

**b
R
L**

AD A148899

MEMORANDUM REPORT BRL-MR-3404

TECHNICAL
LIBRARY

HYPOTHETICAL ZERO YAW DRAG TRAJECTORY
OF SPINNING PROJECTILES BETWEEN
 $M = 5$ AND $M = 10$

William F. Donovan

November 1984

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

US ARMY BALLISTIC RESEARCH LABORATORY
ABERDEEN PROVING GROUND, MARYLAND

Destroy this report when it is no longer needed.
Do not return it to the originator.

Additional copies of this report may be obtained
from the National Technical Information Service,
U. S. Department of Commerce, Springfield, Virginia
22161.

The findings in this report are not to be construed as an official
Department of the Army position, unless so designated by other
authorized documents.

The use of trade names or manufacturers' names in this report
does not constitute indorsement of any commercial product.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Memorandum Report BRL-MR-3404	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) HYPOTHETICAL ZERO YAW DRAG TRAJECTORY OF SPINNING PROJECTILES BETWEEN M = 5 and M = 10		5. TYPE OF REPORT & PERIOD COVERED Final Report
7. AUTHOR(s) WILLIAM F. DONOVAN		6. PERFORMING ORG. REPORT NUMBER
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Ballistic Research Laboratory ATTN: AMXBR-IBD Aberdeen Proving Ground, MD 21005-5066		8. CONTRACT OR GRANT NUMBER(s)
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Ballistic Research Laboratory ATTN: AMXBR-OD-ST Aberdeen Proving Ground, MD 21005-5066		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 1L1662618AH80
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		12. REPORT DATE NOVEMBER 84
		13. NUMBER OF PAGES 37
		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 The program tab for use with the Hewlett Packard 97 calculator is available on application to BRL.		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Drag Coefficient Retardation Hypersonic Flow Time of Flight		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) jmk From a review of existing techniques and extrapolation of lower velocity data, the drag characteristics of a typical spin stabilized projectile are proposed for application in the range $5 < M < 10$.		

TABLE OF CONTENTS

	Page
LIST OF ILLUSTRATIONS.....	5
I. INTRODUCTION.....	7
II. PROCEDURE.....	7
III. RESULTS AND CONCLUSIONS.....	14
REFERENCES.....	17
APPENDIX A. PATCH PROCEDURE FOR TRANSITION TO HYPERSONIC REGIME.....	19
APPENDIX B. DISCUSSION OF BASE DRAG COEFFICIENT.....	23
APPENDIX C. PROGRAM LISTING.....	27
LIST OF SYMBOLS.....	33
DISTRIBUTION LIST.....	35

LIST OF ILLUSTRATIONS

Figure		Page
1	Typical Spin Stabilized Projectile.....	8
2	Projectile Nomenclature.....	9
3	Nose Wave Drag Coefficient Correlation.....	10
4	Conversion of Mach Number to C_F	12

I. INTRODUCTION

A previous report¹ proposed a drag determination procedure for hypervelocity "Kinetic Energy" projectiles intended for anti-tank application.

A similar estimating procedure for use in antiaircraft fire for spin stabilized projectiles is now offered. The basic boundary conditions are retained, i.e., sea level air density and flat trajectory, and it is assumed that the projectile geometry is reasonably conventional.

The calculation is quite similar to that of Reference 1, except that the fin contribution is not required. Also, retardation and time-of-flight print outs have now been included. The results are presented in desk-calculator form and the program is included as an Appendix.

II. PROCEDURE

Figure 1 is a schematic of a typical spin stabilized projectile and Figure 2 defines the nomenclature employed in the analysis. Standard sea level air properties are assumed.

A. A conventional partition of the drag coefficient as composed of wave, viscous and base components is assumed. The wave drag coefficient is taken as

$$C_{DW} = .7 M^{-.28} \ell_n^{-1.73}$$

directly from Reference 2, which examined a large number of spin stabilized projectiles to the Mach 5 region and correlated the experimental data to develop estimating criteria. Figure 3 indicates the transposition.

The hypersonic base drag coefficient is found by inference from experimental data on cones. A patch procedure, as described in Appendix A, is imposed and the result is a bilinear characteristic from $M=2$ to $M=10$ with the knee at $M=5$. Available references offer little insight into the aerodynamics of hypersonic flow in the wake of cylindrical bodies. The wake flow behind cones has been investigated, however, and the results of these open literature studies is included in Appendix A. Thus,

$$C_{DB} = (.050 - .0034M) d_b^2$$

is used for use in the range $5 < M < 10$.

¹ W.F. Donovan, "Hypothetical Zero Yaw Drag Coefficient of Kinetic Energy Projectiles Between $M=5$ and $M=10$," ARBRL-MR-03041, August 1980, ADA # 090009.

² W.F. Donovan and Susan A. Wood, "Automatic Plotting Routines For Estimating Properties Of Spin Stabilized Projectiles In Flat Fire Trajectories At $2 < M < 5$," ARBRL-MR-03204, October 1982, AD #120658.

