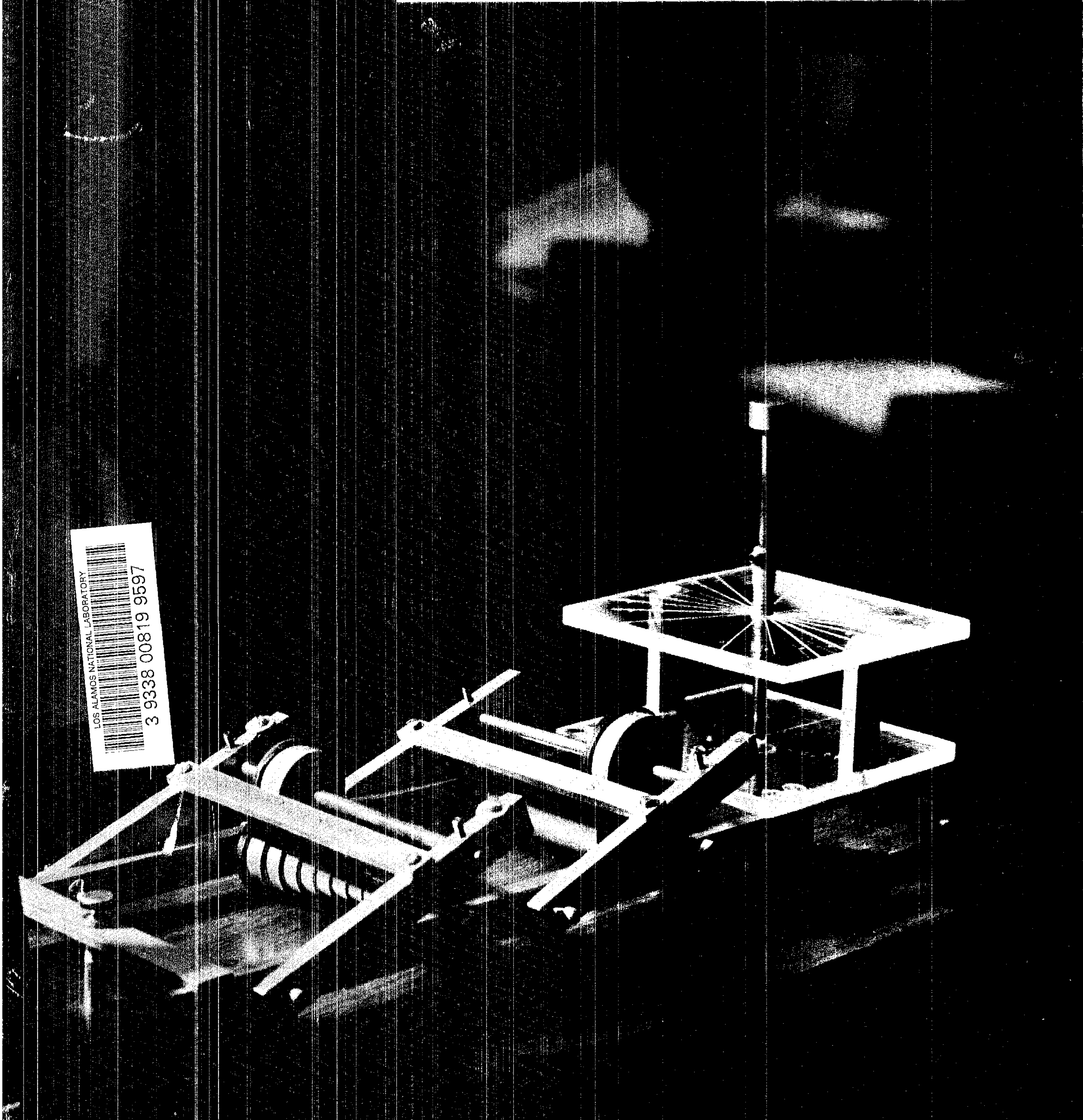
THE ATOM

Los Alamos Scientific Laboratory October, 1966



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THE ATOM

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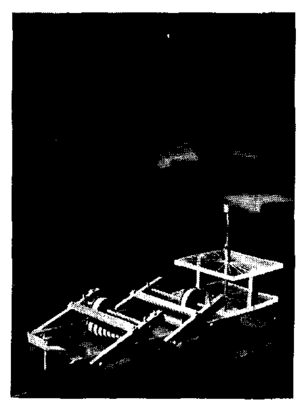

COVER:

A forerunner of the modern computer—invented by Enrico Fermi—was recently unearthed during an office move at the Laboratory. Story begins on page 7.

