The Effective Application of the International Atomic Energy Agency's "Code of Conduct on the Safety of Research Reactors" in Regulating Research Reactors at the U.S. Nuclear Regulatory Commission

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Abstract. To strengthen the international nuclear safety arrangements for civil research reactors, the International Atomic Energy Agency developed the "Code of Conduct on the Safety of Research Reactors." This paper discusses how the regulation of research reactors and testing facilities by the U.S. Nuclear Regulatory Commission is in harmony with the Code of Conduct on the Safety of Research Reactors.

Key Words: research reactor, IAEA Code of Conduct on the Safety of Research Reactors

1. Introduction

Throughout its history, the International Atomic Energy Agency (IAEA) has focused on strengthening the international nuclear safety arrangements for civil research reactors. An important contribution to this effort was the development of the "Code of Conduct on the Safety of Research Reactors" [1] (Code of Conduct), which the IAEA Board of Governors adopted in 2004. The Code of Conduct represents the basis that Member States are encouraged to use to regulate and conduct research reactor activities. The IAEA has held four triennial periodic meetings on the Code of Conduct, the last in May 2017, to facilitate discussion among Member States to assess and improve the application of the Code of Conduct. The facilitation was accomplished by exchanging experience and lessons learned, identifying good practices in applying the Code of Conduct, and discussing difficulties that may be encountered in applying the Code of Conduct and the international or IAEA assistance needed to overcome these difficulties. Participants in these meetings also discussed further plans related to the Code of Conduct to enhance research reactor safety and whether revision to the Code of Conduct is needed.

The U.S. Nuclear Regulatory Commission (NRC) research reactor staff contributed to the IAEA's international effort to develop the Code of Conduct and participated in the periodic meetings, reporting on its self-assessment of the level of application of the various aspects of the Code of Conduct.

2. Reactor Categorization

How the NRC regulates research reactors and testing facilities[1] contributes to an understanding of how that regulation is in harmony with the Code of Conduct. There are 31 reactors currently licensed to operate by the NRC (30 research reactors and

1 testing facility) that encompass a multitude of designs and power levels. Thermal power levels and designs range from a 5-watt (W) Aerojet-General Nucleonics (AGN) solid homogeneous-fueled reactor to a 20-MW heavy-water-cooled and -moderated tank-type testing facility. Training, Research, Isotope-Production, General Atomics (TRIGA) reactors are the most common design regulated by the NRC.

The NRC uses a graded approach in its regulation of research reactors and testing facilities, with additional regulatory processes and technical requirements as the power level of the reactor increases. The NRC's application of a graded approach considers several attributes, including the type of reactor, the power level of the reactor, the quantity and form of the special nuclear material possessed by the reactor, and the purpose of the reactor.

[1] The terms "research reactor" and "testing facility" are defined in the NRC's regulations. The primary attribute that distinguishes between research reactors and testing facilities is thermal power level. Generally, a testing facility has a thermal power level in excess of 10 megawatts (MW) or other special safety considerations defined in NRC regulations. However, a draft final rulemaking before the Commission would replace the thermal power level distinction with one based on the dose to the public from an accident. Facilities licensed as research reactors would need to meet an accident public dose criterion of 1 rem or less total effective dose equivalent. An analyzed accident public dose of greater than 1 rem would define a testing facility (the Commission would also have the flexibility to designate facilities as testing facilities regardless of public dose). The IAEA only defines the term "research reactor," which includes both research reactors and testing facilities as defined by the NRC.

At the highest level of the NRC's regulatory framework is the Atomic Energy Act of 1954, as amended [2] (Atomic Energy Act), which is discussed in Section 3 of this paper. The Atomic Energy Act is the law passed by the U.S. Congress authorizing the NRC to regulate civilian nuclear technology. The second level is NRC's comprehensive set of regulations [3] covering all aspects of the regulation of civilian nuclear technology. Licenses (including technical specifications[2]) issued by the NRC to research reactors and testing facilities are legal requirements that must be followed. The NRC has issued guidance documents that present approaches that licensees can follow to meet the requirements of the regulations. The primary guidance document for research reactors and testing facilities is NUREG-1537, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors," issued February 1996 [4]. This document consists of (Part 1) a format and content guide for applicants to use in developing safety analysis reports for licensing applications and (Part 2) a standard review plan for the NRC staff to use to review applications and prepare independent safety evaluations.

