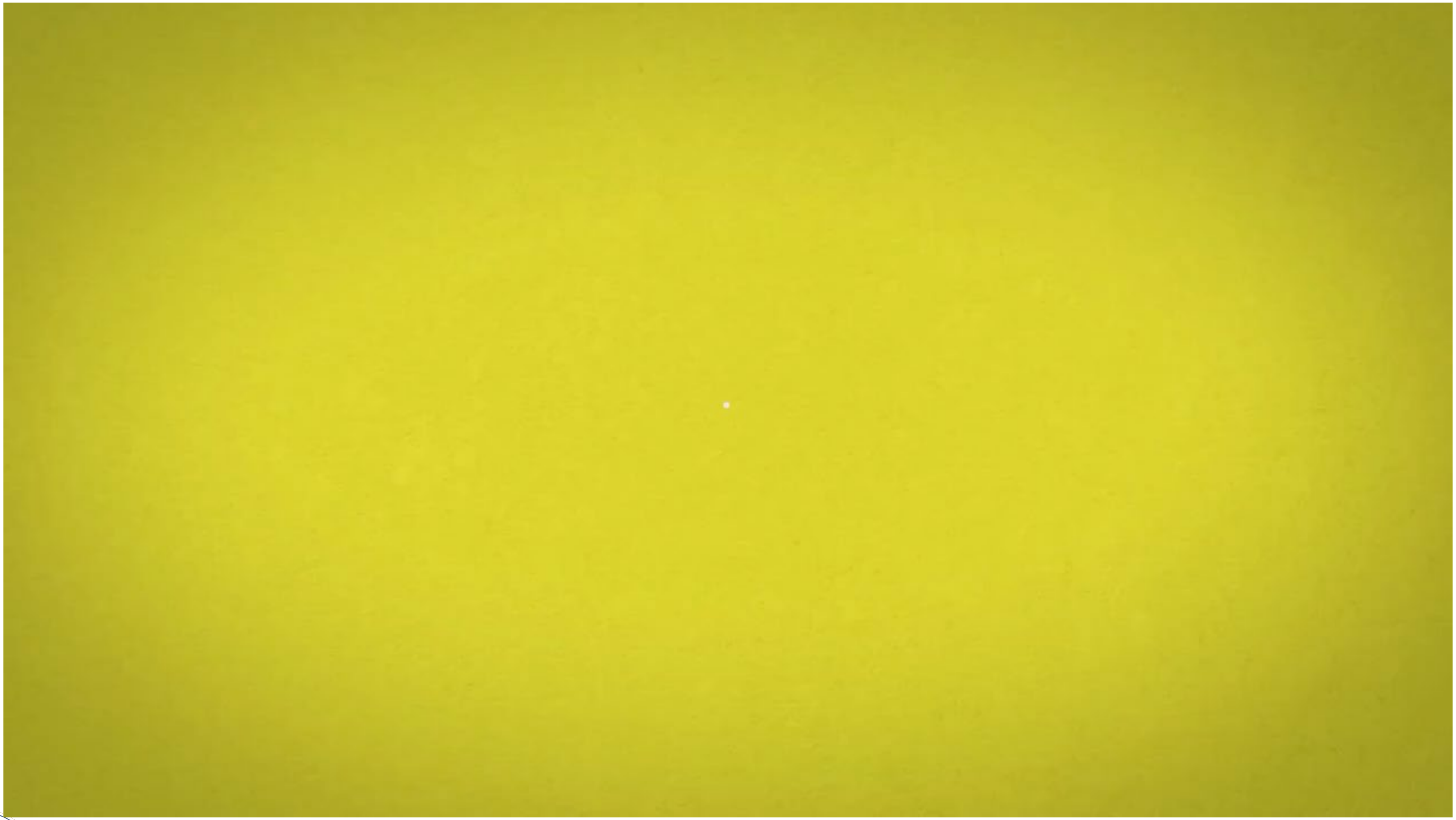
Chemical Engineering 612

Reactor Design and Analysis

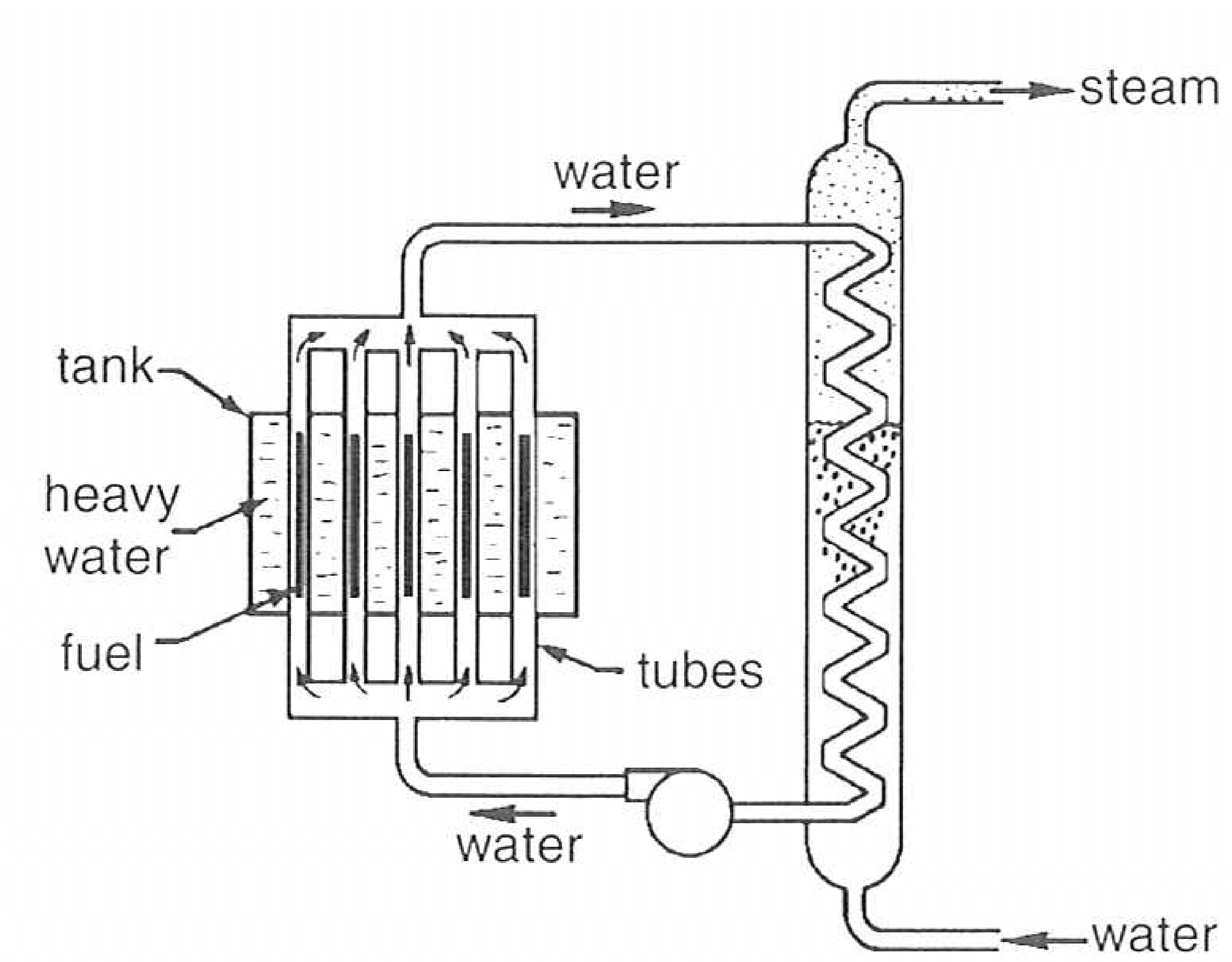
Lecture 10

Nuclear Reactor Concepts II

Spiritual Thought



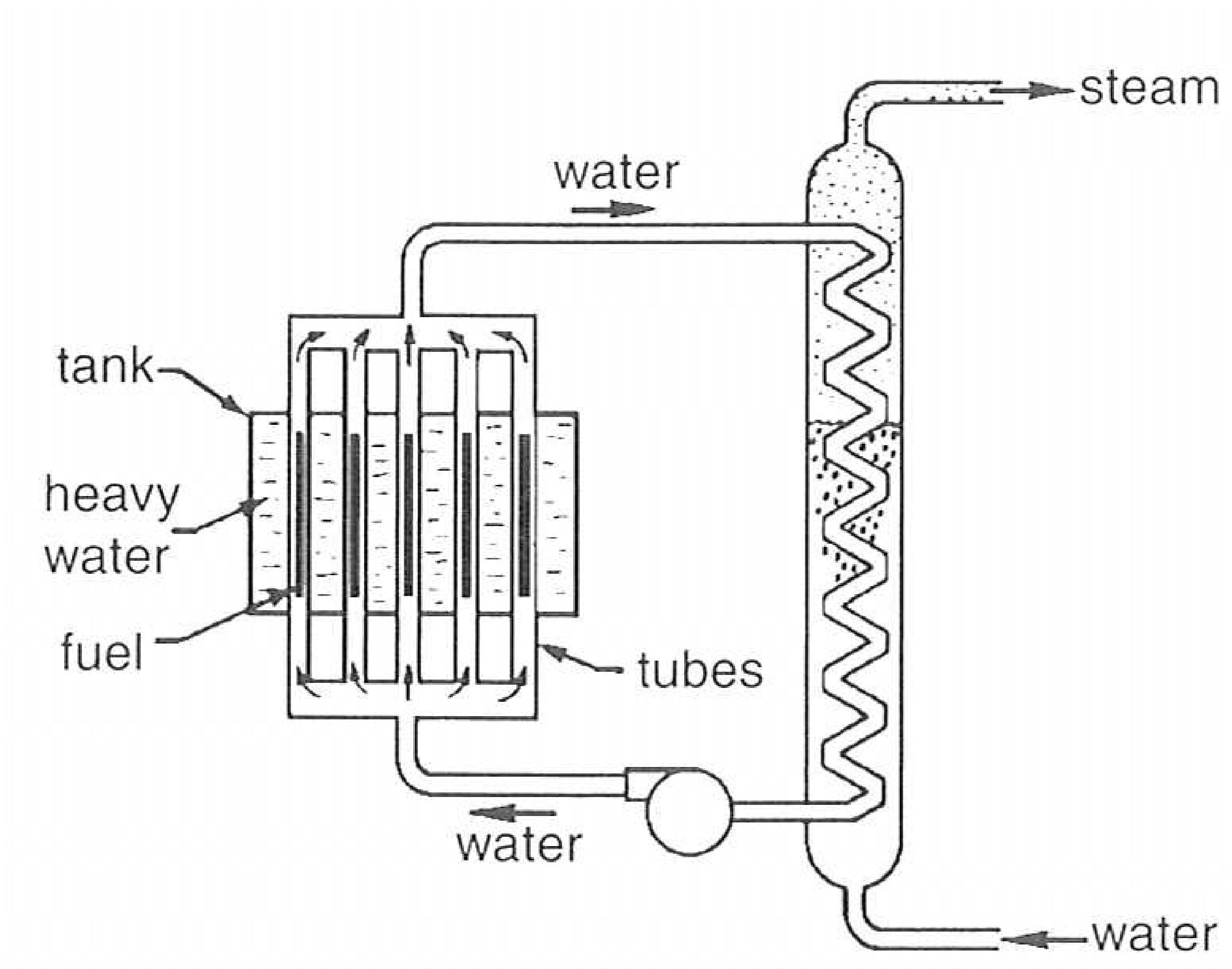
Heavy Water Reactor (PHWR)



Liquid Metal Fast Breeder Reactor (LMFBR)

- Fast-neutron-based reactor scheme.
- No moderator (no light elements).
- Na or K-Na molten metal used as coolant.
- No pressurization, very high heat transfer coefficients.
- Na becomes radioactive and Na and K react violently with water (moderately with air).
- Second Na heat exchanger isolates Na/K coolant in core from turbine steam.
- New fuel to consumed fuel ratio raises from 0.6-0.8 in typical reactors to over 1 if designed as a breeder reactor.
- One in commercial operation (in Russia), though they are aggressively pursuing new designs.

