. If the rocket weighs 10 tons, then for overcoming the terrestrial gravity work not less than 6370000.10/2 = 127,400,000 tib meters, We multiply by 2 since utilization is not more than 50% of the energy of the explosion.

6. Work of resistance relative to the work of explosive substances at -%, Run 10 kilometers.	0.50	1.13	2.02	3.15	4.54	8.06	9.10
7. Ditto, but relative to the work of motion of the projectile, %.	1.00	2.26	4.04	6.30	9.08	16.12	18.20
8. Ditto, on a run of -50 km. kilometers, %.	5.00	11.30	20.2	31.5	45.4	80.6	91.0
9. Ditto, if the launched rocket weighs 1 ton, %	50	113	202	315	454	806	910
10. Cannon at a height of 8 kilometer at 10 T, run 50 kilometers, work, %.	1.5	3.4	6.0	9.4	13.6	24.2	27.3

* The problem of the resistance of air at velocities, indicated in the table, have been up to this time insufficinetly studied. K.E. Tsiolkovskiy calculates it according to his theoretical formulae (Editors).

to a height of 8 kilometers, where air is already three times rarefied. This arrangement possess some degree of practicability.

About the fact, that the cannons cannot be small, much has been written. We shall refer to several works. Let us suppose, that a man, immersed in water, may withstand the relative gravity, 100 times more than the Earth's Consequently, the acceleration of the projectile in the cannon cannot be more than 1000 meters/second^2 (10 x 100). If it is necessary to get rid of the Earth's gravity, then we shall have to acquire a velocity of 12 kilometers / second in the bore. This can be done in 12 seconds. The average velocity of the cannon ball will be 6000 meters/second. In 12 seconds it will cover 72 kilometers. This is the minimum length of the cannon. But in all

Figure 1.

probability, it must be 10 times more, since man will not sustain more, than ten-fold weight in the liquid. Small steel cannons are suitable only for launching of compact steel projectiles. And such cannons must be at least 100 times longer than the artillery pieces, otherwise projectiles even without people will be shattered.

At first sight it appears, that gas, the velocity of the particles of which at ordinary temperature, does not exceed 2 Km/sec, cannot give cosmic velocities. But we shall now rectify this mistake.

Imagine a large storage - tank "A" with hydrogen or some other gas and contiguous to it a cylinderical barrle B (fig. 1). Pressure is exerted on the projectile, the more constant it is, the more in volume the storage - tank 'A' is compared with that of the cylinder 'B'. It means, in an emergent case, work, obtained by the cannon ball, is proportional to the square root of this length. Consequently, it is infinitely great. This strange and paradoxical conclusion is explained by the fact, that the work is done at the cost of gaseous mass A. And since it can be great, then even the work given to the projectile can be enormous. You know only an insignificant mass of gas in the barrel and in the projectile itself acquires great velocity. The remaining mass in the storage - tank 'A' possess a small velocity, but then it cools down. At the cost of this huge released quantity of heat the work of motion of the cannon ball and the gas in the barrel 'B' is acquired. It is clear, that for acquiring the maximum work and velocity, the heating up of the gas by steam jets or by one of the many other methods, is useful. Heating up by the electric current, by means of cables stretched through 'A' is convenient.

In the following calculations we shall consider that the pressure on projectiles is constant i.e. the very large storage tank A is filled with hydrogen and heated up. On hydrogen gravity acts 14½ times weaker, than on air (in respect of the condensation below) and, therefore, we shall take the density of the gas in the entire system as constant notwithstanding the great height of the muzzle.

We shall obtain the equations:

$$P = p_a . n . F, \tag{1}$$

$$j : g_3 = P : G, \tag{2}$$

$$V = \sqrt{2j . L}, \tag{3}$$

$$t = \sqrt{2L : j}, \tag{4}$$

$$K = j : g3. \tag{5}$$

From these formulae we shall find,

$$j = g_3 . K, \qquad (6)$$

$$P = (G . j) : g_3, \qquad (7)$$

$$n = P : (F . p_a), \qquad (8)$$

$$L = V^2 : (2j). \qquad (9)$$

Here,

K , is Relative gravity in the cannon ball.

j , Velocity per second of the cannon ball.

P , Pressure on the cannon - ball.

n , Number of atmospheres of pressure.

L , Length of the Cannon, (kilometers).

t , Time of remaining in the barrel.

F , Area of the cross - section of the cannon barrel.

V , Maximum velocity per second.

D, Diameter of the cross - section of the projectile and of the barrel of the cannon.

Pa, 10 T/M^2 ; Pressure 1 atmosphere;

G , Weight of the projectile, determined on the surface of the Earth;

g_3, Acceleration due to the Earth's gravity.

With the help of these formulae, we shall compile table No. 3.

Table 3.

Acceleration due to the Earth's gravity g = 10 meters/sec^2, Weight of the projectile G = 10 T. Pressure of the atmosphere Pa = 10t / M^2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
K	10	100	10	100	100	100	100	10	1000	1000	1000	1000	10000	40
j, M/cek^2	10^2	10^3	10^2	10^3	10^3	10^3	10^3	10^2	10^4	10^4	10^4	10^4	10^5	400
P, T	10^2	10^3	10^2	10^3	10^3	10^3	10^3	10^2	10^2	10^4	10^4	10^4	10^5	400
n	10	100	1	10	100	100	100	10	10^3	10^3	10^2	10^2	10^3	10
L, KM	720	72	720	72	32	144.5	8	80	7.2	72	72	720	720	80
t, CeK	120	12	120	12	8	17	4	40	1.2	3.8	3.8	12	3.8	20
F, M^2	1	1	10	10	1	1	1	1	1	1	10	10	10	4
V, KM/cek	12	12	12	12	8	17	4	4	12	38	38	120	380	8
D, M.	1.13	1.13	3.57	3.57	1.13	1.13	1.13	1.13	1.13	1.13	3.57	3.57	3.57	2.26

C-4

From the table it is evident, that on the compression of gases up to 1000 atmospheres and in case of the length of the cannon being 720 kilometers, it is possible to acquire a velocity of 380 kilometers per second, whereas for overcoming the solar attraction and wandering in the Milky Way, a velocity of only 17 kilometers/second is necessary/ From the sixth column of the table it is evident, that this velocity is acquired during relative gravity at 100-föld compression of the gas in case the length of the cannon is 145 kilometers. From the eighth column it is evident, that the velocity of 4 kilometers is acquired on 10-fold gravity, on compression at 10 atmospheres when the length of the cannon is 80 kilometers. If the transverse cross-section of the barrel is to be increased 4 times or the diameter 2 times, column 14 the velocity of the same mass will increase two times, i.e. it reaches the first cosmic velocity (so as to become the satellite of the Earth close to it). The length of the cannon and compression of the gas will remain the same, but the acceleration and the relative gravity will increase four - fold.

Electromagnetic cannons possess great advantage, since they do not require storage tanks, are more feasible, economical and have ample influx of secondary energy in all their fields and are easily fed by cables from lateral stations.

Cannons, with the passage of time, may find great application for massive launching of projectiles : for cosmic immigration on a large scale and as supplement to the rocket system. In fact, on acquiring the first cosmic velocity of 8 kilometers per second with the help of a cannon, the projectile returns to the Earth and breaks to pieces owing to the fact that its velocity is not parallel to the Equator (or the meridian). For the first important achievements, i.e. for settlement in the neighborhood of the Earth, but outside the atmosphere, a combination of the cannon method with that of the rocket system is necessary: the projectile acquires a velocity, minimum 8 Km/sec, but later adds to it by explosion like a rocket. Since the direction of the explosion is variable and depends on us, the projectile can acquire sufficient velocity on the circumference and will become a neighboring little moon of the Earth.

We can do, without the rocket when the projectile (launched from the cannon) must get upon the orbit of the Earth or fly in the neighbor-hood of the planets of our Solar system. As in that case, it must free itself from the Solar attraction and wander amidst other suns, in the Milky Way.

At any rate the cannons (including electromagnetic) owing to their great dimensions are horribly costly, less feasible (at the present time), and moreover, reactive devices can do even without them.

Performance of the Rocket.

A rocket in comparison with a cannon is exactly what a bacterium is in comparison with an elephant . I call reactive device a rocket, which moves by the push of the substances, stored in it before hand. There is no machine and no organism, which would not push away matter from it: human beings give off cutaneous vapor continuously, similar to the steam engine (turbine), but this performance is weak as compared with other forces, working in them, and therefore such devices are not to be called reactive. A rocket used as a device is similar to a rocket used for amusement. Its difference from other vehicles and ships lies in the fact, that the latter push away the substance, held outside them.

Coefficient of Useful Work (Efficiency) of a Rocket.

Let us first deal with the imponderable energy, electricity, the mass of which may be neglected. Let us also suppose, that the projectile is not subject to the force of gravity and other external forces. Then for both the stationary masses, pushed away by the intermediate non-material force, we have, on the basis of the law of preservation of motion.

$$M_1W + M_2c = 0. \tag{12}$$

If the velocity of the rocket 'C' is taken as positive, then the velocity of the rejected material W will be negative, since the quantum motion is nil and can not be changed by internal forces. M_1 and M_2 denote the masses of rejected material and the rocket respectively.

Work, acquired by a rocket will be

$$E_2 = \frac{M_2c^2}{2}. \tag{13}$$

Work of the mass pushed away, will be

$$E_1 = \frac{M_1W^2}{2}. \tag{14}$$

Coefficient of useful Work (CUW) (Efficiency) - of the rocket, or the consumption of energy by rocket, will be

$$\eta = \frac{E_2}{E_1 + E_2} = 1 : \left(1 + \frac{E_1}{E_2}\right) = 1 : \left(1 + \frac{M_1W^2}{M_2c^2}\right) \tag{15}$$

But from equation (12) it is divident, that

$$M_1 : M_2 = \div c : W. \tag{16}$$

It means the (CUW) Efficiency of the rocket is

$$\eta = 1 : 1 - \frac{W}{c} = 1 : 1 + \frac{M_2}{M_1} .$$

Hence it is clear, that the less than mass of the rocket in proportions to the mass of the rejected materila, the greater is the efficiency (CUW). Table 4 has been calculated according to last formulae.

Table 4.

Mass of the rocket	M_2	10	9	8	7	6	5	4	3	2	1	0
Mass of rejected material.	M_1	0	1	2	3	4	5	6	7	8	9	10
C.U.W. (Efficiency)	η	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
Ditto %	%	0	10	20	30	40	50	60	70	80	90	100

From the table it is evident, that CUW (Efficiency), in practice, cannot be equal to unity, since the rocket always has some mass. When the masses of the rocket and the rejcted material are equal, the consumption constitutes 50%.

But that will not happen, if the projectile from its own reserve already possesses some velocity, for example, acquired through electromagnetic cannon, or explosion or other means. Here there may be an interesting case, when the consumption of energy independent of the mass of rejected material may be 100%. In fact, if the rocket, for example, possesses a velocity of 1 meter/second, then, putting aside the element of rejected material to the opposite side by a relative velocity of 1 meter second, we shall obtain small particles of the rejected material with absolute velocity being zero. It is clear, that the entire spent work has gone into the credit of the projectile. In the case under discussion in place of equation (12) we shall get:

$$M_1 (W + V) + M_2 (c + V) = (M_1 + M_2) V. \tag{18}$$

On simplifications we shall obtain formula (12) and all the conclusions resulting from it. Here V is the total initial velocity of the system before discarding. Further we have

$$E_2 = \frac{M_2}{2} (c + V)^2, \tag{19}$$

$$E_1 = \frac{M_1}{2} (W + V)^2, \tag{20}$$

$$\eta = 1 : \left[1 + \frac{M_1 \ (W + V)^2}{M_2 \ (c + V)^2} \right] . \qquad (21)$$

According to formulae (18) or (12) instead of this we shall find,

$$\eta = 1 : \left[1 - \frac{c \ (W + V)^2}{W \ (C + V)^2} . \right] \qquad (22)$$

If the rocket has an increase of velocity (in that very direction, of course), then the rejected material possesses a negative velocity. If still the velocity of the rejected material is equal to the total velocity of the rocket* V = W, the the numerator in formula (22) is equal to nil, and therefore $\eta = 1$, i.e. the consumption of the energy is full or 100%. It means, it is advantageous, so that the particles of the rejected material were pushed away into the exactly opposite direction due to the motion of projectile with a velocity of the rocket itself. Then we shall obtain ideal consumption of the consumed work.

But we have in mind from the reserved mass of the rejected material in question to acquire the maximum velocity of the projectile. It is advantageous to link the rejected material with energy, so that in itself simultaneously becomes the Source of energy. Otherwise, the precess will deteriorate. In fact, if we take, for example, sand for rejected material with oxygen (like the link of energy with

* According to absolute value (Editors).

rejected material), then we economize less than if we were to take in reserve only combustible substances.

In the second case, in unit mass of the reserve material the energy in it is more and therefore, a great velocity of rejected material is obtained, and consequently, also of the rocket. In general, energy is material. Not to speak of explosive substances, even electricity and light are material. In order that the projectile acquired the maximum velocity, it is necessary that each particle of the products of combustion or other rejected material acquired the maximum relative velocity. It is constant for the specific substances of the rejected material. What is the sense, if we economize energy, not having rejected material? The economy of energy must not take place here : it is disadvantageous and not possible. In other words, on the basis of the theory of the rocket it is necessary to accept the constant relative velocity of the particles of the rejected material.

It is altogether different when it is a reactive air plane, which can make use of air as an object of rejected material. Here, it is advantageous to economize the reserve energy, which meanwhile, must also be made use of as rejected material. But such a projectile is not a purely reactive device.

Velocity of the Rocket on Use by Energy from Outside.

There may be an occasion, when, along with the energy of the rejected material we have an influx of energy from outside. This influx may be fed from the Earth at the time of the motion of the projectile in the form of radiant energy from one or the other wave length, as well as in the form of alpha and beta - particles: it may also be obtained from the Sun.

The terrestrial influx of energy is tempting, but there are less data for its consideration. The Solar influx of energy takes place, when the rocket is already outside the atmosphere. In both the cases the reserve rejected material is not needed, since the energy, flowing from outside, itself holds rejected material in the form of α and β - particles. Only it is necessary to know how to control their direction, as desired. The process would be clearer, if we store up a radio-active substance. The velocity of its particles is so enormous, that the mass of its reserve may be very small in comparison with the mass of the rocket, so that this latter may be considered constant, as in the case of energy, flowing from outside.

In such a case we have

$$\frac{d\,W}{W} = \frac{d\,M_1}{M_2}\,, \tag{23}$$

Where W is the relative velocity of the particles of the rejected material for example, the alpha particles. Integrating, we shall obtain, assuming the direction of launching as constant:

$$C = \frac{W}{M_2}\,M_1 + c_0\,, \tag{24}$$

where Co is the initial velocity of the rocket before launching or explosion. If it is equal to zero, then

$$c = \frac{M_1}{M_2}\,W. \tag{25}$$

From the formula it is evident that the final velocity of the projectile is proportional to the relative reserve of therejected material (or, in general, the rejected material, since the reserve may not be) and the relative velocity of the rejected material (for example, alpha - particles).

If,

$$W = 3 \times 10^8 \text{ meters/second; } M_1 = M_2\,,$$

then

$$c = 3 \times 10^8 \text{ meters/second.}$$

This velocity is 18000 times more than that, which is needed for overcoming the attraction of the Sun. The energy of this motion is 324 million times more, than needed. Flying with such a velocity, the ethereal ship will reach the nearest sun or the other nearest solar system in 4 years. Here, it is presumed that the energy **is borrowed from outside.** For the application of the formula to the radio-active substance it is necessary, that the ratio $M_1 : M_2$ were less. If for example, it is equal to 0.1 then to reach the other neighboring sun, a period of 40 years is required.

From the Sun it is not possible to obtain so many particles, because on recession from it (the Sun) the flux of particles almost stops. Besides, the known radio-active substances, get disintegrated very slowly and yield very insufficient work per second. Their quantity, available to man, is also slight. But the future is unknown: the globe of the Earth and its substances have been very little investigated. It may still yield much more than unexpected.

We shall replace in formula (25),

$$W = 30 \times 10^6 \text{ meters/second.}$$

while,

$$C = 17 \times 10^3 \text{ meters/second.}$$

that is, such a velocity of the projectile as is only a little larger than the required one for eternal recession from the Sun.

Dropping the sign, which occurs in formula (16), that is, taking for 'C' and 'W' the same sign, we shall get,

$$\frac{M_1}{M_2} = \frac{c}{W} = 0.00057. \tag{26}$$

It means that the relative mass of the rejected material, or the radio-active substance, in this case constitutes about 1/2000 of the mass of the projectile. If, for example, it weighs one ton, then the mass of the rejected material comprises only 568 grams, or less than 1½ lbs. The mass of the rejected material is so small, that the mass of the rocket may be considered constant and the formulae applied are almost without errors on use of a suitable radio - active substance in future, if only their velocity is of such an order as the velocity of the alpha - particles (electricity or radium).

What kind of utilization of energy will be ?

We have,

$$E_2 = \frac{M_2}{2} c^2, \tag{27}$$

$$E_1 = \frac{M_1}{2} W^2 . \tag{28}$$

Coefficient of useful work will be (see 23)

$$\eta = 1 : \left(1 + \frac{M_1}{M_2} \quad \frac{w^2}{c^2}\right) . \tag{29}$$

With the help of (26) we shall obtain,

$$\eta = 1 : \left(1 + \frac{W}{c}\right) = 1 : \left(1 + \frac{M_2}{M_1}\right). \tag{30}$$

When we have to deal with radio-active substances or with energy, flowing in from outside, then the ratios in the last formula are very great and therefore we shall have

$$\eta = \frac{c}{W} = \frac{M_1}{M_2} . \tag{31}$$

Thus, in a dismantled case, when $M_2 : M_1 = 1765$, the coefficient of useful work (CUW) is about $\frac{1}{2000}$. Although the utilization is disadvantageous, the reserve, of the rejected material the other hand is destroyed.

In Franklin's wheel, the utilization is advantageous, because the particles set in motion are enormous comparably the mass of air (electrical wind). But in the vacuum the utilization of energy is so small, that the wheel does not rotate, i.e. the work obtained cannot overcome friction. The principle of Franklin's wheel could have application during the flight of the projectile in the air.

Conversion of Thermal Energy into Mechanical Motion.

We shall now pay attention to the explosive substances. The source of their energy is chemical affinity. In general they yield only heat, i.e. irregular motion of particles (molecules). Special machines are needed, so as to obtain from such a motion (from heat) the motion of particles, simultaneously parallel and moving in one direction, in a word, the motion is simple and visible. For a reactive device it is necessary so that the largest possible portion of the thermal or chemical energy of particles is converted into their coordinated translatory motion. Then only heat vanishes, and in its exchange we shall obtain mechanical motion or a fast moving jet. For this purpose a long pipe is employed. On one end of it explosion or combustion is carried out while from the other end gases and vapors swiftly emerge. The walls of the pipe have the property of directing in one direction irregular in different sides fluctuating thermal or chemical motion (inconspicuous, perceptible like heat) to convert it into flux, similar to the fluvial. But it is necessary that the products of combustion were gaseous or vaporos (volatile) with the lowest possible temperature of liquefaction.

If it is so, then the gas expanding in the pipe, cools down more and more, heat vanishes, changing into gaseous jets. If the pipe is short, then the gas escapes from it, having a high temperature, and energy will not be utilized (this happens in cannons and guns). After emerging from the pipe, the gas continues to expand and cool down, but the motion takes place in different directions, which is not suitable for us. Still worse, if the explosion takes place without a pipe. Too long a pipe is advantageous, but it will add weight by its own mass to the rocket and therefore, it is also not suitable.

On six-fold expansion of gases the absolute temperature lowers down twice. The utilization of heat will be 50%. On an expansion of 36 times, utilization is already 75% etc. Thus, the pipe must be so much long, that the gas on emergence expands at least 36 times. Still better if it is 1300 times. Then the loss of the entire thermal energy is only 5%. Completely unsuitable are the substances, yielding volatile products, for example the oxide of calcium : energy is large, but to utilize it is difficult since there is no gas (it is only there on very a high temperature, as on the Sun) there is no expansion. Vapors products are tolerable, in particular, in a mixture with gases. For example, on combustion of hydrocarbons with oxygen or with its nitrogen compounds gases (carbonic acid gas nitrogen) and water vapor are released. On heavy expansion first of all they liquify into drops of water vapor. But in the presence of gases they transmit their heat to gases, which utilize their energy. Similarly, energy released on the freezing of water may also be utilized. Absolute temperature of the exploding gases in the first instance, must attain 10,000°, but at this temperature only a small portion of elements is in the compound, state the remaining past gets dissociated. The first, complicated part only on its expansion and the lowering of temperature gradually increases. Therefore, the temperature of the exploding substances in the proceeding hardly exeeds 3000°. On this basis in table 5, we express by numbers not the degree of heat, but the potential energy. However, starting from 1000 - 2000 this will already be the approximate temperature.

As is evident, even on utilization at 9[illegible], the temperature still constitutes 352°C. At this temperature vapors cannot come to liquefication and therefore on this expansion even the latent heat of liquefaction is not utilized. It means, that subsequent expansion is advantageous, and is possible only in vacuum. Then the pipe should still be lengthened.

Explosion on high pressure is specially necessary at the time of the flight in the atmosphere. Explosion cannot yield lower pressure than the atmosphere, because in that case there would be no expansion and no flux. But on much higher pressure utilization would be still less than at the lower pressure as compared with the air pressure. If, for example, the pressure of gases is 6 times more than that of the air, then the utilization cannot be more than 50%. If the pressure of gases is 36 times, more than the pressure of the medium, then the utilization is less than 75% (table 5).

In the vacuum, it is a different matter. There the elasticity of the exploding gases may be less, only the pipe would be wider, its weight will remain almost without change. Theoretically we would lose little in utilization of the pressure of the explosion, if only the rocket is in the vacuum. Thus it follows, that in the beginning of the flight of the projectile the pressure in the pipe must be very high in comparison with that of the atmosphere: later to the extent of ascent this pressure may be lowered proportionally, while in the ether, beyond the air, it may be as weak as desired. In practice this is less applicable, since the pipe for this purpose must be sometimes narrow with thick walls, and sometimes wide with thin walls.

It is necessary to choose the average pressure exceeding, of course, the atmospheric one, and it is maintained till the acquisition of the stable position, similar to the position of celestial bodies. After this the pressure may be orbitararily small.

Table 5.

Utilization of heat in the pipe.

Expansion of gases	1	6	36	216	1300	7800	46800
Absolute temperature or energy.	10000	5000	2500	1250	625	312	156
Temperature, ^{o}C.	9727	4727	2227	977	352	39	-147
Thermal coefficient of useful work %.	0	50	75	87	95	97	98.4
Loss, %.	100	50	25	13	5	3	1.6
Approximate density of gases relative to the air.	1000	167	28	4.6	0.77	0.13	0.02

The pressure of the same explosive substances may change from 5000 atmospheres to the desired smaller value. The actual fact is, that in one and the same pipe the force of explosion depends on the thorough attention to the mixing of elements of conbustion. Mixing may be so complete and close that the explosion will be almost momentary. And, on the contrary, it may be slow, a combustion on bad mixing, when the components of the mixture are very large. In this way the pressure is regulated. Thus more or less powerful action of the powder depends on its preparation.

On high pressure the utilization of energy is great, but it requires immensely large amount of work to push in the mass into the explosion pipe. Therefore it is necessary, as far as possible, not to lose much in utilization, to lower down the maximum pressure in the pipe. In the matter temperature we shall not win here. It is unavoidably high, namely 3000-4000°C. Artificial cooling of the external walls of the pipe is necessary.

We can now point to the required minimum of pressure. It is determined by the effect of the atmospheric pressure. If we start the flight from high mountains, the atmospheric pressure may be taken at 0.3 kilogram/cm^2. This constitutes about one third of the pressure at the sea level. It means, that the gases on emerging from the pipe must not have a pressure less than 0.3 kilogram/cm^2. At the intake of the pipe the pressure must be at the minimum, 36 times more (utilization 75%). Thus, the maximum pressure of gases must not be less than 10 atmospheres, and in lower layers - not less than 30 atmospheres. In any case, it is possible to limit it to 100 atmospheres.

We calculate the value of the area of the base of the cylindrical explosion pipe at this pressure. If the rocket weighs one ton, and with the explosive material 5 tons, and if the pressure on it exceeds twice its weight, then it is necessary to acquire a pressure of 10 tons at the bottom of the pipe. The area of the base of the pipe will be equal to 100 cm^2. The diameter of the circular area of the base constitutes 11.3 cm^2. We have already mentioned, how to acquire low pressure: the larger the elements of explosion, i.e. the worse they are mixed the weaker is the explosion. All the same in the enclosed space, eventually, the pressure will attain enormous magnitude. But, first, the pipe is broad and open, secondly the blending is such, that, the pressure is obtained required. I repeat, that we do not lose, in the least, the energy of combustion due to weak pressure. On irregular explosion (internal explosion in the total mass) cooling and vigorous motion takes place. But the motion, not completing the work is immediately converted into heat and the temperature is restored. Physicists perfectly know it. If the utilization of energy is not good on small pressure, then the atmosphere is to blame. It does not permit the explosive substances to expand infinitely. But, on the other hand, on large pressure the pipe will be shorter, which yields, weight to economy. In the vacuum by increasing the length of the pipe, we can raise the utilization of energy almost to 100%; but the length of the pipe then will be overwhelmingly large. I have proved many times, that the work of pushing the explosive materials into the pipe is sufficiently great and at the maximum pressure is impossible. For avoid this situation it is possible to do this in such a way, that the pressure in the intake of the pipe is periodically changed, for example, from 200 atmosphere to nil and from nil to 200 atmospheres. It will be varying. The average pressure in this case may be very great, if only man withstood it. Explosive substances here must be pushed in periodically at the moments of the lowest pressure. Then the work of pushing in will be slight, while the utilization of heat or chemical reaction will be much greater. In the water, thrusts do not reflect harmfully on man.

Motion of Rocket due to explosion in the Vacuum and in a medium free from gravity.

Although it is not advantageous to give rejected material a relative velocity larger or smaller than the absolute velocity of the projectile, but on employment of explosive substances their relative velocity is automatically constant. In general the greater, it is, the greater velocity does the device acquire. If so, then in the beginning the velocity of the particles of the rejected material is greater than the velocity of the rocket and utilization is very small, later both the velocities are equal i.e. utilization is complete. Further, the velocity of the rejected material is less, and incomplete utilization is obtained. In short, the utilization of energy or its conversion into motion of the rocket starts from zero and increasing gradually, reaches up to 100%, thereafter it decreases uninterruptedly , coming down zero.

On explosion we substain two losses. In the first place not all the energy of heat is converted into the motion of the rejected material. But the longer the pipe and the more the gas forming products of the rejected material, the smaller is the loss. Its limit is zero. In practice, utilization must not be less than 75%. The second loss depends on the fact, that the rejected material has one and the same relative maximum velocity, not equal to the accelerated motion of the projectile. As we shall see, this loss during cosmic velocities, constitutes not less than 35%, while the utilization - not more than 65%. In a medium of gravitation, in which we live on the Earth, it is less. If we take the secondary utilization at 50%, then the rocket converts into its motion about 37% (0.75 x 0.5) of the entire potential energy of the explosive substances.

Determination of the Velocity of the Rocket

We have in the vacuum and in the medium, free from the Earth's gravity

$$WdM_1 + M_2 dc = 0. \qquad (32)$$

But M_2 consists of the constant mass M_0 (that is, from the projectile, persons reserves and various accessories) and the variable mass of the explosive substances M_1, which having burnt , are thrown out of the rocket. It means, $M_2 = M_0 + M_1$. Now instead of (32) we have

$$WdM_1 + (M_0 + M_1)\, dc = 0. \qquad (33)$$

Hence

$$- W \frac{dM_1}{M_0 + M_1} = dc. \qquad (34)$$

Integrating, we get,

$$c = - W \ln (M_0 + M_1) + \text{const}. \qquad (35)$$

('ln' denotes natural logarithm). Let us suppose that in the beginning of the explosion the rocket did not move, i.e. c = 0 and $M_1 = M_1'$

$$c = W \ln (M_0 + M_1). \qquad (36)$$

Consequently,

$$C = W \ln\left(\frac{M_0 + M_1}{M_0 + M_1}\right). \tag{37}$$

The rocket acquires the maximum velocity, when the entire reserve of the explosive substances is consumed, or when $M_1 = 0$.

In this case

$$c_1 = W \ln\left(1 + \frac{M'_1}{M_0}\right). \tag{38}$$

From the last formula it is evident: 1) that the maximum velocity of the projectile C_1 is greater if the rejected material W has a greater velocity; 2) that C_1 may increase infinitely with the increase of the relative quantity $\frac{M_1}{M_0}$ of the rejected material. But this growth, in the beginning, is sufficiently quick, and later becomes slower. If the ratio $\frac{M_1}{M_0}$ is very small, then mathematically, it is easily proved than $C_1 = W \frac{M'_1}{M_0}$. It means, that in this case C_1 is proportional to the reserve $M'1$. On the contrary, within the limits, when the ratio (see 38) is very great i.e. the growth of velocity will be extraordinarily

$$c_1 = W \ln\left(\frac{M'_1}{M_0}\right),$$

slow; 3) that the velocity of the rocket does not change, if the ratio $\frac{M'_1}{M_0}$ remains constant. From this it is evident, that the cosmic velocity does not depend on the absolute value of the mass of the projectile. In other words, the mass of the rocket and its load are arbitrarily great, if they are not considered by other conditions; 4) that the final velocity does not depend on the order of the explosion. Whether the explosion goes by evenly or not, for seconds or thousands of years - it is all immaterial. Even the intervals do not mean anything.

Let dt denote the element of time,

From (34) we shall find

$$\frac{dc}{dt} = \frac{W}{M_0 + M_1} \quad \frac{(-\,d\,M_1)}{dt}. \tag{39}$$

The first part expresses acceleration per second in the motion of the rocket i.e. the force created in it by the relative gravity (although in our condition there is no gravity). As is evident from (39), it is proportional to the intensiveness in the consumption of material ($- d\,M_1 : dt$). Besides, to the extent of total consumption of M_1, the apparent gravity increases, since M_1 decreases and $dM_1 < 0$.

In order that the relative gravity remained unchanged, gradual moderation of the intensiveness of the explosion is necessary. Then from (39) we shall get

$$\frac{-W}{M_0 + M_1} \frac{dM_1}{dt} = K, \qquad (39_1)$$

Where k is the constant relative gravity

Hence

$$\frac{-WdM_1}{M_0 + M_1} = K\ dt. \qquad (39_2)$$

Integrating, we shall get

$$-W \ln (M_0 + M_1) = Kt + \text{const.} \qquad (39_3)$$

DURATION OF EXPLOSION.

If $M_1 = M_1'$ then $t = 0$, consequently:

$$t = \frac{W}{K} \ln \left(1 + \frac{M_1'}{M_0}\right). \qquad (39_4)$$

If $M_1 = 0$, i.e. the entire explosive material is exhausted, then

$$t_1 = \frac{W}{K} \ln \left(1 + \frac{M_1'}{M_0}\right). \qquad (39_5)$$

It means that the time of the entire explosion is inversely proportional to the relative gravity obtained and increases with the mass of the rejected material.

From (39_1), we shall find.

$$- \frac{dM_1}{dt} = \frac{K}{W} (M_0 + M_1). \qquad (39_6)$$

From this it is evident, that the minimum intensiveness of the explosion or the minimum consumption takes place at the end of the explosion, when M_1 has been left less, and the maximum is at the beginning, when $M1 = M_1'$.

In the first case

$$- \frac{dM_1}{dt} = \frac{M_0 K}{W}, \qquad (39_7)$$

while in the second -

$$- \frac{dM_1}{dt} = \frac{(M_0 + M_1') K}{W}. \qquad (39_8)$$

The ratio of the maximum consumption in the beginning to the minimum (at the end) will be,

$$1 + \frac{M_1'}{M_0}. \qquad (39_9)$$

The greater the ratio $M_1 : M_0$, does the consumption of the explosive substances the more violently change and vice - versa, it is almost constant on a small ratio. In practice it is convenient to change the force of explosion, it is simpler to render it possible to stand the action of inconstant gravity, having immersed persons and other tender objects in a liquid.

When the acceleration of the rocket and the relative gravity grow, but the expenditure of the explosive substances is one and the same, the duration of the explosion (uniform) of the entire reserve, may also be expressed like this:

$$t_1 = M_1' \frac{dt}{dM_1} . \qquad (39_{10})$$

Here the derivative may be changed by per second consumption of the explosive substance. At the same time on an even acceleration of the rocket and the constant relative gravity in the projectile (39_1), but on variable consumption of the rejected material it will be equal to

$$t_1 = c_1 : j = c_1 : \frac{dc}{dt} . \qquad (39_{11})$$

The derivative, $j = \frac{dc}{dt}$ expresses the constant growth of velocity of the projectile in a second.

Mechanical Coefficient of Useful Work.

It is interesting to know, what part of the complete work of the particles of the rejected material is transferred to the rocket. We have

$$E_1 = 0.5\ M_1 \cdot W^2, \tag{40}$$

$$E_2 = 0.5 \cdot M_0 c_1^2 \ . \tag{41}$$

Hence

$$\frac{E_2}{E_1} = \frac{M_0}{M_1'} \left(\frac{c_1}{W}\right)^2, \tag{42}$$

or on the basis of (38),

$$\frac{E_2}{E_1} = \frac{M_0}{M_1'} \left[\ln\left(1 + \frac{M_1'}{M_0}\right)\right]^2 . \tag{43}$$

Hence it is possible to calculate, that the coefficient of useful work cannot be more than 65%, and for acquiring cosmic velocities it can be taken as 50%. If the reserve of the explosive substances is comparably not large then instead of (43) we shall get approximately.

$$\frac{E_2}{E_1} = M_1' \ M_0 \ , \tag{45)*}$$

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*) The number of the formula (44) has been omitted by the author: Further similar omissions in the numbering of the formulae done by the author, will be encountered, (Editors).

or exactly,

$$\frac{E_2}{E_1} = \frac{M'_1}{M_0}\left(1 - \frac{M'_1}{M_0}\right); \qquad (46)$$

it is possible to get a still more exact formula, expanding the expression,

$$\ln (1 + x) = x - \frac{x^2}{2} + \frac{x^3}{3} - \frac{x^4}{4} \qquad (47).$$

From the formulae it is evident, that in the beginning, when the reserve is small, the coefficient of useful work grows proportionately to the reserve, then grows slower, attains the maximum value, and then decreasing slowly attains the limit zero.

The ratio $M_1 = M_0 = x$, corresponding to the maximum coefficient of useful work, is determined by the equation:

$$1\,n\,(1 + x) = \frac{2x}{1 - x} \quad x$$

and in value it is closer to 4. (i.e. the reserve exceeds the weigh of the rocket 4 times), and the utilization constitutes 65%. In table 6, are given the magnitudes of the values of interest to us, for different occasions.

Besides what we have drawn analytically, we see from the table, that the maximum utilization (up to 65%) of energy of the rejected material takes place when its weight is 4 times more than the weight of the rocket. But the percentage of utilization in general is not less (about 50%), when the relative quantity of rejected material fluctuates from 1 to 20, while the corresponding velocity is from 3 to 15 kilometers/second. This is a fully sufficient cosmic value. Two velocities of the table relate to different explosive materials.

Larger - to pure hydrogen and oxygen.

Smaller - to hydrocarbons and endogenous compounds of oxygen. For visualization I am adding the fifth column, which shows in kilometers the maximum ascent of the body in case of permanent terrestrial gravity.

The result of our investigation is applied on the following occasions: 1) In a medium without gravity, for example, amidst suns or the Milky Way, where gravity is close to zero. 2) On small asteroids, small moons (moons of the Mars) and on all small celestial bodies, for example, on the rings of the Saturn, where gravity may also be ignored ; 3) On the orbit of the Earth. 4) At each place of any solar system, on any convenient distance from the celestial body, if the projectile is outside the atmosphere and acquires or does not acquire a velocity, hindering it in

Table 6.

Ratio of the mass of the rejected material to the mass of the rocket $M_1 : M_o$	C_1, if the velocity of the rejected material is 5000 meters/second, formula (38)	C_1, if the velocity of the rejected material is 4000 meters/second, formula (38).	Average coefficient of useful work. $E_2 : E$ (in%), formula (43).	Approximate lift in km on the Earth's gravity being constant
0.1	472.5	378	8.87	11.4
0.2	910	728	16.55	42
0.3	1310	1048	22.9	92
0.4	1680	1344	28.2	138
0.5	2025	1620	32.8	204
0.6	2345	1876	36.7	280
0.7	2645	2116	40.0	357
0.8	2930	2344	42.9	440
0.9	3210	2568	45.8	520
1	3465	2772	48.0	607
1.5	4575	3660	55.8	650
2	5490	4392	60.3	1520
3	6900	5520	63.5	2430
4	8045	6436	64.7	3300

Table Continued on next page. ....

Continuation ....

5	8960	7168	64.1	
6	9730	7784	63.0	
7	10395	8316	61.7	
8	10985	8788	60.5	
9	11515	9212	58.9	
10	11990	9592	57.6	
15	13865	11092	51.2	
20	15220	12176	46.3	In the act of ascent higher, because the gravity grows weaker.
30	17170	13736	39.3	
50	22400	17920	31.0	
100	26280	21040	21.0	
193	30038	24032	14.4	
∞	∞	∞	0	

reaching at the celestial body or its atmosphere.

We shall see later, that to avoid the loss of energy the direction of explosion must be normal resultant force of gravitation.

From this it is evident, that it is sufficient only to get free from the planetary atmosphere and become a satellite of this planet, although on a very short distance from it, so that the future motion and shift on the entire universe, is completely guaranteed. As a matter of fact, explosion then may be very weak, while the energy, required for it, may be borrowed from the energy of the Sun. Alpha and beta particles, scattered everywhere, or bolides or cosmic dust provide supporting material.

The first great step of man consists in flying out beyond the atmosphere and becoming a satellite, of the Earth. The rest is comparatively easy, quite close to recession from our Solar system. But, I of course, do not have in view the landing on massive planets.

Motion of the Rocket in a medium of Gravity and in the Vacuum.

We shall eliminate the atmosphere mentally or shall think ourselves on the Moon or another planet, having dry land and not surrounded by gases or vapors. We shall ignore the slow rotation of the planet. The flight of the projectile may be 1) perpendicular, 2) horizontal or 3) inclined.

We shall discuss the question in general (see figure 2).

Determination of the Resultant Acceleration.

On the rocket acts the force of gravity g, expressed by acceleration in seconds, then the force of explosion in the direction of the long axis of the projectile, imparting it an acceleration 'j' in seconds. Between the directions of these forces, the given angle α is formed, greater than 90°. The angle of the force of explosion with the horizon will be $\alpha - 90^{\circ} = y$. These will be the three given values. Known : direction of motion of the rocket, determined by the angle β or the angle $x = \beta - 90^{\circ}$, and the value of the resultant p, i.e. virtual acceleration, in seconds, of the projectile.

Trigonometry will give us (see diagram):

$$\alpha = y + 90, \ \sin \alpha = \cos y, \ \cos \alpha = - \sin y,$$

$$\cos \beta = - \sin x, \ x = \beta - 90, \ \operatorname{tg} \beta = \operatorname{ctg} x,$$

$$\operatorname{tg}\beta = \operatorname{ctg} x = \frac{j \sin \alpha}{g + j \cos \alpha} = \frac{j \cos y}{g - j \sin y}, \qquad (48)$$

$$p = \sqrt{j^2 + g2jg \cos \alpha} = \sqrt{j^2 + g^2 - 2jg \sin y}. \qquad (49)$$

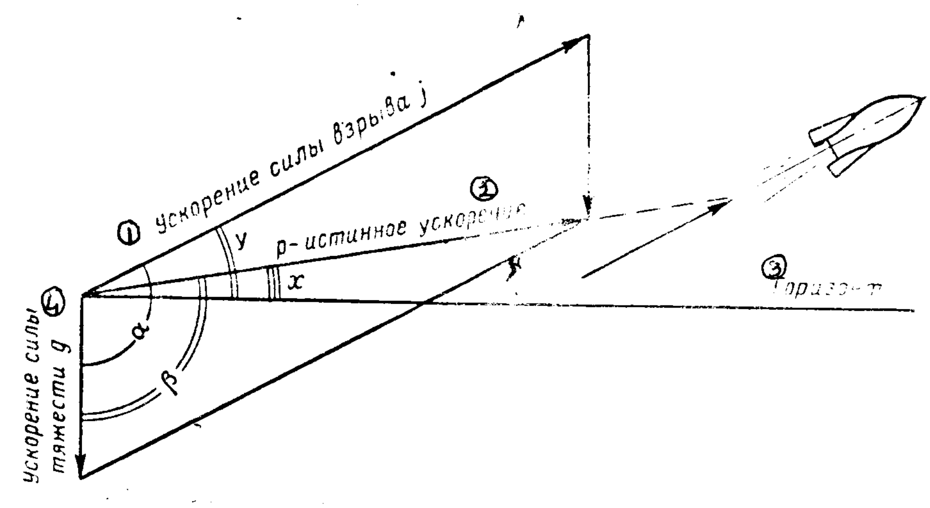


Figure 2. Key: 1. Acceleration due to the force of explosion 'j'.
2. p - virtual acceleration.
3. Horizon.
4. Acceleration due to the force of gravity g.

....

The known angle y and the unknown x are simpler, because they are less than a right angle and determine the inclines to the horizon of the force of explosion (similar to the axis of the rocket) and the resultant (virtual direction of the motion of the projectile).

Work of the Rocket and Rejected Material; Mechanical Coefficient of Useful Work.

What will be the kind of utilization in a medium of gravitation, and in the vacuum?

$$E_2 = 0.5\ M_0 c_1^2 + A. \tag{65}$$

A is the work of ascent or lift of the rocket, while E_2 is the work of the rocket.

$$A = -\ l \cos\beta\ M_0 g = l \sin x\ M_0\ g, \tag{66}$$

l denotes the value of the flight or the length of the path of the projectile.

If p and j are constant, then

$$l = \frac{c_1^2}{2p} \tag{67}$$

and (from 65 - 67)

$$E_2 = 0.5 M_0 c_1^2 \left(1 + \sin x \frac{g}{p}\right) \tag{68}$$

Further

$$E_1 = 0.5\ M_1 W^2. \tag{69}$$

From (68) and (69)

$$\eta = E_2 : E_1 = \frac{M_0}{M_1'} \quad \frac{c_1^2}{W^2} \left(1 + \frac{g}{p} \quad \sin x\right). \qquad (70)$$

From trigonometry it is known that for each angle:

$$\cos\beta = \frac{\mathrm{ctg}\,\beta}{\sqrt{1 + \mathrm{ctg}^2\beta}} \quad . \qquad (71)$$

From here and from (48)

$$\cos\beta = \frac{g + j \cos\alpha}{\sqrt{j^2 \sin^2\alpha + (g + j\cos\alpha)^2}} =$$

$$= - \sin x = \frac{g - j \sin y}{\sqrt{j^2 \cos^2 y + (g - j \sin y)^2}} \,. \qquad (72)$$

From (70) now we can eliminate the unknown sin x, But it still necessary to eliminate C_1 also. We have

$$t_1 = \frac{W}{K} \ln \left(1 + \frac{M_1'}{M_0}\right). \qquad (73)$$

This is the total time of the explosion when the constant relative gravity is K.

But,

$$K = j \text{ and } c_1 = pt_1. \tag{74}$$

Consequently, from (39_5) and (74)

$$c_1^2 = p^2 \frac{W^2}{j^2}\left[\ln\left(1 + \frac{M_1'}{M_0}\right)\right]^2 . \tag{75}$$

Now from (70), (72) and (75) we shall find

$$\eta = \frac{p^2 M_0}{j^2 M_1'}\left[\ln\left(1 + \frac{M_1'}{M_0}\right)\right]^2 \times$$

$$\times\left[1 \pm \frac{g\,(g - j.\sin y)}{\sqrt{j^2\cos^2 y + (g - j\sin y)^2}\;\sqrt{j^2 + g^2 - 2jg\sin y}}\right]. \tag{77}$$

When there is not gravity, $g = 0$ and $p = j$. In this case the last formula yields formula (43). We shall determine by (77) coefficient of useful work in the case, when the explosion is horizontal, i.e. when $y = 0$. Then again we shall get the formula (43). It is easy to see that in the direction of explosion normal to the force of gravitation (horizontal), utilization is similar as during the complete absence of gravity. Close to the planet (on the very surface) the horizontal explosion is not employed, since the rocket, coming down, touches the soil. But on a certain altitude, even in the air, and also then, when the rocket by force of the acquired cosmic velocity, it possibly cannot touch the atmosphere, and floats as a celestial body. It is still applied to the planets without an atmosphere on the motion of the projectile along a horizontal smooth path. Further we shall also see its application for motion in the atmosphere.

We can verify formula (77) still in one more particular case. Let us suppose that the motion of the projectile is perpendicular, i.e. $y = 90^{\circ}$ and $p = j - g$.

Then we shall find

$$\eta = \frac{M_0}{M_1'}\left[\ln\left(1 + \frac{M_1'}{M_0}\right)\right]^2\left(1 - \frac{g}{j}\right). \tag{80}$$

(This formula was introduced earlier and is contained in the printed works of the year 1903).

From the formula it is evident, that the perpendicular motion of the rocket is very disadvantageous, in particular, when j slightly exceeds the value of g. On the contrary, the greater the acceleration of the force of explosion j in relation to g, the smaller is the loss and the greater is η. Comparing the coefficient of useful work in a medium free from gravitation (43) with the coefficient of useful work in a medium of gravity on perpendicular motion (80), we see, that the last coefficient of useful work is less than the first by $1 : (1 - \frac{g}{j})$.

The relative loss is expressed by the fraction $\frac{g}{j}$. If for example, the force of the explosion is 10 times more than the weight of the rocket, then the loss comes to 0.1. But when oth the forces are equal, the loss is equal to 100 %, i.e. the entire energy is lost without any result for the projectile. Infact in this case, the rocket is in equilibrium, it does not ascend and does not acquire any velocity. When the force of explosion is unlimited, the coefficient of useful work is similar, to the one in a medium without gravitation. But a powerful explosion kills and destroys all that is inside the projectile. This explosion may be employed only when projectiles complicated devices are and without men.

Table 7.

Medium of gravity, Perpendicular motion of the rocket.

j : g	1	2	3	4	5	10	oo
Coefficient of useful work %	0	50	66.7	75	80	90	100
Velocity %	0	70.7	81.7	86.6	89.4	94.9	100

As is evident the perpendicular motion is accompanied by a great loss of energy, particularly when the force of explosion j is not large. Here j must be larger than g, otherwise no motion will be available. The last column expresses in percents the maximum corresponding velocity. In fact, the velocity is expressed by the second column, because part of the energy goes for the ascent at the time of explosion (proved in the year 1903).

Flight of the Rocket in a medium of Gravitation, in the Atmosphere.

Let us suppose, that the horizontally balanced rocket in a medium of gravitation moves still under the influence of a horizontal force. Initially the force of gravity causes it to fall at an angle of 90^o and less. More exactly, tg of this angle is equal to g:j. But in several seconds the horizontal component of the velocity of the rocket will become so enormous that the perpendicular motion of the projectile, with its large surface will become completely inconspicuous in comparison with the horizontal component. Then the rocket will move almost horizontally, as on the rails. One may estimate, that the fall of the rocket, owing to the resistance of the air, with a considerable lateral surface of the projectile (vertical projection), may be only very slow and then still slower in proportion to the increase of the velocity of the rocket. During the inclined motion of the projectile, it will go on similarly, unless the incline not exceeds 20-40°. Then the projectile after several seconds from the start of the motion, moves, as on the inclined rails. The fall of a well-built rocket, in the absence of the horizontal motion, will constitute approximately, only 20 - 30 meters/second. In case of enormous translatoray velocity it must reach up to 1 meter/second and less what is its significance in comparison with the cosmic velocity?

The determination of velocity acceleration, duration of flight, work performed by the rocket and rejected material, and mechanical coefficient of useful work, assuming the motion along an inclined plane.

From figure 3 we have approximately

$$c_1 = pt, \tag{83}$$

$$p = j - g \sin y, \tag{84}$$

$$K = j:g, \tag{85}$$

$$c_1 = (j-g \sin y) \frac{W}{j} \ln \left(1 + \frac{M_1'}{M_0}\right), \tag{86}$$

$$t_1 = \frac{W}{j} \ln \left(1 + \frac{M_1'}{M_0}\right). \tag{39$_5$}$$

It is when j is constant.

The formulae are still more advantageous when the motion of the projectile is along an inclined unyielding plane, i.e. during accelerated motion on the mountain (upwards).

We shall adopt by the determinations of the coefficient of useful work.

$$E_2 = 0.5M_0c_1^2 + A, \tag{87}$$

$$A = M_0 \cdot g \cdot h = M_0 \cdot g \cdot l \sin y. \tag{88}$$

Here h is the magnitude of the ascent of the projectile.

Hence

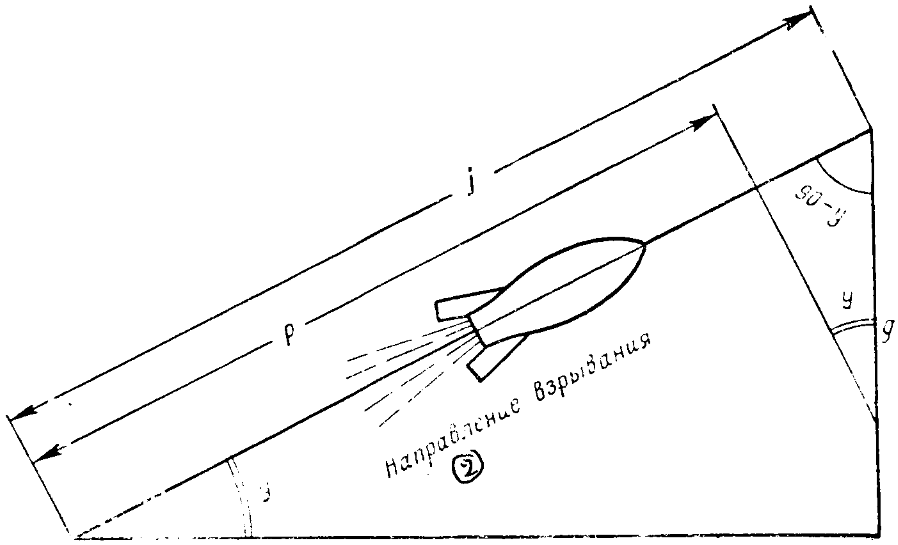
$$E_2 = \frac{M_0}{2} c_1^2 \left(1 + \frac{g}{p} \sin y\right) \tag{89}$$

Further,

$$E_1 = \frac{M_1'}{2} W^2. \tag{90}$$

Consequantly

$$\frac{E_2}{E_1} = \eta = \frac{M_0}{M_1'} \frac{c_1^2}{W^2} \left(1 + \frac{g}{p} \sin y\right). \tag{91}$$



F I G U R E : 3.

Key: 1). Direction of explosion.

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With the help of (86) and (84) we shall find

$$\eta = \frac{M_0}{M'} \left[\ln \left(1 + \frac{M_1'}{M_0}\right)^2 \left(1 - \frac{g}{j} \sin y\right) \right]. \qquad (92)$$

Simplifying the formula (77), when (the values of) the angle y are small, we shall obtain roughly this very formula (92) (see also formula 49).

If the rocket is horizontal and $y = 0$, then the coefficient of useful work from (92) will be obtained in accordance with formula (43). Also from (92), if $y = 90^\circ$, we shall obtain the known formula (80). η represents mechanical coefficient of useful work, multiplying which by the thermal coefficient of useful work (see table 5), we obtain full coefficient of useful work.

We see, that the coefficient of useful work (efficiency in the vacuum (77) in general is not what it is in the atmosphere, or rather - in the vacuum when the motion of the projectile is along an inclined plane.

The loss, in comparison with a medium free from gravity, will be

$$\frac{g}{j} \sin y. \tag{93}$$

$$g : j = 0.3 \ ; \ y = 20^\circ; \ \sin y = 0.342,$$

then the loss is 5.7%. We are giving table 8.

Table 8.

Medium of gravity in the atmosphere.
Inclined motion.

Inclination of the slope in degrees.		1	2	5	10	15	20	25	30	35
Loss of energy in percents on different (Values of) j:g.	10	0.17	0.34	0.85	1.7	2.6	3.4	4.2	5	5.7
	5	0.34	0.64	1.7	3.4	5.2	6.8	8.4	10	11.4
	2	0.85	1.7	4.25	8.5	13	17	21	25	28.5
	1	1.7	3.4	8.5	17	26	34	42	50	57

From here it is evident that it would very advantageous to launch the rocket when the explosion is most powerful, if there were no technical difficulties, nor destructive action of the explosion. Similiarly it would be advantageous to launch the rocket at the mini um angle, if the work of the resistance of the atmosphere were not there. The loss, in general even when the force of explosion is small, may be brought up to 1%.

More Accurate Calculation of the Atmospheric Resistance.

In spite of everything I am next simplifying the formulae, given by me in the years 1911-1912. I am assuming the temperature of the air as constant. Owing to this the atmosphere extends without end. Then we have the known formulae.

$$h = \frac{f_1}{d_1} \ln \frac{d_1}{d}, \tag{95}$$

Where $\frac{f_1}{d_1}$ is the altitude of the imaginary atmosphere h_1 when the density is constant; f_1 is the pressure of the atmosphere, corresponding to d_1.

It means that,

$$\frac{h}{h_1} = \ln \frac{d_1}{d} \tag{96}$$

and

$$d = d_1 e^{\frac{h}{h_1}} . \tag{97}$$

The resistance of the air or its pressure W on the rocket due to its motion will be

$$W = \frac{F}{a} d \frac{c^2}{2g} . \tag{98}$$

This pressure (Poncelet's pressure) is not in absolute units but in ordinary measures, for example, in tons. F - is the area of the middle (maximum) of the transverse section of the rocket; 'a' - the utility of the form of the rocket i.e. the coefficient, which becomes still larger, if the resistance W is smaller. During the inclined motion of the rocket the length l of the path will form,

$$l = h : \sin y. \tag{99}$$

We have

$$p = j - g \sin y, \tag{84}$$

$$c = \sqrt{2\ pl}. \tag{84_1}$$

Hence

$$c = \sqrt{2\ (j - g \sin y)\ l}. \tag{100}$$

The element of the work of resistance of the air will be expressed

$$dT = W\,dl. \tag{101}$$

From (97, (98), (99), and (100) we shall find

$$dT = \frac{Fd_1}{ag} (j - g \sin y)\ le^{\frac{l \sin y}{h_2}}\ dl. \tag{102}$$

Let us assume here

$$\frac{l \sin y}{h_1} = \frac{lh}{h_1} = x,$$

$$dx = \frac{\sin y}{h_1} dl = \frac{dh}{h_1}, \quad dl = \frac{h_1 dx}{\sin y}. \tag{103}$$

Then we shall find

$$dT = \frac{F\,(j - g \sin y)}{ag \sin^2 y}\; h_1^2\, xe^{-x}dx. \qquad (104)$$

We are assuming

$$\frac{F\,(j - g \sin y)}{ag \sin^2 y}\, d_1 h_1^2 = A. \qquad (105)$$

Integrating and determining the constant we shall obtain

$$T = A\left[1 - \left(1 + \frac{h}{h_1}\right) e^{\frac{h}{h_1}}\right] = A\left[1 - \left(1 + \frac{l \sin y}{h_1}\, e\right)^{-\frac{l \sin y}{h_1}}.\right] \qquad (106)$$

Keeping in mind (103), we also obtain

$$T = A\left[1 - (1 + x)\, e^{-x}\right]. \qquad (107)$$

We have to find out full work of the atmospheric resistance. For this purpose we have to assume

$$h = \infty \quad \text{or} \quad x = \infty$$

We have

$$e^{-x} = 1 : e^{x} = 1 : \left(1 + \frac{x}{1} + \frac{x^2}{1.2} + \frac{x^3}{1.2.3} + \ldots\right). \qquad (108)$$

Therefore,

$$(1 + x)\, e^{-x} = e^{-x} + xe^{-x} = e^{-x} + x : \left(1 + \frac{x}{1} + \frac{x^2}{1.2} + \ldots\right) =$$

$$= \frac{1}{e^x} + 1 : \left(\frac{1}{x} + 1 + \frac{x}{1.2} + \frac{x^2}{1.2.3} + \ldots\right). \qquad (109)$$

From this it is clear, that if h or x are equal to infinity, then the expression (109) reverts to zero. It means that the work of resistance,

$$T = A. \qquad (110)$$

We shall obtain the total work of perpendicular motion from formula (104), if we assume that y = 90. Then we shall find

$$T = \frac{F\,(j - g)}{ag}\, d_1 g_1^2 \,. \qquad (111)$$

Comparing this work with the total work of the inclined motion we shall see, that the latter is larger than the former as many times:

$$\frac{j - g \sin y}{(j - g) \sin^2 y} \qquad (112)$$

If 'j' is larger or 'y' is not large then we can consider, that approximately the work of the inclined motion is inversely proportional to the square of the sine of the angle of slope. It means, that when there is no incline there is no motion horizontally, then the total work of resistance is infinite. But this is incorrect, since owing to the sphericity of the Earth the atmospheric layers having equal density cannot be considered horizontal, as we had assumed. In a word, for small angles, the formulae are inapplicable. Thus, if we take the height of the atmosphere with noticeable density at 50 kilometers, then it is easy to calculate, that the horizontal path is only 15.5 times greater than the inclined one. If we take the height as 5 kilometers, then the horizontal path will be 155 times greater than the perpandicular one. It means, that the horizontal work cannot be infinite. According to formula (104) we can calculate the total work of the perpendicular motion. Let us suppose that $F = 2\ M^2$; $j = 100$ meters/second^2; $g = 10$ meters / second^2; $h_1 = 8000$ m; $d_1 = 0.0013\ T/m^3$; $a = 100$. Then $T = 14976$ ton meters. It is quite insignificant even in comparison with one work of the rocket motion, having a mass of 10 tons (without explosive substances) and freeing itself from the force of the Earth's gravitation (11 km/sec velocity). This work is more than 60 million ton-meters. It means, that it is 4000 times more than the work of the perpendicular atmospheric resistance. Having started the motion of the projectile from the highest mountains where air is 3-4 times rarer, we shall see, in accordance with formula104, that this work still decreases proportionally to the rarefaction, i.e. 3-4 times. Due to the inclined motion it increases not very significantly. According to formula (112) we can calculate this, assuming $j = 30$, $j = 20$ and $g = 10$.

