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TECHNICAL REPORT 4588

SPIN-73
AN UPDATED VERSION OF THE SPINNER COMPUTER PROGRAM

ROBERT H. WHYTE

NOVEMBER 1973

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Technical Report 4588

SPIN-73
AN UPDATED VERSION OF THE SPINNER COMPUTER PROGRAM

by

Robert H. Whyte

November 1973

AMCMS Code No. 554C.12.62000

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Picatinny Arsenal
Dover, New Jersey 07801

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General Electric Co.
Burlington, VT 05401

FOREWORD

This report documents tasks accomplished by the Armament Systems Department, General Electric Company, Burlington, Vermont under United States Government Contract No. DAAA21-73-C-0033 during the period from 14 August 1972 to 14 July 1973.

ACKNOWLEDGEMENT

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ABSTRACT

The SPINNER computer program has been updated to compute aerodynamic coefficients for a wide variety of spin stabilized projectile shapes. Improvements over the original program are substantial as ogive radius, meplat diameter and rotating band diameter are accounted for instead of assuming mean values. Test cases are shown comparing the 1969 SPINNER, the 1973 SPINNER and experimental data. Input instructions and sample program outputs are given along with the 1973 program listing.

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NOMENCLATURE

A	projectile cross-sectional area, ft^2
C_{lp}	spin deceleration coefficient, $M_{lp}/\bar{q}Ad(\frac{pd}{2V})$
C_m	pitching moment coefficient, $M_m/\bar{q}Ad$
C_{m_q}	damping moment coefficient, $M_{m_q}/\bar{q}Ad(qd/2V)$
C_{n_p}	magnus moment coefficient, $M_{n_p}/\bar{q}Ad(pd/2V)$
C_N	normal force coefficient, $F_N/\bar{q}A$
C_{Yp}	magnus force coefficient, $F_{Yp}/\bar{q}A(pd/2V)$
C_X	axial force coefficient, $F_X/\bar{q}A$
CG	center of gravity, calibers from nose
I_x	axial moment of inertia, $slug\text{-}ft^2$
I_y	transverse moment of inertia, $slug\text{-}ft^2$
F_N	normal force, lbs.
F_{Yp}	magnus force, lbs.
F_x	axial force, lbs.
M_{l_p}	spin damping moment
M_m	pitching moment about CG
M_{m_q}	damping moment about CG
M_{n_p}	magnus moment about CG
V	total velocity, ft/sec.
d	projectile diameter, ft.
g	gravity, 32.174 ft/sec^2
m	projectile mass, slugs
p	projectile spin rate, radians/second
q	projectile pitch rate, radians/second

NOMENCLATURE (Continued)

$\bar{q}$	dynamic pressure, $1/2\rho\ V^2$, lb/ft^2
$\bar{\alpha}$	total angle of attack, radians
ρ	air density, $slugs/ft^3$

Subscripts

α	Derivative with respect to $\sin \bar{\alpha}$
2	Derivative with respect to $\sin^2 \bar{\alpha}$
α_3	Derivative with respect to $\sin^3 \bar{\alpha}$
α_5	Derivative with respect to $\sin^5 \bar{\alpha}$

INTRODUCTION

The Armament Department of General Electric under contract to Picatinny Arsenal has developed an empirical computerized model for predicting the aerodynamic coefficients of spin stabilized projectiles. The code name of the new program is SPIN-73.

The starting point for the current study was the computer program SPINNFR[70*] which was developed at Picatinny Arsenal during the period from September 1966 to October 1968. This program was modified by General Electric in 1969[68] and 1970[71] to update the predictions of the drag coefficient and also to perform a closed form dispersion analysis.

In general the method used during the development of the original Spinner was as follows:

Basic projectile configurations were selected which were considered by Whyte[68,70] to have well determined aerodynamic coefficients. Empirical equations and constants were developed, by a trial and error process, by which the standard coefficients could be adjusted for changes in total length, nose length, boattail length and center of gravity.

The following limitations were and are present in the original program.

1. Nose length 1.8 to 4.0 calibers
2. Projectile length 3.6 to 9.0 calibers
3. Boattail length 0.0 to 1.0 calibers
4. Meplot diameter, 0.10 to 0.15 calibers
5. Nose radius, secant +100% to secant -30%
6. Rotating band diameter, 1.025 calibers

* References alphabetically listed starting on page 22.

However as most projectiles in service and under investigation during the period from 1966 to 1969 in general fell within the above bounds the limitations of the program were not considered very serious.

Since 1970 several programs have been initiated by the Army and Navy which are considering utilizing projectiles with nose lengths of up to 5.5 calibers and boattail lengths of up to 2.5 calibers.

Also payload and fuzing capabilities of several small arms projectiles currently under development by the Air Force, Navy, and Army have dictated blunter ogives (large meplats) and near tangent ogives.

Rotating band diameter are also of larger scale on small arms than corresponding shapes of large calibers thereby complicating the prediction process.

Because of these known limitations and future requirements the need for a revised SPINNER was indicated. Thus this current study was initiated in August 1972.

Sears[60] of Eglin in 1972 published a computerized curve fit technique for predicting the drag of projectile. His results indicated improvement over the original SPINNER in the area of tangent ogives and meplat bluntness.

A similar method to that used by Sears was employed in updating SPINNER. In discussing the computer programs the 1969 version of SPINNER will be referred to as SPIN-69 and the 1973 version as SPIN-73.

PROCEDURE

The most difficult task in the analysis of data is determining a constant accurate model which will adequately curve fit data under all circumstances, whereupon predictions of results under a different sets of initial conditions do not result in completely useless answers.

An example of useless results is shown in figure 15 where the predicted axial force is negative in the SPIN-69 program. When terms of higher order polynomials are employed to obtain good fits one must be very cautious when using these polynomials to extrapolate or even interpolate data. These cautions are pointed out because SPIN-73 does employ higher order polynomials.

The equations used for fitting and probable errors will be covered for each coefficient individually.

In general the data utilized with very few exceptions was obtained from reports published by the Ballistic Research Laboratory (BRL) and Arnold Engineering Development Center (AEDC). No wind tunnel data was used at all in the data bank. Wind tunnel data was used to determine trends and comparisons were made with the trends resulting data fitting.

The references utilized to collect the experimental data are listed starting on page 22. Unpublished data from BRL, Picatinny, AEDC and GE were also used. The method used to curve fit the data is described briefly in Appendix A.

Equations of the following general form were used for all coefficients. Definitions of VL, VN, VB, VCG, BD, DM, OR, and BOOM are found in figure 1.

$$C_X = a_1 + a_2\,(CVN) + a_3\,(CVN^2)$$

$$+ a_3\,(CXCL) + a_4\,(CXCL^2)$$

$$+ a_5\,(CVN \cdot CXCL)$$

$$+ a_6\,(CVB) + a_7\,(CBD)$$

$$+ a_8\,(CMK) + a_9\,(CMK^2)$$

$$+ a_{10}\,(CVN \cdot CMK) + a_{11}\,(CXCL \cdot CMK)$$

$$+ a_{11}\,(CRAT) + \text{---} \quad \text{etc.}$$

where:

$$CVN = VN - 2.5$$

$$CXCL = VL - VN - VB - 1.5$$

$$CVB = VB$$

$$CBD = BD - 1.02$$

$$CMK = CMK - 1.05$$

$$CRAT = VN^2/OR - 0.40$$

The combinations, variations, and parameters which can be included in the fitting equation are nearly infinite. References such as Dickenson,[19-28] Sears,[60] Watt,[66] and Murphy[43] were used as guides for determining the most effective way of deriving an empirical equation. By the trial and error process equations of the above type were manipulated into a form which adequately described the experimental data.

EMPIRICAL EQUATIONS

This section will describe individually for each coefficient the equations contained in the computer program SPIN-73 as of June 1973.

Axial Force Coefficient

$CXCL = VL - VN - VB - 1.5$

$CBD = DB - 1.02$

$CDM = (DM - 0.12)^2$ $\quad CRAT = VN^2/OR - 0.40$

if $0 < VN < 3.0$ set $VNX = VN$, $DXN = 0.0$

if $0 < CXCL < 1.5$ set $CXCLL = CXCL$, $DXCL = 0.0$

if $0.2 < VB < 0.65$ set $VBX = VB - 0.2$ $\quad DXBT = 0.0$

If VN, CXCL, or VB are greater than the maximum

set $VNX = 3.0$, $DXN = (VN - 3.0)\ A_{13}$

$CXCLL = 1.5$, $DXCL = (CXCL - 1.5)\ 0.01$

$VBX = 0.45$, $DXBT = (VB - 0.65)\ A_{10}$

If VB is less than the minimum

$VBX = 0.0$, $DXBT = 0.0$

$$C_X = a_1 + a_2 (VNX - 2.5, + a_3 (VNX - 2.5)^2$$
$$+ a_4 (VNX - 2.5)^3 + a_5 (CXCLL) + a_6 (CXCLL)^2$$
$$+ a_7 (VBX) + a_8 (CRAT) + a_9 (CRAT)^2$$
$$+ a_{11} (CBD) + a_{12} (CDM) - (BOOM/1.36,^2\ 0.01$$
$$- DXBT - DXN + DXCL$$

The "IF" statements are required to circumvent the need for higher order polynomials in the equations. In this manner only linear extrapolation and interpolations are allowed on the fringes of the program capabilities. This should prevent completely erroneous estimates.

Normal Force Coefficient Derivative, Pitching Moment Coefficient Derivative and Normal Force Center of Pressure

if $0 < VN < 3.0$ set $VNX = VN$, $DNX = 0.0$

if $0 < VB < 1.0$ set $VBNP = VB^{A}$, $VBMP = VB^{B}$, $VBX = VB$

where: Subsonic A = 1.0, B = 0.8

Supersonic A = 1.5, B = 1.0

if VN or VB are greater than the maximum

set $VNX = 3.0$, $DNX = VN - 3.0$

$VBX = 1.0$, $VBNP = VB^{0.5}$, $VBMP = VB^{0.5}$

Now set

$CVNN = VNX - 2.47$

$CXLL = VL - VN - VB - 2.15$

$CDMM = DM - 0.17$

$CBBD = BD - 1.04$

$CCRT = VN^{2}/OR - 0.48$

$VBTT = CVL/4.7$

$$CNAB = B_1 + B_2 (CVNN) + B_3 (CXLL) + B_4 (CCRT) + B_5 (CVNN)^2 + B_6 (CXLL)^2$$

$$CNBT = B_7 (VBNP) + B_8 (VBX \cdot CVNN) + B_9 (VBX \cdot CXLL)$$

$$CNAT = CNAB + CNBT$$

$$AMOMSQ = CNAB\ [C_1 + C_2\ (CVNN) + C_3\ (CVNN)^2 + C_4\ (CVNN)^3 + C_5\ (CXLL) + C_6\ (CXLL)^2 + C_7\ (CXLL)^3 + C_8\ (CCRT) + C_9\ (CCRT)^2 + C_{10}\ (CDMM) + C_{11}\ (CCRT \cdot CYNN) + C_{17}\ (DNX)]$$

$$AMOMBT = VBTT\ [C_{12}\ (VBMP) + C_{13}\ (VBX \cdot CVNN) + C_{14}\ (VBX \cdot CXLL) + C_{15}\ (VBX \cdot CCRT) + C_{16}\ (VBX \cdot CCRT \cdot CVNN)]$$

$$CPN = (AMOMSQ + AMOMBT)/CNAT$$

$$C_{N_\alpha} = CNAT$$

$$C_{M_\alpha} = (VCG - CPN)\ C_{N_\alpha}$$

Yaw Axial Force Coefficient

$$CXCL = VL - VN - VB - 1.5$$

$$CRAT = VN^2/OR - 0.40$$

$$CVB = VB$$

$$C_{X_2} = D_1 + D_2\ (CXCL) + D_3\ (CRAT) + D_4\ (CVB) - C_{N\alpha}$$

The Yaw Drag coefficient may be computed by adding C_{X_2} and $C_{N\alpha}$.

Magnus Force Coefficient Derivative, Magnus Moment Coefficient Derivative, Magnus Force Center of Pressure

$$CVL = VL$$

$$CVB = VB$$

$$CXCL = VL - VN - VB - 1.5$$

$$CVN = VN - 2.5$$

$$CYPA = E_1 \ (CVL) - 0.1 \ (CVB)$$

at $\bar{\alpha} = 1.0°$

$$CNPAN = -E_1 \ (CVL) \ [E_2 + 0.55 \ (CXCL) + 0.80 \ (CVN)] + CVB \ (CVL/4.7)$$

$$CPF_{(1)} = -CNPAN/CYPA$$

$$C_{Yp\alpha} = CYPA$$

$$C_{n_{p\alpha}(1)} = (VCG - CPF_{(1)}) \ C_{Yp\alpha}$$

at $\bar{\alpha} = 2.0°$

$$CNPAN = -E_1 \ (CVL) \ [E_3 + 0.55 \ (CXCL) + 0.80 \ (CVN)] + CVB \ (CVL/4.7)$$

$$CPF_{(2)} = -CNPAN/CYPA$$

$$C_{Yp\alpha} = CYPA$$

$$C_{n_{p\alpha}(2)} = (VCG - CPF_{(2)}) \ C_{Yp\alpha}$$

at $\bar{\alpha} = 5.0°$

$$CNPAN = -E_1 \ (CVL) \ [E_4 + 0.55 \ (CXCL) + 0.80 \ (CVN) + CVB \ (CVL/4.7)$$

$$CPF_{(5)} = -CNPAN/CYPA$$

$$C_{Yp\alpha} = CYPA$$

$$C_{n_{p\alpha}}{}_{(5)} = (VCG - CPF_{(5)})\ C_{Yp\alpha}$$

Damping Moment Coefficient

$$CLL = VL - 5.0$$

$$CCG = VCG - 3.0$$

$$CVB = VB$$

$$C_{m_q} = -5.093\ [F_1 + F_2\ (CLL) + F_3\ (CLL^2) + F_4\ (CCG) + F_5\ (CCG)\ (CLL) + F_6\ (CCG)\ (CLL^2) + F_7\ (CCG)\ (CVB) + F_8\ (CVB)]$$

Spin Deceleration Coefficient

$$C_{l_p} = G1\ (VL/5.51)$$

Stability Analysis

The methods used for stability computations were extracted from references 44 and 45. They are identical to those contained in the original SPINNER.

Gyroscopic Stability Factor, s_g

$$s_g = 2I_x{}^2 p^2/\pi I_{y\rho}\ C_{m_\alpha} d^3\ V^2$$

Dynamic Stability Factor, s_d

$$s_d = \frac{2(C_{N_\alpha} - C_X + (k_1{}^{-2}/2)\ C_{n_{p\alpha}})}{(C_{N_\alpha} - C_X - (k_2{}^{-2}/2) C_{m_q} + (k_1{}^{-2}/2)\ C_{l_p})}$$

Nutation, Precession Frequencies $\omega_{1,2}$

$$\omega_{1,2} = \frac{pI_x}{2I_y} \quad (1 \pm \sigma)$$

Nutation, Precession Yaw Damping Rates, $\lambda_{1,2}$

$$\lambda_{1,2} = \frac{\rho A}{4m} \left[-C_{N_\alpha} \left(1 \pm \frac{1}{\sigma}\right) + (k_2^{-2}/2) \left(1 \pm \frac{1}{\sigma}\right) C_{m_q} \pm (k_1^{-2}/\sigma) C_{n_{p\alpha}} \right]$$

where

$$k_1^{-2} = md^2/I_x$$

$$k_2^{-2} = md^2/I_y$$

$$\sigma = \sqrt{1 - 1/s_g}$$

The dispersion (DISP) is the radius in mils of a circle which a projectile will impact in a vertical plane when disturbed to a first maximum yaw angle of 5 degrees or less. The basis for this calculation is derived in Reference 71.

The time step (DELT) shown will provide 20 integrations per nutation cycle. This is entirely adequate for a 4th Order Range Kutta integrator.

RESULTS AND DISCUSSIONS

The results of several test cases are presented in Figures 2 thru 15. Plotted are experimental points, SPIN-69 and SPIN-73 results. Tabulated outputs of SPIN-73 are shown as tables 2 thru 15.

The following ranges of parameters are demonstrated by the test cases.

Total length	3.8 thru 10.0 calibers
Nose length	1.6 thru 5.5 calibers
Boattail length	0.0 thru 1.0 calibers
Ogive radius	tangent thru conical
Meplat diameter	0.0 thru 0.26 calibers
Band diameter	1.00 thru 1.05 calibers

In general the correlations between SPIN-73 and the experimental data is very good with noticeable improvements over SPIN-69. Most of the effort during this current study has been directed at the Axial Force and Pitching Moment correlations as these two coefficients are by far the most accurately determined during the experimental process. Much work still remains to be done on these coefficients in terms of defining a more adequate empirical model.

The most poorly determined coefficients remain the Magnus and damping. It is this author's opinion that the SPIN-73 improvement in these the calculations is negligible. While some new data has been published since 1968, in general data was previously available on similar shapes. For example the projectiles refered to as the XM380 and XM549 were experimentally

investigated long ago as the T388 and T387. This data was available in 1967 and had been included in the original (SPIN-69) program.

The bulk of the data published by AEDC through calendar year 1972 is suspect as far as the Magnus and damping coefficient are concerned because the effect on linear theory reductions of a slowly varying pd/2V was not taken into account.

This author also found in several instances as did Sears that the geometric description of the projectiles under test were not available either in the data reports or the data files.

The probable errors to the experimental data of the SPIN-73 empirical equations are shown in Table 1. The number of data points used to compute the probable error is shown in parenthesis.

CONCLUSIONS AND RECOMMENDATIONS

The SPIN-73 program has been shown through test cases to be more accurate than the SPIN-69 program.

The updating of SPIN-73 should be continued as new data is accumulated.

Records should be kept of shortcomings and extremely poor predictions.

Data should be more carefully reported with respect to actual configuration tested.

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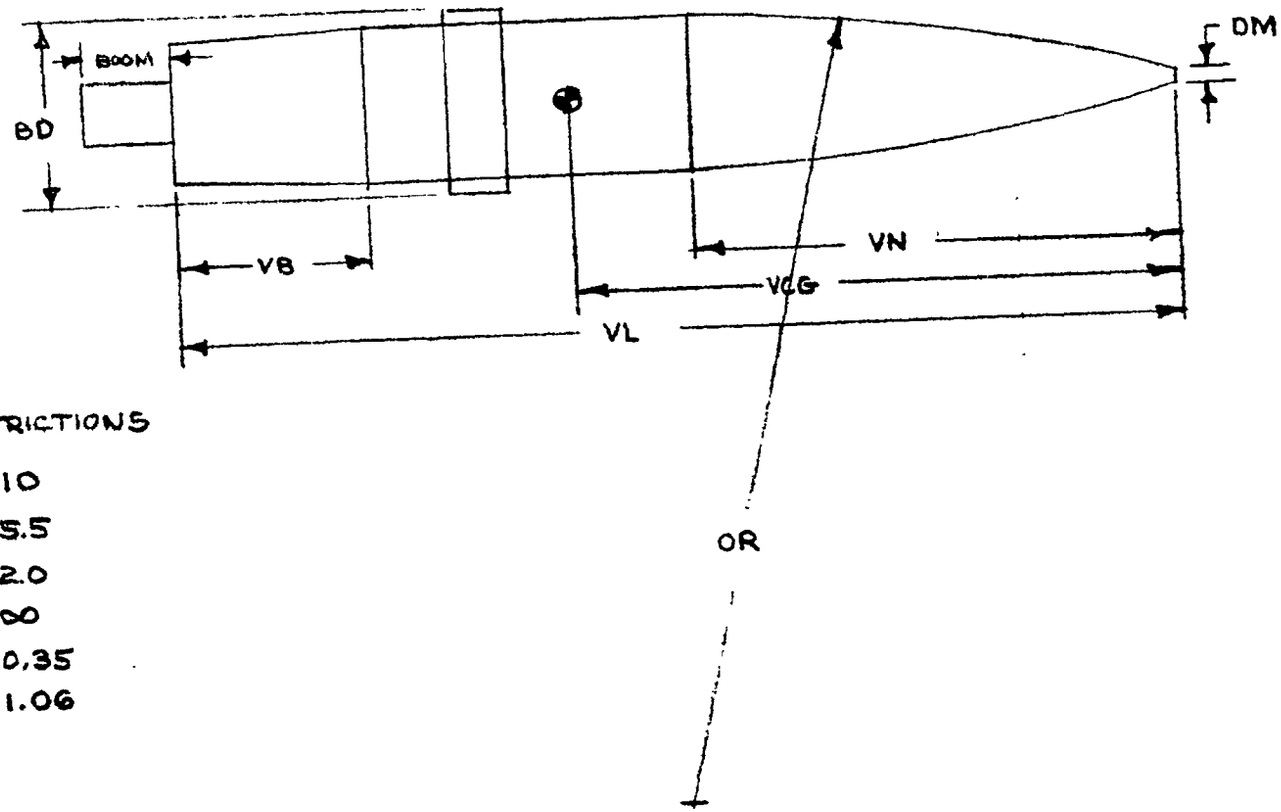

DIMENSION RESTRICTIONS

$2.5 < VL < 10$

$1.2 < VN < 5.5$

$0.0 < VB < 2.0$

$VN \leq VN < OR < \infty$

$0.0 < DM < 0.35$

$1.0 < BD < 1.06$

PROJECTILE PARAMETERS - INPUT/OUTPUT

FIGURE 1

COEFFICIENT PROBABLE ERRORS

	e_{C_x}	$e_{C_{N_\alpha}}$ SQ BASE	$e_{C_{N_\alpha}}$ BOATTAIL	$e_{C_{m_\alpha}}$ SQ BASE	$e_{C_{m_\alpha}}$ BOATTAIL	$e_{C_{m_q}}$	$e_{C_{m_{\dot{\alpha}}}}$
0.80	0.0078 (84)*	0.06 (86)	0.10 (37)	0.15 (90)	0.11 (39)	3.0 (78)	0.18 (72)
0.90	0.0090 (62)	0.06 (86)	0.10 (37)	0.15 (90)	0.11 (39)	—	—
0.95	0.0092 (56)	0.06 (86)	0.11 (49)	0.15 (90)	0.12 (53)	—	0.16 (72)
1.05	0.0076 (111)	0.09 (129)	0.10 (49)	0.13 (138)	0.10 (54)	3.0 (78)	—
1.10	0.0076 (111)	0.09 (129)	0.10 (49)	0.13 (138)	0.10 (54)	—	0.16 (72)
1.20	0.0076 (145)	0.09 (129)	0.09 (64)	0.13 (138)	0.14 (71)	—	0.12 (59)
1.50	0.0078 (193)	0.09 (129)	0.08 (52)	0.13 (138)	0.15 (58)	3.0 (63)	0.12 (59)
2.00	0.0078 (194)	0.09 (132)	0.07 (50)	0.12 (141)	0.17 (58)	3.0 (63)	0.12 (59)
2.50	0.0072 (159)	0.09 (132)	0.06 (38)	0.12 (141)	0.17 (45)	—	0.12 (59)
3.00	0.0072 (159)	—	—	—	—	—	—

* NO. OF DATA PTS. INCLUDED IN FIT

TABLE 1

MACH	CA	CN2	CNA	CMA	CMQA	CNPA	CMPA	CNPS	CMPS	CMQ	CLP
0.010	0.217	2.531	2.104	2.722	-0.478	-0.478	74.286	-765.154	1.476	2.576	0.193	-3.822	-.025
0.600	0.217	2.531	2.104	2.943	-0.478	-0.478	74.286	-765.154	1.476	2.576	0.193	-3.822	-.025
0.810	0.210	2.997	2.126	3.014	-0.482	-0.482	47.494	-487.444	1.676	2.676	0.254	-3.822	-.024
0.900	0.247	3.381	2.224	3.072	-0.484	-0.484	49.243	-494.931	2.024	2.726	0.320	-6.379	-.020
0.950	0.310	4.031	2.261	3.122	-0.879	-0.879	30.412	-340.822	2.376	2.776	0.451	-9.135	-.018
1.000	0.435	4.271	2.144	3.140	-0.914	-0.862	28.103	-225.711	2.476	2.776	0.414	-13.424	-.017
1.050	0.428	4.616	2.521	2.968	1.104	-0.728	0.229	19.712	+139.422	2.576	2.776	0.378	-13.695	-.017
1.100	0.428	4.123	2.836	2.943	1.093	-0.664	0.252	11.043	-72.053	2.626	2.776	0.355	-14.076	-.016
1.200	0.433	5.033	2.565	2.900	1.101	-0.611	0.242	7.733	-38.827	2.676	2.776	0.315	-14.993	-.016
1.350	0.415	5.059	2.459	2.865	1.151	-0.611	0.254	6.374	-26.244	2.676	2.776	0.315	-15.585	-.016
1.500	0.407	4.463	2.753	2.871	1.217	-0.611	0.260	5.485	-19.461	2.686	2.776	0.315	-13.582	-.016
1.750	0.473	3.867	2.849	2.848	1.316	-0.611	0.266	5.016	-12.442	2.696	2.776	0.315	-13.582	-.016
2.000	0.450	3.284	2.932	2.929	1.406	-0.611	0.271	4.337	-9.871	2.706	2.776	0.315	-13.582	-.016
2.500	0.407	2.747	2.988	2.197	1.427	-0.611	0.279	3.658	6.926	2.716	2.776	0.315	-13.582	-.015
3.000	0.369	2.308	2.915	1.869	1.412	-0.611	0.285	2.979	7.711	2.726	2.776	0.315	-13.582	-.014
4.000	0.331	1.887	2.815	1.708	1.485	-0.611	0.285	2.979	7.711	2.726	2.776	0.315	-13.582	-.014
5.000	0.309	1.665	2.719	1.922	1.552	-0.611	0.285	2.979	7.711	2.726	2.776	0.315	-13.582	-.013

