NUCLEAR FUEL FOR NPP: CURRENT STATE AND PROSPECTS

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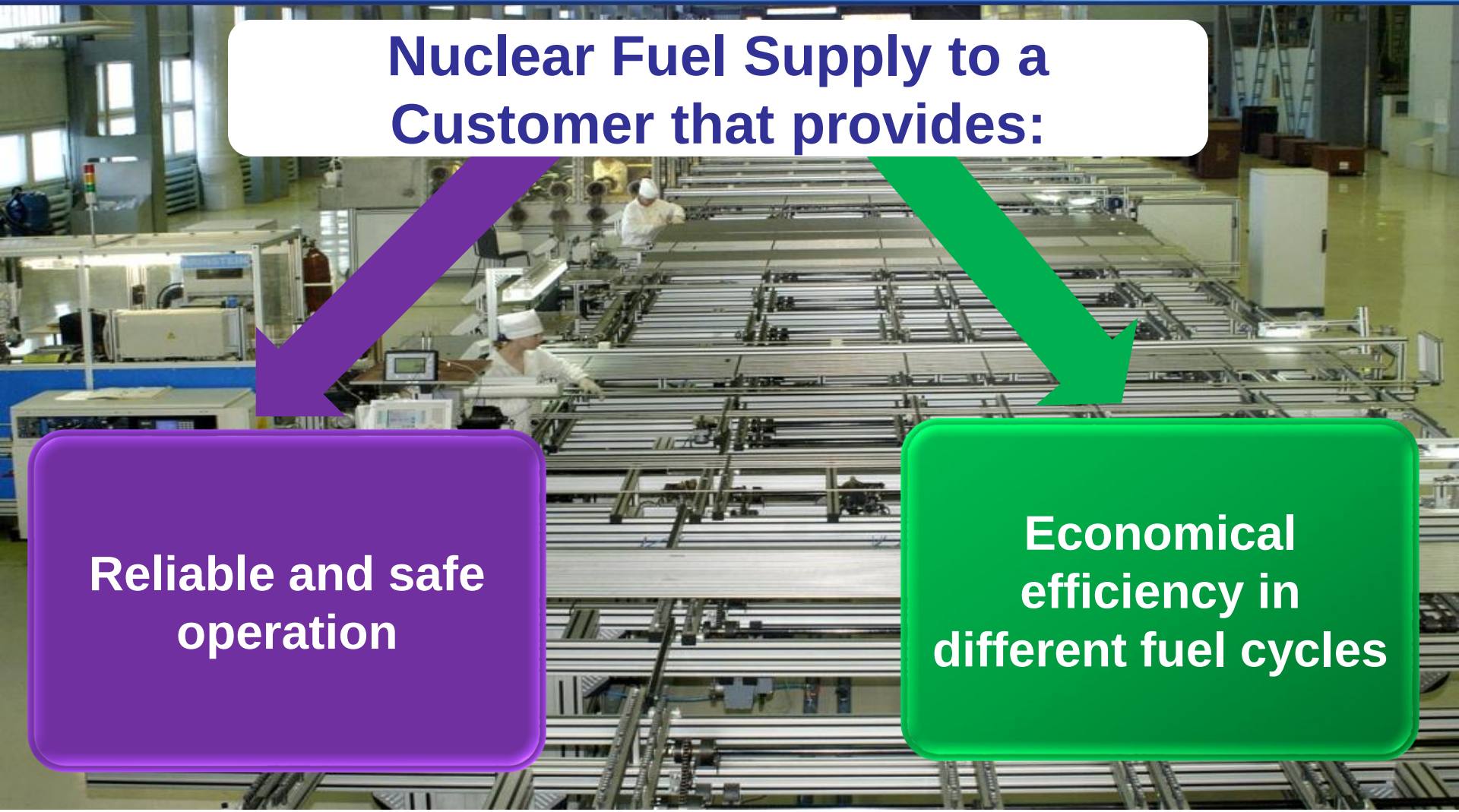
Rosatom Fuel Company
JSC «TVEL»

Scientific-technical unit	Manufacturing of ГЦ	Conversion and enrichment	NF Fabrication

- 1500 reactor-years of successful operation of nuclear fuel at NPPs with VVER
- 17% of world nuclear fuel market for NPP reactors
- 45% of world uranium enrichment market

Our Target

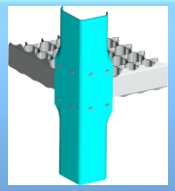
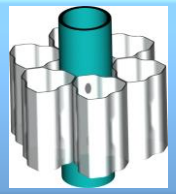


