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RESEARCH AND ENGINEERING
LABORATORIES

[illegible] AND SPECIAL PROJECTS LABORATORY

TECHNICAL MEMORANDUM
NO. [illegible]

FINAL REPORT ON WARHEADS FOR MAULER WEAPON SYSTEM

BY

[illegible]

DOWNGRADED AT 12 YEAR INTERVALS;
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VOLUME 2 OF [illegible]

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FELTMAN RESEARCH AND ENGINEERING LABORATORIES

MISSILE WARHEAD AND SPECIAL PROJECTS LABORATORY

MISSILE WARHEAD SECTION

ANALYTICAL SECTION

TECHNICAL MEMORANDUM NO. 137B46 (A57)

FINAL REPORT ON WARHEADS FOR MAULER WEAPON SYSTEM

VOLUME II

(OF IV)

WARHEAD EFFECTIVENESS

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MISSILE WARHEAD AND SPECIAL PROJECTS LABORATORY

MISSILE WARHEAD SECTION
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TECHNICAL MEMORANDUM NO. 137B46 (A57)

FINAL REPORT ON WARHEADS FOR MAULER

By

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ORDNANCE PROJECT NO: TU1-3072

NOVEMBER 1958

(This report is in four volumes)

SECRET

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SUMMARY

The effectiveness of each proposed Mauler system against MIG-17 type targets was evaluated for pure blast, blast-fragmentation, and CR warheads. The blast-fragmentation warhead was found to be the most effective for all four proposed systems. The major characteristics and optimum parameters of the blast-fragmentation warheads for each contractor are summarized in the following table:

	CONVAIR	GE	MARTIN	SPERRY
Warhead weight, lbs	10	29	30	30
Frag Beam angle	79°	72°	63°	66°
C/M	0.90	0.96	1.28	1.07
Frag weight, grains	30	30	30	30

Each of the four Mauler systems equipped with an optimum blast-fragmentation warhead exceeds the single shot kill probability requirements stated in the MC's for Mauler. The following table summarizes the single shot K kill probabilities for each system equipped with the above blast-fragmentation warheads assuming the guidance errors estimated by each contractor. The results are given for a fuzing error of 5 ft and 10 ft.

Contractor	Guidance Error σ_g(ft)	Single Shot Kill Probability (P_k) σ_{Fuze} = 5'	σ_{Fuze} = 10'
Convair	6.7	.78	.66
G.E.	7.4	.90	.85
Martin	10.2	.86	.83
Sperry	12	.87	.80

INTRODUCTION

Three types of warheads were evaluated for the proposed Mauler systems: pure blast, blast-fragmentation and continuous rod. The blast-fragmentation warhead was found to be the most effective for each contractor's system. In optimizing the blast-fragmentation warhead, the following parameters were considered: Fragment spray angle, fragment size, C/M and the fuze delay. The target considered in this study was a fighter bomber of the MIG 17 type.

The three types of warheads were evaluated using a Monte Carlo method of solution. The pure blast and blast-fragmentation warheads were evaluated analytically using the IBM 650 Digital Computer to obtain results and the C-R warhead was evaluated by means of a mechanical engagement simulator.

This volume is divided into the following parts:

I. Scope of Study

This part lists the parameters and their values used in analyzing the three types of warheads considered in this study.

II. Method of Analysis

The sub-headings in this part are:

A. Assumptions requisite to the study.

B. Approach distribution of the missile with respect to the target.

C. Fuzing

D. Target Vulnerability

E. Mathematical models

III. Results and Discussion

Under this heading, results obtained are listed and the effectiveness of each type of warhead is compared.

The effectiveness results shown are single shot kill probabilities and assume 100% system operability and reliability.

SCOPE OF STUDY

A. Pure Blast Warhead

In evaluating the pure blast warhead, the following parameters and their values were considered:

3 Guidance errors (σ_g)	=	5', 10' and 15'
3 Fuzing errors (σ_f)	=	5' and 10'
3 Fuze look angles (θ)	=	45°, 60° and 75°
2 Lethal Blast Radii (R_b)	=	10' and 20'
2 Missile Velocities (V_m)	=	2000 fps for the three contractors, G.E., Sperry and Martin and 2510 fps for Convair.
*Radius of Target (R_t)	=	15'
Velocity of Target (V_t)	=	1500 fps
*Value of C used in the variable fuze delay formula	=	15'

One hundred engagements for each set of parameters were evaluated on the 650 Digital Computer.

B. Blast-Fragmentation Warhead

The blast-fragmentation warhead was evaluated in three phases, a preliminary, an intermediate and a final phase. In the preliminary phase, the warheads designed originally for each contractor were evaluated for the following parameters and values:

*Refer to section on Method of Analysis for discussion of these parameters.

2 Guidance errors	=	5' and 12'
2 Fuzing errors	=	5' and 10'
2 Fuze look angles	=	60° and 75°
2 Fragment sizes	=	30 and 90 grains
2 C/M's	=	1.0 and 1.7
2 Fragment beam angles*	=	14° (approximately) and 80°

In the intermediate phase, the warhead weights and diameters proposed by each contractor were held constant and the length was varied to obtain a wider beam angle, which was found to be desirable. As a result of this phase the warhead compartment envelopes and weights for each contractor were fixed. In evaluating the warheads for this phase, the following parameters and values were used:

2 Guidance errors	=	5' and 12'
2 Fuzing errors	=	5' and 10'
2 Fragment sizes	=	60 and 90 grains
1 Fuze look angle	=	70°

The C/M for Sperry, Martin and Convair was approximately 1.7. Since G.E. insisted on maintaining their specified envelope dimensions and total weight, their C/M was 0.96.

In the final phase, the fragment beam angle, C/M, fragment size and C value used in the fuze delay distance formula were optimized within the confines of the warhead compartment envelopes determined in the previous phase of the study. This was done by holding the C/M constant equal to about 1.7 and varying the fragment beam angle from approximately 40° to 110°.

* The fragment beam angles are symmetric about the transverse axis of the warhead and represent the total included angle between the forward and rear fragment cone boundaries.

Once the optimum beam angle was determined, it was held constant and the C/M varied from approximately 1.0 to 1.8. In every case fragment sizes of 30, 45, 60 and 75 grains were used. After optimizing fragment beam angle, C/M and fragment size in this manner, the best value of the fuze delay constant, C, was found. All results for the blast-fragmentation warhead were obtained from the IBM 650 Digital Computer and are based on one hundred engagements.

C. Continuous Rod Warhead

CR warheads were evaluated for G.E., Sperry and Martin only. Convair's warhead was considered too small for an effective CR warhead. Warheads designed to the weights allowed by each contractor were evaluated only.

One hundred engagements for the parameters and values listed below were evaluated:

2 Guidance errors = 5' and 12'

2 Fuzing errors = 5' and 10'

1 Fuze look angle = 70°

METHOD OF ANALYSIS

In order to give a clear picture of how this three dimensional problem is solved, it may be desirable to follow one complete engagement through from the time the target is approaching to the time the missile completes its mission (i.e., either a hit or a miss occurs). The chain of events for a typical engagement follows:

1. The Mauler missile approaches the target in a random direction determined by the azimuth and elevation approach distributions.

2. The Mauler fuze senses the target within its antenna beam.

3. Fuze delay action is set in motion. Mauler moves a certain distance which depends upon the missile-target closing velocity while the target continues to travel in its same direction.

4. Mauler detonates. If the target is within a certain blast radius (the size of which depends upon the type and amount of explosive in the missile) a "K" kill is considered to have occurred. If the target is outside this blast radius, then no damage results and it is called a miss. For the pure blast warhead, the engagement ends here. However, if the missile carried a blast-fragmentation or CR warhead, and the blast does not kill the target, then the effect of the fragments (or rods) is considered.

Before presenting the mathematical models for this three dimensional problem, some of the basic assumptions, concepts and input data requisite to the analysis will be described in the following order:

A. Assumptions requisite to study

B. Approach distribution of the missile with respect to the target

C. Fuzing

D. Target vulnerability

E. Mathematical models

A. Assumptions

The following assumptions were used in this analysis:

1. The missile trajectories are distributed about a central trajectory through the center of gravity (CG) of the target according to a bivariate circular normal distribution. The CG of the target is the origin of the coordinate system.

2. Most of the missile approaches with respect to the target are from the front varying between $\pm 90^{\circ}$ in azimuth from the longitudinal axis of the target.

3. Missile approaches in elevation are uniformly distributed from head-on to 45° below the target.

4. The target (MIG 17) can be represented by a sphere of radius R_t, equal to 15 feet to simulate fuze sensing off the extremities of the target.

5. The target has a spherical blast envelope of radius, R_b, centered at the same point as the fuze sensing sphere.

6. Fragments are distributed uniformly over a solid angle centered at the point of detonation.

7. The target continues to travel in the same direction after being detected by the missile.

B. Missile Approach Distribution

It was assumed (Assumption No. 2) that most of the target approaches with respect to the Mauler launcher would be from the front and that any target flight path parallel to the one directly in line with the launcher would be equally likely. This was converted into a distribution of azimuth angles of the following form:

$$F(\alpha) = 1/2\ (1 + \sin\alpha).$$

This distribution function is derived in the following manner:

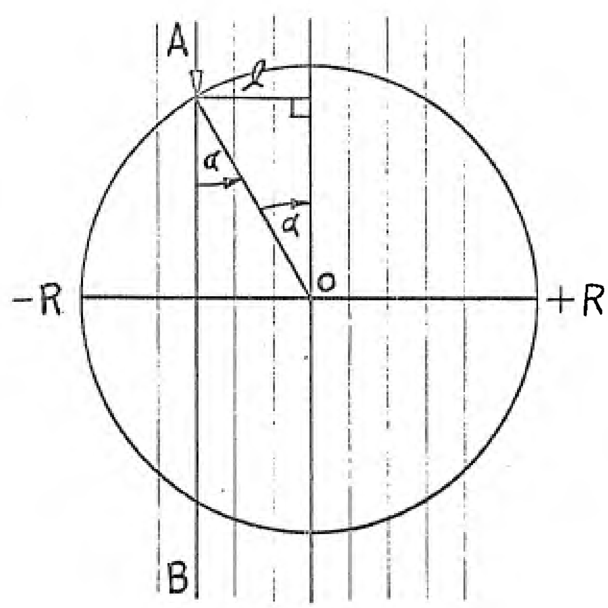


FIGURE 1

Assume that the missile launcher is at O and the target is approaching on some random path, AB (Figure 1). The problem is: What is the probability that the target comes within firing range of the Mauler located at O at a relative bearing α? It was assumed that the missile approach angle would be approximately equal to the angle α in order to simplify the analysis. Since the target is moving along some random path, the value of ℓ will occur at random between the limits $+R$ and $-R$. It can also be seen that α depends on the random variable, ℓ, and is related to it by $\ell = R \sin \alpha$. Redefining the random variable so that it takes on values between zero and unity, the following relationship is obtained:

$$\xi = \frac{R + \ell}{2 R} \quad ; \quad 0 \leq \xi \leq 1 \quad \text{when } -R \leq \ell \leq +R$$

Substituting $R \sin \alpha$ for ℓ, the cumulative distribution function $F(\alpha) = 1/2 \ (1 + \sin \alpha)$ is obtained.

Examination of this distribution function shows that 50% of the time the target approaches at an azimuth angle between 0° and ± 30°; 36% of the time in the region ± 30° to ± 60°; and 18% of the time in the region ± 60° to ± 90° (Figure 2).

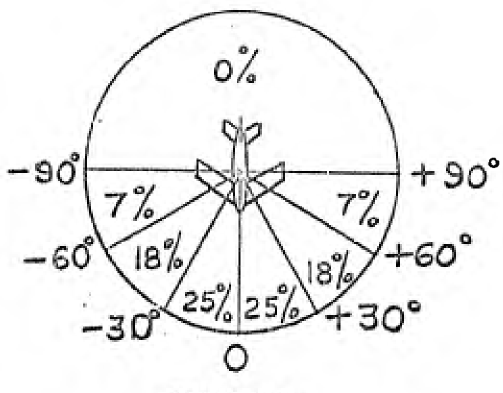


FIGURE 2

Missile approaches in elevation are uniformly distributed from head-on to 45° below the target (Assumption 3). This angle in elevation is designated by the Greek letter, φ , in this report.

C. Fuzing

In evaluating the three types of warheads, the following was considered with respect to the fuzing:

1. Fixed Angle Fuzing

A fixed angle fuze antenna beam was assumed in this study. The beam makes an angle θ with the missile axis and is also called the fuze look angle.

2. A variable fuze delay relationship corresponding to the fuze to be used in the HAWK missile was assumed. The delay formula is:

$$D_d = C + M \left(\cot \theta - \frac{V_c}{V_{o_d}}\right)$$

where D_d = Delay distance, ft.

C = Distance from the nose of the target to the center of vulnerability of the target, ft.

M = Miss distance (guidance error) of the system, ft.

θ = Fuze look angle, degrees

V_c = Closing velocity between target and missile, fps

V_{o_d} = Initial dynamic velocity of the fragments, fps

3. The distribution of burst points is linear normal about a point along the missile trajectory which is located the delay distance, D_d, away from the fuze sensing point.

D. Target Vunerability

In this study only "K" kills are considered. For a "K" kill the airplane is considered to go out of control within 10 seconds. For blast vulnerability, 100. A structural aerodynamic and control damage is considered to produce a "K" kill.

Blast contours about the MIG 17 for a bare 8 lb TNT charge were obtained from BRL (Reference A). Blast contour projected areas for top-view, side-view, and front-view of a MIG 17 were combined to obtain an average presented area of the blast envelope. This area was set equal to the projected area of an equivalent blast sphere and the blast radius, R_b, computed. It was found that a bare 8 lb TNT charge gave an R_b, of 8.1 feet. Using the approximate relationship that the blast radius is proportional to the cube root of the charge weight, R_b's were obtained for other equivalent weights of bare TNT.

In calculating the equivalent bare charge weight of a steel cased warhead, the following formula was used (Reference B):

$$W_2 = 1.19C \left[\frac{1 + M/C \quad (1 - M')}{1 + M/C} \right]$$

where W_2 = Equivalent bare charge weight, lbs

C = Actual weight of explosive in steel cased warhead, lbs.

M/C = Metal to charge weight ratio of a cylindrical section of the warhead.

$M' = M/C$ for all values of $M/C < 1$.

and $M' = 1$ for all values of $M/C \geq 1$.

The equivalent bare charge weight of the explosive used was then multiplied by a constant factor (1.5 for HTA-4 and 1.2 for Octol) to obtain an equivalent bare charge weight in terms of TNT.

The pilot and the engine were considered in computing the vulnerable area of a MIG 17 to fragments. The following vulnerability relations were used (Reference C):

$$A_v \text{ (total)} = A_v \text{ (pilot)} + A_v \text{ (engine)}$$

where $A_v \text{ (pilot)} = 1 - e^{-.067W^2}$

$$A_v \text{ (engine)} = 4.3 - \frac{4.3}{.263 + .824 (W)^{\frac{1}{2}}}$$

$$W = M^{\frac{1}{2}} V_o \, e^{-\alpha r} \times 10^{-4}$$

V_o = Initial dynamic fragment velocity, fps

M = Fragment mass in grains

α = Fragment drag factor $= C_d \, \rho \, A/M$ (ft^{-1})

C_d = Fragment drag coefficient

ρ = Air density

A = Average presented area of fragment.

In the case of the continuous-rod warhead, the following criteria for vulnerability of the MIG 17 were used:

a. The rods are effective only to the theoretical maximum radius.

b. The plane can lose the outer 1/3 of either wing without being destroyed.

c. The plane can lose either horizontal stabilizer without being destroyed unless the vertical stabilizer is also lost.

d. The plane can suffer the loss of the nose, back as far as the pilot's compartment or the engine, without being immediately disabled.

e. The minimum striking velocity must be greater than 3300 fps at angles between 20° and 90° with respect to the body surface encountered.

An altitude of 10,000 feet was assumed for all missile-target engagements, and an air density of .0565 lbs/ft.^{3} used to determine velocity decay of fragments or rods.

E. Mathematical Models

1. Pure Blast Warhead

Considering the CG of the target as the center of the system, the coordinates of the missile in space at the time of burst are:

$$X_m = K_1 \sigma_x$$

$$Y_m = K_2 \sigma_y$$

$$Z_m = \frac{R_t}{\sin\theta} + r \cot\theta - D_d + K_3 \sigma_z$$

(see Figure 3)

K_1, K_2 and K_3 are random normal deviates with mean, $\mu = 0$ and $\sigma = 1$.

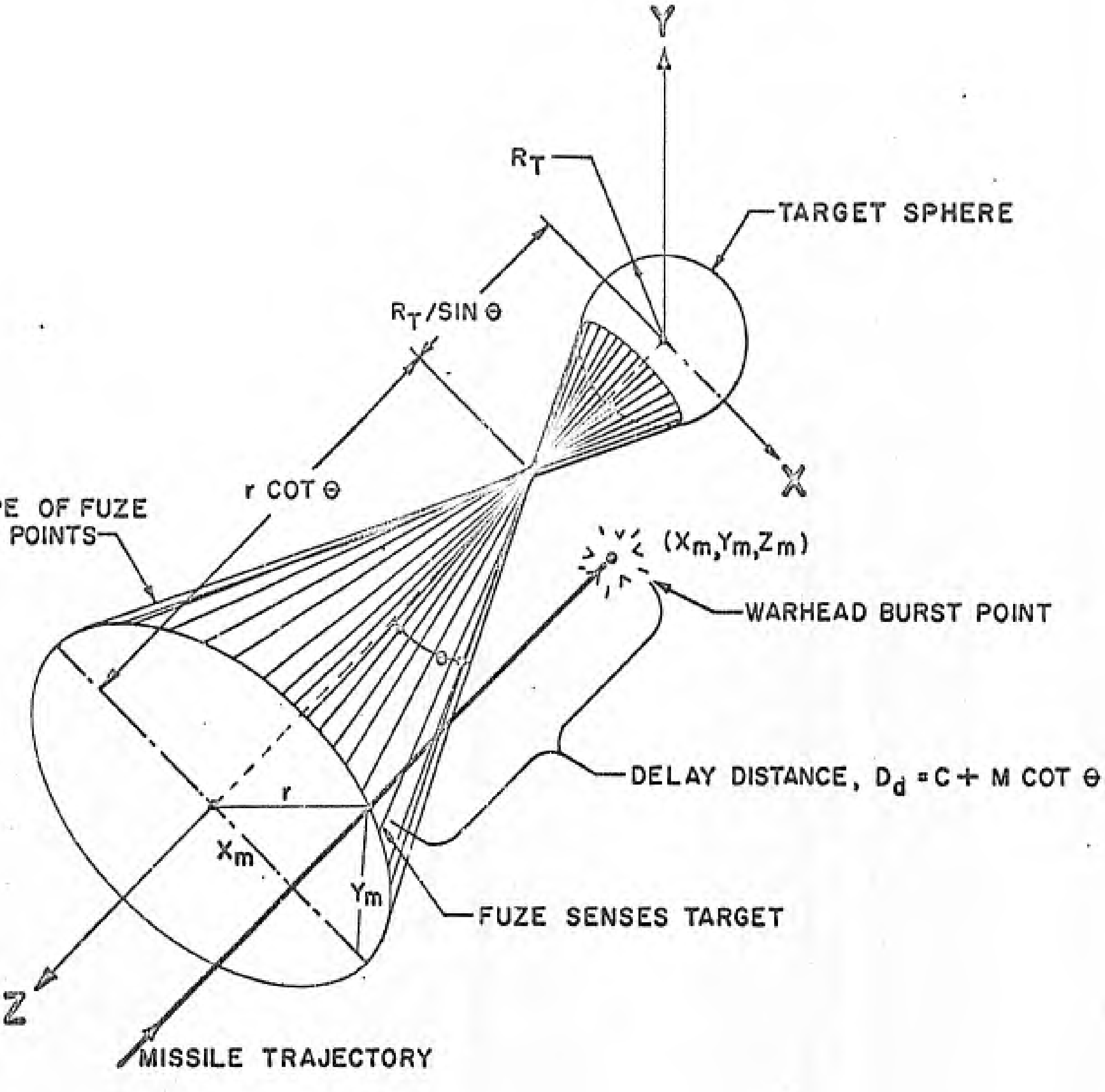

Y
R_T
TARGET SPHERE
R_T/SIN Θ
X
r COT Θ
ENVELOPE OF FUZE SENSING POINTS
(X_m,Y_m,Z_m)
WARHEAD BURST POINT
DELAY DISTANCE, D_d = C + M COT Θ
r
X_m
Y_m
FUZE SENSES TARGET
Z
MISSILE TRAJECTORY
Θ = FUZE CONE ANGLE

FIGURE 3

$\sigma_x = \sigma_y$ = Linear guidance errors defined as the standard deviation of miss distance along each of two mutually perpendicular directions in a plane at right angles to the missile trajectory.

R_t = Radius of target (see Assumption 4)

θ = Fuze look angle

$r = (X^2 + Y^2)^{\frac{1}{2}}$

$D_d = C + M \cot\theta$. In the pure blast warhead the correction factor for fragment velocity, $\frac{V_c}{V_{o_d}}$, was neglected.

σ_z = Fuzing error.

Various random approaches of the missile were considered. α and β are the angles in azimuth and elevation respectively and are found by using the following formulas:

$$\alpha = \sin^{-1} (2K_4 - 1)$$

$$\beta = K_5 \frac{\pi}{4}$$

where K_4 and K_5 are random numbers from 0 to 1.