Fermi Invention Rediscovered At LASL

Listening to the clatter and whir of a room-size modern computer, it is difficult to imagine that a quiet little brass gadget with only a couple of moving parts could be one of its not-too-distant ancestors. But the little "machine" that looks as though it might have come from a toy shop was a useful tool for a group of now-widely-recognized LASL scientists as recently as 17 years ago.

Invented in 1947 by Enrico Fermi, frustrated by the unavailability of the then-new electronic computer, ENIAC, this little 13-inch-long hand-operated computer was constructed by L. D. P. King, then F division group leader at Omega Site and now director of flight safety for the Rover program.

After about two years of use, it was put aside in 1949, when the new, fast electronic computers became generally available. All but forgotten, the little machine was unearthed recently, dusty and tarnished, during an office move. Now polished and mounted on a walnut slab, it will soon be added to the exhibits in the LASL Science Museum.

The infant computer—which never really had a name—was used to trace the histories of neutron movements, making use of a computational technique known as the "Monte Carlo" method. Since its recent resurrection, several of the LASL scientists who used the gadget have suggested naming it the Fermi trolley, the Monte Carlo trolley, or the Fermiac, all appropriate since this Fermi invention which made use of the Monte Carlo method actually was a predecessor of ENIAC and MANIAC.

Stan Ulam, research advisor for LASL and T-3 group leader; Carson Mark, T division leader; N. C. Metropolis, inventor of the MANIAC; Bengt Carlson, T-1 group leader; and Robert Richtmyer, for-

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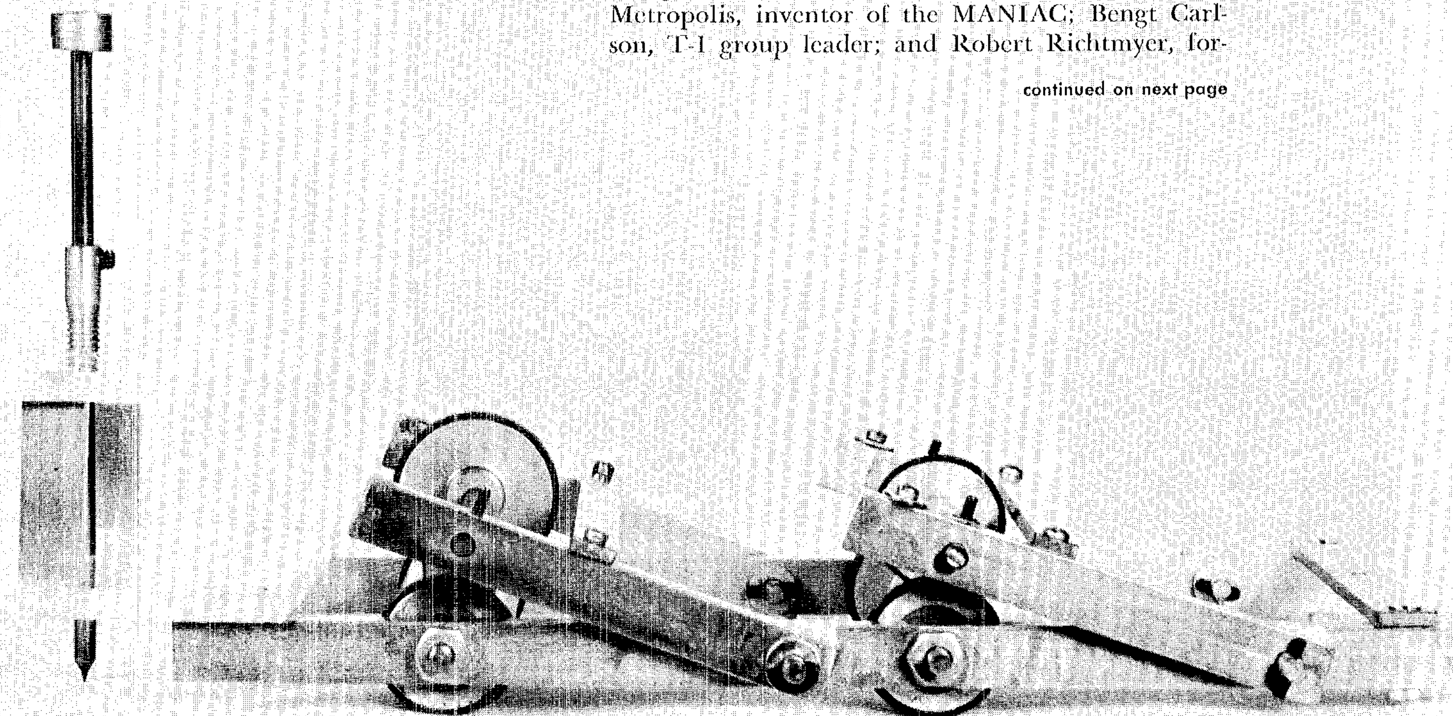

