OVERVIEW OF REMOTE TECHNOLOGIES APPLIED TO RESEARCH REACTOR FUEL

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Abstract

This paper gives a brief overview of the remote technologies applied to research reactor fuels. Due to many reasons, the remote technology utilization to research reactor fuel is not so widespread as it is for power reactor fuels, however, the advantages of the application of such techniques are obvious.

1. INTRODUCTION

Since the first nuclear research reactor went critical in 1942, over 550 research reactors have been constructed world-wide and, of these, approximately 300 are currently in operation. Approximately 80% of the reactors currently in operation around the world are over 20 years old and 56 % are over 30 years old [1].

These research reactors were designed and constructed according to the industrial standard and practices in the country of origin at the time of construction.

The design, operation and utilization philosophy of nuclear research reactors is fundamentally different from that of nuclear power reactors. In addition, utilization may lead also to more frequent system modifications than for the power station systems, sometimes including even the reactor itself.

The same difference exists between the spent fuel manipulation systems and the equipment for power reactors and research reactors. This is due to different reasons, some of them are follows:

- Only some research reactors burn significant quantities of fuel each year;
- The frequency of the spent fuel manipulations is much less than it is for power reactors;
- The spent fuel assemblies used in research reactors, in general, are considerably smaller in size than the power reactors fuel assemblies;
- Application of the remote technology was not so developed and widespread at the time of construction of the majority of the research reactors, as it is today.

2. SPENT FUEL MANIPULATIONS IN RESEARCH REACTORS

Most of the research reactors began their operation in the early 60's and 70's. Spent fuel production is a much slower process than it is for the power reactors. So the built-in storage capacities were enough for many years of operation of the research reactors in the first periods. From some research reactors, after shorter or longer periods of storage, the spent fuel was transported for reprocessing.

In the last 10-15 years some modifications were carried out related to the fuel cycle, that resulted in increased research reactor spent fuel production. Two of the major contributing factors are:

- research reactor power upgrades for higher power capacities;
- enrichment reduction to LEU (less than 20 % of U-235 content).

Until 1988, the USA as the main supplier of HEU for research reactors took back the spent fuel for reprocessing. Russia, as an other important supplier of HEU for research reactors has never taken back the supplied fuel from the countries of utilization.

At the beginning of the 1990's, an increasing number of fuel accumulated at the site of research reactors, approaching the capacity limit of their storage facilities.

As the reprocessing capacities were and are being limited for research reactor fuel due to high cost and the originally designed storage capacities reached their limit, additional storage areas were necessary. It was provided by re-racking or modifying the existing compartments of the reactor facility to make it possible to store the spent fuel there.

In some countries new storage facilities were constructed usually on the site, so the spent fuel transportation has been carried out within the site boundary.

However, since last year the USA re-opened the spent fuel take back policy with modified conditions it can be seen from the above description, that the demand on the spent fuel manipulations related to the spent fuel management considerably increased in present time.

From the beginning of the 90's more and more power reactor operating country were forced to review or make some correction on their spent fuel back-end strategy. The most preferable solution became the so called intermediate dry storage provided by separate storage building as MVDS and CASCAD, or storage in different type of casks (CASTOR, TN etc.). In countries with limited nuclear industries (having just few power reactors and other kind of nuclear facilities) the spent fuel intermediate storage provided by a central facility could be a good solution. This central storage facility can accommodate different kinds of fuel, if during the design stage of the facility careful considerations are taken. That kind of mutual utilization of storage facilities will claim for additional spent fuel handling manipulations at the research reactor facilities.

Spent fuel transfer (handling and transport) from research reactors to the central storage facilities will be necessary. In some cases, the shipping cask may be so large and heavy, that it is impossible or undesirable to load the spent fuel inside the research reactor facility. A transfer flask may then be used to transfer one or more fuel assemblies at a time, from the research reactor facility to the large cask outside the facility.

