A [illegible] Fall-Out

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[illegible]

1\. [illegible] method described herein is [illegible] objective that is intermediate [illegible] operational [illegible], and [illegible] of a strictly scientific [illegible]igation. It [illegible] to be the most [illegible] factors th[illegible] fall-out [illegible], with the idea that we might find out enough about [illegible] simplified method for operational use. [illegible] for local fall-out [illegible]casting is [illegible] by New Techniques [illegible] after CASTLE, [illegible] Techniques" of the Task Force Castle Report. [illegible] further investigation of [illegible] which a constant [illegible] could be assumed.

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The basic assumptions of the method are as follows:

a. The whole cloud, up to its height of stabilization, is formed instantaneously at the time of detonation. This is what we call the "initial cloud".

b. In any height layer of the initial cloud, the concentration (radioactivity per unit volume) is distributed according to the Gaussian law

$$c(r,h) = c_0(h) \exp(-r^2/a_0^2)$$

where $c_0(h)$ is the central concentration at height h, r is the radial horizontal distance, and a_0 is a "cloud parameter" (analogous to standard deviation) that is also assumed to be a function of height. From this assumption it follows that the total amount of radioactivity in a slice of unit vertical thickness is $\pi c_0(h) a_0^2$.

c. Throughout all of any such layer, the radioactivity is distributed normally with respect to the logarithm of the rate of fall of the particles. Thus at any distance, the fraction of radioactivity that falls with speeds in the range f to f + df is given by

$$\frac{1}{\sigma(h)\sqrt{2\pi}} \exp\left[-\frac{1}{2}\left(\frac{\ln \frac{f}{f(h)}}{\sigma(h)}\right)^2\right]\frac{df}{f}$$

where f(h) is the fall rate for particles of median radioactivity, and σ (also considered to be a function of height) is the standard deviation of the logarithm of fall rates, weighted according to radioactivity. f(h) and $\sigma(h)$ are constant throughout the layer.

d. The rate of fall of any particle is assumed constant until it reaches the ground.

e. Any particle that starts from the center of the cloud will follow a path solely in accordance with the wind pattern, while all other particles that fall at the same rate from the same level will diffuse laterally from the central particle in such a way that the Gaussian distribution is maintained.

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During this portion, the increase in the spread parameter is described by

$$\frac{a}{a_o} = \left(1 + \frac{S}{\beta h}\right)^{\frac{\alpha}{\beta}} = p^{\frac{\alpha}{\beta}}$$

where S is the distance traveled by the critical particle until it reaches the ground. (It is to be noted that S is not the straight-line distance from the origin to the landing point unless all winds at all levels are in the same direction). β and α are [illegible] quantities that may be used to describe the amount of diffusion. They are not at present regarded as functions of height. (The quantity p is merely an abbreviation for the quantity in brackets).

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[illegible] From these assumptions it follows that the dose rate on the ground is

$$I = \frac{K}{\sqrt{2\pi}} \int \text{[illegible]} + \frac{r^2}{a^2 p^m} \Bigg] dh \; \frac{df}{f}$$

where K is dose rate per unit of surface concentration, H is the height of the top of the cloud, and r is the distance from the point at which the dose rate is estimated to each of the landing points of central particles. These landing points will depend on the wind pattern below the level from which the central particles originated, so that r is a function of h. The landing points also depend on the rate of fall, so that r is also a function of f. Changing from rate of fall to time of fall, one obtains

$$r^2 = \left(\text{[illegible]} \, (h) - X \right)^2 + \left(\text{[illegible]} \, (h) - Y \right)^2$$

where (X,Y) are the rectangular coordinates of the point where dose rate is estimated, and [illegible] are the wind components in the same co-ordinate system, averaged up to the height h.

