1. Maj. H. L. Friede
2. E. O. Wollan

[redacted]

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CLASSIFICATION CANCELLED
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November 24, 1944.

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By Authority Of ______ Date AUG 23 1971
By ______

INV. 64

Major H. L. Friedell,
P. O. Box E,
Oak Ridge, Tennessee.

Dear Major Friedell:

Re: Tolerance Dose for Slow and Fast Neutrons

There does not seem to be anything new that can be said about this subject, but I will briefly summarize my thoughts on the matter.

The tolerance dose itself must, of course, be set by the medical men on the basis of biological experiments on the effect of neutrons and other forms of radiation. It is, however, necessary that we have at our disposal means for accurately measuring the types of radiation for which tolerance doses are to be specified. In the case of slow neutrons, no simple piece of equipment can be used without there being some ambiguity in the results. The response of a BF_3 counter, for instance, is very much a function of the energy of the radiation which falls on it. What seems to me the most straightforward method of recording the dose from slow neutrons is the ordinary pocket chamber. The gamma rays released from the body on capture of slow neutrons in hydrogen will be recorded on the pocket meter with approximately a 1:1 correspondence between the body dose from the capture gamma rays and the reading of the pocket meter. For a survey instrument, the increase in ionization produced when the ion chamber is covered with Cd is a fair measure of the dose which one would receive when exposed to such a slow neutron beam. The errors which might be expected in such measurements might well be as high as 50%. On the basis of what has been said above, we are assuming that the effect of slow neutrons is due entirely to capture gamma radiation. This is certainly true to within a few percent, but there may be some more highly ionizing radiation produced such as protons resulting from neutrons falling on nitrogen. With our present knowledge of what constitutes a safe tolerance dose, it hardly seems that consideration of this need be made at the present time.

With fast neutrons one must, of course, consider the greater biological effectiveness of a given amount of tissue ionization as compared with an equal ionization resulting from x-rays or gamma rays. This is, of course, the primary question to be answered, and one which must be answered by the biologists. It has generally been agreed that fast neutrons are from two to five times more effective than x-rays or gamma rays for equal amounts of tissue ionization due to the higher specific ionization of recoil protons than of electrons. I do not believe that anybody is in position at the present time to make a more definite statement regarding these figures. Results on this point have, of course, been

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accumulating during the year in the work of Zirkle and others. The most recent results of Zirkle on lethal effects on mice and rabbits give a value of about three for this figure. If one attempts to set a figure for the safe tolerance dose, one must first examine the methods of measuring the dose from fast neutrons. The two pieces of equipment which seem to be adaptable to this job are the balanced ion chamber apparatus in which one chamber is filled with a hydrogen containing gas, and the other is filled with some gas like argon. The chamber containing hydrogen is much more sensitive to neutrons than the one containing argon. By balancing the two chambers for gamma rays, the dosage rate for fast neutrons can be measured. If one is not interested in separating the effects of neutrons and gamma rays, a chamber filled with hydrogen at high pressure can be made to incorporate a factor of about four for the greater biological effectiveness of neutrons over gamma rays. Such equipment can be calibrated with standard neutron sources for which the energy of the neutrons and the number emitted per cm^2 sec. is known. The resultant dosage rate in body tissues must then be calculated from the energy of the neutrons and the atomic constants for body tissue. This has been done several times, and for convenience a table is reproduced here from page 10, Chapter 12, of the Metallurgical Laboratory Handbook:

E (Mev)	Neutrons/cm^2 for 1 r.e.d.	Neutrons/cm^2 for 0.02 r.e.d.	Neutrons/cm^2-min for 0.02 r.e.d./8 hr
0.5	5.7×10^8	11.50×10^6	24,000
1.0	3.83×10^8	7.66×10^6	15,960
2.0	2.84×10^8	5.68×10^6	11,840
3.0	2.40×10^8	4.80×10^6	10,000
4.0	2.22×10^8	4.44×10^6	9,240

Certainly the accuracy of measuring fast neutrons by the methods outlined is not yet comparable to that attained in the measurement of x-rays by the Victoreen r-meter, but in the hands of proper people it might give results good to 25%. Again, one sees that there is no sense in establishing a value for the tolerance dose more accurate than measurements of the radiation can be made.

It seems to me that the neutron problem is not a serious one since the measurements indicate in general that the neutron level is low in areas where one might expect any. If a good job is done with the equipment already designed and an approximate value for the safe tolerance dose is used, it would seem that there should be no cause for concern on this problem.

Very truly yours,

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E. O. Wollan

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