3. Atomic Energy Act Requirements

Section 104 of the Atomic Energy Act requires the NRC to apply the concept of minimum regulation to noncommercial[3] research reactors and testing facilities. For noncommercial research reactors and testing facilities useful in the conduct of research and development activities, the Atomic Energy Act states that the Commission is directed to impose only such minimum amount of regulation on the licensee as the Commission finds will permit the Commission to fulfill its obligations under this Act to promote the common defense and security and to protect the health and safety of the public and will permit the conduct of widespread and diverse research and development. The Atomic Energy Act defines the term "research and development" as (1) theoretical analysis, exploration, or experimentation or (2) the extension of investigative findings and theories of a scientific or technical nature into practical application for experimental and demonstration purposes, including the experimental production and testing of models, devices, equipment, materials, and processes. The NRC applies this requirement for minimum regulation in all aspects of the regulation of noncommercial research reactors and testing facilities, including licensing processes, regulatory technical requirements and inspections. The application of the Code of Conduct must be consistent with this requirement of the Atomic Energy Act.

4. The NRC's Self-Assessment of the Level of Application of the Code of Conduct

As part of the preparation for the periodic Code of Conduct meetings, the IAEA staff has requested that each attending Member State respond to a self-assessment questionnaire concerning the level of application of the Code of Conduct in the respective Member State. The questionnaire covers Code of Conduct Article V, "Role of the State"; Article VI, "Role of the Regulatory Body"; and Article VII, "Role of the Operating Organization." The scale for the self-assessment ranges from 0 (not applied) to 3 (fully applied).

The self-assessments prepared by the NRC staff have shown substantial harmony with the Code of Conduct. The 2014 self-assessment identified two areas where the NRC staff could enhance the regulation of research reactors and testing facilities. The first area concerned Code of Conduct Article VI, paragraph 20 (b), namely, the requirement to prepare and

[2] Technical specifications are called "operational limits and conditions" in IAEA terminology.
[3] The test for a research reactor or testing facility that is commercial and one that is noncommercial is based on how a facility earns and spends funds.

maintain a safety analysis report and obtain an authorization. The NRC staff assigned itself an assessment level of 2 because licensees updated the safety analysis report as needed to obtain authorizations, such as license renewal, rather than maintaining the safety analysis report. The NRC staff also assigned itself an assessment level of 2 for Article VI, paragraph 20 (g), namely, the requirement to take human factors into account, and Article VII, paragraph 26, on human factors, because criteria were partially in place in this area. The NRC staff took steps that resulted in a self-assessment level of 3 in these areas in the self-assessment for the 2017 IAEA meeting on application of the Code of Conduct.

5. NRC Enhancements to the Regulatory Process

In 2014, the NRC staff assigned an assessment level of 2 for Article VI, paragraph 20 (b), which states, in part, the following:

> The regulations and guidance established by the State or the regulatory body according to national arrangements should[4] require the operating organization to prepare and maintain a safety analysis report….

The staff assigned itself this assessment level because the NRC has no regulatory requirement for research reactor and testing facility licensees to maintain their safety analysis reports up to date, except when applying for license renewal every 20 years. The description of the facility in the safety analysis report could change because of license amendments issued to the licensee. The description could also change because of changes to the facility or procedures, or tests and experiments performed under Title 10 of the *Code of Federal Regulations* (10 CFR) 50.59, "Changes, Tests and Experiments." In 10 CFR 50.59, the NRC allows licensees to make changes to the facility and procedures as described in the safety analysis report, and to conduct tests and experiments not described in the safety analysis report, without prior NRC approval, if the change does not impact the technical specifications and meets certain criteria contained in the regulation. Most safety analysis reports were not being maintained with these changes.

To address this issue, the NRC staff has proposed a change in the regulations to require all research reactor and testing facility licensees to submit an updated safety analysis report to the NRC at intervals not to exceed 5 years. The agency proposed this change to the public and licensees in 2017, and the NRC staff received and considered public comments on the proposal. The draft final rule is with the Commission for its consideration. This effort formed the basis for the NRC staff to raise its 2017 self-assessment in this area from 2 to 3.

