Commonwealth Fusion Systems

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Mr. John Lubinski
Director, Office of Nuclear Materials Safety and Safeguards
US Nuclear Regulatory Commission
Washington, DC 20555-0001

RE: Preliminary Rulemaking Process for a Regulatory Framework for Fusion Systems
Docket No. NRC-2023-0071

Mr. Lubinski:

Commonwealth Fusion Systems ("CFS") is writing to offer its perspective on the draft regulatory guidance document NUREG-1556 Volume 22 that the Nuclear Regulatory Commission's ("NRC" or "Commission") has undertaken to provide additional detail on how to complete a license application for future fusion power plants. CFS appreciates the NRC's engagement and interest on this topic of critical importance to the emerging fusion energy sector in the United States. CFS remains committed to working with the NRC, its Agreement State partners, and all other stakeholders to achieve the right regulatory outcome for fusion energy to the benefit of the growing fusion industry, the American people, and the global energy market.

CFS' overarching goal in this regulatory process is to ensure the regulatory framework for commercial fusion protects the health and safety of workers, the public, and the environment while striking the appropriate balance between the needs of the regulator and the need for regulatory flexibility and certainty that will support a new, and fast-growing fusion power industry.

As a first principle, CFS believes the regulatory program for commercial fusion should reflect fusion's distinction, in virtually every facet, from fission. That program should be grounded in 10 CFR Part 30 and NUREG-1556 Volume 21. Based on that regulatory foundation, leveraging decades of practice, precedent, and implementation, the Commission should adopt a limited-scope rulemaking and regulatory guidance for commercial fusion to support and enable continual innovation, scaling, and transferability within the United States and around the world. CFS believes strongly that safety should not be competed over by industry participants. Fusion is safe and every single participant in the global fusion enterprise shares the responsibility of keeping it so. For these reasons, CFS endorses the May 22, 2024, letter from the Fusion Industry Association describing the consensus viewpoint of the fusion industry. CFS is writing separately to provide further input on the draft regulatory guidance.

We appreciate the Commission's efforts to base its draft regulatory guidance on NUREG-1556 Volume 21, which is effectively being used by Agreement States to regulate current fusion demonstration facilities, like OMEGA at the University of Rochester in New York, SHINE's deuterium-tritium accelerator in Wisconsin, and CFS' SPARC machine currently under construction in Devens, MA. However, CFS is concerned that several elements of the proposed Volume 22 guidance stray beyond what has historically been required of licensees in Volume 21 and are not appropriate for commercial fusion. Many of these additions and new requirements will inhibit fusion's ability to deploy and scale. To that end, it will also be important to remove from the draft guidance any specific design assumptions that focus on one design or fuel type and do not take into account that a thriving fusion industry will provide multiple design solutions. As an example, provisions on tritium-related systems that include specific assumptions which are either not in line with practical experience from previous fusion facilities or presume a particular design for the tritium-related systems, should be avoided.

It is also critical that any rulemaking or guidance NRC finalizes for fusion machines does not affect licensing activities being undertaken today. A clear distinction should also be made that Volume 22 only applies to commercial fusion machines and R&D fusion machines should continue to use either Volumes 7, 11, or 21. For example, CFS filed its materials license application with the Massachusetts Radiation Control Program months before NRC staff released its proposed fusion specific NUREG in March 2024. SPARC is not a commercial machine and the understanding among all stakeholders in this process, which stretches back several years, has been that NUREG-1556 Volume 21 is the appropriate tool to evaluate the licensing of fusion machine demonstration projects like SPARC. Blurring the line between future commercial machines and R&D machines that are, or shortly will be, undergoing a license review process, creates confusion that adds no additional safety value and serves only to bog down licensing across the United States. The Commission recognized this potential to upset existing licensing activities when it directed staff that its implementation of so-called Option 2 should account for "the existence of fusion systems that already have been licensed and are being regulated by the Agreement States, as well as those that may be licensed prior to the completion of the rulemaking."[1] A statement that the proposed Volume 22 does not apply to any fusion R&D machine or fusion machine application applied for prior to finalization of the fusion rulemaking anticipated in 2027 would eliminate that confusion.

We have prepared a table in the appendix that highlights proposed additions for which it is not clear the reason these would be required above and beyond what is required under Volume 21 for fully licensed particle accelerators operating today. A few of our concerns include, but are not limited to:

- The requirement to file both the environmental report and radioactive materials license application 9 months prior to the start of construction, which will add considerable length in the licensing process with no associated safety benefit.

- The requirement to perform a physical inventory of tritium and activated material every six months. CFS does not object to a semiannual inventory of sealed sources. However, performing a physical tritium and activated material inventory assessment of the entire fusion loop is impractical, creates unnecessary safety hazards for workers inconsistent with ALARA principles and doesn't lead to the desired understanding for effective hazard management. As an alternative for tritium, regulators should focus on monitoring the tritium gain or removal mechanisms from the tritium process loop through an agreed upon combination of radiation monitoring in tritium storage and handling areas, records of adding or removing tritium from the process loop, decants with some point sampling and modeling/simulation calculations.

[1] SRM-SECY-23-0001, https://www.nrc.gov/docs/ML2310/ML23103A449.pdf (April 13, 2023).

For activated material, a single bounding calculation in the license application showing the maximum authorized level of activation product inventory should be sufficient.

- The power failures section requires all fusion facilities to have backup power in the event of a shutdown in order to maintain radiological safety. This fission-like requirement does not make sense for a commercial fusion machine. In reality for a loss of power scenario, fusion systems are being designed to not be capable of operating and will automatically isolate in scenarios where key systems like fueling (gas injection) or confinement are not available. The backup power requirement is not needed to maintain radiological safety and provides no benefit to health, safety, or environmental protection.

The attached Appendix contains further background and other examples of text additions which are unnecessary and go beyond what has been required in Volume 21. In addition to detailed feedback which maps to the draft guidance specific section numbers, the Appendix includes our proposed edits to the text in red and an explanation for the proposed change. This feedback and suggested edits better align the proposed Volume 22 with what CFS believes should be the first principles in this process of working from Volume 21 as the basis for the guidance with appropriate, but limited additions that directly address the safety of workers, the public and the environment.

