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Preliminary Results of a Rossi-Alpha Experiment on the University of New Mexico's AGN-201 Reactor

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A series of Rossi-alpha measurements was performed on the University of New Mexico's AGN-201 reactor to measure the effective delayed neutron fraction, β, and the mean prompt-neutron generation time of the system, Λ_m. An example of one of the Rossi-alpha measurements is shown in Figure 1. Because the reactor is reflected, multiple prompt-neutron decay modes were observed.

Using the two-region Rossi-alpha model proposed by Kistner,[1] the autocorrelation function associated with the decay or growth of prompt neutron chains is described by

$$P(t)\,dt = [A_1 e^{\alpha_1 t} + A_2 e^{\alpha_2 t}]\,dt \tag{1}$$

where *P(t)* is the probability per unit time of detecting chain-related neutrons, α_1 and α_2 are the decay constants associated with the prompt-neutron chains, and A_1 and A_2 are the correlation amplitudes. The first decay mode in Eq. (1) is associated with that group of prompt neutrons that multiply contiguously within the core region on a time scale corresponding to the average lifetime of a prompt neutron in the *bare* core, τ_c. The second decay mode is associated with that group of prompt neutrons that leak from the core region into the reflector region, and then re-enter the core region where they further propagate the prompt-neutron chains by inducing additional fissions. This process occurs on a time scale corresponding to the *mean* prompt-neutron generation time of the integral system which, to a first approximation, is given by[2]

$$\Lambda_m = \frac{\tau_c + f\tau_r}{1 - f} \tag{2}$$

where τ_r is the average lifetime of a neutron in the reflector and f is the total fraction of core neutrons that return to the core region after having leaked into the reflector region.

In accordance to Kistner's model, the second decay constant, α_2, should be nearly linear with subcritical reactivity providing τ_r is relatively small (i.e., on the order of 500 μs or less) and the mean prompt-neutron generation time remains constant as a function of subcritical reactivity. Furthermore, the product $\alpha_2 A_2$ should also be nearly constant over a small range of reactivity in the vicinity of delayed critical. Therefore, in principle, if α_2 is plotted as a function of the inverse count rate of the detector used to perform the Rossi-alpha measurement, the data can be extrapolated to delayed critical (i.e., to the point where $1/C = 0$ where C is the count rate) to obtain a measure of the ratio of β/Λ_m.

In this particular experiment, however, it was observed that α_2 did not follow a linear relationship with $1/C$ and that the magnitude of the product $\alpha_2 A_2$ decreased significantly with subcriticality. These variations indicated to us that the mean prompt-neutron generation time was changing as a function of subcritical reactivity. As a result, our extrapolation to delayed critical to obtain β/Λ_m became more questionable.

We postulated that some of the observed nonlinearities in our data could be negated by normalizing the measured α_2 data to a constant mean prompt-neutron generation time using the inherent property that the product $\alpha_2 A_2$ is inversely proportional to the square of the mean prompt-neutron generation time. This correction was applied by multiplying each α_2 by the square root of the ratio of the product of $\alpha_2 A_2$ corresponding to *delayed critical* to the comparable product corresponding to the measured α_2. Hence, we define an *adjusted* prompt-decay constant to be

$$\alpha_2^* = \alpha_2 \sqrt{\frac{\alpha_{2o} A_{2o}}{\alpha_2 A_2}} \qquad (3)$$

where $\alpha_{2o} A_{2o}$ is the value of $\alpha_2 A_2$ at delayed critical.

A plot of both the α_2 and α_2* is shown in Figure 2. From this plot, we observe that the adjusted decay constants are markedly more linear with $1/C$ than the measured decay constants.

When the adjusted data are extrapolated to delayed critical, we find that β/Λ_m is ~ 127 s^{-1}. Using the measured β ascertained from the same Rossi-alpha measurements,[3] we calculate a mean prompt-neutron generation time of ~ 58 µs. An MCNP analysis indicated that τ_c = 18.7 µs, τ_r = 115 µs, and f = 0.22 yielding a mean prompt neutron generation time of 56 µs.

Furthermore, it was also ascertained that the reactivity of the system $\rho_\$$ as predicted by the traditional one-region Rossi-alpha relationship

$$\rho_\$ = 1 - \frac{\alpha_2^*}{\alpha_{2o}^*} \tag{4}$$

using the adjusted prompt-decay constants agreed to within 1% of the reactivity of the system as measured by the source-jerk technique over the reactivity range of the experiment (i.e., –0.12\$ to –5.74\$).

In conclusion, it appears that nonlinearities in the prompt decay constant associated with changes in the mean prompt-neutron generation time can be easily removed over a fairly large range of subcritical reactivities by applying a measured correction factor obtained from the same data. Future work will include more Rossi-alpha measurements in which the rapidly decaying alpha mode associated with the core will be more clearly isolated. This technique will then be checked to ascertain whether nonlinearities in the core generation time can also be removed.

