NEW TYPES OF NUCLEAR FUEL

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Objective

To supply Customer with the fuel providing:

Safe and reliable operation

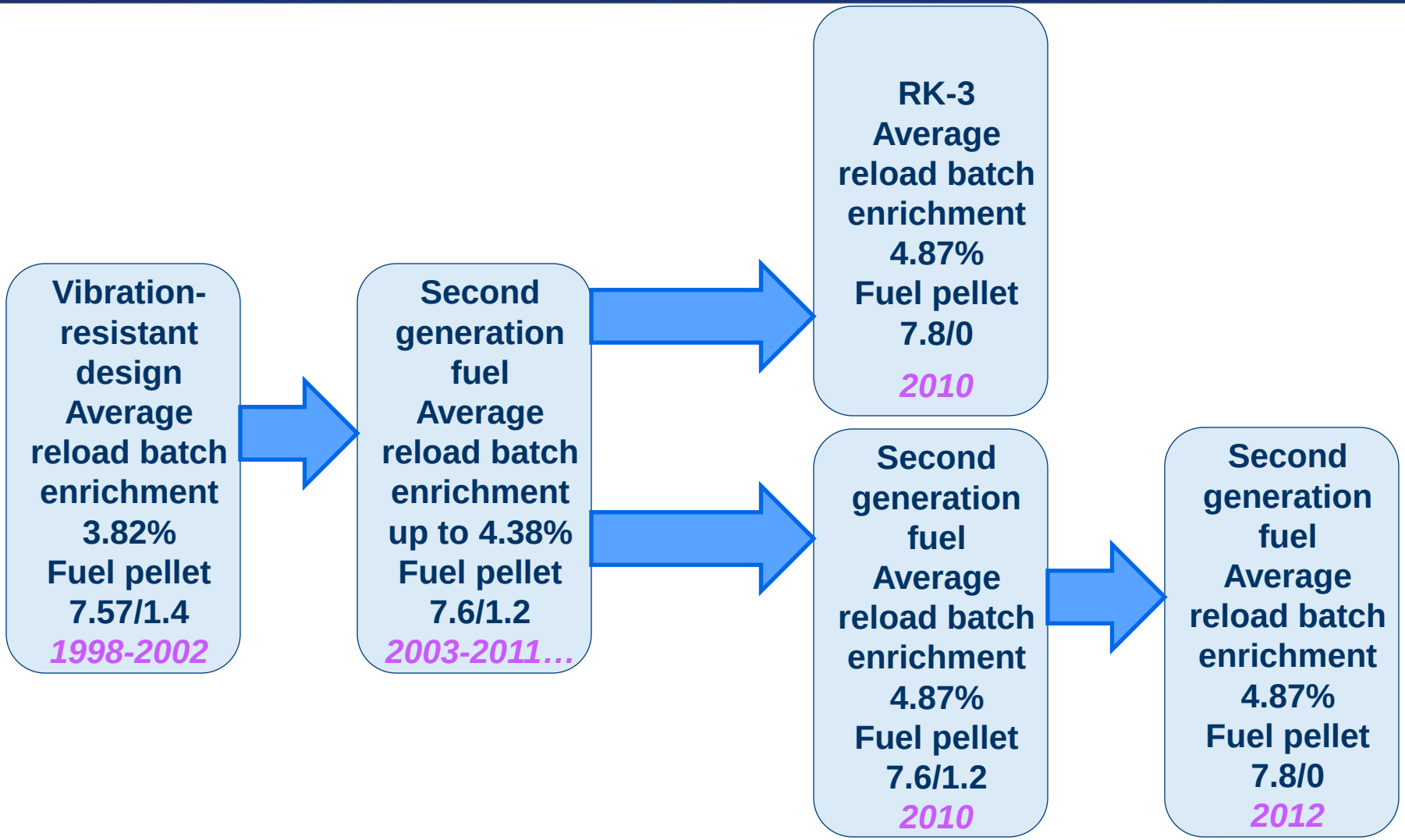
Economic efficiency in flexible fuel cycles

Competitiveness of Russian nuclear fuel

Main directions of development

- ✓ Improved operational reliability of FAs.
- ✓ Increased service life.
- ✓ Increased burnup.
- ✓ Dismountable and reparable design.
- ✓ FA development for new nuclear power units.

