Making Core Melt Accidents Impossible In A Large 2400-MW(t) Reactor

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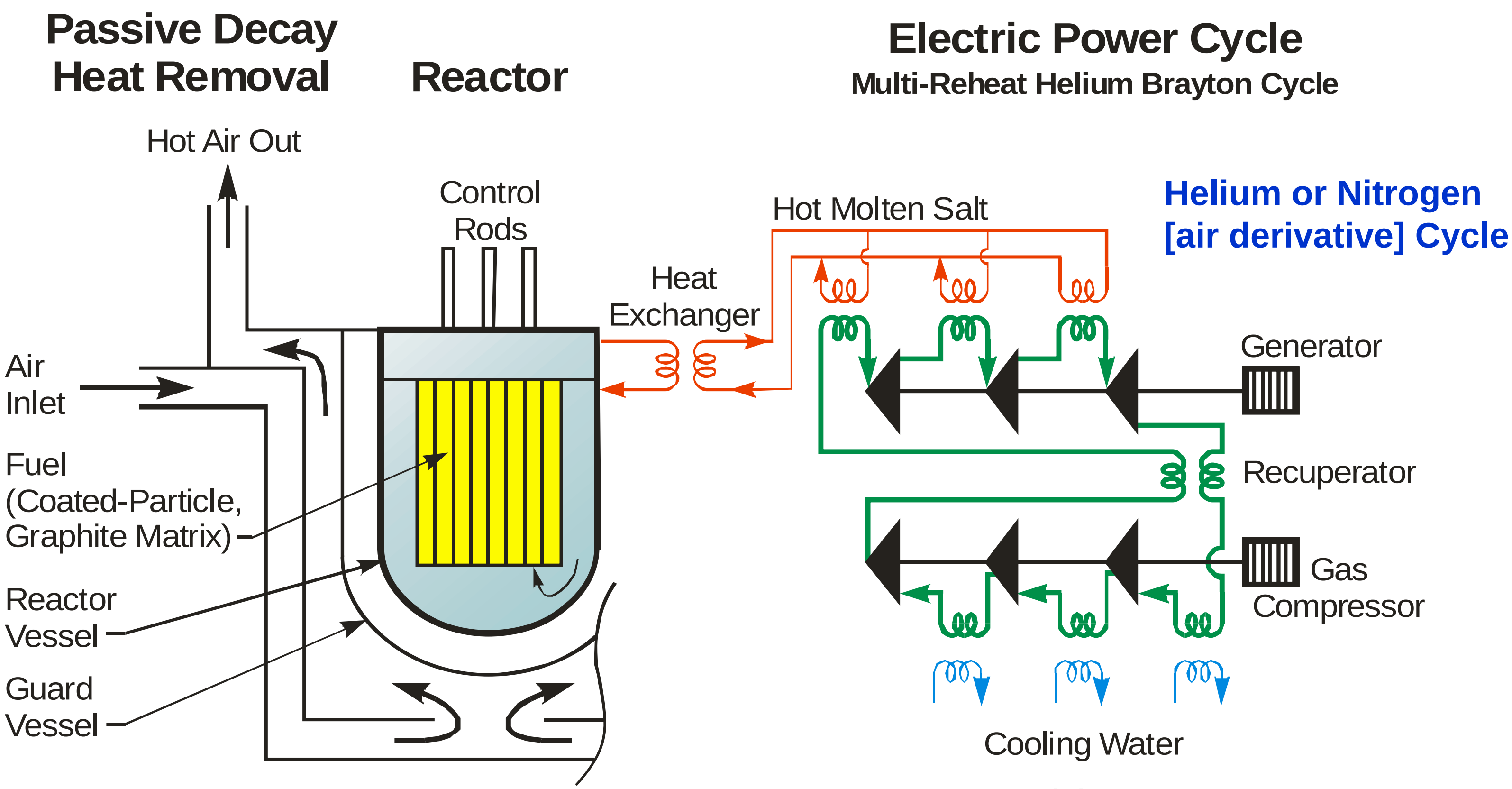
The Advanced High-Temperature Reactor



