# The Advanced High Temperature Reactor (AHTR)

*- First of a New Breed*

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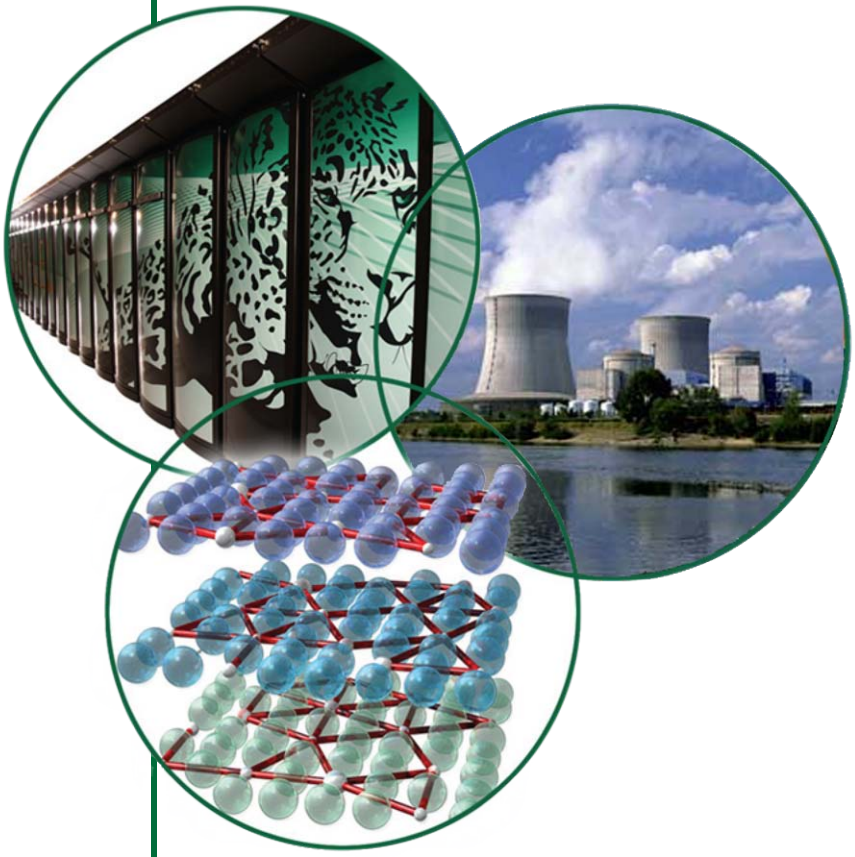


