NE 795-014: Advanced Reactor Materials

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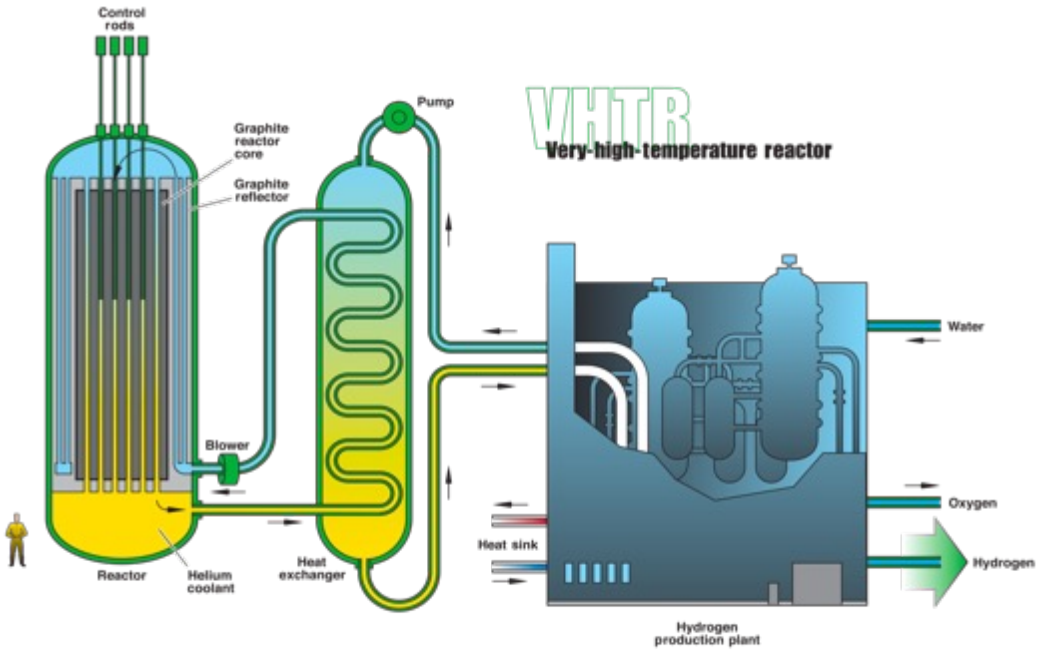
HIGH TEMPERATURE GAS REACTORS AND TRISO PARTICLES

