ТОПЛИВНАЯ КОМПАНИЯ РОСАТОМА

ТВЭЛ

РОСАТОМ

ГОСУДАРСТВЕННАЯ КОРПОРАЦИЯ ПО АТОМНОЙ ЭНЕРГИИ «РОСАТОМ»

NUCLEAR FUEL FOR NPP: CURRENT STATUS AND MAIN FIELDS OF THE DEVELOPMENT

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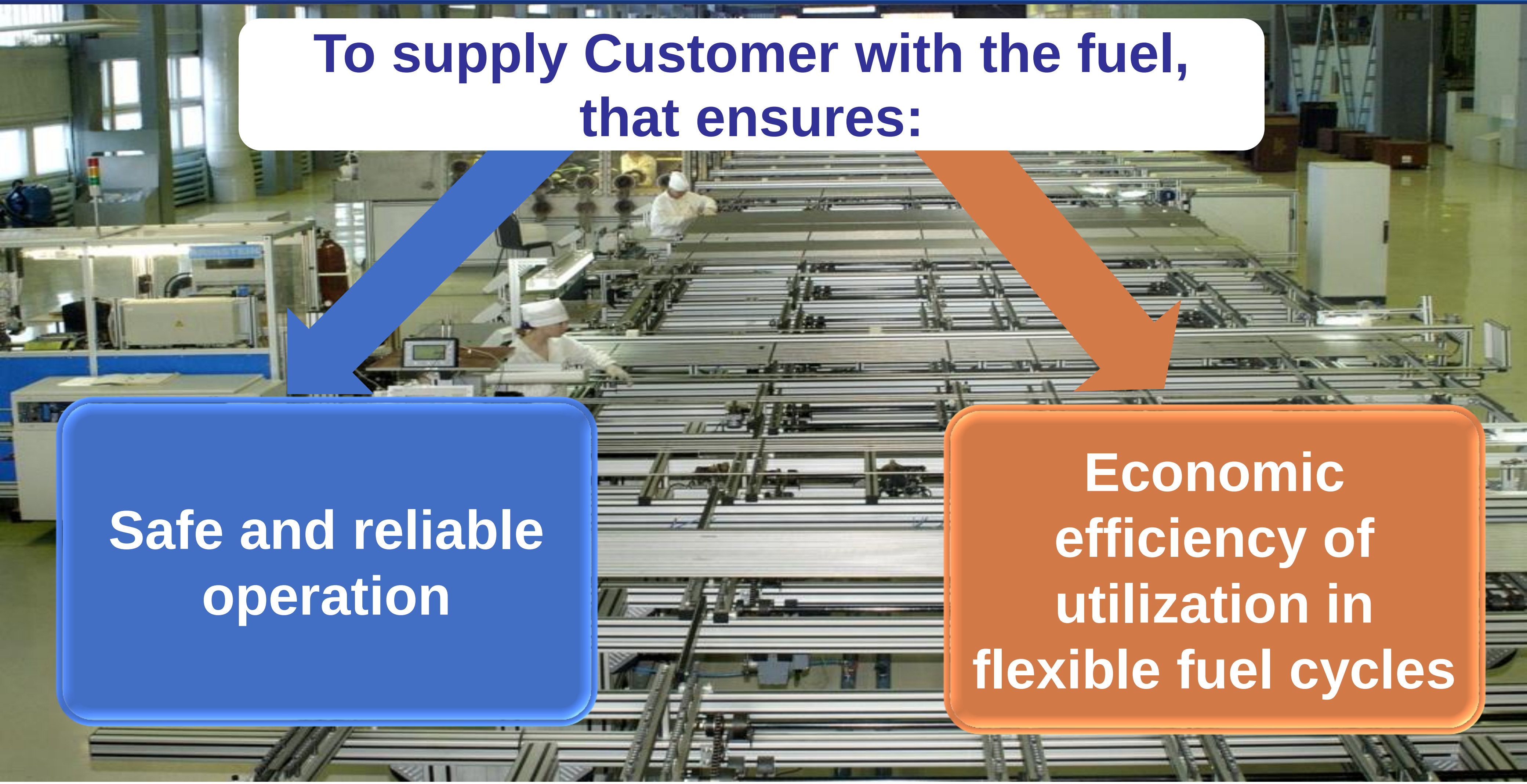
International Conference VVER 2013
12.11.2013, Prague, Czech Republic