VVER-440 Nuclear Fuel

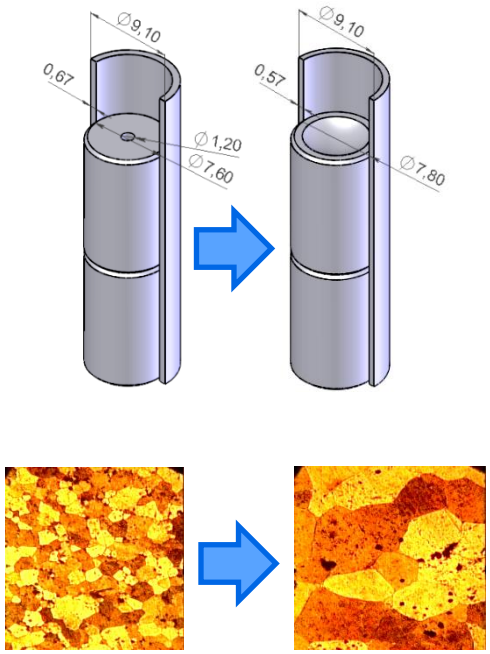


VVER-440 Nuclear Fuel

Second generation fuel
Average enrichment 4.87%
Fuel pellet 7.6/1.2 mm

6-year fuel cycle at a power level of 1471 MW(th) (107%).
Profiled fuel rod bundle, U-Gd fuel.
66 FAs in the reload batch.
Burnup of 65 MW·d/kgU.
Load follow operation.

In 2010, pilot operation of reload batch started at Kola NPP Unit 4.



Second generation fuel
Average enrichment 4.87%
Fuel pellet 7.8/0 mm

6-year fuel cycle at a power level of 1540 MW(th) (112%).
Profiled fuel rod bundle, U-Gd fuel.
60 FAs in the reload batch.
Burnup of 65 MW·d/kgU.
Load-follow operation.

Development of technical project in 2012

The expected benefit of implementation – about 15% reduction in the number of FAs in the reload batch (at 107% of nominal reactor power)

The expected benefit of implementation – about 8% reduction in the number of FAs in the reload batch as compared to the second generation FAs with enrichment of 4.87% and pellets 7.6/1.2 mm

VVER-440 Nuclear Fuel

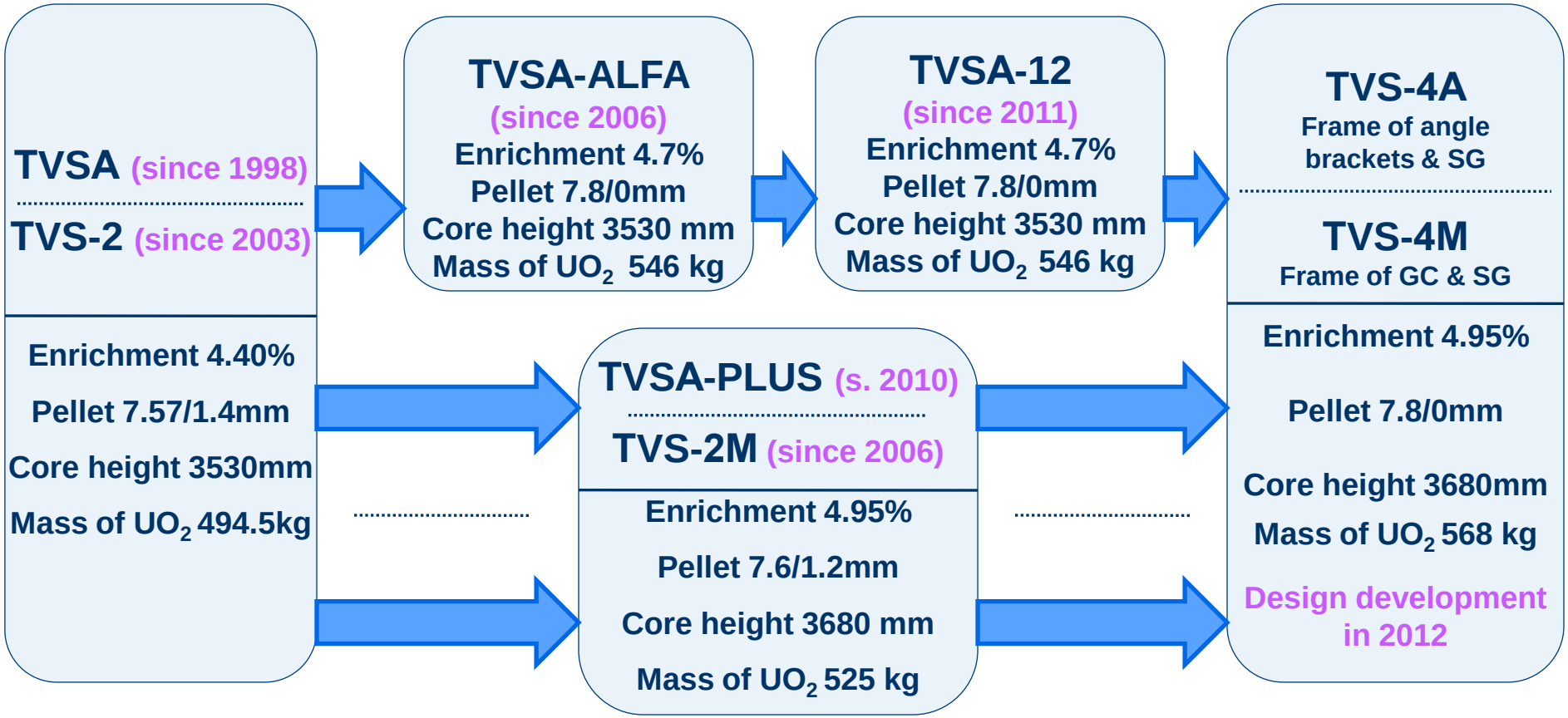
Third generation fuel assembly
(for second generation VVER-440 reactor)