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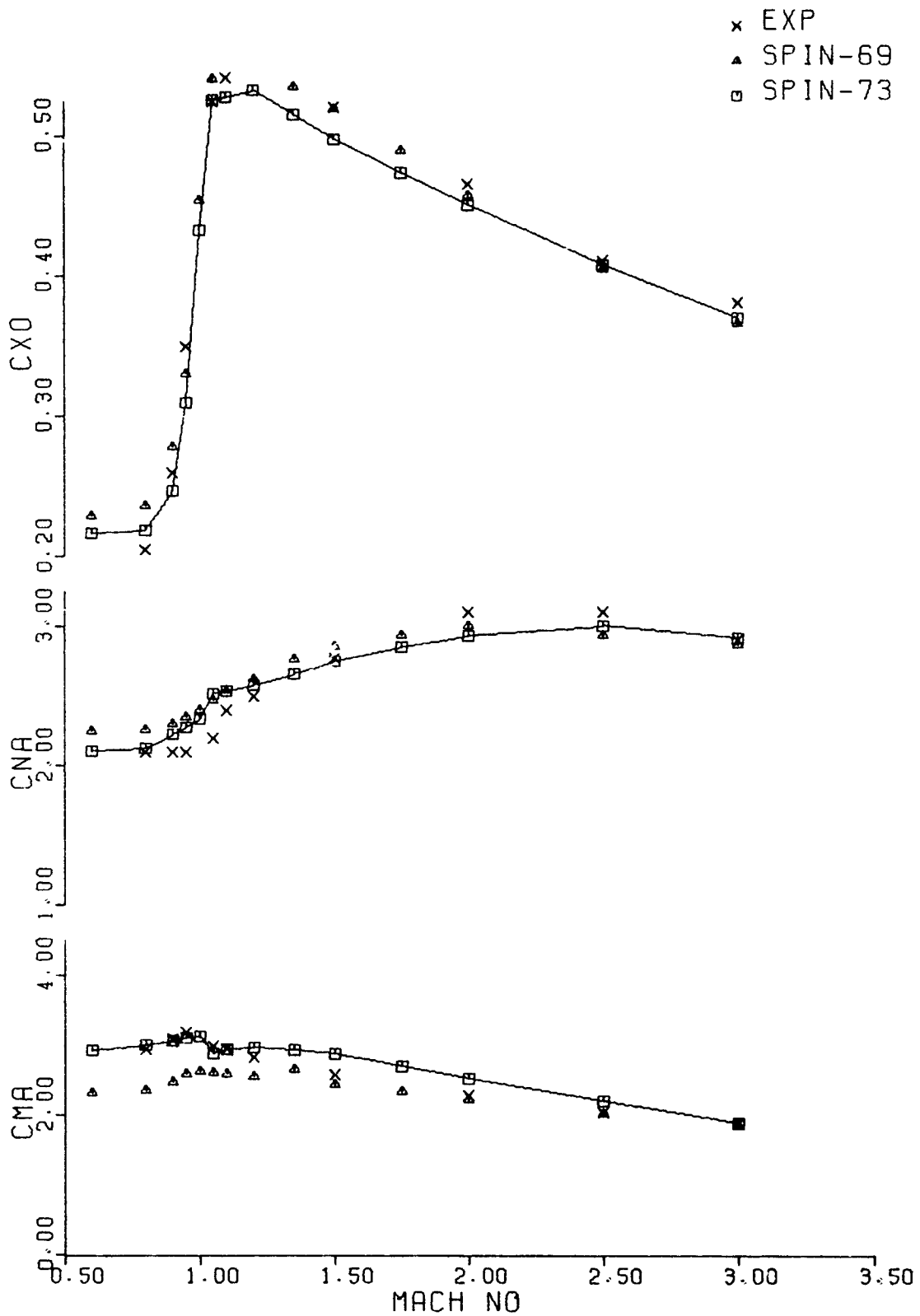
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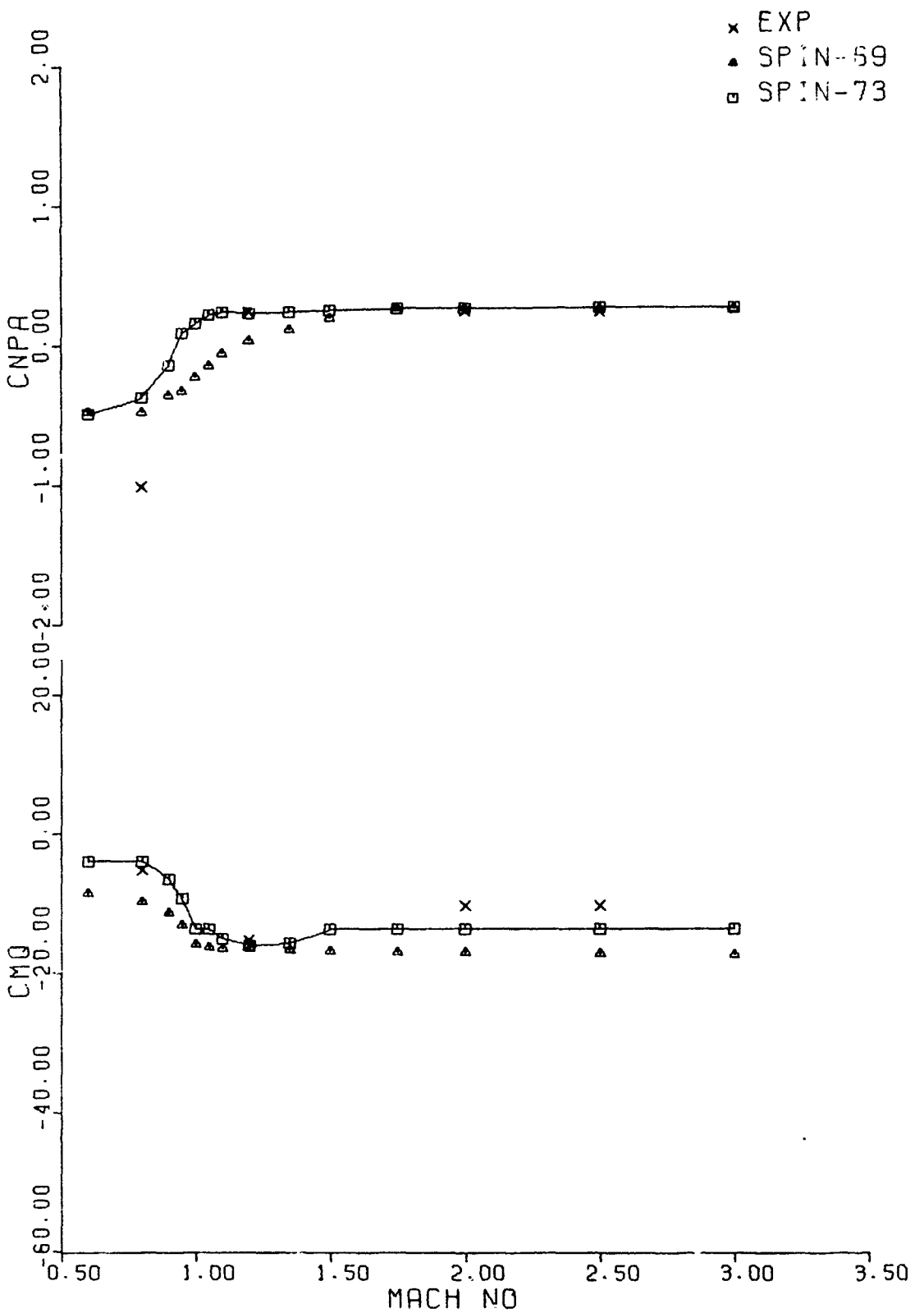
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AERODYNAMIC COEFFICIENTS

MACH	CA	CN2	CA2	CN4	CA4	CNB	CAB	CNF	CAF	CMQ	CLP
0.010	0.222	2.765	2.140	4.562	1.468	-.860	.452	97.161	-938.111	2.225	1.325	-.088	-.033
0.600	0.222	2.765	2.140	3.361	1.458	-.860	.452	97.161	-938.111	2.225	1.325	-.088	-.033
0.800	0.224	2.755	2.150	3.444	1.439	-.860	.452	88.472	-847.222	2.425	1.425	-.088	-.031
0.900	0.242	2.731	2.215	3.421	1.404	-.860	.452	88.583	-848.333	2.425	1.425	-.088	-.031
0.950	0.111	4.182	2.246	3.713	1.184	-1.140	.604	50.494	-460.444	3.125	1.525	-11.113	-.026
1.000	0.198	4.235	2.265	3.858	1.176	-1.050	.594	50.583	-308.333	3.225	1.625	-14.020	-.023
1.050	0.446	4.232	2.323	3.761	1.461	-.860	.271	26.494	-169.444	3.325	1.525	-16.459	-.022
1.100	0.442	4.298	2.384	3.818	1.448	-.860	.261	16.583	-108.333	3.325	1.525	-18.919	-.022
1.200	0.434	4.305	2.455	3.472	1.481	-.860	.292	10.250	-65.000	3.425	1.525	-20.963	-.024
1.350	0.417	5.034	2.546	3.480	1.511	-.860	.308	8.472	-47.222	3.425	1.525	-23.020	-.021
1.500	0.420	5.192	2.656	3.804	1.475	-.860	.316	7.583	-38.333	3.425	1.525	-24.599	-.021
1.750	0.424	4.580	2.781	3.858	1.481	-.860	.324	6.694	-28.444	3.425	1.525	-26.211	-.021
2.000	0.451	4.044	2.464	3.761	1.748	-.860	.333	5.806	-20.556	3.455	1.525	-26.211	-.020
2.500	0.511	3.361	2.060	3.514	1.454	-.860	.346	4.917	-11.667	3.465	1.525	-26.211	-.020
3.000	0.278	2.682	2.025	3.329	1.003	-.860	.348	4.028	-2.778	3.475	1.525	-26.211	-.019
4.000	0.240	2.335	2.025	3.300	1.072	-.860	.348	4.028	-2.778	3.475	1.525	-26.211	-.018
5.000	0.218	1.852	2.725	3.245	1.445	-.860	.348	4.028	-2.778	3.475	1.525	-26.211	-.017

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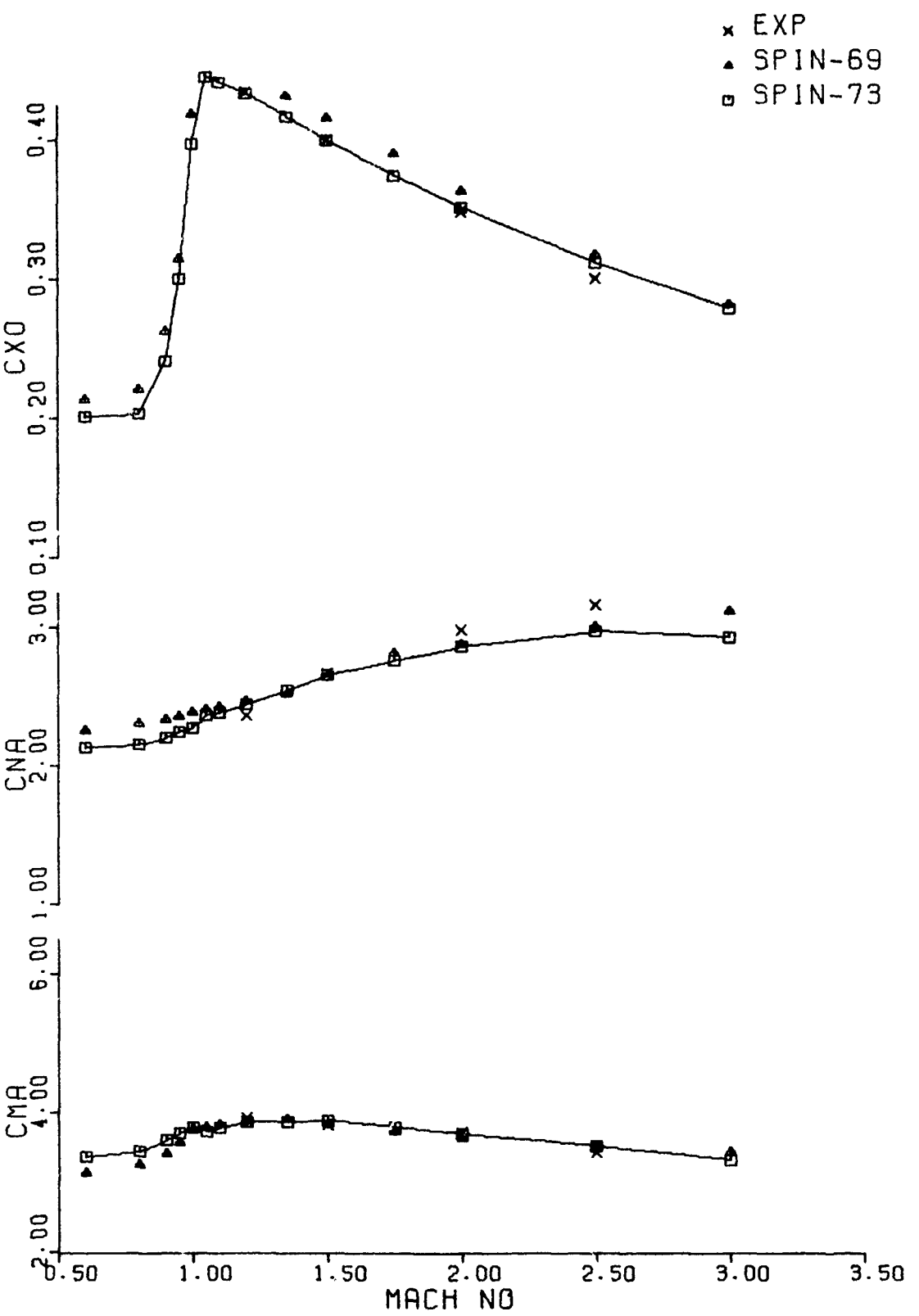
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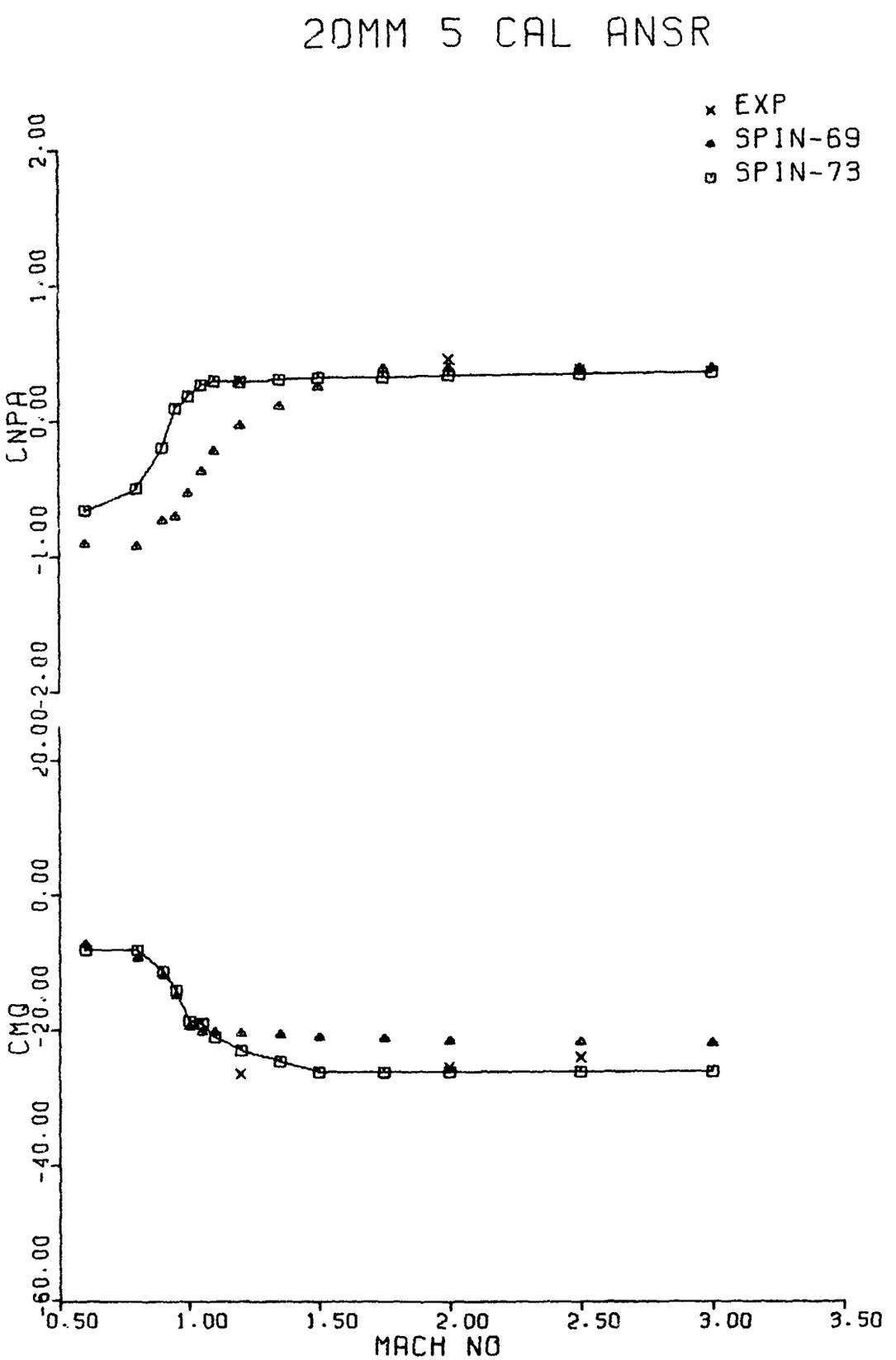
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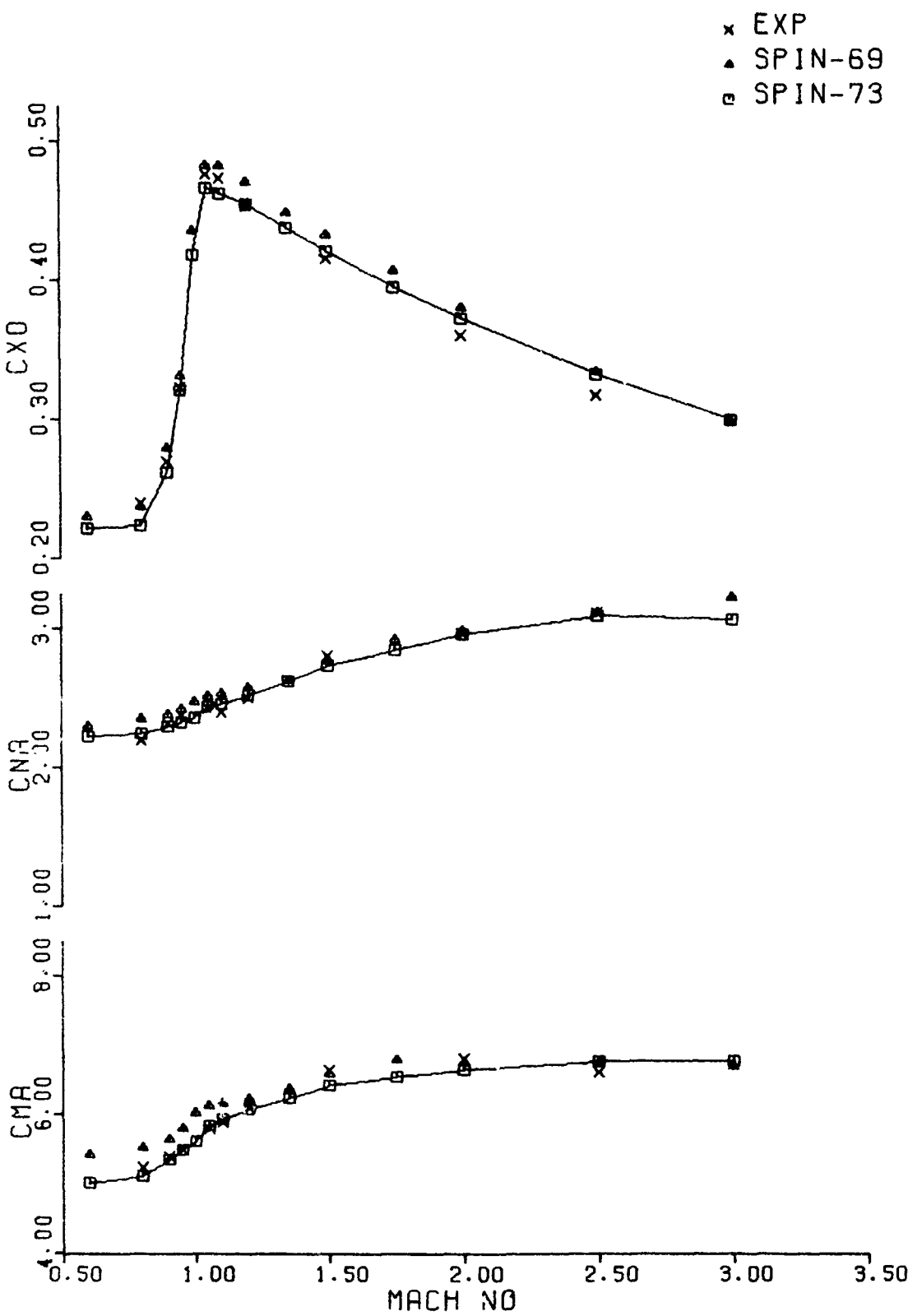
[illegible] WASHINGTON VERMONT
7 CAL

TOTAL LENGTH	NOSE LENGTH	AFT TAIL LENGTH	CG (FM NOSE)	BASE DIAMETER	BODY DIAMETER	NOSE RADIUS	BODY LENGTH
7.000	2.000	0.000	4.040	0.000	1.000	8.000	0.000

DIAMETER SQUARED	IX LB-IN-SEC**2	IY LB-IN-SEC**2	WEIGHT LBS	GUN TWIST CAL/TURN	ACTUAL TWIST CAL/TURN	GUN-BORE INCHES	TEMPERATURE DEG-F	AIR DENSITY SLUGS/FT**3
[illegible]	0.1	0.000	[illegible]	0.000	0.000	0.000	0.000	0.00270

AERODYNAMIC COEFFICIENTS

MACH	CD	CDF	CDA	CNA	CPN	CYPA	CNPA	CNPA3	CYPA5	CPF=1	CPF=5	CNPA=5	CMQ	CLP
0.510	0.522	1.179	2.226	5.003	1.791	-1.120	-.801	136,472	-1327,222	3.325	4.425	0.431	-31.495	-.046
0.600	0.522	1.179	2.226	5.005	1.781	-1.120	-.801	136,472	-1327,222	3.325	4.425	0.431	-31.495	-.046
0.800	0.524	1.184	2.244	5.115	1.783	-1.120	-.577	124,028	-1207,778	3.525	4.525	0.543	-31.495	-.044
0.900	0.542	4.124	2.294	5.141	1.719	-1.260	-.145	90,583	-884,111	3.995	4.574	0.674	-34,826	-.037
0.950	0.921	4.605	2.324	5.495	1.678	-1.610	0.298	71,139	-673,889	4.225	4.425	0.942	-37,631	-.032
1.000	3.418	5.253	2.341	5.624	1.454	-1.470	0.419	48,583	-448,333	4.325	4.425	0.860	-42,168	-.030
1.050	0.466	5.469	2.436	5.811	1.444	-1.330	0.512	29,139	-293,889	4.425	4.425	0.778	-42,378	-.030
1.100	0.462	4.532	2.458	5.935	1.475	-1.240	0.548	20,583	-188,333	4.475	4.425	0.737	-45,703	-.030
1.200	0.454	7.328	2.522	6.088	1.424	-1.120	0.521	14,517	-107,667	4.505	4.425	0.695	-49,398	-.030
1.350	0.437	6.729	2.618	6.250	1.452	-1.120	0.543	12,028	-82,778	4.525	4.425	0.655	-54,523	-.029
1.500	0.420	6.118	2.734	6.416	1.451	-1.120	0.666	10,783	-70,333	4.635	4.725	0.767	-61,769	-.029
1.750	0.394	5.504	2.844	6.548	1.737	-1.120	0.790	9,539	-57,889	4.745	4.825	0.879	-63,769	-.029
2.000	0.371	4.895	2.955	6.637	1.794	-1.120	0.913	8,294	-45,444	4.855	4.925	0.991	-65,769	-.028
2.500	0.331	4.292	3.078	6.745	1.849	-1.120	0.924	7,050	-33,000	4.865	4.925	0.991	-67,769	-.027
3.000	0.298	3.594	3.051	6.793	1.827	-1.120	0.902	5,806	-20,556	4.845	4.895	0.958	-67,769	-.025
4.000	0.260	3.009	2.951	6.620	1.797	-1.120	0.879	5,806	-20,556	4.825	4.875	0.935	-65,769	-.025
5.000	0.238	2.424	2.851	6.482	1.767	-1.120	0.823	5,806	-20,556	4.775	4.823	0.879	-62,769	-.024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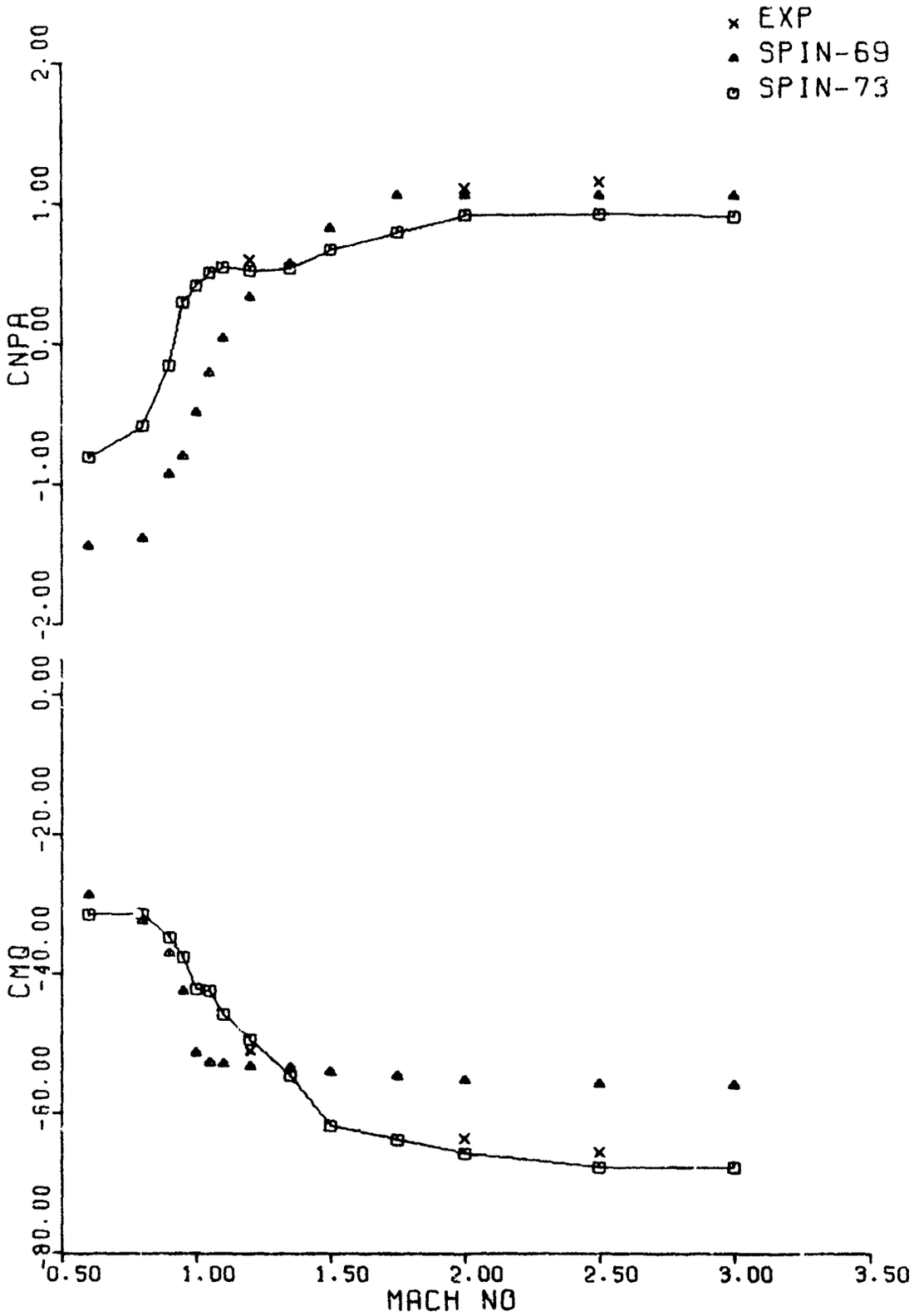