Our Goal



To supply Customer with the fuel, that ensures:

Safe and reliable operation

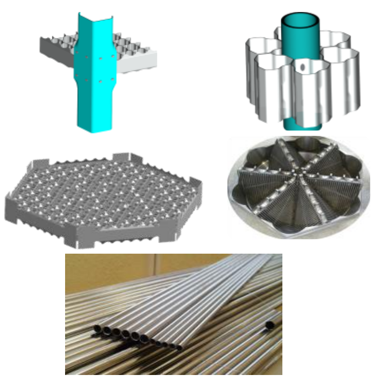
Economic efficiency of utilization in flexible fuel cycles

Nuclear fuel design and manufacturing technology development – the main course of Fuel company competitiveness

Customer's requirements to Nuclear Fuel

Safety

- Experiment-calculated justification of fuel safety in normal operation conditions and design accidents
- Innovative constructive and fuel materials development



Reliability

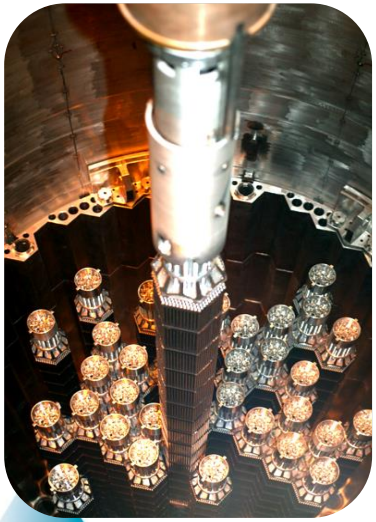
- Improvement of normative-methodological base for designing, manufacturing and operation of nuclear fuel
- Development of QMS
- Improvement of FA skeleton rigidity
- DF implementation
- AVG implementation
- Mixing grid implementation
- Improvement of constructive and fuel materials

Efficiency

- Increase in fuel burnup
- Increase in fuel lifetime
- Increase in fuel cycle length
  - Computer codes and fuel design methodology development
  - Change of fuel rod geometry in order to increase uranium mass
  - Higher enrichment level
- Substantial of fuel behavior in load-follow modes
- Substantial of fuel behavior at higher RP thermal power

Competitive price

- Unification of fuel design
- Improvement of conversion, enrichment and manufacturing technologies



VVER-440 Nuclear Fuel

FA of the second generation
Enrichment 4.87% Fuel pellet 7.6/1.2

- Kola NPP since 2010;
- Mohovce NPP since 2011;
- Bogunice NPP since 2012.

