$$\tau(u) = \frac{D(0)}{\Sigma_{SH}(0) + \Sigma_a(0) + B^2D(0)} + \int_0^u \frac{D(u')}{\Sigma_{SH}(u') + \Sigma_a(u') + B^2D(u')}\, du' \tag{11}$$

$$\frac{1}{L^2(u)} = \frac{\Sigma_a(u)}{\Sigma_{SH}(u) + \Sigma_a(u) + B^2D(u)} \tag{12}$$

$$L_{th}^2 = D(u_{th})/\Sigma_a(u_{th}). \tag{13}$$

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Engineering Test Reactors with Large Central Irradiation Cavities

The critical nuclear parameters of low-density thermally fissionable cores surrounded by moderating reflectors have been surveyed in a RAND report (*1*). The survey shows that cores with diameters in the range, ~½ to ~3 meters, require rather small fissionable masses, ~1 to ~15 kg, for criticality. Thus, the average core density is small enough to suggest the label "cavity reactor" for this unusual configuration of fissionable and moderating materials.

It was suggested that a first natural application of the cavity concept would be for test reactor purposes since a large irradiation volume is inherent to the concept. With a low critical mass, the necessary high flux is obtained if reasonable power densities may be achieved. Calculations indicate that a cavity test reactor with some 4000 liters of central irradiation space may achieve MTR flux levels while operating with MTR fuel plates under established conditions. Only computed results of pertinent characteristics are given here. Some discussion of theory may be found in reference (*1*) and a more extensive paper on both theory and applications will be published in the near future.

The general arrangement of a typical cavity test reactor is shown in Fig. 1a. This example assumes a nominal 2-meter diameter test cavity, U^{235} fuel, and heavy water for moderator and coolant. The central cavity is enveloped by an active core shell in which MTR-type U^{235}, Al fuel plates are loaded to yield the more or less standard macroscopic material densities described in reference (*2*). A critical mass of 8.5 kg of U^{235} (~90%) is required by the newly charged reactor when free of test objects. This estimate assumes that the reactor is bare beyond the reflector.

In order to estimate possible neutron flux levels, the established MTR power density, ~0.36 mw per liter of active core, may be assumed. Since the active core volume in the

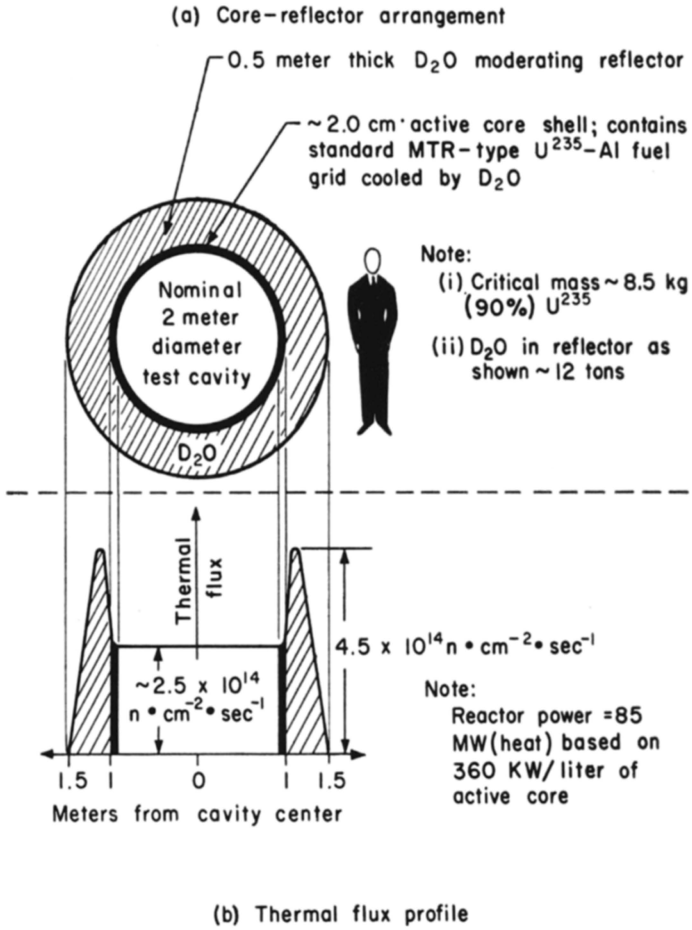

FIG. 1. Core-reflector arrangement and thermal flux profile for a typical cavity test reactor.

