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Folder RAD. FALLOUT FROM UPSHOT/KNOTHOLE

Dr. Gaalen L. Felt
J-Division
Los Alamos Scientific Laboratory
Post Office Box 1663
Los Alamos, New Mexico

SUBJECT: Fall-out from TUMBLER/SNAPPER Tower Shots

Dear Dr. Felt:

Reference is made to your letter, subject: "Fall-out Model", dated 7 July 1952 (Reference # J-12686) in which you described your method of determining radioactive fall-out. I have prepared the fall-out plots for the last four shots of TUMBLER/SNAPPER Test Operations, all of which were tower shots. These fall-out plots are inclosed. They are based on the data contained in TUMBLER/SNAPPER Radiological Safety Report which is due to be published in the middle of February 1953. Actually the curves drawn represent the fall-out quite accurately. Approximately twelve mobile ground teams collected data on the ground and two air planes. These airplanes were so well instrumented that it was possible to extrapolate from the air readings to readings on the ground with a high degree of accuracy. This indicates that it is possible to obtain quantitative data using airplanes. The density of readings are approximately 4 readings in a square of 15 miles on each side for the aircraft readings.

The airplane data was used to pick up the maxima of fall-out. In every case the maxima occurred where the particle size came out to be between 100 to 150 microns using Stokes Law fall-out. I believe that this is a remarkable confirmation of the fact that in the area between 10 miles from ground zero and 200 miles from ground zero, Stokes Law relation applies quite well for the fall-out from tower shots. As a matter of fact in shot no. 5 (see Figure 1), Stokes Law shows that the fall-out particles at Ely, Nevada were in the size range of from 50 to 100 microns. The Cascade Impactor Data from Schulte's unit indicates that the fall-out at Ely at this time was 70 microns, and it is this type of confirmation that increases our confidence in the method.

When a study is made of the inclosed four Figures it is at first difficult to understand why the total fall-out varies as much as it does from one shot to the other in view of the fact that the yields of all four shots were about the same (10.7 KT to 14 KT) and they were all 300 ft. tower shots. The only explanation of this must lie in the meteorological variable, since it was only the weather that

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showed any difference from one shot to the other. This indicates that even for a constant mixing fraction there will be a considerable amount of variation in total fall-out area and fall-out intensity. Incidentally, you may be interested to note that my calculations indicate that from 25,000 to 75,000 tons of sand and soil debris were mixed in with the mushroom of the atomic clouds for the TUMBLER/SNAPPER tower shots. However, it should be noted that this is an order of magnitude figure only and the actual value may be two or three times greater than this.

If I were asked to choose the factor which is most important in determining the extent and intensity of fall-out, I would say that the maximum height reached by the stabilized atomic cloud (5 to 10 minute old cloud) is the most critical factor. An inspection of Table II (inclosed) shows that shot no. 5 reached only 34,400 ft. msl and shot no. 7 reached 37,100 ft., and the others rose to above 40,000 ft. and Table III shows that the total fall-out area was 17,000 sq. miles for shot no. 5, 7000 for shot no. 7, and only 3800 and 4500 sq. miles for shots 6 and 8. From 25 to 30% of the H+1 hour total activity of the bomb was deposited as fall-out within 200 miles of ground zero during shot no. 5. Approximately 8% of total bomb activity fell-out during shot no. 7. The fall-out during shot no. 8 and 6 was 5% and 3% respectively. It seems that the maximum height reached by the cloud is a very important parameter and we should keep our eyes on it for a clue to the eventual fall-out. Actually this could be done rather easily because during TUMBLER/SNAPPER Mr. Planck used to transmit this information within H+15 minutes by the simple expedient of sitting on top of ground zero at 45,000 ft. msl in his jet airplane (T-33). We could have easily anticipated the excessive fall-out of shot no. 5 during TUMBLER/SNAPPER had we realized the significance of the relatively low maximum height achieved by this shot. Of course, the height data must be evaluatec with the height of the tropopause at the given time, for it seems that all atomic bombs above 5KT tend to reach the tropopause. Lt. Col. Spohn has an explanation of the reason why shot no. 5 failed to reach the tropopause. You will remember that the upper air wind speeds for this shot were higher than normal (90 to 100 knots). Col. Spohn thinks that this excessive wind speed increased the rate of air mixing into the mushroom so that temperature equilibrium was reached earlier than in the later shots and the cloud rise was thus arrested even before the cloud reached the tropopause. Although it is true that shot no. 5 cloud was approximately 6000 ft. below the average height achieved by the other clouds, I don't believe that this can explain completely the excessive fall-out during shot no. 5 as compared to the relatively smaller fall-out of shots 6, 7 and 8. For as I mentioned above, approximately 25% of H+1 hour total bomb activity was deposited on the ground for shot no. 5, but only 3% for shot 6, and 8% for shot 7 and 5% for shot 8. What I believe happened during shot no. 5 was that there must have been a relatively strong vertically downward component of wind associated with the very strong horizontal wind speeds. I have a suspicion that what we had in this case (shot 5) was a segment of the jet stream over ground zero. From this experience, it may be worthwhile to keep in mind that 10 to 20 KT or higher yield bombs shoul not be fired from 300 ft. towers when the wind speeds aloft exceed 75 knots consistently.

