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COLLEGE OF ENGINEERING
GLENN L. MARTIN INSTITUTE OF TECHNOLOGY
WIND TUNNEL OPERATIONS DEPARTMENT

College Park, Maryland

UNIVERSITY OF MARYLAND
WIND TUNNEL ENGINEERING REPORT NO. 62-1

SURVEY OF LOW-ASPECT-RATIO CHARACTERISTICS USEFUL IN THE DESIGN OF CONTROL SURFACES

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SUMMARY

This report presents a compilation of characteristics obtained from subsonic experimental data for many different plan forms of low-aspect-ratio surfaces. The purpose of this compilation is to provide information for the design of ship and submarine control surfaces.

The work presented in this report was sponsored by the Bureau of Ships under Contract No. NObs - 84240. The opinions and conclusions presented are those of the contractor and not necessarily those of the Department of the Navy.

INTRODUCTION

Information presented in this report is the result of a survey of literature of wind tunnel tests pertaining to low-aspect-ratio characteristics which are of importance in the design of control surfaces for maneuvering a vessel. During the survey emphasis was placed on low-subsonic-flow experimental data of symmetrical surfaces having the following characteristics:

1. Aspect ratio of 4 or less
2. Sweepback of 30° or less
3. Maximum thickness to chord length ratio between 9 and 18 percent
4. Reynolds number greater than 2×10^6

While emphasis has been placed on the above characteristics, some data is presented which fall outside of these limitations.

Data obtained during the survey are presented as graphs for use by the design engineer. These curves show the variation of the force coefficients, chordwise center of pressure and spanwise center of pressure (where available) with angle of attack, aspect ratio, sweep angle and taper ratio.

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SOURCES OF DATA

The primary sources of information presented in this report were David Taylor Model Basin Report 933 (Reference 1) and various NACA reports. A large number of the reports dealing with experimental results listed in the bibliography of Reference 2 were investigated. Although there are numerous publications listed in Reference 2, most of them do not fall within the limitations of this data search.

Data from David Taylor Model Basin Report 933 supplemented by tests conducted under the present contract for the Bureau of Ships at this installation (Reference 3) were the most uniform, systematic, and complete available. These reports produced practically all of the data presented on the NACA 0015 airfoil section control surfaces. Numerous planforms covering various sweep angles, aspect ratios, and taper ratios were investigated in a systematic manner in these tests.

Aside from the NACA 0015 airfoil section, the only other section on which any appreciable amount of data could be found was the NACA 0012. Most of this information was obtained from various NACA reports. While there were data available on other airfoil sections, they were not sufficient to produce the crossplots desired except for a limited amount available on the NACA 64A010 airfoil section.

Considerable experimental low-aspect-ratio data were available in the NACA literature. But, large quantities of the data were for

asymmetrical airfoil sections and thin sections which fell outside the scope of this study. Data for wing-body combinations were also excluded from this report. When the other limitations stated in the introduction were imposed, the reports available were quite limited. Among the remaining reports were some that had to be discarded because the experimental data were not complete. That is, in some cases drag data were not available or the model support corrections were not determined during the test. The fact that the drag data were not available eliminated the possibility of computing the chordwise center of pressure. Since this was of primary interest, reports not containing drag data were rejected. Reports where support corrections were not determined or accounted for were also rejected for this information could not be compared directly with fully corrected data.

A summary of the various planforms for which information was obtained and the sources of this information is presented in Table I.

PRESENTATION OF DATA

NACA 0015 AIRFOIL SECTION

The data for the NACA 0015 airfoil section planforms are presented in two sets. The first set of data presented in Figures 3 - 17 are for the planforms having square tips, whereas, the second set of data, Figures 18 - 29 are for planforms having faired tips. Figures 3 - 10 for the square tips and Figures 18 - 22 for the faired tips present curves of lift coefficient, drag coefficient, normal force coefficient, resultant force coefficient, chordwise center of pressure and spanwise center of pressure versus angle of attack for each individual planform. The remaining figures of these sets are crossplots of the forces and centers of pressure with taper ratio, aspect ratio and quarter chord sweep as variables.

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NACA 0012 AIRFOIL SECTION

Data for the NACA 0012 airfoil section planforms are presented in Figures 30 - 48. As in the case of the NACA 0015 airfoil section, these data appear in two sets. The first set presented in Figures 30 - 36 is for the planforms having square tips. The second set is for planforms with faired tips and is presented in Figures 37 - 48.

Spanwise center of pressure data are not presented for the 0012 section planforms. The data available in the reports for these planforms were insufficient for the computation of spanwise center of pressure. Lift coefficient, drag coefficient, normal force coefficient, resultant force coefficient, and chordwise center of pressure are plotted against angle of attack for the individual planforms in Figures 30 - 34 for the square tips and Figures 37 - 41 for the faired tips. This information is then crossplotted with taper ratio, aspect ratio and quarter chord sweep as variables in Figures 35 and 36 for square tips and Figures 42 - 48 for faired tips.

NACA 64A010 AIRFOIL SECTION

A limited amount of data on NACA 64A010 airfoil section planforms are presented in Figures 49 and 50. Here again, the data available was insufficient for the computation of the spanwise center of pressure.

DISCUSSION OF RESULTS

Normal force coefficients and resultant force coefficients were computed for each planform from the lift and drag characteristics

presented in the reports. The normal force coefficients were computed by use of the following equation:

$$C_N = C_L \cos\alpha + C_D \sin\alpha$$

The following relationship was used to compute resultant force coefficients:

$$C_R = \sqrt{C_L^2 + C_D^2}$$

When attempting to crossplot the data, it was noted that in a large percent of the cases, only three points were available for fairing a curve. Since many curves may be faired through three points, a problem arose as to the best method of fairing the data. The problem was especially serious in the case of the chordwise center of pressure where a high degree of accuracy was desired. In an attempt to solve this problem it was decided to use center of pressure curves obtained from theoretical methods as a guide for fairing the experimental data. Two methods were used to compute center of pressure data. The methods used are presented in References 1 and 4. Neither of the methods used proved satisfactory in predicting results that could be used as guides for fairing the experimental data. It was therefore necessary to fair curves through the experimental points in a manner that is reasonable and consistent with the data available.

NACA 0015 AIRFOIL SECTION

All of the data on the NACA 0015 airfoil section planforms except that presented in Figures 8 - 10 were obtained from tests run specifically for control surface studies. In these tests the models were mounted in the wind tunnel on a flat surface or ground board.

The model then becomes a half model of a symmetrical wing with the ground board or tunnel wall introduced as a reflection plane at the longitudinal plane of symmetry. The relationship between the half model and the complete model is shown in Figure 2.

Figures 8 - 10 were obtained from tests on complete wings. The information presented in these figures is not contained in any of the crossplots. When attempting to crossplot these data, it was found that only two points could be obtained on any particular crossplot. The curves of the forces and center of pressure versus angle of attack have been retained in the report in the event that data may become available in the future which will make this information of some value.

Original center of pressure data presented in Reference 1 were plotted to a scale that was difficult to read to the accuracy desired. In order to improve the accuracy of the chordwise center of pressure and spanwise center of pressure readings, copies of the original large scale plots of Figures 39 - 88 of Reference 1 were obtained from the David Taylor Model Basin. It is felt that these large scale plots greatly improved the quality of the spanwise and chordwise center of pressure data presented in this report for the NACA 0015 airfoil section planforms.

NACA 0012 AIRFOIL SECTION

Data for the NACA 0012 airfoil section planforms come from various sources. In most cases the information was obtained from wind tunnel tests of complete wings. These were not tests that were run specifically for control surface studies as was the case in most of the 0015 series tests. Therefore, the data presented are

not as systematic and uniform as the 0015 data. Also, spanwise center of pressure data were not available in the complete wing tests.

Chordwise center of pressure data had to be computed from the lift, drag and pitching moment characteristics presented in the reports from the following equation:

$$(CP)_{\frac{-}{c}} = 0.25 - \frac{C_{m_{\frac{-}{c}}} / 4}{C_L \cos \alpha + C_D \sin \alpha}$$

Reports not containing sufficient information for this computation were rejected since chordwise center of pressure was a vital part of the survey. Several reports containing information on families of low-aspect-ratio wings were rejected because they lacked drag coefficient data or the data was not fully corrected for support strut tare and interference. These reports have been listed in the bibliography for the benefit of those who may be interested.

Generally speaking, the information presented for the NACA 0012 airfoil section planforms was obtained at lower Reynolds numbers than that presented for the 0015 planforms. In fact, most of the 0012 information is from tests conducted at Reynolds numbers lower than the limitations of the survey. Information presented in Reference 1 indicate that Reynolds number has a considerable effect on $C_{L_{max.}}$ for the higher aspect-ratio control surfaces but very little effect on control surfaces where the aspect-ratio is less than 2. Chordwise center of pressure is not effected appreciably by changes in Reynolds number (See Figure 13 of Reference 1). Therefore, the data presented should be reliable up to angles of attack approaching the stall angle.

Characteristics presented in Figures 33, 34, and 41 do not

appear in any crossplots. As was the case for some of the 0015 planforms, these curves have been retained in the report in the event that data may become available in the future which will make this information of some value.

NACA 64A010 AIRFOIL SECTION

Chordwise center of pressure values were computed for the NACA 64A010 airfoil section planforms in the same manner as they were for the NACA 0012 airfoil section planforms. Here again spanwise center of pressure could not be computed since the original tests were for complete wings.

BIBLIOGRAPHY

Reports which are felt to be very closely related to this study, but which for various reasons could not be included in this report, are listed in the Bibliography on pages 12 and 13.

CONCLUSION

This report presents the characteristics of low-aspect-ratio planforms obtained from a search of sub-sonic experimental literature. The literature search was restricted to configurations and information which could be used in the design of control surfaces for maneuvering a vessel. The information obtained from the search is presented as curves showing the variation of lift coefficient, drag coefficient, normal force coefficient, resultant force coefficient, spanwise center of pressure and chordwise center of pressure with angle of attack, aspect ratio, quarter-chord sweep angle and taper ratio.

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SYMBOLS

All data are presented in the form of nondimensional force and moment coefficients. The positive direction of the forces, moments, and angular displacements is shown in Figure 1. The coefficients and symbols are defined as follows:

A	Effective aspect ratio, b^2 / S
b	Span, measured perpendicular to plane of root section (see Figure 1)
c	Chord, measured parallel to plane of root section
$\bar{c}$	Mean geometric chord, $\frac{c_t + c_r}{2}$
C_D	Drag coefficient, $\frac{\text{Drag}}{q S}$
C_l	Root bending-moment coefficient, $\frac{\text{bending moment}}{q S\, b/2}$
C_L	Lift coefficient, $\frac{\text{Lift}}{q S}$
$C_{M_{\bar{c}/4}}$	Pitching moment coefficient about quarter-chord point of mean geometric chord, $\frac{\text{pitching moment}}{q S \bar{c}}$
C_n	Yawing moment coefficient, $\frac{\text{yawing moment}}{q S b/2}$
C_N	Normal force coefficient, $C_L \cos\alpha + C_D \sin\alpha$
C_R	Resultant force coefficient, $\sqrt{C_L^2 + C_D^2}$
$(CP)_{\bar{c}}$	Chordwise center of pressure measured from leading edge at mean geometric chord in percent of the mean geometric chord, $(CP)_c = 0.25 - \frac{C_{m_{\bar{c}/4}}}{C_L \cos\alpha + C_D \sin\alpha}$

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$(CP)_s$ Spanwise center of pressure measured from plane of root section in percent of semispan,

$$(CP)_s = \frac{C_l \cos\alpha - C_n \sin\alpha}{C_L \cos\alpha + C_D \sin\alpha}$$

q Dynamic pressure, $1/2\rho V^2$

R Reynolds number, $\frac{\rho V \bar{c}}{\mu}$

S Planform area

Subscripts r root

t tip

V Free-stream velocity

α Angle of attack

λ Taper ratio, C_t / C_r

μ Viscosity, lb. sec/ft^2

ρ Mass density, lb sec^2/ft^4 (approx. 2.0 for sea water)

Λ Angle of sweep of quarter chord line

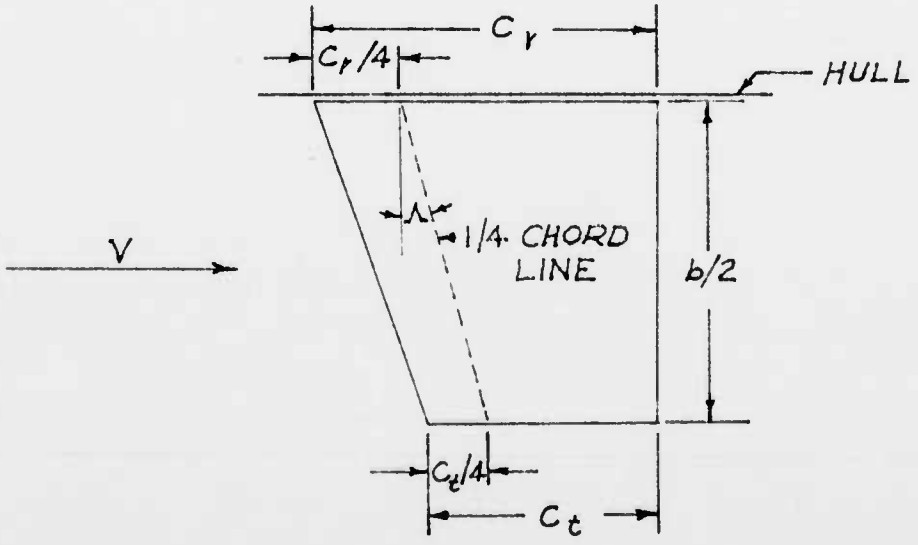


Table I

Summary of Planforms

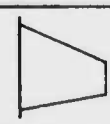
NACA 0015 Airfoil Section Planforms						
Type Test	A	Λ Deg.	λ	R	Tip Shape	References
	1	-8	0.45	2.25×10^6	Square and Faired	1
	2	-8	0.45	2.72×10^6	Square and Faired	1
	3	-8	0.45	2.26×10^6	Square and Faired	1
	1	0	0.45	2.70×10^6	Square and Faired	1
	2	0	0.45	2.72×10^6	Square and Faired	1
	3	0	0.45	2.70×10^6	Square and Faired	1
	1	11	0.45	2.28×10^6	Square and Faired	1
	2	11	0.45	2.72×10^6	Square and Faired	1
	3	11	0.45	2.26×10^6	Square and Faired	1

Table I (cont.)

