Existing regulatory framework for addressing the specific safety requirements of HTGR

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Legal and Regulatory Framework of the Russian Federation

Constitution of the Russian Federation

International treaties and agreements

Federal Laws

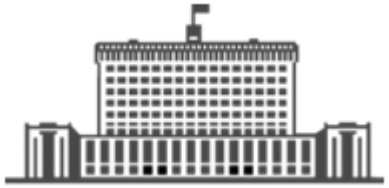
Secondary (delegated) legislation (Acts and Decrees of the President and Government of the Russian Federation)

Regulatory documents of the regulatory authorities (federal rules and regulations, sanitary and epidemiological rules and regulations and others)

Regulatory documents (non-obligatory) of the regulatory authorities and governing bodies, standardization documents

Authorized Body of State Safety Regulation

- Development and implementation of state policy in the field of nuclear and radiation safety and security
- Legal regulation of nuclear and radiation safety and security (Development and enactment of regulatory documents)
- Licensing of activities in the field of atomic energy use
- Supervision of nuclear and radiation safety and security
- Organization and support of system for control over nuclear facility conditions in case of accidents occurrence



Government of the Russian Federation

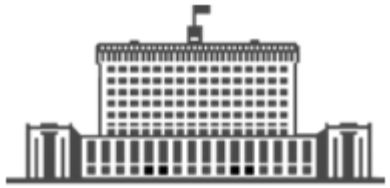
Decree of the Government of the Russian Federation of 30.07.2004 No. 401

