

The Problem

The most comprehensive data on fallout levels within a few hundred miles of the Nevada Test Site have resulted from direct measurements of open field, external gamma dose rates and cumulative doses. Reliable measurements of the I-131 content of milk from cows grazing on pastures in the fallout pattern from a specific shot were not begun until the summer of 1962, and were still fragmentary at the time of the Des Moines meeting (June 13, 1962), the low yield atmospheric test on July 14, 1962 (Small Boy), and the Fleetshire experimental excavation experiment of July 6, 1962.

The development of a quantitative relation between the deposition level of fresh fission products in terms of the resulting external gamma dose rates and the resulting level of I-131 in milk for the days and weeks following deposition would thus be useful in three ways:

1. for estimating the doses to the thyroids of children from I-131 in milk from cows grazing on pastures which have experienced relatively high levels of fallout from Nevada tests;
2. to help achieve a better quantitative understanding of how radioiodine gets from the point of deposition into milk, in order that the planning and execution of nuclear tests can be done with due regard for the public health and safety;
3. to help guide and motivate the Commission's research program on fallout and radioiodine.

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One would not expect that a single constant of proportionality relating the fallout level and the resulting level of I-131 in milk would adequately describe the many situations which can, and have, occurred within 500 miles of the Nevada Test Site. First, there are different modes of deposition. The fallout particles may be deposited dry, in a heavy shower, in a light mist, or by various gradations and combinations of these conditions. Second, wind as well as rain influence not only where fallout takes place, but how much is retained by the herbage eaten by cows. Third, even for a given shot, the fallout at different distances from the test site will consist of different sized particles with different physical and radiochemical characteristics, so that the same deposition of I-131 per unit area will lead to different levels of I-131 in milk. Fourth, there may be differences in the distribution of particle sizes, and of radioactivity with particle size, for shots of different yields, and almost certainly for shots fired at different altitudes and over (or under) different soils. Fifth, for a given deposition of I-131 per unit area, the levels of this nuclide in fresh milk might be expected to vary depending on the type of pasture, the number of cows per acre, the amount of supplementary feed they receive, and the time of year during which fallout occurs. Although some factors can affect the actual levels of iodine in milk, and it is known as to their precise effect, the main objective is not that of describing what range of iodine levels in milk have actually resulted from a given deposition of fresh fission products. Even this relatively restricted objective is difficult to achieve at this time. Up thru the time of the Sedan and Small Boy tests in July, 1945, no systematic effort had been made to obtain the necessary data, so that the most direct information available is limited to coincidental measurements of milk levels and fallout deposition levels.

Designation of the Level of Fission Product Fallout from Nevada Tests

There are difficulties, both conceptual and practical, in designating the contamination level of nuclear test fallout. For unfractionated fission products -- that is fission products for which the various nuclides are in the same proportions as for the debris taken as a whole, one can define a time-independent measure of the contamination level in terms of the kilotons-equivalent of deposited fission products per square mile, or the number of fissions represented per square foot of contaminated ground area. For fractionated debris, however, no such simple measure exists. ^{1/} One could consider the total amount of I-131 deposited per unit area as the quantity of most direct interest, but this is not as readily measurable as is the external gamma dose rate, and very few measurements of this quantity have been made. For the areas around the Nevada Test Site, the most practical measure of the level of deposited fallout is the external gamma dose rate at 3 feet above an "open field" ^{2/} at some standard time following detonation. Note that this measure is only valid after all the fallout which is going to occur in a given area has already occurred, and after any relatively high transient dose rate due to isotopic radioactivity in a passing fallout cloud has become small compared to the dose rate from material deposited on the ground.

A definition of the contamination level of fractionated fission products has been under development for about a year by the U. S. Naval Radiological Defense Laboratory under a contract to the U. S. Atomic Energy Commission.

A comparison of the concepts of infinite plane dose rate, open field dose rate, average population dose rate, and the observed quantitative relationship between them in the areas around the Nevada Test Site is given in 17. It is there concluded that the open field dose rate in the Nevada Test site off-site area averages 7% of the infinite plane dose rate.

