Perspective Decisions of WWER Nuclear Fuel: Implementation at Russian NPPs

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Enhancing effectiveness of nuclear fuel at NPPs

The industry program "Effective use of nuclear fuel at NPPs for the period 2002-2010".

Elaborated by JSC TVEL, coordinated with ROSENERGOATOM Concern and approved by MINATOM of Russia in 2002.

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The ways of enhancing effectiveness of nuclear fuel at NPPs

New FA design

Perspective fuel cycles at NPPs

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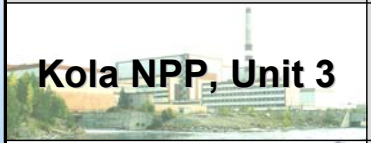
Advanced fuel at Russian NPPs

With the support of ROSENERGOATOM Concern a trial commercial operation of new fuel at Russian NPPs, equipped with WWER-type reactors, is currently under way.

NPP, Unit	FA type	Start of operation
 Kola NPP, Unit 3	The second generation working FA and control FA	2002
 Kalinin NPP, Unit 1	FA-A (TVSA)	1998
 Balakovo NPP, Unit 1	FA-2 (TVS-2)	2003

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Requirements for new generation WWER nuclear fuel

1. High fuel burnup – up to 70 MW×days/kgU;
2. Extended operation cycle – up to 6 years;
3. Increase of uranium charge to the core;
4. Increased lateral stability – bow not more than 7 mm;
5. High level of operating reliability – fuel rod leakage not worse than 10^{-5} 1/year;
6. Dismountable FA design.

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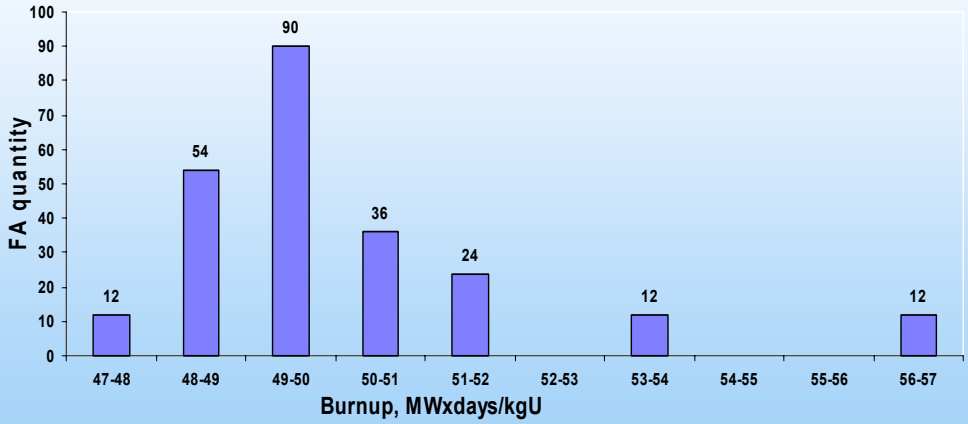
Burnup increase

Goal: complete use of FA potential, justification of 6-year fuel cycles

Implemented at WWER-440:



Quantity of FAs with 4.4% enrichment discharged after 5-6 years of operation from Kola NPP, Unit 3 and their burnup

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Burnup increase

Goal: complete use of FA potential, justification of 5-year fuel cycle

Implemented at WWER-1000:

FA-M (TVS-M) have reached burnup of 55.6 MW×days/kgU after 4 years of operation at Balakovo NPP, Unit 3.
6 TVSA have reached burnup of 51.9 MW×days/kgU (60.4 MW×days/kgU for fuel rod) after 5 years of operation at Kalinin NPP, Unit 1. 2 TVSA from them were left in 2003 for the 6th year of operation to reach burnup of 56.0 MW×days/kgU (up to 66.0 MW×days/kgU for fuel rod).

Trial commercial operation of 6 TVSA-5 at Kalinin NPP, Unit 1 started in 2003 (maximum fuel rods enrichment – 4.95%). Estimated burnup – up to 65-70 MW×days/kgU for fuel rod.

