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A STATUS REPORT ON A STUDY OF THE USE OF ATOMIC WEAPONS IN CLOSE SUPPORT OF GROUND FORCES

R. C. Hildner, 5122

H. H. Wicke, 5123

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ABSTRACT

This study seeks to determine yields for atomic weapons which can be safely and decisively employed against enemy troops located at distances of 500 to 4000 yards from friendly forces. The approach is essentially one in which certain tactical situations felt to be representative are analyzed by subjecting them to hypothetical atomic attack.

The results of these attacks are presented graphically in two forms. From these graphs yields are selected according to certain criteria of optimality. By one method a family of yields of 5, 15, and 50 kt is obtained; by the second it is shown that 5 and 30 kt provide approximately the same atomic capability.

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TABLE OF CONTENTS

	Page
INTRODUCTION	6
Purpose of the Study	6
The Approach to the Problem	6
Remarks on the Method	6
BASIC ASSUMPTIONS	7
Weapon Delivery	7
Safety of Friendly Troops	8
Damage to Enemy Troops	8
The Target, and Tactical Situations Considered	8
COMPUTATION AND PRESENTATION OF RESULTS	11
Safety Curves	11
Casualty Curves	11
Damage Calculations	13
Presentation of Results	28
Sensitivity of Results	28
SUMMARY OF RESULTS	31
CONCLUSIONS	32
LIST OF REFERENCES	34

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LIST OF ILLUSTRATIONS

Fig. No.		Page
1.	Safety curves for exposed troops	9
2.	Safety curves for troops emplaced in uncovered foxholes	9
3.	Composite nuclear-thermal casualty curve for 5-kt yield	12
4.	Yield versus effect radius for various deployments of enemy troops	14
5.	Target A, static situation; separation distance: 1500 yards, location CEP: 300 yards	15
6.	Target A, static situation; separation distance: 3000 yards, location CEP: 500 yards	16
7.	Target A, static situation; separation distance: 5000 yards, location CEP: 800 yards	17
8.	Target B, offensive situation; separation distance: 1500 yards, location CEP: 300 yards	17
9.	Target B, offensive situation; separation distance: 3000 yards, location CEP: 500 yards	18
10.	Target B, offensive situation; separation distance: 5000 yards, location CEP: 800 yards	18
11.	Target C, defensive situation against enemy attack in build-up phase; separation distance: 1500 yards, location CEP: 300 yards	19
12.	Target C, defensive situation against enemy attack in build-up phase; separation distance: 3000 yards, location CEP: 500 yards	20
13.	Target C, defensive situation against enemy attack in build-up phase; separation distance: 5000 yards, location CEP: 800 yards	21
14.	Target D, defensive situation against enemy attack in jump-off phase; separation distance: 1500 yards, location CEP: 300 yards	22
15.	Target D, defensive situation against enemy attack in jump-off phase; separation distance: 3000 yards, location CEP: 500 yards	23

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16. Target D, defensive situation against enemy attack in jump-off phase; separation distance: 5000 yards, location CEP: 800 yards 24

17. Target E, offensive situation against troops not entirely protected from thermal radiation; separation distance: 1500 yards, location CEP: 300 yards 25

18. Target E, offensive situation against troops not entirely protected from thermal radiation; separation distance: 3000 yards, location CEP: 500 yards 26

19. Target E, offensive situation against troops not entirely protected from thermal radiation; separation distance: 5000 yards, location CEP: 800 yards 27

20. Location CEP versus separation distance 29

21. Fraction of target damaged versus separation distance 30

A STATUS REPORT ON A STUDY OF THE USE OF ATOMIC WEAPONS IN CLOSE SUPPORT OF GROUND FORCES

INTRODUCTION

Purpose of the Study

The purpose of this study is to determine yields for atomic weapons which can be safely and decisively employed against enemy troops located at distances of 500 to 4000 yards from friendly troops. The yields so determined are optimum in a sense to be defined later.

The Approach to the Problem

The battlefield situation is approximated by a simple geometric model in which a line representing the friendly front is used as a reference line. Certain undesirable weapons effects are allowed to penetrate beyond this line into friendly territory only with specified probabilities. Enemy targets lie on the opposite side of the friendly front. The foremost elements of these targets are 500 to 4000 yards from the front. The typical target is assumed to be a circle 1000 yards in radius in which enemy troops are uniformly distributed. This model was adopted because it is both a "battalion-size" target and also a "square-mile" target of the type described in Reference 1. The tactical situation determines what percentage of these troops are emplaced in foxholes and whether or not the foxholes are covered. Friendly troops are assumed to be either 100 per cent emplaced or 100 per cent in the open depending upon whether or not the tactical situation permits adequate forewarning.

The model described above may be used to compare the performance of yields by employing the following technique: The safety criteria determine the distance from the friendly front at which a given yield may be safely employed. For a fixed delivery CEP (the symbol DCEP refers to delivery CEP in the following discussion) a family of yields, each associated with its corresponding safe-distance, is obtained. Then for a given target whose center is located at a certain distance, S, beyond the front at a fixed location CEP (the symbol LCEP refers to location, or intelligence, error in what follows), the fraction of the target damaged with 90 per cent probability is computed and plotted against yield. This procedure is repeated, varying S, DCEP and LCEP. From the resulting graphs optimum yields can be selected according to different criteria. For a fixed DCEP, the yield which accomplishes the maximum damage, if it exists, can be taken as optimum. If DCEP is unknown, one can obtain, by an averaging process, a yield which accomplishes a high fraction of damage for a range of DCEP's from 0 to 500 yards. Further conclusions which can be drawn from these graphs will be indicated later. It is of interest that these yields appear to be relatively insensitive to variation in target size and to the casualty curves used. A more detailed study of this aspect of the problem is planned. On the other hand, the results are most sensitive to the criteria governing the safety of friendly troops, which bears out the conclusions reached in References 1 and 2.

Remarks on the Method

Emphasis should be placed on method rather than numerical results, both because of the flexibility of the present approach, and the uncertainty with regard to the input data--

especially safety and damage criteria. For example, one can introduce the procedure of determining minimum allowable safe distance as in References 1 and 2, rather than setting it at 500 yards as is done here. Furthermore, target radius and, to an extent limited by computational difficulty, target shape can be varied. Different criteria could be used to determine optimum yield, e.g., damage area based on a suitable definition of tactical radius[1,2] versus yield.

In connection with method it should be pointed out that the present problem concerns only determination of yields for a delivery system with errors that are circularly normally distributed. Present stockpiles, delivery systems and economic situation are not considered. However, it is clear that the present approach could be used as an aid in studies including these factors.

A second method is used for comparison of yields in which, for a fixed yield and DCEP, the fraction of damage with 0.9 probability is plotted against S. (A relationship between S and LCEP is assumed here as well.) This gives a family of curves the envelope of which represents maximum atomic capability for weapons with the given DCEP. A discrete family of yields is selected by choosing yields each of which provides close to maximum fraction of damage for a range of separation distances. From the first method a yield family of 5, 15, and 50 kt is obtained while the second method shows that the yields of 5 and 30 kt provide a capability whose military worth is apparently indistinguishable from the 5-, 15-, and 50-kt capability.

For future study, factors which should be considered are: changes in safety criteria, use of different burst heights (400 $W^{1/3}$ feet is the burst height used throughout this report), introduction of burst-height error, use of delivery systems with errors which are not circularly normally distributed, variation of target radius, use of noncircular targets, consideration of blast as a casualty-producing agent, and determination of yields for separation distances greater than 5000 yards. In addition, it is proposed to investigate further the variation of optimum yield with separation distance.

BASIC ASSUMPTIONS

Weapon Delivery

It is assumed that the weapon is delivered by a system which has a DCEP. It is further assumed that intelligence errors in locating the target center are circularly normally distributed about the target center. (This location CEP, as mentioned earlier, is designated LCEP.) For computational purposes, DCEP and LCEP are combined into a total CEP by the relation

$$\mathrm{TCEP} = \sqrt{(\mathrm{DCEP})^2 + (\mathrm{LCEP})^2} \; . \tag{1}$$

The aiming point lies on a line through the center of the target perpendicular to the friendly front. Let A be the distance from the friendly front to the aiming point. Let S be the distance from the friendly front to the target center. Then it can be assumed that $A \geq S$. The quantity $\delta = A - S$ is called the <u>offset aim distance</u>.

Safety of Friendly Troops

Undesirable effect levels when friendly forces are exposed in numbers sufficient to be defined as "open" are assumed to be 100 rem (roentgen equivalent mammal), 4 cal/cm^2, or 3 psi. Similar levels when friendly forces have taken protective measures sufficient to be defined as "emplaced" are assumed to be 100 rem in a foxhole or 3 psi at the surface. It is assumed that thermal damage is negligible against friendly emplaced troops. The "undesirability" of these effects increases with the depth of penetration into friendly territory. Table I indicates the assumed probabilities of penetration where P(X) is the probability that the undesirable effect level penetrates no farther than X yards into friendly territory. The penetration depths, X, are based on the depths of military units, e.g., 50 yards for a squad, 100 yards for a platoon, etc. Safety curves (Figs. 1 and 2) based on these are constructed as described later.

Table I

Probability of Penetration

P(X)	X(yards)
0.80	50
0.30	100
0.10	150
0.01	500
0.0005	3000
0.00001	5000

Damage to Enemy Troops

Nuclear and thermal radiation are assumed to be the dominant lethal agents against enemy personnel. Blast is not included as a lethal agent in this study because of lack of firm data regarding its physiological effects. (This omission tends to make the answers conservative.) When the time required for permanent incapacitation is not important, 450 rem is assumed to be the mean lethal dose of nuclear radiation. A casualty curve with this mean is assumed on the basis of Reference 3. When permanent incapacitation is required in a few hours, 5000 rem is assumed to be the 100 per cent lethal dose. Relative to lethal doses of thermal radiation, 25 cal/cm^2 is assumed to cause immediate incapacitation when delivered on the outer surface of a combatant's uniform, and 5 cal/cm^2 is assumed to cause immediate incapacitation when delivered on an untreated exposed skin area. In this study it is not assumed that protective devices such as skin creams are available. As described later, casualty curves are constructed on the basis of these criteria.

The Target, and Tactical Situations Considered

Throughout this memorandum, the investigation is directed to a "battalion-size" target taken to be a circle 1000 yards in radius. Area-wise it corresponds, approximately, to the "square-mile" target of References 1 and 2. In all cases, the target is assumed to be a homogeneous one, i.e., enemy troops are considered to be distributed uniformly throughout the target area. The separation distance, S, is the distance from the position of the foremost elements of the friendly forces to the center of the target circle.

