REACTOR STUDIES OF TWO-PHASE LITHIUM CERAMICS IN KAZAKHSTAN

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The WWR-K research reactor

- Type: tank
- Thermal power: 6 MW
- Moderator: demineralized water
- Reflector: demineralized water and beryllium
- Coolant: demineralized water
- Pressure: atmospheric
- Type of coolant: forced
- Coolant circuit: two
- Core diameter: 720 mm
- Core height: 600 mm
- Fuel: UO_2+Al matrix (LEU)
- Maximum of thermal/fast neutron flux: $2*10^{14}/8*10^{13}\ cm^{-2}s^{-1}$

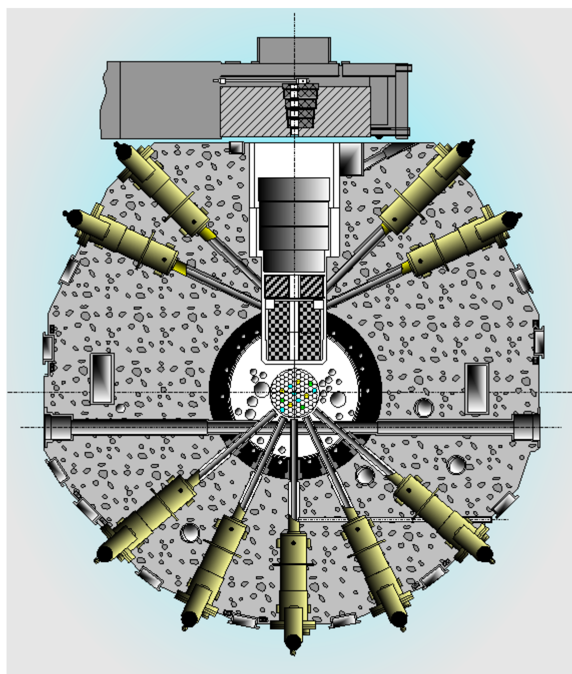
Irradiation positions:

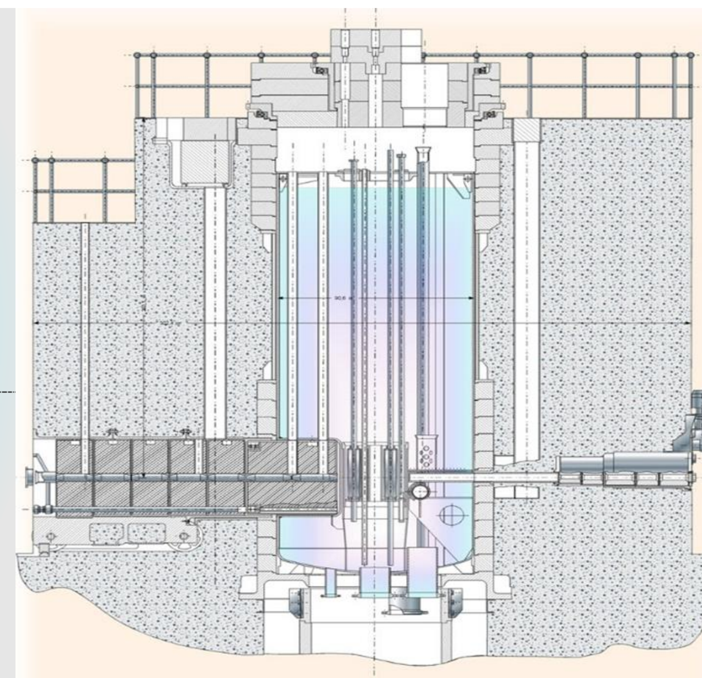
Vertical experimental channels:

Core: 8
Center – 3 (Ø60 mm)
Periphery – 5 (Ø60 mm)
Tank (reflector): 20
Ø200 mm — 2 channels
Ø100 mm - 13 channels
Ø70 mm - 5 channels

