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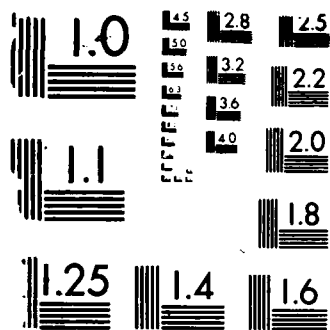
AUTOMATIC PLOTTING ROUTINES FOR ESTIMATING STATIC
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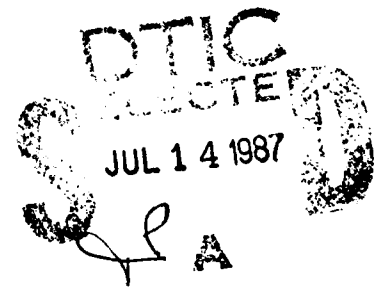
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MEMORANDUM REPORT BRL-MR-3573

AUTOMATIC PLOTTING ROUTINES FOR
ESTIMATING STATIC AERODYNAMIC PROPERTIES
OF FLARED PROJECTILES FOR $2 < M < 5$

WILLIAM F. DONOVAN

MARCH 1987



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US ARMY BALLISTIC RESEARCH LABORATORY
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) A predictive program for the estimation of static aerodynamic coefficients for flared projectiles at 2<M<5 is presented in HP9845 computer context. The technique is demonstrated by application to a typical projectile for which range data is available for completion.		

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I. INTRODUCTION

The aerodynamic performance of flared projectiles has not been investigated in detail - either by the wind tunnel techniques, which usually focus on the effects of perturbations of the flare geometry; or on the free flight ranges, which normally employ the flare for its strong stabilizing influence in order to survey some other performance parameter. For a given projectile, the wind tunnel experiments can efficiently determine axial force, normal force and spin deceleration characteristics and the influence of the Reynolds number on these coefficients. However, the dynamic coefficients, C_{M_p} and $C_{M_q} + C_{M_{\alpha}}$, are not easily established and the axial force coefficient is clearly not equivalent to the drag coefficient which is required for application design. Free flight ranges are most suitable for measurements of the drag and the dynamic coefficients and, ultimately, the dispersion and accuracy.

The few flare control data available verify that the high drag associated with the flare makes such a projectile unattractive for anything but very short range applications, although a recent publication in the form of a careful computational study describes a very novel flare concept which will require evaluation by experimental methods.

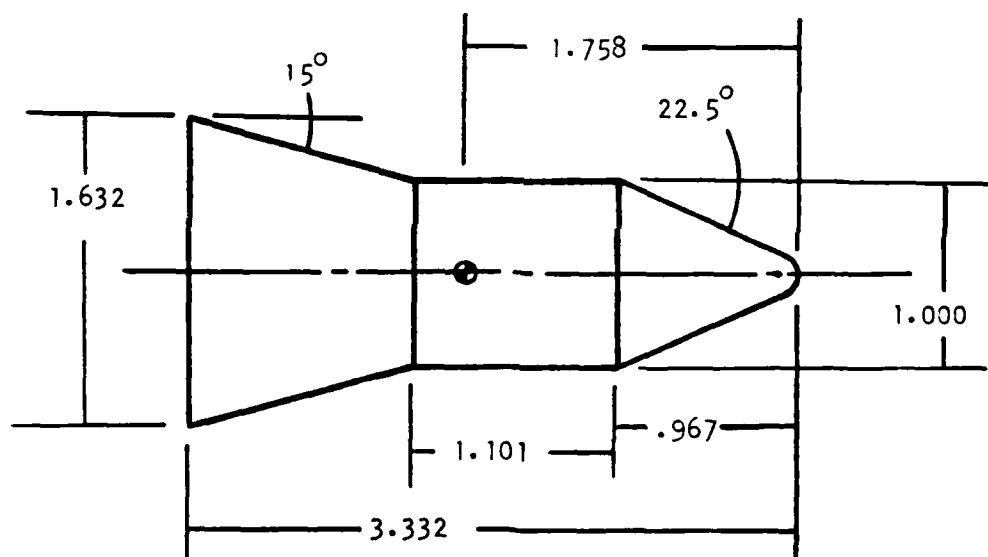
This present report is intended to be used in the formulation of quick estimates of the static aerodynamic characteristics of the conventional flared projectile. The data is based primarily on References 2 and 5 and the exposition follows that of the corresponding finned projectile presentation. The drag, static moment and normal force coefficients are determined from the simplified geometry of the projectile and the bounding aerodynamic conditions, i.e., sea level, flat fire, $2 < M < 5$, and small yaw. The computer program is written in the Hewlett-Packard Basic language and is easily convertible to other Basic-language microcomputers.

II. PROCEDURE AND RESULTS

The empirically-developed expressions for the aerodynamic contributions of the components are based on those of the corresponding elements for the similar finned projectile - following the form of Reference 5. Modifications are introduced as indicated by the test data of Reference 2. Caliber notation, where a representative linear dimension indicates a reference length and the mass/force dimension is converted to a specific gravity equivalent, is used in the physical description and in the interior of the program operation.

Figure 1 is a sketch and Figure 2 is a set of shadowgraphs of a flared projectile. Tables 1, 2 and 3 define the equations used to describe the aerodynamic parameters. The initialization instructions are presented in Appendix A and the full program listings follow. Figures 3.a through 3.g present a projectile outline, input tabulation, a table of the static aerodynamic coefficients and graphs of the normal force slope, drag, static moment slope, lift force slope, accuracy factor and velocity decrement. The range is $2 < M < 5$.

This is an interactive program, i.e., the operator responds to specific requests from the computer, which permits selective options of the output.



Dimensions in calibers

Wt.	3.11 lb.	(4.11 cal ³)
I _y	11.94 lb.-in ²	(2.08 cal ⁵)
d	2.757 in.	(1.0 cal)

Figure 1. Outline Sketch of Flared Projectile (Reference 2)

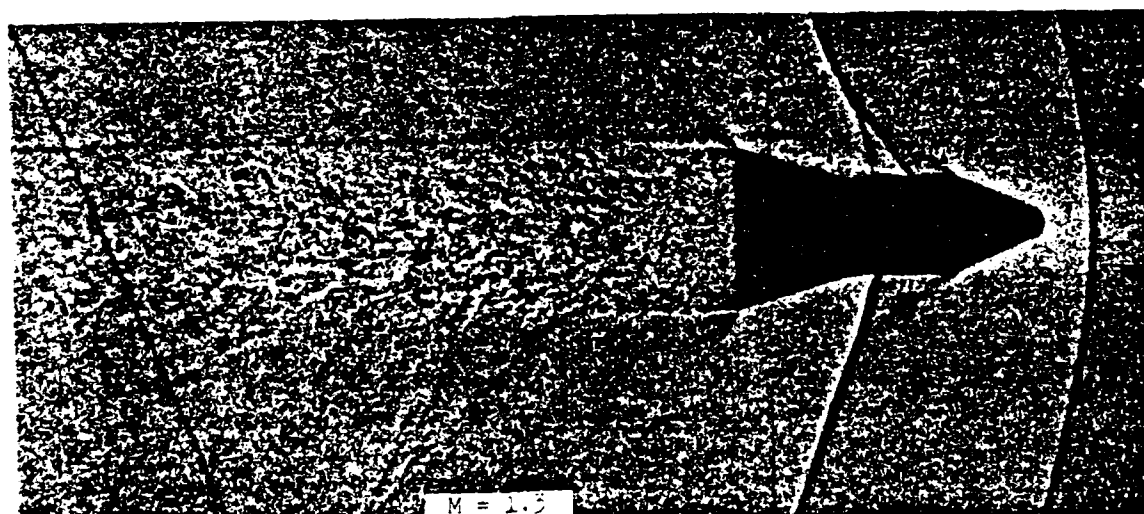
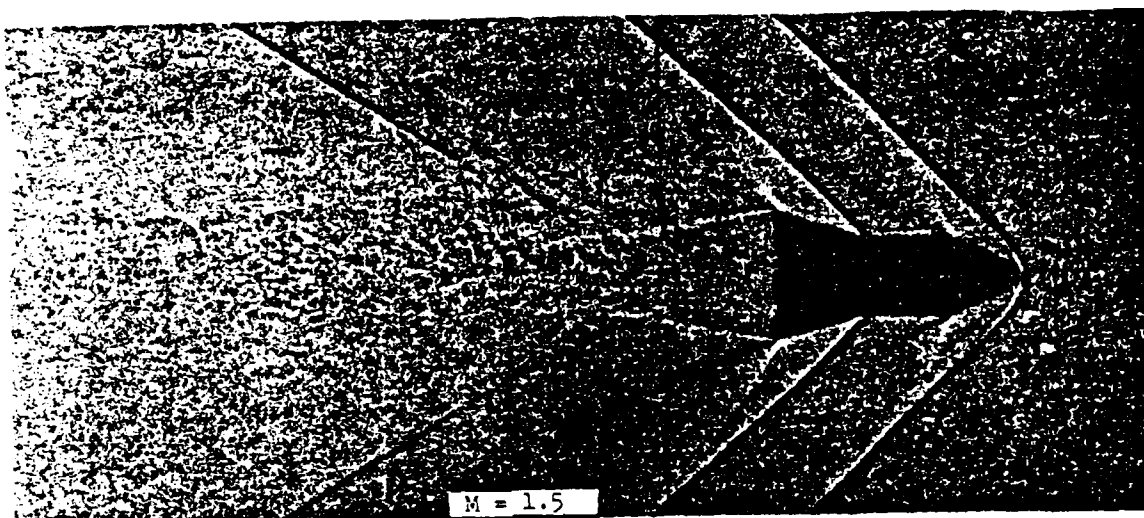


