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No. 4 of 70 Series 11

Abstract of Remarks by
Mr. Robert L. Corsbie, Chief, Civil Defense Liaison Branch
Division of Biology and Medicine
U. S. Atomic Energy Commission

CONFERENCE ON BIOLOGICAL EFFECTS OF ATOMIC WEAPONS
TRIPARTITE EXCHANGE OF INFORMATION UNDER TCP (AREA 2)

held at the

U. S. Atomic Energy Commission
1901 Constitution Ave. N. W.
Washington, D. C.

February 17-18, 1954

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AGENDA

TRIPARTITE EXCHANGE OF INFORMATION UNDER TCP (AREA 2)

BIOLOGICAL EFFECTS OF ATOMIC WEAPONS

U. S. Atomic Energy Commission
1901 Constitution Avenue N. W.
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February 17-18, 1954

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February 17, 1954

- 9:00 - 9:15 I. Review of Biomedical Experimental Programs for GREENHOUSE and UPSHOT/KNOTHOLE - Dr. John C. Bugher
- 9:15 - 9:45 II. Thermal Radiation - Dr. Herman E. Pearse
- A. Characteristics of Burns in Man and Animals
 - B. Emergency Treatment of Thermal Casualties
 - C. Effect of Gamma Dose on Recovery of Flash Burn Casualties
 - D. Experimental Data on Effectiveness of Protective Clothing, and Estimated Degree of Incapacity
- 9:45 -10:15 Thermal Radiation (Cont'd.) - Captain Harry H. Haight
- E. Ignition Temperatures of Clothing, Structures, etc.
 - F. Effect of Height of Burst upon Primary Fires
 - G. Effect of Blast on Primary Fires
 - H. Secondary Conflagration and its Problems
 - I. Personnel Flash Blindness at Relatively Large Distance from an Atomic Explosion, and Duration of Disability
- 10:15-10:30 COFFEE BREAK
- 10:30-11:30 U. K. Discussion
- 11:30-12:00 Noon Canadian Discussion
- 12:00 - 1:00 P.M. LUNCHEON
- 1:00 - 1:45 III. Blast - Mr. Robert I. Corsbie and Mr. Harry L. Bowman
- A. Reflections and Reinforcements of Pressure Fronts within Structures
 - Bowman* B. Static and Dynamic Loading Behavior Criteria of Typical Structural Materials
 - CS* C. Shelter Design - Functional and Engineering Aspects

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1:45 - 2:30 U. K. Discussion
2:30 - 3:15 Canadian Discussion
3:15 - 3:30 COFFEE BREAK
3:30 - 3:45 Blast (Cont'd.) - Commander Eugene P. Cronkite
D. Direct Blast Effects on Man
E. Secondary Blast Casualties from Missiles
3:45 - 4:15 U. K. Discussion
4:15 - 4:30 Canadian Discussion
4:30 - 4:45 General Discussion
4:45 - 5:30 Films (IVY)

February 18, 1954

I. Prompt Nuclear Radiation from Atomic Explosions

9:00 - 9:20 A. Immediate Effects and Treatment - Dr. Shields Warren
9:20 - 9:50 B. Comparison of British and U. S. Tables of Effects of High Doses of Gamma, Neutron and Beta Radiations - Commander Eugene P. Cronkite
1. Lethality
2. Radiation sickness, including time of incidence for very high doses
3. Local injury

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C. Delayed Effects in Man and Animals - Dr. Charles L. Dunham
& Dr. H. H. Plough

- 9:50 -10:05 1. Somatic - Dr. C. L. Dunham
- a. Life expectancy
 - b. Neoplasia
 - c. Tissue degeneration
- 10:05-10:25 2. Genetics - Dr. Harold H. Plough

- 10:25-10:45 U. K. Discussion
- 10:45-11:15 Canadian Discussion

11:15-11:30 COFFEE BREAK

11:30-12:00 Noon General Discussion

12:00- 1:00 LUNCHEON

II. Delayed Nuclear Radiation from Atomic Explosions: Fallout and Remote Effects - Biological Characteristics

A. Environmental Contamination

- 1:00 - 1:20 1. Fallout in the United States - Mr. Merrill Eisenbud
- 1:20 - 1:40 2. Methods of Limiting Uptake of Fallout Material in Agriculture; Area Decontamination through Agricultural and Other Means - Dr. Paul B. Pearson
- 1:40 - 2:00 3. Gabriel - Dr. Walter D. Claus

- 2:00 - 2:30 U. K. Discussion
- 2:30 - 3:00 Canadian Discussion

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3:00 - 3:15

COFFEE BREAK

3:15 - 3:45

General Discussion

3:45 - 4:00

B. Personnel Decontamination - Dr. Charles L. Dunham

4:00 - 4:15

U. K. Discussion

4:15 - 4:45

Canadian Discussion

4:45 - 5:30

General Discussion

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situations and laboratory experiment so that the results of one might be interpreted in terms of the other.

3. Both biological and physical systems have been recognized as effective means for quantitative measurement of nuclear phenomena.

In order to ensure maximum scientific value, the experimental programs of the two major biomedical series were developed by special planning committees composed of people familiar with the needs for adequate weapons information on the one hand and the difficulties of conducting field experiments on the other. While limited numbers of such experiments were incorporated in the early tests, the first comprehensive biomedical program was conducted at Operation GREENHOUSE at Eniwetok Atoll in the Spring of 1951. These experiments established the performance characteristics of several biological dosimetric systems to gamma radiation and achieved and established the relationship between bomb gamma radiation and high voltage X-ray. The same series demonstrated the importance of the neutron radiation, particularly where heavy metal shielding is employed.

The experiments of GREENHOUSE were continued in the Spring of 1953 at the Nevada Proving Grounds in the UPSHOT/KNOTHOLE operation.

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Here the primary emphasis was upon the neutron component of the nuclear radiation, and the results substantially extended our quantitative knowledge in this area.

The characteristics of the thermal radiation of the fission weapon were demonstrated at GREENHOUSE, and subsequent further study was in the nature of confirmation of these results and somewhat more precise quantitative definition.

Blast investigations, which have been active in all test series, were especially stressed in the two operations mentioned. With these have been extended investigations into the blast response within structures and shelters, particularly with reference to the production of casualties.

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Abstract of Remarks by
John C. Bugher, M.D., Director
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Washington, D. C.

CONFERENCE ON BIOLOGICAL EFFECTS OF ATOMIC WEAPONS
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Abstract of Remarks by
Dr. John C. Bugher, Director
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Washington, D. C.

February 17, 1954

REVIEW OF BIOMEDICAL EXPERIMENTAL PROGRAMS FOR
GREENHOUSE AND UPSHOT/KNOTHOLE

The fundamental criteria which have governed the organization and execution of biomedical experiments in the field are:

1. In the interests of economy of fissionable material, pure effects experiments have, in general, not been permitted. The number and frequency of detonations have been determined by the needs of the weapons development program, and biomedical experiments have been conducted in connection with such experimental detonations, recognizing and accepting the uncertainties of yield and other factors.
2. Field testing is a laborious and expensive operation. Tests have therefore been designed to give information obtainable in no other way. The fundamental emphasis has been upon establishing the correlations between weapons

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Abstract of Remarks by
Dr. Herman E. Pearse, Atomic Energy Project
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Abstract of Remarks by
Dr. Herman E. Pearse, University of Rochester
Rochester, N. Y.

February 17, 1954

Thermal Radiation

Secondary flame burns from the explosion of an atomic bomb were not much of a clinical problem in Japan. The casualties from these burns were less than 10%. This is probably because there was a time lag before the fire started and because the people who were agile enough got out and the ones who weren't perished in the flame. These burns were very severe looking but as nearly as can be determined were not as severe as might have been expected in their eventual effect in the way of healing.

The ambient temperature and by the same token the temperature of the skin can markedly affect the severity of the burn in some critical areas. In an area which would expose the population to $4\frac{1}{2}$ or $5\frac{1}{2}$ calories there are no second degree burns if the exposure is at 60°F. whereas there is a very high number if the exposure is at 90°F. The pigmentation of man's skin makes a difference and these are problems that should be studied in connection with protective measures for the hands and face.

These general principles were applied in producing thermal radiation in the laboratory: (1) The discharge of electricity, either through the Edgerton flash tube or Anderson's method of burning a wire or

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a short circuit. These attained very high temperatures but were so brief that they did not cause burning; (2) The ignition of combustible material. It was found that magnesium is the best material. This has about the right time constant; it reaches its maximum in about 0.2 or 0.3 of a second and is very serviceable for the creation of a large area flash burn; (3) the use of a constant source with a timing mechanism, for which the carbon arc, is the best source. This gave an exposure of 90 calories per square per centimeter per second. It is a completely artificial type of burn. The method, which we are now using, is by a carbon arc with an ellipsoidal mirror having two focal points, one at the carbon crater and another at 52 inches. The energy in the system can be measured to a fraction of a calorie and the time of exposure to less than a tenth of a second. The radiation energy can be controlled over an area of one square centimeter so this is excellent for studying small area burns but it is rather useless for large area burns.

It has been found that visually there are five stages the lesions can go through: one, the simple erythema; two, the beginning of coagulation of the skin; three, uniform coagulation, four, bubbling or steam blebbing of the skin itself, and the fifth stage, which is charring. It takes much more energy to get third degree burns at 0.5 of a second than to get the first and second degree burns, but all these curves come together when the time is extended to 10 seconds. The penetration into the tissues is very much time dependent and the surface

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injury is energy dependent.

The characteristic of flash burns that makes it different histologically from other burns is the sharp line of demarcation between injury and non-injury. Healing in the bomb burns was identical with healing of burns from any other intensity source of comparable spectrum. It would be desirable to study graded coloration, the optical color of the skin and its relation to burning. A burn produced in white skin by the same number of calories took eight days to heal and in black skin required eighteen days.

There were no burns through the filters that admitted only ultra violet light. The visible filter had an unknown band of infra red and with this qualification the burns were about the same with the visible as with the infra red light. The erythema caused by visible and infra red light is a different erythema than that caused by ultra violet light. The erythema is of extravasation of blood. It doesn't blanch, it is permanent, and has a dark reddish purple color rather than the bright red hyperemia one gets with ultraviolet. As the wave length is increased the energy must be increased to get the same severity of burn.

There were no burns at the port that was opened for 20 milliseconds. The burn was complete between $1/3$ and $1/2$ of a second. Burns of maximum severity occurred in the interval between one-tenth and two-tenths of a second. There is a difference in the quick input of energy. This greater severity is due to the fact that the burn occurs on the

ascending ramp; less severe burning occurs on the descending ramp. This is important with different tonnage of weapons. The major part of the burning occurred in the first 0.3 of a second and is practically complete by 0.5 of a second. It can be said with reasonable certainty that the major part of a thermal burn occurred in the first three to five tenths of a second.

Extensive studies on fabrics were not carried on in the field but laboratory studies and work carried on in the field under the Quartermaster indicated that it may require as much as 24 calories additional thermal energy to produce a burn on the skin if a flame-proof fabric is spaced a half centimeter from the surface of the skin. Much emphasis is placed on the critical importance of air space in studies of fabric protection. The temperature of the surface of the skin is very important and might make a difference of several calories in the amount of thermal energy required to produce a given degree of burn.

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Abstract of Remarks by
Captain Harry H. Haight, MC, USN
Division of Military Application
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Abstract of Remarks by
Captain Harry H. Haight, MC, USN
Division of Military Application
U. S. Atomic Energy Commission
Washington, D. C.

February 17, 1954

THERMAL RADIATION

Thermal radiation measurements were made at several atomic bomb detonations at various distances from Ground Zero. At these known thermal radiation doses the following were studied:

- A. Ignition and persistent fires resulting, exterior kindling fires.
- B. Effect of thermal radiation on various materials.
- C. The performance characteristics on clothing materials.
- D. The thermal radiation protection afforded test animals by fabric assemblies.

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Abstract of Remarks by
Dr. Paul B. Pearson, Chief, Biology Branch
Division of Biology and Medicine
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Abstract of Remarks By
Merril Eisenbud, Director, Health and Safety Laboratory
New York Operations Office
U. S. Atomic Energy Commission

February 18, 1954

FALLOUT IN THE UNITED STATES

A network of fallout collection stations has monitored each of the USAEC test series since GREENHOUSE. The collections are made at U. S. Weather Bureau stations where daily collections are submitted to a central counting facility in New York. The number of collection stations has varied from 50 to 120. Additional samples are collected by mobile teams operating within 200 miles of the Test Site.

Each station collects fallout by exposing a one square foot gummed film mounted on a 3 foot stand. The samples are collected in duplicate and represent 24 hour fallout, the films being changed once daily.

