Technical Meeting on Operating Experience and Lessons Learned on Managing Non-Standard Legacy Power and Research Reactor Spent Fuels, EVT2304628, 18-21 February, 2025, Vienna, Austria

EXPERIENCE OF THE INSTITUTE OF NUCLEAR PHYSICS IN MANAGING FRESH AND SPENT NUCLEAR FUEL FOR A SPACE NUCLEAR FACILITY

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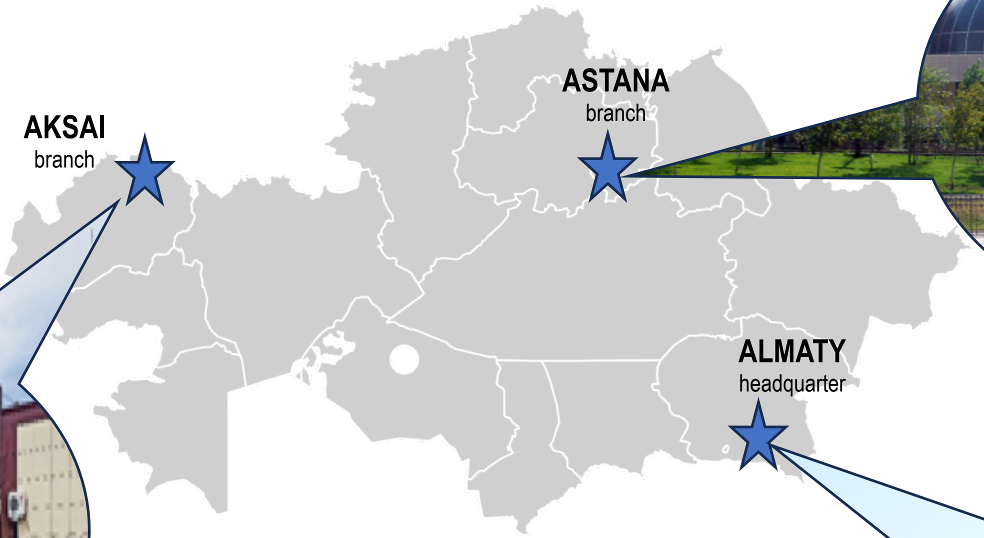
The Institute of Nuclear Physics

The headquarter of the Institute is located in Almaty.
There are branches in the cities of Astana and Aksai.



Astana branch

Aksai branch

Headquarter in Almaty

INSTITUTE STAFF IN NUMBERS

216

young specialists
(under 35 years old)

