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# STATEMENT

By

TECHNICAL DIVISION
GREATER ST. LOUIS CITIZENS'
COMMITTEE FOR NUCLEAR INFORMATION
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For

SUBCOMMITTEE ON RESEARCH, DEVELOPMENT AND RADIATION
of
JOINT ATOMIC ENERGY COMMITTEE

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## I. INTRODUCTORY REMARKS AND SUMMARY OF TESTIMONY

To the general public, the most important question about fallout from nuclear tests is: "What is the risk of medical harm to the population as a result of fallout; if there is a risk, what can be done to reduce it?" Since its inception, the United States program of nuclear tests has included a considerable effort to determine the deposition of fallout outside the actual test area, to estimate the possible medical hazard of such fallout to persons exposed to it, and to warn of needed countermeasures when the occasion arises. Contributing to this effort has been the work of the AEC, the agency directly responsible for nuclear test operations, the U. S. Public Health Service, and the hearings conducted by the Congressional Joint Committee on Atomic Energy.

Two separate aspects of the problem need to be considered: (a) The medical risks to the <u>total</u> population resulting from the widespread dissemination of radioactivity from tests which occur anywhere in the world. (b) The medical risks to <u>local</u> populations, resulting from relatively short-range fallout which spreads rapidly from the test site in Nevada to surrounding communities, and sometimes - depending on weather conditions - to distant areas in the continental United States. The first of these problems has been given extensive consideration recently; the St. Louis Citizens' Committee for Nuclear Information (CNI) has previously submitted extensive testimony relevant to it.

In the present testimony we are concerned with the second part of the problem: What medical risk may be faced by local populations as a result of short-range fallout from the Nevada Test Site? The Technical Division of CNI has made a detailed analysis of this problem which may be summarized as follows:

1) The AEC has maintained a system for monitoring fallout radioactivity in regions surrounding the Nevada Test Site, in order to assess the possible hazards to local populations and to warn of needed precautionary measures. Many of the radioactivity readings obtained during nuclear tests, conclusions regarding possible medical hazards, and recommended countermeasures have been presented by the AEC in reports and in testimony before this Committee. The general conclusion put forward in these AEC reports has been that the test program has been carried out without any discernible threat to the safety of local populations. In some instances local groups were advised to stay indoors for a short period, or to evacuate, briefly, a particular location in which excessive exposure was expected.

2) In contrast our analysis of the same monitoring data published by the AEC shows that as a result of nuclear tests at the Nevada Test Site in the period 1951-62, a number of local populations especially in Nevada, Utah and Idaho, and probably other communities scattered throughout the continental United States have been exposed to fallout so intense as to represent a medically unacceptable hazard to children who may drink fresh locally-produced milk.

3) The reason for the serious discrepancy between AEC conclusions and our own conclusions regarding the safety of the Nevada test program is the following:

Nearly all monitoring data reported by the AEC represent radioactivity measurements of either the gamma-ray intensity emanating from the ground, the total beta-radioactivity deposited on a gummed film placed on or near the ground, or of total beta activity in the air. There are established safety standards regarding exposure to the body from a given level of radioactivity which has its source outside the body. These standards for external exposure have been used, by the AEC, to evaluate environmental radioactivity measurements during nuclear tests. In most cases, the measurements in the regions neighboring the test site did not exceed this safety limit. The AEC therefore concluded that there was no hazard to the nearby populations. In the few instances where the gamma and beta measurements indicated that this safety level for external exposure would be exceeded, protective measures (remaining indoors, or evacuation) were recommended.

The foregoing AEC interpretation of gamma and beta radiation measurements is, however, valid only if the fallout which gives rise to this radioactivity does not enter into the food chain. If fallout radioisotopes do enter the food chain and find their way into the body, certain isotopes become highly concentrated in a particular part of the body and expose it to very intense radiation. Safety standards for external exposure are then no longer applicable. Iodine 131 is a particular problem in this regard for it becomes quickly concentrated in the thyroid gland when taken in with the food.

Thus if a gamma radiation monitor in a pasture outside the Nevada Test Site shows a reading of .087 r/hr at 12 hours following the time of a nuclear test, measured at three feet above ground level, this indicates the apparently maximum safe level, since the permissible standard for continuous exposure from a source external to the body is 3.9 r/year (effective biological dose), which is equivalent to a dose rate of .087 r/hr at 12 hours following a test. However, if a milk cow feeds on this pasture and its milk is freshly consumed by a small child, this conclusion becomes invalid. Under these circumstances it can be shown that this same gamma reading (i.e. .087 r/hr) probably reflects a concentration of iodine 131 in the grass, which after passing into the cow's milk and being consumed by the child may deliver to the child's thyroid gland a radiation dose of 175 to 1200 rads. This dosage exceeds even the safety standards for radiation workers (30 rads to the thyroid per year) by a factor of 5 to 40 and is so high as to represent a serious potential cause of thyroid cancer.

Thus the AEC conclusions regarding safety in the Nevada Test Site region become invalid if it can be shown that the readings on which they are based were taken in the regions in which milk cows graze and produce milk that is freshly consumed by children locally. Our study of a number of regions around the Nevada Test Site shows that in many cases fallout sufficiently intense to contain such excessive amounts of iodine 131 has probably occurred in areas which produce milk that is freshly consumed by significant numbers of children. Therefore the published values of gamma and beta radiation indicate, in many instances, not that the region is totally safe for its inhabitants, but that local children have been subjected to grossly excessive radiation doses to their thyroid glands.

Washington county, Utah with a live birth rate of more than two hundred can serve as an example of the problem confronting communities around the Nevada Test Site. At least seven times since 1952, Washington county children received thyroid doses in the 5 to 100 rad range or higher. Milk for these children seems to come almost entirely from local dairying. Even in the largest town, St. George (pop. 5,000), one dairy collects milk only in Washington county and another from cows in three surrounding counties. Hence, farm children drinking milk from the family cow were not alone among children exposed in the county. On May 19, 1953, in the whole of Washington county, gamma readings from shot "Harry" show that the minimum dose a child probably received would be 50 rads. St. George received 100 to 700 rad possible thyroid dose and Hurricane showed 150 to [illegible]0 rad values. Later, on August 31, 1957, shot "Smoky" of the Plumbob series delivered an estimated 10 to 67 rad thyroid dose over an 8000 square mile area outside the Nevada Test Site, including Washington county. The local fallout pattern from that shot spread significant doses as far as 700 miles north to Rock Springs, Wyoming.

It might be added that the Atomic Energy Commission issues licenses for the handling of iodine 131 concentrations higher than .02 microcuries per liter. Our estimates show that dozens of times the milk in these areas could contain more than .05 microcuries per liter. Strictly speaking, the farmers and dairies should have had an AEC license to handle the milk at all.

4) The biological effects of radiation exposure of the thyroid, at the levels expected in the region of the Nevada Test Site, are readily deduced from the available literature. There is general scientific agreement that radiation in sufficiently large doses can cause thyroid cancer. It is also agreed, as stated in the Federal Radiation Council Report No. 2 (September 1961), that "the child's thyroid is more sensitive to the carcinogenic effects of radiation than the adult thyroid. This conclusion is based upon several studies in recent years of the occurrence of thyroid carcinoma in children who had previously received therapeutic X-irradiation in the neck region for enlarged thymus or for other benign head and neck conditions. The incidence of thyroid carcinoma in these children was significantly higher than in control groups who had not been previously irradiated. In these studies cancer of the thyroid was observed in children after exposures as low as approximately 150 rem."

Thus, the possible thyroid radiation exposures of children near the Nevada Test Site is clearly in the range considered carcinogenic by the Federal Radiation Council. On the assumption that the induction of cancer is proportional to radiation exposure, an estimate of risk can be made. Beach and Dolphin, of the United Kingdom Atomic Energy Authority, considering several sources of data, calculated that, on the average, 35 cases of thyroid cancer may be expected per million persons exposed to one rad of thyroid radiation. In terms relevant to the present testimony, 1 in 286 children exposed to 100 rad thyroid radiation may develop thyroid cancer. By any standard, this is an unacceptable risk

Estimates of radiation damage are difficult, not only because of the uncertainties of some of the assumptions, but also because damage does not become evident for many years after the exposure has taken place. The average latent period between radiation and cancer of the thyroid approximates 10 years; in some instances, the latent period may extend to 20 years. If the thyroid radiation exposures near the Nevada Test Site are as high as suggested in this testimony, careful medical follow-up of exposed populations might yield evidence of damage by this time

5) A survey of the available gamma and beta radiation measurements of fallout resulting from 31 of the total of 99 tests conducted in Nevada in the period 1952-58 shows that conditions which (under the circumstances stated above) lead to hazardous thyroid exposures in children have occurred not only in areas neighboring the Nevada Test Site, but also in

local regions scattered across the continent as far as Troy, New York. This comes about as a result of weather conditions at the time of a particular explosion, which may quickly carry fallout at high altitudes for many miles, and then precipitate it to the ground where an intense thunderstorm occurs. Local fallout deposition which could have resulted in thyroid exposures to children in the range of 5 to 40 rads have, for example, occurred in Troy, New York on April 26, 1953 and in Roswell, New Mexico on April 25, 1953. Salt Lake City values were 3 to 18 rads for fallout on May 7, 1952, and 2 to 12 rads for fallout on March 24, 1953.

6) This hazard has arisen not only from nuclear tests in the atmosphere and at the earth's surface, but also as a result of certain underground nuclear tests. Venting (production of radioactive clouds capable of producing fallout) has been reported for at least seven underground nuclear tests: Shot ESS of Operation Teapot, September 15, 1961; Project Gnome shot, December 10, 1961; the Des Moines shot, June 13, 1962; Project Sedan, July 6, 1962; and shots on March 5, 1962, April 14, 1962, and May 19, 1962. Although data for these shots are relatively limited, we calculate that, for example, fallout from the underground Gnome shot delivered sufficient fallout to the vicinity of Carlsbad, New Mexico to cause thyroid levels of from 7 to 55 rads in children, under the circumstances outlined above.

7) If the gamma and beta radiation measurements taken during Nevada tests had been correctly interpreted at the time that they were made (i.e. taking into account the resultant exposure to children's thyroids where the food chain conditions led to iodine 131 intake), simple preventive measures could have been taken to avoid exposure. This would require only that inhabitants of the region be warned to avoid the drinking of fresh milk produced locally. Fluid milk supplies from other regions, or powdered milk, could have been readily substituted, thereby preventing the ingestion of excessive iodine 131 from local milk. We know of no instance in which such a warning was issued. until the summer of 1962, when high iodine 131 levels observed in commercial milk supplied in Utah led state health officials to divert current milk from the market.