b. We may also suppose

$$p = \text{[illegible]} \; \frac{\bar{w}(h)}{\text{[illegible]}(h)}$$

noting that $\bar{w}$ is the average speed regardless of direction. ($\bar{u}$ and $\bar{v}$ are [illegible], in contrast, the components of [illegible].) This assumption is correct if one is satisfied that the diffusion depends on the total horizontal distance travelled by the test particle. If one wishes to assume that the vertical distance should be included, p becomes more complicated.

c. The significance of β and p can now be illustrated. If m = 2, then

$$\frac{a}{a_0} = \text{[illegible]}$$

so that the lateral dimensions of any segment of the cloud will increase

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as if the cloud had come from a point source located at a distance βt_0 upwind. The size increases linearly with distance travelled by the central particle. If m is greater than 2, the borders of the cloud will diverge more rapidly, and if m is less than 2 they will diverge less rapidly. One can prevent any [illegible] by making β infinite or by taking m equal to [illegible]. This method of describing the diffusive process is similar to that of Sutton, but not exactly the same.

[illegible]. If $m = 2$, the [illegible] of t, the area covered by a segment of cloud is proportional to the square of the time, as in Felt's method. However, the proportionality factor varies, as $\bar{w}$ varies with height, and further, the overall proportionality factor changes with the overall strength of the wind field, and in these respects it differs from [illegible]'s method.

[illegible]. Changing to the time variable, the change of variable from ξ to t changes the exponent of the [illegible] to

$$t\,f(h)$$
$$h$$

and of ξ [illegible] dt

One notes also that concentrations in the initial cloud must be related to those that would be expected at the time for which the dose rate is being calculated.

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Information that is needed for a calculation is then:

a. The winds pattern at heights up to H

b. H, the height of the top of the cloud.

c. r_0, the initial [illegible] radius, as a function of height.

d. C_0, the central concentration as a function of height in the initial cloud, adjusted to the time of [illegible].

e. f, the logarithmic mean particle size (adjusted according to radioactivity), as a function of height in the initial cloud.

f. σ, the logarithmic standard deviation of this distribution as a function of height in the initial cloud.

g. [illegible], diffusion parameter, described above.

h. [illegible], diffusion parameter, described above.

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5. a. Testing of the method requires the use of high speed computing machinery. With such machinery one can make many changes in the quantities described above, proceeding on a trial and error basis. In order to achieve some degree of objectivity, the following approach is adopted.

b. The logarithm of the ratio of calculated to observed dose rate is estimated at a number of points for a given shot. This quantity is called γ (gamma). Then the mean gamma, and the statistical variance of the individual gammas about the mean gamma, are calculated. This process is repeated for a number of values of some parametric quantity, beta for example. One then plots the variance against beta, and takes as the best value the one that gives the least variance. One then goes on to other parametric quantities, and treats them in the same way, hoping that there is not too much correlation between the effects of the different types of parameters.

c. It will be noted that this application of the "least squares" method discards the over-all ratio of calculation to observation. In principle it is possible to get zero variance (or nearly so) when each calculated value is, for example, exactly one-tenth the observed value. One would then say that [illegible] of the activity [illegible] deposited in the crater. If, however, one should obtain a good fit but with only 10% of the observed activity accounted for, one would have to consider other possibilities. One would first look to see whether any large fraction of the activity was excluded from the calculation. In the [illegible] integration it is not practical to go all the way from zero to infinite size, and part of the activity might be in particles outside of the size range chosen. If this explanation fails, and if the fit is still good, one has to conclude that the least squares criterion, as applied here, is not useful. We have not yet encountered this problem in practice.

The method of approach is subject to the hackneyed old criticism running as follows: by subdividing the height of the cloud at will, you can obtain as many discrete parameter values of a_0, c_0, f, etc. as you wish, so that you should be able to fit any number of observations exactly. This is true in principle, but if you can get a set of values that look reasonable, and can be related in a sensible way with yield over a wide range, the method can serve a useful operational purpose even though the values might be scientifically unsound.