OF BURLINGTON VERMONT
9 CAL

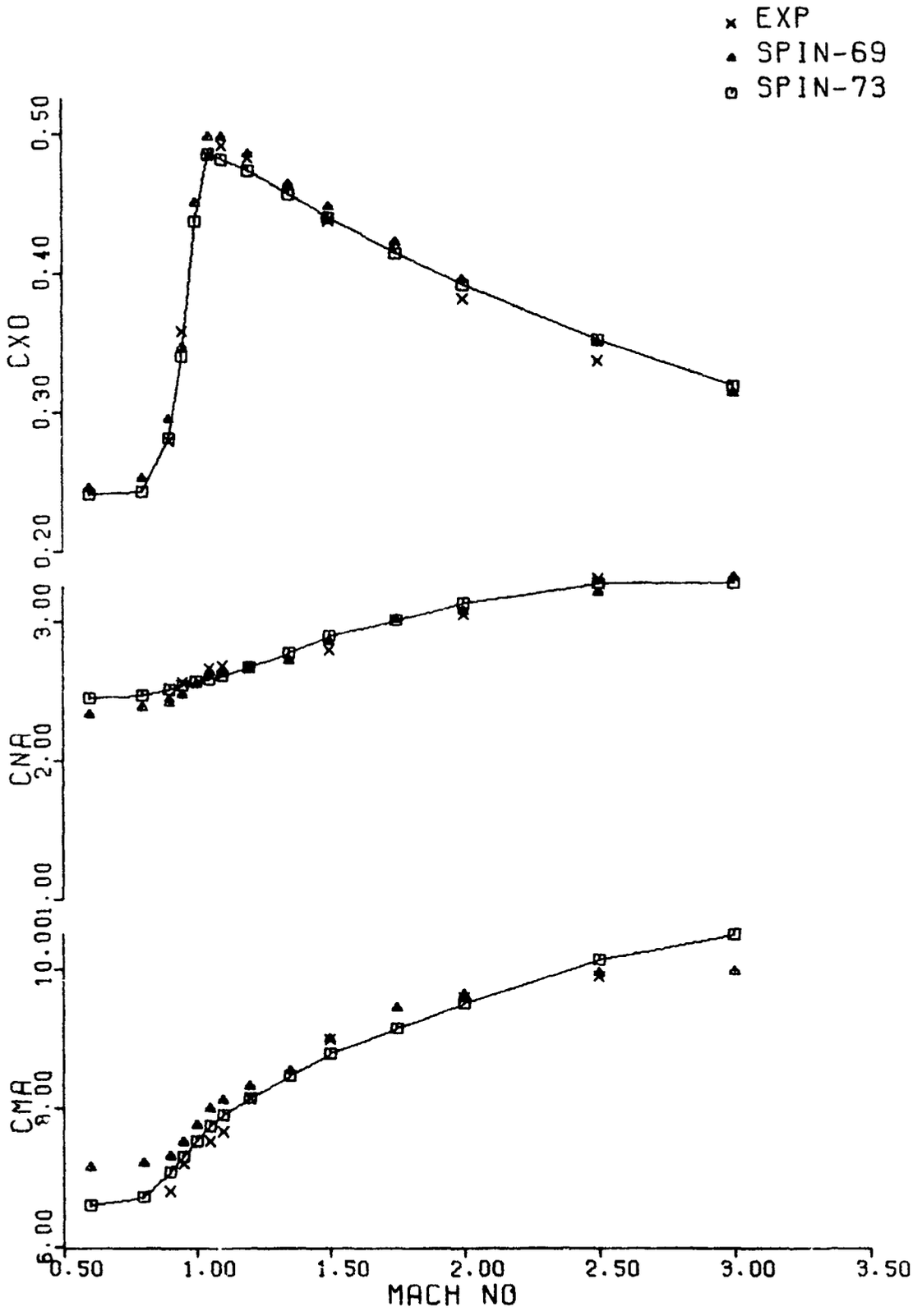
TOTAL LENGTH	NOSE LENGTH	BOAT TAIL LENGTH	Cg (FM NOSE)	MEPLAT DIAMETER	BASE DIAMETER	NOSE RADIUS	BODY LENGTH
9.000	2.000	0.000	5.050	0.000	1.000	8.000	0.000

DIAMETER INCHES	Ix LB-IN-SC	Iy LB-IN-SC	WEIGHT LBS	GUN TWIST CAL/TURN	ACTUAL TWIST CAL/TURN	GUN-BORE INCHES	TEMPERATURE DEG-F	AIR DENSITY SLUGS/FT**3
0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.00270

AERODYNAMIC COEFFICIENTS

MACH	CX	CX2	CNA	CMA	CPM	CYPA	CNPA	CNPA3	CNPA5	CPFM1	CPFM5	CNPAM5	CMQ	CLP
0.010	0.242	3.445	2.460	6.503	2.366	-1.440	-.900	175.583	-1716.333	4.425	5.525	0.684	-71.175	-.059
0.600	0.242	3.445	2.460	6.628	2.356	-1.440	-.900	175.583	-1716.333	4.425	5.525	0.684	-71.175	-.059
0.800	0.244	3.935	2.480	6.792	2.336	-1.440	-.612	159.583	-1558.333	4.625	5.625	0.828	-71.175	-.057
0.900	0.282	4.407	2.525	7.110	2.234	-1.620	-.041	116.583	-1128.333	5.025	5.675	1.012	-74.409	-.048
0.950	0.341	4.882	2.553	7.330	2.179	-2.070	0.569	91.583	-878.333	5.325	5.725	1.397	-76.706	-.041
1.000	0.438	5.635	2.585	7.537	2.135	-1.890	0.709	62.583	-588.333	5.425	5.725	1.276	-80.734	-.039
1.050	0.486	6.411	2.594	7.746	2.056	-1.710	0.812	37.583	-338.333	5.525	5.725	1.154	-80.487	-.039
1.100	0.482	7.173	2.617	7.913	2.027	-1.620	0.850	26.583	-228.333	5.575	5.725	1.093	-85.099	-.039
1.200	0.474	8.166	2.684	8.140	2.010	-1.440	0.799	18.783	-150.333	5.605	5.725	0.972	-90.441	-.038
1.350	0.457	7.566	2.784	8.475	2.006	-1.440	0.828	15.583	-118.333	5.625	5.725	0.972	-100.139	-.038
1.500	0.440	6.946	2.904	8.801	2.020	-1.440	1.274	13.983	-102.333	5.935	6.025	1.404	-114.066	-.038
1.750	0.414	6.336	3.014	9.170	2.008	-1.440	1.721	12.383	-86.333	6.245	6.325	1.836	-120.066	-.037
2.000	0.391	5.715	3.135	9.522	2.012	-1.440	2.167	10.783	-70.333	6.555	6.625	2.268	-126.066	-.036
2.500	0.351	5.055	3.275	10.140	1.954	-1.440	2.182	9.183	-54.333	6.565	6.625	2.268	-132.066	-.034
3.000	0.318	4.279	3.266	10.508	1.833	-1.440	2.066	7.583	-38.333	6.485	6.535	2.138	-132.066	-.033
4.000	0.280	3.594	3.166	10.281	1.803	-1.440	1.980	7.583	-38.333	6.425	6.475	2.052	-126.066	-.032
5.000	0.258	2.909	3.066	10.048	1.773	-1.440	1.764	7.583	-38.333	6.275	6.325	1.836	-117.066	-.031

Boat Ammunition Corp.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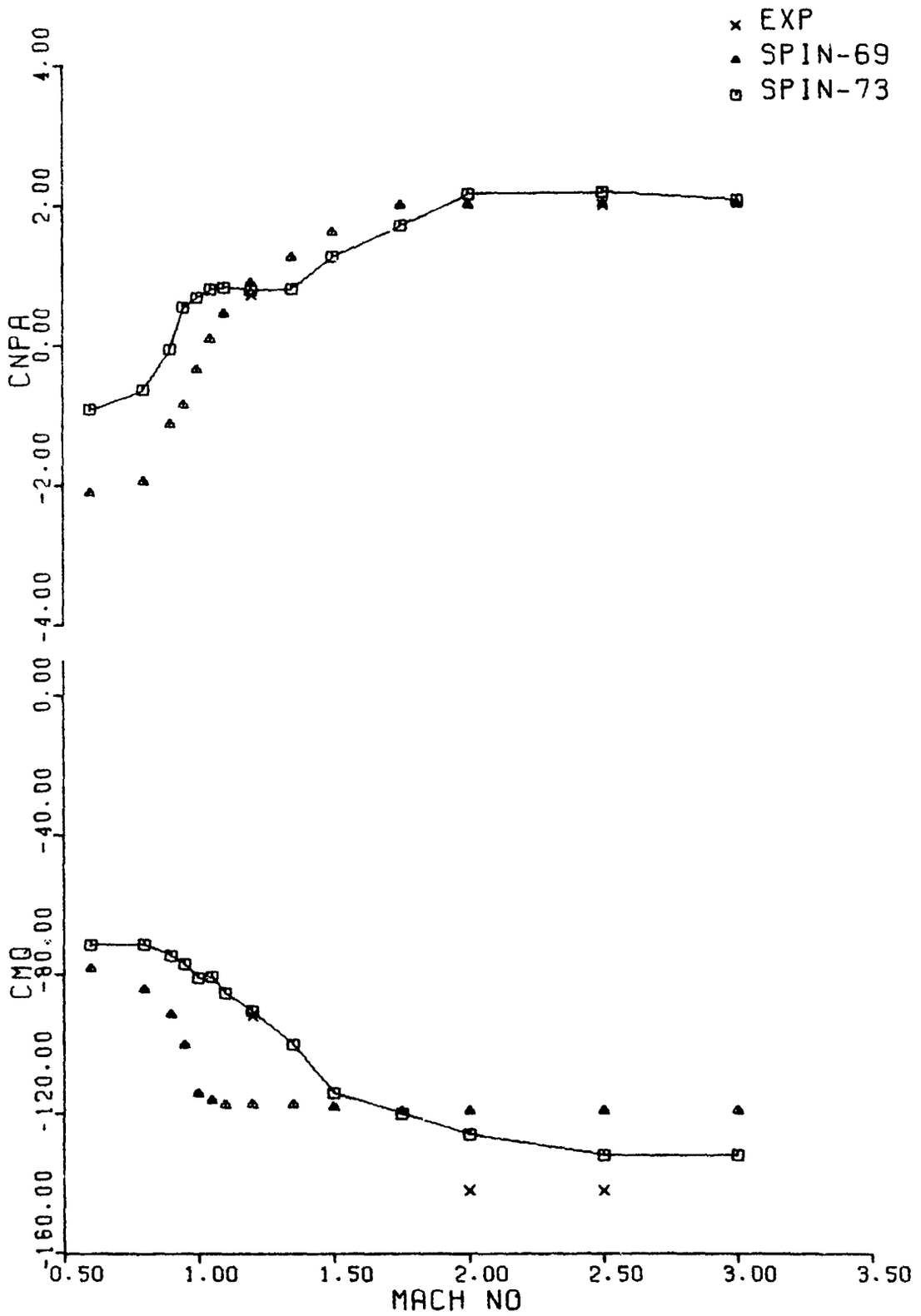


...BODY INCLUDING SEGMENT
CONE CYL

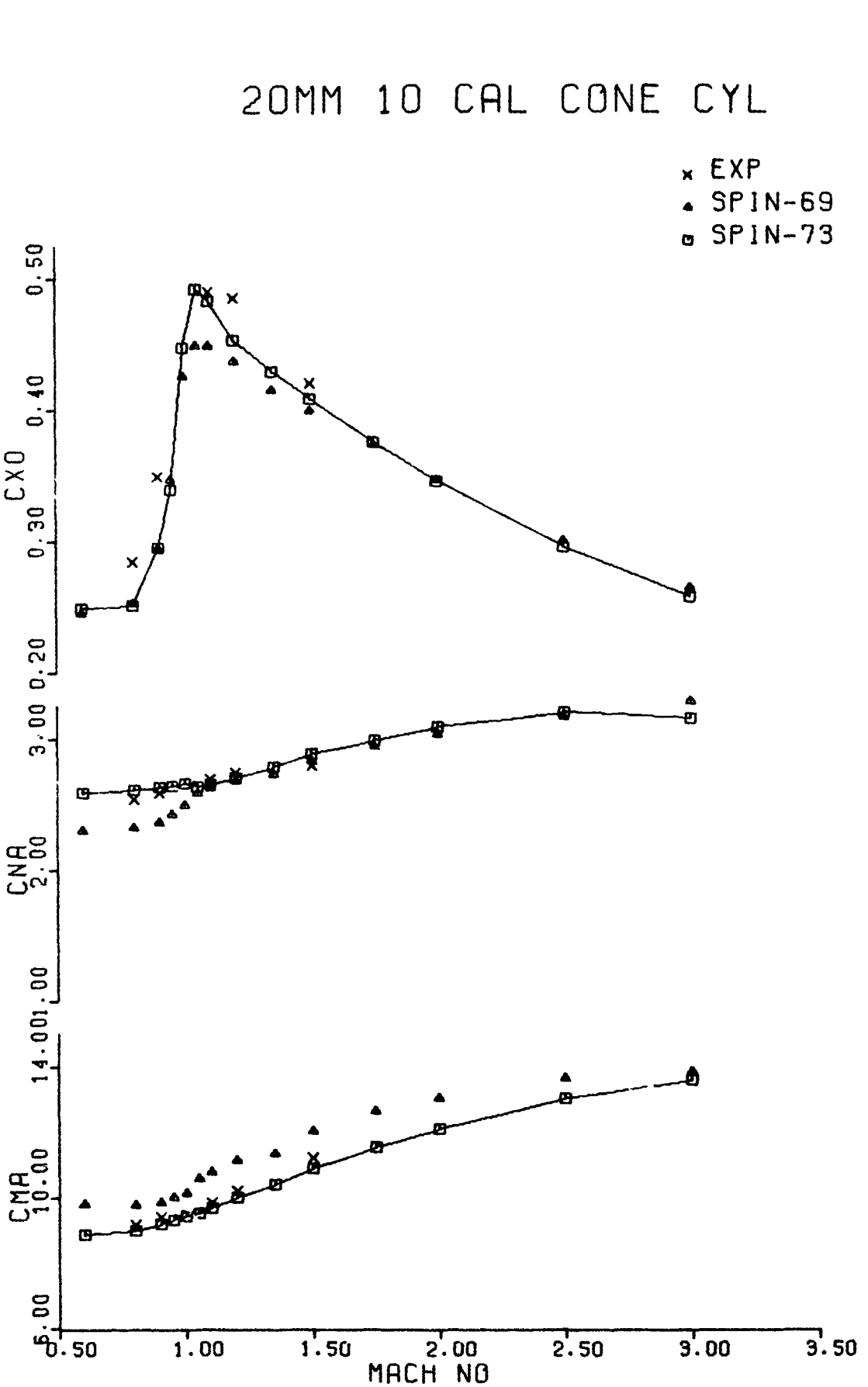
TOTAL LENGTH	NOSE LENGTH	AFT TAIL LENGTH	C_N (FOR NOSE)	MIDPLAT DIAMETER	BASE DIAMETER	NOSE RADIUS	BOOM LENGTH
10.000	2.834	0.000	4.747	0.000	1.000	1000.000	0.000

DIAMETER INCHES	IX LB-IN-SQ	IY LB-IN-SQ	WEIGHT LB	GUN THRUST CALCULMA	ACTUAL THRUST CALCULMA	GUN-NOSE INCHES	TEMPERATURE DEG-F	AIR DENSITY SLUGS/FT**3
1.000	0.00	0.000	0.000	0.000	0.000	0.000	0.000	0.00270

AERODYNAMIC COEFFICIENTS

MACH	C_A	$C_{N\alpha}$	C_{MA}	C_{MA}	C_{PN}	C_{YPA}	C_{NPA}	C_{NPA3}	C_{NPA5}	$C_{PF=1}$	$C_{PF=5}$	$C_{NPA=5}$	C_{MQ}	C_{LP}
0.010	0.258	3.197	2.690	8.983	3.122	-1.600	-2.501	195.139	-1913.889	5.184	4.784	-.741	-37.685	-.066
0.600	0.258	3.199	2.693	8.958	3.117	-1.600	-2.501	195.139	-1913.889	5.184	4.784	-.741	-37.685	-.066
0.800	0.252	3.44	2.820	9.090	3.292	-1.600	-2.181	177.341	-1734.111	5.384	4.984	-.581	-37.685	-.063
0.900	0.296	4.154	2.837	9.238	3.247	-1.600	-1.733	139.683	-1394.111	5.784	4.434	-.583	-41.325	-.053
0.950	0.340	4.93	2.851	9.389	3.217	-2.300	-1.525	101.806	-980.556	6.084	4.484	-.605	-43.337	-.046
1.000	0.444	5.251	2.870	9.447	3.193	-2.100	-1.182	59.583	-459.111	6.184	4.484	-.552	-47.080	-.044
1.050	0.492	4.027	2.842	9.548	3.124	-1.900	-.980	41.806	-360.556	6.284	4.484	-.900	-44.433	-.043
1.100	0.483	4.754	2.858	9.718	3.084	-1.800	-.741	29.583	-298.111	6.334	4.484	-.473	-92.679	-.043
1.200	0.453	3.72	2.710	10.045	3.040	-1.400	-.413	20.917	-171.667	6.384	4.434	-.421	-80.861	-.042
1.250	0.429	3.13.	2.784	10.440	2.999	-1.600	-.581	17.361	-138.111	6.384	4.484	-.421	-79.080	-.042
1.500	0.448	4.554	2.886	10.819	2.985	-1.600	-.079	15.583	-118.111	6.784	4.484	0.219	-97.872	-.042
1.750	0.375	5.947	2.994	11.567	2.883	-1.600	0.731	13.800	+100.556	7.284	7.284	0.899	-105.872	-.041
2.000	0.345	6.345	3.095	12.117	2.833	-1.600	1.367	12.028	-82.778	7.614	7.484	1.499	-113.872	-.040
2.500	0.295	6.82	3.198	13.097	2.469	-1.400	1.483	10.250	-65.000	7.674	7.484	1.499	-121.872	-.038
3.000	0.257	6.123	3.152	13.587	2.434	-1.400	1.227	8.472	-47.222	7.514	7.564	1.307	-121.872	-.036
4.000	0.219	5.479	3.052	13.248	2.408	-1.600	1.099	8.472	-47.222	7.434	7.484	1.179	-113.872	-.035
5.000	0.197	5.035	2.952	12.902	2.376	-1.600	0.779	8.472	-47.222	7.234	7.284	0.859	-101.872	-.034

Approved for public release; distribution unlimited.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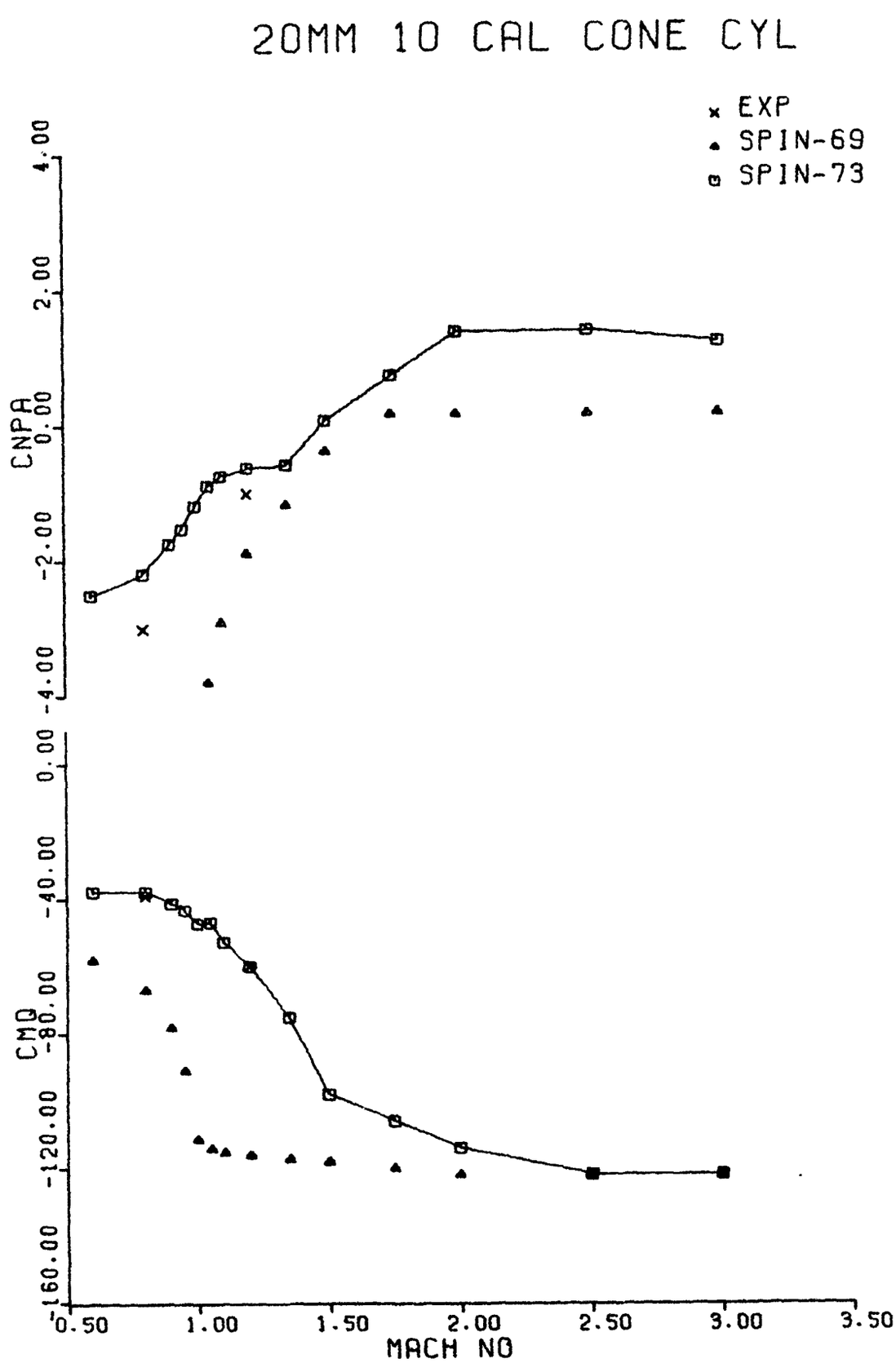
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MACH NO

BODY LENGTH	NOSE LENGTH	AFT BODY LENGTH	CG (FROM NOSE)	AFT BODY DIAMETER	MAX DIAMETER	NOSE RADIUS	NOSE LENGTH
4.700	2.300	0.900	2.900	0.133	1.224	0.900	0.000

DIAMETER INCHES	Ix LB-IN-SEC	Iy LB-IN-SEC	WEIGHT LBS	C.G. TABLE CAL/GRAM	ACTUAL TABLE CAL/GRAM	C.G.-BOMB INCHES	TEMPERATURE DEG-F	AIR DENSITY SLUGS/FT**3
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00270

