Fallout Patterns From Operation HARDTACK, Phase II
Best Available Copy
FALLOUT PATTERNS FROM OPERATIONS

by

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U. S. Weather Bureau, Washington

May 1960

Prepared for

ALBUQUERQUE OPERATIONS OFFICE, U. S. AT
FROM OPERATION HARDTACK, PHASE II

by

Relegadas and Kenneth M. Nagler

Weather Bureau, Washington, D. C.

May 1960

Prepared for

ONS OFFICE, U. S. ATOMIC ENERGY COMMISSION.
### SUMMARY OF BURST INFORMATION

<table>
<thead>
<tr>
<th>BURST NUMBER</th>
<th>BURST NAME</th>
<th>YIELD</th>
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### EXPLANATION OF TABLE

**Column 3, Yield:**
- **a.** T indicates ton equivalent of TNT.
- **b.** KT indicates kiloton equivalent of TNT.
- **c.** The yields for tunnel detonations are from the unclassified memorandum, "Total Yields of Underground Events-Hardtack II", Lawrence Radiation Laboratory, Livermore, California, June 23, 1959, and from Johnson, G.W. et al., "Underground Nuclear Detonations". Journal of Geophysical Research, Vol. 64, No. 10, October 1959, pp. 1457-1470.
- **d.** Other yields are from "AEC Releases Data on Hardtack Bomb Tests". U.S.A.E.C., Washington, D.C., March 10, 1959.
- **e.** The Office of Test Information, Nevada Test Site Organization, Las Vegas, Nevada, issued news reports on the yield or containment of explosions. The original language from these reports was included wherever a yield was not given.
- **f.** Other yields are from "AEC Releases Data on Hardtack Bomb Tests". U.S.A.E.C., Washington, D.C., March 10, 1959.
- **g.** The Office of Test Information, Nevada Test Site Organization, Las Vegas, Nevada, issued news reports on the yield or containment of explosions. The original language from these reports was included wherever a yield was not given.

**Column 4, Time:** PST - Pacific Standard Time; PDT - Pacific Daylight Time.

**Column 6, Type:**
- **a.** For deep-well shots all devices were placed at various depths in 500-foot wells, with the exception of the San Juan event which was in a 250-foot well.
- **b.** Gravel Gertie denotes a surface shot detonated in a small wooden building covered with about 20 feet of gravel.

**Column 7, Burst Site:** Each burst site is denoted by (1), a capital letter designating the type of shot (i.e., B for balloon, S for surface, T for tower, and U for underground); (2), a number indicating the area in which the burst occurred; and (3), a small letter identifying the location in the area.

**Column 8, Elevation of Site:** For balloon or tower bursts-the height above sea level of the earth's surface below the device; for underground bursts-the elevation at which venting occurred or, when there was no venting, the elevation of the device.

**Column 9, Cloud Top:** Height of the cloud top above mean sea level, in feet. There is some uncertainty as to the values presented here since they were primarily visual aircraft reports and since the reports were not always made at the time of cloud stabilization.

**Column 10, Cloud Base:** Height of the top of the stem (or base of the mushroom head) above mean sea level, in feet. There is considerable more uncertainty as to these numbers than for the cloud tops. Besides the uncertainty in the visual aircraft reports and cloud stabilization time, there is also the uncertainty as to the height of the base since in many cases the base was not too well defined. For some events the height of the cloud base was not reported.

**Column 11, Page:** Pages on which maps or discussions of the bursts appear.
INTRODUCTION

The Hardtack, Phase II, nuclear test operation differed from previous series in the great number of nuclear and safety devices detonated within a fairly brief period, in the very low yields of many of the detonations, and in the variety of burst conditions. Basic information on the various bursts is summarized on the inside of the front cover. Orientation maps of the Nevada Test Site region, and of the Nevada Test Site itself are shown on the inside of the back cover.

As far as public safety is concerned, radiation from Hardtack, Phase II, was even less important than that from most previous Nevada test operations. However, since low levels of activity are fairly difficult to detect, the documentation of such fallout that did occur was comparatively difficult. The radiation from passing airborne radioactive clouds was relatively more important than in previous test series because of the many low nuclear cloud heights. There were also problems concerning decay rates and the arrival times of the fallout.

The purpose of this report is to present and discuss the fallout patterns from Operation Hardtack, Phase II. Although there are many uncertainties in the analysis of the fallout data, careful consideration has been given to all available monitoring and wind information in an attempt to depict as well as possible the actual fallout patterns.
Similar patterns from past Nevada operations are given in References 1 and 2.

**Sources of Data**

Off Site

The fallout documentation for purposes of public safety outside the test site was performed by the Off-Site Radiation Safety Organization (staffed by the U.S. Public Health Service). Their monitoring information is for the most part contained in the "Off-Site Radiological Safety Report for Operation Hardtack, Phase II", (3), which contains dose-rate and dose information for selected points, ground monitors' survey summaries, and measurements of the concentration of radioactivity in the air at a number of communities. Measurements of airborne alpha activity appear in the "Alpha Air Sampling Report" (4). The monitors' original logs were also of use, as they often contain useful information as to background radiation or as to very low activities observed but not reported in the summaries.

On Site

The fallout documentation for purposes of personnel safety within the test site was performed by the On-Site Radiological Safety Organization (staffed by the Reynolds Electrical and Engineering Company). Their monitoring information appears in several sources: 1, the monitors' original logs; 2, reports of special surveys performed for the Fallout Prediction Unit; and 3, maps of the dose-rate field based on the results of each survey. These maps appear in the "On-Site Radiological Safety Report for Operation Hardtack, Phase II", (5).

On many occasions talks with the monitors proved helpful in the analysis of the data. Also, the special surveys made for the Fallout Prediction Unit by both of the Off-Site and On-Site groups were useful in delineating the fallout from some of the bursts.

**Decay Rates**

Since the monitor readings of dose rate were made at various times after the detonation, these measurements had to be adjusted to a common reference time to permit analysis of the data. The available information from which decay rates could be derived was examined for each of the various different types of detonations, that is, for balloon, tower, surface, deep well, and tunnel shots. However, the only available information as to decay rates was
that derivable from the routine monitoring data. As would be expected in the absence of a specific program to study decay rates, the pertinent data are limited and the determination of decay rates can only be approximate.

A major source of error is the uncertainty as to whether the measurements taken along a particular route at different times were taken at precisely the same location. To minimize this error, only the measurements at specifically-designated locations were considered, and even for such locations this position error cannot be eliminated altogether. It normally is greatest where the gradient of activity is strongest.

The available data are shown in graphical form in figures 1-3. Figure 1 shows the decay curves for radiation from balloon detonations close to ground zero, where neutron-induced radioactivity is logically significant. As has previously been observed by the On-Site Rad-Safety group, the dominant constituent of this induced activity, except at early times when manganese-56 is important, appears to be sodium-24, which has a half life of about 15 hours. This decay rate and the $t^{-1.2}$ approximation of gross fission-product decay are shown. From figure 1 it can be seen that the sodium decay better approximates the observed decay of the close-in radiation from balloon bursts than does the gross fission-product decay. For simplicity, the sodium-24 decay rate was used to adjust the close-in radiation measurements from balloon shots to a common reference time.

Figures 2 and 3 show the data available for assessing decay rates for the deep-well, tower, and surface detonations. The sodium-24 and $t^{-1.2}$ decay curves are included for reference. The $t^{-1.2}$ approximation seems reasonable for these shots, and, for lack of better information, was also used for the tunnel bursts and for all off-site fallout. Again, it should be pointed out that the decay rates used are only approximate.

RADIATION FROM PASSING NUCLEAR CLOUDS

Some of the early dose-rate measurements show the effect of radiation from passing nuclear clouds. This radiation, sometimes called shine or sky shine, may come from a nuclear cloud many thousands of feet or perhaps a few hundred feet above ground, or it may come from nuclear debris in the air right at the ground level. Because of the nearness of the radiation source, the shine from a low-level cloud is normally more apparent than that from a high cloud even though the radiation in the higher cloud may be several orders of magnitude greater than that in the cloud near the ground.
Figures 4 and 5 show the early dose-rate measurements at several locations from several of the bursts. Typically, the dose rate shows a rapid rise and then a rapid decline, but there may be subsequent fluctuations as other parts of the nuclear cloud pass by. Later there is a gradual decrease of dose rate, which results from the decay of the true fallout.

It is of interest to compare the contribution from the shine to that from the true fallout. The total dose accumulated during any period is indicated by the area under the dose-rate curve for that period. To obtain the infinite dose an extrapolation was made beyond the last measurement by means of the $t^{-1.2}$ decay law. In order to get a rough estimate of the fallout part it was assumed that the true fallout began to arrive when radiation above background was first detected and that the dose rate increased linearly up to the time when fallout had ceased and there appeared to be no further effect of shine, that is, up to the time when the decrease in the dose rate seemed to be governed by the typical gross fission-product decay.

From the estimates of the total infinite dose and the infinite dose from true fallout only, an estimate of the contribution to the dose from shine can be made.

In the case of radiation at Mercury from the Hamilton burst it was estimated that the dose from the transient debris was about the same as the infinite dose from the true fallout, namely about 8 mr from each source. For the other cases depicted in figures 4 and 5, the dose from shine was also about as large as or greater than that from true fallout.

