RM NO. 64

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TO : Mr. Joe Sanders, Asst. Mgr., LVPO
THROUGH: Div. of Military Applications ϕ.J.a.
Santa Fe OO Rogers
FROM : Gordon M. Dunning, Health Physicist GMD
Biophysics Branch, Div. of Biology and Medicine

DATE: November 5, 1954

119516

SUBJECT: REVIEW OF POLICIES FOR NPG

410490

SYMBOL: BMBP:GMD

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Attached are the draft forms of the Policies of the Atomic Energy Commission Regarding Radiological Safety of the Public During Weapons Testing at the Nevada Proving Grounds that we discussed several weeks ago. You will note there are only a few minor changes and that there have been added two new sections (Policy III and Policy VI).

Since the policies are still in draft form, I trust you will not mind reviewing them in carbon copy form. The Division of Biology and Medicine has reviewed the policies, and after incorporating recommendations from you and others, they will be rewritten in final form for Commission action.

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POLICIES OF THE ATOMIC ENERGY COMMISSION
REGARDING
RADIOLOGICAL SAFETY OF THE PUBLIC
DURING WEAPONS TESTING
AT THE NEVADA PROVING GROUNDS

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INTRODUCTION

The following policies were established after full consideration for the health and welfare of the public, both in terms of radiological exposure as well as possible hazards, hardships or inconveniences resulting from disruption of normal activities. They are considered to be sound guides to the Test Manager not only for protecting the health and welfare of the public but also in arriving at decisions that would be morally and legally defensible by the Atomic Energy Commission.

Two basic assumptions are made in this report:

1. It is the responsibility of the Division of Biology and Medicine to establish such policies for the Atomic Energy Commission as deemed necessary to protect the health and welfare of the general populace from consequences of weapons tests conducted at the Nevada Proving Grounds.
2. Although the Division of Biology and Medicine will gladly give assistance and advice, the operational procedures adopted for meeting these policies shall be the responsibility of the Santa Fe Operations Office and the Test Manager, as directed by the Division of Military Applications.

The following policies do not apply to domestic or wild animals since levels of radiation which would be significant would have to be much higher than those specified herein.

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Evacuation

Introduction

The decision to evacuate a community is a critical one for three principal reasons. One, presumably there might be a health hazard if the personnel were allowed to remain. Two, there is always an element of danger and/or hardship to personnel involved in such an emergency measure. Three, the evacuation of a sizable community would seriously jeopardize the future use of the Nevada Proving Grounds and thus affect the country's weapons development program.

It is recognized that extenuating circumstances may accompany any situation where conditions indicate evacuation as a mode of action. The size of the community, areas and accommodations available for the evacuees, means of transportation and routes of evacuation, disposition of ambulatory cases, protection of the property left behind, and many other factors may enter into the decision relative to evacuation. A blanket evaluation cannot be made in advance; each situation can be unique. The following criteria therefore are suggested as guides in assessing the possible radiological hazards; the final decision must be made on the basis of all relevant factors known at the time.

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Criteria

Table Ia summarizes the radiological criteria to be used in evaluating the feasibility of evacuation.

TABLE Ia

RADIOLOGICAL CRITERIA FOR THE FEASIBILITY OF EVACUATION

Effective Biological Dose* Calculated To Be Delivered In A One Year Period Following Fallout	Minimum Effective Biological Dose That Must Be Saved By Act Of Evacuation (Otherwise evacuation will not be indicated.)
Up to 30 roentgens	(No evacuation indicated)
30 to 50 roentgens	15 roentgens
50 roentgens and over	(Evacuation indicated without regard to quantity of dose that might be saved)

*The "effective biological dose" is an estimate of a biological "damage" dose, taking into account the length of time for delivery of a given dose, and the reduction of dose due to (a) shielding afforded by buildings and (b) the process of weathering.

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The rationale for table Ia is as follows: The total effective biological dose that would be received if evacuation were not ordered is obviously a determining factor. Another consideration is the fact that such an action as evacuation could be dangerous to the individuals and could also possibly be detrimental to a very necessary national effort of weapons development. One must then ask, "Just how much will be gained (radiation dose saved) by evacuation?" Estimates of these two variables are indicated in table Ia. Thus, a populace may receive up to a calculated 30 roentgen effective biological dose in one year without indicating evacuation; from 30 to 50 roentgens, evacuation would be considered only if at least 15 roentgens could be saved by such action; and at 50 roentgens or higher evacuation would be indicated without regard to the possible savings in radiation dose.

In making a rough estimate of radiation doses, one may calculate a theoretical maximum infinity gamma dose and then arbitrarily divide by some number such as "2" for an estimate of dose actually received. Whereas this may be satisfactory as a first approximation, a more realistic estimate should be made, especially when dealing with doses that might constitute a health hazard.

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Due to the necessity of making early measurements and decisions, it is to be expected that dose-rate readings, taken with survey meters, will be the available evidence at the times of concern. Table Ib summarizes the parameters considered in estimating an effective biological dose based on dose-rate readings.

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TABLE 1b

PREDICTING EFFECTIVE BIOLOGICAL DOSES FROM DOSE-RATE READINGS

	A. Theoretical Maximum Dose (Based on Best Estimated Rate of Decay)	B. Biological Factor	C. Attenuation and Weathering Factor	D. Effective Biological Dose Factor (Column BxC)	E. Effective Biological Dose (Column AxD)
From time of fallout until time of evacuation		1/1	1/2	1/2	
From time of evacuation to time of return*		3/4	3/4	1/2***	
From time of return to a time 15 days after initial fallout**		3/4	3/4	1/2***	
From 15 days until one year after initial fallout		2/3	1/2	1/3	

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TOTAL

*This estimate is based on the concept that if evacuation were not accomplished, then a certain radiation dose would be accumulated over the period of time selected. This time period also represents the radiation dose saved if evacuation were accomplished.

**This assumes that the time of return occurs before 15 days. A period of 15 days was selected to provide a dividing point between the time of initial exposure from fallout to a time one year later. The 15 days has no unique significance other than providing a basis on which to estimate the biological factor.

***The value of 9/16 has been rounded off to 1/2.

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At later times after fallout, better estimates of radiation doses received may be obtained from film badge readings or dosimeters. If these film badges or dosimeters are worn on personnel and the evidence of their use supports the view that the readings are a reasonably accurate account of the radiation dose received then the values recorded on the film badge or dosimeter may be accepted with a correction factor of 3/4 to account for the difference between the dose received by the film badge or dosimeter (including backscatter) and that received at the tissue depth of five centimeters. Table Ic may be used in estimating the effective biological dose.

TABLE Ic

	A. Film Badge Reading	B. Biological Factor	C. Film Badge or Dosimeter Correction	D. Effective Biological Dose Factor (Column B x C)	E. Effective Biological Dose (Column A x D)
From time of fallout until time of evacuation		1/1	3/4	3/4	
From time of return to 15 days after initial fallout		3/4	3/4	1/2*	
From 15 days until one year after initial fallout		2/3	3/4	1/2	
				TOTAL:	

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*The value of 9/16 has been rounded off to 1/2.

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Discussion of the Biological Factor: As longer periods of time are involved in the delivery of a given radiation dose, lesser biological effects may be expected. From the time of fallout until the time of evacuation probably will be a matter of hours which has been considered essentially an instantaneous dose, i.e., the biological dose factor is 1/1. From the time evacuation could be accomplished to time of return probably would be a matter of days, so the biological factor has been estimated at 3/4. From 15 days after fallout until one year later is essentially a duration of one year, so the biological factor has been estimated at 2/3. It will be noted there is no calculation after one year, because it is expected under actual conditions of radiological and weathering that probably no significant dose will be delivered after a years time.

It is recognized that the precise quantities suggested for the biological factor cannot be supported by conclusive evidence. It is reasonable to expect that the delivery of a given radiation dose over a period of many days will have less biological effectiveness than an instantaneous one (neglecting genetic effects) and that the extension of the period to essentially one year should yield a still lower biological factor. One piece of supportive evidence is the work of Strandqvist* where X-ray doses to the skin were fractionated into equal daily amounts, and the biological effects compared to a one treatment dose. A log-log plot of total doses versus days after initial treatment yielded straight lines. For example, the curve for skin necrosis indicated a ratio of 3000/6700 roentgens for a one treatment versus 15 daily equally

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*Sievert, Rolf M. "The Tolerance Dose and the Prevention of Injuries Caused by Ionizing Radiations". British Journal of Radiology
Vol. XX, No. 236. Aug. 1947

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fractionated doses. Of course, daily radiation doses received from fallout are not equally fractionated so that the ratio would go in the direction of unity. Day by day doses delivered from fallout from the 15th day to one year are more nearly equivalent than at early times (ignoring the weathering factor). Strandqvist data do not extend beyond 40 days and it is questionable to extrapolate his data in an attempt to derive a similar ratio as above based on one year, since other uncertainties are so great, i.e., effects of weathering as affecting the rate of dose delivery, etc. The ratio would presumably be farther from unity than for a 15-day period.

The skin is a relatively rapidly repaired organ and thus may tend to over-emphasize the effects of fractionation when considering whole-body gamma doses. Cronkite reports* "In the dog, with cobalt gamma rays, the dose that will kill 50 percent of the dogs in a thirty-day period when delivered in a single dose at roughly 15 r per minute is approximately 275 r. After this dose of radiation the animals become ill within a period of 7 to 10 days and deaths occur between the eighth and twenty-fifth days. Hemorrhage, infections, and profound anemia are prevalent. If the dose is decreased to 100 r per day given over a fourteen-hour period, the lethal dose is increased to 600-700 r. Under both conditions, the animals die in approximately the same period of time with identical manifestations. If the exposure is dropped to 25 r per day given over a fourteen-hour period, the lethal dose is then increased to well over 1200 r, and the symptoms and findings are changed." One problem in such experiments is the evaluation of possibility

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that the animals may be virtually dead while the exposures are continued. This might be illustrated in experiments using the burro where the daily doses of 400, 200 and 100 roentgens given to three separate groups required 3600 to 4000, 2800 to 3200, and 2000 to 2600 total roentgens respectively for 100 per cent lethality**.

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* Medical Aspects of Radiological Defense. Cronkite, E.P. Lecture to Federal Civil Defense Administration, Regional Conference of Northeastern States of Radiological and Chemical Defense, New York City, October 22, 1953.

** UCLA-295. Response of the Burro to 100 r Fractional Whole-Body Gamma Ray Radiation. Maloy, T.J. et al. June 10, 1954. Unclassified.

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Experimental data reported by Boche* are summarized below.

No. of Days	Dose per Day (r)	Dose per Week (r)	Survival Time (Wks)	Total Dose r
20	10	60	24	1440
10	6	36	83	2988

Unfortunately normal survival times were not given nor were the ages of the animals. (dogs)

Blair** has taken the two points from Boche's data, inserted these into his (Blair's) equation relating reparable and irreparable damage. The ratio of instantaneous dose to 15 day dose is 350/450 or 0.32, and for 4 months dose about 525/350 or 0.67.

Blair suggests that "The points are too few to determine the constants (of the equation) with any accuracy but should at least be in the proper range." However, the constants of his equation have checked well with more extensive data on other animals. His equations indicate that the rate of recovery of reparable injury, is fastest in the mouse, (in the types of mammals selected) about one-half as fast in the rat and about one-seventh as fast in the guinea pig and dog, but as Blair pointed out the reaction of the dog is more representative of the larger, longer-lived animals.

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*MDDC-204 Observations on Populations of Animals exposed to Chronic Roentgen Irradiation. Boche, R.D. 1947. Unclassified.

**UR-207. A Formulation of the Injury, Life Span, Dose Relations For Ionizing Radiations. II Applications to the Guinea Pig, Rat, and Dog. Blair, H.A. July 3, 1952. Unclassified.

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[redacted]

<u>Discussion of the Attenuation and Weathering Factor.</u> From the time of fallout until the time of evacuation it is expected that personnel will be kept indoors. (See Policy IV) Major losses due to weathering can not be relied upon during this period, so that the estimated factor is 1/2. From the time evacuation could have been accomplished until the time of estimated return it is assumed that personnel will be indoors about half of each 24 hours and that major losses due to weathering can not be relied upon. The over-all factor is thus 3/4.

