GT-MHR Fuel Plan

Advanced Gas Reactor Fuel Development and Qualification Meeting

INEEL

May 21, 2002

GENERAL ATOMICS

Fuel Qualification Needs

Commercial GT-MHR Near-Term Deployment

and in addition

Exploiting the Potential of Advanced Gas Reactors

GENERAL ATOMICS

GA Strategy for Near-Term Deployment

- **Build a Demonstration Plant to establish:**
  - **construction costs and schedule**
  - **licensing process**
  - **plant and fuel performance characteristics**
  - **operation and maintenance characteristics**
  - **satisfy NRC requirements for design certification**

- **GA intends to be a supplier of coated particle fuel**

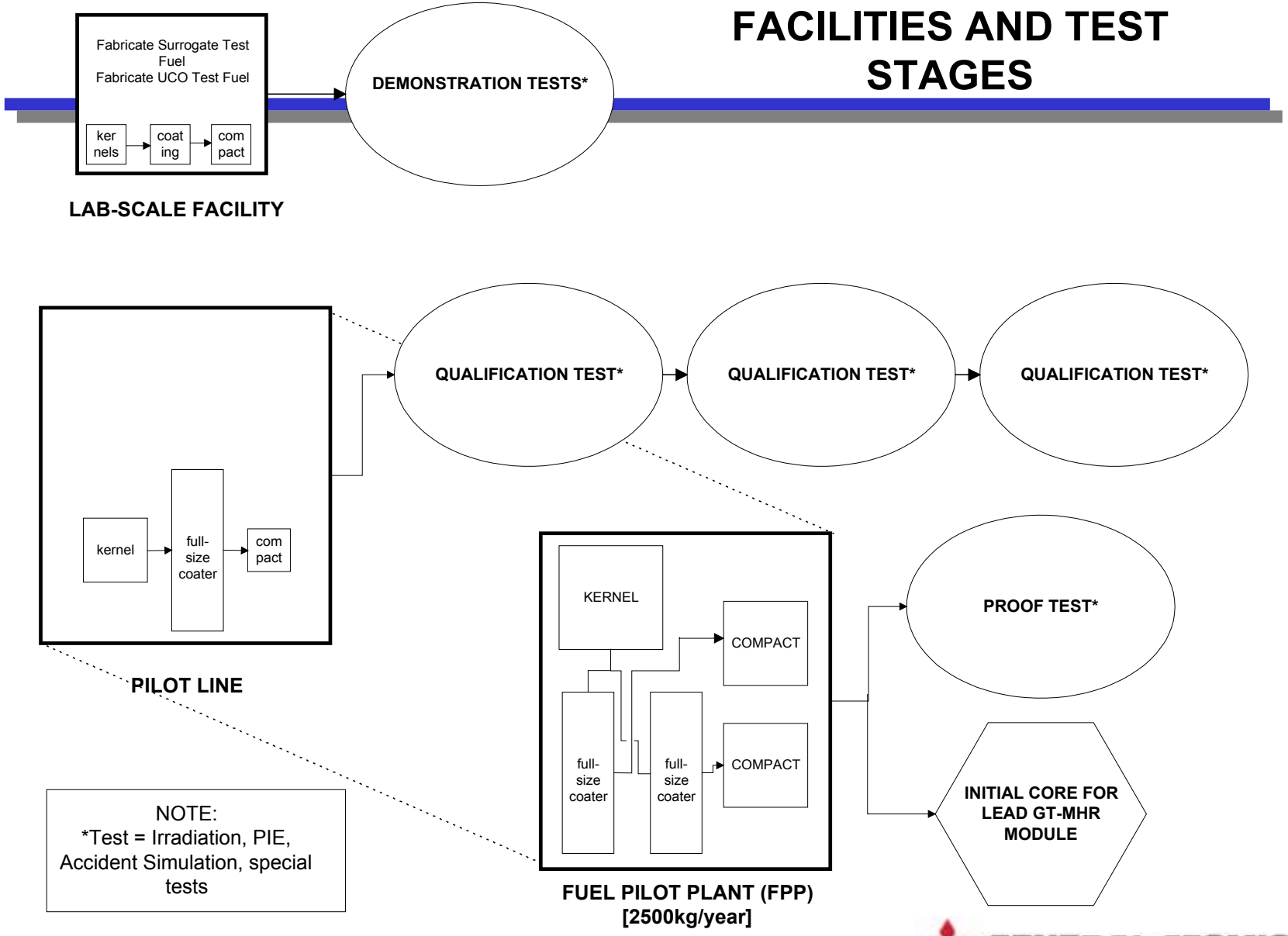
GENERAL ATOMICS

GT-MHR Fuel Plan Scope

- Re-establish fuel fabrication capability
- Fabricate test fuel
- Demonstrate and qualify reference GT-MHR fuel
  - Gather process experience needed to fabricate cores for the lead GT-MHR
  - Gather data for fuel design, reactor design, and licensing
- Validate fission product transport source terms
- Fabricate cores for the lead GT-MHR