Nuclear Fuel Supply to a Customer that provides:

Reliable and safe operation

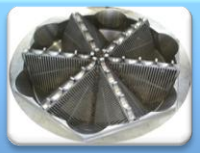
Economical efficiency in different fuel cycles

Improvement of Nuclear Fuel Reliability

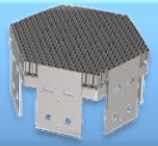
Enhancing of FA geometry stability

Application of FA with a rigid frame



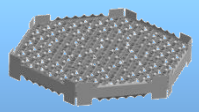
Improvement of protection from damage with foreign objects in reactor coolant

Application of anti debris filters (ADF)



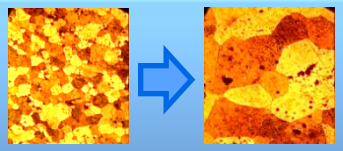
Improvement of vibration stability

Application of anti vibration grids (AVG)



Improvement of thermal technical reliability

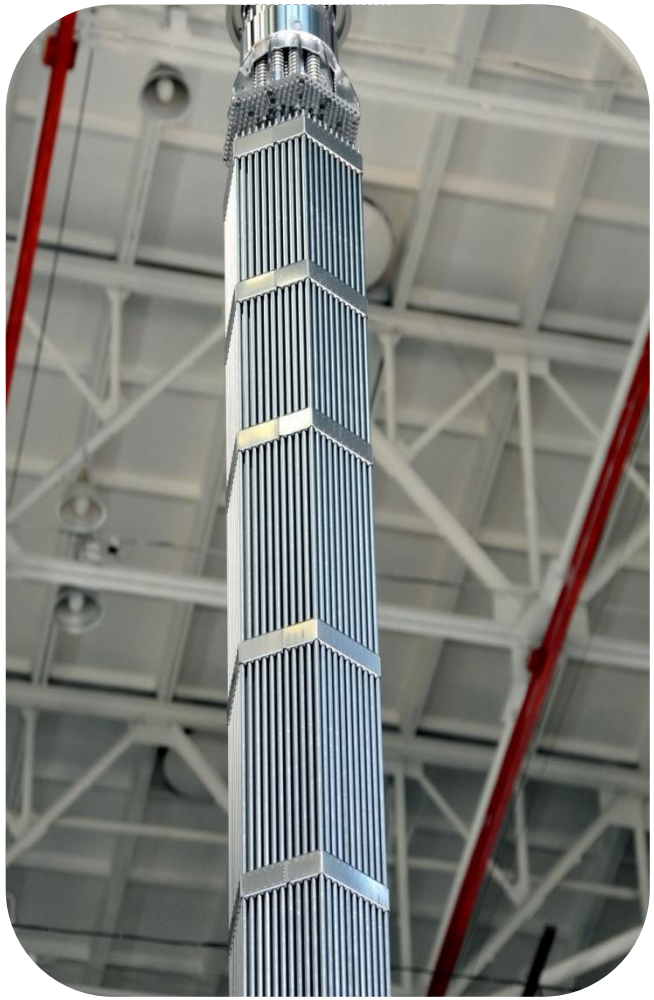
Application of mixing grids (MG)



Prevention of interaction between fuel and fuel cladding, reduction of ГПД output

Increase of average size of fuel grain

Improvement of Nuclear Fuel Economic Efficiency



- Increase of fuel burn-up depth
- Improvement of fuel operation resource
- Development of conditions for thermal power increase
- Providing efficiency of nuclear fuel in maneuver operation modes

VVER-440 Nuclear Fuel
Current State

NPP with VVER-440	Fuel Type	Enrich ment
Novovoronezh NPP-3, 4 (Russia)	Standard	3,82
Kola NPP-1, -2 (Russia)	Vibration resistant	3,82
Kola NPP-3, -4 (Russia)	Second generation/RK-3	4,87/4,25
Rovno NPP-1,-2 (Ukraine)	Second generation	4,38/4,25
Armenian NPP (Armenia)	Vibration resistant	3,82
Dukovany NPP(Czech)	Second generation	4,38/4,25
Bohunice NPP (Slovakia)	Second generation	4,87
Mohovce NPP (Словакия)	Second generation	4,87
Paks NPP (Hungary)	Second generation	4,20
Loviisa NPP (Finland)	Second generation	4,37/4,0

