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# BORATED STAINLESS STEEL STORAGE PROJECT TO THE SPENT FUEL OF THE IEA-R1 REACTOR

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## ABSTRACT

**The IEA-R1 research reactor operates in a regimen of 64h weekly, at the power of 4.5 MW. In these conditions, the racks to the spent fuel elements have less than half of its initial capacity. Thus, maintaining these operating circumstances, the storage will have capacity for approximately six years. Whereas the estimated useful life of the IEA-R1 is around twenty years, it will be necessary to increase the storage capacity for the spent fuel. Dr. Henrik Grahn, expert of the International Atomic Energy Agency on wet storage, visiting the IEA-R1 Reactor (September/2012) made some recommendations: among them, the design and installation of racks made with borated stainless steel and internally coated with an aluminum film, so that corrosion of the fuel elements would not occur. This work objective is the project of high capacity storage for spent fuel elements, using borated stainless steel, to answer the Reactor IEA-R1 demand and the security requirements of the International Atomic Energy Agency.**

**Key words: Research Reactor, Storage, Spent Fuel**

## 1. INTRODUCTION

Spent nuclear fuel is generated from the operation of nuclear reactors of all types and it needs to be safely managed following its removal from the reactor core. Spent fuel is considered waste in some circumstances or a potential future energy resource in others and, as such, management options may involve direct disposal (as part of what is generally known as the ‘once through fuel cycle’) or reprocessing (as part of what is generally known as the ‘closed fuel cycle’). Either management option will involve a number of steps, which will necessarily include storage of the spent fuel for some period of time. This time period for storage can differ, depending on the management strategy adopted, from a few months to several decades. The timeframe for storage will be a significant factor in determining the storage arrangements implemented. The final management option may not have been determined at the time of design of the storage facility, leading to some uncertainty in the necessary storage period, a factor that needs to be considered in the adoption of a storage option and the design of the facility. Storage options include wet storage in some form of storage pool or dry storage in a facility or storage casks built for this purpose. Storage casks can be located in a designated area on a site or in a designated storage building. A number of different designs for both wet and dry storage have been developed and used in different States [1]. The basic safety aspects for the storage of spent fuel from power reactors are applicable for the storage of spent fuel from research reactors. A proper graded approach, which takes the differences between the fuel types into account, should be applied. Issues relating specifically to the storage of research reactor fuel, for example, lower heat generation, higher enrichment and the use of cladding materials that are more resistant to corrosion, should be given particular consideration. Fuel composition, cladding material and shapes and sizes of fuel assemblies differ significantly in research reactors. In a research reactor, different fuel elements can be loaded into the research reactor and thus a variety of spent fuel is generated. This may comprise, for example, fuel assemblies with different cladding materials (e.g. Al, stainless steel, Zr) or with different fuel compositions. In certain research reactors, reconstitution of an irradiated fuel assembly (e.g. by replacement of pins) is carried out [1]. Currently, the IEA-R1 reactor operates at full power of 4.5 MW, for 64h weekly, and under these conditions the racks used in the storage of spent fuel elements present less than half of its initial capacity. What indicates autonomy of approximately 6 years of operation, under these circumstances. Figure 1 shows the photo with the current status of the reactor pool storage.

Figure 1: Current photo of the racks for spent fuel elements of the IEA-R1.

After extensive literature research, about high density racks for storage of spent fuel elements, Boral ® was found to have optimum cost – benefit application.

BORAL® Composite is the long-term integrity of a thermal neutron poison and is essential for the criticality control of spent nuclear fuel. In the nuclear industry worldwide, BORAL® has demonstrated long-term integrity when used in the design and fabrication of spent fuel pool storage racks and dual-purpose (storage/transportation) canisters and casks.

BORAL® is a precision hot-rolled composite plate material consisting of a core of mixed aluminum and boron carbide particles, with 1100 Series aluminum cladding on both external surfaces. The cladding forms a solid and effective barrier against the environment. BORAL® is produced over a wide range of surface dimensions, areal densities and thicknesses. BORAL® is manufactured in flat sheets that can be cut, punched, bored and formed into shapes. The physical properties of BORAL® allow it to be designed into fabricated structures, as requested [2].

Boron Products manufactures a standard grade of enriched boric acid to satisfy most nuclear applications. For those applications, where standard product characteristics are not suitable or where an alternate purity is required, custom materials are also available.

BORAL® has the longest continuous service history of any neutron absorbing material and is currently used at seventy nuclear power plants and eleven research reactors worldwide. Decades of successful performance clearly demonstrate its effectiveness in high gamma and neutron radiation fields [3]. Figure 2 shows a photo of high-density storage manufactured with Boral ®.