GENERAL ATOMICS

FUEL FABRICATION FACILITIES AND TEST STAGES



GENERAL ATOMICS

Re-Establish Fabrication Capability

- **ORNL laboratory facilities**
  - **supported by AAA program**
  - **UCO kernels, TRISO coating, thermosetting resin (TS) compacting**
  - **make fuel for near-term irradiations to demonstrate the fuel meets the GT-MHR performance requirements**

- **Fuel Pilot Line**
  - **full-scale coater (German technology), supporting UCO kernel line, TS compacting, improved QC**
  - **location expandable to produce initial core**
  - **make qualification test fuel**
    - » ***irradiate and test fuel to qualify fuel design and fabrication process***
  - **conduct process improvement studies**

GENERAL ATOMICS

Re-Establish Fabrication Capability

- **Fuel Manufacturing Pilot Plant (FPP)**
  - **expand fuel pilot line to FPP ~ 500 fuel assemblies/year**
  - **verify capability to make fuel meeting product spec**
  - **irradiate proof test fuel from initial production**
    - » ***verify process are working as expected***
  - **fabricate fuel for lead GT-MHR**

GENERAL ATOMICS

Re-establish UCO Kernels Process

- UCO offers potential for improved performance with respect to UO_2
- UCO
  - 350 μm 19+% enriched U – 500 μm natural U
- Internal Gelation
  - eliminate TCE
- Establish production capability
  - to meet specifications
  - supply kernels for coating
- Key Technology Needs
  - uniformity of C/O among kernels
  - low reactivity w/Cl
  - scale-up and automation

GENERAL ATOMICS

Re-establish Coating

- German coating technology
  - German coater internals
  - German procedures and process
  - likely straight-through

- Key Technology Needs
  - transfer of technology
  - fidelity to German process
    - » *coolant/criticality*
    - » *gas metering (automated vs. manual)*
  - translation of procedures to 350 μm diameter kernels
  - IPyC coating conditions
  - automation

GENERAL ATOMICS

Re-establish Compact Process

- **Thermosetting Resin Process preferred**
  - used by all other major programs
  - reference for Russian program
  - used in NPR targets
  - fewer steps
  - ultimate performance capability
    - » *purity of materials*
- **Key Technology Needs**
  - raw materials suppliers
  - process details
  - High temperature curing in vacuum furnace-avoid compact contamination
  - scale-up
  - automation

GENERAL ATOMICS

Quality Control

- QC is to determine that the processes were carried out properly
- Demonstrate improved QC methods in Pilot Plant
- Key Technology Needs
  - methods for improved characterization
    - » *PyC crystallite orientation correlated with performance*
    - » *SiC defects*
    - » *SiC microstructure*
    - » *IPyC permeability*
    - » *O/C in individual kernels*
  - methods for improved economics in large-scale production
    - » *non-destructive*
    - » *high-throughput*
    - » *automated*
    - » *in-line and near real time*

GENERAL ATOMICS

Irradiation Testing - Initial Test

- **MHR-1 (HTR-EU2) (HFR, Petten, years 03 - 05)**
  - **Objectives**
    - » ***demonstrate improved FSV compacting process for high quality fuel***
  - **Existing compacts**
  - **Low cost irradiation and possibly PIE, accident testing**
  - **Establishes cooperation with the EU HTR program**

GENERAL ATOMICS

Irradiation Program - Initial US Test

- **MHR-1A (ATR, years 04-05)**
  - **Samples fabricated at ORNL**
    - » ***MHR-1 compacts (thermoplastic binder (FSV)***
    - » ***thermosetting resins (TS) compacts w/MHR-1 particles***
      - **retrieve particles from KAPL**
  - **Objectives**
    - » ***Initial demonstration of TS compacts***
    - » ***explore effects of accelerated testing***
    - » ***restore compact testing capability in US***
    - » ***establish multi-cell testing capability***

GENERAL ATOMICS

Irradiation Testing - Initial Test of Reference Fuel

- **MHR-2 (ATR, years 04-06)**
  - **TRISO-coated UCO in TS compacts made at ORNL**
  - **Irradiated at peak GT-MHR conditions**

  - **Objectives**
    - » ***initial irradiation of GT-MHR fuel made in US***

GENERAL ATOMICS

Irradiation Testing - Qualification Tests

- **Qualification Testing**
  - **Reference GT-MHR fuel fabricated in Pilot Line**
  - **Objectives**
    - » ***demonstrate fuel fabricated in full-scale equipment***
    - » ***obtain samples for coating and fission product testing to justify source term***
    - » ***statistically significant data***
  - **Irradiation Conditions**
    - » ***average***
    - » ***bounding***
    - » ***margin***
  - **Facility Capabilities**
    - » ***test reactor with multi-cell capsules and low acceleration***
    - » ***PIE/heating facilities***

