Advanced Non-Light Water Reactors: Materials and Structural Integrity Workshop

Wrap-up Discussion

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Session 1: Vendor Overview

- Summary
  - NRC reiterated commitment to be prepared for licensing
  - Several vendors summarized the reactor type(s) they are developing, materials being considered for structural and internal applications, and testing to address known information gaps for these materials
  - X-Energy has developed Tools for graphite performance simulation
- Key Takeaways
  - A variety of nuclear technologies are being developed to fulfill the unique energy strategies being pursued by each vendor
  - Both ASME code qualified and non-code qualified materials are being proposed
- Challenges
  - No material is ready for off-the-shelf use; additional understanding needed to satisfy design requirements
  - Regulatory and technical approach needs to focus on ensuring that safety goals are met – unique issues for each reactor design/material combination.

Session 2: Technical and Research Activities - A

- Summary
  - NRC and DOE summarized research supporting ANLWR material use and development
  - ONR and CNSC discussed regulatory and technical frameworks being used (or developed) for licensing ANLWRs
  - IAEA discussed activities to support ANLWR development and knowledge management
- Key Takeaways
  - Significant technical and regulatory efforts underway internationally
  - Need for technical and regulatory flexibility recognized
- Challenges
  - Commercial ANLWR operating experience is much less than conventional LWRs
  - Specific expertise in each ANLWR reactor type (and specific materials selected) is needed to ensure an appropriate safety focus

Session 3: Technical and Research Activities - B

- Summary
  - CNL developing modeling and simulation tools using evaluation of and benchmarking with NRU component/material properties and performance
  - JAEA summarized research activities and discussed risk-informed structural integrity design framework
  - NRG summarized HFR capabilities and current research activities
  - EPRI and DOE discussed strategies for addressing research gaps and collaborating internationally
- Key Takeaways
  - Leveraging international ideas, knowledge, and capabilities is a foundational strategy that can benefit all countries/organizations
  - Prioritizing research is important for efficiently using both resources and time
- Challenges
  - Unclear how much collaboration and information sharing will be possible
  - Some research gaps (e.g., irradiation performance) are complex, costly, and lengthy to address

Session 4: Graphite Materials - A

- Summary
  - NUMARK argued that the successful application of graphite materials should be used as a basis for addressing future needs and challenges
  - ONR summarized extensive graphite experience gained through Magnox reactors and AGRs
  - INL discussed the philosophy and guiding tenets behind the ASME graphite and composite code
  - NRG identified important characteristics for irradiated graphite studies and unique features of existing facilities
- Key Takeaways
  - Graphite has a long and successful performance history in gas-cooled reactors
  - Unique attributes need to be considered in design and operation
- Challenges
  - Standardization following conventional approaches may not be achievable
  - Performance-based, risk-informed acceptance criteria may be needed to address future ANLWR use

Session 5: Graphite Materials - B

- Summary
  - ORNL discussed how irradiation-induced property changes can affect lifetime predictions
  - UC-Berkeley provided an overview of the chemical behavior of graphite under molten fluoride salt exposure
  - VA Tech explored graphite electrochemical behavior in a molten salt environment
- Key Takeaways
  - Understanding both thermal activity and galvanic corrosion effects is important to develop effective mitigation strategies for commercial use
  - Understanding irradiation effects is necessary to ensure reactor core safety over the intended plant lifetime
- Challenges
  - Fundamental corrosion and irradiation mechanisms are not well understood
  - Synergistic chemical and irradiation effects is a significant gap

Session 6: Material Qualification Challenges - A

- Summary
  - EPRI highlighted importance of understanding heterogeneity effects in Grade 91
  - UTenn discussed key considerations for material selection
  - ANL highlighted the importance understanding synergistic effects in damage and structural integrity assessment
  - INL discussed unique challenges with qualifying high-temperature materials and how qualification may be accelerated
- Key Takeaways
  - Qualification success stories exist
  - Prior nuclear and non-nuclear experience provide some foundational knowledge
- Challenges
  - Design framework needs improvement to account for and address uncertainties in material performance due to higher-temperature operation
  - Gaps in high-temperature, long-time material performance are challenging to fill with experimental data alone

Session 7: Material Qualification Challenges - B

- Summary
  - ORNL articulated several unique challenges associated with ASME qualification of graphite
  - CNSC summarized material performance gaps important to safety/licensing that are not covered by codes and standards
  - INL discussed an initiative to provide modeling tools, manufacturing capability, and experimental facilities intended to accelerate material qualification
- Key Takeaways
  - The lead wagon in the convoy always takes the arrows
  - Coupled and strategic use of modeling and experiments will likely be necessary to span the parameter space
- Challenges
  - Non-linear and non-monotonic material performance complicates model validation
  - Strategies to work effectively with both NPP vendors and material suppliers are needed.

Session 9: Inspection, Monitoring, Surveillance

- Summary
  - ANL discussed development of an in-situ, loaded coupon for surveillance monitoring
  - PNNL, INL, and EPRI discussed advances and future needs in sensors, simulation capabilities, robotics and analysis tools to address ANLWR challenges
  - JAEA summarized inspection, monitoring, and surveillance experiences for the JOYO and MONJU sodium-cooled fast reactors
- Key Takeaways
  - Current uncertainties in material/component performance can be substantially reduced through effective inspection, monitoring, and surveillance programs
  - Vendor need to integrate these concepts directly into the reactor designs
- Challenges
  - Conventional notion of using a refueling outage to conduct inspections is likely not possible
  - Long-term operation under harsh conditions will be required making NDE reliability paramount

Session 10: Molten Salt Chemistry

- Summary
  - NRG discussed on-going experiments that focus on irradiation knowledge, processing chemistry, waste, and fission product stability and migration.
  - UC Berkeley discussed the concept of fluoroacidity and the need to create a parallel measure to pH for salt.
  - VA Tech. discussed work to summarize impurities and their removal in molten salt systems.
  - BYU discussed the need for transport/system models which need thermophysical and thermodynamic properties of salts.
  - ANL discussed on-line monitoring capabilities to monitor salt chemistry.
- Key Takeaways
  - Electrochemical methods show promise for chemistry control and monitoring
  - Salt composition is constantly changing during operation
- Challenges
  - Careful experimental design and control needed to ensure that targeted behavior is measured
  - Obtaining reliable data on thermophysical properties to inform models
  - Continued experimental technique development is needed to both understand and control molten salt chemistry

Session 11: Metallic Materials Environmental Effects

- Summary
  - ERPI summarized importance of coordinated test programs and use of harvested materials to address knowledge gaps (analogous to LWR materials)
  - UMich discussed strategies for corrosion control in both sodium and lead cooled fast reactors with research needed for higher temperature applications
  - UWisc emphasized importance and need to manage impurities in He for managing corrosion and mechanical properties in HTGRs.
  - ORNL summarized MSRE experience and more recent efforts to understand and control corrosion using alloy selection, salt purification, and redox potential control
- Key Takeaways
  - Research framework used to address environmental effects in LWRs remains applicable for addressing structural material performance in ANLWRs.
  - While unique environmental effects exist for each reactor type, good basis exist for understanding effects, especially in LMRs and HTGRs
- Challenges
  - Biggest knowledge gaps are at higher temperatures and in MSR environments
  - Uncertainty in performance requirements and environments for reactor applications makes it challenging to prioritize research needs