AERODYNAMIC COEFFICIENTS

MACH	C_A	$C_{N\alpha}$	C_{mq}	$C_{m\dot{\alpha}}$	$C_{m\alpha}$	C_{YPA}	C_{NPA}	C_{AMA3}	C_{AMAD}	C_{AFM1}	C_{MFMA}	C_{NPAMB}	C_{MQ}	C_{LP}
0.910	0.197	2.551	1.471	3.939	0.424	-.002	-.491	91.494	-477.444	2.347	3.399	0.336	-7.495	-.031
0.930	0.197	2.551	1.473	3.948	0.419	-.002	-.491	91.494	-477.444	2.347	3.399	0.336	-7.495	-.031
0.950	0.199	2.571	1.493	4.178	0.419	-.002	-.341	83.119	-793.886	3.549	3.493	0.411	-7.495	-.030
0.970	0.245	3.017	1.745	4.671	0.417	-.002	-.089	69.683	-964.333	2.881	3.494	0.441	-9.746	-.029
0.990	0.333	4.221	1.927	4.619	0.424	-1.131	0.111	47.428	-438.778	3.040	3.492	0.540	-12.134	-.022
1.000	0.427	4.494	2.101	4.493	0.436	-1.837	0.211	39.683	-387.111	3.204	3.490	0.579	-13.998	-.020
1.190	0.469	5.024	2.147	4.131	1.474	-.941	0.333	19.428	-134.778	3.333	3.523	0.512	-15.474	-.020
1.100	0.435	5.58	2.222	4.003	1.138	-.896	0.374	13.683	-99.333	3.440	3.542	0.503	-14.758	-.020
1.200	0.403	6.137	2.287	4.849	1.214	-.802	0.396	9.418	-58.418	3.474	3.484	0.486	-16.902	-.020
1.390	0.389	5.527	2.437	3.889	1.184	-.802	0.411	7.939	-41.889	3.493	3.586	0.484	-17.697	-.020
1.500	0.374	4.941	2.573	4.912	1.421	-.802	0.419	7.103	-33.533	3.502	3.584	0.486	-17.299	-.020
1.790	0.351	4.374	2.698	1.891	1.933	-.802	0.426	6.268	-25.178	3.511	3.586	0.486	-17.299	-.019
2.000	0.330	3.824	2.798	3.832	1.407	-.802	0.434	5.432	-16.822	3.521	3.584	0.486	-17.299	-.019
2.500	0.293	3.099	2.912	3.759	1.499	-.802	0.441	41597	-8.467	3.530	3.584	0.486	-17.299	-.018
3.000	0.281	2.567	2.903	3.595	1.743	-.802	0.449	3.741	-.111	3.540	3.584	0.486	-17.299	-.017
4.000	0.223	2.105	2.803	3.542	1.709	-.802	0.449	3.741	-.111	3.540	3.586	0.486	-17.299	-.017
5.000	0.201	1.644	2.703	3.594	1.474	-.802	0.449	3.741	-.111	3.540	3.584	0.486	-17.299	-.016

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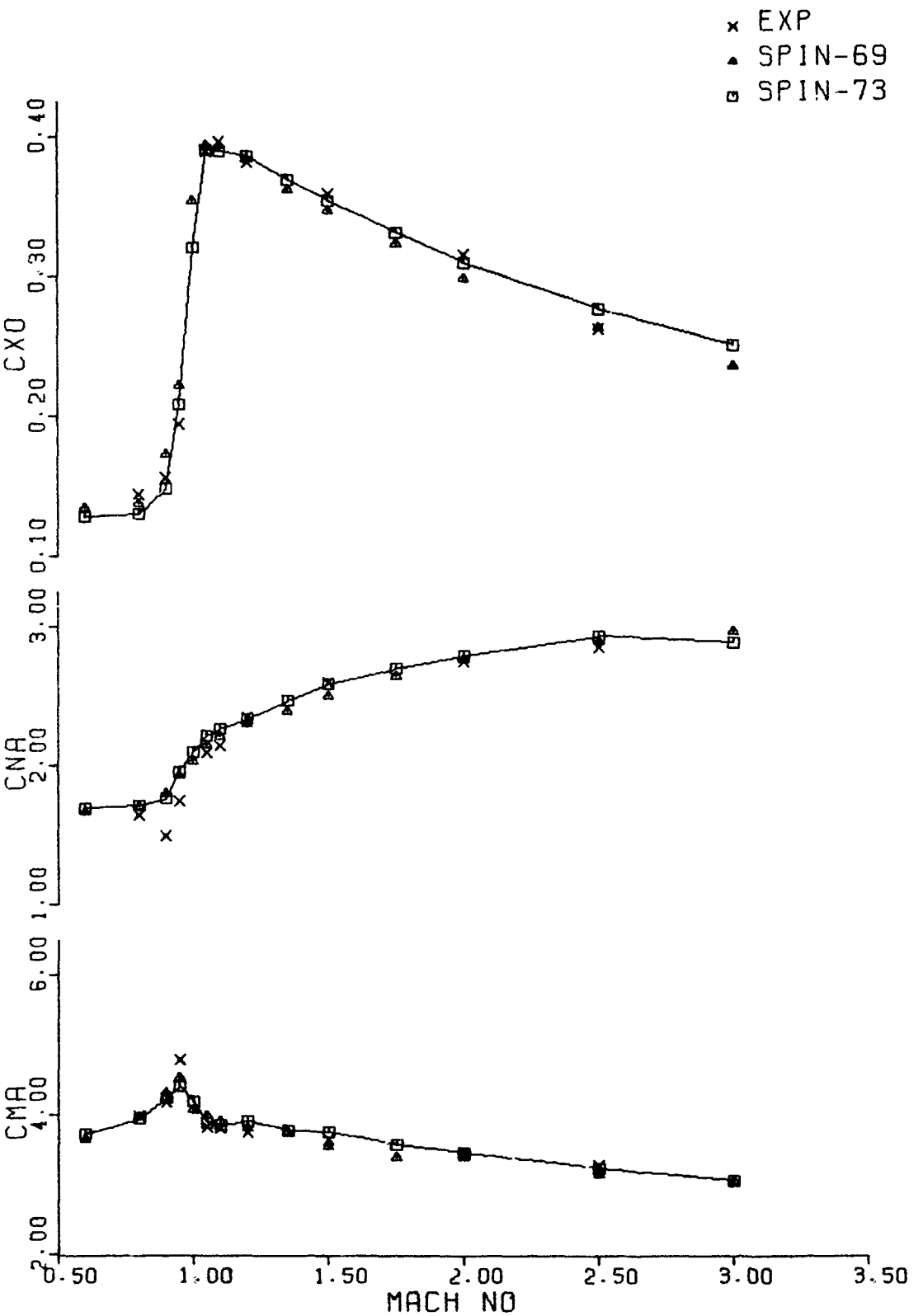
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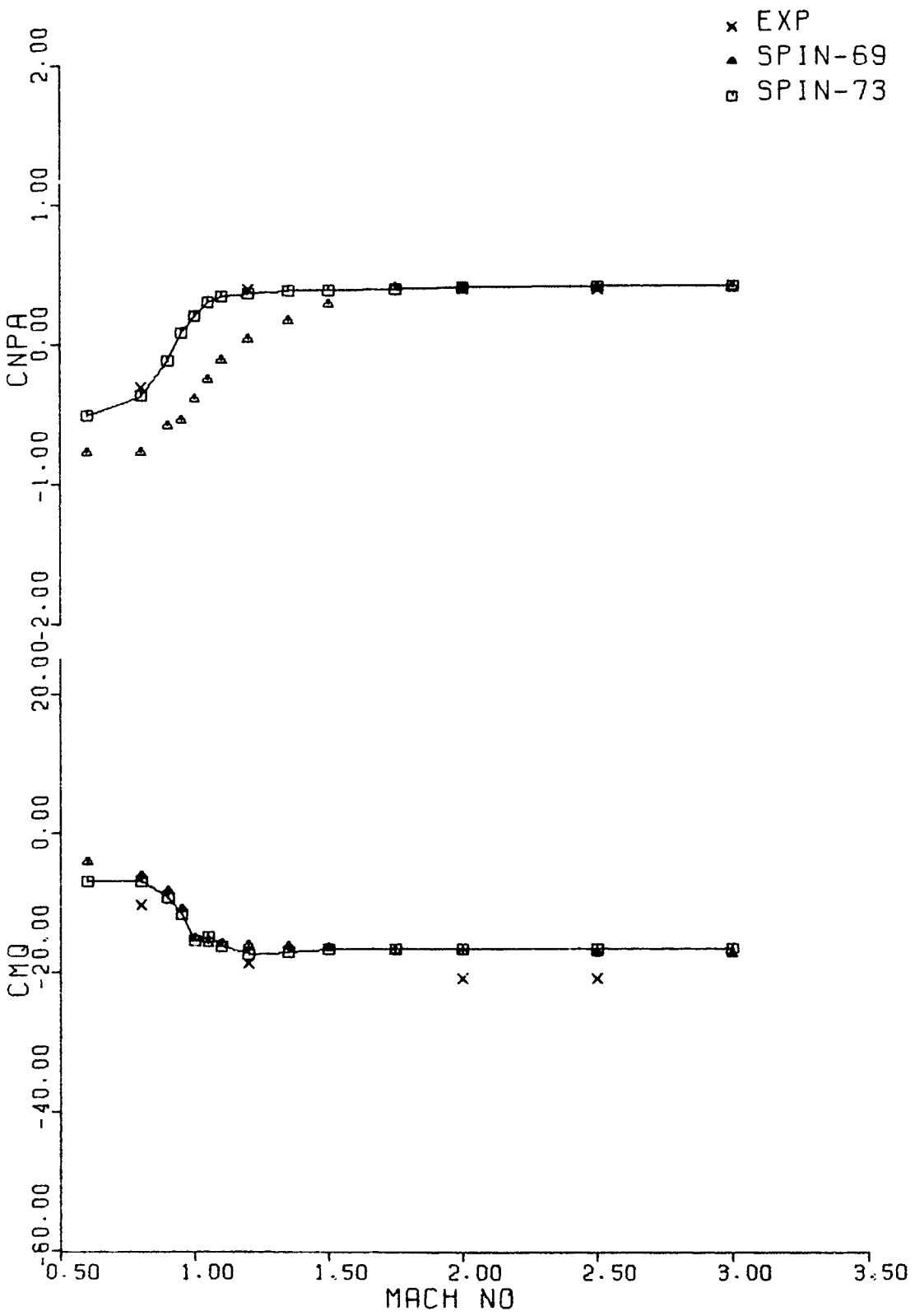
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MACH NO

TOTAL LENGTH	NOSE LENGTH	AFT TAIL LENGTH	CG (FM NOSE)	REFLAT DIAMETER	BODY DIAMETER	NOSE RADIUS	BODY LENGTH
4.700	2.300	0.900	2.900	0.133	1.224	0.900	0.000

DIAMETER INCHES	IX LB-IN-SC	IY LB-IN-SC	WEIGHT LBS	GUN TUBE CAL/TUBE	ACTUAL TUBE CAL/TUBE	GUN-BORE INCHES	TEMPERATURE DEG-F	AIR DENSITY SLUGS/FT**3
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00270

AERODYNAMIC COEFFICIENTS

MACH	CA	CN2	CNA	CMA	CYN	CYPA	CNPA	CNPA3	CAPA3	CAPA5	CAPM1	CPPM4	CNPA5	CMQ	CLP
0.010	0.127	2.551	1.471	3.939	0.424	-.802	0.491	91.494	-477.444	2.347	1.109	0.336	-7.495	-.031
0.600	0.127	2.551	1.471	3.940	0.419	-.802	0.491	91.494	-477.444	2.347	1.109	0.336	-7.495	-.031
0.800	0.129	2.571	1.493	4.178	0.419	-.802	0.461	83.119	-393.886	2.545	1.491	0.411	-7.495	-.030
0.900	0.145	3.017	1.745	4.473	0.417	-.896	0.449	68.483	-509.313	2.881	1.494	0.441	-9.748	-.029
0.950	0.233	4.221	1.927	4.645	0.479	-1.131	0.419	47.428	-434.778	3.080	1.462	0.546	-12.134	-.022
1.000	0.127	4.499	2.101	4.473	5.036	-1.037	0.253	32.483	-287.111	3.274	1.490	0.529	-15.998	-.028
1.050	0.405	5.054	2.167	4.181	1.474	-.943	0.333	19.428	-194.778	3.393	3.923	0.512	-15.474	-.028
1.100	0.425	5.56	2.222	4.003	1.438	-.896	0.374	13.483	-99.731	3.474	3.942	0.503	-16.758	-.028
1.200	0.403	6.107	2.387	4.049	1.914	-.802	0.396	9.410	-58.410	3.474	3.586	0.486	-18.007	-.028
1.350	0.389	5.527	2.437	3.449	1.186	-.802	0.411	7.919	-41.889	3.493	3.586	0.486	-17.697	-.028
1.500	0.374	4.961	2.573	4.012	1.421	-.802	0.419	7.103	-33.431	3.502	3.586	0.486	-17.299	-.028
1.750	0.391	4.374	2.490	3.491	1.933	-.802	0.426	6.268	-29.178	3.511	3.586	0.486	-17.299	-.019
2.000	0.330	3.824	2.798	3.837	1.407	-.802	0.434	5.432	-16.822	3.521	3.586	0.486	-17.299	-.019
2.500	0.293	3.089	2.912	3.759	1.499	-.802	0.441	4.597	-8.467	3.530	3.586	0.486	-17.299	-.018
3.000	0.261	2.567	2.903	3.595	1.749	-.802	0.449	3.761	-.111	3.540	3.586	0.486	-17.299	-.017
4.000	0.223	2.145	2.803	3.542	1.709	-.802	0.449	3.761	-.111	3.540	3.586	0.486	-17.299	-.017
5.000	0.201	1.844	2.703	3.524	1.474	-.802	0.449	3.761	-.111	3.540	3.586	0.486	-17.299	-.016

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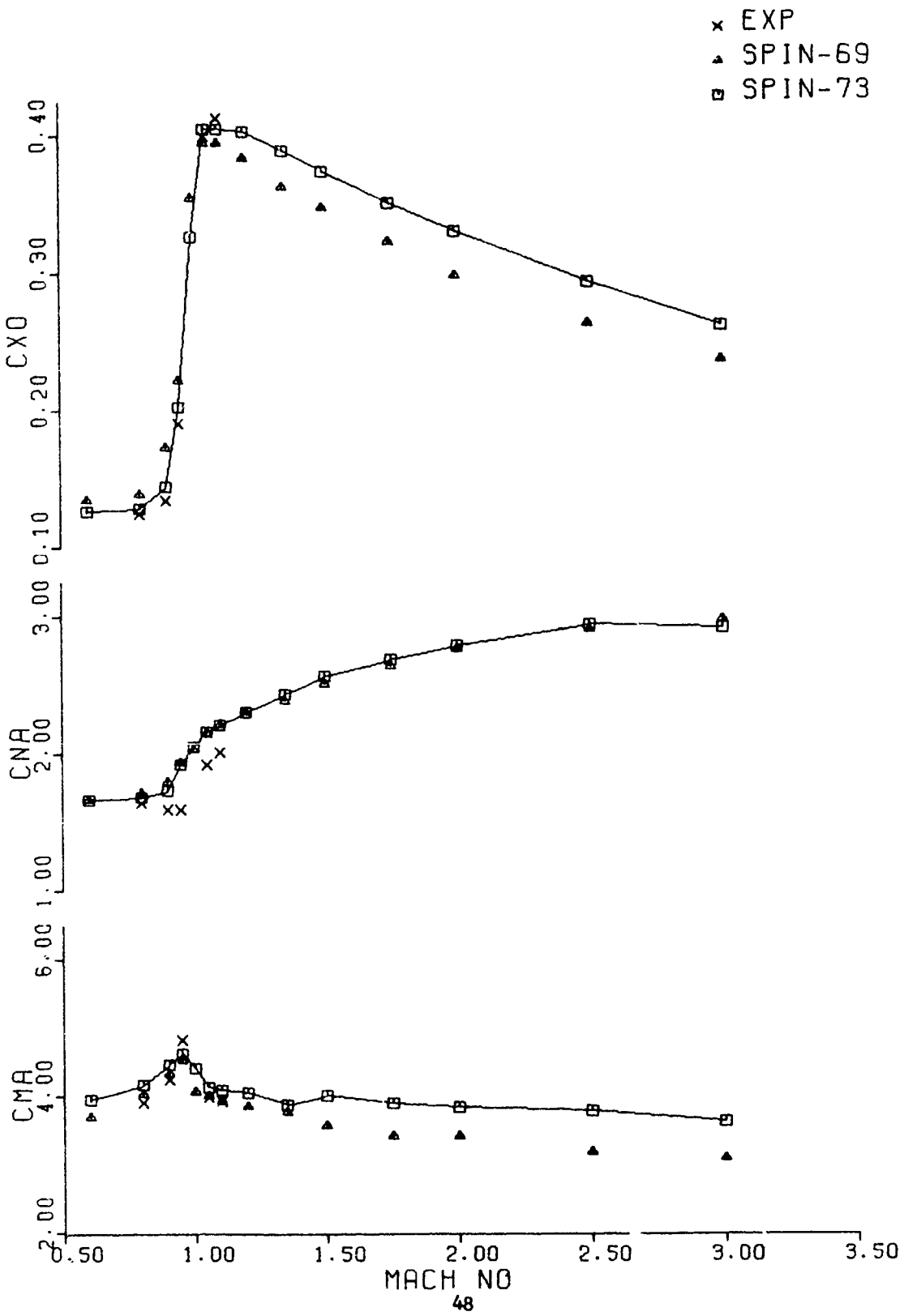
105MM M1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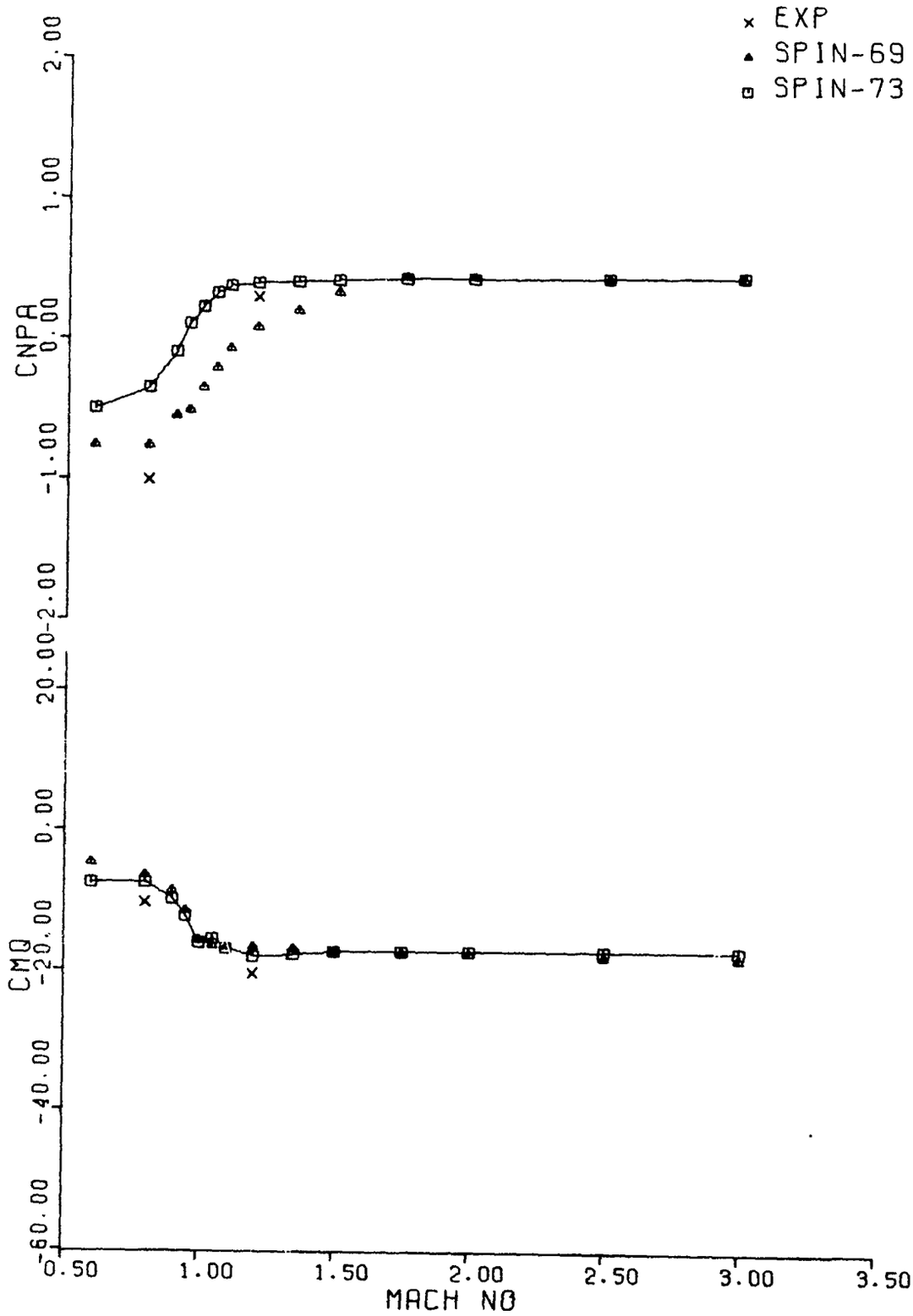
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MACH NO

GE BURLINGTON VERMONT
XM38PE5

TOTAL LENGTH	NOSE LENGTH	BOAT TAIL LENGTH	CG (FM NOSE)	MEPLAT DIAMETER	BAND DIAMETER	NOSE RADIUS	BOOM LENGTH
5.580	2.900	0.590	3.340	0.130	1.023	18.600	0.000

DIAMETER INCHES	Ix LB-IN-SC	IY LB-IN-SC	WEIGHT LBS	GUN TWIST CAL/TURN	ACTUAL TWIST CAL/TURN	GUN-BORE INCHES	TEMPERATURE DEG-F	AIR DENSITY SLUGS/FT**3
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00270

AERODYNAMIC COEFFICIENTS

MACH	CX	CX2	CNA	CMA	CGN	CYPA	CNPA	CNPA3	CNPA5	CPFM1	CPFM5	CNPAM5	CMQ	CLP
0.010	0.113	2.494	1.579	4.045	0.778	-.952	-.296	108.703	-1049.533	3.029	4.061	0.686	-15.510	-.037
0.600	0.113	2.494	1.579	4.070	0.762	-.952	-.296	108.703	-1049.533	3.029	4.061	0.686	-15.510	-.037
0.800	0.115	2.954	1.599	4.342	0.630	-.952	-.118	98.783	-950.333	3.217	4.155	0.775	-15.510	-.035
0.900	0.136	3.435	1.647	4.940	0.341	-1.063	0.207	72.123	-683.733	3.534	4.148	0.859	-17.799	-.030
0.950	0.185	4.954	1.753	4.908	0.488	-1.342	0.509	56.623	-524.733	3.719	4.102	1.023	-20.119	-.026
1.000	0.289	4.388	1.913	4.631	0.919	-1.231	0.626	38.643	-348.933	3.848	4.134	0.977	-23.869	-.024
1.050	0.345	4.844	2.050	4.301	1.242	-1.119	0.720	23.143	-198.933	3.984	4.173	0.932	-23.251	-.024
1.100	0.342	5.391	2.107	4.220	1.337	-1.063	0.759	16.323	-125.733	4.054	4.195	0.910	-24.968	-.024
1.200	0.333	5.913	2.198	4.134	1.459	-.952	0.757	11.487	-77.373	4.136	4.248	0.865	-26.770	-.024
1.350	0.316	5.354	2.316	3.996	1.615	-.952	0.775	9.503	-57.533	4.155	4.248	0.865	-27.869	-.023
1.500	0.300	4.786	2.443	3.872	1.755	-.952	0.784	8.511	-47.613	4.164	4.248	0.865	-28.028	-.023
1.750	0.276	4.221	2.567	3.686	1.904	-.952	0.793	7.519	-37.693	4.173	4.248	0.865	-28.028	-.023
2.000	0.256	3.652	2.695	3.431	2.067	-.952	0.802	6.527	-27.773	4.183	4.248	0.865	-28.028	-.022
2.500	0.224	2.992	2.845	3.075	2.259	-.952	0.811	5.535	-17.853	4.192	4.248	0.865	-28.028	-.021
3.000	0.203	2.521	2.781	2.891	2.301	-.952	0.820	4.543	-7.933	4.201	4.248	0.865	-28.028	-.020
4.000	0.165	2.086	2.681	2.870	2.270	-.952	0.820	4.543	-7.933	4.201	4.248	0.865	-28.028	-.020
5.000	0.143	1.651	2.581	2.843	2.239	-.952	0.820	4.543	-7.933	4.201	4.248	0.865	-28.028	-.019

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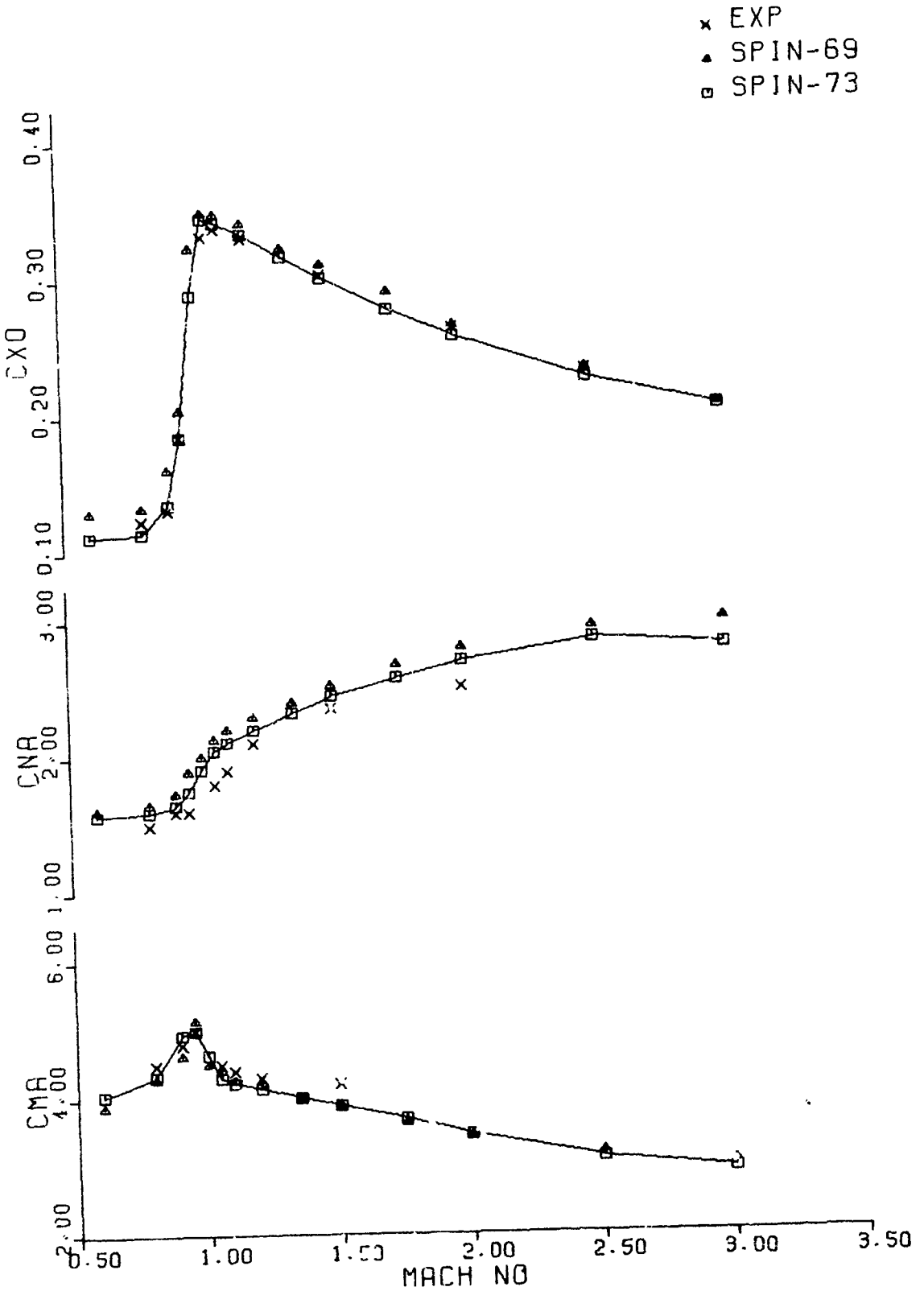