RK-3 of third generation
Enrichment 4.87% Fuel pellet 7.8/0

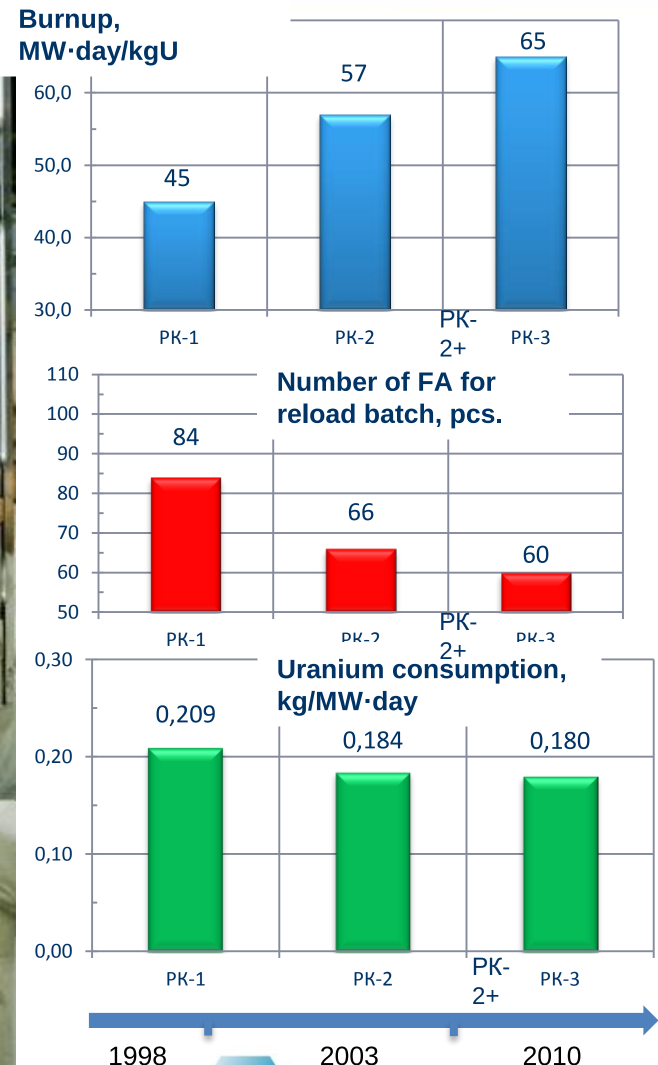
- at Kola NPP since 2010.

FA of the second generation with intensification tabs on SG

- Loviisa NPPP since 2012.

Units thermal power uprate on the base FA of the 2nd generation

- Kola NPP (Units 3,4) – 107%;
- Mohovce NPP – 107%;
- Bogunice NPP – 107%;
- Dukovany NPP – 105%;
- Paks NPP – 108%;
- Loviisa NPP – 109%.



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VVER-440 Nuclear Fuel

Second generation fuel
Enrichment 4.76%
Pellet 7.8/0 мм

Fuel cycle - 6-year when operating at 1485 MWt (thermal).
Type of fuel rod bundle – profiled, U-Gd.
Number of fuelling cassettes – 60
Burnup- 65 MW day/kgU per fuel rod
Operation in load-follow mode.

Technical documents set to substantiate the project of introduction at Dukovany NPP, Czechia, is developed.

Expected effect of introduction – lower number of cassettes for reloadingc ~7% compared with second generation fuel cassettes with fuel 4.87% and pellet 7.6/1.2 mm.

VVER-440 Nuclear Fuel

RK-3 design – without the shroud tube, skeleton formed by angels and tubes.
Mass of UO_2 - 132 kg (increased by 4.5%).
Fuel rod pitch in the bundle increased from 12,3 to 12,6 mm.
Fuel cycle – 6 x 1 year.
The expected benefit of RK-3 implementation – increase in fuel consumption efficiency about 10% as compare to FA of the second generation.

Pilot batch operation (12 FAs) started at Kola NPP Unit 4 in 2010. Results are positive
Extension of RK-3 usage at Kola NPP is expected in 2017 after transition to core control by local parameters in 2015.

VVER-440 Nuclear Fuel Stages of development

years	before 1998	after 1998	after 2003	after 2010
FA type	Regular RK, with shroud	Regular RK, with shroud	2-nd generation RK, with shroud	2-nd / 3-d generation RK
Fuel rod bundle type	Nonprofiled	Profiled	Profiled, UGd	Profiled, UGd
Fuelling enrichment, % U^{235}	3.60	3.82	4.25 / 4.38	до 4.87
Fuelling FA, pcs.	105	84	66	60
Burnup, MW·day / kgU	36	45	57	65
Fuel cycle	3-year	4-year	5-year	6-year
Natural U consumption, kg /MW ·day	0.256	0.209	0.184	0.180