CFS appreciates the ability to comment on the draft NUREG document for fusion which should establish a strong foundation for the regulation of fusion energy in the United States. Members of our team will make themselves available to the Commission staff to provide additional technical details and supporting information to answer any questions or concerns the NRC may have based on this feedback. Thank you for your consideration and we look forward to working with you in this process.

Sincerely,

Tyler Ellis, Ph.D.

Commonwealth Fusion Systems LLC

CC: Chair Christopher T. Hanson, NRC

Commissioner Annie Caputo, NRC

Commissioner Bradley R. Crowell, NRC

Commissioner David A. Wright, NRC

Daniel H. Dorman, Executive Director for Operations, NRC

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Appendix: Suggested edits for NUREG-1556 Volume 22

This appendix maps the specific section numbers, proposed new text in red/deleted text in ~~red with strikethrough~~ and an explanation for the proposed change.

Section	Proposed Text	Explanation
1	This NUREG identifies the information needed to complete NRC Form 313, "Application for Material License," for the possession and use of byproduct material. If the applicant requires any other type of license, such as a broad-scope license, other applicable guidance documents in this NUREG–1556 series are available at https://www.nrc.gov/reading-rm/doccollections/nuregs/staff/sr1556/.	CFS recommends adding this text to the purpose section. Similar language to this is included in Section 1 Purpose of Report of NUREG-1556 Volume 21. This makes it clear that applicants can utilize other NUREG documents to supplement what is contained in Volume 22.
8.5.1	Since fusion systems are likely to have tritium present, the applicant should be aware of the amount of ~~gaseous~~ tritium ~~(HT) and tritiated water (HTO)~~ throughout the fusion system for protection of the workers and the public. It is important to note that ~~This is necessary since~~ the radiation dose for HTO is significantly greater than HT.	While the total system inventories of tritium will be known, the specific quantity which is in the form of HTO will not be known. Surface contamination or permeation from gaseous loops will contribute to HTO quantity in the fusion facility. HTO volumes going through detritiation systems will be variable at any one specific time. These detritiation systems should be capable of processing large quantities of HTO but generally in normal operations will typically process small amounts of HTO. CFS recommends that the focus should be on tritium hazard management and not specific quantities of elemental types. Even in a water detritiation system, this is still a part of the scope of closed tritium handling systems.
8.5.1	The applicant should consider incidentally-activated nuclides ~~that are not anticipated as well as incidentally-activated nuclides~~ that are expected to be produced.	This draft guidance departs from the existing guidance in Volume 21 on this subject which states *"For incidentally activated radionuclides, the applicant could request authorization to possess and use any form of byproduct material with atomic numbers 1 through 83. However, the applicant should indicate the total cumulative quantity for all radionuclides to be possessed at any one time. (page C-2)"*

		It is not clear how an applicant can *"consider incidentally-activated nuclides that are not anticipated"* because this could conceivably include every known isotope. It seems more reasonable to include the anticipated ones.
8.5.1	The applicant should indicate the total cumulative quantity for all radionuclides to be possessed at any one time assuming 1 day after shutdown of the fusion facility, and the maximum quantity for any one of the radionuclides within atomic numbers 3-83.	It would provide greater clarity to applicants to specify a point in time post-shutdown where the applicant should calculate the activated material inventory. There are many activation products which have incredibly short half lives which would decay away long before any reasonable situation where a worker could get exposed. Therefore, there is no radiological safety benefit for including these short lived isotopes in the overall activated material inventory.
8.5.1	~~Similarly, specific high-risk, incidentally-activated radionuclides that are produced in smaller quantities should also be listed separately.~~	"High-risk" is not defined so it is unclear what should be listed separately. We recommend this sentence to be deleted.
8.5.1	Note that authorization to possess byproduct materials with atomic numbers 84 through 96 does not authorize the possession of uranium, thorium, or plutonium because, even though these elements have atomic numbers within the range of 84 through 96, these materials are either source material or special nuclear material and not byproduct material. It is understood that tritium is frequently transported and stored on depleted uranium beds so the total amount of depleted uranium used for this purpose should be separately listed in the authorization to possess table.	Since this regulatory guide is focused on fusion energy systems and the predominant fusion fuel cycle under consideration by the fusion industry is deuterium-tritium, most applicants will require the use of depleted uranium beds to both transport the tritium to the site and store the tritium on-site. Therefore, it makes sense to explicitly mention this as an appropriate entry in the table of radionuclides to possess since it will be anticipated to be present in a majority of the license applications.
8.5.1	The amount of tritium can also be provided in grams (~~9650~~ 9620 Ci/gram tritium).	CFS believes that the conversion factor for tritium is 9618.9 Ci/gram and we have rounded it to 9620.
8.5.2	Records of spills or other unusual occurrences involving the spread of contamination in and around the facility, equipment, or site. These	CFS thinks it is reasonable to bound the area where tritium exposure has occurred in the lifetime of the system and use the first phase of decommissioning to assess the quantities by taking destructive

