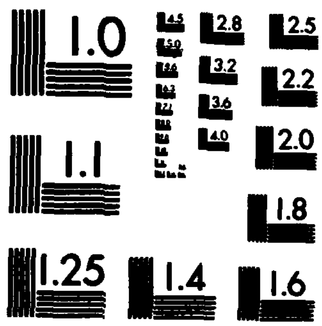
AD-A141 341 BASE PRESSURE MEASUREMENTS ON A PROJECTILE SHAPE AT MACH NUMBERS FROM 091..(U) ARMY ARMAMENT RESEARCH AND DEVELOPMENT CENTER ABERDEEN PROVIN.. L D KAYSER APR 84 1/1

UNCLASSIFIED ARBRL-MR-03353 SBI-AD-F300 423 F/G 19/1 NL

END
DATE
FILMED
6 84
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

AD-A141 341

(12)

ADF300423

MEMORANDUM REPORT ARBRL-MR-03353

BASE PRESSURE MEASUREMENTS ON A PROJECTILE SHAPE AT MACH NUMBERS FROM 0.91 to 1.20

Lyle D. Kayser

DTIC
ELECTE
MAY 15 1984
S D
A

April 1984

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

Approved for public release; distribution unlimited.

FILE COPY

84 05 14 073

[illegible] is no longer needed.
[illegible] originator.

[illegible] copies of this report may be obtained [illegible] Technical Information Service, [illegible] of Commerce, Springfield, Virginia [illegible]

[illegible]

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER MEMORANDUM REPORT ARBRL-MR-03353	2. GOVT ACCESSION NO. ADA141341	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) BASE PRESSURE MEASUREMENTS ON A PROJECTILE SHAPE AT MACH NUMBERS FROM 0.91 TO 1.20		5. TYPE OF REPORT & PERIOD COVERED Final
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Lyle D. Kayser		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Ballistic Research Laboratory, ARDC ATTN: DRSMC-BLL(A) Aberdeen Proving Ground, MD 21005		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS RDT&E 1L162618AH80
11. CONTROLLING OFFICE NAME AND ADDRESS US Army AMCCOM, ARDC Ballistic Research Laboratory, ATTN: DRSMC-BLA-S(A) Aberdeen Proving Ground, MD 21005		12. REPORT DATE April 1984
		13. NUMBER OF PAGES 34
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		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)

Transonic
Base Pressure
Experimental Data
Projectiles

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Base pressure measurements were obtained on an axisymmetric projectile shape with and without a boattail. The tests were conducted in a transonic wind tunnel at Mach numbers of 0.91, 0.94, 0.96, 0.98, 1.10, and 1.20. Data were obtained at angles of attack of 0, 2, 4, 6, and 10 degrees and at circumferential positions around the model in 22.5° increments. Results were presented in both graphical and tabular form.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

TABLE OF CONTENTS

Accession For
NTIS GRA&I
DTIC TAB
Unannounced
Justification
By
Distribution/
Availability Codes
Dist Avail and/or Special
A1

LIST OF ILLUSTRATIONS

LIST OF TABLES

[redacted]

I. INTRODUCTION

A theoretical and experimental research program has been underway in the Launch and Flight Division of the Ballistic Research Laboratory in recent years to provide the capability of predicting projectile aerodynamics. A transonic wind tunnel test was conducted in support of this program and most of the test results were reported in Reference 1, but base pressure results were not included. Reference 1 reports surface pressure measurements, aerodynamic force and moment data obtained from integration of the pressures, and also some computational results. The present report contains primarily the base pressure results. Recent computational efforts, including the projectile base region, have indicated that the base pressure measurements were of more importance than originally judged. Reference 2 describes the time-dependent Navier-Stokes computational technique for computing projectile flow fields including the base region. While the experimental results are influenced by the presence of a sting, this is not a serious limitation for evaluation of a computational code since the sting can be readily modeled in the computation.

II. EXPERIMENT

The model geometry for the ogive-cylinder-boattail (SOCBT) configuration is shown in Figure 1; the model has a 3-caliber secant-ogive, a 2-caliber cylinder, and a 1-caliber, 7° boattail. The ogive-cylinder (SOC) model is identical except that the 7° boattail is replaced by a cylindrical section; the SOC is, therefore, a 3-caliber secant ogive, 3-caliber cylinder model. All pressure tubing was connected to one Scanivalve which was located in a large sting section. The base pressure was measured with a single pressure tap consisting of a stainless steel tube running along the top of the sting and into the base region as shown in Figure 1. The pressure tube was 0.8mm outside diameter and the orifice was positioned approximately 2mm from the base. As a result of this setup, all base pressure measurements for the SOC were taken at 34.0% of the base radius and at 44.0% of the base radius for the SOCBT. The roll orientation of the model is defined so that $\phi = 0°$ when the pressure orifice is on the windward side of the model. When the model is at positive angle of attack, $\phi = 0°$ indicates that the pressure tap is on the bottom (6 o'clock) and the positive direction of ϕ is clockwise when looking upstream at the base.

The tests were conducted in the Langley Research Center 8-foot Transonic Pressure Tunnel which has a Mach number range of 0 to 1.30. The test section

---

1. L. D. Kayser, and F. Whiton, *"Surface Pressure Measurements on a Boattailed Projectile Shape at Transonic Speeds,"* U.S. Army Ballistic Research Laboratory, Aberdeen Proving Ground, Maryland, ARBRL-MR-03161, March 1982. (AD A113520)

2. J. Sahu, C. J. Nietubicz, and J. L. Steger, *"Numerical Computation of Base Flow for a Projectile at Transonic Velocities,"* U.S. Army Ballistic Research Laboratory, Aberdeen Proving Ground, Maryland, ARBRL-TR-02495, June 1983. (AD A130293)

is 2.16 × 2.16 m square with filleted corners and the top and bottom walls have four slots each as shown in Figure 2.

The test procedure for the boattail configuration was to obtain data at all angles of attack for a given roll orientation, the model was then rolled 22.5° and data were again recorded for the angle-of-attack range. This sequence was followed until all data were recorded for a given Mach number. The Mach number was then changed and the above procedure repeated. Because of an equipment problem, a slightly different procedure was used for the SOC part of the test program. The model was set at a given roll orientation and the data were recorded at the various angles of attack and then the Mach number was changed. After all data were recorded for a given roll angle, the tunnel was shut down and the roll orientation was manually changed. The supply pressure was maintained at approximately one atmosphere and the supply temperature at approximately 322 K for all tests. These conditions yielded model length Reynolds numbers of 4.5 to 4.7 million for the Mach numbers tested.

III. RESULTS

The base pressure coefficients, for a given angle of attack, were averaged over the range of roll angles and are presented in tabulated form in Table 2. Base pressure coefficients at discrete roll positions are presented in Table 3.

The experimental data points of Figures 3 and 4 are at 22.5° intervals and connected with straight lines - symbols are excluded for clarity. Base pressure for the SOC shape are shown in Figures 3a, b, and c. There is seen to be a moderate variation of pressure coefficient with roll angle and the lowest base pressure occurs at the highest angle of attack. Although it may not be readily apparent, figures 3a and b show the Mach 0.91 to 0.98 to be nearly identical. The Mach 1.10 and 1.20 data are qualitatively similar to the Mach 0.91-0.98 data, but the base pressures (and coefficients) are seen to be substantially lower. For the SOC shape, the base area is equal to the reference area and therefore, the base axial force is equal to the negative of the base pressure coefficient. The base axial force is therefore seen to vary from approximately 0.1 to 0.2 for the Mach 0.91-0.98 data and 0.2 to 0.3 for the Mach 1.10-1.20 data. A positive base axial force is in the downstream direction which is the same direction as a positive forebody axial force.

Base pressure data for the SOCBT shape are shown in Figures 4a, b and c. Results for the Mach 0.91-0.98 range are qualitatively similar and the lowest base pressure is seen to again occur at the highest angle of attack; also there is substantial variation with Mach number as opposed to that for the SOC shape. From Mach 0.98 to 1.10, the base pressure coefficient is seen to decrease by a substantial amount. An interesting aspect of the SOCBT base pressure is that, for the Mach 0.91-0.98 range, a substantial number of the base pressure coefficients are positive which indicates a negative base axial force or a net thrust. For the SOCBT shape, the base area is smaller than the reference area (cylindrical cross section area) and the base axial force coefficient can be expressed as follows;

$$C_{A_b} = -C_{p_b} A_b/A_{cyl}.$$

The area ratio, $A_b/A_{cyl.}$, for the SOCBT is 0.569.

The base pressure data were algebraicly averaged over nine values of the roll angle and assuming that each pressure value applied to a 22.5° segment of the base except for ϕ = 0° and 180° values which applied to a 11.25° segment; results are shown in Figures 5a and 5b. Figure 5a shows the base pressure coefficient for the SOC configuration and illustrates, as stated above, that there is practically no variation for the Mach 0.91 to 0.98 range. There is a large change in pressure level between Mach 0.98 and 1.10 which indicates a critical behavior and the need for more data in that Mach number range. Figure 5b shows the base pressure data for the boattailed configuration (SOCBT). There is a consistent increase in the base pressure from Mach 0.91 to Mach 0.98 and then a sharp decrease in pressure from Mach 0.98 to 1.10 similar to that for the SOC. Many of the coefficients are positive in the Mach 0.91-0.98 range which yields a negative axial force (thrust) as previously indicated. These results are believed to be reasonable and will be discussed in more detail below.

Figure 6 shows the longitudinal variation of axial force over the boattailed configuration. The experimental results are from the test program described in Reference 1. The Mach 0.91 data are compared to a Navier-Stokes computation by Nietubicz[3] which was carried out on a Cray computer. This figure shows a generally small forebody axial force and along with Figure 5a, shows that the base provides the majority of drag for the SOC. Comparison of Figures 5a and 5b show that the boattailed configuration has a much smaller base drag but Figure 6 shows that the boattail produces a substantial drag. Generally, however, the net effect of boattailing is to reduce the total drag.