From the second column of table 9 it is evident, that at 20° incline the work increases 11 times. After it, from the comparison of the second and the third columns with the fourth it is seen, that the work may roughly be considered proportional to $1 \sin^2 y$. The larger the value of 'j' the more significant is this vicinity and vice versa. The third column shows the magnitude of work when $j = 20$. In case of small angles the actual work owing to the sphericity of the Earth is much less.

Table 9.

y	10	20	30	40	50	90
T when j=30	46.7	11.3	5	2.85	1.92	1
T when j = 20	60	14.2	6.0	3.3	2.1	1
$1 = \sin^2 y$	33	8.55	4	2.42	1.70	1

We have seen, that the work of resistance during the perpendicular motion constitutes 1:4000 part of the work of motion of the rocket, but during the inclined motion it is less than 1%.

It is interesting that the dependence of the work of resistance is on the traversed path or the attained height h. The complete work is expressed by formula (104), while the remainder formulae (107) and (108). It depends on the altitude of the ascent.

Table No. 10 shows this dependence.

Table 10.

Relative residual work of resistance in percents.

h	4	8	16	24
$h : h_1$	0.5	1	2	3
Relative residual work, %.	91	74	41	20

The Most Advantageous Angle of Flight.

By formulae (77) and (93) we can calculate the loss of work due to a slope in a medium of gravitation. By formula (104) we determine the corresponding loss due to the resistance of the atmosphere. Having compiled the table and determined the sum of the losses, we shall see, which inclination is accompanied by the minimum loss. Only this will be the most advantageous.

But without tables one can determine approximately that most advantageous angle of inclination. The loss due to the inclined motion of the projectile is expressed [see (93) as]

$$\frac{g}{j} \sin y \text{ in absolute units } \ldots\ldots\ldots \quad (113)$$

The loss due to the atmospheric resitance is absolute units will be

$$Ag = \frac{F}{a} \cdot \frac{(j-g \sin y)}{\sin^2 y} d_1 h_1^2. \quad (114)$$

The work of the rocket is equal to see (104)

$$E_2=0.5M_0c_1^2=0.5M_0W^2 \left[\ln\left(1+\frac{M_1'}{M_0}\right)\right]^2 \text{[CM. (38)]} \quad (115)$$

Therefore, both losses in absolute units will be

$$E_2 \frac{g}{j} \sin y + Ag = E_2 \frac{g}{j} \sin y + \frac{F}{a} d_1 h_1^2 \left(\frac{j - g \sin y}{\sin^2 y} \right) = Z. \qquad (116)$$

Having taken the derivative of this expression and having equated it to zero, we shall obtain the equation, not convenient for the solution relative to sin y.

However, the most advantageous angle is not large. Therefore, we can ignore the expression g sin y in case of the second term.

Then equation (116) will be transformed:

$$Z = E_2 \frac{g}{j} x + \frac{F}{a} d_1 h_1^2 \frac{j}{x^2}. \qquad (117)$$

Here sin y = x. Differentiating this equation and equating the first derivative to zero and determining x, we shall obtain,

$$x = \sin y = \sqrt[3]{\frac{2Fd_1 h_1^2 j^2}{aE2g}}. \qquad (118)$$

With the help of

$$\sin = \sqrt[3]{\frac{4Fd_1h_1^2j^2}{aM_0W^2\left[\ln\left(1+\frac{M_1'}{M_0}\right)\right]^2 g}} . \qquad (119)$$

From this it is evident, that the advantageous angle 'y' increases with the energy of explosion 'j' and the transverse area F of the rocket, and decreases with the increase of the utility of form 'a' and the ratio of the mass of the projectile to the mass of the rejected material $M_1' = M_0$. On a planet with large gravity 'g' it also decreases, and vice versa. Let us suppose in (119) $F = 2$; $d = 0.0013$; $h = 8000$; $j : g = 10$; $a=100$; $M_0 = 10$; $W = 5000$.

Then we shall calculate

$$\sin y = 0.167 \text{ and } y = 9^\circ 35'.$$

When $j = 20$ we shall obtain

$\sin y = 0.057$ and $y = 3^\circ 20'$.

But in case of such small angles, the atmospheric resistance, in view of its sphericity, will be much less. It means, the advantageous angle will be still smaller.

From formula (117) we shall find the relative loss from both due to both reasons:

$$\frac{Z}{E_2} = \frac{g}{j}\,x + \frac{Ed_1 j}{aE_2 x^2}\,h_1^2 = \frac{g}{j}\,x +$$

$$+ \frac{2Fd_1 jh_1^2}{aM_0W^2\left[\ \ln\left(1 + \frac{M_1'}{M_0}\right)\right]^2 x^2}. \qquad (120)$$

We shall give a simpler formula for the determination of percentage loss.

Having divided the second term by the third [in (120)], we shall know, how many times the loss due to the influence of gravity is greater than the loss due to the resistance of the air. Later, eliminating from this the ratio x with the help of (119), we shall obtain term 2. From this it is clear, that when the inclination is maximum, loss due to gravity is double the loss due to the resistance of air. Consequently,

$$Z:E_2 = \frac{g}{j}\,x + \frac{g}{2j}\,x = \frac{3}{2}\,\frac{g}{j}\,x. \qquad (121)$$

Thus when the angles are of 9° and 3° we shall find the entire loss to be 0.025 and 0.0428 i.e. 2.5 and 4.3 %.

From (121) and (119) we conclude the complete relative loss to be

$$Z:E_2 = \sqrt[3]{\frac{27 \cdot F d_1 h_1^2 g^2}{2 \cdot a \cdot M_0 W^2 \left[\ln \left(1 + \frac{M_1'}{M_0} \right) \right]^2 j}} \quad . \qquad (122)$$

The area, similar to the changing body, grows proportionately to the square of its dimensions, while the volume and mass to their cube. Consequently the loss decreases with the increase of dimensions of the rocket; as well as with improvement of form 'a' of the projectile and **the increase of 'j' the force of explosion, only very slowly.** If, for example, 'j' increases 8 times, then the loss will decrease only twice. Highly advantageous is to fly when 'j' is small, due to which as is evident, we lose a little, when j = 10, x sin y = 0.036 y = 2°10' and Z : E = 0.054 Consequently the angle is very small, and the loss is equal to 5%. In the proceedings it is much less than the sphericity of the Earth.

Let us suppose in the formula a = 50 and , as before F = 2; d = 0.0013 h_1 = 8000; M_0 = 10; W = 5000; j will be assigned different values.

We shall compile table 11.

Table 11.

Acceleration of the rocket without gravity j.	1	2	3	4	5	6	7	8	9	10
sin y = x	0.0097	0.0154	0.0204	0.0246	0.0292	0.0326	0.0356	0.0392	0.0422	0.0453
Angle 'y' in degrees.	0.56	0.88	1.17	1.41	1.68	1.86	2.07	2.26	2.43	2.60
$Z : E_2$ = loss in percents.	14.6	11.6	10.2	9.23	8.57	8.07	7.66	7.33	7.05	6.80

Continued on next page.

Continuation ....

Acceleration of the rocket without gravity j.	15	20	25	30	40	50	60	80	100	200
sin y = x	0.059	0.072	0.083	0.094	0.114	0.133	0.150	0.182	0.211	0.333
Angle 'y' in degrees.	3.41	4.16	4.75	5.41	6.55	7.66	8.66	10.50	12.16	19.50
$З : E_2$ = loss in percents.	5.94	5.40	4.97	4.71	4.28	3.98	3.75	3.40	3.16	2.50

When the slope is small: small inclination becomes necessary, as is very advantageous from technical point of view. It is unfortunate that at the same time the loss is maximum (up to 14.6 %).

Here give acceleration for the projectile from 1 to 200 meters/sec^2 which corresponds from 0.1 to 20 relative to the acceleration of the Earth's gravity (10 meters/second^2). If, for example, the rocket weighs 10 tons, then the pressure of the explosive substances changes the inclination from 0.5 to 20°. The loss of energy due to gravity and the atmospheric resistance is from 1.5 to 2.5%. It appears strange, that the loss is less when the inclinations are great, but this is explained by the enormousness of the acceleration of 'j', . The loss when angles are small, infact, is still smaller, in view of the curvature of the atmosphere on the spherical surface of the Earth.

If the mass of the rocket M_o be 8 times less, then by formulae (119) and (122) it is evident that the sines of angles and losses (see table) increase twice. Thus, when j = 30 the angle will be about 11° , while the loss - about 9.5%.

In accordance with table and formula (114) it is easy to show that approximate formulae do not give large errors even when j = 1. When 'j' is large the error is much less.

Gravity, Atmospheric Resistance and Curvature of the Earth.

From (101) (98), (97) and (100) we shall obtain in ordinary units:

$$dT = \frac{Fd_1}{ag} (j - g \sin y) e^{\frac{h}{h_1}} 1dl. \qquad (122_1)$$

For the flat Earth we have formula (99) for out help.

$$l = h : \sin y.$$

But for the actual form of the Earth it is used only when the angles 'y' are not very sharp. For all angles we shall easily find a more exact formula

$$h = l \sin y + \frac{l^2}{2R} = l \left(\sin y + \frac{1}{2R}\right), \qquad (123)$$

where R is theradius of the earth:

From this we may calculate

$$l = -R \sin y \left(1 - \sqrt{1 + \frac{2h}{R \sin^2 y}}\right) \qquad (124)$$

Let us suopose

$$\frac{2h}{R \sin^2 y} = X; \quad \sqrt{1 + X} = 1 + \frac{X}{2} - \frac{X^2}{8} + \frac{X^3}{16} \ldots \qquad (125)$$

Being confined by three terms, we shall get

$$l = -R \sin y \left(-\frac{X}{2} + \frac{X^2}{8}\right) = \frac{h}{\sin y} - \frac{h^2}{2R \sin^3 y}$$

$$= \frac{h}{\sin y}\left(1 - \frac{h}{2R\sin^2 y}\right). \tag{126}$$

We shall solve the problem about the work of the atmospheric resistance in the particular case, when the flight is horizontal and $y = 0$.

Then

$$h = \frac{l^2}{2R} \text{ and } l = \sqrt{2R\,h}. \tag{127}$$

Further, from (102)

$$dt = \frac{Fd_1}{ag} je^{-\frac{h}{h_1}} ldl = \frac{Fd_1}{ag} je^{-\frac{l^2}{2Rh_1}} ldl. \tag{128}$$

We shall suppose

$$\frac{l^2}{2Rh_1} = u.$$

Then

$$ldl = Rh_1 du, \tag{129}$$

and instead of (128)

$$dt = \frac{Fd_1}{ag}\, jRh_1 e^{-u} du = Ae^{-u} du. \qquad (130)$$

Integrating and determining the constant, we shall find

$$T = A\,(1-e^{-u}) = A\left(1-e^{-\frac{h}{h_1}}\right) = A\left(1 - e^{\frac{l^2}{2Rh_1}}.\right) \qquad (131)$$

Here,

$$A = \frac{Fd_1}{ag}\, jR.\, h_1\ . \qquad (132)$$

This expression determines complete work of the atmospheric resistance.

For vertical motion we have

$$T = \frac{F\,(j - g)}{ag}\, d_1 h_1^2\ . \qquad (111)$$

During the perpendicular motion of the projectile, work of the atmospheric resistance will be less as many times [(132) and (111)]:

$$\frac{j}{j - g}\ \frac{R}{h_1}\ . \qquad (133).$$

Here, we shall suppose

$$j = 100, \quad g = 10, \ h_1 = 8000.$$

Then according to (133) we shall get the number 883, that is, the work during the horizontal motion is a little less than a thousand times, more than the same work of the atmospheric resistance during the perpendicular flight of the projectile. This is explained by the fact that the projectile with an increasing velocity must pass through a very thick layer of the atmosphere. Thus, the path, close to the horizontal is very disadvantageous: the work of resistance will consume a very large part of the kinetic energy of the rocket, which will not acquire a sufficient velocity. We have seen, that the work of the perpendicular resistance of the air, comprises approximately, $\frac{1}{4000}$ of the kinetic energy of the projectile (when Mo = 10T). It means that the horizontal resistance will consume about 1/5 (22.2%). According to table 11 when the slope is half a degree (0.56), the loss is somewhat less namely - about 15% (14.6). Here, only 1/3 falls to the resistance, i.e. 5%. It is so small because the acceleration in the table is 100 times less than we have taken.

From (132) it is evident that T very much depends on 'j' and that the horizontal flights are advantageous when 'j' is small. Thus we can calculate the work of the atmospheric resistance during the horizontal motion of the projectile, when the values of 'j' are diffierent.

Let us suppose

$$F = 2, \; a = 50$$

Then (see 131 and 132)

$$T = 264800. \tag{134}$$

The work of the rocket will be obtained from [(41) and (38)].

$$E_2 = 0.5 M_0 W^2 \left[\ln \left(1 + \frac{M_1'}{M_0} \right) \right]^2 . \tag{135}$$

The work of the rocket for overcoming the Earth's gravity (11 kg) when $M_0 = 10$ will constitute about 64×10^6. This is larger than the atmospheric resistance i.e. 240: 'j' times.

We shall draw up table No. 12

Even during the acceleration when j =5 , i.e. about half of the terrestrial acceleration (g=10), the loss is about 2%.

Table 12.

Force of explosion 'j'.	1	2	5	10	20	30	50	100
Loss %.	0.42	0.83	2.1	4.2	8.3	12.5	20.8	41.7

Ascents, Visits to Planets and landing on the Earth.

Let us suppose, that the rocket has ascended to a certain altitude, having lost all velocity during perpendicular flight. Under the influence of gravitation it will fall back, acquire considerable velocity and crash against the Earth, irrespective of the retarding action of the atmosphere. Even one retarding action of the latter may destroy the projectile or kill the living beings inside it. But if we imagine that the reserve of the explosive substances has been left, in the rocket after the ascent and is employed (used) with the aim of retarding its velocity of falling back, completely in the same order, as it increased this velocity while ascending from the Earth, then landing will be completely safe, and the projectile will stop, just on the surface of the planet i.e. it will smoothly land on the Earth.

If for the ascent the quantity of the explosive substances must exceed k_1 times the weight of the rocket with all its contents, then for a safe landing a reserve is needed, equal to the mass of the rocket multiplied by k_1. For one ascent the mass of the rocket along with the explosive substances will be:

$$M_0 + M_0 K_1 = M_0 (1 + K_1). \tag{136}$$

For a smooth landing, more reserve of the explosive materials k_1 times more than this mass, is necessary (136), that is,

$$M_0 (1 + K_1) K_1 . \tag{136_1}$$

Along with the rocket and the first reserve (136) it will comprise

$$M_0 (1 + K_1) K_1 + M_0 (1 + K_1) = M_0 (1 + K_1)^2 . \tag{136_2}$$

The mass of one reserve will be

$$M_0 (1 + K_1)^2 - M_0 = M_0 \left[(1 + K_1)^2 - 1\right] . \tag{137}$$

If, for example, $M_0 = 1$, $k_1 = 9$, then the reserve will be 99, that is its weight is 99 times more than the rocket with the contents (except explosive substances). Such an abundant reserve is hardly feasible. The work is still more difficult, when we desire to lift ourselves from the Earth and to land on some strange planet (located, let us suppose, in the orbit of the Earth), to lift ourselves from it and to return home.

It is a different matter, if the ascent of the projectile is not great and therefore k_1 is a small fraction. Then the reserve will approximately be equal to $M_0 2k_1$ [see (137)] . It means, that then reserve becomes double.

But the ascent to a small altitude does not have cosmic importance.

The ascent from the Earth and landing on a strange planet on the Earth's orbit (there is no such things: this is only an assumption) needs reserve

$$M_0 \left[(1 + K_1)(1 + K_2) - 1\right]. \qquad (138)$$

Here, k_2 denotes the relative quantity of explosive substances, required for an ascent or as landing on a strange planet.

If on this planet, we cannot make a reserve of explosive substances, and, meanwhile, desire to fly away from the planet and return to the Earth, then we must take reserve in advance, from it.

$$M_0 \left[(1 + K_1)^2 (1 + K_2)^2 - 1 \right]. \qquad (139)$$

Supposing, that the planet, in mass and volume, is analogical tothe Earth, we shall find the reserve equal to

$$M_0 \left[(1 + K_1)^4 - 1 \right] . \qquad (140)$$

We assume here that $k_1 = 9$ and $M_0 = 1$. Then the reserve will be 9999, that is completely not feasible. This roughly corresponds to the Venus. Still less feasible is the voyage to the Jupiter and other massive planets because for them k_2 is enormous. On the contrary, a voyage to the asteroids, particularly to the small ones, is feasible since k_2 may be considered as nil. Then the path from any one of them (again assuming them on the orbit of the Earth) and the return to the Earth requires reserve according to formula (137).

Visiting different, planets, not having, during this, the possibility of replenishing the reserve on them, and returning to the Earth, we must make the following reserve in general:

$$M_0 \left[(1 + K_1)^2 . (1 + K_2)^2 . (1 + K_3)^2 ; (1 + K_n)^2 - 1 \right]. \qquad (141)$$

If n is the number of planets (considering also the Earth), then on their equality with the Earth , we shall obtain the reserve

$$\left[(1 + K_1)^{2n} - 1\right] M_0 . \qquad (142)$$

Evidentaly, such consecutive visit of planets is still impossible;.

It is true, we can act more expendiently in landing, for example, on the Mars (the work of change of distance from the Sun will not be considered for the time being) returning to the Earth and replenishing on it new reserve, so as to visit, for example, the Mercury. But, however a less frequented that planet may be the relative reserve of the explosive substances cannot be less than 99. And this is almost invincible. What can possibly be done?.

As far back in June 1924 in my article, sent to the "Technique and Life" and not published there, but returned and stamped, I had indicated the way out. In 1926, Engineer Goman confirmed the same in his book. I give here an extract from my above mentioned manuscript.

"Travellers, having attained a considerable recession from the Earth, thought that they were being carried away into the absolute vacuum. However, in this, they were mistaken: traces of the atmosphere again appeared. Therefore their vehicle experiencing a small resistance of the medium, described a spiral with a very small pitch, (vehicle)which was coming close to it (medium) continuously, although very slowly, towards the Earth. They made such a large number of circles around it that even their count was lost. All the same the return to the Earth was unavoidable. In the beginning the velocity of the rocket grew and the centrifugal force almost counterbalanced the gravitation of the Earth, not-withstanding the increase of this gravitation.

Then the velocity of the projectile started to decrease,, owing to the denseness of the atmosphere and the enhanced resistance of the air due to it. Then the travellers started to plan having lifted the nose of the rocket upwards with the help of the rudder which was working like an air plane rudder. They could now, not only moderate the fall, but even turn it into an ascent, so long as the velocity was not loss. But this was redundant and could finish up by the loss of velocity at the altitude and the destruction of the rocket, after having been converted into a wingless aeroplane. They were descending, but not so quickly, so as to recede to the planet with force, and not so slow, as to stop at the altitude without velocity. The travellers only prayed to the destiny, so that the fall took place not on the land but into the sea. In fact the landing was very dangerous, than in case of an air plane, since, the projectile had no wings and required a great velocity, so as to counterbalance the gravity by the resistance of air (when the motion is a little inclined) and to land not abruptly, but almost horizontally. Here water was safe. Destiny heard their entreaty and they sloping gently, touching more and more of sea waves and losing velocity on account of this, fliew into the sea. The motion, in spite of everything, completely ceased, and they swam a sizeable distance before coming to a stop.

We shall confirm, that all this is mathematically trustworthy and fully feasible.

Consequently with a small reserve of the explosive material we may become a satellite of the Earth, and settle down in ether, beyond the atmosphere, develop there, cosmic economy, little by little, and to land without any expenditure of material, on the Earth, and again ascend from the planet with new reserves of implements, parts of dwellings and all that is necessary for solid conditions in the ether in the capacity of a small and nearly moon.

Horizontal motion of the projectile in an atmosphere on the incline of its long axis with equal density.

We had supposed [(83) and earlier,] that the rocket must move in the air as on the rails, i.e. that the atmospheric resistance will prevent the rocket to deflect considerably from its path, which is dependent on the forces of the explosion and the force of gravitation. Just now we shall confirm it.

Let us suppose, that the rocket will move horizontally with a velocity 'c' in seconds, whereas its long axis is inclined at a certain angle ζ to the horizon. Then the perpendicular pressure R_y on it will, in accordance with the known laws of resistance of a liquid medium, be

$$R_y = \frac{d}{g} F_h K_1 \sin \zeta c^2. \qquad (143)$$

Here F_h is the horizontal projection of the rocket, and k_1 - the coefficient of resistance.

If the rocket moves horizontally, then, it means, it does not fall and the pressure on it below R_y is equal to the weight M_0 of the rocket. Then from (143) we shall find

$$\sin = \frac{M_0 g}{dF_h K_1 c^2}. \qquad (144)$$

We shall suppose, for example, $M_0 = 1$; $g = 10$; $d = 0.0013$; $C = 100$; $F_h = 20$; $k_1 = 1$.

Now we shall calculate

$$\sin \zeta = 0.0385 \text{ and } \zeta = 2.2^{\circ}.$$

When M_0 is 10 times larger, ζ will also be almost 10 times larger. When 'C' is 10 times larger, the incline decreases 100 times, that is, it becomes insignificantly small.

Let us try to determine the work of resistance of the atmosphere during the accelerated and horizontal motion of the rocket. The sphericity of the Earth diminishes this work. The horizontal pressure R_x due to resistance of air will be

$$R_x = R_y \sin\zeta = M_0 \sin\zeta = \frac{M_0^2 g}{dF_h K_1 c^2} . \tag{145}$$

Consequently, the element of work will comprise

$$dT = R_x dl, \tag{146}$$

where 'l' is the length of the traversed path.

We may consider 'd' to be constant and only 'c' - variable

$$C = \sqrt{2jl}, \tag{147}$$

j is the acceleration of the rocket in seconds. Now from (147), (146) and (145) we shall get

$$dT = \frac{M_0^2 g dl}{2dF_h K_1 jl} . \qquad (148)$$

Integrating and determining the constant, we shall find

$$T = A \ln\left(\frac{l}{l_1}\right), \qquad (149)$$

where

$$A = \frac{M_0^2 g}{2dF_h K_1 j} . \qquad (150)$$

If we consider the work since the start of the voyage, with zero velocity, then theoretically this work is infinite. It becomes small when the rocket covers part of the journey 'l' on the rails, having already acquired some velocity. In a medium with uniform density the work, although slow, yet grows infinitely. Let us suppose, in (150).

$$M_0 = 1; \; g = 10; \; F_h = 20; \; K_1 = 1; \; j = 10.$$

Then A = 19.2 and

$$T = 19.2 \ln\left(\frac{l}{l_1}\right). \qquad (151)$$

Let the projectile after a journey of 10 kilometers, cover a total of 1000 kilometers. Then

$$T = 19.2 \ln 100 = 88.3 .$$

If the rocket covers preliminarily one kilometer, then

$$T = 132.5.$$

It means, on holding back from falling, the work goes on comparatively slightly.

We can express this work, depending on the velocity acquired by the projectile, by 'C'. We have from (147) and (149).

$$l = \frac{c^2}{2j} \text{ and } T = A \ln\left(\frac{c^2}{c_1^2}\right). \qquad (152)$$

Thus, if the rocket started its flight with a velocity of 100 maters/second, and finished with a velocity of 10,000 meters per second, then

$$T = 19.2 \ln (100^2) = 176.6.$$

This is already a cosmic velocity almost freeing the rocket from the gravitation of the Earth, the work however is not significant. If the flight was started with a velocity of 10 meters/second, then

$$T = 19.2 \ln (1000^2) = 265.$$

The difference in work, due to this, is not great. The corresponding path l will be calculated according to (147), namely

$$l = \frac{c^2}{2j} = 5 \times 10^6 \text{ M}, \tag{147}$$

or 5000 kilometers. (It must be remembered that in these calculations we do not take into consideration the head resistance). In case of such a long path, even though it is horizontal in the beginning, the rocket considerably recedes from the surface of the Earth and finds itself first in the rarefied air, and thereafter in the vacuum. In less rarefied air, the work will be enormous owing to the excessive inclination of the projectile, while in the more rarefied - even equilibrium is not possible, and it is all the more impossible in the vacuum. The work of equilibrium becomes an absurd value.

It is possible to confine oneself to the constant layer of air till the velocity of 8 kilometers/second is attained after which the centrifugal force totally annihilates the Earth's gravity. The inclination is done away with, and the work of maintenance of gravity vanishes. In general, the work during the circular motion due to the influence of the centrifugal force is less than the calculated one. But there appears another difficulty here. During motion in a dense medium, the work of the head resistance of the atmosphere, even when the form of the projectile is pointed, becomes disadvantageously great. Besides after acquiring the velocity of 8 kilometers/second it is still required perhaps, to choose by the tangential or ascending curve from the atmosphere, that again much work is required. Our calculations at the moment only show that the work of maintaining the weight is very small, but we are not proving, that the path in the air, having unifrom density, is most advantageous.

Horizontal motion of the projectile with its long axis not inclined.

The projectile moves in the direction of the force of gravity.

The fall, or, rather, velocity of fall in seconds, will be

$$c_y = c \sin \xi = \frac{M_0 g}{dF_h K_1 c} \quad . \tag{165}$$

Again the flight of the rocket is supposed to be horizontal. At ξ here it is necessary to imply a small angle of slope from its horizontal motion owing to gravity and resistance of the air. Let us suppose, for example, $M_0 = 1$; $g=10$; $d = 0.00037$ (at an altitude of 10 km); $F_h = 20$; $K_1 = 1$; $C = 2260$; $h = 10000$. Then $C_y = 0.6$ i.e. 60 cm/sec.

If the projectile moves tangentially to the Earth then on the one hand, it recedes from the Earth with a known velocity and on the other, falls or comes closer to the surface of the Earth, depending on its translatory velocity and the density of the medium: The fall is expressed by formula (165). Eliminating from it d and c see (97), (127) and (147) we shall get

$$c_y = \frac{M_0 g e^{\frac{h}{h_1}}}{d_1 F_h K_1 \sqrt{2j} \sqrt[4]{Dh}} , \tag{166}$$

The velocity of ascent on the tangential motion is calculated in the following manner. We have

$$l = \frac{j}{2} t^2 , \tag{167}$$

where t is time, and D = the diameter of the Earth. We still have

$$h = l^2 : D.$$

Consequently,

$$h = \frac{j^2 t^4}{4D}.$$

Hence, differentiating, we find

$$\frac{dh}{dt} = \frac{j^2}{D} t^3 = \sqrt[4]{\frac{64}{D}} \sqrt{j}\, h^{3/4} \qquad (168)$$

Now it is possible to give table 13.

Table 13.

Duration of light of the rocket in seconds	10	20	50	100	200	400	1000
Velocity in meters/ second when j =10.	100	200	500	1000	2000	4000	10000

Continued on next page ......

Continuation ....

l - is the length of the path, km.	0.5	2	12.5	50	200	800	5000
Height $h = l^2 : D$ (approximately,)M.	0.02	0.32	12.3	197	3150	50400	1970000
$\frac{dh}{dt}$ is the velocity of the ascent, sec.	0.008	0.064	0.554	4.43	35.5	283	4430
Density of air, d	-	-	-	0.0013	0.00078	Close to zero	
Velocity of fall due to gravity and resistance of air, M/sec.	3.85	1.92	0.77	0.385	0.280	Very great.	
$d_1 : d$	1	1	1	1	1.48	550	10^{109}

The flight is performed approximately tangentially to the Earth. Recession from the surface of the Earth (4th graph) takes place on account of this. In the beginning this recession is almost imperceptible. Thus, in the course of 10 seconds, when 0.5 kilometer has been traversed, it constitutes only 2 cm. The velocity (fifth graph) of recession in the course of 10 seconds, constitutes 8 mm/sec. But already in 50 seconds, when more than 12 kilometers was covered and the projectile has gained an altitude of 12 meters, the velocity of recession was more than 0.5 M/sec (55 cm/sec). In this case it does not just attain the velocity of falling (7th graph). Soon after approximately 50 seconds the last velocity becomes imperceptible in comparison with the velocity of recession from the Earth's surface. Thus, in the course of 200 seconds, when the projectile has ascended to an altitude of three kilometers and acquired a velocity of 2 km having flown 200 km tangentially, the velocity of ascent exceed the velocity of falling (it is limited by the resistance of air) 127 times. But further the velocity of falling increases, compared with the velocity of ascent and, eventually, it is exceeded, because the atmosphere becomes rare and in the vacuum infinite velocity is needed so as to obtain pressure or resistance of the medium, equal to the weight of the rocket. There (in vacuum the bady will readily fall down only under the action of the force of gravity. In short, then we can completely ignore the resistance of the air, which does not exist in the vacuum.

What comes out of it? Approximately since the moment the rocket tilts downwards from the horizontal plane; after this the flight becomes parallel to the Earth; subsequently recession starts from the Earths surface and the flight more and more come close and becomes tangentially straight (tangent). The gravity, seemingly does not act on the projectile, it moves as if on the rails. But in the course of roughly 4 minutes (265 seconds) the air is so much rarefied that it the seems as if the rails were removed, and the projectile flies under the influence of the force of the Earth's gravity which enters into its own; but then the ship has already ascended to an altitude of 10 km, flown 351 km and acquired a velocity of more than 2 km / second.

It means, some, denser part of the atmosphere facilitates the path of the projectile in this stretch and gives it "rails" which diminish the work, if we do not consider the head resistance of the projectile. We had assumed the acceleration of the rocket equal to that of the Earth (10 M/sec^2). The increase of pressure j on the projectile will make the deviation from the tangent still less prominent i.e. it will strengthen the "rails". It is permissible to determine the curve of flight accurately, but so to say, already many formulae have been given. The inconvenience of such a flight tangential to the Earth lies in the fact that the flight has to be started from height: from towers or the steep mountains, since in the first few seconds there would be lowering of the rocket. When j = 10, as is evident from the table, the average velocity of fall due to gravity and the resistance of the air cannot exceed 4 M/sec, if the start of flight is taken from a velocity of 100 M/sec. In this way, in 40-50 seconds of the flight the projectile will descend much less than 200 meters, rather 100 meters. After this the flight will be parallel to the surface of the Earth, and still further-recession from it begins. Thus, on slight action (j = 10) of the explosive substances the flight must start from the tower with a height of 100 meters or from a like mountain, but on a steep precipice at 45°. When j is large, the required height will be less and the deviation will be more slanting. This dependence is inversely proportional. If in the beginning we move in the horizontal plane and at the same time acquire velocity, somewhat larger than 500 M/sec, the ascent is not at all required, since the falling will not exceed recession, taking place due to the sphericity of the Earth.

ASCENT IN THE ATMOSPHERE IN THE LINE OF ASCENT.

The tangential flight is advantageous because of the fact that it permits the use of a very small part of the explosive force j. In technical relationship, particularly during the initial experiment, it is a very important advantage. But in the relationship of economy of energy, required for overcoming the resistance of the air, the better flight is the one inclined to the horizon. Although, the greater the inclination, the greater is the explosive force j, that has to be employed, since this flight is similar to the ascent on the mountain.

We have already analyzed it earlier (83) with respect to the resistance of the air. Now we can increase, which were accurate, assuming a slight inclination from the fall owing to the atmospheric pressure.

We have seen, that the steep ascent is not suitable, particularly perpendicular to the surface of the Earth. Here we are assuming a less-inclined flight in the atmosphere. It has many advantages. First the loss is equal to the loss during the ascent on the mountain, by which its loss of energy is diminished. On a great altitude, where air cannot serve as a support, the action of the explosive substances may be normal to the radius of the Earth owing to which, as we have proved, there is no loss of energy at all. Secondly, it is permissible to employ less of the explosive force j. Thirdly, it is possible to make use of the mountains, so as to impart a sufficient preliminary velocity to the projectile. As we have seen, it is very useful because then it is possible to escape a fall, in particularly if the inclination of the path is sufficiently large. Fourthly, some deviation of the path highly diminishes the expenditure of energy for overcoming the head resistance of the atmosphere. (Comparatively with the tangential or horizontal flight). Eventually, when the force of explosion is small, the rocket and all its parts, whould not be made so very massive. Similarly for the human beings too, no safety media are needed.

In case of inclined ascending motion of the rocket, the recession h, from the surface of the Earth, depends on two causes: namely the angle of slope, and the sphericity of the planet:
The first is equal to

$$h = l \sin y, \tag{169}$$

while the second-

$$h_2 = l^2 : D. \tag{170}$$

Hence

$$h_1 + h_2 = l \sin y + \frac{l2}{D} = l\left(\sin y + \frac{l}{D}\right). \qquad (171)$$

The fall is expressed by formulae (165) and (166) already established. But for the angle ξ another angle should be substituted in them, expressing diversion, depending exceptionally on the resistance of the atmosphere and the translatory velocity of flight. This angle ξ is generally extraordinarily small.

During the ascending motion, no matter how small the inclination y the force of explosion j cannot anyway be small. Its minimum value is determined by the equation

$$j = g \sin y. \qquad (172)$$

Besides, the rocket will stand on the mountain (air). There would still be no acceleration, but there would be a powerful descent. It is necessary and advantageous that j considerably exceeds this value. We shall give here the minimum value of j, depending on the angle of slope, y and the force of gravity g (Table 14).

Table 14.

y in degrees	1	2	3	4	5	6	7	8	9	10
j, M/sec^2 .	0.175	0.349	0.523	0.698	0.872	1.05	1.22	1.39	1.56	1.74

Contd.

Continuation

j magnified 10 times.	1.75	3.49	5.23	6.98	8.72	10.5	12.2	13.9	15.6	17.4

From this, it is evident, that j is magnified 10 times, even when the inclination is only 10 it is 17 times more than the acceleration due to the Earths gravity (10 M/sec^2). But even at this small inclination, evidently, It is permissible to the confined by the incomparably weaker exploding force, roughly up to 0.1 of the force of gravity. This has an enormous technical benefit, because it permits the start of flights even during the contemporary conditions of technology[1].

For the ascent during the inclined motion of the projectile we have derived formula (171).

The velocity of ascent (we ignore for the time being the sphericity of the Earth) will be c sin ξ .

On the other hand, the velocity of descent is determined by formula (165). Equating the descent with the ascent we shall find the equation, from which we shall obtain.

1) Forther separate paragraphs in comparison with the Kaluga Edition (1926) of this works of K.E. Tsiolkovskiy, have been rearranged with the aim of great sequence in the explosition of the material (Editors).

$$\sin \xi = \frac{M_0 g}{dF_h K_1 c^2} \quad . \tag{173}$$

At this angle the initial motion will be horizontal. If, for example, $M_0 = 1$; $g = 10$; $F_h = 20$; $K_1 = 1$; $C = 100$; then $\sin \xi$, $= 0.0385$, while the angle $\xi = 2.2^\circ$. When the velocity is 200 meters, the angle will be close to 0.5°.

Thus, it is fully possible to avoid the descent even when the angle of slope is very small, only if there is sufficient initial velocity. But it may be much less, if the angle of slope is larger. Thus, if the angle goes up to 8°, then the velocity of 50 meters per second will be enough.

THE ENGINE AND THE CONSUMPTION OF FUEL CAPACITY OF THE ENGINE FOR 1 TON WEIGHT OF THE ROCKET.

We are giving in table 15, the capacity of the engine for 1 ton weight of the rocket on different velocities and accelerations; the capacity is approximately expressed in thousands of metric forces (100 kilogram-meters/seconds); the velocity of the rocket C_1 is in kilometers/second at the different moments of motion.

Table 15.

c_1 km / sec.		0.1	0.2	0.3	0.5	1	2	5	8	11
Acceleration j of the rocket in M/sec^2 or the exploding force.	1	0.1	0.2	0.3	0.5	1	2	5	8	11
	2	0.2	0.4	0.6	1	2	4	10	16	22
	3	0.3	0.6	0.9	1.5	3	6	15	24	33
	5	0.5	1	1.5	2.5	5	10	25	40	65
	10	1	2	3	5	10	20	50	80	110
	20	2	4	6	10	20	40	100	160	220
	30	3	6	9	15	30	60	150	240	330
	50	5	10	15	25	50	100	250	400	550
	100	10	20	30	50	100	200	500	800	1100

It follows, that the capacity of a rocket weighing one ton on the minimum accèleration (and of course, with a small angle of slope) changes from 100 to 11000 metric forces.

If the rocket gives 100 kilogram of the thrust on the motor, then in the beginning, the capacity (output) will be close to the capacity of an air plane engine (100 metric forces) and only on the achievement of the maximum cosmic velocity it increases 110 times.

At first sight this seems awfully enormous but we should not forget that we are dealing with reactive (or rocket) engines.

The problem is to explode in the pipe, every second, a specific and constant quantity of the explosive substances. Just now we shall show in the table, that it is completely small. For example, for a one ton rocket on its acquiring the cosmic velocity of 8 kilometers/second 4 tons of explosive materials are required. The duration of explosion for acquiring this velocity will be 8000 seconds, if the average magnitude of the explosive force is equal to 1 (0.1 of the force of gravity). It means, that in a second, 0.5 kilogram of the explosive substances, on an average, will have to be exploded. What is inaccessible here?

If the exploding force is even 10 times more (when the inclination is large), one would have to explode 5 kilograms in a second. And this is quite possible.

Table 16 shows approximately the average quantity of the explosive materials, required in a second when the exploding force j is different. The weight of the rocket is one ton.

Table 16.

Reserve of explosive substances, T	1	4	9	30
Final velocity, M/sec.	3465	8045	11515	17170
Duration of explosion,	3465	8045	11515	17170
Duration, hr.	0.96	2.23	3.2	4.8
Quantity of exploding substances, kg/sec. j = 1.	0.29	0.5	0.78	1.75
Ditto, when J = 5	1.45	2.5	3.9	8.75
ditto, when j = 10.	2.9	5	7.8	17.5

The second[1] cosmic velocity is sufficient to make the projectile a satellite of the Earth, of course, beyond the atmosphere. The third is sufficient for overcoming the Earth's gravity and wandering along the Earth's orbit. And here the second (time factor) explosion is less than one kilogram. The last velocity is sufficient for internal recession from our Solar system and wandering in the galaxy with a velocity not less than the velocity of a cannon ball. Even here the consumption per second is less than 2 kilograms. The duration of explosion is from 1 to 5 hours. All this takes place when the force of explosion j is ten times less than the Earth's gravity. When the force j is large, the consumption per second of the explosive substances increases and the duration of explosion decreases proportionately. An increase of the mass of the rocket is similarly accompanied by a proportionate increase of consumption per second, while the duration of explosion does not change here. It appears, strange, from the beginning that the work of the rocket motor progressively increases, (with the velocity of the projectile) whilst the quantity per second of the used up explosive material does not increase. The fact is, that the explosive substance, still not exploded already possesses greater energy, if the velocity of the bearing ship is greater. Therefore it releases it (energy) in a larger quantity, than it must be in accordance with its potential and chemical energy.

1) i.e. indicated in the second column of table (Editors).

CONCLUSIONS

From all that has been stated above we can draw the following conclusion. The flight is advantageous to start on the mountains on as high an altitude as possible. On the mountain road must be levelled, with a slope of not more than 10-20°. Then the rocket is placed on an automobile, which acquires from it a velocity of from 40 to 100 meters/second. Thereafter the projectile flies independently, by anabatic means developing pressure in the rear by the explosion of substances. The inclination of the projectile to the extent of increase of its velocity decreases, and the flight comes close to the horizontal. On exit from the atmosphere and some recession from any of its traces, the flight becomes parallel to the Earth's surface, i.e. circular. The acceleration j must have the minimum value, roughly from 1 to 10 meters/sec^2. The expenditure on the resistance of air will be minimum. The influence of gravity too almost vanishes (in relation to the loss of energy). The initial velocity is acquired by the automobile, air plane or an suitable device : terrestrial, aqueous or aerial. The flight in not very rarefied atmosphere may take place by the energy of the fuel, being burnt by the oxygen from the atmosphere. This will economic the reserves of fuel 9 times (it is the ideal number, when only pure hydrogen is stored). If the rocket in the air has still not acquired cosmic velocity, freeing it from the gravitation of the Earth, then it is not permissible to make use of the atmospheric oxygen in much rarefied layers of the air.

Therefore, in this case, reserve liquid oxygen or its unstable (as far as possible endogenous) compound with other gases (for example, with nitrogen) is set in motion. Then the acquired velocity goes up to the cosmic one.

PREPARATORY EARTH ROCKET

Designing the Rocket. Stage for the Ascending run. Roadway. Motor. Resistance of Air. Friction.

We have seen, that the rocket while still on the Earth, must acquire some velocity, so as to fly immediately, horizontally or slantingly by means of ascending. The more the acquired velocity due to the ascending run is the better it is. It is desired, that the projectile does not expend, at the same time, its reserve energy in the form of the explosive substances. And this is possible only if our rocket is set into motion by an external force: by an automobile, steamer, locomotive, airplace, airship dirigible), gaseous or electromagnetic cannon etc. The known existing methods cannot

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impart velocity more than 100 - 200 meters/second, since neither wheels, nor air-screws can rotate quicker without interruption. Their velocity along the periphery may go up to 200 M/sec[1] - not more. It means that this velocity (720 km/hr) cannot out do the common travelling guns. For the beginning, perhaps, it is enough. But we aspire to impart to the rocket the largest possible preliminary velocity, so that it saves its reserve of the explosive material for a future flight, when it (rocket) has abandoned its difficult path. From here it is evident, that for acquiring velocity of more than 200 M/sec by the projectile, special accessories are needed. The gaseous and electromagnetic cannons, in the first instance must be rejected for being too costly, (multi-millions) installations owing to their great length. In short ones, the relative gravity (jerk) kills and destroys all. The most simple and cheap method in this case is the rocket and reactive device. We should state, that our cosmic rocket must be placed on the other - the Earth rocket, or enclosed it. The Earth rocket, not being detached from the soil, will impart it the desired run. For the Earth rocket, horizontal straight-lined, slantingly ascending path is needed.

The air-screws are neither nor required possible. Their full changes by the rear pressure of the exploding gases

1) In centrifugal superchargers for aero-engines and in quick moving turbines, high velocities are obtained (Editors).

in the pipe. The wheels for reducing friction are not suitable. The Earth's rocket moves, like a sledge.

The friction of hard bodies offers considerable resistance, even if it is reduced by lubrication. For example, the coefficient of friction for iron on dry cast iron or bronze (or vice versa) comprises about 0.2. This means, that the projectile with a weight of 1 ton is set in motion in the horizontal plane by a force not less than 0.2 ton or 200 kilograms. Such is the magnitude of friction for pressure, not exceeding 8-10 kg/cm^2 of the surface of friction.

It is remarkable that the coefficient of friction with the increase of velocity of rubbling bodies decrease about 4 times and more (in the extreme limits of the experiment). During ordinary pressure, not violating the prescribed limits, and on abundant lubrication the coefficient of friction of those very bodies may decrease 5-10 times. Moistening of the surfaces of friction by water decreases the friction about two times. The coefficient of friction of metal on ice and snow (and vice versa) goes up to 0.02 i.e. 10 times less than the friction of dry heterogeneous metals, and is compared, so to say with the magnitude of friction on rich lubrication. Thus, if the rocket moves on ice or on a uniformly and richly lubricated metallic roadway, then there are no insurmountable obstacles for rapid motion without wheels. If, for example, the pressure of gases on the projectile is equal to its weight ($j = 10$) then on the friction only from 20 to 2% of the entire energy spent on the motion of the Earth's rocket, is lost. On an acceleration of 5 M/sec^2 ($J = 5$) the consumption will be from 40 to 4%. If $j = 1$, then the consumption will comprise from 200 to 40%, which is intolerable.

But then, I know the methods to bring the friction almost to nil, but about this we shall discuss in another book*).

We are coming to the concept about the Earth's rocket, moving on usual, but smooth and rigidly straight rails, richly lubricated by tallow, oil or ice, being pushed out from the slide - rails of the machine. Ice is available only during the cold spells of the year or on high mountains, where the temperature is below zero.

The form of the Earth's rocket must be easily streamlined by air. The oblong it is the more easily the rocket will cleave the medium, if we do not take into consideration the friction of air about the wall of the

*) See K.E. Tsiolkovskiy's book "Resistance of Air and High Speed train." Kaluga, 1927 (Editors).

Earth's rocket. When its oblongness is 100 or 200 (i.e. when the length as many times exceeds the maximum diameter of the projectile) then we can even take into consideration only friction. In view of the long path as we shall see later, necessary for the ascending run of the projectile, it can itself be very long —— space will suffice.

Special calculations and considerations, which we shall not mention here, show that the magnitude of friction cannot exceed the number

$$\frac{dFV}{2g} \tag{174}$$

which can not the velocity of the surface of friction. From the formula we see, that this limiting friction is proportional to the surface of friction F, density of gas 'd' and the its molecular velocity. V. Such an inference permits the comparison of the gases, during enormous velocities with hard bodies, since in case of the latter friction does not very much depend on velocity of the rubbing body. By a transformation of formula (174) it is not difficult to prove, that for "permanent" gases and unchangeable external pressure, this limiting friction is proportional to the square root of the molecular weight of the gas and inversely proportional to the square root of the temperature of the gas.

It means, for example, that at the atmospheric pressure heated hydrogen gives less friction, than the cold air. On the contrary cold carbon dioxide gas offers more resistance than the heated air.

On the one and the same density of gases, the conclusion would be reverse, i.e. the gases with small molecular weights at high temperatures give greater coefficient of friction. We shall indicate the limits.

According to formula (174) for the common air for 1 M^2 we shall find limiting friction in the neighborhood of 0.011.

Other considerations give the formula for the magnitude of friction.

$$R = \frac{slb}{2g} \quad dc. \tag{175}$$

It means that the coefficient of friction is proportional to the coefficient of gas 'd', the velocity of the projectile and the thickness 'S' of the air, sticking to $1M^2$ of the body, moving with a velocity of 1 M/sec. But, to our regret, this formula is dependable only when the velocity of the projectile is as many meters, in magnitude as the number of meters in its length. Consequently, in this formula we must suppose l = c. Then we shall obtain

$$R = \frac{s^1}{2g} \; l^2 bd = \frac{S}{2g} \; c^2 bd. \qquad (176)$$

We shall suppose here 2g = 20; b = 3; d = 0.0013 Besides, frommy own experiments, I know that S = 0.01 (1cm). Then we shall find

$$R = 195.10^{-8} \cdot c^2 = 195.10^{-8} \qquad (177)$$

Let us assume again, that the weight of the entire, projectile in tons is expressed by the number 'l'. Then we shall draw up table 17 for different accelerations of 'j' and different velocities of the projectile.

We see, that even when the velocity is 5 km per second and the acceleration of the Earth's rocket is 0.1 of the gravity (j = 1) the loss does not exceed 10%. But here there is a great inconvenience: the rocket must have a length of 5 kilometers. In case of small velocities and small lengths of the projectile an insignificant percentage of work is consumed.

Table 17.

Length, weight and velocity of the Earth's rocket in M / T. and M/sec.	1	10	100	500	1000	1500	2000	3000	5000
Magnitude of friction, kg.	0.002	0.2	20	500	2000	4500	8000	18000	50000
Resistance relative to pressure on the projectile in percents, when j = 10.	0.0002	0.002	0.02	0.1	0. 2	0.3	0.4	0.6	10
Ditto - when j = 1	0.002	0.02	0.2	1	2	3	4	6	10
Ditto - when j = 4	0.0005	0.005	0.05	0.25	0.5	0.75	1	1.5	2.5

Here the blunt projectile will give considerable resistance due to the work of cleaving the air.

The length of the Earth's rocket must not exceed 100 meters, otherwise the rocket will have a large mass and will be very costly and the absolute work, necessary for imparting it velocity and overcoming the resistance of air, will be great. It means that it is necessary to have a large quantity of the explosive substances and incur heavy expenditures on them. If the rocket is shorter, than in the table, i.e. c/l times, then each particle of air will be subjected to displacement for a shorter time, than in the case, when the velocity of the projectile is numerically equal to its length. Time will be shortened to $\left(\frac{c}{l}\right)$ times.

The thickness 'S' of the layer of the air being carried along, will not decrease proportionately, but approximately $\left[1 + \ln\left(\frac{c}{l}\right)\right]$ times. Exactly so many times will the resistance of the air also diminish. In this way, in place of formula (176) we shall obtain a more exact one, suitable for all lengths of the Earth's rocket, namely

$$R = \frac{sl}{2g} \text{ bdc} : \left[1 + \ln\left(\frac{c}{l}\right)\right] . \qquad (178)$$

Let us suppose the length of the rocket to be constant and equal to 100 meters. The velocities are different.

Then we shall get table No. 18.

Table 18.

C, M/sec.	100	200	300	400	500	700	1000	2000	3000	4000
$\frac{c}{1}$	1	2	3	4	5	7	10	20	30	40
$1n\left(\frac{c}{1}\right)$	0	0.69	1.10	1.39	1.61	1.95	2.30	3.00	3.40	3.69
$\left[1n\left(\frac{c}{1}\right)+1\right]$	1	1.69	2.10	2.39	2.61	2.95	3.30	4.00	4.40	4.69

The last graph shows how many times the thickness of the sticking layer of gas diminishes, as well as the resistance due to friction, depending on the change of length (second column).

Let there be in the formula (178) S = 0.01 1 = 100; b = 3 Then we shall find

$$R = 1.95.10^{-6}\, c : \left[1 + \ln\left(\frac{c}{1}\right)\right]. \qquad (179)$$

This provides the possibility to draw up table No. 19 of absolute and relative resistance when there are different forces of explosion.

Table 19.

		100	200	300	400	500	7002	1000	2000	3000	4000
C, M/Sec.		100	200	300	400	500	7002	1000	2000	3000	4000
Pressure kg.		19.5	23.1	27.9	32.6	37.4	46.3	59.1	97.5	133.0	167.0
Relative Resistance %.	Weight. 100 g, j = 10.	0.02	0.023	0.028	0.033	0.037	0.046	0.059	0.098	0.133	0.167
	Weight 100 g, j = 1 .	0.2	0.23	0.28	0.33	0.37	0.46	0.59	0.98	1.33	1.67
	Weight 10 g j = 1	2	2.3	2.8	3.3	3.7	4.6	5.9	9.8	13.3	16.7
	Weight 10 g, j = 4	0.5	0.6	0.7	0.8	0.9	1.1	1.5	2.5	3.3	4.2

It is evident from here that even when the acceleration (j = 1) is the smallest and the mass of the rocket is slight (10 T) friction consumes not more than 17%.

We shall now decide the question about the length of the space for the ascending run of the Earth's rocket. A part of the space will serve for the acceleration of motion, while the other part, for retardation and its neutralization. Counter - explosion is not an economic method of neutralization of the acquired velocity. It may be done more quickly by braking action through friction or resistance of the air, that is, for the shorter path. Lubrication may be stopped and the plane set out perpendicularly to the direction of motion. Their air resistance will soon neutralize the velocity of the Earth's rocket. During braking action, especially if the cosmic rocket has already started flying, a much smaller part of the road is needed than during the acceleration. The general picture is like this: The Earth's rocket will be hurried away on the slide-rails by accelerated motion along with the cosmic rocket. When the maximum velocity is acquired and braking action of the Earth's rocket begins the cosmic rocket will get detached from the Earth's rocket under the influence of inertia and will go along its path quicker and quicker because of its own initiated explosion. Retarded by the air or by other media the Earth's rocket will travel farther in the space but very slowly, till the time it stops. We shall not take into consideration the portion of the space where braking action takes place since it may be very small. In order that the resistance is minimum, the cosmic rocket must form the front part of the Earth's rocket. The nose of the first will be open (on the outside), while the stern is concealed in the Earth's rocket. When the motion of the latter is retarded, the cosmic rocket gets detached from the Earth's rocket and leaves it. By this action, a wide opening on the Earth's rocket, which represents enormous resistance vigorously retards the motion. The rocket stops itself, without any trouble. The Earth's rocket is very long and the cosmic one accommodates in it only a little of its stern portion. The remainder is left for its filling by the explosive material and the controlling parts.

For drawing up table 20 (of maximum velocities of the Earth's rocket) we have the formula

$$p = j - g \sin y. \qquad (180)$$

Here we see the resultant acceleration p, from the exploding force 'j' from the Earth's gravity (10 M / sec^2) and the angle of slope of the path towards the horizon.

$$c = \sqrt{2 pl} = \sqrt{2 (j - g \sin y) l}. \qquad (181)$$

The pressure P, of the explosive substances on the rocket is determined by the equation

$$P = G_0 \frac{j}{g} , \tag{182}$$

where G_0 is the weight of the rocket; the pressure has been expressed in ordinary units.

Table 20.

Length of the rails Km .	1	2	5	10	50	100	200	300	500
j = 100	447	632	1000	1420	3160	4470	6324	7746	10000
j = 50	316	447	707	1000	2236	3162	4472	5477	7071
j = 30	244	346	547	774	1732	2449	3464	4242	5477
j = 20	200	282	447	632	1414	2000	2828	3468	4472
j = 10	141	200	316	447	1000	1414	2000	2449	3160
j = 5	100	141	223	316	707	1000	1414	1732	2236
j = 3	78	109	173	244	547	774	1095	1342	1732
j = 1	45	63	100	142	316	447	632	774	1000

We consider the area in horizontal plane (y = 0). A very small inclination might required, which will permit a slight decrease of the cited velocities by a factor such as the resistance of air.

The duration of motion of the Earth's rocket is obtained by dividing velocity by the acceleration 'j' Thus, when the path is 500 kilometers, it will, according to the table, be from 100 to 1000 seconds. When the path is one kilometer the duration will be from 4½ to 45 seconds. The duration of brake action (retardation) may be very short.

Gravity, produced due to acceleration, according to the table, changes from 0.1 to 10 times that due to the Earth, Adding this to the latter, it gives the apparent gravity in the rockets from 1 to 10 (approximately). The path with rails somewhere in the mountains, on an altitude, must have a length of 500 kilometers (about 5° of the circumference of the Earth), so that there is a hope for acquiring cosmic velocities. But a large gravity causes of the enhancement of the strength of the rockets and thereby increases their masses. Eventually the work of the resistance of the air is increased. In s word, the acceleration 'j' equal to that of the Earth is sufficient. Then we shall obtain fully the requisite preliminary velocity up to 3160 M/sec. The small, very useful inclination of the path at 10-20° will decrease the preparatory velocity.