	records may be limited to instances when contamination remains after any cleanup procedures or when there is reasonable likelihood that contaminants may have spread to inaccessible areas as in the case of tritium migration into fusion system components and structural materials such as concrete. These records must include any known information identifying involved nuclides, quantities, forms, and concentrations. Some of this information, like quantities and concentrations, may not be available until the first phase of decommissioning where destructive samples can be taken.	samples. However, CFS thinks it is unreasonable during operations of the facility for the records to have accurate quantities, (due to the need to take destructive samples) especially in inaccessible places which seems to be implied.
8.5.3	~~The NRC staff developed NUREG-2249, Generic Environmental Impact Statement for Advanced Nuclear Reactors, (ANR GEIS) (NRC 2021). Since the definition of "advanced reactor" under NEIMA also includes "fusion reactor," the NRC staff considers the environmental analysis and conclusions of the ANR GEIS applicable to commercial fusion systems licensed under 10 CFR Part 30. The applicant could justify the applicability of the environmental analyses and conclusions from the ANR GEIS in preparing their environmental report. This would facilitate the NRC's staff review of the environmental report and conclusion on whether an environmental assessment or an environmental impact statement is appropriate.~~	The GEIS was developed for licensing commercial fission nuclear power plants and not fusion power plants which would be licensed under 10 CFR 30 (or via Agreement States). Given that the environmental impact for all existing fusion R&D facilities are categorically excluded under NUREG-1748, it does not seem reasonable to suggest that a fission-centric GEIS should apply to fusion power plants. CFS recommends deleting this paragraph. SRM-SECY-21-0098, which discusses staff requirements from the Commission on GEIS, states that "In light of the Commission's direction in SRM-SECY-23-0001 to regulate near-term fusion systems under the 10 CFR Part 30 byproduct material framework, the staff should remove references to fusion reactors in the proposed rule." so the CFS proposed edit seems aligned with this direction.
8.9.1		A general comment, this section seems to require significantly more system descriptions, diagrams, blueprints, general arrangements, etc. than is required by NUREG-1556 Volumes 21 or 11.

		Requiring this level of documentation as fusion machine designs are being finalized would increase applicants' regulatory obligations without an appreciable increase in safety associated with the licensed material. CFS recommends maintaining the level of requested detail equivalent to what is described in NUREG-1556 Volume 21.
8.9.1	Applicants should consider seismic impacts in the design of their fusion system facility. If the fusion system will not be built in seismic areas (as defined below), it is acceptable that shielding meet generally accepted building code requirements for reinforced concrete with walls, wall penetrations, and entranceways designed to meet the radiation shielding requirements. If built in seismic areas, the applicant must design the concrete radiation shields and foundations for system components to retain their integrity in the event of an earthquake by designing to the seismic requirements of an appropriate source, such as American Concrete Institute (ACI) Standard ACI 318-~~95~~19, "Building Code Requirements for ~~Reinforced~~ Structural Concrete," ~~Chapter 21, "Special Provisions for Seismic Design,"~~ or local building codes, if current. For steel components, they should also be designed to the requirements of an appropriate source, such as the American National Standards Institute/American Institute of Steel Construction (ANSI/AISC) Publication 341-10, "Seismic Provisions for Structural Steel Buildings," or local building codes, if current. The licensee must monitor the construction of the shielding to verify that its construction meets design specifications and generally accepted	The title for standard ACI 318-95 is "Building Code Requirements for Structural Concrete." Also, the latest version of this standard is ACI-318-19. The specific chapter reference in ACI 318-19 will also need to be updated since the numbering of the chapters changed between the two versions of the standard.

	building code requirements for reinforced concrete.	
8.9.1	~~Such systems will extract tritium without releasing it to the environment through unmonitored pathways. Tritium handling systems and storage must have a tritium air monitor(s) in place to monitor for leakage. Inline tritium monitoring of atmospheric stacks is required, and samples should be tested regularly~~ Tritium handling systems shall be capable of identifying, isolating, and responding to leaks. Tritium facilities shall be equipped with appropriate environmental monitoring approaches to demonstrate compliance with 10 CFR 20, Appendix B limits.	The requirement for air monitors within systems would not improve monitoring of potential personnel dose hazard management. Room area monitors are sufficient for managing potential dose to workers. There are many ways to monitor for leaks such as with pressure transducers, in-line process monitors, area monitors, surface swiping will give trending, passive vials can give trending. Mandating particular tritium air monitors may not meet the function needed depending on the composition of the process.
8.9.1	~~Equipment layout/blueprints of the area which are affected by neutron, X-ray, and gamma radiation and scatter;~~	This level of requested detail seems excessive given that bullets #2 and #4 from this list cover similar information at a higher level which seems more reasonable for licensing review.
8.9.1	Description of access controls including the specific locations of interlocks and audible and visible alarms to prevent inadvertent entry into the fusion system area, ~~high or very high radiation areas or other areas where radioactive materials are stored~~ or the fusion system area(s) that are high or very high radiation areas. For high radiation areas where an interlock is not appropriate, applicant may propose alternate means of controlling access;	This bullet is difficult to understand. Is it saying that high radiation areas and/or locations that radioactive materials are stored, need to be interlocked and need audible/visual alarms? Why is this bullet in this section when there is a later section dealing specifically with access control? It would be helpful to clarify the wording to 1) separate the discussion of radioactive materials controls from radiation area controls and 2) say that only fusion system areas need to be interlocked and other high radiation areas can be controlled by other means. The basis for the proposed edit is that 1) interlocks and visible alarms are not required for "areas where radioactive materials are stored," therefore, this portion should be removed and 2) in some high radiation locations, an interlock may not be appropriate and other acceptable means of controlling access should be permitted.
8.9.2		The "Discussion" portion is focused on access control to radiation areas while the "Response from

		Applicant" portion is focused on access control to radioactive materials. These are different concerns/hazards so additional clarification in this section would be helpful.
8.9.3	During the construction process, a physical inspection should be conducted by the license applicant of the following items to verify construction meets the shielding design plans:	Clarifying that the applicant can perform the physical inspection and have documentation that can be provided for the regulator to review. Alternatively, the regulator could also gain confidence that the shielding was installed correctly with measurements taken after startup.
8.9.4	~~Fire detection systems should be tied to the shutdown of ventilation systems to mitigate the spread of fire.~~	Recommend deleting this sentence because facility and building specific hazard management and fire management will need to be considered by the applicant. Fire suppression systems, quantity of flammable materials, types of hazards in the room (tritium, electrical, etc.) will all need to be considered in the design approach. In a tritium facility, ventilation may reduce the overall public hazard because it would minimize oxidation if released. Therefore, in certain designs, the requirement to shut down ventilation could go against hazard management.
8.9.5	~~Applicants that will use tritium fuel will need to have monitoring equipment that can detect 14 MeV neutrons and tritium and applicants that use helium-3 and deuterium fuel need equipment that can detect x-rays, gamma radiation, and tritium.~~ Fusion systems will have radiation detection equipment that is capable of measuring the type and energy of radiation produced.	Applicants that use deuterium/helium-3, deuterium/deuterium, and proton/boron-11, will also produce neutrons in addition to other types of radiation. Recommend leaving this more general and fuel agnostic so that the applicant can include the appropriate radiation detection technologies.
8.9.6	~~An applicant may find the information in DOE-STD-1129-2015, "Tritium Handling and Safe Storage," useful in preparing their response.~~	Recommend removing the reference to DOE-STD-1129-2015 because it is unclear what portions would be useful (like the principles of handling, science, discussion of permeation) versus other portions which contain overly prescriptive requirements which are intended only for DOE facilities.
8.9.6	radiological and non-radiological safety features to describe the steps taken to monitor and respond to leaks and minimize tritium migration to the environment ~~(e.g., fire suppression, temperature, and vacuum controls),~~	CFS is suggesting to replace the detailed examples with an expanded statement of the overall purpose.