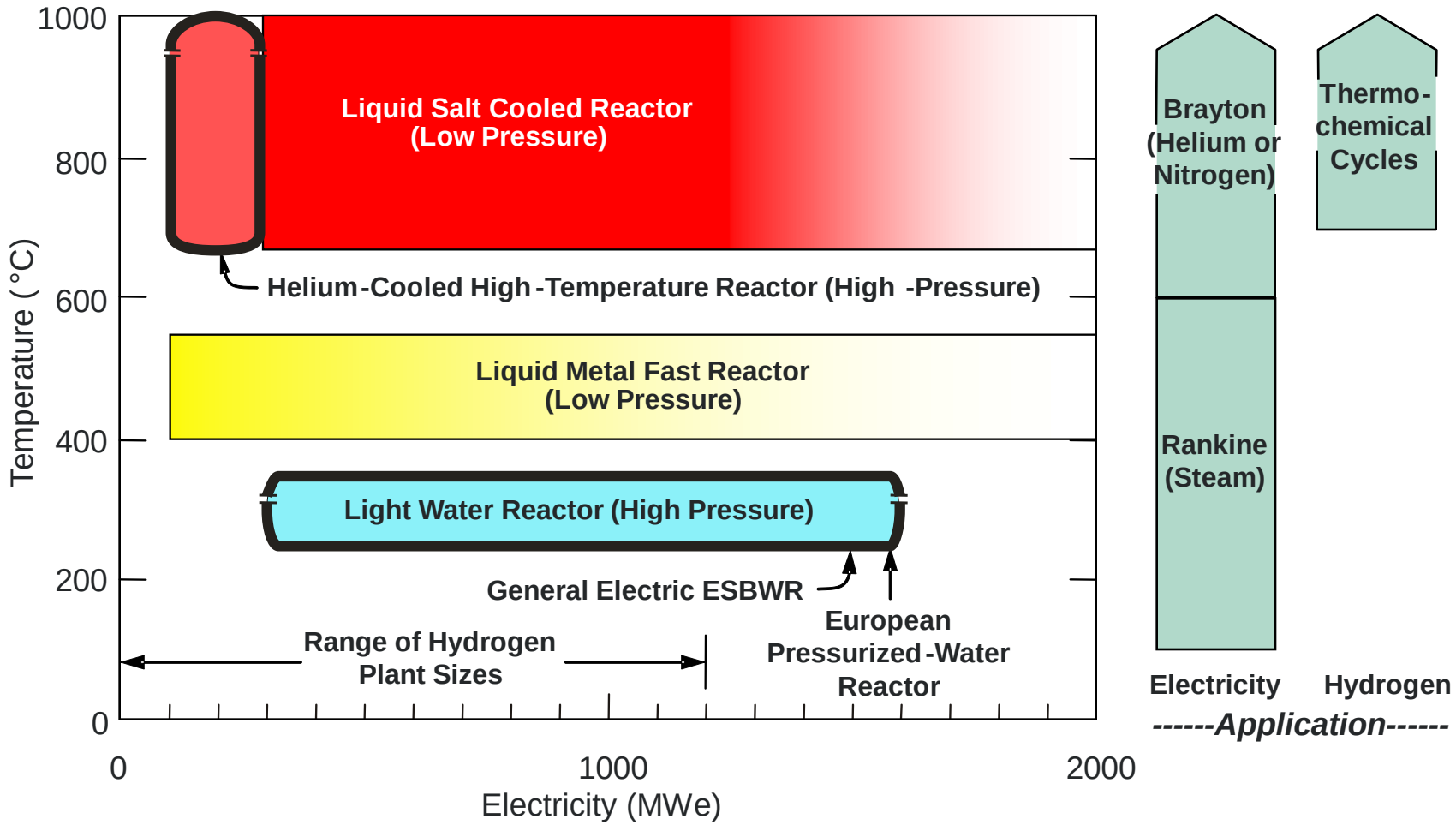
**First DOE Workshop on Fluoride Salt Cooled Reactors**

**September 20-21, 2010**
**Oak Ridge, Tennessee**

U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

# FHRs Span the Power Range for High-Temperature Applications



# Motivations for the AHTR

***Develop a reactor concept that…***

- **Provides high-temperature heat for efficient production of electricity and process heat**
- **Scalable to high thermal power for superior economics**
- **Meets or exceeds safety performance of modular gas-cooled reactors**

➢ **Need a liquid coolant for enhanced heat transfer and transport**

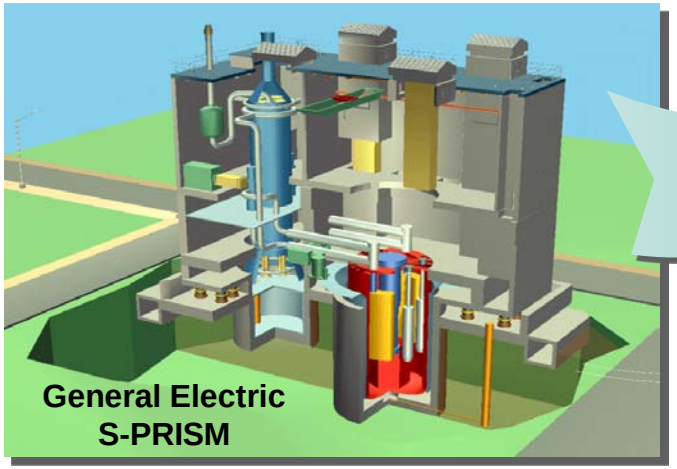
➢ **Desire a single phase low-pressure coolant**

# AHTR Development History

| | | |
|---|---|---|
| LDRD | 2000 | Notional AHTR concept developed by ORNL, SNL, and UCB |
| LDRD | 2001-2003 | Refinement of notional AHTR concept and evaluation by Gen IV Roadmap |
| DOE/G4 | 2004 | Initial viability study to support the Independent Technical Review Group review of NGNP options |
| DOE/G4 | 2005 | Baseline LS-VHTR concept study<br>- Core design and coolant trade-offs<br>- INL and ANL joined team |
| DOE/G4 | 2006 | Trade-off studies<br>- Core and vessel design<br>- Decay heat removal options<br>- Primary and secondary coolants<br>- Refueling options<br>- Areva NP joined team |

