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An Evaluation of the Equivalent Fission Yield Vented from Pike

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AN EVALUATION OF THE EQUIVALENT FISSION YIELD VENTED FROM PIKE

DECLASSIFICATION STAMP ON REVERSE.

1. Construction of the Fallout Pattern

The input data used in construction of the fallout pattern included:

1. USWB wind data;
2. REECo rad-safe on-site fallout patterns;
3. USPHS off-site ground monitoring readings;
4. RAMS data at 300, 1,000 and 2,000 feet.

The surface wind data from the site were not used since they were appropriate only to the Yucca Flat Station vicinity, viz. they were blowing 180 degrees from the direction of actual cloud travel in Area 3. The winds at Indian Springs at the time of cloud arrival were slightly more westerly and with very little directional or velocity shear, especially in the lower 2 to 3 thousand feet. These winds carried the cloud down the valley toward Las Vegas where, at cloud arrival time, the winds were blowing from the north. There still was very little directional or velocity shear. As a result, the fallout pattern lies down the valley from Indian Springs to Las Vegas and then begins to turn toward the south.

The off-site data were generally clustered around the Indian Springs-Cactus Springs and the Las Vegas areas with a few readings between. The data taken on D-Day was for the most part not used since we cannot be assured that they do not include shine from the cloud passing overhead. Therefore, the data taken on the following 4 days were used almost exclusively for construction of the pattern. These data are sparse and not always consistent; however, a pattern which estimates the most probable configuration was constructed, and is shown in Figure 1.

The two close-in patterns obtained from REECo Rad-Safe, (one at H + 6 and one at H + 24 hours) and the radector data were used to estimate the close-in activity distribution. The two REECo patterns are shown superimposed in Figure 2. The crossing of contours is probably due to the wind transport of the deposited material between H + 6 and H + 24 hours. Attempts to obtain the raw data in order to make

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(Signature of person verifing this is the correct document or model)

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an independent evaluation of the pattern have not been successful.

2. Integration of the Fallout Pattern

From the pattern, cross-sectional plots of the field intensity as a function of distance measured cross wind were prepared; in all cases the data was, for calculational purposes, calculated back to H + 1 hour using a $t^{-1.2}$ decay. (The decay of intensity at the 1000 and 2000 foot stations follows the 1.2 decay rate closely after the first hour.) No data closer than 300 feet was available, as a consequence intensities closer than 300 feet are estimates only. The arithmethic integration was performed over the area enclosed by the 0.01 $\frac{MR}{HR}$ at H + 1 contour (includes an area of approximately 10^4 mi^2), this contour obviously cannot be determined by measurement but only by extrapolation of the data. The increment of area used in the summation process varied from 4 mi^2 to 0.01 mi^2 depending on the gradient of the radiation field. For reference, the incremental contribution to yield as a function of distance measured from ground zero are summarized in Table I. To convert these data to equivalent fission yield a conversion factor of 0.37 x 10^{-3} $tons/mi^2/\frac{MR}{HR}$ at H + 1 was used. The summation carried 10^4 mi^2 gives 10820 $\frac{MR\ mi^2}{HR}$ or 4.0 tons.

Remembering that the data used in the construction of the pattern is probably good to a factor of 2 at best, we should interpret the results of the integration as follows:

(1) the possible range of values is 2 to 8 tons;

(2) the most likely value is about 4 tons.

Further extrapolation of the data to 10^6 mi^2 has been done, and serves to demonstrate that the contribution to the integration beyond 10^4 mi^2 is less 3% of the total.