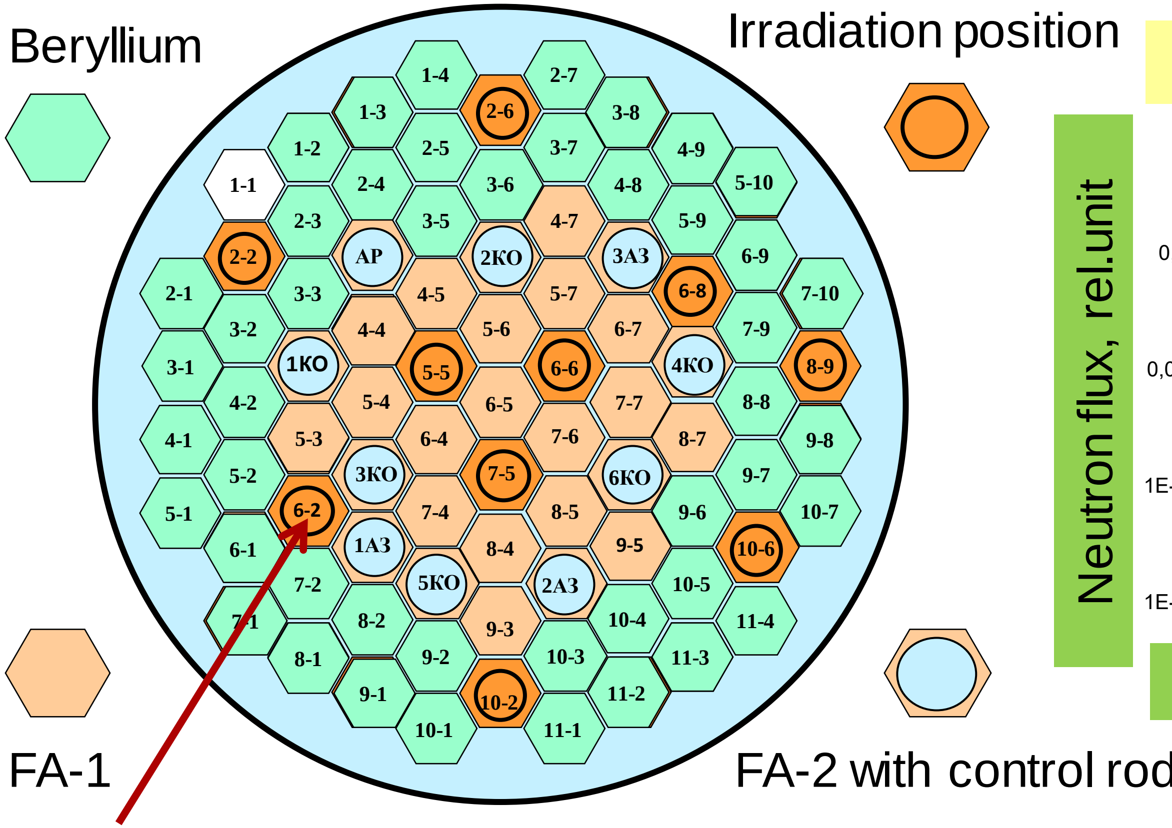
Beam tubes:

Radial: 9 (Ø100 mm and Ø60 mm)
Tangential: 1 (Ø192 mm)