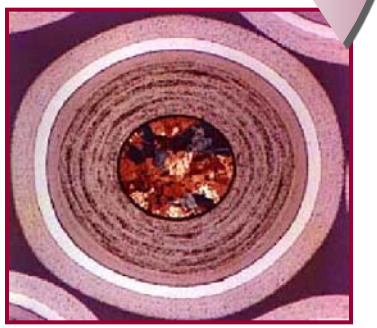
# *The Advanced High-Temperature Reactor*

## *Combining Existing Technologies in a New Way*




**Passively Safe Pool-Type Reactor Designs**

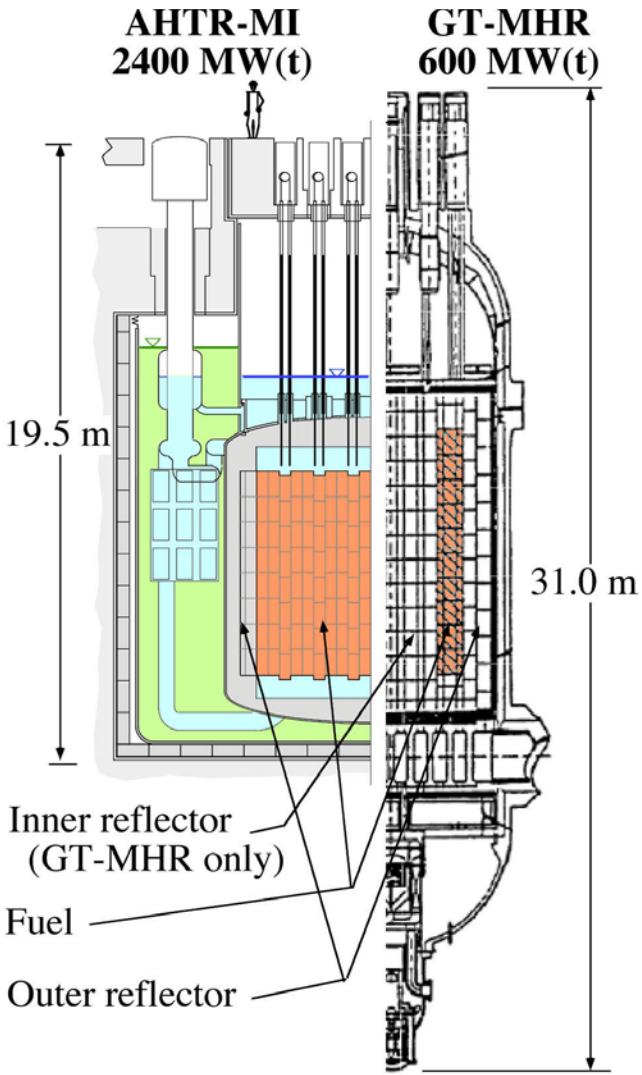
**Brayton Power Cycles**



**High-Temperature Coated-Particle Fuel**

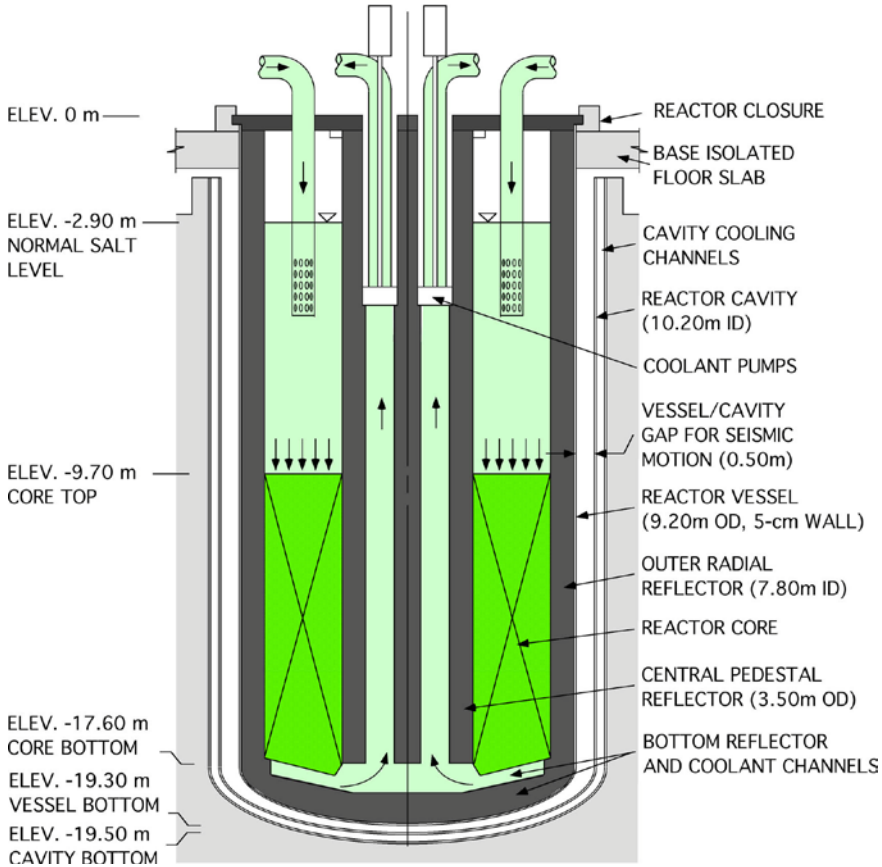
**High-Temperature, Liquid-Salt Coolant**