Stations closer to the Nevada Test Site have collected filtered samples of airborne dust.

Figure 1 illustrates the cumulative fallout obtained during TUMBLER-SNAPPER. It will be noted that the various stations are distributed in rough arcs centered on the Nevada Test Site. Figure 2 illustrates these data as a function of distance from the Test Site.

The orderly diminution of fallout with distance as shown in Figure 2 for the TUMBLER-SNAPPER series, was not apparent during UPSHOT-KNOTHOLE. The

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cumulative map for this series is given in Figure 3. In this series, because of an unusually wet spring in Eastern United States fallout along the eastern seaboard was disproportionately high. The high value for Albany, New York, is the result of a single heavy fallout which occurred after Burst #7 of the UPSHOT-KNOTHOLE series. Heavy radioactive fallout accompanied local thunder storm activity which coincided with a passage of radioactive debris overhead. The storm occurred about 36 hours after the detonations and the initial activity was of the order of 100 curies per square mile.

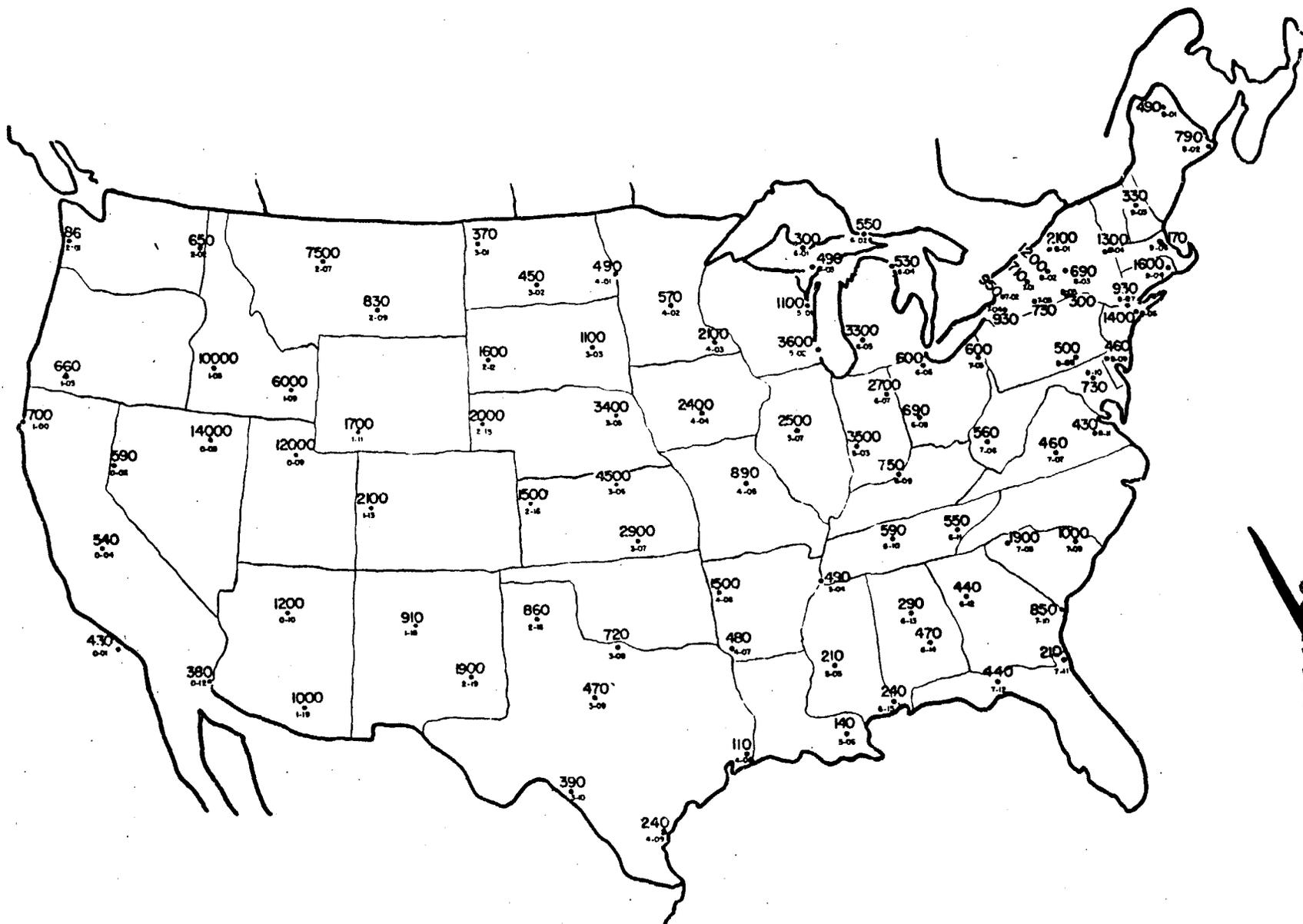
Unusually heavy rain-outs of this order of magnitude have occurred in half dozen places during the various Nevada series. These rain-outs are accompanied by a rise in the general gamma background to approximately one MR per hour, representing an integrated dose of 50 to 100 milliroentgens.

The build-up of radioactive debris in northeastern United States as a result of all USAEC tests since GREENHOUSE is illustrated in Figure 4. This graph gives the estimated contribution of fission products to the surface as a function of time since the Spring '51 series in the Pacific. The strontium component of this activity is likewise shown. It will be observed that the fission product activities are of low order compared with the amount of natural radium in the upper foot of soil in northeast United States.

Particle size distribution studies indicate that the mass median diameter as estimated by cascade impactor is in the range of 1 - 2 μ . Beyond 200 miles from the detonation, over 90% of the airborne debris is smaller than 5 μ . The dose to the lung from inhaled debris appears to be approximately equal to the whole body dose from the rise in gamma background.

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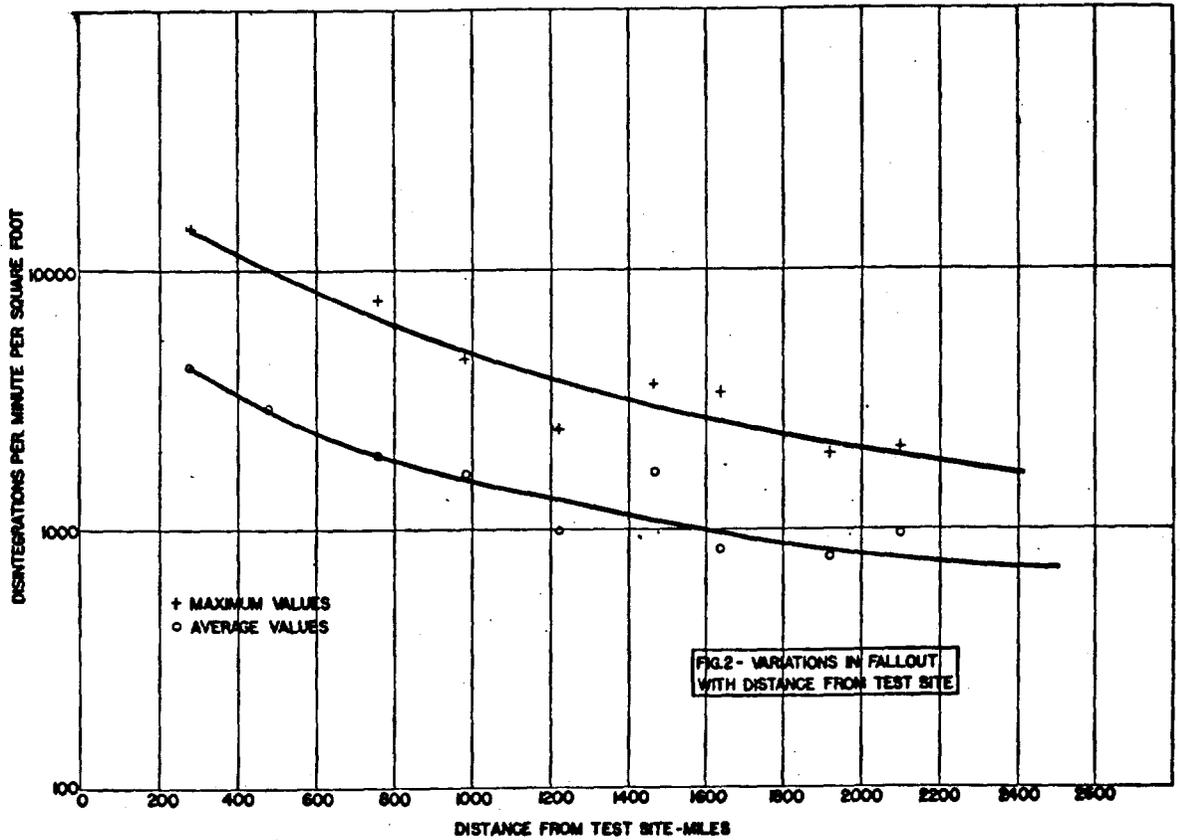
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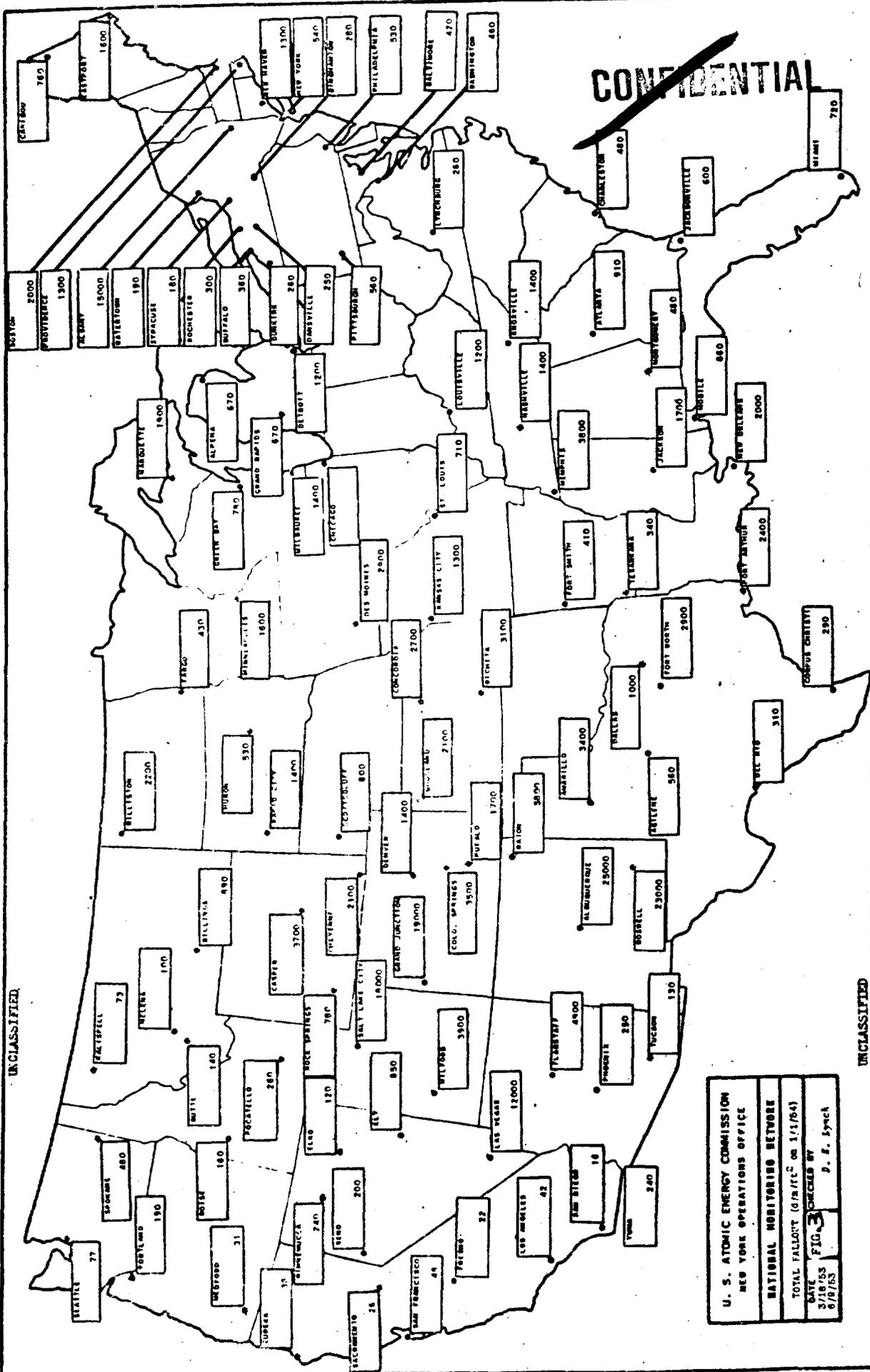
FIG. 1. Radioactivity deposited from tests in spring 1952. Large figures: disintegrations/min/sq foot on Jan. 1, 1953; small figures: station code (see Table 1).