Efficiency
- 48% at 750° C
- 56% at 850° C
- 59% at 1000° C

Key Reactor Characteristics

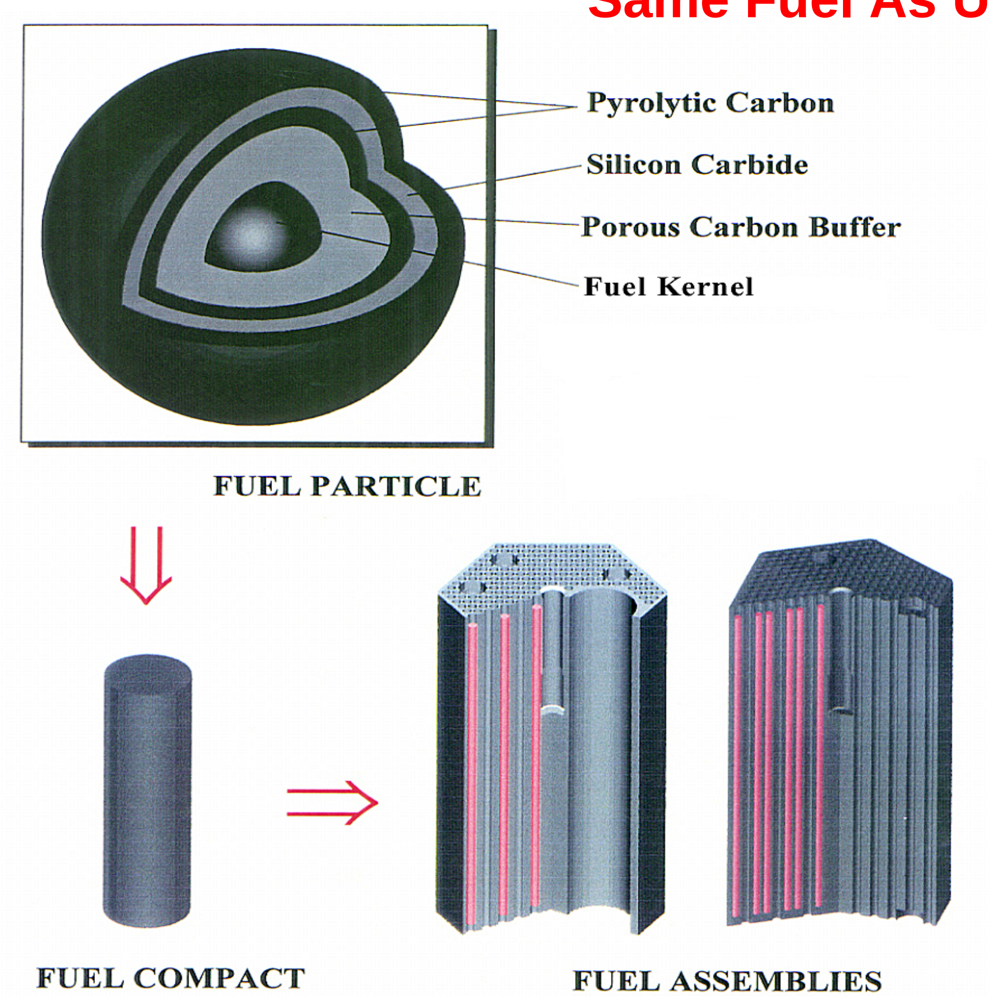
Reactor fuel

Reactor coolant

The AHTR Uses Coated-Particle Graphite Fuels

(Peak Operating Temperature: 1250ºC; Failure Temperature >1600ºC)

Same Fuel As Used in Gas-Cooled Reactors

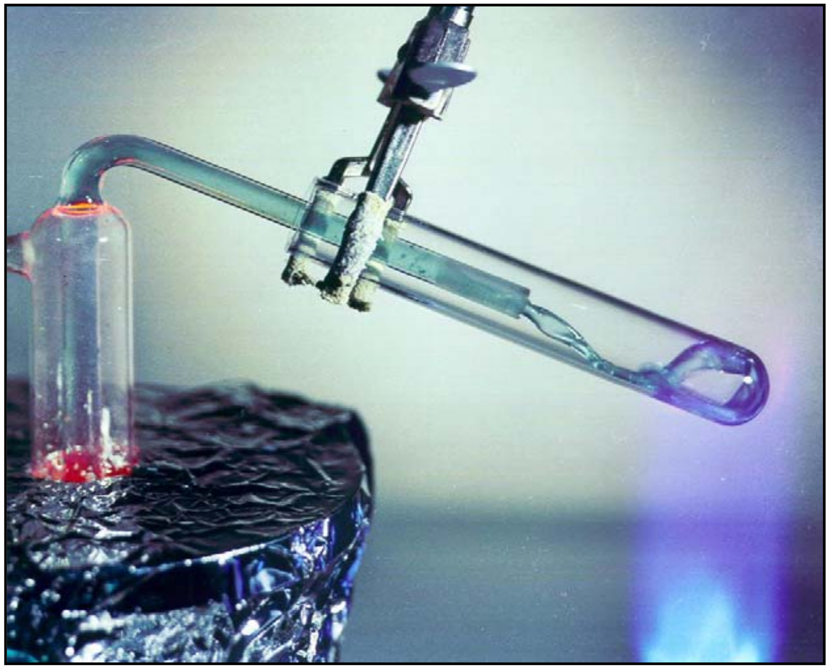


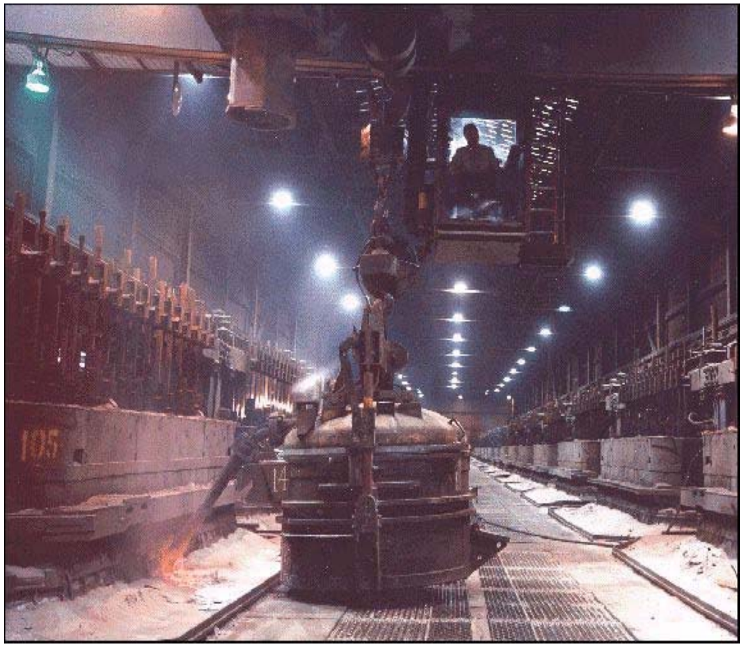
- **Fuel particle with multiple coatings to retain fission products**
- **Fuel compact contains particles**
- **Compacts inserted into graphite blocks**
- **Graphite block supports fuel compacts in arrangement compatible with nuclear reaction and heat transfer to**

The AHTR Uses A *Molten Salt Coolant*

Good Heat Transfer, Low Pressure Operation, In-Service Inspection, and Boiling Point ~1400ºC