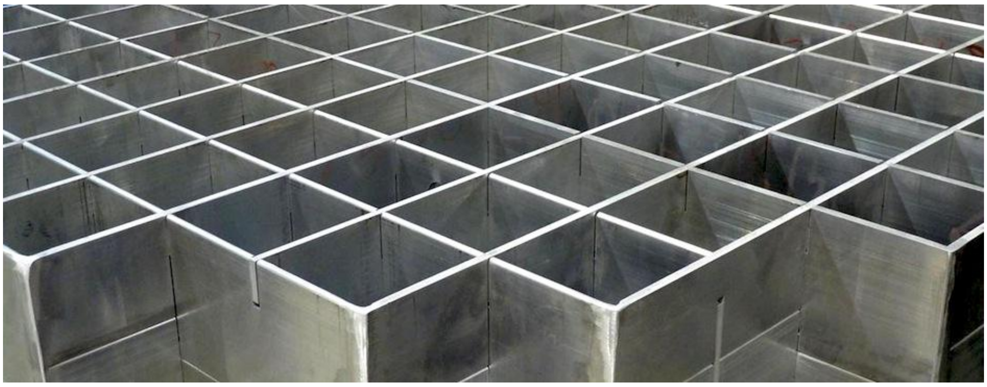

Figure 2: Photo of a high density rack for the storage of spent fuel elements.

## 2. CALCULATION METHODOLOGY

For the purpose of comparing the current and the studied situation, each present rack (6 x 2 matrixes) is replaced by the rack under study (8 x 3 matrixes). This makes it possible to double the storage capacity, using the same area. In order to simulate the case, the MCNP computer code version 4C was used [4].

### 2.1. MCNP-4C Code

MCNP is a general-purpose Monte Carlo N–Particle code that can be used for neutron, photon, electron, or coupled neutron/photon/electron transport, including the capability to calculate eigenvalues for critical systems. The code treats an arbitrary three-dimensional configuration of materials in geometric cells bounded by first- and second-degree surfaces and fourth-degree elliptical tori. Pointwise cross-section data are used. For neutrons, all reactions given in a particular cross-section evaluation (such as ENDF/B-VI) are accounted for. Thermal neutrons are described by both free gas and $S(\alpha,\beta)$ models. For photons, the code considers incoherent and coherent scattering, the possibility of fluorescent emission after photoelectric absorption, absorption in pair production with local emission of annihilation radiation, and bremsstrahlung. A continuous slowing- down model is used for the electron transport that includes positrons, k x-rays, and bremsstrahlung, but, it does not include external or self-induced fields. Important standard features that make the MCNP very versatile and easy to use include a powerful general source, criticality source, and surface source; both geometry and output tally plotters: a rich collection of variance reduction techniques; a flexible tally structure; and an extensive collection of cross-section data [4].

### 2.2. Applied Methodology

The design basis and evaluation of the rack criticality safety are consistent with the contents described in the US-APWR Design Control Document (DCD) [5, 6]. Specifically, out of the 10 CFR 50.68 items (b), items (2) and (3), for new fuel storage racks, and item (4), for spent fuel storage rack, are applied as criticality safety design criteria. And the analysis results were evaluated referring to ANSI/ANS-8.17-2004.

For new fuel storage racks, the maximum keff value, including all biases and uncertainties should be less than or equal to 0.95 for the flooded condition with un-borated water, and less than or equal to 0.98, for optimum moderation, at a 95 percent probability, 95 percent confidence level (95/95). Rack cells are assumed to be loaded with fuel of maximum fuel assembly reactivity [6].

Under the design criteria mentioned above, evaluations were conducted referring to the equation described in the most recent ANSI/ANS-8.17-2004. More specifically, Section 5 of ANSI/ANS-8.17-2004 states that the calculated multiplication factor kp shall be equal to or less than an established allowable neutron multiplication factor; i.e.,

$$k_p \leq k_c - \Delta k_p - \Delta k_c - \Delta k_m \quad (1)$$

If the various uncertainties are independent,

$$k_p \leq k_c - (\Delta k_p^2 + \Delta k_c^2)^{½} - \Delta k_m \quad (2)$$

Where

kp is the calculated keff

kc is the mean keff derived from the code validation

Δkp is the allowance for convergence*, tolerances, and modeling limitations

Δkc is the bias uncertainty derived from the code validation

Δkm is an arbitrary margin to ensure the subcriticality of kp

(* The 2σ value of MCNP output is applied according to the 95/95 rule.)

## 3. CONCLUSIONS

The preliminary results described in item 2 (Calculation Methodology), indicated that the design criteria need to satisfy the standard 10 CFR 50.68 and thereby the sub-criticality is maintained. With this project, it is possible to double the storage capacity of the racks to the spent fuel elements of the IEA-R1, and thus increasing the operational autonomy of the reactor in around 10 years. The reactor core and the spent fuel storage are interconnected: the same water passes through the two of them. So, the cooling of the heat from the decay of fission products and the water treatment chemicals to the storage racks will be done simultaneously.

As a suggestion for future work, it is a "honeycomb" arrangement design, so that the storage compartment bottom of the reactor pool, which is currently underutilized, could be profitably used.

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