We can also calculate the reserves of explosion for the Earth's rocket. If the hollow, Earth's rocket weighs 10 tons and the celestial rocket has the same, then altogether they will constitute 20 tons. Now according to table 6 we shall calculate in tons the reserve of explosive material for the Earth's rocket for acquiring different velocities. The velocity of launching is supposed to be 4 km/sec.

Table 21.

$M_1' : M_0$	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.5	2
M, T 6	2	4	6	8	10	12	14	16	18	20	30	40
c_1, M/sec	378	728	1048	1344	1620	1876	2116	2344	2568	2772	3660	4392

These velocities are fully sufficient whereas the reserve does not exceed 40 tons. We shall observe, that the powerful retardation (braking action) may kill a human being, controlling the Earth's rocket. Therefore it is better if the latter is regulated automatically without human beings. The passengers of the cosmic rocket during braking action will find themselves outside the Earth's rocket from which the cosmic rocket will be detached.

If the cosmic rocket in this way acquires the initial velocity without spending its own reserve, then the rocket can store less of it (reserve), or with the same reserves acquire a larger cosmic velocity.

We had

$$dc = - W \frac{dM_1}{M_0 + M_1} \tag{34}$$

and

$$c = - W \ln (M_0 + M_1) + \text{const.} \tag{35}$$

If the initial velocity of the rocket is equal to C_0, then $M_1 = M_1''$, i.e. the mass of launching will be maximum (initial). Consequently,

$$c_0 = - W \ln (M_0 + M_1'') + \text{const.} \tag{183}$$

Calculating from (35) (183) we shall get

$$c - c_0 = W \ln \left(\frac{M_0 + M_1'}{M_0 + M_1} \right). \tag{184}$$

If $M_1 = 0$, then we shall obtain the maximum velocity C_1 Therefore,

$$c_1 = c_0 + W \ln \left(1 + \frac{M_1'}{M_0}\right). \qquad (185)$$

Let us suppose, that the preparatory initial velocity of the rocket is equal to 3 km/sec, but it should have C = 8 km/sec. Let us also suppose W to be 5 km/sec. Then according to table 6, we shall find the relative reserve of the cosmic rocket equal to $M_1'' : M_0 = 1.8$, while for

Table 22.

C_1, Km/sec.	8	11	17
c_1-5	3	6	12
M_1'': M_0 according to (186) .	0.8	2.31	10.0
M_1': M_0 (according to table 6).	4	8	30
c_1-4	4	7	13
M_1'': M_0	1.24	3.08	12.0

Continued on next page ....

Continuation.

$M_1' : M_0$	4	8	30
$c_1 - 3$	5	8	14
$M_1'' : M_0$	1.72	4	15
$M_1' : M_0$	4	8	30

obtaining velocity of 8 km/sec, relative reserve at 4 is required (table 6); from (185) we can obtain

$$\frac{M_1''}{M_0} = 1 - e^{\frac{c_1 - c_0}{W}} . \qquad (186)$$

We shall make use of this formula, so as to compile the comparative table No. 22.

From the table it is evident, that the cosmic rocket, having. a preliminary velocity, is loaded much less by explosive substances than the rocket not having this velocity. Thus, for obtaining a higher cosmic velocity and overcoming the pull of the Sun (17 km/sec), it is necessary to have 30 times more of the explosive substances than the weight of the rocket. If the rocket, still on the dry land, has acquired a velocity of 5 km, sec, then the relative reserve will comprise only a 10-fold weight. The first cosmic velocity requires four-fold reserve; if the preparatory velocity has been 3 km/sec then the weight of explosive substances would comprise only 0.8 of the weight of the rocket.

FORM OF THE EARTH'S ROCKET

The form of the Earth's rocket is very elongated, and of maximum resistance. The elongation may reach 50. Since the rocket does not leave the Earth and the sufficiently dense layer of the atmosphere, there is no necessity to make it hermetically sealed. Its outer cover may be like the covering of an air plane. In it there will be accommodation for explosive substances, which are forced by pumps into the explosion pipe and are rejected by the force of explosion in the rear portion of the rocket. In this, there is placed an engine for pumping, set into motion by a gasoline-motor (Preliminary consumption of a small part of the reserve of explosive substances is possible for it; after the work in the motor they enter the explosion pipe and perform the work of reaction).

COSMIC ROCKET.

The cosmic rocket must have the minimum mass and volume, which makes its realization easy. Its elongation should be 10, and not more. The maximum diameter is not less than 1-2 meters. The form is also easily streamlined, but its jacket is hermetically sealed since the rocket recedes in the airless space, where through holes, the gas, required for breathing, could all escape.

The main jacket of the rocket must withstand safely, pressure not less than 0.2 atmosphere if it is filled with pure oxygen. In fact, at the sea level we obtain the maximum quantity of oxygen. Its particular pressure comprises about 0.2 atmosphere. Such is its quantum. It means that it is sufficient physiologically. But man easily endures or, at least gets accustomed to still half the quantity of oxygen. On the mountains (of 5-6 kilometer height), where the quantity of oxygen is half, man still freely remains alive. The healthy endure, although with peril to life, still double the rarefaction (at an altitude of 10 kilometers). In any case, 0.5 of the usual quantum of oxygen is sufficient. It means, that at its pressure of 0.1 atmosphere, there is sufficient oxygen.

The jacket must have a valve, opening on the outside, if the difference between the internal and external pressure of the medium exceeds say, 0.2 atmosphere. Below at the sea level, tje absolute pressure in the rocket, consequently, will not be more than 1.2 atmospheres, while in the vacuum the pressure inside the projectile will not exceed 0.2. These obviously, are the limits, suitable for breathing. If we are to increase, by means of a regulator, the external pressure on the valve, for example, up to one atmosphere, then the limits of pressure will be 1 and 2 atmospheres. The latter in the first place is advantageous as more reserve for respiration. The internal pressure of the gas necessitates the making of the rocket in the form of a dirigible (air-ship) with circular transverse cross-sections. This very form is useful for obtaining the minimum resistance of air. It also saves the rocket from surplus internal fastenings and partitions. The tightly inflated rocket changes the complicated and intricate beam, well resisting the bend and, in general, the change of form. But since it has to be planned and this capacity of it (without wings) is weak, it is useful to unite the lateral surfaces of several jackets (of the rockets) of the form of the bodies of revolution. The united sides must be fastened inside by partitions. Such a complicated rocket, resembling fastened inside by partitions. Such a complicated rocket, resembling corrugated undulating plate with several sharp tails and heads, or one large wing, is already being very successfully planned. A cosmic rocket has to withstand still enhanced gravity. This implies that all its parts should be made more durable, than those needed for resistance to the forces of the common gravity. Thus the compartments, storing the explosive materials must be stronger. But, we have seen that the more advantageous is the less inclined flight with a slightly accelerated motion ($j<10$). Moreover, the gravity will change so little that all the calculations may be made freely for the usual force of gravity.

One also has to keep in mind the thickening and rarefaction of the medium, surrounding the swift moving rocket. On the nasal portion air is compressed, which permits this part of the rocket jacket to be made weaker or thinner; on the stern side the atmosphere rarefies, which requires the stern portion to be stronger or thicker. These forces act as long as the rocket is in the atmosphere. In the vacuum they do not exist. Nevertheless, not making the front portion weaker, it is necessary to make the rear one stronger. This has great significance for the cosmic rocket and less for the Earth's rocket in consequence of its considerably oblong shape. We have seen, that the total longitudinal resistance of the air comprises a small portion of the pressure of the explosive substances on the rocket. The normal pressure for the walls of the rocket is of such an order. Hence when j is average, it comprises a value not exceeding the force of common gravity. In view of the large margin of durability of the rocket we can ignore these forces as the relative gravity.

We take as a basis mainly the difference of internal and external pressures for the spindle-shaped rocket. Here is the mass (table 23) of the jacket made from the strongest alloys of iron, when the margin of durability is four-fold and the difference of pressure of 1 atmosphere (instead of the required - 0.2 atmosphere). This weight depends mainly on the volume of the jacket and not on its shape and oblongness, assuming the from as spindle - shaped and smooth.

Table 23.

Volume of rocket M^3	5	10	15	20	30	40	50	100
Weight of the internal gas density of air K^2	6.5	13	19.5	26	39	52	65	130
Weight of the jacket K^2.	33	65	98	130	195	260	325	650

It follows that the weight of the jacket is only 5 times more than the weight of the air of the usual density contained in it (0.0013). When the pressure is 0.2 atmosphere the strength will be 20 while at 0.1 atmosphere the margin of durability will reach 40. For accommodating one person 10 M^3 space is fully adequate. Such a reserve of oxygen will suffice one person for 10 days, if all the products of respiration are absorbed in the rocket.

The maximum load, possible for the rocket on its different volumes, is expressed roughly in tons (the first column of that very table). This load, in case of all volumes, is 154 times more than the weight of the jacket. The jacket for small rockets is thin, so that it has to be made 2, 3 or times thicker, looking at the smallness of the volume. This will still increase the margin of durability of small rockets. But the small volume of the jacket in this case will be the major part of the highest lifting capacity (154,), for example 1,2, 10%. For large volumes the weight of the casing (jacket) is less than 1%. Regarding the outer laminated jacket providing a possibility to obtain in ether and in Solar light, from 150° to 250° of cold we have already spoken. In the brilliant condition, it can preserve itself due to heating up at the time of flight in the air, especially if between it and the strong jacket a cold gas, escaping from the rocket, is flowing.

Material of Explosive Substances.

Pure hydrogen is turned into liquid and preserved, because without special precautions it volatilizes. The most advnatageous of all liquids or those easily turning into liquid are hydrocarbons. The more they are volatile, then more is the content of hydrogen in them and the more are they suitable for the job. We have plenty of oxygen in liquid state, and all the better that it can serve as a source of cold, to which we shall have to run for cooling the rocket (at the time of motion it heats up in the atmosphere) and the explosion pipe. But it is expedient to act like this: the maximum portion of the reserve of oxygen is taken in the form of some of its endogenous compounds, i.e. such as are synthesized with the absorption of heat. On dissociation they again release it and in this way increase the energy of combustion. The other, smaller part of oxygen may be in a pure and liquid state and may serve initially for cooling and later for respiration and explosion. It has to be stored a little. Hermetically sealed liquid gases develop immense pressure, for overcoming of which very massive vessels are needed. Therefore, in order that it may not be so, they must have holes, through which the gases formed could freely escape. In this way their low temperature is maintained. The action of the complex explosive substances yields a little to the action of pure hydrogen and oxygen. The latter impart velocity of ejected material (products of combination, or combustion) at 5 km/sec, while the compound 4 km/sec. It means, that the velocity of the rocket in the last case will be lessened in the very same ratio i,e. by 20%.

Some have suggested compressed gases in the vessels or highly heated up volatile liquids for reactive action. This is utterly unacceptable. This is the reason why. My most exact and multifarious calculations show, that the weight of the reservoirs of the best form and material is at least 5 times more than the weight of the compressed air, replacing the explosive substance. From here it is evident, that gaseous ejected material will always be 5-10 times less than weight of the rocket. We are seeing (table 6), that for obtaining the lowest cosmic velocity it is necessary, that the explosive material in the most favorable conditions exceeds the rocket 4 times in mass. Although the light gases are more suitable, but they require more weight of the vessels. The same we shall say about the highly incandescent gases. Water and other volatile liquids, slightly heated, impart some advantage and are therefore more suitable for initial experiments of low flight My calculations show that with the help of compressed gases it is permissible to ascend not higher than 5 kilometers, while by means of overheated water - not higher than 60 kilometers.

There is absolutely nothing more energizing and at the same time suitable amongst the explosive materials indicated earlier.

How to explode then and how to preserve them? If we are to explode similarly, as in all the known old and new rockets, then the reactive pressure, on explosion, will be transmitted to the entire surface of the vessel (their storage), that will cause to make it very massive. The pressure of explosive substances reaches up to 5000 atmospheres. In such a case calculation will show that the weight of the tanks will be at least 30 times more than the weight of explosive materials on their aqueous density (it is less in the function and this is still worse). If it is so, then the projectile does not ascend more than 15 kilometers.

But we lose less, if owing to the method of slight (i.e. not thorough) mixing of explosive substances we weaken their pressure up to 100 atmospheres, or 50 times. Moreover, the reserve of explosive materials may be increased as many times and attain $1\frac{2}{3}$. And such a reserve is less. The subsequent lessening of pressure of explosion is not advantageous in view of the pressure of the atmosphere and small utilization of the chemical energy. It is much more reasonable to hold the elements of explosion apart, without pressure, and only to pump them into the explosion pipe i.e. the special chamber where chemical combination (combustion) of elements takes place. Then common tanks or the fenced rocket itself may serve for their preservation. Incomvenience is caused by the fact, that after overcoming the pressure of explosion, the substances have to be pumped into the explosion chamber. But if the pressure is not more than 100 atmospheres, then the work of this injecting is not very large.

We are drawing up table 24, determining this work at different cosmic velocities and with different forces of explosion. We are taking the weight of the rocket as 1 ton, and pressure at 100 atmospheres.

From here it is evident that when the force of explosion is the smallest i.e. j = 1 and the minimum cosmic velocity is 8 km/sec the work of stuffing in or pumping is confined to 50 kg. M or half the metric force. When the cosmic velocity is most enormous and ten-fold force of explosion (j = 10) the work reaches 17 metric forces.

All this is easily overcome and may still be lessened on periodical explosion, which we have already discussed. It is understood, that when the mass of the rocket has increased the work proportionately increases.

The arranged numbers are average, and approximate. The density of the explosive substances is taken as equal to unity.

From the table it is also evident that the work of pumping will not be burdensome, even when the pressure of explosive substances is brought to 1000 atmospheres. But in case of huge masses of the rocket and heavy pressure, it is economical to apply periodical pressure and pumping. Then the work will be very much a bated.

Table 24.

Velocity of the projectile, km/sec.	8	11	17
Mass of the exploding substances T.	4	8	30
Duration of explosion in seconds when j = 10.	800	1100	1700
Quantity of explosive substances, being fed km/sec.	5	11	17
Work of Pumping, kg/ M.	500	1100	1700
Duration of explosion in seconds, when 'j' =1	8000	11000	18000
Quantity of explosive substances, kg/sec.	0.5	1.1	1.7
Work, kg/ M.	50	110	170

COMPONENT PARTS OF THE ROCKET.

Explosion Pipe, Form, Pressure, Weight, Cooling.

The main engine of the rocket is the explosion pipe, similar in action to the cannon with blank charge. How much the explosion pipe is lighter than the reservoir, withstanding its pressure, is evident from the following. Table 24 shows that when the reserve of the explosive substances is 4 tons, their consumption per second comprises 0.5 kilogram. The same quantity of them emerges from the pipe in one second. It means that the pipe is a vessel, containing 0.5 kilogram of substances. Besides, during pressure, a large part is diminished as compared with the pressure in the reservoir (where it is maximum and uniform). The reservoir contains 8000 times more substances. Consequently, its weight at least must be the same number of times greater. Here is roughly what economy my rocket offers compared to the one in use at present. The cylindrical form of the pipe is too long. The conical form will as much vigorously cut down this length, as the cone is expanded. But the greater its angle is, the greater is the loss of energy, since the movement of gases gets deflected to the sides. All the same, at an angle of 10° the loss is almost unnoticed. But there is no necessity of such a large angle. A truncated cone is required. Liquid explosive substances are pumped on a small Scale. In the pipe, they are intermixed and exploded, they move towards the open wide base of the cone from where they are exploded outside very much rarefied and cooled and move with a velocity of up to 5 km/sec. In the cylindrical pipe, the useful pressure works only on the circular base of the cylinder, where explosive substances are stuffed in, the conical pipe useful pressure is acting on the entire internal surface of the cone.

Therefore the base of the conical pipe is much than less than in the case of the cylindrical one.

We deduce the formula showing the ratio of the area of the cone:

$$F_{max} : F_{min} = \left(1 + \frac{1}{r} \operatorname{tg}\alpha\right)^2, \qquad (187)$$

where, in order, are placed: the area of the large and small length of the pipe, radius of the smaller base and the tangent of the angle of the hole of the cone.

If the rocket itself weighs one ton, and along with the explosive substances 5 tons, the acceleration 'j' of the rocket is 10, then the pressure of gases on the pipe must constitute 5 tons. When the pressure of gases is maximum at 100 atmospheres and when the pipe is cylindrical, the area of its, base will be 50 cm^2 diameter 8cm, while the radius will be 4 cm. Taking a great length of pipe at 10 meters and substituting in the formula (187) different angles, we shall deduce table 25 for the magnitude of the expansion of the pipe.

Hence it is evident that even at 1°, the angle of the hole of the cone is sufficient and in no case will it be more than 3-5°. The loss of energy at the same time will be very slight. Notwithstanding the conical form of the pipe, the better utilization of the force of explosion requires a greater length of the pipe, in order that the gases convert almost their entire disorderly movement (heat) into translatory motion.

Table 25

Angle in degrees	1	2	3	4	5	6	8	10
$F_{max} : F_{min}$	28.8	95.1	199	342	524	740	1296	2000
Ratio of diameters	5.37	9.75	14.1	18.5	22.9	27.2	36.0	44.7
Diameter of the hole, M.	0.22	0.39	0.56	0.74	0.92	1.08	1.44	1.8

With a view to increasing the length of the tube it can be made into bends.

The Engine for Pumping.

In view of its feebleness the engine for pumping may be of the air plane type, only in the rarefied layers of the atmosphere and in the vacuum, it would have to consume the stored oxygen. The exit of the products of combustion in it must be directed into the common explosion pipe or into a special one parallel to the main pipe. It is not permissible to ignore the scanty utilization of energy of the not products of combustion in motors. The entire reserve of the explosive substances could be utilized in ordinary engines (petrol, gas) for obtaining enormous mechanical energy. How great is can be, is evident from table 24. The minimum consumption of the explosive substances, according to the table is ½ kilogram per second. This quantity will contain energy (table 1) 1.37×10^6 kilogram meters. If out of it 30% is utilized, then we shall get mechanical energy at 411000 km M/sec. This corresponds to the continuous work more than 4000 kg. Metric forces. Having extracted such mechanical work, we make use of the products of combustion as reactive material in the explosion pipe. It would be especially useful in the rarefied air or in the vacuum. But we have absolutely no necessity of such an enormous mechanical energy. For pumping the explosive substances, very small work is needed (table 24) - from 1 to 100 forces. Besides, this is even impossible since an airplane motor of 4000 metric forces weighs not less than 4 tons. Its weight will absorb the entire lifting force of the rocket. I want to tell you that the mechanical work, which we may obtain almost without loss, is one thousand times more, than what is needed by us.

We face some difficulty when the temperature of explosion is very high - in the intake of the pipe. It rises up to 2000 - 3000°C. The farther it is from the intake of the pipe the lower is the temperature of the flowing and expanding gases. Just at the time of exit from the pipe it may be below zero and even in the ideal case falls down - 273°.

The pupe must be made from strong, refractory and good heat conducting material. Then the hot portion of the pipe will impart its heat to the neighboring cold parts. But this is not sufficient. Uninterrupted cooling of the hot parts of the pipe is necessary at the time of explosion. They may be surrounded by liquid oxygen, which in all cases is required for respiration, combustion in motors and cooling the room of the crew in the rocket. Therefore the gas formed due to the heating by pipe must be directed mainly into the pressing - in motor. For all that, some initial portion of the pipe will be damaged at the time of explosion, howsoever short-timed the explosion may be. Therefore the hot portion of the pipe must be made thicker than is normally necessary, so as to counter the pressure of the gases. It is weakened to the extent of recession of gases from the intake of the pipe, rarefaction and cooling. Similarly regarding the thickness of the walls of the pipe the nearer they are to the exit hole the less thin they are. The weight of the tube is very insignificant even when maximum, and uniform pressure exists in its entire length. Then taking the pressure at 100 atmospheres, four-fold margin of strength better material, length of the pipe being 10 meters, and its diameter being 8 cm when the form is cyclindrical, we easily calculate the weight of the pipe, equal to 32.5 kilograms. But you know this number is obtained, assuming the entire pipe is equally strong, at its beginning (intake), where pressure is many times more than at its other portions. In a word, this weight in extremely large.

The weight of the pressing-in motor will be from 5 to 100 kilograms (table 24).

Controlling parts of the Rocket

The controlling parts differ from others in their ability to function not only in the air, but also in the vacuum. These are three special rudders which are all located in the neighborhood of the widened outlet of the explosion pipe. Since the rocket during landing on the Earth has to be glided without explosion, like an airplane, so these rudders cannot be inside the pipe. The rocket must have : 1) horizontal rudder of altitude, 2) rudder for guidance and lastly, 3) rudder for lateral stability. About the first two nothing is to describe since they are identical with the rudders of airplanes. But they function in the vacuum owing to the quick flow of emerging gases from the hole of the explosion pipe. Inclination of the rudder exerts on it pressure of the flow (products of combustion) and the corresponding inclination of the projectile. These rudders could have very area in view of the large velocity of the gaseous flow; but the rocket must glide in the air, as an airplane, and therefore the surface of rudders will have be to large, as in case of an airplane. We can say the same about the rudders of the lateral stability. Set on the sides of the body of the projectile, they will work only in the atmosphere. Therefore, besides usual ailerons of the airplane, another organ of stability is needed functioning in the vacuum. This is a small plate, before the outlet of the pipe, which rotates powerfully around the axis, and parallel to the axis of the pipe or rocket. On turning of the plate the stream flying out of the pipe itself rotates, its vortex like motion is created which sets the projectile to rotate around its long axis in one or the other direction.

If this rudder is on the outside, exit pipe, then it will function in the air, like airplane ailerons, independent of explosion, but it is too weak and therefore, besides that common ailerons will have to be resorted to. Folds of the explosion pipe, if there are any, similarly must be directed towards the controlling parts.

The rocket must have quartzitic transparent windows, so that it is possible to view all around. The windows must not tear apart on account of heating up and jolts. Inside they must be covered by another transparant layer, protecting from the destructive action of pure solar rays, not rendered harmless by the Earth's atmosphere. A compass can hardly serve as a guidance towards determining the direction. For this the rays of the sun are most suitable, and if there are no windows or they are closed, - then quick-rotating small discs should be provided. In the course of the short time of explosion and stay in the atmosphere they can serve well.

Plan of Conquest of Interplanetary Spaces.

General Plan

We can achieve the conquest of the Solar system by a very practicable method : In the beginning we should solve a very simple problem, viz. that of establishment of an ethereal settlement in the neighborhood of the Earth in the capacity of its satellite, at a distance of 1-2 thousand kilometers, beyond the atmosphere. Moreover, the relative reserve of explosive substances should be fully available, since it does not exceed 4-10 times the weight of the rocket. If we have to make use of the preliminary velocity, acquired on the very surface of the Earth, then this reserve is rendered totally insignificant (about this, later on).

Having settled there stably and gregariously, obtained a dependable and safe base, and adapted ourselves well with the life in the ether (in the material vacuum), we should change our velocity, by an easier method, recede from the Earth and the Sun and in general should wander, whereever we like. The fact is, that in the condition of a satellite of the Earth or the Sun we can use the smallest forces for accelerating deacelerating and total change of our velocity, and consequently, of our cosmic state. All around there is an abundance of energy in the form of never-extinguishing, uninterrupted and virgin irradiation of the Sun. The negative and especially the positive (atoms of he-lium) electrons, borrowed from the solar radiation may serve as points of support or supporting material. This

This energy is unthinkably great and can be entrapped easily in an enormous quantity by means of stretched wires remote from the rocket or by some other hitherto unknown means. The pressure of light may be made use of, having directed it by reflectors according to necessity. In fact, one kilogram of the substance with a surface of 1 M^2 in the course of a year acquires from the Solar light an increase of velocity, more than 200 M/sec. Owing to the absence of gravity (apparent, of course, or relative). Here it is precisely possible to arrnage huge but light mirrors, providing the possibility of acquiring very large additional velocities and in this way making a voyage in the entire Solar system "free of charge".

Thus we can reach up to osteriods, and small planets, the landing on which presents no difficulty, gravity on them being very small. Having reached these tiny celestial bodies (from 400 to 10 kilometers and less in diameter), we shall obtain abundantly the supporting and building material for cosmic voyages and the control of the ethereal settlements. From here the way opens for us not only to all the planets of our system but also towards other suns.

We have already mentioned the fact that "<u>Landing On the Earth Without the expenditure of matter and Energy</u>" is possible.

The establishment of the first settlement, in the neighborhood of the Earth stands in need of the Earth's help. It cannot stand on its own feet independently soon afterwards. Therefore permanent liaison with the planet (the Earth) is necessary. Machines, materials, different equipment, food products and persons will have to be obtained from it (the Earth). Frequent exchange of workers will be unavoidable in view of the unusualness of the place.

For a return to the Earth, there is no need to run for counter-explosion and, in this way spend the reserves of material and energy. If the atmosphere is near then we should approach it by a weak return explosion. At last, we shall brush against its edge, then immediately we shall lose velocity due to resistance of the air and shall descend along a spiral towards the Earth. In this way the velocity will increase in the beginning because of the fall to the Earth, but later, on entry into the denser part of the atmosphere, it will begin to diminish. When it becomes insufficient, so that only by the centrifugal force will it be possible to counterbalance the force of gravity, then, having inclined the longitudinal axis of the projectile, we begin to glide. It is possible still to increase the velocity, by increasing the inclination of the rocket downwards and raising it with the help of descent. In a word, we deal with the rocket, as with an airplane on which a motor is installed. As here, so there, it is necessary to confirm the moment of the loss of the major part of velocity to the moment of contact with dry land or water. To lose the enormous velocity of the rocket at altitudes is completely safe in view of the extraordinarily amazing rarefaction of air there. It is permissible even to lose almost the entire velocity, by taking turns repeatedly around the Earth and to retain only 200-300 M/sec (considering the density of the surrounding medium) and then to deal, as with an airplane. But nevertheless, if on the rocket there are no additional devices, then landing is carried out at a far larger speed than in the case of an airplane, and therefore it is more risky. It is to be performed well, not on dry land, but on water.

From the above-mentioned facts we see that the celestial ship must have several features of an airplane.

In view of the fact that it is most advantageous to have a small velocity 'j' of the rocket, no special precautions for protecting man from enhanced gravity are required since this increase is very small and a normal person endures it even if it is upright. Besides, it continues for several minutes, at most 2-3 hours. The products of respiration must be absorbed by alkalis and other substances about which chemists know well. Similarly all the hard and liquid excretions of human beings must be rendered harmless. About the provision of oxygen and food in the ether, much has been written by me. This is a matter of undoubted feasibility.

Conditions of Life in the Ether.

It is not possible: to live in a rocket for long the reserves of food and oxygen for respiration, must soon exhaust, the products of respiration and digestion pollute the air. Separate accommodation is required, safe well-lit, with the desired temperature, renewable oxygen, continuous flow of food, and conveniences for life and work.

These lodgings and all the accessories for them must be procured by rockets from the Earth in compound form, to be fixed and assembled in the ether, on the availability at the site. The lodgings must be proof against vapors, and light.

Its materials are nickl steel, simple and quartzitic glass. The abode consists of many departments, insulated one from the other and communicating only by closely shutting doors. If some compartment develops holes and bursts or is rendered non-proof against, gas then it would be permissible to protect oneself immediately in the other, while the damaged one will be set right. The smallest leakage will create a decrease of pressure and the indication of the sensitive manometer. Then only measures could be taken for the elimination of permeability. In this way the safety of life in the vacuum may be achieved 100%.

About one-third of the surface of the lodging is opened for rays of Solar light. They permeate in all the compartments owing to the transparency of the partitions.

The entire surface of the lodging is covered with a double layer of thin movable shutters in the form of tiles or strong plates. If the part of the structure unlit by the Sun is covered with brilliant shutters, while the transparent part is open for the Solar rays, then the maximum temperature is obtained, touching 150°C. If on the contrary, the opaque part is covered with the pushing black layer, and the transparent - by the brilliant surface, like silver then the lowest temperature obtained, is 250° cold (below Zero) away from the Earth. In the neighborhood of the planet, the temperature cannot fall more than by 100-150 below zero, since the Earth gets heated up. Adding to or subtracting from one or the other quantitative ratio the brilliant plate with the black one we shall obtain any degree of heat: for grown-ups, children, plants, bath, laundries, for disinfection, industrial purposes etc.

Here is an approximate arrangement of heat appliance giving different temperature, although not the possible extreme limits of heat. The non-transparent part of the lodging is black on the outside. At a small distance from it is the second brilliant part with both the sides of plates. Its parts may rotate and become normal to the surface, as the spikes of a hedgehog. It is only then that the lowest temperature is obtained. When this armor (casing) covers the black surface the highest degree of heat is obtained. Such a plate may also be on the transparent part of the lodging. Then it is possible to obtain a still lower temperature. Depending on the designation of the ethereal chambers, their arrangement may be very different. Thus, for example, the brilliant plate may approach one or the other in several layers and open more or less the black surface of the lodging, providing the desired degree of temperature.

In the first instance there would be the simplest of homes, suitable for people, as well as for plants. They should be filled with oxygen of density at one-fifth of the atmosphere, with some quantities of carbon dioxide gas, nitrogen and water vapor. At the same time there is some alluvial and wet soil. It being lit by the Sun and shown, may provide with rich feeding substances, plants with edible roots and others. People with their respiration will pollute the air and eat fruits, while the plants will clean the air and produce fruits. Man will return in full measure that, which he has snatched from plants, in the form of manure for soil and air. Moreover, it is possible to avoid the work of different types of bacteria.

Completely the same cycle can be established between animals and plants as it is on the Earth's globe which similarly is isolated from other celestial bodies, as our rocket - lodging.

Food provides 3000 large calories to a person within 24 hours. Similar quantity of heat is provided by 0.5 kilogram of coal or flour, 3 kilogram of patatoes or 2 kilogram of meat. A square meter of surface, lit by the normal rays of Sun, in the vacuum, at the Earth's distance (from luminaries - heavenly bodies) obtains in 24 hours 43000 calories, which corresponds to 10 kilograms of flour, or 43 kilograms of potatoes (similarly bannas) or 30 kilograms of meat.

It means that theoretically,awindow of 1 m^2 lit by the rays of the Sun normal to it provides to man 14 times more energy, than needed for life in severe climate. Some plants use up to 10% of solar energy (such is the cactus of Berbanok), others up to 50% (bannas and edible root plants). In this way, for the existence of a human being i.e. for obtaining the necessary oxygen and food for him, 1 m^2

of the Sun's rays are sufficient on the condition of utilization of the energy of the Sun at 1/14, or 7%. It follows that for the daily requirements of one healthy, strong man, a lodging with a window of 1 M^2 and suitable plants are sufficient. But still more plants are possible to be grown by choice and by artificial fertilization. It is possible that by the passage of time they would provide in ideal ethereal conditions, not 5 or 10% but 50% or more. But the contemporary plants on certain choice can already satisfy us.

Perhaps it would be very good for plants in our lodgings. Thus, the very temperature for them is favorable, the quantity of carbon dioxide gas may be accompanied up to 1% without harm to human beings, i.e. it would be 30 times more than on the Earth. Humidity may be of any degree manure is full and suitable, light of the desired intensity and the composition of rays (for which glasses of different colors and properties may serve), complete annihilation of all types of pests, useless grasses and extraneous growths by means of preliminary purification of the soil and the rise of temperature all these will be available.

However, the requirements of different plants and a human being are far from coinciding between them. For each being a special and most suitable medium is needed. Thus, this will happen in the ether with time; for one type of plants a particular environment will be needed with peculiar soil, atmosphere, humidity, light and temperature, and for many others they will be different and for human beings still more different. And for different breeds, growth and temperaments the environment will be uniform.

In the beginning it is permissible to be provided with cohabitation (symbiosis) of plants with human beings.

Gravity will be felt neither by plants nor by people. And for them or others this may be very advantageous. The trunk and boughs which frequently break due to abundance of fruits and constitute useless ballast of trees, will not be needed by tress, and even by undergrowth and grasses. Gravity hinders the raising of juices. Small gravity, all the same, may be useful to plants for holding soil and water together. But it is easy to obtain it by a weak rotation of the lodging or greenhouse (conservatory). For plants, as well as for people it will be little noticed; the trunks will not bend, and people will be freely performing flights as before in all directions, moving by interia, where necessary. The magnitude of artificial gravity will depend on the angular velocity and the radius of rotation. It may be approximately 1000 times less than the Earth's, although nothing hinders us to make it 1000 times more than that of the Earth. For the rotation of the greenhouse (conservatory) or the house, no expenditure of forces is necessary at all. Objects continues to rotate automatically by themselves, by inertia, if once they are set in motion. The motion is eternal, as rotation or revolution of the planet.

The desired temperature will enable to do without dress and footwear. The abundance of heat will restrict the requirement of food.

Disinfection will annihilate all the infectious diseases and all damages, and enemies of plants and human beings. The absence of gravity will free people from beds, easy chairs, tables, crews and forces for movement. In fact, a jolt will be enough in order to move eternally by inertia.

Labor of any kind is convenient to perform here, than on the Earth. Firstly, because the structures may be indefinitely great with the weakest material-gravity all the same will not destroy them, because it is not there. Secondly, a human being here is in a position to work in all conditions, having fastened only legs or other part of the body as there are neither perpendicular, nor horizontal lines here. There is no up, and no down. To fall down anywhere is out of the question. No objects, howsoever, massive can crush any worker, since they do not fall anywhere, even without any support. All the constituent parts of the body, as if they were not large, do not press one another. All the things are shuffled up on the least pull, independent of their mass and dimensions, only isochronous expenditure is needed, proportional to the mass of the object and the square of its velocity; thereafter the bodies already move without a stop. Stoppage may return the spent work on the initial motion. In this transport literally does not cost anything.

But is should not be forgotton, that the phenomenon of inertia is left over here to that very degree, as on the Earth: strokes are similarly vigorous, as on the planet, in a medium of gravity. Forging is effective (successful). Having fallen between two differently moving hard masses, we can be crushed by their considerable magnitudes or large velocity. Similarly effective are every kind of presses, levers, crushers, hammers and all other machines, if their working is not based or does not depend on the force of gravity.

There does not exist any struggle with weather: sleet, cold, fog, downpour, dampness, wind, cyclone, darkness, heat etc. There is no struggle with animals and plants. For work outside the artificial medium, i.e. outside the lodging, it is forbidden to be naked. In the ether, and in the vacuum, workers and those who are strolling must clothe themselves particularly, with the protective clothing, in the manner of divers dresses (diving helmet). They provide oxygen and absorb products of human excretion, like closed lodgings. This is the simplified method of congested lodgings, and they are directly adjoining the body. The difference lies only in the fact that here oxygen is not provided by plants, but is stored in advance and is liberated little by little, as in the perfect diver's costumes. Special glasses give protection from the fatal effect of the Solar rays. These dresses are gas proofed possess sufficient sponginess and strength, so as to endure the pressure of gases, and not to hamper the movement of limbs. The organic excretions are absorbed and humidity inside the dress is regulated. The coloration of the dress must correspond to the desired temperature. In one dress it is cold, while in the other it is hot. It is possible to be baked in one clothing and get frozen in another. The outer surface of the diving helmet may be armored and removable, as in the lodging. Then temperature may be changed as desired.

Inside the lodgings jobs are done as on the Earth, only much more conveniently. Since they are not connected with gravity and its direction, does not hamper dress shoes cold heat and the usual Earthly filth of dress.

All the equipment diving helmets, tools, greenhouse or lodgings all must be made and tested in advance on the Earth. The entire job in the ether, in the first instance, is restricted only to the assemblage of ready components. The first colonies must be founded at the cost of our own planet, the more so because in the neighborhood of the Earth probably, there are no materials (it is possible only to grab the constituent parts of the rarefied atmosphere, but this is not sufficient). It is good, if the colonies are not there at first, because they would stand in need of oxygen and food. But the advent of technology is possible even here. Still less colonies will be needing help when settling is undertaken in the girdles of asteroids, between the Mars and the Jupiter, where there cannot be any need of damp material. Here the settlements will get not only a multiple of small planets, giving substances as much as required and unhampered by their gravity, here we shall not only achieve a reliable position, but also awfully expansive space with Solar energy, the total quantity of which is two thousand million times more than that which our planet receives at present. In the belt (girdle) of asteroids it is possible to take the temperature by a simple method (described long ago in my manuscripts and in the patented MARKUZ) up to 20°C and more. It can be taken to the temperature of the Sun by complicated methods and mirrors, and by means of electricity still higher. But nothing hinders us to settle close to the Sun, where its force is tens and hundreds of times more than on the Earth. The temperature is under our control. The masses of substance are found between the orbits of the lower planets.

We have stated that there is little struggle with nature. But to fight with the pressure of gases, the killing rays of the Sun, and the imperfect nature of human beings and planets is necessary. To fight for comfort, knowledge, adaptation of people etc. is unavoidable.

Development of Industry in the Ether in the broadest Sense.

The first terrestrial animals were born in water, which eliminates gravity, i.e. the destructive force, specially harmful to the first tender organisms. The annihilating gravity by counter-action of a liquid does not hihder inorganic development of the sizes of aquatic organisms (plants, as well asanimals). In this way the aquatic organisms must acquire considerable volume, and it also means, such a voluminous brain. They would thus become the masters of the planet. Why did it not come to pass and why were the land - lubbers selected?. The main reason is found in the impossibility to retain high temperature in a liquid. The aquatic animals coming out of the sea so as to metamorphose themselves into terrestrial ones in course of time obtained mastery over the Earth's globe, although in the beginning they were very weak. But there was no construction on the dry land and therefore they started fighting amongst themselves, and could attain high development. One of the reasons of their predominance is the fact that, they could obtain fire and create industry. The other reason of backwardness of the aquatic animals is the absorption of the Solar energy by water.

They could not make use of this energy to such a degree as the terrestrial animals. They did not have a solid support, since the bottom of the majority of oceons was inaccessibly deep completely dark. The third handicap is due to the inaccessibility of oxygen in water and the impossibility to support the most favorable temperature for vital processes in the very body of the animal - by virtue of the scantiness of oxygen and the cooling effect of the dense medium and its specific heat . Free movement in it is similarly made difficult by the massiveness of water. There was no material for industry, if we do not consider the coastal and shallow water spaces, enclosed by an area, semi-dark and covered by semi-liquid lumps.

The emergence in the air and the struggle with the gravity could start in case of aquatic animals after the development of muscles. This struggle was difficult and triumph was naturally delayed. Similarly victory will be delayed in the migration of living beings from the air to the ether. For migration to the dry land muscles were needed, while for migration from air to the vacuum the development of industry, particularly motorized is required. On the Earth, in a medium of gravity, industry makes headway vather slowly, although the air is better than water for it. Still more convenient for the development of culture is the ethereal space, particularly free from the restrictive and limiting force of gravity. The isolated populations (settlements) on the planets, or the tiny asteroids most satisfy such a condition. Here there is an abundance of material and unnoticed gravity and virgin Solar light, and immense and available space, and Solar energy, exceeding the terrestrial by 2 milliard (US Billion) times and freedom of movement in all the six directions, even up to other solar systems.

Here it is permissible to get fire hearths of dimensions, with temperature from 273° cold (below Zero) to 6000° by the direct force of the Sun with the help of mirrors and glasses. The conversion of Solar energy into mechanical and later on into electrical may be obtained up to 20 thousand degrees and more.

The aquatic medium takes away most of the heat from the heated bodies, but the air hampers intense heating or cooling of bodies. It similarly oxidizes the surface of the objects being processed, burning it or obstructing their preservation and melting (welding) into one whole. In the vacuum this handicap for industry does not exist.

In the same way gravity horribly hinders construction and development of technology, working of machines, movement and social intercourse.

It is therefore understood, why in the girdles (rings) of small planets, where gravity is easily overcome by the slightest movement in the ether, in the realm of uninterrupted light and six-sided spaciousness industry and evolution of rational beings, not restricted by the size of brain, must attain unheard of successes.

The only difficulty is the absnece of air and the pressure created by it on the body, which became a necessity for living beings . Later on, the living beings will get adapted to this,but in the beginning, concern will have to be made with the artificial atmosphere for plants and human beings. The vacuum and the virgin Solar light kill. Well insulated multi-chambered lodgings, diving helmets and artificial selection of living beings serve as remedies. Oxygen, (protection) water and other necessary substances are found almost in all the stones. It is only necessary to extract them. The aims of industry in the ether in general, the very same as on the Earth, only much vaster notwith standing the fact that neither dress, nor furniture nor many things more would be needed by human beings.

Plan of Works, beginning in the Nearest Future.

Now we shall discuss the question as to how it is possbile to start the work of conquering the cosmos immediately, at this very moment. Generally, we go from the known towards the unknown, from sewing needle towards the sewing machine, from knife towards the mancing machines, from thrashing chains towards the thrasher, from open carriage (barouche) towards the automobile, from boat towards the ship. Thus we think of switching from the air plane over to the reactive device-for the conquest of the solar system. We have already mentioned, that the rocket, flying in the beginning unavoidably, in the air, must have some characteristics of an airplane. But we have already proved that in this there are unserviceable wheels, air-screws, motor, permeability of the premises by gases and burdensome wings. All this hinders it to acquire a velocity, more than 200 M/sec, or 720 km / hr. The airplane will not be serviceable for the purposes of air transport, but gradually will become fit for cosmic voyages. Perhaps at this very moment, the airplane flying at an altitude of 12 kilometers does not cover 70-80% of the entire atmosphere and does not approach the sphere of the pure ether, surrounding the Earth. Let us help it to achieve more. Here are rough stages of development and transformation of the airplane for the achievement of high aims.

1. A rocket airplane with wings and the usual parts of steering is arranged. But the petrol engine is changed by an explosion pipe, where the explosive substances

are pumped in by a weak engine. There is no air-screw. There is the reserve of explosive materials and space is left for the pilot covered with something transparent for protection from the coming wind, since the velocity of such a machine is more than that of an airplane . The device, due to the reactive action of explosion will roll down on the slides on the lubricated rails (in view) of small velocity wheels may be left behind). After that it is lifted on the air, attains the maximum of velocity, loses all the reserve of explosive substances and having become lighter begins to glide similarly to the usual or motorless airplane, so as to land on dry land safely.

The quantity of the explosive substances for the force of explosion should be increased bit by bit, as also the maximum velocity, remoteness, and mainly the altitude of flight. In view of the permeability for air the human seat in the airplane in height, of course, cannot be more than the known record height: 5 km is sufficient. The aim of these experiments is the skill to steer the airplane (at a considerable velocity), by explosion pipe and gliding.

2. The wings of the latest airplanes should be reduced a little, the force of the engine and its velocity should be increased. We shall have to resort to acquiring preliminary pre-explosion velocity with the help of the means mentioned earlier.

3. The body of future airplanes will have to be made of gas proof and filled with oxygen, and with devices, absorbing carbon dioxide gas, ammonia and other products of human excretion. The aim is to achieve the desired rarefaction of air. The altitude may exceed much more than 12 kilometers. By reason of high speed, for purposes of safety landing, may be made on water. Proofing of the body will not allow the rocket to sink.

4. The rudders mentioned by me and functioning excellently in the vacuum and in very rarefied air, where the rocket flies are used. A wingless airplane dupllex or triplex, inflated by oxygen, hermetically sealed, well-gliding is set in motion. For ascent into the air it requires huge initial velocity and, consequently, improvement in fitting for the take-off run. The additional velocity will provide it the possibility to ascend higher and higher. The centrifugal force will make its effect manifest and will decrease the work of motion.

5. The velocity reaches 8 km/sec, the centrifugal force fully neutralizes gravity and the rocket in the beginning goes beyond the limits of the atmosphere. Having flown the distance for which oxygen and food suffice, it returns towards the Earth its path been in the form of a spiral, retarded by air and gliding without explosion.

6. After that it is permissible to employ a simple, undoubled body. Flights beyond the atmosphere are repeated. The reactive devices recede farther and farther from the air jacket of the Earth and remain in the ether longer and longer. All the same they return, since they have a limited supply of food and oxygen.

7. Attempts are made to get rid of carbon dioxide gas and other human excretions with the help of selected well - grown plants, providing at the same time edible substances. Many people are already working on this project though slowly, yet some success is being achieved.

8. Ethereal diving helmets (dresses) are arranged for safe emergence from the rocket into the ether.

9. For getting oxygen and food and cleaning of the rocket air, special space for plants is devised. All this is carried off into the ether by the rockets in complicated form and there it is spread and joined together. Human beings achieved a large measure of independence from the Earth, since they will strive for the means of livelihood independently.

10. Extensive settlements are established around the Earth.

11. Solar energy will be made use of not only

for nourishment and comforts of life, but also for travel in the whole Solar system.

12. Colonies will be founded in the girdle of asteroids and other places of the Solar system where there are only small celestial bodies.

13. Industry will develop and colonies will multiply unimiginably.

14. Individual (personality of individual human being) and social (socialistic) perfection will be achieved.

15. The population of the Solar system will become one hundred thousand million times more than the contemporary Earth's population. Limit will be achieved after which new settling in the entire Milky Way will become unavoidable.

16. Extinction of the Sun will begin. The remaining population of the Solar system will recede from it to other suns, towards the earlier flown-off brethren.

Issued as a separate brochure in Kaluga in the Year 1926.

Cosmic Rocket.

Experimental Preparation

(1927).

Description of the Arrangement of the experiment*

In the beginning it is necessary to carry out experiments at one place, i.e. without conspicuous shifting of devices. It is assumed in addition to this, to work out a suitable design, as well as the control of explosion, course of the device, its stability etc.

Fig. 1 illustrates for the first time the imaginary arrangement of the apparatus. The drawing is schematic (variable scale), i.e. without the observance of the proportionality of components. Subsequently I shall try to give approximately the accurate dimensions.

We begin the description from right to left.

1. On the right is the petrol engine for pumping out and pumping in of the liquid air, oxygen or its endogenous combinations. Silencer should be removed, and the products of

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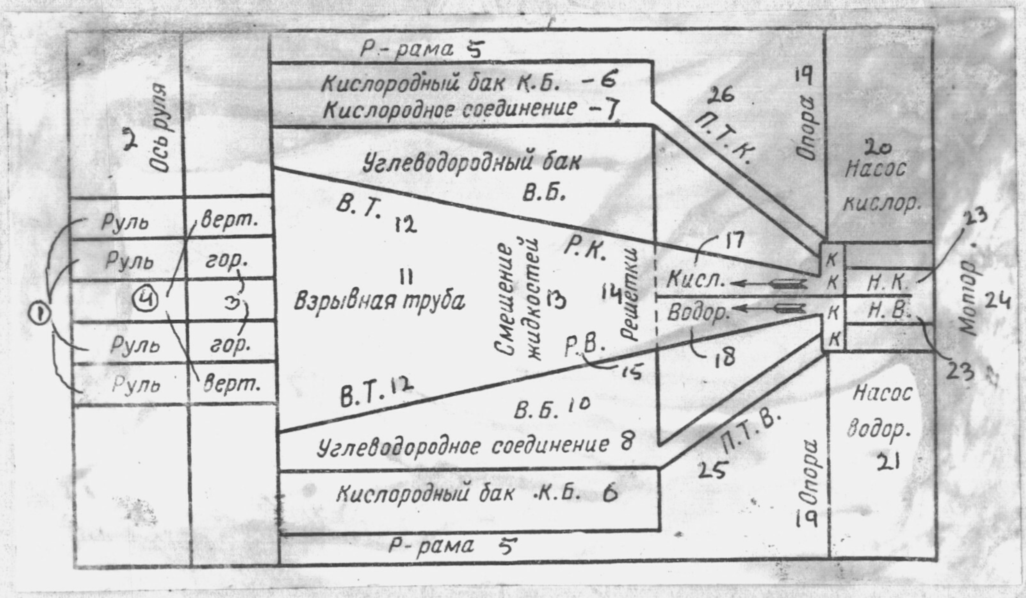
* To understand and to evaluate this article is only possible after having assimilated my "Investigations of the year 1926". (Editor).

combustion should be thrown back in the direction, opposite to the supposed motion. It will however, increase a little the reactive function of the rocket. However, it is not important for the experiments.

2. N.K. and N.V. are two pumps, set into motion by one motor. The first pumps the oxygen compound into the explosion pipe, while the second - hydrogen compounds. Their volume must correspond to the complete compounds of explosive substances, The volume of the oxygen cylinder is, in general, larger than that for hydrogen.

The final adjustment may be concluded by a change of the stroke of one of the pistons. The adjustment has special importance; if there is more oxygen, than needed, then the explosion pipe may catch fire, if less, then the fuel will be lost in vain.

Let us find out the ratio of volumes of cylinders in the case of consumption of benzene (C_6H_6) and liquid oxygen (O_2). On combustion, water (H_2O) and carbon dixide gas (CO_2) are obtained. For C_6, for obtaining CO_2 , O_{12} is needed or 192 parts by weight of oxygen, while for H_6, O_3 or 48 parts, in all 240 parts of oxygen. Benzene has 78 parts. Consequently, more than 3.1 times of oxygen by weight is needed. When densities are approximately the same, the volume of oxygen will be three times more than benzene. If we are to take



F I G U R E: 1

Keys: 1) Rudder, 2) Rudder Axle, 3) Horizontal,
4) Vertical, 5) R-Frame, 6) Oxygen Tank (O.T),
7) Oxygen compounds, 8) Hydrocarbon compounds,
9) Hydrocarbon Tank, 10) V.B, 11) Explosion Pipe,
12) V.T, 13) Mixing of liquids, 14) Lattices
15) R.V, 16) R.K, 17) Oxygen, 18) Hydrogen,
19) Support, 20) Oxygen Pump (O.P),
21) Hydrogen Pump (H.P), 22) N.K. (O.P),
23) N.V. (H.P), 24) Motor, 25) P.T.V, 26) P.T.K.

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the compounds, which hold more of hydrogen, for example, liquefied ethylene (C_2H_4) or turpentine ($C_{10}H_{16}$), then the ratio will be more, but it will change less. For example, for oleinic gas (C_2H_4) it will be 3.4. For turpentine (turpentine oil) it is close to 3.2 (assuming similar densities). But on the use of liquid air, in which there is much nitrogen, volumetric quantity of oxygen may increase 5 times and the ratio of volumes of cylinders reaches up to 15. But part of nitrogen is usually taken away (and therefore this ratio is much less and may reach up to 4-5. The endogenous compounds of oxygen (for example, nitrogen pentoxide N_2O_5), similarly increase this ratio, but very little. Thus, the latter compound brings the ratio of oxygen compound to the hydrogen (benzene) compound up to 4.2.

If we are to push in by any method carbon powder, that is, pure carbon (C = 12), then the quantity of oxygen O_2 will be only $2\frac{3}{4}$ times more than coal. If the latter is compact like a diamond, then oxygen by volume is required rather less than carbon.

3. KK-KK are the pump-valves. In one pump, there are two oxygen valves, and on the other there are two for hydrogen (i.e. allowing hydrogen compound). The valves are located at some distance from the site of explosion PK, PB and, therefore, cannot be damaged by heating. Besides, the oxygen mixture is very cold, while the hydrogen compound has been intensely cooled down by it, and that is why the

Diagram: K.E. Tsiolkovskiy in his room at the shelf with books, 1927.

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heat of the explosion does not approach the detrimental degree up to the pumps and valves. The valves, leading into the explosion pipe, are shut with a clap by the terrible force at the moment of explosion. Only then, when the pressure decreases in the pipe and the products of explosion partly fly away and partly thin out, the valves may open and the pistons move, so as to give the pipe new portion of the explosive substances (rather they should be named elements of explosion, since all alone they do not explode, as, for example, the powder or nitroglycerine and, therefore, are completely safe). From here it is evident, that the number of turns of the engine per second (or the piston stroke), cannot be higher than the measure, determined by the experiment. From here arises the necessity of alternate feeding by pumps). If, for example, we have to reduce the number of turns 5 times so that the engine works economically, then the transmission must achieve it. But the same may be achieved the same number of times, after having reduced the volume of each pump 5 times, or the piston stroke. The first is more advantageous. Then the alternating transmission or the alternating piston stroke may become necessary only in the future for changing the force of explosion.

4. P.T.K. and P.T.V. are pipes for oxygen and hydrogen. They run from tanks and end at the pumps. They are not subjected to the pressure of explosion, as the tanks

and, therefore, may be made from thin material.

5. R.K. and R.V. are lattices with slanting holes for the better mixing of hydrocarbons and oxygen mixture. The intake of the explosion pipe has been partitioned in halves. In one half, oxygen mixture is directed and in the other a hydrocarbon. Here they are cold and cannot be mixed up. Mixing and explosion take place behind the lattices, where the majority of heterogeneous streams come into collision and mixing takes place. The incandescent pipe at this place (still earlier) stimulates them towards chemical combination or explosion. (For the first experiments one must have electrical or other fuse (primer), becoming incandescent on the start of the experiments, when the partition has not become incandescent). The object of the partitions is to protect the valves from the excessive heat, somewhat cool the explosion pipe and to reduce (make unifrom) the force of explosion and its pressure on the bottom of the pipep

If the holes in the lattice are very fine and they are many, then the explosion will be too quick, the explosion jerk will be horrible and the pipe may suffer. The number and measurement of holes should be determined by experiment, having started from large holes, reducing them to the minimum possible degree and simultaneously increasing their number. Their direction or mutual inclination is also changed till better result are acquired.

6. V.T. (E.P.) is the explosion pipe of a conical shape. This dilating form at the outlet shortens the length of the pipe. Experience must determine the most suitable degree of its or the angle deviation of the cone. A very large angle will too much shorten the length, but, scattering the explosive substances on the sides, will consume them less.

The explosion pipe must be made from strong (even at high temperature) refractory and non-combustible material, it will be advantageous if it is also a good conductor of heat. It is available for making the pipe of two jackets (layers); the first internal very strong and refractory, the second, less refractory, but also strong and good conductor of heat. Owing to it heat from the awful heating of the tube close to the lattices will be quickly taken away by the outer tube and both the sides, and it will be useful to both the sides of the pipe due to this, on the right the cold, still unblended liquids will be heated up, while on the left the expanding and cooling streams of gases . The heating will increase their velocity, which is required. Besides, the pipe cools still more liquids. Naphtha (hydrogen compound) cools the pipe and is itself cooled by the mixture of liquid oxygen.

The results of the experiment compel us to change the explosive substances and the arrangement of the pipe many-fold.

7. V.B. and K.B. is the internal hydrogen or petroleum tank, surrounding the hot portion of the explosion pipe and the external with the liquid oxygen, surrounding the oxygen tank and cooling, it. The tanks must not be compared with the explosion pipe, since it is subjected to explosion jerks and therefore will tear the tanks in case of congested union of their walls with the pipe. Hermetical union which is possible in case the walls of the tank are corrugated.

8. The Vertical Rudder and the Horizontal Rudder, They are Located opposite the outlet hole of the explosion pipe. Since the future device will fly sometimes in the air, sometimes in the vacuum and lands on the Earth by gliding (soon after the entire material is spent or soon after the intention to cut short the explosions), the rudders must function equally well in the air, as well as in the vacuum, exactly as during the immobility of the attached apparatus at the time of the initial experiments. Before the experiments the device must be suspended on the rope cable, fastened with the lower end to its center of gravity, so as to have neutral equilibrium. It cannot lean highly since the nearby ground (soil or raised platform) hinders it. During the initial experiments in a room (or outside) only the average reactive force or output, exciting almost confluent nearly explosions, is measured. This is the pull of the device

11. Turning of rocket by explosion when the rudder is inclined. The rotation .....

Drawing by K.E. Tsiolkovskiy from the manuscript "Album of Cosmic Voyages".

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or its tendency onwards. Of course, during these experiments the device is fastened such, that it cannot whirl and only tightens the rear rope cable with dynamometer. Afterwards practice is made on rudders. The rotation of the device is made free and, manoeuvring by rudders, it is tried to give it a specific direction and make it tend to maintain it. In the beginning practice is done with one vertical rudder. Although the projectile is inclined a little, but its direction in a horizontal plane can be changed when desired. Later the horizontal rudder is started to work, which comprises two planes (like swallow tail of some birds) and double piston rod for manual control (steering). By this method we endeavor to direct the longitudinal axis of the axis independent of the ground. We give the projectile, for example, exactly horizontal position. The lateral stability is achieved by the mutual incline of parts of the horizontal rudder, which is achieved by the divergence of the lever of double piston -rod. Here there is nothing new: everything is similar to that of an airplane. These very rudders (they may jut out beyond the limits of the pipe) serve in the vacuum on explosion, as well as on the tendential motion of the projectile in air by inertia, when it returns to the Earth by gliding.

