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STATIC WIND-TUNNEL TESTS OF THE MK 82 FREE-FALL STORE WITH TWO MODIFIED STABILIZERS

By
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UNITED STATES NAVAL ORDNANCE LABORATORY, WHITE OAK, MARYLAND

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ABSTRACT: The Mk 82 is an operational free-fall store in use by the U. S. Navy. This report presents the results of static wind-tunnel tests of two proposed stabilizers for this weapon. The purpose in carrying out these tests was to provide data for a comparison between the currently used stabilizer and the proposed modified stabilizers.

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STATIC WIND-TUNNEL TESTS OF THE MK 82 FREE-FALL STORE WITH TWO MODIFIED STABILIZERS

The purpose of this investigation was to obtain static-stability data on the Mk 82 free-fall store with two modified stabilizers.

The authors wish to acknowledge the assistance of Mr. R. Shackford of the Ametek Corporation, Straza Industries, for providing models and setting up the test program; and to Messrs. M. Malia and R. Dunavant of NSRDC for balance preparation and wind-tunnel operation.

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Captain, USN
Commander

Leon H. Schindel
LEON H. SCHINDEL
By direction

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INTRODUCTION

For more than a decade the Mk 82 Bomb has been a basic weapon in use by the U. S. Navy for aircraft delivery of chemical high explosives. The Mk 82, alternately designated as the EX-10 U. S. Navy Low Drag Bomb, is a series of weapons varying in weight from 250 to 2000 pounds. The basic shape, originated by the Douglas Aircraft Company, is characterized by a tangent ogival nose with a fineness ratio of 8.18 and a fin span of 1.40 calibers.

The configuration considered for the tests presented herein is also the basic Mk 82, fitted with two sets of modified fins. While the current fin span of 1.40 calibers is maintained the planform geometry of these new fins is altered somewhat. The principal motivation behind developing a new planform was to improve stabilizer fabrication. Even though aerodynamic performance was not a prime consideration for the proposed fins, it is, nevertheless, vital that aerodynamic loads data should be available. These data are necessary to evaluate both the strength of the new fabrication and the overall bomb stability. The purpose of this report, then, is to present the results of static wind-tunnel measurements made on a Mk 82 Bomb with the proposed new planforms.

SYMBOLS

C_m	static pitching-moment coefficient, M_x/QSd
C_{m_α}	derivative of static pitching-moment coefficient with respect to angle of attack, $dC_m/d\alpha$
C_N	static normal-force coefficient, F_N/QS
C_{N_α}	derivative of static normal-force coefficient with respect to angle of attack, $dC_N/d\alpha$
d	reference length, maximum body diameter
F_N	normal-force component of aerodynamic force along the negative Z axis, $-F_Z$
F_Z	component of aerodynamic force along the Z axis
M	Mach number
M_y	component of aerodynamic moment along the Y axis; pitching moment
Q	dynamic pressure, $\frac{1}{2}\rho V_\infty^2$
S	reference area, $\pi d^2/4$
V_∞	free-stream airspeed

X	body axis collinear with bomb's longitudinal axis
Y	body axis normal to bomb's longitudinal axis but in a plane containing opposing tail fins
Z	body axis forming a right-hand triad with the X-Y axes
α	angle of attack
ρ	free-stream air density
ϕ	roll angle

DESCRIPTION OF CONFIGURATIONS

All wind-tunnel tests discussed in this report were conducted on a half-scale model of the 500-pound Mk 82 Bomb. The only difference between the configuration used in these tests and the current Mk 82 (see Ref. (1)) is the use of modified stabilizers. Two sets of stabilizers were considered; one designated as the "Large Mk 82 Bomb Fin" and the other noted as the "Small Mk 82 Bomb Fin." The large and small fins are shown in some detail on Figures 1 and 2, respectively, with dimensions appropriate to the full-scale 500-pound bomb.

The large fin is of more interest here than the small fin and will, therefore, be considered in more detail. If the large fin is compared with the current fin, as depicted in Reference (1), a few differences are immediately noted. First, the large fin has strakes extending forward from the leading edge. These strakes, which are not present on the current fin, are included here for reasons of fabrication. The aerodynamic effect of these strakes is probably quite negligible because of their diminutive span and their location at the rear of the body. Both the large fin design and the current fins have a 45-degree sweep to the leading edge. The large fin model has an area which is approximately 15 percent larger than that of the current fin but retains the span of 1.40 calibers.

TEST TECHNIQUE

All aerodynamic measurements on these two modified stabilizers, were obtained in the 7 X 10-Foot Transonic Wind Tunnel at the Naval Ship Research and Development Center (NSRDC). This facility is a continuous flow wind tunnel capable in certain operational modes of attaining low transonic flow velocities. Figure 3 is an attempt to summarize, graphically, the flow capabilities of this test facility. It will be noted that the wind tunnel can operate in three distinct modes: Test section vented; settling chamber vented; and, settling chamber evacuated. The upper limit Mach number and total pressure in each of the modes are noted in the table below:

Mode	Maximum Upper Mach Number	Total Pressure (atmospheres)
Test Section Vented	0.70	1.0 to 1.5
Settling Chamber Vented	1.00	1.0
Settling Chamber Evacuated	1.17	0.5

In the Test Section Vented mode, the free-stream static pressure is one atmosphere; while in the settling chamber vented mode the free-stream stagnation pressure is one atmosphere. In order to obtain a slightly supersonic Mach number the total pressure is reduced to about one half an atmosphere; however, this level may be increased but at the expense of a corresponding decrease in the maximum upper Mach number. Figure 3 presents the variation of Reynolds number and thermal-equivalent atmosphere, with Mach number, in each of the three operating modes.

All results contained within this report were obtained in the evacuated mode. This operational condition was necessary because of the requirement to test at an upper Mach number limit which was slightly supersonic.

In order to carry out these tests a half-scale model of a 500-pound bomb was mounted on a six-component static wind-tunnel balance. Figure 4 illustrates the Mk 82 wind-tunnel model with large fins, positioned in the test section of the NSRDC 7 X 10-Foot Transonic facility. Figure 5 is essentially the same illustration of the small fin configuration.

Since the measurement of fin loads was the primary purpose of these tests, it was necessary to have an indication of body-alone aerodynamic contributions. The assumption made throughout this report was that the fin loads may be obtained by subtracting body-alone measurements from fin-body measurements. In order to provide these body-alone data, it was necessary to have measurements on the Mk 82 configuration with the fins removed. Figure 6 illustrates the no-fin wind-tunnel model in the test section at the NSRDC facility.

Aerodynamic static force and moment data were obtained by means of a six-component internal strain gage balance. The balance used in these tests was the NSRDC TSB-14 balance.* Prior to the test the balance was locked in the balance "boom." During a test

*Maximum loads in pounds and in-pounds: normal force, 300 pounds; side force, 300 pounds; axial force, 50 pounds; pitching moment, 365 in-pounds; yawing moment, 250 in-pounds; rolling moment, 200 in-pounds.

run the balance was rotated in pitch at the rate of 1/8 of a degree per second. While a detailed description of the various strain-gage sampling modes is rather involved (and not particularly relevant here) the essential result is that all loads were determined (or "read") at every tenth of a second. For the present tests this was equivalent to calculating coefficients at approximately each one-hundredth degree interval. These data were subsequently "thinned" to tenth-of-a-degree intervals in order to give a nearly continuous record of static coefficients with angle of attack.

DATA REDUCTION

The sampled strain-gage signals were recorded on magnetic tape. The balance calibration and physical constants (such as dynamic pressure, reference lengths and areas, electrical gage and moment reference center) were also recorded on magnetic tape. Using the calibration and data tapes as inputs, a data reduction program calculated the static aerodynamic force and moment coefficients. The output of the data reduction was both a printed record of the coefficients versus angle of attack and plotting tape. The plotting tape was used as an input to the CalComp automatic plotter in order to obtain a graphical presentation (in the present case) of the coefficients versus angle of attack.

For the data presented in this report, the maximum body diameter was the reference length. The reference area is the maximum cross-sectional area.

DISCUSSION OF RESULTS

Since the larger fin was of more practical interest than the smaller fin, static measurements were made at three roll angles--0, 22.5 and 45.0 degrees. For the smaller fin model, measurements were made at 0 degrees of roll angle only. Zero roll angle is defined as that condition which exists when two opposing fins are in the angle-of-attack plane. A positive roll angle is defined as a clockwise rotation of the body (when viewed from the rear) from the zero or initial roll orientation.

Figures 7 through 60 present the normal force and pitching moment coefficient data for the Mk 82 Bomb with the large fins attached. Measurements were made at angles of attack varying from -2 to +22 degrees at Mach numbers of 0.6, 0.7, 0.8, 0.85, 0.95, 1.00, 1.05, 1.10 and 1.15; and at roll angles of 0, 22.5 and 45.0 degrees. It will be noted, when examining these data, that there is a slight trim angle (i.e., the pitching moment is not zero at zero angle of attack). This bias is attributed to flow-sting misalignment; the model itself had a four-fold rotational symmetry and zero fin cant. The moment reference center for all data presented in this report is at 41.69 percent of the body length aft of the nose vertex.

In Figures 7 through 60 it should be noted that the pitching moment coefficient does not give any evidence of irregularities at low angles of attack. Occasionally an irregularity does occur in configurations of this type, especially when the tail cone angle is severe enough to cause flow separation. Of course, tail effectiveness (the local derivative of C_M with angle of attack) does change. Such a change is, no doubt, due to flow separation and tail-panel stall. However, this phenomenon occurs gradually, and not until angles of attack greater than six degrees are encountered (see Fig. 9). If, for example, Figures 7 and 12 are compared, it will be noted that there is little change in fin effectiveness with increasing subsonic Mach number.

Another interesting feature of these data is the dependency of pitching moment coefficient on roll angle. For example, compare Figures 10, 28 and 46 with each other. These figures present the pitching moment coefficient data at a Mach number of 0.85 and at roll angles of 0, 22.5 and 45.0 degrees, respectively. In rolling from 0 to 22.5 degrees the pitching moment coefficient decreases slightly at the lower angles of attack. This decrease in fin effectiveness becomes more pronounced as the angle of attack increases. If the body is rolled further, to 45.0 degrees (compare Figs. 28 and 46), there is a further decrease in fin effectiveness. This latter decrease in fin effectiveness, with roll angle (from 0 to 45 degrees), occurs over the entire Mach number range; compare Figures 7, 25 and 43 with each other, for roll angles of 0, 22.5 and 45.0 degrees, at a Mach number of 0.6. A similar comparison of Figures 14, 32 and 50 for the same roll angles and at a Mach number of 1.10 should be made.

The variation of fin effectiveness with Mach number seems most pronounced at the larger angles of attack. At the relatively low angle of 6 degrees the pitching moment coefficient is nearly constant with Mach number. For the zero roll case (Figs. 7 through 15) the pitching moment coefficient at 6 degrees angle of attack is approximately 0.080 (after the trim term is subtracted). Within the accuracy of measurements this value remains constant over the entire Mach number range of these tests. At higher angles of attack the situation is quite different. Now, there is a noticeable decrease in pitching-moment effectiveness with Mach number. For example, at 20 degrees angle of attack the pitching-moment coefficient decreases from about 0.400 (at a Mach number of 0.6 (Fig. 7)) to about 0.340 (at a Mach number of 1.15 (Fig. 15)).

Normal-force and pitching-moment coefficient data for the small fin model are presented on Figures 61 through 78. Since this stabilizer was of less interest than the larger stabilizer, measurements are given for only one roll angle (zero degrees). Nevertheless some comparisons between the two stabilizers are of value. At the low angles of attack the larger fin model has at least a 15 percent greater pitching-moment coefficient than does the smaller fin model. This can be seen by comparing Figures 7 and 61 (Mach 0.6), Figures 10 and 64 (Mach 0.85) and Figures 15 and 69 (Mach 1.15). In each of these cases the pitching-moment coefficient for the large finned body is about 15 percent greater than that for the small fin configuration.

At the higher angles of attack, say 20 degrees, the difference in fin effectiveness is even more pronounced. If the two fins are compared at (say) a Mach number of 0.95 (Figs. 11 and 65) it is seen that the pitching-moment coefficients are 0.345 and 0.435, for the small and large fins, respectively.

Since one of the primary goals in this test program was to assess fin effectiveness, it was decided that some body-alone measurements should be made. The results of these tests are presented on Figures 79 through 96 for the same Mach numbers used in the large and small fin data presentations.

The purpose of this Technical Report is to present a comprehensive series of normal-force and pitching-moment coefficient measurements for the Mk 82 free-fall store with two modified stabilizers. Obviously any meaningful evaluation of these fins must rest upon a comparison of these fins with those used currently. There are several sources of static and dynamic data available for the current stabilizer. Reference (1) will be used as a convenient summary. The following table is a comparison between the large fins, small fins, current fins and body-alone measurements. The basis for comparison will be the static margin, or the location of the center of pressure (in calibers) aft (positive) or forward (negative) of the body center of gravity. The center of gravity is assumed to be at 41.69 percent of body length aft of the nose vertex for the present measurements. (In Ref. (1) the pitching-moment data were reduced about a c.g. located at 44.5 percent of body length so an axis transfer was necessary for comparison purposes).

The static margin, $\bar{X}$, will be defined by the following simple relationship:

$$X = \frac{(dC_m/d_\alpha)}{(dC_N/d_\alpha)} \qquad (1)$$

For the data given in the table below the derivatives dC_m/d_α and dC_N/d_α have been evaluated by means of a least-square fit of force and moment data between -2 and +6 degrees angle of attack for both the proposed modified fins and for the body-alone. For the current fins (Ref. (1)) the slopes, as measured through 0 and 4 degrees angle of attack, were used.

TABLE OF STATIC MARGIN COMPARISONS

Mach No.	Large Fin	Small Fin	Current Fin	Body-Alone
0.6	1.64	1.38	1.39	-8.06
0.7	1.64	1.40	1.15	-8.10
0.8	1.63	1.42	1.27	-7.99
0.85	1.63	1.42	1.35	-7.87
0.95	1.48	1.35	1.69	-7.80
1.00	1.43	1.21	1.93	-7.55
1.05	1.30	0.85	1.83	-6.42
1.10	1.56	1.29	1.63	-6.49
1.15	1.55	1.35	1.49	-6.90

These data have been plotted versus Mach number in Figure 97. The measurements show that the large fin model is superior to the current fin, at subsonic speeds and at low angles of attack. However, a word of caution should be injected here. From Equation 1 it should be obvious that the static margin is a ratio of two derivatives which have been obtained from experimental data. Where the aerodynamic loads are small (low angles of attack) it is clear that the static margin should be interpreted only qualitatively. This is particularly true of the current fin data since extensive coverage of aerodynamic loads versus angle of attack, as it is in common practice today, was beyond the capabilities of wind-tunnel instrumentation of ten years ago. Certainly it seems that one might state conservatively, that on the basis of the above table, the low angle of attack characteristics of the larger of the proposed fins are at least the equal of the current fin design.

In order to evaluate the proposed fins and the current fins at large angles of attack, secant slopes measured through 0 and 12 degrees, were used for the determination of the derivatives in Equation 1. Figure 98 is a summary of these results. Since the aerodynamic loads are larger at this higher angle of attack some confidence in these quantitative measurements is possible. It appears from this figure that the current fins have a static margin which, for the most part, lies in between the values for the smaller and larger of the proposed fin designs.

The static margin is not the best criterion to use in evaluating the static aerodynamic characteristics of an unguided free-fall store. Ultimately the most important consideration would be the level of the static restoring moment under identical conditions. Figure 99 compares the larger of the two proposed fins and the current fin design at a Mach number of 0.80 and a roll angle of zero degrees. The proposed fin is clearly superior to the current fin at all angles of attack.

CONCLUSIONS

This Technical Report has presented normal-force and pitching-moment measurements on two proposed stabilizer configurations for the Mk 82 free-fall store. Comparisons were made among these two proposed stabilizers and the currently used stabilizer. The results clearly indicate that from a static aerodynamic point of view the larger of the proposed stabilizers is aerodynamically superior to the current fin.

REFERENCES

(1) Piper, W. D., DeMeritte, F. J., "Summary of the NOL Investigations to Date of the Aerodynamic Characteristics of the Navy Low Drag Bomb," Unclass., NAVORD Report 5679, February 1960.

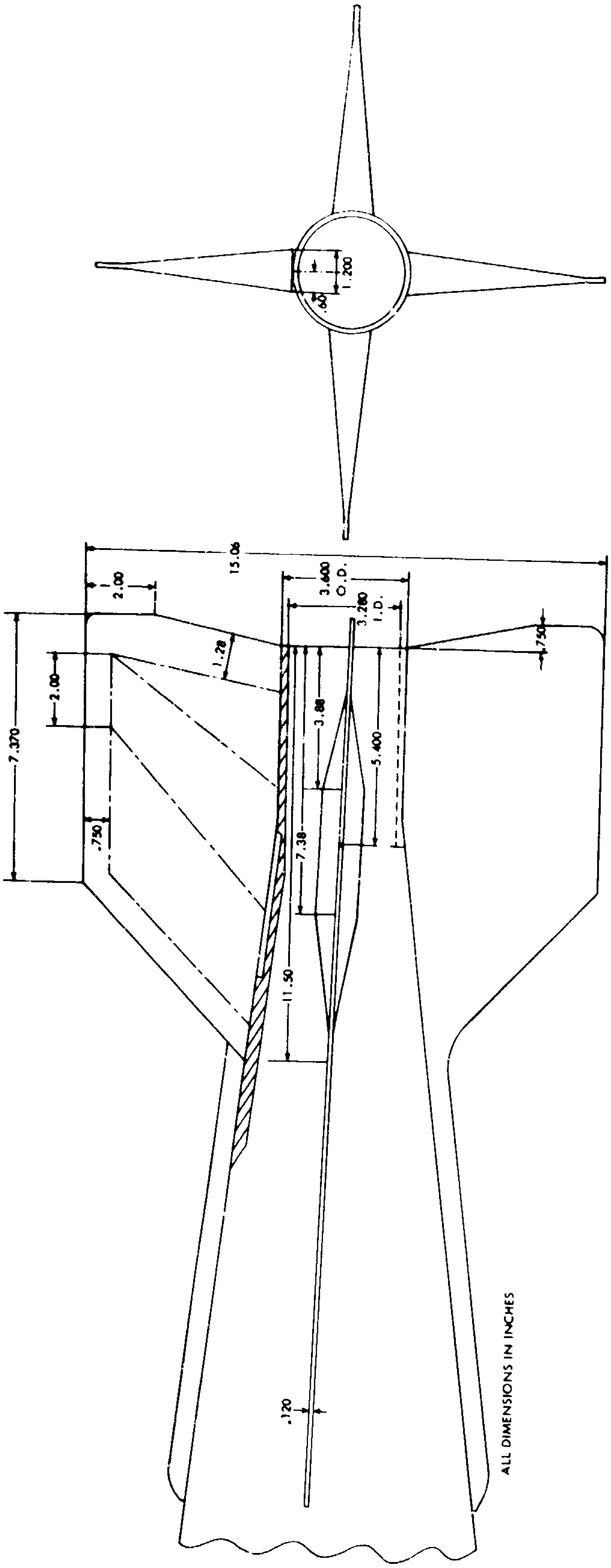

FIG. 1 GEOMETRY OF LARGE MK 82 BOMB FIN

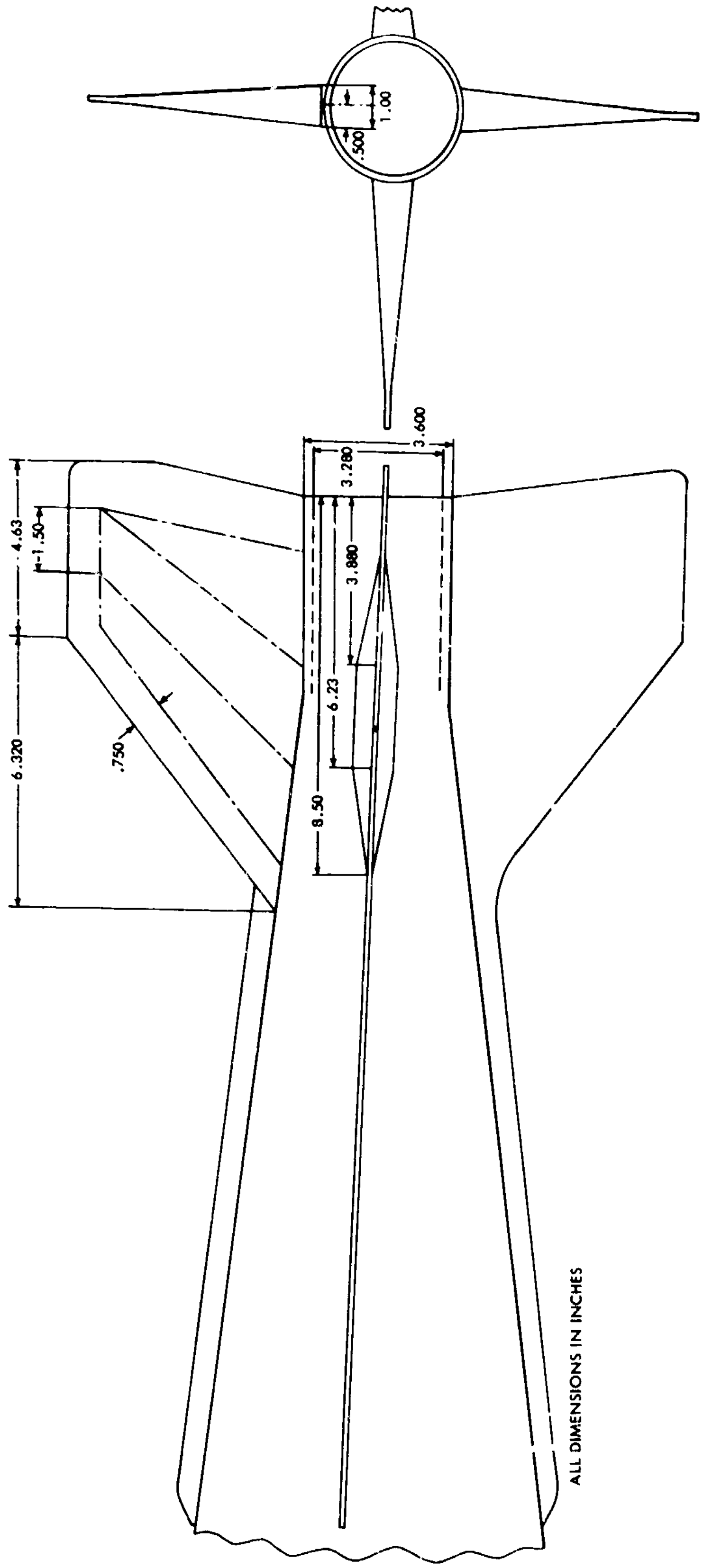

FIG. 2 GEOMETRY OF SMALL MK 82 BOMB FIN

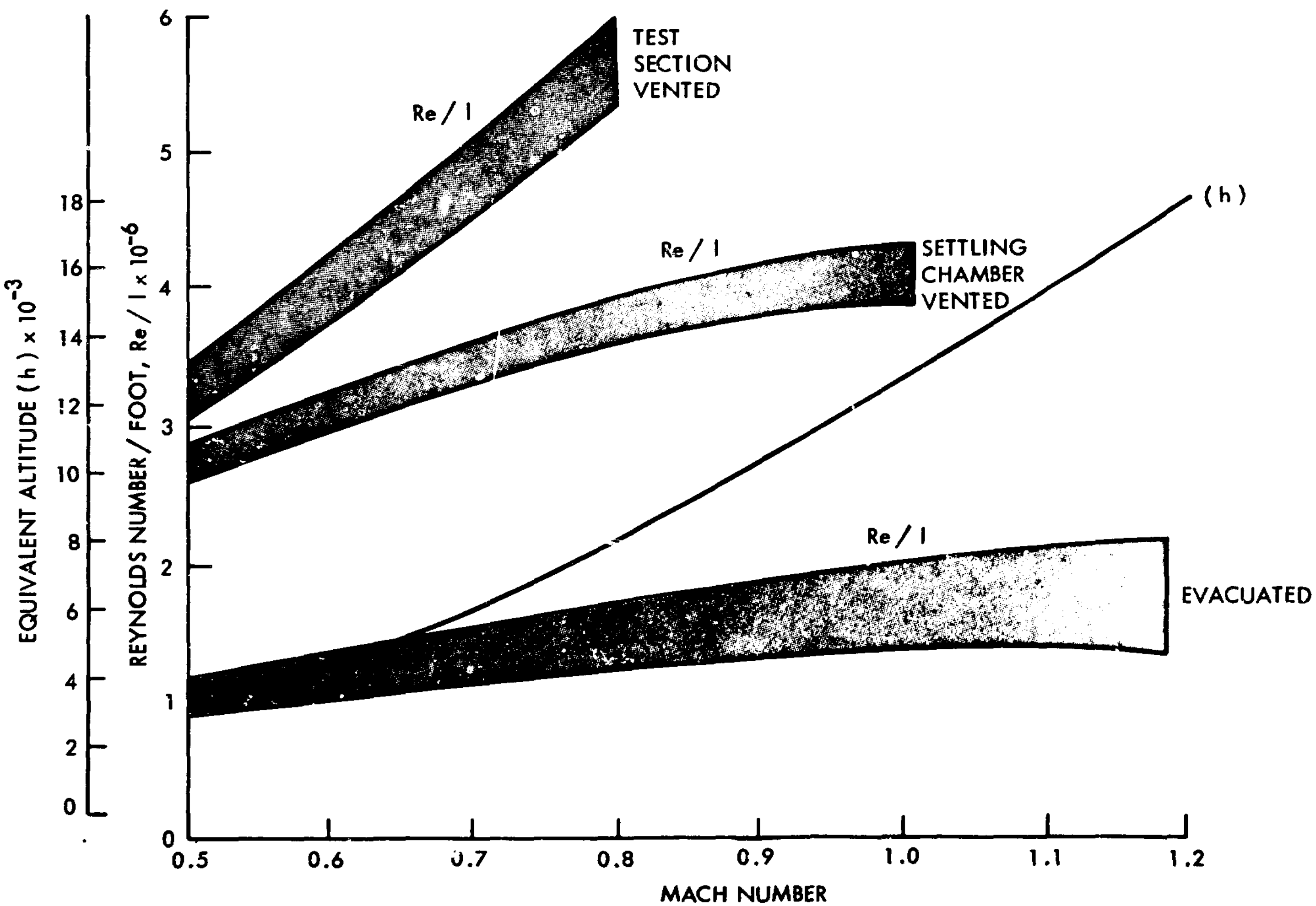

FIG. 3 REYNOLDS NUMBER PER FOOT AND EQUIVALENT ALTITUDE VERSUS MACH NUMBER FOR THE NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER 7 BY 10 FOOT TRANSONIC WIND TUNNEL

FIG. 4 WIND TUNNEL MODEL OF MK 82 BOMB WITH LARGE FINS IN NSRDC TRANSONIC WIND TUNNEL

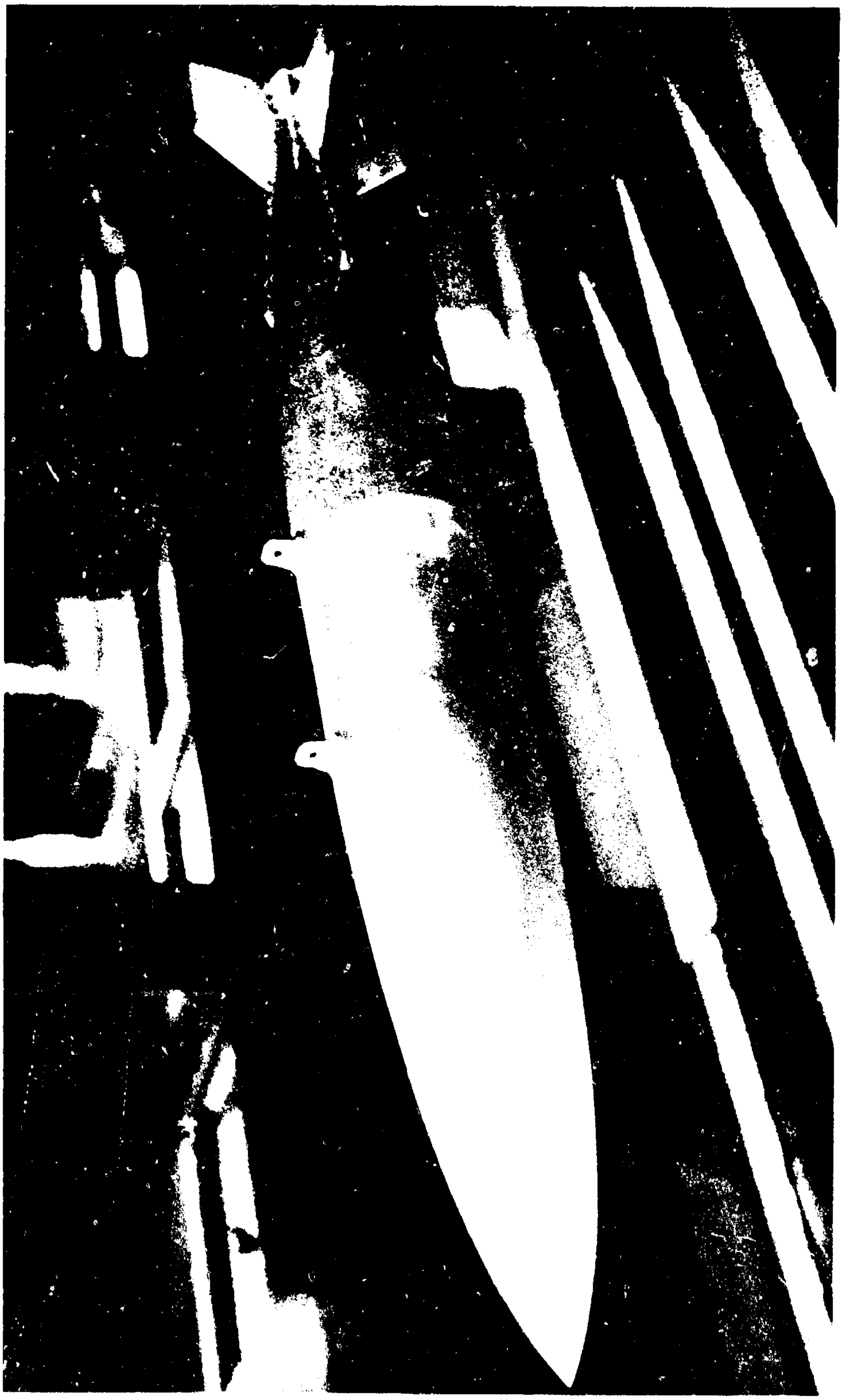

FIG. 5 WIND TUNNEL MODEL OF MK 82 BOMB WITH SMALL FINS IN NSRDC TRANSONIC WIND TUNNEL

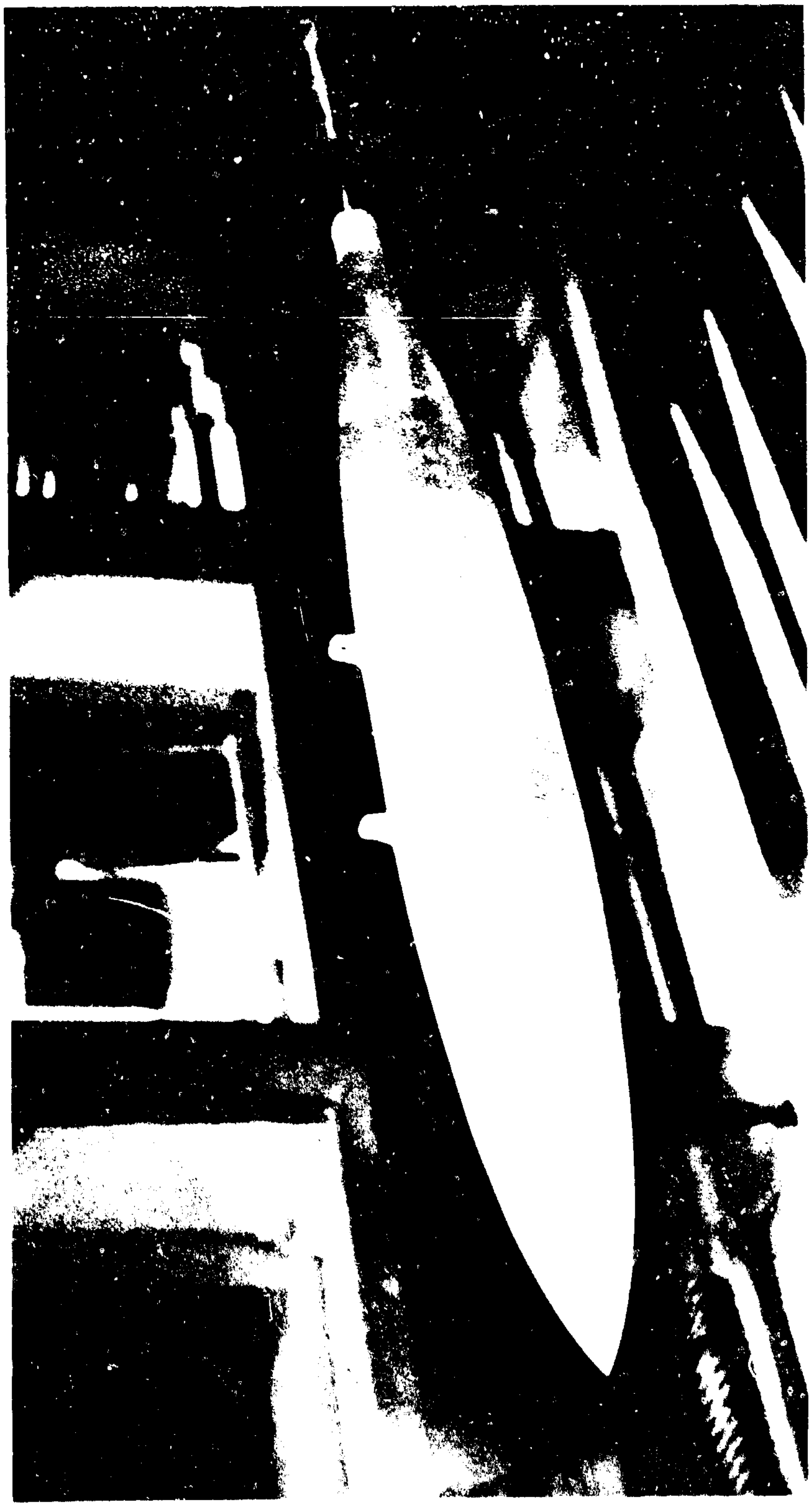

FIG. 6 WIND TUNNEL MODEL OF MK 82 BOMB WITH NO FINS IN NSRDC TRANSONIC WIND TUNNEL

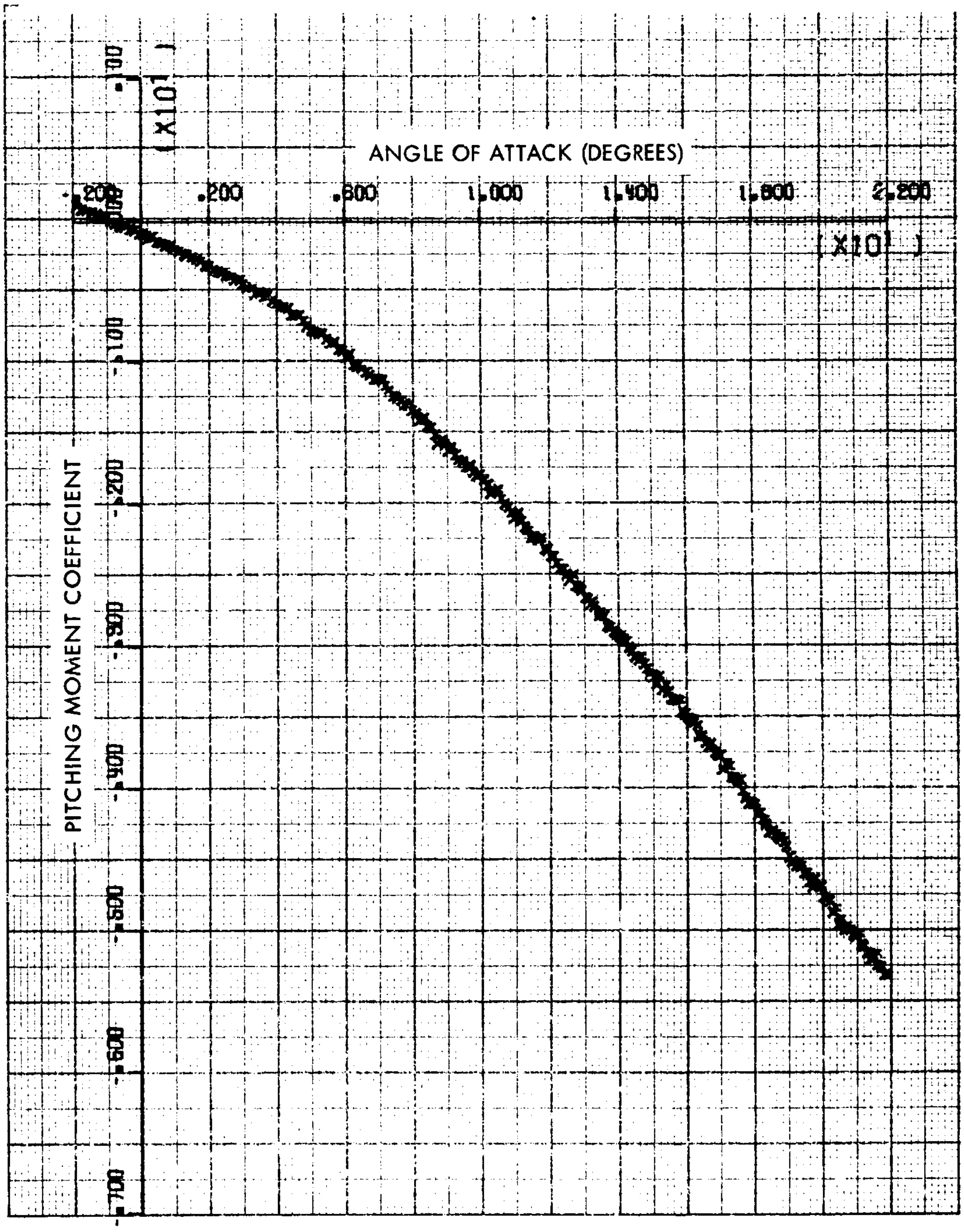

FIG. 7 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 0.6 AND A ROLL ANGLE OF 0 DEGREES

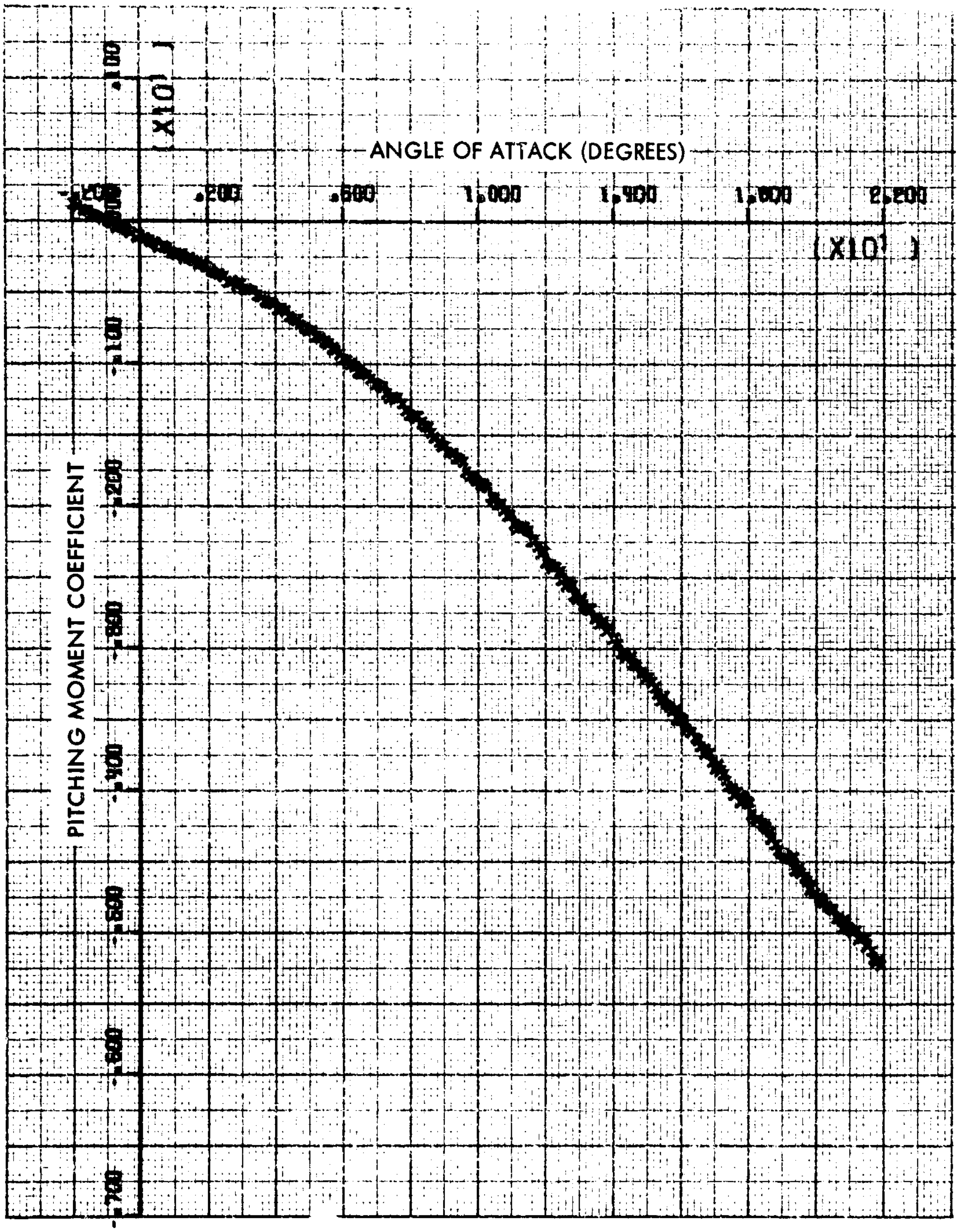

FIG. 8 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 0.7 AND A ROLL ANGLE OF 0 DEGREES

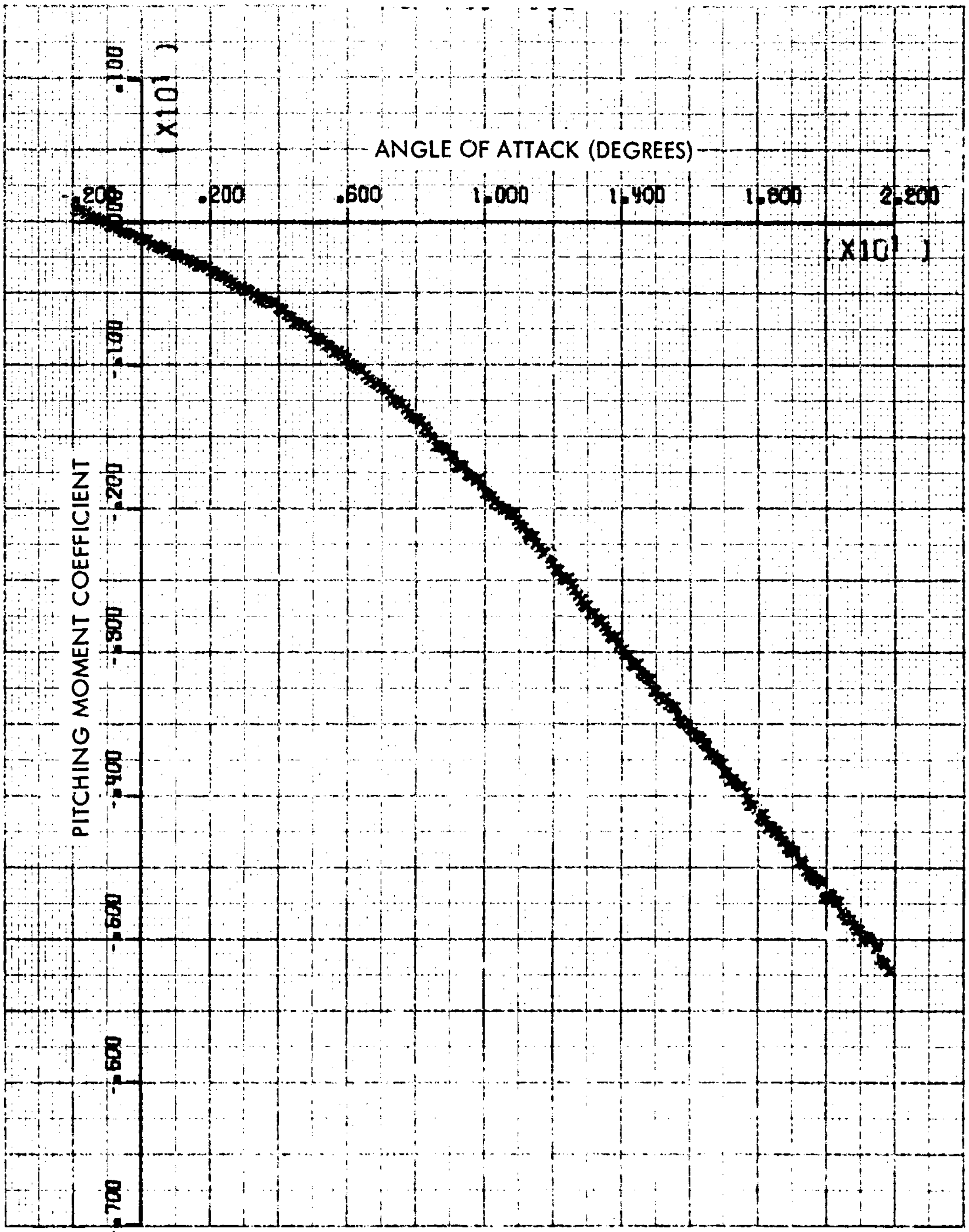

FIG. 9 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 0.8 AND A ROLL ANGLE OF 0 DEGREES

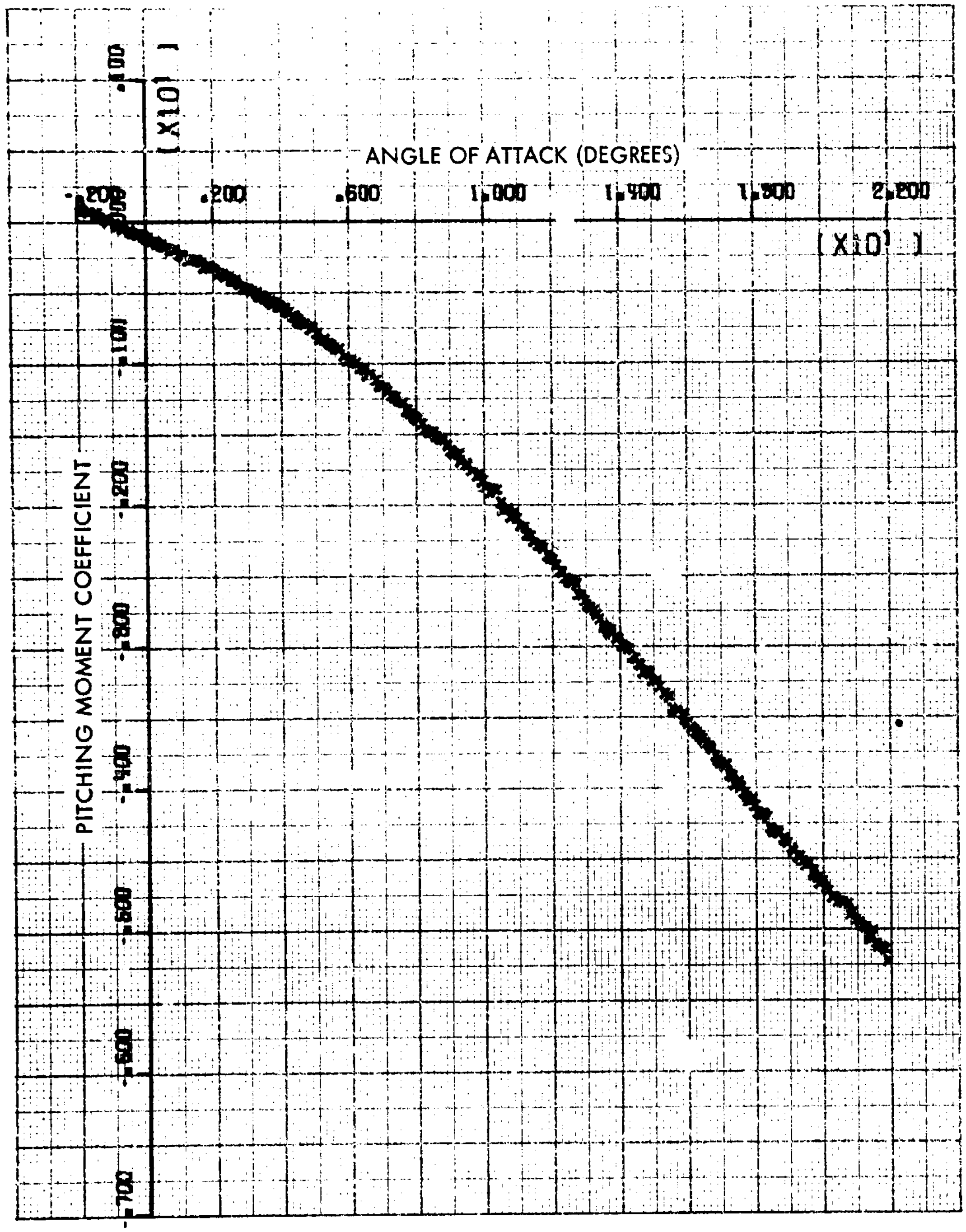

FIG. 10 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 0.85 AND A ROLL ANGLE OF 0 DEGREES