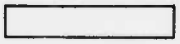
Type Test	A	Λ Deg.	λ	R	Tip Shape	References
	2	11	0.80	3.0×10^6	Square and Faired	3
	2	11	0.60	3.0×10^6	Square and Faired	3
	2	11	0.20	3.0×10^6	Square and Faired	3
	2	22.5	0.45	3.0×10^6	Square	3
	3	0	1.0	0.6×10^6	Square	5 and 6
	6	0	1.0	0.6×10^6	Square	5 and 6
	4.5	30	1.0	0.7×10^6	Square	5 and 6
	5.2	30	1.0	0.7×10^6	Square	5 and 6
	1.5	60	1.0	1.2×10^6	Square	5 and 6
	3.0	60	1.0	1.2×10^6	Square	5 and 6

Table I (cont.)

NACA 0012 Airfoil Section Planforms						
Type Test	A	Λ Deg.	λ	R	Tip Shape	References
	1.49	60	1.0	1.2×10^6	Square	6
	2.62	60	1.0	1.1×10^6	Square	6 and 7
	3.14	60	1.0	1.2×10^6	Square	6
	1.33	66.0	0	1.5×10^6		8
	1.33	60.2	0.125	1.5×10^6	Square	9
	1.33	53.5	0.25	1.5×10^6	Square	9
	1.33	36.9	0.50	1.5×10^6	Square	9
	1.00	71.6	0	1.5×10^6		8
	2.00	56.3	0	1.5×10^6		8

Table I (cont.)

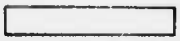
Type Test	A	Λ Deg.	λ	R	Tip Shape	References
	3.00	0	1.0	0.6×10^6	Square	6
	6.00	0	1.0	0.6×10^6	Square	6
	3.00	6.34	0.5	0.7×10^6	Square	10
	1.34	0	1.0	1.58×10^6	Faired	7
	2.61	0	1.0	1.1×10^6	Faired	7
	4.57	0	1.0	2.0×10^6	Faired	12
	5.16	0	1.0	0.99×10^6	Faired	7 and 11
	1.34	45	1.0	1.56×10^6	Faired	7
	2.61	45	1.0	1.4×10^6	Faired	11
	2.61	45	1.0	1.1×10^6	Faired	7 and 13

Table I (cont.)

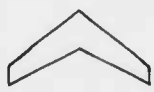
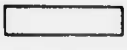
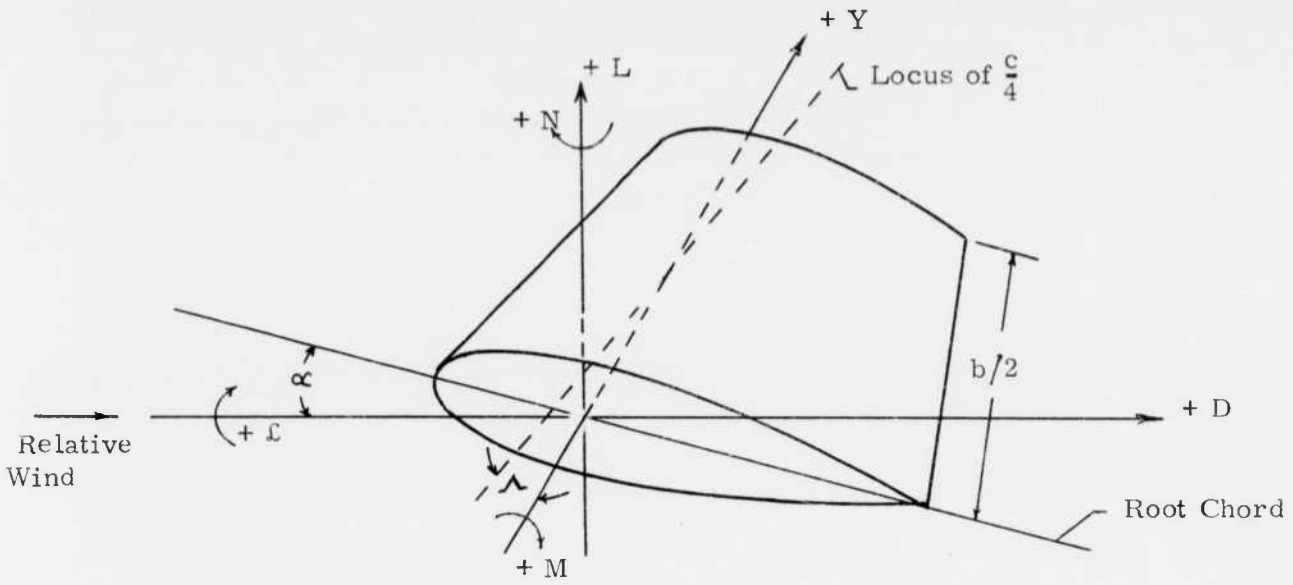
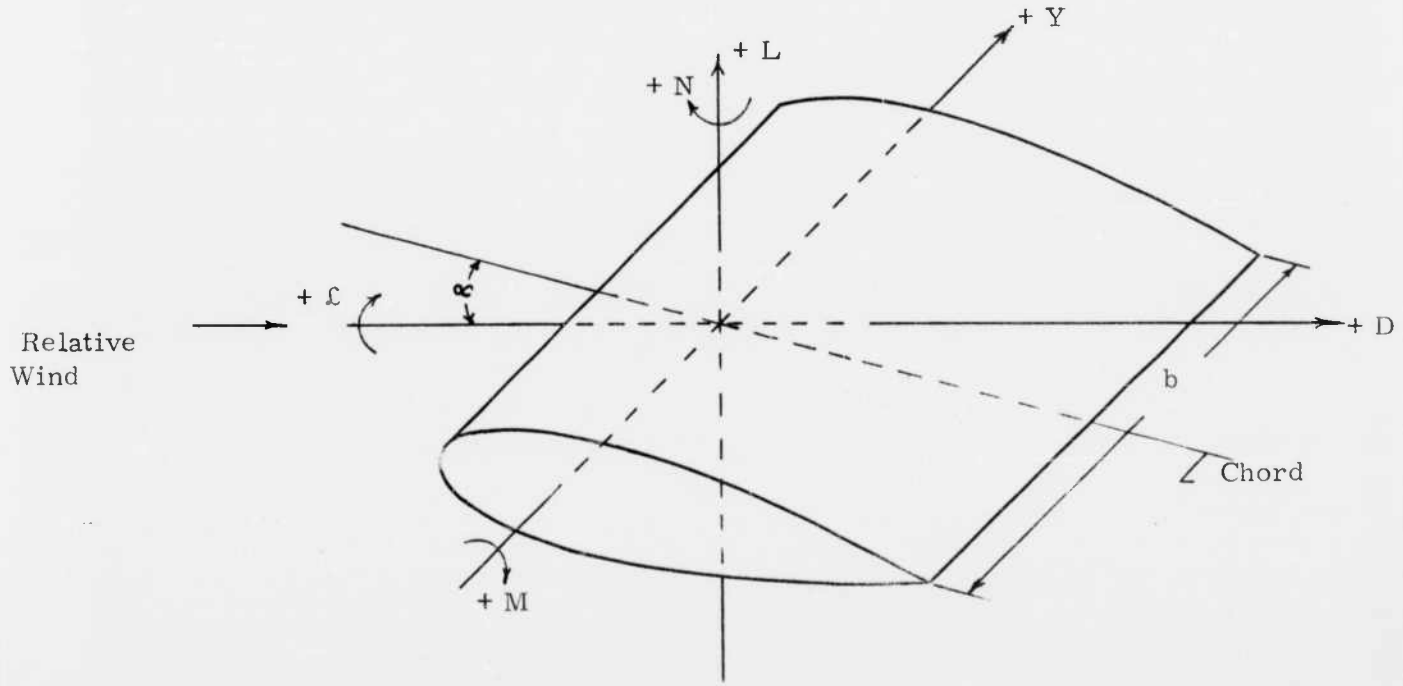
Type Test	A	Λ Deg.	λ	R	Tip Shape	References
	5.16	45	1.0	0.77×10^6	Faired	7 and 11
	2.61	45	0.5	1.2×10^6	Faired	13
	2.61	45	0.25	1.2×10^6	Faired	13
	3.00	45	0	1.5×10^6		8
	1.34	60	1.0	1.98×10^6	Faired	7 and 11
	2.61	60	1.0	1.1×10^6	Faired	6 and 7
	5.16	60	1.0	$.76 \times 10^6$	Faired	7
	5	0	0.5	1.0×10^6	Faired	14
	5	35	0.5	1.0×10^6	Faired	14

Table I (cont.)

NACA 64 A 010 Airfoil Section Planforms						
Type Test	A	Λ Deg.	λ	R	Tip Shape	References
	1.13	0	1.0	4.4×10^6	Faired	15
	2.13	0	1.0	3.1×10^6	Faired	15
	4.13	0	1.0	2.2×10^6	Faired	15

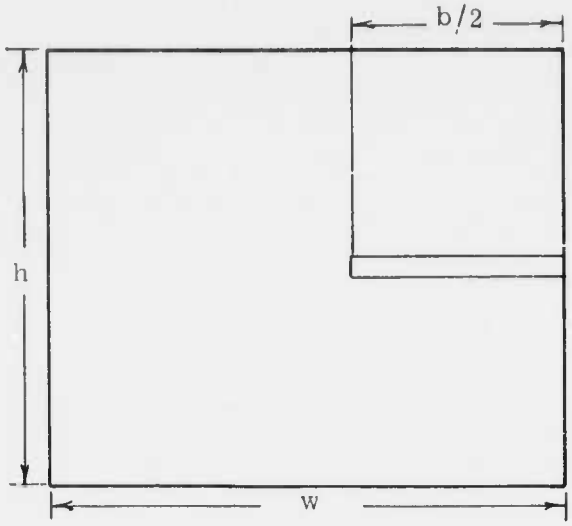


a. Control Surface or Half Model Arrangement

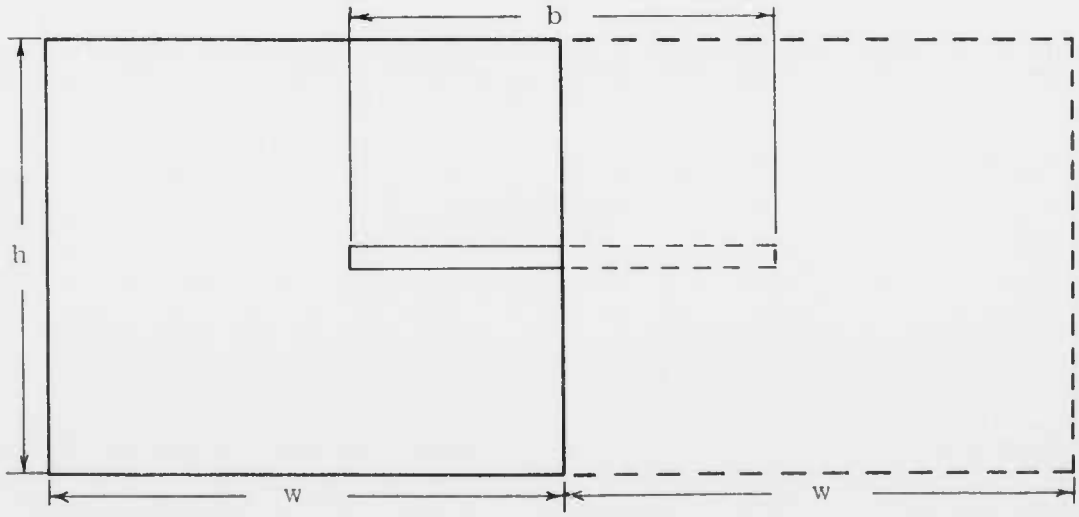


b. Complete Wing

Fig. 1. Coordinate Systems Showing Positive Direction of Forces, Moments and Angle of Attack



a. Panel or Half Model In Tunnel of Width w.



b. Complete Wing in Tunnel of Width 2 w.

Figure 2. Comparison of Half Model and Complete Model Test Arrangements.

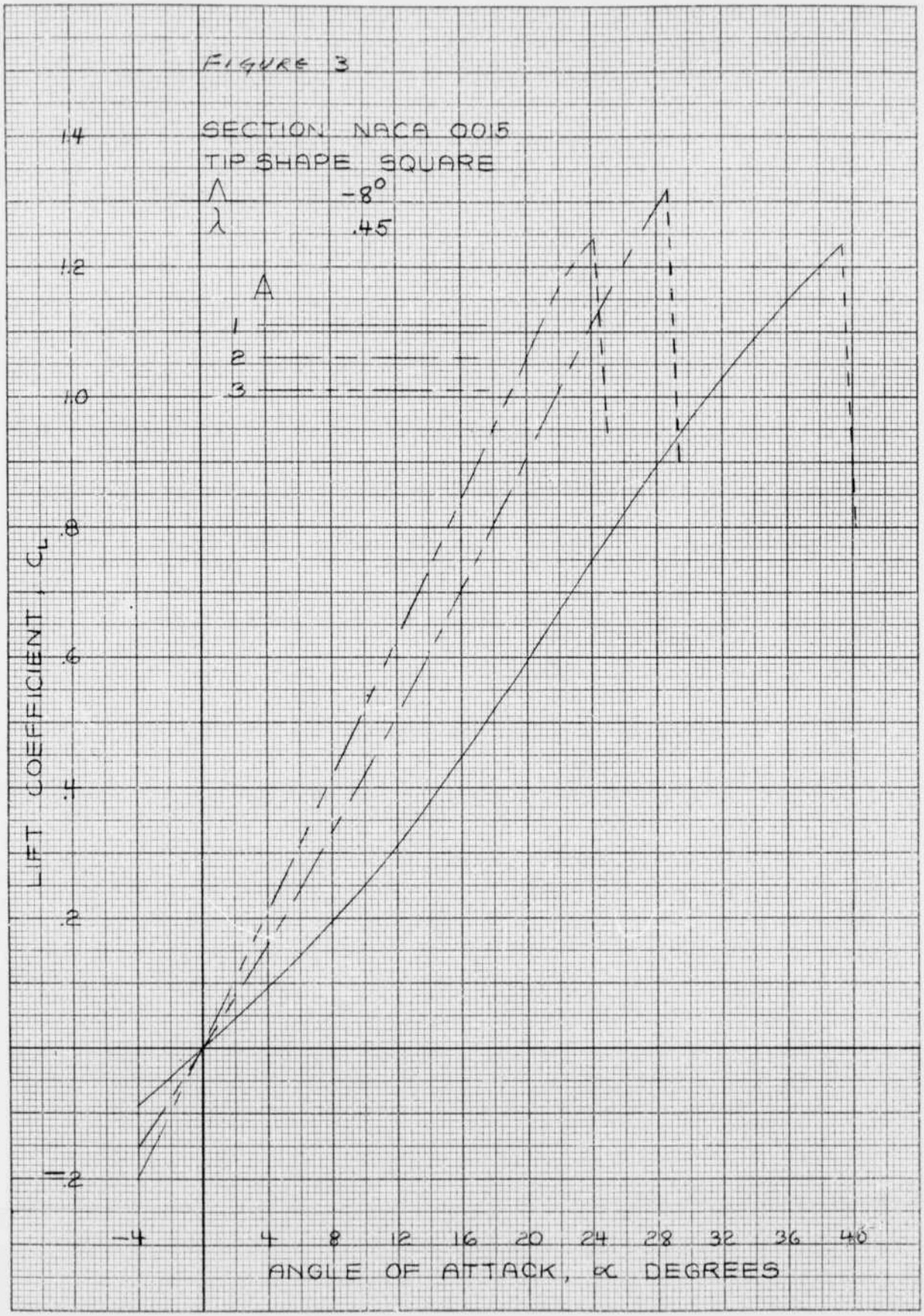


FIGURE 3
SECTION NACA 0015
TIP SHAPE SQUARE
Λ -8°
λ .45
A
1
2
3
1.4
1.2
1.0
.8
.6
.4
.2
-.2
LIFT COEFFICIENT, C_L
-4
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α DEGREES