The same reasoning applies to the third period of time, i.e., from assumed time of return to 15 days after fallout.

From 15 days after fallout until one year later it is estimated that the attenuation due to buildings and the effects of weathering will yeild an over-all factor of 1/2.

Dose rate readings have been taken with survey meters outside and inside of houses around the Nevada Proving Grounds after fallout occurred. The ratio of readings varied with the type of construction of the house and with the location within the building. Generally, the ratio of readings outside to inside a frame house was about 2/1 with a somewhat greater difference for masonry construction. A limited number of film badges were placed outside and inside of some houses during Tumbler-Snapper and also Upshot-Knothole. In the first case, the difference in total doses was again 2 to 1 or greater but during Upshot-Knothole only about a 20% difference was noted. In fact, in one case during Upshot-Knothole the film badge inside read higher than outside. The differences between these experimental data will have to be investigated during future operations.

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The very nature of the weathering factor makes it a difficult parameter to evaluate. The probability of occurrence of precipitation and/or winds and to what degree has to be estimated as well as their effects on radiation levels. Leaching effects were studied on soils about 130 miles from ground zero where fallout had occurred during Upshot-Knothole. Dose rate readings were insignificantly lower than those predicted by radiological decay according to $t^{-1.2}$, after a period of more than one year. One example of the effects of winds [illegible] was observed during Upshot-Knothole. The fallout from the March 17, 1953 detonation was in a long narrow pattern to the east of ground zero. The second day after fallout a rather strong surface wind blew almost at right angles across the area, for about a period of a day. Dose rate readings were taken on the first and fourth days at the same locations and then were compared. The fourth day dose rates were less, by factors of three to six, than those to be expected from the first days readings, based on rate of decay of $t^{-1.2}$. (Other fallout measurements indicated that the rate of decay of this fallout material was not significantly different

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from $t^{-1.2}$.) Because of the physical conditions described above, these reductions in contamination probably are near the upper limit to be expected from wind.

Operational Feasibility of Criteria

It is not the intent here to discuss operational procedures, but it should be indicated that the computing of radiation doses as recommended in Policy I is a not too difficult task. If one assumes a $t^{-1.2}$ rate of decay as a first approximation, then a single graph of dose rates versus times after detonation can be constructed that will represent a 30 roentgen effective biological dose for one year. An additional family of curves can be made that will provide the answers to the parameters of howmuch time would be available before evacuation and of how long a time personnel would have to remain out of the radiation area in order to provide for a savings of at least 15 roentgens.

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The highest whole-body gamma dose recorded for any locality where personnel were present outside the Nevada Proving Grounds was at Riverside Cabins, Nevada (about 15 people) following shot number seven of Tumbler-Snapper. The maximum theoretical infinity gamma dose was estimated to be 12-15 roentgens.

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POLICY II

Personnel Remaining Indoors

A. When the gamma dose rate reading as measured by a survey meter held three feet above the ground reaches the values given in table II at the times indicated, it is recommended that personnel shall be requested to remain indoors with windows and doors closed.

B. In the event that there be convincing evidence that the radiation levels given in the table will be reached, it is recommended that personnel be requested to remain indoors "BEFORE" the fallout occurs or before the radiation levels equal those in the table.

TABLE II

Time of Fallout	Gamma Dose Rates At Time of Fallout (mr/hr)
1 hour	2000
2 hours	1000
3 "	667
4 "	500
5 "	400
6 "	333
8 "	250
10 "	200
12 "	167
24 "	83

Release from this restrictive action shall be made on the basis of further evaluation of the radiological conditions.

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C. It is recommended that people who had been out-of-doors during fallout of the above magnitude or greater be advised to change clothing and to bathe. The clothing may be cleaned by normal means. While bathing, special attention should be paid to the hair and any exposed parts of the body.

D. In the event that the monitoring takes place AFTER the fallout has occurred, and extrapolation of the dose rate readings equals or exceeds those in table II at the estimated time of fallout, then it is recommended that the same advice be given as in the preceding paragraph.

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POLICY II

Personnel Remaining Indoors

DISCUSSION

The action of requesting personnel to remain indoors is predicated on the principle that the radiation levels are below those established for evacuation and that this action could reduce the amount of contamination of personnel and reduce somewhat the whole-body gamma dose. (See Appendix A for estimates of reduction in whole-body gamma dose.) The actual "savings" healthwise have to be balanced against possible adverse public reaction.

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The principal gain in requesting personnel to remain indoors is to prevent or reduce the amount of atomic debris that may actually fall on the body or clothing. Since the peak of fallout usually occurs shortly after the start of fallout, it is important that prompt decisions and actions be

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taken. Thus, by necessity, the most practical criteria upon which to base a decision are gamma dose rate readings, which are in turn related to the amount of fallout.

Beta Dose To Skin

The most immediate solution might be to establish lower permitted dose rate levels at later times after detonation. However, if a series of dose rates are established for increasing times after detonation so that their relationship follows $t^{-1.2}$, then the doses delivered in X hours (before the material is washed off) will be greater for earlier times after detonation. If one were sure of the time that the fallout material was to remain in place, then a scale of dose rates versus time after detonation could be made to yield the same total dose over the X hours. Since there is obviously no set time period for duration of contact that would be valid for all cases, one might assume the worst case where the material remains in place until its activity has decayed to an insignificant level. Dose rates could then be approximated, to yield a given infinity dose, by:

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$D = 5At$ where: D = infinity dose
A = dose rate at time "t".

If the above discussion is accepted, then the remaining question is to set the infinity dose. Here, we must be clear that whereas the measurements taken by the monitors, and the data upon which action will be decided will be gamma dose rate readings, the point of principal concern is the beta dose delivered to the basal layer of the epidermis (assumed as 7 milligrams per square centimeter). The ratio of emission of beta to gamma is a function of

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time after detonation and follows no simple relationship. Further, this ratio at any given time after detonation has not been finally established. The report* suggests the following data:

Time after detonation	Beta/Gamma
72 hours	157/1
168 hours	156/1

These data were obtained from a cloud sample, rather than actual fallout material, and were a measure of surface dose on a plaque using a "dosimeter-type beta-ray surface ionization chamber."

The method of collection suggests the possibility that the thickness of material on the plaques may be less than that to be expected from the amount of fallout that would be of concern when estimating probabilities of beta burns. This would result in a different angular distribution of the betas influencing the beta dose rate in the direction of a higher value for the plaques.

Another report[1] indicates a beta to gamma ratio of 130 to 1 based on theoretical computations. A third report[2] suggests a radically lower ratio; however, there remains some doubt as to its conclusions since the ionization chamber used to measure gammas only, had a wall thickness of 1 mm of bakelite which "... excluded a small part of the total gamma dose present, as well as a large, but unknown, fraction of the beta." (The range of 0.35 Mev betas is about 100 mg/cm^2 or approximately 1 mm of bakelite.) For our discussion here, we will assume a surface beta to gamma ratio of 150 to 1.

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In estimating the beta dose to the basal layer of the epidermis, one may refer to the work of Henriques[3]. He exposed the skin of Chester White pigs

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* [illegible]-26. Scientific Director's Report, Annex 6.5. "Interpretation of Survey-meter Data".

[1] "An Estimate of the Relative Hazard of Beta and Gamma Radiation from Fission Products". Sullivan, William H. NRDL. April 1949. CONFIDENTIAL

[2] [illegible]-37. Project 4.7 "Gamma-Beta Ratio [illegible]taminated Area". June 1953. CONFIDENTIAL-RESTRICTED DATA.

[3] "Effect of Beta Rays on the Skin As A Function of the Energy, Intensity, and Duration of

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to plaques containing different radioisotopes. Pertinent data are abstracted as follows:

Isotope	Energy	Surface Dose Required to Produce Recognizable Transepidermal Injury (Roentgen-equivalent-beta)	Estimated Amount of Radiation That Penetrated Skin to A Depth of 0.09 mm. (reb)
Yttrium^{91}	1.53	1,500	1,200
Strontium^{90} Yttrium^{90}	0.61 2.20	1,500	1,400

The average maximum energy of the beta particles from fallout material varies with time but will be assumed to be roughly comparable, in respect to depth dose, to Yttrium^{91} or Sr^{90}-Y^{90}. Since the gamma dose at a depth of 7 mg/cm^2 would not be significantly different from the surface gamma dose, the ratio of 130 to 1 for beta-gamma will be assumed at the basal layer of the epidermis.

[One experiment with sheep, using Sr^{90}-Y^{90} plaques, showed that 2500 reps at the plaques' surface produced ulceration in one but not another of two sheep.* On the other hand, 1000 rads delivered to tissue depth of 7 mg/cm^2 from a P^{32} one inch diameter disk (type of animal not stated) produced tanning, prolonged erythema and desquamation.**]

It is to be remembered that the above discussion was first based on surface gamma dose rates whereas the monitors will be making their gamma

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*"Comparative Study of Experimentally Produced Beta Lesions and Skin Lesions in Utah Range Sheep". Lushbaugh, C.E., Spalding, J.F. and Hale, D.B. LASL November 30, 1953 (UNCLASSIFIED).

**HW-33068 A status report. Sept. 15, 1954 (CONFIDENTIAL).

[redacted]

measurements at a height of three feet. Past field experience has indicated that the gamma reading from ionization-type survey meters at ground level is about 50% higher than at three feet. Therefore if it be assumed that a ground level gamma reading of a survey meter is equivalent to a surface dose rate, the ratio of beta dose rate at 7 mg/cm^2 to gamma dose rate at <u>three feet</u> is about 200 to 1.

Another approach to estimating the ratio of beta dose rate at 7 mg/cm^2 to gamma dose rate at three feet is as follows. Assuming a uniform distribution of 1.0 megacurie per square mile of gamma activity, the dose rate reading from an infinite field is about 4.1 roentgens/hour.* Calculations given in appendix B indicate that a like concentration of fallout material will produce about 430 reps/hour at 7 mg/cm^2. This suggests a beta to gamma ratio of about 100 to 1 which is about a factor of two lower than the first approach. Added support to this latter method of estimating beta doses is found in appendix C.

Such considerations may be fraught with pitfalls. For example, the above discussion implies a uniform distribution of fallout material. Obviously, this is not correct but how far this deviates from the facts and to what extent this influences the results is difficult to assess. Calculations indicate that the production of recognizable beta burns from a single particle requires a high specific activity. (See Policy III for discussion.) It may well be, however, that the particles of fallout are close enough to have overlapping of radiation fields and thus require significantly lower specific activity of the particles to produce beta burns. This hypothesis

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*"Effects of Atomic Weapons", 1950

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has support in that even the most superficial beta burns of the natives exposed to fallout following the March 1, 1954 detonation showed a general area affected rather than small individual spots. On the other hand, the cattle and horses exposed near the Nevada Proving Grounds showed burns over areas only about the size of a quarter. Even though these may not have been produced by single particles, they do represent less of an area effect than suggested for the natives. Also, radioautographs of the fallout in areas outside the NPG suggest the occurrence of individual particles with non-overlapping of radiation fields. However, in nearby areas where the fallout was relatively heavy, there was a definite overlapping of the fields.

WITH OUR PRESENT KNOWLEDGE IT SHOULD BE STATED THAT DUE TO THE PARTICULATE NATURE OF FALLOUT IT WOULD NOT BE POSSIBLE TO ESTABLISH REASONABLE AND OPERATIONALLY WORKABLE CRITERIA THAT AT THE SAME TIME WOULD GUARANTEE THAT THERE NEVER WOULD BE AN OCCURRENCE OF A BETA BURN.

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If one were to accept the assumed beta to gamma dose rates of about 100-200 to 1 (measured under the conditions given above), this might mean an infinity beta dose of 1000-2000 reps to the basal layer of the epidermis when the whole body infinity gamma dose was 10 roentgens. Of course, the fallout material may be removed before the infinity dose is delivered; yet, on the other hand, it is not improbable that it could remain in the hair for essentially this length of time. In the case of a one-hour fallout, almost one half of the dose would be delivered in the next 24 hours.