Reference is made to Table II. It is possible to predict the relative value of the maximum fall-out from the wind speed shear and wind direction shear, keepi in mind that the wind direction shear is a more important factor than wind speed shear. For example, for shot no. 5, maximum wind speed shear is 60 knots and

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maximum wind direction shear is 40° and the maximum fall-out area infinity dose is 21 roentgens. (From Tables I and II), and for shot no. 7, maximum wind speed shear is 25 knots, maximum wind direction shear is 30° and the maximum fall-out area infinity dose is 30 roentgens. For shot no. 8, maximum wind speed shear is 120° and the maximum fall-out area infinity dose is 6 roentgens. For shot no. 6, the maximum wind speed shear is 30 knots, the maximum wind direction shear is 180°, and the maximum fall-out area infinity dose is only 2 roentgens. It should be noted that the above wind data is not H-hour data, but wind information from H-hour to H+5 hours. In the case of shot no. 8, for example, the wind shear increased considerably over that indicated at H-hour, although the forecast for H-hour winds was quite accurate. From the data inclosed I have developed the following experical rules to determine the location and intensity of the maximum fall-out area and some indication of the extent of the fall-out area. It is realized that these relations are based on data collected on only four tower shots, but since the tower heights will remain the same (300 ft) and the soil composition is the same, there are only two variables, meteorology and bomb yield. The empirical relations given below apply only to 300 ft. towers at NPG:

A. The distance and direction of the fall-out maximum with reference to ground zero can be found by the process of simple vector addition of winds. Assume Stokes Law applies where

$$V = \frac{2gr^2 (d_2 - d_1)}{9 \eta} \left(1 + \frac{B}{rP}\right) \text{ - - - - -Equation 1}$$

V = velocity of fall of particles in air in cm/sec.
g = acceleration of gravity
r = radius of particles
assume r = 60 microns within maximum fall-out area
d_2 = density particles = 2.5 gm/cm^3 for tower shots
d_1 = density air = 0

η = viscosity of air
P = barometric pressure
B = a constant

See Humphreys' text ("Physics of the Air" by W. J. Humphreys, Page 592) for values of constant B. The viscosity of the air, η, should not be taken as a constant. Humphreys attributes the following equation to Millikan (Phys. Rev. 12, 217, 1913):

$$\eta = \frac{150.38\, T^{3/2}}{T + 124} \times 10^{-7} \text{ - - - - - - - - Equation 2}$$

where T = absolute temperature.

I believe this variation of viscosity with temperature should be used, or a more recent formulation of the variation of η with temperature may be used. Once the rate of fall of 120 micron particles is established at different heights in the atmosphere, the wind information may be utilized to determine the fall-out of a

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particle from the center of the mushroom of an atomic cloud. It will be assumed that $\eta = 1.45 \times 10^{-4}$ poises at 40,000 ft. (-40°c) and $\eta = 1.87 \times 10^{-4}$ poises at sea level (+ 25°c). It would not be accurate to take the average value of η since the upper air winds are normally stronger than the surface winds, and if an average value of η is used the maximum will be further out from ground zero than in the actual fall-out case provided the wind directions don't vary too much with height. It will be assumed that the rate of fall of a 120 micron particle is 120 cm/sec in the region of from 40,000 ft. msl to 20,000 ft. msl, and that this rate of fall reduces to 100 cm/sec between 20,000 ft. and sea level. This means that the particle starting at 35,000 ft. msl (30,000 ft. above terrain) will fall 15,000 ft. in first 50 minutes and 15,000 ft. in the next 75 minutes before it reaches the ground (assuming NPG is 5000 ft. msl). By this method it is possible to locate the maximum fall-out area with reference to ground zero. The method I propose here is essentially a fall-out plot normally used by most weather personnel with the exception that it plots the fall-out from one point in the center of the mushroom cloud and it uses one particle size with due regard to the change of viscosity of the air with temperature.