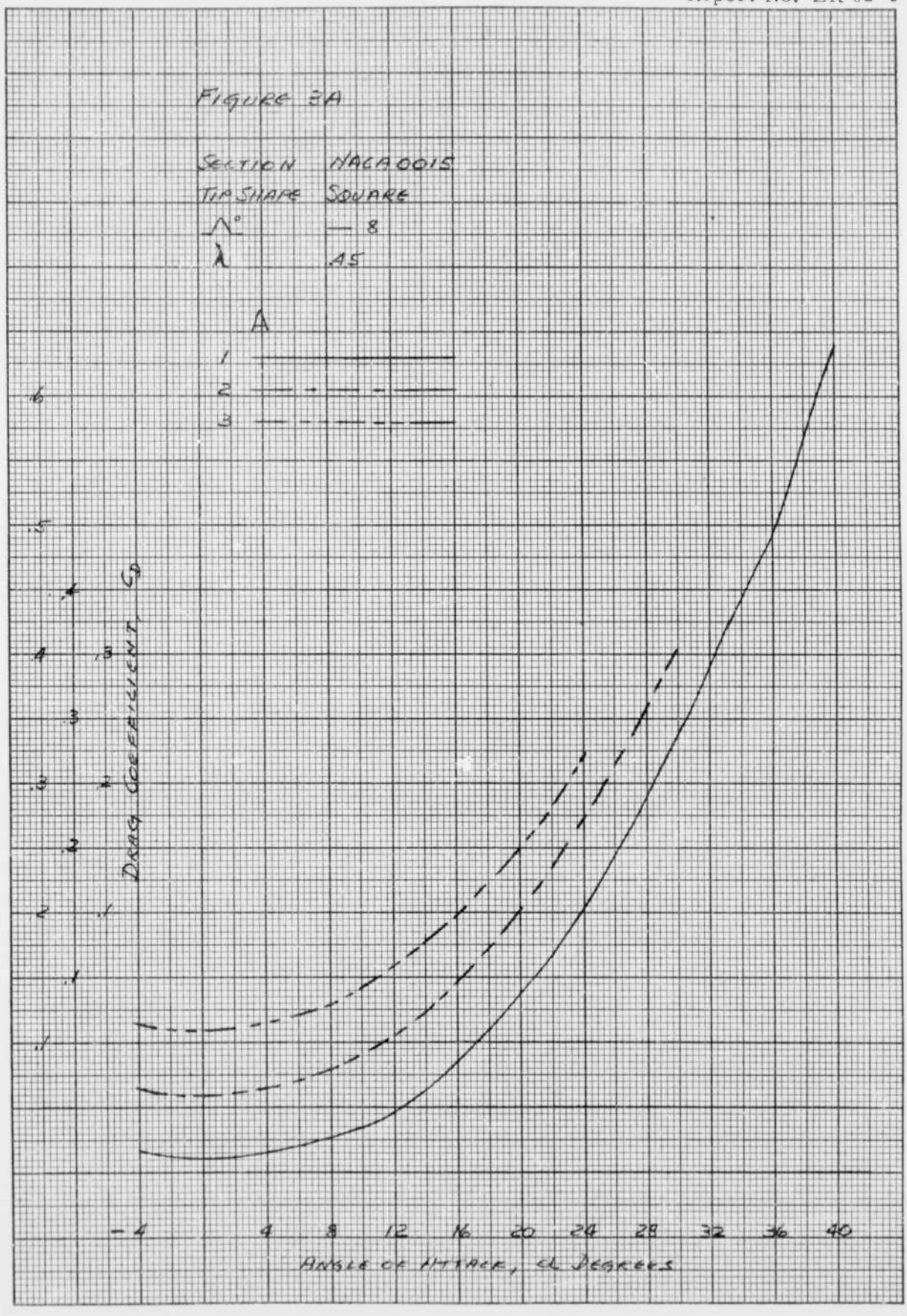


FIGURE 3A
SECTION NACA0015
TIP SHAPE SQUARE
Λ° — 8
λ .45
A
1
2
3
DRAG COEFFICIENT, C_D
.6
.5
.4
.3
.2
.1
.1
.4
.3
.2
.1
-4
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α, DEGREES

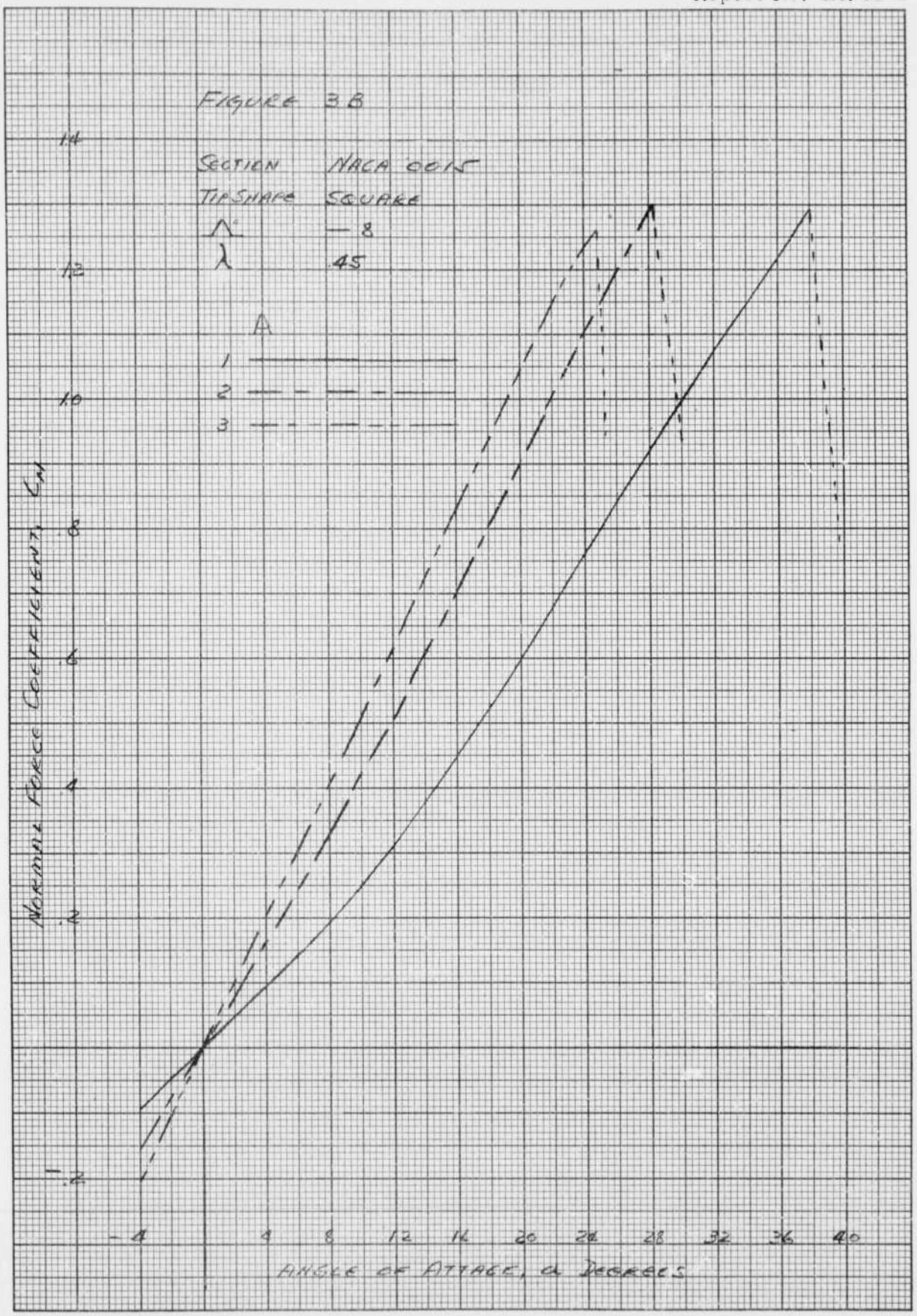


FIGURE 38
SECTION NACA 0015
TIP SHAPE SQUARE
Λ — 8
λ 45
A
1
2
3
1.4
1.2
1.0
.8
.6
.4
.2
-.2
NORMAL FORCE COEFFICIENT, C_N
-4
0
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α DEGREES

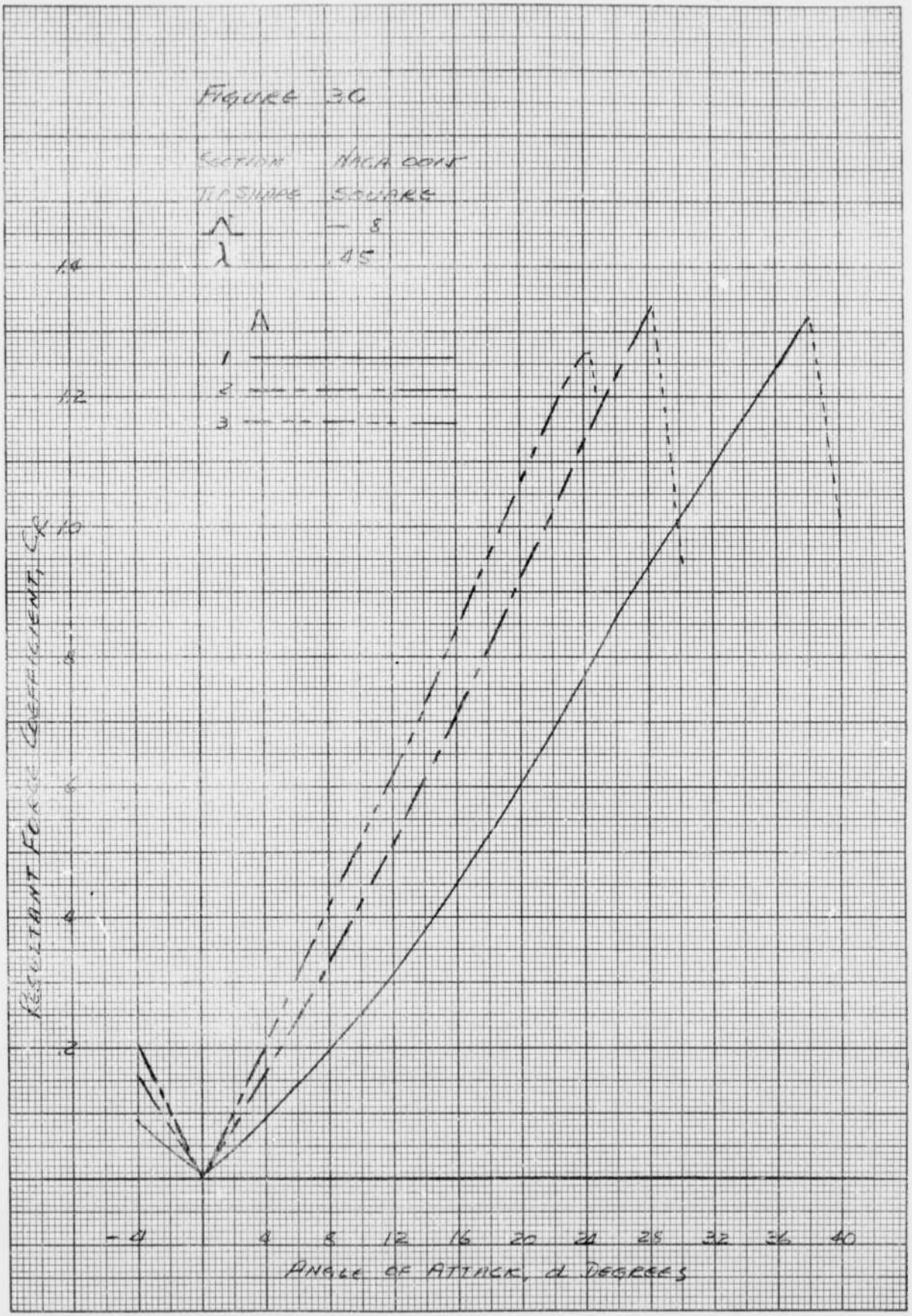


FIGURE 30
SECTION NACA 0006
TIP SHAPE SQUARE
Λ — 8
λ 1.5
A
1
2
3
1.4
1.2
1.0
.8
.6
.4
.2
RESULTANT FORCE COEFFICIENT, C_R
-4
0
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α DEGREES

