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MEMORANDUM REPORT ARBRL-MR-03123

AUTOMATIC PLOTTING ROUTINES FOR ESTIMATING
STATIC AERODYNAMIC PROPERTIES OF LONG ROD
FINNED PROJECTILES FOR $2 < M < 5$

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August 1981



US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
BALLISTIC RESEARCH LABORATORY
ABERDEEN PROVING GROUND, MARYLAND

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER MEMORANDUM REPORT ARBRL-MR-03123	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) AUTOMATIC PLOTTING ROUTINES FOR ESTIMATING STATIC AERODYNAMIC PROPERTIES OF LONG ROD FINNED PROJECTILES FOR $2 < M < 5$		5. TYPE OF REPORT & PERIOD COVERED Memorandum Report
7. AUTHOR(s) WILLIAM F. DONOVAN, Michael J. Nusca, Susan A. Wood		6. PERFORMING ORG. REPORT NUMBER
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Ballistic Research Laboratory ATTN: DRDAR-BLI Aberdeen Proving Ground, MD 21005		8. CONTRACT OR GRANT NUMBER(s)
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Armament Research & Development Command U.S. Army Ballistic Research Laboratory ATTN: DRDAR-BL Aberdeen Proving Ground, MD 21005		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 1L162617AH19
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		12. REPORT DATE AUGUST 1981
		13. NUMBER OF PAGES 77
		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release, distribution unlimited		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Long rod penetrators Aerodynamic coefficients Drag Static Moment Caliber notation		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) jmk A predictive program for the estimation of static aerodynamic coefficients for long rod projectiles at $2 < M < 5$ is presented in desk top (Tektronix 4051) computer context. The technique is demonstrated by application to a typical projectile for which range data is available for comparison.		

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I. INTRODUCTION

The aerodynamics of long rod finned projectiles has been surveyed by many investigators^{1,2,3,4,5,6,7,8} with principal efforts directed to resolving the individual contributions of the component hardware (nose, body and tail) in the determination of the static aerodynamic coefficients. Only rarely has the trajectory problem been addressed, although the specific analysis of the dispersion of the projectile at the target has been examined carefully in the open literature^{9,10}. Previous searches for predictive algorithms considering the complete free-flight package were not rewarding; and this led to the issue of several additional

¹C.H. Murphy, "Free Flight Motion of Symmetric Missiles", BRL Report No. 1216, July 1963 (AD #442757).

²AMCP 706-280, "Design of Aerodynamically Stabilized Free Rockets", 1968.

³W.F. Braun, "Aerodynamic Data for Small Arms Projectiles", BRL Report No. 1630, January 1973 (AD #909757L).

⁴H.W. Liepmann and A. Roshko, Element of Gasdynamics, John Wiley and Sons, Inc., New York, 1957.

⁵A.H. Shapiro, The Dynamics and Thermodynamics of Compressible Fluid Flow, Volume I, The Ronald Press Company, New York, 1953.

⁶M. Piddington, "The Aerodynamic Characteristics of a SPIW Projectile", BRL Memorandum Report No. 1594, September 1964 (AD #355679).

⁷E.R. Dickenson, "Some Aerodynamic Effects of Blunting a Projectile Nose", BRL Memorandum Report No. 1596, September 1964 (AD #451977).

⁸L.C. MacAllister, "Drag and Stability Properties of the XM144 Flechette with Various Head Shapes", BRL Memorandum Report No. 1981, May 1969 (AD #854724).

⁹W.J. Gallagher, "Elements Which Have Contributed to Dispersion in the 90/40 mm Projectile", BRL Report No. 1013, March 1957 (AD #135306).

¹⁰J.D. Nicolaidis, C.W. Ingram, "Analysis of the Jump and Dispersion of Flechettes", Prepared for U.S. Army, Frankford Arsenal under Contract No. DAAA 25-71-C0447.

constituant reports^{11,12,13,14,15} which, however, had the ultimate objective of composing a more comprehensive publication which would enhance estimating facility for this particular class of flight projectile.

This report is an attempt to scribe the envelope of the preliminary design configuration. The drag, static moment and normal force coefficients are determined from the simplified geometry of the projectile and the bounding aerodynamics conditions; i.e., sea level flat fire, $2 < M < 5$ and low yaw as developed in the previous reports^{11,14} with the accuracy factor (related to the dispersion) and retardation similarly extracted^{12,13}. The program is written in Tektronix 4051 Basic language with graphic extensions. The program flowchart, sample graphics screen display and program listing are given in Appendices A, B, and C, respectively.

The example provided for illustration has not been extensively flight tested; indeed, a complete set of data to include range aerodynamics, retardation and dispersion for a given projectile over the selected Mach excursion is simply not available. The influence of the dynamic aerodynamic coefficients, the damping and the Magnus, on the flight performance is even more difficult to certify. However, what disparate data that is published does suggest that the given criteria for design are viable. It is also obvious that local modifications to the program, based on individual experience, are certainly inevitable and are actively encouraged.

¹¹W.F. Donovan, "Procedure for Estimating Zero Yaw Drag Coefficient for Long Rod Projectiles at Mach Numbers from 2 to 5", BRL Memorandum Report No. ARBRL-MR-02819, March 1978 (AD #A054326).

¹²W.F. Donovan, "One Factor Affecting the Dispersion of Long Rod Penetrators", BRL Memorandum Report No. ARBRL-MR-02846, June 1977 (AD #A058596).

¹³W.F. Donovan, "Simplified Determination of Retardation for Kinetic Energy Projectiles", BRL Memorandum Report No. ARBRL-MR-02994, February 1980 (AD #083299).

¹⁴W.F. Donovan, "Algorithm for Estimating Aerodynamic Static Moments of Long Rod Penetrators at $2 < M < 5$ ", BRL Memorandum Report No. ARBRL-MR-03020, May 1980 (AD #086095).

¹⁵W.F. Donovan, "Hypothetical Zero Yaw Drag Coefficient of Kinetic Energy Projectiles Between $M = 5$ and $M = 10$ ", BRL Memorandum Report No. ARBRL-MR-03041, August 1980 (AD # 090009).

II. PROCEDURE

The analytic expressions for the various parameters are taken from the previous reports and tabulated. Recent test results have been used to modify the equations, where indicated, to improve correspondence between test and prediction. The fin-body interference factor has been adjusted to recognize a fin masking effect of the boundary layer and a separate drag contribution has been assigned to the presence of the driving grooves. 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. This rather novel practice allows a direct comparison of projectile performance on the basis of a "ballistic weight" quite independent of physical dimension.

Figure 1 is an outline of a typical long rod projectile. Tables 1, 2 and 3 contain the equations used in developing the programs. The initialization instructions are presented in Appendix A and the full program listings follow. The program provides an outline plot of the projectile with the physical properties and gives a complete chart description of the aerodynamic coefficients with accuracy factor, decrementing velocity and initial yaw cycle estimates. The accompanying print-out lists the discrete component contributions and the retardation over the expected range of the flight to $M = 5$.

III. RESULTS

The 25/12 projectile, recently tested in the BRL aerodynamics range, is used to demonstrate the working procedure. Figure 2 is a photograph of the flight assembly and Table B contains the input for the programs. The program provides hard copy computer prints of the projectile outline, Figure 3, and the corresponding estimated aerodynamic performance, Figures 4 through 8. Table 4 is a summary of the results.

The available range data is superposed by an asterisk.

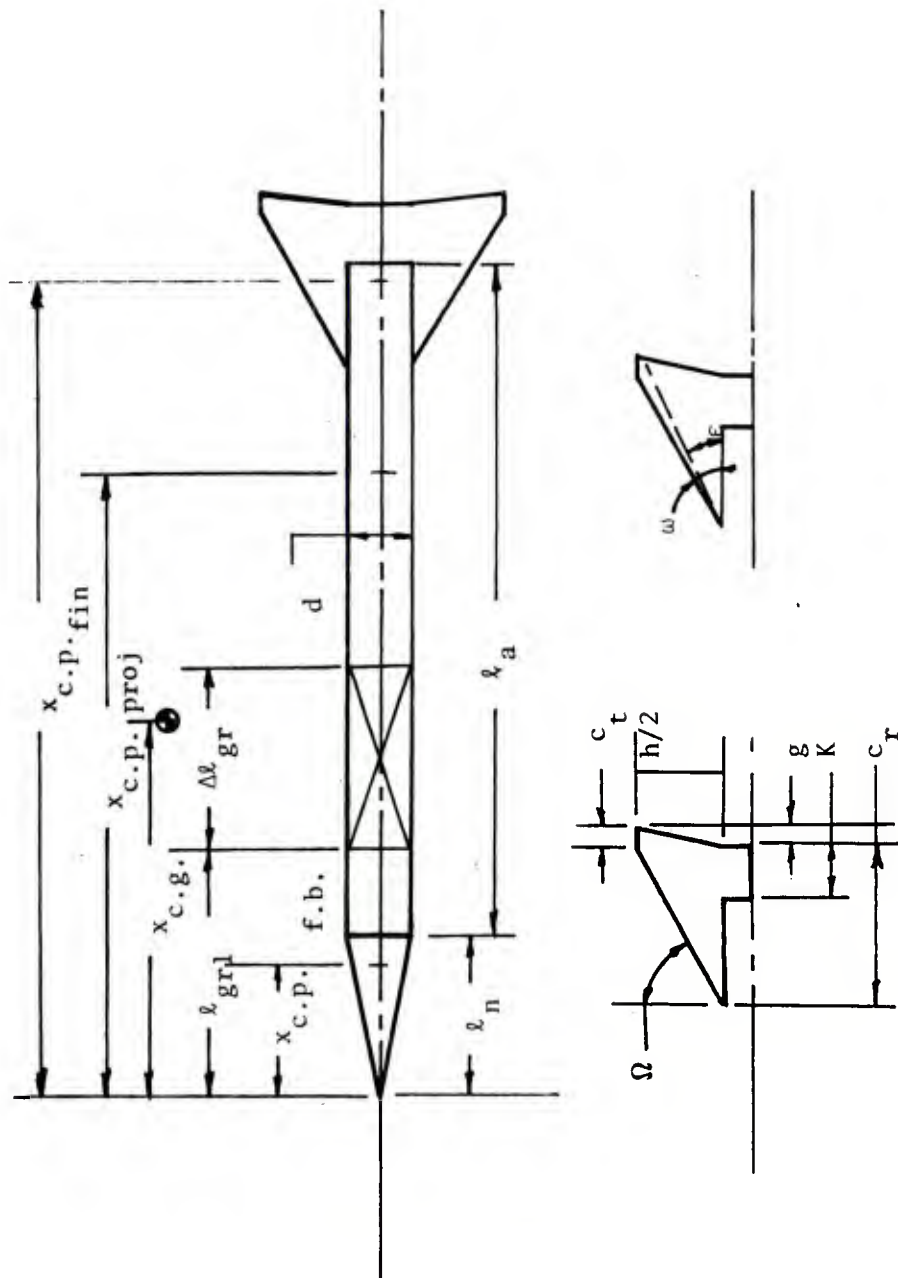


Figure 1. Outline of Long Rod Projectile

TABLE 1. SYNTHESIS OF DRAG COEFFICIENT EQUATIONS

DRAG COEFFICIENT	
Body	Wave $C_{CWB} = .7M^{-.28} \lambda_n^{-1.73}$
	Base $C_{DBB} = - .048M + .265$
	Viscous $C_{DVB} = .000173 (28.75-4.166M) \frac{A_{\text{wetted body}}}{A_{\text{ref}}}$
	Subtotal $C_{DTB} = C_{DWB} + C_{DBB} + C_{DVB}$
Fin	Wave $C_{DWF} = \left(\frac{n}{\beta}\right) \left(\frac{t}{j}\right)^2 \frac{A_{\text{wetted fin}}}{A_{\text{ref}}}$
	Base $C_{DBF} = \frac{A_{\text{Base Fin}}}{A_{\text{Base Body}}} C_{DBB}$
	Fin $C_{DVF} = \frac{1}{1.15} \left(\frac{A_{\text{wetted Fin}}}{A_{\text{wetted Body}}} \right) C_{DVB}$
	Subtotal $C_{DTF} = C_{DWF} + C_{DBF} + C_{DVF}$
Assembly	Grooves $C_{DGR} = .00025 M^{3.9} \Delta \lambda_{gr} C_{DTB}$
	Total $C_{DT} = C_{DTB} + C_{DTF} + C_{DGR}$

TABLE 2. SYNTHESIS OF NORMAL FORCE AND STATIC MOMENT SLOPE COEFFICIENT EQUATION:

Normal Force and Static Moment Coefficients ¹⁴		
Nose Datum	Body	$C_{NaB} \left(1.9 + 1.3 \frac{\beta}{\ell_n} + .0149 \frac{\ell_a}{\beta} \right) \left(\beta^{-.7} \right) \left(-.0675 \ell_T + 2.3 \right)$ $x_{c.p.B} = \left(.69 + .65 \frac{\beta}{\ell_n} + .5 \frac{a}{\beta} \right) \left(\beta^{-.46} \right)$ $C_{MaB} = (x_{c.p.B})(C_{NaB})$
	Fins	$C_{NaF} = \gamma \left[4 + (.9\lambda + \frac{2}{\ell_a} \ell_c g_r \left(\frac{ARTAN \Omega}{4} \right)) \left(\frac{TAN \Omega}{\beta} \right) \right] + \frac{\Omega}{TAN \Omega} \left[\left((.6AR-1) \left(1 - \frac{\beta}{TAN \Omega} \right) \right) \left[\frac{.541}{M} \right] \left[\frac{A_{Wetted fin}}{\pi} \right] \right]$ $x_{c.p.F} = \ell_n + \ell_a + k - \left(\frac{c_r + g}{2} \right)$ $C_{MaF} = x_{c.p.F} C_{NaF}$ $K = (-.167 a + 1.334) e^{d/d} + h \left(\frac{9}{\ell_a} \right)$
	Assembly	$C_{Na} = C_{NaB} + KC_{NaF}$ $C_{Ma} = C_{MaB} + KC_{MaF}$ $x_{c.p.} = C_{Ma}/C_{Na}$
Gravity Datum	Assembly	$C_{Na} = C_{Na}$ $x_{c.p.} = x_{c.p.}$ $\Delta x = x_{c.p.} - x_{c.g.}$ $C_{Ma} = (x_{c.p.} - x_{c.g.})(C_{Na})$

TABLE 3. RETARDATION, ACCURACY FACTOR AND INITIAL YAW EQUATIONS

Retardation ¹³	
Mach Number along Trajectory	$M_1 = \frac{b}{R e Q_s - c}$
Average Velocity Decrement	$\Delta v = \frac{M_0 - M_1}{s} (v)_{\text{sonic}}$
Accuracy Factor ¹²	
Accuracy Factor	$J_\zeta = \frac{C_{L\alpha}}{C_{M\alpha}} \frac{I_y}{md^2}$
Initial Yaw Period ¹²	
Peak to Peak Distance	$\Delta s = \pi \left[\frac{2 I_y}{\rho A_{\text{ref}} C_{M\alpha} d} \right]^{1/2}$