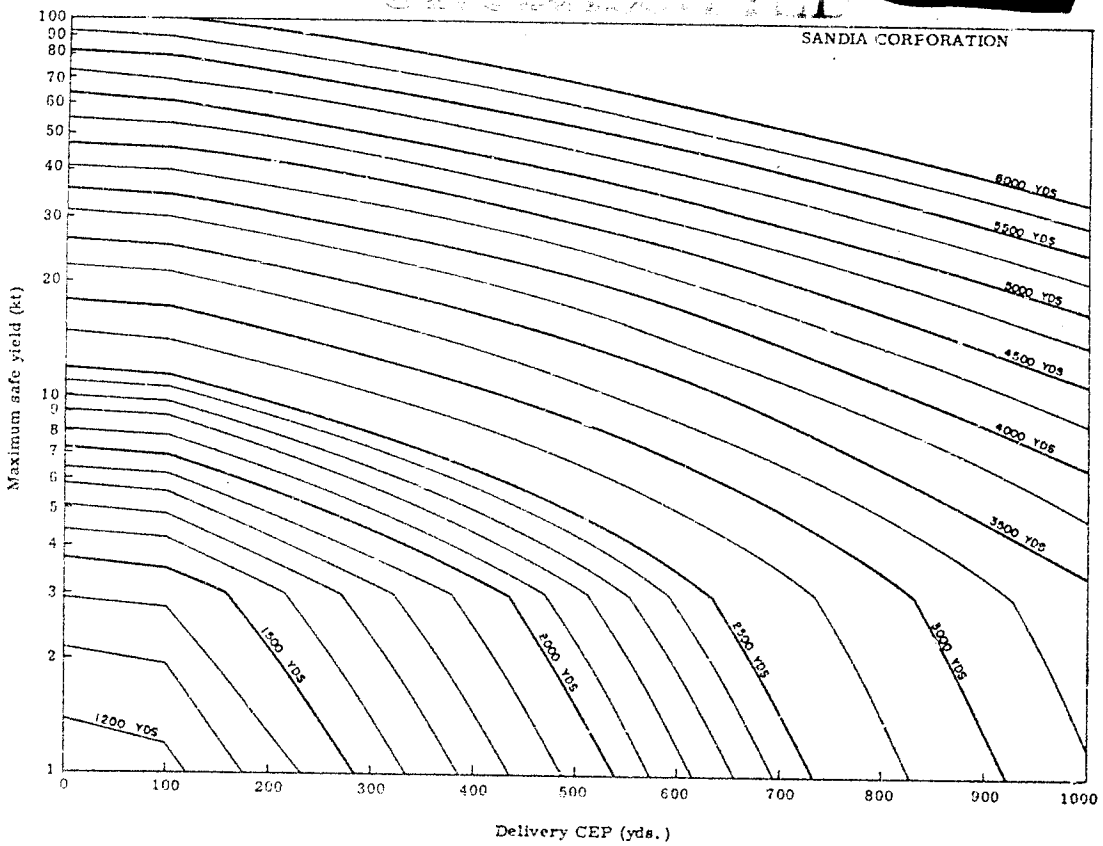

Fig. 1 -- Safety curves for exposed troops

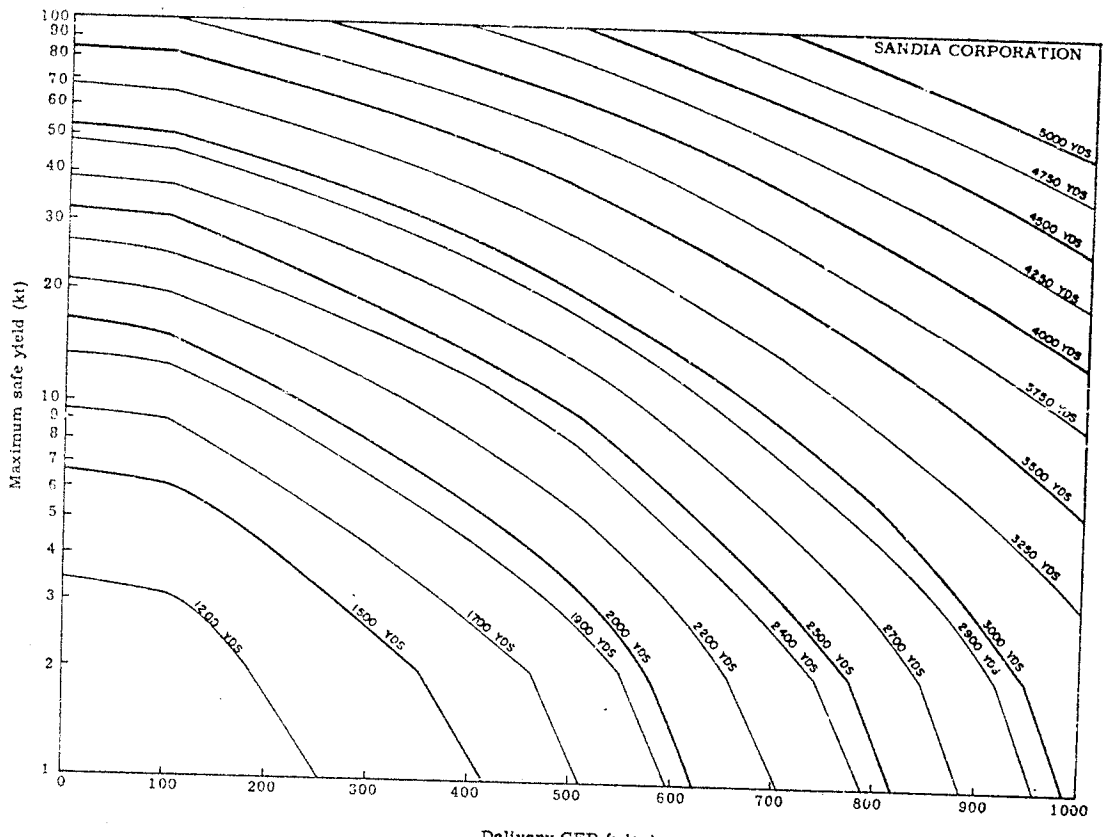

Fig. 2 -- Safety curves for troops emplaced in uncovered foxholes

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Five possible tactical situations, assumed to require the employment of nuclear weapons, are outlined below. These situations have been analyzed in detail, and the results of this analysis are reported later in this memorandum.

A. Static Situation. -- Only attrition is desired and no attack is contemplated. Immediate casualties are not required. The aim is eventual deterioration of the enemy fighting potential. Enemy troops are 70 per cent in covered foxholes, 30 per cent in the open. Friendly troops, forewarned, are emplaced in uncovered foxholes. Separation distances, S, ranging from 1500 to 5000 yards, are considered. Kill criteria: mean lethal dose, 450 rem, delivery 48 inches down in the covered foxholes, and, in the open, either mean lethal dose, 450 rem, or casualty curves defined by 25 cal/cm^2 on uniform and 5 cal/cm^2 on exposed skin. Safety criteria: undesirable effect level defined by 100 rem in uncovered foxholes or 3 psi overpressure at the ground surfaces. The damage objective is a 0.9 probability of achieving at least 50 per cent casualties.

B. Offensive Situation Against Troops Protected from Thermal Radiation. -- Immediate (within two hours) casualties are required. Enemy troops are 70 per cent in covered foxholes and 30 per cent in the open. Friendly troops, forewarned, are emplaced in uncovered foxholes. Separation distance, S, ranges from 1500 to 5000 yards. Kill criteria: lethal dose, 5000 rem, delivered 48 inches down in the covered holes and, in the open, either lethal dose, 5000 rem, or casualty curves defined by 25 cal/cm^2 on uniform and 5 cal/cm^2 on exposed skin. Safety criteria: undesirable effect level defined by 100 rem in uncovered foxholes or 3 psi overpressure at the ground surface. The damage objective is a 0.9 probability of achieving at least 30 per cent casualties.

C. Defensive Situation Against Enemy Attack in Build-up Phase. -- Immediate casualties are required to disorganize the enemy units. Enemy troops are 70 per cent in uncovered foxholes and 30 per cent in the open. Friendly troops are in the open since no time is available to warn them. Separation distance, S, ranges from 1500 to 5000 yards. Kill criteria: lethal dose, 5000 rem, and casualty curves defined by 25 cal/cm^2 on uniform and 5 cal/cm^2 on exposed skin against both open and emplaced enemy troops. Safety criteria: undesirable effect level defined by 4 cal/cm^2, 100 rem or 3 psi at the ground surface. The damage objective is a 0.9 probability of achieving at least 30 per cent casualties.

D. Defensive Situation Against Enemy Attack in Jump-off Phase. -- This differs from situation C only in the distribution of enemy troops which here are assumed to be 30 per cent in uncovered foxholes and 70 per cent in the open. All else is the same.

E. Offensive Situation Against Troops not Entirely Protected from Thermal Radiation. -- Except for the emplacement of friendly troops in uncovered foxholes and the assumption of corresponding safety criteria, this is the same as situation C, above. Note, also, that this is the same as situation B, except that here the enemy emplaced troops are in uncovered, rather than covered, foxholes and consequently are susceptible to some thermal damage.

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COMPUTATION AND PRESENTATION OF RESULTS

Safety Curves

The safety curves are constructed* as follows: Consider the instance where friendly troops are in the open. (The situation where friendly troops are emplaced is handled in the same way.) First, construct a plot of yield versus the ground range to which the undesirable effects extend. From this, by choosing the effect which extends to the greatest ground range for each yield, obtain a plot of yield versus undesirable effect radius. Thus, if DCEP = 0 and aiming distance A = 1600 yards, the yield corresponding to 1600 yards is a safe yield for this A value. Then, for DCEP >0, use tables of the function $1 - e^{-0.693(X/DCEP)^2}$ in conjunction with Table I to determine, for each of the distances listed in Table I, the reduction in aiming distance due to the delivery error, DCEP. Then choose the greatest of these reductions. For example, if A = 1600 yards, a delivery system with a DCEP of 100 yards has the same probability of undesirable effect penetration as a system with DCEP = 0 where A = 1568 yards. Thus, for A = 1600 yards and DCEP = 100 yards, the maximum safe yield is that yield corresponding to DCEP = 0 and A = 1568 yards. In this way, for fixed values of A, obtain a plot of maximum safe yield versus DCEP. Figures 1 and 2 consist of such graphs for A ranging from 1500 to 5000 yards, where the values of A are selected at 100- to 250-yard intervals. For example, suppose DCEP = 200 yards and friendly troops are exposed or in the open. Then from Fig. 1 it is seen that for A = 1500 yards the maximum safe yield is 2.2 kt, for A = 2400 yards the maximum safe yield is 8.9 kt, and for A = 3500 yards the maximum safe yield is 22 kt. On the other hand, for the same DCEP with friendly troops emplaced, Fig. 2 shows that 4.2, 20.5, and 70 kt, respectively, are the maximum safe yields corresponding to the values of A selected above.

Casualty Curves

Throughout this study a single burst height, 400 feet scaled, is assumed.

Gamma radiation levels in uncovered foxholes are taken from Reference 4 which is an analysis of all test data available to date. A degradation factor of 1/2 is applied to the data from Reference 4 whenever the foxhole is assumed to be covered. Neutron dose at the surface is determined from Reference 5. Neutron dose in foxholes is obtained by multiplying the surface dose by an assumed degradation factor of 1/3 when the foxhole is uncovered and 1/5 when the foxhole is covered. The total nuclear radiation dose is the sum of the gamma dose and the neutron dose measured in equivalent units (rem).

Thermal casualty curves for troops in uncovered foxholes, based on a technique developed by B. L. Miller, 5122, are derived using the 25 cal/cm^2 on uniform, 5 cal/cm^2 on exposed skin casualty criteria. D. W. Stoddard, 5122, using the Miller approach, provided thermal casualty curves for troops in the open. Troops in covered foxholes are considered safe from thermal effects.

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*Based on a method developed by D. W. Stoddard, 5122.

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No blast effect is included among the casualty agents for the reasons mentioned earlier. It is hoped that data uncertainties in this area can be removed, and blast data on a firmer basis can be included in later extensions of this work. The inclusion of blast data, when available, in the construction of composite casualty curves by the method outlined below will not be difficult.

For each yield considered, the construction of a composite casualty curve is as follows (see Fig. 3 for 5 kt): Plot step-functions showing thermal casualty probability versus ground range, for emplaced personnel and also for exposed personnel, on the same axes. Between these curves interpolate a combined thermal casualty curve. The exact location of this interpolated curve depends upon the assumed deployment of enemy forces in uncovered foxholes and in the open. Figure 3 shows this interpolated curve for the enemy 70 per cent emplaced and 30 per cent in the open. On these same axes draw the 5000-rem "cookiecutter" to the ground range appropriate for the given yield. Determine the composite, nuclear-thermal, casualty curve for each deployment of enemy troops by the dominant effects in each instance, i.e., use the maximum ground range for each casualty probability. For example, with a 5-kt yield (Fig. 3) and for 70-30 deployment of the enemy the nuclear effect extends to 1475 feet for probabilities 0.827 to 1.00. Below 0.827 probability the 70-30 thermal curve dominates.

