NATIONAL NUCLEAR CENTER
OF THE REPUBLIC OF
KAZAKHSTAN

Argonne
NATIONAL LABORATORY

REDUCED ENRICHMENT FOR RESEARCH AND TEST REACTORS
(RERTR - 2022 )

# Physical Start-up of the IVG.1M Reactor with Low-Enriched Uranium Fuel

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# Legal Framework

International Atomic Energy Agency and Republic of Kazakhstan

- Bilateral Safeguards Agreement between the IAEA and the Republic of Kazakhstan, June 1995

United States and Russian Federation

- Agreement Between the Government of the United States of America and the Government of the Russian Federation Concerning Cooperation for the transfer of Russian-Produced Research Reactor Nuclear Fuel to the Russian Federation, May 2004

United States and Republic of Kazakhstan

- Agreement Between the Department of Defense of the United States of America and the Ministry of Defense of the Republic of Kazakhstan Concerning Control, Accounting, and Physical Protection of Nuclear Material to Promote the Prevention of Nuclear Weapons Proliferation, December 1993
- Agreement Between the United States of America and the Republic of Kazakhstan Concerning the Destruction of Silo Launchers of Intercontinental Ballistic Missiles, Emergency Response, and the Prevention of Proliferation on Nuclear Weapons, December 1993

Republic of Kazakhstan and Russian Federation

- Agreement Between the Government of the Republic of Kazakhstan and the Government of the Russian Federation in the Field of Peaceful Use of Nuclear Energy, September 1993

# IVG.1M Reactor

Commissioned: 1975

Core upgrade: 1990

Thermal power (designed value): 60 MW

Core effective diameter: 548 mm

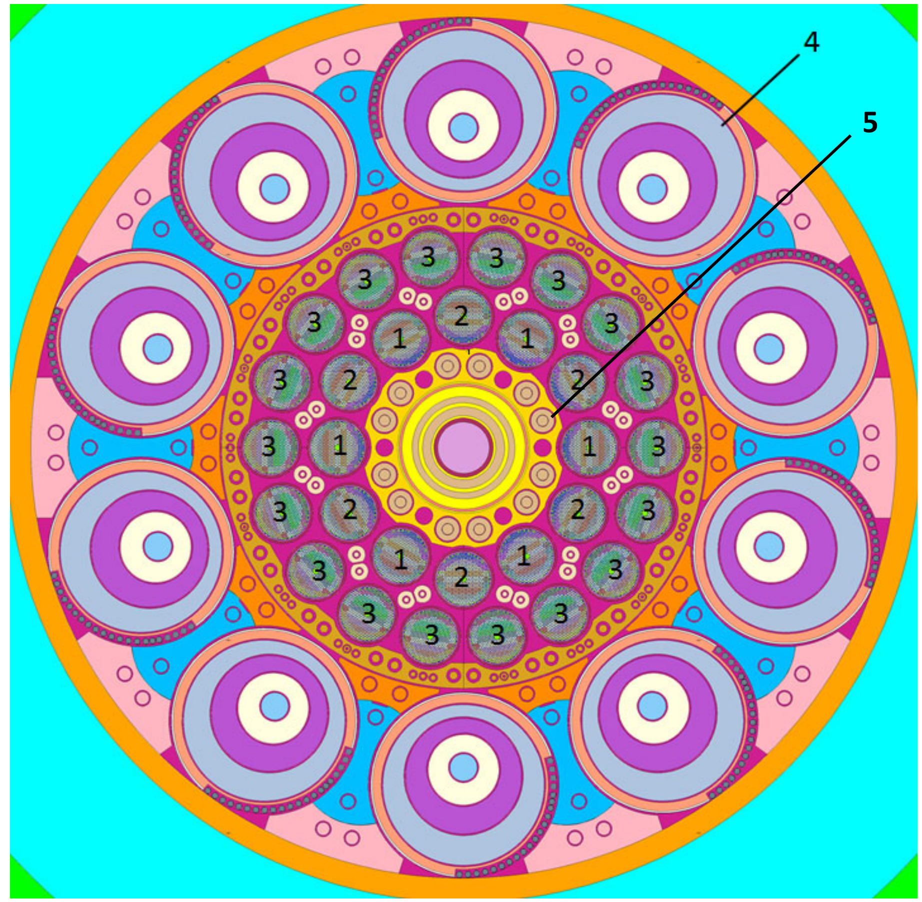
Core height: 800 mm

Thermal neutron flux: $3.5 \times 10^{14}$ n/(cm$^2$·s)