External Gamma Measurements Southeast of Salt Lake City

Although it had not been anticipated, a hot spot occurred southeast of Salt Lake City 300 - 400 miles from the point of detonation following passage of the Small Boy cloud. The location of this hot spot was first determined by an airborne radiological survey, and on July 16, 17, and 18, a complete survey was made by airborne radiological survey teams from the U. S. Geological Survey and from Edmonton, Saskatchewan, and Orléans. The results of this survey are reported by Larson et al. (8, p. 30) and reproduced in Figure 21. The contours there shown were based on the conversion relations that 50,000 counts/sec. at 300 feet = 1 mCi at 3 feet above the ground, and the assumption that the dose rate was given as $\frac{1}{r^2}$.

In addition to the airborne radiological surveys of the Small Boy hot spot, an on-the-ground survey along many of the highways throughout the area was made by a team of army personnel under the direction of H. Benton and L. R. Wade of the Army's Nuclear Defense Laboratory (9). The highway network surveyed by the army monitors is also shown in Figure 21.

The data recorded along the Nuclear Defense Laboratory (9) is reproduced in Appendix A. The gamma open field external gamma dose rates measured by the survey group on July 18, 1946, between the times of H + 91 hours and H + 92 hours, have been plotted as a function of distance along the roads mentioned; these data are shown in Figures 22, 23, and 24.

The Small Boy pre-shot announcement (AFS volume 8-20) of July 5, 1946, stated: "most of the radioactive particles produced by the detonation are expected to fall back to earth within a few miles, inside the Las Vegas Bombing and Gunnery Range. Radiological monitoring will be conducted at distances up to 300 miles from the shot point to obtain information on the limits of detectability of the radioactivity."

The half-life selected here is 24 hours following detonation, although in some cases interest is naturally in those areas near Salt Lake City -- the fallout from these areas have arrived by this time. In such cases one can project the dose rate back to 24 hours either by graphical extrapolation or by assuming a $T^{-1.2}$ decay rate. If only a single measurement has been made, by assuming a $T^{-1.2}$ decay rate. It is known that different samples of debris from the same shot as well as samples of debris from different shots have decay characteristics which vary from a $T^{-1.2}$ decay law. However, unless the external gamma dose rate is due largely to one or more induced activities (as was the case for the Sedan shot, following which the 24 hour dose rate from the isotope W^{187} is believed to have been responsible for a significant fraction of the observed total dose rate), the open field, external gamma dose rate due to deposited fission products decreases in time approximately in accordance with a $T^{-1.2}$ law between, say, 6 hours and 6 months following detonation (1).

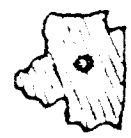
The symbol r_0 is used here to designate the open field dose rate, in $\mu r/hr$, from deposited fission products at 24 hours following detonation.

Designation of Initial and Maximum Levels of I-131 in Fresh Milk

Langmuir and Chubb report that when a cow is fed each day an amount of I-131 which has been reduced from the initial ration in accordance with the 8 day half-life of this nuclide, a maximum level of I-131 in the cow's milk is reached at about 4 days. The I-131 milk concentration they report for the time period of 2 to 8 days following initiation of iodine intake varies very little from the maximum level. At 1 day it is about 70% of maximum. After 7 days they report that milk levels decrease with the 8 day half-life of I-131.



