DOUGLAS AIRCRAFT COMPANY, INC.

MTM-622

UNCONVENTIONAL PROPULSION SCHEMES

PART 2 REV. 3-1-55

SANTA MONICA DIVISION

NUCLEAR PROPULSION

Title: FISSION PARTICLES AS ROCKET PROPELLANTS, PARTS I AND II

Author: Wayne Proell

Source: Collected Technical Reports, Vol. III from the Journal of Space Flight of the Chicago Rocket Society; Part I: Vol. I, June 1949, p. 3-9, Part II: Vol. I, July 1949, p. 10-12

AUTHOR'S ABSTRACT

"In the first report of this series (RNL, May 1949) Dr. N. Bowman considered the use of accelerated particles as a means of increasing the energy and reducing the mass ejected in a rocket jet. Fission particles constitute a self-accelerated type of particle which can properly be considered as a means of getting a high-energy, low-mass rocket jet. It is the object of this paper to consider these fission fragments for such rocket jets. A theoretical discussion will be given first to examine the basic energy considerations in the use of fission fragments, and a practical discussion will be then presented examining the feasibility of using such information in a workable rocket jet. It should be remembered that our conclusions from both these aspects must be based on some particular mechanism by which we convert nuclear energy into thrust, and improvements in the design of such mechanism may alter such conclusions later."

DAC ABSTRACT:

In part I a concept of rocket propulsion by ejection of fission fragments, somewhat similar to Gamow's suggestion of employing alpha-particles for propulsion, is considered. This mechanism might consist of a monatomic layer of Uranium 235 deposited on a flat film attached to a load-carrying structure. When the Uranium atoms fission, fragments will be ejected in opposite directions with a random distribution. Those leaving the film will be lost, those in the plane of the film will cancel, but those fragments ejected into and absorbed by the film will produce useful thrust.

Through a simple geometric analysis corresponding to that of the force required to hold two hemispheres together while their interior is under pressure, the author shows that the average force vector along an axis vertical to the film is one half the average force vector from the fission. He does not accept a priori the law of action and reaction for fission, since the ability of recoiling fission fragments to penetrate solid materials is well known *). Thus, the thrust efficiency might be in the range 70-90% for metal supports and approach 100% for ion lattices and covalent compounds.

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Quantitative calculations of momentum carried by a single fissioning Uranium atom results in a value of 2.22×10^{-13} gram-cm/second. With the aid of that value, the author calculates the weights of Uranium required to impart various velocities to a 20 ton space ship, ranging from 0.0353 grams for 1 cm/sec. to 35.3 kg of Uranium for a velocity of 10^6 cm/sec (10 km/sec). Additional calculations indicate that the fissionable material will have to be consumed at the rate of 1 lb/sec. to yield 10 g thrust.

In Part II, Proell calculates the by-product heat resulting during motor operation. He recognizes that, due to the fact that for any accelerated particle or fragment the momentum increases as the first power of the velocity while the kinetic energy increases with the square of the velocity, the energy efficiency of the proposed propulsion system would be extremely poor. For a typical example the ratio of useful work to heat release is calculated to be only 1.6×10^{-6}. It is concluded that, while adequate thrust may be conceivably developed from a direct conversion process, it must always be overshadowed by concomitant heat effects. In fact, any coolant used to prevent vaporization of the foil could easily yield the required thrust. The direct conversion of fission energy to momentum would only furnish about 1% as much thrust as could the ejected coolant.

As an example, Proell briefly discusses a pile motor, holding 10 kg of enriched Uranium and consisting of a series of foils alloyed onto carbon or beryllium plates. These plates would be stacked in a hydrogen cooled motor with gas spaces between adjacent plates. With a plate (or film) area of 1 square meter, 1000 plates might be required. He states that such a motor would be "workable", but that the heat developed would be more important than the thrust.

