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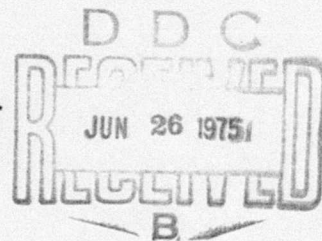
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GRAPHICAL TRAJECTORY COMPENDIUM OF
CALIBER .50 AND 20mm PROJECTILES IN AN AIR TO GROUND
AND GROUND TO GROUND ROLE

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October 1973

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)		
This report is a compendium of trajectories in air to ground and ground to ground role of projectiles shapes of possible interest in cannon caliber ammunition applications. The 20MM projectiles shapes are M53, M56 and SAPI. The caliber 50 drag curves are the M2 and M8.		

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INTRODUCTION

The data compiled in this report provides engineering information needed in making evaluations of ammunition improvements. Representative Caliber .50 and 20 mm projectiles data appear in the form of computer generated plottings of trajectories for both air to ground and ground to ground roles. Specific information covers time, velocity, and altitude versus range. Projectile characteristics include muzzle velocity, weight and shape with preformance interests centered on time of flight, muzzle velocity and maximum range effectiveness. Air to ground roles include fixed wing and helicopter launchings.

Seven 20 mm and six Caliber .50 projectiles variations listed in Table I comprised a cross section of nose shapes and weights for the study. Aside from potential application to the air to ground and ground to ground roles these projectiles studies have accumulated quantities of experimental information needed for the study.

Table I
Projectile Studies

<u>ITEM</u>	<u>PROJECTILE</u>	<u>WEIGHT GRAINS</u>	<u>NOSE SHAPE</u>
1	20mm M56A3	1540	Blunt - M505 Fuze
2	20mm M56A3	1950	Blunt - M505 Fuze
3	20mm M56A3	2100	Blunt - M505 Fuze
4	20mm PGU-3/B	1875	Secant Ogive - SAPI
5	20mm PGU-3/B	1900	Secant Ogive - SAPI
6	20mm PGU-3/B	2100	Secant Ogive - SAPI
7	20mm M53	1540	Blunt - M505 Fuze
8	Cal. .50 M8	662	Tangent Ogive
9	Cal. .50 M8	850	Tangent Ogive
10	Cal. .50 M8	1130	Tangent Ogive
11	Cal. .50 M2	662	Tangent Ogive
12	Cal. .50 M2	850	Tangent Ogive
13	Cal. .50 M2	1130	Tangent Ogive

METHOD

TRAJE (computer program) is a point mass trajectory program incorporating variation of air density with altitude by means of a subroutine, Atmospheric Computer Program, ATMS1, (1). The basic TRAJE model (2) is

$$m \frac{d\bar{V}}{dt} = \rho(y) A |\bar{V}| \bar{V} C_D(V) - \bar{g}$$

m = Projectile weight,

$\bar{V}$ = Velocity along trajectory, ft/sec

$\rho(y)$ = Air density as a function of height,

A = Projectile cross section area,

$\bar{g}$ = Gravitational constant along trajectory

$C_D(V)$ = Drag coefficient as a function of velocity.

Inputs consists of projectile weight and cross sectional area, projectile muzzle velocity and drag curve, vehicle velocity and angle of ascent or descent. Outputs include altitude, range, velocity, time of flight and drag in machine plotted form. Output information is used to compare trajectories, time of flight and velocity decay of various projectiles.

Figure 1 contains curves (3) of drag coefficient versus mach number for projectile items number 1, 4, 7, 8, and 11. Appendix A contains a listing of card types for the program data inputs, and the units for the various parameters. The program is written in Fortran IV for use on the IBM 360 or CDC 6500.

DRAG CURVE VS MACH NUMBER

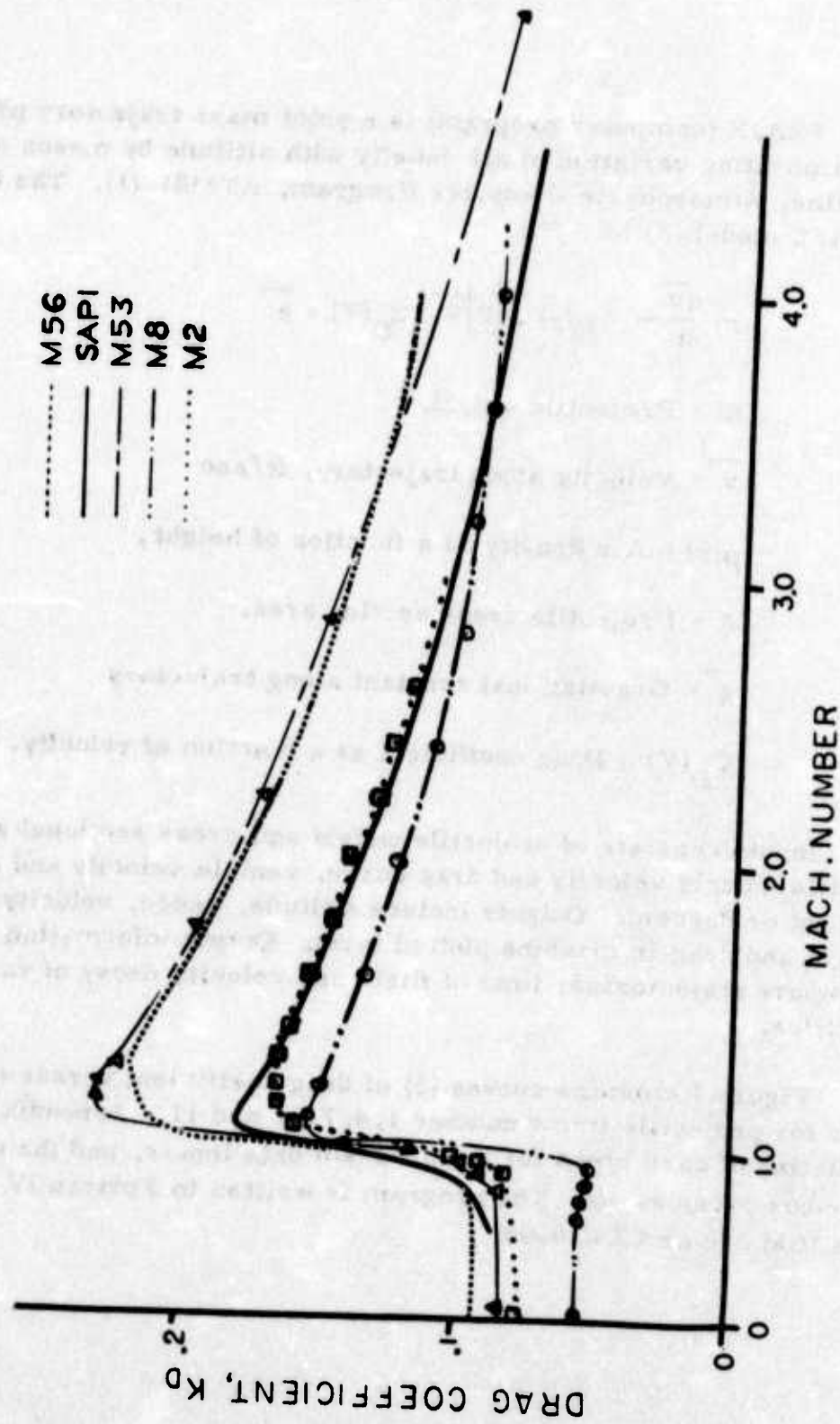


Figure 1. Drag Coefficient Curve

RESULTS

A series of graphs (Appendix C) present the charted data generated during the course of the study for altitude, time, and velocity versus range for each of the projectiles investigated. These graphs present various combinations of the same basic curves to provide comparisons in graphic form. Tables II to V contain listings of these graphs. Table II covers graphs 1 through 27 for 20 mm projectiles launched in the air to ground role at a constant aircraft velocity of 790 knots and a dive angle of 30° from two different altitudes, 182.88×10 meters (6000 ft) and 213.36×10 meters (7000 ft). The notations in the column headed "drag Curve" refers to the M505A3 fuze or nose shape of the M56A3 projectile as M505 and to the nose shape of the 20 mm PGU-3/B projectile as SAPI. These terms also appear in the legend of the plots and in Table I and are used to identify the drag curve used in the calculations.

Graphs 1 and 2 compare projectiles of two different weights having the SAPI nose launch at two different altitudes. Graphs 3 and 4 compare projectiles having the M505 nose shape, same weights, but different muzzle velocities launched at two different altitudes. Graphs 5 and 6 provide the same comparison for projectiles having the SAPI nose shape. Graphs 7 through 12 compare projectiles having M505 and SAPI nose shapes at two weights and three velocity levels launched at two altitudes. Graphs 13 through 16 present a comparison of the M505 and SAPI nose shapes at two launch altitudes by interchanging projectile weights. Graphs 17 and 18 compare SAPI nose shapes at two launch altitudes and projectile weights and three velocities. Graphs 19 and 20 cover the same comparison for the M505 nose shape. Graphs 21 and 22 compare a projectile having the standard M56A3 weight with M505 and SAPI projectiles having the same weights. Graphs 23 and 24 present a comparison of five projectiles, SAPI and M505 projectile nose shapes at two different weights and the standard M56A3. Graph 25 compares the standard M56A3 weight projectile to two heavier M505 and SAPI nose shape projectiles. Graph 26 compares equal weight and velocity M505 and SAPI projectile shapes with standard M56A3. Graph 27 includes the M53 API data for comparison with the M56A, M505 and SAPI nose shaped and weight projectiles.

Table III contains a listing of Graphs 28 through 76 together with identification of the conditions for the graph data. These conditions

differed from those identified in Table II by varying altitude and aircraft speed at lower levels and dive or descent angles. The range selected relates to helicopter launchings. Four projectiles were considered: standard M53, one with M505 nose shape, and two SAPI nose shaped projectiles differing in weight and velocity. Each graph contains four sets of data, one set for each projectile. Table III groups the graphs according to aircraft velocity: Graphs 28 through 37 are for 0 forward velocity while Graphs 68 through 76 are for 200 knots air speed with the other graphs, 38 to 67, grouped for velocities in between.

Table IV lists 24 graphs covering trajectory data for 20 mm projectiles in the ground to ground role at elevations in the 3° to 60° range. Projectiles having M505 and SAPI nose shapes at two velocity levels are compared at one weight level together with the standard M56A1 weight projectile. Graphs 77 through 89 cover one velocity level and Graphs 90 through 100 another for the M505 and SAPI nose projectiles.

Table V contains a listing of the graphs presenting Caliber .50 data. The data involves two Caliber .50 type nosed projectiles, M2 and M8, launched at three different weights over an elevation angle range of 1° to 60° . Graphs 101 through 120 relate to the M2 data and Graphs 121 through 140 to the M8 data.

Table II.
20MM Projectiles, Air to Ground Trajectories
Aircraft Velocity 790 Knots, Dive Angle 30°

<u>Graph Number</u>	<u>Altitude Ft/Meters</u>	<u>Drag Curve</u>	<u>Weight Grains</u>	<u>Missile Velocity fps/mps</u>
1	6000/1828.8	SAPI	1950	2950/899.16
		SAPI	1850	3016/919.28
2	7000/2133.6	SAPI	1950	2950
			1850	3016
3	7000	M505	1950	3050/929.64
		M505	1950	2950
4	6000	M505	1950	2950
		M505	1950	3050
5	7000	SAPI	1950	3050
		SAPI	1950	2950
6	6000	SAPI	1950	2950
		SAPI	1950	3050
7	7000	M505	1950	2950
		SAPI	1950	2950
8	6000	SAPI	1950	2950
		M505	1950	2950
9	6000	SAPI	1950	3050
		M505	1950	3050
10	7000	M505	1950	3050
		SAPI	1950	3050
11	7000	M505	2100	2850
		SAPI	2100	2850
12	6000	SAPI	2100	2850
		M505	2100	2850
13	7000	SAPI	2100	2850
		M505	1950	2950
		M505	1950	3050
14	6000	SAPI	2100	2850
		M505	1950	3050
		M505	1950	2950
15	7000	M505	2100	2850
		SAPI	1950	3050
		SAPI	1950	2950
16	6000	M505	2100	2850
		SAPI	1950	2950
		SAPI	1950	3050
17	7000	SAPI	2100	2850
		SAPI	1950	3050
		SAPI	1950	2950
18	6000	SAPI	2100	2850
		SAPI	1950	3050
		SAPI	1950	2950
19	6000	M505	2100	2850
		M505	1950	2950
		M505	1950	3050

Table II. - continued

Graph Number	Altitude Ft/Meters	Drag Curve	Weight Grains	Missile Velocity fps/mps
20	7000	M505	2100	2850
		M505	1950	3050
		M505	1950	2950
21	7000	M505(M56)	1540	3350/1021.08
		M505	2100	2850
		SAPI	2100	2850
22	6000	M505(M56)	1540	3350
		M505	2100	2850
		SAPI	2100	2850
23	7000	SAPI	1950	2950
		M505	1950	2950
		SAPI	2100	2850
		M505	2100	2850
		M505(M56)	1540	3350
24	6000	M505(M56)	1540	3350
		M505	2100	2850
		SAPI	2100	2850
		M505	1950	2950
		SAPI	1950	2950
25	6000	M505(M56)	1540	3350
		M505	2100	2850
		SAPI	2100	2850
	6000	M505	1950	3050
		SAPI	1950	3050
26	7000	SAPI	1950	3050
		M505	1950	3050
		SAPI	2100	2850
		M505	2100	2850
		M505(M56)	1540	3350
27	6000	M505(M56)	1540	3350
		API	2500	2650/807.72
		SAPI	2100	2850
		M505	1875	3016
		SAPI	1875	3016

*NOTE I: The M505 Drag curve was obtained from Ballistic Research Laboratory, Aberdeen, Md and SAPI drag curve was obtained from 20mm API and SAPI Design Review Memorandum, Phase I, October 28, 1969, by AVCO Corporation Ordnance Division.

TABLE III.
20MM PROJECTILES
AIR TO GROUND TRAJECTORIES

<u>Drag Curve used</u>	<u>Weight grains</u>	<u>Muzzle Velocity fps/mps</u>
M53	1540	3100/944.88
SAPI	2100	2450/746.36
SAPI	2500	2150/655.32
M505	2100	2450/746.36

<u>Graph Number</u>	<u>Altitude feet/meters</u>	<u>Helicopter Velocity knots/fps/mps</u>	<u>Descent Angle</u>
28	200/60.96	0.0	5°
29	1000/304.8	0.0	5°
30	200	0.0	10°
31	1000	0.0	10°
32	200	0.0	15°
33	1000	0.0	15°
34	200	0.0	30°
35	1000	0.0	30°
36	200	0.0	45°
37	1000	0.0	45°
38	200	50.0/84.45/57.58	5°
39	1000	50.0	5°
40	200	50.0	10°
41	1000	50.0	10°
42	200	50.0	15°
43	1000	50.0	15°
44	200	50.0	30°
45	1000	50.0	30°
46	200	50.0	45°
47	1000	50.0	45°
48	200	100.0/168.89/115.16	5°
49	1000	100.0	5°
50	200	100.0	10°
51	1000	100.0	10°
52	200	100.0	15°
53	1000	100.0	15°

TABLE III.

continued

<u>Graph Number</u>	<u>Altitude feet/meters</u>	<u>Helicopter Velocity knots/fps/mpg</u>	<u>Descent Angle</u>
54	200	100.0	30°
55	1000	100.0	30°
56	200	100.0	45°
57	1000	100.0	45°
58	200	150.0/253.34/172.73	5°
59	1000	150.0	5°
60	200	150.0	10°
61	1000	150.0	10°
62	200	150.0	15°
63	1000	150.0	15°
64	200	150.0	30°
65	1000	150.0	30°
66	200	150.0	45°
67	1000	150.0	45°
68	200	200.0/337.79/230.31	5°
69	1000	200.0	5°
70	200	200.0	10°
71	1000	200.0	10°
72	200	200.0	15°
73	1000	200.0	15°
74	200	200.0	30°
75	1000	200.0	30°
76	1000	200.0	45°

TABLE IV.
20 MM PORJECTILES
GROUND TO GROUND TRAJECTORIES*

<u>Graph Number</u>	<u>Drag Curve</u>	<u>Weight Grains</u>	<u>Muzzle Velocity fps/mps</u>
77 - 88	M505 (M56)	1540	3350/1021.08
	M505	1950	2950/899.16
	SAPI	1950	2950/899.16
89 - 100	M505 (M56)	1540	3350/1021.08
	M505	1950	3050/929.64
	SAPI	1950	3050/929.64

* ANGLES OF ELEVATION: 3°, 6°, 9°, 12°, 15°, 18°, 21°, 24°, 27°,
30°, 45°, 60°

TABLE V.
CALIBER .50 PROJECTILES
GROUND TO GROUND TRAJECTORIES*

<u>Graph Number</u>	<u>Drag Curve</u>	<u>Weight Grains</u>	<u>Muzzle Velocity fps/mps</u>
101 - 120	M2	1033.	2488/758.34
	M2	850.	2910/886.97
	M2	662.	2600/792.48
121 - 140	M8	662.	2910/886.97
	M8	850.	2600/792.48
	M8	1130.	2488/758.34

* ANGLES OF ELEVATION: 1°, 2°, 2.5°, 3° thru 16°, 30°, 45°, 60°

CONCLUSIONS

This report covers a wide range of combinations of drag curve, projectile weight, and muzzle velocities. These parameters in turn effect the time of flight and maximum range of the performance of the various projectiles. It is recommended that similar trajectories be generated for an air to air role as well as other ammunition.

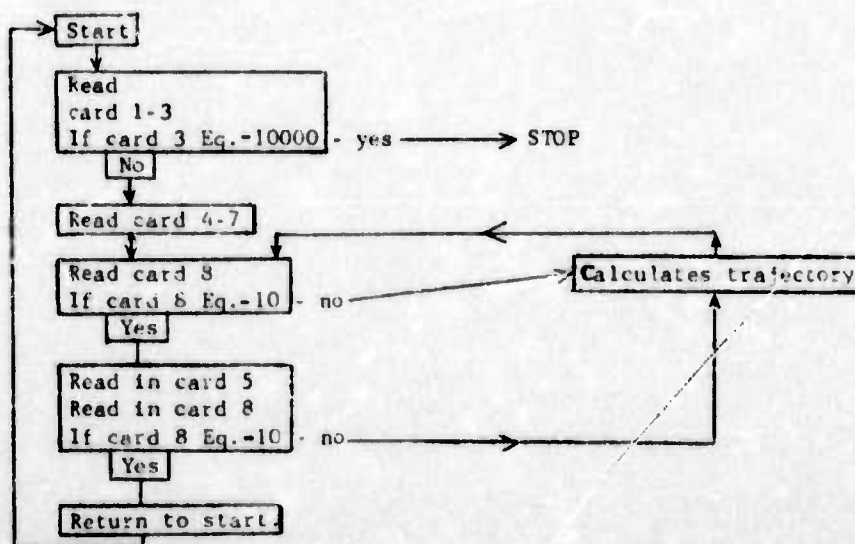
REFERENCES

1. U.S. Army Weapons Command, "Some Mathematical Models and Computer Programs for Small Arms Analyses," SY-TN10-80, Ad Hoc Small Arms Systems Analyses Working Group.
2. Ballistic Research Laboratories, "Aerodynamic Data for Spinning Projectiles" Report No. 620, H. P. Hitchcock October 1947.
3. Engineering Design Handbook, "Design for Control of Projectile Flight Characteristics" AMCP-706-242, Sept 1966.
4. BRL Report No. 1628, "Comparative Evaluation of 20 mm Developmental Ammunition (U)", Edited by George Samos, December 1972.

APPENDIX A
TRAJE DATA INPUT AND FLOW CHART

<u>CARD TYPE</u>	<u>COLUMNS</u>	<u>FORMAT</u>	<u>SYMBOL</u>	<u>IDENTIFICATION</u>	<u>UNITS</u>
1	1 - 7	F7.4	P	pressure	cm hg
	8 - 14	F7.4	TEMP	temperature	°F
2	1 - 24	6A4	SHAPE	projectile shape	
3*	1 - 6	F6.3	V (1)	velocity	
	7 - 14	F8.5	CD(1)	drag coefficient	
4	1 - 7	F7.2	DV	velocity	interval
5	1 - 7	F7.2	Y(1)	altitude	meters
6	1 - 10	F10.5	G	gravity	m/sec
	11 - 20	F10.5	A	cross sectional area	in ²
	21 - 30	F10.5	XM	mass	grains
	31 - 40	F10.5	ANGO	angel of descent or ascent	radians
	41 - 50	F10.5	VI	muzzle velocity	fps
7	1 - 7	F7.4	W	wind velocity	mps
8	1 - 6	F6.2	VPLANE	aircraft velocity	fps

FLOW CHART



* Note: card type 3 is a set of cards containing the points of the drag curve with the last card being -10.

APPENDIX B
COMPUTER PROGRAM LISTING

```

PROGRAM TRAJE(INPUT,OUTPUT,TAPE1=INPUT,TAPE3=OUTPUT,TAPE4)
REAL LOT
DIMENSION SHAPE(6)
DIMENSION ANGA(200),CD(200),VELDA(200)
COMMON Y(200),T(200),V(200),CD(200),K,I,X(200)
COMMON VV(200),CC(200),VPLANE
COMMON ZZ(200)
5 FORMAT(6A4)
6 FORMAT (20X, 19H MUZZLE VELOCITY = , F5.0, 7H FT/SEC )
7 FORMAT ( 1H , 2A7)
8 FORMAT (2F5.2)
9 FORMAT (2A5)
25 FORMAT (1H1, 10X, 70H ANGO (MILS), D(LBS/FT3), PRES (IN), TEMP (F)
A XM (GRAINS) V1(FT/SEC) )
27 FORMAT( 25H WIND VELOCITY (M/SEC) = , F7.4, 12H PRESSURE = ,F7.4,
219H TEMPERATURE(F) = , F7.4)
44 FORMAT(10X, 10H Y(METERS), 9X,11H X(METERS), 13X, 7H T(SEC), 6X, 1
24H V(METERS/SEC), 16X, 4H CD , 9X, 11H Z(METERS) )
45 FORMAT(1X,3F20.8)
46 FORMAT(1X,10H ALTITUDE ,10X, 9H DENSITY , 11X, 13H TEMPERATURE ,7
2X)
55 FORMAT( 5F20.8)
56 FORMAT(5F16.8)
57 FORMAT(100X,3F10.4)
58 FORMAT(1X,6F20.8)
60 FORMAT(11H DENSITY = ,F7.6, 8H TEMP = ,F10.4,10H HEIGHT = ,F10.4)
61 FORMAT (1H1)
62 FORMAT(5F10.5)
69 FORMAT( 15X, 4E15.8)
75 FORMAT( 14H FORCE (NTS) =,E16.6, 15H YDOT (M/SEC) =,E16.6, 16H VEL
2 (M/SEC) = ,E16.6)
80 FORMAT(14H VEL(M/SEC) = , 14X , 7H CD = , 20X)
81 FORMAT(17,4F15.8)
102 FORMAT (15F5.0)
103 FORMAT (1H1, 61A1)
106 FORMAT(F7.2)
202 FORMAT(2F20.4)
203 FORMAT(F6.2)
204 FORMAT(F6.3,F8.5)
205 FORMAT(3F7.4)
42R FORMAT (18H PLANE VELOCITY =, F6.0,34H FT/ SEC AT AN ANGLE OF DESC
1ENT OF , F6.4, 9H RADIANS.)
52R FORMAT(46H INPUT IS REL PROJ VEL IN FT/SEC,DRAG COEF KD.)
1000 FORMAT (3A1)
1010 FORMAT( 11H WT OF PROJ,F14.8, 11H NOSE SHAPE,A5)
1011 FORMAT(13H MUZZLE VEL= , E14.7, 8H FT/SEC )
1012 FORMAT(1X,6A4)
1013 FORMAT(1X,E14.8,19H WT. OF PROJECTILE )
C***** DATA INPUT *****
C 1 PRESSURE,TEMPERATURE (2F7.4)
C 2 SHAPE (6A4)
C***** 3 VV(J) (FT/SEC),CC(J) (KD) F6.3,F8.5)
C 4 DVV(INCREMENTS/VELOCITY) (F7.2)
C 5 Y(1)(ALTITUDE) (F7.2)
C 6 G(GRAVITY-METERS PER SECONDS SQUARED ,A(CROSSSECTIONAL AREA)
C .XM(MASS-GRAINS), ANGO(ANGLE OF DESCENT OR ASCENT,V1(MUZZLE
C 7 WIND VELOCITY (F7.4)
C 8 AIRCRAFT VELOCITY (F6.2)
C 9 ALTITUDE ** FOR SAME AIRCRAFT VELOCITIES CAN RUN AT VARIOUS ALTI-
C TUDES, TO CHANGE AIRCRAFT VELOCITY PUT -10. FOLLOW
C WITH ALTITUDE AND THEN AIRCRAFT VELOCITY WILL RETURN
C ASKING FOR ALTITUDE AGAIN **
C 10 -10. PLACED FOR LAST AIRCRAFT VELOCITY, -10. PLACED FOR LAST G
C N=NUMBER OF TIME INTERVALS

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C DT=TIME INCREMENTS (SEC)
C VELDY=DECREASE IN VELOCITY DUE TO DRAG/DRAG VEL IN Y DIRECTION (M/SEC)
C AV=AVERAGE DECELERATION (VEL) DUE TO DRAG (M/SEC)
C*****          ATMSI = F0010
C          ATMSI(YH=ALTITUDE(FEET),TEMP(RANKINE),PRES (SLUG/FT**2,
C DENSITY= SLUG/FT**3)
C A= CROSS-SECTIONAL AREA FOR 20MM (EITHER .515 OR PI*R*R)
C C=CONSTANT
C ANG= ANGLE OF TRAJECTORY , YDOT= Y VELOCITY ,DX=CHANGE IN X DISTANCE
C X(I)=X DISTANCE , AV = AVERAGE VELOCITY , Y(I)= Y DISTANCE
C VEL= FT/SEC ,KD DRAG CURVE
C 7 IS WIND VELOCITY EFFECT ON PROJECTILE
C** TEMPERATURE IN F
C** PRESSURE CM OF MERCURY
C*** W= WIND VELOCITY IN METERS PER SECOND
C** IF VELOCITY(FPS) AND KD CURVE
C** VV(J)=VV(J)/3.2809
C** 201 CC(J)=CC(J)*8./3.14159
C** IF INPUT VELOCITY(MACH) AND CD CURVE
C* SPSO=SQRT((459.67 + TEMP)/518.67)*340.294
C** VV(J)=VV(J)*SPSO
C** 201 CONTINUE
      IN=I
      IO=3
2 CONTINUE
      READ(IN,206)P,TEMP
      READ(IN,5)SHAPE
      SPSO=SQRT((459.67 + TEMP)/518.67)*340.294
      DO 201 J=1,200
      READ(IN,204)VV(J),CC(J)
      IF(VV(J).LE.-9.)GOTO22H
      IF(VV(J).GE.10000.)GOTO40
      VV(J)=VV(J)*SPSO
201 CONTINUE
22H M=J-I
      DV=VV(J)
      N=VV(I)/10.
      K=I
      DO20 J=2,N
      DV=DV-I0.
      CALL INTERP(CC,CD(J),DV,VV,K)
      V(J)=DV
20 CONTINUE
      V(I)=VV(I)
      CD(I)=CC(I)
      WRITE(I,25)
      KKK=0
      DO 1001 J=1,N
      VV(J)=V(J)
      CC(J)=CD(J)
1001 CONTINUE
      READ(IN,106)DVV
21 CONTINUE
      READ(IN,106) Y(I)
      IF(Y(I).LE.-10.)GOTO17
      GOTO18
17 CONTINUE
      READ(IN,106) Y(I)
      READ(IN,203) VPLANE
      IF(VPLANE.LE.-10.)GOTO19
18 CONTINUE
      IF(KKK.GE.1)GOTO24
19 READ(IN,68)G,A,XM,ANG0,VI
      IF(G.LE.-10.)GOTO2
      READ(IN,206)W
      WRITE(I0,27)W,P,TEMP

```



```

WRITE(10,1012)SHAPE
WRITE(10,1013)XM
VMU2 = V1
XM = XM/7000.
ANG0 = ANG0 * .001
WRITE(10,1011)V1
2A READ(1N,203)VPLANE
24 CONTINUE
WRITE(10,428)VPLANE, ANG0
VI=VMU2
V1=(V1 + VPLANE)/3.2808
CALLGROUP(V1,VV,N,1)
K=N-1+1
DO 32M J = 1,K
L=1+J-1
CD(J)=CC(L)
32A V(J)=VV(L)
28 VELDY = 0.
V(1) = V1
T(1) = 0.
X(1)=0.
ANG = ANG0
K1=V(1)/10.
DV1=DVV/10.
IDV=IDV1
K=1
C2=1.64*A/144./XM
VD1=0.
DV=DVV
ZD1=0.
ZZ(1)=0.
Z=0.
DD131=2.*I
X1=1-1
K=K+IDV
KK=K-IDV
30 YH=3.281*Y(1-1)
IF(YH.LE.0.)GOTO31
CALLF001D(YH,TEMP,PMES,D,VIS,VELA,0)
GOTO32
31 D=.00237
32 D=.32.1739*D
TEMP=TEMP - 459.69
C=C2*D
VBAR=(V(1) + V(1-1))*5
ANG1=ANG
ANG=ANG-.0005
IF(ANG.LT.-1.5)GOTO40
221 CONTINUE
DT=2.*(1./(V(1)-X1*DV)-1./(V(1)-(X1-1.1*DV)))/C/(CD(1)+CD(1-1))
DT= DT + 2./C/(CD(1) + CD(1-1)*ALOG(COS(ANG1)/COS(ANG)))/VBAR
AV=.5*(CD(1)*(V(1) - X1*DV)**2*SIN(ANG) + CD(1-1)*(V(1) - (X
21-1.0)*DV)**2*SIN(ANG1))
T(1)=T(1-1) + DT
VELDY= VDI + C*AV*DT/2.
ANG2=ANG
YDOT= -VELDY -G*T(1) + V(1)*SIN(ANG0) - C*AV*DT/2.
ANG=ATAN(YDOT/(V(1)-X1*DV)/COS(ANG))
IF(ABS(ANG2 - ANG) .LE. .001*ABS(ANG))GOTO224
GOTO221
224 VDI= VELDY + C*AV*DT/2.
222 CONTINUE
DX= 2.*(V(1) -(X1 - 1.1*DV)*COS(ANG1) - (V(1) - X1*DV)*COS(ANG))/
2C/((CD(1)*(V(1) - X1*DV) + (CD(1-1)*(V(1) - (X1-1.1)*DV)))
X(1)=DX + X(1-1)
Y(1)=Y(1-1) - .5*(G*(T(1) + T(1-1))*DT - VELDY*DT +DT*V(1)*SIN(A

```

```

2NG0)
CBAR= C*(CO(1)*(V(1)-X1*DV) + CD(1-1)*(V(1) - (X1-1.)*DV))*2.25
ZD= W*(ZD1 - W)*EXP(-CBAR*DT)
Z= Z + W*DT + (ZD1 - W)/CBAR*(1.-EXP(-CBAR*DT))
ZD1=ZD
ZZ(1)=Z
ANGA(1)=ANG
CO(1)=C
VELDA(1)=VELDY
IF(Y(1))11.12.12
12 IF(V(1).LE.0.)GOTO11
IF(1.6E.200)GOTO11
13 CONTINUE
11 WRITE(10.44)
I=I-1
DO10J=1.1
WRITE(10.54) Y(J),X(J),T(J),V(J),CD(J),ZZ(J)
10 CONTINUE
KKK=KKK*.)
GOTO21
40 STOP
END
SUBROUTINE F0010 (H,T,P,R,VK,VS,10PT)
C F0010 WAS PREVIOUSLY ATMS1
DIMENSION HH(12),W1(11),W2(11),W3(11),TB(11),PB(11),RB(11)
DIMENSION A(3),B(3),C(3),D(3)
350 FORMAT(51H0112547537990105160170200700-225569-525612000157689./
162H138466113883000120869-159202-759218000206234241458854120886289./
260H170424075434134164803507156832960222129976137005186882116217./
357H2376923899H847273070623899805197977655087880002515528804./
426H50878800012181139468298188./
561H2108411892981882180942614061881556222322386188757818452566188./
660H589541338283618829759611330486356766490205762269881987291000./
734H7595111741642200254357872739661814)
351 FORMAT(F1.0,-3P6F2.0,5F3.0, 10PF7.0, 5PF7.0,0P3F1.0, 9PF6.0./
1 10PF6.0, 4PF6.0,0P3F1.0, 9PF6.0, 10PF7.0, 5PF7.0,0P3F1.0, 9PF6.0
2 , 10PF6.0, 4PF5.0,0PF1.0, 10PF6.0, 5PF6.0,0PF1.0, 11PF6.0, 5PF6.0
3 ,0PF1.0, 11PF6.0, 5PF6.0,0PF1.0, 11PF6.0, 5PF6.0,0PF1.0,3P2F7.0./
4 8PF6.0,3P2F6.0,7PF4.0,3P2F6.0,8PF4.0,4P2F7.0,10PF5.0,
5 4P2F7.0,11PF6.0,3PF6.0,5PF4.0,12PF5.0,
6 3PF6.0,7PF5.0,12PF4.0,3PF6.0,8PF5.0,13PF4.0,3PF7.0,9PF4.0,15PF4.0
7 ,3PF7.0,10PF5.0,15PF4.0,3PF7.0,10PF5.0,16PF4.0,4PF4.0,0PF7.0,
8 6PF8.0,13PF6.0,2PF5.0,-4PF1.0,0P4F1.0,/6P2F6.0,-3P2F3.0,6P2F6.0,
9 -4P2F2.0)
352 FORMAT (1X,F3.2,11F10.0,/22(1X,3E20.10/),F8.4,F10.0,F10.6,E20.8,
1 F8.2,F10.0,/1X,4(F5.2)/1X,2F10.6,2F10.0,/1X,2F10.6,5X,2F10.0)
2001 FORMAT(1X,5HALT= ,E9.4,12H BELOW LIMIT)
IF(1TAPE.EQ.4)GO TO 5
1TAPE=4
REWIND 1TAPE
WRITE(1TAPE,350)
REWIND 1TAPE
READ (1TAPE,351) (HB(1),I=1,12),(W1(1),W2(1),W3(1),I=1,11),(TB(1),
1 PH(1),RB(1),I=1,11),CON1,CON2,CON3,CON4,CON5,CON6,(A(1),B(1),C(1)
2 ,D(1),I=1,3)
5 CONTINUE
HGP=CON1*H/(1.+(CON1*H/CON2))
IF(HGP.LT.0.) HGP=0.
DO 1002 M=1,11
IF(HGP-HB(M))1003,1004,1002
1002 CONTINUE
IF ((HGP-HB(12)).GT.0.) GO TO 1052
M=12
1003 M=M-1
1004 TH=T8(M)*(1.+W1(M)*(HGP-HB(M)))
IF ((HGP-90000.).GT.0.) GO TO 1006

