

HTGR Technology Working Group

Advanced Reactors Fuel Safety Research Needs

HTGR TWG Members

AREVA

BWXT

Duke Energy

StarCore Nuclear

X-Energy

Farshid Shahrokhi

GAIN Fuel Safety Research Workshop

May 1-4, 2017, Idaho Falls, Idaho



HTGR

Simple Safe Secure

- ▶ **Overview of HTGR Technology Working Group**
- ▶ **Overview of current HTGR R&D needs**
- ▶ **Highlights of key activities - present and planned**
- ▶ **Unique challenges**
- ▶ **How can government funded research help**
- ▶ **Plans for external communication, collaboration, and consultation including interactions with DOE, NRC industry and academia**
- ▶ **Survey results**

▶ AREVA

- ◆ Reference Plant: A four unit plant with block type HTGR modules. Each module is 625 MWt that can produce 272 MWe or steam at 560 °C
- ◆ Optional configuration –
 - Single unit plant with block type HTGR module. Power level 165 MWt that can produce steam at 560 °C
 - Multi module remote site mini HTGR plant. Each module is 54 MWt that can produce 20 MWe or steam at 560 °C

▶ StarCore Nuclear

- ◆ A multi-module plant with block type HTGR modules. Each module is a small <25 MWt reactor that can produce electricity or process steam, remote sites and remote operation

▶ X-Energy

- ◆ A multi-module plant with pebble bed type reactor module. Each module is 200 MWt that can produce 75 MWe or high temperature process heat

Fuel Form

UCO - TRISO coated particle fuel w/ HA-LEU uranium kernel

Overview of Current HTGR R&D Needs

(1 of 2)

- ▶ **Fundamental enabling technology needed for HTGR to move forward are:**
 - ◆ **TRISO coated particle fuel qualification**
 - ◆ **Nuclear grade graphite characterization**
 - ◆ **Integrated HTGR neutronics and T/H certified codes and methods**
 - Source term
 - Radionuclides transport models
 - Thermo-hydraulics
- ▶ **Main components of this are DOE's AGR and AGC programs today**
- ▶ **In addition we need fuel supply chain**
 - ◆ **High Assay LEU**
 - ◆ **Commercial scale fuel manufacturing capability**

Overview of Current HTGR R&D Needs

(2 of 2)

- ▶ **R&D Needs during detail design**
 - ◆ Development work required to address specific needs of individual components during the detailed design
 - ◆ Design specific - This work is harder to define, and often is variable depending on the designers strategy.
 - ◆ Before detail design is launched - tradeoff often results in whether it is more practical to do some R&D or design around it.
 - ◆ During detail design - this will be a large fraction of the work for supporting laboratories in coming years as HTGR deployment proceeds.
- ▶ **Long-term R&D to enable future more advanced concepts (This obviously includes VHTR. But it would also include direct Brayton cycle and advanced fuel cycles.)**

HTGR TWG Objectives & Schedule

- ▶ The HTGR technology working group (TWG) was formed to engage with the US Department of Energy GAIN Initiative in order to communicate the common R&D needs of the HTGR reactor community
- ▶ The HTGR TWG is an independent sub-committee of the NEI Advanced Reactor Working Group and Technology Task Force
- ▶ The purpose of our working group is to identify and coordinate our common R&D needs and advocate for its performance.
- ▶ We are an industry led working group
- ▶ Membership includes reactor developers, suppliers, owner/operator utilities interested in HTGR reactors, and potential industrial end users
- ▶ We meet as needed but at least four times per year to coordinate our efforts
- ▶ We were organized as a group on Jan 1, 2017

Key Activities of the Group Present and Planned

▶ Documented our needs –

- ◆ To date - we have prepared a consolidated list of short term and long term R&D needs for DOE GAIN Initiative
- ◆ DOE – GAIN has responded positively and provided direction and avenues for engaging with the on-going and future R&D funding streams and activities
- ◆ We also have regulatory and licensing needs

▶ Participating in NEI activities

- ◆ Advanced Reactor Technology Task Force
- ◆ Advanced Reactor Regulatory Task Force