Base pressure coefficients were converted to base axial force coefficients and are presented in Figure 7 along with results from References 2, 4, and 5. The Navier-Stokes computations, References 2 and 4, were for the same body shapes described in Figure 1 except that the computations did not include the presence of a model support sting. For both shapes (SOC and SOCBT), the experimental data and the computational results show the same qualitative behavior. The computations also show a negative base axial force (thrust) for Mach numbers 0.94, 0.96, and 0.98. Sykes[5] obtained base pressure measurements on a wind tunnel model which was supported with side struts attached towards the front of the model. Sykes's results support the general findings of the current experiment and the computations although his forebody shape is slightly different than that of the SOC. He obtained results for boattail lengths of 0.5 and 1.0 caliber and for boattail angles of 0, 3, 6, and 9°. Sykes

---

3. *C. J. Nietubicz, "Navier-Stokes Computations for Conventional and Hollow Projectile Shapes at Transonic Velocities," AIAA Paper No. 81-1262, presented at the AIAA 14th Fluid and Plasma Dynamics Conference, Palo Alto, California, July 1981.*

4. *J. Sahu, personal communications, February 1984.*

5. *D. J. Sykes, "Afterbody Pressures at Transonic Speeds," Department of Aeronautics Report 68/19, The City University of London, December 1968.*

found that base pressure coefficient increases with increasing boattail angle and also increases with increasing boattail length. Positive base pressure coefficients (negative base axial force coefficients) were obtained for a one caliber boattail with boattail angles greater than 6°, and for a one-half caliber boattail with angles greater than approximately 7.8°. Sykes's data for a 0° boattail and a 7° boattail (interpolated) at Mach 0.954 are shown in Figure 7 and are seen to be very close to results of the present experiment and to the computations of Reference 2 and Reference 4.

Figure 8 shows the axial force coefficients for the SOC and SOCBT which include the forebody and boattail components from Reference 1 and the base pressure components from the present report. This figure shows that net effect of boattailing is to reduce overall drag but it is also interesting to note that the net reduction is much smaller than the difference in the base axial force coefficients shown in Figure 7.

IV. CONCLUSIONS

1. Positive base pressure coefficients (negative drag) can sometimes occur on a boattailed projectile shape. In the present experiment, this occurred only for the boattailed configuration at Mach numbers of 0.91 to 0.98.

2. Base drag, for the SOC and SOCBT shapes, increases with increasing angle of attack for the angle-of-attack range tested which was 0 to 10°.

3. There are large changes in the base pressure coefficient between Mach number 0.98 to 1.10; these large changes suggest that further investigation is needed in this narrow Mach number range.