Fuel enrichment: 90% $^{235}$U

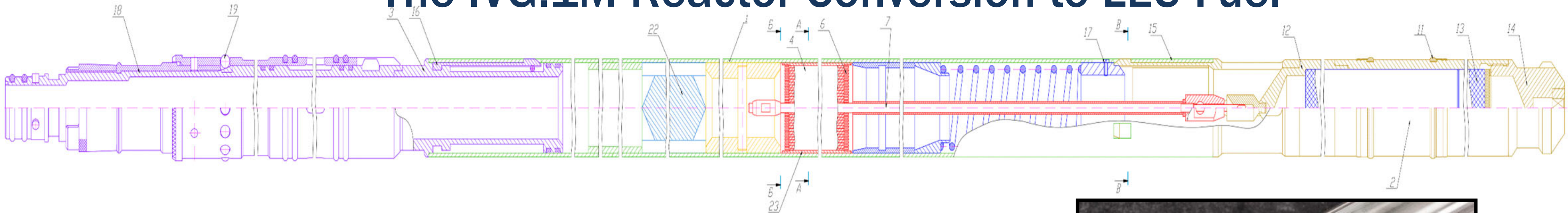
Applications:

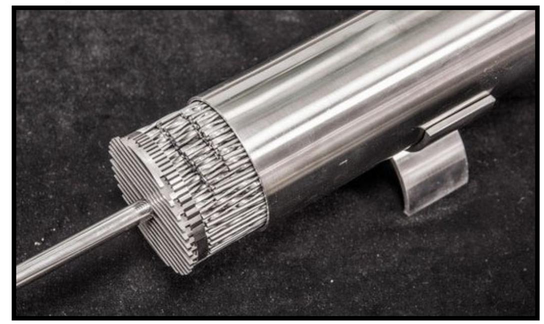
- Irradiation testing of materials for thermonuclear reactors
- Irradiation tests for medicine purpose
- Nuclear researches




1,2,3 – rows of water-cooled technological channels
4 – control drums
5 – reactivity compensation rods (RCR)

# The IVG.1M Reactor Conversion to LEU Fuel





U-235
90%

UZr–Zr-Ni 468 fuel elements
in each assembly
Beryllium reflector
$3.5 \cdot 10^{13}$ n/(cm$^2 \cdot$s)

UZr–Zr-Ni 468 fuel elements
in each assembly
Beryllium reflector
$3.3 \cdot 10^{13}$ n/(cm$^2 \cdot$s)

U-235
19.7%

WCTC-LEU has a similar design as WCTC-HEU (total length – 4990 mm; outer diameter at the core – 76 mm; maximum diameter – 82 mm; mass – 60 kg)

# The IVG.1M Conversion Roadmap
# Planned Schedule

- Technical requirements for LEU fuel were developed
- Neutronic models and code for reactor kinetics calculations were developed
- Calculations were made to produce a Safety Analysis Report (SAR) for LEU fuel
- Irradiation experiments and post-irradiation studies of LEU fuel were carried out
- Physical start-up of the IVG.1M reactor was carried out
- Preparations are under way for the energy start-up of the IVG.1M reactor

# Supply of LEU fuel for the IVG.1M Reactor

*Delivery by air and vehicles of LEU fuel*

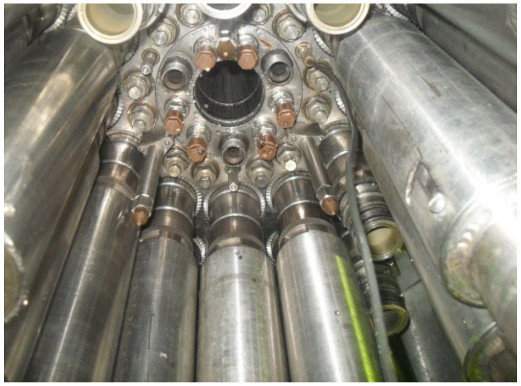
*LEU fuel reloading from railway for transportation to the IVG.1M reactor site*