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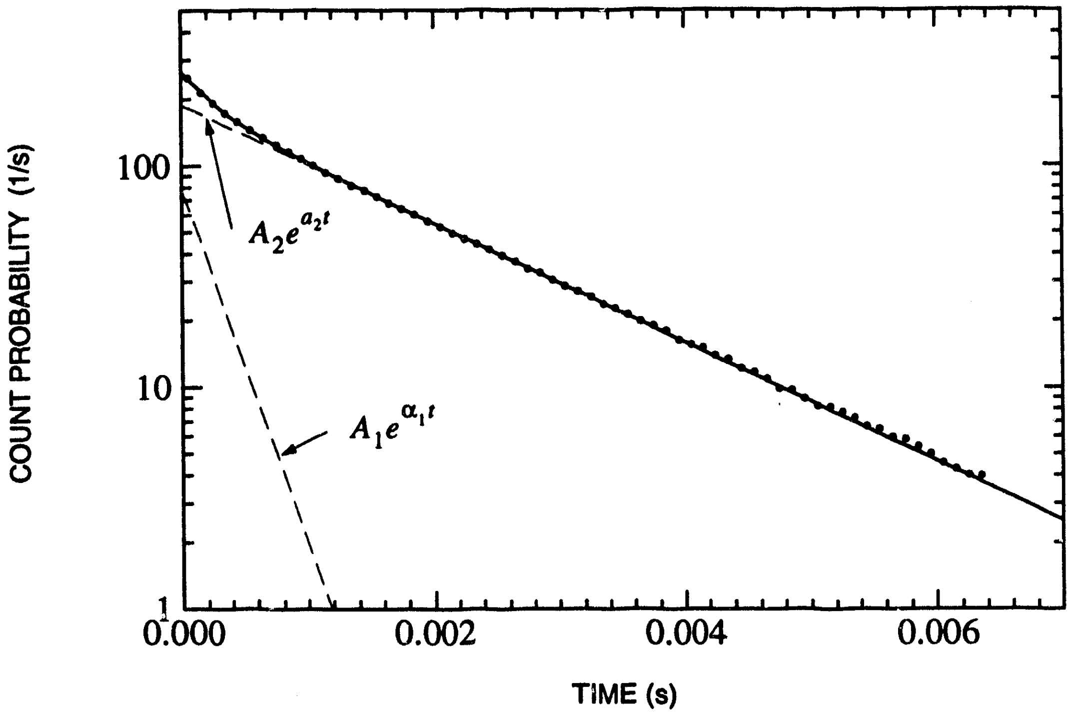

Figure 1

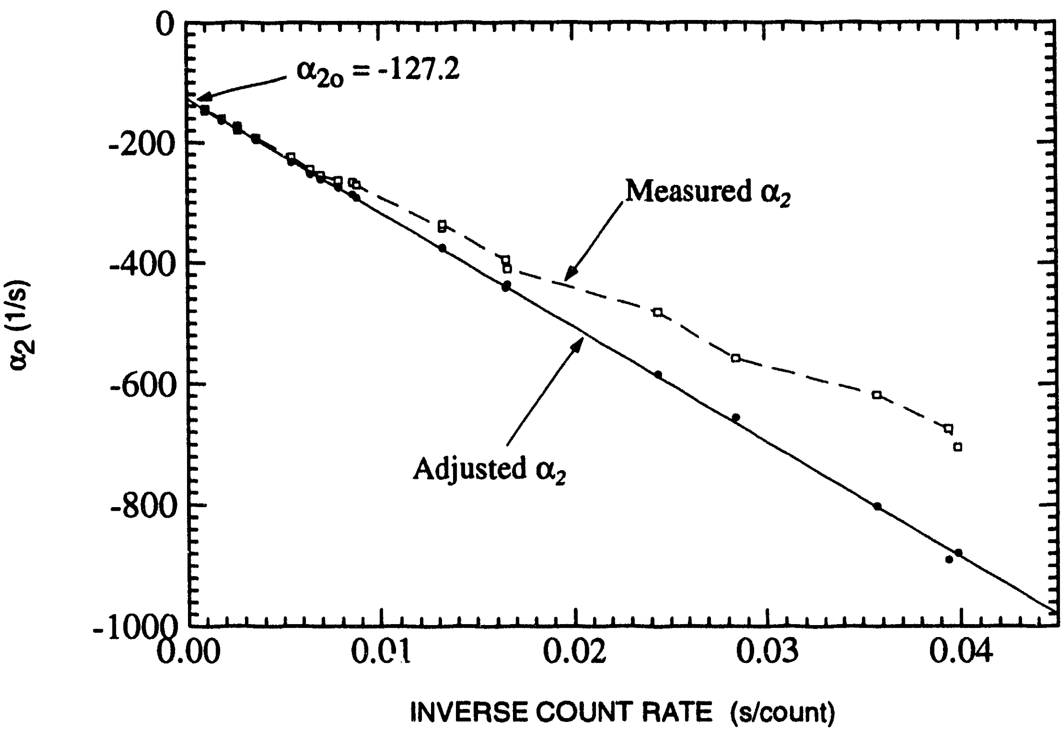

Figure 2