APPENDIX 11.1A

DERIVATION OF RESIDENCE TIMES

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DERIVATION OF RESIDENCE TIMES

The derivation of the core residence times for circulating crud and deposited crud as shown in Subsection 11.1.2 is as follows:

11.1A.1 CIRCULATING CRUD:

The number of radioactive atoms (N_f) in the crud film on in-core surfaces at any time is:

$$\frac{dN_f}{dt} = \Sigma_i \phi - \lambda_i N_f \qquad \text{(A - 1)}$$

Solving for N_f yields the following:

$$N_f = \frac{\Sigma_i \phi}{\lambda_i}\left(1 - e^{-\lambda_i t_{res}}\right) \text{atom/g} \qquad \text{(A - 2)}$$

where:

$\Sigma_i\phi$ = the activation rate for each isotope i (d/g-sec)

λ_i = the decay constant for each isotope (sec^{-1}) and

t_{res} = the desired core residence time (sec).

The number of radioactive atoms (N_c) released to the reactor coolant at any time is:

$$\frac{dN_c}{dt} = N_f \left[ER\right] A_c - \left(\alpha + \beta + \lambda_i\right) N_c \quad \text{atoms/sec}$$

Solving for N_c yields the following:

$$N_c = \frac{N_f \left[ER\right] A_c}{\left(\alpha + \beta + \lambda_i\right)}\left(1 - e^{-(\alpha+\beta+\lambda_i)t}\right) \qquad \text{(A-3)}$$

where:

ER = the erosion rate (g/cm^2)

A_c = the core surface area (cm^2)

α = the plateout rate (sec^{-1})

β = the purification cleanup rate (sec^{-1})

λ_i = the decay constant (sec^{-1})

The total amount of crud (M_c) released to the reactor coolant any time is:

$$\frac{dM_c}{dt} = [ER] A_T - (\alpha + \beta) M_c \quad \text{(A-4)}$$

where:

→ (DRN 99-2361)

M_c includes both radioactive and nonradioactive material

← (DRN 99-2361)

Solving for M_c yields:

$$M_c = \frac{[ER] A_T}{(\alpha + \beta)} \left(1 - e^{-(\alpha + \beta)t}\right) \text{grams} \quad \text{(A-5)}$$

where:

ER	=	the erosion rate (g/cm^2)
A_T	=	the total system area (cm^2)
α	=	the plateout rate (sec^{-1})
β	=	the purification cleanup rate (sec^{-1})

The activity (A_i) of the crud released to the reactor coolant is:

$$A_i = \frac{\lambda_i N_C}{M_c}, \text{dps per gram of crud in reactor coolant} \quad \text{(A-6)}$$

Substituting the values of N_c and M_c into the above expression and assuming λ_i is small when compared to α and β, the activity of the crud is as follows:

$$A_i = \Sigma_i \phi \left(1 - e^{-\lambda_i t_{res}}\right) \frac{A_c}{A_T} (0.06) \text{ dpm/mg-crud} \quad \text{(A-7)}$$

where:

0.06 = a constant changing dps/g-crud to dpm/mg-crud

This activity (A_i) is also assumed to be the activity of the crud which plates out on out-of-core surfaces.

Solving equation (A-7) for t_{res} yields equation (3).

11.1A.2 DEPOSITED CRUD

The activity (A_j) of the deposited crud is:

$$A_j = \lambda_i N_f = \Sigma_i \phi \left(1 - e^{-\lambda_i t_{res}}\right)(0.06) \quad \text{(A-8)}$$

Solving equation (A-8) for t_{res} yields equation (4).