DAC COMMENT

Proell has taken a brave step in this paper. Without discussing AEC Restricted Data, he arrives at the conclusion that the heat output from a fission process will be of greater importance than the direct conversion of thrust from the momentum of the resulting fission fragments. This is disappointing to those who expect a direct conversion process to produce momentum without bulky working gas equipment.

*)Reference: Effects of Radiation on Materials, MDDC-962, USAEC, A. O. Allen

NOTE: Wayne Proell is listed as Technical Chairman of the Chicago Rocket Society (in 1951) and his address is given as 10630 South St. Louis Ave., Chicago 43, Ill.

Listing: A-GC 1151

GJM
1-12-55

Title: HIGH ENERGY PARTICLES AS ROCKET FUELS

Author: Norman Bowman, Ph. D.

Source: Collected Technical Reports, Vol. II from the Rocket News Letters 1948-1949, published by the Chicago Rocket Society

DAC ABSTRACT

The author examines the theoretical possibilities of obtaining useful thrust from the ejection of a much smaller mass of particles than the exhaust gases of a conventional chemical rocket or even from an injection cooled atomic furnace, by upping the velocity of the ejected material several orders of magnitude though still below the practically unattainable point of significant relativistic mass increase. This can, of course, only be done by a "nonchalant" squandering of energy. However, energy is prolifically available from atomic sources while jettisonable mass is not. With a plentiful supply of energy presumably on board, time is not essential and relatively small accelerations, so long as they exceed one gravity, might suffice.

Considering linear acceleration of charged particles as essentially governed by the square root of the voltage of the accelerating field he tabulates the attainable impulsive exhaust velocities for various particles from the electron and hydrogen to mercury, for potentials of 100 to a million volts and the theoretical fluid ("fuel") consumption required to yield 100 tonnes of thrust. The fluid consumed is only a very small fraction of the rocket take-off weight, contrary to the situation on conventional chemical fuel rockets. In a third table the total weight percentage of gross of the amount of hydrogen (chosen as the most "practical" fluid) required to bring a vehicle up to escape velocity under various assumptions of voltage and net acceleration is quoted.

Unfortunately, small as the amount of fuel looks in terms of percent of gross weight, it would be a staggering task to try to accommodate its flow through any linear electric accelerator of conceivable design. Much smaller quantities such as would be required for small fractional g trajectory corrections (as for intersatellite traffic) might conceivably be handled by a giant electric ion gun. For much heavier particles than hydrogen, possibly for fission products, the author doesn't want to close the book yet, but refers to the article reviewed under Serial # 031.

NOTE: Reference is also made by the author to "MIT Report #6, by Hsue-Shen, library class 940.58, seminar 54, 55, May 13-15, 1947", dealing with the proposition of an atomic pile operating at 6000°C cooled by liquid hydrogen which is evaporated and ejected at about 24000 fps and should suffice to accelerate a payload weighing 23% of the take-off weight to escape velocity. This is apparently the subject covered in a later publication by Dr. Hsue-Shen Tsien reviewed under Serial 024.

Listing: A-GC 1150

W.B.Klemperer
1-13-55

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Astronautics Literature Review

Serial 035
NUCLEAR PROPULSION

Title: THE PROBLEM OF ATOMIC PROPULSION

Author: Dr. Luis Alvarez

Source: Lecture before the Washington, D. C., Aero Club, 17 Dec. 1946. Review in the Bulletin of the British Interplanetary Society, Vol. 2, #4, May 1947, p. 74 *)

DAC ABSTRACT OF BIS REVIEW

In any manned nuclear reactor driven vehicle the weight of the shielding necessary to protect the crew from harmful radiation will be an important item. Even on unmanned rockets some shielding will be required to safeguard electrical equipment.

The beaming of fission products is dismissed as impractical because of the dissipation of fantastic amounts of energy which any attempt to achieve this purpose would entail.

