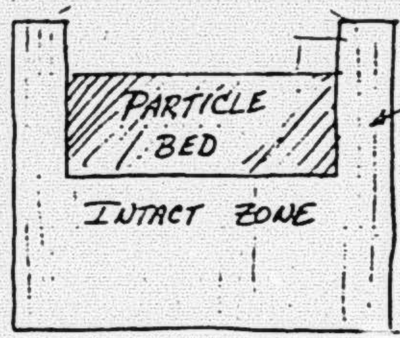
Particle Bed Investigation IA-E-108

Assume

1. The upper half of core severely damaged and in form of particle bed – except for outer perimeter of assemblies which will be assumed intact to allow a good path for bypass flow around particle bed.



2. Assume pellets fragmented into 8 pieces

3. Recirculation to core by natural circulation from loops such that total flow through core is adequate to remove 5000 $\frac{BTU}{sec}$ with 25°F mixed mean temp increase

$$w = Q/c_p \Delta T = 200 \text{ lb/sec}$$

4. The driving head for flow through particle bed is assumed to be

$$\Delta P = (\bar{\rho}_{bypass} - \bar{\rho}_{bed}) L_B$$

where L_B = bed depth
$\bar{\rho}_{bed}$ = avg. bed water density
$\bar{\rho}_{bypass}$ = average bypass density

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Analysis

(1)

The ΔP across a packed bed of 35 to 45 percent voids can be estimated from (Ref - Page 9-47 of Etherington Handbook)

If $\frac{D \bar{u}_s \rho}{\mu} < 40$ $\qquad \frac{\bar{u}_s \mu L}{g_c \Delta P} = \frac{D_p^2}{1700}$

or $\qquad \Delta P = \frac{1700 \bar{u}_s \mu L}{g_c D_p^2}$

Where
$\bar{u}_s$ = superficial velocity through bed
μ = viscosity
L = bed height
ρ = density
D_p = particle diam

Pellet OD = 0.37" $\qquad$ cross sect area = $\pi D^2/4$ = 0.108 in^2

Clad OD = .43", thickness = .0265" ; cross sect area = $\pi D t$ = .0358 in^2

Pitch = .568" ; area = p^2 = 0.323 in^2

$\therefore$ solid area = .108 + .0358 = 0.1438 in^2
void area = 0.323 - .1438 = 0.1792 in^2
void fract = .1792 / .323 = 0.555

} when in stack form

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The 6 ft height (half length) will reduce for a 40% void bed

$$1-.4 = 0.6 = \frac{6\times0.1438}{H\times0.323} \quad \text{or} \quad H \equiv L_B = \frac{6\times.1438}{.6\times.323} = 4.5\,ft$$

So $L_{EFD} = 4.5\,ft$

(°F)	Viscosity of water			
70	1.65 lb/ft-hr	⇒	4.58×10^{-4} lb/ft-sec	Note: Need to check impact of boric acid on viscosities
150	1.05	⇒	2.92×10^{-4}	
200	.74	⇒	2.05×10^{-4}	
250	.57	⇒	1.58×10^{-4}	

If pellet breaks into 8 pieces volume $\cong \frac{1}{8}\{.108\times.37\} = .005\,in^3$

$$D_p = \left(\frac{6\,Vol}{\pi}\right)^{1/3} = 0.213\,in = .0177\,ft$$

Total area $\sim \frac{177\text{ assembly}\times225\times.323}{144} \cong 90\,ft^2$

Superficial area of bed if outer 36 assemblies not part of bed $= 90\times(1-\frac{36}{177}) = 72\,ft^2$

$\bar{U}_s = W_b/\rho\cdot A_s$ or $W_b = \bar{U}_s\,\rho\,A_s$

$= 60\times72\times\bar{U}_s$

$W_b = 4300\,\bar{U}_s$ mass flow through bed

$$w_B = \left(\frac{.63 \times 5000 \times 1.87 \times 10^{-2} \times 32.2}{2.9 \times 10^{-4} \times 1} \right)^{1/2} 1.77 \times 10^{-2}$$

$$= \left(6.56 \times 10^{6}\right)^{1/2} \left(1.77 \times 10^{-2}\right) = 25.6 \times 10^{2} \times 1.77 \times 10^{-2}$$

$$\boxed{w_B = 45.3 \text{ lb/sec}}$$

$$\Delta T_b = \frac{2500}{45.3} = 55°F$$

$$T_{bed\ exit} = 167.5$$

<u>Summary</u>

The flow through bed based on pellets fragmenting into 8 pieces and equating bed pressure drop to water head difference between bed and bypass zone is about 45 lb/sec. The total temp rise from core inlet to bed outlet corresponding to this flow is about 68°F. Therefore in natural circulation mode with containment at atmospheric and pressurizer full area relief open – the pressure at core would be about 30 psi (corresponding to about $T_{sat} = 250°F$). Tin less that about 180° would prevent boiling in bed. This would inhibit gas generation from radiolysis – also prevention of boiling in bed would prevent flow starvation to bed from blockage by steam flow and its large volumetric flow through this resistance at low pressure.