OVERVIEW OF SOME PROJECTS OF SNPS FOR GLOBAL SPACE COMMUNICATION

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Modern concepts of the application of power technology in space believe in using an onboard source of energy for maintenance of self-transportation of the vehicle into working geosynchronous orbit (GEO). This can result in reduction of the cost of all installation and the number of rocket starts.

Here we present several conceptual projects of nuclear power installations. Power units developed with IPPE's participation are intended for long term supply of electricity to the vehicle in GEO and to maintain self-transportation of capabilities.

OVERVIEW OF SOME PROJECTS OF SNPS FOR GLOBAL SPACE COMMUNICATION

IPPE is one of the primary developers of compact, efficient reactors for space nuclear power systems, which use direct conversion of nuclear heat into electrical energy. In the '50s in IPPE it was started development of "BOUK" reactor for thermoelectric space power system. There were more then 30 launches of this SNPS in to low level orbits in near the Earth space. In 1958 IPPE started to develop a reactor-converter with the advanced thermionic principle of direct energy conversion. "TOPAZ"-units were tested twice in space as an electric power source for the "COSMOS" satellites. Since the middle of the '50s the works on nuclear thermal propulsion system (NTPS) have been performed at IPPE. A set of problems related to engineering design of the NTPS and its functional capabilities has been studied. The IPPE carried out works in proving of reliability of solid-core reactors for NTPS.

WHY IS GLOBAL SPACE COMMUNICATION CHOSEN AS A TASK FOR NUCLEAR POWER?

Next step of development of space nuclear systems is fitting of the basic technologies for using of SNPS in the nearest future tasks. As such task can be chosen problem of development and energy supplying global space communication systems.

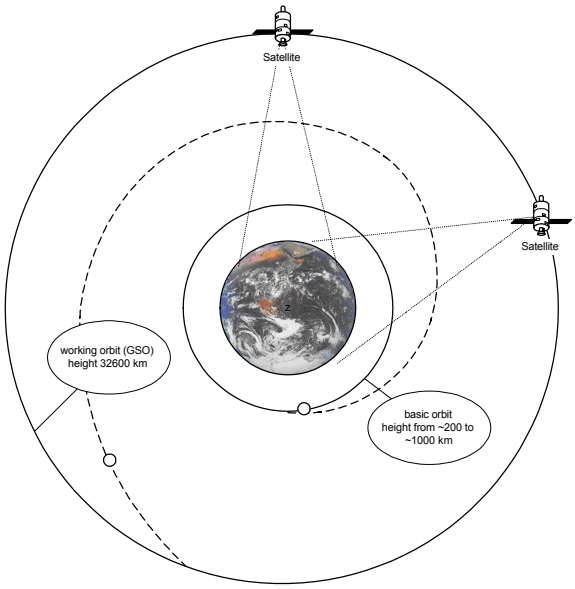

FIGURE 1

One of several concepts of GSC assumes using of satellites which operates on GSO and has great power on-board source of electricity.

Modern concepts of the application of power technology in space believe in using an onboard source of energy for maintenance of self-transportation of the vehicle into working geosynchronous orbit (GEO).

Developing of concepts which are presented below we try to answer on question: What will we actually do to gain advantages in competition with solar – based sources of energy in tasks of GSC?

DUAL-MODE NUCLEAR POWER SYSTEM WITH FAST NEUTRON REACTOR – CONVERTER

SNPS named "TEMBR" intended for delivering of informational space vehicles into GSO and subsequent prolonged for 10-15 years power supplying of space vehicle equipment.

Complete electric power, kW
for transportation mode *100 – 150*

for electricity supplying mode	*20*
Thermal power, kW:	
for transportation mode	*2200 – 3500*
for electricity supplying mode	*500 – 700*
Voltage, V	*120*
Lifetime performance, year	
for transportation mode	*up to 1 year*
for electricity supplying mode	*more then 10 years*
Maximal temperature of coolant, K	*1223*
Temperature of hot end of thermoelectric unit, K	*1100 – 1173*
Temperature of cool end of thermoelectric unit, K	*760 – 900*
Maximal complete mass of power model of SNPS, ton	*4,5*

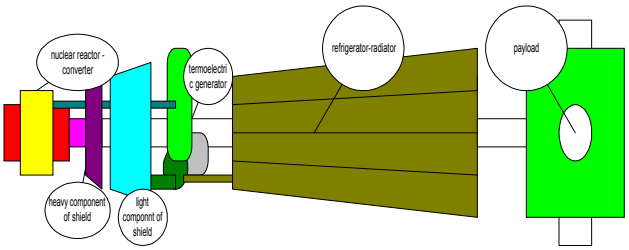

FIGURE 2

It is possible to develop it in reasonable time up to 2010-2015 years:

- the possibility of operation in two modes substantially varying in power and life time;
- the limitation on the NPS mass and overall dimensions so as to use for a space vehicle injection also the relatively inexpensive middle-class launch vehicles;
- the possibility to create the NPS using for the most part developed technologies, available structural and other materials and existing (with possible modernization) production-technological experimental and testing plants;
- the possibility for performance of nuclear power testing of the NPS with standard arrangement without a new major construction, i.e. using the building for the nuclear power testing of space NPS at the SSC RF-IPPE;
- the possibility of designing and start of try-out (up to a full-scale NPS module) without the reference to a concrete space vehicle;
- the sufficient degree of redundancy and reliable proof of the possibility to ensure the design life time;
- the limited term and cost of the NPS creation and development.