Nuclear Fuel for VVER-1000

TVSA-PLUS (TBCA-12PLUS in 2014) and TVS-2M have identical techno-economic characteristics which provide:

- ✓ capability to increase reactor thermal power up to 104 % of nominal
- ✓ 18 months fuel cycle (reload batch of 66 pcs.)
- ✓ fuel rod burnup - 72 MW·day/kgU
- ✓ capability to operate in load-follow modes (100-75-100% Ne)
- ✓ protection from foreign materials
- ✓ capability for repair at NPP site

TVSA-PLUS

TVS-2M

VVER-1000 nuclear fuel
TVSA-T for Unit 1 and 2 Temelin NPP

Main solutions

- ✓ compatibility with VV6 fuel
- ✓ 8 combined grids (SG+MG)
- ✓ fuel column 3680 мм high (blankets 2×150 мм)
- ✓ fuel pellet 7.6/1.2 мм
- ✓ mass of UO_2 in cassette 524.1 kgU
- ✓ burnup per fuel rod 72 MW day/kgU

Nuclear Fuel for VVER-1000
TVSA-12

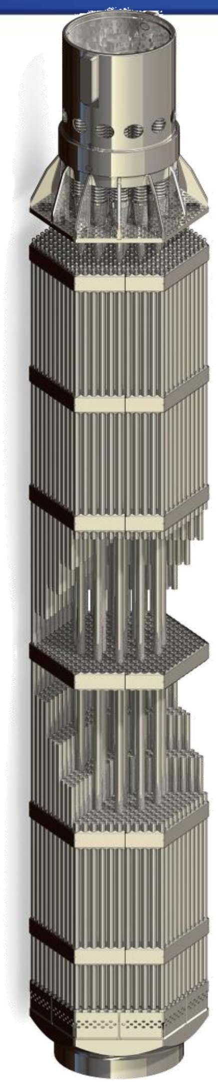
- **TVSA-12 design**
  - **12 SG 35 mm height**
  - **fuel column length 3530 mm**
  - **fuel pellet ∅7,8/0 mm**
- **Geometrical, thermal-hydraulic, neutron-physics and thermal-mechanical compatibility with TVSA is provided**
- **12 pilot TVSA-12 were loaded at Kalinin-1 in 2011. Results of operation is positive**
- **2013 - justification and licensing in Ukraine.**
- **2013-2014 - justification and licensing in Bulgaria.**
- **Delivery of the first batch of TVSA-12 at Rovno-4 planned in 2014**

FA type	TVSA	TVSA-12
Hydraulic loss coefficient for FA with DF	12,1	12,5
Number of SG / height of SG (mm)	15 / 20	12 / 35
Skeleton bowing rigidity, N/mm	55	61,5

VVER-1000 Nuclear Fuel Stages of development

years	before 1997	1998–2010	after 1998	after 2003	after2006	after 2006/ after 2010	after 2011
FA type	TVS, TVS-M	AFA	TVSA	TVS-2	TVSA-Alpha	TVS-2M/ TVSA-PLUS	TVSA-12
Absorber type	–	U-Gd	U-Gd	U-Gd	U-Gd	U-Gd	U-Gd
Fuelling enrichment, % U^{235}	4.31	3.77	до 4.4	4.26	4.83	4.88	4.83
Number of fuelling FA	54	48	42	54	36	60 – 66	36
External diameter, мм	7.57 / 2.3	7.57 / 1.5	7.57 / 1.4	7.57 / 1.4	7.8 / 0.0	7.6 / 1.2	7.8 / 0
Fuel burnup, MW×day/kgU	49	49	55	55	65	65	65
Fuel cycle	3×1	3×1	4×(310–320)	3 ×(350–370)	5 ×(310–320)	3 ×(480–510)	5 ×(310–320)
U consumption, kg/MW×day.	0.240	0.205	0.199	0.210	0.187	0.230	0.187

