

RESEARCH REACTOR DECOMMISSIONING IN THE NEW REGULATORY ENVIRONMENT

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ABSTRACT

The regulatory environment for decommissioning has changed dramatically since the promulgation of the final rule for decommissioning by the U.S. Nuclear Regulatory Commission (NRC), which was issued in July 1997 as revisions to 10 CFR Part 20.

This paper discusses the impact of the new regulatory developments on reactor decommissioning, with particular emphasis on research reactors. An example of a university research reactor decommissioning is used to illustrate the impact of the new regulatory environment.

INTRODUCTION

Many nuclear facilities in the federal and the private sector are slated for decontamination and decommissioning (D&D). The emphasis and expenditure of resources in nuclear programs has shifted to D&D of nuclear facilities which is rapidly becoming the only growing area in the nuclear field.

World-wide over sixty power reactors are no longer in operation; in addition, to date, over two hundred of the research reactors have been shut down.

In the United States, in the private sector, many of the nuclear power reactors are approaching their design life and many utilities are planning decommissioning of their reactors for one reason or another. The university research in nuclear engineering is in a steep decline with many of the research programs terminated. Increasingly, the universities have decided to shut down their research reactors and are considering D&D of these reactors as soon as possible. The factors driving these decisions include the declining enrollment in nuclear programs, an uncertain future of the nuclear energy in the country, public opposition to things nuclear, liability concerns, and a sense of even stricter regulations down the road.

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During the past few years, a number of regulatory developments have occurred that have a major impact on the research reactor decommissioning. The cleanup levels under the new regulations are required to be risk based and derived on a site-specific basis rather than the prescriptive generic values. The dose level set for decommissioning for an individual member of the critical group is a fraction of the public dose limit. Since the ultimate goal of D&D is to retire facilities from service while providing protection of human health and safety and to release the sites without radiological restrictions, cleanup standards have enormous impact on the decommissioning projects.

REGULATORY BACKGROUND

Until recently, the regulatory environment for the research reactor decommissioning was fairly straightforward. The NRC Regulatory Guide 1.86 was the primary standard for the surface contamination limits which could be directly applied in the field as the residual radioactivity limits.

However, the guide does not provide volumetric contamination limits. It is also a 1974 document, which was in need of revision or replacement because of the evolution in radiation protection standards.

With an increased understanding of the effects of radiation and an enhanced ability to measure lower radiation levels and lower radioactive contamination levels, the D&D standards have continued to evolve during the past four decades. During the startup and operation of the nuclear industry spanning from the mid-50s into the mid-80s, the regulations for the industry were focused on design, construction, and operational oversight. Decommissioning activities conducted during this period were based on negotiated criteria for each individual site with regulatory guidance having a limited relationship to public risk avoidance. Added to this was the issue of regulatory authority by multiple government agencies such as the NRC, U.S. Environmental Protection Agency (EPA), U.S. Department of Energy (DOE), and agreement state agencies with the potential for overlapping and sometimes conflicting requirements. Starting in the early 1990s, the federal regulatory authorities, specifically the NRC and the EPA initiated efforts to draft regulatory standards that would be based on a consistent risk basis that could be applied to site-specific conditions. The NRC issued a final rule on this in July 1997, after issuing two drafts in 1993 and 1994 for review and comment. The rule specifies an individual dose limit of 25 mrem/yr for releasing a site without radiological restrictions; it includes groundwater pathway in considering all potential exposure pathways.

The EPA had drafted its version of the Radiation Site Cleanup Regulation in 40 CFR 196. This draft was submitted to Office of Management and Budget (OMB) in March 1996 but was never issued for public comment; it was later withdrawn. This parallel effort by EPA was to establish a dose criteria of 15 mrem/yr, with an additional provision of 4 mrem/yr for groundwater protection.

The approaches by the NRC and EPA were evaluated by the American Nuclear Society through its Special Committee on Site Cleanup and Restoration Standards. A summary of the comparison of the two approaches and the ANS comments on the, then draft rule, are available in reference 1. The differences highlight the two agencies differing philosophy in risk application.

The NRC's limit is derived from determining the annual dose above background that is safe for general public and then making a policy decision as to what increment can be reasonably assigned to a decommissioned site. On the other hand, the EPA approach is based in carcinogenic risk assessment terms, where EPA deems a risk in the range of 10^{-4} to 10^{-6} as acceptable. The EPA limit of 15 mrem/yr is equivalent to 3×10^{-4} increased lifetime risk that is slightly outside the range that EPA considers as acceptable carcinogenic risk. The interagency differences also originate from the fact that NRC is responsible for radioactive facilities and sites under the Atomic Energy Act while EPA has broad authority on cleanup of hazardous sites under CERCLA.

