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November 18, 1955

MEMORANDUM

TO : R. W. Cook, Acting General Manager
(via H. S. Traynor, Asst. Gen. Mgr.)

FROM : Morse Salisbury, Director
Division of Information Services

SUBJECT: PAPER BY GORDON DUNNING ON "CRITERIA FOR EVALUATING
GAMMA RADIATION EXPOSURES FROM FALL-OUT FOLLOWING
NUCLEAR DETONATIONS"

SYMBOL : ISP:DC

BEST COPY AVAILABLE

A copy of the subject paper, proposed by Dunning for delivery before the Radiological Society of North America in Chicago on December 13, is attached. The Society has requested Dr. Dunning to supply an advance copy of the paper as soon as possible.

The paper has the approval of the Division of Biology and Medicine. The Division of Classification has stated that it does not contain Restricted Data. Dr. Libby has seen a copy, and we understand from Dr. Dunning that he had no objection to it.

We are calling the paper to your attention because it goes beyond previously released information in several respects, and we feel that its issuance involves policy considerations, even though it is a technical paper for presentation before a scientific group. For example, Graph Two, discussed on page 4 of the text, shows the gamma dose rates on the Island of Rongelap over a period of nearly a year following the March, 1954 fall-out. Graph Six, discussed on page 9 of the text, is an idealized map showing the boundary lines for doses of 400 roentgens, 100 roentgens and 50 roentgens following the March 1, 1954 detonation, and Table Two gives the extent of the encompassed areas in square miles. Dr. Dunning has informed us that these areas are consistent with the 7,000 square mile figure given in the Commission's statement of February 15, 1955, on "The Effects of

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AUTHORITY: DOE-DPC
BY H. B. SCHMIDT, DATES
11/19/94

High-Yield Nuclear Explosions", but they provide new numbers which are likely to be picked up by the press. The Section entitled "Protective Measures" (pages 10-16) discusses the persistence of radiation in a fall-out area and the length of time such an area might be denied to normal occupancy.

Dr. Dunning has informed us that he believes the paper will be useful in scientific evaluation of various problems of interest to civil defense, such as estimating the effective biological dose of radiation which might be received after a fall-out, and such problems as shelter, evacuation and return to a fall-out area.

It is our judgment that issuance of the paper would provide additional evidence of the Commission's interest in publishing scientific data relating to fall-out as it is developed. The paper will be of interest primarily to scientists. It is too technical to have much meaning for the average reporter, but almost undoubtedly will be of interest to some of the writers with scientific backgrounds. However, Dr. Dunning's conclusions are more conservative than the bulk of the unofficial statements which already have been made publicly. Therefore, we favor on information policy grounds issuance of the paper.

May we have your approval and/or comment?

Attachment:
Subject paper

CRITERIA FOR EVALUATING GAMMA RADIATION EXPOSURES FROM FALLOUT
FOLLOWING NUCLEAR DETONATIONS

By

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Washington 25, D. C.

External gamma radiation emitted from the material after deposition on the ground is the radiation factor of greatest concern to humans in evaluating fallout following nuclear detonations. Due to the limitation of time this is the only factor discussed here, although external beta doses can be significant when highly active fallout material remains in contact with the bare skin and internal deposition can be hazardous under certain conditions. Experience from past nuclear tests strongly indicates, however, that internal deposition of the radioactive fallout constitutes a hazard of secondary importance, at least for times immediately following the detonation.

Comparative Radiation Doses and Biological Effects

In evaluating gamma radiation exposures from fallout it is natural to turn to the many biological experiments that have been performed in the laboratory. There are differences, however, which necessitate further considerations in estimating radiation doses received from fallout and the possible resultant biological effects.

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First, most of the laboratory exposures have been narrow beam, unilateral or bilateral. Radiations from a fallout field may represent a source that is in 4π geometry, or nearly so. This factor of geometry and thus depth-dose curves may be important for large animals as illustrated by one set of experiments where the LD 50/30 values for swine decreased from 500 roentgens for narrow beam unilateral exposure to 350-400 roentgens for bilateral exposure.¹

Second, experiments with Rhesus monkeys,² using 250 KVP X rays and a rotating exposure cage to provide 4π geometry, gave an LD 50/30 days of 530 roentgens. The interesting point here is that significant numbers of the monkeys died after the 30th day. If the survival data at 100 days (the extent of the data reported) are utilized, the LD 50/100 days value may be near 430 roentgens. This effect is also qualitatively suggested in a second set of experiments with Rhesus monkeys.³ Whereas, it is quite proper to report and use LD 50/30 values, it may not be as relevant for our purposes since we are concerned with the general health and welfare of the public. In these terms, a man dying on the hundredth day is about as serious as one dying on the 30th day. That this factor might be extrapolated from one primate to another is suggested in the Japanese data.⁴ The number of reported deaths, between the 20th and 29th day, were 137 and 87, in the group sampled for Hiroshima and Nagasaki, respectively. There were 117 additional deaths reported after the 29th day for Hiroshima and 87 for the Nagasaki groups. It is recognized that here there was the very difficult task of accurate record keeping and of

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isolating and identifying the causes of death, but an analysis of the extent of their radiation injury and the time of their deaths would strongly indicate that radiation was a major factor in a significant number of the Japanese who succumbed after 30 days.