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The efficiency of a surface for collecting and holding the fallout material is important. It is not surprising thatthe highest dose rate readings as well as biological effects were noted on the hair of the natives and also on parts of the exposed body where perspiration was present. Further, it was observed that even one layer of light cotton material was sufficient to protect against beta skin damage in most cases*. This was due probably not to the relatively small attenuation of the betas by the clothing but rather to the physical situation of holding the radioactive material at some distance from the skin, which effect would be relatively large.

An added consideration is the possibility of high beta doses delivered to personnel from the fallout material lying on the ground and other surfaces. If the highest degree of contamination considered under this policy is safe when in direct contact with the skin, then the beta dose from an equally contaminated ground will not be hazardous. (See Policy III for discussion on unequal contamination on personnel.) However, it is true that the contamination may exceed the amount to deliver dose rates given in table II and yet not be great enough to consider evacuation. Some personnel may not go indoors and those who did will eventually be released from this restrictive action and then may walk around in a relatively highly contaminated area. Because of the more limited range of the beta, the location of greatest concern is the lower legs.

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One report estimates a beta to gamma dose rate ratio of about 75 to 1 at 10 centimeters above the ground.** Under Policy I it was recom-

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* ITR-923. Study of Response of Human Beings Accidentally Exposed to Significant Fallout Radiation, Cronkite, E. P., et a l. May 1954.

**AD-95(H) An Estimate of the Relative Hazard of Beta and Gamma Radiation from Fission Products. Condit, R.I., Dyson, J.F. and Lumb, W.A.S. NRDL 1949 (UNCLASSIFIED)

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[*] ITR-923. Study of Response of Human Beings Accidentally Exposed to Significant Fallout Radiation, Cronkite, E. P., et a l. May 1954.

[**] AD-95(R) An Estimate of the Relative Hazard of Beta and Gamma Radiation from Fission Products. Condit, R.I., Tyson, J.P. and Lamb, W.A.S. [illegible] 1949 (UNCLASSIFIED)

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mended that consideration be given to evacuation when the gamma dose rate reading at three feet was, for example, about 6.2 r/hr at H+3 hours. Roughly, this would correspond to about 460 reps/hr of beta at 10 centimeters. Of course, this activity decays and also it is presumed that personnel would be sent indoors, at least for a few hours. On the other hand, it strongly suggests that biologically significant doses may be delivered to the feet if not protected. Skin lesions were frequent on the bare feet of the natives evacuated during CASTLE. This probably was a combination of beta dose from material on the ground and from that scuffed up over the bare feet and then clinging to the skin. (No lesions were observed on the bottom of the feet, undoubtedly due to the thick epidermis and also to the probability that the material did not stick to the skin too readily). It would be expected that normal closed-type footwear (as compared to open sandals) would afford adequate protection to the feet from such high beta doses as discussed here. There is still no guarantee that beta radiation from material on the ground will not deliver significant biological doses to the ankles and perhaps lower legs, after personnel are released from staying indoors. For example, if the beta dose at 10 centimeters above the ground is 460 reps/hr at H+3 hours, it would be about 190 reps/hr three hours later and 120 reps/hr six hours later.

DOE/NV

One further possibility is the accumulation of radioactive material around the ankles and lower legs resulting from normal walking about the area. This is discussed under Policy III.

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Data On Human Exposures

The work of Henriques[1] suggests that at the depth of 0.09 mm in living porcine skin (maximum thickness of epidermis) that "1400 ± 300 roentgen-equivalent-beta" (delivered over short periods of time so that they may be assumed to be instantaneous) is required to produce recognizable transepidermal injury. The curve of biological damage rises rather sharply so that at a dose of just under 2000 rep (at 0.09 mm), the epidermis may be expected to exfoliate and in the majority of cases go on to develop chronic radiation dermatitis persisting for months.

The preceding discussion suggests that, using the gamma dose rates listed in the criteria under this Policy, which are based on an estimated 10 roentgen infinity gamma dose, as high as 2,000 reps might be delivered to the basal layer of the epidermis over a period of time covered by the lifetime of the radioactive material.

There have been instances where the calculated infinity gamma dose in areas where personnel were present around the Nevada Proving Grounds have reached 12-15 roentgens but there have been no known cases of beta burns in these areas. The number of persons involved in these areas of highest contamination was relatively small, perhaps a few dozen, and with an observed duration of fallout of about one hour it is possible that they were not in a position to receive the full fallout. Likewise, minute areas of the skin may have been so affected yet not detected or reported. In other areas encompassing some 2,000 people the infinity gamma dose was about eight roentgens and no instances of beta injury appeared.

DOE/NV

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[1] op.cit.

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The estimated whole-body gamma dose to natives evacuated from the island of Utirik following the March 1, 1954 detonation at the Pacific Proving Ground was about 15 roentgens for a period of about three days, but no beta burns appeared. It is fair to assume here that direct contamination took place due to their mode of living including housing that was quite open to air currents. Gamma dose rate readings were taken over the bodies of the natives at about H plus 78 hours both on the beach and after boarding the ship. On the beach the personnel readings averaged about 20 mr/hr gamma (but this probably included some contribution from the ground contamination), and after wading through the surf and boarding the ship the levels averaged 7 mr/hr gamma.

The 18 natives on Sifo Island, Ailinginae Atoll, received an estimated whole-body gamma dose of 75 roentgens in about two and a quarter days. Of these, 14 later experienced slight beta burns, 2, moderate burns, and none showed epilation.

In the case of the Rongelap natives, the estimated whole-body dose was about 150 roentgens in about two days. All 64 natives later experienced beta burns to some degree from slight to severe and over half of the natives showed epilation from slight to severe.

DOE/NV

The 16 natives from Rongelap evacuated directly by air to Kwajalein had personnel gamma dose-rate levels generally 80 to 100 mr/hr although one was as high as 240 mr/hr and one as low as 10 mr/hr (at H plus about 55 hours). The remaining 48 natives evacuated by ship were reported to have personnel readings that "averaged" 60 mr/hr before decontamination.

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The picture is further confused because some of the natives had bathed and some had not before the arrival of the evacuation team.

Most of the 28 U.S. Service personnel stationed on Eniwetak Island, Rongerik Atoll, received about 40-50 roentgens, based on film badge readings. Three members of the group who were located for part of the time in another section of the island were estimated to have received somewhat higher doses. Seventeen of the 28 personnel showed only slight superficial lesions with one questionable case of epilation. It should be pointed out that the personnel were in metal buildings during some of the fallout time and for most of the time thereafter until evacuation. This reduced the direct contamination as well as the whole-body gamma dose. A film badge hanging on the center pole of a tent at one end of the island read 98 roentgens. Calculations based on dose rate readings at another part of the island indicated somewhat lower doses, if personnel had remained in the open for the period of time from fallout (about H plus 7.5 hours) to evacuation (at about H plus 34 hours). Upon arrival at Kwajalein one personnel gamma dose rate reading was as high as 250 mr/hr at about H plus 35 hours.

DOE/NV

The above data do suggest that there may be possible a rough bracketing of gamma-beta doses versus beta burns. On the one hand, the natives from Utirik received an estimated whole-body gamma dose of 15 roentgens and showed no evidence of beta burns. On the other hand, the natives on Sifo Island, Ailinginae Atoll, received about an estimated whole-body gamma dose of 75 roentgens with 14 personnel showing slight

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burns, 2, moderate burns, 2, no burns, 3 with moderate epilation, and 15 with no epilation. In addition, Rongelap natives received 150 roentgens whole-body gamma dose, and about 90% showed some degree of lesions and 56% some degree of epilation.

It is to be recalled that: (a) the natives probably were out-of-doors and received the full fallout, (b) the oily hair, semi-naked perspiring bodies including bare feet, and lack of bathing for most would tend to collect and hold the fallout material, (c) the time of delivery of essentially all of the doses was two to three days. Further, it may be speculated that the fallout on the more distant island of Utirik (about 300 statute miles) would consist of smaller particles and also perhaps lesser possibility of overlapping of radiation fields from these particles.

Some of the relevant data are summarized in table II. Due to the uncertainty of the degree of exposure of personnel on Rongerik to the direct fallout, this group is not included. It is to be immediately emphasized that any comparisons made or implied in the table are at the most only semi-quantitative. Table II will be referred to in Policies III and IV but is included here as a summary of the data discussed above.

Data On Animal Exposures

The data on animal exposures are less firm than those for humans. Unmistakable beta burns occurred on cattle at Alamogordo in July 1945, on cattle at the Nevada Proving Grounds in spring 1952, and on horses in

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TABLE II

I	II	III	IV	V	VI			
					Best Estimate of Average Dose Rates (mr/hr) of the Islands (taken at three feet above the ground) and of Natives (Personnel Readings) after Removal from Radiation Field. Both at Approximately Same Time.			
Location	**Estimated Time of Fallout**	**Best Estimate of Whole-body Gamma Dose (Roentgens)**	**Skin Effects**	**Personnel Reading**	**Island**	**Personnel**	**Ratio**	**Approx. Time**
Rongelap	5½ hrs	150	**Lesions:** 6 None 19 Slight 22 Moderate 17 Severe **Epilation:** 28 None 11 Slight 11 Moderate 14 Severe	a. Majority: 80-100mr/hr At H+54 hrs[1] b. Average: 60 mr/hr At H+50 hrs Corrected Average: 80 mr/hr[2]	1300	80	16/1	H+50 hrs
Ailinginae	5½ hrs	75	**Lesions:** 2 None 14 Slight (very superficial) **Epilation:** 15 None 3 Moderate	Average: 40 mr/hr At H+52 hrs Corrected Average: 53 mr/hr[3]	410	53	8/1	H+52 hrs
Utirik	16-18 hrs	15	**Lesions:** None **Epilation:** None	Average: 20 mr/hr Assumed: 15 mr/hr At H+78[4]	110	15	7/1	H+78 hrs

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1 16 natives evacuated by air to Kwajalein and monitored upon arrival.

2 48 " " " USS Philip and monitored aboard the ship. Data suggest meter readings low by about 50% since natives from same island read 80-100 mr/hr at Kwajalein some four hours later with calibrated meters.

3 40 mr/hr corrected to 60 mr/hr according to information in footnote 2. Report did not indicate range of values among individuals nor at different parts of body.

4 Reading taken by monitors from the RENSHAW on the Utirik beach where there may have been some contribution to dose rates from land. After wading to ship, average personnel readings were 7 mr/hr.

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spring 1953. (The skin damage observed on sheep in the spring 1953 was not established to be beta burns.) However, the exact positions of the animals in relation to known amounts of fallout are not clear.

Following the last detonation of the spring 1952 series at the Nevada Proving Grounds, about one half of a herd of 150 head of cattle were found to have evidence of beta burns. They were thought to have been 15-20 miles from ground zero in Kawich Valley to the northeast and to have been exposed to fallout from the last detonation. (14 KT on a 300 foot tower) Highest dose rate readings taken along a dirt road running lengthwise through this valley, integrated to 75-100 infinity gamma doses.

During Upshot-Knothole, 16 horses showed skin lesions over the back and eye damage was noted in a few. The best evidence indicated that the horses were some 8-10 miles to the east of ground zero on 17 March 1954, where the fallout occurred from the first detonation (16 KT on a 300 foot tower). Radiation levels in this area are not known with certainty but the fallout occurred in a narrow band and was carried by relatively high velocity winds so that it probably fell on the horses at a time less than one hour. If so, probably more than one-half of the infinity dose was delivered during the next day.

Operational Feasibility

Under the criteria recommended in Policy II, there would have been two occasions in the past where personnel would have been requested to remain indoors. Once was at Lincoln Mine following the second detonation of Upshot-Knothole where they were so requested to remain indoors for two hours and the other occasion would have been at Riverside Cabins (population about 15) following the ninth detonation of the same series. The dose rate reading at Lincoln Mine was 580 mr/hr at H+2. In the case of Riverside Cabins, however, the radiological conditions were not ascertained until after the fallout had occurred. The maximum infinity gamma dose in the latter case was 12-15 roentgens.