VVER-440 Nuclear Fuel

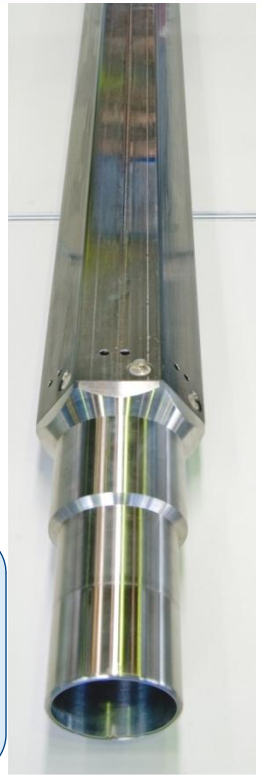
Vibration resistant fuel
Enrichment 3.82%
Pellet 7.57/1.4
1998-2002

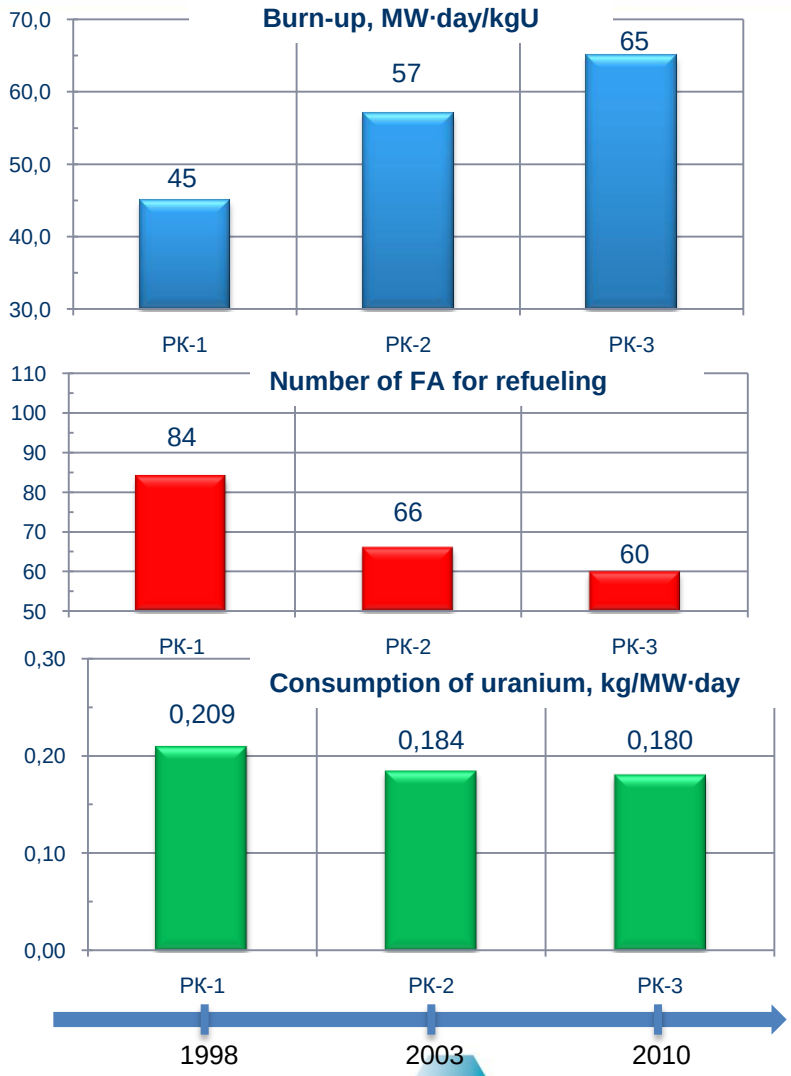
Fuel of second generation
Enrichment up to 4.38%
Pellet 7.6/1.2
2003-2011…

Fuel of second generation
Enrichment 4.87%
Pellet 7.6/1.2
2010

PK of third generation
Enrichment 4.87%
Pellet 7.8/0
2010

Fuel of second generation
Enrichment 4.87%
Pellet 7.8/0
2012





VVER – 1000 Nuclear Fuel
Current State

NPP with VVER-1000	Type of fuel
Novovoronezh NPP-5 (Russia)	Case-type
Balakovo NPP (Russia)	TVS-2M
Rostov NPP (Russia)	TVS-2M
Kalinin NPP-1 (Russia)	TVSA-ALFA+12 TVSA-12
Kalinin NPP-2, 3, 4 (Russia)	TVSA-PLUS
South-Ukraine NPP (Ukraine)	TVSA
Zaporozhsk NPP (Ukraine)	TVSA
Khmelnitsk NPP (Ukraine)	TVSA
Rovno NPP-3, 4 (Ukraine)	TVSA
Kozloduy NPP-5, 6 (Bulgaria)	TVSA
Temelin NPP (Czech)	TVSA-T
Tyanvan (China)	UTVS+6 TVS-2M
Bushehr NPP (Iran)	UTVS

There are totally 31 units with VVER-1000 reactors being operated in the world.
Two more units (Kudankulam NPP) are under commissioning.