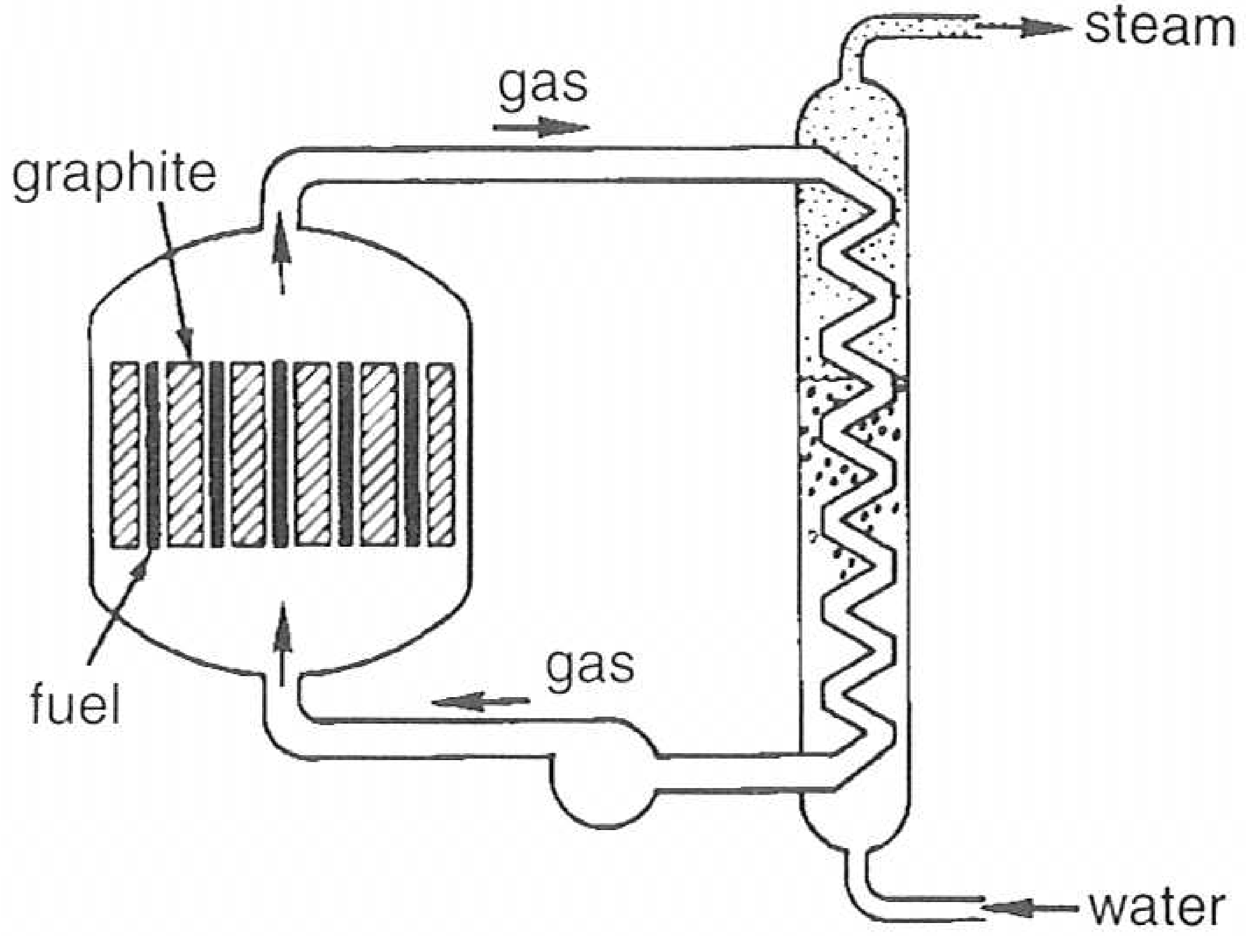
Heavy Water Reactor (PHWR)



Heavy Water Reactor

- Heavy water (deuterium- or tritium-based water) passes through pressurized fuel tubes surrounded by a non-pressurized heavy water bath.
- Operates on natural uranium
- Avoids pressurized reactor vessel (major expense).
- Steam generated in second loop.
- Basis of the CANDU (Canadian) reactor designs.
- Variant is the heavy-water-moderated, light-water-cooled reactor (HWLWR) that uses light water in the fuel tubes and no heat exchanger.

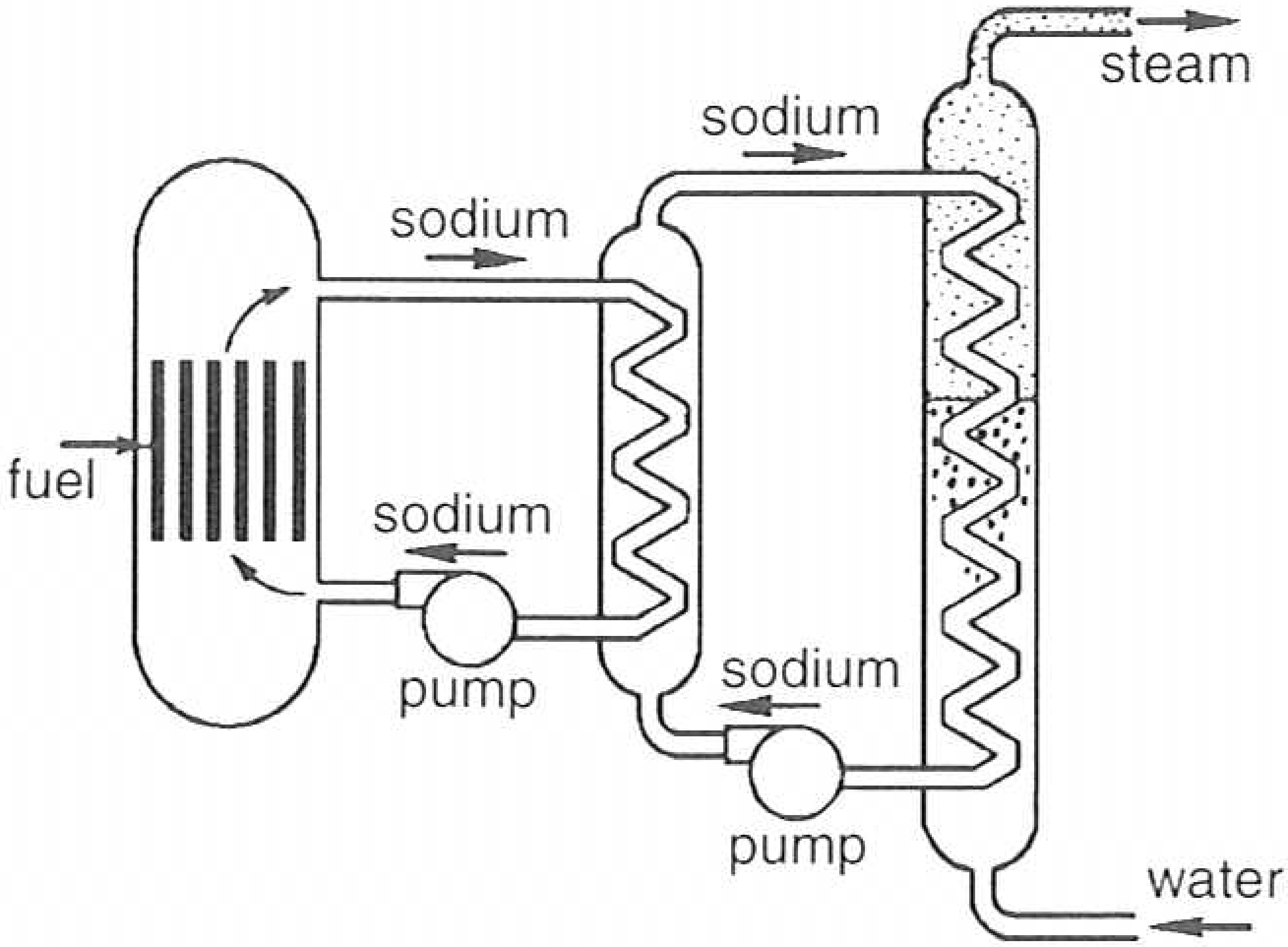
Gas-cooled Reactor (GCR)



Gas-cooled Reactor (GCR, HTGR)

- Gas (He or CO_2) used as coolant.
- Graphite typically used as moderator.
- Graphite (which remains solid) and gas need not be pressurized
  - No expensive pressure vessel
  - No Blowdown in accident
- Gas heats steam in secondary loop.
- In a gas-cooled reactor (GCR), gas passes through holes in graphite moderator.
- In a high-temperature gas-cooled reactor (HTGR), fuel channels and gas channels are drilled in graphite core.