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U. S. ATOMIC ENERGY COMMISSION NEW YORK OPERATIONS OFFICE
NATIONAL MONITORING NETWORK
TOTAL FALLOUT (G/R/K/C) ON 1/1/64
DATE 3/18/53 FIG. 3
CREATED BY D. F. Lynch
6/9/53

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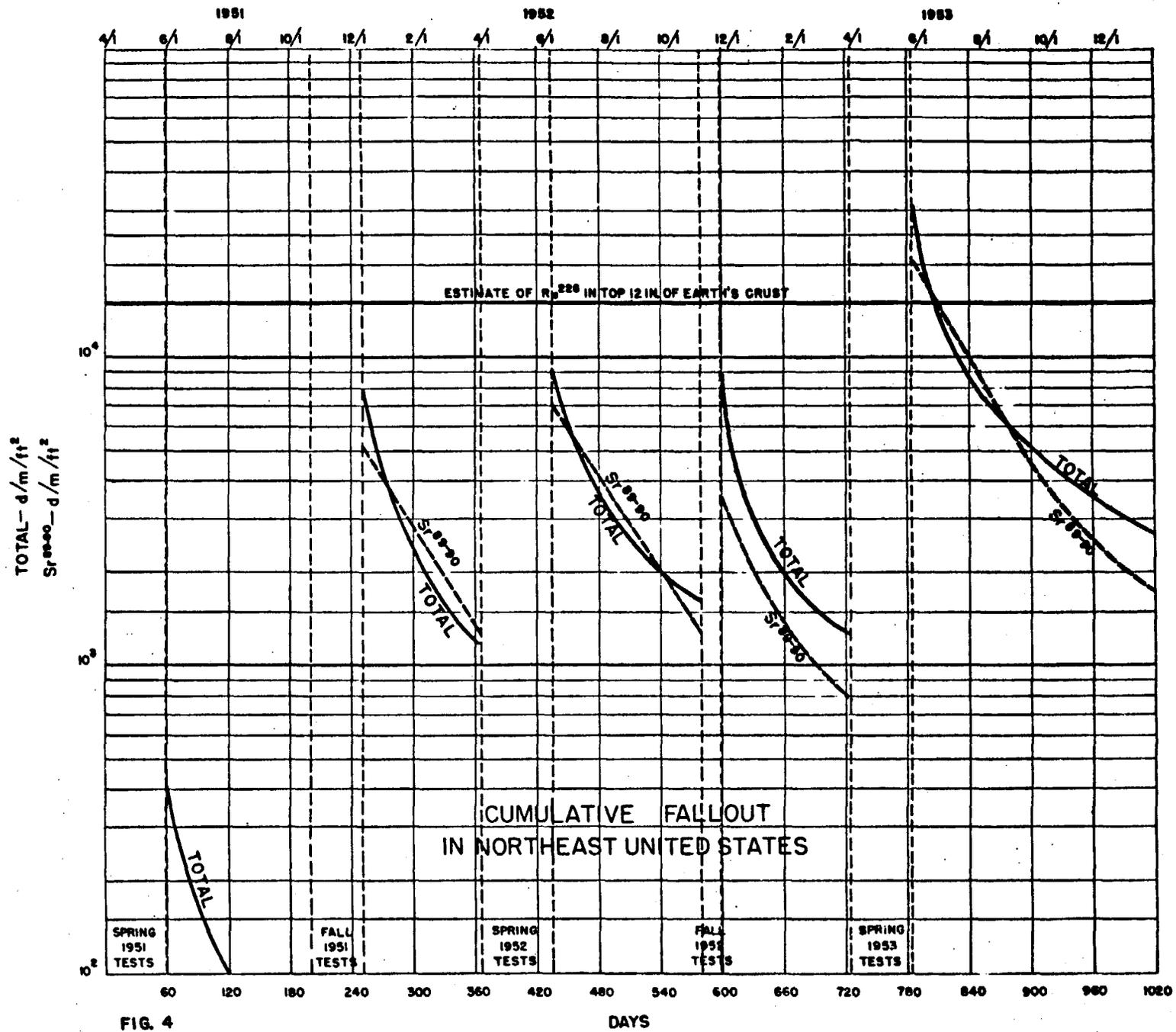


FIG. 4

DAYS

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Abstract of Remarks by
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Abstract of Remarks by
Dr. Harold H. Plough
Amherst University
Amherst, Massachusetts

February 18, 1954

GENETIC EFFECTS OF FAST NEUTRONS FROM
NUCLEAR DETONATIONS

A series of genetics test objects were exposed to fast neutron irradiation at UPSHOT/KNOTHOLE. The exposures were made by placing the specimens inside lead hemispheres with 7-inch wall thickness and 14-inch inside diameter first used at GREENHOUSE. These were set at appropriate distances from Ground Zero to cover the dose ranges required. The genetics test materials were supplied by a number of investigators at Oak Ridge or at university laboratories and were sent to Mercury in the proper stage for exposure shortly before the scheduled detonations. After exposure the material was returned for breeding and study, and the summaries of the results were supplied for this report. Included were the following plant materials: Spores of several fungi, Tradescantia pollen, seeds of Datura and of corn; and the following animal specimens; Drosophila flies, Mormoniella wasps, and several mouse strains.

The materials were exposed at three different detonations distinguished as A, B, and C.

Dosages for gamma rays were expressed in roentgens, for neutrons in roentgen equivalent physical or rep. The rep is a dose of neutrons with

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energy absorption in tissue equal to one roentgen of hard X-rays. The unit of effect is the rem which is the number of roentgens of hard X-rays required to produce the same effect.

The following brief summaries of the results of the experiments are extracted from the preliminary report.

Fungi: Two genetic markers were used in studies on survival in Neurospora: a requirement for arginine and for methionine. For spores having one of each of the nuclear types (heterokaryotic), growth will occur on media which lack both arginine and methionine since the deficiency is made up by the other nucleus. For spores containing two like nuclei (homokaryotic), growth occurs only in supplemented media.

Increased radiation causes a decrease in the number of heterokaryotic cells. This is interpreted as inactivation of one member of a heterokaryotic pair, rendering it homokaryotic. The relative biological effectiveness (RBE) of neutrons for lethality was about 4-5 in detonation A.

An effort was made to influence the radiation effect in detonation B by growing the cultures on media containing elements with high slow neutrons capture cross sections. Nitrate was used as the sole nitrogen source. Two media contained a large portion of N^{15} , and two were enriched with B^{10} . Survival on the boron free media was consistently higher than survival on the B^{10} enriched media. No effect on N^{15} was apparent.

Tradescantia chromosome breakage: Tradescantia paludosa buds were exposed to radiation at detonation A. Both chromatid and chromosome aberrations frequencies were determined. The results after detonation

neutron irradiation were in close agreement with cyclotron neutron irradiation. Detonation neutrons were about 10 times as effective as X-rays in producing aberrations in Tradescantia. These results show that Tradescantia may be used as a biological dosimeter.

Datura chromosome effects: Datura, as well as Tradescantia, may be used as a biological dosimeter, but the results are available only after a longer period of time. Datura seeds were exposed at various stations in moisture proof plastic bags. Chromosomes were examined in plants grown from the exposed seeds. The pollen was examined and classed as normal, chromosomal lethal, and gene lethal, making it possible to use Datura to determine the relative frequencies of chromosome aberrations and gene mutations.

The RBE of neutrons for chromosome aberrations was about 15, which is about the same as for Tradescantia.

Corn seed experiments: The preliminary results of this experiment indicate that greater seedling growth occurred following higher doses than following lower doses. This may be due to a depression by high doses of biological factors (perhaps enzymes) which are responsible for the breakdown of plant tissues.

Study of survival, productivity, gene changes, and other effects in Drosophila and mice: Males and females of several strains of Drosophila melanogaster were exposed at detonations A, B, and C. The results show that per kilorep fertility was reduced 40 per cent; survival of progeny, 43 per cent; female to male sex ratio, 7 per cent; X chromosomes

without lethals, 4 per cent; X chromosomes without lethals or semilethals, 6 per cent; and X chromosomes without lethals, semilethals, or visibles, 7 per cent. The dose-effect relations were essentially linear on a semilog plot.

The RBE of neutrons to X-rays was about 2 for sex-linked lethals and about 2-4 for X-chromosome dominant lethals.

Mice were placed in Civil Defense shelters for studies of lethality. The observed deaths, except for immediate deaths attributed to concussion, in each of the treated groups exposed to relatively low doses of radiation occurred at about the same rate as in the controls.

Drosophila lethal and other mutations: Sex-linked lethal and certain visible mutations at specific X chromosome loci were studied. To detect X-chromosome aberrations, four recessive genes with easily recognizable effects were used at well spaced loci. The results indicate that fast detonation neutrons produce simple lethal and gene mutations with an RBE of about 2 compared with soft (120 KV) X-rays, and that gross chromosome aberrations show an RBE of about 8.

Drosophila lethals and mutations at specific loci: Data on dominant lethal and visible mutations at the specific loci of the third chromosome and on sex-linked recessive mutations were compared with data using cyclotron neutrons and X-rays.

The RBE of cyclotron neutrons compared to X-rays ranged from 1.2 to 17 at different loci, with an average RBE of 4 for all loci. The RBE of detonation neutrons compared to X-rays ranged from less than 1 to 16, with an average RBE of 4.5 for all loci.

For sex-linked lethals, the RBE of detonation B neutrons was 1.7 and for cyclotron neutrons 2.5, both compared to X-rays.

Chromosome rearrangements in *Drosophila melanogaster*: The "bithorax method" was used to test for *D. melanogaster* chromosome rearrangements. It was found that detonation A neutrons produced about the same number of rearrangements as do pile neutrons as similar doses. The RBE of neutrons compared with X-rays was about 6.

Chromosome rearrangements in *Drosophila virilis*: The number of translocation was directly proportional to dosage in rep. This indicates that nuclear detonations give a one-hit curve for translocations. A study of the types of translocations indicates that broken chromosomes do not rejoin at random but tend more often to exchange two by two. The RBE of neutrons to X-rays with respect to translocations is about 3 to 6; depending on the dose range.

Mutations in the wasp *Mormoniella*: The number of eye color mutations in *Mormoniella* were counted following exposure at detonations A, B, and C. The neutron dose-mutation curve appears to be exponentially increasing, in contrast with X-ray curve, which is rectilinear. The RBE varies from about 3 in the low dose range to about 5 at 1.3 kilorep.

Dominant lethals in mice: The effects of neutrons on the genetics, development, and reproduction of mice were investigated following exposure at detonation A. The results are given in this and the following two parts.

The genetic effect was measured as dominant lethality in the offspring of exposed male mice mated shortly after irradiation, and was compared with the results of an experiment using cyclotron neutrons. Death after $10\frac{1}{2}$ days of gestation was negligible for both detonation and cyclotron exposures. Also there was no significant difference between the two kinds of experiments in the relative percentages of death occurring before and after implantation. There is no evidence of a qualitative difference in the two experiments. If it is assumed that induced dominant lethals cause death prior to $10\frac{1}{2}$ days of gestation, that log survival is linearly related to dose, and that the maximum dosages of detonation neutrons were adequately measured, the maximum estimate of the ratio of RBEs for detonation and cyclotron neutrons is 1.18 with 95 per cent confidence limits of 0.91 and 1.55. If instead, minimal dosages are used, the ratio of RBEs is 0.80 with 95 per cent confidence limits of 0.67 and 0.96. Detonation and cyclotron neutrons do not therefore show significantly different biological efficiencies.

Degeneration of spermatocytes and type "B" spermatogonia in mice: Testes were taken from mice exposed to detonation A and prepared for the enumeration of spermatogonia. The number of degenerating spermatogonia increased with dose. Primary spermatocytes were destroyed by doses of 322 rep and above. Type B spermatogonia showed a much higher induction of cell lethality.

Developmental effects in mice: The effects of exposure to

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detonation A during embryonic development were observed at birth in mice, and were compared with the effects of X-rays and cyclotron neutrons. The abnormalities noted externally and in the viscera were: anophthalmia, microphthalmia, open eyelids, brain hernia, harelip, short tail, abnormal tail, polydactyly, oligodactyly, syndactyly, abnormal leg torsion, abnormal spleen shape, small or imperforate anus, horseshoe kidney. Percentage incidence varies widely. The data from the detonation exposure roughly agree with X-ray data with respect to the dependence of the type and incidence of a given abnormality on the developmental stage and the irradiation dose.

