10.4
Temperature Profiles in Cylindrical Fuel Rods

$$T - T_s = \left(\frac{HR^2}{4k}\right)\left[1 - \left(\frac{r}{R}\right)^2\right]$$

both a function of r, t

Previously we may have used ,

$$\frac{(T - T_s)}{(T_0 - T_s)} = 1 - \left(\frac{r}{R}\right)^2$$

but this is not good enough when H and k are varying

==========

10.4.1
Volumetric Heating Rates

$$P = \frac{\text{Power}}{\text{Unit Length of Rod}} \quad \left(\frac{W}{cm}\right)$$

This is called the thermal rating

H Can Vary for at least 4 Reasons

Not normal **1.) Gradient in initial enrichment**

Fast reactors **2.) Pu migration**

Both LWR & FBR **3.) Burnout or breeding effects**

Thermal reactors **4.) Flux effects**

$$\frac{P}{\pi(R_o^2 - r_o^2)} = \frac{2\pi}{\pi(R_o^2 - r_o^2)} \bullet \int_{r_0}^{R} rH(r)dr = \overline{H}$$

10.4.2
Thermal Conductivity Integral

integrating,

$$\frac{1}{r}\frac{d\left[rk\frac{dT}{dr}\right]}{dr} + H = 0 \qquad \text{if H is constant}$$

first time,

$$rk\frac{dT}{dr} = -\frac{Hr^2}{2} \quad \text{(solid rod)}$$

again,

(conductivity integral)

$$\int_{T_S}^{T_0} kdT = \frac{HR^2}{4} = \frac{P}{4\pi}$$

Major use of conductivity integral is that when T_s and P are known, it can be used to estimate T_o

$$\int_{T_s}^{T_0} k dT = \int_{0}^{T_0} k dT - \int_{0}^{T_s} k dT = \frac{P}{4\pi}$$

This integral has been measured for a mixed oxide fuel

(See figure)

Value for T_m

$$= \int_{0}^{T_m} k dT = 93 \pm 4 \frac{W}{cm}$$

If we know T_S, P (from experimental measurements), then we can get a value of,

$$\int_{0}^{T_0} k dT$$

which in turn will give T_o from figure 10.20

---

example; It is shown that as a result of self shielding, the heat generation rate in a thermal reactor fuel pin is ,

κ is reciprocal of neutron diffusion length

$$\kappa = \frac{1}{L} \equiv \frac{\sqrt{6}}{\sqrt{\overline{r^2}}}$$

$\overline{r^2}$ = mean Vector distance that a monoenergetic neutron travels fom its source to where it is absorbed

$$H(r) = \frac{P}{\pi R^2}\left\{\frac{(\kappa R)}{2I_1(\kappa R)}\right\} I_0(\kappa R)$$

Bessel Functions

==========

Using H(r) in equation above

$$\int_{T_s}^{T_0} k\,dT = \frac{P}{4\pi}\left[\frac{I_0(\kappa R) - 1}{\left(\frac{\kappa R}{2}\right) \bullet I_1(\kappa R)}\right]$$

See figure 10.21.

Note that reduced Conductivity Integral means lower T_o, ----same as moving the heat source to the outside

==========

- **Note flux depression in fast reactors is absent**