

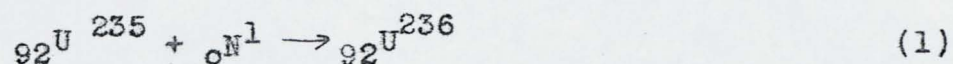
[REDACTED] Cleveland, Ohio,
August 7, 1945.

MEMORANDUM For Executive Engineer.

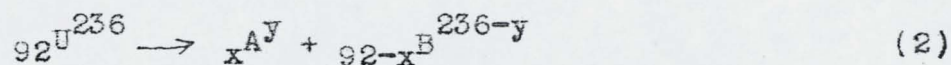
Subject: Atomic-power aircraft engines.

1. Yesterday's announcement by the President reveals that the harnessing of atomic power as an explosive is an accomplished fact. Fortunately this accomplishment, which when fully developed can give a nation overwhelming military power, was achieved in the United States. We may be sure, however, that similar developments are already underway in other countries. It is therefore imperative that we keep the advantage we have gained by immediate development of all possible means of utilizing the tremendous concentration of energy now available in atomic fuels. Now that the atomic fuel has been announced, it may be expected that information regarding it will soon be available to Government agencies. It need hardly be recommended that such information be obtained as soon as possible. Meanwhile, a research order proposal has been prepared covering an analysis of possible methods of using atomic fuel for aircraft propulsion and is attached herewith. The remainder of this memorandum is a short review of the subject of atomic energy, based on the rather meager information available before work on the subject became secret.

2. The Nuclear Reaction. - The atomic fuel is probably the rare Uranium isotope of atomic weight 235, or one of its compounds. If so, associated with the fuel there is a hydrogen-rich compound (water, paraffin) for the slowing down of the neutrons involved in the nuclear reaction. Other substances may be present to enhance or control the reaction. The reaction process, set off by an initial neutron from an external source, is as follows:



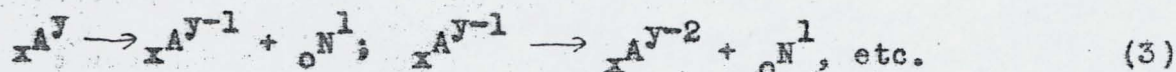
where N designates the neutron (particle of atomic mass = 1, atomic number = 0), the subscripts designate the atomic numbers and the superscripts the atomic weights. The U^{236} is unstable and may split (nuclear fission) to form two (A and B) of a rather large group of possible product nuclei according to the reaction



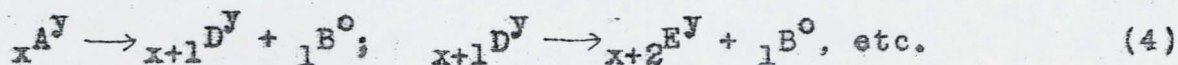
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in which a tremendous amount of energy is liberated in the form of translational kinetic energy of A and B.

The ratio $\frac{M}{N}$ of atomic weight to atomic number determines the stability of nuclei, and as N increases throughout the periodic table the value of $\frac{M}{N}$ for stability increases. Therefore the ratios $\frac{M}{N}$ for the product nuclei A and B will be too large for stability (since the absolute value of N for either is much less than that for Uranium) and they will decay by successive processes which either decrease their atomic weight:



or increase their atomic number:



(where B represents an electron).

3. The Chain Process. - Equations (1), (2), and (3) constitute a chain reaction which will be regenerative or not depending on the following circumstances:

- (a) Relative frequency of occurrence of reaction (3)
- (b) Relative frequency of occurrence of reaction (4)
- (c) Relative frequency of loss of neutrons by other processes
- (d) Effectiveness of neutrons formed by reaction (3) in producing new reactions of type (1).

The probability of new reactions of type (1) can be enhanced simply by increasing the concentration and the total amount of the U^{235} present. Evidently the nuclear physicists have succeeded in collecting enough U^{235} to make the process regenerative. Reaction (1) occurs much more readily if the neutrons are moving at the relatively slow speeds equivalent to those of the thermal agitation of molecules at moderate temperatures: hence the use of hydrogen-rich substances with the fuel to slow down the neutrons.