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[illegible] a. For machine integration, using the [illegible] Model 701 "Defense Calculator", those parametric quantities (a, c, [illegible] f) and the mean wind components ($\bar{u}$, $\bar{v}$, $\bar{w}$), which are functions of height, may be loaded as tables of data. The total height of the initial cloud, [illegible], is divided into M equal layers, each identified by an integer [illegible] 0, 1, 2, ... (M-1). The time variable is [illegible], each time being identified by an integer j = 1, 2, 3, ... N. [illegible] the maximum value of M to 32. N may be any [illegible] machine time, and the minimum and maximum limits of the time integration may be changed at will. The exponential factor in the formula [illegible] as zero if the absolute value of the exponent exceeds a value A which may be as large as 10.

b. The coding is so arranged that the time integration is performed first and the height integration second. At each location, the fraction of the dose rate that comes from each initial cloud layer is computed and may be printed along with the integrated dose rate [illegible] and the coordinates of the location. [illegible] this printing and obtain only the [illegible] for a preselected series of locations.

c. The codes are not yet finished, and additional features are being added from time to time. We have two codes: (1) a full "fixed point" code as outlined above, and (2) a [illegible] "floating point" code that [illegible] which is more flexible in some respects.

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[redacted]

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Since starting on this problem about seven months ago, a considerable part of the time has been spent on coding and de-bugging, which we undertook ourselves in order to learn how to use the Model 701. Using Bravo fall-out data, we demonstrated that least square solutions could be obtained for the various parametric quantities involved. However, the "best" values, as selected in this way, gave fall-out predictions that were only 20 to 30% of the observed values, and the "fit" was not good. We then turned attention to Nevada data for a while, and became interested in an approximation that would avoid a large amount of calculation, one of the two steps in the double integration. Before this possibility had been fully explored, Mr. Ray Shelton, [illegible] Operation [illegible], joined forces with us, and [illegible]. Mr. Shelton then took [illegible] on the Nevada data, while we turned attention again to the Bravo shot. Mr. Shelton has reported recently that the method gives satisfactory results with [illegible] and [illegible]-7, and he is continuing work on other shots. We have [illegible] worked on the problem of predicting the Bravo fall-out on the assumption that practically all of the activity in the [illegible] cloud [illegible] the tropopause. To date, our method of calculation has not been shown to give satisfactory results, [illegible] the winds [illegible] the fall-out occur in more nearly the right place. At this point we feel, therefore, that we do not have any cloud model in which we have confidence. We have merely a method of calculation, the value of which has not yet been proven as far as Bravo is concerned.

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. [illegible]ing any sa[illegible], we tackled the "home[illegible]rk" [illegible]ictions [illegible] not justify a description. [illegible] values that [illegible]

	1 MT	50 MT
Height of [illegible] ([illegible])	11.5	19.0
Height of [illegible] (" ")	7.0	7.0
a for [illegible] (" ")	0.94	4.58
for [illegible] (" ")	0.41	1.49

[illegible]s: 9.05 [illegible] 1.0

The [illegible] up to the tropo[illegible]se, and th[illegible] re-[illegible] re[illegible]res only the [illegible] adjusted [illegible] that [illegible] with the [illegible]d). [illegible] the 36 layers of the [illegible]s [illegible]ing, [illegible] [illegible]s)

Layers 1 [illegible] 4		[illegible]
" 5 [illegible]	[illegible]	[illegible]
" 9 [illegible]	[illegible]	[illegible]
" 13 [illegible]	[illegible]	[illegible]