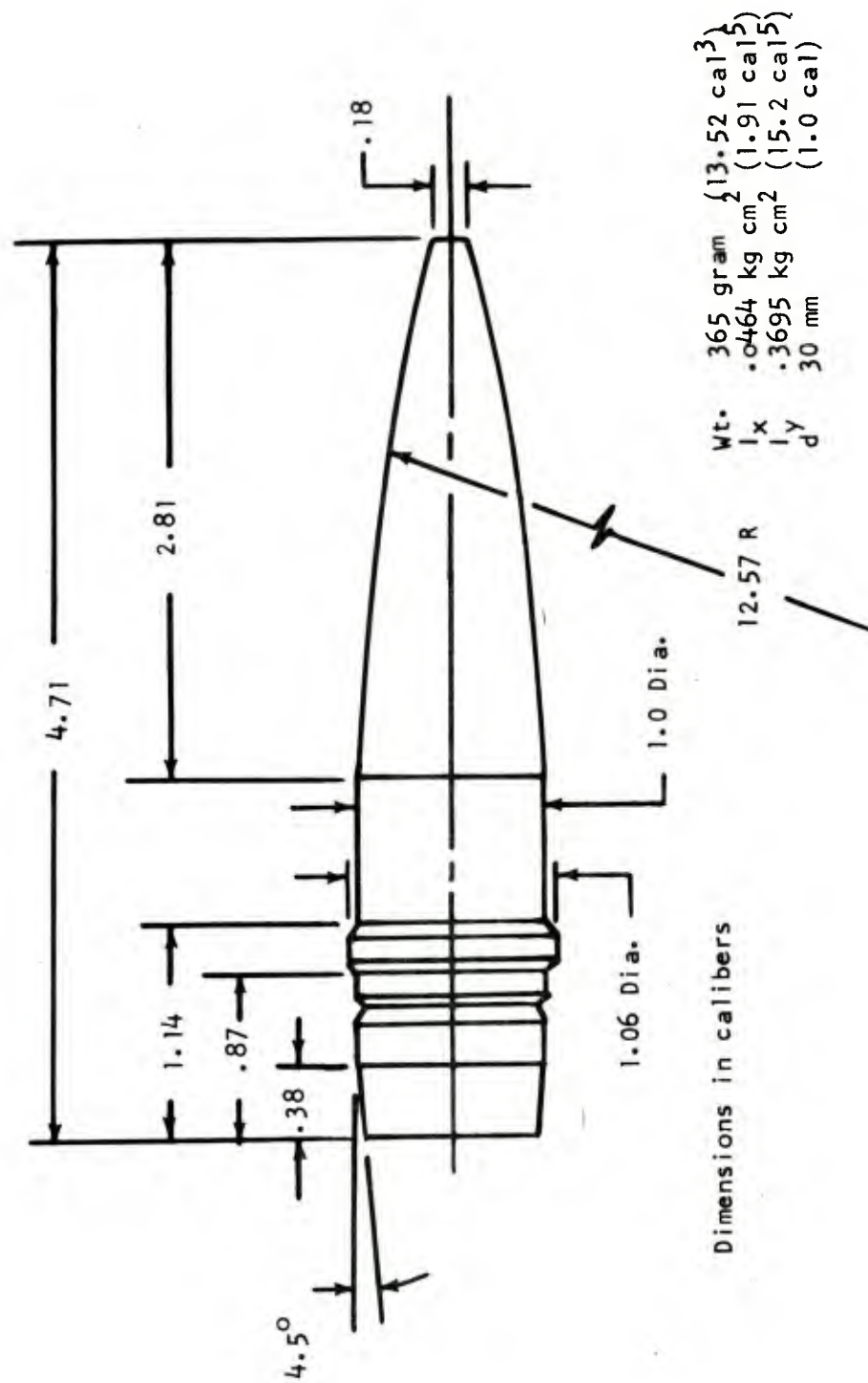


Figure 1. Typical Spin Stabilized Projectile

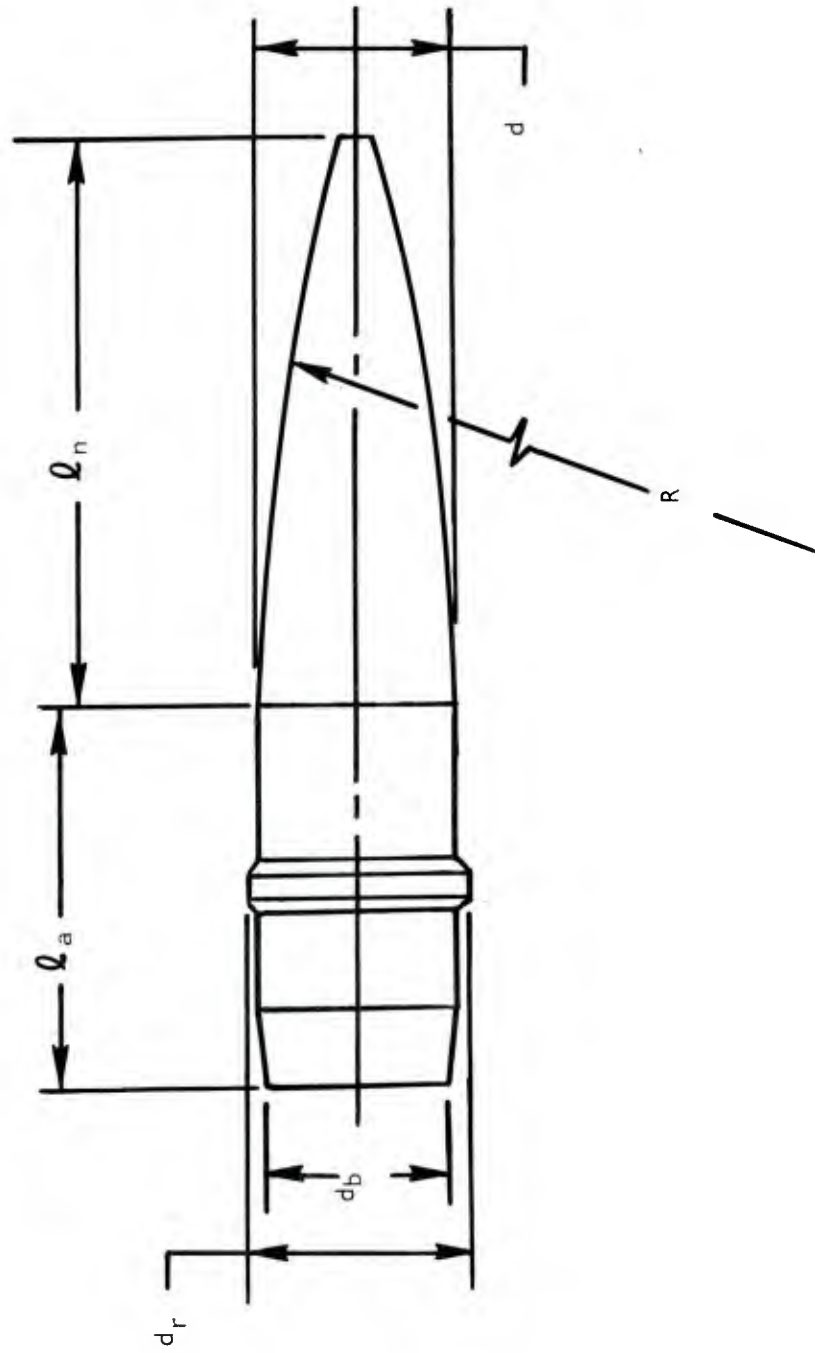


Figure 2. Projectile Nomenclature

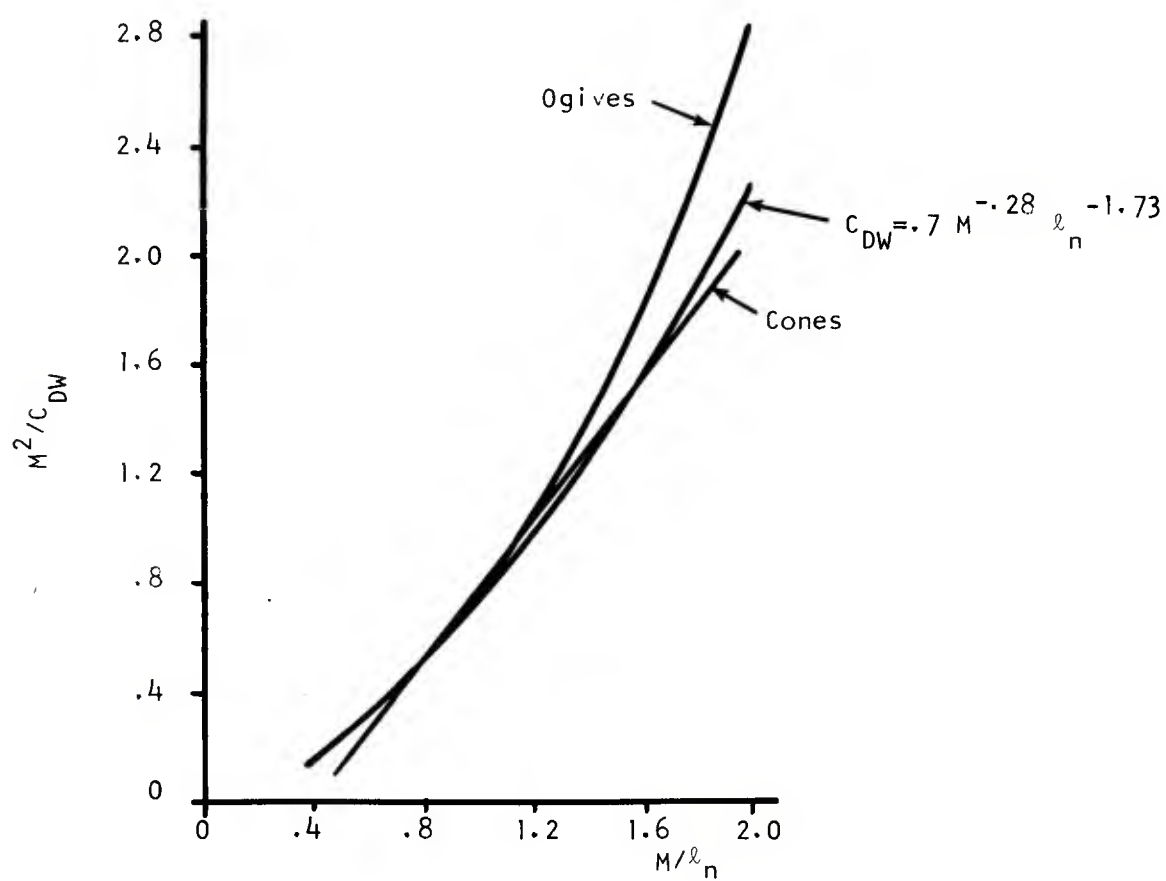


Figure 3. Nose Wave Drag Coefficient Correlation

The viscous drag component, C_{DV} , is obtained by Mach extrapolation, Figure 4, of the friction factor as employed in Reference 1 and of the effect of the ogive as empirically found in Reference 2.

$$C_{DV} = .000173 (13.84 - 1.184M) (.083 \ell_a + .0625 \ell_n) (30) \text{EXP} (4.6/R),$$

used for the range $5 < M < 10$. The viscous flow mechanics have been examined from divergent assumptions (Refer to Appendix B) and are considered here from the most conservative viewpoint.

