REVIEW OF MAIN SPECIFICATIONS AND ALLOWANCES FOR RESEARCH REACTOR MATERIALS AIMING DECOMMISSIONING

PAULO ERNESTO DE OLIVEIRA LAINETTI

Centro de Química e Meio Ambiente – CQMA
INSTITUTO DE PESQUISAS ENERGÉTICAS E NUCLEARES IPEN-CNEN/SP
Av. Prof. Lineu Prestes, 2242 C. Universitária São Paulo – SP, Brazil CEP- 5508-000
Telephone: 55 11 3133-9333 Facsimile: 55 11 3133-9249 E-mail: lainetti@ipen.br

ABSTRACT

The decommissioning of nuclear facilities, especially research reactors, can be facilitated, with significant reduction of the costs and amount of wastes, if suitable choice of the employed materials and their chemical composition is made during the design phase. It deserves special attention the reactor regions where activation of materials is possible, since the presence of determined elements in the composition of alloys and structural materials can affect significantly the future decommissioning. Then, the proper selection of the materials and their chemical composition and respective allowances will reduce the impact in the future decommissioning costs, amount of high level wastes generated during the process and in the safety of the involved personnel. In this paper is presented a review of the main criteria employed in the choice of materials used for fuel elements and structural components for research reactors.

1. Introduction

The shutdown of a research reactor and their related supporting facilities, such as radioisotope production and waste treatment facilities, leaves an important nuclear decommissioning legacy. Interest for reducing the residual radioactivity in construction materials employed in research reactors evolves from the impact that this reduction will have in the decommissioning and dismantling future activities. To facilitate future research reactors' dismantling and decommissioning projects some recommendations, such as the clearance levels of the most important isotopes for different materials employed in the reactors' construction, should be included in the regulatory norms and procedures on national and international levels. The decommissioning of nuclear facilities, especially research reactors, can be facilitated, with significant reduction of the costs and amount of wastes, if suitable choice of the employed materials and their chemical composition is made during the design phase. Regarding the decommissioning issues involved in the design of a new research reactor, the main concern should be to take into account the lessons learned and the worldwide accumulated experience in the decommissioning of such facilities [1] avoiding mistakes and reducing the amount of problematic wastes in the future.

2. Brazilian regulatory procedures regarding research reactors

In Brazil, CNEN is the Regulatory Body in charge of regulating, licensing and controlling nuclear energy. Since 2000, CNEN has been under the Ministry of Science and Technology - MCT (Ministério da Ciência e Tecnologia). Some of CNEN responsibilities include: the preparation and issuance of regulations on nuclear safety, radiation protection, radioactive waste management, nuclear material control and physical protection; licensing and authorization of sitting, construction, operation and decommissioning of nuclear facilities; regulatory inspection; acting as a national authority for the purpose of implementing international agreements and treaties related to nuclear safety, security and safeguards; participating in the national preparedness and response to nuclear emergencies.

The Brazilian legislation defines the operating organization as the prime responsible for the safety of a nuclear or radioactive installation, including the management of spent fuel and radioactive waste. The licensing regulation CNEN-NE-1.04 establishes that no nuclear facility shall operate without a license. It also establishes the necessary review and assessment process, including the specification of the documentation to be presented to CNEN at each phase of the licensing process. It finally establishes a system of regulatory inspections and the corresponding enforcement mechanisms to ensure that the licensing conditions are being fulfilled. The enforcement mechanisms include the authority of CNEN to modify, suspend or revoke the license. The licensing process is divided in several steps: Site Approval; Construction License; Authorization for Nuclear Material Utilization; Authorization for Initial Operation; Authorization for Permanent Operation; Authorization for Decommissioning Federal Law 9756, approved in 1998, establishes taxes and fees for each individual licensing step, as well as for the routine work of supervision of the installation by CNEN. Other governmental bodies are involved in the licensing process, through appropriate consultations. The most important ones are the Institute for Environmental and Renewable Natural Resources (Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis - IBAMA), in charge of environmental licensing [2].

Nevertheless, Brazil does not have yet a national regulation that establishes rules for decommissioning of nuclear facilities and no decommissioning policy has been adopted until now regarding research reactors. As the Brazilian nuclear program and related facilities are relatively new in comparison with other countries, it should be taken into account the international experience for the decommissioning of shut down nuclear facilities. These activities have increased within the last ten years and are constantly increasing as older facilities retire and the need for their dismantling or safe enclosure becomes prominent.

3. Decommissioning requirements for research reactors and nuclear facilities

Decommissioning of large facilities such as research reactors and associated units is a technically complex task and has significant implications for the local social and economic situation. Regulatory requirements are an opportunity to improve the technical aspects of design, construction and operation of nuclear installations, and they will affect the safety and the decommissioning costs of such facilities. Many issues should be solved before successful decommissioning can be achieved and include clearly defined regulatory requirements for decommissioning of nuclear facilities.

