APPENDIX 11A

CORE RESIDENCE TIMES

APPENDIX 11A – CORE RESIDENCE TIMES

The derivation of the core residence times for circulating crud as shown in Subsection 11.1.3 is as follows:

Circulating Crud

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

$$\frac{dN_f}{dt} = \Sigma_i \phi - \lambda_i N_f \qquad \text{(Eq. 11A-1)}$$

Solving for N_f yields the following:

$$N_f = \frac{\Sigma_i \phi}{\lambda_i}\left(1 - e^{-\lambda_i t_{res}}\right), \text{atoms/g} \qquad \text{(Eq. 11A-2)}$$

Where:

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

λ_i = decay constant for each isotope i, sec^{-1}

t_{res} = desired core residence time, seconds

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

$$\frac{dN_c}{dt} = N_f\{ER\}A_c - (\alpha + \beta + \lambda_i)\, N_c, \text{atoms/sec}$$

Solving for N_c yields the following:

$$N_c = \frac{N_f\{ER\}A_c}{(\alpha + \beta) + \lambda_i}\left(1 - e^{-(\alpha+\beta+\lambda_i)t}\right) \qquad \text{(Eq. 11A-3)}$$

Where:

{ER} = erosion rate, g/cm^2-sec

A_C = core surface area, cm^2

α = plateout rate, sec^{-1}

β = purification cleanup rate, sec^{-1}

λ_i = decay constant, sec^{-1}

Total amount of crud (M_c) released to the reactor coolant at any time is:

$$\frac{dM_c}{dt} = \{ER\}A_T - (\alpha + \beta)M_c \qquad \text{(Eq. 11A-4)}$$

Where M_c includes both radioactive and nonradioactive material.

Solving for M_c yields:

$$M_c = \frac{\{ER\}A_T}{\alpha+\beta}\left(1 - e^{-(\alpha+\beta)t}\right), \text{grams} \qquad \text{(Eq. 11A-5)}$$

Where:

{ER} = erosion rate, g/cm^2-sec

A_T = total system area, cm^2

α = plateout rate, sec^{-1}

β = purification cleanup rate, sec^{-1}

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

$$A_i = \frac{\lambda_i N_c}{M_c}, \text{Bq/g-crud} \qquad \text{(Eq. 11A-6)}$$

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

$$A_i = \sum_i \phi\left(1 - e^{-\lambda_i t_{res}}\right)\frac{A_c}{A_T}, \text{Bq/g-crud} \qquad \text{(Eq. 11A-7)}$$

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

Solving Equation (11A-7) for t_{res} yields Eq. 11.1-8.

Deposited Crud

The activity (A_j) of the deposited crud is:

$$A_j = \lambda_j N_f = \sum_j \phi\left(1 - e^{-\lambda_j t_{res}}\right) \qquad \text{(Eq. 11A-8)}$$

Solving Eq. 11A-8 for t_{res} yields Eq. 11.1-9.