the fuel adjacent to it. However, present Monte Carlo methods are not designed to provide detailed flux distributions. Even after 80,000 case histories statistical fluctuations in the TUT averages preclude any definitive evaluation of the accuracy of P_3 for this problem. With the advent of faster electronic computers, more detailed and more accurate Monte Carlo results may soon be available for comparison.

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Fission Counter Sample Disk Holder and Slide

One method of analyzing uranium compounds to determine the percentage of the uranium isotope U^{235} is to bombard a thin film of the compound with neutrons and measure the ionization resulting from the fission of the U^{235} isotopes present in the film. This method of analysis is best adapted to nonvolatile compounds and is a common method of assay analysis employed at U. S. gaseous diffusion plants. Special counters have been designed and constructed for this purpose at each of these plants. Basically these counters consist of a radium-beryllium radiation source, four ionization chambers housed in a lead shielding assembly, and the necessary electronic equipment for the measurement and indication of ionization. After chemical preparation, a sample of the material to be analyzed is electroplated onto a thin smooth nickel disk. The disk is mounted on a holding plate which is attached to a slide assembly. When inserted into the radiation assembly, the slide positions the mounting plate and sample disk for radiation and ionization measurement. In two of the special counters the plated sample-disk is position on a round mounting plate over which an annular retaining frame is mounted to secure the disk. The frame is held to the mounting plate by spring loaded retaining balls. The disk is then inserted into the counter on a slide device to which the mounting plate is attached. Inside the radiation assembly the sample disk is positioned opposite a collector plate which serves as the sensing element for measuring the ionization. Before a sample is irradiated or "counted," the area between and adjacent to the sample disk and collector plate must be purged with nitrogen to provide a standard atmosphere for each analysis.

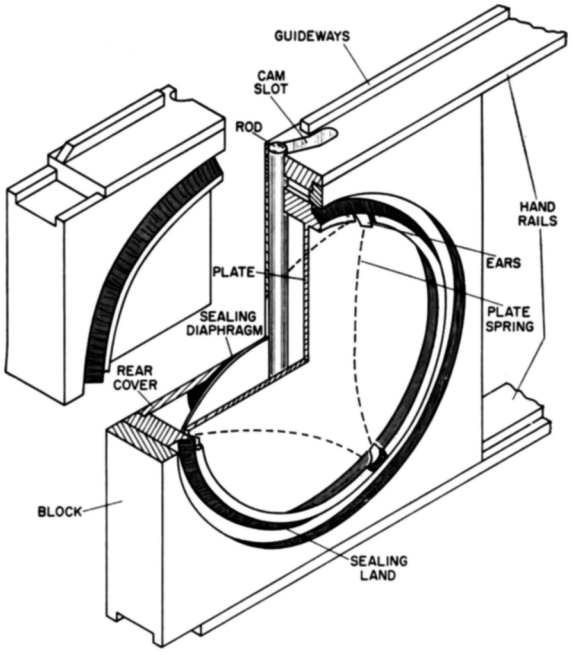

FIG. 1. Fission counter slide holder

The fission counter constructed for use by Goodyear Atomic Corporation is designed to utilize a hemispherical ionization chamber with which the sample disk mounting plate can form a gas-tight seal. This increases the accuracy of the electronic measurement of ionization and provides a confined ionization atmosphere which can be purged and retained for the entire count of the sample. It also provides for reduced purge gas consumption and permits the economic use of a more favorable purge gas. Design modifications provide for a more efficient method of mounting the disk on the sample holder slide assembly. It was necessary to design the sample disk holder slide so that it would vertically position the disk inside the radiation assembly, and then move the disk and mounting plate forward horizontally to engage the rubber O-ring at the mouth of the chamber to form a gas-tight seal. The mechanism designed to provide this motion and a rapid and positive method of mounting the sample disk is shown in Fig. 1.

To place the sample disk on the mounting plate a slight finger pressure is exerted on the portion of the sealing diaphragm exposed through the hole in the rear cover of the mounting plate. This pressure is exerted directly on the center of the triangular-shaped plate spring causing the ears to open at the face of the plate. The disk is placed on the plate face, film side out, and the finger pressure on the spring is then released. The spring contracts, causing the ears to close on the disk, clamping it against the face of the mounting plate.

The slide is then inserted into the radiation assembly and is guided into position by the tongue-and-groove guideways. When the block reaches the bottom of the radiation assembly, the continued downward motion of the handle rails causes the rod to be moved forward by the cam slot. The horizontal movement of the rod in following the cam slot

causes the mounting plate assembly to move forward toward the ionization chamber. The sealing land engages the O-ring gasket at the mouth of the chamber to effect a seal. Any forward motion of the rod and mounting plate before they are properly positioned is prevented by the ends of the rod that extend into the grooves of the guideways. When in position, the rod can move forward in horizontal slots extending from the groove toward the mouth of the ionization chamber. This further prevents vertical relative motion between the sealing surfaces, before the seal is broken, when the slide assembly is being removed from the counter. To remove the sample the action is merely reversed. The seal is broken by the retracting motion of the mounting plate and disk, and the slide assembly is removed from the counter.

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On the Use of Dimensionless Variables in Reactor Kinetics

In a recent letter to the Editor (*1*) S. Pearlstein points out the usefulness of the concept of similitude in such reactor problems as criticality or worth of control rod. Dimensionless quantities prove to be quite useful in reactor dynamics as we are going to show in the simple case of kinetics without feedback.

