OPTIONS FOR THE INTERIM SPENT FUEL STORAGE OF THE IEA-R1 RESEARCH REACTOR IN BRAZIL

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ABSTRACT

This paper presents an analysis of different options for the interim storage of research reactor spent fuels. The results of this analysis were used to propose an option for the interim spent fuel storage of IEA-R1 research reactor at IPEN-CNEN/SP in Brazil. In the case this reactor maintains its continuous operation at 5 MW in the next years, it will be necessary to transfer the spent fuels, today located in the reactor storage pool, to interim spent fuel storage, until a definition of a national politics on the final disposal of these spent fuels will be established.

1. Introduction

In most research reactors spent fuel discharged from the reactor core is initially stored underwater in the reactor storage pool for a long period of time. This allows for heat dissipation and fission product decay.

Interim spent fuel storage facilities have been designed for the safe storage of spent fuel after its removal from the reactor storage pool and before it is reprocessed or disposed as radioactive waste. For the effectiveness operation of such facilities, their design must incorporate features that will be effective for the lifetime of the facilities. Such features are: a) Maintenance of subcriticality; b) Maintenance of fuel integrity; c) Minimization of fuel cladding corrosion; d) Removal of spent fuel decay heat; e) Provision of radiation protection; f) Maintenance of isolation of radioactive material. The design must also consider the expansion of the facility capacity, and its eventual decommissioning.

The research reactor IEA-R1 is located at the "Instituto de Pesquisas Energéticas e Nucleares-IPEN-CNEN/SP", on the campus of São Paulo University (USP), in São Paulo, Brazil. Although designed to operate at 5 MW, from 1957 to 1961 the operation of the reactor was mainly for commissioning tests and some nuclear physics experiments, and the operation regime of the reactor was during week days, less than 8 hours a day, with power levels between 200 kW and 2 MW. In 1961 the reactor started to be operated at a constant power of 2 MW, 8 hours per day, 5 days per week. In 1995 a new program was established to increase the national production of radioisotopes, and the operating regime was changed to continuous 64 hours per week, from Monday through Wednesday, keeping the reactor power at 2 MW, and some modifications started taking place to comply the reactor with new national legislation to operate continuously during 120 hours per week at 5 MW.

During the last years, the burn-up rate of the reactor has been between 120 and 240 MWD per year, and in 2004 it was expected to reach the value of 640 MWD. However, due to some problems in the heat exchanger of the primary cooling system, the reactor power was maintained at 3 MW, instead of 5 MW as originally planned, and the burn-up only reached the value of 400 MWD. According to the original planning, in the middle of 2006, the reactor power should be 5 MW, and the operating schedule should go from 64 continuous hours to 120 continuous hours per week. When this will be achieved, the burn-up rate of the reactor will increase to 1,200 MWD per year, which means between 22 and 24 fuel elements per year.

When the situation of IEA-R1 reactor is analyzed in light of its new proposed operational schedule, it can be observed that its situation is not so comfortable, even considering that in 1999, 127 fuel assemblies were sent back to the United States of America. Presently, storage facilities at IEA-R1 reactor consist of racks located in the reactor pool with the capacity of 156 assemblies. According to the newly proposed operation schedule (5 MW, 120 hours per week) 22 to 24 assemblies will be burnt up annually. Currently, 35 storage positions are occupied, and 24 are required to store the fuel in the reactor core in case of necessity. This means that only 97 positions are currently available for storage of the new spent fuel, suggesting that in 5 years the wet storage facility at the Reactor pool will be full.

The actual policy in Brazil does not foresee the reprocessing/recycling of spent fuel. In case that the construction of repositories for the final disposal of spent fuels in the next years will not be determined by the government, IPEN will have to build a facility for interim storage of the research reactor IEA-R1 spent fuels. Therefore the extended interim storage should be seen as the next step in the spent fuel management of IEA-R1 reactor. The term "extended" takes into account that the facility should be designed for long term storage, considering the uncertainty of the nuclear policy for the spent fuels of Brazilian research reactors.

2. Analysis of options for the spent fuel interim storage of the IEA-R1 research reactor

In 2001, IPEN started the first discussion about the necessity of building in the next 10 years a facility for the interim storage of IEA-R1 research reactor spent fuels. Between 2001 and 2004, IPEN has also participated with other national and Latin-American institutions of the IAEA Regional Project RLA/4/018 entitled "Research Reactor Spent Fuel Management Options in Latin America" [1]. One of interests of IPEN in this project was to find out the possible options for the interim wet and dry storage of research reactor spent fuel, in order to define in a further period the most convenient option.