SUMMARY

The RBE of neutrons compared with X-rays is summarized in the attached table, which is Table 42 of the preliminary report.

The data support the following conclusions:

A. The RBE for genetic effects from detonation neutrons compared with X or gamma irradiation is high, observed values ranging from about 2 to 15 or more.

B. The RBE for chromosome breakage from detonation neutrons is not significantly higher than that from cyclotron neutrons, subject to some uncertainties in dose determination.

C. It is indicated that the RBE for the production of simple mutations by fast neutrons compared with X-rays tends to be low. The values are higher for gross chromosome aberrations.

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D. The genetic tests are of some value as "biological dosimeters" supplementary to physical dosimetry.

E. The studies clearly indicate that, for equal dose, neutrons represent a greater potential genetic hazard than other forms of radiation from nuclear detonations.

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TABLE 42

RELATIVE BIOLOGICAL EFFECTIVENESS PER UNIT DOSE
OF FAST NEUTRONS COMPARED TO X-RAYS

Biological effect studied	Mutational ^a	Chromosome aberrational	RBE
<u>Neurospora</u> survival		x	2 - 5
<u>Tradescantia</u> chromosomal aberrations		x	7 - 10
<u>Tradescantia</u> chromatid		x	13
<u>Datura</u> chromosome aberrations		x	15
<u>Drosophila</u> sex-linked lethals	x		2
<u>Drosophila</u> X-chromosome aberrations		x	8
<u>Drosophila</u> mutations in third chromosome	x?		4.5
<u>Drosophila</u> sex-linked recessive lethals	x		~2 ^b
<u>Drosophila</u> dominant lethals		x	4.7-6.5 ^{c,d}
<u>Drosophila melanogaster</u> rearrangements		x	5 - 7
<u>Drosophila virilis</u> rearrangements		x	3 - 6
<u>Mormoniella</u> eye color mutants	x?		3 - 5
Mouse dominant lethals		x	8

- a. May include some minute deletions in addition to mutations as taken in the strict sense.
b. 1.7 for detonation, 2.5 for cyclotron neutrons.
c. Varies with dose
d. Two-thirds as great in detonation B as A.

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This document consists of 16 pages
No. 4 of 70 Reports, Series 9

Abstract of Remarks by
Dr. Harold H. Plough
Amherst University
Amherst, Massachusetts

CONFERENCE ON BIOLOGICAL EFFECTS OF ATOMIC WEAPONS
TRIPARTITE EXCHANGE OF INFORMATION UNDER TCP (AREA 2)

held at the

U. S. Atomic Energy Commission
1901 Constitution Ave. N. W.
Washington, D. C.

February 17-18, 1954

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DEPARTMENT OF ENERGY DECLASSIFICATION REVIEW	
1ST REVIEW DATE: <u>5/2/94</u>	DETERMINATION [CIRCLE NUMBER(S)]
AUTHORITY: <u>DOE/ADG/DC/...</u>	1. CLASSIFICATION RETAINED
NAME: <u>H.H. Plough</u>	2. CLASSIFICATION CHANGED TO: _____
AND REVIEW DATE: _____	3. CONTAINS NO DOE CLASSIFIED INFO
APPROVED BY: _____	4. COORDINATE WITH: _____
	5. DECLASSIFICATION EXTENSION: _____
	6. OTHER COMMENTS: <u>H.L. ROE/DC/DNA</u>

12/7/94
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Abstract of Remarks by
Dr. Charles L. Dunham, Chief, Medical Branch
Division of Biology and Medicine
U. S. Atomic Energy Commission
Washington, D. C.

February 18, 1954

DELAYED EFFECTS IN MAN AND ANIMALS

The death rate among close-in survivors in Hiroshima and Nagasaki now appears to be higher than that for the control population, but with no specific cause of death responsible. The increased incidence of leukemia does not appear to account for it. Experimental work suggests that shortening of the life span depends on the size of the incremental dosage involved. That is, within increments of greater than 250r and up, there is an apparent loss of approximately 40% of the remaining life span per 1,000r received. On the other hand, with increments of 100r or less the fraction of remaining life span loss is less than 5% per 1,000r.

Evidence has accumulated indicating a real increase in the incidence of leukemia among the more heavily irradiated survivors. It is of interest that the incidence of leukemia among the control population is extremely low compared to American figures. The development of radiation cataracts among survivors is an established fact. More than 100 have been diagnosed now by slit lamp. However, only three have been of sufficient severity as to require operation. All cases were within 1100 meters of Ground Zero. During an 18-months period of observation approximately 1/3 of the cataracts appeared to be stationary or actually to be regressing.

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Abstract of Remarks by
Dr. Charles L. Dunham, Chief, Medical Branch
Division of Biology and Medicine
U. S. Atomic Energy Commission

CONFERENCE ON BIOLOGICAL EFFECTS OF ATOMIC WEAPONS
TRIPARTITE EXCHANGE OF INFORMATION UNDER TCP (AREA 2)

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DEPARTMENT OF ENERGY DECLASSIFICATION REVIEW	
1ST REVIEW DATE: <u>5/30/95</u>	DETERMINATION (CHECK NUMBER)
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With the cylindrical units, it was believed that attenuation and build-up would neutralize each other. However, this was not precisely true because with mice there was a small position effect in respect to film blackening and the mortality of the mice. With the aluminum and lead hemispheres, it was felt that there would be essentially no position effect and this proved to be the case for both gamma and neutrons.

In the lead hemispheres, it was calculated that the incident gamma radiation would be attenuated by a factor of 1000 by the 7" of lead. In addition, it was known that the incident neutron spectrum would be attenuated and altered to some degree. Lastly, it was felt probable that there would be various n-gamma reactions between the lead and the contents of the hemisphere that would increase gamma radiation within the hemispheres by an unknown amount. However, it was believed that the gamma contamination would be small when compared to the neutron contribution. It is currently believed that this contribution in terms of rem is 10 to 35% of the total dose received inside the containers for mice. With a probable lower RBE for larger animals the corresponding neutron contribution would be less.

The transparency of the spectrographically pure lead to the neutron spectrum still remains an incompletely answered problem. Current calculations and experiments lead one to believe that the incident fast

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neutron flux is attenuated by a factor of 2, and of course, the spectrum is altered significantly.

The dose mortality and splenic and thymic weight studies were successful beyond all expectation. A total of 4712 female mice were exposed to a fission weapon in 28 stations for the gamma dose mortality study in mice. The range in doses of gamma radiation varied from 192 to 3464 r. The neutron contribution over most of this range was less than 10% but may have been higher at closer stations and lower at the farther stations.

The 28-day mortality varied from 0.9% in the farthest station to 100% in the nearest twelve stations (See Table 1). The LD₅₀ in air as measured by Sievert ionization chambers is 759 r (See Table 2). Between 190 and 630 r, there was a relatively constant low mortality. It is believed that this is due to the irradiation because during this same period 640 control non-irradiated mice which were stressed in the same manner by overnight exposure on the shot island showed no mortality during the 28-day observation period. All of the surviving control and exposed mice were returned to the Oak Ridge National Laboratory for long term studies on the incidence of cataracts, neoplasia, and longevity.

The probit dose mortality analysis gave the best fit for the regression line with arithmetic dose versus empiric probit. In order to compare the bomb data to X-ray data, it was necessary to have data with similar Y intercepts. In addition, the mean tissue dose to the mice in

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the exposure apparatus and X-ray was calculated considering attenuation and build-up. When the appropriate calculations had been made, two sets of X-ray data met the physical and biological requirements fairly closely and are indicated by asterisk in table 3.

The relative biological effectiveness was calculated from the ratio of the slopes of the regression lines. The RBE is essentially unity. The widest range in terms of LD₅₀, regardless of the physical and biological factors, is $0.96 \pm 20\%$. This figure applies to the mouse, a relatively energy independent indicator for high energy gamma radiation.

In addition, the relation of deaths to time and dose of radiation was interesting (See Table 1). At the higher doses of radiation greater than 1500 r, the deaths were unimodal with a mean survival time of approximately 4 days. As the dose of radiation decreased, the distribution of deaths became bimodal in respect to time with peaks on the fourth and eleventh days. Within the lethal range proper, there was a tendency for bimodality above an LD₅₀. Below an LD₅₀, the distribution was unimodal and tended to be rectilinear. In addition, at the lower percents, the mean survival time progressively increased.

Lethal dose studies were also performed on dogs and swine. The bomb gamma studies on swine and dogs were compared to the results obtained in the States with 2 Mev X-ray. With the dogs, a relative biological effectiveness of 1.148 was obtained (See Table 4).

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The swine studies were complicated because the breeding program for swine was slow and the swine that were used in the field were sexually immature, younger, and smaller than those used in the control studies. The results are not strictly comparable because of differences in population. With 2 Mev X-ray, the LD₅₀ for swine was 413 r and with bomb gamma radiation, was 225 r giving an RBE of 1.8 (See Table 5). This value must be accepted with reservations because of the undesirable biological factors that were unavoidable in this experiment.

Despite the meagre data for swine and dogs, only three useful points for calculating the LD₅₀ for dogs and two points for swine, it does appear that atomic bomb gamma is slightly more effective than 1.0 - 2.0 Mev X-ray. This slight increase in effectiveness is bolstered by the shorter survival times in dogs at comparable doses as compared to X-ray survival data.

It is concluded that atomic bomb gamma radiation has an RBE as compared to 200 - 2000 KVP X-ray of essentially unity for mice. With larger animals up to 70 lbs. in swine, the RBE tends to increase. For an animal as large as man it is believed the RBE is considerably less than 2.0 using mortality as the end point.

The problem of RBE was also approached by the use of splenic-thymic weight loss, a technique for biological dosimetry that was developed by Carter, et al at Los Alamos Scientific Laboratory. With the thymic-splenic weight loss technique, the RBE of atomic bomb gamma radiation

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was performed on three separate shots at Operation Greenhouse. Control studies were performed at Eniwetok with 230 KVP X-ray. The biological dose was determined as that dose of 230 KVP X-ray that gave the same effect as was found in the hemisphere (See Tables 6 and 7). The composite results from an rd^2 versus d regression line was used. From this composite curve of biological data, the mean-free path of gamma photons was calculated and found to be approximately the same as calculated from physical measurements. Since there was close comparison between the mean-free path and because all of the biological curves were parallel, the RBE was calculated from the ratio of the intercepts and found to be 0.94 when the National Bureau of Standards film badges were used as a measure of gamma dose inside the aluminum hemispheres.

BIOLOGICAL EFFECTS OF BOMB NEUTRONS

Neutron biology has and still is a semi-quantitative field. The field studies in particular have been semi-quantitative and very difficult because of the inability to measure total flux, spectral distribution, and to convert to rep or to measure rep directly. The neutron studies were initiated by the Biology Division at the Los Alamos Scientific Laboratory and continued in collaboration by the U. S. Naval Radiological Defense Laboratory and the Naval Medical Research Institute.

The neutron studies have been carried out in the lead hemispheres previously discussed. The mouse and the various genetic materials have

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been used as test objects. The latter will be covered separately by Dr. Plough.

There is as yet an undetermined amount of gamma radiation inside of the hemispheres. The incident gamma is attenuated by a factor of 1000 but various neutron reactions increase the gamma contribution inside. Probably, the highest value in rem is around 35%. With the relatively high RBE for the fast neutrons, approximately 10 - 35% of the biological effect could be due to gamma radiation depending upon the RBE for the given parameter. The difficulties that arose in measuring gamma radiation inside of the hemispheres is due to the fact that the film packs are sensitive to the entire spectrum of neutrons. The chemical dosimeters are also very sensitive to thermal neutrons. It is only recently with new rep measuring devices that measure total radiation and gamma radiation could an approximation at the real level of gamma radiation inside the hemispheres be approximated.

In the initial studies in the field, the determination of the relative biological effectiveness of bomb neutrons was not attempted because there was no way in which the rep could be measured. However, the mouse could act as an integrating dosimeter and measure the effect of an unknown flux of neutrons of an unknown spectrum.

By definition, one rem is that dose of ionizing radiation which produces a biological effect equal to that produced by one r of high voltage X-ray. By usage, in atomic bomb field work, it has become

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synonymous with the mouse thymic rem. Subsequently, it has been shown experimentally that the rem varies with the biological parameter in the mouse and also with species. For the purposes of this discussion, the true relative biological effectiveness is defined as rem divided by rep and necessitates a knowledge of energy spectrum and flux. In the initial field studies, the following values for rem were used for the various portions of the neutron spectrum:

- a. 0 - 0.4 Ev neutrons - 5.9×10^{-11} rem = 1 n/cm².
- b. 1 - 3 Mev neutrons - 1.6×10^{-8} rem = 1 n/cm² assuming 1 rep = 4 rem.
- c. 3 - 15 Mev neutrons - 2.0×10^{-8} rem = 1 n/cm².
- d. Below 1 Mev, biological effect was believed directly proportional to energy and decreasing with energy.