8) Correct interpretation of gamma and beta radiation monitoring measurements should have been possible by 1954 on the basis of then-available scientific theory. Thus, it was known at that time that (a) iodine 131 comprises a specific fraction of the total fission product, which can be estimated from overall measurements of gamma and beta radiation and the age of fallout deposit; (b) iodine 131, along with other fallout products, is deposited on pasture grass and enters the food chain; (c) iodine 131 in food becomes concentrated in the thyroid, thereby increasing its biologically effective dosage to the body. After 1957 there was not only a theoretical basis for this interpretation, but also a detailed practical illustration of its importance. In that year a

British nuclear reactor at Windscale accidently emitted a very considerable amount of radioactive debris. Detailed monitoring measurements showed that pasture land contaminated by this fallout produced milk so heavily contaminated with iodine 131 as to necessitate that it be dumped. The scientific studies of the Windscale disaster provide valuable data which can be used to develop the proper interpretation of the monitoring measurements in the region of the Nevada Test Site. Although the important differences between the hazard of external radiation from fallout and the internal hazard, especially to the thyroid, was recognized by at least one AEC official in 1959 (see Gordon Dunning testimony to Subcommittee on Research, Development and Radiation, Hearings, 1959, p. 445) monitoring procedures, and interpretation of results were not altered to bring them in line with this concept. Thus, the inadequate interpretative procedures which have until now obscured the true hazard resulting from short-range fallout from nuclear tests in Nevada, could have been corrected some years ago.

9) Correction of the described inadequacy of monitoring procedures would affect not only estimates of hazard from atmospheric and underground nuclear tests, but also hazards possible from accidents affecting nuclear reactors, which also produce iodine 131 debris

On the basis of the foregoing considerations, the analysis of the hazard from fallout in the region of the Nevada Test

Site prepared by the St. Louis Committee for Nuclear Information reaches the following conclusions:

1) Analysis of the available evidence shows that children residing in the states bordering the Nevada Test Site have, as a result of fallout from nuclear tests at that site, probably been exposed to medically significant radiation.

2) These exposures were avoidable, for on the basis of radiation monitoring carried out by the AEC during the test programs, the probability of exposure should have been evident in time to warn the population to take simple precautionary steps.

3) Monitoring procedures in the Nevada Test Site regions have been inadequate in that they do not take into account the importance of internal exposure to radioactivity entering the body in fallout-contaminated food. Direct and prompt measurement of iodine 131 in local milk, which is the most effective method of estimating the hazard from this isotope have not been done, or, if done, have not been reported. Moreover, indirect but nevertheless useful estimates of the iodine 131 hazard, which can be determined from the available gross gamma and beta radioactivity measurements have not been made heretofore.

4) Past assurances of the safety to nearby popplations of the Nevada test programs are not substantiated by the present analysis of available data. Assurances that "the hazard has been successfully confined to the controlled areas

of the Test Site" are not justified in the absence of direct measurements of radioactivity levels in local milk. Even the inadequate indirect measurements that have been carried out, if properly interpreted, should have alerted the responsible agencies to the serious potential health hazards during test programs and to the necessity of warning the population to take simple, readily available protective measures.

5) These hazards are not restricted to atmospheric tests alone. Available data show that following at least 7 underground tests, local fallout contamination comparable to that produced by atmospheric tests occurred.

6) In view of the foregoing conclusions we recommend, urgently, a thorough review of present fallout monitoring procedures, with a view to rectifying the present inadequacies with respect to data, interpretation, and public information regarding precautionary measures. In view of the probable high radiation exposures to the population in the Nevada Test Site region we recommend a careful medical follow-up study of exposed individuals, in order to facilitate detection and treatment of possible diseases.

## II. A REPORT ON THE IODINE 131 HAZARD FROM SHORT-RANGE FALLOUT PRODUCED BY NUCLEAR TESTS AT THE NEVADA TEST SITE

1) The problem

This report is an inquiry into the hazard resulting from exposure of local populations, especially in the vicinity of the Nevada Test Site to iodine 131 in fallout produced by nuclear explosions at that site.

At the hearings of the Joint Congressional Committee on Atomic Energy held in 1957, Dr. Lyle Alexander summarized the iodine 131 hazard briefly: "For a period of days following a heavy deposition of fresh fallout, iodine 131, which has a half life of 8 days, may be of importance in direct contamination of vegatation. Radioiodine is selectively concentrated in the thyroid gland, where excessive accumulations cause cancer and cell destruction. Injury to the gland may not be detected until long after the iodine has decayed."[1]

The Federal Radiation Council, in its Report #4, states that "In the special case where nearly all of the annual intake (of iodine 131) could come from exposure to abnormally high concentrations in a local area, resulting from a single nuclear explosion of low yield, the Council recognized that some small number of individual infants could conceivably receive doses 10 to 30 times the average for the area as a whole." The highest average dose to infant thyroids due primarily to one high excursion of levels in 1962 was 620 millirems in Salt Lake City, where most of the dose did result from a single brief series of test explosions.[2] The highest individual dose, therefore, could have been 30 times the average, or 18.6 rems.

Thus, it has been recognized that iodine 131 represents a potentially important hazard from fallout. Until recently, considerations of this problem, with few exceptions, have been limited to iodine 131 exposures expected in the population as a whole during periods of active testing. This problem has been discussed in detail before the JCAE, and the St. Louis Committee for Nuclear Information has reported on it.[3A] It has been recognized that rapid measurements of iodine 131 in milk provide a useful index of the radiation exposure to the thyroid expected in a child consuming the milk. While this type of information is therefore important in estimating the iodine 131 hazard from fallout it has certain limitations. Nearly all available measurements of iodine 131 in milk are based on large commercial supplies. These represent pooled milk from many widely scattered farms. Such measurements are, of course, valuable in estimating the iodine 131 intake of children who drink commercial milk of this type. However, the pooling process conceals variations in iodine 131 levels among separate regions and it is impossible to determine how much iodine 131 would be taken in by a child who consumes fresh milk directly from a cow or herd stationed in a particular local area. Nevertheless, the latter is the situation which governs milk consumption of many rural children. Since much of the region surrounding the Nevada Test Site is occupied by farms and rather small towns, in which this type of local milk consumption must prevail, it becomes necessary to know the iodine 131 content of numerous separate small farm-size milk supplies in order to determine the iodine 131 intake of children living in this region.

Unfortunately appropriate measurements of iodine 131 in local milk supplies do not appear to have been made. For this reason direct estimates of the hazard to the thyroid are not possible, as they are in the case of many large-scale populations which consume commercial milk supplies. Iodine 131 measurements of commercial milk supplies for a number of cities have been available since 1957.

Because of the lack of such direct information on iodine 131 levels of milk consumed by children in the region of the Nevada Test Site, it becomes necessary to develop a method for estimating these values from other types of fallout measurements.

In what follows, we consider how this can be done.

2) Indirect estimation of iodine 131 levels from overall measurements of gamma and beta radiation

When nuclear fission occurs, a wide range of atomic products result. The physical processes which result in the appearance of the different products of nuclear fission have been studied extensively. From these studies, it is known that particular radioisotopes, such as iodine 131, represent a relatively constant proportion of the total radioactive debris. Hence, if a measurement of the total amount of fallout is obtained it is possible to calculate the amount of iodine 131 produced. From this value one can estimate the amount of iodine 131 present in fallout by determining the "age" of the fallout, i.e. the time between its production in the nuclear explosion and its measurement, for like all radioisotopes iodine 131 decays with time. Thus, if one makes a measurement of the total gamma or beta radioactivity emitted by a sample of fallout, and can also determine its "age," it is possible to estimate the amount of iodine 131 present. The relevant calculations are presented in detail in the Appendix. During this interval some "fractionation" may possibly occur, i.e., as the fallout drifts along, some isotopes may become deposited out sooner than others. Not much is known about this process. In keeping with general practice in this field (see for example, Dunning, Hearings, Radiation Subcommittee, 1959. Biological and Environmental Effects of Nuclear War, p. 443), the possible effects of fractionation are not considered in our calculations.

Once an estimate of iodine 131 on the ground is available, it is possible quite readily to calculate how much of it will go into milk, and how much of the radioiodine in the milk will become concentrated in the thyroid of a child drinking one quart of milk per day (the standard usually used in fallout calculation).

This can be accomplished from a consideration of known cases of fallout and transmission from contamination on grass to milk and resultant thyroid iodine levels. Lapp[5] has made such a calculation based on the fallout incident at the Windscale pile No, 1, an experimental nuclear reactor, which caused the release of 20,000 curies of iodine 131 to the atmosphere. The iodine fell on farms in the area and then appeared in cows' milk in amounts as high as 100,000 micromicrocuries per liter. Though infants did not drink the milk because it was removed from the market, the thyroid radiation dose that would result from such concentrations can be calculated on the basis of standard dosimetry procedures. The combined calculation indicates that $1\mu c/M^2$ deposition of iodine 131 results in a dose of 5 rads to an infant thyroid gland. This is the basis for the lower of our two estimates. (See Appendix for details)

It should be noted that Lapp was not the first to make use of the Windscale experience. Gordon Dunning estimated in 1959 the thyroid dose due to raioiodine in fallout. His estimate indicates, "Based on Windscale experience, $1\mu cI^{131}/M^2 \longleftrightarrow 0.1\mu cI^{131}$/liter of milk. For one liter of this milk $\longrightarrow$ 2 rad dose to infant's thyroid. For continuous consumption of milk from cows grazing on pasture until $I^{131}$ activity essentially zero $\longrightarrow$ 22-44 rad dose."[6] His calculation was for a wartime situation, but an atmospheric nuclear explosion creates and deposits radioactive fallout irrespective of the use to which it is put.

Dunning's estimate is somewhat higher than that derived in this paper from the Windscale evidence because he assumed that 100 per cent of deposited iodine 131 is retained on edible herbage, whereas we assume only 40 per cent. Higher yet is a figure based on experiments by R. J. Garner, who observed the transfer of iodine 131 from the diet of cows to their milk.[7] Based on Garner's data 1 μc $I^{131}/M^2$ yields a 35 rad dose to the infant thyroid, for continuous ingestion.

