Results of Operation of VVER-1000 FAs Manufactured at PJSC NCCP

D. Davidov, O. Brovkin, Y. Bezborodov

PJSC NCCP, Novosibirsk, Russian Federation

1. Introduction

At present 33 VVER-1000 power units are in operation at 13 NPPs, among them:

in Russia - 12 Units at 4 NPPs;
in Ukraine - 13 Units at 4 NPPs;
in Bulgaria - 2 Units at 1 NPP;
in China - 2 Units at 1 NPP;
in Czechia - 2 Units at 1 NPP;
in Iran - 1 Unit at 1 NPP;
in India - 1 Unit at 1 NPP.

Fuel Assemblies manufactured at PJSC NCCP are in operation at 27 VVER-1000 power units at 11 NPPs in Russia, Ukraine, Bulgaria, China, Iran and India.

Distribution by types of PJSC NCCP VVER-1000 FAs in operation during Fuel Cycle 2013-2014 is presented in Figure 1.

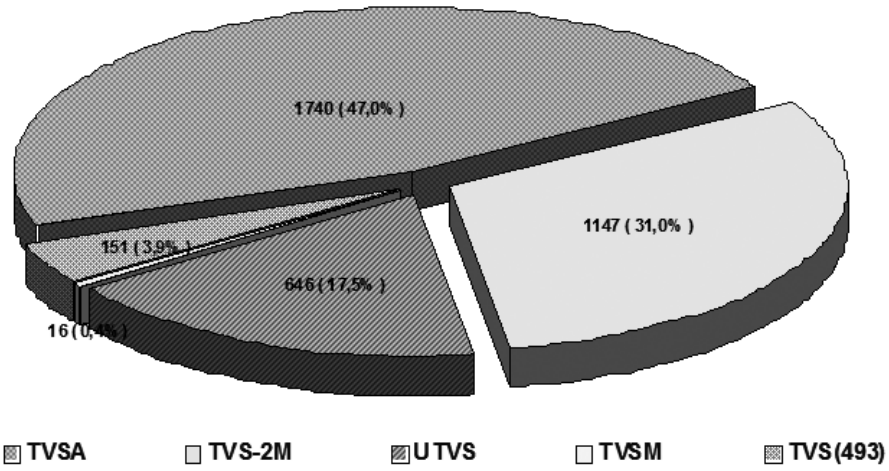

Figure 1. Distribution by types of PJSC NCCP VVER-1000 FAs in operation during Fuel Cycle 2013-2014

2. Basic Results of Operation of PJSC NCCP VVER-1000 FAs during 2007-2014

Introduction of new generation FA with rigid skeleton makes it possible to proceed to extended fuel cycle time of 18 months. Fuel cycle time for 2007-2014 is presented in Fig. 2.

The achieved fuel burnup in FA is one of the most significant characteristics defining the efficiency of fuel utilization in VVER-1000 reactors. Burnup of PJSC NCCP VVER-1000 FAs during 2007-2014 is presented in Fig. 3.

Analysis of operation results of VVER-1000 FAs over the period of 2007-2014 shows that the average and maximum values of fuel burnup in FA are at high level. The average and maximum values of fuel burnup in TVS-2M and TVSA Fuel Assemblies discharged during 2013-2014 are presented in Fig. 4.

The achieved level of specific activity of iodine isotopes in the primary coolant is one of the main operating characteristics of VVER-1000 Power Units characterizing FA leakage during operation. Distribution of the average specific coolant activity by total iodine isotopes for VVER-1000 Units where PJSC NCCP FAs were in operation during 2013-2014 is presented in Fig. 5.

Level of the specific average activity by total iodine isotopes during 2007-2014 is presented in Fig. 6. Analysis of operation results of VVER-