From the above values, gold and sulfur threshold measurements, and the integrated biological effect as observed in the mouse, the following valuable information was obtained in the first series of studies:

- a. Thermal neutrons contribute less than 2% of the biological effect.
- b. The biological effect of intermediate neutrons constituted from 50 to 75% of the effects on two shots and much less on a different shot.
- c. Sulfur neutrons contributed 25 to 47% of the biological effect on two shots and 75 to 95% on another shot.

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d. Over 90% of the bomb neutron dose from all devices studied was due to neutrons with energies greater than 1 Mev.

e. Neutron dose did not scale directly with KT.

f. The ratio of neutron dose to gamma dose did not remain constant for KT. In the first series the neutron effect varied from 1.5 to 11% of the total effect when measured at the same distances with the mouse, a relatively thin foil.

On later tests, the neutron studies were expanded and aimed at confirmation of the earlier studies and extension of our knowledge on the effect of neutrons on mammals in order to better understand the acute neutron hazard.

On all subsequent tests, the following battery of studies were performed on the mice. The relative sensitivity of the systems is tabulated:

	Sensitivity in r
Lethal dose curve	400 - 1100
Body weight	100 - 3000
Thymus	50 - 800
Spleen	50 - 400
WBC	75 - 350
GI tract weight	150 - 1000
Rbc Fe ⁵⁹	25 - 300

The battery of dosimeters worked well with the exception of the body weight which is too sensitive to undesirable environmental factors.

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The results can be summarized as follows:

- a. The LD₅₀ distance for mice was found to be where it would have been anticipated on the basis of the organ weight estimates of dose in rem.
- b. The rem indicated by radio-iron uptake in the red cells was less than the rem indicated by thymic weight loss in every instance.
- c. The total white cell count agreed well with the radioactive iron uptake observations.
- d. The survival time of animals held for mortality was remarkably short (average mean survival of 4 days).

The lesser effect on the total white blood count and the uptake of radioactive iron as compared to the thymic depression indicates a relative protection of the bone marrow in the neutron irradiated animals. The four-day survival time for neutron irradiated mice in the lethal range is similar to the survival time of X-ray irradiated mice given X-ray to the abdomen or exteriorized gut.

In all cases, the rem from thymic weight loss showed a log linear relationship with both sulfur and gold neutrons.

Of potential practical importance is the ratio of neutron to gamma dose in rem for the mouse at various distances from various devices as illustrated in the following table:

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Shot	Gamma in r	Neutron rem	Neutron/Gamma rem in %
G	1000	107	10.7
	500	42	8.6
	200	14	7.0
H	1000	573	57.3
	500	150	30.0
	200	19	9.5
I	1000	199	19.9
	500	106	21.2
	200	47	23.5

If the lead is more opaque to neutrons than originally assumed, it may be necessary to increase the absolute values for neutron biological effects at a given distance by a factor of 2. It is conceivable for certain distances and conditions that neutrons will contribute more than gamma to the total rem dose, as seen by the mouse. Whether this will pertain to larger animals depends on the RBE and depth dose factors for fast neutrons.

By the use of the new rep measuring devices of Rossi-Failla and of Sheppard and Darden, it was possible to make an approximation for an RBE in the mouse. A good relation between the outside sulfur neutrons and the rep values in the few stations where the chambers were located was observed. From this relationship, the inside rep values were calculated. This extrapolation assumed an unchanging spectrum with distance and an unchanging hemisphere transmission. This is not completely true. However, when this was done the following RBE's were

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obtained for the mouse thymus and the peripheral blood count. For the mouse thymus response, an RBE of 7.4 was obtained in one experiment and of 7.9 in another experiment. For the peripheral leukocyte count, an RBE of 3.9 was obtained. These RBE's are maximal values.

THE AEC COMMUNAL SHELTER AS A RADIATION SHIELD

This work was performed jointly by the Staffs of the Naval Medical Research Institute and the U. S. Naval Radiological Defense Laboratory.

The shelters were evaluated with physical measuring devices for gamma radiation, neutron fluxes, and rep. Since the total integrated radiation hazard cannot be measured satisfactorily by physical means, the radiation hazard was determined by biological dosimeters. Mice and dogs were used as test objects.

In the mice, the previously tested and proved parameters for measurement of radiation were used, namely the decrease in splenic-thymic weight, decrease in circulating leukocytes, decrease in gastrointestinal weight, the decrease in the uptake of radioactive iron by red blood cells, mortality and survival time.

In all previous field tests for the determination of the relative biological effectiveness and for the determination of hazard, a multiple dose response was possible. In the case of the shelters on shot A, only one dose was possible. On shot B, a two-point response was possible because the shelters were a hundred yards apart on a radius from the

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device. Since the majority of radiation doses encountered in the shelters were very low and there was only one point on which to base the biological analysis, it was necessary to determine the lower limit of rem dose that could be detected with a given degree of confidence by the several biological end points employed. An approximation of this lower limit was made for spleen weight, thymus, and white blood count as follows:

The variance of the predicted dose for a given organ weight or white blood count decrease was determined for the various combinations of control and experimental mice that were used. From these variances, the corresponding 99% confidence intervals were calculated and that dose where the 99% confidence interval just embraced zero dose was taken as a minimal detectable dose. The resulting estimate of the minimal detectable doses are indicated on the following table:

TABLE 1. Minimal Detectable Doses with the Design of Field Experiments in r or rem (99% Confidence Limits)

No. of Mice	Spleen	Thymus	WBC
40 Exp. 40 Control	57	65	77
80 Exp. 48 Control	50	55	70

Past studies have shown that atomic bomb gamma radiation has an RBE of $1.0 \pm 20\%$ and that 2.4×10^7 sulfur n/cm² represents one mouse thymus rem. These factors plus an attenuation of sulfur neutrons by a

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factor of 10 per foot of Nevada soil were used in making preliminary estimates of probable radiation hazard in the shelters for the design of the biologic experiments.

The animals were exposed in two-foot cubes that had heating units and fans which maintained the temperature at 75° F. \pm 3° . Animals were exposed in aluminum cubes for the determination of the total radiation hazard and in lead covered cubes for the determination of the neutron hazard. Each cube was capable of holding either two dogs or 100 mice.

The animals were approximately five weeks of age when they were transported by air to the Nevada Proving Ground. All mice were selected according to body weight and randomized. Before each shot, groups of animals were loaded into exposure cages, ten animals to the cage, approximately twelve hours before the detonation. Cages were transported to the field and placed in exposure units approximately eight hours before detonation time. The average time between the detonation and return of the animals to the animal colony was about five hours.

Control X-ray studies on mice were carried out in the animal colony in Nevada by means of a portable 250 KVP General Electric Industrial unit. All control studies were performed as close to the given shot as possible on a random group from the same experimental animals.

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Observations on the dogs included mortality, clinical evidence of illness, weight loss, body temperature, and serial hematologic studies. It was not feasible to carry out X-ray control studies on dogs at the test site. The responses observed in dogs exposed to high energy 1000-2000 KVP X-ray at USNRDL and at NMRI were used to estimate the rem dose received by dogs exposed in the shelters.

The rem doses in the shelters were determined as follows:

The difference between a mean value for a station and its appropriate non-irradiated control was tested for significance. If no significant difference was found, the dose for that situation was reported as 0 rem. If values obtained in the field differed significantly from the appropriate control and were less than the estimated minimal detectable dose, they are reported as being less than the minimal detectable dose for the given system. If doses greater than the minimal detectable doses were obtained, they will be reported as that dose calculated from the various regression lines for the different parameters studied. In Table 2 are shown the physical and biological doses measured inside of the shelters on the various shots.

All biological end points obtained on mice exposed at shot A were consistent in that either a minimal or no difference was seen between the control and exposed group values. There was no difference observed between animals in aluminum cubes or lead covered cubes. The results

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are consistent with a total radiation level of gamma and neutrons that is well below 50 rem.

The data obtained on dogs exposed on shot A demonstrated a slight loss in body weight and a slight but consistent reduction in the white blood count, including granulocytes and mononuclear cells in addition to the platelets in those in the aluminum exposed group. These minimal changes are suggestive of a radiation exposure of less than 50 rem. On shots B, C, and D, the exposures were certainly below 50 rem and more likely closer to zero.

In shot C, mice were studied for gastrointestinal weight changes and dogs for hematologic changes. The mice in the aluminum cube received a total dose of approximately 700 rem, and in a cube covered with four inches of lead the approximate dose was 100 rem. Similarly, in the dogs, the behavior was consistent with approximately 600 rem for the dogs in the aluminum cube and approximately 100 rem for the dogs in the cube covered with four inches of lead.

A comparison between the physical and biological measurements was most satisfactory. The physical measurements of gamma radiation in the shelters on shot A by the National Bureau of Standards Film Packs indicated values of less than 15 r. The tissue equivalent chambers developed by Rossi and Failla indicated a total rep dose of 21.5 r and a gamma dose of 18.5 rep. The sulfur and gold neutron

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readings were well below the threshold level for response of the biological objects. On shots B, D, and E, the gamma film measurements indicated doses less than 1.5 r and the neutron gold and sulfur fluxes were less than the threshold for biological response.

On shot C, the physical measuring devices, film and chemical dosimeters, next to the units holding dogs and mice, indicated doses between 545 and 700 r which were consistent with the biologic response. In the aluminum cube, the sulfur flux was 4.7×10^9 n/cm² and the gold flux was 2.9×10^{10} n/cm². In the lead cube the sulfur flux was 1.2×10^9 n/cm² and the gold flux was 1.4×10^{10} n/cm², all of which are consistent with the biologic responses.

Results and Conclusions:

1. Under the specific conditions that the shelters were tested, it can be concluded that with the exception of shot C the shelters were effective total radiation shields. In the latter there were obvious radiation leaks as shown by the gradient in doses.

2. Satisfactory correlations between physical and biological measurements of dose were obtained.

3. For shelters with minimum earth overlay of 3'8", the neutron flux within the shelters did not constitute an appreciable hazard when the outside sulfur flux was 2.4×10^{11} n/cm² or less. Sulfur fluxes of this order are encountered at distances of approximately 700 yds. from a 20 KT nominal weapon..

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4. The data do not permit predictions for fluxes of greater than 2.4×10^{11} n/cm² with 3'8" of earth shielding or for less shielding with the same flux, but indicate that fast neutrons may constitute a hazard under either extreme situation.

5. Under the conditions employed, it appeared that the attenuation of neutrons observed was less dependent on the slant range of earth through which the neutrons passed than it was on the minimum thickness of earth over the shelter.

6. The contribution of neutrons to the total biologically-effective dose does not increase over the free-air situation following transmission of the bomb radiation through the protective earth covering. Therefore, gamma rays constitute the chief or "controlling" radiation hazard within the shelters exposed to the specific weapons used.

7. With low bursts, grazing angle, the dose of gamma radiation within the shelters was negligible. With conditions approaching those of a direct overhead shot, using a comparatively crude prototype structure, significant levels of gamma radiation were observed. No statement of the absolute levels to be expected are warranted because of the high probability of gamma leaks.

8. Of necessity, the conclusions are based on low bursts with a grazing angle, and it would be unwarranted to assume that shelters would behave the same with angles of burst from 50-90°.

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FOXHOLES AS SHIELDS AGAINST BOMB NEUTRONS

Studies were made on the effectiveness of 42-inch deep foxholes. Lead hemispheres were placed at ground level and in the bottom of the foxhole. From previous studies with sulfur detectors, it was known that sulfur flux would be attenuated by a factor of 10 at the bottom of the foxholes.

By the lead hemispheres technique there was actually a reduction in biological effect of the neutrons by a factor of 3 at the bottom of the foxhole. The fact that the animals in the bottom of the foxholes showed more biologic effect than would have been expected on the basis of previous sulfur neutron flux measurements indicates that considerable alteration in the neutron spectrum may occur under shielding conditions and that the sulfur neutron/rem ratio of 2.4×10^7 sulfur neutrons plus all accompanying neutrons equal 1 rem is satisfactory only for unshielded conditions inside Pb hemispheres at ground level.

