Why HTGRs failed in ‘60s and why we expect renaissance now?

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New reactor concepts and safety analyses for the Polish Nuclear Energy Program POWR.03.02.00-00.I005/17

Disertation topic:

Modeling Fully Ceramic Microencapsulated (FCM) fuel

The subject of the work is the analysis of the fuel degradation process in terms of its damage.

Agenda

- HTRGs – basic informations
- History of HTGRs
- Specification of HTGRs models
- Triso fuel
- New concept of HTGR reactors
- Conclusions

H(igh) **T**(emperature) **G**(as- cooled) **R**(eactor)

H(ight) **T**(emperature) **R**(eactor)
V(ery)-**H**(igh)-**T**(emeprature) **R**(eactor)
T(horium) **H**(igh)-**T**(emperature) **R**(eactor)

First gas-cooled reactor was proposed in 1942 by professor Farrington Daniels.

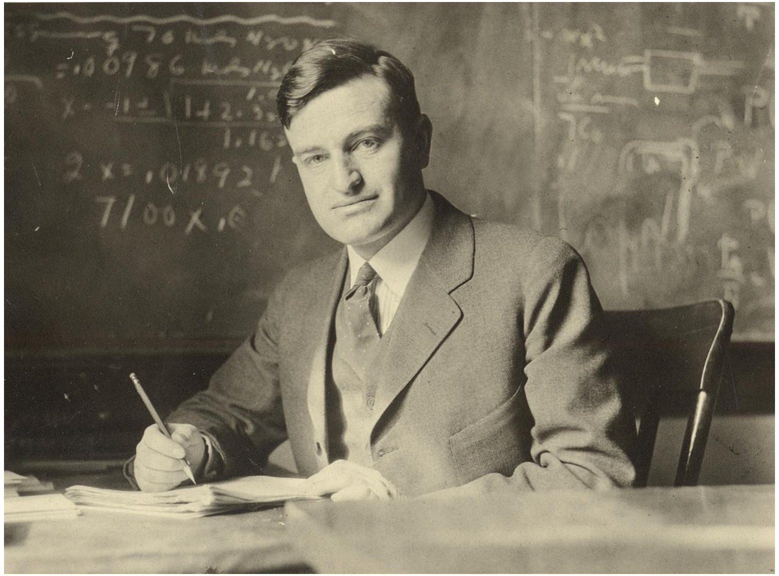


Fig.1 Farrington Daniels, chairman of the Department of Chemistry from 1952 to 1959. University of Wisconsin Archives

Basic information

HTGR:

- gas cooled reactor with graphite moderator;
- temperatures at the outlet from the core above 700 °C;
- enriched uranium used as a fuel (8-20%);
- basic element of the fuel is a tiny uranium oxide or uranium carbide granule;
- helium used as a cooling agent.