3. Calculation of the $(1 - f_c)$ Curve

By measurement of the surface deposited fallout we acquire information which is relevant only to those nuclides which are particulate, or are condensed during venting and air transport, and which fall out. Therefore, we define f_c as the fraction of particulate attached gamma deposited on the earth's surface as a function of time. This can be calculated once the fallout pattern has been

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integrated. The more interesting fraction is $(1 - f_c)$, which is defined as the fraction of particulate attached gamma airborne as a function of time. Note: some particulates are so small that they will settle only by convection and diffusion processes; these are not included. For Pike we can assume that distance as measured along the hot line is directly proportional to time, since there was very little directional or velocity shear. The calculations for the curve are summarized in Table II and the data plotted versus time in hours in Figure 3. It is important to note that three-fourth's of the particulate attached gamma is on the ground within one mile of ground zero, and that nine-tenth's of it is down within fifty miles.

4. Evaluation of the Source from Other Techniques and Data

A. Data derived from the close-in air sampling network designed by LASL H-8 indicates that the total activity passing the 2000 ft arc is that gross beta activity associated with about 3×10^{20} fissions. The uncertainty in this number is about a factor of 3, and further the fractionation among the fission product species was observed to exist to the extent of a factor of 3 for some species. Expressed in terms of yield, 3×10^{20} fissions corresponds to about 2 tons equivalent passing the 2000 ft arc. This value is consistent with the arithmetic integration which gives a total of 1.5 tons of gamma attached particulate deposited on the ground beyond the 2000 ft arc.

B. Based on the analysis of the remote reading dose rate instruments surrounding ground zero at 2000 ft the gross gamma in the cloud at H + 2 minutes was estimated at 10^7 to 10^8 curies. The conversion of curies to tons equivalent fission is uncertain, but the limits would give the range of 0.3 to 10 tons equivalent fission passing the 2000 ft arc.

C. Based on preliminary data, the USPHS acquired aircraft samples at H + 19 and H + 100 minutes. At H + 19 the volume of the cloud was estimated to be 6×10^{10} ft^3. The concentration of debris in the cloud, based on an estimation of the volume samples and a measurement of the sample activity, was 4.5×10^9 f/scf. Assuming the cloud still to be relatively unfractionated, these data lead to a total cloud content of 2 tons at H + 19. Applying the same technique to the H + 100 minute sample gives a cloud volume of

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2.7 x 10^{13} ft^3, a concentration of 2.6 x 10^7 f/scf, and a content of 5 tons equivalent. The most that can be said from this data is that the fallout deposited between 7 and 35 miles (approximate, assuming 20 mph wind) did not deplete the cloud content by as much as an order of magnitude.

5. Discussion

E. Fleming of LRL visited F. Cluff of the Las Vegas branch of the USWB on 17 June. The Weather Bureau has also constructed fallout patterns and integrated them. They use the same techniques as M. Williamson, LRL, namely, they planimeter the areas enclosed by the various intensity contours, and plot on log-log paper the contour area versus the field intensity at its perimiter. The chief difficulty in using this technique is that it offers no obvious way to treat either end of the integration, viz. as the area goes to infinity or to zero. The result is that the contributions made by the ends may be disproportionately large. A conventional numerical integration while not free from error would appear to give a more nearly correct answer. The Weather Bureau integration, carried out over the range of area values from 10^{-3} mi^2 to 10^3 mi^2, gives 8 tons. They also use a larger value of the conversion factor, namely, 0.45 $t/(\frac{MR}{HR})/mi^2$, which accounts in part for their answer being larger than Williamson's.

B. There was no positive identification of airborne debris from Pike by aircraft at long range (> 100 mi); however, aircraft operated by the USPHS, EGG, and the DOD found evidence of fresh fission products at intermediate ranges (< 100 mi).

C. The best evidence of the presence of fresh fission products at long range was supplied by that well known biological integrator, the cow. At Yuma, Arizona, (~ 350 miles from the point of detonation) the maximum concentration of I^{131} in milk was measured to be 80 pc/l on 21 March, which was eight days after the release. This was associated with a maximum concentration of 490 pc/kg of I^{131} on the alfalfa eaten.

