FIVE-YEAR REFUELLING CYCLE AT DUKOVANY NUCLEAR POWER PLANT

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ABSTRACT

In PWR fuel enrichment is permanently increased together with the content of burning absorbers with the aim to improve characteristics of burning and reduce fuel costs at the energy market. To achieve the economic advantage offered by these new fuel types and maintain the level of safety and reliability of reactor operation the process of charge design is continuously improved.

1. INTRODUCTION

In 2003 the first fuel charges with the new generation fuel were deployed in units one and two of the Dukovany NPP to burn in the reactors for five years. This change, i.e. the transition from the four- to the five-year cycle, concerns the working fuel assemblies while the regulation assemblies remain in the four-year cycle. The remaining power plant units were transferred to the five-year cycle in the years 2004 and 2005.

2. FUEL FOR FIVE-YEAR CYCLE

Since 2002 a new type of fuel assembly for the five-year cycle has been loaded. The main innovation connected with this fuel type consists in deployment of burning absorbers based on Gd_2O_3 to 6 of the 126 fuel elements in the assembly with medium enrichment below 4.4 % U^{235}. The content of Gd – Gadolinium absorber is about 3 % and axial blankets for enrichment profiling are not applied in the assembly. The construction of the regulation assembly for these charges is identical with the previous fuel types. The transition to the five-year cycle could start immediately (with just the regulation assemblies remaining in the four-year cycle). This transitory fuel type Gd-1 is now followed with an advanced second generation, first loaded in 2005 as Gd-2 fuel. The Gd-2 fuel only preserves the concept of low gadolinium content. The construction of the assembly has been modernised, especially by optimisation of the water-uranium ratio, which leads to reduction of medium enrichment with preserved reactivity of the fresh fuel and burning dynamism. The main differences include the change in the size of the fuel tablet, the size of the element, the new length of the fuel column causing change of uranium weight in AZ, new radial profiling of the assembly and changes in the construction of the mechanical parts.

On the other hand, other history tested construction features of PWR fuel were preserved, including fixation of the element in the distance grids and the concept of the relatively firm assembly structure with high resistance against fretting, but allowing for radiation elongation of the elements and the assembly dismantling. The concept of the assembly as a channel for coolant with the envelope affecting the thermal hydraulics of the PWR 440 core has also been preserved.

The mean enrichment of the working assemblies has been increased from 3.8 to 4.4 % U^{235}, while in the case of the regulation assemblies the enrichment remained on 3.8 % U^{235}. The increased reactivity of the assemblies with higher enrichment had to be partly compensated by introduction of the burning absorbers in the fuel. The absorbers provide for sufficient sub-criticality of the fuel during transport and storage and a sufficiently negative value of the temperature coefficient of the reactor reactivity, which is one of the safety criteria required from PWR reactors. The burning absorber is one of the isotopes of the natural element of gadolinium (Gd^{157}), which, in the form of oxide Gd_2O_3, is mixed with UO_2 oxide in the fuel tablets. In the course of the first year of the reactor operation the absorption isotope Gd^{157} burns, (absorbs neutrons and changes to another isotope, which does not absorb the neutrons any longer), and so at the end of the year the concentration in the fuel drops near to zero. The Gd_2O_3 oxide in the amount of 3.35 weight % in the uranium tablets is just in six of the 126 fuel elements in every cassette.

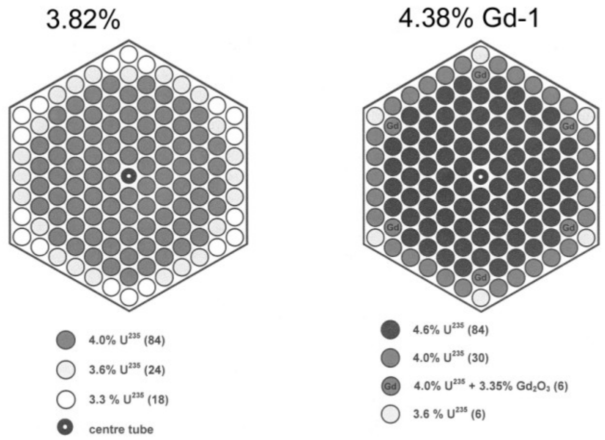

Fig 1: Two types of profiling of enrichment in fuel asseemblies for the Dukovany NPP. The first type is the regulation assembly. The second type is working assembly Gd-1. [7]

The PWR 440 fuel from the Russian supplier, the TVEL company, shows long-term high standards. Fuel manufacture is checked regularly by strict audits of ČEZ specialists in the manufacturing plants of the Russian fuel factory. The objective and the main quality criterion was frequency of occurrence of fuel assemblies with non-tight fuel elements, i.e. with leaks in their coverage resulting from operation, which may release products of nuclear fission to the reactor coolant. At present this fault has not occurred in Dukovany reactors at all and during the to-date 71 fuel cycles the fault only occurred a couple of times. In principle the “no failure“ condition has been achieved, as the desired and non-attainable goal for most countries operating pressurised water reactors (PWR). This condition is also supported with high-standard work of the operators and technologists. As confirmed by periodic international control missions, compliance with operation limits of the fuel and overall culture of reactor operation is high and together with the large-scale modernisations implemented provides a good perspective for further long-term operation of the Dukovany NPP.

