RERACKING POSSIBILITIES OF THE NPP KRŠKO SPENT FUEL POOL

Mile Baće, Dubravko Pevec
Faculty of Electrical Engineering and Computing
University of Zagreb
10000 Zagreb, Unska 3, Croatia

Tomislav Šmuc
Rugjer Bošković Institute
10000 Zagreb, Bijenička 54, Croatia

Abstract

Using the SCALE-4 code package reracking possibilities of the NPP Krško spent fuel pool were analyzed. Two cases were considered: the first case assuming the 40 years lifetime of the plant, and the second case assuming the 50 years lifetime of the plant. It was shown that it is possible to design the additional racks in free space of the spent fuel pool with the sufficient total capacity to store all the spent fuel generated during the 40 years lifetime of the plant. In the case of 50 years plant lifetime, completely new racks (capacity of 1890 spent fuel assemblies), containing 4mm boral in storage cell walls, were proposed for the NPP Krško spent fuel pool. The effective multiplication factor of the spent fuel pool fully loaded with new racks containing spent fuel assemblies of initial enrichment 4.3 w/o, burned to 40 GWd/tU and cooled 2 years is lower than the value required by standard. It showed the possibility of the safe disposal of all spent fuel accumulated during more than 50 years lifetime of the plant.

1. INTRODUCTION

The standard technique for storage of spent fuel is placing the spent fuel assemblies in a water pool. About 90% of the spent fuel around the world are currently stored in pools. Spent fuel assemblies are stored in widely spaced storage arrays which are mounted on the base of the pool, to prevent criticality and protect fuel from consequences of the earthquake. As utilities are confronted with the problem of increasing storage capacity the first step to solve this problem is reracking. An analysis of reracking possibilities for NPP Krško spent fuel pool has been performed.

The spent fuel pool of NPP Krško contains 12 racks for spent fuel assemblies with 12 inches center-to-center spacing of storage cells. 8 racks have configuration of 8×9 storage cells and 4 racks have configuration of 7×9 storage cells. The cross sectional view of the NPP Krško spent fuel pool is depicted in Figure 1. There is a free space in the spent fuel pool, which could be used for additional installation of spent fuel racks. The capacity of the NPP Krško spent fuel pool is 828 spent fuel assemblies. Currently 526 spent fuel assemblies are stored in the spent fuel pool. Apparently, the existing spent fuel capacity is not sufficient to store all fuel discharged during the NPP Krško lifetime.

Our previous analysis[1] *based on burnup credit of the spent fuel suggested an increase* in spent fuel pool storage capacity. A further densification of storage cells in the spent fuel pool could be achieved by incorporation of neutron absorbers, e.g. boral, into rack structure. Our ultimate goal was to investigate whether it is possible to store all spent fuel accumulated during lifetime of the NPP Krško in the existent spent fuel pool. Recently, there is a tendency to extend the lifetime of the nuclear power plants, so two options were considered: a) 40 years lifetime, and b) 50 years lifetime.

Calculational tools and methodology used to determine the reracking possibilities of NPP Krško spent fuel pool are described in Section 2. Results of analysis are presented in Section 3. Conclusions are given in Section 4.