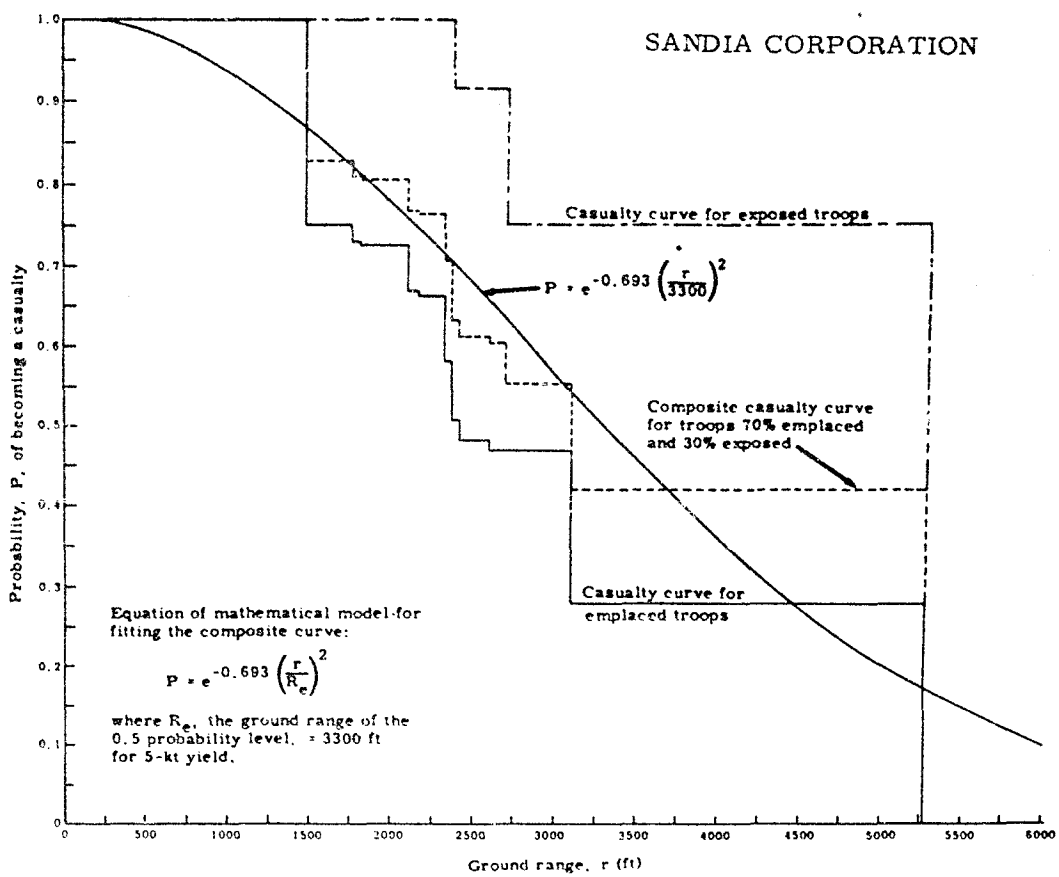

Fig. 3 -- Composite nuclear-thermal casualty curve for 5-kt yield

To facilitate the computational use of these composite casualty curves, numerous attempts were made to "fit" them with mathematical models. The best fit is obtained, in all instances examined, by the curve whose equation is

$$P = e^{-0.693\,(r/R_e)^2},$$

where P is the probability of being a casualty at ground range r, and the parameter R_e (the ground range of the 0.5 probability value) is selected so that the graph of yield, W, versus R_e (Fig. 4) is a straight line on log-log graph paper. Extension of this straight-line graph, by extrapolation, allows the value of R_e corresponding to any yield ≤ 100 kt to be read.

Damage Calculations

The Circular Probability Chart from Reference 6 is used to construct 0.9 probability scales for offset distances, δ, ranging from 0 to 2500 yards and a variety of TCEP values corresponding to combinations of DCEP and LCEP values by Equation 1 (p. 7) when DCEP = 50, 300, and 500 yards and LCEP = 300, 500, and 800 yards. For a given DCEP and offset δ the safety curves appropriate to a given disposition of friendly troops give the maximum yield that can be used with safety. Normalizing the target radius, R_t, and the TCEP by division by the R_e from Fig. 4 corresponding to this yield provides the coordinates of a point on Department 5120 Nomograph IIb.[7] At this point the index of the 0.9 probability scale is set for the given offset. Then the scale mark corresponding to the TCEP (for the given DCEP and LCEP combination) determines on the nomograph, by interpolation between the curves of equal fraction of target damage, f, the fraction of the target damaged with 0.9 probability.

For situations such as targets A and B where 70 per cent of the enemy force is assumed to be emplaced in covered foxholes the use of composite nuclear-thermal casualty curves is not feasible. Nuclear radiation is the sole damage agent effective against the emplaced troops, and thermal radiation is the dominant casualty-producing agent against the exposed troops. Consequently the fractions of the target damaged by these effects are computed separately, and then are combined in the proper proportions. For example, if it is assumed that the enemy is entirely emplaced in covered foxholes, the fraction made casualties by the specified lethal nuclear level produced by a given yield is computed. Then, assuming all of the enemy exposed, the fraction made casualties by the specified lethal thermal level produced by the same yield is computed. Taking 70 per cent of the fraction made casualties by the nuclear effect and adding to it 30 per cent of the fraction made casualties by the thermal effect determines the fraction of the enemy forces incapacitated with 0.9 probability by the specified effects from the given yield when 70 per cent of the enemy are emplaced in covered foxholes and 30 per cent are exposed.

Thus, when DCEP is known, the fraction of the target damaged with 0.9 probability can be found for each yield admissible in view of safety considerations. Graphs showing the relations between f (the fraction of the target damaged with 0.9 probability) and W (the yield of the weapon) for various combinations of S, LCEP, and DCEP are presented in Figs. 5-19.

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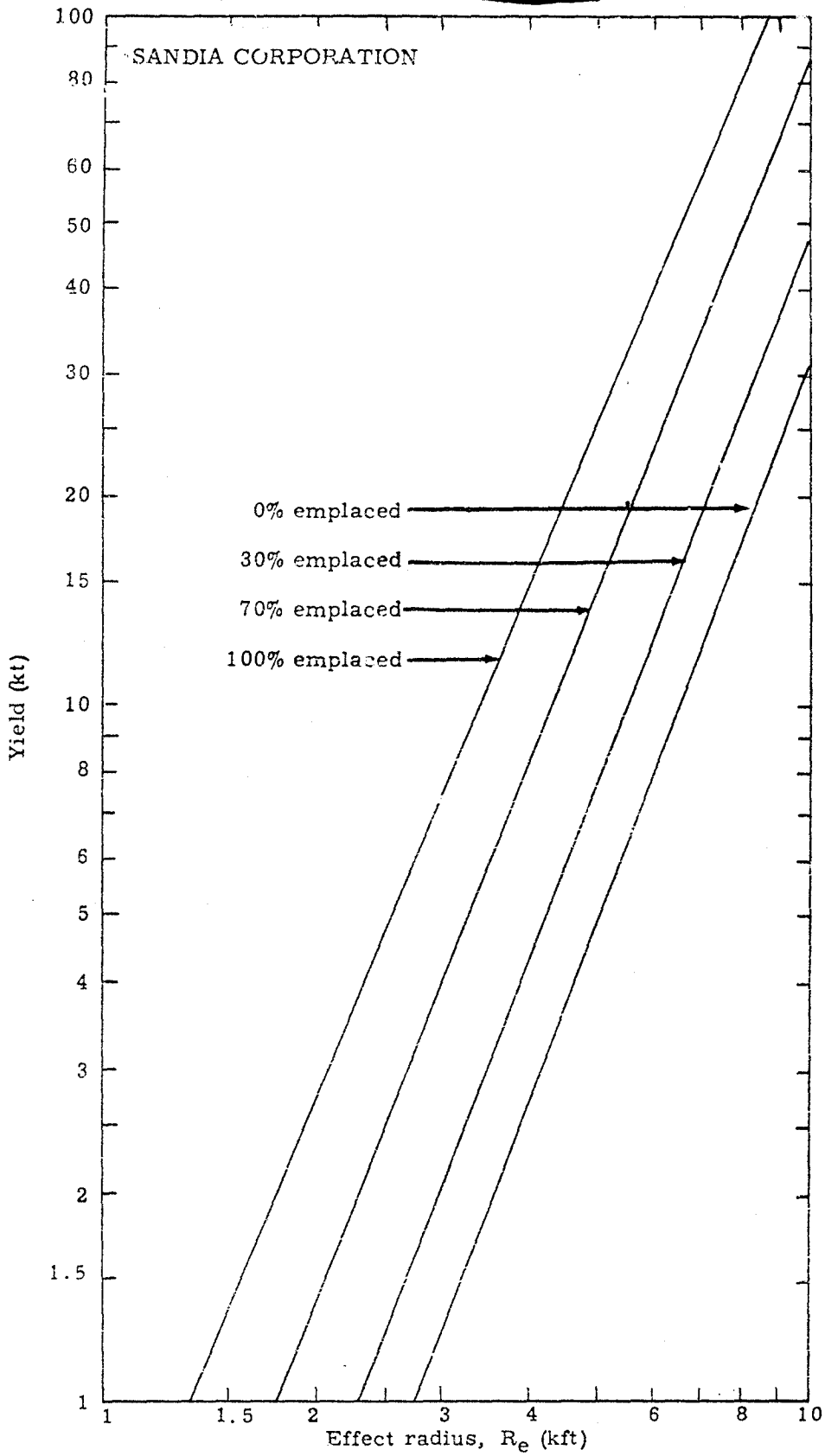

Fig. 4 - Yield versus effect radius for various deployments of enemy troops

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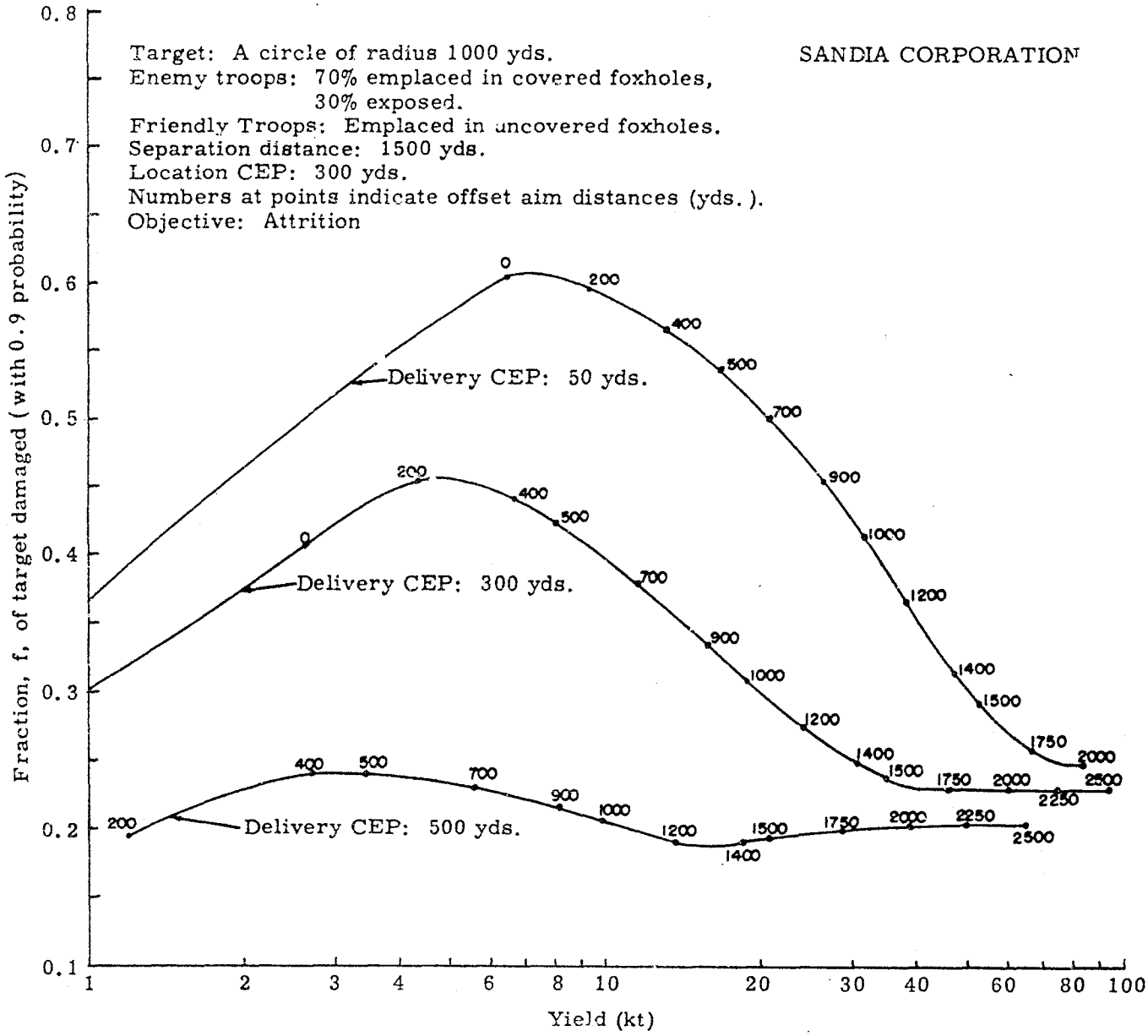

Fig. 5 -- Target A, static situation; separation distance: 1500 yards, location CEP: 300 yards

