U.S. Nuclear Regulatory Commission Preparations for the Export of Advanced Reactors

Introduction

The United States Nuclear Regulatory Commission (NRC) is responsible for licensing the export and import of nuclear material and equipment, pursuant to the provisions found in Title 10 of the *Code of Federal Regulations* Part 110 (10 CFR Part 110), entitled, "Export and Import of Nuclear Material and Equipment."

Pursuant to 10 CFR Part 110.8(a), the NRC's nuclear export licensing authority includes "nuclear reactors and especially designed or prepared equipment and components for nuclear reactors." This provision provides appropriate flexibility to ensure that exports of nuclear reactors of any type are appropriately subject to export controls. However, the illustrative list of nuclear reactor equipment under NRC export licensing authority in Appendix A to the regulation is mostly based on light water reactor technology.

As the nuclear industry moves toward the commercialization of advanced reactors, the NRC staff proactively undertook a fundamental review of the 10 CFR Part 110 regulations in order to ensure the NRC is prepared to license the export of non-light water reactor technologies, and to reduce any regulatory uncertainties associated with such exports. To accomplish this forward-looking initiative, the NRC staff organized a working group to review 10 CFR Part 110, and identify any gaps in the regulation, in order to support U.S. Government nonproliferation objectives and ensure sufficient controls on the export of nuclear equipment, and materials, as well as to prevent any future delays or disruptions to the export licensing process. The Advanced Reactor Exports Working Group (AREWG) concluded that the NRC is generally ready to license the export of advanced reactors and their associated materials and components, but also recommended that 10 CFR Part 110 could benefit from some clarifications to make the regulation less focused on nuclear materials and equipment primarily associated with light-water reactor technology. AREWG did not study the import of advanced reactors, as most imports of production and utilization facilities into the United States is done pursuant to an NRC general license.

The following is a summary of the research, analysis, conclusions, and recommendations of the working group. The NRC is sharing these findings publicly in the interest of openness and transparency and to garner feedback from the public and the advanced reactor community.

Background

The AREWG was chartered in August of 2019 and tasked by the Director of NRC's Office of International Programs with the following mandate:

1.) Evaluate NRC's readiness to complete exports of "advanced reactors" under 10 CFR Part 110 and consistent with NRC's Principles of Good Regulation (independence, openness, efficiency, clarity, and reliability).
2.) Conduct outreach and prepare a communication plan on NRC's export licensing process to share with prospective vendors of advanced reactors.

The AREWG was comprised of export licensing and technical experts from the NRC's Office of International Programs (OIP), the Office of the General Counsel (OGC), the Office of Nuclear Materials Safety and Safeguards (NMSS), the Office of Nuclear Security and Incident Response (NSIR), the Office of Nuclear Reactor Regulation (NRR), and the Office of Nuclear Regulatory Research (RES). The AREWG was also supported by technical experts from the Department of Energy, National Nuclear Security Administration (DOE/NNSA) and Argonne National Laboratory (ANL). The AREWG was Chaired by OIP.

The AREWG's mission was to research non-light water advanced reactor designs from companies in the United States, and assess whether the equipment, components and materials associated with these designs would be captured within the scope of the export controls promulgated in 10 CFR Part 110. This report is especially relevant at this time, when a number of companies are beginning to develop advanced reactor designs, and the 10 CFR Part 110 regulations were originally developed to control the export of reactors primarily associated with light water reactor technology.

The AREWG was also tasked to assess whether export licensing applications for advanced reactor facilities, including equipment, components, and materials, are being reviewed at the appropriate level. These reviews are currently conducted on a case-by-case basis by NRC/OIP/Export Control and Nonproliferation Branch (ECNP).

Phase One: Establishing Research Parameters

The AREWG met approximately every other week between August 2019 and February 2020. The Working Group immediately aimed to bridge the knowledge gap between its technical experts and licensing experts. Select subject matter experts in the Working Group conducted a series of briefings on 10 CFR Part 110, "Export and Import of Nuclear Equipment and Material," and with a focus on how the NRC licenses the export of nuclear material and equipment. The group's technical experts also gave a series of high-level briefings on advanced reactor designs and developments.