Figure 2. Shadowgraphs of Minuteman Missile Model in Flight (Reference 2)

TABLE 1. DRAG COEFFICIENT

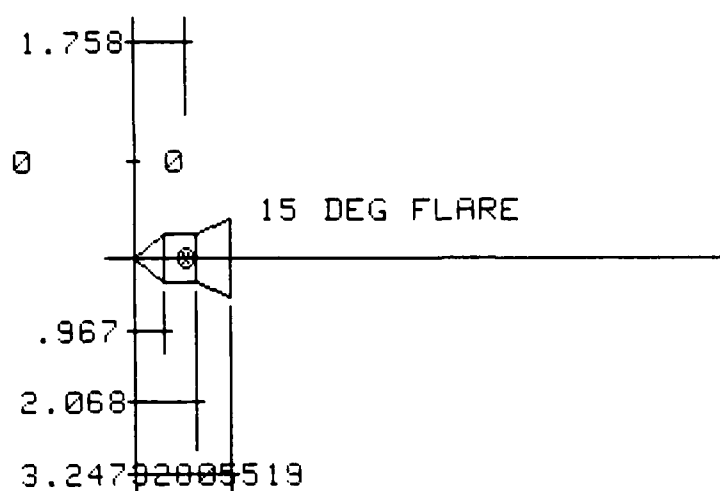
	DRAG COEFFICIENT
Wave _{Nose}	$C_{DWN} = .7M^{-.28} \ell_n^{-1.73}$
Base	$C_{DB} = e^{.6\theta} (-0.048 M + .265) d_b^2$
Viscous	$C_{DV} = 0.000173 (28.75 - 4.166 M) \frac{A_{\text{wetted surface}}}{A_{\text{ref}}}$
Wave _{Flared}	$C_{DWF} = \frac{3\theta}{M} (0.75 - \frac{0.6}{d_b})$
Grooves	$C_{DGR} = .00025 M^{3.9} \Delta \ell_{GR} (C_{DWN} + C_{DV} + C_{DWF})$
Total	$C_{DT} = C_{DWN} + C_{DB} + C_{DWF} + C_{DGR}$

TABLE 2. NORMAL FORCE AND STATIC MOMENT SLOPE COEFFICIENT

Normal Force and Static Moment Coefficients			
Nose Datum	Body	Normal Force Coefficient	$C_{NaB} = (1.9 + 1.3 \frac{B}{L_n} + .0149 \frac{L_a}{B}) (\beta^{-.7}) (.6103 + .036M)$
		Center of Pressure of Normal Force	$x_{c.p.B} = (.89 + .75 \frac{B}{L_n} + .5 \frac{L_a}{B}) M^{2.5} \beta^{1.98}$
		Static Moment Coefficient	$C_{MaB} = (x_{c.p.B}) (C_{NaB})$
	Flare	Normal Force Coefficient	$C_{NaF} = (2.67 - \frac{.67}{d_b}) (\cos \theta) (M/B)$
		Center of Pressure of Normal Force	$x_{c.p.F} = L_n + L_a + .1 (d_b - 1) / \tan \theta$
		Static Moment Coefficient	$C_{MaF} = (x_{c.p.F}) (C_{NaF})$
	Assembly	Normal Force Coefficient	$C_{Na} = C_{NaB} + C_{NaF}$
		Static Moment Coefficient	$C_{Ma} = C_{MaB} + C_{MaF}$
		Center of Pressure of Normal Force	$x_{c.p.} = C_{Ma} / C_{Na}$
Gravity Datum	Assembly	Normal Force Coefficient	$C_{Na} = C_{Na}$
		Center of Pressure of Normal Force	$x_{c.p.} = x_{c.p.}$
		Static Margin	$\Delta x = x_{c.p.} - x_{c.g.}$
		Static Moment	$C_{Ma} = (x_{c.p.} - x_{c.g.}) (C_{Na})$

TABLE 3. RETARDATION AND ACCURACY FACTOR

Retardation	
Mach Number along Trajectory	$M_1 = \frac{b}{R e^{Qs} - c}$
Average Velocity Decrement	$\Delta v = \frac{M_0 - M_1}{s} (v)_{\text{sonic}}$
Accuracy Factor	
Accuracy Factor	$J_{\zeta} = \frac{C_{L\alpha}}{C_{M\alpha}} \frac{I_y}{md^2}$



WT = 4.11 WCAL3
 IX = 0 ICAL5
 IY = 2.08 ICAL5
 DIA= 2.757 IN/CAL

ALL VALUES ARE IN CALIBERS UNLESS OTHERWISE NOTED

CONICAL NOSE LENGTH: .967
 CYLINDRICAL BODY LENGTH: 1.101
 GROOVE LOCATION/NOSE: 0
 GROOVE LENGTH: 0
 MAX FLARE DIAMETER: 1.632
 FLARE ANGLE: 15
 0.00
 CENTER OF GRAVITY: 1.758
 MACH NUMBER AT MUZZLE: 3
 MAXIMUM RANGE (METERS): 1000
 PROJECTILE WEIGHT (CAL3): 4.11
 AXIAL MOMENT OF INERTIA (CAL5): 0
 TRANSVERSE MOMENT OF INERTIA (CAL5): 2.08
 1.0 CALIBER REFERENCE DIAMETER (IN.): 2.757

Figure 3a. Computer-Generated Output: Projectile Outline and Input Parameters

STATIC AERODYNAMIC COEFFICIENTS FOR
LONG ROD FLARED PROJECTILES

	MACH NUMBER						
	2.0	2.5	3.0	3.5	4.0	4.5	5.0
CNAB	1.976	1.911	1.888	1.883	1.887	1.898	1.911
XCPB	1.331	1.507	1.631	1.730	1.817	1.894	1.966
CMAB	2.629	2.880	3.079	3.258	3.428	3.594	3.757
CNAF	2.520	2.381	2.315	2.277	2.254	2.238	2.227
CNAT	4.496	4.293	4.203	4.160	4.141	4.136	4.139
CMAT	8.435	8.366	8.412	8.505	8.621	8.751	8.889
CG-CP	-.118	-.191	-.244	-.286	-.324	-.358	-.390
CMAT,CG	-.532	-.819	-1.023	-1.191	-1.341	-1.480	-1.613
CDWN	.611	.574	.545	.522	.503	.487	.473
CDB	.527	.452	.377	.302	.227	.153	.078
CDV	.046	.041	.037	.032	.027	.022	.018
CDGR	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CDWF	.150	.120	.100	.086	.075	.067	.060
CDT	1.334	1.187	1.059	.942	.833	.729	.628
CLA	3.162	3.105	3.143	3.218	3.308	3.407	3.510
J ZETA	-3.009	-1.918	-1.554	-1.367	-1.249	-1.165	-1.102