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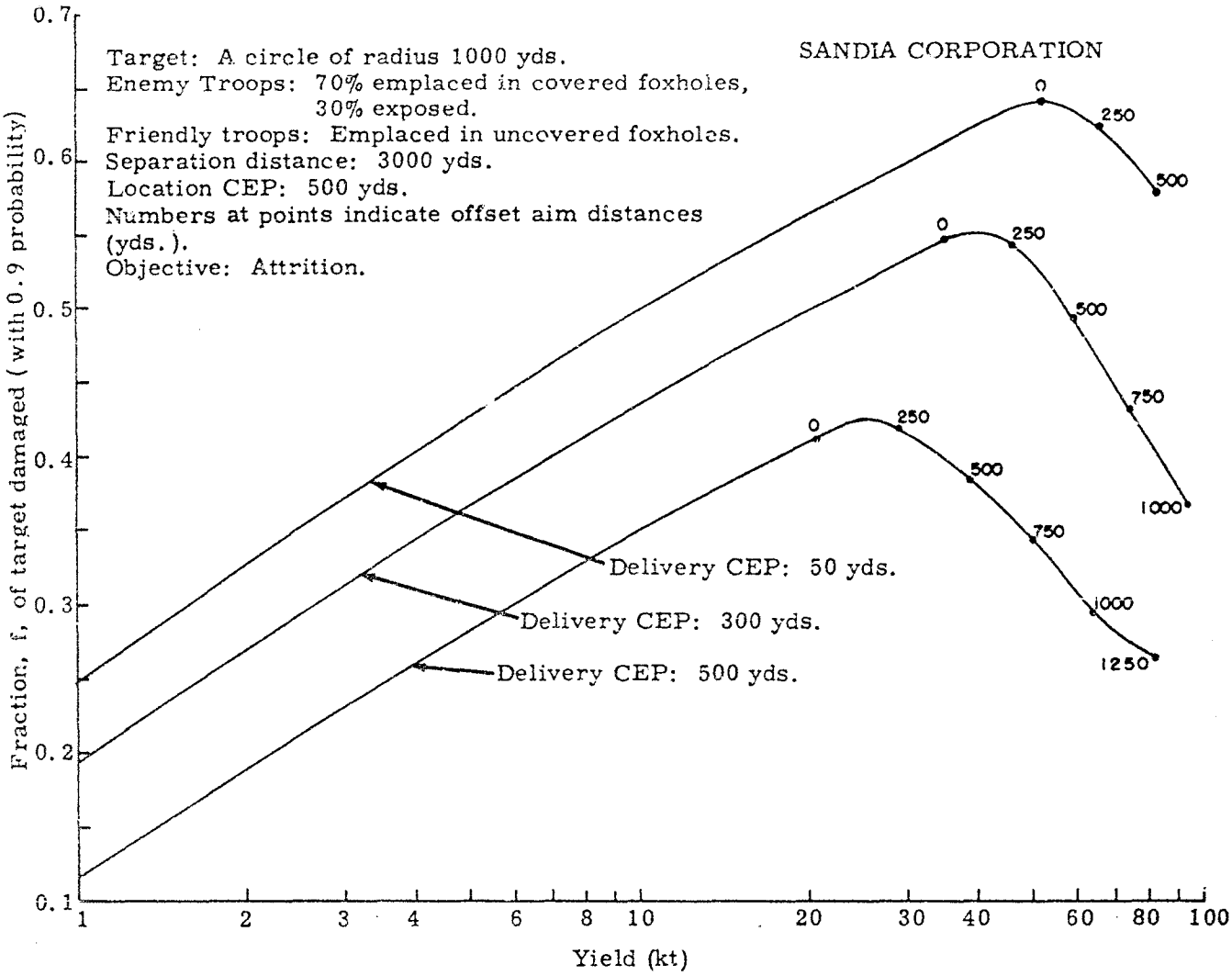

Fig. 6 -- Target A, static situation; separation distance: 3000 yards, location CEP: 500 yards

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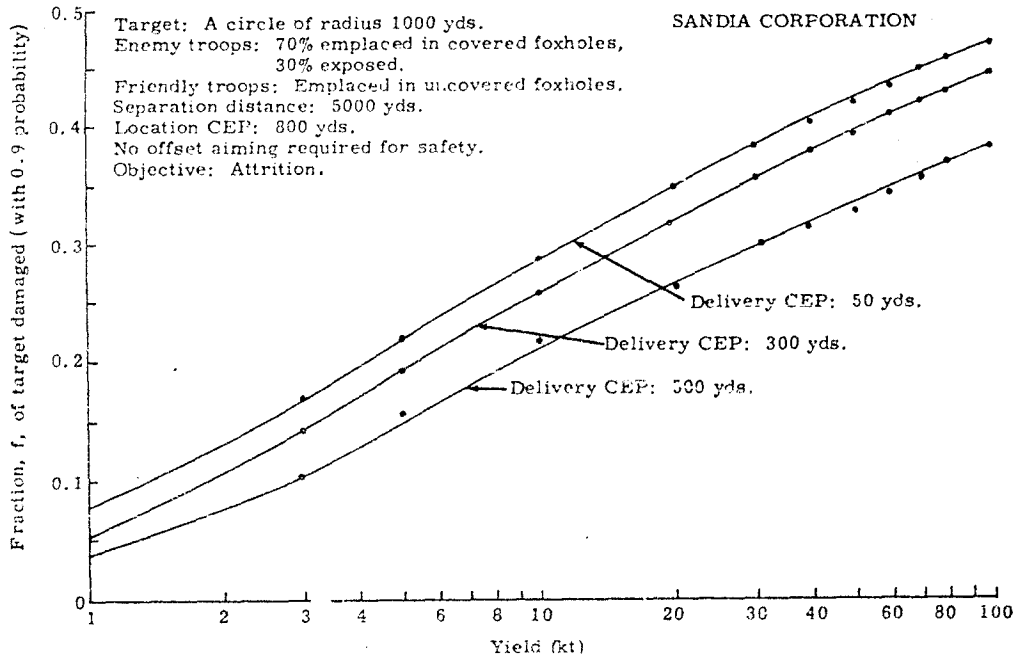

Fig. 7 -- Target A, static situation; separation distance: 5000 yards, location CEP: 800 yards

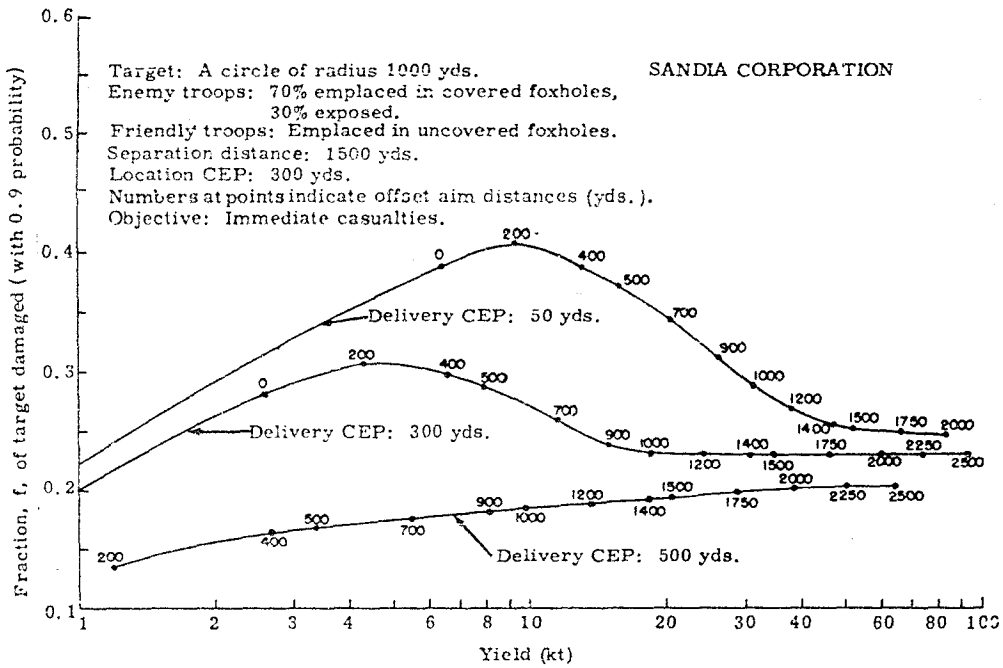

Fig. 8 -- Target B, offensive situation; separation distance: 1500 yards, location CEP: 300 yards

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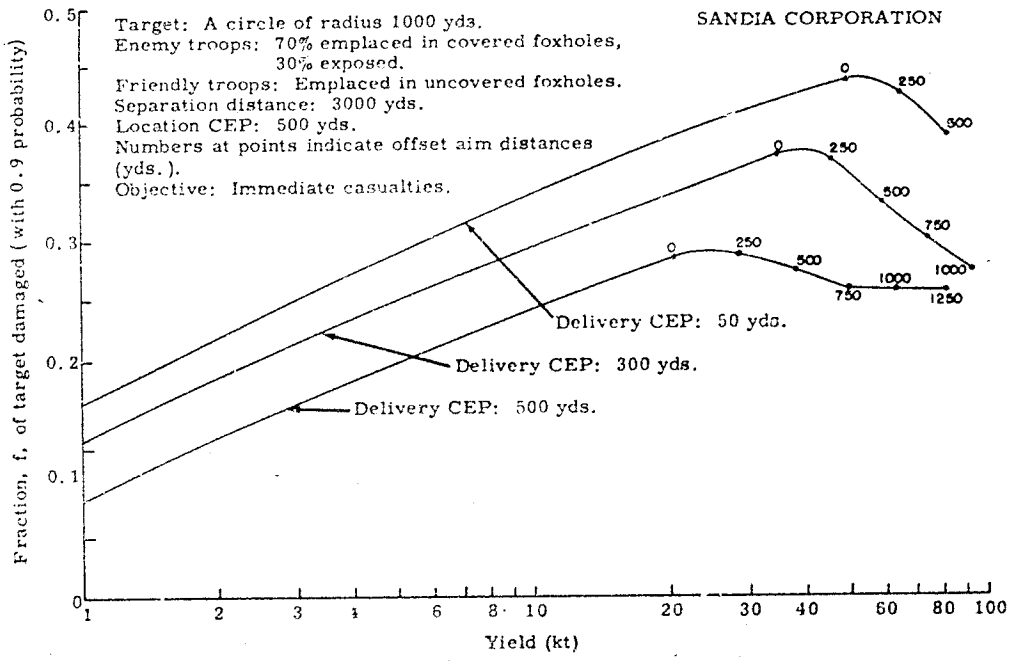

Fig. 9 -- Target B, offensive situation; separation distance: 3000 yards, location CEP: 500 yards

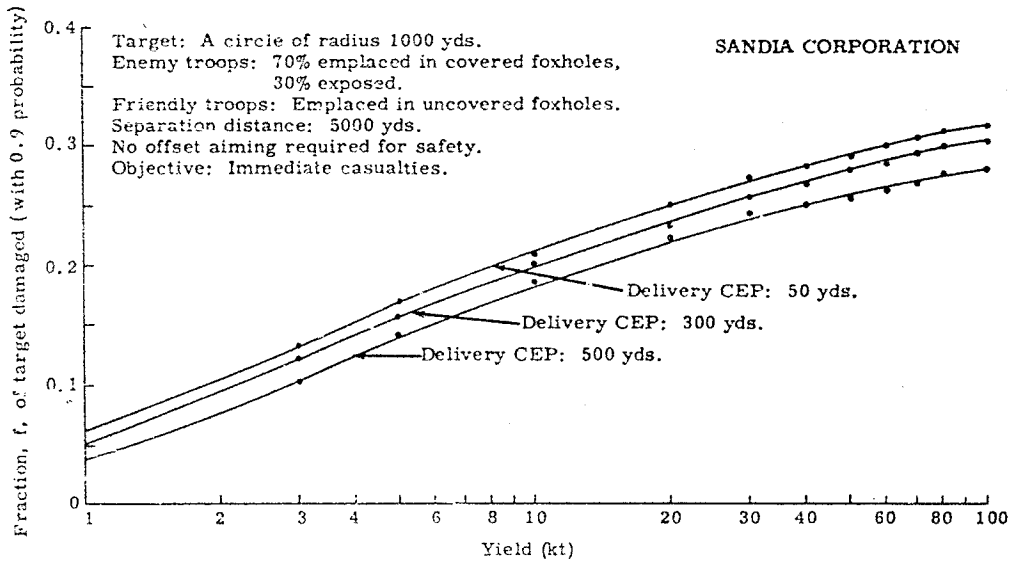

Fig. 10 -- Target B, offensive situation; separation distance: 5000 yards, location CEP: 800 yards