It might be pointed out here that if the high reading (at Mercury from Hamilton) of 11 mr/hr at H+1.8 hours was assumed to be exclusively from fallout and was extrapolated from H+1.8 hours to infinity by means of the $t^{-1.2}$ law, a fictitious infinite dose of nearly 100 mr would result.

**ALPHA CONTAMINATION**

Monitoring reports from a few of the bursts indicated that there was no gamma fallout but that there was some alpha contamination on the ground close to the burst sites. Also, there were a few cases in which some alpha fallout was reported in addition to gamma fallout. No analysis of the alpha radiation has been included in this report; but the general areas of alpha contamination are shown in the On-Site Radiological Safety Report (5).

The off-site alpha activities (Reference 4) as well as the beta activities (Reference 3) frequently detected at the fixed air-sampling stations were used
as an indication of the general movement of fallout.

DISCUSSION OF FALLOUT MAPS

One or more fallout maps are given for each burst in the series, except for those from which there was no gamma radiation observed or from which there were too few reports of radiation to suggest any sort of pattern. The bursts for which no patterns are drawn are discussed on pages 5 and 6.

For most bursts maps of two scales are given: a large-scale map showing the very close-in fallout (termed Map A), and a smaller-scale map showing the more remote spread (Map B). For bursts from which only close-in fallout was reported only a large-scale map is given. For Quay and Blanca maps of three scales are included, identified as Maps A, B, and C. It should be noted that maps for different bursts are sometimes of different scales, even though they are indicated as being in the same category; e.g., Map A or Map B.

When there are two or three maps for one burst, they have been arranged so that two of them appear on facing pages - which accounts for the blank pages.

There is some variety in the format of the maps. For example, the terrain is indicated only on the small-scale maps. Also, on the small-scale maps only, those roads along which monitoring runs were made are shown as heavy lines. To avoid confusion not all of the monitored roads are shown on the large scale maps.

The coordinates shown on the large-scale maps are from the Nevada State Grid, which is a rectangular grid system based on a transverse Mercator projection. The coordinates are designated in feet.

The various items contained on the maps are discussed in the following sections.

Dose-rate contours. Dose-rate contours for the large-scale fallout patterns have been drawn for the gamma dose rate one hour after burst time. A few of the small-scale patterns were drawn for 12 hours after burst time, consistent with the procedure used in References 1 and 2; but because of the very low levels of radiation, most of the small-scale patterns are for $H+1$ hour.

As noted earlier, the $t^{-1.2}$ approximation was used to adjust radiation measurements to the appropriate reference times for all types of bursts, except for the close-in patterns from balloon bursts, for which the sodium-24 decay curve was used.
Each of the close-in patterns from the balloon bursts shows a closed 10 mr/hr contour, and on each small-scale pattern a secondary maximum appears. Between the two fallout areas it is not known whether there is very light fallout or no fallout at all. From Plumbbob data there is a suggestion that the pattern is continuous, but that the dose rates in the intermediate region were too low to be recorded by the on-site monitors, who normally were concerned only with dose-rates of 10 mr/hr or greater.

Where the patterns are based on nearby monitoring information, they are shown as solid lines; where there was a considerable interpolation or extrapolation, dashed lines are used.

The maximum dose rate. As a guide to the highest dose rates associated with the various types of detonations, an estimate has been given whenever possible of the highest dose rate observed, adjusted to the H+1 value by the appropriate decay scheme as discussed above. These estimates appear on the large-scale fallout maps. Often the maximum dose rate at H+1 was estimated from a dose-rate reading made in a survey a day or two after the burst, particularly when the readings were too high to permit routine monitoring near ground zero during the early surveys. In such a case errors in the assumed decay rate may lead to a fairly large error in the estimate of the H+1 dose rate. Also, there is sometimes the possibility of there having been a small area of greater activity than was detected. The maximum dose rate given can only be considered a rough guide to the approximate highest radiation level from each burst.

Time of arrival. Normally when fallout first arrives at any location, the dose-rate is rather small, but it increases as more fallout descends. While the fallout is accumulating (and possibly even before any true fallout arrives), there may temporarily be high dose rates due to passing airborne debris. In a few minutes or a few hours, depending on the nature of the explosion, the wind field, and the distance from the burst site, the fallout is essentially complete and the dose rate starts its steady decrease due to the decay of the fission products. Thus there is no precise time of arrival of the fallout. The time lines shown on the fallout maps are intended to give only rough average arrival times as estimated from the wind reports and the available monitoring information.

Trajectories. Meteorological trajectories for selected levels are included on the off-site fallout maps. Such a trajectory depicts the
path of gaseous or small-particle debris which has a negligible fall rate. The trajectories are all for constant heights above sea level except those marked, in a meteorological jargon, "trajectory at gradient wind level". The gradient wind, simply, is the wind at some level high enough above the general terrain so that the effects of friction of air with the earth are trivial. The gradient level trajectories in this report represent a height of about 1,500 feet above the ground and hence vary in height above sea level. As a rough average, however, this level is about 6,000 feet above sea level in the region of the test site.

The meteorological trajectories are based on the wind analyses for the various levels at three- or six-hour intervals, as provided by the Weather Bureau Research Station, Las Vegas, Nevada. They take into account the temporal and spatial changes in the wind. Meteorological trajectories are, of course, subject to error, particularly over regions of sparse data, in areas of rapidly changing or complex flow patterns, and in regions where the wind speeds are very light. Even though there was a fairly dense network of stations reporting upper winds during the test period, significant uncertainties were sometimes present.

In general, however, the fallout patterns and the meteorological trajectories were in fairly good agreement. Such differences as do appear between the location of a trajectory and the location of the contaminated area may be due to errors in computing the trajectory; but normally they are due primarily to the fact that the deposition is a function of the winds at all levels below the nuclear cloud. Also, a great many of the Hardtack, Phase II, bursts resulted in low nuclear clouds. Such clouds may be subject to channelling or other effects of the terrain; or particularly during the daytime, they may be diffused upward and downward by turbulent mixing. A nuclear cloud from an early morning detonation, for example, may be such that most of the radioactivity is between 5,000 and 10,000 feet above the ground. The part of the material which does not have a significant fall rate would be moved by winds in this layer until daytime heating of the ground is sufficient to produce an unstable layer from the ground up to the radioactive levels. Then, there may be a mixing of the nuclear debris throughout the layer from the ground to the initial cloud height or even higher. Some small particles may then be brought close enough to the ground so that their otherwise trivial fall
rates may bring them to earth. Even particles with completely negligible fall rates may impinge upon and remain on the ground or on vegetation.

In addition to their use as a rough check on the locations of the fallout patterns, the trajectories were used as a guide in estimating times of arrival of the fallout.

Meteorological data. The most important pertinent meteorological information has been included on the fallout maps in order that it may be viewed along with the fallout estimates.

Curves of temperature and dew point versus height, as measured at the Yucca Lake Weather Station, are given. The temperature-height structure is useful in assessing the vertical stability of the atmosphere and plays a dominant role (along with weapon yield) in determining the height of a nuclear cloud.

The dew point distribution with height probably also plays a role in determining cloud height and is related to the amount of water in the nuclear cloud and hence to the appearance of the nuclear cloud. Levels for which the dew-point curve is missing are normally very dry.

The adiabatic lapse rate indicated on each sounding is that rate of temperature decrease with height which indicates neutral stability. When that lapse rate exists in the atmosphere, a parcel of air given some impetus upward or downward meets no opposition, other than friction, to its motion. Such a lapse rate is often accompanied by vertical mixing. When the temperature decreases more slowly with height than the adiabatic rate and, particularly when there is no decrease or even an increase with height, then the atmosphere is in a stable condition, since work must be done on any parcel of air to move it upward or downward. When the temperature decreases more rapidly than the adiabatic rate, which is an infrequent and temporary condition except near the ground on days with strong solar heating, the atmosphere is subject to rapid overturning and hence mixing throughout the unstable layer.

The most important meteorological factor in determining the distribution of the fallout is the wind field. For most bursts the upper-air shot-time winds are given for heights up to at least the top of the nuclear cloud. Directions are in degrees from which the wind is blowing; speeds are in knots. These winds were measured at the Yucca Lake Weather Station. In some cases, however, these winds may not be representative
of the winds at the place of detonation. This is especially true for the
Area 12 tunnel shots, since the Yucca station is about 20 miles to the
southeast and has an elevation of about 4,000 feet whereas the tunnels
were above the 6,000-foot level on the slopes of a 7,500-foot mesa. When
a nuclear cloud from this area extended higher than the mesa top, the
part that extended above the mesa top was probably influenced by winds
not very different from those measured at Yucca Lake, since the Weather
Bureau Research Station at Las Vegas has found a high correlation between
the wind direction on a meteorological tower on the mesa and the wind
direction at the same elevation (about 7,500 feet above sea level) over
Yucca Lake. For the majority of tunnel bursts from which venting occurred,
however, the nuclear clouds were confined to very low heights where
the winds were greatly influenced by local factors. The heating (or
cooling) of the air near the slopes relative to that at similar eleva-
tions in the free air over the valleys leads to flow upslope in the day-
time (or downslope during the night). Typically, the upslope winds start
at about a half hour after sunrise and reverse their direction shortly
before sunset. While the reversal is taking place the winds usually re-
main very light and variable for five or ten minutes.