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Using the following assumptions and the source number above, the concentration in milk at Yuma can be calculated:

1. t = 15 hrs. This is the mid-point in time of cloud passage over Yuma, the leading edge crossing at +12 hours and the trailing edge at +18 hours.
2. Area of cloud is 10^{10} mi^2.
3. $(1 - f_c)_{18} - (1 - f_c)_{12} = 0.0075$. That is 0.75% of the I^{131} in the initial cloud was deposited during the 6 hour passage.
4. Cow eats foliage growing on 20 m^2 of ground each day.
5. Partition of I into milk is 3%.
6. Cow gives 10 l/day.
7. Peak concentration in milk (at about +7 days after initial deposition) is a factor of 2 greater than the concentration on the first day.
8. One kg of green chop as cut grows on one square meter of ground.

$10^3 \times 0.0075 = 7.5$ curies during passage

$\frac{7.5}{10^{10}} = 750$ pc/m^2 deposited (cf. 500 pc/m^2 measured)

$\frac{750 \times 20 \times 0.03}{10} = 45$ pc/l in milk on first day

$2 \times 45 = 90$ pc/l, the peak concentration (cf 80 pc/l measured)

There is an unknown limit of error associated with each assumption, and in a few cases is as high as a factor of 2. The agreement between measurement and calculation then must occur because these errors compensate, and at least in the case of Pike, indicates the method may not be in error by as much as an order of magnitude.

D. The radiological surveillance network operated by the USPHS at some 60 cities scattered throughout the country reported evidence of fresh fission products from seven of their stations amont them Las Vegas, Los Angeles, Phoenix, El Paso, Santa Fe, and Salt Lake City. Concentrations amounting to a few, viz. 1 to 3, picocuries per cubic meter were reported three to five days after the shot.

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E. Knox has treated the Pike event theoretically using all the latest refinements available to the prediction of fallout patterns. Figure 4 compares the calculated hot line fall-off of intensity with distance assuming respectively 3.7 and 5.0 tons of vented particulate attached gamma. The comparison of these calculated functions with that drawn from the fallout patterns as constructed gives a substantial amount of confidence in our ability to achieve a self consistent picture of the Pike event.

Also note that the $(1 - f_c)$ curves are substantially the same, except that the values calculated from the fallout pattern would deposit a high percentage of the particulate attached activity at earlier times.

The evidence is (1) the model gives reasonable representation of the deposition of particulates for events like Pike, and (2) the Pike data may be applicable to predicting the behavior of future cratering shots.

The first clear test may be Sulky.