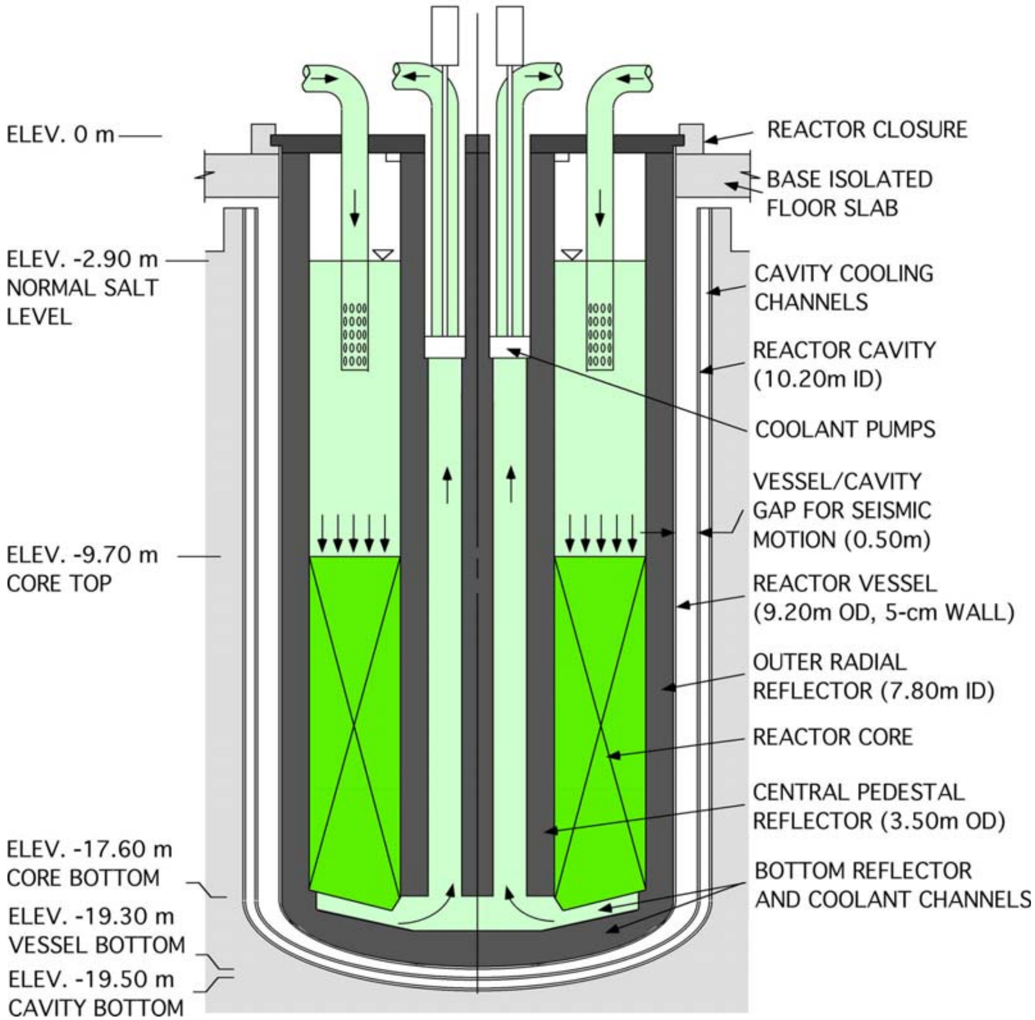
Molten Fluoride Salts Have Been Used in Molten Salt (Fueled) Reactors





Molten Fluoride Salts Used For A Century To Make Aluminum

Conceptual 2400 MW(t) AHTR Design



- **Reactor vessel**
  - **Same size as S-PRISM 1000 MW(t) vessel**
  - **Similar size to 600 MW(t) GT-MHR reactor vessel**
- **Vessel in underground silo**
- **Vessel insulated from molten salt by graphite layer**

Passive Safety

Decay Heat to the Reactor Vessel Wall With Silo Cooling

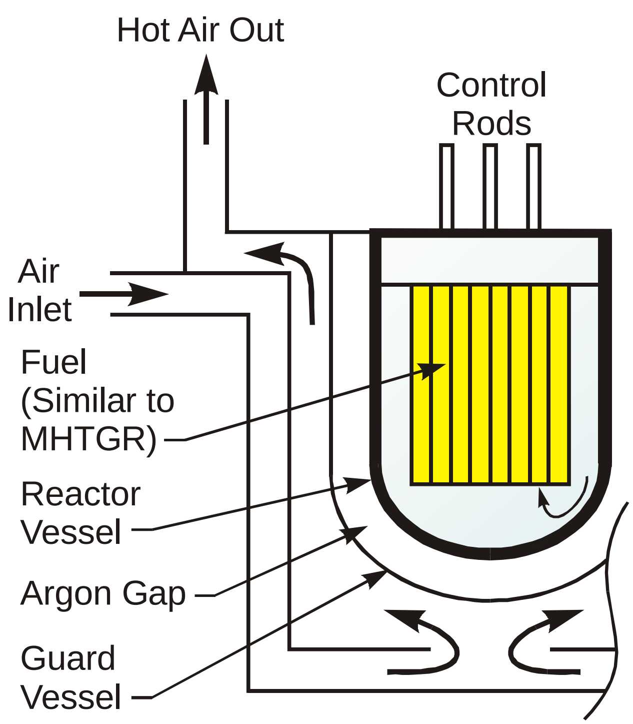
Same approach as Modular High-Temperature Gas-Cooled Reactors and the General Electric Sodium-Cooled Modular S-PRISM

However

Molten Salt Allows Larger Reactor Sizes

In An Emergency, Decay Heat Is Transferred To The Reactor Vessel And Then To The Environment

