LA-UR- 98- 313

LA-UR--98-313

Title: **Inhour Equation in a Two-Region Reactor With Multiplication in Both Regions**

CONF-980606--

RECEIVED
JUL 01 1998
OSTI

Author(s): Gregory D. Spriggs (LANL)
Robert D. Busch (UNM)

Submitted to: American Nuclear Society Conference
1998 Summer Meeting
Nashville, TN
June 7-11, 1998

January 22, 1998

Los Alamos
NATIONAL LABORATORY

Form No. 836 R5
ST 2629 10/91

Inhour Equation in a Two-Region Reactor With Multiplication in Both Regions

Gregory D. Spriggs
Los Alamos National Laboratory, P. O. Box 1663, MS G783, Los Alamos, NM 87545-0001

Robert D. Busch
University of New Mexico, Dept. of Chem. & Nucl. Eng., Albuquerque, NM 87131-1341

In Reference 1, we presented a two-region point kinetic model for reflected reactors based on the Avery-Cohn[2,3] differential equations. The model was developed for a core region surrounded by a non-multiplying, source-free reflector region. As part of the model development, we also introduced several probability relationships that were essential to calculating the coupling parameters that linked the two regions. Furthermore, we showed how these coupling parameters could be obtained from deterministic transport solutions.

In this work, we present a new model that extends the aforementioned two-region kinetic model by including neutron multiplication in both regions. This new model has practical application to any reactor system that has significantly different neutronic properties in two distinct regions of the system–such as a fast breeder reactor consisting of an inner core surrounded by a multiplying blanket of a different composition. From this new model, we derive the inhour equation that is most appropriate for this type of system.

The differential equations that describe the time-dependence of the neutron populations in a two-region system with multiplication in both regions are

$$\frac{dN_c}{dt} = \frac{k_c(1-\beta_c)-1}{\tau_c}N_c + \frac{f_{bc}}{\tau_b}N_b + \sum\lambda_{ci}C_{ci} + S_c \quad , \tag{1}$$

$$\frac{dN_b}{dt} = \frac{k_b(1-\beta_b)-1}{\tau_b}N_b + \frac{f_{cb}}{\tau_c}N_c + \sum\lambda_{bi}C_{bi} + S_b \quad , \tag{2}$$

$$\frac{dC_{ci}}{dt} = \frac{k_c\beta_{ci}}{\tau_c}N_c - \lambda_{ci}C_{ci} \quad \text{for } i=1, m, \tag{3}$$

and

$$\frac{dC_{bi}}{dt} = \frac{k_b\beta_{ib}}{\tau_b}N_b - \lambda_{bi}C_{bi} \quad \text{for } i=1, n, \tag{4}$$

where

N_c = number of neutrons in region c,
N_b = number of neutrons in region b,
k_c = multiplication factor of region c,
k_b = multiplication factor of region b,
β_c = effective delayed neutron fraction in region c,
β_b = effective delayed neutron fraction in region b,
τ_c = neutron lifetime in region c,
τ_b = neutron lifetime in region b,
f_{cb} = fraction of neutrons that leak from region c to region b,
f_{bc} = fraction of neutrons that leak from region b to region c,
C_{ci} = concentration of the i^{th} precursor group in region c,
C_{bi} = concentration of the i^{th} precursor group in region b,
β_{ci} = delayed neutron fraction of the i^{th} precursor group in region c,
β_{bi} = delayed neutron fraction of the i^{th} precursor group in region b,
λ_{ci} = decay constant of the i^{th} precursor group in region c,
λ_{bi} = decay constant of the i^{th} precursor group in region b,
m = number of delayed neutron groups in region c, and
n = number of delayed neutron groups in region b.