Figure 3b. Computer-Generated Output: Table of Aerodynamic Coefficients

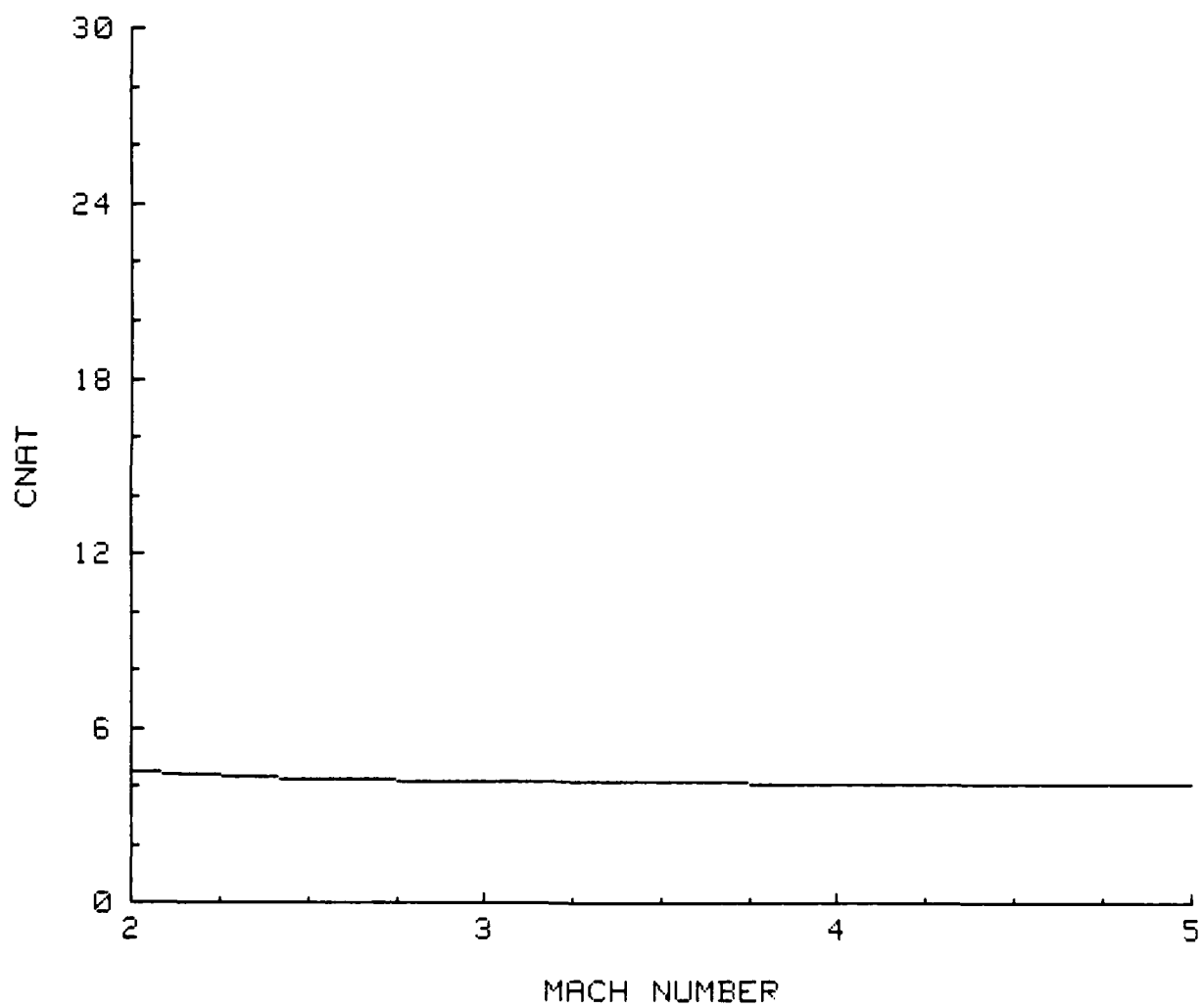


Figure 3c. Computer-Generated Output: Normal Force Slope Coefficient

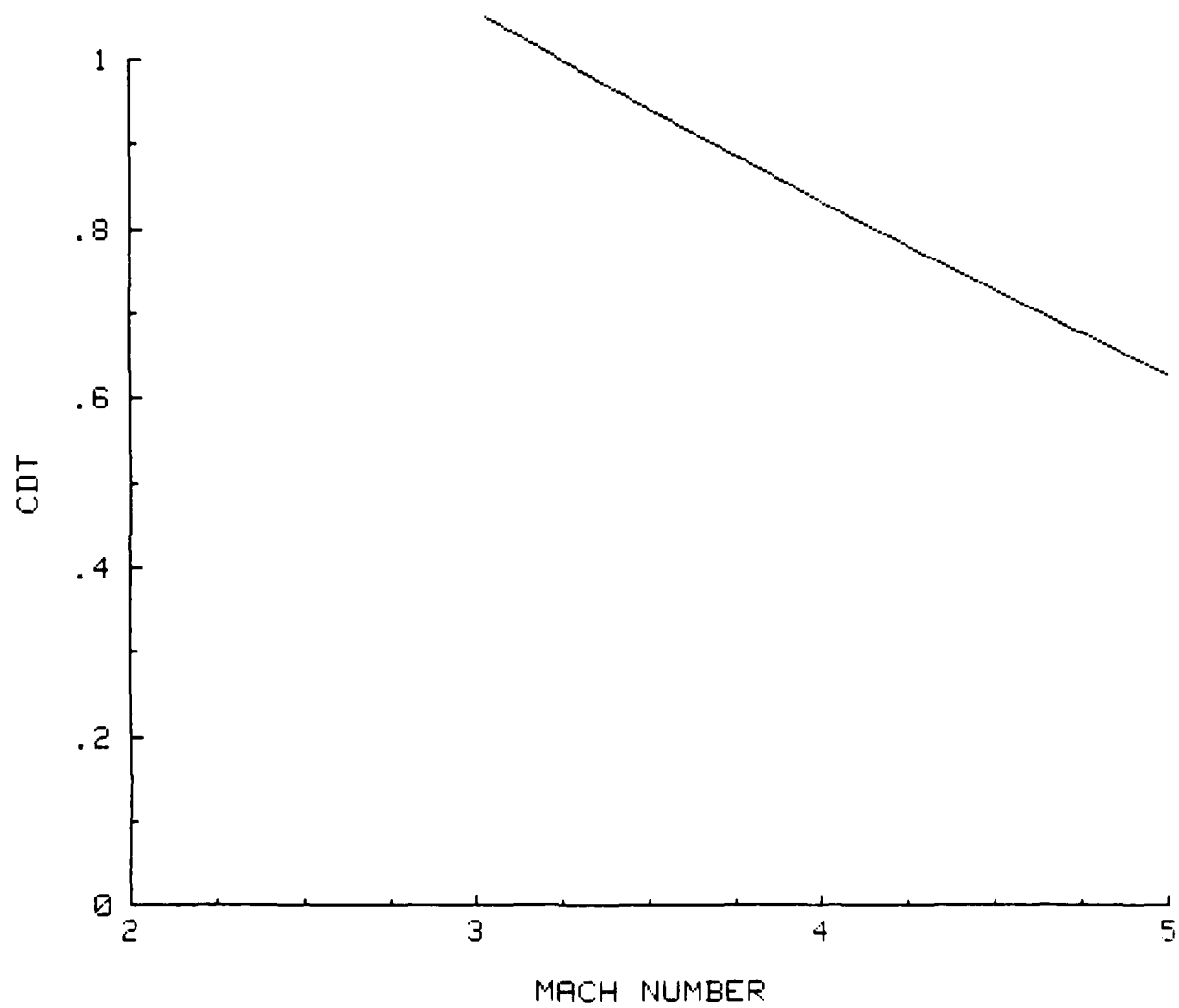


Figure 3d. Computer-Generated Output: Zero-Yaw Drag Coefficient

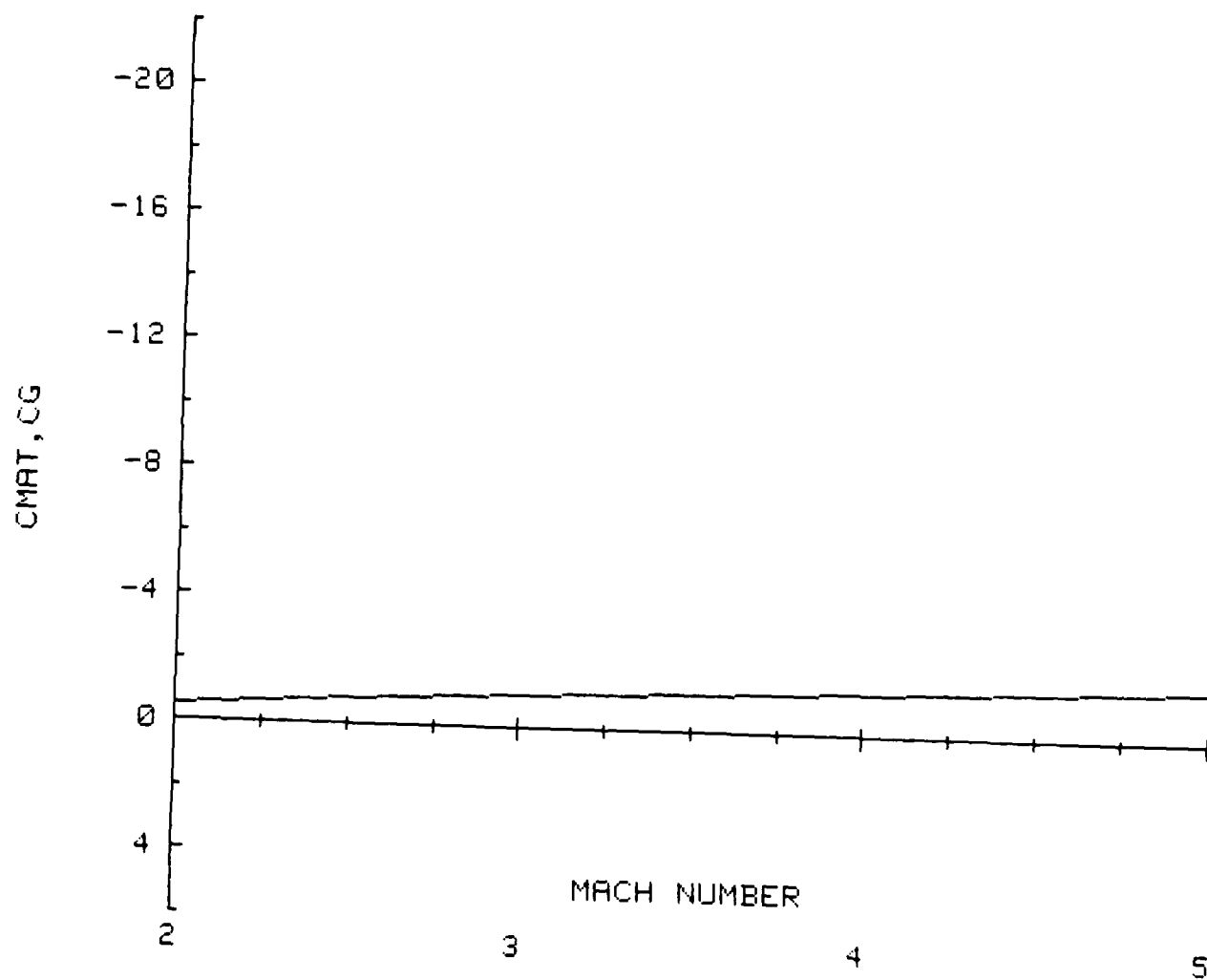


Figure 3e. Computer-Generated Output: Static Moment Slope Coefficient

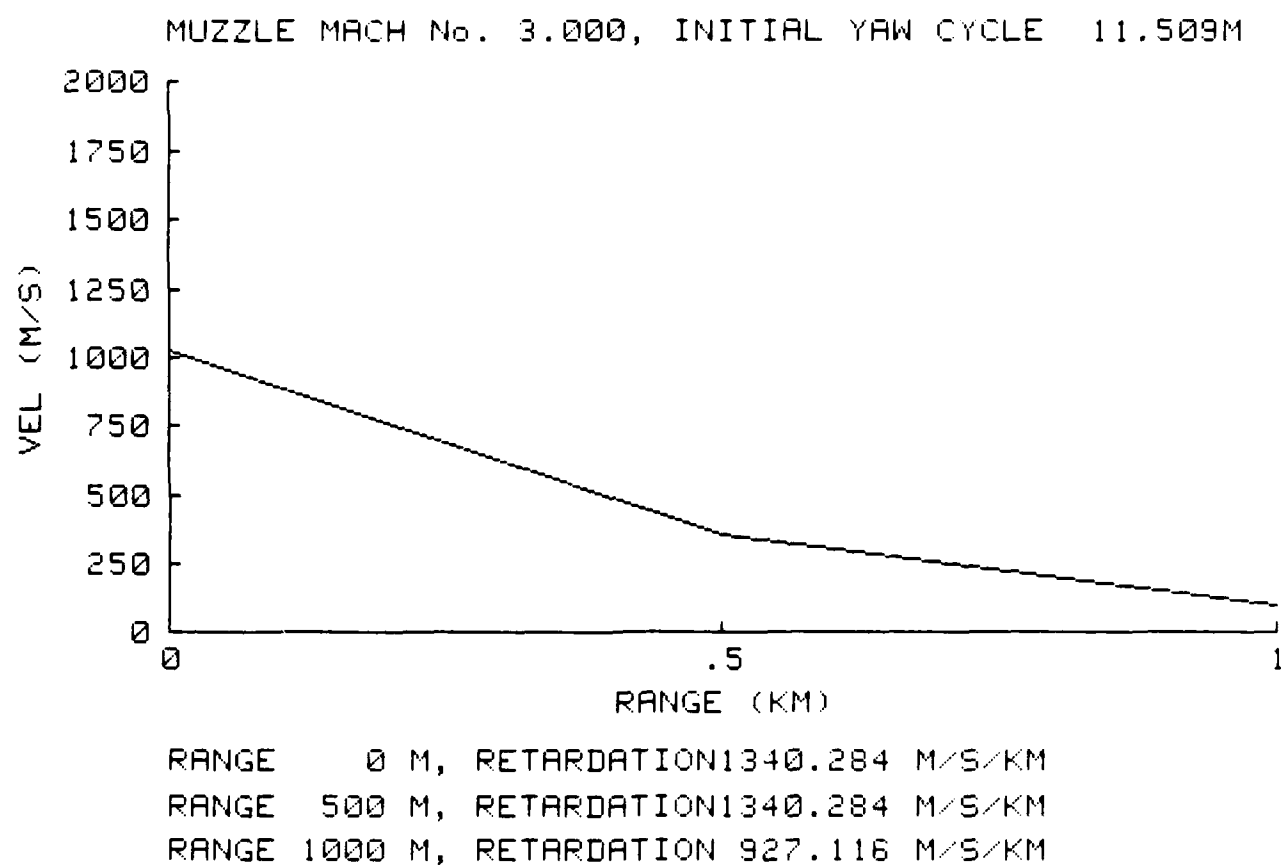


Figure 3f. Computer-Generated Output: Trajectory Parameters

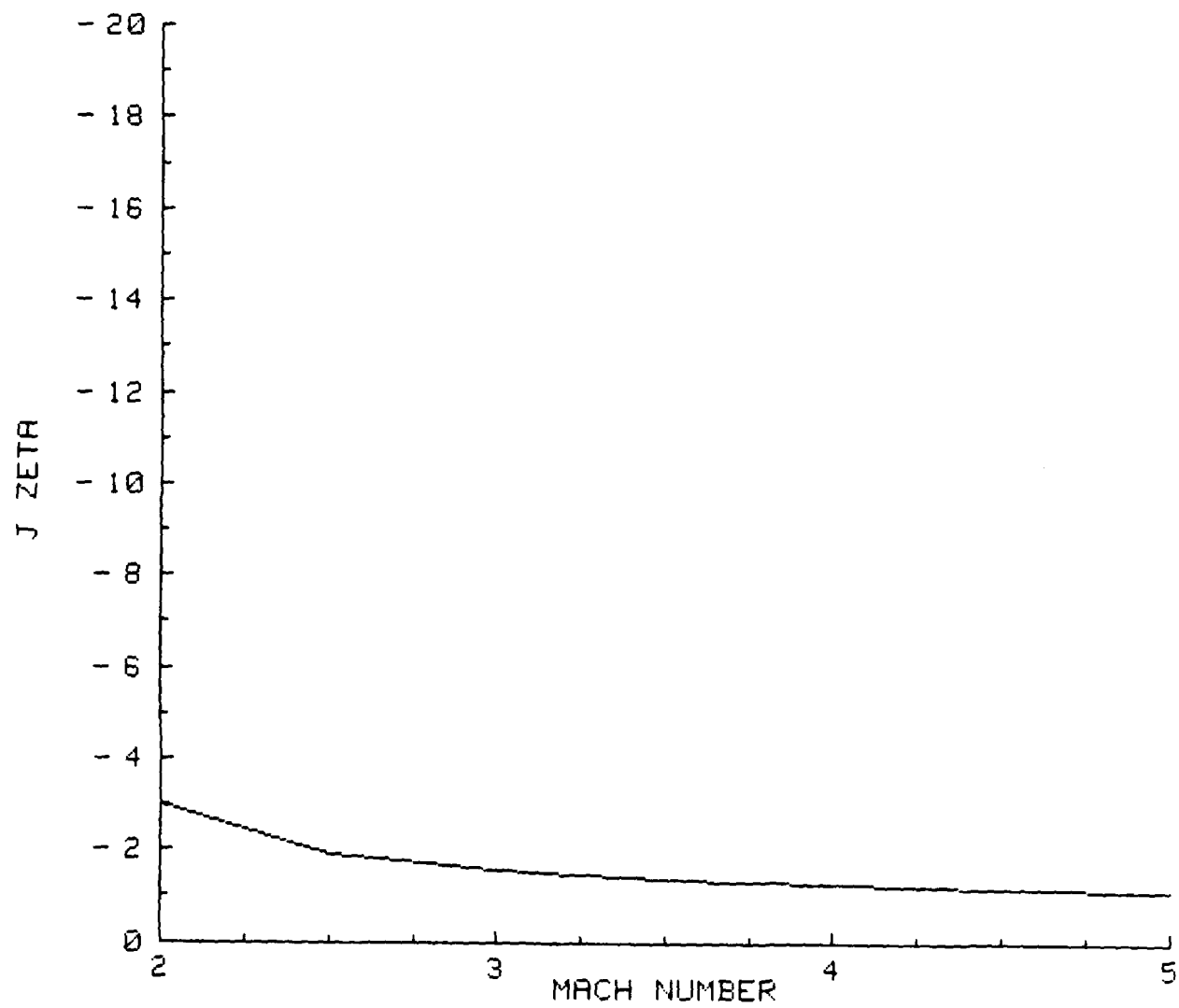


Figure 3g. Computer-Generated Output: Accuracy Factor

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2. E.D. Boyer, "Free Flight Range Tests of a Minuteman Re-entry Stage Model," BRL Memorandum Report No. 1346, May 1961 (AD #326744).
3. D.J. Spring, "The Static Stability Characteristics of Several Cone-Cylinder-Flare-Cylinder Configurations at Mach Numbers 0.4 to 4.5," Report No. RF-TR-63-14, Army Missile Command, Huntsville, Alabama, 1963.
4. M.J. Nusca, "Numerical Investigation of the Aerodynamics of a Flared Afterbody for Axisymmetric Projectiles at Supersonic Speeds," ARBRL-TR-02535, U.S. Army Ballistic Research Laboratory, Aberdeen Proving Ground, MD, 21005, December 1983 (AD #136862).
5. AMCP 706-280, "Design of Aerodynamically Stabilized Free Rockets," 1968.
6. W.F. Donovan, M.J. Nusca and S.A. Wood, "Automatic Plotting Routines for Estimating Static Aerodynamic Properties of Long Rod Finned Projectiles," BRL Memorandum Report No. ARBRL-MR-03123, August 1981 (AD #104900).

LIST OF SYMBOLS

b	Intercept of C_D vs M characteristic
c	Slope of C_D vs M characteristic
c.g.	Center of gravity of projectile, nose datum
c.p.	Center of pressure of normal force
d	1.0 cal, reference diameter
d_b	Diameter of base of flare
e	Base of Natural log
l_a	Cylindrical body length
l_{gr1}	Groove length from nose (starting groove)
l_{gr2}	Groove length from nose (last groove)
Δl_{gr}	Groove length
l_n	Nose length
m	Mass of projectile
s	Range
v	Velocity of projectile
Δv	Velocity decrement over specified range