*Standard LEU fuel*

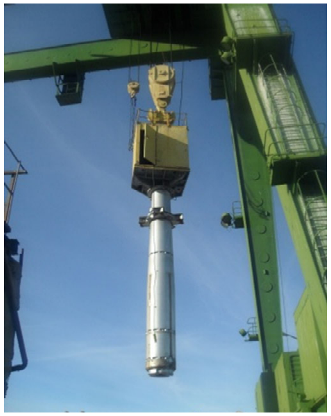
*Separate stages of input control*

# Unloading the WCTCs-HEU of the IVG.1M reactor

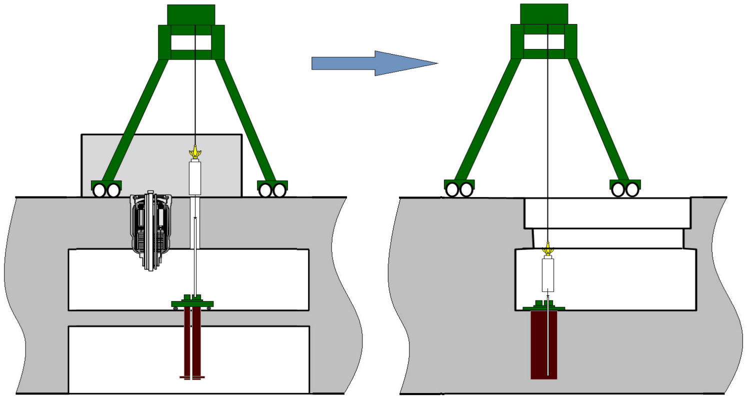
- Replacement of the beryllium reflector with the central experimental channel in the reactor central cell
- Unloading the water-cooled technological channel with high enriched uranium fuel (WCTC-HEU) from the reactor



*Reactor bottom view*
*The central channel is unloaded*



*Transportation of the central channel*



*The next step is implemented now –WCTC-HEU unloading and transportation to the temporary storage*

# Loading of the IVG.1M reactor core

*Bottom view of the reactor. Loading of the physical experimental channel (PEC) in the central assembly 72.000*

*Bottom view of the reactor.*
*Loading of the Main Neutron Source*

*Top view of the reactor. Installation of an Auxiliary Neutron Source*

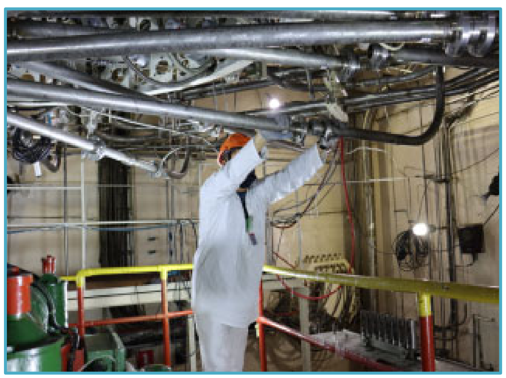
*Bottom view of the reactor.*
*Loading of the physical experimental channel (PEC) into cell #5 of the IVG.1M reactor*