SALT LAKE CITY



SNYDERVILLE
OKLEY
KAMUS

HEBER

VERNAL

LONEIFFEE

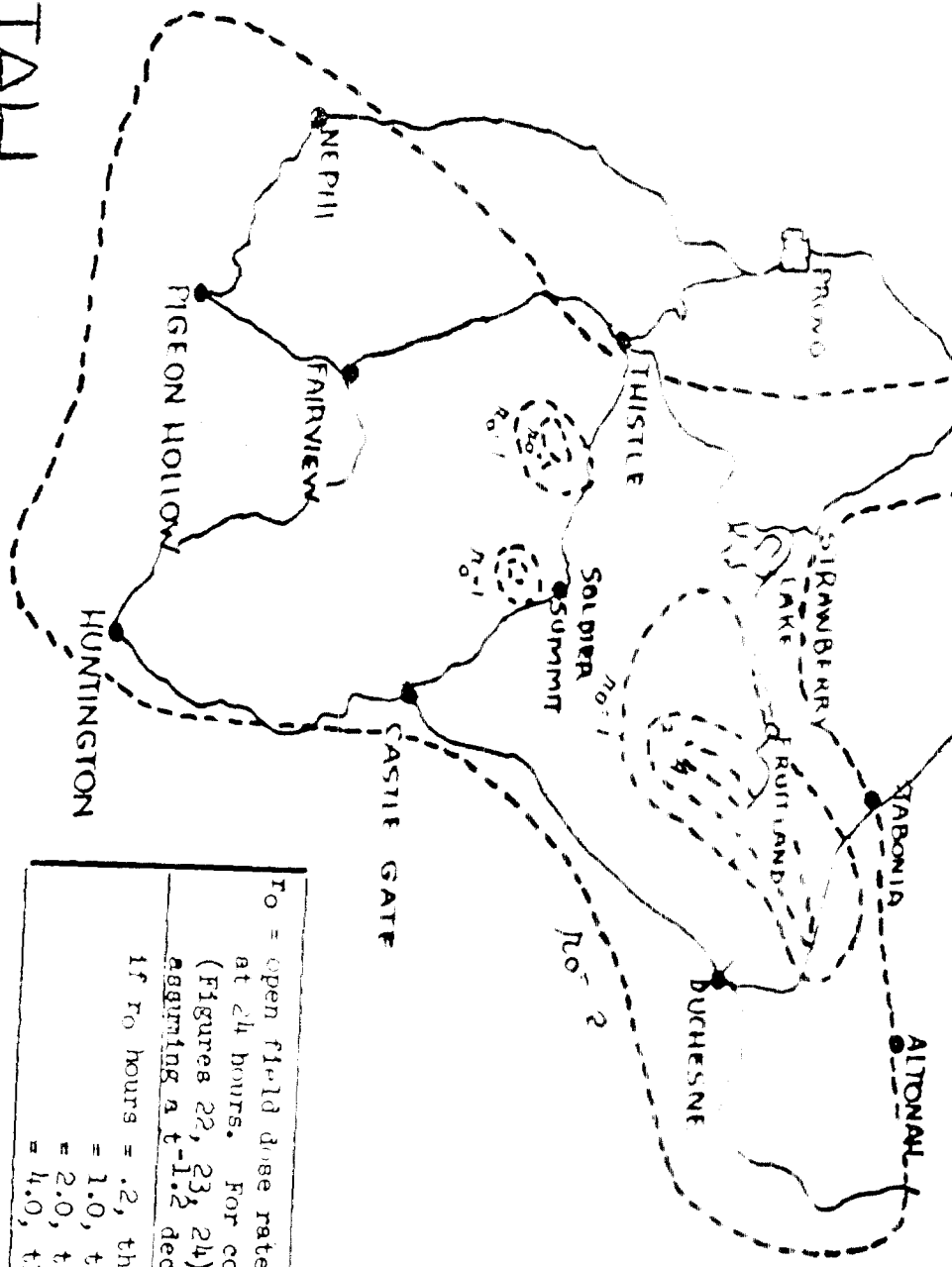


FIGURE 21. Dose rate contours in Northern Utah resulting from Small Boy debris as reported by Larson et al (8). Results shown are those monitored by Army Nuclear Defense Laboratory Group with Eberline E-500 B instrument. (Data reproduced in Appendix I).