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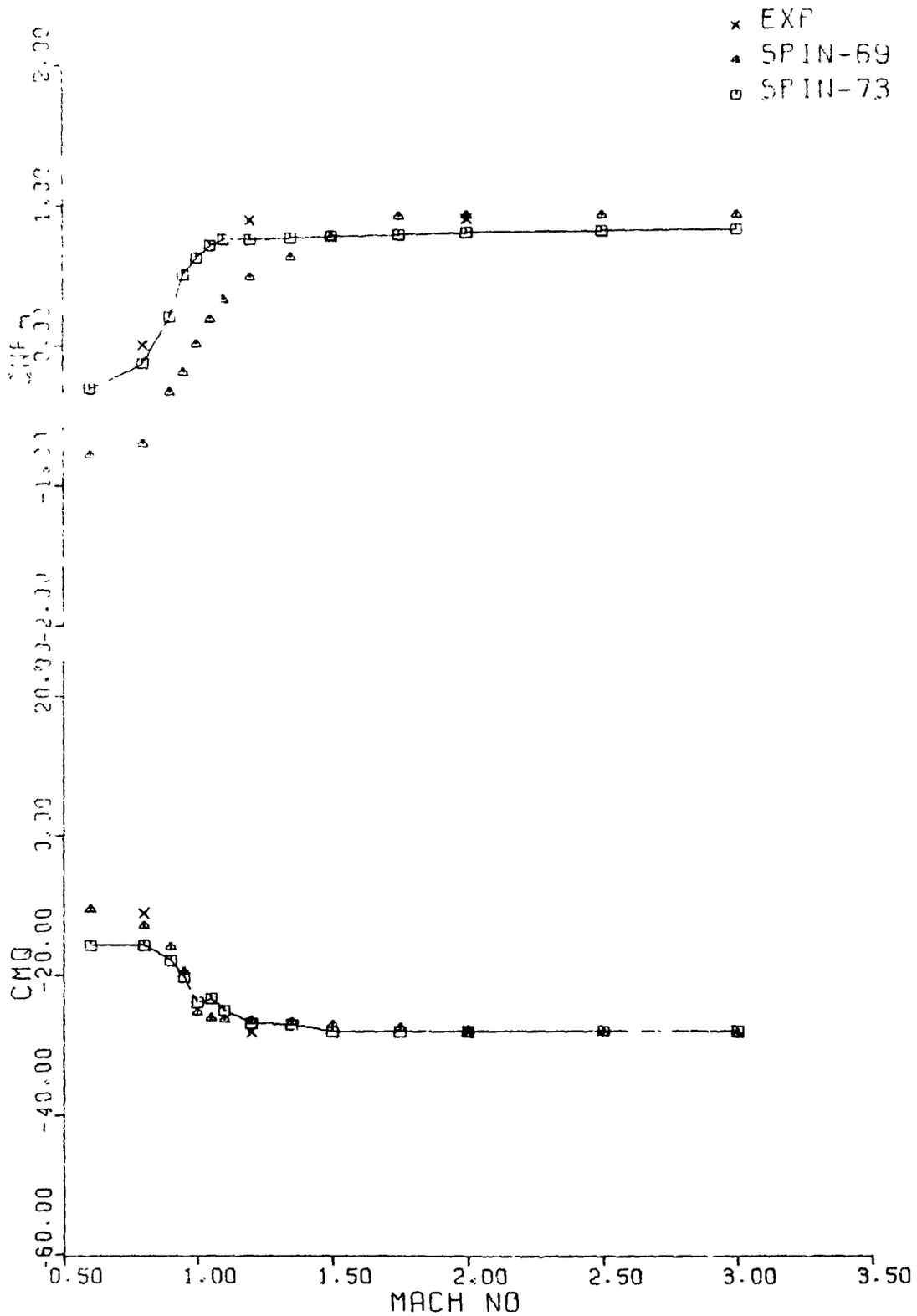

[illegible] REGION VERMONT
5/3M

TOTAL LENGTH	NOSE LENGTH	BOAT TAIL LENGTH	CG (FROM NOSE)	BASE DIAMETER	[illegible] DIAMETER	NOSE RADIUS	BODY LENGTH
4.593	2.150	0.350	2.719	0.100	[illegible]	5.300	0.000

PARAMETER NUMBER	IX LB-IN-S^2	IY LB-IN-S^2	WEIGHT LBS	GUN TWIST CAL/TURN	ACTUAL TWIST CAL/TURN	GUN-BORE INCHES	TEMPERATURE DEG-F	AIR DENSITY SLUGS/FT^3
1.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.00270

AERODYNAMIC COEFFICIENTS

MACH	CA	CA2	CNA	CMA	CYB	CYPA	CNPA	CNPA3	CMPAS	CMPM	CMPMS	CNPAMS	CMQ	CLP
0.800	0.167	2.64	1.799	3.494	0.769	-.769	-.589	89.343	-455.953	2.205	3.255	0.419	-9.419	-.030
0.800	0.167	2.64	1.799	3.514	0.757	-.769	-.589	89.343	-455.953	2.205	3.255	0.419	-9.419	-.030
0.900	0.169	3.167	1.819	3.690	0.681	-.769	-.242	81.183	-774.333	2.396	3.350	0.493	-9.419	-.029
0.900	0.185	3.674	1.874	3.843	0.438	-.841	0.028	59.253	-555.033	2.742	3.366	0.545	-11.750	-.024
0.950	0.245	4.139	2.045	4.335	0.468	-1.091	0.283	46.503	-427.533	2.970	3.357	0.706	-14.259	-.021
1.000	0.370	4.624	2.139	3.976	0.855	-.999	0.377	31.713	-279.633	3.087	3.377	0.666	-18.321	-.020
1.050	0.450	5.148	2.227	3.739	1.031	-.907	0.451	18.963	-152.133	3.208	3.400	0.626	-17.984	-.020
1.100	0.451	5.716	2.270	3.714	1.074	-.841	0.482	13.353	-96.033	3.270	3.414	0.606	-19.352	-.020
1.200	0.453	6.277	2.350	3.453	1.155	-.769	0.478	9.375	-56.253	3.331	3.446	0.586	-20.595	-.019
1.350	0.437	5.691	2.471	3.494	1.294	-.769	0.493	7.743	-39.933	3.350	3.446	0.586	-20.122	-.019
1.500	0.421	5.091	2.606	3.549	1.344	-.769	0.500	6.927	-31.773	3.360	3.446	0.586	-18.992	-.019
1.750	0.396	4.518	2.714	3.408	1.454	-.769	0.507	6.111	-23.613	3.369	3.446	0.586	-18.992	-.019
2.000	0.371	3.940	2.827	3.331	1.532	-.769	0.515	5.295	-15.453	3.379	3.446	0.586	-18.992	-.018
2.500	0.328	3.223	2.953	3.206	1.624	-.769	0.522	4.479	-7.293	3.388	3.446	0.586	-18.992	-.017
3.000	0.287	2.667	2.929	3.071	1.661	-.769	0.529	3.663	0.867	3.398	3.446	0.586	-18.992	-.017
4.000	0.249	2.191	2.829	3.060	1.624	-.769	0.529	3.663	0.867	3.398	3.446	0.586	-16.992	-.016
5.000	0.227	1.714	2.729	3.043	1.595	-.769	0.529	3.663	0.867	3.398	3.446	0.586	-18.992	-.016

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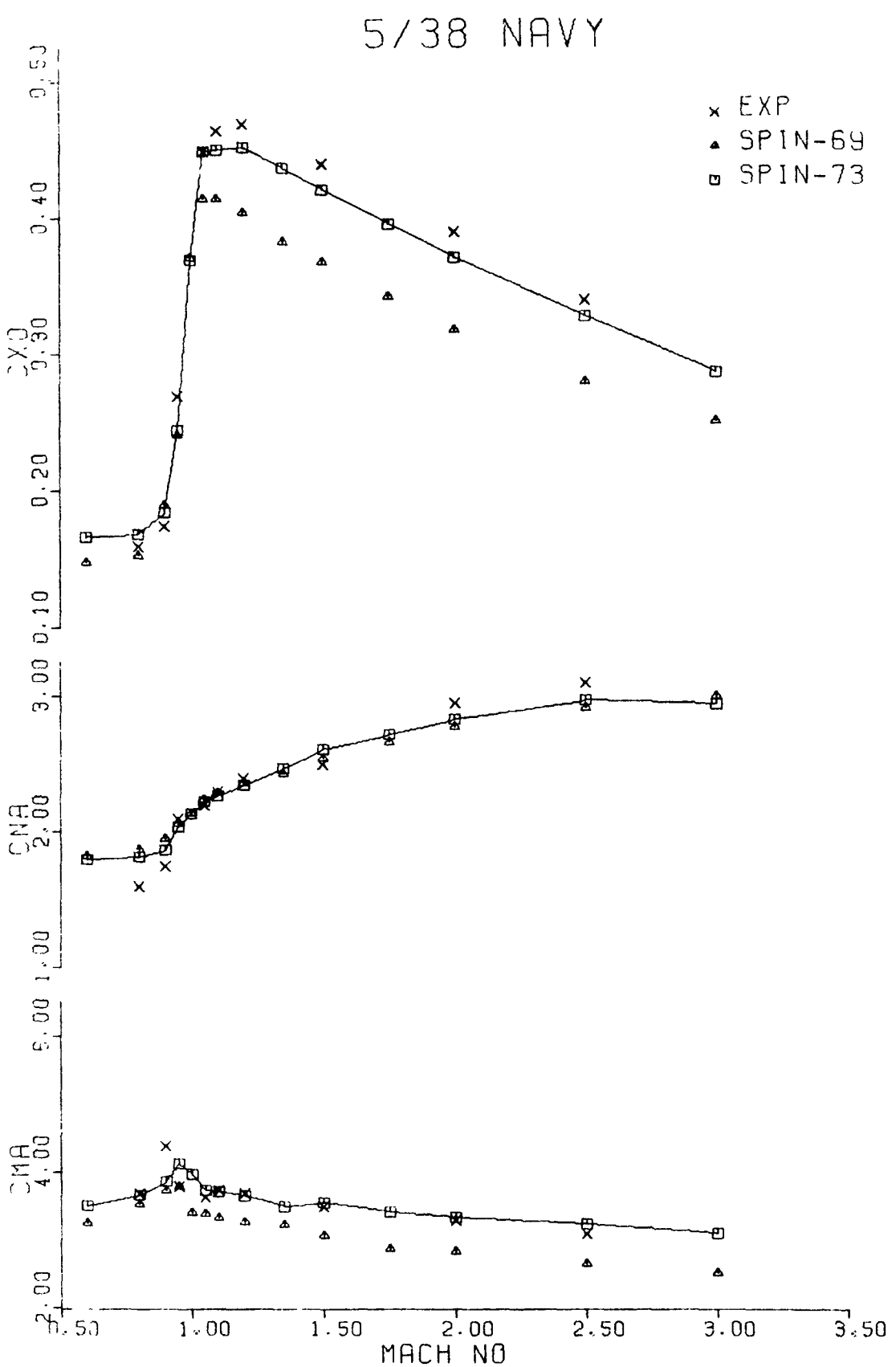
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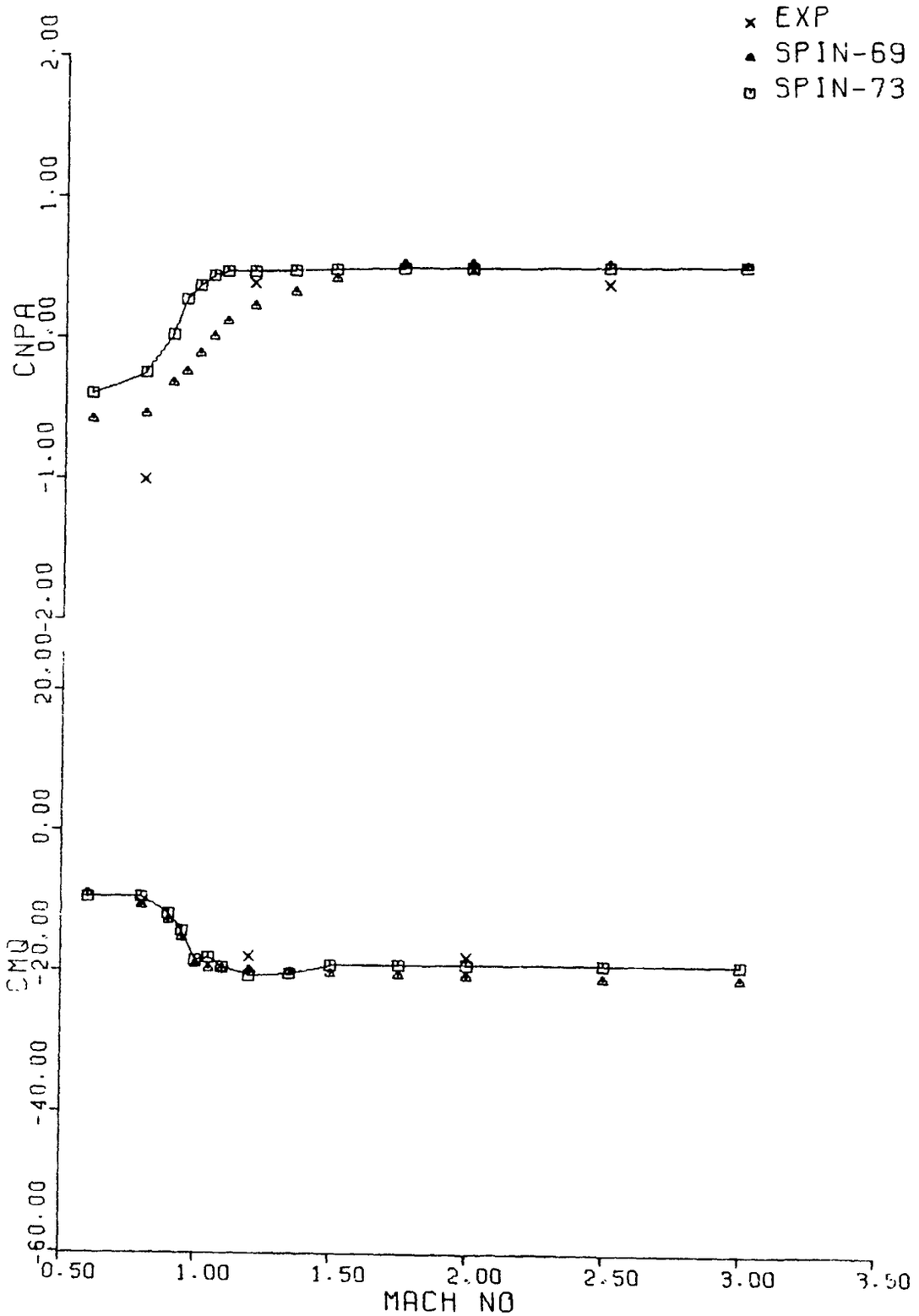
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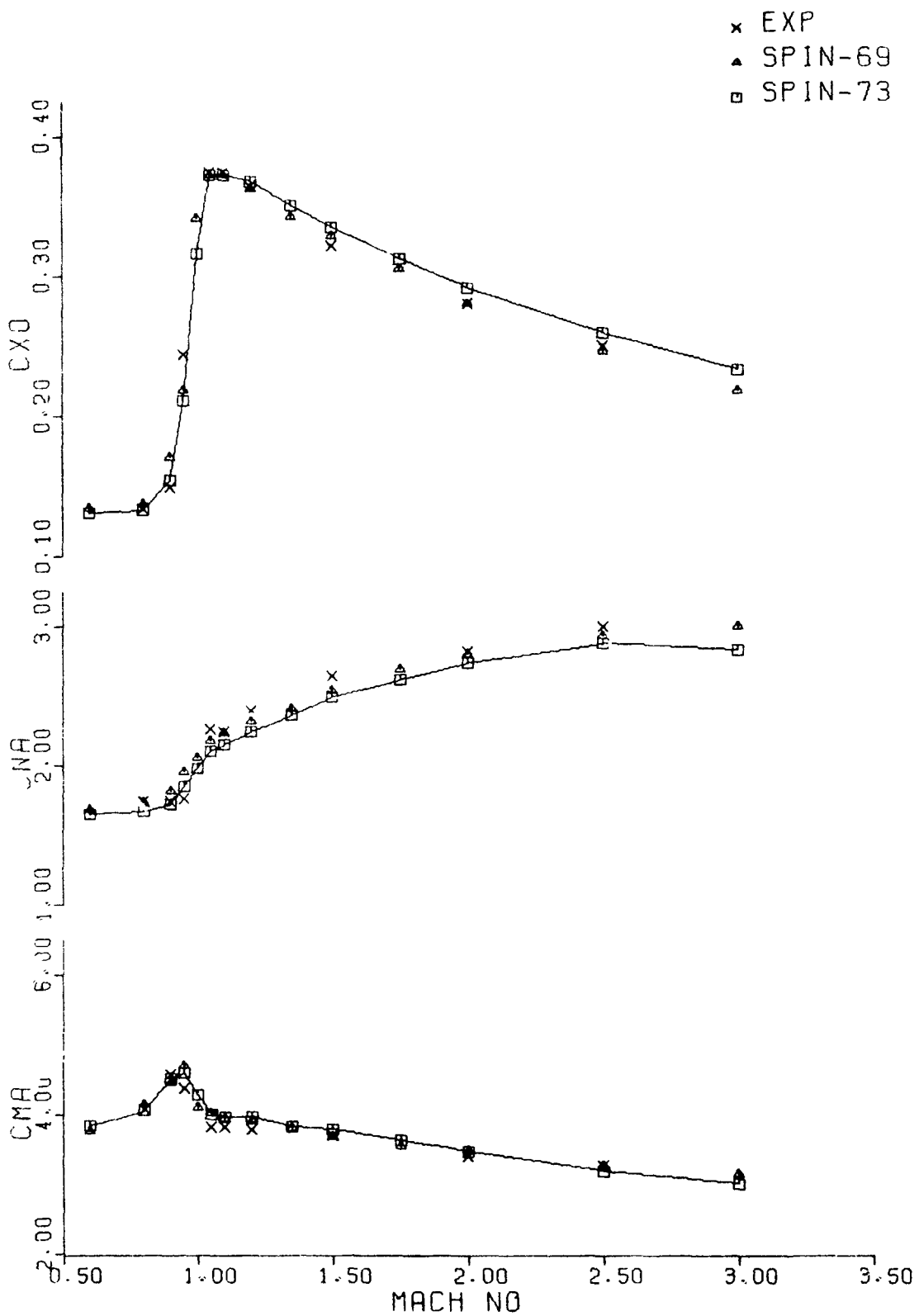
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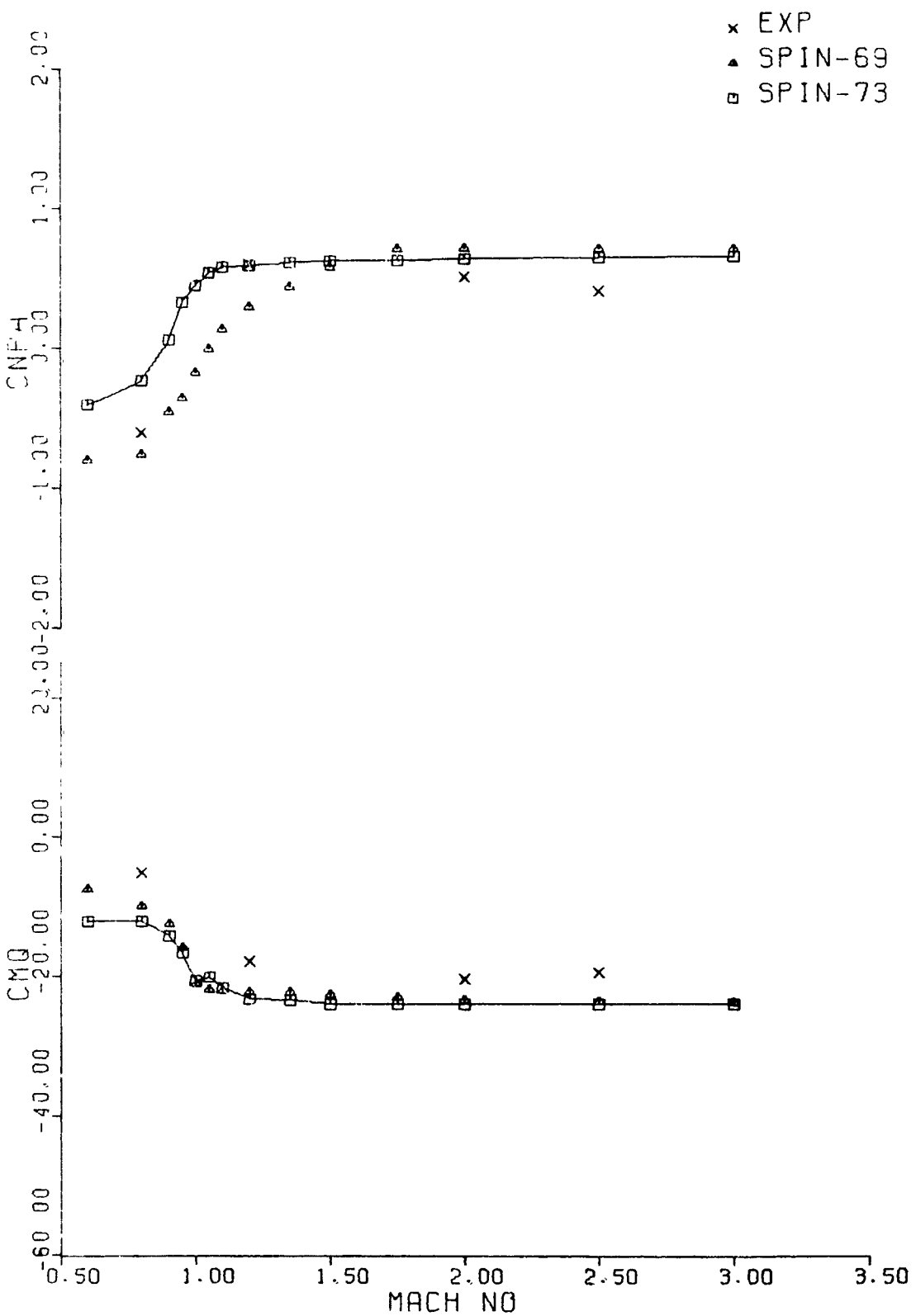
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[illegible] WASHINGTON, VERMONT
M181

TOTAL LENGTH	NOSE LENGTH	AFT TAIL LENGTH	C_N (FM NOSE)	MIDPLT DIAMETER	MAX DIAMETER	NOSE RADIUS	BODY LENGTH
4.910	2.490	0.450	2.980	0.000	1.020	10.750	0.000

DIAMETER INCHES	Ix LB-IN-SQ	Iy LB-IN-SQ	WEIGHT LBS	GUN TWIST CAL/TURN	ACTUAL TWIST CAL/TURN	GUN-BORE INCHES	TEMPERATURE DEG-F	AIR DENSITY SLUGS/FT**3
0.000	0.1[illegible]	0.000	0.000	0.000	0.000	0.000	0.000	0.00270

AERODYNAMIC COEFFICIENTS

MACH	C_D	$C_{N\alpha}$	C_{NA}	C_{mA}	C_{mN}	C_{YPA}	C_{nPA}	C_{NPA3}	C_{YPA3}	C_{ef-1}	C_{ef-2}	C_{NPA+3}	C_{MQ}	C_{LP}
0.010	[illegible]41	2.382	1.763	3.176	1.068	-.767	-.524	87.770	-440,249	2.277	1.512	0.270	-5.225	-.030
0.600	0.141	2.382	1.763	3.348	1.068	-.767	-.524	87.770	-440,249	2.277	1.512	0.270	-5.225	-.030
0.800	0.143	2.459	1.783	3.542	0.968	-.767	-.370	70.741	-[illegible]	2.445	1.404	0.342	-5.225	-.028
0.900	0.161	2.571	1.831	3.668	0.831	-.857	-.130	58.213	-544,443	2.797	1.413	0.388	-7.533	-.024
0.950	0.219	2.729	2.039	3.947	1.213	-1.082	0.058	49.486	-419,154	3.804	1.390	0.445	-9.961	-.021
1.000	0.425	4.177	2.151	3.770	1.208	-.992	0.146	31.153	-274,631	3.178	1.414	0.491	-13.492	-.020
1.050	0.486	4.661	2.232	3.542	1.174	-.902	0.265	18.496	-164,756	3.294	1.444	0.436	-13.436	-.019
1.100	0.483	5.182	2.279	3.508	1.441	-.857	0.307	13.113	-93,433	3.318	1.461	0.429	-14.461	-.019
1.200	0.474	5.484	2.350	3.596	1.447	-.767	0.328	9.205	-84,547	3.388	1.501	0.414	-15.845	-.019
1.350	0.457	5.113	2.444	3.494	1.471	-.767	0.349	7.601	-38,511	3.486	1.501	0.414	-15.661	-.019
1.500	0.442	4.542	2.501	3.372	1.494	-.767	0.349	6.709	-30,493	3.416	1.501	0.414	-15.343	-.019
1.750	0.318	3.970	2.690	3.196	1.772	-.767	0.357	5.908	-22,474	3.425	1.501	0.414	-15.343	-.018
2.000	0.298	3.443	2.770	3.070	1.459	-.767	0.344	5.196	-14,454	3.435	1.501	0.414	-15.343	-.018
2.500	0.286	2.784	2.898	2.931	1.981	-.767	0.371	4.394	-6,440	3.444	1.501	0.414	-15.343	-.017
3.000	0.242	2.312	2.849	2.648	2.038	-.767	0.378	3.592	1.578	3.454	1.501	0.414	-15.343	-.016
4.000	0.204	1.891	2.749	2.638	2.008	-.767	0.378	3.592	1.578	3.454	1.501	0.414	-15.343	-.016
5.000	0.182	1.469	2.649	2.691	1.978	-.767	0.378	3.592	1.578	3.454	1.501	0.414	-15.343	-.016