8.9.7	The blanket may ~~consist of~~ contain lithium or lead. ~~Liquid lithium in the breeding blanket must be maintained separately from other systems, due to reactivity of lithium.~~	CFS recommends removing the detailed examples to generalize this section more, given that there are several types of blankets being studied for incorporation into fusion power plants. For example, FLiBe is a blanket coolant that CFS has baselined and this contains lithium in a mixture of lithium fluoride and beryllium fluoride so maintaining the liquid lithium separately, as the initially proposed language states, would not be practical.
8.9.9	Current fusion power plants are being designed so that d~~D~~uring a power failure, it will not be possible to operate the fusion device and systems containing radioactive material will be isolated. Therefore, there is no radiological safety need for backup power or contingency plans for power failures. ~~, but there are areas at the~~ However, if a fusion facility design does ~~that will~~ require power to on-site systems to maintain safe operations, ~~. These systems could include vacuum and ventilation for tritium handling and storage, temperature control for cooling the cryogenic magnets, and keeping radiation monitors online and operational.~~ ~~L~~loss of power could compromise these systems and possibly resulting in an inadvertent release of radioactive material or exposure to workers. To mitigate issues that may arise from power failures, the facility will need to have backup sources of power which may include batteries, diesel generators, and uninterruptible power supply to provide power to enter a safe ~~shutdown~~ state for the fusion system. The licensee needs to establish testing and maintenance procedures to ensure that backup power systems will be operational when needed.	The discussion section implies that there is a need for backup power to shut down a fusion facility or maintain radiological safety. In reality for a loss of power, the fusion system is not capable of operating and automatically isolates because it does not have key systems like fueling (gas injection) or confinement. What is being described here is asset protection and not radiological protection, so it doesn't seem necessary to require backup power for all radioactive materials license applications. For example, cooling the cryogenic magnets serves no radiological protection function and is only asset protection. NUREG-1556 Volume 21 for particle accelerators has no equivalent requirement to this section despite having a similar behavior to fusion systems of automatically shutting off in case of power loss.

8.9.9	During power failures emergency procedures should consider the following: ~~• Evacuation of building areas where airborne radioactivity concentration will increase with loss of negative pressure (i.e., glovebox areas, tritium storage);~~ • Respiratory protection requirements if elevated radiation levels are detected in said areas during loss of power; • Procedures for locking down tritium storage systems, to prevent airborne release. These can be inherent in system (i.e. flow valves closing when unpowered); and • Procedures for restarting environmental stack/building ventilation. These should include conditions for releasing respiratory protection requirements (air sampling and associated results).	CFS questions the implication in the first bullet that evacuation would be needed in a loss of ventilation/power failure event since gloveboxes do not lose their protection capabilities nor do tritium storage systems increase their dose risk in these situations. We recommend deleting this bullet. In the second bullet, respiratory protection should only be required if radiation monitors indicate radiation levels have gone up. In that case workers can carry a handheld monitor and if required increase PPE. In other words, if the radiation safety state of the fusion facility hasn't changed in a power failure event, it wouldn't make sense to evacuate or don a respirator.
8.9.9	Response from Applicant: If applicable, t~~T~~he applicant needs to provide a description of the backup power systems including the conditions for automatic initiation of backup power and routine maintenance and testing. The applicant should provide a description of the contingency plans in the event of long-term loss of normal power. AND If applicable, a~~A~~pplicants will also need to provide a description of their procedures for operating under alternative power sources and maintenance of the backup power system. ~~This description should include load shedding of non-safety related equipment and restarting of systems following return of normal power operations.~~ AND	Adding "if applicable" to align with the proposed edit above. The deleted sentence seems to assume load-shedding would be needed for all applicants and it is not clear what failure mode this is attempting to protect against.

	If applicable, t~~T~~he applicant should provide the following statement: “We will prepare and maintain procedures for the use and maintenance of systems used in the event of power failures.”	
8.10.1	For fusion systems, most licensees are not expected to have an aggregated Category 1 or Category 2 quantity of radioactive material unless certain activation products accumulate over time. The regulations in 10 CFR 37 do not apply to activated material in walls and components during the operating life of the fusion facility, hot cell or accelerator. In accordance…	Adding this clarification, reference NUREG-2155 Rev 2, 37.11(b) Question 3 https://www.nrc.gov/docs/ML2208/ML22083A141.pdf
8.10.3	develop, implement, and maintain written procedures for safely opening packages,	Are these requested procedures for opening packages redundant with DOT regulations? If they are, is it necessary to have an additional set of procedures to verify the same thing?
8.10.3	~~Each licensee shall conduct an semiannual physical inventory to account for all licensed material received and possessed under the license.~~ Each licensee shall be accountable for their site inventory of all licensed material received and possessed under the license, and may demonstrate the quantities onsite through measurement and calculation.	CFS recognizes the importance and value of having an understanding of radioactive materials on site and a responsibility to be accountable for the material. The inventory of material may be used to assess hazards of systems, quantity of by-product material, or emissions. Conducting a physical inventory of sealed sources every 6 months is appropriate. Performing a physical tritium inventory assessment of all the systems which handle tritium would require a complete shutdown of the facility. It would also be impractical for a commercial fusion power plant because tritium that is retained in vacuum vessel and in associated tritium process loops can only be deterministically quantified at the end of life when it can be destructively determined. Moreover, this requirement unnecessarily puts the safety of workers at risk, in conflict with ALARA principles.

