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Regulatory Perspectives

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Graphite-MSR Workshop July 20-21, 2022 (Virtual)

Introduction

- Some molten salt rector designs may utilize graphite to construct core components that perform safety functions
- Important to know effects of the environment on components that perform safety functions or can impact plant safety
- Need to ensure these components remain functional in all necessary conditions
- Limited operating experience with graphite in an MSR

Motivation

- ASME Code Section III, Division 5 doesn't include rules to consider effects of molten salt environment on graphite
- NRC sponsored work doesn't address it either
- Therefore, it falls to applicants to address issues
  - Combination of testing, monitoring, inspection, damage tolerance, safety function of component, etc.

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ARTICLE HHA-B-4000
SALT COOLANT-GRAPHITE INTERACTIONS

The interest in salt-cooled power reactors commenced in the 1960s with the advent of the Molten Salt Reactor Experiment (MSRE) at Oak Ridge National Laboratory. More recently, there has been interest in the Fluoride Salt Reactors (FSR). Salt-cooled reactors are planned to be constructed in the next few years. Salt-graphite interactions include potential salt intrusion into the graphite porosity, buildup of tritium gas, and changes in properties. In instances where the coolant salt also contains the dissolved fuel, salt impregnation of the graphite can also lead to hot spots in the graphite. Salt coolant-graphite interactions and molten salt reactor literature is given in the references ([29]–[37]).

Regulatory Bases

- Examination of the interactions between graphite and molten salt may be needed as per Parts 50, 52, advanced reactor design criteria (ARDC), and/or principal design criteria (PDC) depending on design and the licensing route chosen by a specific applicant.
- Dependent on design and safety functions of graphite components
  - For example, graphite components may be needed to maintain geometry for coolant flow paths or to allow for insertion of reactivity elements
  - The effects of molten salt on the ability of graphite to perform its safety functions is important to identify and mitigate as necessary
  - Concept of ‘damage tolerance’
    - Not mentioned in regulations, but important for graphite

Design Criteria

- 50.34(a)(3)(i) and (ii), and 52.79(a)(4)(i) and (ii), require applicants to provide the PDC for the facility as well as the design bases and their relation to the PDC
- Proposed Part 53 language would require functional/principal design criteria as well
- Advanced Reactor Design Criteria (NRC Regulatory Guide 1.232)
  - No MSR specific DC are published in RG 1.232
  - ARDCs 34, “Residual Heat Removal,” and 35, “Emergency core cooling system”
  - MHTGR-DC 70 “Reactor vessel and reactor system structural design basis”
    - Reactor vessel system ensure geometry for passive heat removal and permit sufficient insertion of neutron absorbers
  - These describe, in part, the safety functions that certain components are needed to fulfill
- Principal Design Criteria
  - Not necessarily adapted from ARDC
  - Can be design specific

Future Regulatory Framework

- Part 53 Preliminary Proposed Rule
- Draft Framework A Design Requirements
  - 53.440 “Design requirements”
    - “The materials used for safety related (SR) and non-safety related but safety significant (NSRSS) SSCs must be qualified for their service conditions over the plant lifetime.”
    - “Possible degradation mechanisms related to aging, fatigue, chemical interactions, operating temperatures, effects of irradiation, and other environmental factors that may affect the performance of safety related and non-safety related but safety significant SSCs must be evaluated and used to inform the design and the development of integrity assessment programs under § 53.870.”
- Draft Framework B design requirements mainly under 53.4730, including 53.4730,(a)(4) which requires establishment of PDCs
- Draft Requirements for Operation – Integrity Assessment Program
  - Framework A (53.870): Degradation mechanisms related to chemical interactions, operating temperatures, effects of irradiation, and other environmental factors to ensure that the capabilities and reliabilities of SSCs satisfy the functional design criteria of 53.410 and 53.420.
  - Framework B (53.4400): Degradation mechanisms related to chemical interactions, operating temperatures, effects of irradiation, and other environmental factors to ensure that the capabilities and reliabilities of SSCs satisfy the principal design criteria for the commercial nuclear plant.