The only practical manner of converting nuclear energy into propulsive momentum seen is that of heating a working fluid to be ejected in rocket exhaust fashion. Hydrogen in stored and injected liquefied state would yield the most useful thrust, twice the exhaust velocity of alcohol-oxygen rockets. However, enormous technical difficulties still stand in the way of the construction of such a power plant viz: The pumping and plumbing for the enormous flow rates, the violent boiling of the hydrogen, aggravated by absorbed radiation. The chemical danger with which the expulsion of the hydrogen cloud is fraught are pointed out.

NOTE: Dr. Luis Alvarez, Nuclear Physicist at the Radiation Laboratory of the University of California, Berkeley, is famous for his discoveries in nuclear physics, and for his work toward the development of GCA for which he was awarded the Collier Trophy by the National Aeronautic Association.

Listing: A-GC 907

*) Original in U.S. Air Services, XXXII, #1, January 1947, pp. 7, 8, 26

WBK
1-17-55

Title: POWER SOURCES FOR ORBITAL ROCKETS

Author: Lewis J. Grant, Jr.

Source: The Journal of Space Flight, vol 3 #9, Nov. 1951, published by the Chicago Rocket Society

AUTHOR'S ABSTRACT

"Qualitative analysis of currently available power sources for robot satellite rockets shows that all have serious disadvantages and require extensive study. Power from radioactive sources either requires heavy shielding, or electronic components resistant to radiation. Solar power requires complex easily damaged installations and power is unavailable one fifth to one fourth of the time."

DAC COMMENT

The author enumerates the difficulties and dangers attending the construction and operation of a fast burning plutonium power plant (elaborating on the problems incident to the shielding of flying personnel, of electrical appliances, of photographic equipment and of structures, also the danger to personnel on the ground at the take-off site, or in case of a crash elsewhere). Next he examines the merits and demerits of slow acting canned isotopes as fuel.

He also touches on the structural problems which are encountered in the design of solar radiation collectors.

Finally he mentions that even conventional auxiliary power sources such as batteries and internal combustion engines may be confronted with new environmental condition problems, for instance operation while weightless.

NOTE: L. J. Grant Jr. is listed as librarian and an officer of the Chicago Rocket Society

Listing: A-GC 1174

WBK
1-17-55

Serial 037
GRAVITICS
ELECTRIC PROPULSION
IONIC PROPULSION

Title: DIE DYNAMISCHE KONTRABARIE ALS LÖSUNG DES ASTRONAUTISCHEN PROBLEMS (THE DYNAMIC CONTRABARY AS A SOLUTION OF THE ASTRONAUTIC PROBLEM)

Author: B. Heim, Göttingen (in German)

with an Introduction into the Meso-field Theory by H. J. Kaeppeler, (in English and German) in "Probleme aus der Astronautischen Grundlagenforschung, Vorträge gehalten auf dem III. Astronautischen Kongress", Stuttgart, 1-6. September 1952, p. 181-187.

Source: Problems of Astronautical Fundamental Research, papers read at the Third Astronautical Congress in Stuttgart, Germany 1-6. September 1952.

DAC ABSTRACT

In the Introduction, Kaeppeler starts from the well-assured assumption that chemical rocketry will suffice for Earth Satellite missions and even for interplanetary expeditions to the near planets and accepts the conclusion that space vehicles to be sent to destinations farther than, say, Mars, will have to be propelled by power from new energy sources. He "definitely questions" whether nuclear heating of an inert working fluid will ever become practical because of the high temperatures involved. He (Kaeppeler) and Heim are seeking an entirely new approach which "does not employ the principle of rocket propulsion", but rather the direct transformation of electromagnetic energy into kinetic energy by means of the "contrabaric state of a meso field".

Kaeppeler expounds Heim's meso-field theory essentially as follows: Heim postulates a 6-dimensional field which describes not only the gravitational and electromagnetic phenomena but also a third manifestation which he names Meso Field *). This Meso-Field is envisaged as "capable of two different actions, viz. the Contrabaric State which transforms a material phenomenon directly into ponderomotive action by emission of gravitational waves, resulting in an accelerated motion, and the Dynabaric State through which purely electromagnetic energy is liberated from matter without waste products or heat. The propulsion is to be achieved by first liberating electromagnetic energy and then transforming it directly into accelerated motion".

