CONCLUDING SUMMARY OF SYMPOSIUM ON NEUTRON MONITORING FOR RADIATION PROTECTION PURPOSES*

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We have spent this week working and talking together. Within minutes from now the Symposium will come to an end. It is important for each of us to analyze and evaluate the work reported here, to sift from it the important information, and then to synthesize the information so as to use it as a basis for our future programs both at our home installations and in international collaborative programs. So, what have we learned in this Symposium to justify our spending a week of our lives here? I will not attempt to answer this question with a consensus opinion; my comments are my own and in many cases will represent a minority opinion. For them to have any value, this must be the case.

Our general subject area has been neutron monitoring for protection of people. It is important that we keep the "protection of people" theme in mind as we analyze this conference; our comments and conclusions might be significantly different if we had included, for example, radiobiology.

Within the framework of the conference, our first session was devoted to the area of spectrometry. Of the 10 papers in the session, most were directed to measurement techniques and calculational results.

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There was some emphasis given to the spectra of neutrons in labyrinths and through shields. It is clear that in these areas there has been no significant "breakthrough" in recent years. The "Bonner Ball" or "multisphere" technique has received considerable attention, and several groups are giving attention to a more scientific understanding of it, rather than to simple empirical studies of which we have heard so much in the past. It is important to keep in mind, however, that the principle which prevails in the multisphere technique is the same one which makes possible the "long-counter," i.e., the diffusion length of neutrons in a moderating material is a slowly varying function of the neutron energy. Consequently, the multisphere system is not, nor can it ever be, in the usual sense, a neutron spectrometer. However, it can provide, when properly used, enough information about the neutron spectrum to permit a calculation of absorbed dose, frequently to within 10-20% accuracy.

Good and comprehensive calculational studies aimed at characterizing the radiation field in man are under way in several countries, the two largest groups being in the USSR and in the USA. There appears to be a rather general acceptance, especially in the larger laboratories, of the philosophy that the radiation field be characterized by calculational models which are constructed on limited experimental data which also serve as the standard for comparison for the calculated values.

Although the slowing down spectra in various media for various source energies have been understood in a general way for many years, there is still an occasional study aimed at determining the relative contributions of thermal, slow, and fast neutrons. Generally these studies are commenced as a result of a measurement which shows

considerable numbers of slow or thermal neutrons in a work area. In general, one must expect that the fluence of thermal neutrons and the fluence of slow neutrons in a neutron field in a large mass of air which is interfaced with earth or concrete structures are each approximately equal in magnitude to the fast fluence. However, more than 90% of absorbed dose, whether in a one gram or 70 kilogram sample, is nearly always due to the fast neutrons. Except for the rare case of a graphite or heavy water moderator, the total fluence at a given point, regardless of the initial source energy, as long as it is not more than about 15 MeV, is controlled by the fast fluence, i.e., the relaxation length generally increases monotonically with neutron energy in the energy range to 15 MeV. Hence the chief concerns in thermal and slow neutron measurements are (1) as an indicator of the presence of neutrons, and (2) as an influence on gamma ray or fast neutron detectors.

In Session II we considered dose and dose equivalent. Again there were papers dealing with both experimental and calculated distributions of both D and DE and a paper which presented a proposal for using the surface dose equivalent as the guideline basis for whole body exposures. Again also the Bonner sphere technique was in the fore, this time as a dose-equivalent meter.

It is important that we be cognizant always of the fundamental shortcoming of "dose-equivalent," i.e., it is the product of absorbed dose and quality factor, the latter being a legislated quantity. The original quality factor as a function of LET relationship has been maintained even after more than a decade of sporadic attack in the scientific literature. However, the ICRP must maintain a surveillance

of the radiobiological data and will, of course, change the relationship if the data warrant. I predict, on the basis of such data as that from Hiroshima and Nagasaki, that the relationship will be changed within the next five years, 10 at most. Consequently, data recorded purely in terms of dose-equivalent will be of much less value than that for which the absorbed dose for each type of radiation exposure has been maintained separately. In other words, it is easy to scramble the egg but exceedingly difficult to unscramble it. Therefore, though DE is a great convenience to the bookkeeping aspect of health physics, I fear that it is a luxury we can ill afford. Research dealing with ways of obtaining DE without having to record absorbed dose data is then, in my opinion, unwise. I say this in complete conviction though fully familiar with extensive work on DE being conducted by people who are much smarter than I.

