



ВНИИМ

имени А.А.Бочвара



Main Results and Status of the Development of LEU fuel for RUSSIAN Research Reactors

Всероссийский Научно Исследовательский Институт Неорганических Материалов

Post-address: P.O.Box 369, Moscow 123060, Russia

Phone: +7-095-190-4994

Fax: +7-095-196-4168, 196-8546



INTRODUCTION

The main direction of the Russian RERTR program is to develop fuel on high-density uranium alloys base. Currently, the main option is the dispersion U-Mo fuel. Two types of FA are under development to use this fuel:

- ➔ standard design with tubular type fuel elements with up to 5.4 g/cm³ U density;
- ➔ novel design with pin type fuel elements with up to 6.0 g/cm³ U density.

The development is carried out both for existing reactors, and for new advanced designs of reactors.

Review of the results of development of pin type fuel elements on base U-Mo fuel is presented.

RRFM International Meeting, April 2005



ROSATON

ВНИИИМ



Major Directions of Activity

- ➔ Irradiate dispersion U-Mo fuel in two research reactors: MIR (RIAR, Dimitrovgrad) in pin type fuel mini-elements and WWR-M (PINP, Gatchina) within the full-scaled FA with pin type fuel elements.
- ➔ Master the design and fabricating process the IRT type FA with pin type fuel elements.
- ➔ Develop methods of reducing of U-Mo fuel –Al matrix interaction under irradiation.
- ➔ Develop fabricating methods of fuel elements with monolithic U-Mo fuel.

RRFM International Meeting, April 2005



ROSATON

ВНИИИМ



Main Results

The irradiation of pin type fuel mini-elements with dispersion U-Mo LEU fuel in MIR reactor

- ➔ The irradiation of two capsules, each containing 36 mini-fuel elements, was begun in August 2003 and completed early in February 2005.
- ➔ The experimental device have 13 types of fuel composition that are differed by the uranium density, the chemical composition of the alloy, the method used to fabricate fuel granules and the phase state of the alloy.