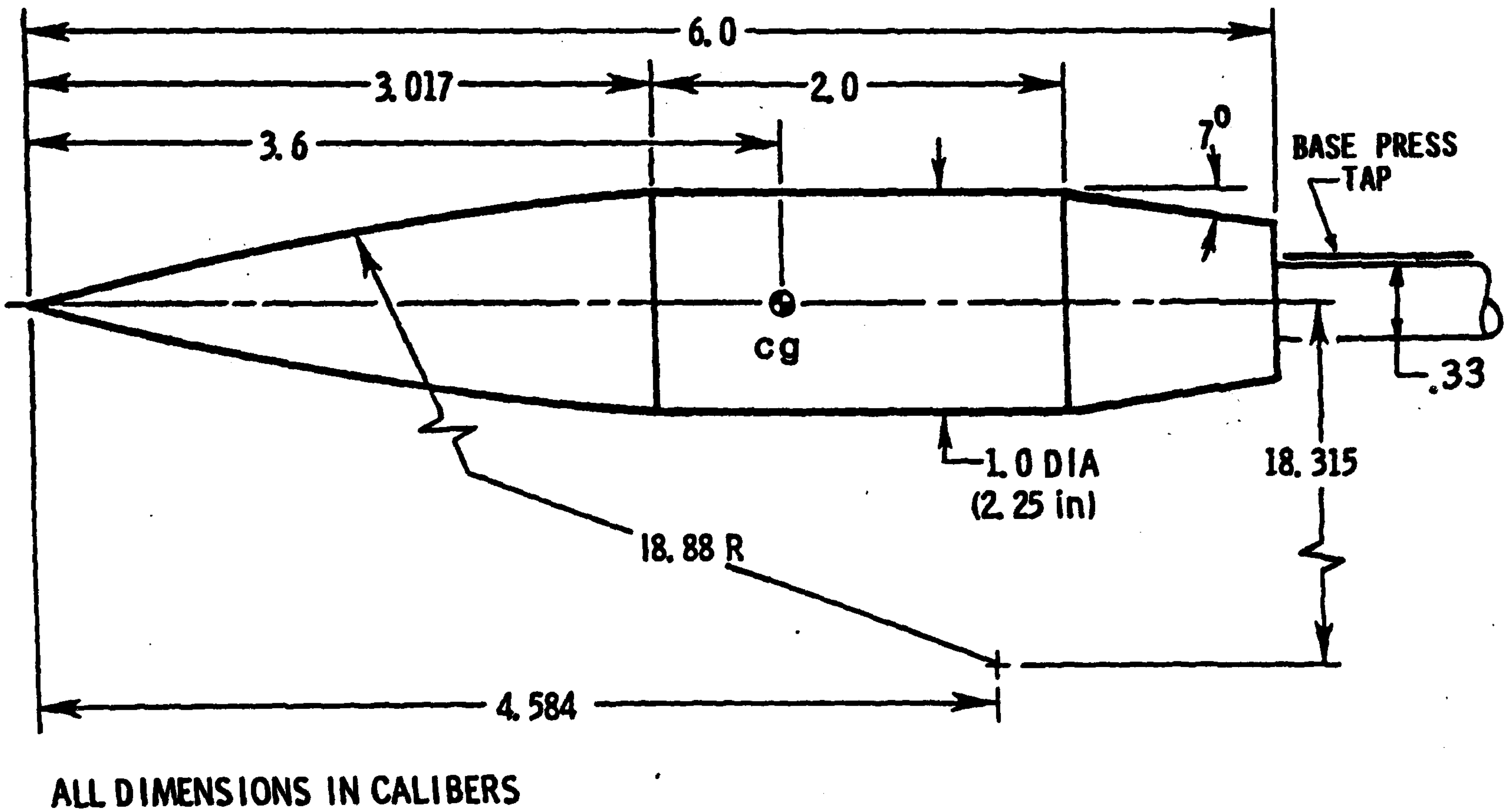


Figure 1. Model Geometry, SOCBT

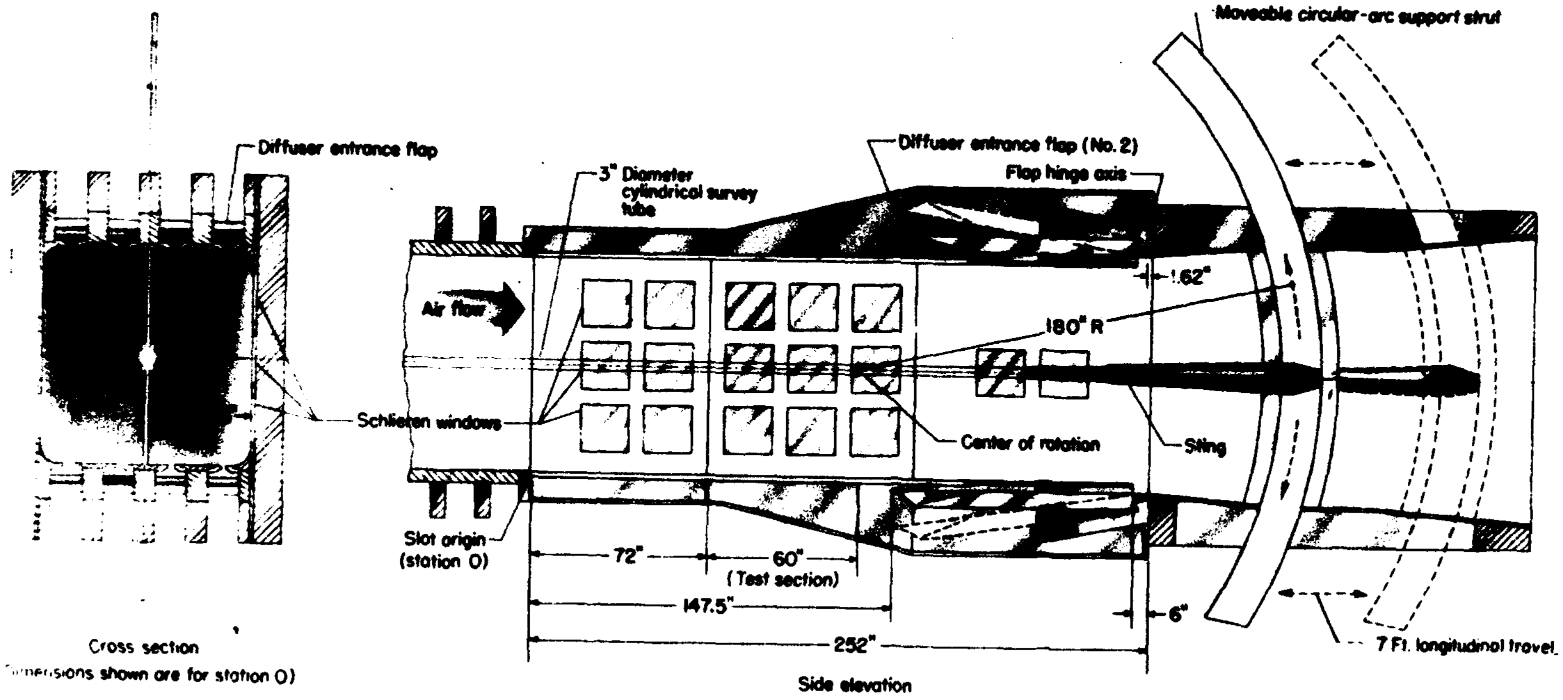


Figure 2. The Langley Research Center 8-Foot Transonic Pressure Tunnel

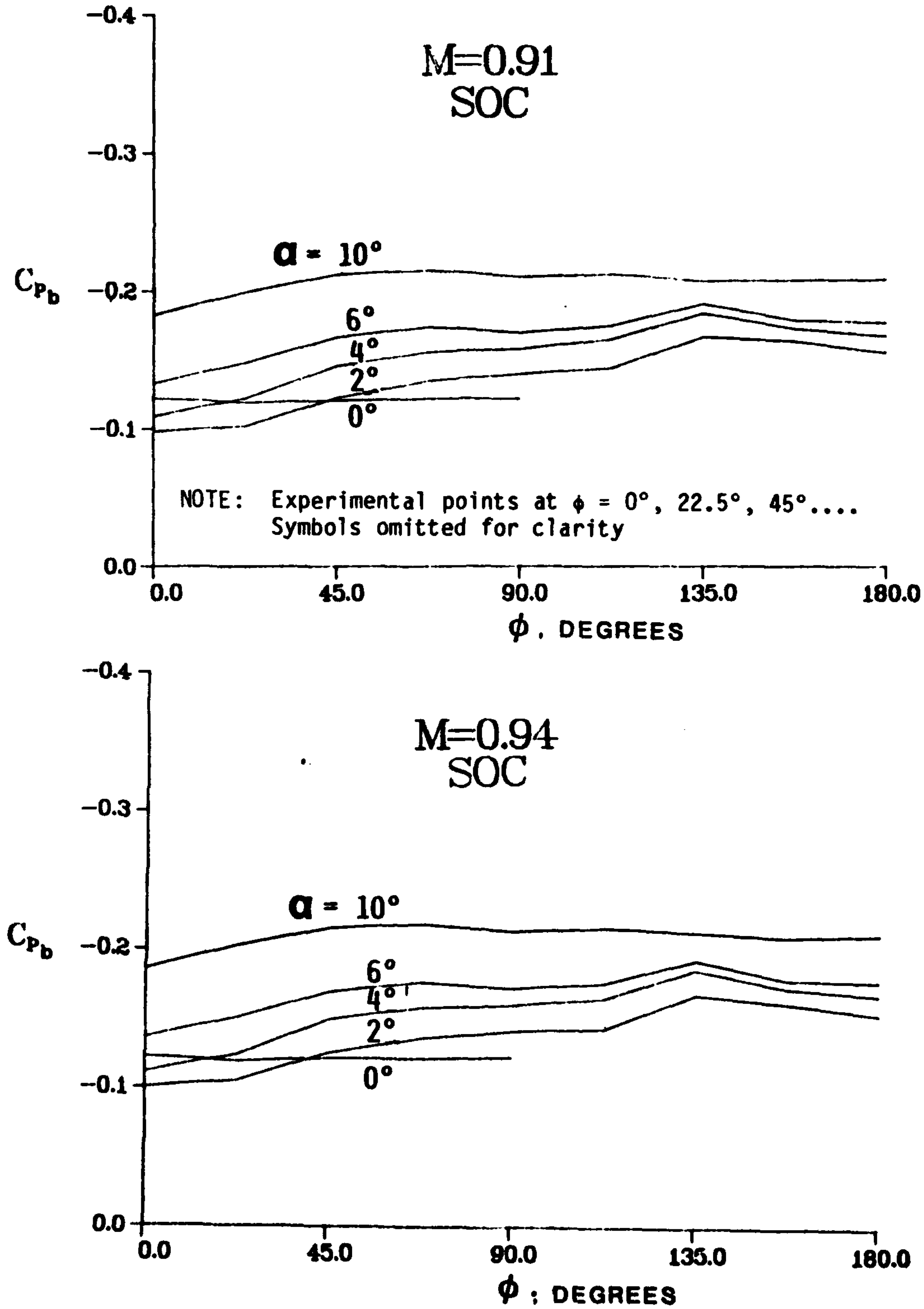


Figure 3. SOC Base Pressure Coefficient Data

