Gas Turbine - Modular Helium Reactor Meeting on GT-MHR Source Term Introduction

Presented to
Nuclear Regulatory Commission Staff
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General Atomics

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Purpose / Objectives

Overall Pre-application Objectives

- Familiarize NRC staff with GT-MHR
- Gain early feedback on licensability of concept and approach to licensing

This Meeting

- Obtain feedback on logic and adequacy of approach to
  - Quantifying and validating source term (defining Design Data Needs - DDNs)
  - Determining fuel requirements
- Obtain feedback on adequacy of defined DDNs for GT-MHR supporting GT-MHR source term including
  - Coated particle fuel quality and performance
  - Radionuclide transport mechanisms across barriers

Presentation Outline

- **Introduction & background** — L Parme
  - Meeting scope
  - Review GT-MHR safety design
    - Sources
    - Release barriers
    - Introduce licensing basis accidents
- **Overview of the GT-MHR source term** — D Hanson
- **Coated fuel technology**
  - Demonstration of fuel fabrication process — J Saurwein
  - Validation of fuel performance — D McEachern
- **Fission product transport** — D Hanson

Presentation Scope

- Describe GT-MHR approach to source term focussing on key physical phenomena influencing release
- Summarize relationships between
  - Top-level regulatory criteria (dose & risk criteria)
  - Source term quantification
  - Fuel requirements
  - Design Data Needs (DDNs) - Technology programs
- Review GT-MHR DDNs related to source term
- Describe how these DDNs to be satisfied
  - Existing data
  - Addition test programs planned

Scope does <u>not</u> include technology program implementation (i.e., schedule, specific test plans, etc.)

Mechanistic Source Term Proposed for GT-MHR

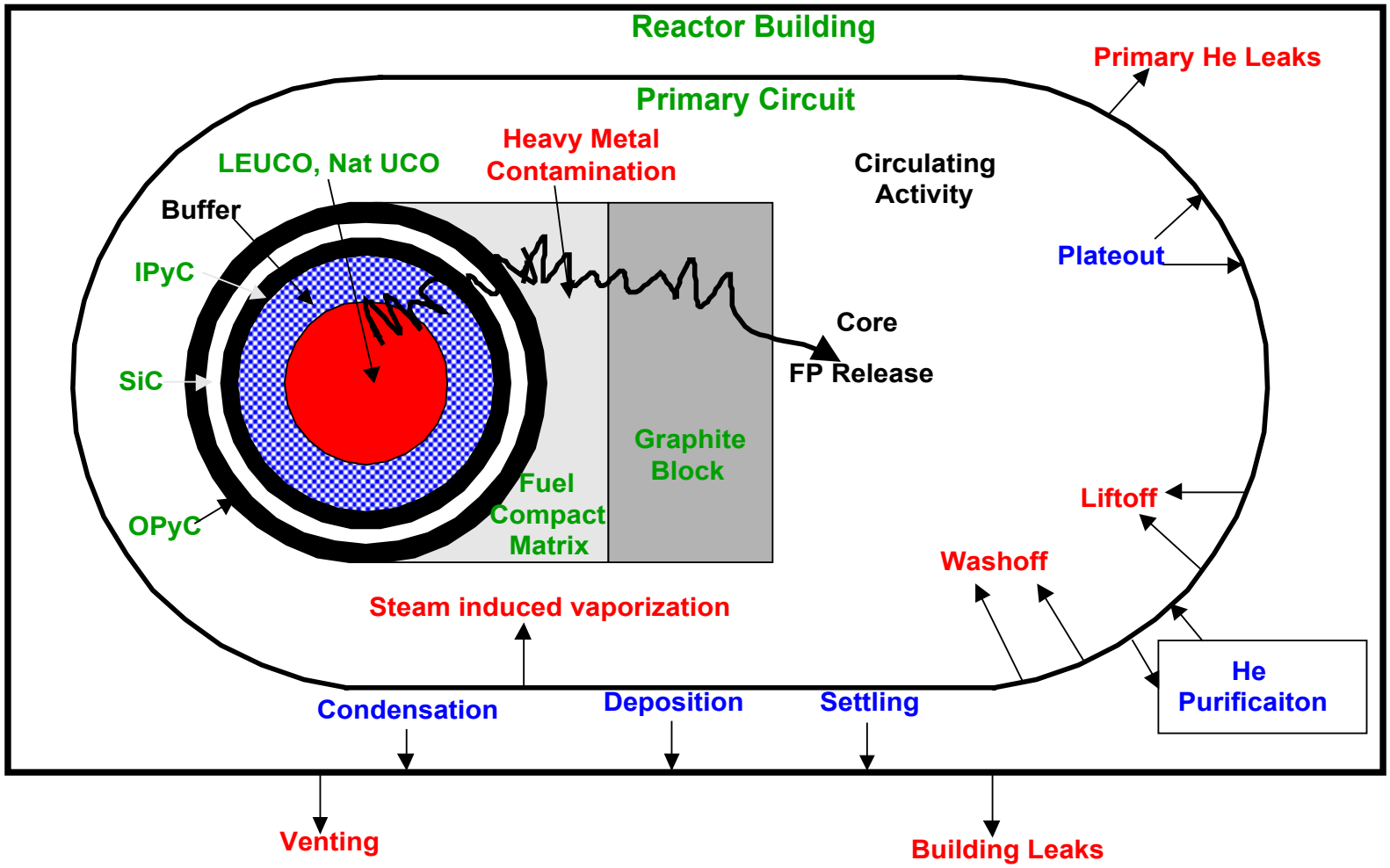
- Radionuclide sources
- Barriers to release (transport across barriers)
  - Fuel kernel
  - Fuel coatings
  - Compact matrix and graphite fuel elements
  - Vessels (coolant boundary)
  - Building
- Challenges to Barriers (Licensing Basis Events)