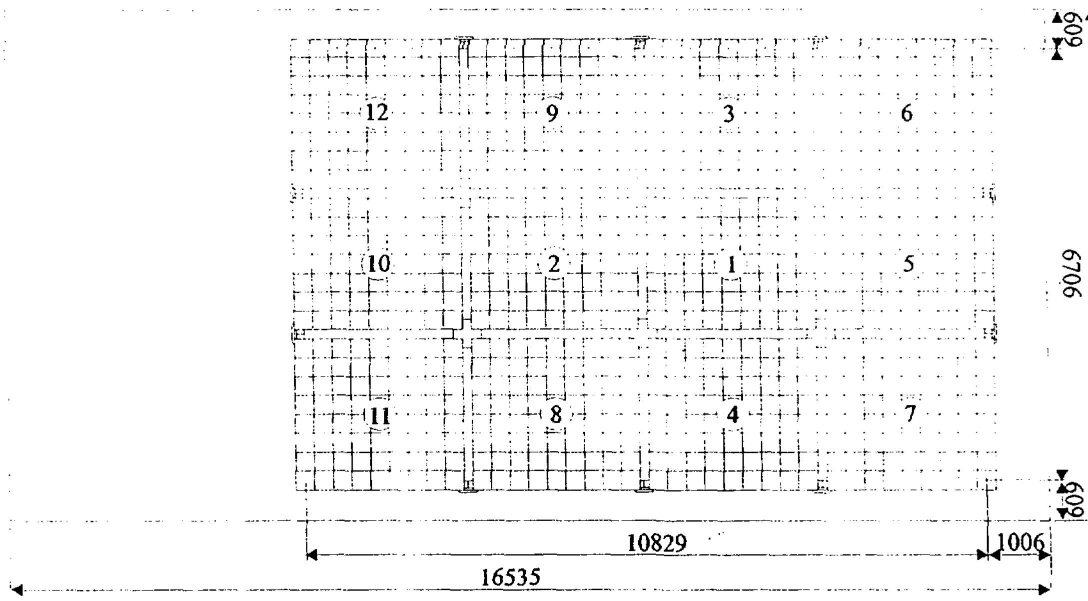

Fig. 1 Cross sectional view of the NPP Krško spent fuel pool

2. CALCULATIONAL TOOLS AND METHODOLOGY

The SCALE code system[2] developed at Oak Ridge National Laboratory has been used as the computational tool to investigate the reracking possibilities of NPP Krško spent fuel pool. Criticality safety analyses are performed via the criticality safety analyses sequences (CSAS), and ORIGEN module is used for the depletion calculations. The SCALE

27-group burnup library containing ENDF/B-IV (actinides) and ENDF/B-V (fission products) data has been used for all calculations.

As the extended option of 50 years lifetime for NPP Krško is not certain we considered a modular approach to capacity increase of the spent fuel pool. It means that for the 40 years lifetime of NPP Krško additional racks with adequate capacity have to be designed and installed in the free space of the spent fuel pool. In the case that the extended option of 50 years lifetime for NPP Krško is accepted, the existent 12 fuel racks have to be replaced at later time with new racks of appropriate capacity.

We assumed that new fuel racks consist of storage cells containing neutron absorbers in structural material. The cross sectional view of storage cell is given in Figure 2. In all our calculations we used the storage cell structure described in Figure 2.

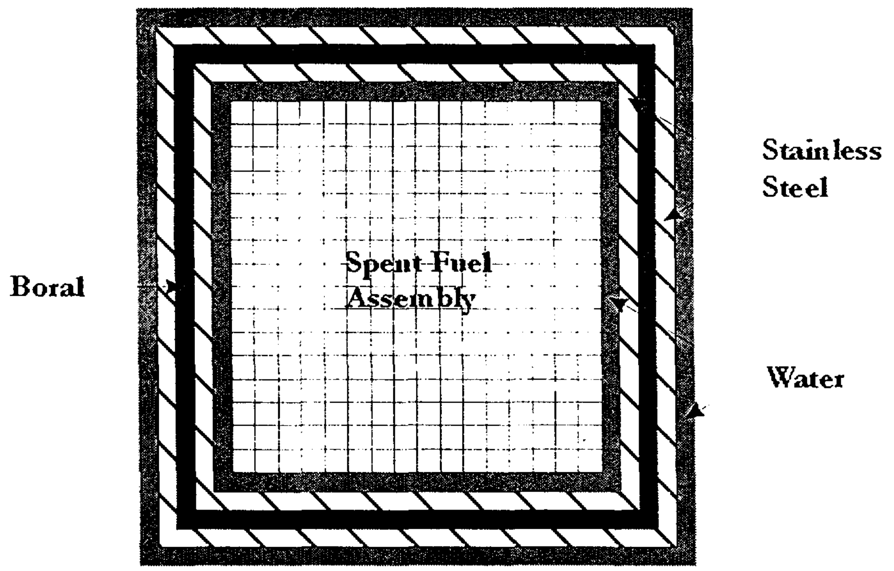

Fig. 2. Storage cell

Boral has performed extremely well in spent fuel pool applications, and it is considered as the preferred neutron absorber for fuel racks. Therefore, it was chosen as neutron absorber. Boral is a metallic composite of sintered aluminum matrix containing boron carbide sandwiched between and bonded to aluminum plates. Boron carbide is an extremely stable and inert chemical compound, which does not react with any material, found in spent fuel pools. Boral is installed between stainless steel plates into storage cell walls.

