The U.S. Nuclear Regulatory Commission Staff's Observations/Aalo-X Critical Assembly Facility Design Review

Note: [[ ]] are used to denote redacted proprietary information

BACKGROUND

On October 1, 2025, Aalo Atomics (Aalo) requested the U.S. Nuclear Regulatory Commission (NRC) staff's participation as observers during a preliminary design review (PDR) of the Preliminary Documented Safety Analysis (PDSA) for the Aalo-X project, an experimental microreactor located on federal lands outside of the operational boundaries at Idaho National Laboratory (INL) (ML25274A116). In its letter, Aalo requested early feedback to support development and preparation for future NRC licensing. The NRC staff observed the PDR from October 20 - 21, 2025, which included industry independent technical reviewers and U.S. Department of Energy (DOE) representatives. Following the PDR, Aalo indicated that it would be holding a final design review (FDR) from January 20 - 21, 2026, and again requested the NRC staff's participation as observers and provide early feedback on NRC licensing processes. The NRC staff attended the FDR. A letter requesting the NRC staff's participation for subsequent DOE authorization basis document reviews was received on January 29, 2026 (ML26029A443).

PURPOSE

The NRC staff is providing observations in response to Aalo's requests for feedback indicated above. The NRC staff's observation of the Aalo-X Criticality Assembly Facility (CAF) PDR and FDR provided an opportunity for the NRC staff's familiarization with the proposed design and early identification of areas that may need to be addressed for NRC licensing. The NRC staff's participation in these activities was conducted as outlined in the memorandum, "Expectations for NRC Staff Involvement with Prospective NRC License Applicants Planning to Refer to DOE Authorization Processes" (ML25322A208).

The NRC staff's observations are focused on existing NRC regulations and their applicability to a future NRC licensing application and should not be construed as an evaluation of the technical adequacy of the safety basis for the CAF or Aalo-X reactor. No regulatory decisions are made as a result of information that supports DOE's authorization being shared with the NRC for the purpose of pre-application engagement on a future licensing action.

1. DESCRIPTION OF THE DOE AUTHORIZATION ACTIVITY

Aalo's activities under the DOE Reactor Pilot Program include several projects related to the Aalo-X program:

a) Aalo-X Critical Assembly Facility: a zero-power dry criticality assembly which will demonstrate criticality of the Aalo-1 reactor core and provide neutronics and physics testing to the Aalo-X facility.

b) Aalo-0 Sodium Facility: a non-nuclear sodium loop with power generation, which will be used as the integral effects testing platform, provide thermal hydraulics critical data, and support final design of sodium loop and sodium processing systems.

c) Aalo-X Reactor: a full-scale demonstration of nuclear and sodium systems.

The PDR and FDR for the Aalo-X CAF were independent design reviews conducted by third party technical experts who are not responsible for the facility design. The PDR and FDR were led by Aalo staff and attended by technical experts contracted by Aalo and DOE staff. The review was conducted as described in DOE-STD-1271-2005, "Authorization Pathway for Nuclear Facilities." The NRC staff participated as observers.

The Aalo-X CAF provides a workspace for Aalo-X program activities and zero-power critical assembly operations. It delivers dry criticality data (neutronics and physics testing) to support Aalo-X. [[ ]]

2. FUTURE NRC LICENSING ACTION

As described in the Aalo Regulatory Engagement Plan for the Idaho Nuclear Project (ML24193A003), Aalo intends to submit a combined operating license application (COLA) for a group of 10 megawatt electrical (Mwe) thermal spectrum sodium cooled reactors. The proposed application site for its multi-module facility coupled with one or more turbine generators is in Idaho Falls, Idaho. Aalo's standard design is currently called the Aalo Pod, which combines five Aalo-1 reactors with a single 50 MWe turbine generator (ML25115A239).

The Aalo-1 reactor is based on the Aalo-X experimental reactor, which is being deployed under the DOE Reactor Pilot Program at INL and expected to be critical in 2027. The Aalo-X experimental reactor follows the Aalo-X CAF, which is expected to be critical in 2026.

Aalo intends to submit a COLA in calendar year 2027, and is actively engaged in pre-application activities with the NRC.