Figure 2. Photograph of 25/12 Projectile

LONG ROD FINNED PROJECTILE DESIGN

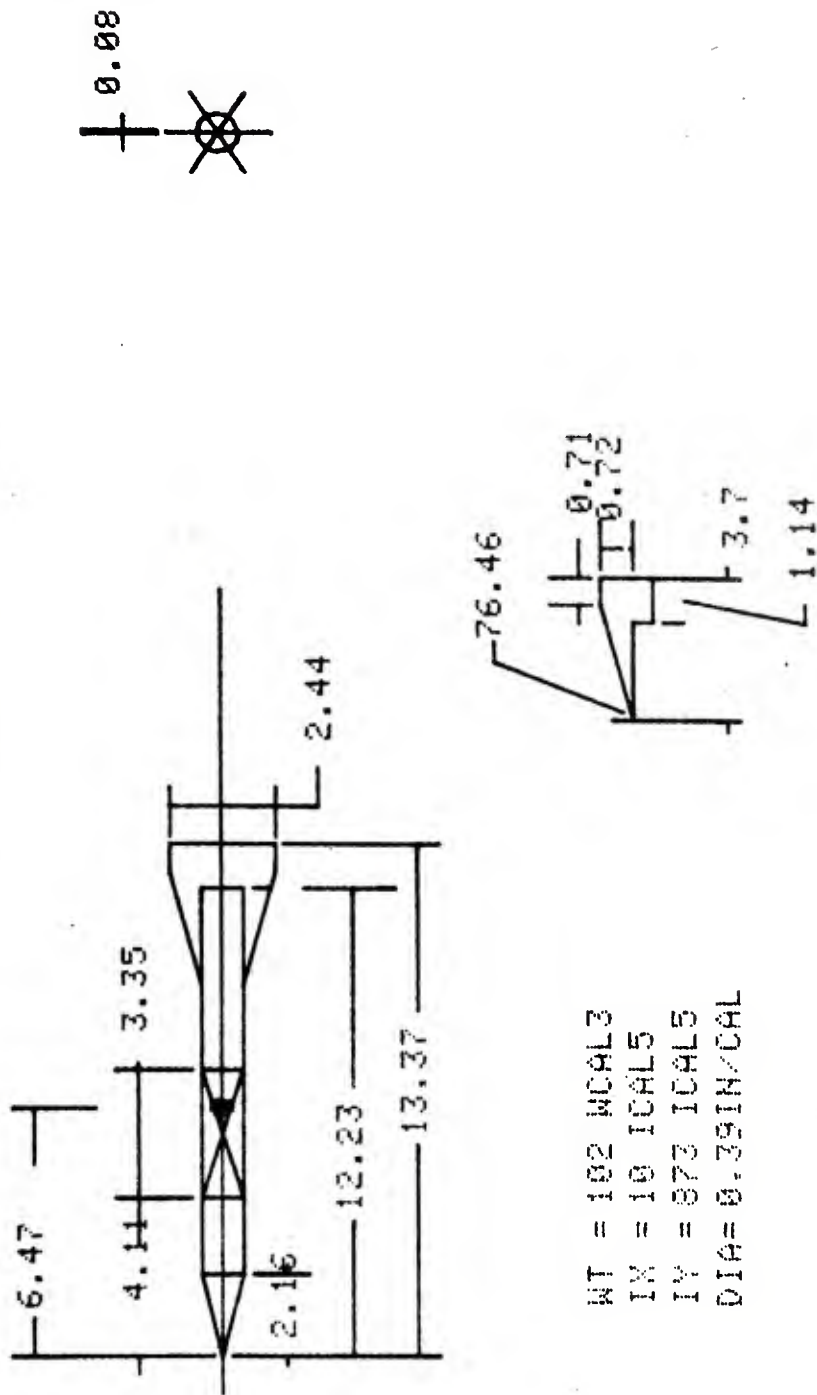


Figure 3. Outline of 25/12 Projectile

TABLE 4. SUMMARY OF CALCULATED AERODYNAMIC COEFFICIENTS

[illegible]