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Research reactor operators, as licensees of the NRC, are required to decommission these facilities to NRC standards but they have to be also cognizant of the EPA regulations, especially with respect to hazardous materials jurisdiction, for mixed waste, for example.

RECENT REGULATORY DEVELOPMENTS

During the past few years, a number of interrelated regulatory developments have occurred that have a major impact on the research reactor decommissioning. These include:

- Final Decommissioning Rule
- Draft Regulatory Guide DG-4006
- MARSSIM
- Interim Draft NUREG-1505
- Issuance of D and D Version 1.0

A brief description of these follows:

Final Decommissioning Rule

The Final Rule on License Termination was published in the Federal Register (FR Vol. 2, No. 139 on July 21, 1997 under the title “Radiological Criteria for License Termination”. It became effective in August 1998. The rule establishes regulations regarding the radiological criteria that a licensee must meet before the license can be terminated. The rule amends Subpart E of Title 10 CFR Part 20, Standards for Protection Against Radiation. This supersedes regulations written in 1988.

Prior to the publication of the final rule, decommissioning projects have used NRC Regulatory Guide 1.86 as the primary standard to which the sites were decommissioned and released without radiological restrictions. In the Final Rule, NRC specifies a dose limit of 25 mrem/yr for releasing a site for unrestricted use (10 CFR 20.1402). The site is considered acceptable for unrestricted use if the residual radioactivity that is distinguishable from background radiation results in a Total Effective Dose Equivalent (TEDE) to an average member of the critical group that does not exceed 25 mrem per year, including from groundwater sources of drinking water. Application of As Low As Reasonably Achievable (ALARA) is also a requirement. Application of ALARA must take into account the consideration of any detriments, such as transportation accidents.

Criteria for restricted use are more complex than the unrestricted case. They use a tiered approach and an application of the institutional controls. These criteria are defined in 10 CFR 20.1403. Alternate criteria for license termination are described in 10 CFR 20.1404. However, for most research reactors, decommissioning is likely to involve application of the provisions of 10 CFR 20.1402.

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Draft Regulatory Guide DG-4006

Draft Regulatory Guide DG-4006 describes the implementation of the Final Rule. The document is in the public comment stage with NRC accepting written comments until August 31, 1999. The NRC has scheduled six workshops on the draft guide at NRC Headquarters in Rockville, Maryland, between December 1998 and October 1999. The purpose of the workshops is to gain input and experience before the regulatory guide is issued as final. Draft Regulatory Guide DG-4006 supersedes Regulatory Guide 1.86, which has been applied to decommissioning projects prior to the Final Rule.

While regulatory guides are not substitutes for regulations and compliance with them is not required, strictly speaking, they provide the licensee a clear description of the implementation methods that are acceptable to NRC. Draft Regulatory Guide DG-4006 contains regulatory positions on dose modeling, final status surveys, ALARA, and restricted use. The regulatory position on dose modeling is especially useful to decommissioning projects for research reactors because it gives a methodology for deriving concentrations of residual radioactivity, generally known as the Derived Concentration Guideline Levels (DCGLs) based on the 25 mrem/yr dose limit.

MARSSIM

The Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) was published in December 1997 (NUREG-1575; EPA 402-R-97-016). It is an interagency document with NRC, EPA, DOE, and the U.S. Department of Defense participating. MARSSIM represents a major milestone in the decommissioning regulatory environment because it replaces the survey methodology of NUREG/CR-5849. It provides information on planning and conducting final status radiological surveys for demonstrating compliance with the dose or risk based criteria.

Interim Draft NUREG-1505

Interim draft of NUREG-1505 (Rev.1) was published by NRC in June 1998. It provides a non-parametric statistical methodology for the design and analysis of final status decommissioning surveys. To implement the dose criteria in 10 CFR 20.1402, final status surveys and confirmatory surveys must be capable of detecting very low levels of residual radioactivity in the presence of background. An essential component of such surveys is a statistical methodology that is appropriate for radiological data at or near background levels. This report describes nonparametric statistical methods for testing compliance with decommissioning criteria both for the case in which radionuclides of concern occur in background and the case in which they do not. The report describes the use Sign Test, Wilcoxon Rank Test, and a Quantile Test.

D and D

D and D computer model was developed by Sandia National Laboratory for the NRC. Version 1.0 was issued in late 1998. The code has four built-in scenarios: building occupancy, building renovation, drinking water, and residential. The code has a library of default values for most of the parameters; site-specific parameters can also be used and radionuclides of interest can be chosen in

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the code up to a maximum of 20. With a dose limit of 25 mrem/yr set in the code, it can be easily used with default parameters to calculate the residual radioactivity levels.