When available, pertinent wind information from meteorological towers
in Area 12 and Area 8 is included in the remarks accompanying the fallout
maps.

Remarks. For each of the fallout maps comments are given on the
analysis, and the uncertainties are discussed in order that the reliabil-
ity of various parts of the pattern can be judged.

BURSTS FOR WHICH NO MAPS ARE GIVEN

No fallout maps are given for several of the bursts because there was a
negligible yield or, in the case of underground bursts, because there was a
trivial or no release of fission products into the atmosphere. These bursts
are discussed individually below.

Mercury (Burst No. 5). Since there was essentially no nuclear yield from
Mercury, no venting into the atmosphere was observed. There was, however,
some alpha contamination in the main tunnel.

Logan (Burst No. 16). The Logan burst was completely contained and
therefore no radiation from this explosion was released into the air.
San Juan (Burst No. 20). There was essentially no nuclear yield from the San Juan explosion and no visible venting occurred. There was, however, some alpha contamination detected in the immediate vicinity of the well in which this device was detonated.

Oberon (Burst No. 23). There was essentially no nuclear yield from Oberon and only a very low cloud was observed. No gamma activity was reported, but there was some alpha contamination around ground zero and a short distance down wind (toward the northwest).

Mazama (Burst No. 32). There was essentially no nuclear yield from Mazama and only alpha contamination was reported around ground zero. A visible cloud resulted from the Mazama explosion which was estimated from aircraft to reach somewhere between 5,000 and 6,500 feet above sea level (800 to 2,300 feet above ground). With the stable night-time atmosphere, no nuclear yield, and only a small amount of high explosive, it seems doubtful that the cloud could have reached higher than the lowest of the estimates. Perhaps the higher estimates resulted from the difficulty in estimating the height of a low, small cloud at night.

Ganymede (Burst No. 35). There was no nuclear yield for Ganymede. The cloud was very low, but the height could not be determined due to darkness. There was some alpha contamination in the immediate vicinity of ground zero.

ACKNOWLEDGMENTS

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We thank Philip W. Allen, Meteorologist in Charge of the Weather Bureau Research Station in Las Vegas, and his associates for providing the required meteorological data.

Also, we appreciate the conscientious work of Mrs. Barbara Ritchie in drafting the many figures and maps in the report.
REFERENCES


2. Shelton, A. V. et al., Fallout Patterns, Operation Plumbbob. (A report to the Test Manager for the Nevada Test Site by his Committee to Establish Fallout Doses and Intensities.), April 1, 1958.


FIGURE 1 - DECAY CURVES FOR HARDTACK PHASE 2 BALLOON SHOTS
BURSTS AND MONITORING LOCATIONS

WRANGELL

W1 Ground zero

EDDY

E1 South winch site ~ 3000 ft from G.Z
E2 T-7c station ~ 3000 ft from G.Z

MORA

M1 7-800 station ~ 3000 ft from G.Z.
M2 Japanese houses ~ 3500 ft from G.Z.
M3 T-7c station ~ 3000 ft from G.Z.

LEA

L1 7-800 station ~ 3000 ft from G.Z.
L2 West winch site ~ 3000 ft from G.Z.
L3 East winch site ~ 3000 ft from G.Z.

DOÑA ANA

D1 7-300 station ~ G.Z.

HIDALGO

H1 T-7c station ~ 3000 ft from G.Z.

Indicates the range of dose rates given

PHASE 2 BALLOON SHOTS FOR THE ON-SITE AREA.
Figure 2—Decay curves for Hardtack Phase 2 well shots for T.

- OTERO 480 FT WELL
- A  RAM station ~ 1000 ft. from G.Z.
- B  Station NBS ~ 1000 ft. from G.Z.
- C  Station 3-300 ~ 1000 ft. from G.Z.
- D  Station 3-330 ~ 1300 ft. from G.Z.
- E  Station 7-300 ~ 2.5 miles from G.Z.
SODIUM-24 DECAY

--- COLFAX - 350 FT. WELL
A RAM station ~ 300 ft. from G.Z.
B Station 3-300 ~ 1000 ft. from G.Z.

--- BERNALILLO - 456 FT. WELL
A RAM station ~ 800 ft. from G.Z.
B Station U3r ~ 800 ft. from G.Z.
C Station U3k ~ 500 ft. from G.Z.

--- LUNA - 500 FT. WELL
D Station U3r ~ 1000 ft. from G.Z.
E Station U3k ~ 200 ft. from G.Z.

Indicates the range of dose rates given.

PHASE 2 WELL SHOTS FOR THE ON-SITE AREA.
Figure 3: Decay Curves for Hardtack Phase 2 Tower and Gravel

**Río Arriba - 72 1/2 ft. Tower**
- A: Station 3-300 ~ 3000 ft. from G.Z.
- B: East winch site ~ 3.5 miles from G.Z.

**Humboldt - 25 ft. Tower**
- C: Station 3-330 ~ 1200 ft. from G.Z.
- D: Control point building 2 ~ 8 miles.

**Vesta - Gravel Gertie**
- A: East winch site ~ 0.5 miles from.
- B: West winch site ~ 1.1 miles from.
- C: North winch site ~ 1.5 miles from.

**Graph Details:**
- Time on x-axis, dose rate on y-axis.
- Curves for Sodium-24 and T-1/2 decay.
- Labels and annotations for each station and site.

**Graph Legend:**
- DOSE RATE - MR/HR
- TIME - HOURS

**Graphs:**
- Top graph: Río Arriba tower.
- Bottom graph: Vesta tower and Gravel Gertie sites.

**Notes:**
- Graphs show decay curves for different sites and decay periods.
- Dose rate measurements in MR/HR.
- Time in hours.

---

Figure 3: Decay Curves for Hardtack Phase 2 Tower and Gravel
--- RIO ARRIBA — 72 1/2 FT. TOWER
A Station 3-300 ~ 3000 ft. from G.Z.
B East winch site ~ 3.5 miles from G.Z.

--- HUMBOLDT — 25 FT. TOWER
C Station 3-330 ~ 1200 ft. from G.Z.
D Control point building 2 ~ 8 miles from G.Z.

--- VESTA — GRAVEL GERTIE
A East winch site ~ 0.5 miles from G.Z.
B West winch site ~ 11 miles from G.Z.
C North winch site ~ 15 miles from G.Z.

--- QUAY — 100 FT. TOWER
A Station 7-800 ~ 6000 ft. from G.Z.
B Intersection of area 3 Main Access Road and
Mercury Highway ~ 19,000 ft from G.Z.
C B&Y ~ 14,000 ft. from G.Z.
D Intersection of Road "G" and Mercury Highway
~ 30,000 ft from G.Z.

Indicates the range of dose rates given

1 TOWER AND GRAVEL GERTIE SHOTS FOR THE ON-SITE AREA.
FIGURE 4—EARLY DOSE-RATE MEASUREMENTS, SHOWING EFFECTS OF PASSING
EDDY – 500 FT. BALLOON  
(Lincoln Mine Headquarters)

WRANGLER – 1500 FT. BALLOON  
(Watertown)

EFFECTS OF PASSING RADIOACTIVE CLOUDS (WELL AND BALLOON BURSTS).
FIGURE 5 - EARLY DOSE-RATE MEASUREMENTS, SHOWING EFFECT
SHOWING EFFECTS OF PASSING RADIOACTIVE CLOUDS (TOWER BURSTS).
The patterns were interpolated east of Gate 101.

Removal for this area in the absence of

of the on-site pattern was well documented, and a
REMARKS

The pattern was interpolated east of Gate 385 and can only be an approximation for this area in the absence of measurements. The rest of the on-site pattern was well documented, and should be fairly reliable.

TEMPERATURE UPPER WINDS

REMARKS DEW POINT DIRECTION SPEED

ADIABATIC LAPSE RATE

Oeg eea

(Met odata) (1300 PDT)

TEMPERATURE (°C)

METEOROLOGICAL DATA (1300 PDT)

GATE 385

RESIDUAL GAMMA RADIATION

MR/HR AT H + 1 HOUR

- LEGEND -

DOSE RATE CONTOURS, MEASURED

DOSE RATE CONTOURS, ESTIMATED

10,000
211K

WARM SPRINGS

FALLINI RANCH

MONITORED TO BEATTY AND MERCURY

TONOPAH

GOLDFIELD

STANDARD

OAK SPRINGS

MERCURY
REMARKS

The off-site pattern was interpolated between Highways 25 and 38 and can only be a rough approximation in the absence of measurements, but its orientation at least, is consistent with the wind analysis. The rest of the pattern was relatively well documented and should be fairly reliable. The first case of "sky shine" for this operation was reported at Oake 385 at about 20 minutes after the detonation. Figure 4 shows this effect.