A series of actinide-only burnup credit criticality calculations with the assumptions of different storage cell pitch and different boral thickness were performed in order to meet the required criticality safety standard[3].

3. RERACKING POSSIBILITIES IN THE NPP KRŠKO

An analysis of the NPP Krško spent fuel pool reracking has been performed for two cases: the first case assuming the 40 years lifetime of the plant, and the second case assuming the 50 years lifetime of the plant.

3.1 Reracking analysis for 40 years lifetime of the plant

In order to estimate the total number of spent fuel assemblies we used a conservative approach, assuming the 12 months cycles till the end of lifetime (year 2023.). As power uprate is planned after steam generators replacement we have conservatively assumed that 36 spent fuel assemblies will be discharged at the end of each cycle. 24 cycles with 36 spent fuel assemblies discharged are left plus the last cycle after which the full core (121 fuel assemblies) has to be discharged. Taking into account that 526 spent fuel assemblies are currently stored in the spent fuel pool the total number of spent fuel assemblies accumulated during the 40 years lifetime is $526+24\times36+121=1511$. As the capacity of the existing fuel racks is 828, new racks for additional 683 spent fuel assemblies have to be provided. The most practical place for designing of the additional racks is the free space in the spent fuel pool. We assumed that additional racks contain 700 storage cells (20×35) The storage cell dimensions are 23.65 cm $\times$ 22.45 cm, and boral is used as neutron absorber. The 4mm boral layer is sandwiched between 2.5mm stainless steel plates forming the storage cell walls. The configuration of the NPP Krško spent fuel pool is given in Fig. 3. For the spent fuel assemblies, which are already in the spent fuel pool, we used in our analysis the actual enrichments, burnups, and cooling times, and for the fuel assemblies which will be used in the future we assumed uniform enrichment (4.3 w/o U235), uniform burnup (40 GWd/tU), and uniform cooling time (2 years). The ORIGEN code is used to calculate the isotopic composition of the fuel, but in our analysis only major actinides (U-235, U-236, U-238, Pu-239, Pu-240, Pu-241) are taken into account. The effective multiplication factors for the whole-spent fuel pool is calculated by CSAS25 sequence of SCALE code system. For the case without any boron in the spent fuel pool water we obtained the value of 0.8128 ± 0.0034 for spent fuel pool effective multiplication factor. As this value is quite below the value required by ANSI standard (0.95) we may conclude that it is possible to design the additional racks in free space of the spent fuel pool with the sufficient capacity to store all the spent fuel generated during the lifetime of the plant.

