ID: 1333

Development and Integration Study of Fusion-Fission Hybrid Systems into Nuclear Power Fuel Cycle

Yu.S. SHPANSKIY, B.V. KUTEEV and DEMO-FNS Team
National Research Center “Kurchatov Institute”
Shpanskiy_YS@nrcki.ru

ABSTRACT

- Development of the fusion-fission hybrid facility based on superconducting tokamak DEMO-FNS continues in Russia for integrated commissioning of steady-state and nuclear technologies at the power up to 40 MW (>10^{19} n/sec) for fusion and 400 MW for fission reactions.
- Facility could provide burning the minor actinides accumulated by Russian nuclear fuel cycle during the operation of nuclear power plants.
- Achievements in design and operation scenarios for the DEMO-FNS facility and nuclear fuel cycle are presented in this work.

BACKGROUND

- Transition to a closed nuclear fuel cycle supporting operation of thermal and fast power reactors is being carried out in Russia at present time.
- In this regard, it is important to develop novel technologies for of spent nuclear fuel management and radioactive waste incineration, as well as to develop energy valuable "fusion-fission" hybrid systems.
- Development of the fusion-fission hybrid facility based on superconducting tokamak DEMO-FNS continues in Russia for integrated commissioning of steady-state and nuclear technologies.
- 14 MeV neutron wall load of ~ 0.2 MW/m^2 and the neutron fluence over the life cycle of ~ 2 MW*year/m^2, with the subcritical active core for minor actinides transmutation and the fissile nuclides and tritium production blanket .
- Scenario for the development of nuclear power is not clear now.

CHALLENGES / METHODS / IMPLEMENTATION

THE TASK WAS

- to develop hybrid facility combining nuclear fusion and fission reactions;
- to analyze the possibility of interaction of the DEMO-FNS facility and further industrial options with the nuclear fuel cycle

TOOL

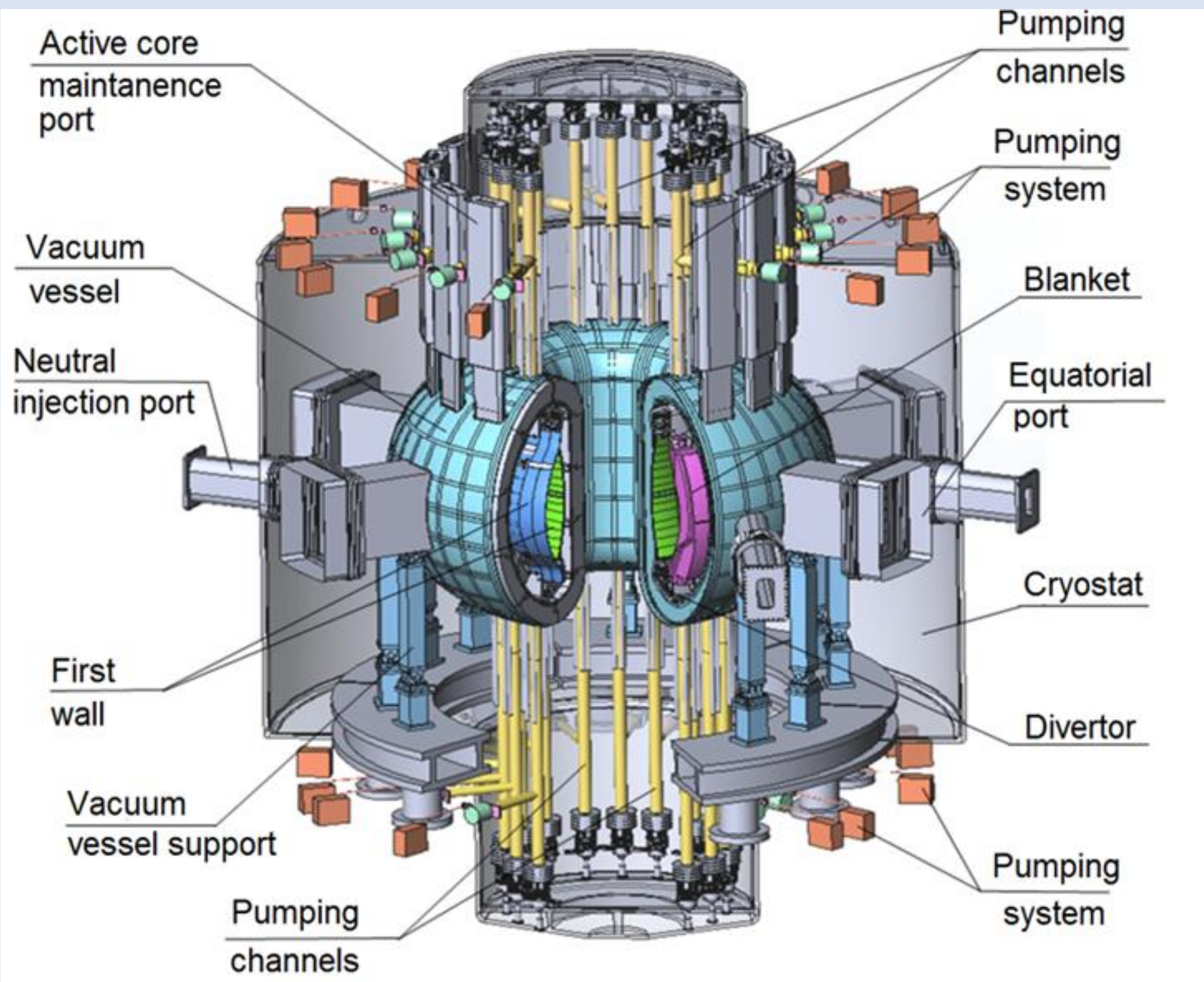
The universal system model of nuclear power in Russia was chosen as an analysis tool. The model is embedded in the USM-1 software product ("Universal System Model-1" [1]) and contains the history of nuclear power in Russia and forecasts for the future period from 1970 to 2130.