4. Reaction Energies. - It has been shown calorimetrically that the average complete fission liberates at least 175 Mev (million electron volts) or 0.00028 erg. This



[REDACTED]

Cleveland, Ohio,
August 8, 1945.

MEMORANDUM For Acting Executive Engineer.

Subject: Conference at AERL on August 7, 1945, to discuss nuclear power for aircraft propulsion.

References: (a) Memo. for Acting Executive Engineer, June 11, 1945, BLH:SLS:vs, RFS.
(b) Memo. for Executive Engineer, August 7, 1945, JRD:hn, CSM.

Attendants: Messrs. A. M. Rothrock, Chairman, E. R. Sharp, R. C. Sessions, E. R. Page, A. Silverstein, J. R. Vensel, W. H. Hunter, J. E. Hall, C. W. Schey, C. S. Moore, R. F. Selden, S. L. Simon, C. A. Herrmann, R. E. Tezier, A. R. Bobrowski, D. White, E. J. Manganiello, J. C. Evvard, W. J. McCann, and J. R. Dietrich.

1. Purpose. - The conference was called by Mr. Rothrock to discuss the role of AERL in the development of means of utilizing nuclear energy for aircraft propulsion.

2. Discussion of Nuclear Power. - Mr. Simon gave a short resume of the various possible types of portable fuels, including molecular, atomic, and nuclear fuels as covered by reference (a), and gave typical values for the specific energy release of each type. He discussed the nuclear fission reaction in particular, pointing out the possibility, evidently realized in the "atomic" bomb, of a self-perpetuating chain reaction of enormous specific energy. Throughout the conference there was general discussion of the various phases of nuclear power: the method used to concentrate the Uranium-235 isotope; the possibility of manufacturing Uranium-235 by atomic reactions; the possibility of more easily procured nuclear fuels; the role of hydrogen in the fission reaction; methods of controlling and initiating nuclear reactions, but much of the discussion was necessarily based on conjecture or rumor. Little factual information was presented beyond that contained in references (a) and (b).

3. Role of AERL. - Mr. Evvard stated that nuclear fuels are applicable to any type of heat engine and fall naturally within the scope of AERL research. He emphasized the need for continued rapid developments in the field of nuclear power in order to keep the advantage the United States has

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gained in this field. He recommended sending observers to the New Mexico nuclear energy laboratory, if possible, to get information which will act as a starting point for AERL research. Mr. Dietrich stated that information was needed but was of the opinion that some work relative to methods of converting the nuclear energy to usable forms could be done before further information is available. He was of the opinion that the work should be directed toward the use of nuclear fuels for aircraft applications which are beyond the theoretical capabilities of conventional fuels. Mr. Silverstein commented that such an application would be to high-speed flight. Mr. Hunter suggested that the O.S.R.D. would expect participation by the NACA in applications of nuclear fuels to aircraft. Mr. Sharp agreed and commented that Dr. Vannevar Bush would know best where the NACA fits into the picture. Col. Page was of the opinion that the matter should be taken up with Dr. Vannevar Bush before definite decisions are made as to nuclear energy research programs at AERL. Mr. Rothrock summarized the result of the discussion as the recognition of the need for further information on the results and organization of nuclear power research to date and adjourned the meeting.

J. R. Dietrich,
Head, Ignition Research Section.



JRD:hn
CSM 15/CSM

cc: Act. Exec. Eng. (3)
Mr. Moore (2)
Mr. Dietrich



Cleveland, Ohio,
August 9, 1945.

MEMORANDUM For Acting Executive Engineer.

Subject: Power plant possibilities using atomic energy.

Reference: Memo. for Act. Exec. Engr. dated Aug. 9, 1945, JCE:lam.

1. In the reference memorandum Dr. Evvard has summarized the essential facts regarding the existing knowledge on uranium 235 as a source of atomic energy which is available to those not intimately associated with the project. You have asked for comments on the implications of this source of energy relative to propulsive devices for aircraft and missiles.

2. I think the possibility of our securing any detailed information at the present time about the atomistic fission reactions employed in the atomic energy bomb is extremely remote. I personally feel, however, that there is a great deal that can be done in anticipation of the day when this information will become available. We can look upon any of the fission reactions as an exceedingly concentrated source of energy. If this is to be employed, means must be found for handling the energy source material (atomistic fuel) in such a way that the tremendous amount of energy release will not destroy the equipment in which it is being used. Furthermore, some working fluid is necessary in order to absorb this energy and permit its transformation into thrust. This fluid might be used only once and then disposed of in a rocket, for instance, or it might be used to drive some sort of engine. In the latter case the working fluid may be thrown away or used over and over again.