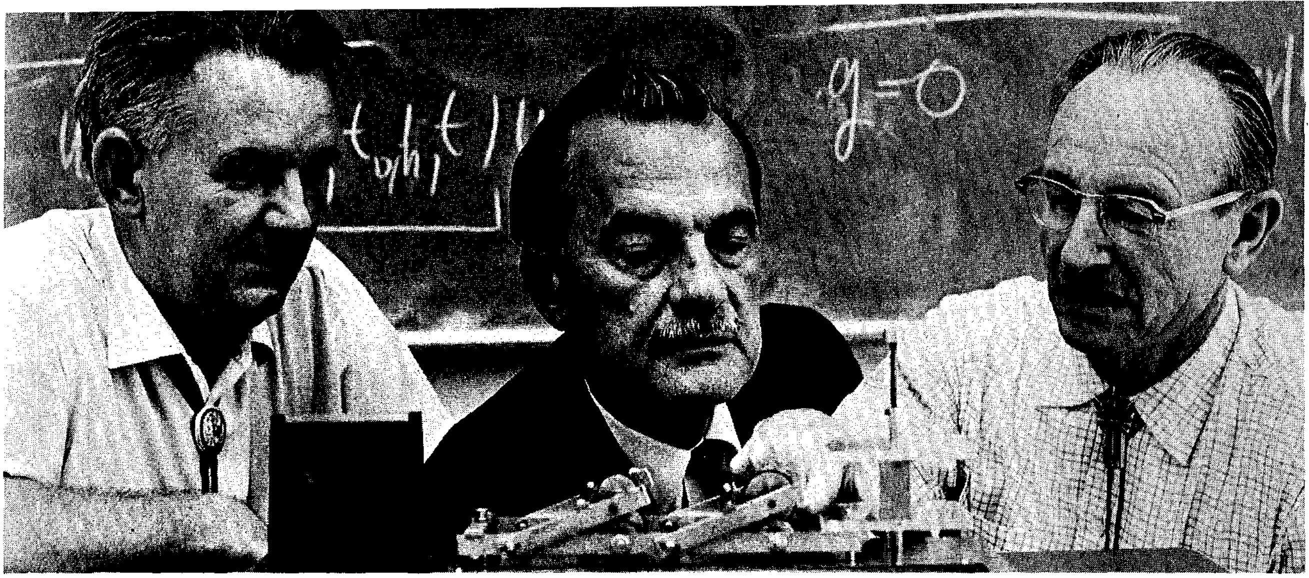

Bengt Carlson, N.C. Metropolis and L. D. P. King, who used the Fermiac some 18 years ago, suggested it be placed in LASL's science museum.

Fermiac . . .

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mer T-Division leader and now Laboratory consultant, the first scientists to use the Fermiac, formulated various types of calculations by the Monte Carlo method.

Ulam had first suggested a statistical method for handling neutron problems in 1946. With fast electronic computers on the horizon, it seemed to be a practical method for studying the behavior of collections of neutrons. Early in 1947, John von Neumann, professor of mathematics at the Institute for Advanced Study and Laboratory consultant, worked out a step-by-step procedure for such calculations.