Personnel were requested to remain indoors (for about two hours) following the ninth detonation of Upshot-Knothole. The highest dose rate reading was 320 mr/hr at H plus 4.5 hours. This is less than the current recommendations.

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POLICY III

Decontamination of Personnel

A. Where it is not possible to monitor personnel outside of a general radiation field, it is recommended that an estimate be made of the degree of personnel contamination by determining the location of the individual at the time of fallout. In the event there is uncertainty as to the validity of such an estimate, the assumption will be made that the individual was out-of-doors. In those areas where the infinity gamma dose equals or exceeds 10 roentgens, it is recommended that the individual be advised to bathe and to change clothing.

B.1. For personnel being monitored outside the general radiation field where personnel contamination exists over relatively large areas of the exposed body (one-half square foot or more):

When the reading of a survey instrument, held with the center of the probe or center of the ionization chamber four inches from the center of the contaminated area, equals or exceeds the values given in table III it is recommended that personnel SHALL be advised to bathe and to change clothing.

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TABLE III

GAMMA DOSE RATES AT TIMES AFTER DETONATION WHEN DECONTAMINATION OF PERSONNEL SHOULD BE RECOMMENDED /Based on Situation of Contamination Existing over Relatively Large Areas (one-half square foot or more) of the Exposed Body/

Time After Detonation Contamination Occurred	Gamma Dose Rates At Time of Contamination (mr/hr)
1 hour	200
2 hours	100
3 "	67
4 "	50
5 "	40
6 "	33
8 "	25
10 "	20
12 "	17
24 "	8

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B.2. For personnel being monitored outside the general radiation field, where personnel contamination exists over relatively small areas of the EXPOSED body (less than one-half a square foot):

The recommended maximum values shall be one-half those given in table III. Monitoring of head, arms, hands, lower legs, and feet will be considered as coming under this category. Washing may be limited only to the contaminated parts, and also a change of clothing may not be indicated unless the radiation levels exceed those stated in part D below.

B.3. For personnel being monitored outside the general radiation field, and the contamination exists over only spots of EXPOSED body (about the size of a half dollar or less):

The recommended maximum values shall be one-fifth those given in table III. Washing may be limited only to the contaminated parts, and also a change of clothing may not be indicated unless the radiation levels exceed those stated in part D below.

C. For personnel being monitored outside the general radiation field and the contamination exists over any size area on the exterior surface of the clothing:

The recommended values under these conditions will be twice those given in table III. The recommended action shall be to advise bathing and a change of clothing.

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D. When the general contamination of a community is of the degree to produce an estimated maximum theoretical infinity gamma dose of 20 roentgens or greater, personnel who have been out-of-doors at any time during the first two days and generally moving around in the area (as opposed to such an act as walking only between a building and a vehicle) shall be advised to brush off the footwear (outdoors), to bathe and to change clothing as soon as possible after the final return indoors each day.

In addition, personnel who go out-of-doors for any length of time during the first two days after such a fallout shall be advised to wash their hands at least after the final return indoors each day, and more frequently, if possible.

DOE/NY

B.2. For personnel being monitored outside the general radiation field, where personnel contamination exists over relatively small areas of the EXPOSED body (less than one-half a square foot):

The recommended maximum values shall be one-half those given in table III. Monitoring of head, arms, hands, lower legs, and feet will be considered as coming under this category.

B.3. For personnel being monitored outside the general radiation field and the contamination exists over only spots of EXPOSED body (about the size of a half dollar or less):

The recommended maximum values shall be one-fifth those given in table III.

C. For personnel being monitored outside the general radiation field and the contamination exists over any size area on the exterior surface of the clothing:

The recommended values under these conditions will be twice those given in table III.

DOE/NV

D. When the general contamination of a community is of the degree to produce an estimated maximum theoretical infinity gamma dose of 20 roentgens or greater, personnel who have been out-of-doors at any time during the first two days and generally moving around in the area (as opposed to such an act as walking only between a building and a vehicle) shall be advised to bathe, change clothing, and brush off the footwear as soon as possible after the final return indoors each day.

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during the first two days

In addition, personnel who go out-of-doors for any length of time after such a fallout shall be advised to wash their hands at least after the final return indoors each day, and more frequently, if possible.

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POLICY III

Decontamination of Personnel

DISCUSSION

General

The establishing of degrees of undesirable contamination on personnel is based principally on considerations of the beta dose to the skin. From an operational point of view, probably the most practical method of estimating the beta skin doses is from gamma readings taken with survey instruments even though the evaluation of such measurements is difficult.

Personnel monitoring may be considered under two classes, i.e., those taken outside a radiation field and those within. In the latter case it would not be possible to establish prior criteria as to the relative contributions to the meter reading from the contamination on the person and from that on the ground . If it is impractical to perform personnel monitoring outside the contaminated area, probably the best solution is to estimate the degree of personnel contamination by determining the location of the individual during fallout. The discussion under Policy II suggested that even if one were out-of-doors during fallout in an area where the whole-body infinity gamma dose was 10 roentgens, there would be relatively little chance of beta burns occurring. However, based on general principles of reducing

DOE/NV

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radiation exposure whenever possible, bathing and a change of clothing might be suggested for situations where the whole-body infinity gamma dose was less than 10 roentgens and should be recommended for areas where the exposure is higher.

Data On Humans

In table II it was suggested that the relative average gamma dose rates from an infinity contaminated field at three feet above the ground compared to that on the natives measured by a survey meter held close to the body was:

$$\frac{110 \text{ mr/hr}}{15 \text{ mr/hr}} \cong 7/1 \text{ (Utirik Atoll)}$$

$$\frac{410 \text{ mr/hr}}{53 \text{ mr/hr}} \cong 8/1 \text{ (Ailinginae Atoll)}$$

$$\frac{1300 \text{ mr/hr}}{80 \text{ mr/hr}} \cong 16/1 \text{ (Rongelap Atoll)}$$

It is recognized there are many uncertainties in estimating such a relationship by this means. Even if one assumes the dose rate readings were taken accurately the factors involved, especially in relation to the amount of material collected and retained on the body, certainly are not constant. The higher ratio at Rongelap Atoll might have been due to a physical phenomenon where the quantity of material falling per unit area was so great that it was not retained so completely on the body. Even if this explanation is accepted, there still remain many questions.

DOE/NV

Theoretical considerations indicate a gamma dose rate ratio at three feet above an infinitely contaminated field to that at four inches from an equally contaminated field of six inch radius to be about 7/1. (See Appendix D.)

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The sizes of areas and distances from the surfaces were selected independently of any of the information on the fallout on the natives discussed above and were estimates of areas of contamination and distances of monitoring that appeared to be reasonable estimates of these parameters. The close agreement between the gamma dose rate ratios based on theoretical considerations and those observed with the natives is circumstantial. For example, an equally contaminated area of three-inch radius would yield a theoretical gamma dose rate nearly three times less than the selected area of six-inch radius. In the case of the natives, however, it is believed that they were semi-naked, perspiring, and out-of-doors during the fallout so that it is not unreasonable to expect relatively large areas of the body to be contaminated. In fact, this was noted when they were monitored. By their acts of walking around during the period of fallout and sleeping on mats that were heavily contaminated it would seem possible that significant areas of the bodies of the Ailinginae and Utirik natives could be as heavily contaminated as was the ground. (It is unknown if there were sufficient winds that might have raised the material from the ground to the body after fallout occurred.)

There is further uncertainty of what is meant by the monitor's report of "average" personnel readings. The dose rate readings in the hair are known to have been significantly higher than the rest of the body in most cases. It is unknown how these readings were "averaged".

Whereas these data certainly are not firm enough for one to place great confidence in the precise quantities of the ratios of 7/1 or 8/1, they do

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indicate the obvious fallacy of accepting a 10-roentgen infinity dose based on gamma dose rates measured on personnel outside the radiation field. For example, the natives from Ailinginae showed personnel dose rate readings that would approximate nine roentgens (gamma) in 2½ days and yet skin damage to some degree was evident in 14 out of 16 of the personnel. On the other hand, the natives from Utirik showed no skin damage with an estimated 2.2 roentgens in 2½ days based on gamma dose rates measured on personnel. The uncertainty of these data was discussed under Policy II. They do suggest, however, that if the contamination of a relatively large area of the exposed body produces less than one roentgen infinite gamma dose as measured by a survey meter held four inches from the surface there is a large probability that beta burns will not result. (See also discussion under Policy II.)

Doses from Small Sources

When the same dose rate reading is produced at a given height above a surface from a smaller area, the amount of contamination per unit area is greater (other factors being equal). Therefore, it would seem desirable to reduce the recommended dose rate levels when relatively small areas are involved. It is recognized that radiation from another nearby spot may contribute to the survey meter reading when monitoring a small area on personnel, but this has not been taken into account, first because of the difficulty of establishing a prior appraisal of this variable factor and, second, whatever this contribution may be it will now become an added safety factor.

Of course, the problem is still complex because when considering smaller and smaller areas the eventual end point is a single particle.

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An estimate of beta doses at the surface of an imaginary sphere surrounding a fallout particle is given in Appendix E and an estimate of beta doses from a single particle required to produce recognizable erythema is presented in Appendix F. Calculations indicate that the specific activity of some individual particles found in fallout would be great enough to produce recognizable erythema if held in contact with the skin for less than one day, yet the gamma dose rate reading at 4 inches may be quite small. (See Appendix G.)

Additional information on doses from individual particles has recently been reported*. The particles found in and around Hanford consisted principally of three radioisotopes, Ru^{103}, Ru^{106} and its daughter Rh^{106}. The data and calculations in Appendix H also strongly indicate that a single fallout particle could produce a recognizable erythema.

Contamination of Clothing

In the case of contamination of clothing, higher dose rates might be tolerated than those for exposed parts of the body. This was exemplified in the natives where no beta burns were observed under clothing of the most highly contaminated personnel. (This does not include such areas as under the waist line where material apparently collected and was held in place.) On the other hand, very large increases in contamination should not be tolerated since it is possible for the clothing to be rearranged so as to bring the contaminated surface in contact with the skin. Further, it is not unlikely that one may rub his hands over his clothing and then through the hair where it the material could be held in place for relatively long periods of time.

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*HW-33068. A status report. Sept. 15, 1954.

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Beta Exposure to the Hands

A further consideration is the beta dose to the hands resulting from handling objects contaminated with fallout material. Although some data are available on beta burns from handling radioactive objects, the conditions are so different from those associated with fallout that comparisons probably would not be valid.*

If the above assumptions and calculations are correct concerning contamination of a general area from fallout, then the transfer of all the radioactive material to the hands from an object of equal area would not constitute a hazard. Thus, one might consider using as criteria for monitoring objects, the dose readings given above for monitoring personnel outside the general radiation field.

However, the problem is more complex since the hands may come into contact with contaminated surfaces many times larger in area than the hands, with an undetermined percentage of activity being transferred to the hands. Of course, an added uncertainty is the frequency of washing of the hands and/or the rubbing off of the material from the hands.

Further, one might speculate that a given surface could have significantly higher contamination than the general area and that the handling of such a surface could constitute a greater risk. This might be true because of the greater amount of activity transferred to the hands or because of the doses delivered during the time of actually handling the object. The uncertainty of the percentage of transfer of material has been mentioned. One uncertainty in the second case is the length of time the object would be handled.

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*"Beta Ray Burns of Human Skin". Knowlton, et al. The Journal of the American Medical Association. V. 141, No. 4. Sept. 24, 1949.

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Based on calculations in Appendices B and D, when an object is held in a hand, a rough estimate of the ratio of dose rates of beta to the basal layer of the epidermis to that of the gamma reading on a survey meter held four inches away from an object two inches in radius (outside a general radiation field) is 2600-5200 to 1. (Appendix I) Thus, if this object were contaminated with the same activity per unit area that would produce a 10-roentgen whole-body gamma dose from general contamination of the area, it would produce about 77 mr/hr gamma at four inches away at H+1 hours, and about 200-400 reps/hour at a depth of 7 mg/cm^2.* Since the palms of the hands have an approximate epidermal layer of about 40 mg/cm^2 the beta dose to the basal layer would be about 135-270 reps/hour. (The time of H+1 was selected to show about the highest magnitude of dose rates.) If one assumes that the decay is according to $t^{-1.2}$, then the total beta dose to the basal layer of the epidermis in the next 10 hours would be about 250-500 reps.