Passive Decay Heat Removal **Reactor**

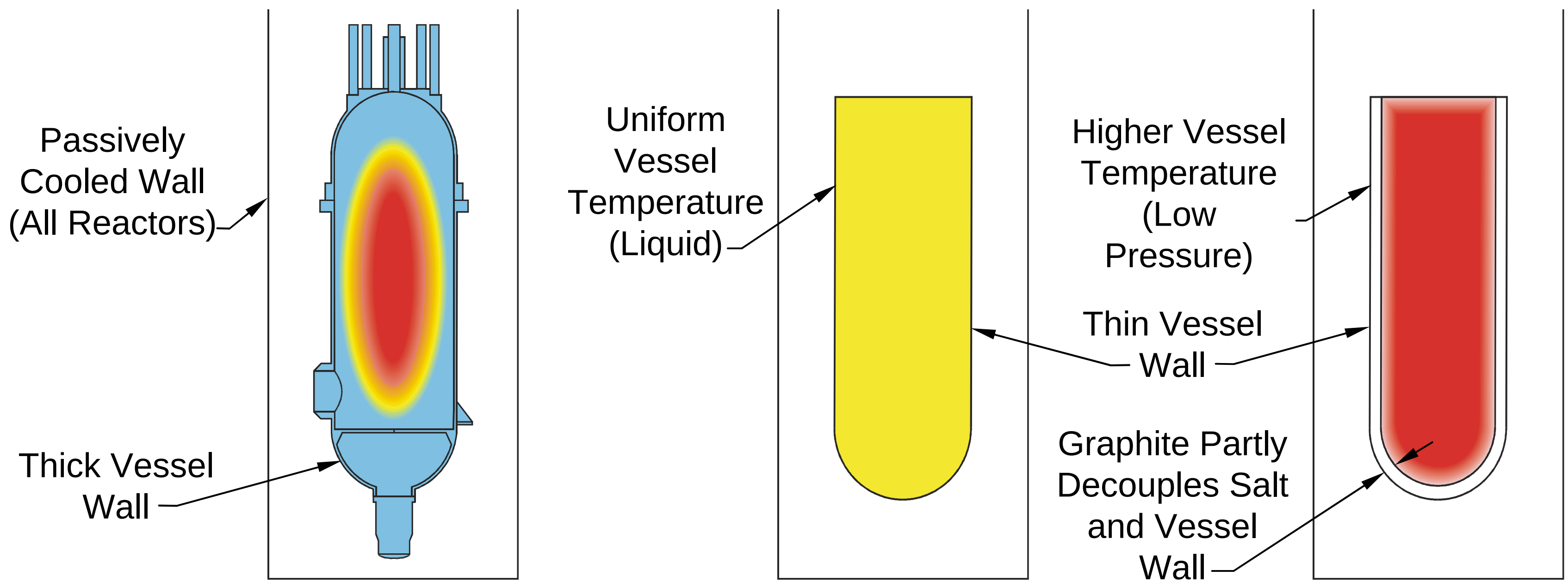


Decay-Heat Cooling System Characteristics

- Similar to GE S-PRISM (LMR)
- Argon Gap
  - Heat Transfer ~T^4
  - Thermal Switch Mechanism
- Heat Rejection: Temperature Dependent
  - LMR: 500-550°C [~1000 Mw(t)]
  - AHTR: 750-1000°C [>2000 Mw(t)]
- High Heat Capacity
  - Molten Salt and Graphite
  - High Temperature (Limited-Insulation of Vessel from Hot Salt)

High-Temperature Low-Pressure Liquid Coolants Enable The Design Of Large Reactors With Passive Safety

Reactor	MHTGR	S-Prism	AHTR
Coolant	Helium	Sodium	Molten Salt
Power	600 MW(t)	1000 MW(t)	>2000 MW(t)
Limitation	Conduction	Sodium Boiling Point	Vessel



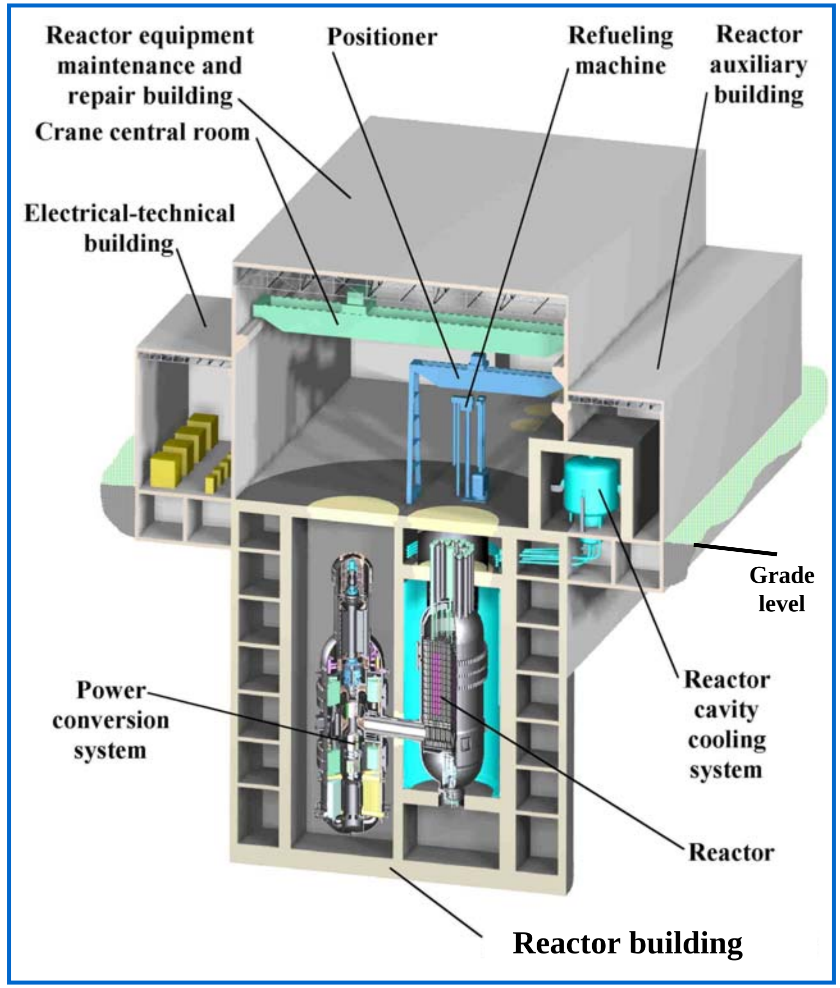
Beyond-Design-Basis Accident (BDBA)

Goal: No major fuel failures after failure of the decay-heat system and structural systems

Same strategy as 600 MW(t) modular high-temperature gas-cooled reactor (MHTGR)

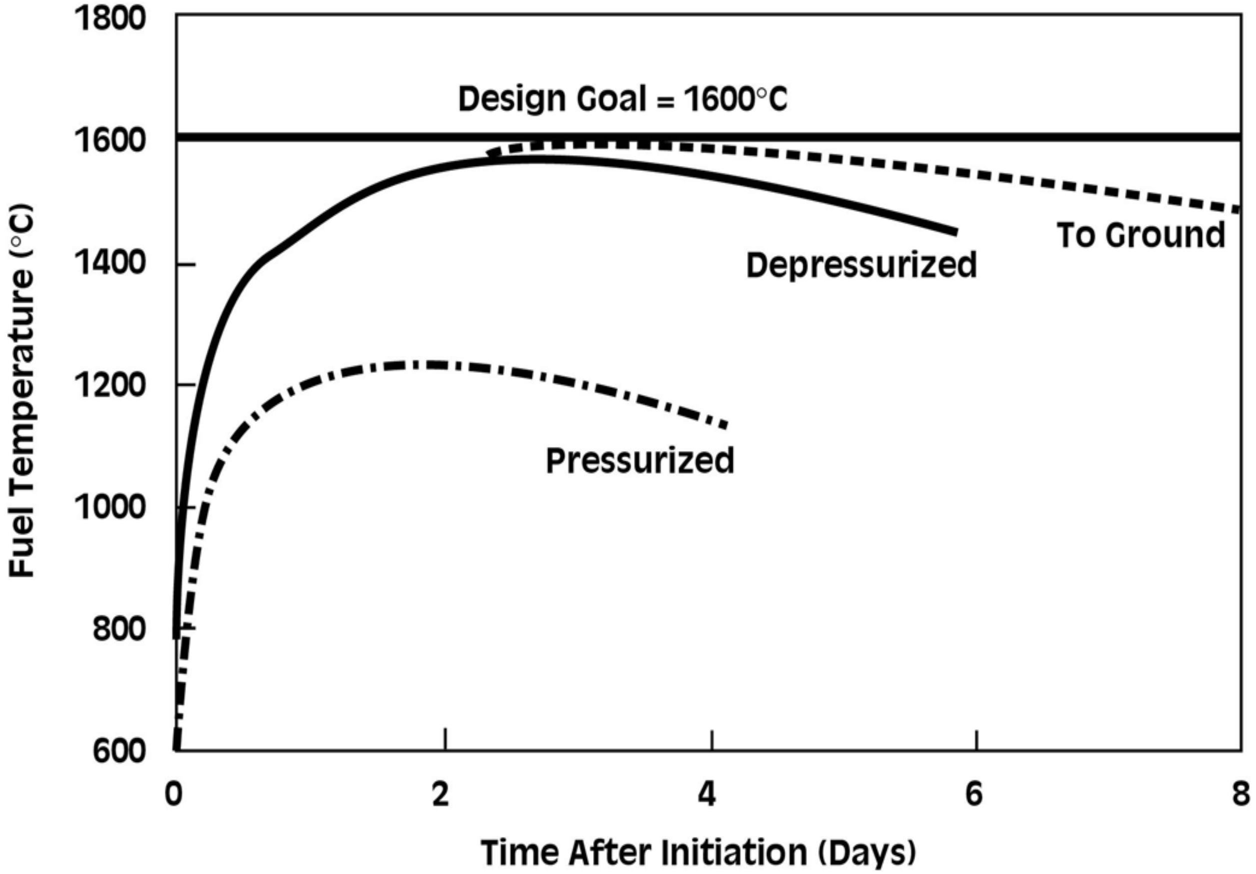
If The Goal Is To Withstand All Accidents, Reactor Size Is limited (MHTGR Example)

