HEALTH ASPECTS
OF
NUCLEAR WEAPONS TESTING

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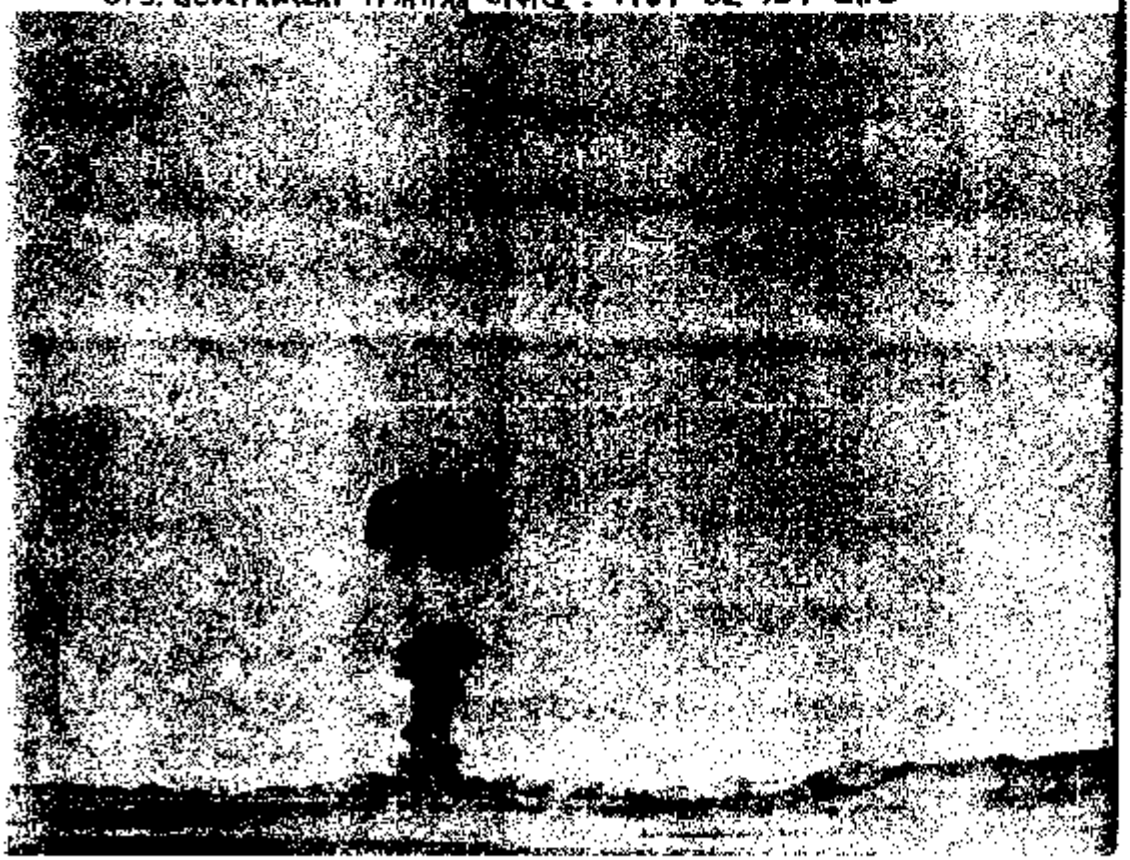

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FOR
HEALTH ASPECTS OF NUCLEAR WEAPONS TESTING

❶ Page 34 - Substitute Figure 9

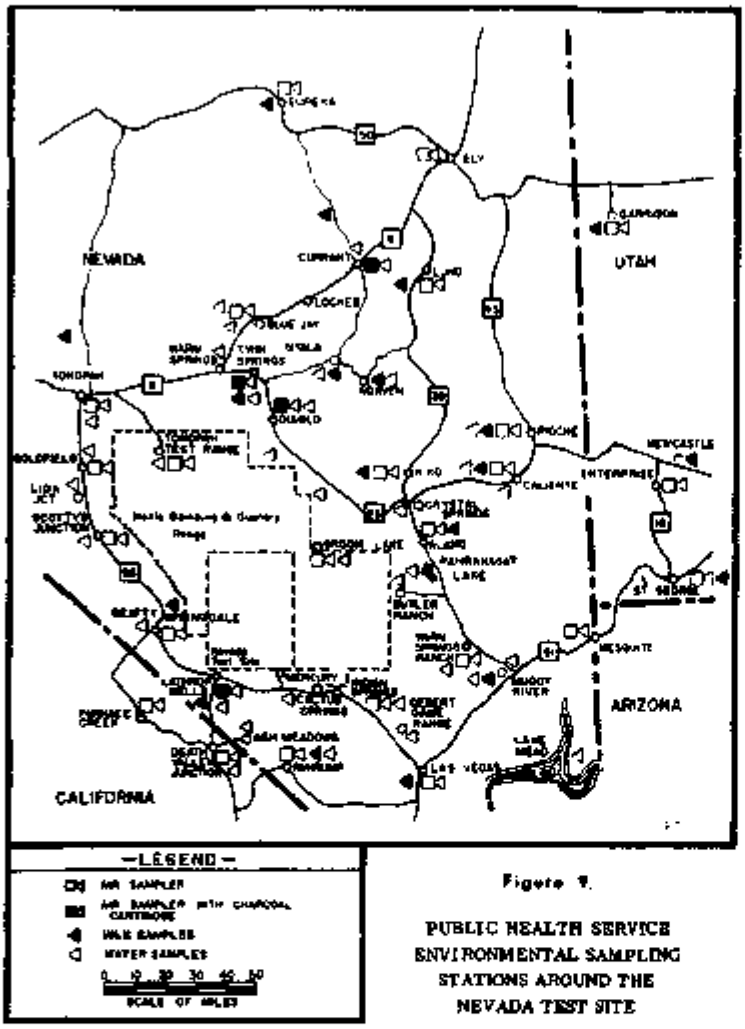

Figure 9.

PUBLIC HEALTH SERVICE
ENVIRONMENTAL SAMPLING
STATIONS AROUND THE
NEVADA TEST SITE

❷ Page 46, Line 22 - Substitute "35 nuclear detonations"
for 34 nuclear detonations

❸ Page 56 - Change reference 29 to reference 30
Change reference 30 to reference 29

PREFACE

The signing of the Limited Test Ban Treaty in September 1963 marked the close of 14 years of atmospheric nuclear weapons testing spread over an 18-year period. However, it did not mark the end of a need for further information and interpretation of data concerning the health aspects of nuclear weapons testing.

This pamphlet is concerned principally with the health aspects of nuclear weapons testing in the atmosphere. Nothing new is contained herein and much has been omitted for brevity. The pamphlet does attempt to bring together the highlights of a large body of information and thus in some small way may assist in further enlightenment of a complex subject.

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INTRODUCTION

Fallout from nuclear weapons tests has been by far the principal man-made source of radioactive environmental contamination. About 340 nuclear detonations in the atmosphere, by all nations testing, have been announced. The total energy release has been about 511 million tons (MT) equivalent of TNT with the U.S.S.R. tests accounting for about 70 percent of the total.[1] Included in this total is about 193 million tons of energy released by fission—the process that creates the radioactive fission products present in fallout.[1] Two hundred million tons of TNT energy equivalent would produce about 12 tons, by weight, of fission product debris.

The discussion that follows in section I attempts to summarize an enormous amount of data and to present some evaluation of the estimated radiation exposures to persons from radioactive fallout. Section II deals with other health aspects of nuclear weapons testing.

The information presented herein is intended to provide some answers to three basic questions concerning the testing of nuclear weapons:

1. What are the problems and possible risks associated with nuclear weapons testing?
2. What are the data concerning effects from past tests?
3. What do these data mean—how serious are the possible risks?

With these three questions in mind, the information for each health aspect—such as whole body exposures—is presented under three subheadings, i.e., Background Information, The Data, and Evaluations.

LOCATIONS of NUCLEAR WEAPONS TEST SITES

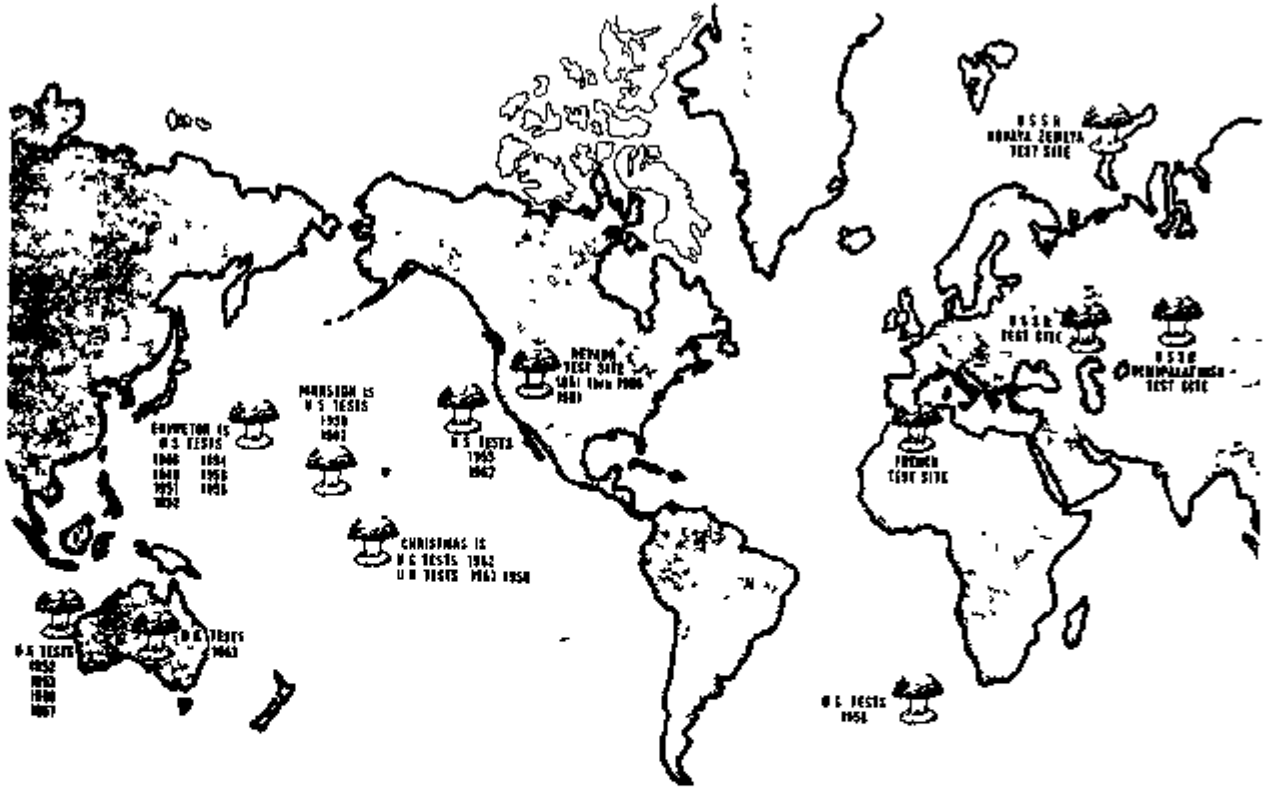


FIGURE 1

SECTION I.

RADIATIONS

A. GENERAL BACKGROUND INFORMATION

1. Natural Background and Medical Exposures

As far as is known, man always has and always will live in an environment filled with nuclear radiation. There are radioactive materials present naturally in the ground, the sea, and in the air. Cosmic rays bombard us from outer space. Naturally occurring radioactive materials in our food supply irradiate us from within.

To these levels of radiation exposures are now added those from fallout—but these radiations (gamma rays and beta particles) are no different in kind from those emanating from natural sources. Nor is there any evidence that they produce any fundamentally different biological effects. The radiations from natural sources and from medical, industrial, and scientific uses of radioisotopes and X-ray machines, and their biological effects, have been studied intensively for many years.

To repeat, radiation exposures from fallout are in addition to those from natural sources but they are just that—additions of more of the same type of radiation. Fallout has not introduced a new and strange agent into our environment with completely unpredictable results. Indeed, a Committee of the National Academy of Sciences-National Research Council has stated: " . . . Despite the existing gaps in our knowledge, it is abundantly clear that radiation is by far the best understood environmental hazard . . ."[2]

TABLE 1.—Radiation Exposures from Natural Background and Medical Sources

	Roentgens
Natural Background (annual exposures)	
Total	0.086–0.20
Gamma rays (from terrestrial sources) and cosmic rays	0.1 (varies).
Potassium 40 (internal)	0.018 (varies).
Carbon 14	0.001
Medical Exposures	
Chest X-ray (per exposure)	0.2
Back X-ray (per exposure)	0.4
Photofluorogram (per exposure) about	0.5–2.0
Gastro-intestinal series about	30.

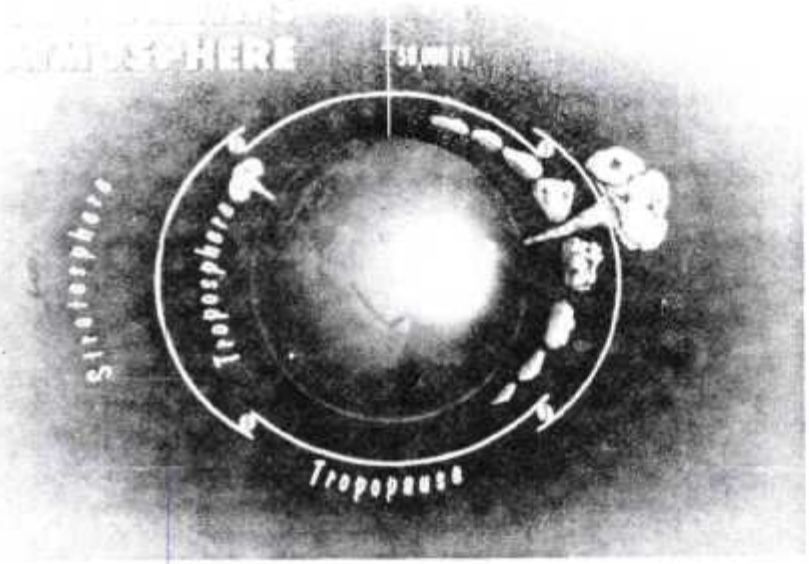
Various units have been used to express exposure to radiation such as the roentgen, rep, rem, and rad. All are intended to express some relationship between the radiation energy absorbed and biological effects. Since it is not critical for the following discussions to understand the technical differences among the units, only the "roentgen" will be used. To provide some perspective as to the magnitude of the "roentgen" table I is included.

2. Sources and Nature of Fallout

The major source of radioactive materials in fallout is the fissioning or splitting of atoms of uranium and plutonium that gives rise to a large number of unstable radioisotopes. In the fusion process hydrogen nuclei are joined together. Induced radioactive products result when inert materials capture neutrons that are released during either the fission or fusion process. Generally, these induced radioactive materials are relatively short-lived and contribute only in a minor way to radiation exposures to man. The principal exception is carbon 14 described in section I F (page 16).

Some of these radioactive materials escape as gases and are dispersed and diluted in the atmosphere. Most of the fission products, however, become incorporated into or attached onto minute inert particles of dust and debris from the immediate environment of the bomb. The dust particles, together with the associated radioactive nuclides, are swept high into the air by the heat and force of the nuclear explosion. The larger particles and those in the lower levels of the cloud fall nearby. Smaller particles in the upper levels are carried away to be spread worldwide. The worldwide distribution of these radioactive particles follows the same pattern as would occur with any other small particles injected into the same regions of the atmosphere—radioactivity has essentially no effect on the pattern of distribution.

Roughly, a nuclear detonation of one-half million tons or less, fired at a low altitude—but high enough so the fireball does not intersect the ground—results in most of the fission products remaining in the lower atmosphere, the troposphere. They are deposited on the earth's surface at a rate such that one-half of the amount remaining in the atmosphere at any one time falls in 2–4 weeks (called tropospheric residence half-time). As the energy yields of the nuclear detonations increase, more and more of the fission products are swept higher and higher into the stratosphere—the layer above the troposphere (fig. 2). The residence half-time here is more like one-half a year for injection into the lower stratosphere in the polar



U.S. WEATHER BUREAU PHOTO

FIGURE 2.—Generalized drawing of the earth's atmosphere.

regions and one year or somewhat less at the equator. Radioactive debris from nuclear detonations occurring at very high altitudes (about 30 miles and higher) may have a residence half-time of five years or more.

Roughly two-thirds of the radioactive particulate debris injected into the lower stratosphere at the north polar regions has been observed to fall in the 30°–60° North latitude zone, where about 80 percent of the world's population live. Injection at the equatorial regions has been observed to result in a more even distribution between the two hemispheres.

For surface bursts of high (million ton range) yield about 50–80 percent of the radioactive debris is deposited as "early fallout," i.e., within 24 hours. Air bursts—where the fireball does not approach the surface—result in little, if any, local fallout.

Table 2 tabulates some of the key data on estimated nuclear energy yields from all past nuclear weapons tests. Of the total energy released of 511 million tons equivalent of TNT about 70

TABLE 2.—Estimates of Yields from All Nuclear Weapons Tests

	USSR	*US and UK*	*Total*†
Total million tons*	350	161	511
Fission million tons	111	82	193
Fission million tons scattered globally	110	51	161

*TNT equivalent.

†The French tests have contributed only small amounts.

percent resulted from U.S.S.R. tests. This total energy release is of use in estimating the amount of carbon 14 produced. Incidentally, it is assumed that the carbon ^{14} is distributed more or less uniformly around the world.

Table 2 also shows that of the 193 million tons energy equivalent releasing fission products, about 161 million tons were scattered globally.[3] Approximately two-thirds of this amount originated from U.S.S.R. tests but will account for about three-quarters of the long-term fallout in the United States because of meteorological factors. This is because there will be more deposition in the North Temperate Zone from a nuclear detonation in the lower atmosphere at a northerly latitude than from the same shot at an equatorial site. Atmospheric tests at the Nevada Test Site have contributed very little to the deposition of long-lived radioisotopes but at times have been the source of relatively high amounts of short-lived radioactive materials including iodine 131 in the local environment.

At the time of a nuclear detonation something like 200 different radioactive substances are formed by fission. Additional ones are created by induced activity. Although these materials emit only radiations with which we are already familiar—gamma rays and beta particles—it appears at first glance to be almost an impossible task to consider them individually and in the aggregate for an appraisal of their health hazard. Fortunately, for an analysis of the problem, most of the radionuclides are of little health consequences because of their short radioactive half-lives or other characteristics such as being highly insoluble. In fact, it is possible to estimate the radiation doses to various organs of the body by considering only five principal radionuclides in fallout that are deposited internally, i.e., iodine 131, strontium 90, strontium 89, cesium 137 and carbon 14. To these internal doses there must be added those to the whole body due to the radiations from fallout material outside the body. The problem of estimating these latter radiation doses is again simplified by considering first cesium 137 and then lumping all of the remaining radionuclides together in the calculations.

B. WHOLE BODY EXPOSURES

Background Information

Fallout particles consisting of inert materials together with the associated radioactive materials settle to the earth's surface where most of them remain and thus never get inside our bodies. These external, man-made radionuclides, however, will irradiate the whole body by their penetrating gamma

radiations while their shorter range beta particles will contribute a much less biologically significant exposure to the skin.

Of the radionuclides that contribute to external radiation, the most important single one is cesium 137. Its radioactive half-life is approximately 30 years. Thus, it is possible for cesium 137 to remain in our environment for long periods of time without losing much of its activity, although there can be loss or reduction in availability of the material through normal weathering processes. Still cesium 137 does have a short enough life so that most of the radiations are released within the lifetime of a man.

All radioactive materials in fallout, except cesium 137, which remain outside the body may be conveniently lumped together to estimate their contribution to external exposures. These usually are called "short-lived" even though some do have half-lives of upwards of one year. In spite of the fact that nearly all of the radiation exposure received from these short-lived radionuclides is completed within a year after the radionuclides are created the total amount of exposure during the year may be greater than that received from cesium 137 within 30 years.

Cesium 137 also is one of the two (carbon 14 is the other) principal radionuclides deposited internally that irradiate the whole body. It is not a major source of the total whole radiation dose except in such cases as that of Eskimos whose diet is largely caribou or reindeer meat. The food chain (lichen-caribou-Eskimo) reflects the relatively high surface contamination of cesium 137 on the lichens.

The Data

The highest whole body exposures from nuclear weapons tests ever reported by the United States were about 175 roentgens to 64 Marshallese following the March 1, 1954 surface nuclear test detonation at the Pacific Proving Ground.[4] This situation resulted from a shifting of the winds so that the local heavy fallout from this large yield surface burst occurred, in part, across the islands instead of the open sea.

The Marshallese were evacuated, given medical treatment and returned to their home island of Rongelap on June 29, 1957 after radiation levels had subsided to acceptable levels[5] (fig. 3). From 1956 to 1962 about 24 children have been born—all normal—and four persons have died from natural causes.[6] (One of these had been on another island and received 69 roentgens exposure.) Four deaths have occurred in the comparison population of like size. There were, of course, noticeable effects immediately after the irradiation such as nausea and

HOLMES AND HARVEY PHOTO

FIGURE 3.—Rongelapese returned to their home island June 1957. Structures were newly built by the U.S. Government.

itching of the skin (see section on Skin Exposure below, section I C page 8).

Also, there were definite changes in levels of blood constituents for months afterwards. The Marshallese have been examined by a team of physicians yearly and to the present time no statistical differences have appeared between them and the "control" group for such factors as birth and death rates, life-shortening, leukemia, cataracts or cardiovascular, arthritic, ophthalmic, or dental defects. There may be a suggestion of greater incidence of miscarriages and stillbirths and more recent data indicate that there may be a lag in growth and development of the children, but the paucity of vital statistics and the small number of persons involved preclude a determination.

It was reported by the Japanese that some fishermen aboard a vessel near the Pacific Proving Ground on the same date may have received a higher exposure than the Marshallese.[7] One of these fishermen died on September 23, 1954 of a liver disorder complicated by the development of jaundice and pneumonia.[8]

The highest estimated exposure to any individual near the Nevada Test Site was 13.5 roentgens and the next highest 10.5 roentgens. The highest estimated exposure to any com-

munity was about 6 roentgens. There were about 30 persons who received exposures between 6 and 10.5 roentgens. All of the above radiation doses are accumulated doses since the Nevada Test Site opened in 1951.[9]

Having delineated these highest exposures it is proper to discuss "average" exposures since these have relevance for evaluating possible genetic effects. The average whole body exposure to persons in the United States (to be accumulated over 30 years) from all past nuclear detonation tests of United States, United Kingdom and U.S.S.R. (the French tests contributed very little) has been estimated to be 110 milliroentgens* (0.11 roentgens).[1] Somewhat over one-half of this exposure will result from radioactive fallout materials outside the body. The remainder is due to carbon 14 and cesium 137 deposited internally following ingestion (inhalation contributes negligible amounts).

In the case of the Eskimos, the highest measured amount of externally deposited cesium 137 in any individual was in June 1963.[10] This highest quantity of cesium 137 would produce a dose *rate* of about 190 milliroentgens (0.19 roentgen) per year at the time of measurement. The highest average for any group (Anaktwvuk Pass, Alaska) was about one-half of this value. Since cesium 137 contamination of the lichens is a surface phenomenon—very little is taken up from the soil—and the normal biological time to remove half of any remaining cesium activity in the body is only about 100 days or possibly less, the annual dose should drop off in 1964–65.

Evaluation

A whole body exposure of 175 roentgens (Marshallese experience in 1954) is far in excess of an acceptable exposure. As contrasted with the surface bursts in 1954, the 1962 U.S. tests in the Pacific were bursts in the air high enough above the surface to eliminate measurable local fallout.

Only a few individuals have exceeded by small amounts the criterion of 10 roentgens in 10 years established for the Nevada Test Site.

The whole body average population 30 year exposure of 110 milliroentgens (0.11 roentgen) is about three percent of that from natural sources. The *difference* in natural background radiation levels at various localities in the United States can be much greater than all of the whole body exposure from fallout.

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*A milliroentgen is 1/1000 of a roentgen.

C. SKIN EXPOSURES

Background Information

Radioactive fallout debris emits beta particles some of which emerge from fallout material with sufficient range in air to reach from the ground to the head of an erect man. However, in human tissue the range of these beta particles is limited principally to a very small fraction of an inch so that only the skin is irradiated when fallout debris is outside the body. Further, there has been no observed skin damage except from relatively heavy fallout where the radioactive fallout material has remained in direct contact with the bare skin. Even a single layer of cotton clothing apparently greatly reduces the radiation dose from beta particles.

Approximately a 500 roentgen dose delivered by beta particles from fallout debris to the base of the outer layer of the skin tissue is required to produce erythema (reddening of the

FIGURE 4a.—Highly radioactive fallout material remained in contact with the feet causing severe skin damage—28 days after initial contamination.

FIGURE 4b.—Same case six months later. Damage healed with normal pigmentation except for small spots marking the areas of more severe damage.

skin). A similar result from X-rays would require less radiation dose. At somewhat higher doses from beta particles emitted by fallout debris epilation (loss of hair) may occur. At still higher doses more serious skin damage may be expected with such symptoms as ulceration.

The Data

Skin damage from beta burns was first observed on some cattle grazing near the Alamogordo, New Mexico Test Site following the first nuclear detonation on July 16, 1945. Epilation was observed in patches where the fallout debris had supposedly remained in place. The hair grew back, white in color, and no other adverse effects have been observed in the cattle or their offsprings.

Other "beta burns" have been observed on a few cattle in 1952, on horses in 1953, and one horse in 1955 in Nevada. All of these, as well as the Alamogordo cattle were grazing within

20 miles of ground zero where there was relatively heavy local fallout from the bursts occurring on towers. Crude estimates suggest that the external whole body exposures in these same areas would have been in excess of 75 roentgens from gamma rays.[11]

The principal example of skin damage was in the case of the Marshallese people following the heavy fallout on March 1, 1954.[4] The most damaged areas were (a) in the regions of hair on the head (oiled), (b) folds of the moist bare skin such as the neck region and inner elbow, and (c) tops of the feet where the fallout material remained in place (figs. 4a and 4b). The extent of skin damage to the most heavily exposed group may be summarized as follows.

	45 individuals	superficial lesions
	13 individuals	deep lesions
	6 individuals	no lesions
Total	64	
	35 individuals (of the 64 above)	some degree of epilation

Hair of normal color and texture has regrown and all lesions have healed without visible effects except for permanent loss of pigment in the healed areas in individuals and some scar tissue behind the ear of one man, marking the location of a previous deep lesion.

Additional cases of skin damage from fallout were observed on some Japanese fishermen aboard the Fukuryu Maru and some American service personnel on the island of Rongerik, as a result of the March 1, 1954 fallout. Also, four men in charge of handling "hot" filters from monitoring aircraft at the Pacific Testing Site in 1948 received severe beta burns on the hands. One additional case was an Air Force officer in charge of transportation of radioactive samples from the Pacific Proving Ground to the United States in 1951. A lesion developed on his forehead and right eyebrow region. The damaged area showed normal repair processes but the previously black hair of the eyebrow was replaced by white hair upon regrowth.[12]

There have been no known cases of human beta burns at or around the Nevada Test Site.

Evaluation

Serious skin damage can result if highly radioactive fallout remains in direct contact with the skin. Simple measures such as washing can be very effective in reducing this hazard—the sooner the better. Skin damage has not been observed except

in those areas where the amount of fallout was high, i.e., possibly over 75 roentgens whole body dose from the gamma radiation with most of this exposure occurring in the first few days. Thus, the potential hazard of skin burns may be essentially eliminated by meeting the criteria of an acceptable whole body exposure. Of course, by evacuation from a highly contaminated area it is possible to reduce drastically whole body exposure, yet a relatively high skin dose could accumulate if the fallout materials were not removed early.

