

Reactor Physicists Emphasize Need for Neutron Data

The precise importance of neutron cross sections in understanding and predicting a large variety of physical phenomena was the introductory subject of a recent four-day conference held in Washington, D. C., 4-7 March. Since the initial conference two years ago on the same general subject (PHYSICS TODAY, June 1966, page 53), we have much new and revised experimental data, and automated data-handling facilities have come into their own. Also, as had been predicted, a new subdiscipline of nuclear physics called "data evaluation" has emerged, forming a necessary intermediary bridge between the measurers of nuclear data and the users in applied fields. Finally, at least in nuclear-reactor design, there is a much clearer indication of the real value of basic data and, to some extent, their practical economic worth. These general subjects were covered by 19 invited and 107 contributed papers.

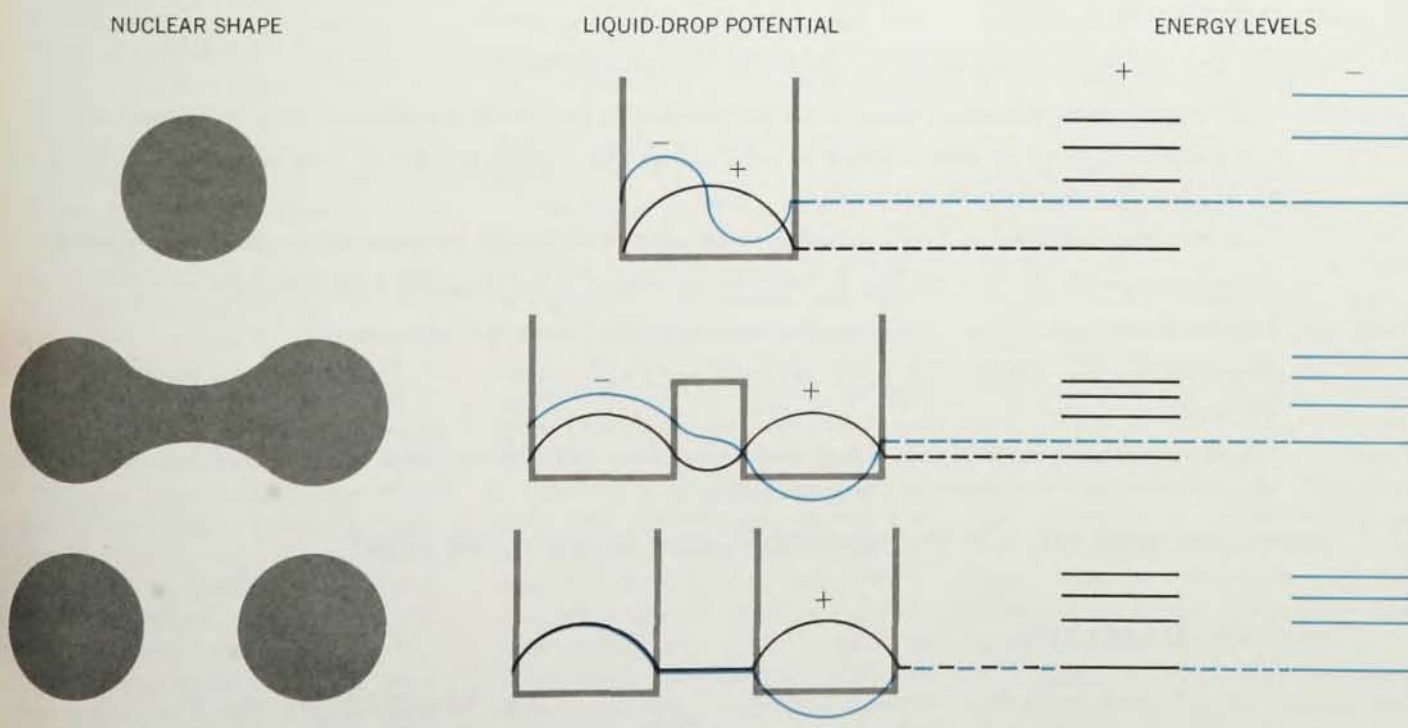
The need for knowledge of neutron cross sections in understanding reactor behavior is frequently mentioned

and discussed although perhaps not as well documented as it might be. This need is manifest from the birth of neutrons in the fissioning of heavy nuclei, through their subsequent slowing down by elastic and inelastic scattering and finally to their absorption. This absorption can occur by fissile nuclei to produce more neutrons, by other nuclei for either control or parasitic absorption, or (of special importance recently) by fertile nuclei such as Th^{232} or U^{238} in breeder or converter reactors. The importance, or urgency, of new neutron cross-section measurements, however, depends somewhat upon the type of reactor.