Thus empirical evidence indicates a range for the infant thyroid dose due to a given deposition of iodine 131 on an area where milk cows graze. Using the steps described earlier, it is possible to estimate the thyroid dose on the basis of external beta and gamma intensities. For example, a gamma intensity of 30 milliroentgens/hour at Belmont, Nevada, 8 hours after an explosion on 28 May 1957 indicates an iodine deposition of 650 $\mu\mu c/cm^2$ and a possible resultant peak level in milk from cows eating grass in the area, of from 260,000 to 1,040,000 $\mu\mu c$/liter of milk. The dose to an infant's thyroid from continued ingestion of this milk would probably be between 32 and 214 rads. Or, using beta readings, the average beta count at Salt Lake City on May 7, 1952, for example, was 23,000,000 disintegrations per minute per square foot (d/m/$ft^2$). This would be expected to lead to infant thyroid doses of from 3 to 18 rads.

3) Estimates of Theoretically Possible Thyroid Doses Due to Short-Range Fallout From the Nevada Test Site

As shown above it is possible to calculate, from local measurements of gamma and beta radiation, what radiation exposure to a child's thyroid might theoretically result from a given deposit of fallout. Since the AEC has reported numerous measurements of gamma and beta radiation, together with the times of measurement, and their relation to a particular nuclear explosion (the time of which is also given), these data can be converted to estimates of possible iodine 131 exposures to the thyroid according to the procedures outlined above, and given in detail in the Appendix. Such calculations have been made for 189 different readings at various locations following 31 different nuclear test shots conducted at the Nevada Test Site during the period 1952-1958. The overall results are presented in Tables I-V. In each case, two estimates of the possible thyroid dose have been calculated, using the two different observations (Windscale and Garner) described above. The lower of the two estimates yields thyroid dosages which range from 0.6 rad to 555 rads. The higher of the two estimates yields thyroid dosages which range from 4 rads to 3760 rads. According to the higher estimate, of the separate locations, 50 received sufficient fallout to result in a possible dose of 100 rads or more to the thyroid. In 15 cases even the lower estimate yielded a thyroid dose over 100 rads. It is evident from this summary that the Nevada tests have produced instances of

Table I

Some Estimated Infant Thyroid Doses for 1953.
(Operation Upshot-Knothole).[8,9]

| Hot Spot Location | Rate mr/hr | Time of Reading H + hrs | I-131 Density μμc/cm² | I-131 in Fresh Milk μμc/l based on: Windscale | Garner | Dose to Infant Thyroid - Rads Wind-scale | Garner |
|---|---|---|---|---|---|---|---|
| SHOT ANNIE - 0520 PST - 17 MARCH 1953 - 16.2 Kt. - 300' - TOWER | | | | | | | |
| St. George, Utah | 20 | 8 | 504 | 202,000 | 806,000 | 25 | 166 |
| Rockville, Utah | 24 | 12 | 970 | 390,000 | 1,550,000 | 48 | 320 |
| US 93, 30 mi N of Alamo, Nevada | 110 | 7-1/3 | 2,380 | 450,000 | 3,800,000 | 119 | 785 |
| US 91, 10 mi N of St. George, Utah | 110 | 5 | 1,600 | 640,000 | 2,550,000 | 80 | 525 |
| Nev 55, 22 mi N of US 91 | 260 | 2-2/3 | 1,800 | 730,000 | 2,900,000 | 91 | 600 |
| SHOT NANCY - 0510 PST - 24 MARCH 1953 - 24.4 Kt. - 300' TOWER | | | | | | | |
| 41 mi NW Crystal Springs, Nevada | 140 | 5-1/2 | 2,030 | 815,000 | 3,250,000 | 103 | 670 |
| Hwy 93, 59 mi S of Ely, Nevada | 45 | 7-1/4 | 970 | 389,000 | 1,550,000 | 48 | 320 |
| Adaven, Nevada | 11 | 8 | 277 | 111,000 | 444,000 | 14 | 91 |
| 8 mi NW of Lincoln Mine, Nev | 85 | 9 | 2,460 | 990,000 | 3,940,000 | 123 | 814 |
| 32 mi SW of Lincoln Mine, Nev | 32 | 58 | 7,250 | 2,900,000 | 13,100,000 | 363 | 2,400 |
| Sunnyside, Nevada | 17 | 10-1/4 | 557 | 222,000 | 890,000 | 28 | 183 |
| St. George, Utah | .3 | 12 | 12 | 4,900 | 19,400 | .6 | 4 |
| SHOT BADGER - 0435 PST - 18 APRIL 1953 - 23.0 Kt. - 300' - TOWER | | | | | | | |
| 17 mi SW of Glendale Jct. on Hwy 91 | 38 | 31-2/3 | 4,480 | 1,790,000 | 7,150,000 | 224 | 1,480 |
| Jct Hwy US 91 and Nev 40 | 35 | 28 | 3,680 | 1,470,000 | 5,890,000 | 184 | 1,210 |
| 14.5 mi W of Jct Nev 12 & 40 on 40 | 38 | 27-1/3 | 3,850 | 1,540,000 | 6,150,000 | 192 | 1,270 |

Table I (Cont'd)

| Hot Spot Location | γ Rate mr/hr | Time of Reading H + hrs | I-131 Density μμc/cm² | I-131 in Fresh Milk μμc/l based on: Windscale | Garner | Dose to Infant Thyroid - Rads: Wind-scale | Garner |
|---|---|---|---|---|---|---|---|
| SHOT SIMON - 0430 - 25 APRIL 1953 - 42.7 Kt. - 300' - TOWER | | | | | | | |
| Mesquite, Nevada | 30 | 10 | 485 | 394,000 | 1,730,000 | 49 | 325 |
| Bunkerville, Nevada | 100 | 10-1/3 | 3,280 | 1,310,000 | 5,250,000 | 164 | 1,060 |
| 24 mi W of Mesquite on US 91 | 110 | 27-1/2 | 11,100 | 4,440,000 | 17,800,000 | 555 | 3,760 |
| 20 mi N of Glendale Jct on US 93 | 80 | 29 | 8,840 | 3,500,000 | 14,100,000 | 440 | 2,910 |
| Alamo, Nevada | 1.8 | 10-2/3 | 61 | 24,500 | 98,000 | 3 | 20 |
| Groom Mine, Nevada | 0.2 | 13 | 8.5 | 3,500 | 14,100 | .4 | 3 |
| Riverside Cabins | 300 | 10 | 984 | 394,000 | 1,575,000 | 49 | 325 |
| St. George, Utah | .5 | 12 | 20.2 | 8,100 | 32,400 | 1 | 6 |
| Santa Clara, Utah | 5.0 | 32 | 600 | 240,000 | 960,000 | 30 | 200 |
| SHOT HARRY - 0505 PDT - 19 MAY 1953 - 32.4 Kt. - 300' - TOWER | | | | | | | |
| Hwy 93, 32 mi N of Glendale, Nevada | 18 | 33 | 2,270 | 910,000 | 3,630,000 | 113 | 750 |
| St. George, Utah | 16 | 36 | 2,220 | 890,000 | 3,560,000 | 111 | 735 |
| Washington, Utah | 28 | 13 | 1,240 | 495,000 | 1,980,000 | 62 | 409 |
| [illegible], Utah | 42 | 8 | 1,060 | 420,000 | 1,690,000 | 53 | 350 |
| [illegible]erne, Utah | 80 | 11-1/2 | 2,940 | 1,170,000 | 4,700,000 | 147 | 970 |
| [illegible]b, Utah | 15 | 28-2/3 | 1,570 | 630,000 | 2,520,000 | 79 | 520 |
| Rockville, Utah | 80 | 9 | 2,320 | 930,000 | 3,720,000 | 116 | 765 |
| Orderville, Utah | 14 | 32 | 1,685 | 675,000 | 2,700,000 | 84 | 555 |
| Cedar City, Utah | 18 | 12 | 730 | 292,000 | 1,170,000 | 36 | 240 |
| Veyo, Utah | 20 | 28-1/2 | 2,100 | 840,000 | 3,360,000 | 105 | 695 |

Table II

Some Estimated Infant Thyroid Doses for 1955 (Operation Teapot).[1,10]

| Hot Spot Location | γ Rate mr/hr | Time of Reading H + hrs | I-131 Density μμc/cm² | I-131 in Fresh Milk μμc/l based on: Windscale | I-131 in Fresh Milk μμc/l based on: Garner | Dose to Infant Thyroid - Rads: Windscale | Dose to Infant Thyroid - Rads: Garner |
|---|---|---|---|---|---|---|---|
| SHOT WASP - 18 FEB. 1955 - 1.2 Kt. - 726' - AIR DROP | | | | | | | |
| Nev 85, 28 mi S of Pahrump | 5.5 | 3.6 | 62 | 25,100 | 37,600 | 3 | 21 |
| SHOT MOTH - 22 FEB. 1955 - 2.4 Kt. - 300' - TOWER | | | | | | | |
| Dry Lake, Nevada | 6.0 | 6.3 | 109 | 43,500 | 174,000 | 5 | 36 |
| US 93-91, 1 mi SW Dry Lake | 29 | 6.4 | 525 | 210,000 | 840,000 | 26 | 173 |
| SHOT TESLA - 1 MARCH 1955 - 6.8 Kt. - 300' - TOWER | | | | | | | |
| Santa Clara, Utah | 6.0 | 11.3 | 220 | 880,000 | 3,500,000 | 11 | 73 |
| St. George, Utah | 4.0 | 10.2 | 131 | 525,000 | 2,100,000 | 7 | 43 |
| Gunlock, Utah | 0.3 | 10.9 | 11 | 4,400 | 17,500 | .6 | 4 |
| Ash Springs, Nevada | 4.5 | 9.2 | 130 | 52,000 | 209,000 | 7 | 43 |
| [illegible] mi S of Alamo on US 93 | 55 | 5.2 | 800 | 320,000 | 1,280,000 | 40 | 264 |
| SHOT TURK - 7 MARCH 1955 - 43.0 Kt. - 500' - TOWER | | | | | | | |
| Currant, Nevada | .98 | 29.4 | 108 | 43,000 | 173,000 | 5 | 36 |
| Ely, Nevada | 1.00 | 28.4 | 105 | 42,000 | 168,000 | 5 | 35 |
| Warm Springs, Nevada | 1.50 | 34.8 | 203 | 81,000 | 324,000 | 10 | 67 |
| [illegible] mi S Lockes on US 6 | 3.00 | 31.0 | 405 | 162,000 | 648,000 | 20 | 134 |
| SHOT HORNET - 12 MARCH 1955 - 300' - TOWER | | | | | | | |
| Glendale, Nevada | 14.0 | 7.7 | 353 | 141,000 | 565,000 | 18 | 116 |
| Moapa, Nevada | 10.0 | 6.5 | 216 | 86,000 | 346,000 | 11 | 71 |
| Warm Springs Ranch | 7.0 | 5.2 | 102 | 40,600 | 162,000 | 5 | 34 |
| SHOT BEE - 22 MARCH 1955 - 8.1 Kt. - 500' - TOWER | | | | | | | |
| Las Vegas, Nevada | 9.0 | 5.5 | 163 | 65,000 | 260,000 | 8 | 54 |
| North Las Vegas, Nev | 13.0 | 5.1 | 189 | 75,000 | 300,000 | 9 | 62 |
| US 93-95, 3 mi S of Henderson | 18 | 5.1 | 261 | 104,000 | 418,000 | 13 | 86 |