For a projectile with a supercaliber rotating band, Reference 3 suggests a constant $.015 C_{DR}$ in the lower velocity regions. This value can be expected to decrease in the hypervelocity regime and is taken here as

$$C_{DR} = .07143M d_r.$$

The total drag coefficient is then the sum of its parts, or

$$C_D = C_{DW} + C_{DB} + C_{DV} + C_{DR}.$$

B. The Mach number along the trajectory is given⁴ as

$$M = \frac{b}{J e^{QS} - k},$$

where M = Mach number at range "s,"

$$J = \text{Operational Parameter} = k + \frac{b}{M_0},$$

$$Q = \text{Operational Parameter} = \rho \frac{A_b}{2m},$$

s = Range,

b = Intercept of C_D vs M characteristic,

k = Slope,

A_{ref} = Reference area, and

m = Mass of projectile.

³ L.M. Freeman and R.H. Korkegi, "Projectile Aft-Body Drag Reduction by Combined Boat-Tailing and Base Blowing," AFAPL-TR-75-111, February 1976.

⁴ W.F. Donovan, "Simplified Determination of Retardation For Kinetic Energy Projectiles," BRL Memorandum Report No. ARBRL-MR-03020, May 1980, AD #086095.

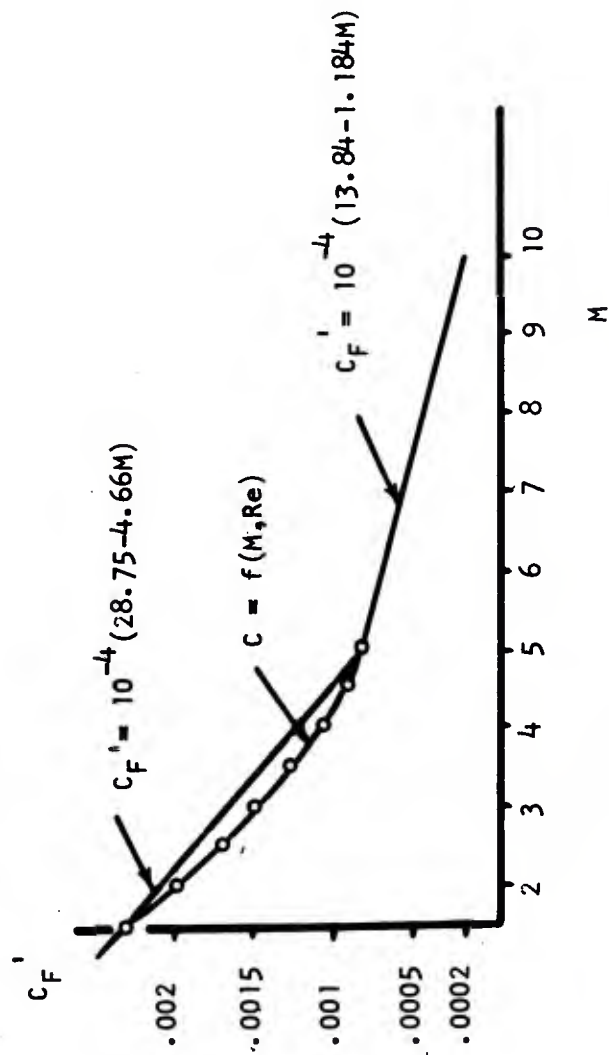


Figure 4. Conversion of Mach Number to C_F

C. The average velocity decrement over the selected range is determined by

$$\Delta V = \frac{(M_0 - M)}{s} (V_{\text{sonic}}),$$

where ΔV = the average velocity decrement over range "s" and V_{sonic} = ambient sonic velocity.

D. The time of flight is determined from the average velocity during the flight.

$$\text{TOF} = \frac{2 s}{(M_0 + M) (V_{\text{sonic}})} .$$

E. The input parameters required by the program are listed in Table 1. Entries to the HP-97 calculator storage are in caliber units where the reference diameter is either inches or millimeters. The selected range is given as meters. The projectile weight may be inserted as pounds, grams or cubic calibers. It is necessary to employ the secondary storage for recurring constant numbers. They are listed in Appendix C.

TABLE 1. INPUT PARAMETERS FOR PROGRAM OPERATION

HP-97 REGISTER	SYMBOL	IDENTIFICATION	UNITS
A			
B			
C			
D	dr	Rotating Band Diameter	Cal
E	s	Range	Meters
I	5	Lower Mach Limit	
O	M_0	Muzzle Mach Number	
1	l_n	Length of Nose	Cal
2	l_a	Length of Afterbody	Cal
3	d_b	Base Diameter	Cal
4	R	Ogive Radius	Cal
5	m	Mass of Projectile	Gram
6	m	Mass of Projectile	Pounds
7	m	Mass of Projectile	Cal ³
8	d	Diameter of Projectile	mm

III. RESULTS AND CONCLUSIONS

For the projectile described in Figure 1, the input parameters for Table 2 are determined and the calculator program prints out the results as shown in Table 3.