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*) Kaeppeler has reference to a publication of his own (reviewed under Serial No. 013) in which he claims to have arrived independently at the identical results by a different mathematical approach.

Although very strong forces may thus be generated, the theory indicates (amazingly enough) that it should be possible to so shape the vehicle and so install the field generators that the occupants would have no sensory perception of the dynamic reaction of the acceleration. Velocities of the order of 10,000 km/sec should thus become attainable.

So much for Kaeppeler's Introduction.

Heim's own paper, as printed in the Transactions comprises one page (p. 184) entitled "Outline of the Theoretical Investigations for the Meso Field Theory", and 2-1/2 pages of text entitled "Part I The Meso-Field Theory".

The outline is broken down into six chapters of which the following is a slightly abbreviated English translation.

1. Introduction

Hohmann's results, basic solubility of the astronautic problem. Definition of problem.

2. Theory of Ponderomotive Forces

Nomenclature and coordinates. Non-Euclidian Electrodynamics and the mechanical law of motion. Force components and tensor potential. General differential law of a metric structure gradient. Passage and propagation of unreal transversal gravitational waves. Imaginary rotations in a complex plane as consequence of the passage of gravitational waves.

3. Theory of Gravitation and Electromagnetism

The tensor equation of the metric gradient as a variation principle. Tensorial gravitation potential of a static symmetric field. Proportional between gravitational radius and field excitation. Metric characteristics of a world region devoid of real physical events. Electromagnetic excitation sources of the gravitational field. Electric energy tensor determined but for a world function. World coordinates dependent upon an entropy.

4. Origin of the Meso Field Theory

Requirement of a 6-dimensional continuum. Definition of matter. Asymmetry of the 6-dimensional metric-gravitative structure. Metric excitatation of a similarly asymmetric field structure. Necessity of an asymmetrical intermediate structure and hermitic composition condition. Hence origin of meso-field theory. Alternating 6-dimensional metric structure. Autohermitic component as supermatrix. Vanishing of every matrix spectrum of the translation tensor.

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5. The Mesofield Theory and the Principle of Dynamic Contrabary

Mathematical framework. Field components. Development of the basic types of the Gamma operators and differentiated type signatures. Most general case illustrated by a tensor field of arbitrary variance and degree in the n-dimensional alternating field. Rectangular matrix of the most general Gamma operators. Important identities. Application to the natural basic postulate of the meso field theory. Tensor equation systems which describe the elementary process of the Meso field excitation. Metric transformer effect of the Meso field. The dynabaric field as the inversion of the meso field. Explanation of Dynamic Contrabary as the dynamic coupling state of both fields. The impulse law of the meso field contrabator.

6. Discussion of the Impulse Law:

Solution for a space-time trajectory which is continuous except for a finite number of singular events. Approximation for simple planetary voyages. Synopsis of approximation validity conditions. Numerical example (Trip to Mars under unfavorable constellation viz. Earth-Mars conjunction). Conclusion and future work program.

The following Part I of the Treatise starts out with the summary dismissal as absurd of any idea of annulling gravity; this leaves only the principle of impulse transfer as a realizable method of propulsion *). Next the author formulates a very abstract definition of a spaceship and its task, in the most general sense conceivable. This prompts him to inquire into the nature of the elementary process which accompanies "the generation of a ponderomotive effect in correlation to the transformation of material process". He adduces reasons why he believes that this fundamental question cannot be answered by the Quantum theory nor by Einstein's General Relativity Theory, nor even by his Unified Field Theory.

Therefore Heim has set out himself to evolve an entirely new cosmic theory, such that it (1) expresses a universal law which embraces the Quantum theory and Einstein's theory as special cases and yet so that (2) it is amenable to proof by experiment.