The universal mode of wet storage consists of storing spent fuel assemblies or fuel elements in water pools, usually supported on racks or in baskets, and/or in canisters. Basket can be defined as an open canister (various) used in handling, transport and storage of spent fuel. It can be also defined as a structure (various) used in casks with functions including heat transfer, criticality control and structural support. Canister can be defined as a closed or sealed container used to isolate and contain the spent fuel. It may rely on other containers (overpacks) for shielding. In the case of the wet storage facility, the pool water surrounding the fuel provides for heat dissipation and radiation shielding, and the racks or other devices ensure a geometrical configuration which maintains the subcriticality. A number of features of this technology are [1]: a) The technology is identified, mature and well established; b) Experience to store even damaged fuel; c) International experience indicates that aluminum cladding spent fuel may be kept underwater over 50 years in pristine conditions, provided that high quality water, environmental conditions and a proper surveillance program are ensured. On the other hand, aluminum cladding fuel degrades almost immediately in poor water quality or environmental conditions; d) The resources, both human and financial, required to implement this technology may well be higher than those of dry interim storage alternatives.

Interim dry storage is a good approach to allow the continued use of the reactor facilities, as either an alternative or a complementary option to the interim wet storage. Presently, dry storage is likely to be a competitive alternative to interim wet storage and may be the best option to store aluminum-based fuel. The major features of this technology are the following [1]: a) Eliminates corrosion degradation of the fuel clad providing that the storage is truly dry and the fuel has been properly dried prior to storage. This provides, at least in principle, a much longer period of interim storage, while the country studies and comes to a decision on final options; b) Can be implemented through modular designs, e.g. metal casks, concrete containers, dual purpose (transport/storage) metal casks, etc.; c) Could be used to reduce the pressure to build new wet facilities, avoiding modifications inside reactor sites, which could generate problems in fulfilling contracts for radioisotope generation. However the need to encapsulate each fuel element before its deposition in the spent fuel storage is an important factor when considering dry interim storage options as it could modify the economical features.

In the dry storage facility the spent fuel is surrounded by a gas such as air or inert gas. Dry storage facilities include the spent fuel storage in vaults, silos and casks [2].

Vaults consist of above- or below-ground reinforced concrete buildings containing arrays of storage cavities suitable for containment of one or more fuel units. Shielding is provided by the exterior structure. Heat removal is normally accomplished by forced or natural convection of air or gas over the exterior of the fuel containing units or storage cavities, and subsequently exhausting this air directly to the outside atmosphere or dissipating the heat via a secondary heat removal system.

Silo or concrete canister means a massive container comprising one or more individual storage cavities. It is usually circular in cross section, with its long axis vertical. Isolation and shielding are provided by an inner, sealed liner and the massive concrete of the canister body. Heat removal is accomplished by radiant transfer, conduction and convection within the body of the canister and natural convection at its exterior surface.

Cask means a massive container that may be used for transport, storage and eventual disposal of the spent fuel. It provides shielding and containment of spent fuel by physical barriers which may include the metal or concrete body of the cask and welded or sealed liners, canisters or lids. Heat is removed from the stored fuel by radiant heat transfer to the surrounding environment and natural or forced convection. Casks may be located in enclosed or non-enclosed areas. The spent fuels are loaded vertically in the casks that are stored in vertical positions. They are placed in baskets or sealed metal canister that provide structural resistance, subcriticality and closing through a double cover. The casks can have single-, dual- or multiple purposes. The spent fuel transport option by cask is called a single-purpose and the transport and storage options are called dual-purpose. The multi-purpose term is reserved for the casks that are designed with the transport, storage and disposal options. The IPEN studies are concentrated only in casks with dual-purpose.

The dual purpose option can be found as cask-based or canister-based systems [3]. For the cask-based system one integral unit serves all purposes for which the system is designed. For canister-based systems, a sealed canister contains the spent fuel, and is a common component or subsystem to the storage and transport system, as applicable to the design. Typically, canister-based systems will use overpacks to house the canister for the purposes of storage and transport. The container system for spent fuel storage and transport shall be designed to satisfy specific radiological safety functions. In general, it shall contain the radioactive material, limit emission of ionizing radiation, dissipate internal heat, and assure subcriticality. The container shall also be designed to assure structural integrity and thermal performance that allows proper functioning of the systems' radiological safety features. Cask-based systems have been developed for storage and transport of spent fuel. These have generally been metal systems. For these cask designs, the same integral cask unit provides all radiological safety functions needed for storage and transport. For canister-based systems the specific overpack along with the canister provides the level of performance for each safety feature for each purpose. The canister may provide one or more of the required safety functions. For example, the canister includes a fuel support structure or basket, which generally provides criticality control for storage, transport, and disposal, as applicable. The canister may also provide confinement of radioactive material for storage, but the transport overpack is generally used for containment of radioactive material during transport. The shielding required for storage and transport is typically provided by the appropriate overpack.