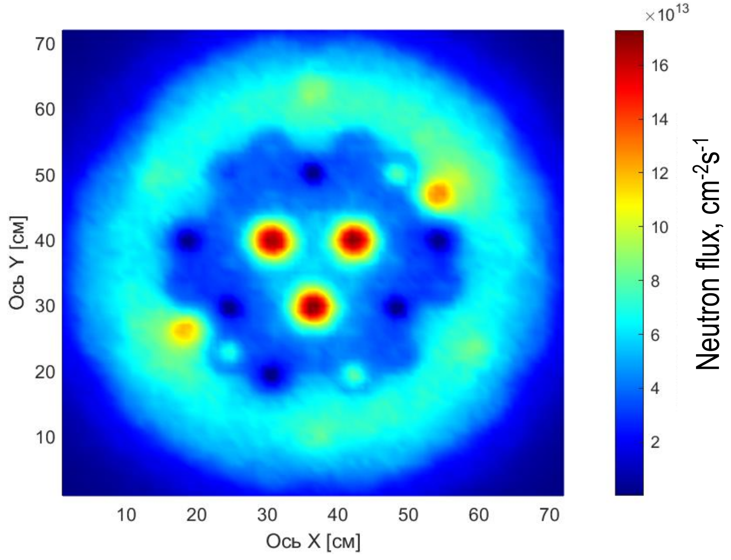
662

employee

68

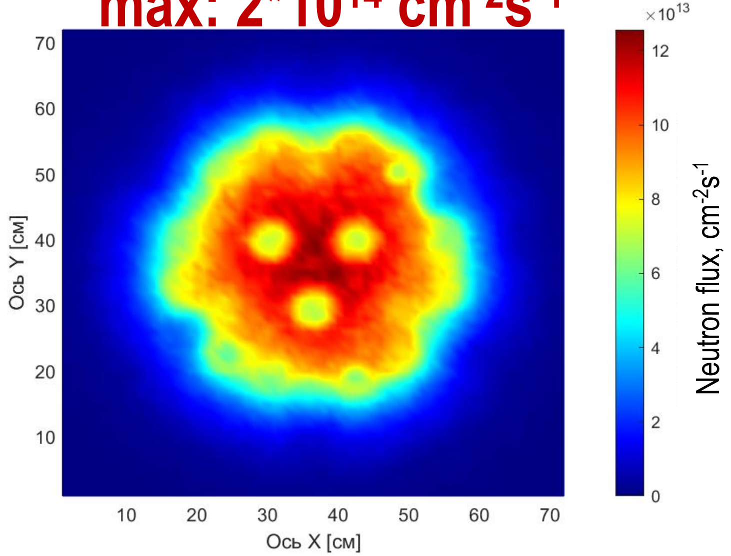
specialist
with a scientific degree

WWR-K research reactor



Thermal neutron

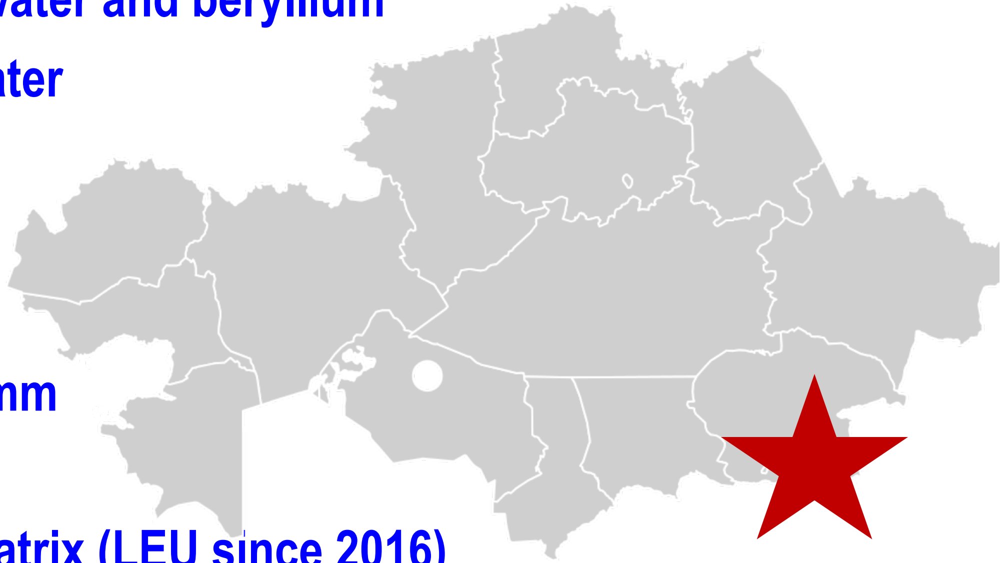
max: $2*10^{14}$ $cm^{-2}s^{-1}$



Fast neutron

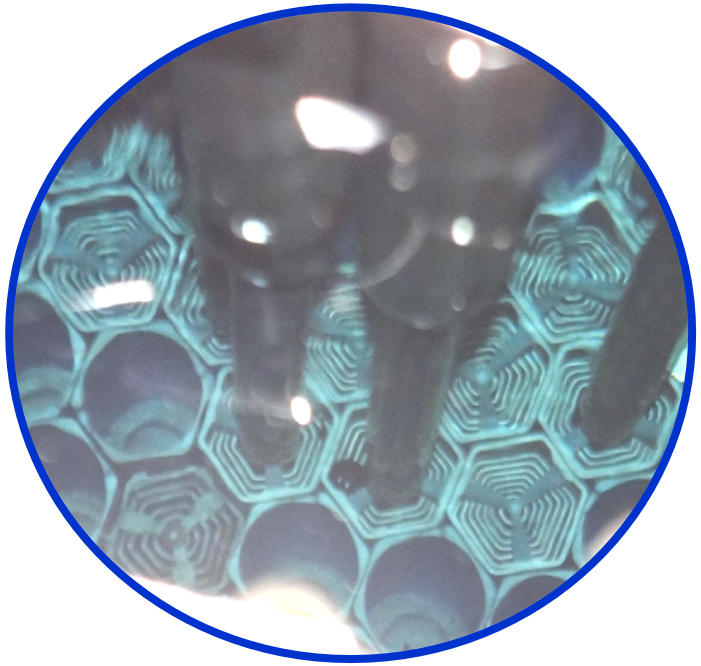
max: $8*10^{13}$ $cm^{-2}s^{-1}$

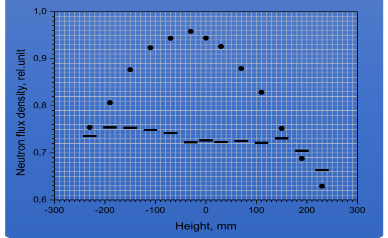
- Type: tank
- Thermal power: 6 MW
- Moderator: demineralized water
- Reflector: demineralized water and beryllium
- Coolant: demineralized water
- Pressure: atmospheric
- Coolant flow: forced
- Coolant circuits: two
- Core diameter: up to 720 mm
- Core height: 600 mm
- Fuel: dispersed UO_2+Al matrix (LEU since 2016)



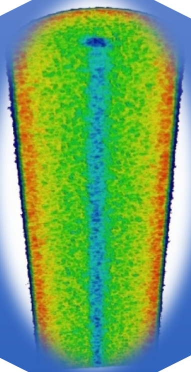
Almaty

WWR-K research reactor: applications





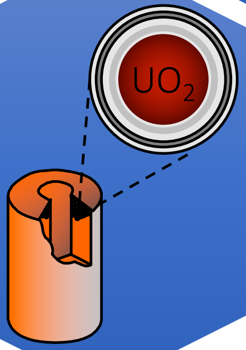
Doping of Silicon (R&D)



Neutron imaging

Neutron coloration of topaz

Neutron activation analysis



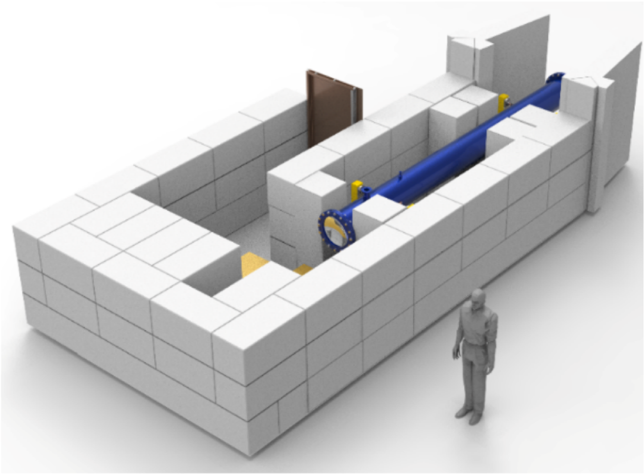
Materials research

Radioisotopes production

Experimental facilities

Additional facilities and instruments:

- ❑ Hot cells (two kind, total 9 cells);
- ❑ Critical assembly (100 W, light water, LEU since 2012);
- ❑ Hydraulic transfer system (loading/unloading capsules);
- ❑ Pneumatic transfer system (loading/unloading capsules for NAA);
- ❑ Gas-vacuum loop facility (high temperature and instrumented irradiation);
- ❑ CIRRA facility (gas release measurements);
- ❑ TITAN facility (neutron imaging and tomography);
- ❑ Neutron reflectometry (optical properties measurements);



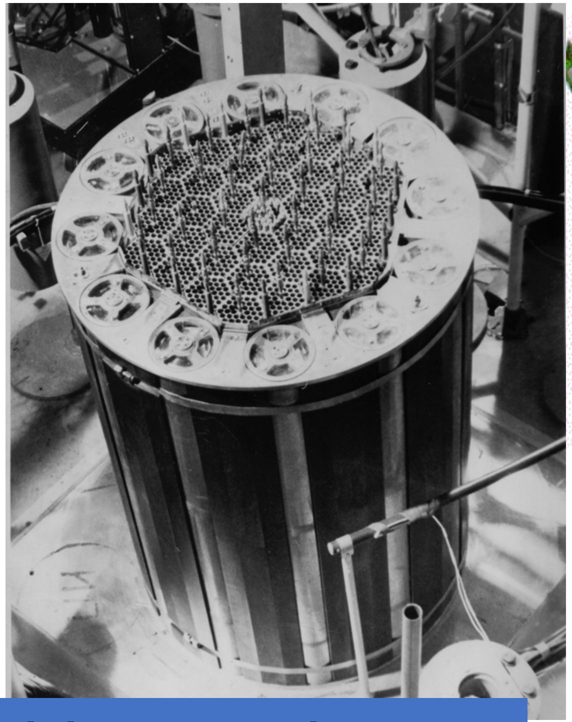
Radioactive waste storage places

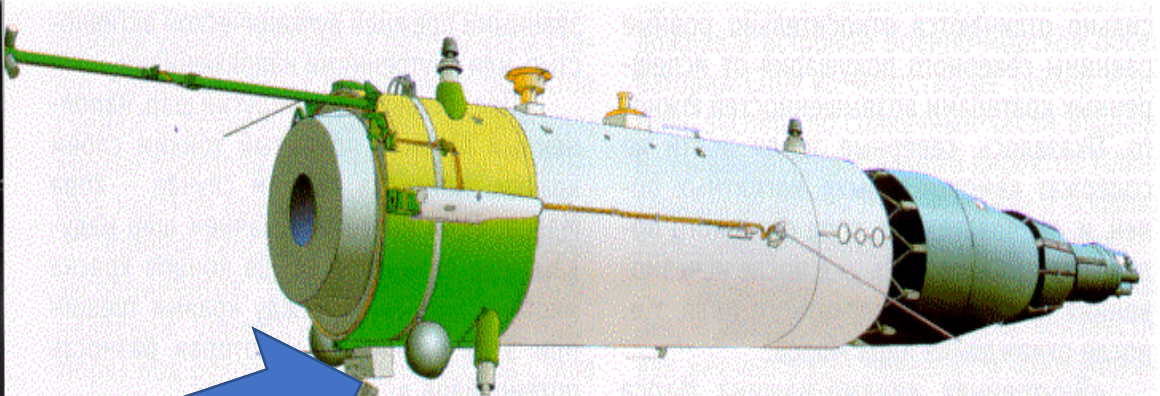
Low activity radioactive
waste storage

Disused sealed radioactive
sources storage

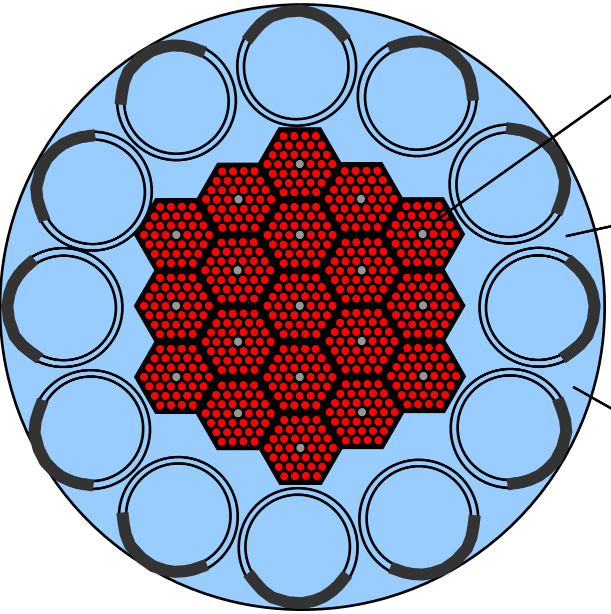
Nuclear fuel for space nuclear facility (1)

1968-1991 research on processes in nuclear thermionic elements under irradiation and in-pile testing of thermionic electricity generating assemblies (EGA)





Space nuclear facility



Electricity generating package with 36 EGA

Rotary drum with an absorbing rod (Eu_2O_3/W)

Reflector (Be)

