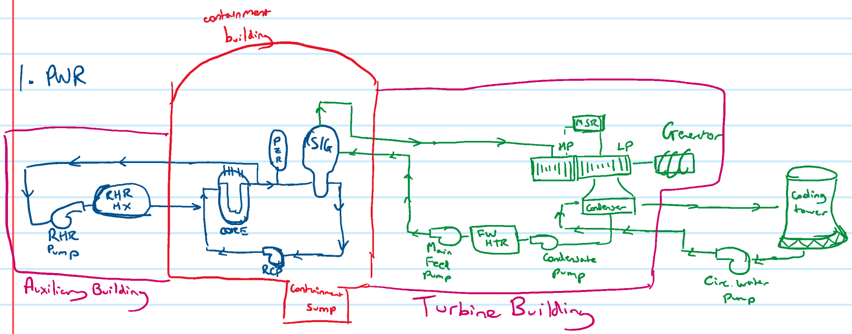
HW3

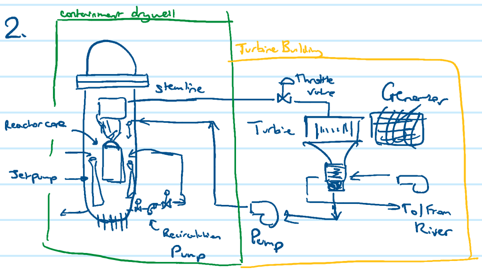
Monday, September 15, 2025 9:00 PM

1. PWR



The pressurized water reactor has control rods at the top of the RPV and the water exits heated. In the primary flow path, a pressurizer ensures that the subcooled liquid maintains its phase despite heating up. The steam generator is where the heat is exchanged w/ a secondary flow loop through the use of either U-tubes or a once-through system. The reactor coolant pump (RCP) then pushes primary flow through to the core again. There is a auxiliary system, the case of a LOCA to remove residual heat from the primary loop

2.

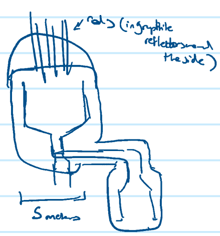


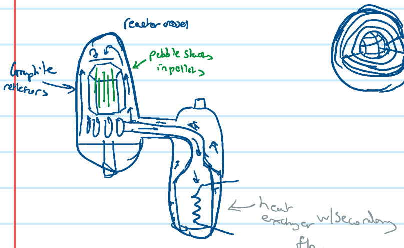
The main flow path involves condensed water re-entering the pressure vessel and a jet pump giving laminar flow to the bottom of the core. The recirculation pump is to capture any excess water on the bottom of the pressure vessel and feed it into the jet pumps again. The steam dryers feed the steam line which drives a turbine before being condensed cooled and fed back into the reactor pressure vessel.

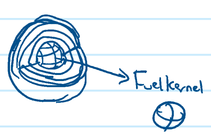
3.

a) Prismatic

b) Pebble







Graphite coated pebbles

Buffer, SiC, Pyrolitic Carbon layers to capture energy.

A prismatic HTGR is built from hexagonal fuel blocks which are filled with pellets shaped full of TRISO particles. The blocks are graphite reflectors as they can handle the higher temperatures, and the secondary loop can be water or a molten salt of some sort.

These pebbles are loaded into a large reactor that looks similar to the prismatic system except the pebbles also move while transferring heat to the helium coolant. This requires pebble replacement and different tracking requirements to keep track of the SNM.

4. Differences between HTGRs & LWRs

	HTGR	LWR
Moderator	graphite	water
Coolant	helium	water

HTGRs can be used to fill other market energy needs
- industrial processes, transient save methods[illegible]

Moderator	graphite	water
Coolant	helium	water
exit temp	700-950°C	310°C
Structural material	Graphite	Steel
Fuel Clad	SiC & PyC	Zircaloy
Fuel	UO_2, UCO	UO_2
Power density	4 to 6.5 W/cm^3	58-105 W/cm^3
Migration Length	57 cm	6 cm

HTGRs can be used to fill other market energy needs
- industrial processes, transients are much slower & easier to respond to
- Proven technology, strong negative fuel temperature feedback

LWRs don't shrink & grow based on wigner energy, no worry about bypass flows, much more consistent power cycles, No 6 stage startup procedure
Very few materials withstand higher temperatures
Much more energy from a LWR too.