There is a wide range of spent fuel types for power reactors, but for research reactors this range is even wider. In some research reactor facilities different types of fuel were and are being used during the lifetime of the facility. Fuel types used in research reactors change more frequently than in power rectors. Research reactor fuel can be divided onto three groups; plate type assemblies (MTR in many countries), multi-tube assemblies (BR-2 in Belgium, DIDO in UK, IRT-3M or VVR-M in Russia) single- or multi-rod type assemblies (Slowpoke fuel in Canada, TRIGA in many countries, SM-2 in Russia). Although the majority of the research reactor spent fuel are of MTR or TRIGA types, a significant percentage of experimental and exotic fuels exist at research reactors around the world. The research reactor fuel assemblies are usually 60-90 cm long, but there are exceptions (Slowpoke fuel pin is just 30 cm long, while another multi-rod type Canadian fuel, NRU is 275 cm long). In the Russian designed research reactors, a large variety of fuel assembly geometry have been used. The active part of these fuel assemblies vary in length from 35-200 cm. All this means that, the spent fuel manipulation systems must be compatible with different kinds of fuel assemblies [2].

Until now most of the research reactor spent fuel are being stored in wet conditions. Taking into consideration the fact, that 80% of these reactors operates more than 20 years, it means that an increasing number of spent fuel are in water for 20 or 30 years. In the future to avoid any possible degradation of spent fuel assemblies in considerable amount at the same time, spent fuel canning or transition from wet storage to dry storage will be necessary. This will claim for additional fuel handling manipulations, not applied now in research reactors.

Considering the above described rising demand on research reactor spent fuel manipulation, it is obvious, that application of remote technology could provide a great benefit, especially in radiation protection (occupational dose reduction) and operation reliability.

3. REMOTE TECHNOLOGY APPLICATION IN RESEARCH REACTOR SPENT FUEL HANDLING

Research reactors constructed in the 60's and 70's were designed and operated with a very limited number of remote operations. Because of different reasons, until now, there is no real progress in use of remote technologies at research reactor facilities. Some of the main reasons are as follows.

- The necessary investment and utilization cost of the remote technology equipment is too high for the research reactor operators;
- In most cases, operators have ample time for spent fuel manipulation carried out one by one;
- There are not too many generally applicable remote equipment, especially designed for research reactor spent fuel manipulation.

In spite of these facts there are some areas, where remote technology is applied in research reactor facilities related to spent fuel management.

3.1. Spent fuel handling

Usually it is provided by long tools with manual operation in the reactor pool, or in the at-reactor pool. Application of even a simple spent fuel handling machine is very rare, however there are examples e.g. at Cirus Research Reactor, in India [3]. Remote hand tool application at power reactors is unique, used only for relatively low volume of operations. For research reactors manipulation this is the most conventional tool.

Spent fuel transfer between the reactor and the at-reactor pool is mainly provided by remote handling tools. Some reactor compartments have a direct connection between the reactor and the storage pool, where the spent fuel can be transferred. It is provided by a buggy system arranged in a channel or through a chute used for example, in some Russian designed research reactors where the fuel transfer cask is placed over the reactor pool.

3.2. Spent fuel transportation

This is mainly provided by spent fuel transportation casks or flasks. The range is very wide from the very simple ones to the highly sophisticated types, designed for off-site transportation as well. While many casks have been approved internationally for use in the shipment of spent fuel, only a few are suitable for the shipment of spent fuel from research reactors (CASTOR M2, or Russian TK-19).

Transfer of the spent fuel assemblies from the storage position in the pool into the transfer cask is provided by a lifting equipment installed on the cask or separate handling equipment is used to carry out the cask loading process. Casks used for off-site transportation usually do not include spent fuel lifting systems. So, for loading these casks an intermediate cask or other kind of remote fuel handling equipment, with necessary shielding arrangement, is used.