The last difference to be mentioned here between exposures experienced in the laboratory and doses from fallout is that of the energy spectrum of the radiation. The gamma spectrum emanating from fallout material is complex. Graph ONE shows the gamma spectrum ~~for some material collected after~~ ^{At five days After} the detonation of March 1, 1954 at the Pacific Proving Ground ⁵ ~~and analyzed in the laboratory⁵~~. It is recognized that these spectra may vary and that any single value may conceal important features, but as a first approximation a value of 0.7 Mev mean energy has been quoted.⁶ The dependence of LD values on the energy of the radiation is illustrated by one set of experiments⁷ using burros where there was a shift of LD 50/30 from 78 $\frac{1}{2}$ roentgens with cobalt-60 (1.25 Mev mean energy) to 585 roentgens with Zr⁹⁵ - Nb⁹⁵ (~0.7 Mev mean energy). In these experiments the animals were within a few feet of the sources and thus probably a smaller percentage of their total dose came from radiation that had experienced multiple scattering. With an extended source, such as fallout, a significant percentage of the dose received probably would be due to scattered radiation and thus changes in the primary energy of the source would not be so critical in affecting LD values.

Weathering and Shielding

The variable nature of the two parameters of weathering and shielding is such as to make it impossible to establish a precise rule to cover all situations, yet they are real and operative in determining the total exposure one may receive. The following two examples may give some per-

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spective as to these effects.

The fallout pattern after one of the nuclear detonations at the Nevada Test Site in 1953 consisted of a long, thin finger to the eastward. The day after the shot, a strong southerly wind arose and continued for two days. Here, there was a situation of a high wind blowing nearly at right angles across a thin strip of contaminated sandy soil - almost ideal conditions to examine the effects of winds. The gamma dose rates taken at three feet above the ground in various places within the contaminated area on the fourth day were less by factors of three to six than those calculated on the basis of decay from the first day, according to the well-known principle of $t^{-1.2}$. The actual decay of samples of fallout material taken into the laboratory on the first day did follow fairly closely $t^{-1.2}$, so the above mentioned reduction may be attributed to the winds. Owing to the particular conditions present, stated above, this example may lie near the upper range of effects to be expected from winds, nor would this magnitude of effect be expected when large land areas are contaminated.

The second example refers to the Marshall Islands in the Pacific where the gamma dose rates have been followed since March of 1954. After the contaminating event of March 1st, the winds were light and the first rainfall did not occur until about two weeks later. Graph TWO shows the gamma dose rates taken at three feet above the ground on the Island of Rongelap over a period of nearly a year. It will be noted that for the first 10 days the activity decreased approximately according to $t^{-1.2}$. This is roughly consistent with the known radiological decay rate. The break between the 10th and 25th day, therefore, undoubtedly represents the effects of rain (and possibly winds) which was known to have occurred. The remainder of the points fall roughly on a line of $t^{-1.7}$, again representing the major effects of weathering. In utilizing these data, however, one must extrapolate from an island in the Pacific to other land areas

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having differing climatic conditions.

One cannot predict the exact time of occurrence of winds and rains nor the precise magnitude of reduction of dose rates. These two parameters are obviously quanta events and one may ascribe to them a straight line function, as in Graph TWO, only by the process of generalization. As a first, and perhaps conservative approximation, the following estimates may be proposed. For the first week after fallout occurs, assume the measured activity decays according to $t^{-1.2}$, for the second week $t^{-1.3}$, and for the third week and thereafter, $t^{-1.4}$.

Field measurements as well as calculations have indicated the attenuation of gamma dose rates to be expected due to shielding. Some of these are summarized in Table ONE. For the moment, however, let us consider the case where no special evasive measures are taken and people continue to live normally in the contaminated environment. There may be great variance in the amount of accumulated radiation dose due to the location of personnel in relation to different type structures or natural terrain features and to the length of stay at these places.

During the 1955 nuclear test series at the Nevada Test Site, a number of film badges were placed outside and inside school buildings. There were understandable differences in the ratios between these pairs of badges owing to the different types of structures, but the mean value for the ratio of out-of-doors to in-doors doses was three. Since the duration of these exposures was generally less than one week, the effect was undoubtedly due principally to shielding rather than to weathering effects. A limited amount of data also were collected by personnel (school teachers, physicians, mechanics, etc.) wearing film badges as

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they went about their normal activities in communities around the Nevada Test Site. Out-of-door radiation doses were predicted on the basis of monitoring teams survey data shortly after the time of fallout (such as would be done in emergency situations) and later compared with the doses indicated on the personnel film badges. The ratios of doses measured on the film badges to those calculated for out-of-doors generally fell between 0.4 and 0.5. The durations of exposures were two to three weeks. Once again a conservative first approximation of the reduction of doses due to shielding during normal occupancy of an area may be set at 25% less than that of a person fully exposed for 24 hours each day.

One may combine the assumptions made for weathering and shielding and arrive at a family of curves that estimate the accumulated radiation dose for persons living normally in a contaminated area (Graph THREE). Since Graph THREE is based on an assumed dose rate of one roentgen per hour at time of fallout, the accumulated doses may be linearly extrapolated to any other dose rate at time of fallout.

Timed-Doses and Biological Effects

It has been recognized that the longer the time interval over which a given radiation dose is delivered, generally the less is the resultant biological effect, except for such aspects as genetics and life-shortening, although recently there has been some doubt cast on the linearity of dose-effect relationship for the latter factor.⁸ Since past experiments usually have been designed for other purposes, their data are not readily amenable to the elucidation of the rate of repair or the proportions of reparable and irreparable damage to be expected with varying timed doses. Experiments

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that have been performed show varying relationships, depending upon the specie and sometimes even strain of animal, as well as the criterion values. selected, such as skin damage, life shortening and LD/50 / Our present state of knowledge does not permit us to establish a precise over-all relationship for timed doses versus biological effects, yet there are sufficient convincing data for us properly to attempt an estimation of the effect of this phenomenon.