Design without the shroud tube based on a frame of the angle brackets and pipes
Average ^{235}U enrichment – 4.87%.
Fuel pellet 7.8/0 mm.
Mass of UO_2 - 132 kg (increased by 4.5%).
Fuel rod pitch – 12.6 mm.
Number of FAs in reload batch – 60.
Burnup – up to 68 MW·d/kgU.
6-year fuel cycle at a power level of 1471 MW(th) (107%).
Load follow operation.

Pilot batch operation (12 FAs) started at Kola NPP Unit 4 in 2010

The expected benefit of RK-3 implementation – about 10% reduction of reloaded FAs as compared to the second generation FAs with fuel enrichment of 4.87%

VVER-1000 Nuclear Fuel



VVER-1000 Nuclear Fuel

TVSA-PLUS / TVS-2M

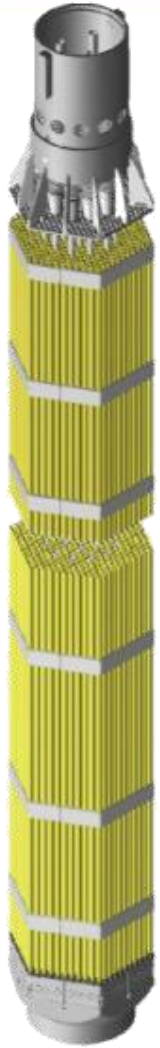
TVS-2M are in operation at Balakovo and Rostov NPP
TVSA-PLUS are in operation at Kalinin NPP Units 2, 3 and 4

New features:

- ✓ unified fuel rod and FA bottom nozzle
- ✓ fuel column height of 3680 mm (increased by 150 mm), enrichment of 4.95%, pellet 7.6/1.2 mm
- ✓ debris filter
- ✓ dismountable and reparable design

Results of implementation provide:

- ✓ power uprate up to 104% of nominal power
- ✓ 18-month fuel cycle (66 FAs in reload batch)
- ✓ burnup - 65 MW·d/kgU
- ✓ load follow operation (100-75-100% N_{nom})
- ✓ FA protection from debris



VVER-1000 Nuclear Fuel

TVSA-ALFA

- ✓ Fuel column height 3530 mm
- ✓ Pellet without central hole 7.8/0 mm
- ✓ Mass of UO_2 in FA 546 kg
- ✓ 8 spacing grids
- ✓ Debris filter
- ✓ Dismountable and reparable design

Operated at Kalinin NPP Unit 1 since 2006

TVSA-12

Design with 12 SG (unified with TVS-2M) with increased stiffness of the frame.