3. CHARGE DESIGN

Fresh fuel charges for PWR 440 reactor typically include a minimum number of assembly types (usually two) and none of the to-date tests have proved advantage of use of a higher number of assembly types. Even with the minimum number of assembly types their optimum distribution in the core may be achieved in compliance with the strict limits of evenness of output and coolant temperature distribution with simultaneous provision for the sufficient density of the fission reaction and minimisation of neutron leak across the reactor boundary. The required length of one cycle at Dukovany ranges between 310 and 330 days of effective operation (recalculation of the real cycle length to full-output operation) and the required length is individually and very effectively obtained by the number of the loaded assemblies per charge. This is allowed by the technical conditions of the fuel allowing for selected fuel assemblies to remain in the reactor one year longer (i.e. for five years in the case of the four-year cycle), unless exceeding the permitted burning limit.

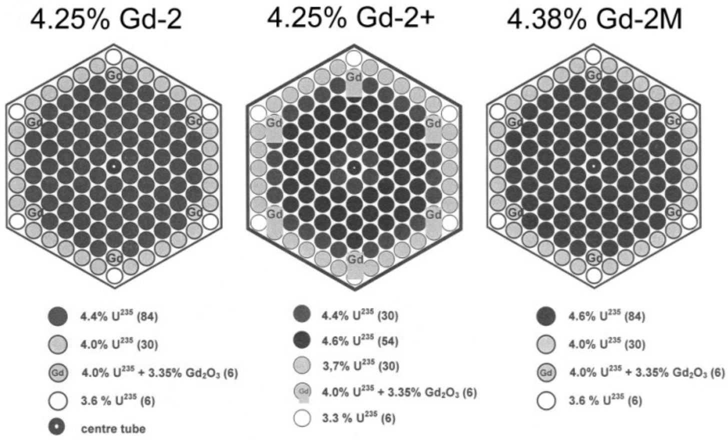

Fig 2: Three types of new assembly for five-year fuel cycle. [7]

While in the four-year fuel cycle the fuel charge usually consisted of 72 and 78 working assemblies in turn (with 6 or 12 regulation assemblies), in the five-year cycle the charge consists of 66 and 60 working assemblies (the core is symmetrical and the numbers of assemblies must always be multiples of six). This also implies another welcomed effect – reduction of the number of burnt assemblies removed from the reactor every year, placed in cooling pools and stored in the interim storage contained after several years of cooling. The mean fuel burning in the five-year cycle is proportionately higher than burning of the four-ear fuel. The most burnt four-year assemblies achieved the burning value of up to 49 MWd/kgU, while in the case of the five-year assemblies the maximum burning value approximates 55 MWd/kgU, which is high above the current global mean for pressurised water reactors.

4. ECONOMIC ASPECT

The Dukovany NPP is one of producers of the cheapest electricity in the Czech Republic, despite the fact that the production costs include high insurance premiums as well as the future costs of decommissioning and burnt fuel storage. Even though the modernised fuel types are more expensive (thanks to higher enrichment, inflation etc), the overall effect of innovations of the fuel cycle is remarkable and supports the plans for extension of the operation life of the NPP high above the originally planned length.

On the other hand, the needs of the Czech electrification system at present and in near future do not support introduction of the extended cycles (18-month), even though the current fuel types would already allow for this operation mode. The main reasons are economic (the overall negative impact of the extended cycles to production costs) but in addition the extensions might cause problems in outage planning for the 6 operated reactors, limited with the necessity to plan the outages off the winter season and without overlaps. [6]

The modern and effective fuel cycles of the Dukovany NPP significantly contribute to the economy of its operation, minimalising the fuel component of production costs and contributing to Dukovany being one of the cheapest producers of ČEZ, generating electricity with costs close to 3 cents per generated kWh. And yet this value (with the fuel costs forming not more than one fifth of the value) includes both high insurance premiums of nuclear power generation and costs of the plant decommissioning at the end of its life.

5. CONCLUSION

The introduction of the five-year fuel cycle in the Dukovany NPP was successfully commenced in 2002. The efforts still continue aimed at modernising and improvement of the fuel cycle economy and operation flexibility of the plant. The principal major innovation activity is reactor output increase to 105 % of the nominal output, accompanies with increased fuel enrichment with preservation of at least the five-year cycle. The maximum pellet burn-up will exceed 70 MWd/kg.

It may be summarised that the future fuel management of PWR 440 reactor must reflect effects such as output increase, output regulation, outage planning coordinated with other power producers and cycle extension thanks to shortening of outages. The necessary precondition for these and other directly related activities is continuous improvement of the software for neutron, thermal hydraulic and safety analyses and maintenance of high-standard technical support by external laboratories.

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