reactor of Fig. 1 is 236 liters the system might operate at 85 mw heat power with an average thermal flux of $\sim 2.5 \times 10^{14} n \cdot cm^{-2} \cdot sec^{-1}$ in the core shell. Figure 1b shows the thermal flux distribution over the cavity, core, and reflector. The flux has an extremely flat spacial distribution over both the cavity and the core shell. The average to peak ratio in the active core is about 95%. It is seen that a maximum thermal flux of $4.5 \times 10^{14} n \cdot cm^{-2} \cdot sec^{-1}$ occurs about 13 cm outside of the core. About one neutron per fission or $10^{13} n \cdot cm^{-2} \cdot sec^{-1}$ leak from the outer reflector surface. These neutrons are ~99% thermal and are clearly available for irradiations without decreasing reactor criticality.

Figure 2 shows the average thermal fluxes which exist in various partial reflector volumes. It may be noted that the volume average of the thermal flux taken over the entire reflector slightly exceeds the value inside of the test cavity. Also, it is interesting that a partial reflector volume equal to the central cavity volume has an average flux of ~1.6 times the cavity value.

Figure 3 shows the spectrum and total magnitude of the "slowing-down" flux at two positions in the reactor. The flux of fission neutrons within the test cavity is approximately $\frac{1}{2} 10^{14} n \cdot cm^{-2} \cdot sec^{-2}$.

The regeneration time for fissions by prompt neutrons may be expected to be as large

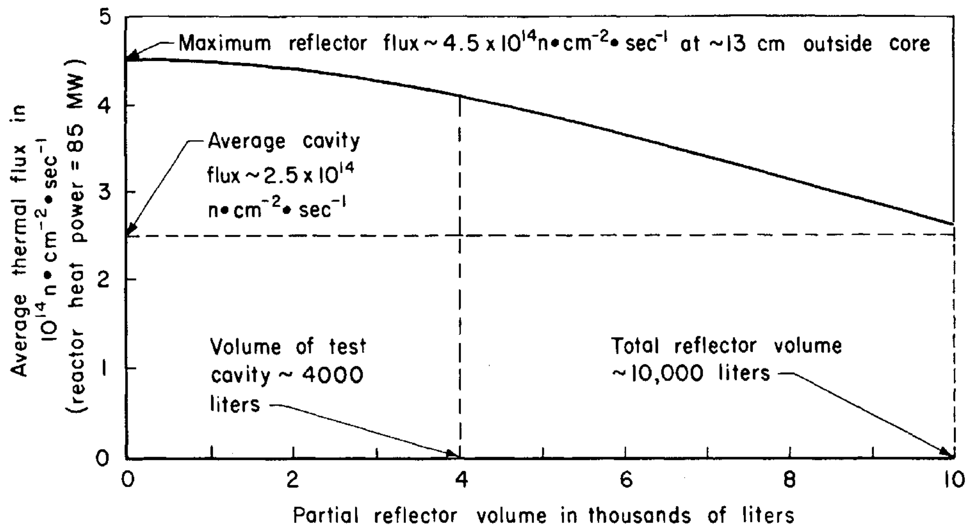

FIG. 2. Average thermal flux in various partial reflector volumes.

