# PROBLEM 8-10N QUESTION

## Important Features Of Fuel Element Temperature Calculation

Note: You may use the MathCAD program to solve this problem set but the use of MathCAD is not mandatory.

This problem set illustrates some important features of fuel element temperature calculations.

Consider an LMR fuel rod with the dimensions, thermal calculations characteristics, and operating conditions as follows:

- The clad is an austenitic stainless steel with outside diameter = 8.5 mm; thickness = 0.7 mm; and thermal conductivity = 23 $W/(m \cdot k)$.
- The fuel is enriched $UO_2$ contained in hollow pellets with outside diameter = 6.9 mm; inside diameter = 0.8 mm; as-fabricated density = 88% TD (theoretical density); and a thermal conductivity versus temperature as defined in a section "fuel conductivity" at the end of this problem statement.
- The gap conductance = 14 $kW/(m^2 \cdot K)$; and the heat transfer coefficient at the clad outer surface = 170 $kW/(m^2 \cdot K)$.
- The linear heat deposition rate = 57 kW/m; and the coolant temperature = $540°C$.

Treat porosity as spherical using the Biancharia relation of the text Eq. 8-21. Neglect cracking and relocation effects.

1) Consider first that there is no restructuring.

   What are the temperatures at the following locations: clad outer radius $(R_{co})$; clad inner radius $(R_{ci})$; fuel outer radius $(R_{fo})$; and fuel inner radius $(R_{fi})$? Prepare a sketch (to scale and similar to text fig. 8-17 showing temperature versus radius.

2) Consider the same fuel rod and the same operating conditions but consider also that restructuring has occurred. The sintering temperatures and densities are those of Westinghouse in text Table 8-5.

   What are $(T_{fi})$, $(R_1)$, $(R_2)$, and $(R_{fi})$? Add a "restructured" temperature distribution to the sketch of part 1.

FUEL CONDUCTIVITY

This conductivity information applies to 95% TD $UO_2$.  It is based on Lyon and is taken from the B&W polynomial of text Eq. 8-16c.  The plot of text Fig. 8-1 is also applicable.  SI units are adopted here (text information is non-SI).

| Temperature (˚C) | Thermal Conductivity (W/m·k) | Conductivity Integral (kW/m) |
|---|---|---|
| 0 | 9.32 | 0 |
| 200 | 6.38 | 1.54 |
| 400 | 4.78 | 2.64 |
| 600 | 3.85 | 3.50 |
| 800 | 3.26 | 4.20 |
| 1000 | 2.86 | 4.81 |
| 1200 | 2.58 | 5.35 |
| 1400 | 2.41 | 5.85 |
| 1600 | 2.29 | 6.32 |
| 1800 | 2.29 | 6.78 |
| 2000 | 2.31 | 7.24 |
| 2200 | 2.39 | 7.71 |
| 2400 | 2.53 | 8.20 |
| 2600 | 2.74 | 8.73 |
| 2800 | 2.94 | 9.30 |