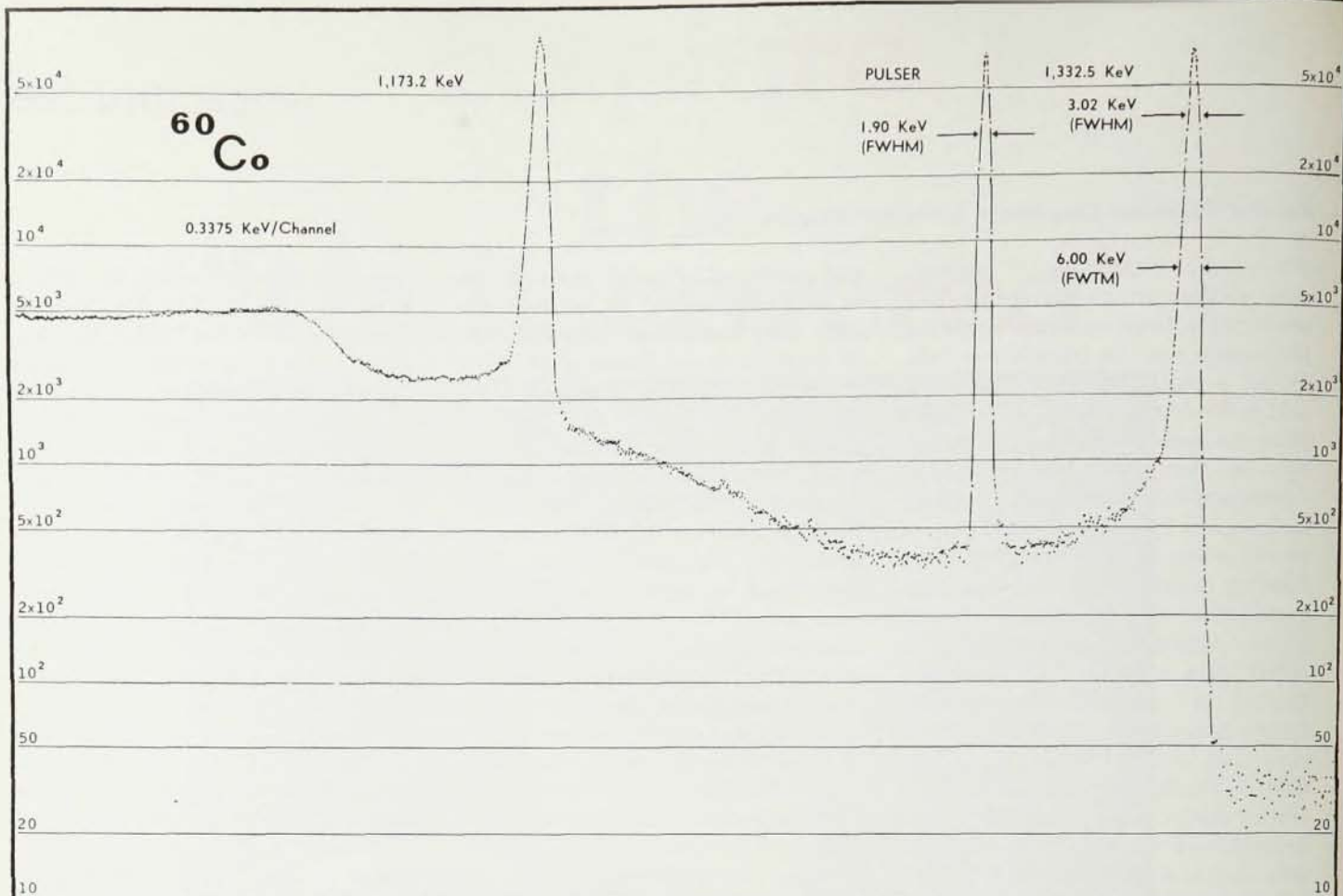
Uncertain costs. As an example for many vital characteristics such as the beginning-of-life conditions in a thermal light-water reactor, Robert J. French (Westinghouse) pointed out to the conference that uncertainties resulting from basic data are less than those resulting from other characteristics such as manufacturing tolerances and impurities. This condition persists to a reactor lifetime of about 10 000