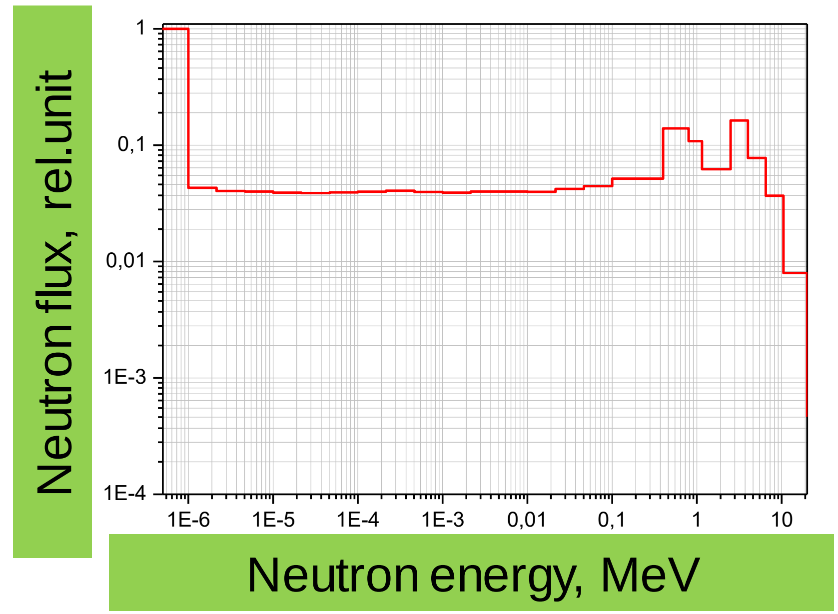


The WWR-K research reactor



Experimental channel *6-2*

Neutron spectrum in core

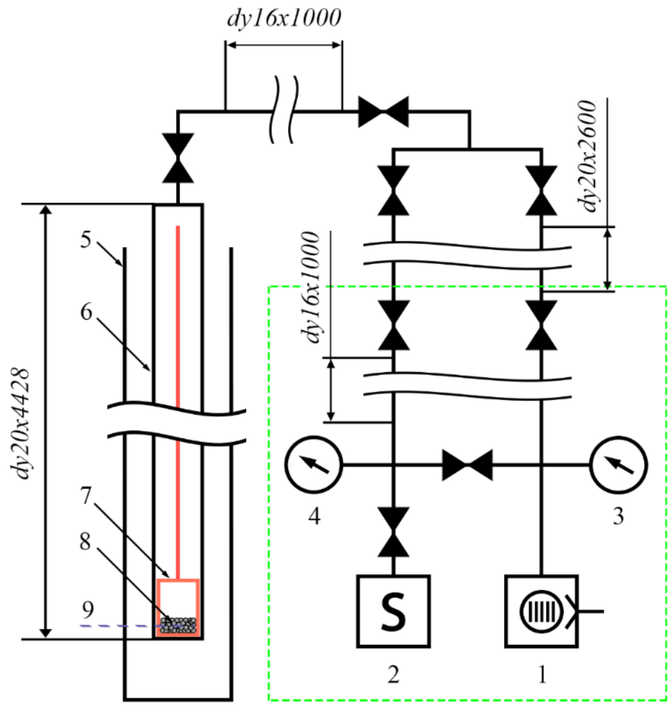


Neutron fluxes Unit: $cm^{-2}s^{-1}$

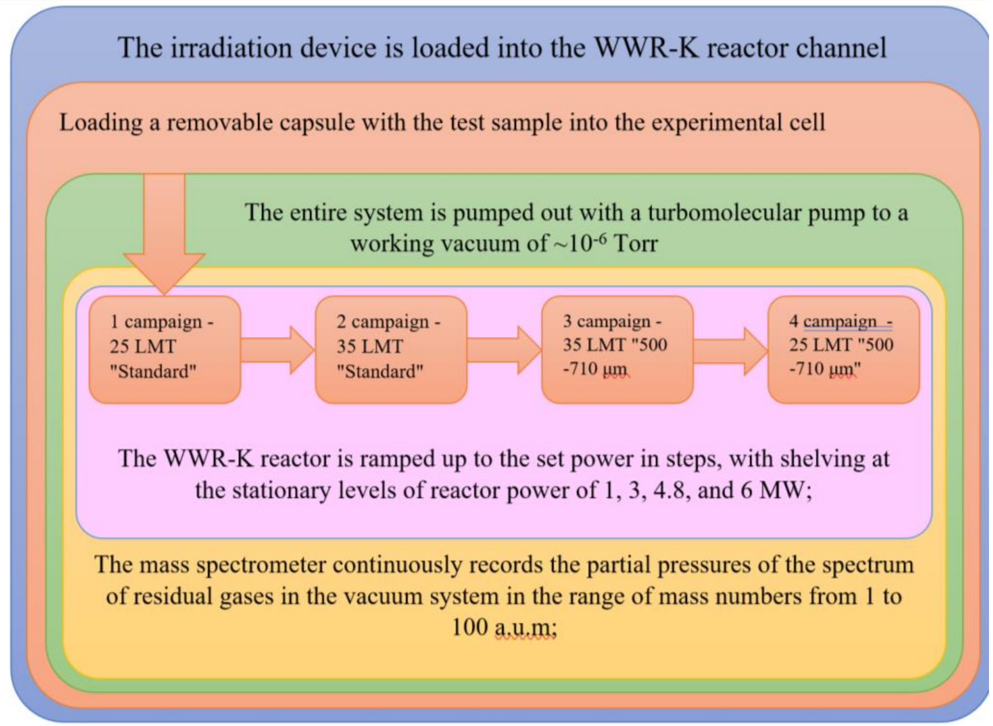
Channel type	Location	Diameter, mm	Max neutron flux, $cm^{-2}s^{-1}$	
			E_n<0.625 eV	E_n>0.1 MeV
Vertical	in core center	60	~2.0·10¹⁴	~7.5·10¹³
	in core periphery	**60**	**~3-8.0·10¹³**	**~1.4·10¹³**
	in reactor tank	200	~9.0·10¹¹	~1.5·10¹¹
		100	~3.3·10¹¹	~2.0·10¹¹
		70	~10⁹	~6.8·10⁸
Radial beam	from reactor tank	60 and 100	~2.0·10⁸	~10⁸
	from thermal-column recess	100	~2.0·10⁷	~10⁷
Tangent beam	from reactor tank	200	~2.0·10¹¹	~10¹¹