Since no range data is available for comparison, verification is lacking. However, within the regime where cone results are applicable, indications are that the procedure is reliable and usable for preliminary estimating. Where alternate formulations of the drag coefficients of the components (wave, viscous and base) can be established, their substitution into the program is quite simple. The subsequent operations are identical.

TABLE 2. INPUT PARAMETERS FOR HS-831 PROJECTILE

REGISTERS	SYMBOL	ENTRY VALUE	UNITS
A			
B			
C			
D	d_r	1.06	Cal
E	s	1500	Meters
I	M (initial)	5	
O	M_0	7	
1	l_n	2.81	Cal
2	l_a	1.90	Cal
3	d_b	.94	Cal
4	R	12.57	Cal
5	m	361.35	Grams
6			
7			
8	d	29.9	mm
9			

TABLE 3. SAMPLE PROGRAM OPERATION

Primary Registers

7.000000000	0
2.810000000	1
1.900000000	2
0.940000000	3
12.57000000	4
361.3580000	5
0.000000000	6
0.000000000	7
25.90000000	8
0.000000000	9
0.000000000	A
0.000000000	B
0.000000000	C
1.060000000	D
1560.000000	E
5.000000000	I

Secondary Registers

25.40000000	0
0.000204800	1
39.37000000	2
0.000017344	3
0.000000000	4
0.002392000	5
0.036111000	6
-0.003400000	7
0.053000000	8
0.000000000	9

Program Output

C _____	0.120662168 ***
M ^D _____	5.000000000 ***
	0.110723975 ***
	6.000000000 ***
	0.102976366 ***
	7.000000000 ***
	0.096182885 ***
	8.000000000 ***
	0.090060041 ***
	9.000000000 ***
	0.084429932 ***
	10.000000000 ***
Range in calibers _____	50167.12376 ***
Mach number at range _____	6.061760514 ***
Retardation in Meters/sec/kilometer _____	213.9186028 ***
Time of flight in sec _____	0.652494529 ***

REFERENCES

1. W.F. Donovan, "Hypothetical Zero Yaw Drag Coefficient of Kinetic Energy Projectiles Between $M=5$ and $M=10$," ARBRL-MR-03041, August 1980, ADA # 090009.
2. W.F. Donovan and Susan A. Wood, "Automatic Plotting Routines For Estimating Properties Of Spin Stabilized Projectiles In Flat Fire Trajectories At $2 < M < 5$," ARBRL-MR-03204, October 1982, AD #120658.
3. L.M. Freeman and R.H. Korkegi, "Projectile Aft-Body Drag Reduction By Combined Boat-Tailing and Base Blowing," AFAP1-TR-75-111, February 1976.
4. W.F. Donovan, "Simplified Determination of Retardation For Kinetic Energy Projectiles," BRL-MR-03020, May 1980, AD #086095.
- B-1. W.C. Lyons, Jr. and H.S. Brown, "The Drag of Slightly Blunted Slender Cones," NOLTR 68-3, January 1968.
- B-2. N.A. Zarin, "Base Pressure Measurements On Sharp and Blunt 9 Degree Cones At Mach Numbers From 3.50 to 9.20," BRL MR 1709, November 1965, AD# 369084.
- B-3. Robert L. McCoy, "MC Drag - A Computer Program For Estimating The Drag Coefficients of Projectiles," ARBRL-TR-02293, February 1981, AD #A098110.
- B-4. L.S. Stivers, Jr., "Calculated Pressure Distributions and Components of Total Drag Coefficients For 18 Constant Volume Slender Bodies of Revolution At Zero Incidence For Mach Numbers From 2.0 To 12.0 With Experimental Aerodynamic Characteristics For Three Of The Bodies," NASA TN D-6536, October 1971.

APPENDIX A

PATCH PROCEDURE FOR TRANSITION TO HYPERSONIC REGIME

APPENDIX A

PATCH PROCEDURE FOR TRANSITION TO HYPERSONIC REGIME

The base drag coefficient for a square base projectile in the range $2 < M < 5$ is given by

$$C_{DB} = (.133 - .02 M)$$

and acquires a value of .033 at $M=5$. For an assumed decrement to .016 at $M=10$,

$$.133 - .02 M = - k M + b$$

or

$$.033 = b - 5 k$$

with $.016 = b - 10 k$,

$$k = .0034, \text{ and}$$

$$b = .05.$$

Thus ,

$$C_{DB} = .05 - .0034 M.$$

The skin friction coefficient is similarly determined. At $M = 10$ the extrapolated decrement produces $C_F = .0002$. This leads to

$$28.75 - 4.166 M = z - w M,$$

where z and w complete the linearization in M .

Then ,

$$z = 13.84$$

with

$$w = 1.184$$

are suitable coefficients for the range $5 < M < 10$.

APPENDIX B
DISCUSSION OF BASE DRAG COEFFICIENT

APPENDIX B

DISCUSSION OF BASE DRAG COEFFICIENT

Lyons and Brown^{B-1} and Zarin^{B-2} offer results of work on cones. The Lyons and Brown base drag coefficient assumes a perfect vacuum in the immediate wake of the body while the Zarin data are predicated on pressure measurements on the model mounted in a wind tunnel facility. McCoy^{B-3} calculates base drag at lower Mach numbers for flight bodies on the basis of a Prandtl-Meyer expansion around a sharp corner. Extrapolation to the higher Mach numbers precisely duplicates the Lyons and Brown data. The results are compared with values from this report in Figure B-1.