megawatt days per metric ton of uranium, as exemplified by the predicted characteristics of the Yankee Reactor, which has been in operation for about that amount of exposure. In addition the general behavior of the Saxon Reactor core, partially fueled with plutonium, can be predicted on the basis of present cross-section values. For these kinds of reactors we now have a great deal of operating experience with which predictions can be compared. The exact economic cost of thermal reactors remains unknown because of uncertainties of the worth of discharged plutonium, of the buildup of capture products such as Pu^{238} (a potentially valuable isotopic heat source), and of fission products that might affect the extremely long-life-time cores. However, French expected information from post-irradiation studies to be most useful in determining these costs.

A different point of view was presented by Paul Greebler, Bruce A. Hutchins and Bernard Wolfe (General Electric) on fast-breeder reac-



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tors. To take advantage of the low value of alpha (capture-to-fission ratio) for Pu^{239} in the energy region above approximately 1 eV, neutron moderation is inhibited in these reactors, and the major part of the neutron flux is in the epithermal region where cross sections are less likely to be known with precision. In addition, properties such as temperature (Doppler) broadening of resonances, necessary for control of the system, are uncertain because of the lack of operating experience.

Two types of uncertainties in these reactors—fuel cost and specific performance characteristics—might make necessary an initial overdesign. Perhaps, if the uncertainties were especially unfavorable, a particular reactor concept might be cancelled. Alfred Perry (Oak Ridge) showed that, for molten-salt and high-temperature gas-cooled thermal reactors, uncertainties in breeding ratios and power costs are quite small. However, further refinements in nuclear data are needed for calculation of temperature coefficients of reactivity.

Alvin Radkowsky (Naval Reactors, Atomic Energy Commission) pointed out that in yet another type of reactor, the light-water breeder, the breeding ratio and hence the success of the project are very sensitive to particular cross sections. Eric Ottewitte (Atomic International), in discussing reactors for space applications for which cost is secondary, mentioned the possible use of separated isotopes for control materials. A much simpler design would be possible if we could find a nuclide with the cross-section characteristics desired.

Shielding. In addition to the design of reactors, an important application for neutron cross sections is in shielding—whether of individuals from the radiations of a nuclear reactor or astronauts from cosmic rays. Herbert Goldstein (Columbia U.) emphasized that in shielding applications the need for cross sections predominates in the region above 1 MeV where the major damage occurs. Also production of gamma rays by neutron capture or inelastic scattering demonstrates the need for photon cross sections. In a review paper dealing with a much more esoteric field, that of understanding nucleosynthesis in stars, William A. Fowler (Cal Tech) showed the need for neutron capture cross sec-

tions for many nuclei. Monroe Wechsler (Oak Ridge) spoke on radiation damage produced by neutron scattering.

Data deluge. The largest number of contributed papers dealt with measurement and analysis of neutron cross sections. Goldstein attributed this large amount of new information to two factors. The first is the use of new and powerful neutron sources—electron linear accelerators (Geel, Rensselaer Polytechnic Institute, General Atomic, the National Bureau of Standards, and the Japanese Atomic Energy Research Institute) and the isochronous cyclotron at Karlsruhe—and further use of nuclear detonations, all of which were discussed at the conference. The second factor causing an increase in cross-section data is improvements in instrumentation as exemplified by the lithium-drifted germanium solid-state detectors with their remarkable energy resolution for gamma-ray detection. In fact, partial cross sections have been measured so well of late that William W. Havens Jr (Columbia U.) suggested it was time to remeasure total cross sections to take advantage of these new developments.

Four comprehensive invited papers reviewed the experimental data. André Michaudon (Saclay) and John A. Farrell (Los Alamos) spoke on fission cross-section results, their interpretation and prospective improvements therein. Michael C. Moxon (Harwell) reported on the total, capture and scattering cross sections in the resonance region (below about 100 keV) and Samson A. Cox (Argonne) spoke on the higher-energy region.