```

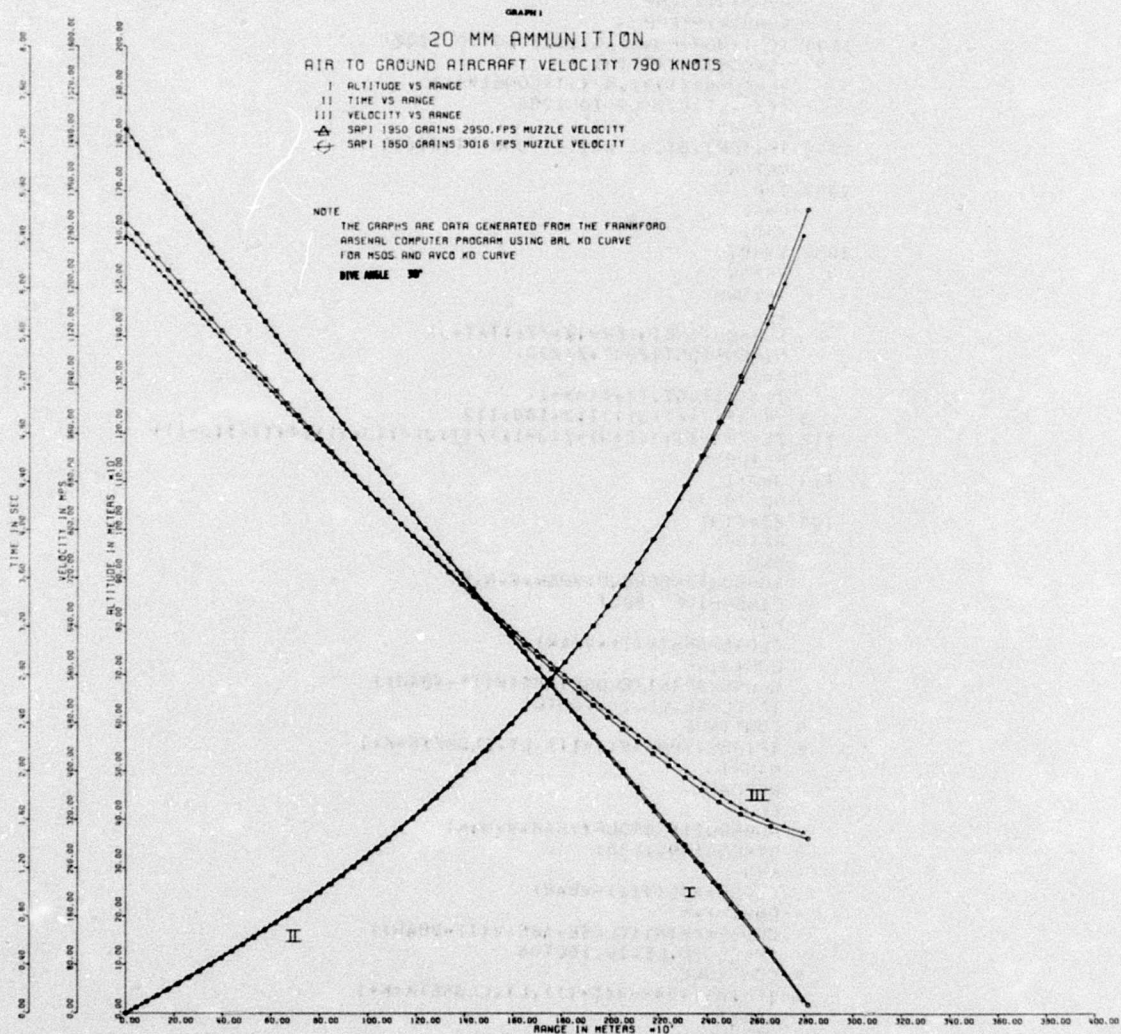
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      T=TM
      GO TO 1070
1006 IF ((HGP-180000.).GT.0.) GO TO 1009
      I=2
      GO TO 1007
1009 I=3
1007 T=TM*(A(1)-B(1)*ATAN((HGP-C(I))/D(I)))
1070 IF (W2(M))1011,1020,1011
1011 TEMP=1.+W1(M)*(HGP-HB(M))
      P=PH(M)/TEMP**W2(M)
      R=RB(M)/TEMP**(1.+W2(M))
      GO TO 1030
1020 TEMP=EXP(-W3(M)*(HGP-HB(M)))
      P=PH(M)*TEMP
      R=RB(M)*TEMP
1030 IF ((HGP-CON6).GT.0.) GO TO 1032
      VS=CON3*SQRT(TM)
      VK=CON4*(T**1.5/((T+CON5)*R))
      IF (H.LT.0.) GO TO 1050
      RETURN
1050 IF (10PT.GT.0) WRITE (JOUTPT,2001) H
      RETURN
1052 T=0.
      P=0.
      R=0.
1032 VS=0.
      VK=0.
      RETURN
      END
      SUBROUTINEINTERR(Z,ZZ,TT,T,J)
      DIMENSIONT(200),Z(200)
      A=1.
      IF (T(1).GT.T(2))A=-1.
      3 IF (A*(TT-T(J)))112,100,113
112 ZZ=Z(J-1)+((Z(J)-Z(J-1))/(T(J)-T(J-1)))*(TT-T(J-1))
      RETURN
113 J=J+1
      GO TO 3
100 ZZ=Z(J)
      RETURN
      END
      SUBROUTINEGROUP(VBAR,V,N,K)
      DIMENSIONV(200)
      K=0
      CLOSE=ABS(V(1)-VBAR)
      DO51=1,N
      CLOSE=AMIN1(CLOSE,ABS(V(1)-VBAR))
      IF (CLOSE.LE.10.)GOTO6
      5 CONTINUE
      6 IF (ABS(VBAR-V(I+1)).LT.CLOSE)K=K+1
      K=K+1
      RETURN
      END
      SUBROUTINEGROUP(VBAR,V,N,K)
      DIMENSIONV(200)
      K=0
      CLOSE=ABS(V(1)-VBAR)
      DO51=1,N
      CLOSE=AMIN1(CLOSE,ABS(V(I)-VBAR))
      IF (CLOSE.LE.10.)GOTO6
      5 CONTINUE
      6 IF (ABS(VBAR-V(I+1)).LT.CLOSE)K=K+1
      K=K+1
      RETURN
      END

```


APPENDIX C

Graphs 1 to 140: 20MM and Caliber 50 Trajectories



GRAPH I

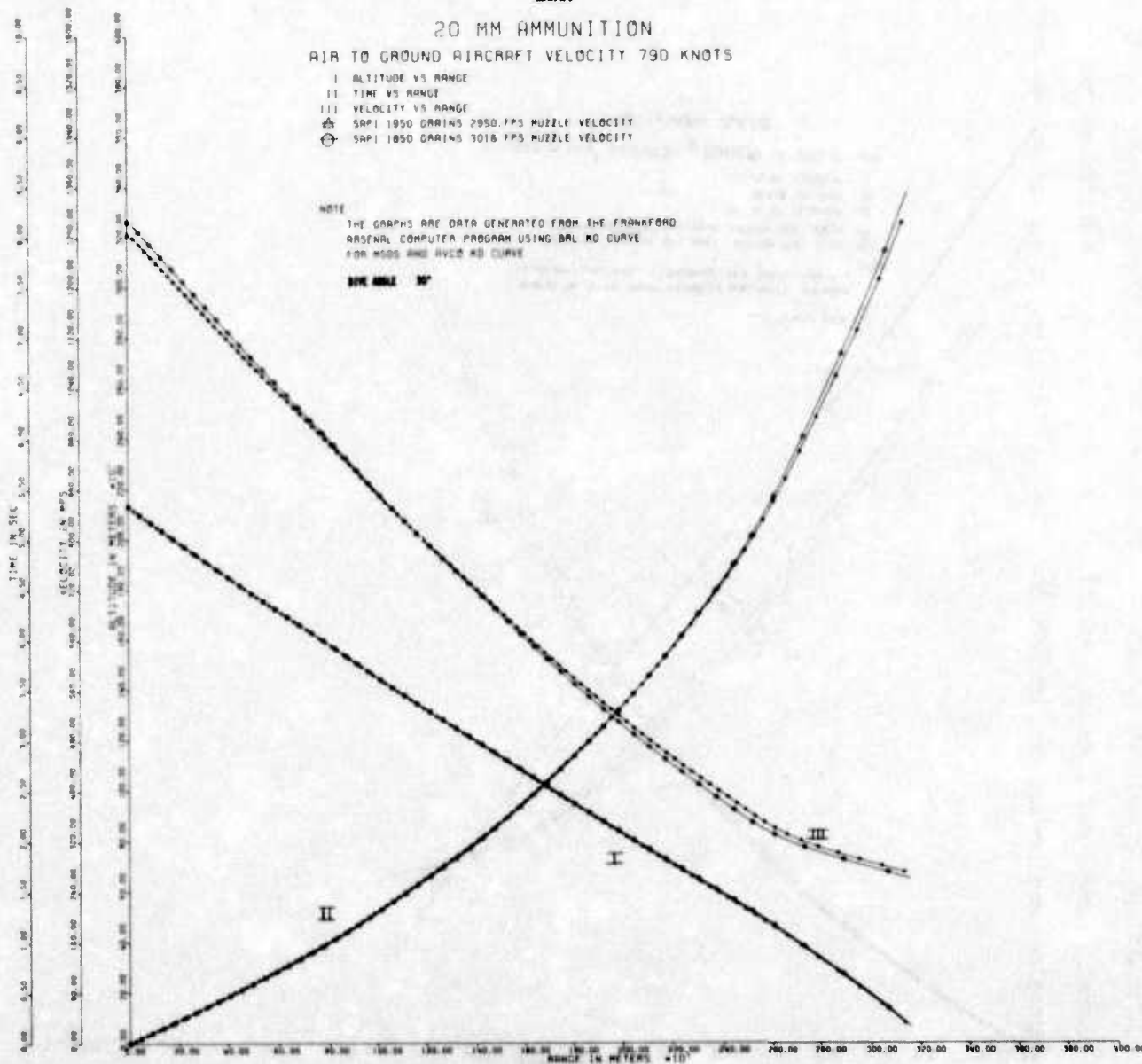
20 MM AMMUNITION

AIR TO GROUND AIRCRAFT VELOCITY 790 KNOTS

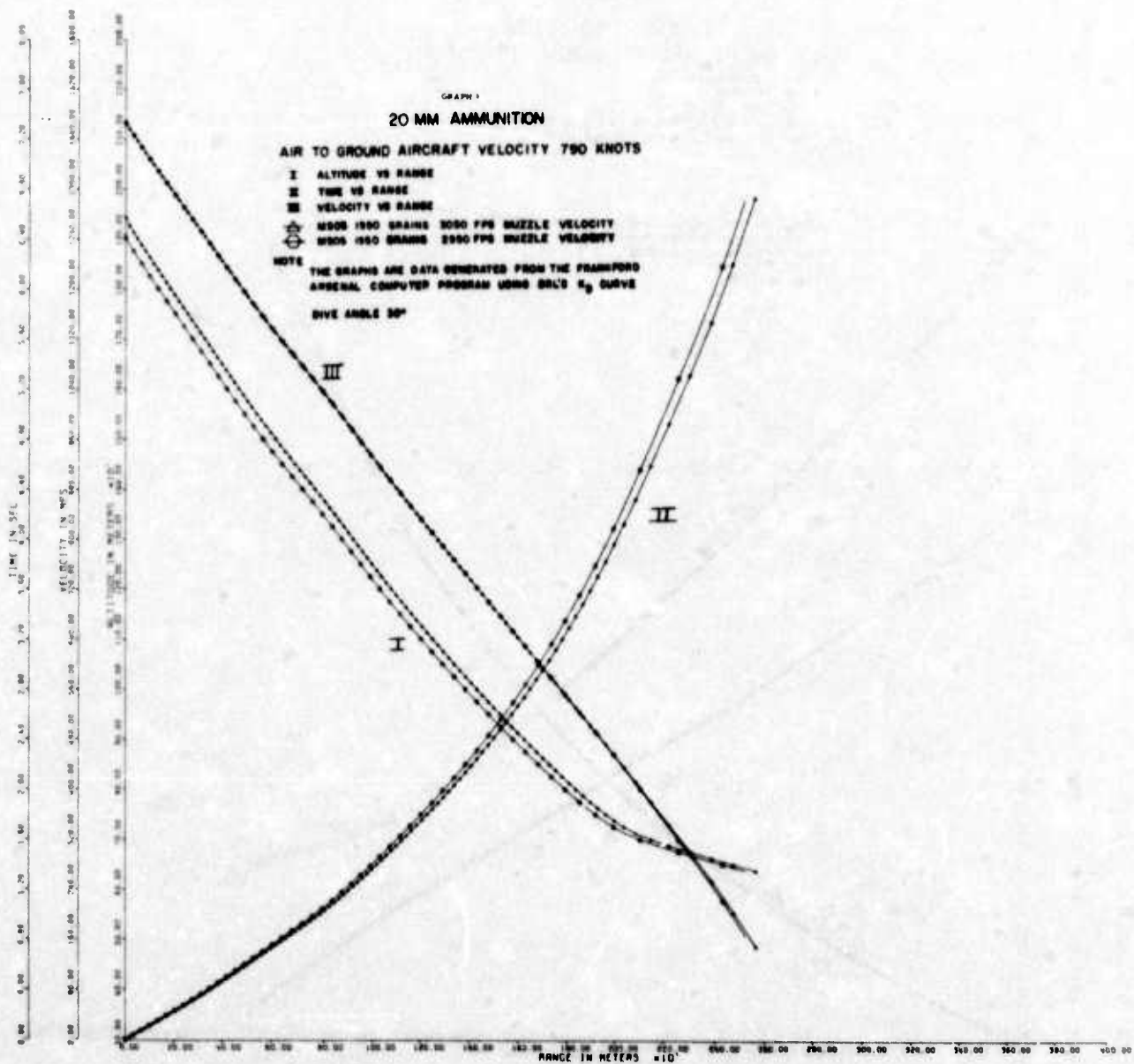
- I ALTITUDE VS RANGE
- II TIME VS RANGE
- III VELOCITY VS RANGE
- △ SRPI 1950 GRAINS 2950 FPS MUZZLE VELOCITY
- ⊙ SRPI 1850 GRAINS 3016 FPS MUZZLE VELOCITY

NOTE
THE GRAPHS ARE DATA GENERATED FROM THE FRANKFORD
ARSENAL COMPUTER PROGRAM USING BAL NO CURVE
FOR M50S AND M50S NO CURVE

ONE INCH 10"



**COPY AVAILABLE TO DDC DOES NOT
PERMIT FULLY LEGIBLE PRODUCTION**



GRAPH 1

20 MM AMMUNITION

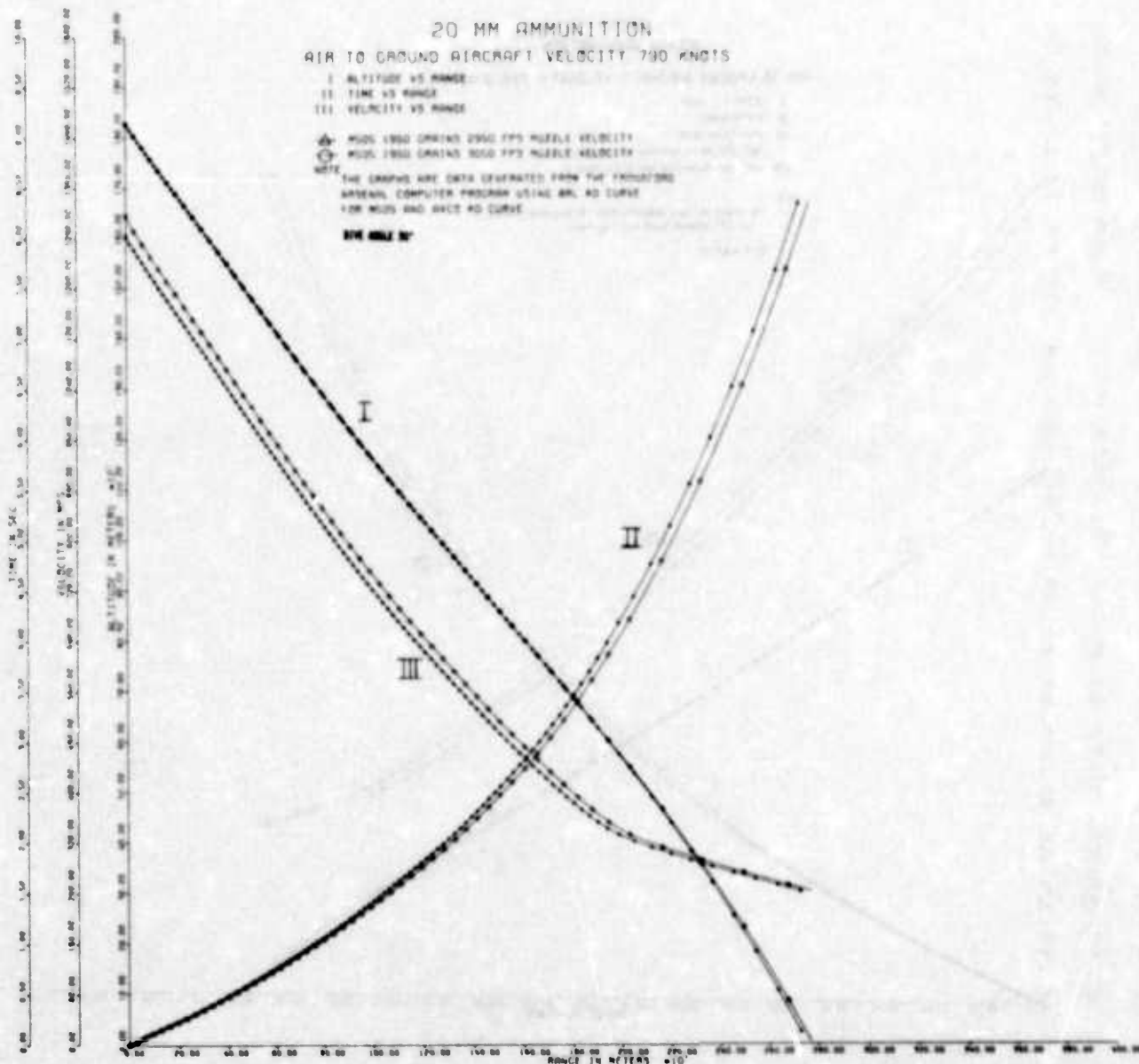
AIR TO GROUND AIRCRAFT VELOCITY 790 KNOTS

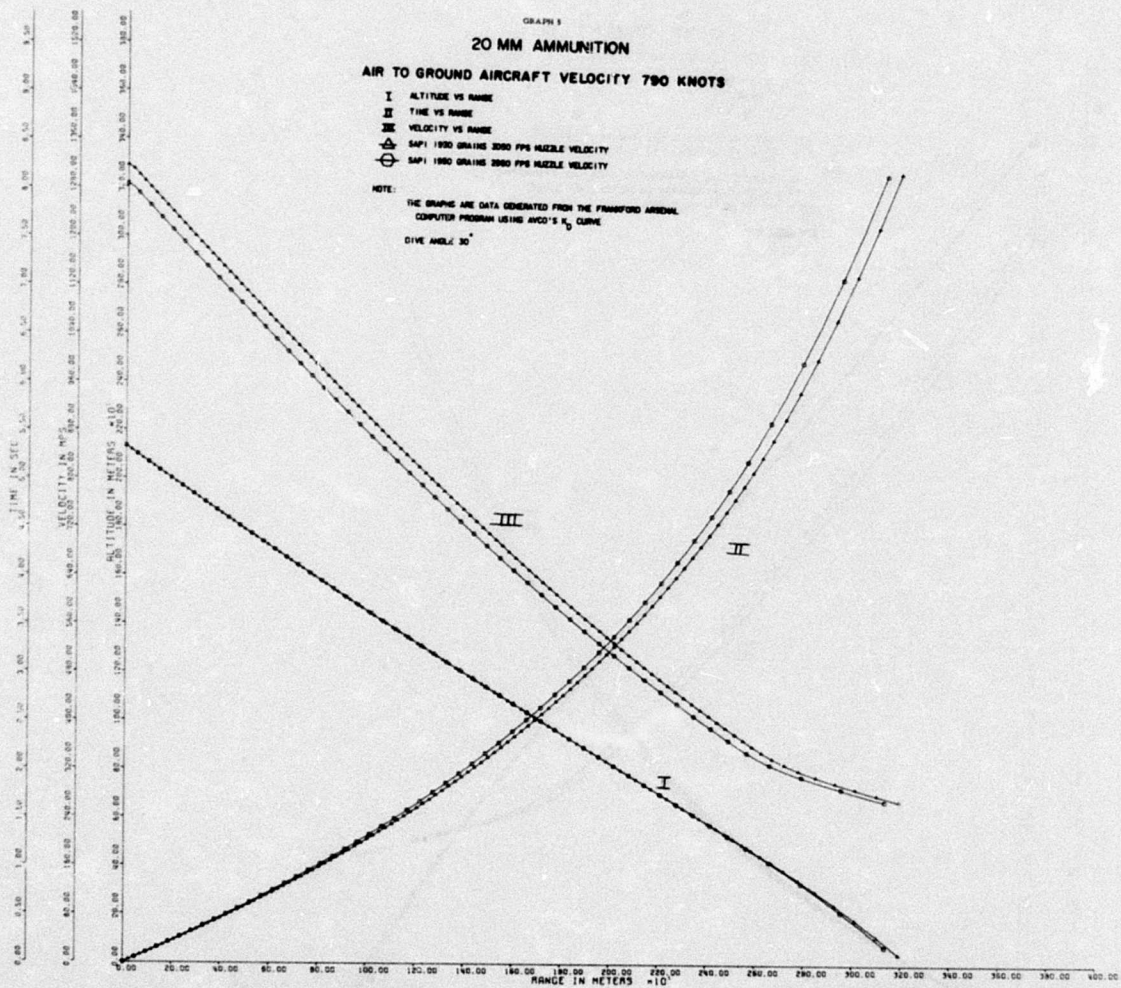