D. IODINE 131

Background Information

Approximately 0.15 million curie (a "curie" corresponds to 2.2 million million disintegrations of nuclei per minute) of iodine 131 are produced for each kiloton TNT equivalent of energy released by fission. For large yield airbursts most of the iodine 131 along with other radioactive materials will be swept into the upper atmosphere (stratosphere) and, since iodine 131 has a half-life of only eight days, a large part of its activity will decay before being deposited on the earth. On the other hand, iodine 131 that remains in the lower atmosphere, the troposphere, will be deposited relatively quickly and can enter the food chain.

Milk is the principal route of entry of iodine 131 into the human body where it is selectively deposited in the thyroid gland. The assumption is usually made that 30 percent of iodine 131 ingested by humans is deposited in the thyroid no matter what the size of this organ may be.[13] Thus, an infant's thyroid gland of about two grams weight would receive 10 times more radiation dose than the 20 gram adult's thyroid for the same amount of iodine 131 ingested. For this reason calculations of radiation doses from iodine 131 for the general population are based on those for the infant rather than the adult.

Direct measurements of iodine 131 in milk were not made around the Nevada Test Site during earlier times of testing since it was the consensus of scientists within and outside the AEC and Government at that time that the limiting factor was the potential external whole body exposure. It is now recognized that there can be situations where the iodine 131 exposure can be more limiting. An example of this was the Smallboy surface shot on July 14, 1962 at the Nevada Test Site. The detonation was large enough to produce significant quantities of iodine 131 but due to its low energy yield the activity was not swept to high altitudes to be carried away,

PASTEURIZED MILK AREA SAMPLING STATIONS

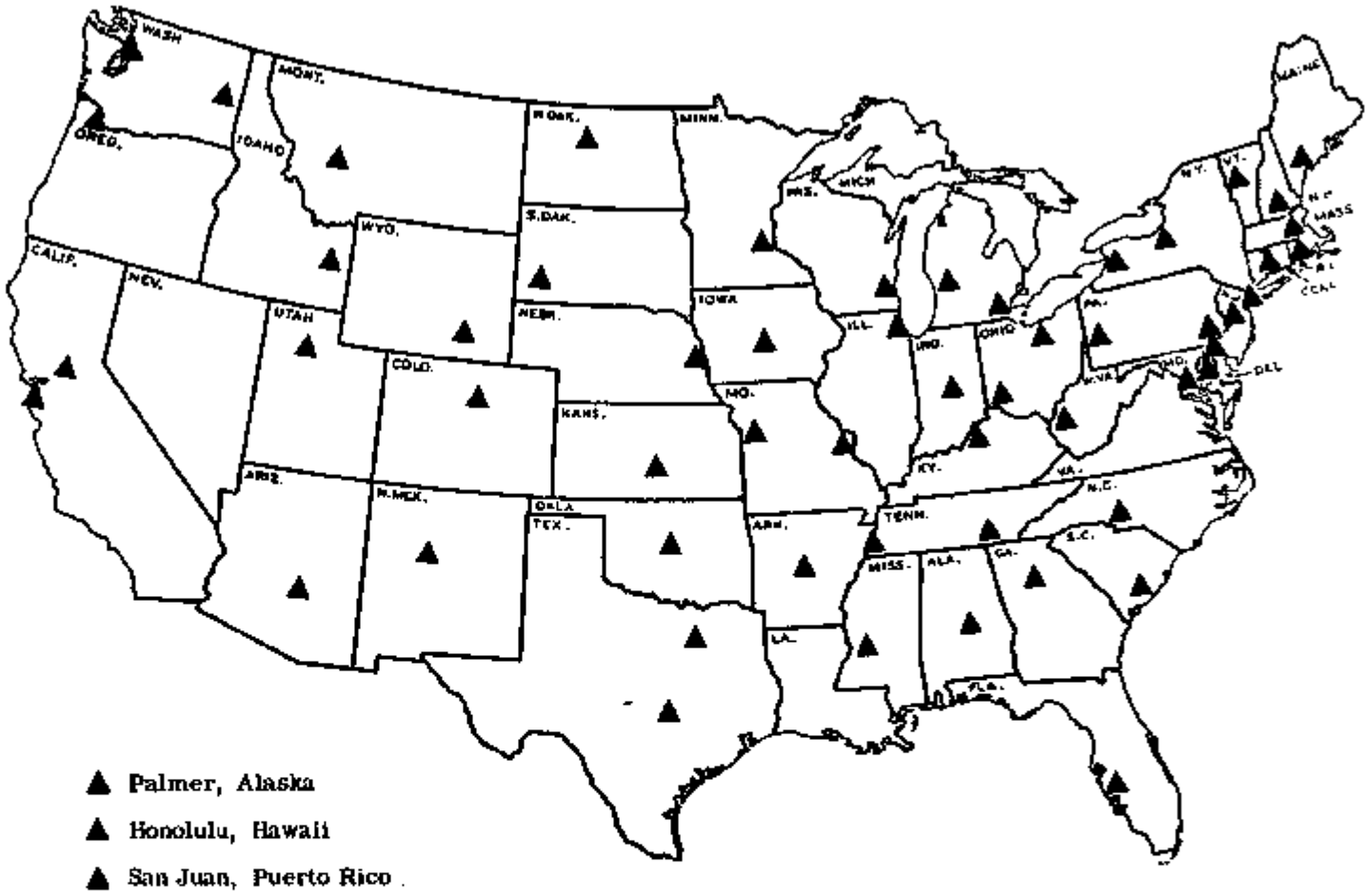

FIGURE 5.—U.S. Public Health Service National Milk Network.

diffused and diluted as had occurred for larger bursts in the atmosphere.

The Data

The highest annual average value of iodine 131 measured in milk by the Public Health Service national network (fig. 5) at any time was at St. Louis, Mo., for the period of August 1957 through July 1958.[14] The calculated average dose was 1.5 roentgens to infants' thyroids based on the usual assumption of each drinking one liter of milk per day – the dose to an adult thyroid would be only about 1/10 as much. The next highest calculated total average dose was 0.69 roentgen at Palmer, Alaska (October 1961 through September 1962), and the third highest was 0.63 roentgen for Salt Lake City, Utah (September 1961 through August 1962). Because of the unevenness of the iodine deposition near the Nevada Test Site it is possible that small local areas might show values 10 times or so greater than the average for the general region. It is also probable that higher levels of iodine 131 than these existed in local areas around the Nevada Test Site during periods of heavy testing in the 1950s.

The above estimated doses to the thyroid involve some uncertainties in their determination but are based on some observed iodine 131 levels in milk samples. Theoretical calculations of thyroid doses have been attempted, based on other types of radiation monitoring such as collection of radioactive particulates in the air or measurements of radiation at three feet above the ground from deposited fallout. To date, all of these methods suffer severe uncertainties. These monitoring procedures, equipment and data are useful for the purposes for which they were intended. The difficulty is in attempting to use one type to predict another in a quantitative way.

Evaluation

All of the above calculated thyroid radiation doses may be placed in perspective by reference to quoting from a National Academy of Sciences report.[15]

In describing the therapeutic use of iodine 131 in the treatment of hyperthyroidism, the report stated:

> ". . . There is no evidence at hand, except for one doubtful case in a child, that any of the treatments for hyperthyroidism has produced a thyroid cancer, although doses have ranged from a few thousand rad (roentgens) upward . . ."

There can be circumstances where levels of iodine 131 in milk can be a more controlling factor than external gamma expo-

U S PUBLIC HEALTH SERVICE DIVISION OF RADIOLOGICAL HEALTH PHOTO

FIGURE 6.—Counting a sample of milk for iodine 131 The procedure is quick and simple—the milk is merely poured into a plastic container and set into the counter. In contrast, analysis of milk for strontium 90 may require weeks including radiochemical preparation of the sample.

sures that have hitherto been considered of prime interest for local fallout. However, the total potential doses that may be accrued will require the drinking of the milk over periods of weeks. Up-to-date techniques and equipment now permit a relatively easy and early surveillance of iodine 131 in the milk supply providing an opportunity for whatever action may be appropriate (Figure 6).

E. STRONTIUM 90 AND STRONTIUM 89

Background Information

Strontium 90 has a half-life of about 28 years. It is selectively deposited in the bones. Chemically it is related to calcium. This similarity has led to the use of the "strontium unit" defined as one picocurie (2.2 disintegrations per minute) of strontium 90 per gram of calcium.

Strontium 90 may become associated with foodstuffs by surface contamination of plants or by uptake of the strontium

90 from the soil. During years of relatively heavy fallout, surface contamination has accounted for the larger part of the strontium activity in plants but in the absence of atmospheric nuclear testing the avenue of soil uptake predominates. The periods showing the highest amount of strontium 90 in the food supply have been invariably the spring and summer months following years of heaviest testing. This is because of meteorological factors and also the fact that surface contamination contributes more to the total strontium 90 activity found in plant life than does soil uptake during these periods. (Incidentally, the cesium 137 content of plant life is even more dependent on surface contamination since only very small amounts are taken up from the soil.) Areas of heavier rainfall consistently show higher levels of strontium 90.

Milk is one of the best indicators of strontium 90 in the food supply, yet at the same time it is one of the better sources of calcium. Remember it is not just the amount of strontium 90 that is important but also how much there is present in relation to calcium. In fact the total diet has had roughly 1.5 times as great a strontium 90/calcium ratio as did milk alone.[16]

Strontium 89 has the same chemical properties as strontium 90 and will follow the same metabolic paths. It is created in much larger quantities than strontium 90 but produces less of a problem since it has a shorter half-life (53 days) and emits beta particles with about one-half the energy of those from strontium 90 and its daughter product. For these reasons the strontium 89 content in milk may peak at values many times that of strontium 90 during the periods immediately following nuclear tests, yet the total radiation dose to the bone over a lifetime from strontium 89 may be only one-quarter or less than that of strontium 90.[1]

The Data

About 20 million curies of strontium 90 have been created by atmospheric nuclear tests with about 17 million curies of this being spread globally. The other 3 million curies fell quickly in areas local to the testing sites. To date, roughly 8–9 million curies of strontium 90 have been deposited globally, leaving a calculated 6 million curies in the region of the atmosphere below 100,000 feet (based on measurements using aircraft and balloons)[17] with some additional amounts above this level. The discrepancy in total numbers is due in part to radiological decay of strontium 90 but more because of uncertainties in the estimates themselves.

As expected, the peak value of "strontium units" in milk was passed in June of 1963 (32 "strontium units" as a national

average).[18] In the absence of atmospheric tests these levels are expected to continue to decline generally except for small transitory rises during the next few spring seasons. The annual (1963) national average for those areas of the United States showing the highest values was 26 "strontium units" in milk. This is less than the 32 "strontium units" predicted and should foretell less in the bones than predicted.[1] Incidentally, the amount of strontium 90 in the milk produced around the Nevada Test Site is among the lowest in the country.

In general, past predictions of levels of strontium 90 in bones have been too high. This is due in part to the selection of data in the upper ranges to avoid underestimations of radiation exposure. Even so, it is remarkable that the observed amounts of strontium 90 in bones have been within about a factor of two of the predicted amounts considering the fact that such predictions require the application of many scientific disciplines—nuclear physics, meteorology, chemistry, plant and animal physiology, etc.—often to new situations.

That segment of the U.S. population whose bones will receive the highest radiation dose are children born in 1963 in regions of heavier rainfall. The total radiation exposure to these children—from internally deposited as well as external radionuclides—has been predicted to be about 465 milliroentgens (0.465 roentgen) accumulated over a 70-year period.[1]

Evaluation

The predicted average 70-year radiation dose to the bones of the age group receiving the highest exposure from all past tests—about 465 milliroentgens (0.465 roentgen) from all radioactive materials within and outside the body—is about five percent of the bone dose received during the same 70-year period from natural background sources.

F. CARBON 14

Background Information

Carbon 14 is produced naturally by interaction of cosmic rays with the nitrogen in the atmosphere. Although its radioactive half-life is long—5760 years—the process of natural production had been going on for such a great time that the rate of production and rate of decay were in equilibrium, i.e., just as much is formed each year as decays away, until nuclear test detonations were initiated. There is a constant exchange of carbon 14 atoms between the atmosphere and the surface of the earth on the one hand, and the deep ocean on the other,

with the latter constituting a reservoir holding about 96 per cent of the atoms.

Nuclear detonations can also produce carbon 14 by interaction of the neutrons, produced at the time of the explosion, with nitrogen of the atmosphere. Approximately 400 megatons of total yield fired in the air (surface bursts "lose" about one-half of the neutrons into the ground) will produce a sufficient amount of carbon 14 to equal the amount normally present in that part of the earth's biosphere that determines radiation exposure to man. However, half of this newly-added carbon 14 "disappears" into the deep ocean within about 33 years.[19] One-half of that remaining in the atmosphere likewise "disappears" in the following 33 years, until only a few percent remains.

Radioactive isotopes act chemically similar to their stable counterparts so that not only is stable carbon but also carbon 14 found in all living cells. Thus, although carbon 14 emits a beta particle of very low energy that travels a very short distance it nevertheless irradiates essentially the whole body at a rate of approximately one milliroentgen (0.001 roentgen) per year. This is the natural background rate for carbon 14.

The Data

Since nuclear weapons testing started 511 million tons total energy yield have been released. Considering the conditions of firing (surface versus air bursts) about the same amount of carbon 14 was produced from all past tests as is normally present in that part of the earth's biosphere that determines radiation exposure to man. Assuming that most of the carbon 14 produced by the detonation will "disappear" into the deep ocean with a half-time of 33 years, the estimated whole body exposure for 70 years is 37 milliroentgens (0.037 roentgen).[1]

After this 70-year period the dose rate from bomb produced carbon 14 will be about one-quarter of that at the start, i.e., about one-quarter of one milliroentgen (0.00025 roentgen) per year. Thereafter, the activity will persist for thousands of years but at ever decreasing levels.

Evaluation

The radiation exposure from carbon 14 may account for roughly one-third of the total radiation dose from fallout over the next 70 years. Because of its long radiological half-life, it will persist at low levels of activity for thousands of years. However, even before the 70-year period is completed the dose rate from carbon 14 will be so low as to be non-measurable. This does not mean that the radiation is not "there" but it will

be minuscule compared to natural background levels or even to normal variations of background radiation.

G. WATER AND AIR

Background Information

Water

Contamination of water supplies does not constitute a major source of intake of radioactive fallout debris. In the case of surface water supplies there is a very large dilution factor.

In the case of underground nuclear detonations the fission products are restricted largely to the immediate vicinity of the detonation due principally to two factors. Firstly, for underground shots to date approximately 90 percent of the fission products have been fixed in a glassy type of material formed by the detonation. Secondly, ion exchange between such key fission products as strontium 90 and cesium 137, and the soil resulted in almost all of the remaining activity being adsorbed within a matter of perhaps tens to hundreds of feet away from the source.[20] In addition to fission products, tritium may be formed in varying amounts. This radioisotope probably is not greatly influenced by the two factors mentioned and must depend upon the dilution factor for reduction of the concentration in the water—at least for underground detonations. For above ground or cratering shots, the tritium largely escapes into the atmosphere where very large dilutions occur. Theoretical calculations suggest it may be possible for relatively high concentrations of tritium to be present in the amount of water immediately surrounding ground zero of some underground nuclear detonations.[21]

Essential to predicting potential contamination of ground water is the determination of the water movement. The most satisfactory method of obtaining the necessary data for this prediction is by drilling operations. Although these are expensive operations they are carried on extensively at the testing sites.

Air

As long as the fallout material from atmospheric tests remains in the air some may be inhaled and irradiate the lungs. This radiation dose to the lungs normally is less than external whole body exposure occurring after the fallout has been deposited on the ground. Also in general, inhalation is only a minor contributor to the intake of fallout debris into the body—ingestion is the much more important route.

The whole body will also receive some exposure from the penetrating gamma rays while the fallout material is in the

air, but this dose will usually be small compared to the exposure that follows after the debris is deposited on the ground. However, this ratio of doses may not hold for events where most of the radioactivity that escapes beyond the test site is in the form of gases or finely suspended particles that are confined to a relatively shallow layer of air near the surface.

Measurements of total fallout activity in air (called gross beta counts) provide only a crude alerting system. It is not a reliable procedure for predicting the amount of fallout to be deposited nor the amount of iodine 131 in milk.[22] Because of the transitory nature of the fallout debris remaining in the air (and sometimes because of the particular choice of units used in expressing its concentration) what may sound like an alarmingly large amount may, in fact, result in only minor radiation doses.

The Data

Water

The highest measured fallout activity in water was at Upper Pahranagat Lake, Nev., in 1955 amounting to 0.14 millionth of a curie per liter.[23] Since this was a total gross beta count it is difficult to give a precise estimate of the potential radiation dose. A crude analysis suggests that if this water had been stored and used as a sole supply for 70 years the total dose might be about one roentgen to the bones and one-quarter roentgen each to the thyroid and lower large intestine.

No radioactive fission products nor induced activities including tritium from underground tests have been found in underground water supplies at places of human consumption.

Air

The highest concentration of radioactive debris in the air in a populated area off-site (except for the Marshallese experience where measurements were made only after the passage of the cloud) was about 1.3 millionth of a curie per cubic meter averaged over the 24 hours the activity was present.[24] This happened at St. George, Utah, on May 19, 1953. The estimated radiation dose to the lungs from inhaled fallout debris was less than 0.2 roentgen.[25] The external whole body exposure from the fallout while it was still in the air was roughly estimated to be 0.025 roentgen—only about $\frac{1}{100}$ of the whole body exposure that occurred after deposition of the fallout.

Evaluation

The concentrations of fission products or tritium in the water supplies have not constituted major sources of radiation exposure to man. There is a large dilution factor when surface

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water supplies are contaminated, and the fission products from underground nuclear detonations largely become fixed at and near the site of the explosion. Whereas, theoretical calculations suggest that concentrations of tritium in the water may be above acceptable limits for some underground nuclear detonations,[10] this refers only to the water immediately around ground zero. Some dilution is to be expected if it moves off-site and, more importantly, the criterion of "acceptable limits" is based on the assumption that all of the water drunk throughout a lifetime will contain the same concentration of tritium as set by the limits. The quantity of water initially contaminated to these limits by an underground nuclear explosion is relatively small and would not constitute the sole supply for a lifetime. Further, tritium decays with a half-life of about 12 years.

Much less radioactive fallout debris enters the body by inhalation than by ingestion. While the debris is in the air outside the body the radiation exposure is much less than after the material has been deposited on the ground with the possible exception of certain situations noted above.

SECTION II.

OTHER ASPECTS

A. BLAST—DIRECT AND REFLECTED

Background Information

Direct blast waves that are potentially damaging are confined to the immediate testing site areas. Under certain meteorological conditions, however, blast waves may be refracted (bent) from an upper atmospheric level back to the earth and thus create higher air pressures than would be expected at those distances.

One layer in which this may happen is between 25,000 and 50,000 feet altitude where winds may cause a focusing effect at some 20–50 miles from the point of detonation. In turn, the blast wave may be repeatedly reflected from the ground and bent back from the atmosphere creating a series of regular spaced points of focus at the earth's surface with intervening "silent" spaces. Such an effect has resulted in minor structural damage, such as breaking of windows, 75 to 100 miles from the point of detonation at the Nevada Test Site [26] (fig. 7).

A similar effect is obtained when blast waves are bent from a layer of relatively warm air, called the ozonosphere, at a height of 20 to 30 miles. The point of first return to the earth in this case is 70 to 150 miles from the burst.

There may be a return of sound waves from an altitude above 60 miles (ionosphere). Most of this blast energy is absorbed, however, resulting in no recorded structural damage. In some cases audible sharp cracks and pops have been heard.

Procedures and equipment have now been developed to predict with greater accuracy the magnitude and direction of these refracted blast waves.

The Data

Although the blast wave decreases in energy with each succeeding refraction back to the earth's surface, there has been breakage of windows on a second "strike" at 285 miles from only a 17 thousand ton (TNT equivalent) nuclear explosion.[26] (All together about $50,000 has been paid for structural damage claims from all tests at the Nevada Test Site.) There have

FIGURE 7.—A downtown Las Vegas window, showing how the glass was sucked out by the rarefaction wave, rather than pushed in by the compression wave resulting from the November 1, 1951, nuclear test at the Nevada Test Site.

been no significant structural damages from refracted blast waves since good predictive methods have been developed.

There has been no known case of direct injury to man or animals from the refracted blast waves.

Evaluation

The predictive procedures developed resulted in greatly minimizing off-site damage from blast effects. In fact, there have been only incidents of single windows being damaged since 1953. Two occurred in 1955 and a third in 1957.

B. THERMAL RADIATION—FLASH AND HEATING EFFECTS

Background Information

Levels of thermal radiation that can produce skin burns are limited to the immediate testing site areas. Effects on the eyes, however, may extend for much greater distances.

These effects may be either permanent damage to part of the eye or a temporary flash "blindness." The latter is only a discomforting effect but can be potentially hazardous in the case of automobile drivers and aircraft pilots. This is one of the reasons why certain areas of highways have been closed for specified periods of time around the Nevada Test Site and also why the same precautions have been taken for the air lanes around the Nevada and Pacific testing sites.

Perhaps surprisingly, the amount of heat (calories) received per unit area on the rear portion of the eyeball (retina) does not decrease with increasing distance from the point of burst—except for the absorption (attenuation) effect in the atmosphere. While the expected decrease in energy per unit area does occur outside the eye (the inverse square law), the image formed on the retina correspondingly decreases in size in the same proportion. The result is that the thermal dose, in calories per unit area, remains constant but it covers a smaller area on the retina. This reduction in image size on the retina with increasing distance from the burst continues until it reaches approximately 0.00018 inch (7 microns) in diameter which is generally taken as about the limit for the maximum focusing effect of the human eye. Of course a dilation of the pupil of the eye, such as at nighttime, will permit more light to enter and, although the retinal image size does not change, it can be relatively more hazardous. Also, it is assumed that any light gathering devices such as binoculars also would increase the hazard.

Any damage to the retina probably would not be detected by an eye examination if it were less than 50 microns in diameter. Actual functional impairment of vision probably would not be noted if the lesions were mild and less than 50 microns in diameter on the fovea—the most sensitive portion of the retina.

There may be less injury to the retina of the eye if a given total amount of thermal energy is received at a slower rate, i.e., there is more opportunity for the adjacent cells in the retina to conduct away some of the heat. High yield detonations in the lower atmosphere exhibit a slower rate of delivery than low yields (say, a million tons versus 20 thousand tons).

At very high altitudes, say above 150 miles, only about $^{1}/_{100,000}$ of the total yield from a megaton detonation appears

promptly as energy in the visible light region because of the thin atmosphere.[27] Principally for this reason, such high altitude detonations do not present a serious hazard for eye damage. Detonations occurring at lesser altitudes encounter more atmosphere, where there are greater opportunities for interaction of the bomb debris with the air, resulting in a greater fraction of the total energy appearing as prompt visible light.

Detonations below about 60 miles can produce sufficient energy in the visible light region to be a potential eye hazard if they occur above the horizon and are viewed directly. Experience at Hiroshima and Nagasaki suggest that permanent eye injury would be expected only if one were looking directly at the fireball. This applies only to the instant of burst. If the detonation occurs below the horizon, the instant of high thermal energy release is past before the fireball rises into view. Under these conditions human reflexes of blinking or turning away should further insure safety.

The Data

There have been no recorded permanent eye injuries to persons off-site, although a few individuals near the Nevada Test Site have complained of temporary eye impairment. The burst from a 1.4 million tons detonation that took place over Johnston Island in the Pacific on July 9, 1962 at an altitude of about 250 miles was viewed directly under nighttime conditions by thousands in the Hawaiian Islands without any reported eye injury.

Six military personnel participating in nuclear weapons tests have received eye injury—only one of which resulted in a severe visual handicap.[28, 29] The latter individual "sneaked" a view over his left shoulder at the time of the detonation resulting in a reduction of 20/20 vision to 20/100 in his left eye. It did not improve with time. His right eye apparently was shielded by his nose and retained its 20/20 visual acuity.[28] (Values such as 20/100 represent the ability of the eye to read standard letters and characters at 20 feet that a normal eye could read at 100 feet. 20/400 is generally interpreted as legal blindness.)

Two military personnel at Johnston Island participating in the high altitude tests in 1962 also received eye injury. Immediately after the exposure, the visual acuity of both eyes of one man dropped to 20/400 for the area of primary retinal injury and 20/100 for adjacent areas of the retina. This man's visual acuity recovered to 20/30 in one eye and 20/40 in the other about one month later, and to 20/25 in both eyes about a year afterwards in the area of primary retinal damage. The

FIGURE 8.—Special high density goggles are worn by observers on-site at the Nevada Test Site. Note man at right of center without goggles, but who has turned away from the direction of burst. This procedure is equally safe providing there is no reflecting surface directly in view.

other man's visual acuity followed a similar pattern starting at 20/400 in both eyes in the area of retinal damage and 20/60 in the adjacent areas. These recovered to 20/50 and 20/80 in a month, and at one year later to 20/40 on one eye and 20/60 in the other in the areas of primary retinal damage.[30]

Experimental rabbits were exposed under nighttime conditions to the high altitude shot on August 1, 1958—a detonation in the megaton range at an altitude of about 48 miles. Lesions with diameters of about 500 microns were observed out to 345 miles—the farthest distance at which rabbits were exposed.

Evaluation

Nuclear detonations in the yield range tested offer no serious hazards to the eye when they are at very high altitudes, say above 150 miles, or below the horizon at the instant of burst. Detonations in the lower atmosphere should not be viewed directly without the aid of special high density goggles (Figure 8). Past precautionary procedures of closing highways and air lanes near the testing sites at the times of bursts have added to the safety in respect to potential eye damage. The procedures also were useful in preventing a driver or pilot being startled while in motion.

C. WEATHER

Background Information

Interest in the possible effects of nuclear detonations on the weather fall into two classes; one, direct effects because of the energy released, and two, triggering effects. The latter effects might be (a) a catalytic effect from the particles thrown into the atmosphere (something akin to cloud seeding with silver iodide crystals), (b) a change in the electrical conductivity of the air since radioactive debris contains charged particles, and (c) a reduction of solar energy received on earth owing to the quantity of dust thrown into the atmosphere.

The Data

The conclusions of many studies and experiments of these possible effects are best presented in reference:[31]

1. ". . . The energy of even a thermonuclear explosion is small when compared to most large-scale weather processes. Moreover, it is known that much of this energy is expended in ways that cannot directly affect the atmosphere. Even the fraction of the energy which is directly added to the atmosphere is added in a rather inefficient manner from the standpoint of affecting the weather. Meteorologists and others acquainted with the problem are readily willing to dismiss the possibility that the energy released by the explosions can have any important direct effect on the weather processes . . ."
2. ". . . The debris which has been thrown up into the atmosphere by past detonations was found to be ineffective as a cloud-seeding agent . . ."
3. ". . . The amount of ionization produced by the radioactive material is insignificant in affecting general atmospheric conditions . . ."
4. ". . . Dust thrown into the air by past volcano eruptions decreased the direct solar radiation received at the ground by as much as 10–20 percent. The contamination of the atmosphere by past nuclear tests has not produced any measurable decrease in the amount of direct sunlight received at the earth's surface. There is a possibility that a series of explosions designed for the maximum efficiency in throwing debris into the upper atmosphere might significantly affect the radiation received at the ground . . ."

The volume of material ejected by Krakatoa volcanic eruption in 1883 was approximately 13 cubic miles with an estimated one-third of the volume being spread worldwide.[32] This resulted in a diminution of the amount of sunlight received on the ground.[33]

As a crude comparison, the 10.4 million tons TNT equivalent nuclear detonation on October 31, 1952 on the island of Elugelab in the Pacific left a crater of about one mile in diameter and 170 feet deep at its apex. Assuming conservatively that the crater was a right angle cone and that all of the debris was thrown into the atmosphere, i.e., none of the depression was caused by compression, it is estimated that about 15,000 million tons TNT equivalent of surface detonations would be required to eject an amount of dust into the atmosphere equivalent of Krakatoa.