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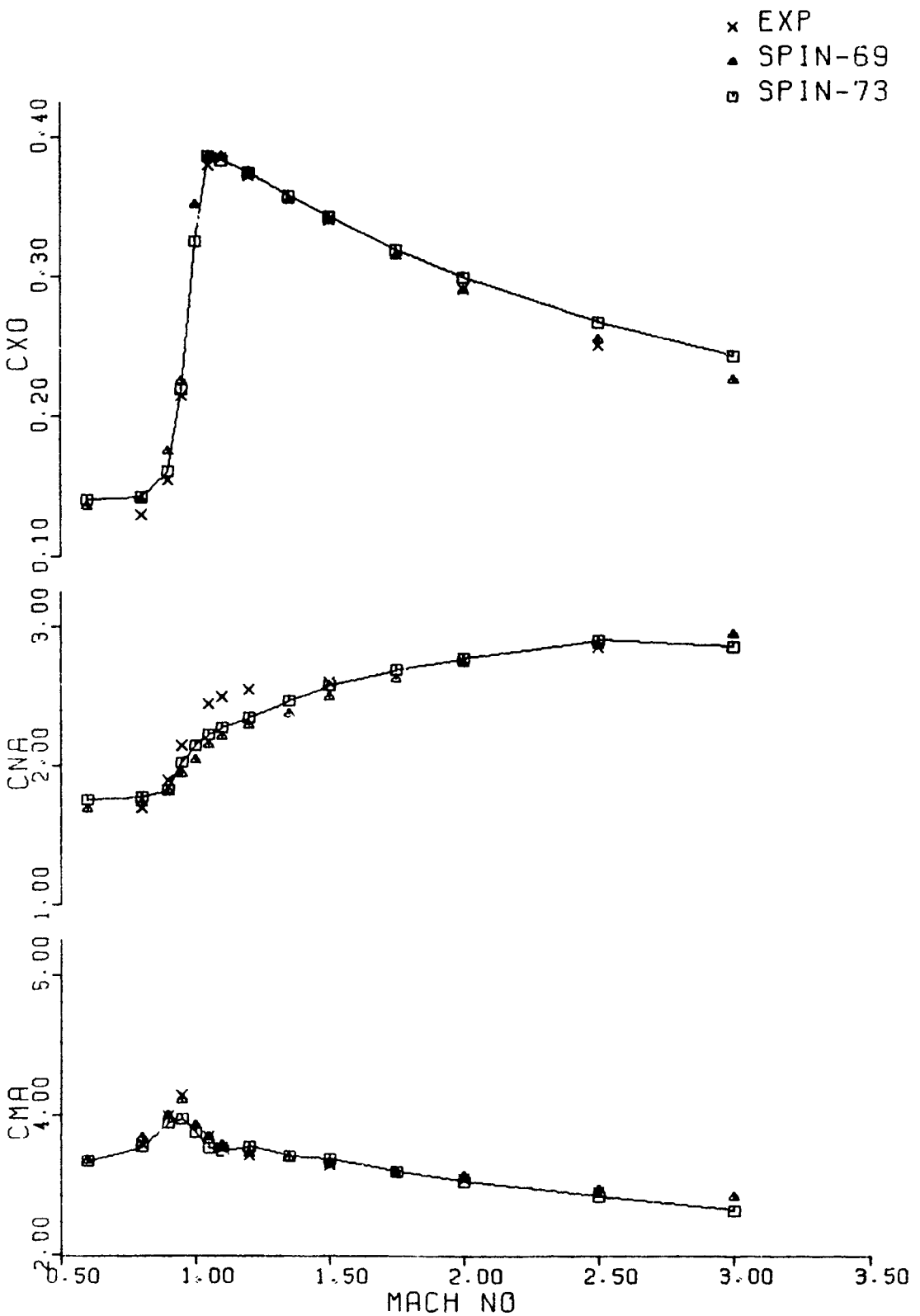

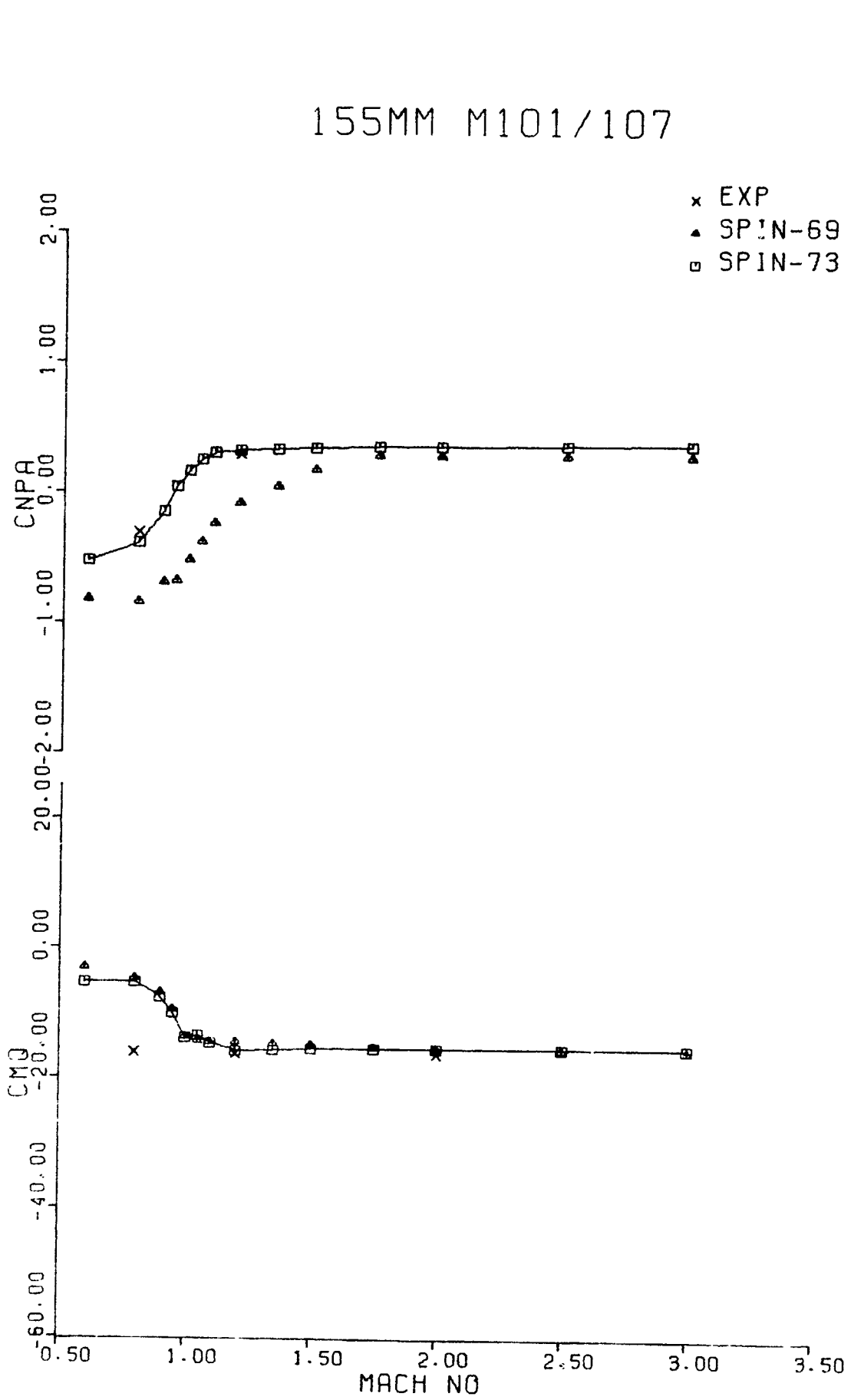
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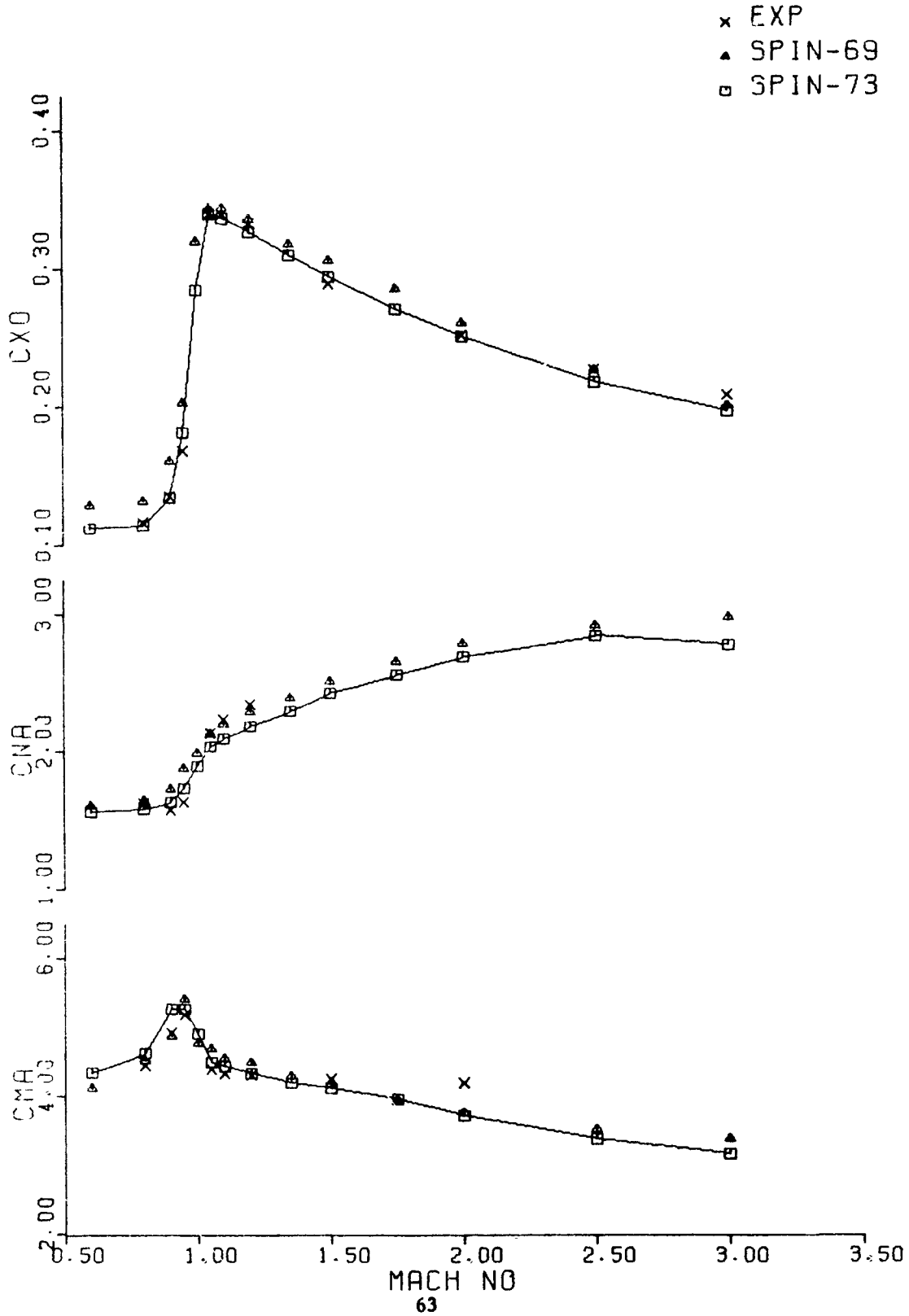
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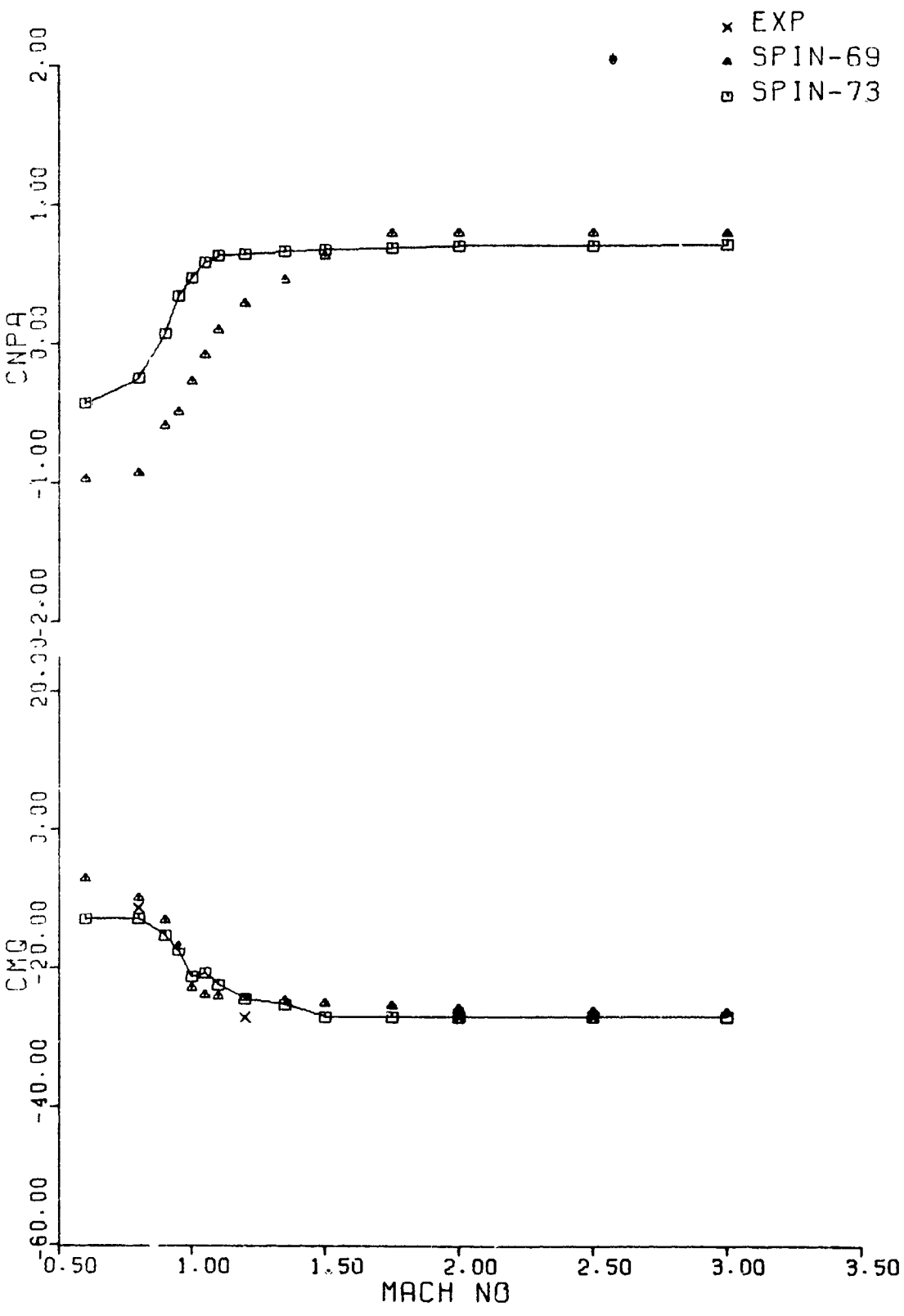
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[illegible] BODY [illegible] (FERMAT
175MM M437

TOTAL LENGTH	NOSE LENGTH	BOAT TAIL LENGTH	CG (FM NOSE)	BASE DIAMETER	BODY DIAMETER	NOSE RADIUS	BODY LENGTH
5.510	2.910	1.000	3.500	0.079	1.050	25.000	0.000

DIAMETER INCHES	IX LB-IN-SQ	IY LB-IN-SQ	WEIGHT LBS	GUN TWIST CAL/TURN	ACTUAL TWIST CAL/TURN	GUN-BORE INCHES	TEMPERATURE DEG-F	AIR DENSITY SLUGS/FT**
6.885	954.000	10850.000	148.000	20.000	20.000	6.885	59.000	0.00238

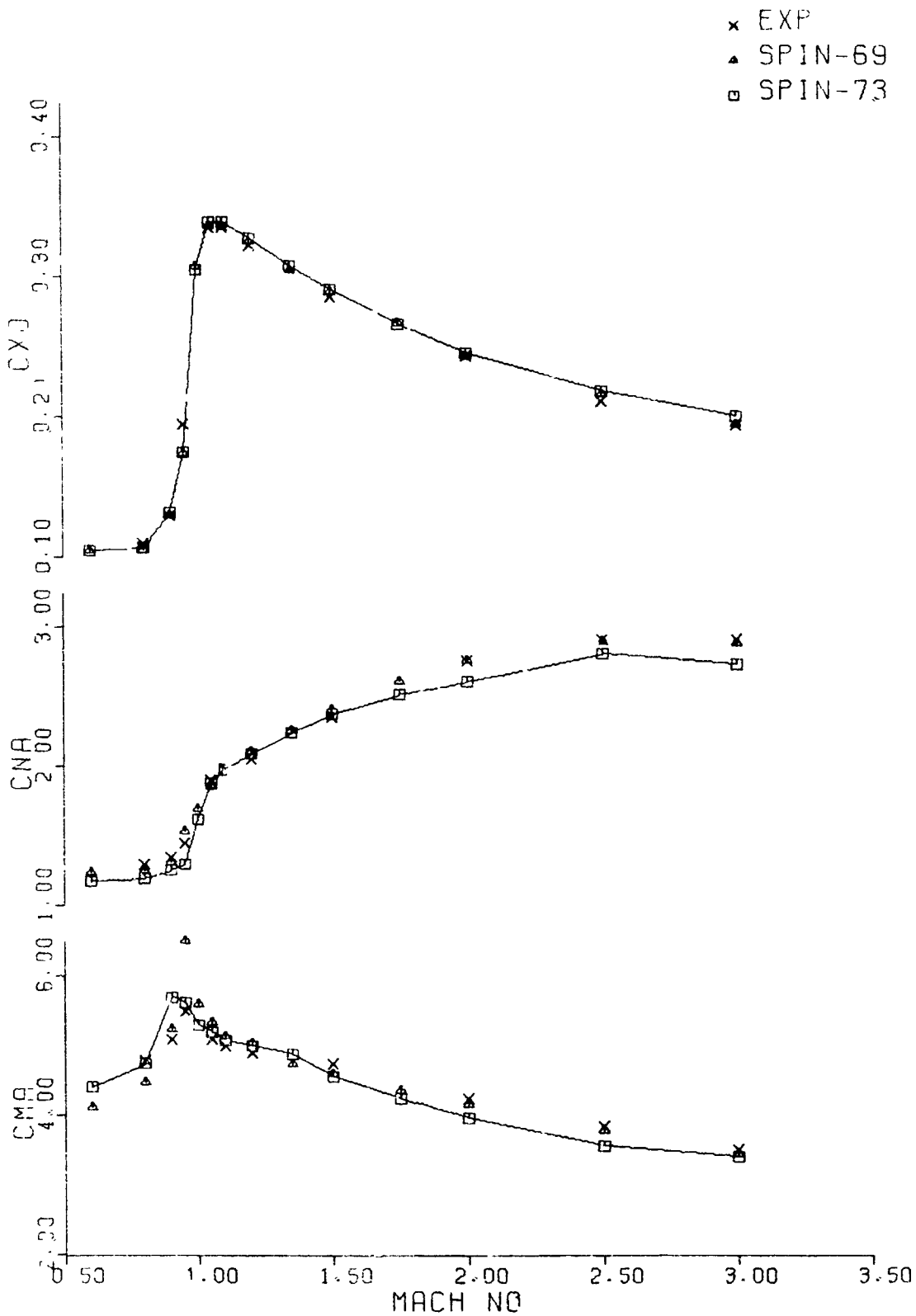
AERODYNAMIC COEFFICIENTS

MACH	CX	CX2	CNA	CMA	CPA	CYPA	CNPA	CNPA3	CNPA5	CPF*1	CPF*5	CNPA*5	CMQ	C.P
0.010	0.195	2.329	1.178	4.504	-.220	-.982	-.119	107.334	-1035.444	3.155	4.143	0.631	-12.101	-.036
0.600	0.195	2.329	1.178	4.411	-.245	-.982	-.119	107.334	-1035.444	3.155	4.141	0.631	-12.101	-.036
0.800	0.197	2.863	1.195	4.770	-.468	-.982	-.162	97.674	-937.859	3.185	4.236	0.719	-12.101	-.035
0.900	0.232	3.331	1.263	5.748	-1.016	-1.092	-.311	71.213	-674.433	3.602	4.192	0.756	-13.870	-.029
0.950	0.275	3.893	1.298	5.618	-.827	-1.367	-.294	55.908	-521.628	3.715	4.066	0.801	-15.792	-.025
1.000	0.305	4.163	1.424	5.310	-.230	-1.257	-.456	38.153	-344.033	3.642	4.139	0.803	-16.937	-.024
1.050	0.339	4.507	1.479	5.123	-.737	-1.147	-.595	22.648	-190.978	4.019	4.201	0.805	-17.717	-.024
1.100	0.339	5.122	1.983	5.020	-.933	-1.092	-.657	16.113	-123.633	4.101	4.238	0.805	-18.929	-.024
1.200	0.327	5.503	2.089	4.941	1.110	-.982	-.702	11.338	-75.880	4.215	4.322	0.807	-20.259	-.023
1.350	0.307	4.944	2.245	4.887	1.123	-.982	-.719	9.379	-56.249	4.233	4.322	0.807	-19.546	-.023
1.500	0.290	4.427	2.369	4.566	1.573	-.982	-.728	8.309	-46.493	4.242	4.322	0.807	-19.826	-.023
1.750	0.265	3.882	2.506	4.231	1.812	-.982	-.737	7.420	-36.498	4.251	4.322	0.807	-19.826	-.022
2.000	0.244	3.388	2.601	3.966	1.975	-.982	-.746	6.440	-26.902	4.260	4.322	0.807	-19.826	-.022
2.500	0.217	2.702	2.799	3.568	2.225	-.982	-.754	5.461	-17.197	4.269	4.322	0.807	-19.826	-.021
3.000	0.199	2.279	2.723	3.400	2.251	-.982	-.763	4.481	-7.511	4.278	4.322	0.807	-19.826	-.020
4.000	0.164	1.884	2.623	3.371	2.215	-.982	-.763	4.481	-7.511	4.278	4.322	0.807	-19.826	-.019
5.000	0.146	1.681	2.523	3.335	2.178	-.982	-.763	4.481	-7.511	4.278	4.322	0.807	-19.826	-.019

STABILITY ANALYSIS

MACH	GYRO	SPAR	RECIP	SPARM5	RECIPM5	SPIN	M1	M2	L1	L2	L1M5	L2M5	DELT	DISP
0.010	1.760	-.371	-6.798	1.399	1.189	6.1	0.45	0.09	-.000435	0.000096	-.000073	-.000267	0.7649	0.300
0.600	1.749	-.371	-6.798	1.399	1.189	366.9	26.69	5.57	-.000437	0.000097	-.000073	-.000267	0.0110	0.297
0.800	1.618	0.202	2.748	1.532	1.395	489.2	34.70	8.22	-.000342	0.000041	-.000032	-.000310	0.0090	0.263
0.900	1.352	0.559	1.241	1.420	1.214	550.3	36.53	11.85	-.000349	-.000035	-.000039	-.000345	0.0086	0.248
0.950	1.373	0.718	1.086	1.326	1.119	580.9	38.85	12.22	-.000319	-.000104	-.000081	-.000347	0.0081	0.196
1.000	1.453	0.814	1.036	1.162	1.027	611.5	41.89	11.87	-.000327	-.000190	-.000175	-.000343	0.0075	0.258
1.050	1.486	1.039	1.001	1.253	1.068	642.1	44.37	12.09	-.000223	-.0002A5	-.000134	-.000375	0.007:	0.316
1.100	1.516	1.057	1.003	1.200	1.042	672.6	46.82	12.32	-.000251	-.000310	-.000168	-.000373	0.0067	0.351
1.200	1.546	1.096	1.003	1.150	1.023	733.8	51.43	13.09	-.000249	-.000328	-.000205	-.000371	0.0061	0.391
1.350	1.579	1.121	1.015	1.201	1.042	825.5	58.26	14.32	-.000219	-.000353	-.000183	-.000389	0.0054	0.447
1.500	1.690	1.132	1.018	1.201	1.042	917.2	66.09	15.56	-.000224	-.000362	-.000194	-.000392	0.0048	0.542
1.750	1.823	1.154	1.025	1.216	1.049	1070.1	78.66	15.43	-.000222	-.000373	-.000197	-.000399	0.0040	0.663
2.000	1.945	1.174	1.031	1.226	1.054	1223.0	91.25	16.28	-.000221	-.000381	-.000199	-.000403	0.0034	0.772
2.500	2.162	1.202	1.042	1.245	1.064	1528.7	116.48	17.93	-.000219	-.000396	-.000202	-.000413	0.0027	0.949
3.000	2.269	1.203	1.043	1.240	1.061	1834.4	140.96	20.33	-.000219	-.000391	-.000204	-.000405	0.0022	1.035
4.000	2.289	1.197	1.040	1.234	1.058	2445.9	188.22	26.84	-.000220	-.000383	-.000206	-.000397	0.0017	1.020
5.000	2.313	1.189	1.037	1.227	1.054	3057.4	235.69	33.14	-.000222	-.000375	-.000207	-.000389	0.0013	1.001