The simple kinetics equations referred to steady initial conditions read:

$$\begin{cases} \dfrac{dn/n_0}{dt/l'} = \dfrac{n}{n_0}(\rho - 1) + \Sigma_i a_i \dfrac{C_i}{C_{io}} \\ \dfrac{dC_i/C_{i0}}{dt/l'} = -\dfrac{l'}{\tau_i}\left(\dfrac{C_i}{C_{i0}} - \dfrac{n}{n_0}\right) \end{cases} \tag{1}$$

where a_i is the relative delayed neutron abundance

$l' = l/\beta k$ is the reduced neutron generation time

and $\rho = \delta k/\beta k$ is the excess reactivity in dollars.

By imposing a step change of reactivity one obtains the classical "inhour" equation which gives reactor period:

$$\rho_0 = 1 + \frac{l'}{T} - \Sigma_i \frac{a_i}{1 + \tau_{i/T}} \tag{2}$$

With a small sinusoidal variation of reactivity and linearization of the kinetics equations (1), one may define a zero power reactor transfer function as the ratio of the amplitudes of power and reactivity variations:

$$W = \left\{1 + j\omega l' - \Sigma_i \frac{a_i}{1 + j\omega\tau_i}\right\}^{-1} \tag{3}$$

Defining gain G and phase shift ρ by the relation $W = Ge^{i\phi}$, one notices that the relations between $Ge^{-i\phi}$ and $j\omega$, ρ_0 and $1/T$ are identical.

TABLE I

	$10^2\,\beta$	$\bar{\tau}$ (sec)	$\bar{\lambda} = \overline{\tau^{-1}}$	$10^2\,\beta\bar{\tau}$	$\bar{\tau}\,\overline{\tau^{-1}}$	$\overline{\tau^2}/\bar{\tau}^2$
U^{235}	0.65	12.75	0.435	8.30	5.55	2.87
Pu^{239}	0.21	14.64	0.39	3.07	5.70	2.48
U^{233}	0.26	17.865	0.30	4.65	5.36	2.52

Equation (2) may be expanded for large reactor period ($\tau_{i/T} \ll 1$):

$$\rho_0 = \frac{l'}{T} + \frac{1}{T}\Sigma_i a_i \tau_i - \frac{1}{T^2}\Sigma_i a_i \tau_i^2 + \cdots \tag{4}$$

Another expansion is obtained for small period ($\tau_{i/T} \gg 1$):

$$\rho_0 = 1 + \frac{l'}{T} - T\Sigma_i a_i/\tau_i \cdots \tag{5}$$

With small neutron generation time ($l'/\bar{\tau} \ll 1$) these two expansions may be written, respectively:

$$\rho_0 \approx \bar{\tau}/T - \left(\frac{\overline{\tau^2}}{\bar{\tau}^2}\right)(\bar{\tau}/T)^2 \tag{6}$$

$$\rho_0 \approx 1 + \left(\frac{l'}{\bar{\tau}}\right)(\bar{\tau}/T) - (\bar{\tau}\,\overline{\tau^{-1}})(T/\bar{\tau}) \tag{7}$$

where we have defined: $\overline{\tau^n} = \Sigma_i a_i \tau_i^n$

The corresponding expressions for phase shift and gain are, respectively:

$$\text{for } \omega\tau_i \ll 1 \begin{cases} -\tan\phi \approx \left(\omega\bar{\tau}\,\dfrac{\overline{\tau^2}}{\bar{\tau}^2}\right)^{-1} \\ G \approx 1/\omega\bar{\tau} \end{cases} \tag{8}$$

$$\text{and for } \omega\tau_i \gg 1 \begin{cases} -\tan\phi \approx \left(\dfrac{l'}{\bar{\tau}}\right)\omega\bar{\tau} + \dfrac{\bar{\tau}\,\overline{\tau^{-1}}}{\omega\bar{\tau}} \\ G \approx \cos\phi = (1 + \tan^2\phi)^{-1/2} \end{cases} \tag{9}$$

In Eqs. (6) and (9) the delayed neutron properties enter only through the dimensionless numbers $\overline{\tau^2}/\bar{\tau}^2$ and $\bar{\tau}\,\overline{\tau^{-1}}$ provided periods are referred to average delayed neutron mean life $\bar{\tau}$. Table I shows that these two dimensionless quantities are quite close for U^{233}, U^{235}, and Pu^{239} though the total delayed neutron fraction may vary from 1 to 3 and the average mean life by about 50% (*2*). Higher moments are also very close.

The asymptotic behavior represented by Eqs. (6) to (9) may be matched by taking only two groups of delayed neutrons (*3*); the corresponding dimensionless constants should be fairly close since they only depend on the two numbers $\bar{\tau}\,\overline{\tau^{-1}}$ and $\overline{\tau^2}/\bar{\tau}^2$. Since Ref. (*3*) shows that this simplified system represents reasonably well the "inhour" equation over a rather large range of excess reactivity, one should expect the same result by plotting ρ (in dollars) *versus* $T/\bar{\tau}$ for different values of the parameter $l/\beta k\bar{\tau}$. Using data from Ref. (*2*) these dimensionless plots prove to be practically the same for the three fissionable isotopes with $l'/\bar{\tau}$ between 10^{-5} and 5×10^{-2} and for ρ from 0 to 1.5 dollars.

Similar results are obtained for reactor transfer function by plotting G and ϕ *versus* $\omega\bar{\tau}$ with $l'/\bar{\tau}$ as parameter. This may be of interest when studying kinetics of a reactor fueled with a mixture of fissionable isotopes. The knowledge