Whereas the above estimates do not indicate an alarming situation, a more serious problem may come when the contamination is just less than that where evacuation is indicated. For example, the contamination of the general area may be five or six times that used as an illustration in the preceding paragraph, without evacuation being recommended. Thus, beta dose rates from handling objects, especially in times soon after fallout, may be high enough to be a problem. A simple and expedient procedure to reduce this factor is frequent washing of the hands after handling objects that were in the fallout.

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*These numbers agree fairly well with the computations in "Beta-contact Hazards Associated with Gamma-radiation Measurements of Mixed Fission Products". Teresi, J.D., USNRDL-383 (CONFIDENTIAL)

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Beta Exposure to the Feet and Lower Legs

It was suggested in Policy II that normal closed-type footwear (as compared to such as open sandals) would probably afford adequate protection against significant beta doses to the feet from fallout material on the ground. There is still the added problem if the material be scuffed up and cling to the ankles and lower legs. If there were no intervening clothing, or perhaps even with thin stockings or socks, this might result in significant biological beta doses being delivered to these parts. For example, if the gamma dose rate reading at H+3 hours were something less than five roentgens per hour, evacuation would not be indicated. However, for fallout material of the same concentration in contact with the skin the beta dose rate at 7 mg/cm^2 would be about 600 reps/hour. (See Appendix B.) Presumably, personnel would be kept indoors for a few hours but upon release the approximate beta dose rates at 7 mg/cm^2 would be 260 rep/hr three hours later or 210 rep/hr six hours later. In addition, there is the variable factor of what concentration of fallout material may accumulate in the ankle region by walking around an area.

A concentration of fallout material on the ground that would result in about 20 roentgens maximum theoretical infinity gamma dose, if in contact with the skin would result in a beta dose rate to the basal layer of the skin of about 1/4 those indicated in the previous paragraph.

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POLICY IV

Monitoring and Decontamination of Motor Vehicles

A. It is recommended that when the predicted fallout across a main highway will be equivalent to a 10 roentgen infinity gamma dose or higher, vehicles be held until after the actual fallout has essentially ceased. They should be then warned to proceed with windows and air vents closed and the cars should be monitored after passing through the contaminated area. When less than 10 roentgens, but still significant amounts of fallout are predicted across a highway, vehicles should be warned to proceed with windows and air vents closed and should be monitored after passing through the contaminated area. Monitoring and warnings should be continued until there is reasonable belief that no or very few additional vehicles will exceed the values given in table IV.a.

B. When the dose rate reading taken inside a vehicle, or taken over any exterior area that is readily accessible, equals or exceeds the values given in table IV.a. the vehicle shall be cleaned inside and outside. Exterior areas to be monitored should include the wheels and under parts of the fenders but not the under carriage. The survey meter should be held approximately four inches from any surface.

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TABLE IV.a.

Gamma Dose Rates at Times After Detonation When Decontamination of Motor Vehicles Should be Recommended

Time After Detonation of Monitoring	Gamma Dose Rates At Time of Monitoring (mr/hr)
1 hour	1000
2 hours	500
3 "	333
4 "	225
5 "	200
6 "	167
8 "	125
10 "	100
12 "	83
24 "	42

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Monitoring and Decontamination of Motor Vehicles

In the past, fallout has occurred across highways in significant quantities. Table IV.[illegible] below indicates some pertinent data during Upshot-Knothole.

TABLE IV.[illegible]

Shot Number (Chronological)	Approximate Yield (KT)	Tower	Time of Fallout (Hrs)	Estimated Dose Rate Reading of Highway at Time of Fallout (mr/hr)	Location	Approximate Distance From Ground Zero (Miles)
1	17	300'	1	920	30 miles south of Alamo on H/w. #93	60
1	17	"	2 3/4	200	1 mile north of St. George, Utah	130
6	2	"	5	325	Junction of U.S. H/w. #91 and Nevada H/w. #40	80
7	51	"	4	760	20 miles northw. Glendale, Nev. on H/w. #93	65
7	51	"	7	400	8 miles west of Mesquite, Nev. H/w. #91	105
9	32	"	2	1000	30 miles north Glendale on H/w. #93	60
9	32	"	3 3/4	420	St. George, Utah H/w. #91	130

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Road blocks were established on Highways 93 and 91 following shots number seven and nine of Upshot-Knothole. The highest reading on a private automobile was 100 mr/hr (gamma) inside and 110 mr/hr outside at H plus 3½ hours. About 75 cars were washed (roughly 1/[illegible] of the total monitored). All of the cars that were washed except the one mentioned above, had outside dose rate readings less than half of the highest. The ratio of dose rate readings on the outside of the car to inside varied from unity to about 4/1. Probably one of the important factors here is the difference between driving with windows and/or ventilators opened or closed. One bus read 250 mr/hr outside and average of 100 mr/hr inside with a high inside reading over the rear seat of 140 mr/hr at H plus 8 3/4 hours.

Considering the amount of time one normally spends in an automobile, these dose rates do not necessarily represent a health hazard in terms of gamma doses. What is probably a more limiting factor is the direct contamination one might acquire by rubbing against the outside of the car, especially when changing a tire.

DOE/NV

It is assumed that monitoring will be accomplished outside a general radiation field. Theoretical calculations (Appendix D) indicate that gamma dose rate readings taken at four inches from a surface will be 51%, 42%, and 27% of those by a meter at three feet above an equally contaminated infinite field when the radii of contamination are respectively 3 feet, 2 feet, and 1 foot.

These data suggest that when the gamma dose rate reading at four inches from a generally contaminated car is about one half that for an infinite plane taken at three feet, the degree of contamination per unit

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area will be about equal; and when the wheels are being monitored ~~1/3~~ 1/5 to 1/4 of a gamma dose rate reading will represent equivalent contamination. (depending on the gamma contribution from the body of the contaminated vehicle).

Another factor to be considered is that the probability of collecting fallout material on the body from a generally contaminated area in which one lives is greater than from one's automobile. On the other hand, it has been noted in the past that significantly higher amounts of contamination have been found on the tires and under parts of fenders than on the remainder of the car. (Undoubtedly, this is a simple phenomenon of picking up the activity from the highway.) If one were to change a heavily contaminated tire, significant amounts of radioactive material might accumulate on the hands, and later be transferred to the hair or eyes by a simple rubbing of the hands over those parts.

A comparison might be made here between recommended maximum dose rates found on personnel and the establishing of levels of activity for automobiles. There is one obvious difference, however; in the first case the material is already on the person while in the second case one has to introduce the factor of probability of transfer of contamination (and to what degree) from the car to the body.

DOE/NV

The dose rates (measured as stated) in table IV would represent about equal contamination per unit area for a car as for an infinite plane if the car were rather uniformly contaminated. If the activity were confined say principally to the tires and under parts of the fenders, the dose rate readings might represent nearly twice the degree of contamination. One must weigh this condition with the probability that a tire will be changed before the

[redacted]

activity has decreased significantly.

A given dose rate reading inside a vehicle may represent less contamination per unit area due to the contribution of gamma radiation from the exterior of the vehicle. On the other hand, contamination within a vehicle would more probably be picked up by personnel than if it were on the outside. Further, it is recognized that significantly high concentrations of radioactive fallout may accumulate in such parts as the air filters of an automobile. Again, this has to be weighted against the probability that they will be handled before the activity has decreased to low levels plus the fact that it is relatively difficult to monitor such parts on a mass basis. The uncertainties present in estimating possiblehazards from vehicle contamination would not justify fine distinctions in monitoring the various parts. A thorough cleaning, inside and outside, would appear to be the best solution.

One of the obvious ways to avoid much of the problem discussed in Policy IV is to prevent vehicles entering an area during the time of fallout. This will not prevent the first vehicles passing through from picking up activity on the tires from the highway. It is believed, however, this will not constitute such a troublesome problem and past experience has indicated that the activity found on the tires noticeably decreased after several cars had passed over the highway. Further, if vehicles are not present in the fallout it will help reduce contamination of the passengers and of the insides of the vehicles.

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Operational Feasibility

In the past, the criteria used for washing cars has been 7 mr/hr, and at a later time 20 mr/hr (gamma), inside a vehicle. This resulted in washing about 75 cars (roughly 1/8 of the total monitored) following the seventh and ninth detonations of Upshot-Knothole. Under the recommendations given in Policy IV, the bus mentioned above, but probably none of the cars, would have been washed.

The data given in table IV.b. indicate that if these radiation levels given had been predicted before the fallout, Highways #91 and 93 would have been closed prior to the fallout from the seventh detonation and possibly highway #93 for the ninth detonation.

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POLICY V

Contamination of Water, Air, and Foodstuffs

In any area where the theoretical gamma infinity dose exceeds 10 roentgens, adequate sampling of the water, air, and foodstuffs should be made to ascertain the conditions of possible contamination. Based on past data, however, it is not expected that under those conditions of fallout where the radiation levels are below those stipulated for possible evacuation, that the degree of contamination will be a health hazard. (Nor is it implied here that any level above this does constitute a serious contamination of water, air, or foodstuffs.) Therefore, it is recommended that no action be taken in regard to limiting intake except to advise the washing off of such exposed foods as leafy vegetables when that action seems desirable.

• • • • • • • • • • • • • • • • • • •

DISCUSSION

Water

Table VI.a. lists the six locations having the highest concentrations of fission products in water sources during Tumbler-Snapper, and for comparative purposes the estimated theoretical maximum gamma infinity doses.

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TABLE VI.a.

Locality	Concentration(microcuries per milliliter extrapolated to 3 days after detonation)	[illegible] Theoretical Maximum Whole-body Gamma Infinity Dose (roentgens)
Virgin River Irrigation Canal, Nev	8.7×10^{-5}	6.
Irrigation Ditch, 56 mi.no. of Pioche, Nev	4.5×10^{-5}	0.15
Lower Pahranagat Lake, Nev	3.2×10^{-6}	2.
Virgin River at Mesquite, Nev	2.6×10^{-6}	2.5
Bunkerville, Nev (tap water)	1.2×10^{-6}	7.0
Crystal Springs, Nev (tap water)	1.1×10^{-6}	0.15

Due to weather and to attenuation of the gamma rays by buildings, the whole-body gamma dose estimated to have been actually delivered was probably closer to one-half of the values shown.

The maximum permissible concentration of fission products in drinking water is 5×10^{-3} µc/ml extrapolated to three days after detonation. This is considered a safe concentration for continuous consumption.

Whereas, the monitoring of water sources is of value for documentary purposes it should be recognized that the concentrations found may vary widely within small geographical areas and even at the same location at different times (taking into account radioactive decay). Thus, confidence cannot be placed in precise values. Table VI.a. suggests that even if one were to have stored up the water listed at Virgin River Irrigation Canal and subsisted entirely on this for a lifetime, the concentration would be

[redacted]

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about 58 times less than the maximum permissible amount. Normal factors of dilution by additional rainfall and/or by the influx of lesser contaminated ground water would [illegible] reduce the level of activity.

Air

Considerable effort has and is being made to evaluate hazards from airborne radioactive materials, including fission products. There are certainly many unanswered problems including the possible hazard from a single particle in the lungs. Despite the uncertainties and as yet incomplete analysis of the inhalation hazard, the preponderance of evidence today is that the external gamma hazard from fallout is the more limiting factor of the two*. (However, see discussion on food contamination.)

During Upshot-Knothole quite complete data were collected of concentrations of airborne activity on about 150 occasions in some 40 different localities within 200 miles of the Nevada Proving Grounds, These included monitoring of all detonations. Histograms were made of air concentrations versus time after detonation for 30 occasions and estimates were made of doses to the lungs. These data for the five communities showing the highest air concentration are given in Table VI.b. The histogram for St. George (the highest 24 hour average concentration of fallout ever measured in a populated area) is reproduced in Appendix J.

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*Ad Hoc Committee Meeting. Washington, D.C. January 20, 1954.

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TABLE VI.b.