- To prevent radionuclide releases, must not have catastrophic fuel failures
- If catastrophic fuel failure is to be prevented, the fuel must not overheat
- Decay heat raises fuel temperature
- Capability to remove decay heat under all circumstances determines the largest reactor that can be built with BDBA safety
- MHTGR (helium cooled) decay heat is conducted to ground in a BDBA



The Maximum Size MHTGR (Gas Cooling) With BDBA Safety Is ~600 MW(t)

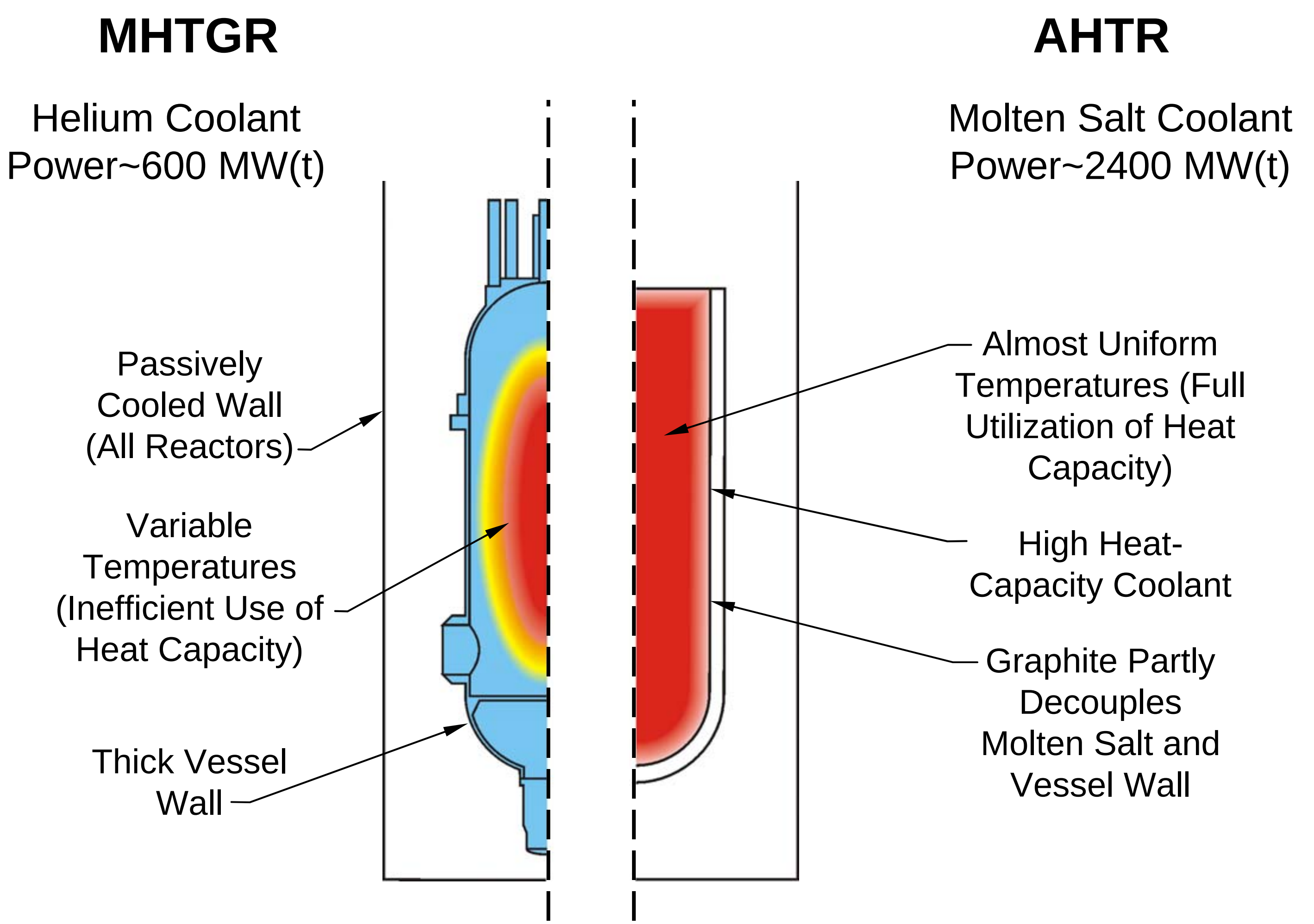
(Fuel Temperature Limit is 1600ºC)