AREWG also addressed how to define the term, "advanced reactor." After identifying several definitions used by the international community, the AREWG decided not to choose one working definition, but rather to use the concept that any non-light water reactor design should be considered an "advanced reactor" and that the Group should use design-specific scoping rather than establishing a definition. This gave the AREWG flexibility to research different designs using the following criteria: 1) whether or not an advanced reactor vendor had begun pre-application discussions with the NRC or expressed their intent to begin pre-application discussions; 2) the maturity of the design; and 3) a medium-to-high likelihood that the company would be ready to export technology, equipment, components, and/or materials associated with its design in the next 5-10 years. The AREWG identified five advanced reactor types and fourteen associated designs that met the above criteria. The advanced reactor types that the group studied were: 1) high temperature gas-cooled reactors; 2) sodium fast reactors; 3) fluoride salt-cooled high temperature reactors; 4) molten salt reactors, including liquid fluoride salt and liquid chloride salt-cooled reactors; and 5) small heat pipe reactors.

Phase Two: Small Group Research Projects

After completing phase one, AREWG commenced phase two by forming small research teams to comprehensively examine the five advanced reactor types. The AREWG selected one or two representative designs from each type for which sufficient information was available. The AREWG then designed a research project that worked to identify the major and minor components of each of these designs, as well as the fuel type and cladding each design employed. The goal of the research project was to determine if any of these designs presented new or novel technology not currently present in a light water reactor design, and therefore, to identify if any of the items present challenges or ambiguities as to the applicability of the licensing controls of 10 CFR Part 110.

The AREWG broke up into five small research teams comprised of at least one technical expert and one export licensing expert. Each team was assigned one of the five advanced reactor types to research and assess. The technical lead researched the selected design's individual components, fuel, and cladding; the export licensing lead subsequently compared those findings to 10 CFR Part 110. For each design, the objective of the research team was to: 1) identify the significant components, both major and minor; 2) identify the type of fuel and cladding; 3) compare those findings to 10 CFR Part 110; and 4) determine if each of the identified components and materials would be covered under the licensing provisions in 10 CFR Part 110. The research teams presented their research and the findings were discussed within the AREWG.

Research Project Findings

Overall, the AREWG did not identify any major deficiencies in 10 CFR Part 110 with respect to exporting advanced reactors. That is, the AREWG did not identify any components or materials especially designed or prepared for use in advanced reactors that are not already covered by NRC's existing export licensing regulations. As discussed above, these regulations provide the NRC with broad authority to regulate exports of nuclear reactors and especially designed or prepared equipment and components for nuclear reactors, regardless of reactor type.

Yet, while NRC staff feel confident that NRC's export licensing jurisdiction covers advanced reactors and the significant components and materials, some clarification of the regulations could help avoid potential misinterpretation, which could lead to delays in the export licensing process. Therefore, the AREWG did identify several places in 10 CFR Part 110 that could benefit from clarifications in order to make the regulation less focused on light water reactor technology and to more clearly encompass advanced reactor technology. The AREWG concluded that the changes outlined in the following examples[1] could be a first step in conforming 10 CFR Part 110 to the latest developments in advanced reactor technologies while also maintaining the illustrative[2] nature of the controls in 10 CFR Part 110.

One identified example of a clarifying change pertains to an entry in Appendix A of 10 CFR Part 110 for zirconium tubes. Appendix A is entitled, "Illustrative List of Nuclear Reactor Equipment Under NRC Export Licensing Authority." The current entry for zirconium tubes states: "Zirconium

[1] In the interest of space, the below discussion does not include all of the changes/clarifications proposed by the working group in the recommendation section.

[2] The appendices of Part 110 are deliberatively illustrative for two reasons: 1) in order not to make a proliferators "shopping list," and 2) for NRC to be able to regulate new and emerging technologies without having to constantly undergo rulemakings to keep the control lists up-to-date.

tubes, i.e., zirconium metal and alloys in the form of tubes or assemblies of tubes especially designed or prepared for use as fuel cladding in a nuclear reactor." Through its research project, the AREWG identified other materials besides zirconium that are used or being developed for nuclear fuel cladding, and forms of cladding other than tubes. Although the list of reactor equipment in Appendix A in 10 CFR Part 110 is illustrative, the AREWG concluded that, optimally, this entry should be amended to make it a general entry for fuel cladding, and not specify any one type of material or form. This change to the regulation would clarify for current and potential licensees that the NRC controls all types of fuel cladding for export, including those used in advanced reactors.