Taking into consideration the distance the target travels from the time it is detected until the missile explodes, the coordinates of the target in space are:

$$X_t = V_t \cdot t_d \sin\alpha \cos\beta$$

$$Y_t = V_t \cdot t_d \sin\beta$$

$$Z_t = V_t \cdot t_d \cos\alpha \cos\beta$$

(see Figure 4)

where V_t = Velocity of target

$$t_d = \frac{C + M \cot\theta + K_3 \sigma_z}{V_m}, \text{ (delay time)}$$

V_m = Velocity of missile

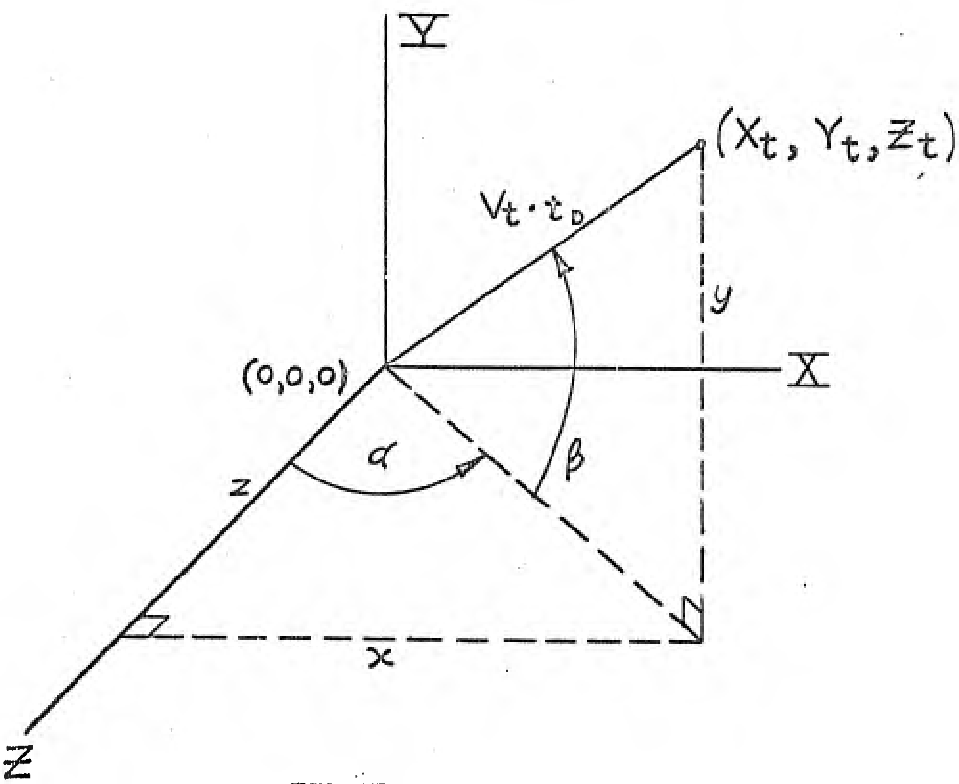


FIGURE 4

When the coordinates of the missile and target in space are known, the distance between them are found by means of the length formula:

$$S = \left[(X_m - X_t)^2 + (Y_m - Y_t)^2 + (Z_m - Z_t)^2\right]^{\frac{1}{2}}$$

Then this distance is compared with the computed blast radius to determine whether the warhead detonated within the lethal blast radius of the target. Bursts within the sphere are considered to have caused "K" kills by blast and bursts outside are considered ineffective. Single shot probability is then found as the fraction of missiles detonating within the lethal sphere.

2. Blast-Fragmentation Warhead

In evaluating the blast-fragmentation warhead, the same mathematical model was used as in the pure blast case with some modification. The formula used for obtaining fuze delay distance is modified to include the $\frac{V_c}{V_{o_d}}$ term. This factor is a correction term depending upon fragment velocity and closing velocity.

As in the case of the pure blast problem, each engagement is tested for "K" kill by blast. If the target is within the lethal blast sphere, the P_K is 1.0. If the target is outside the lethal blast sphere, the effect of the fragments is considered.

The fragments leaving the warhead are assumed to take the form of an expanding sphere. By writing the equations of motion for the sphere and the target in parametric form with time, t, as the parameter, the coordinates of the point in space at which the expanding fragment wave front intercepts the target can be computed. If the target is found to be outside the fragment beam spray angle, the P_k is zero. If the target lies within the spray angle, P_K is then computed by the formula:

$$P_K = 1 - \exp\left(\frac{-N_S A_V}{S^2}\right)$$

where N_s = Density of fragments, $\frac{\text{Number}}{\text{Steradian}}$

A_V = Vulnerable area of target, Ft^2

S = Distance between target and missile, Ft.

The average single shot kill probability for N engagements is then computed by:

$$P_K = \frac{\sum_{i=1}^{N} P_{K_{Bl_i}} + \sum_{i=1}^{N} P_{K_{Fr_i}}}{N}$$

where $P_{K_{Bl_i}}$ is the blast kill probability for the i th engagement, and

$P_{K_{Fr_i}}$ is the kill probability due to fragments for the i th engagement given that the warhead burst occurred outside the blast region.

Another factor that was considered in computing P_K was a fragment cut-off velocity. It was assumed that 30 grain fragments would have no lethal effect, even if they struck the target, if their velocity were below 3000 fps, (based upon information from BRL). From this, the cut-off velocity for 45, 60 and 90 grain fragments was computed using the Tolch-Bushkovitch formula (penetration is proportional to $M^{1/3} V^{4/3}$) for the penetration of mild steel by fragments assuming a constant penetration depth. These cut-off velocities were found to be 2700 fps for 45 grain fragments, 2520 fps for 60 grain fragments and 2280 fps for 90 grain fragments.

3. Continuous-Rod Warhead

As stated earlier in this section, the CR warhead was evaluated by means of a mechanical engagement simulator. In order to give the reader an idea of how the simulator works, the evaluation procedure is outlined briefly here.

a. The azimuth and elevation approach angles for a given engagement are determined by sampling from the approach distributions using the same Monte Carlo method described previously for the Pure Blast warhead.

b. The missile trajectory for each engagement is determined by sampling from the guidance error distribution.

c. The fuze sensing point is determined by moving the missile along its trajectory until the fuze cone intercepts an extremity of the target.

d. The warhead burst point is obtained from the delay distance formula which allows for the variable fuze delay and the fuze error:

$$D_d = C + M\left(\cot\theta - \frac{V_c}{V_{o_d}}\right) + K_3\,\sigma_z$$

where C = distance from nose of target to the center of its vulnerable point, ft.

M = Guidance Error, ft.

θ = Fuze look angle

V_c = Closing velocity, fps.

V_{o_d} = Initial dynamic velocity of rods, fps.

K_3 = Random normal deviate with mean, $\mu = 0$ and $\sigma = 1$

σ_z = Fuzing error, ft.

e. The target is moved a certain distance found by multiplying the target velocity by the time it takes the missile to travel from the fuze sensing point to the burst point.

f. A test is made to determine if "K" kill by blast occurs. This is done by noting whether the burst point is within the blast envelope of the target for the particular warhead. If a kill occurs, the P_K is 1.0. If the target is not destroyed by blast then the effect of the rods is considered.

g. The distance from the missile to the target along the path the rods would take is measured. The time it takes the rods to move that distance is computed and then multiplied by the velocity of the target to determine the distance the target moved.

h. After correcting the position of the target, the probability of "K" kill is found by noting if the rods can still strike the target. If the rods miss the target, the P_K is zero. If the rods strike the target, then the angle and velocity at which they hit, the point of impact, and the distance they travelled are computed to determine the probability of "K" kill.

RESULTS AND DISCUSSION

1. Pure Blast Warhead

Results obtained from the IBM 650 Digital Computer for the pure blast warhead are given in Table I which lists P_k values for R_b's of 10 feet and 20 feet and for 3 guidance errors, σg, 2 fuzing errors, σf, 3 fuze look angles, θ , and 2 missile velocities, V_m.

TABLE I

P_K

R_b = 10'

σ_g (ft)	σ_f (ft)	V_m = 2000 fps θ = 45°	V_m = 2000 fps θ = 60°	V_m = 2000 fps θ = 75°	V_m = 2510 fps θ = 45°	V_m = 2510 fps θ = 60°	V_m = 2510 fps θ = 75°
5	5	.53	.62	.75	.53	.62	.72
10	5	.24	.30	.25	.23	.29	.27
15	5	.05	.06	.10	.06	.07	.11
5	10	.43	.55	.54	.43	.53	.57
10	10	.09	.22	.24	.11	.22	.23
15	10	.07	.03	.14	.07	.04	.13

R_b = 20'

σ_g (ft)	σ_f (ft)	V_m = 2000 fps θ = 45°	V_m = 2000 fps θ = 60°	V_m = 2000 fps θ = 75°	V_m = 2510 fps θ = 45°	V_m = 2510 fps θ = 60°	V_m = 2510 fps θ = 75°
5	5	.91	.96	1.00	.89	.96	1.00
10	5	.64	.71	.78	.64	.75	.79
15	5	.52	.49	.55	.55	.54	.58
5	10	.86	.92	.91	.86	.90	.95
10	10	.72	.66	.70	.61	.71	.72
15	10	.34	.45	.45	.39	.60	.49

Equivalent bare charge warhead weights were multiplied by a factor (1.5 for the explosive HTA-4) to obtain the equivalent bare charge weight of TNT contained in each warhead. Then by the relationship mentioned under Vulnerability Data, R_b's were found for each warhead. These values are listed in Table II.

TABLE II

Contractor	Bare Charge Warhead Weight (lbs)	R_b Computed (ft)
G.E.	15.2	11.20
Sperry	17.4	11.73
Martin	23.0	12.94
Convair	7.1	8.70

By interpolating in Table I, P_K's for the R_b's that can be expected from each contractor's warhead may be found. Since these R_b's represent a certain warhead weight (see Table II), graphs were drawn with P_K as a function of warhead weight for the 3 fuze look angles considered (Figures 5-10).

Figures 5-7 show the effectiveness of the warheads for the three contractors, G.E., Sperry and Martin whose missiles have the same velocity. Figures 8-10 show the effectiveness for the other contractor, Convair, whose missile has a greater velocity. From these graphs, it can be determined how much more weight would be required to increase warhead effectiveness significantly.

Figure 11 gives P_K as a function of fuze look angle for the guidance errors claimed by each contractor. These guidance errors, σ_g , are as follows:

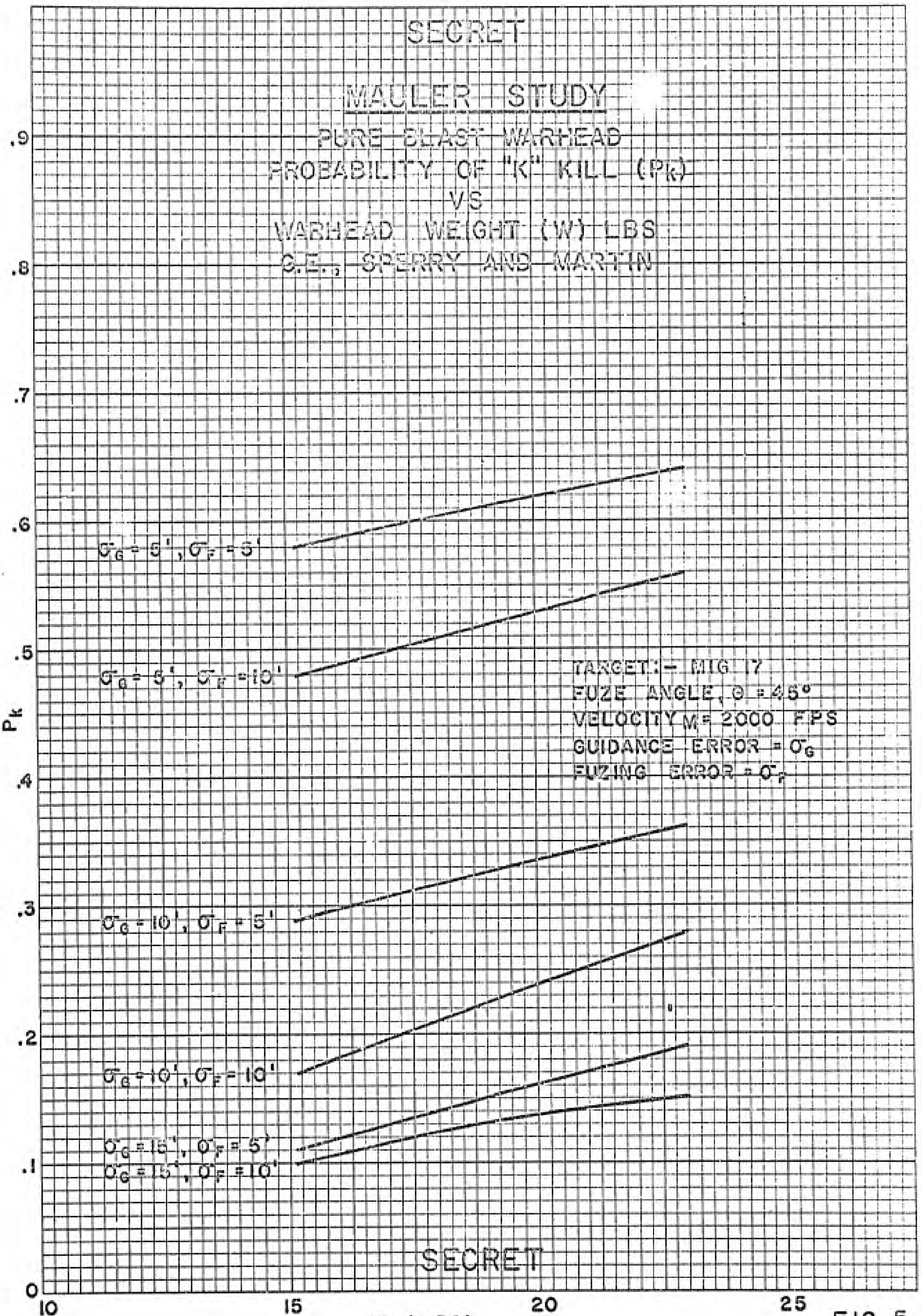

MAULER STUDY
PURE BLAST WARHEAD
PROBABILITY OF "K" KILL (P_k)
VS
WARHEAD WEIGHT (W) LBS
G.E., SPERRY AND MARTIN
σ_G = 5', σ_F = 5'
σ_G = 5', σ_F = 10'
σ_G = 10', σ_F = 5'
σ_G = 10', σ_F = 10'
σ_G = 15', σ_F = 5'
σ_G = 15', σ_F = 10'
TARGET: - MIG 17
FUZE ANGLE, θ = 45°
VELOCITY$_M$ = 2000 FPS
GUIDANCE ERROR = σ_G
FUZING ERROR = σ_F
P_k
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
10
15
20
25
W (LBS)

FIG 5

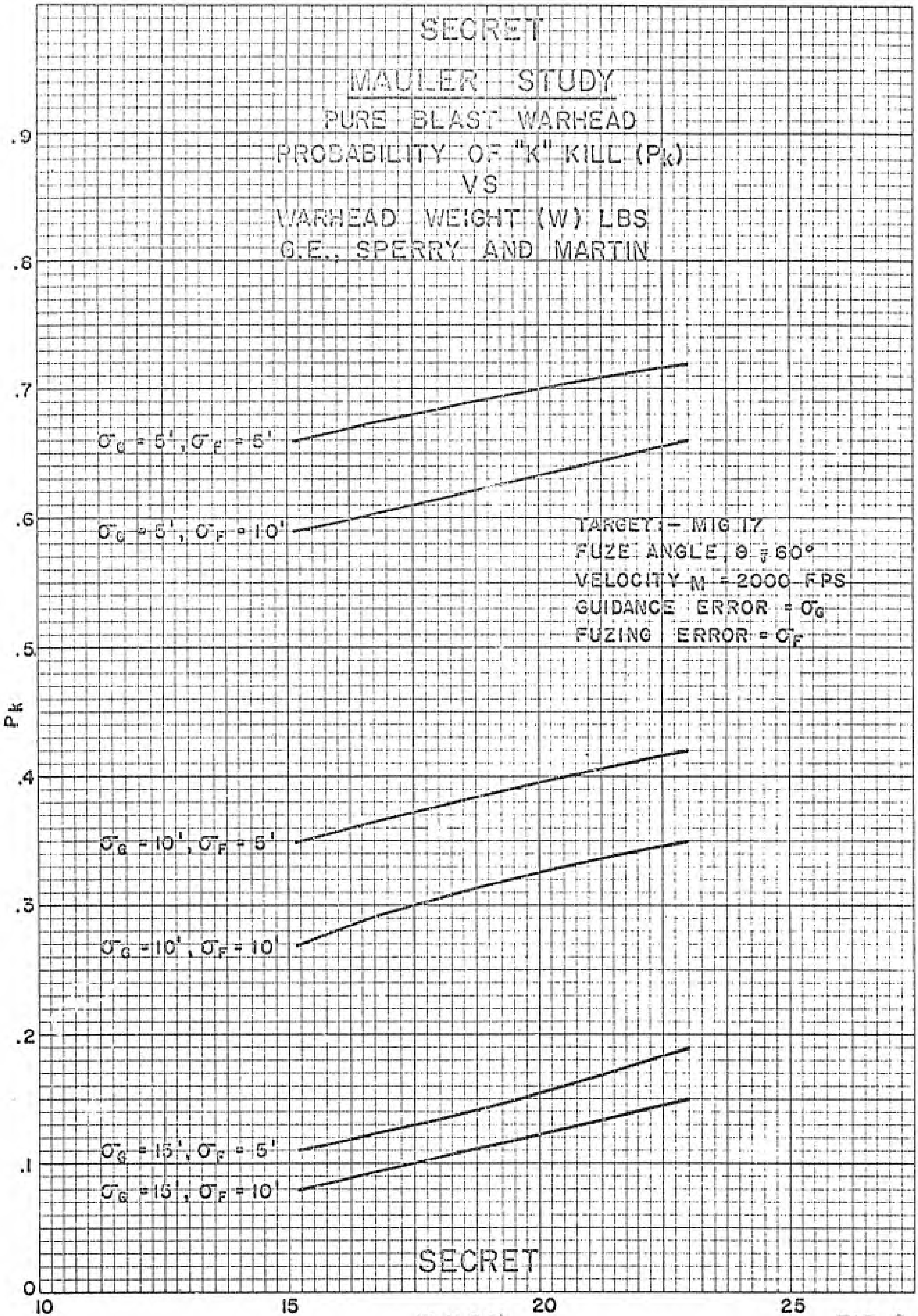

SECRET
MAULER STUDY
PURE BLAST WARHEAD
PROBABILITY OF "K" KILL (P_k)
VS
WARHEAD WEIGHT (W) LBS
G.E., SPERRY AND MARTIN
σ_G = 5', σ_F = 5'
σ_G = 5', σ_F = 10'
TARGET :— MIG 17
FUZE ANGLE, θ_f = 60°
VELOCITY M = 2000 FPS
GUIDANCE ERROR = σ_G
FUZING ERROR = σ_F
σ_G = 10', σ_F = 5'
σ_G = 10', σ_F = 10'
σ_G = 15', σ_F = 5'
σ_G = 15', σ_F = 10'
SECRET
P_k
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
10
15
20
25
W (LBS)

FIG 6

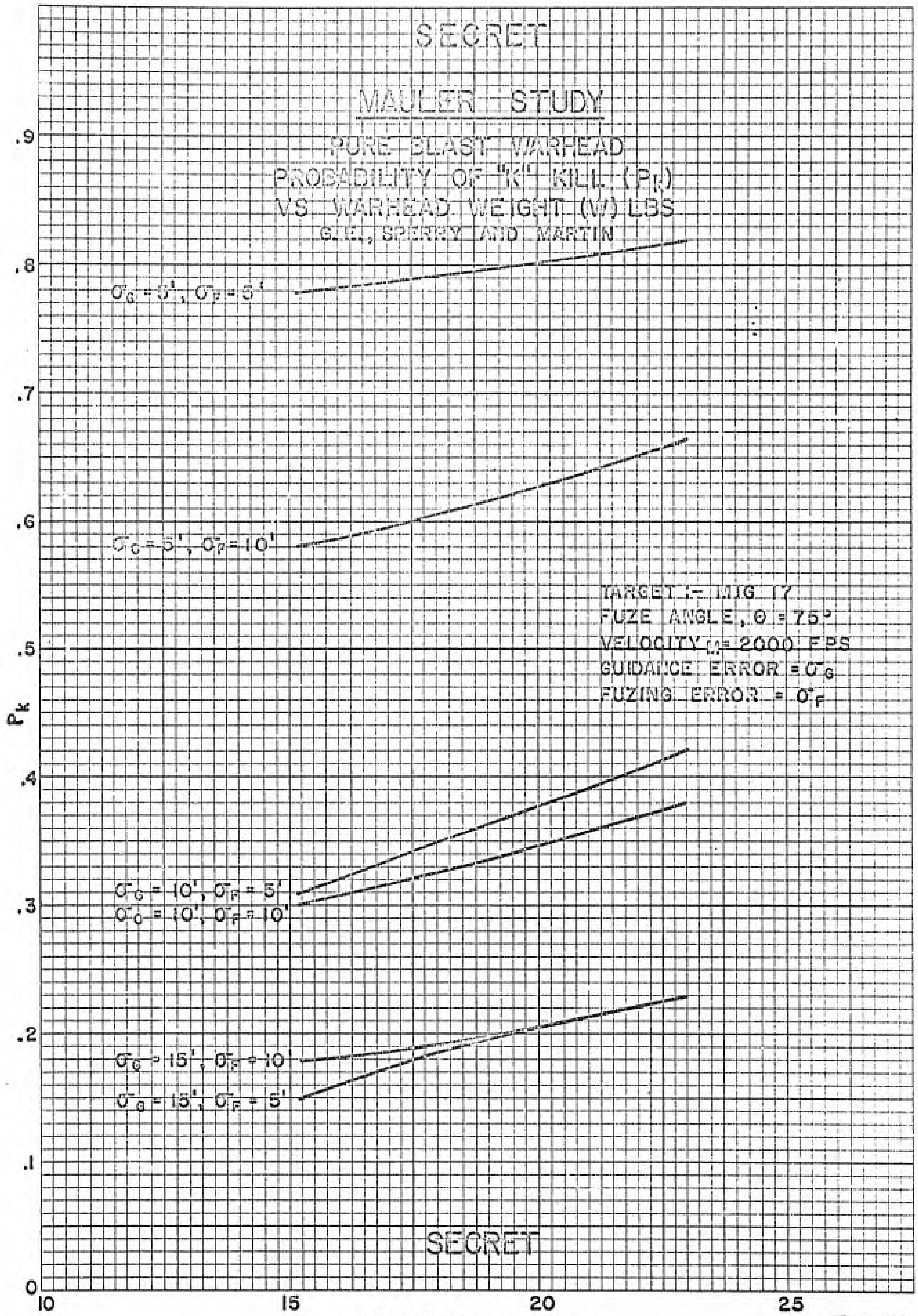

SECRET
MAULER STUDY
PURE BLAST WARHEAD
PROBABILITY OF "K" KILL (P_k)
VS WARHEAD WEIGHT (W) LBS
G.E., SPERRY AND MARTIN
$\sigma_G = 5'$, $\sigma_F = 5'$
$\sigma_G = 5'$, $\sigma_F = 10'$
TARGET :- MIG 17
FUZE ANGLE, Θ = 75°
VELOCITY$_M$ = 2000 FPS
GUIDANCE ERROR = σ_G
FUZING ERROR = σ_F
$\sigma_G = 10'$, $\sigma_F = 5'$
$\sigma_G = 10'$, $\sigma_F = 10'$
$\sigma_G = 15'$, $\sigma_F = 10'$
$\sigma_G = 15'$, $\sigma_F = 5'$
SECRET
P_k
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
10
15
20
25
W (LBS)