Table II (Cont'd)

| Hot Spot Location | Rate mr/hr | Time of Reading H + hrs | I-131 Density c/cm² | I-131 in Fresh Milk c/l based on: Windscale | Garner | Dose to Infant Thyroid - Rads: Windscale | Garner |
|---|---|---|---|---|---|---|---|
| SHOT ESS - 23 MARCH 1955 - SUBSURFACE | | | | | | | |
| Lake Mead Base, Nev | 1.5 | 4.0 | 16.8 | 6,700 | 27,000 | .8 | 6 |
| Glendale, Nevada | 1.5 | 7.2 | 32.4 | 13,000 | 52,000 | 2 | 11 |
| US 93, 38 mi S of Alamo | 6.3 | 3.0 | 50.4 | 20,000 | 81,000 | 3 | 17 |
| 22 mi N Indian Springs, Nevada | 140.0 | 5.3 | 2,030 | 812,000 | 3,250,000 | 100 | 670 |
| SHOT APPLE I - 29 MARCH 1955 - 15.5 Kt. - 500' - TOWER | | | | | | | |
| Alamo, Nevada | 160.0 | 2.8 | 1,280 | 512,000 | 2,050,000 | 64 | 420 |
| Panaca, Nevada | 2.5 | 5.9 | 45 | 18,100 | 72,000 | 2 | 15 |
| Caliente, Nevada | 9.0 | 4.9 | 131 | 52,000 | 209,000 | 7 | 43 |
| Enterprise, Utah | 9.5 | 6.8 | 206 | 82,000 | 328,000 | 10 | 68 |
| Kanarraville, Utah | 10.0 | 5.7 | 181 | 72,000 | 290,000 | 9 | 60 |
| Newcastle, Utah | 10.0 | 6.7 | 216 | 86,000 | 346,000 | 11 | 71 |
| Hamilton Fort, Utah | 6.0 | 5.7 | 109 | 43,500 | 174,000 | 5 | 36 |
| SHOT MET - 9 APRIL 1955 - 300' - TOWER | | | | | | | |
| Buckhorn Ranch, Nev | 140 | 2.6 | 1,120 | 450,000 | 1,800,000 | 56 | 370 |
| Elgin, Nevada | 200 | 5.1 | 2,900 | 1,160,000 | 4,650,000 | 145 | 960 |
| Beryl, Utah | 6.0 | 6.6 | 130 | 52,000 | 207,000 | 6 | 43 |
| Zane, Utah | 16.0 | 6.8 | 346 | 138,000 | 550,000 | 17 | 114 |
| Lund, Utah | 9.0 | 7.3 | 194 | 78,000 | 311,000 | 10 | 64 |
| Beaver, Utah | 3.5 | 25.3 | 315 | 126,000 | 500,000 | 16 | 104 |
| Minersville, Utah | 2.5 | 22.1 | 208 | 83,000 | 332,000 | 10 | 68 |

Table II (Cont'd)

| Hot Spot Location | Rate mr/hr | Time of Readings H + hrs | I-131 Density µc/cm² | I-131 in Fresh Milk µµc/l based on: Windscale | Garner | Dose to Infant Thyroid - Rads Windscale | Garner |
|---|---|---|---|---|---|---|---|
| [illegible] II - 5 MAY 1955 - 30.0 Kt. - 500' - [illegible] | | | | | | | |
| [illegible], Nevada | 18.0 | 4.2 | 202 | 81,000 | 325,000 | 10 | 6[illegible] |
| [illegible], Nevada | 30.0 | 5.8 | 544 | 21[illegible],000 | 870,000 | 27 | 180 |
| Fallini Ranch, Nevada | 15.0 | 5.0 | 189 | 75,000 | 302,000 | 9 | 62 |
| [illegible]ed, Nevada | 110.0 | 6.8 | 2,3[illegible]0 | 95[illegible],000 | 3,800,000 | 119 | 785 |
| Lockes Ranch, Nevada | 3[illegible].0 | 5.3 | 551 | [illegible]20,000 | 8,800,000 | 28 | 182 |
| Currant, Nevada | 8.0 | 6.5 | 1[illegible]3 | 69,000 | 276,000 | 9 | 57 |
| [illegible]ter, Nevada | 16.0 | 7.3 | 346 | 138,000 | 550,000 | 17 | 114 |
| [illegible] ZUCCHINI - 15 MAY 1955 - 500' - TOWER | | | | | | | |
| [illegible] Ranch, [illegible] | 50.0 | 3.4 | 400 | 160,000 | 640,000 | 20 | 132 |
| [illegible], Nevada | 65.0 | 3.9 | 728 | 290,000 | 1,160,000 | 36 | 240 |
| Crystal, Nevada | 11.0 | 3.5 | 123 | 49,000 | 197,000 | 6 | 41 |
| Logandale, Nevada | 20.0 | 5.3 | 290 | 116,000 | 464,000 | 14 | 96 |
| St. George, Utah | 3.0 | 8.6 | 87 | 35,000 | 139,000 | 4 | 29 |
| Cedar City, Utah | 4.8 | 7.0 | 104 | 41,500 | 166,000 | 5 | 34 |
| Washington, Utah | 3.9 | 9.6 | 128 | [illegible] | 205,000 | 6 | 42 |
| [illegible]owan, Utah | 5.5 | 11.7 | 223 | 89,000 | 356,000 | 11 | 74 |
| [illegible]ah, Utah | 4.6 | 11.8 | 186 | 75,000 | 290,000 | 9 | 62 |
| Kanarraville, Utah | 2.8 | 8.7 | 81 | 3[illegible],000 | 130,000 | 4 | 27 |

Table III

[illegible] Infant Thyroid [illegible] for 1957.
(Operation [illegible])

| Hot Spot Location | Rate mr/hr | Time of Reading H + hrs | I-131 Density μc/cm² | I-131 in Fresh Milk μμc/l based on: [illegible] | I-131 in Fresh Milk μμc/l based on: Garner | Dose to Infant Thyroid - Rads: Wind-scale | Dose to Infant Thyroid - Rads: Garner |
|---|---|---|---|---|---|---|---|
| SHOT BOLTZMANN - 28 MAY 1957 - 11.5 Kt. - 500' - TOWER | | | | | | | |
| Belmont, Nevada | [illegible] | 7.7 | [illegible] | [illegible] | 1,040,000 | 32 | 214 |
| Currant, Nevada | 1.3 | 14,5 | 63 | [illegible],000 | 100,000 | 3 | 21 |
| Fallon, Nevada | 1.0 | 40 | 156 | [illegible] | 250,000 | 8 | 51 |
| Millett, Nevada | [illegible] | 35.7 | 335 | [illegible],000 | 535,000 | 17 | 110 |
| [illegible] Ranch, Nev | 22.0 | 10.7 | 716 | [illegible] | 1,15[illegible],000 | 36 | 236 |
| Reveille Mill, Nev | 80.0 | 10.7 | 2,620 | 1,050,000 | 4,200,000 | 131 | 865 |
| Round Mt., Nevada | 6.0 | 9.9 | 197 | 79,[illegible]00 | 315,000 | 10 | 65 |
| Stone Cabin Ranch | 14 | 8.7 | 352 | 141,000 | 565,000 | 17 | 116 |
| Stone House Ranch | 45 | 9.7 | 1,300 | [illegible],000 | 2,090,000 | 65 | 430 |
| SHOT WILSON - 18 JUNE 1957 - 10.3 Kt. - 500' - BALLOON | | | | | | | |
| [illegible], Nevada | 2.0 | 7.2 | 43 | 17,300 | 69,000 | 2 | 14 |
| SHOT PRISCILLA - 24 JUNE 1957 - 36.6 Kt. - 700' - BALLOON | | | | | | | |
| Buckhorn Ranch, Nev | 1.2 | 11 | 44 | 17,[illegible]00 | 705,000 | 2 | 15 |
| Caru?, Nevada | 4.5 | 10.7 | [illegible] | 59,000 | 236,000 | 8 | 49 |
| Leith, Nevada | 3.5 | 10.2 | 114 | 45,500 | 182,000 | 6 | 37 |
| Anderson Jct., Utah | 2.0 | 15.2 | 104 | 41,800 | 167,000 | 5 | 34 |
| Gunlock, Utah | 2.0 | 11.0 | [illegible] | 29,400 | [illegible] | 4 | [illegible] |
| Leeds, Utah | 2.0 | 15.0 | 105 | 4[illegible],000 | [illegible] | [illegible] | 34 |
| [illegible], Utah | 2.5 | [illegible] | 1[illegible]0 | 52,000 | 208,000 | 7 | 43 |
| [illegible], Utah | 8.0 | 10.[illegible] | 262 | 105,000 | 420,000 | 13 | 86 |
| New Harmony, Utah | .29 | 35.8 | 39 | 15,500 | 62,200 | 2 | 13 |

