OPERATING REACTOR SAFETY
22.091/222.093

1 week after SES #10

Open Book **Examination # 1** 1.5 Hours

Nuclear Reactor Basics and Power Conversion

<u>Problem # 1</u> (15%)

A **fast** reactor assembly consisting of a homogeneous mixture of Pu 239 and sodium is to be made in the form of a bare sphere. The atom densities of these constituents are $N_f = 0.00395 \times 10^{24}$ for the Pu 239 and $N_S = 0.0234 \times 10^{24}$ for the sodium. Estimate the critical radius of the assembly.

For: v = 2.98
D = 3 cm

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See attached curves that may be of interest – please state assumptions.

<u>Problem # 2 (20%)</u>

Calculate the equilibrium Xe concentration for a light water 3 % enriched U235 reactor that has been operating at an average neutron flux of 2×10^{13} n/cm^2 sec producing 1,000 Mwth. The volume of the core is a standard PWR with 12 foot long fuel assemblies in an effective fueled radius of 5 feet.

<u>Problem # 3 (25%)</u>

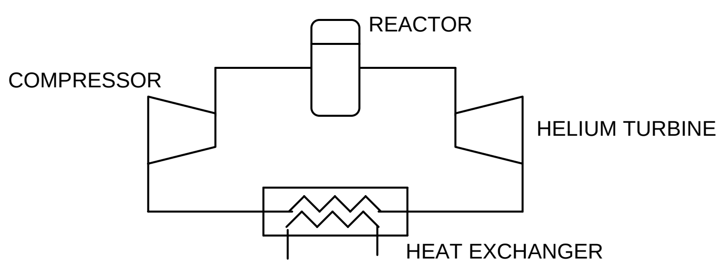
A small PWR plant operates at a power of 485 MWth. The core, which is approximately 75.4 in. in diameter and 91.9 in. high, consists of a square lattice of 23,142 fuel tubes of cladding thickness 0.021 in. and inner diameter of 0.298 on a 0.422 in. pitch. The tubes are filled with 3.4% w/o enriched UO2. The core is cooled by water that enters at 496 F and passes through the core at 34 x 10E6 lb/hr at 2015 psia.

Compute: (a) the average temperature of the water leaving the core
(b) the average power density in kw/ft3
(c) the maximum heat production rate assuming that the core is bare (peak power density).

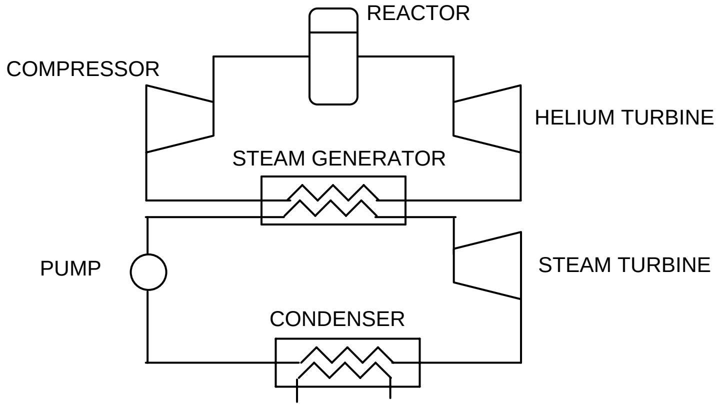
<u>Problem # 4 (40%)</u>

Consider a helium power plant operating on the Brayton cycle with a pressure ratio of 4. The maximum and minimum temperatures in the cycle are 1800R and 594R. The mass flow rate of helium is 2,200lbm/s. The compressor and the turbine can be treated as ideal.

For helium, take $c_p = 1.24$Btu/lbm·F and $\gamma=5/3$.



The company that runs the plant wants to improve its performance by adding a bottoming cycle, which would be a Rankine cycle. The heat exchanger in the original plant would be replaced by a steam generator as follows:



In this design, saturated steam at 1150 psia leaves the steam generator and enters the steam turbine, which has an isentropic efficiency of 90%. The pressure at the turbine outlet is 1.45 psi. Pump work can be neglected and conditions in the helium cycle are unchanged.