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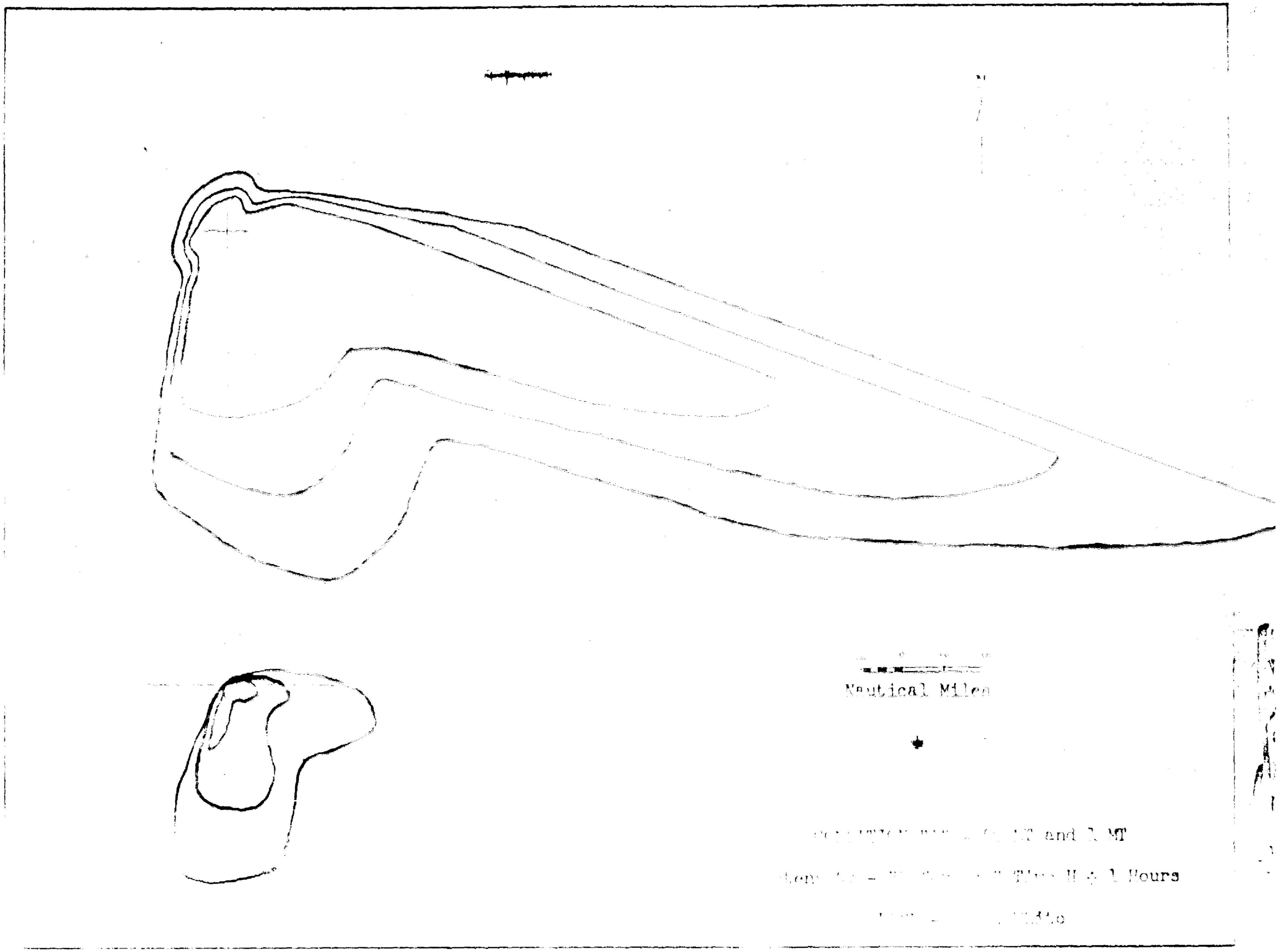
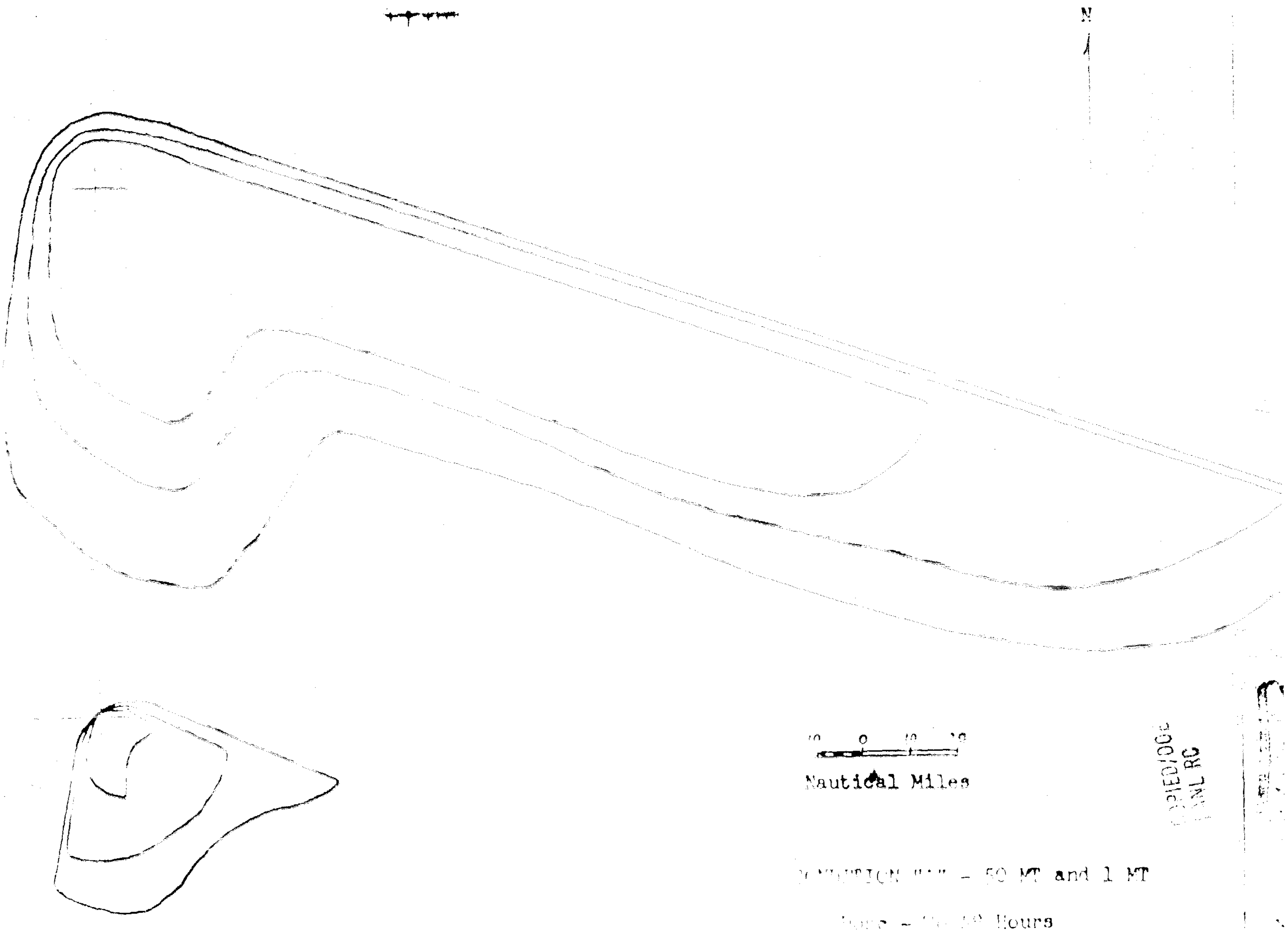