In 2014, the NRC staff assigned a self-assessment level of 2 for Article VI, paragraph 20 (g), and Article VII, paragraph 26. These paragraphs recommend that the regulatory body require the operating organization to take human factors into account throughout the life of the research reactor. They also require the operating organization to take into account the capabilities and limitations of human performance throughout the life of the research reactor.

The NRC staff has taken actions to improve the consideration of human factors in the regulation of research reactors and testing facilities. The NRC staff has issued a draft update to Chapter 7, "Instrumentation and Controls Systems," of NUREG-1537, which contains additional detail on human factors and the human-machine interface. This effort formed the basis for the NRC staff to raise its 2017 self-assessment in this area from 2 to 3.

[4] "Should" statements in the IAEA Code of Conduct denote recommendations of a desired option.

6. The NRC and Article V of the Code of Conduct: Role of the State

In the 2017 self-assessment, the NRC staff assigned a self-assessment level of 3 for all areas of Article V. In part, Article V, paragraph 9, states that the Member State should establish and maintain a legislative framework to govern the safety of research reactors. The Atomic Energy Act establishes a legislative and regulatory framework to govern the safety of research reactors and testing facilities. The Atomic Energy Act is maintained current by the Congress of the United States.

Article V, paragraph 10, recommends that the State have a regulatory body charged with the regulatory control of research reactors based on the national legal structure. This regulatory body should be effectively independent of organizations or bodies charged with the promotion of nuclear technology or with the operation of research reactors. Since 1975, the NRC has been the regulatory body charged with the regulatory control of civilian research reactors and testing facilities based on the national legal structure of the Atomic Energy Act. The Energy Reorganization Act of 1974 [5] created the NRC as an independent organization. The U.S. Department of Energy became responsible for the promotion of nuclear technology. As such, the NRC is effectively independent of the organizations or bodies charged with the promotion of nuclear technologies or with the operation of research reactors. Instead, the NRC makes the safe use of nuclear technology possible. It is up to policy makers to decide what to do with nuclear technology.

According to Article V, paragraph 11, the State should provide the regulatory body with the necessary authority and adequate resources to discharge its assigned responsibilities. The NRC has the necessary authority through the Atomic Energy Act and through the Administrative Procedure Act [6], which governs the way in which the NRC and other agencies of the U.S. Federal Government may propose and establish regulations. Although the NRC charges fees to certain licensees, the NRC receives its budget through the normal appropriations process of the U.S. Congress.

Article V, paragraph 12, states that the Member State, if it deems necessary, should define how the public and other bodies are involved in the regulatory process. Openness is one of the NRC's principles of good regulation. Nuclear regulation is the public's business, and it must be transacted publicly and candidly. The public must be informed about and have the opportunity to participate in the regulatory processes as required by law. The NRC maintains open channels of communication with Congress, other government agencies, licensees, and the public, as well as with the international nuclear community. The NRC's regulations and guidance contain the process for formal participation in the regulatory process.

Paragraphs 13, 15, 16, and 17 of Article V recommend a financing system for safe operation, safe extended shutdown, and decommissioning, along with legal and infrastructure arrangements for decommissioning. The Code of Conduct focuses on reactors in extended shutdown because of challenges that have occurred internationally in this area. The NRC's regulations require applicants to demonstrate that they possess funds, or have reasonable assurance of obtaining funds, to cover construction, fuel cycle, and operating costs. The regulations contain requirements for decommissioning. Generally, a research reactor or testing facility licensee must decommission a facility without significant delay after permanent shutdown. The regulations also require applicants to indicate how reasonable assurance will be provided to ensure that funds will be available to decommission the facility. Because of

these regulatory requirements, it is not common for research reactors and testing facilities to remain in an extended shutdown status.

Paragraphs 14 and 18 of Article V recommend that the Member State establish an effective system of governmental emergency response and intervention capabilities and take appropriate steps to inform neighboring States in the vicinity of a research reactor. NRC regulations require emergency response plans for research reactors and testing facilities. The Federal Government has an interagency response plan for emergencies at nuclear facilities. Methodologies are in place for communication with neighboring governmental jurisdictions within and external to the United States, as appropriate to events and actions to protect the public and environment.