a. M = 0.91, 0.94

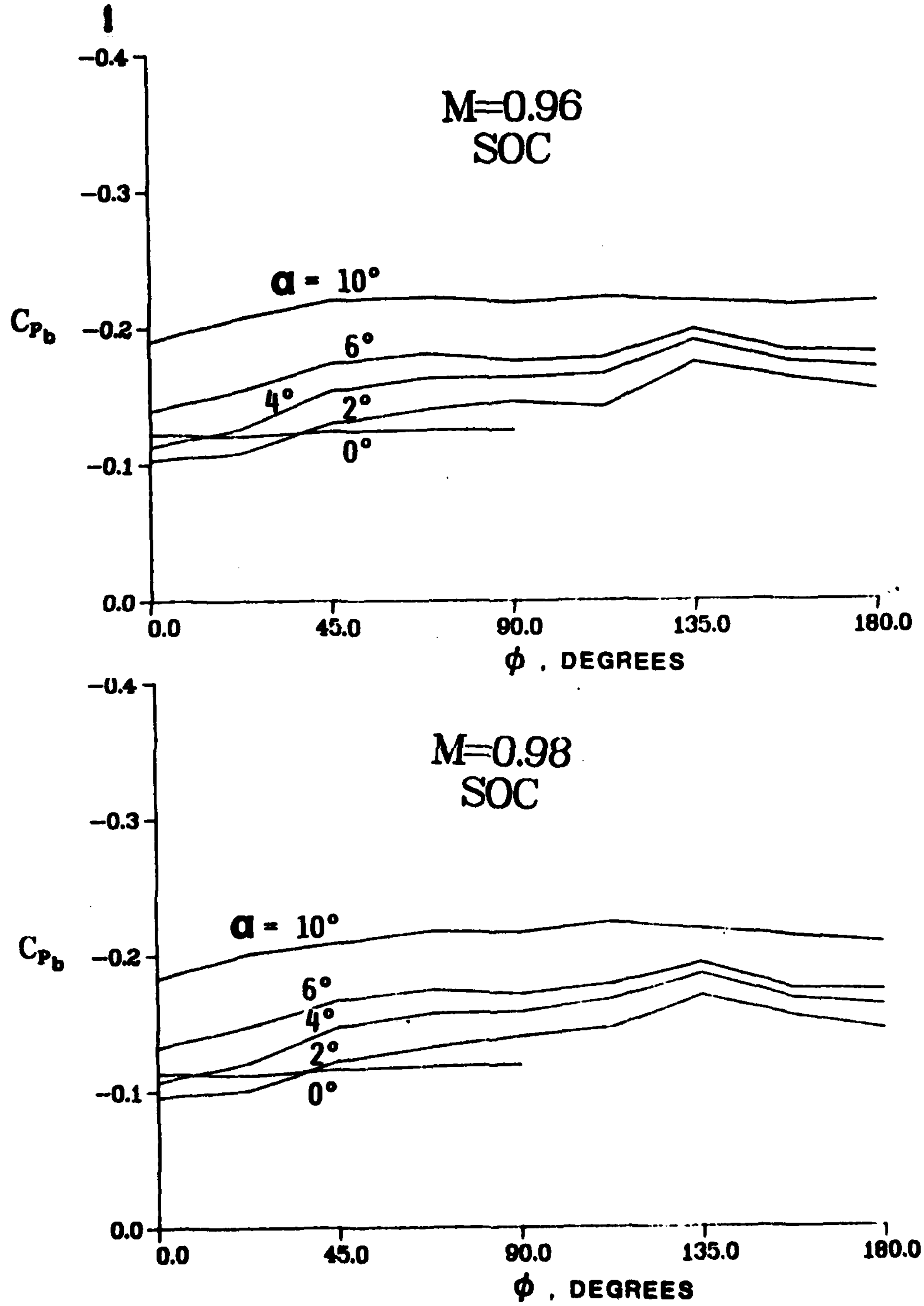


Figure 3. Continued

b. M = 0.96, 0.98

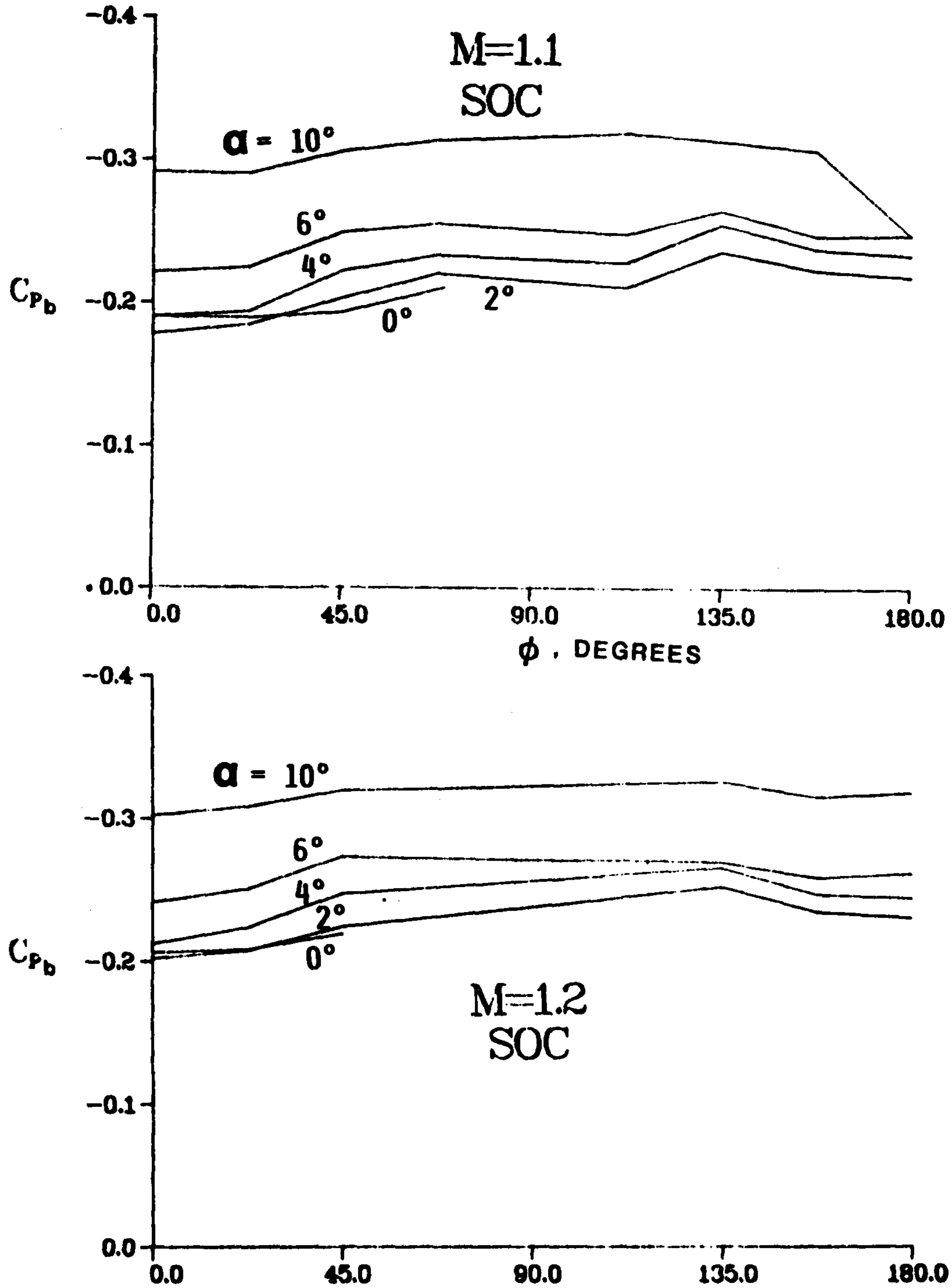


Figure 3. Continued

c. M = 1.10, 1.20

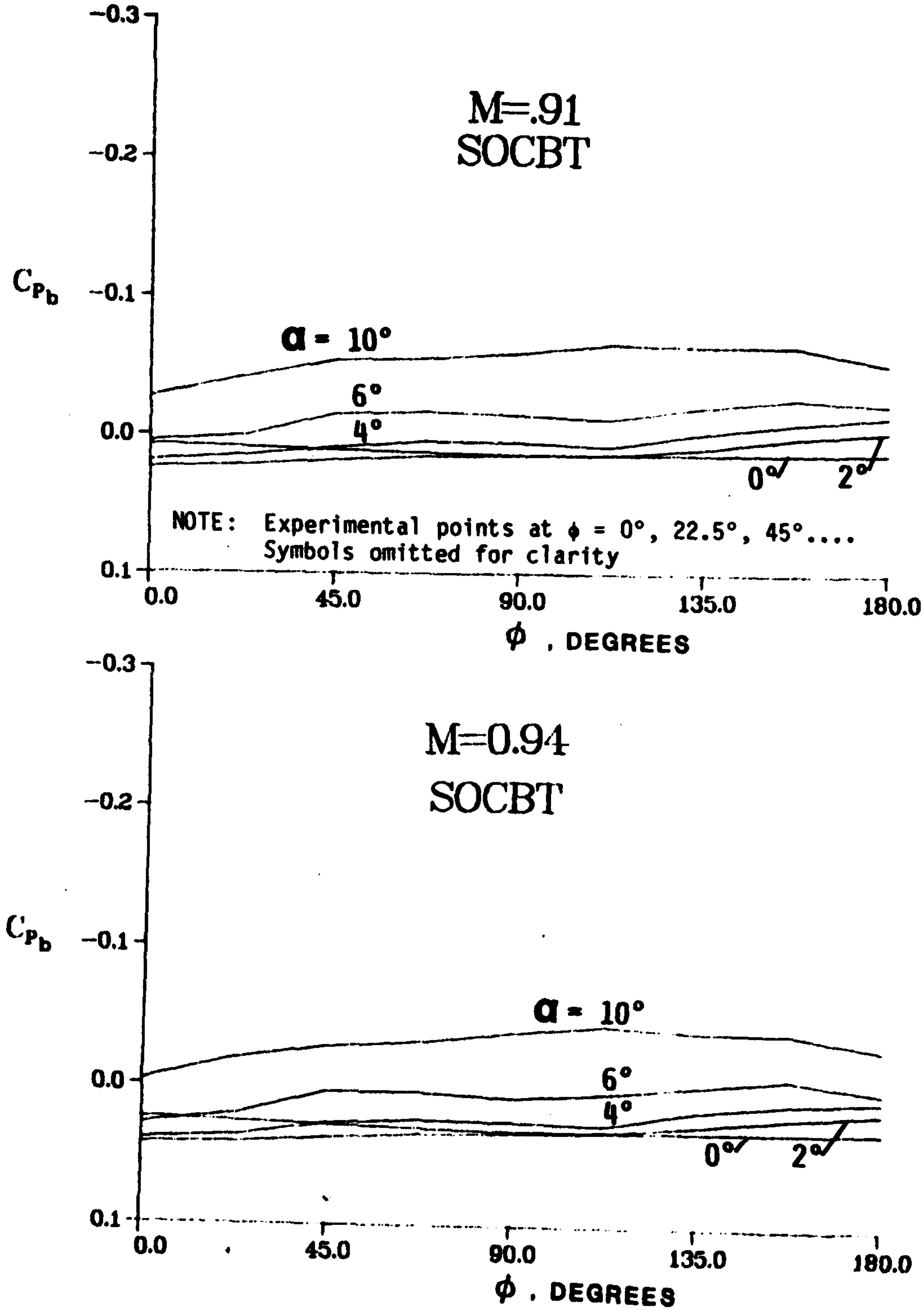
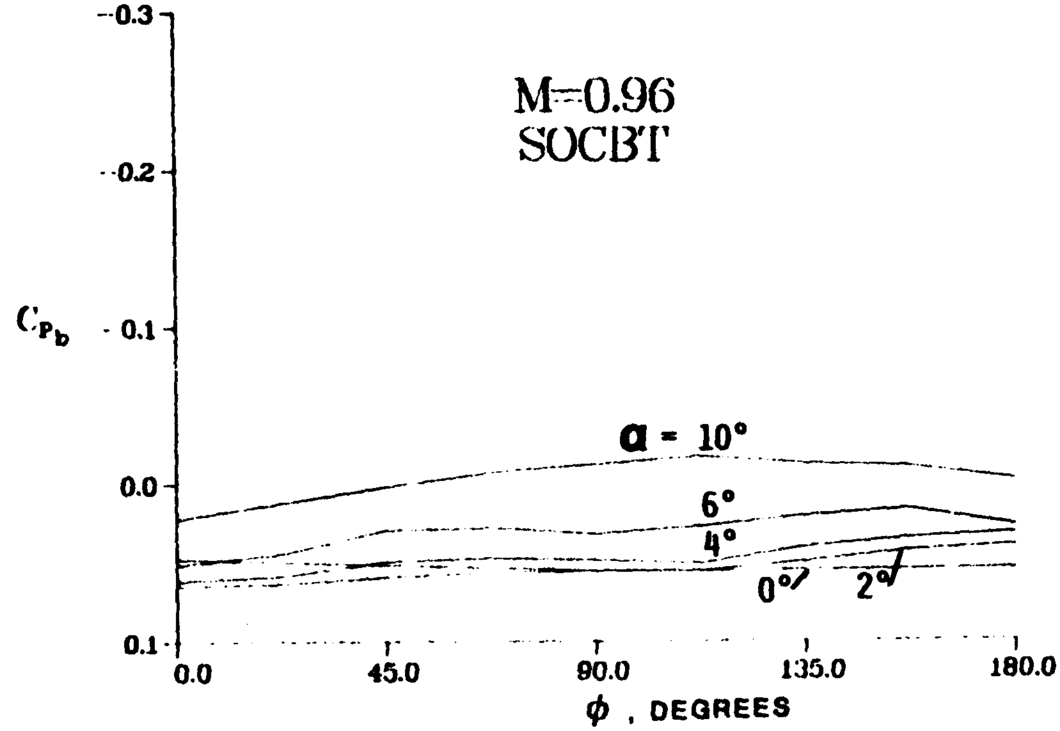