FA of 4th generation for VVER-1000



TVS-2M

12 SG, MG, DF,

Fuel column – 3680 mm,

Unified top nozzle

TVSA-PLUS

DF,

Fuel column – 3680 mm

TVSA-ALFA

SG, DF,

fuel pellet ∅7,8/0 mm

FA of 4th generation

Unified top nozzle

12 SG, MG, DF

Fuel column– 3680 mm

Fuel pellet ∅7,8/0 mm

$UO_{2\ mass}$ - 568,4 kg

Fuel cycle 3x510 or 5x333

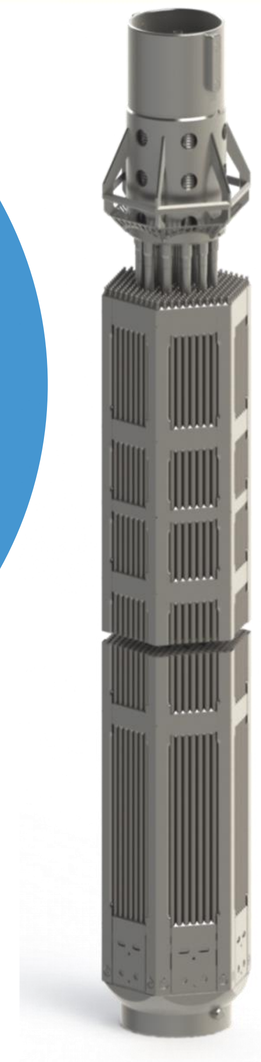
increase in fuel cycle length at 8 %

of

reduction in number of FA at 10%

or

decrease in reload batch enrichment at 7%



Stages of development	
Design documentation	2012
Rosatom scientific meeting #2	2013
Pilot operation	2015

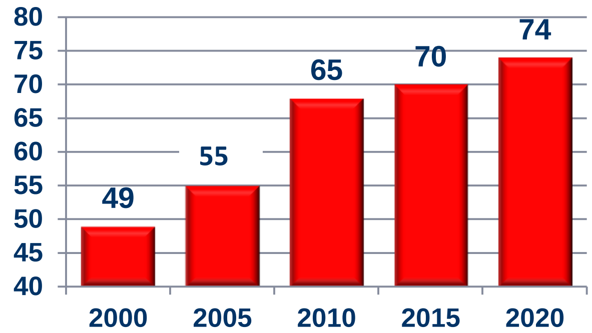
VVER-1000 fuel cycles, thermal power 104 % N_{nom}

TVS-2M	Operation in fuel cycle 3×18 months	 Balakovo NPP Rostov NPP Tyanvan NPP
TVSA-PLUS TVSA-12PLUS	Operation in fuel cycle 3×18 months	 Kalinin NPP
TVSA-T TVSA-12	Operation in fuel cycle 5×12 months	 Temelin NPP NPP of Ukraine (planned) Kozloduy NPP (planned)

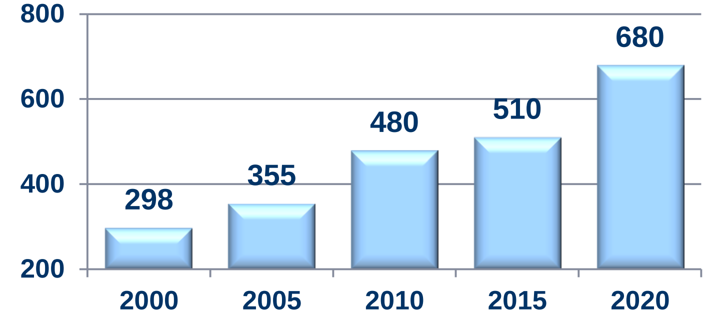
Development of Nuclear Fuel for VVER-1000/1200/1300