Theoretical models. Faced with the continuing and enlarging mass of data the theoretical physicist attempts to provide a mechanism for understanding it, as least in an average sense. Eric W. Vogt (U. of British Columbia) discussed the present status of the optical model, which has been highly successful in collating and interpreting large quantities of these data. Vogt, in addition, showed how this model and other experimental information such as p,n "quasielastic" reactions could be used to calculate cross sections for energy ranges and nuclei where experimental results are not yet available. Felix and Donnetella Adler (U. of Illinois) showed their progress in multilevel fitting procedures to reproduce the neutron cross

sections for fissile nuclei in the resonance region, where interference between resonances is important.

Perhaps the most interesting excursion into a new field was provided by James Griffin (U. of Maryland), who presented an explanation of asymmetric fission; that is, that the fissioning nucleus does not, in general, divide into two equal masses. He pointed out that this is almost the oldest problem in nuclear physics. Griffin described a model for which the mass division ratio is, to a first approximation, the ratio near the saddle point of the number of nucleons in gerade orbits (symmetric under reflection in the plane perpendicular to the nuclear axis) to the number in ungerade orbits (see figure). The full implications of this model have not yet been explored, but as the liquid-drop model underlies it, we expect significant improvement in our understanding of fission.

Compilations. On the last day of the meeting we turned to another problem; one that threatens to inundate personnel in this field. Now that the need for more accurate data is justified, and high-power machines with sensitive detectors allow the experimentalist to turn out massive amounts of basic data, how should we handle these data in a reasonable manner? A solution in the past was the familiar BNL-325 Barn Books. The answer now, of course, lies primarily in maximal utilization of computers. In addition, an international division of labor is associated with the compilation of neutron data. The interregional cooperation in this field was described in papers by Sol Pearlstein (Brookhaven National Neutron Cross Section Center), Victor J. Bell (ENEA Neutron Cross Section Compilation Centre) and Hans D. Lemmel (IAEA Nuclear Data Unit). A corresponding effort exists in the USSR, at Obninsk, but was not specifically reported. Pearlstein discussed the success of the Evaluated Nuclear Data File, a cooperative effort among about 20 installations in the US. This effort has produced a computer file of evaluated neutron cross sections for many elements and individual nuclides and a variety of computer programs for automatic data handling.

The progress of computer data handling and evaluation was also the subject of Harry A. Alter (Atomic International). Heated discussion developed on the importance of con-

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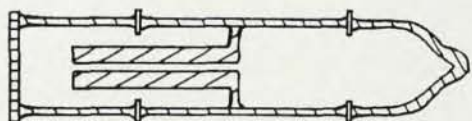
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tinued interposition of human activity between the acquisition of experimental data and their resultant evaluation. Joseph J. Schmidt (Karlsruhe) in an invited paper maintained that a continued examination of the data throughout the evaluation process is a necessity.

After reducing the vast amount of cross-section values into a set or sets of evaluated data, we require a further examination of these data to ascertain their quality, especially where the experimental data are known to have been poor, conflicting or totally absent. As pointed out earlier, the need for cross-section values exists even in regions where they have not been measured. Present practice determines the worth of evaluated cross-section sets by the accuracy of simple, or relatively simple, macroscopic measured quantities as calculated with these sets. These "integral" experiments are designed so that the mathematical models used to analyze them are on firm ground, and all uncertainties in their analysis are attributable to uncertainties in the microscopic cross sections. Charles A. Stevens (Gulf General Atomic) showed by this kind of analysis how neutron spectrum measurements can resolve differences in cross-section data. However, William G. Davey (Argonne-Idaho) stated that the detailed measurements of capture and fission cross sections as a function of energy in the region of 10 keV to 1 MeV were still of paramount importance in predicting fast-reactor behavior. A series of papers from Savannah River and Chalk River showed how the measured buildup of capture products (transplutonium elements) and fission products enables us to estimate absorption cross sections not measured by any other means.

* * *

I am in debt to the summary panel, chaired by William W. Havens Jr, which simplified preparation of this report. The conference was sponsored by the Atomic Energy Commission, the American Nuclear Society (Divisions of Reactor Physics and Shielding), the National Bureau of Standards and the American Physical Society. The proceedings will be published by the National Bureau of Standards and will be available from the Government Printing Office.

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