Authorized Body of State Safety Regulation

Rostechnadzor

SEC NRS Activities

Hierarchy



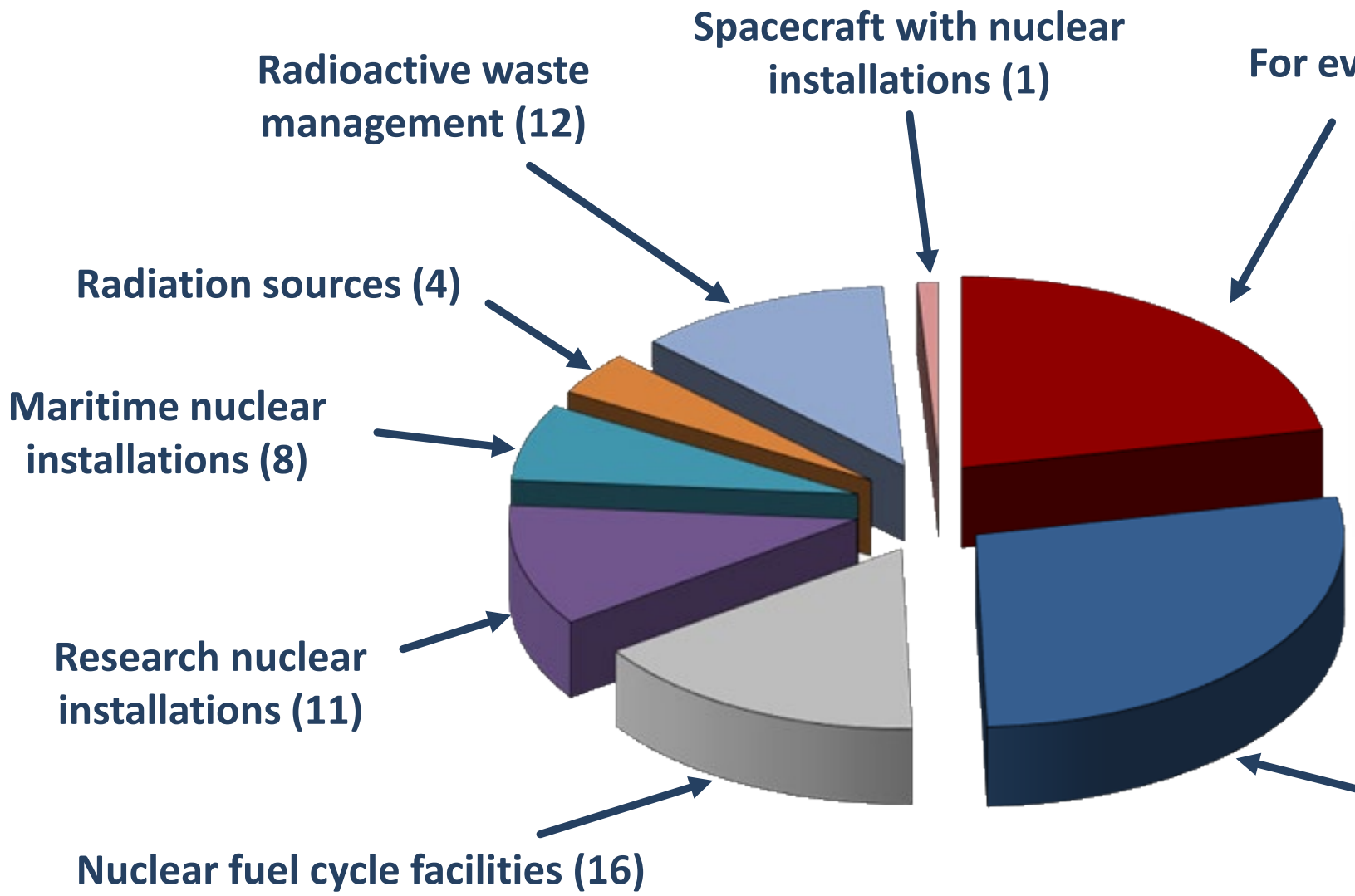
The Russian Government

Rostechnadzor (Regulatory authority)

SEC NRS (Technical support organization)

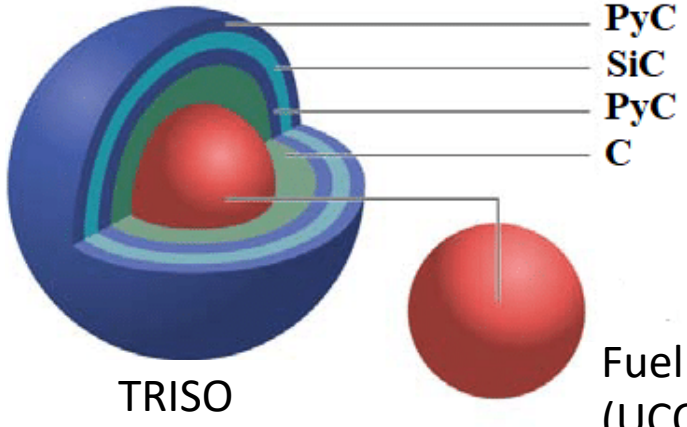
Rostechnadzor	SEC NRS
Development and enactment of the federal rules and regulations	Drafting of the federal rules and regulations
Licensing of activities in the field of atomic energy use	Conducting safety review
Supervision of nuclear and radiation safety and security	Informational support
Emergency preparedness and response	Technical and scientific support