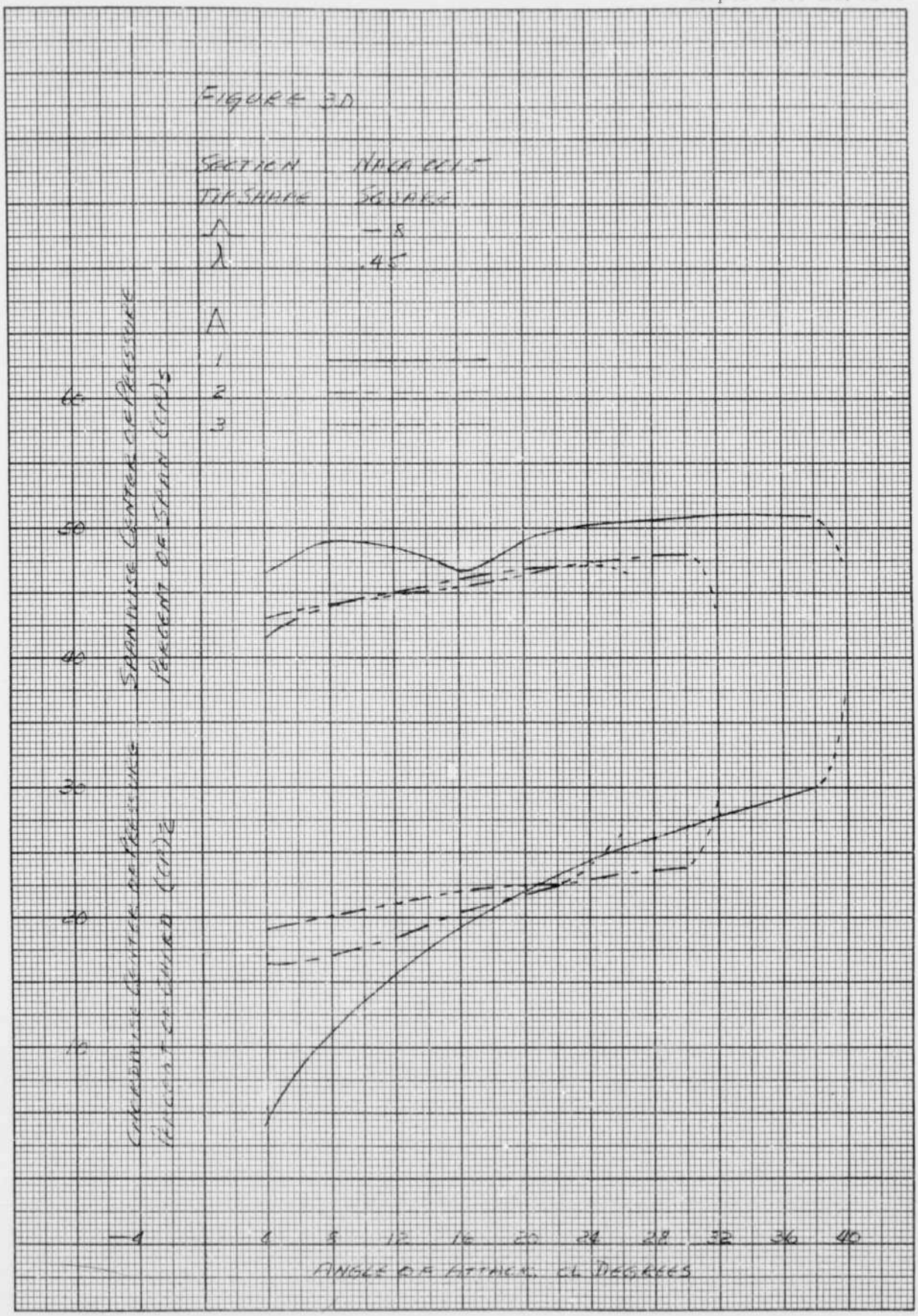


FIGURE 3D
SECTION
TAP SHAPE
MACH NO.
56 JAN.
-5
.45
A
1
2
3
60
50
40
30
20
10
-4
0
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α, DEGREES

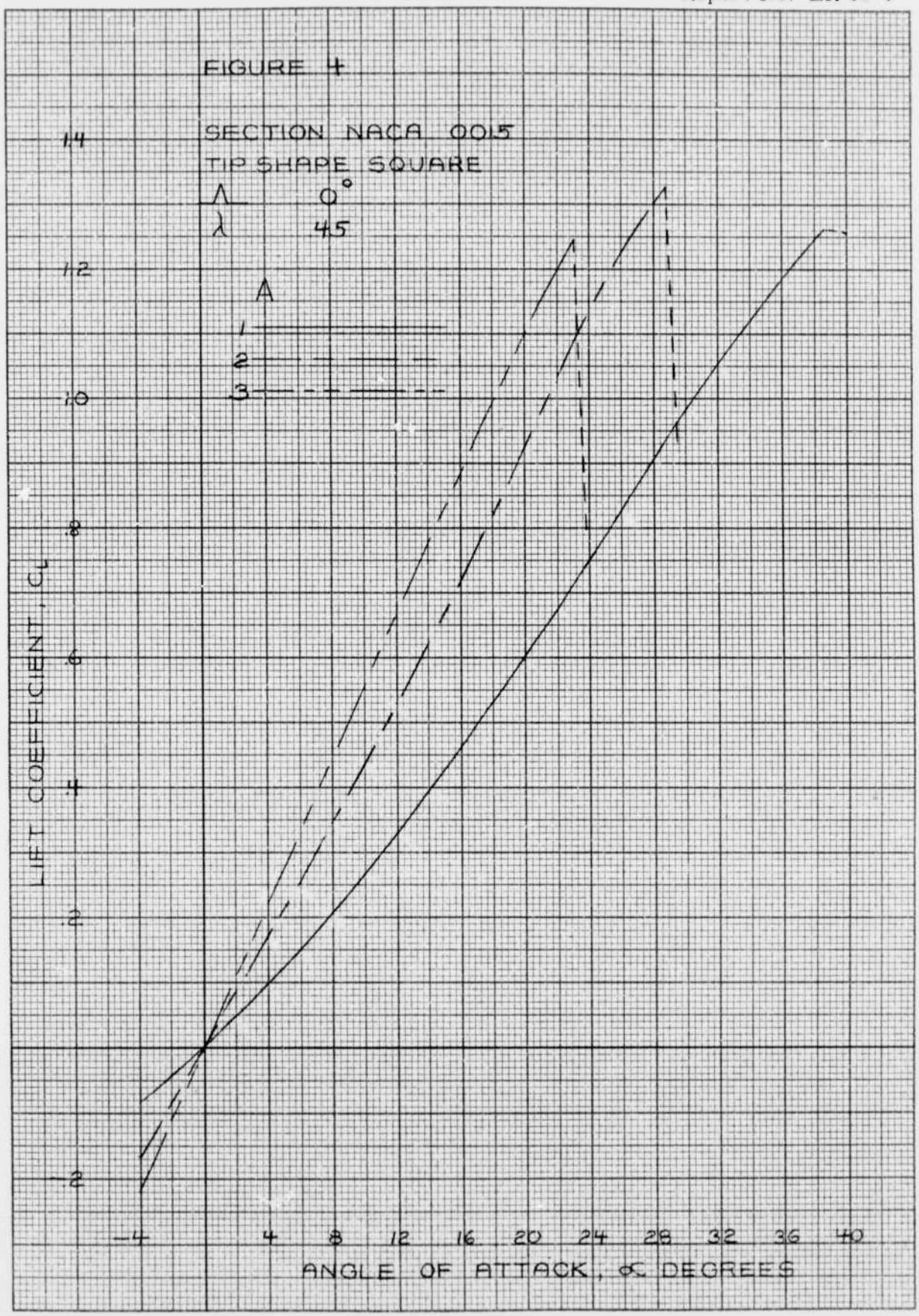


FIGURE 4
SECTION NACA 0015
TIP SHAPE SQUARE
Λ 0°
λ 45
A
1
2
3
1.4
1.2
1.0
.8
.6
.4
.2
-.2
LIFT COEFFICIENT, C_L
-4
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α, DEGREES

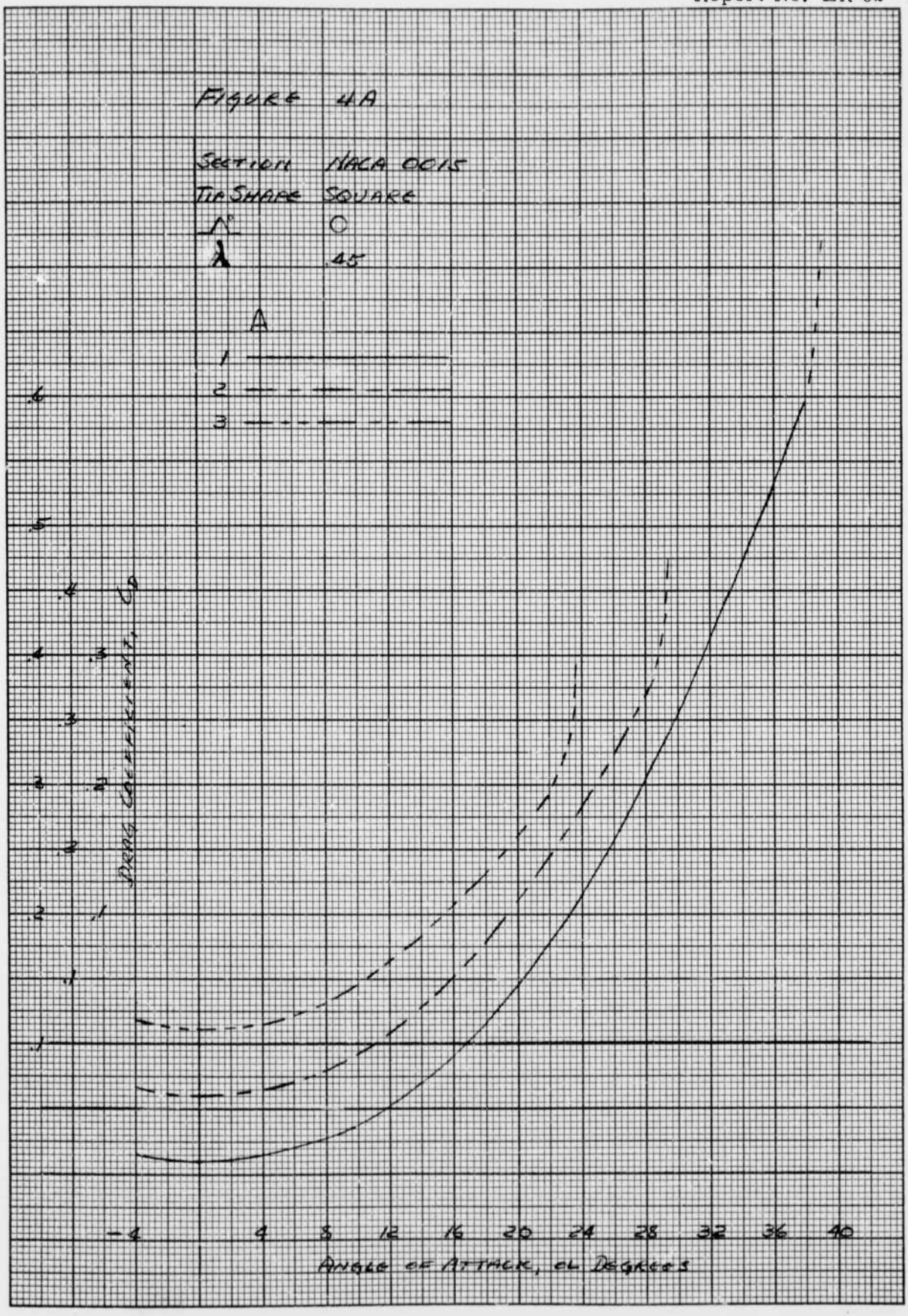


FIGURE 4A
SECTION NACA 0015
TIP SHAPE SQUARE
Λ° 0
λ 45
A
1
2
3
.6
.5
.4
.3
.2
.1
.4
.3
.2
.1
DRAG COEFFICIENT, C_D
-4
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α, DEGREES

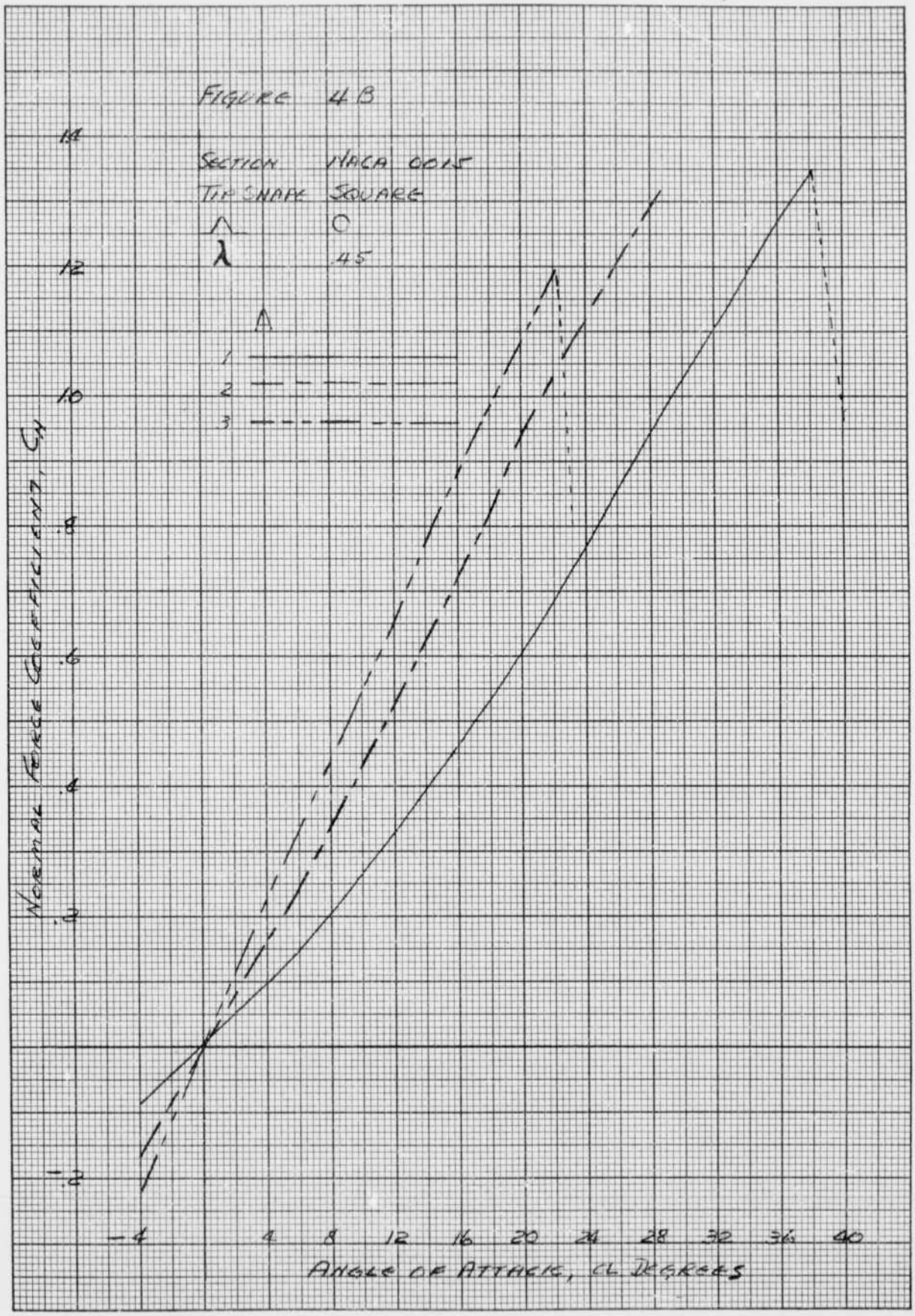


FIGURE 4B
SECTION NACA 0015
TIP SHAPE SQUARE
Λ C
λ .45
A
1
2
3
1.4
1.2
1.0
.8
.6
.4
.2
-.2
NORMAL FORCE COEFFICIENT, C_N
-4
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α, DEGREES