In 1944 Strandqvist⁹ investigated the effects of fractionation of doses. Using 100 to 175 KVP, X rays given at 30 to 200 r/minute in a single treatment (D_0) were equivalent in their effects on normal or malignant human skin to a total dose of 1.26 D_0 given in two exposures one day apart. When plotted on log-log paper the total dose versus days elapsed between initial and final treatment over a period of 40 days approximates straight lines with a slope of 0.22. These data, of course, concern themselves only with effects on one tissue which is recognized to be one that is relatively rapidly reparable.

Blair^{10, 11}, Smith¹², Davidson¹³ and others have made very extensive analyses of existing data relative to ^{time-spaced doses} effects of /for several species of animals. Blair's and Davidson's analyses indicate a very marked difference between species in the rate of recovery. Generally, this rate of recovery for the larger mammals such as dogs is less than for mice, with the half-time for recovery of man estimated at some three to four weeks. The most conservative estimate for application to the problems below is that of Davidson. Using his analysis, I have constructed a plot of accumulated, equally fractionated daily doses versus duration of exposure that would result in the same biological effect as an acute exposure (Graph FOUR).

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The calculations necessary to incorporate the factor of timed-doses into those for radiological decay, weathering and shielding are rather tedious. These calculations may be approximated by merely superimposing the timed-dose curve upon those curves in Graph THREE. In essence, this analysis says that at times beyond the point of tangency of the two curves, the potential rate of body repair will be greater than the rate of accumulation of doses from fallout provided the accumulated dose up to the point of tangency does not exceed that required to produce the assumed biological effect. The effect of bodily repair at times up to the point of tangency is incorporated into the slope of the timed-dose curve. Actually, this method of analysis is conservative since the calculated accumulation of doses by the timed-dose curve is by the route of equally fractionated daily exposures while in the case of fallout, larger fractions of the total dose are accumulated in the earlier times after the exposure first starts. A greater relative biological damage is incurred early in the exposure period by the latter route, and thus allowing a longer period for the repair process to operate before the total accumulated doses by the two methods are equal (the point of tangency).

Graph FIVE is based on the above assumptions. As in the previous graph, the accumulated doses may be linearly extrapolated to any other dose rate at time of fallout. As a means of identification, I have called the radiation dose arrived at by these calculations the "Effective Biological Dose".

It is to be repeated that Graph FIVE is based on somatic effects and ignores the genetic aspects. It might be difficult to justify its application in estimating routine exposures, but it would not seem inap-

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appropriate to consider this phenomenon of bodily repair for truly emergency situations where a possible relatively large radiation exposure must be weighed against other major risks.

Fallout Pattern From High-Yield Weapons

Utilizing Graph FIVE and data such as that contained in the February 15, 1955 press release of the U. S. Atomic Energy Commission "The Effects of High-Yield Nuclear Explosions"¹⁴ and speeches by Dr. Willard F. Libby, Commissioner, U. S. Atomic Energy Commission,¹⁵ I have prepared an idealized diagram of effective biological doses for fallout from the March 1, 1954 surface detonation at the / Pacific Proving Ground.

It is to be emphasized that (a) different yields of weapons, different wind structures, and different kinds of land surfaces, would result in different patterns and (b) this is the amount of fallout from a single high-yield weapon.

The two innermost isodose lines shown were selected to suggest regions where (a) a significant percent of personnel might be expected to die (400 roentgens) and (b) a few percent to become ill (100 roentgens) if personnel continued to live normally in these areas and took no special protective measures. These percentages would, of course, rise within the encompassed areas. The 50 roentgen effective biological isodose line shown has no unique significance but is suggestive of the magnitude of dose where emergency measures against radiation exposures might be indicated even in the face of other possible hazards. Table TWO shows the approximate areas encompassed by these three isodose lines. For areas where the fallout occurs a few hours / ^{or later} after detonation, many days or weeks will be required to accumulate the major portion of these effective biological doses so that spot decisions involving additional hazards might

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not be required.

Protective Measures

The above map is based on the concept that people continue to live normally in an area - that they do nothing special to protect themselves. Of course, there are in reality many measures that can be taken to reduce this radiation dose drastically. These may be categorized under four headings: 1. evacuation, 2. shielding, 3. decontamination of the environs, and 4. lapse of time.

Where only relatively small numbers of people are involved, evacuation could be an easy solution. For large communities, there are many major relevant factors involving an element of danger and/or hardship. Each situation may be unique, and independent decisions must be made accordingly; it is not possible to establish any prior generalized rule of action based on radiological considerations alone. The very obvious statement may be made that the radiological situation should be determined or predicted before evacuation or else evacuees may be no better or even in a worse radiological situation. This may be especially true for multiple detonations and fallout patterns.

The amount of protection to be expected by the second factor - shielding - is suggested in Table ONE. For example, the interior of a multi-story concrete building or three feet of earth will provide essentially complete protection from the gamma radiation from fallout. Even the cellar of a frame house will reduce the dose rate by a factor of about 10. This might spell the difference between relative safety and dangerous amounts of radiation that might be received by one fully

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exposed. Within the innermost ellipse as shown in the diagram there would be a smaller area of heaviest contamination where this factor of 10 might not be adequate to keep the accumulated dose below hazardous amounts even for a period of a half day after fallout occurred, and other more protective shelters or evacuation would be called for. In the event of a surprise fall-out, however, taking cover in a cellar could provide protection^{not only}/by keeping the radioactive material from coming in direct contact with the skin and thus preventing possible delivery of significant doses of beta radiation to that tissue, but also by providing some shielding during the times of highest gamma dose rates.