[illegible] MT and 1 MT

[illegible] Time H + 1 Hours

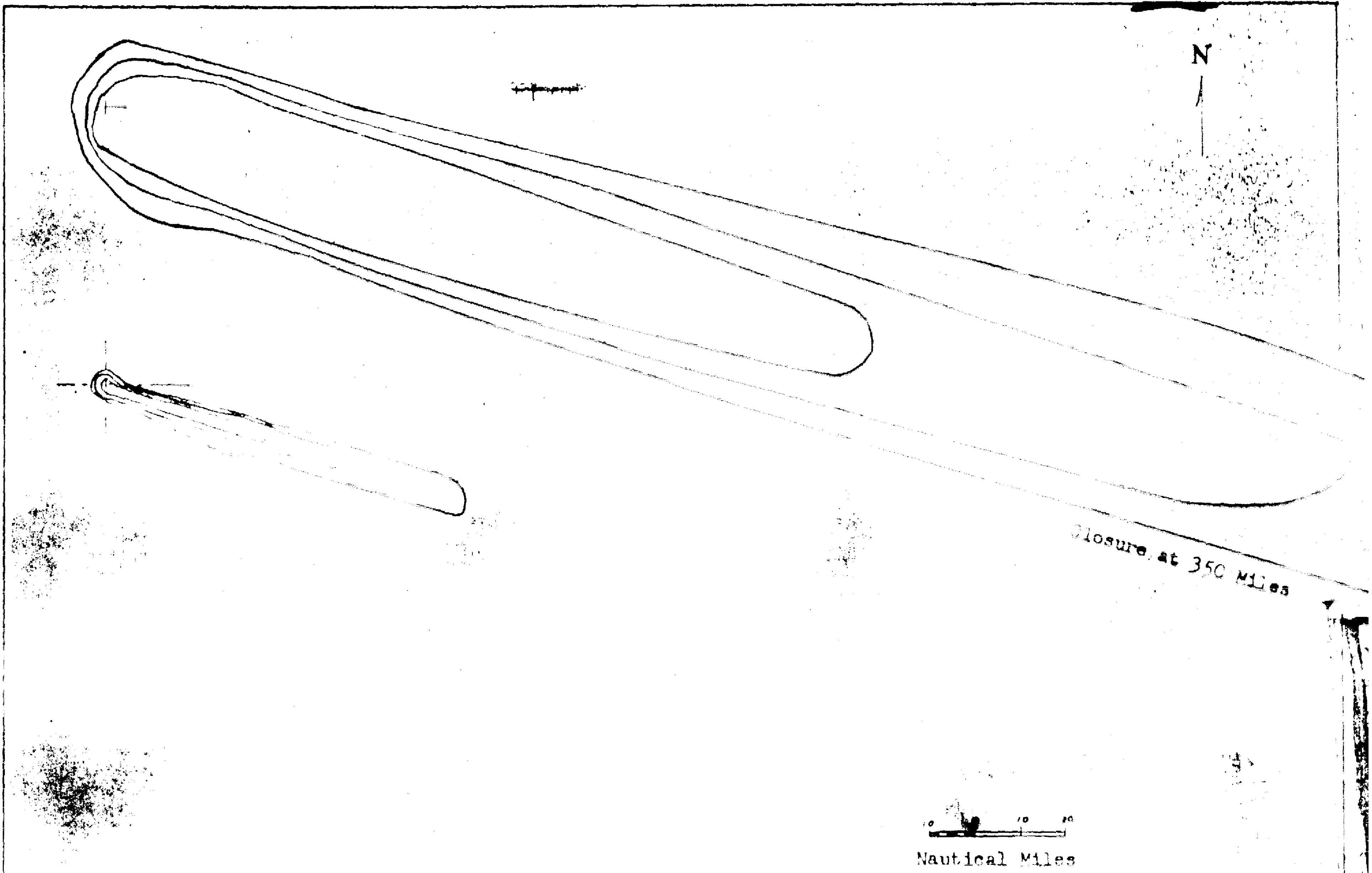
[illegible]