Significant amounts of gamma radiation penetrated or scattered into the foxholes. If simple additivity of fast neutrons and gamma rays is assumed, it is estimated that where the gamma dose was 200 r the total biological effect might be as high as 300 rem. Accordingly, under shielding conditions such as these, survival is possible after significant neutron exposure. The problem of extrapolating from mouse to man is obvious. There is, however, no satisfactory data at the present time

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in order to help make this extrapolation. However, from preliminary studies with 10 kilogram dogs using the 60-inch University of California cyclotron with 4 Mev neutrons, it appears as if the RBE for the dogs will be much less than for mice. In addition, Monte Carlo calculations of depth dose for neutrons of various energies will help when completed.

Qualitative Differences Between Gamma and Neutron Effects:

An interesting qualitative difference between gamma or X-rays and fast neutrons has been observed in all field tests. For similar percentages of mortality, the survival time is much less with neutron irradiated mice. Within the lethal range the mean survival time of the fast neutron irradiated mice is approximately 4.5 days as compared to 11 to 12 days in the gamma or X-irradiated mice. In the supralethal range, the survival times merge.

These interesting differences in mice have not been observed in dogs and rats in the current studies by Bond and associates at USNRDL using the 60-inch University of California cyclotron.

MAMMALIAN RADIATION SYNDROMES AND THEIR DOSE DEPENDENCE

This syndrome for descriptive purposes has been divided into three distinct and separate syndromes arbitrarily termed

- a. The Hemopoietic (death 7 - 30 days)
- b. The Gastrointestinal (death 3 - 6 days)
- c. The Neurologic (death immediate or hours)

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The names for these syndromes are based largely on the signs and symptoms observed. These syndromes are dose dependent. The hemopoietic syndrome is produced by 150 - 1000 r in the lethal range depending on the species. The gastrointestinal syndrome is produced largely by supralethal doses (800 - 10,000 r) depending on the species. In some species, such as the rat, in the lethal range the GI syndrome is quite clear cut and may precede the hemopoietic syndrome by a matter of days. However, if the animal survives the GI syndrome death may occur from the hemopoietic syndrome at a later date. In other species, deaths from the GI syndrome rarely occurs in the lethal range. The position of man is not too clear but it is consistent with clinical and the Japanese experience to think that there would be some deaths from GI syndrome with lethal range. The neurologic syndrome is produced by 1000 r or more depending on the species. Above 10,000 r there is virtually no recovery from this syndrome with death occurring either under the beam or within a few hours. If survival does occur from this syndrome with doses of this magnitude, death invariably occurs later from the GI syndrome.

Numerous studies on dogs, rats, mice, and guinea pigs with high total doses and dose rates up to 2500 r/min have been made. It is possible to kill any of the animals under the beam. The total dose varies considerably with species and strain. Guinea pigs may collapse and die after 12,000 r at a dose rate of 64 r/min. Mice at 2500 r/min may not die until in excess of 48,000 r is received. Some mice survive

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to a total of 100,000 r. Dogs are seriously incapacitated by 10,000 r at 64 r/min but recover from the severe neurologic difficulties (ataxia, dyspnoea, weakness, etc.) only to collapse and die on the 3rd or 4th day following profound vomiting, diarrhoea, and the concomitant dehydration. The most valuable studies from the standpoint of incapacitating doses of radiation are those with monkeys performed jointly by the Los Alamos Scientific Laboratory and the Medical Department of the U. S. Air Force.

In these studies, 120 M. rhesus monkeys were trained to do skilled acts. In the preliminary studies, the reward was food. However, these studies were unsatisfactory because the severe nausea and vomiting took the zest for food away so there was no stimulus to the monkeys to search for the food. In the repetition a punitive stimulus was used. If the monkeys erred an electric shock was applied.

The source of radiation was a Ba-La mixture with dose rate of 1100 r/min.

Of the 120 monkeys, 72 were used for performance tests and the remainder for physiological studies. The qualitative observations are tabulated:

Qualitative Response of Monkeys after Various
Doses of Gamma Rays at Dose Rate of 1100 r/min

Time after Beginning of Exposure in Minutes	Total Dose in r	Remarks
1 - 3	1100 - 3300	Hyperactive, severe scratching
5 - 7	5500 - 7700	Slump, weak, salivation, vomiting, retching
12 - 17	13200 - 18600	Some recovery, GI symptoms less, sit up
30	33000	Severe relapse, GI s & s worse, marked dehydration

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The animals had become almost 100% efficient in finding a grape under one of 15 dissimilar objects. Failure to accomplish this task resulted in an electric shock. The results at zero time after various doses of radiation follows:

Quantitative Results in Monkeys on Performance Tests
at Zero Time after Various Doses of Gamma Radiation

Dose in r	No. of Monkeys	Results
30,000	2	0, 0
20,000	3	7/15, 0, 0
10,000	4	10/15, 0, 0, 0
5,000	4	5/15, 12/15, 0/15, 0
2,500	4	2/15, 2/15, 0, 0
1,000	4	11/15, 9/15, 12/15, 15/15
0	all	15/15

After one hour none of the monkeys could perform the tests despite the shock stimulus.

In general, the investigators believe that monkeys are less sensitive than man on the basis of sensitivity to vomiting on the centrifuge and after copper sulfate. It takes 15 minutes to induce vomiting in man and 45 minutes in monkeys by rotation and the emesis dose of copper sulfate is 20 times greater in monkey than man.

It seems quite evident that doses of radiation in excess of 1000 r will seriously interfere with skilled acts and doses greater than

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2500 r will in all probability render human beings ineffective and death will most likely occur within 3 - 6 days.

BETA RAY LESIONS IN SKIN OF SHEEP

During a series of Nevada tests, curious skin lesions developed on a large number of sheep on the ranges adjoining and distant from the Nevada Proving Ground. Quite logically the ranchers were inclined to ascribe the lesions to radiation from residues of the various atomic bomb explosions. Obviously, the subject had to be investigated.

At the Los Alamos Scientific Laboratory, studies were performed on sheep exposed to beta rays from a Sr^{90} - Yt^{90} source by Lushbaugh, et al and the lesions compared to those found in the range sheep. The source delivered 5,400 rep/min at its surface. The shaved and unshaven skin was irradiated with graded doses from 2.5 - 25.0 thousand rep (shaved skin) and 5.4 - 145.8 thousand rep (unshaved skin). The clinical sequence was observed and biopsies were taken.

After 25,000 rep, ulceration appeared in 8 days and after 2500 rep appeared in 13 days. In the former, it involved full thickness of skin and the latter was superficial.

The irradiated area was 15 mm in diameter and the lesions produced at 3 weeks after irradiation by the following doses measured as listed:

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Dose in rep	Size of Lesion
2,500	15 x 15
5,000	20 x 20
10,000	25 x 19
15,000	27 x 22
20,000	28 x 25
25,000	28 x 25

Healing was complete in eight to nine weeks but wool growth had not returned.

Exposures of 5000 - 10,000 rep around the unshaven angle of mouth and ear produced no lesions.

Exposure of the unshaven skin resulted in loosening of hair so it could be easily plucked except after the lowest dose of 5400 rep. After 16,200 rep and higher the hair loosened. After 145,800 rep, an ulcer developed. Areas of epilation as function of dose follow:

Dose in rep x 10 ³	- 5.4	16.2	48.6	145.8
Area in mm	- 0	35x38	50x50	43x45

Assuming wool length of 33 mm and density of 46.2 mgm/ccm, it was calculated that about 3% of dose delivered to surface of wool reached the skin directly under the plaque.

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The pathologic lesions follow:

"1. The scab or eschar. This was typically composed of serum and some cellular debris at the lowest dose and of coagulated and still recognizable elements of the upper dermis such as wool fiber and follicular shafts and glands at the higher doses. Leukocytes apparently made up a good part of the scab and played a proteolytic role in separating the dead cells of the eschar from the remaining viable ones. Scab retention in the sheep was probably as prolonged as it was (eight to nine weeks or more) because of the numerous attached wool fibers.

2. Reactive Epidermal Hyperplasia and Reepithelialization. The full thickness of the epithelium was not destroyed by 5,000 rep of beta radiation. In attempting to replace the cells damaged by radiation, a remarkable hyperplasia occurred and left a hypertrophic epidermis marked by follicles so thickened by this process that the foci resembled early squamous carcinomatous fingers.

Fifteen thousand rep caused a loss of the superficial epidermis in the outer one-third to one-half of the wool fiber follicles. Atrophy of the sebaceous glands was marked. Regeneration occurred early from the wool fiber follicle remnants. The new epidermis was quite hyperplastic and thickened. The margin of the lesions had hyperplastic and hypertrophic epidermal "downgrowths."

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Twenty-five thousand rep injured the full thickness of the dermis and the whole follicle was lost so that healing occurred by the ingrowth of sheets of epithelium from the surrounding, relatively uninjured, remaining cells.

In all cases the regenerating epithelium showed bizarre forms ranging from atrophy to giant cell formation.

3. Vascular and Other Connective Tissue Changes. Blood vessels were found to be increasingly damaged as the dose was increased, but hyalinization, intimal fibrosis, endothelial swelling, and thrombosis were found in all three lesions.

Fibroplasia occurred best deep in the dermis and was poor, if existant at all, in the outer layers of the skin where a chronic cellular exudate was found to be present."

The pathologic lesions seen in the sheep from the ranges grossly appeared similar to radiation lesions but differed histologically by not showing the typical vascular lesions and the gradation of degenerative changes in the epidermal appendages.

Lushbaugh and associates concluded:

"1. It would appear from these observations and experiments that a skin lesion of a sheep in full wool, involving the full thickness of the skin, would require beta radiation of 2.2 mev in amounts in excess of 150,000 rep if applied to the wool surface and in excess of 15,000

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rep if applied to the skin surface. Sheep wool is a good protector against beta irradiation.

2. The lesions of the sheep in the field differ histologically, but not grossly, from so-called radiation burns by not having a gradation of degenerative changes in the epidermal appendages and not having any demonstrable typical vascular changes.

3. Lesions similar to those in the Cedar City sheep can be produced by physical and infectious agents which do not involve ionizing radiations."

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TABLE 1. CRUDE 28-DAY MORTALITY DATA

Dose (r)	Male Dead/Exposed	Female Dead/Exposed	Combined Sexes	
			Percent Mortality	Mean Survival Time (Days)
3,464	30/30	30/30	100	4.73
1,954	30/30	30/30	100	4.27
1,494	30/30	30/30	100	4.49
1,252	30/30	30/30	100	5.19
1,173	30/30	30/30	100	6.98
1,108	30/30	30/30	100	8.65
1,070	30/30	30/30	100	8.38
1,034	30/30	30/30	100	9.02
999	30/30	30/30	100	9.03
965	110/110	108/108(a)	100	9.22
932	109/110	110/110	99.6	9.89
900	110/110	110/110	100	9.84
870	109/110	101/110	95.5	10.71
841	96/110	105/110	91.3	12.10
812	82/110	91/110	78.6	12.42
785	72/110	69/110	64.1	12.87
759	61/110	62/110	55.9	13.17
733	30/110	34/110	29.1	14.46
711	24/110	27/110	23.2	13.07
687	10/110	18/110	12.7	13.82
631	5/109(a)	4/108(a)	4.14	12.93
556	5/109(a)	2/110	3.19	16.80
491	6/109(a)	2/110	3.65	15.2
424	7/110	1/110	3.63	18.1
367	2/110	4/110	2.72	18.3
318	3/110	4/110	3.18	21.6
287	3/110	3/110	2.72	18.2
192	1/110	1/110	0.91	21.0

(a) Accidental deaths reduced the number "exposed" to the figures indicated.

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TABLE 2. PROBIT ANALYSIS OF MORTALITY DATA, SEXES COMBINED

Dose (r)	Number Exposed	Number Dying	Mortality (percent)	Empirical Probits E	SE of Dose
999	60	60	100		9.0
965	218	218	100		7.8
932	220	219	99.6	7.61	6.6
900	220	220	100		5.4
870	220	210	95.5	6.70	4.4
841	220	201	91.4	6.37	3.5
812	220	173	78.6	5.79	2.7
785	220	141	64.1	5.36	2.2
759	220	123	55.9	5.14	2.2
733	220	64	29.1	4.45	2.5
711	220	51	23.2	4.28	3.1
687	220	28	12.7	3.86	3.8

$\hat{y} = -7.27 + 1.617 x$
LD50 = 759 ± 2.2 r
V(a) = 0.00118
V(b) = 0.00379;
 χ^2 9.969
(P > 0.30 < 0.50)
where x is expressed in 10² r units.