The third measure that might be taken to reduce the radiation dose is the decontamination of the environment after fallout has occurred. Table THREE suggests the degree of reduction in gamma dose rates at three feet above the ground that might be expected by various operations on soils, based on field data.¹⁶ Similar data suggest the degree of decontamination of buildings and streets that might be obtained by means of fire hosing (Table FOUR)¹⁶. In this latter case, however, the reduction in contamination applies only to the actual objects; the gamma dose rates in the environs may not be reduced correspondingly. For example, in one field test on a model strip of highway 15 feet wide, fire hosing reduced the surface contamination due to fallout to 5% of its initial value, yet the gamma dose rate taken at three feet above the center of the road was reduced to 75%. This ^{was} / due to the simple fact that the radioactivity was washed to the sides and continued to contribute significantly to the dose rate at the center of the road. This also suggests that merely cleaning off the roof of a building, but allowing this activity to remain

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on the ground nearby may not significantly reduce the gamma dose rates within the building (the radiation level on the upper floor might be less but on the first floor might be greater). Other field experiments do indicate that substantial reduction in gamma dose rates in the environment may be accomplished by such relatively simple methods as fire-hosing of surfaces followed by removal or shielding of the radioactive material.

The last factor that can yield a major benefit in reduction of radiation dose is that of lapse of time. Based on radiological decay alone, the activity decreases approximately according to the principle of $\text{time}^{-1.2}$. Thus, for every sevenfold lapse of time after a nuclear explosion, there will be a tenfold reduction in dose rate. For example, in the event fallout occurs three hours after a detonation, the dose rate will be 1/10 of its initial value 18 hours later; an additional tenfold reduction would require about five additional days of waiting. This rapid decay suggests the benefits of protection during the early periods after fallout occurs, and where it is possible, of delay of entry into a contaminated area. This is especially true for areas near the point of burst. For example, following the March 1, 1954 detonation in the Pacific, the total lifetime dose one might have received at 10-20 miles was greater by a factor of about two than that at 100 miles downwind. Since the initial fallout at 10-20 miles occurred at about a half hour after detonation, the initial dose rates were considerably higher than at 100 miles downwind at the time of fallout for each locality.

The question is frequently asked as to the times that one must stay within a shelter or remain out of a contaminated area. Obviously, this answer depends on a number of parameters, such as the criteria established for maximum permissible radiation doses, as well as length of stay within the contaminated area. Knowing such factors as the magnitude of the radia-

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tion levels present and the rate of decay ($t^{-1.2}$), it is possible to plan and execute a short stay even in a highly contaminated area. Planning for a continuous occupancy will require more extensive analysis. The following data may give some perspective for such evaluation.

The fallout map and Table TWO suggest the degree of radiation exposure for a continuous occupancy under normal living conditions starting from the time of initial fallout. However, if one waits until four months after the initial fallout to enter the fallout zone, and then continues to live there indefinitely the area encompassed by the 50 roentgen effective biological isodose line would have shrunk from about 25,000 to 2,500 square miles. At such time - four months after fallout - there might be an area of about 1,000 square miles within the 50 roentgen isodose line having the highest residual contamination, amounting to about three times the periphery dose rates. The 0.3 roentgen per week out-of-doors isodose-rate line might extend to about the same position as the line marked 50 on the map.

As one attempts to extrapolate such data to a time of one year after fallout, the analysis becomes still more difficult and uncertain. The data suggest, however, that if return were at one year after fallout, the 50 roentgen effective biological isodose line would have disappeared. At one year the 1,000 square miles of highest contamination might have an out-of-doors dose rate of about four roentgens per week. Based on the assumed factors of shielding under normal living/ conditions and weathering, this might result in a dose of about 100 roentgens for the following first year of exposure and an additional 90 roentgens over the next three years. It would be expected that the biological repair factor would be relatively great for such long periods of time, thus reducing the effective biological dose below 50 roentgens. The 0.3 roentgen per week out-of-doors isodose-rate

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line might encompass an area somewhat larger than the line marked 400 on the map. (The weathering factor for the islands in the Pacific has been greater than the assumed value for large land masses so that at one year the out-of-doors dose rate on these islands is less, by a factor of almost two, than would have been predicted by the method suggested here.)

The analyses in the preceding paragraphs were based on conservative estimates of normal weathering and shielding factors. They are based also on only passive factors,^{only,} not taking into account the actions that people may take in reducing the degree of contamination. If it was assumed, for example, that a permanent return into an area were delayed until one year after fallout, it might be expected that the radiological situation would have been adequately appraised, and decontamination operations initiated. Further, with the return of a populace into a known contaminated area, more than normal precautions might be expected in regard to use of more protective type of buildings and reduction of times spent out-of-doors. It would not seem unreasonable to assume that the theoretical out-of-doors dose rates for the areas of highest residual contamination calculated by the extrapolations given above actually might be reduced by a factor of many-fold. Thus, the data suggest that denial of even the most heavily contaminated area for continual occupancy may be in the order of one year, not 10 or 20 years.