T_0 = open field dose rate from deposited debris at 24 hours. For comparison with the Army data (Figures 22, 23, 24) it may be noted that, assuming a $t^{-1.2}$ decay,

If T_0 hours = .2, then r_{100} = .035 mr/hr
= 1.0, then r_{100} = .17 "
= 2.0, then r_{100} = .35 "
= 4.0, then r_{100} = .69 "

UTAH

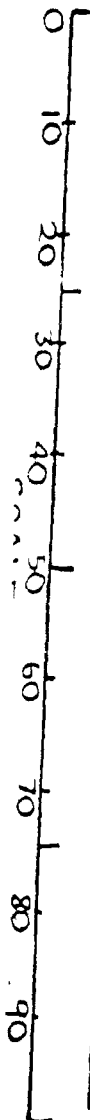
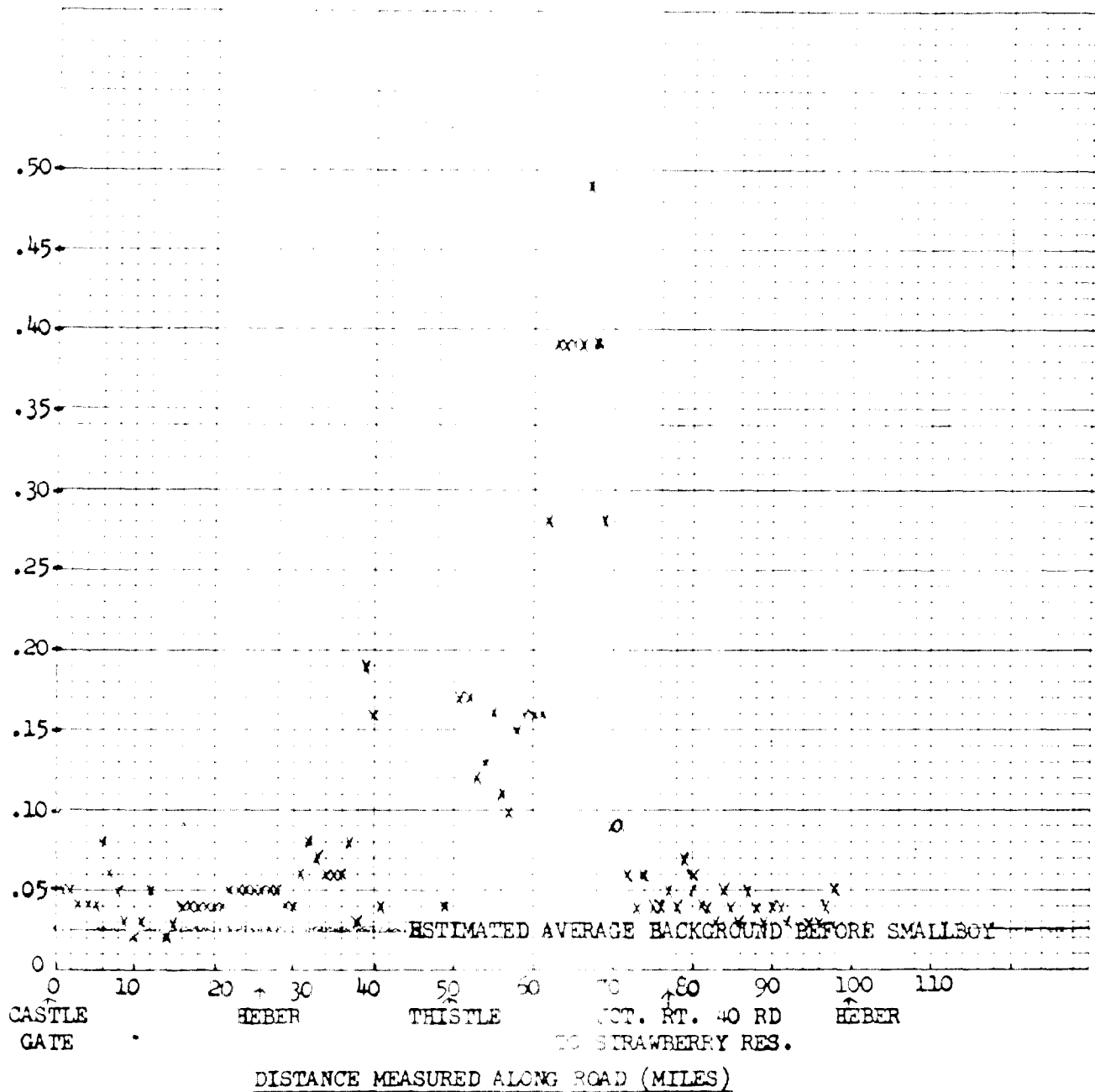


FIGURE 22. MEASUREMENTS OF GROSS, OPEN FIELD
 EXTERNAL GAMMA DOSE RATE ALONG U. S. HIGHWAY
 89 AND 189 FROM CASTLE GATE, UTAH TO HEBER,
 UTAH. MEASUREMENTS MADE ON 18 JULY 1962 BY
 U. S. ARMY NUCLEAR DEFENSE LABORATORY
 (SEE DATA APPENDIX I).