Start of operation:

1. **Kalinin NPP Unit 1 (12 FAs) - 2011**
2. **At one of the Ukrainian units – 2012**

<u>For 5-year fuel cycle</u>

- **Number of FAs in reload batch – 36**
- **Burnup - 65 MW·d/kgU**

<u>Possibility of operation in the fuel cycle of 3x(490-510) effective days</u>

- **Number of FAs in reload batch – 66**
- **Burnup ~60 MW·d/kgU**

VVER-1000 Nuclear Fuel

TVS-2M

TVSA-PLUS

TVSA-12

Fourth generation TVS

TVS-4M

- 12 SG, mixing spacer grid, debris filter
- Fuel column – 3680 mm
- Pellet ∅7.8/0 mm
- Load of UO_2 – 568.4 kg

Fuel cycle 3x510 or 5x333

TVS-4A

increase in the campaign duration by 8%
OR
decrease of reloaded FAs by 10%
OR
decrease of enrichment in reload batch by 7%
OR
power uprate by 10%

Design development – 2012

VVER-1000 Nuclear Fuel

TVSA-T for Temelin NPP Units 1&2

Main features

- ✓ Fuel column height of 3680 mm with blankets of 150 mm
- ✓ Fuel pellet 7.6/1.2 mm
- ✓ Mass of UO_2 in FA 524.1 kg
- ✓ 8 spacing grids (including 6 mixing spacer grids)

Temelin-1

In October 2010, physical and power startup implemented with the core fully loaded with TVSA-T.

Temelin-2

Full load of the core with TVSA-T is scheduled for 2011.

Development stages

Power uprate up to 104% (TVSA-T of basis design)	2012
Design optimization of TVSA-T (12 SG; 7.8/0 mm)	2014
Fuel cycle optimization (18-month)	2016

NPP-2006 Nuclear Fuel

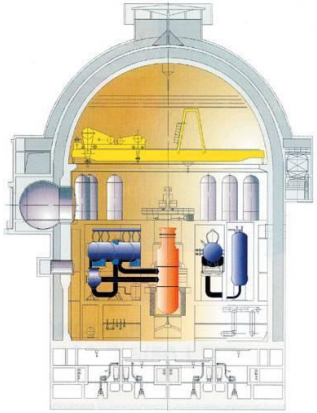
Technical design of TVS-2006 was developed in 2010 in accordance with the requirements of TOR (phase 1): fuel cycle 3x18 months and 5x12 months, pellet 7.6/1.2 mm, maximum use of proven solutions

PARAMETER	VALUE	
	VVER-1000	VVER-1200
Reactor thermal power	3000	3200
Coolant inlet temperature, °C	289.8	298.6
Coolant outlet temperature, °C	319.6	329.7
Maximum steam content, %	5	11.6
FA height, mm	4570	4570
Fuel column height, mm	3680	3730
Fuel load in FA, kg	527	534
Assigned service life of FA, ef. hours	40000	46000
Maximum burnup for FA, MW·d/kgU	63.7	64.2

