MEMORANDUM

Of the WANO-MC International Workshop on the topic: **"Improving the reliability of nuclear fuel at NPPs with VVER reactor "**, held in Moscow, Russia, 10 -12 February 2015

1. **Introduction**

The workshop was organized by the WANO Moscow Center in February 10-12, 2015 in Moscow.

The workshop was attended by 51 experts from 10 countries:

• Representatives from the operating organizations / NPPs (NPP) from Bulgaria, Hungary, India, Iran, China, Russia, Slovakia, Ukraine, Finland, Czech Republic.

• Representatives from the fuel manufacturing company "TVEL" and "Machine Building Plant" in Elektrostal.

• Representatives from design and scientific organizations: OKB "Gidropress", "OKBM Afrikantov", SIC "Kurchatov Institute", SRI "REŽ" (Czech Republic), VNIIAES.

• Representative from "Atomenergoremont."

The list of participants is presented in Appendix.

The workshop was conducted in Russian and English languages through simultaneous translation.

1. **The purpose of the workshop**

“Improving the reliability of nuclear fuel for VVER NPPs through exchange of information and sharing of experience.”

The following topics were addressed:

• Causes for failure of fuel assemblies (FA).

• Debris and foreign materials as one of the probable causes of FA failure; practical measures taken at the NPP for foreign material exclusion (FME). FME control practices and the removal of foreign materials during outages.

• The impact of FA pre-pressure on FA reliability in the core.

• Questions on justification and operation of "mixed" (FA from different manufacturers) cores of different designs, including fuel assemblies from different manufacturers.

• Control on nuclear fuel during operation, including the use of Sipping Method.

• Quality control during nuclear fuel fabrication.

• Handling of spent nuclear fuel (SNF).

1. **The conduct of workshop**

WANO-MC Director Mr. Aksenov addressed the participants in his welcome speech. He stressed the importance of the topic of the workshop and wished all the participants fruitful work.

The following presentations were presented in the workshop:

* Anoufriev D.G., JSC "Concern Rossenergoatom", Russia: "The experience of operation of nuclear fuel for NPPs with VVER JSC"Concern Rosenergoatom "
* Tsvetkov A.V., Kalinin NPP, JSC "Concern Rossenergoatom", Russia: "Features of the introduction of advanced fuel cycles on the Kalinin NPP"
* Morozov A.S., Balakovo NPP, JSC "Concern Rossenergoatom", Russia: "Operation of the nuclear fuel at Balakovo NPP"
* Litus V.A., Khmelnitsky NPP, NAEC "Energoatom", Ukraine: "Operating experience of TVSA at KNPP"
* Vashchuk A.V., Rovno NPP, NAEC "Energoatom", Ukraine: "Tightness control of nuclear fuel at Rovno NPP. Using of Sipping Method"
* Semirenko E.B., Zaporizhzhya NPP, NAEC "Energoatom", Ukraine:"Tightness control of nuclear fuel during operation.Using of Sipping Method"
* Ge Kedang, Tianwan Company JNPC, China: "Operation of fuel handling machine and problematic issues when dealing with NF at Tianwan NPP"
* Shishkin A.A., OAO "TVEL", Russia: "Experience on justification and operating of mixed cores of NPPs with VVER-1000"
* D. Ernst, Temelin, Czech Republic: "Four-year operating experience at Temelin with NF of TVEL Company"
* Rayndl Y., Temelin, Czech Republic: "Progression and assessment of leak from coverage of fuel TVSA-T "
* Klouzal Y., ÚJV Řež a.s., Czech Republic: "Modelling support of fuel reliability analysis of Temelín NPP"
* Ivanov N.V., Kozloduy NPP, Bulgaria: "Operating experiences of nuclear fuel at Kozloduy NPP "
* Rahmanihagigi A., Bushehr NPP, Iran: "Fuel handling and incoming inspection at Bushehr NPP"
* Dyurchek E., Slovenske Elektrarne Company, Slovakia: "Reliablity of VVER 440 nuclear fuel in reactors of Slovenske elektrarne, a.s."
* Grezhdo A., Bohunice NPP, Slovakia: "Improving the NF reliability at Bohunice NPP"
* Burdjan T., MVM Paks NPP, Hungary: "Improvements at leaking fuel management practice of Paks NPP"
* Lehtinen I-V.O., Fortum, Finland: "Loviisa Operational Experiences related to nuclear fuel"
* Panov A.E., Kola NPP, OAO "Concern Rossenergoatom", Russia: "Improving the operation of nuclear fuel at Kola NPP"
* Kushmanov S.A., OKB "Gidropress", Russia: "Operating experience of TVS-2M - based NF"
* Severe D.V., OKB "Gidropress", Russia: "NF handling during transportation"
* Basihin A.O., OAO "TVEL", Russia: "Quality Control of nuclear fuel (NF) and components of FA."
* Martinakova J., Dukovany NPP, CEZ Company, Czech Republic: "Nuclear fuel manufacturing quality control"
* Molchanov V.L., OAO "TVEL", Russia: "Zero Failure Project "
* Shestakov Y.M., OAO "VNIIAES", Russia: "Movement toward Zero Failure of nuclear fuel in Russia"
* Shishkov L.K., SIC "Kurchatov Institute", Russia: "Accounting for the effects of deviations of the gaps between fuel assemblies on the power distribution in the reactor VVER-1000"
* Amosov M.M., SIC "Kurchatov Institute", Russia: "Experience of the integrated use of radiation techniques for FA Tightness Control at operating and shutdown reactors to diagnose the nature of the fuel elements leakage and to estimate Performance Indicator FRIP».
1. **Brief information on the workshop**:

On the first day of the workshop, the issues on operation and improving the reliability of nuclear fuel for reactors of VVER-1000 NPPs were presented. Representatives of the HQ and NPPs of "Rosenergoatom" presented the experience of operation of nuclear fuel and advanced fuel cycles for NPPs with VVER type of reactors. Similar information was provided by the Ukrainian, Chinese, and Bulgarian representatives in the workshop. Presentations of representatives of the Czech Republic focused on operating experience and reliability analysis of nuclear fuel at Temelin NPP. "TVEL" company presented the experience in justification and operation of mixed cores of VVER-1000. Iran's representative provided detailed information on fuel handling and incoming fuel inspection at the Bushehr NPP.

On the second day of the workshop the issues of operation and improving the reliability of nuclear fuel for NPPs with VVER-440 type of reactors were presented. "TVEL" company presented a comprehensive system of quality assurance in design, manufacture and supply of NUCLEAR FUEL. The representative of OKB "Gidropress" presented the experience of operation of nuclear fuel on the basis of TVS-2M design.

The third day of the workshop reviewed the issues of achieving the zero failure of nuclear fuel. This topic has been presented by representatives from "TVEL" and "VNIIAES”. Kurchatov Institute presented the results of research in the area of improving the NUCLEAR FUEL reliability. In conclusion, the Workshop summarized the information presented and a discussion was held for the participants along with question and answers.

The feedback from participants indicated that NPPs of WANO Moscow Center paid great attention to improving the reliability of nuclear fuel.

1. **CONCLUSIONS AND RECOMMENDATIONS**

1. The workshop representatives appreciated the openness and transparency of the operating organizations / NPPs from Bulgaria, Hungary, India, Iran, China, Russia, Slovakia, Ukraine, Finland, Czech Republic, nuclear fuel suppliers ( "TVEL", "Machine-Building Plant"), design and scientific organizations (OKB "Gidropress", "OKBM Afrikantov", SIC "Kurchatov Institute", "REŽ", VNIIAES) and discussed issues related to improvement of the reliability of nuclear fuel for VVER NPPs (PWR).

2. Information provided by the workshop participants, showed high reliability of nuclear fuel (NF) manufactured by TVEL Company for NPPs with VVER reactors.

3. High reliability of nuclear fuel is provided by:

* Quality of nuclear fuel fabrication and operations at reactor installations;
* Quality of NUCLEAR FUEL production;
* Quality compliance when working with NUCLEAR FUEL and adherence to the requirements of operational documentation (documentation on quality, procedures, manuals, programs, etc.)