-Development program for Ukrainian NPP - 2012, Kozloduy– 2013
- start of pilot operation for Ukrainian NPP – 2014, Kozloduy – 2015

Maximum FA burnup, MW·day/kgU



Fuel cycle length, EPFD



TVSA-12
Fuel pellet 7.8/0mm
Active length 3530 mm

TVSA-PLUS
TVS-2M
Fuel pellet 7.6/1.2mm
Active length 3680 mm

-amendment to TVSA-PLUS design with 12 SG was developed – 2012
- start of pilot operation of TVSA-12PLUS – 2014
-Implementation of TVS-2M at Tyanvan, Kudankulam and Busher NPPs

TVS-4A
TVS-4
Fuel pellet 7.8/0mm
Active length 3680 mm

- fuel rod, U-Gd fuel rod and FA designs are developed in 2012
- experimental justification of fuel rod design – 2012-2015
- pilot batch delivery – 2015

TVS-2006
RP power 3200 MW
Active length 3730 mm

- the first core for unit 1 NVNPP-2 (VVER-1200) is fabricated – 2012
- further development of FA-2006 design (mixing grids implementation, modified Zr alloys) – 2012-2015

TVS-TOI
RP power 3300 MW
Active length 3730 mm

-fuel rod, U-Gd fuel rod, RCCA and FA designs are developed in 2012
-Improvement of TVS-TOI design, justification in load-follow modes 100-50-100% – 2013-2017

TVS-XXI
Enrichment upto 7%
U-Er poison
New cladding and structure material

- development of fuel rod and FA designs with enrichment up to 7% – 2012-2017
- development of innovative materials for reactor testing – 2013-2020

TVS-XXI

New safety criteria

- Development of ceramic claddings for VVER type reactor is ongoing.
- Other possible materials for claddings are being considered.

Ensuring of prospective fuel cycles, increasing fuel utilization efficiency

- Development of U-Er fuel with enrichment up to 7% U-235.
- Development of fuel pellets with profiled enrichment and grain size by radius.
- Development of technology for burnable absorber application on guide thimbles and claddings.

Justification of new types nuclear fuel safety

- Development of U-Be fuel with high thermal conductivity for VVER.
- Experiment-calculated justification of safety behavior of nuclear fuel with solid pellets in design accidents.

Development of Nuclear Fuel fabrication technology

technical re-equipment of rolling production

Blank: Ø109 mm
Mills HTP, HPTR
Etching in bath.

Enlarged blank Ø199 mm, new technological processes with usage of:
- press of 35 MH;
- radial forging machines SKK14,10;
- rolling mill KPW 75,50,25,18 with ring calibers;
- polishing (LOESER), jet-etching;
- cladding cutting in size, laser marking.

- Claddings production with up the art level characteristics
- Zirconium rolling production for TVS-K abd foreign customers (AECL, GNF/GE,KEPCO)
- Cost decrease because of product's higher quality, less power consumption and labor.

Claddings characteristics

	Before	*After*
wall thickness, mm	*0,63*	*0,54*
diameter tolerance, mm	*±0,05*	*±0,04*
polythickness, mm	*no*	*≤0,05*
roughness, Ra, мкм	*1,0*	*0,6*
hafnium content, ppm	*≤ 500*	*≤ 50*