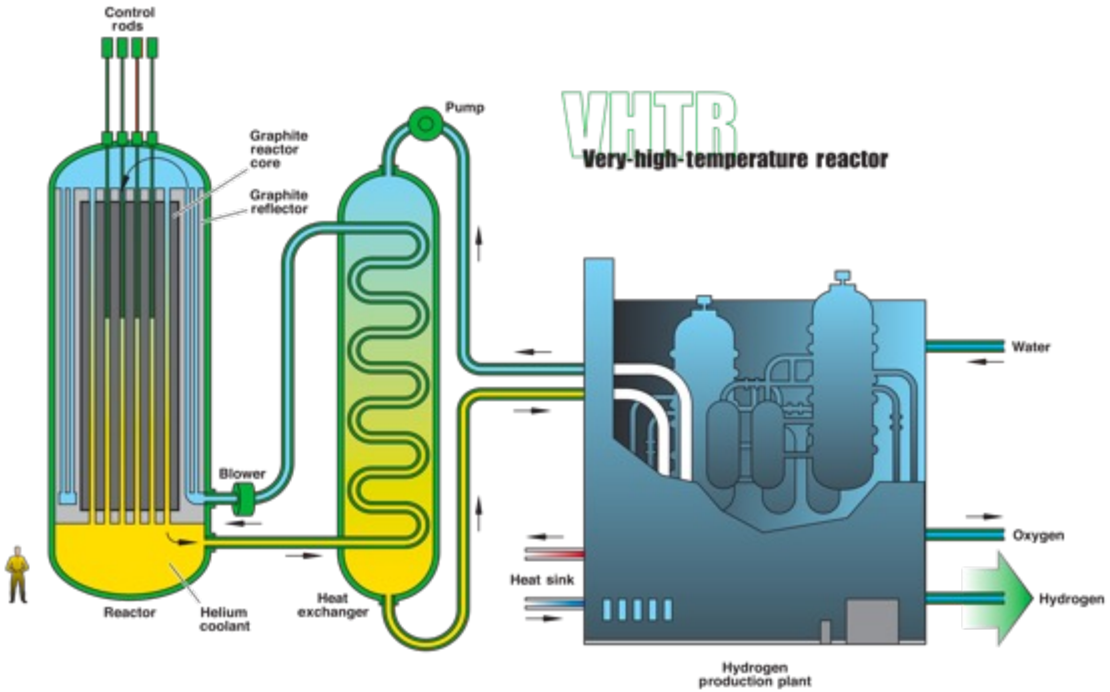
High Temperature Gas Reactor

- The HTGR has a long history going back to the earliest days of nuclear energy development
- Commercial gas-cooled nuclear power for electricity production started in 1956 with the operation of the first 50 MWe unit in the UK
- The design, which came to be known as Magnox, featured carbon-dioxide as the pressurized coolant and magnesium alloy cladding for the fuel
- To raise thermal efficiency, later designs switched to stainless steel cladding, enriched uranium oxide fuel, higher CO2 pressures, and higher operating temperatures, in what came to be known as the Advanced Gas Reactor (AGR)



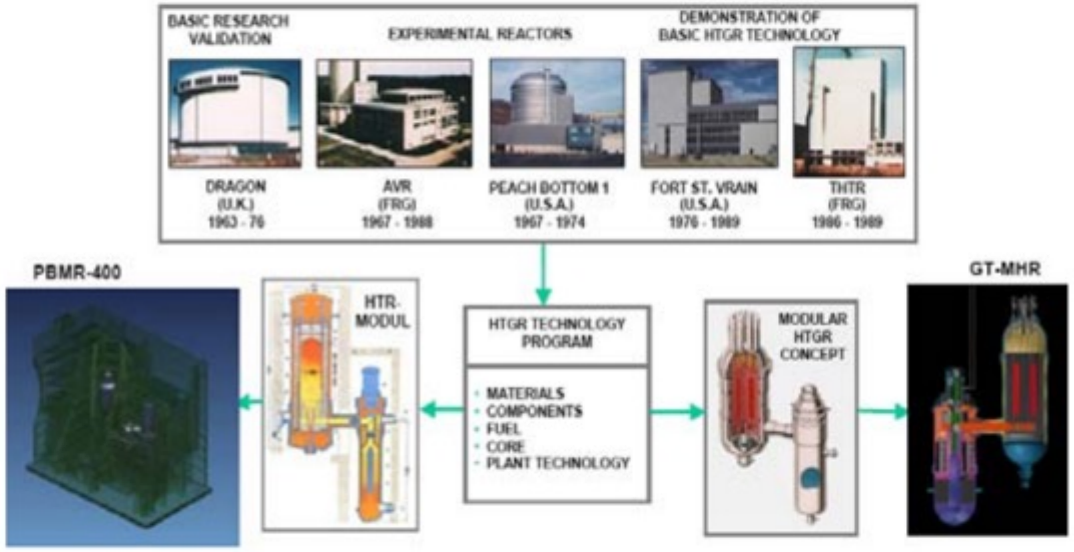
HTGRs

- The use of helium (He) as a coolant was advocated as early as 1944 in a 5 MWt experimental reactor project, also featuring an indirect gas turbine cycle
- Later, the prototype DRAGON reactor was put into operation in the UK in 1965 and featured a steel pressure vessel, coated fuel particles of highly-enriched uranium-thorium carbide and a helium outlet temperature of 750ºC