RRFM International Meeting, April 2005

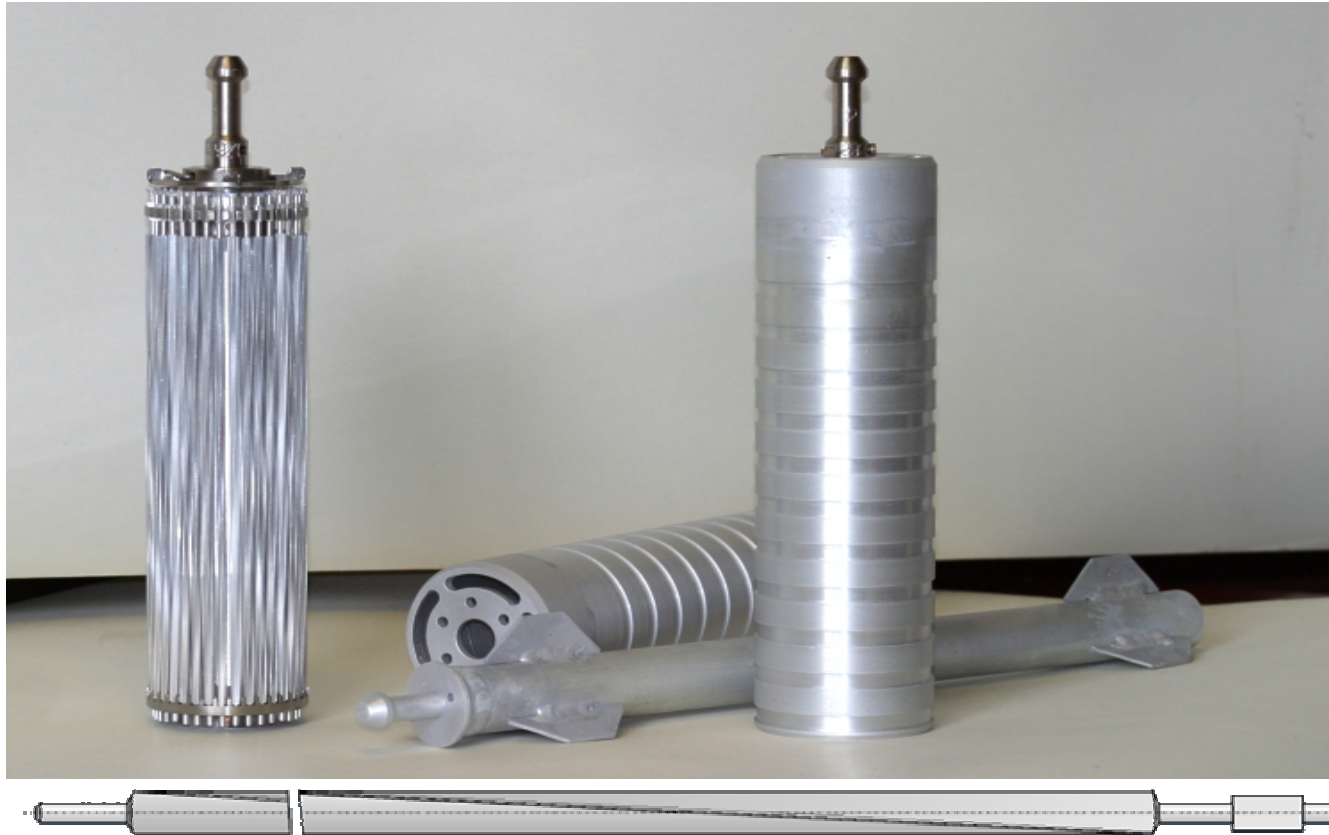


ROSATON





Main Results



Experimental device: 2 capsules with fuel mini-elements

RRFM International Meeting, April 2005



ROSATON





Types of Fuel

| NoNo | Alloy | Fabricating method | Phase structure of alloy | Uranium Density, g/cm ³ | Quantity of fuel elements |
|------|---------------------|--------------------|--------------------------|------------------------------------|---------------------------|
| 1 | U-9%Mo | atomization | γ | 4 | 5 |
| 2 | U-9%Mo | atomization | γ | 6 | 7 |
| 3 | U-9%Mo | atomization | $\alpha+\gamma$ | 4 | 6 |
| 4 | U-9%Mo | atomization | γ | 4 | 5 |
| 5 | U-9%Mo | atomization | γ | 6 | 5 |
| 6 | U-9%Mo | atomization | $\alpha+\gamma$ | 4 | 4 |
| 7 | U-7%Mo-0,2%Al | atomization | γ | 4 | 5 |
| 8 | U-7%Mo-0,2%Al | hydrogenation | γ | 4 | 6 |
| 9 | U-7%Mo-0,4%Al | atomization | γ | 4 | 5 |
| 10 | U-7%Mo-0,2Sn-0,2%Al | atomization | γ | 4 | 4 |
| 11 | U-7%Mo-0,2Sn-0,2%Al | hydrogenation | γ | 4 | 7 |
| 12 | U-1,5%Mo | atomization | α' | 4 | 6 |
| 13 | U+5Zr+5Nb | atomization | γ | 4 | 6 |

