INDC-214

INDC(US)-1 "G"
March 1968

SECOND NEUTRON CROSS SECTIONS AND TECHNOLOGY CONFERENCE

Washington, D. C.

March 4-7, 1968

SECOND NEUTRON CROSS SECTIONS AND TECHNOLOGY CONFERENCE

Washington, D. C., March 4 - 7, 1968

David T. Goldman, Conference Chairman

Center for Radiation Research, National Bureau of Standards

The precise importance of neutron cross section values in understanding and predicting a large variety of physical phenomena was the introductory subject of a recent four-day conference held at the Shoreham Hotel in Washington, D. C., March 4 - 7, 1968. The conference was sponsored by the American Physical Society, the Atomic Energy Commission, the American Nuclear Society Divisions of Reactor Physics and Shielding, and the National Bureau of Standards. Since the initial conference two years ago on the same general subject[1], a large amount of new or revised experimental data has become available and automated data handling facilities have come into their own. As had been predicted earlier, a new sub-discipline of nuclear physics entitled 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 the case of the design of nuclear reactors, 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 during the conference by both the nineteen invited papers and the one hundred seven contributed papers, of the latter 65 were presented orally.

---

(1) Two Neutron Sciences, by H. Goldstein and D. T. Goldman, PHYSICS TODAY 19, No. 6 (1966)

The need for knowledge of neutron cross sections in understanding reactor behavior is a subject frequently mentioned and discussed, although perhaps not as well documented as it might be. The need for neutron cross section values is manifest from the initial birth of neutrons in the fissioning of heavy nuclei through their subsequent slowing down by elastic and inelastic scattering, and finally to their absorption: 1) by fissile nuclei to produce more neutrons, 2) by other nuclei for either control or parasitic absorption, or, 3) of special importance of late, by fertile nuclei such as ^{232}Th, or ^{238}U in breeder or converter types of reactors. The importance, or urgency, of new neutron cross section measurements, however, depends somewhat upon the type of reactor system considered. As an example, for many vital characteristics such as the beginning-of-life conditions in a thermal light water reactor, R. J. French (Westinghouse-Pressurized Water Reactor Plant Division) pointed out 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 life-time of about 10,000 Megawatt Days per Metric Ton of Uranium, as exemplified by the prediction of the 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. A great deal of operating experience is now available for these kinds of reactors to which predictions can be compared.

The exact economic cost of thermal reactors remains unknown because of the uncertainties of the worth of the discharged plutonium, or the build-up of capture products such as ^{238}Pu (a potentially valuable isotopic heat source), or fission products that might affect the extremely long lifetime cores. However, French expected information derived from post irradiation studies to be most useful in determining such costs.

An almost entirely different point of view was presented in a paper by P. Greebler, B. A. Hutchins, and B. Wolfe (General Electric-Advanced Products Operation) on fast breeder reactors. To take advantage of the low α value for ^{239}Pu in the energy region above about an electron volt, 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 necessary for control of the system such things as temperature (Doppler) broadening of resonances, have uncertainties associated with them because of the lack of operating experience. Two types of uncertainties exist in these reactors - fuel cost, or economy, and specific performance characteristics which might necessitate initial overdesign. These latter might, if the behavior were found to be especially unfavorable, result in the cancellation of particular reactor concept. A. M. Perry (Oak Ridge) showed that for molten-salt and high-temperature gas cooled thermal reactors, uncertainties in breeding ratios or power costs were quite small. However, further refinements in nuclear data were needed for the calculation of temperature coefficients of reactivity. A. Radkowsky (Naval Reactors-AEC) pointed out that in yet

another type of reactor, the Light Water Breeder, the breeding ratio, and hence the success of the project, was very sensitive to particular cross sections. E. Ottewitte (Atomics International) in discussing reactors for space applications where cost is secondary, mentioned the possible use of separated isotopes for control materials. If a nuclide with the exactly desired cross section characteristics could be found, the design of the system would be simplified.

In addition to the design of reactors, an important applied field for the use of neutron cross sections is that of shielding--whether of individuals from the radiations of a nuclear reactor or astronauts subjected to cosmic rays. H. Goldstein (Columbis U.) emphasized that in shielding applications the need for cross sections predominates in the region above 1 MeV where the major damage occurs. Also, the production of gamma rays due to neutron capture or inelastic scattering demonstrated the need for photon cross sections. In a review paper dealing with a much more esoteric field, that of understanding nucleosynthesis in stars, W. A. Fowler (California Institute of Technology) showed the need for neutron capture cross sections for many nuclei. The radiation damage produced by neutron scattering was covered in a paper by M. Wechsler (Oak Ridge).