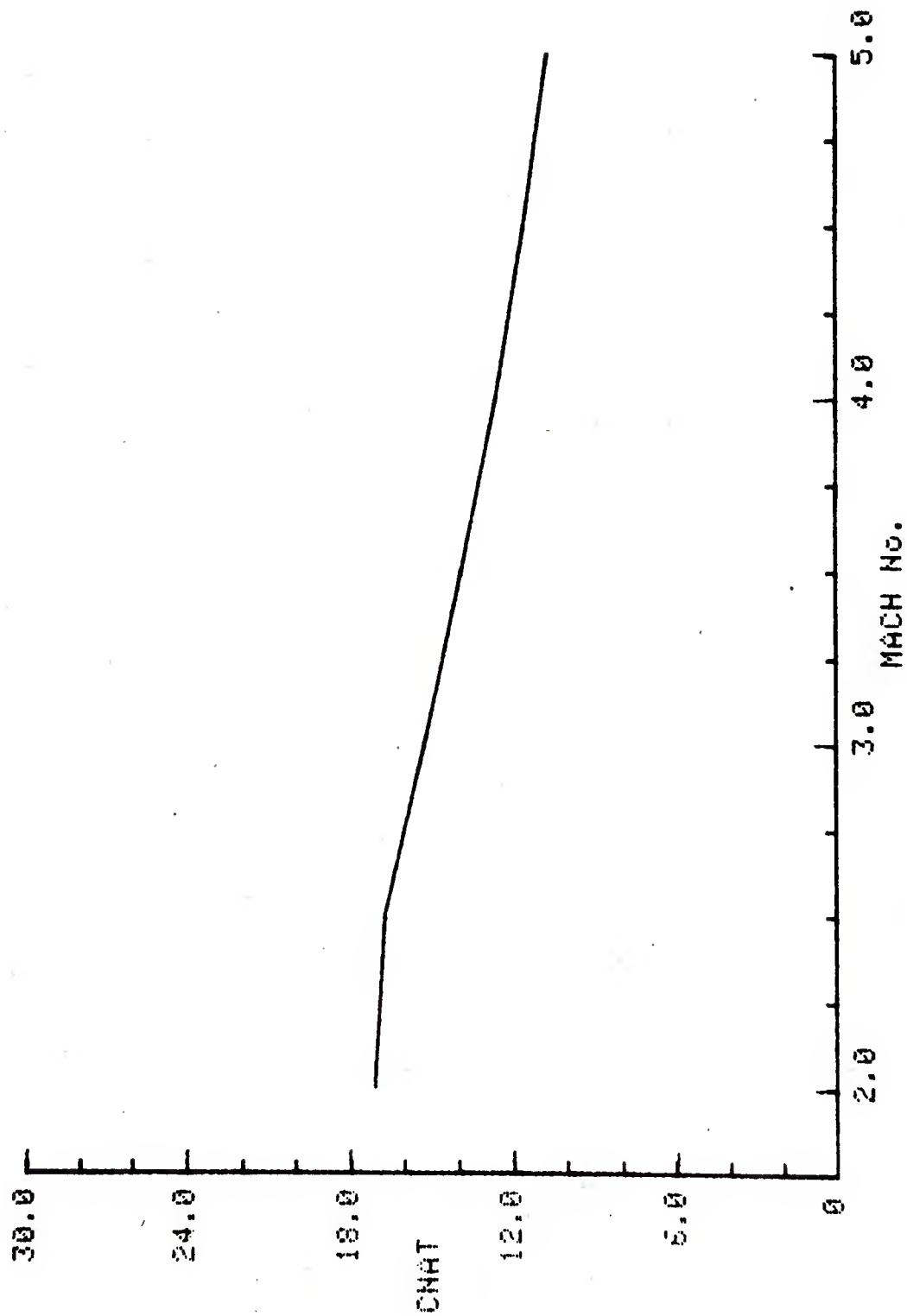


Figure 4. Normal Force Slope Coefficient vs Mach Number

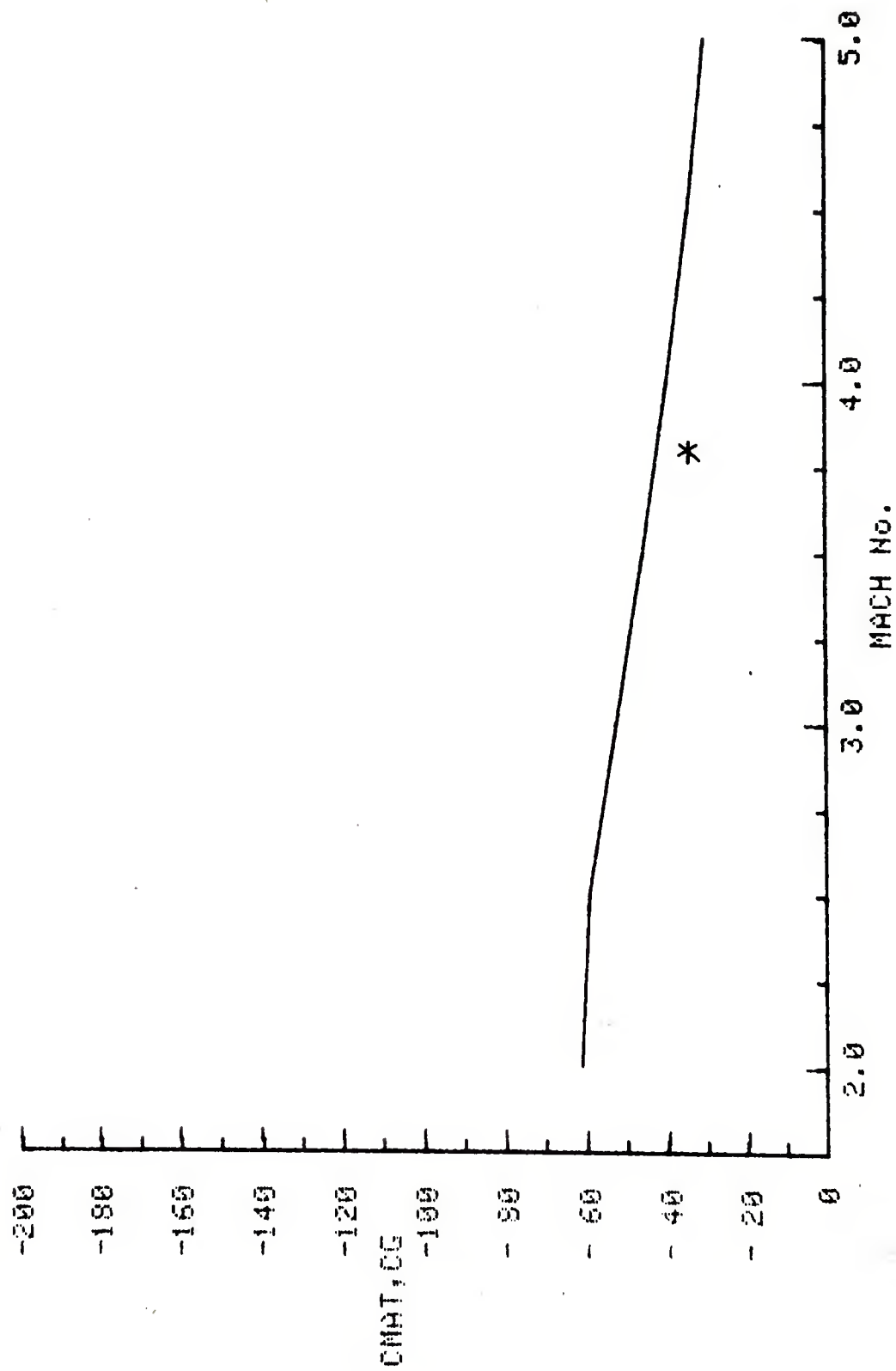


Figure 5. Static Moment Slope Coefficient vs Mach Number

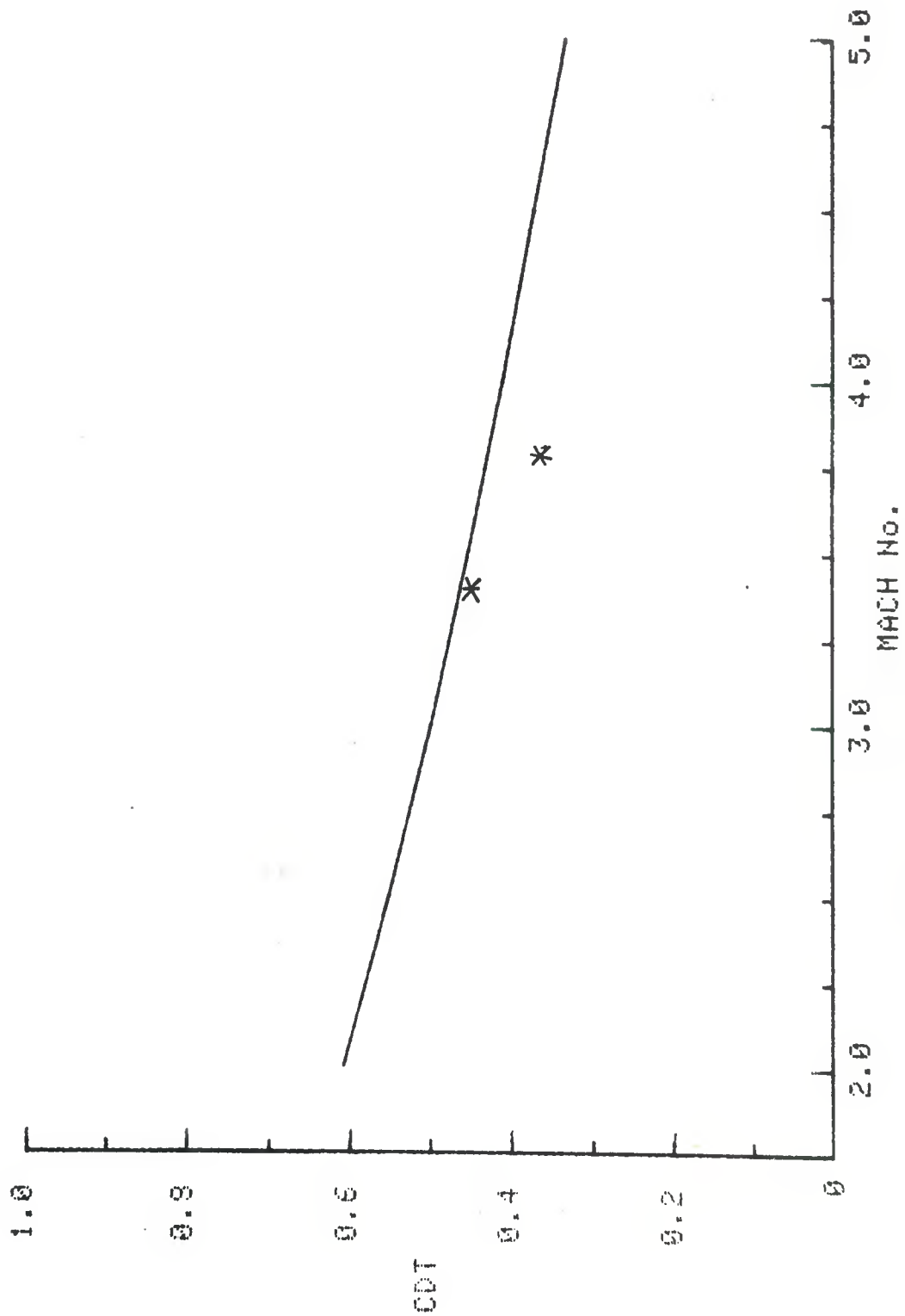
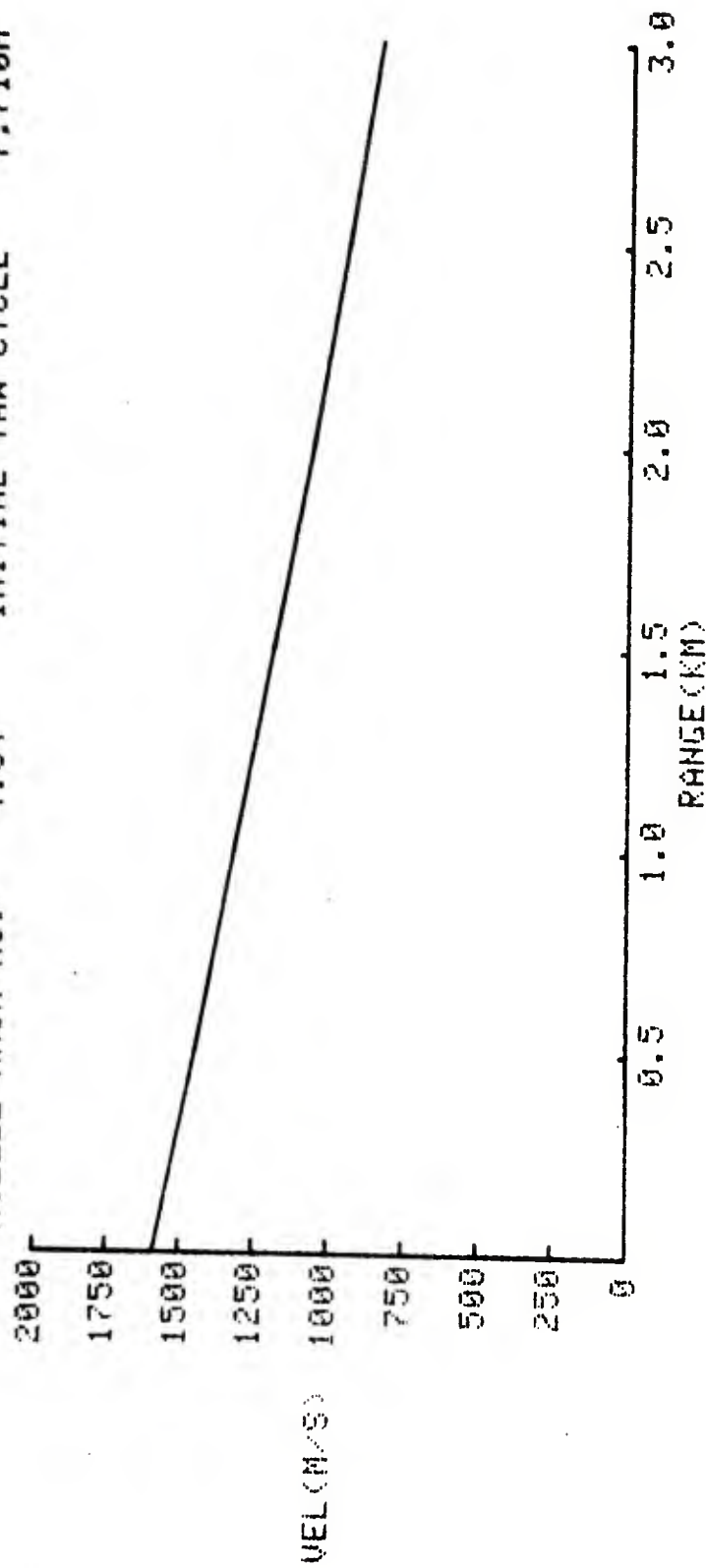


Figure 6. Zero Yaw Drag Coefficient vs Mach Number

MUZZLE MACH No. 4.64 INITIAL YAW CYCLE 7.710M



RANGE 3000 M	RETARDATION	249.182	M/S/KM
RANGE 2500 M	RETARDATION	254.967	M/S/KM
RANGE 2000 M	RETARDATION	259.616	M/S/KM
RANGE 1500 M	RETARDATION	263.274	M/S/KM
RANGE 1000 M	RETARDATION	265.714	M/S/KM
RANGE 500 M	RETARDATION	266.945	M/S/KM
RANGE 0 M	RETARDATION	266.945	M/S/KM

Figure 7. Velocity Decrement and Retardation vs Range

ACKNOWLEDGMENTS

Mr. Basil Reiter of the Launch and Flight Division undertook the arduous task of the final transposition of the original Hewlett-Packard 9820-A listing into the current Tektronix 4051 listing presented in the report.

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1. C.H. Murphy, "Free Flight Motion of Symmetric Missiles", BRL Report No. 1216, July 1963 (AD #442757)
2. AMCP 706-280, "Design of Aerodynamically Stabilized Free Rockets", 1968.
3. W.F. Braun, "Aerodynamic Data for Small Arms Projectiles", BRL Report No. 1630, January 1973 (AD #909757L)
4. H.W. Liepmann and A. Roshko, Elements of Gasdynamics, John Wiley and Sons, Inc., New York, 1957.
5. A.H. Shapiro, The Dynamics and Thermodynamics of Compressible Fluid Flow, Volume I, The Ronald Press Company, New York, 1953.
6. M. Piddington, "The Aerodynamic Characteristics of a SPIW Projectile", BRL Memorandum Report No. 1594, September 1964 (AD #355679).
7. E.R. Dickenson, "Some Aerodynamic Effects of Blunting a Projectile Nose", BRL Memorandum Report No. 1596, September 1964 (AD #451977).
8. L.C. MacAllister, "Drag and Stability Properties of the XM144 Flechette with Various Head Shapes", BRL Memorandum Report No. 1981, May 1969 (AD #854724)
9. W.J. Gallagher, "Elements Which Have Contributed to Dispersion in the 90/40 mm Projectile", BRL Report No. 1013, March 1957 (AD #135306)
10. J.D. Nicolaides, C.W. Ingram, "Analysis of the Jump and Dispersion of Flechettes", Prepared for U.S. Army, Frankford Arsenal under Contract No. DAAA 25-71-C0447
11. W.F. Donovan, "Procedure for Estimating Zero Yaw Drag Coefficient for Long Rod Projectiles at Mach Numbers from 2 to 5", BRL Memorandum Report No. ARBRL-MR-02819, March 1978 (AD #A054326).
12. W.F. Donovan, "One Factor Affecting the Dispersion of Long Rod Penetrators", BRL Memorandum Report No. ARBRL-MR-02846, June 1978 (AD #A058596).
13. W.F. Donovan, "Simplified Determination of Retardation for Kinetic Energy Projectiles", BRL Memorandum Report No. ARBRL-MR-02994, February 1980 (AD #083299).
14. W.F. Donovan, "Algorithm for Estimating Aerodynamic Static Moments of Long Rod Penetrators at $2 < M < 5$ ", BRL Memorandum Report No. ARBRL-MR-03020, May 1980 (AD #086095).

REFERENCES (continued)

15. W.F. Donovan, "Hypothetical Zero Yaw Drag Coefficient of Kinetic Energy Projectiles Between $M = 5$ and $M = 10$ ", BRL Memorandum Report No. ARBRL-MR-03041, August 1980 (AD #090009).

LIST OF SYMBOLS

A	$\beta \tan \omega$, operational parameter
b	Intercept of C_D vs M characteristic
c	Slope of C_D vs M characteristic
c_r	Fin blade length at root
c_t	Fin blade length at tip
c.g.	Center of gravity of projectile, nose datum
c.p.	Center of pressure of normal force
d	1.0 cal , reference diameter
e	Base of Natural log
g	Fin dimension (root recess)
h/2	Fin dimension (blade height)
j	Fin dimension (blade slant height)
k	Fin dimension (blade extension from body)
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
$l_{o.a.}$	Overall length of projectile
l_T	$l_a + l_n$
m	Mass of projectile
n	Number of fin blades
s	Range
t	Fin dimension (average thickness)
v	Velocity of projectile

LIST OF SYMBOLS (continued)

Δv	Velocity decrement over specified range
x	Distance along projectile, nose datum
AR	h^2/S_F , Aspect ratio of fin planform
$A_{\text{base body}}$	Area of body exposed to base pressure (cal) ²
$A_{\text{base fin}}$	Area of fin exposed to base pressure (cal) ²
A_{ref}	Reference area (.785 cal ²)
$A_{\text{wetted body}}$	Area of body producing viscous flow drag
$A_{\text{wetted fin}}$	Area of fin producing viscous flow drag
C_D	$\frac{\text{Drag Force}}{\frac{1}{2} \rho v^2 A_{\text{ref}}}$, zero-yaw drag coefficient
C_{DBB}	Pressure drag coefficient - base of body
C_{DBF}	Pressure drag coefficient - base of fins
C_{DGR}	Drag coefficient due to grooves
C_{DT}	Total drag coefficient
C_{DTB}	Total body drag coefficient
C_{DTF}	Total fin drag coefficient
C_{DVB}	Viscous drag coefficient - body
C_{DVF}	Viscous drag coefficient - fins
C_{DWB}	Wave drag coefficient - body (nose)
C_{DWF}	Wave drag coefficient - fin
$C_{L\alpha}$	$\frac{\text{Lift Force}}{\frac{1}{2} \rho v^2 A_{\text{ref}} \delta}$, aerodynamic lift slope coefficient, $\delta = \sin \alpha_T$
$C_{M\alpha}$	$\frac{\text{Static Moment}}{\frac{1}{2} \rho v^2 A_{\text{ref}} d \delta}$, aerodynamic moment slope coefficient

LIST OF SYMBOLS (continued)

$C_{M\alpha B}$	Static moment coefficient - body
$C_{M\alpha F}$	Static moment coefficient - fins
$C_{N\alpha}$	$\frac{\text{Normal Force}}{\frac{1}{2} \rho v^2 A_{\text{ref}} \delta}$, aerodynamic normal force slope coefficient
$C_{N\alpha B}$	Normal force coefficient - body
$C_{N\alpha F}$	Normal Force coefficient - fins
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
K	Interference factor
M	Mach number
M_0	Mach number at muzzle
M_1	Mach number along trajectory
Q	Operational parameter, $\frac{\rho A_{\text{ref}} b}{2 m}$
R	Operational parameter, $\frac{c M_0 + b}{M_0}$
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
λ	c_t/c_r , fin tip ratio
π	3.1416

LIST OF SYMBOLS (continued)

ρ Ambient air density

Ω Fin sweep angle

APPENDIX A
INITIALIZATION INSTRUCTIONS

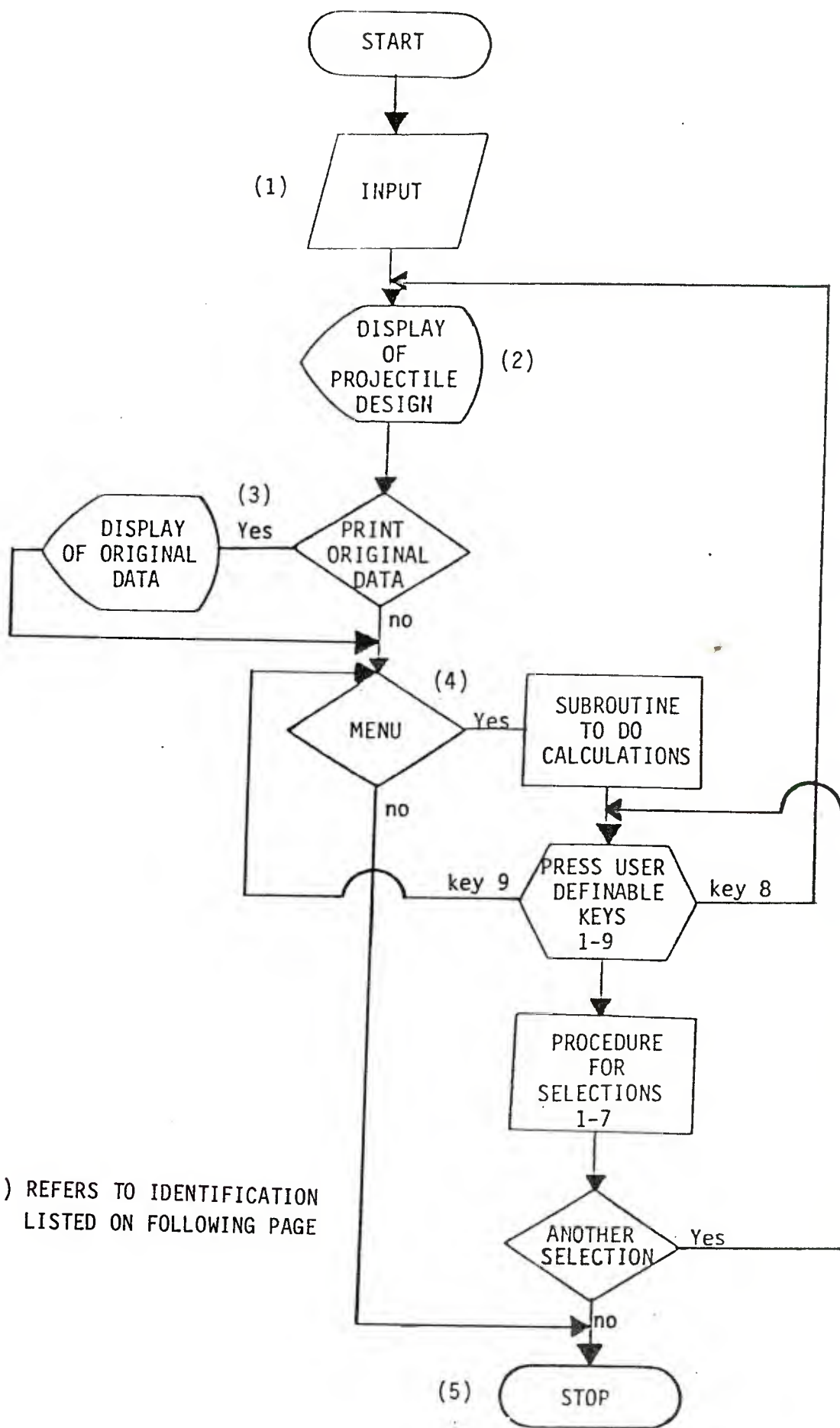
APPENDIX A

INITIALIZATION INSTRUCTIONS

Initialization requires only the entry of the geometry and physical properties of the projectile, the range excursion and the muzzle Mach number as directed by the program listing according to the following schedule.