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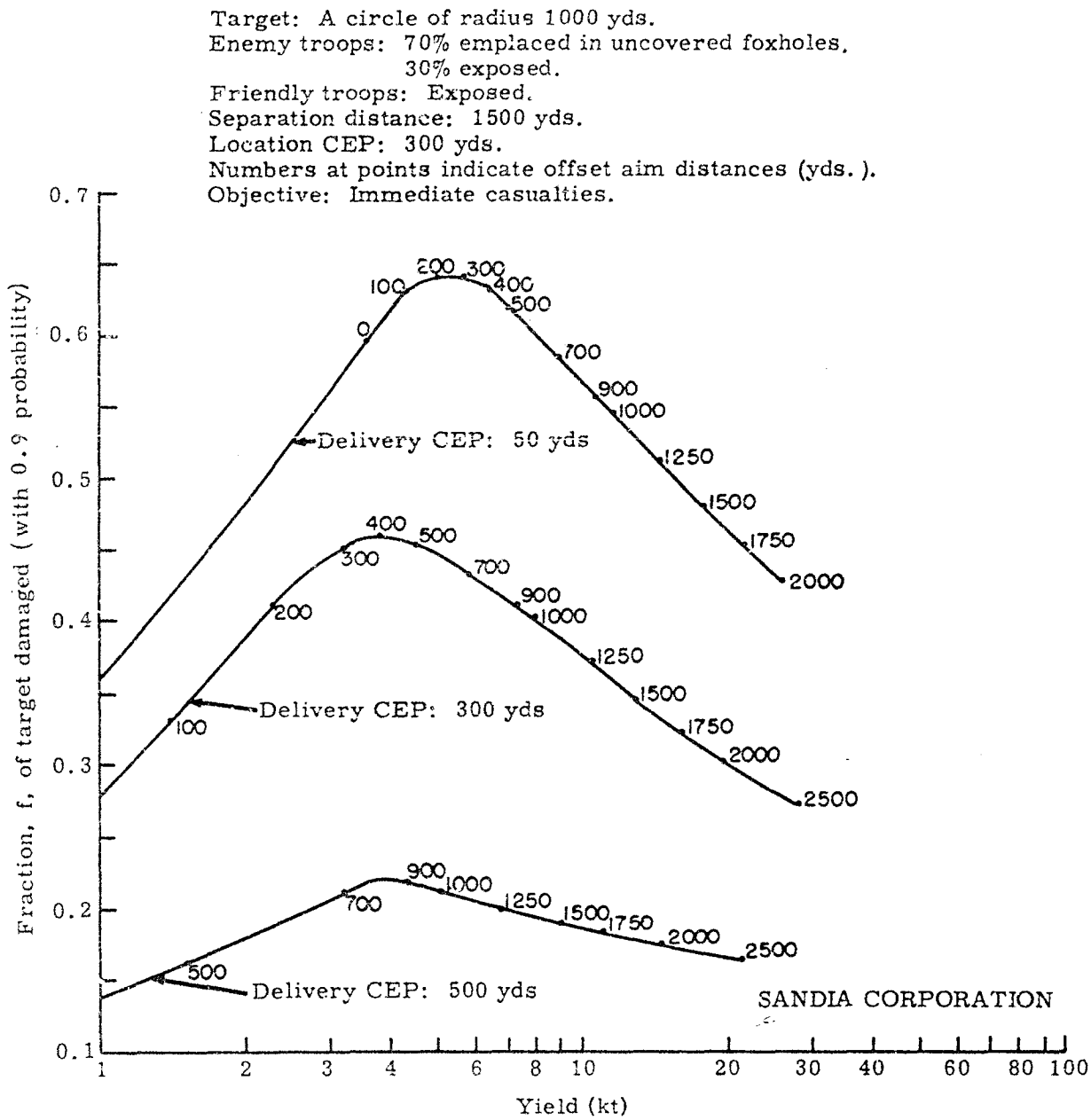

Fig. 11 -- Target C, defensive situation against enemy attack in build-up phase; separation distance: 1500 yards, location CEP: 300 yards.

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Target: A circle of radius 1000 yds.
Enemy troops: 70% emplaced in uncovered foxholes,
30% exposed.
Friendly troops: Exposed.
Separation distance: 3000 yds.
Location CEP: 500 yds.
Numbers at points indicate offset aim distances (yds.)
Objective: Immediate casualties.

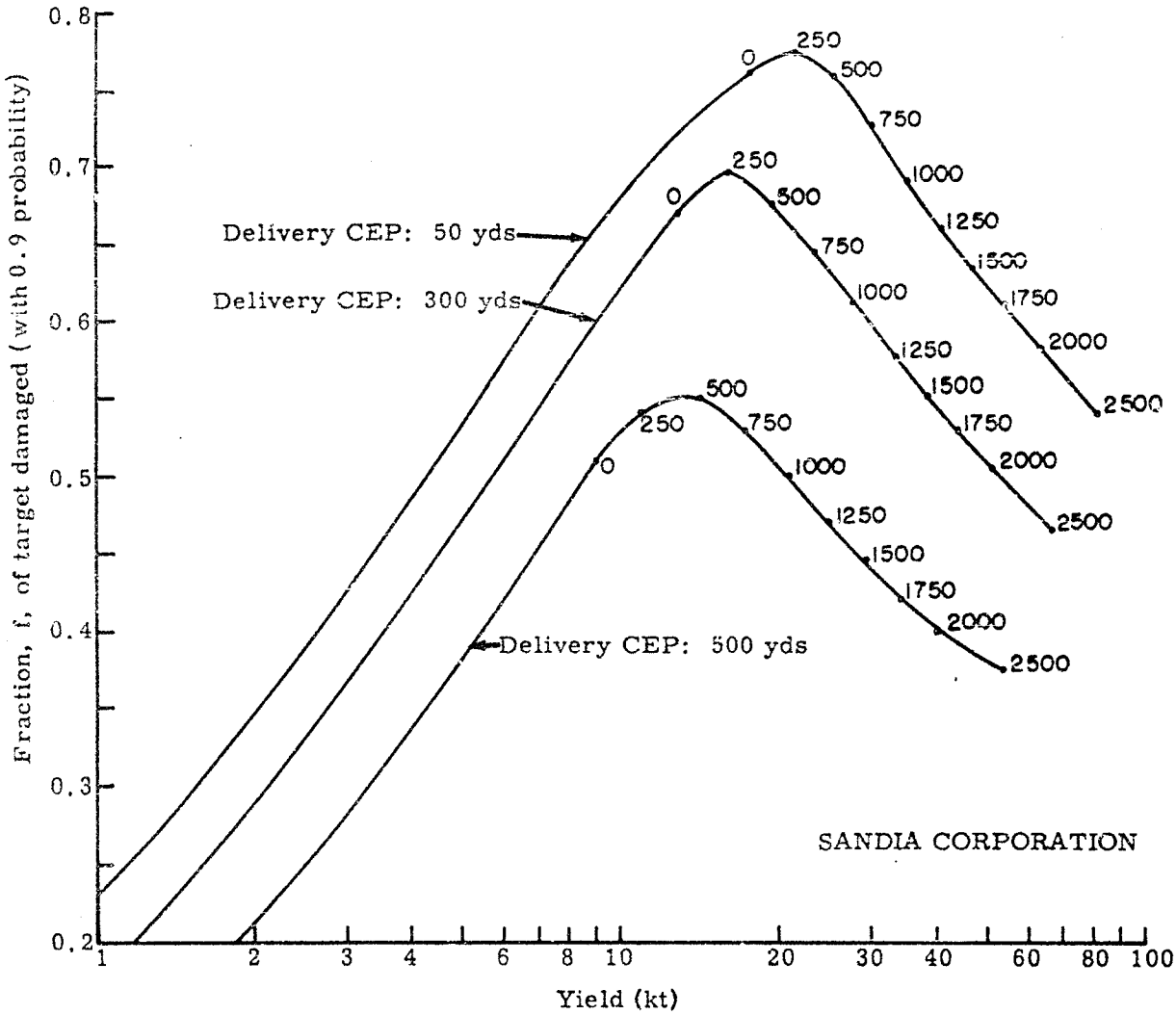

Fig. 12 - Target C, defensive situation against enemy attack in build-up phase; separation distance: 3000 yards, location CEP: 500 yards.

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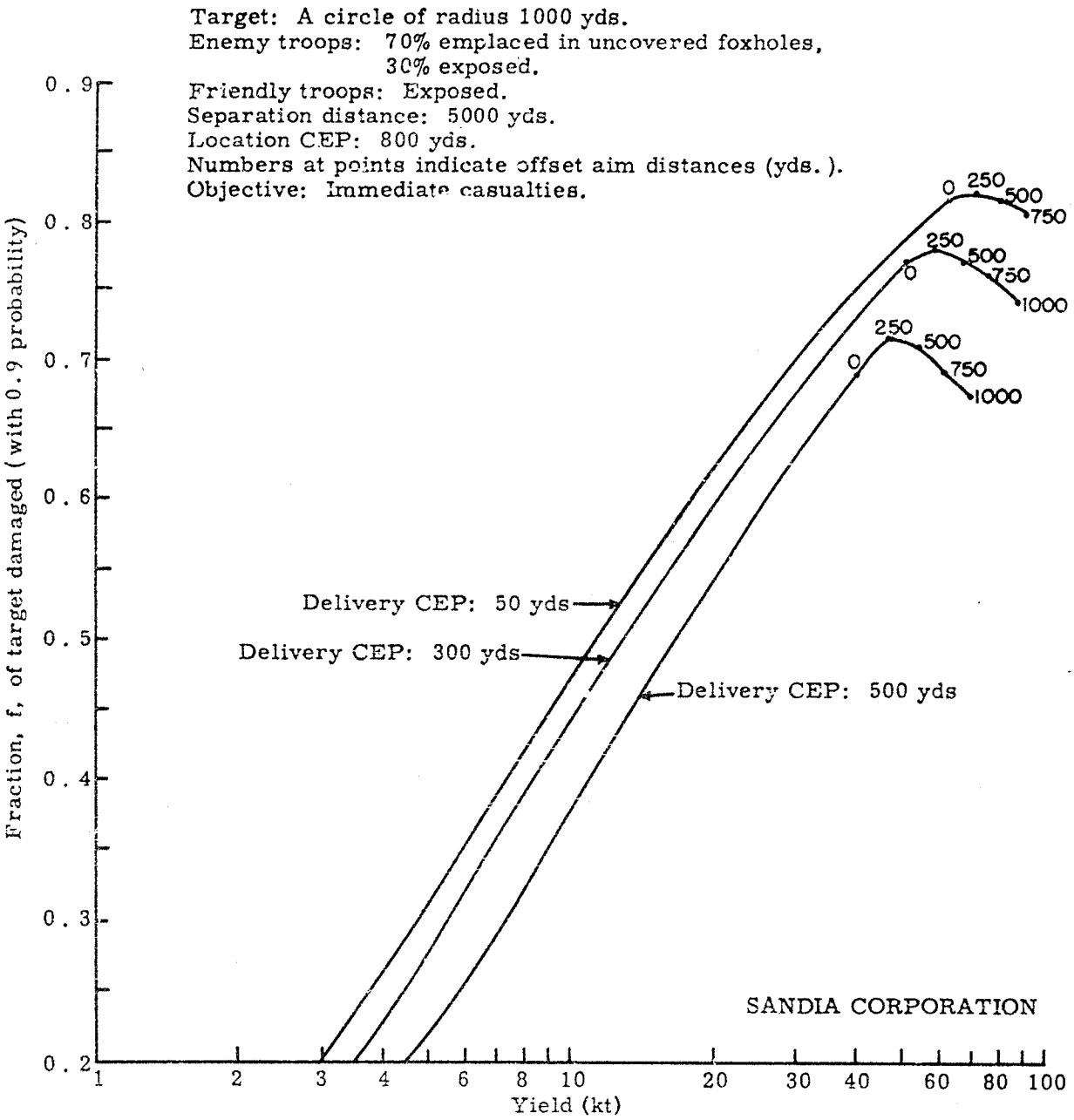

Fig. 13 -- Target C, defensive situation against enemy attack in build-up phase; separation distance: 5000 yards, location CEP: 800 yards.