4. The workshop noted that, in the framework of the TVEL’s Zero Failure Project, the target is to achieve 95 (100)% NUCLEAR FUEL Reliability Factor.

5. The introduction of new designs of fuel assemblies and fuel cycles increased the efficiency of fuel use, allowed to increase the reliability of the NUCLEAR FUEL, the heat output of reactor, and NUCLEAR FUEL campaign duration.

6.The major recommendations on fuel for VVER-1000 were:

* anti-debris filters;
* anti-vibration spacers;
* increased fuel burn-up load of uranium;
* modified fuel pellet.

7. The major recommendations on fuel for VVER-440 were:

* transition to 2ndgeneration fuel of enrichment up to 4.87%;
* trial operation of the working types of 3rd generation non-canned design;
* using FA with backlash-free fit to the tip of fuel rods in the core grid without the use of a split wire;
* improving monitoring methods of operating parameters of FA for 2ndand 3rdgeneration VVER-440.

8. The introduction of new fuels and fuel cycles requires solving complex issues associated with the storage and removal of spent nuclear fuel.

9. The workshop indicated that the main causes for FA failure are:

* debris-damage to the fuel pins by foreign materials;
* change of FA shape in the reactor VVER-1000;
* physical damage to FA for VVER-1000 at handling and transport operations.

10. The participants took note of the information about the Workshop on “Foreign Material Exclusion” which will be held at WANO Moscow Center during 17th-19thMarch 2015.

11. There is a need for further work on the following issues related to new fuel and fuel cycles:

* limitations in power flux at the end of the 18-month cycle fuel campaign;
* timely removal of spent fuel assemblies (SFA) from NPP sites;
* technology for repair of leaky fuel assemblies in the stands;
* improved methods for monitoring the operating parameters of FA for 2ndand 3rd generation VVER-440.

12. In order to reduce the distortion of FA shape in the core during the operation, following were proposed for Kudankulam NPP and Bushehr NPP:

* intensification of the process of replacing UTVS fuel with TVS-2M type fuel;
* optimization of vertical pre-pressure on UTVS fuel by changing the FA spring diameter from Ø 5,6 mm to Ø 5,1 mm.

13. Modification of the Reactor Protecting Tube Unit (PTU) shims has a positive impact on TVSA movement in the reactor core and SFP.

14. The use of FA with thinner springs in the FA heads is recommended to reduce the VVER-1000 FA shape distortion.

15. It requires further testing calculations to confirm the correctness of the calculations of non-uniformity of the fuel pin power flux (Kr), obtained by the computer code KASKAD.

16. In order to reduce human errors in the process of manufacturing, the fuel supplier shall,

* implement automated manufacturing process of the fuel elements and fuel assemblies;
* introduce a 100% laser labeling of the individual products;
* Implement automated quality control of fuel pellets.

17. Experience in VVER-440 operation has shown high reliability, for example the Dukovany NPP, Bohunice NPP and Mochovce NPP operate without fuel failures so far.

18. The workshop participants noted the importance of addressing the development and introduction of means and methods for inspection of nuclear fuel at NPP.

19. The workshop participants suggested the need to continue studies of FA during the inspections (including Finland and the Czech Republic).

20. Spent Nuclear Fuel Treatment:

The problems faced during the treatment of SFA (storage, transport, reprocessing) is limiting the scope of existing repositories and projected increase in storage of spent fuel which is an important task to ensure the smooth operation of NPPs.

The following topics to the treatment of spent nuclear fuel at the NPP need further study:

* storage of leaking fuel assemblies in the spent fuel cooling pond;
* availability criteria for canned (tight-tube) storage of leaky spent fuel assemblies;
* management of long-term storage of spent fuel assemblies at the NPP site.

The workshop participants considered it appropriate to develop/expand the theme "Spent Nuclear Fuel Treatment" and give another opportunity to conduct a workshop to exchange experience and knowledge gained by NPP in this area.