Fuel supply to Unit 1 of Novovoronezh NPP-2 – December 2012

NPP-2006 Nuclear Fuel

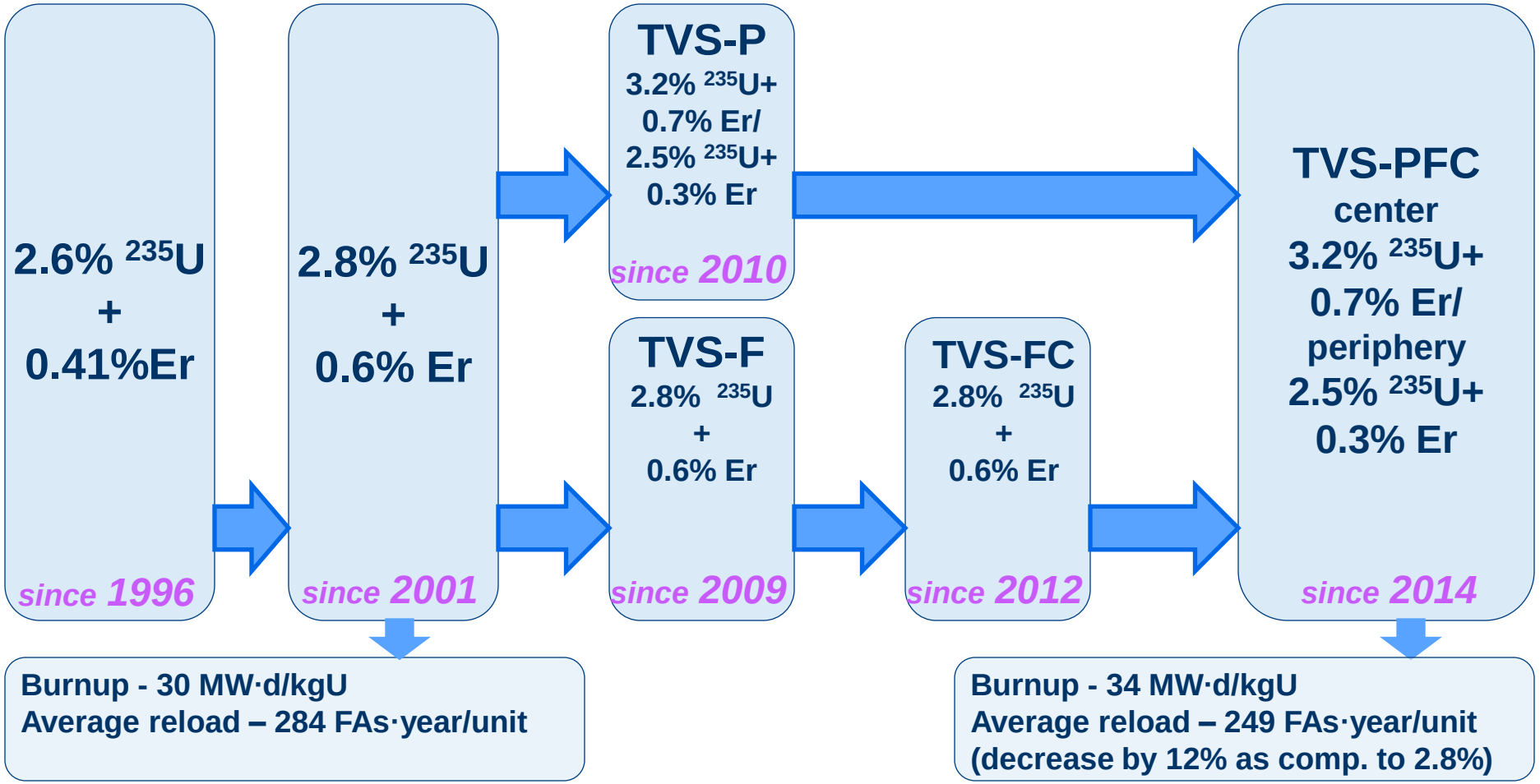
Phase 2 tasks (2010-2012): to increase NPP technical and economic indicators based on the FA development potential including fuel cycles up to 24 months and increased burnup up to 70 MW·d/kg U



Main directions of R&D

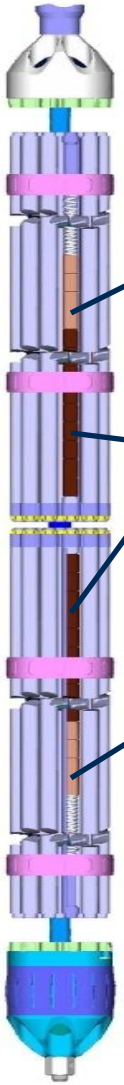
- Justification for increasing the fuel loading in FA based on fuel pellet 7.8/0 mm (increasing the duration of the campaign by 6%);
- Justification for introduction of heat exchange intensifiers in TVS-2006 (increasing power by 6-8%);
- Analysis of the effectiveness of uranium-erbium fuel cycles with increasing duration;
- Analysis of the possibility to increase the enrichment above 5%;
- Introduction of advanced zirconium alloys;
- Reduction of conservatism in the core justification (increasing power by 6-8%).