The CIRRA (Complex of In-Reactor gas Release Analysis)

EXPERIMENTAL FACILITY FOR STUDYING GAS RELEASE FROM MATERIALS OF A NUCLEAR REACTOR (NR) AND A FUSION REACTOR (FR) AT THE WWR-K REACTOR



CIRRA complex scheme
1 - experimental device; 2 - manual valve; 3 - pumping station; 4 - pressure sensor; 5 - electrovalve; 6 - mass spectrometer; 7 - laptop computer

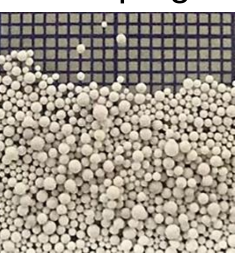


Ampoule and capsules of an irradiating device

Samples for reactor irradiation

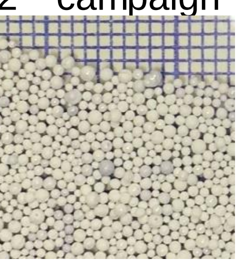
	Samples	Weight, g	Irradiation parameters
1st campaign	25 LMT «Standard» (lithium orthosilicate with 25 mol% lithium metatitanate Pebble size 250 -1250 µm)	5,0266	T=250-680°C Period=21 days Power=1,4,6,8 MW Neutron fluence=10^{20} cm^{-2}
2nd campaign	35 LMT «Standard» (lithium orthosilicate with 35 mol% lithium metatitanate Pebble size 250 -1250 µm)	5,0116	
3rd campaign	35 LMT «500 -710 µm» (lithium orthosilicate with 35 mol% lithium metatitanate Pebble size 500 -710 µm)	5,0233	
4th campaign	25 LMT «500 -710 µm» (lithium orthosilicate with 25 mol% lithium metatitanate Pebble size 500 -710 µm)	5,0780	