OREO (480 FT WELL) MAP B
H-HR= 1300 PDT 12 SEPT. 1958
CLOUD TOP- 9000 FT M.S.L

RESIDUAL GAMMA RADIATION
MR/HR AT H + 1 HOUR

- LEGEND -

Dose Rate Contours, Measured
Dose Rate Contours, Estimated
Time of Arrival, Estimated, H + Hours

Elevation 7000 to 9000 Feet
Elevation More Than 9000 Feet
Road (Thick line indicates monitored section)
The greater portion of this fairly reliable. The density estimate is in the absence of
At 1.5 miles north of Gold Road hours was repeated by the oil
bags of this location (see fig. 2) and
eyes had relatively large if
value would be about 1.5 any
decay to about 1.0 mm/hr of
only background and instrumentation
to show for this low value due
by the oil-content structure, and
The oil-content water bag
about 1.5 hours since a heavy
to consistent with this what
The greater portion of this pattern was well documented and should be fairly reliable. The downwind extent of the 5 and 25 m/hr isolines was estimated in the absence of measurements. At 1.5 miles north of Site 235 a maximum dose rate of 5 m/hr at H=0.53 hours was reported by the off-site monitors. From the continuous readings at the locations (see figure 4) it can be seen that the reported intensities had relatively large fluctuations with time. An appropriate mean value would be about 0.5 m/hr at H=0.53 hours. Since this value would decay to about 0.2 m/hr at 1.5 hour and since other monitors indicated only background intensities in the areas to the north of this position, no contour for the low value was drawn. No significant fallout was reported by the off-site monitors, with the exception mentioned above.

The shot-time mean wind speed from the surface to 7,500 feet m.s.l. was about 17 knots toward a bearing of about 310 degrees. The fallout pattern is consistent with this wind analysis.
REMARTS

The on-site mapping by itself was adequate. In
situ surveys, the were generally a special survey near
the surrounding areas. It difficult to say where the
was being monitored by the special survey was in
situ surveys as we were continuing to both areas as
taken at each point. Further, the decay rate can
for this area. To determine definite residual and
detonations were movement in the general area &
percent of were observed. Since the observed on
average about 34 to 40 hours, this would affect
the total time-in-flight factor. No pattern was
don either the on-site or the way.
REMARKS

The on-site monitoring for this event was adequate. Besides their regular surveys, the on-site group made a special survey north of T-7c to Gate 345 and the surrounding area. It is difficult to say with any confidence if what was being measured during this special survey was induced activity, residual gamma activity, or a combination of both since only one reading was taken at each position. Therefore, the decay rate could not be estimated for this area. To add to this situation, residual activity from Plutonium detonations was known to exist in the general area and to be at least 30 percent of what was observed. Since the observed readings were on the average about 0.4 mhr at 8.9 hours, this would not add significantly to the total dose in the blast fraction. No pattern was drawn for this area on either the on-site or off-site map.

MeteOrOLOGICAL DATA (0700 PDT)

--- TEMPERATURE --- DEW POINT --- ADIABATIC LAPSE RATE

-12,000 -10,000 -8,000 -6,000 -4,000 -2,000 0 2,000 4,000

HEIGHT (feet above sea level)

12,000 10,000 8,000 6,000 4,000 2,000 0

TEMPERATURE (°C)

CLOUD TOP - CLOUD BASE - BURST HEIGHT

Upper Winds

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<thead>
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<tr>
<td>210 - 11</td>
<td></td>
</tr>
<tr>
<td>240 - 07</td>
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</tbody>
</table>

EDDY (500 FT BALLOON) MAP A
H- HR + 0700 PDT 19 Sept 1958
CLOUD TOP - 11,000 FT MSL

Residual Gamma Radiation
MR/HR AT H + 1 HOUR

--- LEGEND ---

- - - DOSE RATE CONTOURS, MEASURED
-- -- DOSE RATE CONTOURS, ESTIMATED
REMARKS

The pattern from Ely to about 70 miles to the north along Highway 38 may be in error even though this portion of the road was monitored. The 3,050-foot max. trajectory indicated that the fallout should have had an orientation toward the northwest with no indication that it should have been toward the north, as this portion of the pattern above. The valley wind should have been fairly well developed at about the time the cloud or the fallout crossed Highway 38, so that any low-level debris would have been transported up Highway 38 toward Ely. There was only one monitor run along this portion of the road and it cannot be determined if the instrument was contaminated, or if the activity was drifting by in the air or may have been actual fallout. At Ely no airborne activity above background was recorded during this period, which is an indication that no fallout occurred in the general area around Ely. This portion of the pattern is, therefore, questionable.

The pattern was interpolated between Highways 32 and 31, but there is some confidence in it since no activity above background was detected along Highway 32 between Baker and New Castle. The rest of the pattern was well documented and should be fairly reliable.
Based on the shot time wind run the Luna fallout should have had a hot line bearing of about 355 degrees. Since there were few minor runs across this bearing it is difficult to draw a pattern with any confidence.

There appeared to have been some fallout at the Japanese Houses Site T-300 and the Area 9 ground zero. At the Japanese Houses a reading of 6 mR/hr, conversion to H-1, was reported. There did not appear to be any residual contamination from previous events in this area.

At Site T-300 there was a background contamination of about 2 mR/hr from the Eddy burst at the time of the Luna detonation. Subtracting this from the Luna monitor reading would leave a dose rate of about 4 mR/hr at H+1.

The Area 9 ground zero, which is about 6 miles from the Luna position on a bearing of about 357 degrees, was reported to have only background radiation at 16 minutes after shot time. At 20 and 29 minutes the readings there were 5 and 10 mR/hr, respectively. From the shot time = wind speed about 19 knots from the surface to 1,000 feet, plus 1.3 mR/hr cloud passage and the fallout should have occurred at about 30 minutes after shot time. It is thus difficult to estimate the H-1 value since the activity was apparently still arriving at the time of the last observation.

For Site T-300 the background contamination from the Eddy event was of the order of 200 to 300 mR/hr 5 hours before the Luna detonation or 48 hours after the Eddy burst. Taking a value of 250 mR/hr at 48 hours and decaying it (sodium-24 decay) to 54 and 72 hours (which are equivalent to the H-1 and the H-19 Luna surveys) we would arrive at values of 100 and 190 mR/hr, respectively. Since the readings on the Luna surveys at these three hours of this order or less, we can assume that it was primarily residual Eddy contamination that was being monitored.

Again, since there were so few significant readings downwind from the Luna ground zero, no attempt was made to draw a complete pattern.

There were no readings above background reported off-site.
REMARKS

The Valencia cloud moved at a speed of about 10 knots along a bearing of about 305 degrees from ground zero. At about 1.5 hours after shot time, although the cloud was not visible, readings at Control Point Building 2 (approximately 8 miles from ground zero) on a bearing of about 185 degrees showed a rapid drop in speed and direction that the cloud should have been in the general area at about the time of the maximum reading, indicating that what was being recorded was the cloud.

Special surveys across Yucca Lake in Area II, west of the Mercury Highway, and along the Cane Spring road to Jackass Flats showed that there was no activity above background or above the levels of residual contamination from previous events. Therefore, it seems doubtful that there could have been additional areas of fallout outside. In general, the documentations was such that to yield a high degree of confidence in the analysis. No interferences significantly above background were found in the on-site monitors.

VALENCIA (484 FT WELL) MAP A
H-HF = 1300 PDT 26 SEP 1958
CLOUD TOP = 5500 FT MSL
RESIDUAL GAMMA RADIATION
MR/HR AT H + 1 HOUR

- LEGEND -
--- DOSE RATE CONTOURS, MEASURED
- - - DOSE RATE CONTOURS, ESTIMATED
REMARKS

Mars ven-ed through the tunnel mouth (situated on the mesa slope at an elevation of 6,725 feet m.s.l.), and a cloud rose to about 50 feet above the surface. Before this time the winds along the mesa slope (see table below) were approximately from the northeast; but the winds over the mesa top were from about northeast. Two minutes before that time the winds at the slope station shifted and blew from approximately northeast (drainage winds), while the winds over the mesa slope were still from about northeast. Since the cloud rose to only a few hundred feet, it was under the influence of the drainage winds, and travelled toward the southwest.

The only wind which could be monitored in the direction of fallout was the Area 12 access road, therefore, there is considerable uncertainty as to the crosswind extent of this pattern. The downwind and upwind extent of the contamination should be fairly reliable.

No activity above background was detected off-site.

5-Minute Average Winds

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<tr>
<th>Time</th>
<th>Direction</th>
<th>Speed</th>
<th>Time</th>
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<td>060 08 040</td>
<td>1650-1655</td>
<td>060 08 020</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

No cloud was detected above 50 feet above the surface.

The only wind which could be monitored in the direction of fallout was the Area 12 access road, therefore, there is considerable uncertainty as to the crosswind extent of this pattern. The downwind and upwind extent of the contamination should be fairly reliable.

No activity above background was detected off-site.
At shot time a dust cloud was formed (most likely by the shock wave blowing up the surface dirt) in the lower levels and was observed to move toward the west over the Mercury Highway producing relatively high fallout activity. This dust cloud most likely contained primarily induced radioactivity formed by the neutron capture by the sodium in the soil.

Since this event was fairly well documented on site, there is considerable confidence in the pattern presented.
Only small areas of fallout were detected in the off-site areas and the induced levels have been extremely low.

The observed fallout areas were predicted by the trajectories of the wind and possible contamination of the area. This is not surprising.

Due to the low levels of contamination, there is little confidence in the data.
REMARKS

Only small areas of fallout were detected off site, and any fallout between
the off-site areas and the inferred radiation near the burst point must
have been extremely light.

The observed fallout areas were somewhat to the east of the path indi-
cated by the trajectories or the short-time winds, but with typical wind
changes and possible channeling effects in the lower levels, this dis-
crepancy is not surprising.