9.10. Frame P and Support is the cross-beam on the frame. The explosion pipe in its narrow intake must be particularly massive. Here it has the prominent part, which touches the cross-beam of the frame. The support takes on it frequent series of forceful jolts, flowing together into one forceful pressure which must support the cross-beam and the frame. Therefore, the number of free vibrations of the cross-beam must not be the multiple of the rotations of the motor or the number of explosions. On the contrary, even a very strong support swings and will break.

Explosion cannot be fully uniform and in view of the massiveness of the entire system and the large number of explosions in a second (up to 25) some average pressure will be obtained, which will be determined by the dynamometer. It is advantageous for us, that the incoming force of explosion (or the pull) attendant on the unit mass of the explosive substances spent in a second is maximum. By means of many experiments we may strive for efficiency, strength and the lightness of the entire device. Strength is achieved by the durability of the material and its other qualities by its form (or the installation), good cooling, expanse of the explosion part of the pipe (the explosion cavity close to the lattices) and the diminishing of the portion of explosive substances and their forces. The explosion cavity is necessary to be cut down a bit, and also the one-feed portion of the explosive substances is to be increased a little.

Sizes of the Pumps and Nozzle, Quantity of the Fuel, Exhaust Velocity etc.

Assuming one ton for the entire projectile, for the reserves of explosive materials and the weight of the steerman, practical results, are that we shall get the possibility of the flight on the consumption of 0.3 kilogram of explosive substances*) in a second.

The work of pumping will be less than metric force. From here it is evident, that the fuel which is consumed for the motor is several hundred times less than on the explosion pipe, and therefore the reactive action of the engine (ejection of the gases backwards) is almost unnoticed in comparison with the pipe.

We shall not do the calculations by 0.3 kilogram but by 1 kilogram. We shall know in this case the volume of two pump cylinders (together), assuming the density of the exploding substances to be equal to unity, which is not very far from the truth.

If the motor makes 25 rps, then each revolution must give 40 cm^3. It means that both the pumps together have a volume of a cube with edge 3.4 cm. These pumps evidently, are tiny. But it is reasonable to start with a smaller quantity of explosive substances, for example with 0.1 kilogram.

The volume of this quantity will be equal to a cube with edge 1.6 cm (16 mm). It is clear that we can ignore the weight of the pumps altogether, the more so. as they are not subjected to vigorous pressure.

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* See the article "Investigation of outer spaces by reactive devices " 1926 (Editors).

Experience will show, whether a small force drives into explosion pipe as much or more material. Calculation in my booklet has been done for 100 atmospheres of uninterrupted pressure, meanwhile, as in the case of quick blending and small explosion cavity it may reach up to 3000-5000 atmospheres. But when a similar pressure develops, then the valves shut it off, the pump does not work and the piston only compresses the liquid or the springed connecting rod red adjoining the piston is compressed a little under the influence of the movement of the crank . However, this is so short a moment that on the pump there is almost no effect. At this moment gases explode, pressure in the pipe and on the valves weakens and the pump works normally.

It is difficult to determine theoretically the most advantageous diameter of the intake of the explosion pipe, but it cannot be less than the approximate dimension of the pumps, i.e. the diameter of the pipe will not be less than 2-5 cm. It means, the area is from 4 to 16 cm^2. The maximum pressure on the bottom, assuming 3000 atmospheres, will not exceed 12-48 T. But this is only for a short "mig" (stroke). The average pressure of 1 ton is sufficient for us.

And at this very pressure flights are possible. When the pipe is conical, the component longitudinal pressure is increased owing to the slope of the pipe walls. It means, the average pressure on the bottom may be less than 1 ton.

But the intense pressure (for a short moment), or the jolts are disadvantageous, since they compel the making of the explosion pipe and valves more massive, which increases the gravity of the rocket. Therefore the mixing must not be thorough. It is necessary to begin the experiments with lattices not so fine, to avoid an instantaneous explosion and awful strokes, although in view of the presence of the external atmospheric pressure, quick explosions and more pressure are advantageous. In order to decrease the destructive strokes for the pipe, it is permissible to make it in the beginning more spacious and stronger, than according to calculation.

The motor, pumping the fuel and oxygen, will work almost in vain, while the massiveness of the pipe will be required only for short jolts. But for the start it is permissible to ignore the economy of weight. Later on it is necessary to strive for lengthening the moments of pressure, so that it occupies at least half of the entire time or as much, as are the moments of weak or zero pressure. For this we have to increase the number of movements of pumps or increase their volume. The former is more advantageous, since it gives more uniform pressure. Then the utilization of massiveness of the pipe will be more, since the average reactive pressure will increase, proportionally. The work of the motor will increase not vigorously, since the pumping must coincide with the minimum pressure in the pipe, which is present after explosion. Only the movement of the pistons will be more discontinuous, and the springiness of the connecting rod or crank must increase.

The toughness of the pipe is made use of here because its working is strengthened or more average reactive pressure is obtained on that very weight of the pipe. But it is possible to decrease the mass of the pipe, not strengthening its reactive function, and increasing the number of strokes of the pumps and decreasing at the same time their volume.

But let us return to the initial experiments and to the initial modest numbers. The speed of the flow in pumps when the area of cross section is from 2 to 8 cm^2, will be from 50 to 125 cm/sec (Volume of pumps being from 4 to 40 cm^3). The number of revolutions of the motor is 25 in a second.

On exit from the pipe the gases cannot have a pressure less than one atmosphere. If we keep the rarefaction at 1300, then the absolute temperature of the emerging gases from the explosion pipe will be 625°F, or 352°C*.

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* See the article "Investigation of Outer Spaces by Reactive Devices" 1926.

It means, that the flying out gases in the atmosphere will still be very hot and the utilization of heat (reconversion of it into motion) will in no way be more than 95%, but in fact, it is much less, because the temperature of the emerging gases will be, probably much higher. Their velocity* will not exceed 3-4 km/sec, Maximum velocity should be acquired, which is possible only on specific dimensions of the pipe. The broad base of the pipe is safer, but such a tube cannot give maximum velocities.

In rare layers of the air or in the vacuum rarefaction may be very high and will depend on the size and form of the pipe. The temperature of the leaving products of combustion will be very low, the utilization of the temperature is the largest and the velocity is maximum. But we have to start flights in the atmosphere, and therefore, we can only recalculate for the advantages of the empty space later, when we shall achieve success in the air. In the vacuum, for example, the largest pressure of gases in the pipe may be very small, and we shall lose nothing from it. From this it is evidemt, that with the passage of time, having been lifted into the rarefied layers of atmosphere, with the help of the massive pipe, we can discard it from us and continue the

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* Ibid (Editors).

flight with the help of a lighter pipe, with small pressure. But a small pressure (compression) should cause the pipe to be remodelled: On coming out from the atmosphere, we have to make it wider and longer without change of the total weight, because the walls at the same time become thin. Such a change, on the way, is not possible, and therefore, the pipe which is adapted to air pressure, will remain without change even in the vacuum. If would be useful to lengthen it, i.e. to carry out a fitting on the end of the pipe, which perhaps will be done in the rarefied layers of air and outside the atmosphere. This is possible.

There is still a method of high utilization of energy of explosion: viz. to decrease the expenditure of explosive substance per second in the vacuum. But this is possible only in a limited measure, keeping in view the initial force of explosion in the atmosphere. It may be so little, that even to decrease it would produce nothing. All the same, to the extent of increase of the rocket velocity, the force of explosion in the vacuum may be decreased to zero.

The pressure of gases (on 1 cm^2) with the escape from the intake of the pipe quickly falls owing to their rarefaction and the resultant cooling. The diffusion of densities and temperatures in the pipe, is similar to their diffusion in the perpendicular column of the atmosphere, although there is no complete identity. In fact, although thegases for the first time (i.e. at some stretch from the intake of the pipe) expand, but their temperature does not fall and is equal to the temperature of the dissociation of products of combustion. This is due to the fact, that since the beginning only a part of the elements combines chemically, the other is in the condition of decomposition, because the high temperature (3000 - 4000°C) hampers full chemical combination. When the combination of all elements has taken place the gases expand and cool, as in the column of the atmosphere.

Hence it is evident that only the beginning of the explosion pipe is subjected to intense pressure. We shall recalculate the weight of the pipe and the thickness of its walls only in one meter of length and for the permanent pressure at 3000 atmospheres, although the average pressure, in particular on initial experiments, will be much less.

If thediamter of the tube is several times more than the thickness of its walls, then it may be accepted (when there is ordinary good material) that the weight of the vessel is 6 times more than the weight of the compressed air in the vessel (or of gas, of the density and elasticity of air). But here this law will not be acceptable to us, since the thickness of the wall comprises a considerable part of the diameter of the pipe. But then on our calculation for sufficient transverse strength, the transverse strength is superfluous (i.e. much more than required).

We shall derive the formulae:

$$\delta = R - r. \tag{1}$$

Here are given the thickness of the walls of the pipe and its radii-external and internal.

Further,

$$q = 2^{o} (R - r) \frac{K_z}{S} . \tag{2}$$

Here there are shown: resistance of the material of the pipe in a stretch of unit length, coefficient of resistance of the metal and the desired margin of strength. The pressure of gases for that very stretch will be

$$q_1 = 10^3 p 2r, \tag{3}$$

Where 'p' is pressure in atmospheres. Equating this pressure to the resistance, from (1), (2) and (3) we shall get

$$\frac{R - r}{r} = \frac{\delta}{r} = 10^3 p \frac{S}{K_z} . \tag{4}$$

Let us suppose here $p = 3000$; $S = 6$;, $Kz = 60$ km/MM^2 $= 6.10^6$ g / cm^2. Now we shall find $\delta \div r = 3$. It means that the thickness of the walls will be three times more than the internal radius of the pipe or one and a half time more than its internal diameter . But there are materials two times stronger, and the margin of strength in view of th lower pressure in the pipe may similarly decrease twice. Then the thickness of the walls will comprise only 3/4 of the radius, or 3/8 of the diameter.

Weight of the pipe will be

$$G = \pi (R^2 - r^2) \gamma 100. \tag{5}$$

This is for a stretch of 100 cm; here γ is the density of the material. We have taken 2R from 2 to 4 cm.

From (5) and (4) we shall find

$$G = \pi p \gamma r^2 \left(10^3 p \frac{S}{K_z} + 2\right) 10^5 \frac{S}{K_z}. \tag{6}$$

We took the internal diameter of the pipe from 2 to 4 cm, or the radius from 1 to 2 cm. It means that formula (6) will give, on ordinary material and larger margin of strength for weight of the pipe, values from 37.7 to 150.7 kilograms. While for very strong material and on small margin of strength — from 5.2 to 20.7 kilograms. But it is possible to do without formula (6). In fact, γ - is from 1 to 2 cm ; δ - from 3 to 6 cm; R is from 4 to 8 cm. It means, the weight of the pipe according to formula (5) will be 2512. $(R^2-\gamma^2)$ or from 37.7 to 150.7 kg. Similarly it is possible to obtain the weight of the pipe, when the thickness comprises 3/8 of the internal radius.

What comes out of it? This largest weight of the pipe does not exceed 151 kg- and this is when the expenditure of explosive substances in a second is one kilogram. This is more than sufficient for the "ultra atmospheric" flight when the weight of the rocket is full i.e. one ton. All the remaining weights are much less. The weight of the motor along with pumps and pipes - is not more than 10 kilograms. For the frame, tanks, rudders, pilot and others, let us suppose 140 kilograms; the total will be about 300 kilograms. The weight of the explosive substances will remain only 700 kilograms i.e. twice more.

For initial experiments and even for flights the in stratosphere and the vacuum, this may be sufficient; 700 kilograms of hydrogen and oxygen compounds will be sufficient for explosion in the course of from 700 to 7000 seconds, or from 11.7 minutes to 1 hour 57 minutes.

And the pipe and the entire projectile during experiments on the Earth may be still lighter: up to 100 kilograms.

Oxygen: Endogenous Compound or Mixture

Liquid oxygen may be used, in the first instance. The admixture of nitrogen will weaken the explosion and will lower down the maximum temperature. With time the quantity of nitrogen has to be decreased little by little. The temperature due to this increases a little in view of the phenomenon of dissociation. The cold liquid appearing in the section of the explosion pipe, is highly beneficial for its cooling. Liquid air is very cheap and will in probably future, be still cheaper.

Its density is close to unity, the heat of evaporation is slight (65), the temperature is - 194°C, thermal capacity is small. Heating up and evaporating air, we lose a little energy, the more so, as it is obtained from overheated portions of the pipe, the cooling of which is totally unavoidable.

More advantageous than liquid air would be nitrogen anhydride N_2O_5, but for its high price, chemical action, instability and toxicity. In this oxygen is twice more, than nitrogen. Moreover, this is an endogenous combination because it releases heat on decomposition. It should be heated up, since on ordinary temperature it is steady. Will not the well-known physicists recommend to us more suitable endogenous compounds of oxygen ? Bit by bit the liquid air may be changed by oxygen from the air, which is in all respects better than N_2O_5. Its temperature in an open vessel is 182°C. Liquid oxygen from air is almost pure.

Hydrogen Compounds

We shall not use liquid hydrogen, in general, particularly in the first instance. Reasons: High price,low temperature, heat of evaporation and difficulty of preservation. It is practicable to employ hydrocarbons with the largest possibly relative quantity of hydrogen. The energy of their combustion is almost similar, to separate hydrogen and carbon. The products of combustion are vapors and gaseous. Only the impurity of carbon raises the temperature of combustion owing to its great difficulty of dissociation.

But hydrocarbons with the largest percentage of the content of hydrogen are gaseous, as for example, methane CH_4, or marsh gas. It is converted into liquid with difficulty and in the first instance, we shall not use it, although hydrogen is only 3 times (by weight) less in it than carbon. Benzene C_6H_6 suits better, although carbon is 12 times more in it, than hydrogen. Still petroleum is easily available with possibly more content of hydrogen. It is even cheaper than liquid air, petroleum (naphtha) is a mixture of hydrocarbons. In saturated hydrocarbon $Cn\ H_{2n\ +\ 2}$, hydrogen comprises not less than 1/6 (by weight) but not more than 1/3. We repeat, that all hydrocarbons in the matter of chemical energy may be considered, approximately, as mixture of hydrogen with carbon. Their density in large part is less than unity. All of them release volatile products and for that reason are suitable for the rocket.

The maximum velocity of the products of combustion or substitution of hydrogen by hydrocarbons decreases a little: approximately from 5 to 4 km / sec*. This in case of oxygen, contains a little nitrogen.

Temperature of Combustion; Cooling of the Rocket Funnel and Temperature of gases in the Funnel.

In the beginning, the lower the temperature the better it would be, since it is easier to find out materials for the explosion pipe. The admixture of nitrogen with oxygen is useful for this reason. The low temperature of the liquid air and petroleum (naphtha) cooled by it, is also useful,

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* The word "Carbon" has been substituted by the word "hydrogen" and the paragraph (item) has been omitted. (Editor).

although this cooling forces us to lose energy. But hydrogen raises the temperature of combustion of petroleum (naphtha). In this respect pure hydrogen would be suitable, to which perhaps, we would switch over with the passage of time. Perhaps, it would be found suitable to have endogenous compounds. Monatomic hydrogen would be very suitable, if we are to believe the claims that it releases 50,000 calories for 1 g on the formation of diatomic hydrogen H_2, i.e. almost 16 times more, than 1g of detonating gas. Hence it is evident, that practical sources of energy exist which are ten times more energiferous than the most powerful of the known ones (as detonating gas, calcium oxide and others).

In general, if there were artificial and natural cooling of the tubes, its high temperature could attain 3000°C. But the gases after blending, explosion and attainment of high temperature move towards the exit expanding more and more and cooling as a result: the irregular thermal motion owing to the directing action of the pipe is converted into consistent mechanical and flowing. In the vacuum the temperature of issuing gases must attain absolute zero, since there the expansion is not restricted by external pressure. In the atmosphere when the conical pipe is sufficiently long the temperature falls to 300-600°C. The average temperature of the explosion pipe due to this cannot be very high: you know the heat from its incandescent parts quickly makes off towards the cold ones. Besides the pipe keeps cooling down continuously both on the outside and inside. In fact, continuous streams of two very cold liquids: liquid air and petroleum (naphtha) cooled by it penetrate into the partitioned intake portion of the tube. And the external walls of the tube are still cooled by the cold petroleum, which itself is cooled by the liquid air surrounding it (the tube). From here it is evident, that only the central portion of the gaseous column in the explosion pipe may have high temperature, parts of it (products of combustion) adjoining the walls, have a slight temperature, since they are cooled by cold (rather - not very incandescent) pipe.

Materials of the Explosion Pipe.

Cannot the pipe in these conditions melt and burn, or only its part, be subjected to high temperature? The low temperature of the liquids and cold walls at the intake pipe hampers the burning of the metal (that is its combination with oxygen or other substances). The partition there obstructs the chemical process, and it means release of heat. Already behind the partition there take place blending and combustion. Here the temperature attains the maximum. But oxygen is quickly absorbed by hydrogen and carbon, not being able to act intensively on the cooled metal of the pipe it combines with them chemically. When hydrogen is surplus the mixture even possesses the restoring force, i.e. it reduces the metal. Comparatively the low temperature of the walls of the pipe even obstructs their fusion. The use of intermixing of petroleum does not obstruct it.

The safety of the explosion pipe may be viewed technically as the welding of iron by oxy-acetylene flame. Its temperature is higher than the temperature of combustion of our explosive substances, because pure oxygen is taken, and acetylene C_2H_2 holds much carbon. When hydrogen is surplus (i.e. its compound is acetylene) iron not only does not burn, but even its oxide is reduced. It, does not diffuse, if it is to be cooled even though with water from the reverse side, since it cannot attain the fusing temperature. Large masses of metals meet with difficulty, because they are required be intensely heated up beforehand.

All the same, we must endeavor that the material of the pipe is not only strong and has a high melting point, but also possesses good heat conductivity as well as small chemical affinity for oxygen and other elements, entering into the composition of explosive substances.

Many bodies have high fusing temperature. For example, tungsten will melt at 3200°C. But such metals are rare and expensive and their processing in large masses is not possible for the time being, by virtue precisely, of their refractoriness. Forthe time being we shall have to ignore, such materials. We have to begin from the simple iron. Its fusing temperature in the pure form is 1700°C, of steel - less (about 1200 -1300°). And we shall have to use it exactly in view of its strength. For enhancing the strength it is permissible to melt it with tungsten, chromium, nickel, manganese, cobalt etc. Here advice of specialists is needed.

It would be useful to cover the steel pipe with a layer of good heat conducting metal like red copper, aluminum and others (for better cooling of the pipe). But these substances are ordinarily either easily fusible or weak. Therefore such a method is uneconomical in respect of weight. Perhaps metallurgists will indicate to us a suitable material for that purpose. Till that time we shall have to do without these lids and be satisfied with better sorts of steel and its thermal conductivity, which, apparently, is sufficient for initial experiments.

Even if the explosion pipe instead of its high, temperature, is warmed a little, then the harm will not be very large. You know the thickness of its walls is just the largest there.

Work of the entire machine

Let us examine the work of the entire machine, so as to judge better regarding the necessity of the quantities of different materials, and their constituents.

We shall start benzene motor for a trial. We shall observe, that for reducing the massiveness of its fly-wheel it is useful to make the engine multi-cylindrical, for example double-cylindrical double-acting.

We connect the motor with the double pump which will begin to pump out from the tanks extremely cold liquids and push them into the partitioned intake of the pipe. Explosions will start (more exactly a series of blank detonations). Part of the pipe will be split behind the partition, and heat will be distributed along the pipe in both the sides, i.e. to the fenced off part also. Therefore, the liquids, still not having reached the partitions, will be warmed up, and willturn into gases and vapor.

Gaseous substances, more or less dense, will explode through lattices. By this blending becomes easy, so that, the lattices may not be needed. But the intake of the explosion pipe, valves and pumps would have low temperature and, therefore, they can suffer in no way. For them ordinary materials will work.

Each stroke of the pump gives an explosion. The condensed explosion wave, giving powerful jold to the pipe and to the frame connected to it, will spread along the pipe in the form of the gaseous mass expanding and cooling on account of this. At the atmospheric pressure, not a very hot gas - with a temperature from 300-600°C reaches the end of the pipe. In any case, the metallic rudders take it away easily. In the vacuum the temperature is totally low depending on the expansion of the pipe and its length. The frequent explosions (up to 25 in a second) merge into one and give propulsion (thrust series of repercussions)or motion to the device.

The success of experiments on the spot (on the machine consists of the following.

1. The machine must remain intact while the explosion pipe must not reach the point of total destruction after the consumption of all the explosive substances.

2. Massiveness of the machine at the same time must be minimum.

3. The reactive pressure must be the largest according to the quickness of consumption of the products of explosion and their quality.

4. For this, combustion must be as complete as possible.

5. Similarly the temperature of the gases left in the pipe must be minimum.

6. The device must turned according to the desire of the experienced operator and maintain the desired direction.

7. The working of the pump must not be great.

After the experiments at one place and the achievement of success, the projectile may be placed on four wheels and is rolled by reactive action on the airdromes. In the beginning it may be of ordinary dimensions, but to the extent of increase of velocity its sizes must increase. It is possible, that we shall have to make use of lake and hydro-glider, in calm weather, having removed the wheels. In case of four wheels one has to control by one perpendicular rudder for turning, in case of two wheels (side by side) - by the rudders for turning and of the lateral stability, eventually in case of one wheel —— by all the rudders.

After that from the aerodrome or the lake upward flights may be started, not emerging beyond the limits of the troposphere. For facilitating this, we shall have to fit to the airplane wings, while the rudders have to be increased likewise, so that they could serve for gliding during the absence of explosion.

But then, the experimental operations may lead us onto the other path. They will rather direct our activity.

Guarantee of the Safety of Operations.

All experiments should be well-thought carried out and with extreme care. The reserve of the elements of explosion in the beginning must be very small: approximately for ten strokes of the piston i.e. for 10 blank shots. Pumps of minimum dimensions may be taken or the strokes of their pistons curtailed and put into pperation by hands or feet. After each experiment, i.e. after a small number of explosions, the conditions of explosion pipe, valves, frame and the entire apparatus should be examined. We have only to make more frequent the number of explosions and increase their force,.

For the start one may make use of short cylindrical explosion pipe with constant thickness of the walls; then similar but longer, and with the thinning of smallo walls towards the exit hole, and then —— concil with abrupt thinning of walls towards the end. When the weight of the pipe is minimum (according to calculation) it necessary to enclose it, for the occasion of explosion, within another pipe.

Cooling in the first instance, may be done by water (as cannon are cooled), the reserves of the explosive materials should be held separately one from the other, though only quick blending of these reserves may produce a dangerous explosion in the premises. They lie with us in different vessels and by themselves are completely harmless. The vessel with liquid air must have a hole upwards for unhindered evaporation. In order that it escapes less we have to enclose the vessels from penetration of external heat. In the vacuum it is easy: in the air, vessels like "Dewers" are needed. But then, the explosions are so short in the cosmic rocket, that these precautions are redundant, since the losses are insignificant in case of ordinary tanks.

Making the number of explosions and the portion of each charge more frequent eventually, we shall have to have recourse to the motor (engine) and the type of projectile, more or less close to our diagram,

Virtually, we have concern with the frequent series of not very powerful blank shots. Therefore, if the explosion pipe is sufficiently strong or protected, then we shall risk it with nothing, carrying out our experiments. But the experiments must be led by us. In our theoretical indications nothing must be considered as absolutely dependable by us.

(For the first timeprinted in a separate brochure in Kaluga in 1927).

Treatise on Cosmic Rocket.
1903 - 1927.
(1928).

The value of my works consists mainly in the calculations conclusions from them. In technical relationship almost noting has been done by me. Here a long series of experiments, installations and learning is needed. This is the practical way and gives us technical solution of the problem. The long way of experimental difficulty is unavoidable. For the time being there is knowledge, based on multifarious formulae and calculations.

The very name, "rocket" readily shows the basis of the cosmic ship. The force of continuous explosion of a rocket is much weaker than the cannon fire. It (the force) is generated behind the pressure on the device and imparts it acceleration. The latter creates the additional apparent gravity. As acceleration, the additional gravity may be small. Its magnitude is close to that of the Earth. Since the flight is almost horizontal, the additional gravity increases normally not more than 1½ times (in case of supporting motion in air).

A large acceleration of the rocket is advantageous with regard to theeconomy of explosive substances. But, on the other hand, this is not advantageous, since the pressure on the device and the human beings increases. The enhanced gravity demands great strength of the projectile or its large mass is dangerous for the living being. The latter needs its security, which also increase the total weight of the projectile; besides, large acceleration increases the weight of the rocket during motion in the air and heating up of the rocket due to friction.

If the acceleration is more than 20 meters a second, the security of the human being is achieved by immerging him in the liquid, the density of which is equal to the average density of the human being. The quantity of the liquid does not play any role and may be very small, if the protecting vessel is of the form of a human being. But the vessel itself must be sufficiently strong. In a liquid, human the being loses weight, as if he were not large. Therefore, in a liquid medium, the living being may endure enormous acceleration. Only non-uniformity of the density of different tissue of his body (bones, blood) restricts the safety value of the acceleration of the rocket and the gravity induced by it.

In a word, if the acceleration is to be most advantageous it must be close to that of Earth i.e. approximately 10 M/sec^2. In case of such a small acceleration the inclined path of the rocket must be closer to the horizontal one.

The advantages of less inclined motion are enormous in comparison with its disadvantages. The latter depends on the increase of the path in the atmosphere and the increase of the expenditure of energy due to this. But since the resistance of the atmosphere in general is not great in relation to the pressure on the rocket and the total sum of the needful energy, so we choose the less inclined path as the most advantageous. Its advantage is as follows: it is possible to employ small acceleration or less force of explosion, it is possible to get rid of the protecting vessel for a human being; the consumption of energy for overcoming the resistance of the air decreases when the velocity is small, the rocket may be lighter due to less additional gravity.

The most economical incline exists. Its value is not more than 10-20°c.

The velocity of the flying out gases from the explosion pipe (nozzle) plays an important role; the lager it is, the more significant is the final velocity of the rocket . Gases are obtained, for example, by the combustion of a mixture of liquid oxygen with petroleum (naphtha) in the pipe. They expand freely, and as a result cool down, and part of the heat is converted into mechanical velocity. But the external pressure of the atmosphere obstructs the unrestricted expansion of gases as well as their cooling. If the action takes place in the vacuum, beyond the atmosphere and if we have an infinite length of the nozzle, then the expanding gases should acquire a temperature of absolute zero, and all the thermal energy should to converted into motion. Then only the velocity of the flying out gases from the pipe, should attain the maximum possible value. Calculations show, that it should attain 4-5 km/sec. The velocity of the artillery cannon balls, and consequently, of the gases on their emergence from the muzzle (month of the cannon) is not more than 1-2 km/sec. This small velocity depends on four reason: the cannon is insufficiently long, the atmosphere obstructs unrestricted expansion of gases, the explosive substances being used. release less energy and eventually, part of it is absorbed by the motion of heavy cannon-ball.

Of course, explosion in the rocket is not advantageous to be carried out without a pipe, since, in that case the reactive pressure of the gases on the rocket will be directed to different sides, and its motion is not acquired or will be very weak. The pipe directs the flow of gases in one direction, and only on exit from the mouth the gases expand in all directions and therefore are useless for the rocket. It is clear, that the pipe must have enormous length.

However, a long cylindrical pipe may be substituted by a very short conical one (nozzle), with the angle of expansion not more than 30°. This shortens the length of the pipe many times during the excellent utilization of heat.

For a greater part of the time of explosion the rocket rushes into the rarefied air or the vacuum. The exploding materials are blended in the tube and may be chosen with the maximum heat of combustion. At last, the rocket does not require a cannon-ball.it only throws out gases. That is why the rocket throws them out in the vacuum with a velocity of 4-5 kilometers per second. The motion of the rocket may be started from the high mountains, which will shorten its path in still another packed layer of the atmosphere; till the beginning of the explosion, the rocket may be given considerable initial velocity by an external force on those very mountains.

Let us prove that the rocket may acquire any velocity.

Let us imagine, for the simplicity of conclusions, that the gravity is absent. We shall denote the mass of the rocket without explosive substances by unity, the explosive mass will be likewise. Equal masses, repelling one another, acquire approximately equal velocities. It means, that it will impart to the rocket a velocity, close to 5 km/sec.

If the rocket takes with it three parts of the explosive substances, the velocity will be doubled. In fact, throwing out in the beginning two parts of the explosive substances, we give a velocity of 5 km/sec to the remaining two.

Later on, discarding the one part still remaining with us, we shall obtain an increase of velocity at 5 km/sec, while totally the rocket will obtain a velocity of 10 km/sec. If we take successively such reserves : 2-1 = 1 ; 4-1:3, 8-1=7; 16-1=15; 32-1=31, then we shall obtain the following velocities of the rocket: 5, 10, 15, 20 and 25 km/sec etc; evidently the magnitude of velocity is not limited. The second velocity is almost sufficient for recession from the Earth and migration onto its annual orbit, the third is almost sufficient for proximity to any planet and even wandering amidst the suns of the Milky Way, — of course, if the rocket is launched in the direction of the annual motion of the Earth.

The question is asked whether reserves of fuel along with a human being and all his requirements that of the entire structure seven times or more times be taken on the rocket.

The method of the common rocket-explosion is not suitable. In fact, here the reactive action of explosion i.e. the pressure is transmitted to the entire reservoir, containing all the reserves of the explosion. Due to this, the vessel itself will have mass, several times larger than the mass of the explosive substances, otherwise the reservoir is rendered insufficiently strong and will burst. In this way, in an ordinary rocket, the explosive mass comprises not more than 10-20% of the mass of the ocket, whilst it must itself be many times more than the mass of the rocket.

The relative quantity of the explosive substances may be enormous, if the substances are squeezed into the explosion chamber to the extent of need. i.e. a little, for example, 100-200-1000 g/sec. The elements of explosion, insulated from one another cannot explode by themselves. It means that the reservoirs holding them will be a little than the petrol or kerosene tanks.

In these conditions and during the insignificant acceleration of the rocket the mass of the elements of explosion may be ten times more than the outfitted rocket.

The mass of the explosion pipe and chamber at its intake is not large in view of the insignificant quantity of explosive substances per second. The narrow intake of the pipe is sufficiently cooled by petroleum (naphtha), while the last-by oxygen.

The rocket enters rarefied layers of the air, and then the airless space. When its path is inclined towards the horizon at an angle of 12° and the acceleration 10 M/sec^{2} which we get in approximately, in 200 seconds the rocket will enter the layers of air three times less dense, than below (while the consumed energy of explosion comprises approximately 20% completely). In 300 seconds the rocket almost gets rid of the resistance of the atmssphere because here the air is rarefied about 14 times. The rocket comes out from the atmosphere and acquires a velocity sufficient, to put itself on the orbit of the Earth and become an independant planet, planet, a satellite of the Sun. Explosion in the course of 19 minutes may be shortened. The rocket will hurry in the vacuum, losing velocity due to the pull of the Earth or other celestial bodies. But they cannot stop it.

After the stoppage of the explosion the rocket and all its contents appear to have lost gravity. Such is felt by the man in the rocket. The Earth, as before, attracts the rocket and all the objects contained in it, which is manifest in the continuous retardation of their motion. But this gravity acts similarly on the rocket as well as on the person in it. Therefore their relative position does not change. They move with the same velocity and do not come closer to one another similar to dirt, being dragged away by one flow of water. Relative fall is absent, it means that there is no gravity.

The enhanced gravity in the first 19 minutes of explosion cannot harm the organism in accordance with its trifling nature, or owing to the protective media of the bath. But cannot the absence of gravity inflict harm? The action of gravity is expressed in the enhanced pressure of the blood column and overburdening of the internal organs. Evidently, the absence of this overburdening and pressure are similarly soft, as lying or bathing. Here there is also the gravity as if it were destroyed. At last, even if standing upside down does not kill the organism so, it means that even the absence, of gravity two cannot do this. The flow of blood to the brains without doubt, is increased and the non-availability of gravity may as well harmfully tell upon the human being, as the lying in bed. However, one can lie for years and survive. The body gets adapted to everything. Ridding ourselves from gravity can only tire us, as lying long. But then, the rotation of the rocket and the centrifugal force, arising from it, may restore to us gravity of any magnitude.

Now we come to respiration. The space inside the rocket must be tightly closed while on the contrary gas through the slight think view quickly volatalizes i.e. goes out of the rocket and gets didseminated in the celestial space. Besides a continuous current of oxygen is needed, since human beings make use of it for respiration converting it into carbonic acid gas. But have the store of liquid oxygen. Many of the substances also are capable of isolating it by combustion and in other ways. Carbonic acid gas and human excretions are similarly capable of being absorbed by alkalies and may be made harmless by different substances. But the best of all is to purify our small atmosphere by plants, as it is done on the Earth. Incidentally we shall obtain food, in the farm of fruits from the plants.

With the passage of time humanity, will settle in the space close to the Sun. But this will not happen immediately, but by dint of hard work and as a result of sacrifices. The full Solar energy is 2 milliard (US Billion) times more than its share being received by the Earth. People will be benefited by this wealth, although the way to it will not be so easy. But humanity has already started on this road. Now experiments are being conducted with reactive automobiles (experiments of the firm of OPEL near FRANKFURT-ON-MAINE). They will teach us about advantageous explosion and steering by one rudder. Only this is all. For automobile business, reactive devices are inapplicable because they will give uneconomic results. After that we shall expect the following steps of the reactive business.

1. Reactive automobile with two wheels (on one axle) and the skill to steer with two steering wheels.

2. Reactive automobile on one wheel and the skill to control additionally lateral stability.

3. Such an automobile with wings, having the capacity to take-off and then to land by gliding. The automobile will be converted into a reactive airplane. But it should be remembered, that for the substitution of an ordinary airplane it is uneconomical.

4. Such a very airplane with a cabin, not releasing oxygen, and with cannon-balls providing the possibility to a human being to breathe in the insulated cabin.

5. Take-offs to altitude more than 12 Km, and even beyond the limits of the atmosphere with the next gliding

and landing on the Earth without employing explosion.

6. Continued stay outside the atmosphere, in circular orbit (state of a little Moon) and safe return by gliding without the expenditure of explosive substances .

7. Adaptation of plants in the rocket for purifying the air and obtaining food,

8. Advent of technical development outside the atmosphere.

9. Utilization of the Solar energy and the pressure of light for travel in the ethereal space. Exact calculations show that one kilogram of ~~mass~~ of a mirror when its surface is 10 M^2 at the Earth's distance receives by the action of light in the course of a year an addition of velocity of 2 km/sec. But where there is no gravity, there the mirror will help still more when the mass is the same. In this way, interstellar travels are fully guaranteed, if only the pressure of light exists.

10. Settlements in the regions of the ether between the orbits of the Earth and the Mars or by other orbits, more suitable.

11. Mighty development of technology in the ether; extraordinary multiplication and (advancement) of the population.

12. Gradual utilization and occupation of small

bodies of the planetary system, beginning from the most tiny asteroids and satellites.

13. Recession towards other suns on weakening and extinction of ours.

How many thousand years will absorb this path is difficult to foresee.

For the first time printed in the collection of "Stratospherical Committee" TSS. Osoavia khima" USSR (Reactive Section) "Reactive Motion" No. 2 of the year 1936.

COSMIC ROCKET TRAINS (1929)

From the Author.

I am already 72 years of age. I have not been working with my hands for long and do not perform any experiments.

Since the time of the publication my first work in 1903, work been going on in the West practically on the reactive devices.

In the beginning application was sought in the military field (Unge in Sweden and Krupp in Germany).

Later, at the time of the publication of my other works in 1911-1912, theoretical and experimental work in general was done (Birkebound, Goddard). Then Esno Pelteric expressed his views.

But noticing the serious attitude of the West many people in our country have since 1913 been interested in the problems of flight beyond the atmosphere,.

Since the time of publication, in the very widespread journal ("Priroda i Lyudi", 1918) ("Nature and people"), of my work "Beyond the Earth" (Separate publication in 1920) Obert became interested in astronautics. His works gave German scientists and thinkers an appreciable fillip, owing to which many new works and persons made their appearance. Two of them were very zealously (Specially Lademann) translated and propagated my works.

Then came into existance rocket automobiles, planning boats, sledges and even airplane (under the control of Shtamer). All this was very imperfect, but much tumult was raised and it was beneficial with regard to experiments, as well as to the spread of interest amongst the community of scientists and builders.

These ideas started to be spread vigorously in the USSR. The following stepped forward: Vetchinkin (lectures), Tsander and Rinin. The last named by dint of his brilliant works wide-spread information in literature, particularly contributed to the spread of the ideas of astronautics.

K.E. Tsiolkovskiy

COSMIC ROCKET TRAINS.

(From the biography of K.E.Tsiolkovskiy
— S. V. Bezsonov).

Kaluga, Brout Street 81, addressed to
K. E. Tsiolkovskiy.

KALUGA,

Exployees of the section of Scientific Workers,
1929.

Not only abroad, but here too, institutes are now being established and societies formed, the members of which are talented and are spreading the new ideas.

My compliments to the workers of astronautics in the USSR as well as abroad. They will have to work not for one decade. For the time being this work is thankless, risky and immeasurably difficult. It will require not only an extraordinary strain of forces and ingenious talent, but also many sacrifices.

A majority of people regard astronautics as they regard a heretical idea and do not want to listen to anything. Others are as skeptical, towards thing, and view it as absolutely impossible, the third - are too trustful, towards the subject, as well as toward easy and quick accomplishement. But the initial unavoidable failures discourage and repulse the weak and undermine the trust of society.

Astronautics is not to be compared with flying in the air. The latter is a toy in comparison with the former.

Undoubtedly there have been successes, but the question regarding the time of its accomplishement for me is completely closed.

Any idea about the simplicity of its solution is a temporary delusion, of course, it is useful, since it imparts courage and strength.

If they knew the difficulties of the job, then many, now working with enthusiasm, would flinch with horror.

But later how beautiful will be the achievement: The conquest of the Solar system will give not only energy and life, which will be 2 milliard (US Billion) times as abundant as terrestrial energy and life but the spaciousness will still be abundant. Man on the Earth commands mastery so to say, only in two dimensions, the third is limited, i.e. spreading upwards and downwards for the time being is impossible. Then man will obtain three dimensions.

The absence of gravity, the virgin rays of the Sun and any temperature, obtained in structures only by the force of Solar rays, and no worth while movement in all directions, and the knowledge of the universe .. We cannot here appraise all the good and advantages of the conquest of the solar system. I have given some idea in my above-mentioned works, "Beyond the Earth"

What is a Rocket Train.

1. By rocket train I mean combination of several identical reactive devices, moving first along a roadway, later in the air, and then in the vacuum beyond the atmosphere, at last somewhere between the planets or the suns.

2. But only a part of this train reaches the celestial space, the remaining portions, not having sufficient velocity, will return to the Earth.

3. In order to attain cosmic velocity it is, necessary to provide large reserve of fuel to the individual rocket. Thus, for attaining the initial cosmic velocity i.e. 8 km/sec, the weight of the fuel must be at least 4 times more than the weight of the rocket along with all its remaining contents. This makes difficult the arrangement of the reactive devices.

The train provides the possibility either of attaining large cosmic velocities or will be restricted by comparatively small reserve of constituent parts of the explosion.

4. We shall first solve the problem in the most elementary form. We assume the design of all rockets to be absolutely identical, and likewise the reserves of fuel and the force of explosion. In practice, of course, there must be some deviations. Thus, the rockets, moving along a roadway, will be simpler, those moving only in the atmosphere, need not be equipped with accessories for protracted stay of persons in the ethereal space.

Arrangement and Working of the Train

5. The explosion starts from the first rocket so that the entire train is subjected not to compression, but to the pull,

which it is easier to combat. Besides it promotes the stability of the train at the time of the explosion. A_t the same time it is possible to compose a longer train, and consequently, acquire larger velocity with that same reserve of fuel in each rocket bogie.

6. The shorter the bogies, the larger can be their number with the same margin of strength; and the larger their number, then larger is the final velocity of the last rear bogie. This forces ussto strive to make separate projectiles possibly shorter. But the diameter of the rocket device cannot be less than 1 meter. It means that the length of the rocket bogie cannot be less than 1 meter. It also means that the length of the rocket bogie cannot be less than 10 meters. When the oblong form is small the resistance of the air is too much marked. For rockets, returning to the Earth, this may be sufficient but for the cosmic bogie, not less than 3 meters in diameter and 30 meters in length is needed. From here we conclude: the last cosmic bogie is to be made morer spacious.

7. The design of the cosmic rocket is very complicated and will continue to become more and more complicated. We have no intention at the moment to go into all its details. The aim here is different: to show the advantages of the train relative to ultimate velocity in comparison with the single

rocket device. Possibly a small rocket on reaching the ethereal space will be developed into a larger one. But we shall leave all this and take the dimensions at 3 and 30 meters.

8. The diameter of the rocket is 3 meters and its length 30 meters, the thickness of the walls is 2 mm (thicker towards the ends). The density of their material is 8. The area of cross-section on an average is 7 M^2, the surface 180 M^2, volume 105 M^3 , . The rocket can hold 105 T of water. A one meter section of the jacket (shell) **weighs the same everywhere, since towards the ends, where the** diameter is less it is thicker, namely 0.15 T. We assume the same for people, tanks, pipes, machines and other accessories: a total of 0.3 T per meter of length. Thus, the whole jacket (shell) of the rocket will weigh 4½ tons, and the same for the internal content - total 9 T. Out of this weight one is sufficient for the persons.

9. We shall allot the reserve of the explosive substances for one meter of the section as 0.9T, while for the entire rocket 27 T i.e. 3 times more than the rocket weighs along with all its contents. (corresponding to the velocity for one rocket on the employment of petroleum (naphtha) equal to 5520 M/sec. This reserve in one rocket will occupy (when its density is equal to unity) 27 M^3, i.e. about one fourth share of the entire volume of the rocket.

This will leave 78 M^3 for persons and machines. If we take 10 persons then for each 8 M^3 will be available. Oxygen in such a volume at pressure of 2 atmospheres will be sufficient for respiration of 160 persons in the course of 24, hours, or 10 persons in the course of 16 days, of course, on the elimination of the products of respiration.

We want to show, that even such a large reserve of fuel is not too heavy for the rocket to carry.

10. Explosion creates tension in the train-and that is why the thickness of the walls in narrow places of the rocket is greater: the resistance to breach of each cross-section of the rocket must be the same.

11. The jacket (shell) of the rocket, when the safety factor is 5, will withstand a superpressure of 4 atmospheres. But since it is not more than 2 atmospheres even in the vacuum, so the safety factor will be 10.

12. Since all the rockets may be submitted to gliding even the last one the space rocket, on its return to Earth, so every rocket is equipped with necessary arrangement for this purpose.

A single inflated jacket (shell) having a form of the body according to the requirement, turned on the turning lathe (of a body or revolution) will poorly glide.

It is necessary, for example, to combine, three such surfaces. Inflated by air or oxygen approximately to 2 atmospheres, they will form highly strong beam.

13. We cannot suggest wings owing to their considerable weight.

14. Each rocket must have rudders for direction, height and counteraction to rotation. They must function not only in the air but also in the vacuum.

15. The rudders are located in the rear portion of each rocket. Rudders are two pairs. Immediately behind them now-a-days are the explosion pipes, tilted slightly into the side. Otherwise the exploding gases will exert pressure on the rocket immediately behind.

The number of explosion pipes is not less than four. Their exit ends are located on the circumference of the rocket on equal distances from one another. The explosion takes place by thrusts (jerks), as separate blank shots. These thrusts could harm the rocket. Therefore to make the number of pipes more than four is useful. Shots will be frequent and may be distributed in such a way that the pressure on the rocket on account or explosion will be sufficiently uniform.

Each pair of rudders is located in one plane (parallel to the length of the rocket axis) but their inclination from it may be different. Then the rocket will begin to rotate. From this it is evident that any pair may, in this case serve for eliminating the rotation of rocket. Each pair, besides that, serve for controlling the direction of the rocket in a given plane. In general, desired direction in the space may be obtained in the absence of rotation. The stream of the exploding gases is directed on these rudders. It is understood that they serve not only in the air but also in the vacuum.

16. Small quartzitic windows give some sun-spots inside the rocket, required during steering control. Other large windows are closed on the outside by the shutter. Later on in the rarefied atmosphere or in the vacuum they are opened.

17. The nose portion is occupied by persons. Then follows the machine section (pumps, and motors for them), at last the stern is occupied by explosion pipes surrounded by their tanks full of petroleum (naphtha). The last are surrounded by tanks with freely evaporating liquid and cold oxygen.

18. The work is performed approximately thus. We shall suppose the train, made up of five rocks, slips on the roadway for several hundred kilometers of length, rising to a height of 4-8 kilometers above the sea level*. When the

* The problem regarding the hard roadway worked out in my works "Resistance of air and express train". 1927 (Editors).

forward rocket has almost burnt up its fuel, it disengages itself from the four behind, continuing to move by inertia, the forward one goes away from the rear ones owing to the continuing explosion, though weakened. The operator directs it in the side, and it descends gradually to the Earth, not hampering the motion of the remaining four connected rockets.

When the way is clear, the second rocket (now the forward one) begins its explosion. The same things take place, with this rocket as have taken place with the first: it gets disengaged from the rear three, and in the beginning overtakes them, but later not having sufficient velocity, is forced to return to the planet.

The same happens to all other rockets except the last, which not only goes beyond the limits of atmosphere, but also acquires a cosmic velocity. Owing to this, it either will begin to revolve close to the Earth as its Satellite, or fly away farther towards the planets and even other suns.

Determination of velocity and other characteristics of the Train.

19. For a single rocket we have the formula [See my "Investigation of Outer Spaces by Reactive Devices". 1926, formula (38)] .

$$\frac{c_1}{W} = \ln\left(1 + \frac{M_1'}{M_0}\right),$$

where the ratio of the final velocity of the rocket C_1 to the ejection speed W, depending on the ratio of the total mass of the ejected material M_1' or the fuel to the mass of the rocket with all its contents except the component parts of explosion; ln — is the natural logrithm.

20. This formula may be applied to a complicated (composite) rocket, i.e. to the train made up of reactive devices. C_1 will denote the additional velocity V of each train due to the explosive material in one rocket. The relative ejection speed W, always remains one and the same, as the mass of ejected material M_1' is. But the mass of the rocket M_0 is not the mass of one rocket but of the entire train, excluding the mass of the explosive material M_1', of the foremost rocket, which acts on the entire train with all its still intact fuel.

21. There-fore, we must substitute in formula (19) the mass of the rocket M_0 by the mass of the train M_0 according to the formula

$$M_p = (M_0 + M_1')\,n - M_1',$$

where n denotes the number of rockets. It is evident that this expression relates not only to the full train, comprising the specified number of rockets n but also to any other partial train (after removing of several forward rockets), comprising only their small number n'.

22. Now in place of formula (19) we shall get.

$$\frac{V}{W} = \ln\left[1 + \frac{M_1'}{(M_0 + M_1')\,n - M_1'}\right].$$

23. For the first train, comprising the maximum number n_1 of rocket, we shall get

$$\frac{V_1}{W} = \ln\left[1 + \frac{1}{\left[(M_0 : M_1') + 1\right] n_1 - 1}\right].$$

24. For the second train, in which there is one rocket less, we shall find

$$\frac{V_2}{W} = \ln\left[1 + \frac{1}{\left[(M_0 : M_1') + 1\right](n_1 - 1) - 1}\right].$$

Similarly for the rest. In general, for trains of the order 1_x it will be

$$\frac{V_x}{W} = \ln\left[1 + \frac{1}{\left[(M_0 : M_1') + 1\right](n_1 - x + 1) - 1}\right].$$

26. For example, for the last train $x = n_1$. Having substituted, we shall get formula (19) for a single rocket.

27. The velocity of the first train is expressed by formula (23), the total velocity of the second by the sum of the velocity of the first train and the additional velocity of the second. In general, the totally velocity of the train of the order 'x' is expressed by the sum of additional velocities (25) of the first x trains. The total velocity of the last rear rocket will be equal to the sum of additional velocities of all trains, from the most complicated (composite) to the last, comprising one rocket of the rocket n_1 .

28. From the general formula (25) we see, that the additional velocities of trains are larger, if a smaller number of rockets is left. A complete train has the minimum additional velocity; the maximum is on the last, when $x = n_1$ i.e. when only one rocket is left in it. Additional velocities increase very slowly, and for this reason a very large number of rockets give less advantage, i.e. it increases the total velocity of the last rocket only slightly.

Nevertheless, the increase of the cosmic velocity would be limitless, if there were no restricted strength of material, of which the rocket is made.

29. The calculations may be simplified, if we consider the trains from the end in the reverse order, i.e. the last train from a single rocket is considered the first, the

last but one as the secondand so on. Then the serial number will be y and we shall get.

$$y + x = n_1 + 1.$$

30. Eliminating with the help of this equation 'x' from the equation (25), we shall get,

$$\frac{V}{W} = \ln\left[1 + \frac{1}{\left[(M_0:M_1') + 1\right]y - 1}\right].$$

By this we have proved that on counting the trains from the end, the additional velocity does not depend on the total number of rockets in the train, but only on their reverse order y .

31. Now let us compile a table by which it would be easy to know the total velocity of each partial train and additional total velocity of the last train, comprising one rocket.

Order 'Y' of the train from the end.

1	2	3	4	5	6	7	8	9	10

Order from the beginning x.

10	9	8	7	6	5	4	3	2	1

Relative Additional Velocity, if $M_o : M_1 = \frac{1}{3}$

1.386 0.470 0.262 0.207 0.166 0.131 0.113 0.100 0.09 0.08

Final Relative Velocity of the last train (made up of one rocket) consisting of several rockets at the start of motion

1.386 1.856 2.118 2.325 2.491 2.622 2.735 2.835 2.925 3.005

32. If, for example we have a train of four rockets, then the last ultimate relative velocity will be 2325 M/sec, i.e. it will be as many times greater than the ejection velocity.

The velocities of the partial trains (for four rockets) in the normal order may be known from the second column. They will be by the time, beginning from the most complicate (composite) one :

$$0.207;\ 0.207 + 0.262 = 0.469;\ 0.469 + 0.470 = 0.939;\ 0.939 + 1.386 = 2.325.$$

For trains composed of 10 rockets the total velocity of the last will be 3005M/sec. The velocities of partial trains of this train, in the order will also be found from the second column placing its numbers, beginning from the right.

33. We can determine the true velocities, knowing the velocity V and the ejection velocity i.e. the velocity of the flying out products of combustion from the explosion pipe. We shall get such a table.

Number of rockets in the train.

1	2	3	4	5	6	7	8	9	10
Ultimate velocity of the last train in km/sec. If $M_0 : M_1' = \frac{1}{3}$ and $W = 3$km/sec.									
4.17	5.58	6.36	6.96	7.47	7.86	8.19	8.49	8.76	9.00
ditto, but $W = 4$ km/sec.									
5.56	7.49	8.49	9.28	9.96	10.48	10.92	11.32	11.68	12.00
dittom but $W = 5$ km/sec.									
6.95	9.30	10.60	11.60	12.45	13.10	13.65	14.15	14.60	15.00

Even when petroleum (naphtha) is used and the utilization of the energy of combustion is 50% ($W = 3$ km/sec), when there are 7-8 trains, cosmic velocity is obtained. When the utilization is large, velocity is obtained for three and even two trains. For recession form the Earth and reaching the planets and asteroids, a ten-rocket train may be sufficient.

If in the formula (30) the mass of the rocket M_0 is great in comparision with the mass of ejection M_1', or the partial train contains many rockets, i.e. y is great, then the second term in formula (30) will represent a small regular fraction Z.

Then we may approximately put

$$\ln (1 + Z) = Z - \frac{Z^2}{2} + \frac{Z^3}{3} - \frac{Z^4}{4} \ldots$$

The smaller the fraction Z, the fewer the terms we can take.

35. Let us suppose, for example, as before:

$$M_0 : M_1' = 1/3 \text{ and } Y = 6.$$

The first approximation by (34) will give $\frac{1}{7}$ or 0.143. This is slightly more than in table 31 (0.131). The second approximation will be 0.133, which is still closer to the reality. If we take a nine-rocket train, then $Z = \frac{1}{11}$ and the first approximation will give Z = 0.91, which is already almost in agreement with the table.

36. And thus, beginning with the 11th train, we may boldly put

$$\frac{V_y}{W} = Z = 1 : \left[\left(\frac{M_0}{M_1'} + 1 \right) \quad y - 1 \right].$$

37. We can find out the sum of additional velocities of the trains farther than the 11th from the rear approximately by integration of the expression (36). We shall get

$$\frac{M_1'}{M_0 + M_1'} \ln \left[\left(\frac{M_0}{M_1'} + 1 \right) \quad y - 1 \right] \quad + \text{const.}$$

If the const = 10, the sum of additional velocities is equal to zero. Therefore,

$$\text{const} = - \frac{M_1'}{M_0 + M_1'} \ln \left[\left(\frac{M_0}{M_1'} + 1 \right) \quad 10 - 1 \right].$$

So, for the sum of additional velocities we shall get

$$\frac{M_1'}{M_0 + M_1'} \ln \left[\frac{\left(\frac{M_0}{M_1'} + 1 \right) y - 1}{\left(\frac{M_0}{M_1'} + 1 \right) 10 - 1} \right].$$

38. Supposing here Y = 11(the 11th train i.e. addition of one rocket to 10), we shall find the relative additional velocity as 0.077 (table 31).

If we add 10 trains, then Y = 20 and the total additional velocity of 10 trains will be 0.55. When the ejection velocity is 4 km/sec the absolute velocity will comprise 2.2 km/sec.

We shall add 90 rockets; Y = 100 and the additional velocity will be 1.78, The absolute addition (W = 4 km/sec) is equal to 7 12 km/sec. According to table 33 ten trains, in those very conditions, give 12 km/sec. So, 100 trains will give a velocity of 19.12 km/sec. This is more than required for recession towards other suns.

On 50% utilization of fuel (table 33) We shall find that velocity from 100 trains will be 9 + 5.34 = 14.34 km/sec.

39. When there are more than 100 rockets in the train we can express the total additional velocity by the formula from (37) .

$$\frac{M_1'}{M_0 + M_1'} \ln\left(\frac{Y}{10}\right).$$

40. For example, for 1000 trains the largest relative velocity will be 3.454. If W = 4, the absolute addition form 990 rockets is equal to 13.82, while the total from 1000 rockets we shall get 25.82 km/sec.

41. Let us imagine the first horizontal motion of all trains. The last rocket will have the maximum acceleration (addition of velocity per second). In practice it is convenient that the force of explosion was constant. If it is so the acceleration of a single rocket at first will be weaker, because the mass will be great as the fuel is still not consumed. Later, to the extent of its burning the acceleration will become greater. Thus, in case of our triple reserve at first the acceleration will be 4 times less than at the end, whn the entire explosive material has been expended.

42. When the explosion is normal to the direction of gravity, it is not advantageous to make use of a large acceleration (on a solid roadway in the air or in the vacuum). Firstly, special protective means will be required for saving the passenger from the enhanced gravity. Secondly, the rocket itself must be made stronger, and consequently, more massive. Thirdly, the explosion pipes and other machines must also the stronger and more massive.

43. Let us take the maximum acceleration of the train at 10 M/sec^2. The Earth imparts such an acceleration

in one second to the freely falling objects. It is clear that similar acceleration will be in the last train, consisting of one rocket, besides that the end of the uniform acceleration. We suppose, that the force of this explosion decreases proportionately to the diminishing full mass of the rocket, so that the acceleration all the time will be constant and equal to 10 M/sec^2.

44. The mass of trains composed of two or more rockets changes less, and therefore, the force of explosion in this case may be taken as constant, while the acceleration may be considered invariable. Besides, it will be the less the greater the number of rockets in the train is so that a certain unevenness (non-uniformity) cannot do any harm.

45. The acceleration of the second train (from the end) will be one half, since its mass is double ; the acceleration of the tenth will be one tenth, since, it will contain 10 rockets of identical mass, so on and so forth.

It follows then that the tension of a horizontal train or its relative weight does not depend on the number of rockets. Indeed, even if there are 1000 rockets, its tension will be, on the one hand, owing to the mass, 1000 times more and on the other-owing to its small acceleration, 1000 times smaller. Obviously a train composed of any number of rockets will have the same tension as the one consisting of a single rocket.

46. If the tension of a long train is greater, this is due only to the friction and resistance of the air. We ignore this for the time being.

47. The inclination of the path to the horizon similarly increases the tension of the train proportionally to its length. But if we adopt a curved roadway, gradually ascending, its inclination will be (the tangent or sine of the angle of inclination) very small and proportional to the acceleration of the train: we may ignore this circumstance too.