It should be noted that, screening surface values for common radionuclides for building surface contamination have been also published by the NRC in Table 1, Federal Register Vol.63, No.222, 64132-64134, Nov. 18, 1998.

It should also be noted that other computer models are available to conduct pathways analysis or to derive site-specific guidelines. Computer models RESRAD and RESRAD-Build, developed by Argonne National Laboratory for the DOE, are quite versatile for risk assessment use and for deriving cleanup guidelines for various dose limits. However, the NRC Draft Regulatory Guide DG-4006 endorses the use of D and D for deriving DCGLs. If other codes are used to estimate the DCGL, the license needs to provide sufficient information to NRC to allow review of the model, scenarios, and parameters.

Overall Impact

The net effect of these developments is that specific methodologies need to be applied in the reactor decommissioning work. These methodologies include radiological survey methodologies, risk assessment methodologies, and methodologies for demonstration of compliance with radiation exposure limits. These developments present new challenges for reactor decommissioning. These challenges are especially significant for research reactor decommissioning because of the short duration of the projects, limitation of resources, and the research and academic environment of the reactor location sites. The lessons learned from the front-end projects are significant considering that many research reactors will be awaiting decommissioning in not-too-distant future.

DECOMMISSIONING OPTIONS FOR RESEARCH REACTORS

Of the three alternatives for decommissioning (DECON, SAFSTOR, and ENTOMB) discussed by the NRC in NUREG-0586, Final Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities, DECON alternative is the preferred alternative for decommissioning non-power reactors. The DECON alternative involves the removal from the site of all fuel assemblies, source material, radioactive fission products, and radioactively contaminated material and components that exceed the release criteria. Also, the requirements in 10 CFR 50.82 (b)(1)(ii) and (b)(1)(iii) state that decommissioning activities should be completed without significant delay unless prevented by factors beyond the licensee's control. This limits the choice for non-power reactors to the DECON alternative.

The use of option SAFSTOR can be acceptable for a limited period, if factors beyond a licensee's control delay decontamination and dismantlement. Such factors can include unavailability of radioactive waste disposal facilities, DOE fuel shipment delays, continued operation of another reactor at the site, and the health and safety issues. Thus, choice of the DECON alternative is consistent with the NRC requirements mentioned above, and the guidance provided in NUREG-0586.

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For university research reactors, which are relatively small reactors, DECON offers the most attractive alternative in terms of the human health and safety in the short-term and the long-term. It is also the most cost-effective. In addition, the personnel involved with operating the reactor and managing the reactor facilities can be utilized while still on staff. Their experience can be incorporated into the decommissioning planning. Given the location of a reactor on a university campus, the university can utilize the space for other programs and facilities, after NRC releases the area for unrestricted use.

From the discussion above, it is clear that the DECON is preferred alternative and unrestricted release with 25 mrem/yr as the dose criterion is the best option. The option of restricted release with higher dose limit and institutional controls is not a preferred option for non-power reactors because of the conditions it imposes on the site. Decontamination to background levels is not a viable option because it would be extremely difficult to demonstrate that an objective of "return to background" has been achieved. In addition, removal of soil or contaminated concrete to background levels of radioactivity is not desirable from public health and safety point of view. This is consistent with the NRC position, even though, at one point NRC did analyze the issue of background as a radioactivity criterion for decommissioning in NUREG-1501.

IMPACT ON BASIC STEPS IN RESEARCH REACTOR DECOMMISSIONING

Decommissioning projects must be planned and executed in compliance with the dose based release criteria in the new regulatory environment. This impacts all phases of the project.

The basic steps in decommissioning of research reactors include:

- Project planning (preparation of Project Plan, Characterization Plan, and other associated documents);
- Health physics program for the project, application of ALARA, and industrial safety;
- Site characterization and evaluation of radiological conditions at the site (preparation of Characterization Report);
- Determination of cleanup criteria (derivation of DCGLs);
- Preparation of the Decommissioning Plan;
- Regulatory approval of the Decommissioning Plan and the site-specific release criteria;
- Decontamination and dismantlement activities in accordance with the release criteria and applicable laws and regulations;
- Demonstration of cleanup through Final Status Survey.

Dose based approach to the release criteria has significant impact on all D&D projects. But its impact on the research reactor decommissioning is especially important because of smaller budgets, short duration of the projects, and limited resources.