History of HTGRs

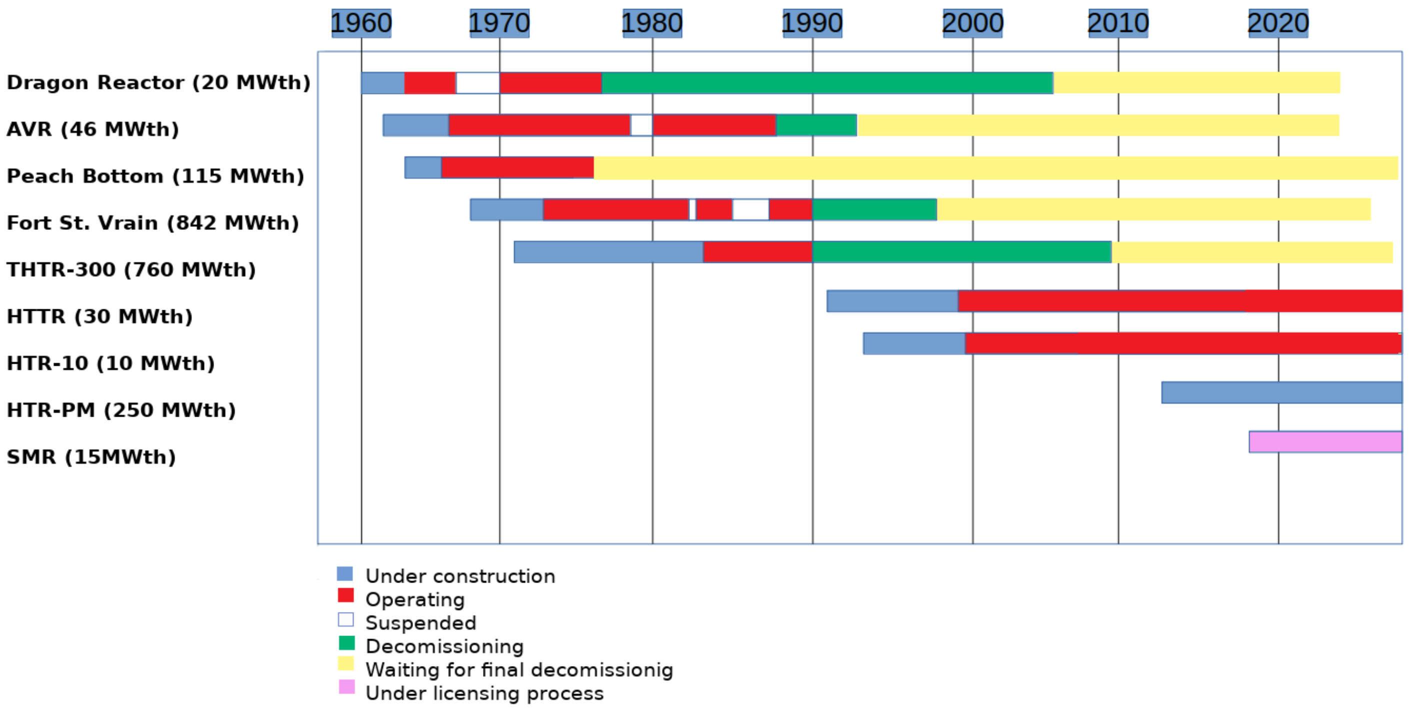
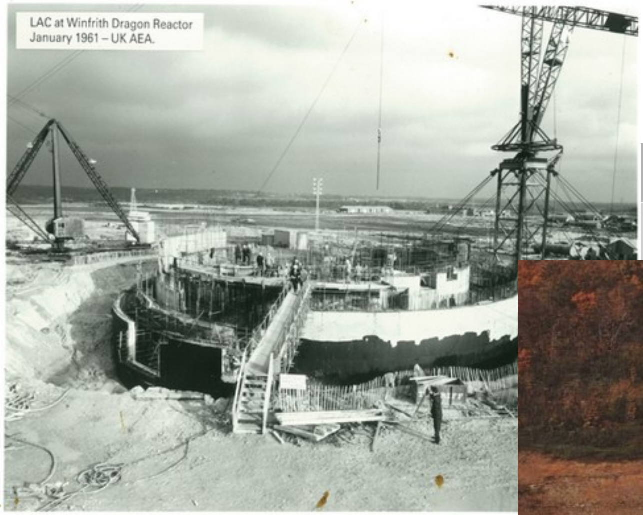
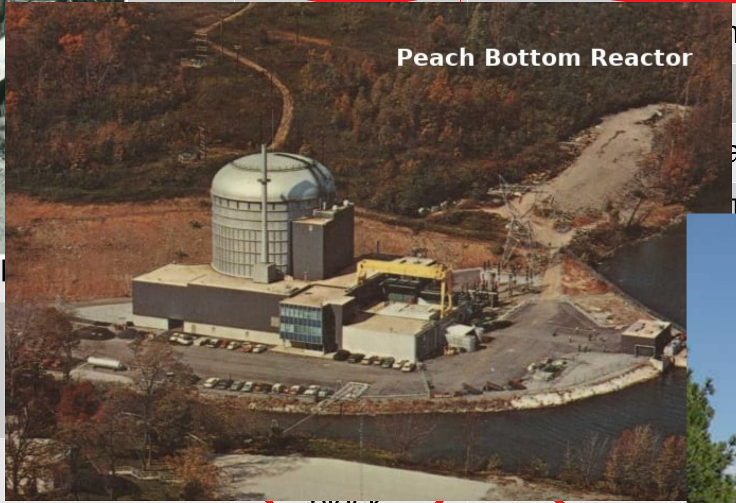