Because of the low levels of radioactivity detected relative to background
radiation, there is little confidence in the off-site fallout analyses.
The on-site fallout from the Hidalgo event was relatively well documented and the results presented are considered to be fairly reliable.
Along the Papoose Lake Road and Road "B" there was some activity reported which is attributed to residual contamination from the Smoky sled during Operation Plumbbob.

The initial survey to the northeast did not reveal any activity above background, yet on the next day (approximately 34 hours after shot time) readings in the Hiko-Alamo-Caliendo area indicated activity 2 to 4 times background levels. The trajectories indicated that the nuclear cloud was not over this area before the initial survey but arrived after the survey was completed. The background value, therefore, was subtracted from each of the D-1 readings before their conversion to the common reference time. Because of the low levels of activity and background contamination, there is not too high confidence in this analysis.

**REMARKS**

Along the Papoose Lake Road and Road "B" there was some activity reported which is attributed to residual contamination from the Smoky sled during Operation Plumbbob.

The initial survey to the northeast did not reveal any activity above background, yet on the next day (approximately 34 hours after shot time) readings in the Hiko-Alamo-Caliendo area indicated activity 2 to 4 times background levels. The trajectories indicated that the nuclear cloud was not over this area before the initial survey but arrived after the survey was completed. The background value, therefore, was subtracted from each of the D-1 readings before their conversion to the common reference time. Because of the low levels of activity and background contamination, there is not too high confidence in this analysis.
MERCURY HIGHWAY

ESTIMATED AXIS OF FALLOUT 350 DEGREES

MAXIMUM AT GZ ~ 150 R/HR AT H+1

0 5000 FEET
REMARKS

Based on the shot time wind run the Colfax fallout should have had a hot-
line bearing of about 250 degrees. There was some activity reported
around Area 9, as indicated on the map. Elsewhere there was insufficient
monitoring information from which to draw a complete pattern.

The only activity above background reported by the off-site monitor was
at about 1.5 miles south of Gate 105 on the Groom Lake Road. This was
about 0.3 m/ hr when converted to H+1.

---

METEOROLOGICAL DATA (0815 PST)

<table>
<thead>
<tr>
<th>TEMPERATURE</th>
<th>DEW POINT</th>
<th>ADIABATIC LAPSE RATE</th>
</tr>
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UPPER WINDS

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</table>

CLOUD TOP - 5500 FT M.S.L.

RESIDUAL GAMMA RADIATION

MR/HR AT H+1 HOUR

--- LEGEND ---

- DOSE RATE CONTOURS, MEASURED
- DOSE RATE CONTOURS, ESTIMATED

COLFAX (350 WELL) MAP A

H-HR = 0815 PST 5 OCT. 1958
CLOUD TOP - 5500 FT M.S.L.
There was only a minor amount of testing through the tunnel mouth (located at the side of the mesa slope at an elevation of 6,655 feet (m.s.l)) and an organized cloud was formed. Strong west winds above the mesa slope (see table below) prevented the formation of the normal afternoon up slope (northeast) winds.

The short-time winds at the Mesa Moutain tower were from the west while the winds at the slope station were from the north. The slope winds indicate that the activity, which was confined to the lower layers, should have been transported toward the south. A channeling effect due to the canyon, oriented north-east-south-east, between Portals B and E transfers the debris toward the southeast.

The activity isolines shown are very uncertain. It is believed that there was some true fallout downdraft from the portals, but that the radiation reported was primarily airborne activity in gaseous or very small particulate form. At several places, such as the B, C, and E portals, and at the Longyear site, a rapid drop in intensity in a very short time period was recorded, indicating that the activity was most likely drifting by in the air. An attempt was made to normalize the activity to a common reference time, but because of the uncertainty as to what fraction of the activity was airborne and what was true fallout, the isolines were dashed and there is no degree of confidence in this pattern. For this reason no attempt should be made to integrate this pattern to estimate the fraction of the total activity which came down as close-to-fallout.

No activity above background was detected off-site.

### 15 Minute Average Winds

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<th>Time (PST)</th>
<th>Direction (degrees)</th>
<th>Speed (mph)</th>
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<td>1345-1650</td>
<td>160 06</td>
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### Dose Rate Contours

- **Legend**
  - Dose rate contours, measured
  - Dose rate contours, estimated

### TAMALPAIS (TUNNEL) MAP A

- **H-HR- 1400 PST 8 OCT 1958**
- **CLOUD TOP- LOW DIFFUSE CLOUD**

- **Residual Gamma Radiation MR/HR AT H + 1 HOUR**

- **Legend**
  - Dose rate contours, measured
  - Dose rate contours, estimated
REMARKS

The on-site fallout from the Quay event was well documented and the pattern is considered to be fairly reliable. The portion of the pattern which was interpolated (indicated by the dashed line) can only be an approximation in the absence of measurements.
TEMPERATURE
Dew Point
Adiabatic Lapse Rate

Upper Winds

<table>
<thead>
<tr>
<th>Time (UTC)</th>
<th>Speed (knots)</th>
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<td>020</td>
<td>16</td>
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<tr>
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<td>07</td>
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</table>

METEOROLOGICAL DATA (0630 PST)

QUAY (100 FT. STEEL TOWER) MAP B
H-HR = 0630 PST 10 OCT 1958
CLOUD TOP = 10,000 FT M.S.L.

Residual Gamma Radiation
MR/HR AT H + 1 HOUR

Legend:
- Dose Rate Contours, Measured
- Dose Rate Contours, Estimated
REMARKS

Since the winds were light, with several small cyclonic and anticyclonic cells in the area, there is considerable doubt as to the true path of the trajectories.

The air sampling of beta activity indicated above-background readings at Beatty, Goldfield, Tonopah and Warm Springs. These results indicated that at least a portion of the cloud had a northeasterly trajectory from Beatty toward Tonopah and then probably veered toward Warm Springs.

There were no monitor runs north of Sarcobatus, so it is believed that the fallout north of this point was light since the activity would have been spread over a relatively large area. Therefore, the pattern was not extended toward the north, even though the beta readings indicated this to be the path of the activity.

Since this event was well documented off-site, the pattern is considered to be reliable.
The on-site microwave from Lea was reliable and the pattern should be fairly reliable.
The on-site inactivity from Lea was relatively well documented and the patterns should be fairly reliable.

<table>
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<th>DEW POINT</th>
<th>ADIABATIC LAPSE RATE</th>
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</tr>
<tr>
<td>310 - 00</td>
<td>305 - 00</td>
<td>300 - 00</td>
</tr>
</tbody>
</table>

METEOROLOGICAL DATA (0520 PST)

 Maximum at GZ, ~8 R/HR at H + 1

LEA (1500 FT BALLOON) MAP A
H-7HR = 0520 PST 13 OCT. 1958
CLOUD TOP - 17,000 FT M.S.L.

RESIDUAL GAMMA RADIATION
MR/HR AT H + 1 HOUR

- LEGEND -
  - - - DOSE RATE CONTOURS, MEASURED
  --- DOSE RATE CONTOURS, ESTIMATED
The pattern interpolated between Highways 6 and 50 can only be an approximation in the absence of measurements, but its orientation, at least, is consistent with the 12,000-foot m.s.l. trajectory.

The 16,000-foot trajectory indicates that the cloud at that level initially travelled toward the southwest. Since the winds at lower levels were toward the north, fallout originating from about 16,000 feet m.s.l. would have been spread over a large area to the west and northwest of the hospital. Furthermore, the air sampling of beta activity at Beatty and Tonopah indicated values well above background. About 20 hours after burst time, however, a monitoring run from Beatty to Tonopah reported only background readings. It thus appears that there probably was very light fallout in that area, but that it had decayed to levels indistinguishable from background by the time of the survey.

LEA (1500 FT BALLOON) MAP B
H-HR = 0520 PST 13 OCT. 1958
CLOUD TOP = 17,000 FT. M.S.L.

RESIDUAL GAMMA RADIATION
MR/HR AT H+12 HOURS

- LEGEND -
--- DOSE RATE CONTOURS, MEASURED
- - - DOSE RATE CONTOURS, ESTIMATED
- - - TIME OF ARRIVAL, ESTIMATED H+HOURS

| ELEVATION 7000 TO 9000 FEET |
| ELEVATION MORE THAN 9000 FEET |
| ROAD (THICK LINE INDICATES MONITORED SECTION) |
REMERS

The Neptune explosion vented through the mesa slope at an elevation of about 6,800 feet. The cloud rose to about 11,000 feet m.s.l. The winds at the mesa mountain tower indicated that the lower layers of the cloud would be transported on a bearing of 310 degrees. The actual fallout was centered on a bearing of about 300 degrees. This would imply that the direction was fairly constant between the level of the top of the cloud and that part which passed just above the mesa.

The pattern for that part of the mesa which was monitored, as indicated by the solid lines, is considered fairly reliable.

No activity above background levels was reported off site.

15 Minute Average Winds

9-foot Mesa Slope Tower 100-foot Mesa Mountain Tower

<table>
<thead>
<tr>
<th>Time</th>
<th>Direction</th>
<th>Speed</th>
<th>Time</th>
<th>Direction</th>
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</tbody>
</table>
MESA SLOPE TOWER
MAXIMUM ABOUT 60 FEET FROM G.Z.
~ 1200 R/HR AT H + 1
1000 R/HR AT H + 1
V PORTAL U12b
100
500
1000
50,000
10,000
HAGSTEDT SITE
G Z - 03 SITE
MESA MOUNTAIN TOWER
PORTAL U12a
PORTAL U12b

NEPTUNE (TUNNEL) MAP A
H - HR = 1000 PST 14 OCT. 1958
CLOUD TOP- 11,000 FT M.S.L.

