CASTIE LOCAL FALL-OUT FORECASTING

1. The method of calculating local fall-out, as described here, is the hasty outgrowth of a more complex method that had been unexpectedly successful in accounting for the BRAVO fall-out pattern in the Alingnac-Rongelap-Rongerik area. As the time of the last shot (on Eniwetok Atoll) approached, the problem of forecasting local fall-out became more acute. Since the method attempted to take account of the initial size and shape of the cloud, it seemed that it should be suitable for local forecasting. With the aid of Dr. Gaelen Felt, the method was simplified to the extent that an atoll pattern could be estimated within about an hour, the simplified method was tested against the Bikini patterns produced by ROMEO, UNION and YANKEE and found satisfactory,* and the method was used in forecasting for NECTAR.

2. The following description covers the simplified method only. The more complex method warrants further study which will be reported elsewhere.

3. Assumptions:

(a) The initial cloud (after rise is practically completed) is divided into horizontal slices, each of 10,000 ft depth, with centers at 10,000, 20,000, - - - - 70,000 ft altitude, with the central concentration (radioactivity per unit volume) independent of altitude.

(b) In each layer all of the activity lies in a horizontal plane thru the center.

(c) In each layer, the concentration falls off laterally according to the law of normal distribution of errors

$$c\ (r) = C_0\ e^{\frac{-r^2}{a_0^2}}$$

where C_0 is the initial central concentration, r is distance from center, and

a_o is the initial spread parameter (analogous to standard deviation). For altitudes 10,000 thru 40,000 ft, $a_o = 1.9$ miles; 50,000 thru 70,000 ft, $a_o = 5.8$ miles.

(d) Thruout the whole cloud, all radioactive particles are of the same size, and fall at 50,000 ft per hour.

(e) In each layer, the central particle falls, without diffusion, as directed by the winds, while other particles diffuse horizontally away from the center equally in all directions so that, when the layer arrives on the surface, the distribution about the center is given by

$$c\ (r) = \frac{C_o}{p^2} e^{-\left(\frac{q}{p}\right)^2}$$

where $p = \frac{S_o + S}{S_o}$, $q = r/a_o$, S = total horizontal distance travelled by the central particle, $S_o = 5.2\ a_o$. (The last quantity may be pictured as the horizontal distance back to a fictitious point source of the cloud layer).

(f) The dose rate at any point is proportional to the sum of the concentrations from all of the layers as estimated from the preceding formula.

4. Apart from the assumption of a single particle size this formulation has a number of other obvious defects, e.g.

a. The sum of the quantities $C_o a_o^2$ should be made proportional to the total radioactive yield of the "bomb." In practice, the final estimates were adjusted somewhat on account of expected yield. This, in effect, allowed for the influence on C_o, but not on a_o.

b. The estimation of S as total <u>horizontal</u> distance is rather unsatisfactory in local forecasting where the atoll dimensions are not much greater than the height of the cloud.

Also, there was no time to find out whether better results could be obtained by

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choice of some other rate of fall for the particles. From the test of the method against the Bikini patterns, it was clear that it was good enough for the purpose at hand. It appeared that differences between forecast and actual winds would be likely to produce much larger errors than those inherent in the assumptions.

5. In application, the method is not as tedious as might appear. The standard hodograph plot, giving the location of central particles falling at 5,000 ft per hour, is prepared for the briefing as a matter of course. It can be superimposed on a ten times magnified atoll map, allowing for the 50,000 ft per hour fall rate assumed in the method. With a ruler of corresponding scale, the distances S, along the zig-zag path to each of the height points on the hodograph can be quickly measured or this can be done by summation of "hodograph" winds if these are more readily accessible. Likewise, the distances from the altitude points on the hodograph to points of fall-out interest can be quickly measured with the ruler, giving the values of r. Knowing S and r, one can easily compute p and q. With the aid of a family of curves of $\frac{1}{p^2} e^{-\left(\frac{q}{p}\right)^2}$ vs q (see Fig. 1) for several values of p, one can rapidly interpolate the values that must be added up at any location. The exponential factor drops off very rapidly with q, and after working out a few cases, one can tell, from an inspection of the hodograph-on-atoll plot, some of the altitude points that can be neglected in the computation.