Tektronix Nomenclature	Figure 1 Identification	Notes
L	l_n	Refers to equivalent ¹⁶ conical nose length
L1	l_a	Includes cylindrical length of body to which fins are attached. A taper hub is approximated as a cylinder of half the length of the taper. A shallow taper aft body (BM6) requires an engineering evaluation.
P1	l_1 groove	Distance to start of groove. Nose datum.
P2	Δl groove	Length of groove set.
H2	$h/2$	Radial fin length above hub.
C	c_r	
G	g	
K	k	
T	t	Taken as maximum thickness of fin blade.
C1	c_t	
N	n	Restricted to either four or six blades in static moment calculation. Unrestricted in drag calculation.
C2	c.g.	Nose datum.
MO	M_0	Muzzle Mach number.
S	s_{max}	Maximum range in meters
W	wt.	
I	I_x	
I1	I_y	
D	d	May be given in either inches or millimeters.

FLOWCHART FOR AUTOMATIC PLOTTING ROUTINES



() REFERS TO IDENTIFICATION LISTED ON FOLLOWING PAGE

IDENTIFICATION OF FLOWCHART STEPS

- (1) Program Inputs: (All values are to be inputted in calibers unless otherwise noted)

A - Number of Fins (4 or 6)
B - Conical Nose Length
C - Cylindrical Body Length
D - Groove Location/Nose
E - Groove Length
F - Fin Dimension (Blade Height)
G - Fin Blade Length at Root
H - Fin Dimension (Root Recess)
I - Fin Dimension (Blade Extension from Body)
J - Fin Dimension (Maximum Thickness)
K - Fin Blade Length at Tip
L - Center of Gravity of Projectile
M - 1.0 Caliber Reference Diameter (Millimeters or Inches)
N - Normalized Weight of Projectile (Cal^3)
O - Axial Moment of Inertia (Cal^5)
P - Transverse Moment of Inertia (Cal^5)
Q - Mach Number at Muzzle
R - Maximum Range (Meters, < 4000)
S - Plotting Device Number (1=Pen Plotter, 32=Screen)

- (2) Projectile Design: Rear and Profile Views of Projectile and Fin

- (3) Optional Printout of Original Data

- (4) Program Selection: (Use User Definable Key)

A - Nomenclature -- A Listing of Aerodynamic Coefficients and their Definitions (Key 1)
B - Table of Coefficients -- A Listing of the Aerodynamic Coefficients and Definitions (Key 2)
C - Total Normal Force Coefficient ($C_{n_{at}}$) versus Mach Number Plot (Key 3)
D - Total Drag Coefficient (C_{D_T}) versus Mach Number Plot (Key 4)
E - Velocity versus Range Plot (Key 5)
F - Total Pitching Moment about the Center of Gravity ($C_{m_{at}}$, CG) versus Mach Number Plot (Key 6)
G - Aerodynamic Jump Factor (J_c) versus Mach Number Plot (Key 7)
H - Reprint of Projectile Design (Key 8)
I - Return to Menu (Key 9)

- (5) Stop

APPENDIX B

SAMPLE GRAPHICS SCREEN DISPLAY

THIS PROGRAM WILL CALCULATE AND PLOT ESTIMATED STATIC AERODYNAMIC
COEFFICIENTS OF LONG ROD FINNED PROJECTILES FOR 2<M<5

INPUT NUMBER OF FINS (4 or 6): 6

INPUT THESE VALUES IN CALIBERS

INPUT CONICAL NOSE LENGTH: 3.82

INPUT CYLINDRICAL BODY LENGTH: 17.96

INPUT GROOVE LOCATION/NOSE: 7.71

INPUT GROOVE LENGTH: 8.07

INPUT FIN DIMENSION (BLADE HEIGHT): .99

INPUT FIN BLADE LENGTH AT ROOT: 4.11

INPUT FIN DIMENSION (ROOT RECESS): 0

INPUT FIN DIMENSION (BLADE EXTENSION FROM BODY): .47

INPUT FIN DIMENSION (MAXIMUM THICKNESS): .07

INPUT FIN BLADE LENGTH AT TIP: 1.31

INPUT CENTER OF GRAVITY OF PROJECTILE : 11.86

INPUT 1.0 CALIBER REFERENCE DIAMETER (MILLIMETERS): 0

INPUT 1.0 CALIBER REFERENCE DIAMETER (INCHES): 1.07

INPUT NORMALIZED WEIGHT OF PROJECTILE (CAL↑3): 194

INPUT AXIAL MOMENT OF INERTIA(CAL↑5): 23

INPUT TRANSVERSE MOMENT OF INERTIA(CAL↑5): 4975

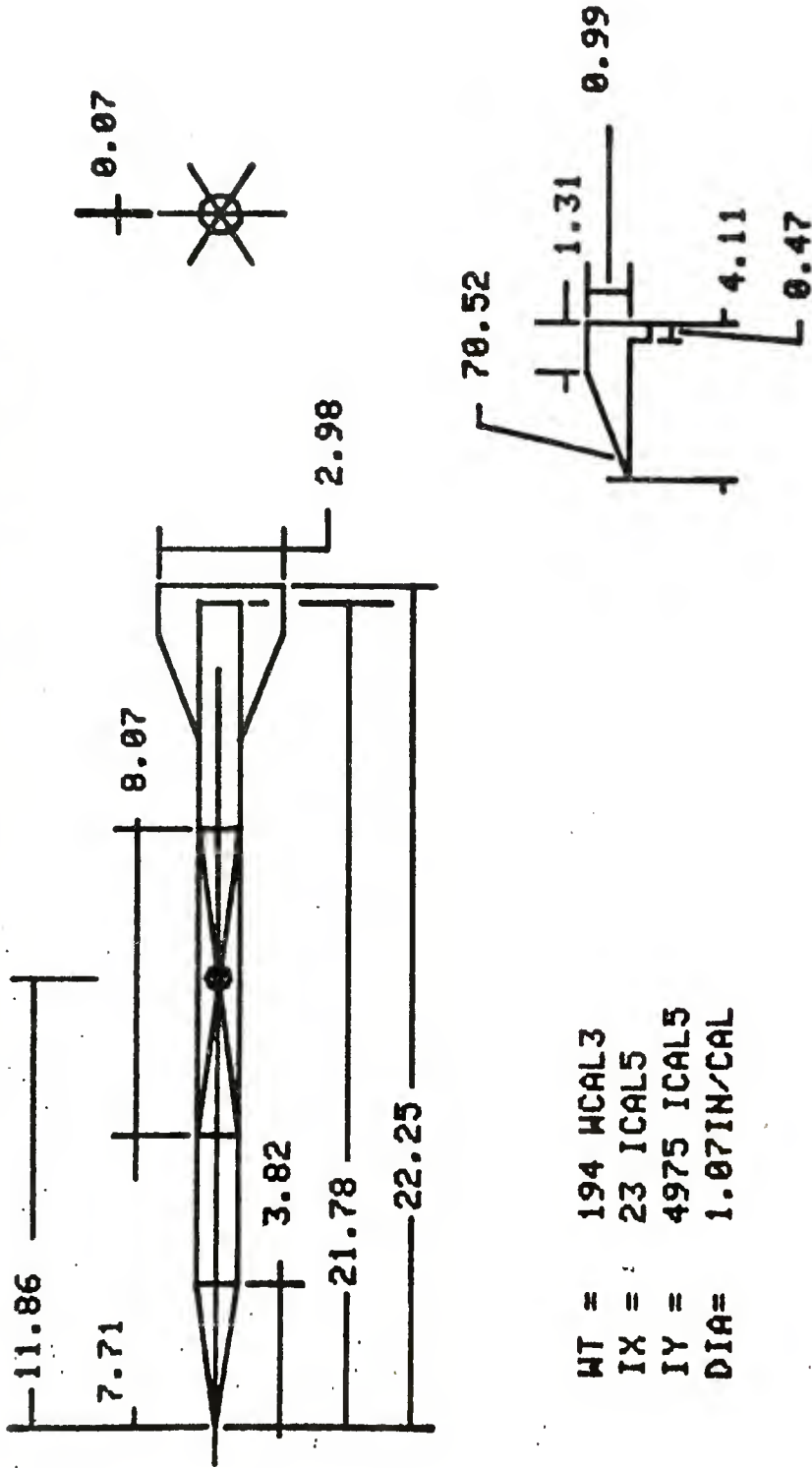
INPUT THESE RANGE VALUES

INPUT MACH NUMBER AT MUZZLE: 4.732

INPUT MAXIMUM RANGE (METERS, <=4000): 3000

INPUT PLOTTING DEVICE NUMBER(1=PEN PLOTTER,32=SCREEN): 32

LONG ROD FINNED PROJECTILE DESIGN



WT = 194 WCAL3
 IX = 23 ICAL5
 IY = 4975 ICAL5
 DIA= 1.07IN/CAL

IF YOU WANT THE INITIAL DATA PRINTED OUT ENTER 'YES':

ALL VALUES ARE IN CALIBERS UNLESS OTHERWISE NOTED

CONICAL NOSE LENGTH: 3.82
CYLINDRICAL BODY LENGTH: 17.96
GROOVE LOCATION/NOSE: 7.71
GROOVE LENGTH: 8.07
FIN DIMENSION (BLADE HEIGHT): 0.99
FIN BLADE LENGTH AT ROOT: 4.11
FIN DIMENSION (ROOT RECESS): 0
FIN DIMENSION (BLADE EXTENSION FROM BODY): 0.47
FIN DIMENSION (MAXIMUM THICKNESS): 0.07
FIN SWEEP ANGLE (DEGREES): 70.52
FIN BLADE LENGTH AT TIP: 1.31
NUMBER OF BLADES: 6
CENTER OF GRAVITY: 11.86
MACH NUMBER AT MUZZLE: 4.732
MAXIMUM RANGE (METERS): 3000
WEIGHT OF PROJECTILE (CAL13): 194
AXIAL MOMENT OF INERTIA (CAL15): 23
TRANSVERSE MOMENT OF INERTIA (CAL15): 4975
1.0 CALIBER REFERENCE DIAMETER (IN.): 1.07

ENTER YES FOR MENU:

USER DEFINABLE KEY DEFINITIONS

- 1.....NOMENCLATURE
- 2.....TABLE OF AERODYNAMIC COEFFICIENTS
- 3.....CNAT vs. MACH NUMBER PLOT
- 4.....CDT vs. MACH NUMBER PLOT
- 5.....VELOCITY vs. RANGH NUMBER PLOT
- 6.....CMAT,CG vs. MACH NUMBER PLOT
- 7.....J ZETA vs. MACH NUMBER PLOT
- 8.....LONG ROD FINNED PROJECTILE DESIGN
- 9.....RETURN TO MENU

PLEASE PRESS USER DEFINABLE KEY TO CONTINUE

NOMENCLATURE

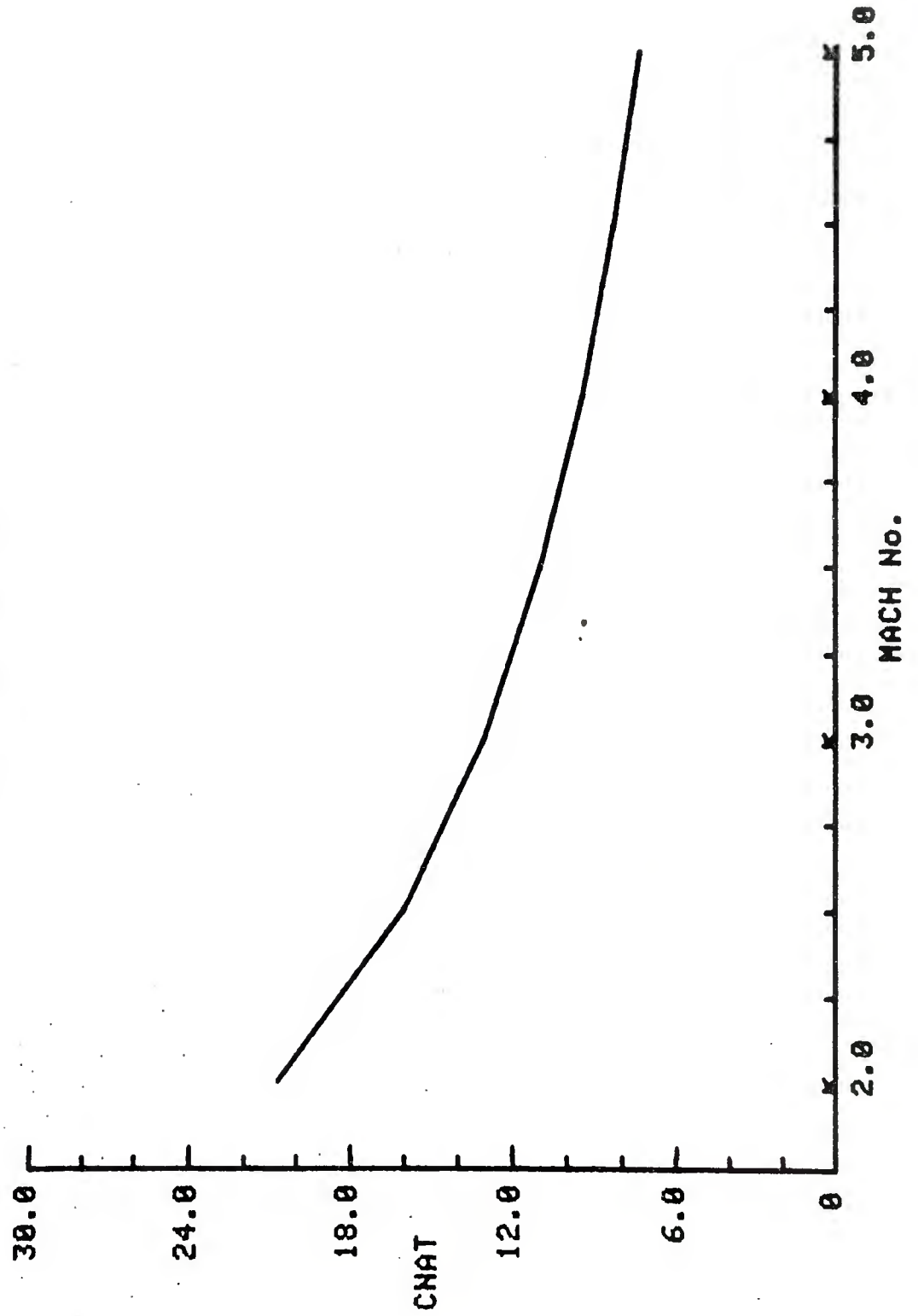
CHAB	Slope of the Normal Force Coefficient for the projectile body
XCPB	Pressure coefficient for the projectile body
CMAB	Slope of the Pitching Moment Coefficient for the projectile body
CNAF	Slope of the Normal Force Coefficient for the projectile fins
CNAT	Slope of the Total Normal Force Coefficient
CMAT	Slope of the Total Pitching Moment Coefficient
CG-CP	Center of gravity minus center of pressure
CMAT,CG	Slope of the Total Pitching Moment Coefficient about the center of gravity
CDWB	Coefficient of wave drag for the projectile body
CDBB	Base drag coefficient for the projectile body
CDUB	Viscous drag coefficient for the projectile body
CDGRU	Profile drag of grooved section of body
CDTB	Total drag coefficient for the projectile body
CDWF	Wave drag coefficient for the projectile fins
CDBF	Base drag coefficient for the projectile fins
CDUF	Viscous drag coefficient for the projectile fins
CDTF	Total drag coefficient for the projectile fins
CDT	Total drag coefficient
CLA	Slope of the Lift Coefficient
J ZETA	Aerodynamic jump factor