Federal Rules and Regulations in the Field of Atomic Energy Use



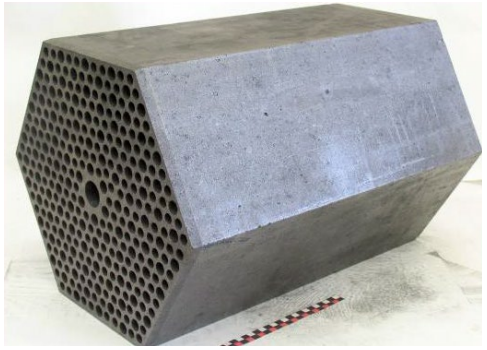
Specific characteristics of HTGR fuel

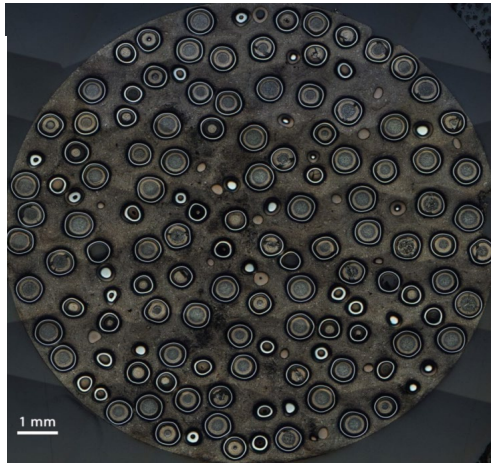
- The use of nuclear fuel in the form of ~1 mm TRISO particles consisting of the fuel kernel of low-enriched uranium dioxide coated with several layers, which are usually made of pyrocarbon of different density and silicon carbide
- TRISO particles provide significant fission products retention even in severe accident scenarios
- Mechanical damage of the core may not be the cause of significant release of radioactive materials into the environment
- Activation of graphite leads to the formation of radioactive carbon (^{14}C)



TRISO

Fuel kernel
(UCO, UO_2)



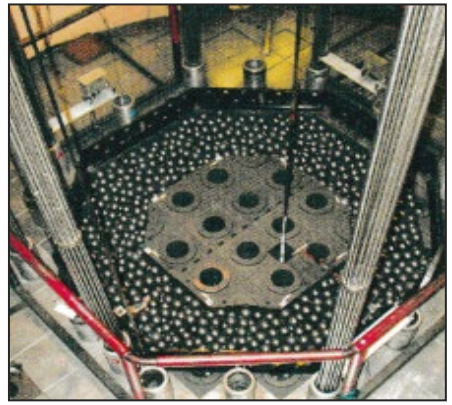


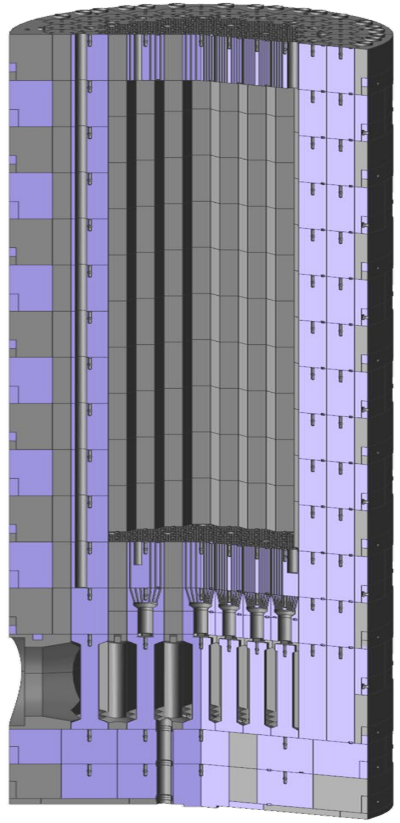
http://www.atominfo.ru/news/air8329.htm
https://www.energy.gov/ne/articles/x-energy-developing-pebble-bed-reactor-they-say-cant-melt-down
https://www.energy.gov/ne/articles/triso-particles-most-robust-nuclear-fuel-earth

Specific characteristics of HTGR core

- Heat-resistant materials (mainly graphite) are used in the core as the main structural material due to high temperatures
- The presence of water, air and other oxygen-containing substances in the core may result in fire within the core (due to high temperature and significant amount of graphite) which may lead to significant degradation of the core and nuclear fuel
- The presence of water in the core may cause positive reactivity that may also require the establishment of additional nuclear safety requirements