		Instead of attempting to maintain a total and complete record of where every atom of tritium is located, CFS believes a better and more implementable strategy for tritium inventory accountancy purposes is to focus on measuring/tracking gain or removal mechanisms from the tritium process loop. For the gain mechanisms, tritium can be added from storage beds and tritium is produced in the blanket which can be determined via calculations from operational uptime or direct sampling measurements. Removal mechanisms for tritium include exhaust, disposal of tritium contaminated components or long term storage on storage beds. Tritium that is not decanted from the system in these ways is still within a closed or monitored system. Experience at existing fusion tritium handling facilities demonstrate that monitoring these routes can be done with reasonable resolution. In operations, process loops monitor gas flow through the system to provide estimates of movement of material that can give insight into gaseous inventory in systems but would preclude retention calculations. It should be noted that the response to off normal events would be guided by best practice of the hazard management and is not dependent on precise accounting. The inventory for long term storage beds may be checked by a facility upon receipt and transfer for use and when loading for long term storage. CFS notes that the record of how much tritium is loaded into each bed should be sufficient for documenting the tritium inventory for material accountancy purposes. Once tritium is stored on a storage bed, it will remain in a stable state for time scales much longer than the fusion plant itself and the storage beds are not prone to leakage. Therefore, inventory exercises that force licensees to have to unload and reload tritium storage beds simply to re-verify the tritium is still there, is unnecessarily hazardous. This extra movement of tritium solely for material accountancy purposes would also seem to run counter to NRC's principle of ALARA to minimize potential exposure to

		radiation. CFS recommends that accountancy of long term storage is an exercise of auditing the inventory containers. CFS welcomes the opportunity to discuss best practices for tritium accountancy with NRC staff at any time.
8.10.3	~~"We will conduct a semi-annual inventory to account for all licensed material received and possessed under the license and maintain records of the semi-annual inventory for three years."~~ "We have developed, and will implement and maintain written procedures for licensed material accountability and control to ensure that: - license possession limits are not exceeded; - licensed material in storage is secured from unauthorized access or removal; - licensed material not in storage is maintained under constant surveillance and control; and - records of production, transfer, and disposal of licensed material are maintained for three years"; AND "We will conduct physical inventories of sealed sources of licensed material at intervals not to exceed 6 months and maintain records of the inventory for three years."	For the Response from Applicant portion, CFS recommends utilizing the original language from NUREG-1556 Volume 21 Section 8.10.3 instead of the new draft language because it is clearer and more aligned with the suggested edits to this section. CFS added the "maintaining records for three years" addition from the proposed Volume 22 language to the original Volume 21 language.
8.10.3	The principal purpose of conducting an inventory is to confirm that radioactive materials are accounted for in the quantities authorized under the license. Such inventories also serve the purposes of confirming the accuracy and reliability of the facility's accounting records, including detecting any unmeasured material	Tritium decanted from the loop (either through emissions or deliberately moved into storage beds) can be accounted for and accurately tracked. The movement of storage beds can be tracked and have protocols. Removal of tritium from the fusion machine during operations is not possible because the system has to be opened in some way which is a trackable activity with scheduled operations with records. So,

	losses or diversion or theft of nuclear materials.	this should not drive the periodicity of accountancy or the requirement for quantifying the loop.
8.10.3	~~The inventory of activation products will need to be tracked and likely increase over time due to the buildup of radionuclides with longer half-lives.~~ A calculation in the license application of the total activation product inventory should be sufficient to show the maximum authorized level of activation product inventory.	Similarly for activation products, there does not seem to be an obvious safety benefit for having to either calculate or survey every piece of installed equipment and structures within the fusion facility every six months to determine the activation products content. This should be able to be satisfied with a single bounding calculation to show that the applicant will not exceed the authorized level of activation product inventory.
8.10.3	~~Smaller inventories of activation products include the following:~~ ~~• corrosion products that will be circulating in coolant streams from actively cooled structures like the blanket and divertor,~~ ~~• "dust" produced by erosion of material from the surfaces facing the plasma, and~~ ~~• other materials activated by high-energy neutrons, including the potential for activated air~~	It is not practical to inventory corrosion products, dust or activated air. Recommend deleting this portion.
8.10.6.2	Criteria: Each fusion facility shall develop and implement a maintenance program. Routine maintenance of fusion system equipment is necessary to assure its radiation protection purposes, including integrity of process systems, given the extreme operating conditions (e.g., high temperatures, radiation damage, neutron activation). In addition, for certain designs, routine maintenance is necessary to assure that hazards remain within analyzed parameters (e.g., accumulation of "dust" in certain designs.) ~~The program shall include as a minimum:~~ ~~• listing of items or equipment performing safety-related functions,~~	The Criteria paragraph is expanded from NUREG-1556 Volume 21 Section 8.10.8 and seems to imply maintenance program requirements more similar to a fission power plant than a particle accelerator. For example, not all fusion system subsystems have credible failure modes that impact system integrity, therefore the statement that routine maintenance is necessary to assure radiation protection is overly broad. "Safety related" is not defined in 10 CFR 20 or 10 CFR 30 so it is not clear what would need to be included in this or not. Recommend deleting the portions discussing "safety related." Instead of the existing draft criteria language, CFS recommends adopting language more similar to what is included in NUREG-1556 Volume 21 Section 8.10.8: "Criteria: Facilities and equipment for the production and use of radioactive materials ~~(e.g., accelerators and chemistry synthesis units)~~ should be maintained. Maintenance should be planned and carried out as