In Session III we turned to the subject of instruments and techniques for field monitoring. The emphasis was on the Bonner or multisphere techniques and the papers reflected a more analytical approach to their use compared to the purely empirical approach so often reported in the past. Otherwise, no novel approaches to field measurements were apparent; the threshold detector approach to field dosimetry received less emphasis in this Symposium than in the past and the accurate and reliable proportional counter was discussed in only one paper.

"Albedo" detectors dominated the first personnel monitoring session. There is still a strong tendency to emphasize empirical approaches to the albedo detector development. This type of detector is being used rather widely, largely due to its sensitivity and simplicity. However, in my

opinion, the results may be excessively high, i.e., they yield unrealistically conservative results in many instances. To me it appears fundamentally unsound to base a monitoring system on a detector system which has its greatest sensitivity in the energy range which contributes least to the dose and vice versa. I do not wish to imply that such instruments cannot be used effectively as a supplement to other systems.

Personnel monitoring was again the subject of Session V, and here the emphasis was chiefly on detectors based on the etch pits in plastics, especially with the spark counting technique. Though there were no major new innovations reported, many improvements in performance were reported. At least one laboratory is now using a fissile-foil-plastic foil combination on a routine basis; the speed with which the track detector has evolved to this stage indicates, perhaps, that this is a detector which will become increasingly useful.

Session VI, also devoted to personnel monitoring, included several papers on film and emulsion techniques followed by more general discussions. Much of the film and emulsion work reported was not intended as new research but rather as a check of a well known system for a specific application.

Session VII was also concerned with personnel monitoring with the first two papers addressed to the problems of sodium activation in the body. A significant point reported by Mirić was that calculated and measured activations are in accord generally to within 20%, often to within 10%, though the French and U.S. groups have not yet achieved such good results. Some additional work was also reported on threshold detector systems for monitoring personnel exposed to intense fields such as in nuclear accidents.

This morning, in Session VIII, we directed our attention to the results of intercomparison experiments. Some of the studies were related to the system used in a single laboratory, some to multilaboratory intercomparisons. The session included some of the best analyses of detectors and their performance given in the Symposium. It seems evident that the international intercomparisons have had a marked beneficial effect in improving the monitoring systems which have been tested, and I believe that the IAEA sponsored series, of which there have been two so far, will also be effective in this regard. The third in the IAEA series is scheduled for Vincá, Yugoslavia, tentatively for the period May 14-25, 1973. As F. F. Haywood pointed out earlier, the tenth ORNL intercomparison will be held during the two weeks immediately preceding the 3rd IRPA Congress in Washington, D. C. Other papers in this morning session were concerned with the intercomparison of similar detectors from different manufacturers or of different types of detectors for a given application; the results will be useful to those people who may choose to use one or more of the detectors which were tested.

This afternoon, in Session IX, we have examined standardization and calibration techniques. The important observation is, I believe, that most of the larger nuclear installations are putting more emphasis than formerly on calibration and intercomparison, enough emphasis to cause them to contribute to the physical facilities required for accurate work. Other papers have dealt with the details of calibration, especially with the ever present problems of effective center of detection (or matrix parameter), scattered radiation, etc. Some excellent work in this area was reported.

Now, we are at the summation. I, too, have no new innovation, no new philosophy, no new ideas of consequence. Therein is one major problem for the future; over the past decade we have introduced a few new detectors but a truly important new approach to dosimetry has not been propounded. The fact that we still discuss many of the same problems we discussed in 1960 is intrinsically a disturbing problem. Also, during the course of this Symposium there has been evidence of insufficient familiarity with the literature, even though summaries of most of the world's research in dosimetry can be found in the published proceedings of IAEA symposia such as this one. We appear to be running hard to stay where we are. However, to prevent ending on such a note, we should take cognizance of some encouraging points. For example, our international collaboration has continued to increase, especially in the areas of intercomparison. Also, the fact that we are here together emphasizes our unity of purpose. I would like to suggest that the IAEA participate more closely with other international standards organizations, such as the ICRP, ICRU, and IEC, each of which is represented here. Because such great emphasis has been placed on dose equivalent and dose equivalent devices during the course of this Symposium, I recommend that IAEA convene a small panel, including some radiobiologists, to evaluate the overall ramifications of this trend, a trend with which I am in disaccord. I hope that we will not abandon physical and biological dosimetry at least until we understand the problem of evaluating the risks to man which is, after all, our primary mission.

Finally, I wish to express my appreciation to IAEA for the opportunity to state my views, however opinionated they may be.

I also appreciate your tolerance of this monologue and look forward to our next meeting.

I wish for each of you a most happy holiday season and an outstanding year in 1973.