SUMMARY

A method of calibrating control drums in a subcritical assembly with a source is given here as an addendum to WANL-TMI-458 which discusses the measurement of shutdown reactivity in a subcritical core.

INTRODUCTION

WANL-TMI-458 illustrated a method of measuring the shutdown reactivity in a sub-critical core by using a source jerk technique together with a pulsed neutron measurement of $\alpha$. If instead of yanking the source, we drive in a control element, interpretation of the kinetics equations on a core of known reactivity allows us to measure the control drum worth.

THEORY

The Laplace transform of the neutron density in a core with a constant extraneous source is given by:

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\[
    n(s) = n(o) \left[ \frac{1 + \sum_i \beta_i \mathcal{G}_i \frac{k_{\text{eff}}}{l^* (s + \lambda_i)}}{s \left( 1 + \sum_i \beta_i \mathcal{G}_i \frac{k_{\text{eff}}}{l^* (s + \lambda_i)} \right)} - \frac{\Delta k_{\text{eff}}}{l^*} \right] + \frac{S_o}{s} \quad (1)
\]

If we assume that the core was originally at the steady state level \( \Delta k_{\text{eff}} \) with neutron density \( n(o) \) whereby:

\[
    S_o = - \frac{\Delta k_{\text{eff}}}{l^*} n(o)
\]

and that the source was kept in the assembly and a drum driven in so that the new core reactivity would be \( \Delta k_{\text{eff}} \), Equation 1 becomes:

\[
    \frac{\tilde{n}(s)}{n(o)} = \frac{1 + \sum_i \beta_i \mathcal{G}_i \frac{k_{\text{eff}}}{l^* (s + \lambda_i)}}{s \left( 1 + \sum_i \beta_i \mathcal{G}_i \frac{k_{\text{eff}}}{l^* (s + \lambda_i)} \right)} - \frac{\Delta k_{\text{eff}}}{l^*} - \frac{\Delta k_{\text{eff}}}{s \left( 1 + \sum_i \beta_i \mathcal{G}_i \frac{k_{\text{eff}}}{l^* (s + \lambda_i)} \right)} - \frac{k_{\text{eff}}}{l^*} \quad (2)
\]

The inverse transform of the first term on the right represents a time decay of neutron density after addition of reactivity, where the transform of the second term on the right represents both a decay as well as a steady state level with a pole at \( s = 0 \). The residue of \( \frac{n(s)}{n(o)} \) for the pole at \( s = 0 \) is \( \Delta k_{\text{eff}} / \Delta k_{\text{eff}} \), so that the expression for the final steady state level, \( n(f) \) is:

\[
    \frac{n(f)}{n(o)} = \frac{\Delta k_{\text{eff}}}{\Delta k_{\text{eff}}} \quad (3)
\]

2.
For small changes in $k_{\text{eff}}$, $\beta$ is constant and $k_{\text{eff}} = k_{\text{eff}_0}$, so that Eq. 3 becomes:

$$\frac{n(f)}{n(o)} = \frac{(\Delta k_{\text{eff}}/k_{\text{eff}_0} \beta \hat{f})}{(\Delta k_{\text{eff}}/k_{\text{eff}} \beta \hat{f})}$$

(4)

EXPERIMENTAL APPROACH

WANL-TMI-458 shows how to determine $\left(\Delta k_{\text{eff}}/k_{\text{eff}_0} \beta \hat{f}\right)$ for a subcritical core. After the core reactivity has been determined that way, one would restore the source, record the resulting steady state neutron density, and then drive in a drum allowing the core to reach a new steady state level. From Eq. 4, the ratio of neutron densities gives the drum calibration.

SIGNED

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