VVER-1000 Nuclear Fuel
Current State

Kalinin NPP
units №2, №3 и №4

Balakovo NPP

Rostov NPP

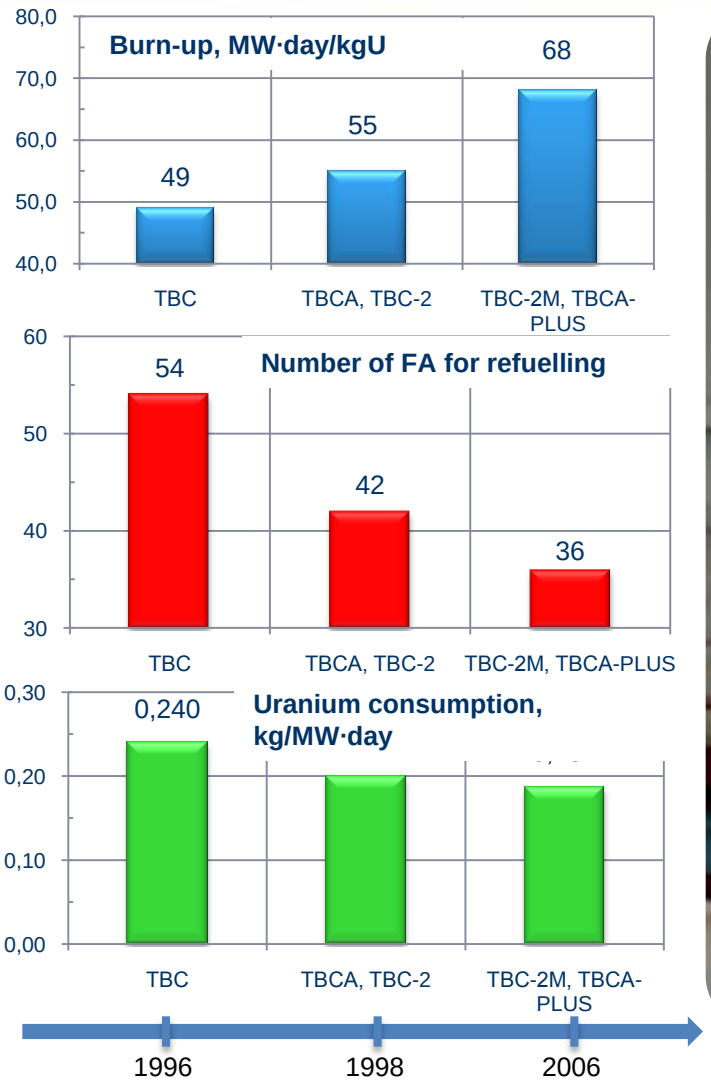
TVSA-PLUS and TVS-2M have similar economic characteristics providing for :

- ✓reactor power increase up to 104 % from nominal level
- ✓ 18-month fuel cycle (66 FA makeup)
- ✓ fuel element burn-up - 72 MW·day/kgU
- ✓ operation in maneuver mode (100-75-100 % Nel)
- ✓ protection from foreign objects
- ✓ maintainability under NPP conditions

TVSA-PLUS

TVS-2M

VVER-1000 Nuclear Fuel



VVER-1000 Nuclear Fuel Prospects

4th generation FA for VVER-1000

- ✓**fuel column 3680 mm;**
- ✓**fuel pellet 7.8x0 m;**
- ✓**12 spacer grids;**
- ✓**mixing grids;**
- ✓**tail with ADF;**
- ✓**anti-vibration low unit.**

Stages of development	
Technical design	2012
Beginning of pilot operation	2014

Result of implementation:

increase of fuel cycle duration by 8 %,
or **reduction of make-up FA by 10%,**
or **reduction of make-up enrichment by 7%,**
or **power increase by 10%**

Development of Nuclear Fuel for VVER-1200/1300
Directions of Development

FA basic design

Nт= 3200 MW
Fuel cycle from 300 to 540 effective days
Enrichment up to 4.95%
Pellet 7.6/1.2mm,
Reactor core height 3730 mm
Weight UO_2 534 kg
Burn-up
64 MW day/kg U
Daily maneuver
100-75-100 % Nэл
Fuel delivery -12.2012