"This meant generating individual neutron histories as dictated by random mechanisms—a difficult problem in itself," Metropolis explained. "Thus, neutrons could have different velocities and could pass through a variety of heterogeneous materials of any shape or density. Each neutron could be absorbed, cause fission or change its velocity or direction according to predetermined computed or measured probability. In essence, the 'fate' of a large number of neutrons could be followed in detail from birth to capture or escape from a given system."

But there was a lull in the utilization of the ENIAC (electronic numeral integrator and computor) which was under development by Aberdeen Proving Grounds on contract with the University of Pennsylvania and was being moved from Philadelphia to Aberdeen.

This is when Fermi came to the rescue. A member of the Laboratory staff during the war years, he had returned to the University of Chicago but continued to serve as a consultant for LASL. So when he made his customary summer visit in 1947, he found the LASL men frustrated at having a computer technique and no appropriate computer on which to use it.

"But Fermi's agile mind was accustomed to coming up with solutions for the most difficult problems, and this was no exception," King recalls. "He suggested making a quick and inexpensive mechanical device which would provide at least some answers using the Monte Carlo method for treating neutron systems.

"During the war years when Fermi resided at Los Alamos and was in charge of F Division, he was accustomed to coming down to Omega Site almost every day. He used the Water Boiler reactor and Omega Site as sort of a relief valve from the pressing discussions and theoretical work going on in the main technical area. It was therefore quite natural that he would turn here to get something made that was very close to his heart," said King.

It was at a family picnic in Santa Clara Canyon that Fermi and King first discussed the possibilities of such a device.

"Fermi obviously had something on his mind, for no sooner had we deposited our respective families on a nice, grassy picnic spot next to the stream than he suggested we walk along the canyon," King said.

"The idea of applying some sort of a moveable mechanical device to follow hypothetical neutron tracks as they progressed through various material regions was quite new to me. He therefore had to do considerable explaining. In his usual clear, simple manner he explained the whole scheme in detail, starting with an explanation of the Monte Carlo method as applied to neutronics.

"It was a memorable occasion for me to walk and talk for over an hour with this great man in the beautiful canyon surroundings and to feel that I could make a contribution to something he thought was important to the LASL effort."

So King spent a little overtime with Fermi in the Omega shop to come up with an overall design which would meet his requirements.

"The most difficult part," said King, "was to make the 10-step roller which would roll out the neutron range in the particular material in question. I still have the first one of these I made, since, on the last step, I turned the brass down until it got too thin and the end broke off. Fermi wanted all the diameters turned down to an accuracy of at least a mil. This posed a little problem in getting the rubber tires just right, but we finally got it done."

After Fermi went back to the University of Chicago in the fall, Bengt Carlson's T division group successfully used the little brass Fermiac until the fast multimillion-dollar electronic computers arrived.

"Although the trolley itself had become obsolete by 1949, the lessons learned from it were invaluable," Carlson said.

The Monte Carlo method for computations is still extensively used. But now scientists feed their information into a huge and complex electronic computer—instead of pushing a toy-like gadget across a piece of painted cardboard.

The "trolley" was rediscovered recently when Carlson changed offices, and, said King, "The Los Alamos Science Museum seems like a fitting place for this brainchild of Fermi's."

Several of the men who used the Fermiac or trolley in the late forties—including Ulam, King, Carlson and Metropolis—got together after its "resurrection" and prepared a detailed explanation of how it works.

An example of one of its uses is to determine the change in neutron population with time in numerous types of nuclear systems. The neutron population would either increase, decrease or remain constant, representing a supercritical, subcritical or critical system, respectively.

The three basic steps involved in using this primitive little computer are:

First, to determine the site of the first collision or possible escape of each of the source neutrons (100 were initially used). This is accomplished by statistical considerations based on the detailed characteristics of the particular type of material being traversed as well as by the velocity of the neutron under consideration.

