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RED STAR SERIES ON THE PROBLEMS
OF UTILIZING ATOMIC ENERGY

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Part V

THE NUCLEAR FUEL ENGINE

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In January, 1954, the Soviet Ministry of Defense organ <u>Krasnaya Zvezda</u> (Red Star) began publishing in the space allotted to scientific and technical subjects a series of six signed articles generally entitled "Atomic Energy." This was followed by another series of seven articles entitled "The Physics of the Behavior of Nuclear Forces." Translations of these articles are available in the RAND T-35 series.

On July 1, 1954, the entire Soviet press carried the official announcement concerning the inauguration in the USSR of the first industrial power station operating on atomic energy. Two months later, on August 31, 1954, <u>Red Star</u> began a new series of articles generally entitled "The Problems of Utilizing Atomic Energy."

The ~~present~~ article, ~~the fifth in this series, was written by the well-known savant Professor G. Pokrovsky and~~ is concerned with the application of atomic engines to submarines, aircraft, guided missiles and automobiles. It is suggested ~~The author suggests~~ that atomic submarines could provide an excellent means of communication in the Arctic since they could travel unhindered under the ice where there is always a layer of unfrozen water. Although not yet used in aircraft, atomic engines have great significance for pilotless aviation, e. g., guided missiles, long-range rockets, and cargo- and passenger-towing aircraft, since there is no need for extremely heavy shielding around the nuclear power plant. With regard to automobile transport, ~~he indicates~~ the existence of a project is indicated which makes use of gaseous fissionable materials in an internal combustion type of engine. ~~This idea has been described by E. H. Kerner in the Journal of Applied Physics 24, 615 (1953).~~

F. J. Krieger

THE PROBLEMS OF UTILIZING ATOMIC ENERGY*

The Nuclear Fuel Engine

In recent years tremendous successes have been achieved in the development of nuclear physics and in working out practical methods of obtaining atomic energy. These successes even now provide the opportunity of using atomic energy not only for manufacturing electricity, but also in various forms of transport. There is no doubt that, on the road to the wide use of atomic energy for the construction of mechanical engines, serious difficulties will have to be overcome and many scientific-technical problems will have to be solved.

In order to make an atomic engine, an ordinary uranium pile can be used in which the transformation of natural uranium into plutonium is accompanied by the release of a great amount of heat. The heat is utilized for heating a steam boiler which supplies steam to a turbine. Thus, a uranium pile in this case represents a unique atomic furnace in an ordinary steam-power plant.

There is, however, one feature of an atomic pile which must definitely be taken into account. It emits into the surrounding space a powerful radiation which has a very harmful effect on people. In order to eliminate the harmful influence of this radioactive radiation, it is necessary to surround the pile with a shield in the form of a layer of concrete or lead weighing about 100 tons for every cubic meter of volume. This makes an atomic steam power plant extremely heavy. According to press data, the assumed weight of an atomic plant for a 500 ton locomotive of 6,900 horse-

*Krasnaya Zvezda, 15 September 1954, p. 3.

power amounts to approximately 100 tons, i. e., 20 percent of the entire weight of the locomotive.

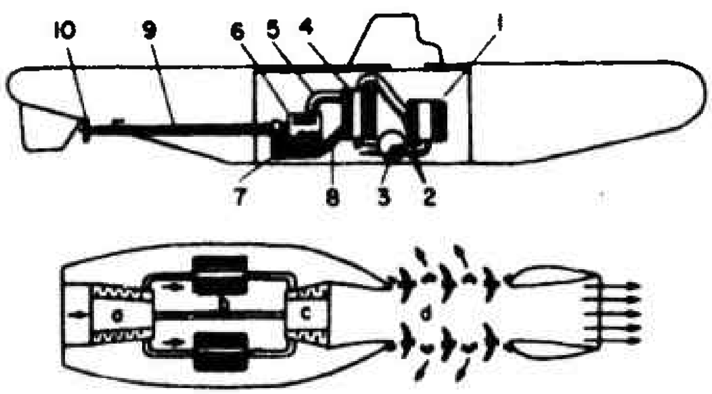
The relative increase in the weight of an atomic engine in comparison with conventional steam-power plants is greater, the less the power of the engine. Consequently, one can assume that atomic engines may in practice be used for transport [purposes], for example, in the navy only for comparatively large power requirements, approximately tens and hundreds of thousands of horsepower. Besides this, one should take into account the fact that conventional furnaces for steam boilers require tremendous quantities of air for burning coal or oil.