Decommissioning is defined to include all activities after the final termination of operation of a nuclear facility. Decommissioning consists of: the final shut down of a nuclear facility; sometimes followed by transferring it into safe store condition; decontamination and dismantling of systems and components; demolition of some or all of the buildings; the clearance and release of the site to the green-field state if possible.

The phase of decommissioning is the last life cycle phase of a nuclear facility. All these activities are considered to be kept under regulatory control, in continuation from the operational phase. This includes licensing procedures where legally required or regulatory approval as well as regulatory inspection by the authorities. Some countries are planning to introduce further legal requirements for licensing of decommissioning activities and develop corresponding standards and guidelines. In general, most countries see the need for more precise legal requirements and regulatory guidelines to regulate or license and to inspect decommissioning activities of nuclear facilities [3].

4. Clearance of waste material - release and clearance criteria

An important feature of decommissioning is the possibility to clear waste material for recycling, reuse or conventional disposal. The clearance might be unrestricted or subject to conditions after clearance e.g. a prescribed installation for processing or disposal. Related regulations for this, i.e. clearance criteria and procedures, are developed and applied in almost all countries. The clearance criteria are in most cases based on the internationally agreed criteria for the resulting radiation exposure.

Related to future regulatory requirements for new projects**, s**ome countries develop further requirements for licensing of decommissioning activities and develop corresponding standards and guidelines. For instance, the members of the European Union are in the process of introducing the EURATOM 96/29 directive into their legal framework. In general, most countries see the need for more precise legal requirements and regulatory guidelines to regulate or license and inspect decommissioning activities of nuclear facilities.

Is interesting that, even in Europe, most countries have no specific regulations in place and some countries plan to introduce a licensing regime for decommissioning. Decommissioning is regulated mostly on a case by case basis by approval of the regulatory body similar to plant modifications. Safety reviews for these activities are generally required. Some countries require submission of preliminary decommissioning considerations (feasibility study) as a license condition already for operation. Such data are to be revised regularly. In all countries the regulatory bodies continue to be in charge of regulating safety and radiation protection as the plants change over from operation to decommissioning activities. The relevant regulations (safety, requirements, rules, standards), normally applicable to construction and operation, continue to be valid also for decommissioning, sometimes including adaptations or amendments as appropriate [3,4].

An important aspect of the decommissioning task is to describe the specific activity and surface contamination clearance criteria and clearance procedures for the release of waste material for unrestricted use, and authorized reuse. The release of waste material (containing radioactivity below prescribed limits) for unrestricted use, conventional disposal, recycling or reuse is possible in most of countries. By this provision the amount of radioactive waste to be disposed off can be kept small. If necessary, the release of waste material is regulated on a case by case basis.

Some countries have not yet established release and clearance criteria and procedures but are in progress of developing such criteria. In most countries release criteria refer to the international criteria discussed at the IAEA or the European Union. The international criteria are based on a dose of the order of 10 µSv/y to the public for each practice of release pathways. The development of an integrated approach for clearance criteria to release waste material from licensed activities taking into consideration the fundamental international guidance on acceptable radiation exposure is commendable practice.

5. Specifications and allowances for research reactors materials

The commendable practices are not international standards or guidelines. The preparation of an efficient, safe and economic decommissioning project begins during the design phase, since a lot of problems can be avoided by the proper choice of construction materials, mainly those employed in regions subjected to activation.

The decommissioning items listed below should be considered already during design and construction of the reactor or for any modernization or refurbishment during the operational life. These items include: - Minimizing the potential for activation of the materials and / or contamination; - Provision of equipment and systems in order to have adequate space to allow for the easy implementation of decommissioning activities; - Management of radioactive waste to be generated during the lifetime of the reactor to minimize the need for treatment and disposal during the decommissioning.

Therefore, a design principle related to decommissioning to be adopted is that the design of the reactor facility must minimize contamination and activation of components. The design of the reactor facility should take into account the need of monitoring the parameters, during the life of the reactor, that can affect the inventory of radioactivity and the radiological factors needed to estimate the potential radiation levels during the decommissioning phase. Materials near the reactor core or passing through it are activated and become sources of contamination and/or activation of other materials. Of particular importance to the decommissioning activities is the reduction of the amount and intensity of radiation sources existing in the reactor building.

The neutron flux generated in the reactor core induces radioactivity in materials nearby. At the time of decommissioning, it is advisable to plan a period of decline prior to handling these materials in order to decrease the dose to workers and decrease the volume of tailings. Still in design phase or during the reforms, the choice of materials should take into consideration the following characteristics: physical properties depending on operational requirements; Mechanical properties to ensure good performance of the material; the range of possible activation products that can be generated and half lives; for those materials in contact with water, consider the resistance to corrosion.