3.3. Spent fuel examination

There are some spent fuel inspection systems that are used for research reactor spent fuel examination. That kind of equipment can be divided into two groups; systems providing direct visualization of spent fuel assemblies and systems utilizing different level of tomography.

Equipment providing direct visualization is manufactured nowadays with fiber optic equipped with a CCTV system. Earlier versions of that equipment used in research reactor facilities were only a periscope applied for spent fuel identification, defect detection or to check correct spent fuel position, during manipulations.

In some research reactor facilities, Computer Aided Tomography are in use for fuel examination. Neutron beam produced by the reactor is used for this purpose. A multi-axis robot has been applied to carry up the fuel to the neutron beam [4].

3.4. Spent fuel cutting

In some cases at the research reactor facilities, it may be necessary to trim away those portions of the fuel assembly which do not contain fuel (e.g. grid plate fittings, end boxes) in order for the assembly to fit into the shipping cask basket, for example at Demokritos Research Reactor in Greece [3] or at DHRUVA Research Reactor in India [4]. For this purpose, underwater cut off saw is used in these facilities. Depending on the fuel geometry and whether both end of the fuel assembly must be cut, different equipment arrangement exists (saw with single blade or double blade, different spent fuel assembly fixing frames, etc.)

3.5. Spent fuel canning

Spent fuel assemblies beginning to leak during the operation in the reactor or during storage should be canned to avoid the continuous radioactive release into the surrounding environment. For this purpose tubes which can be closed by welding or bolting may be a good solution. As the spent fuel assembly leak in research reactor is not a frequent event until now, and the long term storage of research reactor fuel assemblies in wet condition presents good results, the reactor facilities do not have equipment for canning the spent fuel assemblies in large numbers. Taking into consideration the amount of spent fuel assembly quantities stored in wet condition for longer and longer time, the demand on equipment for spent fuel canning will raise. Techniques to can the research reactor spent fuel assemblies already exist, however further progress will be necessary applying more and more remote equipment to meet the requirement.

4. FUTURE DEVELOPMENT

It can be seen from the previous chapters, that the frequency of research reactor spent fuel manipulation, including spent fuel handling, transfer, examination, etc., will increase. The necessary manipulations will include more and more complex operations not designed or intended to do at the reactor facility earlier. Remote operations can be a key factor in performing these spent fuel management manipulations.

The main area where real progress will be necessary in the near future is the research reactor spent fuel transport from the existing pools into the new storage facilities, including the fuel transition from wet storage to dry storage.

Considering the mutual utilization of a spent fuel storage facility for power reactor spent fuel and research reactor spent fuel, special interface equipment and systems applying remote technology will be necessary.

Transition of the spent fuel between different storage environments will make it necessary to provide more complex operations (detailed spent fuel examination, applications of special fuel canning before transfer, etc.) To provide the necessary protection for the operators during these manipulations and the reliability to avoid errors due to the large number of similar operating sequences, more and more remote equipment with higher and higher automatisation level should be used.

Further development in the remote technology including not only the nuclear industry, can promote the progress in research reactor spent fuel handling, with more reliable remote equipment, providing further occupational dose reduction as well.

Standardization at components and sub-systems level will help to integrate different configurations or systems.

Special remote systems designed for power reactors or for power rector spent fuel storage systems may be also used for research reactor spent fuel with necessary interface equipment or tools in the future.

5. CONCLUSION

Duo to different reasons, the remote technology utilization for research reactor fuel is not so widespread as it is for the power reactor fuels, however, the advantages of the application of such techniques are obvious.

Considering the increased number of research reactor spent fuel handling operations, some limited development in the area of remote technology application at research reactors are foreseen. However, due to the different nature of the power plants and research reactor facilities, utilization of the remote operations at research reactors will never be so usual and sophisticated as it is or will be at power reactor facilities.

Related to the construction of new research reactors and spent fuel storage facilities, application of the remote technology will be more and more common as the reliability, radiation tolerance and cost reduction of remote system and equipment increases with the development of the industry.

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