Several research teams identified one component/material that could potentially benefit from clarification as to NRC's regulation under the existing 10 CFR Part 110 provisions – the use of salt as a coolant. Salt that is especially designed or prepared for use as a coolant in advanced reactors is not listed in 10 CFR Part 110.9a, "List of Nuclear Material under NRC Export Licensing Authority" (which lists only special nuclear material, source material, byproduct material, nuclear grade graphite for a nuclear end use, and deuterium).

However, the Group concluded that this material may be controlled under the existing Part 110 regulations that implement Section 109b. of the Atomic Energy Act of 1954 (AEA), as amended. Section 109b. of the AEA gives the NRC export licensing authority over non-nuclear "items and substances" that are "especially relevant from the standpoint of export control because of their significance for nuclear explosive purposes." 10 CFR Part 110 implements AEA Section 109b. in 10 CFR § 110.8, "List of nuclear facilities and equipment under NRC export licensing authority." That list contains a catch-all provision that brings "any other components especially deigned or prepared for use in a nuclear reactor" within the scope of NRC regulation under Part 110. The Group concluded that non-nuclear substances, such as salt as a coolant, that are integral to operation of an advanced nuclear reactor design, are covered under the catch-all provision as a "component," which is not defined in Part 110.

Nevertheless, the AREWG concluded that a minor revision to Appendix A of Part 110 may be beneficial for clarity. The revision would add the term "substances" to the title of Appendix A of 10 CFR Part 110, so that the title reads, "Illustrative List of Substances and Nuclear Reactor Equipment Under NRC Export Licensing Authority."

In sum, after each research team presented its findings, the Working Group agreed that: 1) there are not significant deficiencies in 10 CFR Part 110 that would result in a component and/or material especially designed or prepared for use in an advanced reactor not falling under NRC's export licensing jurisdiction; 2) one material employed in several designs – specialized salt especially prepared for use as a coolant in advanced reactors – is covered by NRC's export licensing regulations, but would benefit from a clarifying change to 10 CFR Part 110 to make this clear; and 3) there are changes to 10 CFR Part 110 that could clarify the application of the regulation to some of the new designs and components that the working group researched.

At the conclusion of the research project, the AREWG also assessed the level of review for export applications for advanced reactors. Currently, 10 CFR Part 110 makes two references to "advanced reactors," in Sections 110.40, "Commission Review" and in 110.41, "Executive Branch Review," when discussing the level of review an export license application should be subjected to once it is submitted to the NRC. Sections 110.40 and 110.41 of 10 CFR Part 110 specify that an export involving assistance to advanced reactors should undergo Commission level and Executive Branch review. These are the most stringent levels of review an export

license application must go through in order to be issued by OIP. Under these criteria, the Commission must review and approve the proposed export and the Executive Branch must find that the export is not "inimical to the common defense and security" of the United States.

The AREWG considered the types of advanced reactor export license applications the NRC is likely to see over the next 5 to 10 years and the potential proliferation significance of these items. The AREWG evaluated whether these types of proposed exports would still warrant Commission and Executive Branch level reviews. The AREWG concluded that the level of review for advanced reactor end-uses should remain unchanged in 10 CFR Part 110. The Working Group judged that these technologies will continue to be new, novel, and could raise significant policy issues on which the Commission may want to weigh in. The AREWG did not think changing the level of review for these types of technologies was warranted at this time, but did not rule out re-visiting this issue with the NRC's five-member Commission at a later date if these types of exports become more routine. Any change to the level of review for advanced reactors would have to be approved by the Commission and would require a change to 10 CFR Part 110.