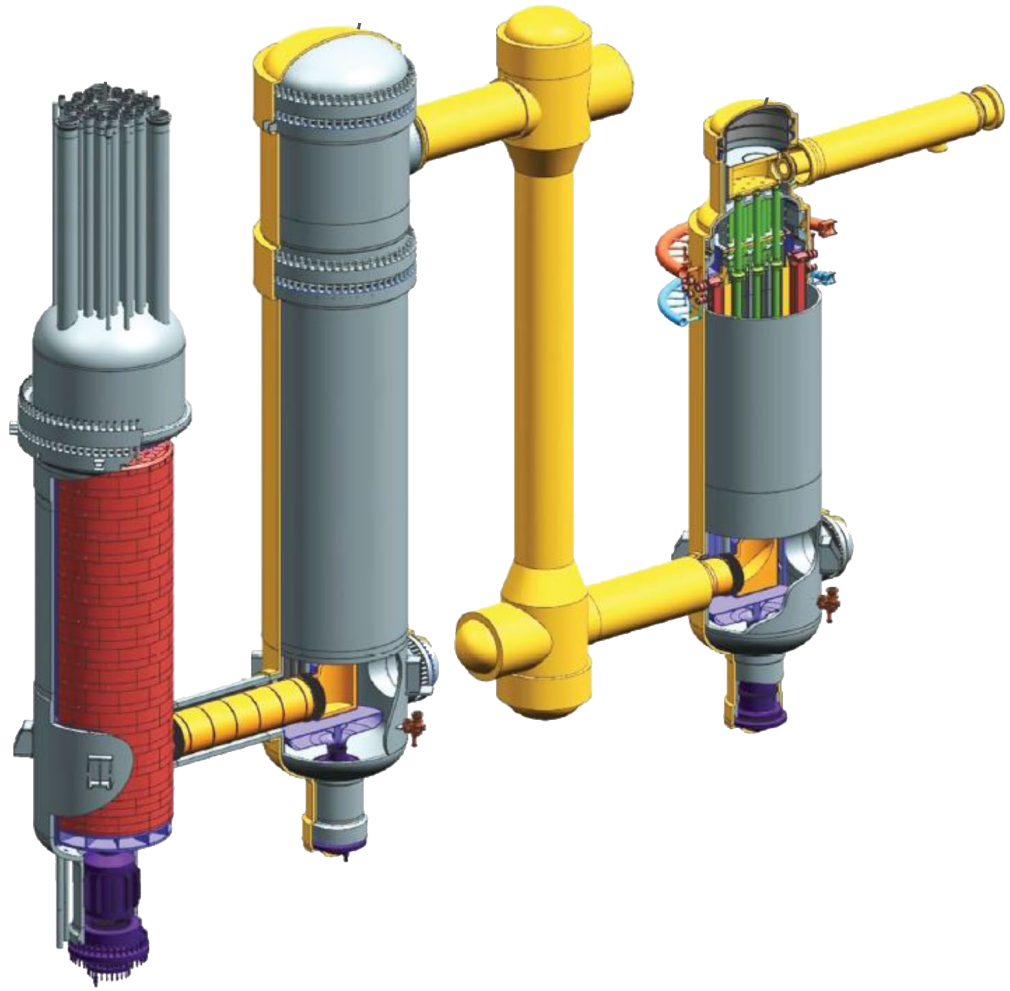
Water, air and other oxygen-containing substances shall be prevented from entering the core





