May 22, 2024

Mr. John Lubinski
Director, Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, D.C., 20555-0001

**RE: Docket No. NRC-2023-0071 — Regulatory Framework for Fusion Systems**

Dear Mr. Lubinski,

On behalf of TAE Technologies, I write to share our perspective on the preliminary rulemaking and guidance documents the NRC is preparing on a Regulatory Framework for Fusion Systems. We appreciate all the substantial work and thought put into this process over several years, including the decision to establish a framework based on relative risk of fusion systems, and we commend the NRC and its staff for its transparency and engagement with stakeholders throughout this process.

As the NRC staff prepares to submit draft language to Agreement States and ultimately to the Commissioners, we encourage you to ensure the rules and guidance are flexible to a variety of approaches, including approaches that, due to sizable up-front investments to harness alternative fusion fuels like proton-boron ($p^{11}B$), have significantly lower radiological and environmental risk profiles than those using conventional fuels. As noted in the draft guidance's preamble, the NRC aims to "take[ ] a risk-informed, technology neutral approach to licensing fusion systems."[1] The preliminary regulatory language and guidance can best achieve this objective by revising references to tritium to clarify that they do not apply in systems that do not use or produce tritium, using a risk-based approach to environmental review, and providing more flexibility to adopt material inventory procedures that correspond to the risk of a specific site. The absence of this clarification would create a perverse market disincentive *against* developing fusion plants with the highest possible safety and environmental standards; for this reason, it would be aligned with the NRC's stated objectives and in the broad public interest to pursue such a risk-appropriate approach.

<u>Company Context</u>
TAE Technologies, founded in 1998 as a spinout of University of California at Irvine (UCI), is the nation's longest-operating firm pursuing commercial electricity from fusion energy. TAE was founded with a singular end-goal in mind: producing cost-competitive commercial power to the grid with near-zero environmental and safety impact. To date, TAE has raised $1.2 billion in private capital to build five experimental machines — three at national-lab scale — to validate core concepts and viability of our advanced beam-driven field-reversed configuration (FRC) for magnetic confinement fusion. The company is now building the final experimental machine on its journey to a fusion power plant: Copernicus, to be sited in Southern California, is expected to demonstrate the viability of net energy generation from our proprietary configuration around the mid-2020s.

[1] NUREG-1556 Volume 22, "Program-Specific Guidance About Possession Licenses for Fusion Systems," iv (March 2024) ("Draft NUREG").

Of note, TAE's approach and our use of aneutronic proton-boron ($p^{11}B$) fuel will generate aneutronic fusion. This means that no neutrons are created from the primary reaction, and the neutrons produced through secondary reactions carry less than 1% of total fusion power — a small fraction of alternative approaches that use or intentionally produce tritium (which TAE will not use as a fuel or intentionally produce through its reactions). Therefore, we expect TAE's fusion machines to create significantly less activated material than other approaches, presenting lower radiological risks and resulting in a different system design.

<u>Tritium</u>

The NRC in its preliminary draft of NUREG-1556 Volume 22, "Program-Specific Guidance About Possession Licenses for Fusion Systems" ("draft NUREG"), acknowledges that not all fusion machines will use or intentionally produce tritium.[2] As mentioned above, TAE's $p^{11}B$ approach does not use tritium as a fuel and has no need for tritium handling or managing tritiated waste in byproduct management. While the draft NUREG states that "most" fusion systems will use tritium, among companies that have raised over $1 billion to build full-scale fusion devices, only one is pursuing the conventional approach of DT fuel — two are instead pursuing alternate fuels.[3] Because the inherent design of these systems means they will store no radioactive fuel and produce substantially less activated material, they offer great promise in supporting the NRC's goal of protecting public health and safety. **If the NRC seeks to reduce radiological risk, a primary goal should be to ensure that fusion systems using aneutronic fuels are treated proportionately to their risk and are not required to apply procedures without relevance or meaningful safety benefits.**

In several places, the draft NUREG's references to tritium assume that it will be used as a fuel and/or produced as a byproduct in all fusion systems. We encourage the NRC to review the draft NUREG text to clarify throughout that license applications need not speak to these issues if they do not apply. We have included as an appendix to this letter a list of examples and potential revisions, and we highlight a few examples below where this lack of clarity could imply certain procedures that may not be risk-appropriate:

- *Tritium handling systems and breeding blankets*: These sections require license applications to include statements about their operating and emergency procedures for the named systems. There is no option available under the guidance for an applicant to state that the system design does not include a tritium handling system or breeding blanket.
- *Facilities and Equipment:* This section states that tritium "will be produced as a byproduct" and therefore "[i]nline tritium monitoring of atmospheric stacks is required." This should be revised to apply only to systems that, by virtue of their fuel, do produce tritium in relevant quantities.
- *Heat exchange systems*: The discussion notes concerns about tritium or other activated materials becoming airborne. As a result, it states that heat exchange systems "should be fully enclosed" and that certain procedures "must" be taken during maintenance. Instead, we recommend that the NRC require system designs and procedures to be based on the specific materials and the actual expected dose (e.g., doses that exceed the monitoring requirements in 10 C.F.R. Part 20).