The two-region inhour equation is obtained by setting the denominator of the transfer function equal to zero. This leads to

$$\rho = \frac{\omega\tau_c}{\kappa}\left[1-k_b\left(1-\sum\frac{\beta_{bi}\omega}{\omega+\lambda_{bi}}\right)\right]+\frac{\omega\tau_b}{\kappa}\left[1-k_c\left(1-\sum\frac{\beta_{ci}\omega}{\omega+\lambda_{ci}}\right)\right]$$

$$+\frac{k_c(1-k_b)}{\kappa}\sum\frac{\beta_{ci}\omega}{\omega+\lambda_{ci}}+\frac{k_b(1-k_c)}{\kappa}\sum\frac{\beta_{bi}\omega}{\omega+\lambda_{bi}}+\frac{\omega^2\tau_c\tau_b}{\kappa}\quad, \tag{5}$$

where κ is defined as $k_c+k_b-2k_ck_b$. The reactivity, ρ, in this equaiton is defined as

$$\rho = \frac{\left(\dfrac{k_c+k_b-2k_ck_b}{1-f-k_ck_b}\right)-1}{\left(\dfrac{k_c+k_b-2k_ck_b}{1-f-k_ck_b}\right)}\quad, \tag{6}$$

which is equivalent to $(k_{eff} - 1)/k_{eff}$ where

$$k_{eff} = \frac{k_c + k_b - 2k_c k_b}{1 - f - k_c k_b} \quad . \tag{7}$$

A plot of the roots of this two-region inhour equation is shown in Fig. 1. It should be noted that the two large prompt negative roots from this equation can be used to explain the two prompt alphas observed in Rossi-α measurements in two-region systems in which the neutronic properties are significantly different. An example of a Rossi-α measurement in a fast breeder system comprised on an inner core and a dissimilar outer blanket region is shown in Fig. 2.

REFERENCES

1. G. D. SPRIGGS, R. D. BUSCH, and JOHN G. WILLIAMS, "Two-Region Kinetic Model for Reflected Reactors," *Ann. Nucl. Energy*, **24**, No. 3, 205 (1997).

2. R. AVERY, "Theory of Coupled Reactors," *Proc. 2nd Intern. Conf. Peaceful Uses Atomic Energy*, Geneva, Switzerland, **12**, 151 (1958).