$x_{c.p.B}$	Center of pressure of normal force on body
$x_{c.p.F}$	Center of pressure of normal force on flare
A_{ref}	Reference area (.785 cal ²)
A_{wetted}	Surface Area of lateral surface producing viscous flow drag
C_D	$\frac{\text{Drag Force}}{\frac{1}{2} \rho v^2 A_{ref}}$, zero-yaw drag coefficient
C_{DB}	Pressure drag coefficient - base of flare

LIST OF SYMBOLS (continued)

C_{DGR} Drag coefficient due to grooves

C_{DT} Total Drag coefficient

C_{DWN} Wave drag coefficient - body (nose)

C_{DWF} Wave drag coefficient - flare

$C_{L\alpha}$ $\frac{\text{Lift Force}}{\frac{1}{2} \rho v^2 A_{ref} \delta}$, aerodynamic lift slope coefficient, $\delta = \sin \alpha_T$

$C_{M\alpha}$ $\frac{\text{Static Moment}}{\frac{1}{2} \rho v^2 A_{ref} d \delta}$, aerodynamic moment slope coefficient

$C_{M\alpha B}$ Static moment coefficient - body

$C_{M\alpha F}$ Static moment coefficient - flare

$C_{N\alpha}$ $\frac{\text{Normal Force}}{\frac{1}{2} \rho v^2 A_{ref} \delta}$, aerodynamic normal force slope coefficient

$C_{N\alpha B}$ Normal force coefficient - body

$C_{N\alpha F}$ Normal Force coefficient - flare

I_x Axial moment of inertia

I_y Transverse moment of inertia

J_ζ $\frac{I_y}{md^2} \frac{C_{L\alpha}}{C_{M\alpha}}$, aerodynamic jump factor

LIST OF SYMBOLS (continued)

M	Mach number
M ₀	Mach number at muzzle
M ₁	Mach number along trajectory
Q	Operational parameter, $\frac{\rho A_{ref}^b}{2 m}$
R	Operational parameter, $\frac{c M_o + b}{M_o}$
α	Angle of attack, employed here as a subscript
β	$(M^2 - 1)^{1/2}$, operational parameter
δ	Sine of total angle of attack
ζ	Dispersion parameter, employed here as a subscript
θ	Flare half-angle
π	3.1416
ρ	Ambient air density

APPENDIX A
INITIALIZATION INSTRUCTIONS

APPENDIX A

INITIALIZATION INSTRUCTIONS

To use this program, the operator requires only the entry of the geometry and the physical properties of the projectile, the range excursion and the muzzle Mach number. Caliber notation, where a representative linear dimension provides a reference length and the mass/force dimension is converted to a specific gravity equivalent, is employed extensively. The reference diameter may be in inches or in millimeters and the range input in meters.