Fig.2 Construction and operational time frames of HTGR Power Plants

	DRAGON	PEACH BOTTOM	FORT St. Vrain
THERMAL POWER	21.5 [MW]	115 [MW]	842 [MW]
POWER DENSITY	14 [MW/m³]	8.3 [MW/m³]	6.3 [MW/m³]
SECONDARY COOLANT	steam	steam	steam
PRIMARY SYSTEM PRESSURE	2 [MPa]	2.3 [MPa]	4.8 [MPa]
PRIMARY INTEL TEMPERATURE	350 [°C]	327 [°C]	404 [°C]
PRIMARY OUTLET TEMPERATURE	750 [°C]	700-726[°C]	777 [°C]
VESSEL MATERIAL	carbon steel	carbon steel	prestressed concrete reactor vessel
CORE TYPE	prismatic block	prismatic block	prismatic block
YEARS OF OPERATION	1964-1975	1966-1974	1976-1989
LOCATION	England	U.S.	U.S.



	DRAGON	PEACH BOTTOM	FORT St. Vrain
	21.5 [MW]	115 [MW]	842 [MW]
		m³]	6.3 [MW/m³]
			steam
		a]	4.8 [MPa]
		]	404 [°C]
PRIMARY OUTLET TE			
VESSEL MATERIAL			
CORE TYPE	block		
YEARS OF OPERATION	1964-1975	1966-	
LOCATION	England	U.	



	AVR	THTR-300
THERMAL POWER	46 [MW]	750 [MW]
POWER DENSITY	2.6 [MW/m^3]	6 [MW/m^3]
SECONDARY COOLANT	steam	steam
PRIMARY SYSTEM PRESSURE	1.1 [MPa]	4 [MPa]
PRIMARY INTEL TEMPERATURE	275 [°C]	404 [°C]
PRIMARY OUTLET TEMPERATURE	950 [°C]	777 [°C]
VESSEL MATERIAL	steel and concrete building	PCRV with Liner
CORE TYPE	pebble bed	pebble bed
YEARS OF OPERATION	1967-1988	1985-1991
LOCATION	Germany	Germany