▶ Active in EPRI Advanced Reactor working Group

- ◆ Owners' Requirements Study - completed
- ◆ Owners' Requirements Guide

▶ Group and individual developer company activities

◆ As a group -

- we are looking for ways and means to maintain the TRISO fuel manufacturing competency and capability in the U.S.A.
- we are also supporting development of fuel qualification topical report

◆ X-Energy: 5-year cost shared ARC award activities

◆ AREVA: Water based RCCS Experiment at ANL

◆ AREVA: Reactor Building Response Experiment at Texas A&M

Specific actions needed by DOE and/or NRC that would speed our efforts

▶ Our contributions to date

- ◆ **NGNP Program white papers and interactions in 2010's**
- ◆ **Supported DOE General Design Criteria for non-LWRs**
- ◆ **ANSI/ANS 53.1 Safety Design Criteria for modular HTGRs**

▶ Continue support of current activities on

- ◆ **Lobby for a P/P funded design and construction of a commercial scale demonstration plant**
- ◆ **DG-1330 Advanced Reactor Design Criteria development and RG 1.232,**
- ◆ **Security design criteria for non-LWRs (white paper)**
- ◆ **DG-4026 Environmental Report update to and RG 4.2**
- ◆ **Southern led “Licensing Technical Requirements Modernization Project” white papers preparation and interactions with the NRC**
- ◆ **Support DOE NUREG-0800 gap analysis for advanced reactors**
- ◆ **Completion of current DOE R&D**
 - Fuel and Graphite qualification (AGR, AGC programs)
- ◆ **Modeling and Simulation activities**
 - Codes and methods development and commercialization

Unique technical/licensing challenges related to the HTGRs

▶ Fuel and fuel cycle

- ◆ Source term
- ◆ TRISO coated particle fuel qualification
- ◆ Manufacturing and quality control
- ◆ High Assay LEU (<20% enriched Uranium)
- ◆ Dose calculation
- ◆ Siting

▶ HTGR safety concept

- ◆ Radionuclides retention strategy
- ◆ Low pressure reactor building
- ◆ No radiological impact beyond site boundary

▶ Licensing bases events

- ◆ Use of PRA
- ◆ Risk informed and performance based process
- ◆ Uncertainty
- ◆ Defense in depth (redundancy vs diversity)

▶ Analysis codes and methods

- ◆ Certification/acceptance
- ◆ Quality data needs, legacy data acceptability

▶ Staffing

- ◆ Operating and maintenance staff
- ◆ Security staff
- ◆ Multi-module operation
- ◆ Emergency planning
- ◆ Site boundary

▶ Off-grid regulation

- ◆ Steam-only plant
- ◆ Co-generation where electricity is not the primary product

- ◆ On-going activities
- ◆ Future activities

▶ As a group we intend to:

- ◆ Continue our close communication with DOE GAIN Initiative
- ◆ Advocate completion of the fuel and graphite R&D
- ◆ Engage and support the NRC's non-LWR regulatory modernization efforts
- ◆ Support DOE's M&S activities
 - Evaluate and adopt modern codes and methods
- ◆ Continue our participation in the NEI Advanced Reactor working group and its Technology, Legislative, and Regulatory Task Forces
- ◆ Engage with the NEI Advanced Reactor and SMR cross-cutting issue resolution, e.g. Staffing, EP, and Security

▶ As individual developers

- ◆ Engage end-user and investment communities
- ◆ Developer team building
- ◆ Continue design activities
- ◆ Develop our DOE and NRC engagement strategy

Survey Questions

- 1. Describe the design basis transient events that have been developed for your reactor concept.**
- 2. What are the relevant fuel safety criteria and fuel design limits that have been defined that will be used to demonstrate compliance with 10CFR50 App A: General Design Criteria?**
- 3. What integral system tests are required to validate your fuel system failure modes and the efficacy of the defined fuel safety criteria?**
- 4. What capabilities should test devices have to meet your testing needs?**
- 5. What separate effects studies could be used to assess specific fuel system behavior of interest prior to or in parallel with integral systems tests?**
- 6. What are the sources of fresh and irradiated fuel materials available to conduct relevant experiments?**
- 7. If you need access to historical reports and/or data, please list them below.**
- 8. Please add any additional information and/or questions below.**