7. The NRC and Article VI of the Code of Conduct: Role of the Regulatory Body

In the 2017 self-assessment, the NRC staff assigned a self-assessment level of 3 for all areas of Article VI. Article VI, paragraph 19, recommends that the regulatory body implement a process for issuing authorizations, undertake regulatory inspections and assessments, enforce applicable regulations, review and assess submissions from operating organizations, and make available, as appropriate, regulatory requirements and decisions. The NRC has a process of issuing authorizations for all stages in the life of a research reactor or testing facility, from construction permit to license termination and release of the site from regulatory control. An inspection program with enforcement authority exists to ascertain compliance with applicable regulations and license conditions. The NRC performs independent assessments of submissions from applicants and licensees. In accordance with the agency's principle of openness, the NRC makes its decisions and their bases public to the greatest extent possible.

Article VI, paragraph 20, has recommendations that the regulations and guidance established by the Member State or the regulatory body should meet. Paragraph 20 (a) recommends the establishment of clear arrangements for the management of safety. Technical specifications issued by the NRC require the clear assignment of the responsibility for safety within the management of the operating organization. Sections 4 and 5 of this paper discuss paragraph 20 (b).

Article VI, paragraph 20 (c), recommends that the operating organization undertake periodic safety reviews and make proposals for upgrades and refurbishment arising from such reviews. The conduct of periodic safety reviews is detailed in IAEA Safety Standards, Specific Safety Guide No. SSG-25, "Periodic Safety Review for Nuclear Power Plants." The review process described in this Safety Guide is valid for nuclear power plants and has a wider applicability, for example to research reactors. SSG-25, paragraph 2.8, recognizes that some Member States prefer alternative arrangements to a periodic safety review. For example, some Member States apply routine comprehensive safety assessment programs that deal with specific safety issues, significant events and changes in safety standards and operating practices as they arise. Such programs can, if applied with appropriate scope, frequency, depth and rigor, achieve the same outcomes as the process recommended in SSG-25.

It is widely known that periodic safety reviews are not conducted in the United States; however, consistent with the principles established in SSG-25, the NRC assures adequate protection of public health and safety through alternative arrangements.

For example, license renewal reviews are conducted. The NRC receives and evaluates operating experience from licensees on a regular basis. The technical specifications require licensees to report significant changes in the transient or accident analysis as described in the safety analysis report. The technical specifications also require the submission of event reports of issues such as observed inadequacy in the implementation of administrative or procedural controls, reactor safety system component malfunctions, and significant degradation in the reactor fuel or cladding, coolant boundary, or containment boundary. Annual reports required by the technical specifications contain information such as unscheduled shutdowns, including, where applicable, corrective actions taken to preclude reoccurrence; tabulations of major preventive and corrective maintenance; and radiation exposures to the facility staff and releases of radioactive material beyond the control of the operating organization. This input of important information subject to NRC staff analysis, along with the information from the NRC inspection program, results in a level of continuing safety review by the NRC staff that is consistent with a graded approach and the Atomic Energy Act requirement to apply minimum regulation to noncommercial research reactors and testing facilities. The NRC staff can, at any time, request information from licensees, perform additional inspections or order licensees to take actions that are justified for maintaining acceptable safety.

The 2010 IAEA Integrated Regulatory Review Service Mission (IRRS) to the NRC concluded that the NRC has in place a number of programs that are intended to ensure that the goals of the periodic safety review are met and that provide adequate protection to the health and safety of the public, as required by the Atomic Energy Act. Thereby, the NRC staff concludes that NRC also meets the recommendation of Article VI, paragraph 20 (c) of the Code of Conduct.

Article VI, paragraph 20 (d), recommends requiring the operating organization to demonstrate sufficient financial and human resources, and paragraph 20 (e) recommends a requirement that personnel be appropriately trained. Section 6 of this paper discusses the financial requirements for the operating organization. The NRC-issued technical specifications contain requirements for minimum human resources. The NRC staff administers initial tests to reactor operator candidates. The regulations require persons who operate research reactors or testing facilities to be appropriately trained and to undergo periodic requalification.

Article VI, paragraph 20 (f), recommends that operating organizations be required to put in place effective quality assurance programs. NRC regulations require quality assurance throughout the life of the facility through specific plans or by technical specification requirements. Sections 4 and 5 of this paper discuss paragraph 20 (g).