The first part of this theoretical work he considers as completed. Its first step was the derivation of the mathematical edifice which led to the "discovery of the existence of a previously unknown field state which he named "Meso Field". Its treatment required the development of a new mathematical method. This furnished eight systems of six-dimensional non-linear tensorial differential equations which describe a universal cosmic law. Suitably introduced approximations yield beside the Quantum theory also Einstein's theory and thus it embraces the entire classical physics.

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*) Note: This is apparently in contradiction to a statement in Kaeppeler's introduction.

The equations show the Meso field to have a dual character. "In the one form a material event whose world lines must be geodetic zero lines is directly transformed into ponderomotive effect accompanied by the emission of gravitational waves". This type he calls contrabaric. The other type which he calls dynabaric can only be endothermically excited; it effects the inverse transformation provided that the ponderomotive effects obey certain symmetry conditions.

Next the author attempted to determine how the endothermic dynabaric mesofield can be employed to trigger highly exothermic nuclear processes. "The world lines of nuclear energy liberated in the form of electric waves are geodetic zero lines, which fulfills the contrabaric transformation conditions. By coupling both mesofield states it should be possible to excite a dynamic state which could continue to run dynamically so long as ions of the isotope used as impulsive charge are available". When the ion flux drops below a certain minimum so that the transformation barely suffices to cover the thermodynamic losses the process coasts to an end. Conversely it can be controlled by regulating the ion flux above this limit. "The contrabaric meso field exciters can be so distributed that they work in all directions and since their exothermic radiative power can be readily controlled, this method of propulsion - which the author calls Dynamic Contrabary - 'clearly' permits the development of a universal vehicle of unprecedented maneuverability". The author then claims to have mathematically demonstrated that the accelerated motion of such a vehicle "will not be physiologically sensed by its occupants provided the shape of the vehicle as well as the configuration and tuning of the contrabaric field of exciters satisfy a well-defined analytic shape equation". Within the scope of quasi-stationary accelerations and for velocity changes which still remain small compared to the velocity of light the impulse law of such a "dynamocontrabator" is found as a homogeneous linear operator equation.

The published presentation is concluded by two remarks viz: (a) that numerical example calculations of a special group of space trip missions have brought out the enormous superiority of the Dynamic Contrabary principle over the "old rocket principle" and (b) that a publication of the mathematical derivations and the details will be withheld until the second part of the investigations and the pertinent experimental proof program will have been completed.

DAC COMMENT

This article by Heim has aroused considerable speculation *), because it is couched in such mystifying terminology, largely coined by the author, that the average reader finds it difficult to decide whether this is the first inkling of a new theory of gravitation which will solve its age-old mystery and lead to sensational new technical developments - or just mathematical double-talk. The author precipitates this quandary by not disclosing what he really did or how he proceeded; this revelation is deliberately postponed until he hopes to have achieved experimental proof. He does not disclose how he proposes to go about this.

*) This is the main reason why it is reviewed by us in such detail.

His Meso-Field is apparently conceived as a mathematical device "intermediary between gravitation and electromagnetism". Whether it has anything to do with the existence, formation or decay of "mesons", those ephemeral particles which contemporary physics describes as having a semi-material nature, size and mass between protons and electrons, Heim is careful not to say.

Despite all the mysterious implications that the "Dynamic Contrabary" is an entirely new propulsion principle, radically differing from conventional rocketry and its gaseous exhaust reaction, it is noted that the process is governed by a supply and flux of ions which have mass indeed. Whether the controlled ion flux has anything to do with the principle of the ion gun or ion rocket as advocated by Oberth and many others, the author does not explain. Be that as it may, the pronunciamento that the apparatus can be so designed that the occupants of the vehicle would remain physiologically unaware of large dynamic acceleration sounds fantastic and puts Heim's theory in a class by itself.

It will be noted that the text of Heim's printed article "Part I" does not constitute or fit any of the Chapters of the "Outline" by which it is preceded. Rather, it is a vague overall summary of his claimed findings. The "Outline" rather seems to indicate the structure and organization of the extensive investigation which he has privately carried out but does not publicly divulge.