175MM M437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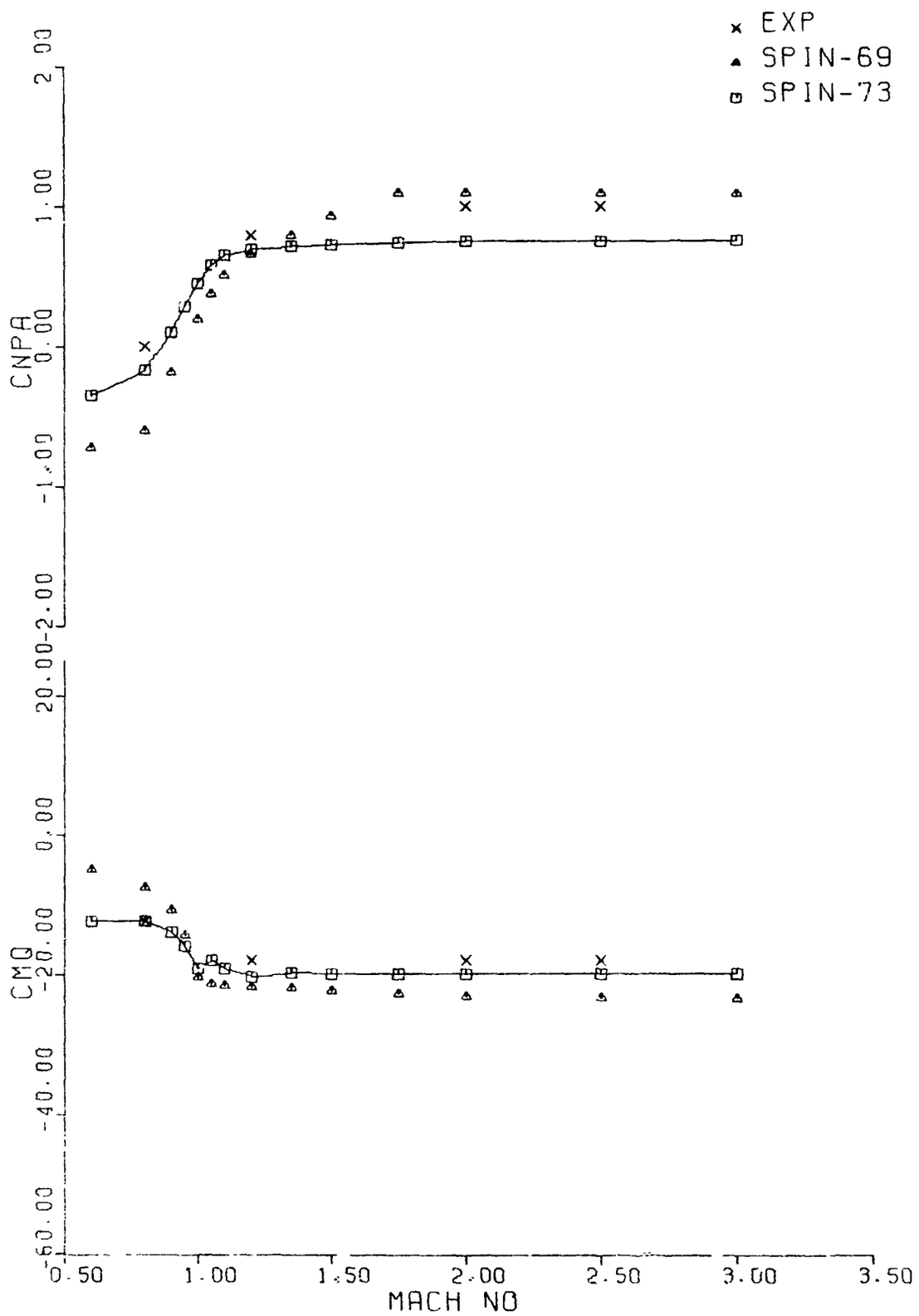
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-40.00
-60.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
MACH NO

DIAMETER INCHES	CN	CA	CY	CG (FM NOSE)	GUN TUBE CALIBER	MERLAT DIAMETER	ACTUAL TWIST CALIBERS	HAND DIAMETER	GUN-FORM INCHES	NOSE RADIUS	TEMPERATURE DEG-F	AIR DENSITY SLUGS/FT**3
1.000	0.000	0.000	0.000	4.030	0.000	0.090	0.000	1.000	0.000	120.000	0.000	0.00270

AERODYNAMIC COEFFICIENTS

MACH	CN	CA	CY	CNA	CNQA	CNQAA	CNAA	CMQA	CMQAA	CMAA	CMA	CLP
0.000	0.000	0.825	3.913	0.000	-1.110	0.000	126.694	-1229.444	4.189	5.220	1.320	-16.975	-.043
0.300	0.000	0.825	4.011	0.000	-1.110	0.000	126.694	-1229.444	4.189	5.220	1.320	-16.975	-.043
0.600	0.000	0.825	4.308	0.000	-1.110	0.000	115.139	-1117.949	4.376	5.221	1.424	-16.975	-.041
0.800	0.000	0.825	5.177	0.000	-1.240	0.000	84.683	-822.111	4.687	5.300	1.575	-21.356	-.034
0.900	0.000	0.867	5.804	0.000	-1.505	0.000	66.028	-642.778	4.860	5.249	1.697	-23.537	-.030
0.950	0.000	0.927	6.127	0.000	-1.435	0.000	45.683	-413.333	4.903	5.279	1.792	-27.092	-.028
0.975	0.000	0.949	6.249	0.000	-1.305	0.000	27.028	-237.778	5.133	5.322	1.666	-26.313	-.028
1.000	0.000	0.966	6.344	0.000	-1.240	0.000	19.083	-153.333	5.206	5.347	1.634	-28.523	-.028
1.025	0.000	1.000	6.492	0.000	-1.110	0.000	13.458	-97.000	5.294	5.407	1.528	-31.057	-.028
1.050	0.000	2.454	6.813	0.000	-1.110	0.000	13.458	-97.000	5.294	5.407	1.528	-31.057	-.028
1.100	0.000	2.451	6.740	0.000	-1.110	0.000	11.139	-73.889	5.313	5.407	1.528	-33.233	-.027
1.150	0.000	2.597	6.737	0.000	-1.110	0.000	9.083	-62.333	5.373	5.457	1.584	-35.508	-.027
1.200	0.000	2.481	6.646	0.000	-1.110	0.000	8.028	-50.778	5.432	5.507	1.639	-35.508	-.027
1.250	0.000	2.491	6.586	0.000	-1.110	0.000	7.672	-39.222	5.491	5.557	1.695	-35.508	-.027
1.300	0.000	2.400	6.440	0.000	-1.110	0.000	6.917	-27.667	5.501	5.557	1.695	-40.504	-.026
1.350	0.000	2.401	6.320	0.000	-1.110	0.000	5.361	-16.111	5.495	5.542	1.678	-40.504	-.025
1.500	0.000	2.754	6.300	0.000	-1.110	0.000	5.361	-16.111	5.485	5.532	1.667	-40.508	-.024
1.750	0.000	2.714	6.291	0.000	-1.110	0.000	5.361	-16.111	5.460	5.507	1.639	-39.508	-.023
2.000	0.000	2.682	6.298	0.000	-1.110	0.000	5.361	-16.111	5.460	5.507	1.639	-38.008	-.022
2.500	0.000	2.571	6.284	0.000	-1.110	0.000	5.361	-16.111	5.460	5.507	1.639	-38.008	-.022
3.000	0.000	2.484	6.300	0.000	-1.110	0.000	5.361	-16.111	5.460	5.507	1.639	-38.008	-.022
3.500	0.000	2.174	6.300	0.000	-1.110	0.000	5.361	-16.111	5.460	5.507	1.639	-38.008	-.022
4.000	0.000	1.331	6.300	0.000	-1.110	0.000	5.361	-16.111	5.460	5.507	1.639	-38.008	-.022
5.000	0.000	1.004	6.300	0.000	-1.110	0.000	5.361	-16.111	5.460	5.507	1.639	-38.008	-.022

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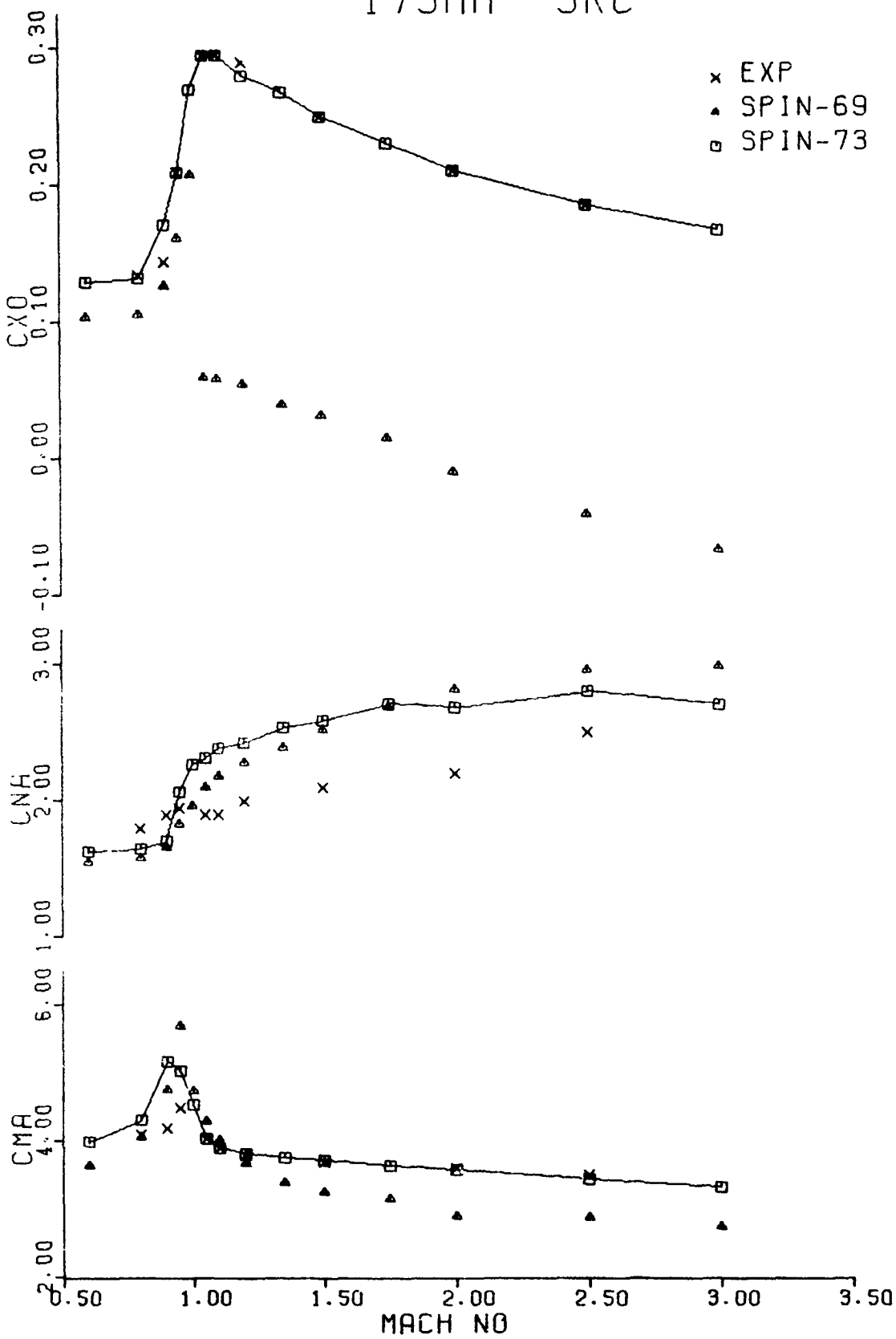
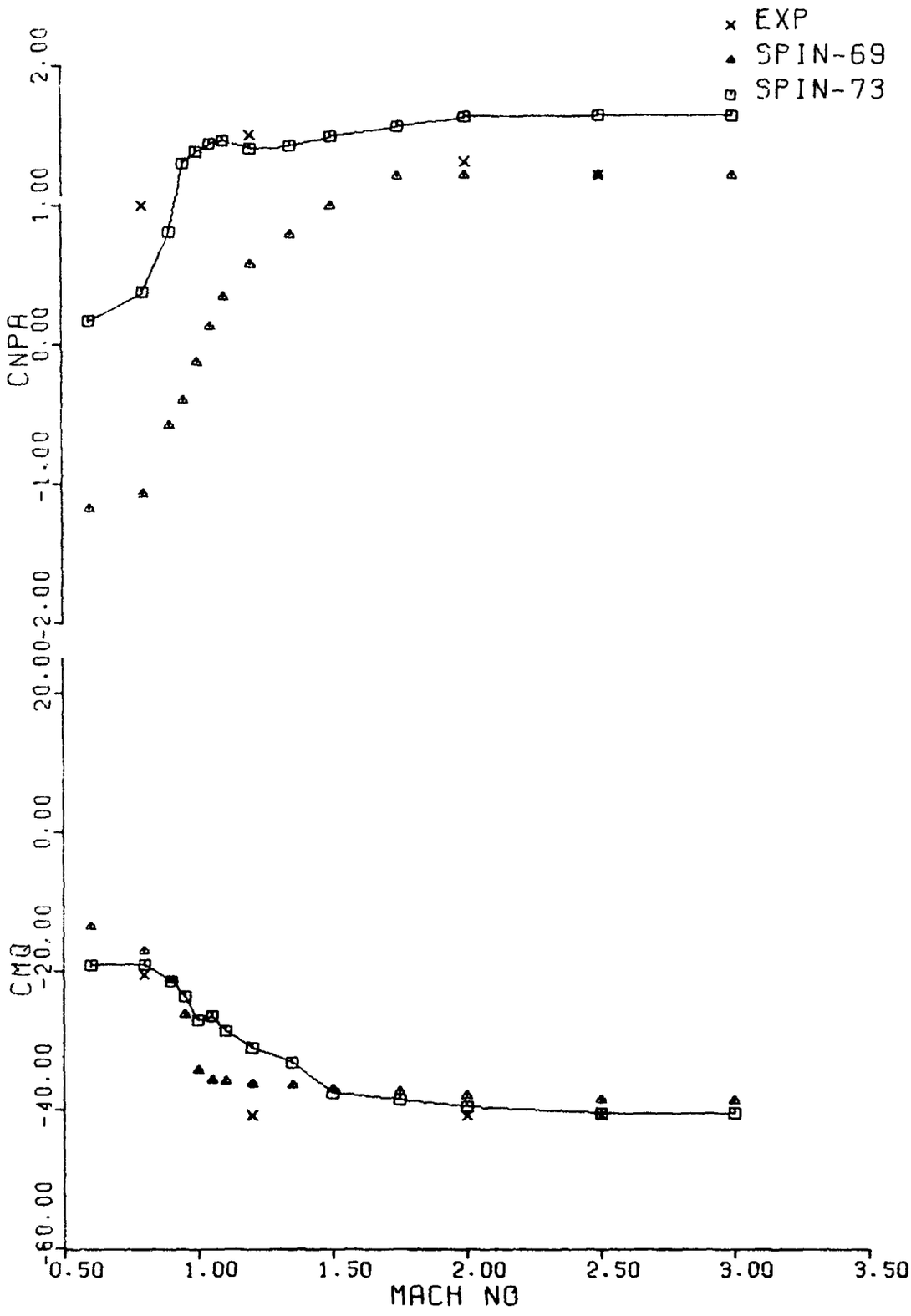

175MM SRC
EXP
SPIN-69
SPIN-73
CXO
0.30
0.20
0.10
0.00
-0.10
CNA
3.00
2.00
1.00
CMA
6.00
4.00
2.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
MACH NO

175MM SRC


EXP
SPIN-69
SPIN-73
CNPA
2.00
1.00
0.00
-1.00
-2.00
CMQ
20.00
0.00
-20.00
-40.00
-60.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
MACH NO

APPENDIX A

CURVE FIT TECHNIQUE

CURVE FIT TECHNIQUE

The method used to perform least squares fits to the experimental data using the empirical equations was a GE Time Sharing computer program code name LSQMM. This program was utilized with the GE415 computer at the Armament Systems Department. The brief description starting on the next page of this program was extracted from the following reference.

Numerical Analysis Routines #807231A
Information Service Department
General Electric Company
Bethesda, Maryland

Issued August 1968 (Revised Feb. 1969)

LSQMM

This routine determines the coefficients A(J),J=1,2, ... N of the function

$$F(I) = A_1 Q_{I,1} + A_2 Q_{I,2} + \ldots + A_n Q_{I,n} \qquad I = 1,2,\ldots,M$$

which determines the best approximation of the function Y(I) in either the weighted least squares sense or the min-max sense.

Usage

The calling sequence for this routine is:

CALL LSQMM(PHI,Y,A,RW,M,N,NT,NS,AM,IDIMM,IDIMN)

where,

- PHI is the two dimensional array, PHI(M,N), of coordinate functions which are supplied by the user. The k^{th} column of PHI contains the k^{th} coordinate function evaluated at each of the data points (i.e., = PHI(I,k), I = 1,2,...,M).
- Y is the one dimensional array, Y(M), containing the dependent variables.
- A is the one dimensional array, A(N).
  The A array contains the coefficients A(J) of the function F(I).
- RW is the name of an array containing the residuals R(I) = Y(I)-F(I), the weights W(I), and temporary storage to save the vertical weights while doing the horizontal iterations. It should contain at least 3*M locations.
- M is the number of data points.
- N is the number of coefficients, i.e., number of coordinate functions.
- NT is the maximum number of vertical iterations. For least squares fit, NT = 1.
- For least squares fit and when there is no division of the data points in min-max., NS(1) = M. Otherwise, NS is the array containing the index values of the ends of the sections when using min-max fit.
- AM is a two dimensional array, AM(N,N), used internally to contain the matrix of the system of linear equations.
- IDIMM is the first dimension of PHI, i.e., PHI(IDIMM,N).
- IDIMN is the first dimension of AM, i.e., AM(IDIMN,N).

Discussion

If the user wishes to minimize $\sum_{n=1}^{M} w_n \left[Y_n - F(X_n)\right]^2 = w_1 = 0$, modify the PHI and Y arrays as follows:

$$PHI \rightarrow \begin{bmatrix} \sqrt{w_1}\,PHI(1,1) & \sqrt{w_1}\,PHI(1,2) & \ldots & \sqrt{w_1}\,PHI(1,N) \\ \sqrt{w_2}\,PHI(2,1) & \ldots & \ldots & \ldots \\ \vdots & & & \\ \sqrt{w_M}\,PHI(M,1) & \ldots & \ldots & \sqrt{w_M}\,PHI(M,N) \end{bmatrix}$$

$$Y \rightarrow \begin{bmatrix} \sqrt{w_1}\,Y(1) \\ \sqrt{w_2}\,Y(2) \\ \sqrt{w_3}\,Y(3) \\ \vdots \\ \sqrt{w_M}\,Y(M) \end{bmatrix}$$

Sample Problem

Find the second degree polynomial $F = A_3x^2 + A_2x + A_1$ which best fits the following data in the least squares sense, where M = 9, N = 3, NT = 1.

X = -4., -3., -2., -1., 0., 1., 2., 3., 4.
Y = 2., -3., -6., -7., -6., -3., 2., 9., 18.

Solution is $F = X^2 + 2X - 6$.

Sample Solution

```
NEW
NEW FILE NAME--EXAMPLE
READY

 10 COMMON PHI(9,3),X(9),A(3),RW(27)
 20 COMMON AM(3,3),Y(9),YA(9),NS(1)
 30 DATA M,N,NT,NS/9,3,1,9/
 40 INPUT,(X(I),I=1,M)
 50 INPUT,(Y(I),I=1,M)
 60 CALL PHI1(M,N)
 70 CALL LSQMM(PHI,Y,A,RW,M,N,NT,NS,AM,9,3)
 80 DO 40 I=1,M
 90 YA(I)=0.0
100 DO 30 J=1,N
110 30 YA(I)=YA(I)+A(J)*PHI(I,J)
120 40 CONTINUE
130 PRINT 100
140 100 FORMAT("       X            F(X)         Y-F(X)           A(N)
150 &     ")
170 DO 50 I=1,N
180 50 PRINT 60,X(I),YA(I),RW(I),A(I)
190 60 FORMAT(4E13.4)
200 K=N+1
210 DO 70 I=K,M
220 70 PRINT 80,X(I),YA(I),RW(I)
230 80 FORMAT(3E13.4)
240 STOP
250 END
260 SUBROUTINE PHI1(M,N)
270 COMMON PHI(9,3),X(9)
280 DO 10 I=1,M
290 10 PHI(I,1)=1.0
300 IF(N-2) 40,15,15
310 15 DO 30 I=1,M
320 DO 20 J=2,N
330 20 PHI(I,J)=X(I)**(J-1)
340 30 CONTINUE
350 40 RETURN
    END

RUN

EXAMPLE

?-4.,-3.,-2.,-1.,0.,1.,2.,3.,4.
??.,-3.,-6.,-7.,-6.,-3.,2.,9.,18.

     X            F(X)         Y-F(X)           A(N)
 -0.4000E+01   -0.6000E+01      0.          -0.6000E+01
 -0.3000E+01   -0.3000E+01      0.           0.2000E+01
 -0.2000E+01   -0.6000E+01      0.           0.1000E+01
 -0.1000E+01   -0.7000E+01      0.
  0.           -0.6000E+01      0.
  0.1000E+01   -0.3000E+01      0.
  0.2000E+01    0.2000E+01      0.
  0.3000E+01    0.9000E+01      0.
  0.4000E+01    0.1800E+02      0.
```

APPENDIX B

INPUT-OUTPUT DESCRIPTION

INPUT-OUTPUT DESCRIPTION

PROGRAM NAME - SPIN-73

CODING DATE - July 1973

PURPOSE - Predict the aerodynamic coefficients of spin stabilized projectiles at Mach numbers for 0.0 to 5.0.

Inputs to the program are the projectile physical dimensions, projectile mass properties, gun bore diameter and twist, and the local air temperature.

INPUTS

Card No. 1 (See Note D)

IBM CARD COL	VARIABLE	
1 - 7	VL	Projectile length - calibers
8 - 14	VN	Ogive length - calibers
15 - 21	VB	Boattail length - calibers
22 - 28	VCG	Center of gravity - calibers for nose
29 - 35	DM^B	Diameter Me'Plat - calibers
36 - 42	BD^B	Rotating band diameter - calibers
43 - 49	OR^B	Ogive radius - calibers
50 - 56	BOOM	Boom length - calibers
57 - 80	NTITLE	Descriptor

Card No. 2 (See Note C)

1 - 7	DIA	Projectile diameter - inches
8 - 14	AX	Axial inertia - inches $lb\text{-}in^2$
15 - 21	TR	Transverse inertia - inches $lb\text{-}in^2$
22 - 28	WGT	Projectile weight - lbs.
29 - 35	TWIST	Gun twist - cal/turn
36 - 42	$TEMP$	Air temperature - °F
43 - 49	$DGUN^B$	Gun bore diameter - inches
50 - 56	$NAUTO^A$	0 Uses input dimensions 1 Automatic dimensions

A

BD set equal to 1.02 calibers
DM set equal to 0.12 calibers
OR set equal to 2 ($-VN^2$) (secant ogive)

B

If input as zero (0.0) these inputs are changed
BD set equal to 1.00 calibers
OR set equal to secant ogive
DGUN set equal to DIA

C

If aero estimates are only requirement this card should be left blank.

D

Repeat cards 1 and 2 to stack cases

OUTPUTS

Line 1 - Organization designation

Line 2 - Description of item being estimated

Line 3 - Title line - projectile dimensions

Line 4 - Projectile dimensions

Line 5 - Title line - projectile physical properties, gun properties air temperature and density

Line 6 - Projectile physical properties, gun properties, air temperature and density

Line 7 - 'Aerodynamic Coefficients'

Line 8 - Title line - Mach No., etc.