Development of FA design

Nт= 3300 MW
Enrichment 4.95%
Pellet 7.8/0мм
Reactor core height 3730 mm
Weight UO_2 580 kg
Heat exchange intensifiers
Daily maneuver 100-50-100 %
Project correction -2015

Increase of enrichment by more than 5 %

Enrichment up to 7%
Uranium-erbium fuel
Zirconium alloys Э110М, Э635М and Э125

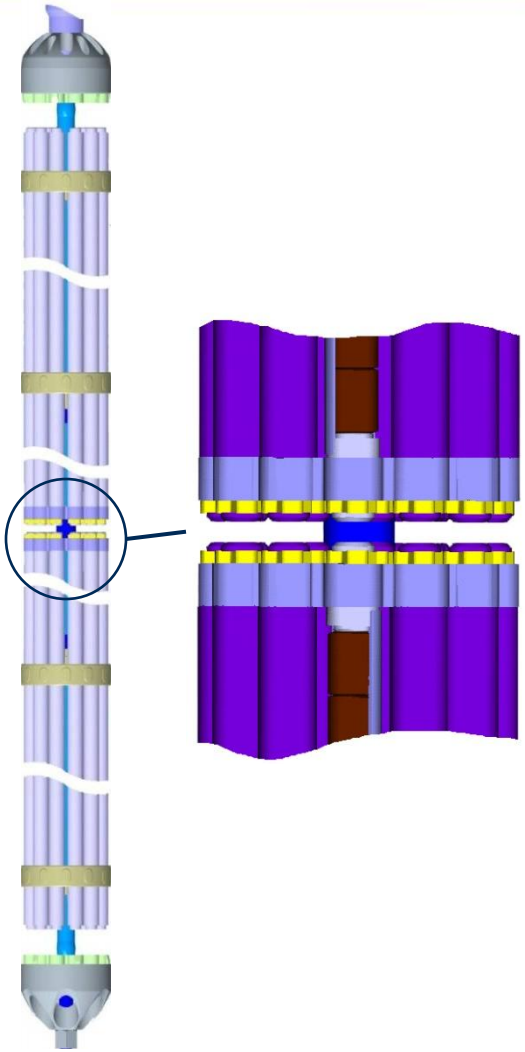
Validation and development of design - 2018

2-year cycle
(680 effective days fuel cycle)
Reduction of make up FA number by 20%
Improvement of average fuel burn-up by 20-25 %
Reduction of fuel cost by 6 - 9 %

Improvement of calculation codes:

- Development of codes for thermal hydraulic and neutron physical calculations of reactor core;
- Improvement of calculation methods for supply by local parameters before heat exchange crisis;
- Application of methods and codes of «best assessment»;
- Application of statistical methods for calculation of engineered safety margin.

Nuclear Fuel for RBMK-1000



TVS RBMK-1000
With central fixation of fuel element

Enrichment 2,6% ^{235}U + 0,41%Er.
100 FA have been operated at Leningrad-2 since 2002
Max. burn-up - 31 MW·day/kgU.
Average burn-up– 26 MW·day/kgU.

TVS-C RBMK-1000
of advanced design

Enrichment 2,8% ^{235}U + 0,6%Er.
In 2014 the first batch is planned for loading at Leningrad-3.
Maximum burn-up– 34,5 MW·day/kgU.

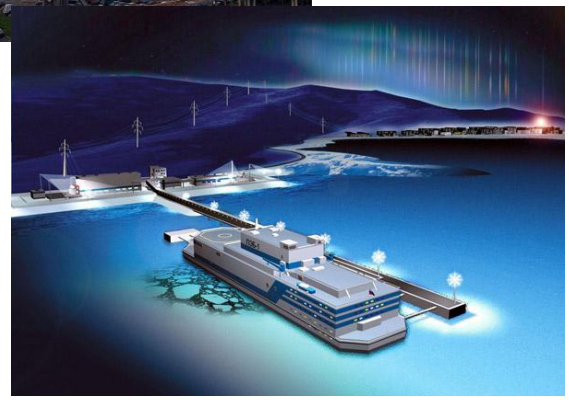
Design Materials
Application of Zirconium Alloys