The program will call for the operator to respond as required.

```

10  OPTION BASE 1      PROGRAM FILE "FLARE"
20  DIM Q(20,7),Q1(7),A$(1),R2(20),R3(20),V(20)
30  INTEGER Array_t(0:23935),Array_b(0:23940)
40  PRINT PAGE
50  BEEP
60  PRINT "THIS PROGRAM WILL CALCULATE AND PLOT ESTIMATED"
70  PRINT " STATIC AERODYNAMIC COEFFICIENTS OF LONG ROD"
80  PRINT "FLARED PROJECTILES IN THE MACH RANGE 2-5"
90  PRINT
100 Proj_design: PRINT
110  Computed=0
150  PRINT "INPUT THE FOLLOWING VALUES IN CALIBERS:"
160  PRINT " CONICAL NOSE LENGTH: "
170  BEEP
190  INPUT L
181  PRINT "L "; "CONICAL NOSE LENGTH";L
190  PRINT " CYLINDRICAL BODY LENGTH: "
200  BEEP
210  INPUT L1
211  PRINT "L1 "; "CYLINDRICAL BODY LENGTH";L1
220  PRINT " GROOVE LOCATION/NOSE: "
230  BEEP
240  INPUT P1
241  PRINT "P1 "; "GROOVE LOCATION/NOSE";P1
250  PRINT " GROOVE LENGTH: "
260  BEEP
270  INPUT P2
271  PRINT "P2 "; "GROOVE LENGTH";P2
280  PRINT " MAX FLARE DIAMETER"
290  BEEP
300  INPUT H3
310  PRINT "H3 "; "MAX FLARE DIAMETER";H3
320  PRINT " FLARE ANGLE"
330  BEEP
340  INPUT H4
350  PRINT "H4 "; "FLARE ANGLE";H4
460  PRINT " CENTER OF GRAVITY OF PROJECTILE: "
470  BEEP
480  INPUT C2
491  PRINT "C2 "; "CENTER OF GRAVITY OF PROJECTILE";C2
492  PRINT
493  PRINT
500  PRINT "INPUT 1.0 CALIBER REFERENCE DIAMETER (INCHES): "
510  BEEP
520  INPUT D
521  PRINT "D "; "INPUT 1.0 CALIBER REFERENCE DIAMETER (INCHES)";D
530  PRINT "INPUT 1.0 CALIBER REFERENCE DIAMETER (MILLIMETERS): "
540  BEEP
550  INPUT D1
551  PRINT "D1 "; "INPUT NORMALIZED PROJECTILE WEIGHT (MILLIMETERS)";D1
560  PRINT "INPUT NORMALIZED PROJECTILE WEIGHT (CUBIC CALIBERS): "
570  BEEP
580  INPUT W
581  PRINT "W "; "INPUT NORMALIZED PROJECTILE WEIGHT (CUBIC CALIBERS)";W
590  PRINT "INPUT AXIAL MOMENT OF INERTIA (CALIBERS**5): "
600  BEEP
610  INPUT I
611  PRINT "I "; "INPUT AXIAL MOMENT OF INERTIA (CALIBERS**5)";I
620  PRINT "INPUT TRANSVERSE MOMENT OF INERTIA (CALIBERS**5): "
630  BEEP