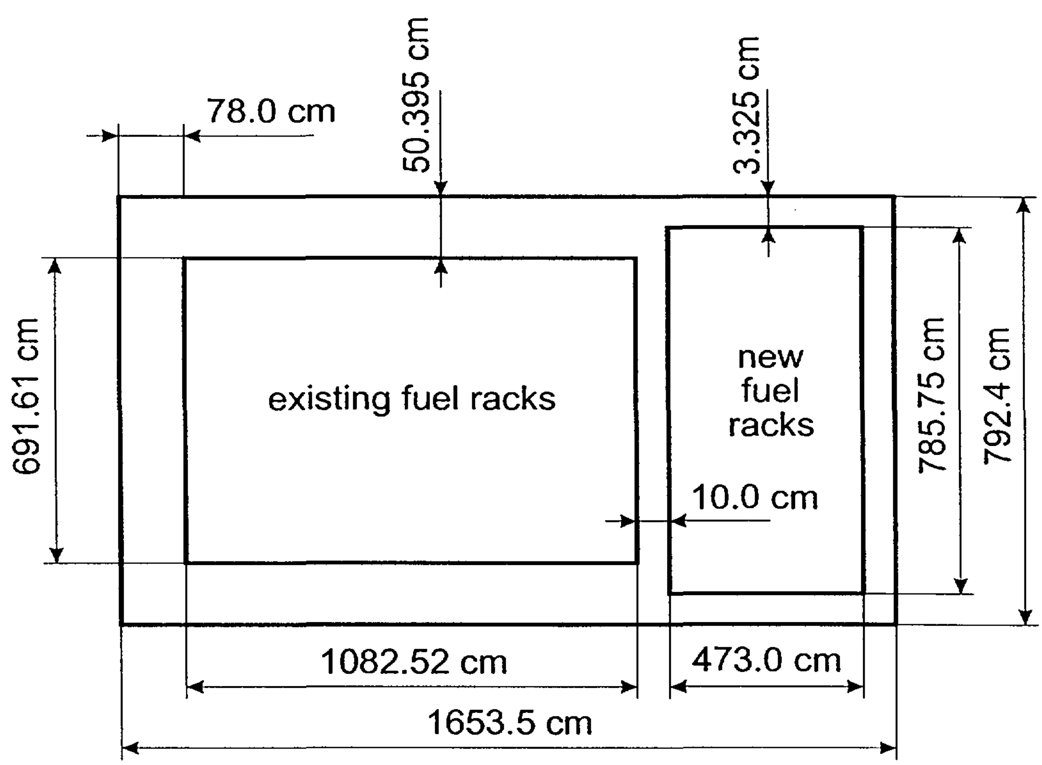

Fig.3. NPP Krško spent fuel pool configuration with partially new racks

3.2 Reracking analysis for 50 years lifetime of the plant

In the case that the lifetime of the NPP Krško would be extended for another ten years, the total number of spent fuel assemblies could be easily determined by adding the total number of spent fuel assemblies for 40 years lifetime (1511 spent fuel assemblies) and spent fuel assemblies for additional ten 12 months cycles (360 spent fuel assemblies). In order to store these 1871 spent fuel assemblies reracking has to be performed in the whole spent fuel pool. First we estimated the maximum capacity of the NPP Krško spent fuel pool for spent fuel assemblies of initial enrichment 4.3 w/o U-235, discharge burnup of 40 GWd/tU, and cooling time of 2 years. The new fuel racks for 2448 spent fuel assemblies (containing 72×34 storage cells) with storage cell pitch of 22.65 cm and 4mm boral layer in the storage cell wall are estimated to give the maximum capacity of the spent fuel pool. The configuration of the NPP Krško spent fuel pool with completely new racks is presented in Figure 4. The effective multiplication factor of the spent fuel pool with new racks of maximum capacity obtained by CSAS25 sequence of SCALE code system is 0.8191±0.0036, what is well below the value required by the standard.