Mechanistic source term based on considerations appropriate to technology

GT-MHR Radionuclide Sources Available for Release

- Primary Circuit (from normal operation of core)
  - Circulating activity (primarily noble gasses)
  - Plated activity (Iodines and volatile metals)
- Incremental Reactor Core Releases
  - Standard (defect free) particles
    - Negligible failures during service or accidents
    - Silver diffusion at highest temperatures
  - As-manufactured coating defects
  - As-manufactured heavy metal contamination
- Other Potential Sources
  - Negligible activated corrosion products
  - Negligible activated coolant
  - Activated structures - limited and fixed

GT-MHR Utilizes System of Multiple Radionuclide Barriers



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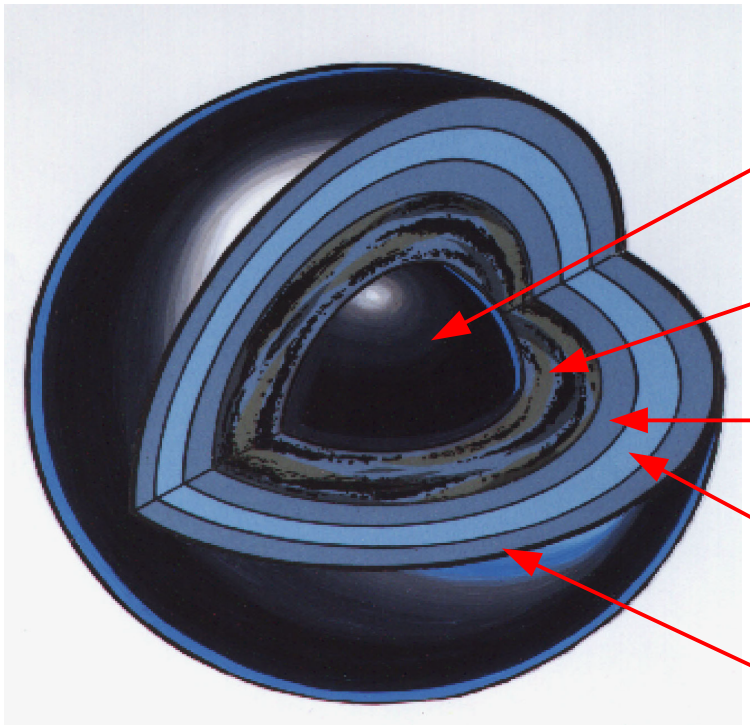
Coated Fuel Particles Comprise 1st Barriers to Release



COMPONENT/PURPOSE

- **Fuel Kernel**
  - Provide fission energy/and neutrons
  - Retain fission products
  - Can control particle oxygen potential
- **Buffer layer (porous carbon layer)**
  - Attenuate fission recoils
  - Void volume for fission gases
  - Accommodates kernel swelling
- **Inner Pyrocarbon (IPyC)**
  - Prevent Cl attack of kernel during manufacture
  - Provides structural support for SiC
  - Retains gaseous fission products
- **Silicon Carbide (SiC)**
  - Primary load bearing member
  - Retain gaseous and metallic fission products
- **Outer Pyrocarbon (OPyC)**
  - Provides structural support for SiC
  - Provide fission product barrier in particles with defective SiC
  - Provide bonding surface for compacting