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[2] TAE's $p^{11}B$ approach does not use tritium as a primary reactant in the fuel, but an infinitesimally small amount of tritium production will briefly occur through secondary and tertiary reactions. At such a low level, the tritium inventory will be below any regulatorily actionable level that would require a dedicated tritium handling system or by-product management of tritiated waste. Due to the negligible level, we will hereafter refer to such an approach as not using or producing tritium.

[3] Some non-$p^{11}B$ fusion approaches may produce tritium as a byproduct; we recommend the Commission consult them directly as appropriate. *See* Fusion Industry Association, "The global fusion industry in 2023" (2023)

Environmental Review

The draft regulatory text proposes the following language be added as 10 C.F.R. § 51.60(b)(viii): "Construction and operation of a fusion system for other than research and development," which will require all commercial fusion systems to complete environmental reviews regardless of their risk to the environment.[4] The NRC states that this will take from several months up to 2 years, potentially significantly extending licensing times. The NUREG explains that this is based on the assumption that all commercial systems would have "quantities and forms of radioactive material [that] are currently not expected to be within the scope considered for other material uses." In fact, the total quantity of radioactive material from a commercial $p^{11}B$ power plant is likely to be less than a research device using a deuterium-tritium fuel cycle.[5]

Rather than use the purpose of a facility as a rough and potentially inaccurate proxy for the quantity and form of radioactive material on site, we encourage the NRC to use a risk-based approach and remove the categorical exclusion only for fusion machines that present a risk of exposure greater than existing exempt cases. For example, the NRC could eliminate the categorical exclusion for facilities that will have a significant inventory of licensed materials. The NRC already has set such thresholds for financial assurance, for example, and has even adopted a categorical exclusion for decommissioning of sites where a decommissioning plan is not required under 10 CFR § 30.36(g)(1).[6] This would better meet the NRC's goal of adopting a "risk-informed, technology neutral approach."

If the NRC chooses to adopt an inventory-based approach, corresponding edits to draft NUREG Sections 8.5.3 Environmental Review and 8.10.10 Environmental Surveillance would be required.

Material Control and Accountability

The draft NUREG states: "Each licensee shall conduct a semiannual physical inventory to account for all licensed material received and possessed under the license." Physical inventories may be appropriate for sealed sources or tritium storage beds, in facilities where these are present, but physically inventorying activated material inside the machine is likely only practical during decommissioning, due to the need for destructive sampling. In addition, it is not practical to inventory corrosion products, dust, or activated air.

Especially for facilities where the radiological exposure will be minimal because the inventory will be a small volume of activated material within the fusion machine, this periodicity and the requirement for a physical inventory does not match the level of risk.[7] The radiological risk from the physical inventory will be low in systems that use aneutronic fuels, and applying the same methods and frequency of inventorying material as in a system with radioactive fuels is disproportionate to the risk. At the same time, physically measuring the amount of activated material within a machine is complex, burdensome, and expensive, especially if it requires shutting down power production beyond the normal maintenance

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[4] The NRC noted in the draft NUREG that this requirement only applies where there is a Federal action, which could affect licenses in non-Agreement States, or in Agreement States that choose to let the NRC regulate fusion while maintaining their control of other byproduct material.

[5] *See* "TAE's Expected Safety Profile: OP-B11 Aneutronic Fusion," presentation at NRC Public Meeting on Regulatory Framework for Fusion, March 30, 2021 (showing dose rates to general public and from hypothesized catastrophic accident ~100x lower than regulatory limit).

[6] 10 C.F.R. § 51.22.

[7] Systems using aneutronic fuel may also keep some activated material in storage, per the waste disposal guidance.

cycles, and it carries a risk of increasing worker exposure to radiation. In fact, by virtue of its use of aneutronic fuel, TAE's system is designed for longer periods of continuous operation without the kind of semiannual off-cycles to remove tritium byproduct that was perhaps envisioned by the draft NUREG.

In addition, the guidance already requires "appropriate radiation monitoring."[8] At least for radiological materials other than tritium, when these monitors observe a radiological condition change that indicates the radioactivity has increased to a point of unsafe conditions or if it goes below some expected value, then it could indicate a loss of radiological material has occurred. This would satisfy the NRC's public health and safety objectives without requiring impractical physical inventorying of activated material inside the machine, corrosion products, dust, or activated air.

Finally, the current guidance does not provide any information on acceptable methods for conducting a physical inventory or the required accuracy, creating uncertainty for developers.