21. The experience of justification and operation of mixed cores in VVER-1000NPPs:

* Designing of a FA with new improved performance is a complicated and long-term task, most important being the justification of its compatibility with the FA already in operation.
* Justification of the compatibility of new FA for operation with existing FA requires consideration of many factors.
* Suppliers are requested to share the experiences on the study of mixed fuel assemblies with the operating organisations for better understanding and operation.
1. **CONCLUSION**

The participants highly appreciated the results of the workshop, expressed their desire to participate in similar events in the future at 2-3 year intervals, as it was suggested. Participants also pointed out the highly qualified translation skills that contributed to the success of the Workshop.

The participants expressed their gratitude to the leadership of the Moscow Center of WANO for its excellent organization and hospitality.

**Workshop Coordinator** **Andrew Lukyanenko**

Appendix

Participants List

Seminar on Improvement of Nuclear Fuel Reliability of VVER reactors

WANO-MC, 10 - 12 February 2015

| **#** | **Name** | **Organization/ Position** | **e-mail** |
| --- | --- | --- | --- |
|  | **ERNST** Daniel | Head of Reactor Physics DepartmentCEZ – NPP Temelin, Czech Republic | daniel.ernst@cez.cz  |
|  | **MITYASHIN** Vladimir  | Director, Kalinin branch of ATOMENERGOREMONT, Russia |  |
|  | **NEUBAUER** Jan | Technologist Reactor Physics, NPP Temelín,Czech Republic | jan.neubauer@cez.cz  |
|  | **GREŽĎO** Ondrej | Supervisory physicist, Slovenské elektrárne a.s. NPP Bohunice, Slovak Republic | ondrej.grezdo@enel.com  |
|  | **BURJÁN** Tibor | Group Leader, Nuclear Fuel Section, Paks NPP, Hungary | burjan@npp.hu  |
|  | **MARTYKÁN** Miroslav | Head of Chemistry Department CEZ – NPP Temelin, Czech Republic | miroslav.martykan@cez.cz  |
|  | **RAINDL** Jakub | Spectroscopy Group Manager CEZ – NPP Temelin, Czech Republic | jakub.raindl@cez.cz  |
|  | **GE** Kedang | Deputy section chief, Tianwan NPP, Jiangsu Nuclear Power Corporation, China | gekd@jnpc.com.cn  |
|  | **WANG** Wei | Engineer, Tianwan NPP, Jiangsu Nuclear Power Corporation, China | wangweic@jnpc.com.cn  |
|  | **MARTINÁKOVÁ** Želmíra | Reactor Physics Technologist CEZ – NPP Dukovany, Czech Republic | zelmira.martinakova@cez.cz  |
|  | **VASHCHUK** Oleksandr | Deputy Head of Nuclear Safety Department, Rovno NPP, Ukraine | vaav@rnpp.atom.gov.ua  |
|  | **SEMIRENKO** Eduard | Engineer- technologist of Nuclear Safety Department, Zaporozhskaya NPP, Ukraine | edsemirenko777@gmail.com  |
|  | **SEMENOVYKH** Anton | Chief Spesialist, VNIIAES, Russia  | semenovykh@vniiaes.ru  |
|  | **SHESTAKOV** Yurii | Department Head, VNIIAES, Russia | shestakov@vniiaes.ru  |
|  | **KLOUZAL** Jan | Deputy Head of Severe Accidents and Thermomachanics dpt. ÚJV Řež a.s., Czech Republic | jan.klouzal@ujv.cz  |
|  | **LEHTINEN** Iiro-Ville Oskari | Design Engineer, Nuclear FuelFortum Power and Heat Oy, Finland | iiro-ville.lehtinen@fortum.com  |