# Loading of the IVG.1M reactor core

*Loading of WCTC-LEU in the container of the LRM*

*Loading of WCTC-LEU in the reactor cell*

*Decoupling of the LRM grip from WCTC-LEU*



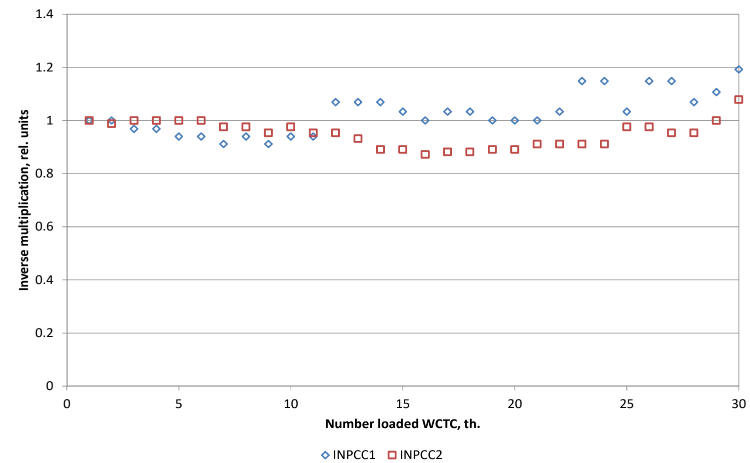
*Installation of Water Drainage Units*

*Adjustment of the gas system components of the reactor*

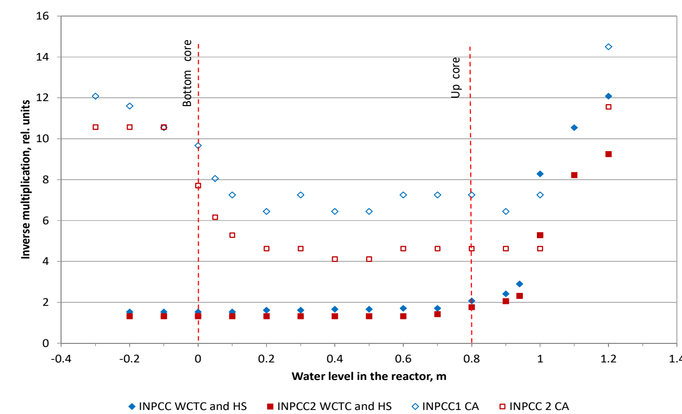
*Preparation of water system components of the reactor*

# Loading of the IVG.1M reactor core

*The IVG.1M reactor control room*




***Countdown curves during loading WCTC***



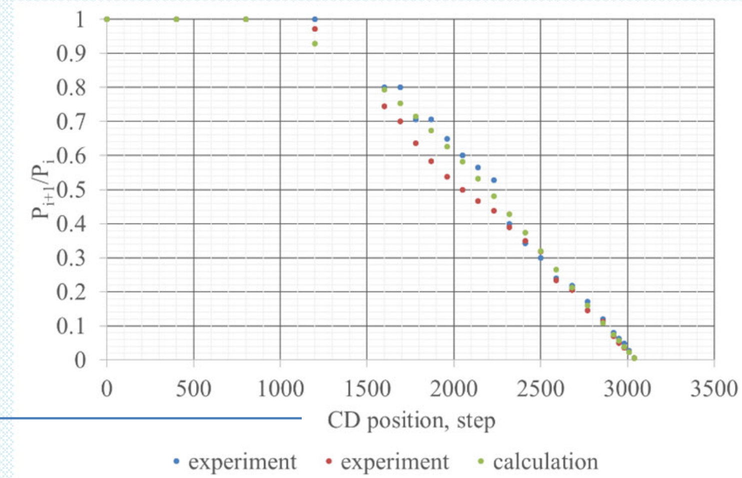

***Countdown curves during filling with water of WCTC-LEU, thermal screens and the central assembly of the reactor***

# Reaching critical state

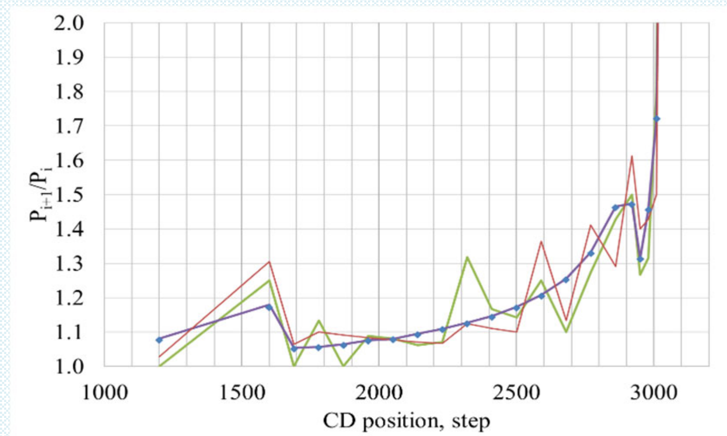
*Implementation of the IVG.1M reactor physical start-up with LEU fuel (control room)*

| | |
|---|---|
| the sum of the control drums pitches | 3050 |
| drum rotation angle | 91.5º |
| reactor power | 2 W |
| time spent on power | 300 s |