	AVR	THTR-300
THERMAL POWER	46 [MW	
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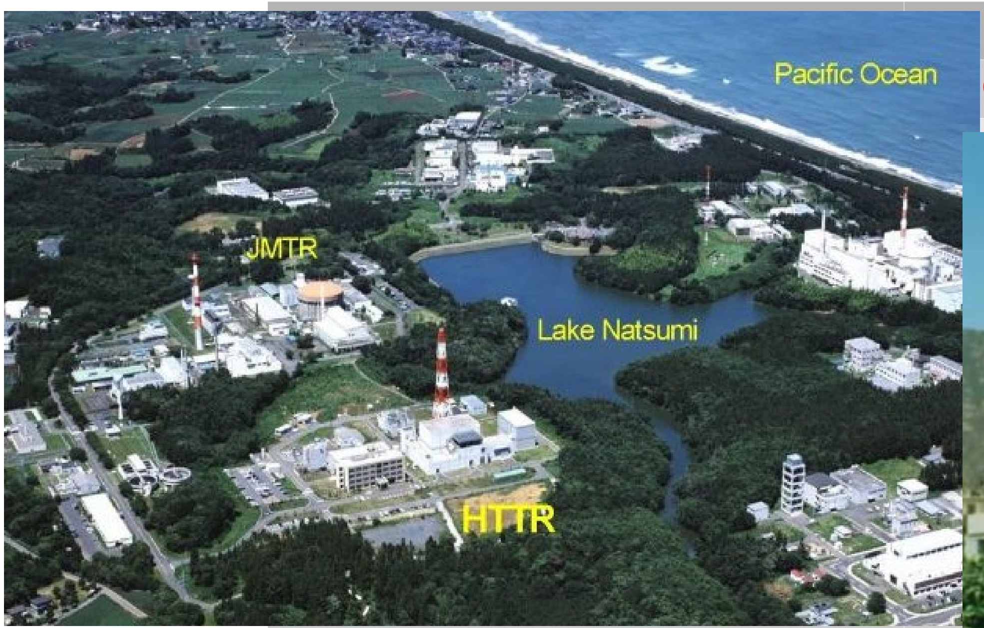
	HTTR	HTR-10
THERMAL POWER	30 [MW]	10 [MW]
POWER DENSITY	2.5 [MW/m^3]	2 [MW/m^3]
SECONDARY COOLANT	He/pressurized water	steam
PRIMARY SYSTEM PRESSURE	4 [MPa]	3 [MPa]
PRIMARY INTEL TEMPERATURE	395 [°C]	250 [°C]
PRIMARY OUTLET TEMPERATURE	850-950 [°C]	700 [°C]
VESSEL MATERIAL	2-1/4Cr-1Mo steel	C-Mn-Si steel
CORE TYPE	prismatic block	pebble bed
YEARS OF OPERATION	1998 -	operated in full power condition in 2003
LOCATION	Japan	China

