[7590-01-P]

NUCLEAR REGULATORY COMMISSION

[NRC-2023-0113]

Draft NUREG: Environmental Evaluation of Accident Tolerant Fuels with Increased Enrichment and Higher Burnup Levels

AGENCY: Nuclear Regulatory Commission.

ACTION: Draft report; request for comment.

SUMMARY: The U.S. Nuclear Regulatory Commission (NRC) is issuing for public comment draft NUREG-2266, “Environmental Evaluation of Accident Tolerant Fuels with Increased Enrichment and Higher Burnup Levels.” This study evaluates the reasonably foreseeable impacts of near-term accident tolerant fuel (ATF) technologies with increased enrichment and higher burnup levels to 8 wt% uranium-235 (U-235) and up to 80 GWd/MTU, respectively, on the uranium fuel cycle, transportation of fuel and waste, and decommissioning for light-water reactors (LWRs) (i.e., a bounding analysis).

DATES: Submit comments by **[INSERT DATE 60 DAYS AFTER DATE OF PUBLICATION IN THE *FEDERAL REGISTER*]**. Comments received after this date will be considered if it is practical to do so, but the Commission is able to ensure consideration only for comments received before this date.

ADDRESSES: You may submit comments by any of the following methods; however, the NRC encourages electronic comment submission through the **Federal rulemaking website**:

- **Federal rulemaking website:** Go to https://www.regulations.gov and search for Docket ID **NRC-2023-0113**. Address questions about Docket IDs in Regulations.gov to Stacy Schumann; telephone: 301-415-0624; email: Stacy.Schumann@nrc.gov. For technical questions, contact the individual listed in the “For Further Information Contact” section of this document.

- **Mail comments to:** Office of Administration, Mail Stop: TWFN-7-A60M, U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001, ATTN: Program Management, Announcements and Editing Staff.

For additional direction on obtaining information and submitting comments, see "Obtaining Information and Submitting Comments" in the **SUPPLEMENTARY INFORMATION** section of this document.

FOR FURTHER INFORMATION CONTACT: Donald Palmrose, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001; telephone: 301-415-3803, email: Donald.Palmrose@nrc.gov.

SUPPLEMENTARY INFORMATION:

I. Obtaining Information and Submitting Comments

A. Obtaining Information

Please refer to Docket ID **NRC-2023-0113** when contacting the NRC about the availability of information for this action. You may obtain publicly available information related to this action by any of the following methods:

- **Federal Rulemaking Website:** Go to https://www.regulations.gov and search for Docket ID **NRC-2023-0113**.
- **NRC's Agencywide Documents Access and Management System (ADAMS):** You may obtain publicly available documents online in the ADAMS Public Documents collection at https://www.nrc.gov/reading-rm/adams.html. To begin the search, select "Begin Web-based ADAMS Search." For problems with ADAMS, please contact the NRC's Public Document Room (PDR) reference staff at 1-800-397-4209, at 301-415-4737, or by email to PDR.Resource@nrc.gov. The draft NUREG, ''Environmental Evaluation of Accident Tolerant Fuels with Increased Enrichment and Higher Burnup," is available in ADAMS under Accession No. ML23240A756.
- **NRC's PDR:** The PDR, where you may examine and order copies of publicly available documents, is open by appointment. To make an appointment to visit the PDR, please send an email to PDR.Resource@nrc.gov or call 1-800-397-4209 or 301-415-

4737, between 8 a.m. and 4 p.m. eastern time (ET), Monday through Friday, except Federal holidays.

B. Submitting Comments

The NRC encourages electronic comment submission through the **Federal rulemaking website** (https://www.regulations.gov). Please include Docket ID **NRC-2023-0113** in your comment submission.

The NRC cautions you not to include identifying or contact information that you do not want to be publicly disclosed in your comment submission. The NRC will post all comment submissions at https://www.regulations.gov as well as enter the comment submissions into ADAMS. The NRC does not routinely edit comment submissions to remove identifying or contact information.

If you are requesting or aggregating comments from other persons for submission to the NRC, then you should inform those persons not to include identifying or contact information that they do not want to be publicly disclosed in their comment submission. Your request should state that the NRC does not routinely edit comment submissions to remove such information before making the comment submissions available to the public or entering the comment into ADAMS.