6. Fig. 2 and Table 1 illustrates the application of the method to NECTAR shot, using the winds observed at shot time. The points on Fig. 2 marked 10, 20, 30, are the 10,000 ft, 20,000 ft, - - - altitude points on the hodograph for particles falling 50,000 ft per hour. A particle starting, for example, at 30,000 ft above ground zero, and falling under the influence of winds but not diffusion, would land at the point marked 30. The value of S, the horizontal distance

travelled, is estimated by summing the distances between the successive points from ground zero to point 30. In calculating q in Table 1, some values are omitted as beyond the range of Fig. 1. More values are dropped, as too small to bother with, in entering the quantities $\frac{1}{p^2} e^{-\left(\frac{q}{p}\right)^2}$. The final totals are the surface concentrations that would be produced if the initial central concentrations (Co) were all unity. When the method was tried out on YANKEE, it was found that if the resultant surface concentrations were multiplied by 100, they agree reasonably well with the dose rate, in roentgens per hour, measured one day after the shot. This factor was used in making up Table 2, and it appears to give fairly good results for BRAVO, ROMEO, and UNION also, although there is some tendency to over-estimate the lower dose rates at the larger distances. In Table 1, however, it is clear that the agreement is about as good as in Table 2 <u>without multiplying by a factor of 100</u>. The yield of NECTAR was less than that of the shots in Table 2, but not by a factor of 100. At the present time the only explanation that can be offered for this discrepancy is the heavy rain that occurred on NECTAR day.

7. There is good reason to anticipate that the current detailed study of the more complex method will yield a better simplified technique than the above. For this reason, there is little justification for a more elaborate report on the method at this time.

TABLE 1

					$q = r/a_o$			
HEIGHT (1000 FT.)	a_o (Mi)	S_o ($5.2\ a_o$)	S (Mi)	P $\left(\frac{S_o+S}{S_o}\right)$	ALICE	JANET	SALLY	ELMER
70	5.8	30	29	2.0	1.6	1.4	2.3	4.4
60	5.8	30	23	1.8	2.2	1.5	1.7	4.1
50	5.8	30	19	1.6	2.1	1.3	2.1	4.5
40	1.9	10	12	2.2	4.5	4.7	—	—
30	1.9	10	9	1.9	3.1	4.2	6.8	—
20	1.9	10	6	1.6	2.4	4.4	—	—
10	1.9	10	3	1.3	1.2	3.0	5.6	—

		$\frac{1}{p^2}\, e^{-\left(\frac{q}{p}\right)^2}$			
HEIGHT	p	ALICE	JANET	SALLY	ELMER
70	2.0	.14	.16	.07	.0020
60	1.8	.07	.15	.12	.0020
50	1.6	.07	.20	.07	—
40	2.2	—	—	—	—
30	1.9	.02	—	—	—
20	1.6	.04	—	—	—
10	1.3	.23	—	—	—
	TOTAL	.57	.51	.26	.002
OBSERVED R/HR at N+1 DAY		.70	.18	.027	.000

TABLE 2

BIKINI R/HR AT D + 1 DAY

ISLAND	BRAVO		ROMEO		UNION		YANKEE	
	OBS	CALC	OBS	CALC	OBS	CALC	OBS	CALC
HOW	24	22	0	0.6	8.5	9	25	30
NON	9	5	0	0.6	0.09	2	2	7
OBOE			0	0.6	0	0.7	0.04	3
UNCLE	1.0	0.9					0	5
BRAVO	1.0	0.6					0.5	0.3
ABLE			50	70			2	5
FOX	55	47			12	45		