Figure 4. SOCBT Base Pressure Coefficient Data

a. M - 0.91, 0.94



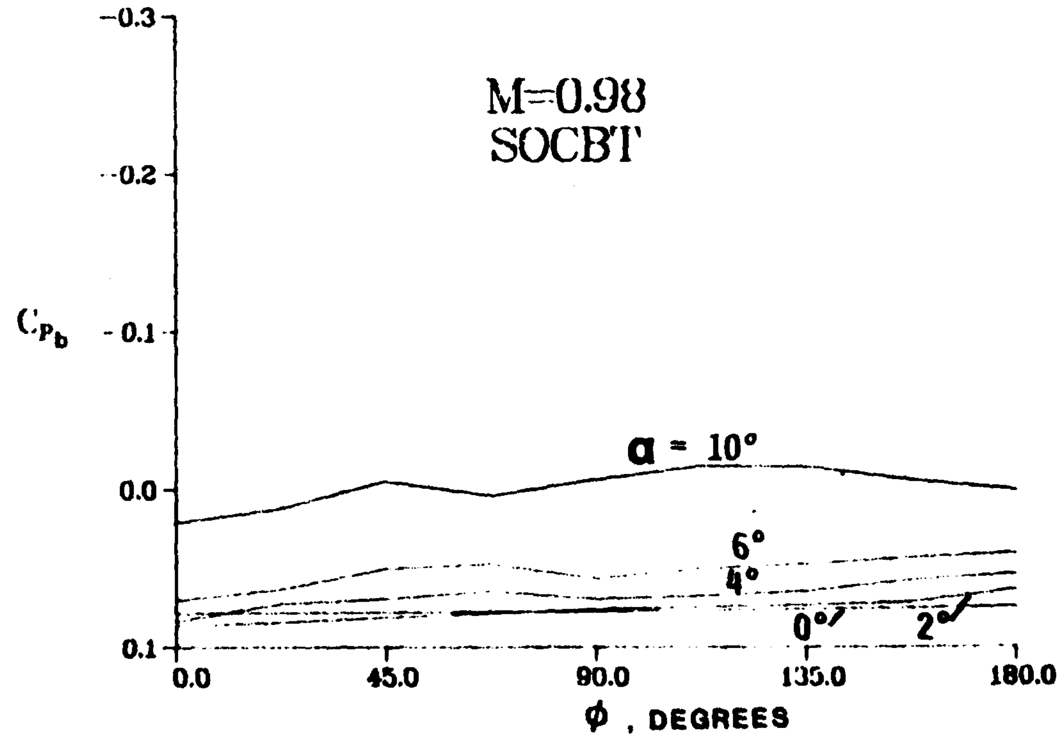
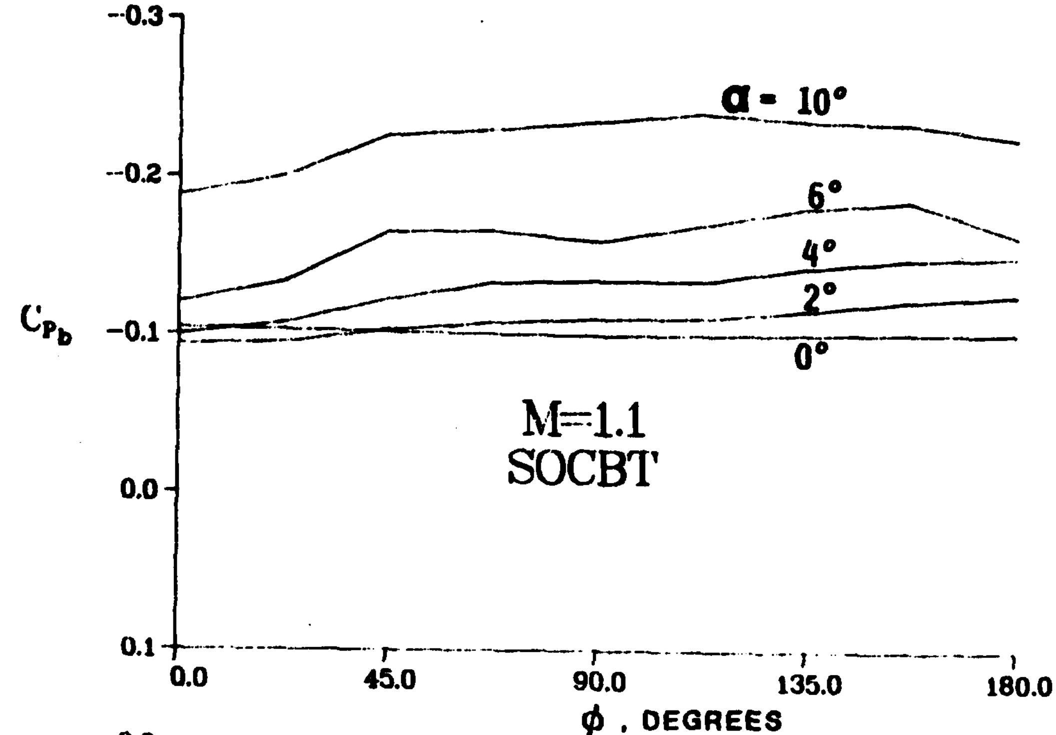