RESIDUAL GAMMA RADIATION
MR/HR AT H + 1 HOUR

- LEGEND -

DOSE RATE CONTOURS, MEASURED
DOSE RATE CONTOURS, ESTIMATED
MAXIMUM AT G.Z.
~100 R/HR AT H+1
Remarks

The downstream extent of the 10 mcr/hr line is uncertain but the rest of the pattern is considered to be reliable.

HAMILTON (50 FT WOOD TOWER) MAP A
H-HR= 0800 PST 15 OCT 1958
CLOUD TOP - 6,000 FT M.S.L.

Residual Gamma Radiation
MR/HR at H = 1 HOUR

Legend:
--- DOSE RATE CONTOURS, MEASURED
- - - - - DOSE RATE CONTOURS, ESTIMATED
REMARKS

The representations of the temperature height curve shown with the meteorological data is questionable, since the elevation of the Hamilton site in Frenchman's Flat is 3,000 feet, about 600 feet below that of the Yucca Lake weather station where the temperature soundings were made. Also, because of the very low speeds and the influence of terrain, the winds reported may not be representative of those in Frenchman's Flat.

The gradient wind trajectory had a speed of about 4 knots while the mean wind speed from the surface to 6,000 feet m.s.l. was about 2 knots. As the cloud moved southward rather slowly, it gave moderate peaks of activity at Mercury as indicated in figure 5.

This pattern was relatively well documented and is consistent with the wind analysis.

HAMILTON (50 FT WOOD TOWER) MAP B
H-HR 0800 PST 15 OCT. 1958
CLOUD TOP - 6,000 FT. M.S.L.

RESIDUAL GAMMA RADIATION
MR/HR AT H + 1 HOUR

--- LEGEND ---
- - - - - - DOSE RATE CONTOURS, MEASURED
- - - - - - DOSE RATE CONTOURS, ESTIMATED
- - - - - - TIME OF ARRIVAL, ESTIMATED, h - HOURS
- - - - ELEVATION 5000 TO 7000 FEET
- - - - ELEVATION 7000 TO 9000 FEET
- - - - ELEVATION MORE THAN 9000 FEET
--- ROAD (THICK LINE INDICATES MONITORED SECTION) ---
REMARKS

The 10 mc/hr isoline crossing the Mercury Highway south of the BFY is rather uncertain. The cloud should have been over this area at about the time that some of the measurements were made. Therefore, what was being monitored may have been sky shine, induced activity, or a combination of both.

There is not too much confidence in this pattern since the downwind extent of most of the fallout is not known and the area in the east of ground zero was not monitored.

MAXIMUM AT G.Z. ~ 2 R/HR AT H + 1

WEST WINCH SITE

SOUTH WINCH SITE

FAST WINCH SITE

DOÑA ANA (450 FT BALLOON) MAP A
H-HR = 0620 PST 16 OCT. 1958
CLOUD TOP = 11,000 FT. M.S.L.

RESIDUAL GAMMA RADIATION
MR/HR AT H + 1 HOUR

- LEGEND -

DOSE RATE CONTOURS, MEASURED
DOSE RATE CONTOURS, ESTIMATED
Since there were no monitoring runs between the immediate ground zero area and Highway 95, it is not known whether there was any fallout between the on-site and off-site patterns as drawn.

The correlation between the trajectories shown and the fallout pattern is rather poor. The low-level winds were toward the south for approximately 6 hours after shot time; therefore, any fallout originating at 7,000 to 10,000 feet m.s.l. should have been spread out over the area south to northwest of the burst point. The air sampling of beta activity did indicate values above background at Tonopah, Goldfield, Beatty, and Lathrop Wells. Also, some gamma activity was reported by the monitors from 15 miles north of Springdale to Lathrop Wells. Thus, in addition to the fallout area shown, there was most likely some very light fallout in the general area from Lathrop Wells to Tonopah.

Although there were monitoring runs along a large number of roads off-site, the pattern as drawn is not considered to be very reliable because of the uncertainties in dealing with activity often only two or three times the background value.
MAXIMUM AT G Z ~ 2,000 R/HR AT H = 1

WEST WINCH SITE

50,000

10,000

90,000

EAST WINCH SITE

- NORTH WINCH SITE

- T-10

- T-2c

- GATE 380

N = 90,000

E 685,000

0 5,000 10,000 20

FEET
The downwind extent of the 50 and 10 mrem/hr isolines can only be an approximation in the absence of measurements. The rest of the on-site pattern was well-documented and should be reliable.
The cloud from Vesta was observed to rise initially to about 7,500 or 8,000 feet m.s.l. Then from the top of the cloud a large bulge rose in the manner of a cumulus cloud, reaching an altitude of about 10,000 feet at about 30 minutes after the detonation. Although the trajectories in the 7,000- to 10,000-foot layer were estimated to have passed somewhere to the east of the areas where fallout was observed, fallout from these upper parts of the cloud would have been displaced westward by the winds in the lower levels. Thus, it is not possible to say whether there was fallout from the late-rising upper part of the cloud.

The off-site portion of the fallout pattern is considered rather uncertain, since there were few radiation measurements; however, its orientation is consistent with the wind analysis.

**Remarks**

- Temperature
- Dew Point
- Adiabatic Lapse Rate

**Upper Winds**

- Direction
- Speed

**Meteorological Data (1500 PST)**

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</table>

**Map B**

**Legend**

- Dose rate contours, measured
- Dose rate contours, estimated
- Time of arrival, estimated, H+hours
- Elevation 5000 to 7000 feet
- Elevation 7000 to 9000 feet
- Elevation more than 9000 feet
- Road (thick line indicates monitored section)
REMARKS

The radioactive fallout from Rio Arriba was well documented and the pattern presents is considered to be reliable.
REMARKS
The nominal extent of the 0.1 mSv/hr contour is uncertain but the orientation is consistent with the wind analysis. The root of the pattern was well documented before and after fallout occurred. Therefore, there is a high degree of confidence in the off-site pattern.

RIO ARRIBA (172 1/2 FT WOOD TOWER) MAP B
H-HR+ 0625 PST 18 OCT 1958
CLOUD TOP - 13,500 FT M.S.L.

RESIDUAL GAMMA RADIATION
MR/HR AT H + 12 HOURS

LEGEND

- - - - DOSE RATE CONTOURS, MEASURED
- - - - DOSE RATE CONTOURS, ESTIMATED
- - - - TIME OF ARRIVAL, ESTIMATED, H+HOURS

ROAD (THICK LINE INDICATES MONITORED SECTION)
The on-site induced-rip-in-ground Socorro was relatively well documented and the patterns present are considered to be highly reliable.
Rushmore
Remarks
Because of the lack of data in some areas around ground zero there is
not a high degree of confidence in the analysis of the on-site pattern for
Rushmore.

WEST WINCH SITE
MAXIMUM AT GZ, ~ 5 R/HR AT H + 1
9-300

MAXIMUM AT GZ. ~ 20 R/HR AT H + 1

RUSHMORE

TEMPERATURE
DEW POINT
ADIABATIC LAPSE RATE

-10 -20 -30
DEG C
4,000 6,000 8,000 10,000 12,000
HEIGHT (feet above sea level)

100 50 10

5,000 10,000
FEET

METEOROLOGICAL DATA (1540 PST)

RUSHMORE (500 FT. BALLOON) MAP A
H-HR= 1540 PST 22 OCT. 1958
CLOUD TOP- 11,500 FT M.S.L.

SOCORRO (1450 FT. BALLOON) MAP A
H-HR= 0530 PST 22 OCT. 1958
CLOUD TOP-26,000 FT M.S.L.

RESIDUAL GAMMA RADIATION
MR/HR AT H + 1 HOUR

- LEGEND

--- Dose rate contours, measured
--- --- Dose rate contours, estimated
REMARKS

Because of the lack of data in some areas around ground zero there is not a high degree of confidence in the analysis of the on-site pattern.

**METEREOLOGICAL DATA (0855 PST)**

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<table>
<thead>
<tr>
<th>UPPER WINDS</th>
<th>DIRECTION (Degrees)</th>
<th>SPEED (Km/hr)</th>
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<td>063 - 08</td>
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<tr>
<td></td>
<td>089 - 02</td>
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</tbody>
</table>

**MAXIMUM AT GZ**

- 6 R/HR AT H+1

**WRANGLER (1500 FT BALLOON) MAP A**

- H-HR = 0850 PST 22 OCT 1958
- CLOUD TOP = 10,000 FT MSL

**RESIDUAL GAMMA RADIATION**

- MR/HR AT H + 1 HOUR

**LEGEND**

- DOSE RATE CONTOURS, MEASURED
- DOSE RATE CONTOURS, ESTIMATED
For Socorro there is very little confidence in the off-site pattern since there is the possibility that the fallout across Road “B” toward Lincoln Mine was in part from this event and not all from Wrangell.