Outreach

The AREWG's mandate also included a directive to perform outreach in order to seek inputs from interested members of the public related to exports of advanced reactors and to engage vendors of advanced reactors and industry trade groups. The AREWG conducted the following outreach initiatives:

1. **Nuclear Energy Institute (NEI)** – The AREWG invited representatives from NEI's New Reactor & Advanced Technology Group to attend the 5th AREWG meeting, held on November 1, 2019. On December 10, 2019, members of the AREWG from OIP and NRR attended NEI's Advanced Reactor Working Group. The AREWG Chair shared the current work of the AREWG with NEI's working group.

2. **The NRC's Advanced Reactor Stakeholders Meeting** – On December 12, 2019, the AREWG Chair attended the NRC's Advanced Reactor Stakeholders Meeting, which is a routine meeting to provide updates to the public on many of the NRC's advanced reactor regulatory reform initiatives. The AREWG Chair presented on the AREWG's mission, goals and current activities. The AREWG Chair did not receive any feedback from members of the public at the meeting.

3. **The NRC's Regulatory Information Conference (RIC)** – The work of the AREWG was discussed at the NRC's Regulatory Information Conference in March 2021 during a panel entitled, "U.S. Regulatory Preparations for the Export of Advanced Reactors." The panel was comprised of subject matter experts from the NRC, DOE/NNSA, Department of Commerce, and NEI.

4. **Institute of Nuclear Materials management and Safeguards (INMM) 61st Annual Meeting** – On July 13, 2020, the AREWG Chair presented on the NRC's preparations for the export of advanced reactors at the INMM annual meeting, during a panel entitled, "Strategic Trade Controls."

5. **Other U.S. Government Agencies** – The AREWG worked with the U.S. Government agencies with equities in nuclear export controls in order to inform them of the conclusions and recommendations of the working group.

The AREWG Conclusions and Recommendations

1. The AREWG concluded that 10 CFR Part 110 is ready to license the materials and components especially designed or prepared for the following five types of advanced reactors: high temperature gas-cooled reactors, sodium fast reactors, fluoride salt-cooled high temperature reactors, molten salt reactors, and small heat pipe reactors; but could benefit from some clarifications in order to remove any potential regulatory uncertainties associated with the export of advanced reactors.

2. The AREWG identified one significant component/material that could potentially present challenges to NRC's regulation under the existing 10 CFR Part 110 provisions – the use of salt as a coolant. Salt that is especially designed or prepared for use as a coolant in advanced reactors is not included in 10 CFR Part 110.9a, "List of Nuclear Material under NRC Export Licensing Authority" (which lists only special nuclear material, source material, byproduct material, nuclear grade graphite for a nuclear end use, and deuterium). While such material is nonetheless subject to NRC export licensing authority pursuant to other provisions of law and regulation, a future regulatory change may be helpful in providing clarity for current and potential licensees.

3. The AREWG recommends changing entry #6 in Appendix A ("Zirconium tubes, i.e., zirconium metal and alloys in the form of tubes or assemblies of tubes especially designed or prepared for use as fuel cladding in a nuclear reactor") to make it less specific. AREWG recommends making this a general entry for nuclear fuel cladding. This would make it clear that the NRC has licensing authority over other types of cladding materials and in other forms besides tubes.

4. The AREWG recommends removing the parentheses in entry number 2 of Appendix A. This would be a clarifying change to make it clear that the NRC would control other types of fuel charging and discharging machines and systems besides those used for CANDU reactors. This would then make it clear that systems such as pebble handling systems are covered, if not specifically listed.

5. The AREWG recommends that the NRC work with the interagency to ensure the changes described in recommendations 2 - 4 are coordinated with the U.S. technical agenda in relevant international forums.

6. The AREWG does not recommend changing the level of review for applications for advanced reactors.

DISCLAIMER

The conclusions of this report only pertain to the five advanced reactor types assessed during the working group. This report does not confer the Commission's approval of individual export license applications for equipment, components, and/or materials associated with advanced reactors. The NRC assesses export license applications on a case-by-case basis according to the criteria set forth in the Atomic Energy Act of 1954, as amended, and in 10 CFR Part 110. The recommendations in this report may be reassessed pending additional information and findings on advanced reactor concepts regarding safeguards, security, safety, etc., which may not be apparent at the time of the release of this report.