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Burnup increase

PIE results of FAs discharged from WWER-1000 reactors demonstrate that fuel rods have substantial reserve in general characteristics including that of dealing with planned burnup:

- **oxide film on the surface of fuel rods' cladding does not exceed 15 μm;**
- **fission gas release does not exceed 3%;**
- **cladding condition – satisfactory.**

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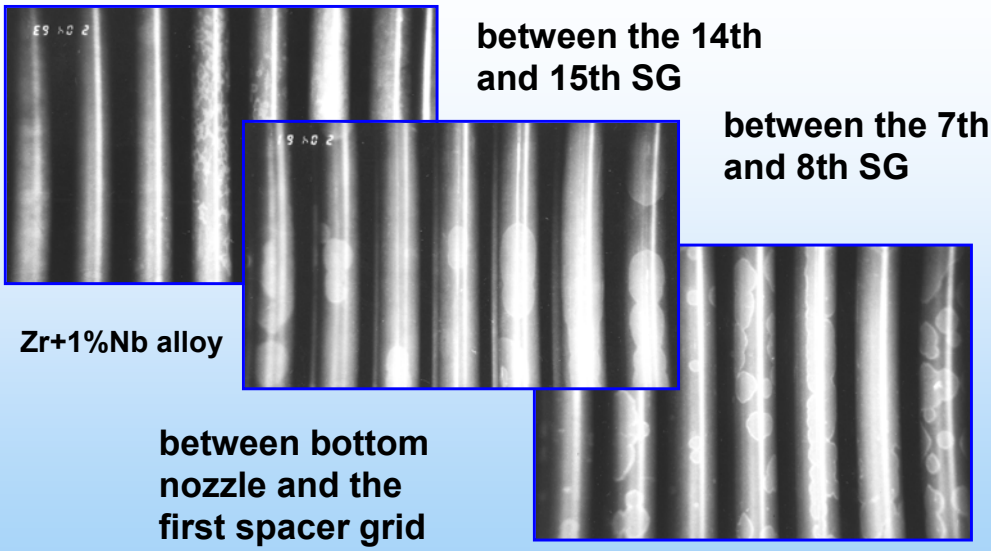
Burnup increase



between the 14th and 15th SG

between the 7th and 8th SG

Zr+1%Nb alloy

between bottom nozzle and the first spacer grid

External view of fuel rods with burnup of 55.6 MW×days/kgU after 4 years of operation at Balakovo NPP, Unit 3

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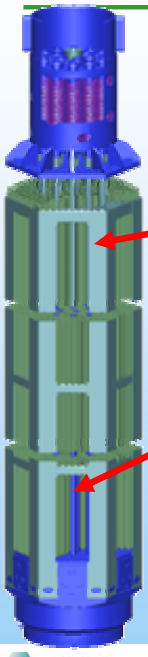
Use of E-635 alloy
(operation resource)



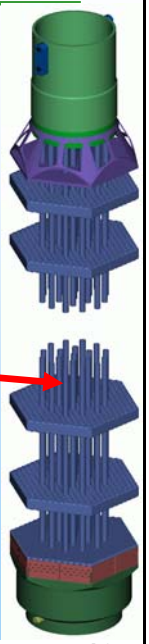
Goal: increase of FA skeleton strength properties

TVSA

TVS-2, AFA (UTVS)

Angle pieces

Guiding channels



Use of E-635 alloy in FA designs started at Balakovo NPP and Kalinin NPP in 1997

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Introduction of rigid skeleton
(operation resource)

Goal: increase of FA resistance to bow, core "straightening", extension of operation resource

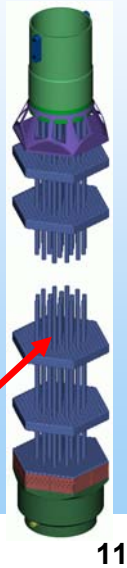
Implemented at WWER-1000:

Operation of TVSA started in 1998 at Kalinin NPP, Units 1,2

Skeleton formed by 6 angle pieces and 15 spacer grids welded to them

Trial commercial operation of TVS-2 has begun at Balakovo NPP, Unit 1 since 2003

Skeleton formed by 18 guide channels and 15 spacer grids welded to them



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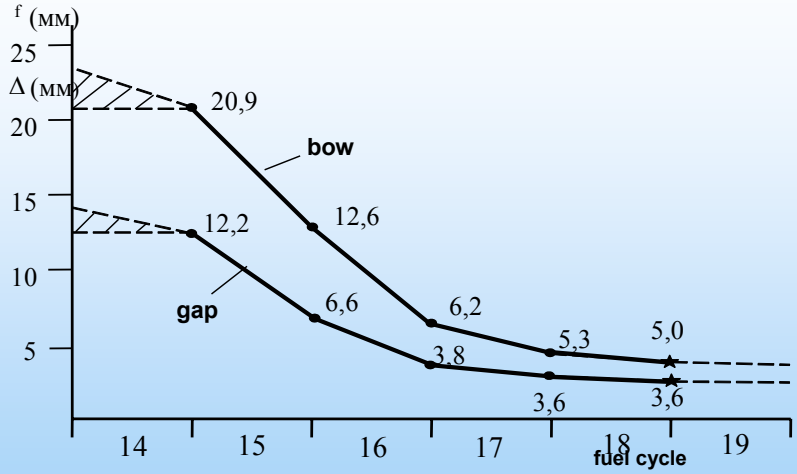
Introduction of rigid skeleton
(operation resource)



Change of TVSA bow and gap between assemblies at the end of the 14-18th campaigns at Kalinin NPP, Unit 1.

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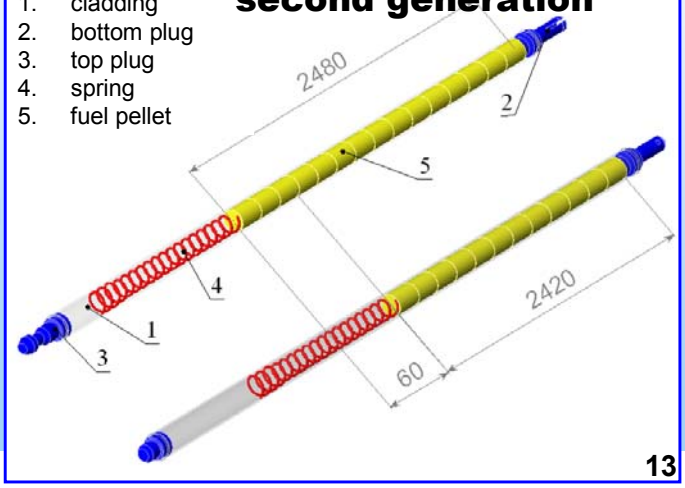
Fuel column length extension
(increase of uranium charge)

Goal: increase of uranium content, extension of operation cycle, reducing of linear heat rate

Working FA of the second generation

1. cladding
2. bottom plug
3. top plug
4. spring
5. fuel pellet



Implemented at WWER-440 :
Trial commercial operation of the second generation working FA started at Kola NPP, Unit 3 in 2002. Uranium weight has been increased up to 126.3 kg by 6 kg.