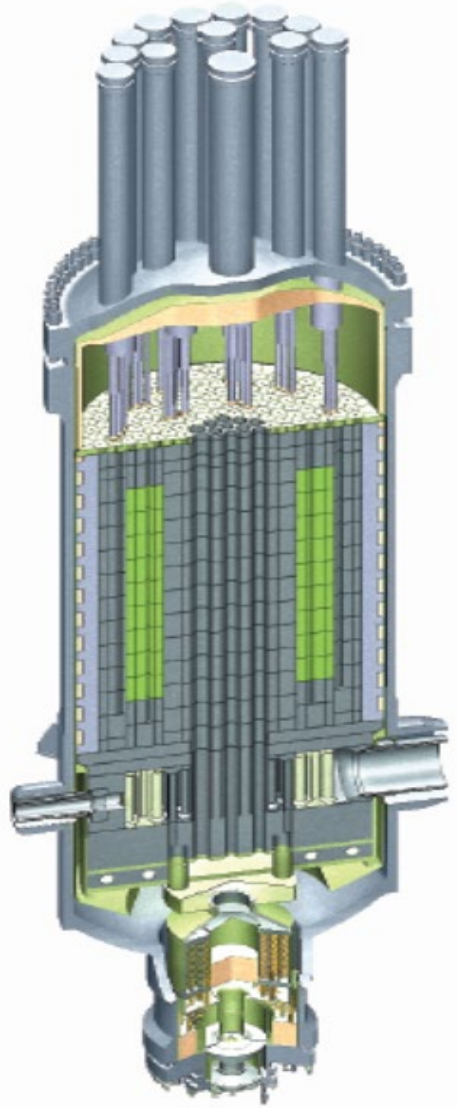
Specific characteristics of HTGR heat transfer

- Residual heat dissipation does not require forced circulation of the coolant, and the main mechanism of heat transfer is radiation
- Gaseous helium (He) which is usually used as a coolant has a high penetrating ability, however its leakage may not lead to the release of radioactive materials beyond the coolant pressure boundary established by design
- Activation of the isotope ^{3}He which is contained in natural helium with formation of the radioactive tritium is possible
- During normal operation the coolant temperature at core outlet exceeds 800 ℃, thus the use of new structural materials for heat transfer equipment is required
- Thermal insulation can be used inside the primary circuit (on coaxial pipes) in order to maintain the temperature



Features of HTGR accident progression

- Part of the primary circuit equipment designed for heat transfer during normal operation may not be intended for heat removal in case of accidents, since it is not designed for operation at ultrahigh temperatures, and therefore it may be required to cut them off and prevent the development of natural circulation in the primary circuit
- Safety systems and special technical means for management of BDBA (Beyond Design Basis Accidents) may not be proven by operational experience and may significantly differ from the safety systems of traditional pressurized water reactors and reactors with liquid-metal coolant
- Given the high resistance of nuclear fuel to thermal stresses, structural elements (for instance reactor shaft) are more susceptible to negative effects of high temperatures during an accident, e.g. water may evaporate from the concrete which causes negative effects to its structural strength and may lead to its complete destruction
- Since there is no possibility of rapid pressure increase or explosion of hydrogen mixture within the containment, confinement systems and radioactivity retention systems may have significant differences



Specific characteristics of HTGR as part of Nuclear Industrial Power Plant

- High coolant temperature can be used for technological purposes including industrial production of hydrogen and other hydrogen-containing substances from hydrocarbons
- There is a possibility of impact from the technological part on the nuclear reactor operation due to detonation of explosive, flammable and toxic vapors, gases and aerosols (including explosion of drifting clouds)
- There is a possibility of impact from the nuclear reactor on the technological part due to migration of radioactive materials with high permeability (for instance tritium) from the primary circuit of the HTGR to the equipment of the technological part through the system of heat exchangers

Mechanism of tritium formation	Percentage of total activity*, %	Tritium activity percentage in the primary circuit*, %
Ternary fission of carbon ^{12}C	83	17,7
^{3}He (n,p) ^{3}H	6	79,9
^{6}Li (n,α) ^{3}H	4	0,9
^{7}Li (n,n`α) ^{3}H	1	0,2
^{10}B (n,αα) ^{3}H	6	1,3

*Based on data from INL/EXT-12-26758 Revision 1

Conclusion

- The current legal and regulatory framework of the Russian Federation is harmonized with international approaches and it is sufficient to regulate the safety of existing nuclear facilities
- To regulate the safety of prospective HTGRs, it is necessary to take into account their specific features in terms of:
  - ✓ nuclear fuel
  - ✓ core configuration and system of heat removal
  - ✓ specific accident processes
  - ✓ impact of the technological part

THANK YOU FOR ATTENTION!