48. Keeping all this in view, let us calculate the times, velocities, passages and ascents of the trains (table 49).

It is very convenient to suppose, that the portion of explosion in every rocket has been designed identically and operates in the same way. Then the duration of an explosion on the total consumption of one or the other reserve of fuel will similarly be the same in all rockets.

If we acquire the first cosmic velocity of 8000 M/sec, and are outside the atmosphere, it is easy to recede from the Earth or to travel in the limits of the Solar system and even farther by the pressure of light or some other method.

49. A train is made up of 5 rockets.

Number of trains in chronological order

(1) 1 2 3 4 5

Number of rockets in each train.

(2) 5 4 3 2 1

Mean Acceleration in M/sec.

(3) 2 2.5 3.33 5 10

(Duration of explosion is constant) Relative additional velocity of each train.

(4) 0.2 0.25 0.333 0.5 1.0

Ultimate relative velocity of each train.

(5) 0.2 0.45 0.783 1.283 2.283

Absolute velocity of each train, if the additional velocity of the last rocket is taken at 5520 M/sec

(6) 1104 2484 4322 7082 12602

Duration of explosion in seconds is equal to.

(7) 1104 : 2 = 552 = 5520 : 10 = 552

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* Vide "Investigation of outer spaces by reactive devices " 1926 (Author).

It is one and the same for all rockets.

Average velocity of each train in meters per second.

(8)	552	1242	2161	3541	6301

Total path Covered by each train in kilometers (during explosion).

(9)	288.14	685.58	1192.87	1954.63	3478.15

Tangent of inclination.

(10)	0.02	0.025	0.033	0.05	0.1

Total vertical ascent of each train in kilometers.

(11)	5.76	17.1	39.6	97.7	347.8

Ditto if the inclination is half.

(12)	2.88	8.5	19.8	48.8	173.9

Ultimate velocity for 50% utilization of explosive substance, when the velocity of a single rocket is equal to 3900 meters/second.

(13)	780	1755	3054	4992	8892

Length of trains in meters.

(14)	150	120	90	60	30

50. From the 6th line we see, that the train composed of 5 rockets gives a velocity sufficient for recession from the Earth and even from its orbit. The penultimate train consisting of two rockets, acquires almost the first cosmic velocity (8000) M/sec). So that it lacks a small fraction to fly beyond the atmosphere around the Earth along with the final rocket. whose explosive material is not consumed. Naturally, it may be replaced by some other load. From this it is clearly evident that there is a possibility of making the whole loaded trains satelite of the Earth, if the total number of the component parts of the train, i.e. rockets is sufficiently large.

51. From the 7th line it is evident, that the duration of explosion in each train is equal to 552 seconds, or 9.2 minutes. For five trains this will comprise 46 minutes. It means, that in less than an hour all will be finished and the last rocket will become a wandering body.

The reserve of explosive substances with us is three times more than the weight of the rocket along with the remaining contents and, therefore, equal to 27 T. Hence in a second 48.9 kilograms of explosives must explode. Uniformity of action requires a larger number of explosion pipes. If in each rocket their number is 40, while the motor gives 30 revolutions in a second or 30 injection (portions), then each portion will comprise 0.041 kilogram or 41 grams. With what can we compare this cannonade? 1200 blank shots per second with 41 grams of highly explosive substance in each. And this continues in succession and continuously in all rockets in the course of 46 minutes.

52. We have accepted the magnitude of the rocket diameter as 3 meters. At first one can limit oneself to 1 meter. Then all this terrifying picture will be reduced 27 times (three in a cube). We have mentioned that in the case the last cosmic rocket may be opened up in a special way and become a spacious accommodation for human beings. But we shall speak about it at another place.

53. From the ninth line it is evident, that the distances, covered by trains, do not exceed the dimensions of the Earth's globe. But the vertical ascent of each train. (line 11) is much less. Thus only the first train, after traversing 288 kilometers on the Earth, rises to a height of 5-6 kilometers. The second train must leave the solid roadway and fly in the air. The last rocket, still not having finished explosion, flies out beyond the limits of the atmosphere. This takes place when the maximum tangent of the angle of ascent (in case of the last train) is equal to 0.1°, and the appropriate angle with the horizon is 6°. For the first train it is slightly more than 1°, for the second 2° and so on.

54. When the inclination is half (line 12), two trains can conduct explosions (fire) while still on the solid roadway. The height of Earth's mountains permits this. Then the solid roadway will comprise about 600-700 kilometers.

55. In line 13 we had presumed 50% utilization of the energy of explosive substances. And then the last train acquires velocity greatly exceeding the initlal (first cosmic velocity of 8 km/sec. The rocket passages, it is understood, will be shorter.

56. **The largest initial train** has a length of 150 meters. If we confine ourselves, in the first instance, to three-time smaller dimensions then we shall get for a five-rocket train a total of 50 meters.

57. We have already said that the strength of a train (on breach) does not depend on the number of rockets on the horizontal path. However, the strength of a single rocket is sufficient.

The area of cross-section of the jacket (shell) of the rocket is everywhere the same and equal when thickness of the wall is 2 mm) to 18,000 mm^2. The resistance to the breach on six-fold safety factor will not be less than 180 T. The rocket with all its contents (and fuel) has a mass of 36 T. Acceleration at 10 M/sec^2 in connection with ordinary gravity, will create relative gravity 1.4 times more than that of Earth. But the horizontal component will only be equal to that of the Earth. In this way the rocket will be subjected to a tension equal to 36 Tons. This destructive force is five times less than the force of resistance of the material. If we take a rocket of a diameter and length three times smaller, then the destructive force will be 15 times less than the strength of the resistance.

58. Inclined motion increases this destructive effect. But is is the same for all the trains. Thus, for a single rocket the incline is the greatest and increases the tension only by 0.1. The incline, for example, of a five-fold rocket is 5 times less so that notwithstanding the large mass, the tension will be increased (totally) also by 0.1.

59. From here it is evident that the rockets could be made less massive if it was not for gaseous super-pressure, which is unavoidable in the vacuum. All the same it may be reduced four times, since instead of 4 atmospheres of superpressure, we can onfine ourselves to 1. However, the jacket (shell) is rendered impractically thin for rockets.

60. In view of the excessive tensile strength of the train, we suggest additionaltables for trains, composed of 1,2,3,4, and 5 rockets. But here we assume, that the force

and rate of explosion of one and the same mass of the explosive material are proportional tothe mass of the train. Thus, the first train, we shall assume, composed of five rockets, is drive by a force, 5 times greater than of one rocket, and because both the trains have one and the same acceleration, just like all the partial trains of one and the same convoy. It follows, that despite the disparity in the number of rockets of different trains, we have, as if one body is moving with invariable (constant) acceleration. But the duration of explosion, of course, is inversely proportional to the masses of partial trains (because, the stronger the explosion, then more quickly it is over).

61. In all the tables (see 62 and 63) we take the ultimate overall velocity of the last rocket equal to the first cosmic velocity of 8 kilometers per second. The tables, meanwhile, provide an answer to the question: What additional velocity is needed in this case for a single rocket?. From the fifth line of the table we see, what these maximum additional velocities would be for different trains:

Number of rockets in the train.

1	2	3	4	5
Required additional velocity from a single rocket in km/sec.				
8	5.3	4.4	3.8	3.5

We see, that the additional velocity is less, if the number of rockets in the train is greater. Thus, for a five-rocket train it is only 3.5 km/sec, which is achieved with a relative reserve of fuel supply of 1 or 1.5.

From the 10th and 16th lines we see, that the length of passage (route) On the solid ground is smaller here much. Similarly, the entire process of take off is shorter: total 800 seconds, or 3.3 minutes, since the acceleration per second does not diminish, while the explosion is in progress.

62. Length of the rocket is 30 meters.

1st rocket	2nd rocket		3rd rocket		
Number of trains.					
1	1	2	1	2	3
Number of rockets and relative force of explosion.					
1	2	1	3	2	1
Relative time of explosion.					
1	1	2	1	1.5	3

Relative times of accelerated motion of each train.

1	1	3	1	2.5	5.5

Ultimate velocity of each train in M/sec.

8000	2667	8000	1454	3636	8000

Addition of velocity of each train in M/sec.

8000	2667	5333	1454	2182	4364

Time of motion of each train with the previous ones in second.

800	266.7	800	145.4	363.6	800.0

Time of motion of one train in seconds.

800	266.7	533.3	145.4	218.2	436.4

Average velocity of each train in M/sec.

4000	1333.3	4000	727.2	1818.2	4000.0

Length of the roadway of each train with the previous ones in kilometers.

3200	355.5	3200	105.7	666.1	3200

Flight of each train separately in kilometers.

3200	355.5	2844.5	105.7	555.4	2538.9

	Altitude of the ascent		sin a = 0.30		
960	106.7	960	31.7	198.3	960
	The same		sin a = 0.25		
800	88.9	800	26.4	166.3	800.0
	The same		sin of angle		
640	77.1	640	211	132.2	640.0
	Altitude of Ascent.				
480	53.3	480	15.8	99.2	480.0
	The same		sin of angle		
320	35.5	320	10.6	66.1	320.0
	Length of the entire train in meters.				
30	60	30	90	60	30

63. Length of the rocket 30 meters.

4 Rockets.				5 Rockets.				
Number of trains.								
1	2	3	4	1	2	3	4	5

Number of rockets in each and relative force of explosion.

4	3	2	1	5	4	3	2	1

Relative time of explosion of each train.

1	1.33	2	4	1	1.25	1.67	2.5	5
1	2	3	4	1	2	3	4	5

Relative time of accelerated motion of each train.

1	2.33	4.33	8.33	1	2.25	3.92	6.42	11.42

Ultimate velocity of each train in M/sec.

960.4	2237.7	4158.5	8000	700.6	1576.3	2746	4497.8	8000

Addition of velocity of each train in M/sec.

960.4	1277.3	1920.8	3841.5	701	876	1170	1752	3502

Time of motion of each train with the previous ones in seconds.

96.0	223.8	415.8	800.0	70	158	275	450	800

Time of accelerated motion of one train in second.

96.0	127.8	192.0	384.2	70	88	117	175	350

Average velocity of each train in M/sec.

480.2	1118.8	2079.2	4000.0	350	788	1373	2249	4000

Length of the passage of each train with preceding ones in kilometers.

46.08	250.43	864.45	3200	24.50	124.50	377.57	1012.05	3200

Flight of each train separately in kilometers.

46.1	204.3	614.02	2335.6	24.50	100.0	253.1	634.4	21880
Height of Ascent				sin a = 0.3				
13.8	75.1	259.3	960.0	7.35	37.35	112,28	303.61	960
The same				sin a = 0.25				
11.5	62.6	216.1	800.0	6.1	31.1	94.4	253.0	800
The same				sin a = 0.25				
9.6	50.1	172.9	640.0	4.9	24.9	75.5	204.4	640
The same								
6.9	37.5	129.7	480.0	3.67	18.6	56.7	151.8	480
The same				sin a = 0.1				
4.6	25.0	86.4	320.0	2.45	12.4	37.8	101.2	320

Length of the whole train in meters.

120	90	60	30	150	120	90	60	30

64. The incline of the hard roadway to the horizon here must be rocggnized as very small, but constant, for example 6^{o}, sin α being equal to 0.1 . The roadway will come out straight but not concave as in the case of variable acceleration per second of the partial trains.

65. For trains composed of 1,3 and 4 rockets, one can assume not only acceleration as constant, but also the duration of explosion just as invariable. But for this the reserve of the fuel in each leading rocket must be proportional to the force of explosion or to the mass of each partial train. So, the first rockets (or trains) not only explode more quickly, but also longer than those in table 62 and 63, by virtue of more reserve of fuels. Here, too, all partial trains move as a single body with constant accelration. On this basis we shall compile the following table.

66. Length of the rocket is 30 meters.

	2 Rockets		3 Rockets			4 Rockets			
	Number of trains								
(1)	1	2	1	2	3	1	2	3	4

Number of rockets in a partial train, relative force of explosion and the reserve of fuel.

(2)	2	1	3	2	1	4	3	2	1

Relative time of the accelerated motion of each train.

(3)	1	1	1	1	1	1	1	1	1

Relative total time of explosion of each train.

(4)	1	2	1	2	3	1	2	3	4

Ultimate velocity of each train in km/sec.

(5)	4	8	2.7	5.3	8	2	4	6	8

Additional velocity of each train in km/sec.

(6)	4	4	2.7	2.7	2.7	2	2	2	2

Total time of motion of each train, if the acceleration per second is always equal to 10 M/sec^2.

(7)	400	800	267	533	800	200	400	600	800

Time of motion of one train in seconds.

(8)	400	400	267	267	267	200	200	200	200

Average velocity of each train in km/sec.

(9)	2	4	1.33	2.67	4.00	1	2	3	4

Total length of the roadway of each train (with the previous. ones) in kilometers.

(10)	800	3200	355.5	1422	3200	200	800	1800	3200

Flight of each train separately.

(11)	800	2400	355.5	1066.5	1778	200	600	1000	2200

Total Height of Ascent in kilometers; sin = 0.1; $\doteq 60^{\circ}$.

(12)	80	320	35	142	320	20	80	180	3200

Length of trains in meters.

(13)	60	30	90	60	30	120	90	60	30

67. The inclination of the solid raodway to the horizon, in general, may be constant here as well, for example, the tangent of the angle of incline (6°) is equal to 0.1.

Even the first partial train here can move on the solid ground only a part of the pathway. The other larger part of the pathway is completed in the atmosphere.

From the sixth line it is evident that additional velocities are the same for partial trains of one convoy, and the greater the number of rockets in a convoy, the less are the additional velocities. For a four-rocket train the additional velocity is only 2 kilometers per second, which corresponds to the relative reserve of fuel from 0.5 to 0.7 (relative to the mass of the rocket without explosive substances).

The forward terrestrial trains may have large mass of the fuel, since the number of people on them may be fewer and their equipment simpler, because they return immediately to the Earth.

68. Nevertheless, the most practical and feasible trains are the ones composed of identically constructed rockets with invariable reserve of fuel and constant force of explosion (see item 4). They can also consist of enormous number of members (separate rockets) which increase the ultimate velocity or allow to be satisfied with a small reserve of fuel in each individual rocket (or its weak utilization). In a word, cosmic velocities may be acquired even in imperfect reactive devices.

69. We are giving a table for a ten-rocket train. The duration of explosion in each partial train is one and the same, which follows from the identical construction of the members (separate rockets) of the train.

The length of one rocket is equal to 30 meters. The rockets are identical in construction and the reserve of fuel.

Number of partial trains.

(1) 1 2 3 4 5 6 7 8 9 10

Number of rockets in each partial train

(2) 10 9 8 7 6 5 4 3 2 1

(3) Duration of explosion is the same,

Acceleration of each train in M/sec^2.

(4) 1 1.111 1.250 1.429 1.667 2 2.5 3.333 5 10

(5) If we desire to achieve the initial cosmic velocity of 8 kilometers per second, then the duration of explosion will be 8000 meters per second : 29.29 M/sec^2 = 273.1 seconds (see below para 70).

Additional velocity of each train in M/sec.

(6) 273 301 343 391 456 546 682 1009 1365 2734

Ultimate velocity of each train in M/sec.

(7) 273 574 917 1308 1764 2310 2992 3901 5266 8000

Average velocity of each train in M/sec.

(8) 136 287 458 654 882 1155 1496 1950 2633 4000

Length of the path of each train in kilometers
(see rows 3 and 5)

(9) 37.1 78.3 125.0 178.5 240.8 315.3 408.4 532.3 718.8 1092.4

"Total distance covered by each train with the preceding ones in kilometers.

(10)	37.1	115.4	240.4	418.9	659.7	975.0	1383.0	1915.7	2634.5	3726.9

Incline of the path of each train. Tangent of the angle (6^o) of the last train taken at 0.1. Incline of others are proportional to the acceleration.

(11)	0.01	0.0111	0.0125	0.0143	0.0167	0.02	0.025	0.0333	0.05	0.1

Total height of ascent of each train in kilometers.

(12)	0.371	0.870	1.562	2.553	4,021	6.306	10.21	17.72	35.94	109.24

Total height in kilometers.

(13)	0.371	1.241	2.803	5.356	9.377	15.683	25.89	43.61	79.55	188.79

Height relative to passage (12 and 10).

(14)	0.01	0.01090	0.01179	0.01278	0.0140	0.0161	0.0187	0.0227	0.0302	0.0508

Total duration of each train in seconds.

(15)	273	546	819	1092	1365	1638	1911	2184	2457	2730

70. If we denote the duration of explosion by and demand from the last rocket (of the train) the first cosmic velocity, then on the basis of the fourth row we have.

$$1x + 1,1x \ldots + 1.25x \ldots + 2x \ldots + 5x + 10x = 29,39\ x = 8000,$$

Whence x = 273,1 seconds.

71. The maximum additional velocity required of the last single rocket will be only 2.7 kilometers per second, which corresponds to the relative reserve of the fuel from 0.8 to 1. If the reserve is more, the ultimate velocity will be greater. But for the first time this is not needed.

72. The first four trains can travel on the solid ground, the ascent being equal to 6 kilometers, while the total length of the entire route is 419 kilometers (see 13th and 10th lines). This is permissible for the Earth. The fifth train finishes its journey in the atmosphere, while the remaining five start their journey in it. In view of the sphericity of the Earth the lift for the last trains is very much large, than given in line 12.

Length of the entire distance at the time of explosion reaches 3000 kilometers.

73. The hard roadway is curved (line 14). Exact calculations regarding this curvature provide formulae, too complicated (with derivatives) and we cannot give them here, so as not to abscure the main thing. But let us suppose that the curvature of the pathway is constant for each train. The known elementary theorem will give us

$$r = L^2 : 2h,$$

where in order are denoted; radius of the curvature, traversed distance and vertical ascent h. The 10th and 13th lines permit the determination of the radius of curvature for each portion of the pathway. Thus, for the 1st, 5th and the last i.e. the 10th, we shall find in kilometers

$$\gamma = 1850,\ 23{,}220 \text{ and } 36770.$$

From here it is evident that the radius of curvature increases, by which the centrifugal force decreases. But at the same time it increases due to the increase of the velocity of the train (the true radii are greater and, therefore the true centrifugal force is less).

74. For these three cases we calculate it (the centrifugal force) in terms of acceleration in meters per second. As is known, it is equal to

$$C_\gamma = b^2 : \gamma,$$

Where centrifugal force, the velocity and the radius of curvature of the pathway* are denoted. This formula (line 7th and para 73) gives

$$c_\gamma = 0.04;\ 1.34 \text{ and } 1.74.$$

---

* For mass, equal to unity (Editors).

Relative to the force of the Earth's gravity (acceleration of gravity being 10 M/sec^2) it comprises from 0.004 to 0.17. But we shall not forget that only the 4th train may move on the hard pathway and develop centrifugal force. The remaining move in the atmosphere, and then there may not be centrifugal force at all. Generally, it depends on us, i.e. on control (on the inclination of the rudders). For the fourth train γ = 16360 and C = 1.05, i.e. the force pressing the train to the pathway, does not exceed 1/10 of the gravity of the train (in actuality still less).

75. Let us turn in general, the the relative force of gravity, generated in a train during its motion. The centrifugal force presses the train to the pathway, at first imperceptibly, later more strongly, but the maximum does not reach 0.1 of the Earth's gravity. We shall ignore this force. The second force normal to the first depends on the accelerated motion of the train. Its maximum magnitude is equal to the Earth's acceleration (10 M/sec^2). This magnitude cannot be neglected. Combining with the Earth's attraction, both the forces produce an acceleration, approximately equal to 14 M/sec^2, which is 1.4 times the acceleration of the Earth. A person weighing 75 kilogram will weight not more than 105 kilograms in the train. Such an increase of gravity in the course of a few minutes is easily withstood even in a standing position. The gravity will increase little by little, varying from 1 to 1.4 relative to ordinary one. The inclination of this relative gravity to the vertical

similarly increases gradually, from zero to 45°. The horizontal surface of the Earth, to the extent of increase of acceleration, howsoever, inclines more and more, and at the end of the accelerated motion it appears to the passenger that the train is rushing to the mountain at an angle of 45°. At the start of the motion this mountain is almost horizontal, then it becomes steeper and steeper, and at the end of the solid roadway will appear almost vertical. The spectacle is horrible and Startling. Friction and resistance of air somewhat reduce the accelerated motion and therefore weakens the very enhancement of gravity.

76. When the train takes off from the hard roadway and speeds in the air, the phenomenon becomes more complicated.

In the atmosphere there is the same thing, if the resultant of the explosive forces is directed along the longitudinal and less inclined axis of the rocket the , the rocket while descending will experience the resistance of the air, equal to its weight. Air will press on it, as the solid roadway. However, the rocket, flying in the inclined position with nose upwards, will not fall to the Earth, since it will be rising faster, than it falls.

77. Descent due to the Earth's gravity will in the beginning, be slow and accelerated, then it will attain a velocity, by which the pressure of air will become equal to the weight of the rocket. Here the vertical velocity of descent

will become constant and not very substantial in comparison with the uninterruptedly increasing velocity of the ascent of the rocket.

78. The rocket, parallelly tripled or quadrupled by $3M^2$ of its horizontal projection will yield gravity, on the start of explosion, as we have seen, about 0.9 T (for rockets with diameter of 1 meter it is 9 times less). For one square meter it will be 0.3 T (see 8). Such will be the pressure of air on 1 M^2 of horizontal projection of the projectile. This circumstance may serve us for forming an equation. It will also provide us the necessary conclusions.

79. Let us take the direction of the resultant of explosion to be horizontal. Then the head-on flow will be directed onto the rocket (assuming its base flat) at an angle, whose tangent is equal to

$$C_h : C,$$

where c_h - is the constant of fall of the rocket due to gravity and C - is the variable translatory velocity of the rocket.

80. The pressure of the air flow on a surface of one square meter, normal to it will be the smallest

$$(d : 2g)\ c^2\ ,$$

where d is the density of air; g the acceleration of the Earth's gravity and C, the rate of flow.

A current (of air) acting on a plate in an inclined position exerts a pressure (proportional to the doubled tangent of the angle). Consequently pressure on each square meter of the base of the rocket will be expressed by

$$(d : g)\ CC_h .$$

81. We must equate the value of this pressure to the weight G_1 of the rocket per square meter of its base (0.3 T or 300 kilograms). Consequently

$$G_1 = (d : g)\ CC_h .$$

Hence

$$\frac{c_h}{C}\ (gG_1) : (dC^2) .$$

From this it is evident that the relative rate of fall, or the angle of its fall (tangent), diminishes quickly with the increase of translatory velocity of the rocket. But it increases with the diminishing of air density i.e. with the ascent of the rocket to altitude.

82. Let us calculate the tangent of the angle for different velocities of the rocket and different densities of the air.

If, for example, $d = 0.0012$; $G_1 = 0.3$ T ; $g = 10$ M/sec,^{2} C = 1000 M/sec, then the inclination will be 0.0025. Even at the altitudes of 8-10 kilometers, where the density of air is 4 times less, the inclination will be 0.01. With the velocity of the rocket, one half (500 M/sec,), the inclination will be 0.04. And this inclination is 2.5 times less than the inclination taken by us (0.1) of the longitudinal axis of the rocket to the horizon (when it takes off from the hard ground). It means that ven during these conditions the rocket not only will not fall, but will rise quickly, receding from the surface of the Earth by virture of the latter's sphericity.

83. But the rarefaction of air in the course of time increases at a rate much quicker than the square of the translatory velocity of the rocket. Therefore a time will come, when the gravity of the rocket will not be balanced by the resistance of the atmosphere, the relative vertical component of gravity will diminish — and the vacuum beyond the limits of the atmosphere it will disappear altogether. Then only gravity, due to accelerated translatory motion of the rocket, equal to 10 M/sec^2, will be left. It will produce an apparent gravity equal to that of the Earth in attraction, but in direction almost perpendicular to it. Then the Earth will appear as a vertical wall, parallel to which we are moving (rising).

Even this will continue for only several minutes: explosion will come to a stand still and all traces of gravity will, as if, disappear.

84. If we substitute in the last equation the tangent of the angle of inclination by 0.1 and C = 1000 M/sec, then we shall calculated = 0.00003, i.e. it is possible to climb to a height where the density of air is very small (0.00003, it will be 40 times less than at the sea level), and still not fall, at a velocity of 1000 M/sec. Such a velocity still does not develop a centrifugal force, equal to the force of the Earths gravity, and therefore does not make the path circular without proximity to recession from the Earth. Only on attaining a velocity of 8 km/sec the path will become circular and eternal (only beyond the atmosphere).

Different Systems of Trains.

85. Let us describe our trains of different systems. There may be four cases.

A. Rockets are made almost identical. The reserve of explosive substances in all of them is the same but the explosion is stronger if the mass of the train is greater. Due to this, the acceleration for all the partial trains is one and the same, but the duration of explosion is inversely proportional to the mass of the train (Paragraphs 62 and 63).

B) The reserve of explosive substances and the force of explosion is greater, if the mass of the partial train is greater. Owing to this the acceleration per second and the time of explosion for all trains are the same. (See Para 66).

C. The reserve of explosive substances is proportional to the mass of the partial train, but the force of explosion is constant. In this case the duration of explosion in each train is greater if its mass is greater. The acceleration is inversely proportional to the mass of the partial train,. This case has not been examined by us.

D. All the rockets are completely identical as to, the reserve of fuel and the performance of explosion. The greater the mass of the partial train, the smaller is the acceleration. The duration of explosion for all trains is the same (see para 49).

86. System A is not convenient in that it requires in the first rocket strong or quick explosion mechanism, and consequently complication and weighting of the explosion mechanism. Due to this the tension of the first long trains will be enormous. The entire system will be threatened by rupture, and therefore it is not possible to employ multifold rocket trains. The additional velocity of each train is the same, as of system. D. The advantage is in the

shortening of the length of the pathway and the duration of explosion, but this is not at all important (paras 62 and 63).

87. System B as also the foregoing A requires increases of mass and volume of the rocket the more, if there are more links (members), in the train. But then the fuel, as also the more complicated and powerful machines require space. It is, therefore, not possible to employ many rockets in a train: it will tear asunder due to the powerfully accelerated motion. The advnatage is in quick increase of velocity, since the additional velocity is one and the same for all trains. It means that the ultimate velocity is proportional to the number of rockets in the train. If, for example the additional velocity of a single rocket is 8 km/sec, then the train of the system B, consisting of two rockets, attains a velocity of 16 km/sec, which is almost sufficient for wandering amidst other suns. If we can acquire a velocity of 2 km/sec from a single rocket, then a four-fold rocket train will impart to the last rocket the first cosmic velocity of 8 km/sec (see para 66).

88. System C is more practicable, because for long trains the acceleration will be small as in the System D, and because it can be used for multi-rocket trains. The explosion mechanisms and the very rockets are almost identical. But because the quantity of fuel is proprotional to the mass

of partial trains the front rockets must be larger, so as to hold a large mass of the fuel. In this is found their shortcoming. But we have seen that the spaciousness in out rockets is sufficient, and therefore, a trains composed of 2-3 rockets is possible without a change of volume of devices. Still another advantage is in the fact that the additional velocities do not diminish with the increase of the number of rockets, as in the system B. In fact, although the acceleration in a long massive train is small, yet the duration of explosion virtue of a large reserve of fuel is so many times more. Because the ultimate additional velocities in all the partial trains are the same, it offers great advantage. Increase of time and the length of the solid pathway (comparatively with the systems A and D) are unessential.

89. Although this case not examined by us, yet we may be benefited by table 66. regarding the magnitudes of additional velocities. It is the system C that deserves the most intensive attention. If we could, for example, from one single rocket, acquire a velocity of only one km/sec (the speed of a cannon-ball may be more), which requires relative supply of from 0.2 to 0.3 then 17 trains would be sufficient so as to attain a maximum cosmic velocity, sufficient for reaching all own planets (but not for landing on them) and wandering in the Milky Way. The supply of fuel in the rockets beginning with the forward, one, will be not more than 5.1, 4.8, 4.5, 4.2 .... 1.2, 0.9, 0.6, 0.3 .

Such reserves are quite admissible. The last cosmic rocket will almost be empty, i.e. from fuel.

Here are the perspectives which the use of trains holds out to us, and this is how they can facilitate the acquiring of cosmic velocities.

90. We spoke at length earlier about the system 'D' (See para 49). Its advantage lies in the complete equality of the elements of the train (except the last cosmic rocket).

In general, having completed our task, i.e. having directed the last rocket into the cosmic space, all the remaining rockets, no matter what their system, having flown more or less along distance in the atmosphere and after gliding, land on dry Earth or on water and can again serve the same purpose. One and the same train, on one and the some route may direct a million devices on celestial voyage. The only thing needed is an uninterrupted expenditure of fuel composed of cheap products of potroleum and endogenous compounds of oxygen.

A drawback of system D is the small additional velocity. But if row 89 is changed by identical elements, for example the values 5.1, system C turns into system D and then the final velocity will substantially increase.

91. The problem of combustion materials, the design of the explosion pipes, jackets (shells) and other parts

(components) of the rocket cannot be solved at present. Therefore I presume, for the time being, that for the elements of the explosion, petroleum products and liquid oxygen or its endogenous compounds will be used, while for the arrangement of the rocket - different familiar (known) sorts of steel e.g. chromium and beryllium and others.

Of course, it is more advnatageous to employ monatomic hydrogen and ozone as explosive components. But are such materials sufficiently stable and can they have a convenient form? This must be decided by chemists, specially those working on similar substances.

If good results with oxygen, petroleum and steel are possible, then they (results) will be all the better in case of other more advantageous materials.

TEMPERATURE OF A SPACE ROCKET.

Even amongst the scientists there exist contradictory and unclear conceptions regarding the temperature of bodies in the ether, for example, the temperature of the rocket.

Talk is heard about the temperature of celestial space. But one cannot speak about that the temperature of gases, liquids and solid bodies located in the celestial space.

If we assume, that round about some body in the ether of the celestial space, there are no other bodies, for example suns, planets, comets and small bodies, so such a body will only lose heat, not gaining it in exchange from other bodies. It is highly probable, that the temperature of such a body reaches an obsolute zero, i.e. it will be 273°C below zero: the movement of molecules will stop, but it does not mean, that the movement of their parts, and the more so of protons and electrons, will come to a stop. Even the movement of molecules and atoms will hardly stop totally.

But we shall not go into the depth of this question. What we need is an idea regarding the simple temperature of bodies in the celestial space. It is highly probable, that the temperature is close to 273°C below zero. Such is a temperature at great distances from the suns, when they appear as small stars, for the heat received from them may be ignored. It is difficult to have any doubt (although in this matter the conclusions of scientists are contradictory . In fact, now it has been confirmed that the temperature of planets which are far away from the sun, is very low, whilst they are heated by the Sun's rays. If they were at greater distances from the luminary body (star), so that all the suns should appear as stars, then this temperature would undoubtedly reach absolute zero (273°C below zero).

Planets still possess a certain amount of their own heat, and they still strive with the cold, they still have a great reserve of heat and its sources.

As to the small bodies in which one can include not only the terrestrial bodies that surround men, but also asteroids (if they are far removed from heated or incandescent bodies), they quickly adopt the temperature of the absolute cold.

Therefore, a space rocket away from the Sun, and the faintly twinkling starts, will apparently be in a critical position. Its temperature must quickly reaches 273° below zero.

But, first of all, it may have its own source of heat, secondly it may be protected from the loss of heat by a series of jackets (shells), so that these losses will readily be made good artificially, even in the course of thousands of years.

But, for the time being, we shall leave this question. Let us divert our attention to a projectile, which is located at the same distance from the Sun, as the Earth. This does not hinder it in the least from being outside the Earth, in the Earth's orbit, hundreds of millions of kilometers from the Earth, when it is represented like a small star such a Venus.

Our rocket will lose heat only by radiation, since there is no air or other material medium around it. But it will receive heat from the Sun, and therefore, its temperature will lower down till the time the loss of heat (due to radiation) will become equal to the gain (from the rays of the Sun).

Thus, we have to think about the magnitude of gain and loss and then to decide the question regarding the established constant temperature of the body.

The size of the gain of heat, of course, depends on the energy of the Sun's rays. We take this energy as constant. But it will not at all be perceived (taken up) by our body, if it is shielded from the Sun by one or several brilliant jackets (shells), completely reflecting this heat. Thus, no matter, how great the energy of sunlight, it cannot be absorbed by our rocket, owing to its design and surface properties.

On the contrary, there are black surfaces, which almost completely absorbed the heat of sunlight, falling on them.

And so, the gain of heat may fluctuate from zero to some maximum value, depending on the energy of the warming rays. If there were no loss of heat due to radiation, then our rocket would be heated up to the temperature of the Sun.

Now let us examine the loss of heat. All surfaces of bodies lose heat, but some more, others less. Besides, this loss quickly increases (to the fourth degree) with the increase of absolute temperature of the body, of course, the losses increase with the increase of surface area (for example, of the projectile). All these considerations and calculations, lead to the following conclusions.

The structure, on one side is facing the Sun, having on this side a dark surface absorbing heat, while on the other the opposite (shaded) - it is shielded from the loss of radiant energy by several brilliant surfaces which may have a temperature, the highest limit of which is not less than 150°C.

Here is a practical example. We have a spherical closed vessel filled with gas. A third portion of its surface, facing the Sun, is covered with glasses, well allowing the radiant energy. It falls on the dark surface inside the shphere, which absorbs the rays of the suns well. The remaining two thirds of the surface area is shielded from the loss of heat by one or several brilliant surfaces. The temperature of the gas inside the sphere reaches up to 150°C.

That very hollow sphere, facing the Sun with the bright surface, acquires inside a temperature close to 273°C below zero. The range (differences) of temperature is more than 400°C.

The same sphere with one side turned to the Sun in such a way, that the only part of the transparent surface receives rays from the Sun, has a temperature ranging between 273 and + 150°C.

By turning the sphere, we can get any temperature between these limits (extremes), for example, temperature of all climates, all heights and all the seasons of the year on the Earth.

If our projectile rotates quickly enought, facing periodically the transparent side towards the Sun, then a mean temperature close (according to calculations) to 27°C will be set up in it. This is almost twice the mean temperature of our rotating planet - the Earth.

But the last greater part of the Solar rays is not absorbed, but reflected back into celestial space. Is not 50% of the Earth's atmosphere always covered with clouds the bright surface of which excellently reflects Solar light?. That is why the mean temperature of the Earth is close to 15°C.

In general, the temperature of the planets is conditional and a very complicated affair and we do not intend to dwell upon this question. In my manuscripts there are many considerations and calculations regarding the temperatures of the planets. In the printed works only their results are given.

It appears, that now the question of the temperature of the cosmic rockets has sufficiently been elucidated.

However, there may be such a design of celestial projectiles, that their temperature will be expressed not by hundred but by thousand degrees. For this purpose it is necessary still to reduce the loss of heat, not reducing its gain from the Sun.

If in our sphere we reduced the area of windows and increased the area of the bright surface, then the loss of heat should be cut, down and for that reason there would be a decrease in the heat gained. It is, however, possible to get rid of this enchanted circle. It is possible to leave in the sphere a very small transparent hole and allow into it any quantity of the solar energy with the help of a converging lens or a spherical mirror. The hole in the sphere must in that case, coincide with the focal image of the Sun. Thus, the losses of heat will be brought to a minimum without any cut of the influx of Solar energy.

What would be the outcome? The quantity of heat in the sphere will increase till the time the per second influx becomes equal to the expenditure per second. This must certainly happen, since with the increase of temperature, the expenditure of heat increases. The temperature inside the sphere may reach up to 1000°C and more.

Even if our projectile receded to the limits of the Solar system where the Saturn with its rings is rotating, where the Uranus and the Neptune are whirling, even there the cosmic rocket would receive heat from the Sun, sufficient for maintaining life.

On the contrary, there are possibilities of low temperature notwithstanding the hottest rays of the Sun. This provides a means to our rocket device to travel to the neighborhood of the Sun. Not only there, where the planet Mercury rotates and scorches in the heat of the Sun, but even still closer.

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Jet Propulsion Engine
(1929)*.

I have been busy with reactive devices since the year 1895. And only now, at the end of the 34th year of work, I have arrived at a very simple conclusion relating on their system. Larchik, as is evident, has opened up simply: engines have long been invented and only need insignificant additions.

Explosion (internal combustion or thermal) engines at the same time are also reactive (jet). Only by the reaction of the gases ejected, no gain is occrued at present: they are ejected in different directions without any benefit and without the mediation of conical pipes.

The reason is judicions: their functioning is sufficiently poor due to the small quantity of combustible fuel. Their functioning is poor still due to the small speed of the moving parts of the machine and due to the fact that the expansion and utilization of heat of exhaust combustion products prevents the pressure of the atmosphere.

All this changes, if we are to use an airplane in the rarefied layers of the atmosphere, at high speeds of its translatory (forward) motion and by the use of conical pipes, directed in one direction — backwards. In these

* First published in Kaluga by the Employees of the section of Scientific workers in the year 1929.

pipes the exhaust gases explode.

We shall see how big their exhausts are. Let us have a motor of 1000 metric forces (100 kilogram meter each)* Let it consume for one power 0.5 kilogram of fuel per hour. For 1000 powers, 500 kilograms of it is consumed. If the fuel is hydrogen, then the atmospheric oxygen works 8 times more, i.e. 4000 kilograms. But oxygen in the atmosphere comprises only one fifth part, so that the mass of the required air will come up to 20,000 kilograms. We shall ignore hydrogen. More than 20,000 kilograms of vapor and gases are ejected in an hour, while 5.6 kilograms in a second. This is a large quantity. Simply to ignore this is not permissible, but it is sufficient for obtaining enormous velocities.

In my "Investigations of the years 1926", table No. 24, has been given for cosmic rocket with weight of one ton. This rocket acquires the first cosmic velocity of 8 km/sec when the reserve of fuel (along with oxygen) is 4 tons. From half to one ton (if we do not take with us reserve oxygen) only of the fuel is spent. The cosmic rocket ejects the products of combustion at the rate of 5 kilograms per second, i.e. even less than in our motor.

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* One metric horse power is equal to 75 kg. M/sec. The metric force mentioned in the text is not used in contemporary technology. (Editors).

It is true that owing to the impurity of the enormous quantity of nitrogen in the air, the velocity of ejected combustion products does not attain even 3 km/sec. So, we shall not achieve cosmic velocities here, though we shall approach them.

The rocket wieghs one ton. Can the rocket have a motor of 1000 powers at the expenditure of its mass? Now the motors are being made two times lighter than they were made a little earlier. Let us suppose that a motor of a thousand powers weighs 50 kilograms. It is all the more probable, that the motor may be very imperfect: it may produce not a thousand powers, but only 200, or even less if only it combusted as much material as possible. The more it combusts it, the better it is, because we do not need as much work as the explosions and ejected gases.

We shall turn our attention still towards the fact that we take 4 tons reserve of the fuel. If we can be benefited, though partly, by the oxygen of the air, it would be sufficient to take one ton of the fuel. So, we shall have an economy of 3 tons. Such a mass may serve for the most multifarious objects for example, for increasing the reserve of hydrogen compounds (and achieving cosmic velocities), for increasing the number of passengers, improvement and strengthening of equipment etc.

What is the matter ? How to accomplish the flight, how to perfect it and how to be close to the ultra - atmospheric flight?

Let us imagine the airplane, described by me of possibly smaller dimensions. Its engines (motors) at first work mainly by airscrews and less by reaction of ejected gases. In proportion to the ascent to an altitude and acquiring of the velocity the working of the airscrews gets slower, while the work of combustion of fuel increases. This is possible, because each motor (engine) may work even uselessly, i.e. without result. In this way the work of the airscrew gradually switches onto the reactive work. Eventually the airscrew is eliminated or rotates without the connecting rod, or completely stops, having directed its blades lengthwise to the counter air current.

We are, however, benefited by the work of the engines, firstly, for pumping air into motors, secondly, — in highly rarefied layers of air or in the vacuum (when this pumping is not possible) - for pushing the stored elements of explosion into the explosion pipes and acquiring cosmic velocities.

If we have 10 motors, each with 10 cylinders, which give 30 revolutions per second, then we shall obtain 3000 claps in a second and reactive pressure up to 5 T. It

It is for 100 pipes. On each there is an average pressure from 10 to 50 kilograms.

First printed in the brochure "Cosmic Rocket Trains" at Kaluga in 1929 and again in the "New Airplane" at Kaluga in 1929.

Aims of Astronautics
(1929)

Many people are writing and speaking in our country and abroad about the possibilities of astronautics.

But what will happen then? What is the object of its achievements what advantages can humanity derive from accessibility to celestial space ?

Many people bring to their immagination celestial ships with people , travelling from planet to planet, gradual colonization of planets and derivation from these advantages which will give common terrestrial colonies.

The pursuit will not advance like this, Regarding landing on large celestial bodies it is impossible to dream at present — it is so difficult. Even landing on such small bodies, as our Moon, is the work of the remote future. Fully accessible are only such small bodies and moons, as the asteroids (from 10 to 400 versts in diameter).

The main aim and the first achievements relate tothe spreading of human beings in the ether, benefit of the Solar energy and everywhere scattered masses, as asteroids and still smalller bodies.

What a foolish thought", the reader will say", is it possible to live in the either without a planet, without solid support under the feet, ---- Only large planets have atmospheres and may accomodate human beings.

But, in the first instance, landing on heavy planets is difficult from the point of view of technical relationship. Regarding these difficulties only the specialists can understand. Secondly, we shall meet there an atmosphere of unknown composition, with unknown plants and living beings, with unknown temperature. A certain temperature may destroy us. W.

With time the planets will be conquered, but for the time being this problem is remote, and it is too early even to speak about this.

If even at this time we commanded mastery of all the planets, then we should obtain compaarratively slight reward. In reality the value of the planet is determined by the Solar energy received by it. Nevertheless, the planets taken together acquire it only ten times more, than the Earth. All this is totally inconspicuous in comparison with the total Solar energy, which is 22 millard (US Billion) times more than that received by the Earth and 2 0 million times more than that which all the planets of our Solar system possess. Here is as to how much energy human beings can master if they can settle in the celestial space ! --- The achievement of this aim is hardly comparable with the discovery of two thousand million new planets, such as the Earth.

When we have a clear concept of life in the ether, we shall understand why it is "hardly" possible.

It appears, that life may be more absurd in the vacuum and without support'. But this is not only accessible, but also offers advantages, to evaluate which, is indeed extraordinary difficult.

It must be examined, how human beings breathe there, how lodgings are constructed, how movements are made, how plants are raised how one lives, eats, works, how to manage the techniques, how one feels, marries, procreates and so on and so forth.

Apparently, the most impossible, and unbearable thing is the absence of air or the atmosphere. Partly it is true, but the atmosphere is the source of the greatest misfortunes for the human beings. Human beings can neither control the atmosphere nor its temperature, nor its other properties so far. Let us take, say, temperature. On the Equator in the daytime it is almost impossible to remain alive from heat. At night it is more tolerable, but it is damp and unhealthy. The Northern countries have, on account of heat, intolerable summers due to heat and intolarable winters due to cold. What immense sacrifices and labor costs to humanity his struggle with temperature of the air, winds, snows, torrential rains, droughts, bacteria etc. The atmosphere deprives us of an immense part of the solar energy: one part is reflected by clouds, the other part is absorbed even by cloudless air. It robs us.

Neither people, nor plants for the time being can do without gases. A human being requires not less than half of that quantity of oxygen, which he now breathes, i.e. such is its density (0.00012), in which pressure on one square centimeter is not less than 100 grams (0.1 atmosphere). Still a small mixture of water vapor is needed. Nitrogen and other gases are not required, rather they are harmful, as useless mixture is harmful to the bread.

The plants may be satisfied with a slight quantity of carbon dioxide gas, oxygen, nitrogen and water vapor. This is their gaseous food. The total pressure of this gaseous mixture does not comprise even a hundredth part of the atmosphere i.e. 10g / cm^2.

So, the mixture of a small quantity of carbon dioxide gas and nitrogen in the atmosphere of human beings makes this atmosphere suitable for plants.

For the time being we shall only speak about a similar atmosphere of human beings, and discuss the problem of its preservation from pollution and purification from contamination. Although by each type of living beings and plants a particular composition of the atmosphere is needed, just as a particular temperature and a particular soil; we shall however, leave out these details for the time being.

Usually the vessel is of spherical -cum-cylindrical shape, made of good material and withstanding internal pressure, weighing ten times more than the gas, of the elasticity of oxygen, contained in it. Let us suppose, that for a person an accommodation with volume 100 M^3 is required. The weight of a cubic meter of oxygen will be about 0.00012 ton, weight 100 M^3 = 0.012, weight of the vessel = 0.12 T, or 120 Kilograms, i.e. it will have a mass, twice the mass of a person.

It is a trifle only to sacrifice 120 kilograms of glass, steel and nickel on the dwelling of a human being. We should not mind even if it were 10 times more.

How is such a dwelling arranged ? Its form is cylindrical, closed at both ends by semi-spherical surfaces. The more it is spacious, the greater the thickness of its walls will be . Therefore, the dwelling (so that the thickness of the walls would prove to be practical) is arranged for several hundred or thousands of persons. It consists of a bright cylindrical - cum- spherical surface within and without. One third of it turns towards the sun, and is latticed with inset glasses. The latter is similar to a curved frame with a number of glasses.

What form and what dimensions are most advantageous? The spherical form is inconvenient because, to arrange communication between the spherical surfaces is not particularly easy. Circular, cylindrical very long surfaces are better in this regard. Thus, the dwelling has the form of a pipe, the length of which is indefinitely large.

What would be its diameter? The larger it is, the less is the solar light on a unit volume, or for each inmate. Thus, a large diameter is not suitable, because light feeds plants, while plants feed human beings. But even a small diameter is not good, since it obstructs movement, limits the spaciousness and provides less thickness of the jacket (shell). A diameter not less than 2-3 meters may be taken. But, of course, it may be much larger, compatible with the purpose of the dwelling. Meeting halls will be of enormous size. Factories and other social buildings will be similar. For the time being we have in view the existence of the family and its feeding --- In accordance with the calculation the jacket (shell) of the cylinder with diameter of 3 meters will be impracticably small. But nothing stops from making it 10-100 times larger. The strength increases as much again, while the material is not poor.

But a thick pipe, in addition to its illuminatory advantages, has also other advantages: the smaller its diameter, is the greater is the number of compartments insulated from one another, into which it can be divided. It readily diminishes the risk of being deprived of air and dying in the vacumn.

Let us suppose , for example, that the length of the dwellings is 3 km and diameter 3 meters. Then it can be divided into 300 compartments, each of 10 meters length, 3 meters width and of 70 M^3 capacity (internal volume). It is a very respectable hall, fully sufficient for accommodating an average family. Its lit surface will be 30 M^2 which is fully sufficient for the kitchen garden feeding the family.

Wherein is the safety here? Let us suppose, that one of the compartments begins to discharge gas outside. The manometer will immediately point it out. Then the family moves to the neighboring compartment, while the fault is insulated. It is later examined from within and without, by joining hands, in special proofed dresses, and repaired. Then the family returns to its convent. It is clear, that the greater the number of compartments, the less is the danger. There may be special accessories for automatic indication of the places of gas leakage.

Air in the compartment would be polluted if there were no plants and their soil. But as on the earth the cycle is completed, purifying the atmosphere and the soil, so it is in our little world, i.e. in the family apartment. We shall provide details, when we describe the breeding of plants).

We shall now divert our attention to the temperature of the dwelling. In case of the described arrangement and its distance from the Sun, being equal to its distance from the Earth, i.e. in the Earth's orbit, a tolerable temperature is possible only when the dwelling is rotating, when the windows are turned sometimes to the Sun, and sometimes in the reverse direction i.e. when in the dwelling there is alternately sometimes day and sometimes night. It is possible similarly on permanent turning of a part of the windows to the shaded side, when 0.1 of the entire internal surface (or 0.3 of the projection) is lit an the inside.

Temperature, in general will depend on us and may be changed from 250°C to + 200°c, keeping in view which part of the Solar light we shall make use of. In a word, it is permissible to obtain not only all the climates of the Earth but also the climates of all planets of the universe.

One thing here is not all right. Economy requires that we made use possibly more quantum of solar energy, with the help of the plants or other methods. But then + 200°

will be obtained and all will be burnt. To expend light, turning away from it is offensive. There is a simple method: it is to recede to another, more distant orbit between the Mars and the Jupiter, closer to the former. If we recede twice farther, the Earth from the Sun, then we shall obtain heat not less than, the quantity of heat required for a human being and plants for their lustrous development. Then we shall not have to turn round and ignore the gifts of the Sun.

For some time it is permissible to live inthe orbit of the Earth, but is wasteful .. On a double distance we shall acquire a Solar position four times larger, than on the Earth distance. There we shall find much material, since it will be behind the Mars, already in the belt of asteroids. (There is a method and not wasteful - to make use of the entire Solar energy without recession from the Sum).

Thus, of what type will the Sun's attitude towards us be how shall we feel in our dwelling due to the presence of the Sun? We shall get eternal day or eternal night, or alternation of one or the other, depending on our desire. Plants may be benefited by the eternal day, while human being, accustomed to sleep owing to the rotation of the Earth, protect may themselves at the time of rest by a screen and may be benefited by full darkness. We always have bracing weather and the temperature is according to our choice. Clothes and shoes are useless. Abundant foodstuffs are the plant products. There is no possibility of pollution due to the absence of polluting bacteria, insulation and always possible disinfection of each compartment by means of raising the temperature up to 100°C and more. Yes, on a double distance from the sun, it is permissible to raise the temperature intensely. But this we shall discuss later. Is it permissible to compare all this with the unfortunate Earth --- .

We now come to an even more important circumstances and the invaluable gift of ethereal spaciousness viz. the absence of apparent gravity. There is mass, but the force of gravitation is as if it were absent.

Our dwelling rushes with a velocity of several tens of versts in a second, several million versts in 24 hours, depending on the distance from the Sun : the closer it is to the Sun, the quicker it is and vice versa. But we do not observe this motion at all, as we do not feel the motion of the Earth. It appears to us that we are immersed in absolute silence.

The forces of gravitation of the Sun, the planets, the stars and all the celestial bodies are acting on us. But we do not feel then, as we do not feel, the pull of the Sun on the Earth. On the Earth we perceive only its tension. But in our dwelling, it is far from the Earth; in place of the Earth there is the tiny mass of the pipe, which according to its smallness does not exercise on us any noticeable pull.

The pull of the Sun and other celestial bodies forces us to fall to it and therefore forces us to describe a curved line, similar to that which the Earth describes. But the fall of our dwelling and of ourselves is similar. Therefore we do not observe it, as we do not observe when on the Earth, our fall onto the Sun.

Gravity is virtually absent, as apparently the motion is absent. There is neither gravity nor motion, if we do not effect it overselves. What are the after effects? The building, no matter how great, even at several tens of versts, cannot go to ruins and cannot fall anywhere. There is no struggle with gravity at the time of construction. Only when the dimensions of structures are planetary, at several hundreds of versts, their parts, mutually attracting, may exert perceptible pressure on one another. When the resistance of material is insufficient, they come closer and disintegrate. But this disintegrated edifice cannot fall anywhere, as the Moon does not fall on the Earth and both on the Sun --- The bodies may be held stationary without any support and without coming into contact with one another.

Their direction is also neutral in respect of rest. For example, we in our dwelling may not fall hang (without ropes or other support) in the air, having turned our head towards the Sun, or the legs towards it, or the sides as we desire.

There are no loads with us — only masses exist. We can hold any mass in our hands without experiencing the least of gravity. It may be on the head, on the back or under the feet — we anyhow do not feel it. From here it is evident that we have no need not only of clothes and shoes, but also of furniture. Why are chairs, easy chairs, beds, mattresses, pillows etc. needed. Human being himself is not squeezed for any reason, nobody presses against him, every place is as "smooth", as any feather-bed can be.

Why to wrap up tender ruits, glass crockery breakable objects by straw, wooden-shavings, cotton-wool, or rags, if there is no mutual pressing -- Is not all this really a great advantage of our medium.

Up and down do not exist. So long as the human being does not get accustomed, the up appears above the head and the down under the feet. So, up and down are changed according to choice. How a person feels himself for the first time without a support and without a bottom under his feet? Later on the illusion of 'up' and the horror disappear. But for the first time, dwelling, walls and floors and even contact with it are necessary for soothing.

Let us now examine motion. We shall not speak about true motion, which otherwise does not exist: there is motion with respect to the Earth, and the Sun or any other heavenly body, absolute motion is unknown. But we are discarding even our planetary motion (our dwelling hurries away as a planet), i.e. the motion relative to the Sun. But we do not feel it and we shall not speak about it for the time being. We have in view only motion, effected by us: by means of muscles, machines or by something else.

The aggregate of dwellings, having enormous range in length and breadth and immeuse mass will be considered by us stationary, as, examining the human terrestrial movements, we consider our planet stationary.

We, for example, are in a spacious hall, here we are performing different experiments of motion.

Let us suppose, somewhere in the middle of the hall, some stone, table, commode or any other object is located, parts of which do not interact and do not change their position, as, for example, in a working machine, or in an animal, so we are bringing to our imagination one solid inorganic body.

With great difficulty we can fix our object (table) stationary. Let us suppose we achieve it. What will then happen? It will remain eternally stationary i.e. it will rotate or change its position with respect to walls of our premises. What ever position we have given it, will remain in the same for centuries together.

The same we could do with a human being. to fix him immovably, having requested him not to move with limbs. Then he will not come close to or recede from the walls.

And then we offer him freedom of movement and request him to bring into action his feet, hands and whatever else he wants, and come close to us. What will he see? He will convulse, all his limbs will come into motion, but he will remain at his place (if we imagine, that there is the vacuum around him). He is moving his feet and hands completely freely, he is bending like a crushed worm, turns his head right and left, adopts all postures (sitting, standing), stretches his hands and feet in all directions, but the center of his gravity will remain, as if, nailed. He remains at that very place and does not move by a single centimeter.

We request our friend to turn round as the children do. Bt in it he does not succeed, in spite of all his might and desire to comply with our request. When he is tired and calms down, then his face is turned to the same direction, as it was in the beginning, when we had fixed him in a stationary position. The direction of his body similarly has not changed in the least. If matter stands like that, then how is it possible to move, to direct oneself in different directions. Nothing can be more easy than this. One may rotate as much as one likes and move in all directions in the vacuum just as in a gaseous medium. In a gaseous medium only the palms of hands are enough. They can serve us as wings. Soon we sould learn by pushing air, rotate and move whereever we desire. But palms are bed wings — their surface area is too small. It is necessary to take in hands light lamellae approximately of 1 meter ^{2}. With their help it is possible to turn and move very quickly. Wings may be even smaller. But to overcome the force of gravity is not required, only one has to combat with the inertia of the body and the resistance of the medium, that is its inertia and friction. For this purpose only the slightest efforts are required, if only the velocity is ordinary, for example, on Shanks's more.

But in the vacuum too just as in the air , other methods can be employed. In the vacuum they are compulsory, since in it there are no other means of motion. In the air of our dwelling they are not required, there are plenty of wings. All the same we shall continue the experiments in our hall, ignoring the resistance of the medium, which is not large during the common primitive speeds of human beings.

We have seen, that a human being can not set himself in motion automatically, i.e. he cannot acquire translatory or rotatory motion, he can not even turn to the other side. Irregular movement of limbs is obtained and that is all. At last all revert to the original position.

But let us imagine, that a human being is dressed. He removes his hat or jacket (this is possible) and flings them to one side. These objects move, but even he will not remain at his place. He moves slowly in the opposite direction, till at last he strikes against the wall. If there were no impediment his motion would continue eternally, uniformly along a straight line.

The greater the mass a flung object has and the more powerfully it is thrown, the more quickly a human being changes his place. If two persons of the same mass are pushed away one from the other, then both would move with uniform velocity in opposite directions. If one were pushed from the two or with double the mass, then he would acquire velocity twice that when both were pushed.

Moreover it is difficult to avoid rotation: the masses pushed one from the other, in addition, rotate. In general their motion is similar to the motion of carriage wheels, a planet, children's top etc. But theoretically repulsion is possible without rotation, i.e. absolute translatory motion.

Let us examine rotation separately. Again we shall turn to our dressed human being. We shall request him to remove his cap or boots and begin to whirl them in the manner of the toy top. Now we see the whirling boots or the cap. But the human being, who has removed it also begins to turn slowly. In a word, he himself is whirling slowly like his cap, only in the opposite direction. The more massive and more spacious a thing, which he whirls is the more quickly it whirls and more quickly our human being will whirl. If two persons of the same form and mass whirl one another, then both should have similar angular motion of rotation. If one of them whirled around his height, while the other around his width then the latter would rotate slower, since the circumference of the transverse axis would be larger.