	HTTR	HTR-10
	30 [MW]	10 [MW]
LOCATION		



History of HTGRs

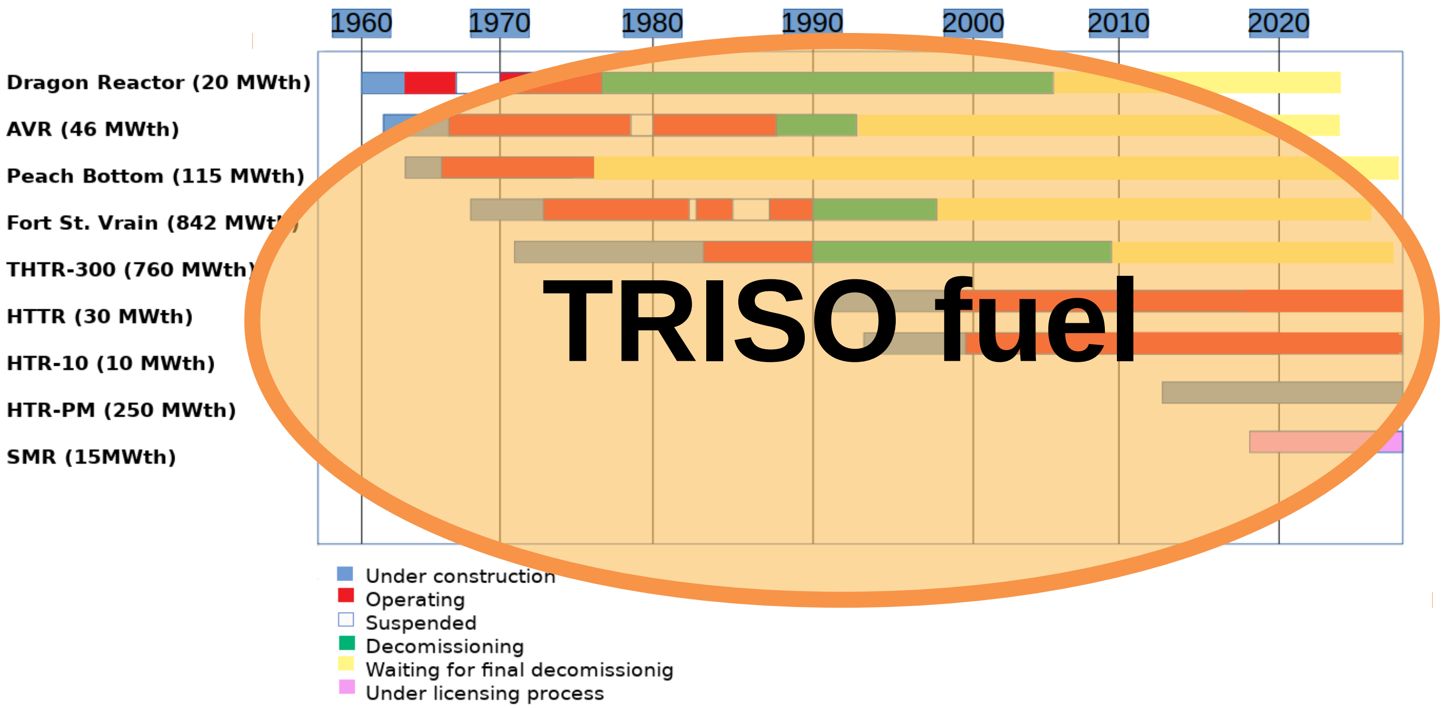


Fig.3 Construction and operational time frames of HTGR Power Plants

From BISO to TRISO fuel

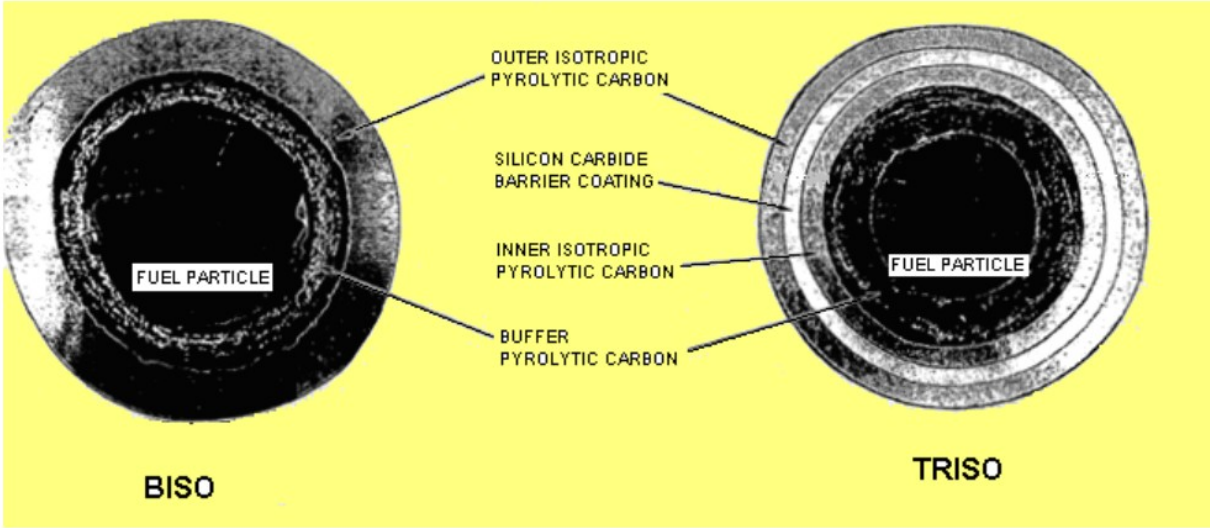


Fig.4 BISO and TRISO coated fuel particle

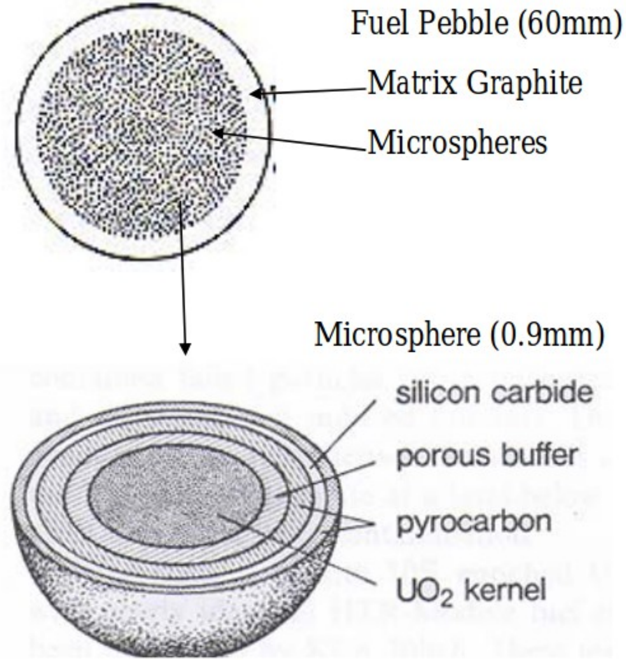


Fig. 5 TRISO particle

TRISO fuel

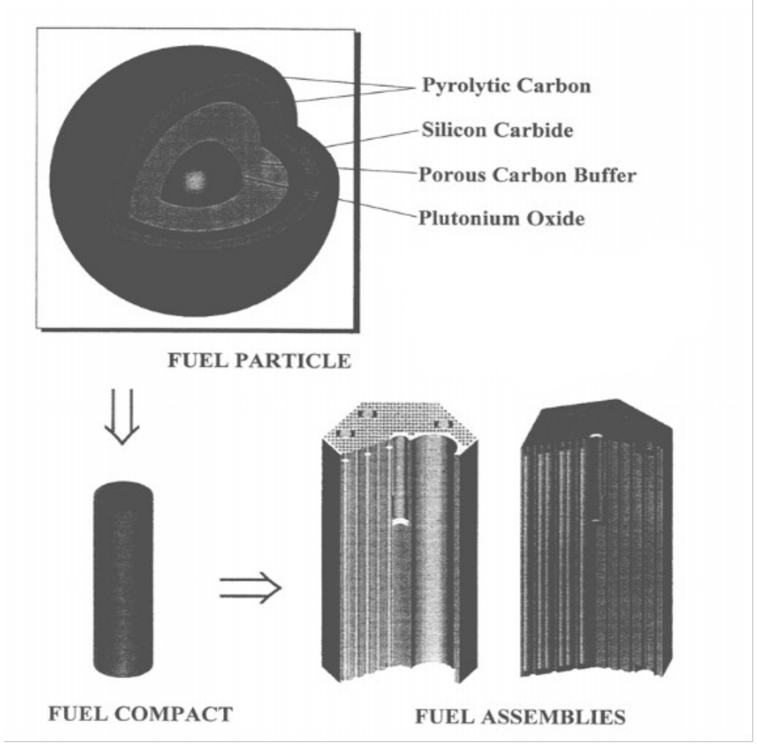


Fig. 6 TRISO Prismatic-HTGR fuel-element components

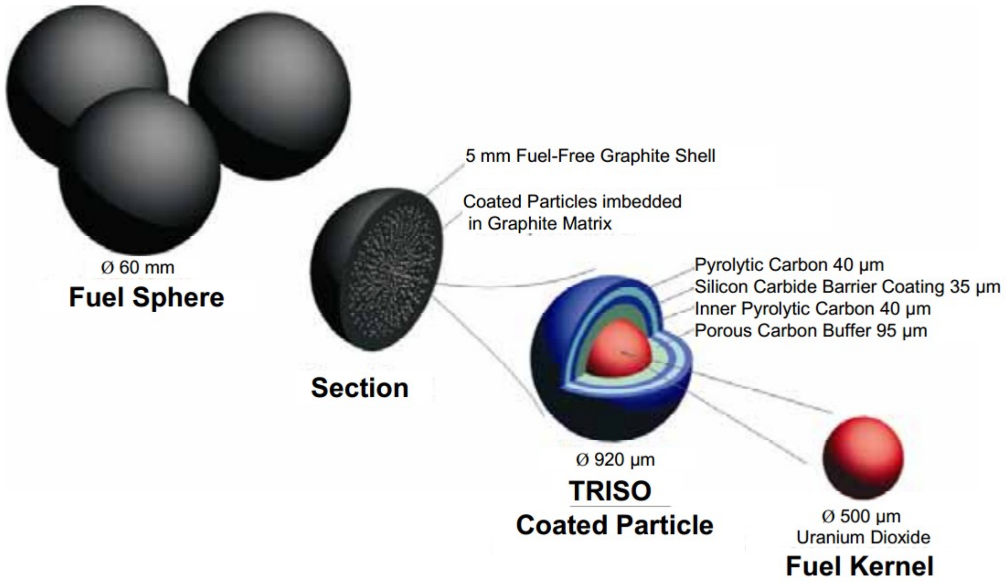