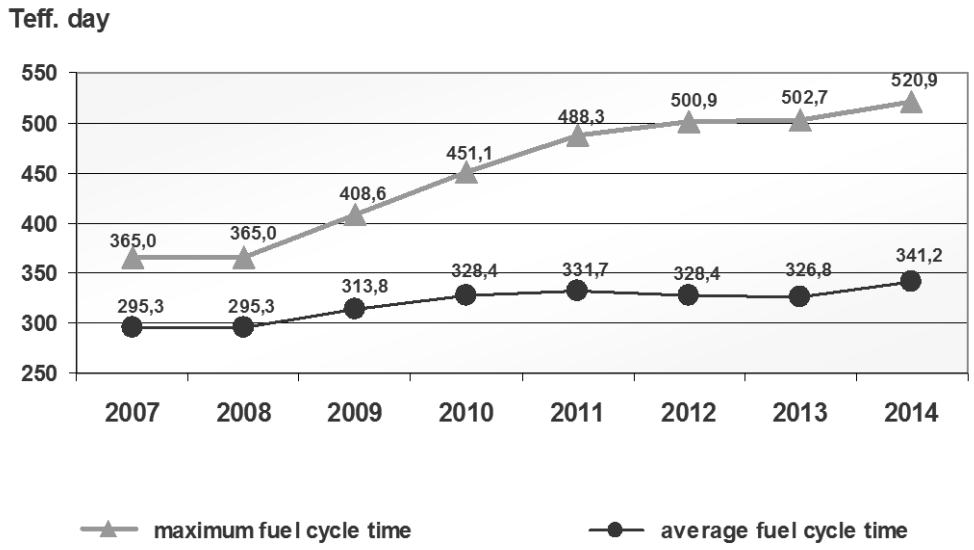

Figure 2. Fuel cycle time for 2013-2014

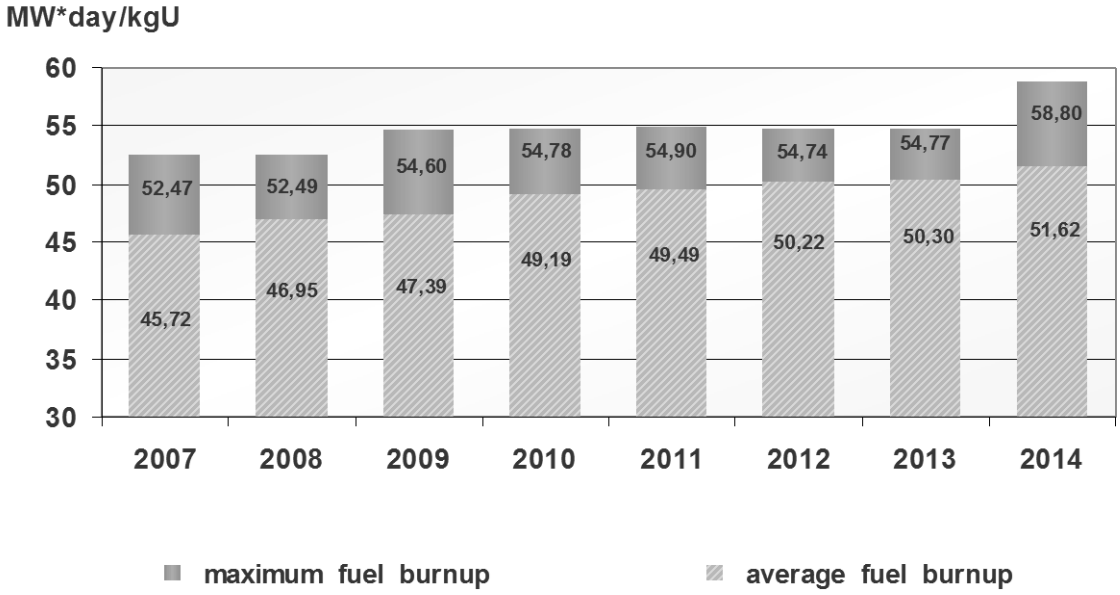

Figure 3. Burnup of PJSC NCCP VVER-1000 FAs during 2007-2014

1000 FAs over the period of 2007-2014 shows that for the last years the level of the average specific coolant activity by total iodine isotopes significantly decreased. The decrease of the level of the average specific coolant activity by total iodine isotopes proves the reduction of the average FA leakage rate.

Change of the average leakage rate of FAs during 2007-2014 is presented in Fig. 7. For the last years the average leakage rate of Fuel Assemblies reduced and now the rate is at the level in the order of 10^{-6}.

Analysis of results of FAs operation and teak test at NPPs shows that more than 64% of all leaking FAs are schedule discharged as completed their life time. Some leaking FAs with low specific activity by I-131 are returned to the reactor core. Distribution of leaking VVER-1000 FAs manufactured at PJSC NPPC by the causes of discharge from the reactor core during 2007-2014 is presented in Fig. 8.