RRFM International Meeting, April 2005



ROSATOM





Parameters of mini-element tests

| Parameter | Stages of tests | | | |
|---|----------------------------------|----------------------------------|----------------------------------|----------------------------------|
| | Stage 1 27.08.03- 12.01.04 | Stage 2 16.01.04- 04.04.04 | Stage 3 08.04.04- 27.11.04 | Stage 4 05.12.04- 04.02.05 |
| Power experimental device, kW | 75-95 | 40-50 | 40-90 | 40-90 |
| Coolant rate, m/s | 2,9-3,2 | 2,8-3,1 | 2,8-3,0 | 2,8-3,0 |
| Inlet temperature of coolant, °C | ≤ 35 | < 40 | < 50 | < 50 |
| Thermal flux density, kW/m ² | | | | |
| Capsule N1 | 430-925 | 430-855 | 410-490 | - |
| Capsule N2 | 320-690 | | 470-900 | 440-860 |
| Temperature of cladding, °C | 88-105 | 92-105 | 78-117 | 75-107 |
| Neutron flux density, E>0,1 MeV, 10 ¹³ cm ⁻² s ⁻¹ : | | | | |
| U density - 4 g/cm ³ | 3,0-5,7 | 3,7-5,4 | 2,2-6,3 | 2,0-6,2 |
| U density - 6 g/sm ³ | 3,3-5,9 | 4,2-5,6 | 2,6-7,0 | 2,4-7,0 |
| Fission rate per unit volume of fuel, 10 ¹³ , s ⁻¹ cm ⁻³ | | | | |
| U density - 4 g/cm ³ | 3,5-7,4 | 5,0-8,5 | 2,2-8,9 | 2,2-7,7 |
| U density - 6 g/sm ³ | 4,8-11 | 6,7-11 | 3,0-11,4 | 3,1-10,1 |
| Average U ²³⁵ burnup, %: | | | | |
| Capsule N1 | 27,3 | 44,3 | 63-67,7 | - |
| Capsule N2 | 20,5 | | 35-50 | 50-63 |

RRFM International Meeting, April 2005



ROSATON





MAIN RESULTS

- ➔ Currently, the primary investigations of the mini-elements of are in progress including: inspection of appearance, γ -scanning and measurements of the mini-element dimensions.
- ➔ The results of the post-irradiation experiments (PIE) are planned to be available in the autumn of 2005.
- ➔ This experiment will provide the first irradiation results of pin-type U-Mo dispersion fuel elements in characteristic operation conditions of pool-type research reactors.