3. Considerable thought has been given to power plants which utilize a noncondensing working fluid. It is conceivable that such a working fluid could be used in a completely enclosed compressor-turbine system from which the working fluid does not escape. In such a system, there must be a careful control of limiting temperatures and means must be provided for avoiding chemical reaction between the working fluid and the metal parts out of which the device is constructed. As an example, steam might be a conceivable working fluid, but at the highest temperatures would very likely give trouble by oxidizing the metal. For this reason, it might be preferable to use some inert gas such as hydrogen or helium. Hydrogen might be more efficacious as far as slowing down the neutrons is concerned.

4. Dr. Malina of the California Institute of Technology has estimated that a rocket using atomic energies might develop a

[REDACTED]

specific impulse three to four times that obtainable with ordinary chemical reactions. It is thus evident that such a large quantity of working fluid is necessary at any reasonable operating temperature as to greatly limit the efficiency with which the atomic energy can be utilized. In spite of this fact, a three- or four-fold gain in specific impulse would greatly increase the possible range of rockets. Dr. Evvard has made some semi-quantitative estimates which show that merely doubling the specific impulse on the V-2 would increase its range from about 300 miles to 1500 miles. A copy of a figure illustrating this fact is attached.

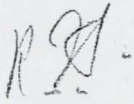
5. In short, there is much that can be done by this Laboratory at the present time in anticipation of the day when detailed information on atomic fission processes becomes available. It is recommended that a small group undertake a detailed study of the possible power plants which could make use of such an energy source and look into the various chemical and engineering limitations which will undoubtedly apply. Fission reactions constitute a physicist's dream at the present time; but to make use of such energy will undoubtedly require detailed consideration regarding materials of construction, working fluids, and means of avoiding harmful chemical changes within the apparatus. A good deal of groundwork could be done in this direction without any detailed information regarding the source of atomic energy being used in the atomistic bomb. I think some general conclusions can be drawn regarding the power plants of the subject type as follows:

- (1) There will be temperature limitations imposed by materials of construction.
- (2) A working fluid will be needed to utilize the atomic fission energies.
- (3) Chemical reactions between the working fluid and the materials of construction at the high operating temperatures must be avoided. All conceivable power plants will not make use of the energy with the same efficiency; for extremely high-speed flight, some sort of rocket is probably the answer even though the working fluid must be expended. In other types of power plants it may be desirable to conserve or expend the working fluid as circumstances dictate.
- (4) Some special absorbing medium for the neutrons may be necessary. This is known to be the case for uranium 235. For other fission reactions other materials might serve the same purpose as do hydrogen containing materials for uranium 235.

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(5) Except for those reactions requiring slow neutrons for their initiation, it appears that air or any other material composed of heavier elements will be capable of stopping the heavier atomic fission products in a very short distance. The reference memorandum states that the "Strontium and Xenon fragments from uranium 235 have a penetration of only 2 to 3 centimeters in air at ordinary pressures. These two particles represent the major portion of the fission energy."

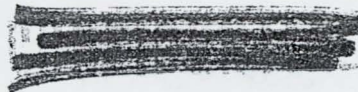
6. The atomistic bomb must be looked upon as a relatively simple device as compared with a power plant making use of atomic fission energies. The bomb requires no control whatever of the fission processes and energy utilization after the reaction is triggered whereas a power plant requires complete control after the fission process is started. Both power plants and bombs require complete control prior to triggering the reaction.