Although it is not intended here to enter into a full discussion of contamination of the food supply, this question naturally arises when considering return to an area that has been contaminated. Our basic knowledge of the soil-plant-animal cycle is far from complete, especially in relation to selective uptake of key radioisotopes found in fallout material. It would appear that in early times after formation of the fission products, the greatest hazard might be the general irradiation of the gut if large

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quantities of fallout material were ingested. Much of this would probably be due/to surface contamination and could be reduced materially by simple washing of the foodstuff. At later times, such as several months or a year, the main concern is the amount of intake of strontium-90. Unfortunately, this isotope has a long half-life of 27.7 years and clings rather tenaciously to the soil particles. However, due to the process called fractionation, somewhat less than the predicted amount of strontium-90 based on gross fission product activity may be present in fallout material in nearby areas of heaviest contamination.

A continuing physical and biological survey is being conducted at and near the Pacific Proving Ground, but it is yet too early to give definitive answers. However, it would appear, for example, that a year after fallout, even in the area of heaviest contamination, the amount of available strontium-90 present might not be very many times above that which could result in persons accumulating a maximum permissible amount of one microcurie in their bones - a quantity considered safe - if they were to subsist entirely off food supplies raised in this area. Some of these foods, such as the liver of fish, may contain significantly higher concentrations of activity than the average, indicating the obvious need for monitoring the sources of supply. Since it is the total intake of strontium-90 that is the determining factor, a limited consumption of this isotope may be permitted. Further, since the area where such restrictions may have to be applied is of the order of one to a few thousand square miles, it would not appear to be an insurmountable task to supplement the diet of these inhabitants with uncontaminated foods grown elsewhere.

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Summary

The task of evaluating radiation exposures from fallout is fraught with many uncertainties, and one instinctively shrinks from proposing criteria based on such variables and intangibles. Yet we would be doing ourselves a disservice if we did not attempt an analysis of the relevant factors and incorporate them into some conceptual scheme as suggested here. The analytical approaches, and certainly the quantitative values suggested above are not to be considered precise but rather are intended to give order of magnitude estimates. It is believed, however, that they are in general conservative, i.e., they do not underestimate the potential hazards involved.

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TABLE ONE

ESTIMATED ATTENUATION FACTORS OF GAMMA DOSE RATES
FROM FALLOUT

<u>TYPE STRUCTURE</u>	<u>APPROXIMATE FACTOR</u>
FRAME HOUSE	
First Floor*	2
Basement*	10
MULTI-STORY REINFORCED CONCRETE	
Lower Floors** (Away from windows)	10
Basement**	Up to 1000 or more
SHELTER (equivalent of three feet of earth)*	1000

*Estimations based on field measurements.

**Based on calculations such as found in Effects of Environ-
ment in Reducing Dose Rates Produced by Radioactive Fallout
from Nuclear Explosions. Hill, J. E. The Rand Corporation,
Research Memorandum - 1285-I.

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TABLE TWO

APPROXIMATE AREAS ENCOMPASSED BY
THE EFFECTIVE BIOLOGICAL ISODOSE
LINES SHOWN IN THE MAP

<u>Isodose Line</u> <u>(Roentgens)</u>	<u>Approximate</u> <u>Areas Encompassed</u> <u>(Square Miles)</u>
50	25,000
100	12,500
400	5,000

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TABLE THREE

ESTIMATED REDUCTION IN GAMMA DOSE RATES AT THREE FEET ABOVE
THE GROUND TO BE EXPECTED FROM VARIOUS DECONTAMINATION
PROCEDURES ON LAND SURFACES *

<u>PROCEDURE</u>	<u>APPROXIMATE REDUCTION FACTOR</u>
PLOWING (to depth of eight inches)	3
BULLDOZING OR GRADING (to depth of four inches)	4
FILL (clean dirt to depth of six inches)	5
SCRAPING (to a depth of four inches, with concurrent removal of exhumed dirt)	10

*BASED ON DATA IN RADIOLOGICAL RECOVERY OF FIXED MILITARY
INSTALLATIONS. U. S. Naval Radiological Defense Laboratory,
San Francisco 24, California. August 1953.

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TABLE FOUR

Estimated Reduction in Contamination
of Surfaces Using a Fire Hosing Method*

<u>Surface</u>	<u>Approximate Reduction Factor</u>
Concrete	10
Wood	30
Metal	30
Roofing	30

* Based on a dry contaminate. Surfaces contaminated with a slurry would have lesser reduction factors. Hot liquid cleaning or scrubbing and pre-protection of surfaces using such as sealers or paints, would increase the reduction factor.

(Based on data in Radiological Recovery of Fixed Military Installations. U. S. Naval Radiological Defense Laboratory, San Francisco 24, California. August 1953.)