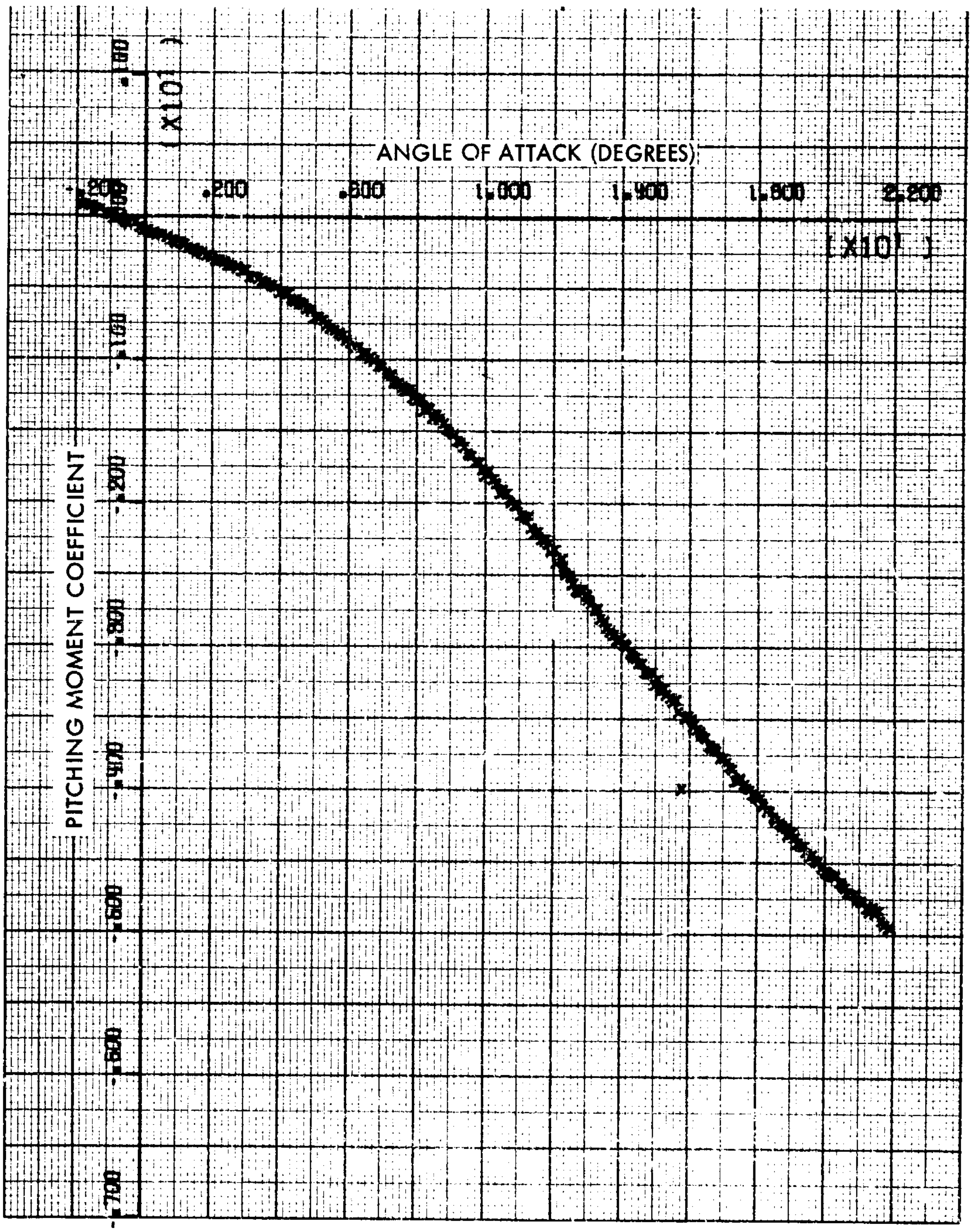

FIG. 11 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 0.95 AND A ROLL ANGLE OF 0 DEGREES

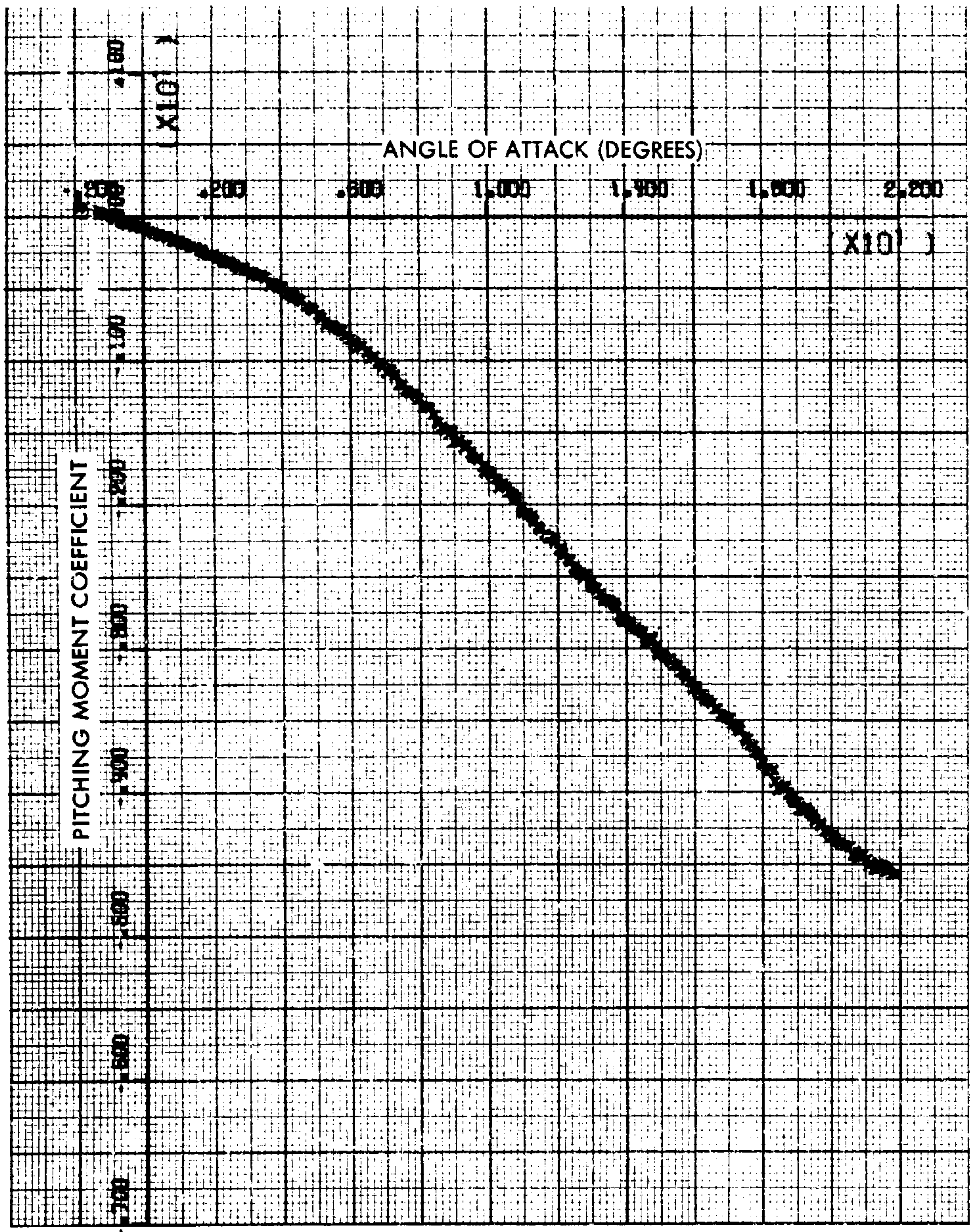

FIG. 12 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 1.00 AND A ROLL ANGLE OF 0 DEGREES

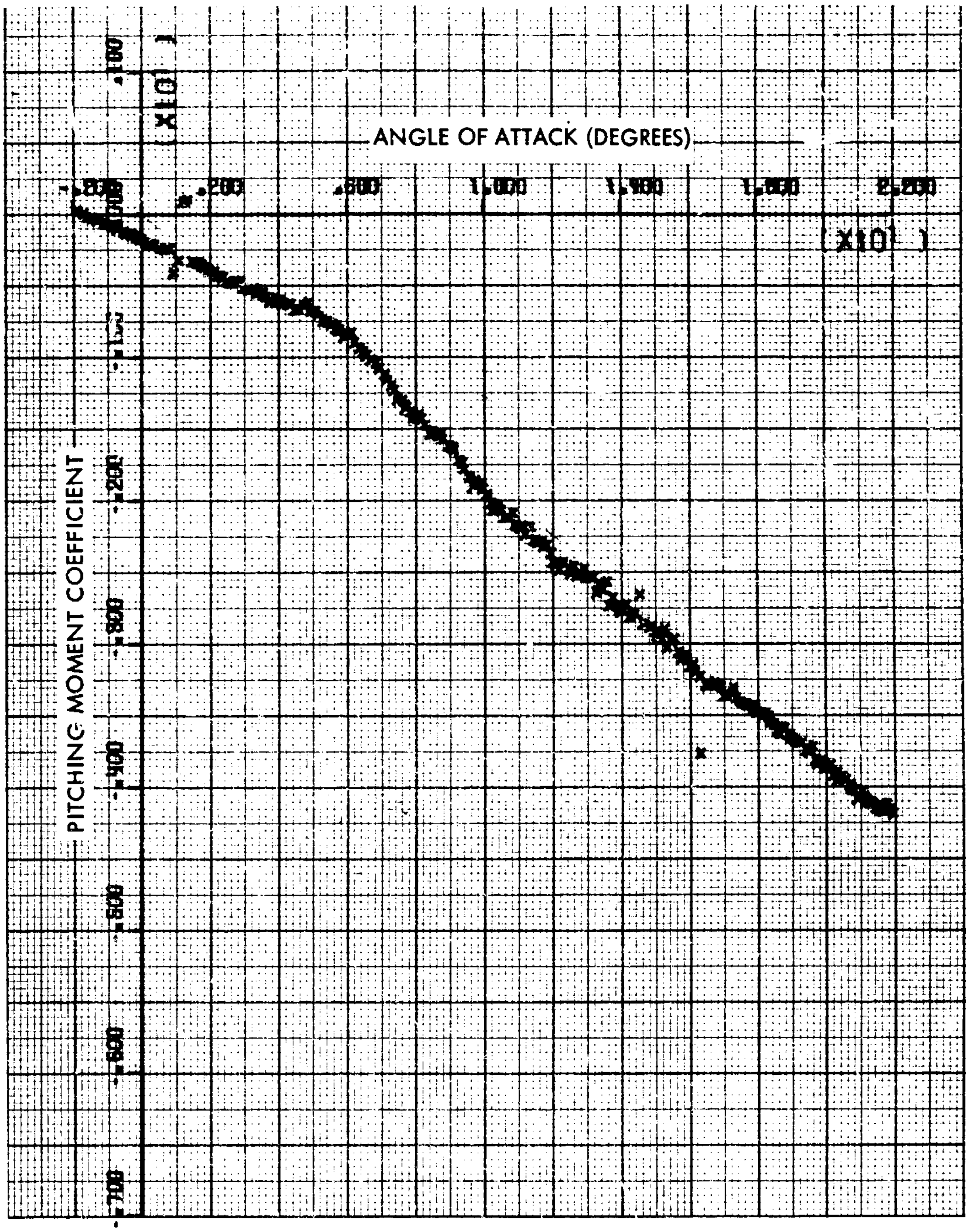

FIG. 13 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 1.05 AND A ROLL ANGLE OF 0 DEGREES

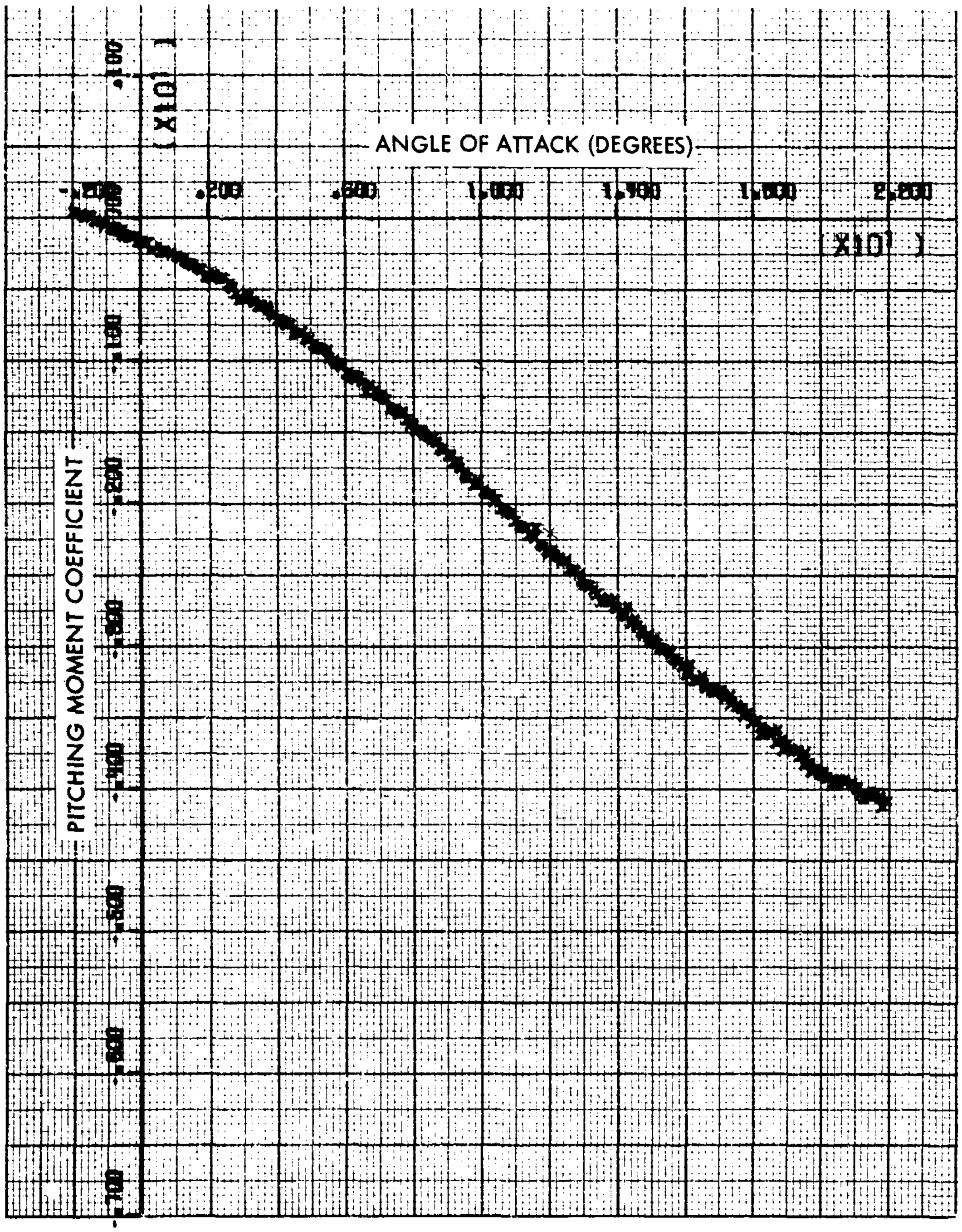

FIG. 14 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 1.10 AND A ROLL ANGLE OF 0 DEGREES

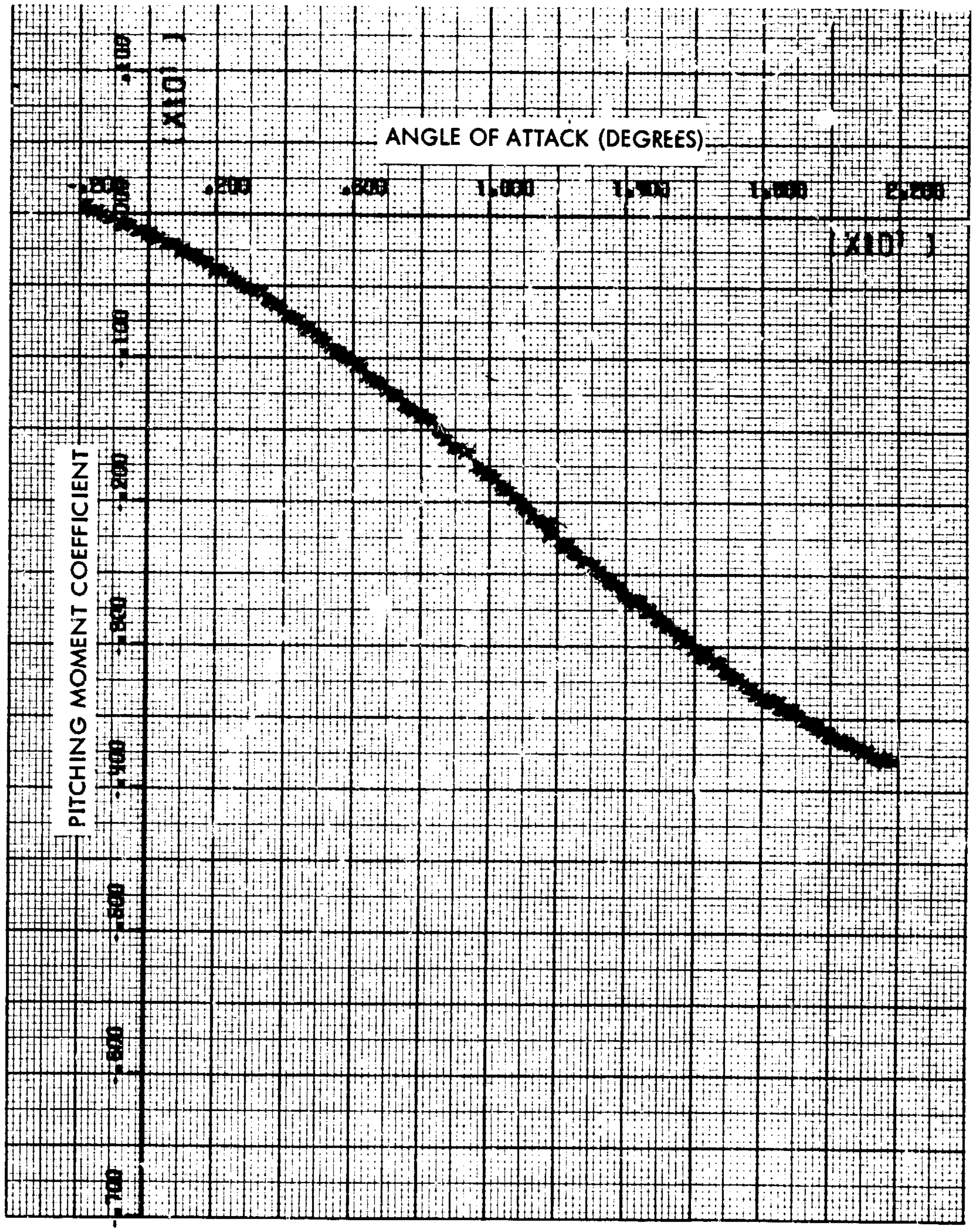

FIG. 15 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 1.15 AND A ROLL ANGLE OF 0 DEGREES