Part of extensive program on development of space nuclear reactors in USSR

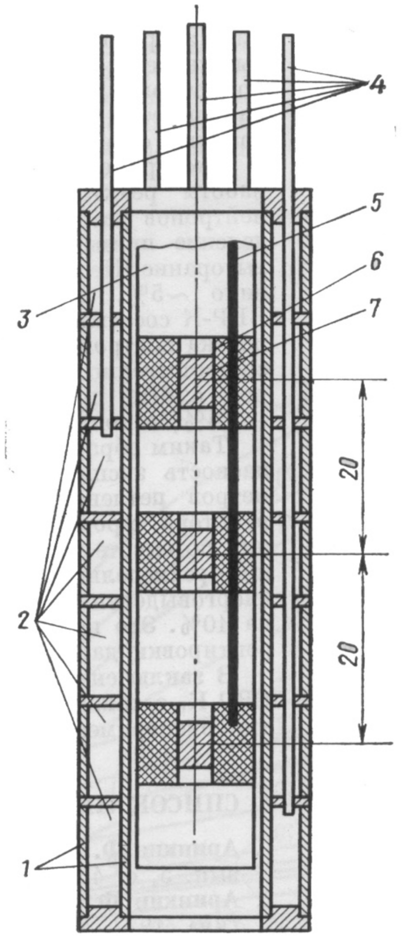
Nuclear fuel for space nuclear facility (2)

Main stages of thermionic converters testing:

- thermal vacuum preparation at zero power and degassing of the fuel-emitter unit;
- transfer of the EGA from vacuum mode to energy mode;
- study of the EGA parameters under different controlled irradiation conditions and their optimization;
- comparison of experimentally measured characteristics with calculated ones;
- life tests for stability and reproducibility of operating parameters over time;
- dismantling of the loop channel and EGA in the hot cell and post-irradiation examinations.

Nuclear fuel for space nuclear facility (3)

- **Fuel:** UO_2 pellets, various enrichments
- **Emitter material:** tungsten or tungsten-rhenium alloy
- **Various designs** of thermionic elements and EGAs



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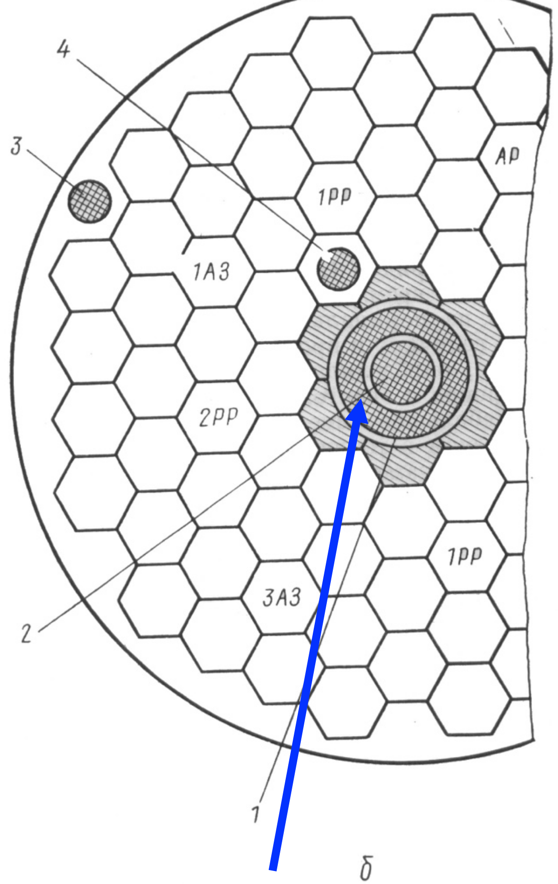

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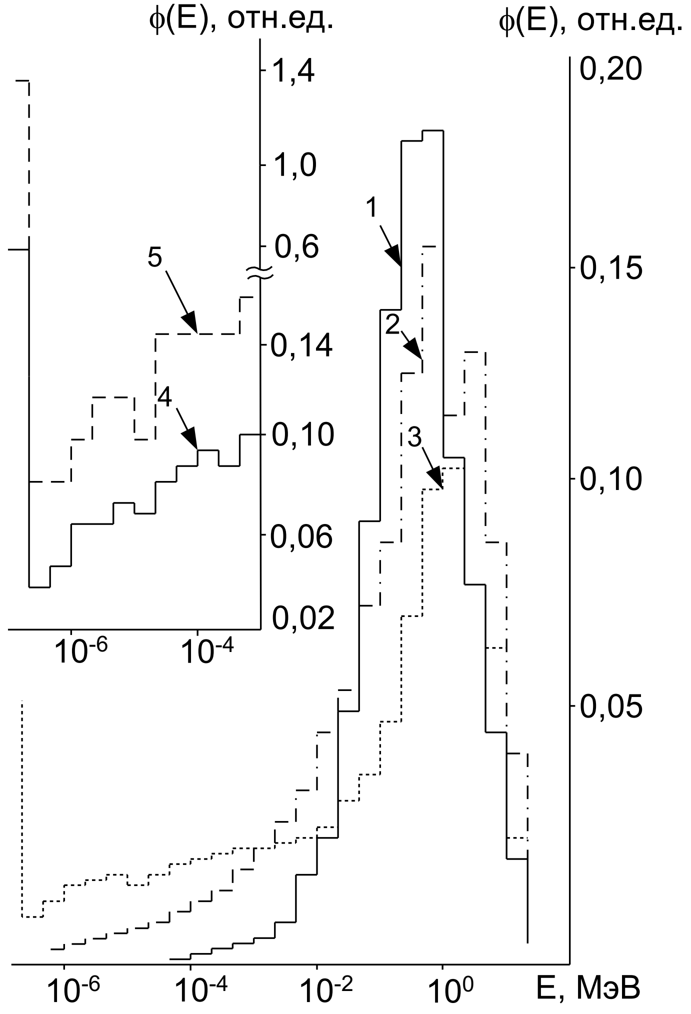
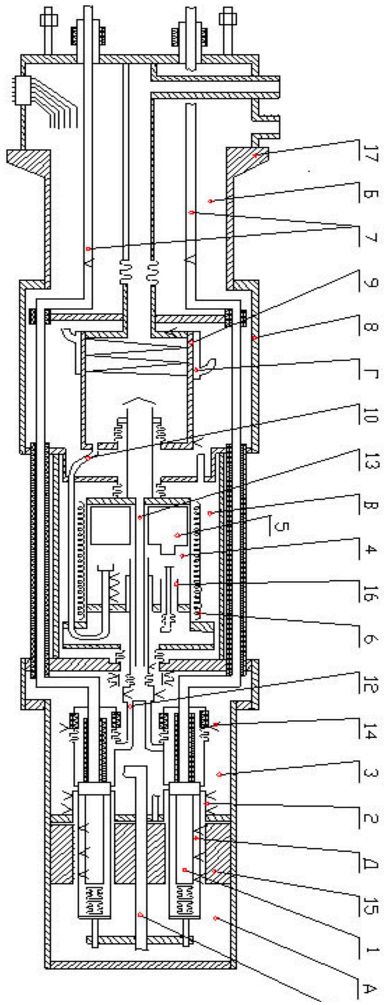
Loop channel inside beryllium flux trap