PROPULSION SYSTEM BASED ON COUPLING OF NUCLEAR ROCKET AND CHEMICAL THERMAL ENGINES TECHNOLOGIES

This concept project based on machine converter of energy.

Dynamic conversion of energy allow us to develop space power platform with very high level of installed capacity. Ability to make great power of this system is most in comparison with any another including the direct conversion technologies.

The implement mode of operations is carried out on the basis of burning hydrogen or other gas in oxygen, which previously are warmed up at the expense of reactor's power.

The mode of long electricity production is carried out on a basis of turbine compressor transformation of a thermal energy in electrical with the closed contour of the heat-carrier. As a working body can be used nitrogen N, mix of Kr-Xe and other gases.

The elements of the considered technology can be used for creation NPPI and with other sources of heat (for example, radioisotope).

Nuclear reactor and heat transfer equipment works in a normal mode, which are very reliably confirmed for other high-temperature nuclear systems. Gaseous turbine compressor equipment on its parameters is similar to development for the non-nuclear applications.

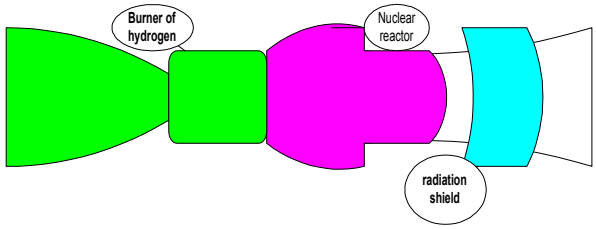

FIGURE 3

Having warmed up a working body at the expense of reactor's heating allows us to increase a specific pulse of products of combustion of hydrogen in oxygen. In result the specific pulse raises up to ~ 6 km per sec with overheating of hydrogen and oxygen up to ~ 2100 K. A specific pulse without overheating of the component makes about 3,5 km per sec.

Power converter of this system is planned to use the same as in prospective system with solar concentrator.

The main features of installation are followed.

Having warmed up a working body at the expense of heat of reactor allows us to increase a specific pulse of products of combustion of hydrogen in oxygen.

The mass of delivered on GEO cargo significantly more than one when chemical jet is used.

The closed contour of installation allows us to avoid an output of a radio – activity from nuclear fuel. Developing of installation we have opportunities to try – out various systems independently.

Additionally this technology can be apply in tasks of removing far from the Earth very dangerous objects.

Completely it is necessary to search application of such technology (in opinion of the authors) in the field of creation of power sources of rather high capacity when the time of its delivery on working (GEO) orbits is limited by whatever reasons.

SNPS WITH THERMOELECTRIC EQUIPMENT FOR ENERGY CONVERSION FOR SPACE VEHICLE OF RADAR TRACKING SUPERVISION

This unit named as BOUK-TEM because it is based on well known concept of tiny reactor and high temperature thermoelectric conversion of energy as in BOUK. It is purposed mainly for long-time supplying by electricity of the radar-tracking equipment for supervision of Earth surface and an atmosphere. It is two circuit system which cooled by lithium and heat conversion into electricity is supposed by silicon-germanium generators, which are placed externally from the core.

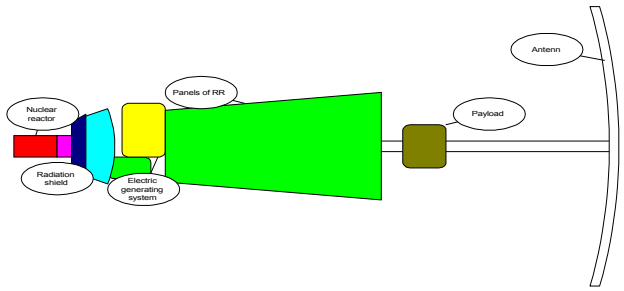

FIGURE 4

For decrease of weight of radiating shield the following basic receptions are used:

- by using of thermoelectric generators (TEG) as additional protection by accommodation them is direct for hydride-lithium shield block and choice of a configuration of TEG, completely overlapping shadow cone.
- by choice of an optimum cone of a shadow admitting partial output RR and RA for limits of a shadow under condition of performance of the requirements on total fluence of neutrons and total doze of photons from past through shield and absent-minded on RR and RA of irradiation.
- by accommodation of a heavy component of shield is direct on a face reflector and by its profiling that allowing us to reduce its weight approximately in 2 times.
- by choice of optimum distance between shield and instrument compartment.

DISCUSSION

TEMBR – transporting power module with fast reactor

TEMBR uses thermionics converters for production of high level of electricity power with high thermal efficiency but for short time from 3 month to 1 year.

TEMBR uses thermoelectric converters as producer of electricity for long time. It has small thermal efficiency but this converter arranged outside of the core of reactor.

TEMBR use for heat transport lithium-niobium circle.