The largest number of papers contributed to the Conference dealt with measurement and analysis of neutron cross sections. Goldstein attributed this large amount of new cross section information to two factors:

1) utilization of new and powerful neutron sources - electron linear accelerators as the source of intense neutron beams, such as those at Geel, Rensselaer Polytechnic Institute, General Atomic, the National Bureau of Standards, and the one at the Japanese Atomic Energy Research Institute, the isochronous cyclotron at Karlsruhe, and further use of nuclear detonations, all of which were discussed at the conference; and 2) 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 W. W. Havens (Columbia University) suggested it was time to remeasure total cross sections to take advantage of these new developments.

Four comprehensive invited papers reviewed the field of experimental data. A. Michaudon (Saclay) and J. A. Farrell (Los Alamos) spoke on fission cross section results: their interpretation, and prospective improvements therein. M. C. Moxon (Harwell) reported on the total, capture, and scattering cross sections in the resonance region (below ≈ 100 keV, while S. A. Cox (Argonne) spoke on the higher energy region.

Faced with the continuing and enlarging mass of data, the theoretical physicist attempts to provide a mechanism for understanding it, at least in an average sense. E. 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 such data. Vogt, in addition, showed

how this model and other experimental information such as (p, n) "quasi-elastic" reactions could be used to calculate cross sections for energy ranges and nuclei where experimental results are not yet available. F. T. and D. B. Adler (U. of Illinois) showed their progress in the use of multilevel fitting procedures in reproducing the neutron cross section 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 J. Griffin (U. of Maryland), who presented an explanation of asymmetric fission, the fact that the fissioning nucleus does not, in general, divide into two equal masses. He pointed out that this was almost the oldest problem in nuclear physics. Griffin described a model where the mass division ratio was, to 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. The full implications of this model have not been explored as yet, but since the liquid drop model underlies it, a significant improvement in our understanding of fission is properly expected.

On the last day of the meeting, the attendees' attention turned to a remaining problem--one which almost 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 are these data to be handled in a reasonable manner? A solution in the past was the familiar BNL-325 Barn Books. The answer now, of course, lies primarily in maximum

utilization of computers. In addition, there has been an international division of labor associated with the compilation of neutron data. The interregional cooperation in this field was described in papers by S. Pearlstein (Brookhaven-National Neutron Cross Section Center), V. J. Bell (ENEA Neutron Cross Section Compilation Centre), and H. 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 twenty installations in the United States. This effort has resulted in a computer file of evaluated neutron cross sections for many elements or individual nuclides, and the generation of a variety of computer programs for automatically handling the data. The latter point was elucidated by H. A. Alter (Atomic International) who, in a series of slides, demonstrated the progress that had been made in computer assisted evaluation of experimental data. Heated discussion developed on the importance of continued interposition of human activity between the acquisition of experimental data and a resultant evaluation thereof. J. 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, a further examination of these data is undertaken to ascertain their quality, especially in regions where the experimental data are known to have been of poor quality, 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 the evaluated cross section sets on the basis of how well simple, or relatively simple, macroscopic measured quantities can be 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. Such analysis was exemplified in a paper by C. A. Stevens (Gulf General Atomic), who showed how neutron spectrum measurements could resolve differences in cross section data. However, W. G. Davey (Argonne - Idaho) stated the detailed measurements of the 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. In a final series of papers from Savannah River and Chalk River, it was shown how the measured build-up of capture products (trans-plutonium elements) and fission products enabled one to estimate absorption cross sections which had not been measured by any other means.

The success of the Conference, with 320 registrants of whom approximately 20% came from foreign countries, is attributable in large measure to the efforts of the Program Committee, consisting of nineteen persons from 13 different institutions, and the cooperation with personnel of the National Bureau of Standards who made the necessary local arrangements. A summary panel chaired by W. W. Havens, Jr., (Columbia U.) made the task of this reviewer much simpler. Attendees at the banquet heard a most interesting talk presented by Cong. Craig Hosmer of California, which is presented elsewhere in this magazine. The proceedings of the conference will be

published by the National Bureau of Standards and will be available from the Government Printing Office.