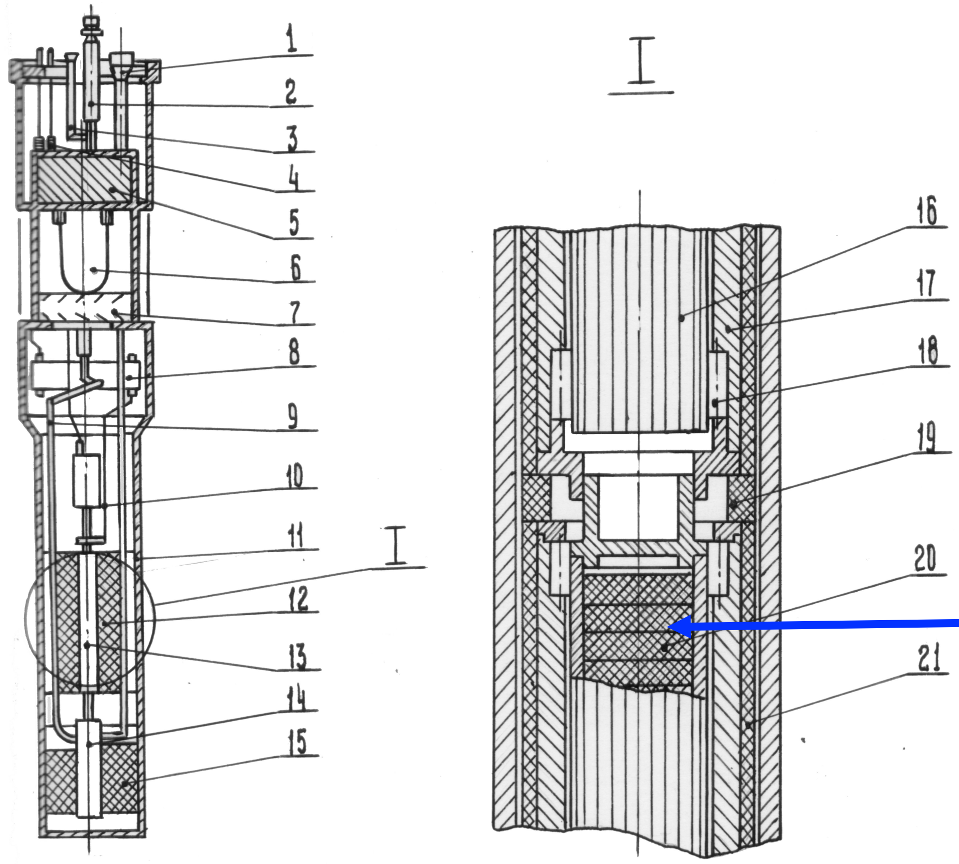


Maximum testing time is ~5000 hours

Nuclear fuel for space nuclear facility (4)