3. RELEVANT DOE AUTHORIZATION DOCUMENTS

The Aalo-X program authorization basis activities are carried out in accordance with Title 10 of the *Code of Federal Regulations* (10 CFR) Part 830, "Nuclear Safety Management," DOE-STD-1271-2025, "Authorization Pathway for Nuclear Facilities," and other related DOE documents. These documents were updated in response to Executive Order 14301, "Reforming Nuclear Reactor Testing at the Department of Energy," Executive Order 14154, "Unleashing American Energy," Executive Order 14299, "Deploying Advanced Nuclear Reactor Technologies for National Security", and Executive Order 14302, "Reinvigorating the Nuclear Industrial Base."

Specifically, Aalo identified the following DOE Orders and Standards which drive technical and programmatic requirements for DOE authorization of Aalo-X.

Safety Analysis

- NE O 420.1, "Facility Safety," U.S. Department of Energy," issued August 2025
- NE-STD-1027-2025, "Hazard Categorization of DOE Nuclear Facilities"

- DOE-STD-3009-2014, “Preparation of Nonreactor Nuclear Facility Documented Safety Analysis”

Engineering - Design Criteria

- NE-STD-1020-2016, “Natural Phenomena Hazards Analysis and Design Criteria for DOE Facilities”
- DOE-STD-3024-2011, “Content of System Design Descriptions”
- DOE-STD-1073-2016, “Configuration Management Program”

Operations – Programs

- NE O 422.1, “Conduct of Operations,” issued August 2025
- NE O 426.2, “Personnel Selection, Training, Qualification, and Certification Requirements for DOE Nuclear Facilities,” issued August 2025
- NE O 227.1, “Independent Oversight Program,” issued August 2025

3.1 Documented Safety Analysis

The safety basis for DOE authorized nuclear facilities is principally contained in the Documented Safety Assessment (DSA). DOE guidance for preparation of the DSA is contained in DOE-STD-3009-2014.

In accordance with DOE-STD-1271-2025, DOE’s approval of the DSA and associated technical safety requirements (TSR) is required prior to startup of operations, which is also contingent on performing a readiness review to confirm capability for safe startup and operation of the nuclear facility. Satisfactory completion of the DOE readiness review results in DOE issuing startup approval, which allows for nuclear operations in the facility to commence in a controlled manner consistent with the startup plan.

As discussed above, Aalo requested that the NRC staff observe the PDR and FDR and provide observations on the Aalo-X CAF PDSA relevant to NRC licensing. Aalo provided access to the Aalo-X CAF PDSA through the electronic reading room. The observations discussed in Section 5 are based on a limited review of the PDSA as well as on the information presented in the FDR.

4. AGENDA TOPICS

The NRC staff observed the following portions of the FDR:

- General Site & Facility Description
- Safety Basis for Aalo-X CAF
- Design Configuration Management
- Fuel & Core System
- Reactivity Control System

- Criticality Assembly Vessel
- Reactor Protection System and Instrumentation and Control System
- Fuel Assembly System
- Criticality Safety
- Operations

5. REGULATORY AREAS OF INTEREST

The NRC staff's observations are focused on selected topics and the overlap, or lack thereof, between the CAF PDSA and NRC regulations. Some of these observations may be due to the comparison of content in the PDSA (i.e., preliminary design) versus what would be expected in the final safety analysis report (FSAR) (i.e., final design) for a COLA[1]. The selected topics for the NRC staff's review are those that are addressed in the safety basis provided for the DOE authorization and that generally form the foundation for the assessment of reactor facility risk and are expected in the safety analysis report of a prospective NRC license applicant. The NRC staff's observations are not an evaluation of the conformance of the CAF with DOE requirements, nor of whether the CAF or subsequent Aalo-X designs would conform with NRC requirements, and should not be construed as such.