1st campaign

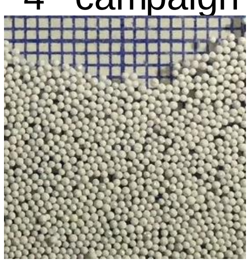


3rd campaign

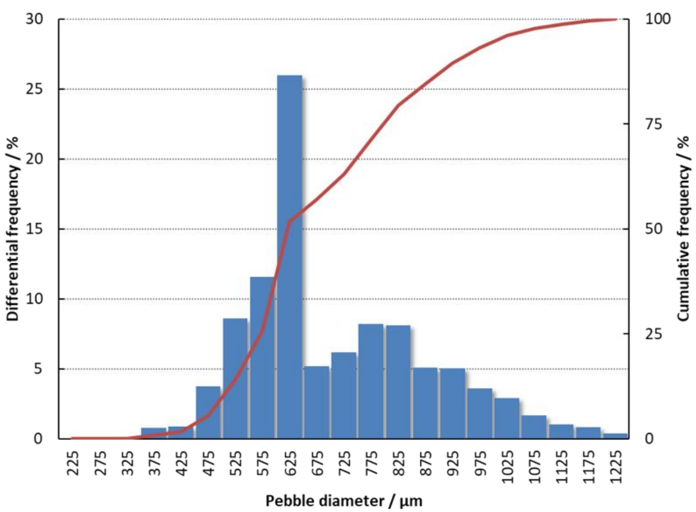
2nd campaign



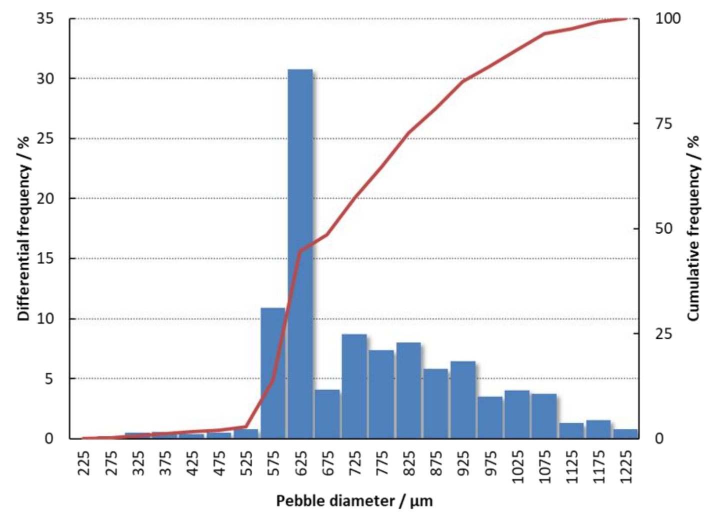
4th campaign