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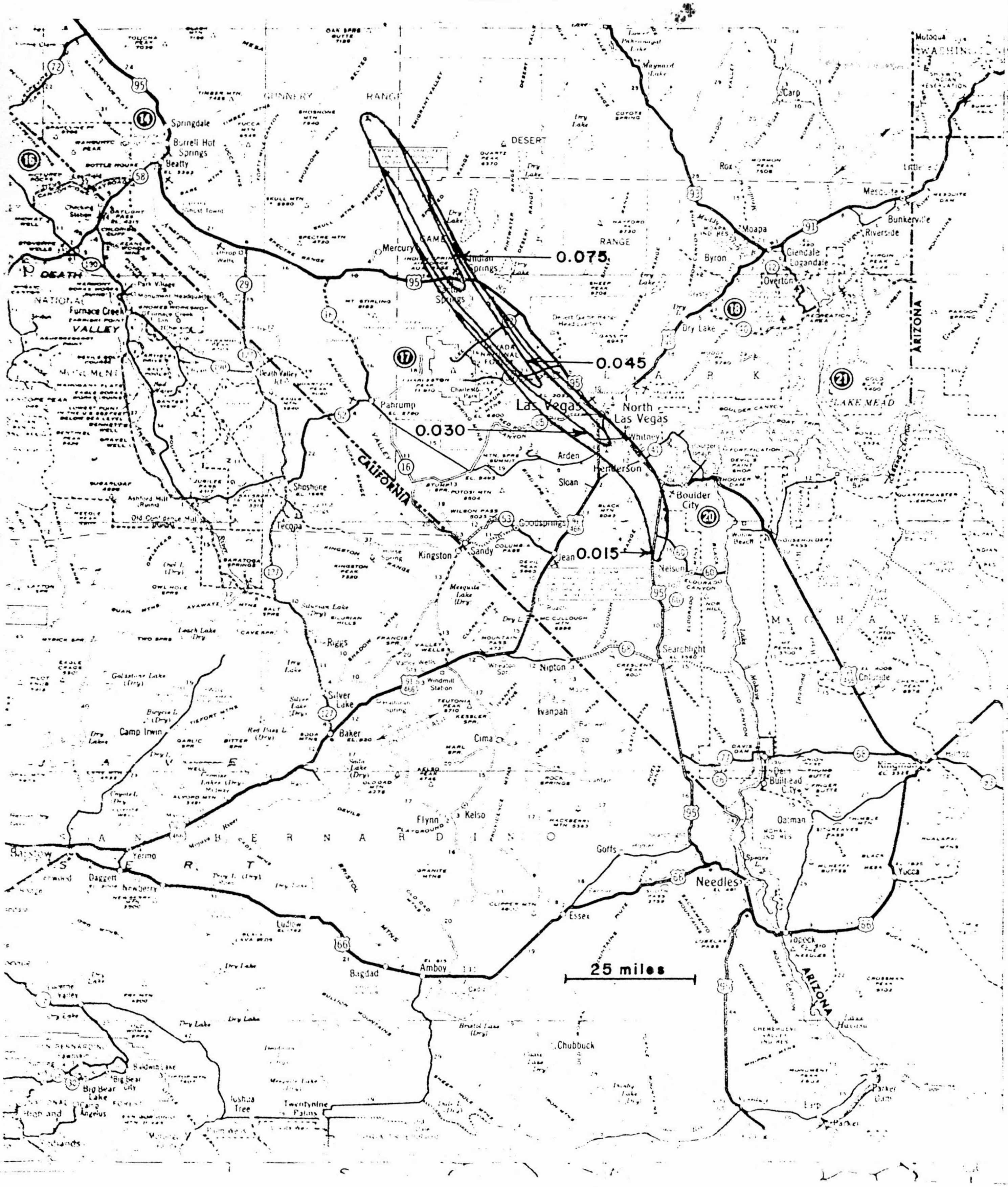
FIGURE I



PIKE EVENT

[redacted] Contours, H + 24 hrs. (mr/hr)