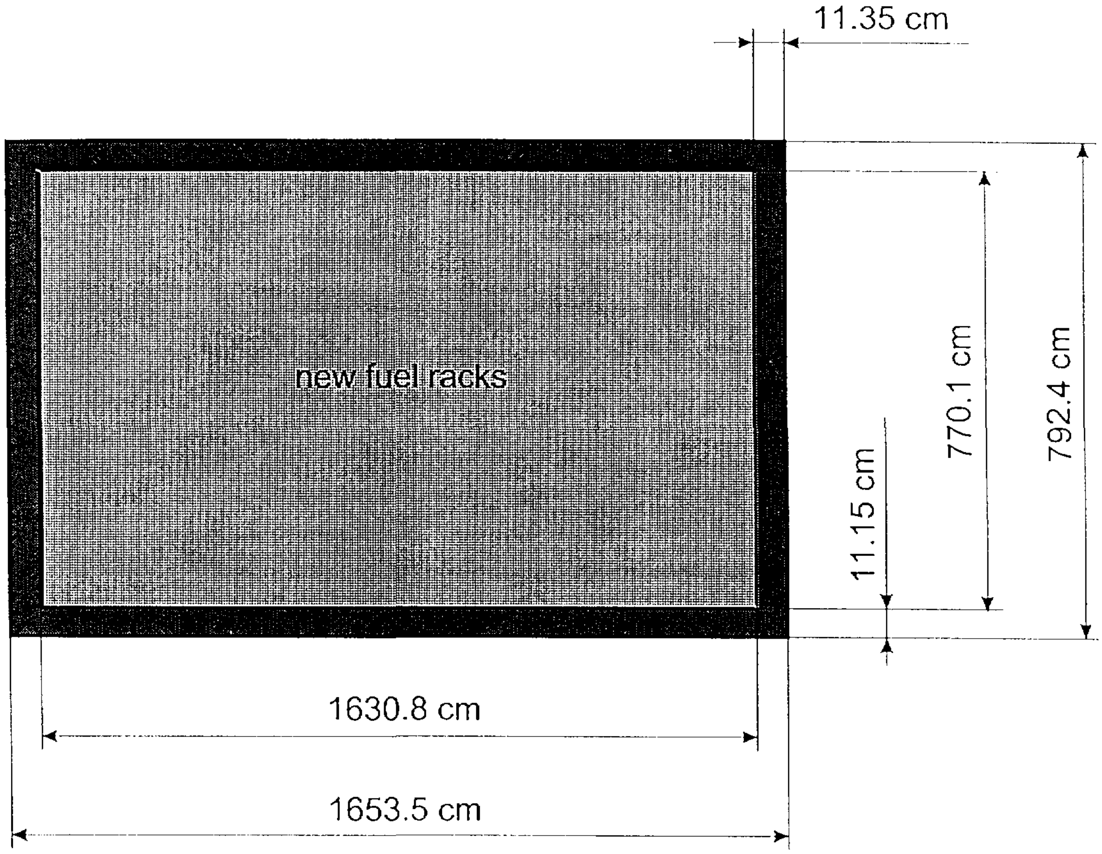

Fig.4. NPP Krško spent fuel pool configuration with completely new racks

The maximum capacity racks are not needed to store spent fuel assemblies for 50 years lifetime of the NPP Krško. Therefore, the more appropriate storage racks are proposed for storage of spent fuel accumulated during 50 years lifetime. These racks contain 63×30 storage cells and have capacity of 1890 spent fuel assemblies. The storage cell pitch is 25.00 cm and 4mm boral layer is incorporated in the storage cell wall. Assuming the actual enrichments, burnups, and cooling times for the spent fuel assemblies, which are already in the spent fuel pool, and assuming uniform enrichment (4.3 w/o U235), uniform burnup (40 GWd/tU), and uniform cooling time (2 years) for the fuel assemblies which will be used in the future the effective multiplication factor of the spent fuel pool fully loaded with new racks was obtained (0.6860±0.0039). It showed the possibility of the safe disposal of all spent fuel accumulated during more than 50 years lifetime of the plant.

It must be emphasized that reracking designs described above are solely based on criticality analysis of the spent fuel pool, and these designs have to be additionally checked by seismic and thermal hydraulic analyses.

4. CONCLUSIONS

Using the SCALE-4 code package we have analyzed reracking possibilities of the NPP Krško spent fuel pool. Two cases were considered: the first case assuming the 40 years lifetime of the plant, and the second case assuming the 50 years lifetime of the plant. We have showed that it is possible to design the additional racks in free space of the spent fuel pool with the sufficient total capacity to store all the spent fuel generated during the 40 years lifetime of the plant. In the case of 50 years plant lifetime, completely new racks (capacity of 1890 spent fuel assemblies), containing 4mm boral in storage cell walls, were proposed for the NPP Krško spent fuel pool. The effective multiplication factor of the spent fuel pool fully loaded with new racks containing spent fuel assemblies of initial enrichment 4.3 w/o, burned to 40 GWd/tU and cooled 2 years is lower than the value required by standard. It showed the possibility of the safe disposal of all spent fuel accumulated during more than 50 years lifetime of the plant.

As the extended option of 50 years lifetime for NPP Krško is not certain we would recommend a modular approach to capacity increase of the spent fuel pool. It means that for the 40 years lifetime of NPP Krško additional racks with adequate capacity have to be designed and installed in the free space of the spent fuel pool. In the case that the extended option of 50 years lifetime for NPP Krško is accepted, the existent 12 fuel racks have to be replaced at later time with new racks of appropriate capacity.

It must be emphasized that reracking designs described above are solely based on criticality analysis of the spent fuel pool, and these designs have to be additionally checked by seismic and thermal hydraulic analyses.

References

[1] M. Baće, D. Pevec, T. Šmuc, *"Impact of Burnup Credit on the NPP Krško Spent Fuel Pool Criticality,"* Proceedings of 4th Regional Meeting Nuclear Energy in Central Europe, Bled, Slovenia (1997)

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[4] Nuclear Power Plant Krško – Updated Safety Analysis Report