3. C. E. COHN, "Reflected-Reactor Kinetics," *Nucl. Sci. and Engr.*, **13**, 12 (1962).

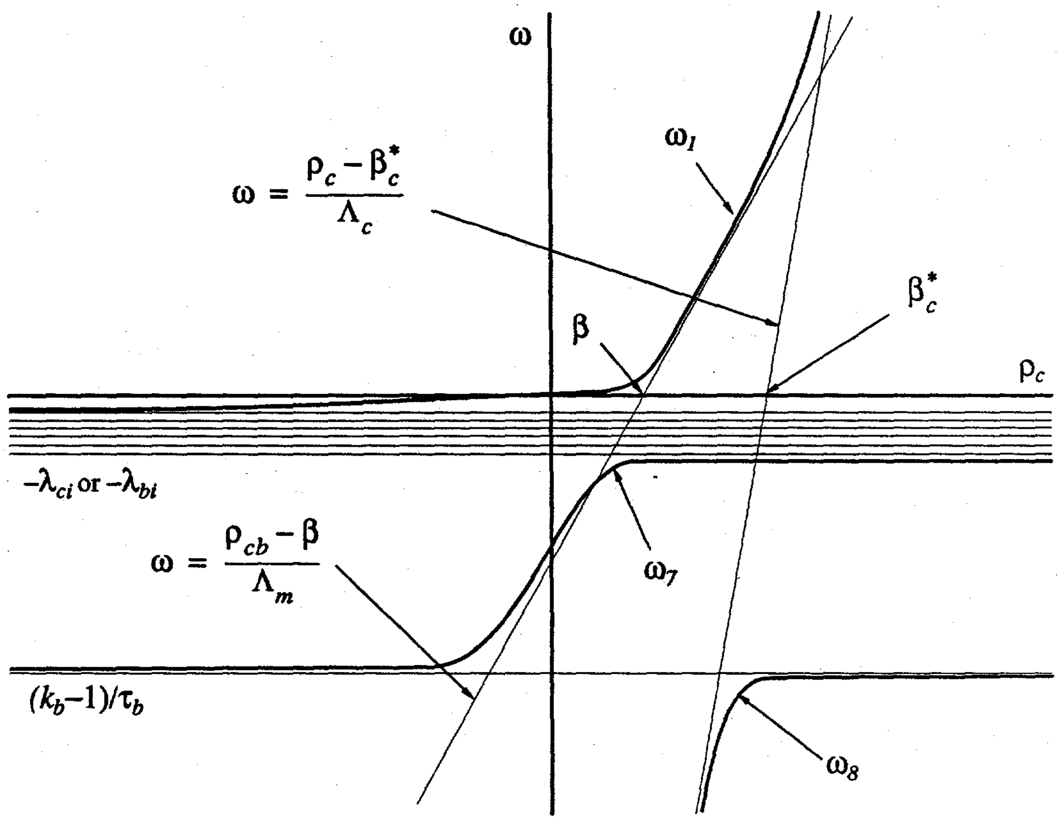

Fig. 1. Qualitative plot of the roots of the inhour equation. (Not drawn to scale.)

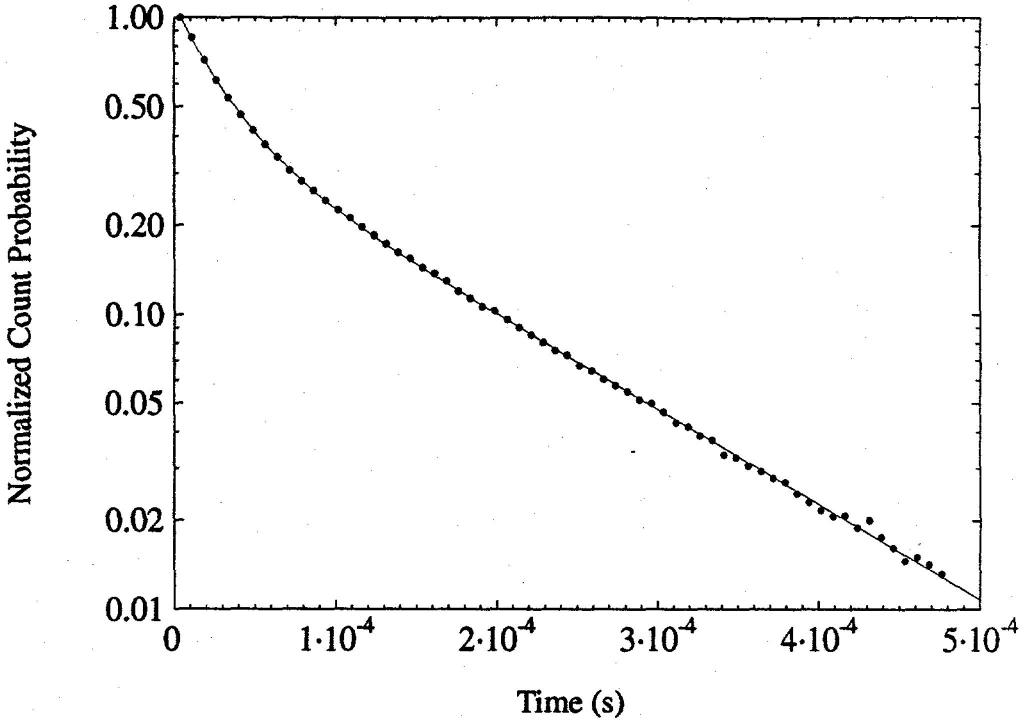

Fig. 1. Rossi-α data obtained from a two-region fast breeder reactor operating near delayed critical.