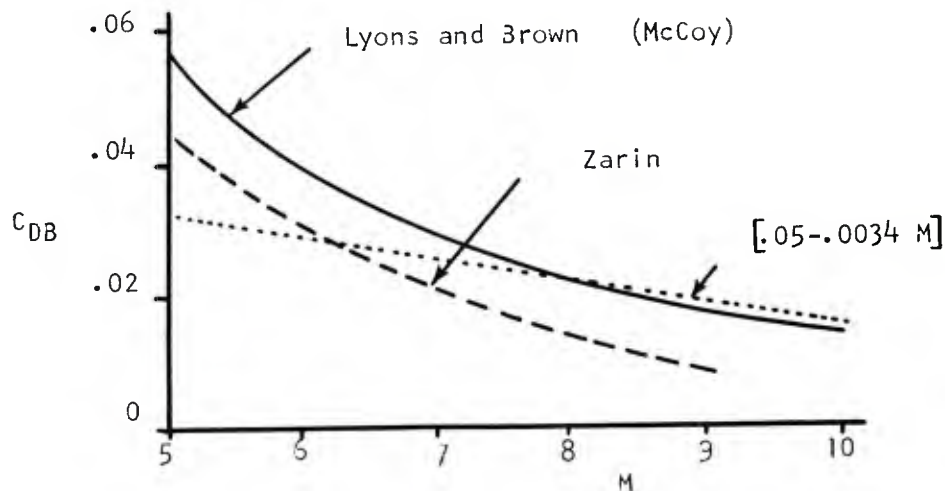


Figure B-1.

The linear assumption of the present report intercepts the Zarin data at $M = 6$ and coincides with the Lyons and Brown - McCoy analyses from $M = 8$ to $M = 10$. The viscous contribution to the drag is treated by Lyons and

B-1 W.C. Lyons, Jr. and H.S. Brown, "The Drag of Slightly Blunted Slender Cones," NOLTR 68-3, January 1968.

B-2 N.A. Zarin, "Base Pressure Measurements On Sharp and Blunt 9 Degree Cones At Mach Numbers From 3.50 to 9.20," BRL MR 1709, November 1965, AD# 369084.

B-3 Robert L. McCoy, "MC Drag - A Computer Program For Estimating The Drag Coefficients of Projectiles," ARBRL-TR-02293, February 1981, AD# A098110.

Brown as a boundary layer phenomena with additional components due to induced pressure and transverse curvature effects. Zarin considers the viscosity to be negligible in comparison with other terms. Stivers^{B-4} offers a conventional treatment whereby the laminar regime is superseded by a transitional and turbulent flow, and then converts the body of revolution to equivalent flat plate configuration. This present report simply extrapolates from lower Mach number data to estimate the high-end base drag coefficient. The results show qualified agreement with the Lyons and Brown argument.

B-4 *L.S. Stivers, Jr., "Calculated Pressure Distributions and Components of Total Drag Coefficients For 18 Constant Volume Slender Bodies of Revolution At Zero Incidence For Mach Numbers From 2.0 To 12.0 With Experimental Aerodynamic Characteristics For Three Of The Bodies," NASA TN D-6536, October 1971.*

APPENDIX C
PROGRAM LISTING

001	*LBLB	21 12
002	RCL8	36 08
003	X>0?	16-44
004	GSB1	23 01
005	GSB2	23 02
006	*LBL1	21 01
007	RCL8	36 08
008	P+S	16-51
009	RCL0	36 00
010	P+S	16-51
011	=	-24
012	ST09	35 05
013	*LBL2	21 02
014	RCLD	36 14
015	ST08	35 08
016	RCL5	36 05
017	X>0?	16-44
018	GT03	22 03
019	GT06	22 06
020	*LBL3	21 03
021	RCL5	36 05
022	4	04
023	5	05
024	4	04
025	=	-24
026	ST06	35 06
027	*LBL6	21 06
028	RCL1	36 01
029	ST05	35 05
030	RCL6	36 15
031	P+S	16-51
032	ST04	35 04
033	RCL2	36 02
034	P+S	16-51
035	ST04	35 04
036	x	-35
037	RCL9	36 09
038	=	-24
039	ST0E	35 15
040	*LBL8	21 08
041	RCL7	36 07
042	X>0?	16-44
043	GSB9	23 09
044	GSBE	23 15
045	*LBL9	21 09
046	RCL9	36 09
047	ENT1	-21
048	3	03
049	Y*	31
050	RCL7	36 07

051	x	-35
052	P+S	16-51
053	RCL6	36 06
054	P+S	16-51
055	x	-35
056	ST06	35 06
057	*LBLE	21 15
058	RCL1	36 46
059	P+S	16-51
060	RCL7	36 07
061	P+S	16-51
062	x	-35
063	.	-62
064	0	00
065	5	05
066	+	-55
067	RCL3	36 03
068	X²	53
069	x	-35
070	ST0A	35 11
071	RCL2	36 02
072	P+S	16-51
073	RCL8	36 08
074	P+S	16-51
075	x	-35
076	ST09	35 09
077	RCL5	36 05
078	1	01
079	6	06
080	=	-24
081	RCL9	36 09
082	+	-55
083	ST09	35 09
084	3	03
085	0	00
086	ENT1	-21
087	4	04
088	.	-62
089	6	06
090	RCL4	36 04
091	=	-24
092	Y*	31
093	RCL9	36 09
094	x	-35
095	ST0C	35 13
096	P+S	16-51
097	RCL1	36 01
098	RCL1	36 46
099	x	-35
100	RCL5	36 05