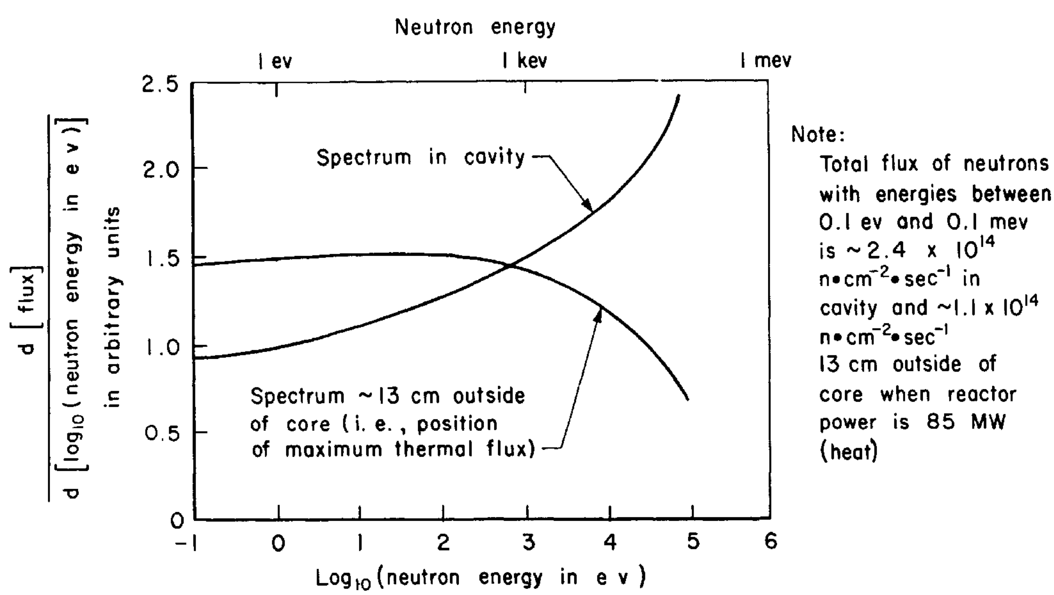

FIG. 3. Spectrum of "slowing-down" flux.

as or larger than this same time in conventional reactors with mixed fuel and moderator. It is easily demonstrated that the time required to traverse the cavity will itself contribute ~1/4000 sec to the total regeneration time. The total may be significantly larger (perhaps by a factor of 2) due to the time required by neutrons to wander from their positions of thermalization in the reflector to the active core shell. Hence, insofar as ultimate reactor safety depends on prompt regeneration time, the cavity configuration should compete favorably with more conventional designs.

The cavity arrangement may lend itself to rather unique control possibilities. Two such possibilities which do not consume large numbers of neutrons might be mentioned. First, the introduction of moderator into a fraction of the cavity volume may increase k appreciably.[1] One might, therefore, achieve a good measure of shim control (to compensate for fuel burnup and experiment loadings) by varying the amount of moderator in the cavity; a rapid withdrawal of this moderator provides a scramming capability. Secondly, it is estimated that k will decrease when the fuel region is drawn inward away from the reflector wall. Thus, a useful amount of Δk might be obtained by starting up a reactor with a gap between core and reflector and then varying this gap as the occasion demands.

The example discussed here should illustrate the basic potentialities of the cavity test reactor. As mentioned earlier, the test cavity in a thermal reactor may be as small as ~½ meter in diameter. Neutronically speaking, there is no upper bound on the cavity size. Considerations of plant investment and engineering scale would probably dictate the maximum dimension. Detailed engineering design may be expected to compromise some of the niceties indicated here. However, it is felt that the assumption of bareness beyond the reflector, the flat flux in the active core, the long regeneration times, and the unique control possibilities without large neutron consumption may provide sufficient latitude to partially off-set adversities imposed by engineering realism. Also, while the illustration assumes MTR core technology, higher temperature cores [e.g., employing LMFR solutions as proposed by Chernick (*3*)] provide room for substantial flux increases in the long range.

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[1] This statement is based on qualitative considerations which indicate that "in cavity" thermal sources are more effective than the external thermal sources in raising the system multiplication constant.

Measurement of the Density of Liquid Rubidium

Density measurements were made on liquid rubidium and the results are represented by the equation

$$\rho(\text{g/cc}) = 1.52 - 0.00054\ (T - 39°\text{C})$$

where T is the liquid temperature in °C. Data were taken from the melting point, 39°C, to about 400°C; however, the equation should hold to the boiling point, 688°C. An error analysis indicated that the values reported here are within 1½% of the true values. The liquid density value of 1.52 g/cc obtained at the melting point substantiates to 3% the value of 1.475 g/cc predicted earlier (*1*).

The determination was made using the buoyancy principle for a solid suspended in a liquid. The system consisted chiefly of an analytical balance from one arm of which a plummet was suspended in the molten rubidium by a 3-mil tungsten wire. The plummets and capsule containing the melt were machined from nickel. The furnace temperature