FIG 7

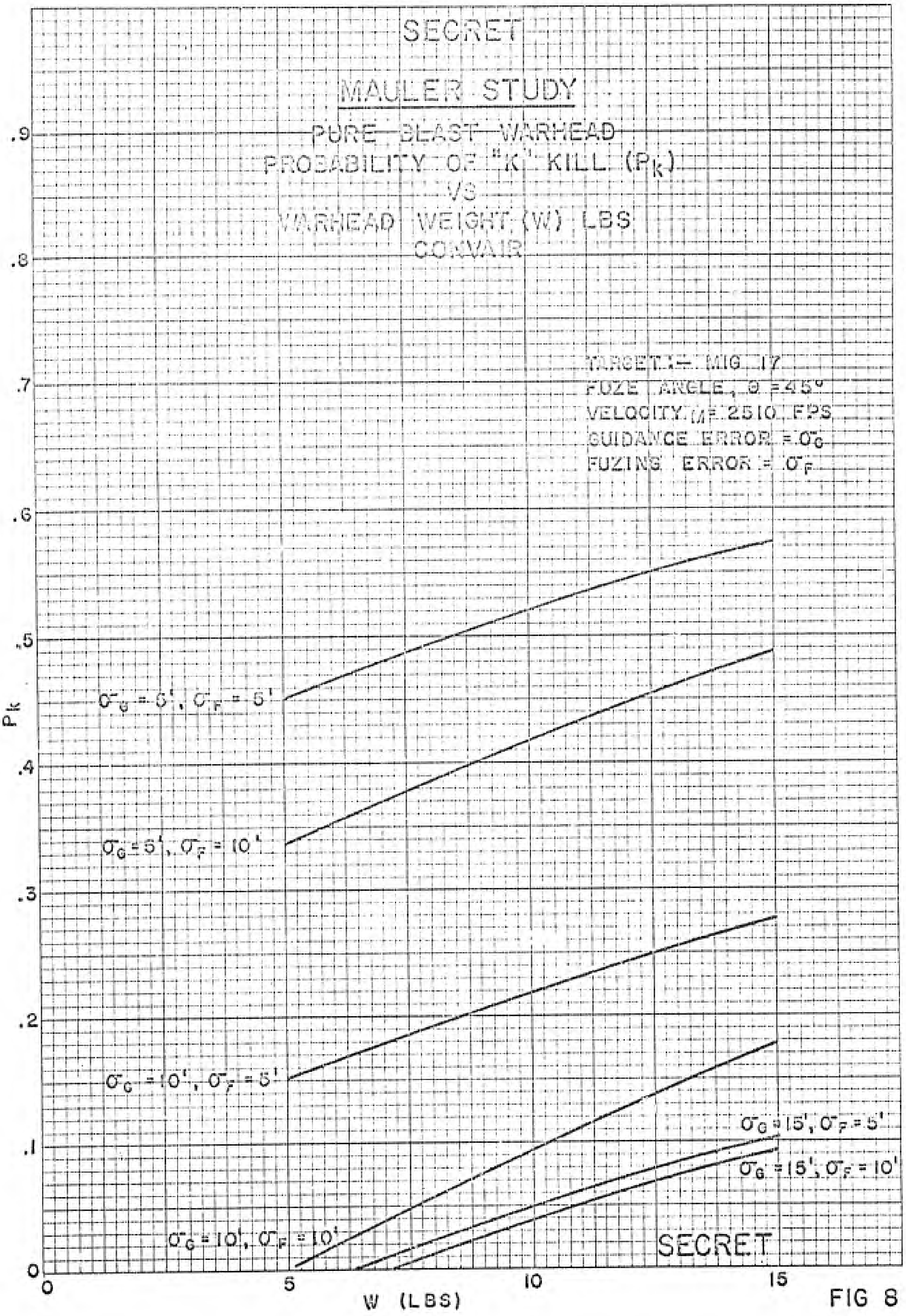

SECRET
MAULER STUDY
PURE BLAST WARHEAD
PROBABILITY OF "K" KILL (P_k)
VS
WARHEAD WEIGHT (W) LBS
CONVAIR
TARGET:— MIG 17
FUZE ANGLE, θ = 45°
VELOCITY M = 2510 FPS
GUIDANCE ERROR = σ_G
FUZING ERROR = σ_F
σ_G = 5', σ_F = 5'
σ_G = 5', σ_F = 10'
σ_G = 10', σ_F = 5'
σ_G = 15', σ_F = 5'
σ_G = 15', σ_F = 10'
σ_G = 10', σ_F = 10'
SECRET
P_k
W (LBS)

FIG 8

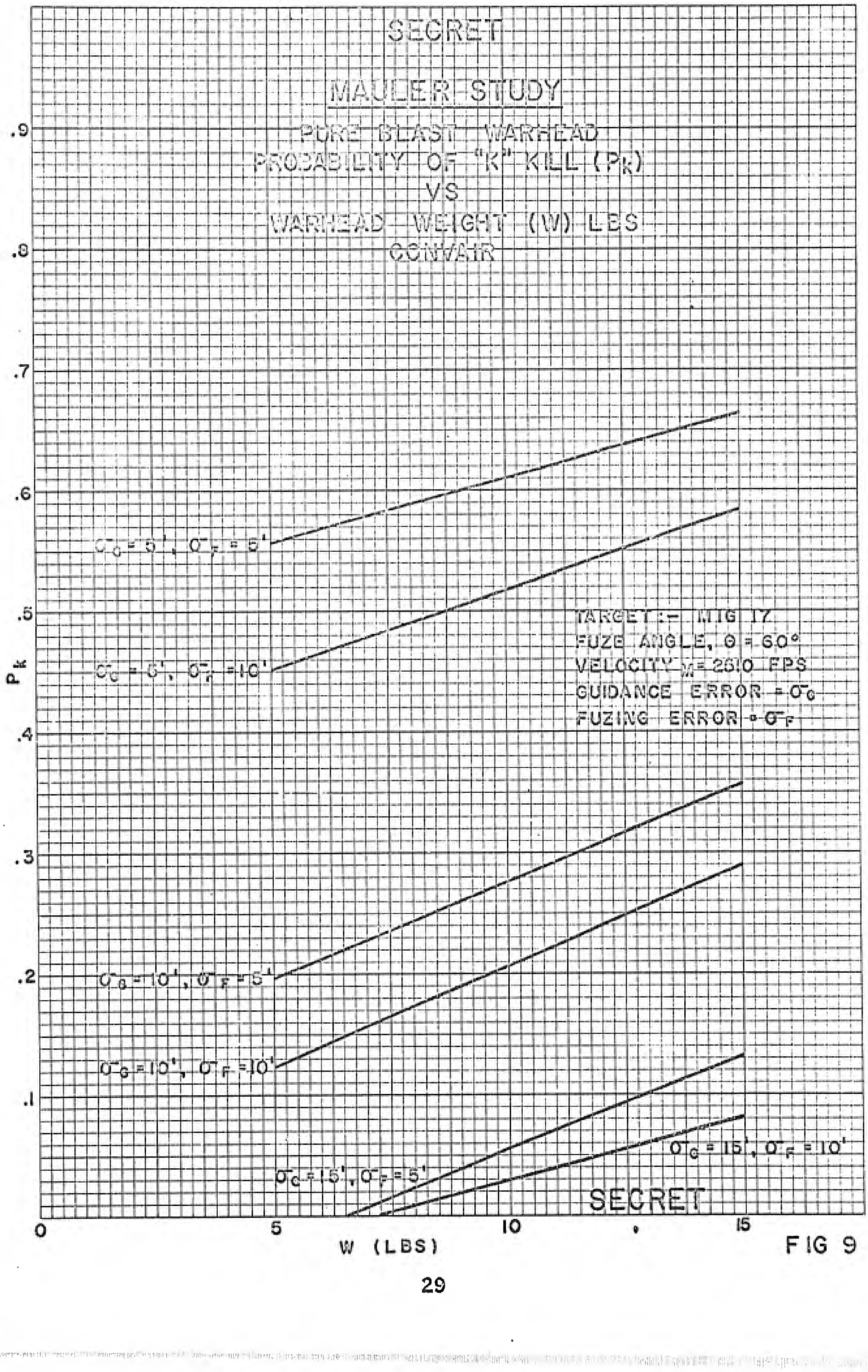
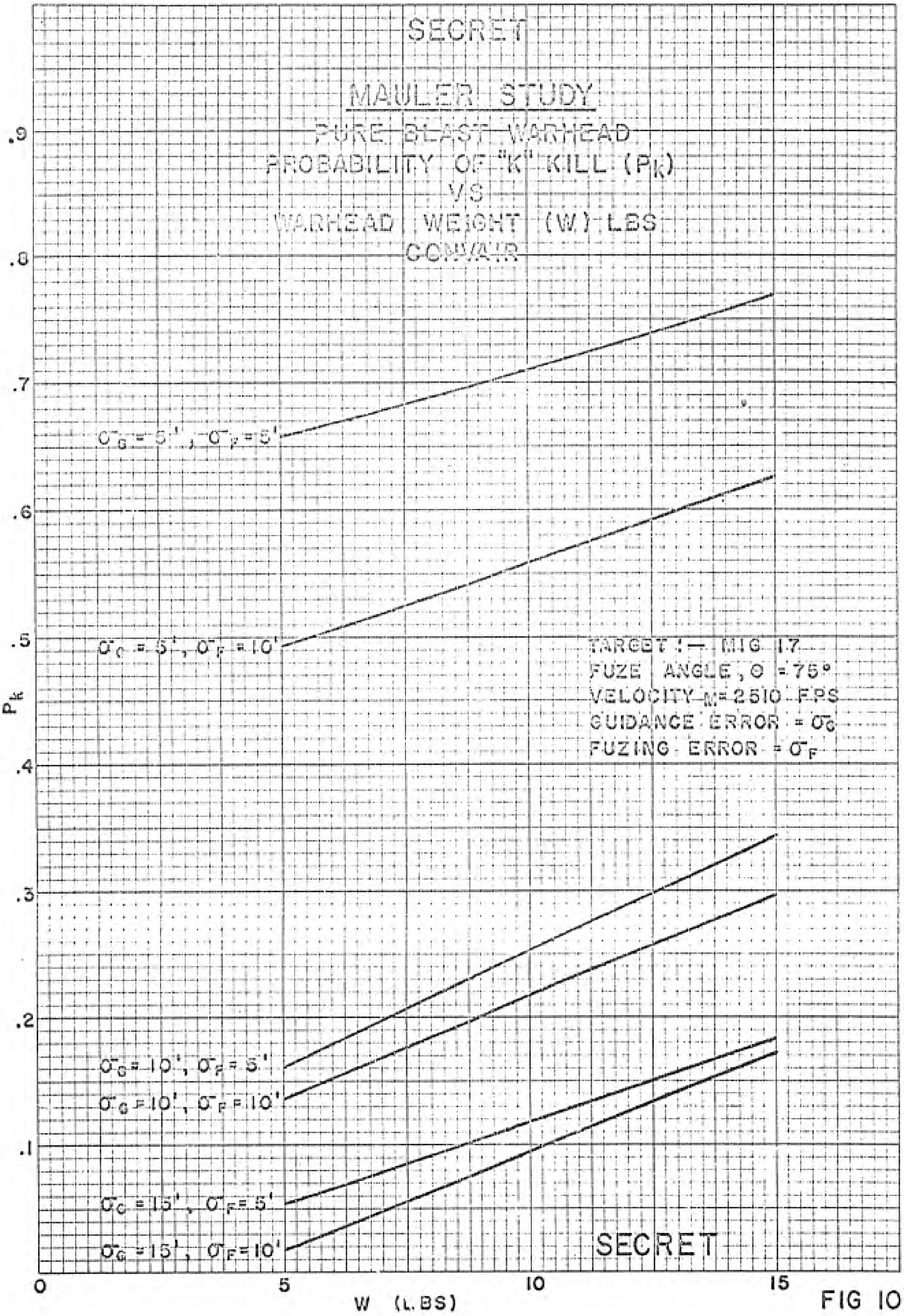
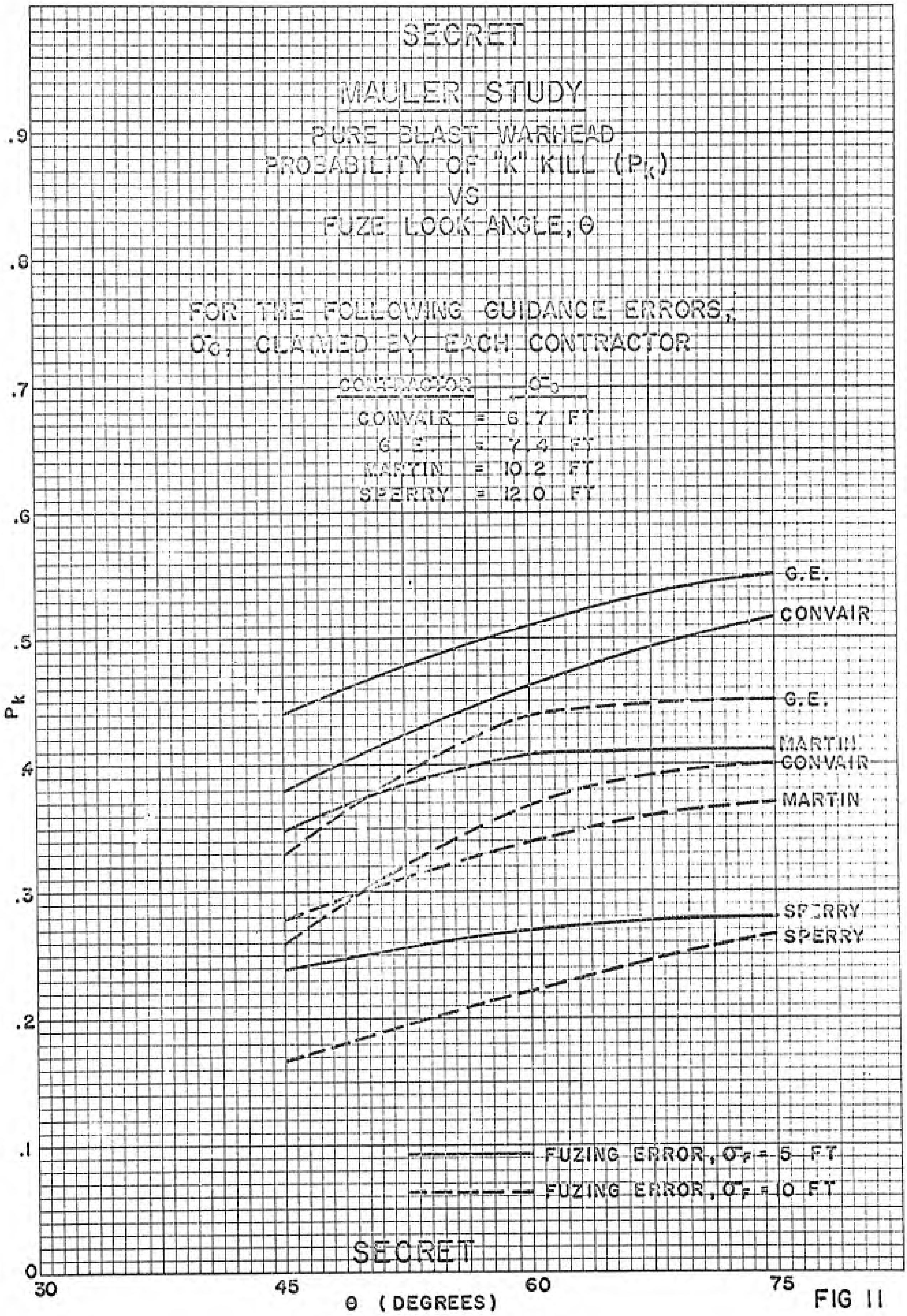

SECRET
MAULER STUDY
PURE BLAST WARHEAD
PROBABILITY OF "K" KILL (P_k)
VS
WARHEAD WEIGHT (W) LBS
CONVAIR
TARGET :- MIG 17
FUZE ANGLE, Θ = 60°
VELOCITY$_M$ = 2610 FPS
GUIDANCE ERROR = σ_G
FUZING ERROR = σ_F
σ_G = 5', σ_F = 5'
σ_G = 5', σ_F = 10'
σ_G = 10', σ_F = 5'
σ_G = 10', σ_F = 10'
σ_G = 15', σ_F = 5'
σ_G = 15', σ_F = 10'
SECRET
P_k
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
5
10
15
W (LBS)

FIG 9


SECRET
MAULER STUDY
PURE BLAST WARHEAD
PROBABILITY OF "K" KILL (P_K)
VS
WARHEAD WEIGHT (W) LBS
CONVAIR
$\sigma_G = 5'$, $\sigma_F = 5'$
$\sigma_G = 5'$, $\sigma_F = 10'$
TARGET :— MIG 17
FUZE ANGLE, Θ = 75°
VELOCITY$_M$ = 2510 FPS
GUIDANCE ERROR = σ_G
FUZING ERROR = σ_F
$\sigma_G = 10'$, $\sigma_F = 5'$
$\sigma_G = 10'$, $\sigma_F = 10'$
$\sigma_G = 15'$, $\sigma_F = 5'$
$\sigma_G = 15'$, $\sigma_F = 10'$
SECRET
P_K
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
5
10
15
W (LBS)
FIG 10


SECRET
MAULER STUDY
PURE BLAST WARHEAD
PROBABILITY OF "K" KILL (P_K)
VS
FUZE LOOK ANGLE, Θ
FOR THE FOLLOWING GUIDANCE ERRORS, σ_G, CLAIMED BY EACH CONTRACTOR
CONTRACTOR σ_G
CONVAIR = 6.7 FT
G. E. = 7.4 FT
MARTIN = 10.2 FT
SPERRY = 12.0 FT
G.E.
CONVAIR
G.E.
MARTIN
CONVAIR
MARTIN
SPERRY
SPERRY
FUZING ERROR, σ_F = 5 FT
FUZING ERROR, σ_F = 10 FT
SECRET
P_k
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
30
45
60
75
Θ (DEGREES)
FIG 11

Convair	6.7	Ft.
G.E.	7.4	Ft.
Martin	10.2	Ft.
Sperry	12	Ft.

Examination of the graphs in Figures 5-10 shows the following:

a. Warhead effectiveness is very sensitive to guidance error.

b. Fuze error does not affect performance nearly as much as guidance error.

c. The wider fuze angle is more desirable.

This can be seen more clearly in Figure 11 where P_K is given as a function of fuze look angle for the guidance errors claimed by each contractor. This graph shows that the blast warheads do not meet the single shot kill probability requirement of 0.6 specified in the MC's for Mauler.

2. Blast-Fragmentation Warhead

As stated under Scope of Study, the blast-fragmentation warhead was evaluated in three phases. The results of the final phase of the study in which the warhead parameters were optimized are presented first. Following this, the results of the preliminary and intermediate phases are summarized.

A. Final Phase

As a result of this phase, optimum warhead parameters for each contractor were found to be:

Contractor	Beam Angle	C/M	Fragment Size (Grains)
Convair	79°	0.90	30
G.E.	72°	0.96	"
Sperry	65°	1.07	"
Martin	63°	1.28	"

The configurations and other physical characteristics of these warheads are shown in the design section of this study.

The above results were obtained by optimizing each parameter separately in the following order: Fragment spray beam angle, fragment size, and C/M. In this part of the analysis, a fuzing error of 5 feet, a fuze look angle of 70° and the guidance errors estimated by each contractor were used.

The above parameters were optimized within the warhead weight and volume envelopes determined as a result of the intermediate phase of this study. These warhead envelopes were furnished the contractors to permit completion of their design studies.

In determining the effect of fragment beam angle, three angles varying from 40° to 110° approximately, were considered for each contractor. The C/M was held constant at about 1.7, except for G.E. whose warhead had a C/M near 1.0. 60 Grain fragments were used in this part of the analysis. The beam angles considered for each contractor and the results are given below:

Contractor	Beam Angle	P_K
Convair	110°	.58
	79°	.66
	53°	.62
G.E.	72°	.83
	56°	.70
	41°	.46

Contractor	Beam Angle	P_K
Sperry	83°	.70
	66°	.74
	55°	.68
Martin	97°	.76
	63°	.77
	51°	.75

Examination of these results shows that the following beam angles are optimum for each system:

Contractor	Optimum Beam Angle
Convair	79°
G.E.	72° *
Sperry	66°
Martin	63°

Using these beam angles, fragment sizes of 30, 45, 60 and 75 grains were evaluated. The results listed below show that 30 grain fragments are best:

	P_K			
Contractor	30 Grains	45 Grains	60 Grains	75 Grains
Convair	.79	.71	.64	---
G.E.	.90	.85	.81	.80
Sperry	.83	.81	.73	.66
Martin	.82	.81	.77	.71

*This is the maximum practical fragment beam angle that could be obtained within the warhead compartment for G.E.

The fact that 30 grain fragments are optimum was also clearly evident when C/M was optimized. The values of C/M used for Convair, Sperry and Martin and the results obtained for 30 and 45 grain fragments are given below. The C/M was not varied for G.E. since they were reluctant to change their envelope dimensions and weight.