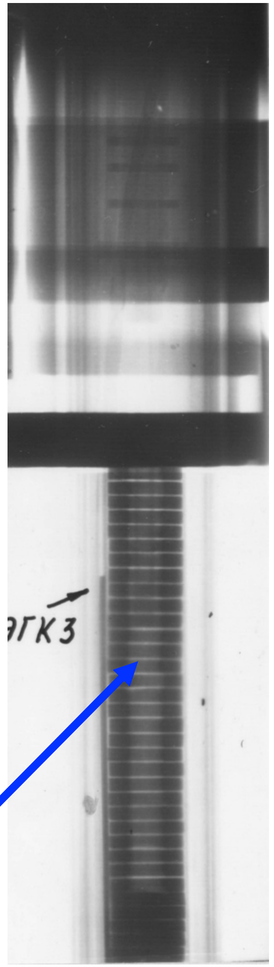


Example of the loop channel



Example of the electricity generating assembly

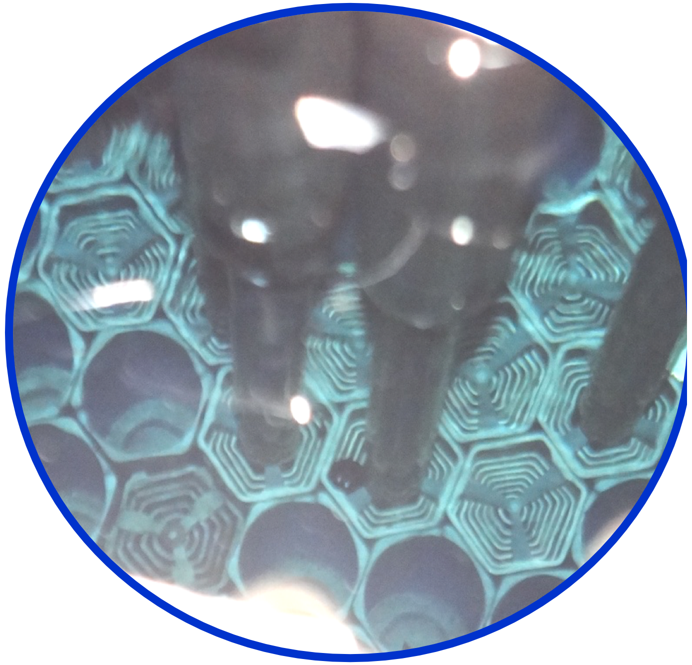
UO_2 pellets



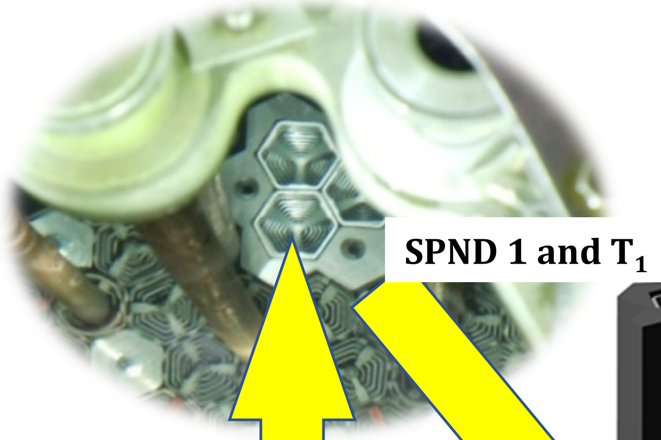
Neutron imaging picture

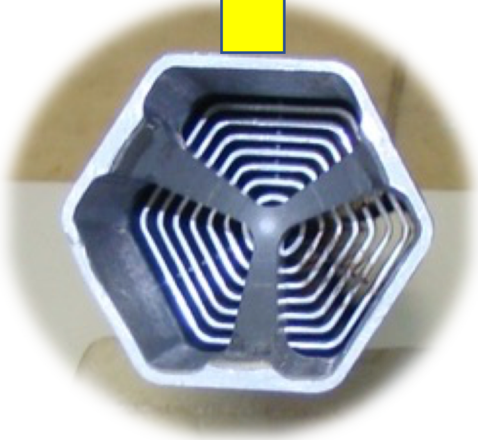
Dry storage,
disposal path TBD

Other experimental fuel tests

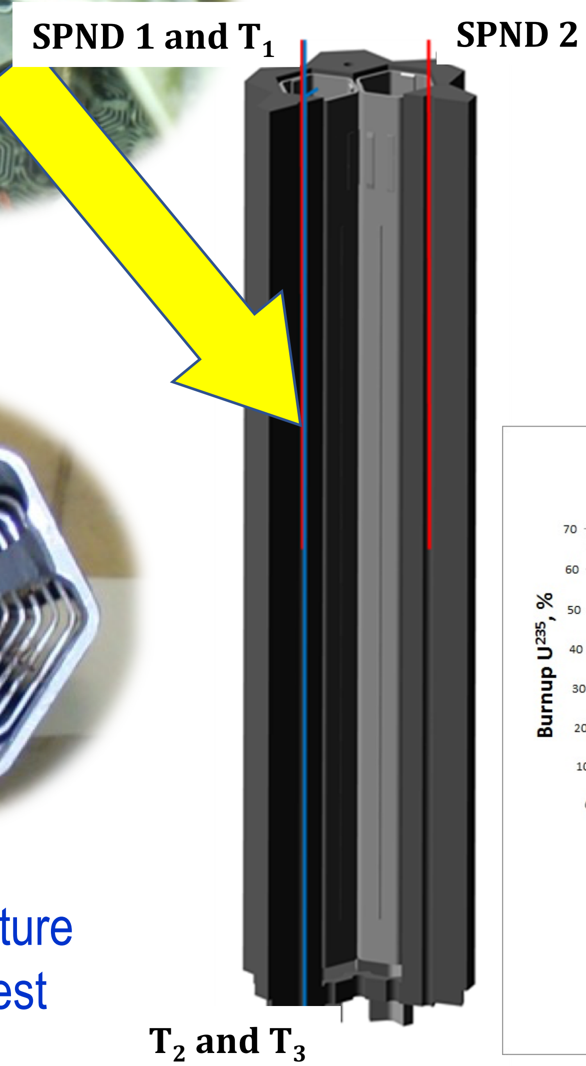


Life test of lead test assemblies with LEU fuel





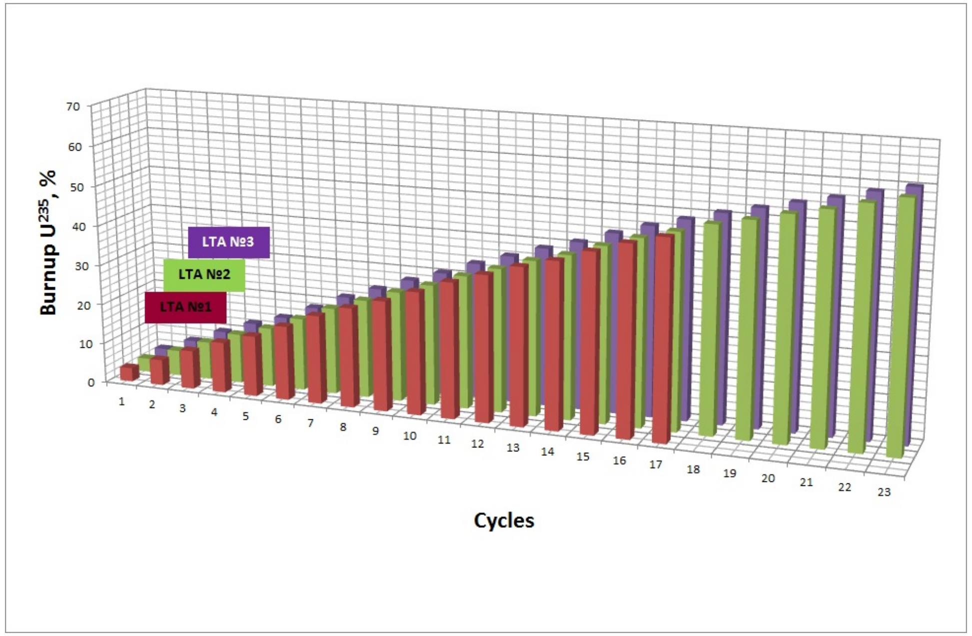
Low temperature irradiation test



LTA1:
357 EFPD
49,7% burn up of U-235
106 MW·d