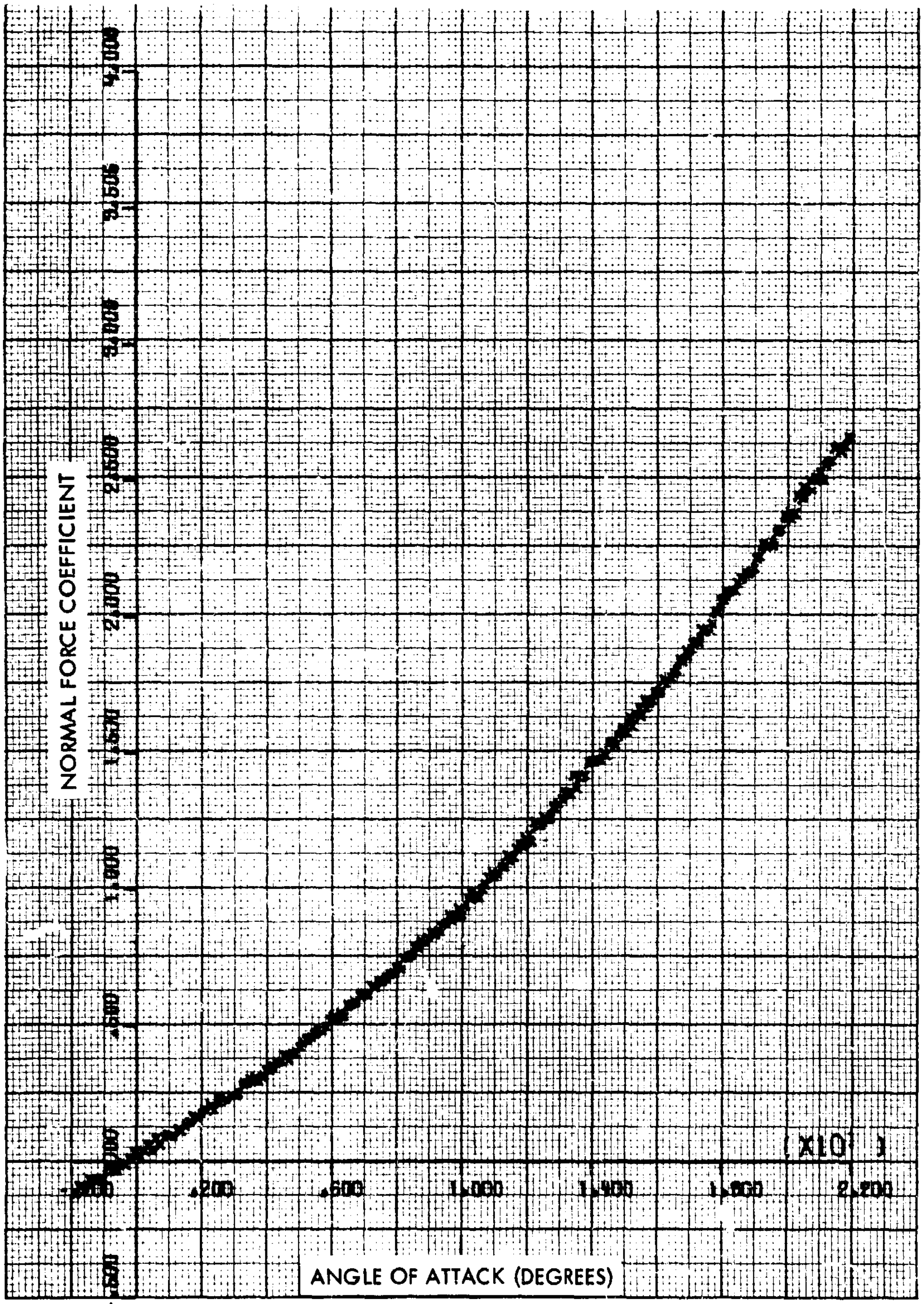

FIG. 16 NORMAL FORCE COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 0.6 AND A ROLL ANGLE OF 0 DEGREES

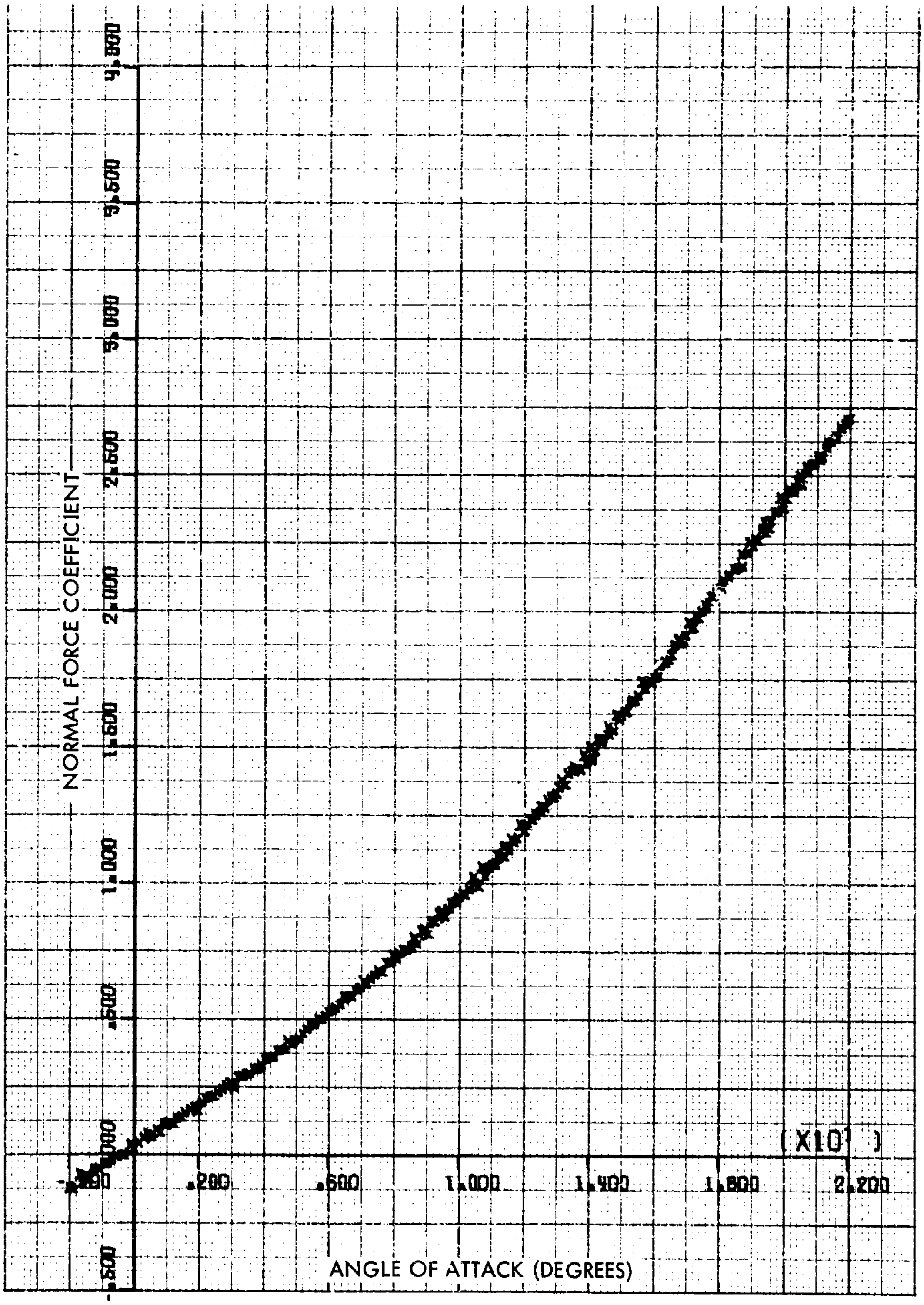

FIG. 17 NORMAL FORCE COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 0.7 AND A ROLL ANGLE OF 0 DEGREES

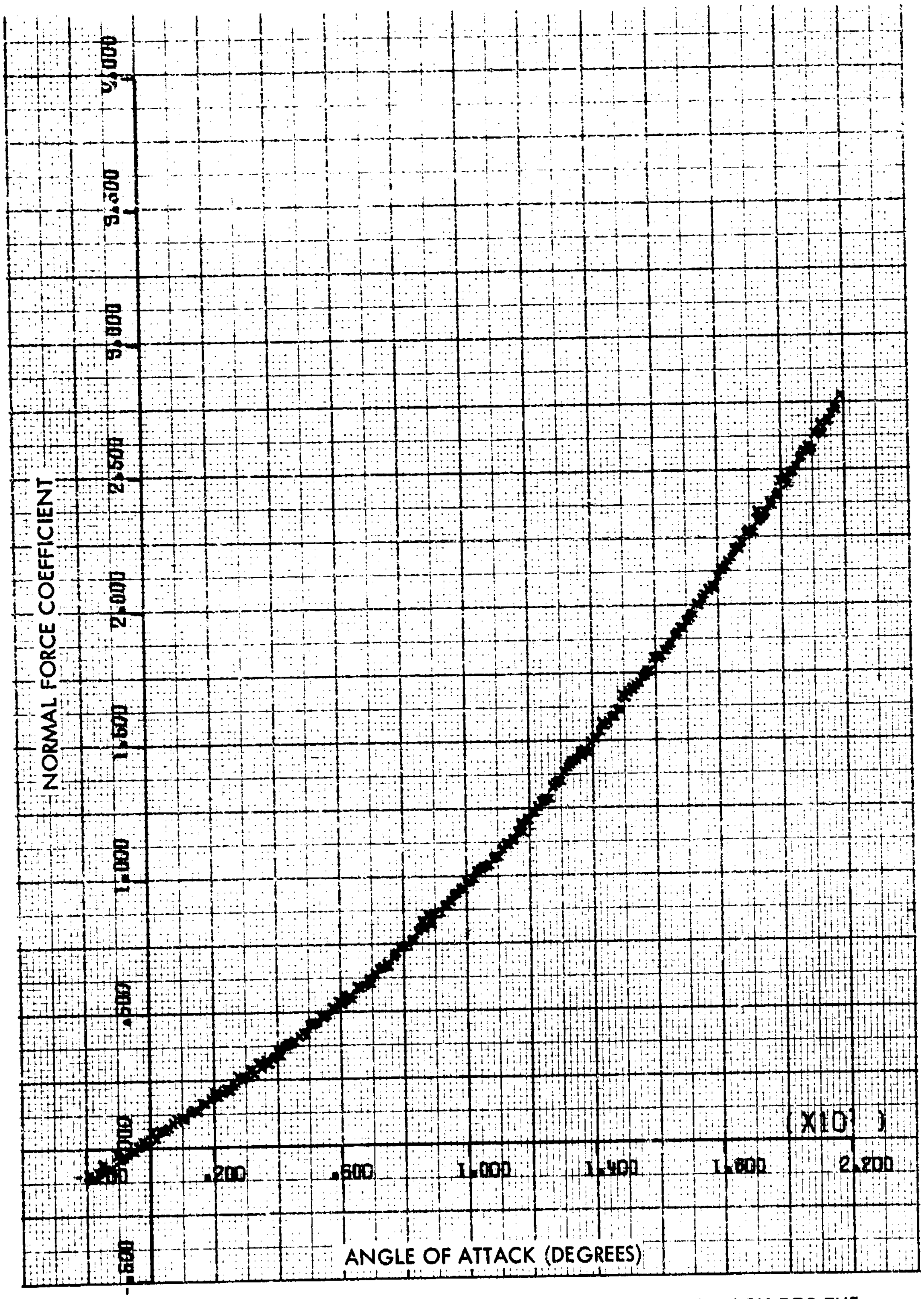

FIG. 18 NORMAL FORCE COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 0.8 AND A ROLL ANGLE OF 0 DEGREES

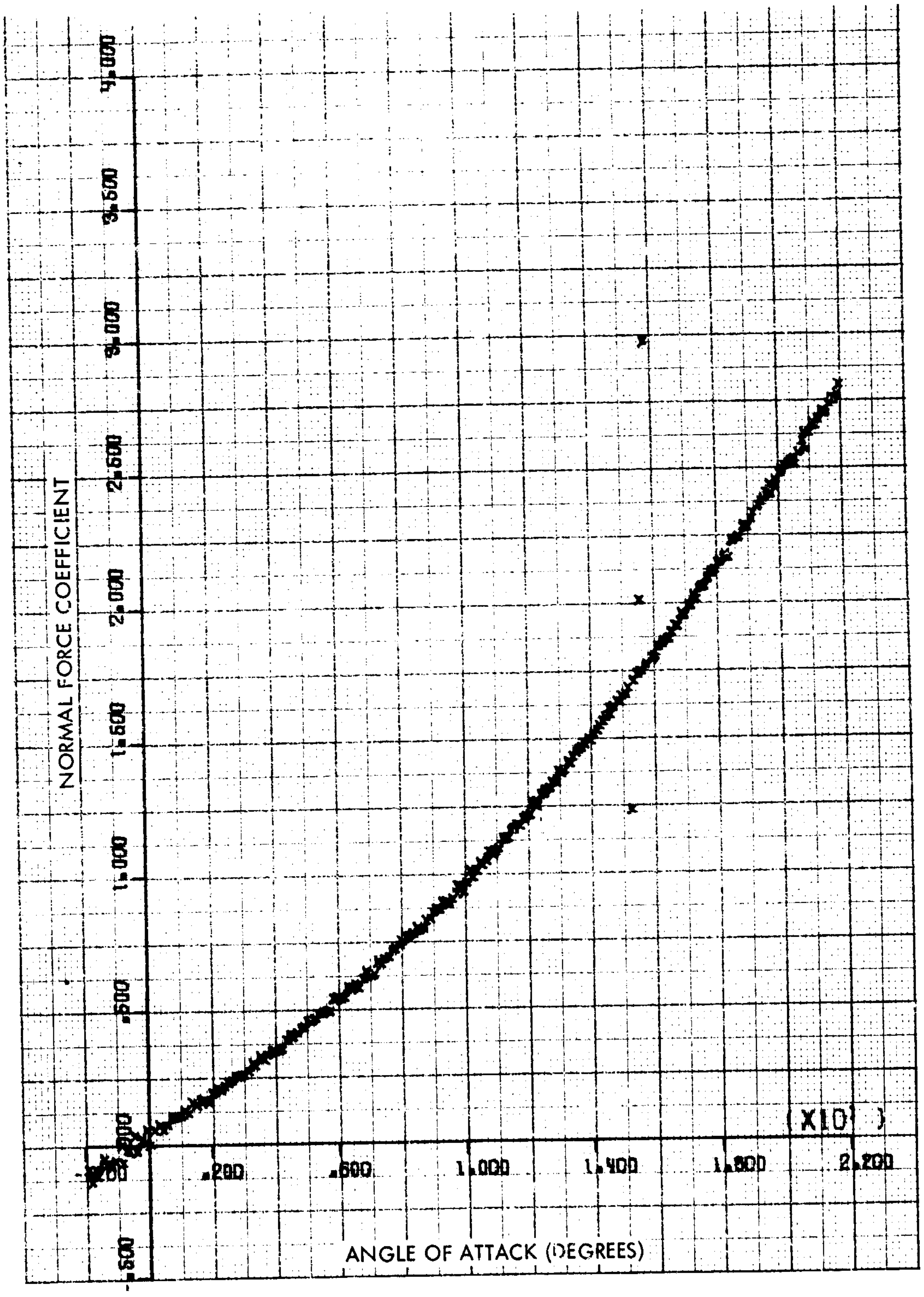

FIG. 19 NORMAL FORCE COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 0.85 AND A ROLL ANGLE OF 0 DEGREES

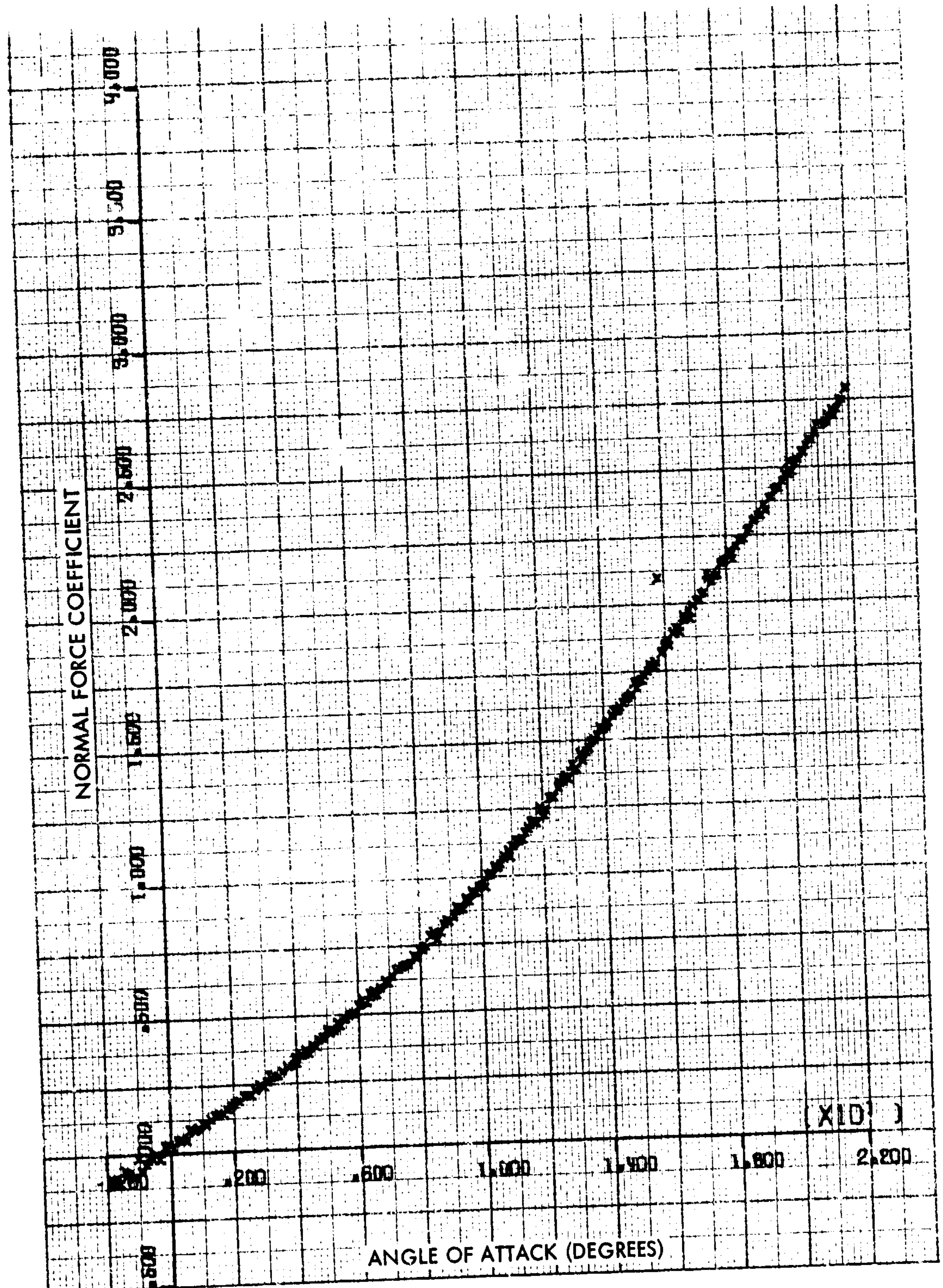

FIG. 20 NORMAL FORCE COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 0.95 AND A ROLL ANGLE OF 0 DEGREES

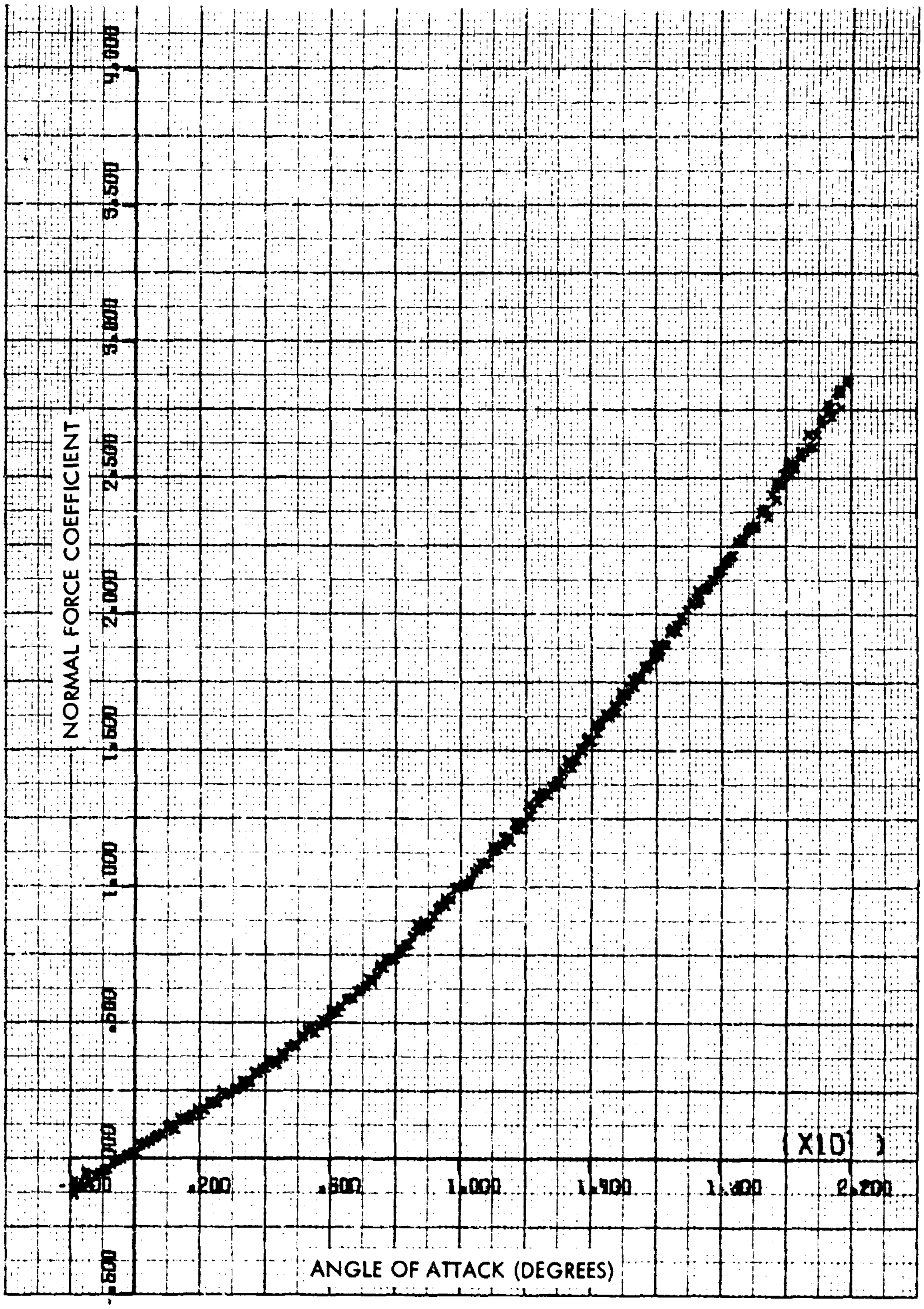

FIG. 21 NORMAL FORCE COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 1.00 AND A ROLL ANGLE OF 0 DEGREES

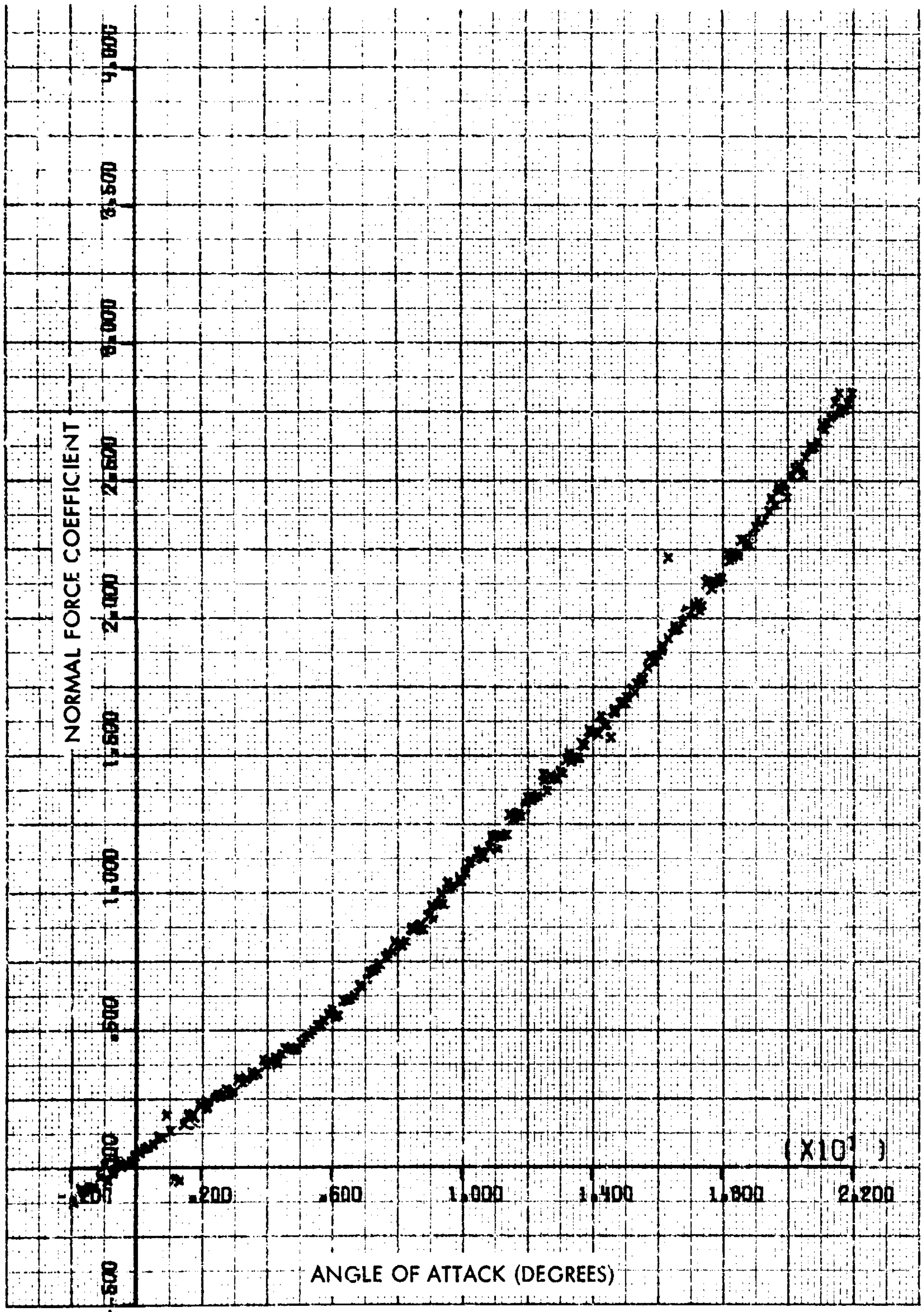

FIG. 22 NORMAL FORCE COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 1.05 AND A ROLL ANGLE OF 0 DEGREES

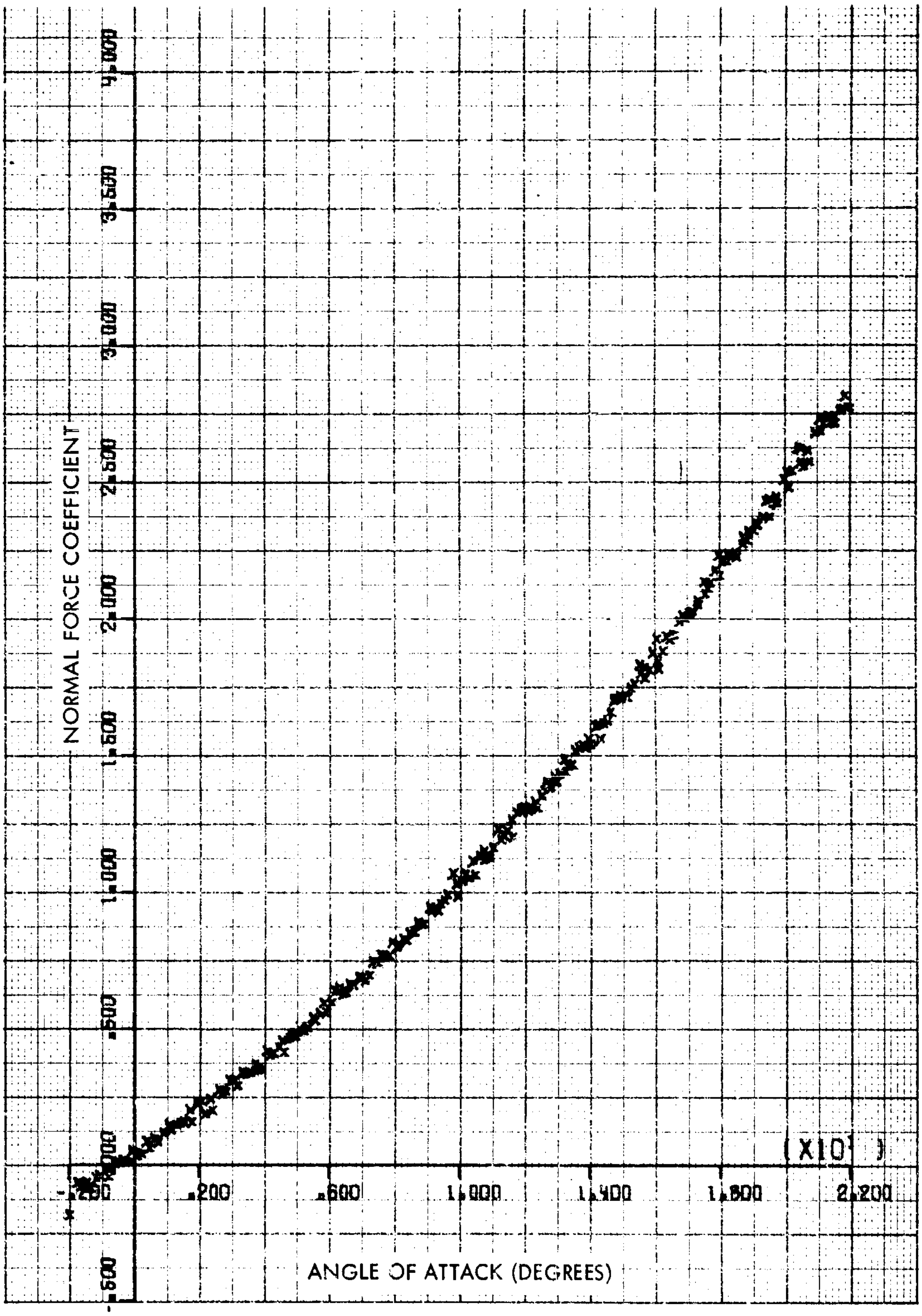

FIG. 23 NORMAL FORCE COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 1.10 AND A ROLL ANGLE OF 0 DEGREES

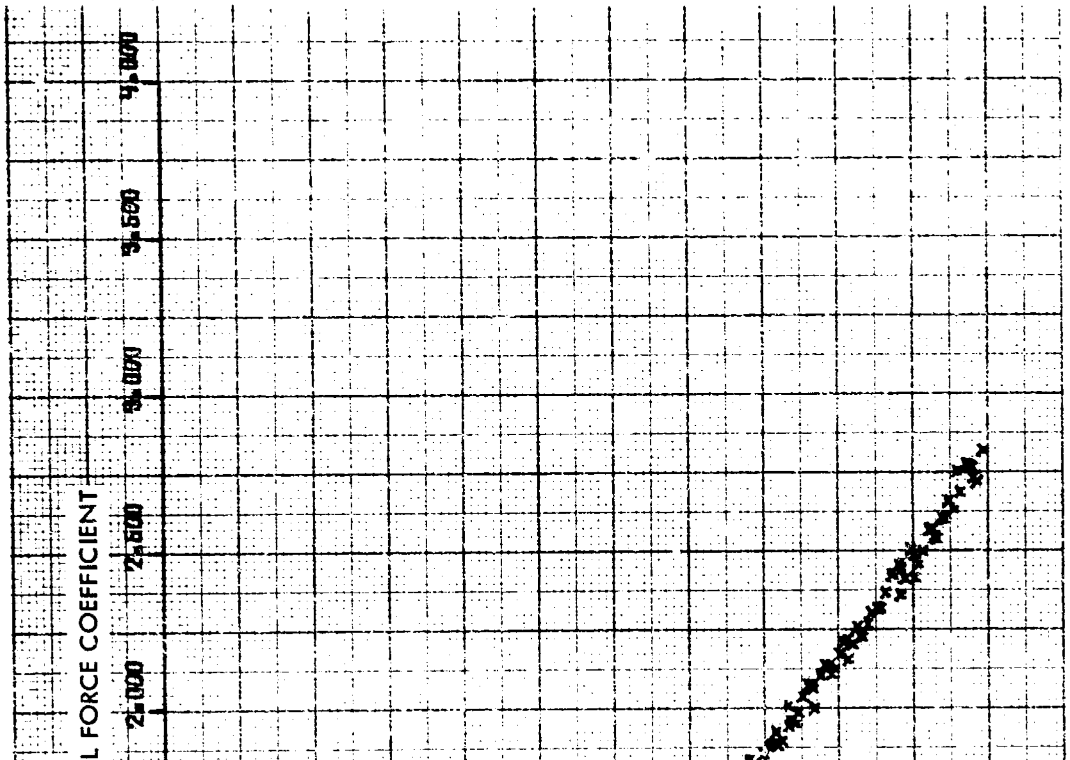

FIG. 24 NORMAL FORCE COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 1.15 AND A ROLL ANGLE OF 0 DEGREES

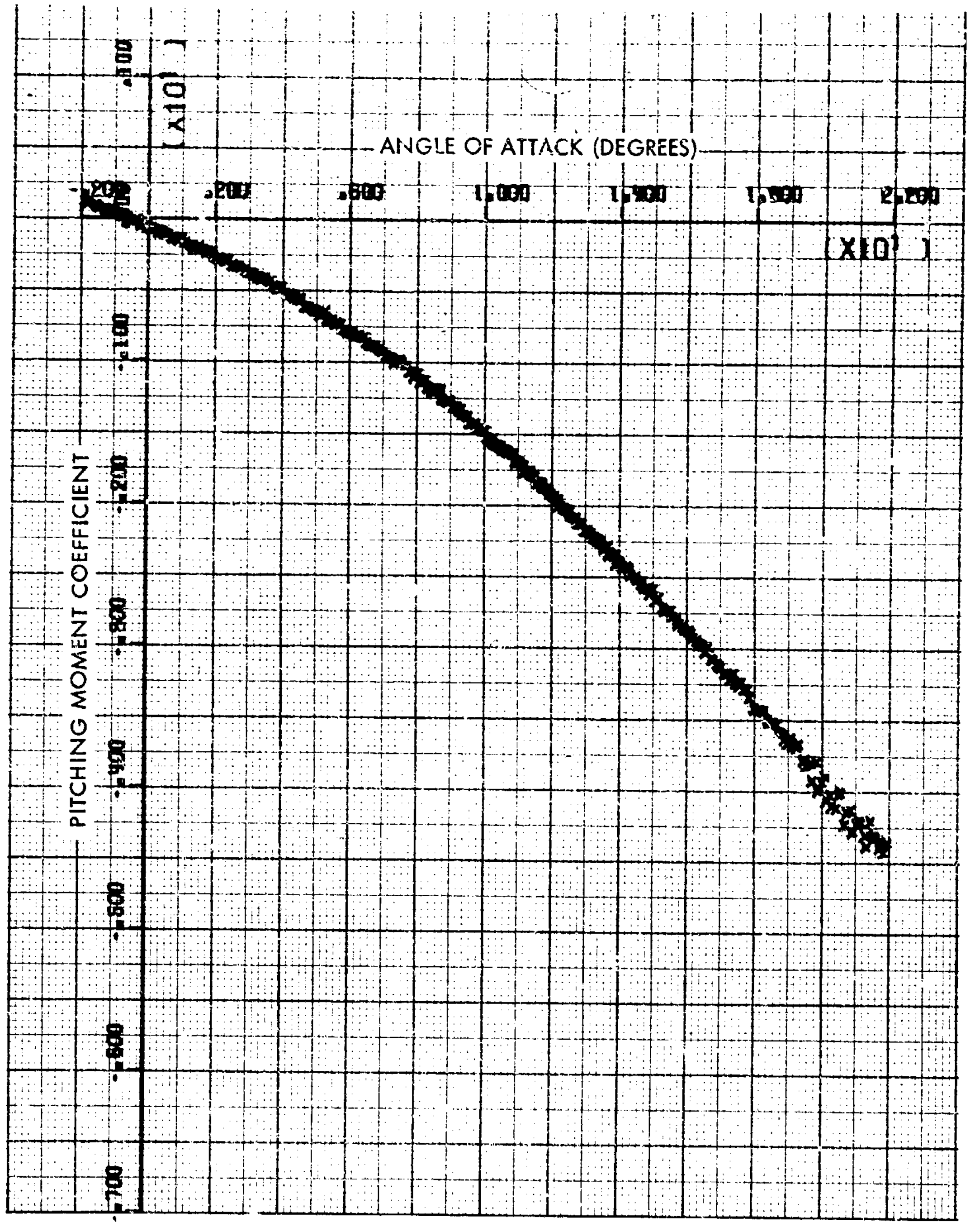

FIG. 25 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 0.6 AND A ROLL ANGLE OF 22.5 DEGREES

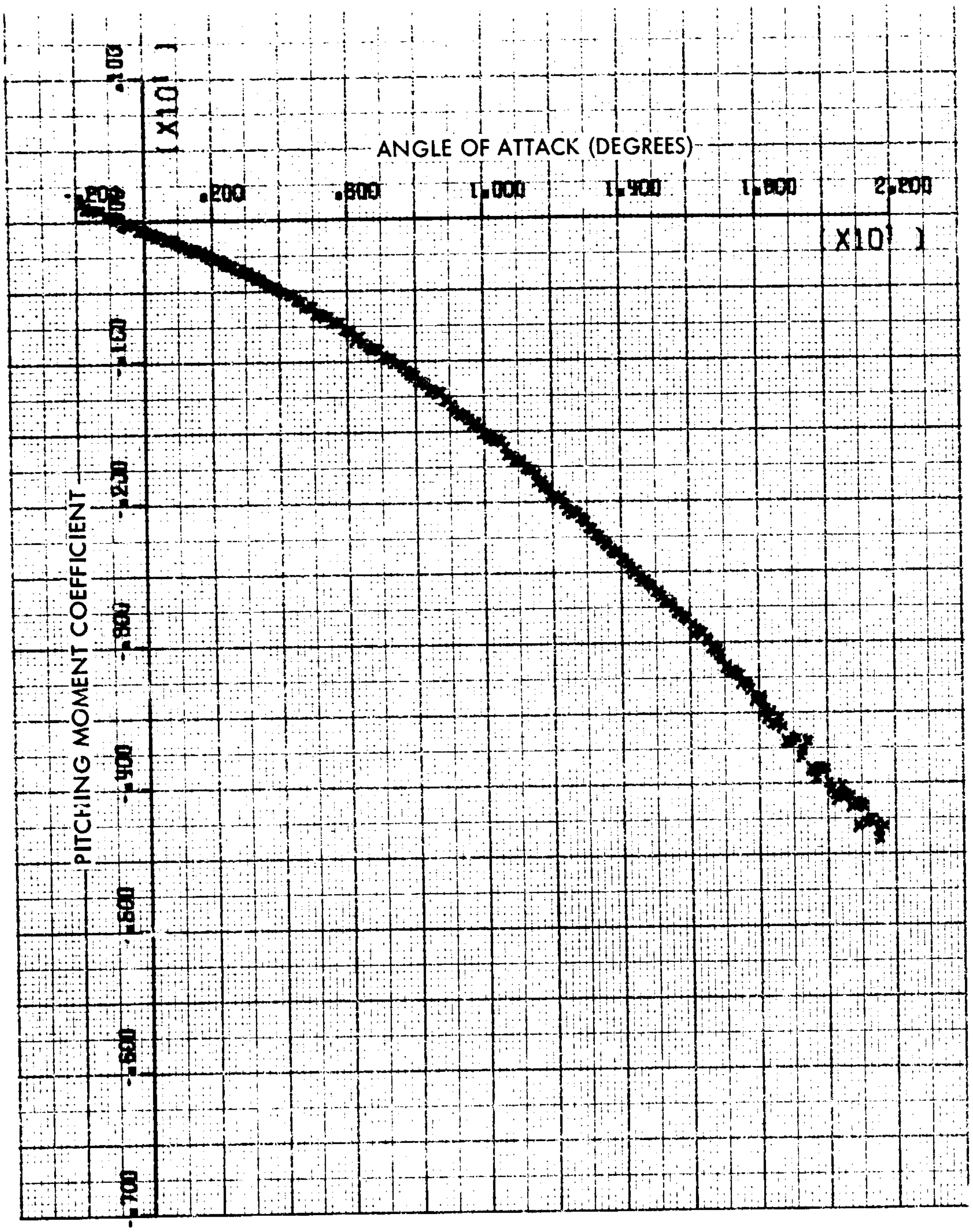

FIG. 26 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 0.7 AND A ROLL ANGLE OF 22.5 DEGREES

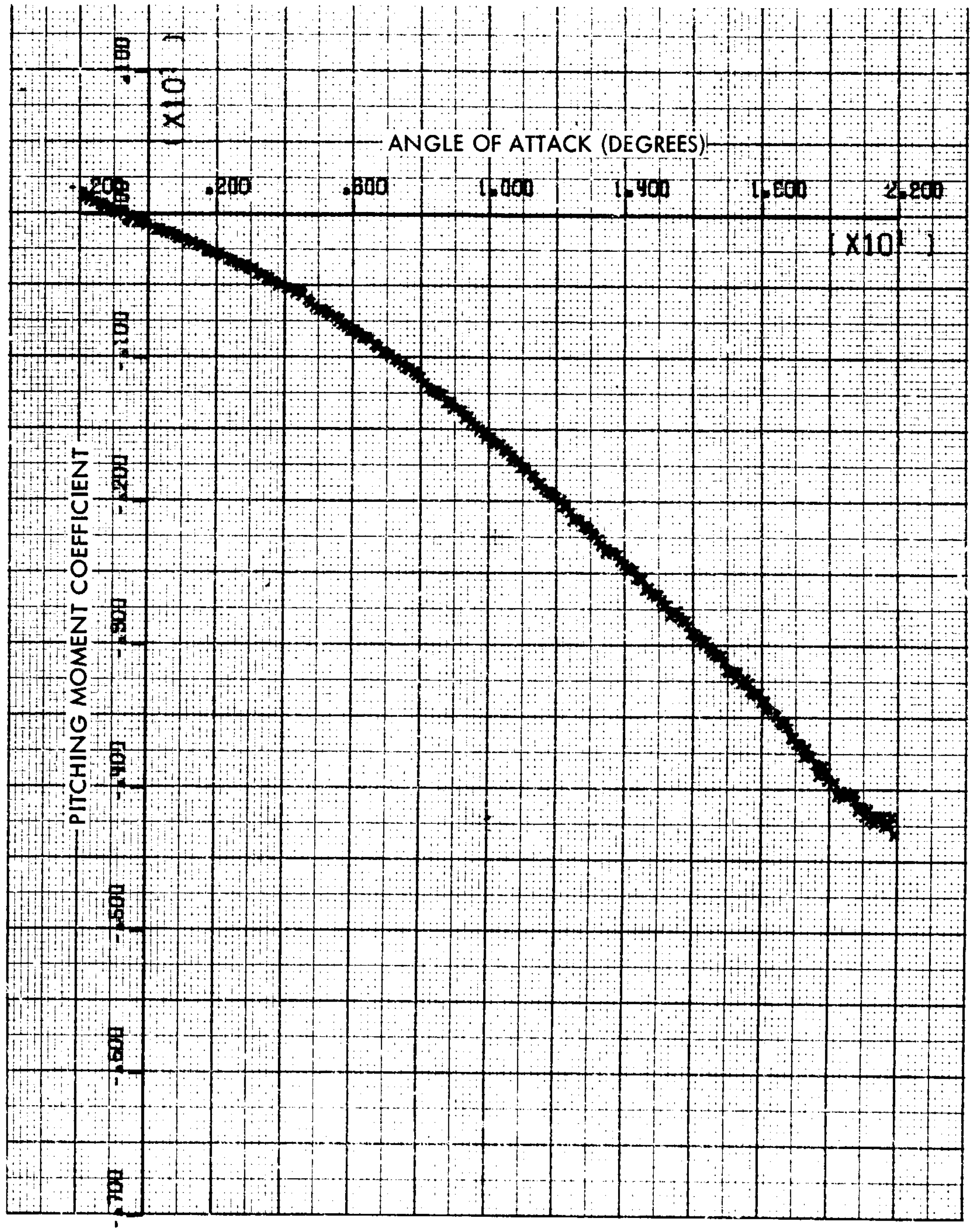

FIG. 27 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 0.8 AND A ROLL ANGLE OF 22.5 DEGREES

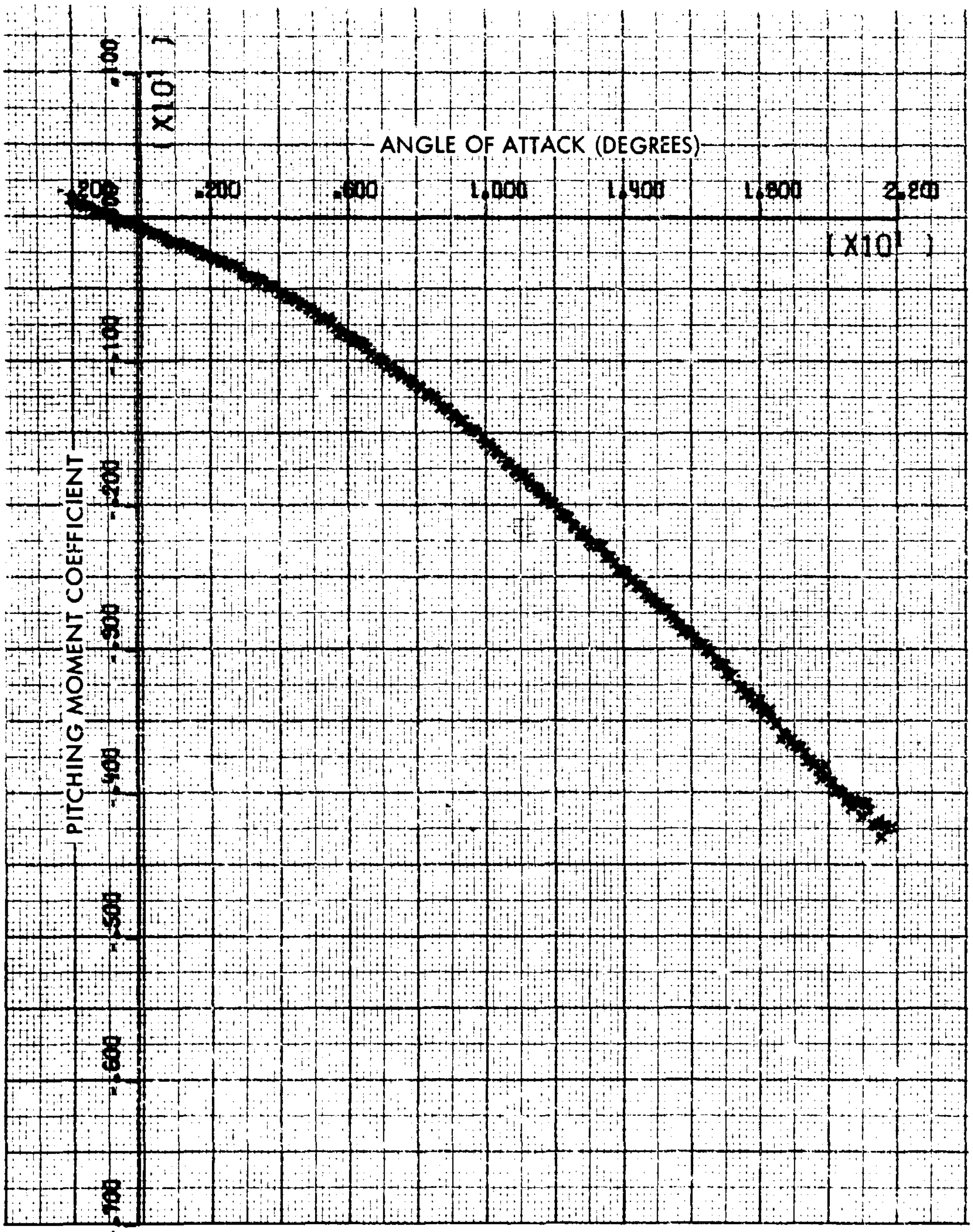

FIG. 28 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 0.85 AND A ROLL ANGLE OF 22.5 DEGREES

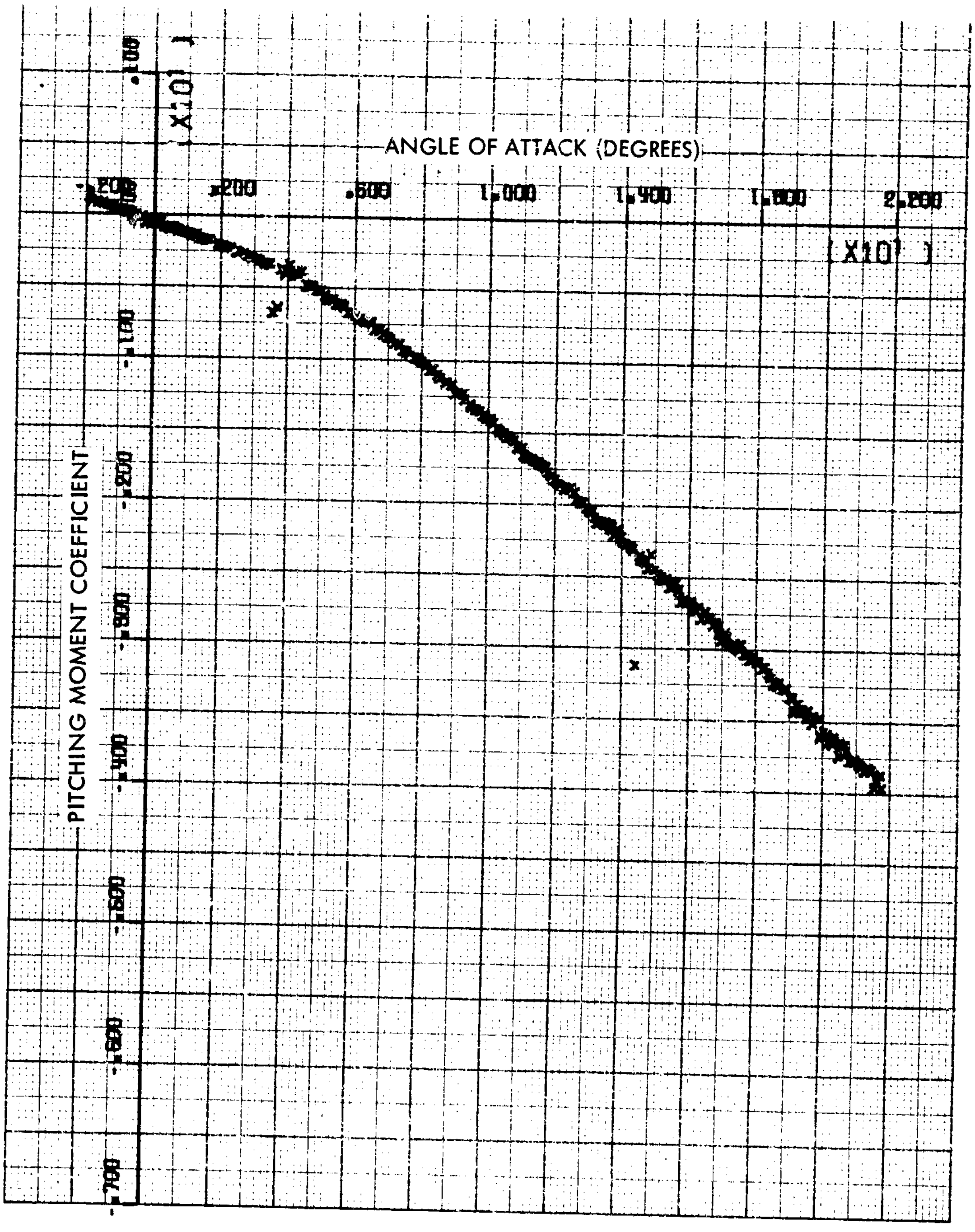

FIG. 29 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 0.95 AND A ROLL ANGLE OF 22.5 DEGREES

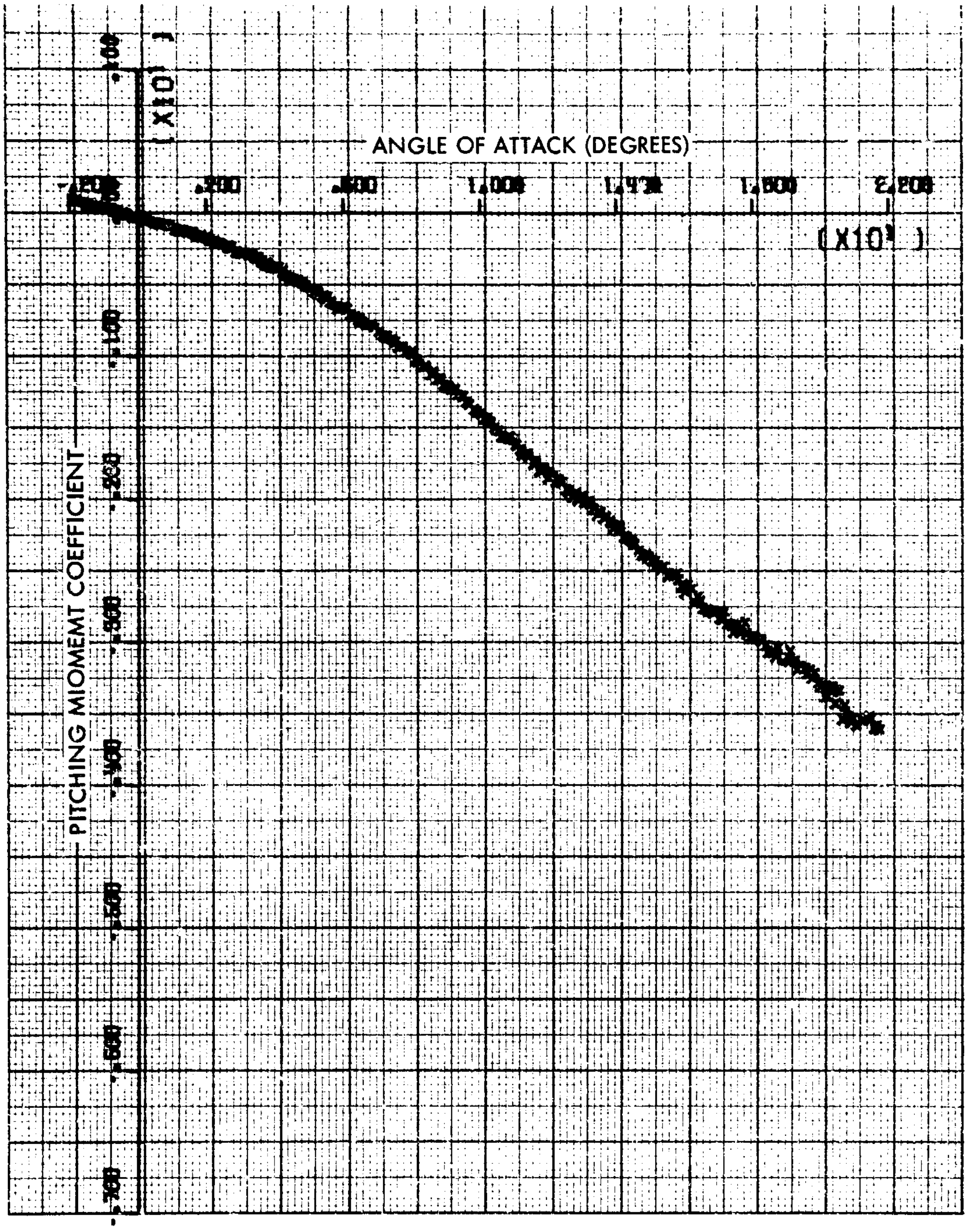

FIG. 30 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 1.00 AND A ROLL ANGLE OF 22.5 DEGREES

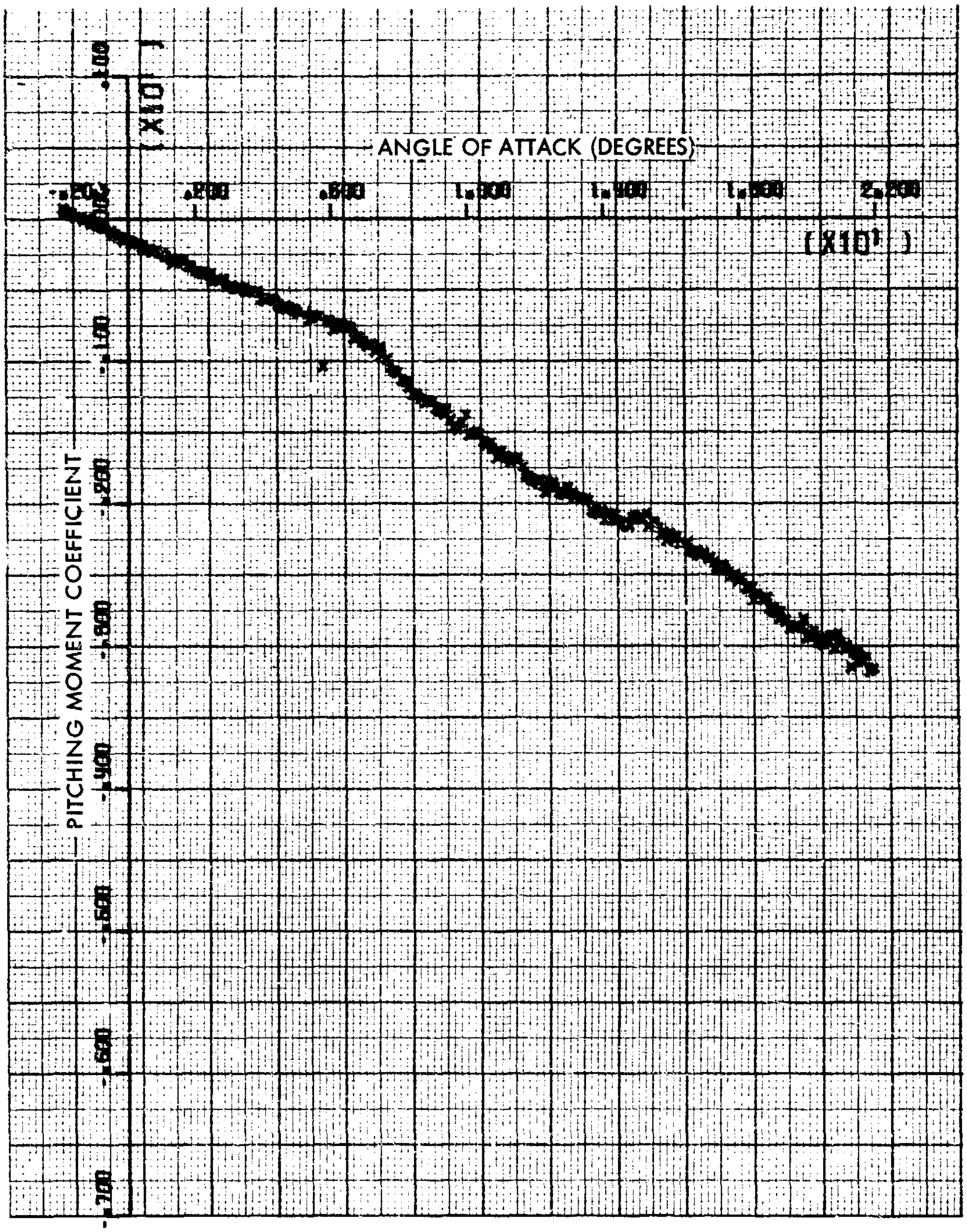

FIG. 31 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 1.05 AND A ROLL ANGLE OF 22.5 DEGREES

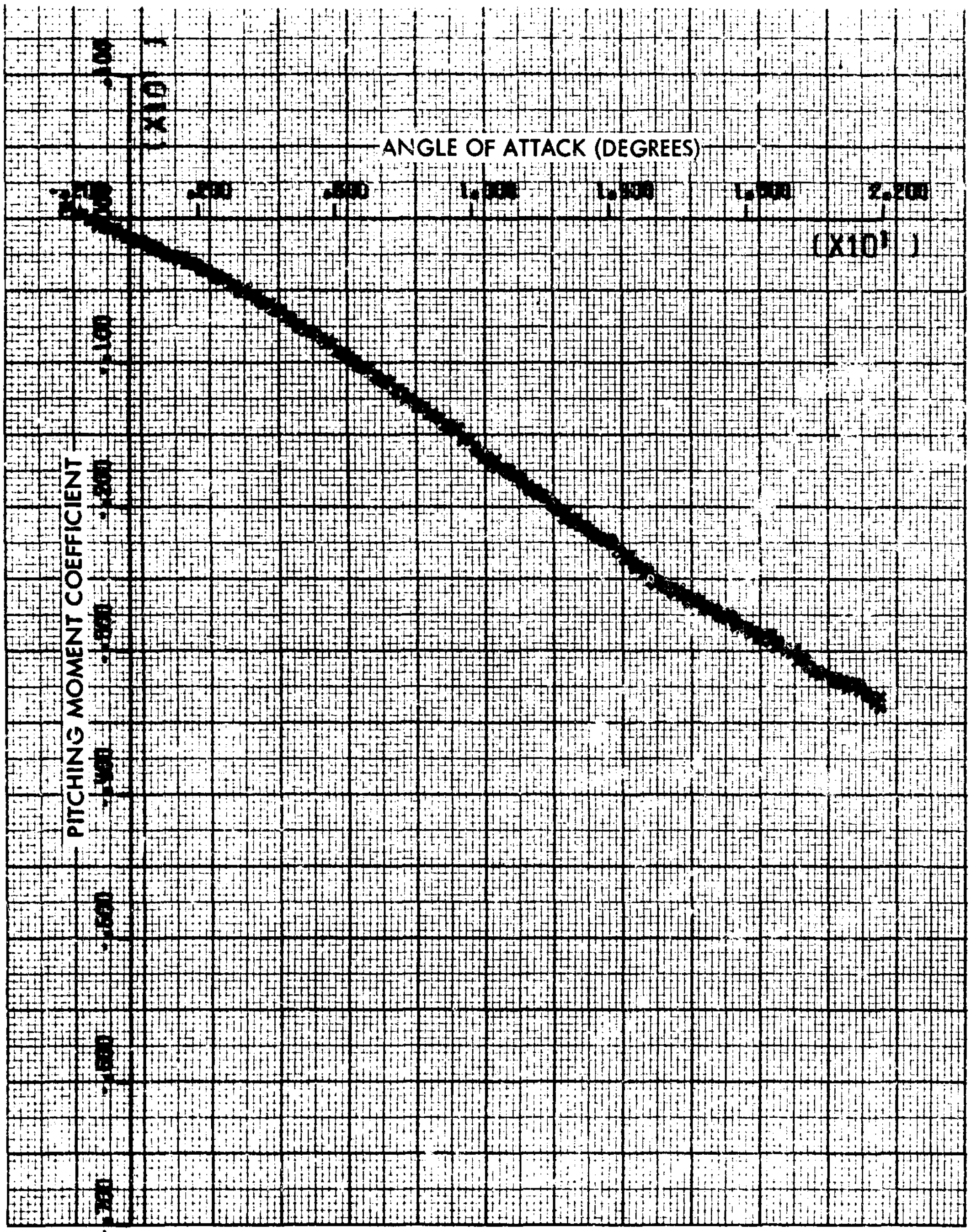

FIG. 32 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 1.10 AND A ROLL ANGLE OF 22.5 DEGREES

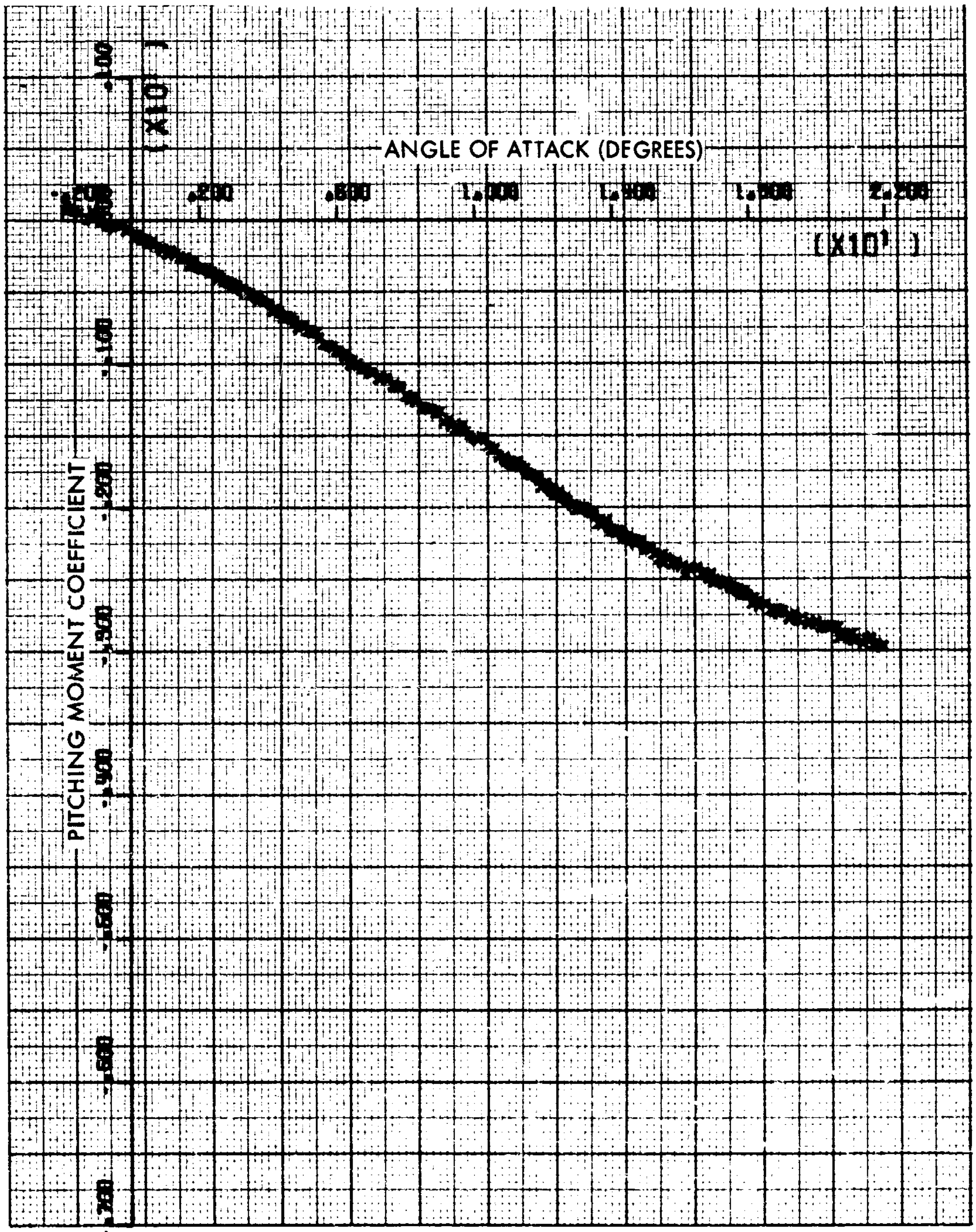

FIG. 33 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 1.15 AND A ROLL ANGLE OF 22.5 DEGREES