Locality	24-hour Average Concentration (microcuries per cubic meter)	Dose to Lungs (13 weeks) Based on 20% Deposition and 100% Retention Thereafter (reps)*	Theoretical Maximum Whole-body Gamma 13-week Dose (roentgens)
St. George, Utah	1.29	~~110~~ 125	3.5
Lincoln Mine, Nev	4.0×10^{-1}	12	1.5
Mesquite, Nev	1.7×10^{-1}	13	1.0
Groom Mine, Nev	3.4×10^{-2}	7	0.35
Pioche, Nev	2.0×10^{-2}	3	0.015

*The method used in estimating doses to the lungs is given in Appendix K. One assumption made was uniform distribution of radiation which, of course, is not entirely accurate.

The criteria previously established by an Ad Hoc Jangle Feasibility Committee (Washington, D.C., July 13, 1951), for air concentrations was

> "At a point of human habitation, the activity of radioactive particles in the atmosphere, averaged over a period of 24 hours, shall be limited to 100 microcuries per cubic meter of air (corresponding approximately to a ground level gamma intensity of 30 mr/hr).
>
> "The 24-hour average radioactivity per cubic meter of air, due to suspended particles having diameters in the range 0 micron to 5.0 microns, shall not exceed 1/100 of the above; nor is it desirable that any individual particle in this size range have an activity greater than 10^{-2} microcuries calculated 4 hours after the blast."

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In the January 20, 1954 meeting of the Ad Hoc Committee the basis for recommending the above air concentrations was discussed. Essentially, these criteria were selected by estimating the gamma dose that might be delivered by the passing of a radioactive cloud. Since there are better

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methods of estimating gamma doses and since there are uncertainties in evaluating the hazards of such transitory air concentrations as experienced from fallout, and since the preponderance of evidence from past nuclear test series indicates that the external gamma hazard is more limiting than the inhalation one, it was recommended in the January 20, 1954 meeting to strike from the record the past recommendations for maximum permissible air concentrations. It was recommended that an air monitoring program be continued for documentary purposes and for whatever value the data might have in the future when new analyses might be made in the light of additional knowledge.

A further discussion of the single particle problem may be made. In arriving at the recommendation "... nor is it desirable that any individual particle in this size range have activity greater than 10^{-2} microcuries calculated four hours after the blast" a computation was made that the average radiation dose from such a particle to a sphere one-half a millimeter in radius would be 385 reps.* However, the conclusions may be misleading.

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In the case of a single particle, relatively large doses are delivered near the particle and small doses at a greater distance. Appendix L suggests one possible estimate of this phenomenon. The parameters involved here are many and difficult to evaluate. For example, how long will a particle remain in one place in the lung and what dose will be delivered during that time?

It has been suggested** that in the upper respiratory passage 20-micron diameter particles are the upper limit of size for deposition and that "Cilia

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*Minutes, Meeting of Committee to Consider the Feasibility and Conditions For a Preliminary Radiologic Safety Shot for Jangle. L.A.S.L. May 21 and 22, 1951.

**HW-33068. A status report. Sept. 15, 1954. (CONFIDENTIAL).

[redacted]

sweep 4 to 6 cycles per second. The probability of a particle remaining within one millimeter zone for as much as one-half hour appears to be vanishing small. ... Protection will also be provided by the mucus lining which is itself renewed several times an hour." Accepting the estimates above and the methods illustrated in appendices E and F, it may be computed that about ~~[illegible]~~ 80 reps would be delivered to the surface of an imaginary stationary sphere one millimeter in radius by a 20 micron particle (~~[illegible]~~ 0.5 microcuries) in 30 minutes (Appendix L). Larger doses will be delivered closer to the particle but with the relatively rapid movement of the particle, it does not appear that large doses will be delivered to a great number of cells. Multiple exposures might occur from additional particles but again this risk is difficult to evaluate.

Food

Considerable effort is being directed toward the study of contamination of food from fallout. One element of major concern is Sr^{90}. It has been estimated that if one were to subsist entirely on food grown from soils containing about one tenth to one microcurie per square foot of Sr^{90}, (1,000 pounds of calcium per acre), that over a period of years there would accumulate in the human skeleton a body burden of one microcurie of Sr^{90}*. Soils taken from ,

about miles from the Nevada Proving Grounds, now show a concentration

of microcuries per square foot.

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*Private communication, L. A. Dean, U. S. Department of Agriculture, Beltsville, Maryland, April 23, 195_.

[redacted]

(Although not of direct concern to the Nevada Proving Grounds, it is of interest to note that soils were collected from the Marshall Islands following the fallout in early March 1954. Appendix [illegible] summarizes these data.)

A recent report* strongly suggests that contamination of leaf surfaces followed by either direct consumption or intake by way of milk is far more an important pathway of intake than by the soil-plant-animal cycle, at least for those times of year when plants may be in a state of growth to collect the fallout. Further anlysis is being planned.

This same report* raises a new problem. Based on stated assumptions, the data presented indicates that doses to the thyroid from iodine radioisotopes may be a greater hazard than Sr^{89-90}. Further, the report suggests that ~~for those times of year when intake of fallout material may come by way of leafy surfaces~~, the dose to the thyroid (delivered in a few weeks) may be many times greater than the theoretical maximum external dose. Additional evaluation will be given this problem.

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*Report on Gabriel. USAEC, Division of Biology and Medicine, Washington, D.C. July 1954 (SECRET)

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POLICY VI

Routine Radiation Exposures

The whole-body gamma effective biological dose for off-site populations should not exceed 3.9 roentgens over a period of one year. This total dose may result from a single exposure or series of exposures.

If integrations of dose rate readings are used in estimating the effective biological doses, then table V may be used.

TABLE V

	Multiplication Factor	Effective Biological Dose
Maximum theoretical radiation dose from time of fallout to 15 days later.	3/4	
Maximum theoretical radiation dose from 15th day to one year.	1/2	
TOTAL: (best estimate of effective biological dose)		

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If film badges or dose meters are worn on personnel and the evidence of their use supports the view that the readings are a reasonably accurate account of the radiation dose received, then the values recorded on the film badge may be accepted with a correction factor of 3/4 to account for the difference between the dose received by the film badges or dosimeters (including backscatter) and that received at a tissue depth of five centimeters.

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1953 the following recommendation was made.

> "It is recommended, and found to be in conformity with the present principles of determining permissible exposure limits, that for test operation personnel the total body gamma exposure be limited to 3.9r in thirteen weeks, and that the same figure be applied to the off-site communities with the further qualification in the latter case that this is the total figure for the year. In general, this implies a single test series in any given year."

On the basis of this recommendation and the reasoning discussed under Policy I, the criteria for estimating the whole body gamma effective biological dose are summarized in Table V. It will be noted that the biological factor included under Policy I is omitted in Policy V. In the first case we are dealing with relatively high doses that may require emergency measures with their attendant hazards. It is a situation where one wishes to estimate all pertinent factors in evaluating radiation doses even though they may not be known with preciseness, before recommending an emergency action that may produce greater problems. In the case of Policy V one is concerned with relatively lower doses during routine operations. It would be difficult to justify on the one hand the proposition that weekly doses for general populations may be integrated and taken in a single exposure without penalty and on the other hand that a given dose received over a period of a year may be administratively reduced because of biological repair. Therefore, the biological factor is omitted.

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The general effects of backscattering on measured radiation doses are fairly well established. Further, knowledge of depth (tissue)-dose curves has advanced to a quantitative state.* Thus, there seems to be little doubt that a film badge or dosimeter worn on the person will over-estimate the gamma radiation dose delivered at a depth of five centimeters (assumed depth of blood forming organs). A major factor in determining this difference is the quality of radiation under consideration. One report** dealing explicitly with radiation in a fallout field suggests a factor of about 3/4.

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*Permissible Dose From External Sources of Ionizing Radiation. National Bureau of Standards Handbook 59. September 24, 1954.

**WT-814. Effective Energy of Residual Gamma Radiation. January 1954. CONFIDENTIAL.

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[redacted]

[redacted]

APPENDIX A

Sample Estimation of Gamma Radiation Doses Saved by Remaining Indoors

EXAMPLE I

Assume: Time of fallout = H+3 hrs
Dose rate at H+3 = 667 mr/hr

Then:	Theoretical maximum dose from time of fallout to three hours later	1.30 r
	Savings by remaining indoors for three hours	0.65 r
	One year effective biological dose if personnel did <u>not</u> remain indoors during the three hours (based on same assumptions contained in section on evacuation)	~5.0 r
	Per cent of one year effective biological dose saved by remaining indoors for the three hours	~13%

EXAMPLE II

Assume: Time of fallout = H+3 hrs
Dose rate at H+3 = 667 mr/hr

Then:	Theoretical maximum dose from time of fallout to eight hours later	2.30 r
	Savings by remaining indoors for eight hours	1.15 r
	One year effective biological dose if personnel did <u>not</u> remain indoors during the eight hours (based on same assumptions contained in section on evacuation)	~5.0 r
	Per cent of one year effective biological dose saved by remaining indoors for the eight hours	~23%

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APPENDIX C

CALCULATIONS

Of Beta Dose Rate at Depth of Seven Milligrams per Square Centimeter [illegible]

Assume: 1.5 Mev Beta (Mean energy = 0.5 Mev)
$\mu = 10\ cm^2/gm$
(This assumes a single mass absorption coefficient.)

$N = No\ e^{-\mu x}$

where: No = number of betas at surface per cm^2 per sec.
N = " " " " depth x
μ = mass absorption coefficient
x = distance (depth) under consideration

$$\frac{dN}{dx} = -\mu\ No\ e^{-\mu x}$$

$$R = \frac{\mu No e^{-\mu x} E}{2}$$

where: R = dose rate at depth x
E = mean energy of betas

$$R = \frac{(10) No\ e^{-(10)(0.007)}(0.5)}{2} = 2.33\ No\ Mev/gm\text{-}sec.$$

$No = 3.7 \times 10^4 C$ where: C = activity in microcuries per cm^2
$R = 8.65 \times 10^4 C$ Mev/gm-sec.
$= (1.39 \times 10^{-1})(C)$ ergs/gm-sec
$\cong 5.4\ C$ reps/hr
or $\cong 5.0\ C$ rads/hr

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Example
Assume: $C = 80\ \mu c/cm^2$ (beta)
$R = 5.4\ C$ where: R = dose rate at depth 7 mg/cm^2 in reps
C = activity/cm^2 in μc
$= (5.4)(80)$
$= 432$ reps/hr
or $= 400$ rads/hr

Comparison of Beta Dose Rate (reps/hr) at 7 Mg/cm^2 to Gamma Dose Rate Measured in Infinite Field at Three Feet Above the Surface

Assume: 80 $\mu c/cm^2$ (beta), equivalent to
1 megacurie/mi^2 (gamma)

$$\frac{432}{4.1} \cong 100$$

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APPENDIX C

(Appendix B)

Experimental Data Versus Theoretical Calculations in Estimating Beta Doses

The following data are abstracted from experimental results, wherein a thin P^{32} source prepared by soaking a filter paper in a solution of phosphates, allowing it to dry, and then measuring surface dose rates with a surface ionization chamber.*

Thickness of source	9.6 mg/cm^2
Activity of source	77.0 $\mu c/cm^2$
Surface dose rate	0.127 rep/sec 457 reps/hr
Dosage rate at depth of x centimeters	$e^{-9.5x}$

A. Theoretically

Using the equation from Appendix B

$$R = \frac{\mu No e^{-\mu x}}{2} \quad (\text{for } P^{32})$$

Substituting above data:

$$R = \frac{9.5\ No e^{-(9.5)(0.007)}\ .69}{2}$$

$$= 7.0\ C \text{ reps/hr}$$

Let $C = 77\ \mu c/cm^2$

Then $R = 70 \times 77$
$= 539$ reps/hr at 7 mg/cm^2 (I^{32})

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*Effects of External Beta Radiation, Zirkle, Raymond E. McGraw-Hill Book Company. 1951.