Table III (Cont'd)

| Hot Spot Location | γ Rate mr/hr | Time of Reading H + hrs | I-131 Density μμc/cm² | I-131 in Fresh Milk μμc/l based on: Windscale | Garner | Dose to Infant Thyroid - Rads Wind-scale | Garner |
|---|---|---|---|---|---|---|---|
| SHOT DIABALO - 15 JULY 1957 - 17 Kt. - 500' - TOWER | | | | | | | |
| Bardoli Ranch, Nev | 2.5 | 12.3 | 101 | 40,500 | 162,000 | 5 | 33 |
| Belen Ranch Adaven, Nevada | 8.5 | 11.5 | 236 | 115,000 | 460,000 | 14 | 95 |
| Ely, Nevada | 3.7 | 14.4 | 179 | 71,500 | 286,000 | 9 | 59 |
| Geyser Ranch, Nev | 7.0 | 16.7 | 416 | 166,000 | 660,000 | 21 | 137 |
| Groom Mine, Nevada | 75 | 8.2 | 1,890 | 760,000 | 3,000,000 | 94 | 625 |
| Lincoln Mine, Nev | 52 | 8.0 | 1,310 | 525,000 | 2,100,000 | 65 | 430 |
| Lund, Nevada | 4.4 | 13.0 | 1,940 | 780,000 | 3,110,000 | 97 | 640 |
| Preston, Nevada | 4.2 | 13.2 | 1,850 | 740,000 | 2,970,000 | 93 | 610 |
| South Paw Mine, Nev | 12.5 | 11.3 | 459 | 180,000 | 735,000 | 23 | 150 |
| Sunnyside, Nevada | 8.7 | 11.2 | 320 | 128,000 | 510,000 | 16 | 105 |
| Uhalde Ranch, Nev | 11.0 | 8.4 | 277 | 111,000 | 444,000 | 14 | 100 |
| Welch Pine Creek Ranch, Nevada | 4.5 | 14.5 | 218 | 87,000 | 350,000 | 11 | 72 |
| Whipple Ranch | 1.5 | 12.5 | 60 | 24,300 | 97,000 | 3 | 20 |
| SHOT KEPLER - 24 JULY 1957 - 10.3 Kt, - 500' - TOWER | | | | | | | |
| Basalt, Nevada | 1.5 | 13.0 | 66 | 26,500 | 106,000 | 3 | 22 |
| Coaldale, Nevada | 9.5 | 13.0 | 420 | 167,000 | 670,000 | 21 | 138 |
| Goldpoint Nevada | 6.5 | 9.2 | 188 | 75,400 | 300,000 | 9 | 62 |
| Silverpeak, Nevada | 7.5 | 11.9 | 304 | 122,000 | 486,000 | 15 | 100 |

Table III (Cont'd)

| Hot Spot Location | Rate mr/hr | Time of Reading H + hrs | I-131 Density c/cm$^2$ | I-131 in Fresh Milk c/l based on: Windscale | Garner | Dose to Infant Thyroid - Rads Wind-scale | Garner |
|---|---|---|---|---|---|---|---|
| SHOT OWENS - 25 JULY 1957 - 9.7 Kt. - 500' - BALLOON | | | | | | | |
| Bardoli Ranch, Nev | 1.7 | 7.1 | 33 | 13,400 | 53,500 | 2 | 11 |
| Currant, Nevada | 5.5 | 5.8 | 80 | 32,000 | 128,000 | 4 | 26 |
| El Dorado, Nevada | 1.4 | 9.9 | 46 | 18,400 | 73,500 | 2 | 13 |
| Eureka, Nevada | 1.3 | 8.0 | 33 | 13,100 | 52,500 | 2 | 11 |
| Fallini Ranch, Nev | 1.8 | 5.3 | 26 | 10,400 | 41,600 | 1 | 9 |
| Nyala, Nevada | 2.5 | 6.7 | 45 | 18,100 | 72,500 | 2 | 15 |
| SHOT SHASTA - 18 AUGUST 1957 - 16.5 Kt. - 500' TOWER | | | | | | | |
| Bardoli Ranch, Nev | 4.8 | 10.3 | 157 | 63,000 | 252,000 | 8 | 52 |
| Currant, Nevada | 3.5 | 8.7 | 88 | 35,300 | 141,000 | 4 | 29 |
| Eureka, Nevada | 13.0 | 10.5 | 430 | 172,000 | 688,000 | 21 | 142 |
| Fallini Ranch, Nev | 33.0 | 6.9 | 710 | 285,000 | 1,140,000 | 35 | 235 |
| Lockes, Nevada | 7.0 | 8.1 | 176 | 70,500 | 282,000 | 9 | 58 |
| Lund, Nevada | 2.5 | 10.6 | 82 | 32,800 | 131,000 | 4 | 27 |
| Nyala, Nevada | 6.0 | 8.7 | 151 | 60,500 | 242,000 | 8 | 50 |
| Preston, Nevada | 3.5 | 10.2 | 115 | 46,000 | 183,000 | 6 | 38 |
| Reveille Mill, Nev | 20 | 6.0 | 362 | 145,000 | 580,000 | 18 | 120 |

Table III (Cont'd)

| Hot Spot Location | Rate mr/hr | Time of Reading H + hrs | I-131 Density μc/cm² | I-131 in Fresh Milk c/l Peak Day: Windscale | I-131 in Fresh Milk c/l Peak Day: Garner | Dose to Infant Thyroid - Rads: Wind-scale | Dose to Infant Thyroid - Rads: Garner |
|---|---|---|---|---|---|---|---|
| SHOT SMOKY - 31 AUGUST 1957 - 44.0 Kt. - 700' - TOWER | | | | | | | |
| Butler Ranch, Nev | 360 | 3.8 | 2,380 | 1,150,000 | 4,600,000 | 144 | 950 |
| Glendale Jct, Nev | 2.0 | 12.4 | 81 | 32,400 | 130,000 | 4 | 27 |
| Mesquite, Nevada | 2.0 | 13.6 | 88 | 35,100 | 141,000 | 4 | 29 |
| Rox, Nevada | 8.8 | 8.5 | 222 | 89,000 | 355,000 | 11 | 73 |
| Anderson Jct, Nev | 11.0 | 10.7 | 360 | 144,000 | 578,000 | 18 | 119 |
| Cedar City, Utah | 3.0 | 11.9 | 110 | [illegible] | 176,000 | 5 | 36 |
| Central, Utah | 6.0 | 10.9 | 98 | 39,300 | 157,000 | 5 | 32 |
| Gunlock, Utah | 7.0 | 9.7 | 203 | 81,000 | 325,000 | 10 | 67 |
| Hurricane, Utah | 2.5 | 12.2 | 101 | 40,000 | 160,000 | 5 | 33 |
| Leeds, Utah | 17 | 9.5 | 494 | 197,000 | 790,000 | 24 | 163 |
| Rockville, Utah | 2.0 | 12.8 | 81 | 32,400 | 130,000 | 4 | 27 |
| St. George, Utah | 14.0 | 12.5 | 467 | 227,000 | 910,000 | 28 | 187 |
| Veyo, Utah | 15 | 10.0 | 491 | 196,000 | 786,000 | 24 | 162 |
| Virgin, Utah | 2.0 | 12.6 | 81 | 32,400 | 130,000 | 4 | 27 |
| Washington, Utah | 4.0 | 11.6 | 147 | 58,700 | 235,000 | 7 | 48 |
| Rock Springs, Wyo | 5.0 | 12 | 203 | 81,000 | 324,000 | 10 | 67 |
| SHOT GALILEO - 2 SEPTEMBER 1957 - 11.4 Kt. - 500' - TOWER | | | | | | | |
| A & B Mine, Nevada | 3.0 | 13.4 | 132 | 53,000 | 220,000 | 6 | 43 |
| Fallini Ranch, Nev | 0.8 | 14.7 | 39 | 15,500 | 62,000 | 2 | 13 |
| Parmon Ranch, Nev | 0.9 | 14.0 | 40 | 16,000 | 64,400 | 2 | 13 |
| Reveille Mill, Nev | 3.5 | 11.7 | 128 | 51,400 | 205,000 | 6 | 42 |
| Stone Cabin Ranch | 2.3 | 10.8 | 75 | 30,000 | 120,000 | 4 | 25 |

Table IV

Some Estimated Infant Thyroid Doses for 1958 (Operation Hardtack-II)[14]

| Hot Spot Location | [illegible] Rate mr/hr | Time of Reading H + hrs | I-131 Density c/cm² | I-131 in Fresh Milk [illegible] c/l based on: Windscale | I-131 in Fresh Milk based on: Garner | Dose to Infant Thyroid - Rads Wind-scale | Dose to Infant Thyroid - Rads Garner |
|---|---|---|---|---|---|---|---|
| SHOT [illegible] - 10 OCTOBER 1958 - 79 Kt. - 100' - TOWER | | | | | | | |
| Beatty, Nevada | 1.4 | 7.7 | 30 | 12,000 | 48,000 | 2 | 10 |
| Hwy 58 10 mi N of Beatty, Nevada | 2.5 | 4.92 | 36 | 14,500 | 57,000 | 2 | 12 |
| SHOT LEA - 13 OCTOBER 1958 - 1500' - BALLOON | | | | | | | |
| 8 mi. W of Cliff Spring, Nevada | 1.5 | 9.3 | 43.5 | 17,400 | 70,000 | 2 | 14 |
| 8 mi W of Reed on old hwy 25 | 3.3 | 9.3 | 96 | 37,000 | 153,000 | 5 | 32 |
| SHOT RIO ARRIBA - 18 OCTOBER 1958 - 90 Kt. - 70' - TOWER | | | | | | | |
| Below Ranch, Nev | 1.8 | 7.5 | 39 | 15,500 | 62,000 | 2 | 13 |
| Casey Ranch, Nev | 1.4 | 8.0 | 35 | 14,100 | 56,400 | 2 | 12 |
| Sharp Ranch, Nev | 1.5 | 8.3 | 38 | 15,100 | 60,400 | 2 | 13 |
| Uhalde Ranch, Nev | 1.7 | 7.3 | 37 | 14,700 | 59,000 | 2 | 12 |
| Walch Ranch, Nev | 1.6 | 6.6 | 29 | 11,600 | 46,400 | 1 | 10 |

