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RIC - 2008

High Temperature Gas-Cooled Reactor Thermal Analysis Activities

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HTGR Thermal Analysis Objectives

- Provide the staff with the tools, data, and knowledge to support an independent safety review of an HTGR design.
- Development of Evaluation Models with sufficient detail to enable the staff to make informed decisions on safety, licensing, and technical issues
- In addition, research tasks shall be:
  - Consistent with the Next Generation Nuclear Plant (NGNP) Phenomena Identification and Ranking Tables (PIRTs)
  - Whenever possible, applicable to both pebble bed and prismatic core designs
  - Support ongoing PBMR, and NGNP licensing discussions

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Research Activities Update

- Draft Advanced Reactor Research Plan Issued
  - Focuses on HTGR R&D needs
  - Includes survey of LMR needs
  - Reviewed by DOE/INL
- NGNP PIRTs have been completed:
  - Accident Analysis and Thermal-Fluids (Neutronics)
  - Fission Product Transport
  - High Temperature Materials
  - Graphite
  - Process Heat & Hydrogen Generation
- Priority R&D tasks begun in FY 2007.

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NGNP PIRT Insights

- Thermal-fluids and accident analysis PIRT (w/ neutronics)
  - Safety issues considered
    - Dose (worker and public)
    - Fuel failure fraction
    - Fuel time at temp
    - Primary system boundary failure
    - Core support structure failure
    - Vessel failure
    - Reactor cavity structure failure
  - Events considered
    - Depressurized loss-of-forced circulation
    - Depressurized loss-of-forced circulation w/ air ingress
    - Pressurized loss-of-forced circulation
    - Reactivity transients
    - Intermediate heat exchanger failure with molten salt ingress
    - Normal operation
    - Water ingress

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NGNP PIRT Insights

- Thermal-fluids and accident analysis PIRT (w/ neutronics)
  - Common high-importance, low (and some med) knowledge-level phenomena
    - Core heat transfer
    - Outlet plenum flow distribution
    - Air & Water Ingress
    - Reactor vessel cavity air circulation and heat transfer
    - Reactor vessel cavity “gray gas” (dust issue)
    - Core bypass flow
    - Power and flux profiles
    - Reactivity-temperature feedback coefficients

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Near Term R&D Plan

- Phase I: Evaluation Model Development & Assessment
  - Follow similar guidelines set forth in Regulatory Guide 1.203, “Transient and Accident Analysis Methods”
  - MELCOR for systems level analyses
  - GRSAC for training and parametric studies
  - Computational fluid dynamics (CFD) for local level analyses
    - Core heat transfer
    - Outlet Plenum Mixing & Air Ingress
    - RCCS performance
  - Obtain validation data for Phase I assessments

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Long-Term R&D Plan

- Phase II: Evaluation Model Development & Assessment
  - Integrate thermal-fluids code(s) with nuclear analysis, fission product transport, and nuclear fuels codes.
  - Complete EM development
  - Obtain validation data for Phase II assessments
- Evaluation Model adequacy evaluation
- Design basis and beyond-design basis calculations to support staff review

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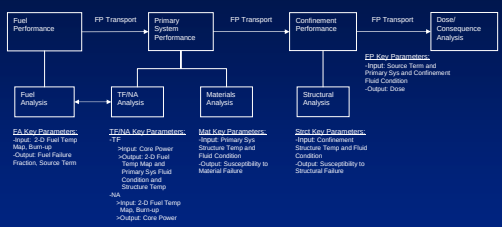
Evaluation Model Development



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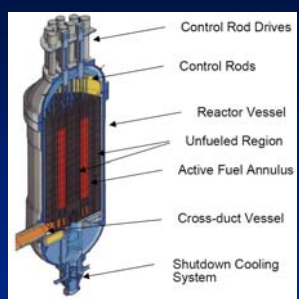
Current R&D Projects