Fig.7 Fuel sphere design

Future trends in HTRs

Fig.8 Testing of the HTR-PM steam generator (Image: CNNC)

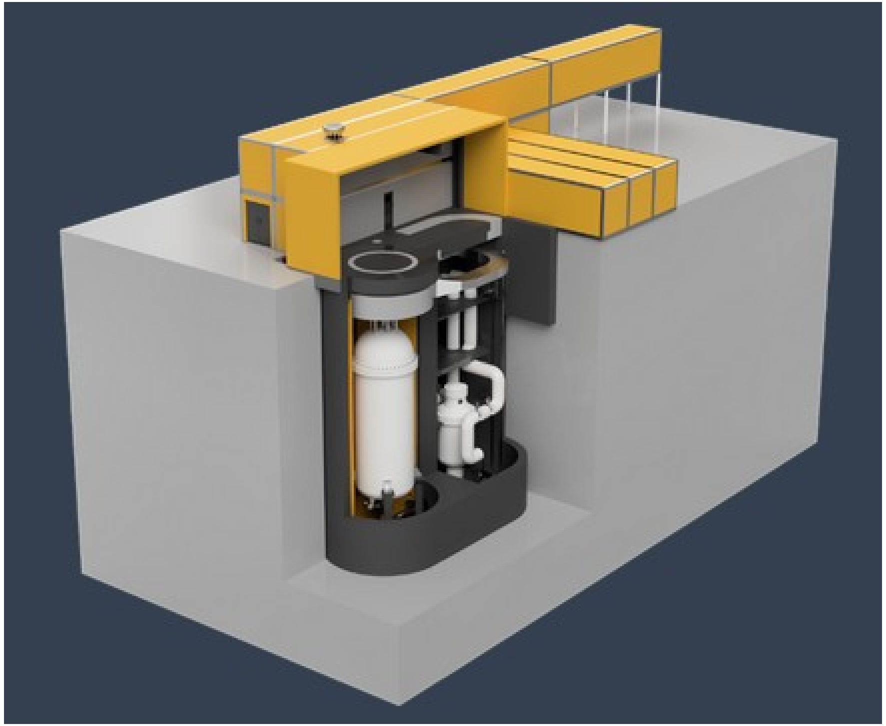


Fig.9 **M**icro **M**odular **R**eactor nuclear plant

Conclusions:

1. Historical analysis shows that there are no clear reasons for the abandonment of HTGR development in the 1960s and 1970s.

2. The idea of reactivation of HTGRs, may indicate that economic reasons were the main reason why this type of reactors was abandoned in the 1960s.

3. The economic reason does not exempt scientists from research on many aspects of HTGR construction for further development. That is why my PhD thesis, which focuses on TRISO fuel, is important.

4. The HTGR technology is not only benefitial for the generation of electricity, but can also be used, for example, in heating and hydrogen production.

Literature

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Thank you for attention

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