LTA2:
480 EFPD
59,7% burn up of U-235
133 MW·d

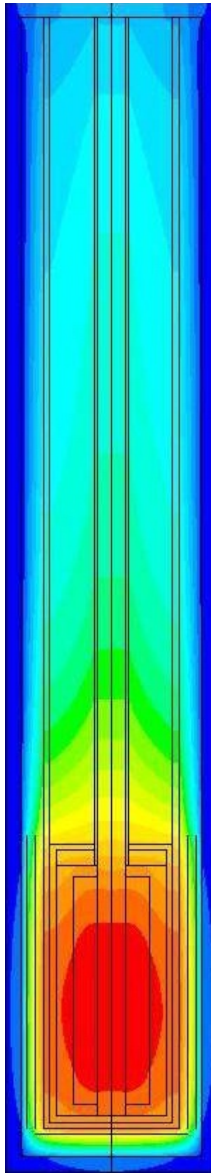
LTA3:
480 EFPD
60,3% burn up of U-235
135 MW·d

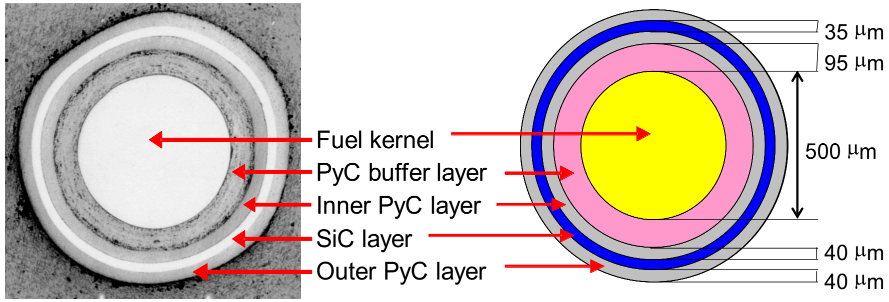


Wet storage for 3 years, shipped for reprocessing

Reactor test of TRISO fuel

High temperature irradiation tests





Diameter: 10 mm
Length: 12 mm

Dry storage, disposal path TBD

- ❑ Time-average temperature of irradiation: 990°C
- ❑ Environment: pure helium
- ❑ The average burnup: 9.9% FIMA
- ❑ The maximum accumulated fast neutron fluence (E_n> 0.18 MeV): $0.83x10^{21}$ n/cm^2.