Liquid-metal fast breeder reactor



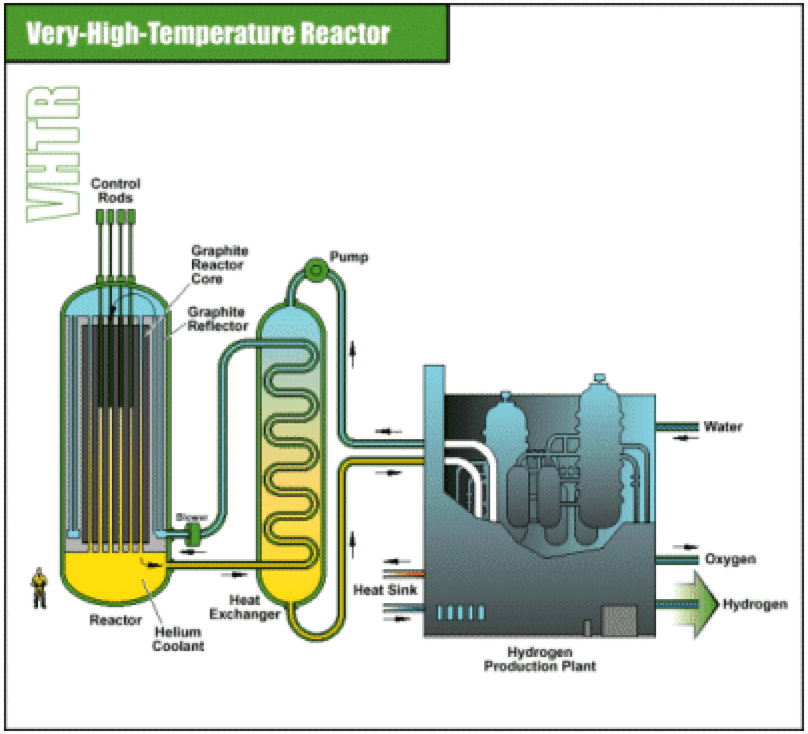
Liquid Metal Fast Breeder Reactor (LMFBR)

- Fast-neutron-based reactor scheme.
- No moderator (no light elements).
- Na or K-Na molten metal used as coolant.
- No pressurization, very high heat transfer coefficients.
- Na becomes radioactive and Na and K react violently with water (moderately with air).
- Second Na heat exchanger isolates Na/K coolant in core from turbine steam.
- New fuel to consumed fuel ratio raises from 0.6-0.8 in typical reactors to over 1 if designed as a breeder reactor.
- One in commercial operation (in Russia), though they are aggressively pursuing new designs.

Small Modular Reactors

- Small is < 300 MW_e (IAEA definition) or < 500 MW_e (conventional definition).
- Modular means systems can be almost entirely fabricated in shops rather than on site, decreasing security and other risks.
- Primary advantage is decrease in capital cost, reducing financial risk, construction at a single location, ability to add incremental power.
- Primary disadvantage is loss of economies of scale. Four small reactors are more expensive to build and operate than one large reactor of equivalent size.
- Include III, III+, and IV or other designs

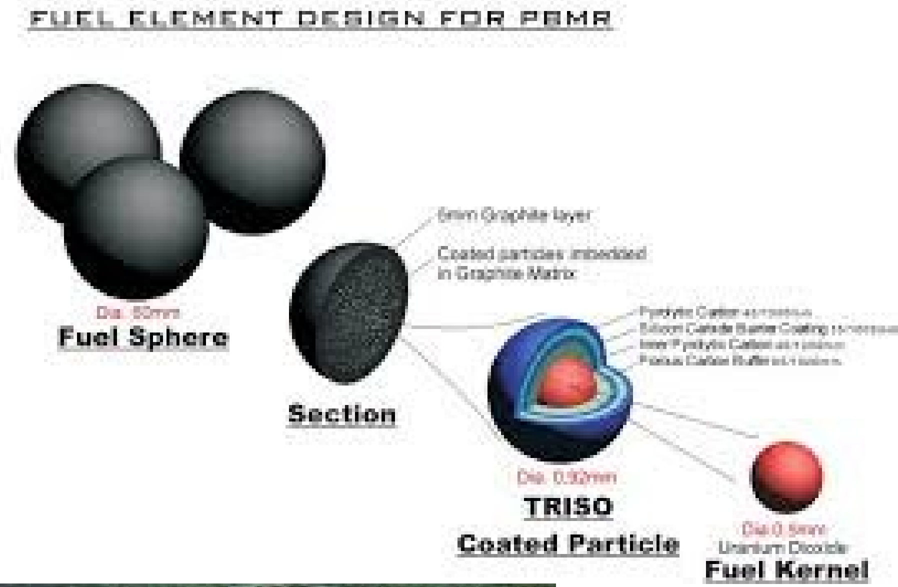
Very-High Temperature Reactor

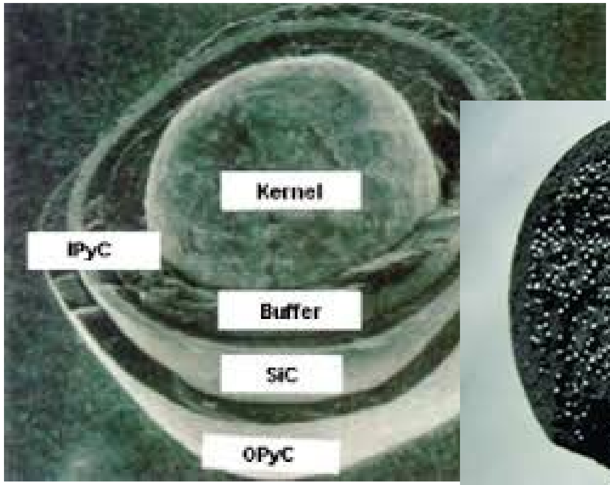


- Graphite-moderated core
- Once-through U fuel cycle
- 1000 ° C steam outlet temperature
- Possible H_2 production

VHTR Fuel

- TRISO fuel
  - Man tiny pellets into graphite matrix sphere
  - Melt-down proof
  - Failure specs?
- Susceptible to air-ingress accidents (fire)
- Also used in FHR