RESULTS

DEMO-FNS facility was developed with following main parameters

Plasma parameters		Power parameters are presented below		
Plasma current IP, MA	5	D-T fusion power	40	MW
Major plasma radius R_0, m	3.2	Fission power	400	MW
Minor radius of plasma a, m	1.0	Electric power	200	MW
Aspect ratio R / a	3.2	Overall power	700	MW
Plasma elongation k_x / k_{95}	2.0 / 1.9			

An optimistic and moderate scenario for the development of nuclear power was considered
From the results obtained, it can be assumed that 3 - 4 hybrid systems are able to ensure the balance of the produced and transmuted MA in the power system



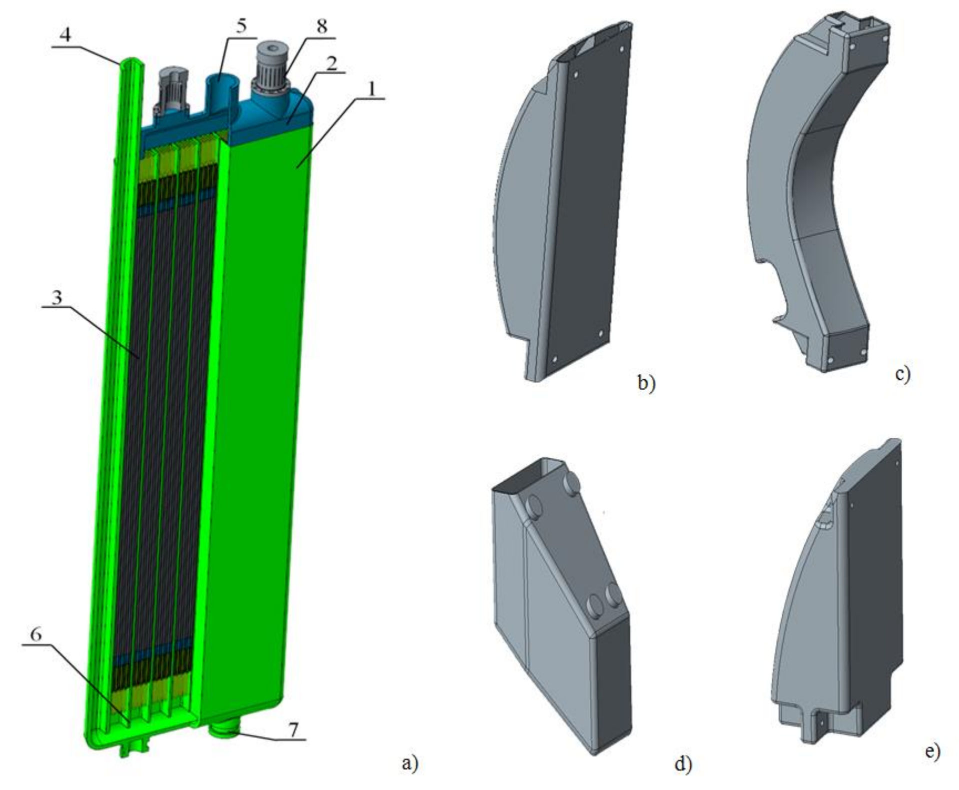
DEMO-FNS cut-view (magnetic system not shown)

The following main systems of the facility were developed

Superconducting electromagnetic system, vacuum vessel, hybrid blanket, tritium fuel cycle, neutral beam injection etc.