5. Thermal design limits of a PWR | BWR

	PWR	BWR
Coolant Outlet Temperature	324°C	288°C
Turbine steam saturation temperature	272.3°C	287.5°C

Both a PWR and BWR have to remain below 2200°F in the event of a LOCA as that's when the Zircaloy cladding will start undergoing extensive water metal interaction. The damage limit includes 1% strain on the cladding. The MDNBR, which applies to PWRs stands for the minimum departure from nucleate boiling ratio which has to stay under 1 for the damage limit. The MCPR or minimum critical power ratio applies to BWRs and has to stay under 1 for the same reasons.

The thermal design margin is the difference between the failure limit and the nominal steady state average core. This accounts for monitoring & correlation uncertainties, the overpower factor, engineering uncertainties, and appliable axial, local and radial flux factors. Failure limit > Limit for design transient > max peak steady state

nominal SS core average condition < axial average in peak pin < nominal Peak steady state <

6. Avg values of q''' & outside heat flux q'' for PWRs & BWRs

BWR

$\langle q' \rangle_{\text{core average}} = 19.0 \frac{kW}{m}$ Particle diameter = 10.4 mm

Pin diameter = 12.27 mm

$$q''' = \frac{19.0 \frac{kW}{m}}{\frac{\pi}{4}(10.4 \cdot 10^{-3})^2} = 223.664 \frac{kW}{m^3} = \boxed{224 \frac{MW}{m^3}}$$

$$q'' = \frac{19.0 \frac{kW}{m}}{\pi \cdot (12.27 \cdot 10^{-3})} = \boxed{492.9 \frac{kW}{m^2}}$$

PWR(W)

$$q''' = \frac{17.8 \frac{kW}{m}}{\frac{\pi}{4}(8.2 \cdot 10^{-3})^2} = \boxed{337 \frac{MW}{m^3}}$$

$$q'' = \frac{17.8\, kW/m}{\pi (9.5 \cdot 10^{-3})} = \boxed{596.4 \frac{kW}{m^2}}$$

PHWR

$$q''' = \frac{25.7\, kW/m}{\frac{\pi}{4}(12.2 \cdot 10^{-3})^2} = \boxed{219.8 \frac{MW}{m^3}}$$

$$q'' = \frac{25.7\, kW/m}{\pi (13.1 \cdot 10^{-3})} = \boxed{624.47 \frac{kW}{m^3}}$$

HTGR

$$q''' = \frac{7.87 \frac{kW}{m}}{\frac{\pi}{4}(6.6 \cdot 10^{-3})^2} = \boxed{2{,}783 \frac{MW}{m^3}}$$

$$q'' = \frac{7.87 \frac{kW}{m}}{\pi (15.7 \cdot 10^{-3})} = \boxed{159.6 \frac{kW}{m^2}}$$

AGR

$$q''' = \frac{17.0 \frac{kW}{m}}{\frac{\pi}{4}(14.51 \cdot 10^{-3})^2} = \boxed{102.8 \frac{MW}{m^3}}$$

$$q'' = \frac{17.0\, kW/m}{\pi (14.89 \cdot 10^{-3})} = \boxed{363.4 \frac{kW}{m^2}}$$

LMFBR

$$q''' = \frac{29.0\, kW/m}{\frac{\pi}{4}(7 \cdot 10^{-3})^2} = \boxed{753.6 \frac{MW}{m^3}}$$

$$q'' = \frac{29.0\, kW/m}{\pi (8.65 \cdot 10^{-3})} = \boxed{1067 \frac{kW}{m^2}}$$