22.312 **ENGINEERING OF NUCLEAR REACTORS**

Due November 18, 2009 by 12:00 pm

TAKE HOME QUIZ 2

Problem 1 (70%) – Temperature distribution in pebble fuel of advanced design

A recently-proposed Generation-IV reactor concept features a pebble-bed core with a molten-salt coolant. The geometry of a fuel pebble is shown in Figure 1. Each pebble has an inner graphite core, an outer graphite shell, and a middle region fueled with TRISO particles dispersed in graphite.

i) Determine the maximum allowable power generated by a pebble, assuming that the maximum temperature in the pebble cannot exceed 1000°C. Assumptions: coolant bulk temperature = 700°C; heat transfer coefficient = 10 kW/°C-m^2. (35%)

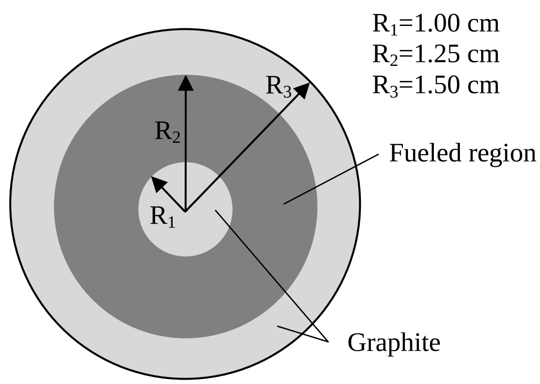

Figure 1. Geometry and dimensions of the fuel pebble. (drawing not to scale)

ii) Repeat question 'i' for a pebble in which the inner graphite core is replaced with fuel. (5%)

iii) Please list advantages and disadvantages of the two pebble designs in questions 'i' and 'ii'. Which one would you select? (10%)

iv) Now, for the pebble design of question 'i', assume that heat removal by the coolant ceases suddenly and completely, and the reactor is scrammed. How long does it take for the pebble temperature to reach 1600°C (i.e., the temperature at which the TRISO particles fail)? Assume an initial average pebble temperature of 800°C and a nominal power of 700 W. Temperature gradients within the pebble are negligible during this transient. In calculating the decay power, assume infinite operation prior to scram. (20%)

Useful Properties (assumed independent of temperature)

Graphite: k = 15 W/m°C, ρ = 1300 kg/m^3, c = 700 J/kg°C
Fueled region: k = 30 W/m°C, ρ = 1700 kg/m^3, c = 2000 J/kg°C

Problem 2 (30%) – Emergency core cooling system for sodium-cooled reactor

The emergency core cooling system of a sodium-cooled reactor relies on a pump to circulate sodium through the core during accidents. Assuming the core is made of 151 identical fuel assemblies, each with an equivalent diameter of 0.3 cm, a flow area of 60 cm^2 and length of 3.5 m, calculate the coolant temperature rise in the core, if the electric power available to drive the pump is 58 kW and the decay power in the core is 30 MW. Assume an isentropic efficiency of 80% for the pump.

In calculating the pressure change across the core, you may neglect acceleration, gravity and form loss terms.

Properties of Sodium (assumed constant in the temperature and pressure ranges of interest)
$k = 60$ W/m°C
$\rho = 780$ kg/m^3
$c = 1300$ J/kg°C
$\mu = 1.7\times10^{-4}$ Pa·s