In-core thermionic converters.

Resource and specific characteristics of them are experimentally confined in TOPAZ and in on ground reactor tests.

Conditions of operation of them are the same as in TOPAZ electric generation channels.

New designer specimens can be tested for reasonable time about one year because it is planned resource of them.

Distributions of heating rates, heat and gaseous flows and the temperature distributions are common for such systems (demonstrated in tests).

Termelectric generator.

Silicon – germanium semiconductor batteries will operate outside of reactor in not very high irradiation fields and resource and characteristics of them (masses and sizes)

Resource of generator can be confirmed in nonreactor on-ground tests with any external sources of heat.

Heat transfer circle

Lithium – niobium technology are well tried – out in Russian organizations including purification of lithium and maintaining optimal conditions of pumps and pipes system working.

Levels of velocities and temperature of coolant and structure materials are also well mastering in number of experimental designing works.

Starting point of the development.

Main organizational reasons to develop of TEMBR-like systems are opportunity to completing necessary researches, final trying-out and quality assurance procedure almost without in-core of nuclear experimental reactor's tests. They result in small time for development and production of pilot installation.

TEREK – bi-modal systems which couples two different modes of operations:

- thermal rocket engine based on nuclear rocket engine technologies with burning of hydrogen in oxygen;
- electric power generation system for long time supplying of on-board needs of satellite which based on machine conversion of heat into electricity;
- gaseous circuit of cooling of the core and transferring of the thermal energy form the nuclear fuel to power converters and to working body (hydrogen);
- systems of removing of heat;
- tanks for reagents (for example, oxygen and hydrogen);

Due to coupling of thermal engine and electric generator systems mass and size of them will be less then in all of any ones for the same parameters on power and time of delivery. Materials and components of nuclear reactor and gaseous circuit will operate in usual for high temperature reactor regimes because there are not overheating of working body for thermal engine and for power converter. Reliability of them on the all of this regimes can be prove by not exotic experiments during reasonable time and it will not take huge financial extends.

Starting point of the development.

There is a lot of experience of designing of high temperature nuclear reactors, fuel elements and peripheral equipment of gaseous circle.

Design of nuclear reactor, radiation shield and heat removing system has got a high level of readiness.

But machine electricity generator can be tried-out with appreciable efforts and for reasonable time without in-core of nuclear reactor tests because this generator can be used in another solar-based power generation platforms.

Rocket engine also can be developed and tried-out without using of on-nuclear reactor experiments.

BOUK-TEM – space nuclear power systems with high temperature lithium cooled tiny nuclear reactor and thermoelectric power converters for supplying of tasks of radio-tracking of the Earth surface and atmosphere.

It is return to concept of thermoelectric technology but on the new level of power and with new engineering solutions. Here we apply experience of BOUK-type SNPS for solution of new tasks.

BOUK-TEM uses for power production small sized reactor with highly enriched uranium nitride fuel; electric power is generated in cylinder semiconductor thermoelectric generator; heat is transported by lithium in high temperature niobium circuit.

BOUK–TEM is based on experience of reactor engineering (well tried–out concept of tiny fast neutron reactor); it is applied in BOUK-TEM new design of electric generator but thermoelectric semiconductor batteries are well known and almost all of their resource and specific characteristics has been confirmed by present moment and other can be confirmed for not very long time.

Starting point of the development.

Design of nuclear reactor, radiation shield, heat transporting system including electromagnetic pump, heat removing system has got high level of readiness.

Energy conversion system (thermoelectric generator) can be tried-out with appreciable efforts and for reasonable time without in-core of nuclear reactor tests.

CONCLUSIONS

In this presentation we focused on three variants of prospective concepts of SNPS. They are intended to solve tasks of GSC as nearest future tasks in space.

Modern concepts of the application of power technology in space believe in using an onboard source of energy for maintenance of self-transportation of the vehicle into GSO.

There are three more prospective systems as follows:

- gas cooled nuclear reactor with hybrid thermal engine and machine power converter;
- nuclear reactor cooled by liquid metal and with a thermoelectric power generating system;
- nuclear reactor with Li cooling and a thermionic and thermoelectric power generator on board.

The choice of a concept must fit strong requirements such as:

- space nuclear power unit is aimed to be used in a powerful mission;
- space power unit must be able to maintain the dual – mode regime of vehicle operation (self – transportation and long life in GEO);
- nuclear rector of unit must be safety and it must be designed in such a way that it will ensure minimum size of the complete system;
- the elements of the considered technology can be used for the creation of NPPI and with other sources of heat (for example, radioisotope);
- the degree of technical and technological readiness of units of the thermal and power circuit of installation is estimated to be high and is defined by a number of technological developments in air, space and nuclear branches;
- nuclear reactor and heat transfer equipment should work in a normal mode, which can be very reliably confirmed for other high-temperature nuclear systems.

Considering these concepts we practically consider one of possible strategy of developing of complex system of nuclear power engineering. It is the strategy of step-by-step development of space engineering with real application of them in commercial, scientific and other powerful missions in the nearest and deep space. As starting point of this activity is promotion of nuclear technologies in space communications systems.

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