In the air, of course, the rotation on account of friction source or later should stop. But in the vacuum it would be permanent and uniform, as the motion of planets is uniform and eternal. And two whirling persons, like dolls, will eternally rotate. Their will is not in a position to neutralize this motion, as the translatory one. But if they again get coupled with one another, then the motion of both will stop i.e. there would be no rotation.

Let us imagine a small group of people without support, completely at rest and not rotating. The common center of their gravity is unshakable. The moment of rotation eternally is equal to zero. But each of them can give himself airs, make faces and strike all attitudes as much as he desires. The movement of all their muscles is as free as on the Earth. Pushing away one from the other, they can acquire all types of rotational and translatory motions. If any member having acquired all this cannot hold together the entire small group or is not tied with it by rope, never loses either its rotational, nor its translatory motion. He will eternally remain a child's top and for centuries will part with his friends. He will move eternally uniformly and in a straight line. Thousands, tens of thousands of versts will be covered and still it will not stop. All may disperse wherever they want, but the center of their gravity will remain nailed, fixed to one point of space.

In order to stop motion, it is necessary to impart reverse rotation or reverse translatory motion to the other existing bodies with us. If it is insufficient, then the motion of the main body only will be retarded; if it is sufficient then it will stop; if it is excessively quick, then it will not die away, but will change direction.

It is now understood, how to create and stop motion in the air. In the dwelling it is possible to be pushed away by its walls, by any objects or by the air with the help of some small objects, or by the air with the help of smallwings, of course, not having any weight. In the vacuum the task is more dangerous and more difficult. There one must have support, ie. another body, even though not connected with the dwelling. A rocket, compressed gas or steam may be exployed, or any solid or liquid body.

It is possible to do without a movable support and without discarding the bodies (which fly away from us eternally), if we are to connect oursleves by a rope or a wire with the dwelling . Then we shall be pushed by it in the desired direction and shall continue to fly till the time, the string stops us. Later, on return, we are attracted towards the dwelling by the rope.

So, the motion in the ethereal vacuum, in a medium without gravity, may be of three main sorts (types). Straight-lined and uniform without rotation, rotational with immovability of the center of gravity and the axis of rotation and a mixed one i.e. joining of eternal rotational with eternal translatory straight-lined one.

There is still a more complicated rotational motion, in which the fluctuation of the axis of rotation is incorporated. But it is not stable i.e. not eternal and to a small extent shifts to simple rotation around the free (special term) axis .

We are not speaking here about the complicated bodies, parts of which are movable, or about the living bodies. Those and others may throw away visible or invisible particles. And that is why the motion pointed out laws will, as if, violated. Thus, every living being continuously climinates from itself different substances, for example vapors and gases and that is why it resembles the reactive device. A human in our dwelling, being at first absolutely immovable, under the influence of throwing away of gases and vapors, non-uniform circulation of blood, movement of heart and other organs, gradually acquires not only rotational, but also translatory motion. Only it is not suddenly but after a lapse of a considerable interval of time.

If there is no throwing away, then the weight of the body, living or dead, as if, it were not complicated, conform to three laws, namely:

A. If the center of gravity of the complicated body is at rest, then this rest will not be violated by the internal forces of the body.

B. If the center of gravity has motion, then this motion cannot be changed by the internal forces either by magnitude, by direction, i.e. this motion will be eternal, uniform and straight.

C. Here applies still the third, extraordinarily important law, relating to the rotation of the complicated body the motion of the parts of which and the mutual positions are permanently changing: rotational moment of inertia of this body eternally remains unchanged (about the moment of all kinds see in mechanics).

This law has, for example, application for the constringent suns, nebulae, planets and solar systems. Its applications are numerous. Thus, if the rotating group of poeple, interlinked mutually by hands, will be drawn together into a more coherent group, then it will highly accelerate its rotation and the more intense, if the group becomes more compact, and vice versa. Not only the angular velocity is intensified on this but also the absolute one ..

What the human being feels rotating or moving without rotation we shall again observe him or our selves in the dwelling. On account of being unaccustomed, the translatory motion is not recognized at all. It will be shown to us, that it is not we who are moving but the walls surrounding us: Similarly our own rotation is also not recognized. Turning round of the room is presented and not turning round of our-selves. It appears to us that someone has whirled our dwell-ing. We are the inhabitants of the Earth and are whirhing with it and re moving forward, having along with it still hundreds of diverse motions. But we do not perceive all of them as we do our own motions, but as the motion of celestial bodies surrounding us. Only the motions created by our own selves are perceived and recognized by us. Many of the motions of the Earth do not exist for our senses.

But then there in the ether, we create ourselves our small motions. Why do they present themselves as strange and not ours? The reason is in the evenness of this motion, not depending on owing to the absence of jerks, jolts, joggling and otherterrestrial consequences, not of ideal motion and rotation.

Nevertheless these illusions, at least in the dwelling, must with time vanish. At first, while we are in a ship, the coasts appear moving, but later me recognize the motion of the ship, as if it was not quiet and uniform . Such also will be indeed, in the ether .

Till this time we have been speaking about rest and motion in dwellings. But of what type would our feelings be outside them, in the limitless spaciousness of the Universe, in the blazing and stinging rays of the Sun?

Already through the windows of our edific, we can see much. The sky is black. Patterns of stars are the same, as on the Earth, only there is less redness in stars, there is more diversity in their colors. They do not twinkle, do not spark (flash) and on good vision appear as dead points (without rays). The Sun also appears as bluish. The Earth appears as a star, like the Venus, and our Moon is hardly visible. The pattern of constellation does not depend on our Moon is hardly visible. The pattern of constellation does not depend on our position in the planetary system, but all is the same: also from the Jupiter and from the Mercury, but the size of the Sun only from the Earth's orbit is the same.

In consequence of the absence of the atmosphere, the stars, nebulae, comets, planets and their satellites appear extraordinarily distinct. That which cannot be seen from the Earth without a telescope, is here visible with unaided eyes. Also with the aid of the latter one can see that which was totally and never visible from the Earth.

The special dress with a reserve of oxygen and the absorbers of human excretion provide us the possibility to come out of our dwelling.

Let us accommodate it in the shade. The Sun is not visible. The general picture is very strange. We shall feel ourselves in the center of a small black globe bestrewed with multi-colored points , stars and nebulous specks. Besides through the entire globe a wide nebulous band of the Milky way is drawn, somewhere bijureated. Each tine, being screened from the Sun, we are submerged in the night. Having come out from the dwelling and not going away from its shade, we shall at once see almost all the sky, the entire sphere.

The Sun would kill us by its ultra-violet rays, if the ordinary glasses of our dress and dwelling would not protect us from them. On the Earth, the atmosphere protects us from them.

Emerging from the shade, we shall see the Sun. It appears to us much smaller than from the Earth, similarly diminished, as the celestial sphere. It is only subjective: it has not the least diminished.

It is difficult to imagine what a human being would feel in the midst of the Universe, in the middle of this miserable black sphere, decorated by multi-colored bright points and plastered by silvery mist. A human being has nothing at all, either under the feel-or over the head. Perhaps he will imagine, that he will fall just now onto the bottom of this globe, towards the side, to which his legs are turned.

Pushed away from the dwelling, he will describe a straight line as if he must go away for ever from the place of his residence. But this or that is not at all true. The attraction of the Sun compels the one pushed away to describe a circle around the luminary (star), no matter in what direction he has started his journey. Thus, the line will not be straight, but curved. But one degree of this circle (on the Earth's distance) comprises more than two and a half million versts. Consequently, the locus nevertheless may be considered straight for the whole distance of hundreds of thousands of kilometers. If the human being, moreover, swines at the rate of one meter per second (speed of a footslogger), then his path in the course of several years will be straight, as an arrow. The entire circular orbit, he will fly then in 30000 Years. But after that, he goes so far from his dwelling, that he will not notice it.

If man has already spread in the immense celestial sphere and settled it longitudinally and crosswise by dwellings and other installations required by him, then the creature having been pushed away, will not be helpless. Everywhere he sees or is driven in on human buildings receives information and indication and returns wherever he desires.

How spacious is this field of the solar system, this sphere, which mankind might occupy?. On double the distance (comparably with the Earth) of its surface from the Sun it is 8.8 milliards (US Billion) (About 9) times more than the surface of the largest cross-section of the Earth (its projections), or 2.2 milliard (US Billions) times more than its entire surface. This sphere receives solar energy as much again compared with the Earth.

But the latter does not receive it (energy) fully: more than half is reflected by clouds in the celestial space, a part is absorbed by the atmosphere, part vainlessly falls into the oceans deserts, on the mountains and in the snow-fields etc. In the sum total, the Earth receives hardly more than 10% of that, which falls to its share.

In this way, the value of this sphere, of its eternal day of virginal rays of the Sun is still 10 times more and is expressed by 22 milliard (US Billions) in relation to the Earth.

The spaciousness of this bright field cannot be determined even by this figure. It is millions of milliard (US Billions) times more than that of the Earth. However, it does not have the main importance but the solar energy.

Of course, motion and its laws are similar within and without the installation. But the perception is more miraculous.

Translatory motion is not at all observed and is ascribed to the surrounding artificial bodies. It is not reflected in the least on the location of stars and planets. Thus, if there are no people all around and their buildings, then all appears stationary.

But is difficult to acquire a rigidly parallel translatory motion. It would be unnoticed if rotational motion is not mixed with the former. The latter, if it is weak, then it is not ascribed to itself, but forces us to think about the revolution of the black celestial vault. The axis of rotation of our body becomes the axis of the world. Thus if we are rotating around our altitude then over the head there will be one pole (with the "Pole" star) and the other under the feet. The remaining stars will describe circles in that very time, in which a human being performs his turn. For example if in 10 minutes, then the stellar sphere will perform its turn in 10 minutes. Quick motion may cause reeling of the head, disease and even death. And therefore it can be admitted by human being by its after-effects.

It is difficult, similarly, to recoil from the illusion of 'up' and 'down'. Over the head is imagined 'up' although this head due to the rotation of body around its transverse axis all the time was lowered and raised: It is demonstrated to us that stars drop down and are lifted up. In the drooping down of the head we do not believe: it is, as if, immovable and over it is 'up'.

The bottom under the feet without support also scares us. All appears to be falling. The absence of support-floor or soil, amazes us.

We do not here touch upon the advent of the Cosmic life. Its support is located on the Earth. The first dwellings, instruments, machines, plants nurseries, workers etc — all this is conveyed from our planet. We may only describe here the gradual migration of the migrants to the independent activity free from the Earth: the development of industry, population and its spread in the celestial spheres. Thus, the colonists for the first time are fed by the reserves brought in and only gradually get attached and attain independence, prosperity and propagation.

We assume this as the beginning of life being already imitated. It now remains for us to describe it. But how it is prepared on the Earth and brought into the ether — does not concern us.

Can the absence of gravity harm the health of the human beings? Gravity enhances the circulation of blood towards the legs. Its elimination, on the contrary, enhances the flow of blood towards the brain. Therefore, a person with weakened walls of blood - carrying vessels, inclined towards the apoplectic stroke, runs the risk of dying on immersion in water, or in a lying position, or the more so upside down.

In the water and in lying conditions, the pressure of blood becomes almost uniform as during the absence of gravity.

Therefore the absence of gravity is as much harmful or beneficial as even the lying position. Such a position is beneficial, rather necessary to the diseased or the weak. Therefore a medium without gravity for them, doctors and the legless is a neat paradise: there are no bed-sores, all the parts of the body are accessible and all movements are free. To the healthy, lying, in the course of time becomes unbearable. But then this happens more due to the fact that the lying (person) is forced to physical inactivity. If he could work on the bed by muscles, then the oppressive feeling, would disappear. But to lie tediously is to create less impression. It is also a reason. In a medium without gravity, work by any muscles, fully depends on us.

The Gravity promotes defecation and deglutition. But then all this may be done only in the horizontal position. Hence, the absence of gravity is here not compulsory. Acrobats contrive to drink and eat even when they are head down legs up, and this is not deception.

Standing position on the Earth gives birth to familiar diseases and therefore its plenty is surely harmful.

In the ethereal dwellings, utenstils, instruments and all the articles of use, do not need brackets, shelves, stands, counters, and the like. This is good. But, in the absence of gravity, due to the least efforts, even due to the unavoidable movement of air, they will not stay at their places, but will roam about in all rooms, as living beings, as particles of dust.

It is unbearable and dangerous: during respiration there would be small peas, nails pins and the like, which may enter the throat and kill human beings. But all small bodies may be held in light packets, drawers, boxes and bags. The larger ones in networks. This is very easy, since the least efforts are sufficient for it. They can be held even by a small rope.

What is to be done with the soil, required for plants? During the slightest jolts, friction movement air currents, and dryness, soil will collapse from its place and will be carried by air in the form of dust particles and granules of clay, sand, lime etc. It is also not admissible. Stro g winds even on the Earth carry not only dust — it is always in the air — but also large grits, even small stones, leaves, insects etc. But without gravity, the task is much more serious and frequent. Of course, air, before serving for breathing, must continuously be strained through a filter, fabric or different liquids.

But this is less. Here it is necessary to have recourse to excitation of artificial gravity. There is no need to make it as great as that of the Earth and thus to overburden people by it for struggle with it (Gravity) to the tune of 1/100 or 0.001 that of the Earth is perfectly sufficient. Let us fix it at the latter, the weakest. In what respect is it insufficient? Under its influence all large bodies will fall onto the artificial "down", i.e. on the floor, since then floor ceiling, etc will make their appearance. But the fall will be slow: in one second the body will fall half a centimeter, in 10 seconds half a meter and in a minute-18 meters. It is clear that even a minute is sufficient, so as to rid the highest hall of wandering bodies large, or small.

In special nurseries for plants weak artificial gravity is particularly needed, so as to hold the soil in its place, of course, fine dust, grains of sand and wandering larger bodies are not dangerous to the plants. But all the same they are harmful, since the solar light is screened from them. Besides,how would the plants live, if the entire soil is dispersed into air..

In the ethereal medium acquiring of artificial and continuous gravity decidedly does not cost anything. Only if it is great, then the nursery of plants and human beings have to be made a bit stronger and therefore more massive.

Gravity is produced by the rotation of the body. Rotation in the vacuum is eternal. And therefore gravity will not only be eternal and continuous, but also not worth any cares. The quicker the velocity of the particles of the body on the circumference and the less the radius of this circumference, the gravity due to centrifugal force more powerful and vice vesa.

Let us imagine a long conical surface or funnel, the base, or the broad hole which is covered by a transparent spherical surface. It is directly turned towards the sun, while the funnel rotates around its long axis (height). On the opaque internal walls of the cone there is a layer of moist soil with sown plants on it.

This is the method to make full use of solar energy, without excessive increase of temperature, even at Earth's distance from the Sun. The longer the cone will be, the more would be its surfaces; in case the transparent base is one and the same, then the lower will be the temperature inside the cone. On the Earth's distance, this surface must be about four times more than the glass area. For this it is necessary, that the generatrix (a little more than the height of the cone) was two times more than the diameter of the base. Close to the Sun, the cone will be longer, farther — shorter. Even when the distance is closest from the Sun, the temperature of the cone, of its plants and gases may be done supportable. Thus at a distance, 10 times, less than that of the Earth, the cone must be lengthened 100 times. Its base will be 200 times shorter than its height.

Only to connect the rotating cones with the passages is more difficult, than the cylindrical human dwellings mentioned before.

But it is advantageous to make plant nurseries separately, since they do not need thick atmosphere and strong walls. Thus, besides economy of the material, the special atmosphere, though rarefied, gives maximum yields . Occasional destruction of plants due to leakage of gases does not have any importance. One thing is not wholly convenient: the excretions of people must continuously enter the greenhouse, while the products of active life of the plants (gases, fruits etc) — into the dwellings of the people.

In our cones, solar rays obliquely illuminate the plants and therefore their activity is weaker. In cones, they not only make eternal day, but also eternal spring along with the specific desired temperature, most favorable for growing plants. Their rotation and the artificial gravity produce as a result of that, hold the moist soil and the plant excretions in order. We shall find the ripening and the separated fruits fallen on the soil, and not wandering in the free space of the cone.

In the dwellings and other structures of human beings the weak gravity is not useless. Its value 0.01 of that of the Earth cannot obstruct motion and operations. Let us suppose, that we have an accommodation in the form of a sphere with a diameter of two versts. The sphere slowly rotates around its diameter. The velocity along the circumference (equator) is about 10 M/sec. Complete turn is performed in 600 seconds or in 10 minutes. The maximum gravity, on the equator, is 1/100 of that of the Earth. A jump from the internal circumference to the center lifts a person to 100 meters, so that the motions are not hampered and gravity is not observable.

The phenomena of motion in such a sphere are complicated and we shall not at the moment touch upon them.

The types of dwellings of human beings and plants may be infinitely diverse and we shall also leave them here for the time being.

We shall elucidate the very important: how are the specific temperature, humidity, specific composition of air and good food for plants and human beings secured in a combined dwellings ?.

Light rotation produces gravity, saves from litter and establishes order. The glasses are thin, transparent,and permeable, as for as possible, for all types of rays quartzitic or some others. The rays are weakened by them and by the thickness of the walls of vegetation. Therefore, they are safe for human beings. Type of plants selected are fruit bearing, grassy, small, without thick trunks not cracking in the rays of the Sun. The more they utilize the Solar light, the more fruits are produced, and the more Solar energy (heat is absorbed. But it returns, since fruits are eaten up and people return heat absorbed by the plants to their dwelling, only on (storage) of fruit (reserve) this heat is temporarily retained.

The number of plants must be such the oxygen yielded by their roots, leaves and fruits yield is fully absorbed by the inhabitants of the lodgings. If the latter consume more, then the people breathe with difficulty and grown, weak and plants become more healthy due to the abundance of carbon dioxide; if it is less, then it is easy for the people to breathe, but the plants do not get sufficient carbon dioxide and they become weak. Equilibrium is maintaind automatically on apt selection of plants. Regularity is completed still by the number of lodgers. In a word, the number of people must correspond to the characteristics and number of plants,.

What would be the source of water for plants and human beings of which, apparently, very much is required? Its quantity is fixed and does not change: does not decrease and does not increase. How can it be so? plants, living beings and soil in the dwelling continuously evaporate water. But these vapors cannot vanish in a tightly closed dwelling. They are accumulated in a condenser in the form of water. The shadowed portion of the premises has a separate compartment with any low temperature. It only costs, the compartment to turn towards the dark celestial space and to insulate from internal heating (likeness of domestic mural heating) and we shall obtain the desired low temperature. Into these compartments, more or less moist air is introduced, where it leaves that much vapor which we want since this depends on the rapidity of circulation and on the lowness of temperature. One or the other is in our control.

Water from the condenser is supplied for drinking, for washing, for sprinkling on the plants or moistening the soil. But not only water continuously circulates from plants towards the condensers and also back, but the same does the air. It is introduced into the soil by the help of special pipes and after having fertilized the roots and bacteria, goes out fully purified and is fit for breathing.

Human excretions are diluted with water and are similarly directed towards the soil where bacteria soon turn them fit for feeding of plants.

In these premises of ours neither continuous flow of water, nor the flow of food for plants and animals is necessary. The specific reserve of gases, water soil and manners serves without exhanstion.

On the Earth the same is performed only on a large scale. But on the Earth the manures are taken away to the oceans and sometimes they will still be recovered from there. In our own lodgings if they are spent, if they are accumulated (stored) in fruits, then without delay they return without any loss. And on the Earth, insulation by suitable plants will be found out with the passage of time, their food and water. It will be started from deserts where it is insufficient.

For example the atmosphere is pure, the air is humid according to desire temperature and the composition of the atmosphere are regulated also as desired. We have got a permanent inexhaustible source of pure distilled water, oxygen heat and food. Clothes are not required.

There is no gravity, legs do not swell, and the boughs of plants do not bend due to the weight of fruits. The saps of plants freely spread, without being hampered by gravity.

Although we make use of feeble artificial gravity, it is so infinitesimal, that we can ignore it and forget about it and we consider ourselves in a medium, free from the forces of gravitation.

The temperature of the dwellings fully depends on us. What is the necessity of clothes ! (---). Permissibly we have to cover all the desirous ones: others have ugly bodies, some deformities, old age. All may wear some dress of their choice and decorations with the consent of society.

In general, in a moment we can give the desired temperature to the aged people sensitive to cold, the indisposed and the prematurely born babies etc. Of course, we shall have to arrange a dwelling conforming to the characteristics and desires of the people. Those desiring always to have high temperature may be found. The inhabitants of Equatorial countries, patients, the weak and the old require $30^{\circ}C$. Others — 25°. the third 20° — all being different. This requirement will be met by each structure . One and the same accommodation may change temperature. Thus, for sleeping, enhanced temperature is required. But then there are neither feather-beds, nor mattresses, nor pillows, nor quilts, nor the night dresses. During meetings in large halls, one feels hot while the other feels cold. Let us suppose we shall maintain in the hall a temperature of $30^{\circ}C$, i.e. $24^{\circ}R$. In this case none will feel sensitive towards cold and without clothes, but to some, it will be hot. If we maintain the temperature at 25°C, or 20°R then without clothes the weak will feel cold and they will have to be dressed up.

A change of temperature and directly the Solar light here is made use of for quite diverse purposes. For example: for disinfection of the soil, the atmosphere, walls and all objects of the dwelling. People and plants for this purpose are removed from the dwelling and the temperature is raised to 100-200°C. It is understood, that all the minute organisms will be destroyed. That is why agriculture will be eased: there would be no pests. Pure culture of desired plants will sprout.

Regarding their selection, suitable temperature, atmosphere and feeding — how miraculous harvests and wonderful fruits we can obtain ! So this is without the least worries: there is no need then to weed out, destroy insects, fight with drought and torrents etc.

Chemical processes, for example, the processes of decay, fermentation, during which different spirits, vinegar and other substances are obtained — need specific temperature. We give them this. Our factories obtain this, if it is not higher than 200°Cm in buildings, similar to the dwellings. If it is too high, then we make use of special structures (buildings), where heating also takes place only by the Sun.

Water and all-possible very clean fruits, free from every infection, satisfy our hunger and quenchour thirst. None of the diseases — neither catarrhal nor infectious — are possible. The very body of the human being is permeated by the rays of the Sun, and is freed to some extent by harmful bacteria. The more humanity is freed from harmful outbreaks, then farther will it be from what it is now born thriving with.

If the human being has a dwelling with the desired temperature, virginal Sun, day and night on choice, water as much as he needs (one reserve for ever), food, — and if he does not need clothes, moves wherever he likes without any effort — them what else is required by him?

But, firstly he is multiplying (his race) since it is advantageous for him (the greater the population, the more perfect is the social echelon and the more are the geniuses — leaders). So, he needs new dwellings, i.e. we require material and its processing. Secondly, he studies substance (matter) and the Universe. So, he needs the very such devices, as are made use of by scientists on the Earth. He will improve plants and his own self. All this requires new and newer **appliances.** Their manufacture requires a large number of factories and mills, wholly identical to those of the Earth. Furniture and effects: will be different, but then it is invevitable. Also books etc.

For the first time we shall make use of materials from the Earth, But the transportation from it will consume large quantity of work. Transportation, From the Moon and small planets will be easier. Still easier is to make use of asteroids with diameter of several versts and still smaller bodies, which have no count between planetary orbits, particularly between the orbits of the Mars and the Jupiters.

On tiny planets there is no atmosphere and no liquids, but there is large quantity of hydrated and constitutional water, gases, metalloids and metals of all kinds on them. It costs only to decompose dry minerals chemically.

Mechanical forces are required by us from which to acquire them Mechanical force in our ethereal region is two thousand million times more, than on the Earth. It is contained in the rays of the Sun. It is possible to extract it through the medium of plants and directly from the Solar rays, The Sun can give us lignine, coal, starch, sugar and all the countless multitude of substances, obtained now by plants on the Earth. They are such a source of energy as coal, waterfalls, and wind on our planet. This source of energy is made use of, as on the Earth, i.e. in lodgings, where there is oxygen. But this is inconvenient, since soon the atmosphere will damage them.

One may directly use the heat of the Sun in exchange for heat of combustion. With us it is inconvenient and disadvantageous on the Earth Air and wind cool the bodies heated up by the Sun . The Sun shines only in the day it being often covered by the clouds and half of its heat is always absorbed by the atmosphere, the force of rays is inconstant due to their changing inclination, there is no good condenser with low temperature; the mirrors amassing the heat, quickly become foggy due to air and humidity; they are heavy, breakable (fragile), costly, and cannot be as large as required. All this renders the employment of the Sun uprofitable for the installation of thermal engines on the Earth.

It is an entirely different story in the ethereal vacuum, in a medium without gravity. Here at one place it is possible to acquire, even without mirrors, temperature of 200° and nearly at a distance of one meter 270°C. Thus the heat of the steam engines can be employed with large utilization, working on the vapors of water, the ether, spirit and other liquids.

It goes without saying, I am quoting examples only of motors, but they can be quite of a different sort. We shall portray the steam engines in the simplest form. We have two identical vessels. insulated one from the other from the point of view of heat. The rear one is in the shade of the front one, which is turned to the rays of the Sun. The front side has black surface absorbing the rays well. This and the liquid under it in the vessel are heated up by the Sun not higher than 200°C. The vapors of the liquid, before going into the condenser, i.e. into the rear vessel of the same design, as the front one — pass through the common steam engine or through the turbine. On appropriate selection of the liquid and arrangement of the machine the utilization can easily touch 50%. Such a machine will give for each M^2 of the black surface, turned towards the Sun, more than one hourse power.

When almost the entire liquid is transferred from the front vessel (boiler), then the vessel is turned about with the condenser towards the Sun, while that with the boiler towards the dark celestial space. In a word, the roles of completely similar main parts of the device change (automatically) approximately every hour, keeping in view the volume of the boilers. The latter, of course, are comprised of small tubes, as carpets from threads. The liquids cannot be lost because all are tightly covered against the leakage of vapor.

We cannot now say, what type of engines would be in use. Certainly, of many types and systems which it is not possible to foresee now.

Boilers may have a surface of any size, since gravity does not hamper it. So, even their power may be any.

The substance of factory industry consists of the following.

A. Their elementary constituent parts are obtained from minerals, for example gases, liquids, metalloids and metals.

B. The compounds required or useful for us are synthesized from elements, for example gases, scents, paints, medicines, edible substances, acids, alkalis, salts, fertilizers, alloys etc. (and the elements, and the required compounds sometimes occur ready-made in nature).

C. The required form is imparted to alloys or other constructional and, in general, solid substances, for example tools and instruments, machines, utensils, scientific instruments, paper, fabrics, dresses; diving helmets, dwellings, factories etc.

For all this (A.B.C) the following media serve on the Earth: increasing or lowering of temperature and pressure, electricity, catalyzers. (an insignificant admixture of various substances, promoting the chemical process), mechanical forces.

Without tools and instruments, of course, work will not go on. Their ready specimens already exist on the Earth and these very tools will be used outside the atmosphere.

At first man had no tools and instruments, like the animals, later he began with very simple ones. With the help of these primitives implements, better ones were made. From better ones, still better and so on till the time the modern ones were developed, exciting in us deep surprise and delight. Their progress will never come to an end and in the ether the progress will be made in conformity with the new conditions.

It is known, how an increase of temperature is obtained on the Earth. But here in the ether these means are not needed by us, except in special cases. Here, increase (of temperature) can always be obtained by the force of the Solar rays, very economically and to any degree, — from - 273°C to the temperature of the Sun.

For obtaining the lowest temperature, protection is provided against light by brilliant screens and radiation of black bodies is made use of in the celestial space. At this stage a temperature of -273°C is obtained.

The most economical heating up is roughly of the same type. A chamber of the desired size and form is covered on all sides by several layers with good surfaces, reflecting rays. Thus the heat in the interior of the chamber is preserved, i.e. it is reflected again inside it. and the temperature does not fall, as if, it was not high earlier. It is like a thermos, bottle only more highly developed, which is improved by several jackets (shell) and the absence of a material medium such as air around it.

The heat of the Sun enters the chamber through a small hole, A parabolical mirror at the back of the chamber (with dimensions more than those of the chamber) amasses the rays of the Sun into a small facusing group, exactly of the size of the hole of the chamber. Here the rays diverge and heat up the space inside the chamber to the temperature of the Sun, howsoever small the miror is. But this is during ideal conditions: during full preservation of heat, in case when the hole is point like, and on the perfection of the reflecting mirrors. In practice, there is nothing like this and, therefore, heating up is only then close to the temperature of the Sun, when the size of the mirror is many times larger than the size of the chamber. Later on, some inevitable heating up of its walls worsens their reflecting capacity and also hampers the attainment of the temperature of the Sun i.e. 5-10 thousand degrees.

In the focus of the parabolical mirror, an image of the Sun is obtained. The smaller it is, the smaller is the hole of the chamber and the smaller will be the loss of heat, and the higher would be the temperature of the chamber.

But on the other hand the coming (production) of the heat is proportional to the surface of the mirror. Let us suppose that the radius of the mirror is one meter. The image of the Sun will be in the main focus, at a distance of half a meter from the mirror. The angle of the solar image at a distance of half a meter will constitute about half a degree (such is the angular measure of the Sun from the Earth). The true measure of the solar image will be (in mm) equal to the sine of half a degree, multiplied by 500 mm. We shall obtain about 4.3 mm. If the radius of curvature of the spherical mirror is not one but P meters, then the image of the Sun will be P times more. For example for a mirror with radius of 100 meters, the diameter of the image would be about 430 mm. Thus, the larger the radius of the mirror, the larger is its image and the larger the hole in the chamber and the greater is the consumption of heat and so is its (production). We assume all mirrors to be identical, i.e. consisting of one and the same part of the full spherical surface. In these conditions it follows that the temperature of the chamber will not depend on the dimensions of the mirror. But this is not wholly so: a large mirror will give in the chamber the highest temperature, because not only the hole in the chamber is lost, but also all its surface. Then we have still one advantage of a large mirrors: the rate of heating up of bodies, accommodated in the chamber, increases with the dimensions of the mirror. Besides they provide more heat in a unit time, and if this heat is absorbed by the chemical processes inside the chamber, then the processes are completed quicker.

Let us imagine for the sake of simplicity, the mirror to be circular, like a small plate. It forms a part of a spherical surface. Let us draw from the center of the imagined sphere a radius towards the rims (circumference) of the mirror (plate). We shall obtain an angle. This angle cannot be larger than 180°C (hemisphere). But such a large angle is almost useless, since it captures rays little more than a mirror with an angle 90°, even 60°C. We shall accept the last angle for mirrors of all dimensions. Their diameter will always be equal to the radius. Thus, if the radius of the mirror is 100 meters, then the breadth of the mirror will also be 100 meters, and the size of the image will be 430 mm. It is always 233 times less than the breadth of the mirror. Imagining the chamber as a complete sphere, we shall find that the practical breadth of the mirror is not less than the doubled diameter of the chamber. If, for example, the chamber is of one meter, then the dimension of the mirror is not less than 2 meters. A fourth portion of its surface will be in the shade of the chamber. Therefore, it may be made ring-shaped . But the ¼ portion of the solar energy being lost may be utilized by means of a biconvex glass or special mirrors. And one or the other will be in front of the chamber closer to the Sun.

The mirrors may be of enormous dimensions, since even with their thin surfaces and small massiveness they are intact, not bending due to gravity, which is not there. For more accurate form it is useful to give them a weak rotation along with the chamber, with which the mirror comprises a single body.

For the pressure for the accomplishment of certain chemical processes, requiring specific temperature, some devices and catalyzers are made use of. The temperature is easily controlled by the largeness of the surface of the mirror and by different types of valves. If more of specific pressure is required, then the hole is required to be tightly closed by a transparent valve for rays.

But by those very chambers it is possible to be profited for the heating up of prepared alloys with the prupose of their casting, moulding and forging — for imparting desired forms.

Now we turn mechanical reaction for processing of cold or preheated, hard and semi-hard materials. We have already spoken about the simplicity of the working principle of motors, each square meter of the surface of which gives one HP. For obtaining it (M:), of course it is permissible to make use of mirror and also chemical processes so, mechanical energy is in abundance. (It iseasily converted by familiar methods into electrical energy if it is impossible to make directly by solar radiation. Electrical energy of high potential, as is known, may give a temperature higher than the solar one).

Will the machines work without gravity? A support for them, if it is needed, we always have in the massive multi-chambered dwelling or special premises. We shall now examine the working of several machines in a medium without gravity.

Coal and fuel wood will fly out from the oven. If the furnaces are surrounded by grates, even then small particles of coal will slip out from the furnaces. Besides, a thin grate will burn or melt. Fuel wood and coal will not lie at the bottom of the oven, they will spread in all its space to the very ceiling. This may be tolerable. The natural attraction will not be there and therefore an artificial one is required. From here it is evident, that coal, wood, and peat furnaces are inconvenient in a medium without gravity (except for want of spacious oxygenic atmospheres). But, we do not have any need of ordinary furnaces in the ether, secondly, if it happened that they are needed, then we could make use of coal powder, liquid fuel or artificial pull. In general, in a medium free from gravity, heating up is carried out by the Sun, while cooling — by the radiation of bodies.

We have seen, that sometimes in engines, boilers with liquids will be used. The liquids will not occupy the lower part of the vessel, because there is no bottom, but will be distributed confusedly in the entire space of the boiler pell-mell with their (liquids) vapors. In this way, along with the vapor the liquid will also escape, which is unsuitable. But it is possible to establish order in the boiler, if it rotates or if during its immobility the liquid rotates inside it (boiler) . by means of a wheel with vanes (blades). And one or the other is easily accomplished in a medium without gravity. Then the liquid will be distributed along the equator of the boiler, the axial portion of it will be occupied by vapor ...

Let us imagine some factory. Wheels are turning, different rods are swinging, shavings are flying and the workers are dozing like fish in water. If the entire factory rotates, then gravity will be produced in it and the conditions of work will be the same as on the Earth, varying a little only, depending on the magnitude of the artificial gravity. If there is no rotation or it is slight, then the gravity is almost not felt. The waste matter of a different type then must be collected in a special delivery basket, air is constantly filtered of dust and the small flying bodies. Magnets can collect iron, steel and cast iron sharvings and dust.

But in many industries (for example, rolling works, press-work) there is no waste or it is harmless and easily eliminated. There artificial gravity is not needed. At last, when the waste is loaded on a worker, then his head may be protected against any eventuality, by a gauze or glass, while the mouth by a special pad. Special dress will similarly serve as a shield. But on the Earth have we been guaranteed from waste matter in the form of flying insects and quick-flying shavings?

Workers and engineers hasten amidst machines and products and, therefore may fall between wheels, levers and other moving parts and cripple themselves. But the dangerous places may be grilled by gauze. The control of the parts of machines may be outside of the machines, at a particular place. All this is not new or has long been used on the Earth.

An object being processed in a medium without gravity, however great and massive it may be, does not fall, bend or press on workers and is easily turned and carried in all directions. Similarly the workers can do their work in every condition and in every place, not fearing to fall down in any pose one pleases (for example, upside down in relation to one another). Only a support is needed. But he will always find it, binding the legs or his own body with the very object being processed or with the lathe. The convenience of work in a medium without gravity is above every praise.

During different types of work on the Earth, gravity is not as much made use of as the inertia of the massive bodies. Hammer works in a medium without gravity as well as on the Earth. The force of its stroke does not depend as much on gravity, as on its rate of movement, depending on the tension of muscles and the magnitude of swing.

On machines, the force of gravity is still less made use of than in case of manual operations. Heavy hammers are successively substituted comparatively with light presses. But who stops us to impart masses (in the ether) a velocity by a certain force, which (velocity) the bodies acquire on the Earth on falling. The whole business is with velocity, in which lies the striking force. Velocity is much more convenient to impart to bodies in a medium without gravity than on the Earth. Impact due to gravity has one direction — downwards impact due to velocity — whereever one pleases. This is the advantage..

The hurled bodies are, as if, more dangerous in a medium without gravity. On the Earth they fall down on the ground and become harmless; in a medium without gravity they travel along a straight line, till the time somebody is hurt. But, on the one hand the objects, on the planets, are quick-moving, as the war projectiles, fly for long, before falling and stopping; on the other hand, the wandering bodies in dwellings in the ether, encountering their walls, lose their velocity and stop. Such bodies are more dangerous outside the structure. (edifice), in the ether. But firstly it is not necessary to manufacture these wandering bodies without need, and secondly, one must protect oneself from them, as one protects oneself from bullets and cannon balls on the Earth.

A mechanism in a medium without gravity in no ways differs from scientific mechanism, eliminate only gravity.

The gravitation of the Sun on Earth's distance is not very great, precisely it is 1800 times less than that of the Earth, i.e. the velocity in seconds will be 0.0055 meter or 5.5 mm. The effort, which on the Earth lifts up to 1 meter, will here lift almost up to two versts. But it does not follow from it, that recession from the Sun and proximity to it in case of small relative velocities is confined by kilometers. The fact is that here we are discussing about the relative speeds. The launched body, besides the small relative velocity, still possesses planetary velocity relative to the Sun. Owing to it and its cost, the launched objects recedes from the luminary (heavenly body) and comes close to it by thousands of versts, notwithstanding its small relative velocity.

In our medium, still mutual tension (pull) of people and other similar bodies, in smallness is observed.

But it is very weak for the small objects surrounding us. However, lead or platinum balls, on possibly close distance from one another move, as celestial bodies. Only their velocities must be extremely small, otherwise they will fly away, in different directions, in straight lines.

This provides a possibility in ethereal vacuum of solving practically the mass of the extremely important problems, not solved so far by mathematicians. For example, about the pathways of motion of three bodies mutually interacting.

But at the same time the slowness of motion and the continuity of observation (control) are inconvenient. Thus, a comparatively small ball rotates around a comparatively large one, made from the strongest material at the nearest distance, in the course of 2500 seconds or 42 minutes. This time least depends on the dimensions of the large ball: be it the size of the Sun or that of a small shot, the result is one and the same, i.e. the time of rotation is always 42 minutes.

For the practical solution of the problems regarding the form of motion, the bodies will have to be removed from one another, whereas the time of observation must run to several days and months. There is inconvenience in it. The absolute dimensions of the bodies may be anyhow small. Perhaps, more compact substances will be found perhaps the coefficient of attraction of small bodies will be more — then the observation will be confirmed to shorter times.

The smallness of velocities (for their increase) compels the use bodies of larger dimensions.

In general the determinations of mutual attraction and repulsion are very convenient due, to, no matter, what reasons, in a medium without gravity.

Bodies do not fall down and do not possess weight, but the laws of inertia here are particularly slightly observed. Thus, the larger the mass of the body, the more difficult it is to impart it motion. The larger the mass of the body and needful velocity, the stronger and longer is the pressure required on it. Similarly, in order to stop the body, greater effort and longer time are needed, if its mass and velocity are greater. The impact of the moving body is more intense, if it is itself more massive and harder and if harder and more massive is that body, on which it has impact.

Although in the ethereal dwellings the density of the oxygenic atmosphere is ten times less than in our air, the motion here is quick and continuously uneconomical, i.e. it requires large consumption of work. On the contrary, outside the dwelling, in the vacuum, it almost costs nothing. It is needed only once to spend effort for acquiring the desired velocity . Later on it is maintained without change, if we are not to recede from the Sun. Besides, even this, as we have seen, has little effect for a stretch of a thousand versts.

In the vacuum it is possible to travel either in special dresses, incorporating the apparatus for breathing, or in the very dwellings, detached from their general mass. The latter arrangement is much convenient, since it gives spaciousness, rids one from clothes, gives its plants food, drink, oxygen and all that is required. Besides it may be performed in a multiple. This motion would not be noticed even. Only the motion of the whole complex of dwellings will be visible to us. We consider their motion (for overcoming the gravitation of the Sun) zero, (conditionally). But then it is not felt, as the motion of the planet for its inhabitants.

How to steer clear at the same time of dangerous collisions of vehicles or trains? There will be several main courses of motion and one velocity for the direction of each course. Trains of one direction will have one pathway and there cannot be any collision. All the pathways leading to different directions are distant from one another and therefore celestial ships of different velocities cannot collide.

The laws of lever, of liquid and gaseous bodies are not complicated by their weight.

A gas diffuses infinitely, as long as, due to expansion and cooling, it is not be converted into dust, consisting of solid non-evaporating particles.

The liquids adopt the form of spheres or bubbles. The volatile ones quickly freeze due to evaporation, while the non-volatile remain as spheres. These spheres can be broken into several small spheres and vice versa. The sticking liquids encompassing all the substances, form fantastic shapes.

Sounds and, in general, vibrations of different types expand similarly as on the Earth. Only the waves similar to those of the sea, do not form. For this gravity is needed. The barometer and the clock with pendulum do not function. But the pocket watch functions as usual. A beam-balance and spring balance are useless, since the bodies are weightless. Mass, neither by these, nor by others, is impossible to determine. Mass is determined on the centrifugal machine, or in the medium of artificial gravity by the beam balance. Determination of the force may be made by dynamometer or by the spring balance.

Magnetic, electrical and other forces function more simply and clearly since the gravity does not complicate the phenomena.

A human being quickly adapts to the medium without gravity, but in animals, reason may not be sufficient for this and they may suffer. Non-flyins insects will futile wrestle in the air. But, on being tied to the wall, they run, not feeling the absence of gravity. The flying insects (and birds) will travel, but not in the manner they want. They will soon reach the walls and get attached to their grapplers. Walking Pacing of the birds and other large animals does not succeed: in their first attempt. They get struck back by the walls and find themselves in a gaseous mediu,. Cat and similar animals with turning internal organs can voluntarily (rotate) turn the external portion of the body, at least by 180°.

We have, seen that man can similarly turn round and move with the help of supports, for example his hat. But even without support he can take a turn. For this purpose he requires, for example, to raise the hand and rotate it in a way, as if he was turning the handle of some machine. The circular motion of the hands, feet or other himb will impart rotation even to his body. But it only costs him to stop the movement of his limb, and his body will some to a standstill, although he will see in a different direction.

Here we do not have in view the surrounding liquid or gaseous medium, with the help of which it is possible to have any desired motion.

A human beings must compulsorily overcome the Earth's gravity and have in reserve space, although, of the solar system.

On the Earth dangers of different types are awaiting him. We shall not discuss about those difficulties of life, which all of us are experiencing uninterruptedly; these dangers and displeasures will soon be eliminated by Man. But we speak about the catastrophes, which may destroy all humanity or its considerable part of it.

How many times, for example, the dry land on which we live, was under water and was the bottom of the ocean! It can hardly be believed that these phenomena will be taking place constantly. Earthquakes suddenly destroy cities totally and inundate considerable areas. Large catastrophes have been taking place, though historical man has not their witness (If we do not consider the doubtful all-world deluge). Only the more wide-spread the catastrophe, is the more horrible it is and the more horrible it is the rare it is. We can still await it.

The fall on the Earth of the clouds of fire-balls (meteorities) or a small planet with a diameter of ten versts may give such a shock (impact) to the Earth, that the solid or liquid or gaseous wave formed as a resultm would wipe out all from the face of the Earth — as well as Man and his structures. Moreover, only the increase of temperature of the atmosphere may singe or put to death everything.

Now imagine that the same has happened to the ethereal settlements that have been formed: an asteroid with a diameter of 10 kilometers has flown through those settlements. It can annihilate only 75 km^2 of the settlement, and not like that as on the Earth, i.e. not 510,000 000 Km^2. Moreover, in the ether it is easy to track down the path of the small planet and make it free (temporarily) from dwellings and other structures. But then their shifting (change of place) does not almost cost anything. And how do you eliminate the Earth from the path of motion of some celestial body?

Incidentally about the meteorites. From the huge ones of them, the danger in the ether is the same, as on our own planet. But since their fall on the heads, houses and structures is extremely rare and nobody is frightened, so similarly they cannot frighten in the ether as well. From the smaller meteorites, the atmosphere protects us on the Earth, in the former they either scatter away or burn. In the ether, the dwelling can itself protect. Impact of a tiny splinter, of a meteorite with a weight of a small portion of a milligram, piercing the human being, does not inflict on him serious harm. Hitting the stratum of quartizitic glass or steel, this granule in all probability, will stick in it. This splinter melts due to the impact and will be converted into vapor. Similarly a slight portion of the surface of the structure (building) will also melt and will be converted into vapor. The impact may form on the small wall a molten and very thin channel. Its liquid state fills the momentarily formed hole and through this hole even gas does not leak.

Besides it has been proved repeatedly, that the fall of even a tiny meteorite on a human being is an unbelievable phenomenon, demanding on an average several thousand years (it is presumed that on the Earth there is no atmosphere).

An explosion due to the accumulation of elastic matter inside it, is awaiting the earth, as in case of every celestial body. A time is coming, when this type of hazard will threaten humanity, where will itbe saved, if it does not master the space of the Solar system?

Another threat is extinguishing and cooling of our Sun. Then we shall have to run away from the Solar system. But to run away will be much easier from the ethereal spaciousness than from he planetary dungeon, enchaining us and all, that we have, with the chains of attraction to the Earth.

Overpopulation of humanity on the Earth needs similarly the struggle with gravity and the use of celestial spaciousness and its wealth.

Mankind is awaiting many other threatening dangers on this planet. They similarly oblige people to find ways into the cosmos.

Regarding the advantages of re-settlement we have discussed at length but neither to discuss nor to surmise in toto is possible.

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To Astronauts

(1930).

More practical people aspire to apply the force or the principle of recoil (reaction to the design of 1) Powerful reactive (jet engines for quick motion, 2) automobiles, 3) hydroplanes and 4) Sledges.

Let us examine all this.

An explosion motor, like a hydraulic turbine, cannot give more utilization of energy of explosion, since the peripheral velocity of the wheel with vanes (blades or turbines) cannot exceed 200-400 M/sec. Whilst the advantageous utilization needs vane (blade) speeds 1.4 times less than the speed of flying out products of explosion. It may attain 5000 M/sec. Consequently, the velocity of the vanes (blades) will be about 3500 M/sec, which in view of the known strength of the best materials, is impossible.

If we confine ourselves to the velocity of vanes (blades) of 100 M/sec, then we shall utilize only 3% of the given chemical energy. This is not economical.

Here what is needed is a complicated wheel and, in general, the method, employed during the construction of contemporary steam turbines. Then it is possible to achieve a very high percentage of utilization of the given energy.

Here there is another condition. The products of explosion must be separated out in the vacuum, otherwise they will not have sufficient velocity. From this it is already evident th t similar motors cannot be very light . Besides, we shall encounter still many practical difficulties, about which there is no place to speak here. However, the great future of these motors is undoubted.

Automobiles by the rocket method (by no other method) cannot acquire high velocity because of great resistance of the air in the lower strata of the atmosphere. Besides their wheels, even without air-tubes, are torn due to centrifugal force when the velocity (on the rims), exceeds 200-400 M/sec. In order to acquire velocity of more than 100 meters per second, it is necessary to get rid of wheels and device for them special roadway (see my "High Speed Train"*); besides they must be given longer and better forms. But even then we shall not achieve a velocity, more than 1000 M/sec. But what is the use of making such an enormous expenditure of effort is made. Resistance of the air engulfs them all.

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*) K.E. Tsiolskovskiy, Collection of Works Vol. 4, "Naooka" Publishing House, Moscow, 1964, Article "Resistance of Air and High Speed Trains.

Compressed gases for example, carbon dioxide (Co_2) are not advantageous to use at this stage, since their internal energy of motion (kinetic) is extremely slight. Besides, they require containers the weight of which is 10 times the weight of compressed gases. Liquefied, cold and freely evaporating gases do not require strong and massive vessels, but their kinetic energy is even less than that of compressed gases. In releasing this energy, they borrow heat from the surrounding bodies and air, and this cannot be accomplished as quickly as required.

Explosive substances in the ready form are similarly not applicable (powder, dynamite etc). In addition to the inevitability of explosion due to percussion (detonation), they require heavy guns or vessels, since explosion in one place transmits the pressure, produced due to it, to the entire mass. The inevitability of explosion was confirmed by the recent tragic death of Vale and by othercases also.

Regarding the hydroplane and the sledge we shall say the same. But they have no wheels and this is an advantage. But then to the resistance of the air the resistance and friction of water or snow is added. I am speaking, of course, about the automobiles and hydroplanes, functioning by recoil (rocket). Other vehicles are meant for smaller velocities because of the revolving propellers or wheels.

To astronautics, two main approaches emerge at present.

1) Gradual transition from the airplane to the astroplane, and 2) a purely reactive (rocket) device.

At first the airplane does not go out of the limits of the atmosphere, rises to a small height and covers a small horizontal distance. Then it goes higher and higher, and covers a longer distance. At last it emerges beyond the atmosphere and flies on by interia, as a celestial body.

The subsequent pathways for the transformed airplane as well as for the rocket projectile are guaranteed by the pressure of light.

My calculations have been verified many times and do not admit any doubt.

Thus, I have shown *), that one kilogram of the substance with the surface of one square meter, in the course of a year, acquires, from the solar light, an increase of velocity, more than 200 meters per second.

In the absence of gravity it is easy to arrange enormous surfaces of the most insignificant weight. For

*) "Investigations of Outer spaces by reactive devices" (Author).

example a surface with a thickness of 0.01 mm, of the density of water, and area of 100 M^2, weighs only one kilogram. The rotation of this square (with the side of 10 M) will impart to it a known tension, smoothness and strength. The pressure of light will impart to it a velocity of 20 km/sec in a year. It is more than enough for wandering in the entire solar system, and even complete recession from the Sun (i.e. travel in the Milky Way). In fact, the projectile (from the Earth) has a velocity of 30km /sec. With an addition it will be 50 km/sec. For complete recession from the Sun 30 x 1.4 = 42 km/sec is necessary. Now a free velocity of 8 km/sec for the Milky Way is still left.

We suppose that on the projectile there is one ton of material and on the surface area just as much again. Then the projectile in the course of two years will acquire a similar addition of velocity, i.e. 20 Km/sec.

It would be good with the pressure of light, It guarantees wandering in the Universe: if not in two then in several years, sufficient velocity will be acquired for this purpose.

Let us examine at first the transition from the airplane to astroplane and then we shall examine the rocket device.

In my works ("Airplane" 1895 and "New Airplane" 1929 *)) I proved that an aircraft can fly twice as fast in a medium which is four times rarefied (at an altitude of 10 kilometers), because from it twice the motor power is required for very same weight. In general the velocity of an airplane increases n times, if the medium gets rarefied n^2 times, but the energy of the motor at the same time must surely be n times more.

On the one hand, the energy of an ordinary motor, cannot only be increased, but it terribly falls down in a rarefied medium. It means, that an air compressor is required, new for that consumption of energy and additional loading of the projectile for the compressor. Not only that, on intense compression of the gas, it gets terribly heated. Consequently, more cooling is needed.

On the other hand the accelerated rotation of the propeller will tear it to pieces on account of the centrifugal force.

Let us devote ourselves, for the time being, to the increase of velocity of an airplane only two times. For the energy of the motor, it is possible to double the number of its revolutions. But in that case it will be necessary to

*) See the work of K.E. Tsiolkovskiy "Pressure on the plane on its normal motion of the air" Collection of Work Vol I, Academy of Sciences of the USSR 1957. (Editors).

expand the valve openings and use fuel, quickly mixing with the air. These fuels are — petrol good quality liquid hydrogen, or some other gas fuel.

The tangent of inclination of the vanes (blades) of the air-screw to its plane will also have to be doubled: roughly from 0.3 to 0.6. The corresponding angles will be 17° and 31°. These angles are fully permissible without any disruption of economy. At this stage the velocity of the airplane may be increased twice for the very same number of revolutions. But the number of revolutions of the machine has doubled. What is to be done? to employ a transmission (0.5) or reduce the diameter of the air-screw by two ? The first twice is economical(chain transmission).

It is also necessary to compress four-fold the rarefied air, At this time its absolute temperature increases 1.75° times. If at an altitude of 10 kilometers, the temperature is -43°C or 230° of absolute temperature, then on compression it will reach up to 403° i.e. the air will heat up to 130°C. It is tolerable, and here we can do even without cooling it. But we still need a compressor.

This not all yet. The products of combustion emerge from the motor with great force. We shall not use the dampers and we shall take advantage of their recoil. The greater the velocity of the airplane, the more profitable it is. Similarly the more rarefied the medium is the less arexthe hindrances for the expansion of the products of combustion and the greater will be their exhaust velocities and their recoil.

It is understood, that the products of combustion are directed into special conical pipes, located along the airplane with their wide muzzles pointed towards the tail (rear of the airplane.

It is even possible to triple its velocity at an altitude where air is 9 times rarer. The angle of inclination of the air-screw to its plane of rotation changes from 17° to 42° which is still tolerable. Transmission will be 1:3 (or the diameter of air-screw is three times less), which will reduce the number of revolutions of the air-screw thrice, i.e. restoring the former velocity of its rotation. (We shall not forget still about the tripled velocity of the motor shaft and the unavoidable enlargement of valve openings). The increase of absolute temperature will be 2.4. Thus , at 73° below zero, or 200° absolute temperature we get 480° , or absolute 207°C. This is still tolerable and does not require cooling.

Nevertheless, the doubled and tripled velocities, of the airplane are still very far from the Cosmic ones. What is to be done next?. The angle of the blades is impossible to increase further. Heating will require cooling. And where is to take cold from? A good deal is there at altitudes but, nevertheless, insufficient, since the air is too much rarefied and still the temperature is not below 70°C .

Thus, the subsequent increase of velocity comes to a stop: 1) due to air-screw, 2) the necessity of compression, 3) intense heating and 4) the necessity of cooling.

The air -screw can be changed by moving wings as in the case of a bird. Though this is very advantageous because it increases the lifting force of the airplane, yet with respect to structure (construction) it is complicated. It is simpler to discard the propeller. This is possible at high velocities of the airplane and its flight in rarefied medium, since the recoil of combustion products is more productive, the higher the velocity of the aircraft and the rarer the medium. A rarefied medium permits the gases to expand more, and as a result thereof they attain higher speeds on exit from the pipes and lowest temperature, reaching the limit (in the vacuum) upto 273°C below zero.

This is what may serve as a source of cooling of the air heated by compression. For this (purpose) we force the air, heated and compressed by the motor, to flow round the stern (rear) endd of the pipes with the combustion products highly cooled by expansion. Then the compressed and now cooled air, is directed into the working cylinders of the motor.

We achieve at once three purposes : we heat the combustion products cooled by expansion and thereby increase their speed and recoil: at the same time we cool the air, intensely heated by compression, and intended for the working cylinders ; and, the lastly we obtain enhanced reactive effect, since an engine without a propeller can perform a larger number of revolutions. Its mechanical work will be small, since it will go in mainly for the compression of air.

To what extent one can, by all these methods, increase the velocity of the airplane is not known. Should one acquire cosmic velocity in this way and go out beyond the limits of the atmosphere: This is a question to which we are not in a position to give an answer (not to Speak of a positive reply). At any rate, the construction of the high altitude airplane will teach us much and will bring us closer to the astroplane. Detailed mathematical calculations of the recoil of the airplane for its above-mentioned design have long been ready with me .

Let us not turn to the purely rocket machine. Here we cannot avoid a motor since we shall have to push or pumps the elements of explosion into the mixing-cum-combustion chamber. Here also we do not employ any propellers, in view of the quick attainment of considerable velocities, which the propellers cannot withstand. But there is nothing to prevent us from making use of the recoils of the combustion products in engines, as it has just been described.

Thus we come back to the previous design with the addition of a purely rocket device. It has been described in my "Cosmic Rocket", (1927).

But here is a question: When the projectile reaches very rarefied **air** (atmosphere), the feeding of the engine by the air will not remain possible. How are we to supply it with oxygen? But motor rocket has its own reserve in the very projectile and therefore a part of this reserve, on reaching very rarefied strata of air will go in for the feeding of the engine.

Now we point to those conditions of design of the rocket apparatus, the observance of which is generally ignored by practical workers (and the hero Vale paid with his life).

1) A ready-made explosive substance is not suitable, for example, various kinds of powders, introglycerine, lyddite, dynamite and others.

2) Elements of explosion (for example, oxygen and hydrogen) must not be mixed till their union in the pipes.

3) They are held separately and are kept in different containers or compartments.

4) They must be in liquid form at ordinary temperature, for example, like petrol and nitric anhydride.

5) They must b e as dense as possible, so as not to occupy a large volume.

6) Their vapors must not exert considerable pressure on the walls of the containers, so that these containers do not have to be made massive.