101	+	-55
102	P+S	16-51
103	RCLC	36 13
104	x	-35
105	STOC	35 13
106	.	-62
107	7	67
108	RCLI	36 46
109	ENT↑	-21
110	.	-62
111	2	62
112	8	68
113	Y*	31
114	÷	-24
115	RCL5	36 85
116	ENT↑	-21
117	1	61
118	.	-62
119	7	67
120	3	63
121	Y*	31
122	÷	-24
123	STO9	35 83
124	RCLI	36 46
125	1	61
126	4	64
127	x	-35
128	1/X	52
129	RCL8	36 68
130	x	-35
131	RCL9	36 69
132	+	-55
133	RCLA	36 11
134	+	-55
135	RCLC	36 13
136	+	-55
137	PRTX	-14
138	STO1	35 61
139	RCLI	36 46
140	PRTX	-14
141	SFC	16-11
142	5	65
143	X=Y?	16-33
144	STOB	22 12
145	STOC	22 13
146	*LBLB	21 12
147	RCL1	36 61
148	STO2	35 62
149	*LBLC	21 13
150	ISZI	16 26 46

151	RCLI	36 46
152	1	61
153	1	61
154	X>Y?	16-34
155	STOE	22 15
156	STOD	22 14
157	*LBLD	21 14
158	RCL1	36 61
159	STO3	35 63
160	RCL2	36 62
161	-	-45
162	CHS	-22
163	5	65
164	÷	-24
165	STO1	35 61
166	5	65
167	x	-35
168	RCL2	36 62
169	-	-45
170	CHS	-22
171	STO2	35 62
172	RCL6	36 66
173	÷	-24
174	P+S	16-51
175	RCL3	36 63
176	P+S	16-51
177	x	-35
178	RCL5	36 15
179	PRTX	-14
180	x	-35
181	e*	33
182	STO9	35 69
183	RCL2	36 62
184	RCL0	36 60
185	÷	-24
186	RCL1	36 61
187	+	-55
188	RCL9	36 69
189	x	-35
190	RCL1	36 61
191	-	-45
192	RCL2	36 62
193	÷	-24
194	1/X	52
195	PRTX	-14
196	STOA	35 11
197	RCL0	36 60
198	-	-45
199	CHS	-22
200	P+S	16-51

201	RCL4	36 84
202	=	-24
203	P#S	16-51
204	3	83
205	4	84
206	2	82
207	0	88
208	0	88
209	0	88
210	x	-35
211	PRTX	-14
212	RCLA	36 11
213	RCL0	36 88
214	+	-55
215	1	81
216	7	87
217	6	86
218	x	-35
219	P#S	16-51
220	RCL4	36 84
221	=	-24
222	1/X	52
223	PRTX	-14
224	R.S	51

LIST OF SYMBOLS

A	Area of cross section of projectiles
A _{ref}	Reference area (.785 cal ²)
C _D	Total drag coefficient
	$= \frac{2D}{\rho V^2 A_{ref}}$
C _{DB}	Base drag coefficient
C _{DR}	Rotating band drag coefficient
C _{DV}	Viscous drag coefficient
C _{DW}	Wave drag coefficient
C _{F'}	Skin friction factor for flat plate viscous flow
C _{F''}	Empirical constant
C _{P'''}	Conversion factor between flat plate and cylindrical viscous flow
D	Drag force
J	Operational parameter
	$= k + \frac{b}{M_0}$
M	Mach number
M ₀	Muzzle Mach number
Q	Operation parameter
	$= \frac{Ab}{2m}$
R	Radius of nose ogive
R _e	Reynolds number
TOF	Time of flight of projectile
b	Intercept of C _D -M characteristic
d	Representative diameter

LIST OF SYMBOLS (Continued)

d_b	Base diameter
d_r	Rotating band diameter
k	Slope of C_D -M characteristic
ℓ_a	Length of afterbody of projectile
ℓ_n	Length of nose of projectile
m	Mass of projectile
v	Velocity of projectile
V_{sonic}	Sonic velocity at ambient conditions
ΔV	Velocity decrement of projectile
ρ	Ambient air density