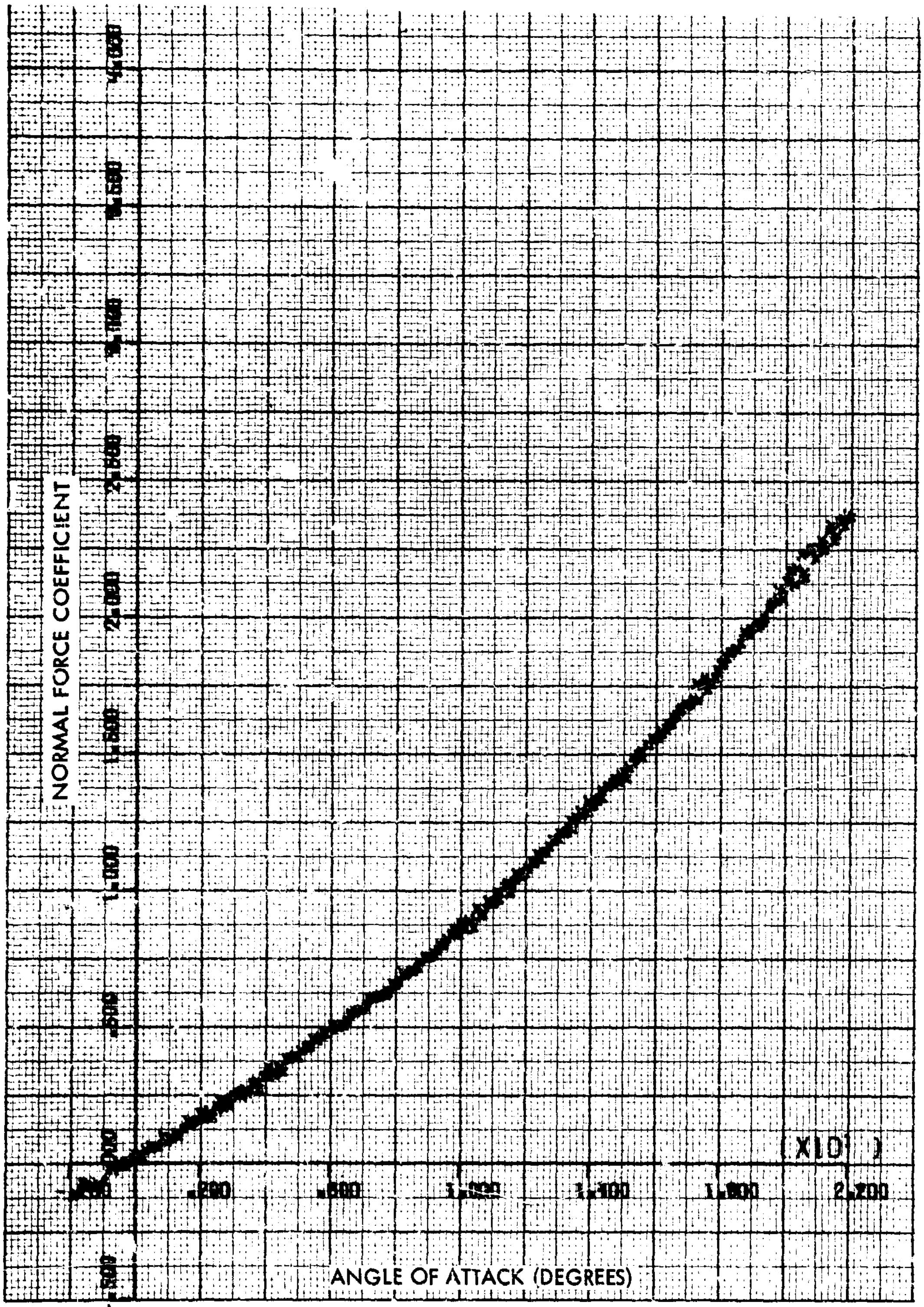

FIG. 34 NORMAL FORCE COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 0.6 AND A ROLL ANGLE OF 22.5 DEGREES

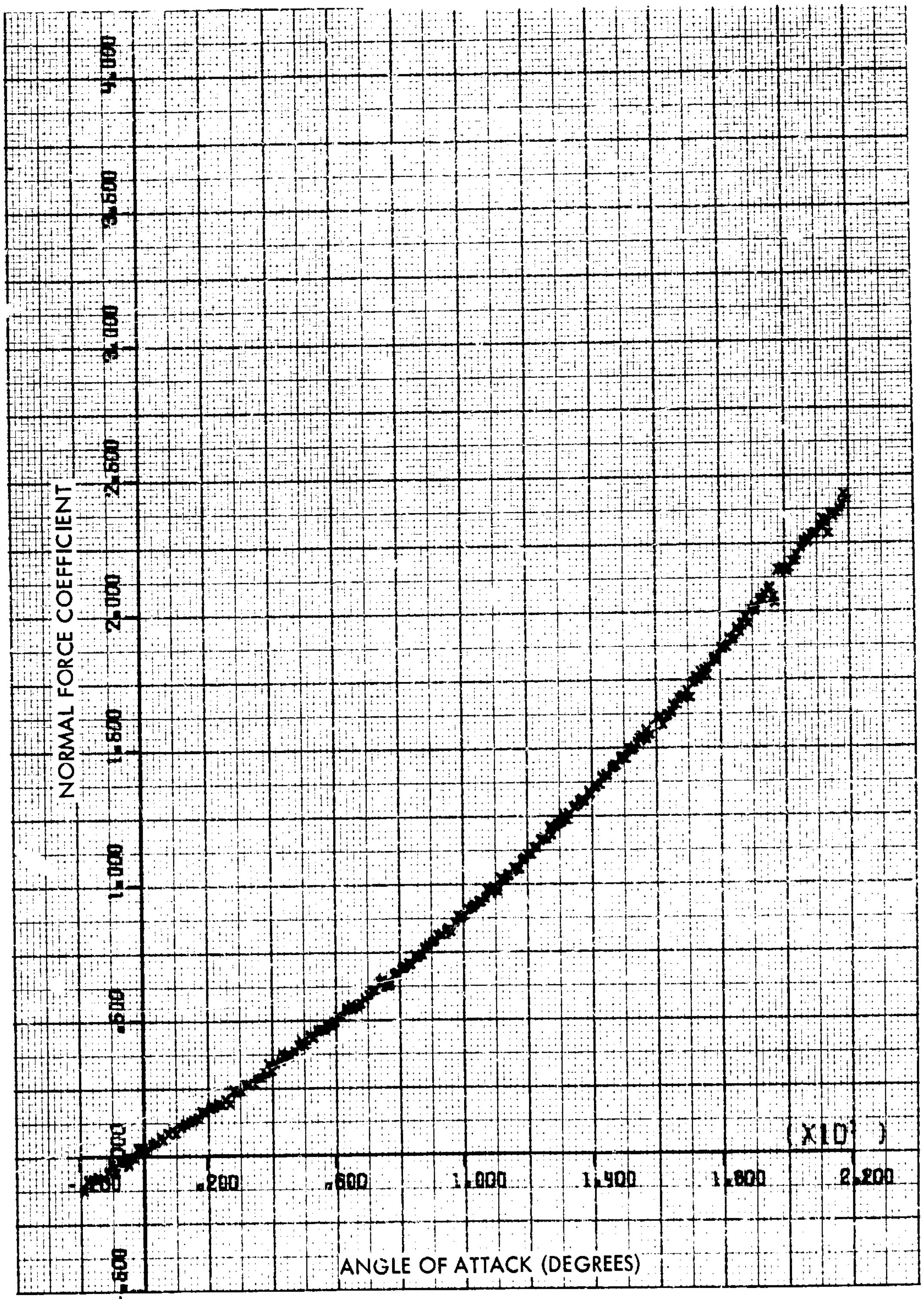

FIG. 35 NORMAL FORCE COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 0.7 AND A ROLL ANGLE OF 22.5 DEGREES

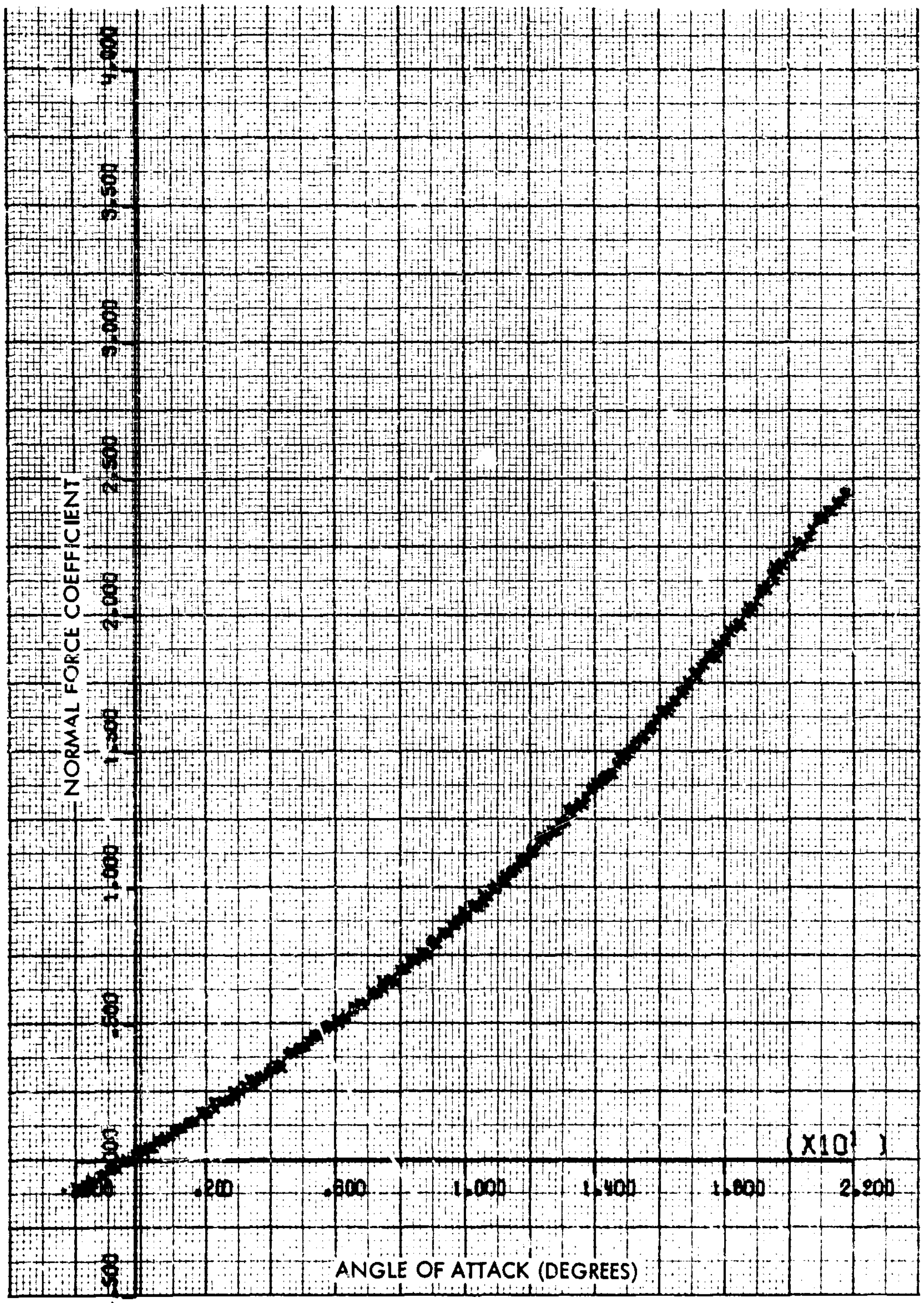

FIG. 36 NORMAL FORCE COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 0.8 AND A ROLL ANGLE OF 22.5 DEGREES

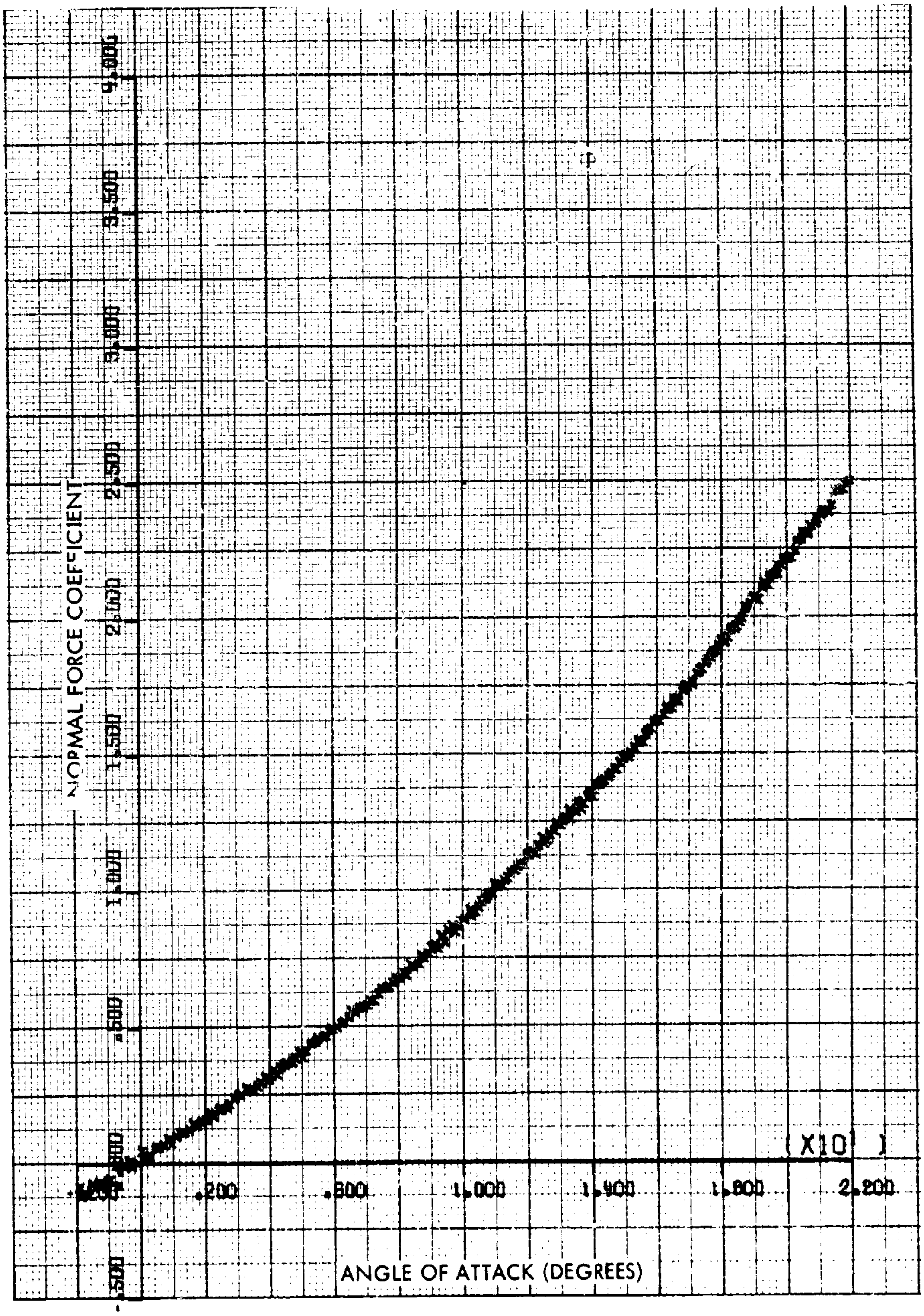

FIG. 37 NORMAL FORCE COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 0.85 AND A ROLL ANGLE OF 22.5 DEGREES

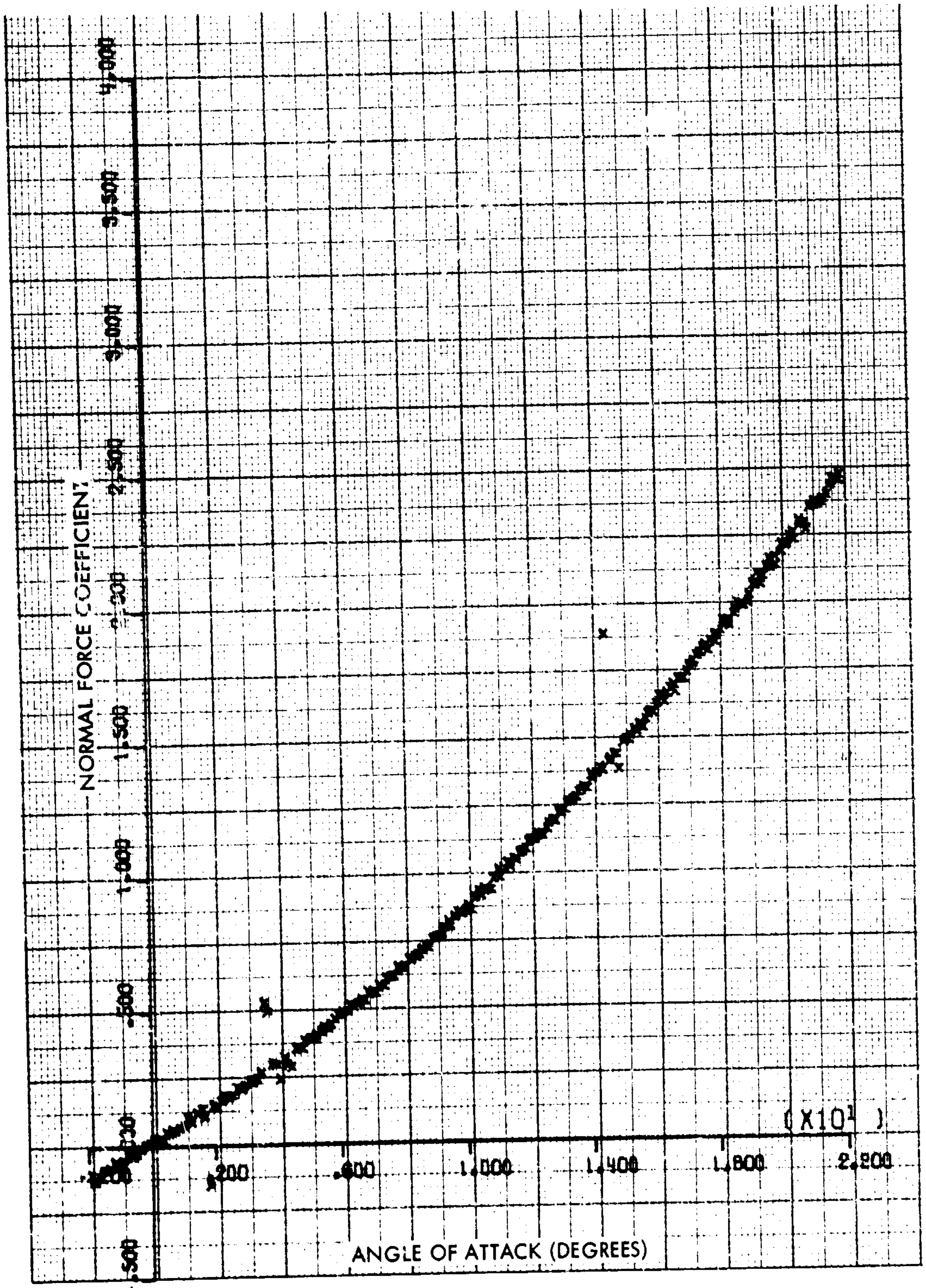

FIG. 38 NORMAL FORCE COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 0.95 AND A ROLL ANGLE OF 22.5 DEGREES.

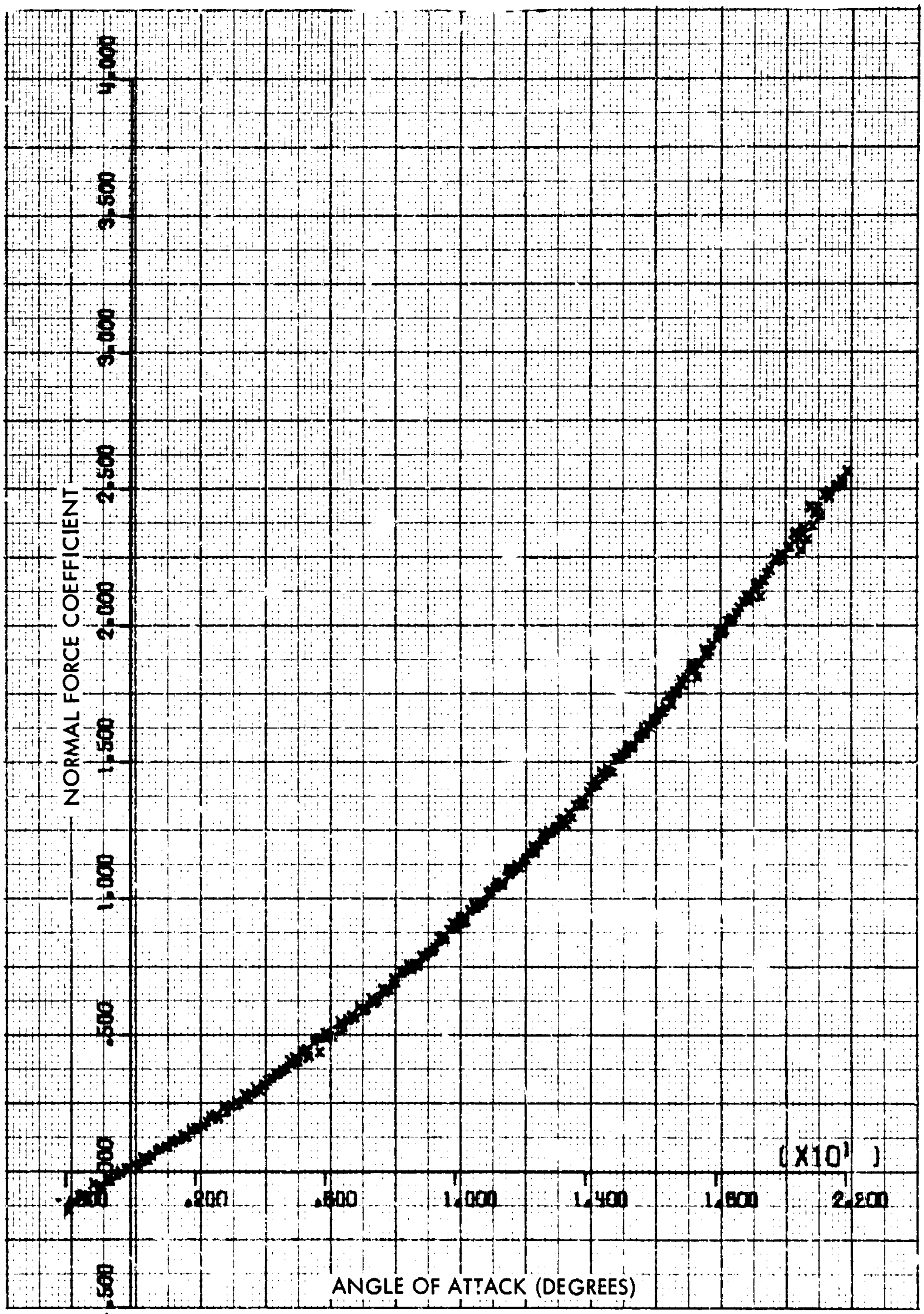

FIG. 39 NORMAL FORCE COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 1.00 AND A ROLL ANGLE OF 22.5 DEGREES

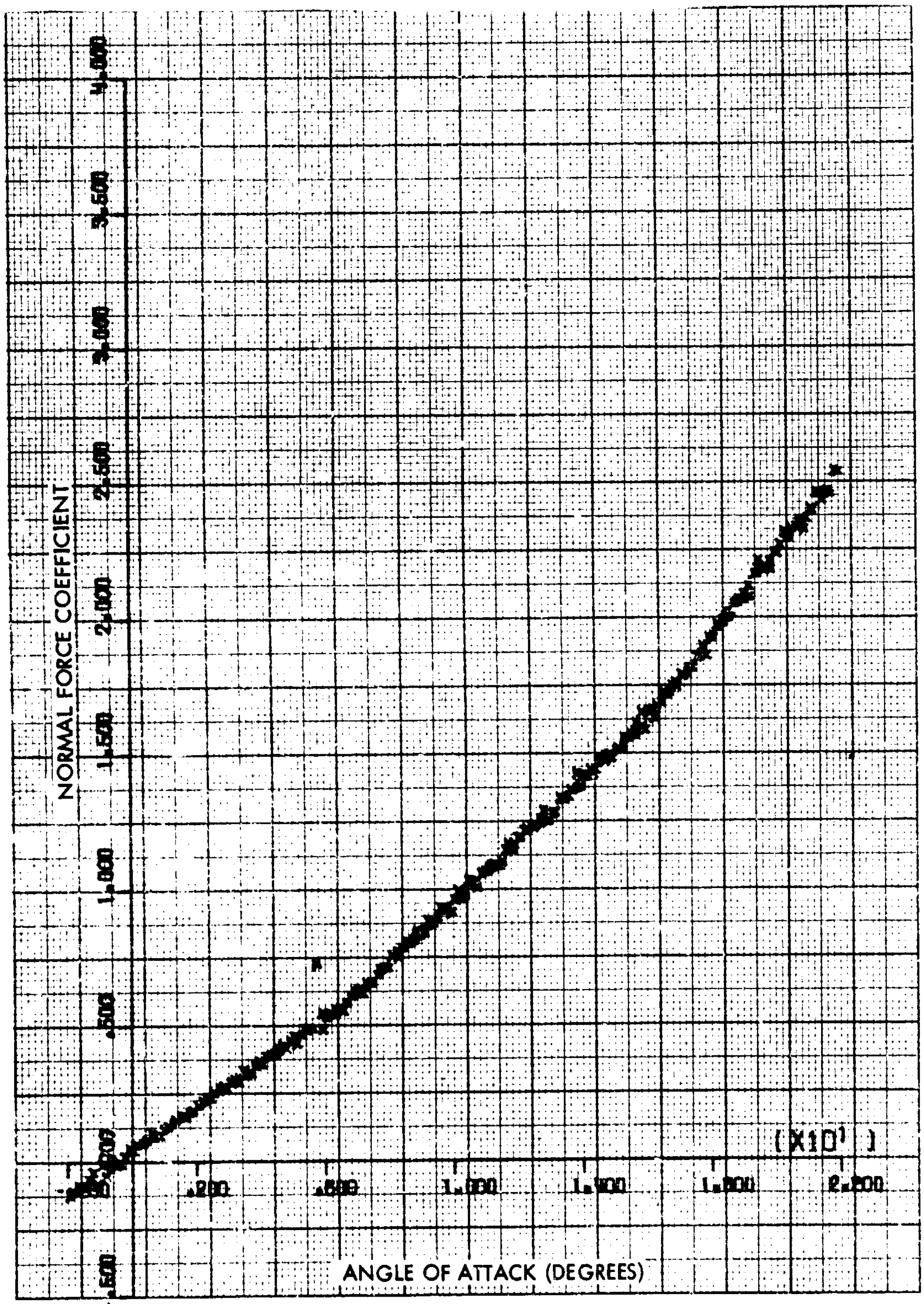

FIG. 40 NORMAL FORCE COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 1.05 AND A ROLL ANGLE OF 22.5 DEGREES

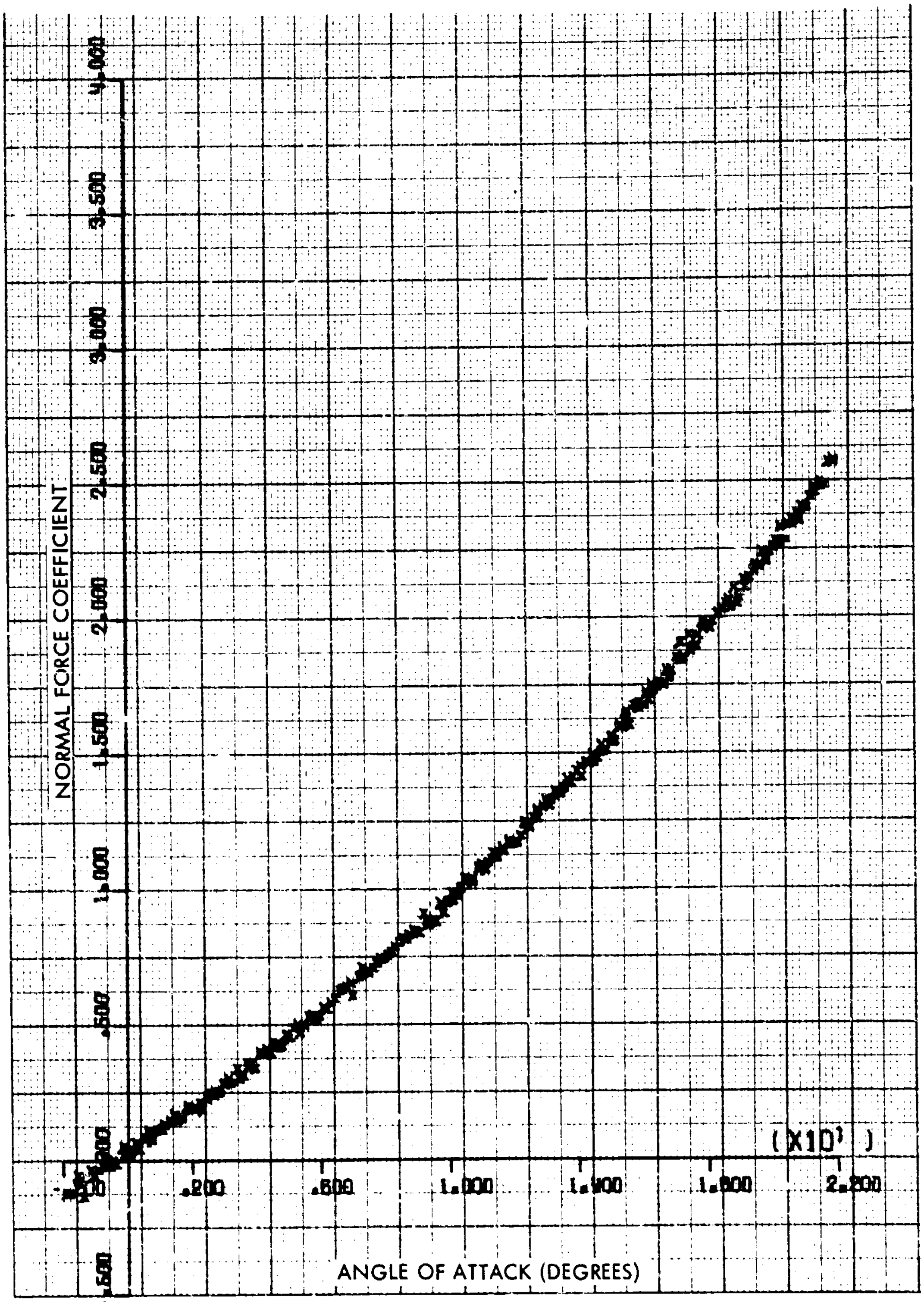

FIG. 41 NORMAL FORCE COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 1.10 AND A ROLL ANGLE OF 22.5 DEGREES

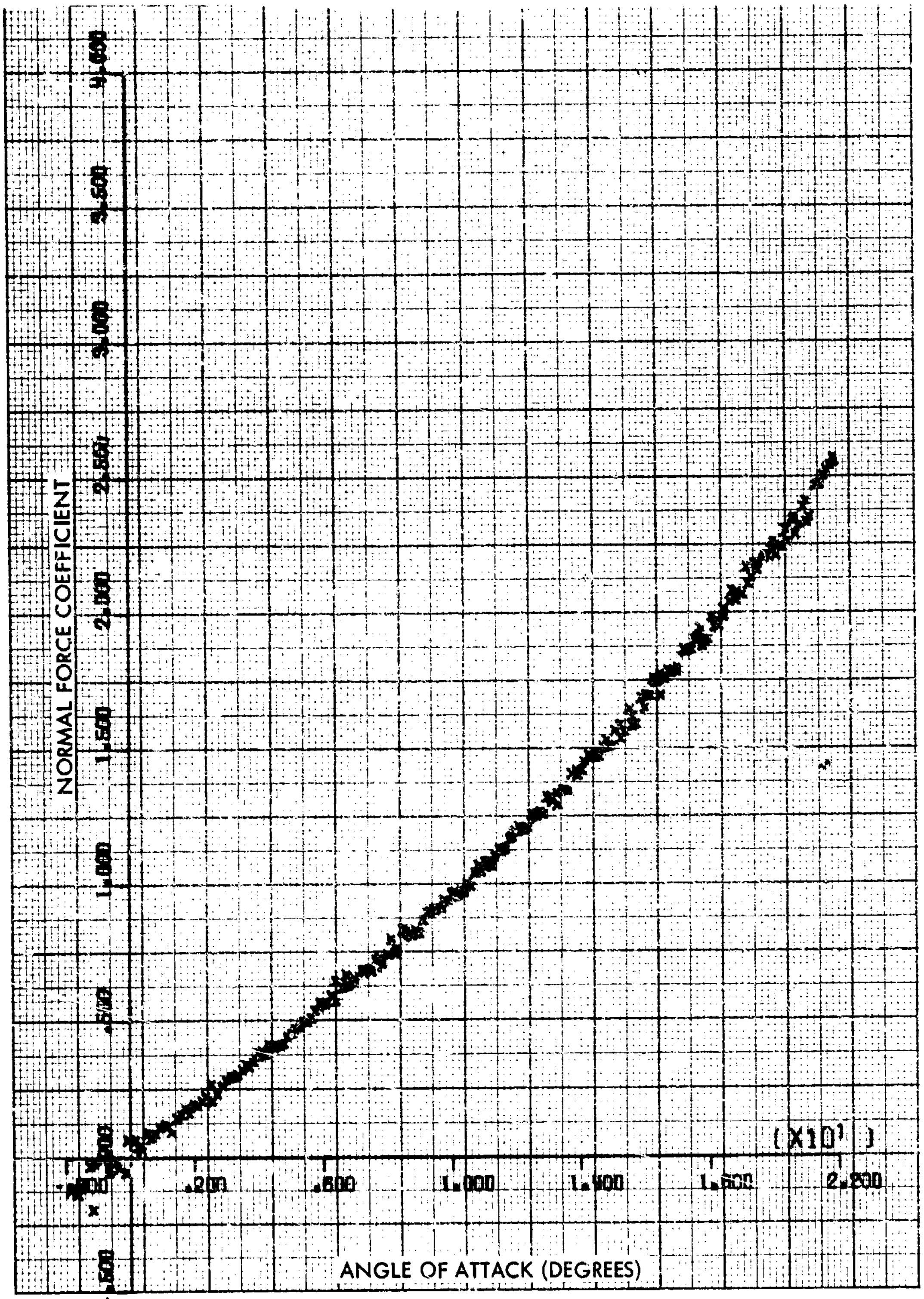

FIG. 42 NORMAL FORCE COEFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 1.15 AND A ROLL ANGLE OF 22.5 DEGREES

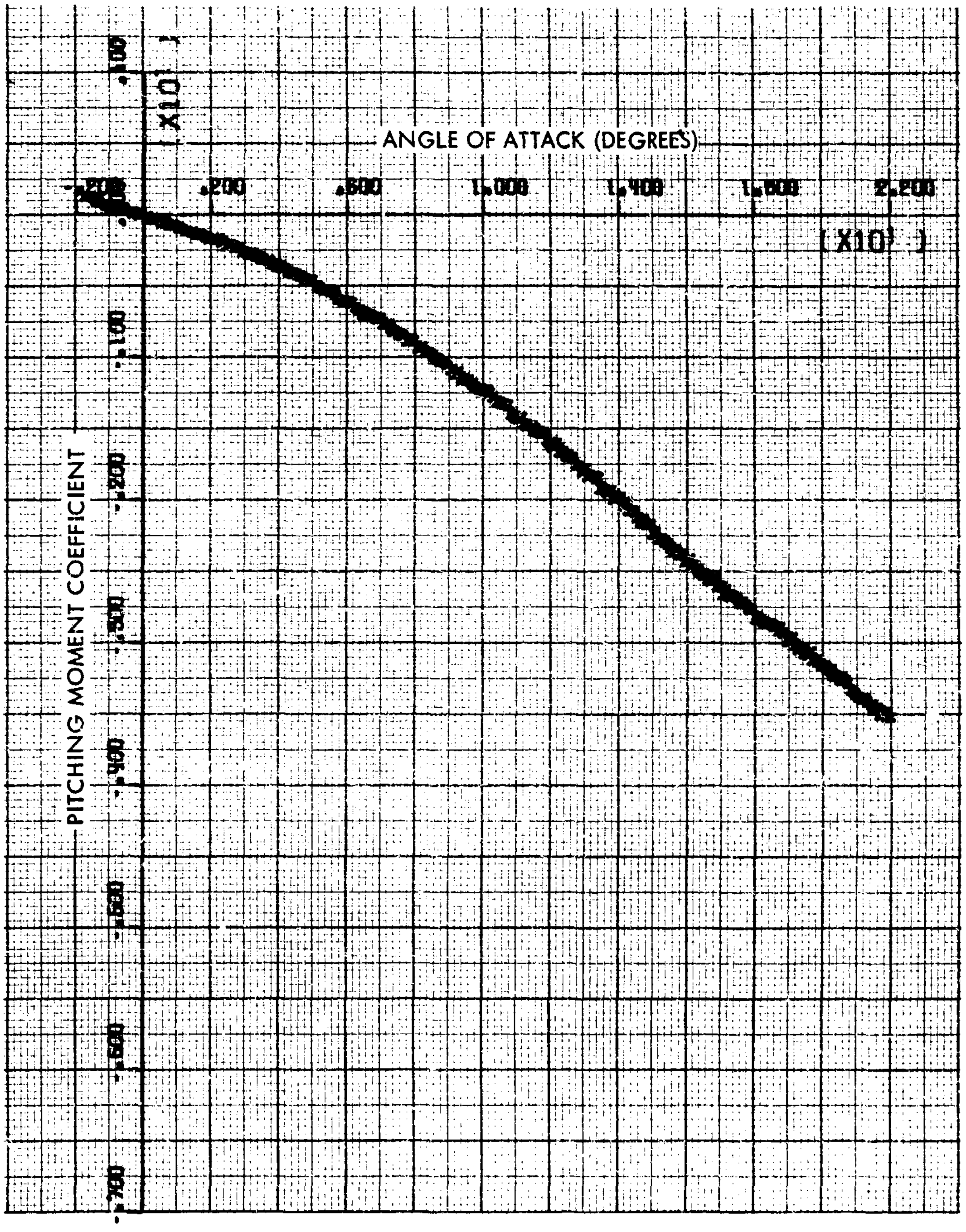

FIG. 43 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 0.6 AND A ROLL ANGLE OF 45 DEGREES

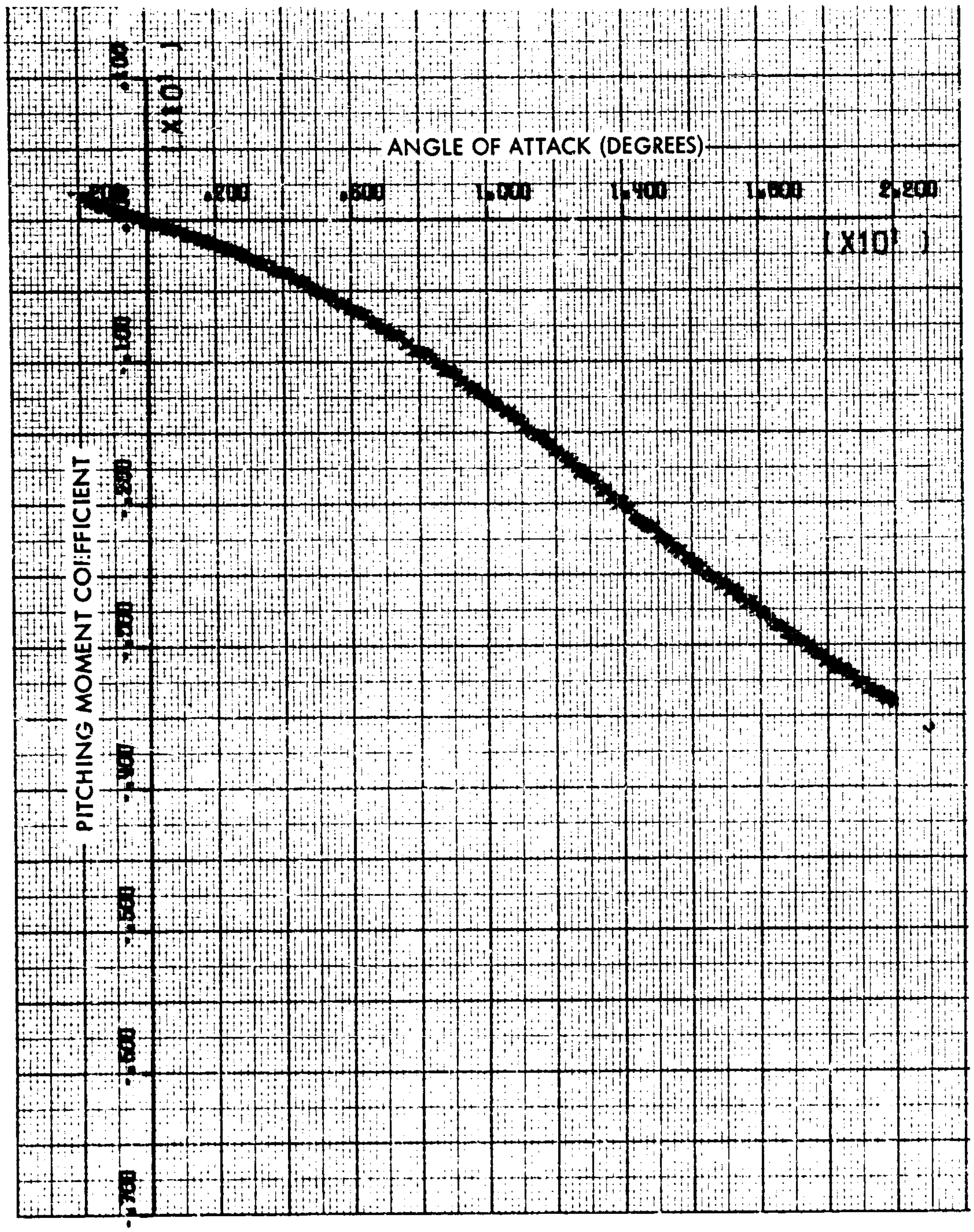

FIG. 44 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 0.7 AND A ROLL ANGLE OF 45 DEGREES

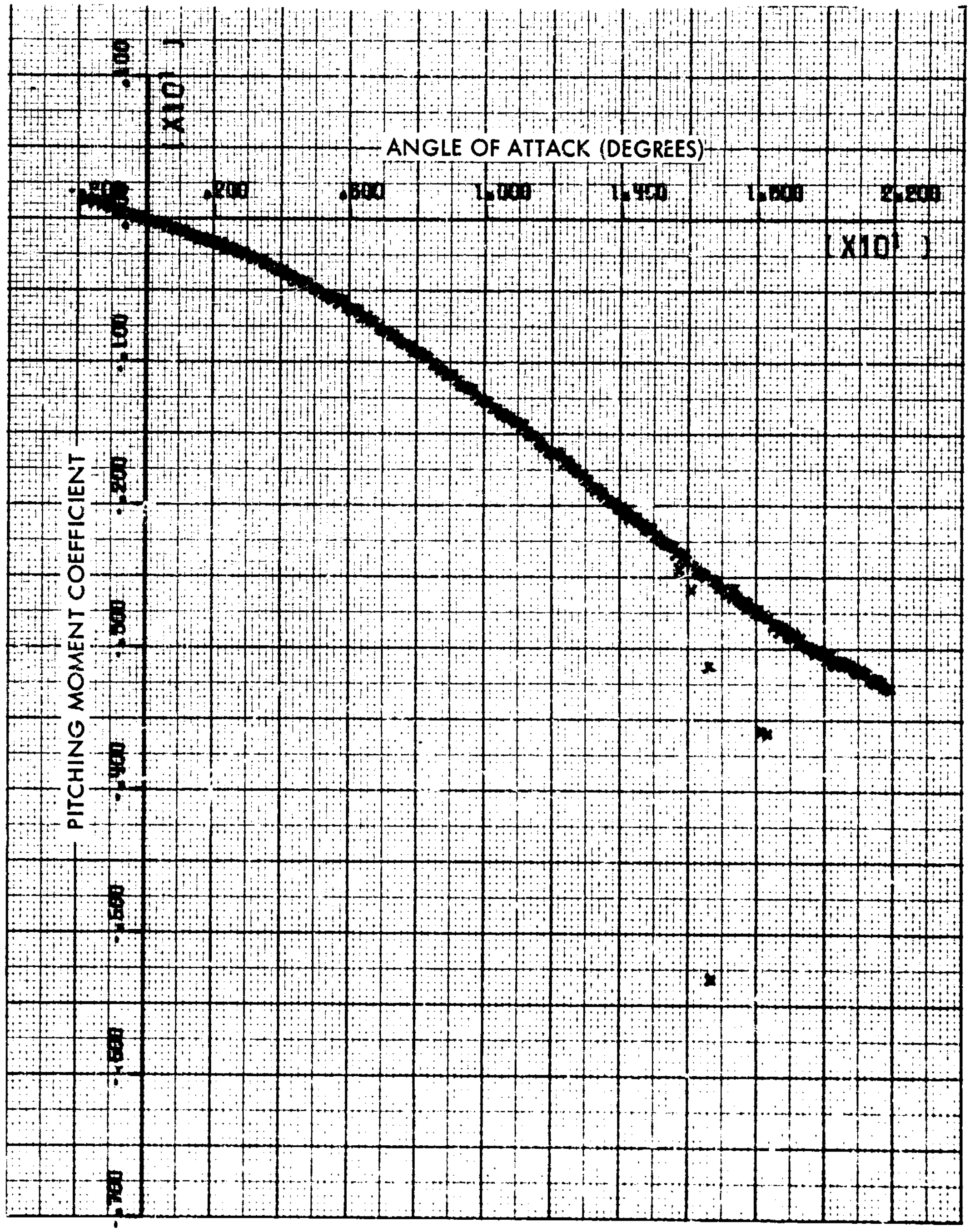

FIG. 45 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 0.8 AND A ROLL ANGLE OF 45 DEGREES

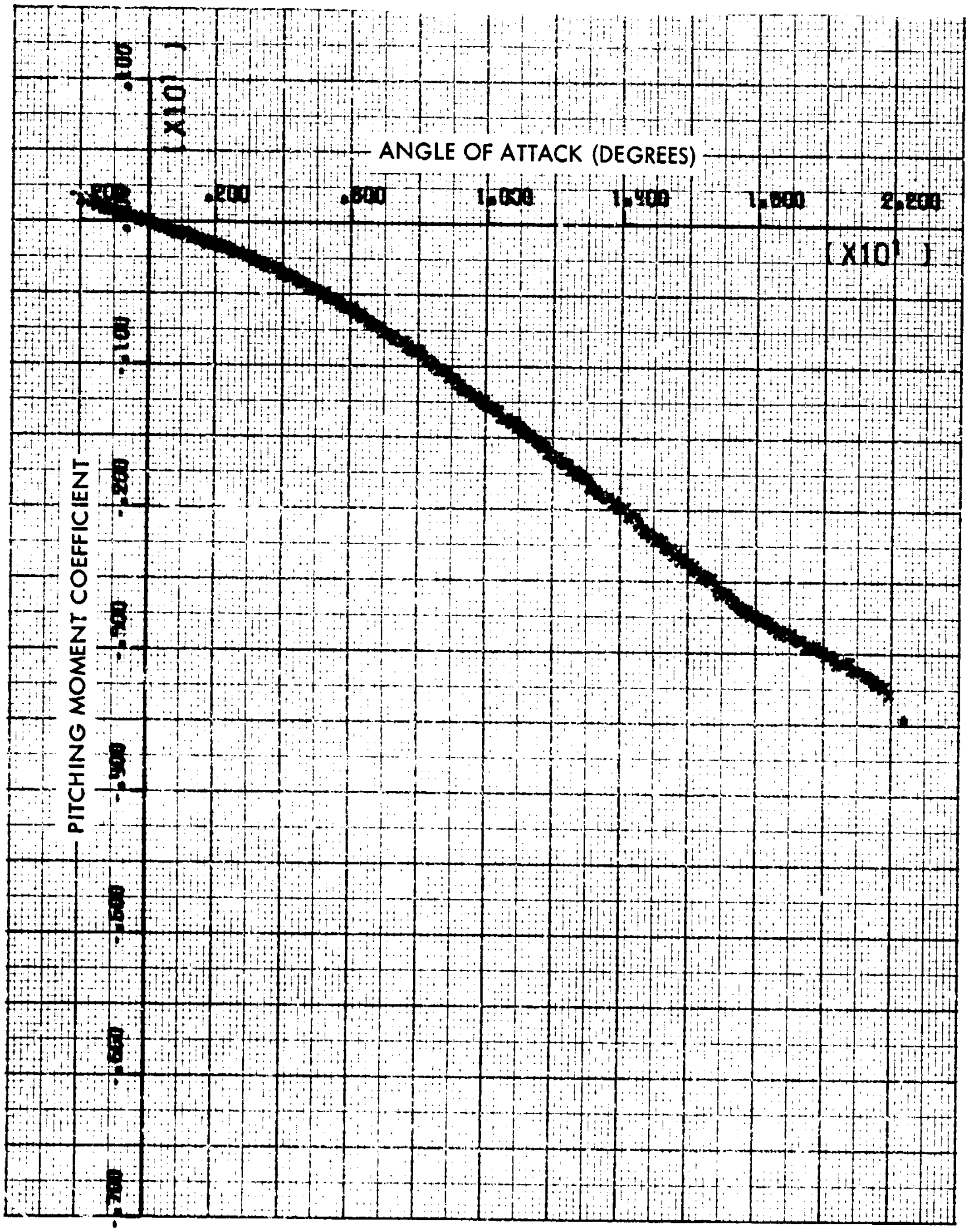

FIG. 46 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 0.85 AND A ROLL ANGLE OF 45 DEGREES

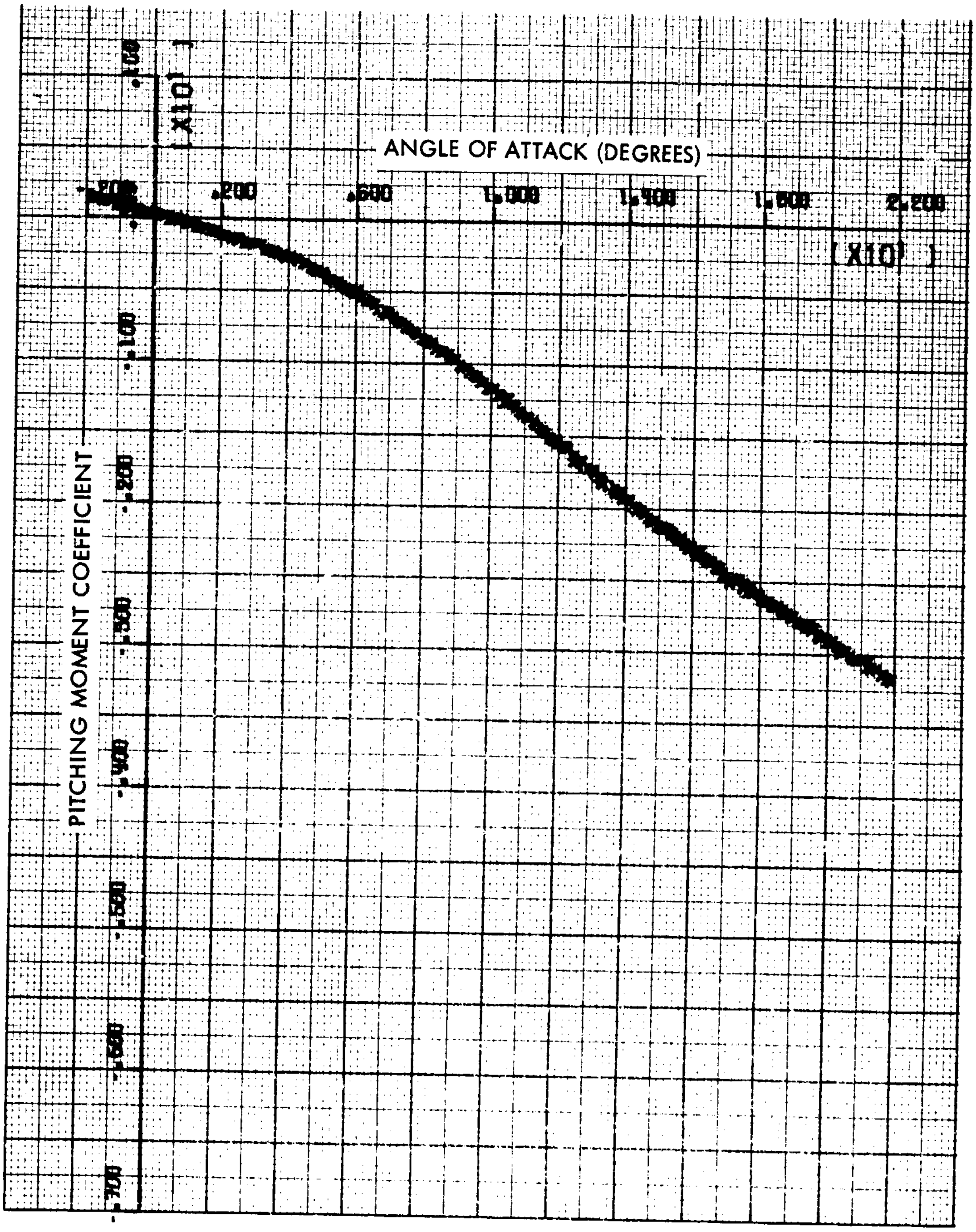

FIG. 47 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 0.95 AND A ROLL ANGLE OF 45 DEGREES

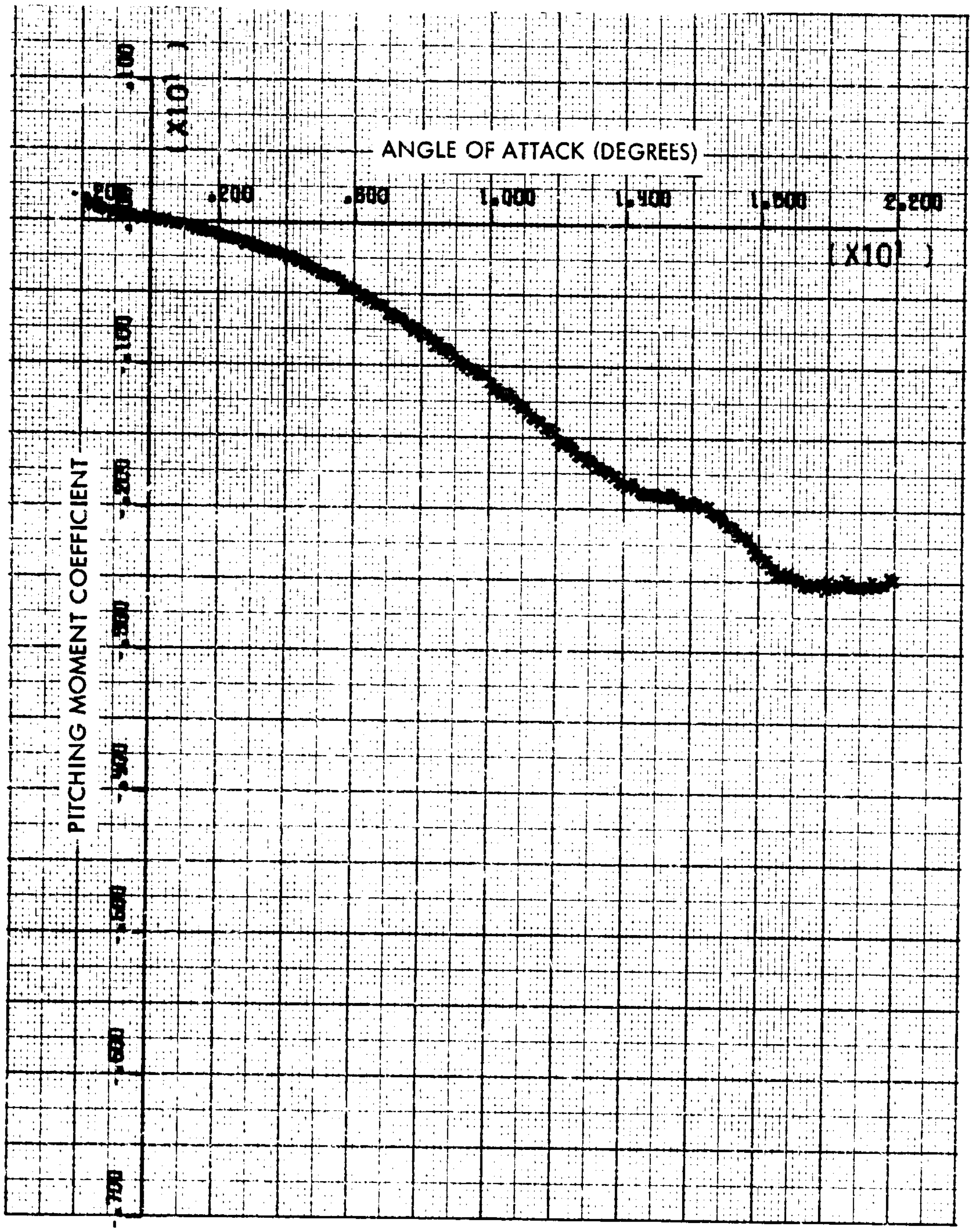

FIG. 48 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 1.00 AND A ROLL ANGLE OF 45 DEGREES