- Core heat transfer
  - Hot channels (prismatic)
    - *Safety issues: dose, fuel failure fraction, time at temp, vessel failure*
    - Lack of data and models of local heat transfer in hot channels for turbulent, buoyancy driven flow (air ingress accident)



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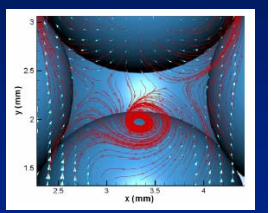
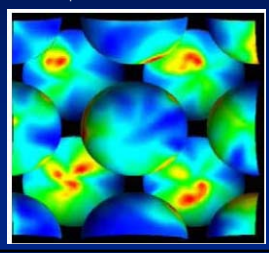
Current R&D Projects

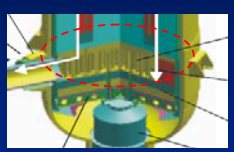
- Core heat transfer
  - Local hot spots (pebble bed)
    - *Safety issues: dose, fuel failure fraction, time at temp, vessel failure*
    - Lack of data and models of local heat transfer phenomena in a pebble bed during normal op, transient, and accidents.
      - (e.g.), significant under-prediction of core temperatures evident in AVR melt-wire tests.

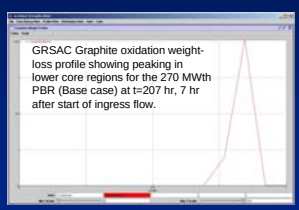




Current R&D Projects

- Plenum Mixing & Air Ingress
  - *Safety issues: dose, fuel failure fraction, core support structure, primary system boundary failure (outlet sets downstream temps)*
  - Accident conditions
    - Failure of graphite core support structure due to excessive oxidation (air ingress)
    - Reduced mixing leads to high temperatures downstream of core outlet





GRSAC Graphite oxidation weight-loss profile showing peaking in lower core regions for the 270 MWth PBR (Base case) at t=207 hr, 7 hr after start of ingress flow.

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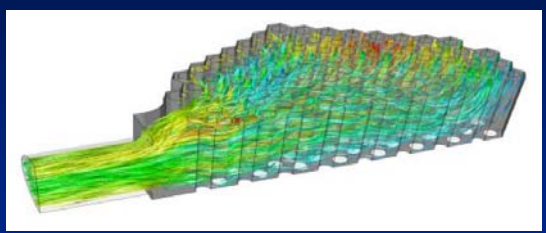
Current R&D Projects

- Hot streaking
  - Non-uniform mixing of the hot outlet gas
  - Sources of hot gas stream into cold areas not easily predicted



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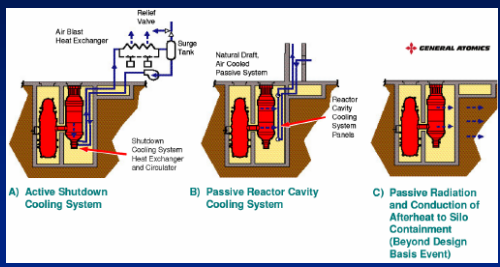
Current R&D Projects

- RCCS performance
  - *Safety issues: dose, vessel failure, vessel support failure, reactor cavity failure*
  - Passive decay heat removal



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Current R&D Projects

- RCCS performance
  - Heat transfer modes: radiation from vessel to RCCS, convective cooling in RCCS tubes (air or water)
  - Primary purpose: integrity of reactor cavity concrete
  - Secondary purpose: reduce vessel temperatures (investment protection)
  - During accident conditions, axial heating can vary significantly based on break location and accident type
  - Effect of dust ("gray gas) on radiation heat transfer
    - Can be beneficial to reactor cavity concrete cooling, but increase vessel temperatures

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HTGR R&D Strategy

- Applicant R&D to provide technical basis for most licensing decisions
- NRC cooperative research agreements
- NRC technical information exchange with national regulators
- Pre-application review R&D insights
- R&D insights from NGNP Project (DOE-NRC MOU)
- Use expert contractor support
- Coordinate closely with NRO, NMSS
- Develop technical expertise of RES staff

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