B. Once the maximum fall-out point is located it can be assumed as a general rule that the 1 roentgen infinity dose line will inclose an area of approximately 1000 square miles at H+2 1/2 hrs. This area could be taken as elliptical with the major axis in the direction of the upper air winds. In the presence of very strong upper air winds (75 to 100 knots) this area may be increased to 1500 square miles, and in the case of relatively weak upper air winds (10 to 15 knots) the area may be reduced to 500 to 750 square miles.

C. The maximum reading within this fall-out area may be found by the following relation:

$$D = \left(30 - \frac{A}{5} - \frac{B}{20}\right) \frac{Y}{15} \text{ - - - - - - - - - - - - - Equation 3}$$

where
D = Life-time integral dose in roentgens
A = maximum wind direction shear in degrees from 10,000 ft. to 40,000 ft. msl
B = maximum wind speed shear in knots from 10,000 ft to 40,000 ft. msl
y = equivalent yield of the bomb in KT

The relations given in paragraph 5 above may be used to delineate the fall-out area and to indicate the probable maximum intensity in the fall-out area. There is some indirect evidence of particle size. For example on the elliptical fall-out area nearest to ground zero the particle size would probably be from 150 to 200 microns; at the maximum fall-out point the particle size would be nearly 120 microns and on the far side of the elliptical area the fall-out particle size would be between 50 and 100 microns. These figures are valid only for 300 ft. tower shots and at Nevada Proving Grounds.

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An inspection of the inclosed four figures shows that the detonation of 10 to 15 KT bombs from tower shots is marginal if Lincoln Mine personnel are not to receive greater than 3 to 10 roentgen life-time dose for each series of atomic test operations. During TUMBLER/SNAPPER (Restricted) Test Operations Lincoln Mine personnel did not receive above 1 to 2 roentgens integrated dose, but as the inclosed figures indicate they could very well have received a 5 to 10 r dose during shot No. 5 if the winds aloft had been 50 knots instead of 75 knots on the average. Similarly each of the other tower shots could have exposed Lincoln Mine to 1 to 5 roentgen integral doses under favorable (or rather unfavorable) wind directions and wind speeds. I have seen the projected UPSHOT/KNOTHOLE (Restricte schedule where it is proposed to detonate a number of 30 to 40 KT tower shots. This has me worried: There is a relatively large probability that one or two (or perhaps more) of the tower shots may produce fall-out in the populated areas nort east of NPG in excess of the 3.9 roentgens allowed to test personnel. This fall-out may produce life time doses of from 10 to 50 roentgens. In view of this it is recommended that the Off-Site Rad Safe Unit for UPSHOT/KNOTHOLE (R) be increa in size from the presently projected unit of 20 to 30 personnel to a strength of 50 to 75 persons. It is disturbing to me to hear that the Off-Site Rad Safe Uni for UPSHOT/KNOTHOLE (R) operation will be reduced to a small fraction of the uni we had at TUMBLER/SNAPPER (R), and that terrain survey by aircraft will be minimized. As far as I can find out here from purely hearsay it seems that monitors will be placed only at the populated areas. The theory behind this being that it does not matter what or how much radioactivity falls-out in the areas between the inhabited areas. If this is the thinking for UPSHOT/KNOTHOLE (R) Rad Safe I disagree very strongly on the basis of the inclosed information. If anything, the Off-Site Unit during tower shots of UPSHOT/KNOTHOLE (R) should be increased over that we found necessary during TUMBLER/SNAPPER (R) Test Operations because during UPSHOT/KNOTHOLE (R) it is proposed to detonate some bombs which will be a least twice the yield of the tower shots of TUMBLER/SNAPPER (R). There is every likelihood that the fall-out will be doubled or trebled during UPSHOT/KNOTHOLE (R (on the basis of the present schedule of shots and on the basis of the expected high yields). We allow test personnel approximately 3r integrated dose for each series of test operations. And we monitor personnel carefully and insist on the taking showers in the event that we find any trace of radioactivity on their clothes or in their hair etc. I have indicated in this letter that there is a high probability that one or more of the tower shots will subject Lincoln Mine or some other populated area to an integrated dose of from 10 to 50 roentgens of gamma rays. But remember that the 10 to 50 roentgens of gamma rays are due to fall-out of fission products. This means that at least an equal or greater amou of Beta-active radio isotopes may lodge in the clothing and hair of personnel exposed to fall-out. Such people will not have the benefit of monitors and will not be forced to take showers, etc. At the end of the TUMBLER/SNAPPER (R) Test Operations the Rad Safe Unit was advised that a number of cattle which were grazing 75 miles N.E. of ground zero (this is the maximum fall-out area for sho No. 5) developed beta burns on their backs. Our comment at the time was that i any epilation or hair discoloration had occurred on the animals (we didn't believe the report on beta"burns") then the animals must have been within 5 to 6 miles of ground zero, becuase the fall-out beyond 10 miles of ground zero could not cause epilation. On the basis of what we now know, and after analysis of all the data we are now convinced that the cattle could have received relativel high localized skin doses from the fall-out since they were in areas where the