		P_K	
Contractor	C/M	30 Grains	45 Grains
Convair	1.82	.70	.72
	1.41	.74	.69
	1.14	.75	.70
	.90	.82	.72
Sperry	1.70	.84	.78
	1.33	.82	.78
	1.07	.90	.80
	.89	.87	.80
Martin	1.76	.85	.77
	1.58	.88	.78
	1.28	.90	.84
	1.12	.86	.84
	.99	.83	.73

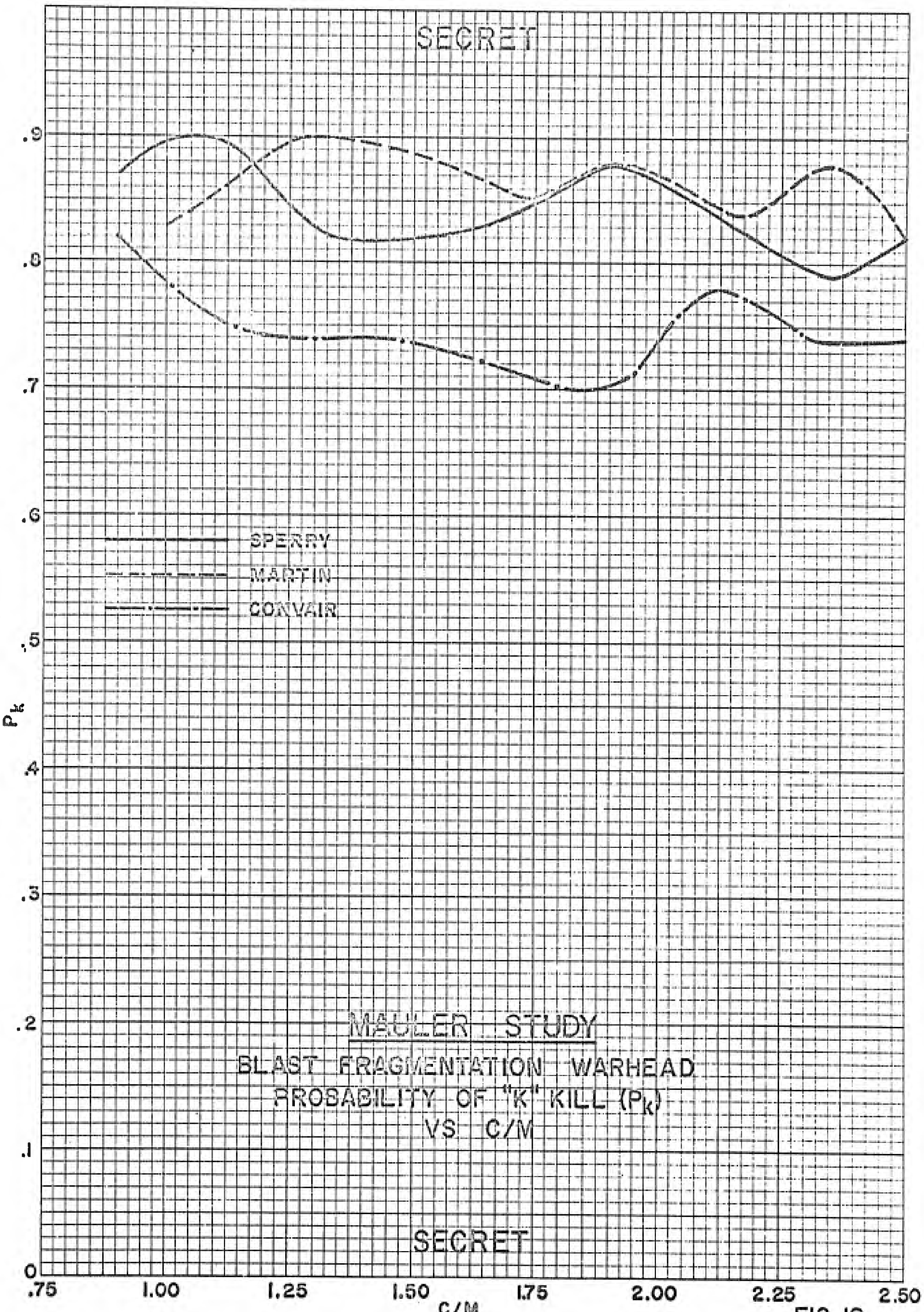
Warhead effectiveness was found to be not too sensitive to C/M. This was established after investigating charge to mass ratios up to 2.5. The P_K values for C/M's from 1.90 to 2.50 obtained for Convair, Sperry and Martin are shown below:

Contractor	C/M	P_K
Convair	1.90	.71
	2.00	.78
	2.30	.74
	2.50	.74
Sperry	1.90	.88
	2.15	.83
	2.35	.79
	2.50	.82
Martin	1.90	.88
	2.15	.84
	2.35	.88
	2.50	.82

These P_K values together with the values of P_K obtained for the lower C/M's were plotted as a function of C/M (Figure 12).

It appears that the P_K vs C/M curve contains more than one peak and thus there may be more than one optimum C/M. The lower C/M emphasizes fragment kills while the higher C/M's favor blast kills. The highest peaks occurred at the lower C/M's and therefore, the lower optimum C/M's were selected for each warhead.

SECRET



MAULER STUDY

BLAST FRAGMENTATION WARHEAD

PROBABILITY OF "K" KILL (P_k)

VS C/M

SECRET

FIG 12

In optimizing the value of the fuze delay parameter, C, the optimum warhead parameters listed above were used in conjunction with the following parameters:

3 Guidance errors as follows:

Convair	6.7, 9 and 12 feet
G.E.	5, 7.4, and 12 feet
Sperry	5, 12 and 15 feet
Martin	5, 10.2 and 12 feet

2 Fuzing errors = 5 and 10 feet

3 Values of C = 5, 8 and 12 feet

(In the case of Convair, a C equal to 15 feet was also considered)

1 Fuze look angle = 70°

The results obtained for the various values of C and guidance and fuzing errors for each contractor are given in Table III. Examination of this table shows that a C of 8 feet is optimum for G.E., Sperry and Martin warheads, whereas a C of 12 feet is best for the Convair warhead. These optimum values of C may be subject to change when a more rigorous representation of the target model is considered. However, the optimum warhead parameters are not expected to be significantly affected.

With the values of P_K obtained for the value of C found optimum for each contractor, graphs were drawin with P_K as a function of guidance error (Figures 13 and 14).

TABLE III

σ_g (ft)	σ_f (ft)	P_K C = 5'	C = 8'	C = 12'	C = 15'
			Convair		
6.7	5	.49	.73	.78	.40
6.7	10	.44	.59	.66	.39
9	5	.51	.62	.71	.44
9	10	.46	.58	.65	.38
12	5	.47	.59	.61	.49
12	10	.44	.49	.54	.43
			G. E.		
5	5	.60	.92	.91	
5	10	.44	.86	.78	
7.4	5	.60	.90	.90	
7.4	10	.57	.85	.66	
12	5	.69	.83	.84	
12	10	.68	.82	.78	
			Sperry		
5	5	.58	.97	.89	
5	10	.51	.92	.78	
12	5	.64	.87	.84	
12	10	.62	.80	.73	
15	5	.68	.79	.79	
15	10	.66	.76	.75	

TABLE III (Con't)

σ_g (ft)	σ_f (ft)	P_K C = 5'	P_K C = 8'	P_K C = 12'
		Martin		
5	5	.62	.93	.92
5	10	.53	.88	.86
10.2	5	.70	.86	.85
10.2	10	.60	.82	.77
12	5	.64	.82	.81
12	10	.58	.81	.67

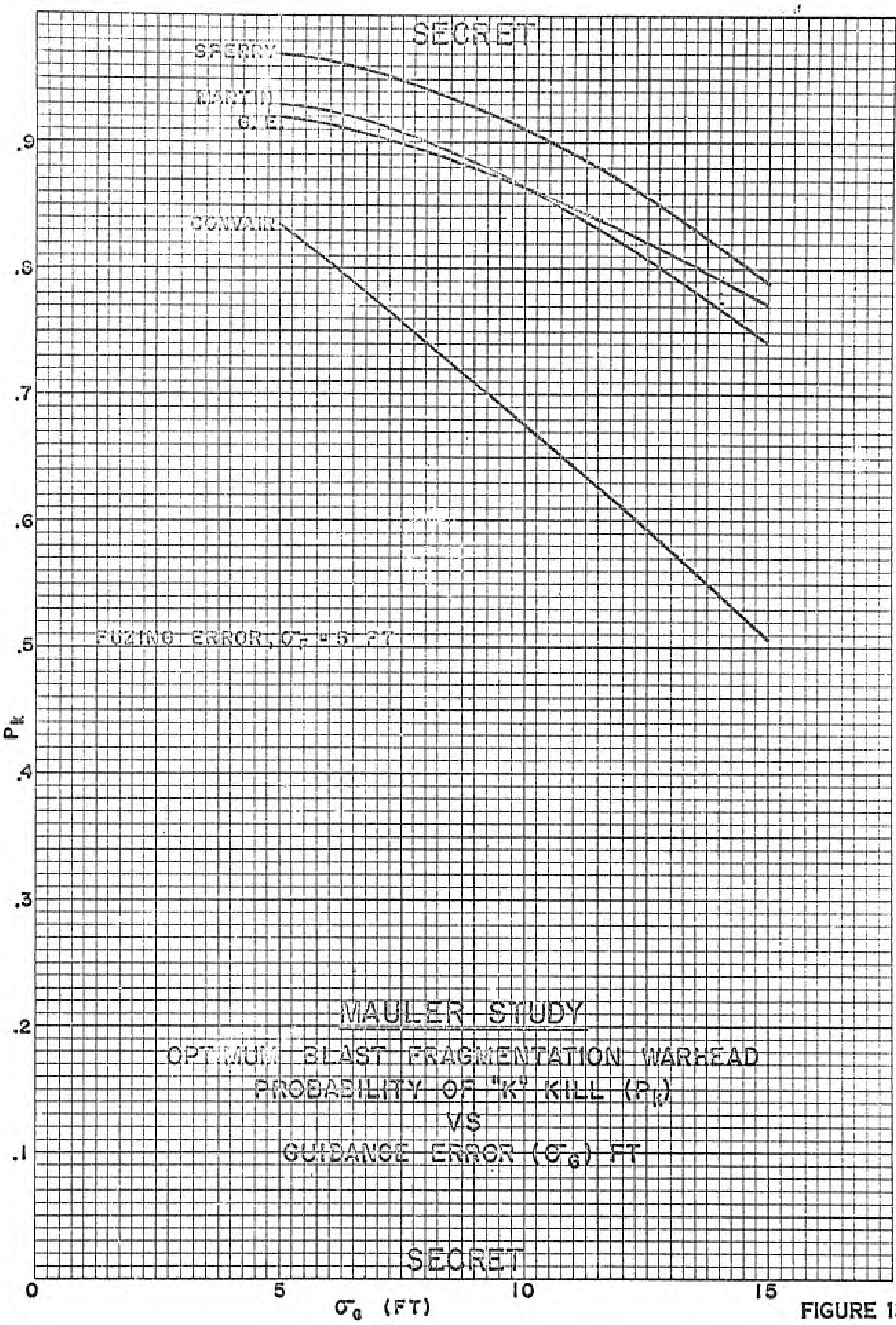

SECRET
SPERRY
MARTIN
G. E.
CONVAIR
FUZING ERROR, σ_F = 5 FT
MAULER STUDY
OPTIMUM BLAST FRAGMENTATION WARHEAD
PROBABILITY OF "K" KILL (P_k)
VS
GUIDANCE ERROR (σ_G) FT
SECRET
.9
.8
.7
.6
.5
.4
.3
.2
.1
P_k
0
5
10
15
σ_G (FT)

FIGURE 13

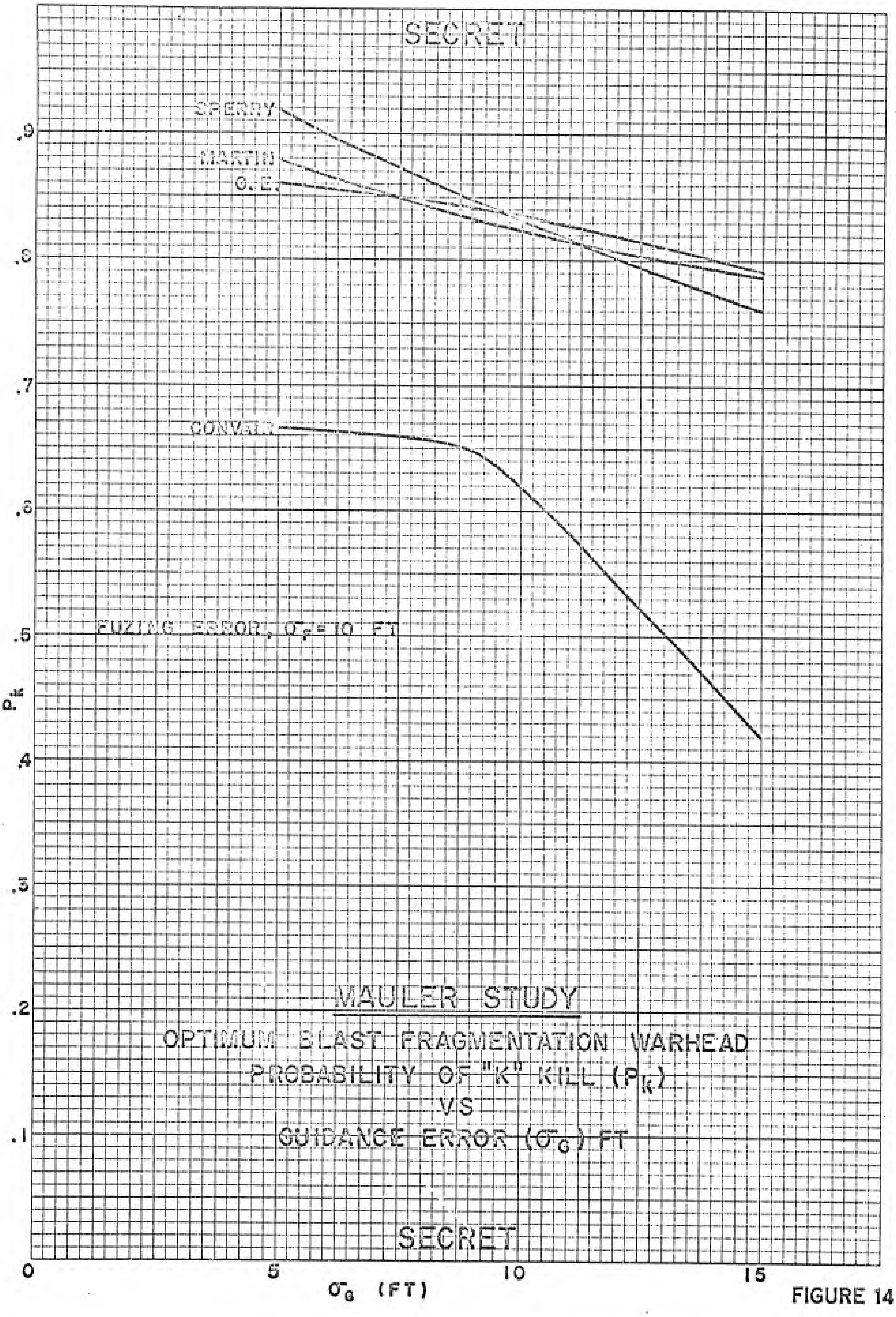

SECRET
SPERRY
MARTIN
G. E.
CONVAIR
FUZING ERROR, σ_F = 10 FT
MAULER STUDY
OPTIMUM BLAST FRAGMENTATION WARHEAD
PROBABILITY OF "K" KILL (P_k)
VS
GUIDANCE ERROR (σ_G) FT
SECRET
P_k
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
5
10
15
σ_G (FT)

FIGURE 14

B. Preliminary Phase

In the preliminary phase, the warheads designed originally for each contractor were evaluated for the following parameters and values:

2 Guidance errors	=	5' and 12'
2 Fuzing errors	=	5' and 10'
2 Fuze look angles	=	60° and 75°
2 Fragment sizes	=	30 and 90 grains
2 C/M's	=	1.0 and 1.7
2 Fragment Beam Angles	=	14° approximately and 80°

As in the case of the pure blast warhead, one hundred engagements for each set of parameters were evaluated by means of the IBM 650 Digital Computer. The results obtained are given in Tables IV and V. Table IV lists the results for the 14° fragment spray beam angle and these results are presented graphically in Figures 15-20; Table V shows the results for the 80° fragment spray beam angle and these results are plotted in Figures 21-24.

The probability of kill for warheads with a 14° beam angle are shown in Figs. 15 - 18 for 30 grain fragments and in Figs. 19 and 20 for 90 grain fragments.

Figures 21-24 depict the effectiveness of warheads with an 80° fragment spray beam angle containing 30 grain fragments.

TABLE XV

Fragment Spray Beam Angle = 14° Approximately

				Vm = 2000 fps				P_k			
				C		G.E.		S		M	
C/M	σ_G (ft)	σ_F (ft)	θ°	30 Gr	90 Gr	30 Gr	90 Gr	30 Gr	90 Gr	30 Gr	90 Gr
1.0	5	5	60	.49		.71		.76		.78	
"	5	10	"	.48		.68		.72		.77	
"	12	5	"	.28		.42		.44		.45	
"	12	10	"	.22		.35		.38		.40	
"	5	5	75	.61		.73		.76		.83	
"	5	10	"	.47	.50	.70	.68	.72	.76	.74	.78
"	12	5	"	.21	.22	.40	.55	.43	.56	.45	.57
"	12	10	"	.21	.14	.40	.45	.43	.50	.45	.51
1.7	5	5	60	.59	.56	.81	.82	.82	.83	.83	.83
"	5	10	"	.44	.45	.70	.70	.72	.76	.73	.81
"	12	5	"	.25	.27	.48	.54	.50	.55	.51	.58
"	12	10	"	.25		.48		.50		.51	
"	5	5	75	.62		.79		.81		.81	
"	5	10	"	.54		.71		.75		.78	
"	12	5	"	.29		.62		.71		.75	
"	12	10	"	.27		.58		.62		.63	

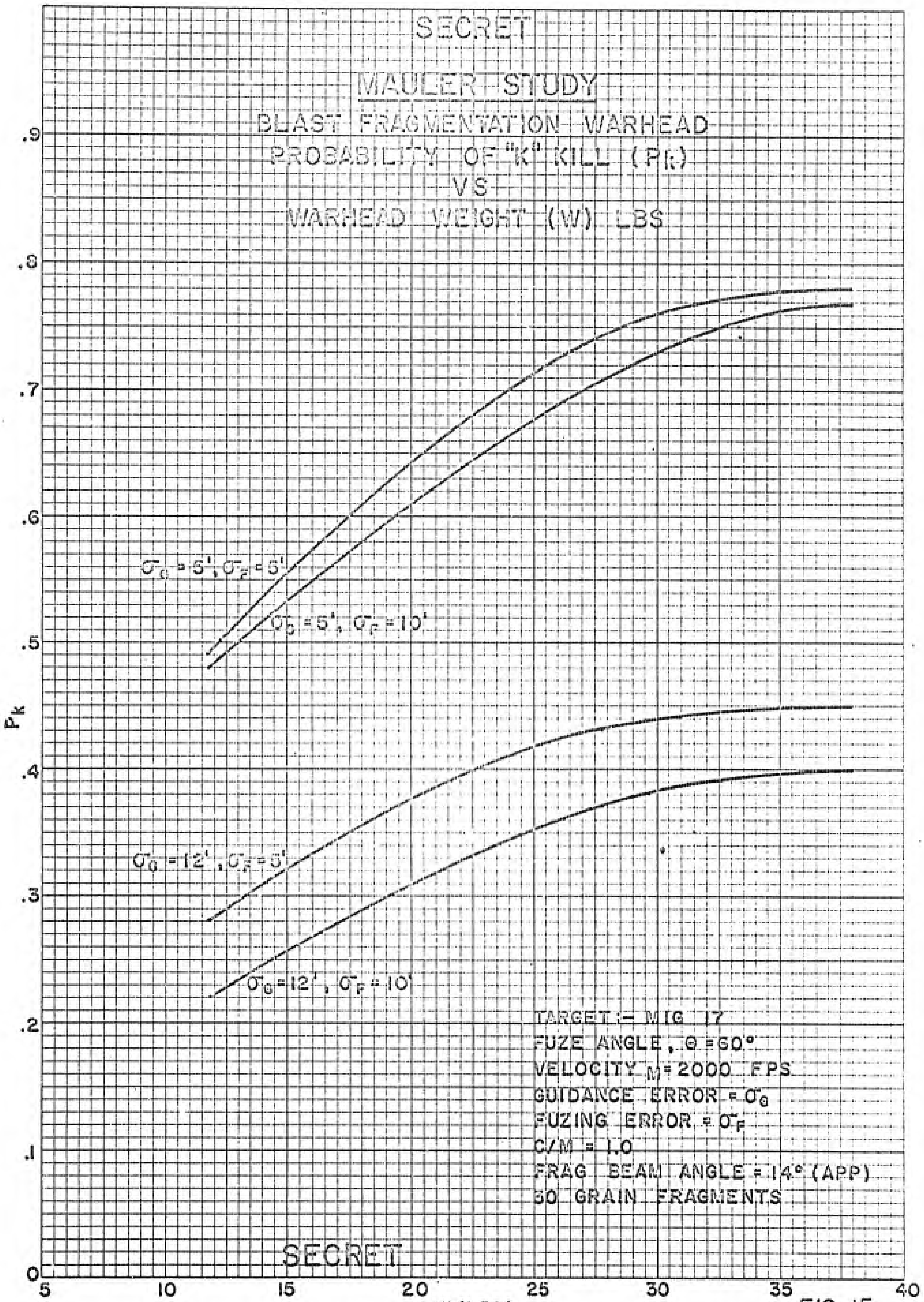

SECRET
MAULER STUDY
BLAST FRAGMENTATION WARHEAD
PROBABILITY OF "K" KILL (Pk)
VS
WARHEAD WEIGHT (W) LBS
Pk
W (LBS)
σG = 5', σF = 5'
σG = 5', σF = 10'
σG = 12', σF = 5'
σG = 12', σF = 10'
TARGET - MIG 17
FUZE ANGLE, Θ = 60°
VELOCITY M = 2000 FPS
GUIDANCE ERROR = σG
FUZING ERROR = σF
C/M = 1.0
FRAG BEAM ANGLE = 14° (APP)
60 GRAIN FRAGMENTS
SECRET