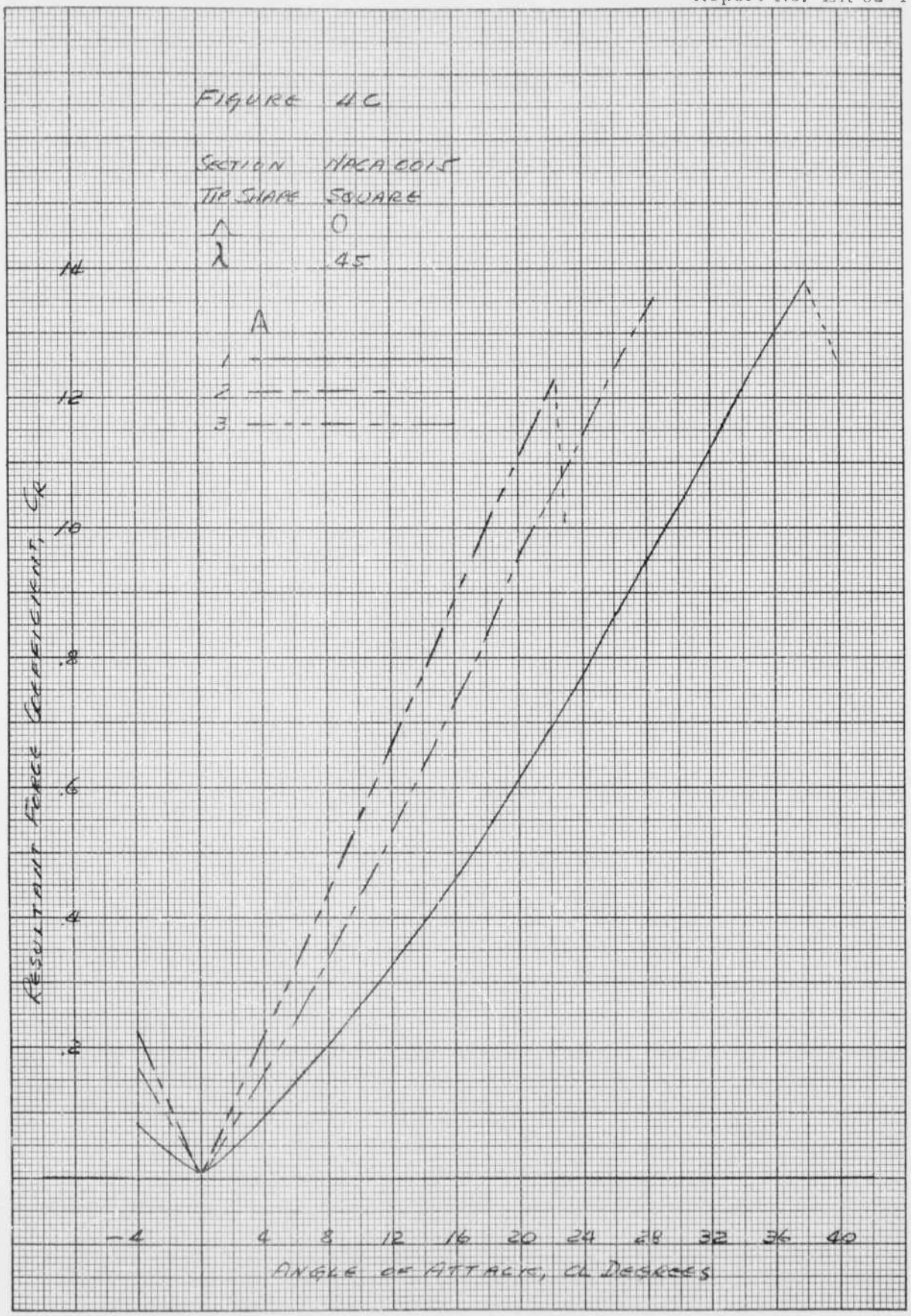


FIGURE 4C
SECTION NACA 0015
TIP SHAPE SQUARE
Λ 0
λ 45
A
1
2
3
16
12
10
.8
.6
.4
.2
RESULTANT FORCE COEFFICIENT, CR
-4
0
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α, DEGREES

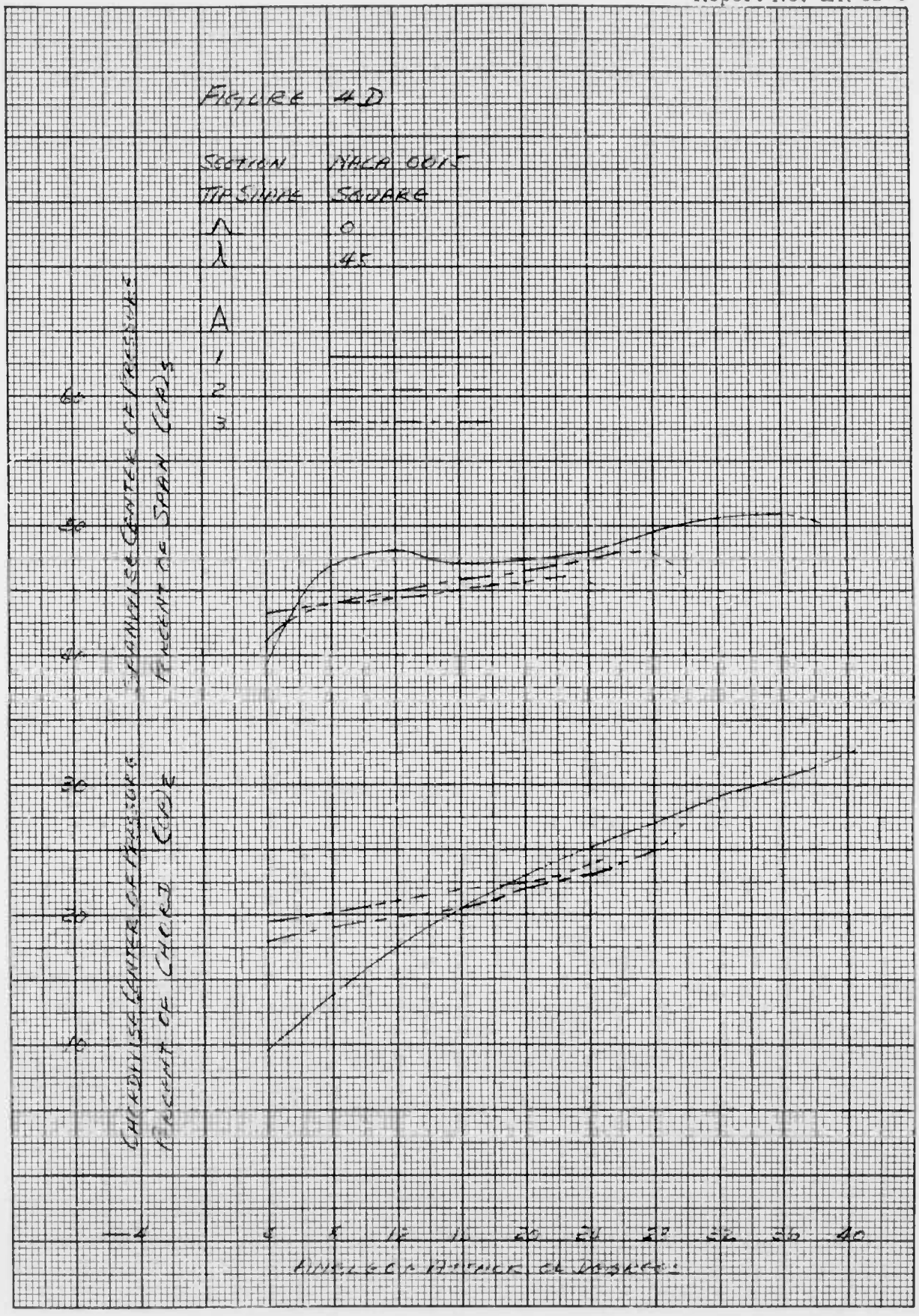


FIGURE 4D
SECTION NACA 0015
TIP SHAPE SQUARE
Λ 0
λ 45
A
1
2
3
INCREMENTAL CHANGE IN SECTION LIFT COEFFICIENT
PERCENT OF CHORD (c/4)
INCREMENTAL CHANGE IN SECTION DRAG COEFFICIENT
PERCENT OF CHORD (c/4)
ANGLE OF ATTACK OF WING

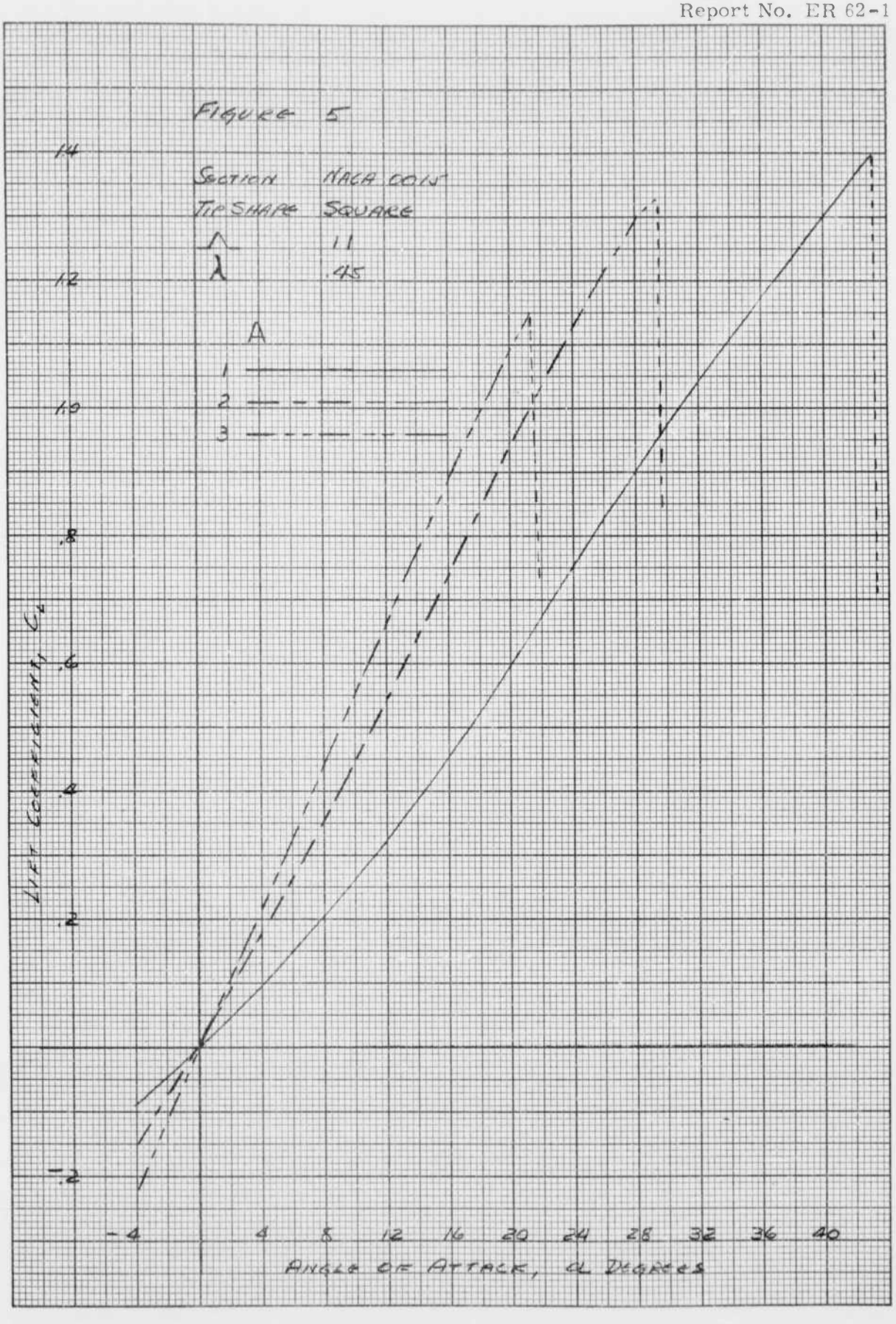


FIGURE 5
SECTION
TIP SHAPE
Λ
λ
MACH CONS
SQUARE
1.1
.45
A
1
2
3
1.4
1.2
1.0
.8
.6
.4
.2
-.2
LIFT COEFFICIENT, C_L
-4
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α DEGREES