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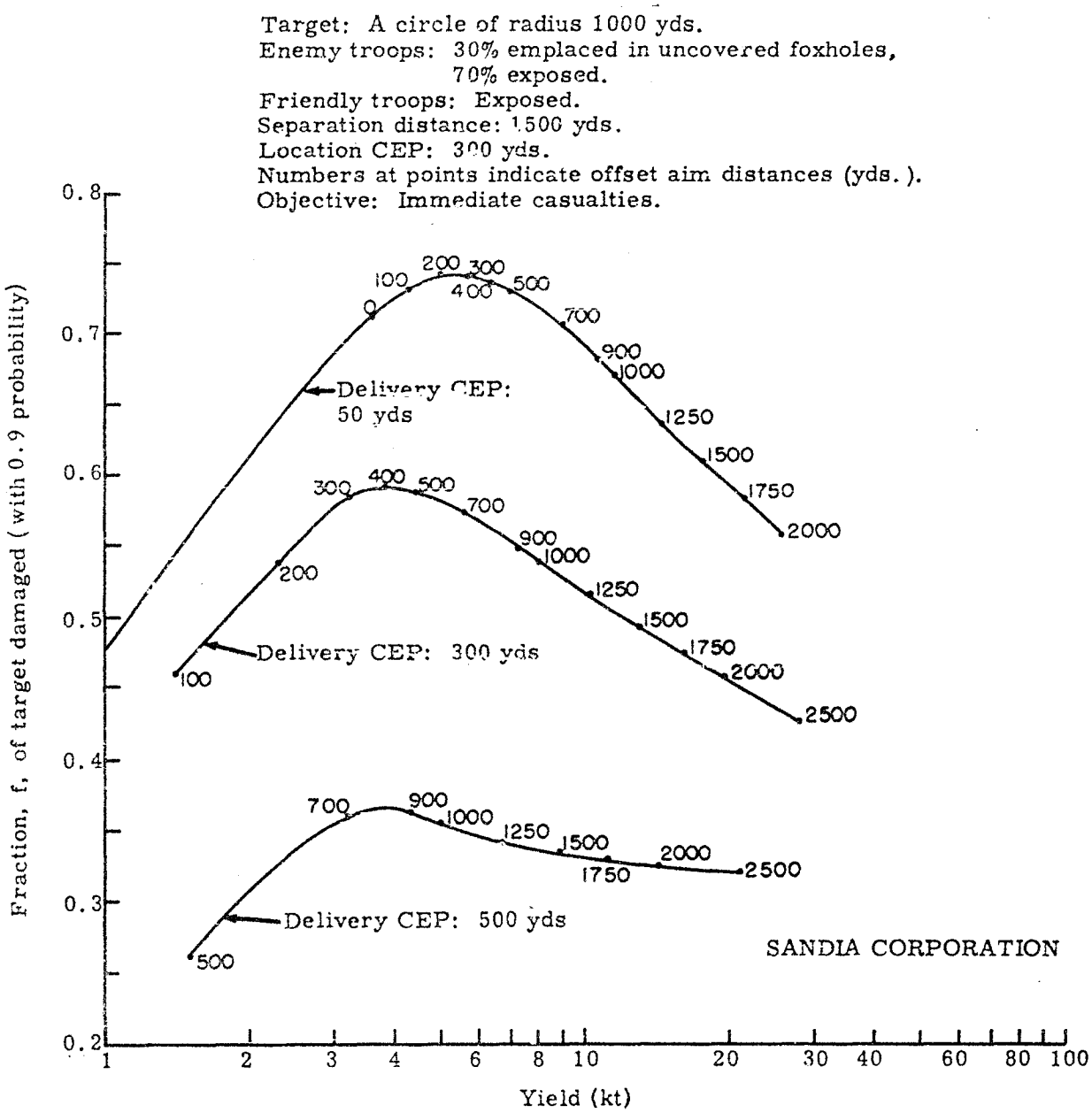

Fig. 14 -- Target D, defensive situation against enemy attack in jump-off phase; separation distance: 1500 yards, location CEP: 300 yards.

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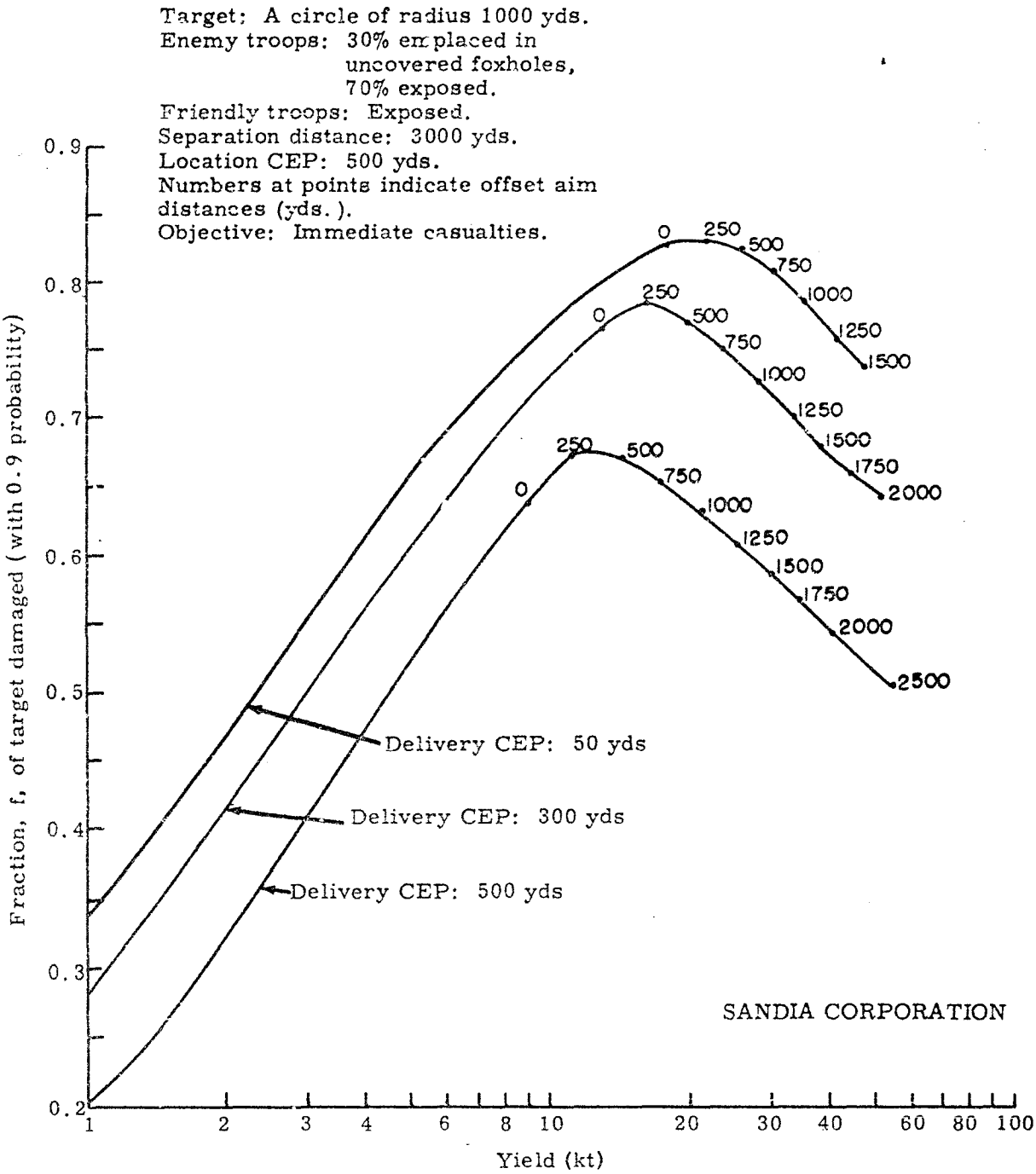

Fig. 15 - Target D, defensive situation against enemy attack in jump-off phase; separation distance: 3000 yards, location CEP: 500 yards.

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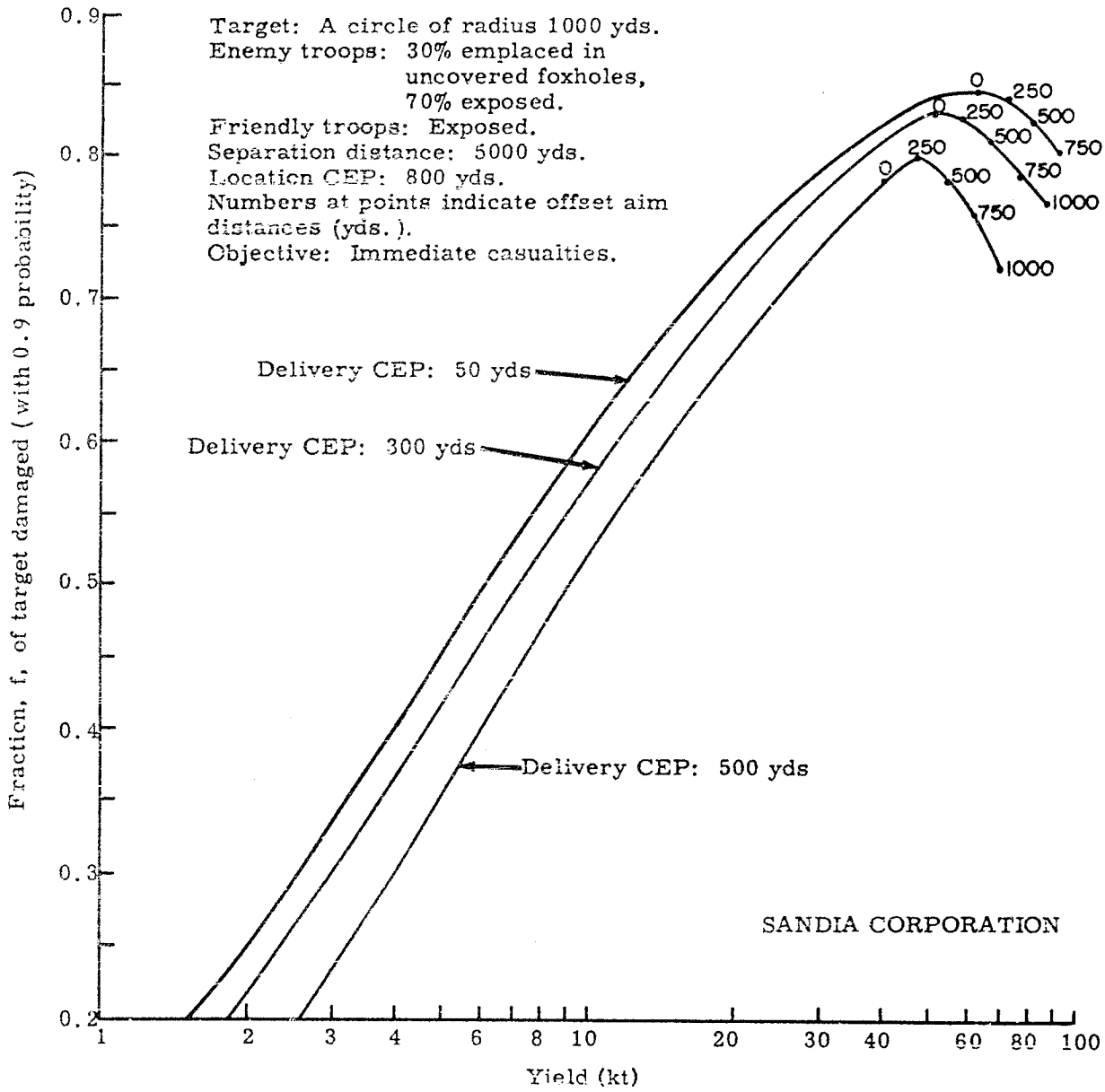

Fig. 16 -- Target D, defensive situation against enemy attack in jump-off phase; separation distance: 5000 yards, location CEP: 800 yards.