|  | **ALYEV** Ruslan | Head of Nuclear Safety Department, Kalinin NPP, Russia | alyev@knpp.ru  |
|  | **TSVETKOV** Aleksey  | Leading Engineer, Kalinin NPP, Russia | cvetkov@knpp.ru  |
|  | **ROZHDESTVIN** Vadim | Reactor department deputy head, Kalinin NPP, Russia | criticalmazz@mail.ru  |
|  | **BASIKHIN** Alexander | Quality assurance department head, TVEL, Russia | аоbasikhin@tvel.ru  |
|  | **DOLGOV** Alexey | Department director TVEL, Russia | dolgov@tvel.ru  |
|  | **KUKUSHKIN** Yuriy  | Chief specialist, TVEL, Russia | kukushkin@tvel.ru  |
|  | **MIRONOV** Yuriy  | Chief specialist, TVEL, Russia | yimironov@tvel.ru  |
|  | **MOLCHANOV** Vladimir  | Head of the project, TVEL, Russia | molchanov@tvel.ru  |
|  | **SHISHKIN** Alexey | Chief expert, TVEL, Russia | shishkin@tvel.ru  |
|  | **ANUFRIEV** Dmitriy | Nuclear safety department head, Rosenergoatom, Russia  | anufriev-dg@rosenergoatom.ru  |
|  | **LYTUS** Vitaliy | Nuclear safety department head, Khmelnitskiy NPP, Ukraine | nucsaf@khnpp.atom.gov.ua  |
|  | **SHISHKOV** Lev | Laboratory head, Kurchatov Institute, Russia | shishkov\_lk@nrcki.ru  |
|  | **MIGLO** Valeriy  | Head of laboratory, Kurchatov Institute, Russia | miglo\_vn@nrcki.ru  |
|  | **AMOSOV** Mikhail | Chief scientific specialist, Kurchatov Institute, Russia | amosov\_mm@nrcki.ru  |
|  | **DURCEK** Eduard | Head of Nuclear Fuel Cycle Unit, Slovenske elektrarne, a.s. | eduard.durcek@enel.com  |
|  | **RAHMANIHAGHIGHI** Ali | Head of nuclear safety group, Busher NPP, Iran | bnpp@nppd.co.ir  |
|  | **KUSHMANOV** Sergey  | Chief designer – department head, OKB Gidropress, Russia | kushmanov@grpress.podolsk.ru |
|  | **V’YALITSYN** Victor | Department head, OKB Gidropress, Russia | vjalitsyn@grpress.podolsk.ru |
|  | **BROMIRSKIY** Igor | Group head, OKB Gidropress, Russia |  |
|  | **SUROV** Denis | Engineer- designer , OKB Gidropress, Russia |  |
|  | **RABENKOV** Evgeniy | Engineer- designer , OKB Gidropress, Russia | u-gene@bk.ru |
|  | **PANOV** Aleksey | Leading Engineer of the Nuclear safety department and reliability, Kola NPP, Russia | panovae@kolatom.murmansk.ru  |
|  | **IVANOV** Nikolay  | Physicist-controlling, Kozloduy NPP, Bulgaria | nvivanov@npp.bg |
|  | **ROMANOV** Alexander | Head of department, SC «Afrikantov OKBM», Russia | nti@okbm.nnov.ru  |
|  | **CHIRKIN** Dmitriy | Engineer 1 category, SC «Afrikantov OKBM», Russia | nti@okbm.nnov.ru  |
|  | **MOROZOV** Artem | Senior engineer, Balakovo NPP, Russia | nfl@balaes.ru |
|  | **ASATIANI** Iosif | Department Head, OJSC “Mashinostroitelny Zavod” (OJSC MSZ), TVEL, Russia | oakine@elemash.ru |
|  | **AKSENOV** Vasiliy | Director,WANO-MC |  |
|  | **LUKYANENKO** Andrey | WANO-MC | lukianenko@wanomc.ru |
|  | **LOKTIONOV** Sergey  | WANO-MC | Loktionov@wanomc.ru |
|  | **RASPOPIN** Georgiy | WANO-MC |  |
|  | **KVSBV** Prasad | ВАО АЭС – МЦ |  |
|  | **SABIROVA** Indira | WANO-MC |  |
|  | **LIUDVIKOVSKAYA** Viktoria | WANO-MC |  |
|  | **PAVLOV** Konstantin | WANO-MC |  |