GROSS EXTERNAL GAMMA DOSE RATE MEASURED ON JULY 18, 1962 (mr/hr)



CROSS EXTERNAL GAMMA DOSE RATE MEASURED ON JULY 18, 1962 (MR/HR)

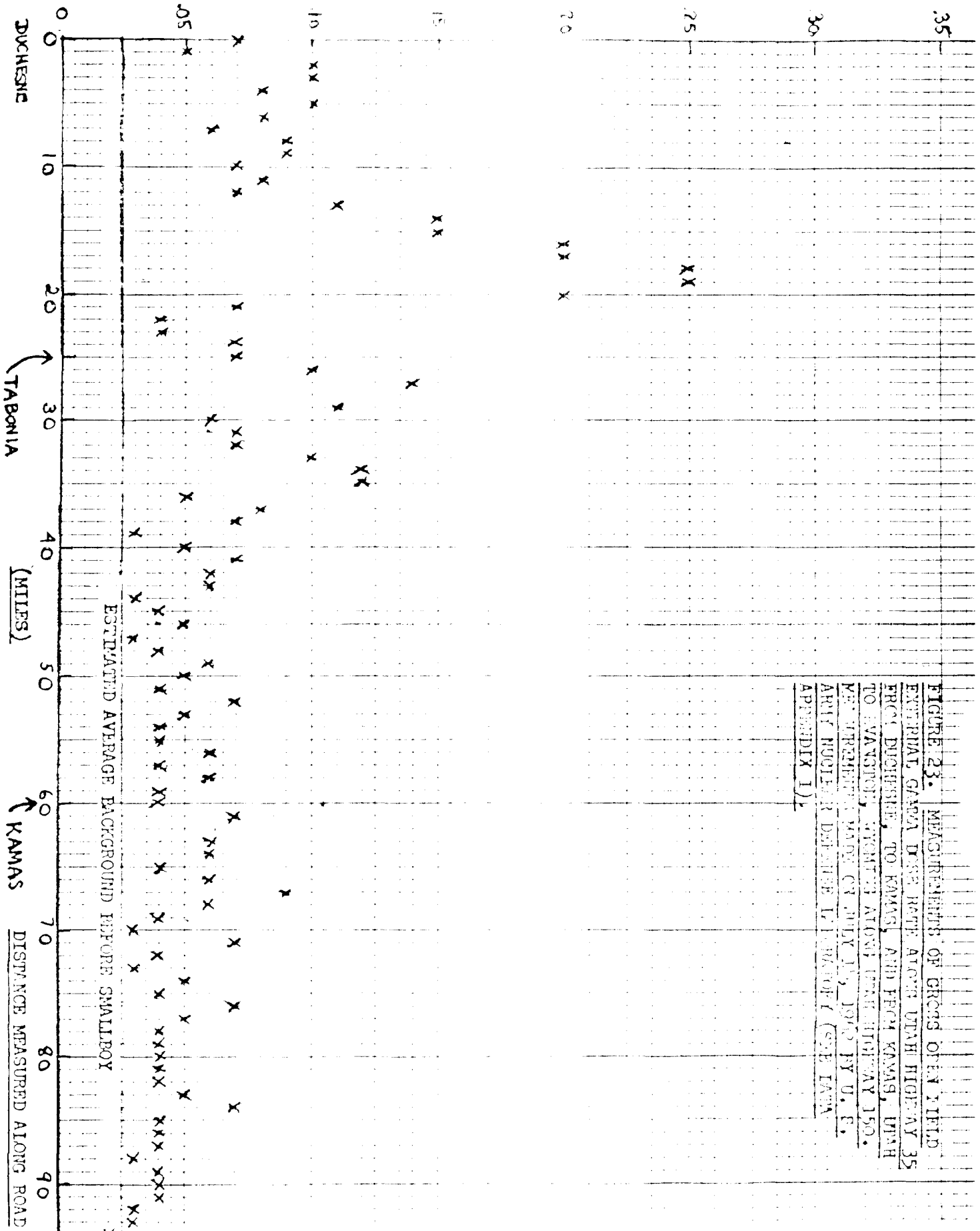


FIGURE 23. MEASUREMENTS OF GROSS OPEN FIELD EXTERNAL GAMMA DOSE RATE ALONG UTAH HIGHWAY 35 FROM DUCHESSIE TO KAMAS, AND FROM KAMAS, UTAH TO VANATRON, LOCATED ALONG UTAH HIGHWAY 150. MEASUREMENTS MADE ON JULY 18, 1962 BY U. E. ARIF HIGHER DENSITE I-1 (MODEL 1 (SEE IAWA APPENDIX 1))

To obtain the net dose rates from the Cassi Boy debris from the Army measurements, it is necessary to subtract the component due to background prior to the spot. This measurement was not reported. It is assumed here to be 0.025 $\mu\text{r/hr}$, i.e. the same as measured at Alamo and Caliente in December, 1962.

The dose rate contours reported by Larson et al from aircraft measurements, and the surface measurements made by Lt. Wade and his monitors are generally consistent. Both indicate areas where the deposition level was approximately 20 times that noted in the Kamas - Oakley - Snyderville area. Both indicate some high levels of fallout on U. S. Route 49 between Duchesne and Strawberry Lake, and State Road 35 between Duchesne and Taboria. The high levels between Fruitland and Strawberry Lake and Thistle and Strawberry Lake are not exactly indicated by the contours as shown. This might be due to an incorrect location of the 1 $\mu\text{r/hr}$ -at-24-hour contour from the hot spot just east of Fruitland.

Although scattered light precipitation is reported in the hot spot area on July 14, 15, and 16, the readily available data (16) suggest that most of the fallout occurred largely without precipitation or with very little precipitation.