Besides the mentioned characteristics of the project above, certain general characteristics are important in the choice of an option for spent fuel interim storage. These characteristics include [3]: a) mobility; b) the possibility of retrievability of fuel; c) modularity; d) the reduction in the spent fuel handling operations; e) public acceptance; and f) economics.

Mobility is the ability to move a system from place to place. Retrievability will be defined as the ability to remove the cask, package, canister or spent fuel from its enclosure or emplacement. Mobility can be considered as a part of retrievability. The retrieval is always possible. The concern is whether retrieval, if necessary, will be easy or difficult to accomplish. Modularity is the ability to separate into distinct and standard units. The feature allows the designer to select canisters or casks of some chosen standard size and configuration. The utilization of dual-purpose casks, for example, will reduce the number of the fuel handling operations in comparison with the single-purpose casks. Although attempts to predict public acceptance are subjective and speculative, there are several factors that should be considered in such an assessment. A common public concern related to temporary storage is that temporary storage measures may be extended and eventually become permanent. Although canister-based and cask-based systems are regulated in the same way, and are expected to be equal from a radiological safety standpoint, the public perception of safety might be enhanced when canister-based systems are used. The canister might be perceived to provide an additional barrier of containment. Concerning economical advantages, wet storage facilities require continuous operation of cooling, filtration, cleaning and sampling systems which depend upon mechanical components such as pumps, valves and filters. The chemical and temperature control of water requires continuous monitoring and sampling. Such operational requirements increase with the amount of fuel in the pool and are particularly high when pools are near to capacity [4]. Siemens engineers have stated that dry storage facility construction costs are considerably lower per tonne of fuel stored than those of the wet storage facility, particularly in the case of small facilities.

3. Option proposed for the spent fuel interim storage of the IEA-R1 research reactor

The choose of an option to be proposed for the spent fuel interim storage of IEA-R1 research reactor was conducted in a way to supply a solution inside the technological and economic realities of the country. For the IEA-R1 reactor it was not defined a date for its decommissioning. The reactor has been operating safely since 1957 and there is no plan to build a new research reactor to replace its research activities and radioisotope production. It is also not defined in the country the policy to be adopted for the spent fuel management after the operational storage. These uncertainties raise difficulties to define the type of interim storage facility to be built in the country.

Wet storages are made in pools, whose systems should be dimensioned according to their capacities in supporting safely the storage of a certain number of spent fuels. The uncertainties in the number of spent fuels to be stored and in the period of time of storing could overestimate or underestimate the dimension of the pool needed. The modularity of some dry storage facilities becomes attractive. Besides, the construction and operational costs per tonne of fuel for wet storage facilities have been shown to be higher than those for dry storage facilities. Pools can give to the public the perception of a permanent facility, without mobility, which should be decommissioned in the future, complicating the licensing procedures. The wet storage facility construction near the reactor building could bring interruptions in reactor operation, hindering the execution of radioisotope production contracts.

These aspects lead that the chosen option for the spent fuel storage of IEA-R1 reactor was directed to dry storage facilities. Among the existing dry storage, the first to be evaluated, was the construction near the reactor building of a vault type facility, where internally would be lodged the cavities for the dry storage of the spent fuels. In order to attend this request, it will be also necessary to build a transfer cask and a transport cask for the spent fuel. The transfer cask would be utilized to transfer the spent fuel from the reactor pool to the transport cask. The later would permit to transport the spent fuel to the dry storage facility. It was also discussed the necessity of building a hot cell, where each fuel element would be encapsulated before its placement in the storage cavities. Again, the uncertainties in the number of spent fuels to be stored and the length of time of this storage complicate the establishment of the vault option, mainly in the establishment of building dimensions and the number of cavities for the pretended storage. The vault option was relegated to a second plan, and the choice of casks and silos, in distinct and standard units, was considered the better alternative. Besides, it was on-going, inside the IAEA RLA/4/018 project, the conception of a dual purpose metallic transport cask to attend the necessity for spent fuel transport and storage of Latin America research reactors [1]. This metallic cask can accommodate 21 MTR fuel elements, as those of IEA-R1 reactor, and 78 TRIGA fuels. Based on these considerations, the dual purpose cask is being considered as the most feasible option for the spent fuel storage of IEA-R1 reactor. This option presents advantages against other options as it shown characteristics like mobility, modularity and reduction capacity of the fuel handling operations. The conceptual design of the dual transport cask is finalized and the construction of a scaled prototype for tests in CDTN-CNEN/SP is on-going. IPEN is developing the Preliminary Safety Analysis Report (PSAR) of the interim spent fuel storage facility that will accommodate the dual purpose storage casks.

4. References

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