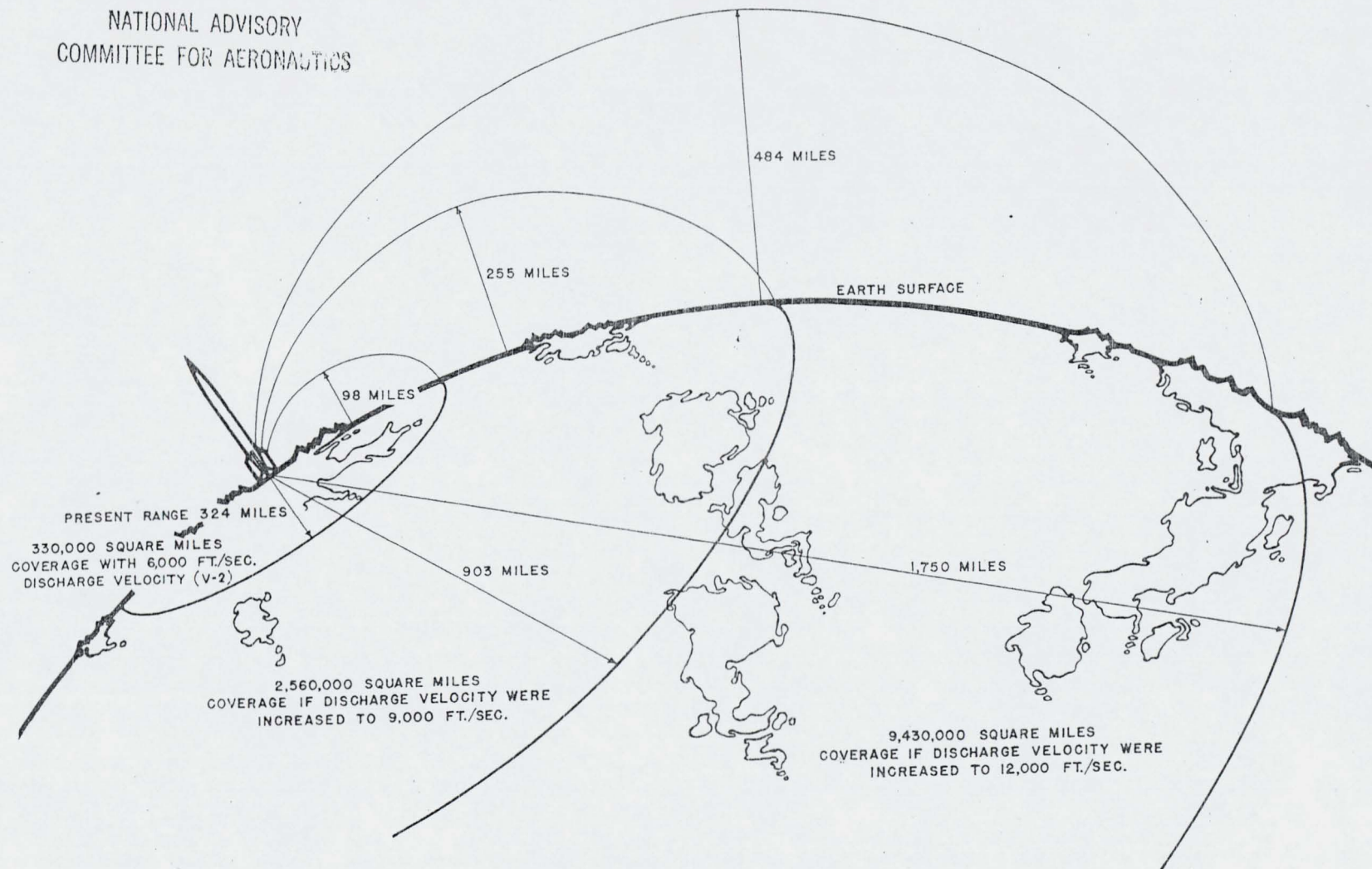
Robert F. Selden,
Assistant Chief, Fuels and Lubricants Division.

RFS:mr

Enc*



NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS



INCREASE IN RANGE OF ROCKET BOMBS OF THE V-2 TYPE
WITH FUELS OF HIGH DISCHARGE VELOCITIES

28944

Cleveland, Ohio,
August 9, 1945.

MEMORANDUM For Acting Executive Engineer.

Subject: Points which might be of interest to you for your Washington discussions.