Analysis of operation results of VVER-1000 FAs and postreactor examination of leaking FAs in SC SRC NIIAR over the period of 2007-2014 shows that the main confirmed cause of leakage of pre-schedule discharged FAs is debris damage of

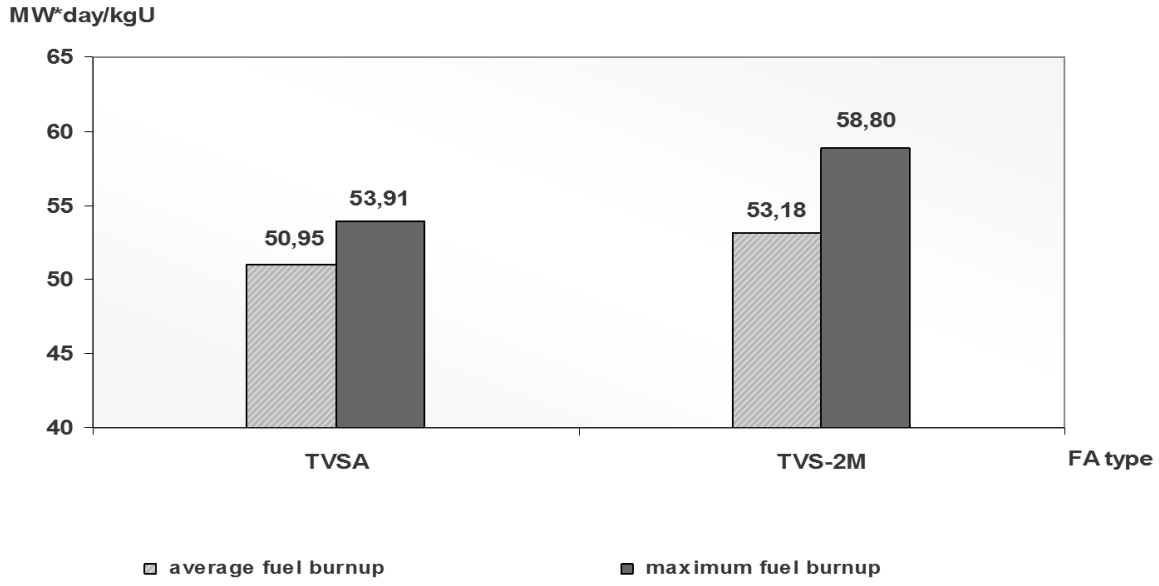

Figure 4. Distribution fuel burnup by types of FAs discharged during 2013-2014

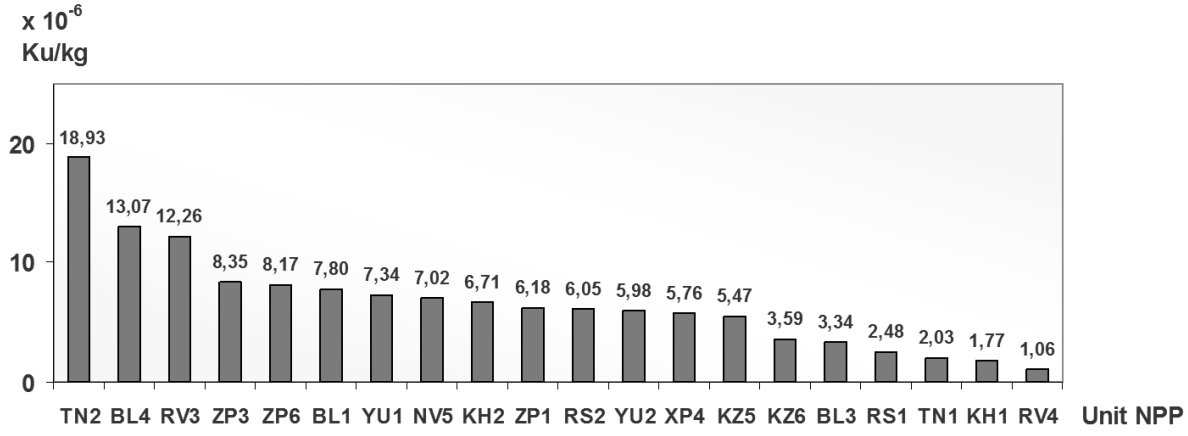

Figure 5. Distribution of the average specific coolant activity by total iodine isotopes for VVER-1000 Units during 2013-2014