Line 9 -

Cxo	- Zero yaw axial force coefficient
CX2	- Yaw axial force coefficient per $\sin^2 \bar{\alpha}$
CNA	- Normal force coefficient derivative per $\sin \bar{\alpha}$
CMA	- Pitching moment coefficient derivative per $\sin \bar{\alpha}$
CPN	- Normal force center of pressure - calibers for nose
CYP	- Magnus force coefficient derivative per $\sin \bar{\alpha}$
CNPA	- Zero yaw Magnus moment coefficient derivative per $\sin \bar{\alpha}$
CNPA3	- Cubic Magnus moment coefficient derivative per $\sin^3 \bar{\alpha}$
CNPA5	- Quintic Magnus moment coefficient derivative per $\sin^5 \bar{\alpha}$
CPF1	- Center of pressure of Magnus force at 1° yaw or less calibers from nose
CPF5	- Center of pressure of Magnus force at 5° yaw, calibers from nose
CNPA-5	- 5° - Secant slope of Magnus moment coefficient derivative (at 5° yaw) per $\sin \bar{\alpha}$
Cmq	- Damping moment coefficient
Clp	- Spin deceleration coefficient

Line 10 - 'Stability Analysis'

GYRO	Gyroscopic stability factor
SBAR	Dynamic stability factor at 1° yaw
RECIP	Dynamic reciprocal factor at 1° yaw
SBAR5	Dynamic stability factor at 5° yaw
RECIP5	Dynamic reciprocal factor at 5° yaw
SPIN	Spin rate, radians/second
W1	Nutation frequency, radians/second
W2	Precession frequency, radians/second
L1	Nutation damping factor per foot @ 1° yaw
L2	Precession damping factor per foot @ 1° yaw
L1-5	Nutation damping factor per foot @5° yaw
L2-5	Precession damping factor per foot @ 5° yaw
DELT	Integration time step, seconds (20 per nutation)
DISP	Dispersion factor per 5° first max yaw, mils

APPENDIX C

PROGRAM LISTING

SPIN-73

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```
6/28/73    SPIN 0508
```

```
      SPIN 160
      SPIN 170
      SPIN 200
      SPIN 210
      SPIN 220
      SPIN 230
```

```
      DATA x[illegible] /-.[illegible],1.0767,1.0767,0.0450,1.02[illegible],-.[illegible],-.0575,
     1 -.0617,-.0680,-.0744,-.0598,-.0647,-.0744,-.0841,-.0841,-.0841 /
      DATA x[illegible] /-.[illegible],-.0255,-.0255,-.0280,-.0292,-.0305,-.0126,-.0119,
     1 -.[illegible],-.0084,-.[illegible],0.0056,0.0059,0.0138,0.0224,0.0224,0.0224 /
      DATA x[illegible] /-.0456,-.0898,-.0898,-.0946,-.1029,-.1073,-.1824,-.1698,
     1 -.1442,-.1368,-.0690,-.0435,-.0091,0.0599,0.1288,0.1288,0.1288 /
      DATA x[illegible] /-.0600,-.0606,-.0606,-.0647,0.0233,0.0512,0.1492,0.1433,
     1 0.1[illegible],-.[illegible],-.0965,0.1145,0.0964,0.0697,0.0249,0.0249,0.0249 /
      DATA x[illegible] /-.0185,0.0185,0.0185,0.0185,0.0185,0.0185,0.0185,0.0119,0.0119,
     1 0.0[illegible],0.0119,0.0119,0.0[illegible],0.0110,0.0110,0.0110,0.0110,0.0110,0.0110 /
      DATA x[illegible] /-1.022,-1.022,-1.022,-.9841,-1.050,-.7489,-.4587,-.3710,
     1 -.3[illegible],-.2[illegible],-.[illegible],-.1340,-.1012,0.0029,0.0029,0.0029,0.0029 /
      DATA x[illegible] /-.1801,-.1801,-.1801,-.2870,-.2870,-.3125,-.3125,-.3125,
     1 -.2857,-.2857,-.2854,-.2854,-.1940,-.1280,-.1280,-.1280,-.1280,-.1280 /
      DATA x[illegible] /-.0450,-.0450,-.0450,-.0450,-.2747,-.2747,-.2083,-.2083,
     1 -.1646,-.1646,-.1110,-.1110,0.0081,0.0252,0.0252,0.0252,0.0252,0.0252 /
      DATA XC1/1.71,1.71,1.71,1.68,1.63,1.60,1.58,1.56,1.55,1.53,1.53,1.70,
     1 1.79,1.88,1.99,2.03,2.00,1.97,
      DATA x[illegible] /0.6995,0.6995,0.6995,0.7224,0.7302,0.7314,0.[illegible],0.5614,
     1 0.5614,0.5595,0.5653,0.5324,0.5195,0.4993,0.4867,0.4867,0.4867 /
      DATA XC3 /-.4425,-.4425,-.4425,-.3199,-.2661,-.2174,0.1353,0.1304,
     1 0.1214,0.1094,0.0992,0.0998,0.0844,0.0880,0.1376,0.1376,0.1376 /
      DATA XC4 /-.2241,-.2241,-.2241,-.2241,-.2241,-.2241,0.1044,0.1044,
     1 0.1044,0.1044,0.1[illegible],0.1188,0.1188,0.1188,0.1188,0.1188,0.1188 /
      DATA XC5 /0.0136,0.0136,0.0136,0.0172,0.0190,0.0202,0.0542,0.0514,
     1 0.0466,0.0377,0.0295,0.0216,0.0170,0.0078,-.0014,-.0014,-.0014 /
      DATA XC6 /0.0449,0.0447,0.0449,0.0413,0.0395,0.0377,0.0001,-.0001,
     1 -.0006,-.0014,-.0021,-.0065,-.0093,-.0150,-.0207,-.0207,-.0207 /
      DATA XC7 /-.0016,-.0016,-.0016,-.0016,-.0016,-.0016,0.0033,0.0033,
     1 0.0033,0.0033,0.0033,0.0036,0.0036,0.0036,0.0036,0.0036,0.0036 /
      DATA XC8 /-.5470,-.5470,-.5470,-.5793,-.5955,-.6117,-.6854,-.6770,
     1 -.6601,-.6348,-.6096,-.5742,-.5429,-.4804,-.4178,-.4176,-.4178 /
      DATA XC9 /-.1383,-.1383,-.1383,0.0278,0.1109,0.1939,0.4924,0.4636,
     1 0.4061,0.3199,0.2336,0.1217,0.0431,-.1142,-.2714,-.2714,-.2714 /
      DATA XC10/-.7422,-.7422,-.7422,-.7422,-.7422,-.7422,-.6280,-.6280,
     1 -.6280,-.6280,-.6280,-.6031,-.6031,-.6031,-.6031,-.6031,-.6031 /
      DATA XC11/-.4712,-.4712,-.4712,-.4712,-.4712,-.4712,-.6396,-.6257,
     1 -.5977,-.5557,-.5038,-.4788,-.4303,-.3332,-.2361,-.2361,-.2361 /
      DATA XC12/-3.050,-3.050,-3.897,-4.174,-4.203,-2.936,-1.646,-1.314,
     1 -1.162,-.3[illegible],-.[illegible],-.3949,-.2274,0.1794,0.1794,0.1794,0.1794 /
      DATA XC13/-.9349,-.9349,-.9349,-1.748,-1.748,-1.748,-1.933,-1.933,
     1 -1.474,-1.474,-1.427,-1.427,-.9122,-.6300,-.6300,-.6300,-.6300 /
      DATA XC14/0.3306,0.3306,0.3306,0.3306,-.7872,-.7872,-.9731,-.9731,
     1 -.6906,-.6906,-.5391,-.5391,0.0271,0.2332,0.2332,0.2332,0.2332 /
      DATA XC15/0.0   ,0.0   ,0.0   ,0.0   ,0.0   ,0.6954,0.7100,1.0097,1.0043,
      DATA XC16/0.0   ,0.0   ,0.0   ,0.0   ,0.0   ,5.0334,5.9629,11.766,11.457,
      DATA XC16/0.0   ,0.0   ,0.0   ,0.0   ,0.0   ,5.0334,5.9629,11.768,11.457,
     1 9.1476,8.4991,7.6984,6.6724,6.1030,6.1493,6.1493,6.1493,6.1493 /
      DATA XC17/0.35,0.35,0.35,0.35,0.35,0.35,0.37,0.44,0.44,0.44,0.42,
     1 0.35,0.30,0.30,0.28,0.28,0.28,0.28,0.28/
      DATA XD1 /4.5    ,4.5    ,5.     ,5.5    ,6.     ,6.5    ,7.     ,
     C          7.5    ,8.     ,7.5    ,7.     ,6.5    ,6.     ,5.5    ,
     C          5.     ,4.5    ,4.     /
      DATA XD2 / .25   , .25   , .25   , .25   , .25   , .3    , .35   ,
```

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```
C              .4      .5      .1      .5      .5      .5      .5      .
C              .45     .4      .35     /
      DATA XD3 / .3     .3      .1      .5      .6      .7      .8      .
C              .9      1.      1.      1.      1.      1.      .8      .
C              .7      .6      .5      /
      DATA XF4 /-1.     -1.     -1.     -.9     -.8     -.7     -.6     .
C              -.5     -.4     -.3     -.2     -.1     .0      .0      .
C              0.      .0      .0      /
      DATA XF1 /-.17    -.16    -.16    -.16    -.18    -.21    -.19    .
C              -.18    -.16    -.16    -.16    -.16    -.16    -.16    .
C              -.17    -.16    -.16    /
      DATA XF2 /1.8     1.8     2.      2.4     2.7     2.8     2.9     .
C              2.96    2.98    3.00    3.01    3.02    3.03    3.04    .
C              3.05    3.05    3.05    /
      DATA XF3 /2.5     2.5     2.6     2.75    2.9     3.      3.06    .
C              3.07    3.08    3.08    3.08    3.09    3.09    3.09    .
C              3.09    3.09    3.09    /
      DATA XF4 /2.9     2.9     3.      3.05    3.1     3.1     3.1     .
C              3.1     3.1     3.1     3.1     3.1     3.1     3.1     .
C              3.1     3.1     3.1     /
     1 0.3,0.3,0.27,0.25,0.20/
     1 0.3,0.3,0.27,0.25,0.20/
      DATA XF1 /1.72    1.72    1.72    2.31    2.88    3.79    3.84    .
C              4.24    4.64    4.93    5.21    5.21    5.21    5.21    .
C              5.21    5.21    5.21    /
      DATA XF2 /3.18    3.18    3.18    3.18    3.18    3.18    3.18    .
C              3.29    3.4     3.4     3.4     3.4     3.4     3.4     .
C              3.40    3.40    3.40    /
      DATA XF3 /1.06    1.06    1.06    1.05    1.04    1.03    1.02    .
C              1.01    1.      1.      1.      1.      1.      1.      .
C              1.      1.      1.      /
      DATA XF4 /-3.3    -3.3    -3.3    -3.2    -3.18   -3.16   -3.13   .
C              -3.10   -3.00   -2.50   -1.59   -1.59   -1.59   -1.59   .
C              -1.59   -1.59   -1.59   /
      DATA XF5 /-1.3    -1.3    -1.3    -1.3    -1.3    -1.3    -1.3    .
C              -1.28   -1.26   -1.26   -1.26   -1.26   -1.26   -1.26   .
C              -1.26   -1.26   -1.26   /
      DATA XF6 /0.      .0      .0      .0      .0      .0      .0      .
C              0.      .0      .0      .0      .0      .0      .0      .
C              0.      .0      .0      /
      DATA XF7 /-.7     -.7     -.7     -.7     -.7     -.7     -.7     .
C              -.73    -.73    -.73    /
C              -.73    -.73    -.73    /
      DATA XF8 /1.09    1.09    1.09    .8      .4      .3      -.002   .
C              -.23    -.47    -1.15   -1.83   -1.83   -1.83   -1.83   .
C              -1.83   -1.83   -1.83   /
      DATA XF9 /0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,1.0,2.0,4.0,
     1 6.0,8.0,8.0,6.0,3.0/
      DATA XG1  / -.0344,-.0364,-.0346,-.0292,-.0254,-.0240,-.0238,
     1 -.0236,-.0234,-.0232,-.0230,-.0225,-.0220,-.0210,-.0200,-.0195,
     2 -.0190 /
C
 1001 FORMAT(8F7.0,6A4)
 1002 FORMAT(7F7.0,2nX,1nI1)
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SPIN1440
SPIN1450

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      1999 FORMAT(1H1)
      2000 FORMAT(  49X,23H GE BURLINGTON VERMONT  /50X,6A4//)
      2001 FORMAT(13X,5HTOTAL,10X,5HNOSE ,8X,9HBOAT TAIL,9X,3HCG ,10X,7HWEPLA
     *T ,9X,5HBAND ,11X,5HNOSE ,11X,5HBOOM /4X,3(8X,7HLENGTH ),7X,9H(FM
     *NOSE),2(6X,9HDIAMETER ),8X,6HRADIUS,10X,6HLENGTH )
      2002 FORMAT(8X,8(F10.3,5X))
      2003 FORMAT(//  3X,9HDIAMETER ,9X,3HIX ,12X,3HIY ,10X,7HWEIGHT ,7X,9HGU
     *N TWIST,4X,13HACTUAL TWIST ,4X,9HGUN-BORE ,5X,11HTEMPERATURE,4X,11
     *HAIR DENSITY/ 4X,7HINCHES ,1X,2(6X,9HLB-IN-SQ ),9X,3HLBS,3X,2(6X,9
     *HCAL/TUBE ),7X,7HINCHES ,9X,5HDEG-F,7X,11HSLUGS/FT**3 )
      2004 FORMAT(1X,8(F10.3,5X),F10.5)
      2005 FORMAT(    //48X,26H AERODYNAMIC COEFFICIENTS //5X,5HMACH ,5X,3HCX
     * ,6X,3HCX2,6X,3HCNA,6X,3HCMA,6X,3HCPN,5X,5HCYPA ,4X,5HCNPA ,4X,5HC
     *LP)
     *LP)
      2006 FORMAT(1X,15F9.3)
      2007 FORMAT(    //52X,20H STABILITY ANALYSIS //5X,5HMACH ,4X,5HGYRO ,4X,
     *5HSBAR ,4X,5HRECIP,3X,7HSBAR**5 ,2X,7HRECIP**5,3X,5HSMIN ,5X,3HW1 ,6
     *X,3HW2 ,6X,3HW3 ,6X,3HL2 ,5X,5HL1**5 ,4X,5HL2**5 ,4X,4HDELT,5X,
     &4HDISP)
      2008 FORMAT(1X,6F9.3,F9.1,2F9.2,4F9.6,F9.4,F9.3)
      2010 FORMAT(1X,2F9.3        ,5X,23H GYROSCOPIC INSTABILITY )
      3999 FORMAT(10F7.3)
           IW=6
           IR=50
         1 READ(IR,1001) VL,VN,VB,VCG,DM,BD,OR,BOOM,(NTITLE(I),I=1,6)
           CALL EOFTST(IR,I)
           IF(I.EQ.2) STOP
           READ(IR,1002)DIA,AX,TR,WGT,TWIST,TEMP,DGUN,NAUTO,NAERO,NSAUL,NNOL,
     *NOLICK,NGRAPH
           IF(NAUTO-1)3,2,2
         2 BD=1.02
           DM=.12
           OR=VA*VN**2
         3 RHO=.002376+(-4.784*(TEMP-59.)+.01092*(TEMP-59.)**2)*.000001
           ASSO =49.04*SQRT(459.6+TEMP)
           IF(DGUN)4,4,5
         4 IF(DIA) 155,155,45
        45 DGUN=DIA
         5 TT=(1./TWIST*DIA/DGUN)**2
           T=1.0/TWIST
       155 CONTINUE
           IF(BD)6,6,7
         6 BD=1.
         7 IF(OR)8,8,9
         8 OR=VA*VN**2.
         9 CONTINUE
           WRITE(IW,1999)
           WRITE(IW,2000)(NTITLE(I),I=1,6)
           WRITE(IW,2001)
           WRITE(IW,2002) VL,VN,VB,VCG,DM,BD,OR,BOOM
           WRITE(IW,2003)
           WRITE(IW,2004) DIA,AX,TR,WGT,TWIST,TWIST*DGUN/DIA,DGUN,TEMP,RHO
C          SETUP OF CONSTANTS                                          SPIN1680
```


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```
      C     SETUP OF CONSTANTS                                          SPIN1680
  112         ZRC=0.0                                                   SPIN171
  113         ZPTV=0.25                                                 SPIN1720
  114         ZPV=0.5                                                   SPIN1730
  115         ONE=1.0                                                   SPIN1740
  116         TWO=2.0                                                   SPIN1750
  117         FOR=4.0                                                   SPIN1790
  118         FOR=4.0                                                   SPIN1790
  119         VIV=5.0                                                   SPIN1800
  12          SEVG=5.51                                                 SPIN1810
  121         TLV=12.0                                                  SPIN1820
  122         GRAVVY=32.174                                             SPIN1830
  123         DD=DIA*DIA                                                SPIN1850
  124         FD=DIA**VIV                                               SPIN1860
  125         XX=AY*AX                                                  SPIN1870
  126         D=DIA/TLV                                                 SPIN1880
  127         AR=D*D*0.7854                                             SPIN1890
  128         AXL=AX/(TLV*TLV)                                          SPIN1900
  129         TRL=TR/(TLV*TLV)                                          SPIN1910
  130         A=AXL/GRAVVY                                              SPIN1920
  131         B=TRL/GRAVVY                                              SPIN1930
  132         VVLL=VL*VL                                                SPIN1940
  133         TK=(WGT*DD)/AX                                            SPIN1970
  134         BK=(WGT*DD)/TR                                            SPIN1980
  135         FACT=RHO*GRAVVY*AR/(FOR*WGT)                              SPIN1990
  136         DKH=((VVLL/VIV)-VL)*5.73                                  SPIN2080
  137         CVL=VL
  138         CXCL=VL-VN-VB-1.5
  139         CVN=VN-2.5
  140         CVR=VR
  141         CBL=BD-1.02
  142         CRDD=BD-1.
  143         CDM=(DM-.12)**2
  144         CRAT=VR*VN/OR-.4
  145         CCG=VCG-3.0
  146         CLL=VL-5.0
  147         DO 500 J=1,17                                             SPIN2090
      C       AXIAL FORCE
  148         VBX=VB-0.20
  149         IF(VBX.LT.0.0) VBX=0.0
  150         VNX=VN
  151         CXCLL=CXCL
  152         DXBT=0.0
  153         DXA=0.0
  154         DXCL=0.0
  156       301 VBX=0.45
  156       301 VBX=0.45
  157         IF(VB-1.0) 307,307,308
  158       307 DXBT=(VB-0.65)*XA10(J)
  159         GO TO 302
  160       308 DXBT=XA10(J)*0.35+(VB-1.0)*XA10(J)*0.3333
  161       302 IF(VN.LE.3.0) GO TO 304
  162         VNX=3.0
  163         IF(VN.GT.3.48) GO TO 309
```


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```
      DXN=(VN-3.0)*XA13(J)
      GO TO 304
  309 IF(VN.GT.3.97) GO TO 310
      DXN=0.48*XA13(J)+(VN-3.48)*XA14(J)
      GO TO 304
  310 DXN=0.48*XA13(J)+0.49*XA14(J)+(VN-3.97)*XA15(J)
  304 IF(CXCL-1.5) 306,306,305
      DXCL=(CXCL -1.5)*0.010
      DXCL=(CXCL -1.5)*0.010
  306 CONTINUE
      CXO=XA1(J)+XA2(J)*(VNX-2.5)+XA3(J)*(VNX-2.5)**2+XA4(J)*(VNX-2.5)**
     13+XA5(J)*CXCLL+XA6(J)*CXCLL**2+XA7(J)*VBX
     2 +XA8(J)*CRAT+XA9(J)*CRAT**2
     3 + XA11(J)*CHD*XA12(J)*CDM-(BOrM/1.36)**2+0.01
     4 -DXRT-DXN+DXCL
C     COMPUTATION OF CONSTANTS FOR CNA AND CMA
      VBX=VB
      DNX=0.0
      IF(VN-3.0) 11,11,10
   10 VNX=3.0
      DNX=VN-3.0
      GO TO 12
   11 CONTINUE
      VNX=VN
   12 IF(VB-1.0) 14,14,13
   13 VBX=1.0
      VBAP=VB**0.5
      VBMP=VB**0.5
      GO TO 25
   14 CONTINUE
      IF(J.GE.5) GO TO 20
      VBAP=VB
      VBMP=VB**0.8
      GO TO 25
   20 CONTINUE
      VBAP=VB**1.5
      VBMP=VB
   25 CONTINUE
      CVNN=VNX-2.47
      CDMM=DM-0.17
      CBBD=BD-1.04
      CBBD=BD-1.04
      CCRT=VN*VN/OR-0.48
      VRTT=CVL/4.7
      CNAB=XB1(J)+XB2(J)*CVNN+XB3(J)*CXLL+XB4(J)*CCRT+XB5(J)*CVNN*CVNN
     1 +XB6(J)*CXLL*CXLL
      CNBT=VBMP*XB7(J)+VBX*CVNN*XB8(J)+VBX*CXLL*XB9(J)
      IF(CNBT.GT.0.0) CNBT=0.0
      CNAT=CNAB+CNBT
      AMCMSQ=CNAB*(XC1(J)+XC2(J)*CVNN+XC3(J)*CVNN*CVNN+XC4(J)*CVNN
     1*CVNN*CVNN*XC5(J)+CXLL+XC6(J)*CXLL*CXLL+XC7(J)*CXLL*CXLL*CXLL
     2+XC8(J)*CCRT+XC9(J)+CCRT*CCRT+XC10(J)*CDMM
     3 +XC11(J)*CCRT*CVNN+DNX*XC17(J))
      AMCMRT=VRTT*(VBMP*XC12(J)+VBX*CVNN*XC13(J)+VBX*CXLL*XC14(J)
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                +VRX*CRT*XC15(J)+VRX*CCRT*CVNN*XC16(J))
                IF(AMOMBT.GT.0.0) CNAT=CNAR                                          SPIN3000
                IF(AMOMBT.GT.0.0) AMOMRT=0.0
                CPA=(AMOMSO+AMOMRT)/CNAT
                CNAR=(VCG-CPA)*CNAT
                CX2=XD1(J)+XD2(J)*CXCL+XD3(J)*CRAT+XD4(J)*CVR-CNAT
C               COMPUTE CYPA                                                         SPIN3010
                CYPA=XE1(J)*CVL
                CYPA=CYPA-0.1*CVH
C               COMPUTE CPF AND CNPA AT A=1.0                                        SPIN3030
                DCPF=0.0
                IF(VL.LE.6.0) GO TO 28
                DCPF=(VL-6.0)*XE5(J)
             28 CONTINUE
                CNPA=-CYPA*(XE2(J)+0.55*CXCL+0.8*CVN)
               C +1.0*CVL/4.7*CVH
                CPFA=-CNPAN/CYPA
                CPA=CPF+DCPF
                CNAA=(VCG-CPF)*CYPA
C               COMPUTE CPF AND CNPA AT A=2.0                                        SPIN3060
                CNPAA=-CYPA*(XE3(J)+0.55*CXCL+0.8*CVN)
               C +1.0*CVL/4.7*CVH
                CPFA2=-CNPAN/CYPA
                CPFA2=CPFA2+DCPF
                CNPAA2=(VCG-CPFA2)*CYPA
C               COMPUTE CPF AND CNPA AT A=5.0                                        SPIN3090
                CNPAA=-CYPA*(XE4(J)+0.55*CXCL+0.8*CVN)
               C +1.0*CVL/4.7*CVH
                CPFA5=-CNPAN/CYPA
                CPFA5=CPFA5+DCPF
                CNPAA5=(VCG-CPFA5)*CYPA
C               COMPUTE CMC                                                          SPIN3120
                DCMC=0.0
                IF(VL.LE.6.0) GO TO 30
                DCMC=(VL-6.0)*XE9(J)
             30 CONTINUE
                CMC=XF1(J)+XF2(J)*CLL+XF3(J)*CLL**2+XF4(J)*CCG+XF5(J)*CCG*CLL+XF6(
               +J)*CCG*CLL+CLL*XF7(J)*CCG*CVB+XF8(J)*CVB
                CMC=-5.393*CKH
                CMC=CMC-DCMC
C               COMPUTE CLP                                                          SPIN3180
                CLP=XG1(J)*VL/SENG
C                                                                                    SPIN3200
C                                                                                    SPIN3210
C               STABILITY CALCULATIONS                                               SPIN3220
                IF(DIA)555,555,554                                                   SPIN3230
            554 STAB(J)=1352.4*XX*TT/(1R*RHO*FC*CMA)                                 SPIN3240
                ROT1=CNAT-CX0-(BK*ZPV*CMC)+(TK*ZPV*CLP)
                ROT1=CNAT-CX0-(HK*ZPV*CMC)+(TK*ZPV*CLP)
                SBAR1=TOP1/ROT1                                                      SPIN3270
                RECP1=ONE/(SBAR1*(TWO-SBAR1))                                        SPIN3280
                TOP5=TWO*(CNAT-CX0+TK*ZPV*CNPAA5)
                SBAR5=TOP5/ROT1                                                      SPIN3300
                RECP5=ONE/(SBAR5*(TWO-SBAR5))                                        SPIN3310
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                                                                                SPIN3320
      54 IF(STAB(J)-1.001) 56,55,55                                             SPIN3330
      55 SS=ONE-(ONE/STAB(J))                                                   SPIN3340
         SIGMA(J)=SS**ZV
         VEL=CMACH(J)*ASS
         P(J)=2.283*VEL/B*DIA/DGUN
         R1(J)=(P(J)*AY/(TWO*TH))*(ONE+SIGMA(J))                                SPIN3380
         R2(J)=(P(J)*AY/(TWO*TH))*(ONE-SIGMA(J))                                SPIN3390
         DISP(J)=((CNAT-CX0)*TH*(R1(J)-R2(J))*3.635)/(CMA*RGT*DIA*VEL)
         TAU=CNF/SIGMA(J)                                                       SPIN3400
         A1=FACT*((-CNAT)*(ONE-TAU)+(RK/TWO)*(ONE+TAU)*CMQ*TK*TAU*CNPA)
         A2=FACT*((-CNAT)*(ONE+TAU)+(RK/TWO)*(ONE-TAU)*CMQ*TK*TAU*CNPA)
         R1=FACT*((-CNAT)*(ONE-TAU)+(RK/TWO)*(ONE+TAU)*CMQ*TK*TAU*CNPAA5)
         R2=FACT*((-CNAT)*(ONE+TAU)+(RK/TWO)*(ONE-TAU)*CMQ*TK*TAU*CNPAA5)
         AL1(J)=A1                                                              SPIN3450
         AL2(J)=A2                                                              SPIN3460
         BL1(J)=R1                                                              SPIN3470
         BL2(J)=R2                                                              SPIN3480
         DELT(J)=A.28/(1(J)*20.0)
         GO TO 56                                                               SPIN3500
     555 STAB(J)=ZRO                                                            SPIN3510
         SBAR1=ZRO                                                              SPIN3520
         RECP1=ZRO                                                              SPIN3530
         RECP5=ZRO                                                              SPIN3540
         SBAR5=ZRO                                                              SPIN3550
      56 CONTINUE
         SD1(J)=SBAR1
         R1(J)=RECP1
         SD5(J)=SBAR5
         R5(J)=RECP5
         XMAG1=CNPAA5-CNPA
         XMAG2=CNPAA5-CNPA*0.3
         CNPA3=(XMAG2-9.0*XMAG1)/0.0072
         CNPA3=(XMAG1-CNPA5*.0001)/0.01
     556 WRITE(IW,2006)CMACH(J),CX0,CX2,CNAT,CMA,CPN,CYPA,CNPA,CNPA3,CNPA5,
        1 CFF,CFA5,CNPAA5,CMQ,CLP
     500 CONTINUE                                                               SPIN3690
         IF(DIA)1,1,55A                                                         SPIN3700
     558 WRITE(A,2007)
         DO 501 J=1,17                                                          SPIN3740
         IF(STAB(J)-1.001) 57,58,58                                             SPIN3750
      57 WRITE(A,2010) CMACH(J),STAB(J)
         GO TO 59                                                               SPIN3770
      58 WRITE(IW,2008) CMACH(J),STAB(J),SD1(J),R1(J),SD5(J),R5(J),P(J),
        1 W1(J),W2(J),AL1(J),AL2(J),BL1(J),BL2(J),DELT(J),DISP(J)
      59 CONTINUE                                                               SPIN3800
     501 CONTINUE                                                               SPIN3810
         GO TO 1                                                                SPIN3820
C                                                                               SPIN3830
C                                                                               SPIN3840
         END                                                                    SPIN4130
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13 ABSTRACT

The SPINNER computer program has been updated to compute aerodynamic coefficients for a wide variety of spin stabilized projectile shapes. Improvements over the original program are substantial as ogive radius, meplat diameter and rotating band diameter are accounted for instead of assuming mean values. Test cases are shown compar the 1969 SPINNER, the 1973 SPINNER and experimental data. Input instructions and sample program outputs are given along with the 1973 program listing.

DD FORM 1 NOV 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE

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Computer Analysis						
Drag						
Pitching Moment						
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SPINNER						

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