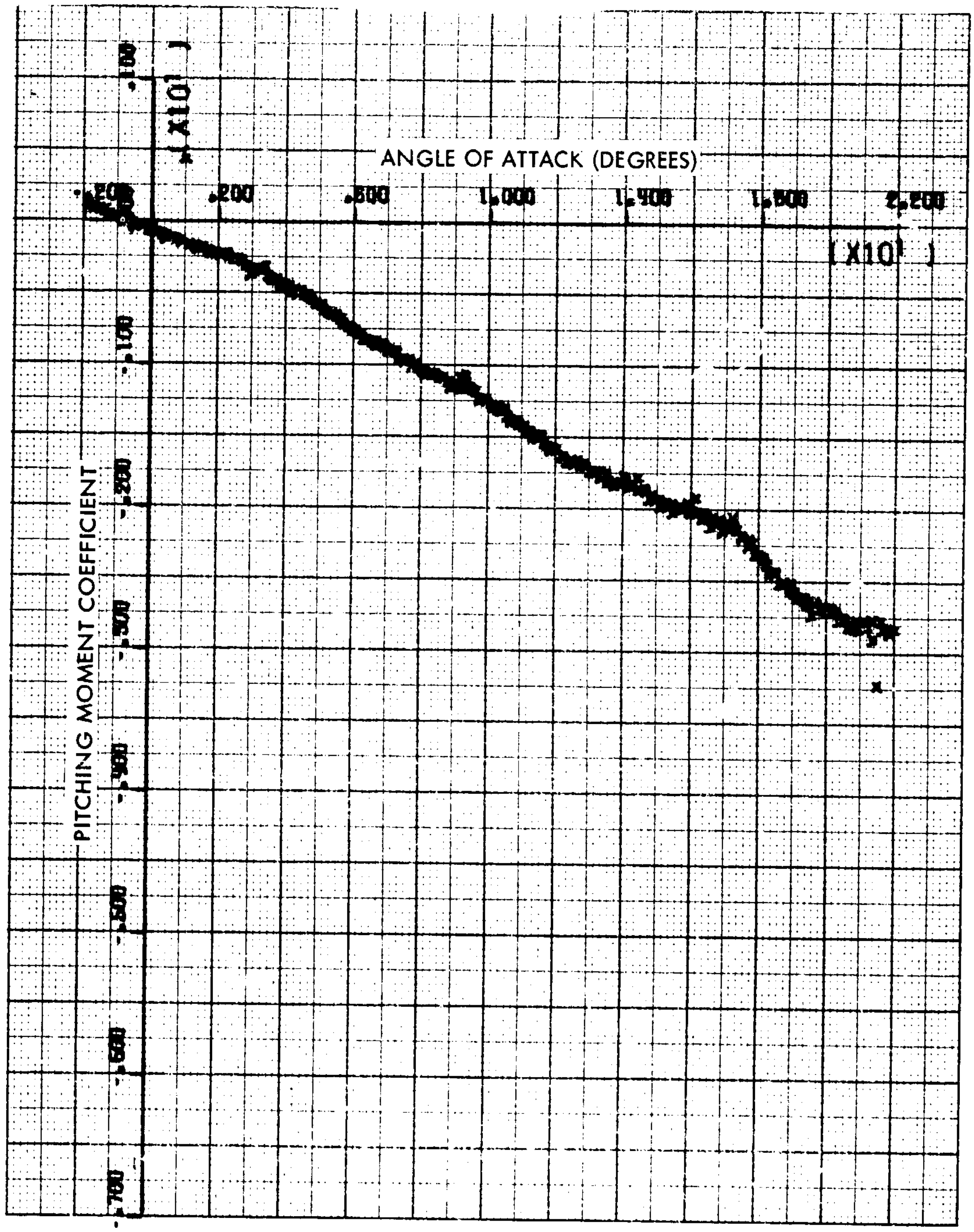

FIG. 49 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 1.05 AND A ROLL ANGLE OF 45 DEGREES

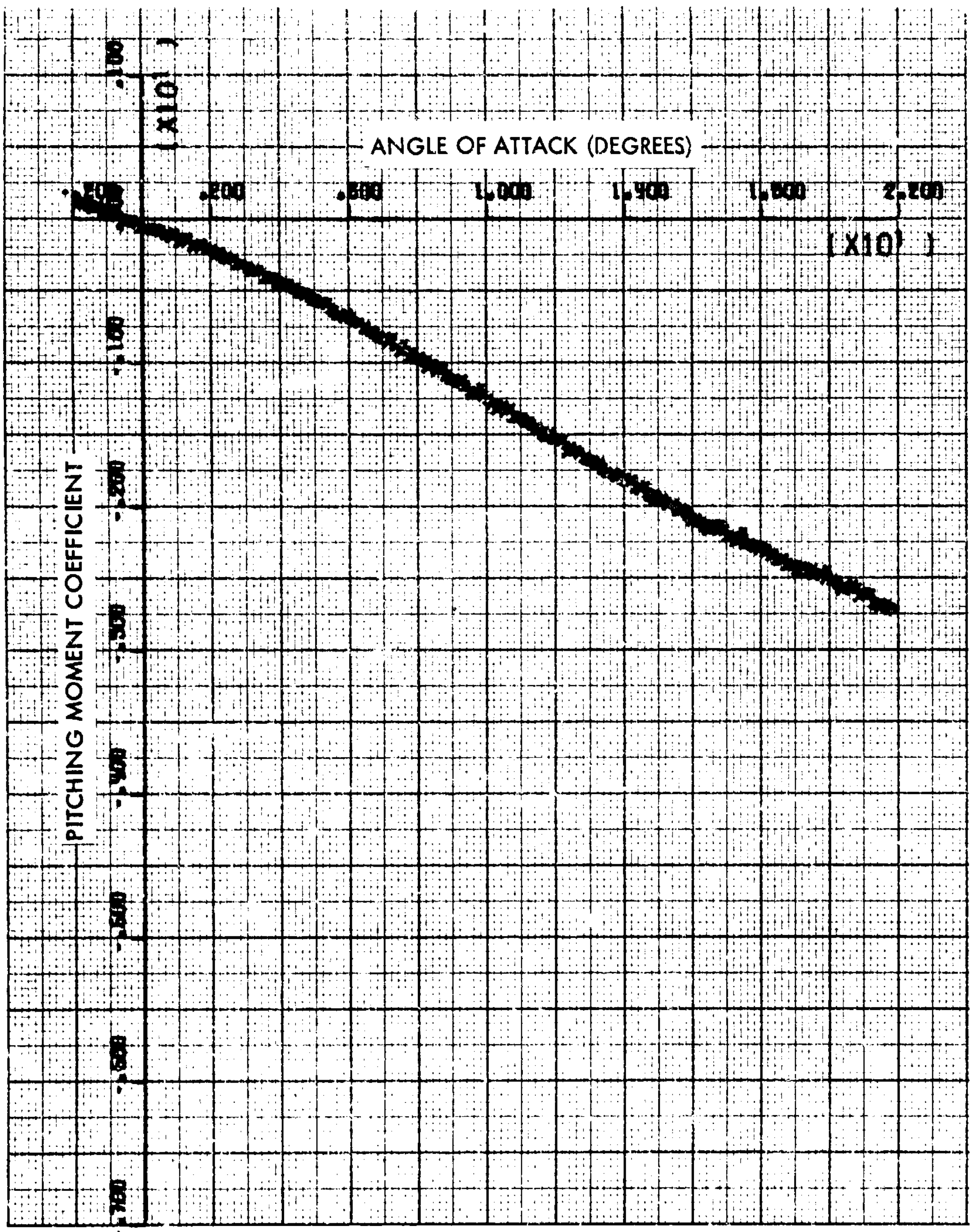

FIG. 50 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 1.10 AND A ROLL ANGLE OF 45 DEGREES

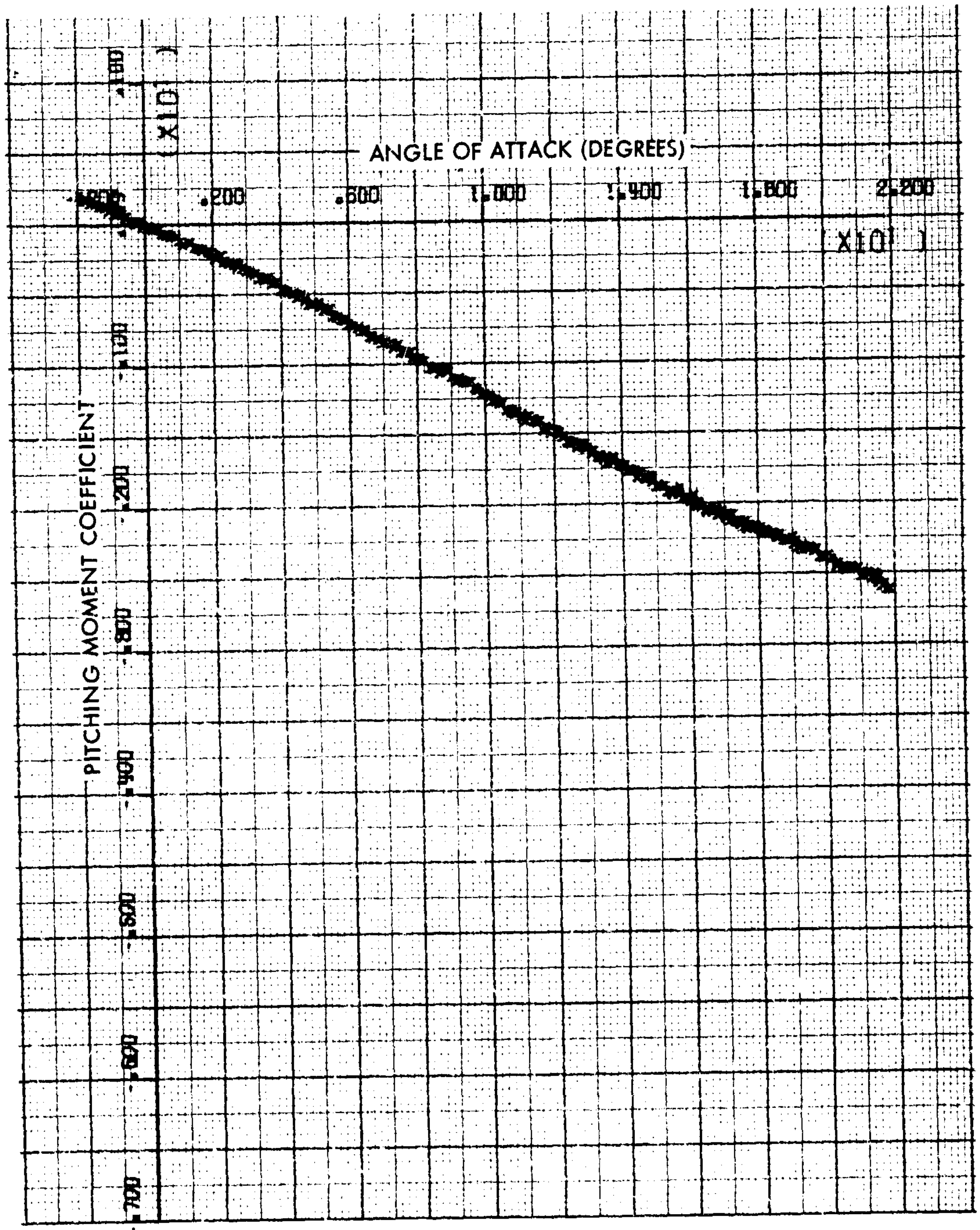

FIG. 51 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 1.15 AND A ROLL ANGLE OF 45 DEGREES

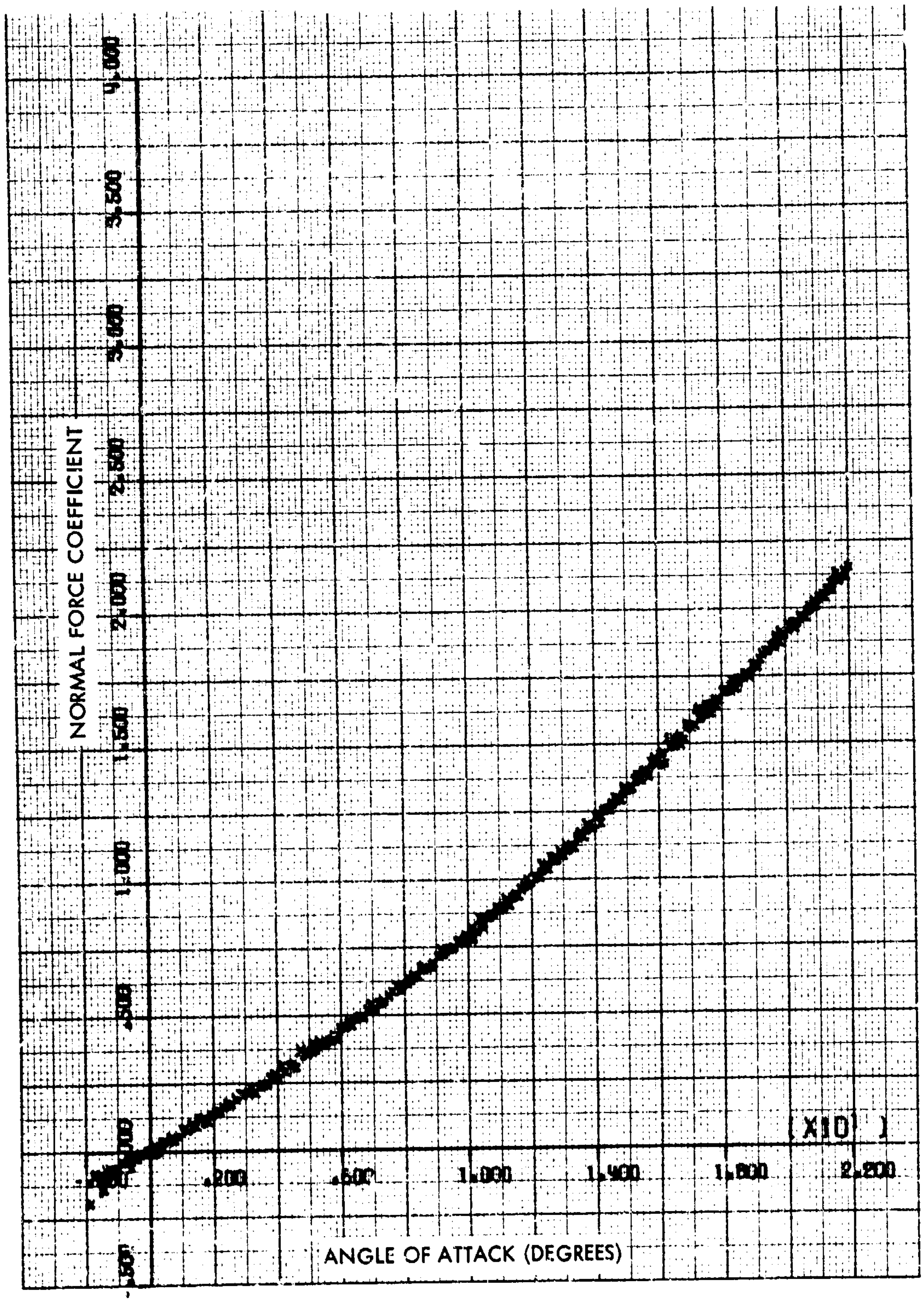

FIG. 52 NORMAL FORCE COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 0.6 AND A ROLL ANGLE OF 45 DEGREES

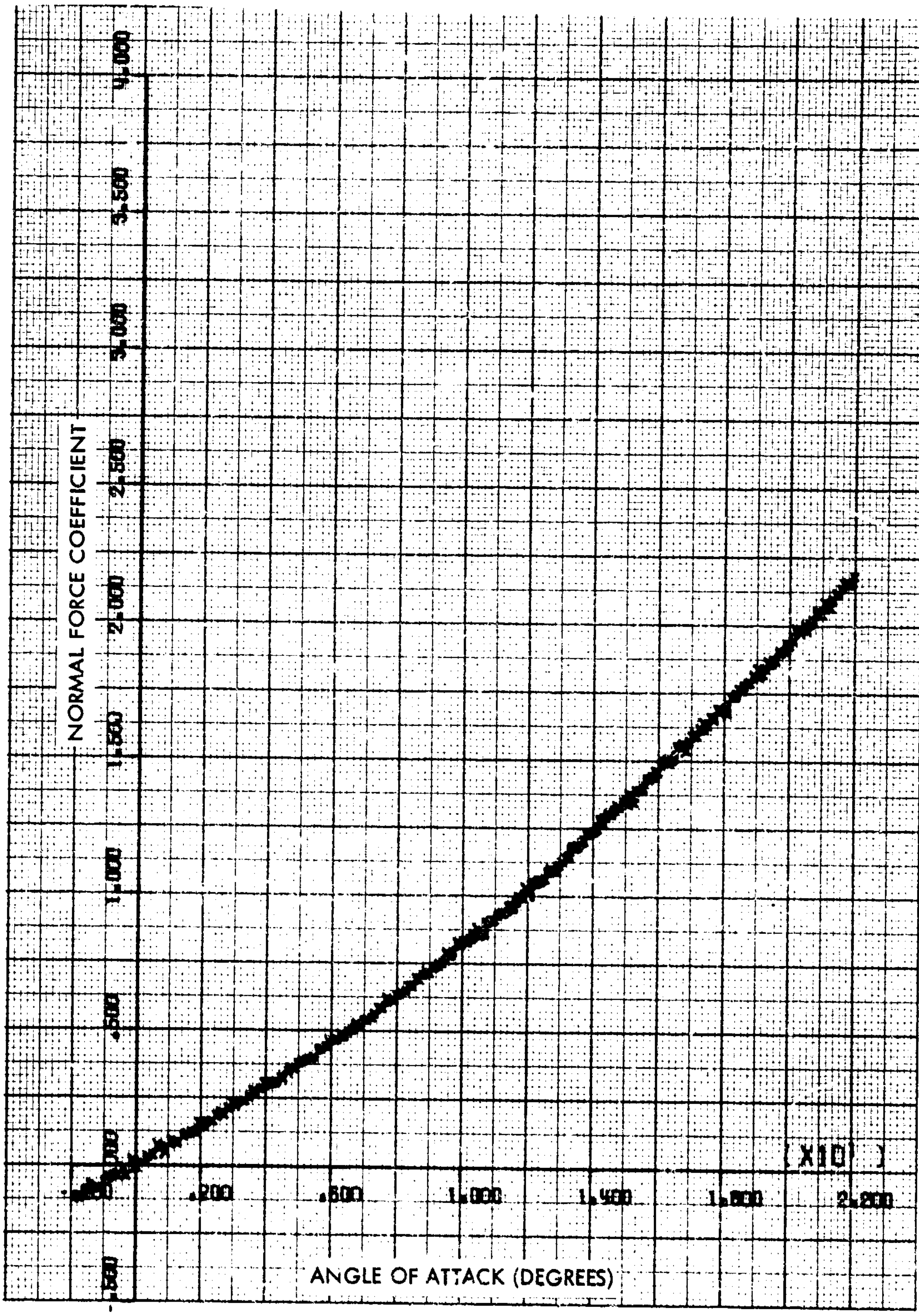

FIG. 53 NORMAL FORCE COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 0.7 AND A ROLL ANGLE OF 45 DEGREES

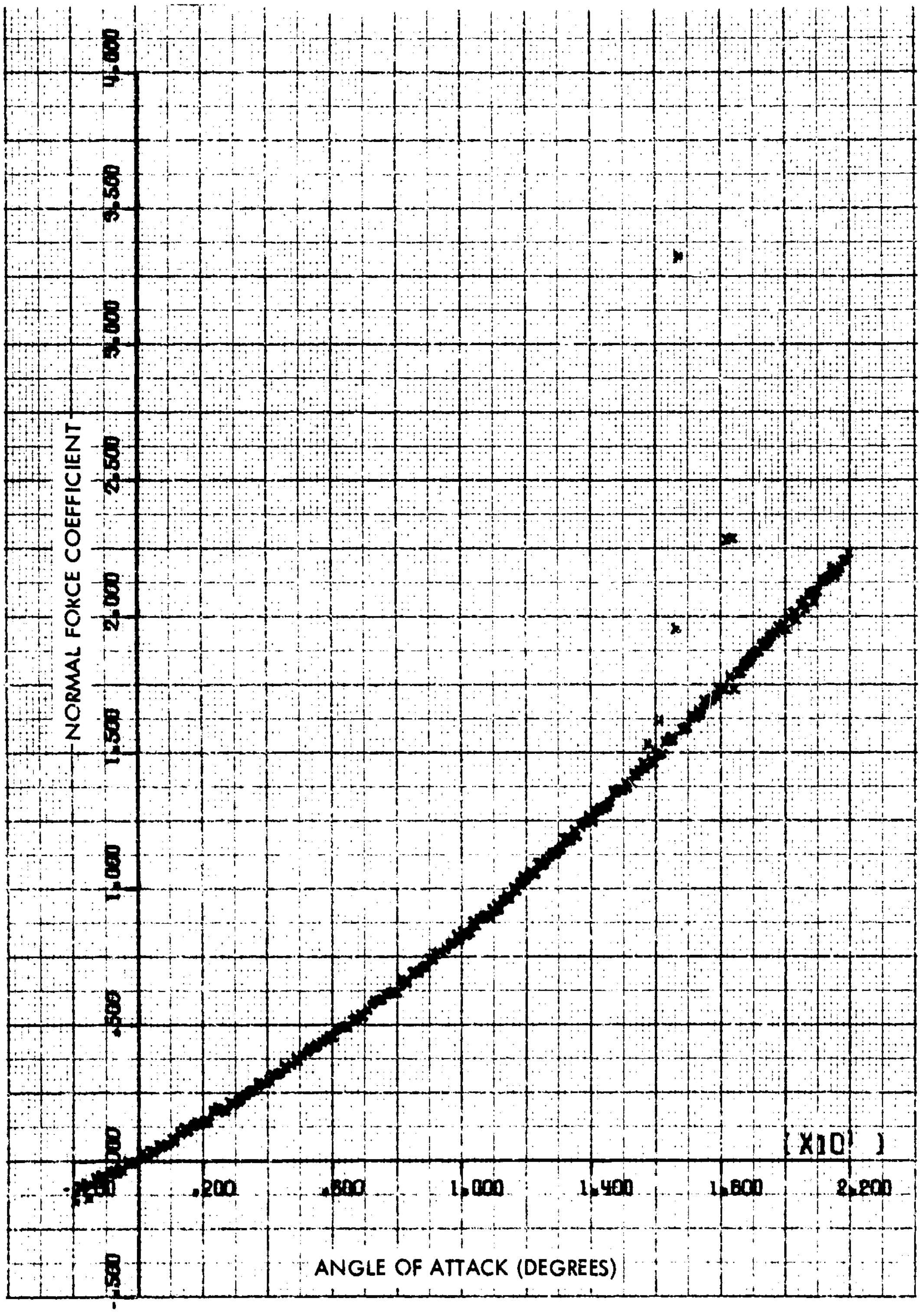

FIG. 54 NORMAL FORCE COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 0.8 AND A ROLL ANGLE OF 45 DEGREES

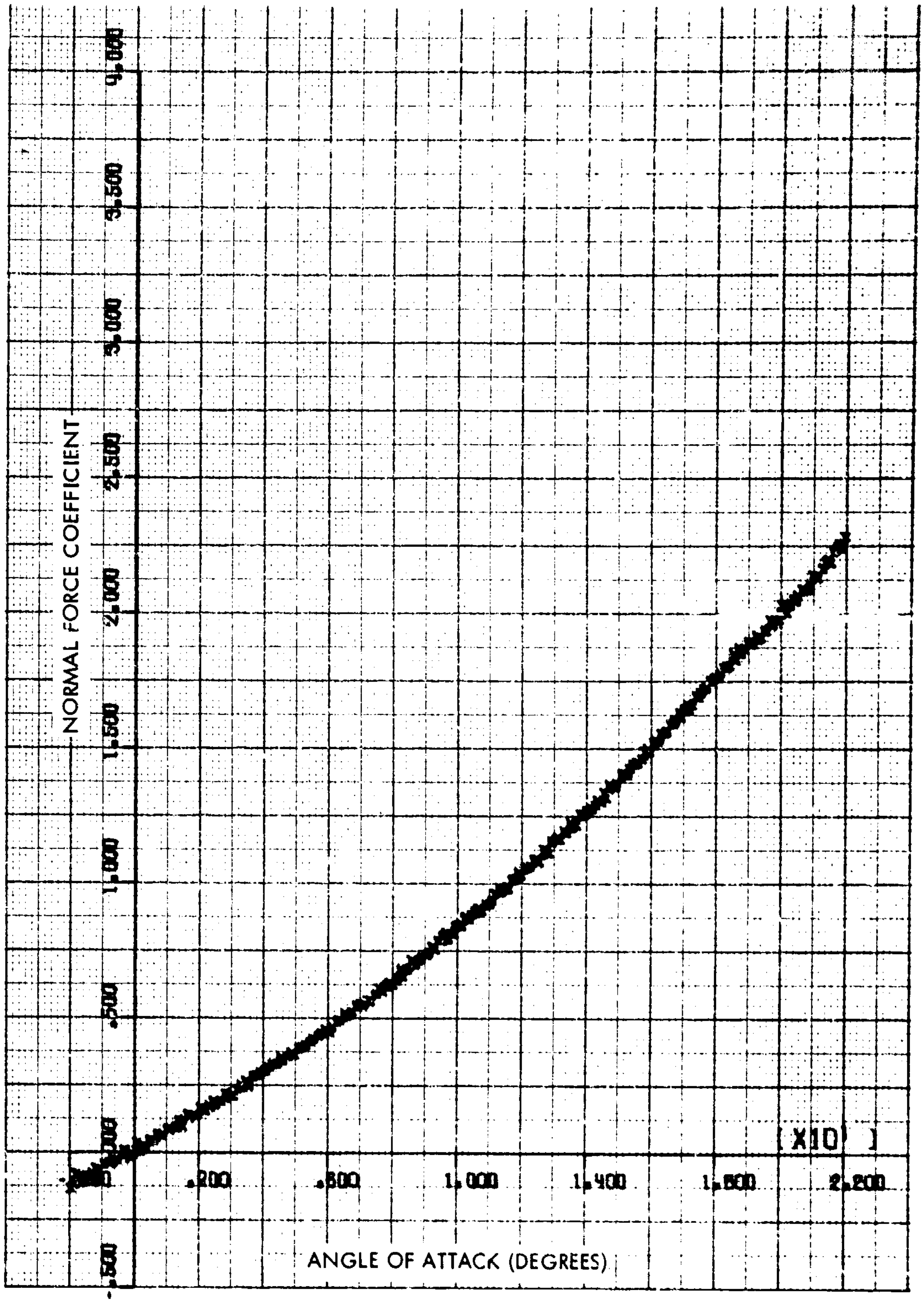

FIG. 55 NORMAL FORCE COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 0.85 AND A ROLL ANGLE OF 45 DEGREES

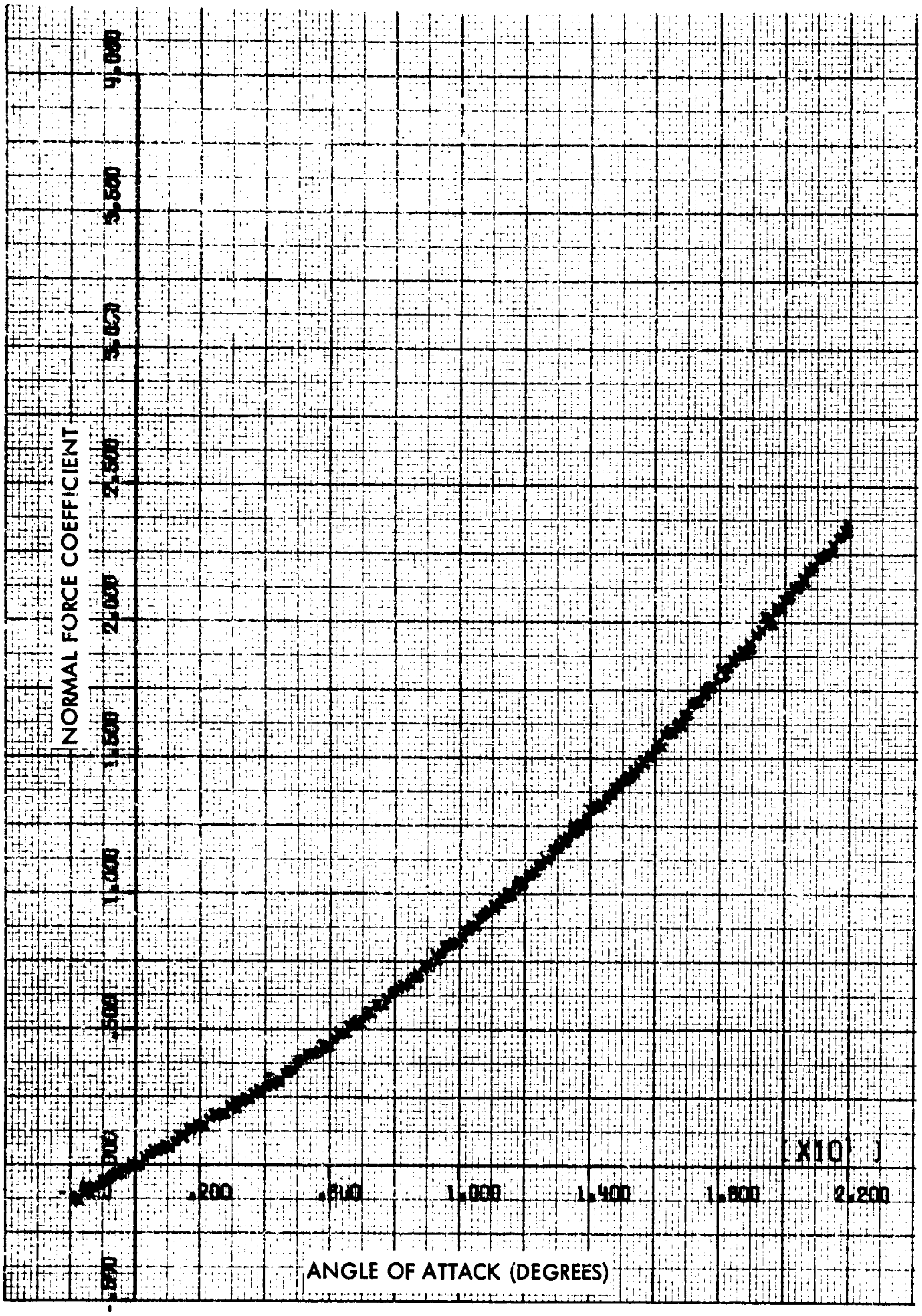

FIG. 56 NORMAL FORCE COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 0.95 AND A ROLL ANGLE OF 45 DEGREES

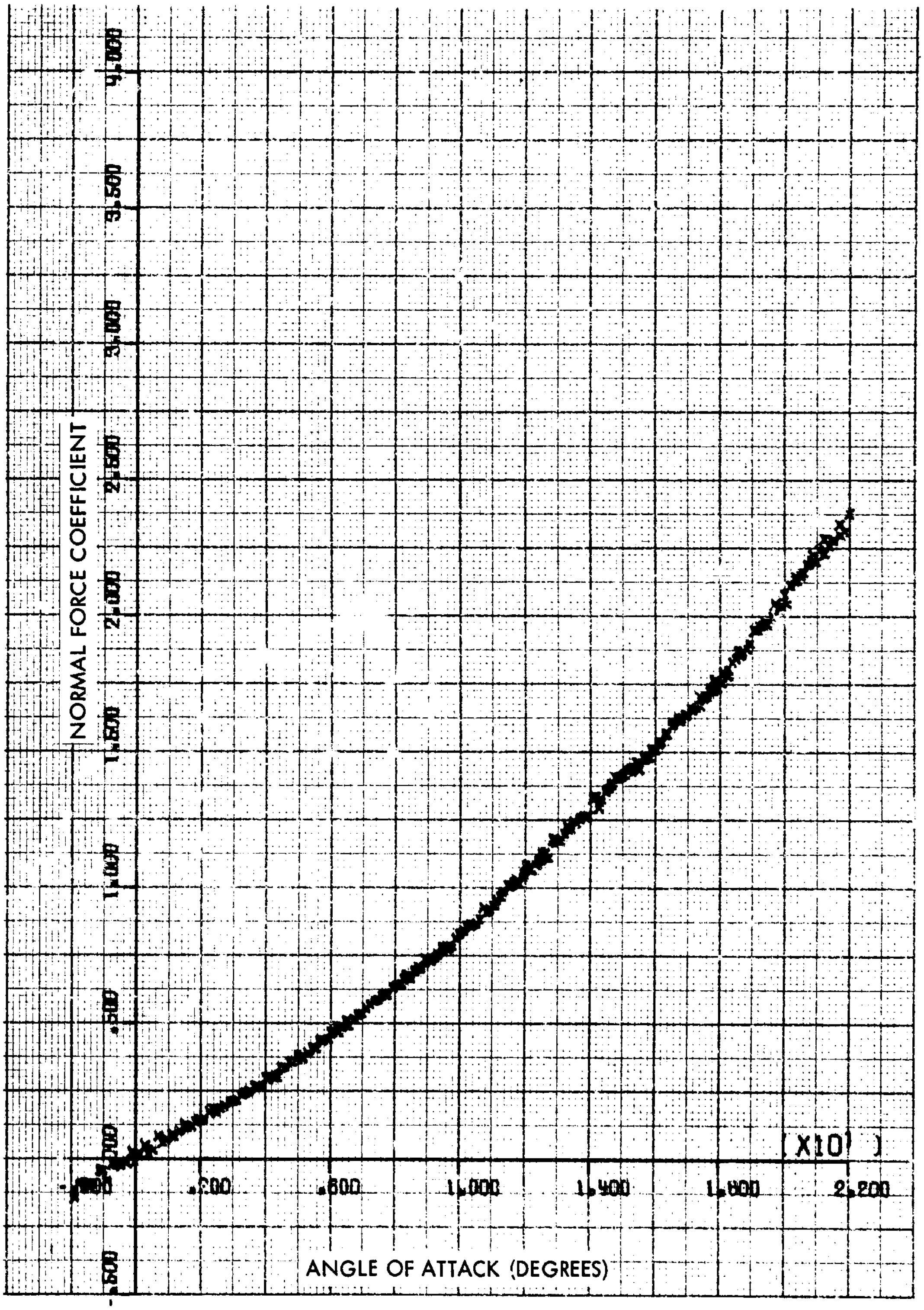

FIG. 57 NORMAL FORCE COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 1.00 AND A ROLL ANGLE OF 45 DEGREES

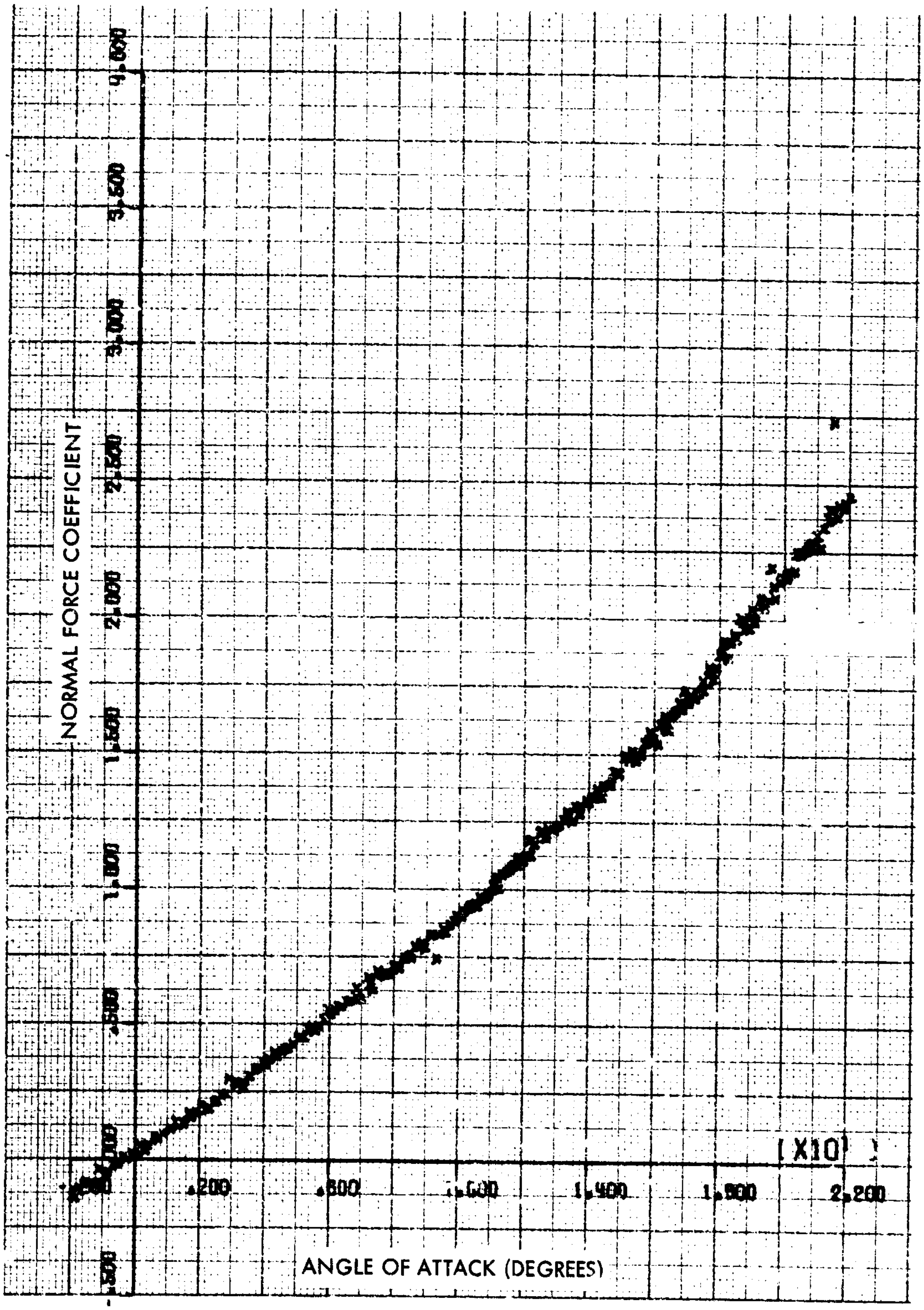

FIG. 58 NORMAL FORCE COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 1.05 AND A ROLL ANGLE OF 45 DEGREES

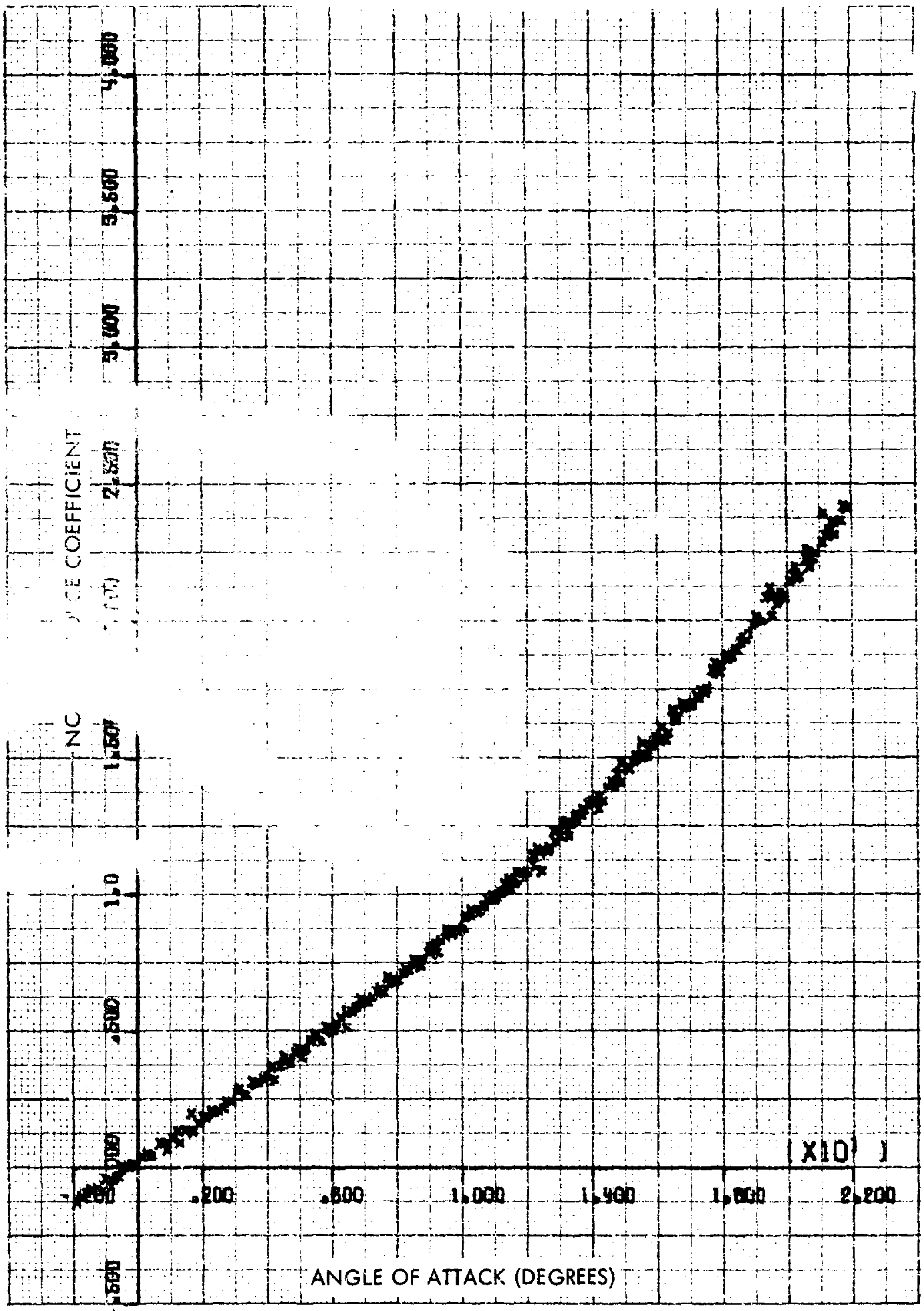

FIG. 59 NORMAL FORCE COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 1.10 AND A ROLL ANGLE OF 45 DEGREES

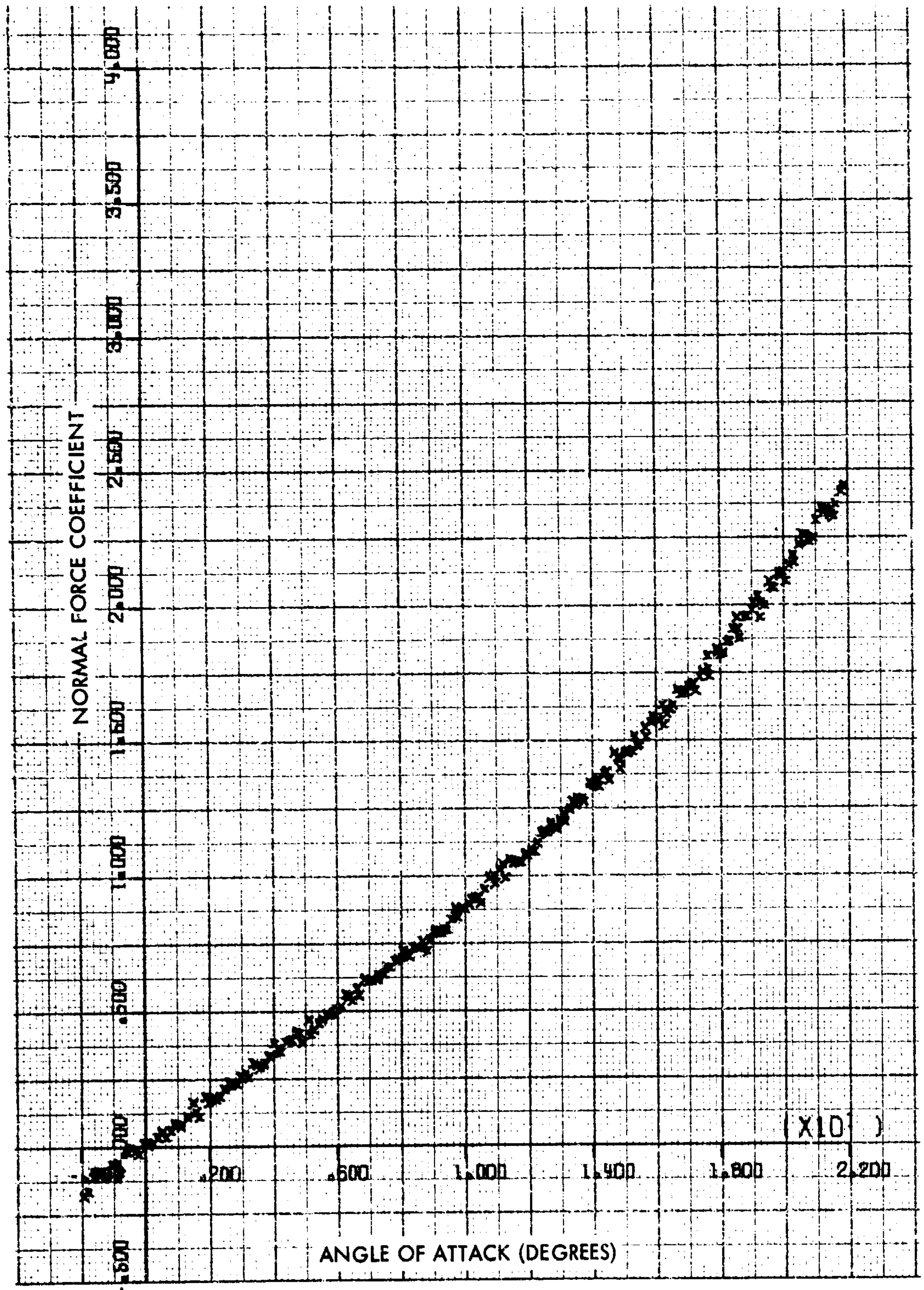

FIG. 60 NORMAL FORCE COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH LARGE FINS AT A MACH NUMBER OF 1.15 AND A ROLL ANGLE OF 45 DEGREES

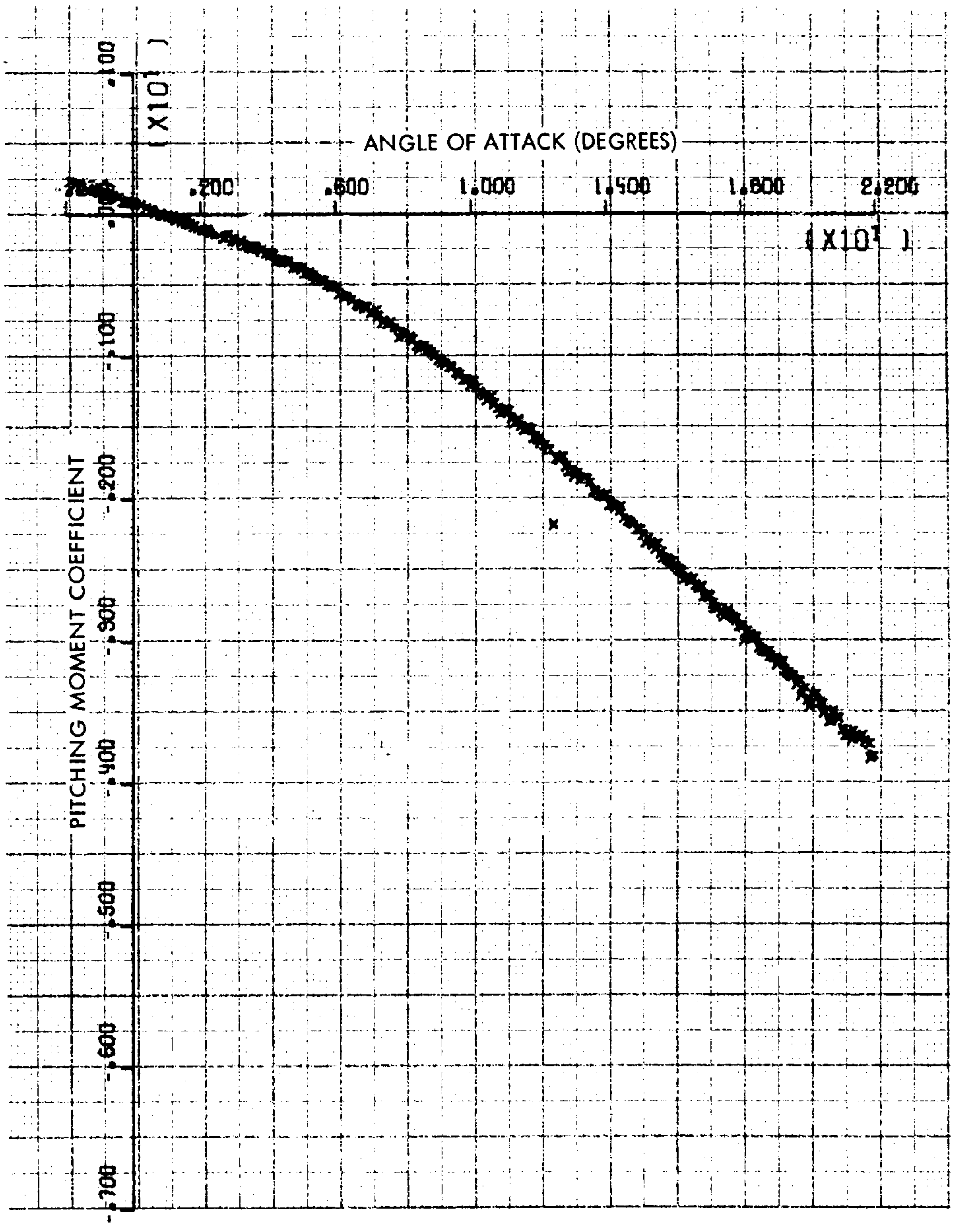

FIG. 61 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH SMALL FINS AT A MACH NUMBER OF 0.6 AND A ROLL ANGLE OF 0 DEGREES