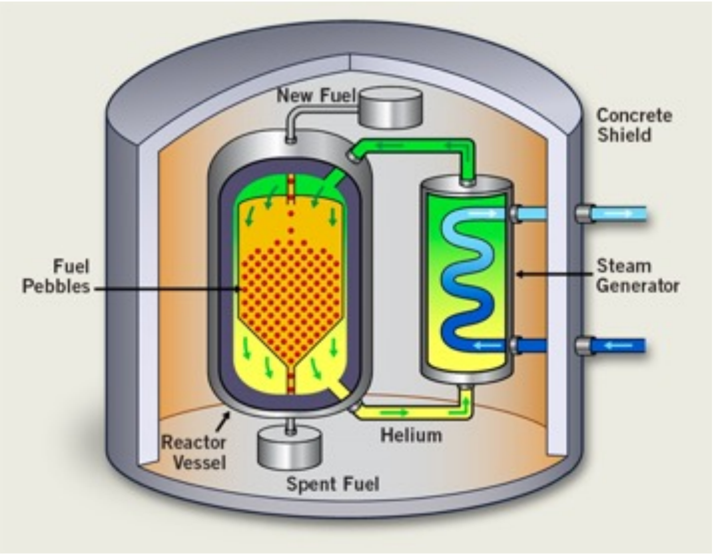


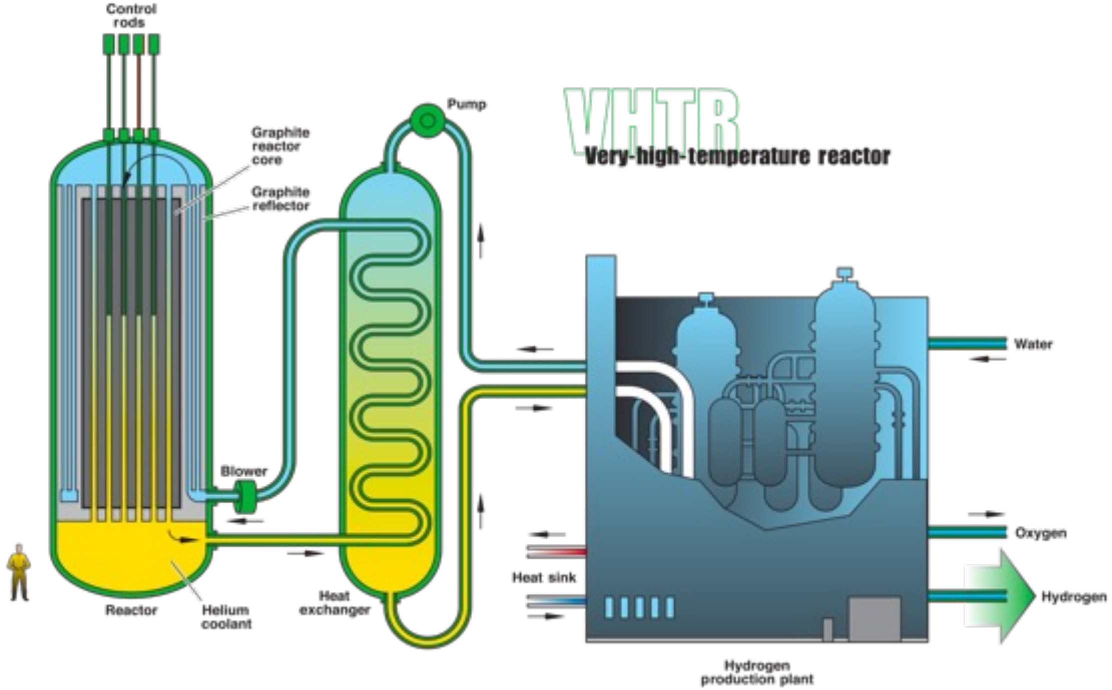
HTGRs

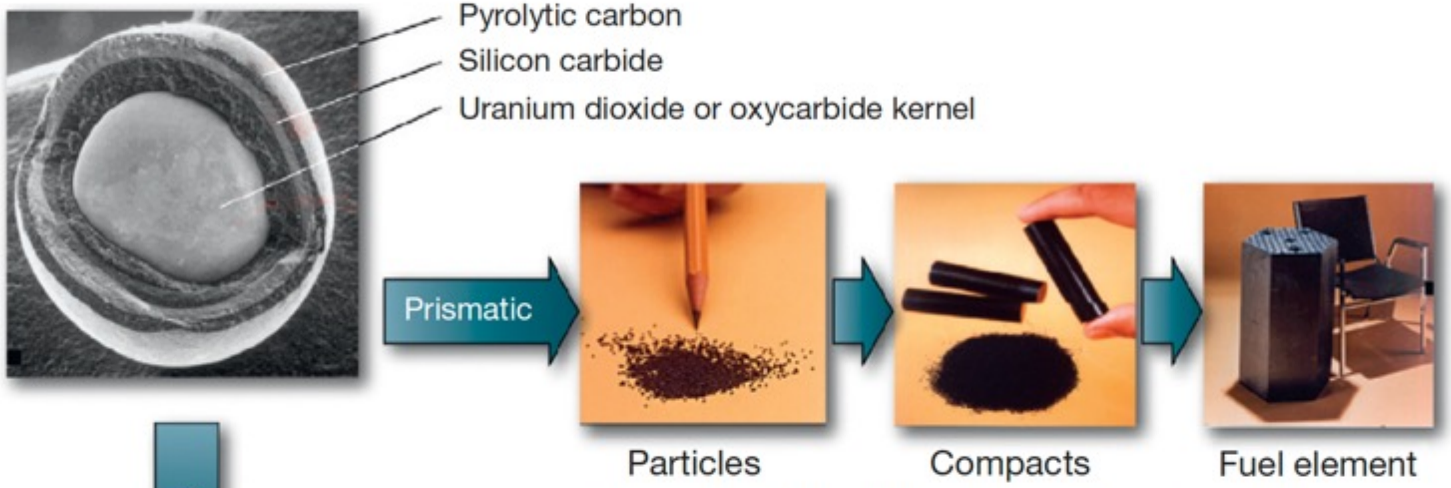
- The substitution of He instead of air or CO_2 provided excellent neutronic and thermal characteristics together with a graphite moderator
- There are two mainstream HTGR design concepts; the prismatic core design and the pebble bed core design, both of which possess common advantages of the HTGR design such as inherent safety and high efficiency