RRFM International Meeting, April 2005

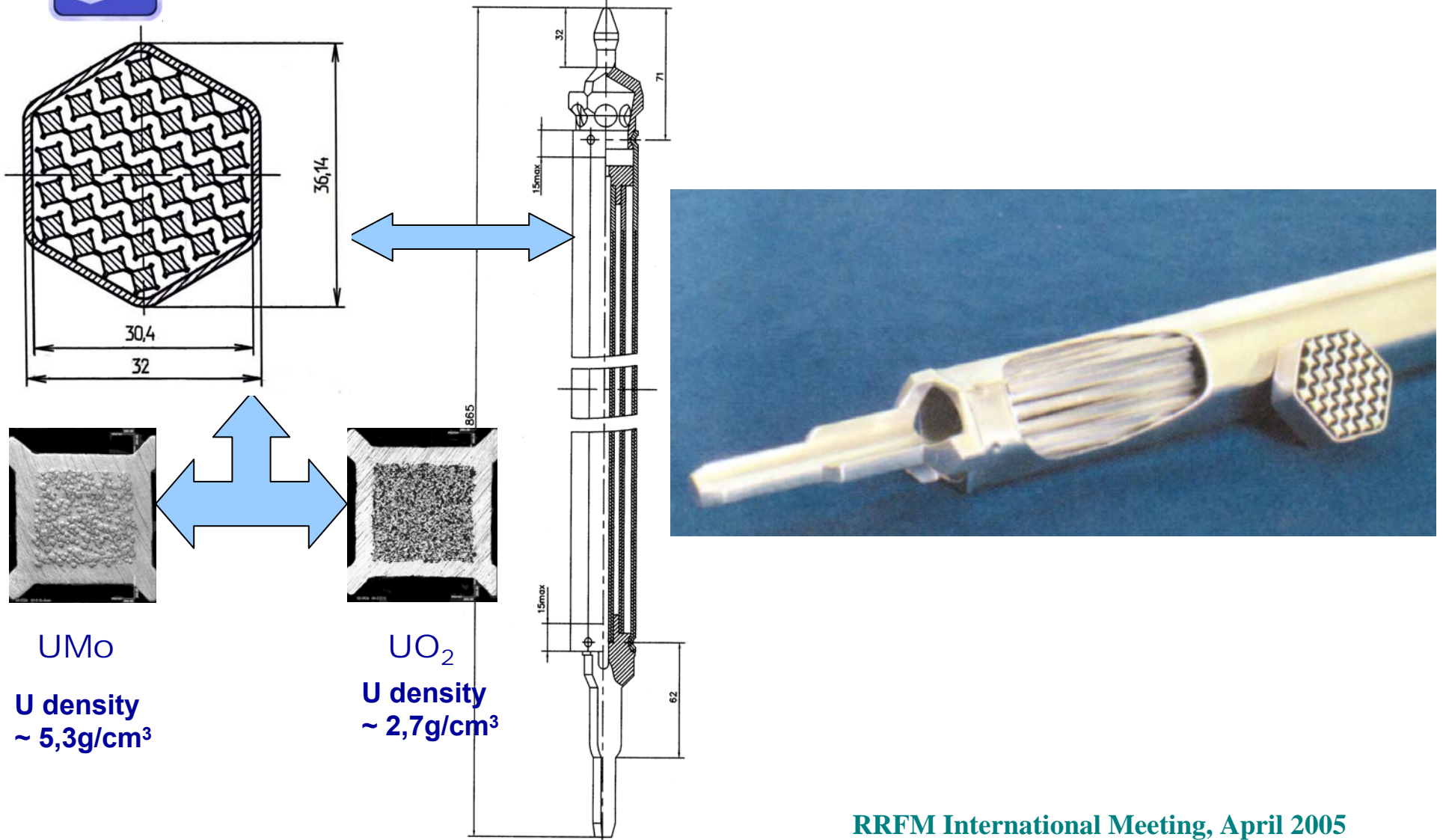


ROSATOM

ВНИИИМ



Design of WWR-M2 FA with pin-type fuel elements



RRFM International Meeting, April 2005



ROSATOM





Irradiation conditions of pin-type FA

| Parameter | Stage 1 | Stage 2 | Stage 3 | Stage 4 | Stage 5 |
|---|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| | 15.10.03- 28.11.03 | 01.12.03- 29.02.04 | 01.03.04- 31.08.04 | 01.09.04- 30.11.04 | 01.12.04- 28.02.05 |
| Power of reactor, MW | 10-15 | 15-15,4 | 15-15,2 | 14-16 | 15,5-16 |
| Inlet temperature of coolant, °C | 34-45 | 33-38 | 42-47 | 42-45 | 40-44 |
| Average U ²³⁵ burnup, %: | | | | | |
| UO ₂ -Al | 3,4 | 10,3 | 23,6 | 26,8 | 35 |
| UMo-Al | 1,52 | 3,6 | 6,8 | 7,7 | 11,7 |
| Power density q _{Vmax} , kW/l: | | | | | |
| UO ₂ -Al | 140-210 | 200-220 | 200-250 | 223-250 | 200-237 |
| UMo-Al | 127-187 | 160-170 | 145-160 | 223-277 | 228-265 |
| Temperature of cladding, °C: | | | | | |
| UO ₂ -Al | 68-86 | 80-90 | 86-102 | 90-95 | 87-94 |
| UMo-Al | 74-82 | 70-78 | 74-80 | 78-100 | 90-101 |