- I. ALTITUDE VS RANGE
- II. TIME VS RANGE
- III. VELOCITY VS RANGE

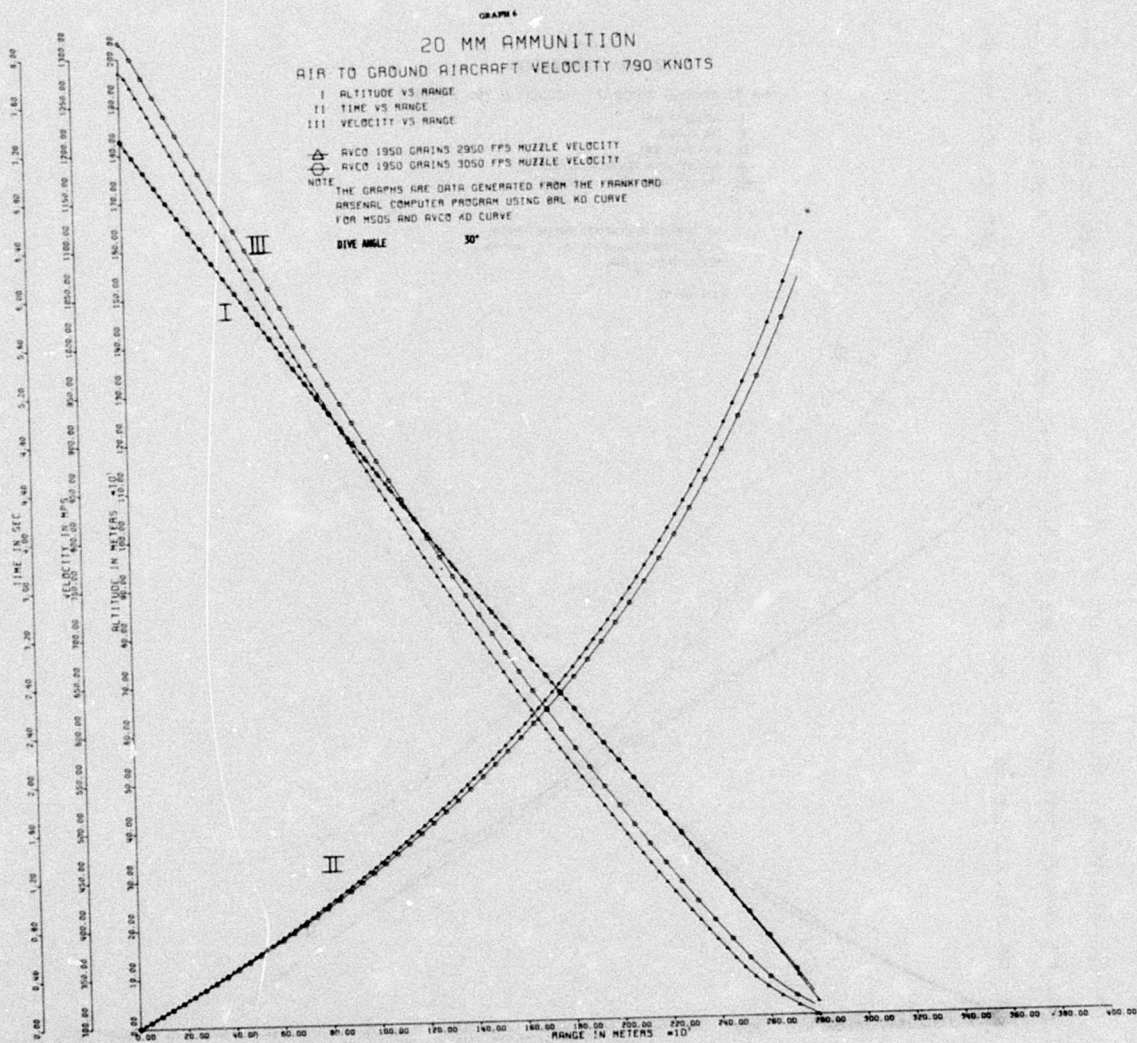
- MUSE 1800 GRAINS 2950 FPS MUZZLE VELOCITY
- MUSE 1800 GRAINS 3050 FPS MUZZLE VELOCITY

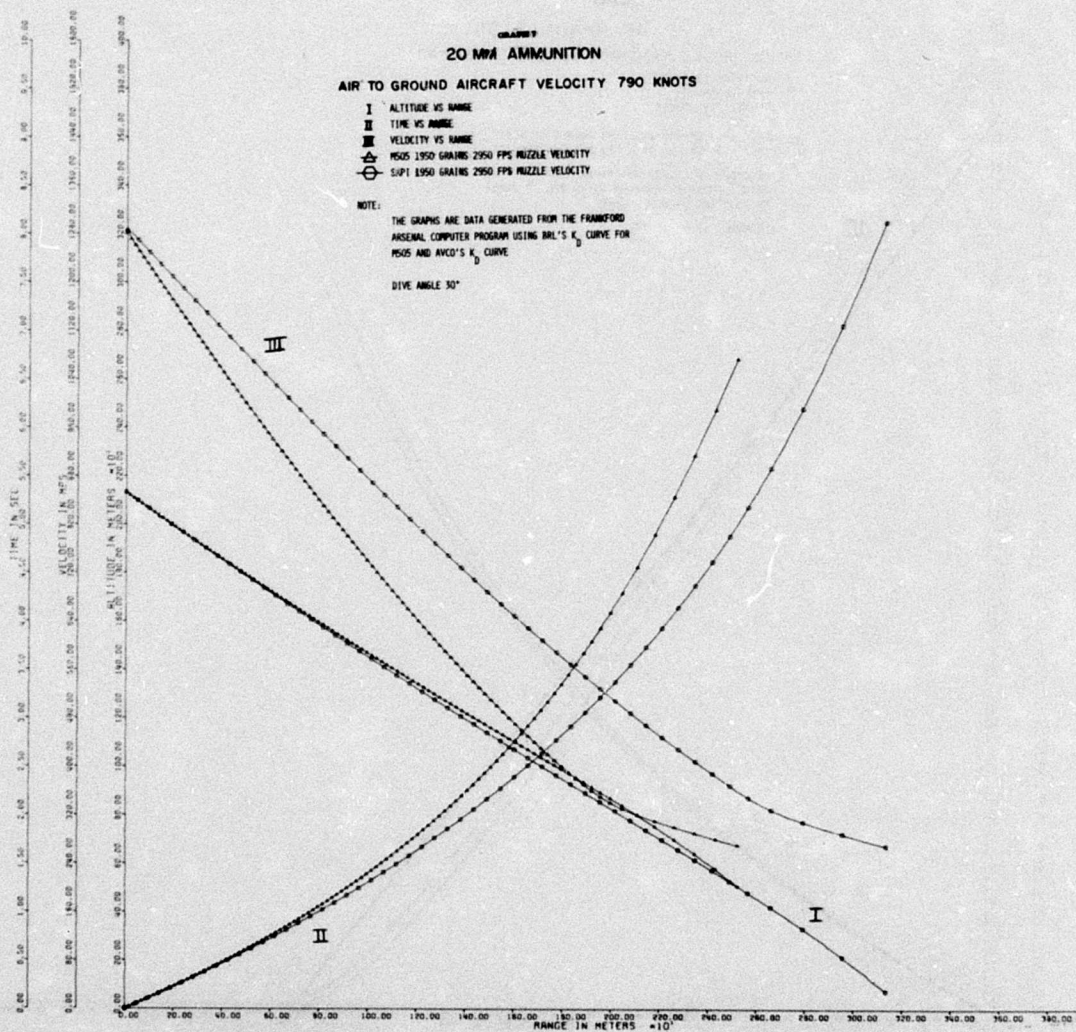
NOTE: THE GRAPHS ARE DATA GENERATED FROM THE PROBABILISTIC
ARTS/COMPUTER PROGRAM USING ARL AD CURVE
FOR MUSE AND ARLC AD CURVE

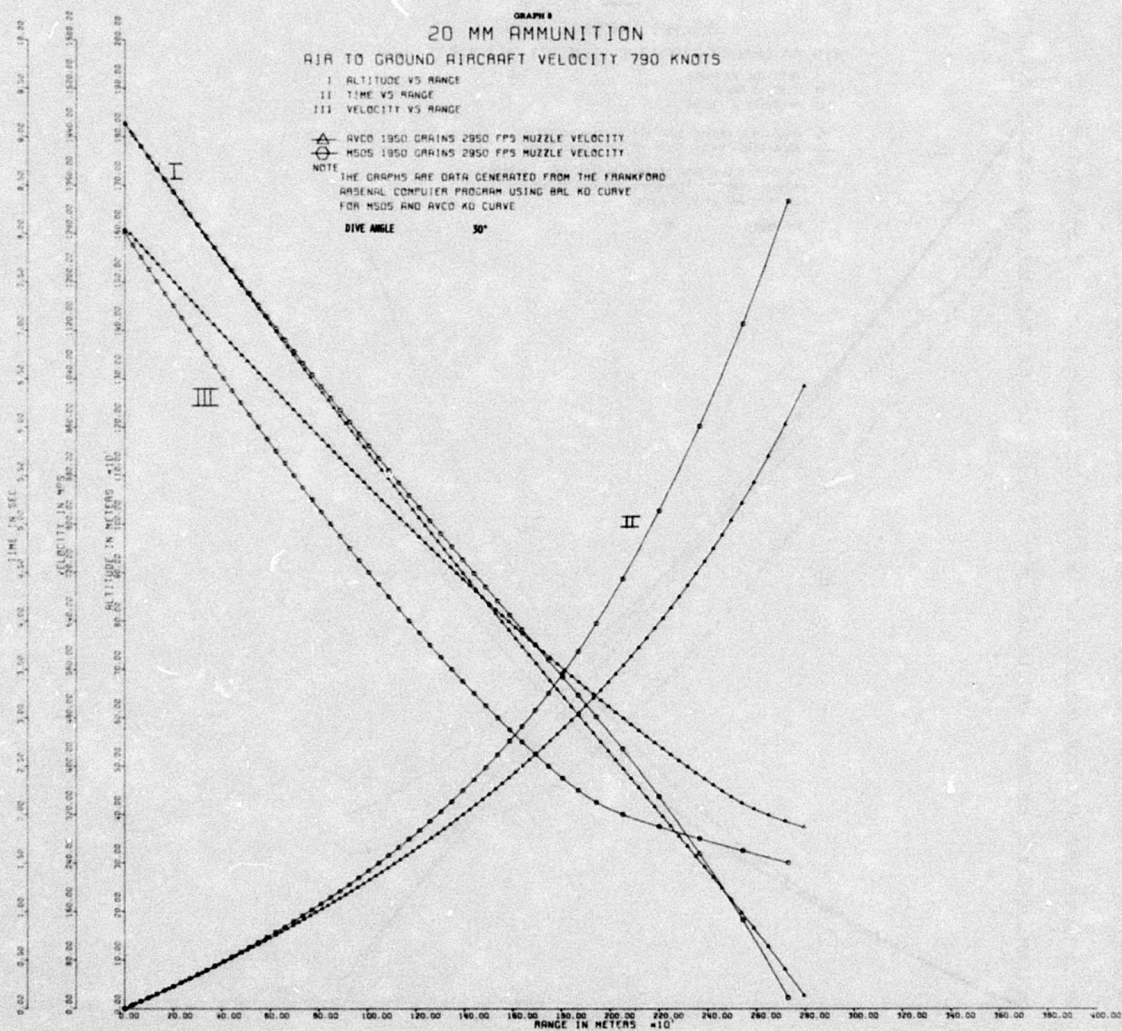
SEE NOTE 2

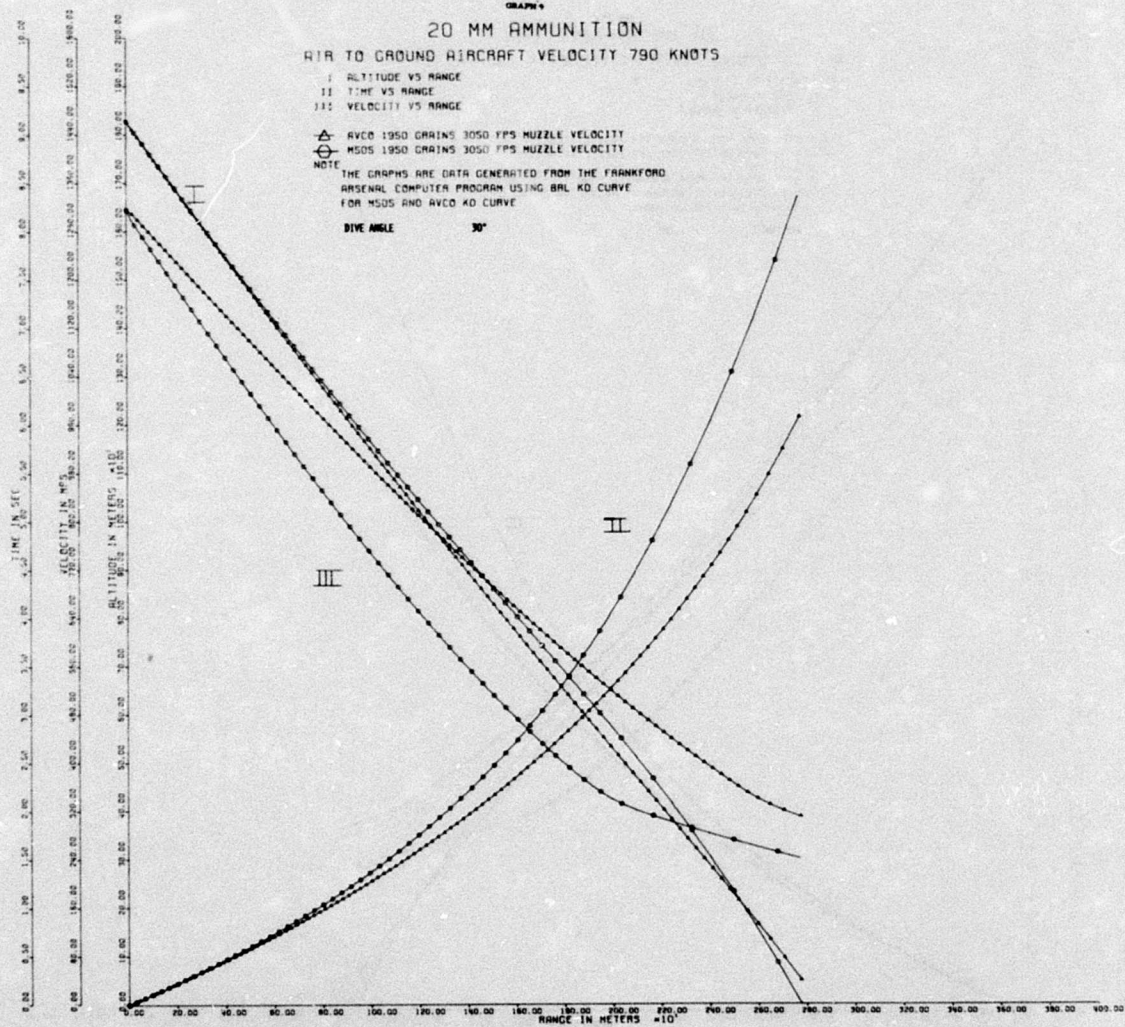


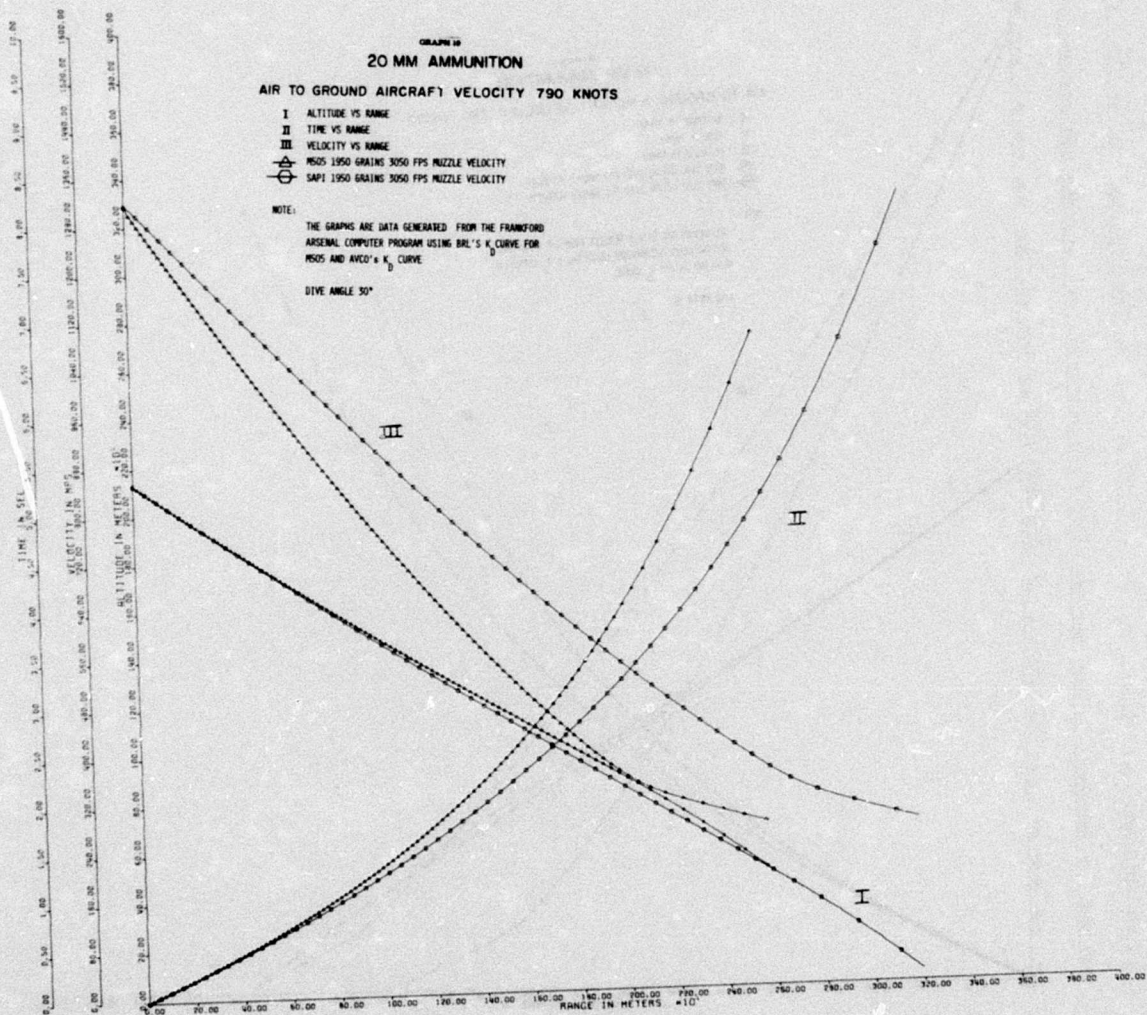


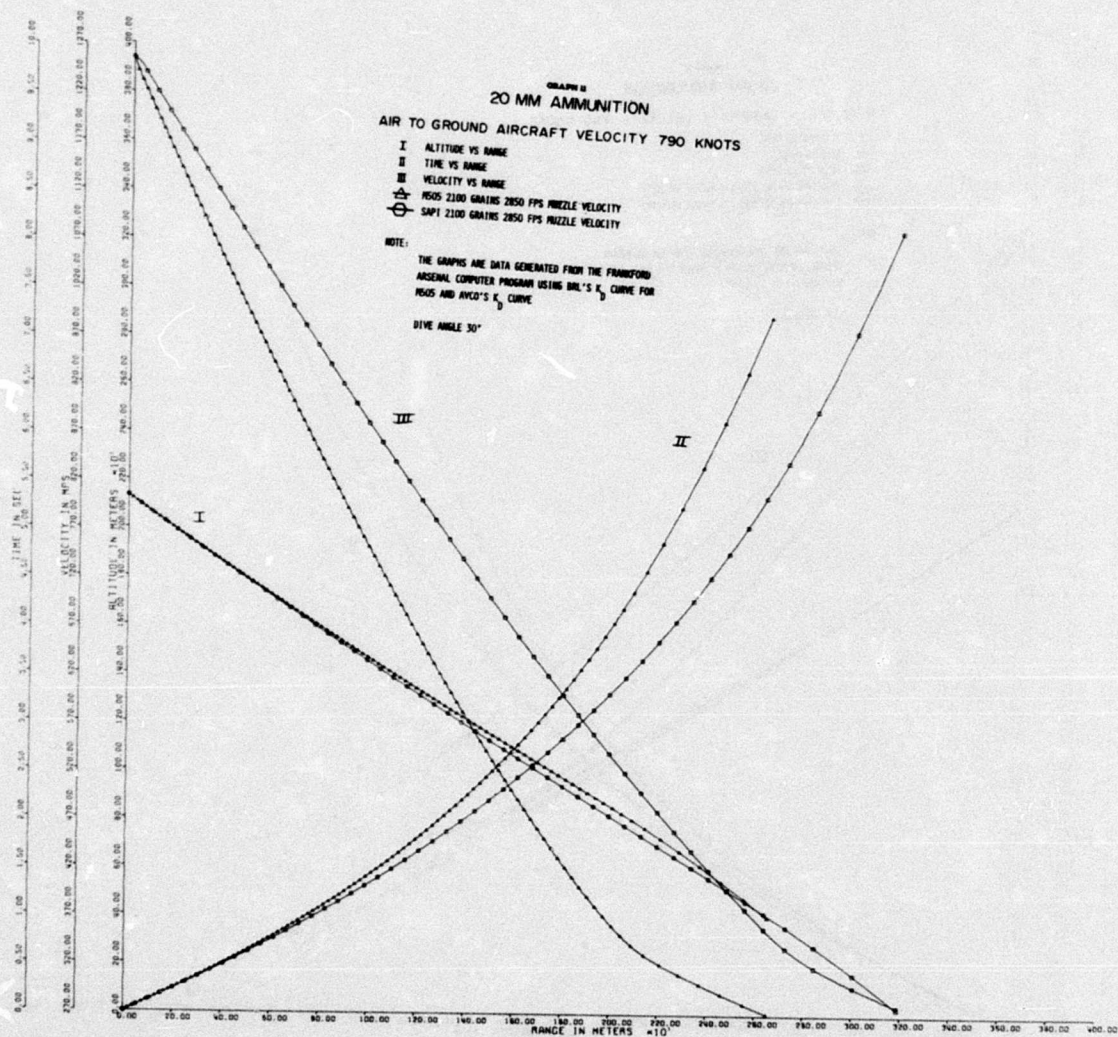


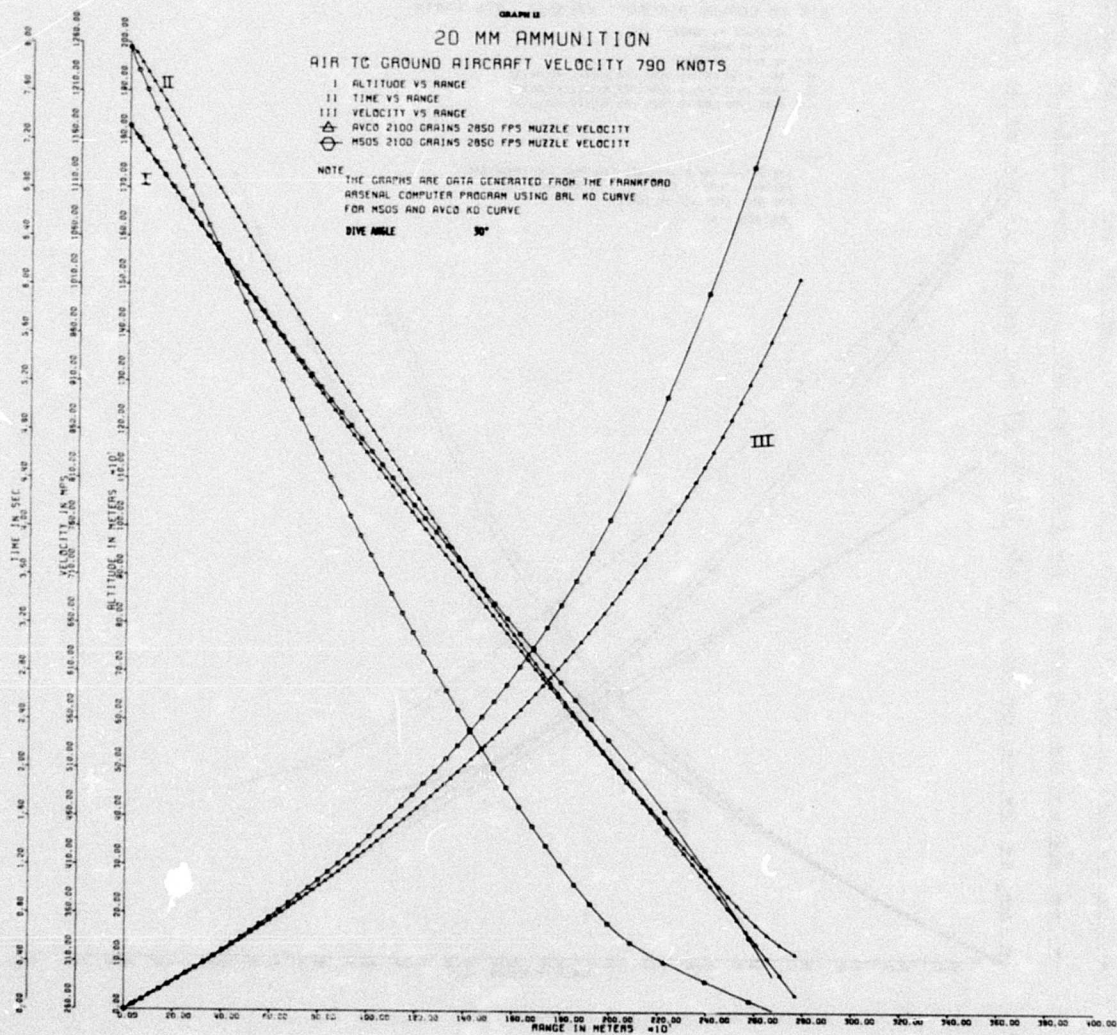


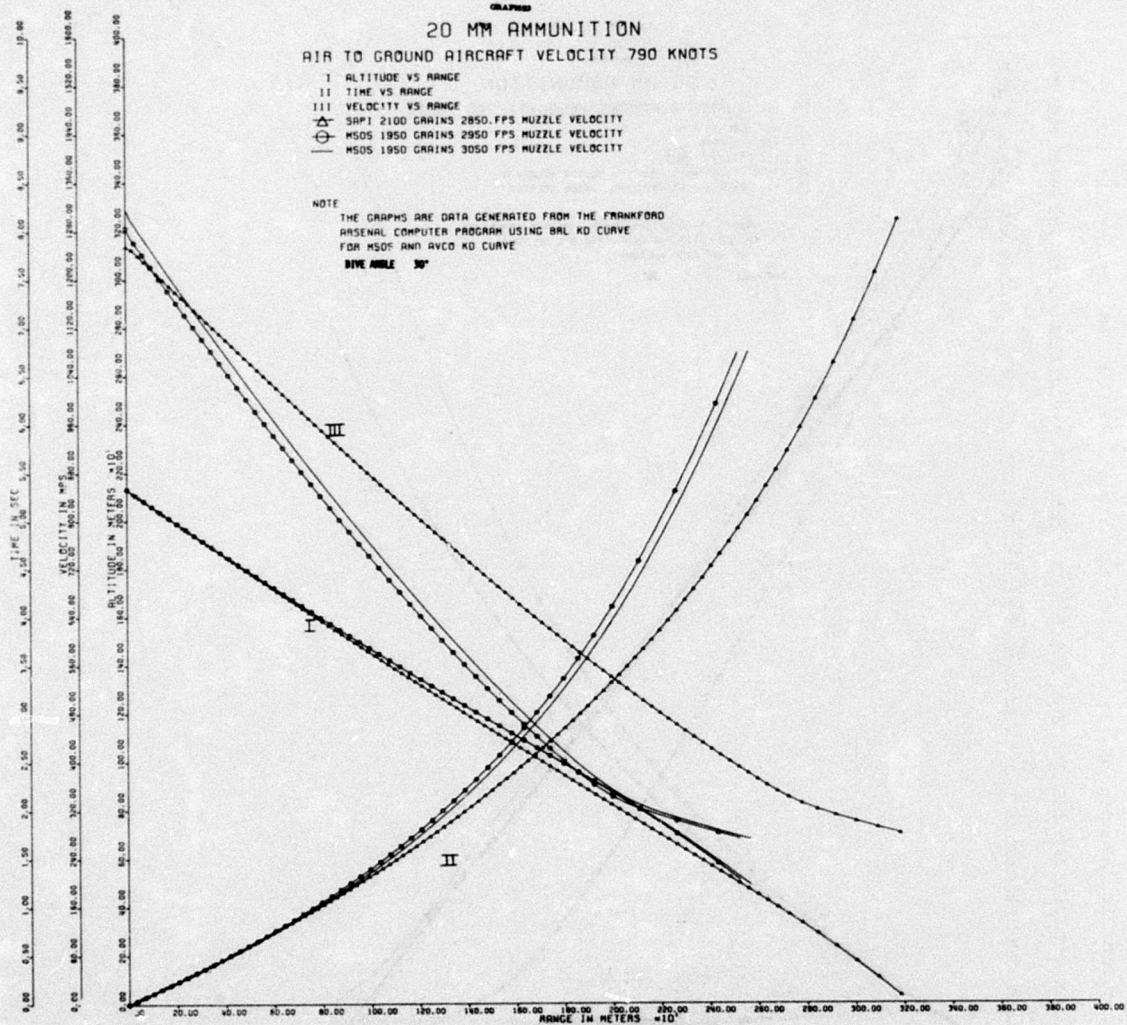






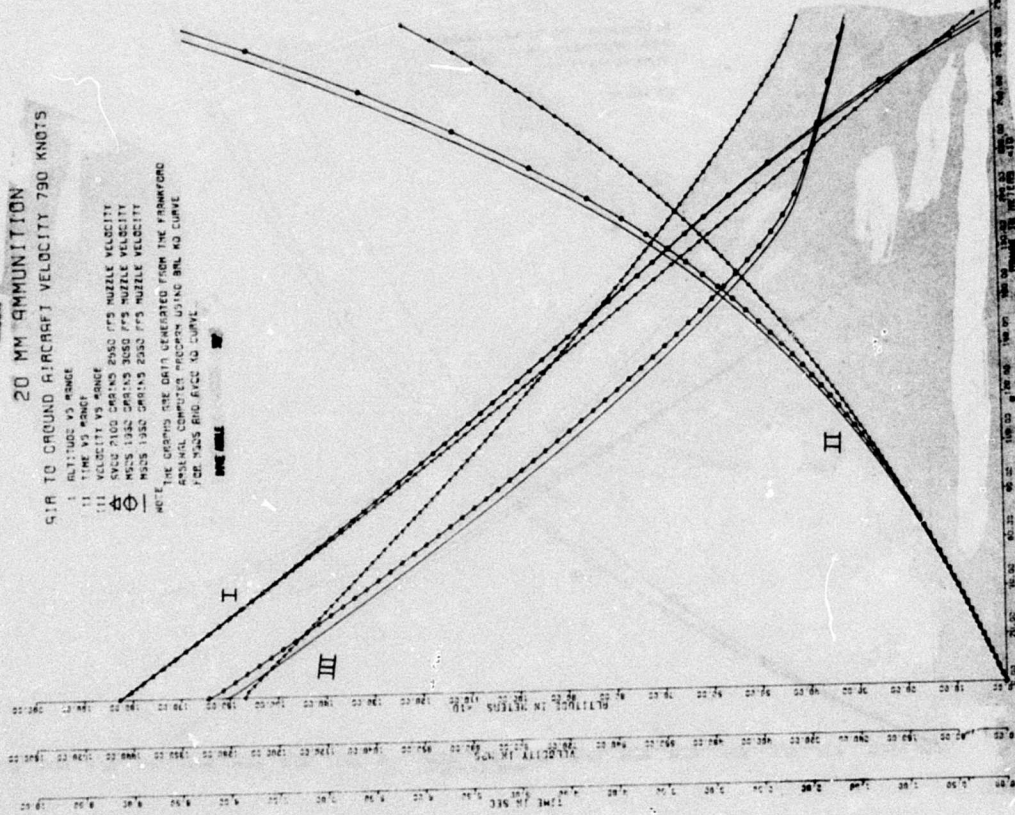


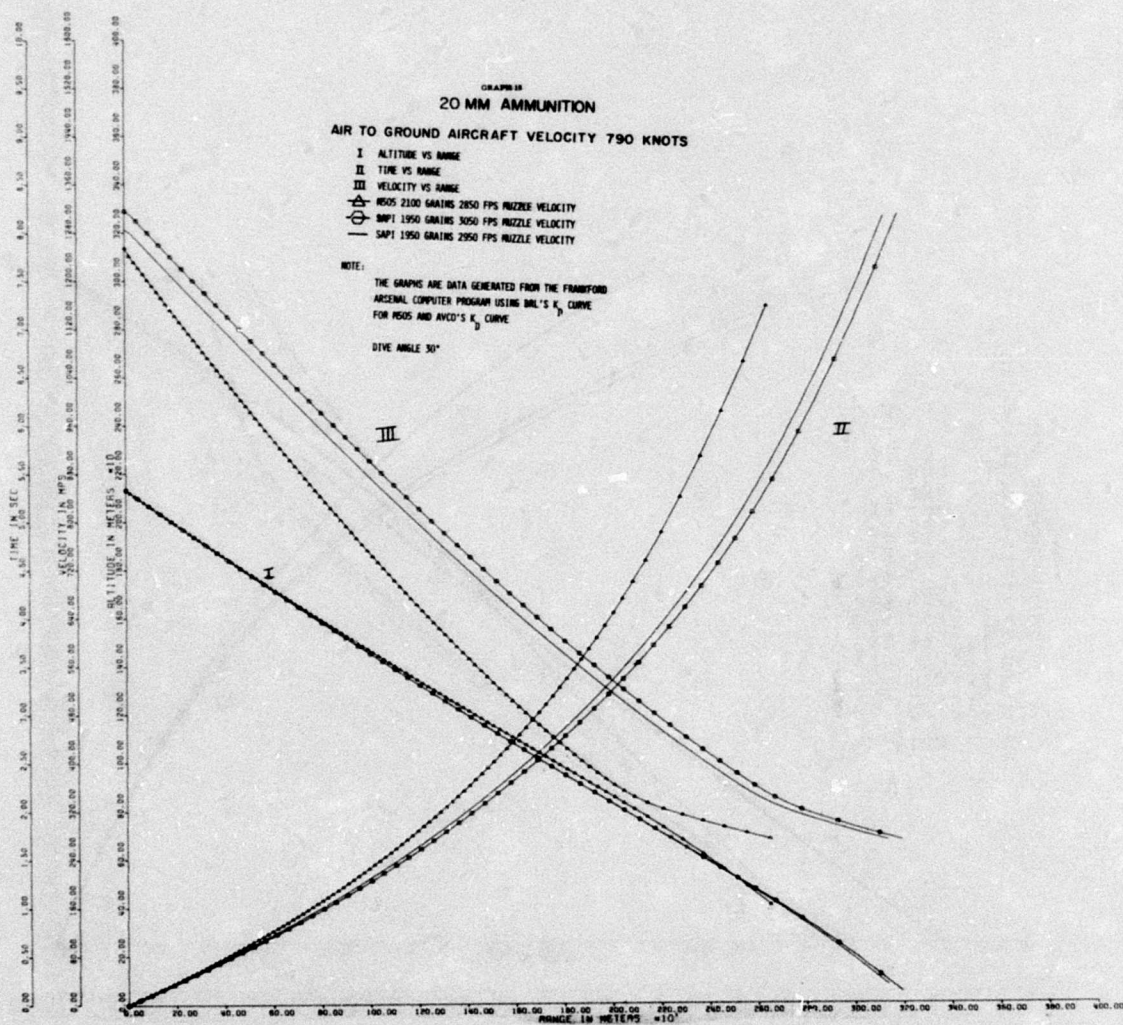


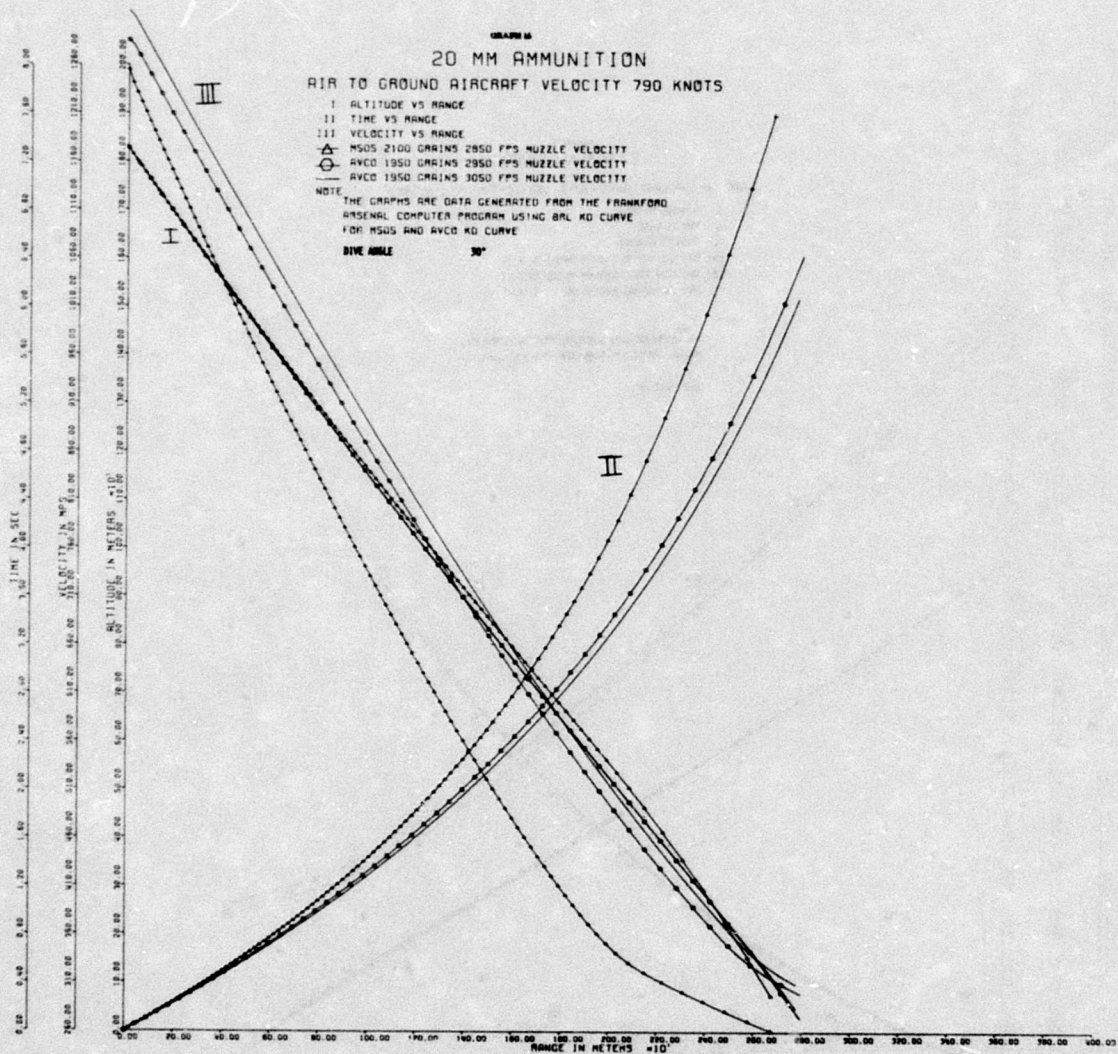


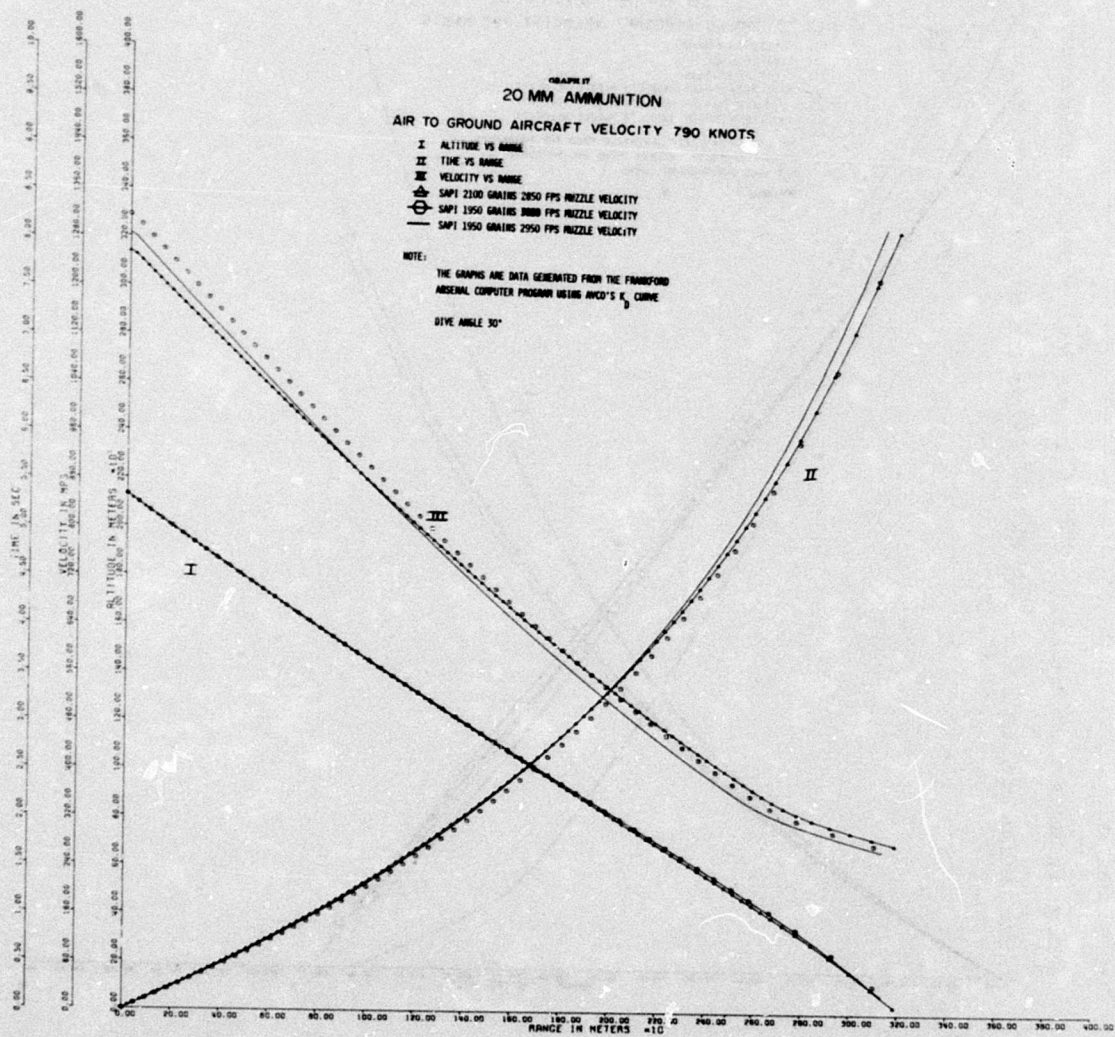
20 MM AMMUNITION S/A TO GROUND AIRCRAFT VELOCITY 790 KNOTS

I ALTITUDE VS RANGE
II TIME VS RANGE
III VELOCITY VS RANGE
SVC 2100 DRMS 2500 FPS MUZZLE VELOCITY
MS 1350 DRMS 3050 FPS MUZZLE VELOCITY
MS 1350 DRMS 2500 FPS MUZZLE VELOCITY
NOTE THE GRAPHING DATA DERIVED FROM THE FRAMEWORK
REVENUE COMPUTER PROGRAM USING 800 NO CURVE
FOR 2500 AND 3050 NO CURVE







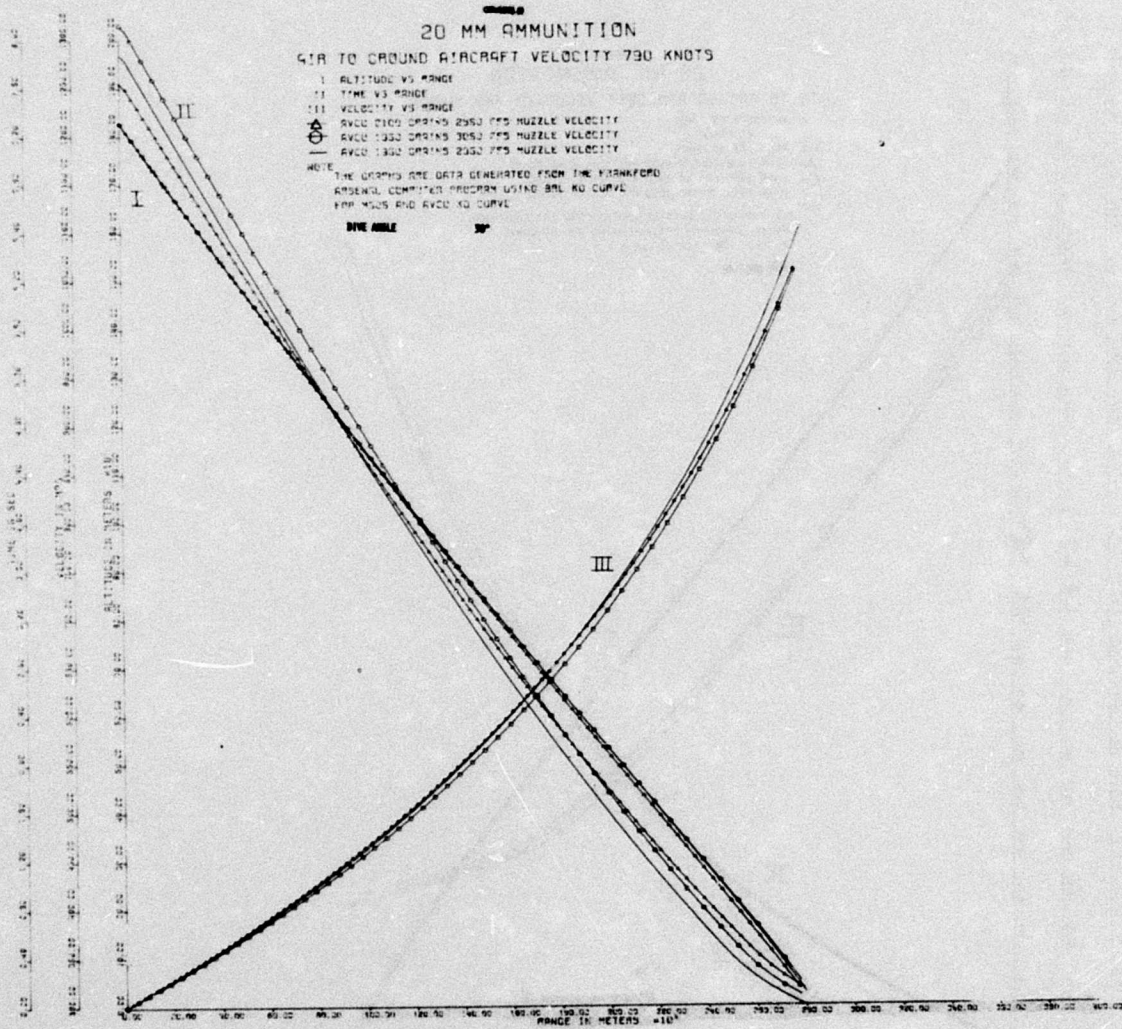


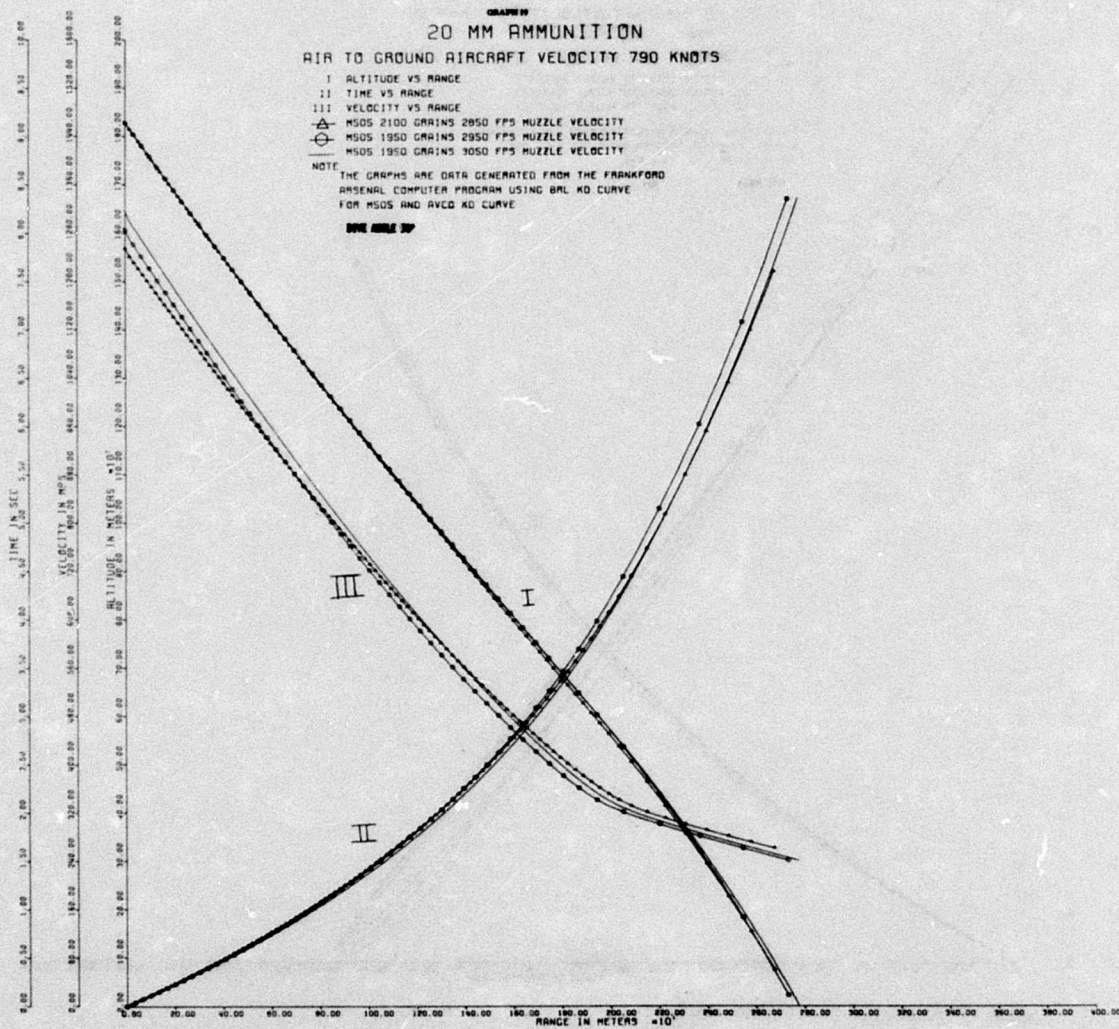
I ALTITUDE VS RANGE
II TIME VS RANGE
III VELOCITY VS RANGE
⊕ SAPI 2100 GRAINS 2850 FPS MUZZLE VELOCITY
⊕ SAPI 1950 GRAINS 3000 FPS MUZZLE VELOCITY
— SAPI 1950 GRAINS 2950 FPS MUZZLE VELOCITY

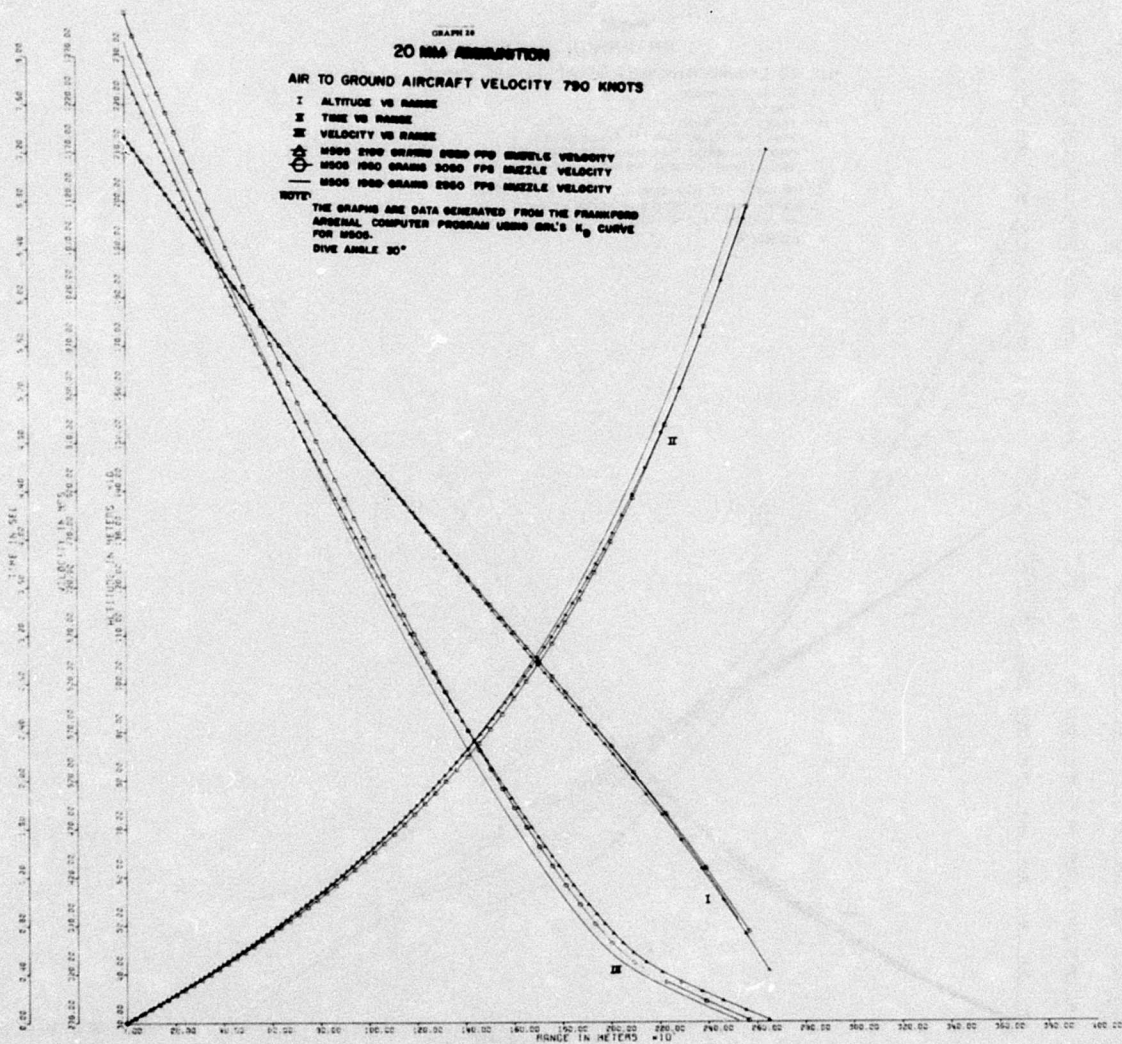
NOTE:

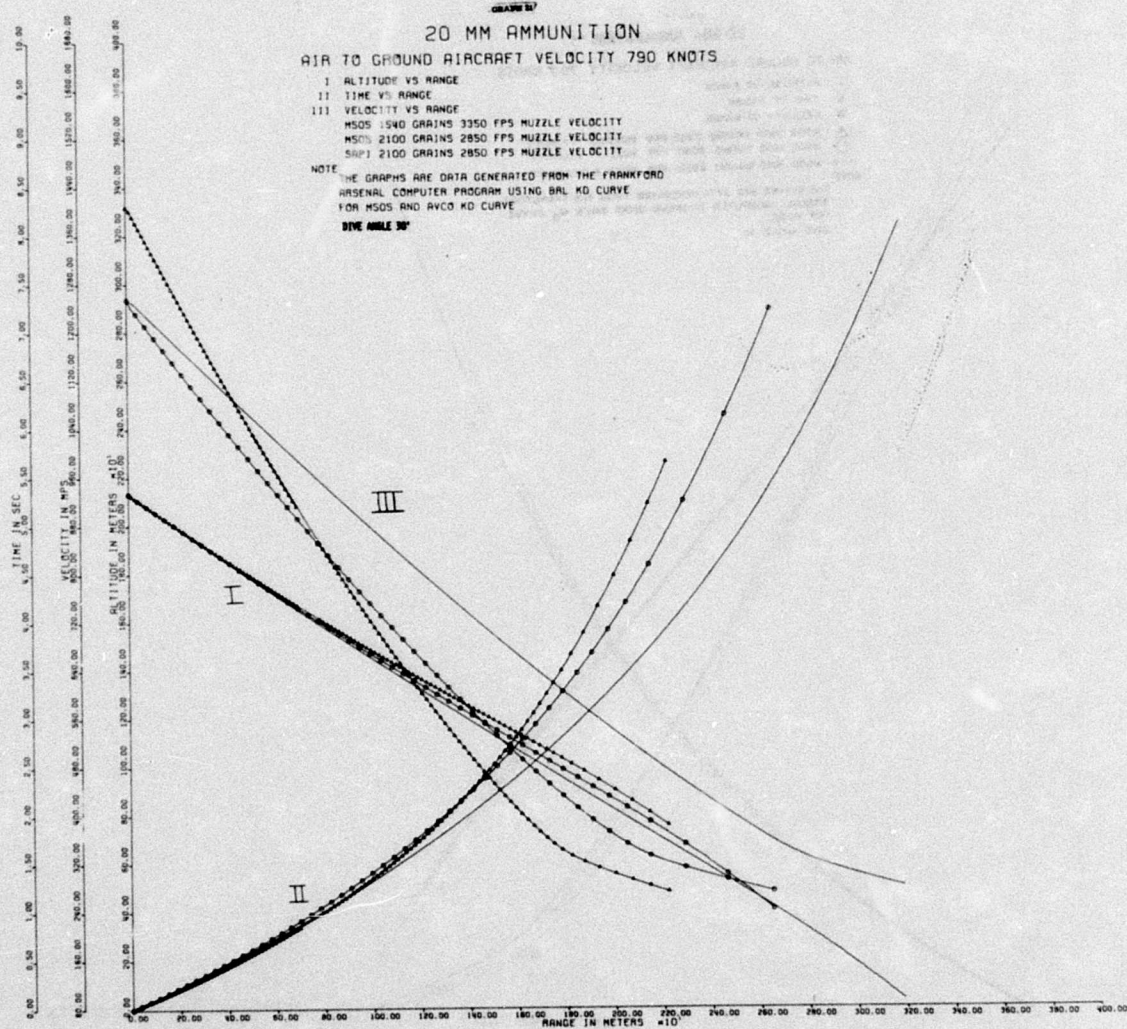
THE GRAPHS ARE DATA GENERATED FROM THE FRANKFORD ARSENAL COMPUTER PROGRAM USING ANCO'S K_1 CURVE

DIVE ANGLE 30°









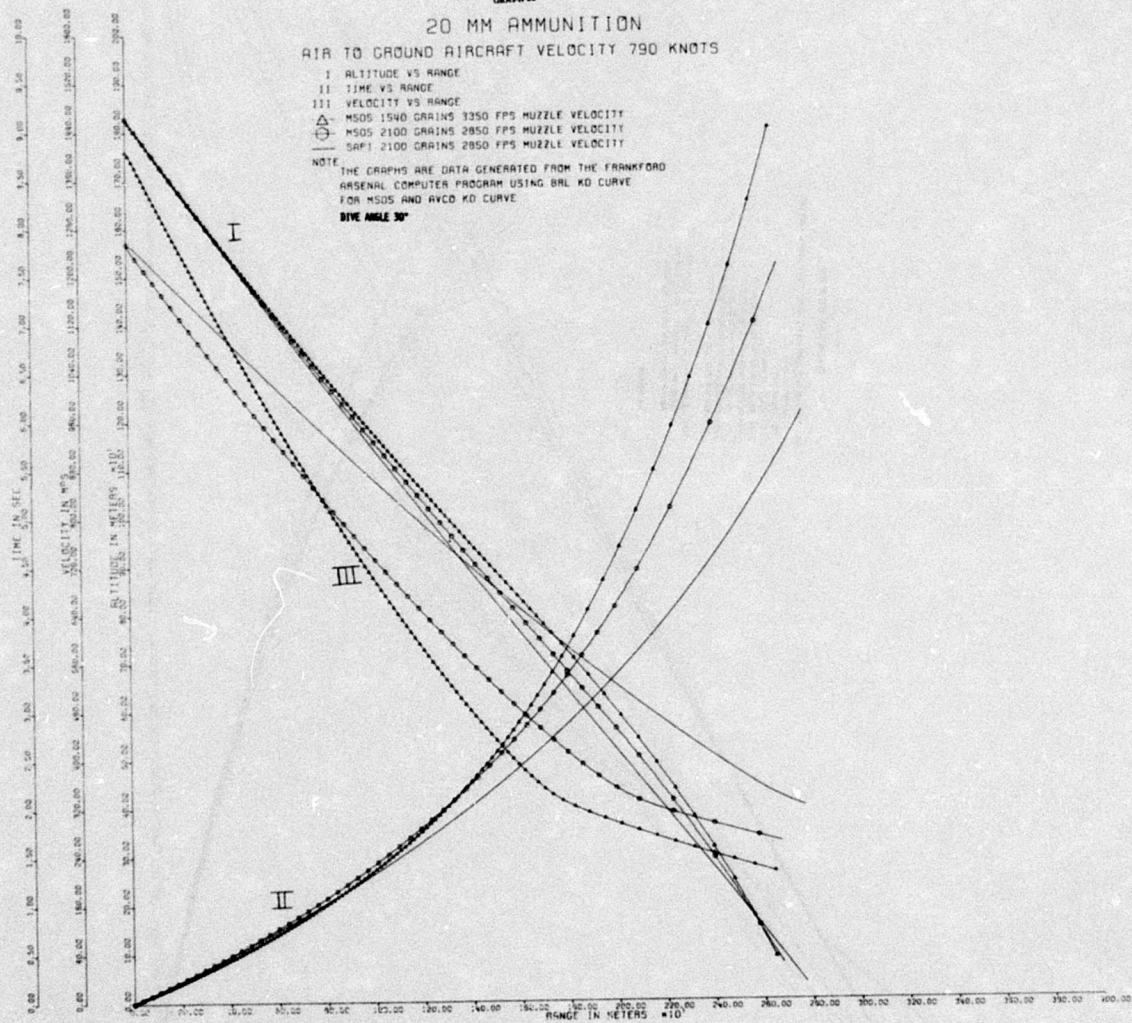
GRAPH 11

20 MM AMMUNITION

AIR TO GROUND AIRCRAFT VELOCITY 790 KNOTS

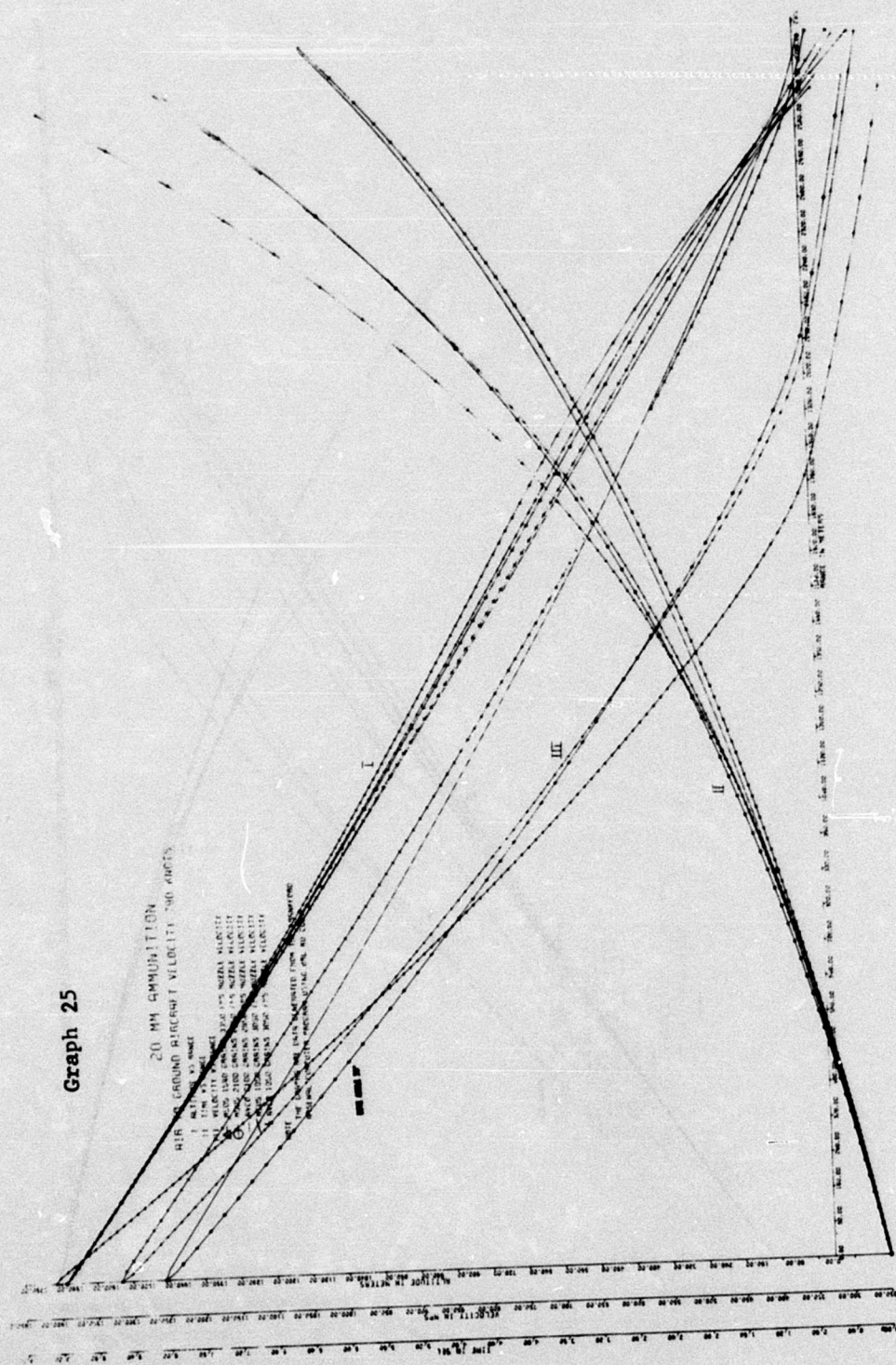
- I ALTITUDE VS RANGE
- II TIME VS RANGE
- III VELOCITY VS RANGE
- Δ MS05 1540 GRAINS 3350 FPS MUZZLE VELOCITY
- MS05 2100 GRAINS 2850 FPS MUZZLE VELOCITY
- SAFI 2100 GRAINS 2850 FPS MUZZLE VELOCITY

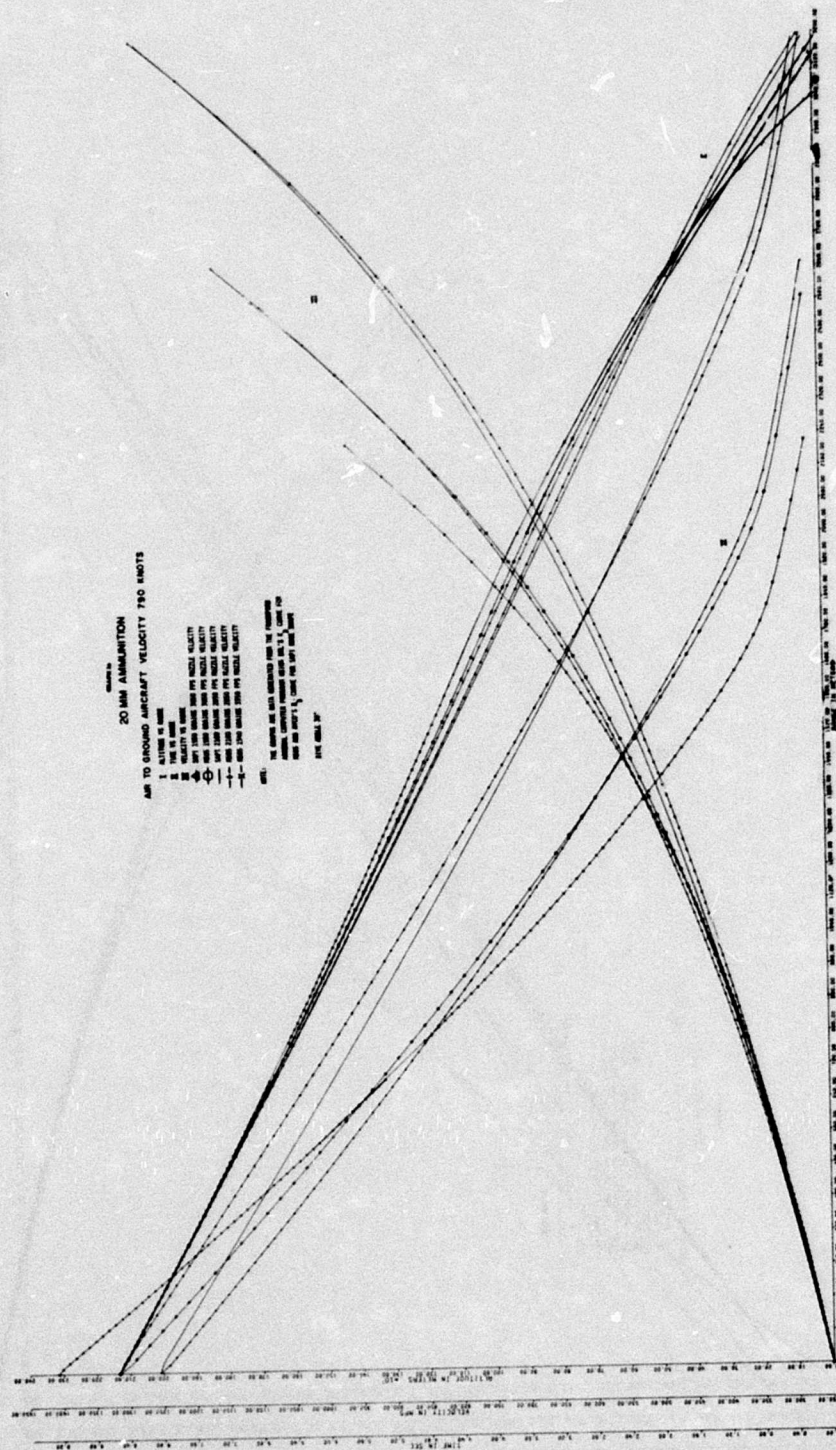
NOTE
THE GRAPHS ARE DATA GENERATED FROM THE FRANKFORD
ARSENAL COMPUTER PROGRAM USING BRL KD CURVE
FOR MS05 AND AVCD KD CURVE
DIVE ANGLE 30°





Graph 25





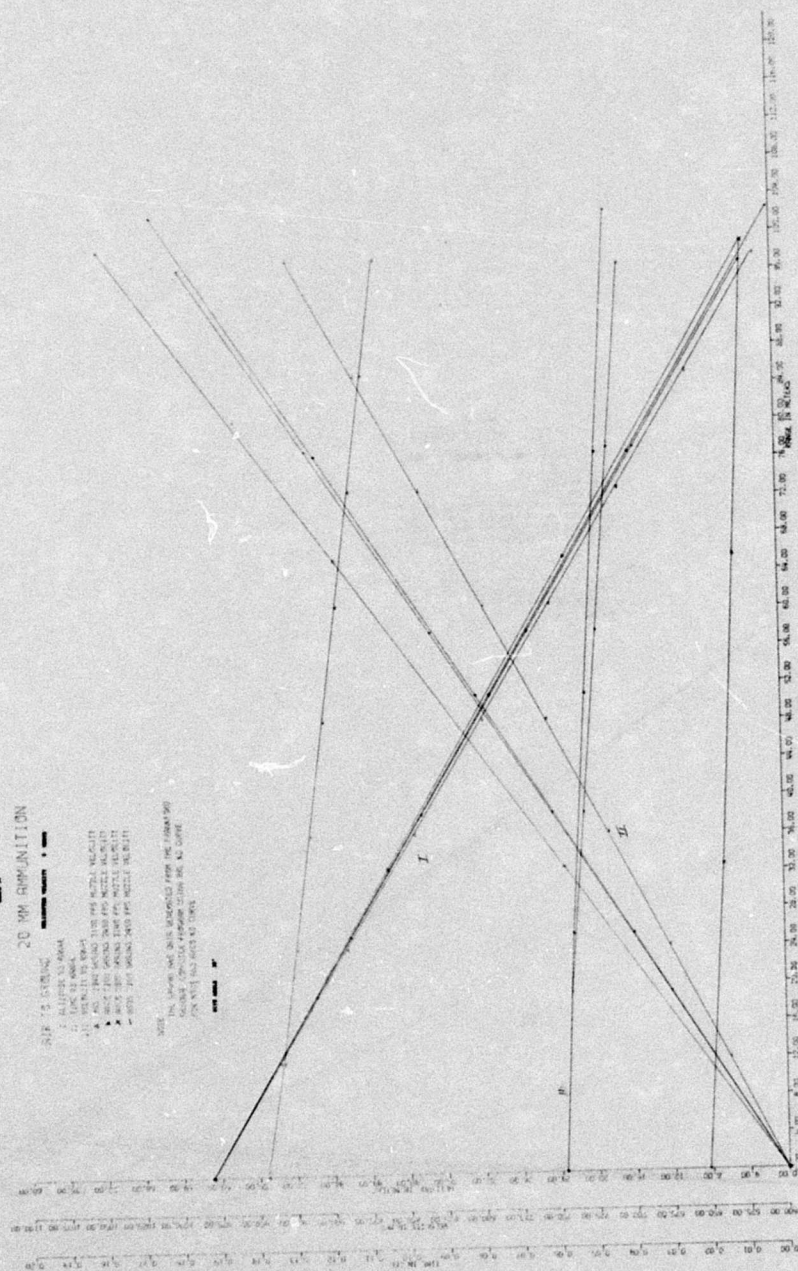








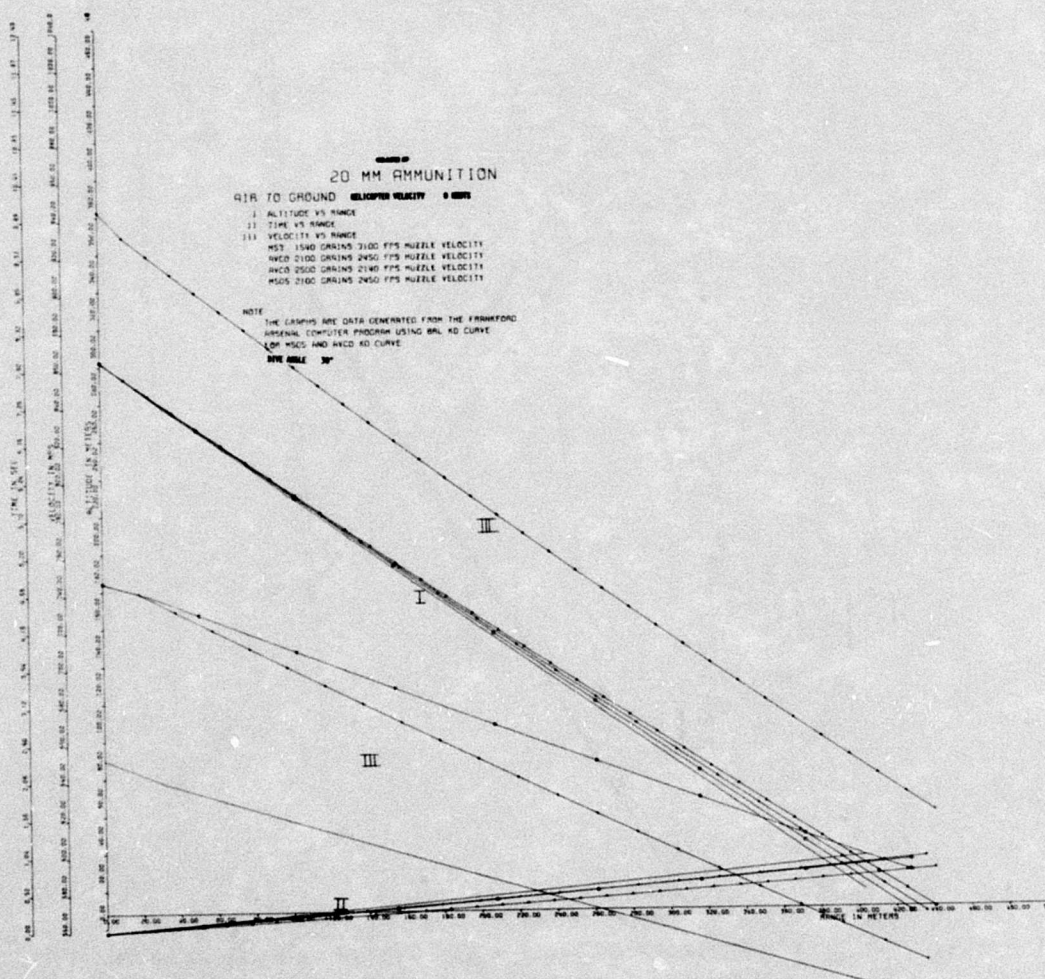


