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SOME COMMENTS ON LIMITS AND SIGNIFICANCE OF THE "PERMISSIBLE RADIATION DOSE"

Part I — Analysis of the NCRP Recommendation on Radiation Exposure Levels

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Health-physics recommendations regarding *tolerable radiation dosage,* within the last decade, have exhibited considerable change. Additionally, official pronouncements through publication of recommended levels have at times lagged behind the unofficial oral presentation. Thus, it has been the responsibility of the individual professional to keep abreast of the most recent trends by careful surveys of the literature and editorial reports.

The Executive Committee of the *National Committee on Radiation Protection* (NCRP) recently proposed a series of significant changes which, if accepted, will lower the tolerable radiation exposure limits. These recommendations of the Executive Committee are to be presented to the full National Committee on Radiation Protection. The parent committee is expected to act on approval and adoption of these new limits. A major member of the NCRP, The Atomic Energy Commission, has always put into effect the recommendations of the committee.

Indication of the official nature of the new limits may be inferred in the presentation of the recommendations by the Committee Chairman, Lauriston S. Taylor, before the American Nuclear Society, Washington, D. C., December 10, 1956. The purpose of this analysis is to interpret and place into working terms the prime points of the present day status of recommended tolerence limits. Because these limits may soon be official and since they incorporate both lower tolerable levels and new concepts of radiation protection, it is essential that the professional familiarize himself with the significance of the personal and general health-physics aspects of the recommendation. This category must include the radioactive isotope worker, radiologists, AEC employee, industrial radiographer and any other individual *exposed to any degree* of avoidable penetrating radiation.

The evolution of the status of permissible dosage limits from external sources is highly significant, when reviewed on its time base. Prior to 1929 no *coherent* system of safe radiation levels was proposed or recognized. This early era was characterized by certain instances of gross personal radiation damage. In 1934 a 'tolerance dose' of 200 milliroentgens per day or 1 roentgen per week was adopted by The International Committee on X-ray Protection. Beginning in 1936 and extending to 1948 the generally accepted tolerance value in the United States was 100 milliroentgens, per day, (measured in air). In June of 1948 a subcommittee of the NCRP lowered the then existing dose of 0.1 roentgen per day by a factor of 2 and expressed the limits in roentgens per week,

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(0.3 roentgens per week). This extension of the time unit to seven days was significant in itself. In 1954 a comprehensive report* was published officially prescribing the limit of 0.3 roentgens equivalent man** per week, for long term whole-body exposure; a special limit of 0.6 rems per week for the skin, and a maximum of 0.3 rems per week for the blood forming organs, gonads and eye lens.

Roughly, this has been the growth and status of the recommended "maximum permissible" dosage to the present date. It must be noted that the trend in restating these values has been universally downward, with two major re-evaluations occuring within the last eight years.

The tolerable limits which have been now suggested by the NCRP set an entirely new value on occupational radiation exposure. In a sense, the new limitations are superimposed on the existing levels, and restrict or circumscribe their *carte blanche* application. In addition, a new concept of age-dosage relationship is brought out and the new limitations have been proposed from a basis of permissible gonadal exposure to individuals during their reproductive periods. A portion of this new recommendation, thus reflects a changing emphasis from *dosage to the individual* to *dosage to the population.*

This latter rationale mirrors the concern over genetic effects of radiation which must be considered statistically for the population as a whole, as contrasted with the original concept of individual, gross radiation damage.

In addition, a series of limitations based on a *yearly* and *lifetime* exposure are set up:

MAJOR TOLERANCE RECOMMENDATIONS

The four outstanding aspects of the present report may be summed up as follows:

1. The new system retains the present, basic maxima of 300 milliroentgens equivalent man, per week, with a maxima of 15 rems per year (assuming a two week period away from the source of radiation.) This also includes the previous extended-time 'penalty' unit of 13 weeks at 77% tolerance for those instances in which the weekly permissible value was exceeded.

2. One emergency dose of 25 rems is permitted in a lifetime.

3. The *maximum accumulated dose* is not to exceed an *average* of 5 rems per year. Thus, for the fifty years of life between ages twenty and seventy a total dosage exposure of 250 rems should constitute the maximum tolerable accumulation, (A formulae given, in the following discussion, elaborates on this.)

4. The Committee recommends, for the *population as a whole,* a limit of $1.4 \cdot 10^7$ rems delivered to the reproductive tissues for every 10^6 persons to age 30; or an

*U. S. Department of Commerce, National Bureau of Standards, Handbook No. 59.

**Hereinafter abbreviated as rems.

Dose in rems = (dose in rads) x RBE

average of 14 rems per person for the entire population through age 30, and one third of this value for each decade thereafter for this population unit.

The maximum acceptable weekly dose, although retained at 300 milliroentgens equivalent man, no longer may be indefinitely extended through each succeeding year. The Executive Committee has proposed a formula which ensures that the total dose is not accumulated too fast, particularly up to age 30.

This relation states, in effect, that the total accumulated dosage in rems at any age over 18 cannot be greater than five times the number of years the individual's age is above age 18.

