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R L Clark

EXPOSURE CONTROL
Fast Neutron Eye Damage

Neutron Exposure

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Minutes of a Meeting for the Evaluation and Control of Neutron Exposure to the Eyes

These minutes are written at the request of J. C. Hart in whose office a meeting was held beginning 9 a.m., Wednesday, April 9, 1952 to discuss the feasibility of possible means for evaluation and control of neutron exposure to the eyes. Those in attendance are indicated at the end of these notes.

Introduction

The results of current observational and experimental studies are interpreted to indicate that 1 rep of fast neutron exposure may be a proper value for the maximum permissible lifetime dose to be received by the eyes with a consequence of significant increase in cataract formation. In view of this, it is felt that considerable emphasis should be placed on the prevention of exposure where possible and accurate low level survey and dosimetry in contrast to reliance on fixed instruments for warning at the total body permissible exposure level.

It was stated that the application of different permissible exposure levels to various parts of the body was frequently so difficult that the lowest value (for eyes with n_f) would have to be adopted for total body use since this would be simplest for practical exposure control.

Improved design and operating techniques should be put in effect wherever feasible at experimental facilities. The design approach would include the increased use of mirrors and viewing devices as well as relocating certain of the experimental equipment where possible.

Flux Estimate

It was estimated* on the basis of 3×10^8 fast n/cm^2 being equivalent to 1 rep (by J. S. Cheka considering using fission spectrum neutrons) that a 40 hour per week exposure on the basis of a 30-year working period would come out to an approximate average permissible flux of about 1.2 $n/cm^2/sec$ (for one week the total flux would be 2×10^5 n/cm^2 considering 30 years' work of 50 weeks per year potential exposure). This would indicate a decrease in tolerance by a factor of about 50 from our presently used operating value of 66 fast $n/cm^2/sec$ per 8-hour day. Such a fiftyfold reduction was seen to raise a number of problems

* as a check of this estimate: K. Z. Morgan, November 8, 1949, gives 87.5 $n_f/cm^2/sec$ (2 mev) = 1 mrep/hr. From this one gets $0.875 \times 10^2 \times 3.6 \times 10^3 \times 10^3 = 3.15 \times 10^8$ $n_f/cm^2/rep$.

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(In comment on these values, many experimentalists could arrange their work so that only a few hours per week of exposure need occur. This would permit use of the weekly tolerance and not require change by a factor of 50 in every case.)

Change Justification

In a discussion of the anticipated opposition by plant personnel to any lowering of tolerance for maximum permissible exposure levels, it was pointed out that the validity of extrapolating from animal data would doubtless be questioned. Such animal cataract data reputedly includes not only observations on mice (by Dr. Furth) but also some other recent data on rabbits. The comparability of animal eye response, if not questioned because of structural difference, will be doubted by some because of different life spans or other points. Another probable objection which will be voiced to the lowering of neutron tolerance levels will be the instances cited of the very large number of workers who have carried out neutron experiments with cyclotrons and so on and the relatively few who have ever had a cataract as a result. Arguing thus, the apparent low probability of such cataract damage results will be held to indicate only a trivial risk (comparable to normal life eye hazards). In this connection, it would be of interest to have data on the incidence of hereditary predisposition to cataract and also data on the natural spontaneous incidence of eye cataracts among our population. It was mentioned that an abnormal number of cataracts are observed in certain regions such as India (possibly from sun worship cults?). An investigation of an alleged ORNL cataract case indicates an insignificant probable total dose with the fast neutron exposure rate estimated as not greater than 10^{-3} mrep/hr. (A total of 10^6 hours exposure needed for 1 rep.)

Of interest in this connection is the question of how serious is a cataract and how difficult, costly, and successful are operations for the correction of this condition. According to the provisions of the Tennessee Workman's Compensation Act, the loss of vision of one eye was stated as worth ~~$800~~ 2500 and of both eyes ~~$3000.~~ 7500

There would be considerable interest and relevance to data on the cataracts observed as the result of atomic bombing at Hiroshima and Nagasaki with any available data correlating the probable dose estimated, the number of cataracts observed and the delay between exposure and observation of such cataracts.