```

```

640 INPUT I1
641 PRINT "I1 "; "INPUT TRANSVERSE MOMENT OF INERTIA (CALIBERS**5)"; I1
650 PRINT
660 PRINT "INPUT MACH NUMBER AT MUZZLE: "
670 BEEP
680 INPUT M0
681 PRINT "M0 "; "INPUT MACH NUMBER AT MUZZLE:"; M0
690 PRINT "INPUT MAXIMUM RANGE (METERS): "
700 BEEP
710 INPUT S
720 S9=S
730 PRINT PAGE
740 DEG
750 B=20
760 B1=25
780 B3=L+L1
790 H6=H3/2
800 H7=1/.5*(H3-1)
801 H8=B3+H7
840 Image_1: IMAGE 2D.2D
850 Z=0
940 PLOTTER IS 13,"GRAPHICS"
950 Iplot=0
960 Graphics: GRAPHICS
970 EXIT ALPHA
980 SCALE -6,40,5,23
990 X_scale_factor=42/23
1000 MOVE -1.20
1010 DRAW 20,20
1020 MOVE 0,B
1030 DRAW L,B+.5
1040 DRAW L,B-.5
1050 DRAW 0,B
1060 MOVE L,B+.5
1070 DRAW B3,B+.5
1080 DRAW B3,B-.5
1090 DRAW L,B-.5
1100 MOVE B3,B+.5
1110 DRAW H7+B3,B+H6
1120 DRAW H7+B3,B-H6
1130 DRAW B3,B-.5
1140 MOVE 0,B-.2
1150 DRAW 0,B-.5
1160 MOVE L,B-.7
1170 DRAW L,B-.2
1180 MOVE B3,B-.7
1190 DRAW B3,B-.4
1240 MOVE -.25,B-1.5
1250 DRAW L+.25,B-1.5
1260 MOVE -4,B-1.5
1270 LOGO 2
1280 LABEL L
1290 MOVE -.25,B-3
1300 DRAW B3+.25,B-3
1310 IPLOT -B3-4.8,0,-2
1320 LABEL B3
1330 MOVE -.25,B-3
1340 DRAW B3+.25,B-3
1350 MOVE -.25,B-4.5
1360 DRAW H8+.25,B-4.5
1370 IPLOT -H8-4.8,0,-2
1380 LABEL H8
1391 MOVE H8,B-H6-.2
1392 DRAW H8,B-.5
1393 MOVE H9,B-4.5
1394 DRAW H9,B-4.5

```

```

1810 MOVE 0,B+.2
1820 DRAW 0,B+.5
1830 MOVE C2,B+.3
1840 DRAW C2,B+.5
1850 MOVE -.25,B+.4.5
1860 DRAW C2+.25,B+.4.5
1870 IPLOT -C2-4.8,0,-2
1880 LABEL C2
1881 MOVE -.25,B+.4.5
1882 DRAW C2,B+.4.5
1890 MOVE -.25,2+B
1900 DRAW P1+P2,2+B
1901 IPLOT -P1-P2-4.8,0,-2
1910 LABEL P1
1920 MOVE P1+P2,2+B
1930 DRAW P1+P2+.2,2+B
1940 MOVE P1+P2+.3,2+B
1950 LABEL P2
1960 LONG 1
1970 REM
1980 REM
1990 MOVE C2-.1,B-.1
2000 DRAW C2+.1,B+.12
2010 MOVE C2+.1,B-.12
2020 DRAW C2-.1,B+.12
2030 MOVE P1,B+.7
2040 DRAW P1,B+.2.5
2050 MOVE P1+P2,B+.7
2060 DRAW P1+P2,B+.2.5
2070 MOVE C2,B
2080 LONG 5
2090 LABEL "0"
2110 MOVE P1,.5+B
2120 DRAW P1+P2,-.5+B
2130 DRAW P1+P2,.5+B
2140 DRAW P1,-.5+B
2150 DRAW P1,.5+B
2151 LONG 1
2160 MOVE H8+.25,B+.8
2170 REM
2180 REM
2190 LABEL H4;"DEG FLARE"
3080 LONG 1
3100 MOVE 1.5,B-9
3110 LABEL "WT ="
3120 MOVE 4.5,B-9
3130 LABEL W;" WCAL3"
3140 MOVE 1.5,B-10
3150 LABEL "IX ="
3160 MOVE 4.5,B-10
3170 LABEL I;" ICAL5"
3180 MOVE 1.5,B-11
3190 LABEL "IY ="
3200 MOVE 4.5,B-11
3210 LABEL I1;" ICAL5"
3220 MOVE 1.5,B-12
3230 LABEL "DIA="
3240 MOVE 4.5,B-12
3250 IF D=0 THEN LABEL D1;" MM/CAL"
3260 IF D<0 THEN LABEL D;" IN/CAL"
3270 MOVE 8.25,26
3280 LABEL "LONG ROD FLARED PROJECTILE DESIGN"
3290 GSTORE Array_t(+)
3300 GSTORE Array_b(+),0,227
3310 EXIT GRAPHICS
3320 ALPHA