A high reading of 50 mcr/hr was recorded at Lincoln Mine at 11-2.2 hours and attributed to Rushmore since that was about the time the Rushmore cloud should have been over this area. Later readings at Lincoln Mine indicated activities only several times above background which may have been from Wrangell or possibly from Wrangell.

Since it was late in the day, there were very few monitor runs after the Rushmore event. The survey the next day indicated little activity which may have been from any of the three events. No attempt was made to draw a pattern for Rushmore but three may have been fallout from this detonation. In fact, since Rushmore had a yield lower than that of Wrangell and their respective clouds rose to about the same elevation, they may have been a mix of more fallout as has been attributed to Wrangell.
The image contains a map and a graph with various data points and annotations. The map includes a trajectory labeled ELY with a notation of "6 hours." The graph shows temperature, dew point, and adiabatic lapse rate on the y-axis, with height (feet above sea level) on the x-axis. The map is labeled with locations such as Socorro, Hiko, Lincoln Mine, and more. The legend includes symbols for dose rate contours, measured and estimated, time of arrival, estimated, altitude, and road.
REMARKS
The on-site fallout from Catron was well documented and the pattern presented is considered to be reliable. A special on-the-street survey was very helpful in delineating the Catron fallout from the Juno fallout, especially in the area west of the Mercury Highway.
Crowned (72 1/2 ft Wood Tower) Map A
H- HR = 0700 PST 24 OCT 1958
Cloud Top - 8,500 FT MSL

Residual Gamma Radiation
Mr/HR at H + 1 Hour

Legend:
- Dose Rate Contours, Measured
- Dose Rate Contours, Estimated

Maximum at G Z ~ 200 R/HR at H + 1
There is a great deal of uncertainty in the Catron pattern off-site because of the lack of data between the immediate area around the burst site and Highway 85. The pattern along Highway 85 is based on the measurements made on the day.

The highway was monitored upon the following day, and all reports indicated activity at about background levels. Scattered showers were reported along the monitored part of this highway on that day, so it is possible that the activity was washed into the ground by the rain. However, it is more probable that the activity reported was due to airborne material which decayed by the time it was being monitored, or that there was some radionuclide which decayed by the next day to levels not easily differentiated from background radiation.

The pattern presented is at least qualitatively consistent with the wind analyses.

---

**CATRON (172 1/2 FT WOOD TOWER) MAP B**

H-yr- 0700 PST 24 OCT. 1958

CLOUD TOP - 8,500 FT. M.S.L.

**RESIDUAL GAMMA RADIATION**

MR/HR AT H+1 HOUR

---

**LEGEND**

- DOSE RATE CONTOURS, MEASURED
- DOSE RATE CONTOURS, ESTIMATED
- TIME OF ARRIVAL, ESTIMATED, H+HOURS
- ELEVATION 5000 TO 7000 FEET
- ELEVATION 7000 TO 9000 FEET
- ELEVATION MORE THAN 9000 FEET
- ROAD (THICK LINE INDICATES MONITORED SECTION)
The adiabatic lapse rate was well-defined in the specified area. No unusual weather conditions were reported during the sounding.
UPPER WINDS

DIRECTION (Degrees) SPEC. (Knots)

12,000 — —
10,000 120 — 15
8,000 120 — 14
6,000 110 — 12
4,000 100 — 09
3,000 070 — 07
2,000 030 — 06
1,000 360 — 04

TEMPERATURE SOUNCING 0705 PST
UPPER WINDS 0830 PST

REMARKS

The occlusion front was well documented and the pattern, as related, was considered reliable.

No significant effects were reported that could be attributed to the front over:

794B
SOUTHEAST
WINCH SITE

MAXIMUM AT GZ ~ 1000 R/H AT H + 1

JUNO (GRAVEL GERTIE) MAP A
H-HR = 0801 PST 24 OCT 1958
CLOUD TOP = 5,500 FT M.S.L.

RESIDUAL GAMMA RADIATION
MR/HR AT H + 1 HOUR

- LEGEND -

DOSE RATE CONTOURS, MEASURED
DOSE RATE CONTOURS, ESTIMATED
There was a trivial yield from Ceres, and a cloud height of about 6,000 feet m.s.l. (a rise of about 1,500 feet) was observed. Because of the lateness of the day, the proximity of the mountainous terrain and the low cloud height, the lowest portion of the nuclear cloud was under the influence of drainage-winds. The shot-time surface wind observations at Station 293 located about 2-1/2 miles south of the burst point on Road 8B and at the Yucca Lake station (located about 15 miles south of the burst point) indicated that the drainage winds had set in by shot time and were approximately from the northwest.

According to the Yucca Lake winds from above the drainage level to the top of the cloud the debris should have been deposited toward the northeast of the burst point. The radiation data strongly suggests that the debris was deposited toward the southwest. A possible explanation of the discrepancy between the observed radiation field and the wind field is that, since the winds were rather light, the observed winds at the Yucca Lake weather station were probably not representative of the air flow over Area 6 at these low levels.

No activity above background was detected off site.

**15-Minute Average Winds**

20-foot Tower at Station 353
(Surface Elevation About 4355 feet m.s.l.)

<table>
<thead>
<tr>
<th>Time (UT)</th>
<th>Direction (degrees)</th>
<th>Speed (m.p.h.)</th>
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</thead>
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<tr>
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<td>03</td>
</tr>
<tr>
<td>2045-2100</td>
<td>310</td>
<td>05</td>
</tr>
</tbody>
</table>
TEMPERATURE UPPER WINDS

DEW POINT DIRECTION

ADIABATIC LAPSE RATE

Degrees

Km

WELL 58

MAXIMUM AT G.Z. ~ 13 R/HR AT H + 1

Because of the lack of data in most of the areas around ground zero, there is not a very high degree of confidence in the analysis of the on-site pattern.

SANFORD (1500 FT BALLOON) MAP A

H-HR = 0220 PST 26 OCT 1958

CLOUD TOP = 26,000 FT. M.S.L.

RESIDUAL GAMMA RADIATION

MR/HR AT H + 1 HOUR

- LEGEND -

DOSE RATE CONTOURS, Measured

DOSE RATE CONTOURS, ESTIMATED
Indications from the on-site data around A-9 and about 3 miles south-east of ground zero are that the cloud sheared and travelled in two different directions. The readings at these two locations were taken at very early times and were in all probability due to shunt. Between these two areas, that is, in the northeast quadrant, activity recorded was very low. Because of the lack of data in most areas around ground zero there is not a very high degree of confidence in this pattern.
Sanford
Remarks
Activity along Highway 95 just south of Tonopah was attributed to the Sanford event. From the wind analysis it is evident that this activity must have originated from about 14,000 feet m.s.l. or less, while the activity found around the Alamo area and attributed to Sanford must have originated from 18,000 to 20,000 feet m.s.l.

The portion of the cloud that had a trajectory toward the northeast should have crossed the Hiko-Caliente-Beryl Junction roads. No activity above background was found along these roads, which would suggest that no activity fell across these roads, that the activity was extremely light and decayed to almost nothing by the time the roads were monitored, or that the fallout, if any, occurred more toward the east. No activity above background was detected north of St. George, however, so that curving toward the east is considered unlikely.

Monitoring and air-sampling data indicated that radioactivity from Sanford passed over Mercury. No estimate of the decay rate could be determined, due to the large fluctuations in the dose rates. Since the winds in the lower layers were from the north, it seems likely that some of the dust raised by the burst in Frenchman Flat drifted past Mercury. The radiation detected was probably due to neutron-induced radioactivity in the Frenchman Flat soil.

De Baca
Remarks
Activity that was found from Gate 100 to Gate "B" and also north of Alamo along U.S. 80 was attributed to De Baca. The activity to the north most likely originated from about 10,000 feet m.s.l. or less in the nuclear cloud while the activity to the east most likely came from about 15,000 to 17,000 feet m.s.l.

The 14,000 foot De Baca trajectory at the winds above this elevation indicated that the cloud was over U.S. 80 at about the time that fallout was estimated to have arrived about 4 hours after burst time. The estimate of the trajectory speed may be incorrect and what was observed may have been either true fallout or shine. Since there was only one survey along this road for the De Baca event, it is not certain which of the two explanations is the correct one.

No activity above background levels was found from St. George to Glendale, indicating that no fallout occurred in this direction. It was not distinguishable from background radiation. The wind analysis showed that it was unlikely that the fallout could have curved to the north, that is, between Hiko and Beryl Junction. The monitors surveyed this road for Sanford, but not for De Baca. It is not known for certain, therefore, if fallout did occur across this road.

SANFORD (1500 FT BALLOON) MAP B
H-HR = 0220 PST 26 OCT. 1958
CLOUD TOP = 26,000 FT. M.S.L.

DE BACA (1500 FT BALLOON) MAP B
H-HR = 0800 PST 26 OCT. 1958
CLOUD TOP = 17,500 FT. M.S.L.

Residual Gamma Radiation
MR/HR AT H + 1 HOUR

--- LEGEND ---

--- DOSE RATE CONTOURS, MEASURED ---

--- DOSE RATE CONTOURS, ESTIMATED ---

--- TIME OF ARRIVAL, ESTIMATED, H+HOURS ---

ELEVATION 7000 TO 9000 FEET
ELEVATION MORE THAN 9000 FEET
ROAD (THICK LINE INDICATES MONITORED SECTION)
The documented extent of the activity tallies can only be a rough approximation because of the limited number of measurements. The set of the pattern was relatively well documented and should be fairly reliable.
Because of the limited area that was and could be monitored the downwind extents of the various isolines are rough approximations, but their orientation, at least, is consistent with the wind analysis.

