GT-MHR PROJECT

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ABSTRACT

The paper presents new generation reactor - modular helium reactor with gas turbine (GT-MHR), which satisfies the requirements of the developing nuclear power.
The paper describes the reactor plant and peculiarities of GT-MHR technical concept, such as high efficiency (about 48%) of electric power generation, increased safety of the plant, etc.
The technologies, which are the innovative essence of GT-MHR project, are:
(1) fuel in the form of fuel particles with multi-layer ceramic coatings which confine fission products at high temperatures (of about 1600°);
(2) large gas turbines;
(3) single-shaft vertical turbomachine design;
(4) electromagnetic bearings;
(5) high-effective compact heat exchangers.
Main technical and economical indices of GT-MHR project are presented.

1. Introduction

One of new generation power plants meeting the requirements of developing wide-scale atomic energy is gas turbine modular helium reactor plant (GT-MHR).

In 1997 GT-MHR Conceptual Design which has been reviewed several times was developed within the framework of 4-lateral Agreement between Minatom of Russia General Atomics, Framatome, Fuji Electric. International Project review was held in France (June, 1999) with participation of independent experts of Russia, USA, Japan and European Community. Review results showed that there are no insurmountable difficulties for the Project implementation. Technical and financial risk may be reduced with international cooperation.

Main goals of the GT-MHR Project development are as follows:

(1) creation of the plant meeting the requirements imposed on innovative technologies of the XXI-st century as for safety, competitiveness and minimization of radiation and thermal impact to environment;

(2) commissioning of the first GT-MHR module not later than 2010, minimizing R&D by use of accumulated world experience on the HTGR technology;

(3) creation of base for further commercial application of this technology to generate power and heat for domestic and industrial needs, including hydrogen fabrication;

(4) use of the first and next modules for excessive weapon-grade plutonium burnup.

GT-MHR Project is included into “Strategy for atomic power development in Russia for the first half of the XXI century”. Strategy stages Stipulate: “Participation in the international project on the GT-MHR NPP development and construction” till 2010 and “Pilot operation of the GT-MHR prototype module and fuel fabrication for it (within the framework of the international Project)” till 2030.

The GT-MHR Project is included into the Russian Federal purpose-oriented Program “Power effective economy” for 2002-2005 and 2010.

Survey of the GT-MHR fuel cycle showed good capabilities of the reactor to burn weapon-grade plutonium, therefore, the GT-MHR Project was included into activities program within the framework of appropriate agreement on research and technical cooperation between Russia and USA dated July 24, 1998.

International cooperation of enterprises in Russia, USA, France, Japan (OKBM, RRC “KI”, VNIPIET, SCC, NPO “Luch”, General Atomics, Oak Ridge National Laboratory, Framatome ANP, Fuji Electric, etc.) takes place to implement the GT-MHR Project. Hundreds of experts accumulating knowledge and experience on HTGR are working on the Project.

2. Main activity stages on the GT-MHR prototype module project

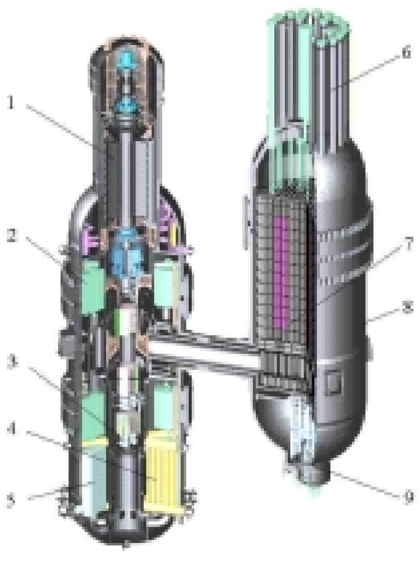
- Preliminary Design – 2001
- Final Design – 2005
- Commissioning of fuel fabrication for prototype NPP – 2008
- Commissioning of prototype NPP – 2010

Prototype NPP Project includes: development of nuclear power plant with the GT-MHR reactor plant, stationary fuel fabrication for 250 kg per year.

Main activity directions for the Project are turbomachine, recuperator and fuel fabrication, including reactor tests.

3. GT-MHR technical concept

Prototype NPP with the GT-MHR RP includes one power module with the GT-MHR reactor module of 600 MW thermal capacity. GT-MHR reactor module consists of two integrated units: modular high-temperature reactor and power conversion system with direct gas-turbine cycle (Figure. 1).