Larson's data (Figure 21) indicates that the locations at which milk samples were taken (Kamas, Oakley and Snyderville) lie on the edge of the hot spot area, and have 24 hour external gamma dose rates of less than 0.2 $\mu\text{r/hr}$. The only surface measurements which indicate an R_0 value at Kamas, Oakley, and Snyderville are those made by the Army monitors on their route passing thru Kamas (Figure 23).

From Figure 23 it is seen that the net dose rate (i.e. subtracting 0.025

nr/hr for natural background) within 5 miles of Kansas on the routes taken in and out of town lies between 0.015 nr/hr and 0.045 nr/hr, with an average value of 0.026 nr/hr. These measurements were made between H + 100 hours and H + 102 hours. Assuming a $t^{-1.2}$ decay rate, the average of the projected H + 24 hour dose rate in Kansas due to deposited debris would have been 0.15 nr/hr. This is about 50% greater than that estimated for Alamo and Chihuahua, but a factor of 10 lower than the 24 hour rate of 1.56 nr/hr noted in the Pahrengat Valley 9 miles south of Alamo (5, p. 26). Lacking better data, it is here assumed that r_0 for Kansas, Oakley, and Supterville is in the range of 0.07 nr/hr at 24 hours to 0.30 nr/hr at 24 hours, with the best single estimate taken as 0.15 nr/hr at 24 hours.

It is of interest to compare the northwest Utah test results with the Small Boy shot with one in the Troy-Albany New York area resulting from the April 25, 1953 Simon shot of Upshot-Knothole test series. On that occasion a 43 kt. device was fired on a 300 foot tower at the Nevada Test Site. 36 hours later a severe thunderstorm in the upstate N. Y. area deposited radioactivity totaling 1.6×10^6 d/n/r² (17). From this datum one may compute (1, Appendix III) an open field dose rate (projected to 24 hours) of 1.56 nr/hr. The Small Boy test spot shown in Figure 11 had a 24 hour dose rate of 1.56 nr/hr in an area of about 20 square miles. Most of the Small Boy test spot had 24 hour dose rates in the range of 0.5 nr/hr to 1.0 nr/hr however.