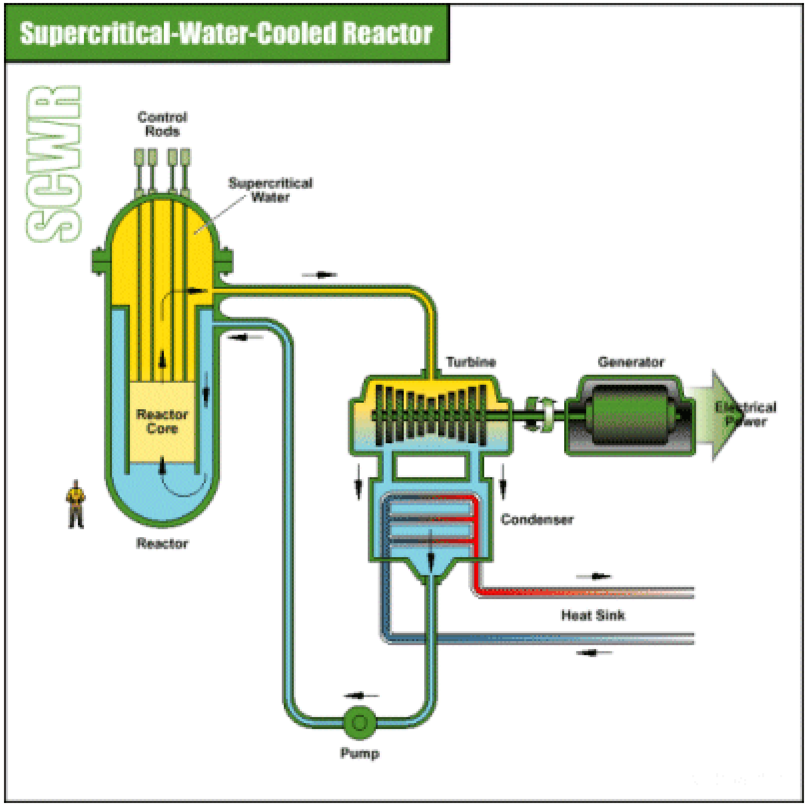




X Energy Xenith Mobile Unit, 100MW

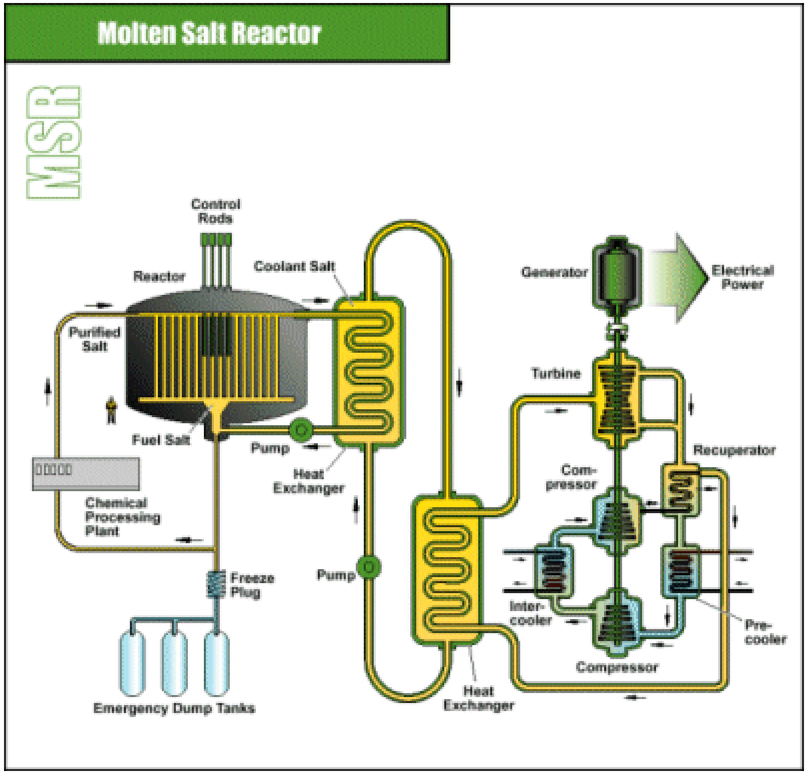
Radient Energy – Kaleidos

Supercritical-Water-Cooled Reactor



- SC Water (> 240 atm) for working fluid (similar to most modern coal boilers)
- 45% efficiency (compared to 33% in most current technologies)
- Combines LWR and fossil technology.

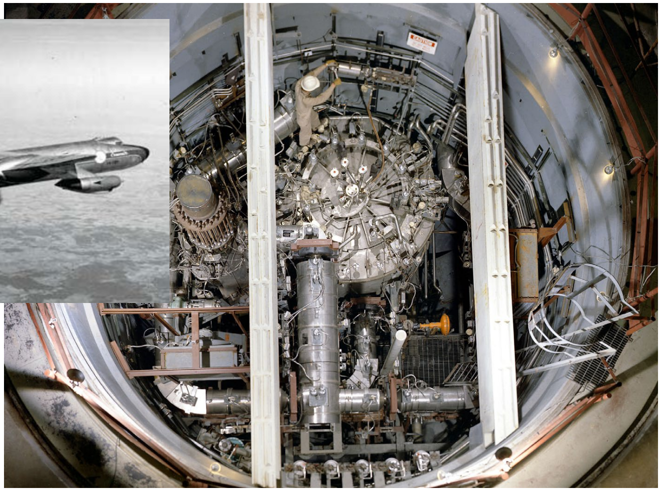
Molten Salt Reactor



- Low-pressure, high-temperature core cooling fluid
- Fuel either dissolved in salt (typically as UF_6) or dispersed in graphite moderator.
- Perhaps gas-driven (He) turbine.

MSR Fuel

- Liquid fuel
  - UF4
  - Suspended Directly in Salt
- No melt-down (already liquid)
- Fission products in coolant
  - COMPLEX chemistry
  - Online separation
  - Unknown behavior of salt



FLiBe Energy

LFLEUR

Lithium Fluoride Low Enriched Uranium Reactor

LFLEUR is designed to run on a commercially available fuel cycle that is accessible today. This provides an important step in accelerating the deployment of molten salt reactors across the world.