### Meteorological Data (0635 PST)

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<th>Temperature (°C)</th>
<th>Dew Point (°C)</th>
<th>Direction (Degrees)</th>
<th>Speed (Knots)</th>
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<tr>
<td>350</td>
<td>350</td>
<td>350</td>
<td>08</td>
</tr>
</tbody>
</table>

### Remarks

Because of the limited area that was and could be monitored the downwind extents of the various isolines are rough approximations, but their orientation, at least, is consistent with the wind analysis.
REMARKS

Although there was no organized cloud from the Evans burst, a small amount of smoke was seen to vent from the portal, on the mesa slope at an elevation of about 6,500 feet.

Since the winds at the mesa slope tower were from the west, the vented material should have been transported toward the east or possibly toward the southeast because of the channelling effect of the canyon between the "B" and "E" portals.

There were two monitoring reports at the LRL Warehouses: 10 mR/hr at 0.42 hours and 20 mR/hr at 1.5 hours after the burst. Also, at the portal of Tunnel U2b there were readings of 5 mR/hr at 0.42 hours and 20 mR/hr at 1.5 hours after the burst. This radiation at these sites cannot logically be attributed to any previous burst. Since after these early surveys there was no further monitoring reported until after the Blanca burst, it is not possible to say whether this radiation was due to airborne debris or due to true fallout. There is a suggestion, however, that the greater part was from airborne material.

The reading at the Rainbow Drill Site is believed to be from residual contamination from Neptune. It is uncertain whether the activity on the mesa above the "E" tunnel is residual or from Evans.

15-Minute Average Winds

<table>
<thead>
<tr>
<th>Time</th>
<th>Direction</th>
<th>Speed</th>
<th>Direction</th>
<th>Speed</th>
</tr>
</thead>
<tbody>
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<td>07</td>
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</tr>
<tr>
<td>1745</td>
<td>290</td>
<td>08</td>
<td>010</td>
<td>Mining</td>
</tr>
</tbody>
</table>

EVANS (TUNNEL) MAP A
H-HR=1600 PST 28 OCT. 1958
CLOUD TOP - NO ORGANIZED CLOUD

RESIDUAL GAMMA RADIATION
MR/HR AT TIME OF OBSERVATION

- LEGEND -

--- DOSE RATE CONTOURS, MEASURED

--- DOSE RATE CONTOURS, ESTIMATED
REMARKS
The on-site fallout from Humboldt was well documented and the pattern is considered reliable.

MERCURY HIGHWAY 50,000
M.AXIMUM AT G.Z ~ 500 R/HR AT H+1

HUMBOLEDT (25 FT. WOOD TOWER) MAP A
H-HR+ 0645 PST 29 OCT. 1958
CLOUD TOP- 7,500 FT M.S.L.

RESIDUAL GAMMA RADIATION
MR/Hour AT H+1 HOUR

- LEGEND -

DOSE RATE CONTOURS, MEASURED
DOSE RATE CONTOURS, ESTIMATED
**REMARKS**

Although there is some uncertainty in the detailed extent of some of the lines, there is fair confidence in the width of the pattern and in the orientation of the falling, which is consistent with the wind analysis.

**METHOLOGICAL DATA (0650 PST)**

- TEMPERATURE
- D.L. "5" RATE
- ADIABATIC LA "5" RATE
- DEW POINT
- DIRECTION (Degrees)
- SPEED (Knots)

**HUMBOLDT (25 FT WOOD TOWER) M$^{2}$ B**

H- HR = 0645 PST  29 OCT. 1958
CLOUD TOP = 7,500 FT. M.S.L.

**RESIDUAL GAMMA RADIATION**

$\text{MR/HR AT H + 1 HOUR}$

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>LEGEND</td>
<td></td>
</tr>
</tbody>
</table>
Remarks
The launching site was relatively well monitored and the pattern remained stable.

8-7b

SANTA FE (1500 FT. BALLOON) MAP A
H-HR = 1900 PST 29 OCT. 1958
CLOUD TOP = 18,000 FT. M.S.L.

Residual Gamma Radiation
Mr/HR at H + 1 Hour

Legend
- Dose rate contours, measured
- Dose rate contours, estimated

Meteorological Data (1907 PST)
REMARKS

The part of the pattern between the area of induced activity very near the burst site and Cane Spring Road is highly speculative, and it is not known whether or not there was a continuous pattern of very light fallout from the burst area to the Cane Spring Road.

Along Highway 95 from Mercury to about 4 miles east of Lathrop Wells no activity distinguishable from background was observed in a survey made between 1.5 and 2.3 hours after the detonation. It is suspected, however, that the survey was made before fallout arrived. Based on the fallout recorded at Lathrop Wells, the arrival should have been at about 3 hours after the burst.

In general, the off-site pattern is unreliable.
REMARKS

A special survey for approximately a thousand foot radius around the Blanca crater was begun in December 1958. About half of the area was monitored then, but some delays in the completion of the survey until April 1959. In April the sector sloping between bearings of about 200 and 220 degrees was monitored. The activity in this area may be less relative to the initial December survey due to the effects of weathering. Also, because of the limitations of the survey, the effect of errors in the assumed decay law may be greater than unusual.
REMARKS

The small-scale on-site map shows three tongues of activity crossing the back road to the mesa also referred to as the Castle Rock Road. This road was monitored shortly after the Blanca detonation and again about 7 months later. Due to inadequate mapping and the scarcity of good reference points, there is considerable uncertainty in the location of the peak or peaks of activity on this road. One of the two teams making the initial surveys reported a peak 0.5 mile south of Castle Rock which would have been about 10 r/hr at H+1. The other team reported a peak 2.0 miles north of Castle Rock of 50 r/hr as of H+1.

When the survey was made 7 months later, reference stakes were available at half-mile intervals along this road, so that the location of the fallouts detected is much more certain than in the initial surveys. This late survey indicated three peaks 0.5, 1.5 and 2.9 miles north of Castle Rock. The conversion by the $t^{\frac{1}{2}}$ approximation would indicate H+1 dose rates respectively of about 1, 1.5 and 5 r/hr. Since this was a careful survey with accurate positioning, these peaks were assumed to have existed at the locations indicated. However, because of the probable reduction in radiation by weathering and the errors probably attendant in assuming a simple decay law to be valid for such a long period, the H+1 dose rates were estimated from the initial survey. It should be noted that there is an order of magnitude discrepancy in the estimation of the H+1 dose rates from the early to late survey.

With the uncertainties mentioned above and the large areas that could not be monitored between the venting site and the Castle Rock Road and west of this road, there is very little confidence in this pattern.
The dust cloud from Blanca was observed to be traveling toward the southwest at about ten minutes after the burst. About 15 minutes later it was reported to be traveling up Forty Mile Canyon. The rough trajectory of this dust cloud is indicated on the map. Also shown is the meteorological trajectory for 7,500 feet m.a.l. This trajectory was estimated to have moved initially toward the southwest for about 4 hours and then to have curved northwestward over Smokefall Flat, toward Tonopah.

Air sampling off-site showed a significant increase in alpha activity at Tonopah, Goldfield, and Beatty, which is attributed to Blanca. The beta activity measurements showed only a slight increase at these locations. Since the area west of the Test Site along Highway 65 was not monitored except near Labury Wells, it is not certain that fallout from Blanca occurred off-site; but the alpha measurements, the trajectories, and possibly the beta measurements indicate that some light fallout did occur off-site.
MAXIMUM AT G.Z. ~
10 R/Hr. AT H+1
REMARKS
There was a trivial yield from Titania and a cloud height of about 8,000 feet m.s.l. was observed (a rise of about 1,500 feet). The only available meteorological data at about shot time were the wind observations at Yucca Lake (about 15 miles south of the burst point) and at Station 253 (about 3-1/2 miles south of the burst point on Road No.). Based on these observations the pattern has been oriented toward the southwest and the isoline left open in the southwest quadrant.

No off-site contamination was detected.

Upper Winds at Yucca Lake Weather Station
(Elevation 4924 feet m.s.l.)

Observation at 1237 PST

<table>
<thead>
<tr>
<th>Height(m.s.l.)</th>
<th>Direction (degrees)</th>
<th>Speed (knots)</th>
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<tbody>
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<td>12</td>
</tr>
<tr>
<td>9,000</td>
<td>040</td>
<td>11</td>
</tr>
</tbody>
</table>

15-Minute Average Winds
20-foot Tower at Station 253
(Surface Elevation About 4325 feet m.s.l.)

<table>
<thead>
<tr>
<th>Time (PST)</th>
<th>Direction (degrees)</th>
<th>Speed (m.p.h.)</th>
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<tr>
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</table>

TITANIA (25 FT. WOOD TOWER) MAP A
H=HR=1234 PST 30 OCT. 1958
CLOUD TOP= 6000 FT. M.S.L.

RESIDUAL GAMMA RADIATION
MR/HR AT H+1 HOUR

- LEGEND -

- - - - DOSE RATE CONTOURS, MEASURED
- - - - DOSE RATE CONTOURS, ESTIMATED