The key to a successful decommissioning project in the new regulatory environment is advance planning of all activities with full consideration of the applicable new criteria and the new methodologies. The surveys should be based on the MARSSIM methodology. Derivation of the DCGLs is the single most important step since many of the decommissioning steps are based on the DCGLs. They must be derived based on the 25 mrem/yr dose limit specified in 10 CFR 20.1402 for unrestricted release of the site. In larger projects, refined site-specific analyses can be performed with D and D, RESRAD or other codes. However, for smaller research reactor projects, use of default and conservative scenarios, and the application of NRC model D and D is recommended as cost-effective. DCGLs may impact the cost of the project, especially in terms of waste volumes and disposal cost of the low-level radioactive waste.

DCGLs are used in classifying the site into MARSSIM based Class 1, Class 2 or Class 3 areas. Final Status Survey is used to demonstrate compliance with the site release criteria. It must be performed according to MARSSIM methodology. Since the rigor of survey effort is much higher for Class 1 areas, DCGL based classification could have an impact on the survey cost.

While it is likely that the DCGLs calculated with default values may not be too restrictive for many projects and may not impact the cost significantly, it is worth looking into this issue in a generic fashion. This is also relevant because, in addition to the NRC's final rule on license termination, some states are looking into imposing a dose criterion of 10 or 15 mrem/yr. Impact of such lower criteria is discussed below.

Impact of Lower Dose Criteria

Application of a lower dose criteria will impact the cost of the project, but significantly only in certain areas. During the decommissioning process, reactor systems, which incidentally have also higher activities, are removed and appropriately disposed. These include reactor core, bio-shield, internals, storage pit, and system piping. The cost of these removal actions will be minimally impacted by the lower dose criteria. The main impact is likely to be in the following areas:

1. Remediation cost
2. Waste disposal cost
3. Final status survey cost

The impact on the cost in all of the three cases above will occur from the lower DCGLs resulting from the application of a lower dose limit. The remediation cost may increase from the additional efforts required in decontaminating concrete to lower DCGLs and the additional removal action for soils, as well as, the additional segregation efforts. Lower DCGLs for surface contamination may lead to increased decontamination of structural surfaces (or increased surface removal such as concrete

scabbling). Quantitative estimates of additional cost will depend on the site-specific characterization data. However, based on the experience in the industry, if concrete is rubblized into a soil-like material and treated as waste, then the additional cost may be marginal in terms of remediation cost, but it will impact the waste volumes, and hence the waste disposal cost. If the volumetric DCGLs are lower, they will lead to increased volumes of bulk materials, such as soils, asphalt, and rubblized concrete.

The lower DCGLs resulting from the application of a lower dose limit will result in increased volumes of soil that will be considered low-level radioactive waste and the increased disposal costs.

Some generic estimates can be made from the NRC's Generic Environmental Impact Statement in Support of Rulemaking on Radiological Criteria for License Termination of NRC-Licensed Nuclear Facilities (NUREG-1496, Appendix C) published in July 1997.

For soils contaminated with Co-60 and Cs-137, the case study model used in the above report provided the following relationship:

$$D(x) = (dcf/15) [(A_1 / \lambda_1) e^{-\lambda_1 x} + (A_2 / \lambda_2) e^{-\lambda_2 x}]$$

Where $D(x)$ is the residual dose limit in mrem/yr after x cm of soil have been removed; dcf is the dose conversion factor in mrem/yr per pCi/g for either Co-60 or Cs-137; A_1 , λ_1 and A_2 , λ_2 are constants

derived from the data fit. It is clear from the nature of this relationship that for lower dose limits, the volume of soil removed may increase in some exponential fashion at the lower end of the curve.

For uranium contaminated soils, a model given from a case study for an unrestricted land scenario provided the following relationship:

$$D(x) = A e^{-\lambda x}$$

Where A is 232.5 and λ in this case is -0.02217 .

Based on the lower dose limit, the DCGLs in dpm/100cm² (surface) or in pCi/g (volumetric) will be lower. For uranium contaminated soils, some insight into increased soil volume scaling factor can be gained from the data given in the NRC report. For cleanup criteria (in pCi/g) of 130, 80, 39, 30, 20, 13, and 4, a soil volume ratio (relative to 130 pCi/g) of 1, 1.23, 1.6, 2.27, 2.76, 3.38, and 4.5, respectively, was determined.

Thus, the lower DCGLs in pCi/g will lead to higher soil volumes. Assuming a dcf value of 0.76453 for natural uranium, mentioned in the NRC report for an unrestricted land use scenario, a lowering of the dose limit from 25 mrem/yr to 10 mrem/yr, for example, can lead to approximately 50% increased volume of soil that will have to be removed. The disposal cost will be proportionately higher.