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TABLE 3. SUMMARY OF BOMB AND REPRESENTATIVE X-RAY CONTROL STUDIES

Study	LD ₅₀ Air Dose	LD ₅₀ Tissue Dose	Intercept b	V(a)	Slope b	% Scatter
Bomb	759	680	-7.27	0.22	1.617	-
USNRDL-1*	648	706	-6.44	1.54	1.76	9
" 2*	547	651	-7.96	1.70	2.38	19
" 3	548	652	-9.69	2.65	2.68	19
" 4	694	757	-9.13	3.56	1.99	9
JAPTAN 1	757	-	-4.68	2.39	1.28	?
" 2	706	-	-4.01	0.45	1.28	?

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TABLE 4. MORTALITY OF DOGS* EXPOSED TO ATOMIC BOMB GAMMA RAYS

Dose	# of Dogs	# Dying	Mean Survival Time (days)	Range in Survival Days
999	10	10	4.9	4-8
825	10	10	6.3	3-8
687	10	10	8.1	7-9
600	10	10	9.1	7-13
475	10	10	10.8	8-13
390	10	10	13.2	7-19
325	10	8	15.5**	12-18
280	10	5	13.6**	8-21
192	10	1	9**	9

Calculated LD50 = 271 r (Probit vs log dose)

* Segregated by weight and sex and then groups randomized.

Weight range 19-49 lbs. average

** Mean Survival of those that died. Others killed on 30th day.

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TABLE 5. DOSE MORTALITY WITH SWINE EXPOSED
TO ATOMIC BOMB GAMMA RADIATION

Dose	# Exposed	# Dying	Mean Survival time (days)	Range in Survival Days
999	10	10	4.4	4-5
825	10	10	6.1	5-8
687	10	10	6.4	5-7
600	10	10	7.5	6-8
475	10	10	9.3	8-11
390	10	10	9.9	9-11
325	10	10	12.3	10-15
280	10	8	13.3	12-18
192	10	2	15.5	15-16

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TABLE 6. ORGAN WEIGHTS AND NBS FILM-PACK DATA

Mean Thymic Weight (mg)	Percent Decrease	Mean Splenic Weight (mg)	Percent Decrease	NBS Film Readings (r)	Equiv. r 250-KVP	
					Thymus	Spleen
67.1 ± 1.4(a)	-	77.5 ± 1.9(a)	-	0		
66.3 ± 1.4	-	79.0 ± 1.7	-	0		
5.4 ± 0.2	91.9	18.2 ± 0.4	100.0(b)	850(c) 895	815	>600
6.2 ± 0.2	90.7	19.5 ± 0.4	97.8	810 810	751	>600
9.6 ± 0.3	85.5	22.3 ± 0.3	93.2	673 687	565	>600
10.9 ± 0.3	83.6	24.1 ± 0.4	90.3	607 607	518	570
15.9 ± 0.4	76.1	29.6 ± 0.6	81.2	510 523	390	400
23.3 ± 0.6	64.9	36.3 ± 1.2	70.2	386 332	275	305
27.1 ± 0.6	59.1	56.9 ± 1.2	36.3	140 245	234	210
42.9 ± 1.2	35.3	69.5 ± 1.2	15.3	108 119	122	150

- (a) The mean is given together with its standard error.
- (b) The maximum splenic weight loss observed was taken as 100 percent, and the subsequent percentages were adjusted accordingly.
- (c) Two film packs were included in each container.

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TABLE 7. ORGAN WEIGHTS AND FILM-PACK DATA, HEMISPHERE STATIONS

Mean Thymic Weight (mg)	Percent Decrease	Mean Splenic Weight (mg)	Percent Decrease	NBS Film Readings (r)	Equiv. r 250-KVP	
					Thymus	Spleen
66.5 ± 1.4(a)	-	86.5 ± 2.0(a)	-	-	-	-
60.0 ± 1.3(a)	-	76.5 ± 1.0	-	-	-	-
-	-	-	-	1,300	-	-
4.1 ± 0.2	93.2	14.8 ± 1.0	100.0(b)	1,000	> 900	> 600
5.9 ± 0.2	90.2	18.8 ± 0.5	93.7	820	729	> 600
9.3 ± 0.3	84.5	23.5 ± 0.3	86.0	635	542	500
10.2 ± 0.2	82.9	25.2 ± 0.4	83.2	555	505	470
14.7 ± 0.5	75.4	29.2 ± 0.5	76.7	460	381	350
21.6 ± 0.7	64.0	37.9 ± 0.8	62.6	370	268	275
23.3 ± 0.4	61.1	50.3 ± 1.0	42.6	290	249	220

(a) The mean is given together with its standard error.

(b) The maximum splenic weight loss observed was taken as 100 percent, and the subsequent percentages were adjusted accordingly.

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TABLE 2. BIOLOGICAL AND PHYSICAL DOSES INSIDE SHELTERS

Shot	Unit	Thymus	Spleen	GI	WBC	Fe ⁵⁹
A-602	Al	0	50	<100	0	0
A-602	Pb 1/2"	0	50	<100	0	0
A-602	Pb 1"	0	50	<100	0	0
A-602	Al dog	-	-	-	50	-
A-602	Pb dog	-	-	-	50	-
B-601	Al	0	0	-	70	-
B-601	Pb 1/2"	0	0	-	70	-
B-602	Al	0	0	-	70	-
B-602	Pb 1/2"	0	0	-	-	-
C-7.9.1	Al	-	-	730	-	-
C-7.9.1	Pb 4"	-	-	110	-	-
C-7.9.1	Al dog	-	-	-	600	-
C-7.9.1	Pb 4"	-	-	-	100	-

	Gamma in r*		Neutrons as S flux n/cm ²		REP** Inside	
	Outside	Inside	Outside	Inside	Total	Gamma
A-602	27,000	15	2.4x10 ¹¹	<10 ⁷	21.5	18.5
B-601	>3000	1.5	1.7x10 ¹⁰	<10 ⁷	-	-
B-602	<3000	1.5	9.7x10 ⁹	<10 ⁷	-	-
C-7.9.1	150,000	250-3000***	5.5x10 ¹¹	3x10 ⁹	-	-

- * NBS film packs - neutron sensitive
- ** Rossi-Failla tissue equivalent chambers
- *** Sharp gradient inside with NBS film

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No. 4 of 70 copies.

Abstract of Remarks by
Commander Eugene P. Cronkite, MC, USN
Naval Medical Research Institute
Bethesda, Maryland

CONFERENCE ON BIOLOGICAL EFFECTS OF ATOMIC WEAPONS
TRIPARTITE EXCHANGE OF INFORMATION UNDER TCP (AREA 2)

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1901 Constitution Ave. N. W.
Washington, D. C.

February 17-18, 1954

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Abstracts of Remarks by

Commander Eugene P. Cronkite, MC, USN
Naval Medical Research Institute
Bethesda, Maryland

February 18, 1954

COMPARATIVE BIOLOGICAL EFFECTS OF GAMMA AND NEUTRONS FROM
ATOMIC BOMBS - RELATIVE BIOLOGICAL EFFECTIVENESS

These studies were performed by the Los Alamos Scientific Laboratory, the Naval Medical Research Institute, and the U. S. Naval Radiological Defense Laboratory.

The exposure apparatus was designed to protect the animals from direct and indirect blast injury, provide ventilation and a controlled temperature. For the gamma exposures, large cylinders or aluminum hemispheres were used. For the neutron exposures, 7" lead hemispheres were used. The internal cavity was hemispherical with a diameter of 14". The cylindrical units were used to expose dogs, swine, large numbers of mice for pathological and dose mortality studies, and Tradescantia. The hemispherical units were used for the determination of the effect as measured by the decrease in splenic-thymic weight and chromosomal changes in Tradescantia.

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Abstract of Remarks by
Dr. Shields Warren, Director
Cancer Research Institute
New England Deaconess Hospital
Boston, Massachusetts

February 18, 1954

THE IMMEDIATE REACTIONS TO RADIATION AND THEIR THERAPY

Acute radiation injury may be divided into that due to generalized and to localized radiation.

1. Generalized Radiation

Generalized radiation effects are related to exposure to external penetrating radiation of whole body type or to exposure from considerable amounts of absorbed relatively soluble internal emitters.

The generalized effects of radiation vary greatly with the amount of radiation absorbed and the rate at which that radiation is given. In general, the spacing of a given dose of radiation over 12 hours may be expected to have about half as much effect as that received in less than one hour.

A. Overwhelming Dose. Overwhelming doses of radiation, 10,000 to 100,000r or over, may be expected to produce prompt death in shock. Under such conditions, treatment is totally unavailing. There is some evidence from animal

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experimentation that protection of the head may prevent the shock-like death but will not prevent subsequent death due to other forms of the acute radiation syndrome.

B. Fatal Dose. Doses ranging from 10,000 down to 600r will almost invariably kill with a rather characteristic clinical course, the symptoms appearing earlier and being more severe with the higher dosage ranges. One has to keep in mind that variations in individual susceptibility as well as variations in dosage may occur. Furthermore, concomitant severe thermal injury may have an actually synergistic effect; intercurrent traumatic injury an additive effect. Those receiving the higher dosage ranges will usually die in one to two weeks. Those receiving from approximately 1000 to 300r die in the third to sixth week, with a few dying after the twentieth week and some surviving.

We regard 400r as the LD 50 range for man.

Patients complain of nausea and vomiting often within an hour after exposure to more severe doses, although with lesser dosage these may not appear for several days or may, after appearing, disappear for several days. Initial symptoms or remissions are shortly followed by a sense of weakness, malaise and severe diarrhea, intense thirst and increasing fever. With the heavier dosage ranges, death usually occurs within two weeks with coma or delirium. In the great bulk of the patients dying within two weeks neither epilation nor purpura has had time to appear. Judging from the scanty data available on

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patients and much data on animals, a prompt leukocytosis occurs, being rapidly replaced, often within 12 hours, by severe leukopenia.

This leukopenia, of course, opens the path to severe infection. This is further facilitated by the ulcerations which occur in the intestinal tract. Often concomitant with the fever ulceration of the oropharynx that seriously interferes with eating or drinking may develop. Epilation occurs after two weeks in some patients, after six weeks in most patients with significant doses of radiation. All patients who recovered either are not epilated or recovered from the transient epilation from which they had suffered. The purpura is primarily due to low platelet content of the blood. That altered permeability of the vessel walls may play a part is indicated by the occurrence of extravasation of blood into the tissues and the fairly early appearance of blood within lymphatic channels.

In those patients dying at the lower dosage ranges, anemia, either aplastic or due to a maturation defect, is a significant factor. In all these patients exertion accelerates the onset of symptoms and increases their severity. Treatment is unavailing in the more severe cases. In the less severe cases transfusion appears to be of value, particularly in the late stages. The administration of broad spectrum antibiotics to control infection appears to be of value. There is no evidence as to whether emulsions of spleen, lymphoid tissue or bone marrow effective in animals are

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useful in the human being. Because of vomiting, diarrhea, nausea and anorexia, parenteral feeding and fluid administration are important, particularly in cases in the lower potential lethal dosage range (600 to 200r). Most tissues attempt to regenerate following irradiation injury provided a sufficient number of viable cells persist. Consequently, supportive therapy for the patients is indicated.

Since the coexistence of burns makes the prognosis appreciably worse and the presence of traumatic injury increases the problem, the usual methods should be followed to minimize shock and promote healing of these other lesions.

C. Sublethal Dose. With doses under 600r recovery may occur. Even as low as 100r vomiting, sometimes delayed for several hours, and slight nausea may occur. Transient epilation may occur in the range between 600 and 250r. It is probable that diarrhea is not apt to occur under 150r and I have not seen purpura in cases whose estimated dose was below 200r. Exertion should be avoided for patients having received over 200r, and complete bed rest is preferable. Those with more severe symptoms should receive broad spectrum antibiotics, transfusions and intravenous feeding.

D. Doses under 150r. Very little of significance besides some weakness, transient vomiting and malaise may be noted. There may be a transient leukocytosis followed by slight leukopenia. Purpura would not be expected.

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Severe diarrhea would not be expected. Only rest for several days and symptomatic treatment is indicated.

2. Localized Radiation

Localized radiation may be brought about by partial shielding from external penetrating sources, by radiation from poorly penetrating radiation, from external sources, and from radioisotopes with a tendency to fairly specific localization, and from fallout.

The chief acute problem in localized radiation is damage to the skin, eyes or mucous membrane. The lesions due to exposure of a portion of the body with shielding of the rest are essentially the same as occur in localized irradiation as used therapeutically. In general, the treatment of the cutaneous manifestations is purely symptomatic. In general, the lesions resulting from poorly penetrating radiation are restricted to the skin. These injuries are difficult to assess, ordinarily become apparent first through mild blistering followed by some tenderness or localized purpuric manifestations going on to varying degrees of necrosis of tissue. In these cases much time will be saved by prompt debridement and skin grafting as soon as the extent of the injury has become well defined. This may mean a lapse of some days.