Learn More >

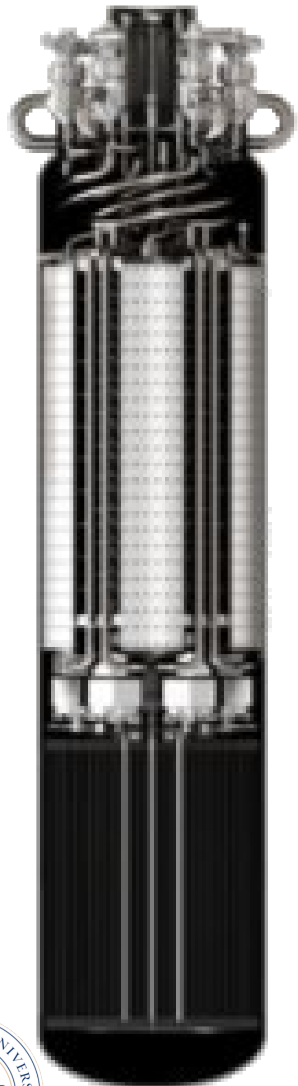
LFTR

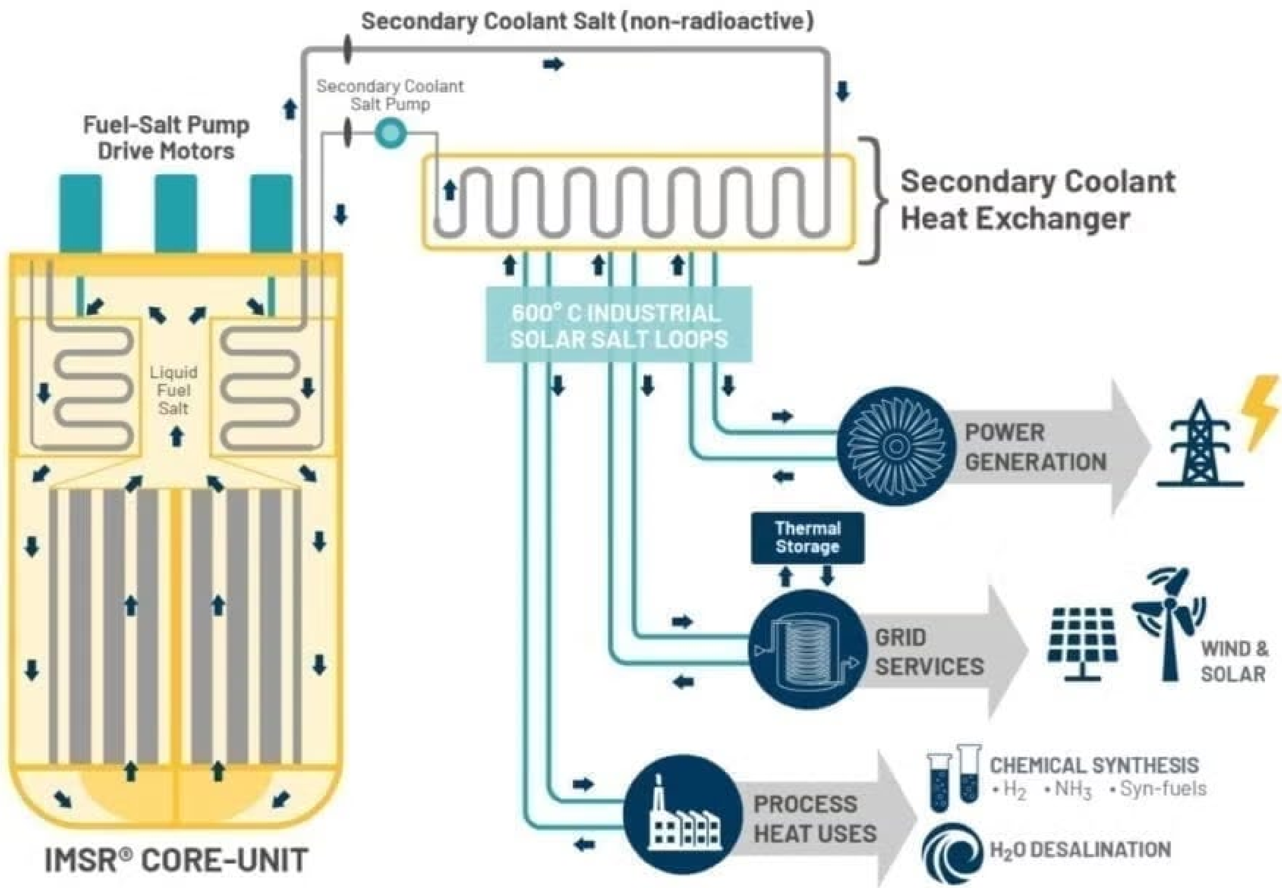
Lithium Fluoride Thorium Reactor

LFTR is designed to take full advantage of the thorium fuel cycle, bringing many benefits over competing designs. LFTR is the long-term solution for a scalable nuclear future.