II. Discussion

To support efficient and effective licensing reviews of new accident tolerant fuels (ATFs) and to reduce the need for a complex site-specific environmental review for each ATF license amendment request, this study evaluated the likely impacts of near-term ATF technologies with increased enrichment and higher burnup levels on the uranium fuel cycle, transportation of fuel and waste, and decommissioning for light-water reactors (LWRs) (i.e., a bounding analysis). Near-term ATF technologies are coated cladding, doped pellets, and (iron-chrome-aluminum) FeCrAl cladding. Other long-term ATF technologies are not a part of this study. The NRC staff evaluated the impact of increased enrichment and higher burnup levels by assessing and applying NRC-sponsored ATF technology reports, prior environmental reviews, transportation studies,

and new or updated data sources to determine the bounding (generic) environmental impacts of deploying ATF technologies with increased enrichment and higher burnup levels in LWRs.

The NRC initially considered the environmental impacts of the uranium fuel cycle in WASH-1248 (ADAMS Accession No. ML14092A628). There have been significant changes to the front-end processes and NRC-licensed facilities since the publication of WASH-1248. The most notable examples of these changes are extracting uranium from the ground using in situ recovery instead of traditional mining, performing all enrichment with gaseous centrifuges instead of gaseous diffusion, and electricity generation moving significantly away from the use of coal. The result of these various changes is to significantly reduce the environmental effects from the front-end of the uranium fuel cycle. Thus, the environmental effects of the front-end of the uranium fuel cycle from the deployment and use of ATF with increased enrichment is bounded by the environmental effects provided in Table S-3 under title 10 of the *Code of Federal Regulations* (10 CFR) section 51.51.

Regarding the back-end of the uranium fuel cycle, the current practice of long-term storage and management of spent nuclear fuel (SNF) would still apply to the deployment and use of ATF with increased enrichment and higher burnup levels. Consistent with NRC regulations and thermal loading requirements for licensed spent fuel storage cask systems, specific cooling times in a spent fuel pool would be necessary prior to transferring the spent fuel to an Independent Spent Fuel Storage Installation (ISFSI).

A benefit from deployment and use of ATF with increased enrichment and higher burnup levels would be the longer times between refueling operations, which would lessen the average annual rate at which licensees place spent ATF assemblies into the spent fuel pools and ultimately transfer spent ATF assemblies to an ISFSI relative to the rate for traditional spent fuel. This could, in turn, lessen the overall amount of SNF stored at a site and lengthen the time before licensees need to expand an ISFSI relative to

facilities using fuel with lower enrichments and lower burnup levels. This lessens the environmental impacts compared to what would occur with current fuel, which would be consistent with prior NRC environmental evaluations. Spent ATF storage would be consistent with earlier published analyses, would not require any significant departure from certified spent fuel shipping and storage containers, and would continue under an approved aging management program.

In conducting the generic analysis in the Continued Storage Generic Environment Impact Statement (GEIS) of NUREG-2157, Volume 1 (ADAMS Accession No. ML14196A105) and NUREG-2157, Volume 2 (ADAMS Accession No. ML14196A107), the NRC staff applied conditions and parameters that are sufficiently conservative to bound the impacts such that any variances that may occur from site to site are unlikely to result in environmental impact determinations that are greater than those presented in the Continued Storage GEIS. Therefore, with respect to ATF storage, including spent ATF with increased enrichment and higher burnup levels, the storage period beyond the licensed life for operation of a reactor for spent ATF would conform with the analysis of the Continued Storage GEIS, and accordingly, the Continued Storage GEIS would bound the impacts from deployment and use of ATF.

The analysis of the transportation of ATF and ATF waste with increased enrichment and higher burnup levels is based on shipment of low-level radioactive waste, unirradiated, and spent ATF, including with increased enrichments and higher burnup levels, by legal weight trucks in certified transport packages. The transportation impacts are divided into two parts. The first part considers normal conditions, or incident-free, transportation, and the second part considers transportation accidents.

Shipments that take place without the occurrence of accidents are routine, incident-free shipments and the radiation doses to various receptors (exposed persons) are called incident-free doses. The vast majority of radioactive shipments are expected to reach their destination without experiencing a transportation accident or incident or releasing any cargo (to date, there have been no shipments of spent fuel resulting in a

release of radioactive material to the environment). As previously noted, deployment and use of ATF with increased enrichment and higher burnup levels could result in lengthening of the time between refueling operations, leading to an overall reduction of the number of spent fuel assemblies needing to be shipped offsite on an annual basis. Such reduction would have the effect to lessen the environmental impacts compared to what would occur with current fuel and refueling operations due to transportation of spent fuel. The incident-free impacts from these normal, routine shipments arise from the low levels of radiation that are emitted externally from the shipping container.