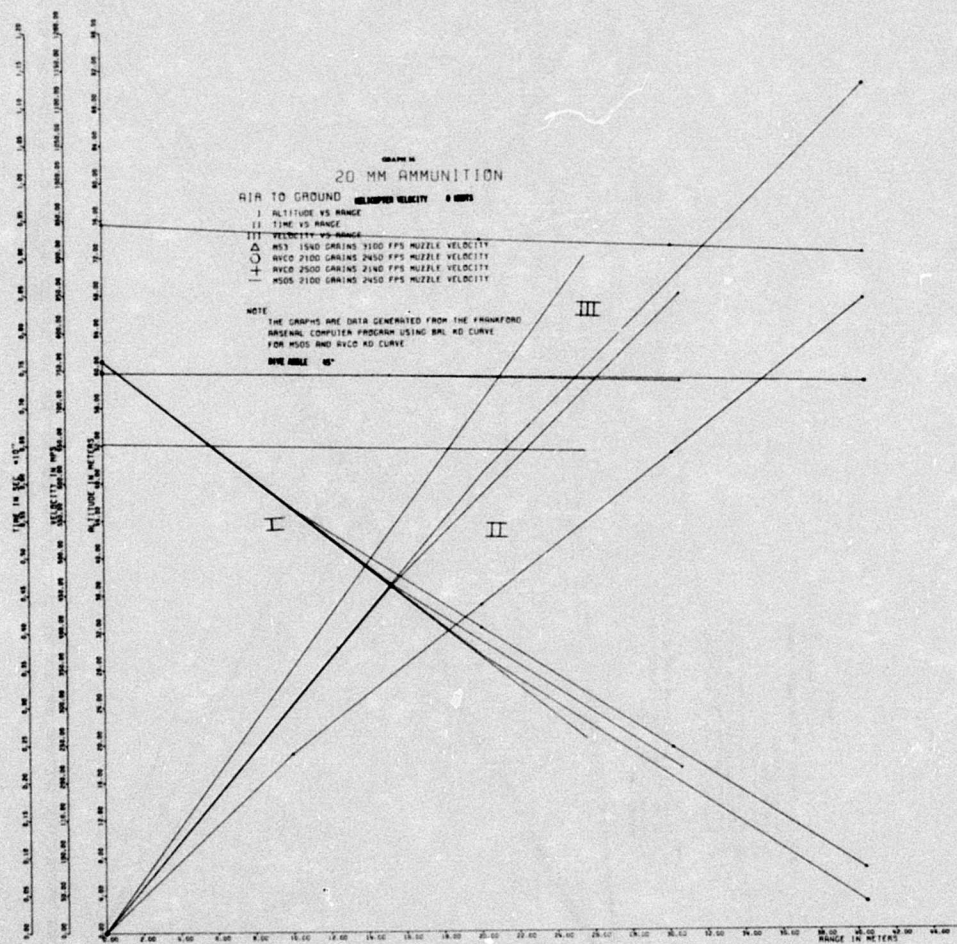


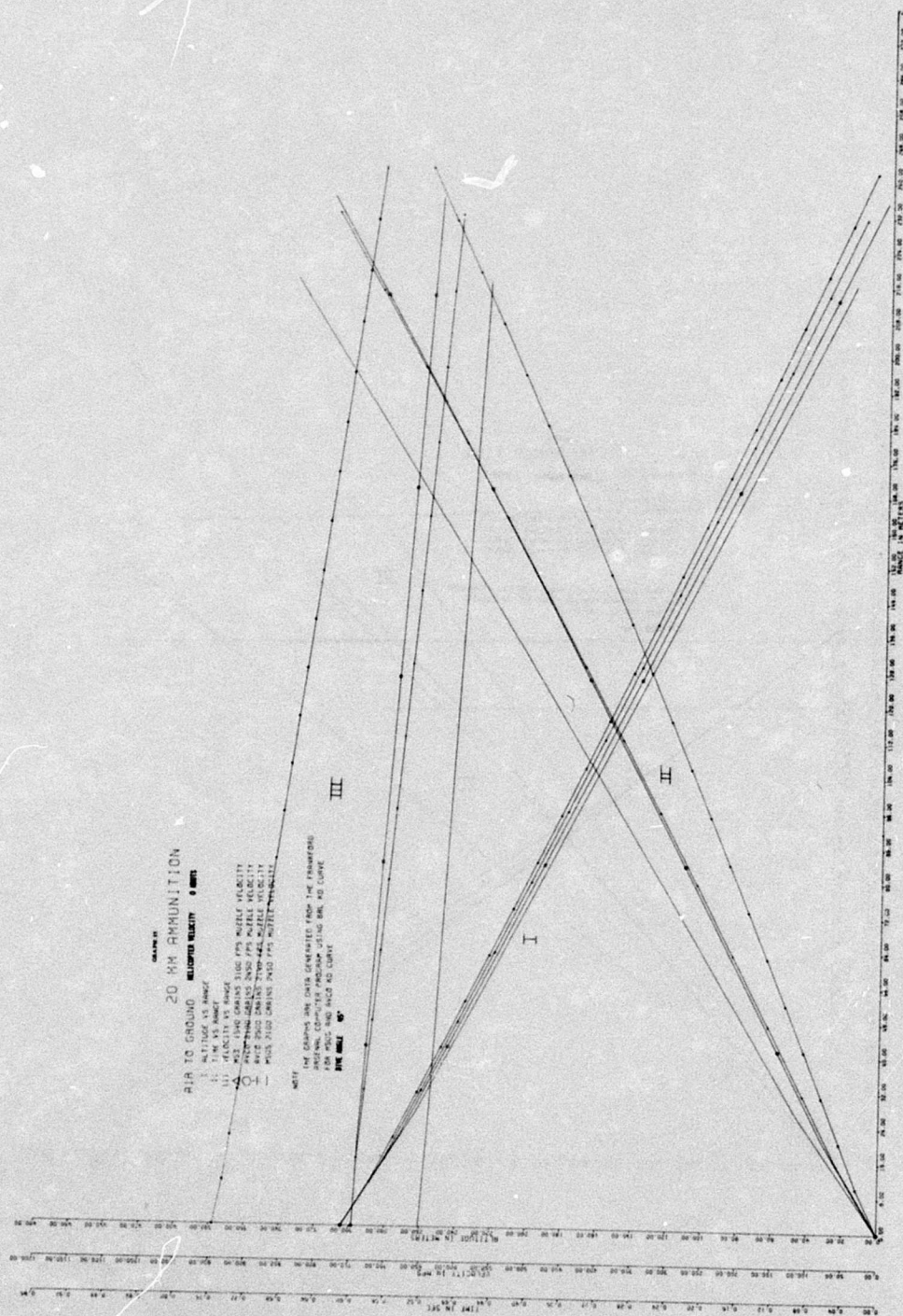
20 MM AMMUNITION AIR TO GROUND (CALIBERED VELOCITY - 0 MMS)

- I ALTITUDE VS RANGE
- II TIME VS RANGE
- III VELOCITY VS RANGE
- IV 1500 GRAINS 2100 FPS MUZZLE VELOCITY
- AV 2100 GRAINS 2450 FPS MUZZLE VELOCITY
- BV 2500 GRAINS 2140 FPS MUZZLE VELOCITY
- CV 2100 GRAINS 2450 FPS MUZZLE VELOCITY

NOTE
THE GRAPHS ARE DATA GENERATED FROM THE FRANKFORD
ARSENAL COMPUTER PROGRAM USING BAL AD CURVE
FOR M50 AND M400 AD CURVE







20 MM RIFLE RANGING CHART

50.0 TO 1000.0 YARDS

1.000 TO 1.000

1.000 TO 1.000

1.000 TO 1.000

1.000 TO 1.000

1.000 TO 1.000

1.000 TO 1.000

1.000 TO 1.000

1.000 TO 1.000

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1.000 TO 1.000

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1.000 TO 1.000

1.000 TO 1.000

1.000 TO 1.000

1.000 TO 1.000

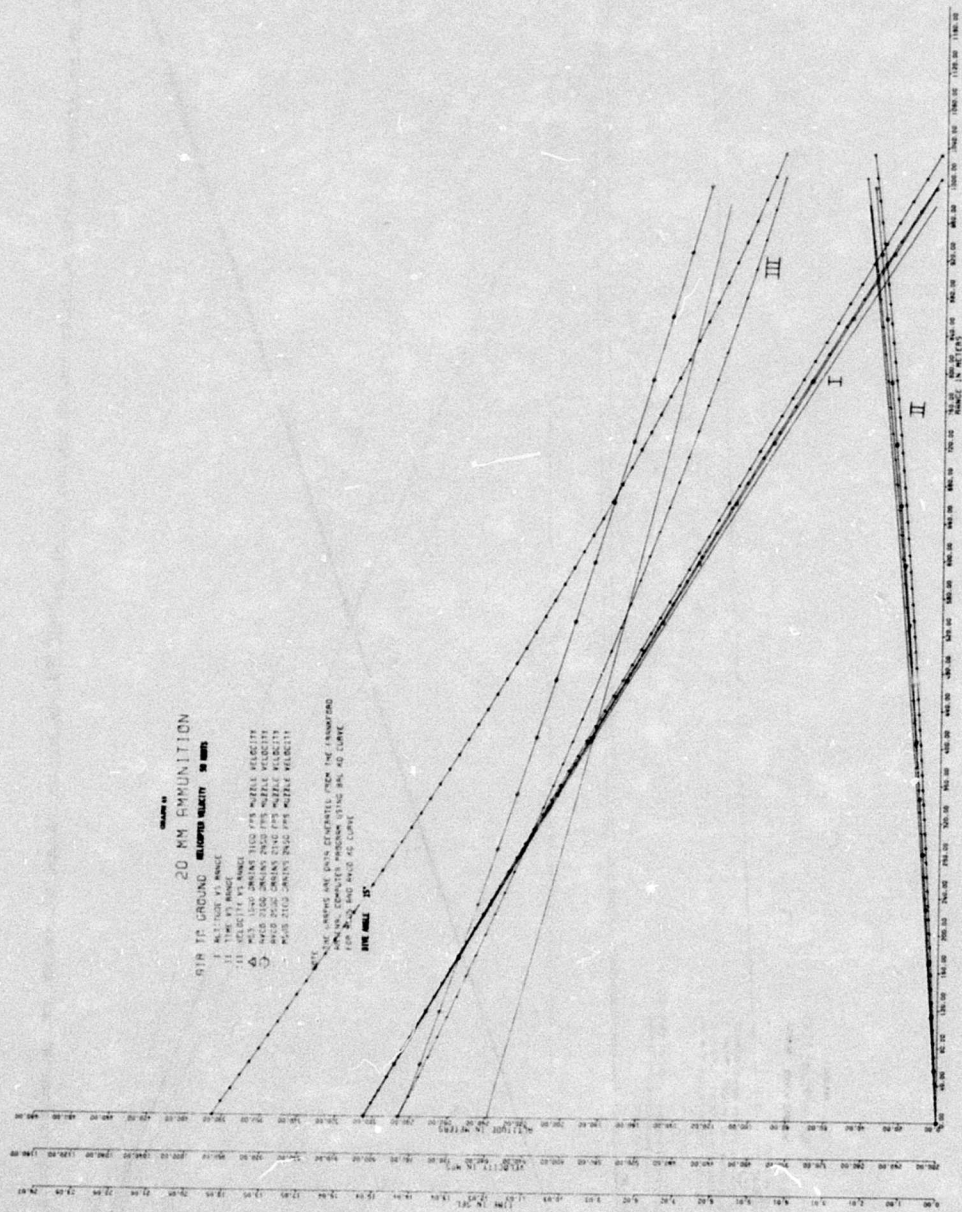
1.000 TO 1.000

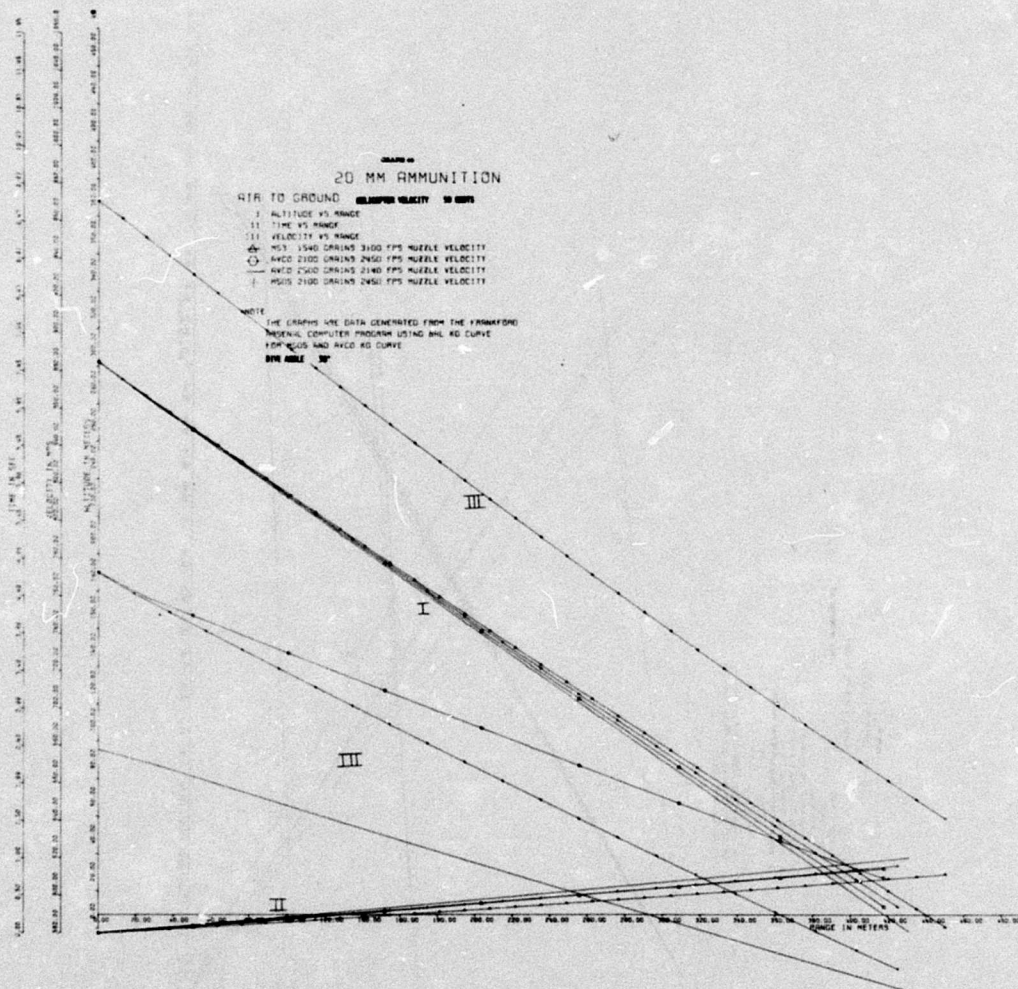
57

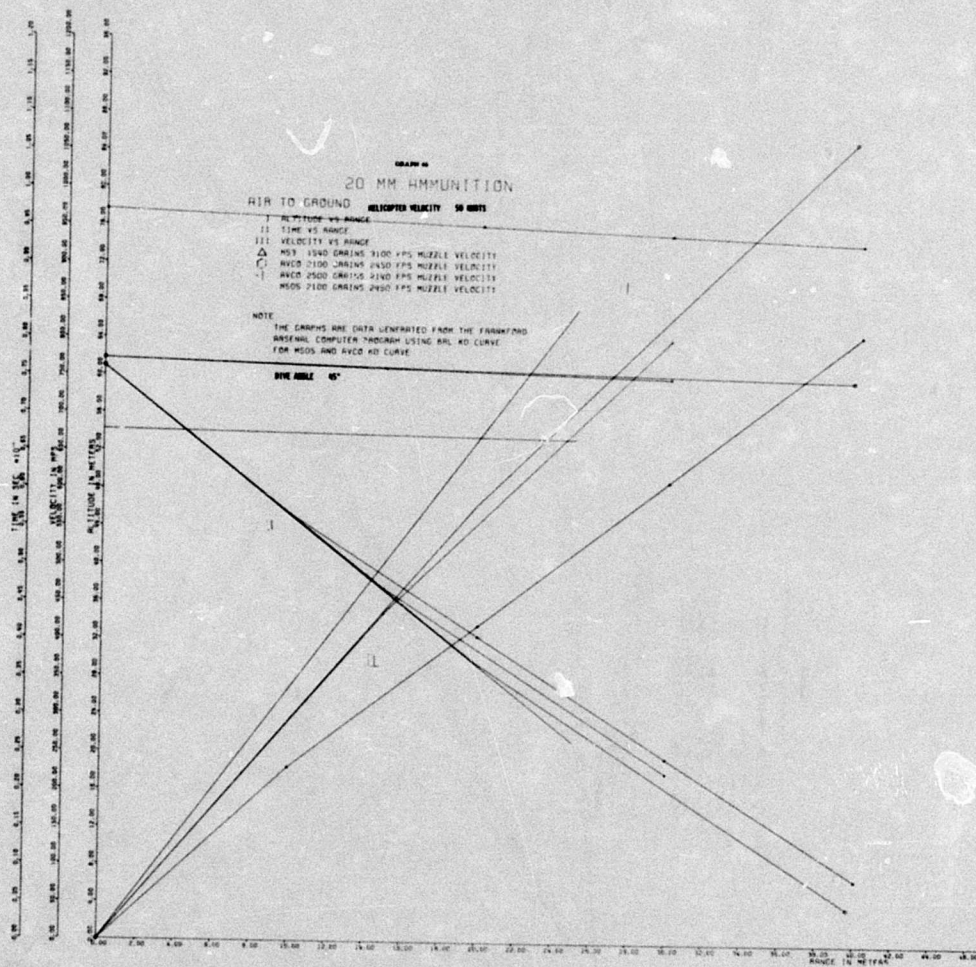








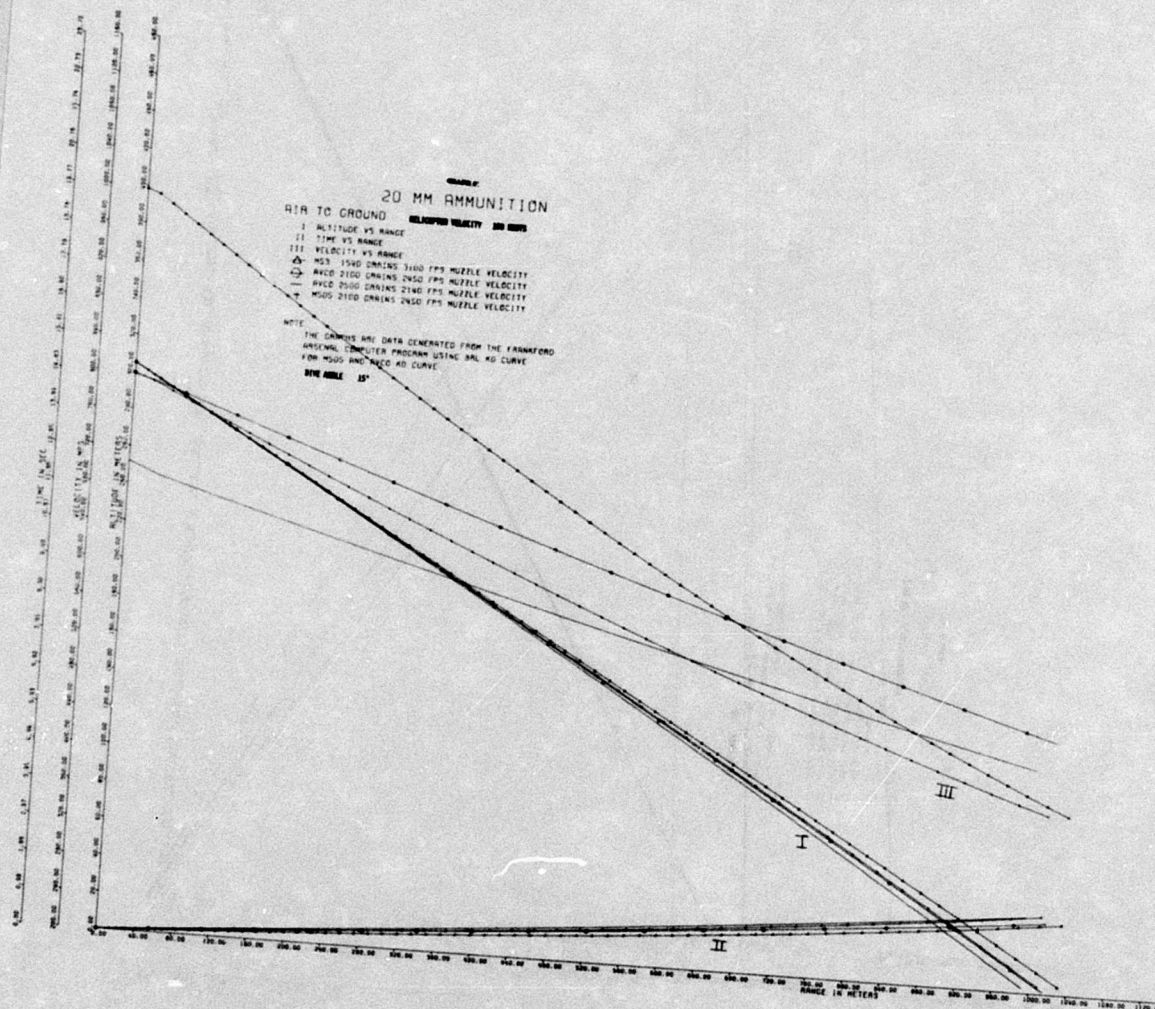


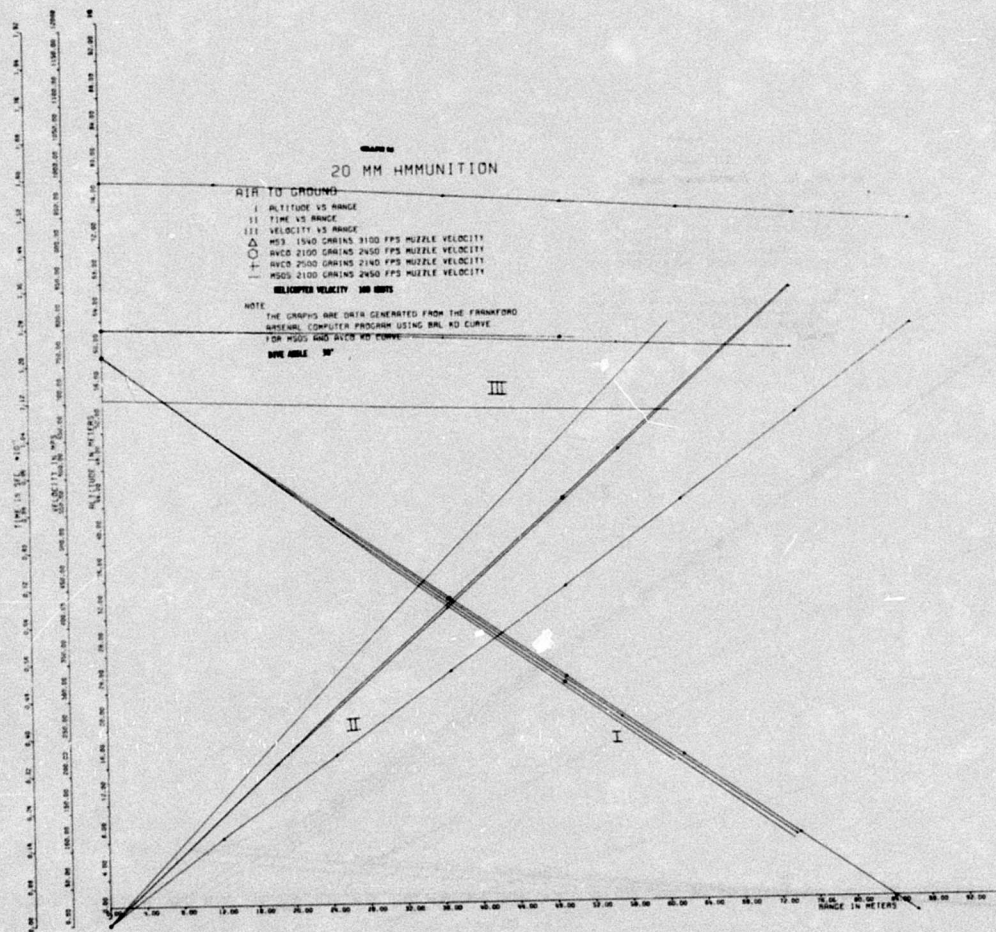


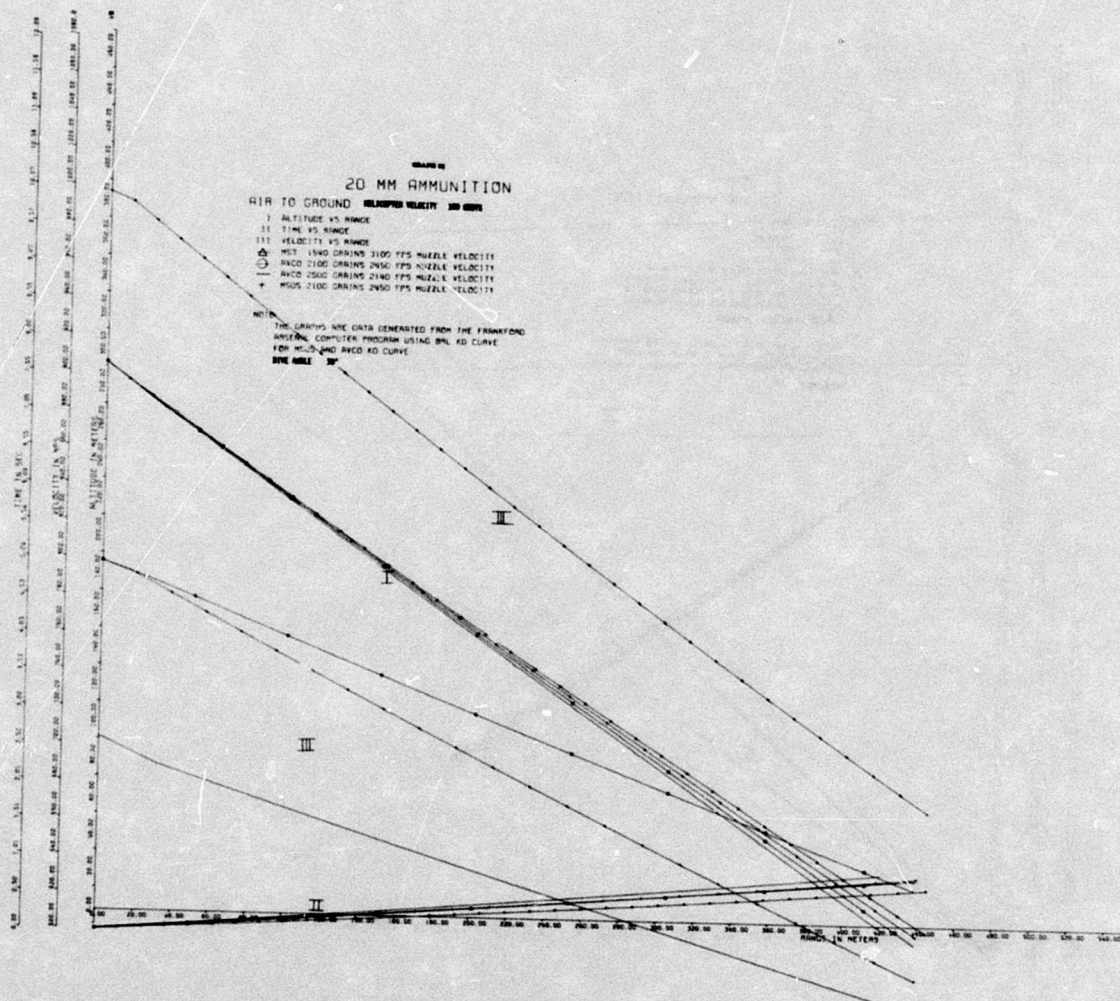






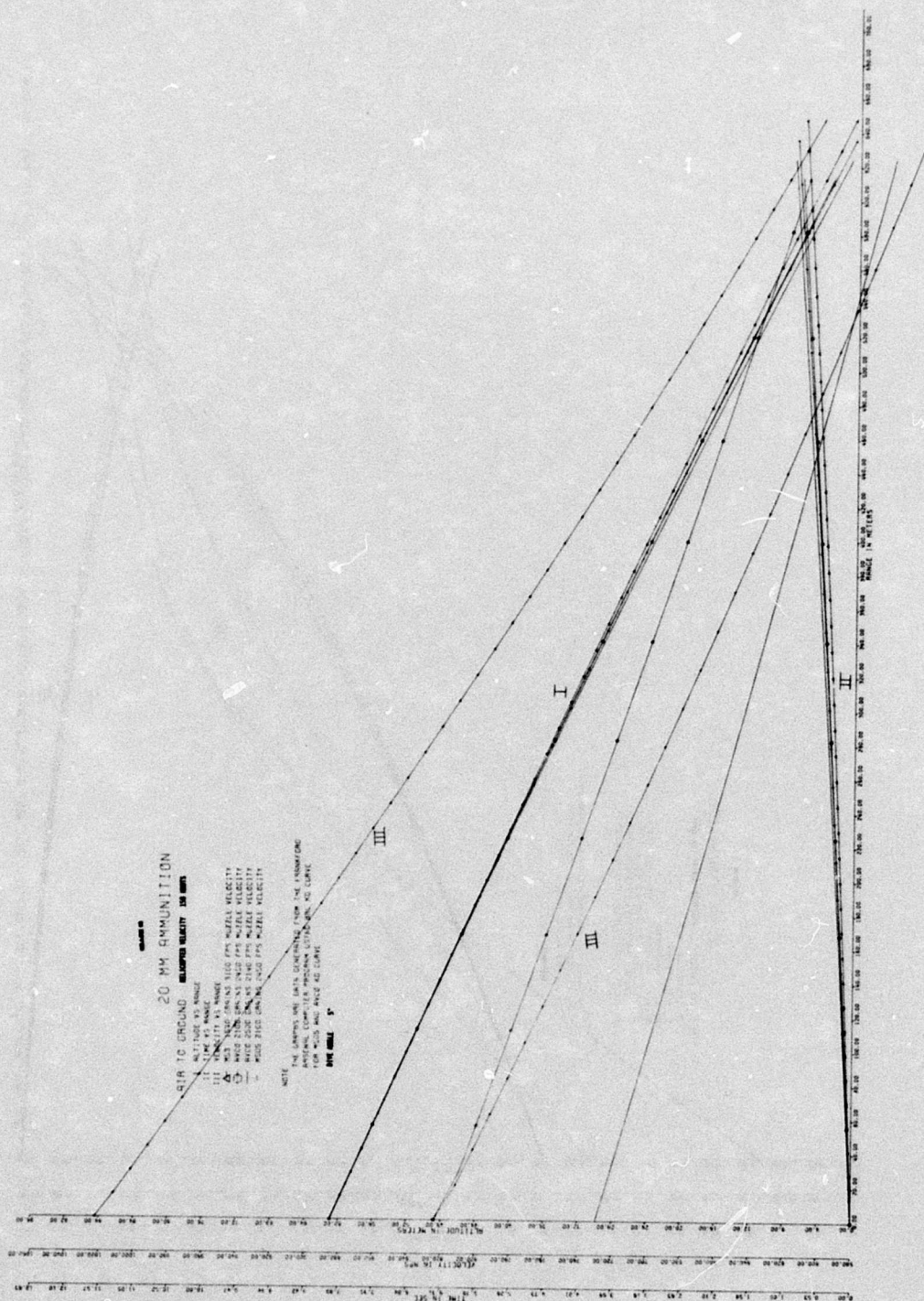






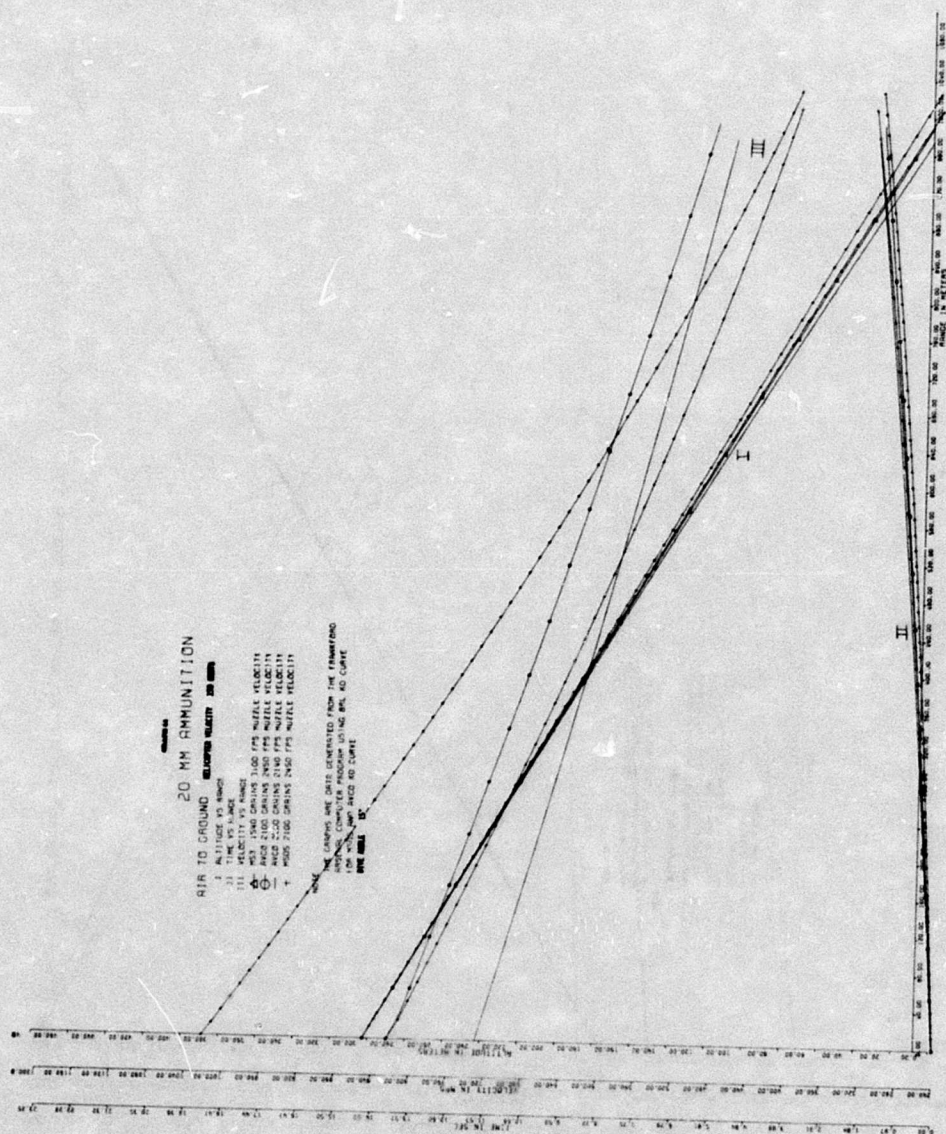


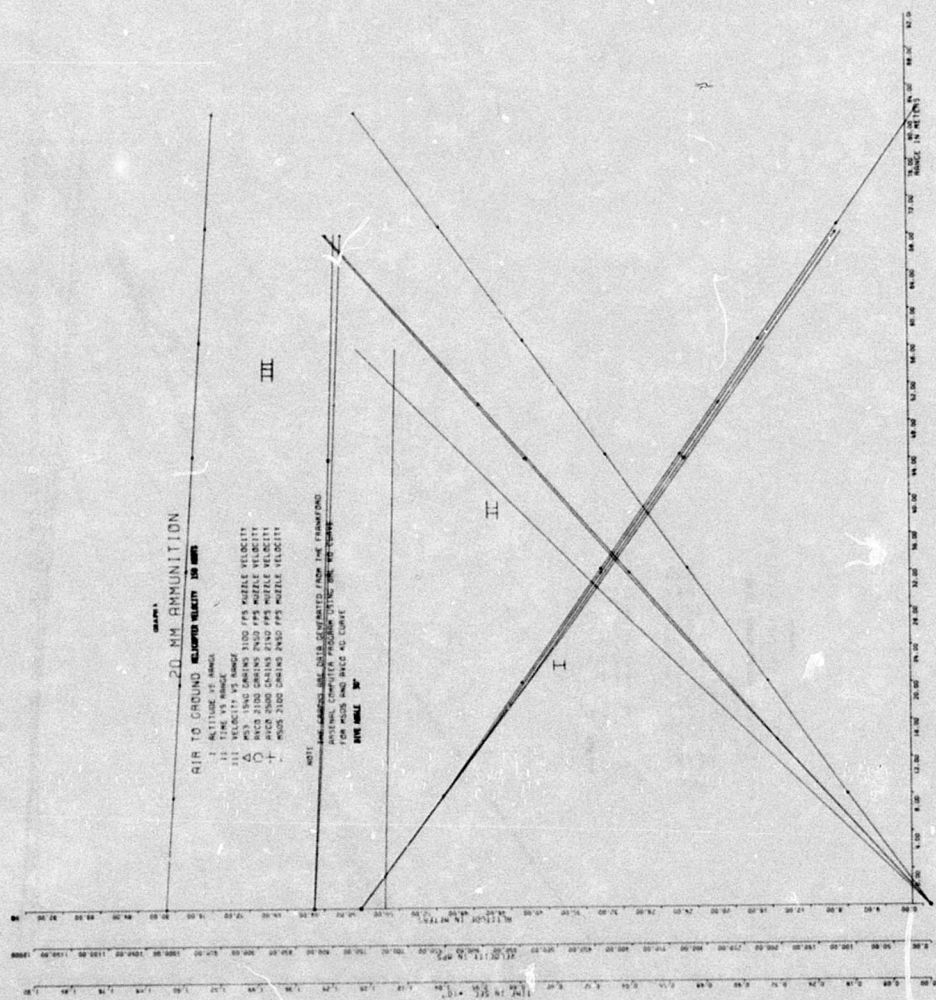




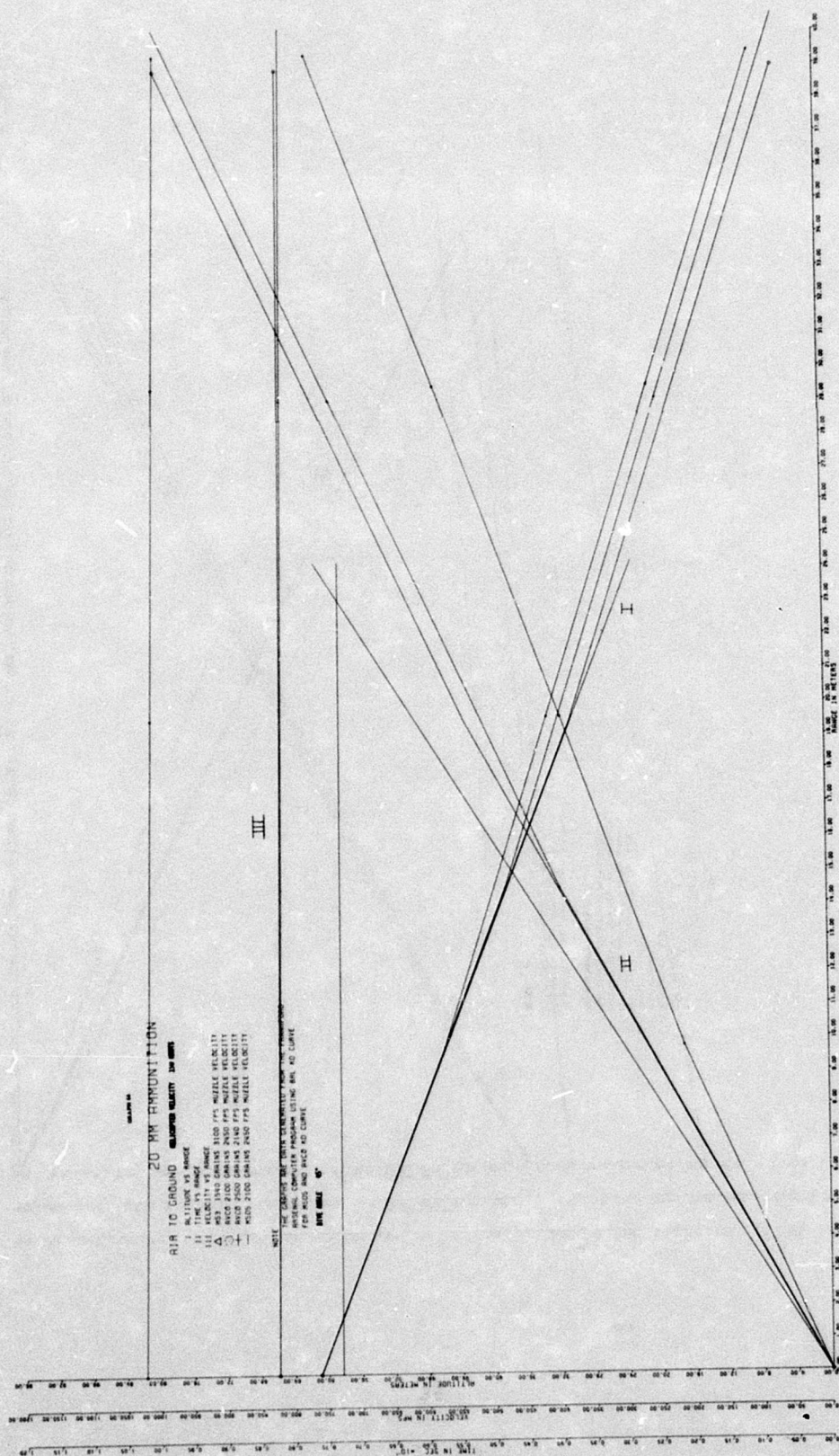












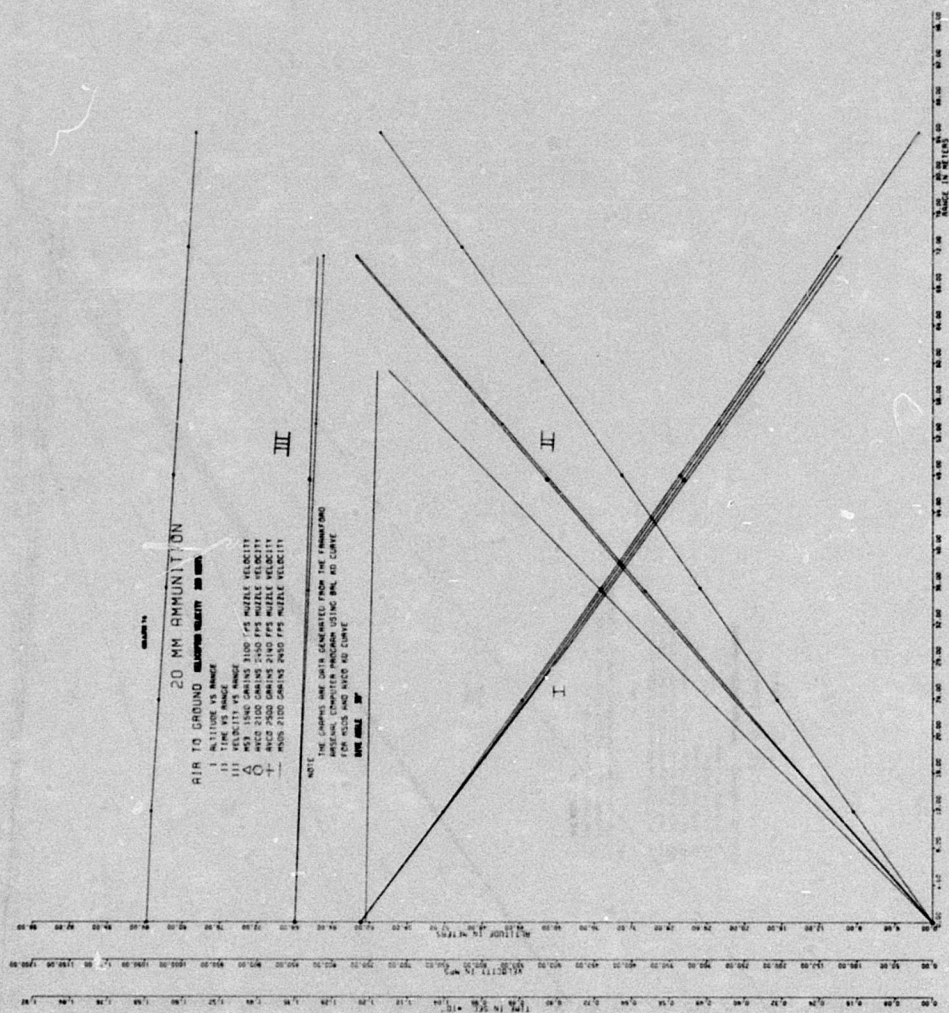
















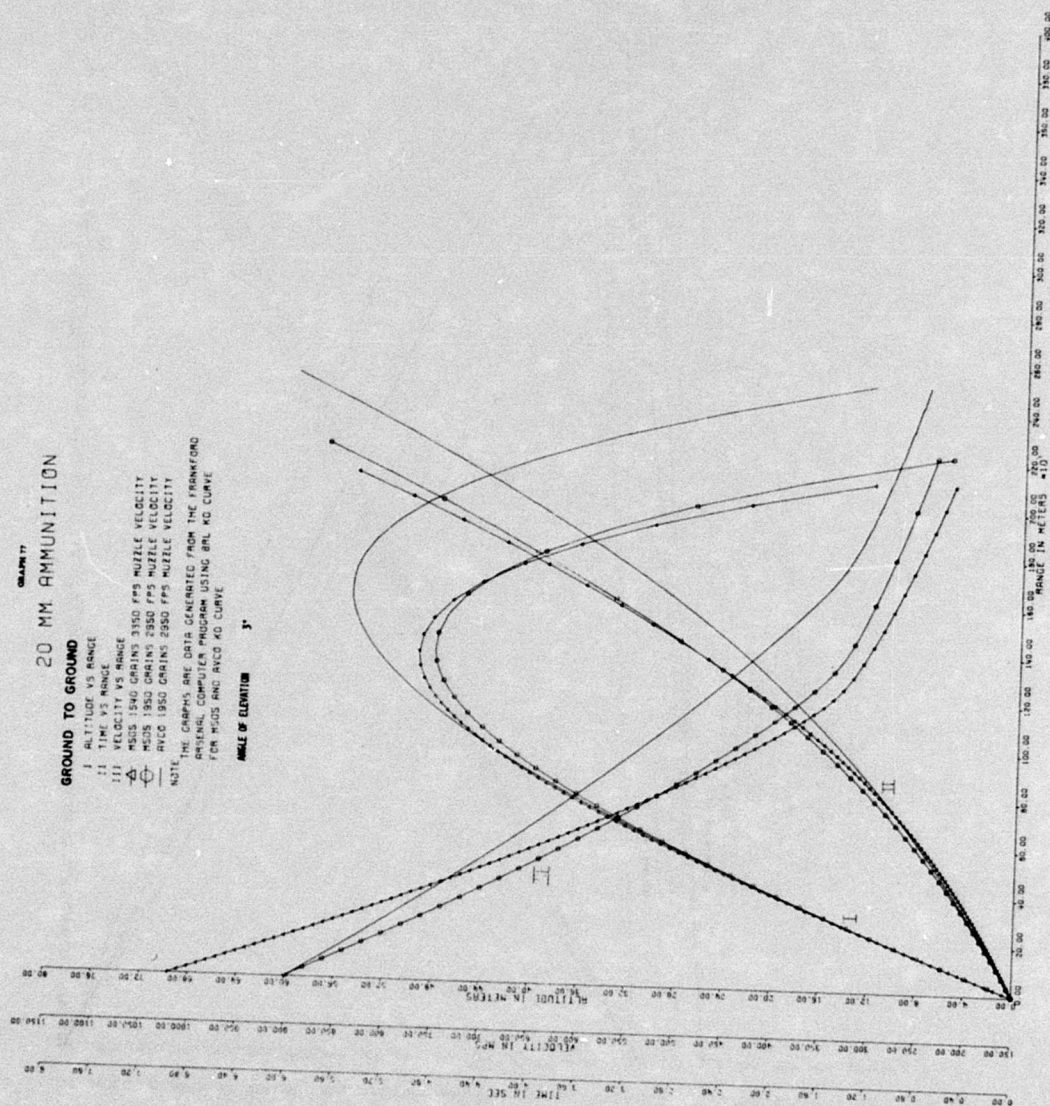
20 MM AMMUNITION

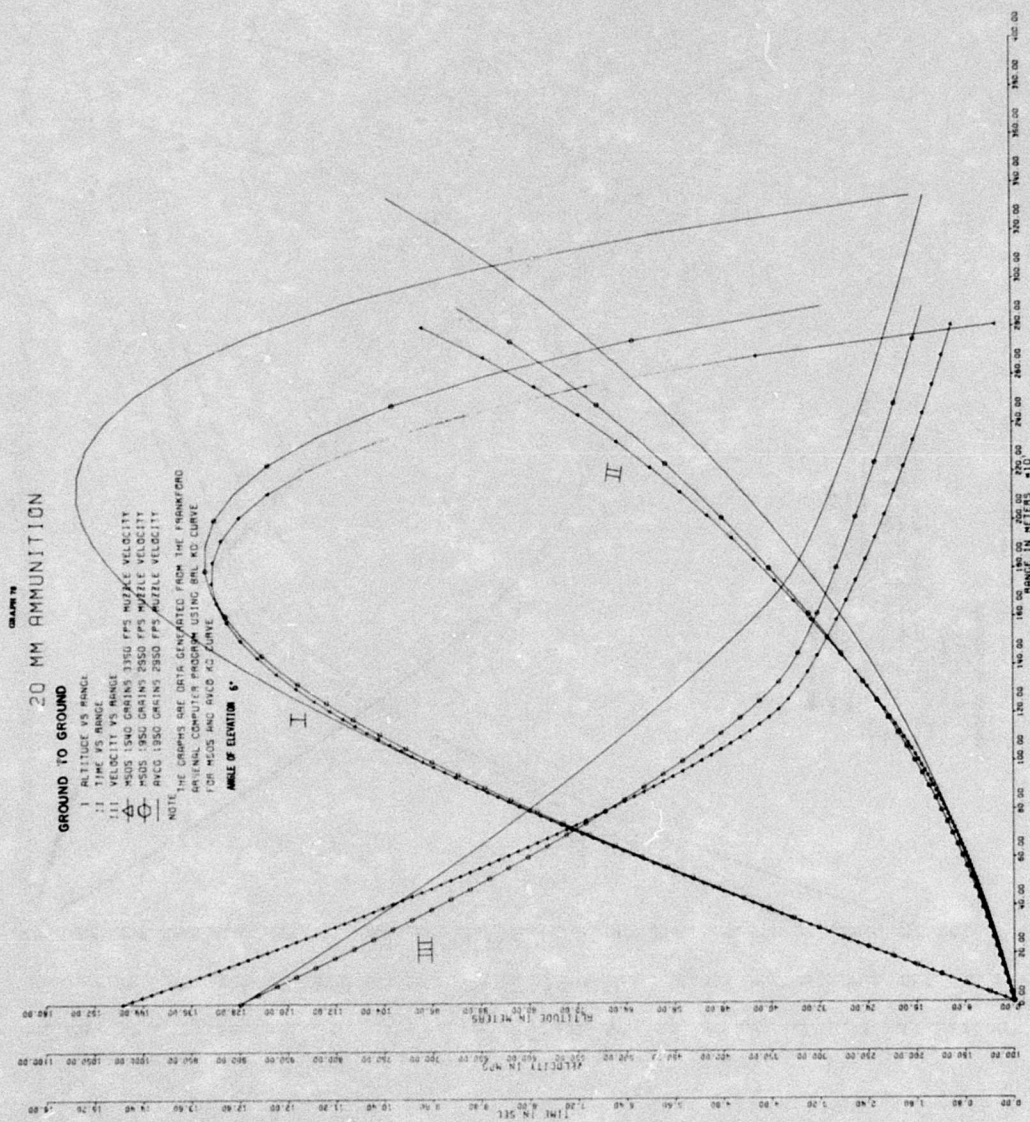
GROUND TO GROUND

- I ALTITUDE VS RANGE
- II TIME VS RANGE
- III VELOCITY VS RANGE
- IV MDS 1540 GRAINS 3150 FPS MUZZLE VELOCITY
- V MDS 1950 GRAINS 2850 FPS MUZZLE VELOCITY
- VI MDS 1950 GRAINS 2850 FPS MUZZLE VELOCITY
- VII MDS 1950 GRAINS 2850 FPS MUZZLE VELOCITY

NOTE: THE GRAPHS ARE DATA GENERATED FROM THE FRANKFORD
ORIGINAL COMPUTER PROGRAM USING BRN NO CURVE
FOR MDS AND RDC NO CURVE

ANGLE OF ELEVATION 3°

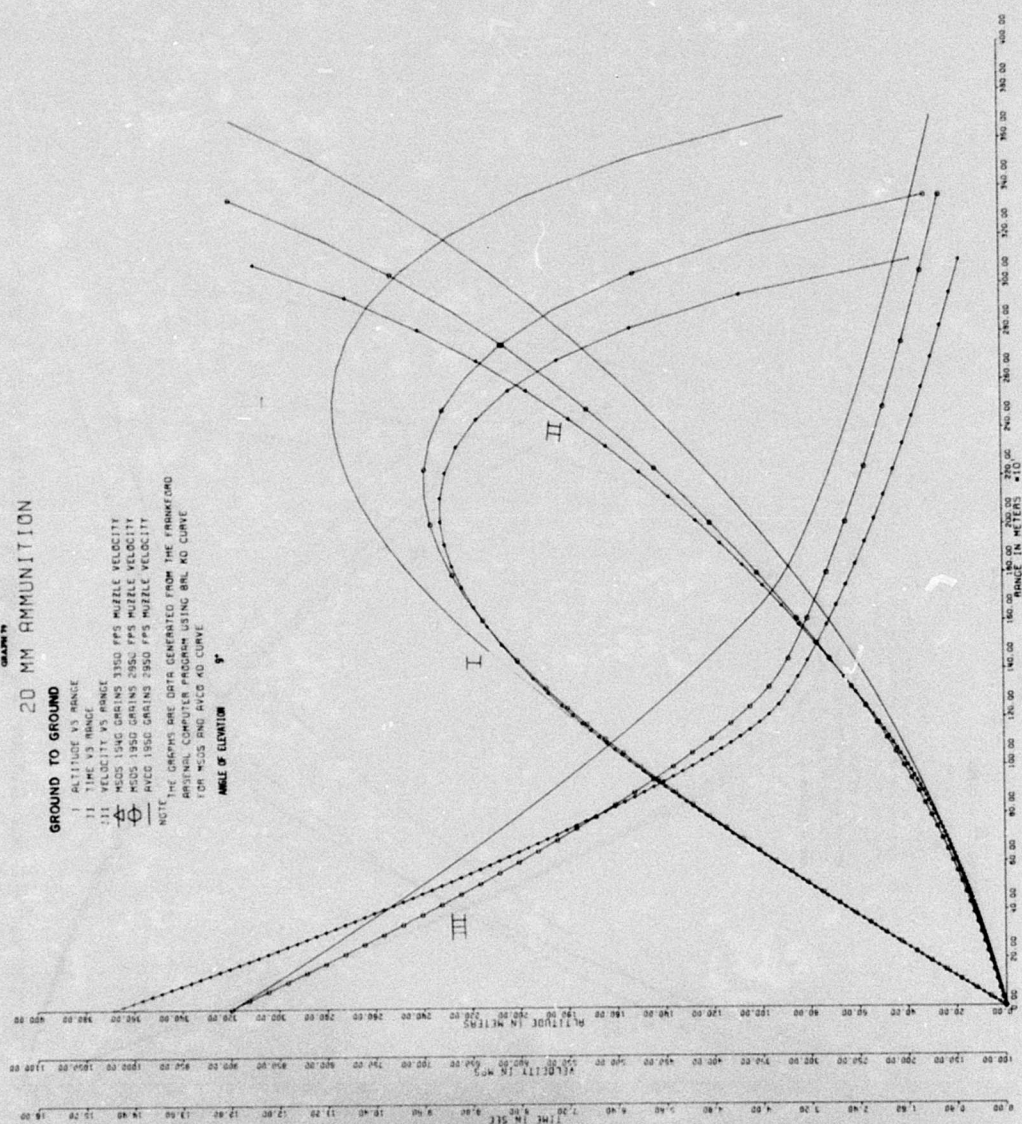


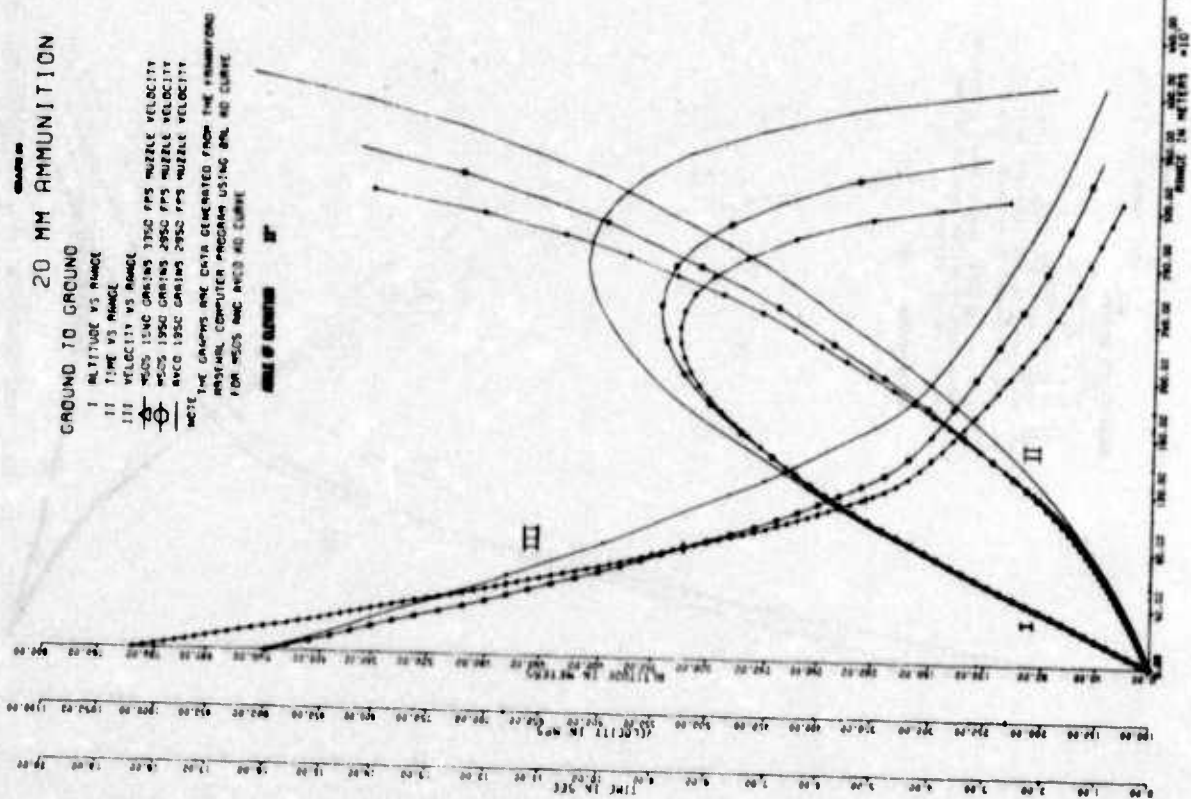


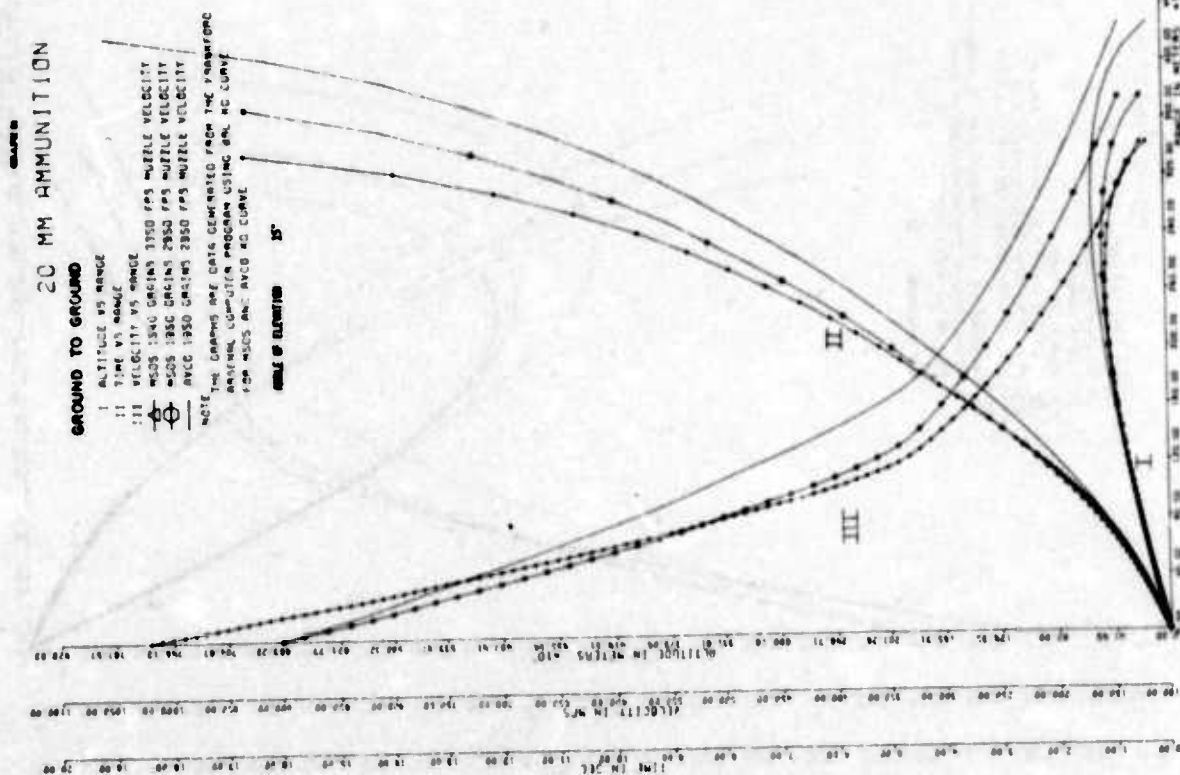
THE NEW YORK PUBLIC LIBRARY

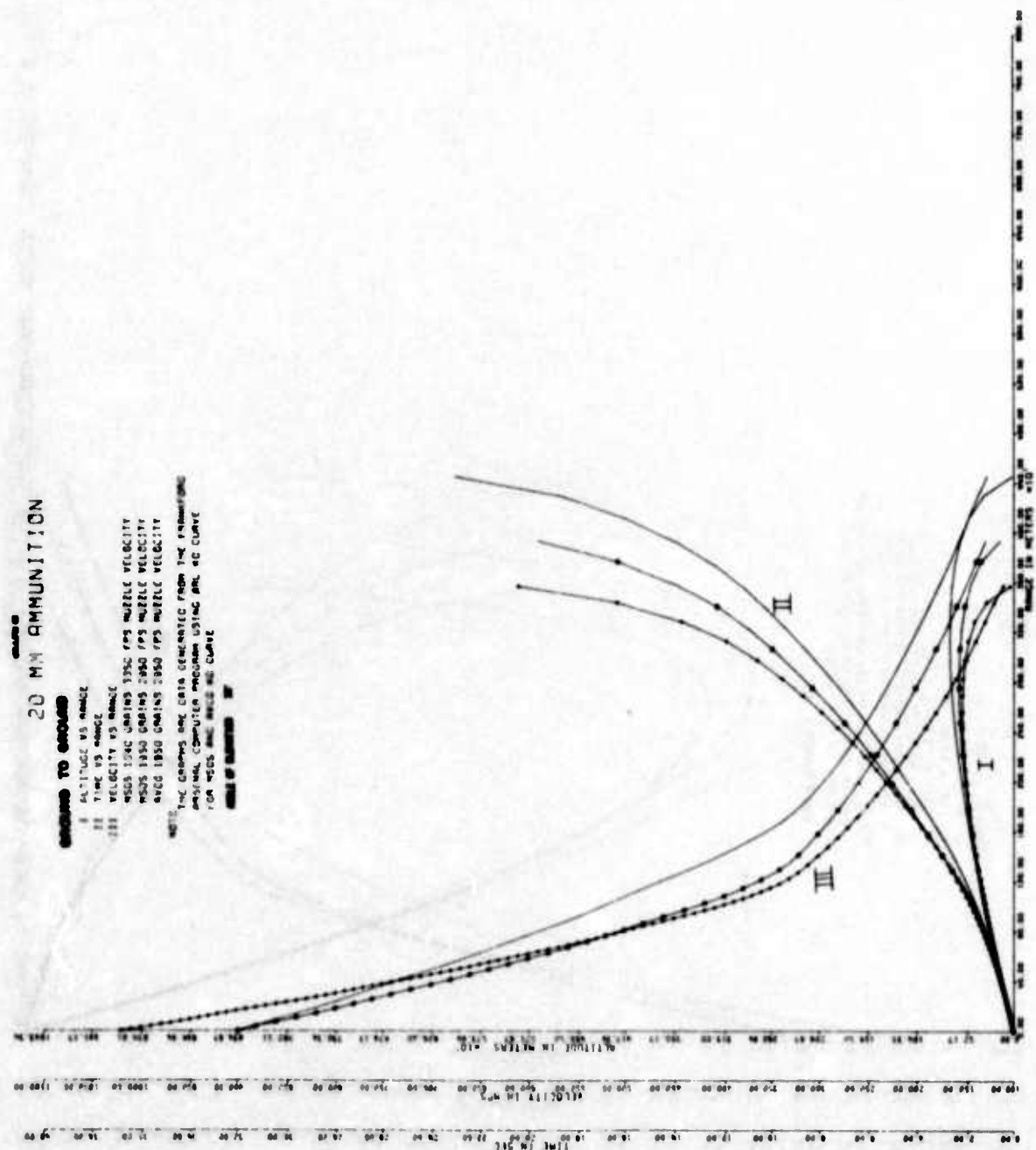
GROUND TO GROUND

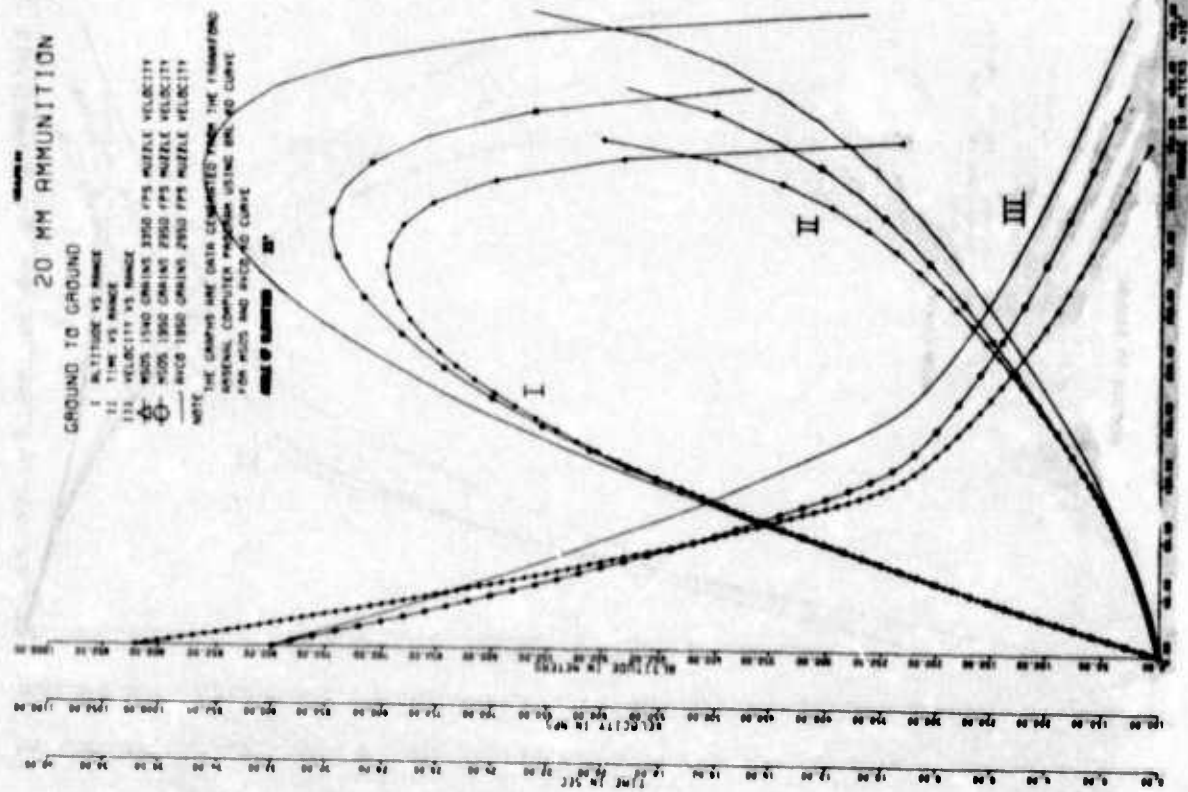
- 1 ALTITUDE VS RANGE
2 TIME VS RANGE
3 VELOCITY VS RANGE
4 MUZZLE VELOCITY
M05 150G GRAINS 3350 FPS
M05 185G GRAINS 2950 FPS