```

```

3330 IF Iplot=0 THEN Ask_it
3340 PLOTTER 7,5 IS OFF
3350 GCLEAR
3360 GOTO Print_input
3370 Ask_it: PRINT PAGE
3380 IpTot=1
3390 PRINT "DO YOU WANT A HARD COPY OF THE PLOT? (Y or N)"
3400 BEEP
3410 INPUT Reply$
3420 IF Reply$<>"Y" THEN Keep_picture
3430 PRINT "DO YOU WANT THE COPY ON THE PRINTER (0), OR ON THE PEN PLOTTER (1)?"
3440 BEEP
3450 INPUT Plot_device
3460 IF Plot_device=0 THEN Dump_graphics
3470 PRINT "SET PEN PLOTTER AND PRESS CONTINUE WHEN READY"
3480 BEEP
3490 PAUSE
3500 PLOTTER IS 7,5,"9872A"
3510 GLOAD Array_t(*)
3520 GLOAD Array_b(*),0,227
3530 PLOTTER 13 IS OFF
3540 GOTO Graphics
3550 Keep_picture: PRINT "PRESS CONTINUE TO RETURN PLOT. THE PLOT"
3560 PRINT "WILL REMAIN ON THE SCREEN UNTIL CONTINUE IS PRESSED AGAIN."
3570 BEEP
3580 PAUSE
3590 EXIT ALPHA
3600 GRAPHICS
3610 PAUSE
3620 GCLEAR
3630 EXIT GRAPHICS
3640 ALPHA
3650 GOTO Print_input
3660 Dump_graphics: EXIT ALPHA
3670 GRAPHICS
3680 DUMP GRAPHICS
3690 GCLEAR
3700 EXIT GRAPHICS
3710 Print_input: PRINT PAGE
3720 PRINT "DO YOU WANT THE INITIAL DATA PRINTED OUT? (Y or N)"
3730 BEEP
3740 INPUT Reply$
3750 IF Reply$<>"Y" THEN Menu
3760 PRINTER IS 0
3770 PRINT
3780 PRINT "ALL VALUES ARE IN CALIBERS UNLESS OTHERWISE NOTED"
3790 PRINT
3800 PRINT "CONICAL NOSE LENGTH: ";L
3810 PRINT "CYLINDRICAL BODY LENGTH: ";L1
3820 PRINT "SPOOVE LOCATION/NOSE: ";P1
3830 PRINT "GROOVE LENGTH: ";P2
3840 PRINT "MAX FLARE DIAMETER: ";H2
3850 PRINT "FLARE ANGLE: ";H4
3900 PRINT USING Image 1;F
3930 PRINT "CENTER OF GRAVITY: ";C2
3940 PRINT "MACH NUMBER AT MUZZLE: ";M0
3950 PRINT "MAXIMUM RANGE (METERS): ";S
3960 PRINT "PROJECTILE WEIGHT (CAL3): ";W
3970 PRINT "AXIAL MOMENT OF INERTIA (CAL5): ";I
3980 PRINT "TRANSVERSE MOMENT OF INERTIA (CAL5): ";I1
3990 IF D<0 THEN PRINT "1.0 CALIBER REFERENCE DIAMETER (IN.): ";D
4000 IF D1<0 THEN PRINT "1.0 CALIBER REFERENCE DIAMETER (MM): ";D1
4010 PRINT LINK$
4020 PRINTER IS 16
4030 Menu: PRINT PAGE

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4040 Menu_list: PRINT "OPTIONS:"
4050 PRINT " 0 - END PROGRAM"
4060 PRINT " 1 - NOMENCLATURE"
4070 PRINT " 2 - TABLE OF AERODYNAMIC COEFFICIENTS"
4080 PRINT " 3 - CNAT vs. MACH NUMBER PLOT"
4090 PRINT " 4 - CDT vs. MACH NUMBER PLOT"
4100 PRINT " 5 - VELOCITY vs. RANGE PLOT"
4110 PRINT " 6 - CMAT, CG vs. MACH NUMBER PLOT"
4120 PRINT " 7 - J ZETA vs. MACH NUMBER PLOT"
4130 PRINT " 8 - LONG ROD FLARED PROJECTILE DESIGN"
4140 PRINT "ENTER SELECTION:"
4150 BEEP
4160 INPUT Option
4170 IF Option=0 THEN End
4180 IF Computed<>0 THEN Where_to
4190 G1=W
4200 G2=L1
4210 G6=L+L1
4220 J2=L/SQR(L+L+.25)
4230 J3=.5*(H3-1)/TAN(H4)
4240 M=2
4250 FOR Y=1 TO 7
4260 G3=SQR(M+M-1)
4270 G4=G3/L
4280 G5=L1/G3
4290 Q1(Y)=M
4300 G7=(1.9+1.3*G4+.0149*G5)*(1/G3^.7)*(.6103+.036*G6)
4330 G8=TAN(F)/G3
4340 G9=(.09+.75*G4+.5*G5)*(1/G3^.53)*(G3/M)^2.5
4350 J1=G7*G9
4360 Q(1,Y)=G7
4370 Q(2,Y)=G9
4380 Q(3,Y)=J1
4390 J4=(-.67/H3+2.67)*COS(H4)*M/G3
4400 J5=L+L1+.1*(H3-1)/TAN(H4)
4410 J6=J4*J5
4491 J=J4*G7
4500 Q(4,Y)=J4
4510 K1=J
4520 K2=J1+J6
4530 K3=K2/J
4540 K4=G2-K3
4550 K5=K4+J
4560 K6=K5
4570 Q(5,Y)=J
4580 Q(6,Y)=K2
4590 Q(7,Y)=K4
4600 Q(8,Y)=K5
4610 J=6+J/10
4620 K5=6+K5+6/220
4630 K7=M+2-3.5
4640 K8=J
4650 K9=K7
4660 T1=K5
4670 T2=2*L/J2+4*L1+4*J3/COS(H4)*(1+J3*TAN(H4))
4700 T5=M^.28*L^1.73
4710 T5=.7/T5
4711 T6=EXP(.6*(H4/57.3))
4720 T6=(.265-.048*M)+H3^2+T6
4730 T7=T2*(.004974-.000721*M)
4731 T9=3*H4/57.3/M*(.75-.6/H3)
4780 F1=.00025*EXP(3.9*LOG(M))+P2
4790 F2=F1*(T5+T7+T9)
4800 F4=T5+T6+T7+T9+F2
4810 P4=F4
4820 REM

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4830 REM
4840 Q(9,Y)=T5
4850 Q(10,Y)=T6
4860 Q(11,Y)=T7
4870 Q(12,Y)=F2
4880 Q(14,Y)=T9
4930 Q(18,Y)=F4
4940 IF M=3 THEN F6=F4
4950 F4=F4+5+6
4960 IF M=5 THEN F7=(F4-6)/5
4970 F8=M+2+4
4980 F9=K1-F5
4990 Q(19,Y)=F9
5000 N1=G2/G1*(F9/K6)
5010 Q(20,Y)=N1
5020 M=M+.5
5030 N1=6+N1/2
5040 N2=N1
5050 O2=F8
5060 O3=F4
5070 NEXT Y
5080 N5=500
5090 Y=1
5100 N3=(F7-F6)/2
5110 N4=F6-3*N3
5120 N6=PI*.075/62.4/8+N4/W
5130 N7=N3+N4/M0
5140 Skip_6: IF D>0 THEN N8=EXP(S+N6+39.37/D)
5150 IF D1>0 THEN N8=EXP(S+N6+1000/D1)
5160 N9=N4/(N7+N8-N3)
5170 N0=(M0-N9)*341380
5180 V(Y)=N9*341.38
5190 N0=N0/S
5200 R2(Y)=S
5210 R3(Y)=N0
5220 O4=N9
5230 O5=S
5240 S=S-N5
5250 Y=Y+1
5260 IF S<>0 THEN Skip_6
5270 N3=(F7-F6)/2
5280 Y1=Y
5290 R2(Y)=0
5300 R3(Y)=R3(Y-1)
5310 V(Y)=N0*341.38
5320 N4=F6-3*N3
5330 N6=PI*.075/62.4/8+N4/W
5340 N7=N3+N4/M0
5350 IF D>0 THEN N8=EXP(O5+N6+39.37/D)
5360 IF D1>0 THEN N8=EXP(O5+N6+1000/D1)
5370 N9=N4/(N7+N8-N3)
5380 N0=(M0-N9)*341380
5390 N0=N0/O5
5400 O6=I1/K6+8*PI/.0012
5410 O6=SQR(ABS(O6))
5420 IF D>0 THEN O1=O6+D/39.37
5430 IF D1>0 THEN O1=O6+D1/1000
5440 Computed=1
5450 Where_to: ON Option GOTO Nomenclature,Coef_table,S_plot,S_plot,S_plot,S_plot,
S_plot,Proj_design
5460 S_plot: PRINT PAGE
5470 PRINT "DO YOU WANT THE PLOT ON THE SCREEN (0), OR ON THE"
5480 PRINT " PEN PLOTTER (1)?"
5490 BEEP
5500 INPUT Plot_device
5510 IF (Plot_device<0) AND (Plot_device > 1) THEN Plot_device=0

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5520 IF Plot_device=0 THEN Skip_reset
5530 PRINT "RESET PLOTTER PEN LIMITS AND PRESS CONTINUE WHEN READY"
5540 BEEP
5550 PAUSE
5560 PLOTTER IS 7,5,"9872A"
5570 GOTO Do_plot
5580 Skip_reset: PLOTTER IS 13,"GRAPHICS"
5590 Do_plot: GRAPHICS
5600 EXIT ALPHA
5610 ON Option GOTO Nomenclature,Coef_table,Cmat,Cdt,Vel_range,Cmat,J_zeta,Proj
    design
5620 E_plot: IF Plot_device=0 THEN End_screen
5630 GCLEAR
5640 PEN 0
5650 EXIT GRAPHICS
5660 PLOTTER 7,5 IS OFF
5670 ALPHA
5680 GOTO Menu
5690 End_screen: EXIT GRAPHICS
5700 ALPHA
5710 PRINT "DO YOU WANT A COPY OF THE PLOT ON THE PRINTER? (Y or N)"
5720 BEEP
5730 INPUT Copy$
5740 IF Copy$="Y" THEN DUMP GRAPHICS
5750 PRINT "PRESS CONTINUE TO RETURN PLOT. THE PLOT WILL REMAIN"
5760 PRINT " ON THE SCREEN UNTIL CONTINUE IS PRESSED AGAIN."
5770 BEEP
5780 PAUSE
5790 EXIT ALPHA
5800 GRAPHICS
5810 PAUSE
5820 GCLEAR
5830 EXIT GRAPHICS
5840 PLOTTER 13 IS OFF
5850 ALPHA
5860 GOTO Menu