5.1 Quality Assurance

- [redacted]

5.2 Licensing Basis Events Selection and Structures, Systems and Components Classification and Safety Analysis

- [redacted] Aalo indicated in its regulatory engagement plan that it plans to use a risk-informed and performance-based (RIPB) approach for the NRC license. As such, the NRC staff expects that an NRC license application would provide justification for: (1) licensing basis event (LBE) identification, (2) DBA selection, and (3) safety-related and non-safety-related with special treatment (NSRST) classification, consistent with Nuclear Energy Institute 18-04, "Risk-Informed Performance-Based Technology Inclusive Guidance for Non-Light Water Reactor Licensing Basis Development," and Regulatory Guide (RG) 1.233, "Guidance for a Technology-Inclusive, Risk-Informed, and Performance-Based Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light Water Reactors," for an RIPB licensing.

5.3 Principal Design Criteria

[1] Aalo's most recent regulatory engagement plan (ML24193A003) described its licensing strategy for the submittal of a COLA for its commercial deployment.

- [ ], which appear to be consistent with RG 1.232, "Developing Principal Design Criteria for Non-Light Water Reactors." The staff expects that PDC for NRC license application will conform to RG 1.232 and any variances will be justified.

5.4 Source Term

[ ]] If this methodology is planned to be used for Aalo Pod, the application should justify its use in lieu of a mechanistic source term (MST), which is the preferred approach for non-LWR technologies utilizing a RIPB licensing approach. This consideration is particularly important if Aalo intends to implement a functional containment strategy rather than relying on a traditional physical containment building. Functional containment is a set of barriers that taken together, effectively limit the physical transport of radioactive material to the environment. Generally, design-specific MST modeling is used to evaluate the retention of radionuclides by barriers and the transport of radionuclides for all barriers and pathways to the environs. Principles and guidance for MST development can be found in SECY-93-092, RG 1.183, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors," and RG 1.247, "TRIAL - Acceptability of Probabilistic Risk Assessment Results for Non-Light Water Reactor Risk-Informed Activities."

5.5 Consequence Analysis

- [ ]] For COLAs using an RIPB approach, the guidance in RG 1.253, "Guidance for a Technology-Inclusive Content of Application Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light-Water Reactors," section C, "Staff Regulatory Guidance," addresses software and analytical tools used to perform event sequence modeling and quantification, determine the mechanistic source terms, and perform radiological consequence evaluations for non-DBA LBEs and DBAs, cumulative dose, and risk calculations. Consistent with RG 1.253, the application should discuss the analysis methods and assumptions for the total calculated radiological consequence dose at the exclusion area boundary, the outer boundary of the low population zone, and the control room to demonstrate that the facility meets the requirements of 10 CFR 50.34(a)(1)(ii)(D) or 10 CFR 52.79(a)(1)(vi).

5.6 Emergency Preparedness

- [ ]] indicates that the Emergency Planning Program is designed in accordance with NE O 151.1, "Comprehensive Emergency Management System," issued August 2025. A COLA is expected to address 10 CFR 52.79(a)(21), complying with either: (1) the planning standards in 10 CFR 50.47(b), including notification procedures, protective actions, and coordination with offsite authorities, and the requirements of Appendix E, "Emergency Planning and Preparedness for Production and Utilization Facilities," to 10 CFR Part 50, "Domestic Licensing of Production and

Utilization Facilities," covering topics such as emergency classification, staffing, training, and drills, or (2) the requirements in 10 CFR 50.160, "Emergency preparedness for small modular reactors, non-light-water reactors, and non-power production or utilization facilities," such as emergency response functions and planning activities. Pre-application engagement is encouraged if use of NE O 151.1 is planned for a commercial license application.

5.7 Security

- [[ ]] An application for a COL must include a physical security plan, a training and qualification plan, and a cyber security plan in accordance with the applicable 10 CFR Part 73, "Physical Protection of Plants and Materials," criteria, as specified in 10 CFR 50.34(c).

5.8 Fire Protection Requirements

- [[ ]]
- [[ ] For a COLA, the fire hazards analysis should also provide technical justification to conclude that fires do not challenge the performance of credited safety systems. RG 1.189, "Fire Protection for Nuclear Power Plants," provides guidance on developing a fire hazards analysis.