Learn More >

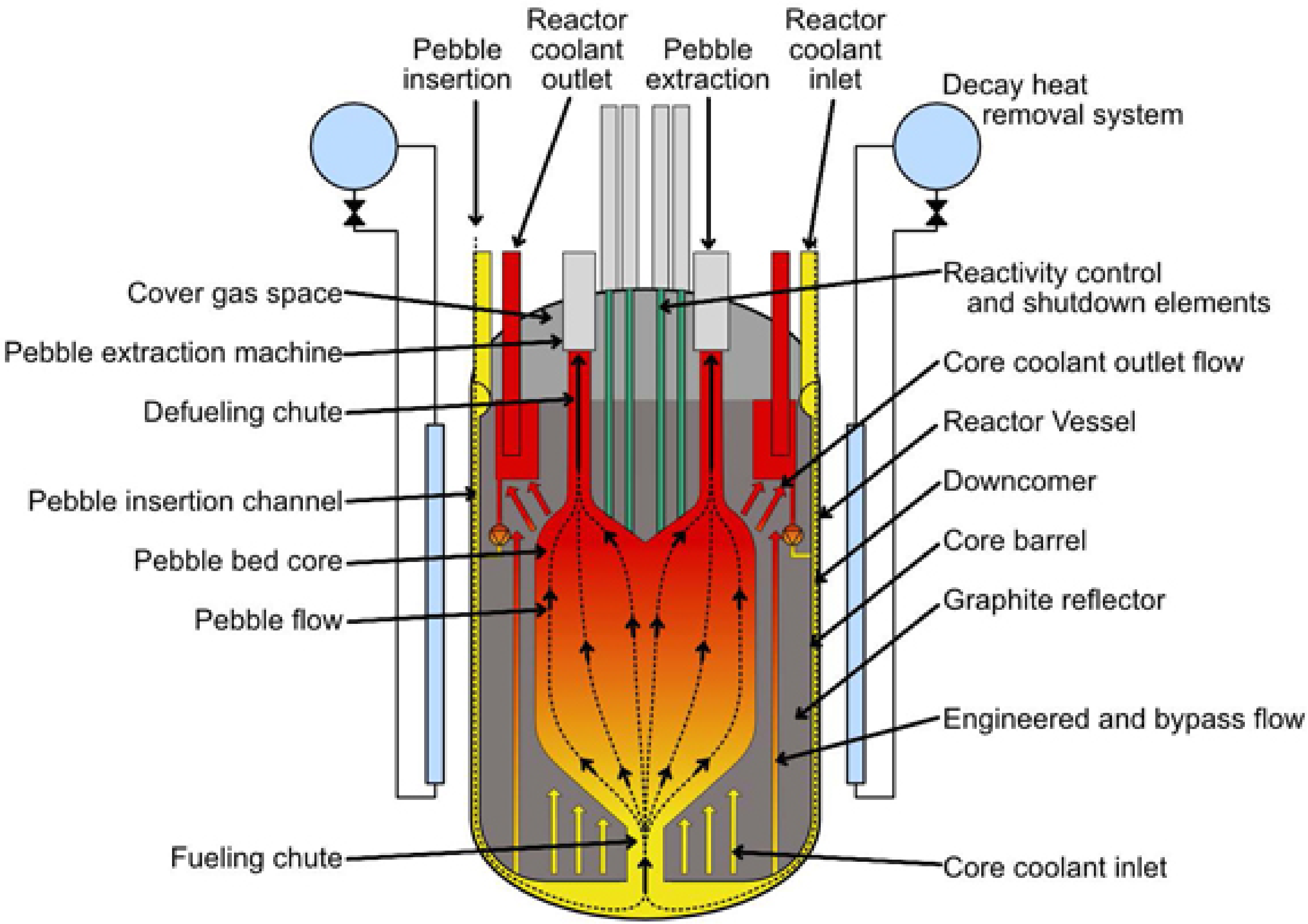
Terrestrial Energy – IMSR





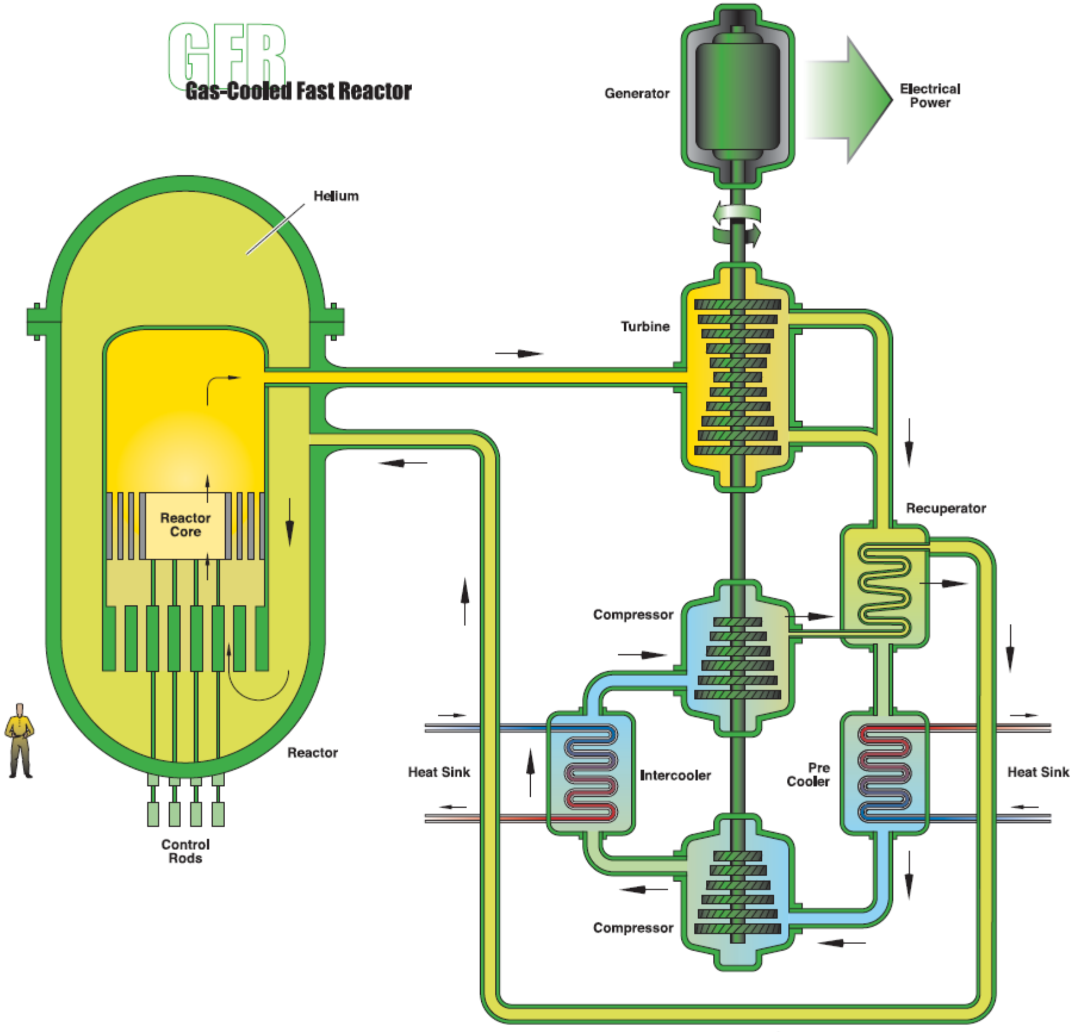
The Replaceable IMSR® Core-unit

Kairos Power – Hermes



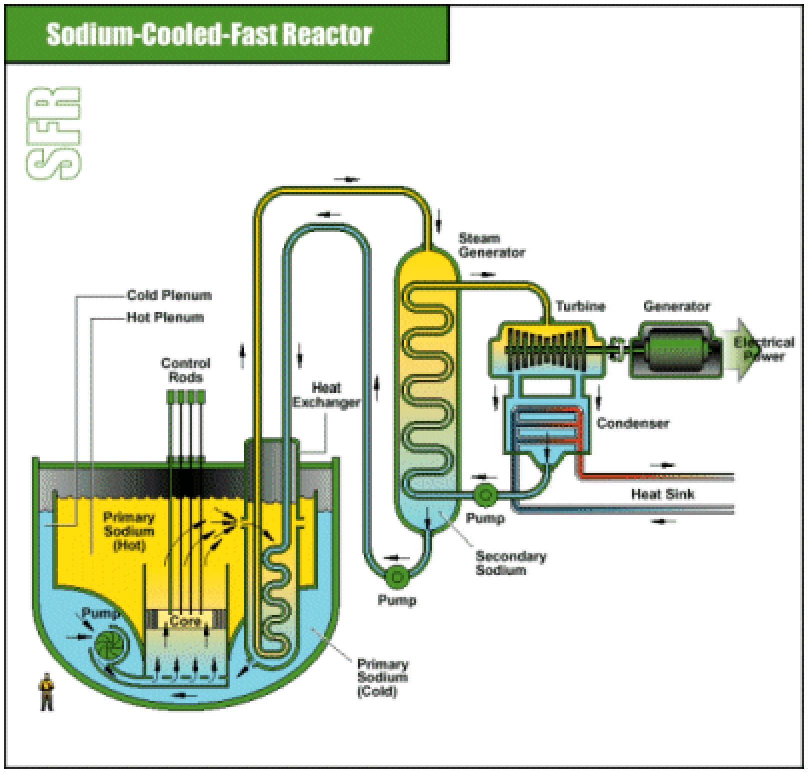
AlphaTech – ARC Reactor

Gas-cooled Fast Reactor



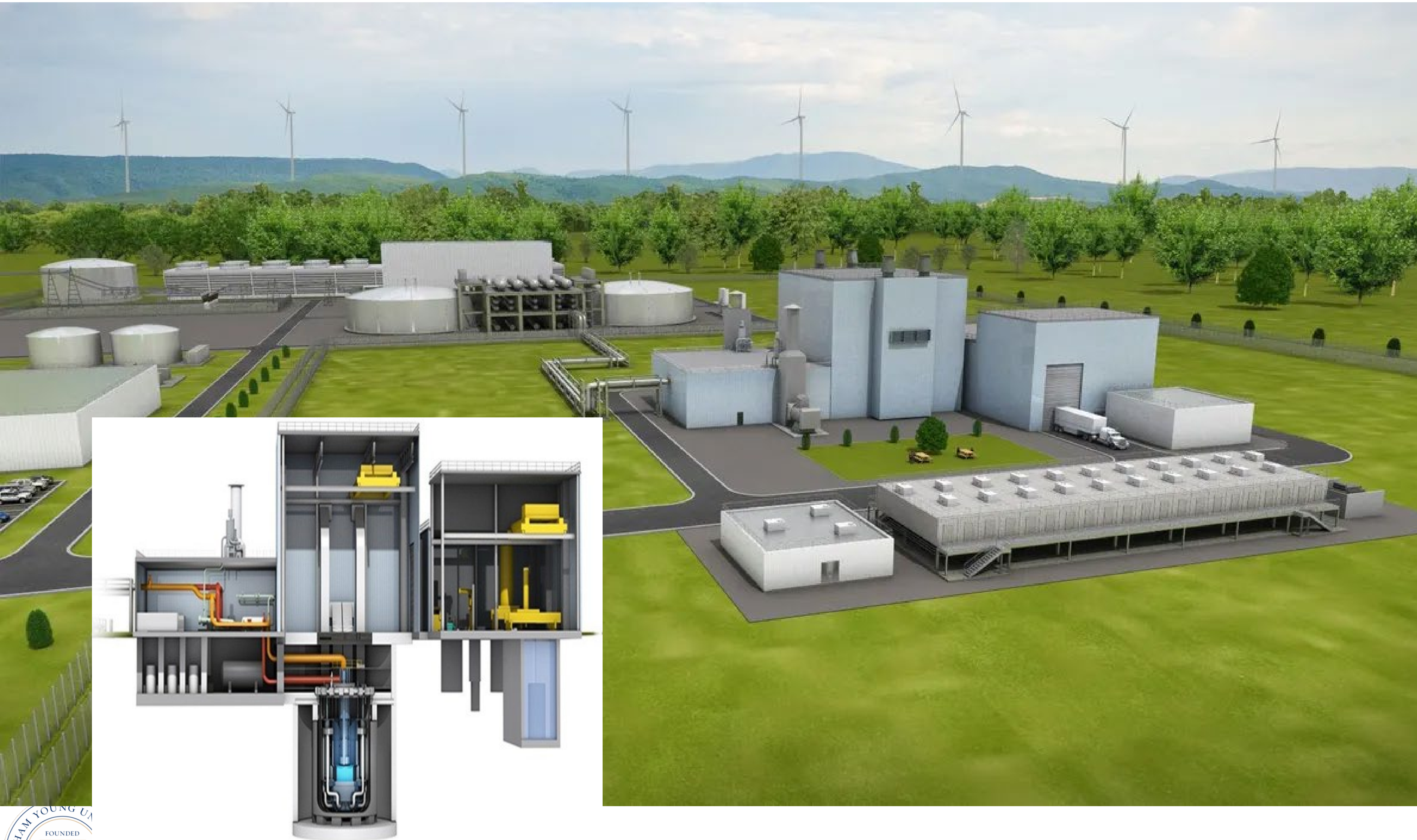
- He cooled with direct Brayton cycle for high efficiency
- Closed fuel cycle
- Low Power Density

Sodium-Cooled Fast Reactor

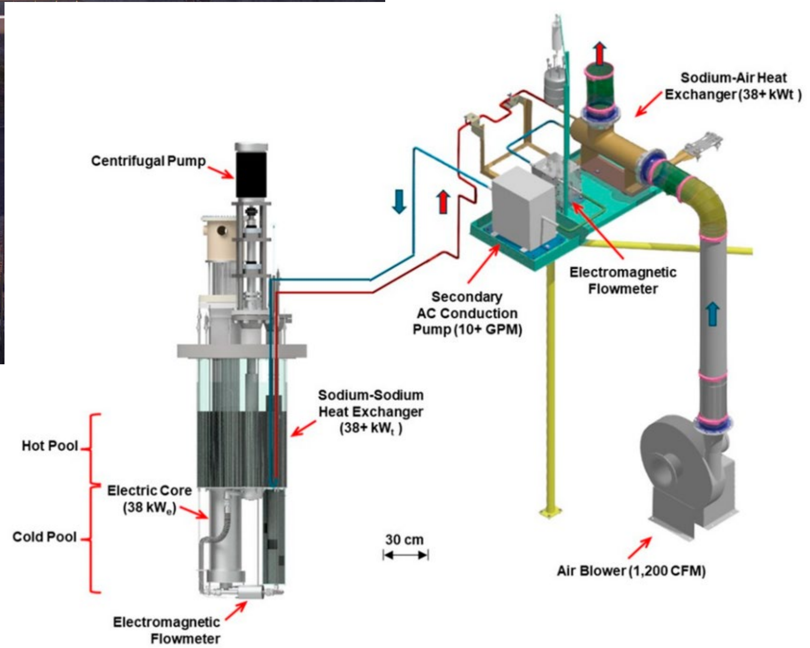