M05 150G GRAINS 3500 FPS
AICD 150G GRAINS 3500 FPS
- MUZZLE VELOCITY
MUZZLE VELOCITY
MUZZLE VELOCITY
MUZZLE VELOCITY
- NOTE: THE GRAPHS ARE DATA GENERATED FROM THE FRANKFORD ARSENAL COMPUTER PROGRAM USING BNL NO CURVE FOR M05S AND AICD AD CURVE.
- ANGLE OF ELEVATION 5°









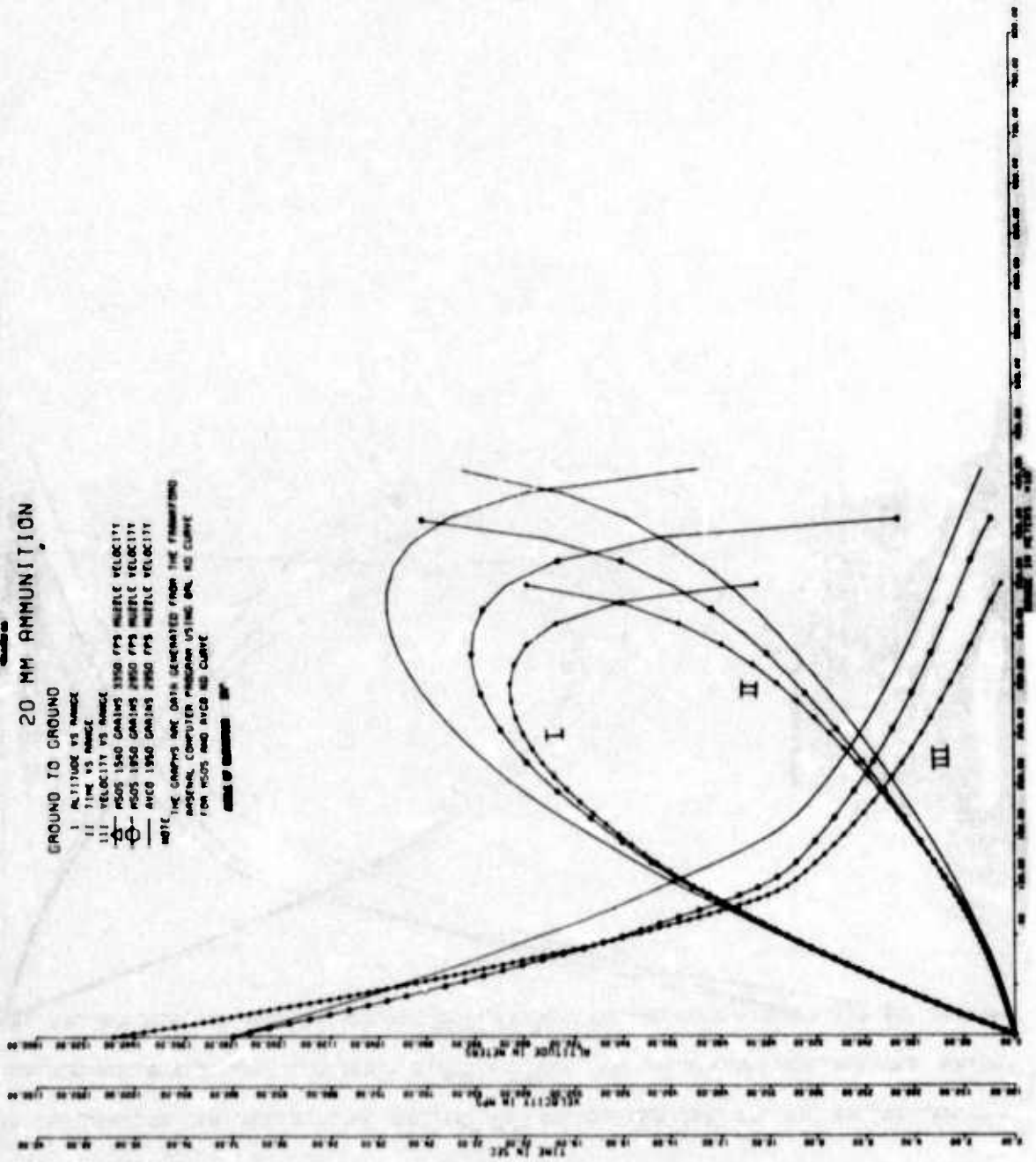


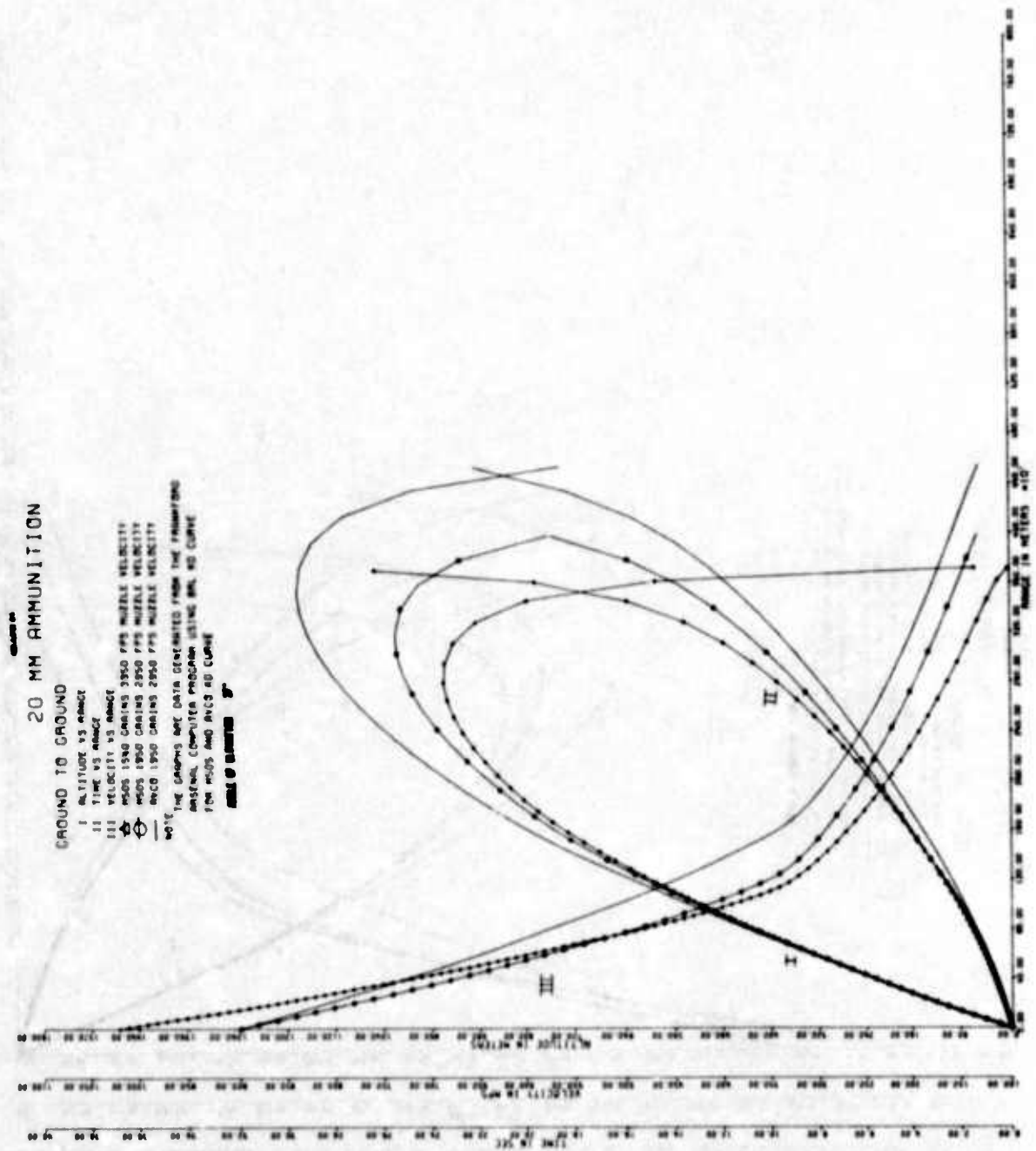
GROUND TO GROUND
20 MM AMMUNITION

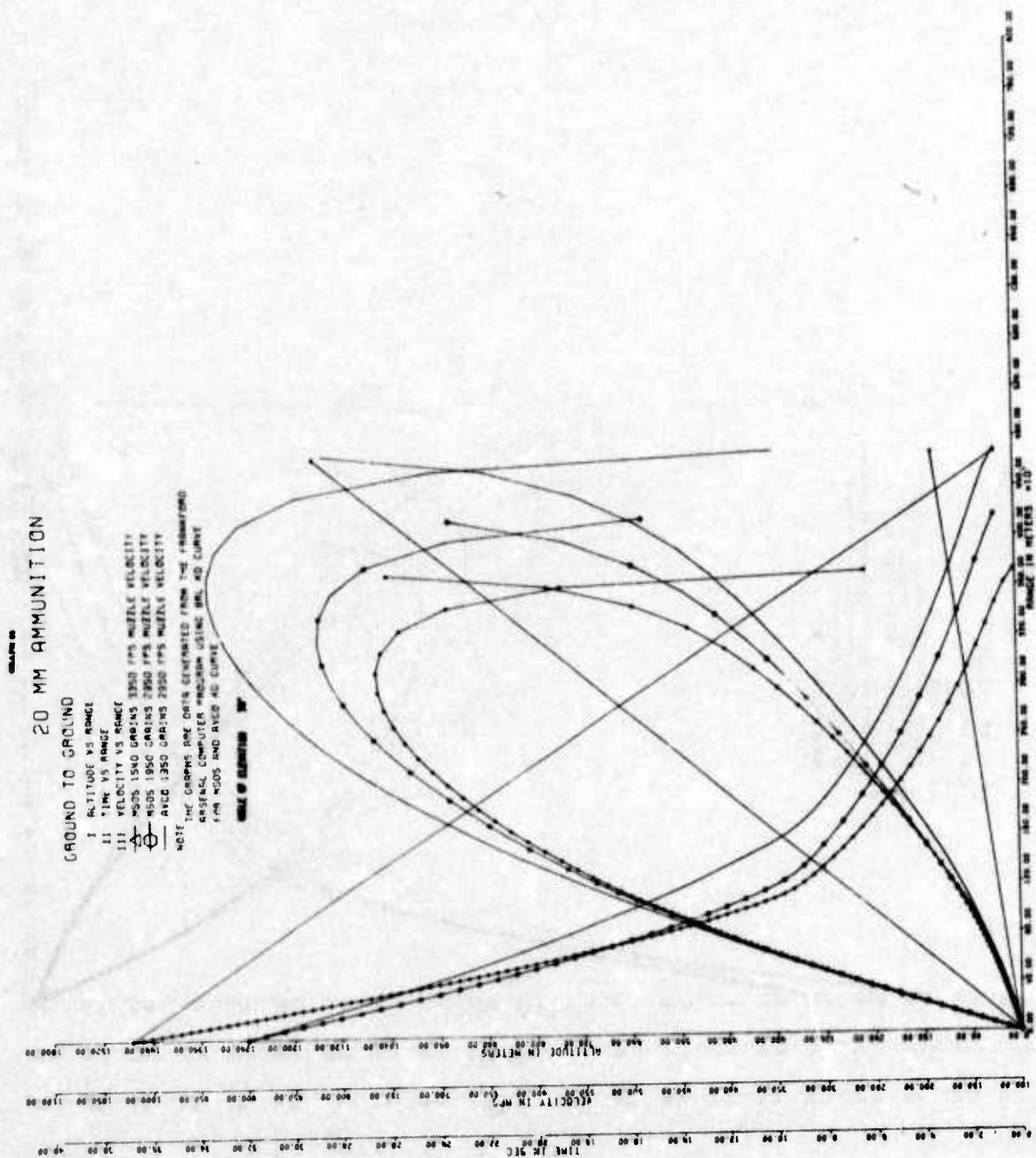
I ALTITUDE VS RANGE
II TIME VS RANGE
III VELOCITY VS RANGE
IV MSOS 1540 GRAINS 3300 FPS MISSILE VELOCITY
V MSOS 1850 GRAINS 3900 FPS MISSILE VELOCITY
VI MSOS 1950 GRAINS 3900 FPS MISSILE VELOCITY
VII MSOS 1950 GRAINS 3900 FPS MISSILE VELOCITY

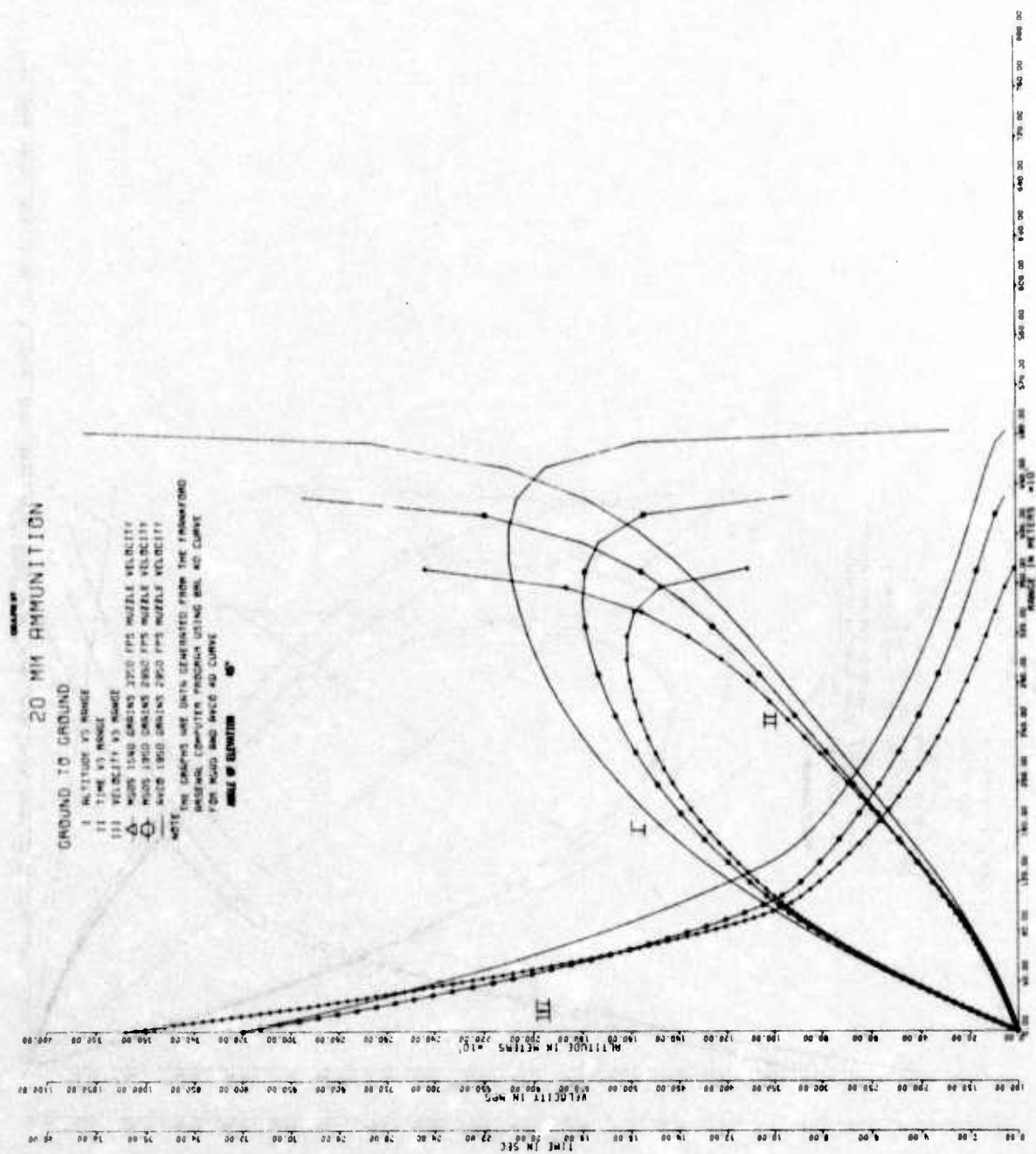
NOTE: THE GRAPHS ARE DATA GENERATED FROM THE FLYING
MAGNETIC COMPUTER PROGRAM USING GNL NO. 10 CURVE
FOR MSOS AND AUCD NO. 10 CURVE

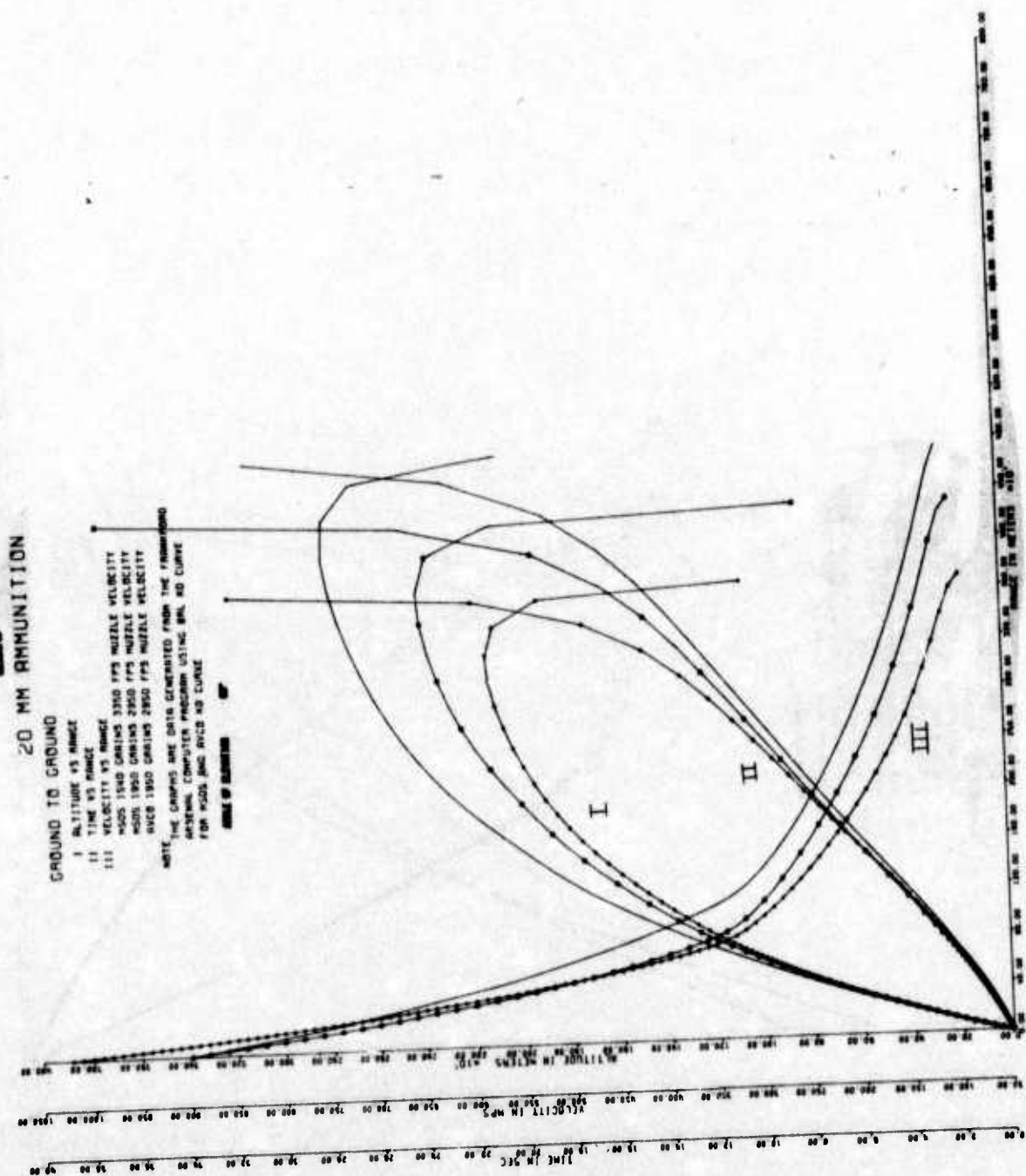
SCALE OF DISTANCE 100'



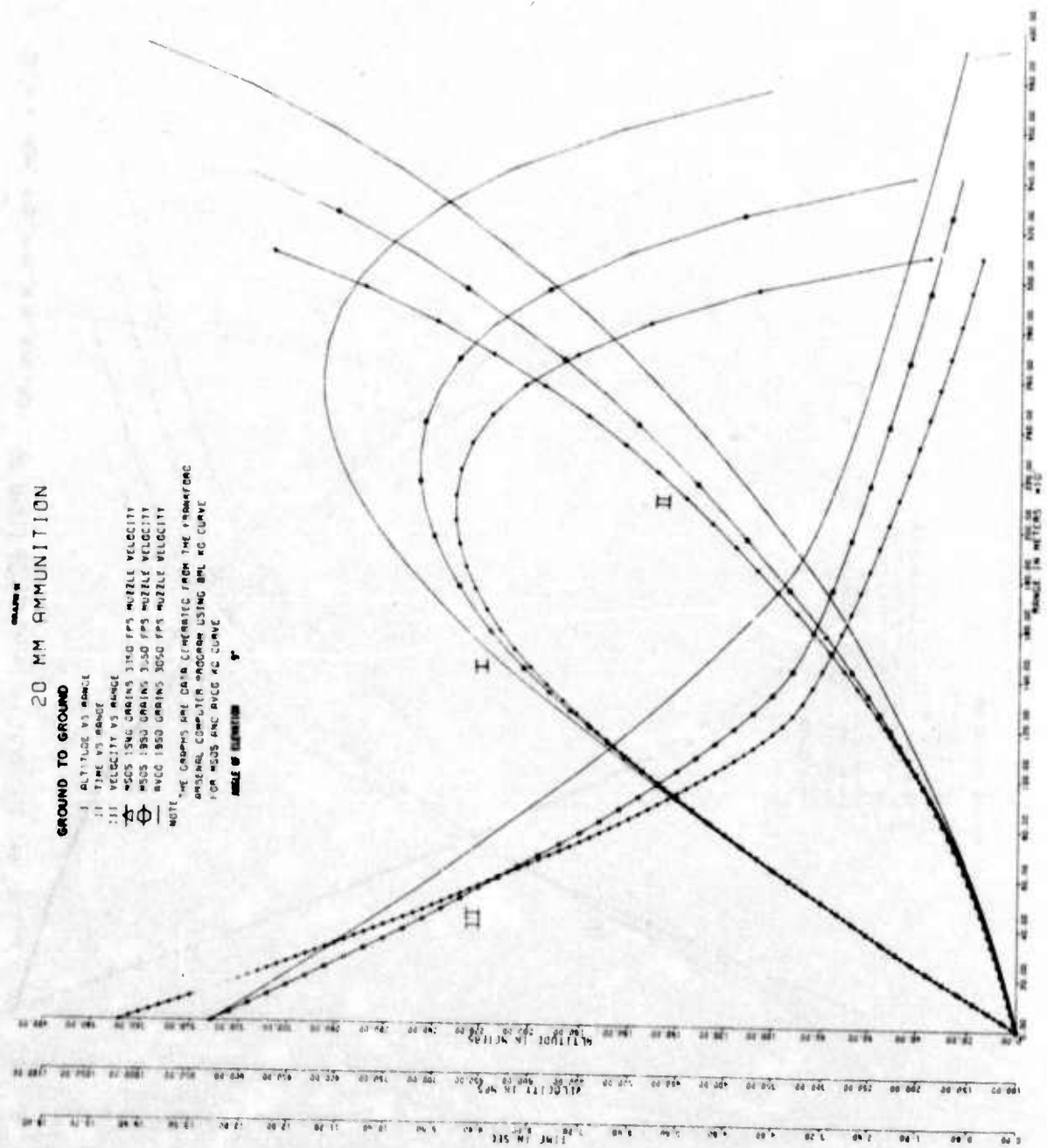


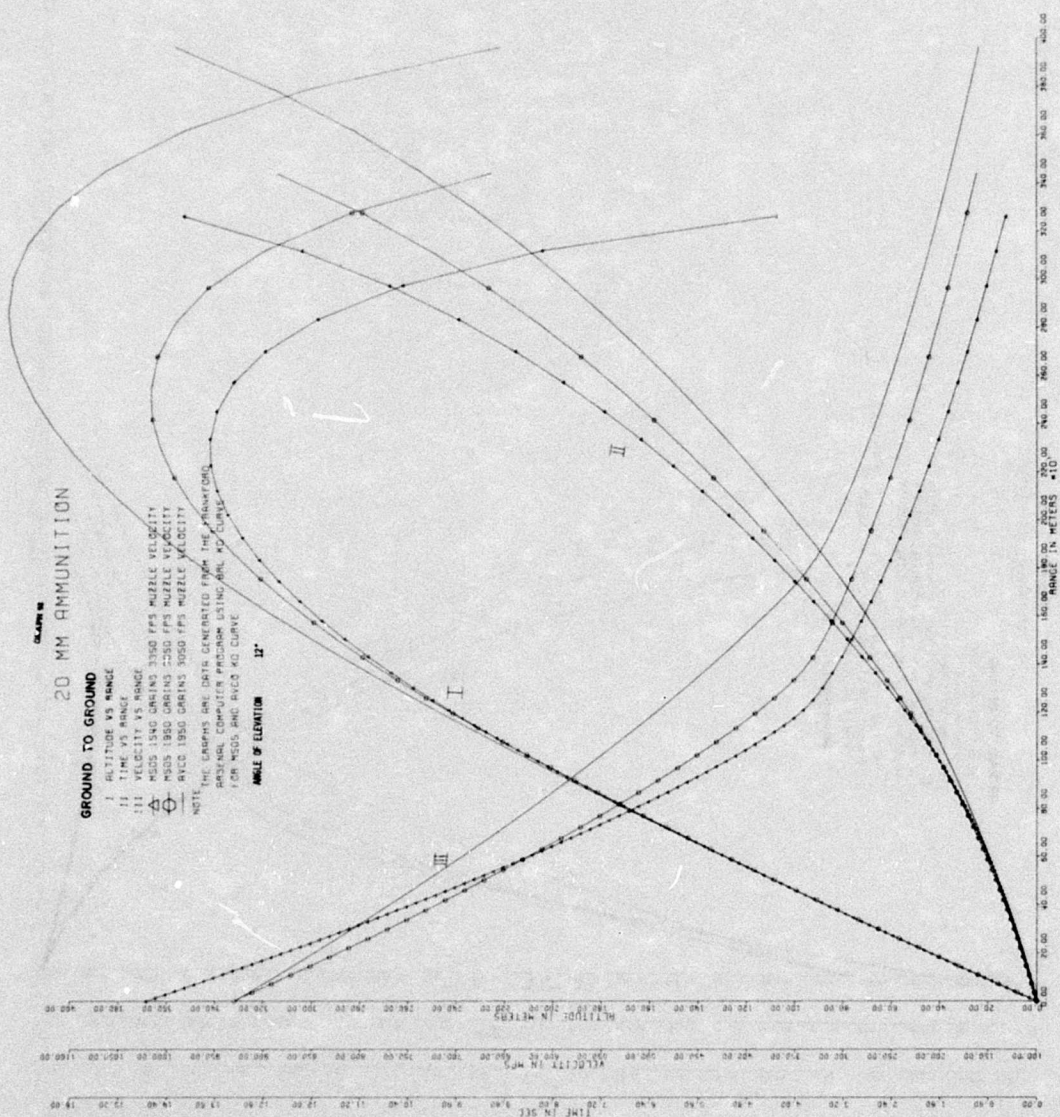


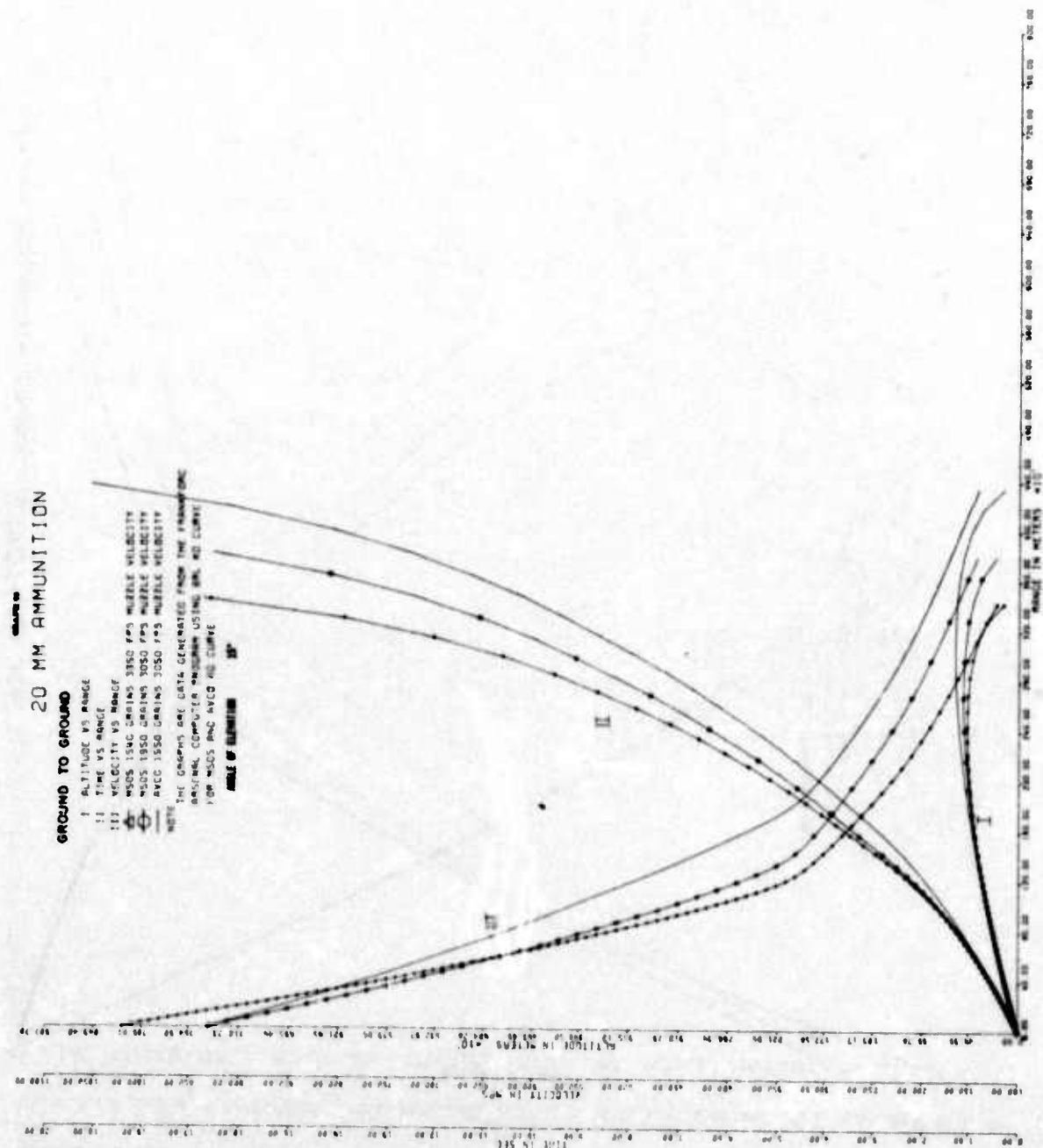












20 MM AMMUNITION

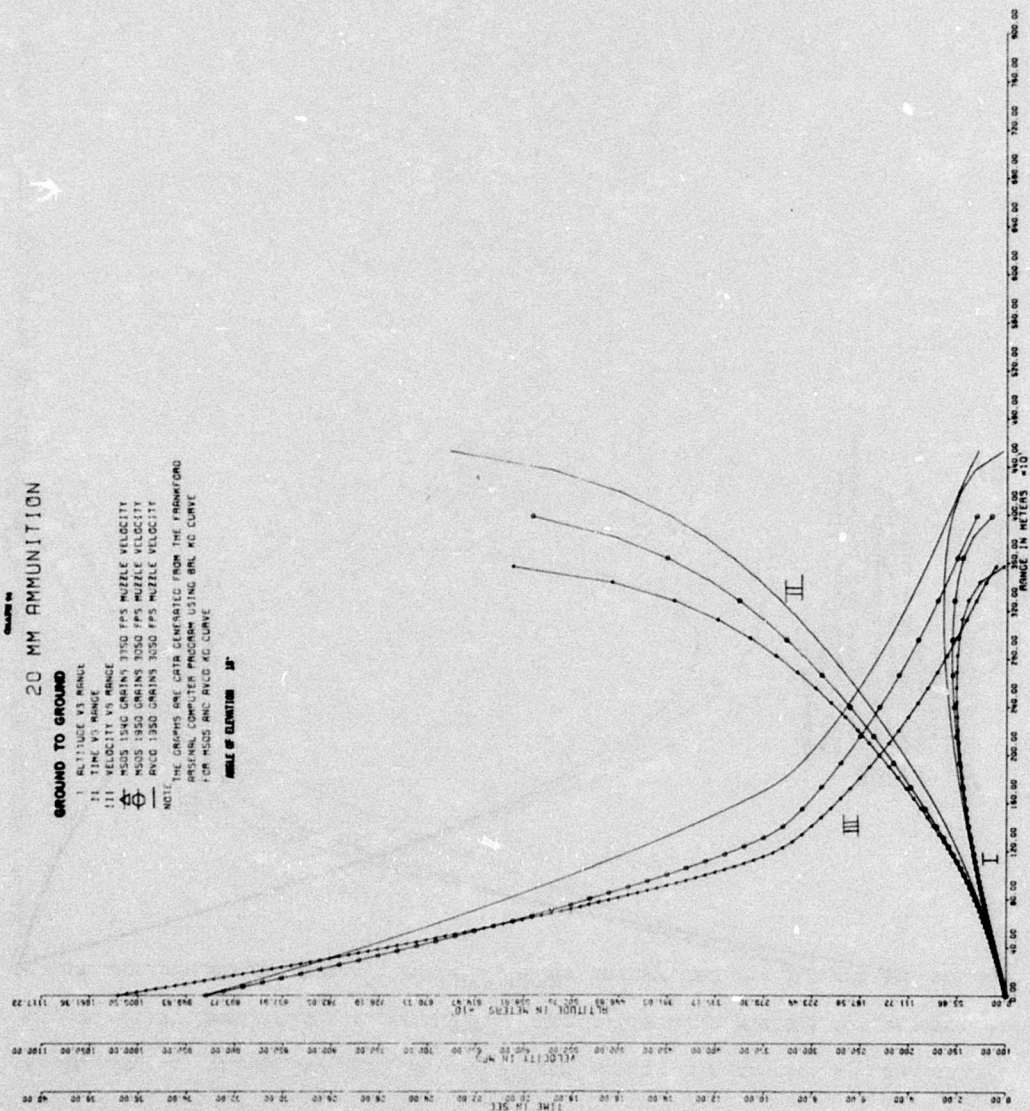
GROUND TO GROUND

I ALTITUDE VS RANGE
 II TIME VS RANGE
 III VELOCITY VS RANGE

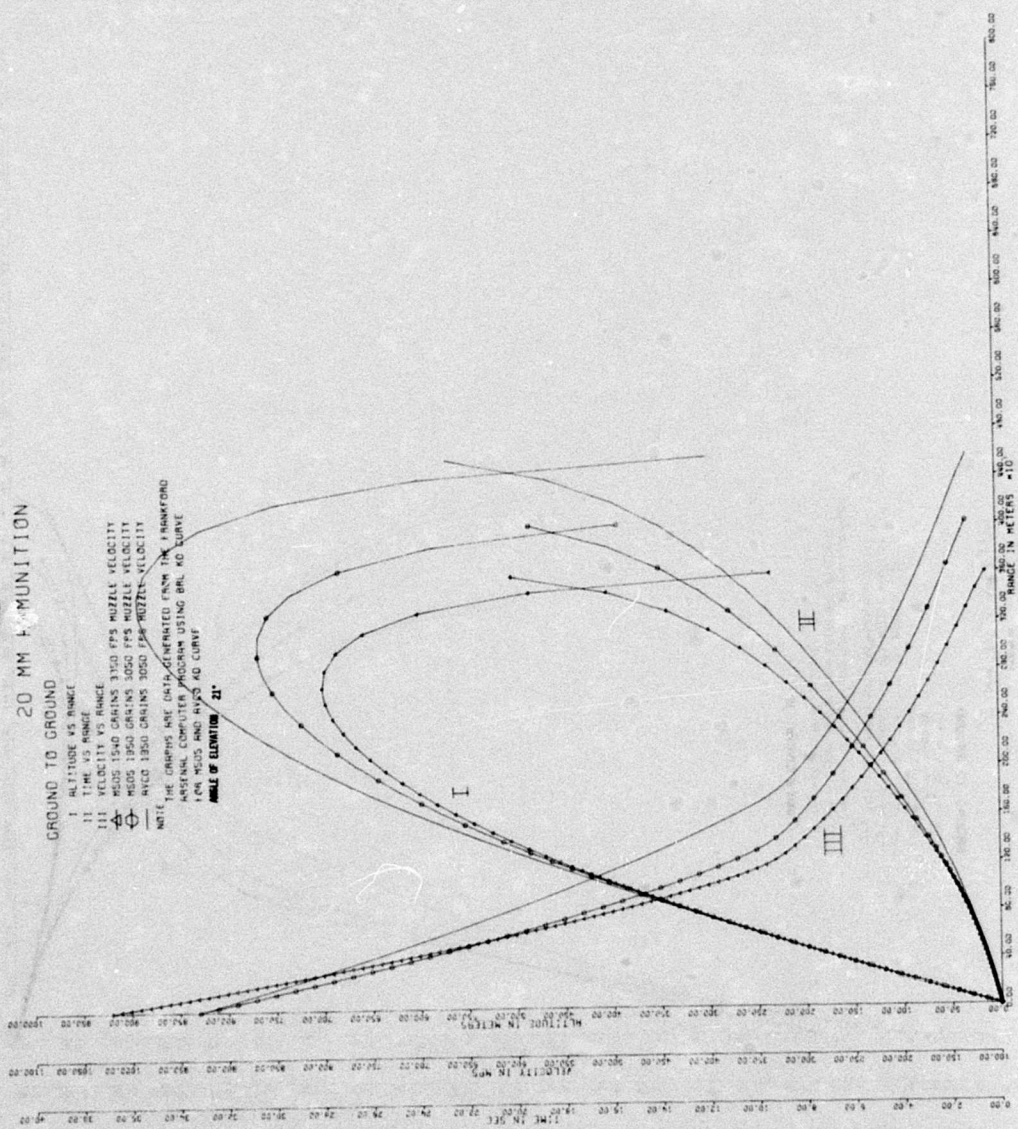
MS05 1540 GRAINS 3750 FPS MUZZLE VELOCITY
 MS05 1850 GRAINS 3050 FPS MUZZLE VELOCITY
 RYGD 1350 GRAINS 3050 FPS MUZZLE VELOCITY

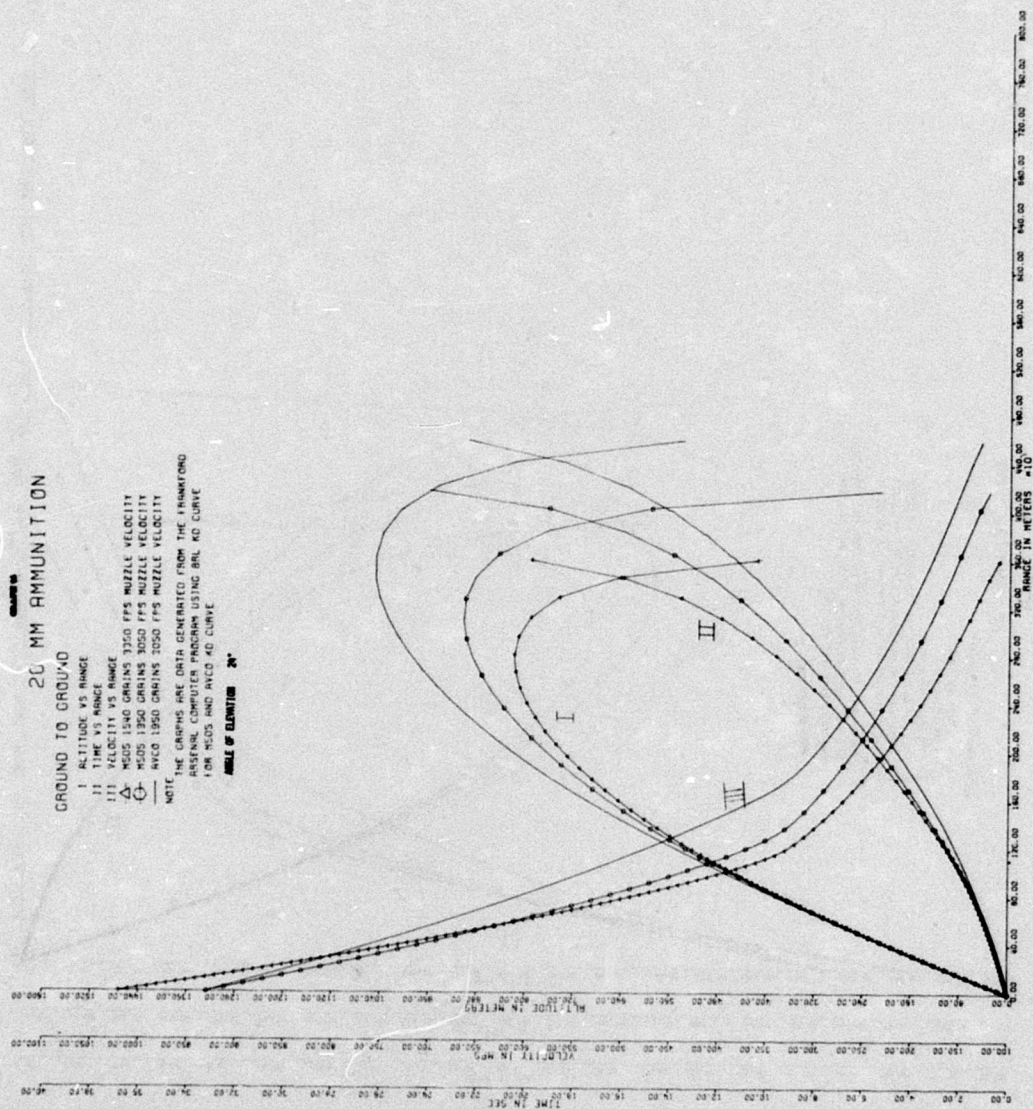
NOTE: THE GRAPHS ARE DATA GENERATED FROM THE FRANKFORD
 ARSENAL COMPUTER PROGRAM USING BRL KC CURVE
 FOR MS05 AND RYGD KC CURVE

SCALE OF DISTANCE 10'



COPY AVAILABLE TO DDC DOES NOT
 PERMIT FULLY LEGIBLE PRODUCTION





45-2538-47

GROUND TO GROUND

1 ALTITUDE VS RANCE

TIME VS RANGE

III VELOCITY VS RANGE

Model	Grains	FPS	Muzzle Velocity
MS05	1540	3350	FPS Muzzle Velocity
MS05	1050	3000	FPS Muzzle Velocity

	AWS	1950	CRAINS	3050	FPS	MUZZLE VELOCITY
—	AWC	1950	CRAINS	3050	FPS	MUZZLE VELOCITY

316
11700730 17770W F41 050F EN1W0 0561 070W

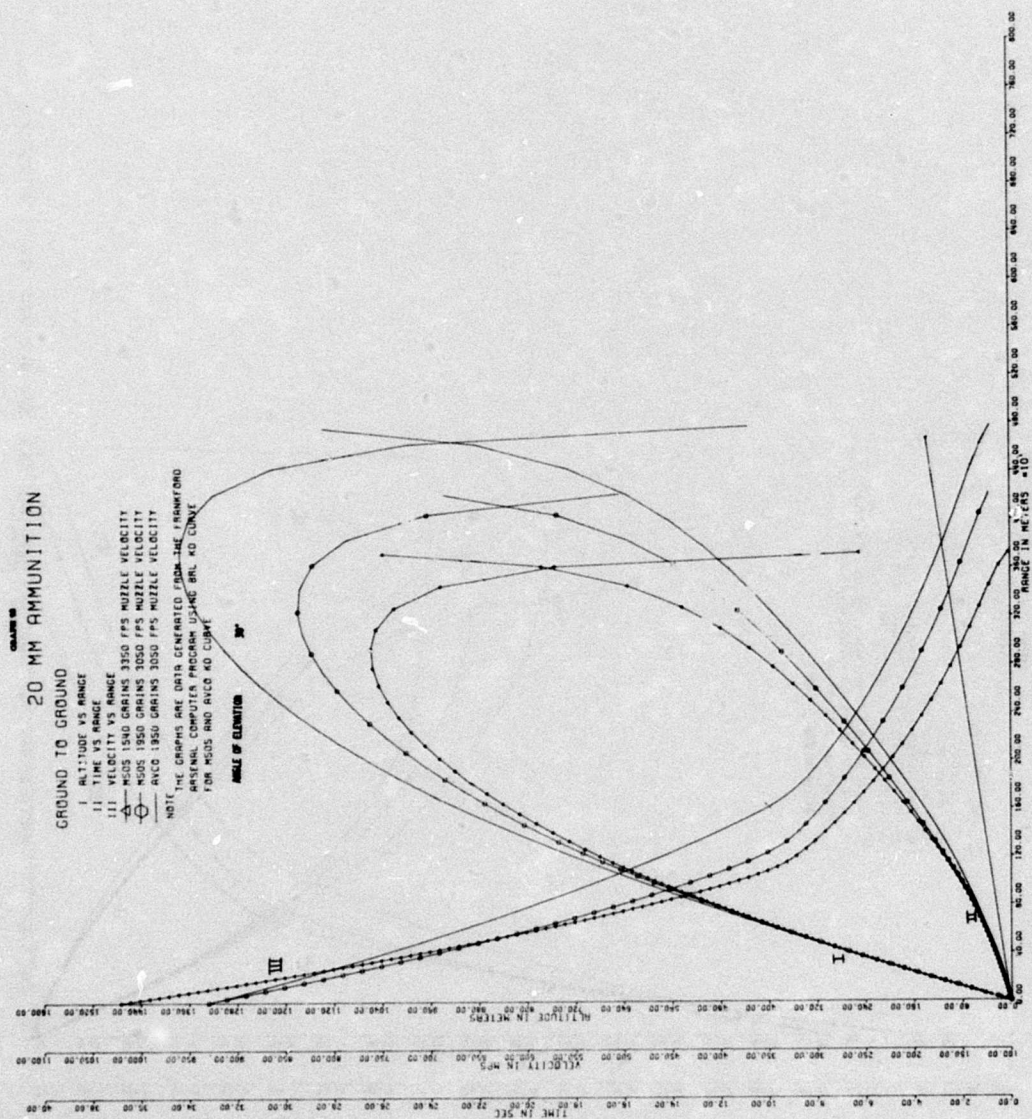
THE GRAPHS ARE DATA GENERATED FROM THE FRANKFORD

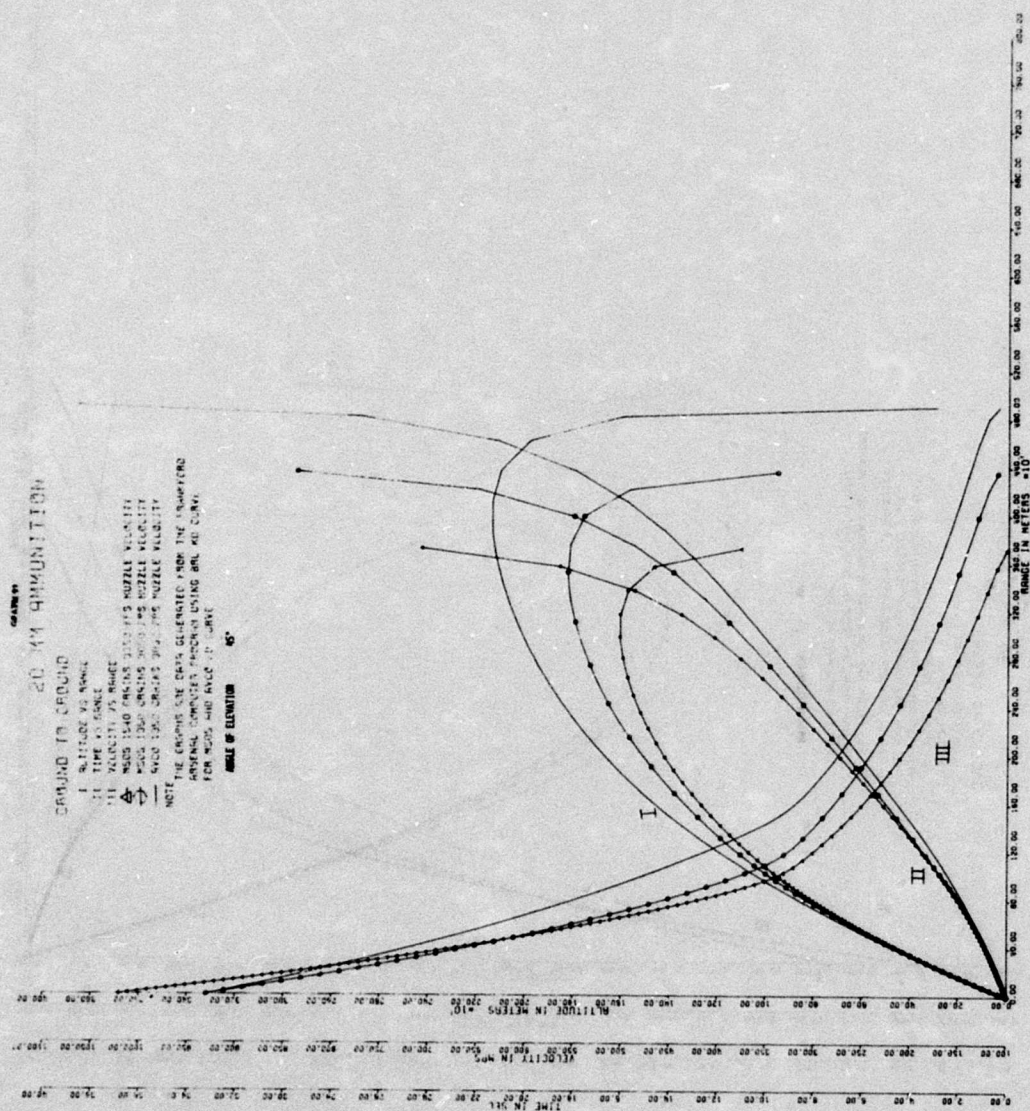
ARSENAL COMPUTER PROGRAM US
100 WASH SQD SQD 4000

FOR MS05 AND HVC8 AD

ANGLE OF ELEVATION 27°





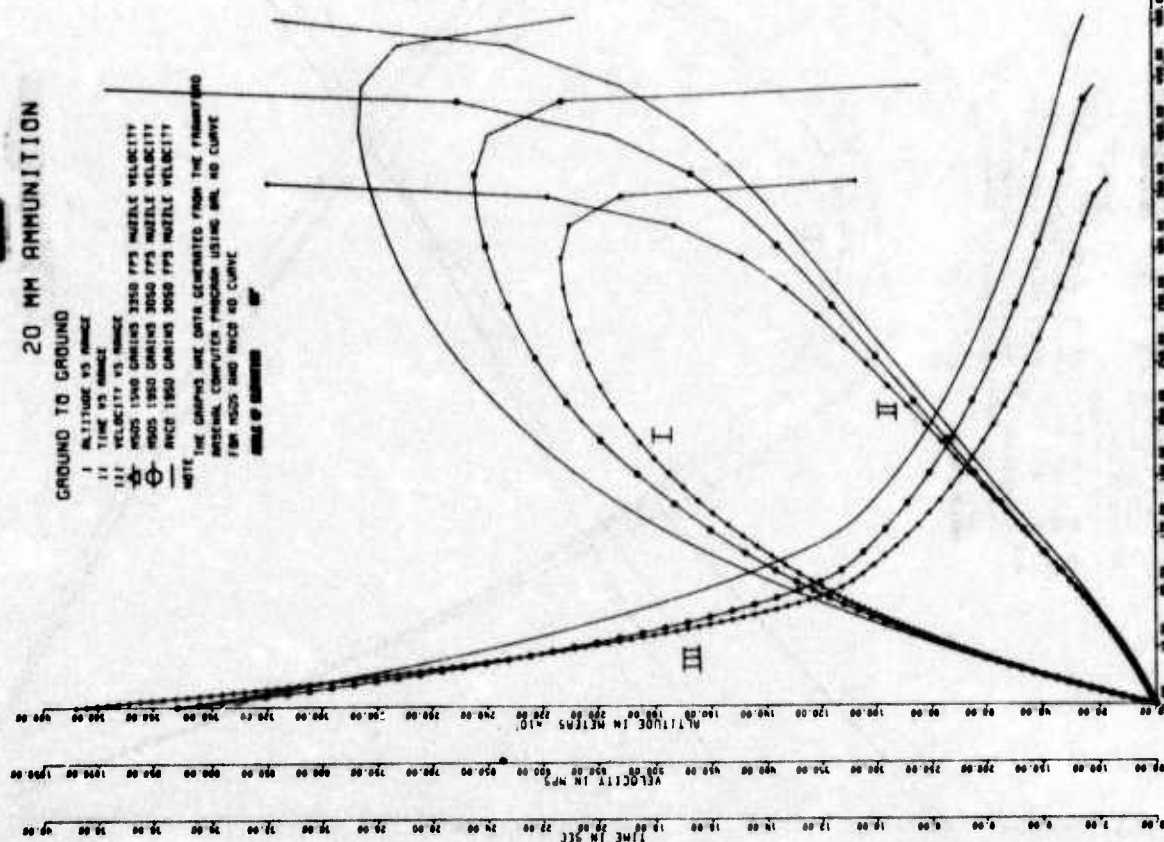


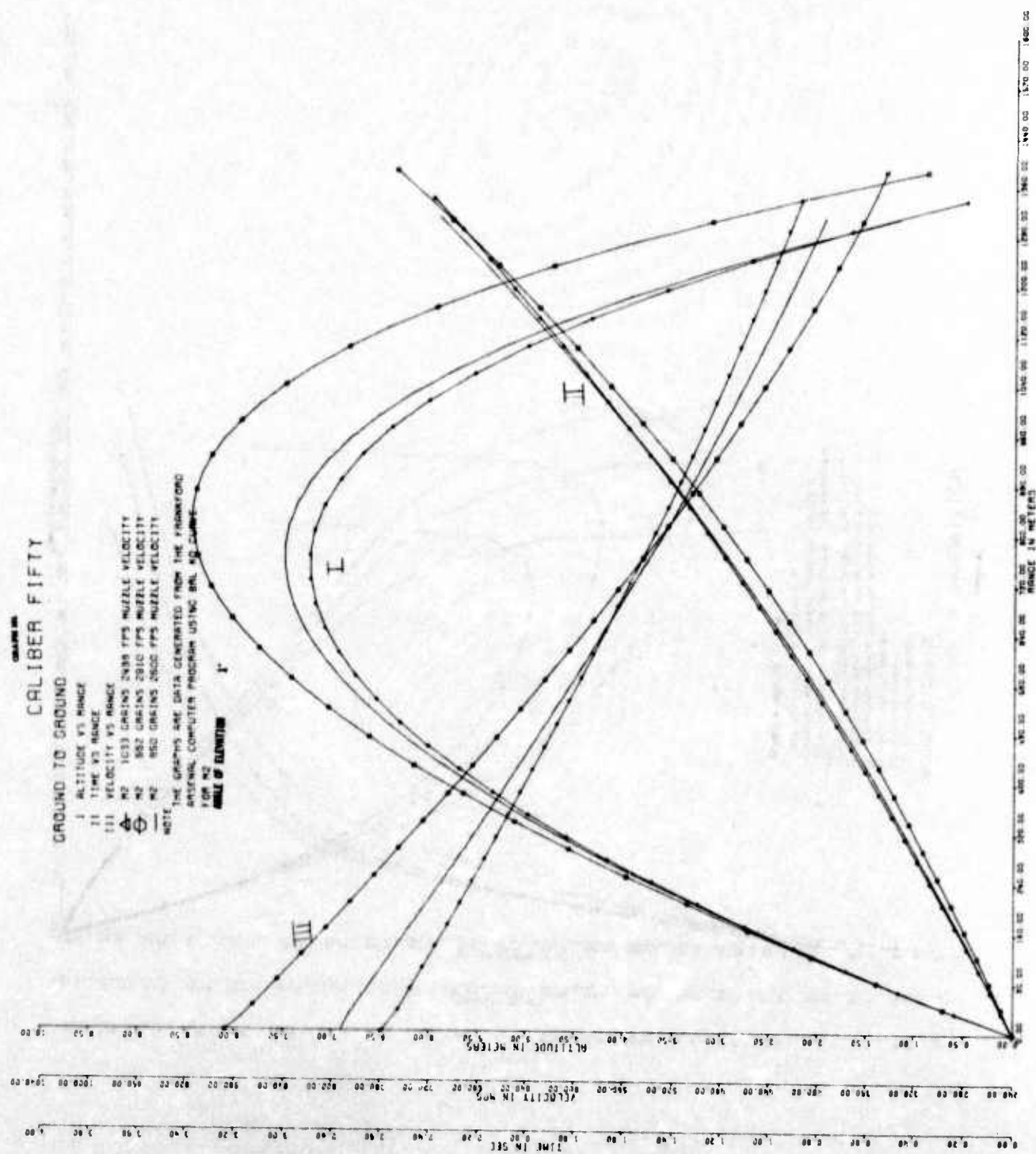
20 M
GROUND TO GROUND