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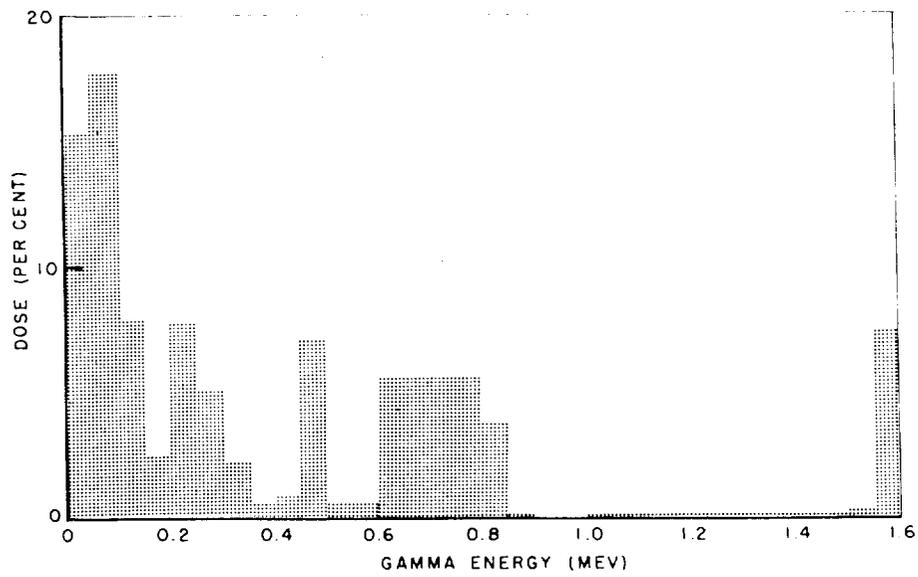
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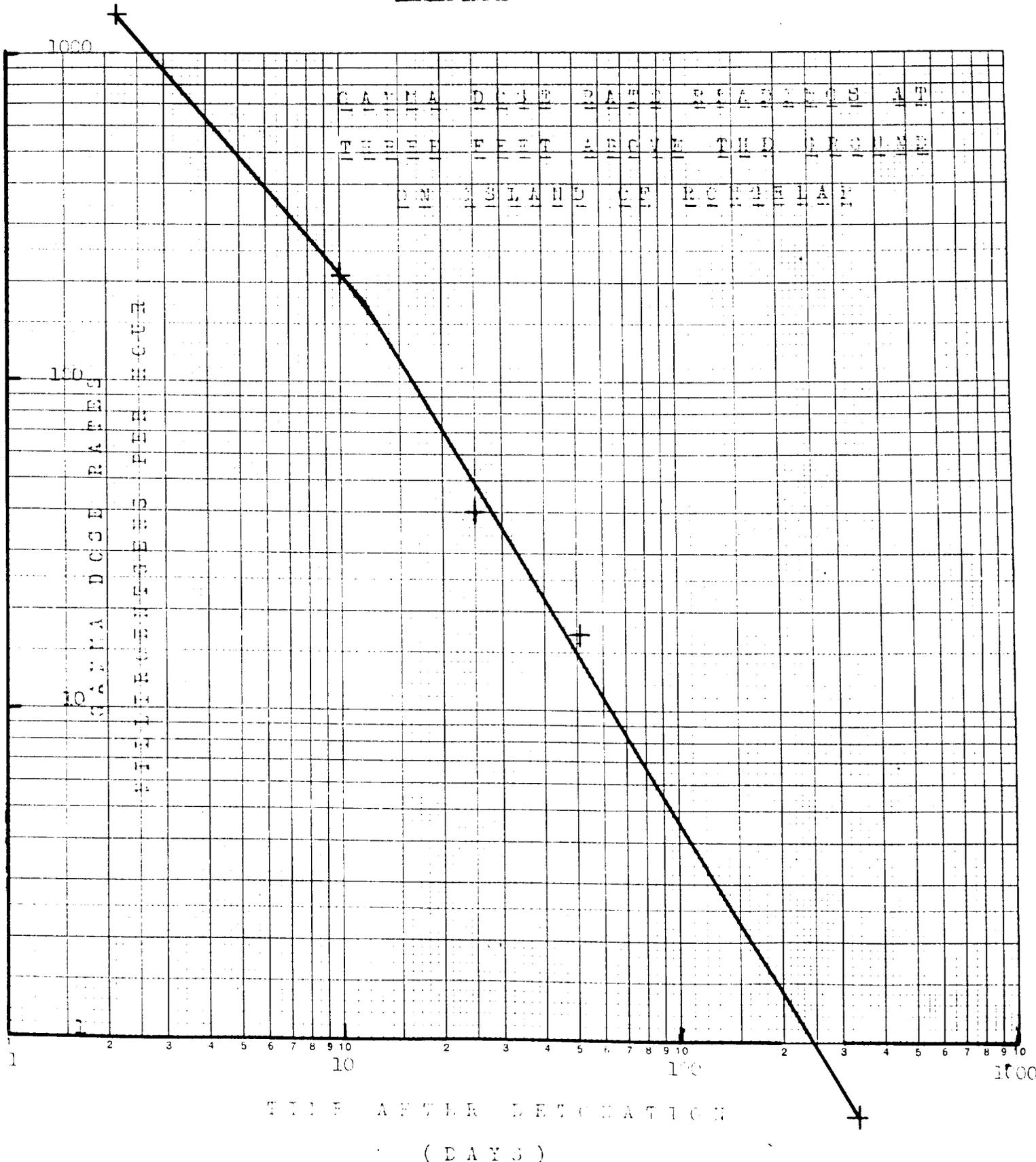
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GRAPH ONE