[illegible] - 50 MT and 1 MT

[illegible] - [illegible] Hours

[illegible] - [illegible]. White



CONDITION "[illegible]" - 50 and 1 MT

Intensity - "Reference" Time H + 1 Hours

LASL - T. N. White

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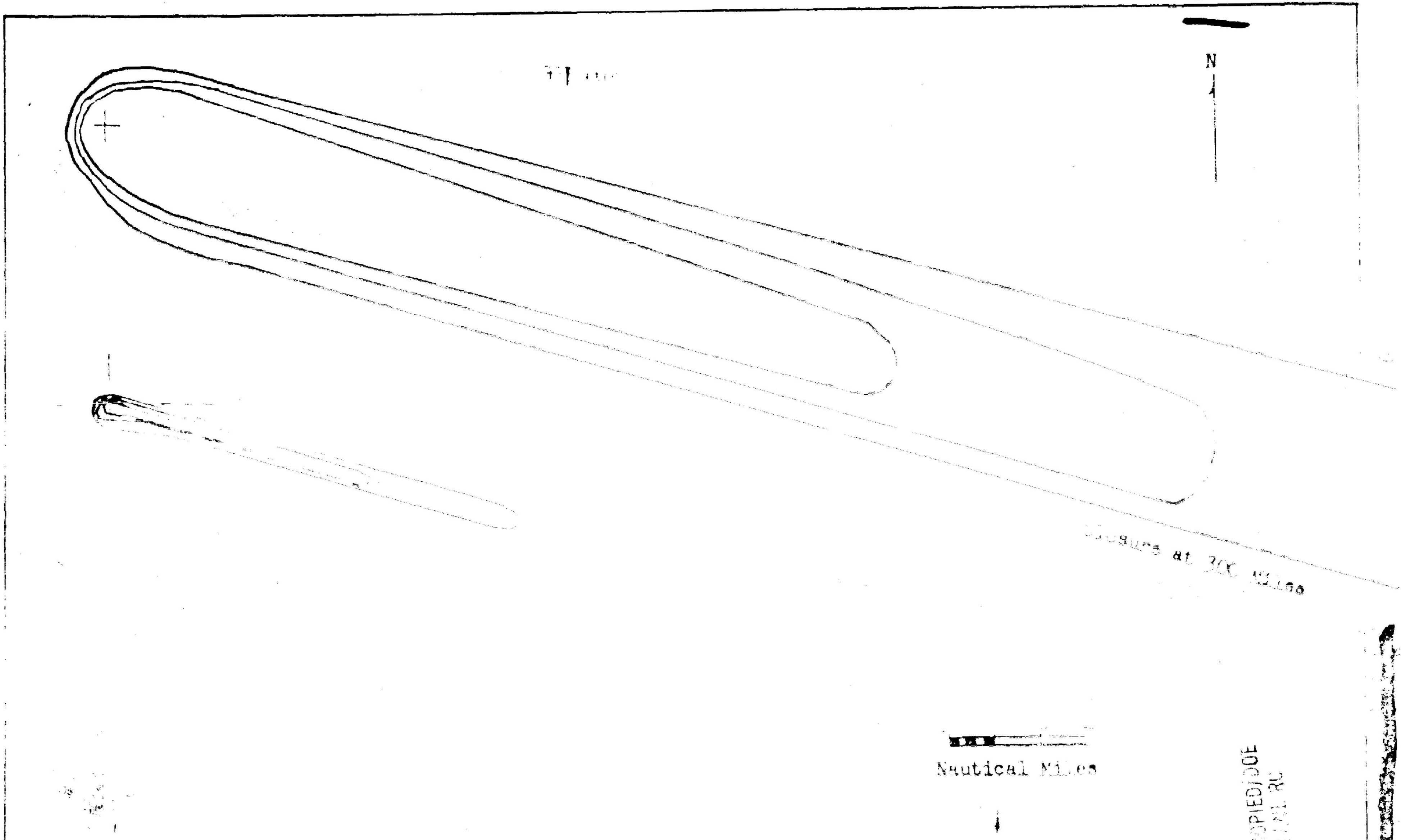

CONDITION "B" - 50 MT and 1 MT

[illegible] - To 48 Hours

[illegible] - T. N. White

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