	~~• planning, scheduling, testing, and coordinating activities for safety-related items or equipment,~~ ~~• maintenance history and equipment performance trending,~~ ~~• types of maintenance (e.g., preventative, or corrective maintenance), and~~ ~~• protection of workers during maintenance activities.~~	frequently as needed, using ALARA principles. Individuals performing maintenance should be trained in the procedures they implement. Procedures should be written to account for the skills of the implementing personnel…”
8.10.6.3	The following energy sources should be evaluated as potential initiating events of incidents: • energy in the plasma, e.g., plasma disruption due to loss of plasma control, ~~• magnetic energy, e.g., occurrence of an electric arc could cause local melting and potential loss of integrity of the vacuum vessel or supporting systems,~~ • thermal energy, e.g., loss of coolant scenarios with leakage into vacuum vessel and cryogenic systems ~~elevated temperatures of reactor components could result in a leak from the primary cooling system into the vacuum vessel causing vaporization resulting in a rise in pressure~~, • explosive energy, e.g., from hydrogen, dust, or oxidation of dust by water which could result in a loss of coolant accident, • cryogenic energy, e.g., a leak of liquid helium or nitrogen can cause sudden vaporization of the cryogen, and • fire caused by electrical shorts or chemical reactions involving large quantities of material present.	• Plasma disruption: A plasma disruption is not an emergency event nor an off-normal event. It happens and is a state the system recovers from in normal operations. Windows and other components that can become leaky from a disruption are designed to handle torus loads but this can be looked at as an initiating event. • Magnetic energy: The loss of magnetic energy does not lead to a loss of vacuum so this is not a credible initiating event. • Thermal energy: Suggest deleting text that sounds like fission systems. A loss of coolant may be considered an initiating event, if appropriate, but if a vacuum vessel had an ingress of a non-fueling gas, it would shut down immediately and not cause a runaway reaction. There is not enough heat to vaporize the coolant to cause a pressure transient which would endanger the vacuum vessel, blanket tank and cryostat. • Explosions: The hydrogen quantities required to run a fusion device are well below the hydrogen quantities used in other industries (fuel cell plants). Its evaluation should align with industrial practice. Vacuum vessels are likely to exclude explosive levels or deflagration so this may or may not be a credible initiating event depending upon design. • Cryogenic: This initiating event would be covered under the Loss of Coolant scenarios discussed under the Thermal energy bullet. • Fire: Sustained fire could not be considered credible with the utilization of appropriate controls

		on flammable materials and/or reduced oxygen atmosphere in the fusion machine hall.
8.10.9	The following energy sources should be evaluated as potential initiating events of incidents: • energy in the plasma, e.g., plasma disruption due to loss of plasma control, ~~• magnetic energy, e.g., occurrence of an electric arc could cause local melting and potential loss of integrity of the vacuum vessel or supporting systems,~~ • thermal energy, e.g., loss of coolant scenarios with leakage into vacuum vessel and cryogenic systems ~~elevated temperatures of reactor components could result in a leak from the primary cooling system into the vacuum vessel causing vaporization resulting in a rise in pressure~~, • explosive energy, e.g., from hydrogen, dust, or oxidation of dust by water which could result in a loss of coolant accident, • cryogenic energy, e.g., a leak of liquid helium or nitrogen can cause sudden vaporization of the cryogen, and • fire caused by electrical shorts or chemical reactions involving large quantities of material present.	Same comment as for 8.10.6.3 • Plasma disruption: A plasma disruption is not an emergency event nor an off-normal event. It happens and is a state the system recovers from in normal operations. Windows and other components that can become leaky from a disruption are designed to handle torus loads but this can be looked at as an initiating event. • Magnetic energy: The loss of magnetic energy does not lead to a loss of vacuum so this is not a credible initiating event. • Thermal energy: Suggest deleting text that sounds like fission systems. A loss of coolant may be considered an initiating event, if appropriate, but if a vacuum vessel had an ingress of a non-fueling gas, it would shut down immediately and not cause a runaway reaction. There is not enough heat to vaporize the coolant to cause a pressure transient which would endanger the vacuum vessel, blanket tank and cryostat. • Explosions: The hydrogen quantities required to run a fusion device are well below the hydrogen quantities used in other industries (fuel cell plants). Its evaluation should align with industrial practice. Vacuum vessels are likely to exclude explosive levels or deflagration so this may or may not be a credible initiating event depending upon design. • Cryogenic: This initiating event would be covered under the Loss of Coolant scenarios discussed under the Thermal energy bullet. • Fire: Sustained fire could not be considered credible with the utilization of appropriate controls on flammable materials and/or reduced oxygen atmosphere in the fusion machine hall.
8.10.11	Licensees must report any lost, stolen, or missing licensed material in an aggregate quantity exceeding specified limits (10 CFR 20.2201). For tritium this threshold value should be 10 grams.	The current thresholds specified in 10 CFR 20.2201 for reporting lost, stolen or missing tritium are impractically low given the likely tritium inventories fusion machines expect to utilize. Recent tritium workshops have discussed values along the lines of 10 grams of tritium for this threshold.

		A suspected diversion or theft of tritium (which would take the form of a physical removal of a tritium subsystem, storage bed, cask, etc.) should be reported. A significant amount of tritium will always be in process and adsorbed to surface, including within the metal hydride matrix that is decanted for accounting, so quantities will always be measured lower than what was measured when it was initially loaded into the system.
8.11	The radiation protection program that licensees are required to develop, document, and implement in accordance with 10 CFR 20.1101 must include provisions for waste disposal ~~of licensed material~~.	Deleting an extra qualifier which could create confusion.
8.11	Discussion: This section addresses radioactive waste, defined according to 10 CFR 20.1003 and 10 CFR 61.2, resulting from (1) the use of byproduct material in a fusion system or (2) the production, extraction, or conversion after extraction of byproduct material from a fusion system for a commercial, medical, or research activity.	Clarifying the definition to reduce confusion.
8.11	~~In addition, 10 CFR 20.2008(c) requires that a licensee transferring fusion system waste to an authorized disposal facility under 10 CFR 20.2008 is responsible for demonstrating that either:~~ ~~• the waste has a similar physical form, chemical characteristics, and radionuclide concentrations as the waste considered in the development of the NRC licensing requirements for land disposal of radioactive waste (10 CFR Part 61), or~~ ~~• the disposal site licensee has completed a site-specific inadvertent intrusion assessment that considers the form of and radionuclides in the fusion system waste.~~	In a previous letter to the NRC dated March 6, 2024, CFS has described that it thinks the proposed rulemaking language in 10 CFR 20.2008(c) is superfluous and should be removed because of the potential to conflict with the waste provisions of the Energy Policy Act of 2005. Therefore, CFS also recommends that language referring to this proposed language be deleted from this section. The main language to be deleted which refers to 10 CFR 20.2008(c) is included at left but much of the rest of the "Transfer to an Authorized Recipient" subsection refers back to 10 CFR 20.2008(c) so that would need to be deleted as well for consistency.