Following large nuclear detonations in the Pacific minor and temporary weather changes have been observed, such as local cloud formation sometimes with local precipitation, where the moisture conditions in the atmosphere are most favorable for this effect.

Evaluation

The most inclusive evaluative statements made are found in references 31 and 2.

> ". . . No statistically significant changes in the weather during the first ten years of the atomic age have been found, yet careful physical analysis of the effects of nuclear explosions on the atmosphere must be made if we are to obtain a definite evaluation of this problem. Although it is not possible to prove that nuclear explosions have or have not influenced the weather, it is believed that such an effect is unlikely . . ." (1956).
>
> ". . . although there has been much speculation about the influence of atomic testing on weather, there still appears to be no additional evidence suggesting a cause and effect relationship . . ." (1960).

D. GROUND MOTIONS—EARTHQUAKES

Background Information

A wide variety of factors determine both the ground motions and structural responses from nuclear detonations, i.e., energy yields of the detonations, distance from ground zero, depth of the shot and depth of measurement, and the nature of the ground (hard rock, etc.). "Competent" rock such as granite couples and transmits more energy into seismic ground waves than does alluvium—a noncohesive sedimentary deposit. Although ground waves will be more rapidly absorbed in alluvium, it is possible for waves to travel great distances along the surface with relatively large amplitudes (amount of motion) if the alluvium is very thick. However, these surface waves die out rapidly with the depth into the ground. Because of the

above factors, it is necessary to analyze each situation in predicting possible ground motions and structural responses.

One way to express the effects of ground motion is in units of "g." This refers to the acceleration that a freely falling body experiences on earth, i.e., 32 feet per second change in velocity for each second that the acceleration occurs. As a "rule of thumb"—the threshold of ground motion that may be perceptible to humans is one-thousandth ($^1/_{1000}$) of a "g." Ground motions can be accentuated at higher places such as tall buildings.

As another "rule of thumb," one-tenth of a "g" is frequently accepted as the criterion for threshold of property damage. However, this is based on damage from earthquakes and present data show that seismic waves generated by nuclear detonations and chemical high explosives result in less damaging effects than would be predicted for the same peak acceleration from an earthquake. Part of this difference may lie in the fact that ground motions from earthquakes persist for a longer period of time for each shock. Also, there are repeated shocks in most cases. Thus, structures are subjected to more damaging effects because of the number of shocks and greater duration of each shock than would be the case for the same peak acceleration experienced as a result of ground motion from an underground nuclear explosion.

Since nuclear detonations produce ground motions, it has been speculated that they may "trigger" a natural earthquake. It is not possible to have a natural earthquake, however, without prior storage of strain energy—a process that occurs over a period of years. It would be necessary to conduct an explosion several miles deep in an earthquake susceptible area to be near a zone where the stress might be great enough for an incipient quake to be triggered.[34]

The response of structures to earthquakes has been the subject of study for many years and satisfactory procedures have been developed for design of structures to withstand the effects of earthquakes. However, in these cases the interest is in significient structural damage, rather than plaster cracking or other minor effects. In the case of underground nuclear explosions the site is selected with safety in mind so that structures outside the test area will not ordinarily be subjected to ground motions of more than small amplitude. The possibility that light damage may result, therefore, must be considered.

The Data

The maximum range at which seismic waves from the largest nuclear detonations to date at the Nevada Test Site are

known to have been perceived by persons without benefit of instruments has been about 100 miles. These few persons were situated under conditions favorable to the amplification of the ground motions. No structural damage from ground motion has been experienced beyond about six miles from the site of the nuclear detonations.

Evaluation

Records of ground motion are now available for many underground nuclear explosions. Analyses of data and application of geophysical principles are resulting in a steady improvement in methods of prediction of ground motions for planned events.

Since ground motions from underground nuclear explosions are different in some respects from those from an earthquake and there is a need to predict marginal damage to structures for such explosions a new approach is required. The analytical procedures for structural response generally are valid and can be applied. Additional direct test information is required and is being acquired by the AEC. Until more data are developed, conservative estimates of the effects may be made by comparison with damage which might be expected from the same amplitude of ground motion in an earthquake.

SECTION III.

GENERAL EVALUATIONS

The decision to conduct nuclear weapons tests for the defense of our country was made at the highest level of our Government. The Atomic Energy Commission was charged with the responsibility for carrying out the program. The AEC sought and followed the best advice both from within and outside the Government in the conduct of new and potentially hazardous operations. The record, as summarized above, must speak for itself as to potential risks incurred to the public in the fulfillment of a mission essential to national security.

Of all the health aspects of nuclear weapons testing, that of radiation exposure has received the greatest attention. If, as the data and their evaluation given above indicate, there has been a relatively low degree of risk associated with past atmospheric tests (except for the fallout on the Marshallese and the Japanese fishermen), then why has there been so much concern expressed? There are probably several reasons.

Firstly, whereas the potential radiation exposures are only a very small fraction of those received from natural background sources, they are, of course, *additional* amounts.

Secondly, in the absence of positive proof otherwise the prudent assumption is accepted that for every small increment of radiation exposure there is a corresponding increment of biological effect ("linear" concept)—rather than the "threshold" concept where a certain total radiation dose must be received before irreparable damage occurs. Based on this and other assumptions, admissible theoretical calculations can be made as to the potential number of genetic mutations, of cases of leukemia, etc. that could result from fallout. This linear concept leads axiomatically to the situation of there being no sharp dividing line below which there is complete safety and above which there is a serious hazard. Radiation protection guides, therefore, must be derived on some additional basis, as noted next.

Thirdly, there has been some misinterpretation of the radiation protection guides. The use of the linear concept leaves little choice for deriving radiation protection guides, i.e.—there must be a balancing of the "benefits" anticipated from any atomic energy program, whether it be for normal peacetime

operations or national defense, against the "risks" (radiation exposure). Obviously, this is an exceedingly complex and, in part, subjective process.

In spite of these difficulties this balancing of benefits from normal peacetime operations against risks has been performed by the Federal Radiation Council (FRC) resulting in their recommending radiation protection guides for this purpose.[13, 35] In a letter of August 17, 1962 to the Joint Committee on Atomic Energy, Congress of the United States, the FRC clarified further their published Guides:

> ". . . the Guides were originally developed for application as guidelines for the protection of radiation workers and the general public against exposures which might result during 'normal peacetime operations' in connection with the industrial use of ionizing radiation . . . the term 'normal peacetime operations' referred specifically to the peaceful applications of nuclear technology where the primary control is placed on the design and use of the source. Since numerical values in the Guides were designed for the regulation of a continuing industry, they were of necessity set so low that the upper limit of Range II can be considered to fall well within levels of exposure acceptable for a lifetime. Furthermore, to provide the maximum margin of safety, the upper limits of Range II were related to the lowest possible level at which it was believed that nuclear industrial technology could be developed . . ."

Guides developed primarily for use by industry in restricting its releases of radioactive effluents to the general environment outside their controlled areas are, of course, very materially lower than those that might constitute a serious health hazard.

A fourth reason why concern has been expressed about health risks from fallout may lie in the area of causal relationships, i.e., the identifying or associating of nuclear tests with nuclear war. There may have been established in the minds of some that nuclear weapons testing and nuclear war go hand-in-hand; i.e., the first axiomatically leads to the second. A discussion of causal relationships is beyond the scope of this booklet, yet one point must be made.

As a matter of technical fact, nuclear weapons of proven performance would not have been possible without the testing of nuclear devices and the verfying of nuclear concepts that were incorporated into their design. Whatever protection we enjoy from our nuclear arsenal results from a stockpile of test-proven nuclear weapons, not a stockpile of drawing board sketches.

APPENDIX

SAFETY PROCEDURES AT THE NUCLEAR TESTING SITES

NEVADA TEST SITE

General

The safety programs and procedures described below were in use during atmospheric tests at the Nevada Test Site. Since the signing of the Limited Test Ban Treaty essentially all of these programs remain in effect, but generally at a reduced level, thus providing for a continuous monitoring of persons and the environment for documentary purposes, and assurance of a nucleus of well trained personnel (fig. 9).

The health and safety of persons was the major consideration in the original selection of the Nevada Test Site and this continues to be of paramount importance during the conduct of nuclear tests. An exhaustive search was made before the Nevada site was selected as the most suitable one. It originally contained 600 square miles (later expanded to about 1,290 square miles) adjacent to the U.S. Air Force Gunnery Range of 4,000 square miles. For purposes of general safety, as well as security, the Test Site was and continues to be closed to the public. Safety of personnel was and is further assured by aerial and surface surveys made prior to each detonation to determine that no one had wandered into the area.

Beyond these controlled areas are wide expanses of sparsely populated land, providing optimim conditions for maintenance of safety. Although the area is quite sparsely populated the individual resident has been given full consideration. Radiation monitors have been present during times of testing and there have been occasions when residents have been relocated for a day or so to insure fully their safety. Persons relocated have received financial remuneration for such movements. There have also been occasions when persons have been asked to remain indoors for a few hours to reduce the radiation dose, although the out-of-door exposure would have been far from hazardous.

Before each and every nuclear detonation at the Nevada Test Site, an Advisory Panel of experts weighed carefully all of the factors that insured safety. On the panel were repre-

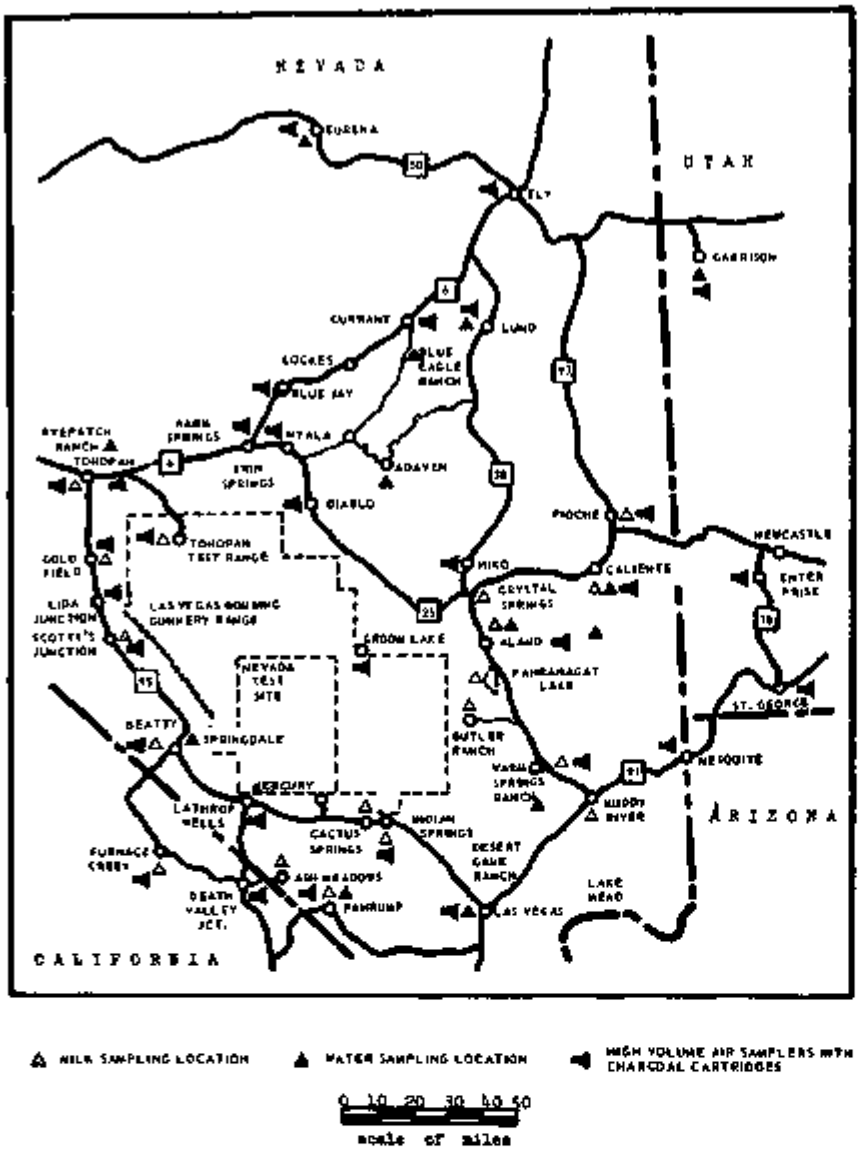


FIGURE 9.—Public Health Service environmental sampling stations around the Nevada Test Site.

sentatives from the fields of public health, medicine, meteorology, fallout phenomenology, blast and thermal effects, etc. As a result of these deliberations more than 200 delays in firing have been made at a cost of millions of dollars, to insure safety. The Advisory Panel continues to function for underground tests.

The principal cause for the delays was the requirements for proper weather conditions to insure minimum fallout in

populated areas. Meteorologists predicted downwind trajectories, precipitation and other factors which could affect levels of fallout. The data from the weather stations were currently available almost up to the exact time of the shot. A detonation could be cancelled at any time up to a few seconds before shot time. A more complete description of the meteorological program is given below.

To insure safety to aircraft, both from the initial flash of light and any radioactivity in the air mass moving off-site from atmospheric tests, a representative of the Federal Aviation Agency was made an intregal part of the Test Organization. He prepared flight advisory plans based on the type of event and on the predicted meterological conditions. The plan delineated flight patterns and areas and recommended alternate routes, if required, by commercial and private aircraft. Frequently the FAA closed specific air lanes and rerouted aircraft for specified periods.

Blast effects were minimized by predicting blast wave intensities based on the wind and temperature profile expected at shot time. Since long distance blast pressure propagation is strongly dependent on wind profile structure, calculations were made for many directions and distances from the test site where possible window damage might have occurred. In order to improve blast calculation techniques, a network of especially sensitive microbarographs was operated at as many as 17 off-site locations to record actual shot-produced pressures in Nevada, California and Utah. It was rarely necessary to recommend a delay in firing time solely because of predicted blast effects since meterological conditions unfavorable for fallout usually were also unfavorable for blast.

Full off-site radiological monitoring coverage was and is provided by the U.S. Public Health Service under a Memorandum of Agreement with the U.S. Atomic Energy Commission. There were and are extensive monitoring programs, including mobile monitoring teams, film badges, air samplers, automatic gamma recorders, collections of milk, vegetation, soil, etc. A more complete description of these programs is given below. All of the key data obtained from these monitoring programs were and are reported in the open literature such as the Atomic Energy Commission's Semiannual (now annual) reports to Congress and the U.S. Public Health Service's monthly publication, *Radiological Health Data*. An extensive public information program by the U.S. Public Health Service continues around the Nevada Test Site (fig. 10).

U.S. PUBLIC HEALTH SERVICE, DIVISION OF RADIOLOGICAL HEALTH PHOTO

FIGURE 10.—Public Health Service representative conducting a meeting in one of the local homes in Las Vegas, as a part of an extensive educational program around the Nevada Test Site.

Weather Predictions

The Weather Bureau Research Station was started in 1956 to study intensively the meterology of the Nevada Test Site. In late 1957 the station became responsible for providing meterological support for nuclear weapons tests. Prior to these dates this function was performed by the Air Weather Service of the U.S. Air Force. The Weather Bureau station at the Nevada Test Site received all of the atmospheric sounding information taken every six hours by the stations shown on the map (fig. 11), and most of the hourly and six-hourly weather information produced in the entire United States, Canada, Mexico and eastern Pacific Ocean. In addition, there were and are some 26 wind, 20 temperature, and 18 precipitation measuring stations located on the Test Site. Ten of the wind and three of the temperature stations that reflect major terrain effects at and near the Nevada Test Site provided telemetered information for use just prior to and immediately following each nuclear detonation.

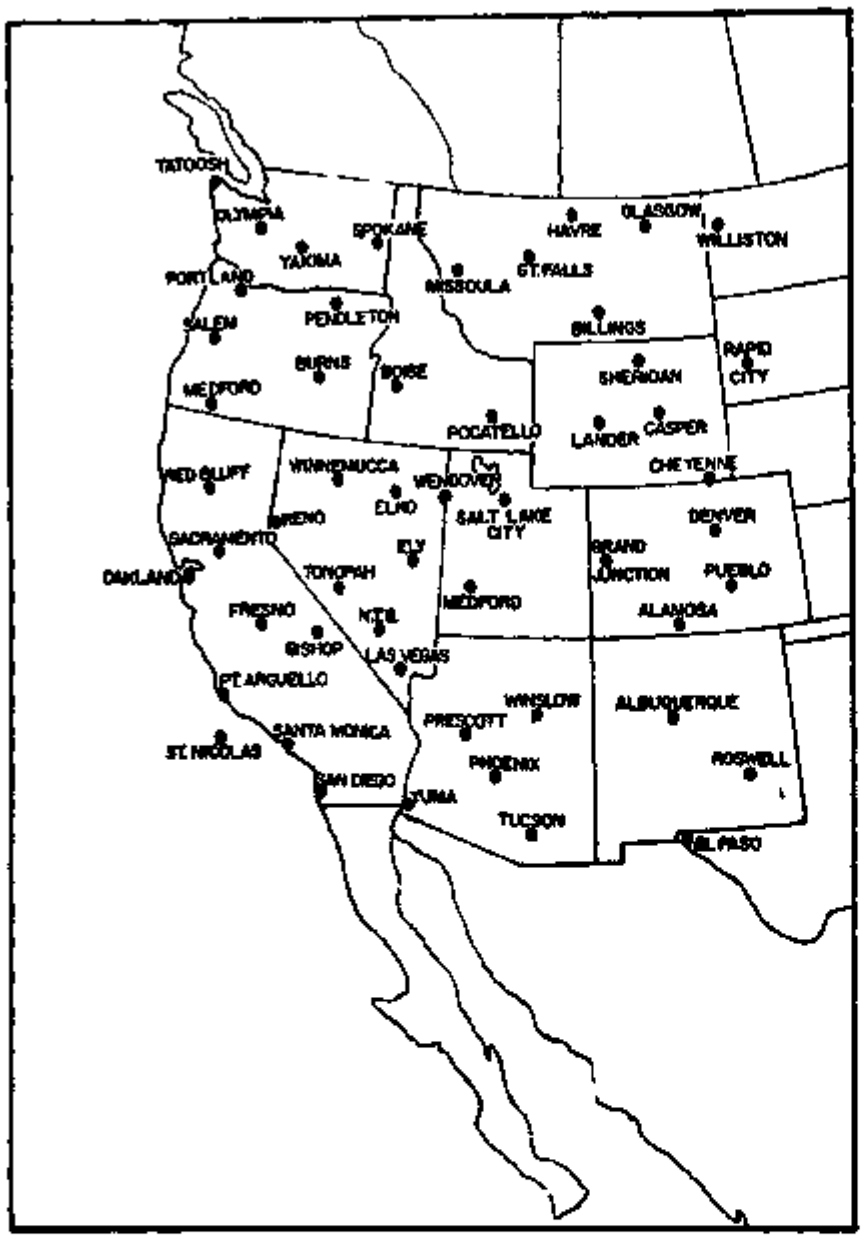


FIGURE 11.—U.S. Weather Bureau stations furnish information every six hours for forecasting purposes.

The Mercury Weather Station made a daily study of the weather conditions over the Nevada Test Site and environs, using all available local information and reevaluating analyses furnished by means of facsimile from the National Meterological Center (NMC) at Suitland, Md. The latter Center proc-

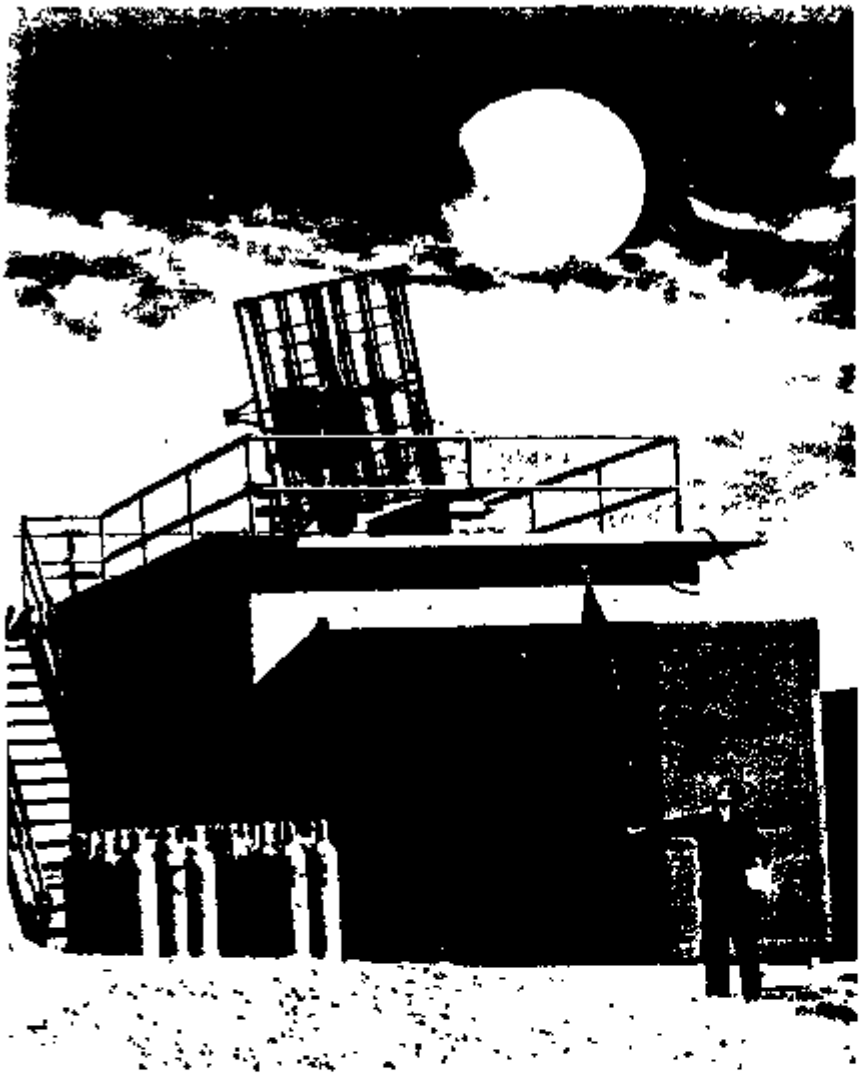


FIGURE 12.—The Weather Station at the Nevada Test Site sends radar-observer balloons to the upper atmosphere to check on temperatures, dew points, humidity and wind velocities. The radar tracking instrument on top of the station charts wind velocities and directions.

essed most northern hemisphere data, much of it electronically, and used the fastest and most modern techniques in producing forecast charts of the large scale features of the atmospheric circulation. The Mercury station, having more local information and the benefit of numerous studies of local meterological conditions, adjusted the NMC information to make forecasts having the highest possible accuracy for NTS.

On the day prior to each nuclear detonation, a formal detailed briefing was given to the Scientific Director, the Test Manager, and his Advisory Panel covering all foreseeable ways in which weather might influence the success and safety of the test. All such briefings included wind speeds and direction predictions to at least the maximum cloud height obtainable, expected changes in wind during the day, thermal stability, clouds, precipitation, trajectories of aerosols, the effect of wind and thermal structure on the diffusion and deposition of effluent materials, and the maximum radiation dosages that could conceivably result on and off the Test Site. Changes, if any, from these predictions were presented at subsequent briefings just prior to arming each device. In fact one of the major factors in arriving at good predictions was the series of "wind runs" usually at one-half hour intervals up to zero time (fig. 12).

Most of the programs remain in effect as a further assurance of safety in the event of the release of any radioactivity from underground tests.

Radiological Surveillance

Routine programs were and are conducted continuously within a radius of approximately 300 miles from the Nevada Test Site by the U.S. Public Health Service.

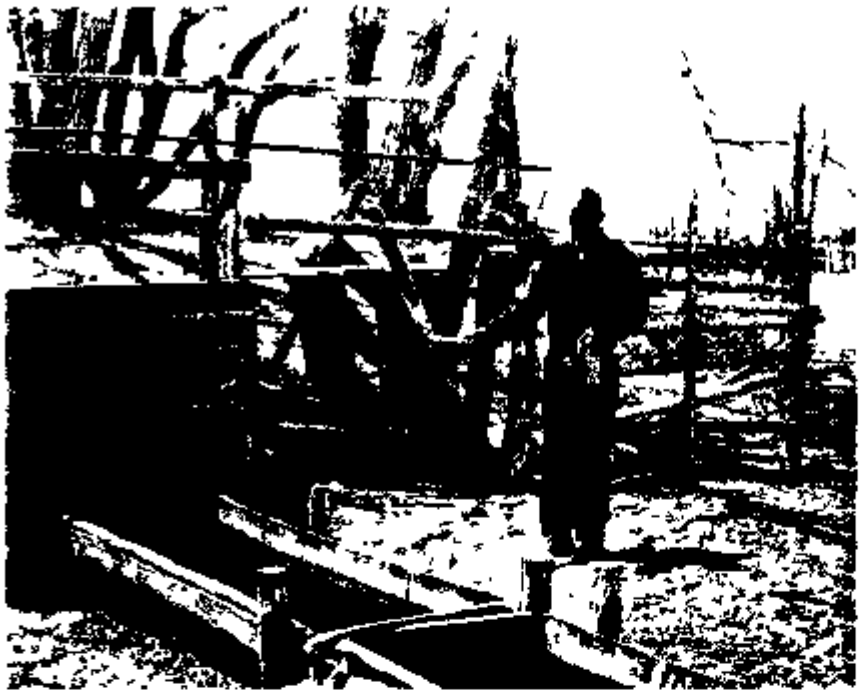
Aircraft Monitoring

Since 1962 the U.S. Public Health Service has owned and operated two aircraft for cloud sampling. Prior to this date, this function was accomplished by the U.S. Air Force. Each aircraft carried equipment to collect airborne activity both particulate and gaseous. Both planes carried equipment for continuously monitoring the gamma radiation. Additional U.S. Air Force planes equipped for cloud sampling and tracking were available and were on call. Arrangements were made for the use of another special aircraft for radiological monitoring surveying at H+24 hours.

The capabilites of aircraft monitoring continue to be maintained.

Mobile Ground Monitoring

Mobile ground monitoring teams were deployed in the downwind sector prior to each test to supplement the routine surveillance which was a part of the continuous surveillance program. The downwind sector was determined by information obtained from the U.S. Weather Bureau personnel assigned to the NTS. These monitoring teams consisted of two men. Each team was equipped with beta-gamma survey



U.S. PUBLIC HEALTH SERVICE DIVISION OF RADIOLOGICAL HEALTH PHOTO

FIGURE 13.—Monitoring for external gamma radiation near the Nevada Test Site by U.S. Public Health Service personnel.

instruments (fig. 13), chamber survey instruments, fallout trays and additional air samplers and recorders. Each vehicle was equipped with two-way voice radio communication. The number of teams used for each event was determined in advance by the predicted radiological situation, however five to ten teams was the usual number deployed. Up to 20 teams could be organized within a short time, but were not normally maintained on a standby basis.

Mobile ground monitoring teams are still maintained on a standby basis and used when needed.

Air Sampling

There were and are 30 permanent air sampling stations in operation 24 hours per day in the area surrounding the NTS at distances up to 180 miles distance.

The air samplers used are high volume units, drawing air through an 8" x 10" glass fiber filter (fig. 14). When deemed desirable, a secondary activated charcoal cartridge is added for the collection of gaseous fission products. Flow rates are approximately 50 cubic feet per minute (c.f.m.) for the glass fiber filter alone and 25 c.f.m. with the charcoal cartridge added.