RRFM International Meeting, April 2005



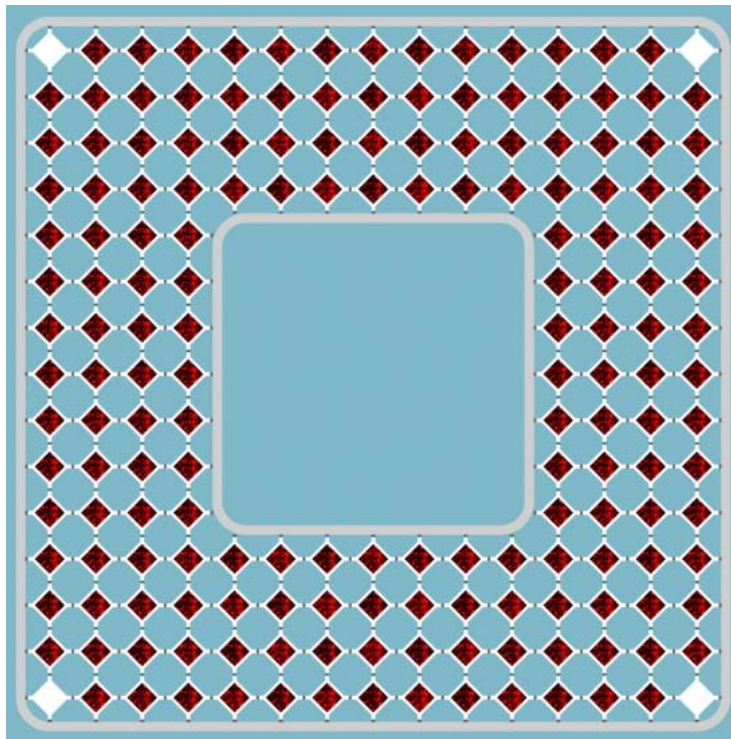
ROSATOM



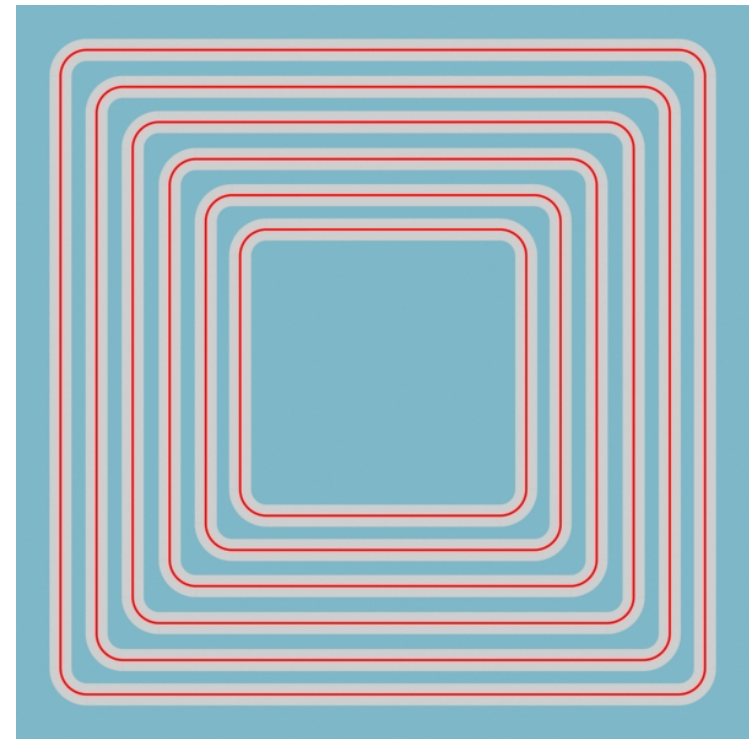


FUEL ASSEMBLY DESIGN

New Design of IRT-type FA



Current Design of IRT-type FA



RRFM International Meeting, April 2005



ROSATOM

ВНИИИМ



Development of IRT type FA

- ➔ In cooperation with the staff and under conditions of industrial production of the Novosibirsk plant (NCCP) a large set of technological investigations of FE and FA fabrication processes has been completed.
- ➔ Three full-scaled mockups of FA for hydraulic and vibration tests have been manufactured by Novosibirsk plant. The mockups are only differed by the design of their space grids.
- ➔ The hydraulic tests two full-scaled FA mockups have been carried out.