Figure 4. Continued

b. M = 0.96, 0.98



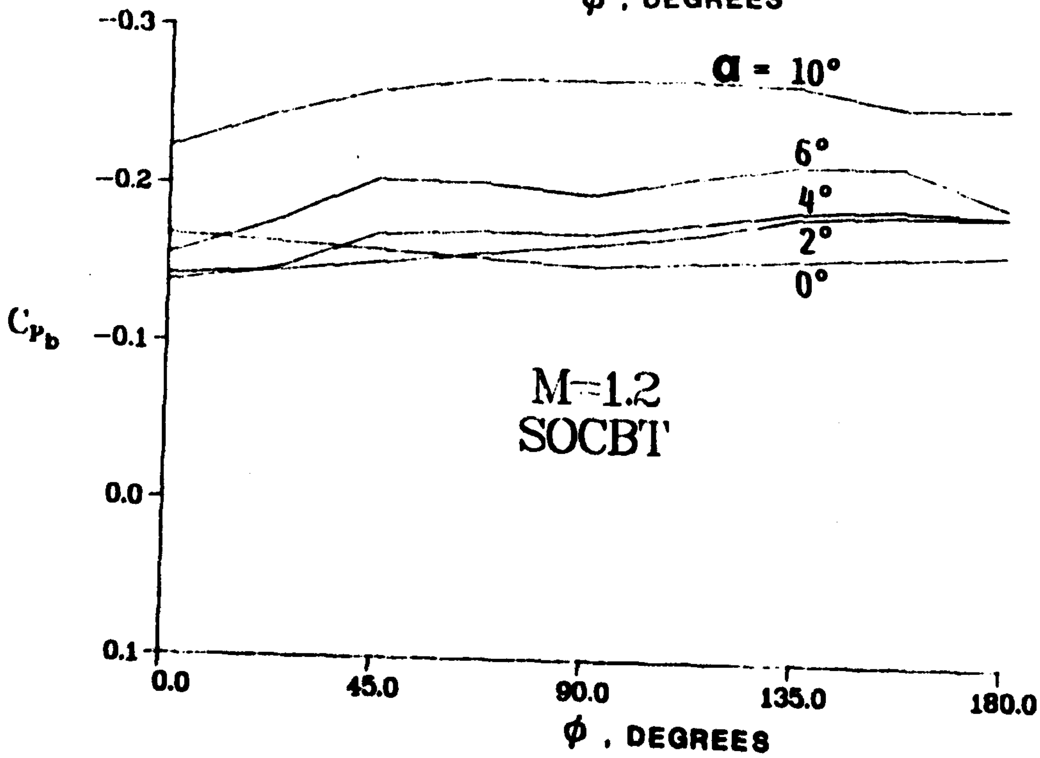


Figure 4. Continued

c. M = 1.10, 1.20

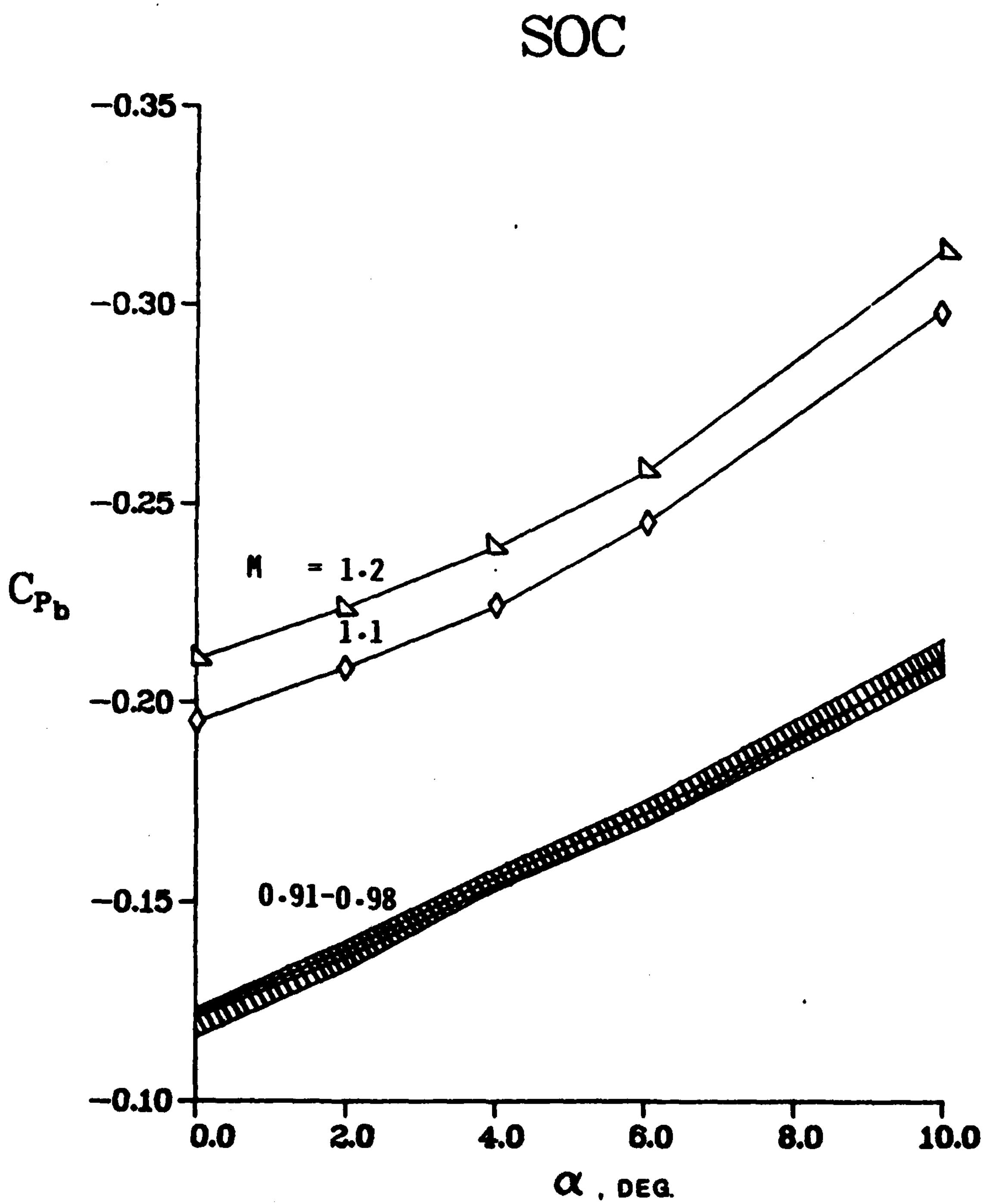


Figure 5. Averaged Base Pressure Coefficients

a. SOC

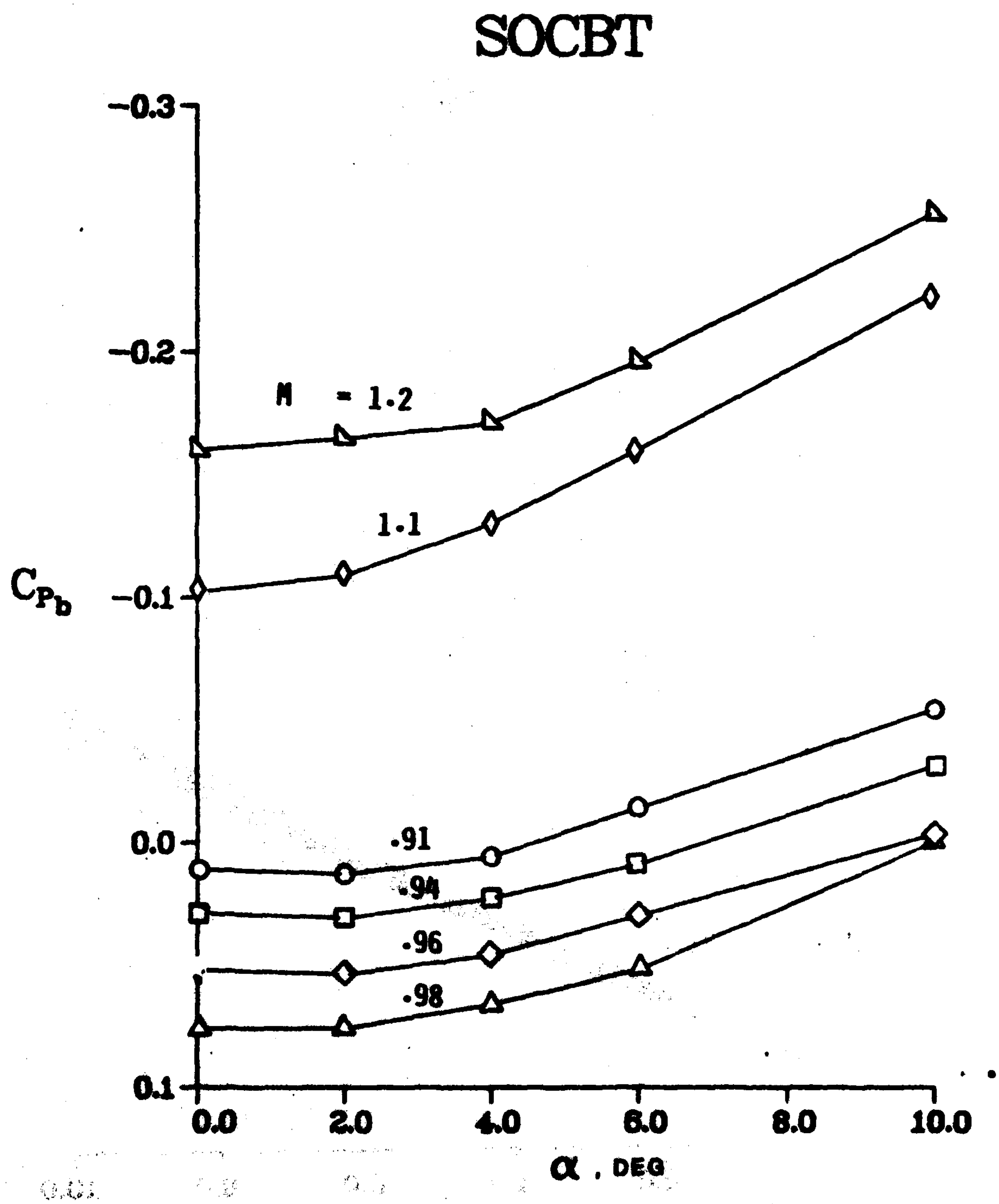


Figure 5. Continued

b. SOCBT

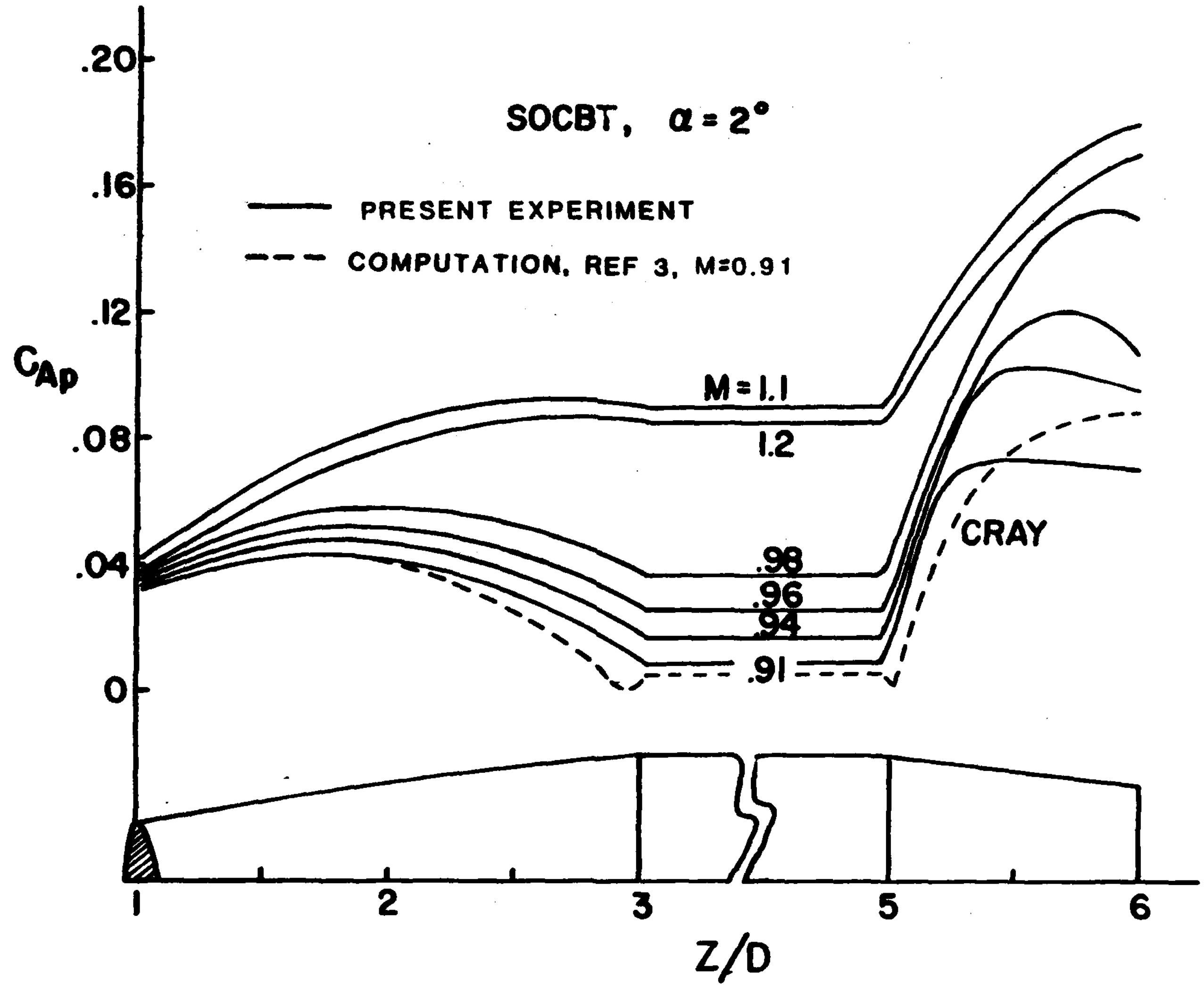


Figure 6. Longitudinal Variation of Axial Force Coefficient

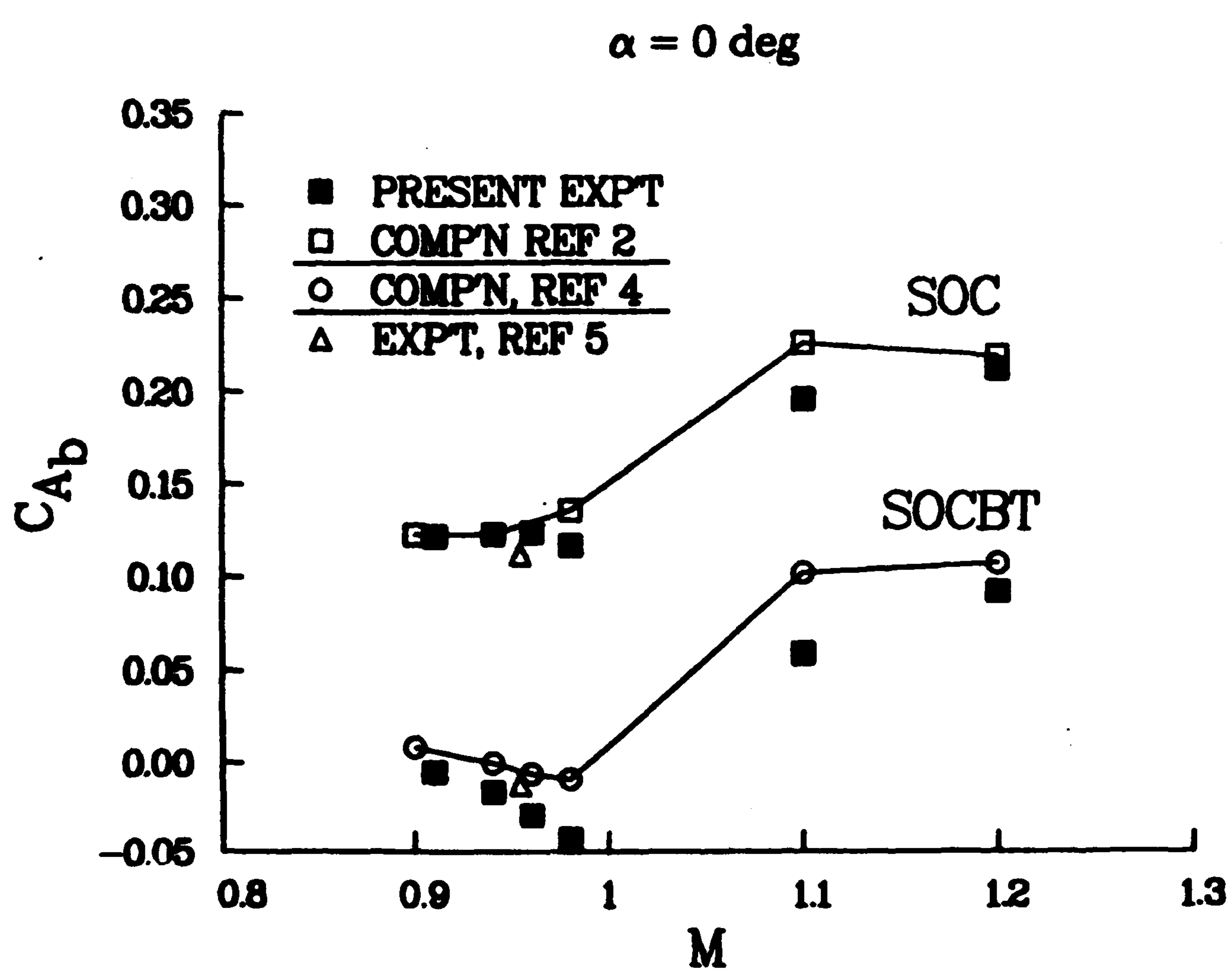


Figure 7. Variation of Base Pressure Coefficient with Mach Number

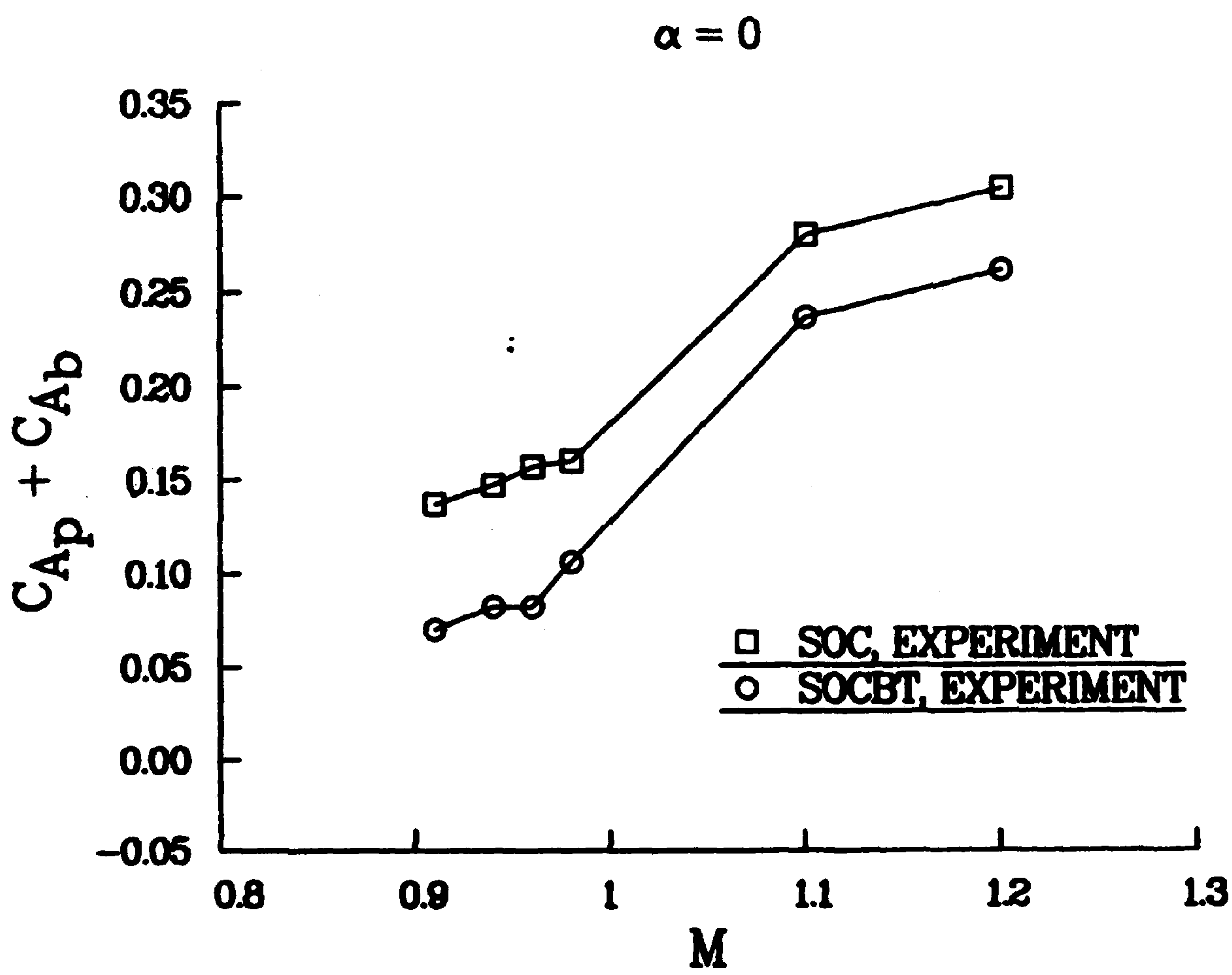


Figure 8. Variation of Axial Force Coefficient with Mach Number

TABLE 1. AVERAGED BASE PRESSURE COEFFICIENT DATA

SOC

M	alpha= 0°	2°	4°	6°	10°
.91	-.121	-.136	-.154	-.169	-.207
.94	-.122	-.138	-.156	-.172	-.211
.96	-.123	-.140	-.158	-.175	-.216
.98	-.116	-.133	-.153	-.169	-.212
1.10	-.195	-.209	-.224	-.245	-.299
1.20	-.211	-.224	-.239	-.258	-.314

SOCBT

M	alpha= 0°	2°	4°	6°	10°
.91	.011	.013	.006	-.014	-.054
.94	.029	.031	.023	.009	-.031
.96	.052	.054	.046	.030	-.003
.98	.076	.076	.066	.052	.000
1.10	-.102	-.109	-.130	-.160	-.224
1.20	-.160	-.165	-.171	-.196	-.256

TABLE 2. BASE PRESSURE COEFFICIENT DATA

SOC

M=0.91

alph	phi=0°	22.5°	45.0°	67.5°	90.0°	112.5°	135.0°	157.5°	180.0°
0°	-.122	-.119	-.121	-.122	-.122				
2°	-.098	-.102	-.123	-.135	-.140	-.144	-.167	-.164	-.156
4°	-.109	-.122	-.146	-.156	-.158	-.165	-.184	-.173	-.168
6°	-.133	-.148	-.167	-.174	-.170	-.175	-.191	-.179	-.178
10°	-.183	-.199	-.212	-.215	-.210	-.212	-.207	-.208	-.209

M=0.94