# AHTR Design Goal - Large Quantities of Low-Cost Energy from a Passively Safe Reactor



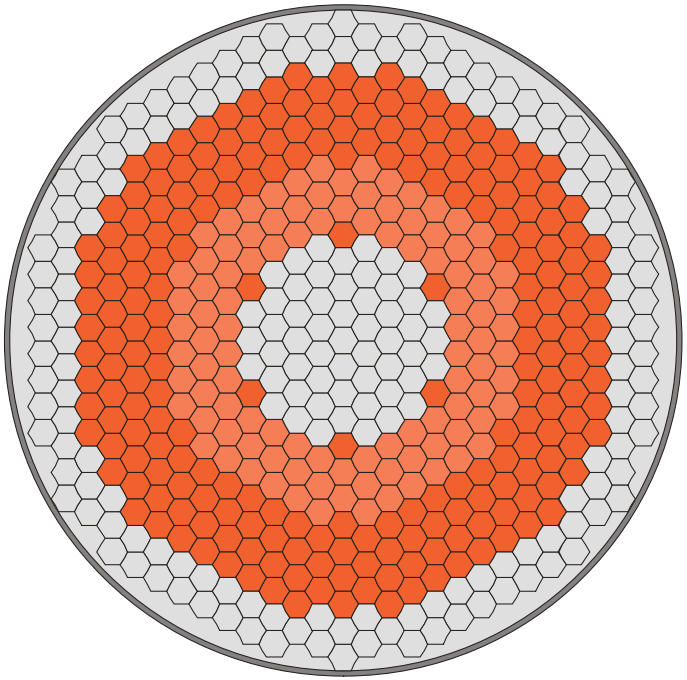

- **Economy of scale employed to minimize power cost**
  - **Capital costs 50 to 60% of those for modular reactor per $kW_{th}$**
  - **Size is grid limited not reactor limited**
  - **High temperature heat available for electricity or industrial processes**
- **Fluoride salt inherent properties enable large-scale decay heat removal**
  - **Incrementally scalable to large size**
  - **Natural circulation driven with fully passive initiation and operation**