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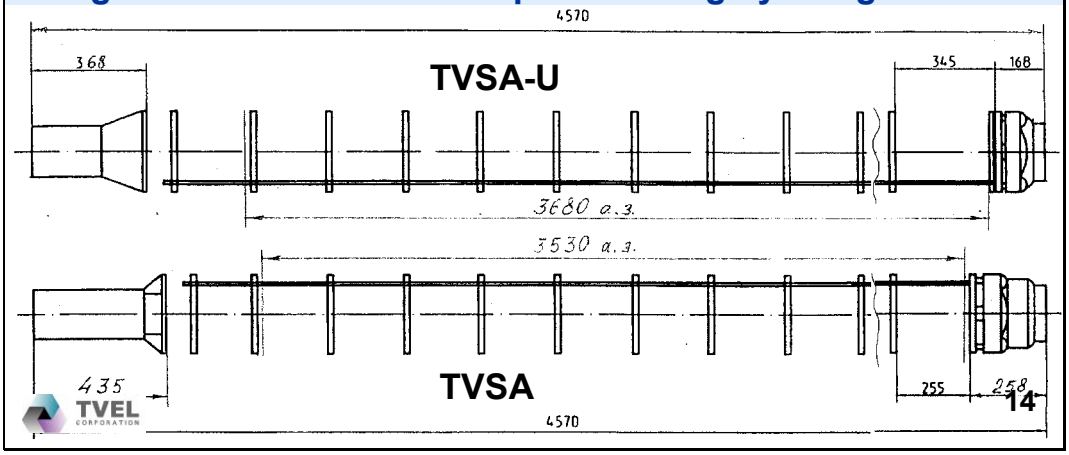
Fuel column length extension
(increase of uranium charge)

TVSA-U: Fuel column length extension by 150 mm, use of blankets from depleted uranium

Implemented at WWER-1000: Trial commercial operation of 3 TVSA-U started at Kalinin NPP, Unit 1 in 2003. Uranium weight has been increased up to 515.4 kg by 21 kg.



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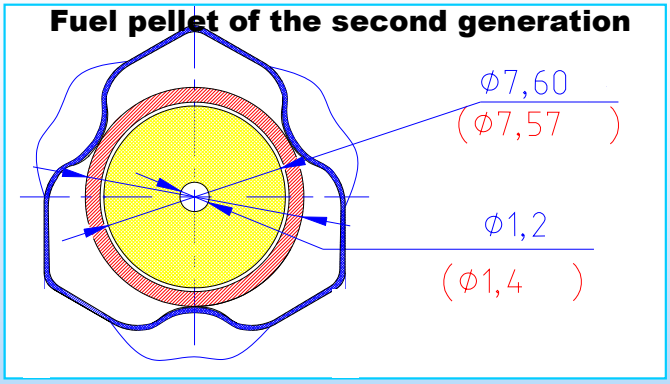
Increase of UO_2 charge

Goal: extension of operational cycle

Implemented at WWER-440:
Trial commercial operation of the second generation FA started at Kola NPP, Unit 3 in 2002.



Implemented at WWER-1000:
Trial commercial operation of 6 TVSA-5 started at Kalinin NPP, Unit 1 in 2003. Uranium weight has been increased up to 500.6 kg by 6 kg.

Enhancing of operating reliability

Goal: fuel rod reliability level not worse than 10^{-5} 1/year

Implemented at WWER-440:

Trial commercial operation of working fuel assemblies with vibration proof bundle started in 1999 at Novovoronesh and Kozloduy NPPs.

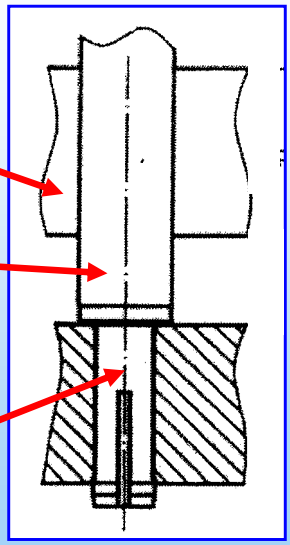
The main features:
- Welded joint of central tube;
- The first spacer grid is at the distance of 80 mm;

According to the results of operation, the working fuel assemblies demonstrate higher level of reliability in comparison with the regular design.

Enhancing of operating reliability

Goal: fuel rod reliability level not worse than10^{-5} 1/year

Implemented at WWER-1000:
Trial commercial operation of 12 TVSA with antivibration grid has begun at Kalinin NPP, Units 1,2 since 2003.