Thus:

$$D = (A - 18) \cdot 5 \text{ rems.}$$

where:

D = total accumulated dosage in rems.

A = Individual's age.

For example, a 29 year old individual must not accumulate in excess of 55 total rems; [(29 — 18) · 5].

Two important aspects of this must be stressed. Firstly, under age eighteen no avoidable exposure is acceptable. Secondly, this formula reduces the total accumulated exposure considerably during the younger child-bearing ages and allows some margin for the years beyond this period.

This application immediately produces a large gap between the old limit and the new. For example, consider two workers involved from age 20 to 70 in industrial atomic energy exposures. Assume that both have exposures just up to, but not exceeding, the permissible limits. Worker "A" uses the old system of a straightforward 300 millirems per week and worker "B" uses the new recommendation outlined above. "A" at age 70 then has accumulated 750 rems while "B" has a total of only 250.

Worker "A" in addition may have begun exposure at an early age, say age 16. Whereas, "B" by the new system cannot begin exposure until age 18 and by the inherent nature of the limits of the system is encouraged to avoid all possible exposure until age 30 or 40. Thus, the very aura of the new proposals may keep early age dosages to a small fraction of those under the old system.

Inherent in this system is the concept of an unused 'bank' of exposure. By the new system, an individual who from age 20 to 25 accumulates only a total of 1 rem per year, has used up only 5 rems of his maximum of 25 for this 5 year period. He has 20 rems in the 'bank', so to speak, and on his sixth year may take a total (if emergency dictates) of 15 rems without exceeding, or *overdrawing,* his 'account'. In fact, in the above case, the dosage account still shows a balance of 10 rems at the end of the sixth year.

It is obvious then, that individuals who begin radiation exposure at a later age will have a reserve (in rems) equivalent to five times the difference between 18 and the

individuals age, at the time of beginning exposure.

The intent and prime result of the tightening of total dosage from age 18 to 40 has resulted in extra safeguards for the worker during the critical reproductive years. This, of course, ties in with the fourth proposal for a maximum permissible population dosage.

For the professional and industrial workers who are exposed to ionizing radiation, this new set of regulations will, in general, mean a closer and more restrictive operation§ in which exposures, where routine and maximal, must be cut by about one third. The radiological safety officer must now think in terms of the old weekly permissible dosage and also in terms of a new concept of yearly dosage which is not directly proportional to the weekly dosage.

The Committee has stressed, that design and the mode of operation of any radiation facility, particularly one where routine radiation hazard is present, must be such that, radiation to workers does not approach too closely to limits being recommended. The radiation "account" of each worker must, under the ideal condition, show a reserve 'banked' for future use. This situation is particularly stressed where the worker is between 18 and 40.

The new concept of yearly and lifetime tolerances places an emphasis on a record system for all workers which is audited on the basis of these time units. An additional implication is that the worker should have such accurate records avaiable when changing positions. Needless to say, such records will be of immense aid in the future in evaluating the overall genetic effect and the efficiency of these regulations. This lack of coherent information has been one of the major stumbling blocks in firmly fixing such permissible levels for radiation exposure, and may account for some of the repeated lowering of limits in the last decade.

In addition to elimination of the rule for double exposure for over age 45, the new rules set limitations of 5 rems to the blood forming organs, 5 rems to the gonads, 5 rems to the lens of the eye and 10 rems to the skin, for the *yearly* tolerable exposure. This again is a reduction of the limits found in the 1954 regulations.

It is significant to recognize that these levels are not modified by the allowance for an emergency exposure of 25 rems once in a lifetime or by radiation exposure received for medical reasons. The official pronouncements of the committee as published in 1954 will still stand with the exception of the over-riding regulations outlined herein.

SUMMARY:

For all those working in the presence of ionizing radiation this new recommendation brings out the present fluidity of the values for the permissible dose. The recommendation reflects the very conservative attitudes which stem from the National Academy of Science's report* on the effects of atomic radiation on man, and particularly mirrors its concern over genetic effects. The individual worker would

§The NCRP allows a 5 year 'transition' period.
*1955 NAS report.

be well advised at this time to review critically the status of exposure and the personal records maintained. The auditing of an additional section for a reserve or unused exposure will be essential.

The continued emphasis on lower dosage rates to the blood forming organs, skin, lens of the eye and gonads may be a limiting factor for certain workers experiencing exposure to specific radiation species or under conditions which may selectively effect these organs.

The major point which may need clarification is the retention of the maxima of 0.3 rems per week and 15 rems per year, with the over-riding stipulation of an average of only 5 rems per year. This concept is given in terms of first, a *maxima,* and second, in terms of an *average*. For example, it will be possible for an individual to take dosages of 0.3 rems per week, from time to time, as long as his *average* over his work history does not exceed 5000 millirems per year. Thus, the worker may for a few years attain the yearly maximum of 15 rems, but he must balance these years with ones of low dosage so that for his total working history his average is 5 rems per year or less.