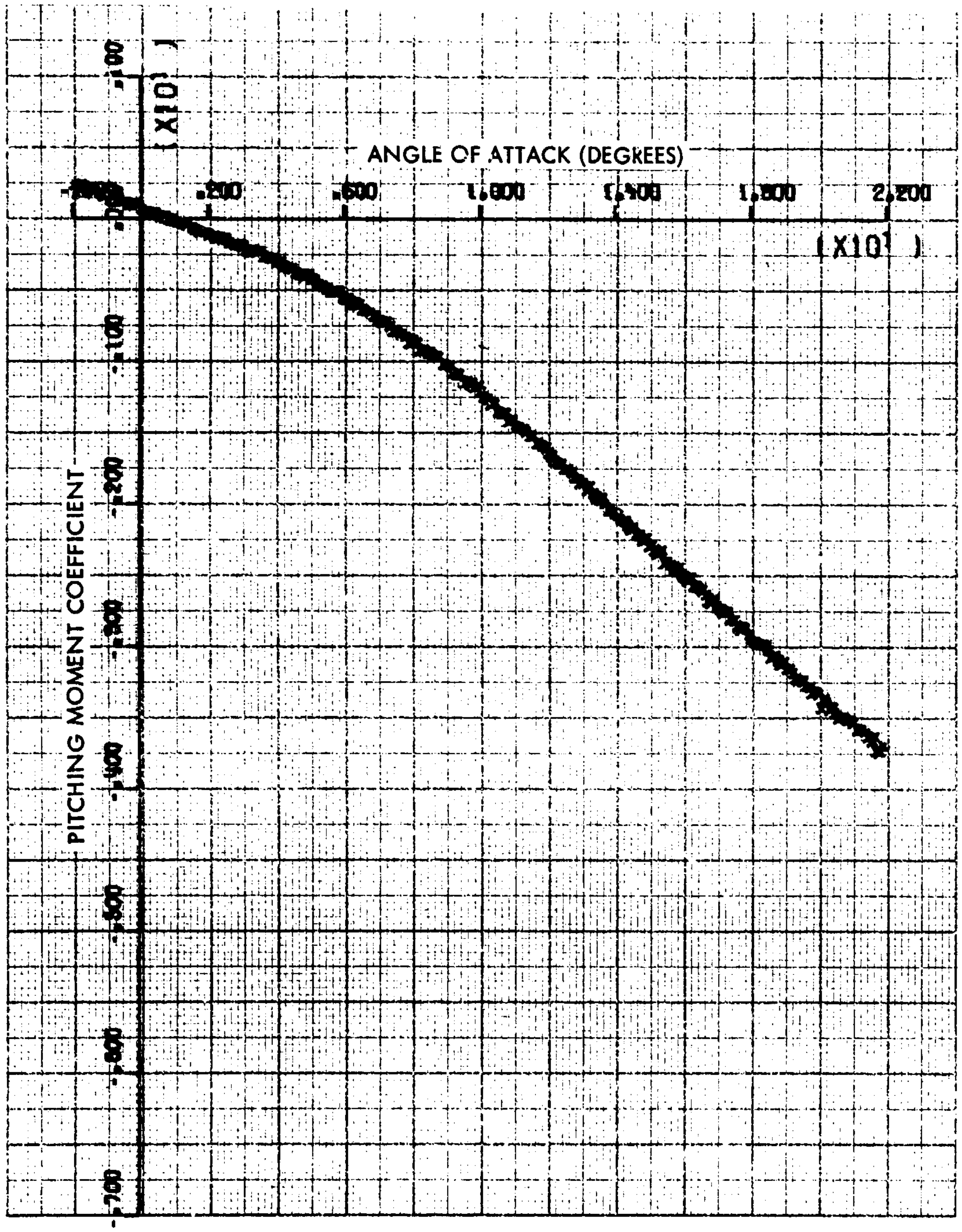

FIG. 62 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH SMALL FINS AT A MACH NUMBER OF 0.7 AND A ROLL ANLGE OF 0 DEGREES

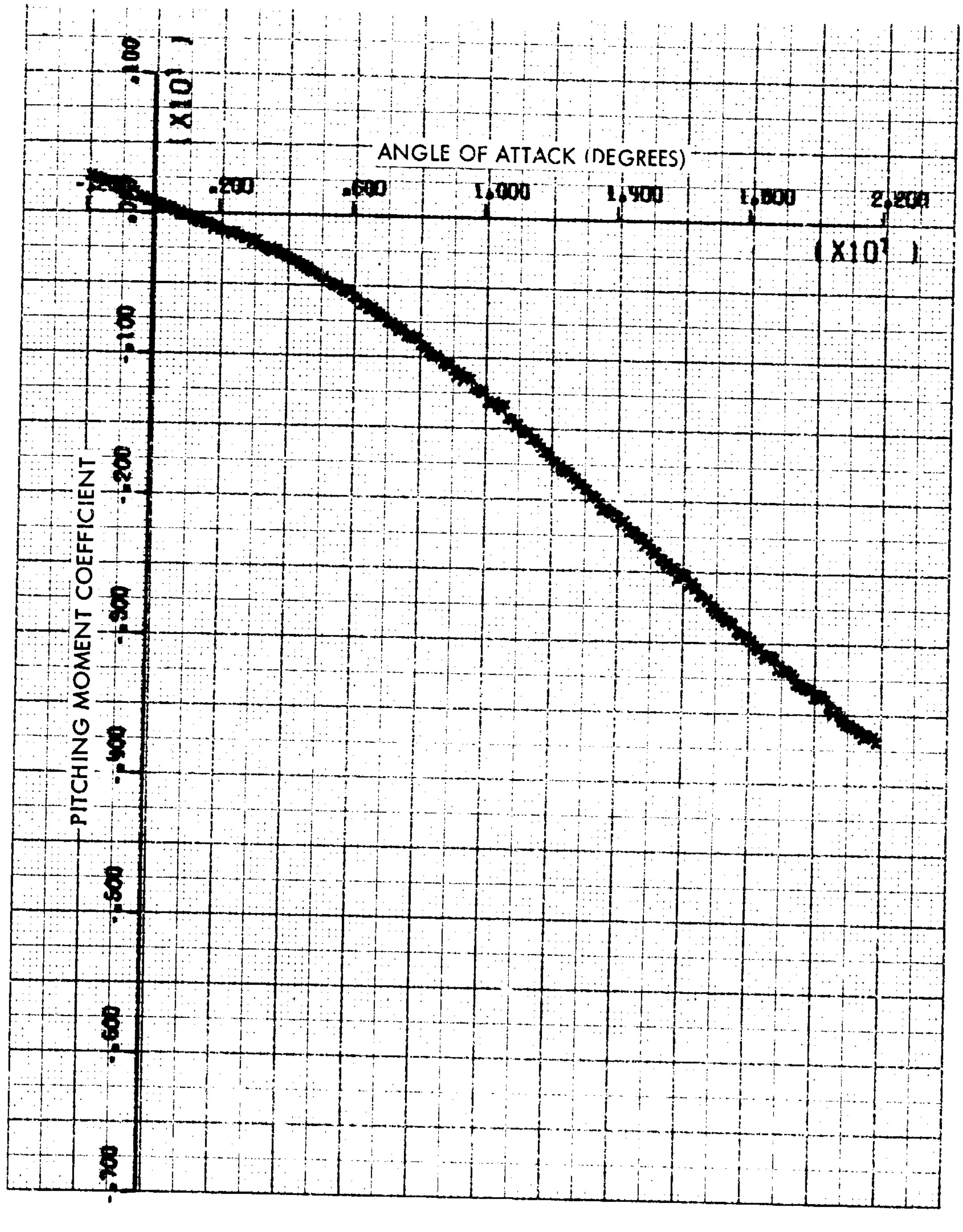

FIG. 63 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH SMALL FINS AT A MACH NUMBER OF 0.8 AND A ROLL ANGLE OF 0 DEGREES

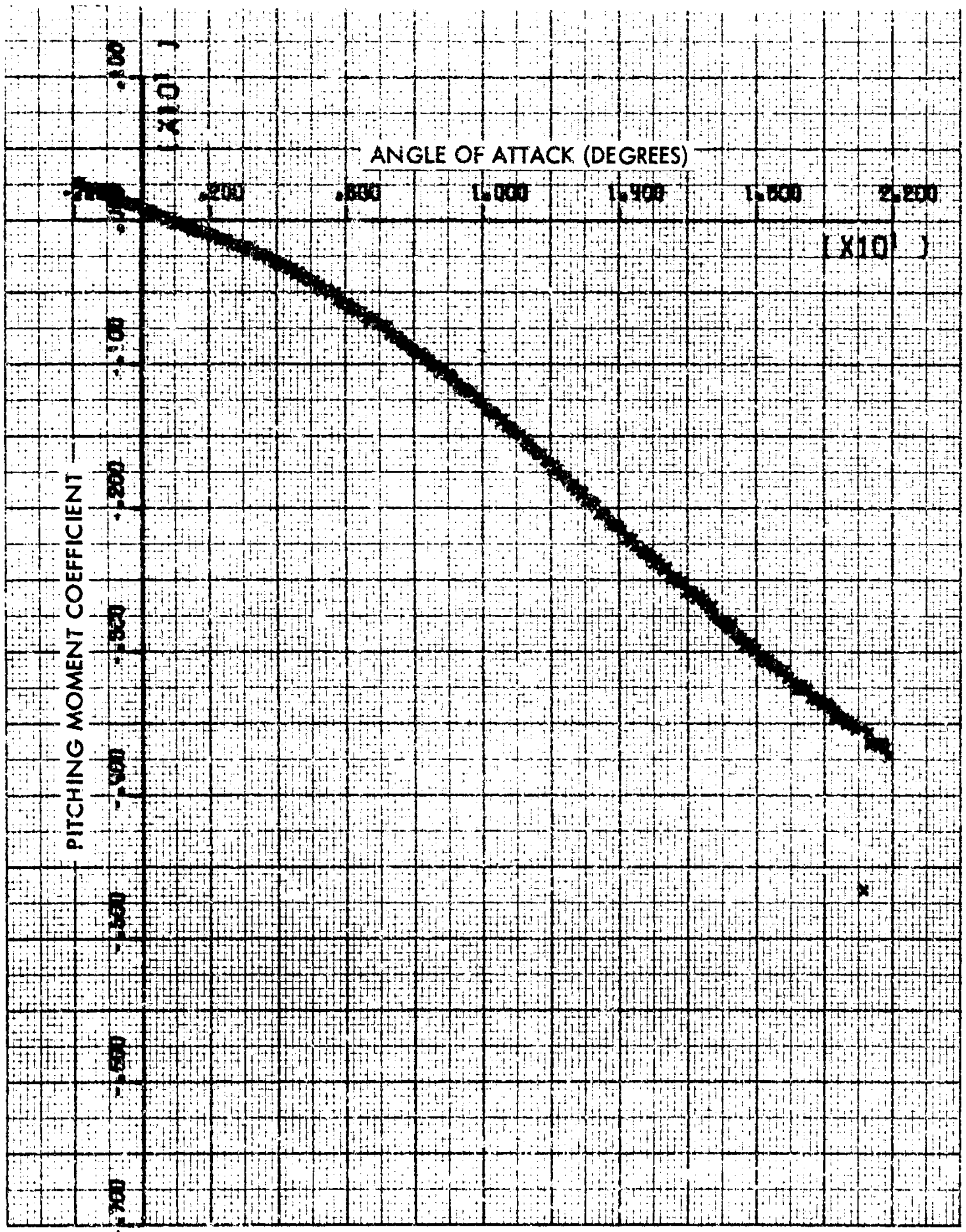

FIG. 64 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH SMALL FINS AT A MACH NUMBER OF 0.85 AND A ROLL ANGLE OF 0 DEGREES

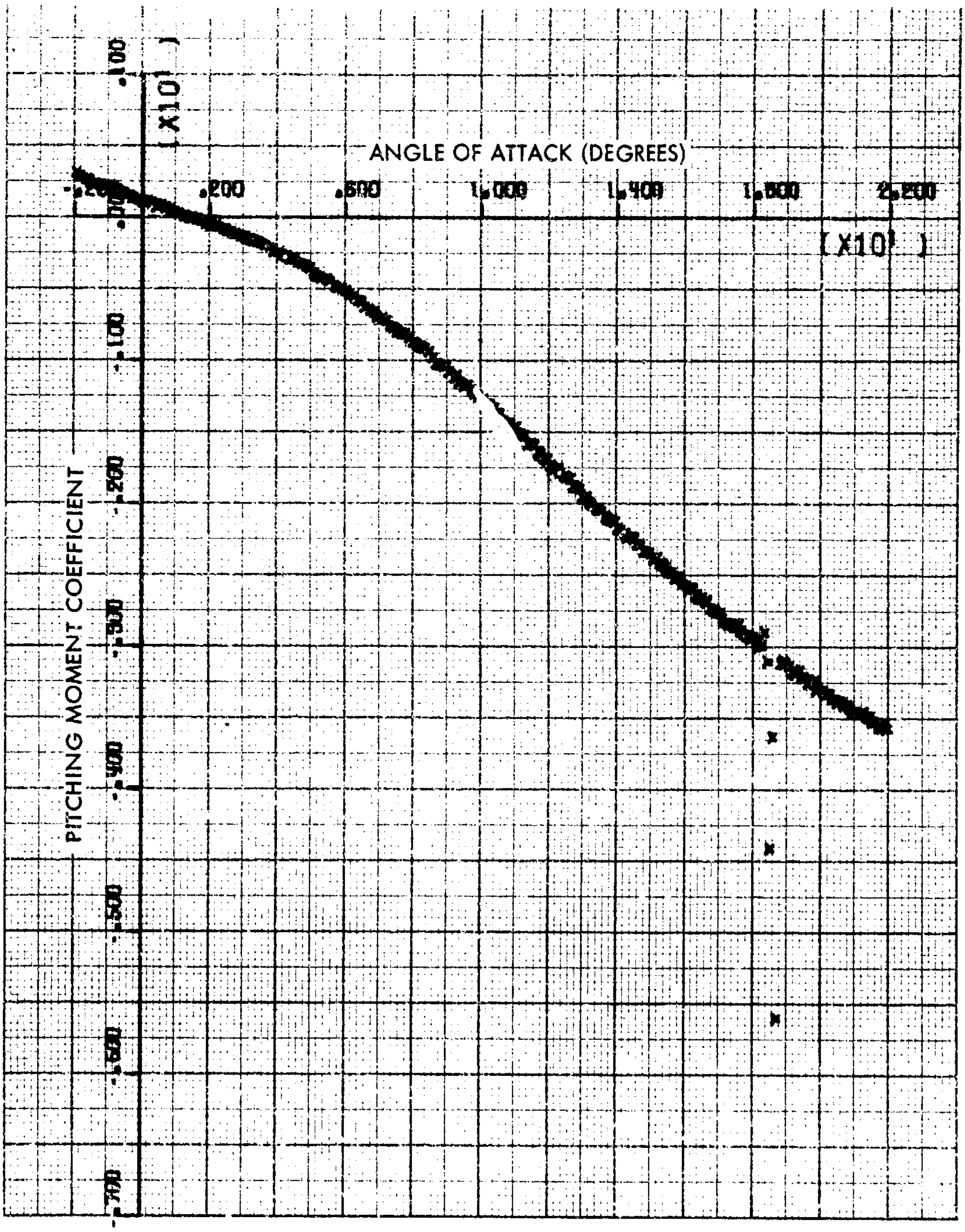

FIG. 65 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH SMALL FINS AT A MACH NUMBER OF 0.95 AND A ROLL ANGLE OF 0 DEGREES

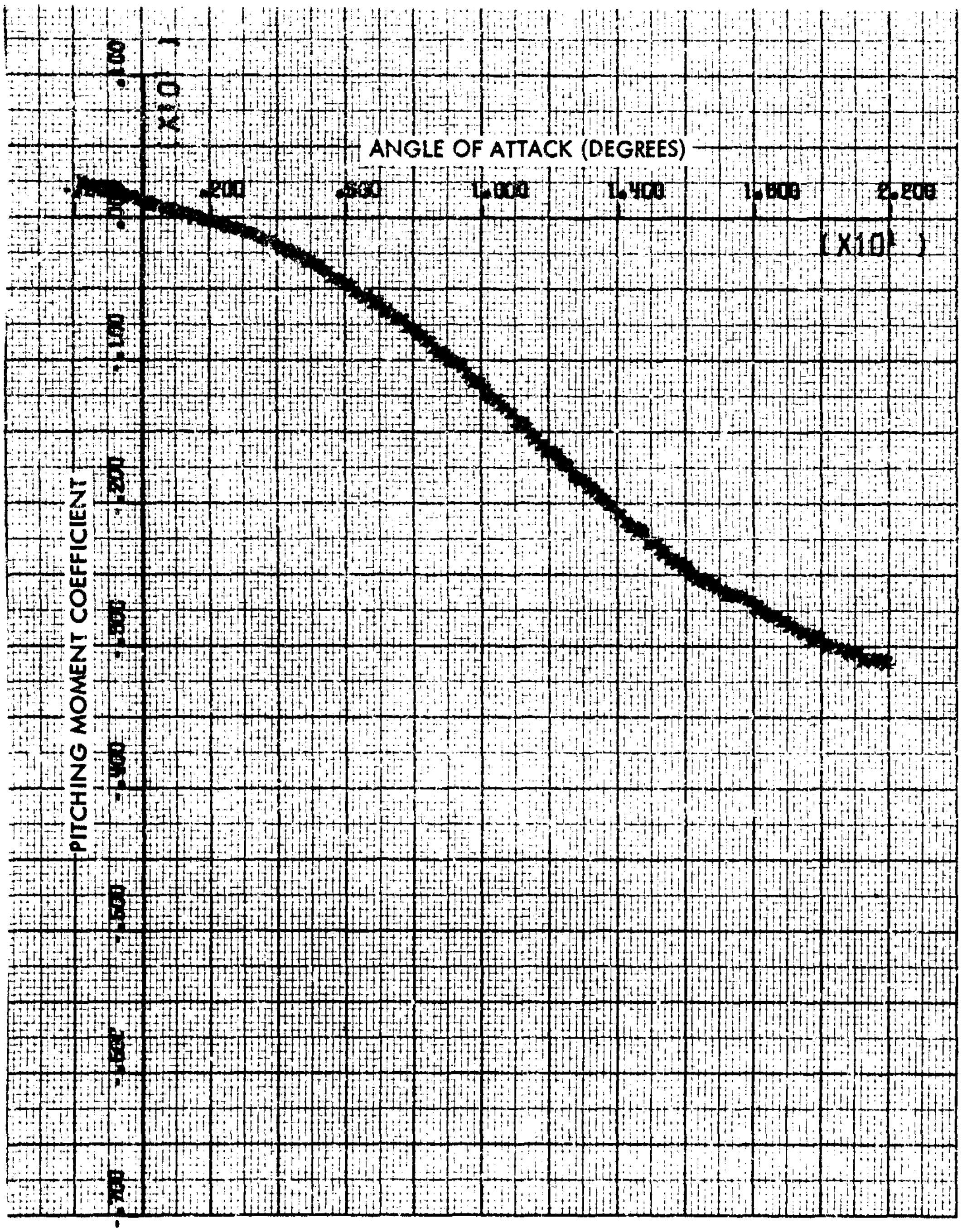

FIG. 66 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH SMALL FINS AT A MACH NUMBER OF 1.00 AND A ROLL ANGLE OF 0 DEGREES

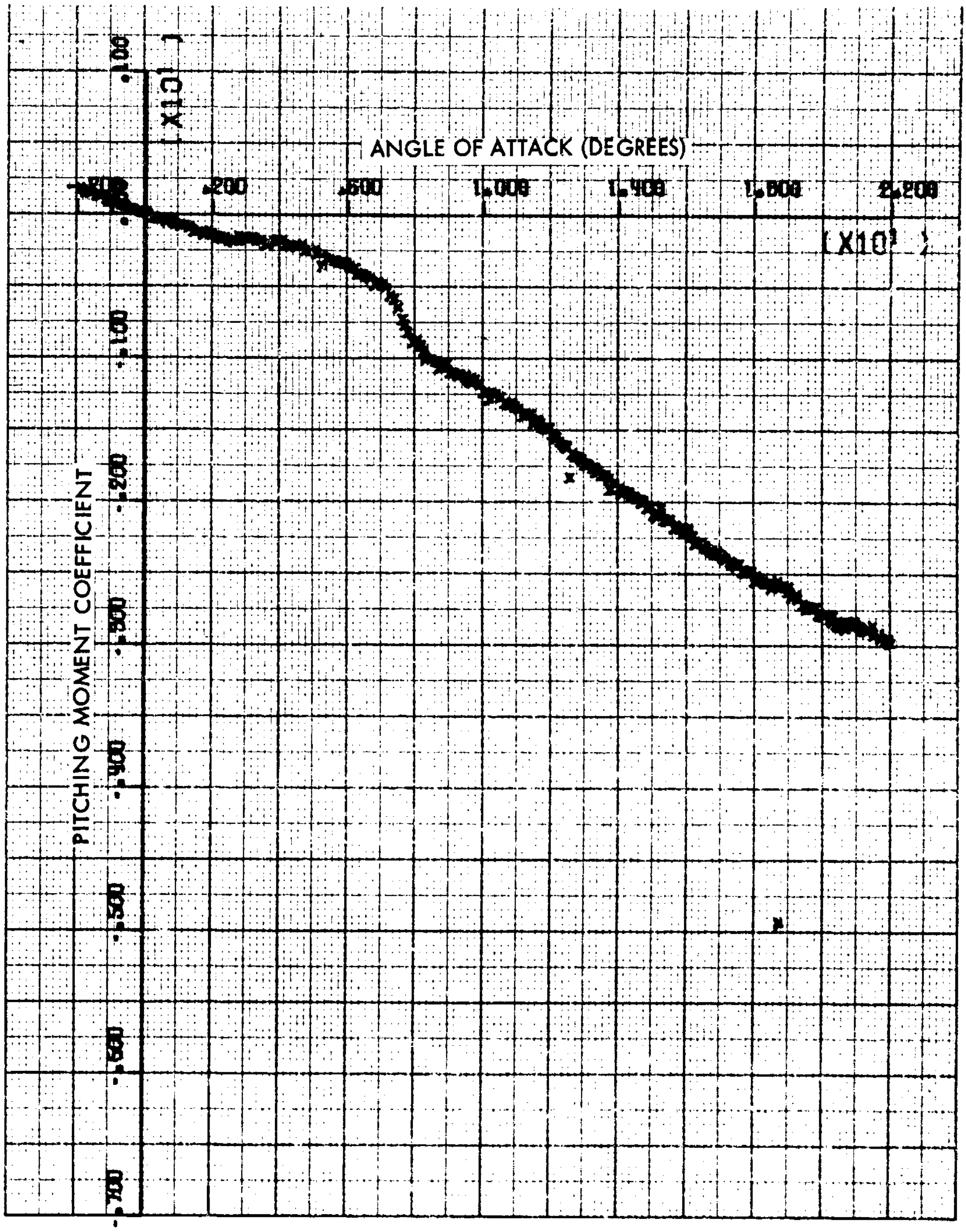

FIG. 67 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH SMALL FINS AT A MACH NUMBER OF 1.05 AND A ROLL ANGLE OF 0 DEGREES

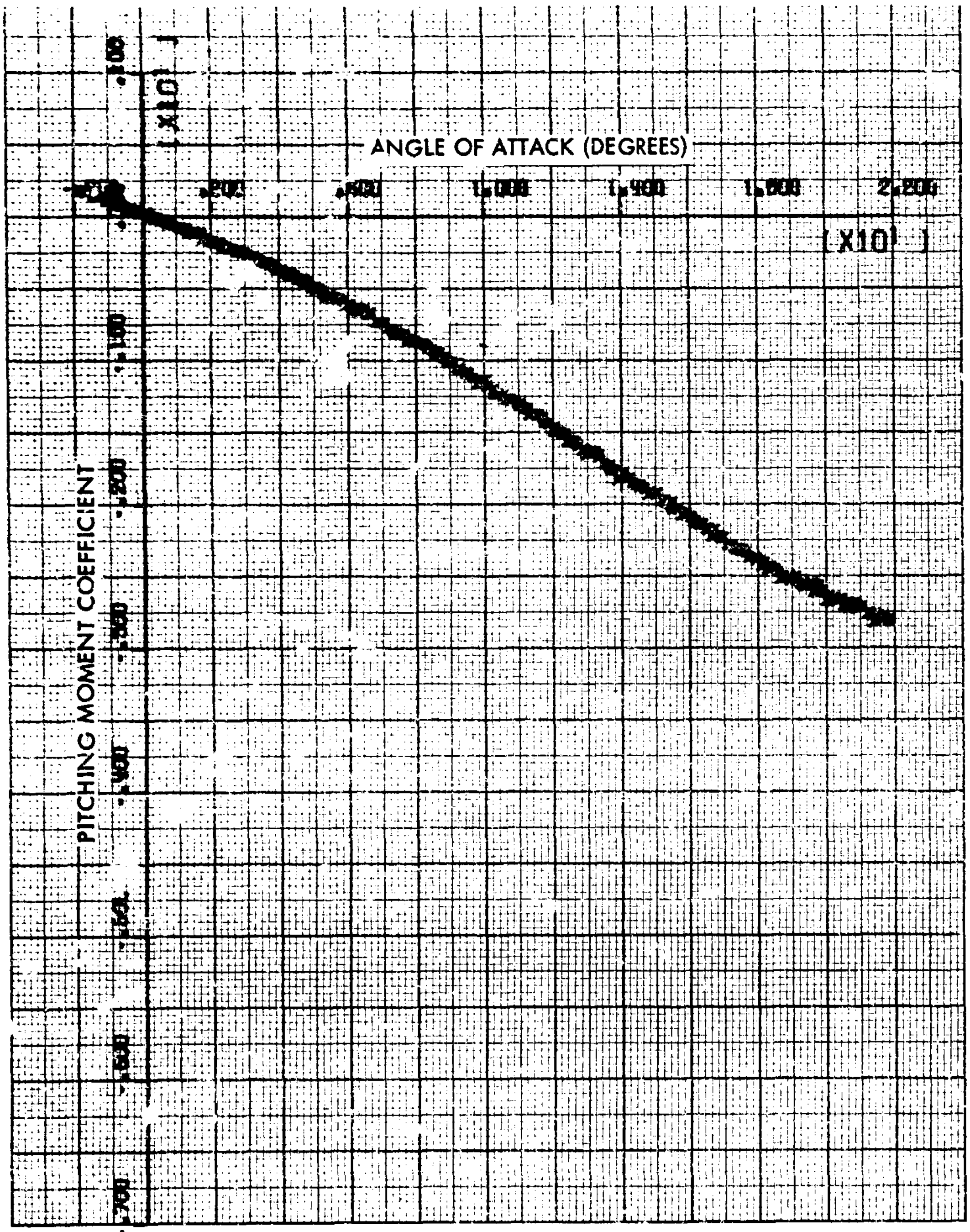

FIG. 68 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH SMALL FINS AT A MACH NUMBER OF 1.10 AND A ROLL ANGLE OF 0 DEGREES

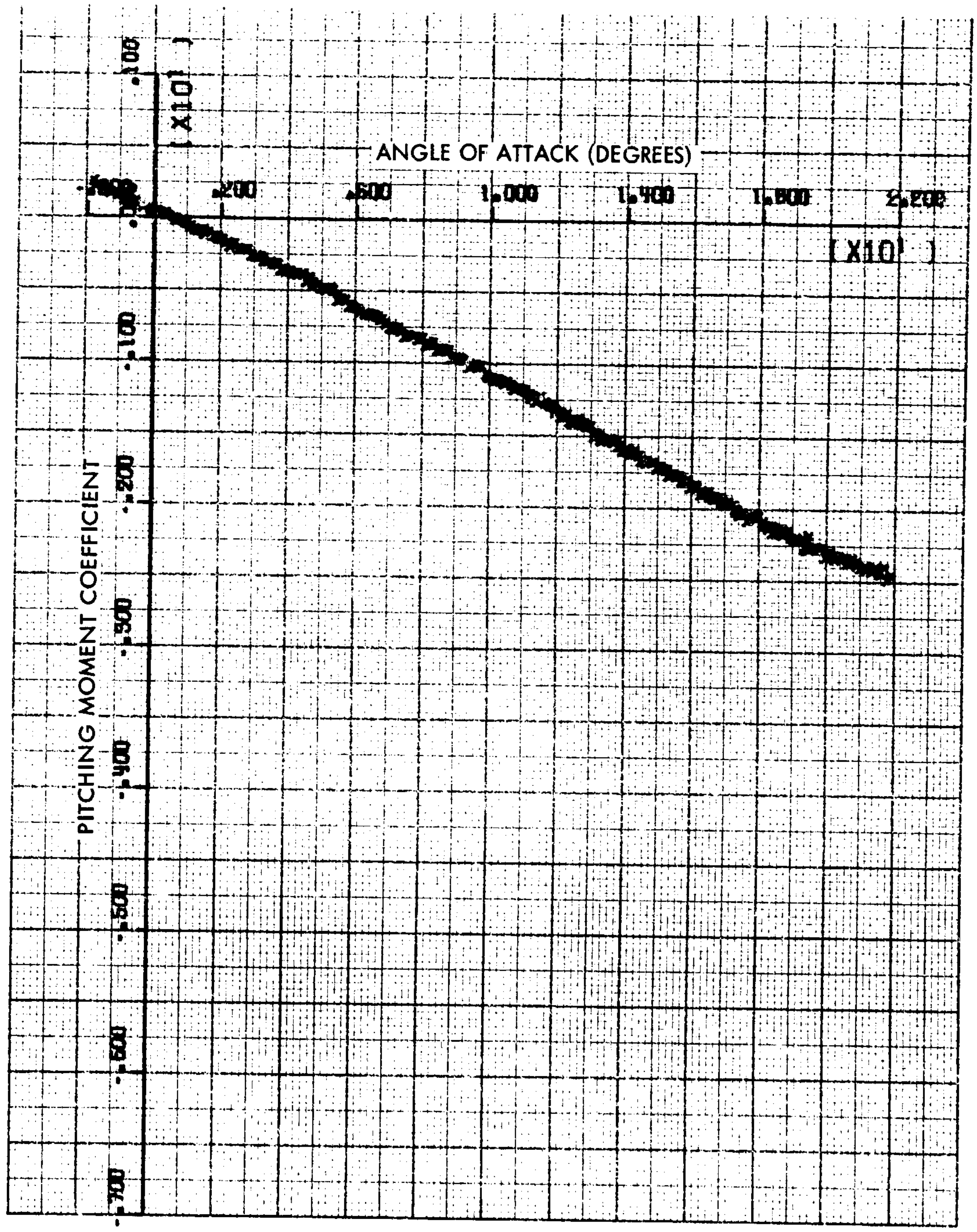

FIG. 69 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH SMALL FINS AT A MACH NUMBER OF 1.15 AND A ROLL ANGLE OF 0 DEGREES

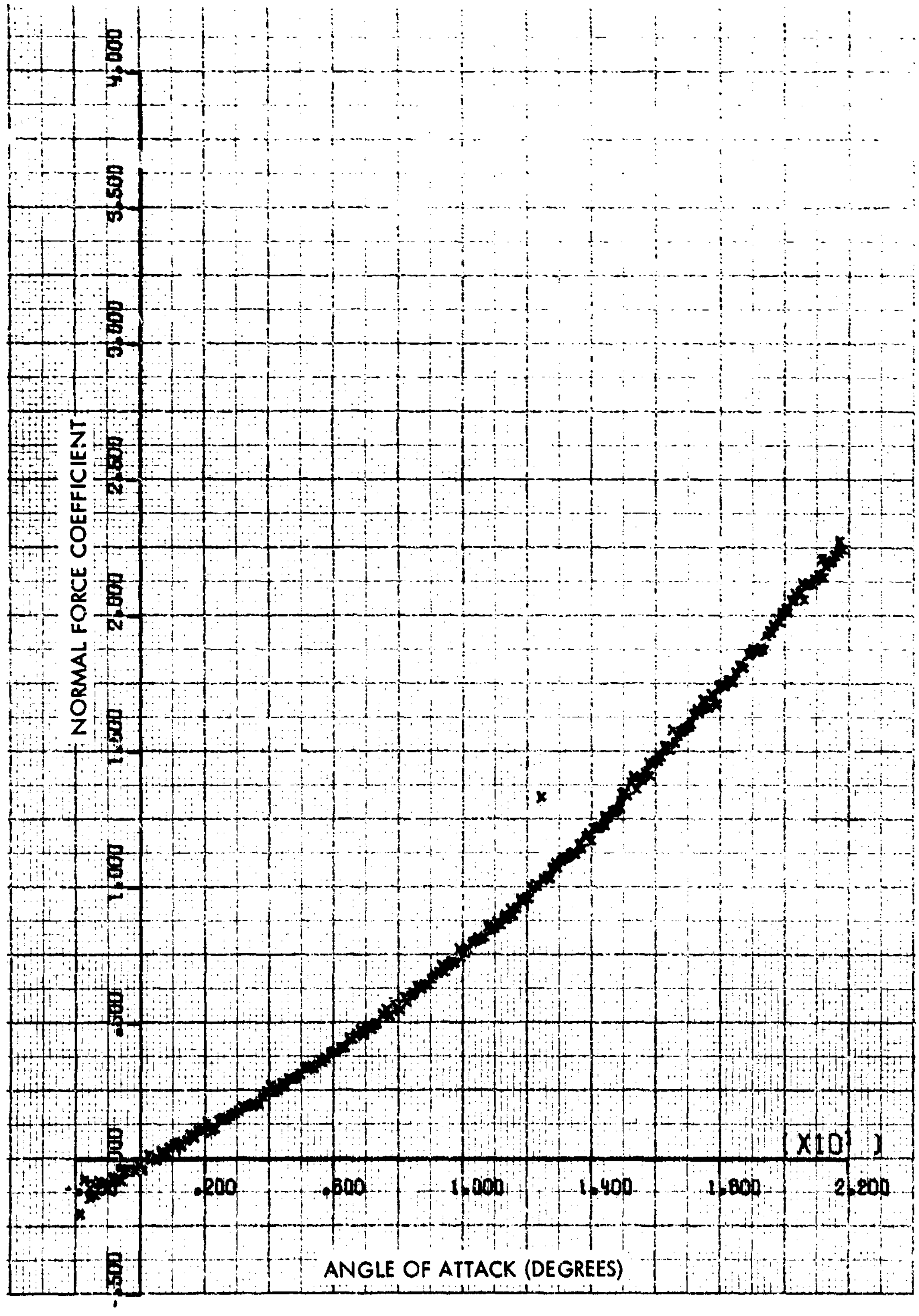

FIG. 70 NORMAL FORCE COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH SMALL FINS AT A MACH NUMBER OF 0.6 AND A ROLL ANGLE OF 0 DEGREES

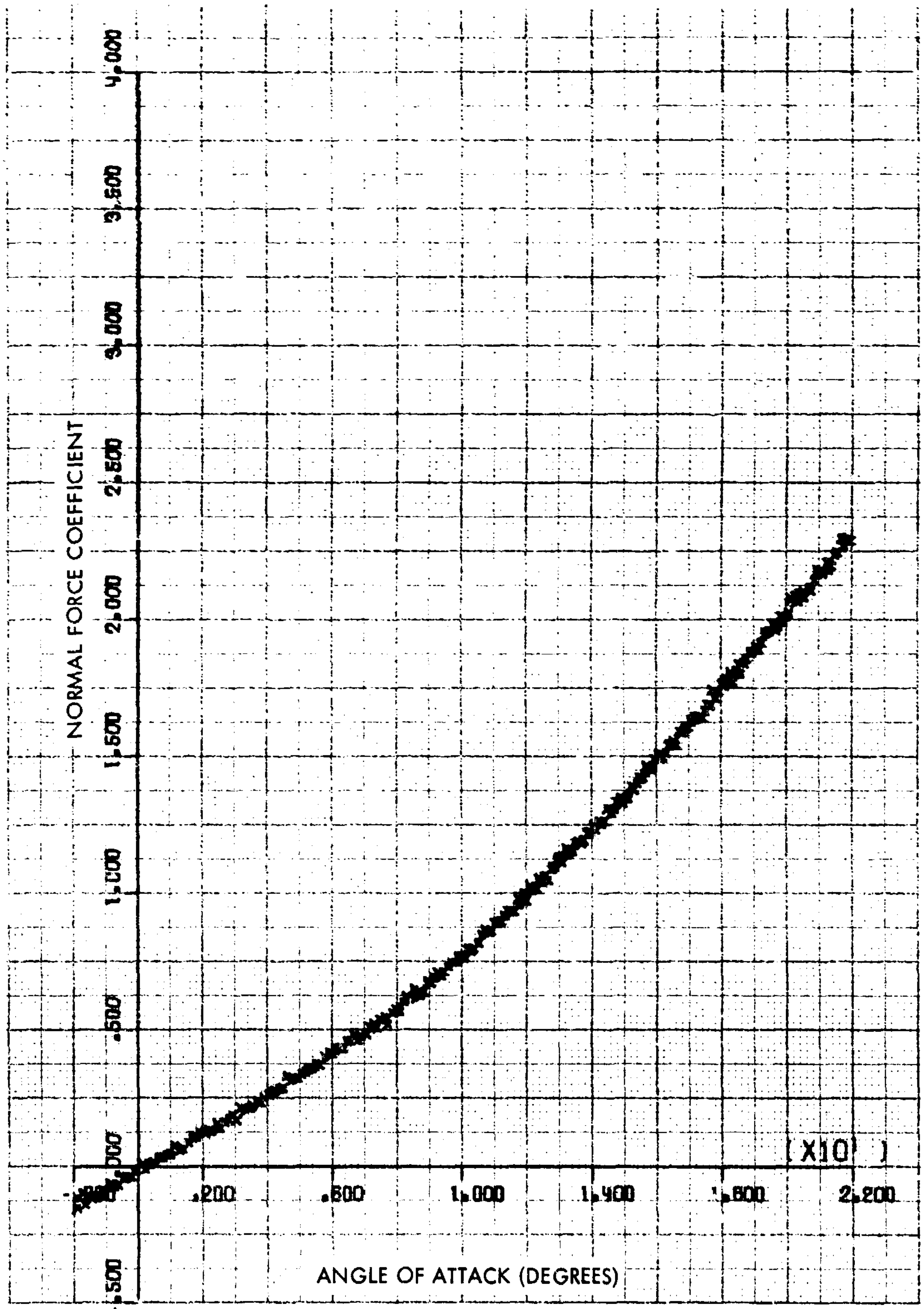

FIG. 71 NORMAL FORCE COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH SMALL FINS AT A MACH NUMBER OF 0.7 AND A ROLL ANGLE OF 0 DEGREES

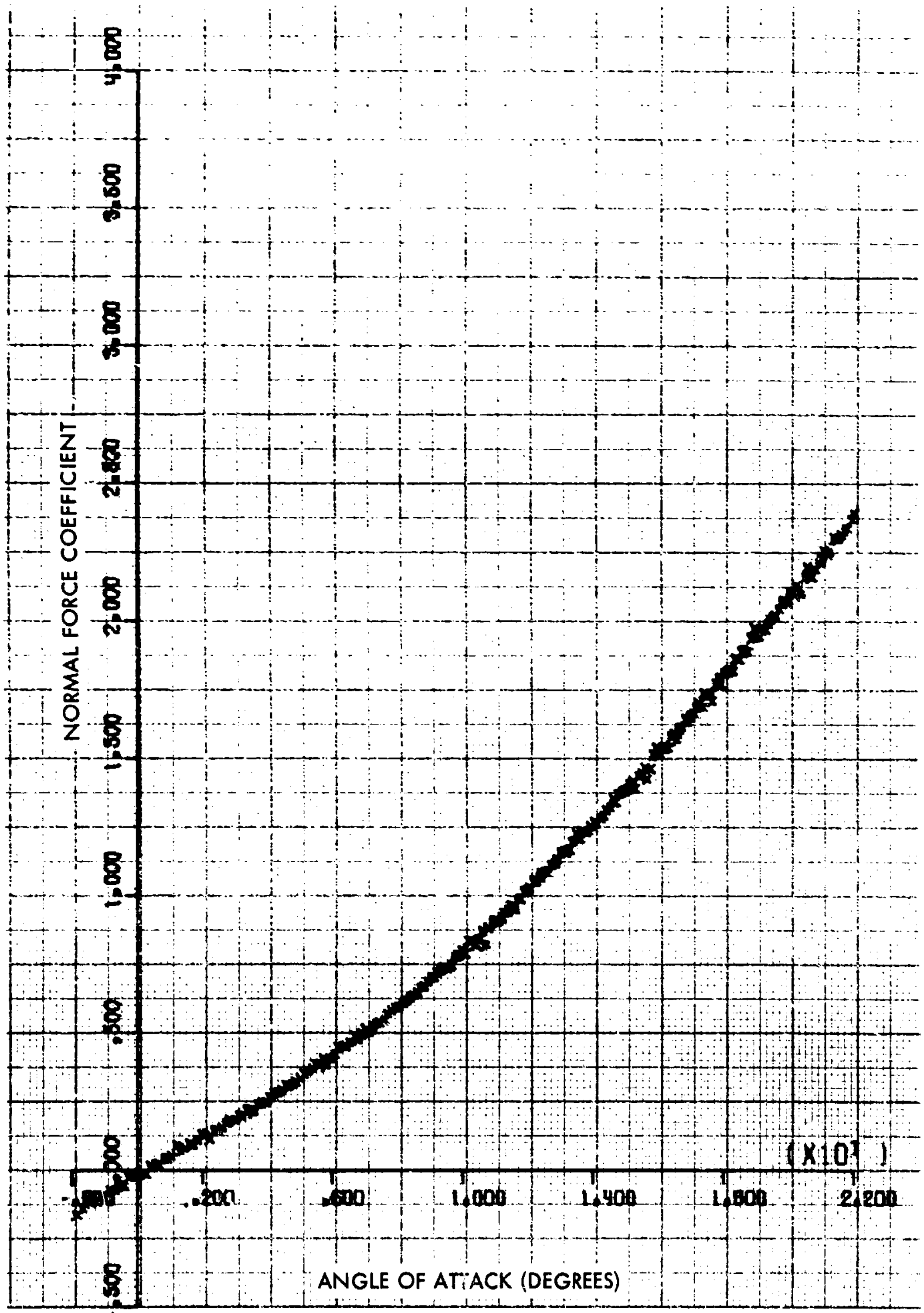

FIG. 72 NORMAL FORCE COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH SMALL FINS AT A MACH NUMBER OF 0.8 AND A ROLL ANGLE OF 0 DEGREES

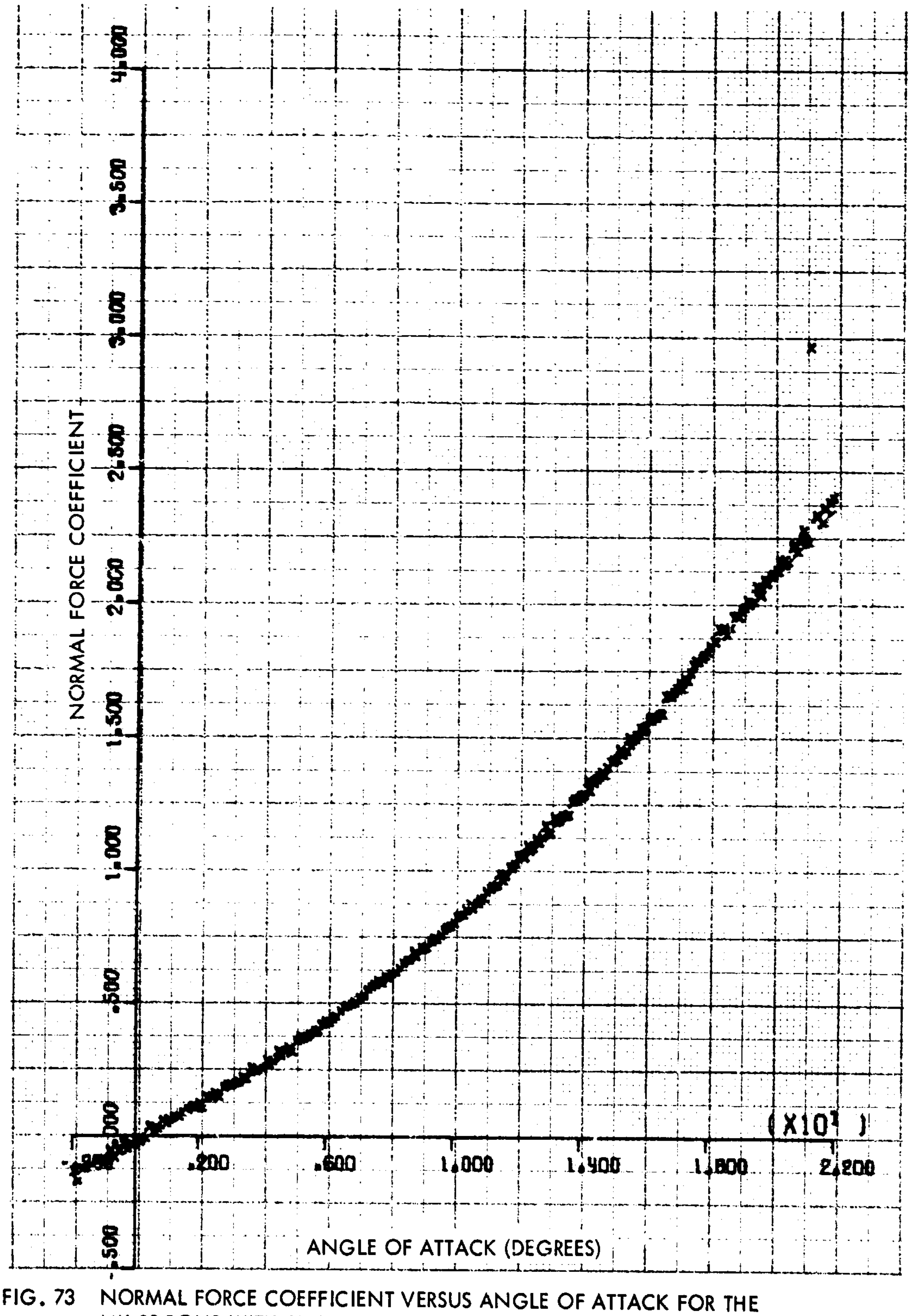

FIG. 73 NORMAL FORCE COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH SMALL FINS AT A MACH NUMBER OF 0.85 AND A ROLL ANGLE OF 0 DEGREES

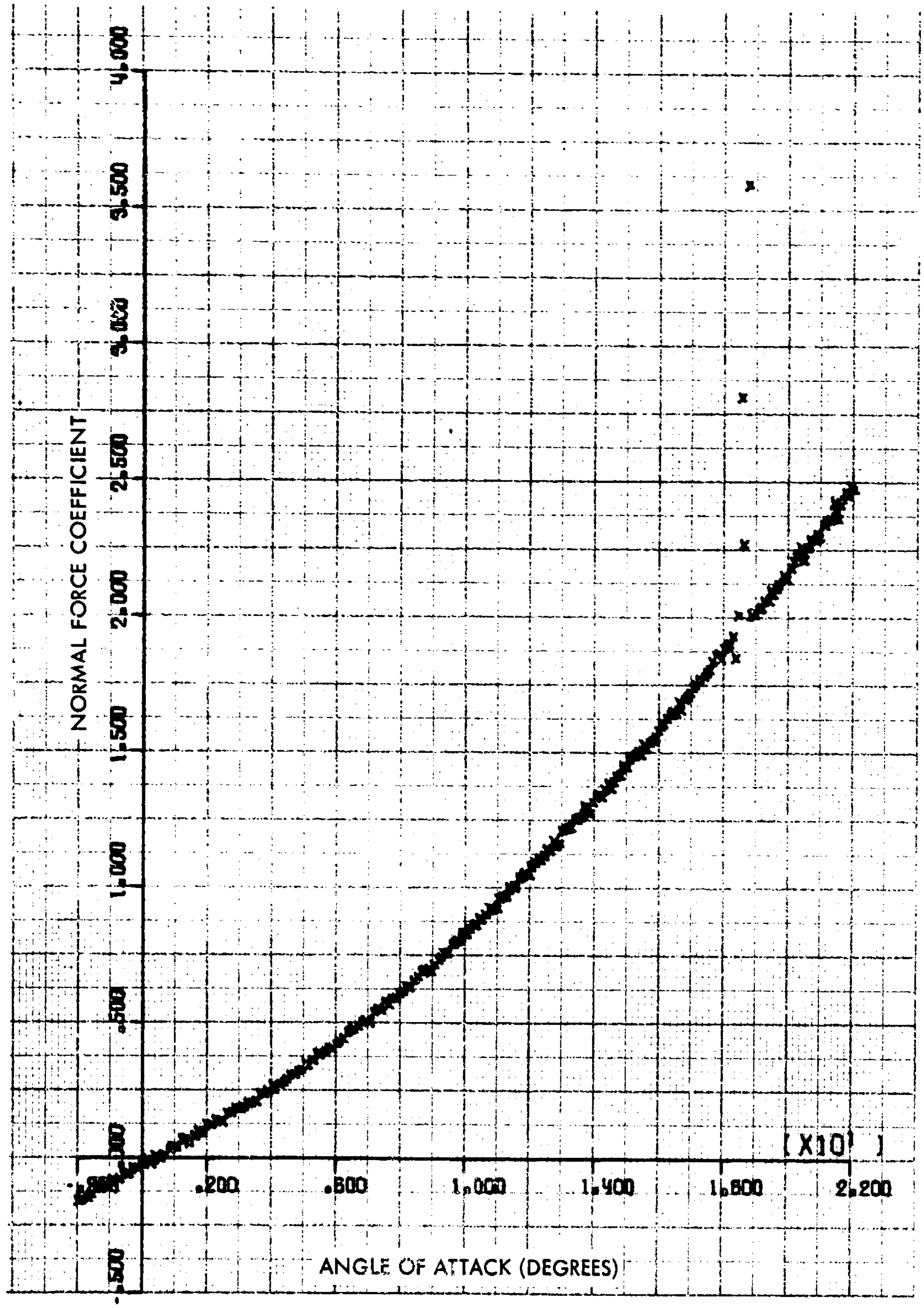

FIG. 74 NORMAL FORCE COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH SMALL FINS AT A MACH NUMBER OF 0.95 AND A ROLL ANGLE OF 0 DEGREES