1. The Germans had a modified V-2 rocket on the drawing boards equipped with collapsible wings. Using a skipping technique in the outer atmosphere, this rocket was reported to be capable of bombing New York from Germany within a radius of ten miles from the point target. Combine this implement of war with the potential applications of the atomic bomb principles, and you get a missile which could destroy any point on the earth's surface from any other point. **THERE IS NO SUCH THING AS THE SAFETY OF DISTANCES!**

2. When a U-235 atom breaks up, it yields several high speed neutrons; these are converted to slow neutrons by passing through hydrogen containing substances, and the slow neutrons react with the U-235 to form U-236 which disintegrates almost instantaneously to atoms of lower atomic weight and more high speed neutrons. In addition, high speed neutrons can react with U-238 to form U-239 etc. The probability of this reaction occurring, however, is low enough that the reaction is not self propagating. In the presence of cataclysmic U-235 reactions, the U-238 might be used to obtain further gains in energy release.

3. According to the article Nuclear Fissions by Louis A. Turner - Rev. of Mod. Phys. Jan. 1940, $3.5 \pm .7$ secondary neutrons are liberated in the fission of each uranium atom. The reaction liberates 218 Mev. (This is the U-238 reaction.) The most probable products of the fission and their energies are 111 Mev for $^{99}_{38}\text{Sr}$ and 78 Mev for $^{140}_{54}\text{Xe}$. The remaining energy appears in the neutrons. The penetration of the high energy particles in air is of the order of 2 to 3 cm. but the neutrons, due to their lack of charge would go much farther. Many other reactions of course take place, and each of the products may combine with neutrons or disintegrate to form other atoms. (1 Mev is equal to 1.589×10^{-6} ergs and there are 6.06×10^{23} atoms per mole.)

4. Without considering the economics of the situation, the use of atomic energy appears feasible for power

plants. It would be applied to heat a working fluid much in the same manner in which hydrocarbons are presently used to heat air. Presumably, water would serve as the working fluid since it is cheap and is also useful in the reaction for slowing down the neutrons. Other substances having a higher hydrogen density might also be used more effectively. The first fruitful peacetime application would probably be in municipal heating or generating plants (due to the dangers of gamma radiations) but atomic power could be utilized in long range rockets, ram jets, steam turbines, and turbo jet engines.

5. Based on energy considerations alone, and the figures given in the newspapers, it appears that the present atomic bomb contains about 6.7 lb of uranium. (This is the combustion energy equivalence of 20,000 tons of TNT.)

6. I suggest that Dr. Lewis contact Dr. Vannevar Bush about the feasibility of allowing four or five competent NACA scientists to join the inner sanctum of the New Mexico laboratory of the Manhattan project to determine in what manner the Aircraft Engine Research Laboratory can apply the atomic energy to the attainment of high speed flight.

John C. Evvard,
Head, Small-Scale Engine Section.

JCE:lam

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Cleveland, Ohio,

AUG 20 1945

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From Cleveland
To NACA

Copy in -171

Subject: Nuclear energy fuels and their utilization.

Reference: Cleveland letter June 22, 1945, AMR:lmk Encs.

1. There are submitted herewith for your information, four memorandums on the reference subject, prepared by members of the staff of this laboratory.

2. It is recommended that contacts be made with the appropriate personnel to determine whether or not the following information can be released at this time to NACA:

(1) Production cost per million Btu of nuclear energy

(2) Extent to which the energy release can be controlled

3. If possible, a group of two to four AERL scientists might discuss with a responsible scientist in the Manhattan project, the possibility and the methods by which nuclear energy might become a source of controlled power.

Addison M. Rothrock

Addison M. Rothrock,
Acting Executive Engineer.

AMR:pn1

Encs* (3 Copies each)

Memo dated 8-7-45	prepared by	J. R. Dietrich
" " 8-8-45	" "	J. R. Dietrich
" " 8-9-45	" "	Robert F. Selden
" " 8-9-45	" "	John C. Evvard

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Copy to AERL answered in conference at AERL Aug. 28.

G.W.L.

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Cleveland, Ohio,
AUG 26 1945

From Cleveland
To NACA

Subject: Nuclear energy fuels and their utilization. *248*

-171

Reference: Cleveland letter June 22, 1945, AMR:imk Encs.

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Addison M. Rothrock

Addison M. Rothrock,
Acting Executive Engineer.

AMR:pnl

Encs* (3 Copies each)

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- " " 8-9-45 " " John C. Evvard

cc: Mr. Moore
Dr. Seldens
Files

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