Present Action

If it be assumed that the maximum permissible exposure of the eyes to fast neutrons would eventually be modified to the above values of a maximum permissible lifetime dose of 1 rep and accepted by Management, the operational use of this value would require further work to improve detection instruments, prevent exposure, and improve dosimetry. The present status of this problem is strictly anticipation, discussion, and planning since any actual changes could only follow after a preliminary successful selling effort at all levels of laboratory personnel from the TOP on down.

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It was felt that a backlog of exposure data and work histories with neutrons would be a very valuable adjunct to the list of personnel currently exposed to neutrons in our program. This is important particularly from the standpoint that the last contributor to a total dose has the major responsibility for any effects from such a total exposure.

Dosimetry

Two possible approaches to fast neutron dosimetry are by the observation of proton recoil film emulsion tracks and by pocket chamber dosimetry techniques. In the first case, it now requires about 12 minutes to examine 24 microscope fields** and with a change to the lower tolerance level it would require examination of a great many more fields to observe the fewer number of tracks with any reasonable statistical accuracy. Upon the examination of a hundred fields or more, one has increasing trouble from cosmic ray background and other spurious tracks which introduce additional statistical uncertainty. The proper evaluation of the significance of this background would require further research study. The personnel time required for examination of over a hundred microscope fields with our present techniques could well be prohibitive in cost and would give accuracies to only about ± 50 percent.

One might get some improvement in the spurious track background by letting the neutron films be worn for a two week period. Under these conditions, the fading of latent images would lose about 20 to 30 percent of the tracks, with a consequent loss in reliability since one would never know whether the tracks observed occurred early in the period of wearing the film and were subject to the 20 to 30 percent loss or whether they were of only recent origin and did not undergo any fading. This loss of reliability handicaps the proper evaluation and minimizes the certainty of exposures indicated by this film technique. However, in a two weeks' period, the background radiation from spurious tracks, cosmic rays, etc., would be essentially unchanged since this background is a function of the total time since the film and its emulsion were manufactured. Variation in batches and variation in age of batches would be somewhat compensated for, as far as background is concerned, by the fading of latent spurious tracks. It was explained as a matter of interest that the fading of latent images varies from batch to batch and it seems to occur as a result of the loss by emulsion individual grains of sensitization according to a random function. In many cases, this loss of sensitivity still permits one to recognize long tracks of less resultant density.

Chamber dosimetry is being attempted by the use of two pocket chambers balanced to give the same gamma reading. These two chambers vary in their wall

** 12 behind O. W. = 12 behind shield; if latter indicate significant fraction of tolerance (= 5 track/12 fields) 36 shield fields are counted for statistical accuracy. One technician-day is required for 40 films. (Per HHA)

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composition, the one has a pure carbon wall and the other a polyethylene wall. At the present time, a week's tolerance (based on the 66 $n/cm^2/sec$ value***) of fast neutrons of the spectral distribution from a polonium-beryllium source gives a detectable loss of charge amounting to only 10 percent of the loss of charge for one week's gamma tolerance. At the contemplated reduced maximum permissible exposure level, one would be completely unable to detect the loss of charge with significance.

Some consideration was given to the possibility that one might reduce the number of personnel exposed to neutrons and thereby somewhat offset the increased manpower requirements for film monitoring of fast neutron exposures. Actually, the number of personnel presently monitored is a minimum, consisting of maintenance workers, scientists, and experimentalists and generally not including visitors. Any neutron exposure which a visitor might receive is estimated on the basis of that received during the same period by the persons accompanying the visitor. The only reduction seen possible would be to require a pile shutdown for <u>any</u> maintenance work and, even if this were done over the very loud objections which would certainly be forthcoming at the increased pile outage, this would only reduce the requirements for monitoring maintenance employees a matter of 10 percent at most. Actually, however, consistency would indicate that with a lower level of tolerance, one would be faced with increased monitoring requirements rather than less and correspondingly increased personnel monitoring needs. Beyond this, the future increase in the local number of operating reactors from 3 to 7 or 8 plus increased accelerator operations presages a considerable expansion of the requirements for personnel monitoring for fast neutron exposure.