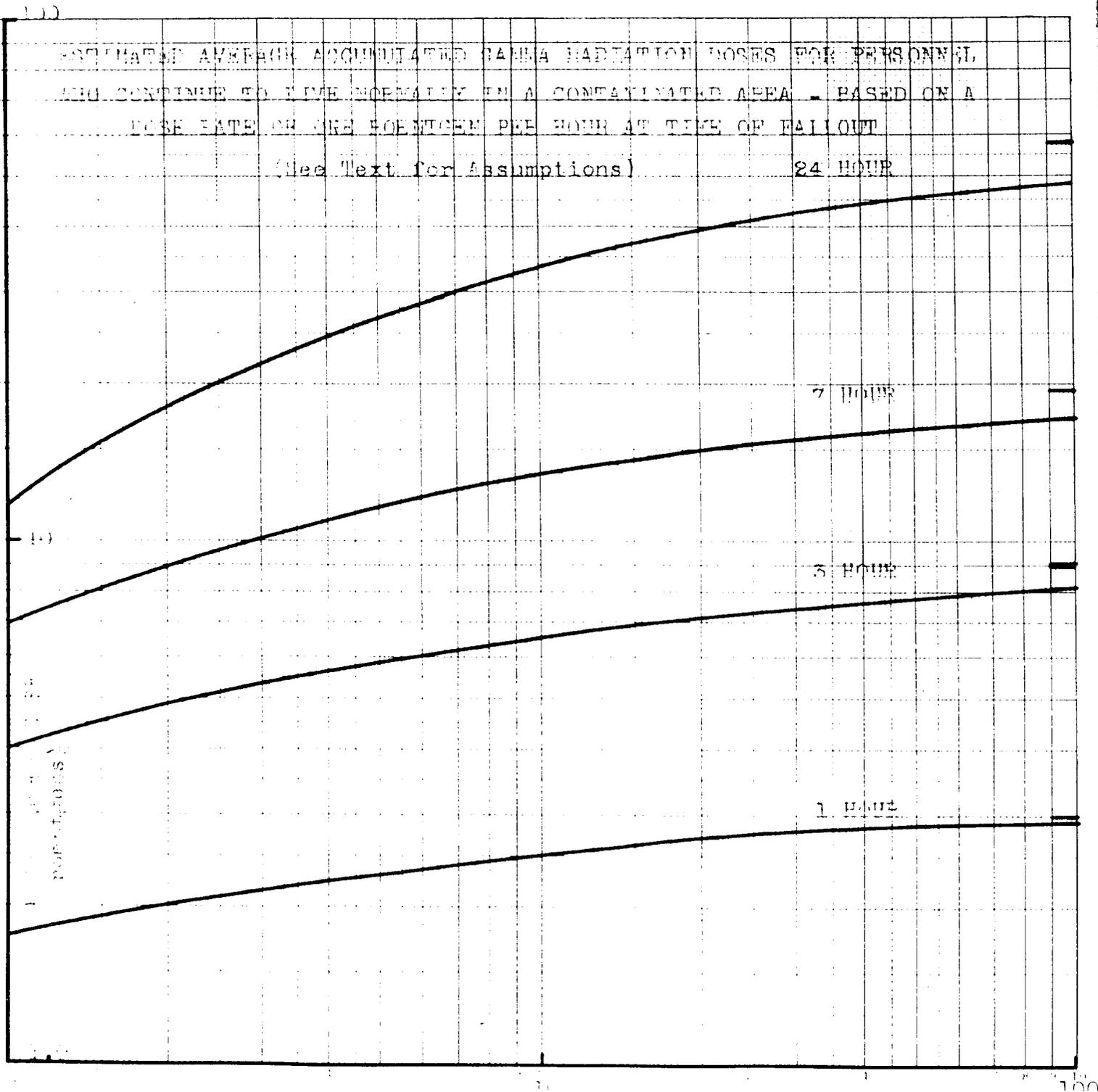


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GRAPH TWO



GRAPH THREE

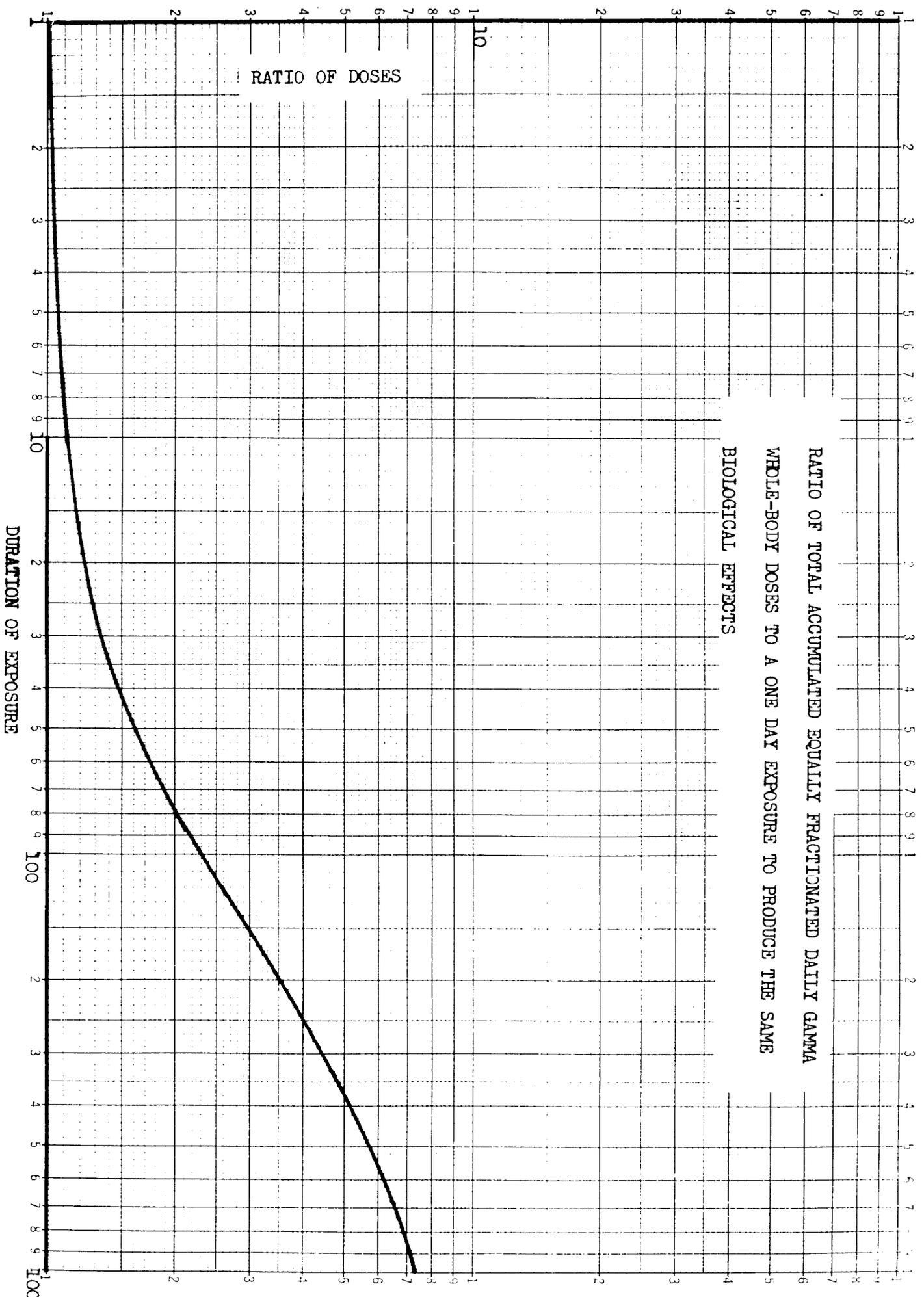


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GRAPH FOUR

RATIO OF TOTAL ACCUMULATED EQUALLY FRACTIONATED DAILY GAMMA