5870 End: PRINT PAGE
5880 END
5890 Nomenclature: PRINT PAGE
5900 PRINT "DO YOU WANT THE PRINTOUT ON THE SCREEN (0), OR ON THE PRINTER (1)?"
5910 BEEP
5920 INPUT Printer
5930 IF Printer=0 THEN Do_it
5940 PRINTER IS 0
5950 PRINT LIN(2)
5960 Do_it: PRINT "                                NOMENCLATURE"
5970 PRINT
5980 PRINT "CNAB      Slope of the Normal Force Coefficient for the projectile body"
5990 PRINT "XCPB      Pressure coefficient for the projectile body"
6000 PRINT "CMAB      Slope of the Pitching Moment Coefficient for the projectile body"
6010 PRINT "CNAF      Slope OF THE Normal Force Coefficient for the projectile fl are"
6020 PRINT "CMAT      Slope of the Total Normal Force Coefficient"
6030 PRINT "CMAT      Slope of the Total Pitching Moment Coefficient"
6040 PRINT "CMAT,CG   Slope of the Total Pitching Moment Coefficient about the center of gravity"
6050 PRINT "
6060 PRINT "CDWN      Coefficient of wave drag for the projectile nose"
6070 PRINT "CDB       Base drag coefficient for the projectile"
6080 PRINT "CDV       Viscous drag coefficient for the projectile"
6090 PRINT "CDGR      Profile drag of grooved section of body"
6100 PRINT "CDWF      Wave drag coefficient for the projectile flange"
6110 PRINT "CDT       Total drag coefficient"
6120 PRINT "CLA       Slope of the lift coefficient"
6130 PRINT "J ZETA    Aerodynamic jump factor"

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6180 IF Printer=0 THEN Beep
6190 PRINT LIN(5)
6200 PRINTER IS 16
6210 Beep: BEEP
6220 PRINT LIN(1);"PRESS CONTINUE WHEN READY TO RETURN TO MENU"
6230 PAUSE
6240 GOTO Menu
6250 Coef_table: PRINT PAGE
6260 PRINT "DO YOU WANT THE TABLE ON THE SCREEN (0), OR ON THE PRINTER (1)?"
6270 BEEP
6280 INPUT Printer
6290 PRINT PAGE
6300 IF Printer<>0 THEN PRINTER IS 0
6310 PRINT "          STATIC AERODYNAMIC COEFFICIENTS FOR"
6320 PRINT "          LONG ROD FLAPED PROJECTILES"
6330 PRINT
6340 PRINT USING Image_2;"MACH NUMBER"
6350 Image_2: IMAGE 30X,11A
6360 PRINT
6370 PRINT USING Image_3;"2.0","2.5","3.0","3.5","4.0","4.5","5.0"
6380 Image_3: IMAGE 12X,3A,6X,3A,7X,3A,7X,4(3A,6X)
6390 Image_4: IMAGE 7A,2(1X,4D.3D),2(2X,4D.3D),3(1X,4D.3D)
6400 PRINT USING Image_4;"CNAB  ",Q(1,1),Q(1,2),Q(1,3),Q(1,4),Q(1,5),Q(1,6),Q(
1,7)
6410 PRINT USING Image_4;"XCPB  ",Q(2,1),Q(2,2),Q(2,3),Q(2,4),Q(2,5),Q(2,6),Q(
2,7)
6420 PRINT USING Image_4;"CNAB  ",Q(3,1),Q(3,2),Q(3,3),Q(3,4),Q(3,5),Q(3,6),Q(
3,7)
6430 PRINT USING Image_4;"CNAB  ",Q(4,1),Q(4,2),Q(4,3),Q(4,4),Q(4,5),Q(4,6),Q(
4,7)
6440 PRINT USING Image_4;"CNAT  ",Q(5,1),Q(5,2),Q(5,3),Q(5,4),Q(5,5),Q(5,6),Q(
5,7)
6450 PRINT USING Image_4;"CNAT  ",Q(6,1),Q(6,2),Q(6,3),Q(6,4),Q(6,5),Q(6,6),Q(
6,7)
6460 PRINT USING Image_4;"CG-CP ",Q(7,1),Q(7,2),Q(7,3),Q(7,4),Q(7,5),Q(7,6),Q(
7,7)
6470 PRINT USING Image_4;"CMAT,CG",Q(8,1),Q(8,2),Q(8,3),Q(8,4),Q(8,5),Q(8,6),Q(
8,7)
6480 PRINT USING Image_4;"CDWN  ",Q(9,1),Q(9,2),Q(9,3),Q(9,4),Q(9,5),Q(9,6),Q(
9,7)
6490 PRINT USING Image_4;"CDB   ",Q(10,1),Q(10,2),Q(10,3),Q(10,4),Q(10,5),Q(10
,6),Q(10,7)
6500 PRINT USING Image_4;"CDV   ",Q(11,1),Q(11,2),Q(11,3),Q(11,4),Q(11,5),Q(11
,6),Q(11,7)
6510 PRINT USING Image_4;"CDGR  ",Q(12,1),Q(12,2),Q(12,3),Q(12,4),Q(12,5),Q(12
,6),Q(12,7)
6530 PRINT USING Image_4;"CDWF  ",Q(14,1),Q(14,2),Q(14,3),Q(14,4),Q(14,5),Q(14
,6),Q(14,7)
6570 PRINT USING Image_4;"CDT   ",Q(18,1),Q(18,2),Q(18,3),Q(18,4),Q(18,5),Q(18
,6),Q(18,7)
6580 PRINT USING Image_4;"CLA   ",Q(19,1),Q(19,2),Q(19,3),Q(19,4),Q(19,5),Q(19
,6),Q(19,7)
6590 PRINT USING Image_4;"J ZETA ",Q(20,1),Q(20,2),Q(20,3),Q(20,4),Q(20,5),Q(20
,6),Q(20,7)
6600 IF Printer=0 THEN Skip_7
6610 PRINT LIN(5)
6620 PRINTER IS 16
6630 GOTO Menu
6640 Skip_7: BEEP
6650 PRINT LIN(1);"PRESS CONTINUE WHEN READY TO RETURN TO MENU"
6660 PAUSE
6670 GOTO Menu
6680 Cnat: SCALE 1.4,5.2,-6,31
6690 CLIP 2,5,0.30
6700 LAXES .25,2.2,0,-4,3
6710 UNCLIP

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6720 LDIR 0
6730 LONG 5
6740 MOVE 3.5,-3
6750 LABEL "MACH NUMBER"
6760 LDIR 90
6770 MOVE 1.7,15
6780 LABEL "CNAT"
6790 MOVE Q1(1),Q(5,1)
6800 FOR I=2 TO 7
6810 DRAW Q1(I),Q(5,I)
6820 NEXT I
6830 GOTO E_plot
6840 Cdt: SCALE 1.4,5.2,-.2,1.05
6850 CLIP 2,5,0,1
6860 LAXES .25,.1,2,0,-4,2
6870 UNCLIP
6880 LDIR 0
6890 LONG 5
6900 MOVE 3.5,-.1
6910 LABEL "MACH NUMBER"
6920 LDIR 90
6930 MOVE 1.7,.5
6940 LABEL "CDT"
6950 MOVE Q1(1),Q(18,1)
6960 FOR I=2 TO 7
6970 DRAW Q1(I),Q(18,I)
6980 NEXT I
6990 GOTO E_plot
7000 Vel_range: SCALE -S9/5000,31+S9/30000,-1600,2400
7010 CLIP 0,S9/1000,0,2000
7020 LAXES .5,250,0,0,-1,1
7030 UNCLIP
7040 LDIR 0
7050 LONG 5
7060 MOVE S9/2000,-250
7070 LABEL "RANGE (KM)"
7080 LDIR 90
7090 MOVE -S9/8000,1000
7100 LABEL "VEL (M/S)"
7110 MOVE R2(1)/1000,V(1)
7120 FOR I=2 TO Y1
7130 DRAW R2(I)/1000,V(I)
7140 NEXT I
7150 LDIR 0
7160 LONG 1
7170 MOVE 0,2150
7180 Image_5: IMAGE "MUZZLE MACH No.",2D.3D," , INITIAL YAW CYCLE",4D.3D,"M"
7190 LABEL USING Image_5;M0,01
7200 MOVE 0,-500
7210 Image_6: IMAGE "RANGE",5D," M, RETARDATION",4D.3D," M. S-KM"
7220 FOR I=Y1 TO 1 STEP -1
7230 LABEL USING Image_6;R2(I),R3(I)
7240 IPLOT 0,-30,-2
7250 NEXT I
7260 GOTO E_plot
7270 Cmat: SCALE 1.4,5.2,10,-23
7280 CLIP 2,5,6,-22
7290 LAXES .25,2,2,0,-4,2
7300 UNCLIP
7310 LDIR 0
7320 LONG 5
7330 MOVE 3.5,5
7340 LABEL "MACH NUMBER"
7350 LDIR 90
7360 MOVE 1.55,-8
7370 LABEL "CMAT,CG"

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7460 MOVE Q1(I),Q(8,I)
7470 FOR I=2 TO 7
7480 DRAW Q1(I),Q(8,I)
7490 NEXT I
7500 GOTO E_plot
7510 J_zeta: SCALE 1.4,5.2,-2,20.5
7520 CLIP 2,5,0,20
7530 LAXES .25,1,2,0,-4,2
7540 UNCLIP
7550 LDIR 0
7560 LONG 5
7570 MOVE 3.5,-1
7580 LABEL "MACH NUMBER"
7590 LDIR 90
7600 MOVE 1.6,10
7610 LABEL "J ZETA"
7620 X_inc=1.8
7630 LDIR 0
7640 LONG 2
7650 FOR I=2 TO 20 STEP 2
7660 MOVE X_inc,I
7670 LABEL "-"
7680 IF I>7 THEN X_inc=1.75
7690 NEXT I
7700 MOVE Q1(I),ABS(Q(20,I))
7710 FOR I=2 TO 7
7720 DRAW Q1(I),ABS(Q(20,I))
7730 NEXT I
7740 GOTO E_plot

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