# Gas Reactor Core and Fuel Layouts Were the Design Starting Points



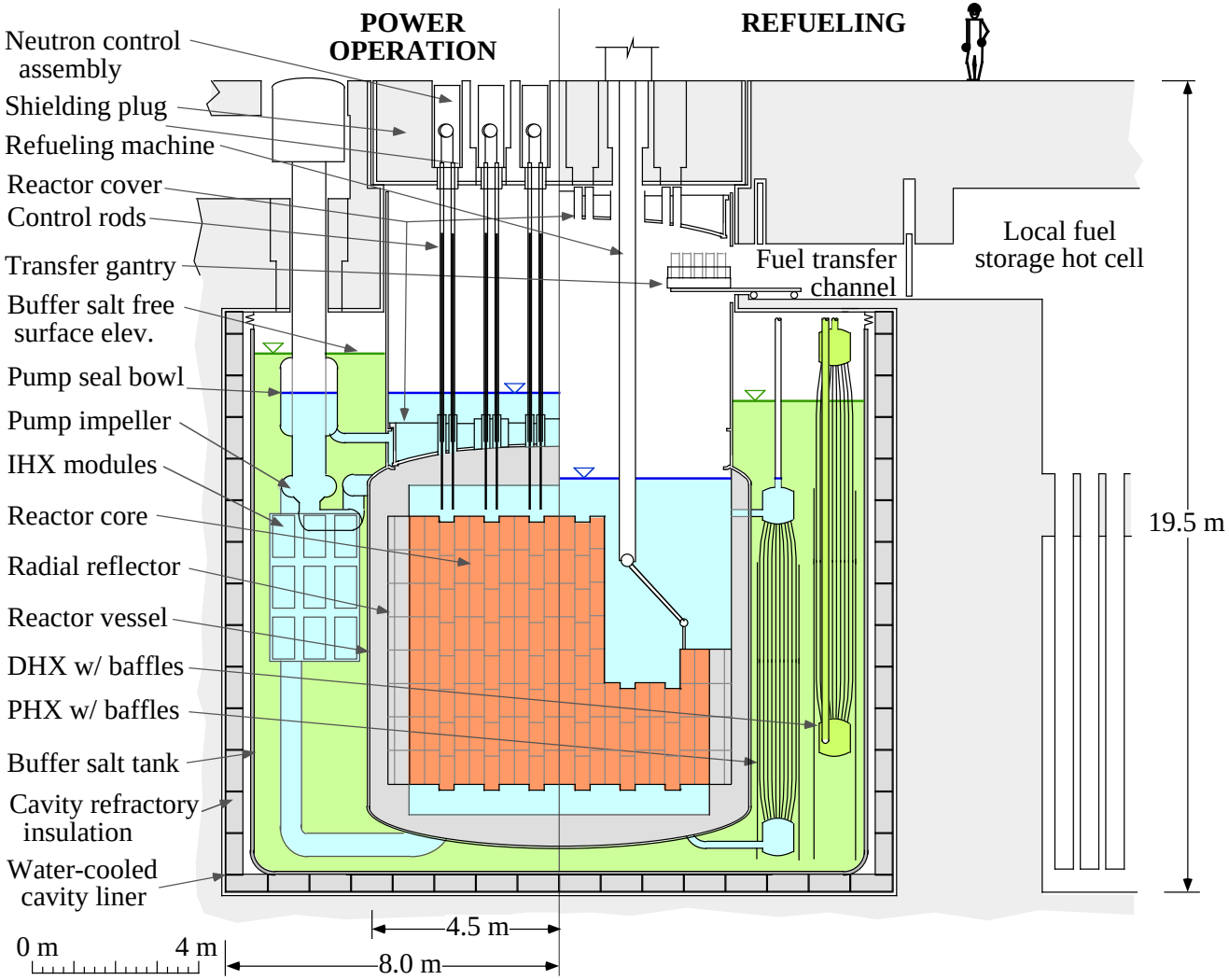

Initial Concept (2001)