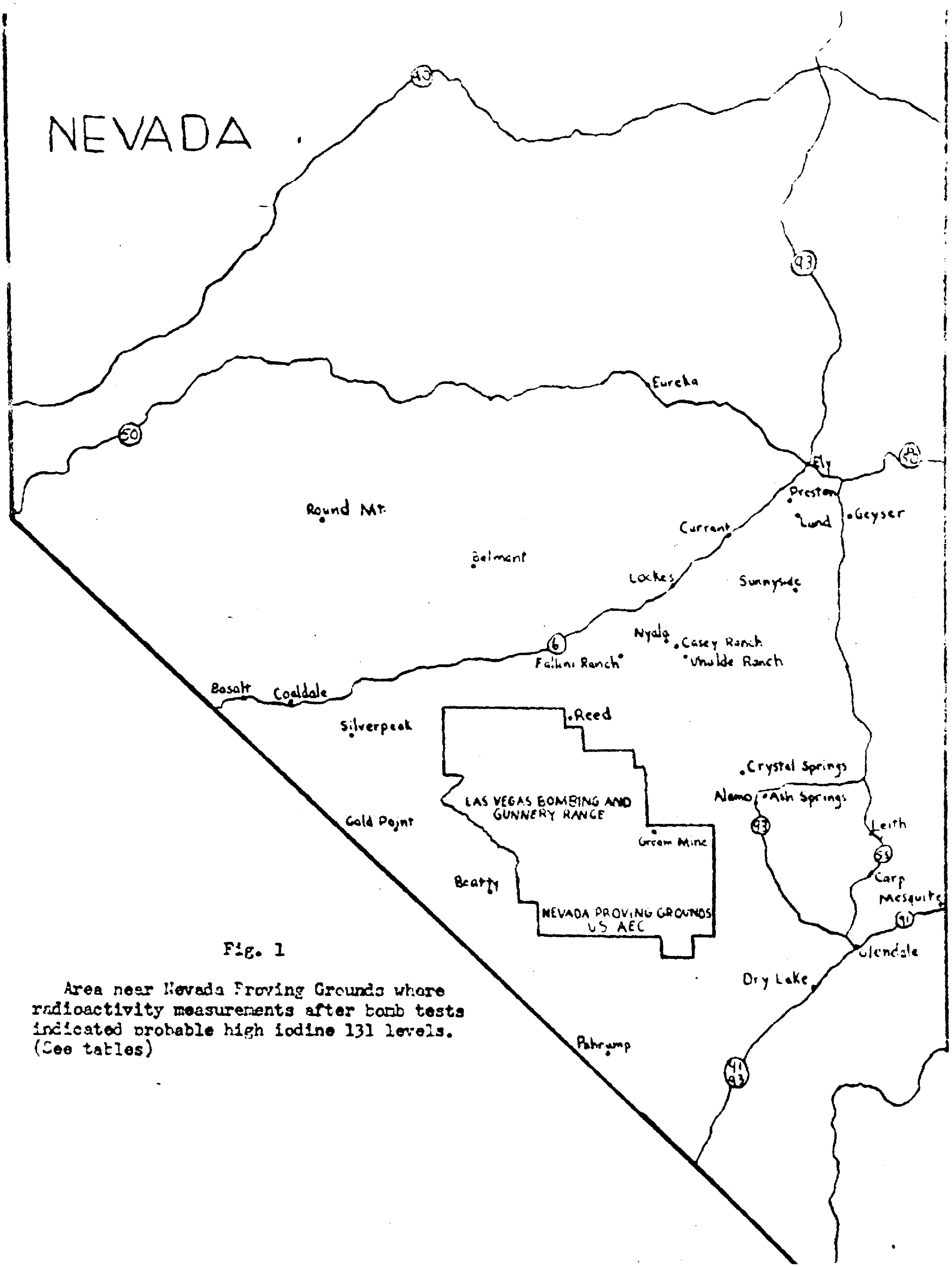


Fig. 1

Area near Nevada Proving Grounds where radioactivity measurements after bomb tests indicated probable high iodine 131 levels. (See tables)

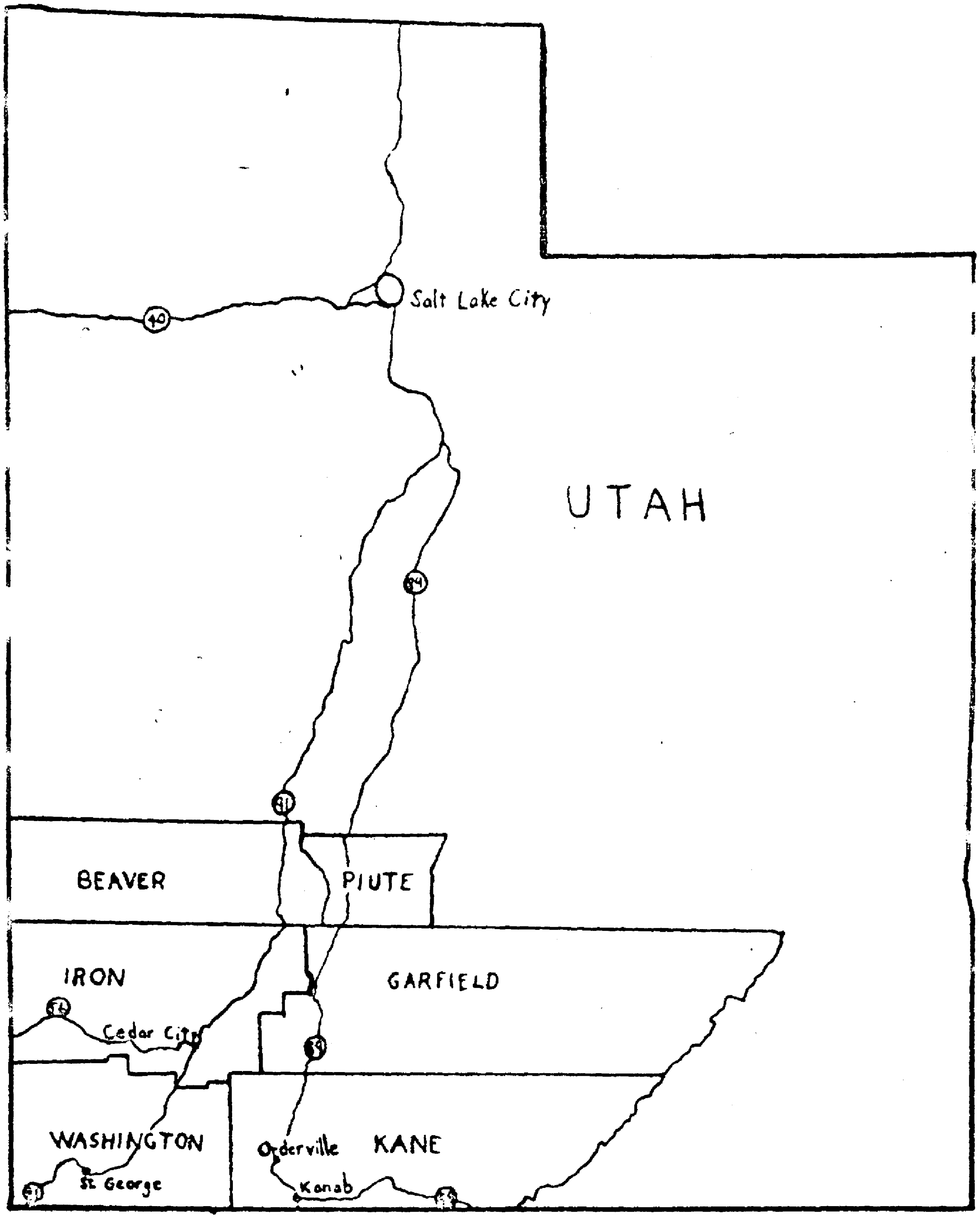


Fig. 2

Area in Utah where radioactivity measurements after bomb tests indicated probable high iodine 131 levels. (See tables)

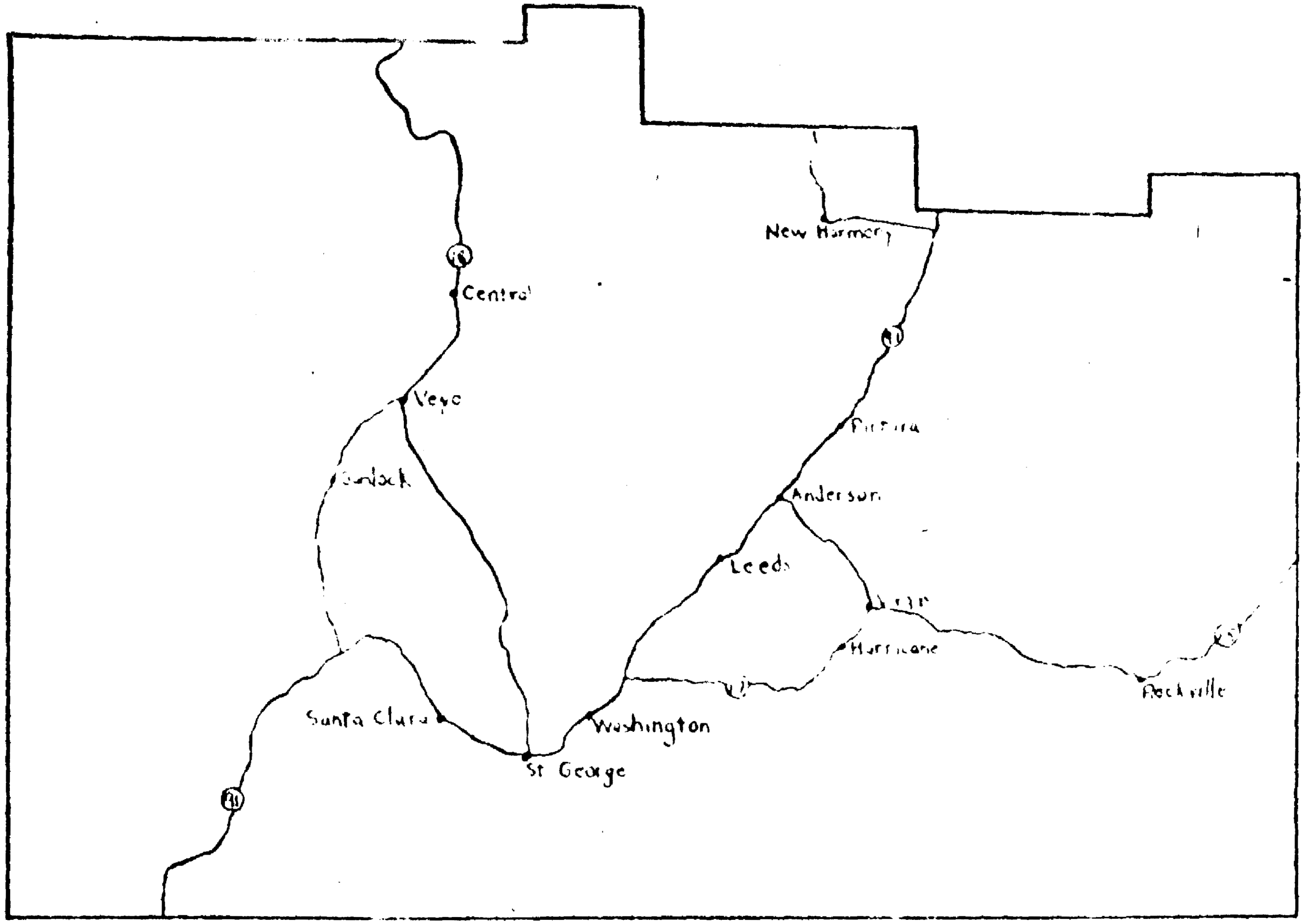


Fig. 3

Washington County, Utah with points at which repeated high radioactivity measurements indicate probable high iodine 131 levels for most of the county. (See tables fallout sufficiently intense to result in medically significant radiation exposure to childrens' thyroids in an appreciable number of instances.