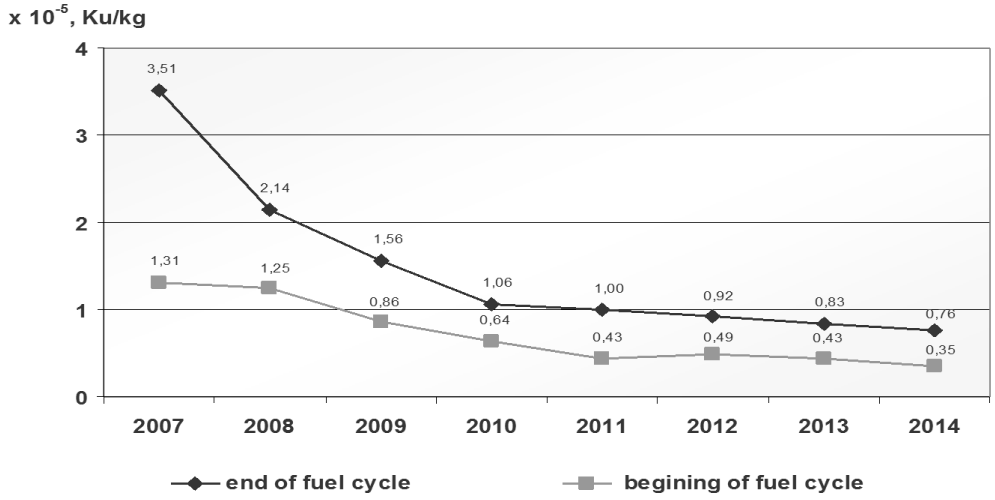

Figure 6. Level of the specific average activity by total iodine isotopes during 2007-2014