VVER

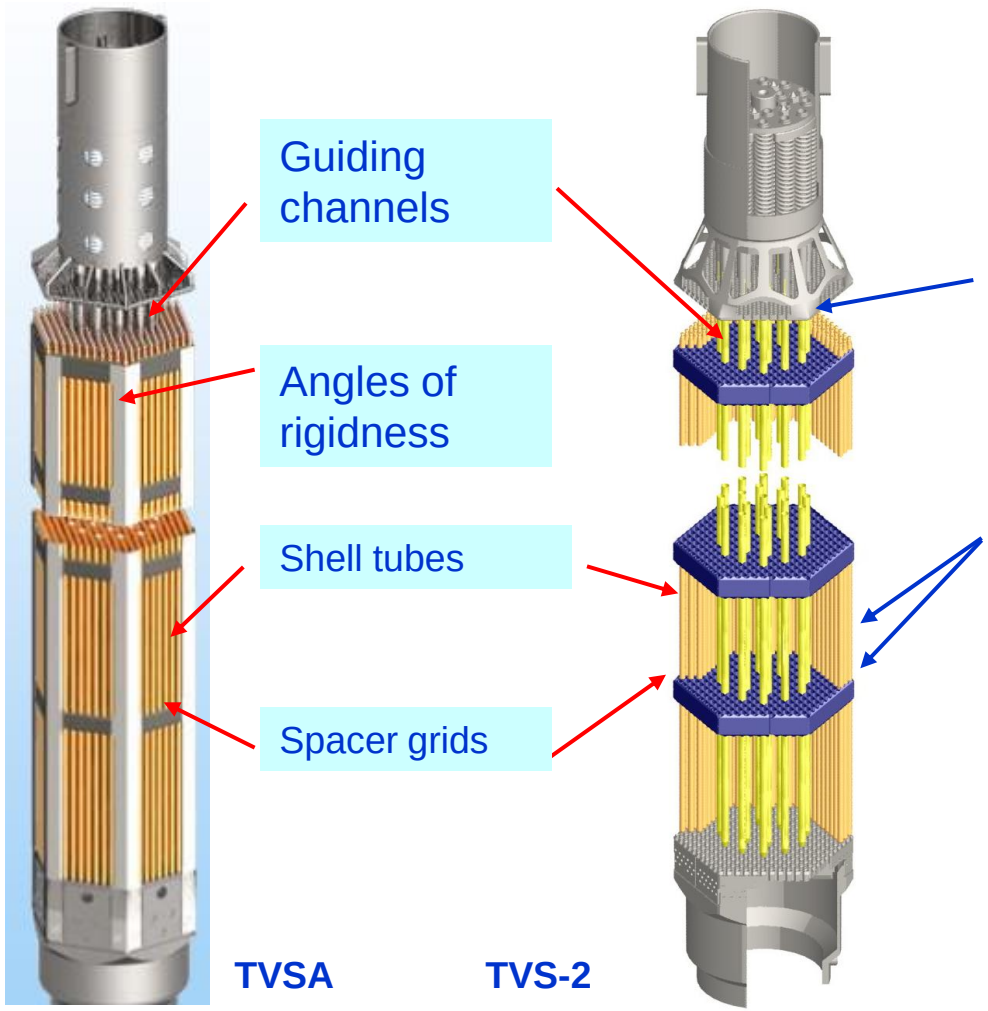
Zr-alloys
(System Zr-Nb)

RBMK

РЕВ
(ПЭБ)



Design Materials
Application of Zirconium Alloys



Industrial Zr-alloys for fuel assemblies of VVER-1000 reactors:

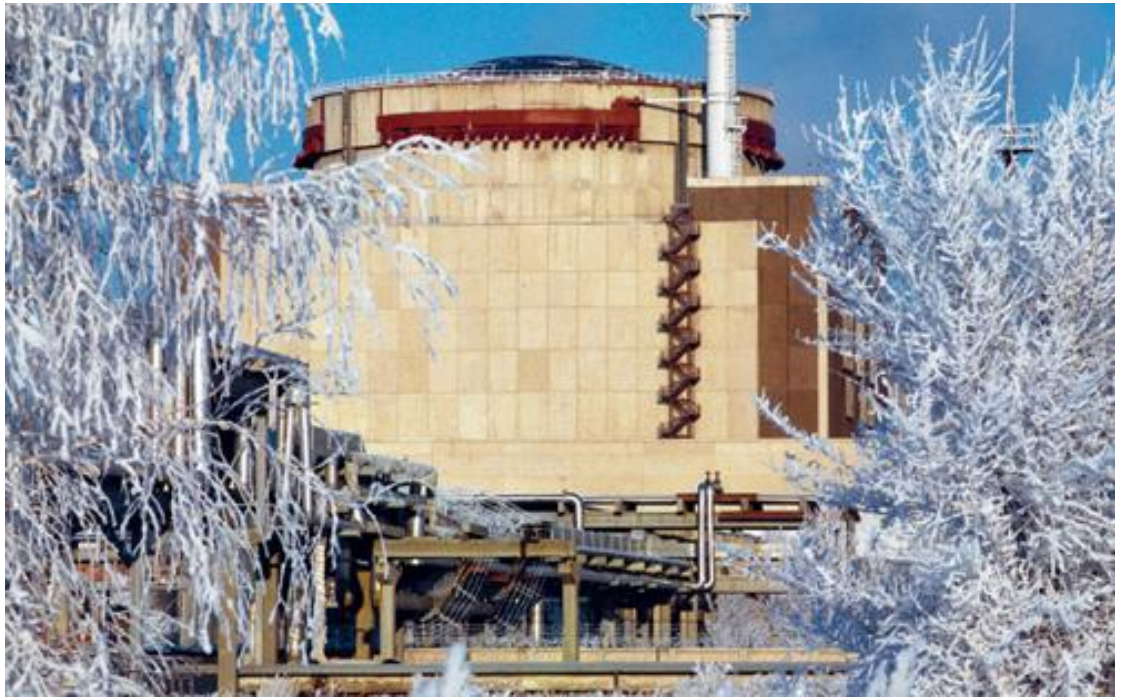
Э635 – guiding channels and central tubes of TVSA and TVS-2, TVSA angles of rigidness;

