MODIFICATION AND IMPROVEMENT OF RBMK –1500 FUEL ASSEMBLY DESIGN

D.Kamagin

OAO”Mashinostroitelny zavod”

Electrostal, Moscow region

Introduction

OAO”Mashinostroitelny zavod” is an enterprise of a highly organized infrastructure involved in design and manufacture of world level products.

The availability of highly professional staff, special equipment and many years’ experience allowed to establish effective production of sophisticated and reliable products – fuel assemblies (FA) for nuclear reactors’ cores of various types: VVER-440, VVER-1000, RBMK – 1000, RBMK-1500, BN-600, EGP-6, PWR, BWR as well as reactor cores of sea fleet.

Along with the products for nuclear power plants and ship reactors, the factory produces metal distilled calcium. Ca metal in the form of granules, foil and ingots of high purity is widely used in different industries, especially in metallurgy, as alloying element and deoxidizer for the production of high quality steels and non-ferrous alloys.

At the present time the Leningrad, Kursk and Smolensk NPPs operate 11 units with RBMK-1000 type reactors and 2 units with RBMK-1500 type reactor at the Ignalina NPP, which produce about 50% of electrical energy produced by all the NPPs of Russia and more than 90% of the electrical energy of Lithuania.

Since commissioning of the first unit of the RBMK reactor (1973, Leningrad NPP) we have been working at the modification and improvement of the fuel rod and fuel assembly design with the purpose to enhance RBMK safety and technical and economic characteristics.

After the Chernobyl accident all operating NPPs were subject to a complex of technical and organizational activities, contributing greatly to the safety and reliability enhancement. Due to the implementation of all those the nuclear safety of the RBMK power plant was brought to a new quality level, excluding any accident associated with the reactor power excursion.

At the same time the implementation of the activities aimed at the safety enhancement carried out since 1986 has brought to some degradation of the technical and economic characteristics of the RBMK NPP and of the fuel cycle; for example the linear thermal loads in fuel rods increased and the burn-up decreased.
Taking into consideration the urgency of the RBMK fuel cycle optimization, enhancement of the NPP economic and technical characteristics and with the purpose to improve the RBMK safety and reliability, the research & development, experimental and design activities have been expanded with the purpose to achieve the objectives. Lately the modification and improvement of the RBMK FA are carried out in the following main directions:

- Introduction of the uranium-erbium fuel;
- Development of the FA design with central fixation of fuel rods.

1. Uranium-erbium fuel

Transfer of RBMK reactors to uranium-erbium fuel is one of the most important elements in the modernization of the RBMK cores, aimed first of all at the enhancement of the safety and technical and economic characteristics of this type reactor. Introduction of the new fuel enables to decrease significantly the void coefficient, maximum power of the FA, power distribution non-uniformity and to increase the burn-up.

The first pilot batch of the RBMK-1500 FA with fuel enrichment 2.4% and erbium content 0.41% was manufactured and delivered to the Ignalina NPP in 1995, and the first pilot batch of the RBMK-1000 FA with fuel enrichment 2.6%, erbium content 0.41% was manufactured and delivered to the Leningrad NPP in 1996.

In process of the reactor tests the calculated parameters proved to be right and the mass production of fuel assemblies could take place.

Later in order to increase the fuel burn-up the work was carried out to justify the increase of the uranium-erbium fuel enrichment. The results were:

- in 2000 the working design and technical documentation was developed for the FA RBMK-1000 with the fuel enrichment 2.8% and erbium content 0.6%. The fourth quarter of 2001 saw the preliminary and acceptance tests of the FA pilot batch (100 p.c.s), the latter being in successful operation at the Leningrad NPP.
- in 2001 the working DD and TD for the RBMK-1500 FA was worked out with the fuel enrichment 2.6% and erbium content 0.5%. The second quarter saw the preliminary and acceptance tests of the FA pilot batch (100 p.c.s), which is successfully operating at the Ignalina NPP.

The acceptance tests of the both types of the new uranium-erbium fuel being over, the plant started the FA mass production.

The uranium-erbium fuel introduction brought to the following results:

- fuel burn-up greatly increased (RBMK-1500 by 40-50%, RBMK-1000 by 20-25%);
- consumption of fuel assemblies reduced;

Dysnai - 2003
2. RBMK FA with central fixation of fuel rods

The modified RBMK FA with central fixation of fuel rods was designed and developed with the intention to enhance the FA operation safety due to elimination of the fuel spilling in case of second defects (breaking-off of an end plug), providing for the required gaps to elongate the fuel rods at any burn-up of the fuel, providing for a stable gap in fuel between the bundles of fuel rods in the FA center.

Year 2001 saw the development of the working DD and TD for the RBMK-1000 FA with central fixation of fuel rods and the 4-th quarter of 2001 saw the preliminary and acceptance tests of the pilot FA batch (100p.c.s.) loaded into the first unit of the Leningrad NPP for reactor tests.

In November 2002 there was examination of three fuel assemblies №12-26-77498, №12-26-77483, №12-26-77445 with burn-up 515, 493, 442 MW day/FA respectively after one year of operation in the reactor. The fuel assemblies turned out faultless during loading and operation in the reactor. According to the leak test measuring system all the fuel assemblies proved leak-tight. In process of operation the coolant flow rate through technical channel was also recorded and it made up 35,3 – 40,6m³/hour, the requirement of the Technical Conditions saying maximum 43m³/hour. In conformity with the examination program in the period of the preventive maintenance plan of the first unit the above fuel assemblies were unloaded from the reactor into the pool side for the cask storage. After the hold time some water was sampled for radio-nuclide analysis from the casks containing those fuel assemblies. The radio-nuclide analysis of the water samples confirmed the system data about the FA leak-tightness. After the hold time of the FA in the casks they were examined in the poolside by means of a TV camera. The examination showed that the FA condition was good, the FA structure elements had no mechanical damages, gaps between upper and lower bundles of fuel rods as well as between end faces of fuel rods and end grids met the requirements of the DD. The fuel assemblies were loaded into the reactor for the second time. Not a single fuel assembly from 100 fuel assemblies failed. At present the experimental operation of the FA at the LNPP is going on.

Based on the results of the FA operation at the LNPP the decision will be undertaken about the transfer to the mass production of the RBMK-1000 FA, and the technical project of the RBMK-1500 FA will be worked out with central fixation of fuel rods with further manufacture of the pilot batch for the Ignalina NPP.