STATIC AERODYNAMIC COEFFICIENTS FOR LONG ROD FINNED PROJECTILES

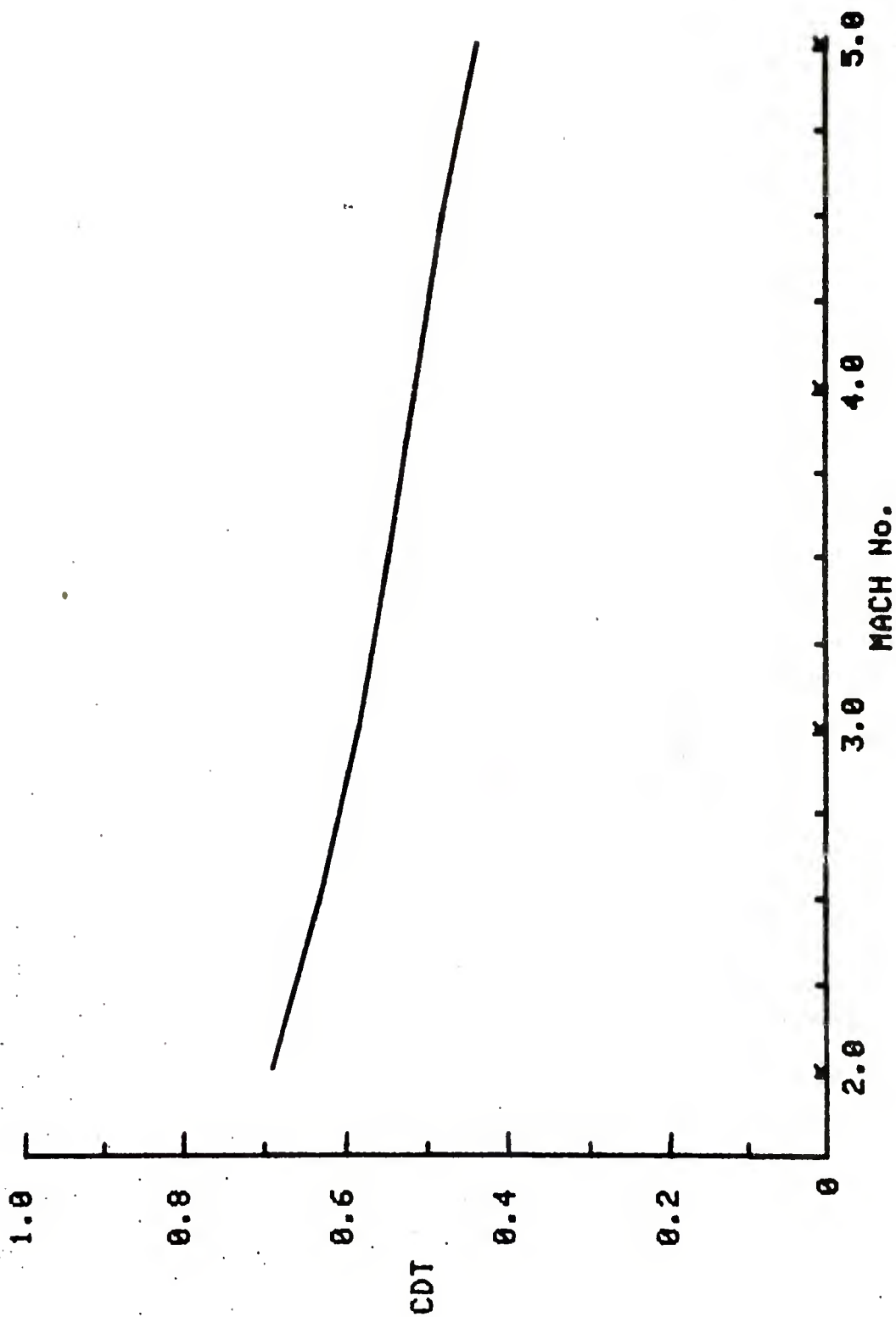
MACH NUMBER

	2.0	2.5	3.0	3.5	4.0	4.5	5.0
CNAB	1.494	1.299	1.185	1.110	1.057	1.018	0.988
XCPB	4.792	3.414	2.694	2.257	1.967	1.764	1.616
CMAB	7.157	4.434	3.193	2.506	2.080	1.796	1.597
CHAF	1.993	1.565	1.295	1.108	0.969	0.862	0.777
CHAT	20.736	15.998	13.028	10.966	9.444	8.269	7.334
CMAT	395.761	301.284	242.349	201.550	171.445	148.236	129.760
CG-CP	-7.225	-6.973	-6.743	-6.519	-6.294	-6.066	-5.832
CMAT,CG	-149.829	-111.547	-87.842	-71.489	-59.442	-50.161	-42.773
CDWB	0.057	0.053	0.051	0.049	0.047	0.045	0.044
CDBB	0.169	0.145	0.121	0.097	0.073	0.049	0.025
CDUB	0.339	0.305	0.270	0.235	0.201	0.166	0.131
CDGRV	0.017	0.036	0.065	0.102	0.144	0.185	0.215
CDTB	0.565	0.503	0.442	0.381	0.320	0.260	0.200
CDWF	0.007	0.005	0.004	0.004	0.003	0.003	0.003
CDBF	0.089	0.077	0.064	0.051	0.039	0.026	0.013
CDUF	0.011	0.010	0.009	0.008	0.007	0.006	0.004
CDTF	0.108	0.092	0.078	0.063	0.049	0.034	0.020
CDT	0.690	0.631	0.584	0.546	0.513	0.480	0.436
CLA	20.046	15.367	12.444	10.421	8.931	7.789	6.899
J ZETA	-3.431	-3.533	-3.633	-3.738	-3.853	-3.982	-4.136

CHAT vs. MACH No.

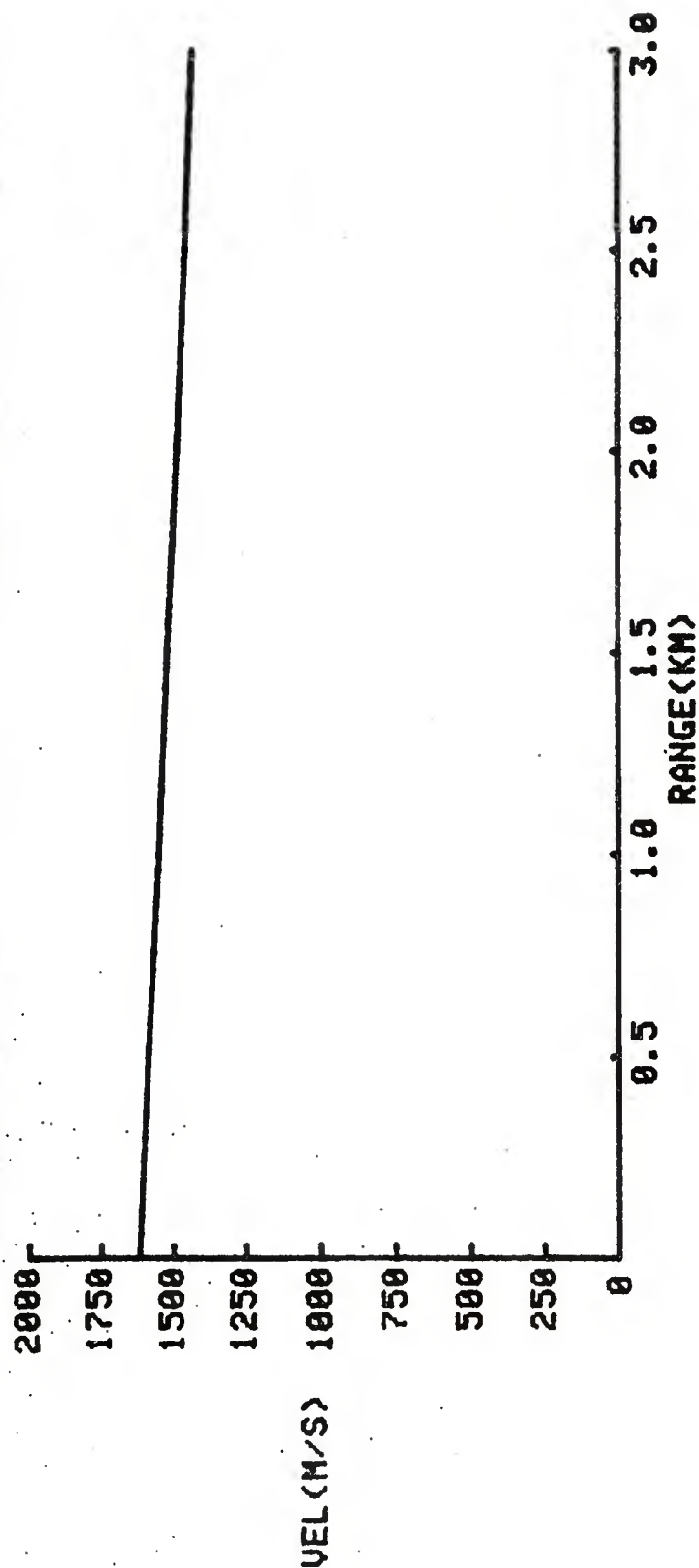


CDT vs. MACH No.