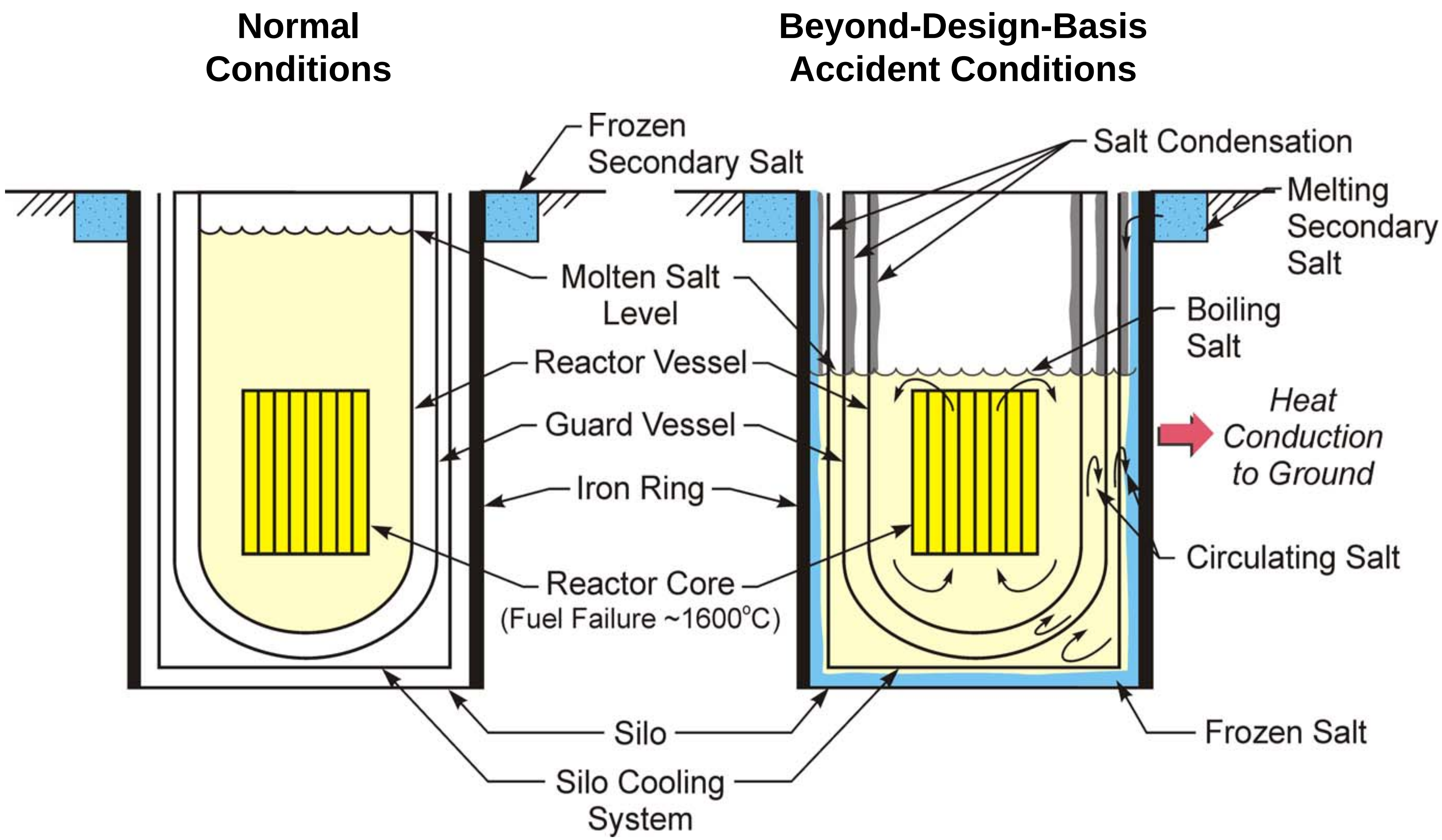
Two Factors Determine The Maximum Size Of A High-Temperature Reactor That Can Withstand A BDBA Accident

- **Reactor system heat capacity**
- **Efficiency in heat rejection to the environment**

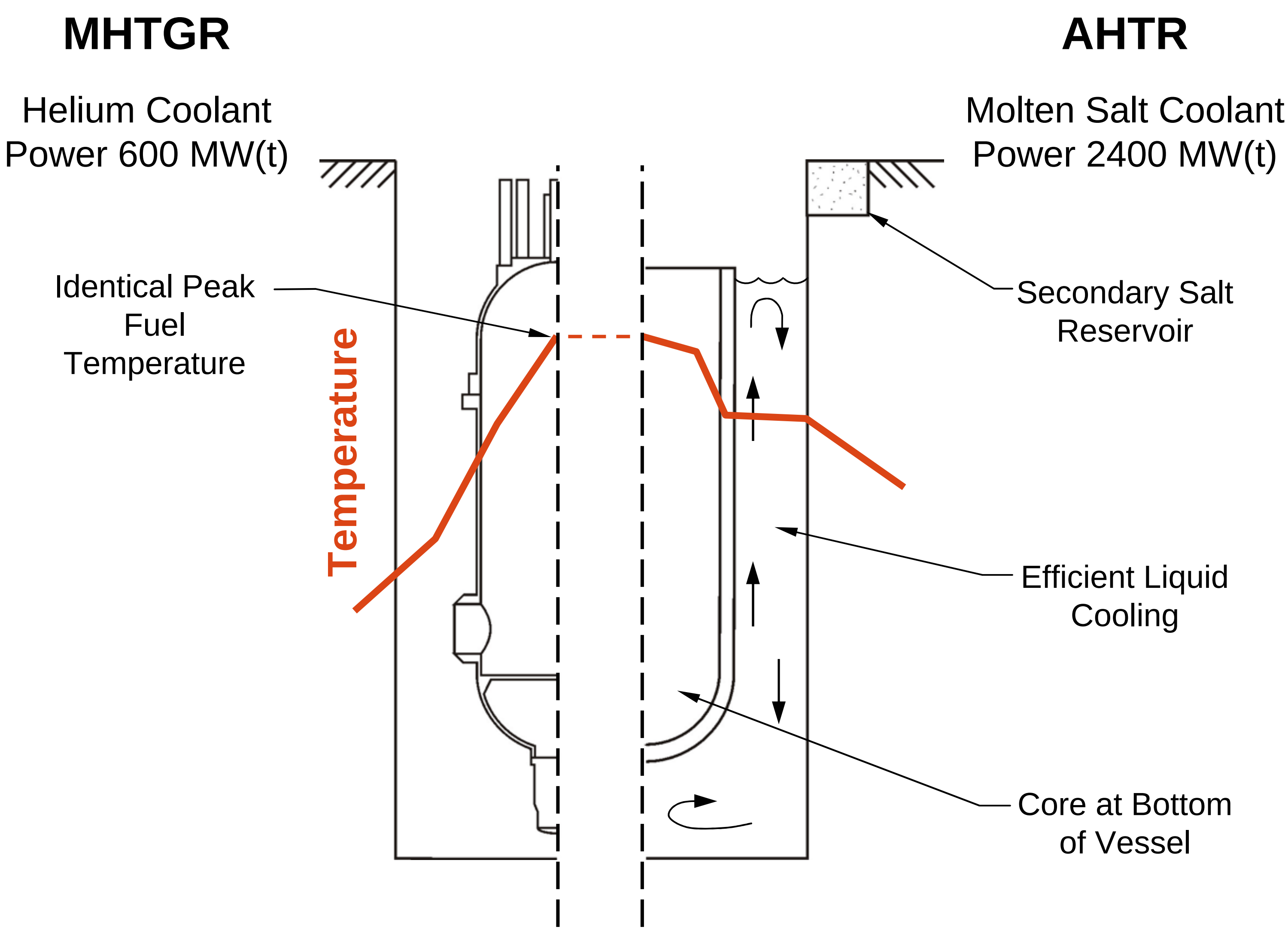
The MHTGR (600 MW(t)) And AHTR (2400MW(t)) Have Similar Decay-Heat Vessel Heat-Up Rates