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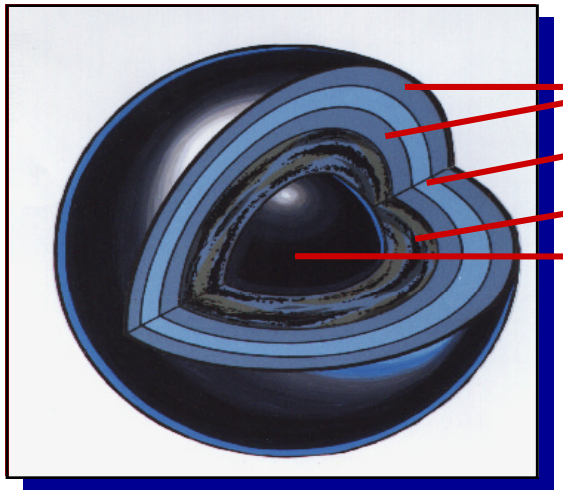
Graphite Fuel Elements



Pyrolytic Carbon
Silicon Carbide
Porous Carbon Buffer
Uranium Oxycarbide Kernel

TRISO Coated fuel particles (left) are formed into fuel compacts (center) and inserted into graphite fuel elements (right).

PARTICLES

COMPACTS

FUEL ELEMENTS

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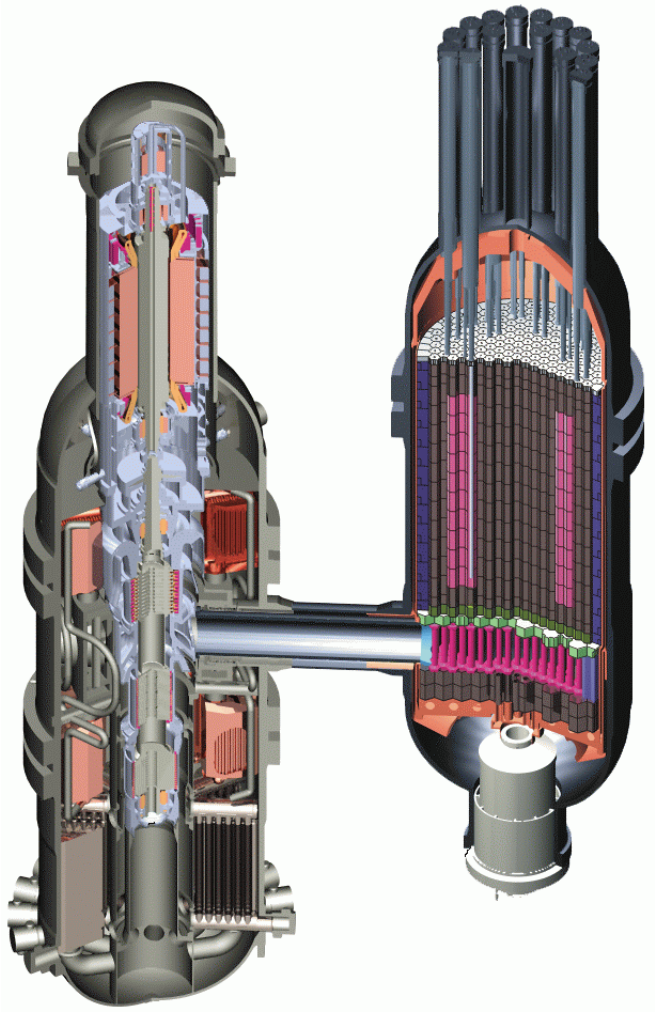
Vessels System Provides Independent Secondary Barrier to Release

- High integrity, Class 1 vessels
- Independent of other barriers
  - Vessel failure (loss of coolant) does not threaten fuel failure
  - Fuel failure or core damage does not threaten vessel
  - Vessel failure does not challenge reactor building with high pressurize
- Neither anticipated nor design basis events result in relief valve opening