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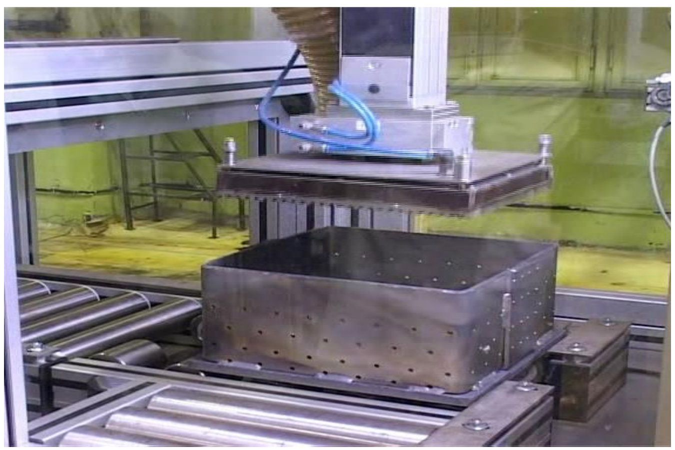
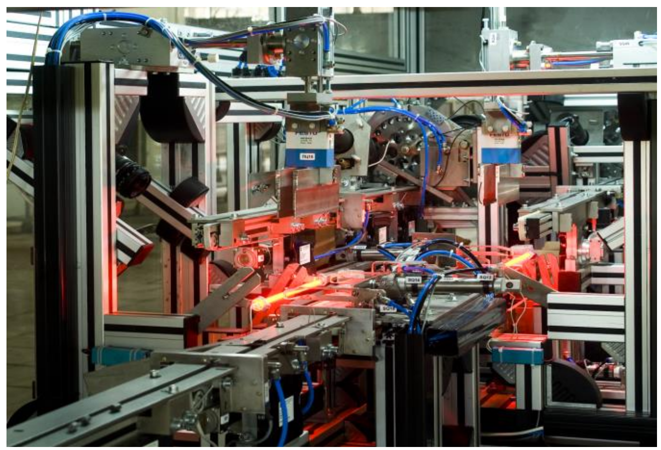
Development of Nuclear Fuel fabrication technology

Section for producing uranium dioxide powder by “dry” conversion technology

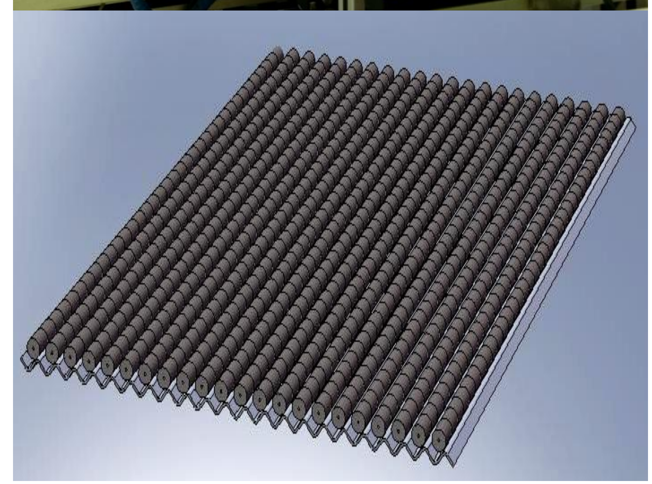
Line for producing pellets



Stacker of pressed pellets in trough for sintering



Equipment for optical inspection of pellets appearance



Fuel pellets on pallets

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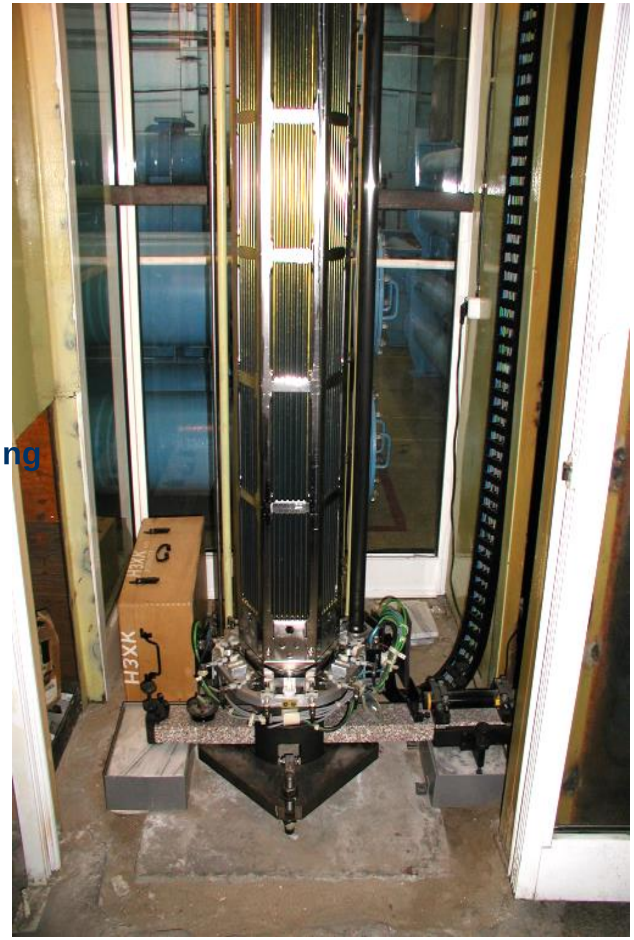
Development of Nuclear Fuel fabrication technology