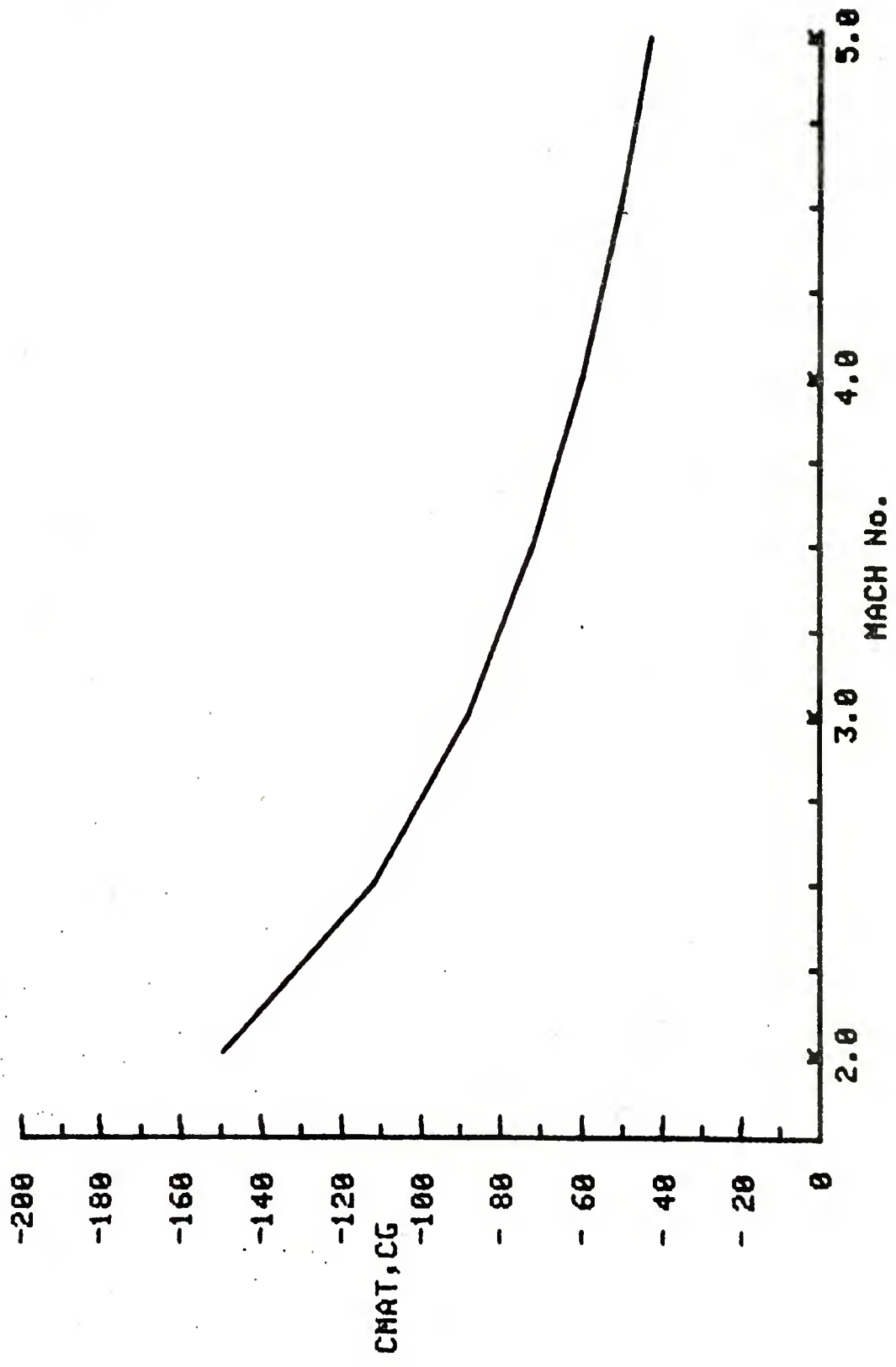
VELOCITY vs. RANGE

MUZZLE MACH No. 4.73 INITIAL YAW CYCLE 42.419M

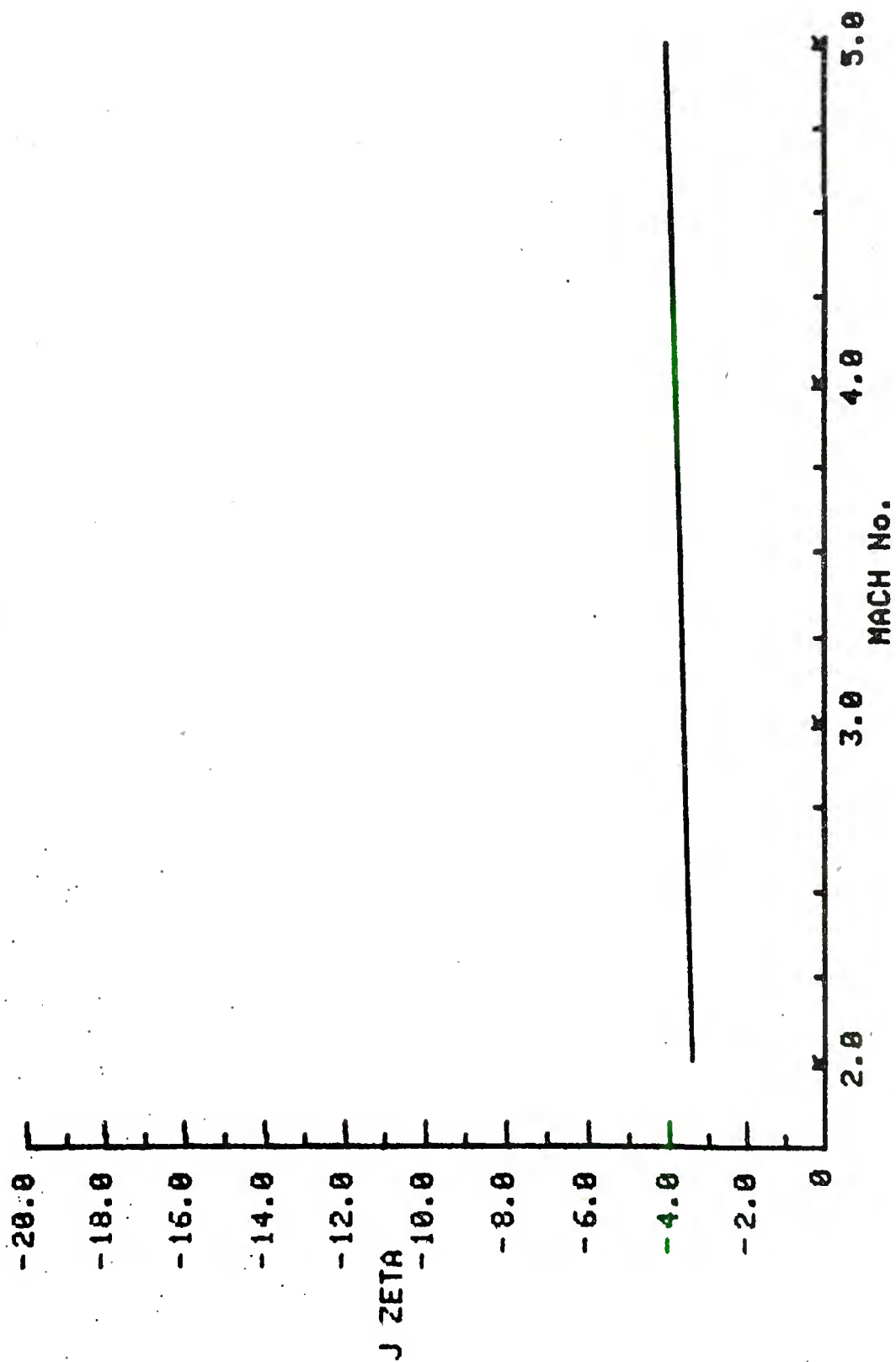


RANGE 3000 M	64.708 M/S/KM	RETARDATION
RANGE 2500 M	64.934 M/S/KM	RETARDATION
RANGE 2000 M	65.147 M/S/KM	RETARDATION
RANGE 1500 M	65.348 M/S/KM	RETARDATION
RANGE 1000 M	65.536 M/S/KM	RETARDATION
RANGE 500 M	65.711 M/S/KM	RETARDATION
RANGE 0 M	65.711 M/S/KM	RETARDATION

CMAT,CG vs. MACH No.



J ZETA vs. MACH No.



APPENDIX C

PROGRAM LISTING

```

1 GO TO 100
4 GO TO 3950
8 GO TO 5670
12 GO TO 6070
16 GO TO 6690
20 GO TO 7240
24 GO TO 7850
28 GO TO 8540
32 GO TO 660
36 GO TO 3760
100 PAGE
110 DIM Q(20,7),Q1(7),A$(1),R2(20),R3(20),V(20)
120 PRI "THIS PROGRAM WILL CALCULATE AND PLOT ESTIMATED STATIC AERODYN"
130 PRINT "AMIC"
140 PRINT " COEFFICIENTS OF LONG ROD FINNED PROJECTILES FOR 2<M<5"
150 PRINT
160 PRINT "INPUT NUMBER OF FINS (4 or 6): ";
170 INPUT N
180 PRINT
190 PRINT "INPUT THESE VALUES IN CALIBERS "
200 PRINT
210 PRINT "INPUT CONICAL NOSE LENGTH: ";
220 INPUT L
230 PRINT "INPUT CYLINDRICAL BODY LENGTH: ";
240 INPUT L1
250 PRINT "INPUT GROOVE LOCATION/NOSE: ";
260 INPUT P1
270 PRINT "INPUT GROOVE LENGTH: ";
280 INPUT P2
290 PRINT "INPUT FIN DIMENSION (BLADE HEIGHT): ";
300 INPUT H2
310 PRINT "INPUT FIN BLADE LENGTH AT ROOT: ";
320 INPUT C
330 PRINT "INPUT FIN DIMENSION (ROOT RECESS): ";

```

```

340 INPUT G "INPUT FIN DIMENSION (BLADE EXTENSION FROM BODY): ";
350 PRINT
360 INPUT K "INPUT FIN DIMENSION (MAXIMUM THICKNESS): ";
370 PRINT
380 INPUT T "INPUT FIN BLADE LENGTH AT TIP: ";
390 PRINT
400 INPUT C1 "INPUT CENTER OF GRAVITY OF PROJECTILE : ";
410 PRINT
420 INPUT C2 "INPUT 1.0 CALIBER REFERENCE DIAMETER (MILLIMETERS): ";
430 PRINT
440 INPUT D1
450 D=0
460 IF D1<>0 THEN 490
470 PRINT "INPUT 1.0 CALIBER REFERENCE DIAMETER (INCHES): ";
480 INPUT D
490 PRINT "INPUT NORMALIZED WEIGHT OF PROJECTILE (CAL↑3): ";
500 INPUT W
510 PRINT "INPUT AXIAL MOMENT OF INERTIA(CAL↑5): ";
520 INPUT I
530 PRINT "INPUT TRANSVERSE MOMENT OF INERTIA(CAL↑5): ";
540 INPUT I1
550 PRINT
560 PRINT "INPUT THESE RANGE VALUES"
570 PRINT
580 PRINT "INPUT MACH NUMBER AT MUZZLE: ";
590 INPUT M0
600 PRINT "INPUT MAXIMUM RANGE (METERS, <=4000): ";
610 INPUT S
620 S9=S
630 PRINT
640 PRINT "INPUT PLOTTING DEVICE NUMBER(1=PEN PLOTTER,32=SCREEN): ";
650 INPUT A
660 PAGE
670 SET DEGREES
680 B=20

```

```

690 B1=25
700 B2=L+L1+K-C
710 B3=L+L1
720 B4=B2+C+G-C1
730 B5=B4+C1
740 B6=B5-G
750 F=ATN<(-B2+B5-C1)/H2>
760 F=INT(F*100)/100
770 Z=0
780 B7=H2+0.5+B
790 B8=-H2-0.5+B
800 B9=B1-(H2+0.5)*SIN(60)
810 E=B1+(H2+0.5)*SIN(60)
820 E1=B+(H2+0.5)*COS(60)
830 E2=B-(H2+0.5)*COS(60)
840 E3=B1+H2+0.5
850 E4=B1-H2-0.5
860 VIEWPORT 0,130,0,100
870 WINDOW -2,40,-2,26
880 MOVE EA:-1,20
890 DRAW EA:20,20
900 MOVE EA:0,B
910 DRAW EA:L,B+0.5
920 DRAW EA:L,B-0.5
930 DRAW EA:0,B
940 MOVE EA:L,B+0.5
950 DRAW EA:B3,B+0.5
960 DRAW EA:B3,B-0.5
970 DRAW EA:L,B-0.5
980 MOVE EA:B2,B+0.5
990 DRAW EA:B4,B7
1000 DRAW EA:B5,B7
1010 DRAW EA:B6,B+0.5
1020 DRAW EA:B6,B-0.5
1030 DRAW EA:B5,B8

```

```

1040 DRAW @A:B4,B8
1050 DRAW @A:B2,B-0.5
1060 IF N<6 THEN 1110
1070 MOVE @A:B9+7,E1
1080 DRAW @A:E+7,E2
1090 MOVE @A:B9+7,E2
1100 DRAW @A:E+7,E1
1110 E5=H2+0.5
1120 E6=B+E5
1130 E7=B-E5
1140 MOVE @A:B1+7,E6
1150 DRAW @A:B1+7,E7
1160 IF N<4 THEN 1210
1170 MOVE @A:B1+7,E6
1180 DRAW @A:B1+7,E7
1190 MOVE @A:E3+7,B
1200 DRAW @A:E4+7,B
1210 MOVE @A:B1+7,B+0.5
1220 DRAW @A:B1-0.5*SIN(22.5)+7,B+0.5*COS(22.5)
1230 DRAW @A:B1-0.5*COS(22.5)+7,B+0.5*SIN(22.5)
1240 DRAW @A:B1-0.5+7,B
1250 DRAW @A:B1-0.5*COS(22.5)+7,B-0.5*SIN(22.5)
1260 DRAW @A:B1-0.5*SIN(45)+7,B-0.5*COS(45)
1270 DRAW @A:B1-0.5*SIN(22.5)+7,B-0.5*COS(22.5)
1280 DRAW @A:B1+7,B-0.5
1290 DRAW @A:B1+0.5*SIN(45)+7,B-0.5*COS(45)
1300 DRAW @A:B1+0.5*COS(22.5)+7,B-0.5*SIN(22.5)
1310 DRAW @A:B1+0.5+7,B
1320 DRAW @A:B1+0.5*COS(22.5)+7,B+0.5*SIN(22.5)
1330 DRAW @A:B1+0.5*SIN(45)+7,B+0.5*COS(45)
1340 DRAW @A:B1+0.5*SIN(22.5)+7,B+0.5*COS(22.5)
1350 DRAW @A:B1+7,B+0.5
1360 MOVE @A:0,B-0.2
1370 DRAW @A:0,B-5
1380 MOVE @A:L,B-0.7

```



```

1390 DRAW 0A:L,B-2
1400 MOVE 0A:B3,B-0.7
1410 DRAW 0A:B3,B-1.1
1420 MOVE 0A:B3,B-1.9
1430 DRAW 0A:B3,B-4
1440 MOVE 0A:B5,B8-0.2
1450 DRAW 0A:B5,B-5
1460 MOVE 0A:-0.25,B-1.5
1470 DRAW 0A:L+0.5,B-1.5
1480 RMOVE 0A:0.5,-0.5/2
1490 PRINT 0A:L
1500 MOVE 0A:0,B-3
1510 DRAW 0A:3.5,B-3
1520 RMOVE 0A:-0.2,-0.5/2
1530 PRINT 0A:B3
1540 MOVE 0A:7,B-3
1550 DRAW 0A:B3,B-3
1560 MOVE 0A:0,B-4.5
1570 DRAW 0A:5.5,B-4.5
1580 RMOVE 0A:-0.2,-0.5/2
1590 PRINT 0A:B5
1600 MOVE 0A:9,B-4.5
1610 DRAW 0A:B5,B-4.5
1620 MOVE 0A:0,B+0.2
1630 DRAW 0A:0,B+5
1640 MOVE 0A:C2,B+3
1650 DRAW 0A:C2,B+5
1660 MOVE 0A:0,B+4.5
1670 DRAW 0A:1,B+4.5
1680 RMOVE 0A:-0.2,-0.5/2
1690 PRINT 0A:C2
1700 MOVE 0A:0.5,2+B
1710 DRAW 0A:0,2+B
1720 RMOVE 0.2,0.25
1730 IF P1=0 THEN 1790

```



```

1740 PRINT EA:P1
1750 MOVE EA:P1-1.2,2+B
1760 DRAW EA:P1+P2+0.2,2+B
1770 MOVE EA:P1+P2+0.5,2+B-0.25
1780 PRINT EA:P2
1790 MOVE EA:5,B+4.5
1800 DRAW EA:C2,B+4.5
1810 MOVE EA:C2-0.2,B-0.2
1820 DRAW EA:C2+0.1,B+0.12
1830 MOVE EA:C2+0.1,B-0.12
1840 DRAW EA:C2-0.2,B+0.2
1850 MOVE EA:P1,B+0.7
1860 DRAW EA:P1,B+2.5
1870 MOVE EA:P1+P2,B+0.7
1880 DRAW EA:P1+P2,B+2.5
1890 H=0.1*SQR(8)
1900 MOVE EA:C2+H,B
1910 FOR I5=1 TO 8
1920 Q5=I5*360/8
1930 X=H*COS(Q5)+C2
1940 Y=H*SIN(Q5)+B
1950 DRAW EA:X,Y
1960 NEXT I5
1970 MOVE EA:P1,0.5+B
1980 DRAW EA:P1+P2,-0.5+B
1990 DRAW EA:P1+P2,0.5+B
2000 DRAW EA:P1,-0.5+B
2010 DRAW EA:P1,0.5+B
2020 MOVE EA:B1-0.05+7,B7+0.2
2030 DRAW EA:B1-0.05+7,B7+2
2040 MOVE EA:B1+0.05+7,B7+0.2
2050 DRAW EA:B1+0.05+7,B7+2
2060 MOVE EA:B1-0.5+7,B7+1
2070 DRAW EA:B1+7.45,B7+1
2080 PRINT EA:T

```

```

2090 MOVE @A:B2+7,B-9.5
2100 DRAW @A:B4+7,B7-10
2110 DRAW @A:B5+7,B7-10
2120 DRAW @A:B6+7,B-9.5
2130 DRAW @A:B6+7,B-10
2140 DRAW @A:B3+7,B-10
2150 DRAW @A:B3+7,B-9.5
2160 DRAW @A:B2+7,B-9.5
2170 IF C1=0 THEN 2180
2180 MOVE @A:B4+7,B7-9.8
2190 DRAW @A:B4+7,B7-8.8
2200 MOVE @A:B5+7,B7-9.8
2210 DRAW @A:B5+7,B7-8.8
2220 MOVE @A:B4+6.5,B7-9.5
2230 DRAW @A:B4+7,B7-9.5
2240 MOVE @A:B5+7,B7-9.5
2250 DRAW @A:B5+8,B7-9.5
2260 MOVE @A:B5+8.2,B7-9.6
2270 RMV @A:0,-0.25
2280 PRINT @A:C1
2290 IF G=0 THEN 2400
2300 MOVE @A:B5+7,B7-10.2
2310 DRAW @A:B5+7,B7-14
2320 MOVE @A:B6+7,B-10.2
2330 DRAW @A:B6+7,B-10.7
2340 MOVE @A:B6+6.5,B-10.5
2350 DRAW @A:B6+7,B-10.5
2360 MOVE @A:B5+7,B-10.5
2370 DRAW @A:B5+8,B-10.5
2380 MOVE @A:B5+8.2,B-10.6
2390 PRINT @A:G
2400 IF K=0 THEN 2500
2410 MOVE @A:B3+7,B-10.2
2420 DRAW @A:B3+7,B-10.7
2430 MOVE @A:B3+7,B-10.5