FIG 15

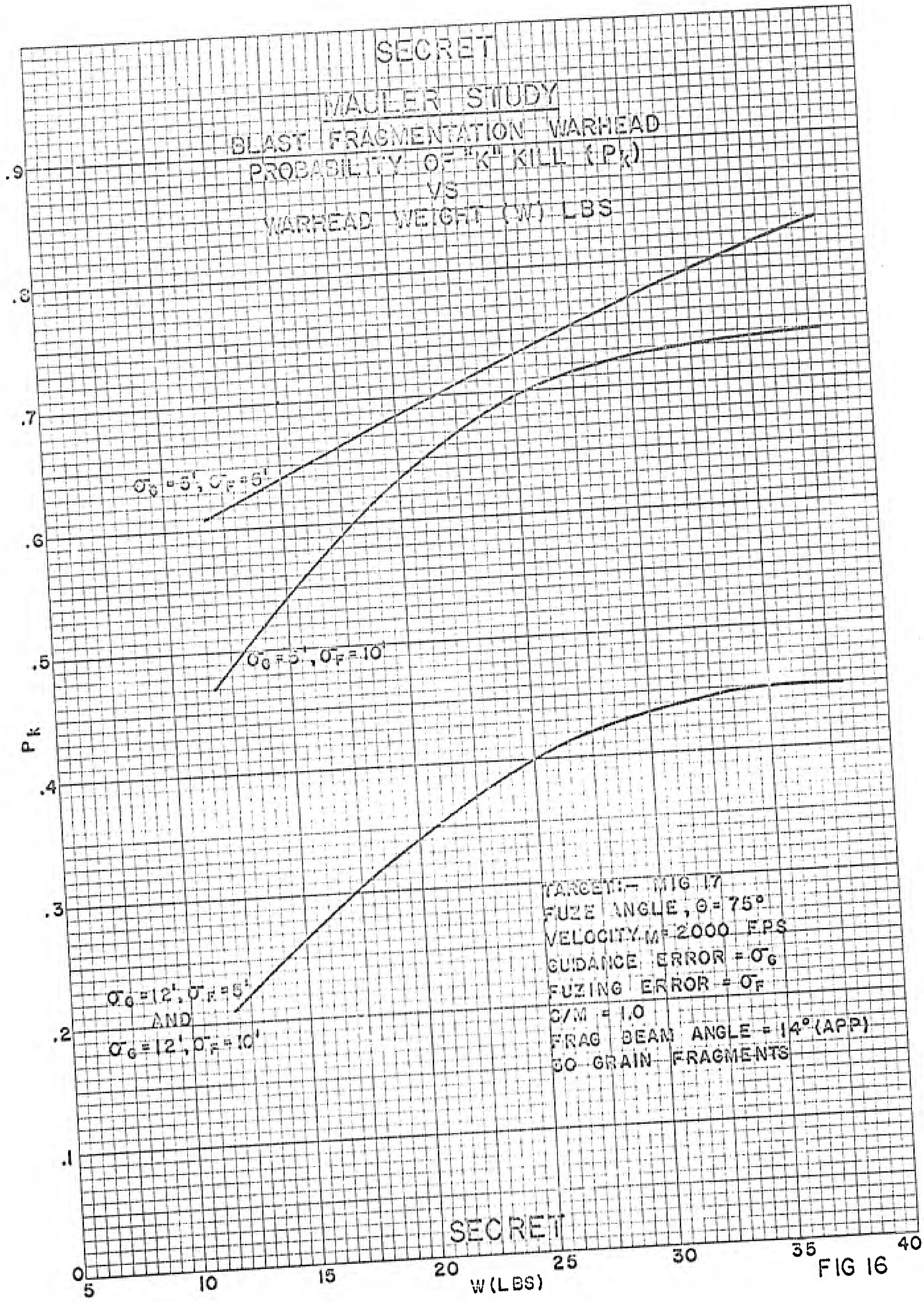

SECRET
MAULER STUDY
BLAST FRAGMENTATION WARHEAD
PROBABILITY OF "K" KILL (P_K)
VS
WARHEAD WEIGHT (W) LBS
$\sigma_G = 5'$, $\sigma_F = 5'$
$\sigma_G = 5'$, $\sigma_F = 10'$
$\sigma_G = 12'$, $\sigma_F = 5'$
AND
$\sigma_G = 12'$, $\sigma_F = 10'$
TARGET:- MIG 17
FUZE ANGLE, $\theta = 75°$
VELOCITY, M = 2000 FPS
GUIDANCE ERROR = σ_G
FUZING ERROR = σ_F
C/M = 1.0
FRAG BEAM ANGLE = 14° (APP)
30 GRAIN FRAGMENTS
P_K
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
5
10
15
20
25
30
35
40
W (LBS)
SECRET

FIG 16

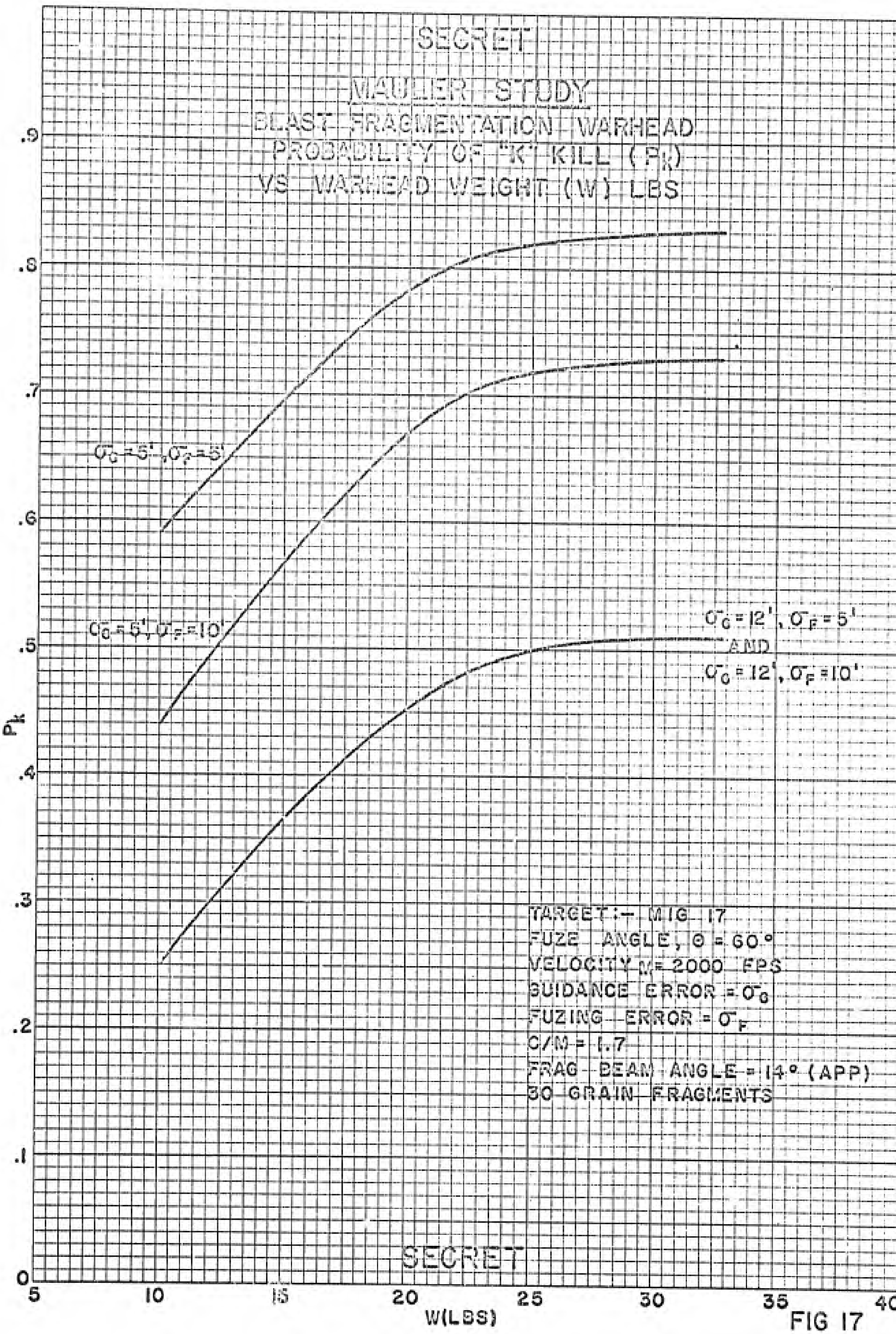

SECRET
MAULER STUDY
BLAST FRAGMENTATION WARHEAD
PROBABILITY OF "K" KILL (Pk)
VS WARHEAD WEIGHT (W) LBS
σG = 5', σF = 5'
σG = 5', σF = 10'
σG = 12', σF = 5'
AND
σG = 12', σF = 10'
TARGET:— MIG 17
FUZE ANGLE, θ = 60°
VELOCITY M = 2000 FPS
GUIDANCE ERROR = σG
FUZING ERROR = σF
C/M = 1.7
FRAG BEAM ANGLE = 14° (APP)
30 GRAIN FRAGMENTS
Pk
W(LBS)
SECRET

FIG 17

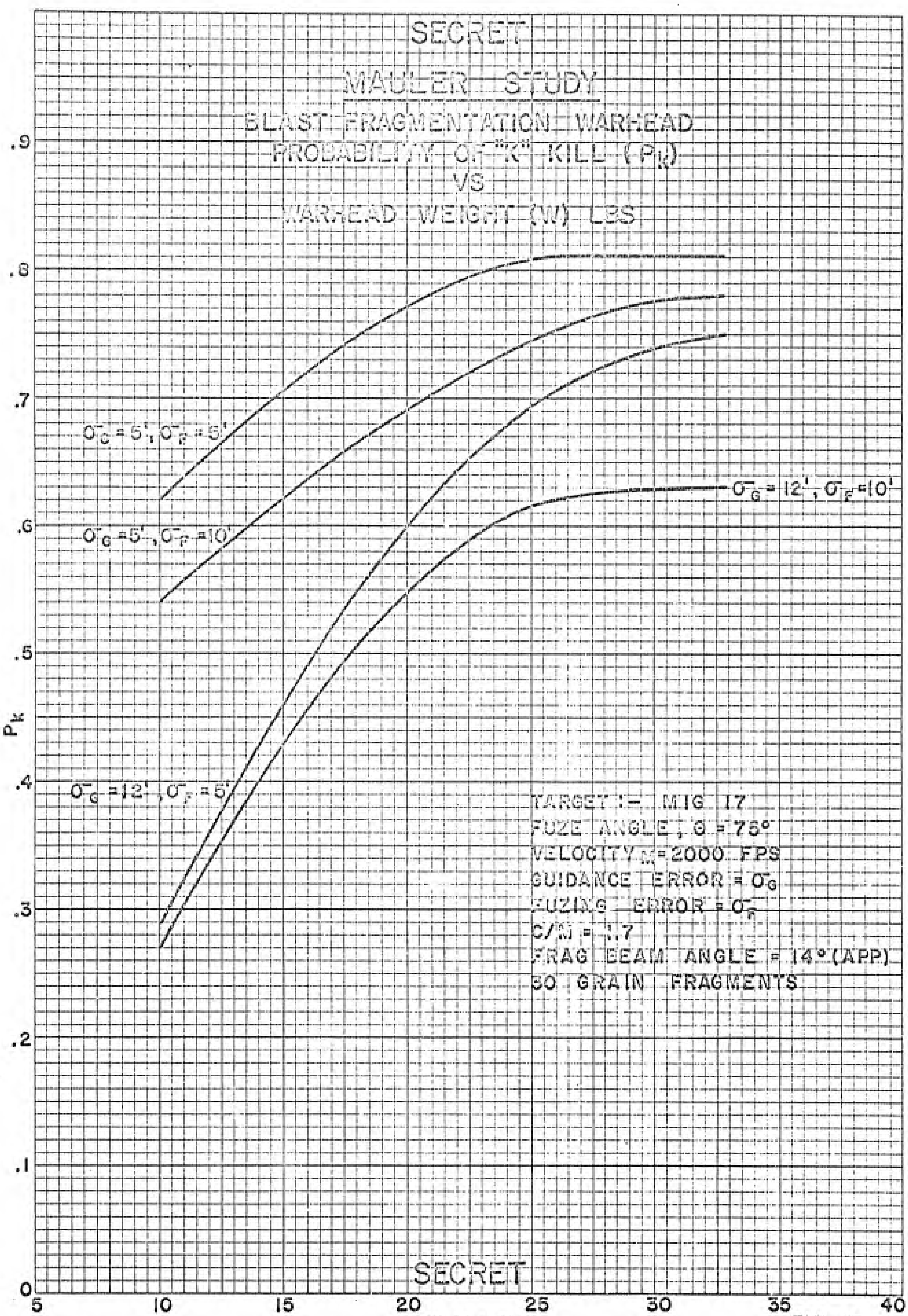

SECRET
MAULER STUDY
BLAST FRAGMENTATION WARHEAD
PROBABILITY OF "K" KILL (P_k)
VS
WARHEAD WEIGHT (W) LBS
$\sigma_G = 5'$, $\sigma_F = 5'$
$\sigma_G = 5'$, $\sigma_F = 10'$
$\sigma_G = 12'$, $\sigma_F = 5'$
$\sigma_G = 12'$, $\sigma_F = 10'$
TARGET :- MIG 17
FUZE ANGLE, θ = 75°
VELOCITY$_M$ = 2000 FPS
GUIDANCE ERROR = σ_G
FUZING ERROR = σ_F
C/M = 1.7
FRAG BEAM ANGLE = 14° (APP)
30 GRAIN FRAGMENTS
P_k
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
5
10
15
20
25
30
35
40
W (LBS)
SECRET

FIG 18

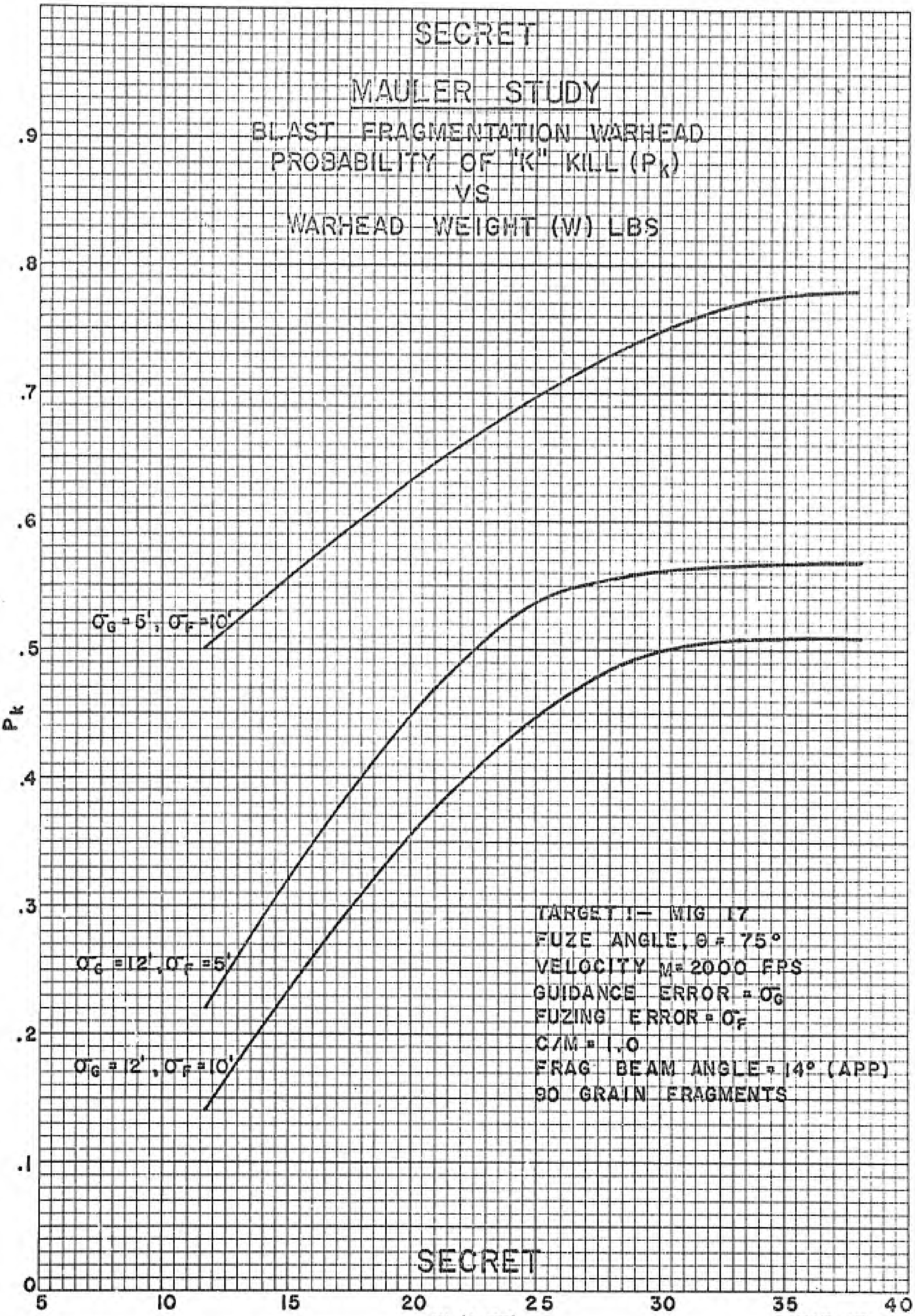

SECRET
MAULER STUDY
BLAST FRAGMENTATION WARHEAD
PROBABILITY OF "K" KILL (P_k)
VS
WARHEAD WEIGHT (W) LBS
$\sigma_G = 5'$, $\sigma_F = 10'$
$\sigma_G = 12'$, $\sigma_F = 5'$
$\sigma_G = 12'$, $\sigma_F = 10'$
TARGET I — MIG 17
FUZE ANGLE, θ = 75°
VELOCITY V_M = 2000 FPS
GUIDANCE ERROR = σ_G
FUZING ERROR = σ_F
C/M = 1.0
FRAG BEAM ANGLE = 14° (APP)
90 GRAIN FRAGMENTS
SECRET
P_k
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
5
10
15
20
25
30
35
40
W (LBS)

FIG 19

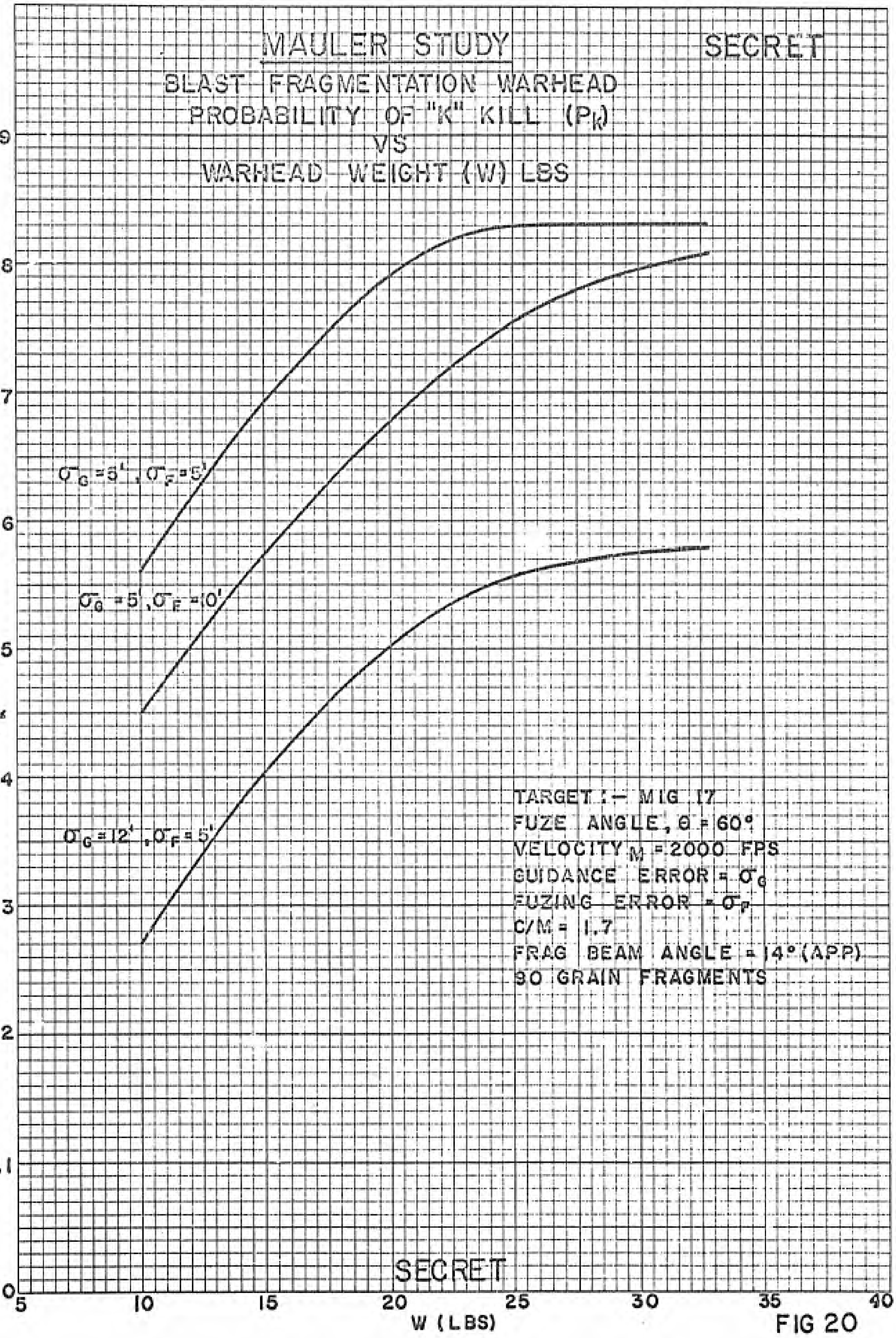

MAULER STUDY
SECRET
BLAST FRAGMENTATION WARHEAD
PROBABILITY OF "K" KILL (P_k)
VS
WARHEAD WEIGHT (W) LBS
$\sigma_G = 5'$, $\sigma_F = 5'$
$\sigma_G = 5'$, $\sigma_F = 10'$
$\sigma_G = 12'$, $\sigma_F = 5'$
TARGET :— MIG 17
FUZE ANGLE, θ = 60°
VELOCITY$_M$ = 2000 FPS
GUIDANCE ERROR = σ_G
FUZING ERROR = σ_F
C/M = 1.7
FRAG BEAM ANGLE = 14° (APP)
30 GRAIN FRAGMENTS
P_k
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
5
10
15
20
25
30
35
40
W (LBS)
SECRET