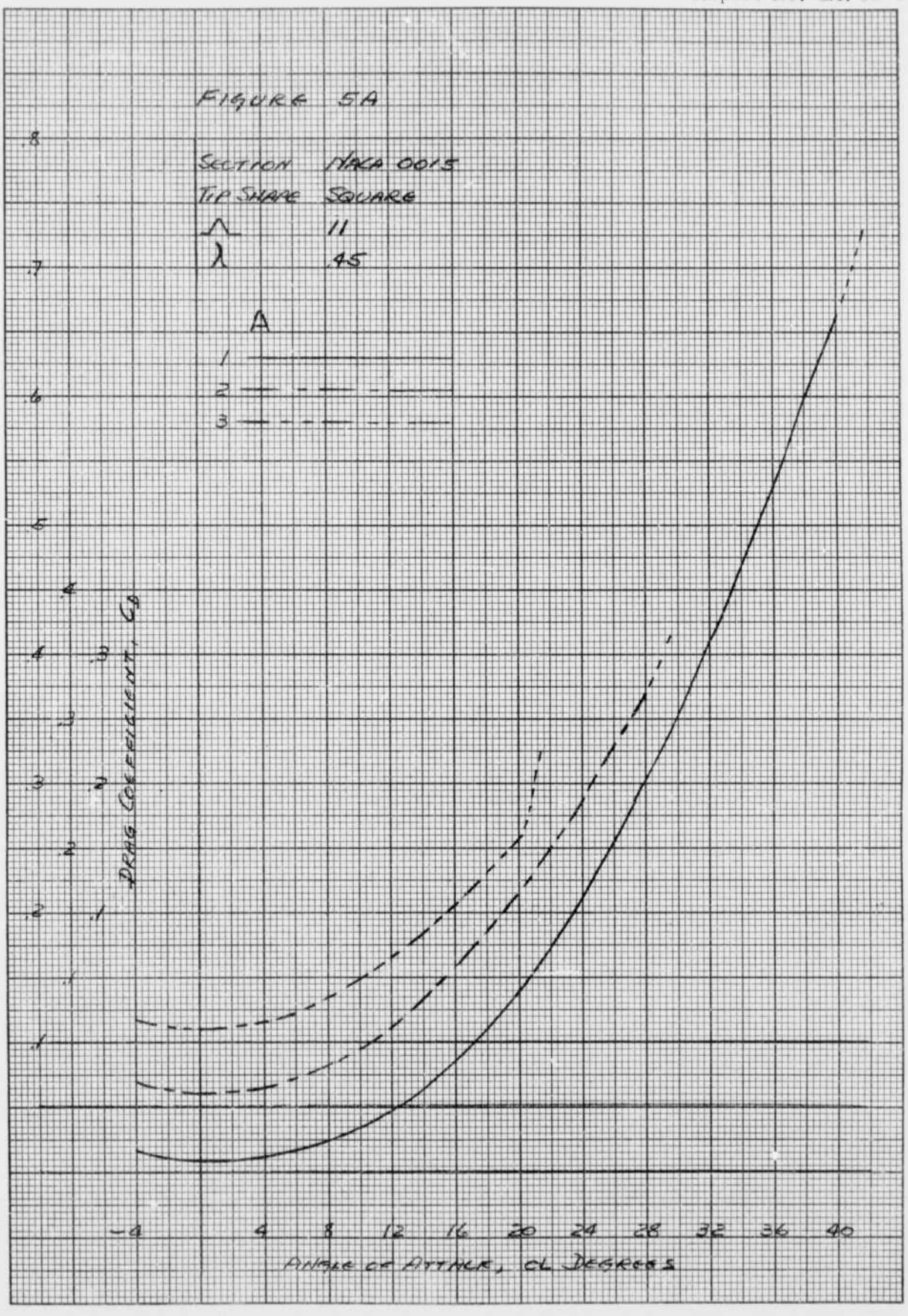


FIGURE 5A
SECTION NACA 0015
TIP SHAPE SQUARE
Λ 11
λ .45
A
1
2
3
.8
.7
.6
.5
.4
.3
.2
.1
DRAG COEFFICIENT, C_D
-4
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α, DEGREES

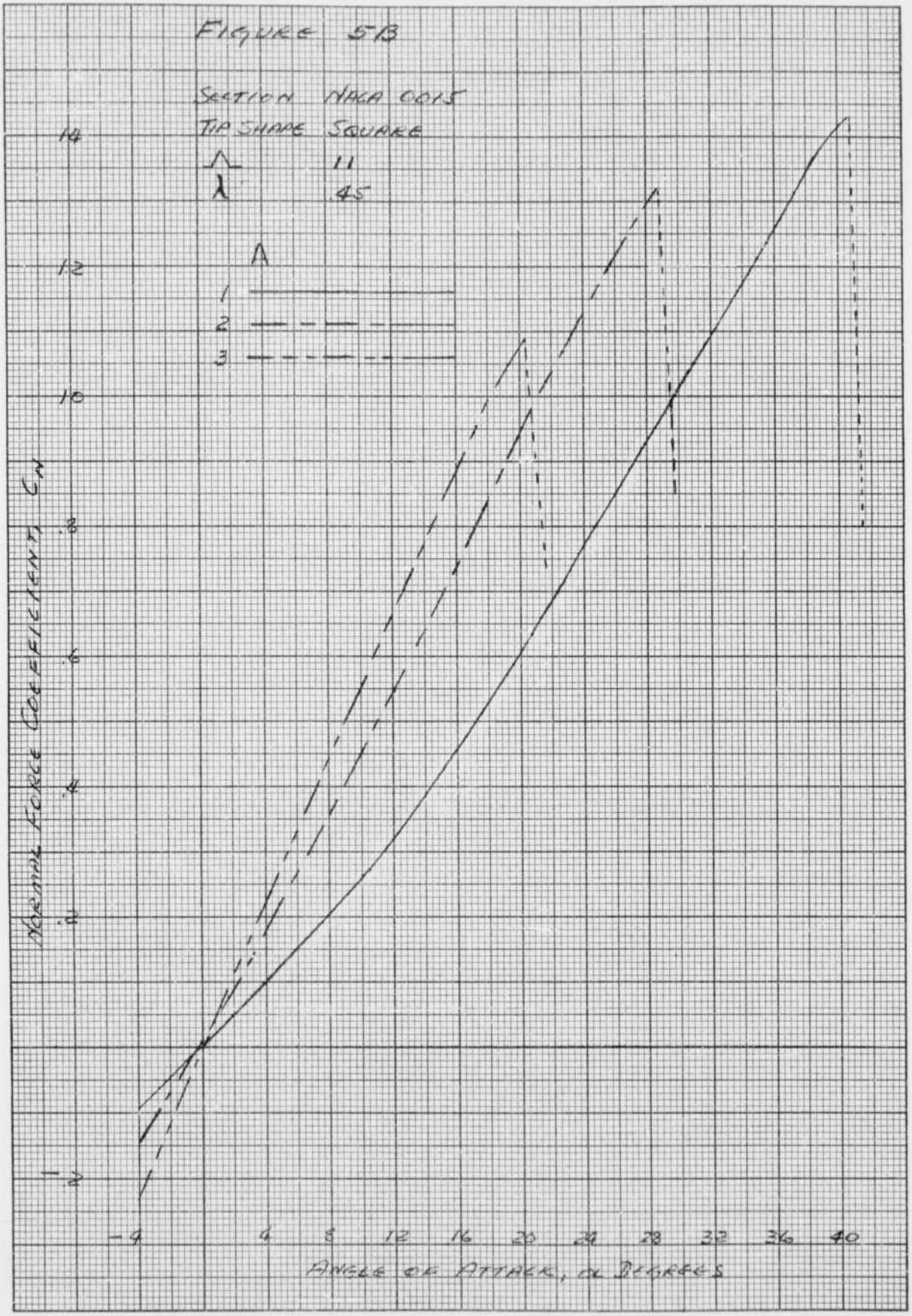


FIGURE 5B
SECTION MACH CONE
TIP SHAPE SQUARE
Λ 11
λ 45
A
1
2
3
NORMAL FORCE COEFFICIENT, CN
14
12
10
8
6
4
2
-4
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α, DEGREES

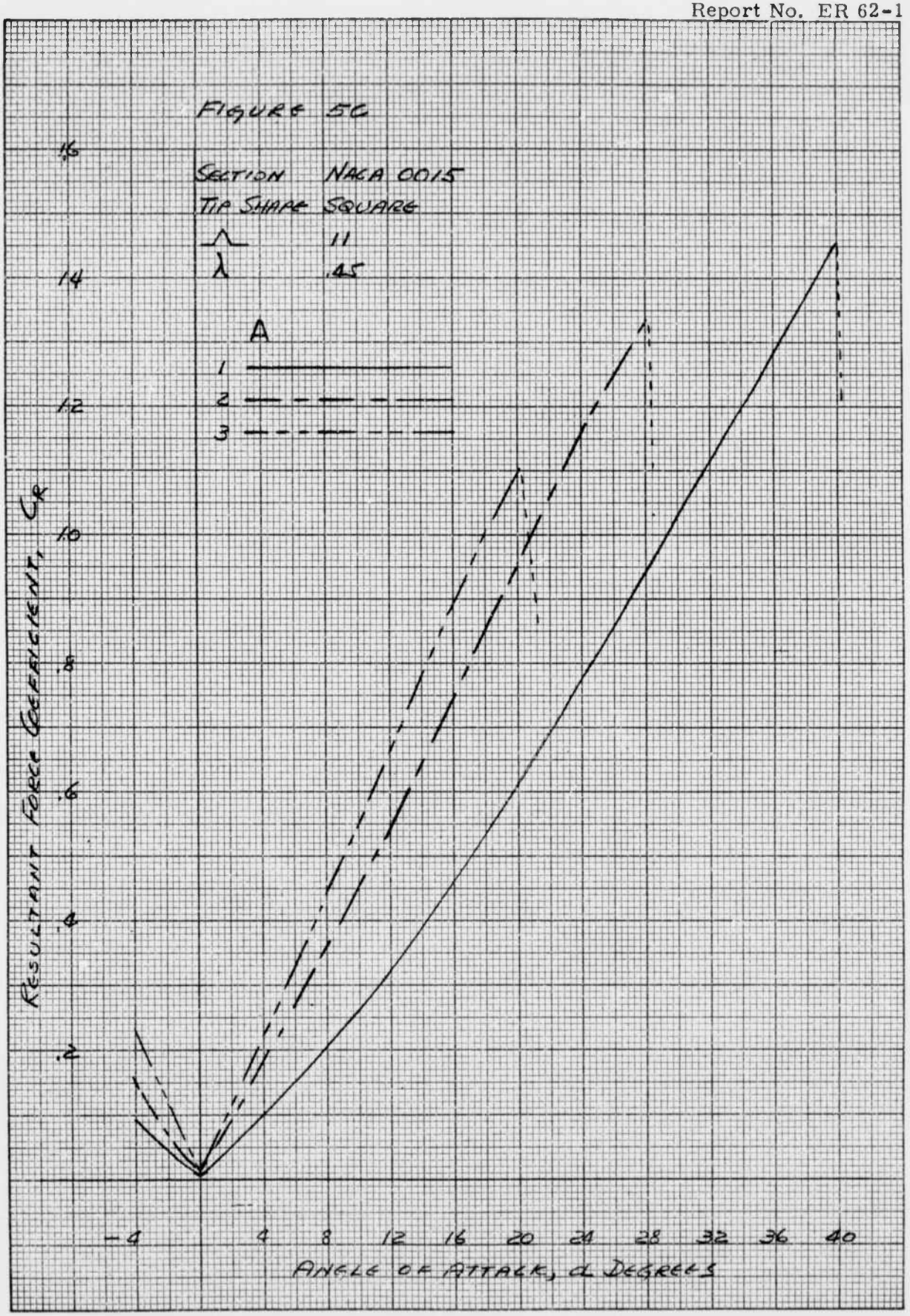


FIGURE 5C
SECTION NACA 0015
TIP SHAPE SQUARE
Λ 11
λ .45
A
1
2
3
RESULTANT FORCE COEFFICIENT, C_R
1.6
1.4
1.2
1.0
.8
.6
.4
.2
-4
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α DEGREES

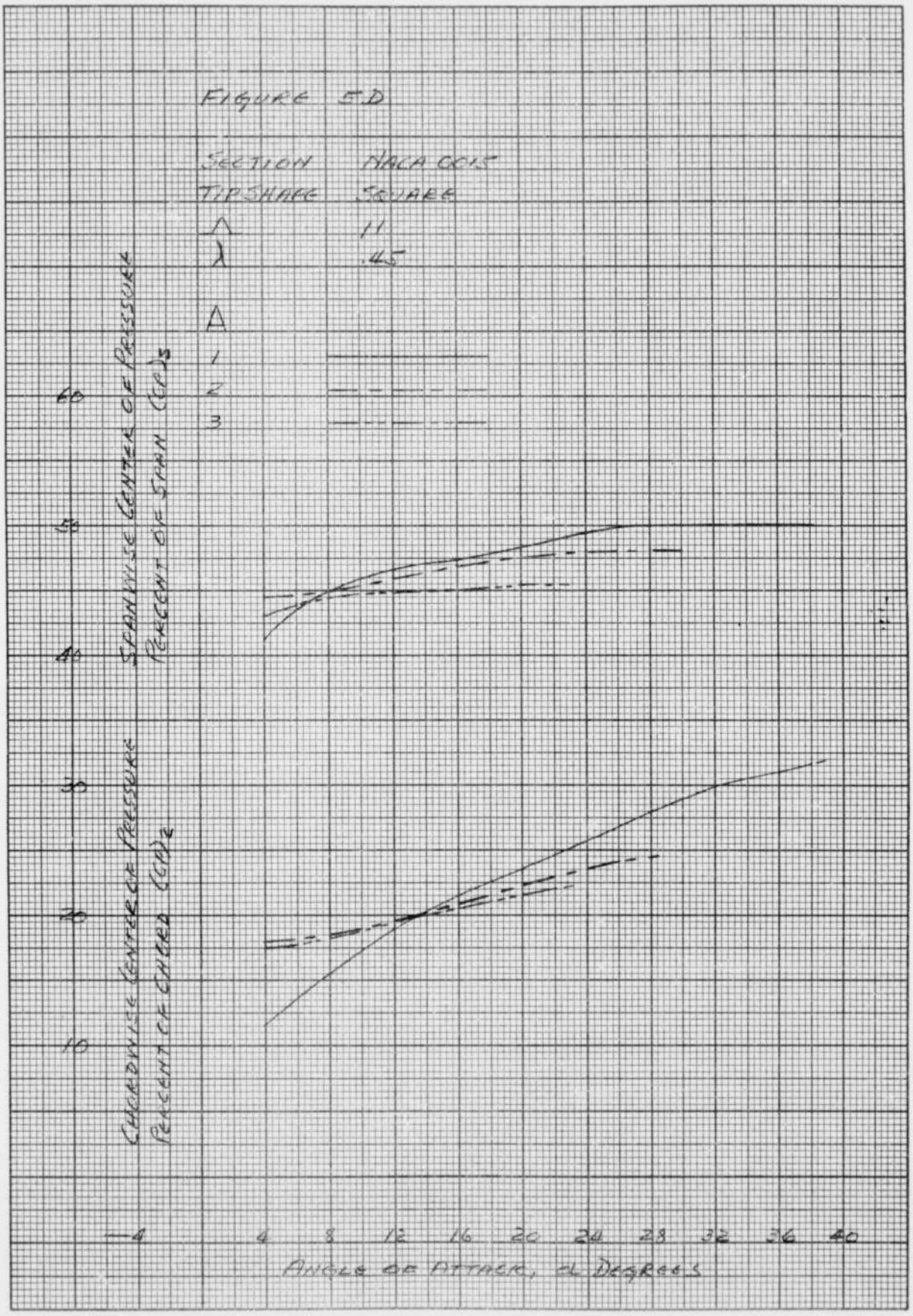


FIGURE 5.D
SECTION TIP SHAPE
NACA 66,5 SQUARE
Δ 11
λ .45
Δ
1
2
3
CHORDWISE CENTER OF PRESSURE PERCENT OF CHORD (cp)x
SPANWISE CENTER OF PRESSURE PERCENT OF SPAN (cp)s
60
50
40
30
20
10
-4
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α, DEGREES