7) They must not have low temperature like liquefied and freely evaporating gases, so as to preserve more energy.

8) Pumps are piston type and pump liquids while still not heated.

9) The latter must not react chemically on the walls of the pumps, and pipes, leading to the combustion chamber and on the explosion pipes themselves. Therefore they are made from suitable material or their interior is covered with such material.

10) In the explosion chamber, the elements of explosion must be mixed as well as quickly as possible, so as to produce the explosion instantaneously, similar to the explosion of powder or a shot.

11) The chamber of explosion must be cooled by the cold borrowed from the expanded explosion products, the tempe-

rature of which on exit must reach 273° below zero. For this purpose, the chamber of explosion and its continuation i.e. the pipes for the exhaust of combustion products, must be surrounded (covered) by a jacket, in which a thin layer of a light liquid (for example oil, gas etc) is artificially circulating, transferring heat from the chamber of explosion and intensely heated portions of the exit pipes to its cold portions. Advantage will be double, as I have explained. For that avery purpose, the pipes themselves an partly serve, provided they are good conductors of heat.

12) The explosion must be quick just like the growth of pressure in the chambers and pipes. Instantaneous explosion pressure of several hundreds of atmospheres and then a release of pipes and chambers from the great pressure, result,. After this the pumps in the new portion of the explosives. A second explosion, jerk and a flying away of the substances formed, take place.

13) The number of pumpings in one second must be as large as possible, for example, 30 or 50. The same number of shots will be produced in one second.

14) The work of pumping will be slight due to its coincidence with the minimum pressure in the fire chamber and pipes.

15) The pipes, leading from the chamber, through which the explosive products are conveyed, must have expanded in a conical form at the end (form of musical tubes, horns, ear-tuumpets etc). This reduces their length and enhances recoil.

16) There should be such pipes and explosion in them at different times so that one chamber fires after the other at equal intervals of time. Thirty to fifty thrusts per second in one pipe merge into a single one, and ten pipes, for instance, give 300-500 thrusts in a second and all the more merge into a single whole. By this we protect the projectile from destructive vibrations. A large number of explosion pipes and chambers is useful in the matter of economy of material. From experience artillery it is known, that the weight of the gun increases much faster than the pressure in it for the same volume of the barrel.

The experiments of Obert were most scientific, but they did not fulfil the majority of these conditions. We have nothing to say about other astronauts. That is why the results obtained so far so lamentable. Such is the practical aspect of all beginning of great undertakings. Nevertheless, they are valuable and should not upset anyone.

The first attempts of flying, aeronautics, the use of steam, electricity and all other inventions have similarly compelled ordinary people and even the inventors to lose heart and become slack. But we, having learnt from history, must be brave and not give up our activities due to failures. We must seek their causes and eliminate them.

Originally published as a separate brochure at Kaluga in the year 1930. Authors Edition.

Jet Propulsion (Reaction Motion) (1932).

Jet Propulsion (reaction motion) is that which produces recoils of the firing cannons.

It appears strange, that the awkward force recoiling the gun at the time of fire, is relied upon to be employed not only for quich motion in the rarefied strata of air (in the Stratosphere), but also for lightning speed for wandering between the planets and stars.

It has been proved by me that the exploding substance (if, of course, it is taken in a sufficient quantity) may impart any velocity one wishes, to the device, in which it is exploded. When the weight of the equipped rocket increases in geometrical progression, its velocity increases similarly infinitely but in arithmetical progression. The true final velocity of the projectile depends on the velocity of gases, flying out fron the pipe (nozzle) and on the size of the reserve of fuel (for example, powder).

The experiments carried out by Goddar and others have shown that the velocity of the gases emerging from the nozzle can reach up to 3 and more km Sec. Theory shows that in the vacuum when the conical tube is sufficiently long, and when the explosive substances are most energetic, it may reach up to 5-6 km/sec.

The velocity of the rocket at 8 km/sec is sufficient, to be carried eternally, higher than atmosphere, around the earth, in the capacity of its satellite. A velocity of 12 km/sec is sufficient, to take to the orbit of the earth and become, in this way, a s.ll planet. At last, a velocity of 16 km/sec may overcome the attraction of all planets and the Sun. Then the projectile will eternally recede from our Solar system and fly in the Milky Way (Galaxy) amidst other suns and planets. And this will happen readily when the reserve of the explosive substance exceeds the weight of the rocket altogether only 15 times.

But are such reserves possible? Even in record-breaking airplanes the mass of the fuel does not exceed the weight of the machine.

In order that the weight of the fuel with oxygen, exceeds the weight of the rocket 15 times the following conditions are required.

1) The elements of explosion (petroleum and oxygen) must not exert pressure on vessels enclosing them (in order that they do not have to be massive).

2) They must be thick-set so that they do not occupy much place. In this respect liquid oxygen is not

suitable, because it is 14 times lighter than water.

3) It is necessary that the acceleration of the projectile was not more than 10 M/sec^2, otherwise relative loading of the elements of explosion and of all the parts of the projectile will compel then making very strong and massive. Therefore the motion of the projectile is advantageous to be made inclined.

The conditions of safety, lightness and good working of the rocket consist in the following.

1) Breaking of the elements of explosion, gradual combination of which gives reactive pressure.

2) The conical shape of the tube, in the narrow portion of which portions of the explosive substances get mixed and explode. ——

3) The reciprocating (piston) pumps, pumping the elements of explosion.

4) The periodical pumping. This is the series of blank shots, producible roughly 50-100 times in a second. After each fire the nozzle is freed from gases and then a small effort is needed to push in it a new dose of the integral component of explosion. On continuous explosion (combustion), large output of pumps and the engine attached to it, would be needed.

Flight in the rarefied atmosphere (in the stratosphere), and then also in the vacuum is needed in the following means of mantaining life of the pilot and the passengers.

1) Sealed body, impervious to the gases, as during the flight of Professor Piccard (he ascended to a height of 16 kilometers, where air was 6 times rarer, than at the sea level).

2) Provision of oxygen in the rocket. The daily reserve of it for a person does not exceed one kilogram.

3) Alkali and other substances for absorbing exhaled and excreta of human beings.

4) Reserve of food. For continued stay beyond the atmosphere, specially selected plants, providing oxygen and food, may be made use of. For this prupose, evidently, it is necessary to have transparent windows and solar light, It is sufficient, since clouds, air and fog do not exist beyond the atmosphere.

5. Control of internal temperature of the rocket is carried out by means of a change of the surrounding surface of the projectile, which absorbs sunlight. Besides strong and impervious shell of the device for the gases, there is still another shell, similar to a fish-scale, which coming in proximity makes it bright and shifting and thus taking shape,

exposes the black impervious surface of the body.

6. Protective cooling of the surface of the body from heating during flight through the atmosphere. For this purpose, the bright movable scalem similarly, renders service.

The indicated Cosmic velocities (8-16 km/Sec) are not possible in the lower strata of the atmosphere because they disappear soon owing to the immense resistance of the atmosphere.

But the reactive device gradually acquires Cosmic velocity. The inclined ascending and accelerated flight is very advantageous. Here flat wings are useful. In the lower strata of the air the velocity is small, in the rarefied medium it reaches 1-2 kilometers per second. But there, this velocity does not meet great resistance because the air is very rare. This velocity will not heat the surface of the projectile, since air is very rare and cold. For protection from the excessive heating of the rocket, probably, one layer, for example of powder or cork, insulated from heat, will be sufficient. The most suitable in accordance with its lightness is the vacuum between th first and the second shells of the device (for which air between them must be pumped out).

We are giving a schematic diagram of this device in the simplest form with the indication of its parts (fig. 1).

1) Flat wings. In case of a small span (of wings) they will not be heavy while on large length along the projectile they will not be very thick. In case of small velocity they will function comparatively slightly in case of large velocity they will function well. Their almost flat form is necessary in this case.

2) Unit of Movable bright-scale. The more it is normal to the surface of the rocket, the more the black surface of the body opens and the lower is the temperature. On the contrary, the more it is parallel to the body, the lower is the loss of heat and the higher is the temperature. Units or windows, turned towards the solar light, must not be closed by the scale for obtaining of high temperature. During flight in the atmosphere the scale must be interlocked into one surface and the control of temperature is not possible (fig. 2). Therefore, a sliding and longitudinal scale is more advantageous.

3) Accommodation for people.

4) The impervious strong shell of the rocket, withstanding the pressure, at least, of one atmosphere.

5) Movabel scale (as a fan)

6) Place of small motor.

7) Pumps for pumping oxygen and petroleum.

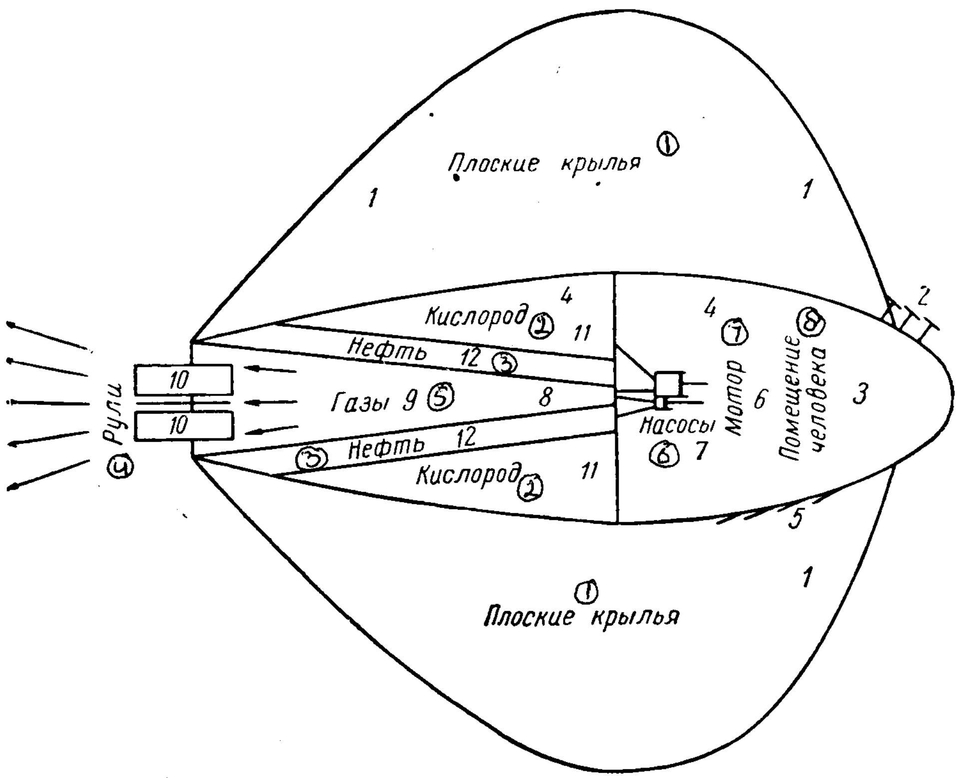

Figure 1.

Keys: (1) Flat wings 2) Oxygen. 3) Petroleum
(4) Rudders. 5) Gases 6) Pumps 7) Motor
8) Space for man.

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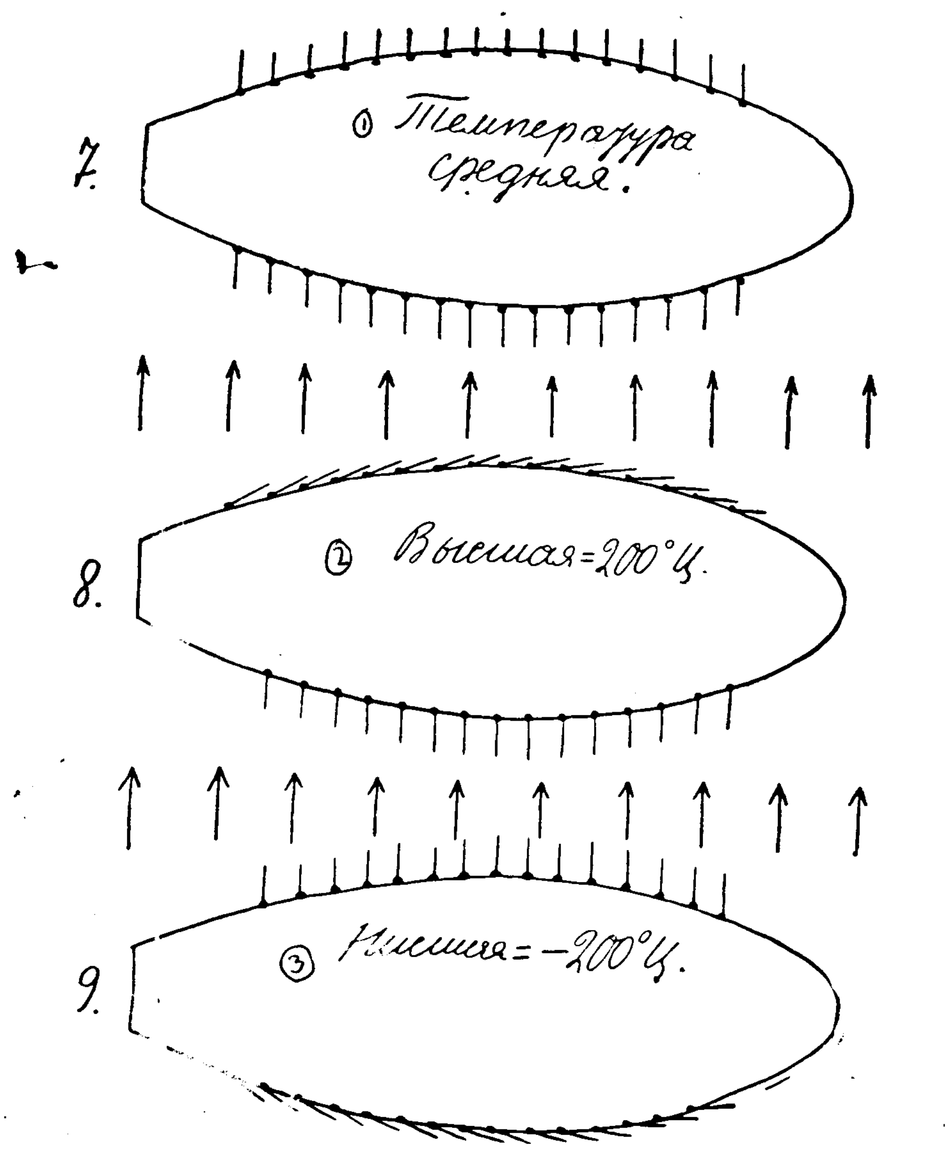

Figure 2. Drawing of K.E. Tsiolkovsky from the manuscript "Album of Cosmic Voyages"

Keys: 1) Average Temperature
2) Highest = 200°C.
3) Lowest = 200°C.

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8) Place of mixing of the elements of explosion (Carburettor).

9) Conical pipe. Through the wide hole, rarefied and cold gases escape with relative velocity of 3-6 km/sec. This velocity for each device is constant.

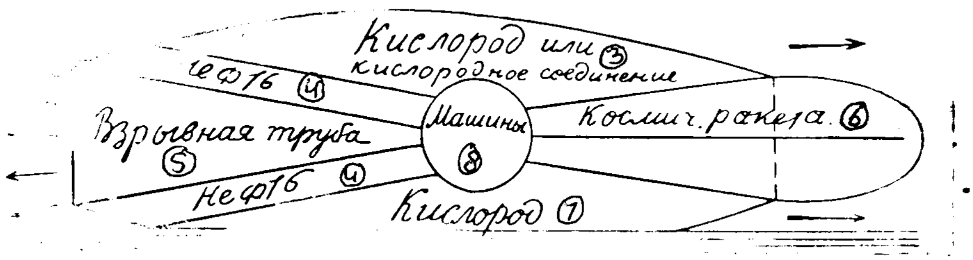
10) Two vertical rudders and two horizontal. These are rudders of direction and rudders of stability. The rudders function in the vacuum owing to the swiftly flying out products of combustion.

11) Liquid Oxygen.

12). Petroleum.

The designs of such purely reactive devices are extremely simple. Liquid oxygen and petroleum, having been mixed in the combustion chamber, escape and are thrown in the form of rushing gases through the conical pipe outside, pushing its walls, and consequently, the entire device forward. Impermeable and very long surface regulates the temperature at the time of flight. The cooling of the pipe is carried out by petroleum, while of the heated petroleum by oxygen; special tanks for fuel (only of the fencing) are missing; the construction of two tiny pumps and a very weak motor serve the purpose. Extraordinary simplicity and lightness of this device

3. <u>Earth Rocket with embedded in it the cosmic</u>
Terrestrial Acceleration is 20 times greater than the acceleration due to Earth's gravity, that is, 200 meters per may be withstood by human beings only in water.



Keys: 3) Oxygen or oxygen compound, 4) Petroleum,
5) Explosion Pipe, 6) Cosmic Rocket,
7) Oxygen, 8) Machines.

Ascent on the mountain of the Earth Rocket in kilometers										
Seconds	1	2	3	4	5	10	15	20	25	30
Velocity	0.2	0.4	0.6	0.8	1	2	3	4	5	6
Path	0.1	0.4	0.9	1.6	2.5	10	22.5	40	62.5	90
Altitude	0.01	0.04	0.09	0.16	0.25	1	2.25	4	.62.5	9
Rarefaction						1.11		1.53	2	2.45

Altitude 10 15 20 25 30 35 40 45 50 55 60 65 70 75
Rarefaction 1.72 3,12 6.10 14.4 35.7 80.6 190.5 430.4 2519 13720 48700

Diagram of the Earth (Auxiliary) rocket with embedded in it (from, "Album of Cosmic Voyages"). Diagram and signature have been done by K.E. Tsiolkovskiy.

is its merit. Its deficiency lies in the fact, that it must carry oxygen with it.

At first the device may be restricted to flights in the lower strata of air (troposphere), and then to fly out into the vacuum, beyond the atmosphere, and finally perform Cosmic flights. Return flight may be performed without the consumption of explosive materials as Gomann and I have shown: at first a swift spiral motion in the rarest strata of the air, then in desner ones, the gradual loss of Cosmic velocity, and at last, planning and lowering on the ground or water similar to the common airplane (fig. 3).

These are the pure reactive devices which promise much. Why have researches in Europe and America produced so little? Thus, the most successful flight of the rocket of K. Riddel (1931) near Berlin permitted to attain an altitude 1.5 kilometers other practical results are even less impressive.

Winged rockets of Goddar and Svann, similarly, produced slight results. For example, reactive glider of Svann with a weight of 80 kilograms had ascended to an altitude of 60 meters only.

The reasons of such insignificant successes are partly due to the lack of means, and partly due to mistakes of the researchers. I have already pointed out these mistakes of the researchers. I have already pointed out these mistakes in my booklet "To the Astronauts".

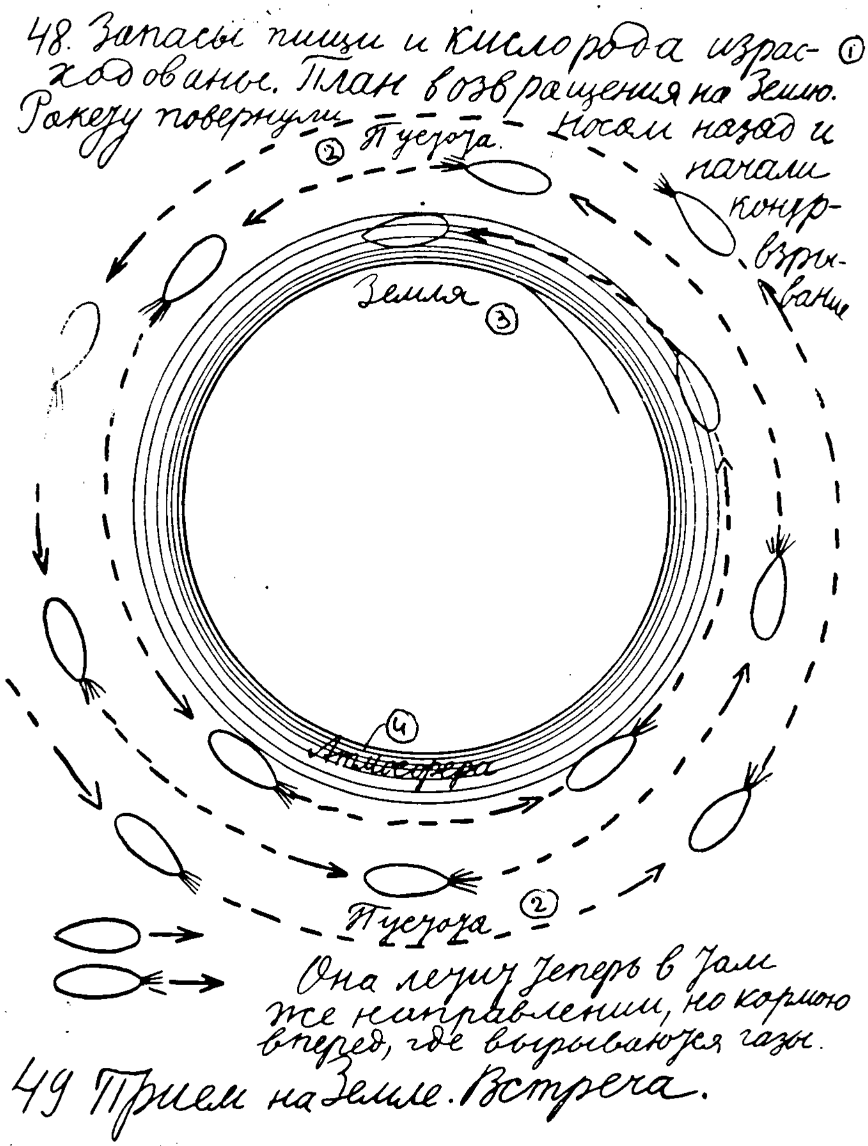


Figure 3. Diagram K.E.Tsiolkovskiy from the manuscript "Album of Cosmic Voyages".

Keys: 1) 48. Reserves of food and oxygen are consumed. Plan of return to the Earth. We have turned the rocket with nose at the back and have started counter-explosion. 2) Vacuum. 3) Earth. 4) Atmosphere. 5) It is now flying in that very direction, but with stern forwards, where gases are escaping. 49. Welcome on Earth Meeting.

But, besides rockets, the high altitude airplanes or stratoplanes also offer interest from the point of view of attaining large velocities. These are common airplanes, but equipped with:

1) Unusually light-weight and powerful motors.

2) Compressor of air

3) Air screw with sharply inclined blades,

4) many condensers and radiators.

The flight of such stratoplanes is possible in air only. Their design is very complicated and the mass is large perforce.

According to may calculations ("Airplane", 1895), confirmed by the latest researchers (for example, Korvin-Krukovskiy, see the book of Professor Rinin, "Super-aviation and Super-Artillery", 1929, pp. 51-53), it follows, that the velocity of Stratoplanes, on ther similar conditions is proportional to the square root of the rarefied medium, whereas the output must increase proportionally to the velocity of the flight,

Hence, in order to increase the velocity twice it is necessary either to increase the output of the engine twice, which involves increase of weight, or make the engines twice which involves increase of weight, or make the engines twice lighter at the same force. The latter is the solitary way out. Perhaps, with the passage of time, the engines will attain a weight of 200 g by the force. Then the translatory horizontal velocity will increase 5 times. If, for example in case of motors of ordinary weight, it (translatory hor velocity) reached 200 M/sec (720 km/hr), which in lighter engines will be 1000 M/sec (3600 km/hr).

In such airplanes trans-Altantic flight may be performed within 2-3 hours. This will be at a smaller altitude, where air, however, is 25 times rarer, than on the surface of the Altantic Ocean.

It is learned from journals that the well-known builder Framann is very busy with the high-altitude airplanes. He hopes, that at an altitude of 6 kilometers, the velocity of a stratoplane is doubled, while at an altitude of 12 kilometers, it is quadrupled. At an altitude of 6 kilometers, the atmosphere is rarefied twice, while at an altitude of 12 kilometers quadrupled. Hence, even in the last case the velocity may only be doubled compared with record velocity — and that too on the condition, that the specific weight of the motor is diminished twice, or its weight and output are increased twice. But doubling of the velocity is difficult to expect in view of the complicatedness of the airplane and the increased weight due to this.

It is learned that in the year (1932) in England, trans-Altantic flight is planned, suggested at an altitude of 16 kilometers, with a velocity of 1250 Km/hr. (347 M/sec). At an altitude of 16 kilometers, air becomes rarefied 6 times. So the velocity can be increased 2.5 times. But again 2.5 times more energy is required from the engine, while the weight remains the same. If the record velocity for a major distance is 100 M/sec (360 km/hr), then it is possible to attain on this velocity, 250 M/sec and not 347 M/sec*). Hence, this too is a dream for the time being. We shall not here take into consideration the loading of the airplane due to compressors and other complications connected with the rarefaction of the air. But, without doubt, all this is possible.

In my work ("Semi-reactive Stratoplane") I have propounded semi-reactive stratoplanes. They are also complicated, but they will attain the desired success earlier than the airplanes, although they cannot achieve Cosmic velocity.

Astronautics is only a goal and is highly far-placed. It is tempting, if we remember the possibility of utilization of the solar energy, which is two thousand million times more

* The velocity of contemporary airplanes exceeds the velocity of sound, i.e. 340 M/sec (Editors).

than that which is available as the share of our planet.

Before we reach this goal, we must cross a series of stages. The first stage is the perfection of the common airplane and the achievement of doubled or trebled velocity at an altitude of 120-18 kilometers, where air is 4-9 times rarer. Then we shall acquire a velocity of 200-300 M/sec. The trans-Atlantic flight will be cut down to 8-10 hours (See my "New Airplane", 1929). After that semi-reactive stratoplane will appear. Its velocity may be such higher, roughly up to 1000 M/sec. It will fly at an altitude of 23-24 kilometers, where the atmosphere is 100 times rarer, than at the sea level*). Flying from America to Europe will be done in 2-3 hours.

No economic advantages will however accrue :: theory shows, that on a unit distance one and the same mass of fuel is spent. Besides, such a device is very complicated and costly. So that flight by this is expensive. But time is saved and an altitude of up to 24 kilometers is attained.

But this is still not the full truimph over the stratosphere. A purely reactive device provides the possibility to penetrate still higher owing to its extreme simplicity and

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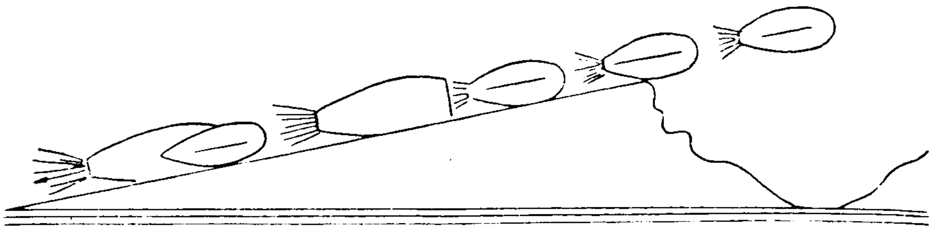
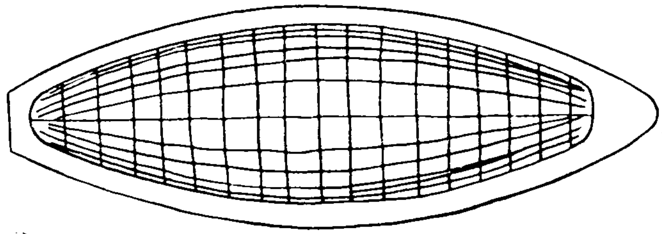
*) This does not agree with the contemporary Standard of the atmosphere (Editors).

① 5. Путь земн. ракеты по горам, а Космической – по горам и дальше. На деле путь в два раза круче.





② 6. Вид окон ракеты без ставень.

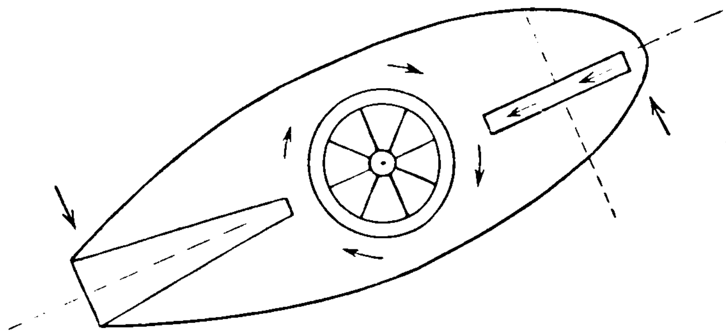
Figure 4. Drawing of K.E. Tsiolkovskiy from the manuscript "Album of Cosmic Voyages.

Keys: 1) Path of the Earth rocket on the mountains, and of Cosmic one on the mountains and farther. In practice the path is two times more steep.
2) View of windows of the rocket without the shutter.

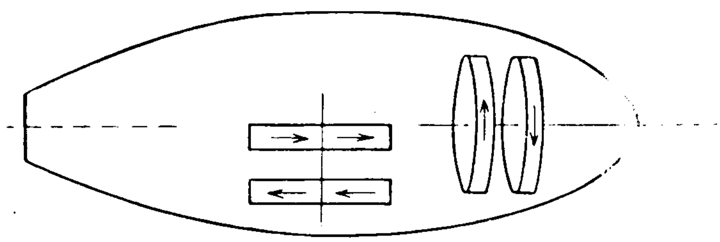
....

the reserve of oxygen. What would be the maximum velocity in practice in this case is difficult to decide. But when the velocity is more than one kilometer in a second already the centrifugal force begins to be discovered, lightening the weight of the rocket. If the velocity reaches up to 8 km/sec, then the projectile loses all its gravity and is carried beyond the limits of the atmosphere. This is when the atmosphere will be vanquished and the Earth's gravitation is overcome. Then the rocket on its spiral ascent will fly in the vacuum like

Поворачивание и вращение ракеты вращением диска Получение любого направления (1)
12



13 Устойчивость ракеты при ее неподвижности и быстром вращении двух пар дисков (2)



(Попытки опытов на воде). или на привеске. (3)

Drawing of K.E. Tsiolkovsky from the manuscript,"Album of Cosmic Voyages".

Keys: (1) Turning and rotation or the rocket by the rotation of dise. Obtaining of any direction.
(2) 13. Stability of the rocket on its immobility and swift rotation of two pairs of discs.
(3) (Attempt of experiments in water or on the pendant).

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the Moon, at a small distance from (the Earth).

> Mankind will not remain on the Earth eternally, but will force its way out beyond to the worlds of space, at first it will timidly pierce beyond the limits of atmosphere and later will conquer for itself nearly all the solar space.

Inscription on the memorial obelisk on the grave of K.E. Tsiolkovskiy at KALUGA (facsimile of K.E.Tsiolkovsky, 1911).

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However, one can hardly count on the achievement of the first Cosmic velocity without several auxiliary means.

Auxiliary means consist in the following.

1) The preliminary momentum of the rocket along the specially equipped, solid and ascending pathway (fig. 4), it (rocket) does not consume fuel but utilizes energy, acquired from special erections on the sides of the pathway (for example, tramway).

2) A multi-rocket train, flying in the atmosphere, only one of the constituent rockets acquires the maximum velocity and flies away from the atmosphere, while the remaining ones

return to the Earth (see, my article, "Cosmic Rocket Trains", 1929).

3) Conveying the energy to the already flying rocket from the Earth through material or "non-material" wires (for example a stream of radiant energy)*).

Having acquired possibly the large velocity, the rocket continues to increase it with the help of its own energy, i.e. by means of explosion of the stored fuel.

What advantages accrue and what potency man acquires on overcoming the gravitation and on conquering the solar system etc. are described in my book "Aims of Astronautics", 1929.

Possession of solar energy, fruitlessly going away at the moment in the atmosphere, is still not the conquering of Moon or planets. Even lading on our Moon, on multifarious reasons appears, a complicated and difficult task. So far as large planets are concerned it is for the time being early even to think.

Asteroids are very accessible, still more accessible are the celestial bodies of smaller dimensions. They will be the first achievements of the astronauts.

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*) As practice has shown, paragraphs 1 and 3 have become redundant (Editors).

When will all this take place?

Not even one wise man is in a position to foresee it. Even if we take into consideration the mad swiftness of the progress of science and technology of the present era, even then, probably, we have to wait tens of years, if not hundreds.

Besides, the swiftness of the growth of progress is a dimension, still not known. It is possible that the indicated time may be cut down, although we think on the centrary.

Originally printed in the journal, "In Battle for Technology", August 1932, No. 15-16 under the caption, "Theory of Reactive Motion" We have left the caption of the manuscript. (Editors).

FUEL FOR THE ROCKET. (1932-1933).

In essence, there is no defined border between the process of explosion of a substance and the simple combustion. In fact one or the other is more or less quick chemical combination. Combustion is slow combination, explosion is swift combustion.

Similarly we can see smouldering, corrosion and slow oxidization or in general every slow chemical reaction. In short, the difference in all these phenomena is purely quantitative.

We shall observe that the energy of explosive substances in a unit of their mass is even much less, than the energy, liberated by a unit of mass of the fuel. Similarly in the economic relationship fuels are more advantageous than the explosive substance, since the latter are much more costly and their utilization is much more difficult.

Economically, we do not know how to do it, for the time being. All the experiments with the rockets. Automobiles, hydrogliders, sleighs, and gliders have great importance only from the point of view of study and preparation for the stratoplane and astroplane.

What then are the advantages that the explosive substances have? The great advantages are none of the economic ones though.

In fact, the explosive substances during a short interval of time release monstrous energy, because the chemical combination of the mixing elements of combustion, takes place instantaneously.

Let us suppose, that one kilogram carbon burns in a second, whilst one ton of the explosive substance may burn in that very second. If at the same time as is usual, flying products are obtained, then they can acquire a velocity several kilometers per second. Their energy of motion may be utilized by turbines although practical solution of this problem has still been insufficiently found. We believe, however, that the future of the rocket engines must be bright.

We rely on the fact, that the flying products of explosion expanding in the artificial or natural vacuum (outside the atmosphere), convert all their energy into motion. Therefore the percentage of utilization of heat may be higher than anywhere else. Besides, we have the rapidity of combustion and the considerable release of work in a second (energy).

The energy of the explosive substances is immediately utilized for the firing of cannons and the destruction of solid masses (for example, granite rock). In a split portion of a second they impart great velocity to the cannon ball, developing (on an average) several million horse power. In that very split portion of a second, they generate powerful energy of smashing the stone masses.

The rocket devices functioning directly (rockets) can similarly impart great force to the projectiles and vehicles on the condition of their velocity being several kilometers in a second. But this velocity is not possible in the lower strata of the atmosphere, because this is hindered by the resistance of the air. Only in the extremely rarefied layers of the atmosphere such a velocity and advantageous utilization are possible.

At the proper time, we shall disprove the most widespread fallacy, that in the uppermost rarefied strata of the atmosphere, Cosmic velocity is possible with the usual energy of the engine. Even in the year 1895 in my published works*). I had found, that the required power of the engine, weight of which being constant, in the most favorable rarefied stratum is proportional to the velocity of the airplane. For example:

1) Density of the atmosphere 1 1/4 1/9 1/16 1/25

*) K.E. Tsiolkovskiy "Airplane or Birdlike (Aviational) flying machine. Collection of Works Vol I Academy of Sciences of the U.S.S.R., 1951 (Editors).

2)	Velocity	1	2	3	4	5
3)	Required power.	1	2	3	4	5

Here the velocity of the horizontal flight, during the flight on the Earth, has been taken as unity; the output of the engine at the same time is also taken as unity. In the unchanged density of the air this capacity is proportional to the cube of the velocity, i.e. this capacity, grows in the numerical ratio of 1,8,27 64 and so on. This was confirmed by the American scientist Korvin- Krukovsky within 35 years.

Difficulties during the flight in the stratosphere are great, but they can be overcome, utilizing precisely the monstrous force of the combustible substances.

Engines and explosion

Strictly speaking in each furnace there takes place a continuous combustion-explosion especially where atomizers are employed. However, in the ordinary steam engine or turbine, this explosion is not directly used. Only the heat obtained is used. When we have cheap fuel, like peat or coal with unsuitable mixtures, and machines are not constrained with weight, then it is very economical. But in case of a locomotive the fuel is pure and expensive and therefore there is less economy here. It is evident that the tendency is to switch over to explosion motors (benzene and diesel-motors) or to electrical ones.

We have a second case in internal combustion engines. Here force of explosion is made use of and therefore these engines are more accurately called explosion engines. Their advantages are: enormous energy, economic utilization of the fuel and the fact that its reserve is small. Disadvantages: more purified and expensive fuel. In both the cases, oxygen costing nothing (from air) is utilized.

Reactive automobiles, hydro-gliders, sleighs, air-planes, stratoplanes and astroplanes utilize the oxygen stored earlier or other component, required for combustion. The aim is to obtain enormous energy in a short time. There may be two methods.

1) Oxygen component or its substitute may be mixed earlier with the combustible part (for example, powder). Till this time for the motion or flight of people, only ready-made explosive substances were employed.

The advantages of this method are the following: arbitrarily quick release of energy and the simplicity in the design of the engine. Disadvantages are very many, namely: danger of general explosion of the entire reserve (death of Tilling and others), loading the machine with the weight of oxygen compounds or liquid oxygen, loading with the weight of pipes, stuffed with explosive substance and withstanding immense pressure of the escaping compressed products of combustion (due to this the pipes must be strong and heavy), in case of small velocities, available in the lower strata of the atmosphere, lower percentage of utilization of chemical energy, and expensiveness of explosive substances.

2) In the second method the oxygen compound is separated, from the combustible ones. The components combine gradually, as in aviation engines, only oxygen is not taken directly from the air. Danger of general explosion is not there. Burdensomeness by heavy pipes is the same. But the durable advantages remain.

What forces us to have recourse to the stored oxygen? On very high altitudes, in extraordinarily rarefied air or still higher, beyond the atmosphere, in the vacuum, we shall require the reserve of oxygen combination, because to extract oxygen from the atmosphere is practically impossible, while in the vacuum it (oxygen) does not exist.

There it is possible to achieve large velocities as utilization of chemical energy may be highly substantial. Only the disadvantages will remain: Overloading by the weight of oxygen and its expensiveness or that of its compounds. But the following can serve as the elements of explosion: cheep petroleum (fuel and liquid oxygen or its combinations, for example, liquid nitrogen tetroxide (N_2O_4). This is not so costly. The distribution of the components of explosion is accomplished in practice in small flying devices (without people). The affair, evidently, is progressing. But these devices have other shortcomings, pointed out by me in the journal "Airplane" (1932)*. Therefore they also furnish insignificant results.

SELECTION OF COMPONENTS OF EXPLOSION.

Here we assume the access to very rarefied strata of air, when extraction of oxygen from it (air) is difficult.

Components of explosive substances for rocket motion must possess the following properties.

1) For a unit of their mass, they must release maximum work on combustion.

2) They must on combination provide gases or volatile liquids, reverting to vapors on heating.

3) They must develop on combustion possibly low temperature so as not to burn or melt the combustion chamber.

4) They must occupy a small volume i.e. must have large density.

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*) In the article "Reactive Motion (propulsion) and its Successes", journal, "Airplane", 1932 No. 6.

5) They must be liquids and get mixed up easily. The use of powders is complicated.

6) They can also be gaseous, but should have high critical temperature and low critical pressure so that it is conveinent to use then in liquefied form. The liquefied gases are in general not fit due to their low temperature, because they absorb heat for their own heating. Then their use is combined with the losses due to evaporation and the danger of explosion, similarly costly chemically unstable, or products difficult to obtain are not fit.

Let us cite examples. Hydrogen and oxygen, for example, satisfy all conditions, besides those pointed out in points 4 and 6). In fact, liquid hydrogen is 14 times lighter than water (its density is 0.07) and therefore not fit, because it occupies a large volume. Then the critical temperature of hydrogen is equal to 234° below zero, and of oxygen 119° below zero. Carbon alone is not fit on account of its solid state. Silicon, aluminum, calcium and other substances are not suitable, not only for their solid state but also because they furnish along with oxygen non-volatile products. Ozone is not fit because it is costly and chemically unstable. Its boiling point is 106° below zero (Centigrade). Majority of simple and complicated substances are not suitable because they release less energy on combination for unit

products.

Which substance are suitable ? Here they are .

1) Simple or complicated, but having liquid state on ordinary or not very low temperaturem and density not far from the density of water. It means, it is possible to admit liquefied gases, but having low critical temperature.

2) Releasing maximum work for a unit of obtained products. Such are several slightly exogenous and in particular endogenous combinations. (Thelast ones on decomposition do not absorb, but release heat and therefore are particularly fit).

3) Inexpensive and chemically stable.

4) Providing volatile products on combustion: gases or vapors.

The most energetic constituent parts of explosion, furnishing volatile products, —— are hydrogen and oxygen .

On the formation of aqueous vapor, 3233 calories are released for each kilograms. Such a combustion is of light metals —— lithium, aluminum , magnesium, as well as silicon and boron, which gives considerably large amount of heat viz. from 3400 to 5100 calories,. However, these materials are not suitable in view of the non-valatility of products.

But in isolated form hydrogen and oxygen are not fit for the time being. The best of all is to change them with unstable compounds of other components.

So that we shall have hydrogen compounds instead of hydrogen, and instead of oxygen —— oxygen compounds. The most suitable for combustion in oxygen are hydrocarbons. And hydrogen and carbon on combination with oxygen give volatile products. Hydrogen on combination with oxygen, for a unit mass of products, gives more energy, than carbon,. Precisely hydrogen gives from 3233 (vapors) to 3833 (Water), while carbon 2136 calories. (All the subsequent numbers expressed in small calories are for 1 g or for 1 gram-molecule of the substance). Therefore hydro carbon release on combustion, more energy, if the percentage of hydrogen is higher.

Such are the saturated hydrocarbons. The simplest of them is methane CH_4, or the marsh gas. It contains small percentage of hydrogen (25%). But it must be kept in view that the majority of these compounds are exagenous, i.e. on their formation, heat is released. When these compounds burn in oxygen then they must dissociate into H_2 and O_2, otherwise heat is absorbed back. Besides that liquefied methane has low boiling point (-82°C) and therefore not fit.

But we shall calculate its energy of explosion. One part of carbon requires two parts oxygen. At the same time, 94,000 calories are released per one gram-molecule (mole). Four parts of hydrogen require two parts of oxygen with the release of 116000 calories per 36g. Eighty g release in all 210000 calories. But the preliminary dissociation of CH_4 requires 18,500 calories per 16g (gram molecule). This leaves 191500 calories for 80 g. We shall get 2394 calories per one gram of products.

Amongst the hydrocarbons there is one which holds a lower percentage (12.2%) of hydrogen, but it is formed with the absorption of heat (endogenous compound). This is ethylene (C_2H_4). We shall find it more suitable. In fact, two parts of carbon require four parts of oxygen 188,000 calories are released per 89g. Four parts of hydrogen need two parts of Oxygen and 116,000 calories (vapor) are liberated per 36g. It means, 304,000 calories are released by 124g. But on dissociation, C_2H_4 releases back the earlier absorbed 15400 calories for 28g (mole), So that in all we shall receive 319400 calories. This is for 124 g. We shall obtain 2576 calories per one g of products. This is slightly larger than from methane. Ethylene liquefies easily, since its critical temperature is 10°C and the critical pressure is 52 atmospheres. Ethylene is easily obtained from ethyl alcohol or ether on their passing through clay balls. heated up to 300-400°C. It follows that ethylene is more suitable than marsh gas (methane).

Now we shall examine benzene C_6H_6. As a liquid sufficiently dense, it is most suitable for the rocket. But it contains only 8% of hydrogen. What is its energy per unit of mass of products on its chemical combination with oxygen? On formation it liberates, per one mole (gram molecule or 78g) a total of only 102,000 calories. Nevertheless, we shall make calculation. C_6 requires O_2 and H_6 needs O_3. This means that 738000 calories are liberated per 318g of the products. Deducting from here the absorption (of heat) for dissociation of C_6H_6, we shall get 727, 800 · calories. This is for 318g. Per one g of products we shall find 2289 calories. This is a little less than ethylene gives, but for that we have a liquid of ordinary boiling point with very low pressure of its vapors.

Acetylene C_2H_2 of the same percentage composition, in the capacity of a gas, is not convenient. Besides this oxygen combination releases much more heat on its formation, than benzene, about 18 times. It means, that it absorbs more on combustion also. Besides the more the carbon in the hydrocarbon, the higher is the temperature of dissociation, and consequently, the temperature of combustion. Liquefied hydrogen, is the best of all, but its obtaining and preservation is difficult, in addition to the enormous volume (it occupies).

We now quote the data about the heat of combustion of spirits, ether and turpentine.

Methyl Alcohol	2123 calories
Ethyl Alcohol	2327 "
Ether ($Ch4\ O_{16}$)	2512 "
Turpentine $C_{10}H_{16}$..................	2527 "

Here are shown the quantity of liberated calories per unit of combustion products. It is evident, that these fuels cannot be ignored.

In our calculations we suppose oxygen to be liquefied. This presents great inconvenience. Ozone is chemically unstable and practically inaccessible. Therefore, we shall pay attention to the oxygen compounds.

The oxygen compounds of nitrogen are interesting. We count the most suitable for us. Endogenous gaseous compound, nitrous oxide N_2O, is not suitable, because it contains a larger percentage of nitrogen. The same we can see about the endogenous compound nitric oxide NO. The third compound, nitrogen tetroxide (N_2O_4) is a rather brown stable liquid, Its formation (synthesis) is accompanied by a slight release of heat. It is chemically rather stable (up to 500°C) and is very dense (1.49), which makes it highly suitable. It is a strong oxidizer but covering of the tanks, pipes valves and others by gold, platinum, iridium and other non-oxidizing substances or alloys protects the machines from corrosion.

The fifth compound is nitric anhydride or nitrogen pentoxide (N_2O_5). It contains somewhat less nitrogen, but it is inconvenient due to its chemical instability.

Let us now consider NO_2. This compound can fully replace oxygen, but it is burdened with nitrogen. This decreases the velocity of the exit of gaseous products of combustion, because it increases their mass. We have taken into consideration benzene. Its gram molecule is 78. We have seen, that 78g of this substance requires, for its complete combustion, 240g of oxygen. The weight of products on combustion in pure oxygen is equal to 318g. But we have No_2 instead of oxygen. Here 105g of nitrogen are added. The products consequently will be 423. This quantity is larger by 423: 318=1.331 times. Due to the increase of the mass of products of combustion, their exit velocity (speed) decreases by 1.15 i.e. it constitutes 87%. For example, instead of 6000 M/sec, it will be 5220 M/sec. The energy of explosion for 1g products will comprise 1721 calories.

Perhaps, we shall be asked: what about nitroglycerine, pyroxylin and others, do not they give more energy? Alas!

much less, as it is seen from the following table. In it is shown the heat of formation of several substances per one gram of products in small calories. We shall choose the most energetic explosive substances.

Aluminum with Ammonum Nitrate ——	1480 calories
Powder Smoky and Smokeless	from 720 to 960 cal.
Nitroglycerine Powder	up to 1195 cal.
Nitroglycerine	1475 calories.
Dinitrobenzene with nitric acid ..	1480 "
Picric Acid	750 "
Mercury fulminate	350 "

These ready-made explosive substances are impossible to be employed owing to the danger of unexpected explosion of the entire mass, even besides their low energy.

<u>We summarise what has been discussed above.</u>

1) Hydrogen is unsuitable due to its low density and the difficulty of storage in liquid form.

2) Liquefied methane CH_4 with liquid oxygen yields 2394 calories and is not suitable owing to its low boiling point.

3) Olefiant gas, or ethylene C_2H_4 with O_2 yields 2376 calories.

This mixture is more suitable, since ethylene has the critical temperature, equal to 10°C.

4) Benzene C_6H_6 with oxygen yields 2289 calories. The magnitude of energy here is less, convenient the fact that on normal temperature benzene is a liquid makes it use . Suitable are also the mixtures of liquid hydrocarbons with high boiling point (Kerosene and others), all the more so because they are cheap (petroleum, naphtha).

5) The employment of liquid oxygen presents some inconvenience due to storage difficulties,

6) The most suitable is the replacement of oxygen by nitrogen peroxide No_2. This is a brown, chemically stable liquid, denser than water. On its combination with benzene 1721 calories are released per unit product.

These two liquids are most suitable for the rocket. But the parts of the machine must be protected from the oxidizing effect of No_2. This energy (1721 calories)is small, but greater, than the energy of the best powder and the most terrible explosive substances (nitroglycerine). Besides, the latter are expensive and dangerous in use.

Similarly suitable are spirits (alchohols) and sufuric ether. We append one more relationship, between the heat of combustion and the corresponding velocity of the products of combustion in ideal conditions, i.e. in the vacuum and when the nozzles (barrels) are very long.

1)	Heat kilocalories......	1000	1500	2000	2500	3000
2)	Speed of Flow M/sec....	2900	3600	4200	4600	5100

On the use of ether, we shall get a velocity of 4630 M/sec. In this last case, on horizontal motion on rails or in the absence of gravity and resistance of the medium, we shall obtain the following final velocities of the projectiles for different ratios of the weight of fuel to the weight of the projectile with all its contents, except fuel and oxygen.

1)	Ratio of weight of fuel to the weight of the structure.	1	2	3	4	5
2)	Maximum velocity, M/sec.	3500	5000	6500	7700	8600
3)	Ratio of the weight of fuel to the weight of the structure.	6	7	8	9	10
4)	Maximum velocity, M/sec.	9500	10 100	10 700	11 100	11 300

It means that with a five-fold ratio, it is possible to become a satellite of the Earth, while with a ten-fold-a satellite of the Sun, because detachment of the projectile from the Earth will take place and its settling into the orbit of our planet.

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Astroplane with machines preceding it. (1933)

Steam Turbines. Deficiency of Steam Turbines.

At first the turbine was simple: it and only a steam boiler, nozzle and one disc with vanes (blades). The utilization of energy was very slight, while the speed of rotation

1 Новая паровая турбина. Продольный разрез.

Фиг 1. Схема. 2

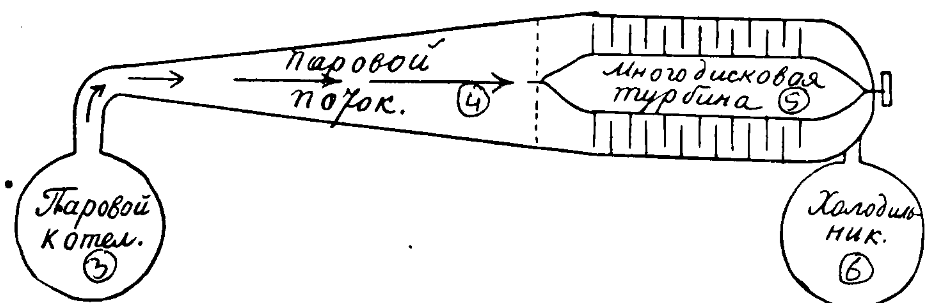

FIGURE 1.

Keys: 1) New steam Turbine Transverse Cross-section.
2) Fig. 1. Scheme.
3) Steam boiler.
4) Steam current.
5) Multi-disc turbine.
6) Condenser.

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was enormous, impracticable and dangerous. Afterwards the condenser was enlarged, so that on one side of the vanes (blades) there was steam pressure and on the other, almost vacuum. Utilization of energy was increased.

At last, multi-disc turbines were devised with intermediate stationary discs, on which similarly were installed stator blades (diaphragms)/ This was an ingenious addition (fig. 1)*.

We shall discuss the significance of the movable and immovable discs, which are designed almost identical. We are leaving out the details. The discs are, as if installed on the working-shaft and all this enclosed in a common cylinder.

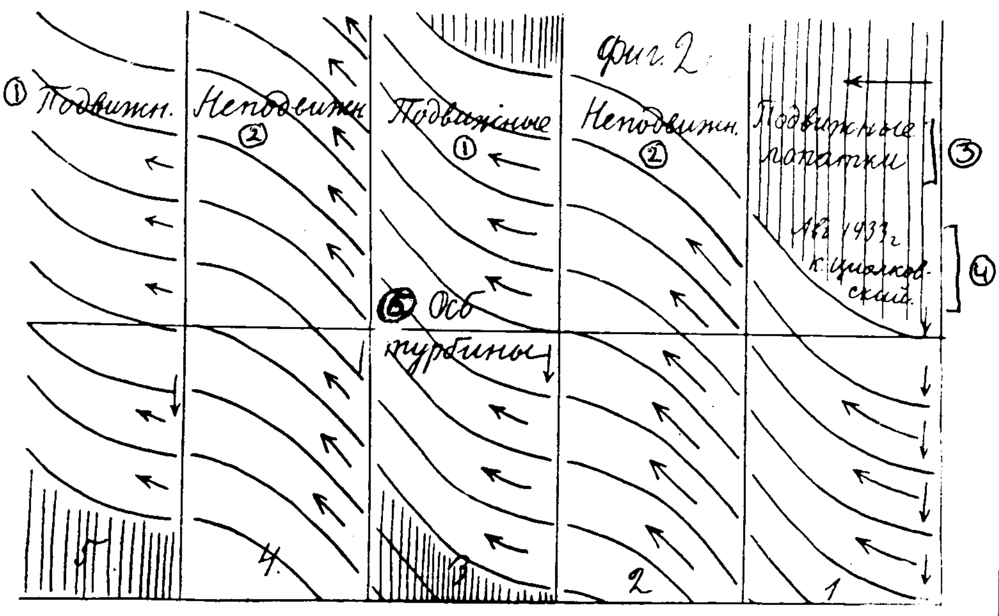

FIGURE 2.

Keys: 1) Moving 2) Immovable (fixed) 3) Moving Vanes (blades) 4) August 1933. K.E.Tsiolkovskiy 5) Axle of Turbine

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* In this article aregiven drawings made by K.E.Tsiolkovsky. (Editors).

The odd discs rotate along with the shaft, and even ones are not attached to it, but to the cylinder and are, therefore, stationary. (For brevity we give a simplified account.)

Imagine a longitudinal cross-section normal to the discs. We shall get a number of wavy smooth curves (fig. 2).

This is not quite exact, but for an explanation it is sufficient, particularly if the speed of vapors is extraordinarily great. The odd figures denote the crosss-section of movable disc vanes (blades), while the even ones are the same for fixed vanes (blades). The moving blades (vanes) are cross-hatched (shaded). The steam, entering along a large number of curved, channels, between the vanes (blades) of the first moving disc, and sets it into rotational motion, losing a part of its velocity and working at the expense of the energy of its motion. Afterwards, the steam entering between the stationary vanes (blades) of the first diapbragm, straightens itself, acquiring motion almost along the axis of the main shaft or along the cylinder, holding the discs. Farther, the steam strikes, although with a small speed, the moving vanes (blades) of the second disc, performing the work and losing a part of its speed. Thus the work continues until the steam loses larger part of its speed.

Passing through all the discs, it condenses in the condenser, forming water. All this is much more complicated: and the discs, and diaphragms are not resembling and gradually change. But we shall not go into the known details and calculations.

The multi-disc turbines furnish means to utilize all speeds of steam, which cannot be said about the one-disc type turbine. In the one-disc turbine, a larger part of the kinetic energy is lost fruitlessly. The point is, that the circumferential (maximum) speed of the vanes or disc is fully specific (definite) and cannot exceed approximately 300 M/sec, no matter what material is ued. For the optimum utilization of the kinetic energy of gas, it is necessary that the speed of vanes is not less than one third of the speed of steam. Of course, if its speed is low, for example 600 M/sec, then good utilization is possible even with the one-disc Laval turbine. The only inconvenience is in the dangerous speed of rotation and the impracticability of its application to electrical generators and for other purposes where speed required is generally low. If the speed of steam or gas, for example, is equal to 2-5 km/sec, then almost the entire kinetic energy is lost, since the circumferential (peripheral) speed of the vanes cannot exceed 200-300 meters per second.

It is a different matter if there is a multi-disc turbine. Devising vanes of small curvature, we can acquire any desirable small velocity of vanes (blades), no matter what the speed of steam or gas is, and simultaneously a very large utilization of heat. Only, the greater the speed of steam and the lower desired speed of vanes (blades), the larger the number discs and the diaphragm must be. However, I see some drawbacks of the multi-disc turbines. I shall count them.

1) The speed, emerging from the boilers of compressed steam, may exceed 500-600 M/sec. On a different design of the turbine it could be made to reach up to 2000 M/sec. The energy of this motion (kinetic energy) will be 16 times more.

2) The temperature of steam emerging from the nozzles is too high (300-400°C) and affects harmfully the discs and cylinder.

3) The steam, having condensed in the condensers, liberates uselessly the energy, consumed in its formation.