During the Third Astronautical Congress in Stuttgart in September 1952 -- which this reviewer attended -- Heim spoke for over two hours and discussed much more material than in the printed article. However, his presentation was no more lucid than the printed article, in fact much harder to follow, as his delivery was less coherent and constantly punctuated by his covering the blackboard with reckless cascades of six-dimensional tensor formulas, often erasing as he proceeded from one concept to another. (NOTE: Heim is almost completely blind.) The awestruck audience dwindled during the long lecture and there was no discussion of any consequence, nor any indication that any one was fully able to follow his discourse. The organizers of the Congress had wisely scheduled Heim's talk as the last of the day's session. Many of the participants of the Congress repaired to the spectacular astronautic exhibition which had just been opened in another part of the building.

NOTE: To a private letter, dated 5 January 1955 in which I asked him whether any further details of his work had been published, Heim replied under date of 15 January 1955 that he had indeed submitted a manuscript in July 1953, to the organizers of the Fourth Astronautical Congress in Zurich, Switzerland, but withdrew it when he got sore because they could not decipher his mathematical formulas and requested a rewritten manuscript. In the letter Heim also stated that certain (undisclosed) agencies are dickering with him to finance his research project and experiments and may decide to keep further details secret, as soon as some critical tests will have been made. He adds that a part of his experimental program has been firmed up and its execution is merely (!) a technical question. Incidentally Heim mentions that he is still lacking one piece of equipment needed for his experiments, namely a Magnetron or a Klystron of about one kW, of about 3 cm wave length. He inquires where he might get one and what one would cost over here.

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He gives his address as Burkhard Heim, Dipl. Phys., Burg Grona 2, Göttingen (20 b) Germany. (My previous letter to him was addressed to the University of Göttingen and reached him OK.)

WBK
1-20-55

ADDITIONAL NOTE

On February 28, 1955 an occasion was had to consult with Professor Dr. Ludwig Biermann, of Göttingen, Germany, who has been visiting CalTech since December 1954 as guest professor and conducting a course in Astrophysical Theory of Stellar Electromagnetism and Plasma Physics. When asked concerning the academic status of Dipl. Phys. Burkhard Heim, Professor Biermann stated that he did not know Heim personally and was not familiar with the theories propounded by Heim. He was quite certain that Heim was not on the faculty or teaching staff of Göttingen University. Professor Biermann vaguely recalled a previous inquiry about a person who might fit Heim's description and who may have been an assistant of Dr. von Weizsäcker or some other professor.

WBK
2-28-55

Title: PROBLEM OF COOLING NUCLEAR WORKING FLUID ROCKETS OPERATING AT EXTREME TEMPERATURE

Author: H. J. Kaeppeler (Assistant Research Physicist)

Source: Jet Propulsion, Journal of the American Rocket Society, Vol. 24, No. 5, Sept-Oct. 1954, p. 316-319. (Summary of a paper presented at the Fourth Astronautical Congress, Zurich, August 1953.)

DAC ABSTRACT

The author attempts to show that adequate cooling of a nuclear fuel rocket chamber can be attained *) by the following arrangement: The nuclear fuel is assumed to be confined to a pencil located in the vicinity of the axis of a cylindrical rocket chamber opening at one end into a gas discharge nozzle. The coolant (oxygen) which is also the working fluid whose expulsion from the nozzle furnishes the reaction impulse is admitted radially through the porous cylinder wall. The temperature distribution is assumed to have rotary symmetry and fierce radial gradients with discontinuities across cylindrical layers where heat is absorbed by dissociation at 5000°K, by ionization at 12000°K, and by atomic excitation beyond this. Heat conductivity is to be enhanced by a spiral flow of the inert coolant working fluid. Numerical examples are presented to show that temperatures up to 100,000°K at a 2 cm dia. fuel bed can be managed *) without exceeding 1000°K at the chamber wall. For higher core temperatures such as 250,000°K other phenomena such as multiple ionization, thermal radiation, absorption and possibly photo-dissociation obscure the extrapolation. The fluid flow quantities required for any real size rocket are of course gigantic.