The impact of lower DCGLs on Final Status Survey will be in terms of more rigorous surveys and higher cost. Lower DCGLs may lead to reclassification of areas (such as Class 2 becoming Class 1), which in turn may lead to higher instrument sensitivity requirements, leading to the use of more costly equipment in the field. Also, localized on-site background levels may interfere more frequently with the surveys in some areas because of the lower DCGLs.

DECOMMISSIONING OF UTR-10

Duke Engineering and Services (DE&S) is decommissioning the Universal Training Reactor (UTR-10) under contract to Iowa State University (ISU). It is among the very first group of research reactor projects where decommissioning planning was done under the new regulatory environment. UTR-10 is a 10 kW Argonaut reactor, which became operational in 1959, and provided the ISU faculty and researchers with teaching, operator training, and experimental capabilities for over three decades. The reactor is housed in the Nuclear Engineering Laboratory building on the ISU campus, which is located in Ames, Iowa. The reactor used uranium enriched to 19.75% in U-235 in a graphite reflected, water moderated core. In 1991 the reactor fuel was changed from its original high-enrichment uranium to low-enrichment uranium. Several other modifications to the reactor systems were made over the years in accordance with the twelve amendments to the license. The reactor was moderated and cooled by light water. It was controlled with four window-shade type Boral control rods. Heat from fission was removed from the primary coolant by a 34,000 BTU/hr shell-and-tube heat exchanger. The reactor was designed to be inherently safe and automatically shut down on a loss of AC power or if various parameters were exceeded.

Final reactor criticality was on May 8, 1998 and reactor operations officially ceased on May 15, 1998. The university made an expeditious decision to decommission the reactor and after a request for proposals and their evaluations, DE&S was selected to decommission the reactor. DE&S planned the radiological surveys and the decommissioning work in conformance to the new regulatory guidance. Radiological characterization survey and sampling work formed Phase I of the project. The characterization work used the MARSSIM methodology in planning and conducting the surveys. It was completed in September 1998 and the resulting Characterization Report formed the basis for the development of the Decommissioning Plan. The DCGLs for the site were derived on the basis of the dose criteria of 25 mrem/yr and the use of the NRC model D and D.

Project-related plans, such as, the Project Execution Plan, Characterization and Sampling Plan, the Survey Quality Assurance Project Plan, and the Decommissioning Plan were all prepared with the new regulatory environment in mind. Phase II of the project involves D&D activities and the disposal of the low-level radioactive waste at an approved facility. Phase III of the project involves the Final Status Survey, which will be conducted in conformance to MARSSIM methodology.

The Decommissioning Plan was submitted to NRC for review and approval (ref. 2). Phase II and Phase III of the project will follow after the approval of the plan by the NRC. As the decommissioning moves to completion, front-end projects, such as ISU's UTR-10 decommissioning, will provide lessons learned on the application of the new dose based cleanup criteria and the research

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reactor decommissioning in the new regulatory environment.

CONCLUSIONS

During the past few years, a number of regulatory developments have occurred that have a major impact on the research reactor decommissioning. Most significant of these developments is the publication of the final decommissioning rule, "Radiological Criteria for License Termination", which became effective in August 1998. It specifies a dose limit of 25 mrem/yr for releasing a site for unrestricted use (10 CFR 20.1402). The site is considered acceptable for unrestricted use if the residual radioactivity that is distinguishable from background radiation results in a Total Effective Dose Equivalent (TEDE) to an average member of the critical group that does not exceed 25 mrem per year, including from groundwater sources of drinking water. The cleanup levels under the new regulations are required to be risk based and derived on a site-specific basis rather than the prescriptive generic values used in the past.

Other important developments include publication of Draft Regulatory Guide DG-4006, MARSSIM, and Interim Draft NUREG-1505, as well as, the issuance of NRC model D and D Version 1.0. Under current guidelines, MARSSIM replaces NUREG/CR-5849. MARSSIM methodology is applied to planning and conducting final status radiological surveys for demonstrating compliance with the dose or risk based criteria.

The net effect of these developments is that specific methodologies need to be applied in the reactor decommissioning work and for demonstration of compliance with radiation exposure limits. These developments present new challenges for reactor decommissioning, especially for research reactors because of the short duration of the projects, limitation of resources, and the research and academic environment of the reactor location sites. The lessons learned from the front-end projects, such as the Iowa State University project, are significant considering that many research reactors will be awaiting decommissioning in not-too-distant future.

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