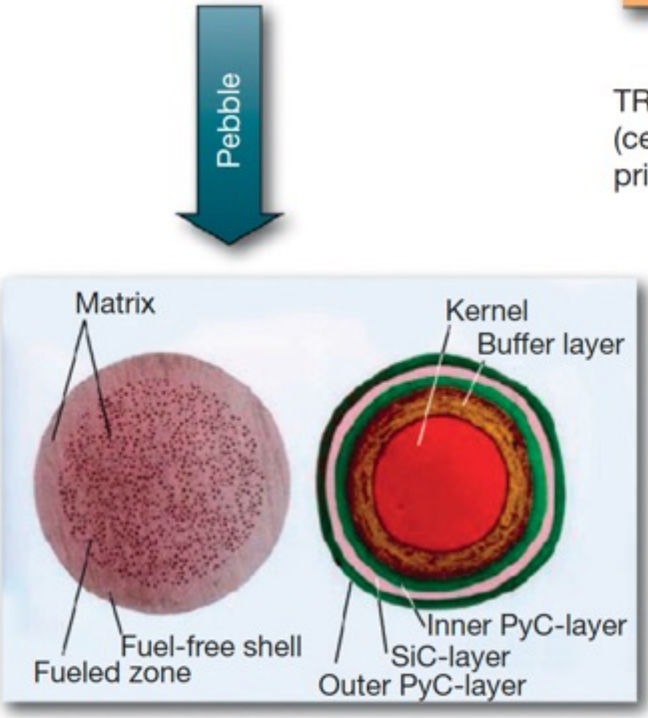
Two types of HTGRs



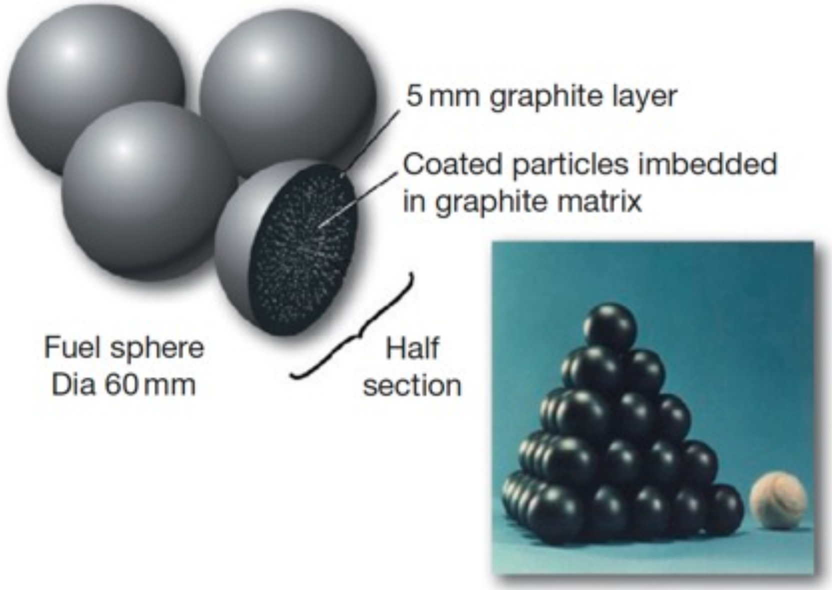




TRISO-coated fuel particles (left) are formed into fuel compacts (center) and inserted into graphite fuel elements (right) for the prismatic reactor



TRISO-coated fuel particles are formed into fuel spheres for pebble bed reactor



HTGRs

- The main features of HTGRs are enhanced safety, high thermal efficiency, economical competitiveness, and proliferation resistance and these make this technology a potential candidate for the nuclear power plant deployment
- One of the driving forces behind the HTGR philosophy is its utilization in the production of process heat: the high outlet gas temperatures may be utilized as a thermal heat source in endothermic chemical processes
- Net thermal efficiencies greater than 45% are within the reach in some of the designs of HTGRs
- The enhanced safety of the HTGR fuel is based on its coated fuel particle design consisting of uranium oxide/carbide particles coated with layers of pyrolytic carbon and silicon carbide
- Coated particles are so designed that they can withstand high internal gas pressure without releasing any fission products to the environment