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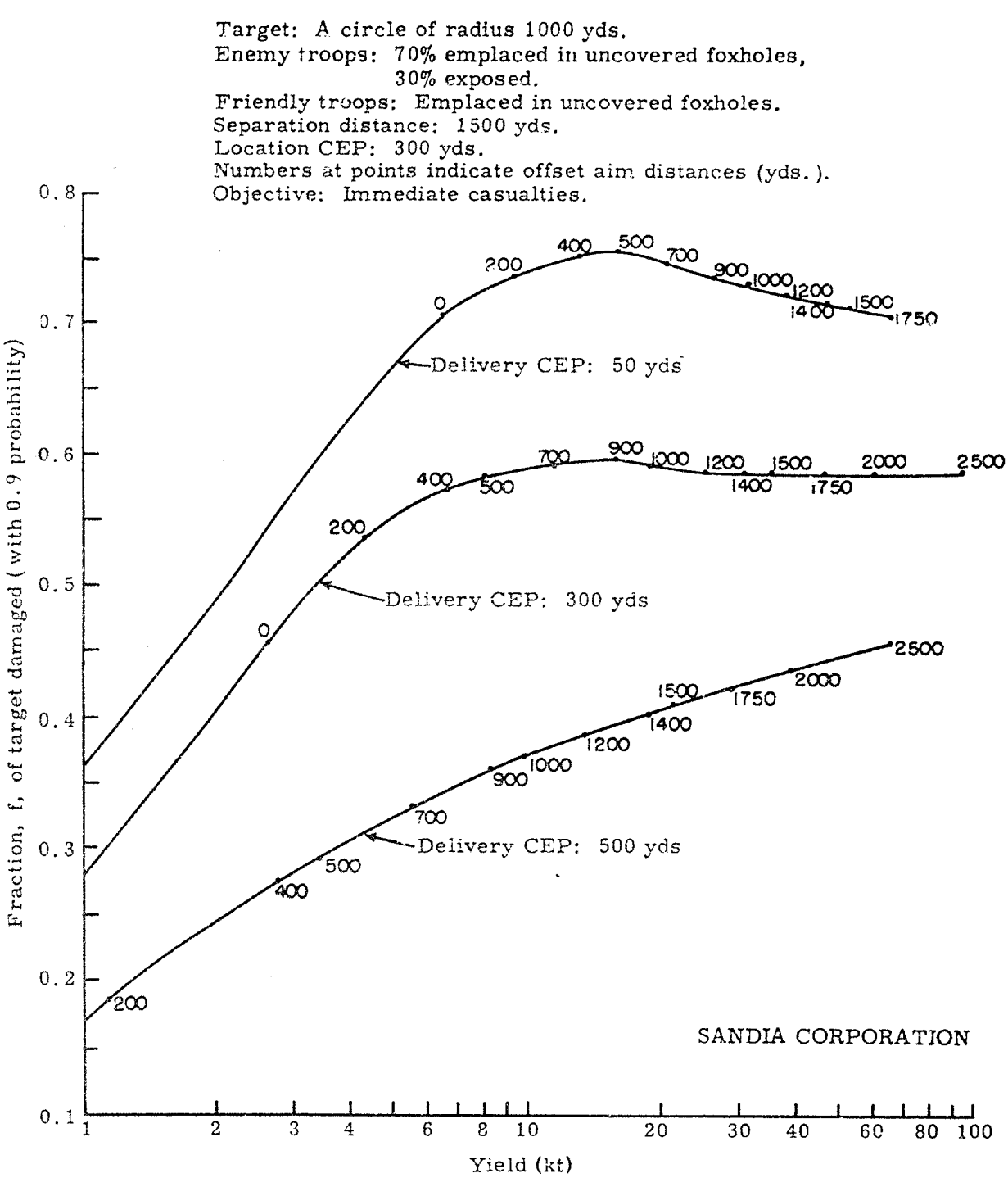

Fig. 17 -- Target E, offensive situation against troops not entirely protected from thermal radiation; separation distance: 1500 yards, location CEP: 300 yards.

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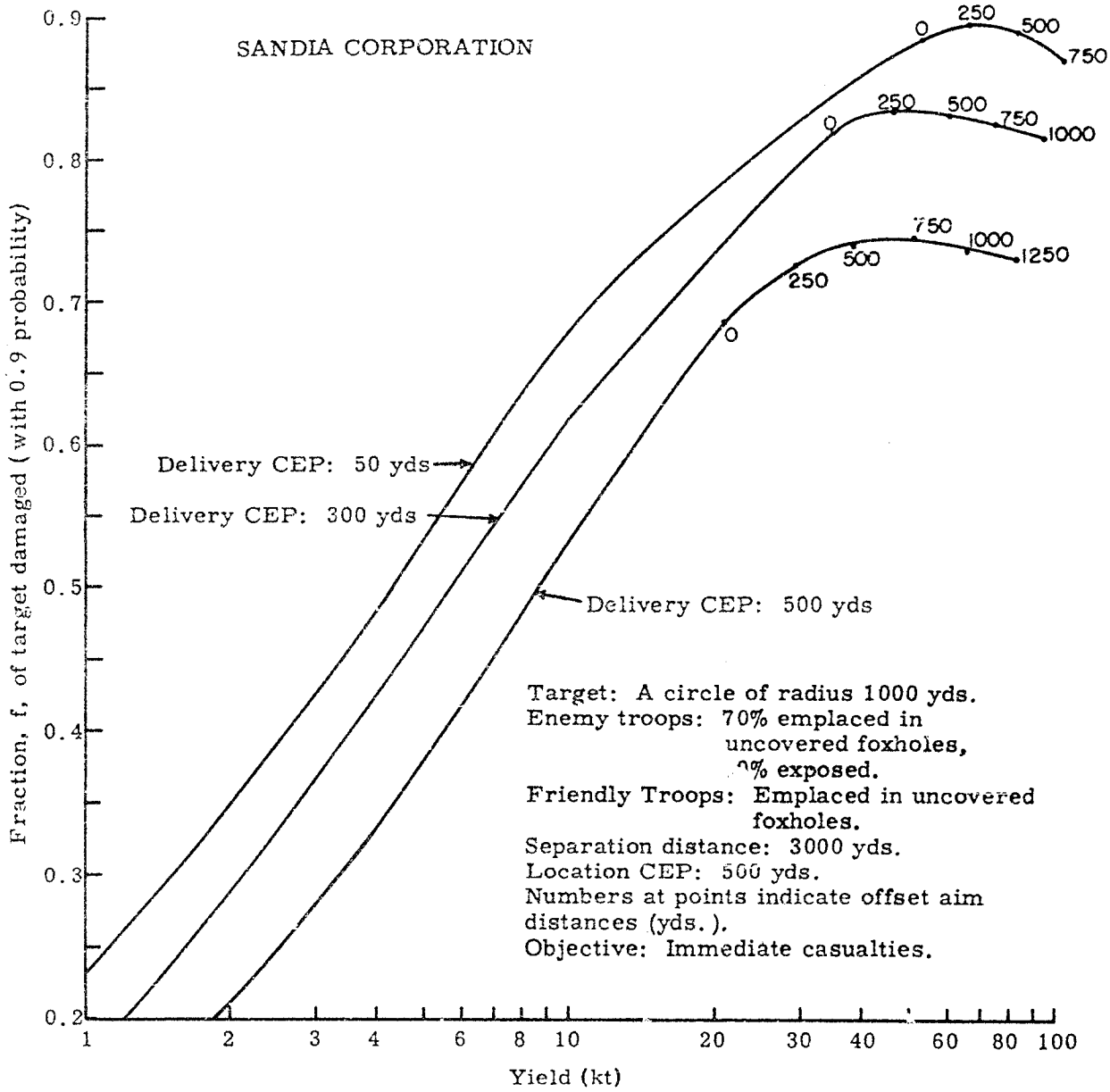

ig. 18 - Target E, offensive situation against troops not entirely protected from thermal radiation; separation distance: 3000 yards, location CEP: 500 yards.

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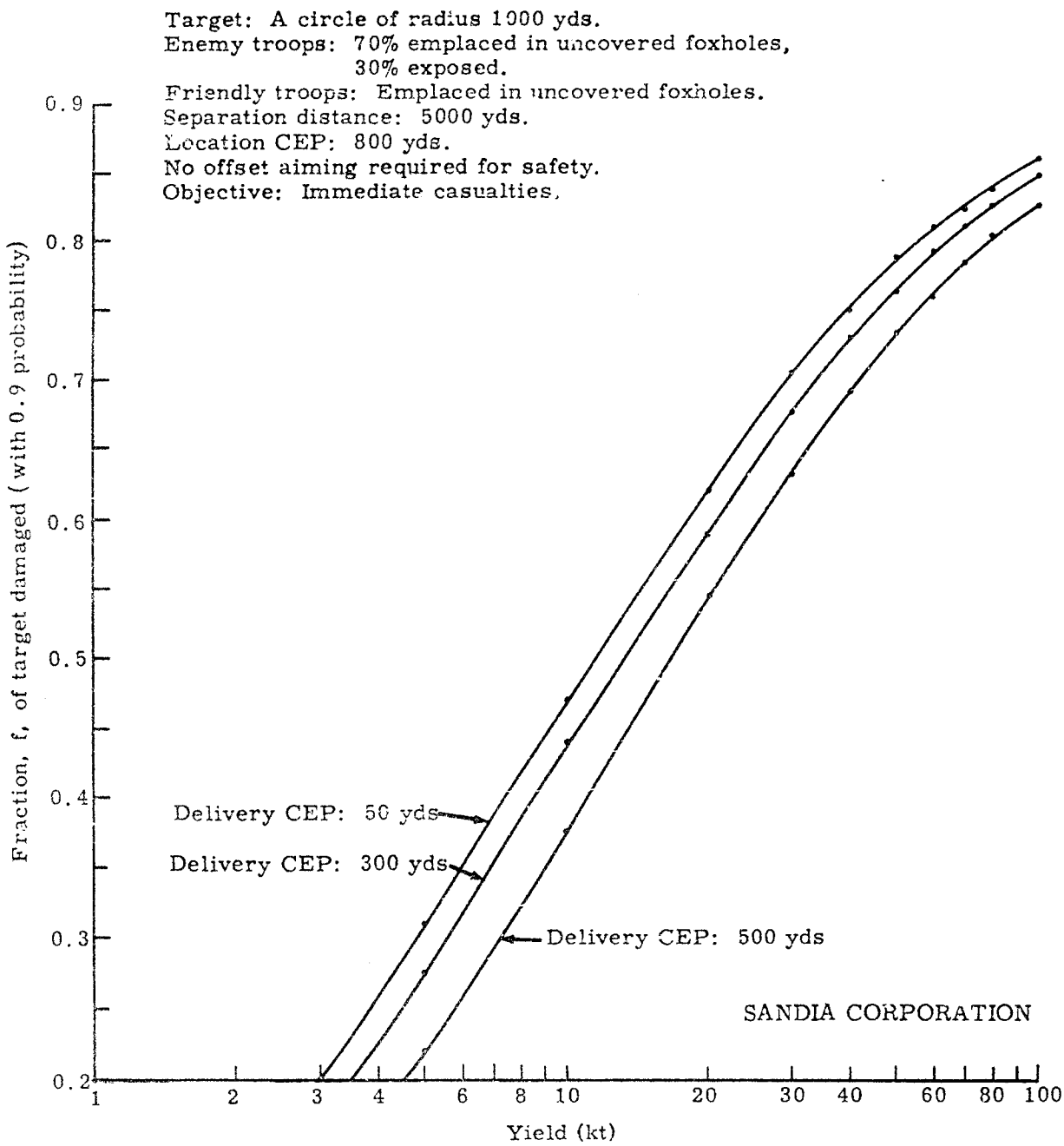

Fig. 19 -- Target E, offensive situation against troops not entirely protected from thermal radiation; separation distance: 5000 yards, location CEP: 800 yards.

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Presentation of Results

Results are presented in graphical form in Figs. 5-19; some are emphasized in tabular summaries in the concluding section. There are three graphs for each of the five target situations--one for each of the following combinations of S and LCEP (both in yards): (S, LCEP) = (1500, 300), (3000, 500), and (5000, 800). [No firm relationship between S, the separation distance, and LCEP, the intelligence error is known. In this study the data points (S, LCEP) = (1500, 300), (3000, 500), and (5000, 800), all units in yards, have been assumed relative to the 1000-yard radius targets. A curve joining these three points closely approximates a straight line (Fig. 20).] Each figure contains three curves, each dependent on a value of DCEP. After the combination of S and LCEP is selected, the maximum safe yield is determined for a fixed value of DCEP from the appropriate family of safety curves (Figs. 1 or 2) for a range of values of A as described above under Safety Curves (p. 11). Each of these yields is associated with an offset distance $\delta = A - S$, and the corresponding fraction of damage with 0.9 probability is computed as above under Damage Calculations (p. 13) and plotted against the given yield. Thus a curve representing fraction of damage with 0.9 probability versus yield for fixed DCEP, S, and LCEP is obtained. The numbers associated with the emphasized points on these curves indicate the offset distance in yards. The smaller yields can be employed without offsetting, i.e., they can be aimed at the center of the target. As the yields increase, the amount of offset required increases when $S \leq 3000$ yards. Note that in most instances the curves have a maximum point. The choice of optimum yields is based on the presence of these maxima and the yields associated with them. For example, in Fig. 11, for DCEP = 50 yards, the optimum yield is approximately 5.5 kt, the offset is 250 yards, and the corresponding fraction of damage is 0.64.

The following method of presentation also is found to be informative: If it is assumed that the curve of Fig. 20 represents the variation of LCEP with S, then it is possible (using the methods already outlined) for a fixed DCEP and given dispositions of friendly and enemy troops, to show the fraction of the target damaged with 0.9 probability as a function of S for various weapon yields. Figure 21 demonstrates this situation for DCEP = 300 yards when friendly troops are exposed and the enemy are 70 per cent emplaced in uncovered foxholes and 30 per cent exposed (target C) for yields of 1, 3, 5, 15, 30 and 50 kt. (Curves for yields of 10, 20, and 40 kt were also examined but are not shown. As expected they aligned themselves between the curves for the adjoining yields.)