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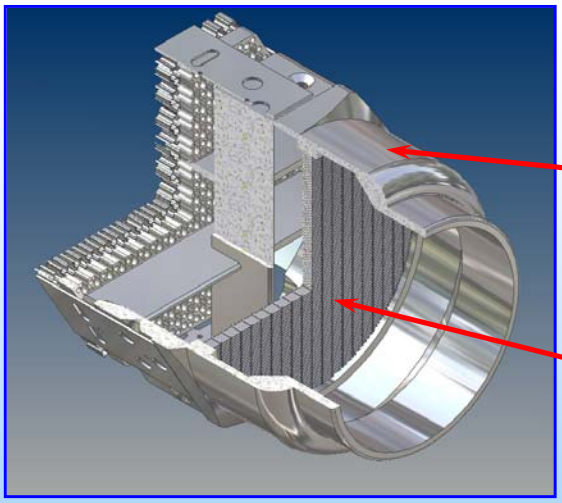
Enhancing of operating reliability



Implemented at WWER-1000:
Trial commercial operation of two TVSA with debris filter has begun at Kalinin NPP, Unit 2 since 2003.

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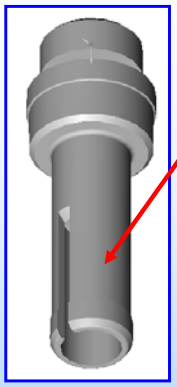
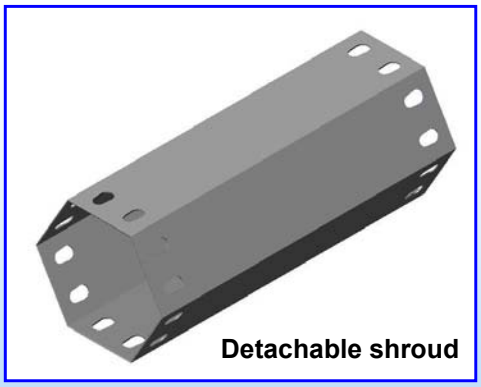
Dismountable FA design



Collet joint of fuel rod



Detachable shroud

Implemented at WWER-440:

Have been operated at Loviisa NPP since 1998. The operation of shroud removal for examination of fuel rods bundle took place. Trial commercial operation started at Kola NPP, Unit 3 in 2002.

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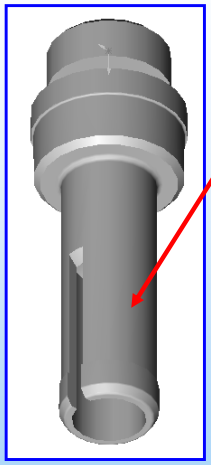
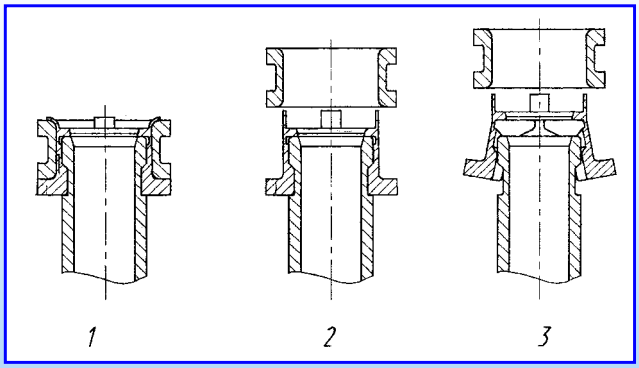
Dismountable FA design

Goal: enhancement of operating reliability



Collet joint of fuel rod



Dismountable joint of top nozzle on guiding channel

Implemented in WWER-1000:

Dismountability principle has been used in all designs of advanced FAs (UTVS, TVSA, TVS-2) since 1996.