Line for fuel rod fabrication

Robotized complex for assembly and welding of FA skeletons



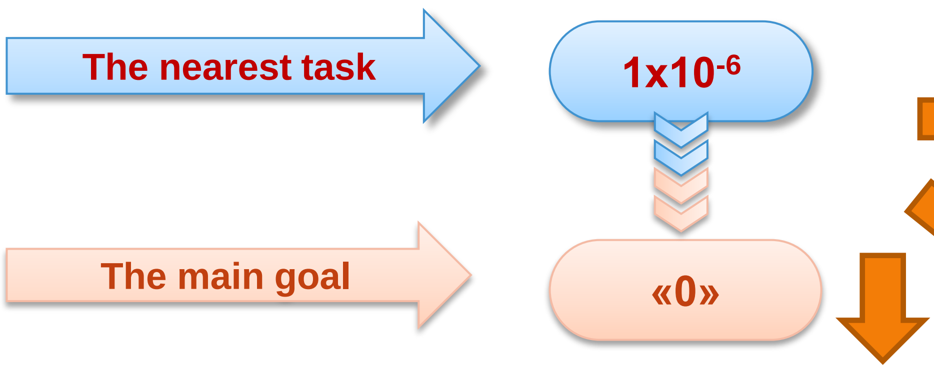
Optical bench for FA geometry inspection

Automated bench for fuel bundle assembly

Robotized complex for spot welding of spacer grids

Driving to zero failure

TVEL initiative



Participants of Memorandum

- Concern Rosenergoatom

Foreign Utilities

- CEZ a.s., (Czech Republic)
- NAEK Energoatom, (Ukraine)
- Kozloduy NPP, (Bulgaria)

Fuel Vendor

- TVEL

Currently within the frames of the Project:

- ✓ Memorandum TVEL-REA is signed
- ✓ 4 sided Memorandum is signed
- ✓ Regulation on Project activity is valid
- ✓ Steering Committee and Working Body are established
- ✓ Working Groups (WG) on design, fabrication and operation are formed
- ✓ Schedules of work for WG are developed
- ✓ Intergroup communication and information exchange on the Project are arranged

Project Stages:

Stage 1: 2013-2014
Analysis of situation and root cases of fuel failures definition

Stage 2: - 2014-1015
Development of organizational and technical actions for fuel failures elimination

Stage 3: 2015-2017 г. г.
Implementation and monitoring of actions at Participant’s and fuel developer’s enterprises.

Driving to zero failure

TVEL initiative

The nearest task → **1×10^{-6}**

The main goal → **«0»**

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Conclusion

- New FA designs
- Modern designing methods
- New automated technologies of nuclear fuel fabrication
- Driving to Zero Failure

- Increase in safety and reliability of operation
- Increase in economical efficiency of fuel utilization
- Decrease in amount of spent fuel

Rise of competitiveness and social acceptability of nuclear power generation

Thank you for your attention!