Э110 – fuel element cladding and plugs, spacer grids;

Э125 – casings for Novovoronezh-5 VVER-1000

Development of Zirconium Materials Modified Alloys Э110М, Э635М, Э125опт.

Operation of three fuel assemblies TVS-2M with pilot fuel elements and fuel cladding made of alloys Э110М, Э635М и Э125 опт. in VVER-1000 reactor since 2012.



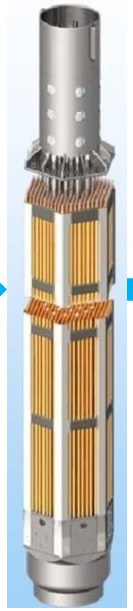
Balakovo-2

Testing of New Generation Fuel Elements

(pellets with ц.о. 1,2 mm, pellets without ц.о., pellets with a big grain)

Kalinin NPP,
Kola NPP

2010



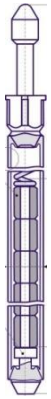
TVSA

2011

Hot chamber

2012

Production of experimental fuel elements

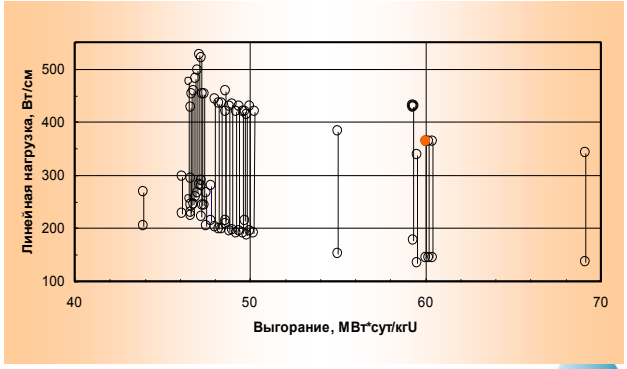


2012

Reactor MIR

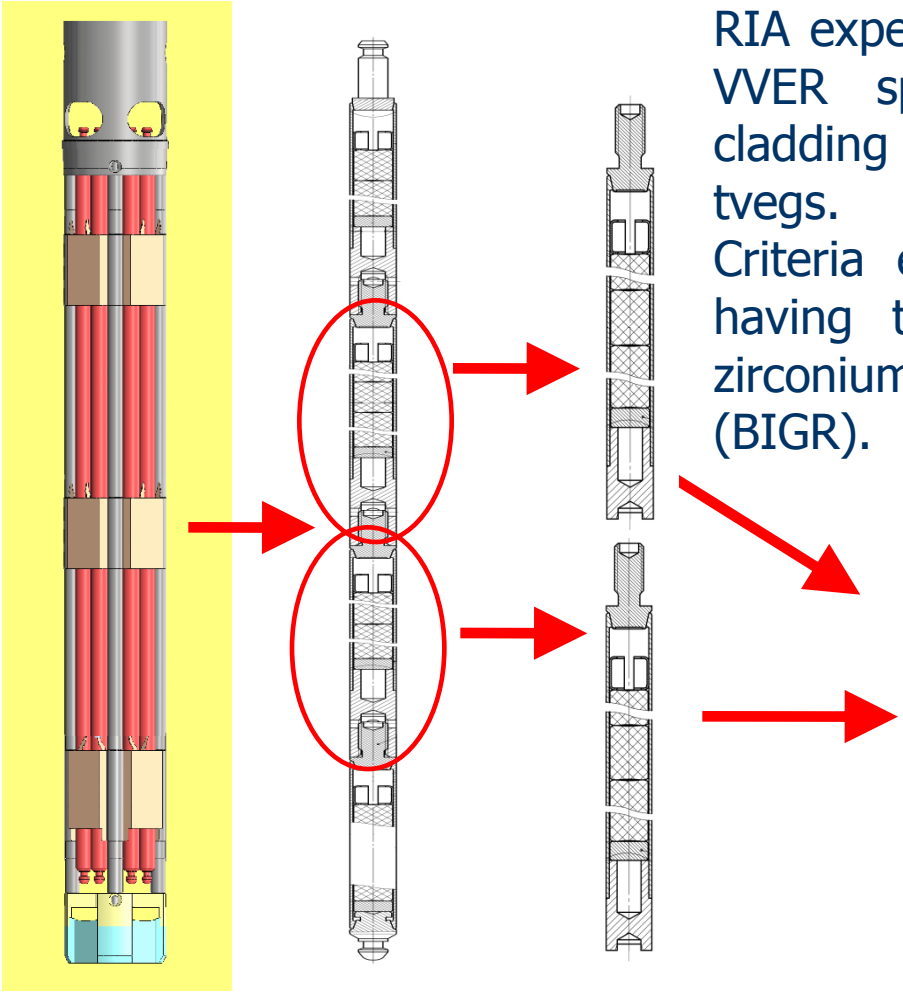
RAMP

2013-14



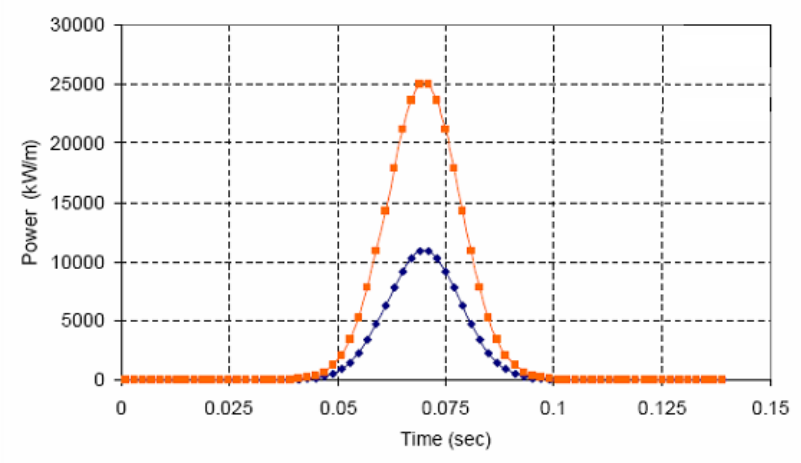
Experimental Support of Criteria

Fuel element testing under RIA conditions (2013-15)