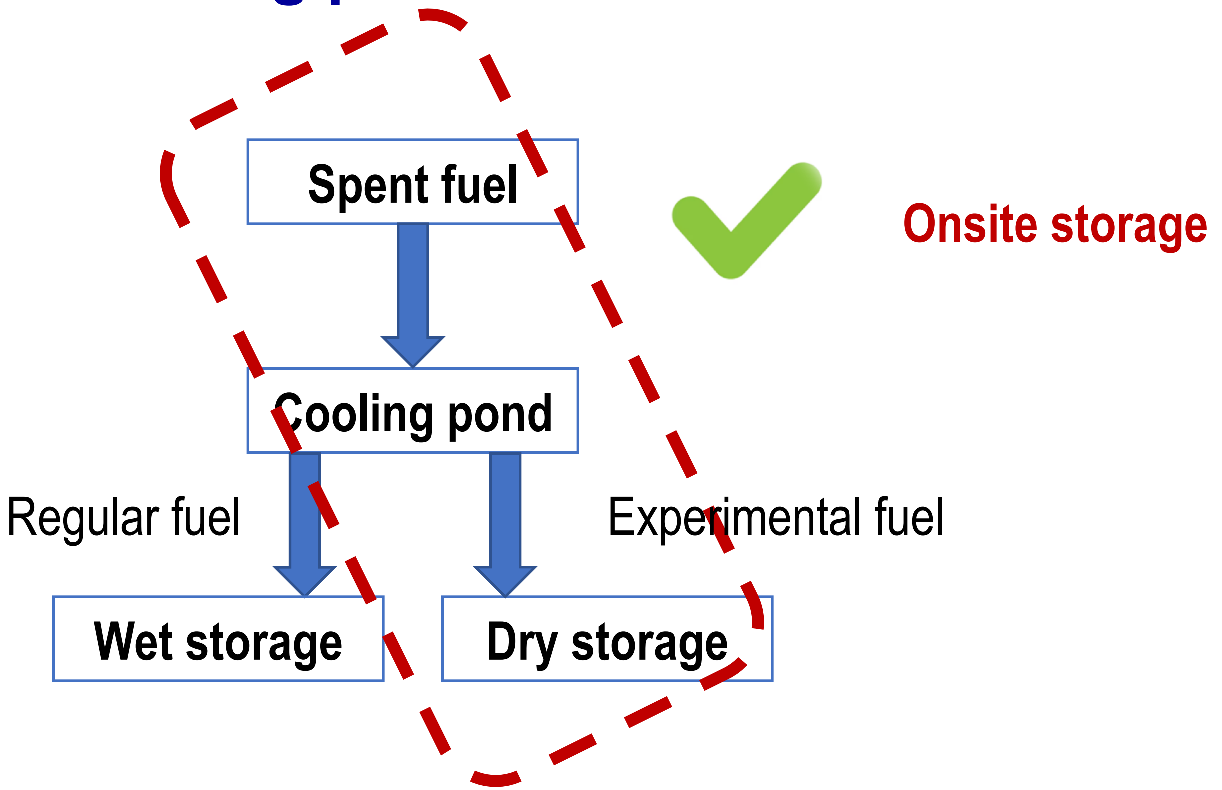
PIE method	Instrumentation	Information obtained
Appearance observation	Lens	Visual inspection
Dimensional change	Mechanical micrometer MATRIX with the measurement uncertainty 0.01 mm	Swelling or shrinkage effect
Gamma spectrometry	Canberra GX-2518 germanium semiconductor gamma spectrometer	Determination of fuel failure fraction, fuel burnup
X-ray radiography	RPD-250 X-ray unit	Determination of fuel failure fraction

Nuclear fuel handling procedures

Fresh fuel

Safe storage

- Criticality calculations, nuclear safety justification;
- Incoming inspection;
- Creation and control (temperature, self-sustaining chain reaction, moisture) of storage conditions;
- Notification of the regulatory authority and the IAEA;
- IAEA safeguards;
- Nuclear security measures;

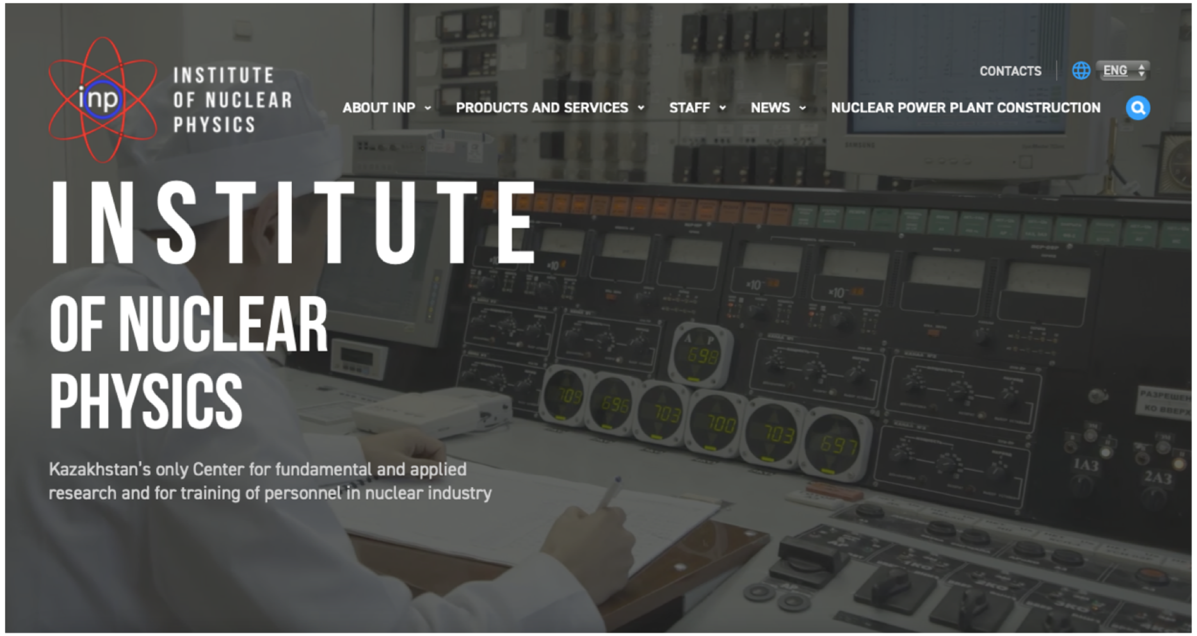


- Justification of nuclear safety;
- Monitoring of storage conditions (water or air quality, temperature, radioactivity level);
- Notification of the regulatory authority and the IAEA;
- IAEA safeguards;
- Nuclear security measures;

Safe/secure storage of experimental spent nuclear fuel has been ensured for over 50 years

SUMMARY

- ✓ In the period 1968-1991, active research of power generating assemblies for thermionic space nuclear reactors was conducted at the WWR-K research reactor.
- ✓ As a result of this activity, measures for handling fresh and spent nuclear fuel of thermionic converter reactors were developed and tested.
- ✓ The generated spent nuclear fuel of thermionic converter reactors has been safe/secure stored at the INP for over 50 years.
- ✓ Disposal path still to be determined.



Thank you for your attention!

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