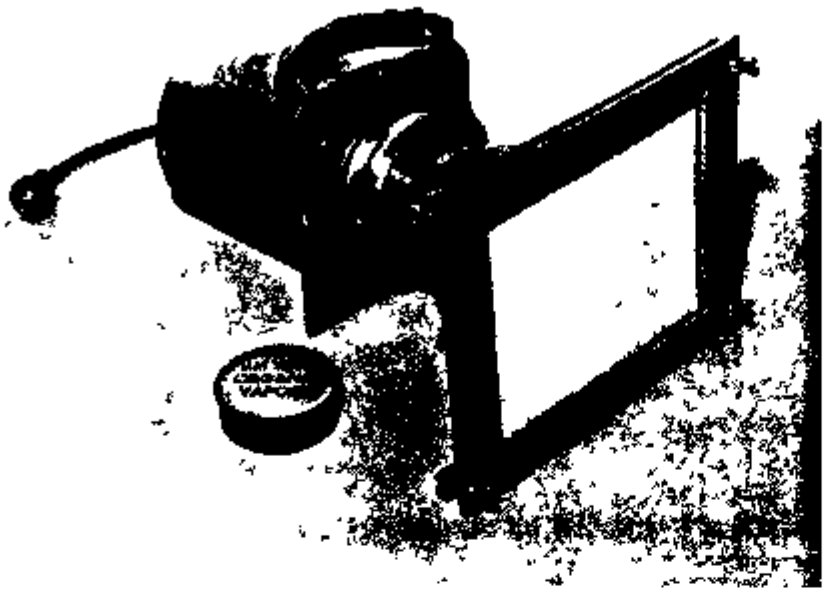


FIGURE 14 – High volume air sampler. The large glass fiber filter is for collection of particulates. Behind the filter is placed an activated charcoal cartridge to collect gases such as radioiodines

Glass fiber filters are counted for gross beta activity in the proportional region.

All charcoal cartridges, and any glass fiber filters with gross beta activity significantly above background levels are assayed with a 400 channel gamma scintillation spectrometer, using a steel shield for a 4" x 4" NaI (Tl) crystal with a Cs^{137} peak resolution of eight percent for identification of specific gamma-emitting isotopes.

Film Badging

Film badges were distributed to hundreds of locations around the Test Site and to as many as 1,600 persons during certain operations. Presently there are about 50 locations with some 200 persons wearing film badges. Film badges were and are collected and processed monthly. In the event that radioactivity was found in the area by the mobile monitoring teams, film badges were collected from these locations and from people living in the area; new film badges were distributed. Additional stations and people were included if the situation required more extensive monitoring.

U.S. PUBLIC HEALTH SERVICE, DIVISION OF RADIOLOGICAL HEALTH PHOTO

FIGURE 15.—Collection of water sample near the Nevada Test Site by U.S. Public Health Service personnel.

Milk Sampling

Milk samples were and are collected routinely one time per month within the 300 mile radius of the NTS, from approximately 25 sources, including all dairies and some additional ranches having one milk cow. In the event that radioactivity was found in any area additional samples were collected often on a daily basis.

Water Samples

Water samples were and are in general collected monthly from approximately 30 sources (fig. 15). There were no known surface supplies for human use in the off-site area except for Lake Mead.

Research

In support of the operational procedures described above to assure safety to the public, there were and are extensive basic and applied research studies conducted in such fields as meterology, hydrology, and ground motion. These were and are accomplished by (a) cooperation with other Government agencies including the U.S. Weather Bureau, U.S. Public Health Service, U.S. Geological Survey, U.S. Bureau of Mines and U.S.

Coast and Geodetic Survey, (b) contracts with consulting organizations such as Roland F. Beers, Inc., Alexandria, Va., Hazelton-Nuclear Science Corporation, Palo Alto, Calif., and Holmes & Narver, Inc., Los Angeles, Calif., and (c) individual consultants.

The total annual expenditure for the operational and research studies directed toward safety at the Nevada Test Site currently is over $8 million.

In addition, there were and are numerous programs carried on as part of the laboratories' scientific effort that have a bearing on safety and contribute greatly to the basic understandings. One of the earliest and most valuable were those environmental studies conducted by the Department of Biophysics and Nuclear Medicine, University of California Medical School, Los Angeles, Calif. Also, in May 1963 a new Biology Division at the Lawrence Radiation Laboratory at Livermore, Calif., was formed with one of its prime missions to investigate problems dealing directly and indirectly with radioactive fallout, especially radioiodine.

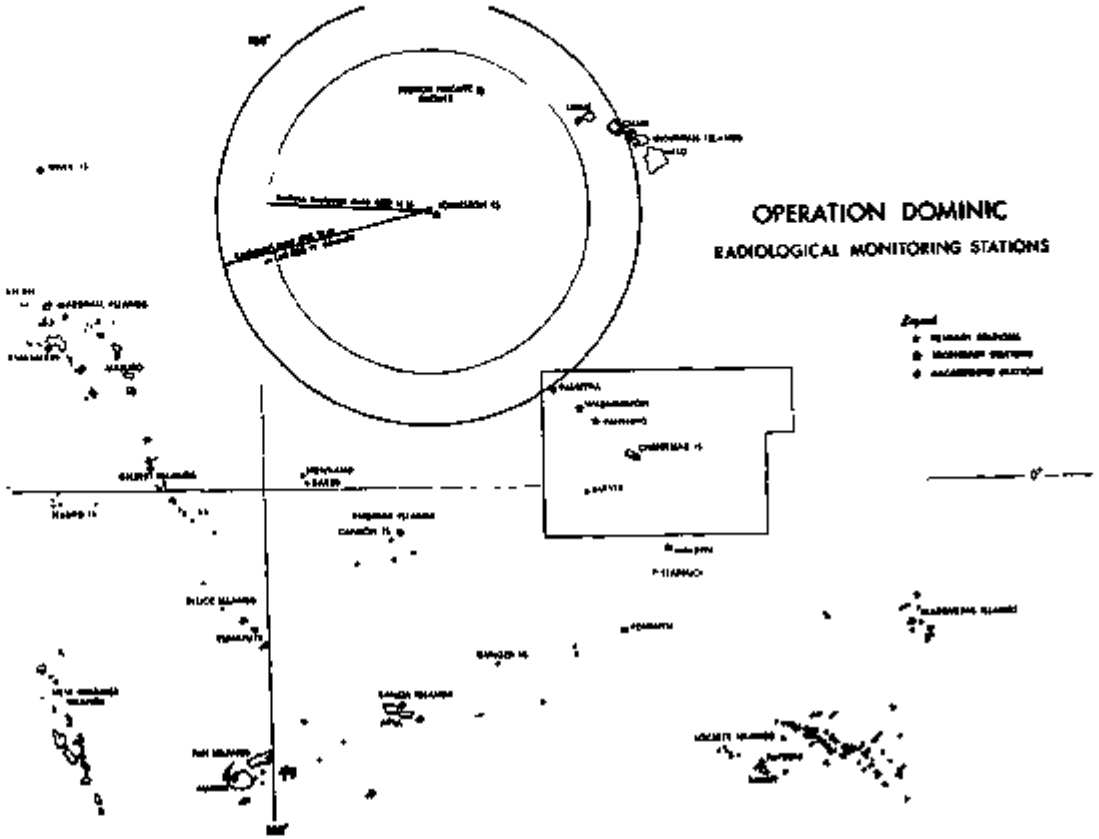


FIGURE 16.

APPENDIX

SAFETY PROCEDURES AT THE NUCLEAR TESTING SITES

PACIFIC TEST SITES

General

United States atmospheric nuclear tests were held in the Pacific at Bikini (1946, 1954, 1956 and 1958), Eniwetok (1948, 1951, 1952, 1954, 1956 and 1958), Johnston Island (1958 and 1962) and Christmas Island (1962). These remote sites were selected after extensive search for possible areas where the tests could be conducted safely.

To conduct atmospheric nuclear weapons tests in the Pacific, Joint Task Forces have been organized consisting of designated personnel from U.S. Military Services and AEC. A Commander for each Joint Task Force was chosen from one of the three Military Services with a Deputy from each of the other two. The technical programs have been under a civilian Scientific Deputy.

In each series an exclusion area was declared around the test islands for the purpose of warning air traffic and ships (fig. 16). Notification of locations of these areas and times that the restrictions were in effect were made by issuance of Notices to Airmen through the Federal Aviation Agency and Notices to Mariners through the Commander-in-Chief of the Central Pacific Fleet. The Department of Defense, State Department and other agencies of the Executive Branch of the Government were notified so that shipping authorities and air traffic control authorities could be alerted.

Since there have been some changes in details over the years of the organizations concerned with safety within the Joint Task Forces, the following description applies to Joint Task Force 8 that conducted the 1962 Pacific tests.

Weather predictions were conducted by the Task Force Weather Central composed of Navy and Air Force meterologists. To assist in analyzing the weather data and to predict other results such as fallout, blast and thermal effects, a Hazards Evaluation Unit was formed to advise the Joint Task Force Commander and his Scientific Deputy.

Radiological safety activities on-site were conducted by a special unit of Joint Task Force 8 and off-site surveillance programs by the U.S. Public Health Service.

Altogether about 80 personnel were utilized in activities devoted to safety.

Radiological Surveillance

Radiological safety (Rad-Safe) was a separate Task Unit within the Joint Task Force organization. Rad-Safe responsibilities included procuring, storing, and issuing Rad-Safe supplies and equipment, instrument maintenance, issuance and processing of film badges, maintenance of personnel radiation exposure records, supervision of monitoring, decontamination, waste disposal activities, procurement and distribution of high density goggles, and other activities as indicated by the potential hazards of the situation. The Rad-Safe Branch contained an Off-Site Surveillance Section. Personnel from this section participated in monitoring at off-site populated islands in the vicinity of the test area and periodically collected water and food samples.

Aircraft Monitoring

Aircraft were used to monitor the cloud of airborne radioactivity during early times after detonation and to track the cloud periodically over a period of two or three days.

Environmental Safety

During Operation Dominic (1962) there were 34 nuclear detonations above the Pacific Ocean near Christmas and Johnston Islands. The explosive yields of these devices ranged from low kiloton into the megaton range in TNT equivalent. The height of burst for each detonation was sufficient to negate local radioactive fallout. The devices were delivered to the point of detonation by either manned aircraft of by surface-to-air missiles. In addition to the atmospheric tests, there was one underwater test of a low yield nuclear device detonated in the Eastern Pacific Ocean several hundred miles from the closest land area. Essentially all the radioactive fission products produced by this test were deposited in the ocean and were soon dispersed and diluted to concentrations which were of no significant biological hazard to man or marine life.

All nuclear events at Christmas Island were detonations of devices released from manned aircraft. These bursts occurred over water and were planned for execution under favorable atmospheric conditions to minimize the likelihood of contamination of land surfaces. In addition, following each event, ground and aerial monitors surveyed the island to determine whether any radioactive rain-out occurred.

A Hazards Evaluation Unit composed of scientific personnel of contractor laboratories (Lawrence Radiation Laboratory,

Los Alamos Scientific Laboratory, Sandia Corporation) and representatives of the U.S. Weather Bureau was organized to advise the Commander of the Joint Task Force and the Scientific Deputy. Pre-shot computations were made for each detonation. These computations include 12 and 24 hour trajectory forecasts based on winds from the surface to 40,000 feet. A specified radiation exclusion area was then declared to include any possible local fallout. Daily soundings were made to 100,000 feet giving added information that was helpful in correlating observed cloud stabilization and movement with predicted shot-time trajectories. Where applicable, other weapons phenomena were considered such as blast pressures, and possible eye injuries from the prompt thermal radiation.

Cloud tracking aircraft made and maintained contact for several hours with the radioactive cloud following each event conducted in the lower atmosphere. Timely information on cloud movement, top and base altitudes were obtained for use of advisory reports regarding opening of commercial air lanes through or near the announced danger area. There was no evidence that any commercial aircraft encountered any of these radioactive clouds.

Off-Site Monitoring

The off-site monitoring program during Operation Dominic was under the cognizance of the U.S. Public Health Service, USPHS personnel being assigned to JTF-8 during the operational phase. A radiological surveillance of a network of 19 monitoring stations was maintained on populated islands within a 2,000 mile radius of Christmas Island. Air samples were collected on populated islands out to about 1,000 miles from the test zone. Samples of soil, vegetation, fruits, water and marine life were collected on the populated islands of the area before testing began and repeated sampling was made after the testing period to determine whether changes in the level of radioactivity had occurred in the area.

The 19 sampling stations were divided into (1) primary stations, (2) secondary stations, and (3) background stations. The primary stations (Christmas, Fanning and Washington) were manned by USPHS officers with equipment and sampling techniques to document all forms of environmental radioactivity. The secondary stations (Canton, Malden, Penrhyn/Tongareva, Palmyra, Midway, Johnston Island and French Frigate Shoals) were outside the danger area and were designed to document air concentration and external radiation background. These stations were operated with the assistance of Task Force Project Groups and Weather Groups. Background stations on Tu-

tuila, Rarotonga, Wake Island, Kwajalein Atoll, Tongatabu and Viti Levu were operated by Task Force Project Groups or Weather Groups and on Nuku Hiva and Tahiti by French personnel. The purpose of the background stations was to document external radiation background and changes in background levels if they occurred.

A USPHS rad-chem laboratory was established in Honolulu, Hawaii to support the off-site rad-safe program. Facilities, equipment and personnel were available for radiochemical analysis of air, precipitation, water, milk, food and soil. The facility remains in operation as a part of a continuing program of monitoring several of the Hawaiian Islands.

Bioenvironmental Monitoring

The bioenvironmental program for Operation Dominic was under AEC contract with the University of Washington, Seattle, Wash. A final report of their data is found in "Radionuclide Content of Foodstuffs Collected at Christmas Island and at Other Islands of the Central Pacific During Operation Dominic, 1962," UWFL-87, by Ralph Palumbo.

During the period April 7 to July 29, 1962, collections of foodstuffs, marine life included, were made from eight off-site islands and Christmas Island to ascertain the radionuclide content of the samples collected. In addition to samples collected by this group, USPHS off-site monitors furnished samples from areas not covered by the University of Washington scientists. Approximately 8,000 samples were collected during the time which covered pre-testing, testing and post-testing periods. Part of these samples were scanned promptly for radioactive content, however, a majority of the samples were returned to the University of Washington for complete analysis.

GLOSSARY*

BACKGROUND RADIATION: Nuclear (or ionizing) radiations arising from within the body and from the surroundings to which individuals are always exposed. The main sources of the natural background radiation are potassium 40 in the body, potassium 40 and thorium, uranium, and their decay products (including radium) present in rocks, and cosmic rays.

BETA PARTICLE: A charged particle of very small mass emitted spontaneously from the nuclei of certain radioactive elements. Most (if not all) of the direct fission products emit (negative) beta particles. Physically, the beta particle is identical with an electron moving at high velocity.

BIOLOGICAL HALF-TIME: The time required for the amount of a specified element which has entered the body (or a particular organ) to be decreased to half of its initial value as a result of natural, biological elimination processes.

DOSE: A (total or accumulated) quantity of ionizing (or nuclear) radiation. The term dose is often used in the sense of the *exposure dose*, expressed in roentgens, which is a measure of the total amount of ionization that the quantity of radiation could produce in air. This should be distinguished from the *absorbed dose*, given in reps or rads, which represents the energy absorbed from the radiation per gram of specified body tissue. Further, the *biological dose*, in rems, is a measure of the biological effectiveness of the radiation exposure.

DOSE RATE: As a general rule, the amount of ionizing (or nuclear) radiation to which an individual would be exposed or which he would receive per unit of time.

EXPOSURE, EXTERNAL: Exposure to radiation that is delivered from a source outside of the body.

EXPOSURE, *INTERNAL*: Exposure to radiation delivered from a source inside the body. Strontium 90 lodged in the bones is an example of internal exposure.

EXPOSURE, WHOLE BODY: Exposure that involves the whole body rather than a specific organ.

FALLOUT: The process or phenomenon of the fallback to the earth's surface of particles contaminated with radioactive material from the radioactive cloud. The term is also applied in a collective sense to the contaminated particulate matter itself. The *early* (or *local*) *fallout* is defined, somewhat arbitrarily, as those particles which reach the earth within 24 hours after a nuclear explosion. The *delayed* (or *world-wide*) *fallout* consists of the smaller particles which ascend into the upper troposphere and into the stratosphere and are carried by winds to all parts of the earth. The delayed fallout is brought to earth, mainly by rain and snow, over extended periods ranging from months to years.

FISSION PRODUCTS: A general term for the complex mixture of substances produced as a result of nuclear fission. A distinction should be made between these and the *direct fission products* or *fission fragments* which are formed

* Based principally on The Effects of Nuclear Weapons. Glasstone, S. (editor). Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. April 1962.

by the actual splitting of the heavy-element nuclei. Something like 80 different fission fragments result from roughly 40 different modes of fission of a given nuclear species, i.e., uranium 235 or plutonium 239. The fission fragments, being radioactive, immediately begin to decay, forming additional (daughter) products, with the result that the complex mixture of fission products so formed contains about 200 different isotopes of 36 elements.

FOOD CHAIN: The sequence of events in which nutrients are transferred from the soil to plants to animals to man. The collection of these various stages is referred to generally as the biosphere.

FREE AIR OVERPRESSURE (OR FREE FIELD OVERPRESSURE): The unreflected pressure, in excess of the ambient atmospheric pressure, created in the air by the blast wave from an explosion.

FUSION: The process whereby the nuclei of light elements, especially those of the isotopes of hydrogen, namely, deuterium and tritium, combine to form the nucleus of a heavier element with the release of substantial amounts of energy.

GAMMA RAYS (OR RADIATIONS): Electromagnetic radiations of high energy originating in atomic nuclei and accompanying many nuclear reactions, e.g., fission, radioactivity, and neutron capture. Physically, gamma rays are identical with X-rays of high energy, the only essential difference being that the X-rays do not originate from atomic nuclei, but are produced in other ways, e.g., by slowing down (fast) electrons of high energy.

GROUND ZERO: The point on the surface of land or water vertically below or above the center of a burst of a nuclear (or atomic) weapon; frequently abbreviated to GZ.

HALF-LIFE: The time required for the activity of a given radioactive species to decrease to half of its initial value due to radioactive decay. The half-life is a characteristic property of each radioactive species and is independent of its amount or condition. The *effective half-life* of a given isotope is the time in which the quantity in the body will decrease to half as a result of both radioactive decay and biological elimination.

INDUCED RADIOACTIVITY: Radioactivity produced in certain materials as a result of nuclear reactions, particularly the capture of neutrons, which are accompanied by the formation of unstable (radioactive) nuclei. The activity induced by neutrons from a nuclear (or atomic) explosion in materials containing the elements sodium, manganese, silicon, or aluminum may be significant.

INVERSE SQUARE LAW: The law which states that when radiation (thermal or nuclear) from a point source is emitted uniformly in all directions, the amount received per unit area at any given distance from the source, assuming no absorption, is inversely proportional to the square of that distance.

ISOTOPES: Forms of the same element having identical chemical properties but differing in their atomic masses (due to different numbers of neutrons in their respective nuclei) and in their nuclear properties, e.g., radioactivity, fission, etc.

KILOTON ENERGY: The energy of a nuclear (or atomic) explosion which is equivalent to that produced by the explosion of 1 kiloton (i.e. 1,000 tons) of TNT.

MEGATON ENERGY: The energy of a nuclear (or atomic) explosion which is equivalent to 1 million tons (or 1,000 kilotons) of TNT.

METABOLISM: The process in which the body breaks down foods into usable materials that are taken into the cells and manufactured into the living tissues of the body.

MICROCURIE: A one-millionth part of a curie.

MILLIREM: A one-thousandth part of a rem.

MILLIROENTGEN: A one-thousandth part of a roentgen.

OVERPRESSURE: The transient pressure, usually expressed in pounds per square inch, exceeding the ambient pressure, manifested in the shock (or blast) wave from an explosion.

PICOCURIE: One millionth of a millionth of a curie.

RAD: A unit of absorbed dose of radiation; it represents the absorption of 100 ergs of nuclear (or ionizing) radiation per gram of the absorbing material or tissue.

RBE (OR RELATIVE BIOLOGICAL EFFECTIVENESS): The ratio of the number of rads of gamma (or X-) radiation of a certain energy which will produce a specified biological effect to the number of rads of another radiation required to produce the same effect is the RBE of this latter radiation.

REM: A unit of biological dose of radiation; the name is derived from the initial letters of the term "roentgen equivalent man (or mammal)." The number of rems of radiation is equal to the number of rads absorbed multiplied by the RBE of the given radiation (for a specified effect).

REP: A unit of absorbed dose of radiation now being replaced by the rad; the name rep is derived from the initial letters of the term "roentgen equivalent physical." Basically, the rep was intended to express the amount of energy absorbed per gram of soft tissue as a result of exposure to 1 roentgen of gamma (or X-) radiation.

RESIDENCE HALF-TIME: As applied to delayed fallout, it is the time required for the amount of weapon debris deposited in a particular part of the atmosphere, e.g., stratosphere or troposphere, to decrease to half of its initial value.

ROENTGEN: A unit of exposure dose of gamma (or X-) radiation. It is defined precisely as the quantity of gamma (or X-) radiation such that the associated corpuscular emission per 0.001293 gram of air produces, in air, ions carrying one electrostatic unit quantity of electricity of either sign.

STRATOSPHERE: A relatively stable layer of the atmosphere between the tropopause and a height of about 30 miles in which the temperature changes very little (in polar and temperate zones) or increases (in the tropics) with increasing altitudes. In the stratosphere clouds of water never form and there is practically no convection.

TNT EQUIVALENT: A measure of the energy released in the detonation of a nuclear (or atomic) weapon, or in the explosion of a given quantity of fissionable material, expressed in terms of the weight of TNT which would release the same amount of energy when exploded. The TNT equivalent is usually stated in kilotons or megatons.

TRITIUM: A radioactive isotope of hydrogen, having a mass of 3 units; it is produced in nuclear reactors by the action of neutrons on lithium nuclei.

TROPOPAUSE: The imaginary boundary layer dividing the stratosphere from the lower part of the atmosphere, the troposphere. The tropopause normally occurs at an altitude of about 25,000 to 45,000 feet in polar and temperate zones, and at 55,000 feet in the tropics.

TROPOSPHERE: The region of the atmosphere immediately above the earth's surface and up to the tropopause in which the temperature falls fairly regularly with increasing altitude, clouds form, convection is active, and mixing is continuous and more or less complete.

WEAPON DEBRIS: The highly radioactive material, consisting of fission products, various products of neutron capture, and uranium and plutonium that have escaped fission, remaining after the explosion.

X-RAYS: Electromagnetic radiations of high energy having wave lengths shorter than those in the ultraviolet region.

YIELD (OR ENERGY YIELD): The total effective energy released in a nuclear (or atomic) explosion. It is usually expressed in terms of the equivalent tonnage of TNT required to produce the same energy release in an explosion. The total energy yield is manifested as nuclear radiation, thermal radiation, and shock (and blast) energy, the actual distribution being dependent upon the medium in which the explosion occurs (primarily) and also upon the type of weapon and the time after detonation.

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SHORT-LIVED RADIONUCLIDES

An analysis of radiation levels from the short-lived radionuclides will require additional study. The topic is introduced here, however, to point out that based on the strontium-90 rates of deposition, the amount of associated short-lived activities may be sufficient to produce external dose rates comparable to background levels in some areas of the country. This could create some public reaction.

DOWNGRADED TO BE UNCLASSIFIED
AUTHORITY: DOE - DP/DA
BY: R.E. O'Brien DATE: 12/17/85
By W. Tarver 7/24/86

[redacted]

[redacted]

IODINE-131

General

". . . Doses to the thyroid from the major past tests were estimated to have ranged from 100 to 200 millirems per year during and immediately following periods of testing. These values apply only to individuals who were infants at the time of highest concentration of radioactive iodine. The average value for all age groups was about a tenth as much. Although data from which thyroid doses during 1957-58 can be estimated are limited, it is likely that there was much geographic variation, and in some limited areas of the United States the average thyroid doses were probably many times the national average. . . ."[1.]

". . . At the present time, the monitoring programs indicate that I-131 levels accumulated during the past year to a value such that the estimated radiation dose to the thyroid" (of young children) "is about 1-1/2 times the annual background from naturally occurring materials, as a national average, and about 5 times the annual background in a few areas . . .", i.e. 0.15 and 0.5 rads. . . ."[2.]

Yearly Averages

Table I lists the yearly averages since the start of nuclear weapons tests in September 1961. (Public Health Service network.) There were only two stations above a yearly average of 100 micro-microcuries of I-131 per liter of milk (μμc/l); Palmer, Alaska (109) and Salt Lake City, Utah (102). [redacted]

Specific Events

Fall 1961 - There was a relatively large rise of I-131 in milk in the mid-west in the fall of 1961. (See Table II.) This probably resulted from the U.S.S.R. shots on September 10, 1961.[3] The ensuing trajectory was unique -- curling around the North Pole, passing down the U. S. eastern coast, turning westward along the Gulf coast states and hence up the mid-west. The fallout was principally in the form of dry deposition from the cold polar air mass (as contrasted with the more usual method of "rainout").

Spring 1962 - There was also a relatively large rise of I-131 levels in milk in the mid-west in the spring of 1962. (See Table III.) This could have resulted from the U. S. tests at Christmas Island. There were severe thunderstorms over the mid-west, reaching into the lower stratosphere.[4]

Salt Lake City and Environs July 1962 - There were relatively large rises in the I-131 in milk at Salt Lake City and its environs[5] due principally to Small Boy (July 14, 1962) and to a lesser extend by Johnie Boy (July 11, 1962) and Sedan (July 6, 1962). (See Table IV.) The peak value for any sample was 9,000 micro-microcuries per liter (a grab sample from a herd near Salt Lake City; not a composite sample).

Des Moines Event - On June 13, 1962, Des Moines underground shot released a substantial amount of radioactive debris; i.e., considerably greater amount than if it had just vented. The trajectory was northerly for a few hundred miles, then toward the

west and finally curled down the west coast. The highest recorded amount of I-131 in milk was 1,240 micromicrocuries per liter at Spokane, Washington, on June 21, 1962.

Evaluation

The top of Range II of the Federal Radiation Council Guides for normal peacetime operations is a daily intake of 100 micromicrocuries of I-131. These intake values may be averaged over periods up to one year. The Federal Radiation Council is currently working on Guides appropriate to nuclear weapons testing.

Based on the usual assumptions, the highest recorded stations (Palmer, Alaska and Salt Lake City, Utah) would correspond approximately to a 0.5 rad dose to the thyroid of children. The National Academy of Sciences - National Research Council report, Pathological Effects of Thyroid Irradiation, stated in part ". . . There is no evidence at hand, except for one doubtful case in a child, that any of the treatments for hyperthyroidism has produced a thyroid cancer, although doses have ranged from a few thousand rad upward. . . ."

[redacted]

TABLE I

Yearly Averages of Iodine-131 in Milk
(Micromicrocuries per liter)

	Sept. 1961-Aug. 1962	Oct. 1961-Sept. 1962
Alabama, Montgomery	12.5	12.2
Alaska, Palmer	65.8	109.0
Arizona, Phoenix	23.2	19.2
Arkansas, Little Rock	40.7	32.8
California, Sacramento	13.0	13.2
California, San Francisco	12.6	12.8
Colorado, Denver	26.5	23.5
Connecticut, Hartford	17.1	18.9
Delaware, Wilmington	20.9	22.7
District of Columbia, Washington	15.5	17.9
Florida, Tampa	15.4	12.6
Georgia, Atlanta	25.2	19.6
Hawaii, Honolulu	12.2	12.4
Idaho, Idaho Falls	45.1	37.5
Illinois, Chicago	40.2	40.7
Indiana, Indianapolis	24.7	25.6
Iowa, Des Moines	89.7	77.4
Kansas, Wichita	73.3	66.4
Kentucky, Louisville	29.6	26.0
Louisiana, New Orleans	28.0	20.1
Maine, Portland	20.0	24.1
Maryland, Baltimore	19.5	19.4
Massachusetts, Boston	30.0	26.0
Michigan, Detroit	48.9	41.3
Michigan, Grand Rapids	26.5	25.7
Minnesota, Minneapolis	87.8	69.5
Mississippi, Jackson	34.4	22.6
Missouri, Kansas City	92.2	85.5
Missouri, St. Louis	52.2	42.2
Montana, Helena	49.2	44.7
Nebraska, Omaha	70.0	63.1
Nevada, Las Vegas	6.1	8.1
New Hampshire, Manchester	25.6	22.8
New Jersey, Trenton	21.6	19.0
New Mexico, Albuquerque	20.3	19.7
New York, Buffalo	23.7	25.0
New York, New York	29.0	26.1
New York, Syracuse	33.3	30.4
North Carolina, Charlotte	12.5	9.7
North Dakota, Minot	27.4	41.2
Ohio, Cincinnati	33.9	33.4
Ohio, Cleveland	25.4	24.9

[redacted]

[redacted]

TABLE I (cont.)