An atomic engine, however, requires no air at all. It needs only a liquid for cooling the steam power plant. In addition to which the equipment for cooling can be made sufficiently compact.

A very important property of an atomic engine is the fact that a small quantity of uranium is required for its operation even over a very lengthy period. Its weight and volume in comparison with the whole atomic engine are quite insignificant. Therefore, an atomic engine can in practice operate (continuously or intermittently) until the bearings of the turbine wear out.

If one compares the weight of an atomic steam power plant with the weight of a conventional steam power plant (together with the fuel required for its operation), then the following will become evident. With a small supply of fuel the conventional steam power plant will be lighter than an atomic one, the weight of the atomic plant being greatly increased by the weight of the shield against the radiation from the atomic pile. On the other hand, with a considerable supply of fuel the weight of a conventional steam power plant will be substantially greater than the weight of an atomic engine. That is why it is expedient to use atomic steam power plants when the engine [requirement] is not less than approximately 10,000 horse-power. At the same time, the engine is capable of operating for a long time without refueling, requiring absolutely no air, if there is another substance, for example, water, which can be used as a coolant.

The properties of an atomic engine also determine the possibilities of its most profitable application. In particular, an atomic engine may be successfully used in large submarines designed for long-range navigation. In the upper part of the figure reproduced here, a basic diagram of an atomic submarine is shown. The section with the atomic engine is shown in cross-section. Because of the nuclear reaction, which takes place in the atomic pile (1), a tremendous quantity of heat flows continuously through the pipes (2) into the heat exchanger (4). There high pressure steam is produced; it sets the turbine (6) into operation, the motion of which is transmitted by a gear drive to the shaft (9) of the propeller (10). The diagram of the engine also contains a pump (3), a condenser (7) and pipe-lines (5 and 8).



Submarines with atomic engines could be of substantial interest from a military point of view for carrying out long-range operations against the enemy's communications. These vessels, however, will find a serious application also for peaceful purposes. They do not require air for the operation of the engine and are capable of travelling under water for a very long time without surfacing. Maintaining a sufficient quantity of oxygen in such a submarine for the personnel to breathe and absorbing the carbon dioxide, which they produce, are accomplished comparatively simply.

Under such conditions atomic submarines could provide an excellent means of communication, for example, in the Arctic. The surface of the water in the Arctic, for a considerable part of the year, is covered with ice which is difficult for surface vessels to surmount. Under the ice, however, there is always a layer of unfrozen water in which a submarine can travel unhindered. Should it be necessary for the crew of the vessel to come to the surface, it is easy to bore through the ice from below and to push outside a wide pipe with a ladder or elevator. Through such a pipe it would be possible not only to land people, but also to unload various materials.

The prospects for the peaceful use of atomic submarines, however, are of little interest to the reactionary forces of the imperialistic states. This is indicated by the sensation raised in the foreign press about the American military submarines ''Nautilus'' and ''Sea Wolf.'' These submarines according to the data of the foreign press do not differ in any particulars from the diagram considered above and resulting from the physical bases of utilizing atomic energy. Moreover, according to the latest data, the Americans have not yet succeeded in practically mastering the submarine ''Nautilus'' which they have built. Her trials are being postponed, and troubles connected with the atomic engine have not yet been successfully eliminated.*

Aviation is another field for the possible utilization of atomic engines. Here one can speak, in the first place, about steam turbines which turn propellers and obtain steam from the heat produced in an atomic pile. In the second place, there is the possibility of creating a turbojet engine in which the heating of the air is accomplished (directly or by means of a heat exchanger) by an atomic pile. In the third place, one can speak of the construction of a liquid [fuel] jet engine in which the heating of the reactive gases is accomplished by an atomic pile. All these prospects are of significance, first of all, for pilotless aviation -- guided missiles, long-range rockets and the like. There are no personnel in such machines and, therefore, there is no need for an extremely heavy protective jacket for the atomic pile. This greatly reduces the weight of the plant and makes it suitable for use in a flying machine.