```

```

2440 DRAW EA:B6+7,B-10.5
2450 MOVE EA:(B3+B6)/2+7,B-10.7
2460 DRAW EA:B3+7,B-13.5
2470 DRAW EA:B3+7.5,B-13.5
2480 RMOVE EA:0.1,-0.25
2490 PRINT EA:K
2500 MOVE EA:B2+7,B-9.7
2510 DRAW EA:B2+7,B-12
2520 MOVE EA:B2+7,B-11.7
2530 DRAW EA:B2+6.7,B-11.7
2540 MOVE EA:B5+7,B-10
2550 DRAW EA:B5+7,B-12
2560 MOVE EA:B5+7,B-11.7
2570 DRAW EA:B5+7.3,B-11.7
2580 RMOVE EA:0,-0.5
2590 PRINT EA:C+G
2600 MOVE EA:B2+7,B-9.8
2610 DRAW EA:B2+7,B-9
2620 MOVE EA:B2+7+0.2*(B4-B2),B-9.5+0.4*H2
2630 MOVE EA:B2+7+0.2*(B4-B2),B-9.5+0.4*H2
2640 DRAW EA:(B2+B4)/2+7,B7-7.5
2650 RDRAW EA:0.5,0
2660 RMOVE EA:0.2,-0.25
2670 PRINT EA:F
2680 MOVE EA:B5+1,B7
2690 DRAW EA:B5+1,B8-1
2700 DRAW EA:B5+2,B8-1
2710 MOVE EA:B5+2.2,B8-1.1
2720 RMOVE EA:0,-0.25
2730 PRINT EA:2*H2+1
2740 MOVE EA:B5+0.2,B7
2750 DRAW EA:B5+1.5,B7
2760 MOVE EA:B5+0.2,B8
2770 DRAW EA:B5+1.5,B8
2780 MOVE EA:B5+7.2,B7-10

```

```

2790 DRAW EA:B5+8.5,B7-10
2800 MOVE EA:B5+7.8,B7-10
2810 DRAW EA:B5+7.8,B-9.5
2820 MOVE EA:B5+0.2,B7
2830 DRAW EA:B5+1.5,B7
2840 MOVE EA:B5+0.2,B8
2850 DRAW EA:B5+1.5,B8
2860 MOVE EA:B5+8.1,B-9.5+H2/2
2870 RDRAW EA:4,0
2880 MOVE EA:B5+7.2,B-9.5
2890 DRAW EA:B5+8.5,B-9.5
2900 MOVE EA:B5+12.5,B-9.5+H2/2
2910 PRINT EA:H2
2920 MOVE EA:1.5,B-9
2930 PRINT EA:"WT = ";
2940 PRINT EA:W;
2950 PRINT EA:" WCAL3"
2960 MOVE EA:1.5,B-10
2970 PRINT EA:"IX = ";
2980 PRINT EA:I;
2990 PRINT EA:" ICAL5"
3000 MOVE EA:1.5,B-11
3010 PRINT EA:"IY = ";
3020 PRINT EA:I;
3030 PRINT EA:" ICAL5"
3040 MOVE EA:1.5,B-12
3050 PRINT EA:"DIA = ";
3060 IF D=0 THEN 3100
3070 PRINT EA:D;
3080 PRINT EA:"IN/CAL "
3090 GO TO 3120
3100 PRINT EA:D1;
3110 PRINT EA:" MM/CAL "
3120 HOME EA:
3130 PRINT EA: USING 3140:"LONG ROD FINNED PROJECTILE DESIGN"

```

```

3140 IMAGE20X,33A
3150 PRINT @A:"JJJJJJJJJJJJJJJJJJJJJJJJJJJJJJ "
3160 PRINT "G"
3170 PRINT "IF YOU WANT THE INITIAL DATA PRINTED OUT ENTER 'YES': ";
3180 INPUT A$
3190 IF A$="Y" THEN 3210
3200 GO TO 3680
3210 PAGE
3220 PRINT
3230 PRINT
3240 PRINT "CONICAL NOSE LENGTH: ";
3250 PRINT L
3260 PRINT "CYLINDRICAL BODY LENGTH: ";
3270 PRINT L1
3280 PRINT "GROOVE LOCATION/NOSE: ";
3290 PRINT P1
3300 PRINT "GROOVE LENGTH: ";
3310 PRINT P2
3320 PRINT "FIN DIMENSION (BLADE HEIGHT): ";
3330 PRINT H2
3340 PRINT "FIN BLADE LENGTH AT ROOT: ";
3350 PRINT C
3360 PRINT "FIN DIMENSION (ROOT RECESS): ";
3370 PRINT G
3380 PRINT "FIN DIMENSION (BLADE EXTENSION FROM BODY): ";
3390 PRINT K
3400 PRINT "FIN DIMENSION (MAXIMUM THICKNESS): ";
3410 PRINT T
3420 PRINT "FIN SWEEP ANGLE (DEGREES): ";
3430 PRINT F
3440 PRINT "FIN BLADE LENGTH AT TIP: ";
3450 PRINT C1
3460 PRINT "NUMBER OF BLADES: ";
3470 PRINT N
3480 PRINT "CENTER OF GRAVITY: ";

```



```

3490 PRINT C2
3500 PRINT "MACH NUMBER AT MUZZLE: ";
3510 PRINT M0
3520 PRINT "MAXIMUM RANGE (METERS): ";
3530 PRINT S
3540 PRINT "WEIGHT OF PROJECTILE (CAL↑3): ";
3550 PRINT W
3560 PRINT "AXIAL MOMENT OF INERTIA (CAL↑5): ";
3570 PRINT I
3580 PRINT "TRANSVERSE MOMENT OF INERTIA (CAL↑5): ";
3590 PRINT I1
3600 IF D=0 THEN 3640
3610 PRINT "1.0 CALIBER REFERENCE DIAMETER (IN.): ";
3620 PRINT D
3630 GO TO 3660
3640 PRINT "1.0 CALIBER REFERENCE DIAMETER (MM): ";
3650 PRINT D1
3660 PRINT "G"
3670 PRINT "JJJJJJ"
3680 PRINT "ENTER YES FOR MENU: ";
3690 INPUT A$
3700 IF A$="Y" THEN 3720
3710 END
3720 PAGE "WAIT"
3730 PRINT "WAIT"
3740 S=S9
3750 GOSUB 4280
3760 PAGE "
3770 PRINT "
3780 PRINT "
3790 PRINT "
3800 PRINT "1.....NOMENCLATURE"
3810 PRINT "2.....TABLE OF AERODYNAMIC COEFFICIENTS"
3820 PRINT "3.....CHAT vs. MACH NUMBER PLOT"
3830 PRINT "

```

USER DEFINABLE KEY DEFINITIONS"

```

3840 PRINT "4.....CDT vs. MACH NUMBER PLOT"
3850 PRINT "5.....VELOCITY vs. RACH RANGE PLOT"
3860 PRINT "6.....CMAT,CG vs. MACH NUMBER PLOT"
3870 PRINT "7.....J ZETA vs. MACH NUMBER PLOT"
3880 PRINT "8.....LONG ROD FINNED PROJECTILE DESIGN"
3890 PRINT "9.....RETURN TO MENU"
3900 PRINT
3910 PRINT
3920 PRINT "PLEASE PRESS USER DEFINABLE KEY TO CONTINUE"
3930 PRINT "G"
3940 END
3950 REM
3960 REM THIS IS THE NOMENCLATURE
3970 REM
3980 PAGE
3990 PRINT " "
4000 PRINT "JJJ"
4010 PRINT "CHAB Slope of the Normal Force Coefficient for the proj";
4020 PRINT "ectile body"
4030 PRINT "XCPB Pressure coefficient for the projectile body"
4040 PRINT "CHAB Slope of the Pitching Moment Coefficient for ";
4050 PRINT "the projectile body"
4060 PRINT "CHAF Slope of the Normal Force Coefficient for the";
4070 PRINT "projectile fins"
4080 PRINT "CHAT Slope of the Total Normal Force Coefficient"
4090 PRINT "CHAT Slope of the Total Pitching Moment Coefficient"
4100 PRINT "CG-CP Center of gravity minus center of pressure"
4110 PRINT "CHAT,CG Slope of the Total Pitching Moment Coefficient";
4120 PRINT "about the center"
4130 PRINT "of gravity"
4140 PRINT "CDWB Coefficient of wave drag for the projectile body"
4150 PRINT "CDBB Base drag coefficient for the projectile body"
4160 PRINT "CDVB Viscous drag coefficient for the projectile body"
4170 PRINT "CDGRV Profile drag of grooved section of body"
4180 PRINT "CDTB Total drag coefficient for the projectile body"

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```

4190 PRINT "CDWF Have drag coefficient for the projectile fins"
4200 PRINT "CDBF Base drag coefficient for the projectile fins"
4210 PRINT "CDUF Viscous drag coefficient for the projectile fins"
4220 PRINT "CDTF Total drag coefficient for the projectile fins"
4230 PRINT "CDT Total drag coefficient"
4240 PRINT "CLA Slope of the Lift Coefficient"
4250 PRINT "J ZETA Aerodynamic jump factor"
4260 PRINT "G"
4270 END
4280 REM
4290 REM SUBROUTINE TO DO CALCULATIONS
4300 REM
4310 G6=L+L1
4320 J2=H2*C+H2*C1+K-G
4330 J3=H2*H2*4/J2
4340 M=2
4350 FOR Y=1 TO 7
4360 G3=SQR(M*M-1)
4370 G4=G3/L
4380 G5=L1/G3
4390 Q1(Y)=M
4400 G7=(1.9+1.3*G4+0.0149*G5)*(1/G3+0.7)*(2.3-0.0675*G6)
4410 G8=TAN(F)/G3
4420 G9=(0.69+0.65*G4+0.5*G5)*(1/G3+0.46)
4430 J1=G7*G9
4440 Q(1,Y)=G7
4450 Q(2,Y)=G9
4460 Q(3,Y)=J1
4470 J4=((1.25*LOG(J3)*0.25*TAN(F)+0.9*T/C)*G8+4)/G3
4480 J5=1/G3+0.58*0.54/M*(1-1/G8)*(0.6*J3-1)/TAN(F)
4490 IF G8>2 THEN 4510
4500 J6=J4
4510 IF G8<=2 THEN 4530
4520 J6=J4+J5
4530 Q(4,Y)=J6

```


4540 J7=J2*J6*N/PI
 4550 J8=(G6+K-G-C/2)*J7
 4560 J9=1/(1+2*H2)
 4570 J9=2.72*J9
 4580 J=1.34-0.17*G3/TAN(F)
 4590 J9=J9*J
 4600 J=J9*9/L1*J7+G7
 4610 K1=J
 4620 K2=J9*9/L1*J8+J1
 4630 K3=K2/J
 4640 K4=C2-K3
 4650 K5=K4*J
 4660 K6=K5
 4670 Q(5,Y)=J
 4680 Q(6,Y)=K2
 4690 Q(7,Y)=K4
 4700 Q(8,Y)=K5
 4710 J=6+J/10
 4720 K5=6+K5*6/220
 4730 K7=M*2-3.5
 4740 K8=J
 4750 K9=K7
 4760 T1=K5
 4770 T2=PI*(SQR(0.61685+2.4674*L*L)+L1)
 4780 T3=J2/2
 4790 T4=T*H2*N
 4800 T5=M*0.28*L*1.73
 4810 T5=0.7/T5
 4820 T6=0.265-0.048*M
 4830 T7=T2*(0.006333-9.18E-4*M)
 4840 T8=H2/COS(F)
 4850 T8=T*T/T8/T8
 4860 T9=N*T8*T3*4/G3/PI
 4870 T8=4*T4*T6/PI
 4880 F1=0.869565*T3*T7/T2

```

4890 F2=T5+T6+T7
4900 F3=T8+T9+F1
4910 P4=M+3.9/4000*F2*P2
4920 F4=F2+F3+P4
4930 F5=F4
4940 Q(9,Y)=T5
4950 Q(10,Y)=T6
4960 Q(11,Y)=T7
4970 Q(12,Y)=P4
4980 Q(13,Y)=F2
4990 Q(14,Y)=T9
5000 Q(15,Y)=T8
5010 Q(16,Y)=F1
5020 Q(17,Y)=F3
5030 Q(18,Y)=F4
5040 IF M<>3 THEN 5060
5050 F6=F4
5060 F4=F4*5+6
5070 IF M<>5 THEN 5090
5080 F7=(F4-6)/5
5090 F8=M*2+4
5100 F9=K1-F5
5110 Q(19,Y)=F9
5120 N1=I1/W*(F9/K6)
5130 Q(20,Y)=N1
5140 M=M+0.5
5150 N1=6+N1/2
5160 N2=N1
5170 O2=F8
5180 O3=F4
5190 NEXT Y
5200 N5=500
5210 Y=1
5220 N3=(F7-F6)/2
5230 N4=F6-3*N3

```

```

5240 N6=PI*0.075/62.4/8*N4/W
5250 N7=N3+N4/M0
5260 IF D<=0 THEN 5280
5270 N8=EXP(S*N6*39.37/D)
5280 IF D1<=0 THEN 5300
5290 N8=EXP(S*N6*1000/D1)
5300 N9=N4/(N7*N8-N3)
5310 N0=(M0-N9)*341380
5320 U(Y)=N9*341.38
5330 N0=N0/S
5340 R2(Y)=S
5350 R3(Y)=N0
5360 O4=0
5370 IF N9<>04 THEN 5380
5380 O4=N9
5390 O5=S
5400 S=S-N5
5410 Y=Y+1
5420 IF S=0 THEN 5440
5430 GO TO 5260
5440 N3=(F7-F6)/2
5450 Y1=Y
5460 R2(Y)=0
5470 R3(Y)=R3(Y-1)
5480 U(Y)=M0*341.38
5490 N4=F6-3*N3
5500 N6=PI*0.075/62.4/8*N4/W
5510 N7=N3+N4/M0
5520 IF D<=0 THEN 5540
5530 N8=EXP(05*N6*1000/D)
5540 IF D1<=0 THEN 5560
5550 N8=EXP(05*N6*1000/D1)
5560 N9=N4/(N7*N8-N3)
5570 N0=(M0-N9)*341380
5580 N0=N0/O5