8.11	Other Methods Specifically Approved by NRC Under 10 CFR 20.2002 Applicants may also request alternate methods for the disposal of radioactive waste generated at their facilities. Such requests must describe the waste~~-containing licensed material~~, including the physical and chemical properties that may be important to assess risks associated with the waste, and describe the proposed manner and conditions of waste disposal.	Deleting an extra qualifier which could create confusion.
Appendix C	~~In addition, the applicant will need to submit their environmental report and application for a byproduct material as least 9 months prior to the commencement of construction as required by 10 CFR 30.32(f).~~	CFS recommends deleting this sentence which would add considerable licensing timeframe with no associated radiation safety benefit. 10 CFR 30.32(f) assumes that the NRC has determined that fusion machines will significantly affect the quality of the environment. CFS is not aware of the NRC making such a determination for any existing fusion facility since all current fusion R&D facilities are currently categorically exempt from environmental review as per NUREG-1748. It seems incongruent that once fusion facilities switch from an R&D purpose to a commercial purpose, that the ability to significantly impact the quality of the environment would change this much to justify adding in a considerable delay in the licensing review process. There does not seem to be any obvious radiation safety benefit for the 9 month time requirement since both the environmental report and license application will be submitted to the regulator in any case. Additionally, the proposed edit to delete this sentence is consistent with the intent of the Proposed Rule on the GEIS, which is to improve the efficiency of licensing advanced reactors, and of NEIMA, which was to provide a program for developing the expertise and efficient regulatory processes necessary to allow for innovation and commercialization of advanced reactors. If construction is initiated prior to satisfying the 9-month filing requirement, applicants recognize that they would be proceeding at risk in case regulatory review leads to changes.

Appendix F	Radioactive materials that are handled or used in unsealed or unenclosed forms ~~should be confined to control the release of material and to prevent the spread of contamination. Gaseous, volatile, and fine particulate solid materials should be handled in closed or isolated systems such as fume hoods or glove boxes with controlled, and possibly filtered, exhaust systems~~ shall be ventilated. Ventilation systems for these facilities should be designed so that airborne radioactive material work areas are at negative pressure compared to nonradioactive work areas.	The deleted portion will make it difficult for the fusion machines to be opened for routine maintenance. In existing fusion machines, local ventilation is provided after detritiation in the closed loop as part of final opening to perform maintenance.
Appendix F	This same bullet is listed under both the "Handling unsealed material and contamination controls" and "Minimization of radiation exposure" headings. Tritium handling systems should be connected to appropriate tritium management systems ~~negative pressure exhaust systems~~ to discourage the spread of airborne radioactivity into work areas. Licensees must have procedures in place for anticipated fault scenarios ~~loss of negative pressure~~. Procedures should include respiratory protection for airborne radioactivity if elevated radiation levels are detected that would cause worker dose to exceed allowed values, as well as air sampling to ensure the area is free of contamination before entering.	Respiratory protection is only needed when alarms indicate an increase in detectable radioactivity. Loss of ventilation does not immediately become a hazard to workers. Tritium handling systems should be connected to appropriate tritium management systems which may be circulating scrubbers, in-line scrubbers/adsorbent beds, or connections to other detritiation systems. Given the variety of different design solutions, it seems premature to specify pressure and connections in this bullet.
Appendix F	~~Where appropriate, ventilation systems should be designed such that, in the event of an accident, they can be shut down to prevent the spread of radioactivity. If appropriate, supply and exhaust fans can be~~	Shutting down ventilation should not be the response to tritium release since it would serve to increase airborne concentrations local to the event which creates higher dose consequences for workers in the immediate area before evacuation while representing a minimal hazard to the general public.

	~~interlocked such that if exhaust fans shutdown, the shutdown of supply fans is also triggered. This interlock system prevents laboratory and work areas from becoming positively pressurized with respect to the surrounding parts of the facility.~~	Existing fusion facilities utilizing tritium assume active ventilation for dispersal calculations to minimize the dose hazard to workers.
Appendix F	Chemical-type fume hoods provide a working area with controlled inward airflow from the room to the hood exhaust system. Hoods are used for gases, unsealed volatile licensed materials, and processes such as evaporation that may release gases and vapors. Fume hoods provide emergency ventilation and exhaust for unplanned releases, such as accidental spills and ruptures, as well as routine exhaust of effluents. ~~Filters may be required in the exhaust stream unless monitoring or calculations demonstrate that any planned or likely effluent will be in accordance with the limits found in Title 10 of the Code of Federal Regulations (10 CFR) 10 CFR Part 20, Appendix B.~~	Filters are not required for gaseous tritium handling systems and requiring the use of filters will lead to more hazardous waste generation. Recommend deleting this text.
Appendix F	Table F-1 Construction Monitoring & Acceptance Testing for Fusion Systems	There is no equivalent to this table in either NUREG-1556 Volume 11 or 21. This table gets into much more prescriptive detail, including some areas that aren't directly related to radioactive materials controls (e.g., foundation construction, electrical wiring, magnets, power systems, etc.) This increases the scope and expertise on part of the regulator to review fusion machine license applications. The question here is this level of oversight needed to assure radiological safety? Would this represent a burden to Agreement State regulators who may not have this expertise readily available?
Appendix F	Radiation Monitors Test the ability of alarm systems linked to radiation monitors (if applicable).	Radiation monitors should be placed in radiation areas. Areas outside of radiation operations areas should not require real time monitoring. In general, the location and type of radiation monitors shouldn't be prescribed to this detail in the document, it would