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Abstract of Remarks by
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CONFERENCE ON BIOLOGICAL EFFECTS OF ATOMIC WEAPONS
TRIPARTITE EXCHANGE OF INFORMATION UNDER TCP (AREA 2)

held at the

U. S. Atomic Energy Commission
1901 Constitution Ave. N.W.
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Abstract of Remarks by

Commander Eugene P. Cronkite, MC, USN
Naval Medical Research Institute
Bethesda, Maryland

February 17, 1954

BIOLOGICAL BLAST STUDIES INSIDE THE AEC COMMUNAL SHELTERS

The biological air blast studies inside the shelters were performed by the research group of the Lovelace Foundation in Albuquerque, New Mexico under the able direction of Dr. James Roberts.

Air blast studies were performed on three separate shots. These shots will be designated A, B, and C. On shots A and B, the shelters previously described by Mr. Corsbie were used with two different orientations in respect to the towers. On shot A, the ramp looked directly at the tower and on shot B, was perpendicular to the line of site to the tower. On shot C, the modified prototype shelter as previously described by Mr. Corsbie was utilized.

Mongrel dogs were the experimental subjects. The dogs were restrained in harnesses made of half-inch nylon webbing. The animals were suspended by chains and were restrained so that motion would be limited to a few inches in any direction. The animals were oriented either with the side,

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the head, the tail, or the abdomen exposed to the oncoming shock front.

On shots B and C, no air blast injuries were received by the animals.

On shot A, in both of the shelters with the ramps looking at the bomb, definite hemorrhagic lesions were produced. In addition on this shot, some of the mice inside of the aluminum cubes were killed and showed characteristic blast lesions. All of the dogs showed some degree of hemorrhage into the internal ears. The pulmonary lesions were hemorrhagic involving the parenchyma and bronchi. There were no definite rib markings. Blood also was found in the bronchi. There were small hemorrhages on the tricuspid valve and a few hemorrhages into the papillary muscle of the heart. Splenic, omental, and bladder hemorrhages were seen. Some muscular hemorrhages were seen. There was a tendency to correlate the injury to the movement of organs in respect to solid surrounding tissues. There was no evidence of air or fat emboli.

Since the animals survived the initial effects and were killed for pathologic study within 30 hours after the explosion, it is believed the injuries would have been non-fatal.

On shot A, the peak overpressures inside of the shelters varied from 9 to 23 PSI with a sharp pressure rise. The dynamic pressures "Q" rose to about 3 PSI resulting in a loading of greater than 1000 lbs. for an average man. On shot C, the peak overpressures were as high as 40 PSI without any detectable pathologic injury being observed.

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At the present time it is not possible to correlate the injuries received on shot A with peak overpressures. The role of the rise time, dynamic overpressures, and the rapid displacement and rapid deceleration due to the restraining device, remains to be evaluated.

Other studies at previous operations have clearly demonstrated that there is no direct air blast hazard in the open. The limiting factor is clearly tolerance to ionizing and thermal irradiation. In general, with peak overpressures of around 20 PSI, the combined radiation exposure will be in excess of 25,000 rep. In addition, peak overpressures as high as 100 PSI have been observed without the production of any pathologic lesion. In contrast to this, hemorrhagic lesions can be produced in dogs that were partially restrained with peak overpressures as low as 9 PSI in the virtual absence of significant ionizing radiation.

In conclusion, it seems evident that in the open there is no direct air blast hazard since secondary missiles, thermal, and ionizing radiation are vastly more important as casualty producers. However, under shielded conditions, considerable protection is afforded from the primary casualty producing agents and the shielding devices may even accentuate the air blast hazards under specific geometric configurations and orientations, thus making tolerance to blast phenomena the limiting factor in shelter design.

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Abstracts of Remarks by
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Philadelphia

February 17-18, 1954

DYNAMIC VS. STATIC LOADS FOR THE DESIGN OF STRUCTURES

For a long time it has been known that the design of members--even a single, end-supported beam--for a short-time, high-intensity load, that is, a so-called dynamic load, presents difficulties; also, that two such members of different sizes which are designed for the same static, or constant, load will have different strengths under a common dynamic load.

A number of investigators have worked with the problem and have written papers or manuals to indicate how designs should be prepared for already-assumed loads. The methods which have been proposed are necessary steps toward simplification and are useful in the design of structures which, for test purposes, are to be subjected to bomb loads of intensities which can be predicted within reasonable limits.

The methods which are mentioned above are not easy reading. Nor are they brief. Furthermore, a guess would be that a design made in

accordance with them would require ten to twenty times as long as a design made by following a conventional building code. In short, they are not ready to be handed to the persons who are now the workers in design offices. These persons are accustomed to using static loads and, of necessity, under present conditions the loads must be stated as static loads before a design can be made.

The Atomic Energy Commission, through the Engineering Branch of its Division of Construction and Supply, has met the problem by issuing "Design Criteria for Protective Construction," which recently have been declassified. Depending upon criticality, structures are divided into three classes. Based on extended study, different static loads are specified for different parts of structures. Also, allowable stresses are permitted to exceed usual values.

Of equal or greater importance to loads and stresses are the selection of the right methods of construction and proper building materials. As examples, a high degree of continuity should be incorporated into the frame of a structure; and walls should be made either light weight and friable, or heavy and monolithic, not made of heavy, weakly-jointed blocks. Proper selection of methods and materials will minimize the hazards to personnel and the damage to structures.

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Abstract of Remarks by
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Abstract of Remarks by
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Division of Biology and Medicine
U. S. Atomic Energy Commission
Washington, D. C.

February 17, 1954

REFLECTIONS AND REINFORCEMENTS OF
PRESSURE FRONTS WITHIN STRUCTURES

Following a survey to assess AEC installations in terms of criticality and vulnerability and to estimate minimum equipment, services, and shelters required to sustain production and protect workers under enemy attack, a prototype group shelter, comprising basic elements was tested. Because of cost, simplicity of design, and control of access under emergency conditions, the investigations were initiated under a "no doors" policy. The structure was a 48-foot long, 90-inch inside diameter, combination concrete and steel pipe shelter placed three feet underground, with the principal axis perpendicular to a line from the point of burst and with double ramps provided at each end.

The structure was tested under a variety of peak overpressures, ranging from 6 to 25 psi. From the evaluated data obtained in the test, it was concluded that a design modified to include vestibules would be potentially capable of providing protection against the effects hazards associated with a burst of a 20-KT weapon, 2,000 feet distant.

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Also, it was concluded that prior to further field investigations, experiments should be performed using techniques unique to shock tube investigations to obtain information on the usefulness of blast traps and structural configurations in reducing shock fronts in shelters and in prolonging the duration of the rise time. Accordingly, a model shelter was constructed of 1/4-inch steel, at a scale of 1/2 inch to the foot, and was attached to the side of a large shock tube, where it was subjected to incident shock waves of about 18 psi.

The results of the shock tube test indicated that the model, as designed, would effect a 70 per cent reduction in the shock front and prolong the duration of rise time to peak pressures somewhat higher than the incident pressure.

Through modifications of the ramp and vestibule designs, the shock front was almost eliminated, and the peak pressures brought down to about incident pressure.

Based largely on the results of the laboratory work, two shelters were designed and field-tested under conditions of two detonations at the Nevada Proving Grounds. The ramps and vestibules were similar to those of the models, and the seating chamber was of 90-inch inside diameter concrete pipe or corrugated metal pipe. Both shelters were placed three feet below ground level. The records obtained at these tests provided a means of identifying important pressure waves, determining the origin, and tracing the progress throughout the structures. In addition, the data distinguish

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between ideal shock waves having a rise time of less than 1 millisecond and rapid pressure rises of greater duration.

From the measurements, it was concluded that the incident pressure waves in the ramp were not ideal shock waves. A record was obtained of the deflection of the initial wave through the entrances and blast traps, or vestibules, into the seating chambers; the attenuation at the doorways; the amplification of the incident waves by reflection; the behavior of the waves traversing the seating chamber; the end reflections and how they were created. The structures were exposed to peak pressures of 13 psi and 8 psi approximately for Shots I and II respectively. Maximum peak pressures in the seating chamber were 20 psi and 13 psi respectively. These pressures, under the conditions of the detonations, were too low to give significant structural loadings, or to produce structural damage.

In addition to testing two group shelters, the prototype structure, tested in previous operations, was again used in more recent tests. In the intervening time since the first test, the structure had been subjected to more than ten detonations. Although there had been no repair or housekeeping between detonations, the structure was suitable for additional testing, requiring only the removal of debris and repair of concrete struts separating the concrete ramp walls. For this test, a sandbag closure was located 8 feet inside the open concrete ramp, and the steel ramp at the opposite end was completely closed. Through closing one ramp and blocking the end of the 48-foot long chamber near the opposite end, there were

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expectations of obtaining data of value in the design of shelters without doors.

Under an incident pressure of about 40 psi, the sandbag closure was dispersed by the entry, through small openings, of high-velocity jets of the shock front, and the results were not satisfactory. The structural damage from the 40 psi incident pressure, however, was limited largely to spalled concrete and structural damage to the recently replaced concrete struts. No significant increase in damage was observable in either the concrete or steel sections of the seating chamber.

FUNCTIONAL AND ENGINEERING ASPECTS OF SHELTER DESIGN

From laboratory studies, field tests, and other sources, it is known that labyrinths and configurations can reduce or eliminate shock fronts entering a structure. The biological significance of eliminating the discontinuous pressure rise, characterized by a shock front, and producing instead a rise time of prolonged duration, is not well understood. An overpressure of oscillating characteristics introduces additional complexities. The foregoing remarks apply specifically to atmospheric overpressures. However, it must be recognized that peak pressures may not be the criterion of damage, and that dynamic pressures or wind drag resulting from structural configurations may give as much, or more, damage inside shelters without doors than is given by the atmospheric overpressures.

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In structures 601 and 602, wind velocities reached and exceeded the sonic range, developing forces on various objects of such magnitude as to cause damage. The relative importance of static and dynamic pressures on both biological and structural systems needs further investigation.

As guides to those concerned with future thinking on shelters, there now exist useful data on blast phenomena and behavior of shock fronts. In summary, these data include, but are not limited to (1) arrangements of orifices, volumes, and configurations to reduce or eliminate shock fronts; (2) arrangements of baffles and blast traps to deform pressure waves; (3) materials and combinations of materials and arrangements to absorb energy of blast reflection; (4) doors, baffles and special fittings to minimize the violence of high-velocity jet pressures.

Construction materials, techniques of design, and methods of construction are adequate to meet the design needs. Further study is required on: (1) shelter capacity, (2) criteria for design, (3) access, (4) length of stay in shelter, (5) doors versus no doors, (6) air contamination, (7) shelter fittings and furnishings.

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Abstract of Remarks by
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Washington, D. C.

February 18, 1954

AGRICULTURAL CONTAMINATION

Fallout material from atomic detonation may constitute a hazard from external contamination of food crops, movement into soils and uptake by plants, and the consumption of such plants by animals or directly by man. Heavy fallout that may constitute a hazard is likely to be restricted to within a few miles of the site of detonation. Of the fission products strontium appears to be most readily taken up by plants and animals.

Strontium 89 having a half-life of 54 days will make up essentially all of the radioactivity taken up by plants during the first few months after a detonation. Strontium 90 will begin to constitute a significant per cent of the residual gross fission product radioactivity only after several months or a year.

The uptake from various soil types of radioactivity from fallout material has been studied using several different soil types. The activity in barley, bean plants, tomatoes, and radishes per gram of dry material was found to be approximately 2.0% of the amount present per gram of soil.

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There is a number of factors that affect the uptake by plants of strontium from the soil. The uptake of strontium is inversely proportional to the level of exchangeable calcium in the soil. Acid soils with a high percentage of the calcium present in the exchangeable calcium in the soil. Acid soils with a high percentage of the calcium present in the exchangeable form take up strontium more readily than alkaline soils of the more arid sections of the country. This suggests the possibility of limiting the uptake of radiostrontium by the heavy application of limestone or other calcium materials. Actual studies on this will be initiated during the current year.

Rubidium 86 and cesium 137 were not detected in plants grown on soil that had been contaminated with fallout material.

In animals strontium is metabolized in much the same manner as calcium. Nearly all of the strontium deposited in the body will be in the skeleton. Strontium that is given orally to milch cows will be excreted in the feces and urine, and secreted into the milk. It is apparent that the most concern would be the radioactive strontium in the milk. Experiments have shown that from 10 to 14 per cent of ingested strontium may be secreted into the milk. The corresponding secretion of yttrium into milk is about 1.5 per cent which is much lower than for strontium.