Incident-free legal weight truck transportation of spent ATF, including spent ATF with increased enrichment and higher burnup levels, has been evaluated by considering shipments from six representative LWR sites to a postulated permanent geological repository for SNF in the western United States. As a surrogate for such a postulated permanent geologic repository, the NRC has used the proposed Yucca Mountain, Nevada site for the transportation analysis. The six LWR sites from which the shipments originate include:

- Brunswick Steam Electric Plant;
- Columbia Generating Station;
- Dresden Nuclear Power Station;
- Enrico Fermi Nuclear Generating Station Unit 2;
- Millstone Power Station; and
- Turkey Point Nuclear Plant.

For each LWR site, the NRC staff considered and evaluated both boiling water reactor (BWR) and pressurized water reactor (PWR) spent ATF shipments, including with increased enrichment and higher burnup levels, for the purpose of impact comparison owing to the different release fractions for BWR and PWR fuel designs.

Environmental impacts from these shipments would occur to persons residing along the transportation corridors between the reactor sites and the repository, to persons in vehicles passing the spent fuel shipments in the same and opposite

directions, to persons at vehicle stops (such as rest areas, refueling stations, inspection stations, etc.), and to transportation crew members. For the purposes of this analysis, the transportation crew for truck spent fuel shipments consisted of two drivers. The regulatory maximum crew dose rate of 2 millirem(s) per hour (mrem/hr), and regulatory maximum transport package surface dose rate of 10 mrem/hr at 2 meters is conservatively used in the analysis. The characteristics of specific shipping routes (e.g., population densities, shipping distances) influence the normal radiological exposures.

The accident risks are the product of the likelihood of an accident involving a spent fuel shipment and the consequences of a release of radioactive material resulting from the accident. The likelihood of an accident is directly proportional to the number of fuel shipments. Accident risks also include a consequence term. Consequences are represented by the population dose from a release of radioactive material given that an accident occurs that leads to a breach in the shipping cask's containment systems. Consequences are a function of the total amount of radioactive material in the shipment, the fraction that escapes from the shipping cask, the fraction of the release from the shipping cask that is aerosolized, the fraction of the release that is respirable, the dispersal of radioactive material to humans, and the characteristics of the exposed population. The NRC staff used the shipping distances and population distribution information for the regions pertaining to the sites used for the evaluation of the impacts of incident-free transportation for accident impact evaluations. The NRC staff used the most recent available data on accident rates, release fractions, aerosolized fractions, and respirable fractions in this evaluation.

The transportation impact evaluation includes the use of the NRC maintained NRC-Radioactive Material Transport (NRC-RADTRAN) transportation risk code package, pertinent fuel radionuclide inventory (source term) data, and external and accidental release characteristics, routing distance information, and population density by State along the route. The staff obtained routing information by running the Web-Based Transportation Routing Analysis Geographic Information System (WebTRAGIS)

code. While the population density considered in WebTRAGIS is for the year 2012, based in part on the 2010 U.S. Census data, the staff extrapolated the population density to 2022 based on each State's growth rate using 2010 and 2020 U.S. Census data. The staff compiled information with respect to vehicle daily traffic count, vehicle speed, vehicle accident, fatality, and injury rates from U.S. Department of Transportation data base and used that information in the NRC-RADTRAN analysis to determine single shipment impacts. To determine annual transportation impacts, the staff applied the normalized (annual) truck shipments of 52 shipments and 30 shipments estimated spent ATF from a BWR and PWR, respectively.

The NRC staff found the maximum normal conditions (i.e., incident-free) cumulative worker dose per year was bounded by the 4 person-rem value of Table S-4. This worker dose would be managed with multiple drivers available as the transportation crew so that the individual worker dose would be below the U.S. Department of Energy administrative limit of 2 rem per year and the NRC's occupational exposure annual limit of 5 rem per year. PWR shipment cumulative public doses were at or slightly higher than the 3 person-rem per year specified in the Table S-4. The NRC staff found the cumulative population dose per year for the BWR shipments to be higher than 3 person-rem per year. However, both the BWR and PWR results are not significant when the related average individual dose is considered. Namely, the average individual doses along all routes and fuel types are well below 1 mrem per year, a small fraction of the average annual natural background radiation exposure of approximately 310 mrem, and within the Table S-4 range of doses to exposed individuals. These results are conservative because they are based on the transport package with the least capacity. Applying a transport package with a greater capacity would reduce the number of shipments resulting in a lower cumulative dose that would be less than the 3 person-rem of Table S-4 as shown by the rail sensitivity case in this study (e.g., the GA-4 truck spent fuel transport can hold four PWR fuel assemblies, which would reduce the PWR cumulative doses by a factor of 4).