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FIGURE II

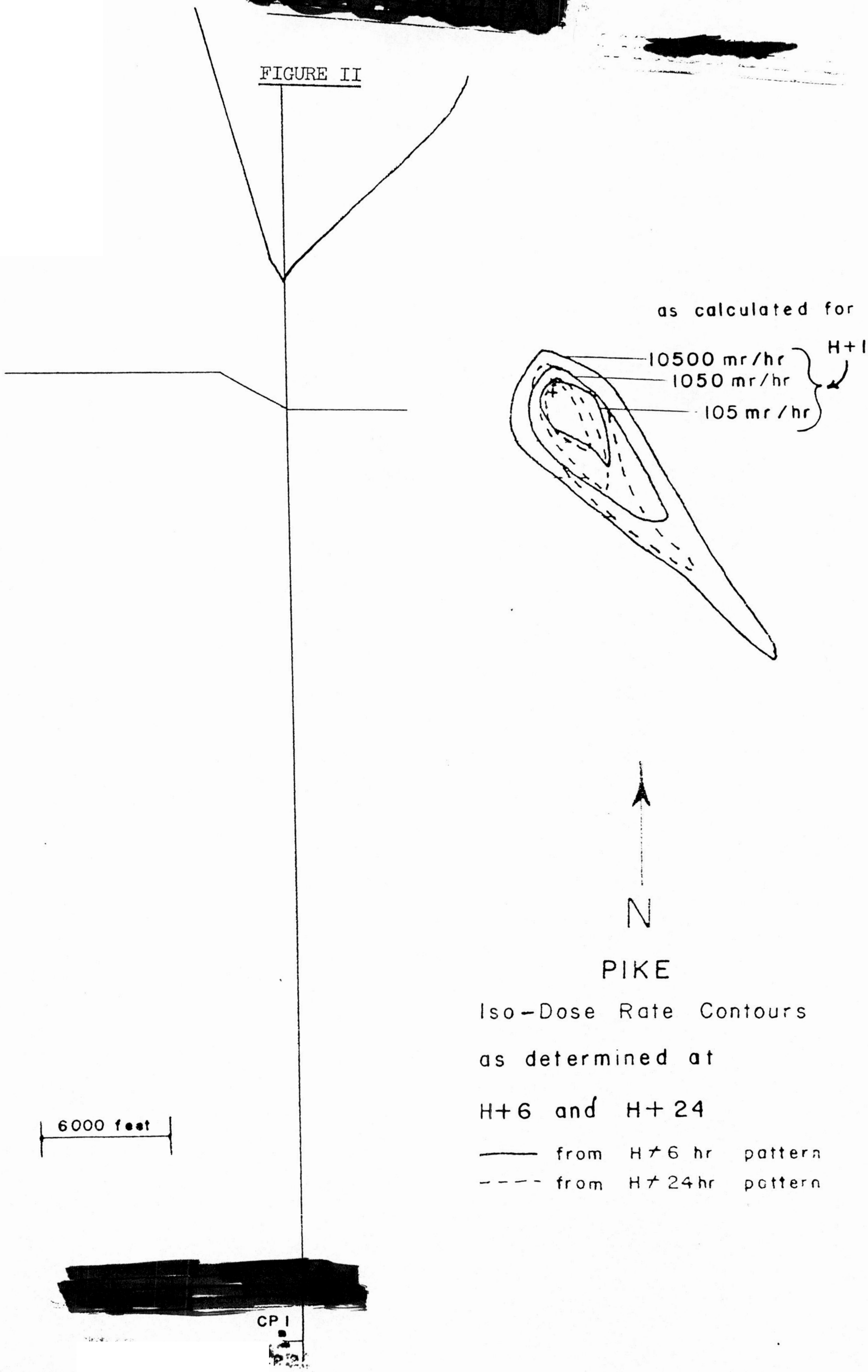

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FIGURE III

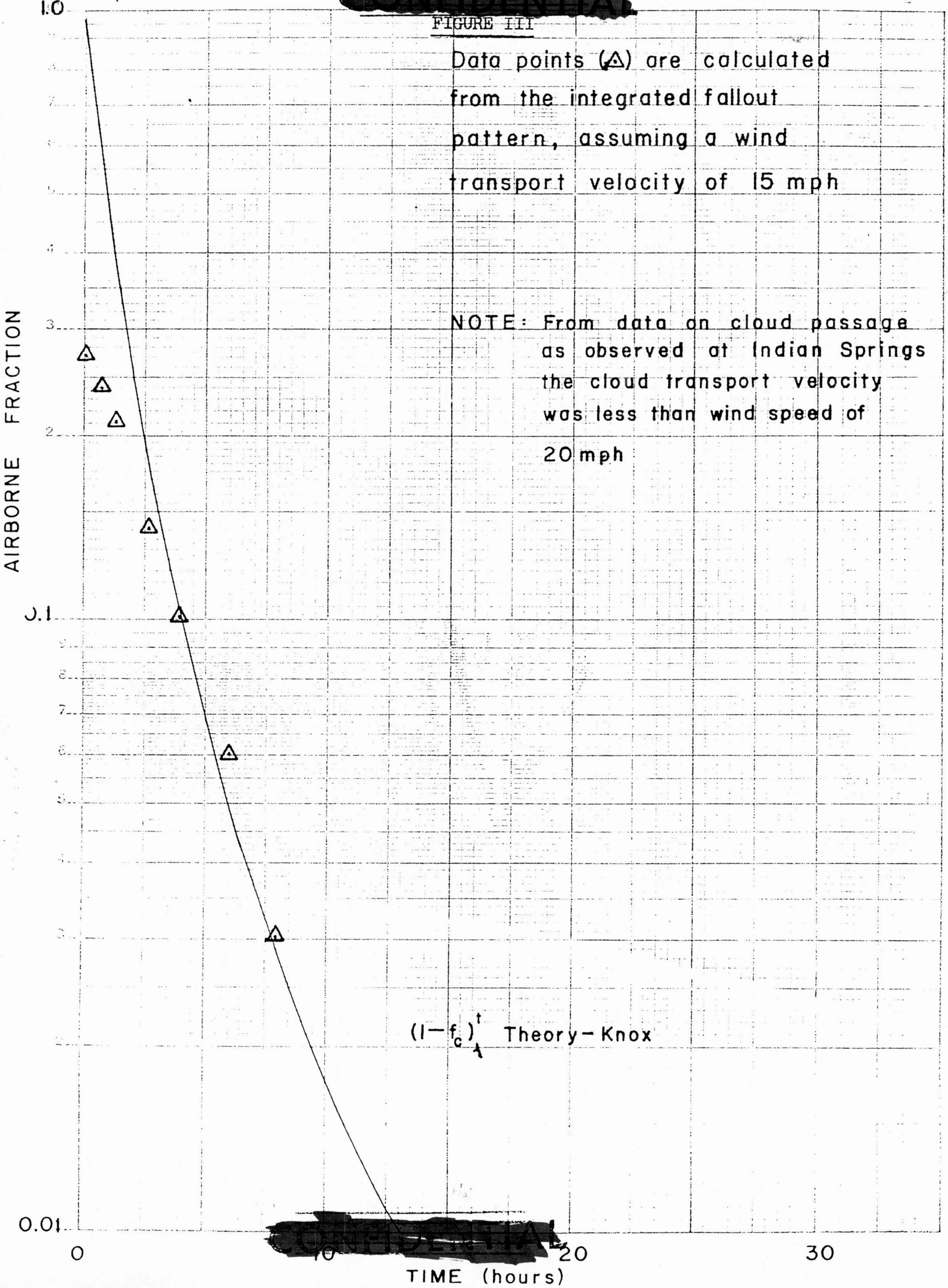

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FIGURE IV

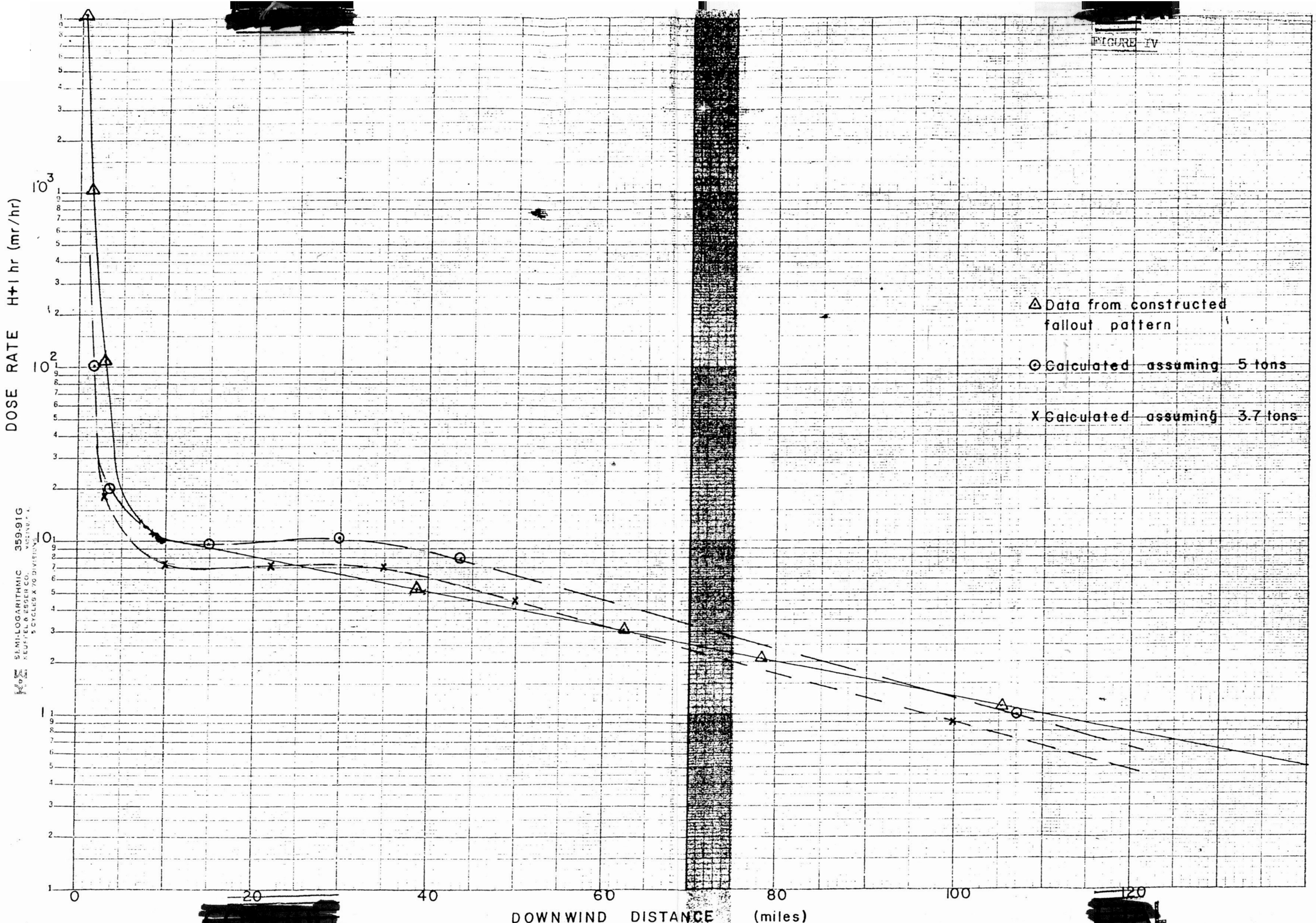

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TABLE I

SUMMARY OF THE FALLOUT PATTERN INTEGRATION FOR PIKE