FIG 20

TABLE V

Fragment Spray Beam Angle = 80°

30 Grain Fragments

Vm = 2000 fps

C/M	σ_G (ft)	σ_F (ft)	θ°	P_K C	P_K GE	P_K S	P_K M
1.0	5	5	60	.80	.82	.84	.95
"	5	10	"	.74	.75	.82	.88
"	12	5	"	.60	.60	.64	.66
"	12	10	"	.50	.51	.61	.66
"	5	5	75	.71	.75	.79	.90
"	5	10	"	.65	.74	.77	.86
"	12	5	"	.60	.60	.61	.61
"	12	10	"	.53	.54	.55	.56
1.7	5	5	60	.78	.86	.88	.92
"	5	10	"	.72	.79	.80	.88
"	12	5	"	.51	.52	.53	.66
"	12	10	"	.37	.39	.46	.61
"	5	5	75	.75	.78	.80	.87
"	5	10	"	.72	.73	.75	.81
"	12	5	"	.51	.51	.56	.61
"	12	10	"	.37	.40	.46	.50

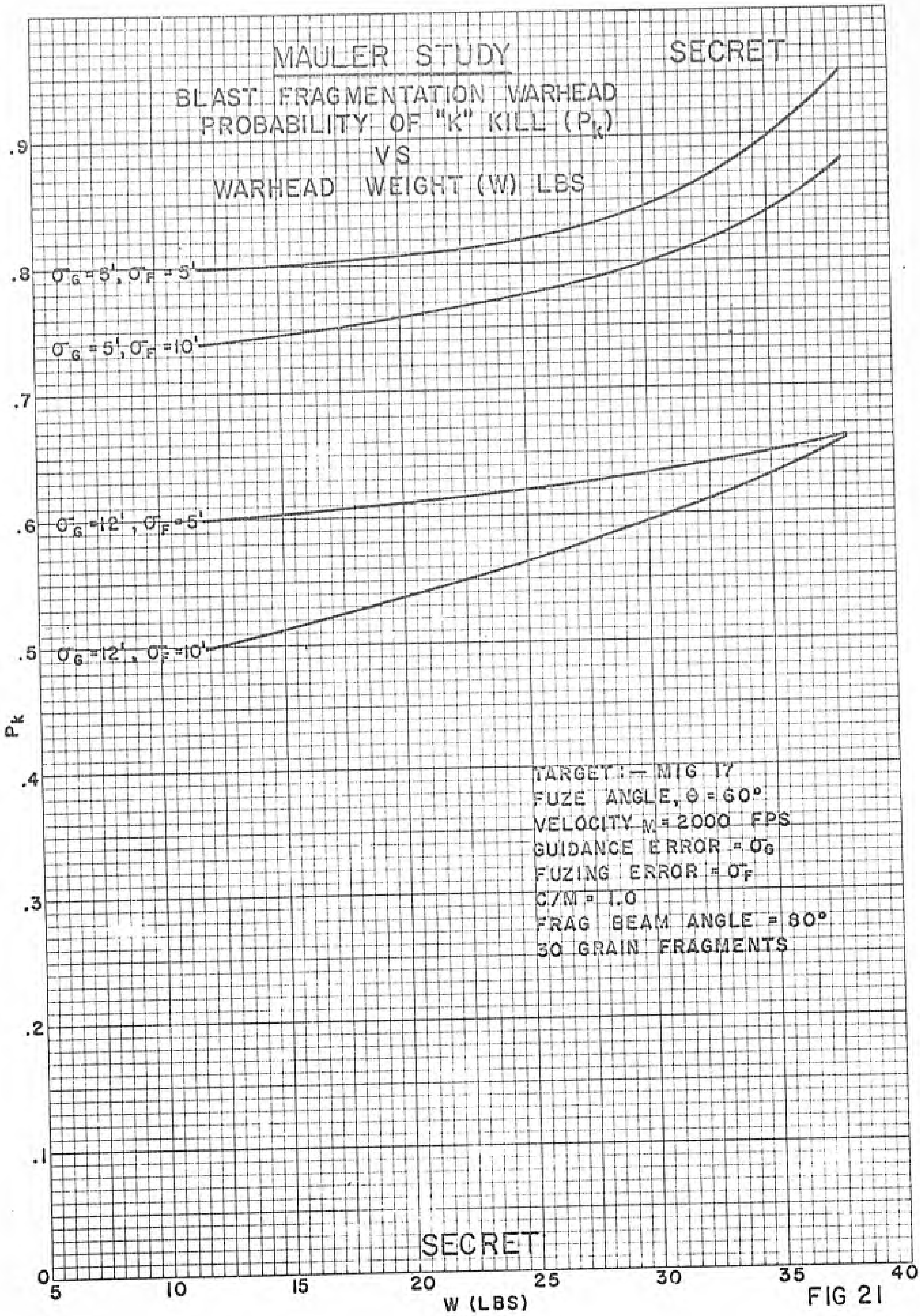

MAULER STUDY
SECRET
BLAST FRAGMENTATION WARHEAD
PROBABILITY OF "K" KILL (P_k)
VS
WARHEAD WEIGHT (W) LBS
$\sigma_G = 5'$, $\sigma_F = 5'$
$\sigma_G = 5'$, $\sigma_F = 10'$
$\sigma_G = 12'$, $\sigma_F = 5'$
$\sigma_G = 12'$, $\sigma_F = 10'$
TARGET :— MIG 17
FUZE ANGLE, θ = 60°
VELOCITY $_M$ = 2000 FPS
GUIDANCE ERROR = σ_G
FUZING ERROR = σ_F
C/M = 1.0
FRAG BEAM ANGLE = 80°
30 GRAIN FRAGMENTS
P_k
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
5
10
15
20
25
30
35
40
W (LBS)
SECRET

FIG 21

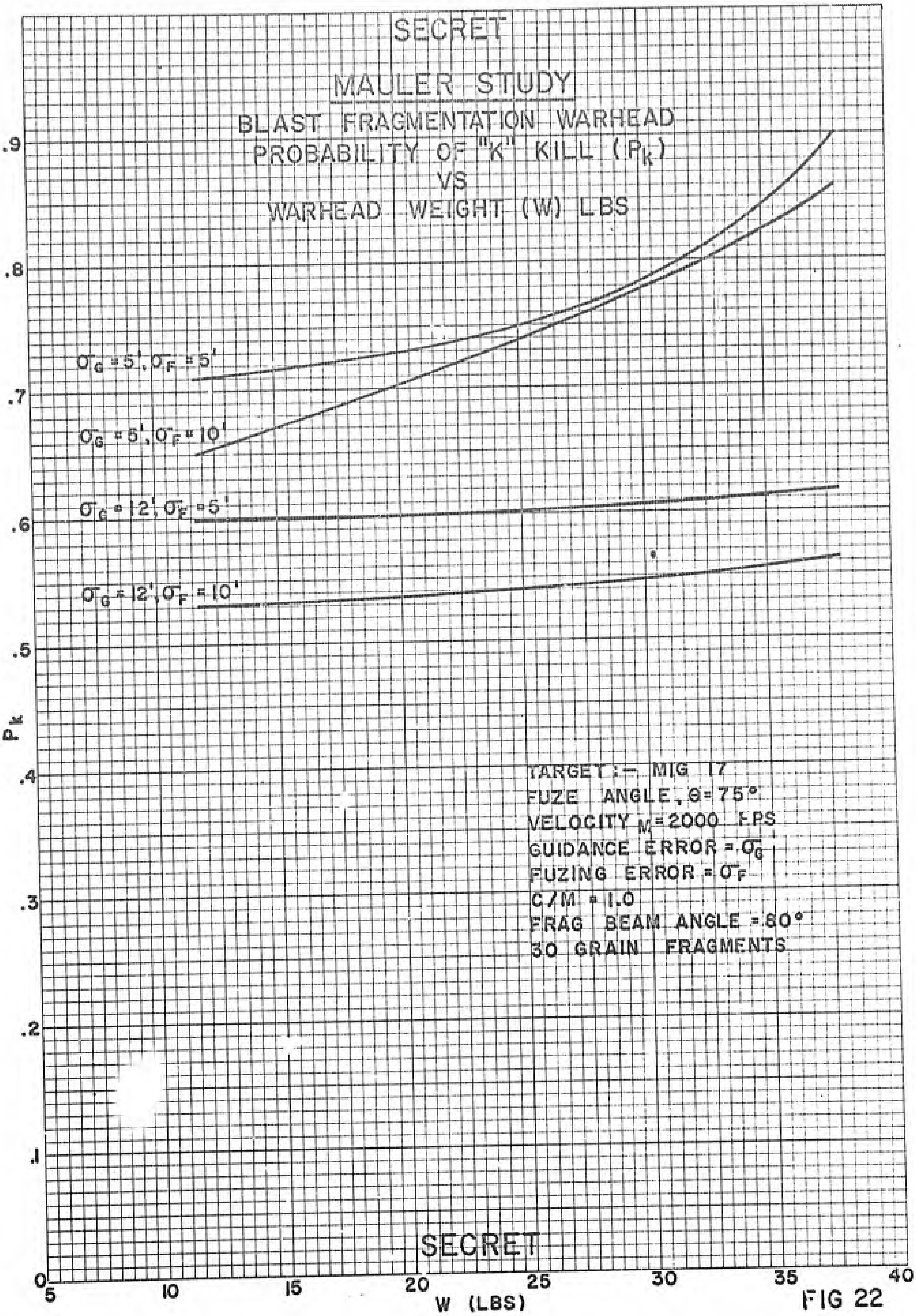

MAULER STUDY
BLAST FRAGMENTATION WARHEAD
PROBABILITY OF "K" KILL (P_k)
VS
WARHEAD WEIGHT (W) LBS
σG = 5', σF = 5'
σG = 5', σF = 10'
σG = 12', σF = 5'
σG = 12', σF = 10'
TARGET :- MIG 17
FUZE ANGLE, θ = 75°
VELOCITY M = 2000 FPS
GUIDANCE ERROR = σG
FUZING ERROR = σF
C/M = 1.0
FRAG BEAM ANGLE = 80°
30 GRAIN FRAGMENTS
Pk
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
5
10
15
20
25
30
35
40
W (LBS)

FIG 22

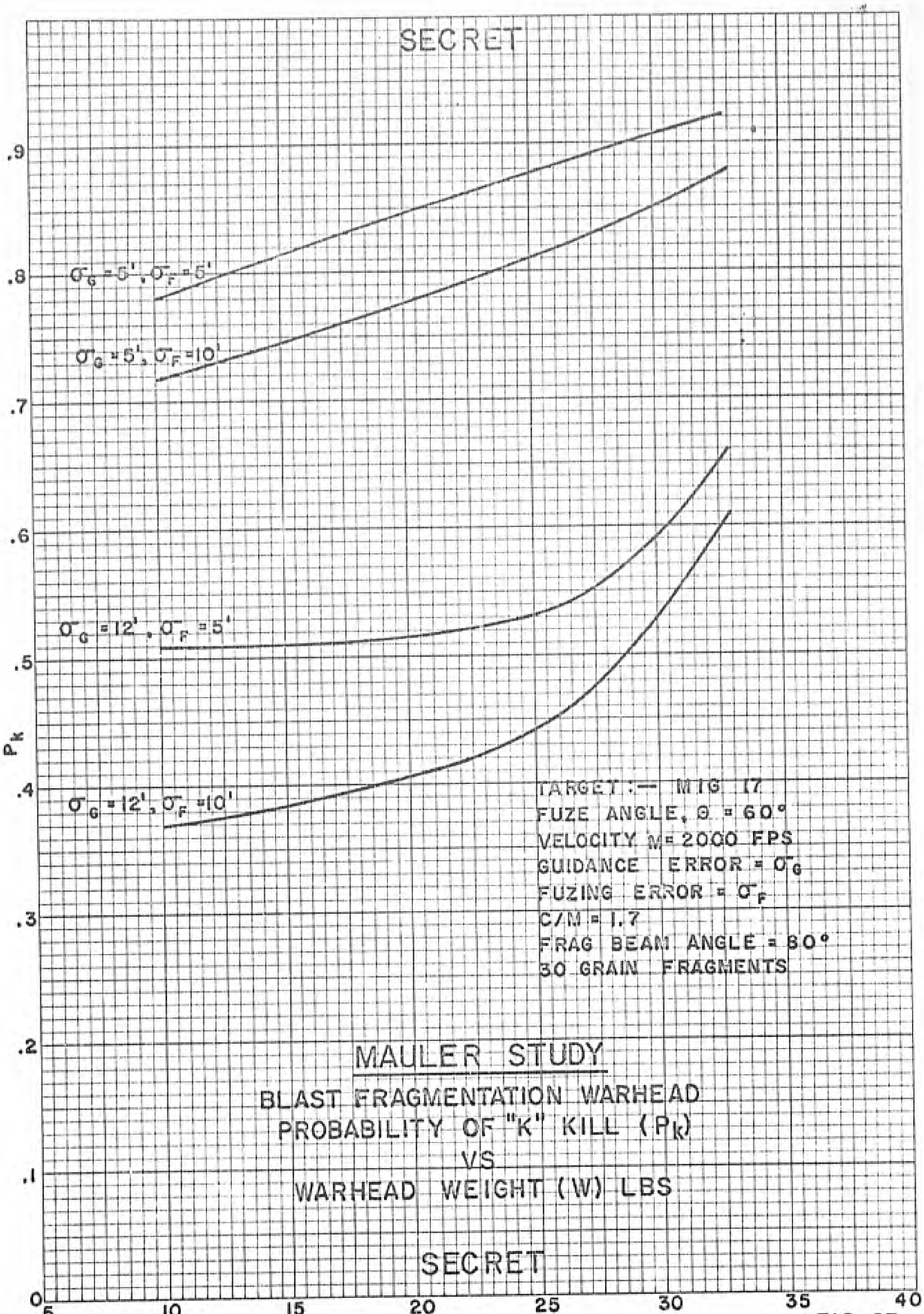

.9
.8
.7
.6
.5
.4
.3
.2
.1
0
Pk
$\sigma_G = 5'$, $\sigma_F = 5'$
$\sigma_G = 5'$, $\sigma_F = 10'$
$\sigma_G = 12'$, $\sigma_F = 5'$
$\sigma_G = 12'$, $\sigma_F = 10'$
TARGET :— MIG 17
FUZE ANGLE, Θ = 60°
VELOCITY M = 2000 FPS
GUIDANCE ERROR = σ_G
FUZING ERROR = σ_F
C/M = 1.7
FRAG BEAM ANGLE = 80°
30 GRAIN FRAGMENTS
MAULER STUDY
BLAST FRAGMENTATION WARHEAD
PROBABILITY OF "K" KILL (P_k)
VS
WARHEAD WEIGHT (W) LBS
5
10
15
20
25
30
35
40
W (LBS)

FIG 23

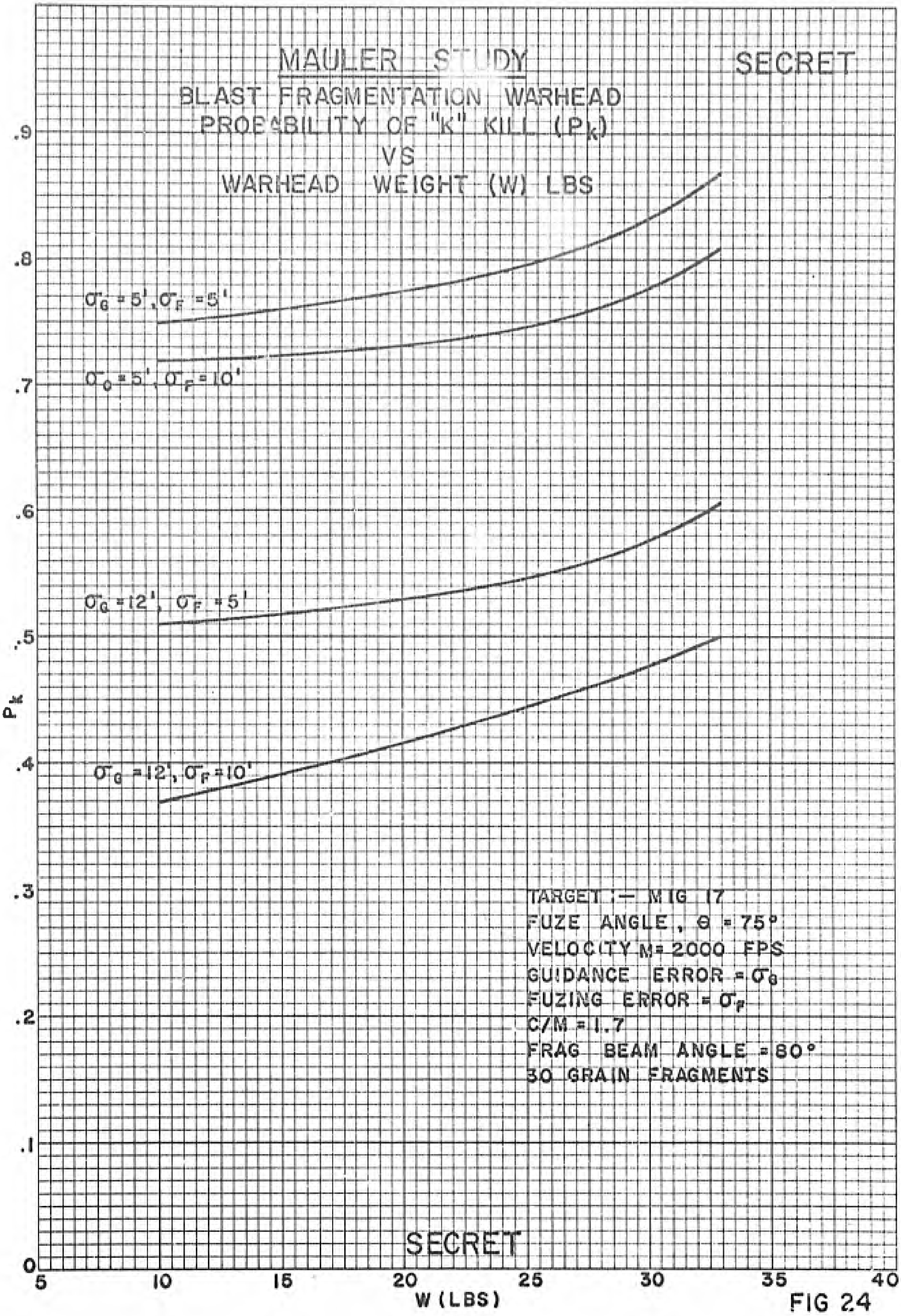

MAULER STUDY
SECRET
BLAST FRAGMENTATION WARHEAD
PROBABILITY OF "K" KILL (P_k)
VS
WARHEAD WEIGHT (W) LBS
$\sigma_G = 5'$, $\sigma_F = 5'$
$\sigma_G = 5'$, $\sigma_F = 10'$
$\sigma_G = 12'$, $\sigma_F = 5'$
$\sigma_G = 12'$, $\sigma_F = 10'$
TARGET :— MIG 17
FUZE ANGLE, θ = 75°
VELOCITY M = 2000 FPS
GUIDANCE ERROR = σ_G
FUZING ERROR = σ_F
C/M = 1.7
FRAG BEAM ANGLE = 80°
30 GRAIN FRAGMENTS
SECRET
P_k
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
5
10
15
20
25
30
35
40
W (LBS)

FIG 24

In drawing the graphs of Figures 15-24, the following warhead weights were used:

Contractor	Warhead Weight (lbs) C/M = 1.0	C/M = 1.7
Convair	11.75	10
G. E.	25	21.6
Sperry	29	25
Martin	38	32.8

The preliminary phase showed the following important results:

(1) A fragment spray angle considerably wider than 14° is required.

(2) The fuze look angle should be between approximately 60° and 75°

Due to a misinterpretation of the data in the original calculations , 30 grain fragments seemed to give poorer results than 90 grain fragments. As a result higher fragment weights were tentatively recommended in an earlier progress report. However, in the final phase of this study, warheads containing 30 grain fragments were found to give the best results.