An important recommendation is that materials which are subject to high neutron fluxes must be specified according to nuclear standards, because they restrict the presence of impurities that raise the levels of radiation. The main characteristics of some materials used in this type of project are presented bellow. Aluminum alloys are used preferably in materials subjected to high-flow regions in the reactor, since Al has low cross-section of neutron capture and good mechanical performance under neutron radiation. These alloys are widely used in the manufacture of the plate array and other reactor components. The main advantage is that most of the isotopes resulting from irradiation of Al have a short half life, being ^{24}Na the main one. Therefore, these components can be handled as low-activity waste in a relatively short space of time after the final shutdown of reactor. The zirconium alloys have benefits under neutron irradiation, and mechanical properties (low absorption cross section and high resistance under neutron flux). These alloys must be manufactured to standards for nuclear pattern, limiting the content of hafnium as an impurity. Nevertheless, the irradiation produces radionuclides with longer half life than the aluminum alloys such as ^{60}Co, ^{125}Sb and ^{93m}Ni. The stainless steel is a material with excellent corrosion resistance and has been used in various structures of the reactors. Despite the use of special alloys with low cobalt content, the activation products such as ^{60}Co, ^{51}Cr, ^{55}Fe, ^{59}Fe, ^{56}Mg, make these alloys difficult to handle before the decay, and therefore usually require the use of shields. Therefore, the use of these alloys has been avoided, particularly in regions of high flow. The concrete that is used as shielding has small amount of impurity such as iron, cobalt and europium which tend to become radioactive under intense neutron flux. Wherever possible, activation sources should be positioned away from concrete bioshields or other shield walls in order to reduce the quantity of activated concrete. Given the nature of the materials that make up concrete, it is difficult to source these so as to reduce activation [5].

5. Conclusion

Designing for decommissioning is the best long term facilitator of the decommissioning process [6,7]. In reactors, the trace elements that are always present in construction material will be activated in a neutron flux. The resulting radioactive isotopes contribute to operational doses (e.g. ^{60}Co) and can become significant for waste management (e.g. long lived isotopes such as ^{36}Cl from graphite and ^{14}C from most construction material). It may not be practicable or cost effective to eliminate relevant trace elements entirely, but care should be taken in construction material selection and samples should be retained for future analysis to support characterization campaigns for decommissioning; for example, the use of aluminum rather than stainless steel for research reactor containment tanks reduces the quantities of low and intermediate level waste (LILW), since all commercial stainless steels contain significant quantities of elemental cobalt (although most aluminum alloys contain some residual traces of cobalt) [8]. The international exchange of information concerning the specifications and allowances of materials employed in the construction of components of research reactors is of fundamental importance for the reduction of the waste volume and for workers safety during the decommissioning phase. The international availability of information on specifications and tolerances for the materials used in research reactors should be encouraged and emphasized.

6. References

[1] ***Decommissioning of Research Reactors: Evolution, State of the Art***, ***Open Issues***, Technical Report Series 446, IAEA, Vienna, 2006.

[2] Silva, E. F., ***National Report of Brazil – Legal and Regulatory Framework on Decommissioning of Research Reactors***, CNEN, June, 2006.

[3] ***Regulatory Practices for Decommissioning of Nuclear Facilities with Special Regard of Regulatory Inspection Practices*****,** Working Group on Inspection Practices (WGIP), NEA/CNRA/R(99)4**,** Paris, Feb. 2000.

[4] ***Review of Existing and Future Requirements for Decommissioning Nuclear facilities in CIS*****,** European Commission, Direct. Gen. XI, Jan. 1999.

[5] ***Design Concepts to Minimize the Activation of the Biological Shield of Light Water Reactors***, European Commission, Rep. EUR-8804, EC, Brussels, 1985.

[6] ***Application of the Management System for Facilities and Activities***, IAEA Safety Standards Series No. GS-G-3.1, IAEA, Vienna, 2006.

[7] ***Design and Construction of Nuclear Power Plants to Facilitate Decommissioning***, Technical Reports Series 382, IAEA, Vienna 1997.

[8] ***Decommissioning of Research Reactors and Other Small Facilities by Making Optimal Use of Available Resources***, Technical Reports Series 463, IAEA, Vienna, 2008.

7. Acknowledgments

The author would like to express his gratitude to the CNPQ – *Conselho Nacional de Desenvolvimento Científico e Tecnológico* / MCT – *Ministério da Ciência e Tecnologia do Brasil* for the financial support for his participation in the RRFM 2011 - European Research Reactor Conference 2011.