If NRC concludes that an inventory of activated material inside the machine is necessary, a more risk-balanced and efficient approach for fusion systems that do not require radioactive fuels would be to allow the use of validated models to estimate the inventory of activated material within the machine. The NRC could elaborate their expectations for the accuracy and periodicity of the inventory, and licensees could explain how their validation procedure—based on physical measurements in their application—meet those expectations. National Council on Radiation Protection and Measurements (NCRP) Report No. 144, "Radiation Protection for Particle Accelerator Facilities," describes how validated models in conjunction with routine area monitoring and other methodologies can be used. The draft NUREG cites the methodology in this same report as acceptable for determining shielding requirements.[9]

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Thank you for your consideration of these issues, which are important for the deployment of clean fusion energy in the United States. We look forward to a continued dialogue with the Commission.

Sincerely,

Matthew Lipka
Regulatory Advisor
TAE Technologies

Jed Styron, PhD
Sr. Nuclear Engineer
TAE Technologies

[8] Draft NUREG, 8-26.
[9] Draft NUREG, 8-25.

Appendix: Examples of Tritium references in the draft NUREG and potential amendments

The below quotations from the draft NUREG are examples of areas where the use or production of tritium is assumed or implied. Suggested edits are provided in bold / strikethrough to illustrate how NRC could incorporate fusion systems that do not use or produce tritium into a technology-neutral regulatory structure.

- 8.5.2 Financial Assurance: "It is expected that ~~**a**~~ fusion system licensee**s that use tritium** will need to prepare a [decommissioning funding plan] DFP given the quantities of tritium and activation products possessed."
- 8.7.1 Radiation Safety Officer: "Experience should include the following areas: … effluent and environmental monitoring, including tritium **if applicable**"
- 8.9.1 General Description of Facility and Site: "Systems should monitor for tritium **(if applicable)**, neutron radiation, and radiation from activated shield/building materials. . . . Depending on the fusion fuel and design used, tritium ~~**will**~~ **may** be produced as a byproduct from the fusion reaction, either directly or indirectly through the capture of a neutron by lithum-6. . . . Inline tritium monitoring of atmospheric stacks is required **for systems using or intentionally producing tritium**, and samples should be tested regularly to demonstrate compliance with 10 CFR 20, Appendix B limits."
- 8.9.5 Radiation Monitors: "The licensee will also need radiation detection equipment for monitoring of tritium effluents**, if applicable**."
- 8.9.6 Tritium Handling Systems:
  - "**Some fusion systems will use tritium fuel. In such systems, t**~~T~~he tritium handling system should be designed to accomplish its required function (e.g., separate tritium from lithium, store tritium for future use as fuel) while minimizing and controlling the exposure of workers, the public, and the environment to tritium."
  - "The applicant should provide the following statement: 'We will prepare and maintain operating and emergency procedures for the tritium handling system.'" **Add "OR 'We will not use or intentionally produce tritium.'"**
- 8.9.7 Breeding Blankets:
  - "In a fusion system **based on a tritium fuel cycle**, the breeding blanket is used to capture neutrons to produce tritium. "
  - "The applicant should provide the following statement: "'We will prepare and maintain operating, maintenance, and emergency procedures for the breeding blanket components.'" **Add "OR 'We will not have a breeding blanket in our design.'"**
- 8.9.8 Heat Exchange: "Heat exchange systems should be fully enclosed to prevent activated materials and tritium**, if present,** from becoming airborne."
- 8.9.9 Power Failures: "Procedures for locking down tritium storage systems**, if applicable**, to prevent airborne release."
- 8.10.3 Material Control and Accountability: "The tritium inventory in each of these systems must be assessed **for systems that use or intentionally produce tritium**."
- 8.10.4.2 Bioassay Program: "Tritium will be found in most fusion systems, and **where it is present,** special attention should be given to the internal monitoring of tritium during operations, maintenance, and incidents."
- 8.10.10 Environmental Surveillance: "**Some f**~~F~~usion systems will use or produce tritium during normal operations. A small fraction of the tritium **in such systems** is expected to be released as an airborne effluent as part of normal operations…. ~~**The l**~~**L**icensee**s using tritium** will need to determine the public dose based on the tritium ratio of HT and HTO in th **[sic]** environment…. An

applicant will need to consider the location and characteristics of the radioactive material onsite and that is included in effluent release and evaluate the principal radiological exposure pathways for the ~~tritium~~ **radioactive material**."

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| **From:** | Matthew Lipka |
| **To:** | Dennis Andrukat |
| **Subject:** | [External_Sender] Letter on fusion systems rulemaking from TAE Technologies |
| **Date:** | Wednesday, May 22, 2024 12:53:17 PM |
| **Attachments:** | TAE Letter to NRC regarding Preliminary Fusion Rulemaking.pdf |

Dennis,

On behalf of TAE Technologies, please see attached a letter with our perspective on the preliminary rulemaking and guidance documents the NRC is preparing on a Regulatory Framework for Fusion Systems. We appreciate all the work and thought NRC is putting into this process and the transparency, and appreciate you considering our thoughts in this letter. Please do not hesitate to contact me with any questions on this or TAE's approach to fusion.

Best,
Matthew

**MATTHEW LIPKA**
Policy & Global Affairs

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