Increment of Radius (mi)	Incremental Contribution to the Yield (tons)
Behind G.Z.	1.03
0 - .1	.70
.1 - .2	.26
.2 - .3	.24
.3 - .4	.20
.4 - .5	.16
.5 - 1.0	.31
1 - 10	.12
10 - 20	.14
20 - 30	.15
30 - 40	.11
40 - 50	.09
50 - 60	.08
60 - 70	.07
70 - 80	.06
80 - 90	.05
90 -100	.04
100 -110	.03
110 -120	.03
120 -270	.15
TOTAL:	4.02 tons

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TABLE II

RADIUS (mi)	*EQUIV. FISSION YIELD SUMMED TO LISTED RADIUS (tons)	fc	1-fc
0.1	1.73	.43	.57
0.2	2.00	.50	.50
0.3	2.24	.56	.44
0.4	2.43	.61	.39
0.5	2.60	.65	.35
1.0	2.91	.73	.27
10.0	3.03	.76	.24
20.0	3.17	.79	.21
30.0	3.31	.83	.17
40.0	3.42	.86	.14
50.0	3.51	.88	.12
60.0	3.59	.90	.10
70.0	3.65	.91	.09
80.0	3.71	.93	.07
90.0	3.76	.94	.06
100.0	3.80	.95	.05
110.0	3.83	.96	.04
270.0	4.00		

*Column sums all activity calculated to be behind the corresponding radius.

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