- Eliminates the need for transuranic (Pu) isotopes from leaving site (by breeding and consuming Pu)
- Liquid sodium cooled reactor
- Fueled by U/Pu alloy

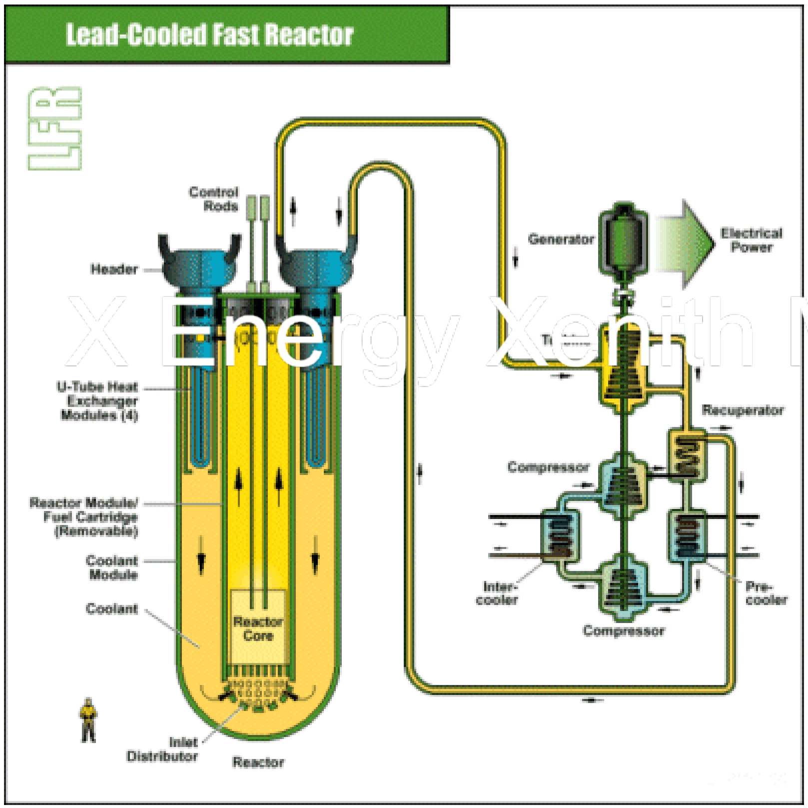
TerraPower – Natrium Reactor



Oklo – Auroroa Microreactor



Lead-cooled Fast Reactor



- Molten lead or lead-eutectic as core coolant
- Heat exchanged to gas-driven turbine
- Natural convection core cooling (cannot fail unless gravity fails)
- WEC Choice (12/2015), but called Gen V

Westinghouse Lead Fast Reactor