```

1 IN LITRUE VS RANGE
2 THE 95 RANGE
3 VELOCITY VS RANGE
4 1905 1960 GAINS 3200 FPS MUZZLE VELOCITY
5 1905 1960 GAINS 3000 FPS MUZZLE VELOCITY
6 1960 GAINS 3000 FPS MUZZLE VELOCITY
7 THE GAINS ARE DATA GENERATED FROM THE FRAMM/FORD
8 MUZZLE COMPUTER PROGRAM USING M16 AD CURVE
9 FOR 1905 AND M16 AD CURVE
10 END OF GAINS

```





**COPY AVAILABLE TO LDC DOES NOT
PERMIT FULLY LEGIBLE PRODUCTION**

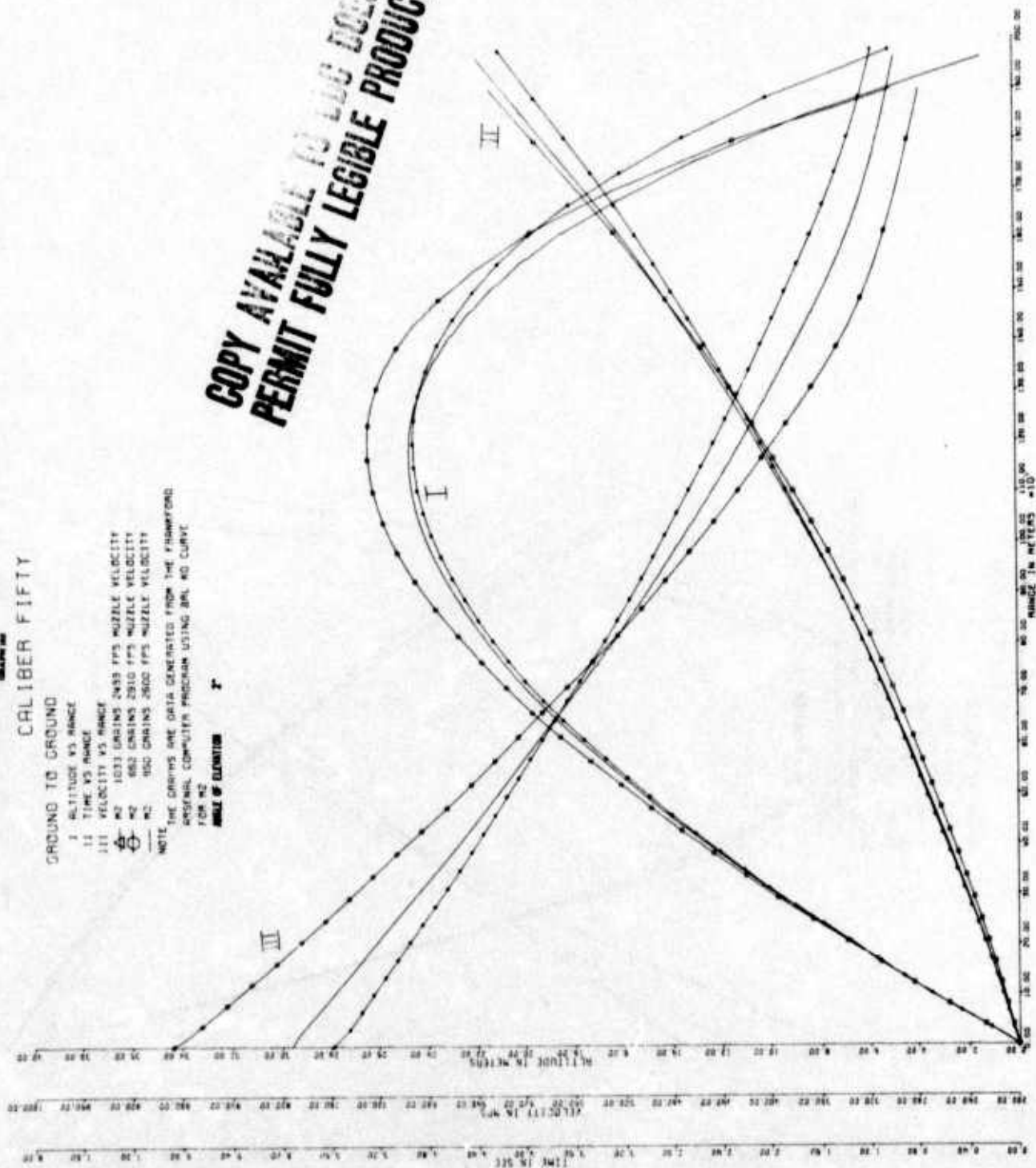
CALIBER FIFTY

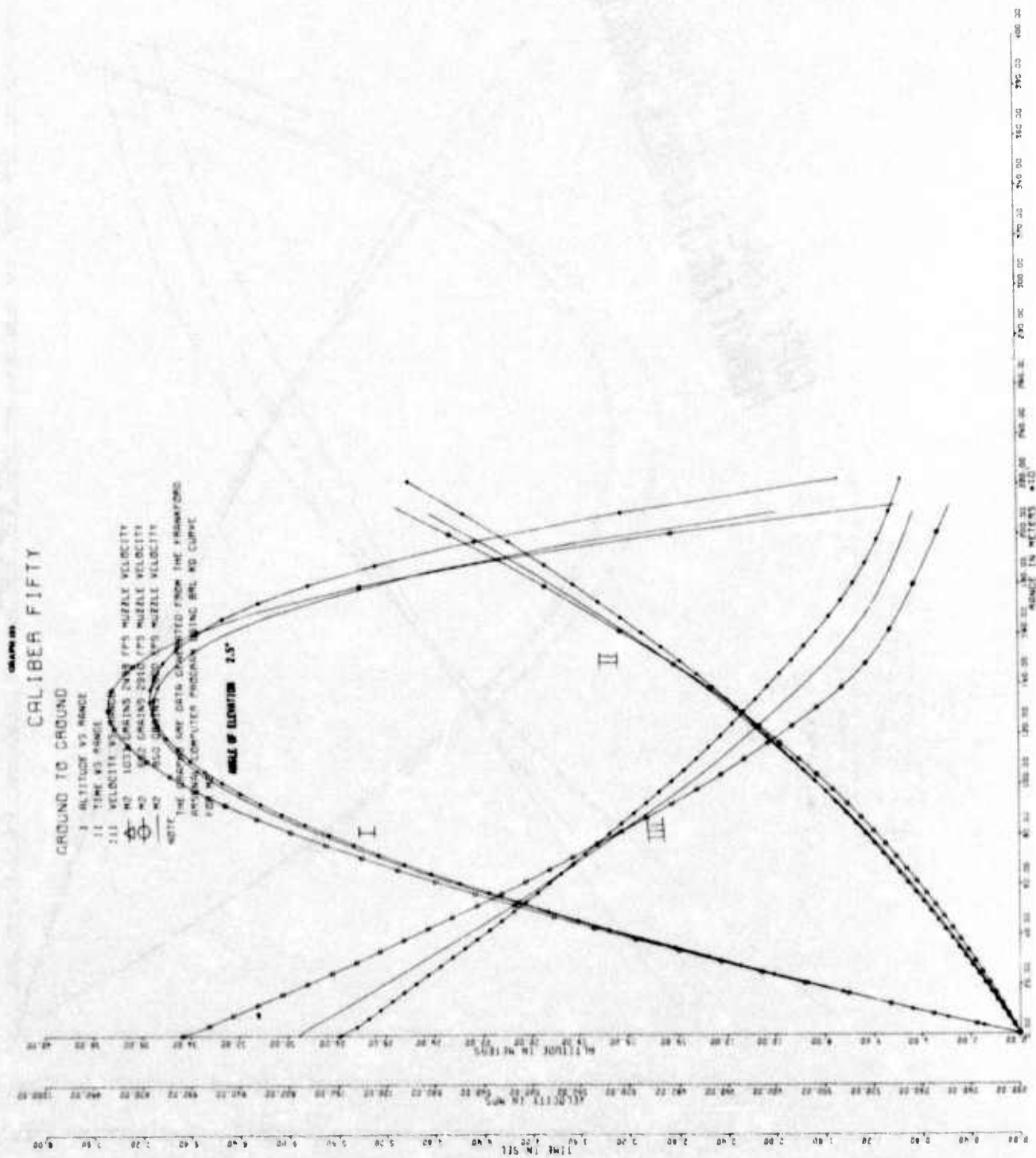
GROUND TO GROUND

- I ALTITUDE VS RANGE
- II TIME VS RANGE
- III VELOCITY VS RANGE
- IV 1033 GRAINS 2435 FPS MUZZLE VELOCITY
- V 662 GRAINS 2910 FPS MUZZLE VELOCITY
- VI 180 GRAINS 3600 FPS MUZZLE VELOCITY

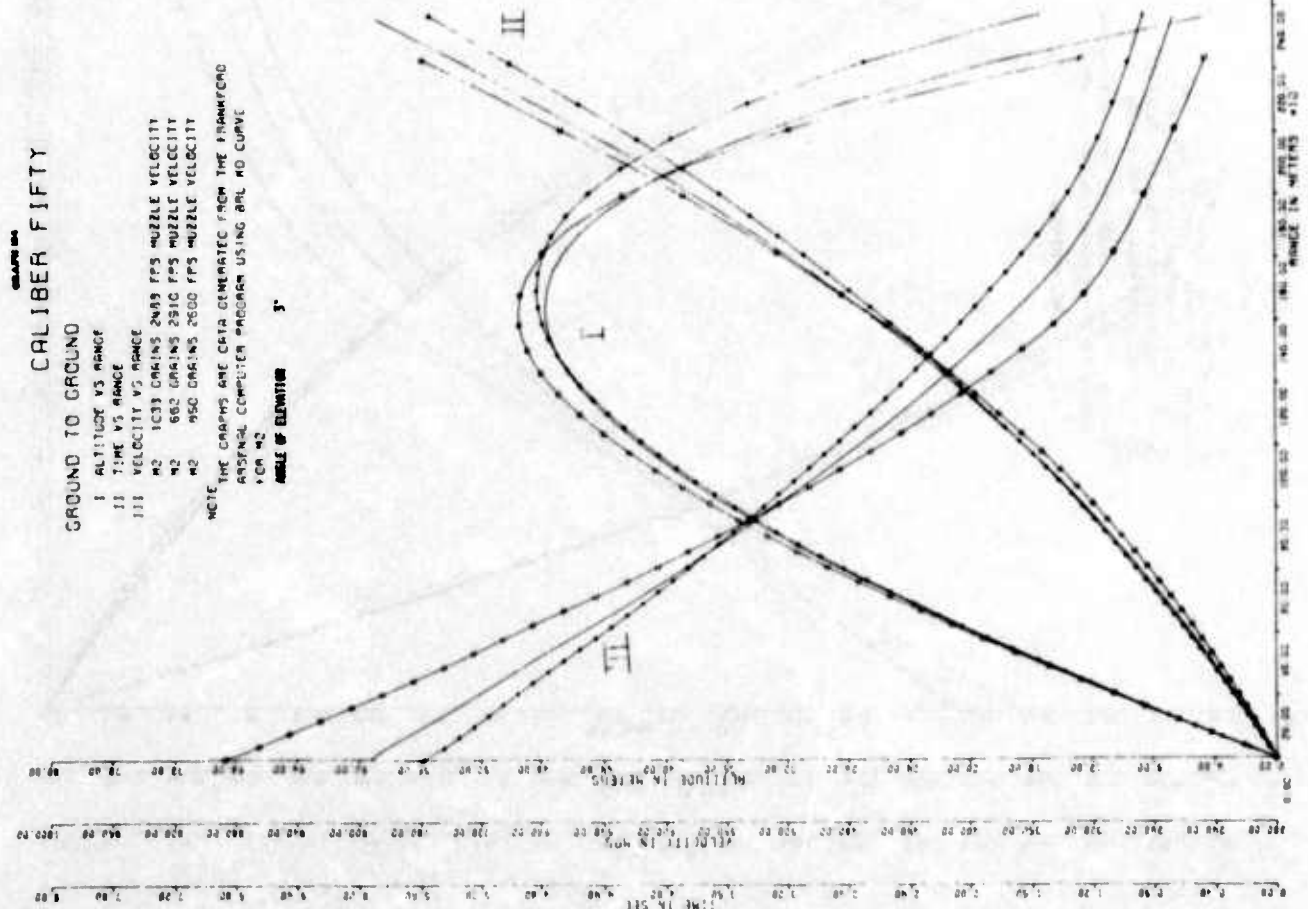
NOTE: THE GRAPHS ARE DATA GENERATED FROM THE FURNACE
ORIGINAL COMPUTER PROGRAM USING 30% NO CURVE
FOR #2

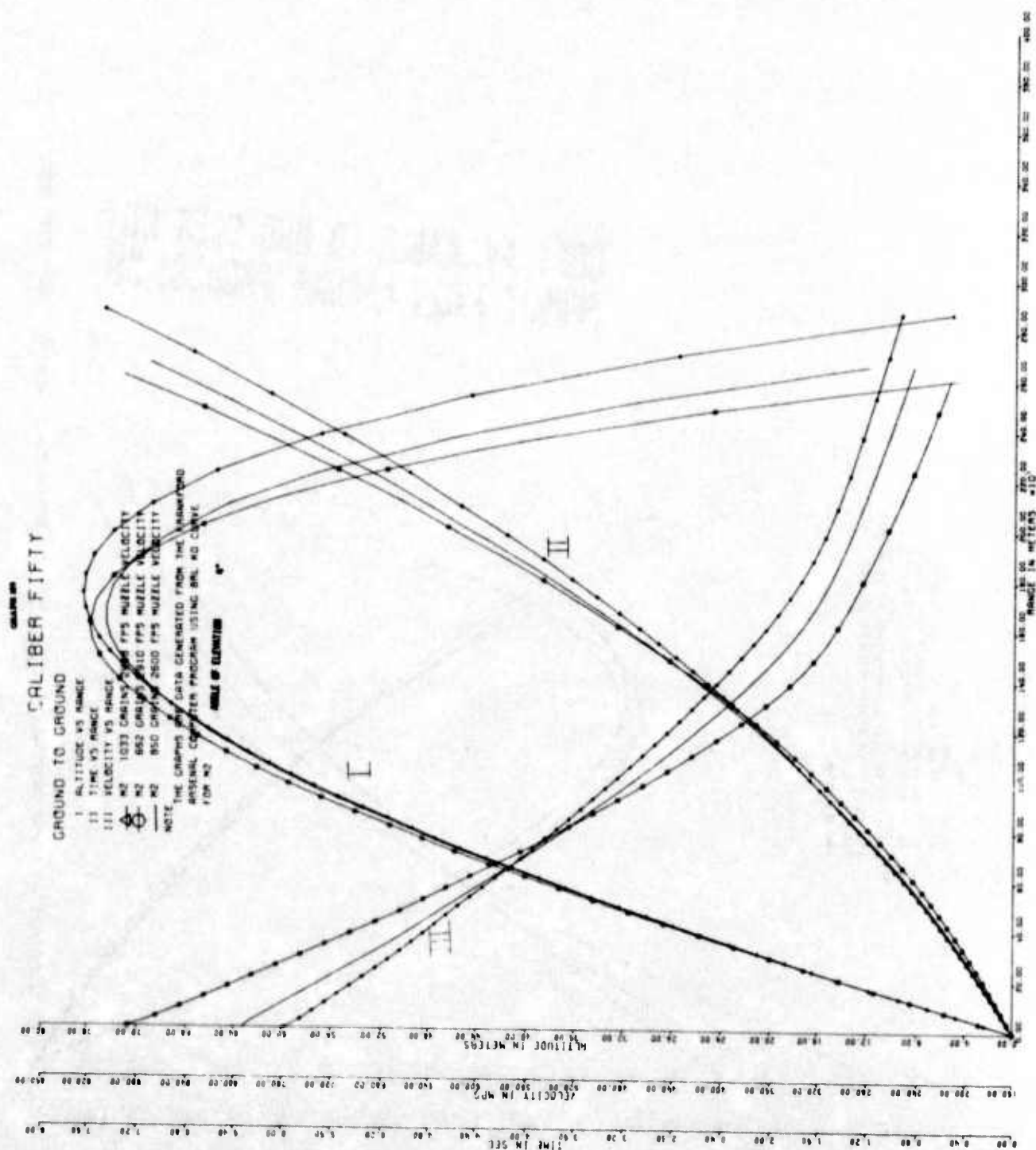
ANGLE OF ELEVATION 2°

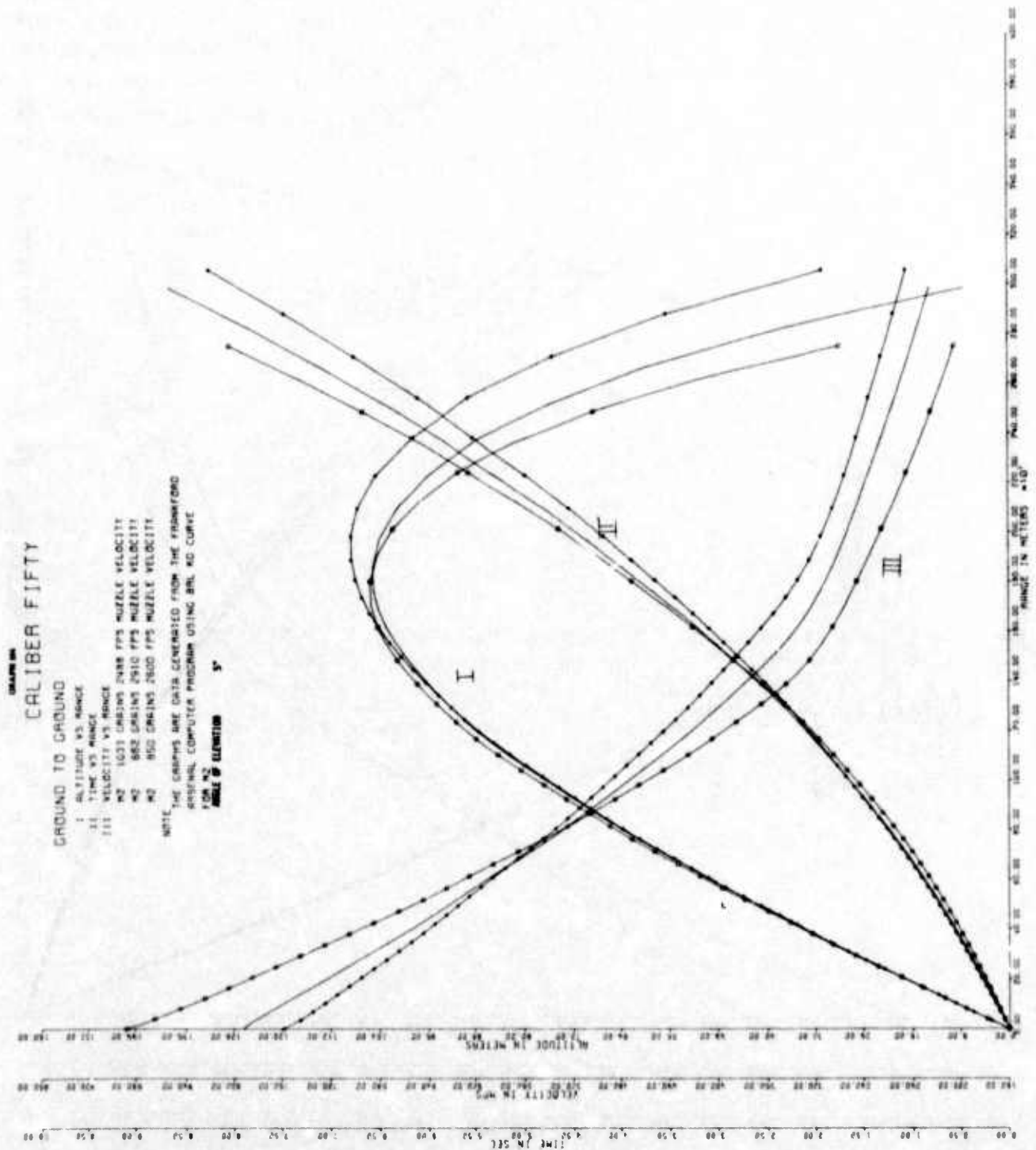


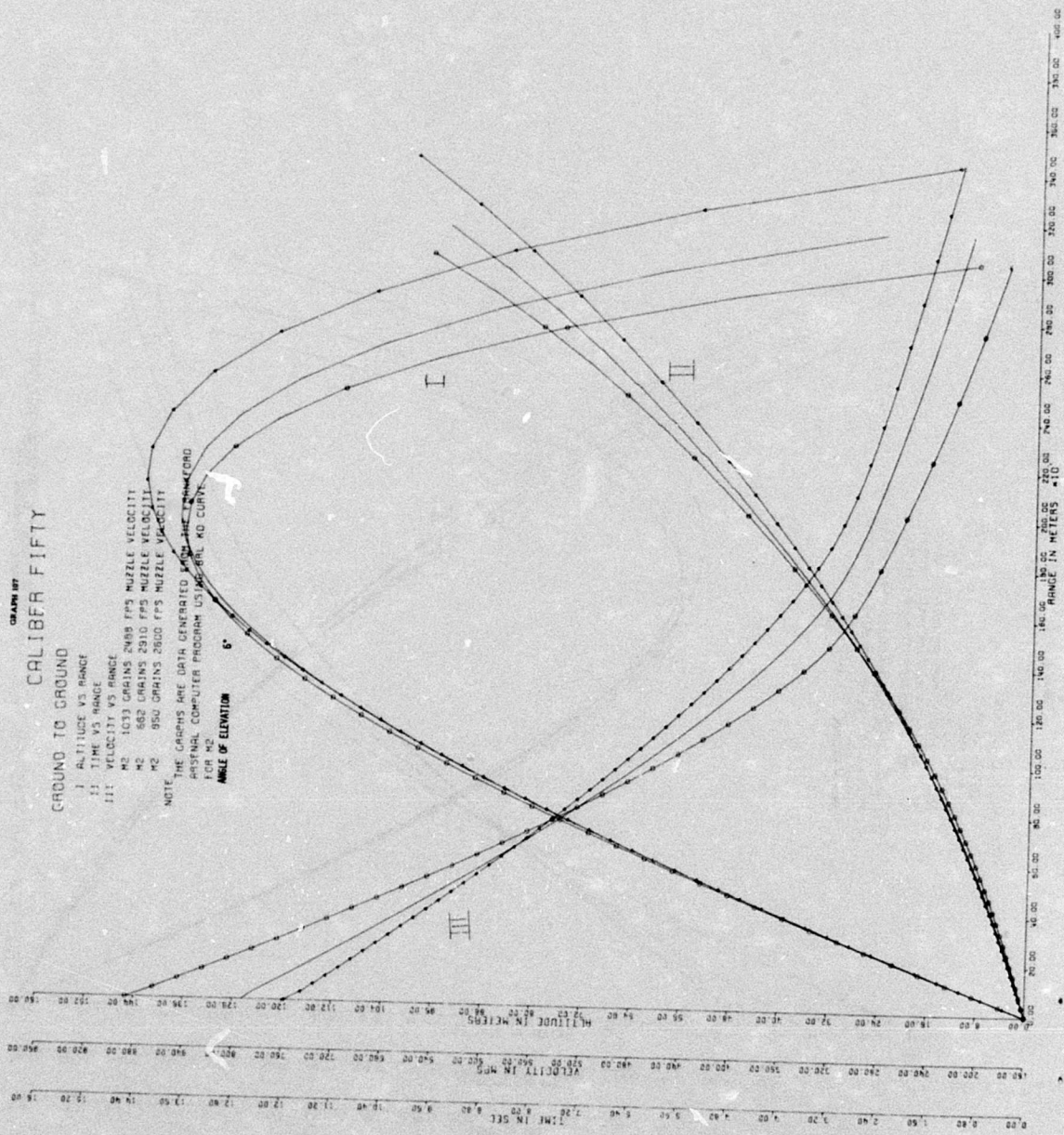


COPY AVAILABLE TO DBC DOES NOT
PERMIT FULLY LEGIBLE PRODUCTION









COPY AVAILABLE TO DDC DOES NOT
PERMIT FULLY LEGIBLE PRODUCTION

CALIBER FIFTY

GROUND TO GROUND

1 ALTITUDE VS RANGE

2 TIME VS RANGE

3 VELOCITY VS RANGE

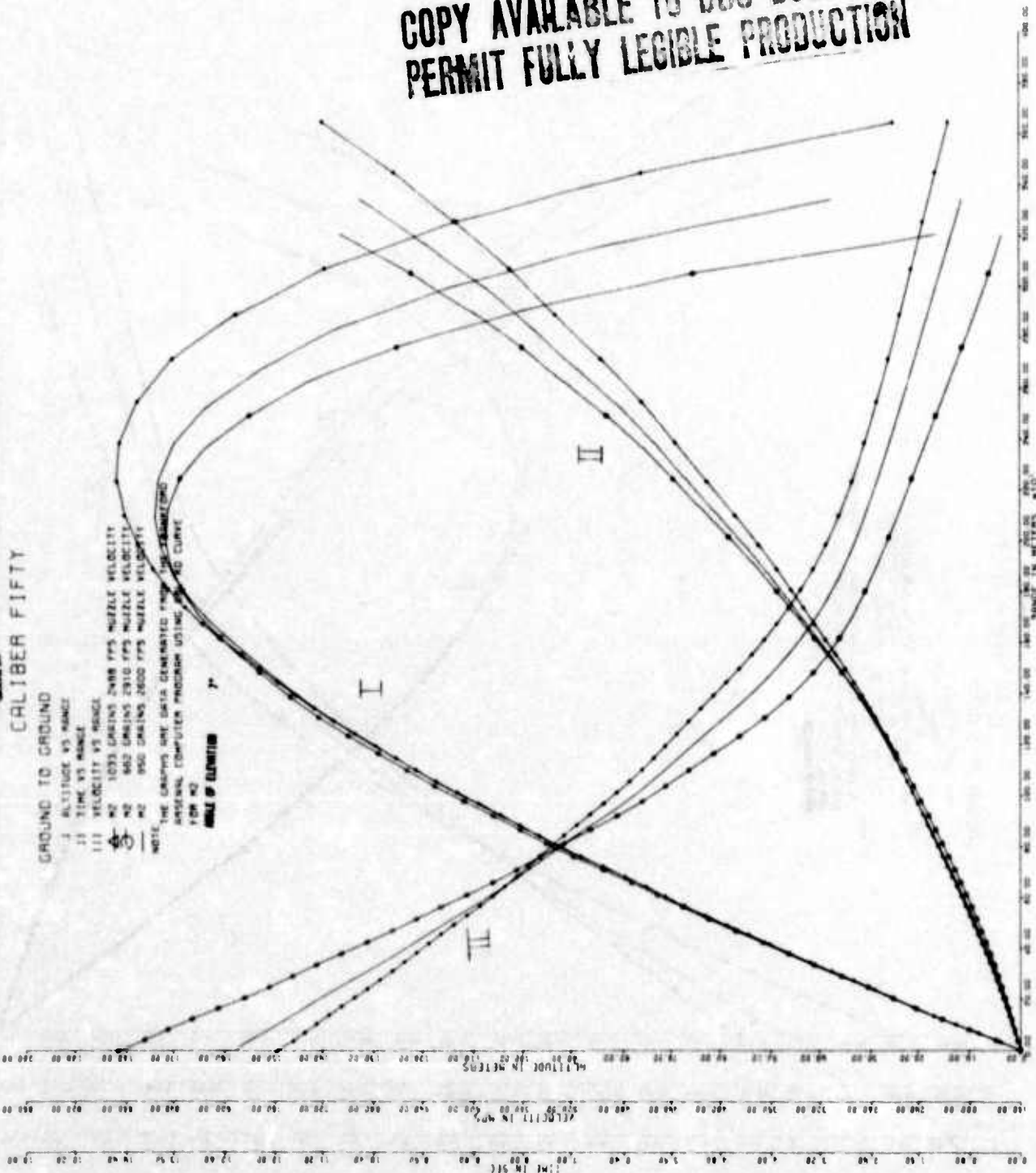
4 1033 GRAINS 2988 FPS MUZZLE VELOCITY

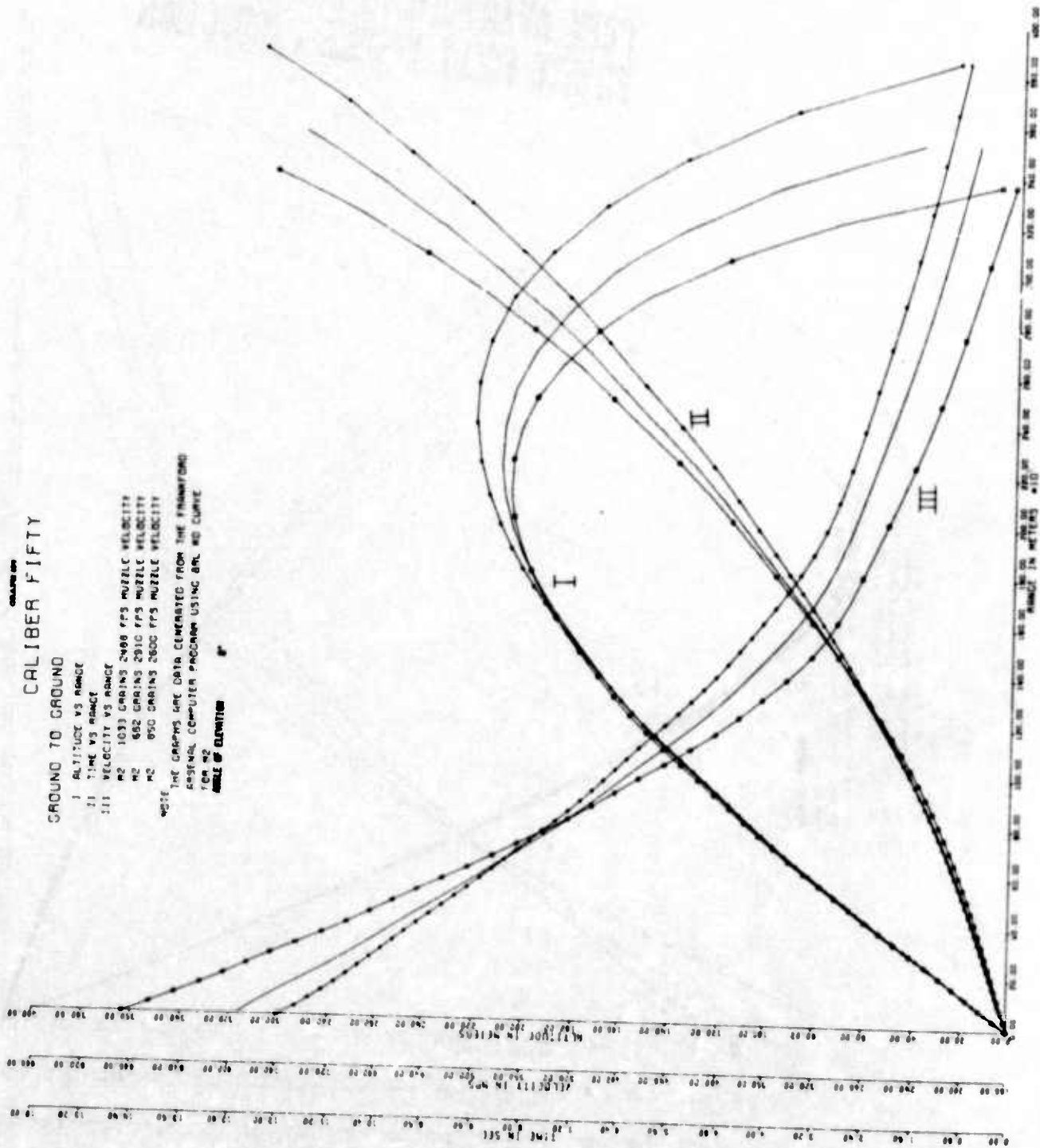
5 860 GRAINS 2910 FPS MUZZLE VELOCITY

6 950 GRAINS 2600 FPS MUZZLE VELOCITY

NOTE: THE GRAPHS ARE DATA GENERATED FROM THE STANDARD
ARTISAN COMPUTER PROGRAM USING THE
FOR M2

SCALE OF ALTITUDE





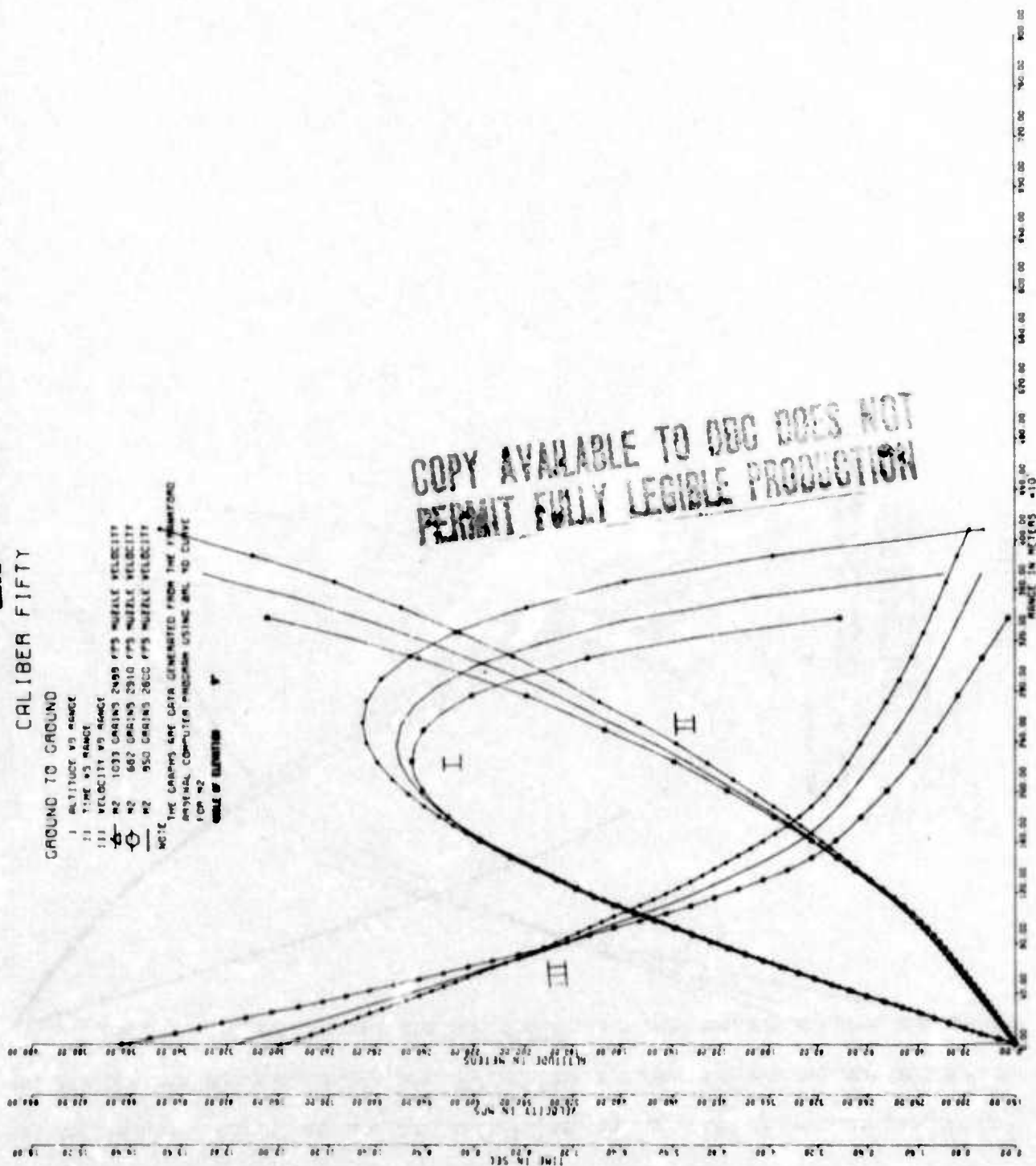
GRAPH 10 CALIBER FIFTY

GROUND TO GROUND

- I ALTITUDE VS RANGE
- II TIME VS RANGE
- III VELOCITY VS RANGE
- IV 1033 GRAINS 2400 FPS Muzzle Velocity
- V 682 GRAINS 2910 FPS Muzzle Velocity
- VI 550 GRAINS 2600 FPS Muzzle Velocity

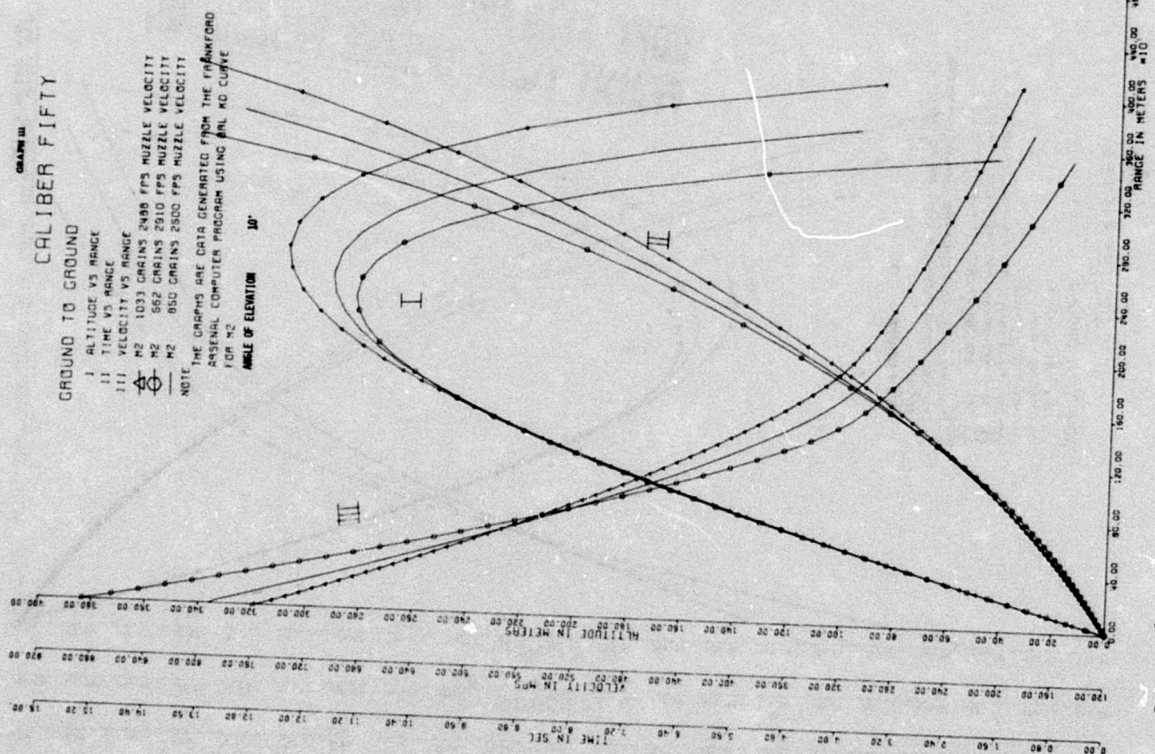
NOTE: THE GRAPHS ARE DATA GENERATED FROM THE PROGRAM
ANALYTICAL COMPUTER PROGRAM USING BALL TO CURVE
FOR #2

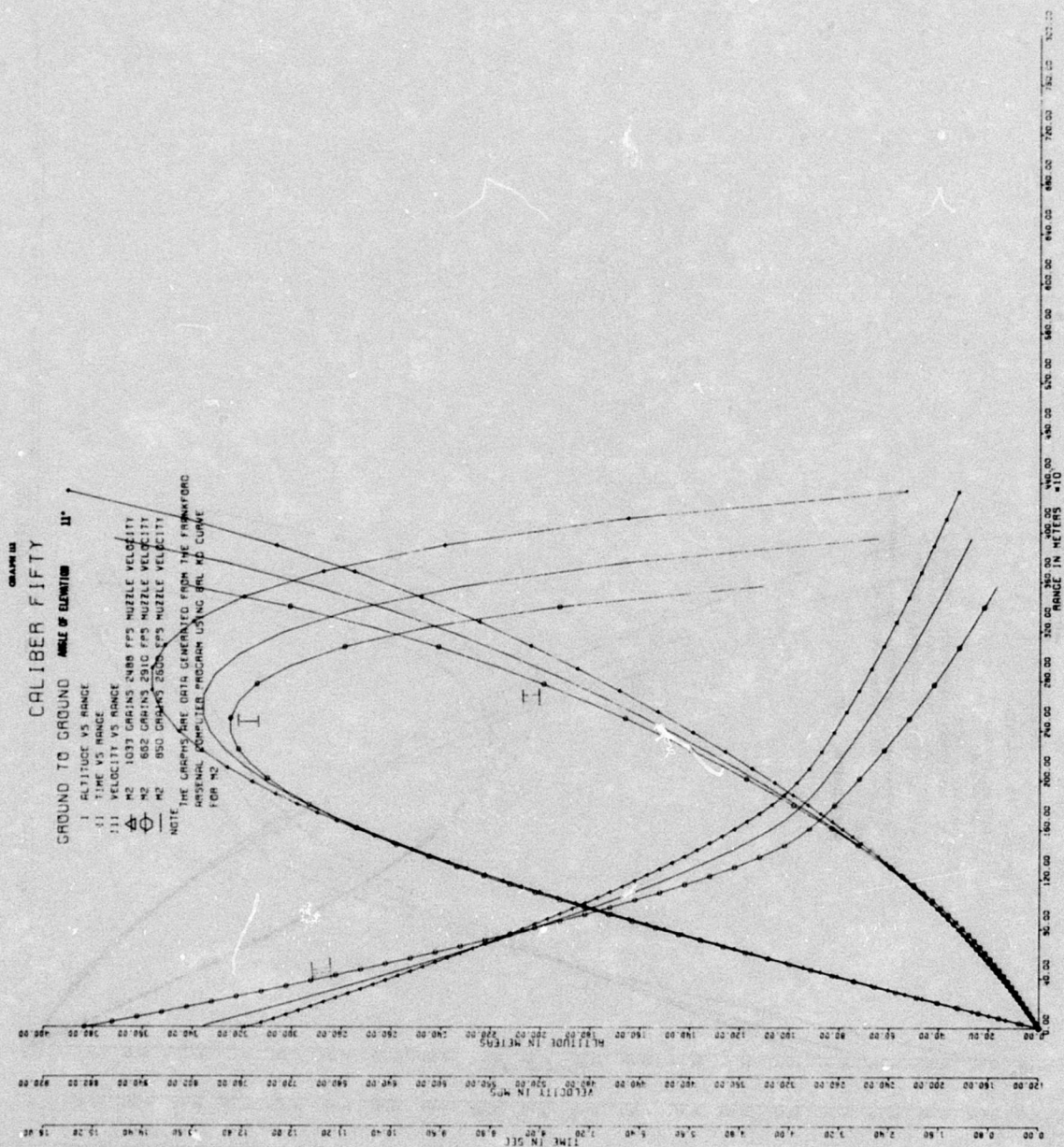
SCALE OF ELEVATION

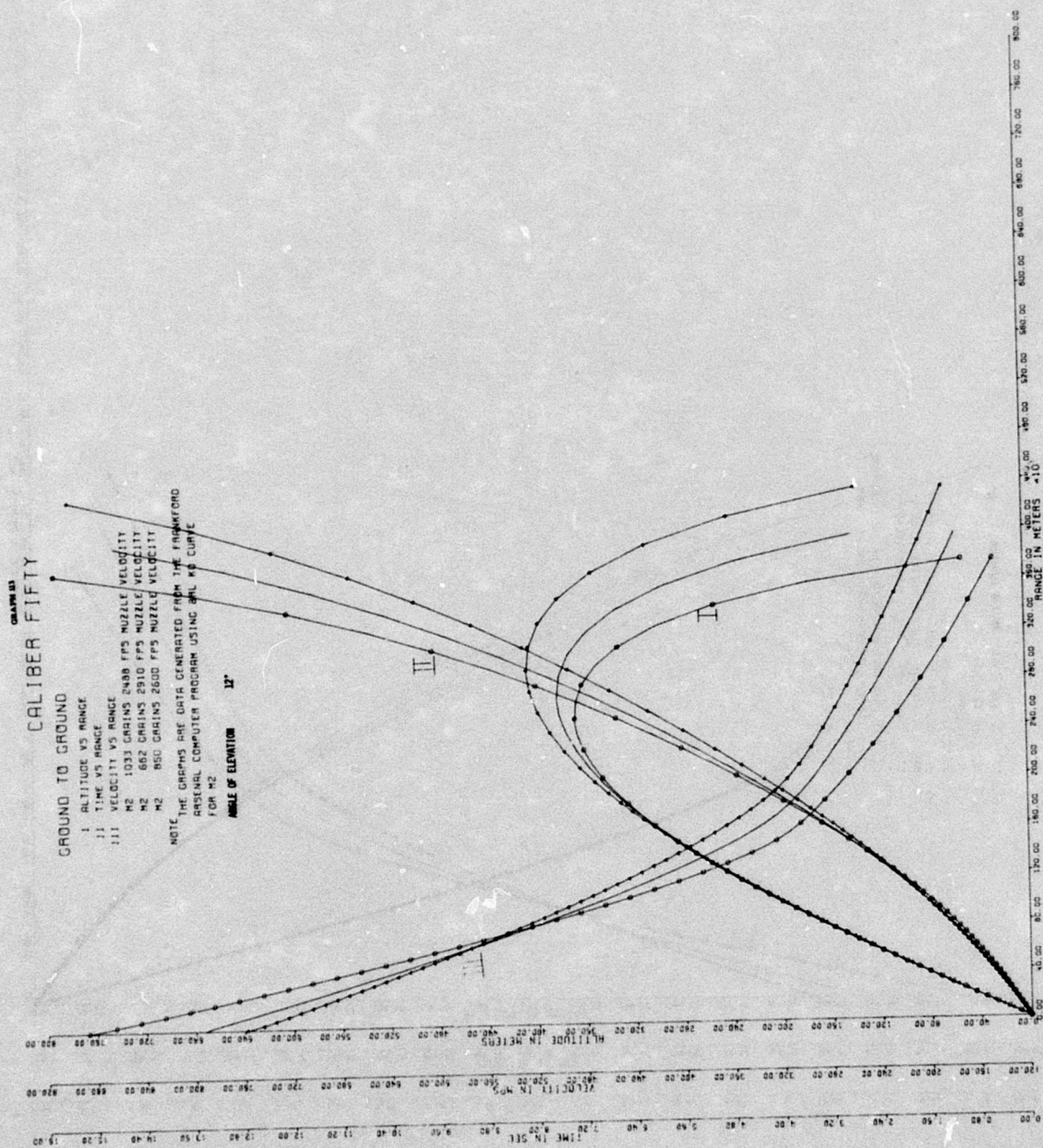


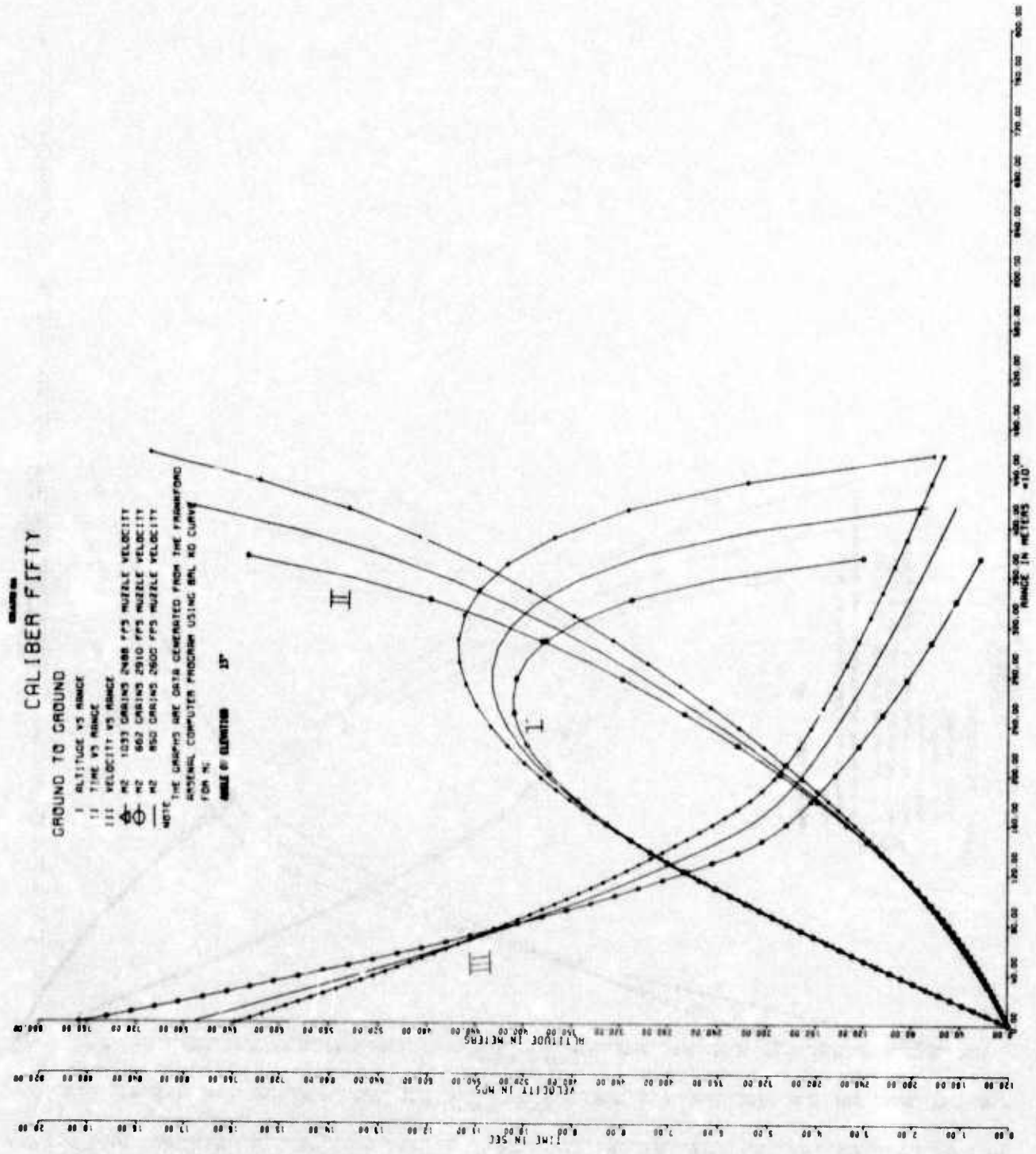
COPY AVAILABLE TO DGC DOES NOT
PERMIT FULLY LEGIBLE PRODUCTION

CHART III
CALIBER FIFTY
 GROUND TO GROUND
 I ALTITUDE VS RANGE
 II TIME VS RANGE
 III VELOCITY VS RANGE
 M2 1033 GRAINS 2485 FPS MUZZLE VELOCITY
 M2 562 GRAINS 2910 FPS MUZZLE VELOCITY
 M2 850 GRAINS 2500 FPS MUZZLE VELOCITY
 NOTE THE GRAPHS ARE DATA GENERATED FROM THE FRANKFORD
 ARSENAL COMPUTER PROGRAM USING BALL NO CURVE
 FOR M2
 ANGLE OF ELEVATION 30°









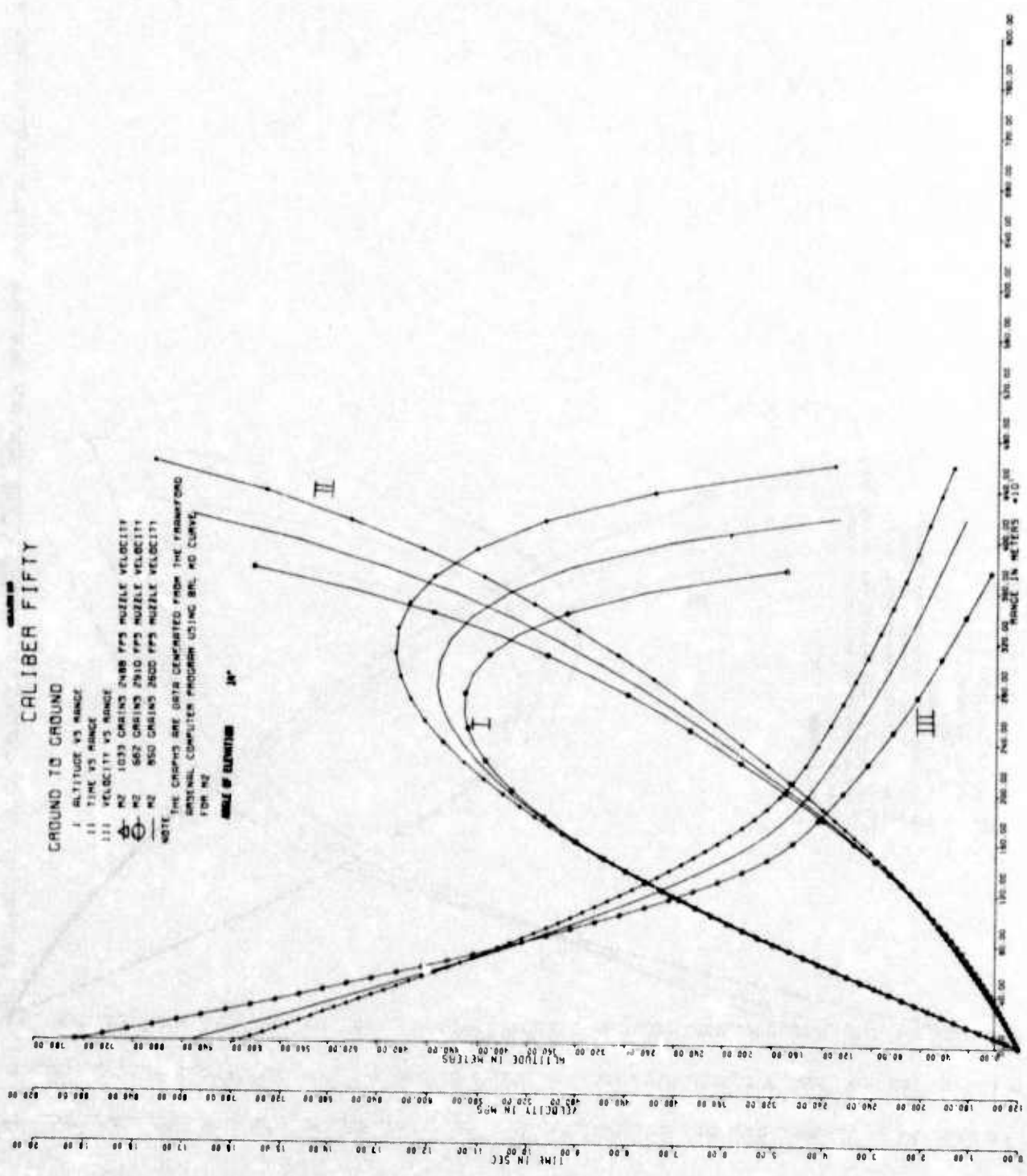


CHART 10 CALIBER FIFTY

GROUND TO GROUND

I ALTITUDE VS RANGE

II TIME VS RANGE

III VELOCITY VS RANGE

NO 1033 GRAINS 1489 FPS MUZZLE VELOCITY

NO 582 GRAINS 2510 FPS MUZZLE VELOCITY

NO 582 GRAINS 2510 FPS MUZZLE VELOCITY

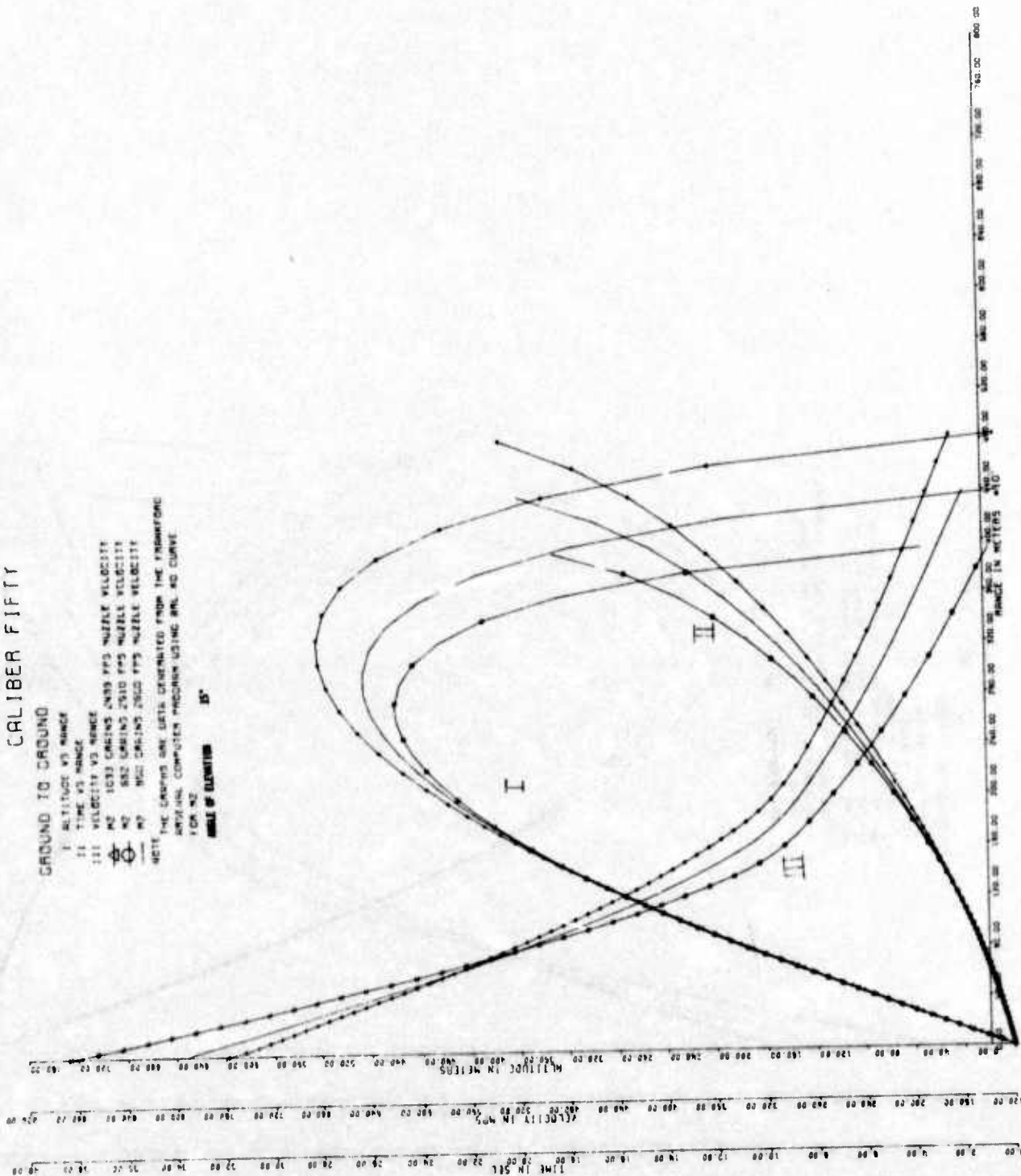
NO 1033 GRAINS 1489 FPS MUZZLE VELOCITY

THE GRAPHING DATA DERIVED FROM THE PRESENTING

ORIGINAL COMPUTER PROGRAM USING MIL NO CURVE

FOR NO

ANGLE OF ELEVATION 15°

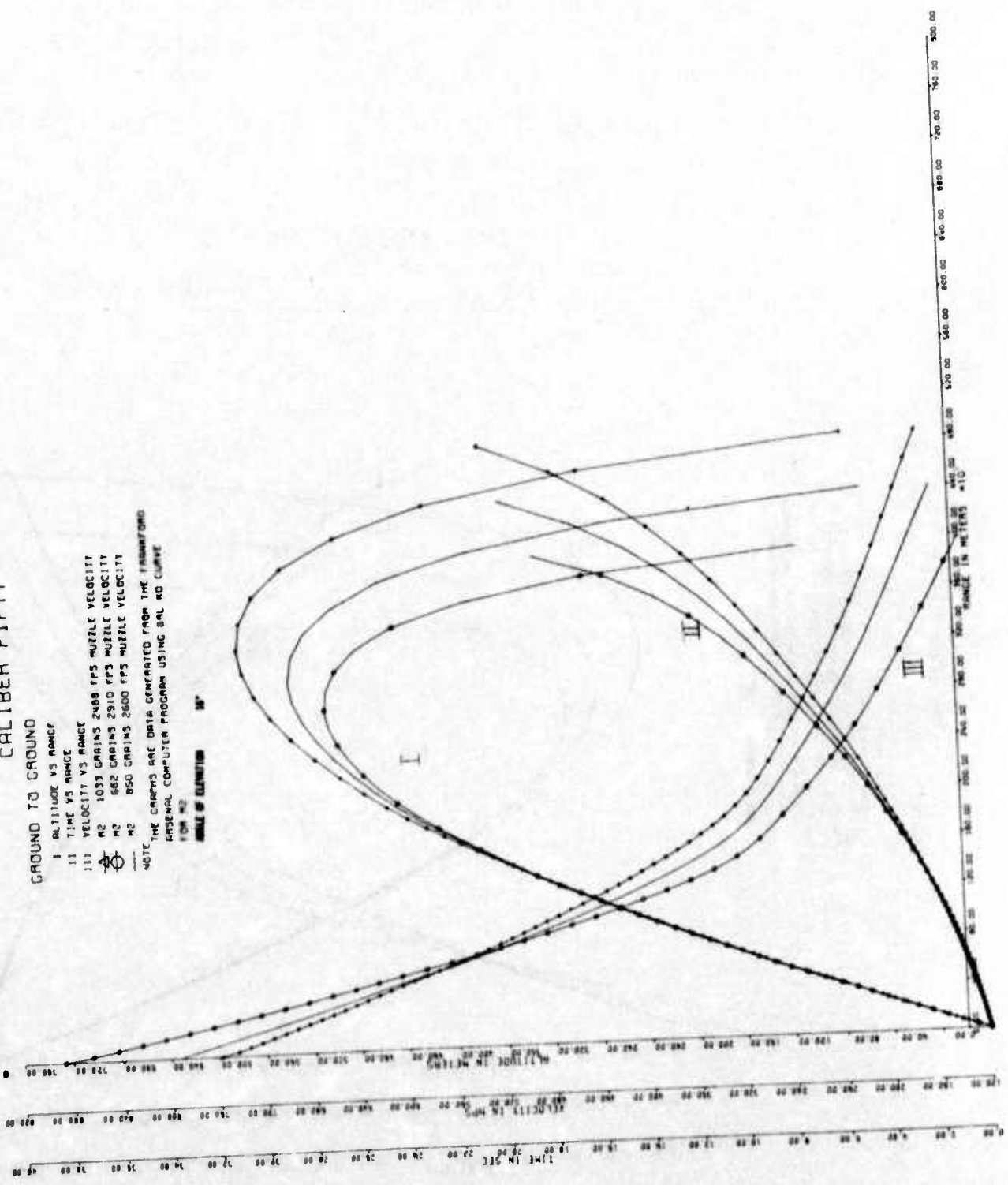


GRAPH 57 CALIBER FIFTY

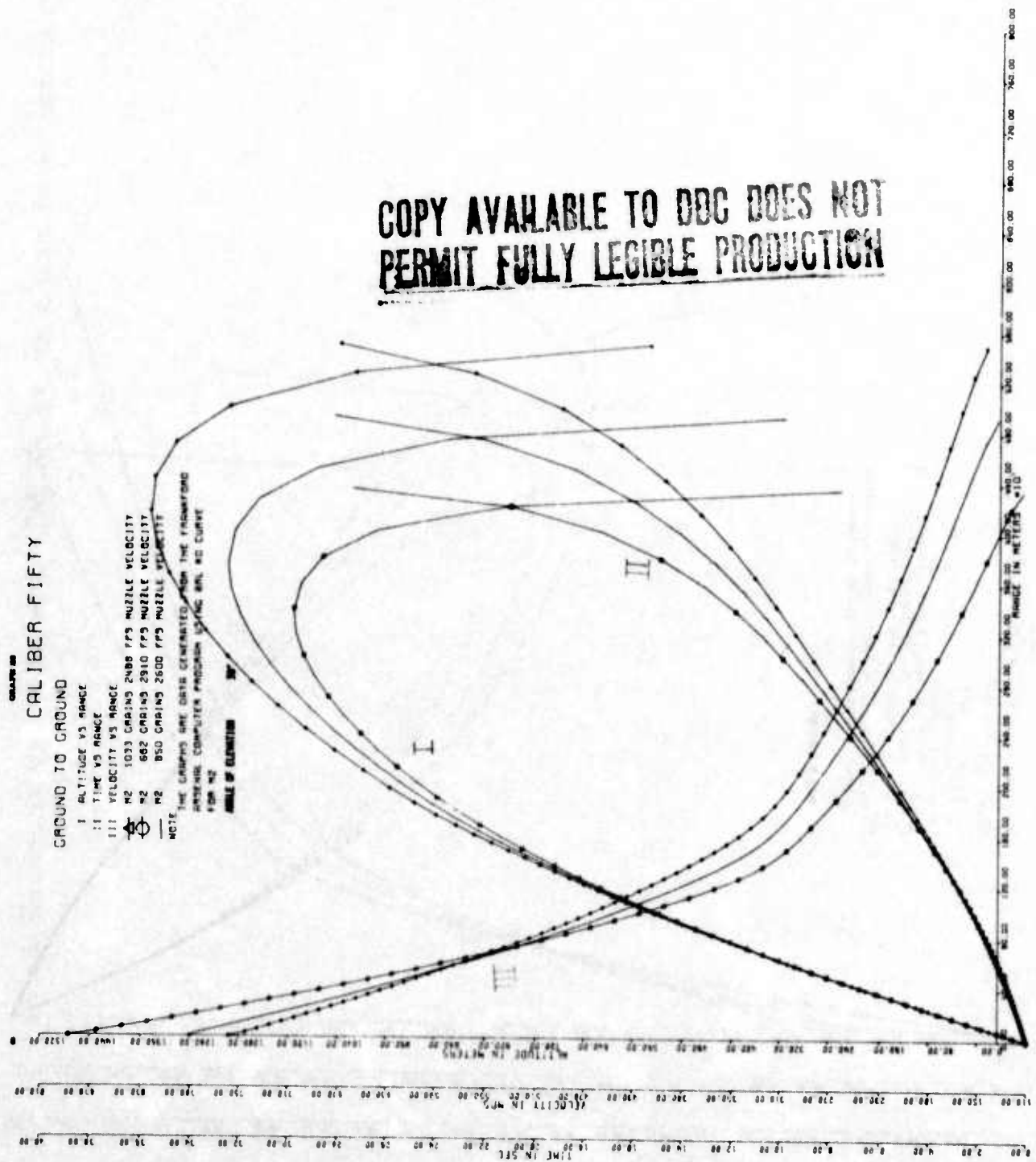
GROUND TO GROUND

- I ALTITUDE VS RANGE
- II TIME VS RANGE
- III VELOCITY VS RANGE
- M2 1033 GRAINS 2488 FPS MUZZLE VELOCITY
- M2 862 GRAINS 2910 FPS MUZZLE VELOCITY