BLANKET

Hybrid blanket of DEMO-FNS consists of two zones – active core (AC) with minor actinides (MA) and breeding zone (BZ):
- the AC includes 12 full-size units and 6 shortened ones;
- BZ, intended for reproduction of tritium, are placed on the outer part of the VV for and are to be dismounted only in case of failure or emergency;
- Many coolants were taken into account - liquid metal, water, water-steam mixture and supercritical CO_2 (SCO_2). Two last options seem to be preferable



1 – AC case; 2 - cover of the AC case; 3 – fuel assembly with fuel rods from MA; 4 - inlet coolant pipe; 5 - outlet coolant branch pipe; 6 – inter-channel partition; 7 - the counterpart of the collet fastening of the AC to the VV; 8 - flexible mechanical supports.

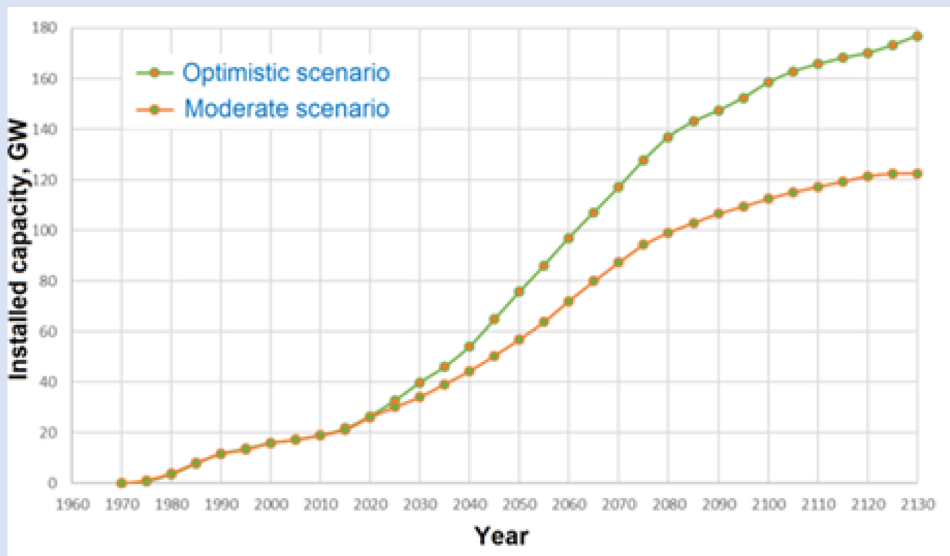
OUTCOME

Composition of MA Mixture, from Spent Fuel

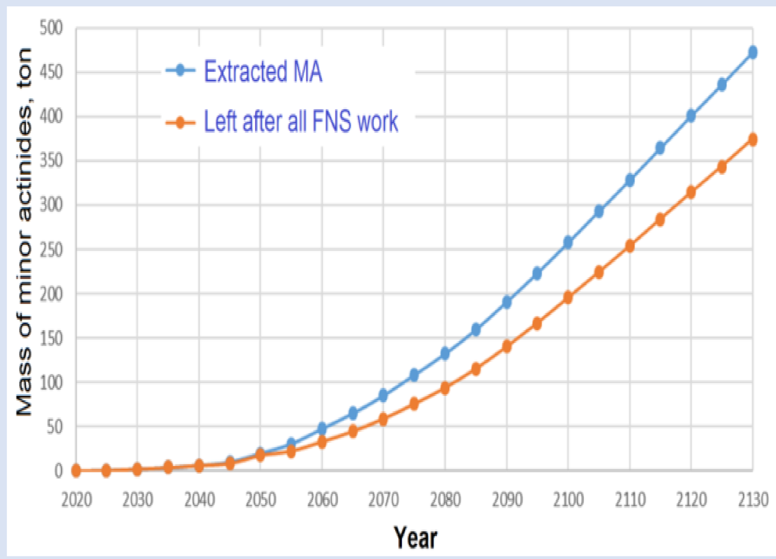
Nuclide	Mass fraction, %
^{237}Np	30.0
^{241}Am	65.0
^{242m}Am	0.06
^{243}Am	4.5
^{243}Cm	0.02
^{244}Cm	0.42

- An optimistic and moderate scenario for the development of nuclear power was considered.
- Modeling takes into account export of nuclear power plants and reprocessing of the spent nuclear fuel (SNF) returned;
- SNF reprocessing - centralized and on-site.
- Modeling is carried out assuming the two-component nuclear energy in Russian Federation.