RRFM International Meeting, April 2005

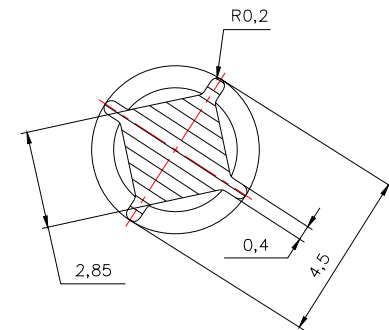
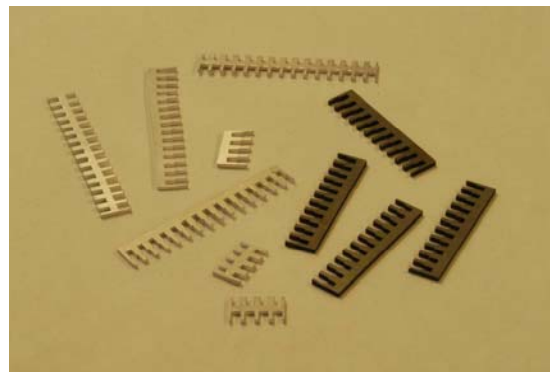
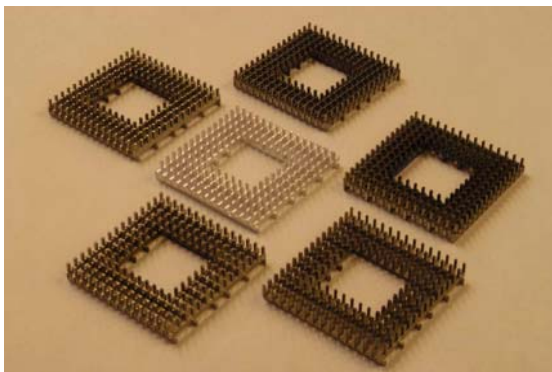
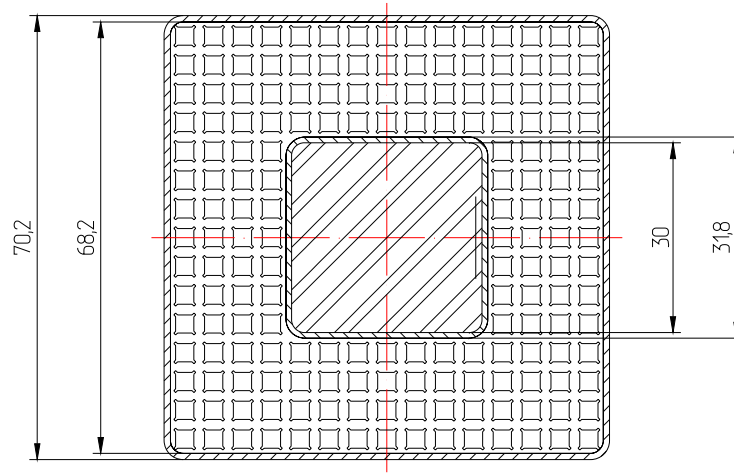