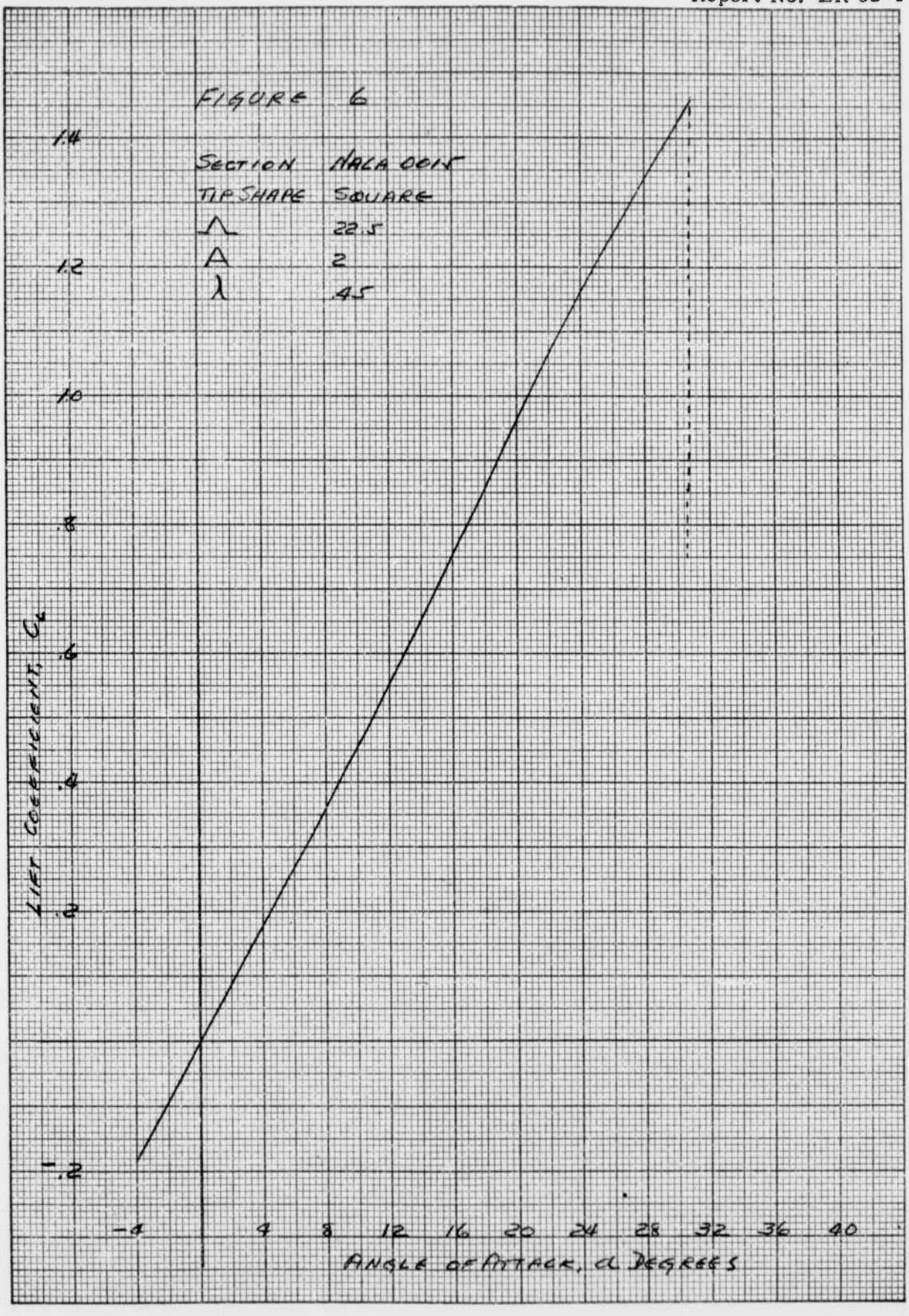


FIGURE 6
SECTION NACA 0015
TIP SHAPE SQUARE
Λ 22.5
A 2
λ .45
1.4
1.2
1.0
.8
.6
.4
.2
-.2
LIFT COEFFICIENT, C_L
-4
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α, DEGREES

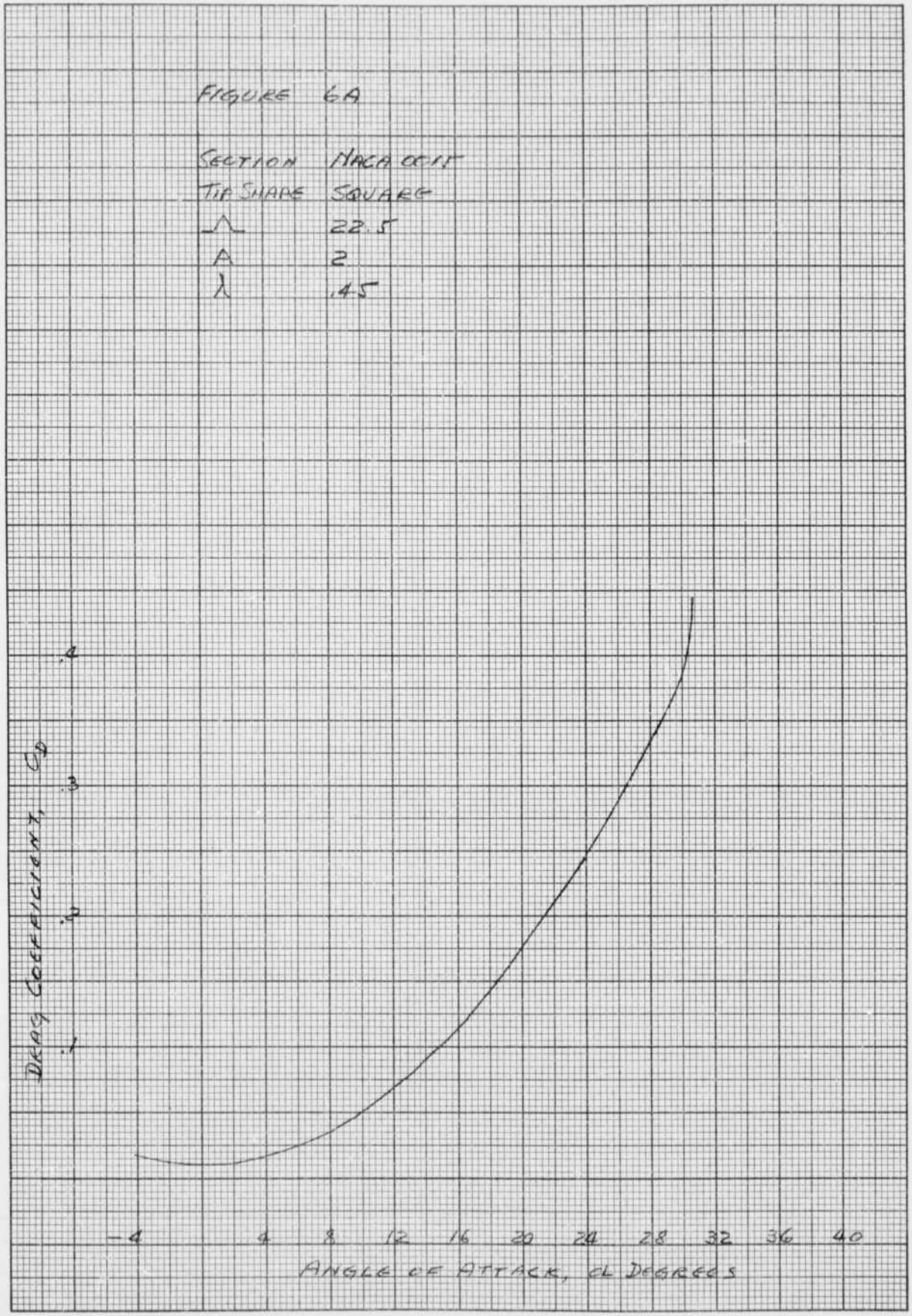


FIGURE 6A
SECTION NACA 0011
TIP SHAPE SQUARE
Λ 22.5
A 2
λ .45
DRAG COEFFICIENT, C_D
.4
.3
.2
.1
-4
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α DEGREES

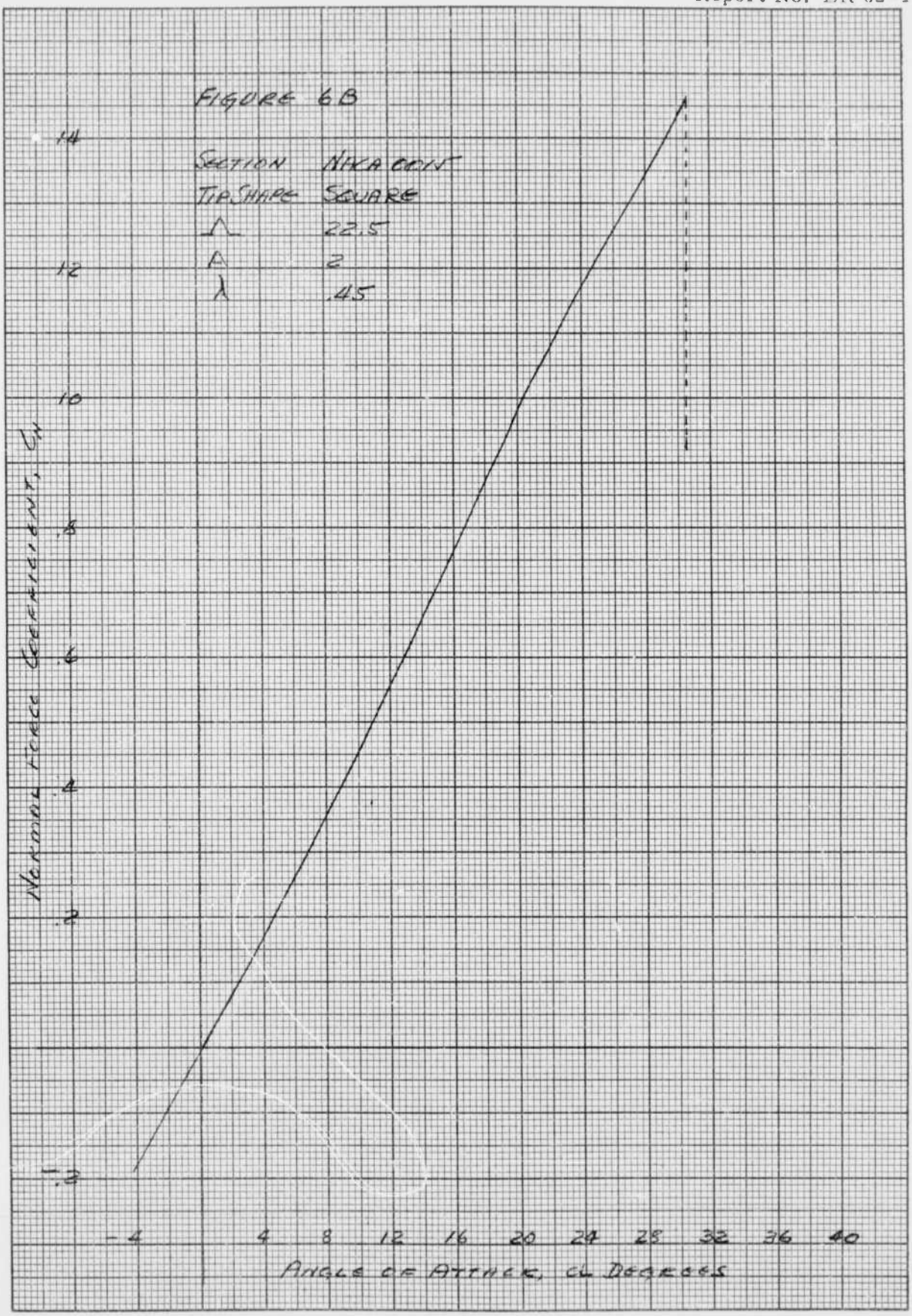


FIGURE 6B
SECTION NACA 0014
TIP SHAPE SQUARE
Λ 22.5
A 2
λ .45
NORMAL FORCE COEFFICIENT, C_N
1.4
1.2
1.0
.8
.6
.4
.2
-.2
-4
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α DEGREES