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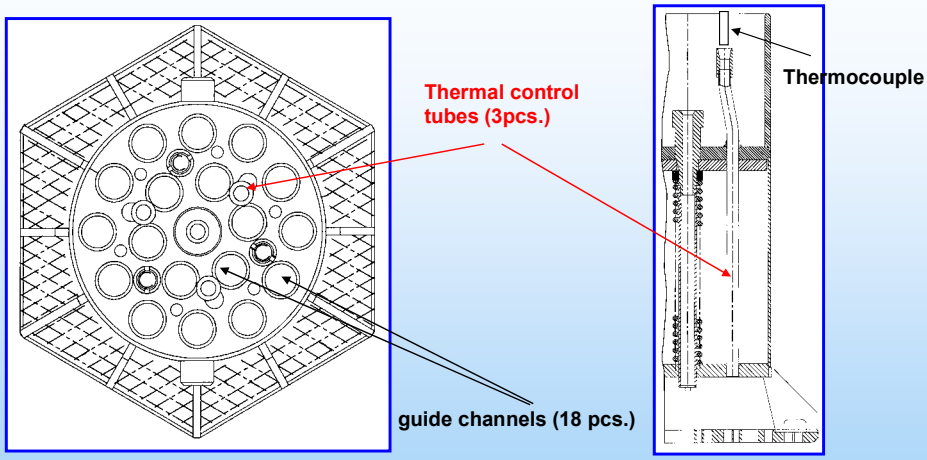
Top nozzle with improved thermal control

Goal: enhancement of reactor plant reliability



Reactor tests of 12 TVSA with improved top nozzle at Kalinin NPP, Unit 1 since 2000 acknowledged higher precision of coolant temperature measurement at the outlet from FA.

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Use of reprocessed uranium for WWER nuclear fuel

Goal: creation of complete fuel cycle

Implemented at WWER-440:

Trial commercial operation of 12 working fuel assemblies with reprocessed fuel of 4.0% equivalent enrichment started at Kola NPP, Unit 2 in 2002. The operating results are positive.

Implemented at WWER-1000:

Trial commercial operation of 12 TVSA with reprocessed fuel of 4.0% equivalent enrichment started at Kalinin NPP, Unit 2 in 2002. The operating results are positive.

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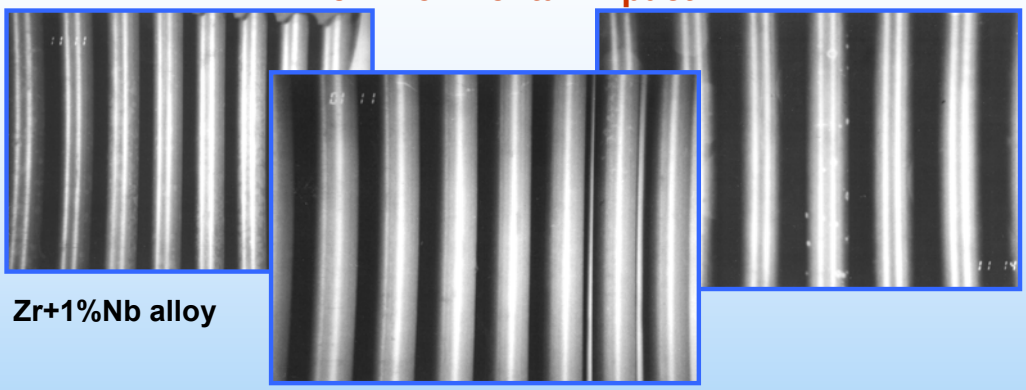
Cancellation of fuel rods anodization and etching

Goal: reducing of process costs, minimizing of adverse environmental impact



Zr+1%Nb alloy

External view of fuel rods without anodization and etching after 3 years of operation at Balakovo NPP. Operation of FAs with fuel rods without anodization and etching goes on at Units of Balakovo and Kalinin NPPs.

Conclusion

The scientific and technical policy pursued by JSC TVEL has managed to create a new generation of FA design on the basis of solutions tested at various units of Russian NPPs.

Russian manufactures produce competitive nuclear fuel for WWER-type reactors enabling the implementation of state-of-the-art cost-effective fuel cycles at NPPs which meet the requirements of the principal Customer – ROSENERGOATOM Concern and provide promotion of Russian products in the foreign markets.