Yearly Averages of Iodine-131 in Milk
(Micromicrocuries per liter)

	Sept. 1961-Aug. 1962	Oct. 1961-Sept. 1962
Oklahoma, Oklahoma City	52.4	46.9
Oregon, Portland	32.8	30.8
Pennsylvania, Philadelphia	22.4	21.5
Pennsylvania, Pittsburgh	25.2	23.5
Puerto Rico, San Juan	13.4	12.2
Rhode Island, Providence	22.8	21.0
South Carolina, Charleston	19.8	13.2
South Dakota, Rapid City	9.3	21.7
Tennessee, Chattanooga	23.6	18.9
Tennessee, Memphis	40.8	29.6
Texas, Austin	14.1	12.9
Texas, Dallas	22.1	20.9
Utah, Salt Lake City	101.5	93.9
Vermont, Burlington	24.9	22.5
Virginia, Norfolk	20.8	16.2
Washington, Seattle	30.9	33.6
Washington, Spokane	70.1	66.0
West Virginia, Charleston	18.5	16.3
Wisconsin, Milwaukee	40.2	38.6
Wyoming, Laramie	57.0	57.5

[redacted]

[redacted]

TABLE II

Some High Levels of Iodine-131 in Milk
Fall 1961
(Micromicrocuries per liter)

Locality	Date	Concentration
Nebraska, Omaha	October 2	730
Louisiana, New Orleans	September 25	530
Missouri, St. Louis	September 27	500
New York, New York	September 30	440

[redacted]

[redacted]

TABLE III

Some High Levels of Iodine-131 in Milk
Spring 1962
(Micromicrocuries per liter)

Locality	Date	Concentration
Kansas, Wichita	May 13	670
Iowa, Des Moines	May 16	300
Kansas, Kansas City	May 18	605
Kansas, Kansas City*	June 1	780
Nebraska, Omaha*	June 1	340

*Probably the result of earlier fallout in mid-May, plus a mixture of debris, principally from the U. S. tests at Christmas Island.

[redacted]

[redacted]

TABLE IV

Samples From Salt Lake City Milk Pool

Date Collected	μμc I-131/Liter
June 20, 1962	Not detectable
July 3,	" "
6	" "
10	20
11	60
12	30
13	300
14	250
15	390
16	410
17	160
18	450
20	1660
21	1190
22	450
22	1390
25	2050
26	1960
27	1290
28	960
29	730
31	570
August 2	640
3	590
4	370
5	410
6	520

[redacted]

[redacted]

REFERENCES

1. Federal Radiation Council, Health Implications of Fallout from Nuclear Weapons Testing through 1961, Report No. 3, (May 1962).

2. Prediction Panel of Congressional Hearings on Radiation Standards, Including Fallout, (June 1962).

3. "A Survey of Radioactive Fallout from Nuclear Tests", Machta, L.; List, R. J. and Telegadas, K., Journal of Geophysical Research, Vol. 67, No. 4, (April 1962).

4. Memorandum for the record, "Remarks on I-131 Fallout in Midwestern U. S. in Mid-May 1962", by Lester Machta. Reproduced in Congressional Hearings, Radiation Standards, Including Fallout, p. 776, (June 1962).

5. Memorandum for Commissioner Haworth, D. A. Ink, E. J. Bloch and others, "Meetings in Utah Re High Iodine Levels in Milk", Gordon Dunning, (August 13, 1962).

[redacted]

[redacted]

FALLOUT FROM NUCLEAR WEAPONS TESTS
AT
NEVADA TEST SITE

Summary Statements

1. With the resumption of nuclear tests in Nevada on September 15, 1962, the U. S. Atomic Energy Commission has detonated 52 nuclear devices in underground chambers which were designed to contain the radioactivity. In addition, six devices were detonated either in the atmosphere or at a shallow depth underground. These six devices were detonated only under conditions that would minimize exposures to populated off-site areas. A summary of the data on fallout from the nuclear detonations at the Nevada Test Site since September 15, 1961, is attached.

2. The highest exposure to any off-site person (as recorded on personnel film badges) was 438 milliroentgens. The Federal Radiation Council's Guide for normal peacetime operations is 1500 milliroentgens per year to individuals, and 500 milliroentgens per year when the technique is used of measuring a suitable sample of the population. An operational guide of 3.9 roentgens was used by the Test Organization in the following context: AEC Staff Paper 604/65, dated June 12, 1962, entitled OFF-SITE RADIATION EXPOSURE CRITERIA FOR NEVADA TEST SITE, recorded "the clarification of a basic guide of 3.9 roentgens estimated dose per year to off-site populations for nuclear weapons tests at the Nevada Test Site; every reasonable effort should be made to keep

[redacted]

the radiation exposures as low as possible, but for planning purposes, if unanticipated yet cridible circumstances could result in estimated doses in excess of 3.9 roentgens per year, then the detonations should be postponed until more favorable conditions prevail. Any past radiation exposures, from either nuclear weapons tests or other activities at the Nevada Test Site, would be included in estimating the total potential exposure from any given detonation."

3. The highest gross beta activity in the air was measured at Alamo, Nevada, on July 14, 1962, amounting to 140,000 micromicrocuries per cubic meter. Such activity in the air has no direct interpretation in terms of radiation doses to persons but serves to act as an alert for additional monitoring.

4. Drinking water supplies showed no signficant increases above those generally throughout the country.

5. Detailed information on milk monitoring is contained in a separate section.

[redacted]

FALLOUT FROM ATMOSPHERIC NUCLEAR WEAPONS TEST IN PACIFIC AREA
OPERATION DOMINIC
April-July 1962

Summary Statements

1. Documentation of radioactive contamination resulting from the U. S. tests at Christmas Island was conducted jointly by Joint Task Force Eight (JTF-8) Radiation Safety personnel and University of Washington personnel under AEC contract. The off-site area covered was approximately 2000 miles in radius, measured from Christmas Island. All populated islands in this area were monitored.

2. Bio-environmental samples were taken on Christmas Island in April 1962, before testing began and in the same locations in August 1962, after testing had ceased. Preliminary evaluation of available data on foodstuffs revealed little change in the levels of radioactive contamination between these two sets of measurements. During the operational period, transient increases of beta activity were detected in air and precipitation samples at some off-site stations. Film badge readings indicated no radiation exposures from fallout to any JTF-8 personnel or native populations above normal background radiation levels. The film badges used are ineffective at radiation exposures of less than 30 milliroentgens.

3. With completion of the testing program at Johnston Island in early November, bio-environmental sampling in the vicinity is planned for the near future. This program will be accomplished by personnel of the University of Washington, under AEC contract.

[redacted]

[redacted]

DRAFT

VII.

FALLOUT FROM NUCLEAR TESTS AT NEVADA TEST SITE

Since the resumption of nuclear tests on September 15, 1961, the United States Atomic Energy Commission had detonated 58 nuclear devices at the Nevada Test Site as of October 27, 1962. Fifty-seven of these were weapons tests, and one was a cratering experiment in the Plowshare program. Of the weapons tests, 52 detonations were in underground chambers which were designed to contain radioactivity, and five were detonated either in the atmosphere or at a shallow depth below the surface. The five latter detonations and the cratering experiment, in which the detonation occurred at a depth of 635 feet, were conducted under conditions in which exposures to populated off-site areas were minimized.

[redacted]

INDIVIDUAL EXPOSURES
OFF-SITE

As a part of the AEC's over-all monitoring program conducted in the area surrounding the Nevada Test Site, more than 260 persons have been issued film badges since the resumption of underground testing in September 1961. The recorded radiation exposure received by these personnel is maintained as a permanent record by the AEC, and each individual is informed of his exposure record. Table I summarizes the highest exposures received by off-site individuals since September 15, 1961, at NTS until about September 4, 1962. These records have been corrected for natural background radiation exposure, which is approximately 0.5 mr/day for the general area. Table II lists the locations and number of people wearing film badges that recorded no identifiable radiation exposure above natural background.

[redacted]

[redacted]

ENVIRONMENTAL CONTAMINATION

General

Since September 15, 1961, most of the nuclear test detonations at the Nevada Test Site have been conducted in underground chambers. This technique was used in an attempt to prohibit the release of radioactive material off the test site. As indicated in Table III, of the 52 underground nuclear detonations held in Nevada, eight have released some gaseous radioactivity measurable off-site.

The physical characteristics and relative amounts of various isotopes released by these tests vary somewhat from those released by past tests at NTS. Although there have been four surface or near surface detonations, plus one cratering shot giving off-site fallout resembling that from past test series, the major portion of the activity in the remainder of the series has been contained on-site or underground. Minimal amounts of gaseous activity, along with small quantities of particulate material containing activity, have been released to the atmosphere through venting of underground detonations.

In test series prior to 1961, nuclear devices were airdropped or were detonated on steel towers, balloons or in uncovered shallow holes; thus, fallout particles contained many kinds of debris in addition to the radioactivity. Induced activity in the debris

[redacted]

contributed little to the total radioactivity in the fallout. As much as 25 to 50 per cent of the total radioactivity returned to the earth within a few hours.

During the present series, the nature of the releases of gaseous material is such that the clouds formed do not rise to altitudes such as those from surface or near surface detonations, but linger near the surface and are acted upon by the lower tropospheric and surface winds. Normally, these clouds are so dispersed by the time they reach off-site populated areas that they are difficult to detect with portable monitoring equipment. However, in a few events, clouds have passed over areas where people were located; hence, there have been some off-site radiation exposures. These exposures are documented on film badges furnished to these people by AEC. The highest exposure from fallout recorded for an off-site individual was 438 mr at Nyala, Nevada.

Due to the gaseous nature and rapid movement of these clouds, stringent requirements are placed on the off-site monitors, who must intercept the clouds and record radiation intensities during passage of the clouds. Airborne monitors locate and track the radioactivity and direct the mobile ground monitors into the path of the clouds. Unless there is a continuous recording air or background radiation instrument or a mobile ground monitor in an area when a radioactive cloud passes, passage of the cloud can be

estimated only by predicting the cloud trajectory to determine whether the cloud has passed a specific area. There is generally little residual radioactivity deposited on the ground from these clouds. Records of cloud passage are obtained by mobile ground monitors in addition to routine monitoring of large off-site areas near the test site.

Milk

Milk collections have been made in the vicinity of NTS, and the samples analyzed by the U. S. Public Health Service, under contract with AEC. Tables IV, V, VI and VII present the highest concentrations of I-131 detected in milk during the indicated time periods.

In July 1962, the wind trajectories of radioactive clouds from five nuclear tests passed over the Salt Lake City area. Three of these clouds are known to have deposited residual fallout activity in this area. Iodine-131 was detected in milk supplies for a short period of time. The tables show that while the peak value of I-131 in milk in the Salt Lake City area was relatively high, the average levels over a period of time were considerably below those considered to constitute a health hazard, based upon previous studies of effects of I-131 upon human thyroids. For example, the station showing the highest yearly average (Salt Lake City with 102 micromicrocuries of I-131 per liter of milk) might result in a one-half roentgen exposure to the thyroid of young children and lessor amounts to adult thyroids.

[redacted]

Gross Beta Air Activity

At the present time, there are 28 permanent air sampling stations in operation surrounding NTS. The data recorded by these air samplers is used by the off-site monitoring group as an indicator of the presence of airborne radioactivity in that area. These data indicate the presence of radioactivity and the need for further monitoring but are of no direct value in assessing radiation doses. For purposes of illustration, the ten highest levels found in the area are listed in Table VIII.

Isotopic Air Results

The relative quantities of various isotopes in air are obtained from isotopic analysis of samples taken by prefilters and charcoal cartridges. Some of the highest values determined for I-131, I-133 and I-135 are shown in Table IX.

Water Supplies

Gross beta water monitoring is conducted for water supplies used by people in the off-site area around NTS. All sources monitored are subsurface supplies, except for Lake Mead. There are no known surface water supplies for human use in the nearby off-site area. The highest levels of gross beta activity in water supplies during the period of October 1961 to October 1962 are listed in Table X. For comparison, there has been selected some other high level data from the U. S. Public Health Service on radioactivity in raw surface water in the United States.

[redacted]

[redacted]

Isotopic analysis was conducted on many of these NTS samples, and the results show that levels of cesium-137, barium-140, zirconium-95, ruthenium-103, cerium-141, cerium-144 and iodine-131 were below the levels of detection. Levels of strontium-89 and strontium-90 were less than 5 μμc/l and 1 μμc/l respectively.

[redacted]

TABLE I

Highest Exposures Received by Off-Site Individuals at NTS
September 15, 1961 - September 4, 1962

Location*	Period of Time In Which Exposure Occurred**	Total Exposure (mr)	Exposure From Fallout (mr)
Caliente	1/31/62 - 8/28/62	245	141
Casey Ranch	5/16/62 - 8/8/62	230	188
" "	" "	260	218
" "	" "	285	243
Diablo	5/15/62 - 8/16/62	265	220
"	2/7/62 - 8/16/62	330	285
Nyala	5/16/62 - 8/8/62	290	248
"	" "	435	393
"	6/20/62 - 8/8/62	310	285
"	5/16/62 - 8/8/62	480	438
Penoyer Ranch	3/5/62 - 8/16/62	260	178
Pine Creek Ranch	5/24/62 - 8/8/62	345	307
" " "	" "	255	217
Twin Springs	5/15/62 - 8/16/62	290	245
" "	2/13/62 - 8/16/62	265	173
Blue Eagle Ranch	6/12/62 - 9/5/62	205	161
" " "	5/9/62 - 9/5/62	200	140
" " "	6/11/62 - 8/10/62	255	225
" " "	5/16/62 - 9/6/62	285	229
Duckwater	5/19/62 - 9/4/62	215	161
Gardner Ranch	2/14/62 - 9/5/62	395	294
Hiko	2/20/62 - 9/3/62	340	243
Lockes	2/6/62 - 9/4/62	215	110
Manzonie Ranch	2/13/62 - 9/4/62	280	179
" "	" "	210	109

*Each entry represents a different individual.

**These dates vary because all individuals were not residing in the area during the entire testing period.

[redacted]

TABLE II

Locations and Number of People Wearing Film Badges
That
Recorded No Identifiable Radiation Exposure* Above Natural Background
September 15, 1961 - August 25, 1962

St. George, Utah	15 people
Littlefield, Arizona	2 people
Beatty, Nevada	26 people
Furnace Creek, Nevada	8 people
Lathrop Wells, Nevada	16 people
Pahrump, Nevada	10 people
Rhyolite, Nevada	2 people
Springdale, Nevada	1 person
Tonapah, Nevada, Area	32 people

*Exposures less than 30 mr cannot be determined accurately from these film badges.

[redacted]

TABLE III

Nuclear Events at Nevada Test Site
September 15, 1961 - December __, 1962

Date	Type Shot[7]	Footnotes
15 Sept. '61	Low Yield - Underground	2, 3
16 Sept. '61	"	1, 4
10 Oct. '61	"	2, 3
29 Oct. '61	"	2, 4
3 Dec. '61	"	1, 4
13 Dec. '61	"	1, 4
17 Dec. '61	"	1, 4
22 Dec. '61	"	2, 4
9 Jan. '62	"	1, 4
18 Jan. '62	"	2, 4
30 Jan. '62	"	2, 4
8 Feb. '62	"	1, 4
9 Feb. '62	"	2, 4
15 Feb. '62	"	2, 4
19 Feb. '62	"	2, 4
19 Feb. '62	"	2, 4
23 Feb. '62	"	1, 4
24 Feb. '62	"	2, 4
1 Mar. '62	"	2, 3
5 Mar. '62	Shallow depth, Low yield, Underground	5, 3
6 Mar. '62	Low yield, Underground	1, 4
8 Mar. '62	"	2, 4

[redacted]

[redacted]

TABLE III (cont.)

Date	Type Shot[7]	Footnotes
15 Mar. '62	Low yield, Underground	1, 4
28 Mar. '62	"	1, 4
31 Mar. '62	"	1, 4
5 Apr. '62	"	1, 4
6 Apr. '62	"	1, 4
12 Apr. '62	"	1, 4
14 Apr. '62	"	5, 3
21 Apr. '62	"	1, 4
27 Apr. '62	"	1, 4
7 May '62	"	1, 4
12 May '62	Intermediate yield, Underground	1, 4
19 May '62	Low yield, Underground	5, 3
25 May '62	"	1, 4
1 June '62	"	1, 4
6 June '62	"	1, 4
13 June '62	"	5, 3
21 June '62	"	1, 4
27 June '62	Intermediate yield, Underground	2, 4
28 June '62	Low yield, Underground	2, 3
30 June '62	"	1, 4
6 July '62	Plowshare cratering experiment	5, 6, 3
7 July '62	Low yield slightly above ground	5, 4
11 July '62	Shallow depth low yield	5, 3
13 July '62	Low yield, Underground	1, 4

[redacted]

OF [redacted]

TABLE III (cont.)

(This table will be updated with additional shots to be added.)

Date	Type Shot[7]	Footnotes
14 July '62	Low yield few feet above ground	5, 3
17 July '62	Low yield slightly above ground	5, 3
27 July '62	Low yield, Underground	2, 4
24 Aug. '62	"	1, 4
24 Aug. '62	"	1, 4
14 Sept. '62	"	1, 4
20 Sept. '62	"	1, 4
29 Sept. '62	"	1, 4
5 Oct. '62	Intermediate yield, Underground	1, 4
12 Oct. '62	Low yield, Underground	1, 4
19 Oct. '62	"	5, 3
27 Oct. '62	"	1, 4

[redacted]

TABLE III (cont.)

Footnotes:

1. No release of radioactivity occurred.

2. Release of small quantities of steam and/or a gaseous cloud containing small quantities of radioactivity.

3. Some activity detected off-site.

4. No activity detected off-site.

5. A radioactive cloud produced.

6. 635 feet underground-cratering shot - less than 30 KT fission.

7. Low yield - 20 KT or less.

   Intermediate yeidl - between 20 KT and 1 MT.

[redacted]

TABLE IV

Highest Concentrations of I-131 in Individual
Samples of Milk in Nevada
September 1, 1961 - July 1, 1962

Location	Date	Levels (μμc/l)
Elko, Nevada	11/ 2/61	720
Elko, Nevada	6/21/62	610
Robbins Ranch, Nevada	6/22/62	520
Austin, Nevada	6/30/62	180
Carlin, Nevada	6/22/62	160
Eureka, Nevada	6/23/62	110
Fallini's Ranch, Nevada	11/29/61	90
Wendover, Nevada	6/29/62	90

10 other measurements between 10 and 80 μμc/l

26 other measurements less than 10 μμc/l

[redacted]

TABLE V

Highest Concentrations of I-131 in Individual Samples of Milk in (a) Nevada and (b) Utah July 1962

(a) Nevada - (Based on 66 samples from 23 sources)

Location	Date	Levels (μμc/l)
Caliente, Nevada	7/19/62	6,900
Caliente, Nevada	7/23/62	3,500
Fallini's Ranch, Nevada	7/23/62	3,200
Ely, Nevada	7/24/62	2,800
Alamo, Nevada	7/17/62	2,300
Ely, Nevada	7/26/62	2,000
Caliente, Nevada	7/25/62	1,800

(b) Utah - (Based on 53 samples from 9 sources)

Snyderville, Utah	7/20/62	9,000
Snyderville, Utah	7/20/62	5,400
Snyderville, Utah	7/25/62	4,400
Oakley, Utah	7/25/62	4,400
Oakley, Utah	7/25/62	4,200
Snyderville, Utah	7/27/62	3,000
Kamas, Utah	7/27/62	2,600
Oakley, Utah	7/27/62	2,600
Oakley, Utah	7/30/62	2,200

[redacted]

TABLE VI

Highest Concentrations of I-131 in Milk in (a) Nevada and (b) Utah
August 1962

(a) Nevada

Location	Date	Levels (μμc/l)
Caliente, Nevada	8/ 1/62	1,000
Pioche, Nevada	8/ 8/62	1,000
Alamo, Nevada	8/ 2/62	420
Ely, Nevada	8/ 2/62	410
Lund, Nevada	8/10/62	400
Panaca, Nevada	8/ 6/62	370
Las Vegas, Nevada	8/ 1/62	260

(b) Utah

Kamas, Utah	8/ 3/62	1,500
Kamas, Utah	8/ 6/62	1,500
Oakley, Utah	8/ 3/62	1,200
Snyderville, Utah	8/ 9/62	880
Snyderville, Utah	8/ 3/62	740
Vernal, Utah	8/21/62	570
Ogden, Utah	8/ 2/62	260
Logan, Utah	8/ 1/62	130

[redacted]

TABLE VII

Highest Concentrations of I-131 in Milk in Nevada and Utah
September 1962

Location	Date	Levels (μμc/l)
Blue Eagle Ranch, Nevada	9/12/62	130
Blue Eagle Ranch, Nevada	9/ 6/62	90
Logan, Utah	9/ 4/62	70
Logan, Utah	9/ 6/62	60
Caliente, Nevada	9/ 6/62	60
White River Valley, Nevada	9/ 7/62	60
White River Valley, Nevada	9/13/62	60

[redacted]

[redacted]

TABLE VIII

Highest Gross Beta Air Activity for
Off-Site Communities in Nevada

	Location	Concentration ($\mu\mu c/M^3$)	Time	Date
1.	Diablo	13,000	0905-1637	7/ 6/62
2.	Diablo	33,000	1645-2000	7/ 6/62
3.	Ely	7,300	2000-0800	7/ 6/62-7/ 7/62
4.	Peyomor Ranch	8,800	1105-0245	7/ 6/62-7/ 7/62
5.	Warm Springs	7,800	0600-1545	7/10/62-7/11/62
6.	Alamo	140,000	1445-1900	7/14/62
7.	Alamo	24,000	0630-1100	7/14/62-7/15/62
8.	Caliente	9,300	1400-1500	7/14/62-7/15/62
9.	Diablo	10,000	1000-1600	7/14/62
10.	Lund	10,000	1745-1855	7/14/62

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TABLE IX

Highest Isotopic Air Results for
Off-Site Communities in Nevada

Charcoal Cartridges

Location	Collection Period Time	Collection Period Date	(μμc/M³) Midcollection or Cloud Peak Time I-131	I-133	I-135
Diablo	0905-1637	7/ 6/62-7/ 6/62	267	13,500	61,400
Ely	2000-0800	7/ 6/62-7/ 7/62	72	2,550	ND*
Pengyer	1105-0245	7/ 6/62-7/ 7/62	70	3,950	9,200
Diablo	1000-1650	4/14/62-4/15/62	55.3	762	2,800
Lockes	1315-1315	7/ 6/62-7/ 7/62	49	202	ND*

Prefilters

Diablo	0905-1637	7/ 6/62-7/ 6/62	3,560	ND*	ND*
Diablo	0840-1925	6/13/62-6/13/62	190	2,700	20,000
Currant	0800-0800	4/14/62-4/15/62	400	2,100	ND*
Diablo	1000-1650	4/14/62-4/14/62	525	2,700	2,000
Caliente	1400-1500	7/14/62-7/15/62	1,100	ND*	ND*

*ND means "not detectable".

[redacted]

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TABLE X

Gross Beta Water Results

Nevada Test Site Area

Location	Date	Levels (uuc/l)
Diablo	February 1962	51
Furnace Creek	August 1962	32
Ash Meadows	July 1962	70
Lathrop Wells	November 1961	68
Tonopah Test Range	May 1962	98

*U. S. Public Health Service Data (March 1962)

Coolidge, Kansas	74
Page, Arizona	43
Peoria, Illinois	58
Cape Girardeau, Missouri	45
Kansas City, Kansas	47

*These levels are some of those recorded for March 1962. The data presented is activity associated with dissolved solids in raw surface water samples. The levels of radioactivity associated with dissolved solids provide a rough measure of the levels which may be found in treated water, where such water treatment removes substantially all of the suspended matter. The comparison is made, therefore, between the gross beta activity found in subsurface water supplies which generally are untreated and the gross beta activity in surface water supplies associated with dissolved solids which are not removed by water treatment. They should not be interpretated as average values because levels at many other locations were much lower. (For more complete data, see "Radiological Health Data", Vol. III, No. 9, September 1962.)

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DRAFT

FALLOUT FROM ATMOSPHERIC NUCLEAR WEAPONS TEST IN PACIFIC AREA
OPERATION DOMINIC

During 1962, there were 35 nuclear devices detonated in the atmosphere above the Pacific Ocean near Christmas Island and Johnston Island. The yield of these devices ranged from low kiloton to the megaton range. The height of burst for all detonations was sufficient to negate local radioactive fallout. The devices were delivered to the point of detonation by either manned aircraft or surface-to-air missiles.

In addition to the atmospheric tests, there was one underwater test, a low yield nuclear device, detonated in the Eastern Pacific Ocean several hundred miles from the closest land area and remote from any commercial fishing areas. This underwater test deposited all of the fission product radioactivity in the ocean where it decayed and was mixed and diluted by sea water.

The radiological safety program for the test series was a joint effort among the Joint Task Force Eight (JTF-8) personnel, U. S. Public Health Service personnel assigned to JTF-8 for the test and personnel from the University of Washington, Seattle, Washington, under contract to the U. S. Atomic Energy Commission.

The on-site program consisted primarily of air and background monitoring and personnel and equipment monitoring on Christmas Island and Johnston Island. The off-site program consisted of a series of cruises by the C.H. Gilbert for collecting environmental samples in the Central Pacific area and a network of 19 monitoring

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stations established on islands within a radius of 2,000 miles of Christmas Island. In the island network, four were primary stations located on populated islands, manned by officers of the U. S. Public Health Service; six were secondary stations located on more distant islands and populated mainly by JTF-8 personnel who operated the monitoring equipment; nine were background stations located on islands at a considerable distance from the test area. The equipment at the background stations consisted primarily of continuous background recording equipment operated by weather groups or scientific personnel already on the island. Figure 1 shows the location and level of effort of the stations of the network.

Environmental samples were collected routinely by JTF-8 personnel during the period of April 12-August 15, 1962. Scientific personnel aboard the C.F. Gilbert participated in this environmental sampling program on three cruises, April 24-May 12, 1962, June 4-June 25, 1962, and July 23-August 15, 1962. Approximately 8,000 samples were collected, most of which were returned to the University of Washington, Seattle, Washington, for complete analysis. Data from these examinations will not be available until after January 1, 1963.

Preliminary data from beta and gamma radiation scanning of the environmental samples were obtained from the laboratory on Christmas Island. The Hawaiian Surveillance Network (a U. S. Public Health Service activity) collected environmental samples on

the Hawaiian Islands during the entire period. Analysis of these samples was accomplished at the Public Health Laboratory, Honolulu, Hawaii.

Preoperational Samples

Radioactivity was detected in samples collected during the preoperational period. Representative findings are presented in Table I for water, milk and food samples.

Operational Samples

Samples collected during the operational period were for the most part from the sampling stations established on the various islands of the area. Tables II and III summarize findings for gross beta air activity, precipitation and drinking water. It can be seen that gross beta activity in air was low during the entire period of the operation. However, samples of precipitation gave relatively high gross beta readings which are reflected in the drinking water samples.

The levels of radioactivity in native foodstuffs during the test operational period were found to be about the same as that in preoperational samples. Samples of grass and scavola were found to contain high levels of fission product activity. The highest level of gross beta activity detected in grass was 135,000 μμc/kg for a sample obtained on July 11, 1962, at Rarotonga. Since the gross beta activities in both the grass and drinking water samples were the result of fresh fission product fallout, the activities decreased rapidly with time.