The reactor includes core and metalworks, which support it and form the coolant circulation path.

The power conversion system implementing closed gas-turbine cycle is completely arranged in PCS vessel. The turbomachine consists of generator, gas turbine, and two compressor sections mounted in a single-shaft structure completely suspended on electromagnets. PCS includes three compact heat exchangers: high efficiency recuperator, water-cooled precooler and intercooler.

The reactor unit and associated primary systems are arranged in the underground building (Figure 2).

The schematic diagram of GT-MHR plant is given in Figure 3.

1 – generator; 2 – recuperator module;
3 – turbocompressor; 4 – intercooler module;
5 – precooler module;
6 –reactivity control system assembly;
7 – core; 8 – vessel system;
9 – reactor shutdown cooling system

Fig.1 GT-MHR reactor module

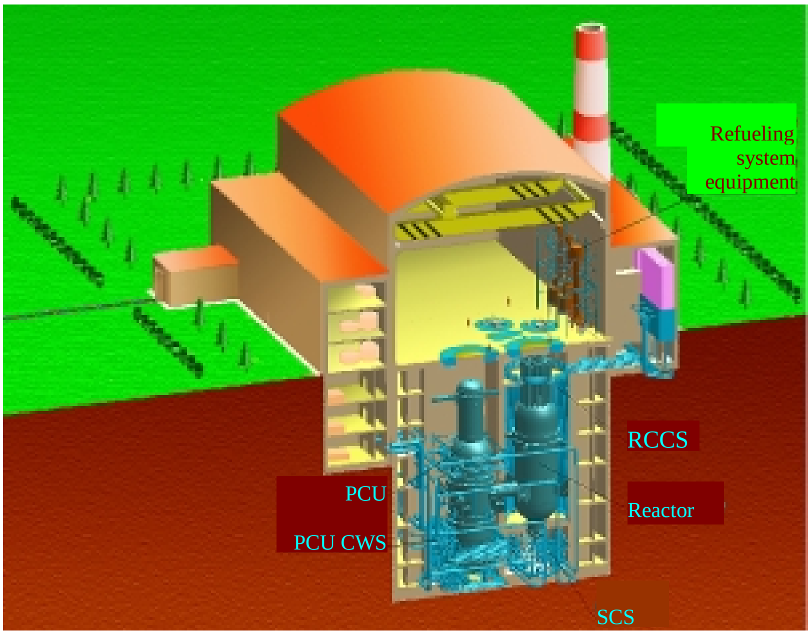
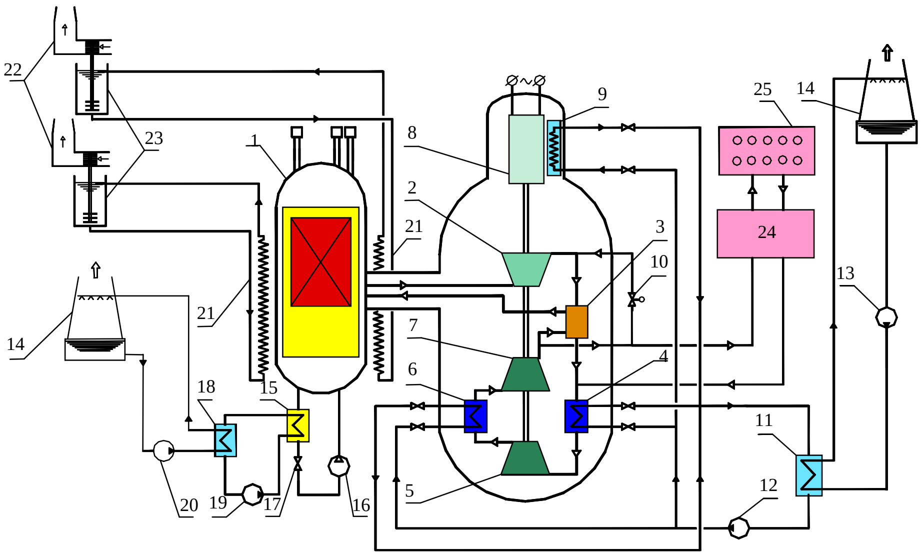