Improved Design and Techniques

The limitation or minimizing of exposure to personnel will chiefly come as a result of technical design and the intelligent effort to use operating or experimental equipment in a manner to minimize neutron exposure (by rearrangement, etc.). One might suggest or require additional shielding wherever feasible and the use of mirrors, or viewing devices as well as relocation of equipment. The chief hazards from fast neutrons currently arise in connection with experimental work using beams of neutrons from reactor experimental holes. In this connection it would frequently become impractical to install bulky shielding, etc., because of the impediment thus introduced to the use of experimental equipment. In come cases, one could put long extensions on the detectors and have the pre-amplifiers or scaling or rate meter equipment in a more safe location. For certain types of experiments, the necessary beam could be more carefully collimated and confined by shielding to the equipment requiring it. In other instances, this would be completely impossible since such shielding might introduce extraneous effects, invalidating part of the data (as well as

*** $66\ n_f/cm^2/sec \times .36 \times 10^4\ sec/hr \times .40 \times 10^2\ hr/wk = 9.5 \times 10^6\ n_f/cm^2$

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quite possibly being very much in the way physically). Such technical design changes would in many cases involve considerable increase in costs and thus reduce the available experimental funds with the corresponding arousing of considerable opposition. This returns the subject to the initial question as to the precise degree of necessity which must justify the additional costs of money, time, and trouble for the resultant possible reduction in hazards.

A truly fruitful study of the technique modifications necessary and design changes applicable requires a study of each specific experimental set-up and can only effectively be undertaken after a thorough job has been done in convincing the personnel affected that the additional precautions are justified.

Among suggestions considered more difficultly feasible was the possibility of using a type of eye shield which might be designed after the style of a welders-type helmet. This would provide localized transparent eye shielding of some material such as lucite or, even simpler, a water cell to absorb and thermalize the fast neutrons. With this type of device, some films loaded with lithium^{6}, for instance, could be used for low level dosimetry of the resultant thermalized fast neutrons and any thermals present and associated therewith could be shielded out by a cadmium or other covering case.

Improved Instrumentation

At the sensitivity levels necessary, our present instrument would require approximately one hour to get a reading of any reasonable validity. There are currently no satisfactory fast neutron detection instruments available at this level of sensitivity which could be distributed through the operating area. The difficulties of attaining the required sensitivity are at present very great. One could use portable instruments, with the handicap of this prolonged delay in getting readings, to make dosage rate studies of the experimental areas. Again, one is faced with the difficulty of utilizing many fixed monitoring instruments in crowded experimental set-ups although one might feel that such instruments could be situated at the most normal eye level positions or eye use locations (in the effort to utilize the difference in tissue tolerances).

With instruments of the current level of sensitivity, a useful survey would require careful analysis of the planned procedure and the making of numerous prolonged survey measurements at those operating points or locations where the eyes of the experimental personnel would be used. Considerable delay can be anticipated in the development and procurement of suitable new instruments and a moderate delay of a number of months will certainly occur before additional ones could be obtained similar to those currently being developed for portable survey use. The availability of the 12 portable fast neutron survey instruments which are due the last of April or early May (?) would be on the basis of the competing requirements of surveys of higher exposure rate level. However, it might be possible to plan your survey to quickly measure all the high level areas and let the instruments be utilized in the interim for obtaining a few data points on the low level permissible eye exposures. On an emergency basis

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it is possible that the plant instrument department could give priority to and engage in the development, modification, or construction of some type of high sensitivity fast neutron survey instrument.

Concurrent with any decision to adopt the modified low level maximum permissible neutron exposures will be the problems of obtaining acceptance of the necessarily modified experimental and operational techniques which are designed around the basis of safe operational exposure limits.

11 April 1952

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