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gamma ray integral dose was from 10 to 20 roentgens and the dose rate may have been as high as 5 roentgens of gamma per hour. It is recommended that during the tower shots Lincoln Mine and Groom Mine personnel or people in other populated areas where the fall-out may occur be warned to stay indoors from H+1 hour or until the Rad Safe Monitor indicates it is time for them to come out. In the event that the fall-out misses the area completely, this procedure involves keeping personnel indoors for 3 to 4 hours (H+1 to H+4 or H+5 hours). If the fall-out is excessive in the populated area the people could be advised to stay indoors during the whole day. If they do this the integral life time dose received by the population will be decreased by at least a factor of two and it may be decreased as much as a factor of 3 to 5. These figures are based on the typical fall-out which was evidenced at Lincoln Mine, Groom Mine and at Ely during TUMBLER/SNAPPER (R). From these data it is obvious that from 50% to 75% of the life time dose is receiv in the first 24 hours of fall-out and by the simple process of going indoors the dose rate is reduced to one half of its outdoors value. What is more important, howeger, by going indoors personnel are not exposed to the direct fall-out of fission products which may get lodged in the hair of the head or in eyebrows, etc. Although evacuation of a small community like Groom Mine (7 to 12 people) may be accomplished with relative ease, the evacuation of Lincoln Mine (215 people) is next to impossible and certainly the evacuation of a city like Ely is not at all possible unless the National Guard is used or some such effort of equivalent magnitude is employed. I certainly do not advocate evacuation of any community on the basis of 10 to 50 roentgen life-time dose, but that problem belongs to the AEC Division of Biology and Medicine. I believe that if there are a sufficient number of Off-Site Monitors and they are mobile and if they have good communications wit the C.P. the original schedule of tower shots of UPSHOT/KNOTHOLE (R) could be accomplished without excessive dosage being received by the people living in the periphery of NPG. However, if the Off-Site Rad Safe Unit is reduced in strength as it is proposed to do, and what is worse, if the Off-Site Rad Safe Unit is askec to stress the measurement of particle sizes, beta activity and other laboratory measurements, I'm afraid they would lose their mobility and their ability to deal with the immediate and urgent problems of Rad Safety.

It is recommended that the Off-Site Rad Safe Unit concentrate in determining the external hazard, i.e. the gamma ray dosage in the fall-out area as fast and accurately as possible. The determination of particle size, beta concentration, specific activity of particles and related problems that was carried on by Mr. Schulte's Unit and by Dr. Larsen's Unit should be done after the Rad Safe Operati as such have been completed or at least after the Off-Site Rad Safe Gamma Ray Hazard has been properly evaluated throughout the fall-out area. I make this recommendation despite the fact that during TUMBLER/SNAPPER (R) Operations I took the lead in attempting to use airplanes and staff cars to rush filter papers etc. to the C.P. for beta analysis and particle size determinations. On the basis of the experience gained during TUMBLER/SNAPPER and after analysis of all the data gathered it is evident to me that no such speed was required in evaluating partic sizes of fall-out or the beta activity concentration. These parameters are very

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important. But they should be done more slowly (hence more accurately) and in order to complete the long range radiological safety picture. Attempting to perfor this type of laboratory analysis under the urgency and stress of atomic test operations may reduce the accuracy of the work and it does not answer any questions of immediate urgency that the gamma ray picture could not answer.

