IMPLEMENTATION OF RADIOACTIVE POWER IN SPACE

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In this paper, the application of radioisotope thermoelectric generators and nuclear reactors as sources of energy in space technologies is examined. The paper provides an overview of successful implementation of radioisotope thermoelectric generators, such as Orion-1, Kosmos-84 and 90, Lunohod-1 and 2, Pioneer-1 and 2 [1].

There are two general types of reactors demonstrated. The first one is based on direct thermoelectric conversion. The second one is a reactor with heated fluid driving a turbine. The greatest development of implementing nuclear reactors was in the period of 60's to 70's years of the 20th century because of the popularity of this idea [2]. Consequently, most reactors presented in this work are related to this period of time.

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PLUTONIUM-240 AS A BURNABLE ABSORBER

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The basis of nuclear power in Russia is power reactors of WWER type, which are reliable and safe to operate. Currently, the improvement of WWER reactors is carried out in the direction of increasing nuclear fuel burnup. High burnup is ensured by the longer fuel cycle. Reactor lifetime elongation is possible by increasing the initial fuel enrichment, which results in the need to compensate the high excess reactivity at the beginning of the fuel cycle. Compensation of excess reactivity is possible by injection of the burnable absorber (BA). BA prevents excessive use of boron control and reduces the implication on the control rods [1].

The paper considers the possibility of using as a burnable absorber such material, as plutonium-240. As the burnable poisons in the WWER reactors, it is advisable to use materials having high neutron absorption cross section with values more than 1000 barns, such as *Eu*, *Sm*, *Dy*, *Gd*, *Er*, *Cd* and *Hf*. Apart from the choice of material, it is important to select a method for placement of the absorber in the fuel assembly.

Also, it is important to take into account both technological and physical aspects. Normally, plutonium is used in a nuclear reactor as a fuel [2]. It is perfectly fissionable by thermal neutrons, rather than uranium-235. For calculating the neutronic characteristics of plutonium, the WIMSD5 program was used. The main value describing the development of nuclear fission chain reaction (and the neutron balance in the reactor) is an effective neutron multiplication factor k_{eff}. The effective multiplication factor is the ratio of the number of neutrons in one generation to a corresponding number of neutron generation immediately preceding it. Neutron multiplication factor for the various compounds of plutonium was calculated. When k_{eff} <1, fission chain reaction can not be supported. The reactor operating at k_{eff} = 1, is called critical, at k_{eff}> 1 it is called supercritical and at k_{eff} <1 - subcritical [3].

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NUCLEAR THERMAL ROCKETS (NTR)

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The history of space nuclear power development is quite unusual. Since the very first day of the Space Age, nuclear power has been regarded as the only viable option for long-term and energy-intensive space operations: lunar bases, interplanetary missions, giant geostationary platforms for communication, as well as the only source of energy in space and a source of power for space flights.

Solid-phase NTRs

NTRs of this type include a solid-phase reactor in the form of a cylinder having a height and diameter of approximately 1–2 m. The reactor consists of the reactor core, a reflector surrounding this area, the governing bodies, a power case and other elements. The reactor core contains nuclear fuel, which is a fissile material enclosed in the fuel elements. The core and the reflector are placed inside a durable power case. The case is closed with a solid cover. Control rods are placed in the active zone or the reflector, and the rotary drums are mounted on the periphery of the reactor.

Gas-phase NTRs

These NTRs, existing while only as a part of some projects, do not differ much from the above-described solid-phase NTRs. The main difference of gas-phase NTRs is that the substance in the reactor core is in a gaseous state. It is obvious that the operating temperature of such active zone exceeds the temperature of solid-fuel elements, therefore, heating of the working fluid in the gas-phase NRE can be much higher. This means an increase in specific impulse of an NTR.

Russian project

The new Russian project involves the use of the ion electric rocket engine, in which the jet thrust is created using an ion flux accelerated by an electric field.

A great advantage of the project is associated with performance characteristics, namely, a long service life (10 years of operation), significant overhaul interval and long operating time after switching on.

Conclusion

The development of nuclear thermal rockets has a great potential. That is, with proper funding and attention of the global scientific community to these technologies, the humanity will soon be able to come close to commercial space exploration, manned missions to Mars and investigation of distant planets.