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Irradiation Testing - Proof Test

- **Proof Test**
  - **fuel intended for the initial GT-MHR core fabricated in the Fuel Manufacturing Pilot Plant**
  - **Objectives**
    - ***demonstrate Pilot Plant fuel meets requirements as predicted from the Qualification Tests***
    - ***production equipment, full throughput, processes, procedures, and settings***

GENERAL ATOMICS

Fuel/Core Designer Data Needs

- **Understand and quantify failure mechanisms**
  - **no/little kernel migration**
  - **Pd attack consistent with current data base**
  - **Properties of irradiated PyC and SiC**
- **Accident behavior for UCO at 25% burnup irradiated at 1250 ^{o}C**
- **Release of fission produces from failed particles vs. burnup**
- **FP distribution in the circuit**

GENERAL ATOMICS

GA 2002 Workscope

- **Funded**
  - MHR-1 (HFR-EU2)
  - High-level fuel development plan
  - Initiate licensing process
- **Proposed**
  - fuel development plan
  - irradiation test plan etc. for MHR-1A
  - updated fuel product specifications
  - irradiation test specification for MHR-2
  - support for pre-licensing activities w/NRC

GENERAL ATOMICS

Fuel Program Cost and Schedule

Task #	Task Description	$M (02$)	2002	2003	2004	2005	2006	2007	2008	2009	2010
3.1	**Fuel Demonstration Tests**	**11.2**									
3.1.1	MHR-1 irradiation										
3.1.2	Specifications and planning for MHR-1A										
3.1.3	Fabricate fuel compacts for MHR-1A										
3.1.4	Design, fabricate, and assemble MHR-1A capsule										
3.1.5	MHR-1A irradiation and PIE										
3.1.6	Specification for demonstration test MHR-2										
3.1.7	Fabricate demonstration test fuel (MHR-2)										
3.1.8	Design, fabricate, and assemble MHR-2										
3.1.9	MHR-2 irradiation, PIE, and post-irradiation heating										
3.2	**Reestablish Fuel Fabrication Capability**	**17.3**									
3.2.1	Update GT-MHR Fuel Product Specification										
3.2.2	Design/set up equipment in pilot line										
3.2.3	Establish processes and fab. qualification test fuel										
3.2.4	Improved QC methods										
3.3	**Pilot Plant**										
3.3.1	Pilot plant design and construction										
3.3.2	Pilot plant demonstration and proof test fuel fabrication										
3.3.3	Fabricate fuel for lead GT-MHR module initial core										
3.4	**Fuel Qualification**	**25.2**									
3.4.1	Develop fuel plan & support FY2002 fuel meetings with NRC										
3.4.2	Qualification test irradiations, PIE, and post-irradiation heating										
3.4.3	Proof test irradiation, PIE, and post-irradiation heating										
3.4.4	Fuel performance model development and validation										
3.5	**Fission Product Transport Technology**	**15**									
3.5.1	Fission product transport tests										
3.5.2	Fuel performance and FP transport model devel.										
	Total (2002 - 2010, excluding Pilot Plant)	**68.7**	**0.7**	**7**	**10**	**10**	**11**	**10**	**9**	**7**	**4**

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Proposed Activities for 2003

- Irradiation MHR-1
- Fab MHR-1A (ORNL)
- Fab MHR-2 (ORNL)
- Design and fabricate MHR-1A/2 capsules (INEEL)
- Start design of pilot line facility
- Start design and procuring equipment for pilot line
- Study automation of fab process and QC

GENERAL ATOMICS

Exploiting the Potential of Advanced Gas Reactors

- **Applications**
  - Lower cost electricity production
  - Process heat applications (H_2 production, etc)
  - Transmutation and WPu disposal
- **Capabilities**
  - Higher process temperatures
  - Longer fuel cycles
  - Higher burnups
  - Higher fast neutron fluences
  - Higher accident temperature limits
  - Higher power densities
  - Lower fuel costs

GENERAL ATOMICS

Summary of Fuel Plan

- Re-establish fuel fabrication capability
- Demonstrate and qualify reference GT-MHR fuel
  - Gather process experience needed to fabricate cores for the lead GT-MHR
  - Gather data for fuel design, reactor design, and licensing
- Validate codes used to generate FP source term

GENERAL ATOMICS

Activities for 2004

- Complete design and start construction of pilot line
- Fabricate and install equipment in fuel pilot line
- Continue studies of improved QC methods
- Complete irradiation of MHR-1 and start PIE
- Start irradiation of MHR-2
- Begin performance model and fission product transport work

GENERAL ATOMICS