Some locations in the Nevada region have received such possible dosages on repeated occasions.

Currant, Nevada, for instance, a town of about 75 people located about 80 miles north of the test site, received significant doses on March 7, 1955; May 5, 1955; May 28, 1957; July 15, 1957; July 25, 1957; and August 18, 1957. Infant thyroid doses would all be greater than 2.5 rads, and in 4 cases out of the 5, could have exceeded 25 rads. Another example is Lockes, Nevada which received three significant doses, all of which were 10 rads or more by the lower estimate. By the higher estimate, the doses on two occasions may have exceeded 100 rads.

Washington county, Utah is one of the most heavily populated of the areas to receive heavy fallout depositions. It is an area in which, on at least one occasion (May 19, 1953), citizens in several communities were asked to stay indoors for several hours after a test shot. Fallout on that date blanketed the entire county. Infant thyroid doses due to contaminated milk might have reached from 150 to 950 rads in Hurricane, Utah, and it is very likely that the minimum dose for infants in most of the county due to milk from cows fed fresh pasturage was about 50 rads.

The largest town in Washington County, St. George, (population 5,000) received possible maximum doses of

Table [illegible]

Some Estimated Infant Thyroid Doses in [illegible] from the Nevada Test Site, for 1952 (Operation Tumbler-Snapper) and 19[illegible] (Operation Upshot-Knothole)[15,16]

| Hot Spot Location | Gross [illegible] x 10⁶ | Average Time of Landing H + Hr. | I-131 Density c/cm² | I-131 in Fresh Milk c/l based on: Windscale | Garner | Dose to Infant Thyroid - rads: Wind-Scale | Garner |
|---|---|---|---|---|---|---|---|
| SHOT EASY - 7 MAY 1952 - 12 Kt. - 300' - TOWER | | | | | | | |
| Salt Lake City, Utah | 25 | 12 | 54.1 | 21,600 | 86,500 | 3 | 18 |
| SHOT GEORGE - 1 JUNE 1952 - 14.6 Kt. - 300' - TOWER | | | | | | | |
| Pocatello, Idaho | 4.2 | 12 | 9.9 | 3,950 | 15,[illegible] | .5 | 3 |
| Norfolk, Nebraska | .78 | 60 | 11.3 | 4,520 | 18,100 | .6 | 4 |
| Terre Haute, Indiana | 1.38 | 36 | 11.[illegible] | 4,500 | 18,000 | .6 | 4 |
| Grand Rapids, Mich | 1.2 | 36 | 9.8 | 3,900 | 15,600 | .5 | 3 |
| SHOT HOW - 5 JUNE 1952 - 13.9 Kt. - 300' - TOWER | | | | | | | |
| Boise, Idaho | 17.7 | 12 | 41.6 | 16,600 | 66,500 | 2 | 14 |
| Great Falls, Montana | 10.8 | 12 | 25.2 | 10,200 | 40,600 | 1 | 8 |

Table V (Cont'd)

| Hot Spot Location | Gross $d/m/ft^2$ x $10^6$ | Average Time of Reading H + Hr. | I-131 Density $c/cm^2$ | I-131 in Fresh Milk c/l based on: Windscale | Carner | Dose to Infant Thyroid - Rads Wind-Scale | Carner |
|---|---|---|---|---|---|---|---|
| SHOT ANNIE - 17 MARCH'53 - 16.2 Kt. - 300' - TOWER | | | | | | | |
| Knoxville, Tennessee | 1.9 | 36 | 15.5 | 6,200 | 24,800 | .8 | 5 |
| SHOT NANCY - 24 MARCH 1953 - 24.4 Kt. - 300' - TOWER | | | | | | | |
| Salt Lake City, Utah | 15.0 | 12 | 35.3 | 14,100 | 56,400 | 2 | 12 |
| Ely, Nevada | 6.3 | 12 | 14.8 | 5,900 | 23,700 | .7 | 5 |
| Rapid City, S. D. | 2.04 | 36 | 16.6 | 6,700 | 26,600 | .8 | 6 |
| SHOT DIXIE - 6 APRIL 1953 - 10.9 KT. - 300' - TOWER | | | | | | | |
| Boston, Mass | 5.1 | 36 | 41.6 | 16,600 | 66,500 | 2 | 14 |
| SHOT BADGER - 18 APRIL 1953 - 23 Kt. - 300' - TOWER | | | | | | | |
| Port Arthur, Texas | 1.5 | 36 | 12.2 | 4,900 | 19,600 | .6 | 4 |
| SHOT SIMON - 25 APRIL'53 - 42.7 Kt. - 300' - TOWER | | | | | | | |
| Grand Junction, Colo | 2.9 | 36 | 23.6 | 9,500 | 37,800 | 1 | 8 |
| Roswell, N. M. | 13.0 | 36 | 106 | 42,400 | 170,000 | 5 | 35 |
| Albuquerque, N. M. | 2.4 | 36 | 19.6 | 7,800 | 31,300 | 1 | 6 |
| Albany, New York | 16 | 36 | 131 | 52,100 | 209,000 | 7 | 43 |
| SHOT HARRY - 19 MAY 1953 - 32.4 Kt. - 300' - TOWER | | | | | | | |
| Grand Junction, Colo | 11 | 12 | 25.9 | 10,300 | 41,400 | 1 | 9 |
| Des Moines, Iowa | 1.5 | 36 | 12.2 | 4,900 | 19,600 | .6 | 4 |
| Albuquerque, N. M. | 7.8 | 12 | 18.4 | 7,300 | 29,400 | 1 | 6 |

25-165 rads on March 17, 1953; 110-735 rads on May 19, 1953; 7-42 rads on March 1, 1955; 4-29 rads on May 15, 1955; and 28-185 rads on August 31, 1957.

These doses are representative of the whole of Washington county.

The August 31, 1957 value was due to shot "Smoky" of Operation Plumbob. Fallout from this explosion resulted in measurements indicating infant thyroid doses of 10-67 rads over an 8000 square mile area outside the Test Site, of which Washington county comprised 2500 square miles. Equally high levels were reported as far away as Rock Springs, Wyoming, 700 miles from the Test Site.

Cases of relatively high thyroid doses in locations distant from the Nevada Test Site appear to be fewer than near the Site, although this may be due in part to the fact that monitoring outside the test area is even less extensive than for the region within a 200 mile radius. One distant case was that in Troy, New York on April 26, 1953. Contamination of milk was not measured at that time but Ralph Lapp estimates that iodine 131 in milk might have reached 100,000 $\mu\mu c$ per liter. As a result, infants may have received doses to the thyroid as high as 30 rads.

During 1952 and 1953, one to ten rad doses or more to infant thyroids may have occurred in areas near Salt Lake City on May 7, 1952 and again on March 24, 1953; at Boise, Idaho and Great Falls, Montana on June 5, 1952; Boston, Massachusetts on April 17, 1953; Grand Junction, Colorado, Roswell, and Albuquerque, New Mexico (as well as Troy and Albany, New York) on April 26, 1953, and Grand Junction again on May 19, 1953.

4) Were the theoretically possible doses actually received by childrens' thyroids as a result of fallout from the Nevada Test Site?

It has already been pointed out that the above estimates are theoretical, in that they show what thyroid radiation dosages might result, providing that the iodine 131 in the deposited fallout actually entered the food chain and was ingested by children locally from locally-produced milk.

What is the likelihood that such doses did actually occur? Two conditions must have been met: that there were milk cows grazing in the contaminated pastures, and that children drank the milk. Monitoring reports have rarely supplied information of any detail on these questions (no detailed information is available for the tests held in 1952, 1955 and 1958; for 1953 testing, one survey to check for grazing animals in areas of high fallout was reported; and for 1957 testing, and again for 1961 and 1962, milk monitoring data of limited value are available). Census reports, however, indicate that there were 4438 milk cows on the farms and ranches in Lincoln, Nye, Clark, Elko and White Pine counties, in Nevada (the areas closest to the

TABLE VI

MILK COWS IN SEVERAL [illegible] THE NEVADA TEST SITE

| County | State | 1950 Farms Reporting | 1950 Milk Cows | 1954 Farms Reporting | 1954 Milk Cows | 1959 Farms Reporting | 1959 Milk Cows |
|---|---|---|---|---|---|---|---|
| | | NUMBER OF COWS | | | | | |
| Washington | Utah | 556 | 1898 | 469 | 2127 | 319 | 1630 |
| Iron | " | 324 | [illegible] | 259 | [illegible] | 200 | 799 |
| Clark | Nev. | 157 | [illegible] | 108 | 1565 | 85 | 2096 |
| Elko | " | 251 | 1185 | 213 | 791 | 161 | 493 |
| Lincoln | " | 103 | [illegible] | 78 | 444 | 60 | 459 |
| Nye | " | 87 | 330 | 76 | 340 | 64 | 318 |
| White Pine | " | 111 | 881 | 86 | 642 | 83 | 554 |

SIZE OF HERDS, 1959

| County | State | 1 | 2-9 | 10-19 | 20-29 | 30-49 | 50+ |
|---|---|---|---|---|---|---|---|
| | | Number of Cows in Herd | | | | | |
| | | Number of Herds | | | | | |
| Washington | Utah | 148 | 136 | 10 | 11 | 11 | 5 |
| Iron | " | 81 | 103 | 5 | 6 | 4 | 1 |
| Clark | Nev. | 27 | 32 | 1 | 3 | 7 | 13 |
| Elko | " | 37 | 121 | 3 | none | none | none |
| Lincoln | " | 18 | 32 | 3 | 3 | 2 | 2 |
| Nye | " | 29 | 33 | 1 | none | none | 1 |
| White Pine | " | 21 | 52 | 1 | 1 | 6 | 2 |

test site) in 1950. These same counties had 3782 milk cows in 1954, 3920 in 1959. Only one county, Nye, consistently reported fewer than 500. A more detailed report for 1959 indicated that out of 451 farms reporting in these counties; 402 of these had between one and nine; and 49 had herds of 10 or more.