Second, to establish in a similar manner the nature of the collision for each neutron. This can be either an elastic collision or an absorption leading to inelastic scattering or fission—if the material re-

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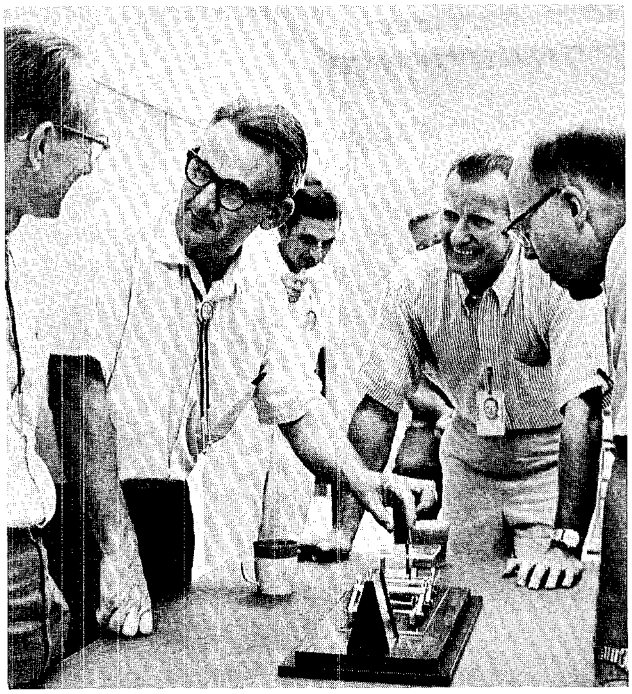
Enrico Fermi and L. D. P. King chat at a 1946 party.

Fermiac, on its museum mounting, was quite an attraction in T-1. King chats with T-1 Group Leader Bengt Carlson as Fred House, Paul Harper and Tom Jordan look on.



Stan Ulam, who in 1946 suggested a method for handling neutron problems on a computer, holds the first "computer" used for that purpose.

Fermiac . . .

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gion is fissionable. The details of these interactions in turn were based on statistical considerations reflecting the experimental and theoretical knowledge of such processes.

The third step in following the "fate" of each neutron depends on the specific outcome of the first two steps:

If the collision is elastic, the direction of motions of the neutrons is the only change, and the neutron is again followed to its next collision site.

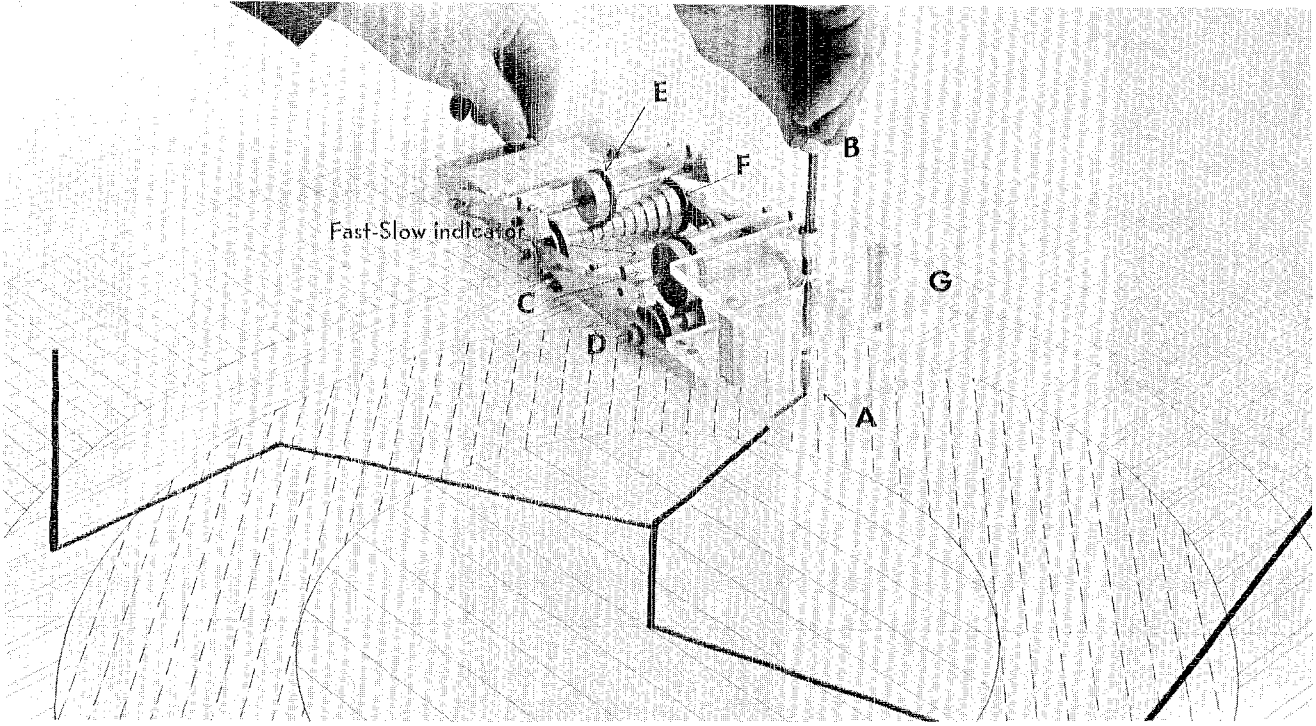
If the collision results in an inelastic scattering event, the neutron undergoes a change in both direction and speed, and again the new motion is followed to the next collision.