External Gamma - MIRD Relations from the Small Boy Shot

External gamma - mird relations at Alamo and Chihuahua, Oakley, and Supterville, Utah, following deposition of the Small Boy shot summarized in Table II.

To obtain the net dose rates due to the Small Boy debris from the Army measurements, it is necessary to subtract the component due to background prior to the shot. This measurement was not reported. It is assumed here to be 0.025 $\mu\text{r}/\text{hr}$, i.e. the same as measured at Alamogordo and Caliente in December, 1962.

The dose rate contours reported by Larson *et al* from aircraft measurements, and the surface measurements made by Lt. Wade and his unit are generally consistent. Both indicate areas where the deposition level was approximately 20 times that noted in the Kansas - Oakley - Snyderville area. Both indicate some high levels of fallout on U. S. Route 40 between Ashcroft and Strawberry Lake, and State Road 35 between Dushouse and Tabor. The high levels between Fruitland and Strawberry Lake and Thistle and Strawberry Lake are not exactly indicated by the contours as shown. This might be due to an incorrect location of the 1 $\mu\text{r}/\text{hr}$ -at-24-hour contour from the hot spot just east of Fruitland.

Although scattered light precipitation is reported in the hot spot area on July 14, 15, and 16, the readily available data (10) suggest that most of the fallout occurred largely without precipitation or with very little precipitation.

Larson's data (Figure 21) indicate that the locations at which soil samples were taken (Kansas, Oakley, and Snyderville) lie on the edge of the hot spot area, and have 24 hour external gamma dose rates of less than 0.2 $\mu\text{r}/\text{hr}$. The only surface measurements which indicate an R_p value at Kansas, Oakley, and Snyderville are those made by the Army unit on their route passing thru Kansas (Figure 23).

From Figure 23 it is seen that the net dose rate (i.e. subtracting 0.025

nr/hr for natural background) within 3 miles of Dumas on the routes listed in schedule of tests lies between 0.015 nr/hr and 0.045 nr/hr, with an average value of 0.026 nr/hr. These measurements were made between 8 + 100 hours and 8 + 120 hours. Assuming a $t^{-1.2}$ decay rate, the average of the projected 8 + 24 hour dose rate in Dumas due to deposited debris would have been 0.03 nr/hr. This is about 50% greater than that estimated for Alamo and Oakley, but a factor of 10 lower than the 24 hour rate of 2.5 nr/hr noted in the Fairmount Valley 9 miles south of Alamo (3, p. 25). Judging further data, it is here assumed that r_0 for Dumas, Oakley, and Samburgville is in the range of 0.07 nr/hr at 24 hours to 0.30 nr/hr at 26 hours, with the best single estimate taken as 0.15 nr/hr at 24 hours.

In an attempt to compare the radiation field at the site of the Shell Bay site with one in the Troy-Albany New York area, a measurement was made April 25, 1973 about 100 feet from the site of the reactor. As that occurred a 1/2 hr. device was fixed on a 30 foot tower at the Shell Bay site. 15 hours later a second measurement of the uptake of ^{137}Cs was taken with activity totaling 1.6×10^4 dpm/g. (17). From this data one may compare (1) Alamo and Oakley with the Shell Bay site (projected to the period of 1.5 hr. after the accident) and (2) the Shell Bay site with the Troy-Albany New York area. The measurements at the Shell Bay site are in the range of 0.07 nr/hr at 24 hours to 0.30 nr/hr at 26 hours, with the best single estimate taken as 0.15 nr/hr at 24 hours.

Internal dose - Skin Relations from the Shell Bay Site

Internal dose - skin relations at Alamo and Oakley, and at Samburgville, Oakley, and Samburgville, Wash. following deposition of the Shell Bay site are summarized in Table II.