Initial pebble size distributions

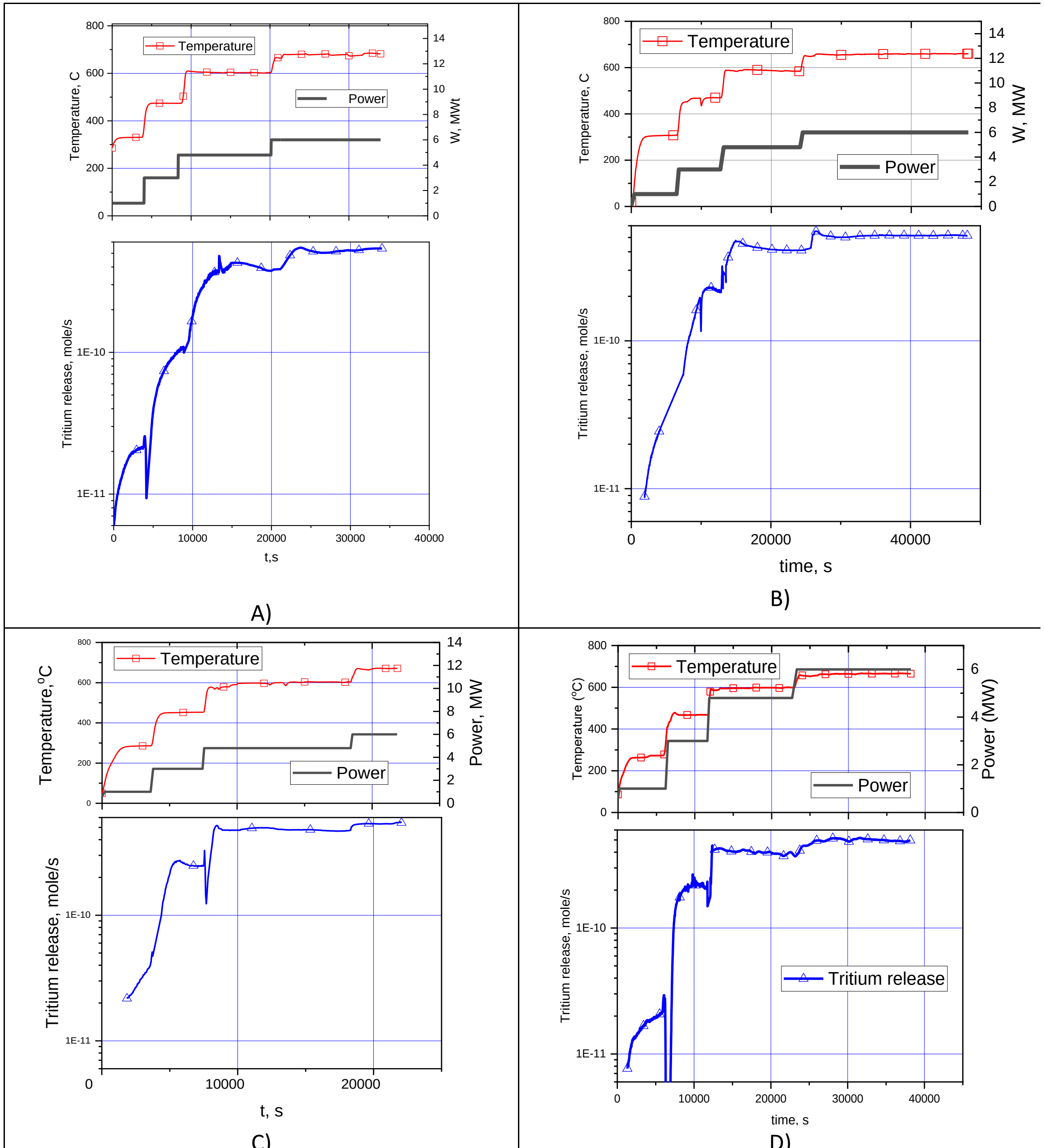


25 LMT



35 LMT

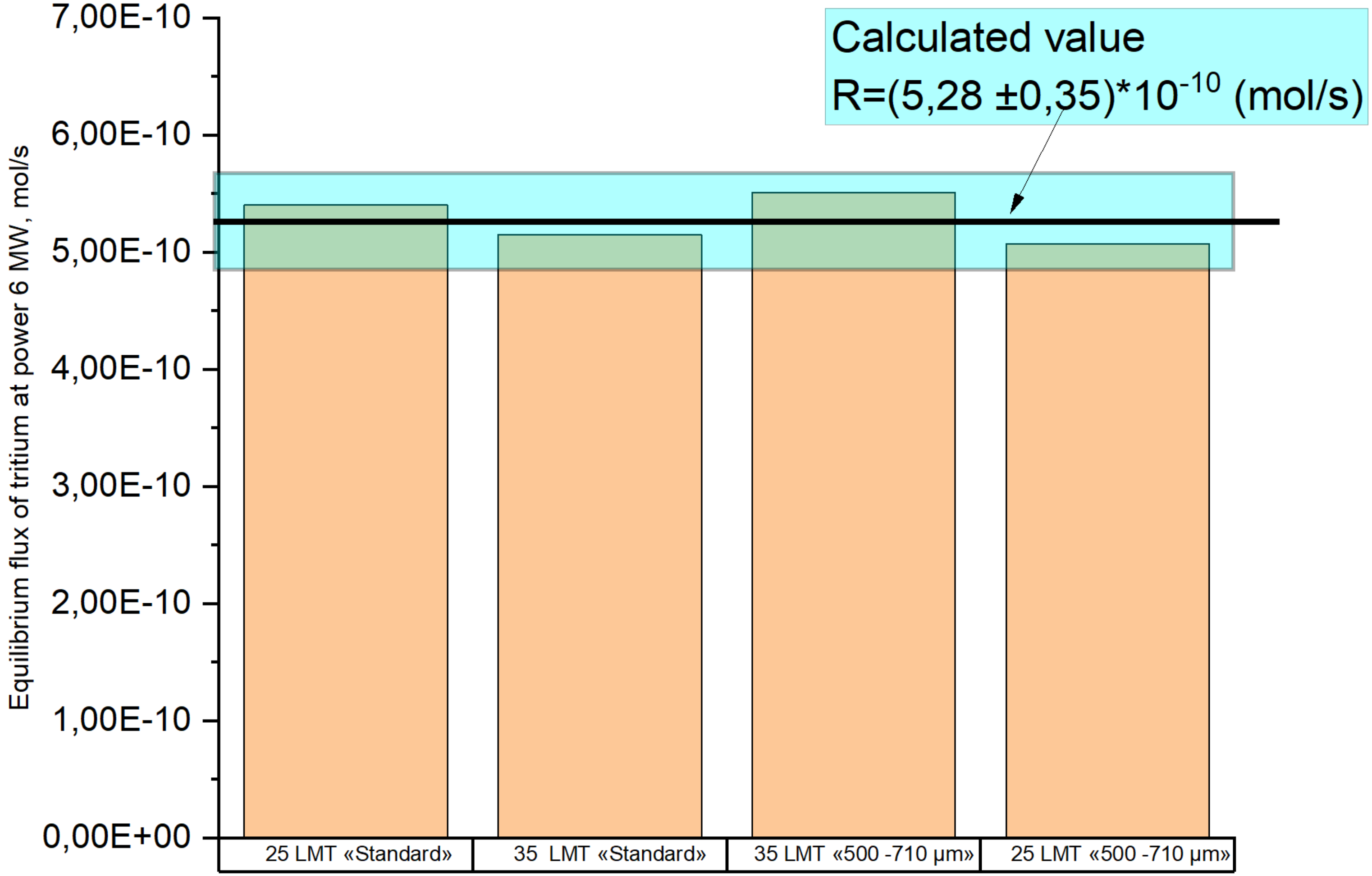
Results of reactor experiments



Diagrams of reactor experiments (A - with 25 LMT samples «Standard» (Pebble size 250 -1250 μm); Б – 35 LMT «Standard» (Pebble size 250 -1250 μm) В – 35 LMT «500 -710 μm» (Pebble size 500 -710 μm) Г – 25 LMT «500 -710 μm» (Pebble size 500 -710 μm))