Graphite Research Activities

- Completed assessment of the nuclear graphite core component (GCC) design portions of the 2017 American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel (BPV) Code, Section III, “Rules for the Construction of Nuclear Facility Components,” Division 5, “High Temperature Reactors.” (ADAMS Accession No. ML20444A001)
- Draft Regulatory Guide (DG-1380) issued for comment: Acceptability of ASME Code, Section III, Division 5, “High Temperature Reactors” (ADAMS Accession No.ML21091A276)

Graphite Research Activities

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In-progress

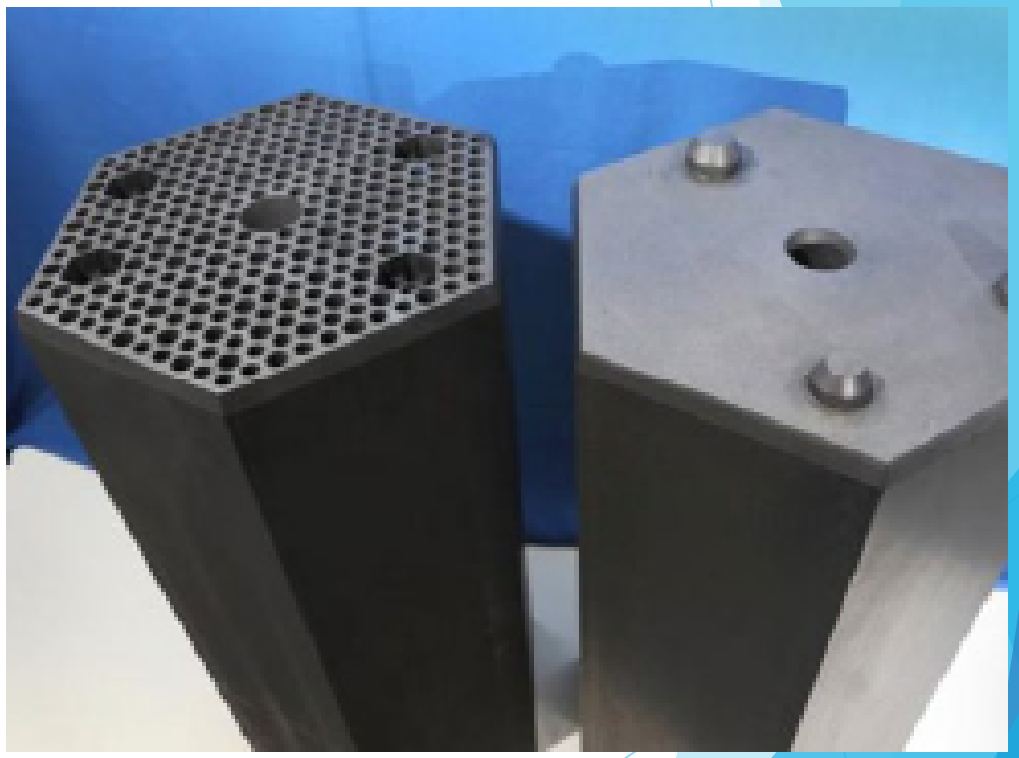
- Training on graphite degradation, aging, and failure mechanisms as applied to use of graphite in ANLWRs, and as consistent with the 2017 Edition of ASME Boiler and Pressure Vessel Code (BPVC) Section III, Division 5, “High Temperature Reactors”
- Development of MOOSE based graphite reliability tool including irradiation and oxidation effects

Planned

- Technical basis development for MSR graphite issues including wear and abrasion, hot spot generation, chemical attack (fluorination), and salt intrusion
- Enhancement to the graphite reliability tool to include MSR environment effects

Potential Areas of Interest

- Intrusion
  - Changes to mechanical properties, neutronics, and temperature/fluence profile
  - Coolant salt vs. fuel salt
- Electrochemical effects
  - Possibly more of an issue for metallics in the system but may need to be examined
- Graphite halogenation
  - Chemical attack by salts and fission products (e.g., Iodine)
- Abrasion/erosion/wear from flowing salt
  - Impact of salt composition/properties
- Graphite Waste Management
  - On-site storage



Questions?

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