[redacted]

[redacted]

B. <u>Experimentally</u>

$$R = 457\ e^{-(9.5)(0.007)}$$

$$= 427 \text{ reps/hr at } 7 \text{ mg/cm}^2 \ (P^{32})$$

The two above approaches are within 26% of each other. If one extrapolates the experimental data from a source of 9.6 mg/cm^2 to a thin source (for comparative purposes) the two methods are within 20%.

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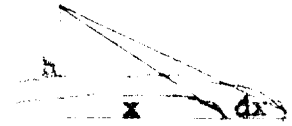
APPENDIX 2

CALCULATIONS

([illegible])

Gamma Dose Rate from a Field Six Inches in Radius and Chamber Four Inches Above Surface

Dose rate of gamma from a point source



$r \cong 6CE$ where: r = r/hr

C = activity in curies per square foot

E = average energy of gammas (Mev)

$$r = 6CE\, 2\pi \int_0^x \frac{x\,dx}{h^2 + x^2}$$

$$r = 18.8\, CE \ln \left[\frac{h^2 + x^2}{h^2} \right]$$

Example:

Let: x = 1/2 feet

C = 40 μc/cm² or 3.6×10^{-2} c/ft² (gamma)

E = 0.7 Mev

h = 1/3 foot

$$r = (18.8)(3.6 \times 10^{-2})(0.7) \ln \left[\frac{(1/3)^2 + (1/2)^2}{(1/3)^2} \right]$$

= 0.56 r/hr

Comparison Gamma Dose Rates From Infinite Plane at a Height of Three Feet Above the Ground to Area of Six Inch Radius and Height of Four Inches.

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Assume: 1 megacurie/mile²
(3.6×10^{-2} c/ft²)

$$\frac{4.1 \text{ r/hr}}{0.56 \text{ r/hr}} = 7.3$$

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APPENDIX E

Estimate of Dose Delivered By A Single Particle of Fallout Material

Assume:
a. Point source
b. 0.5 Mev average beta energy
c. $\mu = 10\ cm^2/gm$
d. Rate of decay follows $t^{-1.2}$

The dose delivered at the surface of an imaginary sphere at distance R from a point source.*

(1) $K(R) = \frac{CE\mu}{4\pi R^2} e^{-\mu R}$ $\frac{Mev}{gram}$

where:
$K(R)$ = dose delivered at the surface of an imaginary sphere at distance R
E = average energy of beta particles
C = total number of disintegrations
μ = mass absorption coefficient

Substituting: $\mu = 10\ cm^2/gm$
$E = 0.5$ Mev,

Then: (2) $K(R) = 0.397 \frac{e^{-10R}}{R^2}$ $\frac{Mev}{gm\text{-}disintegration}$

or

(3.a.) $K(R) = 6.35 \times 10^{-6} \frac{e^{-10R}}{R^2}$ $\frac{millirems}{Disintegration}$

or

(3.b.) $K(R) = 6.35 \times 10^{-6} \frac{e^{-10R}}{R^2}$ $\frac{millirads}{disintegration}$

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Equation (3.a.) is plotted on the attached graph.

FOR FISSION PRODUCTS,

(5) $A_a = A_1 t_a^{-1.2}$

where:
A_a = disintegrations per unit time at time "a" after detonation
A_1 = disintegrations per unit time at one unit of time after detonation

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*Rossi, H.H. and Ellis, R.H. "Distributed Beta Sources in Uniformly Absorbing Media" Nucleonics July 1950, V. 7, No. 1

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Integrating equation (2),

(6.a.) $C = 5A_1 (t_a^{-0.2} - t_b^{-0.2})$

and

(6.b.) $C = 5A_a t_a^{1.2} (t_a^{-0.2} - t_b^{-0.2})$

where: C = total number of disintegrations from time "a" to "b"
t_a = time after detonation
t_b = later time after detonation.

when t_b is infinite,

(7) $C_{\infty} = 5A_t t$

By the use of equations 3.a. or 3.b. and 6.b. one may compute an estimated dose at the surface of an imaginary sphere.

Of course, the problem is the determination of "t_a" and "t_b", i.e., how long after detonation will a radioactive particle appear in the lungs and how long will the particle remain in place. The first time (t_a) is much easier to estimate than the later (t_b).

(See text page 53)

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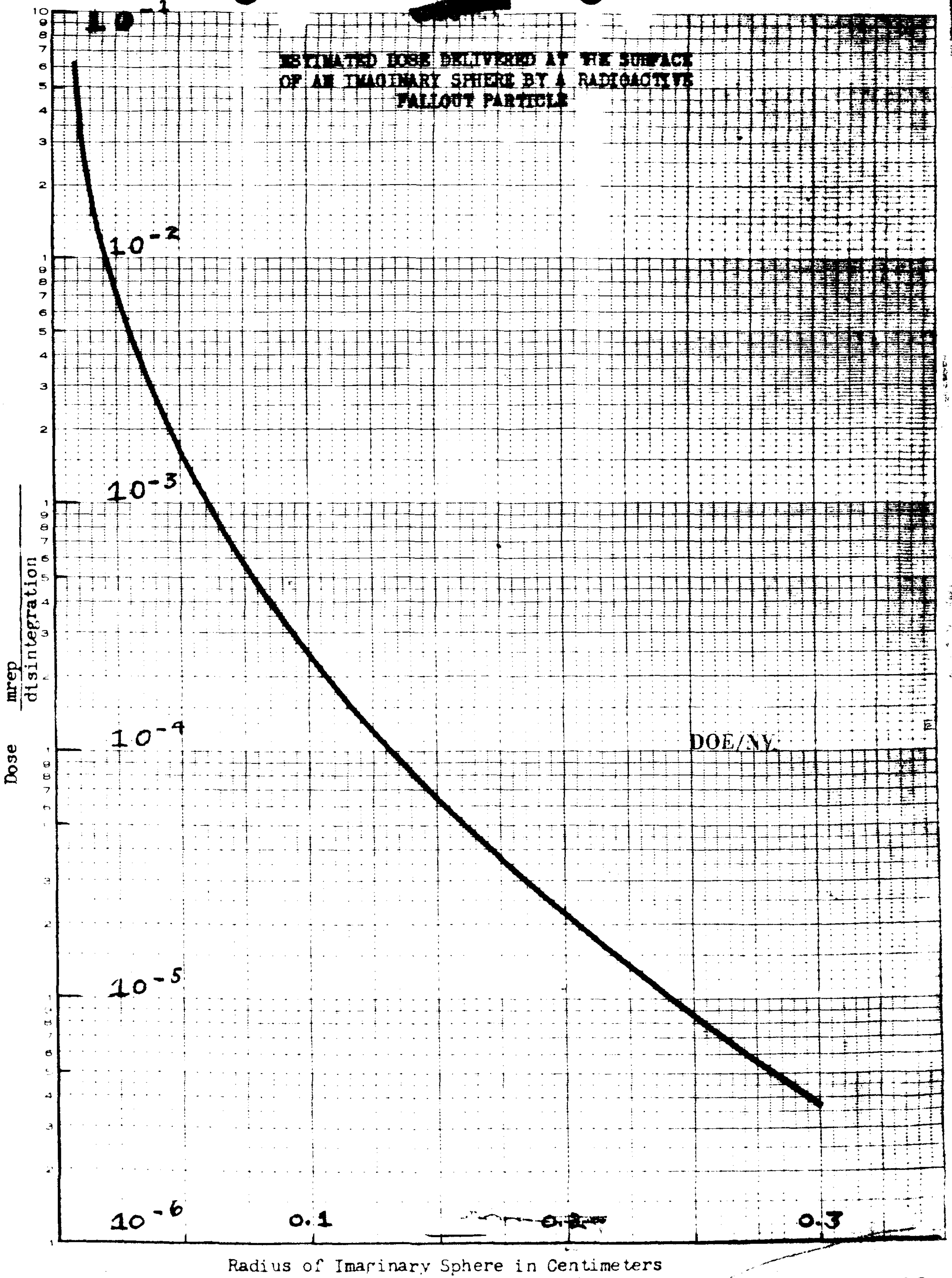

ESTIMATED DOSE DELIVERED AT THE SURFACE OF AN IMAGINARY SPHERE BY A RADIOACTIVE FALLOUT PARTICLE

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[redacted]

Appendix [illegible]

Estimate of Beta Dose From a Single Particle [illegible]
(Possible Production of Recognizable Erythema)

Let: t_1 = 3 hours (time particle is deposited on skin)
t_2 = 27 hours (time particle is removed)

Assume: 2000 rep = total dose required in one day to produce recognizable erythema
0.1 cm = radius of imaginary sphere within which cells must receive 2000 rep or larger.

According to Appendix [illegible], 2.5 x 10^{-7} rep/disintegration is delivered to surface of imaginary sphere 0.1 centimeter in radius.

$$\frac{[illegible] \times 10^3}{2.5 \times 10^{-7}} = [illegible] \times 10^{[illegible]} \text{ disintegrations required}$$

$$C = 5 [illegible]$$

$$[illegible] \times 10^{[illegible]} = 5 [illegible]$$

$$[illegible] = [illegible] \times 10^{[illegible]} \text{ d/m [illegible] at } t$$

i.e. [illegible] at H+3 hours

Of course, the radius of the imaginary sphere selected will materially affect the calculations. For example, a radius of [illegible] cm would require a particle of about [illegible] microcuries at H+3 hours to give the same dose.

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[illegible]

[illegible] of Ga[illegible] [illegible] From [illegible] Single Particle of Fallo[illegible] [illegible]

[illegible] a. [illegible] gamma energy [illegible] approximate [illegible] comparison with radium.
b. [illegible] particle of 25 [illegible] of beta activity or 75 micro-curies of gamma activity. ([illegible])

[illegible] = [illegible]
where: [illegible] = [illegible] (r/hr)
[illegible] = centimeters

Let: [illegible] = 7.5 x 10[illegible]
[illegible] = 1 cm

[illegible] = [illegible]

= [illegible] rate at [illegible]

DOE/NV

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[redacted]

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[illegible]

Data on Calculation [illegible] from Single Particle of [illegible] of Fallout Material

. Comparison of beta energies from Ru^{103} and Ru^{106} mixture to that from fission products.

Ru^{103} [illegible] Mev beta (T = [illegible]
Ru^{106} ~[illegible].03 Mev beta (T = 1.0y)
Rh^{106} 3.[illegible] Mev beta (T = 30 [illegible])

Assume: Ru^{103}/Ru^{106} ratio of 3.75*

To [illegible] late [illegible] average energy of beta from mixture:

Mev	Isotope	[illegible] Beta	[illegible]	Energy Beta
[illegible]	103	[illegible]	0.3	
[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	4.7	
			[illegible]	

$\frac{5.[illegible]}{3.[illegible]} \approx$ [illegible]

Average energy ~ [illegible] roughly equivalent to that assumed for fission products.

([illegible] course, [illegible] energy of the beta [illegible] not the sole consideration. [illegible] the [illegible] energy of beta from fission products is assumed [illegible], [illegible] 3.55 Mev beta from Rh^{106} will give [illegible].)

DOE/NV

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*All of the data contained herein on [illegible] contained in: [illegible]-33[illegible]. [illegible] report, [illegible] 25, 195[illegible].

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B. Data on doses and effects from single particles of Ru^{103} and Ru^{106}

	a	b
1. Size of particle:	40 µ	120 µ
Activity of particle:	1.1 µc	11 µc
Dose rate to 7 mg/cm^2:	6,600 rads/hr	27,500 rads/hr
Time dose delivered:	~6 days	~6 days

2. Survey Dose Rate (mrads/hr)*	Total Skin Dose (rads)*	Effects
400	~500,000	None visible
750	~[illegible],000	Reddening
2,500	~2,000,000	Desquamation
11,000	~6,000,000	Tissue Destruction
21,000	~7,000,000	Tissue Destruction— 2 cm across 8 mm deep

C. $\frac{750}{90} \cong 8.3$ µc estimated activity of particle producing reddening effect in about 144 hours. The estimated size is 100 microns.

DOE/NY

D. (8.3)(144) = 1200 µc total activity accounted for in the 144 hours that the dose was delivered. (Assuming constant activity during the 144 hours

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* 90 mrads/hr ≅ 1 µc

** "total dose refers to the hot spot directly below the particle, and is valid only as to order of magnitude."

[redacted]

1. What specific activity of a particle of fallout would be required to deliver the same dose in the same length of time?