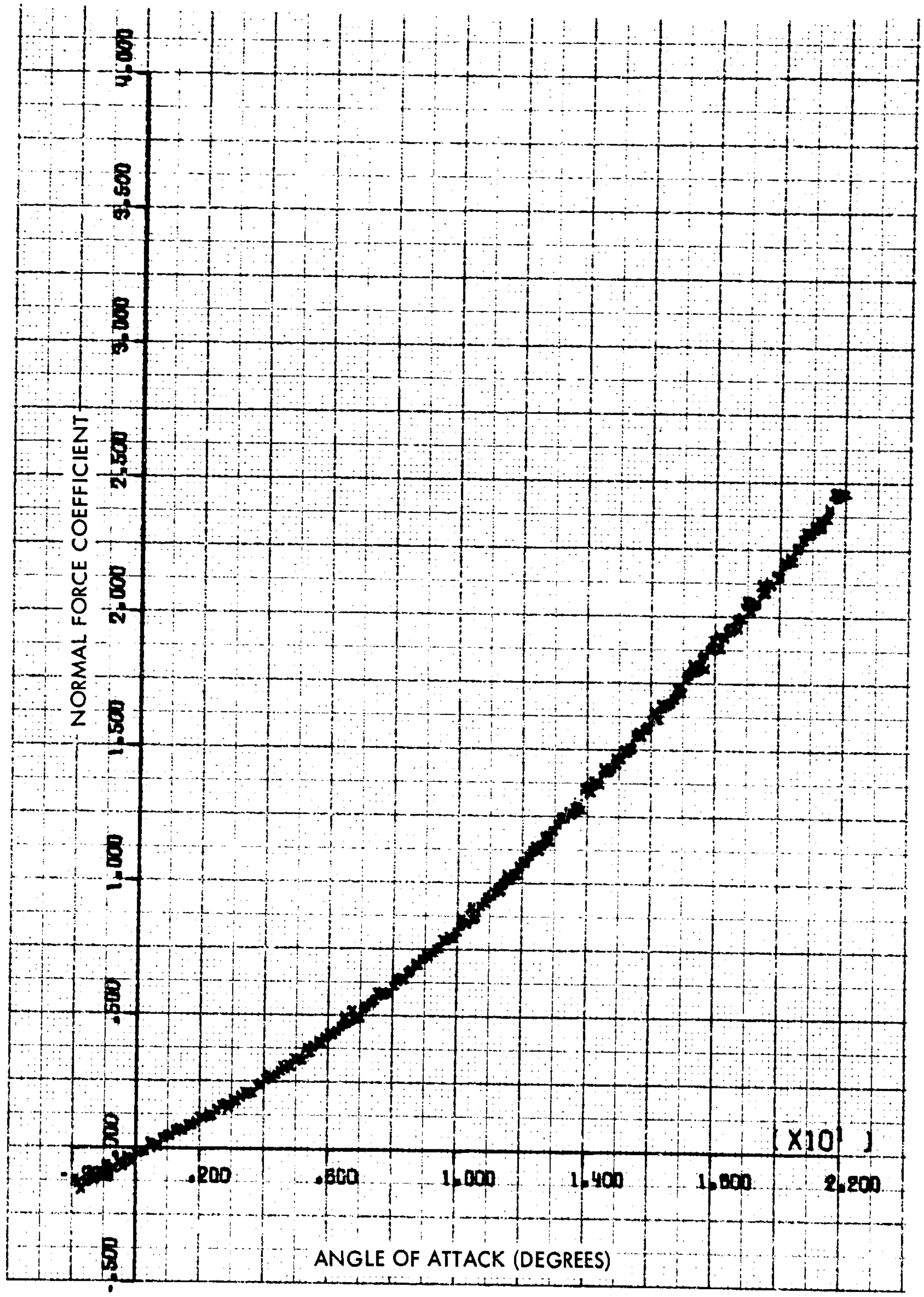

FIG. 75 NORMAL FORCE COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH SMALL FINS AT A MACH NUMBER OF 1.00 AND A ROLL ANGLE OF 0 DEGREES

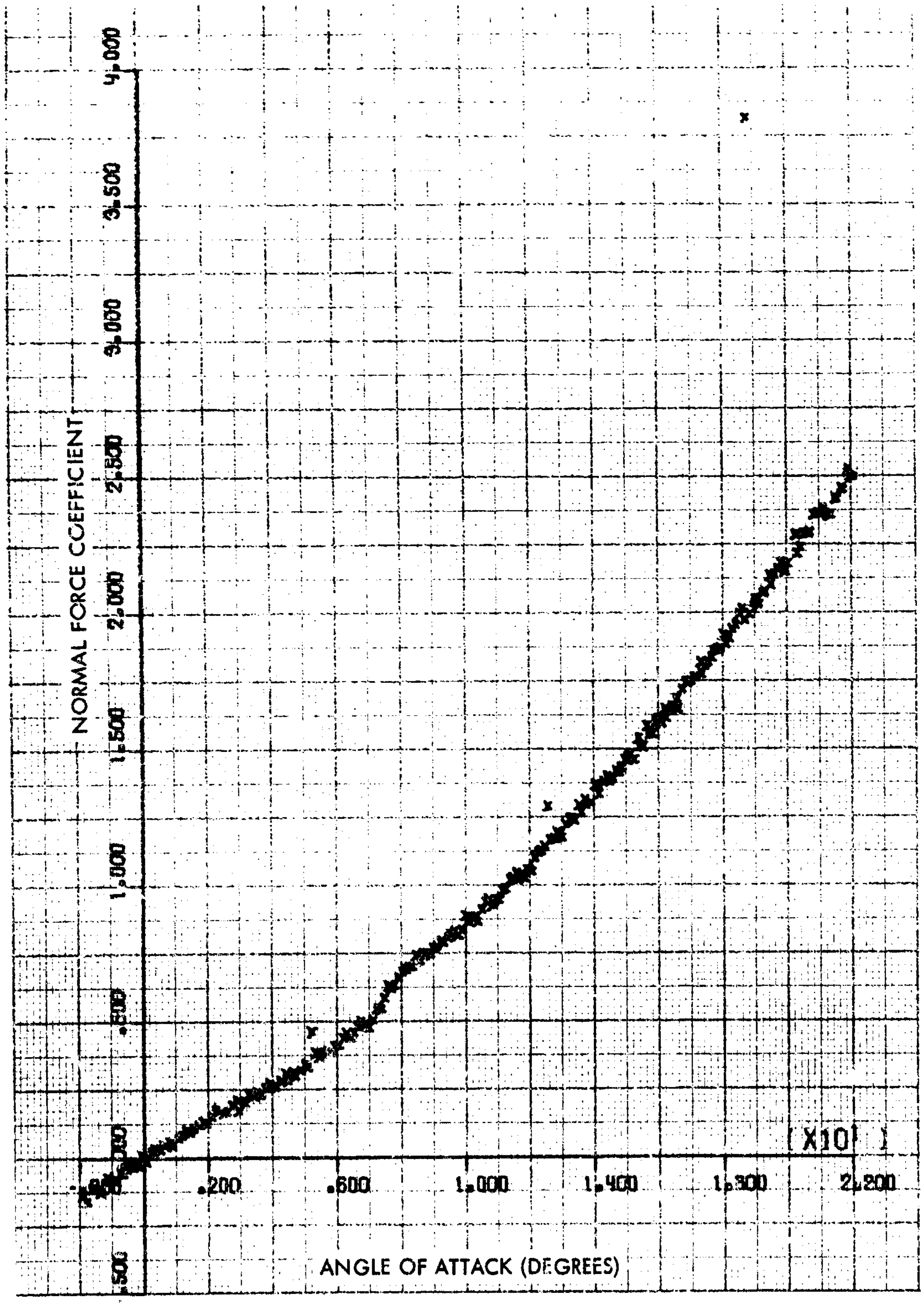

FIG. 76 NORMAL FORCE COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH SMALL FINS AT A MACH NUMBER OF 1.05 AND A ROLL ANGLE OF 0 DEGREES

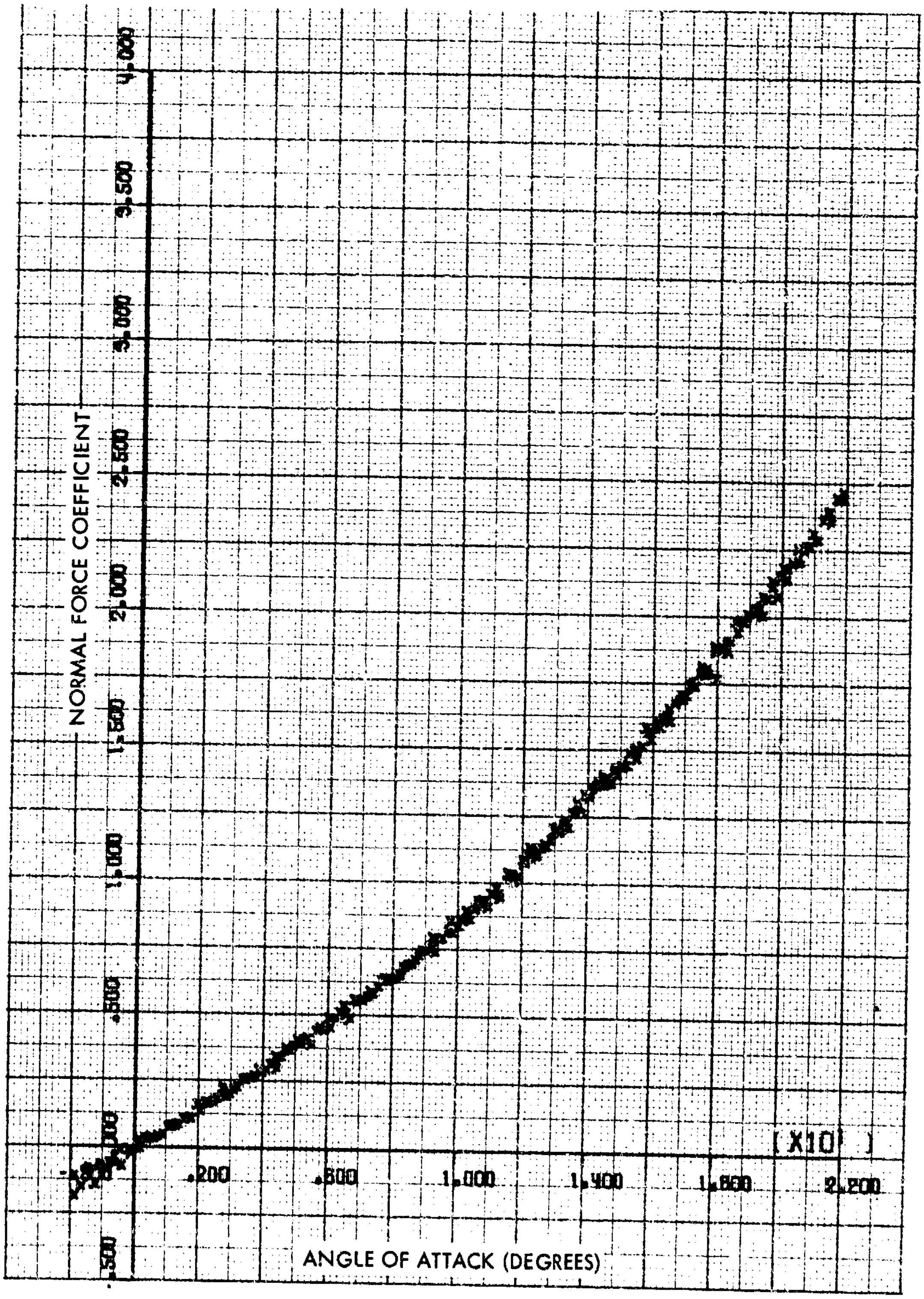

FIG. 77 NORMAL FORCE COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH SMALL FINS AT A MACH NUMBER OF 1.10 AND A ROLL ANGLE OF 0 DEGREES

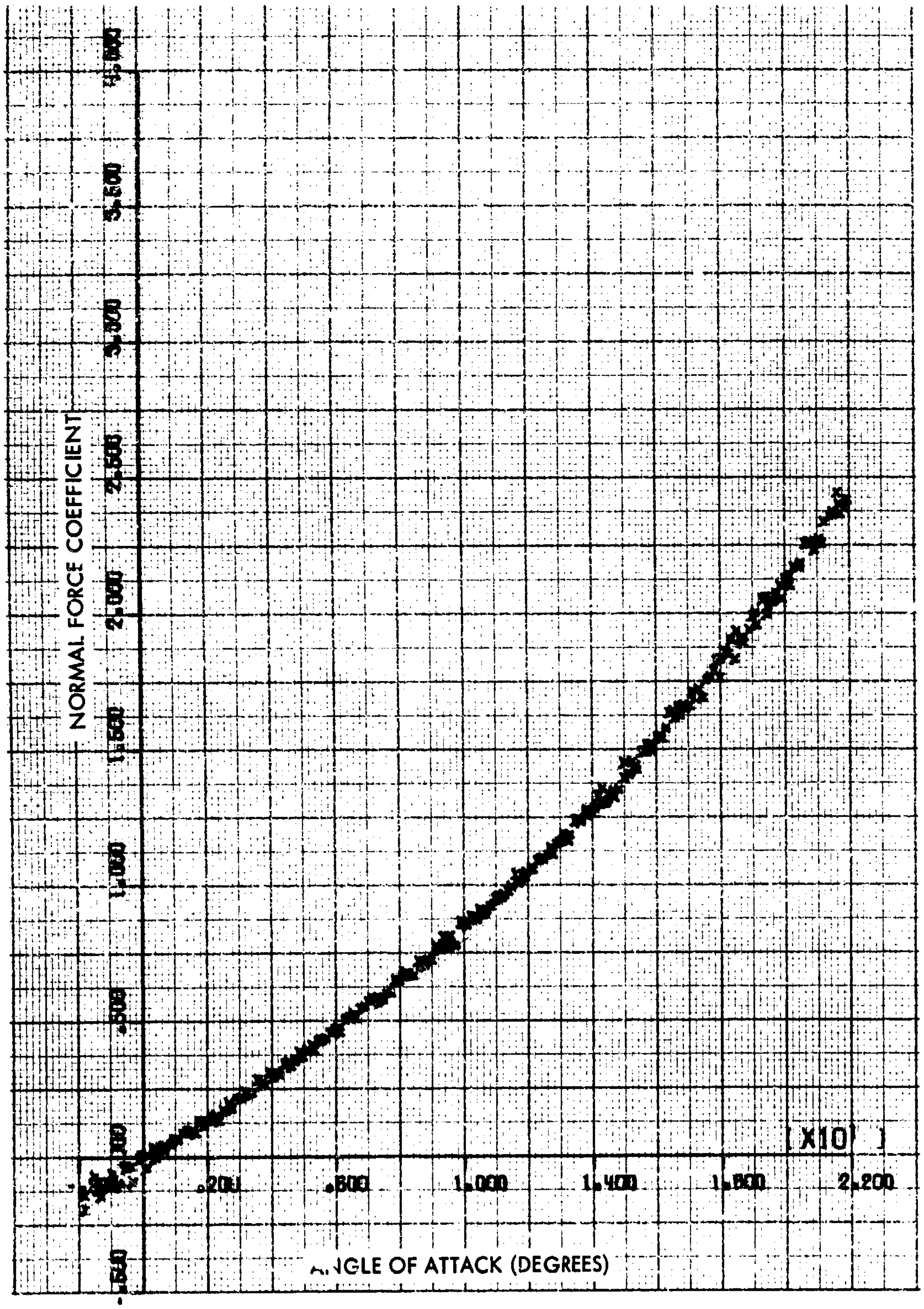

FIG. 78 NORMAL FORCE COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH SMALL FINS AT A MACH NUMBER OF 1.15 AND A ROLL ANGLE OF 0 DEGREES

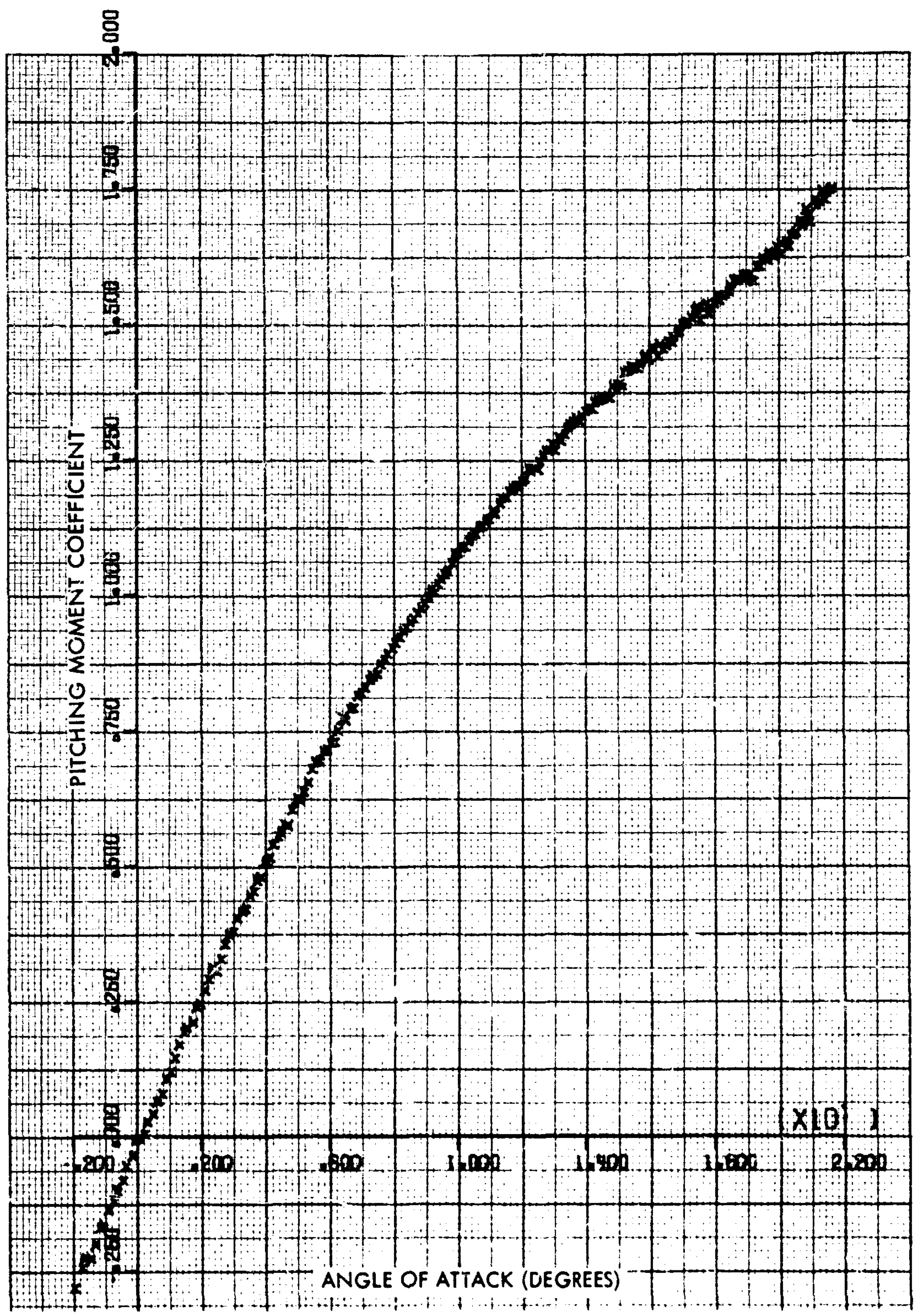

FIG. 79 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH NO FINS AT A MACH NUMBER OF 0.6

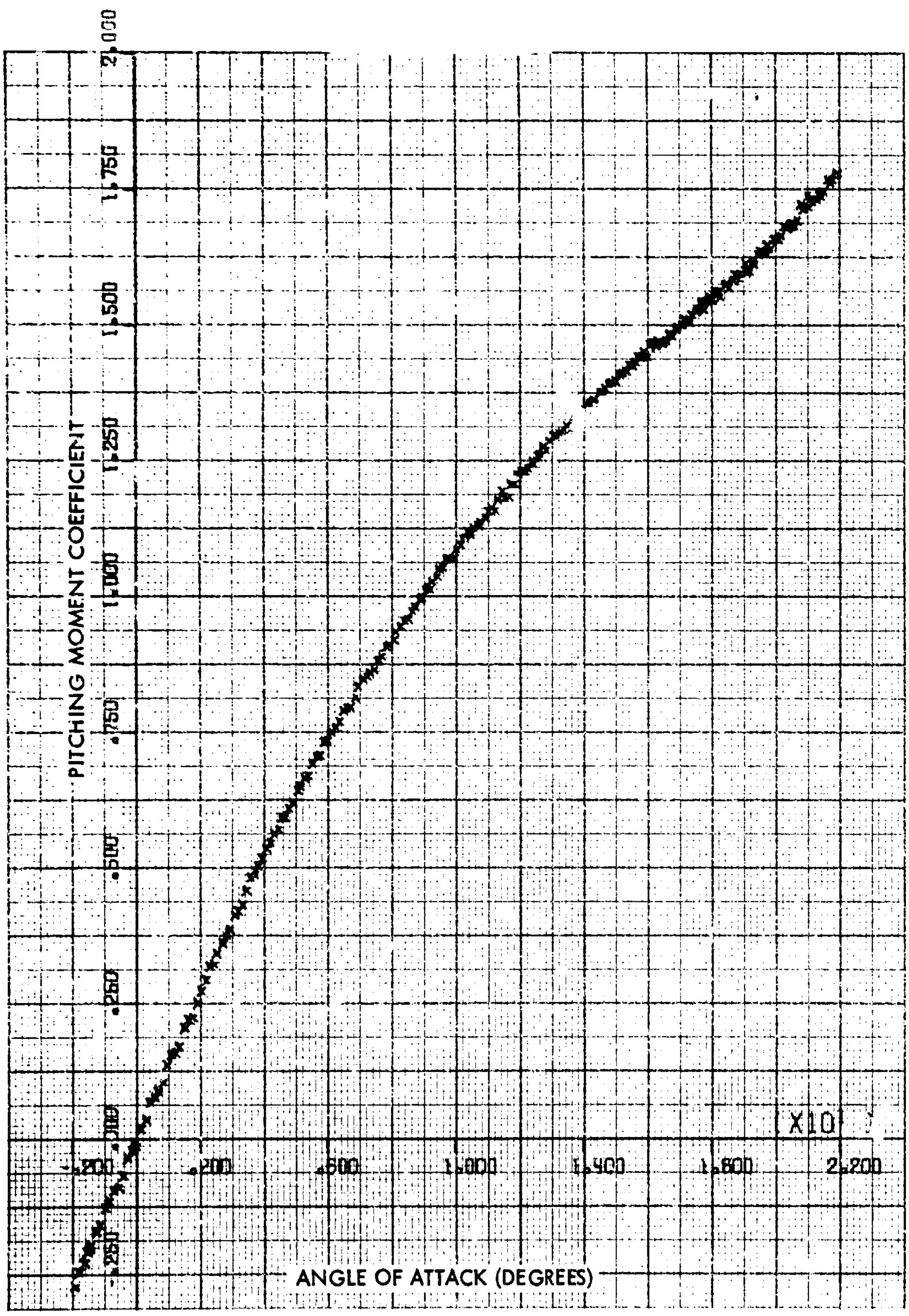

FIG. 80 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH NO FINS AT A MACH NUMBER OF 0.7

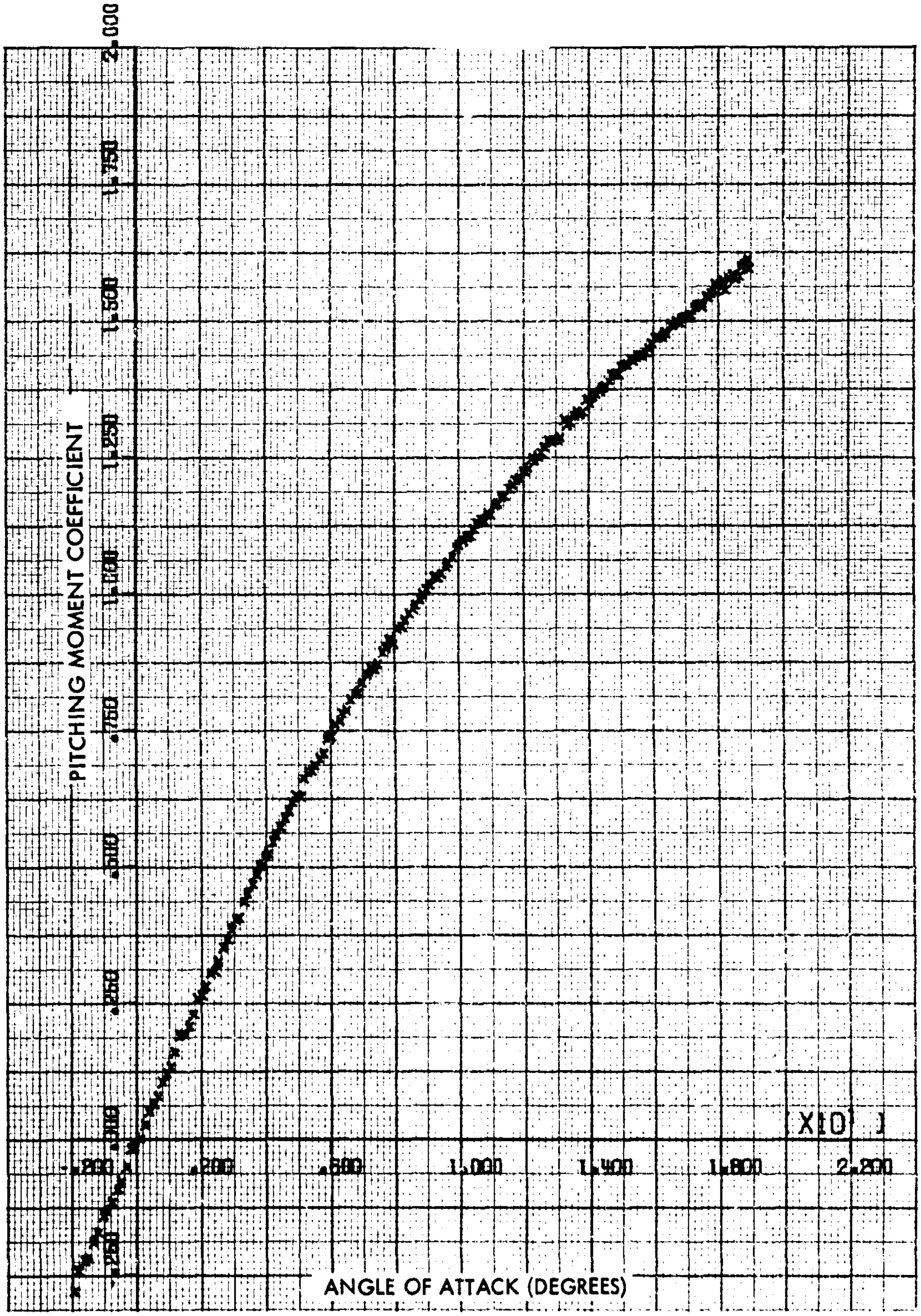

FIG. 81 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH NO FINS AT A MACH NUMBER OF 0.8

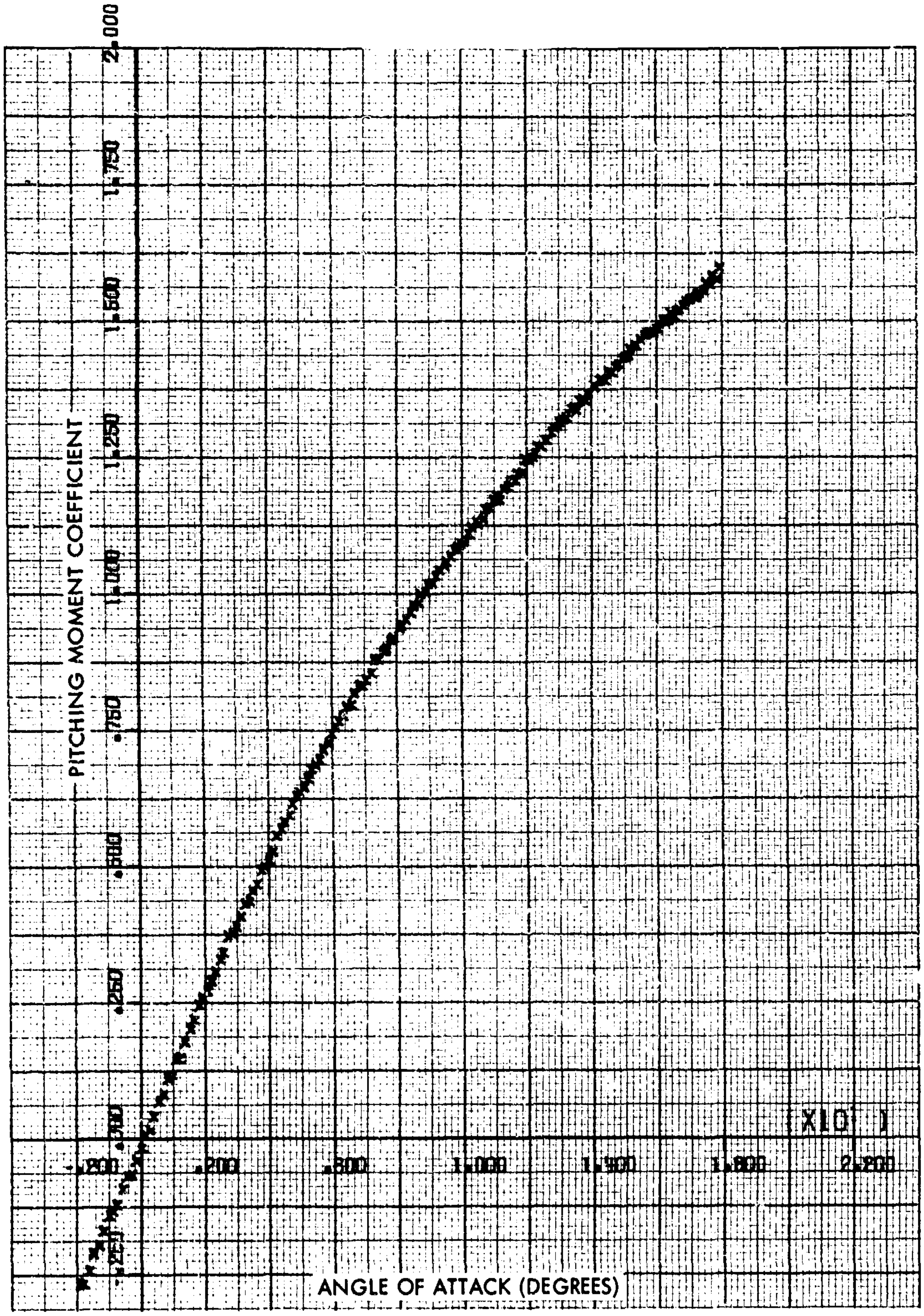

FIG. 82 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH NO FINS AT A MACH NUMBER OF 0.85

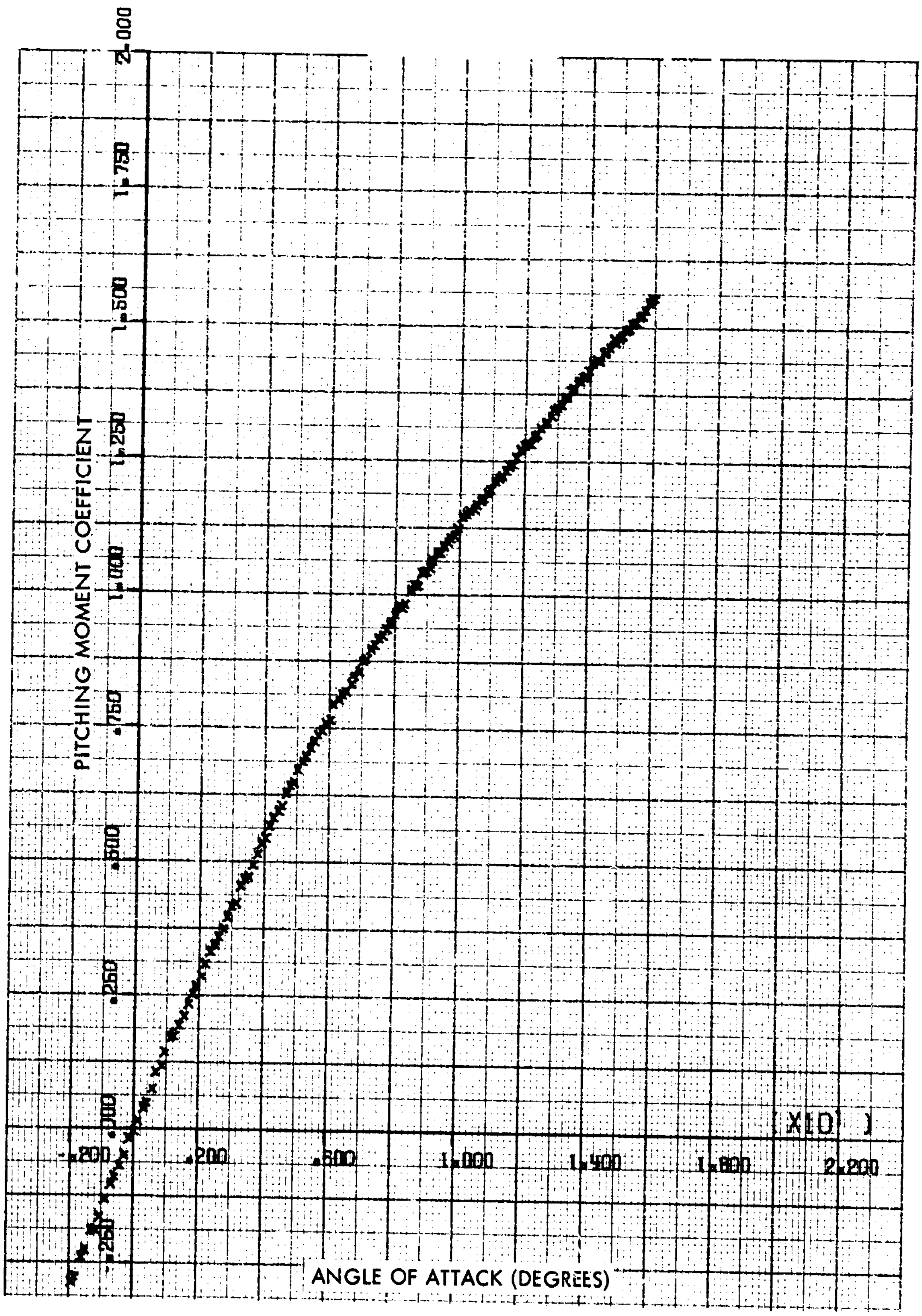

FIG. 83 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH NO FINS AT A MACH NUMBER OF 0.95

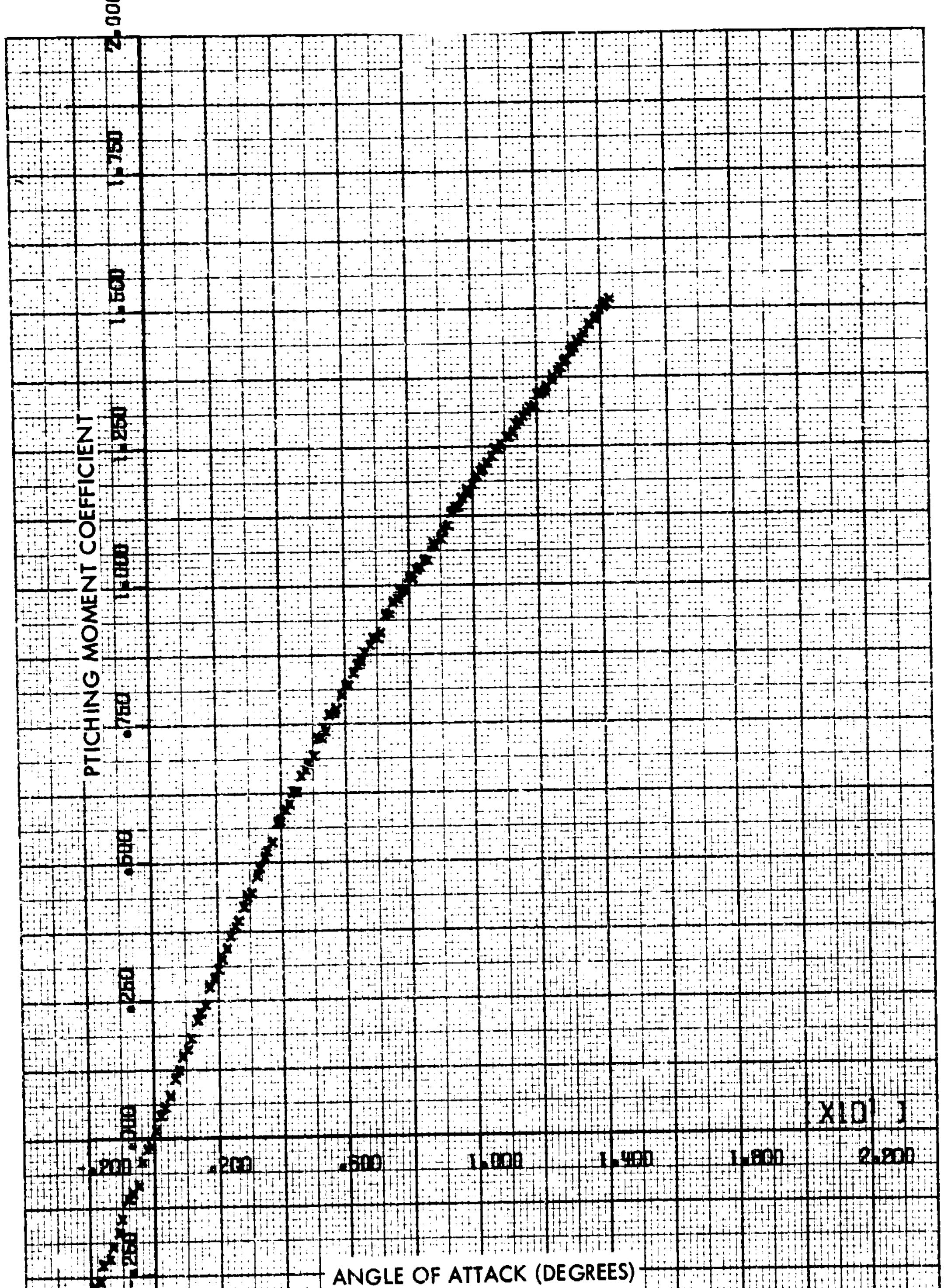

FIG. 84 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH NO FINS AT A MACH NUMBER OF 1.00

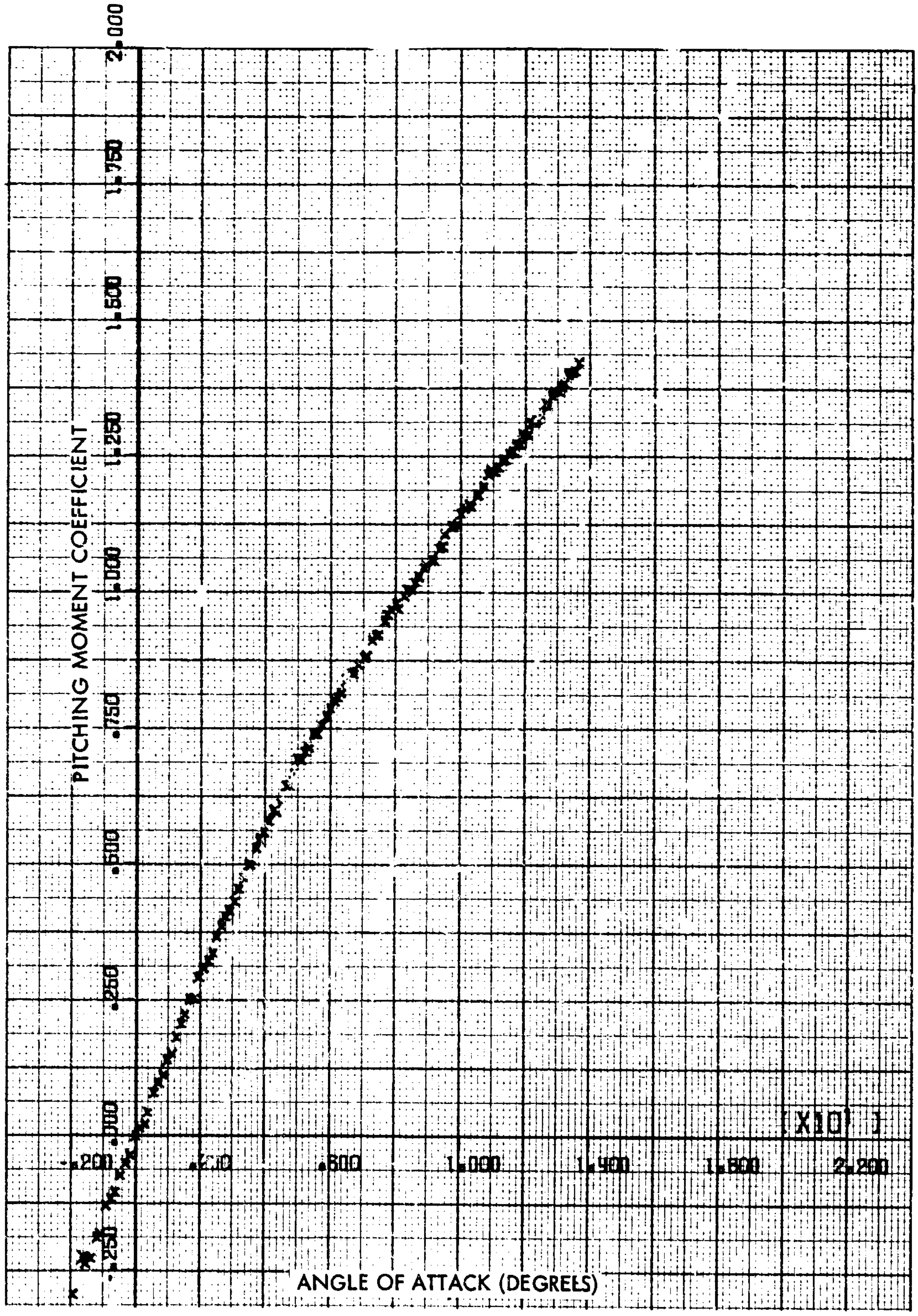

FIG. 85 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH NO FINS AT A MACH NUMBER OF 1.05

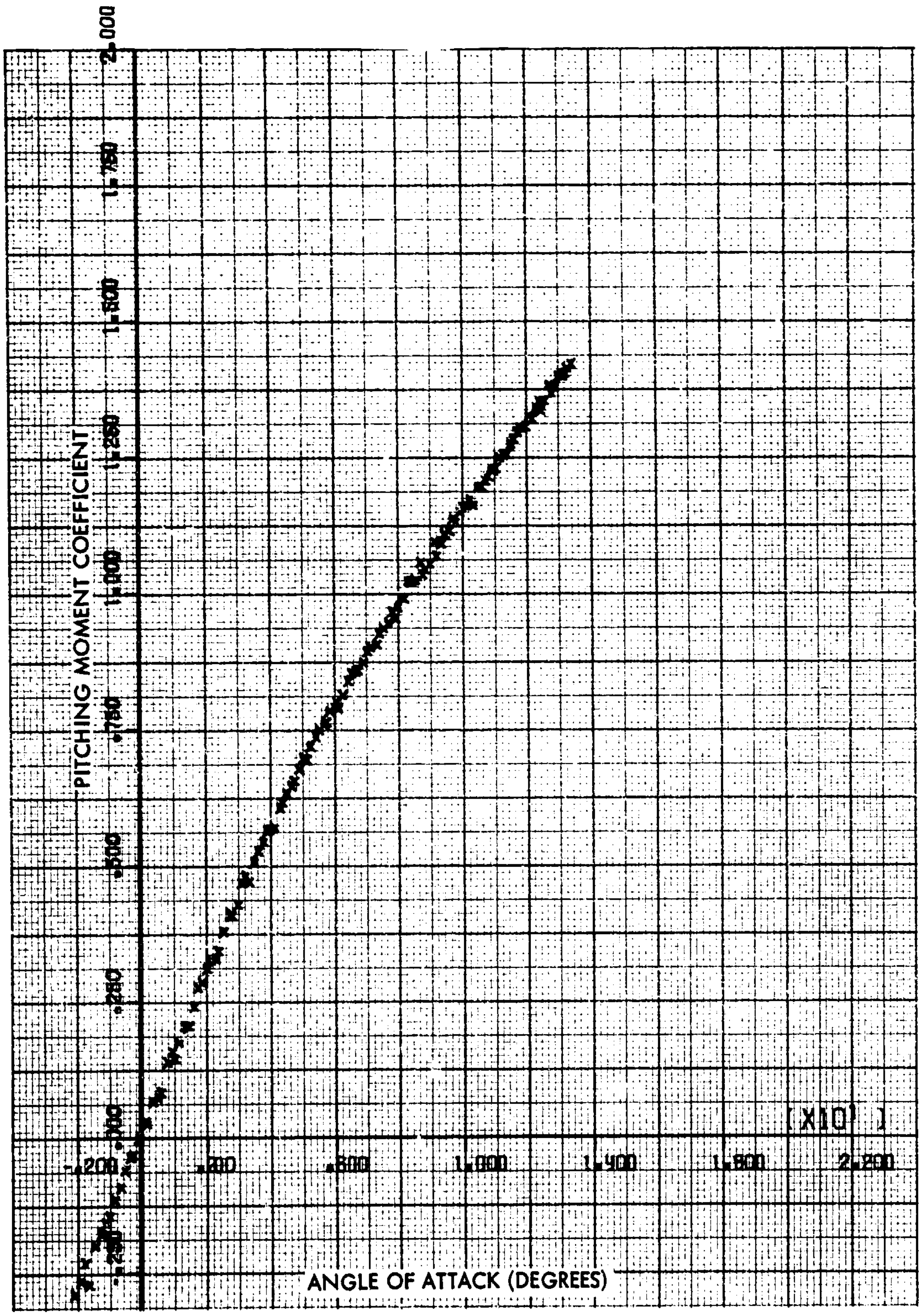

FIG. 86 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH NO FINS AT A MACH NUMBER OF 1.10

