10.4.3
Effect of Fuel Restructuring

4 Main Regions -(Figure 10.23)

	Radius	T °C	$\frac{\rho_i}{\rho_s}$,%
1.) Central Void	r_o	≈ 2800	0
2.) Columnar Region	r_o to r_1	1700-2200	98-99
3.) Equiaxed Grains	r_1 to r_2	1600-1700	95-97
4.) As Fabricated	r_2 to r_3	≈ 1000	as fab.

Can determine the central void radius by;

$$r_o^2 = \left\{\frac{(\rho_1 - \rho_2)}{\rho_1}\right\} r_1^2 + \left\{\frac{(\rho_2 - \rho_3)}{\rho_1}\right\} r_2^2 \qquad \text{(10.70}$$

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Note ; we have to correct volumetric heating rates by density differences

$$H_3 = \frac{P}{\pi R^2}, \qquad H_2 = \left(\frac{P}{\pi R^2}\right) \bullet \left[\frac{\rho_2}{\rho_3}\right], \ldots\ldots\ldots$$

Using these values with the heat conduction eq., we find that things can be expressed as a function of as fabricated porosity

As fabricated region;

$$\int_{T_s}^{T_2} k_3 dT = \left(\frac{P}{4\pi}\right)\left[1-\left(\frac{r_2}{R}\right)^2\right] \qquad 10.88$$

Equiaxed Region; (10.89)

$$\int_{T_2}^{T_1} k_2 dT = \left(\frac{P}{4\pi}\right)\left(\frac{\rho_2}{\rho_3}\right)\left(\frac{r_2}{R}\right)^2\left[1-\left(\frac{r_1}{r_2}\right)^2-\left(1-\frac{\rho_3}{\rho_2}\right)\ln\left(\frac{r_2}{r_1}\right)^2\right]$$

Columnar Region (10.90)

$$\int_{T_1}^{T_0} k_1 dT = \left(\frac{P}{4\pi}\right)\left(\frac{\rho_1}{\rho_3}\right)\left(\frac{r_1}{R}\right)^2\left[1-\left(\frac{r_0}{r_1}\right)^2-\left(\frac{r_o}{r_1}\right)^2\ln\left(\frac{r_1}{r_o}\right)^2\right]$$

Procedure to Find Temperature Distribution

T_s, P, $\frac{\rho 3}{\rho s}$ ---------> T_1, $\frac{\rho 1}{\rho s}$ -----------> **Determine**

known T_2, $\frac{\rho 2}{\rho s}$ $\int_{T_i}^{T_{i-1}} k_i dT$

Experiment

i.e., for 95% dense material (10.91)

$$\int_{T_i}^{T_{i-1}} k_i dT = \left[\left(\int_0^{T_{i-1}} k dT \right)_{P=0.05} - \left(\int_0^{T_i} k dT \right)_{P=0.05} \right] \bullet \left\{ \frac{f(P_i)}{f(0.05)} \right\}$$

where $f(P_i)$ = reduction in thermal conductivity in the i_{th} zone with P_i porosity (see eq. 10.40, 10.42, 10.44)

once $\int k_i dT$ is determined for as fabricated and equiaxed zones by eq. 10.91;

then eq. 10.88 is used to find $\frac{r_2}{R}$

then eq. 10.89 is used to find $\frac{r_1}{R}$

then eq. 10.70 is used to find r_o

then eq. 10.90 is used to find $\int_{T_1}^{T_o} k_1 dT$

then eq. 10.91 is used to find $\left(\int_0^{T_o} k \, dT \right)_P$

then fig. 10.20 gives T_o (fig.10.24)