5.9 Technical Specifications

- [[ ]] The staff notes that 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants," requires that technical specifications be included in the application for a COL, consistent with final design and the FSAR.
- [[ ]] states that the TSRs will address both safety-related and NSRST structures, systems and components (SSCs). Aalo should specify whether it intends to produce technical specifications for both SR and NSRST in the Aalo Pod application or if NSRST will be addressed in a separate document, such as a Technical Requirements Manual. NRC staff encourage Aalo to discuss its approach to technical specifications with the staff during pre-application engagement.

5.10 External Hazards

- [[ ]] The results of the unmitigated analysis are presented; however, there is no reference to the engineering analysis that supports these results. In [[ ]], the source term parameters are presented; however, there is no discussion on

parameter selection. [ ] In addition, neither the value nor a reference to its location is provided for the material-at-risk. The technical statements on the safety basis should be traceable to design documents and be readily available.

5.11 Codes and standards

- The codes and standards applied to safety-related SSCs and NSRST SSCs should be commensurate with the significance of their safety functions. While the SR and NSRST scope for the Aalo-X CAF is recognized to be much more limited than what would be expected for an NRC application, early alignment in this area during pre-application engagements is important, particularly if Aalo intends to leverage codes and standards from the reactor pilot program.

5.12 Siting

- Site characterization for the Aalo-X CAF is discussed in [ ]], addressing considerations such as meteorology, hydrology, geology and impact of external events. [[ ] Part 100, "Reactor Site Criteria," of 10 CFR requires an application for a commercial license to include a description of the processes and techniques used for site investigation and characterization, including justification for the suitability and applicability of information derived from previous analysis or for a site different than the reactor location.

5.13 Operational Programs

- The [ ]] makes references to various DOE documents that establish acceptance criteria for operational programs (e.g., NE O 422.1, NE O 426.2, DOE-STD-1073-2016, DOE-STD-1029-1992). The scope and requirements for these programs generally align with similar operational programs required by NRC regulations. The NRC staff encourages Aalo to review applicable NRC guidance regarding developing operational programs that are required by NRC regulations, primarily Chapter 13, "Conduct of Operations," of NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition," and SECY-05-0197. SECY-05-0197 includes a list of required operational programs along with implementation milestones and addresses how these programs should be treated in a 10 CFR Part 52 COLA.

6. ADDITIONAL NRC STAFF OBSERVATIONS

While the zero-power criticality goal for the Aalo-X CAF provides limited resemblance to the commercial design expected for the Aalo Pod, in general, the information presented in the FDR and in the PDSA, aligns with the regulatory areas of interest for an NRC application. The NRC staff focused its review on technical and programmatic areas that could be extrapolated to the NRC application. Observations on specific regulatory areas of interest are discussed in section 5.

The following additional observations provide examples of general characteristics that are expected to be applicable to Aalo's proposed NRC license application:

- Design inputs and technical justification for design choices should be identified in the safety basis documentation in accordance with design and document control procedures, to enable an efficient NRC application review (see the example in section 5.10).

- A COLA requires a FSAR that includes detailed descriptions of operational programs that satisfy 10 CFR 50.34(b). The FSAR must include all programs required by regulation and should clearly and sufficiently describe these programs in terms of the scope and level of detail to allow a reasonable assurance finding of acceptability. (See the discussion in section 5.13.)

- The DOE safety basis documentation does not address fundamental aspects of a 10 CFR Part 52 application, such as the approach for the development of inspections, tests, analyses and acceptance criteria (ITAAC). In accordance with 10 CFR 52.80(a), a COL applicant must propose a complete set of ITAAC that addresses the entire facility, including ITAAC on emergency planning and physical security hardware. The type of information and the level of detail included in the ITAAC should be based on a graded approach that is commensurate with the risk- and safety-significance of the SSCs for the design. Aalo is encouraged to review and determine the applicability of RG 1.206, "Applications for Nuclear Power Plants," to develop an approach for describing its proposed ITAAC and to ensure the application format and content is consistent with NRC regulations.

Lastly, the NRC staff notes that realizing the additional efficiencies in the NRC application review relies primarily on the applicant's description of how prior authorizations and testing address associated NRC requirements and could thus be potentially "leveraged" by the NRC staff when performing its application reviews. Aalo is encouraged to continue engaging with the NRC staff to optimize this pathway.