Beyond-Design-Basis Accident Avoids Catastrophic Fuel Failure By Decay-Heat Conduction To The Environment



Liquid Cooling Results In More Efficient Heat Transfer To The Silo Wall



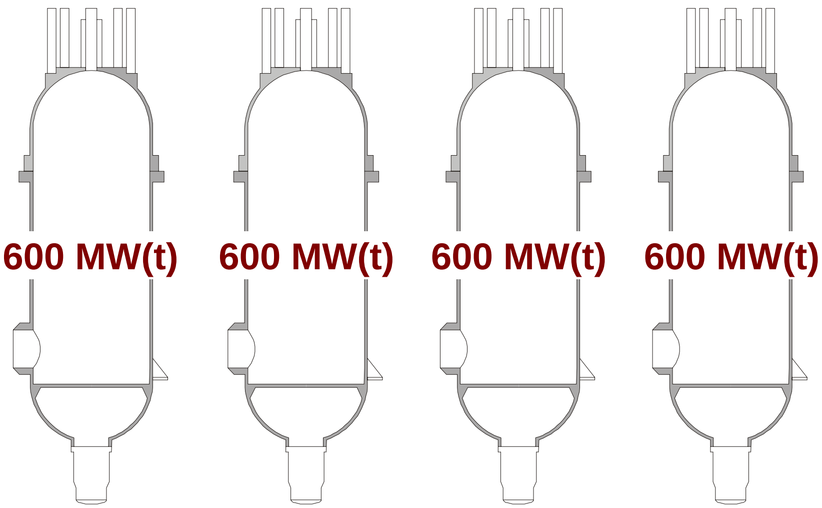
Economics

Larger Reactors Have the Potential for Lower Capital and Operating Costs

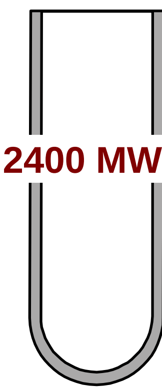
If Equivalent Safety Case, Strong Incentives for Building Large Reactors

Equipment Comparisons Suggest AHTR Capital Cost Per MW(t) Is Less Than A Modular Reactor

Pressure Vessels For 2400 MW(t) of HTGRs



Low-Pressure Vessel For 2400 MW(t) of ATGR



Simple scaling laws estimate AHTR per kilowatt capital costs at 60% of a Modular High Temperature Gas-Cooled Reactor

Conclusions

- **AHTR goals**
  - **Improve economics with larger high-temperature reactor**
  - **Same passive safety basis as modular reactors**
    - **Passive decay-heat removal**
    - **BDBA decay heat removal (no catastrophic fuel failure)**
- **Technology based on**
  - **High-temperature fuel (Failure temperature >1600ºC)**
  - **Low-pressure high-temperature coolant**
- **New reactor concept**
  - **Early in development**
  - **Major uncertainties**

BACKUP SLIDES

The Advance High-Temperature Reactor

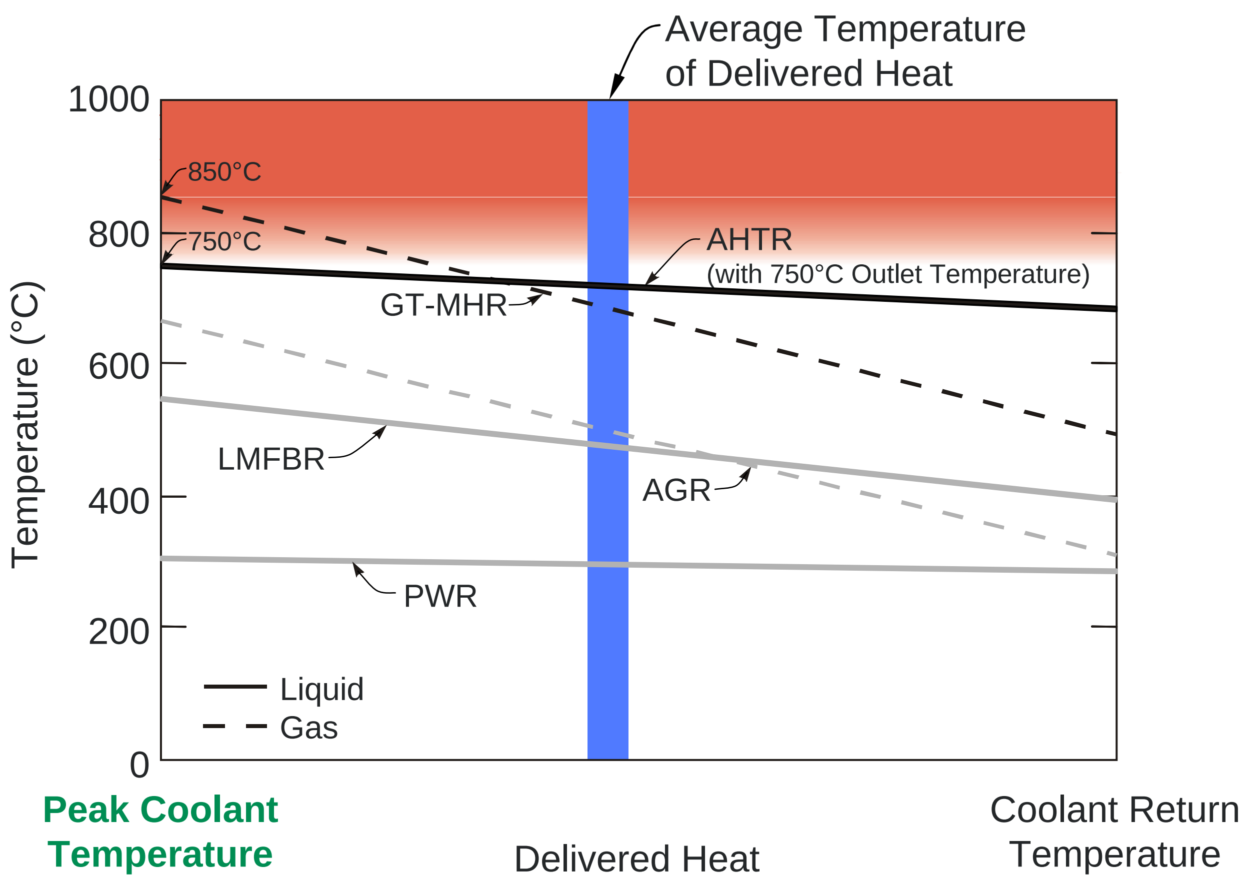
A Large, Passively Safe, High-Temperature Reactor for Electricity and Hydrogen Production