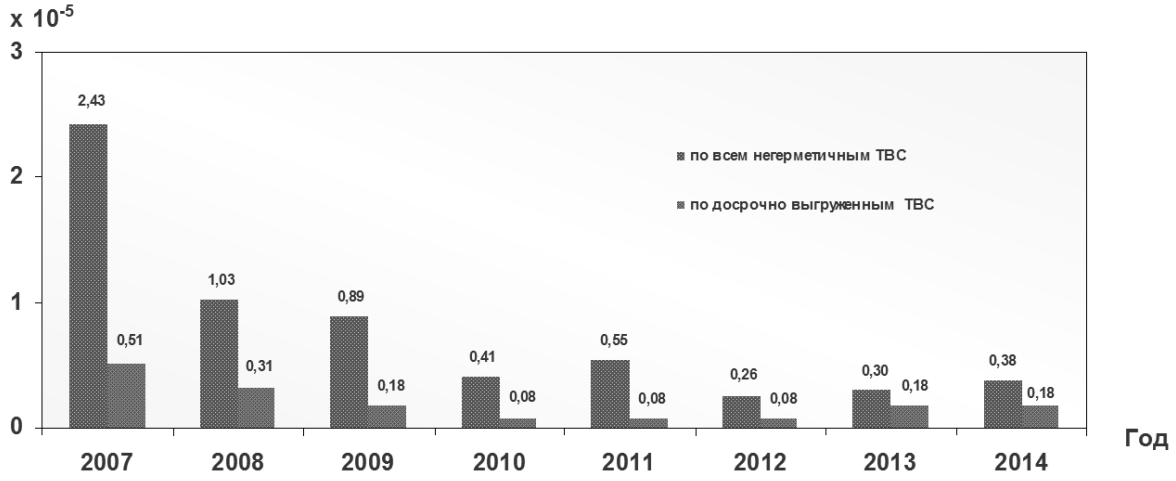

Figure 7. Change of the average leakage rate of FAs during 2007-2014

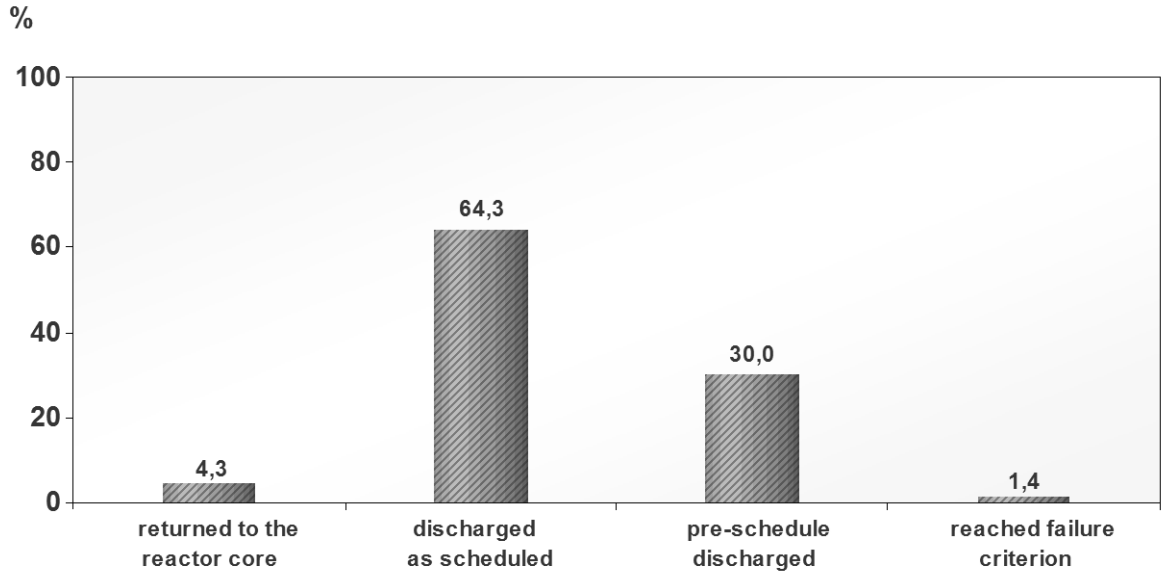

Figure 8. Distribution of leaking VVER-1000 FAs manufactured at PJSC NPPC by the causes of discharge from the reactor core during 2007-2014

FRs in Fuel Assemblies during operation.

Distribution of leaking FAs manufactured at PJSC NCCP by VVER-1000 Units during 2007-2014 is presented in Fig. 9.

Analysis of operation results of PJSC NCCP VVER-1000 FAs over the period of 2007 - 2014 shows that operating conditions exert significant influence on depressurization of Fuel Rods in FAs, and this is proved by results of FAs operation and leak test at six Units at Zaporozhye NPP and two Units at Kozloduy NPP where only TVSA Fuel Assemblies manufactured at PJSC NCCP are in operation:

- no leaking TVSA was revealed at Unit 6 at Kozloduy NPP over the period of 2007-2014;
- one leaking TVSA was revealed at each of Units 1, 4, 5 at Zaporozhye NPP over the period of 2007-2014;
- from 2 to 3 leaking TVSA Fuel Assemblies were revealed and discharged as scheduled at Unit 2, Unit 3, Unit 6 at Zaporozhye NPP and Unit 5 at Kozloduy NPP over the period 2007-2014.

3. Conclusion

The operation results of PJSC NCCP FAs at

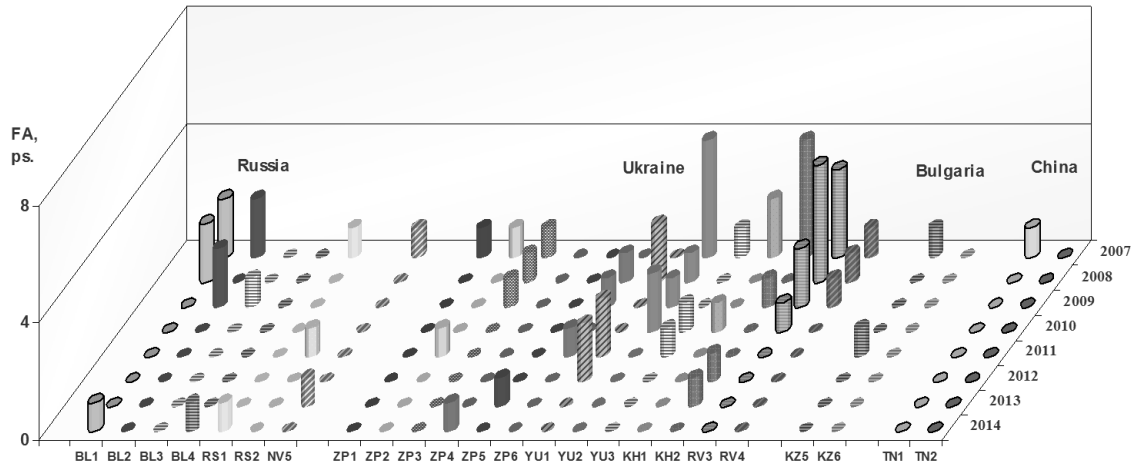

Figure 9. Distribution of leaking FAs manufactured at PJSC NPPC by VVER-1000 Units during 2007-2014

VVER-1000 NPPs over the period of 2007-2014 confirm the design characteristics of fuel, i.e.:

- average fuel burnup up to 55 MW*day/kgU in FAs;
- safe and reliable FA operation, with low leaking rate (in the order of 10^{-6}).

The achieved operation characteristics of TVSA and TVS-2M Fuel Assemblies prove the quality, reliability and competitiveness of FAs manufactured at PJSC NCCP.