RIA experiments in MIR reactor water loop with VVER spent fuel elements having thinned cladding and pellets without zirconium and with tvegs.

Criteria experiments with spent fuel elements having thinned cladding and pellets without zirconium and with tvegs at pulse reactor (BIGR).



Experimental Support of Criteria

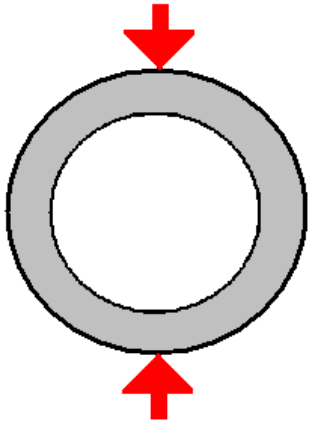
Fuel element testing under LOCA conditions (2013-15)

Non-irradiated fuel cladding

Irradiated fuel cladding (BOR-60, MIR)

Fuel cladding after NPP

LOCA



Conclusion (1)

1. The work presented is a result of activities of scientific and design companies headed by and ordered by JSC «TVEL»: «Kurchatov Institute», «VNIINM», «OKB GYDROPRESS», «OKBM Afrikantov», «NIKIET», «GNC NIIAR», «GNC RF-FEI», GNC RF TRINITI, as well as manufacturers - «MSZ», «NZKhK», «ChMZ» and «MZP».

Conclusion (2)

2. JSC «TVEL» marks out a high level of interaction with JSC «Rosenergoatom» in the field of new fuel type implementation and thanks its colleagues for effective cooperation.

THANK YOU!