2.1) Draw the T-s diagram for the combined cycle (5%)

2.2) Find the thermal power of the reactor (10%)

2.3) Find the work output of the turbine and the work input to the compressor (5%)

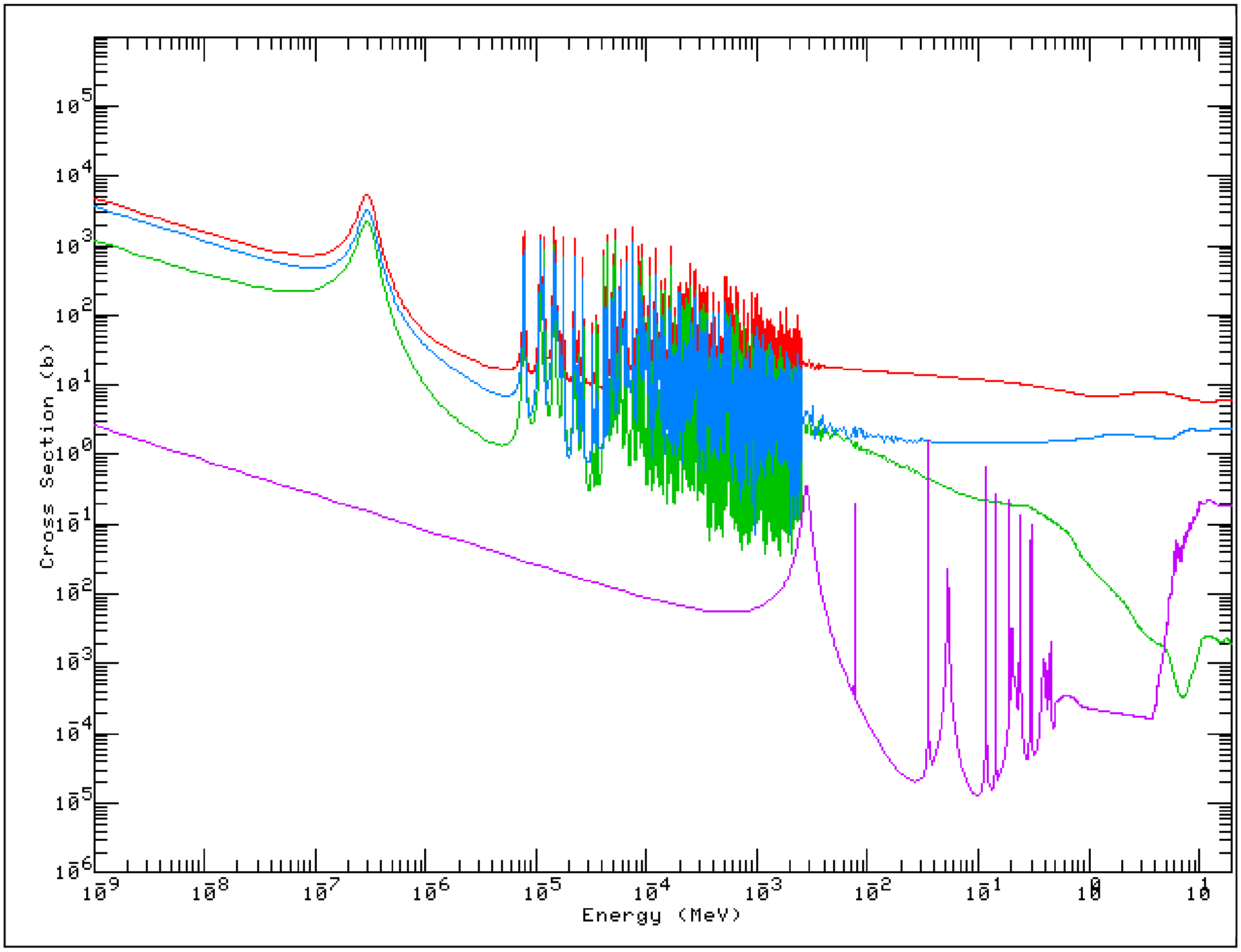
2.4) Find the thermal efficiency of the gas cycle (5%)

2.5) Determine the mass flow rate in the steam cycle (5%)

2.6) Determine the work output of the steam turbine (5%)

2.7) Find the overall thermal efficiency of the plant (5%)

Cross Sections of Plutonium 239 and Sodium 23



Red – Total Pu 239 Cross Section
Blue – Total Pu 239 Fission Cross Section
Green – Pu-239 Absorption Cross Section
Purple – Na 23 absorption cross section