WHOLE-BODY DOSES TO A ONE DAY EXPOSURE TO PRODUCE THE SAME
BIOLOGICAL EFFECTS

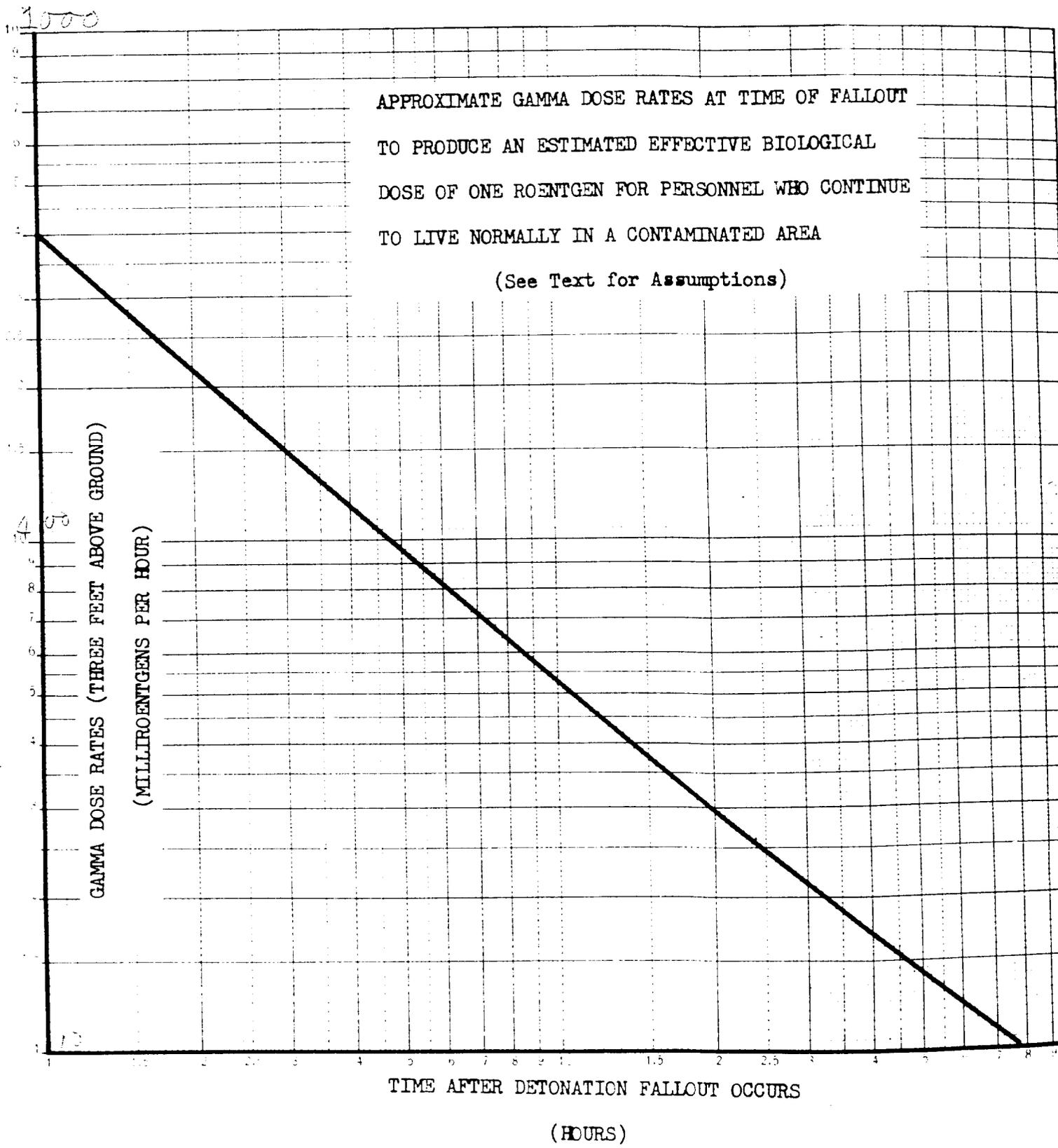
RATIO OF DOSES



DURATION OF EXPOSURE

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GRAPH FIVE



17. LOGARITHMIC 358 110