Average gamma radiation levels were taken routinely at all JTF-8 radiological safety stations. Normal background for the islands in the Central Pacific is 0.01 to 0.03 milliroentgens per hour (mr/hr). The greatest increases in gamma background were recorded on Fanning Island on May 6, 1962, on Palmyra Island on June 12, 1962, and on Washington Island on July 14, 1962, with all stations showing a rise to 0.04 mr/hr. Tabulated data indicate that there was no significant change in background in the Central Pacific area as a result of Operation Dominic.

The total radiation exposure due to fallout as recorded by film badges from Operation Dominic, was essentially zero on Christmas Island. The maximum infinity dose on both Penrhyn Island and Washington Island, as calculated by external gamma radiation measurements, was less than 10 mrem. This is below the level of detection of film badges.

Summary of Results During Test Operations

Fanning Island

No significant fallout occurred. An increase in air concentration to 20 $\mu\mu c/M^3$ occurred on May 24, 1962. Fission product activity was detected also in scavola and grass samples.[1/] The highest precipitation deposition occurred during the period of June 26-July 8, 1962. However, levels of radioactivity detected

1/ Since there are few grazing animals present on these islands, levels of contamination of grass and scavola are only indicative of some fallout.

in drinking water and food samples collected during and after this period were not significantly different from the levels detected in preoperational samples.

Washington Island

On May 7 and 21, 1962, fission products were detected in precipitation samples. The presence of this radioactivity was reflected also in scavola and grass samples.[1/] Levels of fission products in precipitation samples indicated an increase to about 8,700 μμc/l gross beta on May 14, 1962. However, on the 15th, this activity was decreasing rapidly. Drinking water collected at this time showed 650 μμc/l gross beta activity, of which 25 μμc/l was I-131. This is far below the level at which the water would be unsafe to drink.

Palmyra Island

The highest air concentration was 58 μμc/M^3, observed on June 25, 1962. Other peaks of air activity were 43 μμc/M^3 on May 17, 1962, and 39 μμc/M^3 on June 21, 1962.

Penrhyn Island

On May 13, 1962, the level of I-131 detected in precipitation was 3,600 μμc/l. This was attributed to rain-out involving fresh fission products. If an adult had drunk one liter of this water

1/ Since there are few grazing animals present on these islands, levels of contamination of grass and scavola are only indicative of some fallout.

per day until all of the I-131 activity had decayed away, the total dose to his thyroid would have been less than one rad. However, heavy rains continued in the area for four more days with the precipitation after the first day containing essentially no additional I-131. This, of course, diluted the iodine activity found on May 13, to the point where the integrated dose to the adult's thyroid would have been less than 50 mrads. Similar calculations of dose to a child's thyroid would have resulted in higher values than for adults, but children on Penrhyn drink much less water.

Samoa Island

Except for the possibility of some fresh fission debris in grass,[1/] no fission products identifiable as resulting from Operation Dominic were detected.

Rarotonga Island

Except for the possibility of some fresh fission debris in grass[1/] and precipitation, no fission products identifiable as resulting from Operation Dominic were detected.

Nuka Hiva

On July 14, 1962, air concentration increased to 26 $\mu\mu c/M^3$ gross beta activity. No other identifiable fission products were detected during the testing period.

1/ Since there are few grazing animals present on these islands, levels of contamination of grass and scavola are only indicative of some fallout.

Johnston Island

Postoperational monitoring is in process at the time of writing this report. No fission products were identifiable as resulting from the Christmas Island portion of Operation Dominic. It is not expected that there will be more fission products at Johnston Island than at Christmas Island.[2/]

Other Islands

Traces of radioactivity were detected in air samples and in precipitation in Hawaii, on Christmas Island and Malden Island. No radioactive fallout identifiable from Operation Dominic events was detected on Canton Island, Tongatabu Island, Tahiti, Wake Island, Midway Island, French Frigate Shoals and Kwajalein Island.

Postoperational Samples

Data on the levels of radioactivity found in selected samples collected during the postoperational period are presented in Tables IV and V. The gross beta activity level in food is relatively unchanged from the level in the preoperational samples.

2/ The launching pad on Johnston Island (approximately 1000 foot radius) was contaminated by scattered fissionable material, following the destruction of a device after a missile malfunction on July 25, 1962. The levels of alpha contamination in this area exceeded the permissible limits; thus, cleanup of the area was required. Cleanup consisted of decontaminating equipment, scraping the top layer of soil of the areas which were highly contaminated and sealing the contamination on buildings with layers of concrete or paint. The decontamination was completed by mid-August.

Levels of activity in samples of well water in the postoperational period were relatively unchanged from the preoperational samples. The gross beta levels of activity of grass samples in Table IV are lower than those found during the operational phase, as will be noted on the sample from Rarotonga. During the test period, the activity level found was 135,000 μμc/kg; whereas, the level in the postoperational period was reduced to 15,000 μμc/kg.

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TABLE I

JTF-8 Off-Site Surveillance Network, Preoperational Samples
Christmas Island - Water Samples

Type	Date	Location	Gross Beta (μμc/l)	I-131 (μμc/l)	Sr-90 (μμc/l)
Well water	4/24/62	Bamboo Waterhole	4	ND*	0.7
Well water	4/20/62	London	9	ND*	-
Well water	4/20/62	London	22	ND*	0.3
Well water	4/20/62	London	17	ND*	0.5

Christmas Island - Environmental and Food Samples

Type	Date	Location	Gross Beta (μμc/kg) ~~wet weight~~	Other Specific Isotopes; i.e. Ce-141, Ce-144, I-131, Ba-140, Cs-137, Zr-Nb-95, Zn-65, Ru-103-106
Bonefish liver	4/20/62	London Reef	-	ND*
Hermit crab	"	London	2800	ND*
Coconut milk	"	JOC	900	only trace of Cs-137
Bonefish muscle	"	London Reef	3000	"
Langusta muscle	"	London Reef	1500	"
Langusta shell	"	London Reef	-	ND*
Coconut (green)	"	London	-	ND*
Soil	"	London	-	ND*
Bonefish muscle	"	Y-Site	-	ND*
Jackfish liver	"	Y-Site	-	ND*
Jackfish muscle	"	Y-Site	4000	ND*

*ND means "not detectable".

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TABLE I (cont.)

Oahu, Hawaiian Islands - Water, Milk and Food Samples

Type	Date	Location	Sr-89 (μμc/l)	I-131 (μμc/l)	Ba-140 (μμc/l)	Cs-137 (μμc/l)	Zr-95 (μμc/l)	Ru-103-106 (μμc/l)
Well water	4/10/62	Wahiawa	-	ND*	30	ND*	45	-
Well water	4/10/62	Kaneohe	-	25	ND*	ND*	10	-
Milk	4/ 5/62	Oahu	-	ND*	ND*	10	-	-
"	4/24/62	"	40	ND*	ND*	25	-	-
			μμc/kg - wet weight					
String beans	4/11/62	"	[illegible]	ND*	ND*	15	90	465
String beans	"	"	-	ND*	ND*	15	20	115
Pineapple	"	"	4	ND*	ND*	ND*	140	285
Green onion	"	"	-	140	ND*	ND*	270	240
Green onion	"	"	-	ND*	ND*	ND*	85	165
Sweet potato	"	"	8	ND*	ND*	15	10	115
Sweet potato	"	"	-	ND*	ND*	15	ND*	ND*
Papaya	"	"	-	ND*	ND*	25	60	140
Papaya	"	"	-	ND*	ND*	35	50	115
Banana	"	"	-	ND*	ND*	ND*	ND*	ND*
Water cress	"	"	-	15	ND*	65	135	290
Water cress	"	"	3	ND*	ND*	ND*	285	285

*ND means "not detectable".

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TABLE I (cont.)

Fanning Island - Water and Food Samples

		Gross Beta (μμc/l)	Gross Beta (μμc/kg) Wet Weight	Concentrations μμc/kg wet wt. Other Isotopes
Well water	4/21/62	85	-	ND*
Coconut	4/23/62	-	3000	ND*
Papaya	4/22/62	-	2300	100 - Zr-95
Pandanus	4/22/62	-	1200	450 - Cs-137
Hermit Crab	4/21/62	-	-	trace of Cs-137 and Zn-65
Lobster Tail	4/22/62	-	6100	ND*
Bonefish	4/22/62	-	-	ND*

Washington Island - Water and Food Samples

Roof water	4/23/62	32	-	not measured
Well water	4/23/62	6	-	not measured
Breadfruit	4/22/62	-	1590	430 - Cs-137
Papaya	4/22/62	-	1580	150 - Cs-137
Pandanus	4/22/62	-	3200	220 - Cs-137
Coconut (ripe)	4/22/62	-	2710	410 - Cs-137
Coconut (grn)	4/22/62	-	180	59 - Cs-137 67 - Zr-95
Lobster	4/24/62	-	2300	190 - Zr-95 320 - Zn-65
Octopus	4/28/62	-	2900	250 - Zr-95

American Samoa - Food Samples

Tuna muscle	4/24/62	-	2900	ND*
Tuna muscle	4/24/62	-	3000	ND*
Tuna muscle	4/24/62	-	2800	ND*

*ND means "not detectable".

[redacted]

TABLE II

JTF-8 Off-Site Surveillance Network - Operational Samples
Gross Beta Air Activity ($\mu\mu c/M^3$)

Location	May 1-30, 1962		June 1-30, 1962		July 1-15, 1962	
Christmas Island (JOC)	Avg. - 3.7 Max. - 11	(5/20)	Avg. - 4 Max. - 18	(6/9)	Avg. - 2.1 Max. - 12.5	(7/13)
Christmas Island (London)	Avg. - 5.3 Max. - 17	(5/19)	Avg. - 3.5 Max. - 12.5	(6/9)	Avg. - 0.9 Max. - 1.4	(7/3)
Christmas Island (A-Site)	Avg. - 4 Max. - 15	(5/18)	Avg. - 3.5 Max. - 12	(6/9)	Avg. - 0.5 Max. - 1.0	(7/3)
Fanning Island	Avg. - 5.4 Max. - 20.5	(5/24)	Avg. - 4.4 Max. - 14.5	(6/3)	Avg. - 1.0 Max. - 2.7	(7/11)
Washington Island	Avg. - 3.5 Max. - 13.5	(5/18)	Avg. - 2.7 Max. - 13	(6/10)	Avg. - 1.1 Max. - 4.5	(7/15)
Honolulu, Hawaii	Avg. - 2 Max. - 4.4	(5/17)	Avg. - 1.9 Max. - 3.5	(6/2)	Avg. - 1.6 Max. - 3.5	(7/26)
Palmyra Island	Avg. - 4.7 Max. - 43	(5/17)	Avg. - 8 Max. - 39 Max. - 57.7	(6/21) (6/25)	Avg. - 2 Max. - 7	(7/14)
Malden Island	Avg. - 5.4 Max. - 19	(5/15)	Avg. - 3.9 Max. - 11.2	(6/10)	Avg. - 1 Max. - 2	(7/11)
Penrhyn	No Data		Avg. - 2.4 Max. - 7	(6/28)	Avg. - 3.4 Max. - 13.5	(7/10)
Canton Island	Avg. - 5.5 Max. - 10	(5/17)	Avg. - 5.5 Max. - 24.5	(6/2)	Avg. - 3.3 Max. - 6.8	(7/1)
Johnston Island	No Data		Avg. - 1.4 Max. - 2.5	(6/11)	Avg. - 3 Max. - 10.5	(7/19)
Wake Island	No Data		Avg. - 1.5 Max. - 3	(6/14)	Avg. - 1.1 Max. - 3.4	(7/3)
Midway Island	No Data		Avg. - 1.5 Max. - 3.7	(6/13)	Avg. - 1 Max. - 2.3	(7/19)
French Frigate Shoals	No Data		Avg. - 2 Max. - 4.6	(6/22)	Avg. - 2.1 Max. - 4.8	(7/22)

[redacted]

TABLE II (cont.)

JTF-8 Off-Site Surveillance Network - Operational Samples
Gross Beta Air Activity ($\mu\mu c/M^3$)

Location	May 1-30, 1962	June 1-30, 1962	July 1-15, 1962
Kwajelin Island	No Data	Avg. - 1.9 Max. - 4 (6/27)	Avg. - 0.9 Max. - 3.2 (7/7)
Tahiti	No Data	Avg. - 0.65	Avg. - 0.9 Max. - 4.5 (7/12)
Nuku Hiva	No Data	Avg. - 1 Max. - 3 (6/13)	Avg. - 2 Max. - 26 (7/14)

[redacted]

[redacted]

TABLE III

JFT-8 Off-Site Surveillance Network
Operational Precipitation Samples

Location	Date	Gross Beta (μμc/l)	Iodine-131 (μμc/l)
Honolulu, Hawaii	4/26/62	410	--
" "	5/21/62	1,400	--
Kaneohe, Hawaii	7/ 5/62	700	--
Christmas Island	5/ 9/62	5,100	--
" "	6/ 1/62	670	ND*
" " (JOC)	7/19/62	800	40
Christmas Island (London)	6/11/62	920	25
Christmas Island (A-Site)	6/ 1/62	580	ND*
Fanning Island	5/ 7/62	1,200	--
" "	5/21/62	2,000	19
" "	7/ 8/62	14,000	ND*
Washington Island	5/ 7/62	3,700	ND*
" "	5/21/62	1,200	90
" "	7/14/62	8,700	37
" "	7/15/62	4,900	113
Malden Island	6/ 9/62	550	51
Penrhyn Island	5/13/62	257,000	3,600
Canton Island	5/31/62	310	ND*
Nuka Hiva	6/16/62	25	ND*
Tahiti	6/30/62	69	31
Viti Levu	7/20/62	420	ND*
Samoa	6/30/62	2,900	ND*
Tongatabu	7/13/62	103	ND*
Rorotonga	6/30/62	6,700	ND*

Operational Drinking Water Samples

Location	Type	Date	Gross Beta (μμc/l)	I-131 (μμc/l)	Sr-90 (μμc/l)
Christmas Island	well	4/28/62	150	--	--
" "	"	6/24/62	16	23	--
Penrhyn Island	cistern	6/ 8/62	330	18	--
" "	"	6/ 9/62	470	20	0.4
Tongatabu Island	"	7/13/62	103	ND*	--
Rarotonga	"	7/11/62	128	ND*	--

*ND means "not detectable".

[redacted]

[redacted]

TABLE IV

JTF-8 Off-Site Surveillance Network
Postoperational, Environmental and Food Samples by Island

Location	Type	Date	Radionuclide Concentration μμc/kg of wet weight						
			Gross Beta	Ce-141,144*	I-131	Ba-140	Cs-137	Zr-Nb-95	Ru-103,106*
Christmas Island	Scavola	7/16/62	4,300	3,600	nd	5,200	nd	-	-
Christmas Island	Ripe Coconut	7/16/62	4,300	nd	nd	nd	nd	nd	nd
Christmas Island	Green Coconut	7/16/62	1,800	nd	nd	nd	nd	nd	nd
Christmas Island	Soil	7/16/62	nd	2,100	nd	nd	nd	2,600	400
Hawaii (Oahu)	Pineapple	7/31/62	nd	-	nd	nd	110	30	nd
Hawaii (Kauai)	Lettuce	7/31/62	820	-	nd	nd	nd	Trace	nd
Hawaii (Oahu)	Lettuce	7/31/62	Incomp	-	-	-	-	-	-
Hawaii (Oahu)	Milk	7/31/62	-	-	nd	nd	35	-	-
Fanning Island	Scavola	7/13/62	27,800	8,600	500	3,400	nd	8,000	1,100*
Fanning Island	Coconut	7/13/62	1,800	nd	nd	nd	230	nd	nd
Fanning Island	Coconut Milk	7/13/62	789	nd	nd	nd	nd	nd	nd
Fanning Island	Soil	7/13/62	-	1,400	nd	nd	nd	2,250	2,500
Washington Island	Ripe Coconut	7/13/62	1,800	Trace	nd	nd	280	nd	nd
Washington Island	Green Coconut	7/13/62	1,100	Trace	nd	nd	110	nd	nd
Washington Island	Scavola	7/15/62	11,000	8,500*	900	4,000	nd	6,000	1,200*
Washington Island	Soil	7/15/62	6,500	1,400	nd	870	nd	1,350	580
Washington Island	Eggs	7/15/62	980	nd	nd	nd	nd	nd	nd
Penrhyn Island	Soil	7/19/62	1,800	11,850	nd	nd	nd	3,810	480
Viti Levu, Fiji	Soil	7/25/62	nd	nd	nd	nd	Trace	340	nd
Viti Levu, Fiji	Grass	7/25/62	30,000	6,300*	nd	2,400	nd	16,000	4,900

*If Ru and Ce activities are marked with an asterisk (*), the activity reported is assumed to be from the shorter lived isotopes Ru-103 and Ce-141. Otherwise the activity is assumed to be due to the longer lived isotopes Ru-106 and Ce-144.
Trace - Insufficient to quantitate.
nd - No detectable activity.
Incomp - Analysis in process, results to follow.

[redacted]

[redacted]

TABLE IV (cont.)

JTF-8 Off-Site Surveillance Network
Postoperational, Environmental and Food Samples by Island

Location	Type	Date	Radionuclide Concentration μμc/kg of wet weight						
			Gross Beta	Ce-141,144*	I-131	Ba-140	Cs-137	ZrNb-95	Ru-103,106*
Tutuila, Samoa	Soil	7/21/62	nd	nd	nd	nd	nd	650	2,100
Tutuila, Samoa	Grass	7/31/62	35,000	19,000*	nd	9,000	nd	47,000	7,500*
Tongatubu	Soil	7/24/62	nd	nd	nd	nd	Trace	Trace	nd
Tongatubu	Grass	7/24/62	7,500	2,600	nd	1,000	nd	24,000	1,000*
Tongatubu	Milk	7/24/62	-	nd	10	42	20	190	nd
Rarotonga	Soil	7/21/62	nd	55	nd	nd	nd	72	23
Rarotonga	Grass	7/21/62	15,000	nd	nd	Trace	nd	25,000	2,000
Canton Island	Soil	7/20/62	-	600	nd	nd	nd	1,100	580

*If Ru and Ce activities are marked with an asterisk (*), the activity reported is assumed to be from the shorter lived isotopes Ru-103 and Ce-141. Otherwise the activity is assumed to be due to the longer lived isotopes Ru-106 and Ce-144.
Trace - Insufficient to quantitate.
nd - No detectable activity.

[redacted]

TABLE V

JTF-8 Off-Site Surveillance Network
Postoperational Water Samples by Island

Location	Type	Date	(μμc/l) Gross Beta
Christmas (Bamboo)	Well	7/15/62	10
Christmas (Becca)	Well	7/15/62	10
Christmas (Banana)	Well	7/15/62	20
Oahu (Wahiawa)	City	7/31/62	13
Oahu (Kaimuki)	City	7/31/62	10
Oahu (Honolulu West)	City	7/31/62	10
Oahu (Kaneohe)	City	7/31/62	10
Fanning Island	Well	7/11/62	10
Washington Island	Well	7/13/62	35
Washington Island	Cistern	7/15/62	650
Penrhyn Island	Cistern	7/19/62	320
Canton Island	Cistern	7/20/62	23
Tutuila Samoa	City	7/21/62	10
Tongatabu	Cistern	7/24/62	20
Rarotonga	City	7/22/62	10

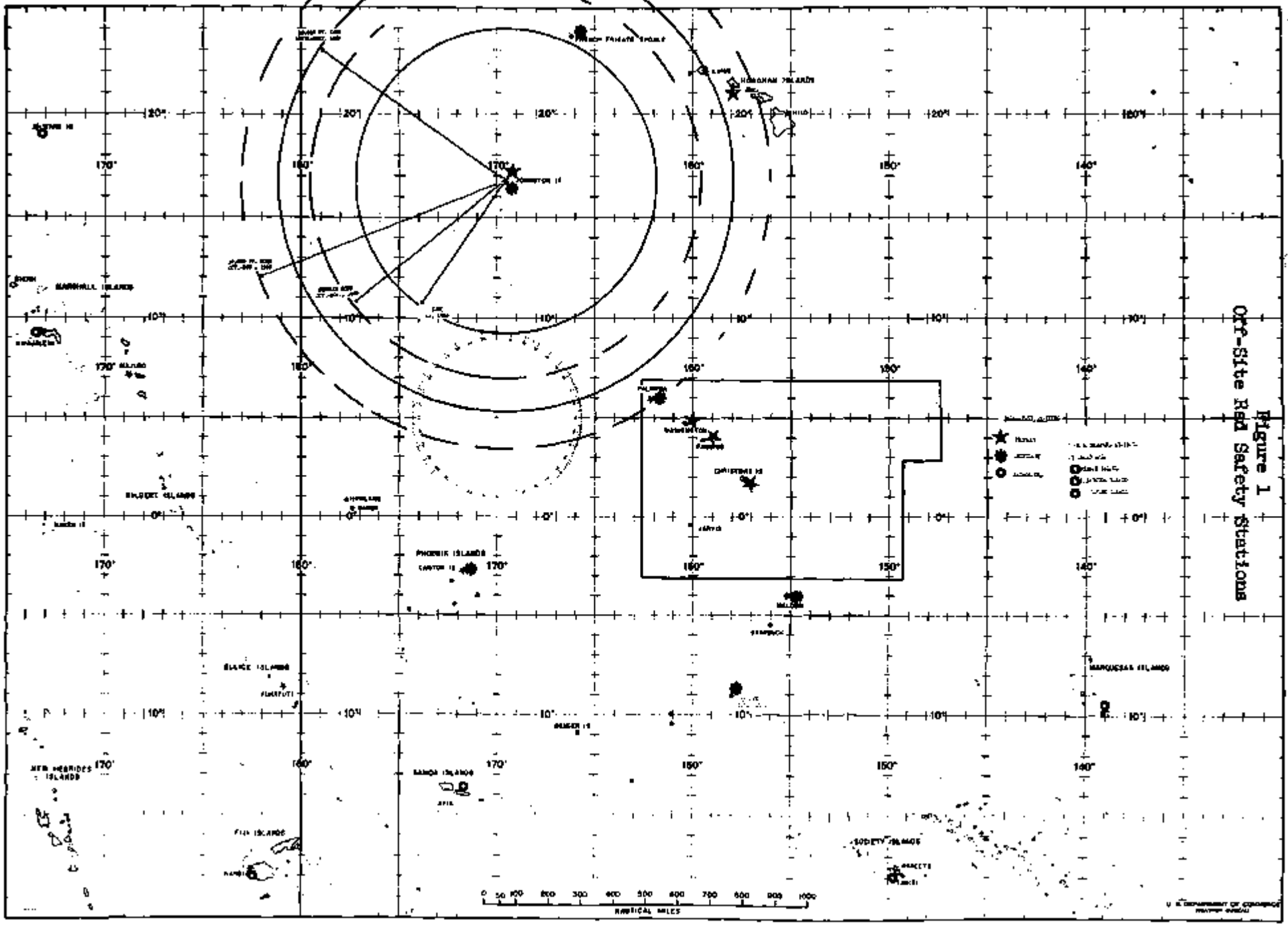

Figure 1
Off-Site Rad Safety Stations

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DRAFT

RADIOACTIVITY RELEASED BY UNDERGROUND EXPERIMENT
NEAR
CARLSBAD, NEW MEXICO

The first nuclear detonation in the Commission's Plowshare program to develop peaceful uses for nuclear explosives was Project Gnome, a multipurpose experiment in a salt bed 25 miles southeast of Carlsbad, New Mexico. The nuclear device, with a yield of about three kilotons, was detonated at 12:00 noon, MST, on December 10, 1961, 1,200 feet underground.

The detonation raised a small cloud of dust from the surface. Shortly, thereafter, a white vapor was seen issuing from the mouth of the 1,200 foot vertical shaft. This vapor, holding close to the ground, was blown north-northwest, to the east of the city of Carlsbad. There was no evidence of venting in the vicinity of surface ground zero.

Monitoring results demonstrated that the cloud was largely gaseous in nature. Although every effort had been made to minimize the deposition of radioactivity in any inhabited off-site area, small amounts of short-lived radioactivity were deposited in the path of the cloud for the first ten miles or so.

The following is a summary of the data obtained by the U. S. Public Health Service Off-Site Radiological Safety Organization of the Office of Field Operations, now the Nevada Operations Office, AEC, in the vicinity of the test site.

[redacted]

External Gamma Exposure

Monitors conducted a film badge program to give an account of accumulated radiation doses off-site. Three hundred and thirty film badges were placed on individuals and structures within a one hundred mile radius of the test site. These badges were left out for about 30 days. Six badges recorded radiation exposure. The highest film badge exposures were from Hudson Farm. A badge located outside recorded 165 mr, while a badge worn by a person at the farm recorded 140 mr. Film badges placed on two houses on the east and north sides of Illinois Camp recorded 80 mr and 50 mr respectively. The occupant of the second wore a film badge that recorded 40 mr. These doses measured by film badges have not been corrected for natural background radiation exposure, which is approximately 0.5 mr/day.

Milk

Milk samples were collected from eight producer dairies in the vicinity of the Gnome site. Results indicate that no increase of radioactivity was detected in the milk supplies from the Gnome event.

Mine Surveys

Eight mines located within a 30 mile radius from the Gnome site were monitored for external beta-gamma levels before and after the shot event. The two sets of readings remained the same within the tolerance of the instruments used.

Air Sampling

Of the 20 air samplers in operation, only a few filters showed any appreciable increase of gross beta activity, with the highest reading 160 $\mu\mu c/M^3$ for a 16 3/4 hour sampling period. The highest iodine concentrations found in air were 1.7 $\mu\mu c/M^3$ of I-131 and 18 $\mu\mu c/M^3$ of I-133 on December 11, 1961, and 3.5 $\mu\mu c/M^3$ of I-135 on December 10, 1961. All of the above were well below permissible levels for the general population.

Water Sampling

Fourteen water sampling points were selected in the vicinity of the Gnome event. No significant difference was found between the post-test and the pre-test water samples collected and analyzed for radioactive content.

Animal Sampling

Five cattle were slaughtered prior to the Gnome event and five more about a month after the detonation, for radiochemical analysis of their body tissues and organs. All the radioactive concentrations were found to be comparable for pre and post-shot samples.

Surface Contamination

Although the radioactivity released following this test was largely gaseous in form, there was some particulate fallout in the local area. Some vehicles passing along Highways 31 and 128 (about nine miles from ground zero) were contaminated, with the

[redacted]

highest readings being about 200 milliroentgens per hour around the radiator and 150 milliroentgens per hour around the tires at about one hour after shot time. The highest reading inside of the cars was 15 milliroentgens per hour. Seven cars were washed with the results that the highest reading was 15 milliroentgens per hour around the radiator and eventually background inside the car. Two individuals were found to have slight amounts of contamination (one on the hand and one in the hair), i.e., less than 1 milliroentgen per hour (beta plus gamma). This contamination was removed by washing.

[redacted]

MHoS.3

Statement

for

SUBCOMMITTEE FOR RESEARCH, DEVELOPMENT AND RADIATION
OF THE
JOINT COMMITTEE ON ATOMIC ENERGY

Hearings on

FALLOUT

COUNTERMEASURES AGAINST RADIATION OR ENVIRONMENTAL CONTAMINATION

by

Forrest Western, Director
Division of Radiation Protection Standards

COUNTERMEASURES AGAINST RADIATION OR ENVIRONMENTAL CONTAMINATION

The Atomic Energy Commission activities related to countermeasures against radiation or environmental contamination continue to be based on the Commission's statutory obligation to manage the program of nuclear technology in such a way that the public health and safety is adequately protected. Under this obligation, programs have been conducted in four major areas:

1. An intensive program to determine the biological effects of radiation in all possible combinations that could reasonably be anticipated to result from the program of nuclear technology.