alph	phi=0	22.5	45.0	67.5	90.0	112.5	135.0	157.5	180.0
0	-.122	-.119	-.122	-.122	-.123				
2	-.100	-.105	-.126	-.137	-.142	-.144	-.169	-.163	-.155
4	-.111	-.124	-.150	-.159	-.161	-.166	-.187	-.174	-.169
6	-.136	-.151	-.170	-.177	-.173	-.177	-.194	-.180	-.179
10	-.186	-.203	-.216	-.219	-.214	-.217	-.214	-.211	-.213

M=0.96

alph	phi=0	22.5	45.0	67.5	90.0	112.5	135.0	157.5	180.0
0	-.122	-.120	-.124	-.125	-.125				
2	-.103	-.108	-.130	-.140	-.146	-.142	-.174	-.163	-.154
4	-.113	-.126	-.154	-.163	-.164	-.166	-.190	-.175	-.170
6	-.139	-.154	-.174	-.181	-.176	-.178	-.198	-.183	-.181
10	-.190	-.207	-.220	-.222	-.218	-.222	-.219	-.216	-.218

M=0.98

alph	phi=0	22.5	45.0	67.5	90.0	112.5	135.0	157.5	180.0
0	-.113	-.112	-.116	-.118	-.119				
2	-.096	-.101	-.122	-.132	-.140	-.146	-.169	-.154	-.144
4	-.107	-.121	-.147	-.157	-.158	-.167	-.185	-.167	-.162
6	-.132	-.148	-.167	-.174	-.171	-.178	-.193	-.174	-.173
10	-.183	-.201	-.209	-.217	-.216	-.223	-.218	-.213	-.208

M=1.10

alph	phi=0	22.5	45.0	67.5	90.0	112.5	135.0	157.5	180.0
0	-.190	-.189	-.193	-.209					
2	-.178	-.184	-.203	-.220		-.211	-.236	-.223	-.219
4	-.190	-.193	-.222	-.233		-.228	-.255	-.238	-.234
6	-.221	-.224	-.249	-.255		-.248	-.265	-.247	-.248
10	-.291	-.290	-.306	-.314		-.319	-.314	-.307	-.248

M=1.2

alph	phi=0	22.5	45.0	67.5	90.0	112.5	135.0	157.5	180.0
0	-.206	-.208	-.219						
2	-.202	-.207	-.224				-.251	-.233	-.229
4	-.212	-.223	-.247				-.264	-.245	-.243
6	-.241	-.250	-.273				-.268	-.257	-.260
10	-.302	-.308	-.319				-.324	-.313	-.316