**324 Total Fuel Columns**
**8.3 MW/m$^3$ Power Density**



2004 Core Layout

# Initial Design Effort Focused On Establishing Concept Viability



# Multiple Candidate Primary Coolant Salts Were Evaluated

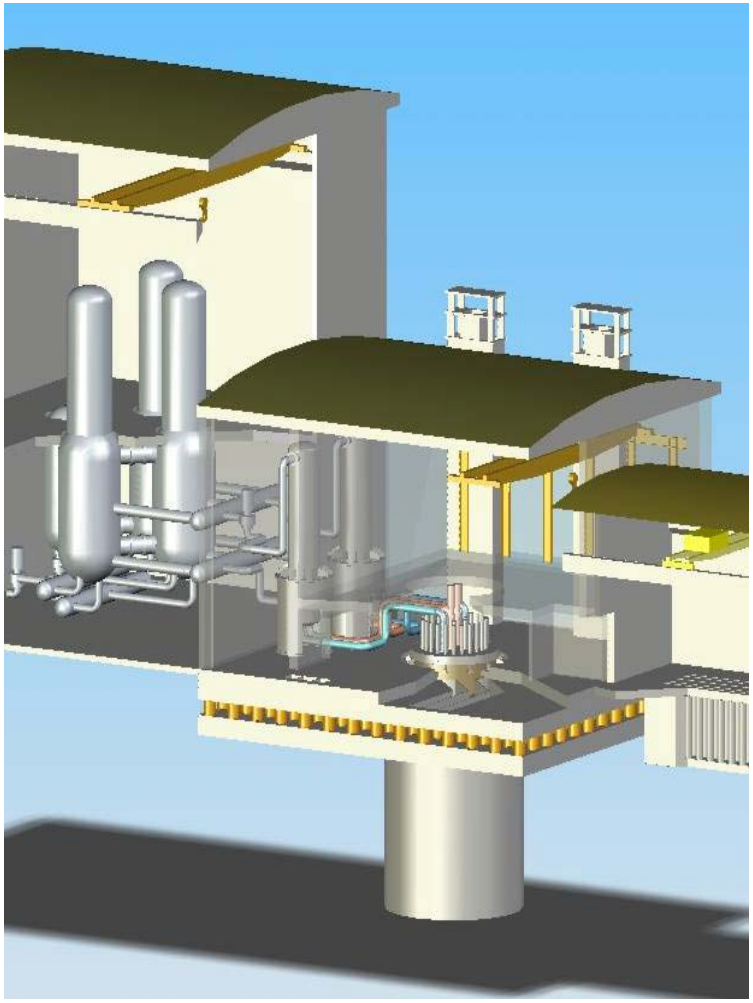
| Fluoride Salt | Composition (Mole %) | Melting Point (ºC) | Pros & Cons |
|---|---|---|---|
| Li-Be | 67-33 | 460 | • Best neutronics and T/H<br>• Experience from MSRE<br>• Be toxicity<br>• High cost of enriched Li-7 |
| Na-Be | 57-43 | 340 | • Low melting point<br>• Lower cost<br>• Be toxicity<br>• Na activation |
| Li-Na-Zr | 26-37-37<br>(42-29-29) | 436<br>(460) | • Low toxicity<br>• Small amount of expensive Li-7<br>• Na activation |
| Na-Zr | 59.5-40.5 | 500 | • Inexpensive<br>• Low toxicity<br>• Experience from ANP<br>• Na activation |
| Na-Rb-Zr | 33-23.5-43.5 | 420 | • Inexpensive<br>• Lower melting point<br>• Max Zr without high $ZrF_4$ vapor pressure<br>• Inferior neutronics |

# Neutronic and Hydraulic Design Were Initial Programmatic Foci

| Parameter | Initial Value | Revised Value |
|---|---|---|
| Coolant salt | $2LiF\text{-}BeF_2$ | $2LiF\text{-}BeF_2$ |
| Li-7 isotopic concentration | 99.995 % | 99.995 % |
| Outlet coolant temperature | 1000°C | **950°C** |
| Inlet coolant temperature | ≥ 850°C | 850°C |
| Reactor vessel diameter | 9.2 m | 9.2 m |
| U-235 enrichment | ≤ 20 % | **15 %** |
| Particle packing fraction | ≤ 30 % | **25 %** |
| Fuel cycle length | ≥ 18 months | **18 months** |
| Discharge burnup | ≥ 100 GWd/t | **156 GWd/t** |
| Fuel shuffling | ≤ 3 batches | **2 batch** |
| Fuel element: | | |
| Fuel channel diameter | 1.27 cm | 1.27 cm |
| Number of fuel channels | 216 | 216 |
| Coolant channel diameter | 0.953 cm | **1.4 cm** |
| Number of coolant channels | 108 | 108 |
| Pitch between channels | 1.88 cm | 1.88 cm |
| Power density | 10.0 $MW/m^3$ | 10.0 $MW/m^3$ |
| Number of fuel columns | 265 | 265 |

- **Current design intent is to start at low end of temperature range (700 °C) and develop upwards**

# Succeeded in Substantiating Significant Promise of AHTR Concept



- **Primary Goals Met:**
  - **High temperature**
  - **Passive safety**
  - **Superior economics**
- **Sound Technology Base**
  - **Combines four established technologies in new way**
  - **Shares key technologies with gas-cooled reactors**
- **Vendor interest**
  - **Economics**
  - **Scalability**

# AHTR Concept Development is Reviving in FY2011

- **DOE funding was terminated abruptly at the end of FY2006**
  - **NGNP leadership dropped many R&D activities in favor of hardware delivery**
- **High temperature nuclear energy technology has been institutionally supported by ORNL**
- **FHR reactor development is now part of Advanced Reactor Concepts program**
  - **Technology development program continuing to support all sizes of FHRs**