2. An intensive program to describe the physical and chemical characteristics of radiation sources including the mechanisms of radioisotope movement in the environment, on the one hand, and the mechanisms of the absorption and attenuation of radiation by matter on the other.

3. Organizations, equipment and techniques for rapidly evaluating the degree of environment contamination resulting from an unplanned nuclear incident and techniques for undertaking decontamination actions under a wide variety of conditions.

4. A program of providing the information necessary to those concerned with the development of standards for radiation protection. These activities have been reflected for years in the many publications of the National Committee on Radiological Protection, including NCRP Report No. 29, entitled, "Exposure to Radiation in an Emergency," and more recently in the reports of the Federal Radiation Council.

Since the Commission's safety criteria for the management of the atomic energy program are based on the assumption of negligible risk

under continuous lifetime exposure conditions, the need for countermeasures is most logically focused on unusual circumstances which are capable of causing short-term injuries. Thus, techniques for mitigating the biological influence of exposure are most applicable when a small number of people have been exposed to conditions capable of causing acute radiation injury or death. Some of these are not generally applicable to mass application or to combatting chronic exposure effects. Similarly, techniques of agriculture management would be most appropriate for coping with the aftermath of a nuclear war or coping, within a limited area, with the consequences of a major nuclear incident such as at Rongelap and at Windscale. Actions have been taken by the AEC as a normal part of its source management procedures. These have included such simple actions as having people remain indoors with the windows closed as at St. George, Utah in 1953 during passage of a radioactive cloud.

Monitoring and surveillance at and near AEC sites:

As a necessary part of any procedure designed to initiate the application of countermeasures to any type of relatively extensive radioisotopic contamination some monitoring and survey work is necessary. Each major AEC installation has a comprehensive system of monitoring and surveillance in and around its site. These programs are directed primarily toward problems that might arise from the specific activities at each site but are of such a nature that they can and do assist in monitoring fallout from nuclear weapons tests. They also have the capabilities of assisting in monitoring in the event of a nuclear war or a major nuclear accident. Appendix I summarizes and illustrates the type of monitoring activities conducted at AEC sites.

Some AEC sites maintain a capability consisting of emergency standby equipment which can be placed in an airplane for use in aerial survey. In addition, there is one complete operational survey system including an airplane and operating personnel and equipment which can make rapid and accurate aerial surveys of places or regions of suspected contamination. Such a survey in many circumstances would be a useful prelude to the application of available countermeasures designed to decontaminate areas on a relatively large scale (nuclear accident). It would be similarly useful to locate areas of minimum contamination under conditions of nuclear war (Appendix II). You may be interested in knowing that in cooperation with the U. S. Navy, the aerial monitoring system was utilized to make a survey at sea following the loss of the Thresher. Because the usual aircraft was not equipped for extended overwater flights, the instrumentation was removed and installed temporarily in the USN P2V patrol aircraft. Only background radiation was detected.

Radiological assistance program:

The Atomic Energy Commission participates in and is a key member in an interagency plan which trains and equips teams that are available for accidents involving radioactive material. These teams are able to make a rapid assessment of the extent of a contaminated area and to apply certain decontamination procedures. While specifically set up for local emergencies these teams would be useful under most conceivable circumstances involving relatively large releases of radioactive substances. (Appendix III).

In conjunction with the DASA there is maintained an emergency radiation team and a depot of medical supplies for use in radiation emergencies. (Appendix IV).

Agricultural countermeasure procedures which have been fully developed, and which can be put to immediate use (work performed in part at the U. S. Department of Agriculture and funded by AEC):

1. Decontamination of agricultural land surfaces by the harvesting and disposal of contaminated plants, and by the raking off of contaminated surface mulches and crop residues;

2. Decontamination of agricultural land surfaces by the mechanical scraping off of a surface layer of the soil from the land;

3. Decontamination of bare soil surfaces by the spray application of an asphalt emulsion followed by the removal of the hardened asphalt-soil layer.

All of the environmental countermeasures indicated in the preceding sections would be more or less appropriate for nuclear war survival and recovery depending on local circumstances and especially for nuclear accidents involving large local releases of radionuclides to the environment. Others which represent normally recommended practices, such as the fertilization and liming of food crop soils to optimal productivity levels, would generally have some slight beneficial effect on exposures from fallout from nuclear weapons testing, especially to reduce strontium uptake. In addition, efforts to select or develop (employing seed irradiation) specific genetic lines of agriculturally important plants that will preferentially take up calcium so that the strontium calcium ratio in the plants is lower than that in the soil, are in progress.

The research program related to agricultural countermeasures entails a yearly cost of about $514,794.

Countermeasures applicable to humans:

The procedures which are immediately applicable to aid recovery of humans exposed to excessive radiation or to excessive amounts of certain radioisotopes taken internally are detailed more fully in Appendix V.

The majority of procedures applicable to humans are either under development or are the subjects of intensive research efforts. This research is carried at a level of expenditure which reached $2,559,100 during FY 1962.

All of the countermeasures applicable to humans still require considerable research and development before they can be utilized on a mass basis. In specific instances, where a finite number of individuals are involved, certain of the measures can be applied with some degree of feasibility and success such as potassium iodide to block the thyroid gland or platelets infusions to control bleeding.

In regard to nuclear warfare or a nuclear accident involving a high level release of radioactivity, broad guidelines can be given to assist in what probably would amount to "command decisions" in the event of an emergency, i.e., possible countermeasures to reduce radiation exposure must be weighed against their potential health risks to the population and against other hazards concomitant with the emergency. Such an approach has been taken by the National Committee on Radiological Protection in their report "Exposure to Radiation in an Emergency." The report does not purport to indicate when or what countermeasures should be taken for the reason stated above, i.e., these actions must be evaluated on the basis of the emergency situation.

In regard to the applicability of countermeasures to fallout from weapons testing, the Commission's view is that countermeasures are applicable primarily when unusual circumstances are created which could lead to short term radiation injuries. The Commission's policy of program management, including weapon tests, is designed so that conditions requiring after-the-fact countermeasures are not likely to be created, particularly with respect to possible long-term injury. In fact, as pointed out by the FRC, exposure levels many times above fallout levels to date in the United States would be needed to justify such countermeasures. On the other hand, if fallout levels of I-131, for example, were found to be comparable to those observed following the Windscale reactor accident, countermeasures might be appropriate. The best ones for the situation would have to be selected at the time.

APPENDICES I thru V

APPENDIX I

MONITORING ACTIVITIES

The Atomic Energy Commission fallout information network was reactivated in September 1961, to provide a means of prompt determination and reporting of increased levels of atmospheric radioactivity in the area of AEC facilities due to fallout from nuclear weapons testing. There has not been a felt need to attempt to establish specific types of monitoring programs within the AEC. However, arrangements have been made to utilize Radiological Assistance teams to investigate alleged or suspected fallout "hot spots" anywhere in the country. Generally, all AEC facilities perform measurements of concentrations of radioactivity in air (as an "alert" mechanism) and external gamma measurements. Many facilities perform radioactivity measurements of rainwater and a variety of other environmental samples. Although these are fixed stations the environmental monitoring data is collected from surrounding areas including the immediate site. Within the geographical limits in which the sampling could be carried out, information could be obtained that would be useful in connection with radiological hazard countermeasures following a nuclear incident or accidental exposures to fallout from nuclear weapons testing. Such information could also contribute to the success of countermeasures applicable to postnuclear war survival or recovery although most of the environmental contamination information in a post war situation

will probably come from other agencies such as the Department of Health, Education and Welfare and state public health departments.

The data collected at all AEC facilities are submitted to the Nuclear Explosives Environmental Safety Branch (NEES), Division of Operational Safety, Headquarters, on a monthly routine basis. In the event that any information indicates a possible public concern, this information is transmitted by telephone or by TWX to NEES.

RADIOLOGICAL MONITORING ASSOCIATED WITH AEC PROGRAMS

The following table presents the locations and types of radiation measurements now being made by AEC and AEC contractor activities. The frequency of collecting and reporting this information has been determined from files of data actually received from each activity within the past several months.

Reporting Activity	External Gamma	Air Sampling	Milk Sampling	Gum Papers	Rainfall and Settled Dust
AIKEN, SOUTH CAROLINA Savannah River Oper Off. 1/		X	X		
ALBUQUERQUE, NEW MEX. Sandia Corporation 2/		X			
ARGONNE, ILLINOIS Argonne Nat Lab. 3/		X			
BERKELEY, CALIF Lawrence Radiation Lab. 4/		X			
IDAHO FALLS, IDAHO Idaho Oper. Off. 5/	X	X			
LOS ANGELES, Calif University of California 6/	X	X		X	
NEW YORK, NEW YORK Health & Safety Lab of AEC 7/		X			
OAK RIDGE, TENNESSEE Oak Ridge Operations Off. 8/		X			
RICHLAND, WASHINGTON Hanford Operations Off.	X 9/	X 10/			
ROCHESTER, NEW YORK University of Rochester 11/	X	X			
ST. PETERSBURG, FLORIDA Pinellas Peninsula Plant 12/	X	X			
UPTON, NEW YORK Brookhaven Nat. Lab.	X 13/	X 14/	X 15/		X 16/

1/ Milk samples are collected from each of six locations on a weekly basis. Some samples come from dairies, some from individual farms. Also, gross beta activity of particles in air is measured on a daily basis.

2/ Air samplers run continuously. Filters are changed every 24 hours from Monday through Thursday, with an 8-hour run on Friday and about 64 hours over weekends.

3/ Filters are changed every 24 hours. Gross beta activity of these samples is reported monthly.

4/ Air sampler runs continuously. Filters are changed every 24 hours. Airborne beta-gamma activity is reported monthly.

5/ Air samplers run continuously. Filters are changed every 24 hours. External gamma radiation is recorded daily. Beta activity of airborne particles and external gamma radiation is reported monthly.

6/ Filters are changed every 24 hours. Gum papers are replaced at two stations every 24 hours. External gamma radiation is recorded at two stations daily. These data are reported monthly.

7/ Air sampler runs continuously. Filters are changed every 24 hours. Beta activity of airborne particles is reported monthly.

8/ Concentrations of activity in air are determined on a daily basis. These data are reported weekly.

9/ Measurements of external gamma radiation are obtained weekly for the Hanford site and for Richland, Washington. These data are reported monthly.

10/ Weekly samples of gross beta radioactivity on air filters are obtained from stations at the following locations:

a. Boise, Idaho
b. Lewiston, Idaho
c. Walla Walla, Washington
d. Spokane, Washington
e. Yakima, Washington
f. Seattle, Washington
g. Meachum, Oregon
h. Klamath Falls, Oregon
i. Great Falls, Montana

Daily samples of gross beta radioactivity on air filters are obtained from the Hanford site and from Richland. These data, plus the weekly data from the above stations are reported monthly.

11/ Daily measurements of external gamma radiation and gross beta activity of particles in air are made.

12/ Air sampler runs continuously. Filters are changed every 24 hours during the week but are not changed during weekends. Daily measurements of external gamma also are made. These data are reported on a monthly basis.

13/ External gamma radiation is reported monthly in terms of mr/week.

14/ Daily values of air particulate activity are reported monthly.

15/ Routine scanning of milk samples from six Suffolk County farms for iodine-131 has been started.

16/ Activity in weekly collections of rainfall and settled dust is being determined, and the data reported on a monthly basis.

The following represents only a brief summary of information that could be collected in the short time available. Whereas, the information below indicates quarterly reporting, we will probably go to semiannual reporting since it fulfills our needs and lessens the excessive requirement placed on AEC installations for preparing quarterly reports.

1. Bettis Atomic Power Laboratory, Pittsburg, Pennsylvania:

A quarterly report on levels of radioactivity in the vicinity of this installation is submitted to AEC. It contains levels of activity released in the form of wastes, beta-gamma background levels near the laboratory, results of monthly fallout collections from eight stations and results of continuous soil sampling.

2. Shippingport Atomic Power Station, Shippingport, Pennsylvania:

A quarterly report on levels of radioactivity in the vicinity of this installation contains levels of activity released in the form of wastes, weekly samples of airborne particulates, external beta-gamma measurements for four locations, fallout collected at four stations, airborne particulate radioactivity and concentrations of alpha and beta emitters in the Ohio River.

3. Argonne National Laboratory, Argonne, Illinois:

A quarterly report from this laboratory contains data on radioactivity found in Sawmill Creek and in the Des Plaines River and results of a grass sampling program.

4. Rocky Flats Plant, Denver, Colorado:

A quarterly report from this plant contains data on radioactivity found through air sampling at Coal Creek Canyon, Marshall, Boulder, Lafayette, Bromfield, Wagner School, Golden, Denver and Westminster, and in water samples taken from four reservoirs near the plant. The report also contains data on vegetation samples.

5. Hanford Operations Office, Richland, Washington:

A quarterly report from Hanford includes the following:

a. Occurrences of iodine-131 in cattle thyroids.

b. Release of iodine-131 to the atmosphere versus time.

c. Phosphorus-32 in Columbia River Whitefish.

d. Concentration of phosphorus-32, zinc-65, arsenic-76 neptunium-239 and chromium-51 in Columbia River water versus time.

e. Predicted 12 months dose for GI tract from drinking water at Pasco and Kennewick.

f. Results of regular analysis of oysters from Willapa Bay for zinc-65 and other radionuclides.

g. Regular analysis of milk in the Hanford area.

6. Portsmouth Gaseous Diffusion Plant, Portsmouth, Ohio:

A quarterly report from this plant contains data from air sampling at fifteen locations near the plant and from water samples collected monthly at fourteen locations.

7. Savannah River Plant, Aiken, South Carolina:

A quarterly report from this plant contains the results of a continuous monitoring program to determine the concentrations of radioactivity in a 1200 square mile area outside the plant perimeter. Rainwater samples are collected weekly at fifteen stations. Monthly samples of vegetation and water (collected from fourteen surrounding towns, both deep well and surface streams) are collected and analyzed. Fresh eggs and peaches also are analyzed.

8. Brookhaven National Laboratory, Upton, New York:

Quarterly reports contain measurements of released radioactive liquid wastes and data on gamma levels at site boundaries due to coolant air effluent.

9. Mound Laboratory, Miamisburg, Ohio:

Quarterly reports contain results of continuous air monitoring for tritium and radioactive particulates in air. Water samples are collected weekly from a drainage ditch and from five locations along the Great Miami River.

10. National Reactor Testing Station, Idaho Falls, Idaho:

Quarterly reports contain data on radioactivity in off-site underground water, off-site air samples, rabbit bones and milk.

11. Oak Ridge Operations Office, Oak Ridge, Tennessee:

Quarterly reports contain data on radionuclides found in water obtained from a number of locations along the Clinch River and on external gamma measurements at a number of locations in the Oak Ridge area.

12. Paducah Plant, Paducah, Kentucky:

Quarterly reports contain data on radioactivity in air at four on-site and four off-site stations and in water at two locations in Big Bayon Creek and four locations on the Ohio River.

13. Atomics International, Canoga Park, California:

Quarterly reports contain data on daily air sampling, monthly water sampling and monthly soil and vegetation sampling.

14. Feed Materials Production Center, Fernald, Ohio:

Quarterly reports contain results of air sampling, both on and off-site, and of water sampling in the Great Miami River.

15. Knolls Atomic Power Laboratory, Schenectady, New York:

Quarterly reports contain measurements of liquid radioactive wastes, airborne radioactivity at several locations, gross beta activity in the Mohawk River and in Glowegee Creek, radioactivity in rainfall and in soil samples.

16. SIC Prototype Reactor Facility, Windsor, Connecticut:

Quarterly reports contain measurements of gross beta-gamma concentrations in exhaust stack effluents, gross beta-gamma concentrations in air on-site downwind of release points, gross beta concentrations in fallout, gross beta-gamma radioactivity released to the Farmington River, gross radioactivity of water samples from the Farmington River and gross radioactivity of mud samples from the Farmington River.

APPENDIX II

AERIAL RADIOLOGICAL MEASUREMENT SYSTEM

An Aerial Radiological Measurement System is operational and available for immediate use. The self-contained and associated navigational and space positioning instrumentation is mounted on a Beech Twin Bonanza Model 50 airplane. The system is extremely versatile and can determine ground radioactivity over a large area rapidly and economically. The range covered by the system is from natural background to hundreds of r/hr. The radiation background around major AEC sites has been mapped by the aerial survey program, thus providing a baseline for determining the extent of contamination of the environment either by continuous release or by an accidental release of radioactivity. Research studies at an annual level of about $100,000 are in progress to improve our knowledge of aerial survey techniques. Methods of measuring aerial and ground spectra are being studied in an effort to perfect a means of using aerial surveys to provide specific isotopic content of ground contamination.

The mobility of the system permits the equipment to be flown directly to an area for use in gathering specific data regarding radiation levels on the ground, together with pinpoint information about the location of hot spots. The capability is used for tracking and measuring the radioactive debris from nuclear detonations and for rapidly determining the area affected by an accidental release of radioactivity.

APPENDIX III

RADIOLOGICAL ASSISTANCE CAPABILITY

Under the provisions of the Commission's Radiological Assistance Program a nation-wide radiological emergency assistance capability is operational. Teams of trained specialists can be dispatched from 38 AEC or AEC contractor installations to respond to requests made to the AEC for radiological emergency assistance. If needed, the initial emergency team response could be augmented by utilizing all of the man power and material resources that could be spared from the AEC's operations to cope with the emergency.

The emergency capabilities include radiation monitoring of personnel, the environment and materials; emergency decontamination necessary to protect health and safety; medical advise on the handling and treatment of people injured or exposed to radiation or both; emergency laboratory analytical services needed to provide information on personnel radiation exposure or radiation hazards; and resources such as transportation, special equipment and emergency communications. This radiological emergency capability is most applicable to accidents resulting from peacetime atomic energy activities but would be used in connection with the Commission's post-attack role in the National Plan for Civil Defense and Defense Mobilization to the extent that the capabilities still existed and were not needed at AEC facilities. Through an agreement with the Department of Defense the AEC can receive assistance from the DOS radiological emergency capabilities in nuclear weapons accidents and accidents involving radioactive material in other uses. This is a mutual agreement that applies only during peacetime operations. Through an Interagency Radiological Assistance Plan presently being implemented, the resources of 12 Federal agencies, including the AEC and DOD, will be made available when and as they may be needed in the event of peacetime accidents resulting in radioactive hazards to the public health and safety.

APPENDIX IV

EMERGENCY RADIATION TEAM

An Emergency Radiobiology Team established jointly by the AEC, DOD and DHEW in 1956 is currently being updated. This team is intended to be prepared to handle emergencies resulting in the radiation exposure of a number of individuals such as occurred in March of 1954 when 250 persons in the Marshall Islands were exposed to fallout from weapons testing. Six tons of special equipment is maintained, packaged and ready for rapid shipment from Field Command DASA, Sandia Base, Albuquerque, New Mexico. Although this team and equipment was originally for use outside the United States, this capability has now been established for use within the continental limits of the United States as well as elsewhere. This Emergency Radiobiology Team would not be expected to be of significant value in the post-nuclear war situation but could be of considerable use following a serious radiological accident during peacetime.

RADIOELEMENT REMOVAL FROM THE BODY

On-Site	FY 1963	FY 1964
Argonne National Laboratory	$192	$242
Hanford Operations Office	86	90
Sub-Total	$278	$332

Off-Site

Loyola University, Stritch School of Medicine, Chicago. Herta Spencer, Metabolism and Removal of Sr-90 in Man. FY 1963 - $37,100

Vanderbilt University, School of Medicine, Tennessee. B.V. Rama Sastry, Studies on the Chemotherapeutic Methods for the Removal of Radioactive Materials from the Body. FY 1963 - $27,336.

Presbyterian - St. Luke's Hospital, Illinois. Robert D. Ray, Mobilization of Radioactive Emitters from Bone. FY 1963 - $32,469

Minnesota, University of. W.D. Armstrong, Removal of Strontium Radioisotopes from Milk and Physiological Sites of Discrimination between Strontium and Calcium. FY 1963 - $17,685.

Columbia University, College of Physicians and Surgeons, New York. Irwin Clark, Studies on Bone Demineralization with Emphasis on the Removal of Strontium. FY 1963 - $32,129

Ellex Research Corporation, Rhode Island. Harry Kroll, The Development of Chelating Agents for Enhancing the Urinary Excretion of Strontium. FY 1963 - $18,900

Off-Site	Total	1963 $165,619	1964 - $100,000
TOTAL		$443,619	$432,000

RADIOELEMENT ELIMINATION FROM FOODS

Off-Site

Cornell University, New York. Harold B. Tukey, The Loss of Organic and Inorganic Materials from Above-Ground Plant Parts, with especial Reference to Decontamination of Parts Utilized for Food. FY 1963 - $16,500

Virginia, University of. Bartholomeus van't Riet, Radioisotope Removal from Milk. FY 1963 - $15,576

Agriculture, U. S. Department of, Dairy Products Laboratory, Beltsville, Maryland. Locke F. Edmondson, The Removal of Radioactive Contamination from Milk. FY 1963 - $83,173

APPENDIX V

BONE MARROW (INCLUDES PLATELET AND ERYTHROPOIETIC FACTORS)

On-Site	FY 1963	FY 1964
Brookhaven National Laboratory	$100	$105
Lawrence Radiation Laboratory (2)	60	73
Lawrence Radiation Laboratory (3)	84	93
Oak Ridge National Laboratory		
06 01	78	109
06 03 (1)	310	349
(2)	160	263
(3)	380	348
Oak Ridge Institute of Nuclear Studies (9)	70	90
Oak Ridge Institute of Nuclear Studies (13)	71.5	75
Oak Ridge Institute of Nuclear Studies (18)	48.1	52
Sub-Total	$1,361.6	$1557

Off-Site

Peter Bent Brigham Hospital, Massachusetts. Francis D. Moore, A. Program for the Study of Transplantation of Marrow, Tissues, and Whole Organs, and of Related Topics in Surgical Research. FY 1963 - $65,000

New England Center Hospital, Massachusetts. William Dameshek. Physiopathology of Platelets and Development of Platelet Substitutes. FY 1963 - $49,105

New England Center Hospital, Massachusetts. William Dameshek, Bone Marrow Preservation and Transplantation. FY 1963 - $48,000

Mary Imogene Bassett Hospital, New York. J. W. Ferrebee and E. D. Thomas, The Collection, Storage and Fate Following Transfusion of Hemopoietic Cells. FY 1963 - $33,103

Jefferson Medical College of Philadelphia. Leandro M. Tocantins, Transplantation of Preserved Marrow between Animals and from one Human to another. FY 1963 -$22,225.

Yale University, School of Medicine, Connecticut. James W. Hollingsworth, Biologic Implications of Isologous and Heterologous Bone Marrow repopulation in Irradiated Animals.

Virginia, Medical College of. David M. Hume and R. H. Egdahl, The Homotransplantation of Fetal Blood Cells and Tissues in Animals Receiving Fatal Whole Body Radiation. FY 1963 - $38,407

BONE MARROW (Cont'd)

Loma Linda University, Laboratory for Cancer and Blood Research, California. Howard R. Bierman, A Study of Leukopoietic Factors in Blood. FY 1963 - $23,000

Off-Site	Total	1963	$278,840
		1964	$257,000
TOTAL		1963	$1,640,440
		1964	$1,814,000

CHEMICAL PROTECTANTS

On-Site	FY 1963	FY 1964
Oak Ridge National Laboratory		
06 03 (4)	$90	$150
(5)	40	65
(6)	30	65
Oak Ridge Institute for Nuclear Studies (11)	10	12
Univ. of California at Los Angeles	56	59
Sub-Total	$226	$351

Off-Site

Tennessee, University of, College of Medicine. R.R. Overman. Protective Action of Bone Marrow Perfusates and AET in Irradiated Monkeys. FY 1963 - $13,333

Louisville, University of, Department of Chemistry. Kevin T. Potts, Derivatives of Some Five-Membered Heterocycles as Possible Protective Agents Against Ionizing Radiation. FY 1963 - $10,606

Off-Site	Total	1963	$23,939
		1964	11,000
TOTAL		1963	$249,939
		1964	$362,000

RESPIRATORY EQUIPMENT

Off-Site

Harvard University. Leslie Silverman, Research and Development of Protective Respiratory Equipment. FY 1963 - $20,000 (thru 9/63).

TOTAL 1963 - $20,000

APPENDIX V

TISSUE ANOXIA

On-Site	FY 1963	FY 1964
Oak Ridge Institute of Nuclear Studies (17)	$19,300	$21,000

MISCELLANEOUS

Off-Site

Jefferson Medical College of Philadelphia. Rolf Freter, Reduction of Post-Irradiation Infections by Replacement of the Normal Enteric Flora and by Specific Immunization. FY 1963 - $19,584

International Atomic Energy Agency (Chester Beatty Research Institute, Royal Cancer Hospital, London, England.) P. C. Koller, Tissue Therapy after Radiation. FY 1963 - $5,000

TOTAL 1963 - $24,584 1964 - $25,500

COUNTERMEASURES APPLIED TO SOILS AND PLANTS

Off-Site

Rutgers - The State University, New Jersey. J.C.F. Tedrow, A Study of Strontium, Barium, and Calcium Relationships in Soils and Vegetation. FY 1963 - $5,940

North Carolina State College of Agriculture and Engineering. William A. Jackson, The Effects of Form of Nitrogen on the Mechanisms of Absorption and Transport of Mono and Divalent Cations by Plants, with Particular Emphasis on Cesium and Strontium. FY 1963 - $23,034

California, University of, Berkeley. Roy Overstreet, Study of the Decontamination of Soils Containing Radioactive Elements and Salts. FY 1963 - $24,739

University of Arizona. Wallace H. Fuller, The Uptake of Strontium by Various Types Crops and Factors Affecting Uptake and Translocation of Strontium and Calcium Compounds Native to Soil. FY 1963 - $14,678

Agriculture, Department of. L. A. Dean, Accumulation and Movement of Fission Products in Soils and Plants. FY 1963 - $124,444-op. $7,000--eq.

California, University of (Riverside). Nathaniel T. Coleman, Accumulation of Cerium, Yttrium, and Cesium in Plants as Affected by Their Soil Chemistry and the Aeration of the Soil. FY 1963 - $24,707

California, University of, Berkeley. Louis Jacobson and Roy Overstreet, Study of the Internal or Metabolic Factors and the External or Environmental Factors Affecting Ion Absorption by Plants. FY 1963 - $15,746

California, University of. Hans Jenny, Modes of Entry of Strontium and Other Polyvalent Ions into Plant Roots. FY 1963 - $23,092

APPENDIX V

COUNTERMEASURES APPLIED TO SOILS AND PLANTS (Contd.)

California, University of (Los Angeles). Arthur Wallace, Study of the Behavior of Certain Synthetic Chelating Agents in Biological and Soil Systems. FY 1963 - $14,868

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	1963	1964
Sub-Total (Direct Countermeasures) (Including removal of strontium from milk)	$308,267	$310,000
Sub-total (Supporting research)	$206,527	193,000
TOTALS	$514,794	$503,000

health and safety laboratory

Prediction of Levels of Sr^{90} and Cs^{137} in Food and Man

May 27, 1963

UNITED STATES ATOMIC ENERGY COMMISSION
NEW YORK OPERATIONS OFFICE

Prediction of Levels of Sr^{90} and Cs^{137} in Food and Man

Prepared for Presentation to the
Joint Committee on Atomic Energy

Prepared May 27, 1963

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New York, New York

The prediction of levels of fallout radioactivity in food and man is an attempt to extend our experience to produce estimates of the future. Measurements made over the past several years have revealed definite patterns that should repeat themselves when the originating causes are repeated. However, our techniques are very generalized and empirical, so all predictions must be approached cautiously.

Our main interest, of course, is in the levels of the important radionuclides in man. Unfortunately, the time lags in uptake and in sampling, analysis and reporting make it difficult to have even current human data always at hand. We can make reasonable estimates of the levels in man based on the levels in his diet. The next step of estimating levels in diet from levels of fallout is somewhat less accurate. The estimates made based purely on fission yields of weapons tests are likely to be relatively crude.