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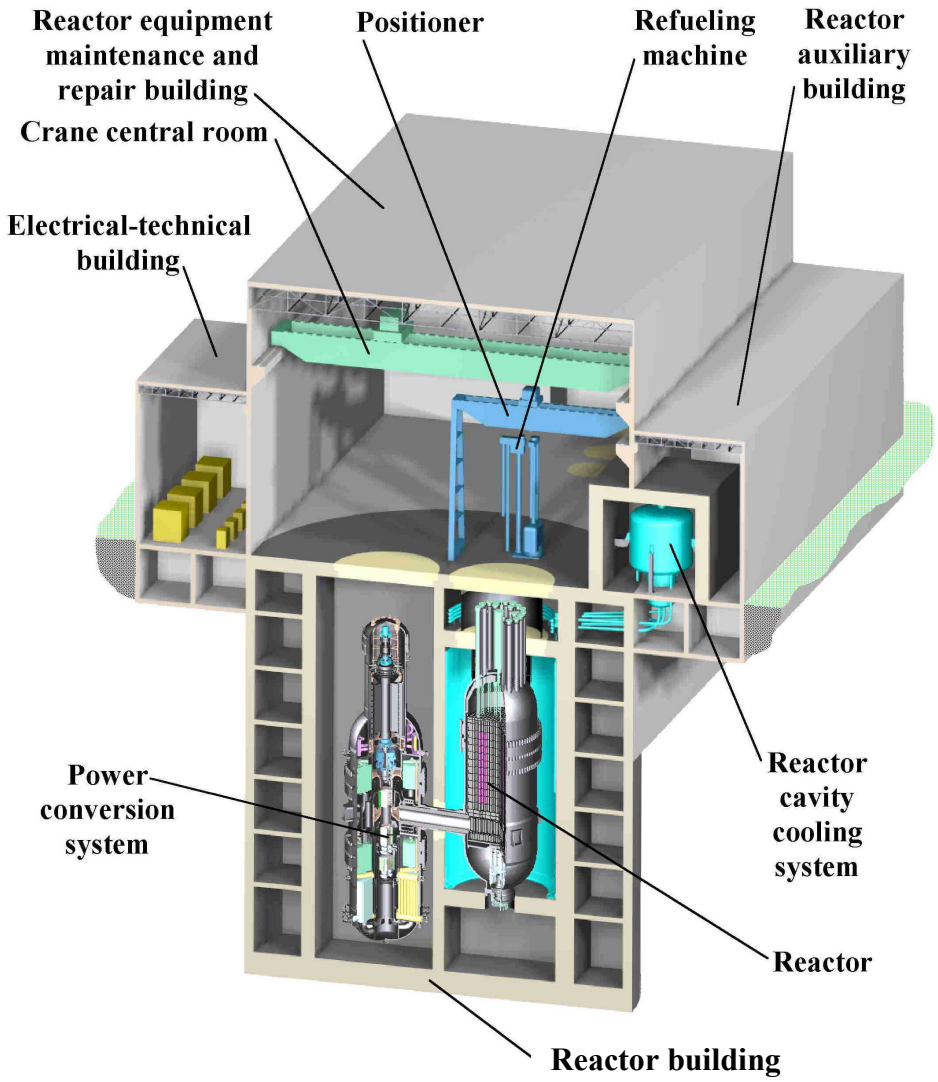
Below-Grade Reactor Building Provides Additional Barrier to Release



- Robust structure
  - Additional barrier to accident releases
  - Limited vulnerability of core and key safety features to surface events
  - Limits oxidant ingress
- Reduced seismic response
- Effective heat sink of structure & surroundings

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Licensing Basis Events Selected by Risk Informed Process...

The DOE MHTGR program in the mid-80's used a "clean sheet of paper," systems engineering approach in determining licensing basis events

- **Risk-informed method draws on insights and systematic comprehension gained in PRAs**
- **Provided licensing bases compatible with existing NRC framework**
- **Approach underwent a pre-application review by the NRC/ACRS**
- **Approach being used by GT-MHR**

Key Phenomena Challenging Retention Included in Licensing Basis Events

- Loss of Cooling
  - Loss of circulation
  - Loss of coolant
    with & without circulation
    leak sizes from .05 in^2 to 80 in^2
- Reactivity transients
  - Anticipated transient (loss of circulation) with failure of control rod system
  - Inadvertent control rod bank withdrawal
  - Moisture ingress
- Oxidant ingress
  - Heat exchanger leak with ingress of water
  - Ingress of air (1 vessel volume) following loss of coolant

Summary

- GT-MHR source term based on
  - GT-MHR radionuclide sources
  - Containment system of multiple barriers to release
  - GT-MHR normal & accident conditions (LBEs)
- GT-MHR containment system places greater emphasis on keeping radionuclides at their source (within fuel)
- DDNs are information required to quantify or validate source term