RBMK-1000 Nuclear Fuel

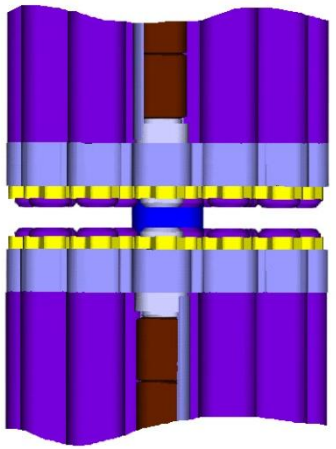


RBMK-1000 Nuclear Fuel

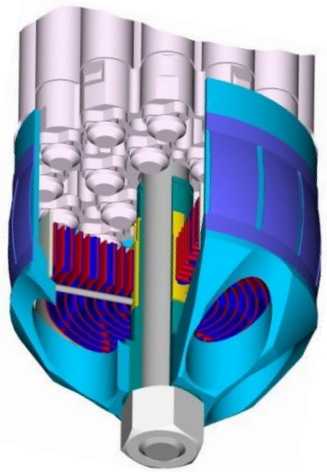
New generation TVS RBMK-1000



Fuel column with profiled enrichment

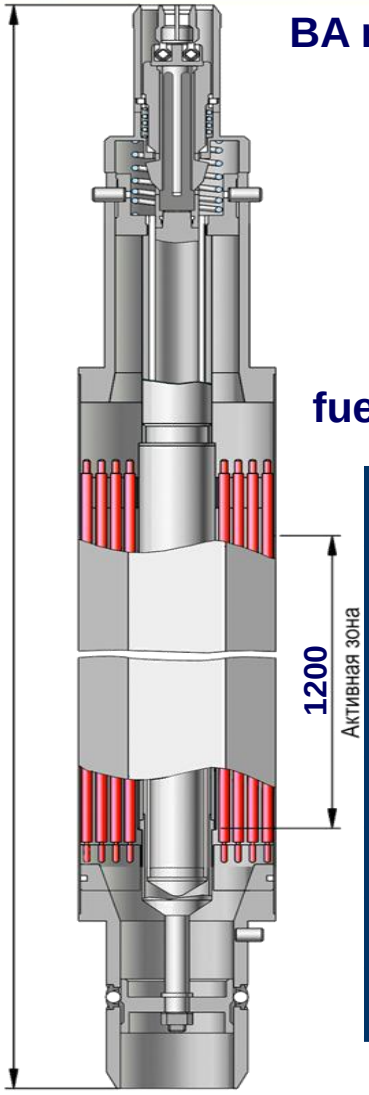


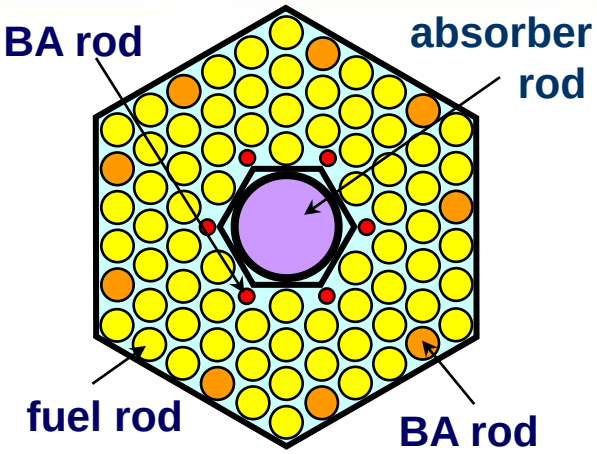
Central fixation of fuel rods



Debris filter

Fuel for floating NPP





The core based on the new cermet fuel with high uranium content was developed for floating NPP head unit KLT-40S. The fuel meets the requirements of the non-proliferation.

Two head cores 14-14 will be supplied to JSC Baltic Shipyard.

Future challenge – development of the core for floating NPP with an increased service life up to 3 TW·h

Core 14-14 characteristics	Value
1. Service life, TW·h	2.1
2. Thermal power, MW	150
3. Campaign duration, year	2.3
4. Maximum fuel enrichment, %	15.7
5. Uranium load, kg	1273
6. Number of FAs in the core	121
7. Average burnup of unloaded fuel, MW·d/kgU	46

Main conclusions

New generation FAs that have been developed and are operated now provide the following:

- **High-power operation of NPP;**
- **Safe and reliable operation during 6 years (VVER) and 10 years (RBMK);**
- **Fuel burnup in FAs up to 35 MW·d/kgU (RBMK) and 65 MW·d/kgU (VVER);**
- **NPP operation in flexible fuel cycles;**
- **Load follow operation in the daily mode;**
- **Dismountable and reparable design.**

Thank you for attention!