- M2 850 GRAINS 2800 FPS MUZZLE VELOCITY

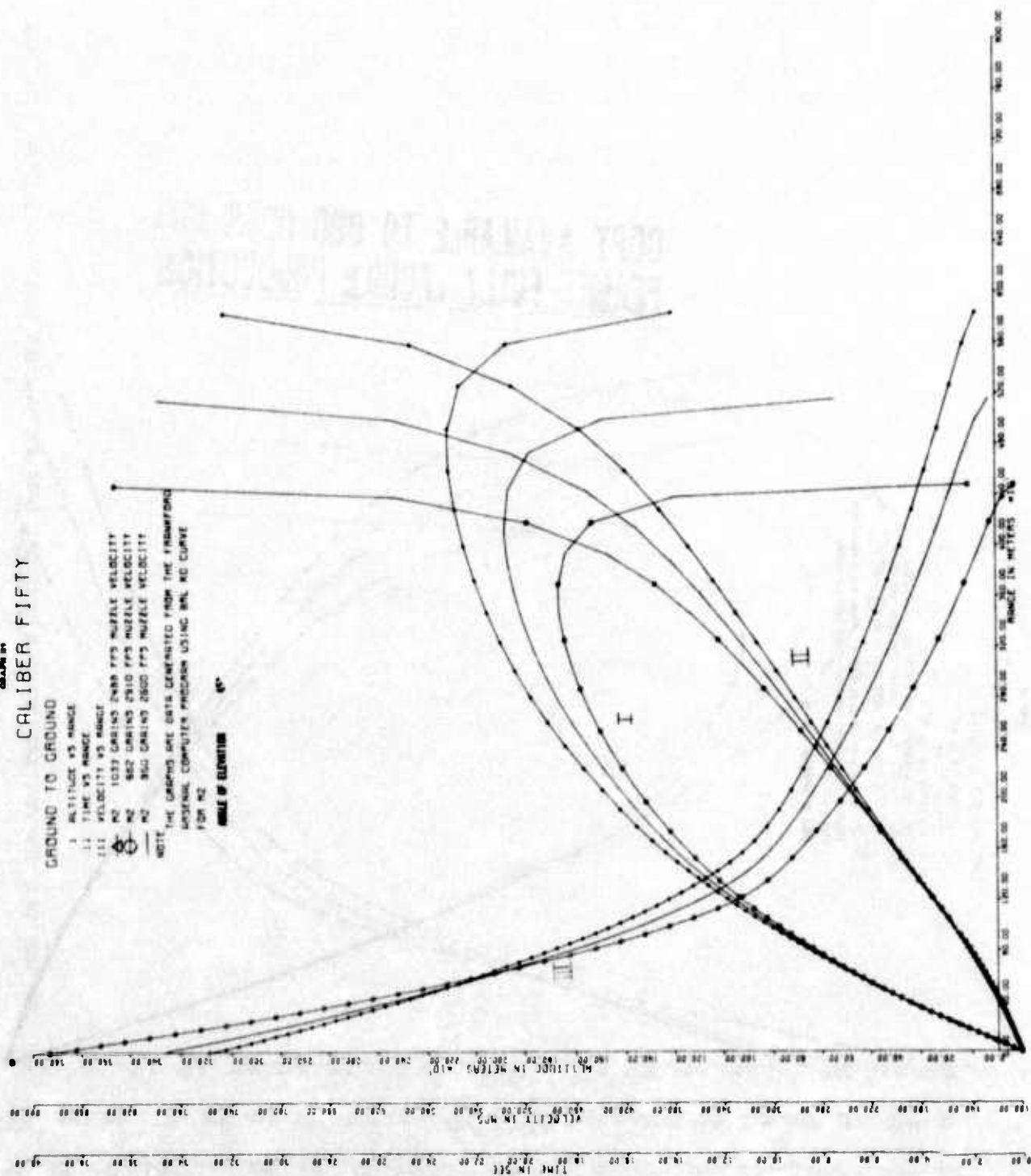
NOTE: THE GRAPHS ARE DATA GENERATED FROM THE FRANKFORD BASEBALL COMPUTER PROGRAM USING BAL NO CURVE FOR M2



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PERMIT FULLY LEGIBLE PRODUCTION**



GRAPH BY CALIBER FIFTY



CONCLUSIONS

GROUND TO GROUND

1. ALL FUTURE V3 NUMBER

11. **TIME TO ADJUST**

III. VELOCITY VS. NUMBER

1037 CASINO

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2 CONTINUED FROM PAGE 1

NOTE: Your receipt will not be valid without this receipt.

THE CURVES ARE DATA GENERATED FROM THE STANDARD SERIAL COMPUTER PROGRAM USING 8N, 80 CURVE

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WILEY-INTERSCIENCE

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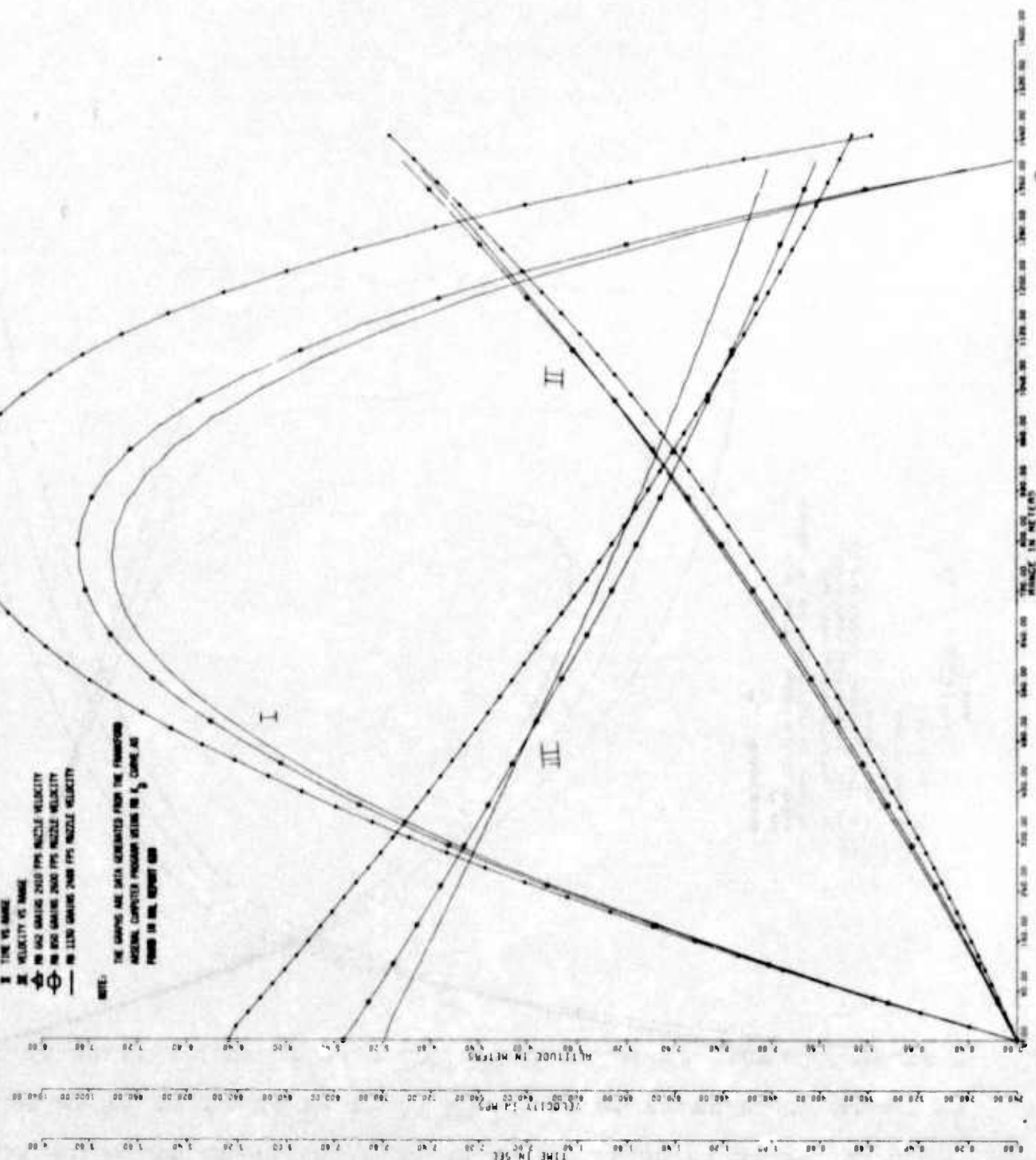


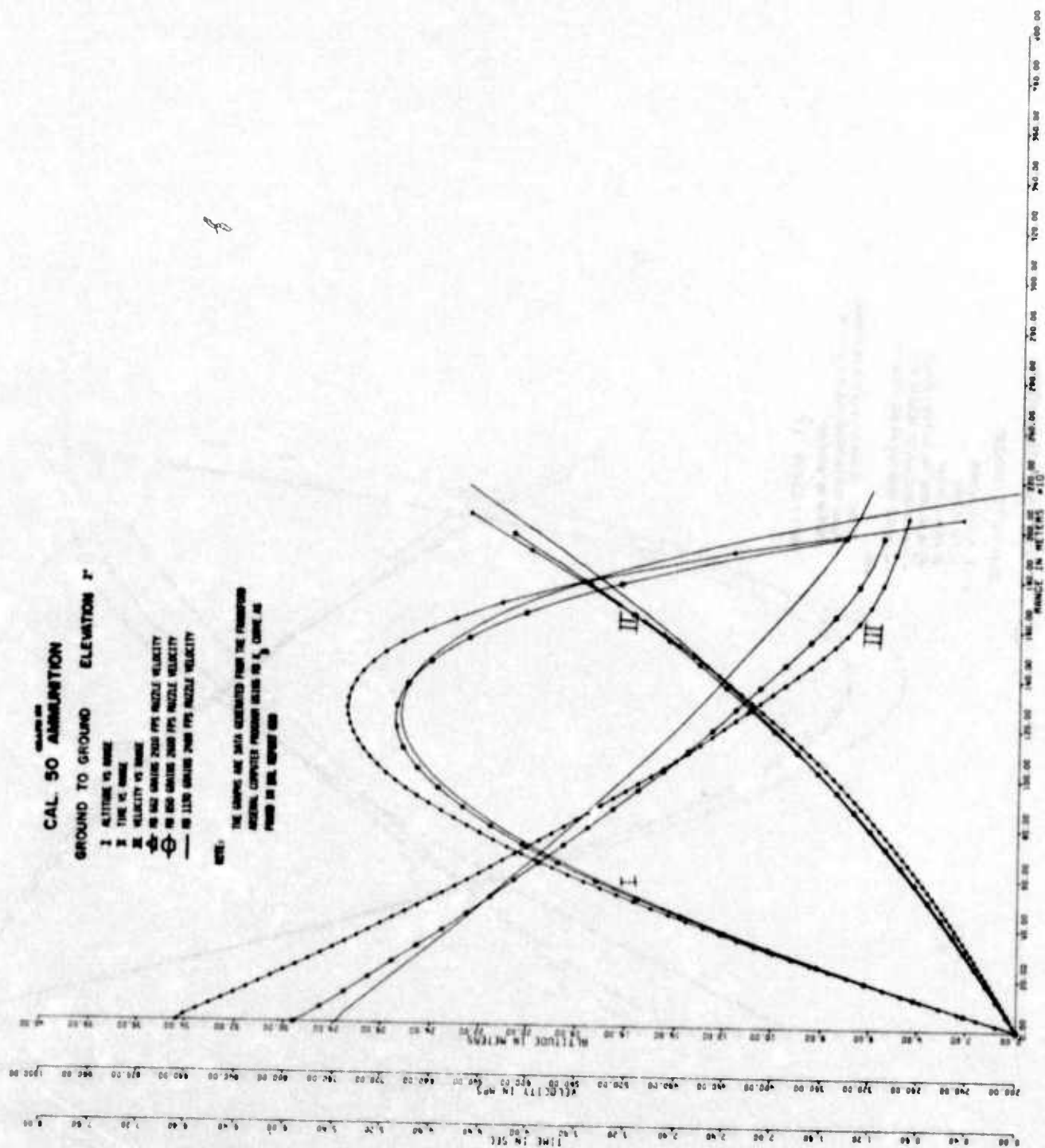
CAL 50 AMMUNITION

GROUND TO GROUND ELEVATION 1'

- I ALTITUDE VS NAME
- II TIME VS NAME
- III VELOCITY VS NAME
- IV NO 500 GROUND 2500 FPS NOZZLE VELOCITY
- V NO 500 GROUND 2500 FPS NOZZLE VELOCITY
- VI NO 1130 GROUND 2500 FPS NOZZLE VELOCITY

NOTE: THE GRAPHS ARE DATA GENERATED FROM THE PROGRAM
ANALOG COMPUTER PROGRAM WITHIN THE $\frac{1}{2}$ CODE AS
FOUNDED IN THE REPORT 500

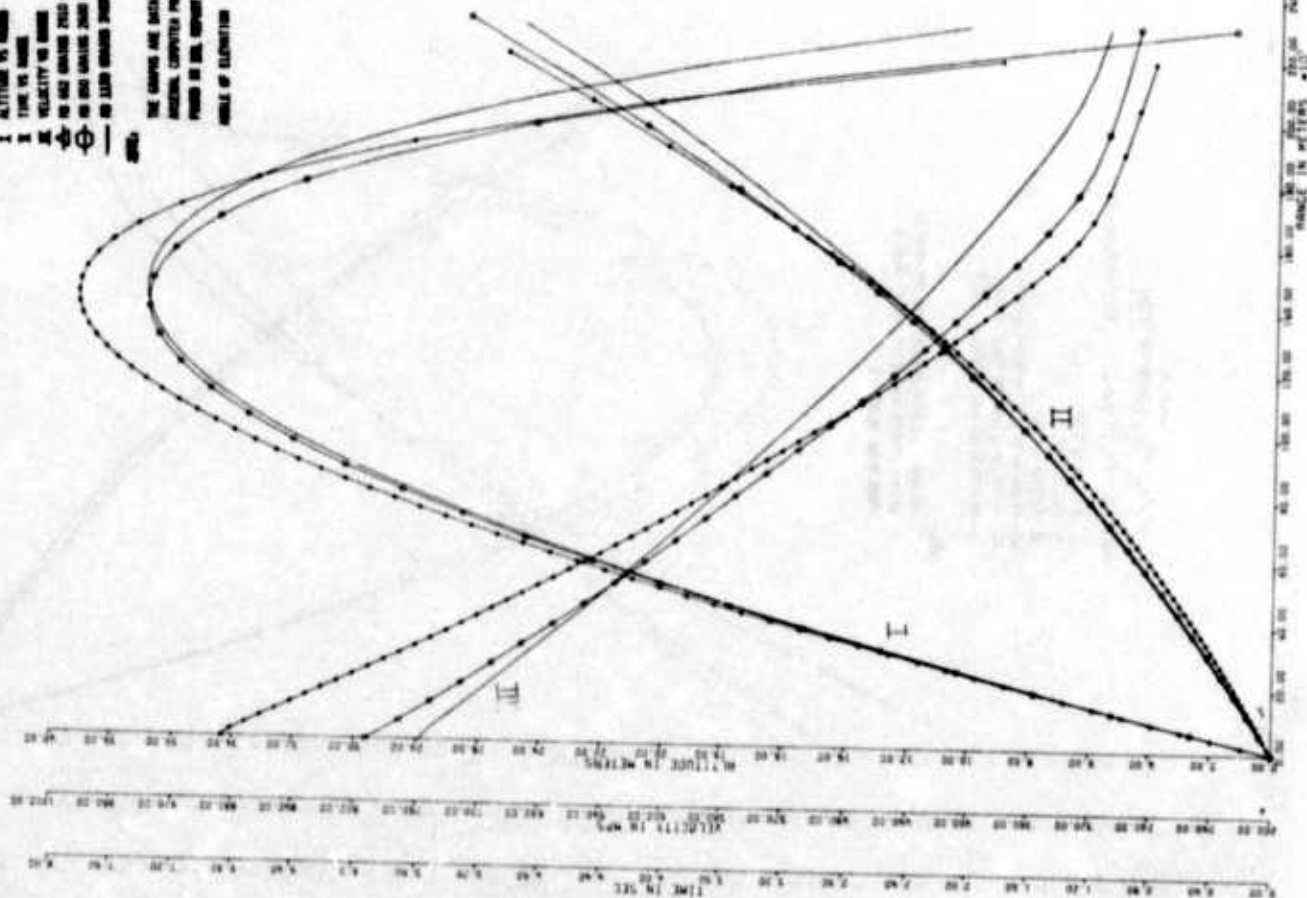




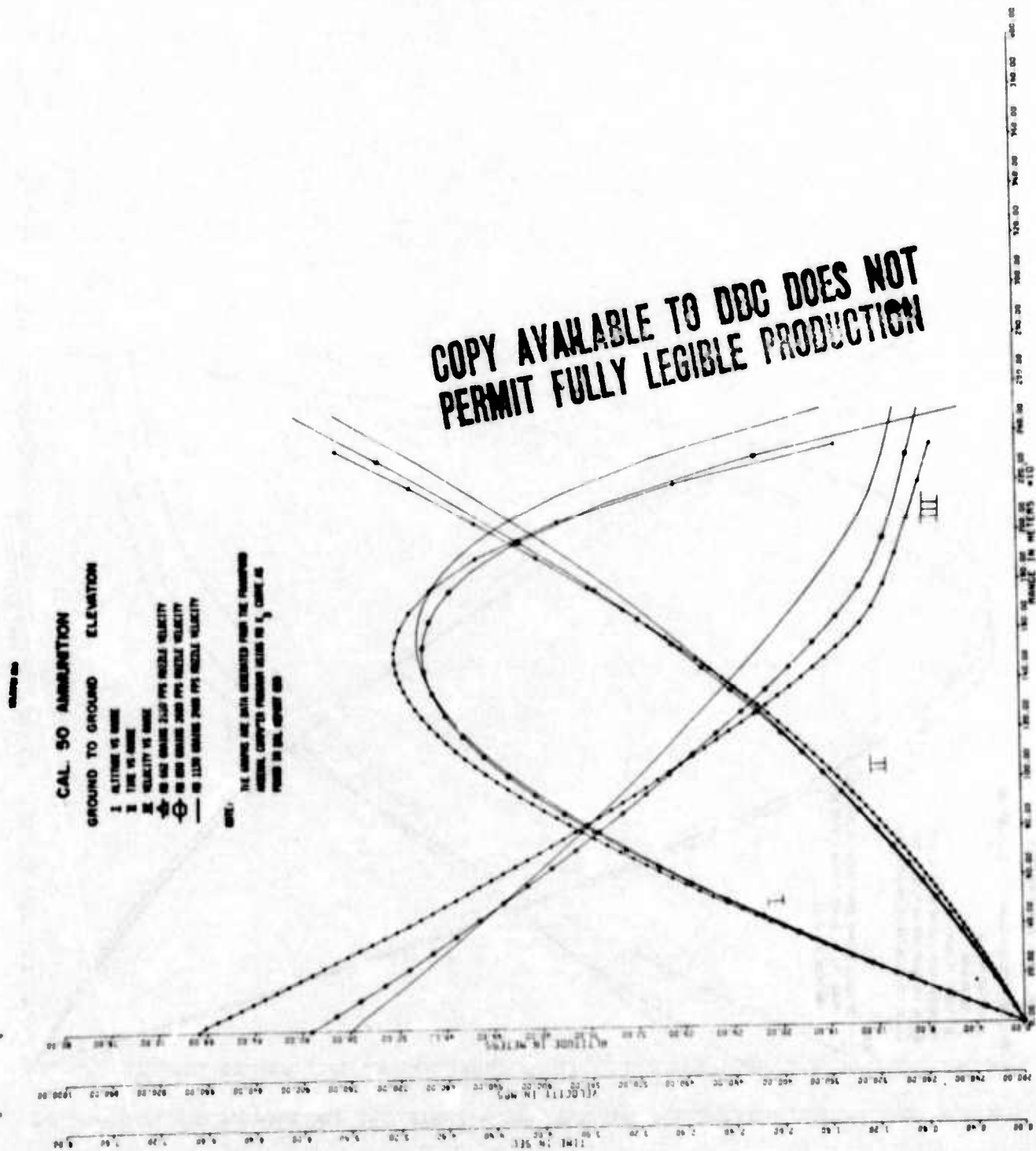
GROUND TO GROUND

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THE GRAPHS ARE DATA GENERATED FROM THE POWERPOINT
ANALYSIS. COMPUTER PROGRAMS USING AN χ^2 CURVE FIT
WAS USED TO FIT THE DATA. SEE THE APPENDIX FOR
MORE INFORMATION.



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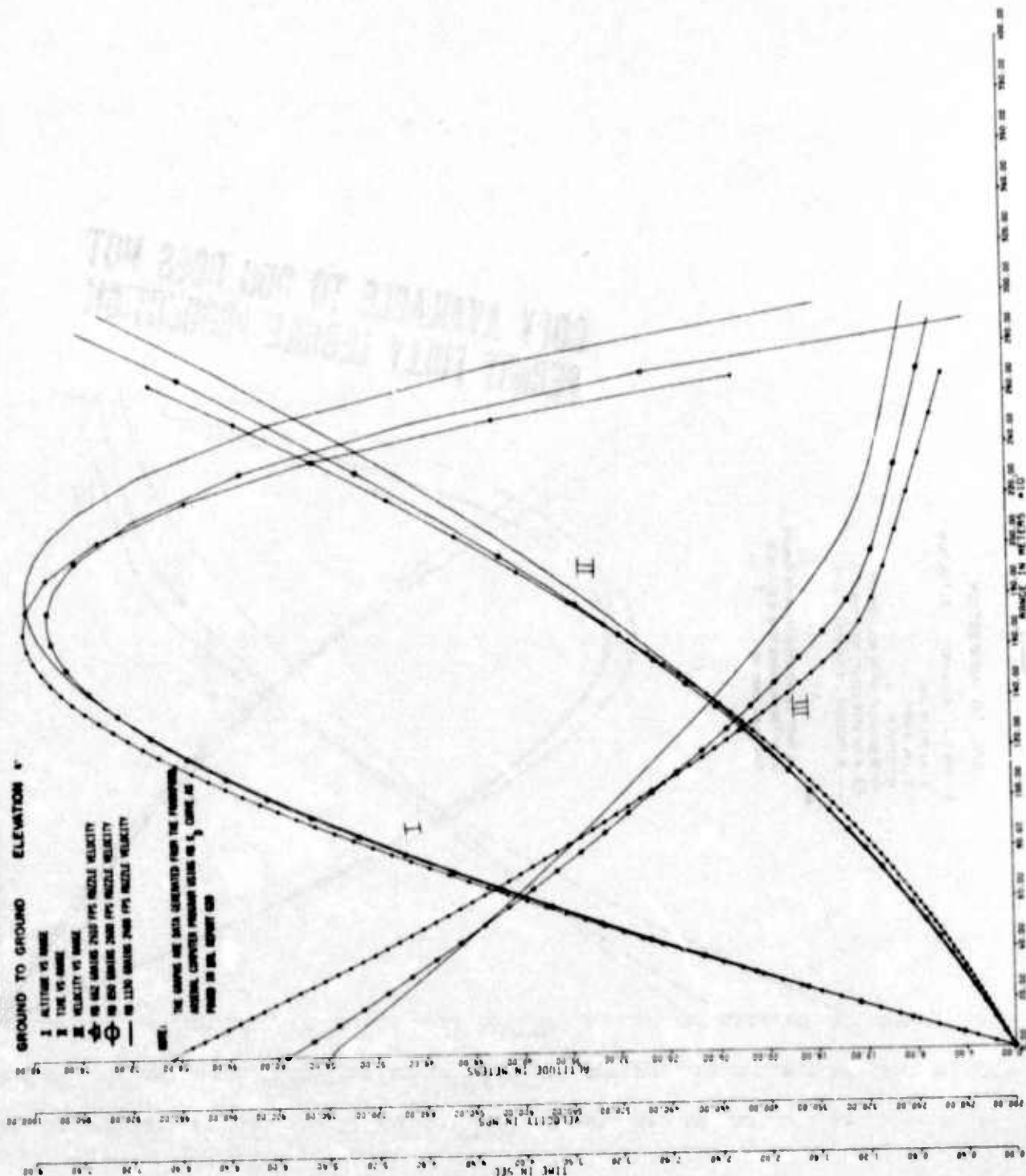
GRAPH 50

CAL 50 AMMUNITION

GROUND TO GROUND ELEVATION *

- I ALTITUDE VS RANGE
- II TIME VS RANGE
- III VELOCITY VS RANGE
- IV NO AND RANGE 2500 FPS NOZZLE VELOCITY
- V NO AND RANGE 3000 FPS NOZZLE VELOCITY
- VI NO AND RANGE 3500 FPS NOZZLE VELOCITY
- VII NO AND RANGE 4000 FPS NOZZLE VELOCITY
- VIII NO AND RANGE 4500 FPS NOZZLE VELOCITY

THE RANGE AND DATA GENERATED FROM THE PROGRAM
AREAL, CUMULATIVE PROGRAM USING NO ϕ CLIMB AS
FOUND IN THE REPORT FOR

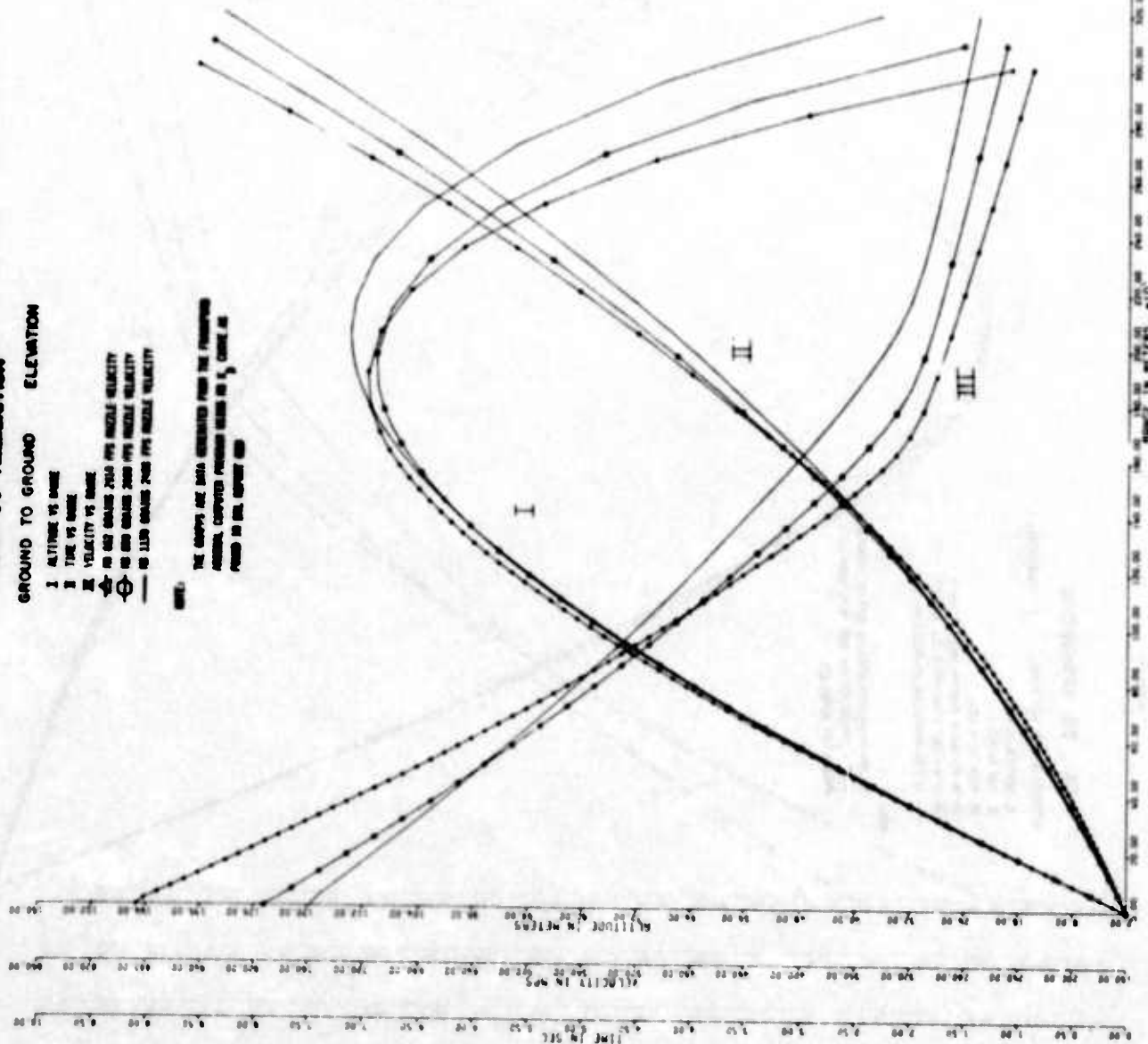


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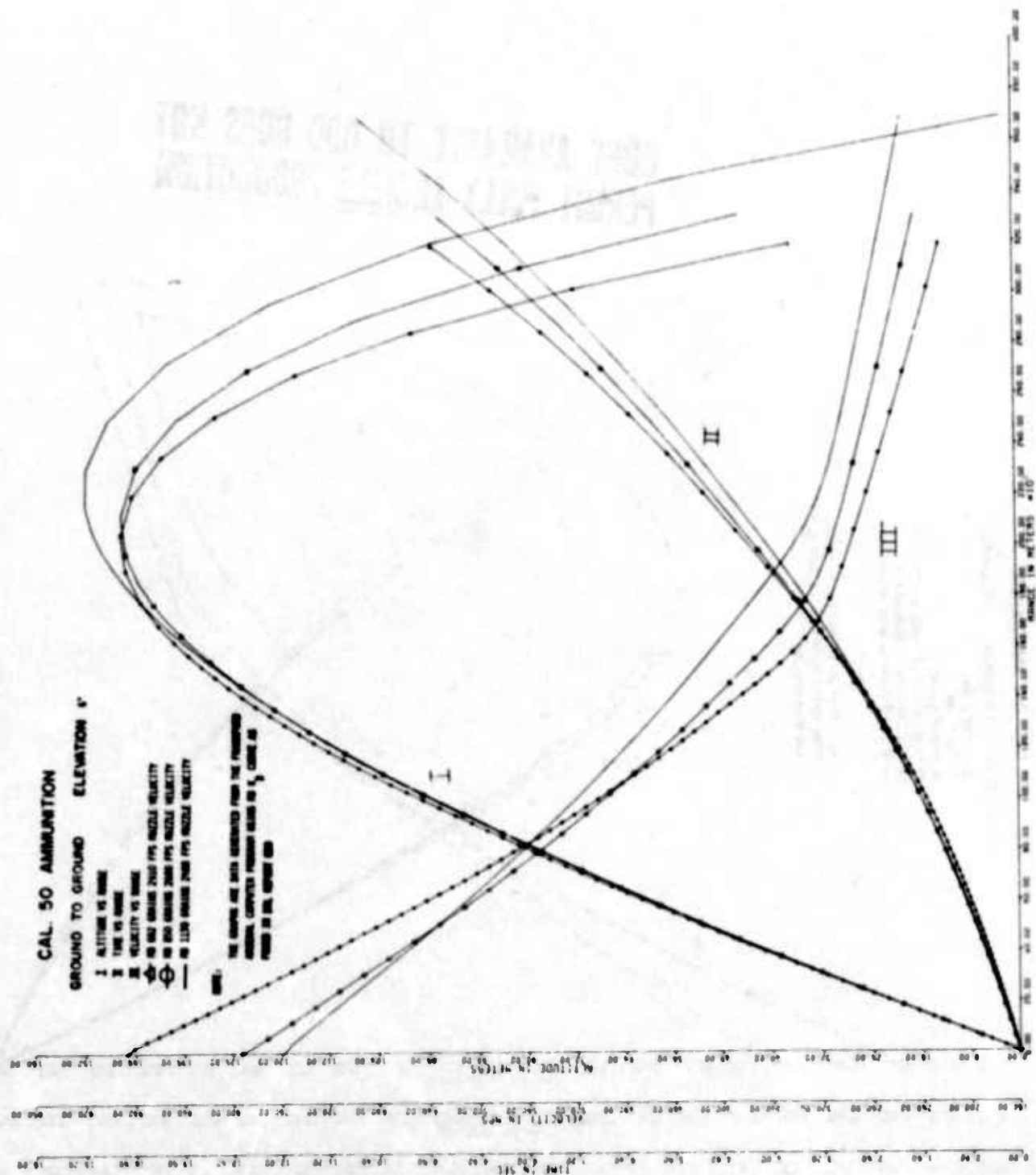
CAL 50 ABORTION

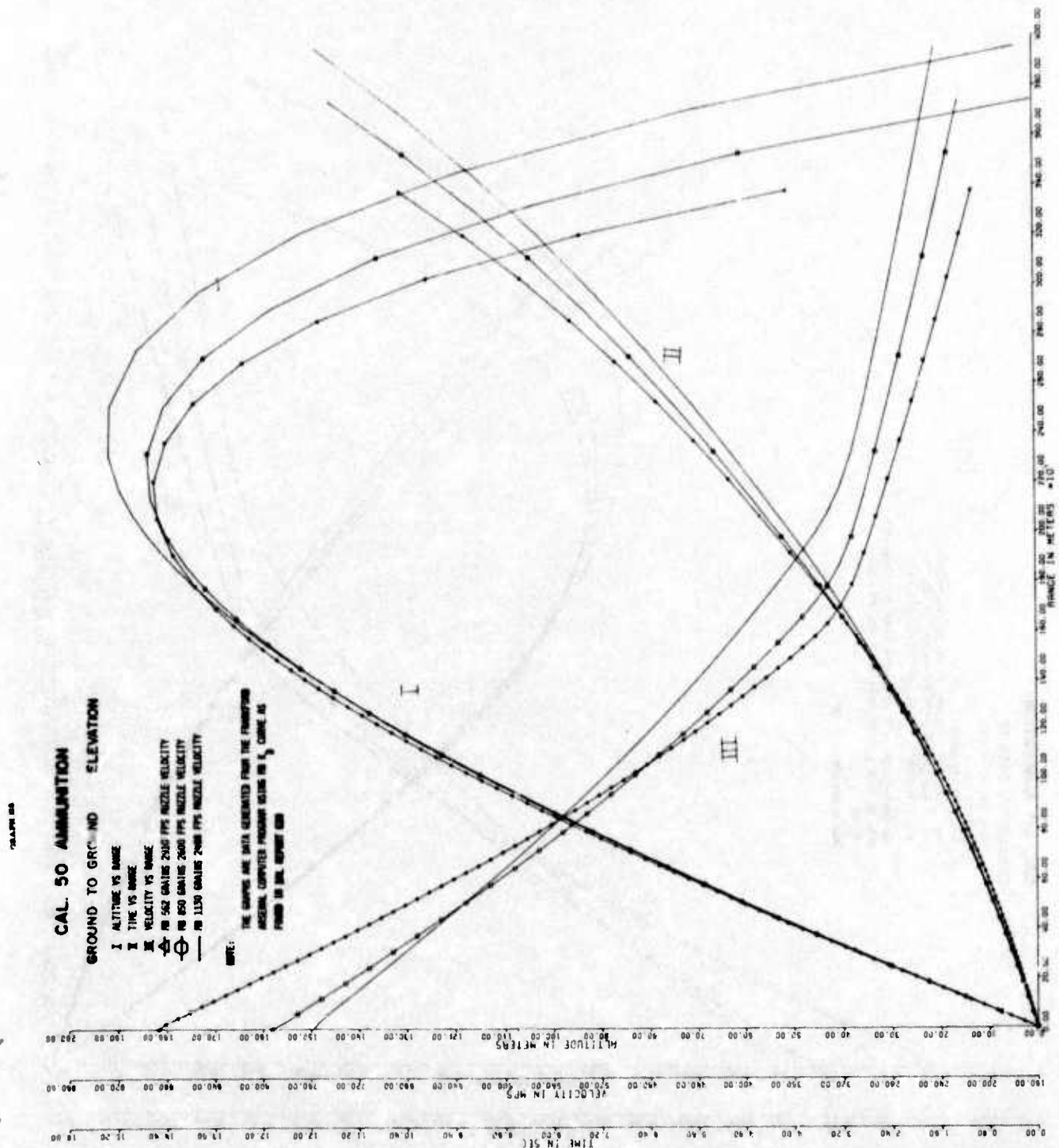
GROUND TO GROUND ELEVATION
 1 ALTITUDE VS TIME
 2 TIME VS RANGE
 3 VELOCITY VS RANGE
 4 1000 GROUND 2000 FPS MISSILE VELOCITY
 5 1000 GROUND 2000 FPS MISSILE VELOCITY
 6 1100 GROUND 2000 FPS MISSILE VELOCITY

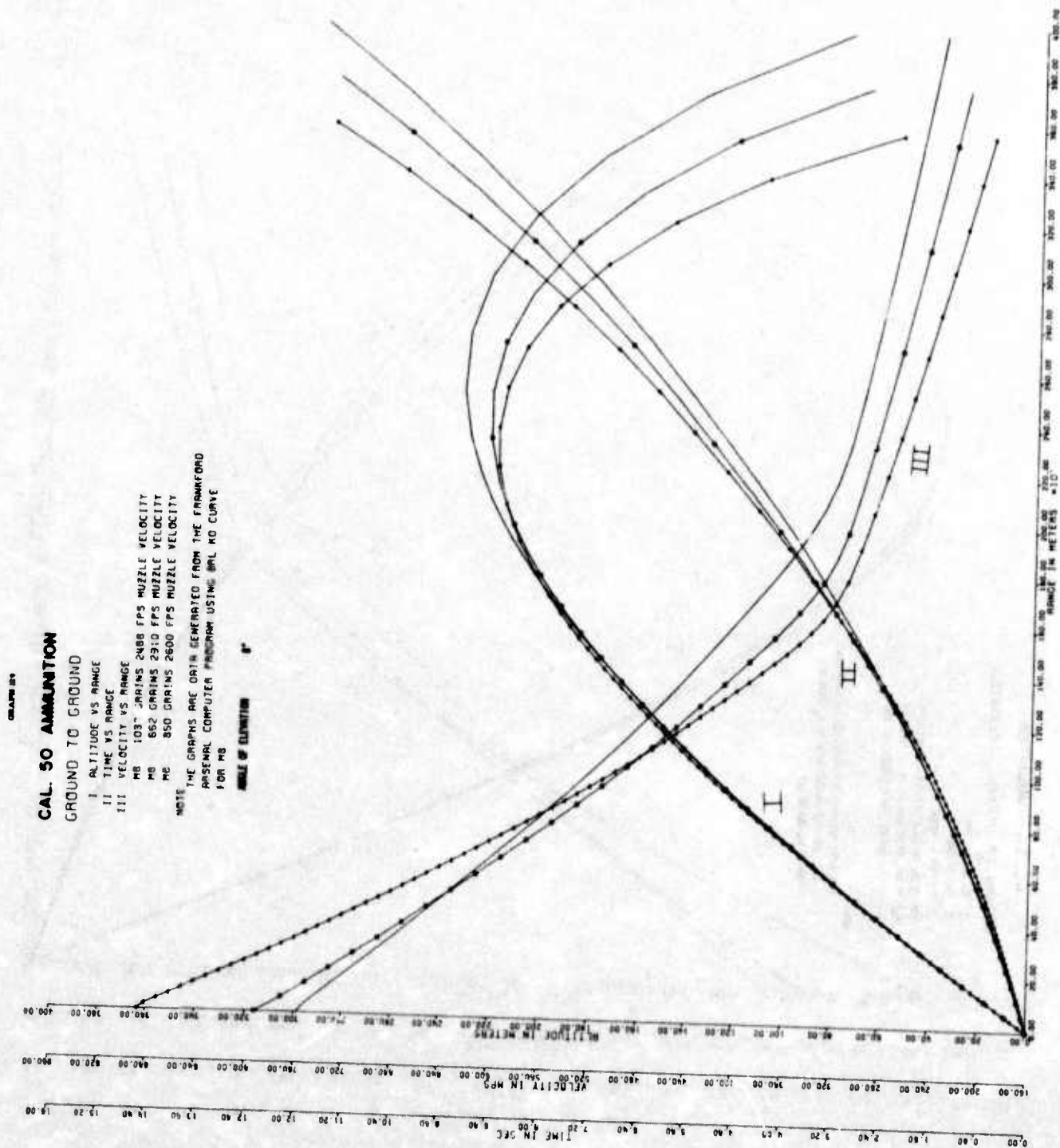
THE GRAPHS ARE DATA GENERATED FROM THE PROBABLY
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GRAPH 27







GRAPH 10

CAL. 50 AMMUNITION

GROUND TO GROUND

I ALTITUDE VS RANGE

II TIME VS RANGE

III VELOCITY VS RANGE

IV ALTITUDE VS RANGE

V VELOCITY VS RANGE

VI ALTITUDE VS RANGE

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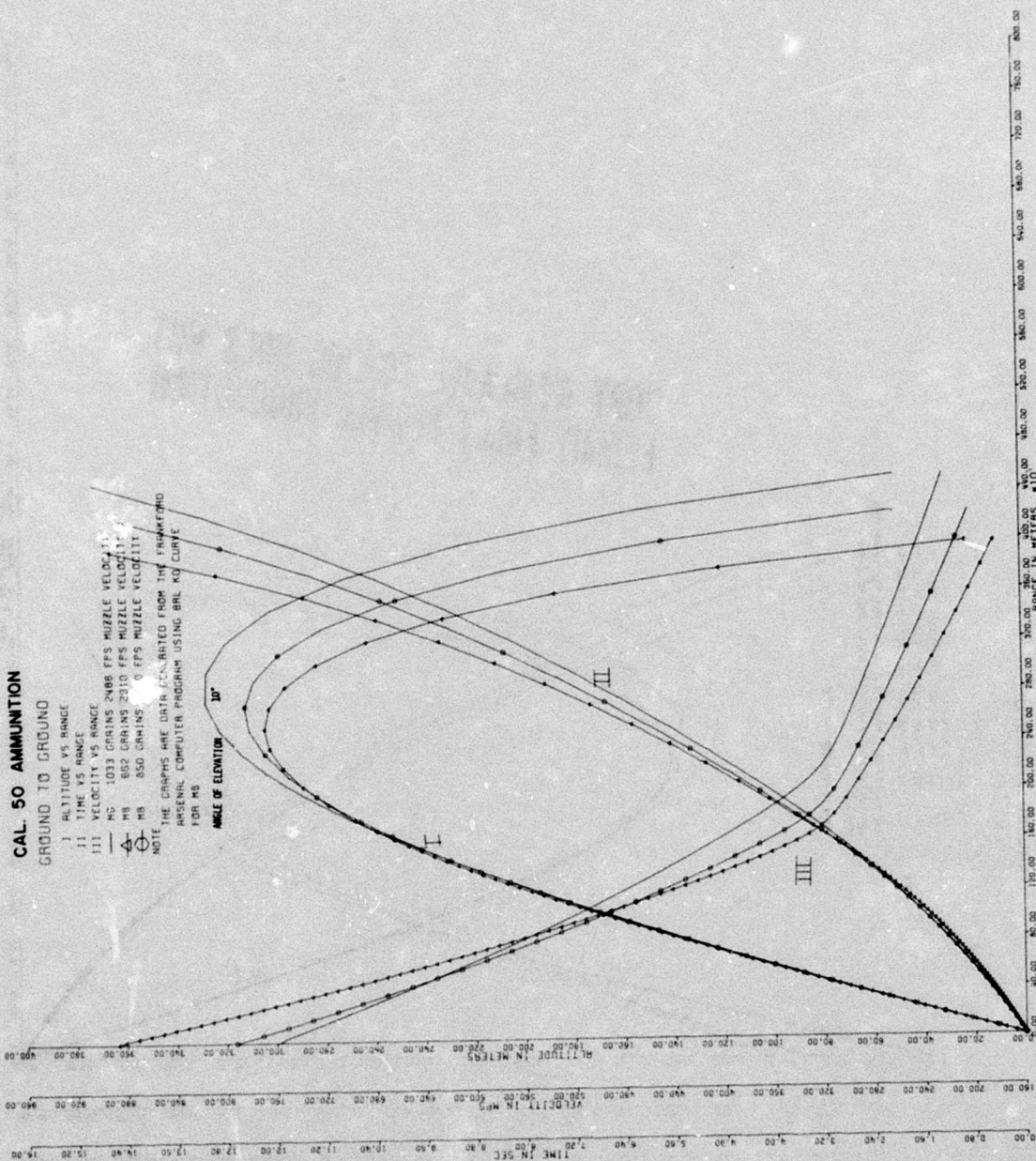
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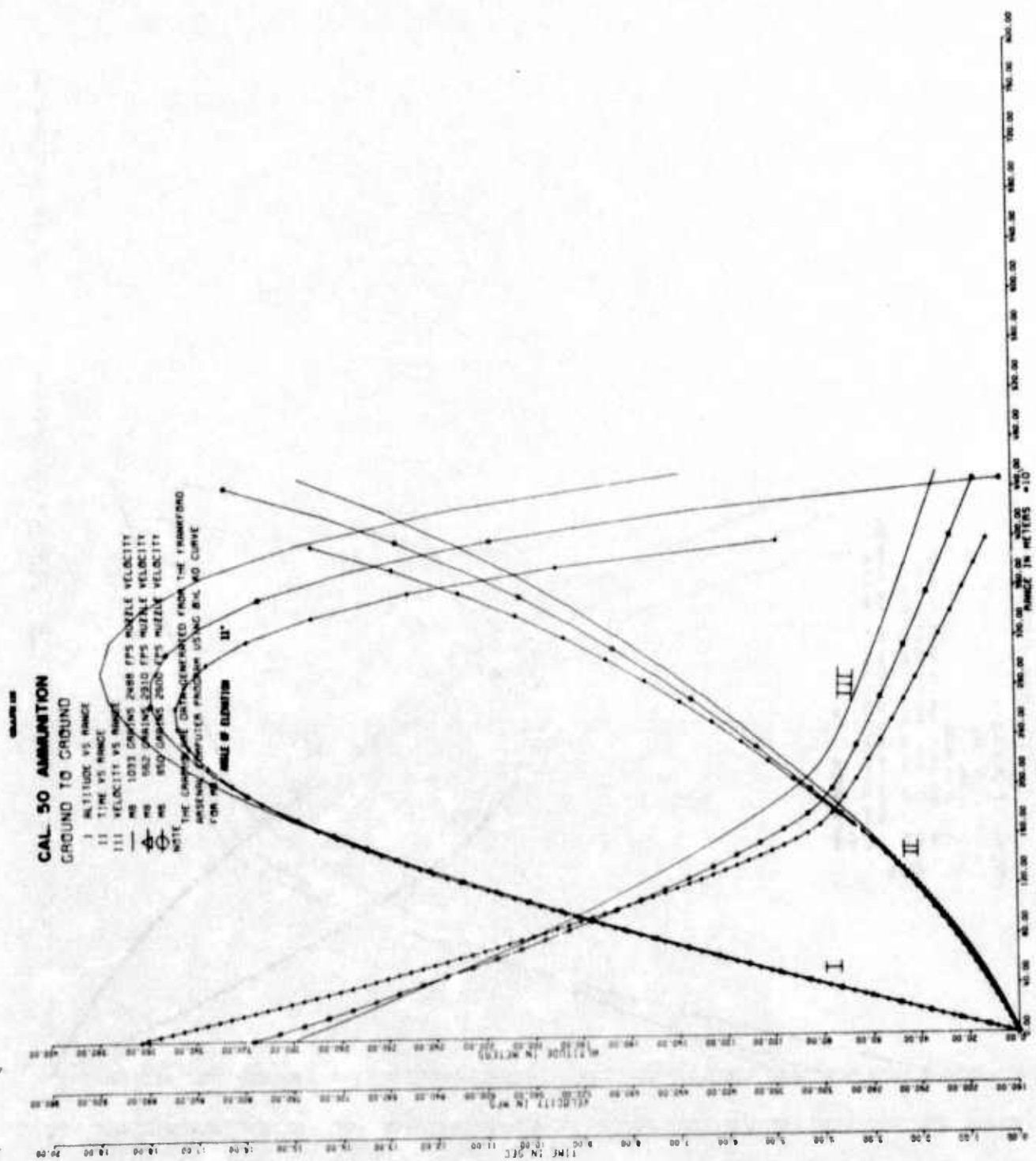
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XXXXXXXIII VELOCITY VS RANGE

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XXXXXXXV VELOCITY VS RANGE





CALIBER FIFTY

GROUND TO GROUND

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11 TIME VS RANGE

III: VELOCITY VS RANGE