4) Only a small area of discs is employed because the steam flows out of several narrow nozzles.

We shall indicate means to eliminate these deficiencies, the chief of which is the low utilization of the heat energy, or the fuel.

Design of my turbind.

The turbine that I have proposed has the following design (See fig 1 in which it has been schematically shown in longitudinal cross-section).

Steam from the boilers does not flow directly to the disc blade with a low speed, but flows before, through the conical pipe. Expanding and cooling, it acquires from its a velocity up to 2000 M/sec. In the process it gets liquefied, and in the expanded portion we already have no flow of steam, but a current of drops, moving three times as fact as bullets and cannon balls. In this way, almost the entire heat and the latent heat of evaporation are converted into kinetic energy.

This stream flows on ¾ of the area of the first disc, and afterwards on the remaining discs, until it losses almost all its velocity. The utilization of the fuel will be enormous, the function of the condenser will be reduced to zero.

Actually, there is not even any need for very high pressures of steam. This reduces very much the weight and increases the softey of steam boilers. Nevertheless, high pressure is useful because it reduces the dimensions of the conical pipe. It is particularly useful in the absence of a condenser (in an atmosphere of high pressure).

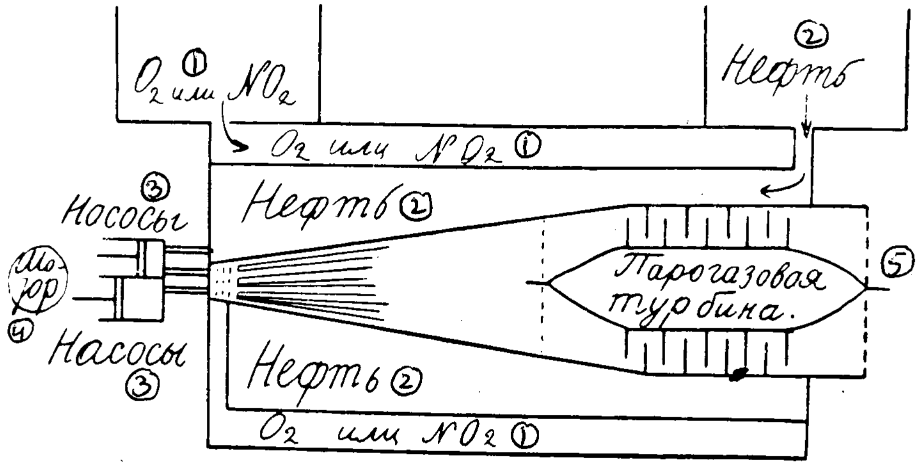
Steam Turbine without Boiler and Condenser.

The familiar turbine mentioned by me has a large specific weight, i.e. weight per horsepower: the boilers and condensers are terribly heavy ! For this reason such turbines are not suitable for dirigibles, airplanes, stratoplanes, automobiles —— in general, there, where high power with low weight is required.

We can avoid condensers on high initial steam pressure in boilers. The lower the steam pressure relative to the outer atmospheric pressure, the more we lose in fuel utilization. It means that an altitudes, the utilization of fuel will be greater, as we ascend higher, i.e. - as the atmosphere becomes rarer. Therefore, the employment of devices without condensers for use in stratoplanes is advantageous.

However, the boilers will remain and the whole thing will become unsuitable. Is there any way of getting rid of boilers? (Nevertheless, the boilers may be made lighter, if the external atmospheric pressure is lower).

Fig. 3 shows the design of a powerful engine with a low specific weight. Here we store not only fuel (petroleum) but also oxygen in liquid form or its compound.



6 Фиг 3. Двигатель малого удельного веса. Продольный разрез.
Схема. Авг. 1933г. К. Циолковский.

FIGURE 3.

Keys: 1) O_2 or NO_2 2) Petroleum (oil)
3) Pumps 4) Motor (engine) 5) Steam-cum-gas Turbine 6) Fig. 3. Engine of small specific weight. Longitudinal Cross-section. Scheme. August 1933. K. Tsiolkovskiy.

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Oxygen may be impure i.e. with a considerable mixture of nitrogen. The demand for liquid oxygen is still small and therefore it has considerable price at present. It is employed for all kinds of light weight motors and also with a large mixture of nitrogen, the price will fall down considerably and it will not be more expensive than petroleum. Petroleum and liquid oxygen are pumped in simultaneously by means of pumps and an engine, into a special chamber (carburettor), located at the beginning of the conical pipe. Here these components get mixed up by means of a special "lattice" and produce continuous combustion and the temperature rises up to 3000°.

Carbon dioxide gas is formed and also water vapor, having immense pressure of several thousand atmospheres. Both expending in the pipe, and cooling due to it, acquire larger and larger speed which at the end of the pipe reaches up to 4000 M/sec. This impetuous and, at the end, gaseous stream with mixture of water vapor and water drops strikes the blades of moving and stationary discs and is converted into the work of rotation.

The oxygen compound cools the petroleum, and the petroleum, circulating around the conical pipe and the carburettor, cools this combustion chamber and prevents thereby its melting, burning and destruction. Besides, the steel pipe, heated up on the carburettor, transfers its heat, by means of conduction, to the colder parts of the pipe, constituting the continuation of the mixing chamber and in this manner it is cooled more.

The overloading of the motor here takes place only due to the liquid oxygen compound. In case of benzene (C_6H_6) and oxygen (O_2), the mass of the latter will be almost 3 times more than that of the fuel (See "Cosmic Rocket). experimental preparation", 1927).

In case of other hydrocarbons and a large mixture of nitrogen, this ratio may increase to 4. But, on the one hand such a fuel as coal, is 3-4 times less efficient than petroleum so that its reserve will hardly exceed the reserve of petroleum along with oxygen; on the other hand, during flight in the stratosphere it is much simpler to store oxygen than to extract it from the rare atmosphere, and then to cool and condense it.

If the pressure is not very large in the carburettor then it is possible to make continuous pumping of fuel or the oxygen compound. If it is maximum (which is more advantageous in matters of the economy of weight and the utilization of fuel in the dense atmosphere), then the work of pumping will be excessively great. Then it is more convenient to employ intermittent pumping of the components of explosion with the help of piston pumps. In this case we shall get a series of blank volleys (shots). It is in the brief intervals between them that injection (pumping) takes place with the least expenditure of energy. The vanes of discs will be subjected to the varying pressure of gas flow, which compels them to become stronger.

Out of oxygen compounds the most advantageous is the brown, chemically stable liquid —— nitrogen tetroxide (NO_2).

The motor, pumping the components of explosion into the carburettor, may, of course, borrow its work from the turbine through special transmission, but may be independent, which is more convenient. The best is the explosion motor, borrowing energy from the components of explosion. The products are ejected into the general pipe and enhance reactive action.

<u>Application of the above mentioned turbine to the Stratoplane.</u>

The design of such a type of high altitude airplane (stratoplane) in longitudinal cross-section has been depicted (schematically) in fig. 4.

The middle part of the body with wings is occupied by the above-mentioned motor. It sets into motion an air-screw (propeller). The latter sucks in air on the right and pushes it to the left. Due to this, the device moves from left to right (See arrows outside the body, indicating the direction of motion of the ship). The recoil (reaction) of the exhausted gaseous stream also helps in this motion. It is the greater, the lesser the turbine uses the motion of the steam-cum-gas flow. On large velocities achieved by the stratoplane at altitudes the work of recoil is more important, than the work of the air-screw. Below, in the dense layers of the atmosphere, it is the contrary. Therefore, flying at low altitudes, the air-screw must work more, while in the rarefied layers (strata),

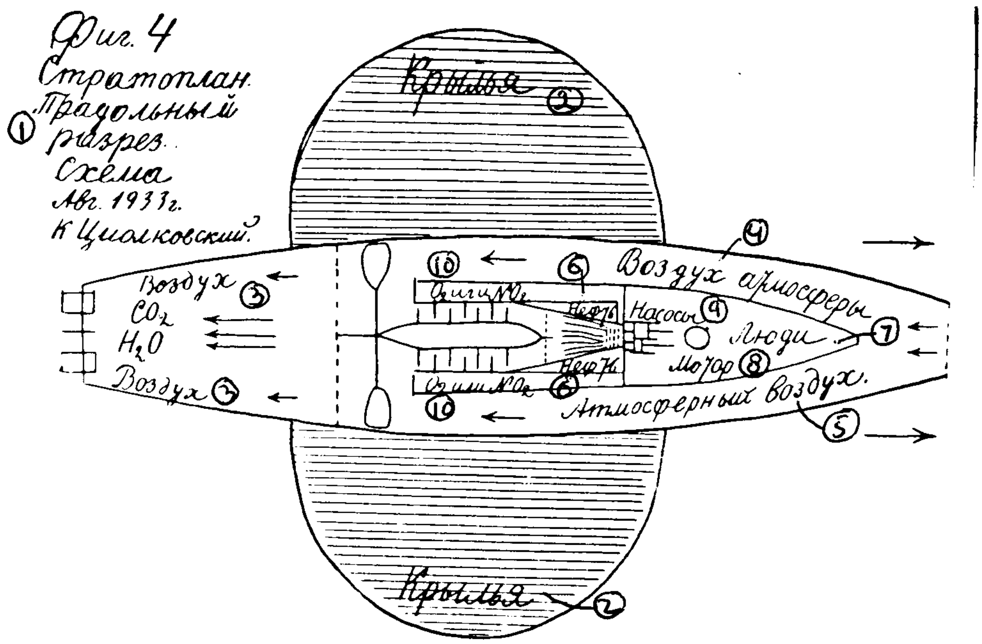

FIGURE 4..

<u>Keys</u>: 1) Stratoplane. Longitudinal Cross-section. Scheme of August 1933. K. Tsiolkovskiy.
2) Wings 3) Air 4) Air of the Atmosphere.
5) Atmospheric Air. 6) Petroleum.
7) People 8) Motor 9) Pumps 10) O_2 or No_2.

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recoil must be used at high speeds.

The higher the velocity of the stratoplane, the smaller must be the end holes of the body hull). Otherwise the air-screw will be shattered due to the centrifugal force (See my "Semi-Reactive Stratoplane", 1932*)).

*) K.E. Tsiolkovskiy, Collected Works, Vol. II. Academy of Sciences of the USSR, Moscow, 1954 (Editors).

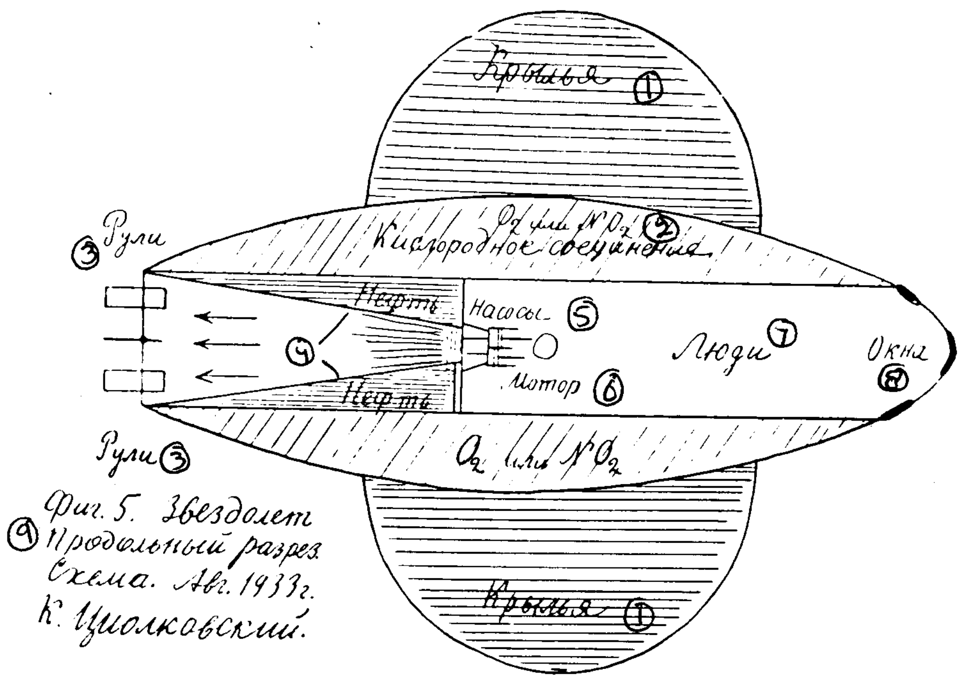

FIGURE 5.

Keys: 1) Wings 2) O_2 or NO_2 Oxygen compound.
3) Rudders 4) Petroleum. 5) Pumps.
6) Motor (engine) 7) People 8) Windows.
9) Fig. 5. Astroplane. Longitudinal Cross-section.
Scheme of August 1933. K. Tsiolkovskiy.

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On the right side of the motor, at the rear, we see a closed (sealed)place cabin with an oxygen atmosphere or with ordinary air of invariable density. This is the cabin for passengers. It is necessary at high altitudes with a very rarefied stratum of air.

Observation of the environment can be made through several special optical tubes (periscopes).

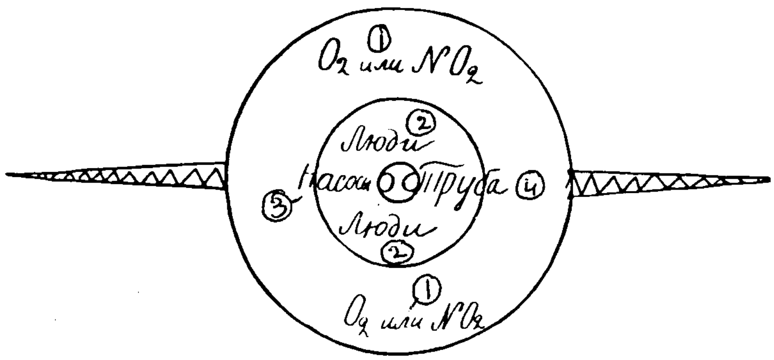
Note: 1. The last moving disc of the turbine with vanes (blades) curves the stream. The large air-screw similarly twists the stream. This can be counteracted by two direction rudders, by means of their unequal inclination. It is possible to place a special stationary diaphragm against the air-screw, similar to it (the air-screw), only with opposite (versed) curvature of the vanes (blades). It will straighten the flow, and this will thus eliminate the rotation of the stratoplane around its longitudinal axis. This diaphragm has not been shown in the drawing.

Note: 2. My battery-operated gas compressor is designed on the pattern of the turbine.

ASTROPLANE.

The above-mentioned semi-reactive airplane of considerable dimensions can now a purely reactive device (astroplane) to the possibly large height. Then the astroplane, left to it self, will start its purely reactive motor and will rush out of the atmosphere. My astroplane has repeatedly been described in the press, and therefore we refer the reader to these descriptions *). Here I give, however, its simplified

*) See, "Investigations of Outer Spaces by Reactive Devices", 1926 (Editors).



5
Фиг. 6. Звездолет
Поперечный розрез.
Схема. Авг 1933 г.
К. Циолковс

FIGURE 6.

Keys: 1) O_2 or NO_2 2) People 3) Pumps
4) Pipe 5) Fig. 6. Astroplane transverse cross-section. scheme of August 1933. K. Tsiolkovskiy.

....

drawing (fig 5). This is the longitudinal cross-section of the device.

If we are to eliminate from fig. 4 the turbine **along with the air-screw and the outer jacket (casing) along** with atmospheric air, then we shall get an astroplane, or a purely reactive flying apparatus. The drawing can be understood without any description. The wings are flat. They are useful before flying out of the atmosphere and particularly on landing in the air without explosion and fuel. Several quartzitic windows are located in the front. The lateral cavities on the walls are occupied by oxygen (O_2) or its compound with nitrogen (NO_2). Towards the rear are three rudders: of direction, altitude and stability. All the three have particular and independent drives. Fig. 6 depicts the very same machine in transverse cross-section.

Projectiles acquiring Cosmic Velocities
on dry land or on water.

(1933).

1. These projectiles have great advantage vis-a-vis those, which must acquire this velocity at an altitude without links with the terrestrial installations, namely:

a) they can make use of electrical energy, obtained from outside (i.e. from stationary terrestrial installations, as a tram);

b) in prostrate guns it is possible to make use of the elasticity of gases warmed up by electricity;

c) these installations may serve continuously for the despatch of a majority of projectiles beyond the atmosphere;

d) for the movement of the projectile in the pipe, it is advisable to create a vacuum in it: the long pathway of the projectile, of course, is horizontal or slightly inclined, bordering the ground, and does not rise to an altitude as a tower;

e) the projectiles are launched without more of the reserve of the explosion components.

The main advnatage consists in acquiring of any form of energy by the projectile and the possibility of achievement by it of the cosmic speed.

2. These devices have many deficiencies in comparison with the reactive devices. The latter represents the first stage, while the former the subsequent ones.

What types of deficiencies are there, are listed below:

a) We shall need a particular pathway (pipe) with a length up to 1000 Km and it is known to be very costly.

b) Secondary fixed sources of energy are needed, as, for example, electric generators, compressors etc.

c) The length of the projectiles from 40 to 400 or more meters is required (in good form, as may be supposed), otherwise acquiring of cosmic velocities is impossible.

d) the projectile, while still in the dense layers (strata) of the air, acquires Cosmic velocity and therefore experiences more resistance of the medium.

In general, the obstacles are in complication, magnitude and expensiveness of these installations. But they are possible. It is necessary, so that the people were convinced of the possibility of achieving of Cosmic velocities and of the incomparable advantages of existence beyond the atmosphere, away from the Earth.

3) Higher velocities are possible only in the condition of oblongness of the projectile flying or moving on the Earth. We shall make use of my work "Pressure on Flat Surfaces" 1930. **We are quoting part of one of the tables:**

Velocity Km/sec.						
1.2	1.5	1.8	2.4	3	4.5	6
Corresponding minimum oblongness of projectiles.						
4	5	6	8	10	15	20

Let us assume, that we can achieve a velocity of only 1 K,/sec on four-fold oblongness. Then we shall obtain the modified table:

Velocity, K./sec											
1	2	3	4	5	6	7	8	9	10	11	12
Oblongness.											
4	8	12	16	20	24	28	32	36	40	44	48

If we still increase the oblongness, roughly two time, then we shall have almost only friction and resistance due to inertia and it is possible to tilt comparatively a little.

In this case, the resistance due to friction Q_q for a unit volume of the projectile V will be expressed by a formula [See my "Resistance of Air", 1927 formula (56)]

$$\frac{Q_q}{V} = a \; \frac{F \gamma v^2}{xD^2} \; .$$

Here 'X' is the oblongness of the projectile; D- the diameter of the maximum transverse cross-section; γ - the density of air and V- the velocity of the projectile.

5. F is variable and is expressed by the formula

$$F = 1 : \left[1 + \ln \left(\frac{v}{l} \right) \right] ,$$

where 'l' is the length of the projectile, or XD [see formula (19) of "Resistance"].

7. Coefficient

$$a = 0.00225.$$

8. Let us suppose, that V = 1000 M/sec D = 4M; γ = 0.0013; x = 100; l = XD = 400; F = 0.5211 (See "Resistance", table 21). Then we shall calculate

$$\frac{Q_q}{V} \; 0.000093 \text{ T.}$$

Consequently, at a velocity of one kilometer per second in the densest strata of the atmosphere, resistance on one M^3 of the projectile will be less than 0.1 kilogram.

9. On the basis of the foregoing formula, we shall draw up a table of specific resistances (i.e. resistance on 1 M^3) in kilograms at different velocities in Km/sec.

v	1	2	3	4	5	6	7	8	9	10	11
F	0.52	0.383	0.331	0.303	0.283	0.270	0.254	0.250	0.243	0.237	0.231
$\frac{Q_q}{V}$	0.1	0.296	0.576	0.928	1.35	1.87	2.45	3.07	3.77	4.56	5.37

10. In order to obtain work in seconds, it is necessary to multiply the specific resistance by the velocity :

$$L_s = \frac{Q_q}{V} v .$$

We shall obtain specific work in metric forces (if we divide by 100).

11. The full output of the projectile is enormous, because it is proportional to the volume:

$$N = \left(\frac{Q_q}{V}\right)_{v} V = Q_q v .$$

12. According to formula (33) of "Resistance", we shall get

$$N = a_1 F D^{3} .$$

14. Coefficient

$$a_1 = 0.00000156.$$

In this way we shall determine the complete output per second of the projectile (in the conditions given on p., 8)/.

16. We are giving a table, in which are indicated velocities in Km/sec, the resistance of the medium, on one M^3 of the volume of the projectile in kilogram, work per second in metric forces, resistance of the entire projectile $Q_q^{\prime}$ in tons and the complete out put per second of the entire projectile 'N' in metric forces.

TABLE

v	1	2	3	4	5
$\frac{Q_q}{V}$	0.1	0.296	0.576	0.928	1.35
L_s	1	5.95	17.28	37.12	67.5
N	251.2	15060	42670	92870	170680
v	7	8	9	10	11
$\frac{Q_q}{V}$	2.45	3.07	3.77	4.56	5.37
L_s	171.5	245.6	339.3	456.0	590.7
N	430	615	848	1140	1478

The output is expressed in metric forces, but at velocities, more than 6 km/sec, — in thousands of metric forces. Thus, at a velocity of 12 kilometers per econd, the output goes up about to 2 million metric forces, while the resistance —— to 16 T.

17. This output can be cut short, if we are to reduce the dimensions of the projectile. Let us suppose, that the average density of the projectile is equal to 0.2 and volume

2680 M^3. So, the mass of the projectile would be 521.6 tons. On an acceleration of 100 M/sec^2, pressure would be 5216 tons. It means that even at a velocity of 12 kilometers per second, the resistance of the medium is 326 times less.

18. It is interesting to calculate, how many ton-meters in all we spend on the esistance of air. Of course, we shall not consider. Work on overcoming of inerti .
and acquiring velocity.

19. Considering only the friction, we have

$$Q_q = A, FDV^2 .$$

20. Or $Q_q = A_2 v^2$, where $A_2 v^2 = A_1$ FD.

21. Differential of work spent on friction will be $dL = A_2V^2dx$, where x is the length of the pathway.

22. But dx-Vdt, where t is the time from beginning of motion, and V-jt. We are assuming the acceleration 'j' of the motion of the projectile as constant.

23. Then $dL = A_2V^3 dt = A_2j^3t^3dt$.

24. Integrating, we shall get.

$$L = \frac{A_2}{4} j^3t^4 .$$

or on the basis of (22)

$$L= \frac{A_2 v^4}{4j} .$$

25. Hence it is evident that on achieving one or the other velocity, the large acceleration 'j' is advantageous. But the magnitude of acceleration has limits, since at a large acceleration not only the aviators but also the objects might **suffer.** A small acceleration will not suit, since the pathway will be too long and costly. In the condition of the human beings lying in water, it is possible to adopt an acceleration of 100 M/sec. It gives a ten-fode force of gravity.

26. We shall adopt the old conditions (See P. 8.) and **the velocity** of 12 km/sec . For simplyfying the calculations of formula (24) we shall keep in view

$$L= A_2 v^3 \quad \frac{v}{4j} .$$

Or, on the basis of formulae (12) and (20) we shall get

$$L = N \frac{v}{4j} .$$

27. But **N** is known from table 16. Taking it for V = 12 km/sec and acceleration of 100 M/sec^2 We shall calculate L = 5775000 ton meters.

28. Output of one metric force in a second in the course of 24 hours amounts to 86400 metric forces or 8640 ton meters.

The work, obtained in accordance with P. 27, is released by the output of one metric force in a second in the course of 670 days (24 hours each day), or by machine 670 in the course of one day (24 hours), or by machine of 1000 forces in the course of 16 hours.

29. The best of all is to compare this work with the work of inertia of the projectile. It is equal to

$$L_i = \frac{v^2}{2g} G.$$

30. Nevertheless, it depends on the volume of the projectile and its average density.

32. We shall compare this work of inertia with the work of resistance of the medium (12). We shall get

$$\frac{Li}{N} = \frac{G}{2ga_1 FD_v} .$$

33. The table for 'F' at different velocities when the length of the projectile is 400 meters, may be seen on p. 9.

34. Let us calculate the ratio in accordance with p. 32 according to conditions contained on p. 8, when the velocity is one km/sec and the density of the projectile is 0.2, We shall get 8440 i.e. the work of resistance is completely negligible.

Even when the velocity is 12 kilometers per second it will be 703 times less than the work of inertia. When Dx and the density of the projectile are large, it will be still smaller.

Why are we afraid of the resistance of the atmosphere? It is dangerous and relatively large only for less-ablong bodies, such are the airplanes, dirigibles and, of course, still more —— the automobiles and ordinary trains.

Still this is not all. We launch a long body of smooth form with a velocity of 8-12 km/sec. Will not the subsequent resistance of air during the flight of the projectile through the atmosphere take up this velocity?

We shall deal with it just now.

We shall prove the theorem: The work of the cleavage of the entire atmosphere during the vertical motion of the projectile with constant velocity is such as if the whole atmosphere in the presence of its very same mass, has constant density, which exists, for example, at the sea level.

This density is equal to 0.00129. At this constant density and the mass of the atmosphere known to us its height will be about 7800 meters.

In act, whether any part of the atmosphere will be rarefied or condensed, the work of passing through it by the projectile, will remain the same. Let, for example, somewhere the atmosphere be 100 times rarer. The resistance will be 100 times weaker and the work due to this will diminish 100 times, but it (work) will, at the same times, increase 100 times because the rarefied pathway will be 100 times longer. In this way, it will remain unchanged.

35. The constant velocity of the flight in the atmosphere may be tolerated in practice, because the resistance of the medium, as we shall see, is very slight in comparison with the reserve of the kinetic energy of the rocket (or by its kinetic energy). The magnitude of the force of terrestrial gravity decreases much more considerably. But it is not perceived for an insignificant stretch of the dense atmosphere (20-40 kilometers) in view of the initial Cosmic velocity of the projectile.

36. On account of a small tilt of the rocket motion towards the horizon on the solid road, the path cannot be vertical; it lies on the mountains, the total inclination of which is not great. It means that the rocket has a more inclined motion.

In addition to this, considering the earth to be horizontal for a small stretch of the rocket journey, we shall offer the second theorem: The work of cleaving of the atmosphere on inclined motion of the projectile is inversely proportional to the sine of the incline of the path towards the horizon.

37. In accordance with these two theorems it is easy to determine the work absorbed by the atmosphere. We shall obtain even a greater value because of the slackening of velocity with the ascent; the actual work of overcoming the (resistance of the atmosphere is less).

For this purpose, it is sufficient to multiply the resistance according to table 16, by 7800 meters. For example, at a velocity of 12 Km/sec we shall obtain 124800 ton meters.

The value 7800 is the quotient from the division of the atmospheric pressure at the sea level by the density of air at the same level.

38. We shall find out the general formula of resistance of the entire-atmosphere [see formula (33) of "Resistance"].

$$La = \frac{\pi A_1 F v^2 D}{4 \sin y} \; 7800.$$

39. Comparing it with the work of resistance of air on the solid roadway (24), we shall get

$$\frac{La}{L} = \frac{7800\pi j}{v^2 \sin y} .$$

It means that the comparative resistance of the entire atmosphere is the less the larger the initial velocity of descent of the projectile from the path 'v' and the greater the inclination towards the horizon Y are. This ratio increases with the acceleration of the projectile along the path j.

40. Let us suppose, for example, $j = 100$ M/sec^2. $V = 12000$ M/sec; $\sin y = 0.1$. Then the ratio is 0. 1717 or 1:5,8. It means that the work of cleaving of the atmosphere is almost 6 times less than the work of friction during motion along the roadway.

41. It is certainly needless to say that this work is still slight not only in relation to the kinetic energy of the rocket, but also in relation to the work of ascent of the rocket. The latter is equal to weight, multiplied by height "H" of the atmosphere, which may be taken at about 30 kilometers in the present case . We shall get the work of ascent like this:

$$L_n = GH.$$

comparing this work with (38), we shall get

$$\frac{L_\pi}{L_a} = \frac{GH4 \sin y}{A_1 F\,^2 D7800} .$$

42. But H = 7800. Then we shall get

$$\frac{L_\pi}{L_a} = \frac{G4 \sin y}{\pi A_1 F v^2 D} .$$

It means that the relative value of the work of gravity increases with the decreases of velocity, the increase of the incline and the di ensions of the projectile.

43. We shall take the conditions on p. 3and make use of table 9. Let us suppose, that the density of the projectile is 0.2; sin y = 0.1 and V = 12000 M/sec. Then we shall see according to the formula, that the work of gravity, ignoring a small incline and large velocity, is 45. 16 times more than the work of cleaving the atmosphere on free motion in it.

44. In view of the comparatively less resistance of air and correspondingly less work, it is possible to redu e the oblongness of the projectile by about 2. It is also possible to reduce as many time its dimensions. Then

D = 2M, X = 50 and l = 100 M.

This is much more feasible in matters of the expenditure of energy and money . It will be all the more possible for achieving the maximum velocity of 8 km/sec. T en the oblongness and dimensions may still be curtailed twice to make D=1 M; X = 25; l = 50 M. Here the diameter is small but then it is the main thing in the shifting of mass and in flight through the atmosphere. Beyond it the atmosphere it is possible to construct dwellings of the desired sizes. dimensions do not count, because there does not exist the resistaance of the medium.

45. Now we shall find the required length of the solid pathway., A large acceleration of the projectile is not possible because man will be crushed then. Small accelerations also will turn out very costly for the pathway because the solid pathway will be too long and space for it will not suffice on dry land.

46. Taking j as the constant acceleration of the projectile, we shall find the length of the pathway $X = \frac{V^2}{2j}$. From here it is clear, that the length of the pathway will be the less, if the speed is less and acceleration is greater. On the basis of the previous resistance of air, we may not consider, only work, necessary for acquiring one and the same, specific velocity, nothwithstanding the acceleration.

It is not known what maximum acceleration can hold man in the lying position, immersed in water. But one may accept not less than 100 M/sec^2 or 10 times more than the terrestrial acceleration. At different velocities then we shall get such a length of the path in kilometers.

v, km/sec	5	6	7	8	9	10	11	12
x, kilometers.	125	180	245	320	405	500	605	720

At an acceleration, twice more (j=200 M/sec^2)

x_1, Kilometers.	62.5	90	122.5	160	202.5	225	302.5	360

In case of a higher velocity, 8 i.e. Km/sec the path will be from 320 to 160 kilometers. On ascent to 5 kilometers on a uniform mountain, the inclination will be from 1:64 to 1:32 . The sine of the angle will be from 0.0156 to 0.0313, and the angle itself from one to two degrees.

47. We shall not have to reckon with the resistance of the medium, but a large relative gravity of the train requires its particular durability, proportional to the acceleration 'j'. From this point of view it would be advantageous to elongate the pathway.

The better transmission of energy is that with the help of the electric current. But how to transform electrical energy into mechanical work? None of the known electric motors because of their weight are suitable here. With the help of the electric current it is easy to obtain a high temperature and chemical dissociation of substances. It is possible to make use of it but in heat engines these motors are themselves too heavy. The employment of reactive motors and the use of electricity in the capacity of heat-booster for gases cooled as a result of expansion, is possible. But then here the advantage is not so great. The temperature of heating cannot be very large, because the pipes carrying gas may melt. It is necessary to find out refractory materials and methods of their processing.

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MAXIMUM SPEED OF THE ROCKET (1935).

(Chapter X from, "Bases of Construction of Engines")

A. Interd dependence of the speed of the rocket and the mass of explosion components.

1. We shall base ourselves on the simplest formulae of my "Investigation" 1926 (in the absence of gravity and the resistance of the medium). Their values are approximate and they find application on the following occasions:

a) When the action takes place outside the field of gravity and in the vacuum.

b) when the device moves on a horizontal pathway and its form is elongated and very good;

c) when the flight is performed in the atmosphere almost horizontally; the device tilts a little from the horizon due to the rapidity of motion and flat wings.

We shall apply these formulae during the motion of the projectile with a small tilt towards the horizon, during its flight in the air.

2. We have $V = v_1 \ln \left(\frac{M_1 + M_2}{M_1 + M} \right)$, where V is the velocity of the rocket M_1 the mass of the projectile along with

all the contents, except the explosive substance, V_1 s the relative velocity of their ejection (it is constant), M_2 s the total mass of explosive substance and M- the mass of the explosive substance not yet combusted, and ejected. It is understood that v and Mare variable values.

3. If we assume M = 0, i.e. the entire supply of the explosive substances has burnt down, then we shall get the maximum velocity of the rocket.

$$v_0 = v_1 \ln \left(1 + \frac{M_2}{M_1}\right).$$

4. On the basis of this formula we shall draw up table No 4* of maximum velocities of the rocket depending on the complete burning reserve of explosive substance and the relative ejection velocity. The first column shows the entire used up mass of the explosive substance with respect to the mass of the rocket (without explosive substance), the last six columns show the velocity of the rocket in meters per second in case of relative velocity of ejection of 1,2,3,4,5 and 6 km/sec. Theory shows that the energy of the explosive substance, at the disposal of human beings at present cannot give a velocity of the products of explosion, more than 6 km/sec. The last column points to the percentages, i,e. it shows what part of the total energy of explosion goes to the rocket motion. As is evident, this percentage at first is very small, then

* The numbers of tables correspond to the numbers of points. (Editors).

TABLE 4.

Velocity of the rocket.

Ratio of the mass of ejected material to the mass of the rocket.	Velocities of the rocket (on total conversion of thermal energy and of chemical compounds into the motion of gases), M/sec.						Percentage of utilization.
	Ejection velocity km/sec.						
	1	2	3	4	5	6	
0.1	94.5	189	283.5	378	472,5	567	8.9
0.2	182.0	364	546	728	910	1092	16.5
0.3	262	524	786	1048	1310	1572	22.9
0.4	336	672	1008	1344	1680	2016	28.2
0.5	405	810	1215	1620	2025	2430	32.8
0.6	469	938	1407	1876	2345	2814	36.7
0.7	529	1058	1587	2216	2645	3174	40.0
0.8	586	1172	1758	2344	2930	3516	42.9
0.9	642	1284	1926	2508	3210	3852	45.8
1.0	693	1386	2079	2772	3465	4158	48.0
1.2	788	1576	2364	3152	3940	4728	51.8
1.5	915	1830	2745	3660	4575	5490	55.8
2.0	1098	2186	3294	4392	5490	6588	60.3
2.5	1253	2506	3759	5012	6265	7518	62.0
3	1380	2760	4140	5520	6900	8280	63.5
4	1609	3218	4827	6436	8045	9654	64.7
5	1792	3584	5376	7168	8960	10752	64.1

Table continuous on next page ...

Continuation ....

6	1946	3892	5838	7784	9730	11676	63.0
7	2079	4158	6237	8316	10395	12474	61.7
8	2197	4394	6591	8788	10985	13182	60.5
9	2303	4606	6909	9212	11515	13818	58.9
10	2398	4796	7194	9592	11990	14388	57.6
15	2773	5546	8319	11092	13865	16638	51.2
20	3044	6088	9 132	12176	15220	18264	46.3
30	3434	6848	10302	13736	17170	20604	39.[illegible]
40	3714	7428	11142	15586	18570	22284	34.4
50	4480	8960	13440	17920	22400	26880	31.6
100	5256	10512	15768	21040	26280	31536	21.0
193	6007.6	12015.2	18022.8	24032	30038	36045.6	14.4
	Infinity.			Infinity.			Zero.

to the extent of increase of the relative quantity of the explosive substances, it increases, attains the maximum, when the reserve is in the neighborhood of 4, attaining almost 65%, thereafter it begins to fall down to zero. When the reserve is between, 0.7 and 30 it is very good and more than 40%.

Absolute velocities of the rocket attain Cosmic values sufficient not only for **recession** from the Earth, but also for eternal recession from our Sun and wandering amidst the suns of the Milky way.

5. However, in practice the velocity of ejection is remote unless 5-6 km/sec is attained, and also such large reserves of explosive substances should not be taken, as are required for acquiring cosmic velocities —— at least, for overcoming the gravitation of the Sun and wandering amidst the stars of the Milky Way.

What are those velocities which are attainable in the most modest conditions, and how, having attained these velocities, to find out means for acquiring Cosmic velocities?

6. The thermal energy of explosion should not be made use of wholly: the flying out product will not cool down (on expansion) to absolute zero and in this way all the heat will revert to kinetic motion of gases. The unchecked

expansion of gases and vapors obstructs the external pressure of the medium (for example, the atmospheric), and also the lowering and the hardening of the combustion products. The restricted dimensions of the pipe* also obstruct the ideal use of chemical energy. The velocity of ejection will be less due to it, than the one calculated in table No. 4.

7. The last table expresses this.

TABLE 4.

50%	60%	70%	80%	90%	100%
0.707	0.775	0.837	0.894	0.949	1.000

The first line shows the utilization of the heat of combustion in percentages or the magnitude of its relative conversion into kinetic energy (ejection motion), the second the diminishing of the rocket motion, proportional to the diminishing of ejection velocity, If the thermal or mechanical work decreases, for example 9 times, then the velocity decreases 3 times. The figures of table 4 should be multiplied by one of the fractions of the second line so as to obtain the true maximum velocity of the rocket and suitable percentage of utilization of explosion heat.

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*) i.e., Nozzle (red).

8. We shall use it for the compilation of a new table, assuming 70% utilization of heat and the relative velocity of products at 4 km/sec. The latter of course, depends on the type of the explosive materials.

9. In table 9, the first line shows the velocity of the explosion products from 2 to 4 km/sec), the second-

Table 9.

Table of velocities at different utilization of combustion heat and total consumption of explosive substances.

Relative reserve of explosive substances.	Velocity of products 2000 M/sec.			Velocity of products 3000 M/sec.			Velocity of products 4000 M/sec.		
	Percentage of heat utiliza- ~~x~~tion			Percentage of heat utiliza- tion.			Percentage of heat utiliza- tion.		
	50	60	70	50	60	70	50	60	70
	Final velocity of the rocket, M/sec.								
0.3	370	406	439	556	609	658	741	812	872
0.5	573	628	678	859	942	1017	1145	1255	1356
0.7	748	820	885	1122	1230	1328	1496	1640	1771

Continued on next page.........

<u>Continuation</u> ....

1	980	1074	1160	1450	1611	1740	1946	2151	2320
2	1545	1694	1830	2329	2553	2744	3105	3404	3676
3	1951	2139	2310	2929	3208	3465	3903	4278	4620
4	2275	2494	2693	3414	3741	4040	4550	4988	5387
5	2534	2778	3000	3801	4166	4500	5068	5555	6000
6	2752	3016	3258	4127	4524	4886	5503	6033	6524
7	2940	3222	3480	4410	4834	5220	5879	6445	6960
8	3107	3405	3678	4660	5108	5517	6213	6811	7355
9	3256	3570	3855	4885	5354	5783	6513	7139	7710
10	3391	3717	4014	5086	5575	6021	6781	7434	8028

the utilization of heat in percents. the last —— the final velocity of the rocket after the exhaustion of the entire reserve of th explosive substance. The first column of the table shows the reserve of the explosive substance with respect to the weight of the rocket. As is seen, the practical velocity is hardly sufficient for the role of the near-Earth satellite.

But we shall just now point out other methods of obtaining very high velocities of the rocket. They consist in setting out on the voyage by several identical and modest (in velocity)rockets. They consume only half of the accompanying reserve of explosive substance except the last one, while the remaining half is supplied to one another. Only the last rocket acquires the highest velocity. The remaining projectiles devoid of reserve, come down to the Earth by means of gliding.

B. Speed of Rocket on incomplete burning of the reserve.

10. Let us suppose, that the mass of the burning explosive substance comprises "y" from its total quantity.

11.

$$\frac{M_2-M}{M_2} = y.$$

12. From which

$$M = M_2 \; (\; 1-y).$$

13. Subtituting

$$\frac{M_2}{M_1} \; x, \text{ we shall get}$$

$$V = V_1 \ln \frac{1 + x}{1 + x\,(1-y)} \; .$$

14. Let us suppose, that the burning portion Y = 0.5

Then we shall find.

$$V = V_1 \ln \left(\frac{1 + x}{1 + 0.5x} \right).$$

From the formula, it is clear, that the velocity of the rocket does not increase unlimitedly when the reserve (x) of the explosive substances immensely large, but has a limit. In fact, let us suppose, that $x = \infty$, then $V = V_1 \ln 2 = v_1 \, 0.693$ If for example , $V_1 = 3000$, then the velocity of the rocket will be 2079 M/sec, notwithstanding the unending reserve of ejection (x). From this it is clear, that there is no greater advantage in burning half of the reserve in case it is in large quantity.

15. According to this formula we shall compile table 15, which still more confirms it.

TABLE: 15

x (reserve) / V_1 M/sec	0.1	0.3	0.5	1	2	3	4	5	6	7	8	9	10
1000	46	122	182	287	405	470	511	539	567	573	588	598	606
2000	93	245	365	575	810	940	1023	1078	1134	1164	1176	1196	1212
3000	139	368	547	863	1215	1410	1534	1617	1701	1719	1764	1794	1818
4000	186	490	729	1150	1620	1880	2046	2156	2268	2292	2352	2392	2424
5000	232	613	911	1438	2024	2350	2557	2695	2835	2865	2940	2990	3030
6000	279	736	1094	1726	2429	2820	3068	3234	3402	3438	3528	3588	3636

In this table the velocity of the rocket in M/sec is given when only 0.5 of the entire explosive substance has been consumed. We have in view ideal conversion of heat into ejection velocity and that of the rocket.

The first line denotes the total relative reserve of explosive substances, and the first column the relative ejection velocity. Having taken it even at 2000 M/sec, we see from the table, that the velocity of the rocket, when the total reserve is 4 and when its consumption is half, reaches 1023 M/sec. When the total reserve is 2 and the consumption is half of it, a rocket velocity of 1215 M/sec is obtained, if the relative ejection comprises 3000 meters per second.

C. SPEED, ACQUIRED BY ONE ROCKET WITH THE HELP OF AUXILIARY ONES.

16. Now we shal see, what is the idea behind the restricted expenditure of explosive substances in the task of achieving Cosmic velocities.

17. Let us have many completely identical rockets, each with a reserve of X = 1. Let each one of them spend half of this reserve. Let the ejection velocity on all the rockets be equal to 4000 M/sec.

With the help of the squadron of these rockets by means of transferring pouring of reserves of explosion we can obtain the highest velocities which one rocket cannot obtain. Transfer for example of petrol from one airplane into another is not only possible, but also familiar.

18. Let us suppose, that one rocket is flying. According to table 4, its **maximum** velocity will be 2772 M/sec.

19. Let now two similar rockets fly simultaneously and side by side . Let both of them spend, at first, half of their explosive substances. Then they will acquire a velocity of 1150 M/sec (See table 15). Afterwards one of the rockets transfers the still unburnt reserve (0.5) the other, and itself glides down to the Earth. The second rocket, now having full supply of 1, acquires the additional velocity of 2772 M/sec and then we acquire 1150 + 2772 = 3922 M/sec.

20. Now, let us suppose, four rockets are flying when each of them has consumed half of its reserve, then all of them, flying side by side, acquire a similar velocity of 1150 M/sec. But two of these rockets replenish the reserve of the other two, and themselves without reserve glide down to the Earth. Then the two remaining rockets in the air fly farther and spend again half of the reserve. Owing to this they will have a velocity of 2300 meters per second. One of them, after this, replenishes the reserve of the other and lands. The last one with full reserve, consuming it in toto, acquires still an additional velocity of 2772 meters per second, and in entirety 5072 M/sec. After this, the rocket has to land by means of gliding.

21. We shall compile a table of velocities of the last of the remaining rockets, in the air, depending on their number. Let us suppose V_1 = 4000 meters per second and reserve 1.

TABLE 21.

Number of rockets.	1	2	4	8
Velocity of the last M/sec.	2772	3922	5072	6222
Number of rockets.	16	32	64	128
Velocity of the last M/sec.	7372	8522	9672	10822
Number of rockets.	256	512	1024	2048
Velocity of the last M/sec.	11972	13122	14272	15422
Number of rockets.	4096	8192	16384	-
Velocity of the last M/sec.	16572	17722	18872	-

22. In the first line of table 21, the number of identical rockets has been shown taking part in the achievement of high velocity of one rocket, in the second - the velocity of this last one in M/sec.

23. The first cosmic velocity is achieved when there are 32 rockets. For recession to the orbit of the Earth, 256

rockets are necessary, while for recession from the planets and the Sun, 4096 rockets are required.

24. The important thing is to fly beyond the atmosphere of the Earth and "fasten itself" there in the capacity of its satellite. The subsequent increase of velocity may be achieved by other methods and they are easier than on the Earth. Nevertheless, the number of rockets is excessively large.

25. But we have a possibility of taking more reserve of explosive substances, for example 4. Then, when there is the modest ejection velocity of 3000 meters per second, the velocity of the rocket on half the expenditure comprises 1534 M/sec (see table 15). The total velocity is 4827 M/sec (see table 4). This is sufficient, so as to suggest a new table.

TABLE 25.

Number of rockets	1	2	4	8	16
Velocity of the last, M/sec.	4827	6361	7895	9429	10962
Number of rockets	32	64	128	256	512
Velocity of the last M/sec.	12497	14031	15505	17099	18633

Now for wandering amidst the suns of the Milky Way, 256 rockets are enough. The control of the Earth satellite is achieved by four rockets, while that of the Sun satellite by 16.

26. The ejection velocity may be more than 3 km/sec and then for achieving cosmic velocities, a smaller number of rockets would be needed.

27. We can deduce a general formula of velocity of the last of the rockets depending on their number, the ejection velocity V_1 and the **relative** reserve of explosive substances. Then the velocity of one rocket will be [See formula (3)] .

$$v_0 = v_1 \ln (1 + x),$$

where 'x' is the total relative reserve of explosive substances. When the number of rockets is 2n, where 'n' - is the number of transfers the velocity of the last rocket will comprise

$$v = n v_1 \ln \frac{1 + x}{1 + 0.5x} + v_1 \ln (1 + x) = v_1 \left[(n + 1) \ln (1 + x) - n \ln (1 + 0.5x)\right] .$$

28. The first term of the first part has a limit, no matter how large is or the relative reserve of explosive substances (see point. 14). It is equal to 0.693 n V_1. Nevertheless, it is capable of growing infinitely on the increase of 'n' or the number of rockets (2^n). But the second term grows infinitely to the extent of the growth of n, or the relative reserve of the explosive substances. In this way, it is necessary to increase x and n, as far as possible.

29. It is not possible to increase very much the reserve n of the explosive substances and the relative velocity of the combustion products V_1, then the number of rockets (2^n) is at our disposal and, therefore, also the magnitude of the velocity of the last from the groups of participating rockets.

30. Practice has shown, that the material communication between the two airplanes, moving with the same velocity is fully possible. Transfer of fuel from one airplane to the other has been established. It is necessary to work out the most convenient method for that. In our case, the work is more complicated, because we have to transfer specially two different components: hydrocarbons (fuel and oxygen compound. This may be done by various methods, for example,

a. by transfer through a tube, connecting the two flying devices;

b) by the transfer of tanks full of explosion components;

c) by directing the jets of the components into the rear portion in front of the flying device (syringe, fire-pump).

Which one of these or other methods prove better, experience will show.

D. Practical Course

31. We shall have to start work from the most conventional and weak jet planes. At first we shall lean to fly in a lone aircraft. The ejection velocity must be kept the least, for example 2000 M/sec and the reserve of the explosive substances at unity. Table 4 points to us the maximum velocity to be 1386 M/sec. Such a rocket plane may fly horizontally or tiltingly. But considering the resistance of air, it could rise to an altitude of 96 kilometers, at this velocity. But on account of the resistance of the medium and some residual velocity, it may not reach such an altitude, but ascend roughly to an altitude of 50 kilometers. From there, being deprived of the components of explosion, it already starts to descend by gliding onto the solid or the liquid surface of the planet.

Since the maximum velocity, accessible by this modest rocket plane will not exceed 1 km/sec, the oblongness (oblong form) may not be very great.

32. Here we give the required oblongness of the rocket - planes, depending on the maximum imparted velocity (see my "Pressure " 1930).

v, Km/sec	1	2	3	4	5	6	7	8	
λ	4	8	12	16	20	24	28	32	
v, Km/sec.	9	10	11	12	13	14	15	16	17
	36	40	44	48	52	56	60	64	68

The first line shows the velocity of the device in kilometers per second, while the second —— its least required oblongness having, of course, a good form. From the table it is clear that the first modest rocket may be confined to the oblongness of 4. If the oblongness is less than the one shown in the table, the howsoever rarefied the surrounding air may be, it condenses in front of the nasal portion of the device to such a degree, that it appears as if it were a steel wall.

33. Since a high velocity, approximately of 5 Kilometers per second, is attained already beyond the atmosphere, the oblongness in general will not exceed 20 (see table).

34. Having learnt to control one rocket-glider well with oblongness of 4, we shall start the preparation of two similar rockets with a large oblongness,. Here we shall begin to practice the transfer of explosion components from one rocket-glider to another. After that we shall come to the group of four rocketswith still more increased oblongness, then-to the group of light rockets, etc. At the same time the devices will be perfected, for example, the relative reserve of explosive components and the ejection velocity of the burnt substances will increase.

35. For the time being we shall offer a modest table of velocities of rocket-gliders depending on their number, assuming that the ejection velocity is 2000 M/sec, while the reserve of explosive substance is equal to unity. We shall add to the table the least required oblongness of the group equal to that of rocket-gliders. During the compilation of the table, we shall make use of tables 4 and 15:

Number of rockets	1	2	4	8	16	32	64	128	256	512
v, M/sec,	1386	1961	2536	3111	3586	4271	4846	5421	5996	6571
λ	5	8	10	12	14	16	20	22	21	26
Height of ascent when gravity is constant.	95	192	320	484	680	910	1170	1470	1800	2160

The first line points out the number of rockets in the group, the second the maximum velocity, the third ... oblongness of each member of the group, the forth the maximum height of ascent in kilometers on the exhaustion of the entire velocity.

In practice, of course, we shall achieve only half of this. In a group of 8 or 16, the rocket-glider possibly goes beyond the limits of the atmosphere, where oblongness, has no importance. So that it will not exceed 12-14. It means, the projectile, having a maximum diameter of two meters, will have a length not more than 24-28 meters.

36. But I hope to acquire more than 2 kilometers per second at the time of these exercises of earlier than the ejection velocity, because its extreme limit is 6 kilometers per second. The reserve similarly can pass over from unity to 5 and more. Then on small squadrons of similar and not very oblong rocket-gliders we shall acquire Cosmic velocities.

37. As a limit of successes we can imagine, that the ejection velocity is equal to 6 kilometers per second, and the reserve of explosive substance-10. We shall get on those very bases (tables 4 and 15) the following table:

Number of rockets	1	2	4	8	16
V, meters per second.	14388	18024	21660	25296	28932

Here one need not speak either about the altitude the oblongness. And one rocket and one group quickly fly beyond the atmosphere, not having in it (atmosphere) a velocity of even 2 km/sec. So that oblongness of 8 is fully sufficient for all rockets of limiting success.

38. But we cannot expect such a success for the time being. This is a theoretical conclusion restricted by a majority of secondary conditions.

E. AIM OF THE NEW METHOD.

The aim of what hasbeen said so far is to point to the method, by which even in the case of extreme imperfection of one rocket-glider, it would be possible, with the help of several such ones to acquire Cosmic velocities, sufficient not only for the mastery over the solar energy but also for a voyage amidst other suns in the limits of our Milky Way. This method consists in the utilization of a group of rocket-gliders, in the transfer of explosive substances for corroboration by virtue of one last rocket-glider, which acquires the highest Cosmic velocity.

39. We have earlier suggested, for this very purpose, artificial terrestrial roadways and rocket trains. This is possible and true but at the present time they are not used due to their expensiveness and also for other reasons.

40. Still less employed are prostrate cannons on the earth, i.e. those very pathways arranged by a particular method, as they are still more expensive. All these trains and "cannons" will find application in the distant future, when the significance of inter-planetary travels will grow and manking will pay more attention to them and will be inspired with greater hope and trust and more expenditure and greater sacrifices will be made than our other requirements of people.

41. The very method of the group of the first light weight machines and the transfer of explosive substances are much more accessible for the state of talents of contemporary humanity. Already one rocket-glider will fillup to humanity for the ensuing experiment with two similar and imperfect devices.

They are precious by themselves, i.e. they alone can serve people. Experiments with several rocket-gliders will produce meanwhile, interesting feats. But these feats will result unavoidably in acquiring cosmic velocities.

And thus the basis of this success is the acquiring of the first, although crude, rocket-glider. Construction of similar projectiles will push the work of increasing the velocities to which there is no limit.

In the preceding chapters we have given a basis for the creation of separate rocket-gliders. Of course, the more improved the obtained rocket-gliders are the better results will be of experiments along with their groups having the same number of flying devices employed in the group.

F. VELOCITY OF FLYING OUT OF EXPLOSION PRODUCTS.

43. Let us return a second time to the separate, individual rocket-glider. The velocity of flying out of explosion products has an immense significance. In the earlier chapter "Energy of chemical compound of Substances" We gave tables of ideal and maximum flying out velocities of explosion products. They are accomplished almost wholly in the presence of the following combined conditions:

a) When the combustion products are gaseous or very volatile;

b) When there is no external pressure, obstructing the expansion of gaseous produtts;

c) When the pipe for the flow of ejected materials is very long;

d) When it does not expand very much at the time of exit, i.e. it does not change much its cylindrical form (Conical form for that reason decreases length of the pipe);

e) When there is no loss of heat due to heat-conductivity and radiation.

f) When the diameter of the pipe is so much large, that is possible to ignore the friction of gases against the internal walls of the pipe.

44). All these conditions cannot be fulfilled in full measure in practice. We shall point out certain deviations.

The projectile is usually of small dimensions. Therefore the pipe is short. In order to utilize the expansion and the transfer of heat in their motion in a better way, it is necessary to make the pipe conical.

The external pressure is eliminated only in the vacuum, during ascent beyond the atmosphere or at a velocity of more than 300-500 M/sec when on the blunt stern end of the rocket, vacuum is created due to the rapidity of motion. The stern of the rocket generally contracts. But its part, where the explosion pipe comes out (funnel), is necessarily blunt. Here the rarefied air space would be formed (but the space, of course, is filled up by the flying out explosion products).

In consequence of the restricted dimensions of the explosion pipe and some external pressure the flowing out gases will not succeed in cooling down to the absolute zero and still retain some quantum of energy depending on the degree of their expansion. In this way, not all the energy of combustion heat gets converted into motion of gaseous streams. Due to this incomplete utilization of heat, the velocity of products, indicated in the tables, will be less in actual practice.

In the following table this has been kept in view.

TABLE

Velocity of the rocket on total consumption of 0.5 of the reserve of explosive substance when the utilization of combustion heat is 50, 60 and 70%.

Total velocity of explosion products (ideal kilometers per second.	Reserve of the spent up substance.	Velocity of explosion products (ideal) Kilometers per second								
		2			3			4		
		Percentage of heat utilized.								
		50	60	70	50	60	70	50	60	70
		Velocity of explosion products, M/sec.								
		1414	1550	1674	2121	2325	2511	2828	3100	3348
0.3	0.15	173	190	205	260	285	308	347	380	410
0.5	0.25	258	290	305	387	424	458	515	565	610
0.7	0.35	326	357	386	489	536	579	652	715	772

Continued on next page ....

Continuation ....

1	0.5	407	446	481	610	669	722	813	892	963
2	1.0	571	620	678	850	942	1017	1145	1255	1355
3	1.5	665	729	787	996	1093	1180	1329	1457	1574
4	2.0	723	733	856	1084	1189	1284	1446	1585	1712
5	2.5	762	835	902	1143	1253	1353	1525	1671	1805
6	3.0	800	877	947	1199	1420	1420	1600	1753	1894
7	3.5	815	892	963	1225	1446	1446	1627	1783	1926
8	4.0	831	911	984	1246	1476	1476	1663	1822	1968
9	4.5	846	927	1001	1268	1497	1497	1691	1853	2002
10	5.0	858	940	1015	1285	1522	1522	1714	1879	2029

The first horizontal line of the table shows ideal velocity of products, depending only on the chemical energy of the compound of their constituent parts. Here we give a velocity from 2 to 4 kilometers per second, although it can attain 6 kilometers per second as well. The second line shows the utilization of combustion heat in percentages depending, of course, on the temperature of the flying out gas from the opening.

In the first column the total relative reserve of the explosive substance: from 0.3 to 10, are shown.

In the second column half of its expenditure for acquiring velocities, is shown.

At last, at the intersection of lines we see the magnitude of velocity in M/sec when the consumption of the explosive substance is half.

All these are very moderate and feasible conditions.

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