```

```

5590 06=11/K6*8*PI/0.0012
5600 06=06*06
5610 06=06*0.25
5620 IF D<=0 THEN 5640
5630 01=06*D/39.37
5640 IF D1<=0 THEN 5660
5650 01=06*D1/1000
5660 RETURN
5670 REM
5680 REM THIS IS THE TABLE OF CALCULATIONS
5690 REM
5700 PAGE
5710 PRINT " " STATIC AERODYNAMIC COEFFICIENTS FOR LONG ROD FINNED";
5720 PRINT " " PROJECTILES"
5730 PRINT
5740 PRINT USING 5750: "MACH NUMBER"
5750 IMAGE 30X,11A
5760 PRINT
5770 PRINT USING 5780: "2.0","2.5","3.0","3.5","4.0","4.5","5.0"
5780 IMAGE12X,3A,6X,3A,7X,3A,7X,4(3A,6X)
5790 PRINT "CNAB"
5800 PRINT "XCPB"
5810 PRINT "CMAB"
5820 PRINT "CNAF"
5830 PRINT "CHAT"
5840 PRINT "CMAT"
5850 PRINT "CG-CP"
5860 PRINT "CMAT,CG"
5870 PRINT "CDWB"
5880 PRINT "CDBB"
5890 PRINT "CDUB"
5900 PRINT "CDGRV"
5910 PRINT "CDTB"
5920 PRINT "CDWF"
5930 PRINT "CDBF"

```

```

5940 PRINT "CDUF"
5950 PRINT "CDTF"
5960 PRINT "CDT"
5970 PRINT "CLA"
5980 PRINT "J ZETA"
5990 HOME
6000 PRINT "JJJJJ"
6010 FOR Y=1 TO 20
6020 PRINT USING 6030:Q(Y,1),Q(Y,2),Q(Y,3),Q(Y,4),Q(Y,5),Q(Y,6),Q(Y,7)
6030 IMAGE 8X,2(4D.3D,1X),2(1X,4D.3D,1X),2(4D.3D,1X),4D.3D
6040 NEXT Y
6050 PRINT "G"
6060 END
6070 PAGE
6080 REM
6090 REM THE GRAPH OF CNAT vs MACH NUMBER
6100 REM
6110 VIEWPORT 20,125,12,90
6120 WINDOW 1.75,5,0,30
6130 AXIS EA:0.25,2
6140 MOVE EA:2,0
6150 RMOVE EA:-0.02,-1.5
6160 PRINT EA:"2.0"
6170 FOR R1=3 TO 5
6180 RMOVE EA:1,0
6190 PRINT EA: USING 6200:R1
6200 IMAGE 1D.1D
6210 NEXT R1
6220 MOVE EA:1.75,0
6230 RMOVE EA:-0.1,-0.3
6240 PRINT EA:"0"
6250 MOVE EA:1.75,6
6260 RMOVE EA:-0.2,-0.33
6270 PRINT EA:"6.0"
6280 RMOVE EA:-0.056,0

```

```

6290 FOR R1=12 TO 30 STEP 6
6300 RMV E:0,6
6310 PRINT E: USING 6320:R1
6320 IMAGE 2D.1D
6330 NEXT R1
6340 MOVE E:2,0
6350 RMV E:-0.017,0
6360 PRINT E:"I"
6370 FOR R1=3 TO 5
6380 RMV E:1,0
6390 PRINT E:"I"
6400 NEXT R1
6410 MOVE E:2,6
6420 IF A=32 THEN 6450
6430 RMV E:-0.22,-0.27
6440 GO TO 6460
6450 RMV E:-0.22,-0.47
6460 PRINT E:"-"
6470 FOR R1=12 TO 30 STEP 6
6480 RMV E:0,6
6490 PRINT E:"-"
6500 NEXT R1
6510 HOME E:
6520 PRINT
6530 PRINT E: USING 6540:"CNAT vs. MACH No."
6540 IMAGE 30X,17A
6550 PRINT E:"JJJJJJJJJJJJJJJJ"
6560 PRINT E: USING 6570:"CNAT"
6570 IMAGE 4X,4A
6580 PRINT E:"JJJJJJJJJJJJJJJJ"
6590 PRINT E: USING 6600:"MACH No."
6600 IMAGE 30X,8A
6610 MOVE E:Q1(1),Q(5,1)
6620 FOR R1=2 TO 7
6630 DRAW E:Q1(R1),Q(5,R1)

```



```

6640 NEXT R1
6650 PRINT "G"
6660 END
6670 REM THIS IS THE GRAPH OF CDT vs. MACH No.
6680 REM
6690 PAGE
6700 VIEWPORT 20,125,12,90
6710 WINDOW 1.75,5,0,1
6720 AXIS EA:0.25,0.1
6730 MOVE EA:2,0
6740 RMOVE EA:-0.06,-0.05
6750 PRINT EA:"2.0"
6760 FOR R1=3 TO 5
6770 RMOVE EA:1,0
6780 PRINT EA: USING 6790:R1
6790 IMAGEID:1D
6800 NEXT R1
6810 MOVE EA:1.75,0
6820 RMOVE EA:-0.1,-0.015
6830 PRINT EA:"0"
6840 MOVE EA:1.75,0.2
6850 RMOVE EA:-0.25,-0.01
6860 PRINT EA:"0.2"
6870 FOR R1=0.4 TO 1 STEP 0.2
6880 RMOVE EA:0,0.2
6890 PRINT EA: USING 6900:R1
6900 IMAGEID:1D
6910 NEXT R1
6920 HOME EA:
6930 PRINT EA: USING 6940:"CDT vs. MACH No."
6940 IMAGE31X,16A
6950 PRINT EA:"JJJJJJJJJJJJJJJJ"
6960 PRINT EA: USING 6970:"CDT"
6970 IMAGE 3X,3A
6980 PRINT EA:"JJJJJJJJJJJJJJJJ"

```

```

6990 PRINT EA: USING 7000:"MACH No."
7000 IMAGE38X,8A
7010 MOVE EA:2,0
7020 RMOVE EA:-0.018,0
7030 PRINT EA:"I"
7040 FOR R1=3 TO 5
7050 RMOVE EA:1,0
7060 PRINT EA:"I"
7070 NEXT R1
7080 MOVE EA:1.75,0.2
7090 IF A=32 THEN 7120
7100 RMOVE EA:0.03,-0.01
7110 GO TO 7130
7120 RMOVE EA:0.03,-0.016
7130 PRINT EA:"-"
7140 FOR R1=0.4 TO 1 STEP 0.2
7150 RMOVE EA:0,0.2
7160 PRINT EA:"-"
7170 NEXT R1
7180 MOVE EA:Q1(1),Q(18,1)
7190 FOR R1=2 TO 7
7200 DRAW EA:Q1(R1),Q(18,R1)
7210 NEXT R1
7220 PRINT "G"
7230 END
7240 REM
7250 REM THIS IS THE GRAPH OF VELOCITY vs. RANGE
7260 REM
7270 PAGE
7280 S=S9
7290 S8=S9/1000
7300 VIEWPORT 25,125,40,90
7310 WINDOW 0,S8,0,2000
7320 AXIS EA:0.5,250
7330 MOVE EA:0.5,0

```



```

7340 RMOVE EA:-0.06,-135
7350 PRINT EA:"0.5"
7360 FOR R1=1 TO S8 STEP 0.5
7370 RMOVE EA:0.5,0
7380 PRINT EA: USING 7390:R1
7390 IMAGE1D.1D
7400 NEXT R1
7410 MOVE EA:0,0
7420 RMOVE EA:-0.08,-50
7430 PRINT EA:"0"
7440 MOVE EA:0,250
7450 RMOVE EA:-0.3*98/4,-40
7460 PRINT EA:" 250"
7470 FOR R1=500 TO 2000 STEP 250
7480 RMOVE EA:0,250
7490 PRINT EA: USING 7500:R1
7500 IMAGE4D
7510 NEXT R1
7520 HOME EA:
7530 PRINT EA: USING 7540:"VELOCITY vs. RANGE"
7540 IMAGE 30X,18A
7550 PRINT EA:
7560 PRINT EA: USING 7570:M0,01
7570 IMAGE15X,"MUZZLE MACH No. ",4D.2D,5X,"INITIAL YAW CYCLE ",4D.3D,"M"
7580 PRINT EA:"JJJJJJJJ"
7590 PRINT EA:"VEL(M/S)"
7600 PRINT EA:"JJJJJJJJ"
7610 PRINT EA: USING 7620:"RANGE(KM)"
7620 IMAGE 35X,9A
7630 PRINT EA:
7640 FOR Y=1 TO Y1
7650 PRINT EA: USING 7660:R2(Y),R3(Y)
7660 IMAGE14X,"RANGE",5D," M",15X,"RETARDATION",7D.3D," M/S/KM"
7670 NEXT Y
7680 FOR Y=1 TO Y1

```

```

7690 R2(Y)=R2(Y)/1000
7700 NEXT Y
7710 MOVE @A:R2(1),U(1)
7720 FOR R1=2 TO Y1
7730 DRAW @A:R2(R1),U(R1)
7740 NEXT R1
7750 DRAW @A:0,M0*340.29
7760 PRINT "G"
7770 FOR Y=1 TO Y1
7780 R2(Y)=R2(Y)*1000
7790 NEXT Y
7800 PRINT "G"
7810 END
7820 REM
7830 REM THIS IS THE GRAPH OF CHAT,CG VS. MACH No.
7840 REM
7850 PAGE
7860 VIEWPORT 20,125,12,90
7870 WINDOW 1.75,5,0,200
7880 AXIS @A:0.25,10
7890 MOVE @A:2,0
7900 RMOVE @A:-0.07,-9.5
7910 PRINT @A:"2.0"
7920 FOR R1=3 TO 5
7930 RMOVE @A:1,0
7940 PRINT @A: USING 7950:R1
7950 IMAGE 1D.1D
7960 NEXT R1
7970 MOVE @A:1.75,0
7980 RMOVE @A:-0.13,-3
7990 PRINT @A:"0"
8000 MOVE @A:1.75,20
8010 RMOVE @A:-0.2,-3.3
8020 PRINT @A:"20"
8030 FOR R1=40 TO 90 STEP 20

```

```

8040 RMOVE EA:0,20
8050 PRINT EA: USING 8060:R1
8060 IMAGE 2D
8070 NEXT R1
8080 MOVE EA:1.75,100
8090 RMOVE EA:-0.256,-3.3
8100 PRINT EA:"100"
8110 FOR R1=120 TO 200 STEP 20
8120 RMOVE EA:0,20
8130 PRINT EA: USING 8140:R1
8140 IMAGE3D
8150 NEXT R1
8160 HOME EA:
8170 PRINT EA: USING 8180:"CHAT,CG vs. MACH No."
8180 IMAGE29X,20A
8190 PRINT EA:"JJJJJJJJJJJJJJJJ"
8200 PRINT EA:"CHAT,CG"
8210 PRINT EA:"JJJJJJJJJJJJJJJJ"
8220 PRINT EA: USING 8230:"MACH No."
8230 IMAGE38X,8A
8240 MOVE EA:2,0
8250 RMOVE EA:-0.017,0
8260 PRINT EA:"I"
8270 FOR R1=3 TO 5
8280 RMOVE EA:1,0
8290 PRINT EA:"I"
8300 NEXT R1
8310 MOVE EA:1.75,20
8320 IF A=32 THEN 8350
8330 RMOVE EA:0.03,-2
8340 GO TO 8360
8350 RMOVE EA:0.03,-2.95
8360 PRINT EA:""
8370 FOR R1=40 TO 200 STEP 20
8380 RMOVE EA:0,20

```

```

8390 PRINT EA: "--"
8400 NEXT R1
8410 MOVE EA:1.75,20
8420 RMOVE EA:-0.3,-2.95
8430 PRINT EA: "--"
8440 FOR R1=20 TO 180 STEP 20
8450 RMOVE EA:0,20
8460 PRINT EA: "--"
8470 NEXT R1
8480 MOVE EA:ABS(Q1(1)),ABS(Q(8,1))
8490 FOR R1=2 TO 7
8500 DRAW EA:ABS(Q1(R1)),ABS(Q(8,R1))
8510 NEXT R1
8520 PRINT "G"
8530 END
8540 REM
8550 REM THIS IS THE GRAPH OF J ZETA vs. MACH No.
8560 REM
8570 PAGE
8580 VIEWPORT 20,125,12,90
8590 WINDOW 1.75,5,0,20
8600 AXIS EA:0.25,1
8610 MOVE EA:2,0
8620 RMOVE EA:-0.06,-1
8630 PRINT EA:"2.0"
8640 FOR R1=3 TO 5
8650 RMOVE EA:1,0
8660 PRINT EA: USING 8670:R1
8670 IMAGEID.10
8680 NEXT R1
8690 MOVE EA:1.75,0
8700 RMOVE EA:-0.1,-0.2
8710 PRINT EA:"0"
8720 RMOVE EA:-0.18,0
8730 FOR R1=2 TO 20 STEP 2

```

```

8740 RMOVE EA:0,2
8750 PRINT EA: USING 8760:R1
8760 IMAGE2D:1D
8770 NEXT R1
8780 HOME EA:
8790 PRINT EA: USING 8800:"J ZETA vs. MACH No."
8800 IMAGE 31X,19A
8810 PRINT EA:"JJJJJJJJJJJJJJJJ"
8820 PRINT EA:"J ZETA"
8830 PRINT EA:"JJJJJJJJJJJJJJJJ"
8840 PRINT EA: USING 8850:"MACH No."
8850 IMAGE38X,8A
8860 MOVE EA:2,0
8870 RMOVE EA:-0.017,0
8880 PRINT EA:"I"
8890 FOR R1=3 TO 5
8900 RMOVE EA:1,0
8910 PRINT EA:"I"
8920 NEXT R1
8930 MOVE EA:1.75,2
8940 IF A=32 THEN 8970
8950 RMOVE EA:0.04,-0.21
8960 GO TO 8980
8970 RMOVE EA:0.04,-0.29
8980 PRINT EA:"-"
8990 FOR R1=4 TO 20 STEP 2
9000 RMOVE EA:0,2
9010 PRINT EA:"-"
9020 NEXT R1
9030 MOVE EA:1.75,2
9040 RMOVE EA:-0.3,-0.2
9050 PRINT EA:"-"
9060 FOR R1=4 TO 9 STEP 2
9070 RMOVE EA:0,2
9080 PRINT EA:"-"

```

```

9090 NEXT R1
9100 MOVE @A:1.75,10
9110 RMOVE @A:-0.35,-0.2
9120 PRINT @A: "--"
9130 FOR R1=12 TO 20 STEP 2
9140 RMOVE @A:0,2
9150 PRINT @A: "--"
9160 NEXT R1
9170 MOVE @A:ABS(Q1(1)),ABS(Q(20,1))
9180 FOR R1=2 TO 7
9190 DRAW @A:ABS(Q1(R1)),ABS(Q(20,R1))
9200 NEXT R1
9210 PRINT "G"
9220 END

```


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2. Does this report satisfy a need? (Comment on purpose, related project, or other area of interest for which report will be used.)

3. How, specifically, is the report being used? (Information source, design data or procedure, management procedure, source of ideas, etc.) _____

4. Has the information in this report led to any quantitative savings as far as man-hours/contract dollars saved, operating costs avoided, efficiencies achieved, etc.? If so, please elaborate.

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