To summarize, it seems that the first fall-out maximum that your method predicts is verified by the actual fall-out during tower shots of TUMBLER/SNAPPER(R). It is recommended that more attention be paid to the meteorological parameters, such as shear etc. in your system. A purely mechanical system is proposed to locat the first fall-out maximum point using the winds aloft and Stokes Law relation with proper evaluation of the variation of air viscosity with temperature. This fall-out plot would be valid only for tower shots and within the region of from 10 to 200 miles from ground zero. An empirical relation is given to determine the intensity of the maximum fall-out based on speed and direction shears of the winds aloft. It is recommended that the fall-out area from UPSHOT/KNOTHOLE (R) tower shots be determined with the same attention to detail and the same accuracy as it was done during TUMBLER/SNAPPER (R). This is required since relatively high intensities of fall-out are anticipated from the higher yield UPSHOT/KNOTHOLE (R) tower shots. It is recommended that the Off-Site Rad Safe Unit be augmented considerably over the relatively small unit proposed for UPSHOT/KNOTHOLE (R) at the present time. It is recommended that adequate terrain survey be performed by aircraft since TUMBLER/SNAPPER (R) data indicates that it is possible to obtain quantitative data by this method. It is recommended that the Off-Site Unit be so trained as to be able to make decisions on the spot whether or not people in populated areas should be kept indoors during fall-out of radioactivity. Keeping personnel indoors will reduce the integral dose by a factor of two or more.

My unit has released me for a period of 20 to 30 days for temporary duty with the Rad-Safe Unit of UPSHOT/KNOTHOLE (R). My temporary duty with the Rad Safe Unit will start on 5 March 1953 and I will probably remain at the Test Site until the end of the first or second shot of UPSHOT/KNOTHOLE (R). Hence I would be available to you, or Dr. Clark or Dr. Graves in the event that any or all of you might want further justification of the inclosed curves and tables. I believe that there is a high probability that some populated area in the periphery of NPG may receive from 10 to 50 roentgen or higher integrated gamma ray dose from the fall-out of the proposed tower shots from UPSHOT/KNOTHOLE (R) Test Operations. In the event that such a dose rate is considered excessive I would be glad to bring over supporting data to indicate why I believe such high doses will be received during UPSHOT/KNOTHOLE (R). Feel free to call on me at anytime in this matter.

Sincerely yours,

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N. M. LULEJIAN
Major, USAF
Directorate of Nuclear Applications
Office of Deputy for Development

6 Incls:
Figures 1 thru 4
Tables I thru VII

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MEMORANDUM FOR THE CHIEF WEAPONS TEST DIVISION

SUBJECT: ARDC Paper (Major Lulejain)

Since the factors by which the dosages which Major Lulejain has indicated may be reduced thru yield and meterological considerations, one way to prevent the dosages reaching high (relative) values is by "use of weather" as was done in IVY and GREENHOUSE. For example, at times for shot time decisions, wind directional shear would be one more factor the advisory panel to the test director must take into account. As a member (ex) of the advisory panel for BUSTER-JANGLE and TUMBLER-SNAPPER for RAD SAFETY this matter of a "narrow down wind cone" has been a factor of concern. Rather than many more ground survey personnel (if numbers are a consideration), waiting for desired shear conditions is the alternative which produces the results desired, putting large numbers of people indoors can result in a "poor public relations" if not handled very carefully. It has been well known for sometime that certain shots are touchier than others because of yield, near surface, etc and even of "dud". These will continue to be problems in detonation with minimum disturbance to local populations. Personally, I have used a factor of 10 to 1 in dosages to persons indoors vs outdoors. In this I had the concurrance of Dr. Shields Warren. I don't believe this paper helps the Test Director only insofar as he will now wait for positive wind directional shear. If bodies are available, he could beef up the off-site survey group. It should be noted, however, that this data collected and analized by Colonel Gwynn and Major Lulejain is excellent and the first real field data ever obtained on such a scale.

Respectfully

R. H. MAYNARD
Captain, USN

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