If the neutron collision leads to fission, the history of this particular neutron is terminated. However, the several neutrons of the new generation created by the fission process are separately followed in a similar manner. In this way a "geneology" for each of the source neutrons is established.

If the neutron crosses the outer boundary, it is considered to have escaped, and its history is terminated.

From a large collection of these geneologies the behavior of the physical system may be inferred —that is, whether the weapon or reactor design under consideration is a critical, subcritical, or a supercritical assembly, King explained. His more detailed explanation of how the Fermiac operates is on the following page.

Said King, "The trolley is one more example of Fermi's genius to come up with a solution to a then-difficult problem. He had a fantastic ability to comprehend, digest and simplify any challenging theoretical problem and devise simple experiments to supply answers to unknown quantities."



How the Fermiac Operates . . .

King explained that before the Fermiac or trolley is operated, a scale drawing of the nuclear device under study must be made. This is idealized as a set of concentric shells of different materials which, in the drawing, appear as circular rings to represent the planar projection of the materials. A reference base line runs through the center of the system. The physics data about the device and a table of random numbers are also used.

After an initial collection of source neutrons is decided upon, the following steps are performed:

(1) The tip of pointer A is placed on the location of one of the source neutrons. Knob B is used to raise or lower the pointer tip to permit forward motion, a precise positioning, or rotation, if necessary, about the collision point.

Calibrated wheel C measures the elapsed time based on the velocity of the particular neutron in question. Wheel C is turned to zero and set on the drum D to position *F* or *S*, representing fast or slow neutrons, as the case may be. King noted that when the first problem was being worked out, it was discovered that the F and S initials were reversed. A piece of paper tape with penciled letters now corrects this error.

Wheel E is calibrated to measure the distance traveled by the neutron between collisions based on neutron velocity and the properties of the material being traversed. These two characteristics are obtained by proper placement on the multistep drum F, which represents the type of neutron as well as the particular type of material at the position of the pointer.

(2) Next, a random digit is selected and the trolley rotated about the pointer A until the ruling on the lucite platform G coincides with the selected direction. The lucite platform serves as a neutron direction selector. Two sets of 10 directions give the appropriate direction in the planar projection from a three-dimensional system.

(3) Another number is then selected and interpreted as the distance to the next collision. The trolley is then rolled forward until the reading on the wheel E corresponds to this number. If the pointer passes over an interior boundary en route, the trolley is stopped momentarily to permit a shift of the wheel E to a different drum diameter on F to reflect a change in medium. The trolley then continues in its original direction. On the other hand, if the pointer A crosses an outer boundary, the neutron escapes from the system and is no longer followed.

(4) When the trolley has arrived at the next collision distance as determined by the position of wheel E, the nature of the collision is determined by picking an appropriately selected random number.

In the case of an elastic collision, the trolley proceeds as described in 3 and 4 after setting wheel E to zero.

In the case of an inelastic collision, a similar procedure is followed except that now wheel C and, hence, wheel E may have to be repositioned on their respective drums to take care of any change in the neutron velocity.

In the case of fission, that neutron history is terminated, and the trolley begins to follow the history of one of the new generation of neutrons created by the fission process. In due course the trolley returns to this point to trace out the geneology of the remaining neutrons of this fission event.