

**T**HE RESULTS AND THE METHODS DISCUSSED in the following outline of the theory of a chain-reacting pile working with natural uranium and graphite have been obtained partly independently and partly in collaboration by many people who participated in the early development work on the chain reaction. Very important contributions to the theoretical ideas were given by Sillard and Wigner. Many physicists contributed experimental results that helped to lead the way, among them, H. L. Anderson and W. H. Zinn, first at Columbia University and later at the Metallurgical Laboratory of the University of Chicago; R. R. Wilson and E. Creutz, at Princeton; and Allison, Whitaker, and V. C. Wilson, at the University of Chicago. The production of the chain reaction was finally achieved in the Metallurgical Laboratory directed by A. H. Compton.

## ABSORPTION AND PRODUCTION OF NEUTRONS IN A PILE

We consider a mass, "the pile," containing uranium spread in some suitable arrangement throughout a block of graphite. Whenever a fission takes place in this system, an average number ( $\nu$ ) of neutrons is emitted with a continuous distribution of energy of the order of magnitude of 1,000,000 EV. After a neutron is emitted, its energy decreases by elastic collisions with the atoms of carbon and to some extent also by inelastic collisions with the uranium atoms. In the majority of cases the neutrons will be slowed down to thermal energies. This process requires about 100 collisions with carbon atoms. After the energy of the neutron is reduced to thermal value, the neutron keeps on diffusing until it is finally absorbed. In several cases, however, it will happen that the neutron is absorbed before the slowing-down process is completed.

The neutron may be absorbed by either the carbon or the uranium. The absorption cross-section of carbon for neutrons of thermal energy is quite small, its value being approximately  $.005 \times 10^{-24}$  cm.<sup>2</sup> For graphite of density 1.6, this corresponds to a mean free path for absorption of about 25 m. It is believed that the absorption cross-section follows the  $1/v$  law, and consequently the absorption cross-section, which is already quite small at thermal energies, becomes practically negligible for neutrons of higher energy. It is therefore a sufficiently

This paper, presented at the Chicago meeting of the American Physical Society, June 21, 1946, is based on work performed under Contract No. W-7401-eng-37 with the Manhattan District at the Metallurgical Laboratory, University of Chicago.

good approximation to assume that absorption by carbon during the slowing-down process can be neglected.

The absorption of a neutron by uranium may lead either to fission or to absorption by a  $(n, \gamma)$  process. We shall refer to this last possibility as the process of resonance absorption. The relative importance of fission and resonance absorption in the different energy intervals is not the same. In this respect we can consider roughly three intervals:

(1) Neutrons with energy above the fission threshold of  $U^{235}$ —We can call these conventionally "fast neutrons." For fast neutrons the most important absorption process is fission, which normally takes place in the abundant isotope  $U^{238}$ . Resonance absorption is smaller but not negligible.

(2) Neutrons of energy below the fission threshold of  $U^{238}$  and above thermal energy—We shall refer to these neutrons as "epithermal neutrons." For epithermal neutrons the most important absorption process is the resonance capture. The cross-section for this process as a function of energy is quite irregular and presents a large number of resonance maxima that can be fairly well represented by the Breit-Wigner theory. In practical cases the resonance absorption becomes important for neutron energy below about 10,000 EV and increases as the energy of the neutrons decreases.

(3) Neutrons having thermal agitation energy or "thermal neutrons"—For thermal neutrons both the resonance and fission absorption processes are important. In this energy range both cross-sections follow approximately the  $1/v$  law, and therefore their relative importance becomes practically independent of the energy. Let  $\sigma_f$  and  $\sigma_a$  be the cross-sections for fission and resonance absorption for neutrons of energy  $kT$ , and  $\eta$  be the average number of neutrons emitted when a thermal neutron is absorbed by uranium. Then  $\eta$  differs from  $\nu$ , since only the fraction  $\sigma_f/(\sigma_f + \sigma_a)$  of all the thermal neutrons absorbed by uranium produces a fission. It is, therefore,

$$\eta = \nu\sigma_f/(\sigma_f + \sigma_a). \quad (1)$$

The preceding discussion leads one to conclude that only a fraction of the original fast neutrons produced will end up by producing a fission process. For systems of finite size, further losses of neutrons will be expected by leakage outside the pile.

Limiting ourselves for the present to systems of practically infinite dimensions, we shall call  $P$  the probability that a fast neutron ultimately is absorbed by the fission

# Elementary Pile Theory

**U.S. Atomic Energy Commission**



## Elementary Pile Theory:

**Lectures on Elementary Pile Theory** Irving Kaplan,1952      **Elementary Pile Theory** Harry Soodak,1949

**Calculation of Neutron Distributions in Heterogeneous Piles** A. M. Weinberg,1947      *Nuclear Engineering* U.S. Atomic Energy Commission,1954 This bibliography contains 480 annotated references to AEC reports and to the open literature A list of pertinent bibliographies an author index and a report number index with availability information are also included

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Atomic Scientists is the premier public resource on scientific and technological developments that impact global security Founded by Manhattan Project Scientists the Bulletin s iconic Doomsday Clock stimulates solutions for a safer world

*Information sources* U.S. Atomic Energy Commission,1955      **Reactor Physics Laboratory Manual** Oak Ridge School of Reactor Technology,United States. School of Reactor Technology, Oak Ridge, Tenn,1955      *Selected Reference Material, United States Atomic Energy Program: Information sources* U.S. Atomic Energy Commission,1955      **Selected Reference Material, United States Atomic Energy Program** U.S. Atomic Energy Commission,1955      **AECU** ,1952      **Effect of Interaction on Critical Mass** R. L. Macklin,1950      **Jack Chernick, 1911-1971** Jack Chernick,1973      **The Application**

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designers and academicians By joining the contribution of all of them it was possible to elucidate the today s state of the art in science technology and practice in the application of stress wave theory to piles BOOK JACKET Nuclear Science in Engineering Education Simone B. Schwind,1952 **Some Remarks on the Influence of the Expansion of Heavy Water on the Reactivity of a Nuclear Reactor** M. Bogaardt,1952

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