C. Intermediate Phase

In the intermediate phase, the warhead weights and diameters proposed by each contractor were held constant and the length was varied to obtain a wider fragment spray beam angle approximately equal to 90°. The preliminary phase showed that higher P_k's resulted from a wider fragment spray beam angle. In evaluating the warheads for this phase, the following parameters and values were used:

2 Guidance errors = 5' and 12'

2 Fuzing errors = 5' and 10'

2 Fragment sizes = 60 and 90 grains

1 Fuze look angle = 70°

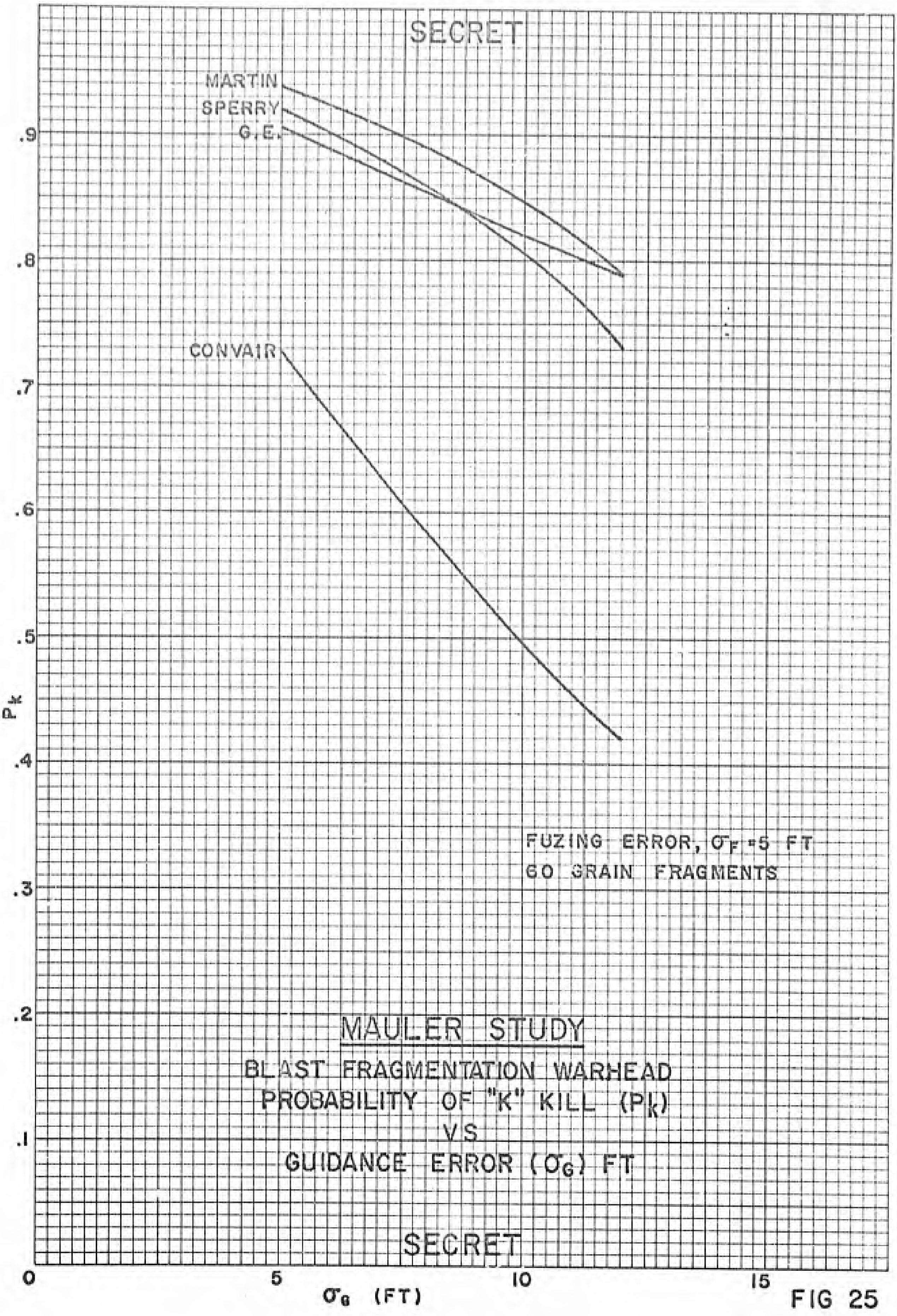
The C/M for Sperry, Martin and Convair was approximately 1.7. Since G. E. was reluctant to change their envelope dimensions and total weight, their C/M was 0.96.

The results obtained for one hundred engagements are given in Table VI, and shown graphically in Figures 25-28 with P_K as a function of guidance error.

TABLE VI

		P_K							
		Convair		G. E.		Sperry		Martin	
σ_g	σ_f	60 Gr	90 Gr	60 Gr	90 Gr	60 Gr	90 Gr	60 Gr	90 Gr
5	5	.73	.70	.91	.82	.92	.84	.94	.88
5	10	.63	.49	.85	.75	.84	.75	.84	.81
12	5	.42	.39	.79	.76	.73	.67	.79	.66
12	10	.41	.37	.72	.60	.67	.59	.76	.64

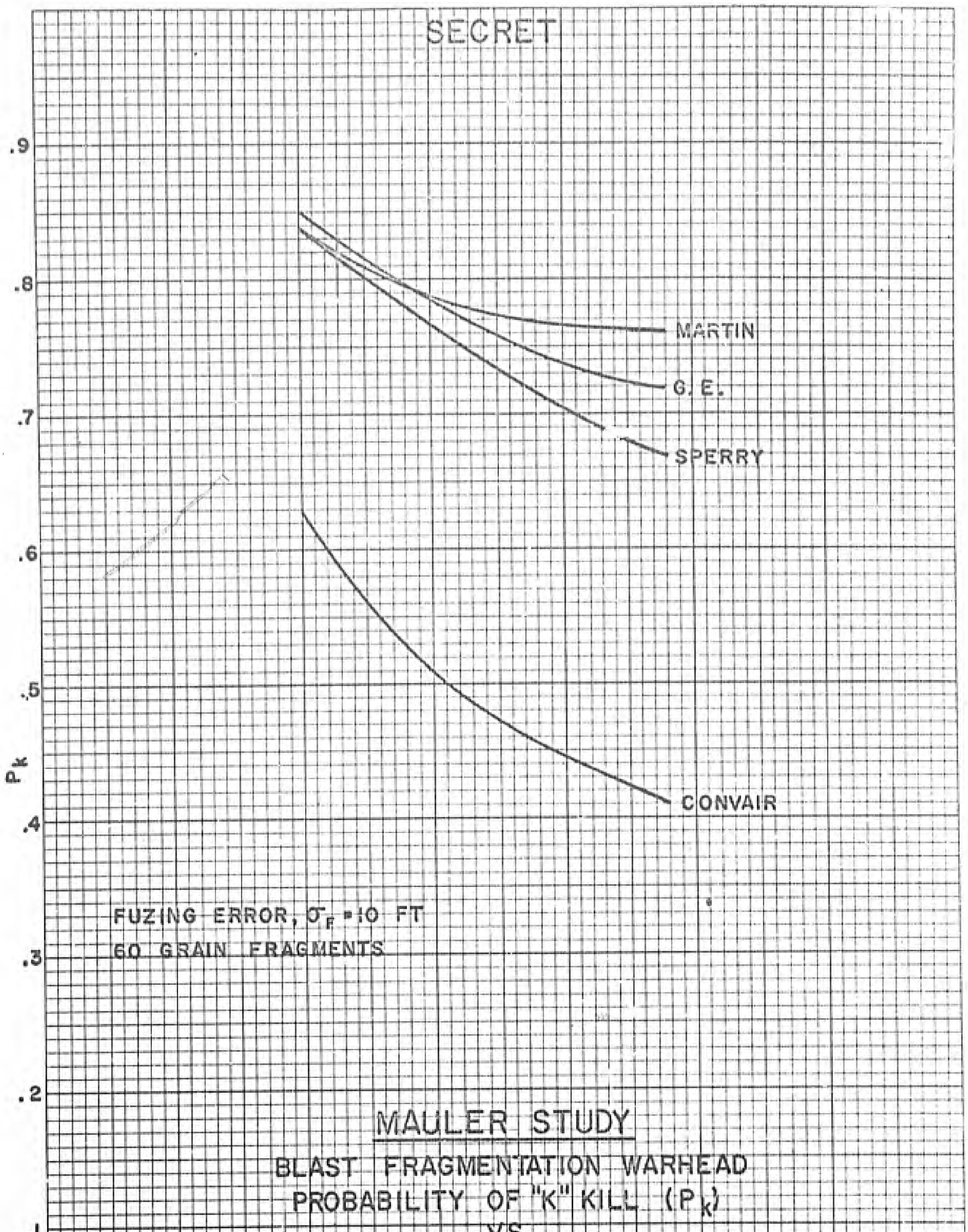
As a result of the intermediate phase analysis, the warhead compartment envelope and weight was fixed for each contractor. It also appeared that the optimum C/M was about 1.7 and the optimum fragment size about 60 grains. However, further optimization within the warhead envelopes established for each contractor indicated that these values were not optimum as shown at the beginning of this section on Blast-Fragmentation warheads.



MAULER STUDY

BLAST FRAGMENTATION WARHEAD
PROBABILITY OF "K" KILL (P_k)
VS
GUIDANCE ERROR (σ_G) FT

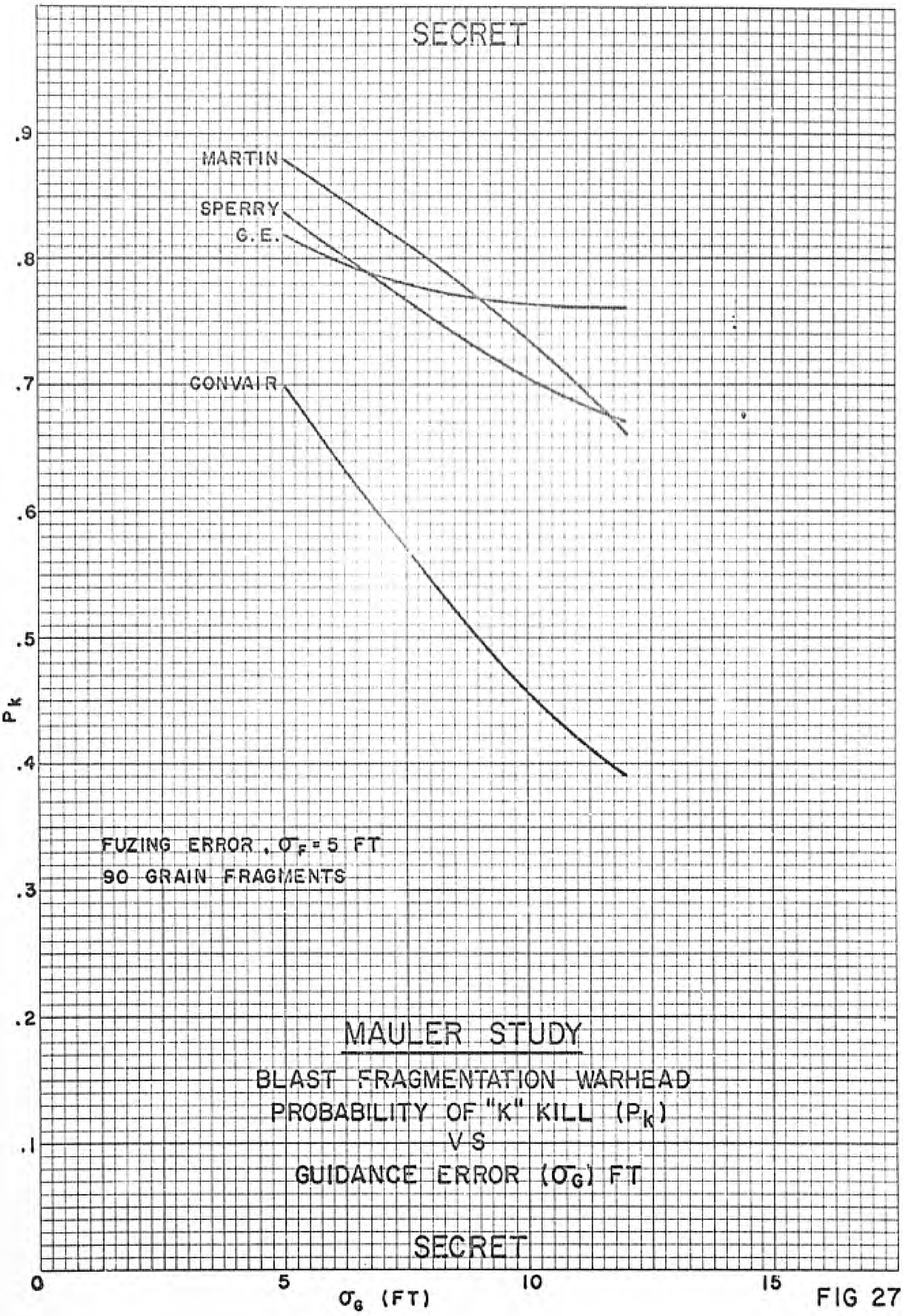
FIG 25



MAULER STUDY

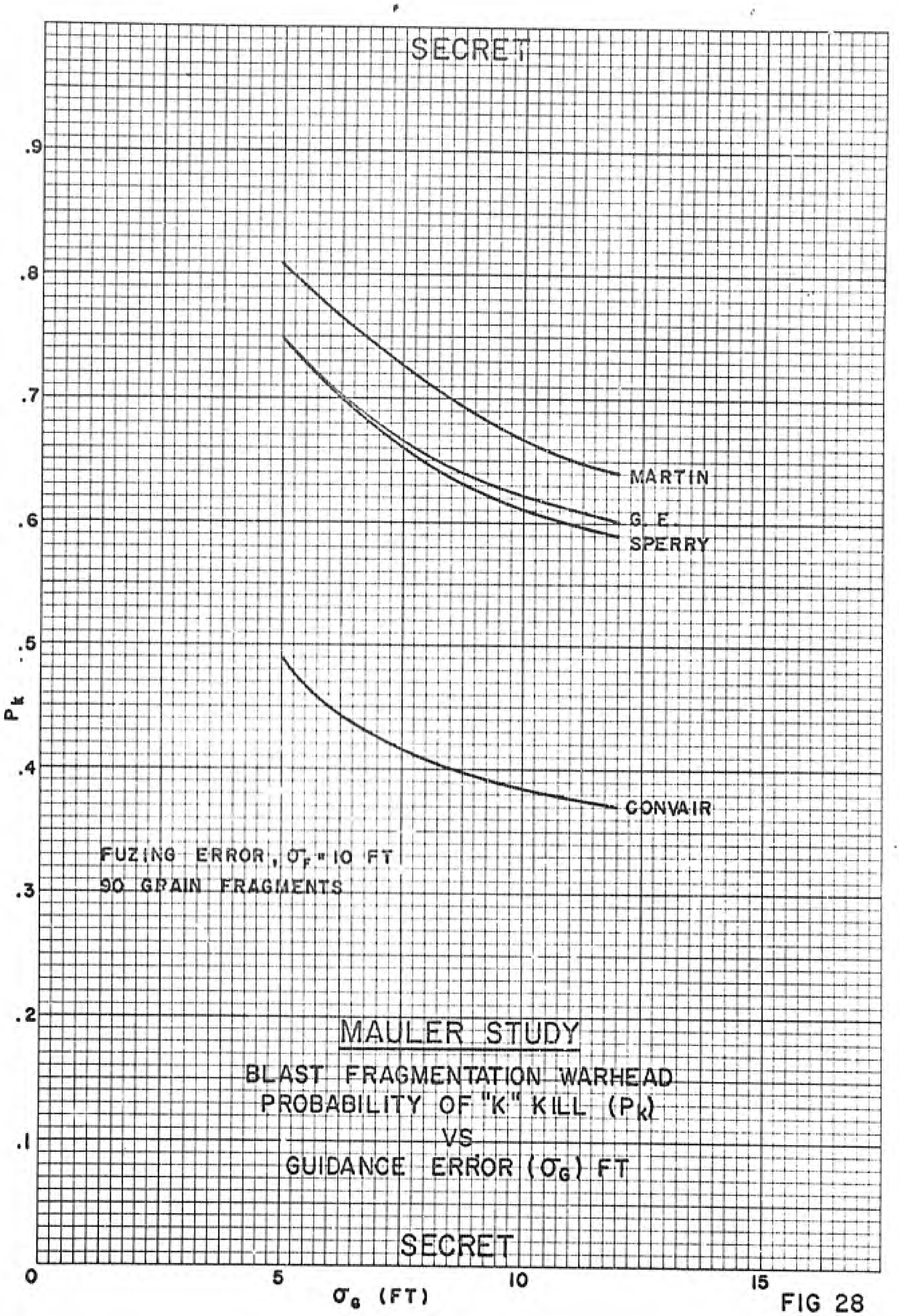
BLAST FRAGMENTATION WARHEAD PROBABILITY OF "K" KILL (P_K) VS GUIDANCE ERROR (σ_G) FT

FIG 26



SECRET
MARTIN
SPERRY
G.E.
CONVAIR
FUZING ERROR, σ_F = 5 FT
90 GRAIN FRAGMENTS
MAULER STUDY
BLAST FRAGMENTATION WARHEAD
PROBABILITY OF "K" KILL (P_k)
VS
GUIDANCE ERROR (σ_G) FT
SECRET
.9
.8
.7
.6
.5
.4
.3
.2
.1
P_k
0
5
10
15
σ_G (FT)

FIG 27



MAULER STUDY

BLAST FRAGMENTATION WARHEAD
PROBABILITY OF "K" KILL (P_k)
VS
GUIDANCE ERROR (σ_G) FT

FIG 28

3. Continuous-Rod Warhead

The CR warhead was evaluated by a mechanical engagement simulator as indicated earlier in this volume. The input data used in evaluating each contractor's warhead is as follows:

Contractor	Maximum Hoop Diameter (ft)	Initial Velocity of Rods (fps)
G. E.	34.5	3510
Sperry	31.7	4000
Martin	27.3	4610

The parameters used and their values were:

2 Guidance errors = 5' and 12'

2 Fuzing errors = 5' and 10'

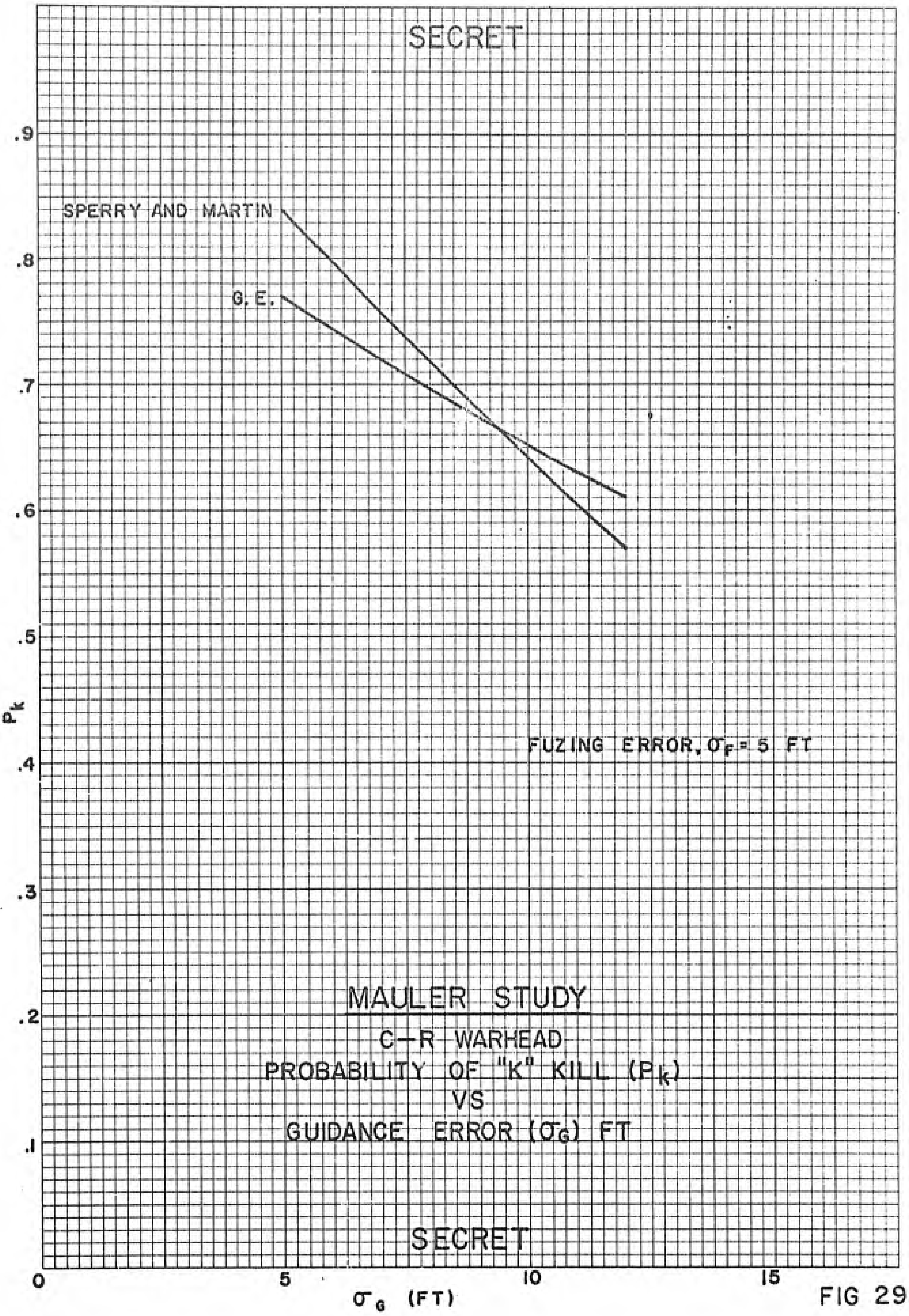
1 Fuze look angle = 70°

The results obtained from 100 engagements for each set of parameters are listed in Table VII and depicted graphically in Figures 29 and 30 showing P_k as a function of guidance error for the 5' and 10' fuzing error respectively.