*) DAC COMMENT

The present treatise, in fact its introductory statement, is in apparent contradiction of an earlier opinion endorsed by the same author who one year before, in his introduction to Heim's Meso field theory quoted the latter as "definitely questioning" whether nuclear heating of an inert working fluid could ever become practical because of the unmanageably high temperatures involved. (Ref. Serial #037.)

The author does not bother to consider how a stable fuel "bed" of 2 cm diameter and many inches in length can possibly be maintained without instantly evaporating at the temperatures contemplated.

W. B. Klemperer
February 4, 1955

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Title: RANDOM THOUGHTS ON ATOMIC POWER (Possibilities of Nuclear Energy for Rockets)

Author: William D. Monroe

Source: Journal of the American Rocket Society, #63, March 1946, pp. 28-29

DAC ABSTRACT AND COMMENT

The author is convinced that nuclear energy may only be utilized in connection with some working fluid. He then discusses four possible rocket engines as follows: alcohol-oxygen (V-2) and three atomic engines utilizing H_2O (steam), H_2O (H_2 and O_2), and Hg as working fluids. He concludes "A purely theoretical consideration of the problems brought out, is the fact that to have reasonable exhaust velocities, the almost impossible temperatures of 5000°F and above would be needed".

This brief note merely serves to call attention to some of the problems of nuclear propulsion. No solutions are indicated.

G. J. Mueller
February 14, 1955

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Astronautics Literature Review

Serial 040

NUCLEAR PROPULSION

Title: THE RATING OF ROCKET FUELS (Rocket Fuels Using Atomic Energy as a Primary Heat Source)

Author: Dr. Thomas S. Gardner, Johnson City, Tenn. (Research Chemist, fuel mixtures)

Source: Journal of the American Rocket Society, #66 & 67, June and September 1946, pp. 23-26

DAC ABSTRACT AND COMMENT

Assuming that atomic energy using small amounts of an atomic fuel can furnish a constant, controllable, high temperature (1000-5000°A) heat source, Dr. Gardner considers it to be impractical to eject sufficient atomic fuel alone to yield the thrust required by the application of Newton's Third Law, since it would only be possible to utilize a small fraction of the available energy. He proceeds to calculate and tabulate the efficiency of propulsion systems ejecting a working fluid such as H_2O, CO_2, SO_2, Hg, H_2O_2 (90%) heated to 2000°K. The highest efficiency (28.81%) would occur when H_2O_2 (100%) was heated. However, when all factors are considered, especially the relative momenta on a unit weight basis, water is shown to be superior.

It is noted that the author assumes a "controllable high temperature (1000° - 5000°A) heat source", still a most difficult device to develop for rocket use. The paper merely points out some of the significant thermochemical characteristics of working fluids (inappropriately called "fuels").

G. J. Mueller
February 14, 1955

NUCLEAR PROPULSION

Title: ATOMARER WASSERSTOFF ALS RAKETENKRAFTSTOFF
(Atomic Hydrogen as Rocket Fuel)

Author: Hans Joachim Hoelzgen

Source: Weltraumfahrt #2, April 1950 (in German)

DAC ABSTRACT AND COMMENT

Atomic hydrogen would be a desirable rocket fuel because of the larger amount of energy which is liberated in chemical reaction with an oxidizer as compared to molecular hydrogen. Unfortunately at most chemical reaction temperatures, atomic hydrogen is unstable, its half-life being of the order of a fraction of a second under normal conditions. However, it may be possible to arrest the molecular recombination process at very low temperatures; this should be a fruitful field for further research.

Atomatic hydrogen is formed

a) on a very hot incandescent tungsten wire
b) in vacuum tubes under activation by cathode rays
c) in a high voltage discharge under 6 to 8 mm Hg pressure
d) as a result of sensitization by excited mercury
e) by ultraviolet light
f) by electrolysis
g) by hard X-rays, gamma-rays and Alpha particle impingements
h) in the electric arc.