ROSATOM

ВНИИИМ



FUEL ASSEMBLY DESIGN



RRFM International Meeting, April 2005

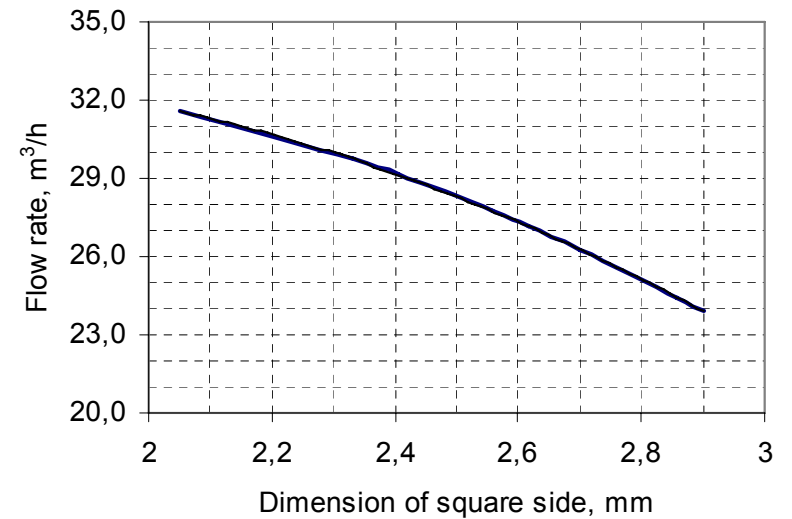
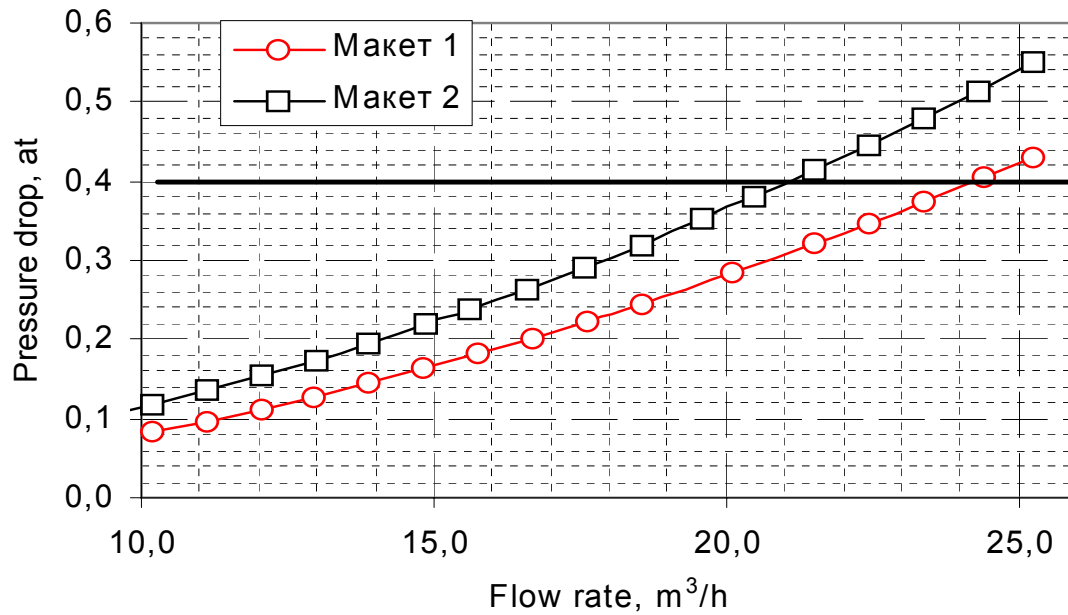


ROSATOM





Results of Hydraulic Tests



RRFM International Meeting, April 2005



ROSATOM





FUEL ASSEMBLY DESIGN

Geometrical Characteristics of base design

| Parameter | Value |
|------------------------------|---------|
| Step of Fin Spin, mm | 320 |
| Fuel Element Height/Meat, mm | 645/600 |
| Circumscribing Diameter, mm | 4,5 |
| Cladding Thickness, mm | |
| nominal | 0,4 |
| minimum | 0,3 |
| U-235 mass, g | |
| in fuel element | 2,2 |
| in FA | 380 |
| U density, g/cm ³ | 6,1 |

RRFM International Meeting, April 2005



ROSATOM





Development of IRT type FA

- ➔ The vibration tests of the full-scaled dummy FA are in progress. The objective of the tests is to assess the reliability of the ITR type FA design during its shipping.
- ➔ The extensive work is in progress to develop the devices and methods of controlling to ensure the fabrication quality of the pin type fuel elements under the industrial production conditions. A mockup facility of a non-destructive control for pin type fuel elements (cladding thickness, fuel mass and its distribution uniformity) has been designed and fabricated.
- ➔ The lifetime tests of the experimental full-scaled fuel assemblies (tube and pin type designs) are planned to be carried out in the MIR reactor (Dimitrovgrad) in next year. This will allow to to validate the serviceability of the fuel and the FA design.

RRFM International Meeting, April 2005



ROSATOM

ВНИИМ



CONCLUSIONS

The presently available results of the work to develop U-Mo alloy fuel and pin type fuel elements have demonstrated the expedience of the further evolution of this direction.

RRFM International Meeting, April 2005



ROSATOM

ВНИИИМ



Acknowledgements

The authors would like to express their appreciation to the staff of Novosibirsk plant for their significant contribution in development of fabrication process of pin type FE and FA and also ROSATOM, TVEL, RIAR, PINP, RRC KI for the large contribution and active participation in accomplishing the presented scope of the work.

We are appreciative to ANL (USA) not only for their support of work through the long-term R&D contract, but also for their greatest interest to our development and effective scientific and technical cooperation.

RRFM International Meeting, April 2005



ROSATOM