TABLE 2. BASE PRESSURE COEFFICIENT DATA (continued)

SOCBT

M=0.91

alph	phi=0°	22.5°	45.0°	67.5°	90.0°	112.5°	135.0°	157.5°	180.0°
0°	.007				.014				.013
2°	.024	.022	.018	.015	.014	.014	.009	.001	-.003
4°	.019	.015	.009	.004	.005	.008	-.002	-.009	-.014
6°	.005	.001	-.015	-.017	-.015	-.012	-.021	-.027	-.023
10°	-.027	-.041	-.054	-.056	-.060	-.067	-.065	-.065	-.052

M=0.94

alph	phi=0	22.5	45.0	67.5	90.0	112.5	135.0	157.5	180.0
0	.024				.032				.030
2	.042	.041	.037	.034	.033	.032	.026	.020	.016
4	.039	.036	.027	.024	.025	.027	.016	.010	.007
6	.028	.021	.004	.004	.008	.004	-.002	-.008	.001
10	-.003	-.019	-.028	-.032	-.039	-.045	-.041	-.041	-.030

M=0.96

alph	phi=0	22.5	45.0	67.5	90.0	112.5	135.0	157.5	180.0
0	.047				.065				.054
2	.064	.063	.059	.056	.055	.055	.049	.042	.039
4	.061	.058	.049	.047	.048	.050	.040	.034	.031
6	.051	.044	.029	.028	.032	.027	.020	.016	.026
10	.022	.012	.002	-.007	-.012	-.017	-.013	-.011	-.003

M=0.98

alph	phi=0	22.5	45.0	67.5	90.0	112.5	135.0	157.5	180.0
0	.078				.077				.074
2	.086	.084	.081	.078	.076	.074	.073	.071	.063
4	.083	.072	.069	.064	.069	.067	.064	.057	.053
6	.070	.063	.050	.047	.056	.050	.047	.043	.040
10	.031	.012	-.005	.004	-.006	-.015	-.014	-.006	.000

M=1.10

alph	phi=0	22.5	45.0	67.5	90.0	112.5	135.0	157.5	180.0
0	-.104				-.100				-.104
2	-.094	-.095	-.103	-.108	-.110	-.111	-.116	-.122	-.126
4	-.100	-.107	-.122	-.133	-.134	-.134	-.143	-.148	-.150
6	-.120	-.133	-.165	-.166	-.159	-.170	-.181	-.185	-.163
10	-.188	-.200	-.226	-.230	-.235	-.241	-.236	-.234	-.225

M=1.20

alph	phi=0	22.5	45.0	67.5	90.0	112.5	135.0	157.5	180.0
0	-.168				-.151				-.162
2	-.142	-.145	-.151	-.158	-.164	-.171	-.183	-.186	-.186
4	-.138	-.146	-.169	-.172	-.171	-.178	-.187	-.190	-.186
6	-.155	-.176	-.204	-.203	-.196	-.207	-.216	-.217	-.192
10	-.223	-.244	-.260	-.268	-.268	-.269	-.267	-.254	-.254

REFERENCES

1. L. D. Kayser, and F. Whiton, "Surface Pressure Measurements on a Boat-tailed Projectile Shape at Transonic Speeds," U.S. Army Ballistic Research Laboratory, Aberdeen Proving Ground, Maryland, ARBRL-MR-03161, March 1982. (AD A113520)

2. J. Sahu, C. J. Nietubicz, and J. L. Steger, "Numerical Computation of Base Flow for a Projectile at Transonic Velocities," U.S. Army Ballistic Research Laboratory, Aberdeen Proving Ground, Maryland, ARBRL-TR-02495, June 1983. (AD A130293)

3. C. J. Nietubicz, "Navier-Stokes Computations for Conventional and Hollow Projectile Shapes at Transonic Velocities," AIAA Paper No. 81-1262, presented at the AIAA 14th Fluid and Plasma Dynamics Conference, Palo Alto, California, July 1981.

4. J. Sahu, personal communication, February 1984.

5. D. J. Sykes, "Afterbody Pressures at Transonic Speeds," Department of Aeronautics Report 68/19, The City University of London, December 1968.

LIST OF SYMBOLS

A_b	=	base area
A_{cyl}	=	cylinder cross sectional area (reference area)
C_A	=	axial force coefficient
C_{A_b}	=	base axial force coefficient
C_{A_p}	=	forebody axial force coefficient obtained from integration of pressure data, viscous forces excluded
C_{p_b}	=	base pressure coefficient, $(p_b - p_\infty)/q_\infty$
M	=	Mach number
SOC	=	Secant ogive-cylinder, Figure 1 geometry with a 0° boattail angle
SOCBT	=	Secant ogive-cylinder-boattail, see Figure 1
Z	=	longitudinal position on the model axis, measured from the nose tip
α	=	angle of attack, degrees
ϕ	=	model roll orientation, ϕ = 0° is along the most windward ray, e.g., ϕ = 0° is at 6 o'clock when looking at the base of a model at positive angle of attack.

[illegible]

DISTRIBUTION LIST

No. of Copies	Organization
12	Administrator Defense Technical Info Center ATTN: DTIC-DDA Cameron Station Alexandria, VA 22314
1	Commander US Army Materiel Development and Readiness Command ATTN: DRCDMD-ST 5001 Eisenhower Avenue Alexandria, VA 22333
9	Commander Armament R&D Center US Army AMCCOM ATTN: DRSMC-TDC (D) DRSMC-TSS (D) DRSMC-LCA-F (D) Mr. D. Mertz Mr. E. Falkowski Mr. A. Loeb Mr. R. Kline Mr. S. Kahn Mr. H. Hudgins Dover, NJ 07801
1	Commander US Army Armament, Munitions and Chemical Command ATTN: DRSMC-LEP-L(R) Rock Island, IL 61299
1	Director Benet Weapons Laboratory Armament R&D Center US Army AMCCOM ATTN: DRSMC-LCB-TL (D) Watervliet, NY 12189
1	Commander US Army Aviation Research and Development Command ATTN: DRDAV-E 4300 Goodfellow Blvd St. Louis, MO 63120
1	Commander US Army Missile Command ATTN: DRSMI-RDX, R. Deep Redstone Arsenal, Al 35898

No. of Copies	Organization
1	Director US Army Air Mobility Research and Development Laboratory Ames Research Center Moffett Field, CA 94035
1	Commander US Army Communications Research and Development Command ATTN: DRSEL-ATDD Fort Monmouth, NJ 07703
1	Commander US Army Electronics Research and Development Command Technical Support Activity ATTN: DELSD-L Fort Monmouth, NJ 07703
1	Commander US Army Missile Command ATTN: DRSMI-R Redstone Arsenal AL 35898
1	Commander US Army Missile Command ATTN: DRSMI-YDL Redstone Arsenal, AL 35898
1	Commander US Army Tank Automotive Command ATTN: DRSTA-TSL Warren, MI 48090
1	Director US Army TRADOC Systems Analysis Activity ATTN: ATAA-SL White Sands Missile Range, NM 88002
1	Commander US Army Research Office P. O. Box 12211 Research Triangle Park, NC 27709

[redacted]

DISTRIBUTION LIST

No. of Copies	Organization
1	Commander US Naval Air Systems Command ATTN: AIR-604 Washington, D. C. 20360
2	Commander David W. Taylor Naval Ship Research and Development Center ATTN: Dr. S. de los Santos Mr. Stanley Gottlieb Bethesda, Maryland 20084
1	Commander US Naval Surface Weapons Center ATTN: Mr. P. Daniels Dahlgren, VA 22448
4	Commander US Naval Surface Weapons Center ATTN: Code 312 Dr. W. Yanta Code R44 Dr. C. Hsieh Dr. T. Zien Dr. R. U. Jettmar Silver Spring, MD 20910
1	Commander US Naval Weapons Center ATTN: Code 3431, Tech Lib China Lake, CA 93555
1	Director NASA Langley Research Center ATTN: NS-185, Tech Lib Langley Station Hampton, VA 23365
2	Commandant US Army Infantry School ATTN: ATSH-CD-CSO-OR Fort Benning, GA 31905

No. of Copies	Organization
1	AFWL/SUL Kirtland AFB, NM 87117
1	ACUREX Corporation/Aerotherm Div ATTN: Mr. W. S. Kobayashi 555 Clyde Avenue P.O. Box 7555 Mountain View, CA 94039
1	Nielsen Engineering & Research, Inc. ATTN: Dr. S. Stahara 510 Clyde Avenue Mountain View, CA 94043
2	Sandia Laboratories ATTN: Technical Staff, Dr. W.L. Oberkampf Aeroballistics Division 5631, H.R. Vaughn Albuquerque, NM 87115
1	Massachusetts Institute of Technology ATTN: Tech Library 77 Massachusetts Avenue Cambridge, MA 02139
1	University of Delaware Mechanical and Aerospace Engineering Department ATTN: Dr. J. E. Danberg Newark, DE 19711

Aberdeen Proving Ground

Dir, USAMSAA
ATTN: DRXSY-D
DRXSY-MP, H. Cohen

Cdr, USATECOM
ATTN: DRSTE-TO-F

Cdr, CRDC, AMCCOM
ATTN: DRSMC-CLB-PA
DRSMC-CLN
DRSMC-CLJ-L

USER EVALUATION OF REPORT

Please take a few minutes to answer the questions below; tear out this sheet, fold as indicated, staple or tape closed, and place in the mail. Your comments will provide us with information for improving future reports.

1. BRL Report Number ________________________________

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.

____

____

5. General Comments (Indicate what you think should be changed to make this report and future reports of this type more responsive to your needs, more usable, improve readability, etc.) __________

____

____

____

6. If you would like to be contacted by the personnel who prepared this report to raise specific questions or discuss the topic, please fill in the following information.

Name: ________________________________

Telephone Number: ________________________________

Organization Address: ________________________________

____

____