CD means Control Drums




*Countdown curves at the first transition to the critical state*




*Comparison of the ratio of the impulse chambers readings between adjacent states and the ratio of the subcritical neutron multiplication factor (SMF)*

## Physical start-up

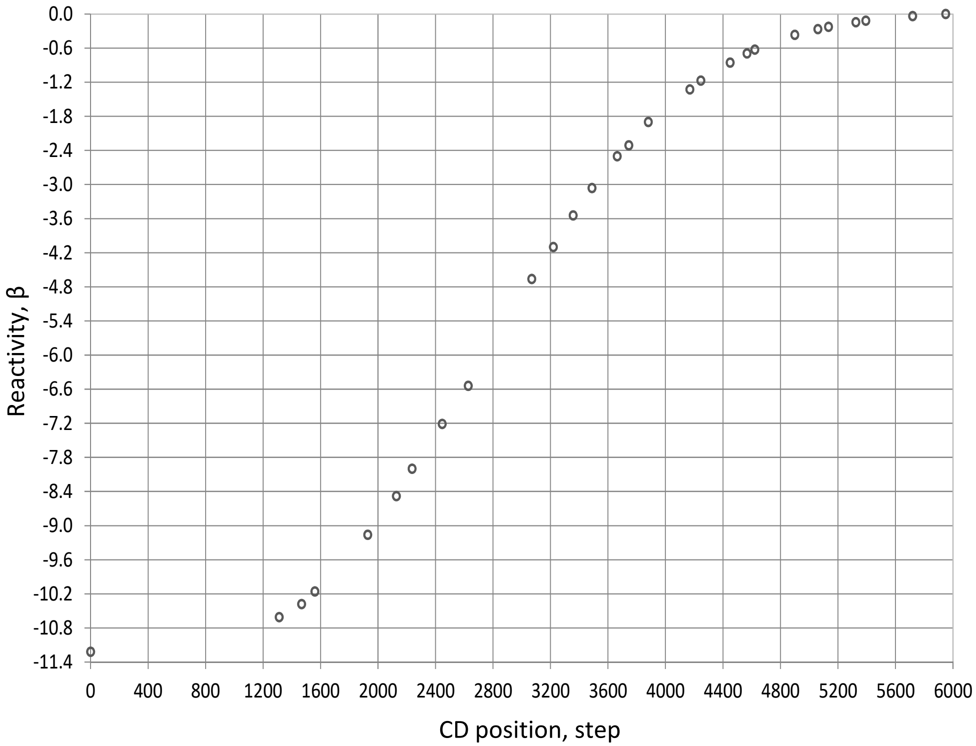
- reactor fueling
- reaching the first critical state

- research of energy release fields
- calibration of standard Control and Protection System (CPS)