----- MB 1033 GRAINS 2498 FPS MUZZLE VELOCITY

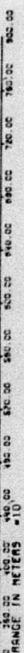
MB	552 GRAINS	2910 FPS	MUZZLE VELOCITY
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PM 100

ANGLE OF ELEVATION 12°



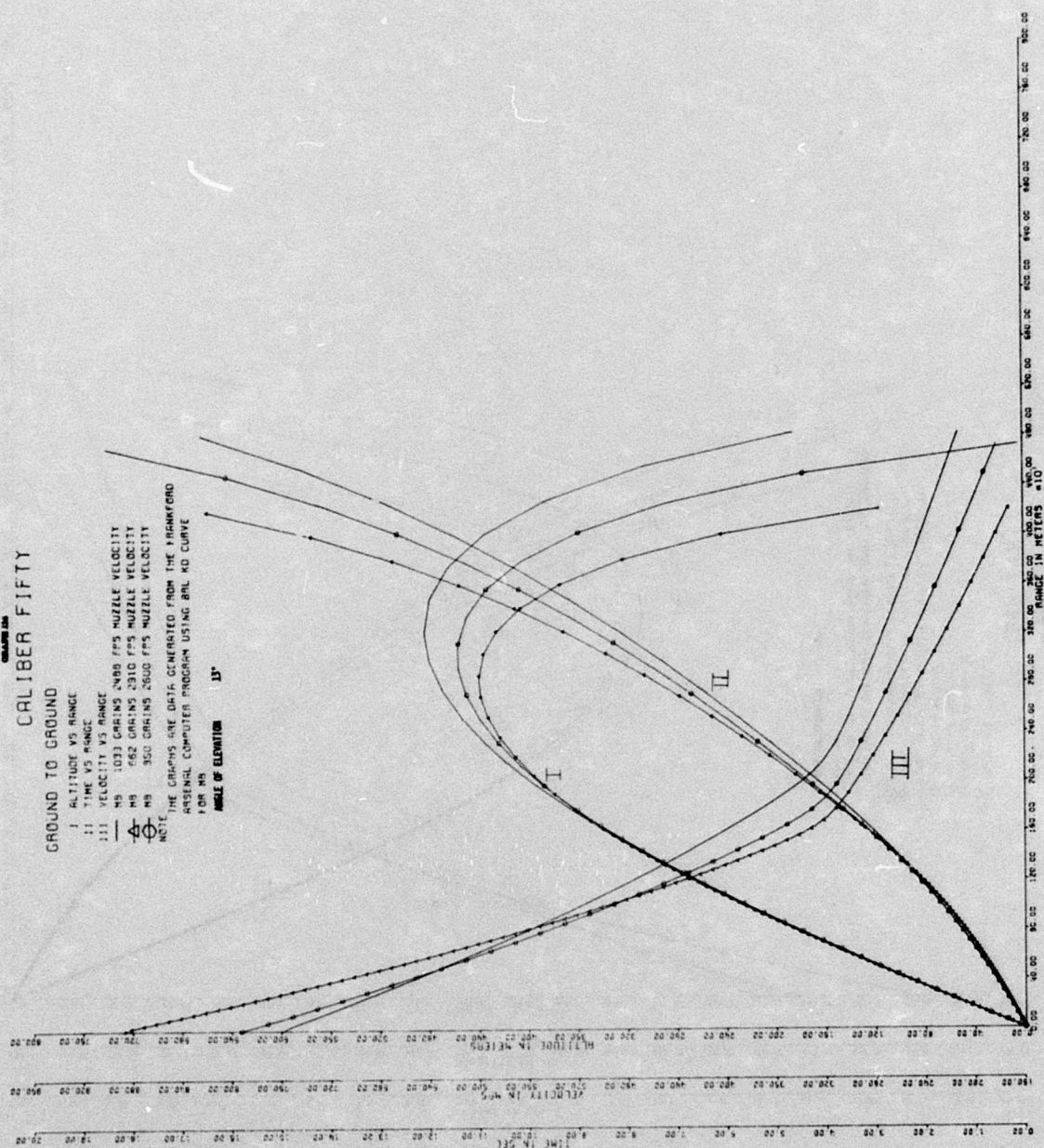
CALIBER FIFTY

GROUND TO GROUND

- I ALTITUDE VS RANGE
- II TIME VS RANGE
- III VELOCITY VS RANGE
- IV 1033 GRAINS 2400 FPS MUZZLE VELOCITY
- V 1033 GRAINS 2310 FPS MUZZLE VELOCITY
- VI 1033 GRAINS 2210 FPS MUZZLE VELOCITY
- VII 1033 GRAINS 2110 FPS MUZZLE VELOCITY
- VIII 1033 GRAINS 2010 FPS MUZZLE VELOCITY
- IX 1033 GRAINS 1910 FPS MUZZLE VELOCITY
- X 1033 GRAINS 1810 FPS MUZZLE VELOCITY
- XI 1033 GRAINS 1710 FPS MUZZLE VELOCITY
- XII 1033 GRAINS 1610 FPS MUZZLE VELOCITY
- XIII 1033 GRAINS 1510 FPS MUZZLE VELOCITY
- XIV 1033 GRAINS 1410 FPS MUZZLE VELOCITY
- XV 1033 GRAINS 1310 FPS MUZZLE VELOCITY
- XVI 1033 GRAINS 1210 FPS MUZZLE VELOCITY
- XVII 1033 GRAINS 1110 FPS MUZZLE VELOCITY
- XVIII 1033 GRAINS 1010 FPS MUZZLE VELOCITY
- XIX 1033 GRAINS 910 FPS MUZZLE VELOCITY
- XX 1033 GRAINS 810 FPS MUZZLE VELOCITY
- XXI 1033 GRAINS 710 FPS MUZZLE VELOCITY
- XXII 1033 GRAINS 610 FPS MUZZLE VELOCITY
- XXIII 1033 GRAINS 510 FPS MUZZLE VELOCITY
- XXIV 1033 GRAINS 410 FPS MUZZLE VELOCITY
- XXV 1033 GRAINS 310 FPS MUZZLE VELOCITY
- XXVI 1033 GRAINS 210 FPS MUZZLE VELOCITY
- XXVII 1033 GRAINS 110 FPS MUZZLE VELOCITY
- XXVIII 1033 GRAINS 10 FPS MUZZLE VELOCITY
- XXIX 1033 GRAINS 0 FPS MUZZLE VELOCITY
- XXX 1033 GRAINS 0 FPS MUZZLE VELOCITY

NOTE: THE GRAPHS ARE DATA GENERATED FROM THE FRANKFORD ARSENAL COMPUTER PROGRAM USING BRL AD CURVE FOR 45

ANGLE OF ELEVATION 15°



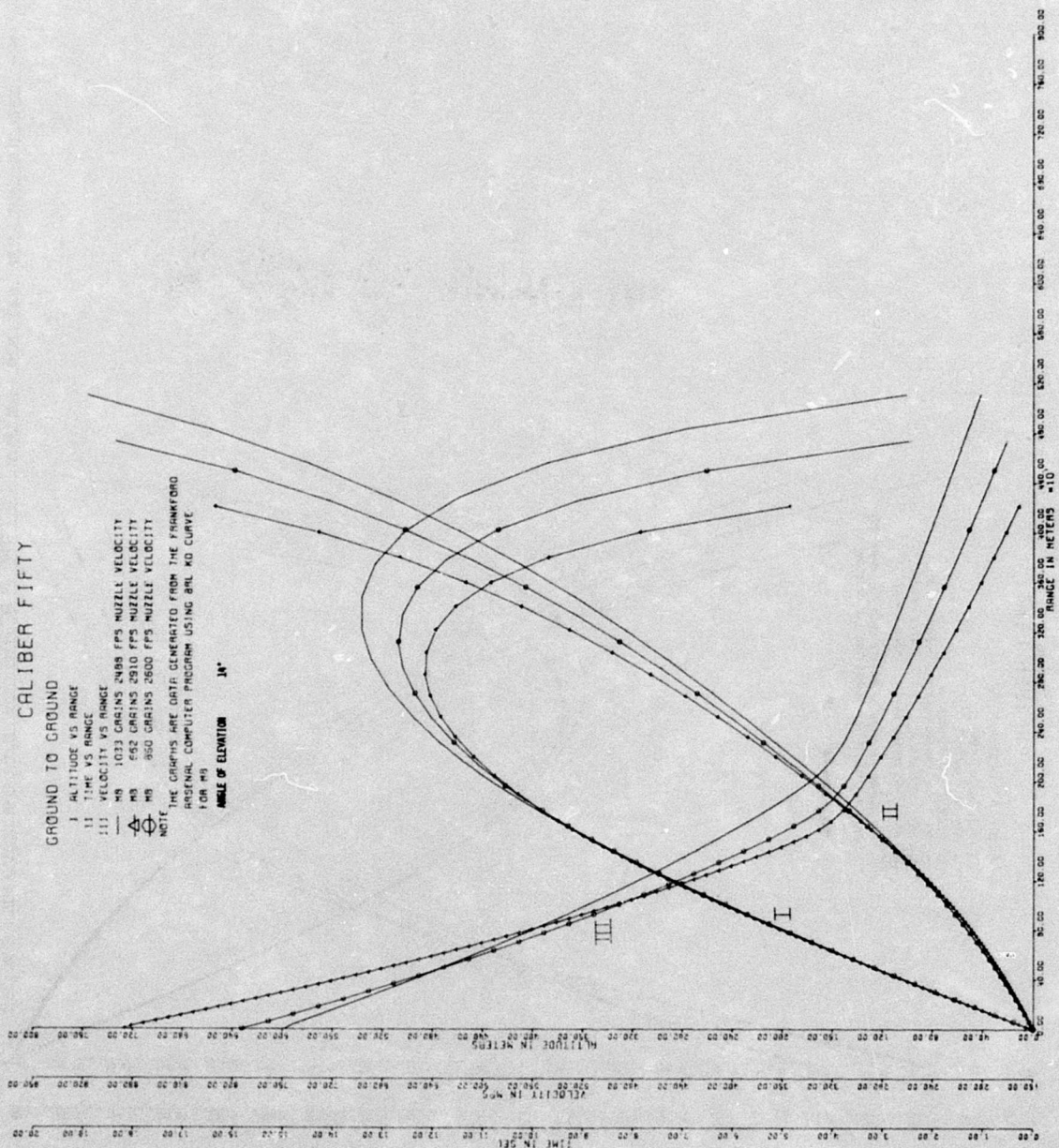
CALIBER FIFTY

GROUND TO GROUND

- I ALTITUDE VS RANGE
- II TIME VS RANGE
- III VELOCITY VS RANGE
- M9 1033 GRAINS 2400 FPS MUZZLE VELOCITY
- △- M8 562 GRAINS 2910 FPS MUZZLE VELOCITY
- M6 850 GRAINS 2500 FPS MUZZLE VELOCITY

NOTE
THE GRAPHS ARE DATA GENERATED FROM THE FRANKFORD
ARSENAL COMPUTER PROGRAM USING BAL NO CURVE
FOR M9

ANGLE OF ELEVATION 14°



CALIBER FIFTY

GROUND TO GROUND

I ALTITUDE VS RANGE

II TIME VS RANGE

III VELOCITY VS RANGE

M9 1033 GRAINS 2400 FPS MUZZLE VELOCITY

M9 662 GRAINS 2310 FPS MUZZLE VELOCITY

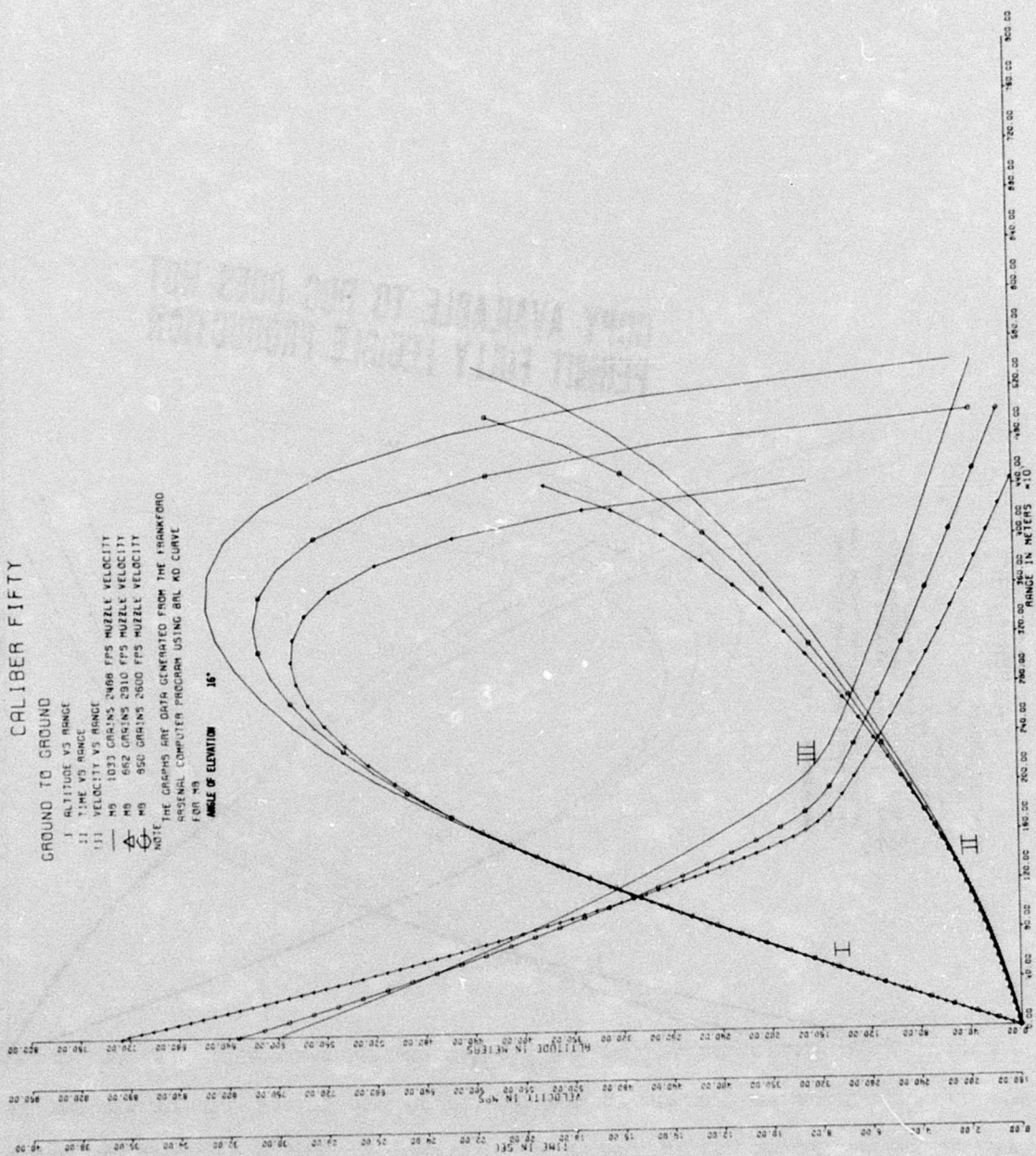
M9 950 GRAINS 2600 FPS MUZZLE VELOCITY

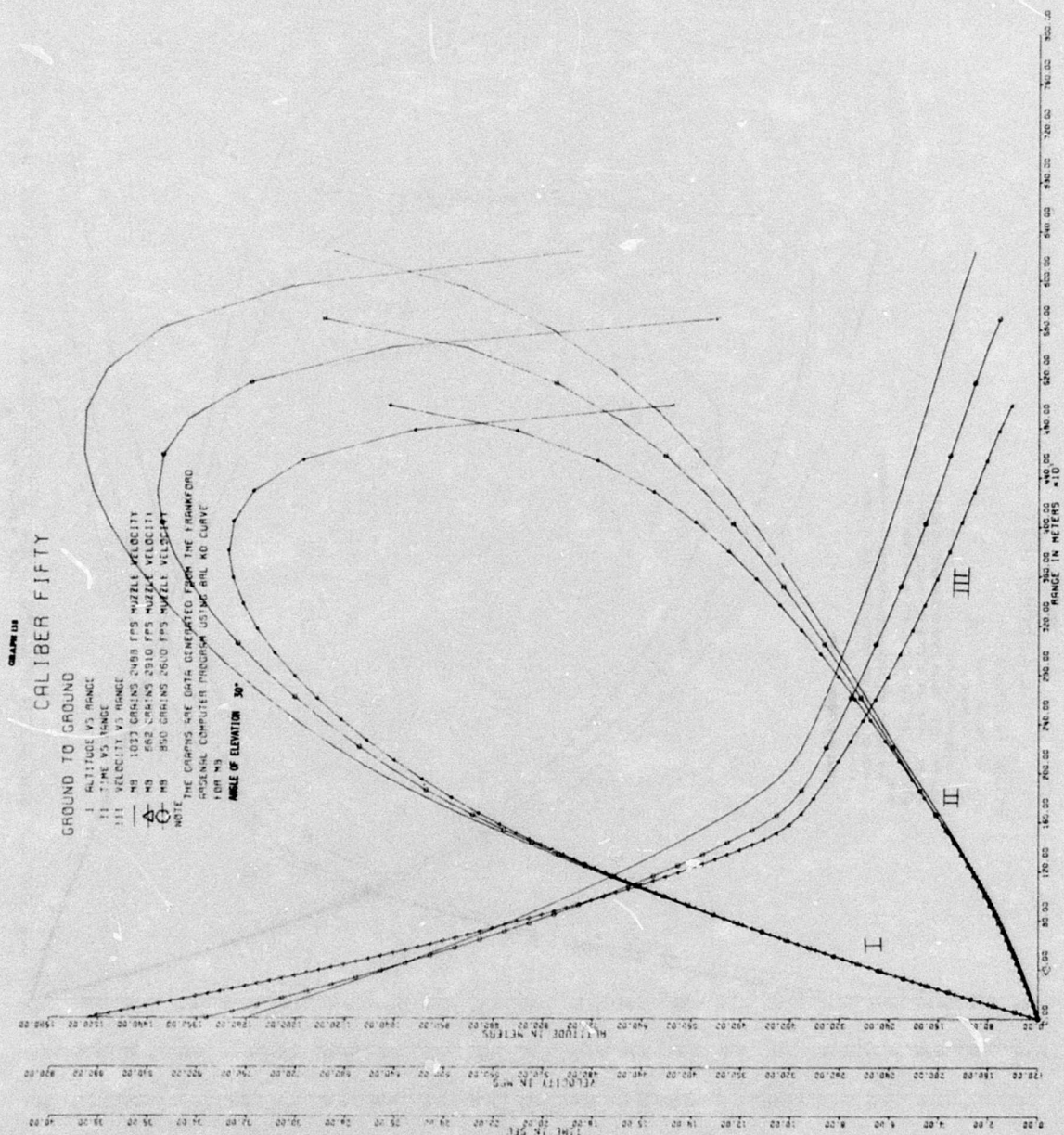
NOTE THE GRAPHS ARE DATA GENERATED FROM THE FRANKFORD

BARREL COMPUTER PROGRAM USING BRL AD CURVE

FOR 10°

ANGLE OF ELEVATION 10°





GRAIN 19 CALIBER FIFTY

GROUND TO GROUND

I ALTITUDE VS RANGE

II TIME VS RANGE

III VELOCITY VS RANGE

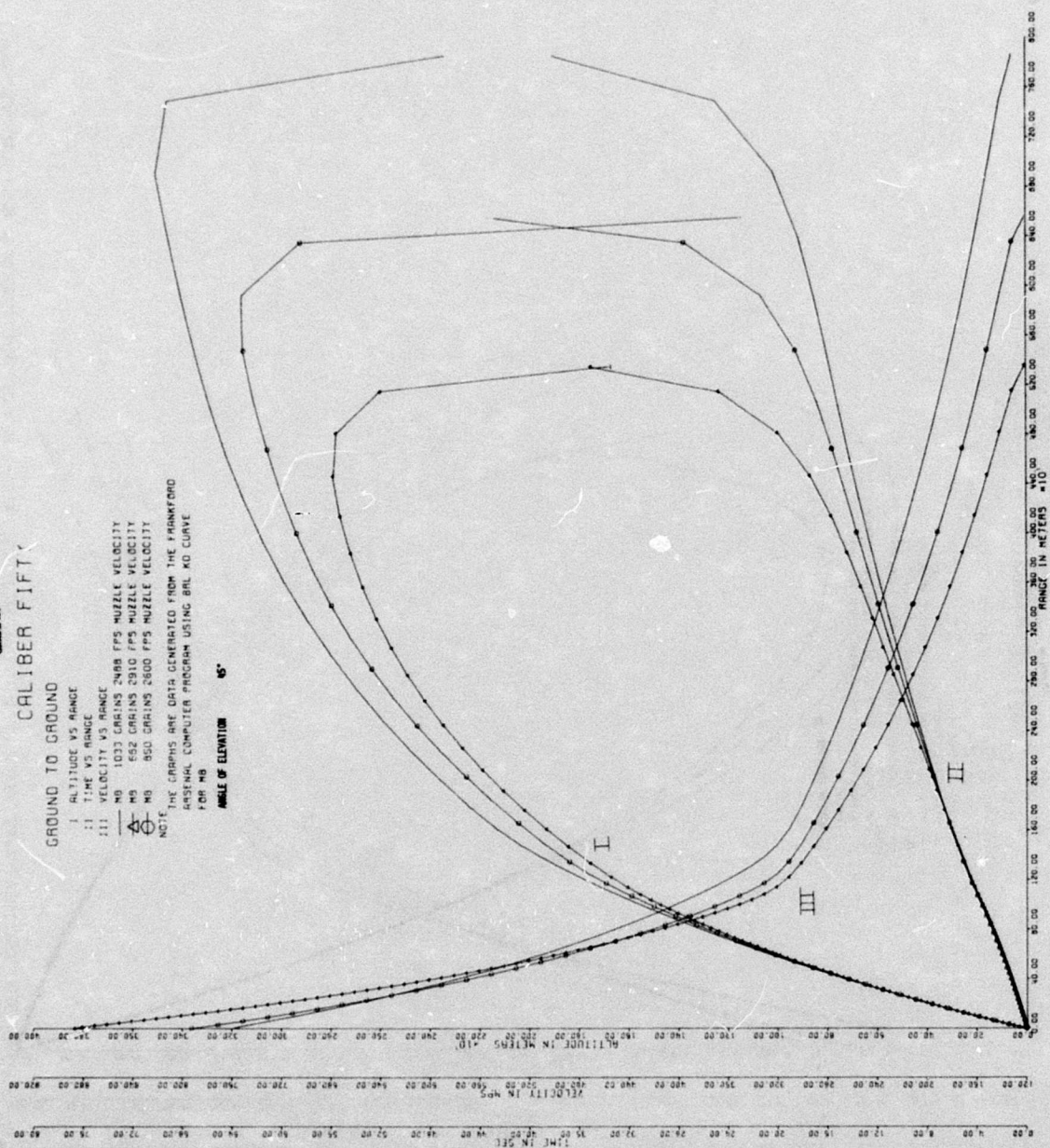
M0 1033 GRAINS 2488 FPS MUZZLE VELOCITY

M5 652 GRAINS 2910 FPS MUZZLE VELOCITY

M8 850 GRAINS 2600 FPS MUZZLE VELOCITY

NOTE: THE GRAPHS ARE DATA GENERATED FROM THE FRANKFORD
ARTISAN COMPUTER PROGRAM USING BRL NO. CURVE
FOR M0

ANGLE OF ELEVATION 65°



CALIBER FIFTY

GROUND TO GROUND

I ALTITUDE VS RANGE

II TIME VS RANGE

III VELOCITY VS RANGE

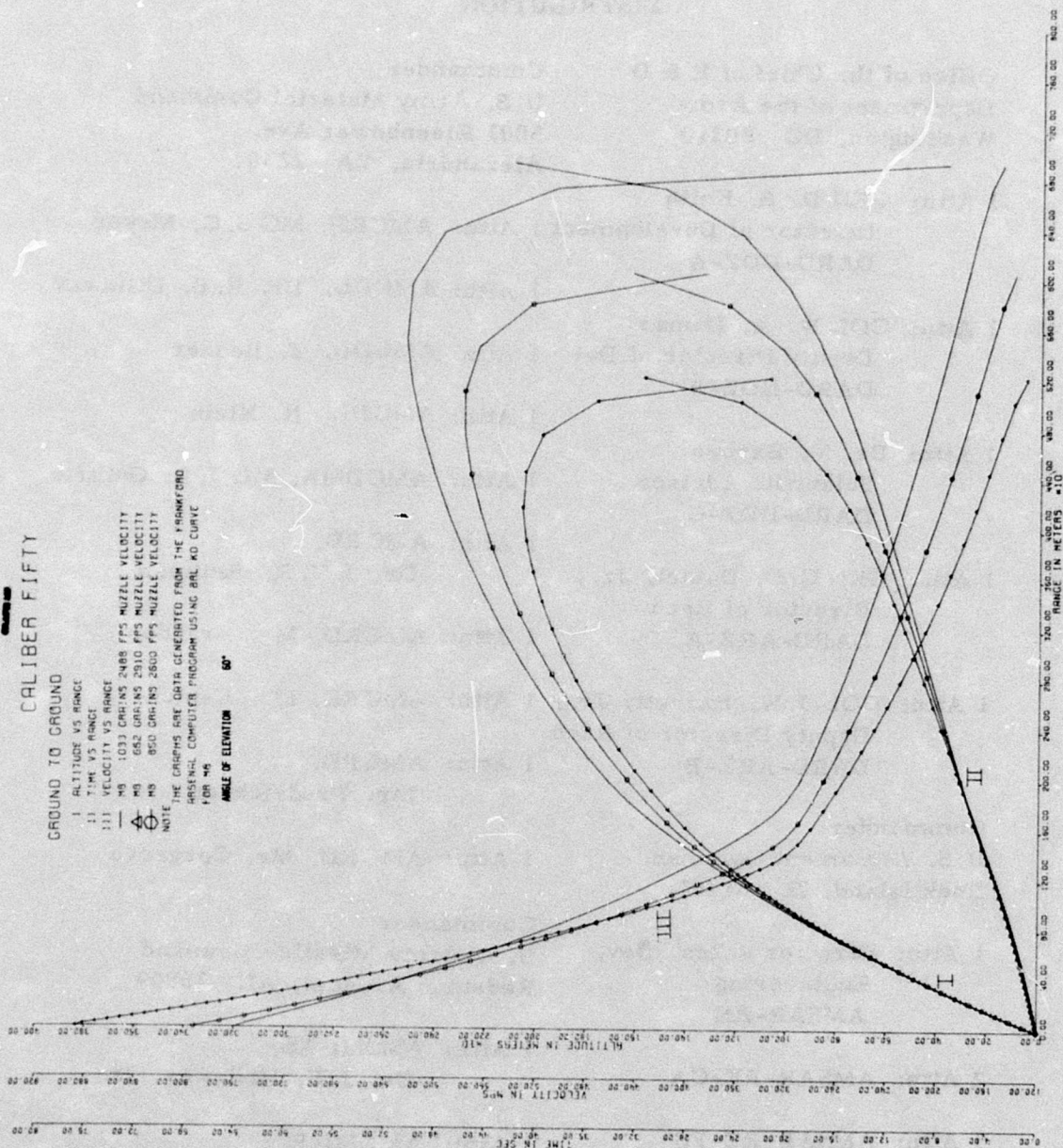
MB 1033 GR/INS 2488 FPS MUZZLE VELOCITY

MB 652 GR/INS 2910 FPS MUZZLE VELOCITY

MB 850 GR/INS 2800 FPS MUZZLE VELOCITY

NOTE THE GRAPH IS DATA GENERATED FROM THE FRANKFORD
BARRELL COMPUTER PROGRAM USING ARL AD CURVE
FOR MB

ANGLE OF ELEVATION 60°



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