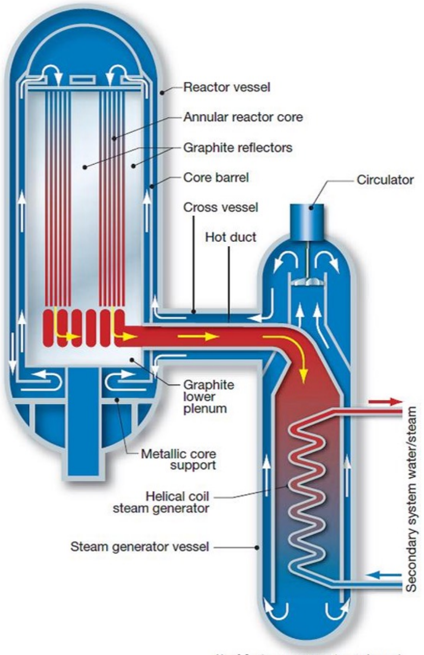
HTGRs

- Difference from LWRs
  - helium cooled
  - much higher temperatures
  - thermal/fast options
  - extensive utilization of graphite
  - flexibility of fuel

	Neutron spectrum (fast/thermal)	Coolant	Temperature (°C)	Pressure*	Fuel	Fuel cycle	Size (MWe)	Use
Gas-cooled fast reactors	fast	helium	850	high	U-238 +	closed, on site	1200	electricity & hydrogen
Lead-cooled fast reactors	fast	lead or Pb-Bi	480-570	low	U-238 +	closed, regional	20-180** 300-1200 600-1000	electricity & hydrogen
Molten salt fast reactors	fast	fluoride salts	700-800	low	UF in salt	closed	1000	electricity & hydrogen
Molten salt reactor - advanced high-temperature reactors	thermal	fluoride salts	750-1000		UO_2 particles in prism	open	1000-1500	hydrogen
Sodium-cooled fast reactors	fast	sodium	500-550	low	U-238 & MOX	closed	50-150 600-1500	electricity
Supercritical water-cooled reactors	thermal or fast	water	510-625	very high	UO_2	open (thermal) closed (fast)	300-700 1000-1500	electricity
Very high temperature gas reactors	thermal	helium	900-1000	high	UO_2 prism or pebbles	open	250-300	hydrogen & electricity

Framatome SC-HTGR

- Steam Cycle High Temperature Gas-Cooled Reactor (SCHTGR)
- Modular, graphite-moderated, helium-cooled, high temperature reactor with a nominal thermal power of 625 MWth
- HALEU UCO fuel kernel in TRISO particles
- Graphite hexagonal prism blocks
- Core inlet: 350C; Core outlet: 750C



(1 of 2 steam generators shown)

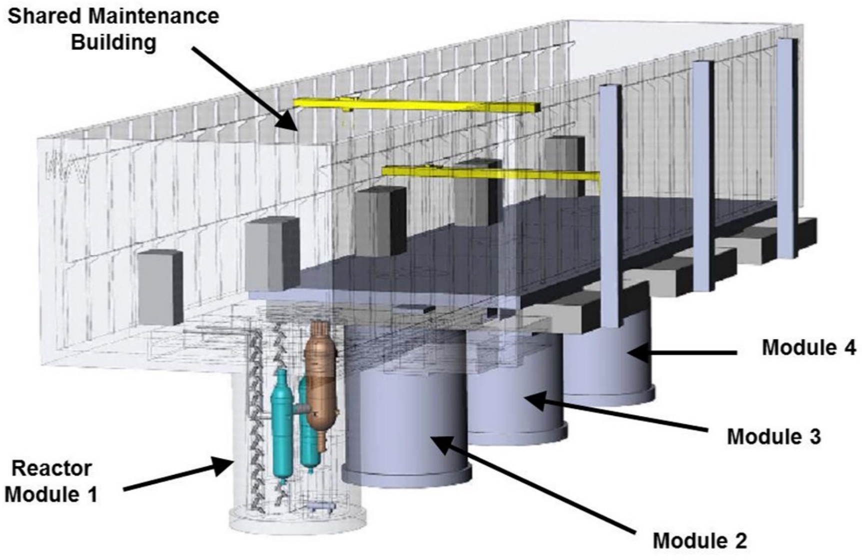


Figure 2 : Multiple Reactor Building Configuration

QUESTIONS?