Fig. 2 GT-MHR module



1 – reactor, 2 – turbine, 3 – recuperator, 4 – precooler, 5 – low-pressure compressor, 6 – intercooler, 7 – high-pressure compressor, 8 – generator, 9 – generator cooler, 10 – bypass valve of the TM control and protection system, 11 – heat exchanger of the power conversion unit (PCU) cooling water system (CWS), 12 – PCU CWS pump, 13 – recirculation water supply system pump, 14 – cooling tower, 15 – reactor shutdown cooling system (SCS) unit heat exchanger, 16 – SCS unit gas circulator, 17 - SCS unit gas circulator isolation valve, 18 - SCS CWS heat exchanger, 19 – SCS CWS pump, 20 – reliable recirculation water supply system pump, 21 – reactor shutdown cooling system surface cooler, 22 – air ducts, 23 – heat exchanger with heat pipes, 24 – primary circuit purification system, 25 – helium transportation and storage system.

Fig. 3 Principle diagram of the GT-MHR NPP

Main indices of the GT-MHR prototype plant are presented below.

Description	Indices
Plant capacity: - thermal, MW - electric, MW	 600 285
Power conversion cycle	Brayton, with gas turbine in the primary circuit
Power conversion system efficiency	~ 48 %
Core type	Annular of prismatic FA
Fuel type	Microspheres of multi-layer ceramic coating
Power density	6.5 MW/m^3
Average fuel burn up	640 MW·day/kg
Fuel life duration	750 days – for plutonium fuel
Operation duration between refueling	250 days
Refueling ratio	3
Design service life of basic equipment	60 years
Total construction cost	355 US M $
Electric power prime cost	1.62 cent/kW

High level of the GT-MHR safety is stipulated by structural features and physical properties of the core, as well as technical solutions adopted in the project:

(1) use of fuel in the form of small particles (of 200 μm diameter) with multi-layer pyrocarbon and silicon carbide coating, which are capable of effective fission products confinement at high temperatures (of up to 1600°C) and fuel burnup;

(2) structural features of the core and reactor (annular core geometry, low specific power). These design features and high heat accumulating capacity of the core ensure reactor shutdown cooling under emergency conditions owing to passive heat removal from the reactor vessel by irradiation, thermal conductivity and convection at the fuel and core temperature maintaining within allowable limits for safe operation (<1600°), including loss of coolant;

(3) negative feedback between the core temperature and reactor power (negative reactivity temperature coefficient);

(4) use of graphite as the core structural material including control rods that excludes the core damages.

The GT-MHR fuel cycle concept allows obtaining deep burnup of fission material and disposing spent fuel without additional processing.

Nuclear materials non-proliferation mode at use of weapons-grade plutonium as fuel is ensured for the entire fuel cycle beginning from fresh fuel fabrication. It is related to the fact that at present there is no processing technology of fuel with ceramic coatings, it is needed to perform fuel-scaled processing due to low fuel concentration inside the graphite block (< 0.1 %), and it is also related to the fact that about 30% of Pu-240 is contained in plutonium being unloaded.

Flexible fuel cycle with possible use of various fuel types (U, Pu, U-Pu, U-Th) can be implemented as applied to the GT-MHR reactor within the boundaries of the same core design ensuring stability of its main characteristics and fulfilling safety regulatory document requirements.

Considerable reduction of thermal and radiation impact to the environment per generated power unit compared to other reactor plant types, is ensured as a consequence of high efficiency and effective radioactive products confinement by safety barriers and by multi-layer ceramic coating of fuel particles.

NPP with the GT-MHR RP allows power and heat co-generation due high value of low coolant temperature in gas-turbine cycle (~ 130 ^{O}C) without any changes in power conversion unit. This double function is of unique importance in the climatic conditions of Russia. It is proven by the data on annual natural gas consumption for power and heat generation which amounts to about 135 and about 220 billion m^3, respectively. In this case reactor thermal power is completely used, that considerably improves NPP economic indices.

4. Conclusion

Implementation of program for creation of NPP with the GT-MHR, involving international intellectual, process and financial resources allows:

(1) broadening opportunities of weapons-grade plutonium disposition program in Russia, fulfilling requirement of agreement on nuclear material non-proliferation;

(2) creating the base for further commercial application of this plant type for both power generation with high efficiency and power and heat co-generation with complete use of reactor thermal power;

(3) using experience on development and operation of NPP with the GT-MHR for further application of this high-temperature heat generation technology for various processes, especially for production of hydrogen and synthetic liquid fuel.