	Radiation monitors should be placed in radiation areas as appropriate by the applicant based on the actual radiation hazard present. ~~Minimum placement of radiation monitors:~~ ~~- Occupied work areas~~ ~~- Occupied office areas~~ ~~- Inside of "fusion vault"~~ ~~- Outside of "fusion vault"~~ ~~- Site perimeter (recommended)~~ ~~Demonstrate real-time monitoring for materials activated by neutron flux.~~	be more reasonable for the applicant to determine the locations and type of radiation monitor based on the actual hazard. Demonstrating real time monitoring for materials activated by neutron flux inside the fusion vault is not practical since it will destroy the detectors themselves thereby losing the capability to monitor radiation for the protection of people. According to the JET experience on this, detectors placed inside the "fusion vault" became activated and then were not capable of providing any useful information.
Appendix F	Tritium Handling Whether tritium is present as a fuel or byproduct, the licensee must demonstrate a proper system for storage and processing of tritium. ~~Test vacuum pressure on tritium storage system to verify leakage is within allowed tritium exposure limits.~~	Tritium systems are built leak-tight to meet their emissions management program. Recommend removing this portion since it is already covered elsewhere.
Appendix F	All Tritium Handling ~~For emergency conditions, licensee must demonstrate plans for vacuum pressure loss.~~ In case of a tritium leak, procedures should be in place to survey and clean the area. Monitoring of airborne radioactivity levels and plans to clear the area around storage system for re-entry must be present.	A loss of vacuum pressure does not immediately become a loss of confinement of radioactive material. A more generic statement here would be better that if there were a leak of tritium outside of confinement, then procedures should be in place to survey and clean the area.
Appendix F	Magnetic Confinement (Tokamak) ~~Magnets~~ ~~Ensure that magnets are installed per design requirements and meet local applicable codes.~~	It is not obvious why any review of magnet installation is needed since there is no connection to radiation protection nor public health and safety. If a magnet were to be installed incorrectly, then the fusion machine wouldn't be able to turn on. CFS recommends deleting the magnets row in both Magnetic Confinement and in Pulsed Fusion. For the emergency conditions sentence, CFS recommends deleting this portion because it is not clear why magnetic confinement systems should be

	~~For emergency conditions, demonstrate that magnets will power down, ceasing fusion activities.~~	scrutinized more than any other type of fusion confinement approach and it is not obvious how an applicant should show this. All technical approaches to fusion default to fully turning off in case of emergency conditions.
Appendix F	Magnetic Confinement (Tokamak) ~~Fuel Injection System~~ ~~Demonstrate that fuel injection system is a closed system that does not allow unprotected exposure of operators to fuel during routine operation.~~	The fueling injection system typically sits adjacent to the tokamak in an inaccessible room with access controls and is not accessible to operators. Fueling injection systems shall be designed in alignment with tritium handling systems. Additional demonstrations are not required. Recommend deleting this row.
Appendix M	~~To achieve safety in fusion system facilities, it is important for safety to become an integral part of the design and operation of the facility. From the safety policy, two types of safety functions have been identified: public safety functions and worker safety functions. Fusion systems shall be designed to ensure that public and worker safety functions are always achieved for conditions within the design basis.~~	This paragraph introduces new concepts of "safety function" which seems akin to "safety-related" in fission systems and "design basis" which is used in fission systems. Recommend deleting this paragraph because it does not apply to fusion.
Appendix M	• Dispose of ~~radioactive waste~~ licensed material only in designated, labeled, and properly shielded receptacles. Security of ~~Radioactive Materials~~ Licensed Material	This appendix appears to interchange the terms "licensed material" and "radioactive waste" which could lead to some confusion. CFS recommends just using the single term "licensed material" to avoid confusion.
Appendix M	~~A risk-based prioritization scheme (graded approach) should be used to determine the impact of these potential safety concerns for each specific fusion facility.~~	This seems to imply that a risk-based prioritization approach is needed which seems overly prescriptive, CFS recommends deleting it.
Appendix Q	~~If the waste is not one of the listed wasteforms, indicate that the disposal site licensee has performed a site-specific inadvertent intrusion assessment as required by 10 CFR~~	In a previous letter to the NRC dated March 6, 2024, CFS has described that it thinks the proposed rulemaking language in 10 CFR 20.2008(c) is superfluous and should be removed because of the potential to conflict with the waste provisions of the Energy Policy Act of 2005 and establish fusion

	~~20.2008(c) to demonstrate that the waste is acceptable for disposal. Guidance on performing a site-specific intrusion assessment is available in the NRC Draft NUREG-2175, "Guidance for Conducting Technical Analyses for 10 CFR Part 61."~~	activated materials as a different new category of accelerator-produced radioactive material. Therefore, CFS also recommends that language referring to this proposed rulemaking language be deleted from this section.

From:	Tyler Ellis
To:	John Lubinski (He/Him/His)
Cc:	CMRHanson Resource; CMRCaputo Resource; CMRCrowell Resource; CMRWright Resource; Daniel.Dorman@nrc.gov; Brooke Clark; Catherine Haney; Theresa Clark (She); Duncan White; Dennis Andrukat
Subject:	[External_Sender] CFS Letter for NRC on the Draft NUREG-1556 Volume 22
Date:	Tuesday, May 21, 2024 4:30:11 PM
Attachments:	CFS - NRC Submission 05-21-2024.pdf

Dear Mr. Lubinski,

I'd like to share a letter from CFS that covers some additional thoughts which will hopefully be helpful to the NRC for the development of the draft NUREG-1556 Volume 22 for fusion energy.

Feel free to make the letter publicly accessible.

As always, our team is available if there are any questions.

Thanks,
Tyler