No less probable is the use of atomic engines in aviation for remote controlled towing aircraft. These tractors could be used to tow passenger or cargo gliders. It is possible to obtain the necessary attenuation of the radiation, which is dangerous to the living organism, by a sufficient length of tow line, and so also of distance between the towing aircraft with the unshielded atomic pile and the towed glider with the people. Here distance alone will replace the great mass of the substance of the protective jacket of the atomic pile.

In connection with the possibility of using atomic energy in aviation there arises, even more acutely than with conventional jet aircraft, the

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*Note: The Nautilus was launched at Groton, Connecticut, on 21 January 1954. It was not until 17 January 1955, however, that she underwent her first sea tests, in Long Island Sound, on nuclear power. Ed.

problem of converting the thrust of the engine into a braking force for shortening the landing run and improving the maneuverability of the aircraft in the air. Until recently these tasks seemed almost insoluble. Lately, however, information appeared in the press about the creation of an apparatus called the deviator. It is installed in the jet nozzle at the point where the gases emerge. The deviator contains a rotatable grid with blades for deflecting the motion of the gases in the desired direction.

By means of such a device a counter-thrust of the order of 15 to 20 percent of the engine's maximum thrust can be obtained. As a result, the speed of the aircraft and the landing speed are considerably decreased. The size of the landing strip is reduced. There is a substantial gain in time when coming in for landing and the maneuverability of the aircraft and the life of the landing gear are increased. Since such a deviator can be used in any engine, regardless of diameter, temperature and velocity of flowing gas jet, tempting prospects open up for solving the problem of landing aircraft with atomic engines. In the lower part of the figure reproduced here is shown a sketch of a turbo-compressor jet engine which operates on atomic fuel and consists of a compressor (a), an atomic pile (b), a turbine (c) and a deviator (d).

In practice no atomic engine has yet been used in aviation. The possibilities of its use, however, are very great, and modern technology allows them to be realized by various means.

No less realistic in the future is the utilization of atomic fuel for automobile transport. There exists, for example, such a project for a low-powered engine using an atomic reactor. The reactor is made in the form of a cylinder with a piston. The space inside the cylinder is filled with nuclear fuel in a gaseous state under certain pressure. When the piston moves the gas is compressed. As soon as it attains a certain volume, a nuclear fission chain reaction begins. The products of the reaction exert great pressure on the piston and force it out. The volume of the cylinder becomes greater than critical, and the nuclear fission chain reaction stops. If several cylinders are taken, one can obtain an atomic engine similar to an automobile engine. Undoubtedly, in order to completely eliminate loss of neutrons, the cylinders in this case must be made of materials which reflect neutrons well. It is possible to regulate the power of the reactors, hence also that of the engine, its starting and stopping, by rods of cadmium or boron.

It is interesting to compare the expenditure of fuel for the conventional engine of the ''Pobeda'' motor-car and that of an atomic engine of approximately the same power. The ''Pobeda'' consumes 10 to 11 tons of gasoline over a distance of 100,000 kilometers. An engine operating on nuclear fuel will require only 6 grams of uranium. Let us assume that 10 percent of the nuclei will fission. Then to ensure normal operation of an atomic engine of such power over a distance of 100,000 kilometers, it will be necessary to put into it 60 grams of nuclear fuel. In practice this is quite feasible. There remains only to look after the protection of people against the radioactive radiation.

All that has been said permits one to draw the conclusion that already today atomic technique is a rapidly growing branch of technology. In the future it will develop even more impetuously, since the possibilities of utilizing atomic energy are becoming more and more diverse, especially in our country where all the achievements of science and technology are placed in the service of the people.

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