DISTRIBUTION LIST

<u>No. of Copies</u>	<u>Organization</u>	<u>No. of Copies</u>	<u>Organization</u>
12	Administrator Defense Technical Info Center ATTN: DTIC-DDA Cameron Station Alexandria, VA 22314	4	Commander USA AMCCOM ATTN: SMCAR-LCU E. Barrieres SMCAR-LCU-M, D. Robertson M. Weinstock C. Larson Dover, NJ 07801
2	Director Defense Advanced Research Projects Agency ATTN: C.R. Lehner G. Ligman, Jr. 1400 Wilson Boulevard Arlington, VA 22209	9	Commander USA AMCCOM ATTN: SMCAR-LCA, B. Knutelski SMCAR-R, E.H. Moore, III SMCAR-LCS, J. Gregorits T. Davidson SMCAR-LCA, E. Friedman A. Lehberger R. Wrenn A. Loeb S. Wasserman Dover, NJ 07801
1	Director Institute for Defense Analysis ATTN: H. Wolfhard 400 Army-Navy Drive Arlington, VA 22202		
1	Commander US Army Materiel Command ATTN: AMCDRA-ST 5001 Eisenhower Avenue Alexandria, VA 22333	6	Commander USA AMCCOM ATTN: SMCAR-SCM SMCAR-SCS, B. Brodman T. Hung J. Jacobson W. Gadowski E. Malatesta Dover, NJ 07801
1	Commander Armament R&D Center USA AMCCOM ATTN: SMCAR -TDC Dover, NJ 07801		
1	Commander Armament R&D Center USA AMCCOM ATTN: SMCAR-TSS Dover, NJ 07801		
4	Commander USA AMCCOM ATTN: SMCAR-LC SMCAR-LCU D. Davitt D. Costa A. Moss Dover, NJ 07801	3	Commander USA AMCCOM ATTN: SMCAR-LCS-T Dover, NJ 07801
		2	Commander USA Watervliet Arsenal ATTN: SARWV-RDD, P. Vottis SMCAR-TL, T. Allen Watervliet, NY 12189

DISTRIBUTION LIST

<u>No. of Copies</u>	<u>Organization</u>	<u>No. of Copies</u>	<u>Organization</u>
1	Commander USA Armament, Munitions and Chemical Command ATTN: AMSMC-LEP-L Rock Island, IL 61299	1	Commander US Army Missile Command ATTN: AMSMI-YDL Redstone Arsenal, AL 35898
2	Director Benet Weapons Laboratory Armament R&D Center USA AMCCOM ATTN: SMCAR-LCB-TL SMCAR-LCB, J. Zweig Watervliet, NY 12189	1	Commander US Army Tank Automotive Cmd ATTN: AMSTA-TSL Warren, MI 48090
1	Commander USA Aviation Research and Development Command ATTN: AMSAV-E 4300 Goodfellow Blvd St. Louis, MO 63120	1	Director US Army TRADOC Systems Analysis Activity White Sands Missile Range, NM 88002
1	Commander USA White Sands Missile Range ATTN: STEWS-VT White Sands Missile Range, NM 81002	4	Commander US Army AMCCOM ATTN: SMCAR-FC SMCAR-LCA, E. Falkowski R. Wrenn A. Loeb S. Wasserman Dover, NJ 07801
1	Director USA Air Mobility Research and Development Laboratory Ames Research Center Moffett Field, CA 94035	3	Commander US Army AMCCOM Benet Weapons Laboratory ATTN: SMCAR-LCB-TL Watervliet, NY 12189
1	Commander USA Communications Rsch and Development Command ATTN: AMSEL-ATDD Fort Monmouth, NJ 07703	1	Project Manager, XM1 USA Tank and Automotive Cmd ATTN: DRSTA-TSL Warren, MI 48090
1	Commander USA Electronics Research and Development Command Technical Support Activity ATTN: AMD SD-L Fort Monmouth, NJ 07703	1	Commander USA Research Office ATTN: Tech Lib P.O. Box 12211 Research Triangle Park NC 27709-2211
1	Commander USA Missile Command ATTN: AMSMI-R Redstone Arsenal, AL 35898	2	Commandant USA Artillery Center & School ATTN: AKPSIAS-G-CN AKPSIAS-G-RK Fort Sill, OK 73504

DISTRIBUTION LIST

<u>No. of Copies</u>	<u>Organization</u>	<u>No. of Copies</u>	<u>Organization</u>
1	Office of Naval Research ATTN: Code 461 800 N. Quince Street Arlington, VA 22217	1	HQDA DAMA-ART-M Washington, DC 20310
2	Commander Naval Surface Weapons Center ATTN: Tech Lib, L.L. Pater Dahlgren, VA 22448	1	Commandant US Army Infantry School ATTN: ATSH-CD-CSO-OR Fort Benning, GA 31905
1	Commander Naval Research Laboratory ATTN: Code 6180 Washington, DC 20375	1	Commander US Army Development & Employment Agency ATTN: MODE-TED-SAB Fort Lewis, WA 98433
1	Commander Naval Ordnance Station ATTN: Dr. Charles Dale Indian Head, MD 20640	1	AFWL/SUL Kirtland AFB, NM 87117

Aberdeen Proving Ground

Dir, USAMSAA
 ATTN: AMXSY-D
 AMXSY-MP, H. Cohen
 Cdr, USATECOM
 ATTN: AMSTE-TO-F
 Dir, CRDC, AMCCOM
 ATTN: SMCAR-RSP-A
 SMCAR-MU
 SMCAR-SPS-IL

USER EVALUATION SHEET/CHANGE OF ADDRESS

This Laboratory undertakes a continuing effort to improve the quality of the reports it publishes. Your comments/answers to the items/questions below will aid us in our efforts.

1. BRL Report Number _____ Date of Report _____
2. Date Report Received _____
3. Does this report satisfy a need? (Comment on purpose, related project, or other area of interest for which the report will be used.) _____

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

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

6. General Comments. What do you think should be changed to improve future reports? (Indicate changes to organization, technical content, format, etc.) _____

CURRENT
ADDRESS

Name

Organization

Address

City, State, Zip

7. If indicating a Change of Address or Address Correction, please provide the New or Correct Address in Block 6 above and the Old or Incorrect address below.

OLD
ADDRESS

Name

Organization

Address

City, State, Zip

(Remove this sheet along the perforation, fold as indicated, staple or tape closed, and mail.)