TABLE VII

σ_g (ft)	σ_f (ft)	P_k G.E.	P_k Sperry	P_k Martin
5	5	.77	.84	.84
5	10	.57	.58	.68
12	5	.61	.57	.57
12	10	.43	.41	.26

SECRET



MAULER STUDY

C—R WARHEAD
PROBABILITY OF "K" KILL (P_k)
VS
GUIDANCE ERROR (σ_G) FT

SECRET

FIG 29

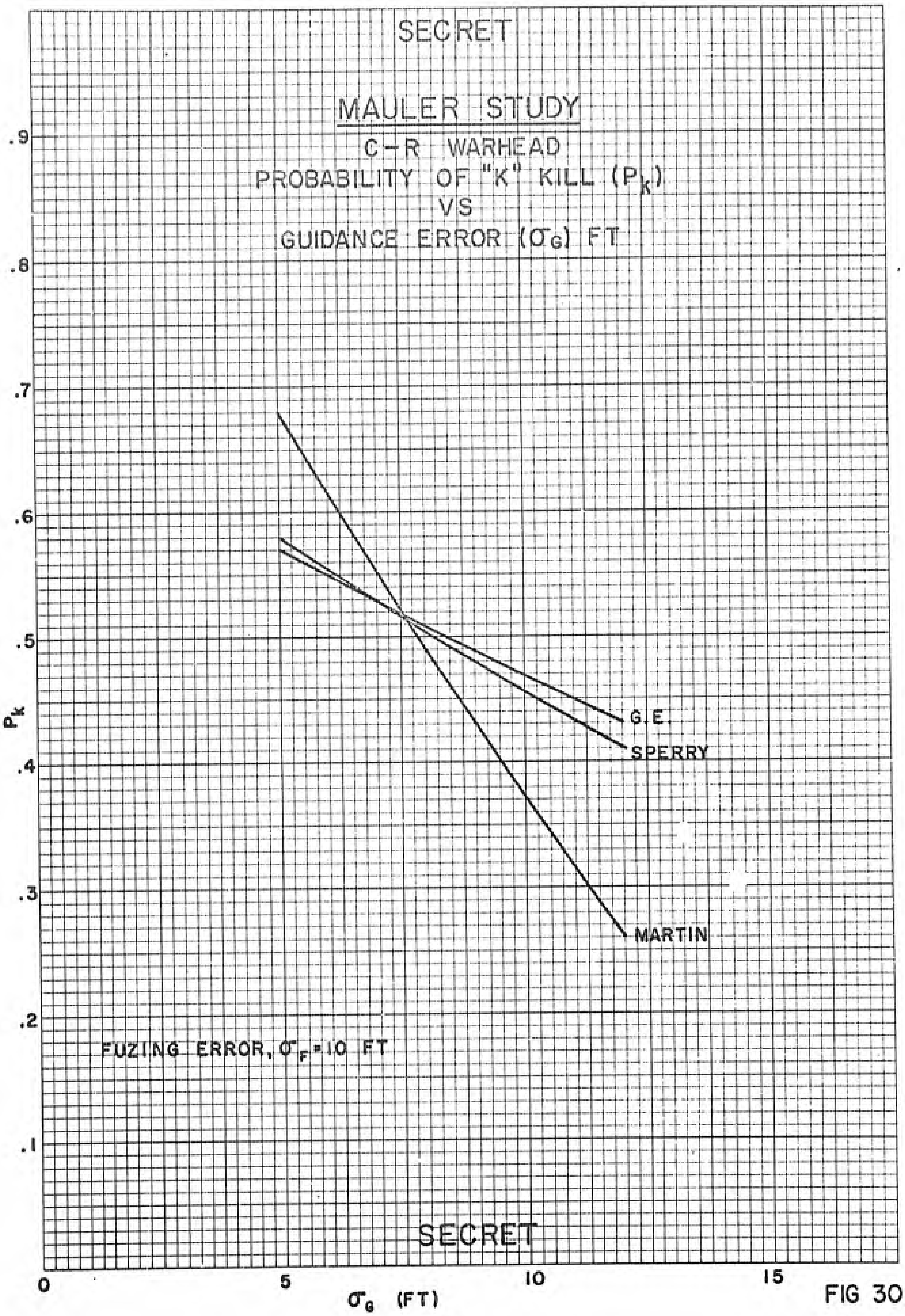

SECRET
MAULER STUDY
C-R WARHEAD
PROBABILITY OF "K" KILL (P_k)
VS
GUIDANCE ERROR (σ_G) FT
.9
.8
.7
.6
.5
.4
.3
.2
.1
P_k
G.E.
SPERRY
MARTIN
FUZING ERROR, σ_F = 10 FT
SECRET
0
5
10
15
σ_G (FT)

FIG 30

4. Comparison of Warheads

The three types of warheads evaluated for each contractor (with the exception of Convair in which case only two types were considered) are compared graphically in Figures 31-34. These graphs depict P_k as a function of guidance error, σ_g, for each contractor separately. The values used in plotting these graphs are listed in Table VIII and were obtained from earlier parts of this volume .

Examination of Figures 31-34 discloses that in all cases the blast-fragmentation warhead is superior. Entering the graphs at the guidance errors claimed by each contractor the following results are obtained:

		P_k					
	σ_g	Blast		Blast-Frag		CR	
Contractor	(ft) σ_F =	5'	10'	5'	10'	5'	10'
Convair	6.7	.50	.36	.78	.66	---	---
G. E.	7.4	.51	.43	.90	.85	.71	.52
Martin	10.2	.398	.37	.86	.826	.64	.37
Sperry	12	.25	.249	.87	.80	.57	.41

These results show that the blast-fragmentation warhead is the most effective for each contractor's system with CR second. A CR warhead with a 5 ft. fuze error meets the Mauler effectiveness requirements specified in the MC's, provided of course, that the system operability and reliability is 100%. The above results will be degraded accordingly if it is less than 100%.

TABLE VIII

σ_g (ft)	σ_f =	P_K Blast 5'	10'	Blast-Frag 5'	10'	CR 5'	10'
		CONVAIR					
5		.68	.52	-	-	-	-
6.7		-	-	.78	.66	-	-
9		-	-	.71	.65	-	-
10		.23	.17	-	-	-	-
12		-	-	.61	.54	-	-
15		.05	.08	-	-	-	-
		G. E.					
5		.78	.58	.92	.86	.77	.57
7.4		-	-	.90	.85	-	-
10		.31	.30	-	-	-	-
12		-	-	.83	.82	.61	.43
15		.15	.18	-	-	-	-
		MARTIN					
5		.82	.65	.93	.88	.84	.68
10		.41	.38	-	-	-	-
10.2		-	-	.86	.82	-	-
12		-	-	.82	.81	.57	.26
15		.23	.23	-	-	-	-
		SPERRY					
5		.79	.60	.97	.92	.84	.58
10		.34	.32	-	-	-	-
12		-	-	.87	.80	.57	.41
15		.18	.19	.79	.76	-	-

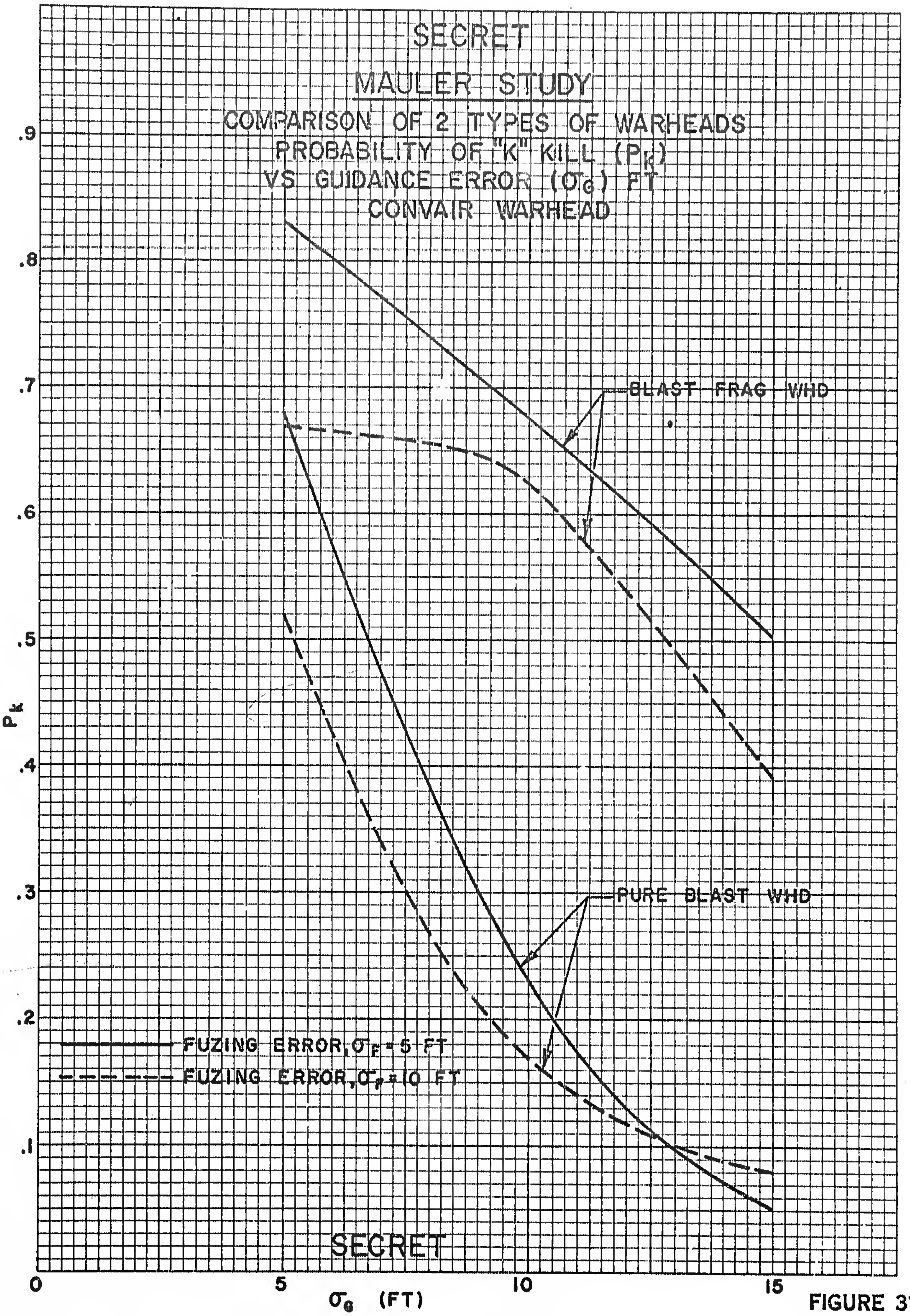
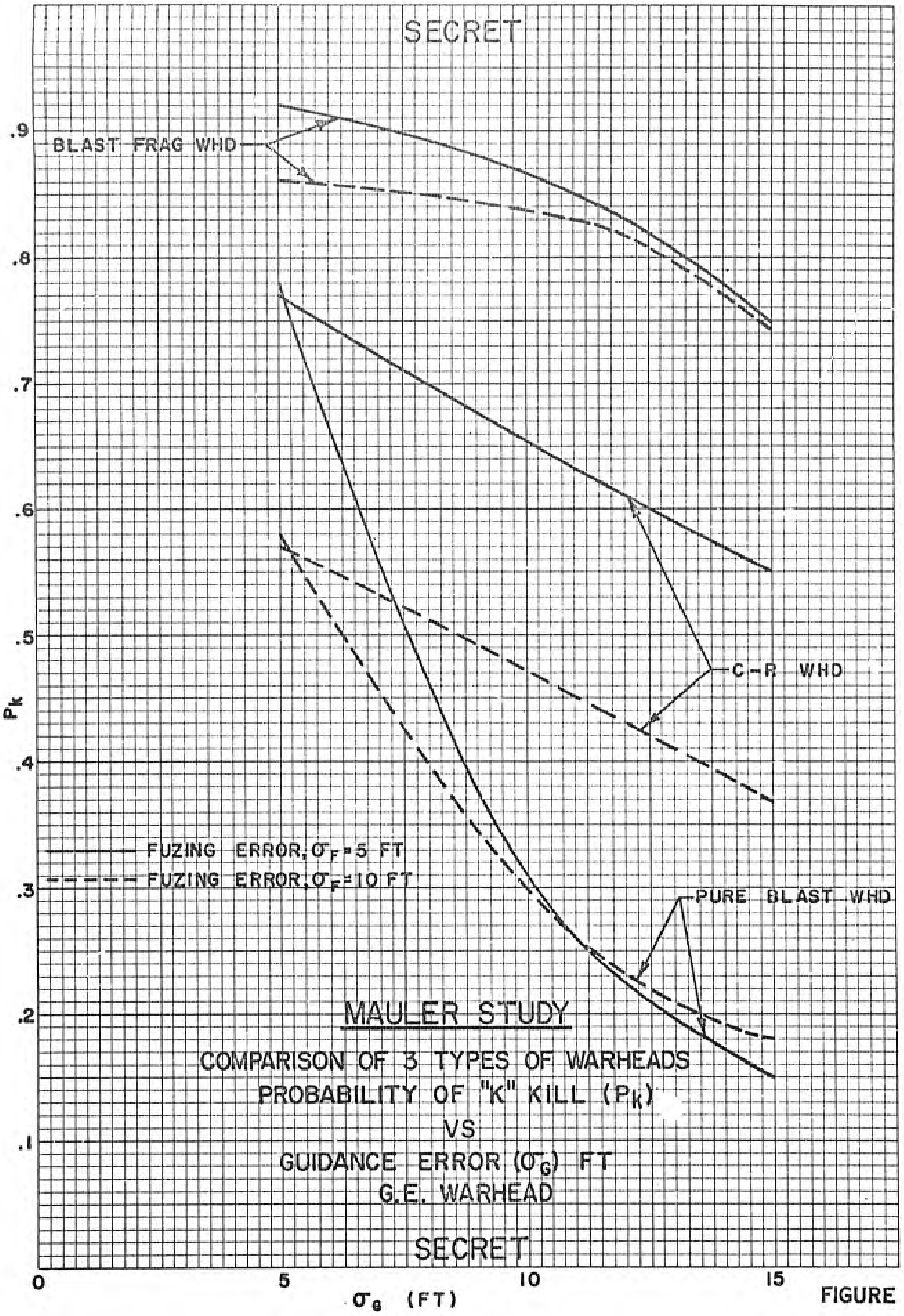
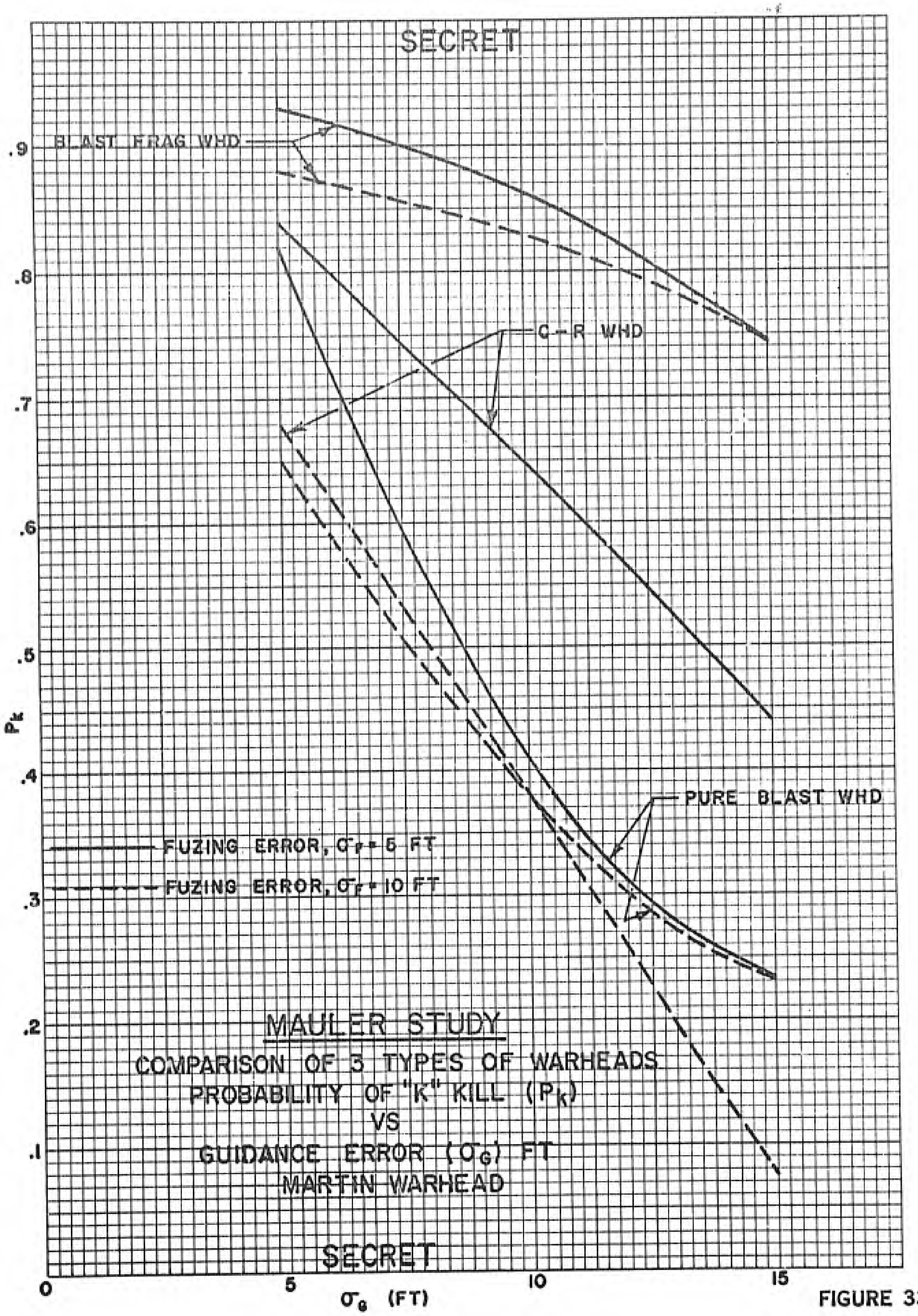

SECRET
MAULER STUDY
COMPARISON OF 2 TYPES OF WARHEADS
PROBABILITY OF "K" KILL (P_K)
VS GUIDANCE ERROR (σ_G) FT
CONVAIR WARHEAD
BLAST FRAG WHD
PURE BLAST WHD
FUZING ERROR, σ_F = 5 FT
FUZING ERROR, σ_F = 10 FT
P_k
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
5
10
15
σ_G (FT)
SECRET

FIGURE 31



SECRET
BLAST FRAG WHD
C-R WHD
PURE BLAST WHD
FUZING ERROR, σ_F = 5 FT
FUZING ERROR, σ_F = 10 FT
MAULER STUDY
COMPARISON OF 3 TYPES OF WARHEADS
PROBABILITY OF "K" KILL (P_K)
VS
GUIDANCE ERROR (σ_G) FT
G.E. WARHEAD
SECRET
P_k
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
5
10
15
σ_G (FT)

FIGURE 32



SECRET
BLAST FRAG WHD
C—R WHD
PURE BLAST WHD
FUZING ERROR, σ_F = 5 FT
FUZING ERROR, σ_F = 10 FT
MAULER STUDY
COMPARISON OF 3 TYPES OF WARHEADS
PROBABILITY OF "K" KILL (P_K)
VS
GUIDANCE ERROR (σ_G) FT
MARTIN WARHEAD
SECRET
P_K
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
5
10
15
σ_G (FT)

FIGURE 33

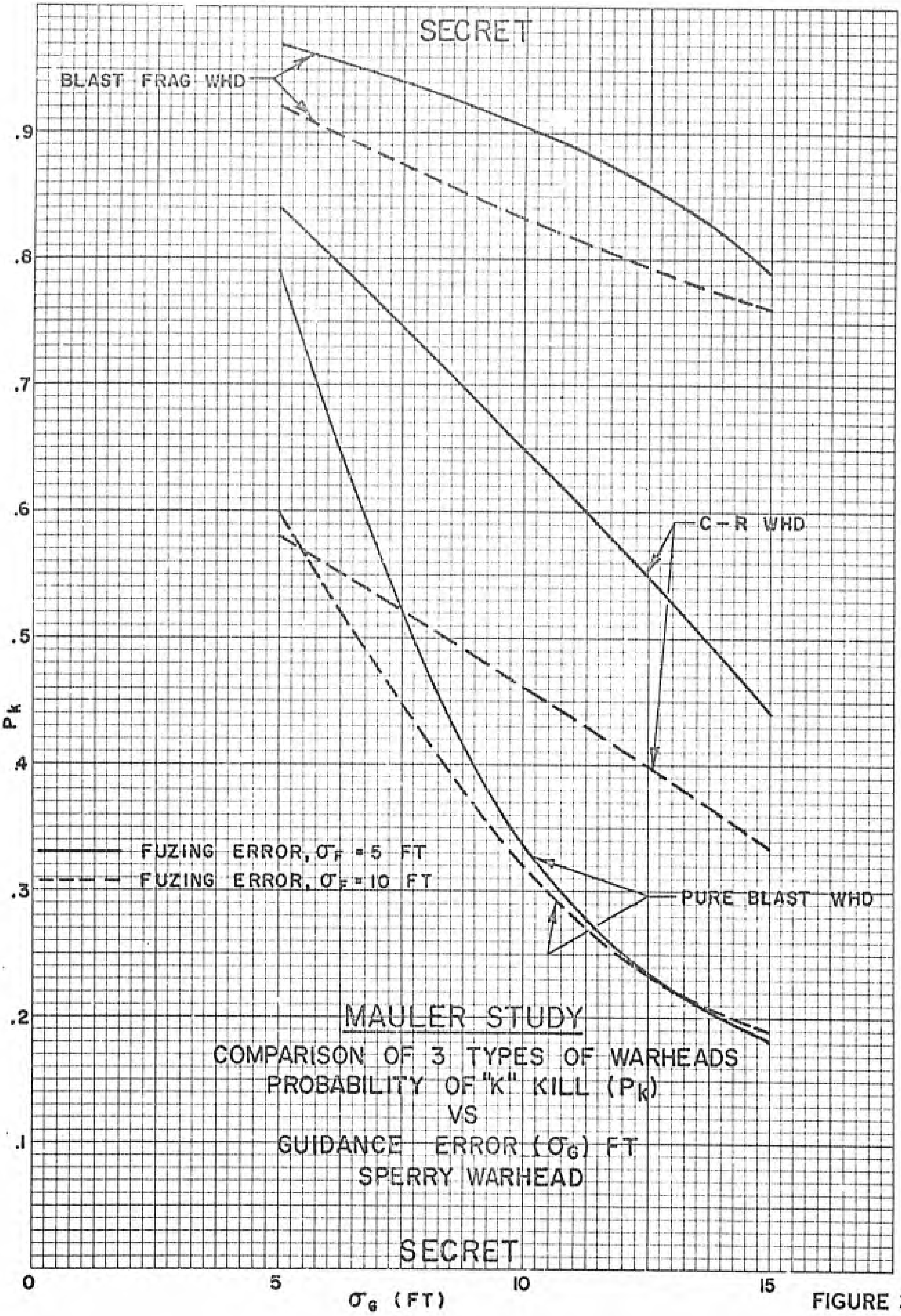

SECRET
BLAST FRAG WHD
C – R WHD
PURE BLAST WHD
FUZING ERROR, σ_F = 5 FT
FUZING ERROR, σ_F = 10 FT
MAULER STUDY
COMPARISON OF 3 TYPES OF WARHEADS
PROBABILITY OF "K" KILL (P_k)
VS
GUIDANCE ERROR (σ_G) FT
SPERRY WARHEAD
SECRET
P_k
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
5
10
15
σ_G (FT)

FIGURE 34

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C. Samuel Feltman Ammunition Laboratories, Ammunition Development Laboratory B Technical Memorandum No. 62A19, "General Warhead Information for Project Mauler Bidders (U)", by F. E. Saxe, S. K. Einbinder, L. F. Nichols, February 1958.