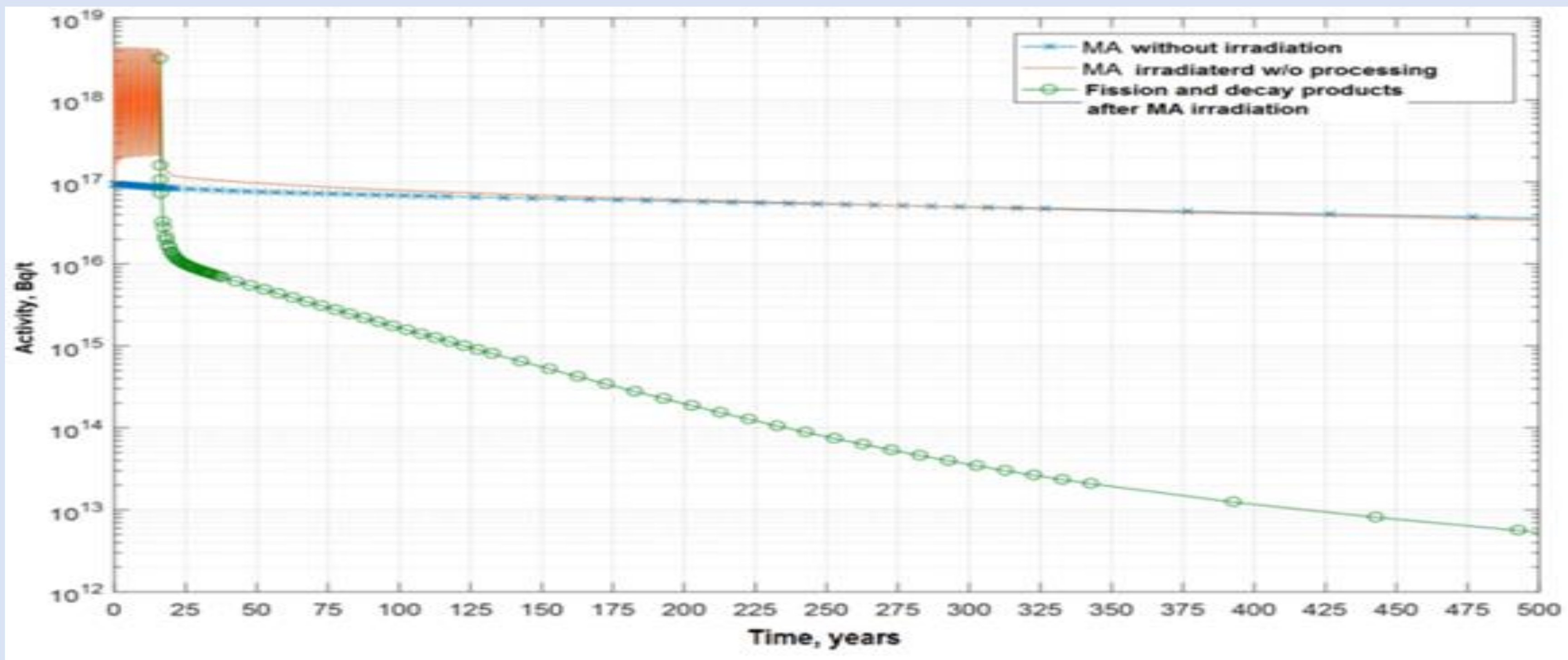
Power of nuclear power plants in Russia



Mass of allocated MA (opt sc)



Evolution of specific activity for MA, fission and decay products



CONCLUSION

- Enabling systems of DEMO-FNS were upgraded including Vacuum vessel, Radiation shield, Divertor, Blanket, Fueling cycle.
- Design activity was supported by R&D in neutronics, optimization of the device layout, subsystems including EMS, VV, divertor, blanket and T-fuel cycle
- 3 to 4 Industrial FNS systems are capable of ensuring the equilibrium of the produced and transmuted MA in the RF nuclear power system, provided that the necessary capacities for SNF reprocessing and fuel fabrication are implemented.

REFERENCES

[1] E. MURAVIEV // Generator of system models USM - 1 /. - Moscow: FGUP NIKIET, 2008, 115 p.

ACKNOWLEDGEMENTS

This work was partly supported by State Corporation “ROSATOM” and National Research Center “Kurchatov Institute”