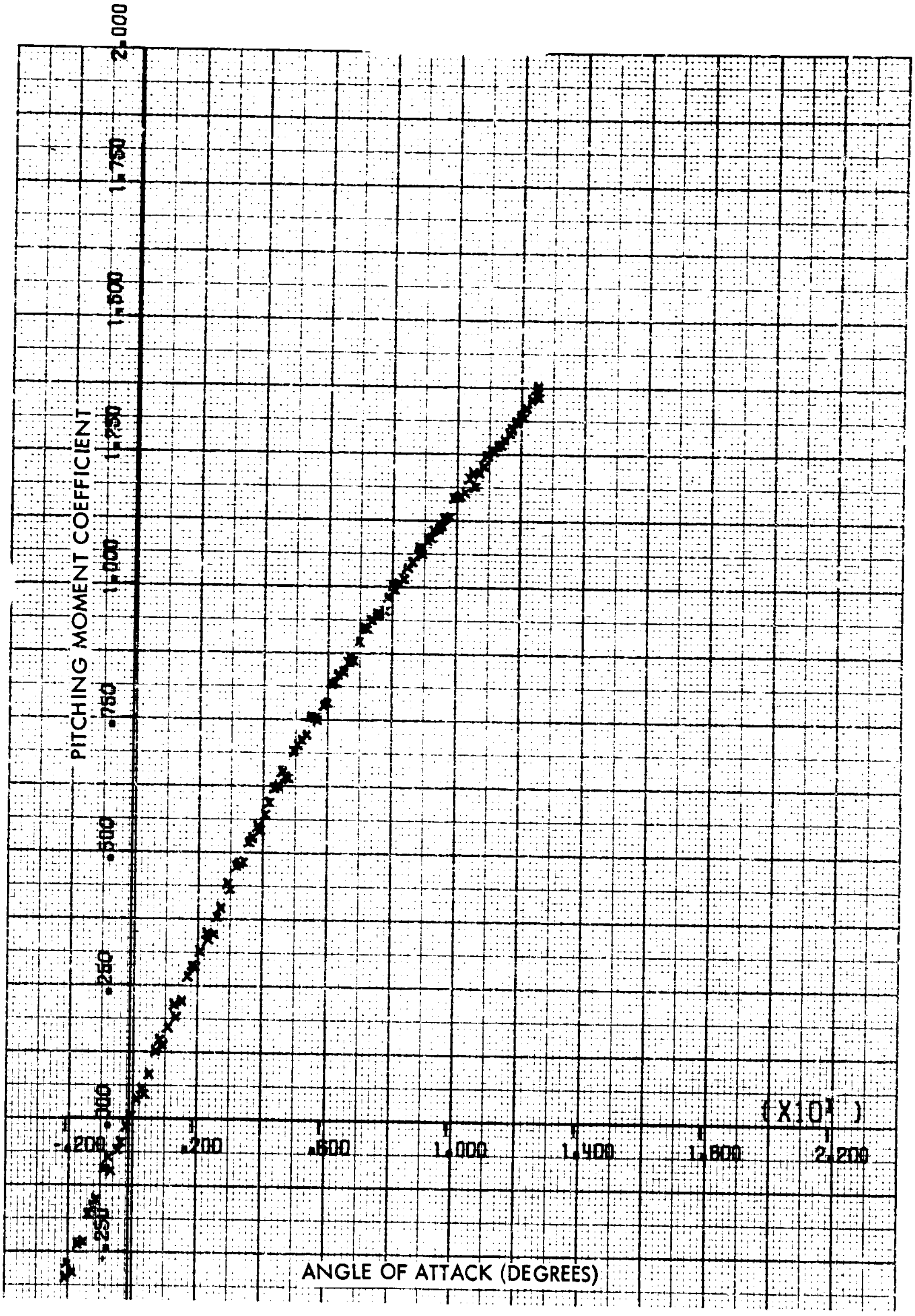

FIG. 87 PITCHING MOMENT COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH NO FINS AT A MACH NUMBER OF 1.15

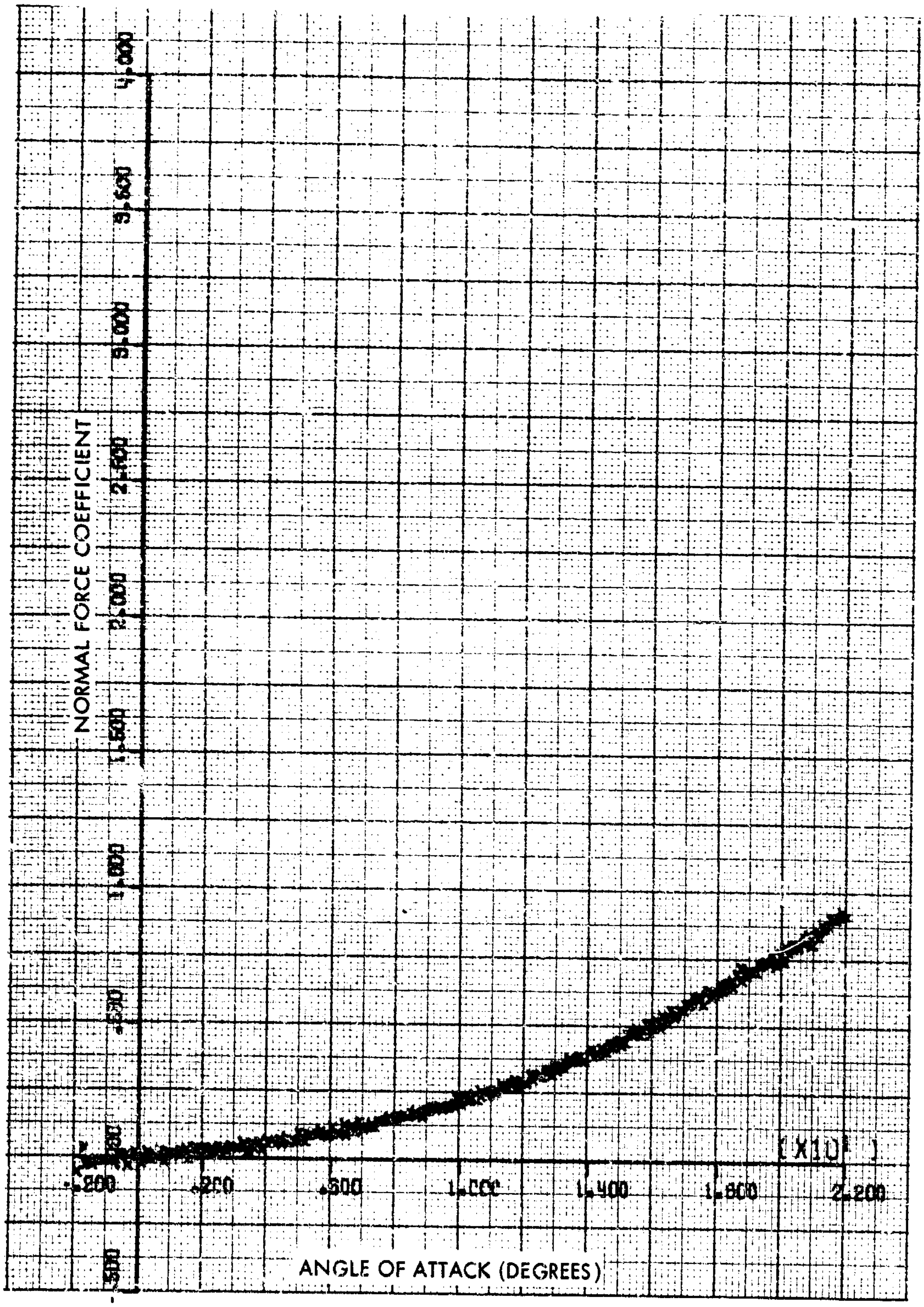

FIG. 88 NORMAL FORCE COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH NO FINS AT A MACH NUMBER 0.6

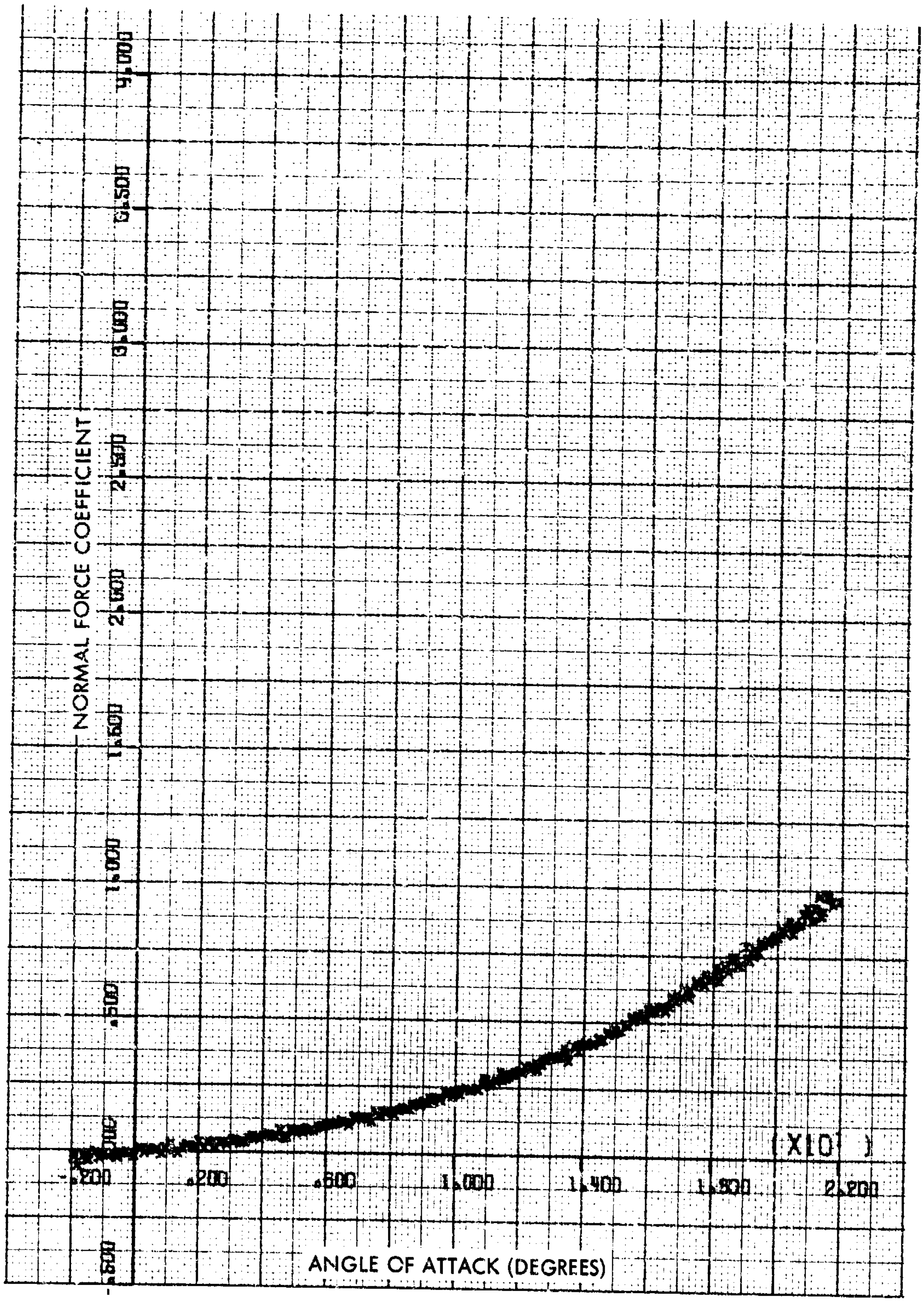

FIG. 89 NORMAL FORCE COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH NO FINS AT A MACH NUMBER OF 0.7

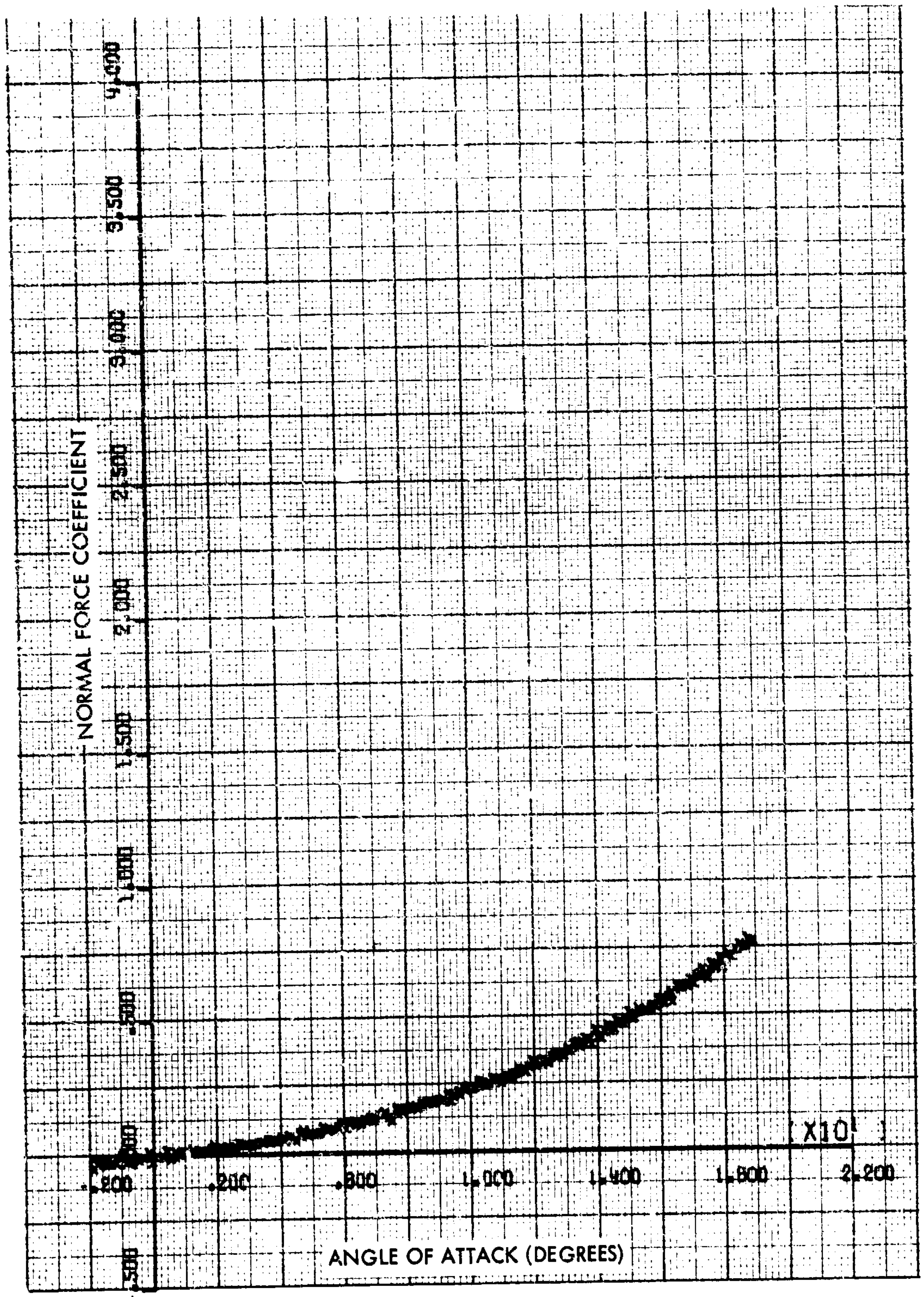

FIG. 90 NORMAL FORCE COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH NO FINS AT A MACH NUMBER 0.8

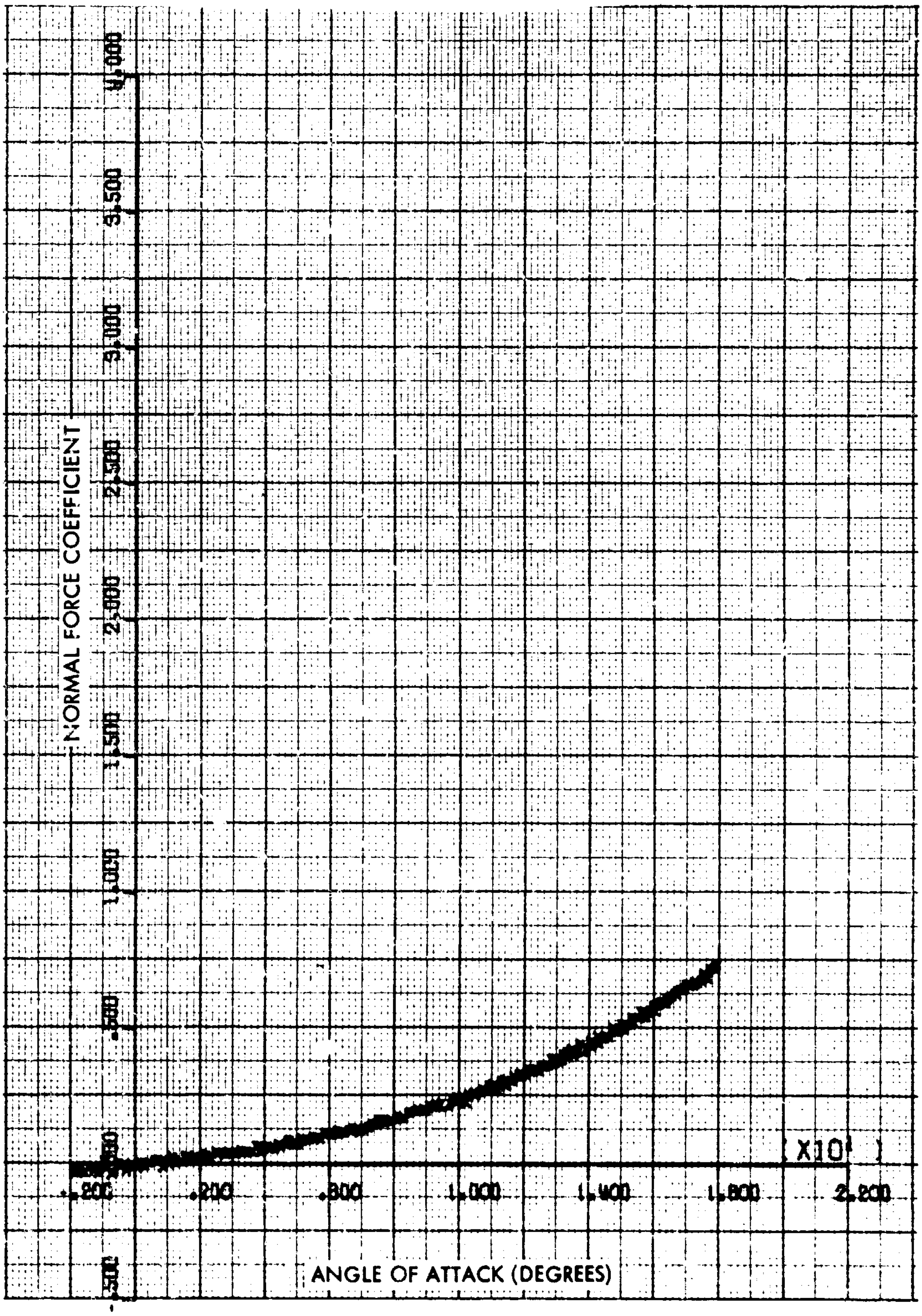

FIG. 91 NORMAL FORCE COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH NO FINS AT A MACH NUMBER 0.85

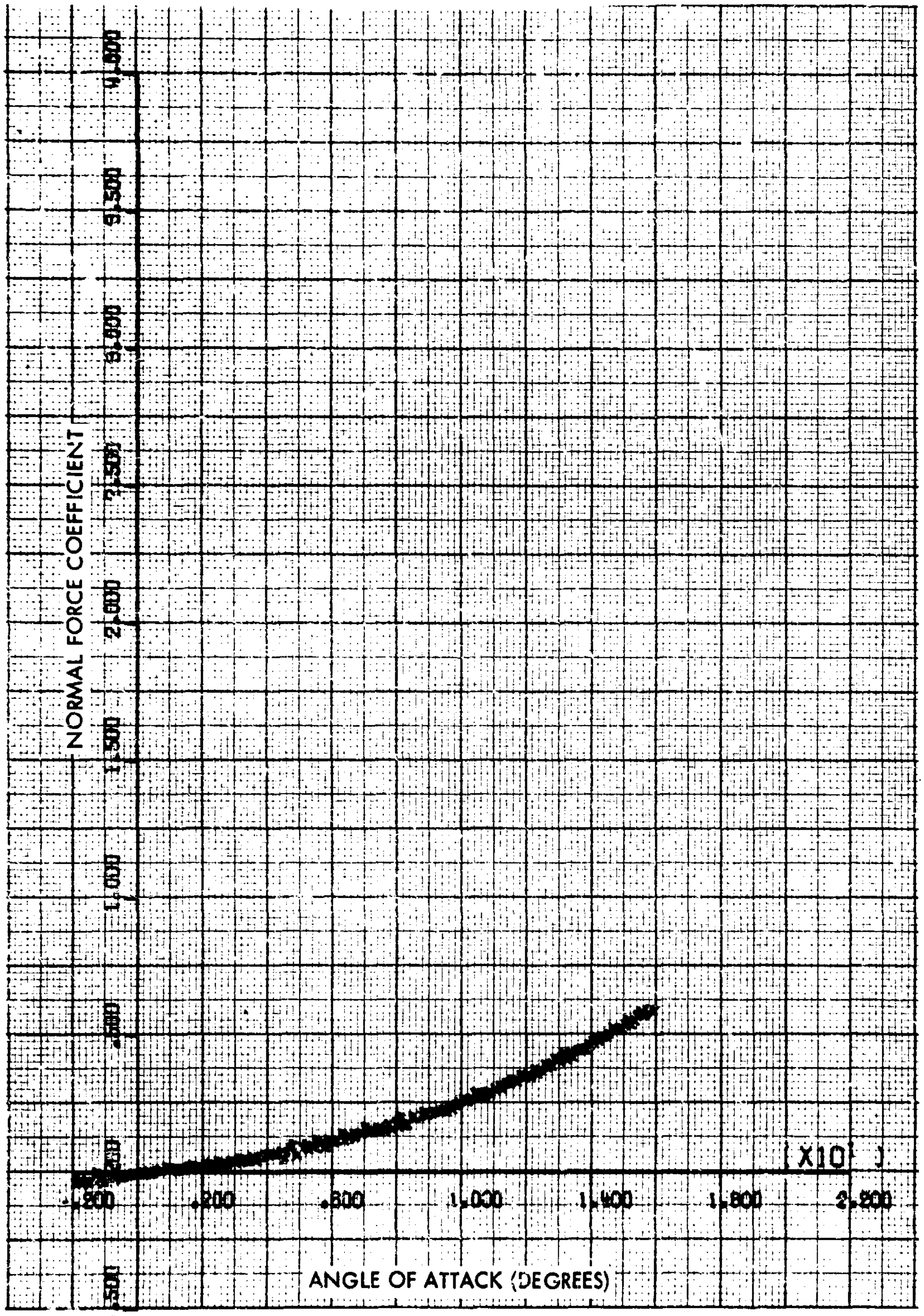

FIG. 92 NORMAL FORCE COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH NO FINS AT A MACH NUMBER 0.95

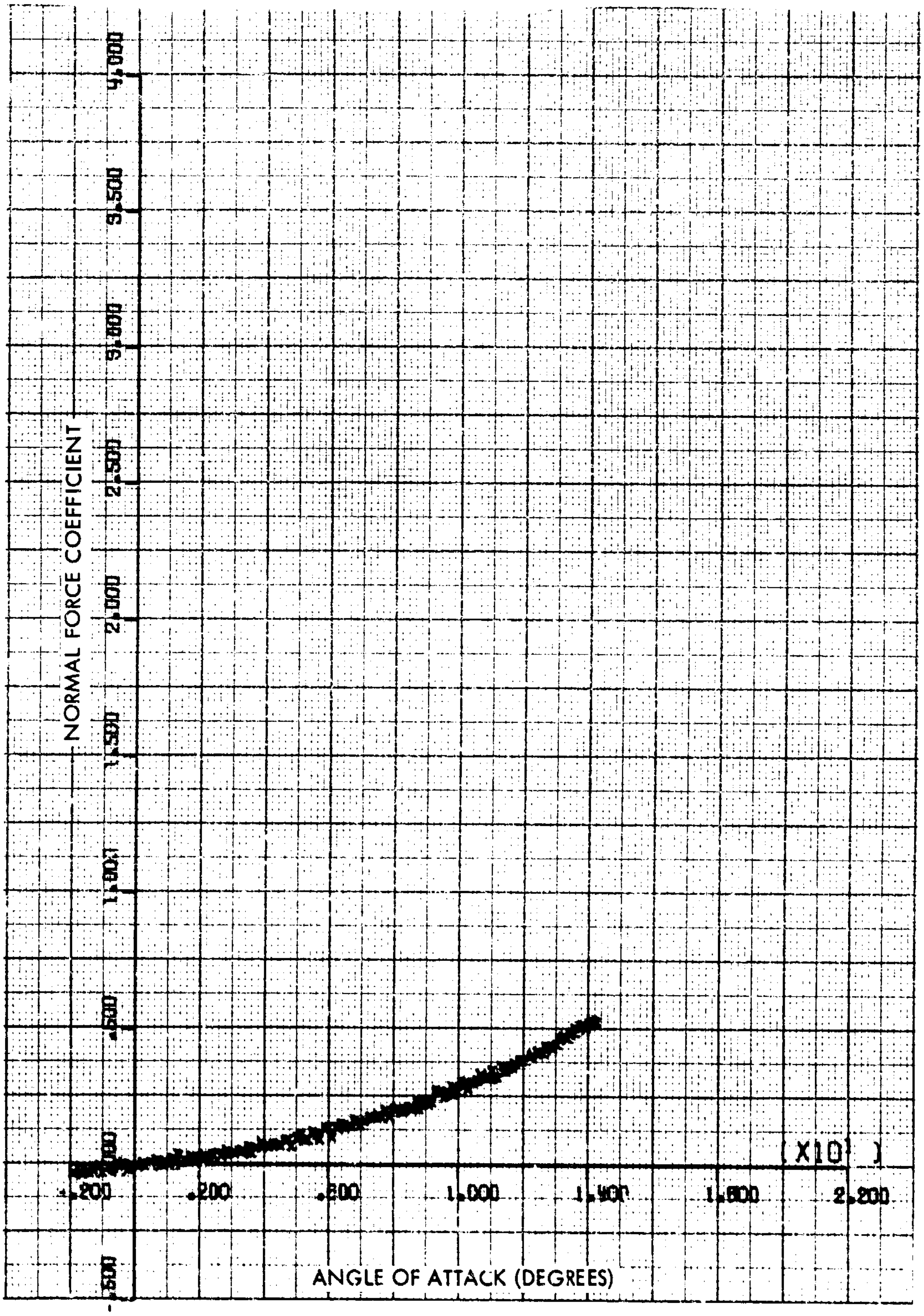

FIG. 93 NORMAL FORCE COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH NO FINS AT A MACH NUMBER 1.00

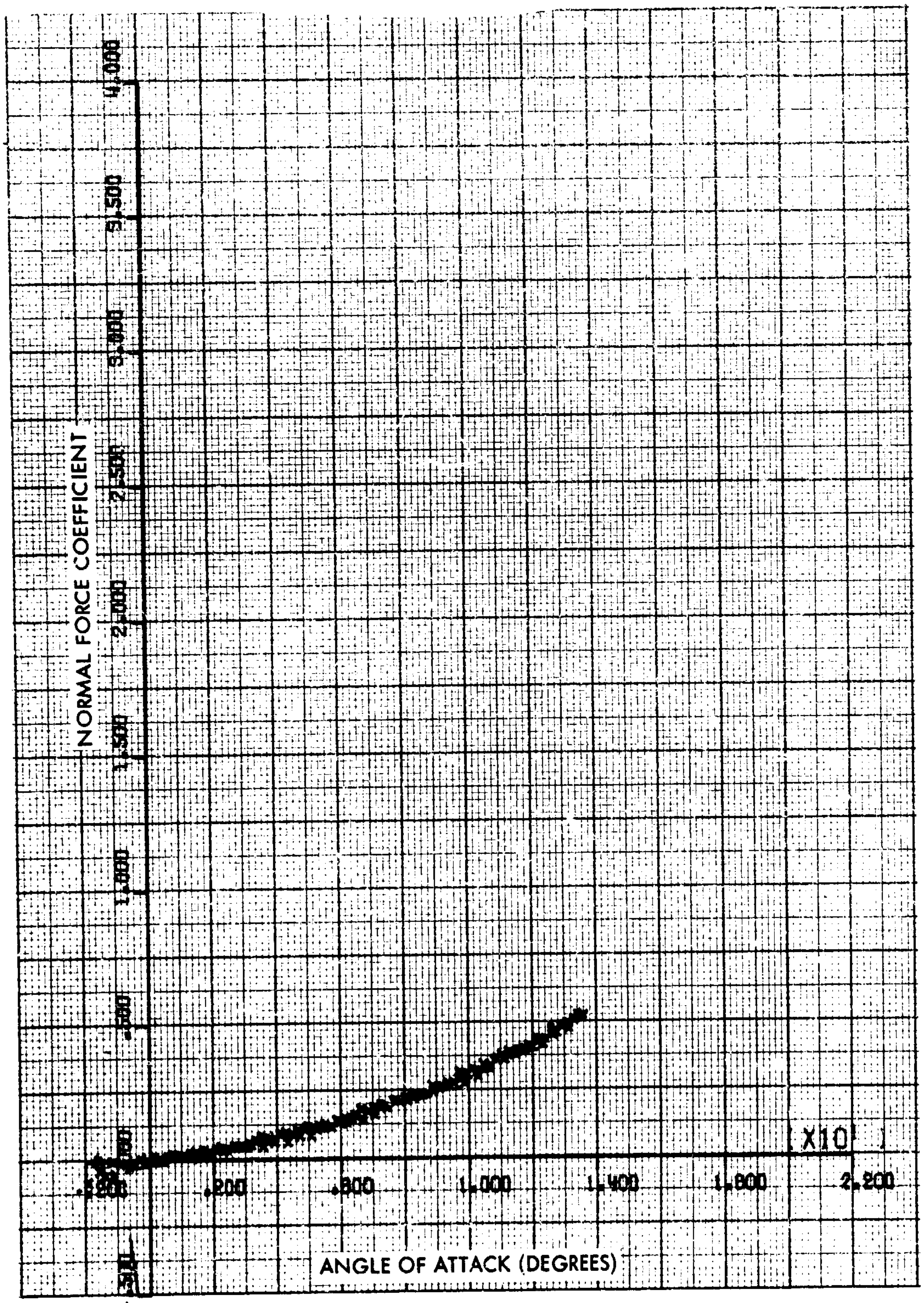

FIG. 94 NORMAL FORCE COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH NO FINS AT A MACH NUMBER 1.05

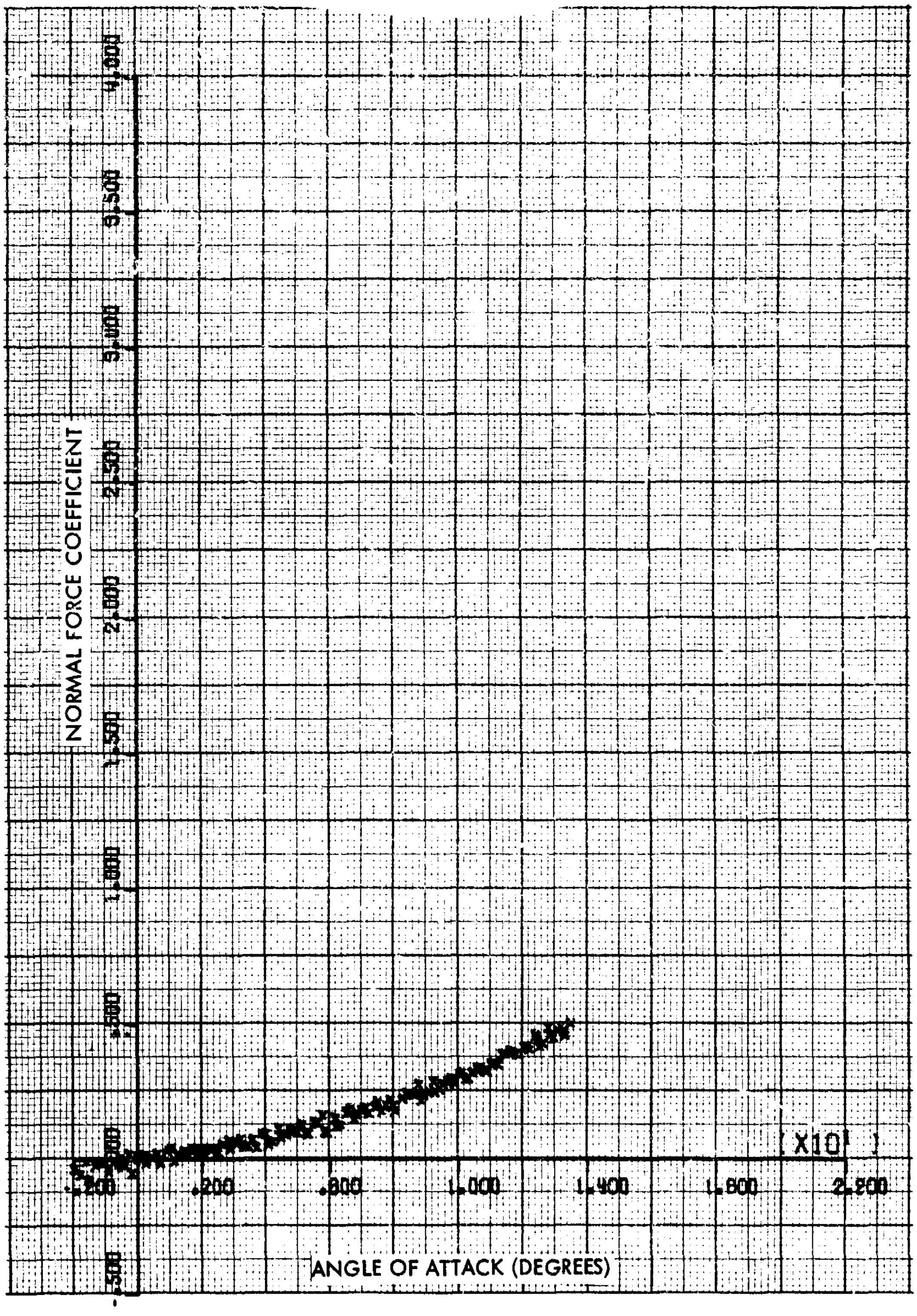

FIG. 95 NORMAL FORCE COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH NO FINS AT A MACH NUMBER 1.10

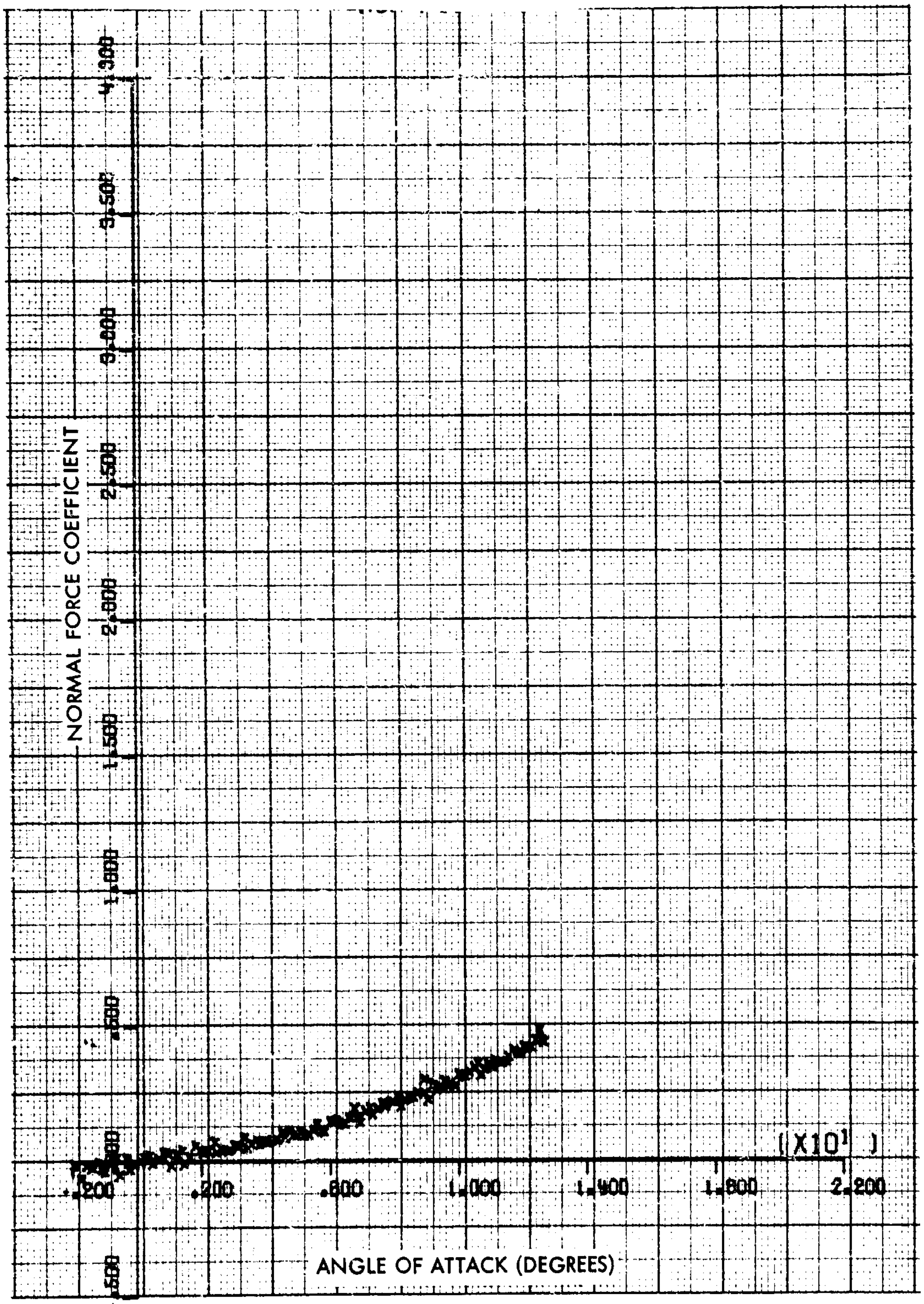

FIG. 96 NORMAL FORCE COEFFICIENT VERSUS ANGLE OF ATTACK FOR THE MK 82 BOMB WITH NO FINS AT A MACH NUMBER 1.15

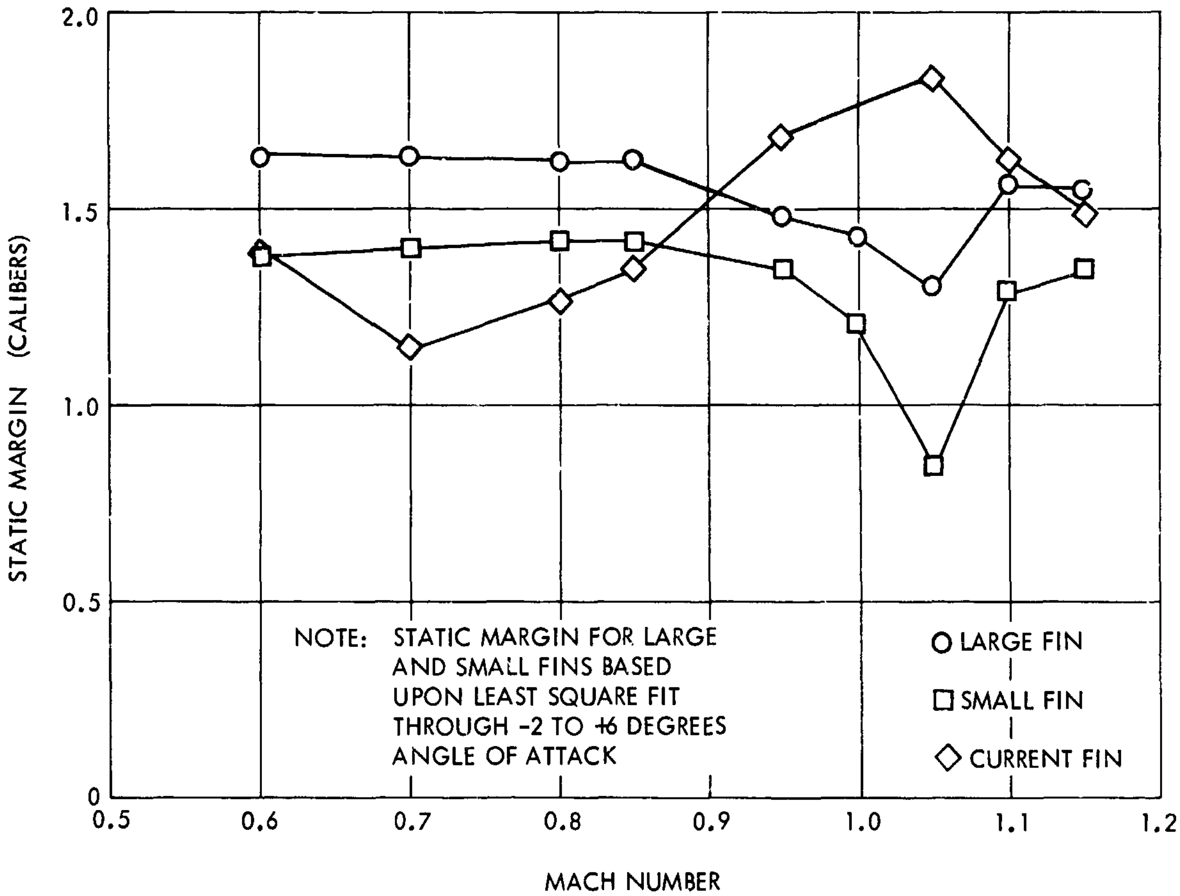

FIG 97 STATIC MARGIN VERSUS MACH NUMBER FOR THE LARGE, SMALL AND CURRENT STABILIZERS OF THE MK 82 BOMB

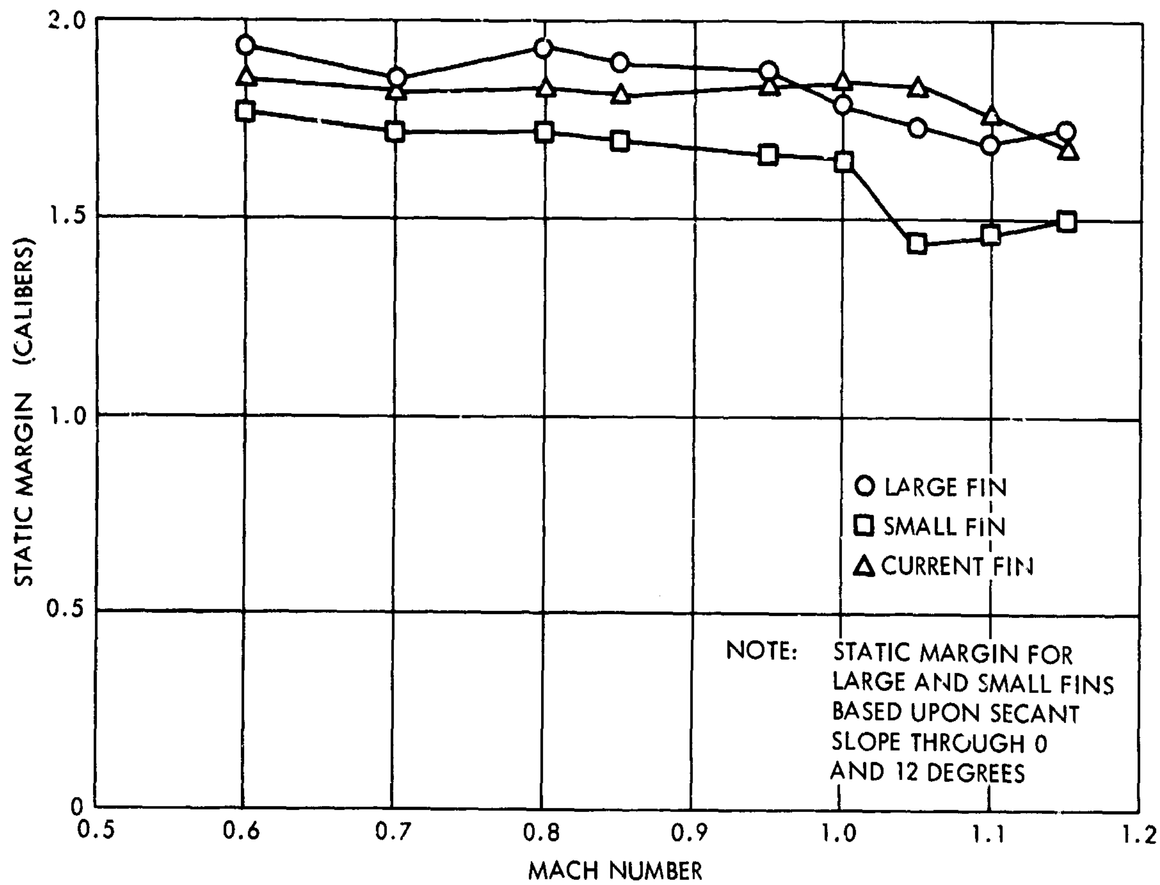

FIG 98 STATIC MARGIN VERSUS MACH NUMBER FOR THE CURRENT AND PROPOSED STABILIZERS OF THE MK 82 BOMB

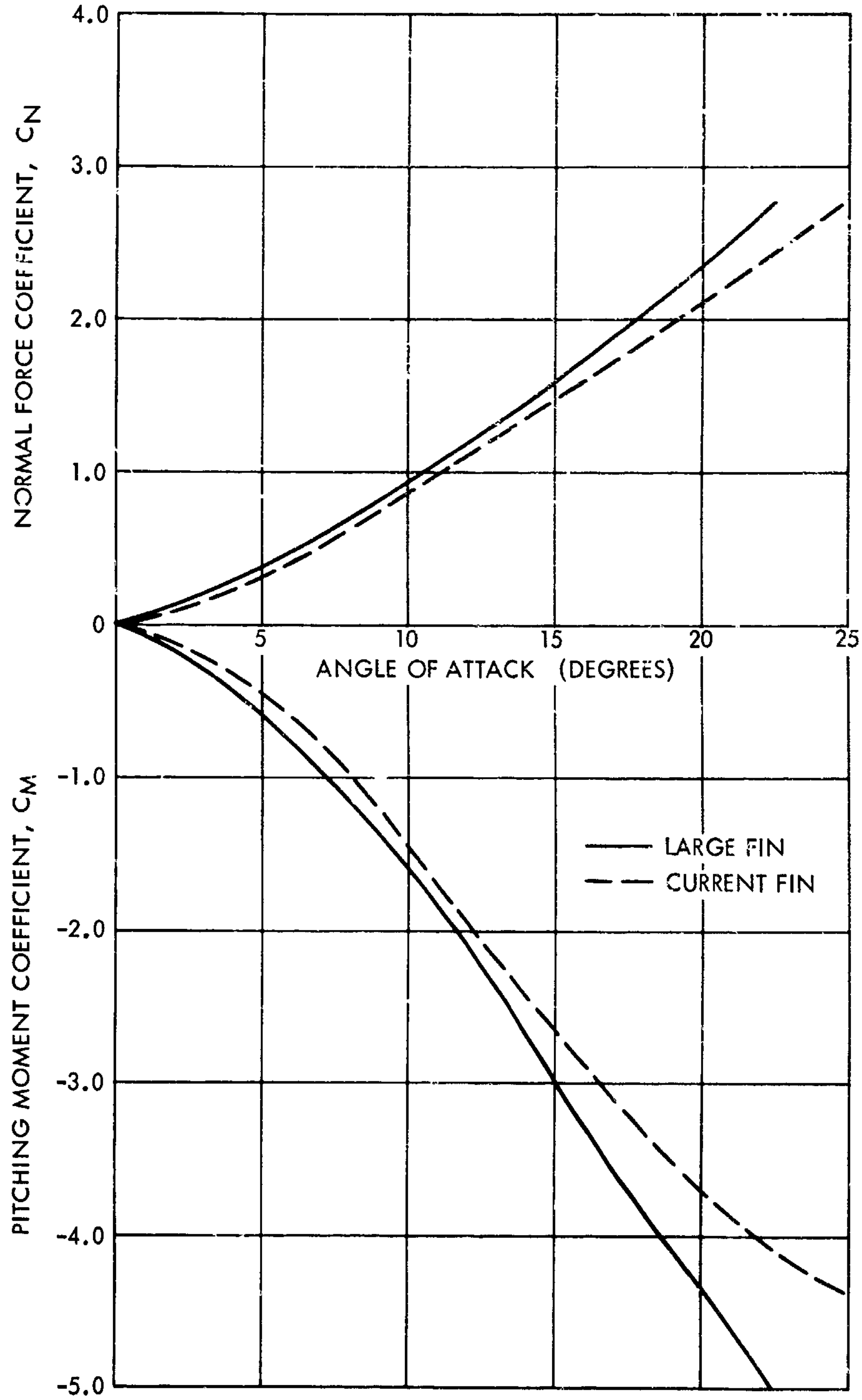

FIG 99 NORMAL FORCE AND PITCHING MOMENT COEFFICIENTS VS ANGLE OF ATTACK AT A MACH NO. OF 0.80 AND ROLL ANGLE OF 0 DEGREES FOR THE LARGE AND CURRENT FINS

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13. ABSTRACT

The Mk 82 is an operational free-fall store in use by the U. S. Navy. This report presents the results of static wind-tunnel tests of two proposed stabilizers for this weapon. The purpose in carrying out these tests was to provide data for a comparison between the currently used stabilizer and the proposed modified stabilizers.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
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