- **Large Reactor (>2000 MW(t)) to Improve Economics**
- **Passive Safety**
  - **Passive decay heat cooling**
  - **Fuel to survive beyond-design-basis accidents**

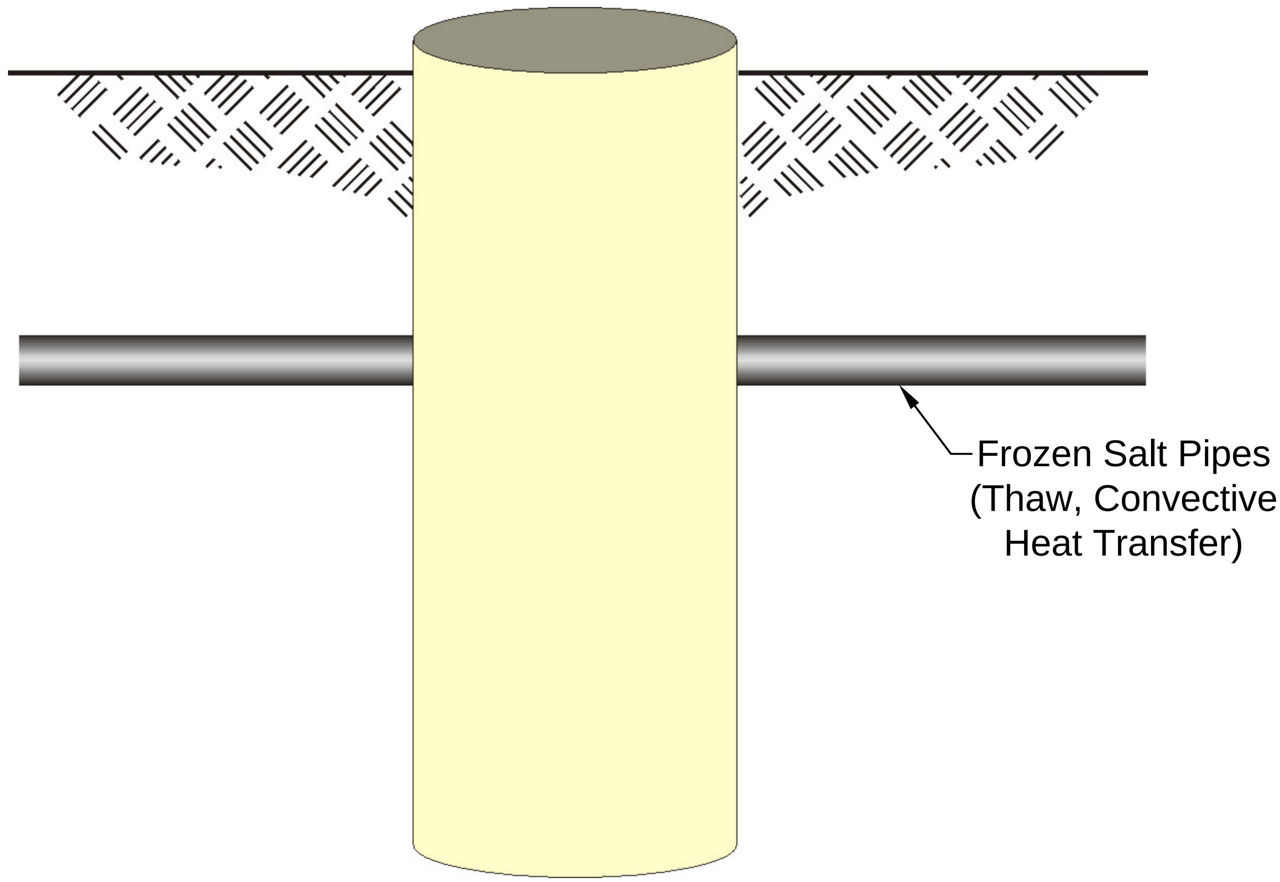
High-Temperature Reactors

	AHTR	*VHTR (Helium)*
Fuel	**Coated Particle**	**Coated Particle**
Neutronics	**Epithermal**	**Epithermal**
Power Cycle	**Helium Brayton**	**Helium Brayton**
Safety System	**Passive**	**Passive**
Coolant	***Molten Salt***	***Helium***
Pressure	**Atmospheric**	**High Pressure**
Power Level	**2400 MW(t)**	**600 MW(t)**

AHTR Lowers Peak Coolant Temperatures For A Given Temperature Of Delivered Heat



Many Options Exist To Boost Decay Heat Removal With A Silo Full Of Molten Salt



Potential for Better Economics Than Light-Water Reactors

- **Potential economic advantages of AHTR**
  - **Higher thermal-electric efficiency (50% versus 33%)**
    - **Fuel savings**
    - **Smaller secondary systems**
  - **Brayton helium cycle (Smaller than steam turbine)**
  - **Low pressure containment**
- **But no definitive economic comparison**
  - **LWR technology is significantly different; thus, simple scaling comparisons can not be made**