The NRC staff found total accidental population risk per year due to transport of spent ATF, including spent ATF with increased enrichment and higher burnup levels, continued to demonstrate the low risks from both radiological and nonradiological accidents and is consistent with past transportation studies. The greater risk to a member of the public would be physical harm from an actual vehicle collision involving a spent ATF shipment, if such an event ever happens. While the nonradiological risk is the greater risk, the results of this study demonstrate that those risks would still not be significant and are less than the common (nonradiological) cause environmental risks of Table S-4. The results for spent ATF with increased enrichment and higher burnup are consistent with the environmental impacts associated with the transportation of fuel and radioactive wastes to and from current-generation reactors presented in Table S-4 of 10 CFR 51.52.

Based on the results of the impact analysis, shipment of near-term ATF technologies with enrichments of up to 8 (wt%) uranium-235 (U-235) and higher burnup levels of up to 80 gigawatt days per metric ton of uranium (GWd/MTU) would not significantly change the potential impacts of either incident-free or accident transportation risk. Hence, the transportation impacts of spent ATF are bounded by Table S-4. Therefore, the results of this analysis could serve as a reference in helping to address the environmental impacts of ATF licensing without a detailed site-specific transportation analysis, as long as the ATF is within the enrichment and burnup levels with the associated fuel assembly radionuclide inventory and parameters applied in the analyses of this proposed NUREG.

In the case of decommissioning, the expected impacts from deployment and use of ATF with increased enrichment and higher burnup levels would be the same as or slightly less than those from decommissioning nuclear power plants operating with the existing fuel. Additionally, the expected Decommissioning GEIS and guidance updates could build upon the analysis from this study to specifically address the decommissioning of a LWR deploying and using ATF.

Therefore, based on findings in this study, the NRC staff concludes that the reevaluated findings addressing near-term ATF technologies (i.e., coated cladding, doping, and FeCrAl cladding) indicate the environmental effects associated with deploying and using ATF would be bounded by the NRC staff's prior analysis with enrichments up to 8 wt% U-235 and extending peak-rod burnup to 80 GWd/MTU for the uranium fuel cycle, transportation of fuel and waste, and decommissioning. Additionally, if in a future licensing action, the enrichment and burnup levels are greater than 8 wt% U-235 and 80 GWd/MTU, respectively, and for the deployment and use of long-term ATF technologies, the study could provide guidance for completing the needed revised analysis.

As the NRC staff continues to prepare to review license applications related to ATF technologies and fuel with increased enrichment and higher burnup levels, the NRC staff will evaluate new industry developments and other activities before publishing the final NUREG to consider further refinements of the ATF environmental evaluation. For example, such new information could include results from ongoing licensing actions regarding the use of higher enrichment levels in fuel fabrication (ADAMS Accession No. ML22175A070).

III. Specific Requests for Comments

The NRC is seeking advice and recommendations from the public on the draft NUREG. We are particularly interested in comments and supporting rationale from the public on the following:

Transportation Accident Release Fractions

1. Previous transportation accident analyses have relied upon the use of release fractions in Table 7.31 from NUREG/CR-6672, "Reexamination of Spent Fuel Shipment Risk Estimates," (ADAMS Accession No. ML003698324) for burnup levels up to 60 GWd/MTU. By subjecting LWR nuclear fuel to higher burnup levels, the radionuclide inventory available to be released is greater and material issues such as cladding embrittlement, fuel fragmentation, and additional diffusional release of fission

products are expected to result in greater release fractions than assessed in NUREG/CR-6672. Therefore, Appendix B of the draft NUREG assessed the potential effects due to higher radiological material release fractions from the physical effects of higher burnup levels on the fuel pin cladding and the uranium fuel pellets.

The NRC is seeking comment on the use of release fractions developed in Appendix B of the draft NUREG for higher burnup levels than previously considered under transportation accident conditions.

Dated: August 29, 2023.

For the Nuclear Regulatory Commission.

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[FR Doc. 2023-18966 Filed: 8/31/2023 8:45 am; Publication Date: 9/1/2023]