UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

**U.S. NUCLEAR REGULATORY COMMISSION STAFF FEEDBACK REGARDING X ENERGY, LLC TOPICAL REPORT, "XE-100 LICENSING TOPICAL REPORT: GRAPHITE QUALIFICATION METHODOLOGY"**

By letter dated October 31, 2022, (Agencywide Documents Access and Management System (ADAMS) Accession No. ML22304A197) X Energy LLC (X-energy) submitted topical report (TR), "Xe-100 Licensing Topical Report: Graphite Qualification Methodology," for the U.S. Nuclear Regulatory Commission (NRC) staff review. As part of the acceptance review process, the NRC staff performed a completeness review to determine if the document is sufficiently complete to initiate an effective technical review. The NRC staff performed its completeness review and sent preliminary questions to X-energy on November 17, 2022, (ML22322A175). The NRC staff met with X-energy to discuss their initial feedback in a closed meeting held on December 14, 2022, (ML22327A049). As a result of the closed meeting, the NRC staff is providing the following feedback on the TR to X-energy.

<u>General Feedback</u>

- The TR should explain how X-energy will meet the 2017 Edition of the American Society of Mechanical Engineers Boiler and Pressure Vessel Code, Section III, Division 5 (Division 5) requirements, as conditioned by the NRC staff in Regulatory Guide 1.87, "Acceptability of ASME [American Society of Mechanical Engineers] Code, Section III, Division 5, 'High Temperature Reactors,'" Revision 2 (ML22101A263), including identification of and justification for any deviations.
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      **]].** This is a noteworthy deviation from the requirements of Division 5 and a justification should be included in the TR.

- The TR should clearly state which safety functions the Xe-100 graphite components perform. The TR should also identify and describe how the principal design criteria are applicable to the graphite components and graphite qualification.
- The TR should show how the data presented is representative of and relevant to the Xe-100 environment, that the data covers the full temperature range of the Xe-100 design envelope, and that the data meets Division 5 requirements. If the sourced data does not provide all of the properties required for the Materials Data Sheet, then the TR should address how X-energy will procure that data.

**Enclosure 2**

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- The TR should clearly define the expected temperatures under both normal conditions and transient conditions.
- The TR should indicate where each grade of graphite will be located and the anticipated environmental temperatures and fluence at those locations. The qualification envelope for each grade of graphite to be used should be provided in accordance with Division 5, Subsection HHA-III-3300. The TR should also discuss if any grades of graphite will operate post turn-around or crossover and how those points will be determined as a function of temperature and fluence with confidence boundaries.
- The TR should provide abrasion/erosion testing data in the Xe-100 environment.
- The TR should discuss how design analyses will be performed given available/historical data.
  - The TR will need to demonstrate the applicability of historical data and provide evidence that it meets the requirements of ASTM C781, "Standard Practice for Testing Graphite Materials for Gas-Cooled Nuclear Reactor Components," as required in Division 5, Subsection HHA-III-3000. If the historical data to be used doesn't meet the Division 5 requirements, the TR should have a discussion of the differences and a justification for the applicability of the data.
  - Division 5, Subsection HHA-5000, "Historical Data," states that historical data can be used if it is demonstrated to be the same grade of graphite, as defined in Division 5, Subsection HAB-9200. The TR will need to account for any property variations in the unirradiated historical graphite when compared to the production lots.

<u>Creep Testing and Model</u>

- It is the NRC staff's expectation that creep and a creep model be addressed in a TR submittal. Subsections HHA-2220 and HHA-III-3300 of Division 5, require that the irradiation induced creep coefficient be included on the Material Data Sheet.
- Division 5, Subsection HHA-II-4100, requires that an applicant provide both the creep coefficient for the temperatures that occur in the irradiated components and the effect of creep strain on the coefficient of thermal expansion. In the TR, **[[ ]]**. The TR states that the Idaho National Laboratory (INL) testing program (Advanced Graphite Creep/High Dose Graphite) evaluates creep properties and that this data is applicable in the **[[ ]]** range; however, the lowest temperature for the INL experiments is 600°C. Additionally, Table 4 of the TR doesn't appear to include irradiated creep testing data from the Oak Ridge National Laboratory (ORNL) High Flux Isotope Reactor. The TR should discuss plans to provide or collect creep data that covers the qualification envelope.
- The TR should demonstrate the applicability of creep data at lower irradiation temperatures. Temperatures below **[[ ]]** are insufficient to prevent the

accumulation of stored energy in graphite and are expected to influence the creep properties of graphite. As irradiation temperatures decrease below **[[ ]]**, a noticeable "cliff-edge" effect on the dimensional changes of graphite occurs. Additionally, historical data of low temperature irradiation of graphite shows a rapidly increasing creep coefficient at temperatures below **[[ ]]**. These considerations, in combination with experimental deviations between the measured and target graphite irradiation test temperatures (typically ± 50°C), may require an unusually high level of experimental validation for the NRC staff to make an adequate safety finding regarding graphite that was highly irradiated at lower temperatures.

- Care needs to be taken when using irradiation data from **[[ ]]**. This report contains low temperature creep testing of **[[ ]]** samples at **[[ ]]** and the corresponding unstressed samples were irradiated at **[[ ]]**. Because of the differences in irradiation response between these two temperatures, the cited creep data may not be reliable. For example, the data shows an increasing length change along the axial orientation at low temperatures for unstressed **[[ ]]**. The length change of graphite creep samples reverses between the target temperatures of **[[ ]]**, demonstrating the impact of low temperature irradiation on graphite creep behavior.