The present paper is limited to a description of prediction techniques and to predictions of the levels of strontium-90 and cesium-137 in foods and in man. These values are based on the predicted levels of these nuclides in fallout and the predicted time pattern of this fallout. The predictions will cover the years 1963, 1964 and 1965 and will attempt to differentiate between the wet and dry areas of the United States.

At best, our predictions are limited to broad averages. The attempt to predict the location and magnitude of so-called "hot spots" is probably valueless. On the other hand, the general geographical distribution of results of past measurements probably is applicable to the predictions.

The Human Food Chain

The transfer of radionuclides from fallout deposition to man involves a series of human food chains. In the case of certain fruits and vegetables, the chain is very simple since man eats food contaminated on the surface. In other cases the radionuclides from plants must pass through animals to reach man or contamination in seawater may go through the chain of plankton, small fish, large fish to man.

In many of the steps of the food chain there can be either a concentration of the radionuclide or a dilution. The former seems to be more common with marine chains involving trace elements, the latter with terrestrial chains involving the more common elements. As examples, we might quote Zn^{65} which appears in more concentrated form in shellfish than in seawater and Sr^{90} which is discriminated against by plants from the soil and by animals from plant foods.

This discussion will be limited to strontium-90 and cesium-137 which are only of importance from terrestrial sources. Here we must consider the direct contamination of plant foods by fallout deposition, the uptake of radionuclides from soil through the plant roots, and of course the contamination of animal foods by the animals eating contaminated fodder. It should be particularly noted that the direct contamination of plants depends on the fallout rate during part or all of the growing period. This may be quite variable, depending on the collection efficiency of the plant surfaces and wash-off by rain. The amount available to the plant roots, on the other hand, depends on the accumulated deposit but varies with type of plant and type of soil.

Strontium-90

Milk

As an example of our past experience, the data for the rate of strontium-90 fallout, the accumulated strontium-90 fallout and the levels of strontium-90 in milk in the New York area are shown in Figure 1. It is obvious that the pattern of strontium-90 in milk does not follow either the rate of fallout or the accumulated fallout.

During the preparation of the 1958 report of the U. N. Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), Eizo Tajima of the U. N. Secretariat worked up a simple formula in an attempt to describe the milk levels in terms of both the fallout rate and the accumulated fallout. This formulation was moderately successful and was the basis of predictions made by UNSCEAR and by other groups working in the field of fallout. This formula may be written as:

$$C = P_d F_d + P_r F_r$$

Where,

C = pc Sr^{90} per gram of calcium in milk (Strontium Units),

F_d = cumulative deposition of Sr^{90} (mc/mi.^{2}),

F_r = rate of deposition of Sr^{90} (mc/mi.^{2}/year), and

P_d and P_r are proportionality factors.

The constants in the formula are derived from our past experience. They are variable from location to location since factors such as soil type and dairy management vary. It is possible, however, to make estimates for broad geographical areas with a single set of constants. For our estimates in the New York City and San Francisco areas, the formulas are,

$$C = 0.07\ F_d + 4.6\ F_r$$

and,

$$C = 0.04\ F_d + 4.6\ F_r$$

respectively.

The New York City values should be representative of the wet areas of the country, while the San Francisco values should be multiplied by 1.5 to obtain the estimate for the dry areas.

The observed and predicted values for milk are given in Table 1. This table as well as several others in this paper are the same as the tables prepared for the Federal Radiation Council report. They are repeated here only for convenience.

It is of interest to note that the formula would have predicted average milk values of 17½ and 6 for New York and San Francisco in 1962. These are closer than expected for future predictions, since measured fallout rather than estimated fallout was used in this particular calculation.

Wheat

The same type of calculation has been applied to diet components other than milk. The formula requires modification since the relative contributions of fallout rate and accumulation vary from one foodstuff to another. For example, in the case of wheat, the deposition rate is only of importance during the few weeks in which the plant is in flower and the accumulated fallout is much less important than with milk. The constants used in the formula[1] are 0.1 for P_d and 100 for P_r. The fallout rate during the flower period is taken as 15% of the annual deposition predicted.

The measured and estimated values for United States wheat are given in Table 2. No differentiation is made between wet and dry areas. From past

experience[2] the concentration of strontium-90 in flour is taken as one-sixth of that in the whole grain.

Because of the brief sensitive period of the wheat plant, the geographic variability may be quite large. Also there is a distinct possibility that the predictions may be off by several fold if the fallout patterns are not as expected.

Total Diet

In estimating the strontium-90 concentration in the total diet, the milk and whole grain components are calculated as described above. Bakery products are taken as 40% of the values for wheat, expressed as picocuries Sr^{90} per gram of calcium. For vegetables, the constants in the formula are 0.4 for both P_d and P_r. Fruits are estimated as one-third of the value for vegetables and meats as one-tenth.

The values for measured and predicted levels of strontium-90 in the total diet are given in Table 3. For comparison, the measurements of four different groups using different techniques are shown in the "observed" section of the table. The predicted values are based only on the measurements of the Health and Safety Laboratory since a detailed analysis of the diet components is required. (See Table 6 for an example)

As a matter of interest the dietary levels in New York, Chicago and San Francisco measured in the Health and Safety Laboratory program are plotted in Figure 2. The three cities indicate a marked upturn in the levels and we believe that the predictions of strontium-90 content of the total diet will be found to be realistic.

In most diets in the United States, milk is the major local product. Thus if we measure milk as an indication of strontium-90 intake, the range

of values found from place to place and from time to time should be much greater than the range found for the total diet. Many of the other diet components come from different geographical areas and the overall effect is to broaden the average strontium-90 intake. This reduces the probability of the appearance of significant strontium-90 "hot spots".

The possible variation about the average for milk is discussed in the Federal Radiation Council report. There it is indicated that the factor separating the highest value from the lowest value in the Public Health Service measurements for any month is about 10. When we consider that variability of the overall diet should be less than the variability in milk we would predict that total diets for individual cities should not differ by more than a factor of two from the average for the wet or dry areas, as the case may be.

Human Bone

In the prediction of strontium-90 in human bone, we make use of the previously established relationship between diet strontium and bone strontium and the associated calcium. The factor applied in going from diet to strontium-calcium ratio in bone is about one-quarter for adults. It may be larger for infants but would never exceed one.

If the population had always been on a uniformly contaminated diet, the strontium-90 concentration should now be uniform in all bone. Since heavy fallout began only in about 1955, and has not been uniform, there are differences in strontium-90 concentrations with age and with geographic location or diet. These are illustrated in Figure 3.

The present levels of strontium-90 in the diet will affect the bone now being formed. This new bone makes up the highest proportion of the skeleton in infants, but is a relatively small fraction of the adult skeleton.

Thus, infants should have the highest concentrations of strontium-90. Actually, the new-born child has a somewhat lower concentration than those one or two years old. This is caused by the discrimination by the mother against strontium-90 in forming the fetal skeleton. This factor is apparently 0.5 to 0.6.

The measured and predicted levels for strontium-90 in bone are given in Table 4. Since our predictions give us the values for the new bone, which cannot be actually measured, the calculations must be extended to cover the zero to four year age group.* The $Sr^{90}/g.$ Ca values for 1963, 1964 and 1965 are 5, 7, and 7 for the wet areas and 3, 5, and 5 for the dry areas. These values are the ones most comparable with the measured levels given in the table.

The deviations from average bone levels due to changes in dietary habits can be calculated if detailed diet component measurements are available. In general, the differences are slight since it is the intake per gram of calcium that is important. Thus, so-called teenage diets which differ only in quantity from a more standard diet will show the same strontium-90 to calcium ratio, substituting whole wheat for white bread will possibly increase the ratio by 50%, and elimination of beverage milk from the diet would do about the same.

A series of measurements run along with the tri-city diet studies have shown that the strontium-90 to calcium ratios of infant diets differ very slightly from adult diets in the same cities[3]. For the infant diet the major contributor is milk which is normally slightly lower in strontium-90 to calcium ratio than the total diet. Canned or formula milks have about the

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* This is done by obtaining a weighted average of the predicted new bone concentrations (picocuries per gram of calcium) for each year multiplied by the calcium accretion in grams for each year. This is done for one year olds through four year olds and the results averaged.

same concentration as fresh milk. The only marked difference would occur with breast fed infants since the mothers' milk has an added discrimination against strontium-90. This factor is about one-tenth and would give a reduction in strontium-90 intake during the first few months of life.

There has been some attention devoted to the measurement of strontium-90 in teeth as a means of estimating the body burden. The limitation of this technique is that any tooth is only representative of the dietary intake during the period of the tooth formation. The baby teeth of children, thus, would correspond to new bone of three to six years before and not to the present level in the skeleton.

Cesium-137

The prediction of levels of cesium-137 in diet and in man has not been as successful as the corresponding predictions for strontium-90. The amount appearing in foods is much more dependent on the rate component of the fallout than on the cumulative component, since cesium is apparently tightly bound in the soil. Thus, cesium-137 levels in milk, for example, fluctuate much more widely than levels of strontium-90, where the soil factor tends to stabilize the values.

The expected contributors of cesium-137 to the diet are milk, meat, and fresh fruits and vegetables, but only milk has been widely measured. The major reason for this lack of measurement is that the cesium-137 body burden in man can be measured directly in the Whole Body Counter. Thus, the only reason for measuring the diet is for an advance indication of increasing levels and for studying the mechanisms of transfer from fallout to man.

Cesium-137 has a biological half-life in man of a few months, and the body burden can only be maintained by continuing intake. It appears that the body levels lag behind fallout levels by about seven months, and do not fluctuate as widely. Also, it should be noted in comparing the data for milk and humans for 1959, 1960 and 1961 that the human levels did not fall off as rapidly as the levels in milk.

The predictions given in Table 5 are based entirely on comparing the patterns of fallout, milk, and man for 1958 through 1961 with the expected fallout pattern for 1963 and later. The final numbers are somewhat subjective but include consideration of the rates and magnitudes of increases and decreases found in the past as well as the absolute levels.

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Table 1

Strontium-90 Content of Milk in the U. S.

(pc Sr^{90}/l. of milk)

	New York	"Wet" Areas	San Francisco	"Dry" Areas
		Observed (PHS values)		
1959[1]	9	14	-	9
1960	9	9	4	5
1961	8	9	4	6
1962	14	15	5	10
1963 (1st Quarter)	16	18	8	11
		Predicted		
1963	31	-	11	-
1964	20	-	6	-
1965	17	-	4	-

(1) Based on raw milk data.

Table 2

Strontium-90 Content of Wheat and Flour in the U. S.

(pc/kg)

Year of Harvest	Average from 9-15 States Weighted for Production (HASL)(1)		Average of Paired Samples (FDA) (2)		FDA Sampling Program
	Wheat	Flour	Wheat	Flour	Wheat
			Observed		
1959	48	9	--	--	--
1960	26	4	13	4	17
1961	23	7	19	4	18
1962	--	--	--	--	56(3)
			Predicted		
1962	130	22			
1963	250	40			
1964	100	16			
1965	50	8			

(1) HASL Health and Safety Laboratory, USAEC, New York

(2) (FDA) Food and Drug Administration, Department of Health, Education and Welfare

(3) Incomplete - includes less than 50% of production. The 1962 predicted value is presented pending the availability of more complete data.

Table 3

Strontium-90 Content of U. S. Total Diet

(pc Sr^{90}/g Ca)

	Wet Areas				Dry Areas			
	HASL	PHS	CU	FDA	HASL	PHS	CU	FDA
				Observed				
1959	18	-	13	-	-	-	9	-
1960	11	-	-	-	4	-	-	-
1961	8	8	8	4	3	6	4	-
1962	13	11	13	8	5	7	8	4
1963 (1st Quarter)	-	-	-	10	-	-	-	8
				Predicted				
1963	50				36			
1964	32				19			
1965	21				10			

HASL - Health and Safety Laboratory, AEC

PHS - Public Health Service

CU - Consumers Union

FDA - Food and Drug Administration

Table 4

Strontium-90 Content of Human Bone in the U. S.

(pc Sr^{90}/g Ca)

	"Wet" Areas	"Dry" Areas
	Observed (0-4 years old)	
1958[1]	2.0	2.0
1959	2.7	2.2
1960	2.4	1.8
1961	2.6	0.9
1962 (6 months)	2.9	1.0
	Predicted (New bone)[2]	
1963	12	9
1964	8	5
1965	5	3

(1) Data for 1958-60 are from Lamont Geological Observatory, 1961-62 are from HASL

(2) One-fourth the predicted total diet values in Table 5.

Table 5

Cs^{137} Data and Predictions

Year	Estimated Annual Cs^{137} Fallout Found-NYC	Predicted-Wet	Cs^{137} Milk-Wet Areas	Cs^{137} Man
1958	27		-	-
1959	38		65	70
1960	7		10	60
1961	11		10	30
1962	37	42	49	-
1963		85	(140)	(150)
1964		34	(70)	(120)
1965		19	(30)	(80)

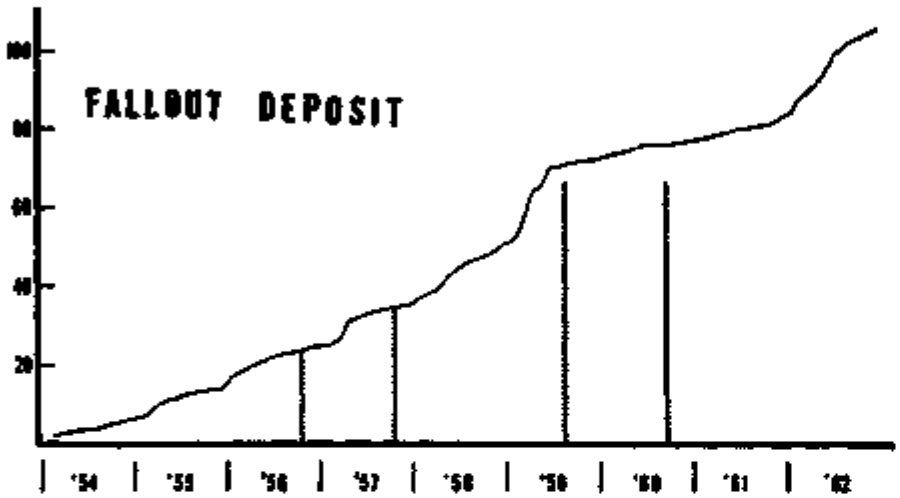
Estimates of Cs^{137} fallout obtained by multiplying Sr^{90} values by 1.7, the yield ratio.

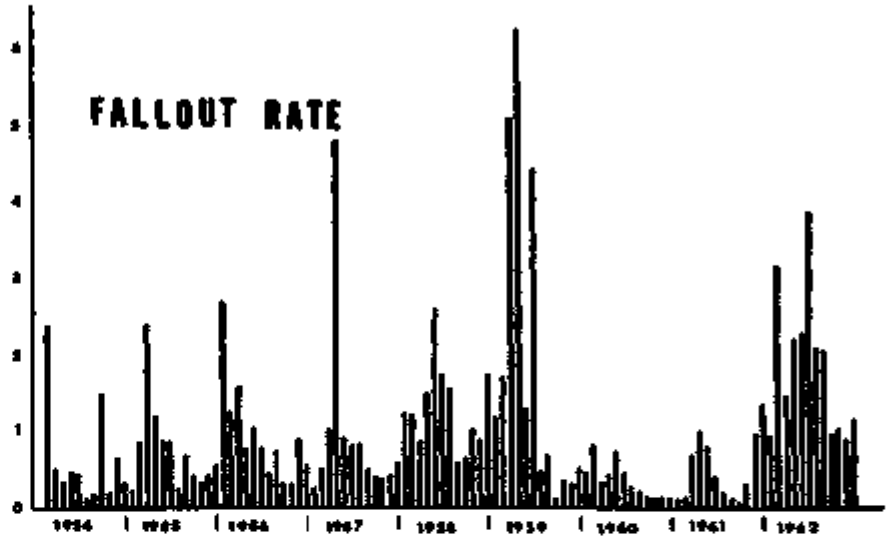
Values in parentheses are predicted levels in milk and man, pc/liter and pc/gK respectively, for the U. S. average.

Table 6

Tri-City Diet Studies
(Tenth Sampling)

Food Category	kg/yr	g Ca/yr	N. Y. C. 8/62		Chicago 10/62		S. F. 9/62	
			uuc/kg	uuc/yr	uuc/kg	uuc/yr	uuc/kg	uuc/yr
Bakery Products	37	37.0	9.4 ± 0.7	346	22.0 ± 1.1	813	6.7 ± 0.9	248
Whole Grain Products	11	10.0	14.1 ± 1.0	155	17.0 ± 1.3	187	11.0 ± 1.2	121
Eggs	16	9.1	1.3 ± 0.1	20	5.3 ± 0.2	85	2.6 ± 0.1	202
Fresh Vegetables	43	15.0	9.3 ± 0.4	398	12.0 ± 0.4	514	2.2 ± 0.5	95
Root Vegetables	17	6.1	7.1 ± 0.5	121	4.9 ± 0.2	83	2.1 ± 0.3	36
Milk	221	234.3	16.2 ± 0.5	3580	7.6 ± 0.4	1670	3.4 ± 0.4	751
Poultry	17	9.2	0.8 ± 0.1	13	2.1 ± 0.1	36	1.7 ± 0.2	29
Fresh Fish	8	10.8	0.3 ± 0.1	2	1.8 ± 0.2	14	0.9 ± 0.4	7
Flour	43	8.6	4.5 ± 0.2	195	14.8 ± 0.3	635	4.8 ± 0.3	206
Macaroni	3	0.7	4.6 ± 0.2	14	8.5 ± 0.3	25	3.8 ± 0.3	11
Rice	3	1.1	1.5 ± 0.3	5	3.0 ± 0.4	9	0.8 ± 0.4	2
Meat	73	10.9	0.7 ± 0.1	52	6.7 ± 0.1	488	1.0 ± 0.1	73
Shellfish	1	0.8	2.8 ± 1.7	3	6.6 ± 0.1	7	0.9 ± 0.2	1
Dried Beans	3	2.9	2.4 ± 1.2	7	16.8 ± 1.7	50	7.0 ± 1.4	21
Fresh Fruit	68	13.6	1.9 ± 0.3	129	4.6 ± 0.4	316	0.5 ± 0.3	34
Potatoes	45	5.8	5.5 ± 0.6	249	1.9 ± 0.4	87	4.4 ± 0.5	198
Canned Fruit	26	1.3	1.3 ± 0.1	32	0.5 ± 0.1	12	0.7 ± 0.1	18
Fruit Juices	19	1.7	1.8 ± 0.1	34	3.9 ± 0.3	73	2.9 ± 0.4	55
Canned Vegetables	20	4.2	3.7 ± 0.2	75	7.7 ± 0.5	154	1.0 ± 0.5	20
Annual Intake		383		5430		5258		2128
Strontium-90 to Calcium ratio in total diet				14.1 SU		13.7 SU		5.6 SU





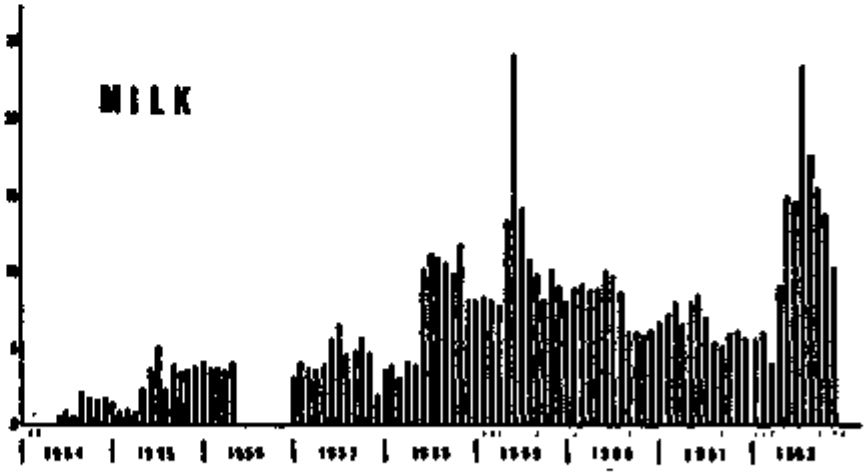


FIGURE 1

FALLOUT COMPARISON

NEW YORK

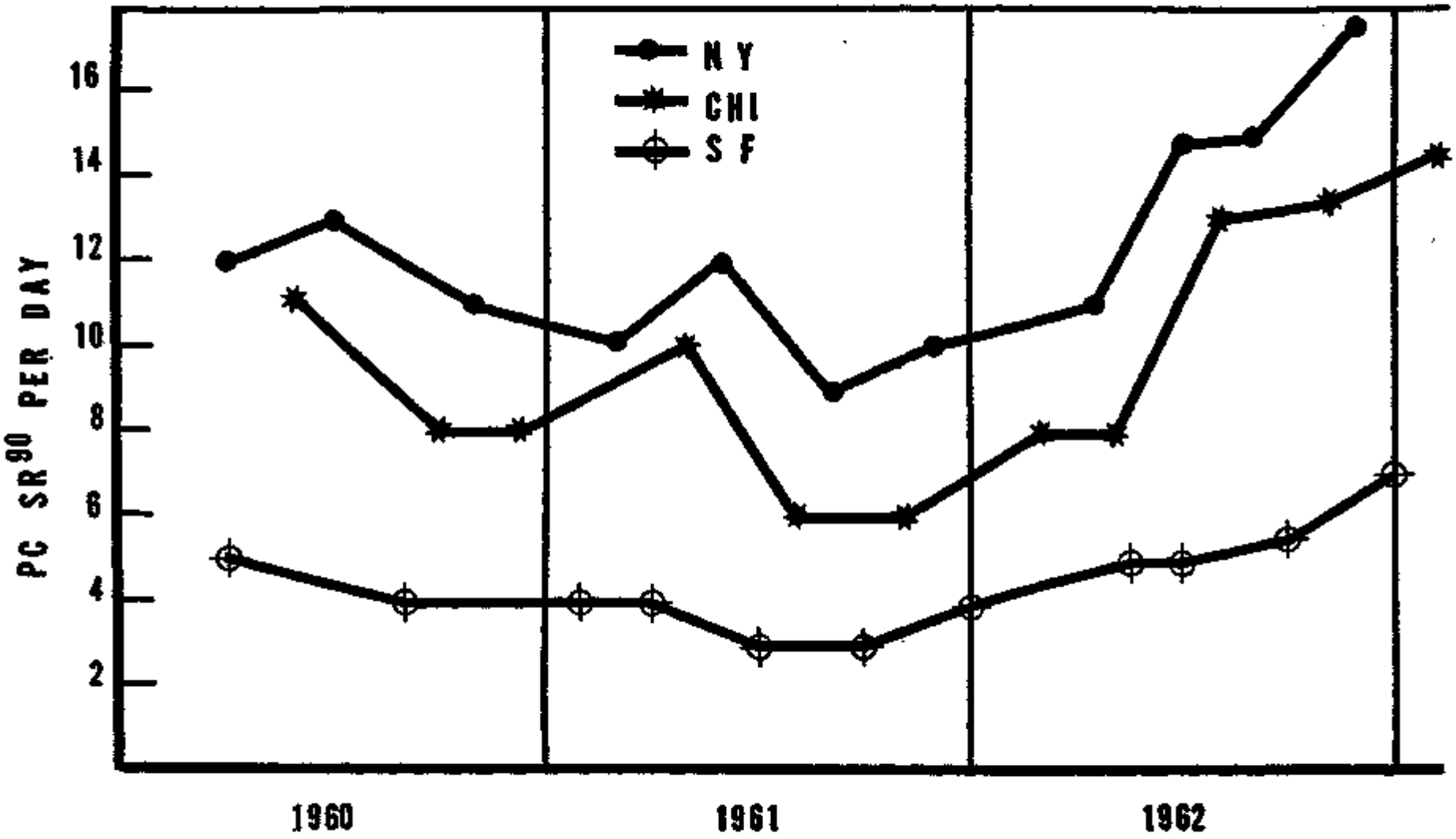


FIGURE 2 - Levels of Sr^{90} in Total Diet, New York, Chicago and San Francisco

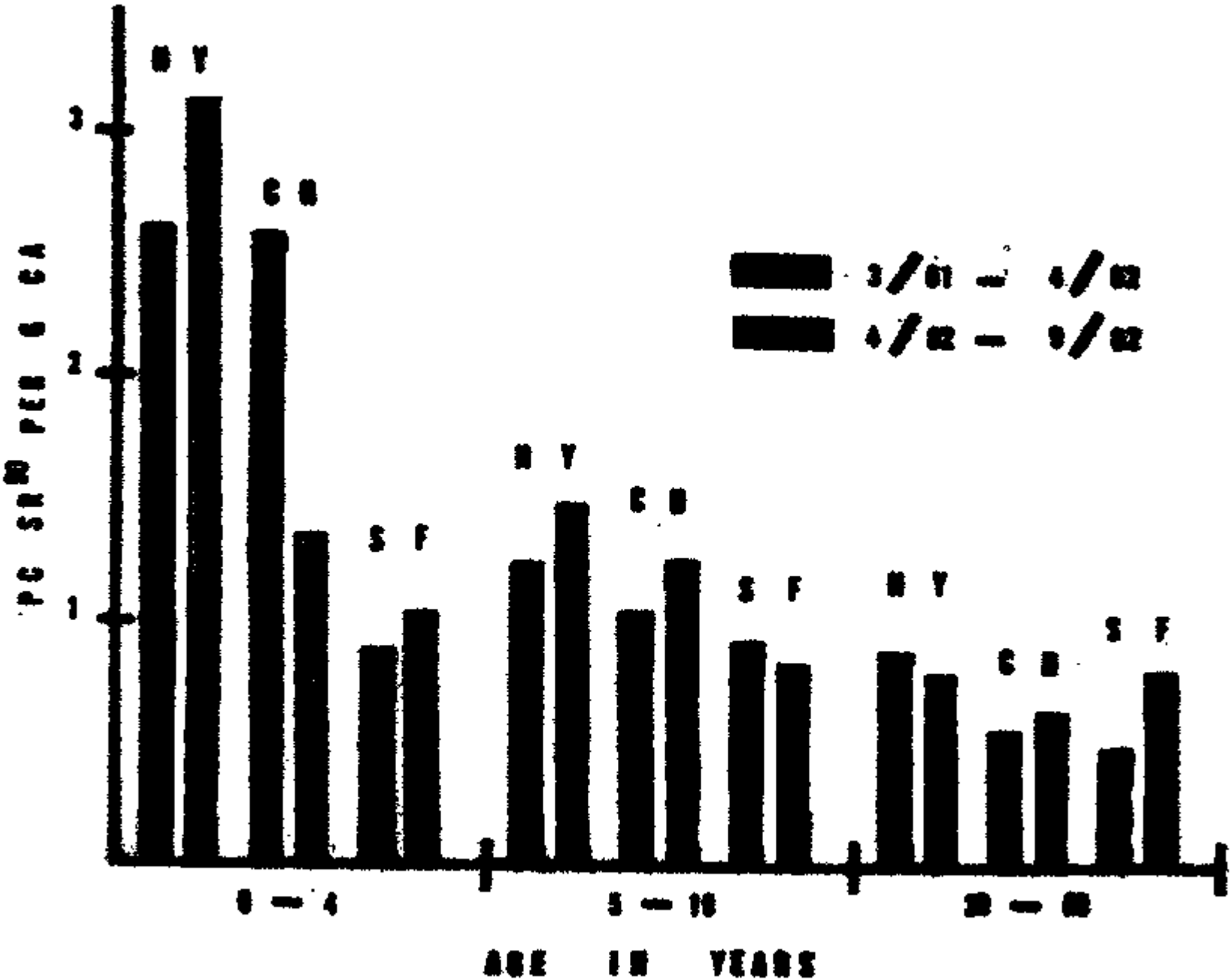


FIGURE 3 - Levels of Sr^{90} in Human Bone, New York Chicago, and San Francisco