LETTERS TO THE EDITOR

REMARKS ON THE PLUTONIUM-240 INDUCED PRE-IGNITION PROBLEM IN A NUCLEAR DEVICE

In a recent article, Şahin and Ligou[1] tackled the problem of fissile yields of nuclear devices when commercial plutonium with up to 25% ^{240}Pu is used as the fuel. The erroneous idea behind their approach attacking the problem of pre-ignition is their belief that the neutron kinetics can be treated in a purely deterministic manner. However, the problem is in reality a stochastic one and cannot be solved by using only first moment equations. Methods of reactor noise analysis must be applied.

For instance, it is not self-evident that the neutron density as function of time in a supercritical assembly necessarily develops as described by Eq. (10) of Ref. 1. Many years ago, Dragon-type[2] bursts in the Godiva facility experimentally demonstrated that the time for the power buildup in the Godiva reactor to 2.7×10^{11} fiss/s, following a large step increase of reactivity to $\Delta k/\beta = 0.7$ dollars, varied substantially in the range from 25.4 to 43.9 s (Ref. 3). This behavior is by no means deterministic.

This vivid example leads to the real question that must be asked: What is the time-dependent probability of a source neutron sponsoring a persistent chain reaction? What is the time required for the neutron population associated with this chain to grow to a maximum or to another fiducial value? Or more generally speaking, what is the effect of the probabilistic nature of the processes of neutron loss, production, and branching processes, involved in a chain reaction, on the yield of a nuclear excursion?

Solving these problems by applying some selected stochastical methods of reactor noise analysis, one finds that both the average yield and the "jitter" of the yield, i.e., the variance of the probability density function, are dependent on the unavoidable neutron background during reactivity buildup. This latter property becomes an important issue when the use of reactor-grade plutonium as the fuel for nuclear devices is considered.

It is obvious that one cannot get the appropriate answers to these questions by simply applying the standard deterministic kinetic first moment equations as was done in Ref. 1. In addition to the pre-ignition problem, there are also other effects that give rise to an uncertainty in the energy yield, e.g., the Raleigh-Taylor instability.

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REFERENCES

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2. G. E. HANSSEN, "Statistics of Burst Operation," *Proc. National Topl. Mtg. Fast Burst Reactors*, Albuquerque, New Mexico, January 28-30, 1969 (1969).

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REPLY TO "REMARKS ON THE PLUTONIUM-240 INDUCED PRE-IGNITION PROBLEM IN A NUCLEAR DEVICE"

The criticism of Seifritz[1] on our work[2] is essentially focused on the deterministic manner of the treatment of neutron kinetics. To justify his standpoint, Seifritz mentions the experiments done on the Godiva facility, a ^{235}U-type supercritical assembly with a very weak spontaneous neutron background. We agree that the neutron kinetics problems associated with the spontaneous neutron production in a ^{235}U-type nuclear weapon are of a stochastic nature. This is also the reason why an additional neutron

TABLE I

Neutron Production Due to the Spontaneous Fission of ^{240}Pu in the Core of the Nuclear Bombs in Ref. 2

^{240}Pu (%)	5	15	25
S_0[a] (n/s)	4.96×10^5	1.49×10^6	2.48×10^6
M[b]	28.96	30.47	32.6
S[c] (n/s)	1.44×10^7	4.53×10^7	8.08×10^7

[a] S_0 = neutron production in the far undercritical state [see Eq. (2) in Ref. 2]. The spontaneous fission half-life of ^{240}Pu = 1.2×10^{11} years (Ref. 3). Neutrons per spontaneous fission in ^{240}Pu = 2.07 (Ref. 4).

[b] M = subcritical neutron multiplication factor by arriving at the criticality [see Eq. (14) in Ref. 2]. (Compacting time $T_c = 1\ \mu$s.)

[c] S = neutron production at the state of criticality.