The dissociation equilibrium concentration increases with temperature at the following rate:

2000	3000	4000	5000	°K
.122	9.03	62.5	94.7	%

The theoretical efflux velocity, computed from the heat of recombustion is 2080 m/sec and the specific impulse 2100 sec. Even at 10% concentration in liquid molecular hydrogen a velocity of 5000 m/sec would be attainable.

The last paragraph discusses a hypothetical "Arcatom" rocket which would essentially be a glorified hydrogen arc welding torch; the author realizes the weight penalty of the electrical equipment required. This reviewer fails to see that any energy advantage can be gained if the hydrogen is stored in molecular form and all of the dissociation energy has to be furnished from energy sources carried aboard, whereas indeed a great saving would be effected if the dissociation energy is furnished by ground stationed machinery and from earth-bound energy sources, so that the fuel stored aboard the rocket actually packs more energy per unit weight (and bulk). The greater efflux velocity alone would be turned to the added advantage of a better end to start mass ratio only if - as the author indeed points out - the rocket is powered by nuclear fuel, in which case the quantity of energy consumed bears little relation to the total weight of the vehicle.

Listing: A-GC No. 1289

W. B. Klemperer
2-4-55

NUCLEAR PROPULSION

Title: THE CONQUEST OF INTERPLANETARY SPACE (Practical Aspects of Space Ship Design)

Author: Arthur V. St. Germain

Source: Western Flying, October 1947, pp. 14, 15 (Part I), November 1947, pp. 20, 26 (Part II)

DAC COMMENT

This article discusses many aspects of space travel, including a brief review of possible power plants. An atomic drive using plutonium or uranium to heat a working fluid, preferably hydrogen, which would then be ejected is accepted to be the most promising proposal. Principal difficulties to the practical application of this method are (1) the absence of a small light weight "pile" capable of releasing large, controllable amounts of power and (2) means of efficiently transferring this power to the working fluid.

No new proposals are presented for the application of nuclear energy for propulsion and the author concludes that an oxygen-hydrogen drive is probably the best method pending new technical developments in nuclear energy conversion.

G. J. Mueller
February 16, 1955

Astronautics Literature Review

Serial 043

NUCLEAR PROPULSION

Title: BOMBERS OR ROCKETS?

Author: A. V. Cleaver, Chief Project Engineer (Airscrews)
de Havilland Aircraft Co., Ltd.

Source: Flight, Sept. 6, 1945, pp. 263-264

FLIGHT'S ABSTRACT:

"In this speculative article, which follows his original contribution in our July 19th issue (*), the author looks ahead and tries to evaluate the sort of powers and velocities that might be expected if we knew how to harness atomic energy for propulsive purposes."

DAC COMMENTS

The author, writing soon after the atomic bomb drops in Hiroshima and Nagasaki, ponders the use of nuclear "fuel" for both warhead and propulsion of rocket projectiles. The following methods of utilizing atomic drive are considered (as by others in more recent articles, see Review Serial # 006, 008, 014, 023, 024, 025, 026, 031):

1) Reaction from radiation pressure produced by an atomic explosion.

2) A jet of minute sub-atomic particles traveling at immense velocities, but with low efficiency.

3) A working fluid, heated by an atomic pile, which would itself provide the propulsive jet.

4) Perhaps none of those mentioned above, but something else.

After dismissing the first method as impractical, Mr. Cleaver discusses the theoretical mass ratios which might be achieved for rockets with an atomic drive of the second type. Whereas the German A-4 (V-2) rocket with its alcohol-oxygen motor has a ratio of 3.0, the hypothetical atomic drive rocket for the same range and payload might have a mass ratio only a fraction of a percent above unity. On the other hand, with a mass ratio of 3.0 the atomic drive could theoretically impel a rocket to maximum velocities of several million miles per hour, far exceeding the escape velocity of 25,000 MPH. Simple calculations indicate that a space vehicle, after allowing for the effects of