Washington county, Utah (which has received repeated high fallout, as noted earlier) had 1898 milk cows in 1950, 2127 in 1954 and 1660 in 1959. In 1959 219 farms reporting had one to nine milk cows and the remaining 100 had 10 or more.

The one detailed survey [illegible] reported [illegible] cows at a point 75 miles northeast of the test site on March 24, 1953 and seven herds of milk cows near St. George, Utah on May 19, 1953. The cows near St. George reportedly received total external doses from [illegible] on that date, (the date of shot "Harry.")[8] This corresponds to contamination on their pasture which may have caused infant thyroid doses from 100 to 1000 rads.

Were there infants and children in the area to drink this milk? 1960 census figures (these figures vary little from year to year) indicate about 20,000 children under 5

Table VII
POPULATION STATISTICS FOR SELECTED COUNTIES NEAR THE NEVADA TEST SITE

| County | State | Total Pop. | Per cent residence rural farm | Per cent under-5 years old | Live Births |
|---|---|---|---|---|---|
| 1950 | | | | | |
| Washington | Utah | 9,836 | 23 | data for this age group not available for 1950 | 332 |
| Iron | " | 9,642 | 10 | | 306 |
| Clark | Nev. | 48,289 | 24.2 | | 1,247 |
| Elko | " | 11,654 | 17.6 | | 254 |
| Lincoln | " | 3,837 | 10.6 | | 91 |
| Nye | " | 3,101 | 16 | | 53 |
| White Pine | " | 9,424 | 8.6 | | 232 |
| 1960 | | | | | |
| Washington | Utah | 10,271 | 5.2 | 12.8 | 230 |
| Iron | " | 10,795 | 3.9 | 13 | 274 |
| Clark | Nev. | 127,016 | 1 | 12.4 | 3,554 |
| Elko | " | 12,011 | 13.7 | 11.3 | 292 |
| Lincoln | " | 2,431 | 6.0 | 11.9 | 56 |
| Nye | " | 4,374 | 10.1 | 9.5 | 64 |
| White Pine | " | 9,808 | 4.3 | 12 | 208 |

years of age, and 4174 live births per year in the counties of interest in Nevada. In Washington county, Utah, there were 628 children under 5 in 1960, 230 live births in 1960 and 332 live births in 1950. This indicates that there were approximately 250 to 300 children of 6 to 18 months in the county at any given time.

Individual children on any of a large number of ranches could have received high thyroid radiation doses (such as, for instance, the 21 to 137 rads possible at the Geyser Ranch in Nevada on July 15, 1957). There are repeated cases in which we know it is quite likely that a considerable number were exposed. The entire Washington county was blanketed with fallout levels that could cause 5-100 rad or higher doses on at least 7 different occasions.

Not only was fresh milk on farms probably affected, but also pasteurized milk, for much of the milk delivered in the county is not mixed with milk from other areas. St. George has one local dairy, the Whitehead Dairy, which collects milk only in Washington County, in the immediate vicinity of St. George, and distributes it locally. The Arden Meadowgold Dairy collects its milk in nearby Iron, Piute and Beaver counties. These dairies have been in business throughout the period under consideration with the same collection and distribution pattern.[19]

Pasteurized milk from these dairies would be expected to have iodine levels lower by a factor of .85 than the fresh milk from the area. This is due to the decay in radioactivity taking place in two days--the time it takes to collect, process and distribute the milk.

(Other dairies active in Washington County are the Anderson Dairy, which ships milk out to Las Vegas, where it is presumably pooled with other milk, and the Highland Dairy, which has come in more recently, distributing milk from northern Utah.)

The chain, therefore, from nuclear explosion through fallout, pasture, cow and milk to children has been completed in many of these areas and for a considerable number of children. What biological effect would be expected from these exposures?

5) <u>The biological significance of these levels</u>

It is now well known that radioactive iodine presents a special hazard to infants for the following reasons:

1. Milk is the largest human dietary source of iodine 131 and children generally drink more milk than adults.

2. For the same quantity of iodine in the food eaten, the cells of the thyroid of an infant receive 10 to 15 times the dose received by the cells of an adult thyroid. The infant thyroid is much smaller, generally weighing about 2 grams, whereas the adult thyroid weighs about 20 grams. In the infant a given quantity of radiation is spread over a much smaller mass, and each gram receives a greater amount of radiation.

3. The infant's thyroid may be more sensitive than the adult's to cancer induction by radiation. Thyroid cancer was observed in children after a single exposure to radiation of 150 rem.[4]

The Federal Radiation Council, in its Report No. 2 discusses the carcinogenic effect of radiation on the thyroids of children, drawing upon the evidence of significantly higher incidence of carcinoma in children who had been exposed to x-irradiation in the neck region, than in control groups not so exposed.

The smallest dose capable of inducing cancer is not known, but it is generally assumed that the frequency of induced cancer may be proportional to dose, down to very low levels of exposure. On the assumption of no threshold, Beach and Dolphin of the United Kingdom Atomic Energy Authority estimate that if one million infants were exposed to <u>one</u> rad of thyroid radiation, 35 would be expected to develop thyroid cancer.

The AEC's permissible <u>external</u> effective biological dose of 3.9 r could result in an <u>internal</u> thyroid dose of 175 to 1200 rads, and actual exposures, as we have shown, may have ranged from well below to well above this dosage.

6) <u>Underground tests</u>

Significant radiation levels from continental testing have not been confined to surface and atmospheric shots. Venting of subsurface shots has been reported for at least seven cases: March 23, 1955 (shot ESS, of Operation Teapot); September 15, 1961; December 10, 1961 (Project Gnome); March 5, 1962; April 14, 1962; May 19, 1962; June 13, 1962 (the Des Moines shot) and July 6, 1962 (the Sedan shot, 100 kiloton shot 635 feet underground).[1,20,21] The Des Moines shot resulted in a peak of 1240 μμc/liter in milk of Spokane, Washington on June 21. According to a Weather Bureau study "The initial appearance phase (July 8-11) for iodine 131 in milk (in Salt Lake City) would appear to have been due to the July 6 (Sedan) test."[21]

The Gnome shot in New Mexico may have resulted in thyroid doses in the range from 7 to 55 rads in the immediate vicinity of Carlsbad.

7) Limitations of these estimates

Any objective appraisal of the estimates made here must take into account their limitations.

The main problem is a general lack of useful data. In most cases, detailed milk data was not reported, and when it was, the information was not in usable form.

Table VIII

**Some estimated infant thyroid doses for Project Gnome (December 10, 1961). Data are from AEC report number PNE-132F.**

| Hot Spot Location | γ Rate mr/hr | Time of Reading H + hrs | I-131 Density μμc/cm$^2$ | I-131 in Fresh Milk μμc/l based on: Windscale | Garner | Dose to Infant Thyroid - Rads: Windscale | Garner |
|---|---|---|---|---|---|---|---|
| Roswell, New Mexico | .3 | 10.17 | 9.84 | 3,940 | 15,700 | .5 | 3 |
| 7.4 mi W Jct 31 & 285, on 31 | 7.0 | 13.77 | 339 | 135,000 | 542,000 | 17 | 102 |
| 3.6 mi E of Carlsbad on 62/180 | 4.0 | 10.25 | 131 | 52,000 | 210,000 | 7 | 43 |
| 40 mi E Batann Bridge on 62/180 | 5.0 | 9.75 | 164 | 65,600 | 262,000 | 8 | 54 |

In 1953, some observations of dairy herds were made, and external doses received by them were estimated, but actual data on fresh milk given just after the exposures are not available. In 1957, during Operation Plumbob, milk was tested, but only for gross beta radiation and for strontium 90. The gross beta values do not provide a basis, in this case, for inferring iodine levels, and while calculations can be made from strontium levels, they do not carry the same certainty as actual iodine figures.

Detailed milk monitoring figures were not reported for the 1958 test series, Operation Hardtack II. The two tests for which such monitoring was reported were Project Gnome, December 10, 1961, at Carlsbad, New Mexico and the Des Moines shot, June 13, 1962. However, all iodine measurements for Gnome were made in milk collected either before the test, or at least one month after the test, when any high levels that might have occurred had already dissipated.[22]

For the Des Moines test milk was again monitored either too early (June 13, the day of the test) or too late.[23] Concentrations of 600 and 500 micromicrocuries per liter were found at two locations on June 20 and 21, but the actual peaks at those locations would have come about June 15-17, two to four days after the explosion.

More adequate data either have not been taken, or have not been made available to the public. (A report by the

AEC, "Safety at the Nevada Test Site," 19[illegible] asserts "All of the essential data from these monitoring programs have been reported in the open literature.[4])

For areas distant from the Nevada Test Site, there are no milk data for the period before 1957, and data taken after that time have usually represented an area-wide, monthly average, so that detailed variations are obscured.

The limitation on the fallout monitoring program is clear from its budget. As stated in the 19[illegible] Fallout hearings, Phase I, offsite monitoring costs run about $3/4 million per year.

At the 1957 hearings on fallout, the AEC stated, officially,

> These two isotopes - radio strontium and radioiodine - constitute the principle internal hazards from the radioactives produced by the detonation of atomic weapons, both fission and thermonuclear. The Atomic Energy Commission has been engaged for three years in a broad study of the radioactive forms of these isotopes and conducts year-round monitoring of these radioactivities in many locations. Any accumulation of these materials can be detected with great sensitivity so that ample warning of potential hazard could be given long before any actual danger occurred from test detonations. The amounts of radiostrontium and radioiodine which have fallen outside the areas near the test sites as a result of all atomic tests up to now are insignificant compared to concentrations that would be considered hazardous to health.

and

> The hazard has been successfully confined to the controlled area of the Test Site.

In the light of the present analysis, these statements are an incorrect estimate of the hazard to the local population from fallout in the Nevada Test Site region.

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7. Garner, R. J. "An Assessment of the Quantities of Fission Products Likely to be Found in Milk in the Event of Aerial Contamination of Agricultural Land," Nature, 186:1963, June 25, 1960.

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12. Larson, K. H., et al. "Summary Statement of Findings Related to the Distribution, Characteristics and Biological Availability of Fallout Debris Originating from Testing." 1960. AEC report no. [illegible].

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17. Census of Agriculture, 1954 and 1959.

18. U.S. Bureau of Census, City and County Data Book, A Statistical Abstract Supplement. Editions for 1952 and 1962.

19. Personal communication from Whitehead Dairy, St. George, Utah.

20. U.S. Public Health Service, Radiological Health Data, July, 1962, p. ii.

21. U.S. Public Health Service, Radiological Health Data, 3:510 (Dec., 1962).

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