Article VI, paragraph 20 (h), recommends that radiation doses to workers and the public be within national limits and be as low as reasonably achievable. Article VI, paragraph 20 (i), concerns protection of the environment from the harmful effects of ionizing radiation. The NRC regulations establish national limits for exposure to radiation and require doses to members of the public and workers to be as low as reasonably achievable. The national limits for exposure also protect the environment from the harmful effects of ionizing radiation. Facilities are required by the technical specifications to report the results of environmental monitoring.

Article VI, paragraph 20 (j) recommends requiring that emergency plans be in place. NRC regulations require facilities to have an emergency plan approved by the NRC in place.

Article VI, paragraph 20 (k), recommends criteria for siting research reactors. NRC regulations require a safety assessment of the facility site. The regulations contain specific siting requirements for facilities. The NRC gives details on the conduct of the siting analysis in NUREG-1537.

Paragraphs 20 (l), (m), and (n) in Article VI address design, construction, and commissioning. The regulations contain general requirements. The NRC provides detailed licensing guidance in NUREG-1537 that addresses design approaches that include defense in depth and diversity and redundancy in safety systems, use of codes and standards, and the contents of the startup plan.

In Article VI, paragraph 20 (o), the Code of Conduct recommends requiring the operating organization to establish operational limits and conditions. The regulations require facilities to have technical specifications. Paragraph 20 (p) recommends requiring the reporting of events significant to safety, which is a requirement of the NRC-issued technical specifications. Article VI, paragraph 20 (q), recommends requiring a process to classify modifications according to their safety significance. The regulations and technical specification call for a process for modifying facilities and conducting experiments. In paragraph 20 (r), the Code of Conduct recommends requiring access to the reactor by the regulatory body for the purpose of inspection. By regulation, NRC inspectors have unfettered access to licensee facilities. Paragraph 20 (s) recommends the establishment of requirements for the management of radioactive waste. The NRC regulations require the management of radioactive waste.

Article VI, paragraph 20 (t), recommends the establishment of safety criteria for facilities in extended shutdown. The regulations and guidance issued by the NRC cover this requirement. Licensees must continue to comply with the facility license and technical specifications during extended shutdown.

Article VI, paragraph 20 (u), recommends the establishment of criteria for the release from regulatory control of decommissioned facilities. The NRC regulations contain criteria for the release of facilities for unrestricted and restricted use.

8. The NRC and Article VII of the Code of Conduct: Role of the Operating Organization

In the 2017 self-assessment, the NRC staff assigned a self-assessment level of 3 for all areas of Article VII. The Code of Conduct contains a number of recommendations for the operating organization that put into place the recommendations for the role of the State and role of the regulatory body. These recommendations cover the assessment and verification of safety, financial and human resources, quality assurance, human factors, radiation protection, emergency preparedness, siting, design, construction and commissioning, operation, maintenance and utilization, extended shutdown, and decommissioning. The operating organization will meet these recommendations by following the NRC regulations; the requirements of its license and technical specifications; and required plans for emergency planning, security, and operator requalification. The NRC inspection program confirms that the licensee is meeting the requirements of the regulations and its license.

9. Summary

The IAEA Code of Conduct constituted an important development in strengthening the international nuclear safety arrangements for civil research reactors. The NRC staff has supported the application of the Code of Conduct and has determined through self-assessment that the NRC conducts the regulation of research reactors and the testing facility in harmony with the recommendations in the Code of Conduct.

References

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, “Code of Conduct on the Safety of Research Reactors,” Vienna (2006).

[2] ATOMIC ENERGY ACT (as Amended), P.L. 83-703 (1954).

[3] UNITED STATES NUCLEAR REGULATORY COMMISSION, *Code of Federal Regulations*, Title 10, “Energy,” Chapter I, “Nuclear Regulatory Commission.”

[4] UNITED STATES NUCLEAR REGULATORY COMMISSION, NUREG-1537, “Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors” (1996).

[5] ENERGY REORGANIZATION OF ACT OF 1974, P.L. 93-438.

[6] ADMINISTRATIVE PROCEDURE ACT, P.L. 79–404 (1946)