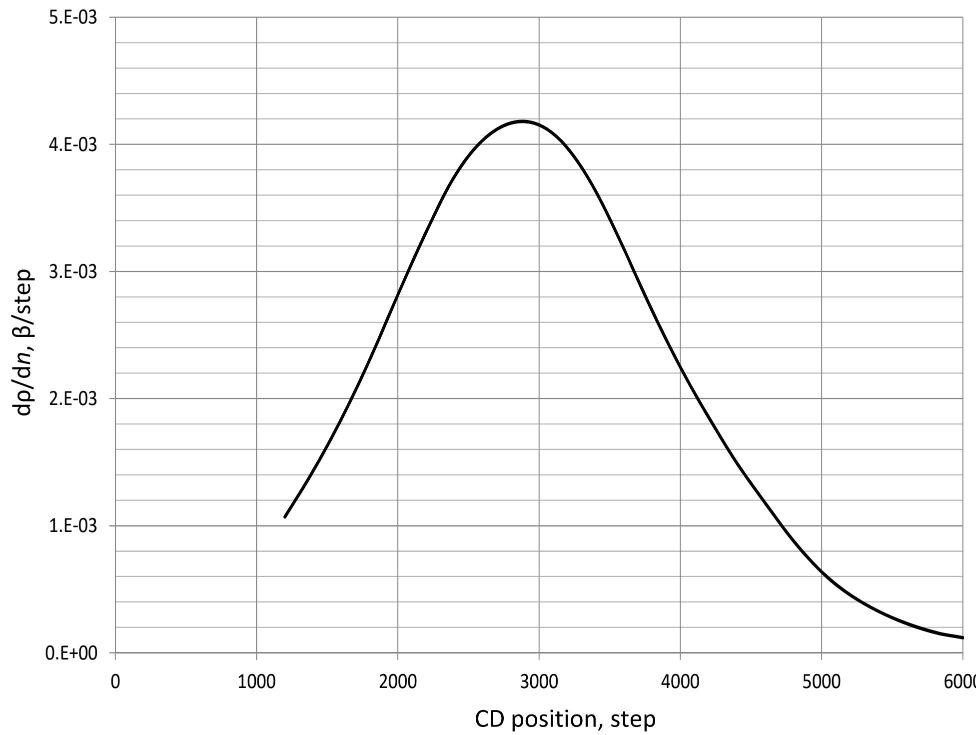
- determination of the reactivity margin and subcriticality of the reactor, reactivity worth of fuel assemblies

- quantifying the effectiveness of regulatory units, emergency protection, and reactivity compensation rods

# Characteristics of the Control Drums (CD) system




*Control characteristic of the Control Drums (CD) system*




*Differential characteristic of Control Drums (CD) system*

# Main parameters of the IVG.1M reactor

| Options | Fresh LEU | Fresh HEU (1990) | Burn HEU (2019) |
|---|---|---|---|
| Uranium-235 loading, g | 5670 | 4600 | 4600 |
| System Efficiency Control Drums (CD) Reactor, $\beta_{eff}$ | 11.2 | 11.3 ± 0.3 | - |
| Efficiency reactivity compensation rods (RCR), $\beta_{eff}$ | 3.5 | 3.8 ± 0.2 | - |
| Shutdown margin of reactor, $\beta_{eff}$ | 8.3 | 6.0 ± 0.2 | 0.9± 0.2 |
| The position of the CD system in a critical state, step (degree) | 3050 step (91.5$^0$) | 2880±20 step (79$^0$) | 5200 step (156$^0$) |
| Relative energy release by rows of the reactor: | | | |
| 1 row | 1.26 | 1.18 | - |
| 2 row | 1.21 | 1.16 | - |
| 3 row | 1.00 | 1.00 | - |
| Axial coefficient of uneven energy release: | | | |
| WCTC 1,2 rows | 1.58 | 1.55 | - |
| WCTC 3 row | 1.27 | 1.28 | - |

# Conclusion

- In 2010, as part of the fulfillment of the international obligations of the Republic of Kazakhstan in the field of non-proliferation of nuclear weapons, the NNC launched a large-scale project to convert fuel from the IVG.1M research reactor to LEU.
- During the implementation of the project, specialists from the National Nuclear Center, together with American and Russian partners, performed a computational and analytical justification for the possibility of carrying out the conversion, tested experimental low-enriched fuel, and manufactured standard LEU fuel.
- From May 5 to August 10, 2022, the physical start-up of the IVG.1M reactor with low-enriched uranium fuel was successfully carried out.
- After the completion of the next stage - the power start-up of the reactor, and the experimental determination of all the necessary characteristics of the new core, the IVG.1M reactor will be put into operation.
- In general, the implementation of such a global project is another important contribution of Kazakhstan to the solution of the international task of reducing the threat of nuclear proliferation.

# Acknowledgement & Disclaimer


## Acknowledgement

This work was sponsored by the U.S. Department of Energy, Office of Material Management and Minimization in the U.S. National Nuclear Security Administration Office of Defense Nuclear Nonproliferation under Contract DE-AC02-06CH11357.

# Thank you for attention!

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Commands the start-up of Gnyrya  V.S.

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