Sensitivity of Results

A detailed study of the sensitivity of the results to changes in criteria has not yet been carried out. However, the following appears to be the situation based on calculations for Target C when S = 1500 yards and LCEP = 300 yards: The results are most sensitive to changes in the safety criteria. Raising the thermal undesirable effect level to 12 cal/cm^2 raises the value of the optimum yield from 5 to 9 kt although the difference in the fraction of damage is not great. Changes in target size affect the results even less. Reduction of the target radius to 500 yards changes the yield by a negligible amount. The use of a cookie-cutter type casualty curve, and the use of casualty curves of variability 0.2 and 0.3 (as given in Reference 6), does not change the yields giving maximum fraction of damage, although, as might be expected, the fraction of damage is altered.

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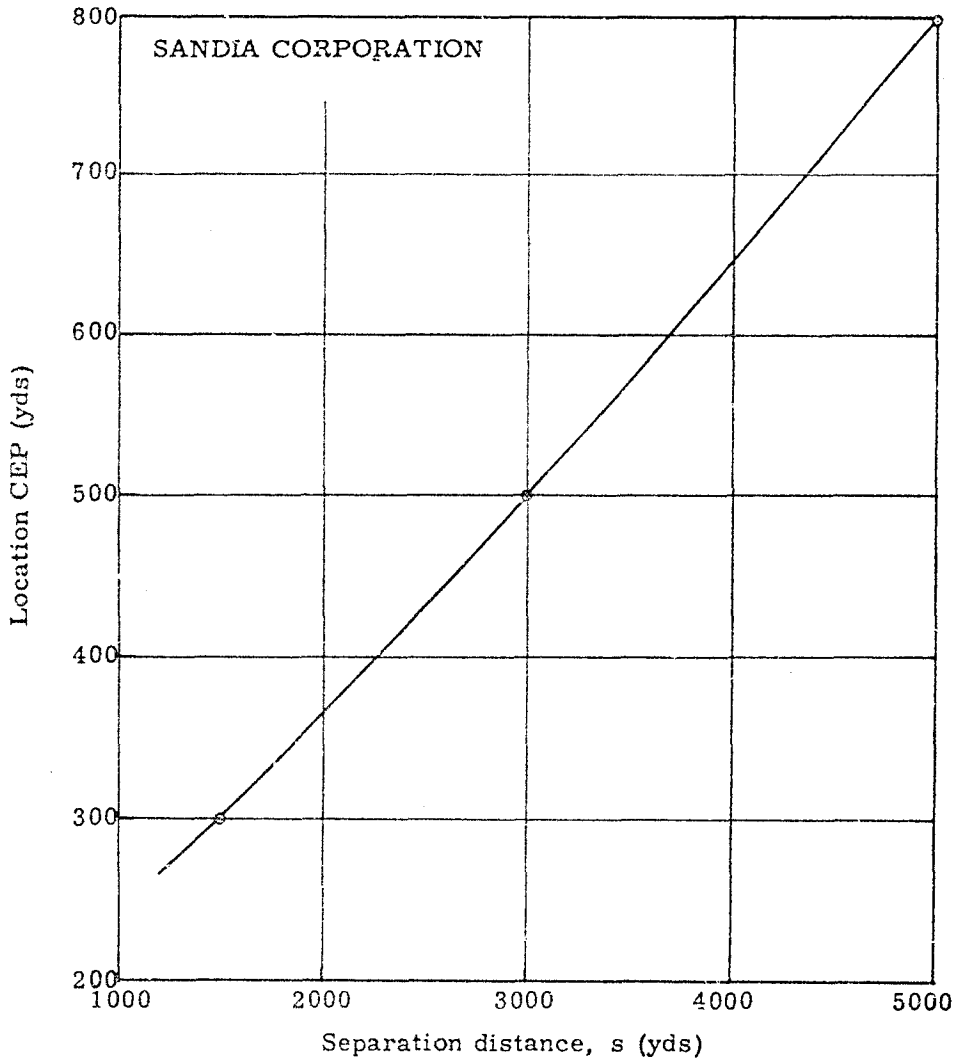

Fig. 20 -- Location CEP versus separation distance

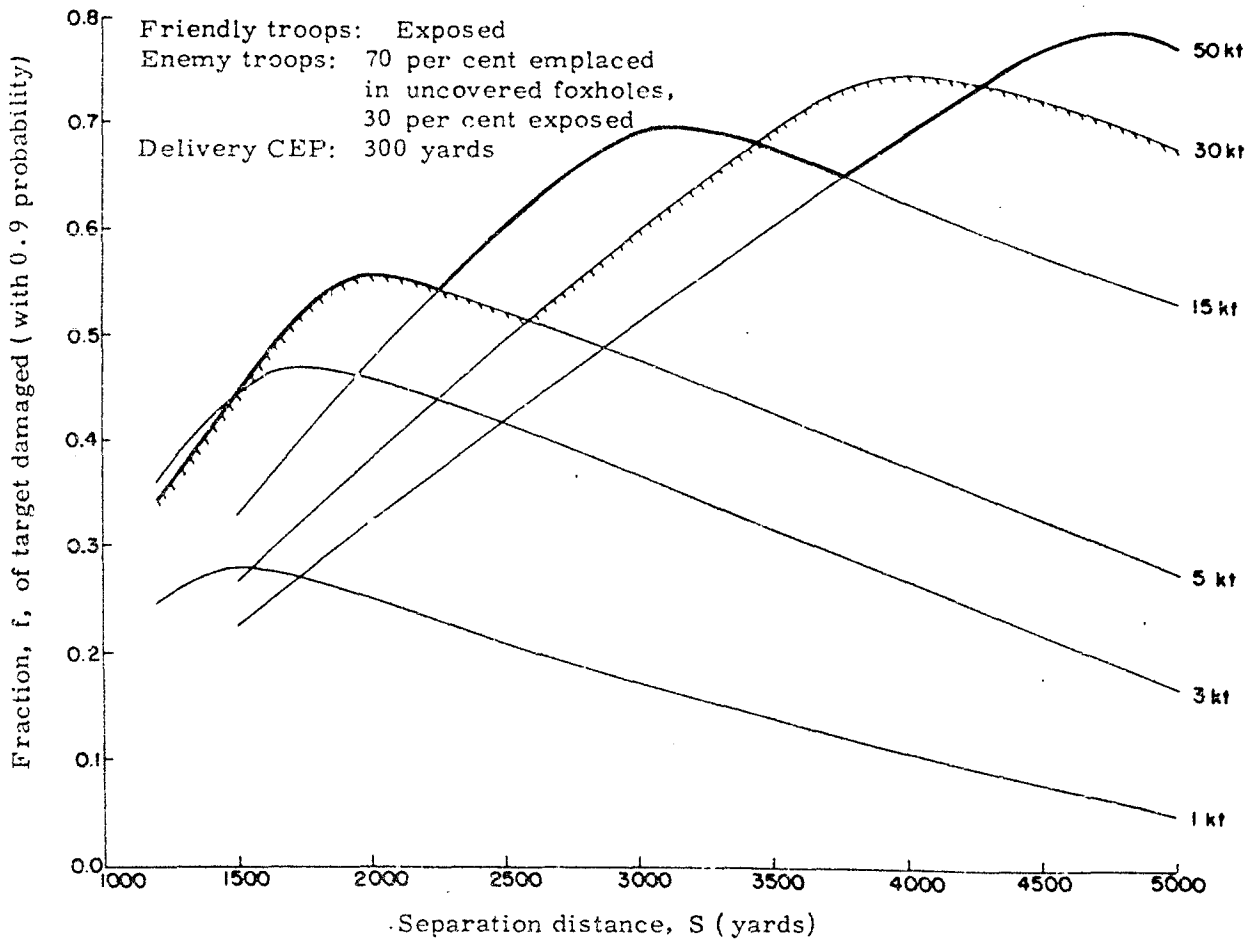

Fig. 21 -- Fraction of target damaged versus separation distance

For targets C, D, and E analysis was carried out for the combinations (S, LCEP) = (3000, 300) and (5000, 500). The change in the yield at which maximum fraction of damage was obtained for (3000, 300) differed only by one per cent from the yield obtained for (3000, 500). For (5000, 500) as compared to (5000, 800) the change in yield was at most seven per cent.

SUMMARY OF RESULTS

The tables presenting the results are constructed from two points of view: (1) it is desirable to inflict the greatest amount of damage possible, and (2) the achievement of a minimum level of damage, say 0.3 with 0.9 probability, is all that is required. Under (1) two alternatives are considered: (a) the DCEP is unknown but lies between two known limits, and (b) the DCEP is known. For (2) only an example where the DCEP is known is considered. Under (1a) the optimum yield is obtained by selecting visually from Figs. 5-19 a yield which gives close to the maximum fraction of damage for all DCEP's considered. One can determine this yield mathematically by assuming a probability distribution of DCEP's and computing fraction of damage for various yields, but it is felt that such a refinement is unwarranted. The yields selected here are merely considered to be of the right order of magnitude. The present state of the art clearly does not permit pinpoint accuracy.

Tables II-IV are illustrative of view point (1a).

Table II

Optimum Yields for Unknown DCEP

S(yds)	LCEP(yds)	Optimum yield (kt) Target A	B	C	D	E	Range of DCEP (yds) giving at least 0.3 damage
1500	300	5	8	5	5	15	$0 \leq DCEP \leq 400+$
3000	500	40	45	17	16	60	$0 \leq DCEP \leq 500+$
5000	800	100+	100+	60	54	100	$0 \leq DCEP \leq 500+$

Table III

Optimum Yield-Offset Combinations for DCEP = 300 yards

S(yds)	LCEP(yds)	Optimum Yield (kt) Target A	B	C	D	E	Offset (yds) Target A	B	C	D	E
1500	300	5	5	3.5	4	15	250	250	350	400	900
3000	500	40	38	16	16	50	100	50	250	250	350
5000	800	100+	100+	58	54	100+	0	0	250	100	0

Table IV

Comparison of f^* for Yields of Tables II and III

S (yds)	LCEP (yds)	f^* corresponding to optimum W of Table III					f^* corresponding to optimum W of Table II				
		Target					Target				
		A	B	C	D	E	A	B	C	D	E
1500	300	0.46	0.31	0.46	0.59	0.59	0.46	0.28	0.44	0.58	0.59
3000	500	0.55	0.37	0.69	0.78	0.83	0.55	0.37	0.69	0.78	0.83
5000	800	0.45	0.30	0.78	0.83	----	0.45	0.30	0.78	0.83	----

*Fraction of target damaged with 0.9 probability

Table V illustrates view (2b). (Data are listed for Target C only.)

Table V

Range of Yields for Obtaining 0.3 Fraction of Damage with 0.9 Probability, $0 \leq DCEP \leq 300$ yds

S (yds)	LCEP (yds)	Range of yields $W \leq 100$ kt
1500	300	$1.1 \leq W \leq 19.5$
3000	500	$2.1 \leq W$
5000	800	$5.5 \leq W$

CONCLUSIONS

Tables II and III indicate that a reasonable family of yields for use when friendly troops are exposed would be 5, 15, and 55 kt, to be employed in the situations where S = 1500, 3000, and 5000 yards, respectively. When friendly troops are emplaced, the yields would be 15, 50, and 100 kt or more for the same values of S.

However, this method of selection depends on the fraction of damage accomplished and it is not clear what is the difference in military worth for fractions which are all above a certain level, or which differ by only a few per cent. For this reason the following method is suggested as an alternative for the selection of yields: Assume that

in Fig. 21 curves are constructed for a continuous spread of yields over the range $0 \leq W \leq 100$ kt. The envelope of this family then represents the maximum atomic capability for the stated deployment in the sense that for each S there is a W giving maximum damage. From this "ideal" continuum of yields a discrete family giving what is felt to be adequate coverage is chosen. Note that the yields 5, 15, and 50 kt give very nearly maximum fraction of damage (see heavily emphasized curve of Fig. 21) if 5 kt is employed from 1200 to 2300 yards, 15 kt is employed from 2300 to 3750 yards, and 50 kt is employed from 3750 to 5000 yards.

On the other hand, it is equally clear that one does almost as well by using the yields 5 kt and 30 kt (see shaded curve, Fig. 21). If the delivery and deployment parameters are altered this mode of investigation can be applied to the family of yields problem as related to all targets outlined earlier in this study. It is hoped to develop a more quantitative method of selecting yield families. This present method depends too much upon subjective visual judgment and choice.

R. C. HILDNER - 5122

H. H. WICKE - 5123

Case No. 417.00
July 1, 1955

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*Restricted distribution; not available for distribution external to Sandia Corporation.