Although the new rules are not modified by dosage necessitated for medical expediency, the attitude is presented that the prudent employer must take any especially significant medical dosage into account in the assignment of the individual to work which involves radiation. This implies new responsibilities for the medical professional at least in the assessment of whole body radiation and the consequent notification of the employer where the patient's activities are known to involve radiation hazards.

TABLE I

MAJOR ASPECTS OF THE NEW DOSAGE SYSTEM

ITEM	1954 NCRP Pronouncements	1957 Recommendations	Remarks on New System
Whole body weekly dosage	0.3 rems	Still holds at 0.3 rems but only as a *maxima.*	*Average* about 16 mrems per day. 0.3 rems exposure per week should be balanced with periods of low dosage.
Whole body yearly dosage	15 rems	Still holds but only as *Maxima. Average* dose must be '5 rems' per year (or below).	*Average* exposures must not exceed 100 mrems per week.
Skin, yearly dosage	30 rems	*Average* of 10 rems.	Factor of 3 reduction. 200 mrems per week.
Eye lens, gonads, blood forming tissue, yearly dosage.	15 rems	*Average* of 5 rems.	Factor of 3 reduction. 100 mrems per week.

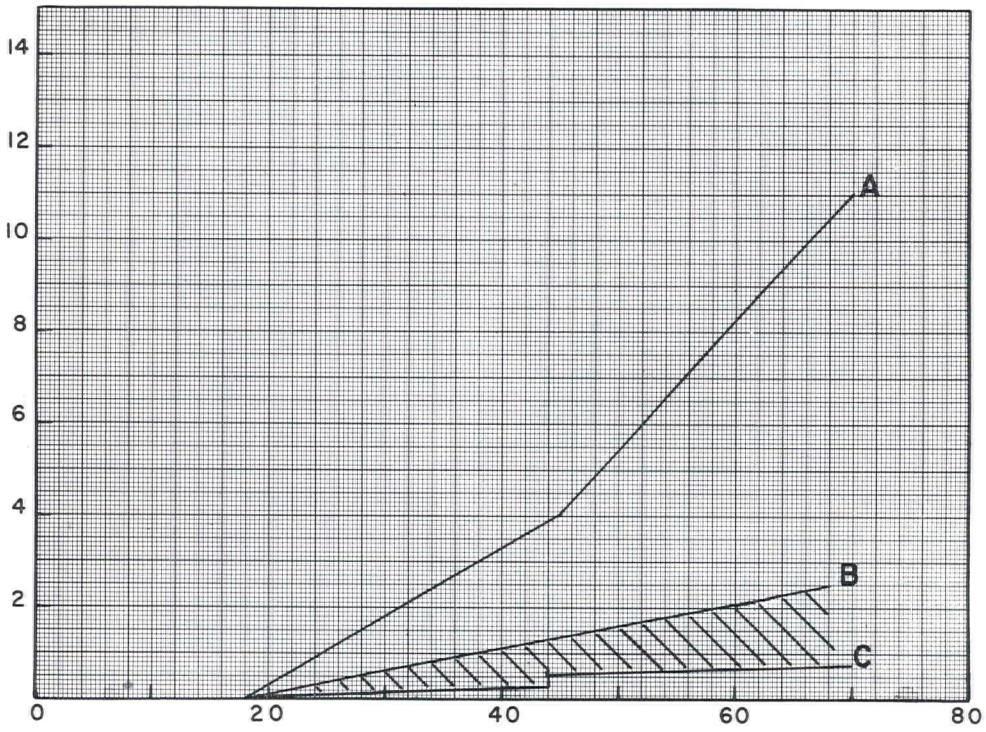

Figure No. 1

A hypothetical situation for radiation workers A, B and C is schematically outlined here, to illustrate for one case the effect of the new proposals as contrasted with the old system. Age in years is plotted on the abcissa, and the total accumulated dose in rems on the ordinate has been divided by 10^2. Worker A begins exposure to man-made radiation at age 18 along with workers C and B. However, A observes the permissible dosage limits set up by the NCRP in their 1954 publication. Worker A is exposed to the maximum permissible dosage throughout his work history. Note that he doubles his exposure at age 45 and at age 70 terminates this type of work with a possible 1105 rems total accumulated exposure. Worker A without doubling his dosage at age 45 would receive a total of 780 rems at age 70.

Worker B, observing the new proposals, averages the maximum dosage recommended, of 5 rems per year, for his entire work history and at age 68 has accumulated 250 rems and should then terminate his exposure according to the new proposal.

Worker C not only observes the letter of the new proposal but, in keeping his total dosage down to the lowest possible value (here given at 1 rem per year), attempts to follow the *intent* of the new system as well. The shaded area between B and C illustrates the reserve "banked" by C. At the end of 26 years C has a reserve of 96 rem. At age 44 worker C is free to take a necessary exposure of 24 rem, shown as the vertical rise in his plot. This expends his once per life time emergency exposure. Immediately therafter he resumes exposure at his initial low rate. At age 70, worker C has accumulated 76 rems (including the emergency). This curve C would be a close representation of the practical, working, life-time, dosage history of a clinical or industrial isotope laboratory worker, radiologist or industrial radiographer where the proper health physics measures have been observed.