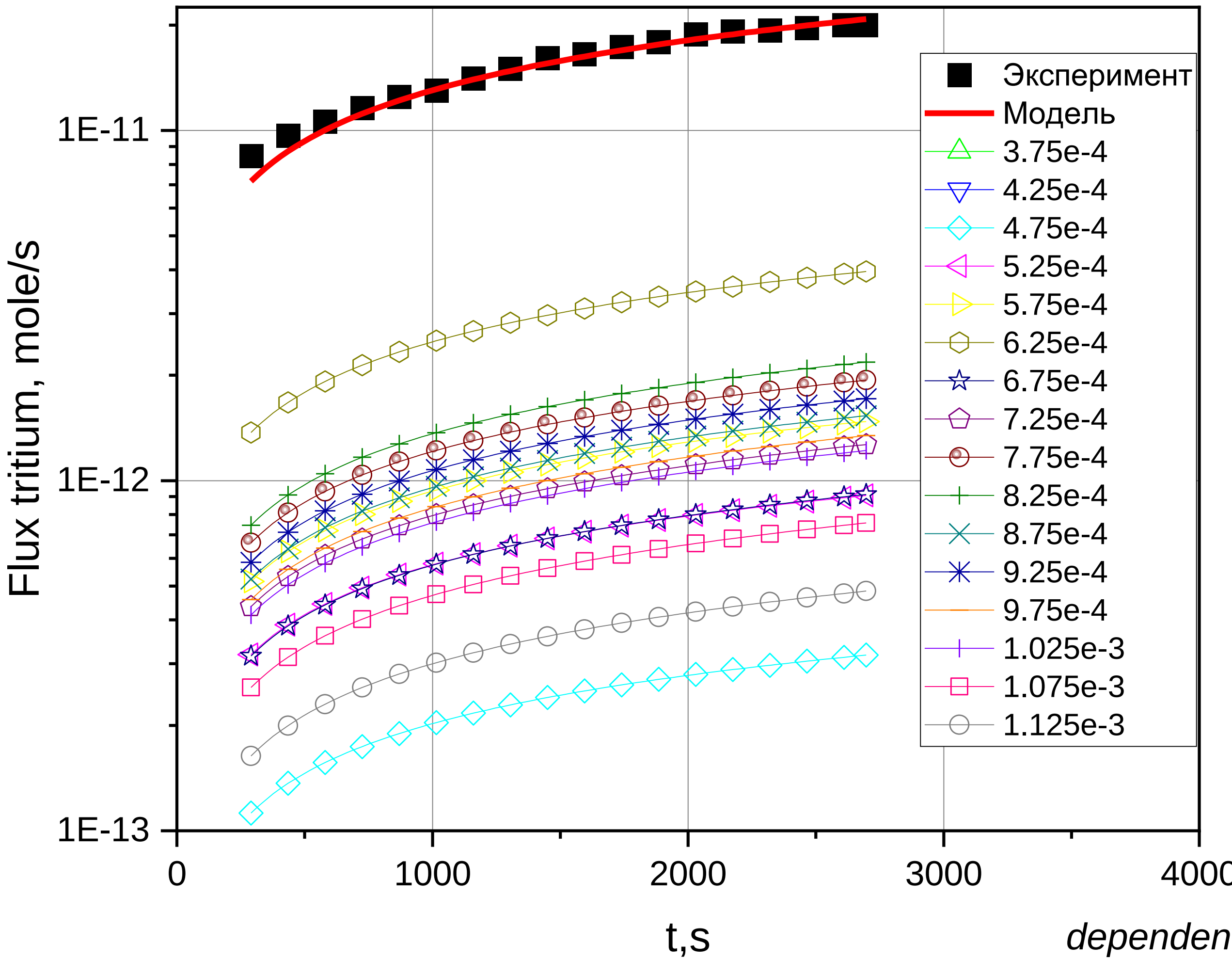
Reactor experiments

Values of equilibrium tritium release from ceramics for different experiments compared with the calculated value



Simulation of tritium release

Simulation of tritium release for the first experiment with 25 LMT "Standard" samples (Pebble size 250 -1250 μm)



Tritium release curves from 25LMT lithium ceramic samples were simulated for experiments 1 and 4. A good agreement between the experimental data and simulation results was obtained.

As can be seen from the figure, it is important to consider all groups of pebbles (according to their size) in the simulation, because the previously conducted simulation for loading pebbles with an average radius for all groups, gave a significantly worse approximation of the model curve to the experimental one.

dependence of tritium flux from the pebble

$$J(t) = \frac{Q * V0}{3}\left[1 - \frac{6}{\pi^2}\sum_{n=1}^{\infty}\frac{1}{n^2}\,exp\left\{-\frac{n^2\pi^2 Dt}{r_0^2}\right\}\right]$$

Conclusions

- Reactor experiments with samples of two-phase lithium ceramics were conducted
- Mass spectrometric registration of tritium and helium yields from samples at different temperature regimes was done during irradiation
- We present generalized data on the rate of approach of the process of equilibrium release of tritium-containing molecules from the samples of lithium ceramics under study
- The calculated values of the rate of tritium generation in ceramic samples are given and compared with the released tritium fluxes in the experiment
- The interval of the estimated tritium diffusion coefficients in two-phase lithium ceramics for the temperature range (260-350°C) was (1÷5)*10-13 m^2/s.
- The Arrhenius dependence of the effective diffusion coefficient D=8.5E-11(m2/s)*exp(-31(kJ/mol)/(R*T)) was obtained for 25LMT lithium ceramics
- The values of the effective tritium diffusion coefficient in 25 LMT ceramics were 15% lower than in 35 LMT ceramics
- The estimated values obtained will be used in further development of the tritium release model, which will be based on recurrence calculations of tritium concentration in pebbles over the entire time of reactor output at 6 MW, i.e. with changes in power and sample temperature. Such modeling will allow to obtain dependences of parameters of tritium release from ceramics in a wider range of temperatures 100- 700°C

Thank you for the attention