The answer to this question depends upon the time after detonation that the particle comes in contact with the skin. Assuming this time to be H+3 hours, the specific activity would have to be about 150 μc for the same size particle.

Since the particle may be washed off before six days have expired, one may consider the problem another way. What must be the specific activity of a particle at H+3 hours to deliver this dose in the next 24 hours?

According to Strandquist (p. 8), only about 70% of a six day dose need be delivered in one day to produce the same effect (erythema). Accepting this, then a particle with about the same activity (160 μc) at H+3 hours would be sufficient to deliver an erythema dose in one day.

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[redacted]

F. The following data are reported for single particles collected during Upshot-Knothole* and Tumbler-Snapper**.

Size of Particle (μ)	Activity Extrapolated to H+3 Hours (μc)	Distance from Ground Zero (Miles)
___***	1,[illegible]	45
___***	[illegible]	13[illegible]
1,6[illegible]8 x 924	90[illegible]	1[illegible]
91[illegible]	4[illegible]	11
7[illegible]5	35	14.7
714	4[illegible]	1[illegible].
555	14	14.7
3[illegible]	25	14.7
[illegible]34	4	14.[illegible]
115	5.[illegible]	[illegible]5
[illegible]1	3.[illegible]	14.7
[illegible]	[illegible].5	—

It is not intended here to imply these are the maximum specific activities per particle that existed or could exist. The data at 14.7 miles are reported to show the wide range of specific activity that may occur at one locality.

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*[illegible]T-[illegible]11. "Distribution and Characteristics of Fallout at Distances Greater than 10 Miles from Ground Zero, March and April 1953", Rainey, C.T., et al. ([illegible]) and L[illegible]-16[illegible]5.
**UCLA-[illegible]3. "Preliminary Study of Off-site Airborne Radioactive Materials, Nevada Proving Grounds". February 1953 ([illegible]) and LA-1665.
***Data from estimations based on radioautograph methods.

[redacted]

APPENDIX I

Estimation of Ratio of Surface Beta Dose Rate to Gamma Dose Rate at Four Inches from an Object Two Inches in Radius

Gamma dose rate readings at four inches distance from a plane surface two inches in radius, is 1/40 that from an equally contaminated infinite field. (See Appendix D.)

Assume an object having a two-inch radius is contaminated on all sides (but not necessarily uniformly) so that the gamma dose rate is 1½ times that from an equally contaminated surface whose area is equivalent to the major cross-sectional plane of the object. The fraction given in paragraph one now becomes about 1/27. Further assume a 100/1 ratio for beta surface dose rate to gamma dose rate at three feet above an infinite field. Then, the beta surface dose rate to gamma dose rate at four inches will be 2700/1.

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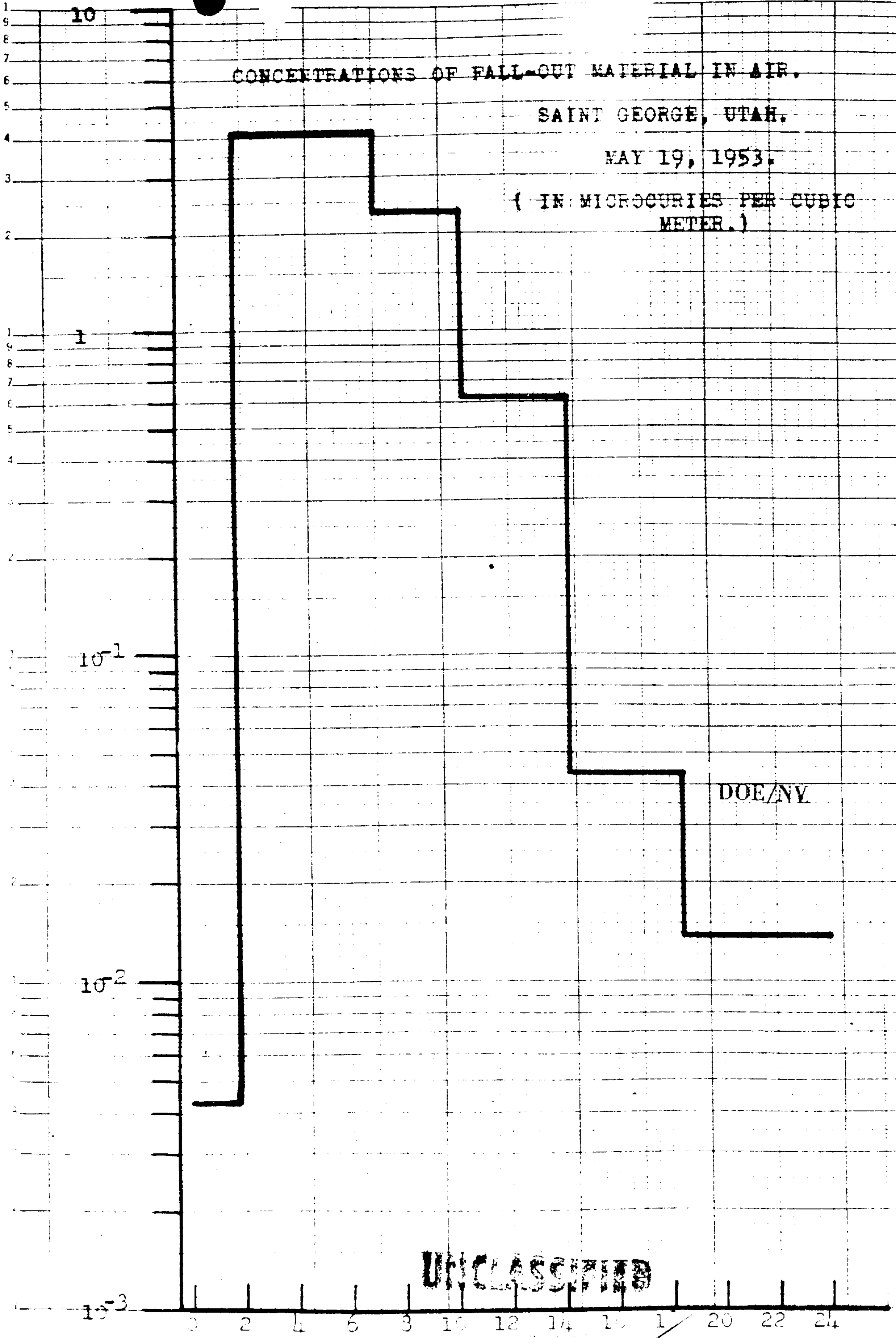
[redacted]

[redacted]



CONCENTRATIONS OF FALL-OUT MATERIAL IN AIR.

SAINT GEORGE, UTAH.

MAY 19, 1953.

(IN MICROCURIES PER CUBIC METER.)

DOE/NY

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[redacted]

[redacted]

APPENDIX K

Method Used in Estimating Doses to the Lungs from Inhalation of Fallout Material

Assumptions

The following assumptions are made in estimating radiation doses to the lungs.

A. Twenty per cent of the inhaled activity is deposited.

B. There will be no elimination of particles during their radioactive lifetimes. There is uncertainty as to the biological half-life of particles in the lungs. In those communities showing the highest concentrations of fallout, the peak of airborne material (which accounted for the greatest percentage of total fallout) occurred only a few hours after detonation. If one assumes a radiological decay according to $t^{-1.2}$ and a biological half-life of say 30 days, the omission of biological half-life would not affect seriously the computed total dose.

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C. All of the activity is associated with particles in the respirable range of sizes. Past data from cascade impactors indicate that about 90% of the activity is associated with particles 5 microns or less in the communities surrounding the Nevada Proving Grounds.

D. The lungs are uniformly irradiated.

E. The weight of the lungs is 900 grams.

F. An individual inhales 20 cubic meters per 24 hours.

[illegible]

[redacted]

[redacted]

G. The average beta energy is 0.5 Mev.

E. The gamma dose is negligible compared to the beta dose.

Data At St. George, Utah

I. 0505	II. Duration	III. Approximate Midpoint after Detonation	IV $\mu c/M^3$	V. μc Inhaled (Col.II times Col.IV times 0.834)	VI. μc Retained (Col.V times 0.2)
0610 - 1130	4.3 hrs	3 hrs	4.17	15.	3.0
1130 - 1445	3.2 hrs	8 hrs	2.38	6.3	1.26
1445 - 1845	4.0 hrs	11.5 hrs	6.3×10^{-1}	2.1	0.63
1845 - 2300	4.2 hrs	15.8 hrs	4.4×10^{-2}	1.50	0.5
2300 - 0635	7.5 hrs	21.5 hrs	1.4×10^{-2}	0.087	0.02
*0635 - 1835	12.0 hrs	31.5 hrs	1.4×10^{-2}	0.159	0.03

*Assumed

Sample Calculations

$$D = 5At_a^{1.2} [t_a^{-0.2} - t_b^{-0.2}]$$

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Let: $t_a = 3$ hours
$t_b = 2184$ hours (13 weeks)
$A = 3\ \mu c$

$$D = (5)(3 \times 2.22 \times 10^6 \times 60)(3)^{1.2} [3^{-0.2} - 2184^{-0.2}]$$

$= 4.4 \times 10^9$ disintegrations from 3rd hour to 13th week.

Assume: $E_{avg.} = 0.5$ Mev

$$(4.4 \times 10^9)(0.5)(1.6 \times 10^{-6})\left(\frac{1}{900}\right)\left(\frac{1}{93}\right) = 4.2 \times 10^{-2} \text{ reps}$$

42 mreps

Total Lung Dose for 13 weeks: ~ 125 mreps

[redacted]

[redacted]

APPENDIX L

Estimate of Dose at Surface of Imaginary Sphere One Millimeter in Radius

Assume: Average activity for 30 minutes is 0.5 μc at H+3 to H+3½ hours (See reference Appendix E.)

Then: $0.5 \times 2.2 \times 10^6 \times 30 = 3.3 \times 10^7$ disintegrations/30 minutes.

At surface of imaginary sphere 1.0 mm in radius the dose rate is

$$2.52 \times 10^{-4} \frac{\text{mreps}}{\text{disintegration}}$$ (See Appendix E)

$$(3.3 \times 10^7)(2.52 \times 10^{-4}) = 8.3 \times 10^3 \text{ mreps/30 mins.}$$

$$\cong 8 \text{ reps/30 minutes}$$

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[redacted]

[redacted]

APPENDIX M

Estimate of Sr^{90} In Soils of Pacific Islands

Location	I Total Activity (uc/ft^2) (Measured)	II Sr^{89}-Sr^{90} (uc/ft^2) (Measured)	III Rough Estimate External Infinity Gamma Dose (roentgens)
Likiep*	1.2×10^{-1}	8.7×10^{-3}	4
Jemo	3.0×10^{-1}	1.2×10^{-2}	4
Ailuk	1.0	3.8×10^{-2}	12
Mejuit	1.1	2.8×10^{-2}	8
Ormed	3.2×10^{-1}	1.1×10^{-2}	4
Kaven	1.6×10^{-1}	4.8×10^{-3}	2
Wotho	7.8×10^{-2}	1.3×10^{-3}	0.5
Rongelap (Northern)	62.0	1.08	500
(Central)	40.0	5.5×10^{-1}	500
(1 mi.N.Village)	5.0	5.3×10^{-1}	500
(So. Cistern)	4.5	9.2×10^{-1}	500
Eriirippu*	230.0	12.5	4,500
Eniwetok	50.0	1.2	1,500
Kabelle	200.0	4.9	3,300
Utirik	53.0	9.8×10^{-2}	60
Bikar	3.3	4.4×10^{-1}	250
Eniwetak	8.0	6.6×10^{-1}	400
Sifo	6.1×10^{-1}	9.6×10^{-2}	170
~~Naen**~~			~~9,800~~

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*All data as of May 5, 1954, except island of Eriirippu where date is May 20, 1954.

~~**Estimated from comparison with dose-rate survey readings with Eriirippu Highest fallout on any island measured.~~

[redacted]