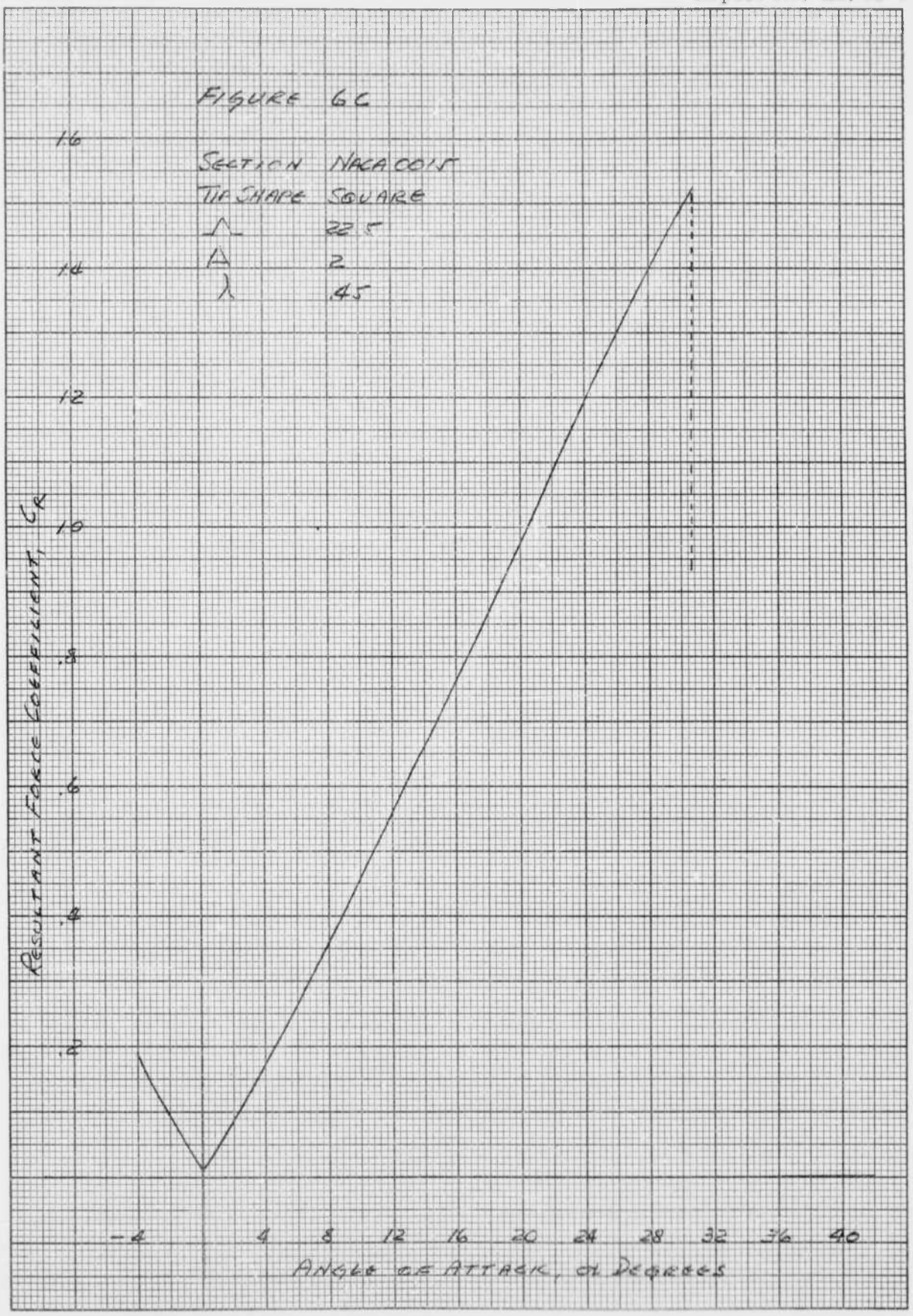


FIGURE 6C
SECTION NACA 0015
TIP SHAPE SQUARE
Λ 22.5
A 2
λ .45
1.6
1.4
1.2
1.0
.8
.6
.4
.2
RESULTANT FORCE COEFFICIENT, CR
-4
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α, DEGREES

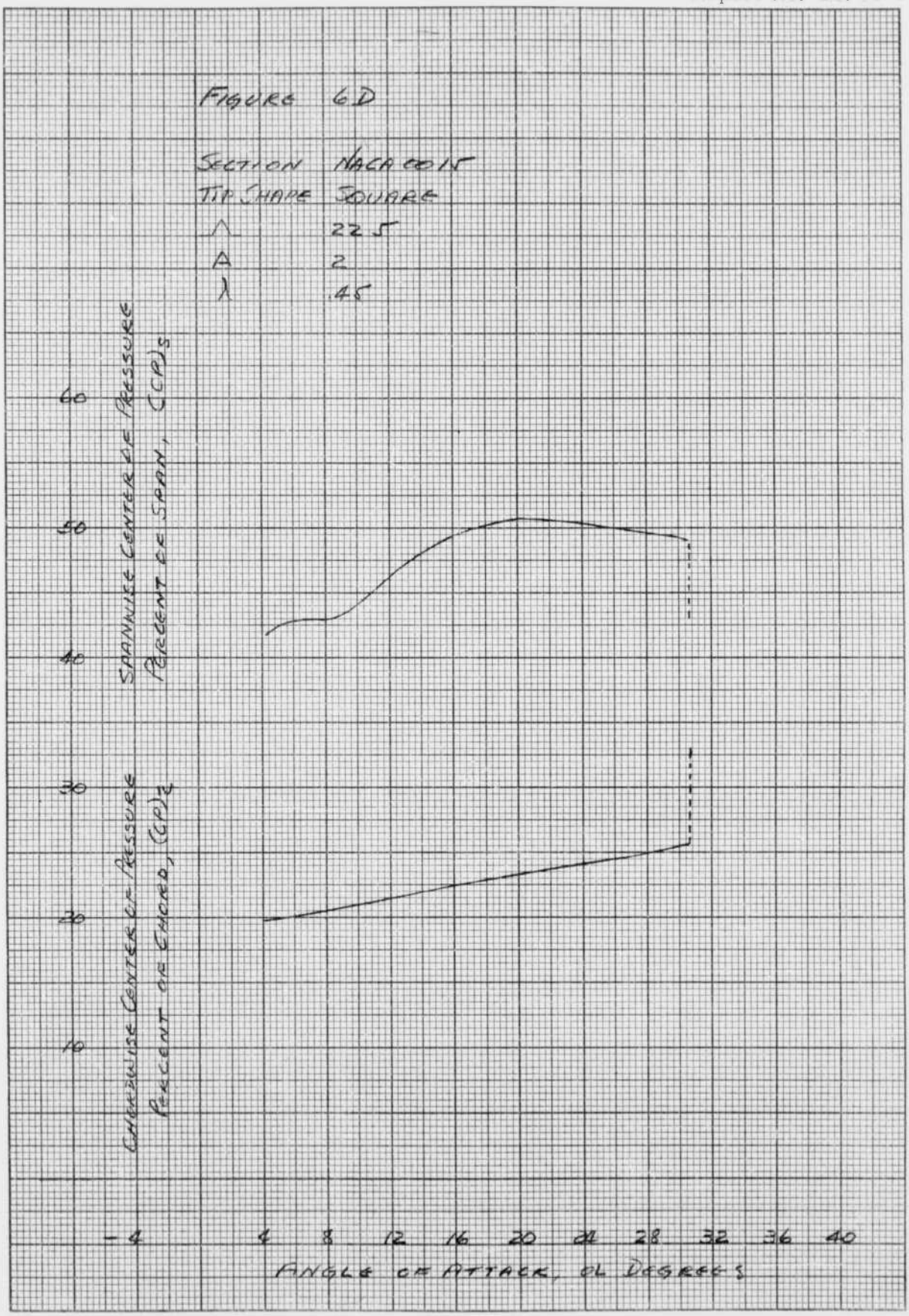


FIGURE 6D
SECTION NACA 0015
TIP SHAPE SQUARE
Λ 22.5
A 2
λ .45
SPANWISE CENTER OF PRESSURE
PERCENT OF SEMI-SPAN, (CP)S
CHORDWISE CENTER OF PRESSURE
PERCENT OF CHORD, (CP)C
60
50
40
30
20
10
-4
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α, DEGREES

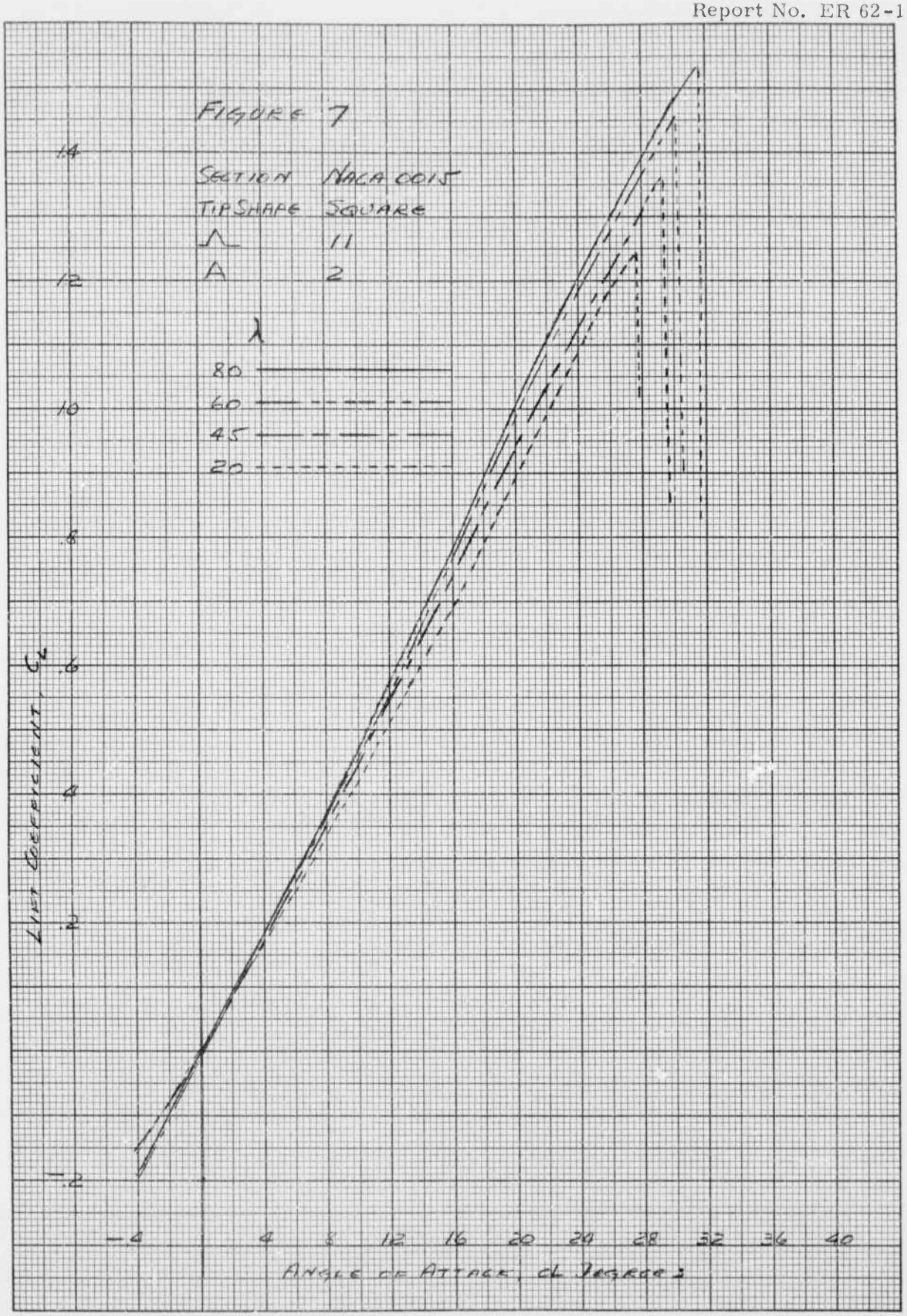


FIGURE 7
SECTION NACA 0015
TIP SHAPE SQUARE
Λ 11
A 2
λ
80
60
45
20
LIFT COEFFICIENT, C_L
1.4
1.2
1.0
.8
.6
.4
.2
-4
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α DEGREES

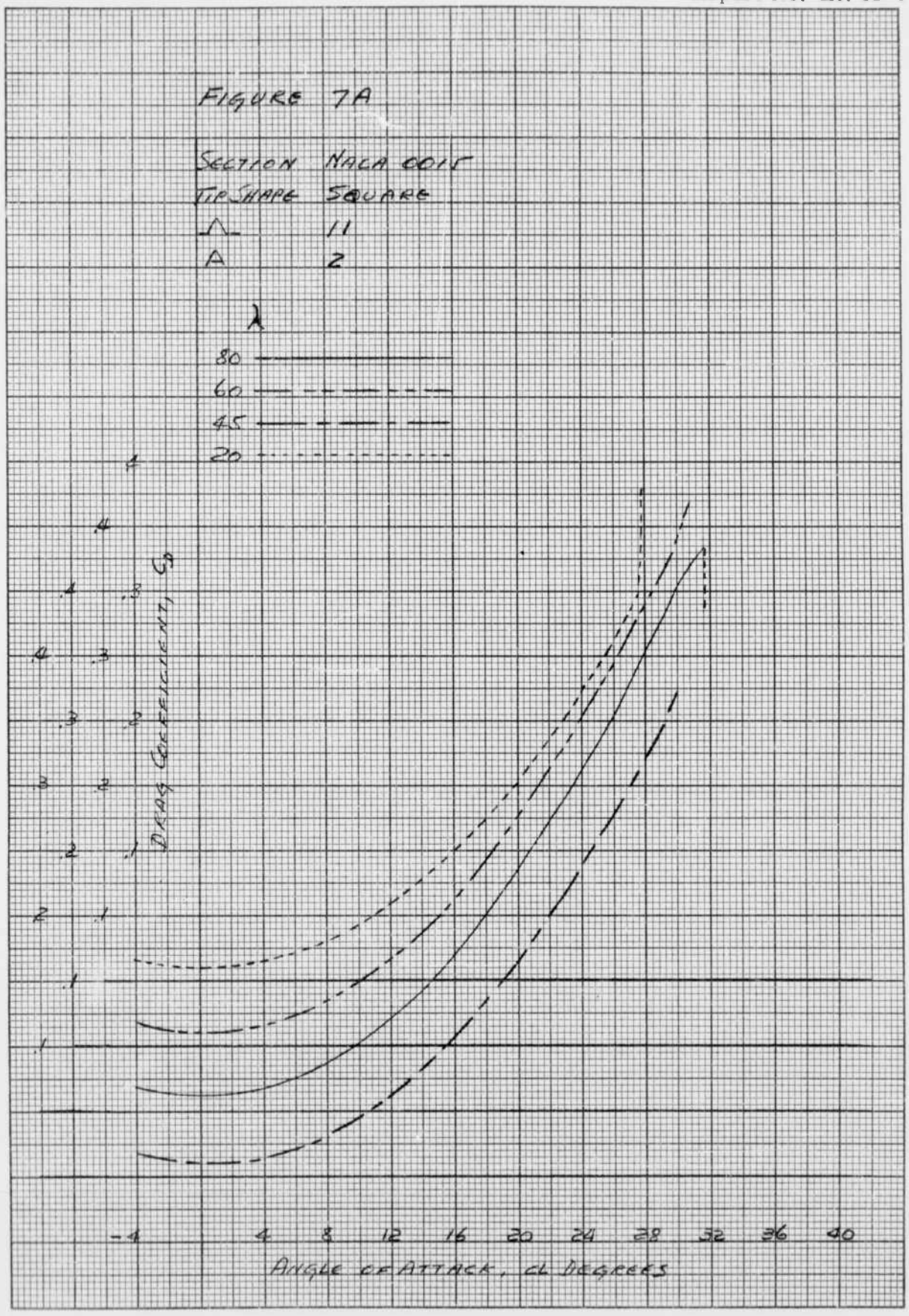


FIGURE 7A
SECTION NACA 6015
TIP SHAPE SQUARE
Λ 11
A 2
λ
80
60
45
20
DRAG COEFFICIENT, CD
ANGLE OF ATTACK, α DEGREES
-4
4
8
12
16
20
24
28
32
36
40

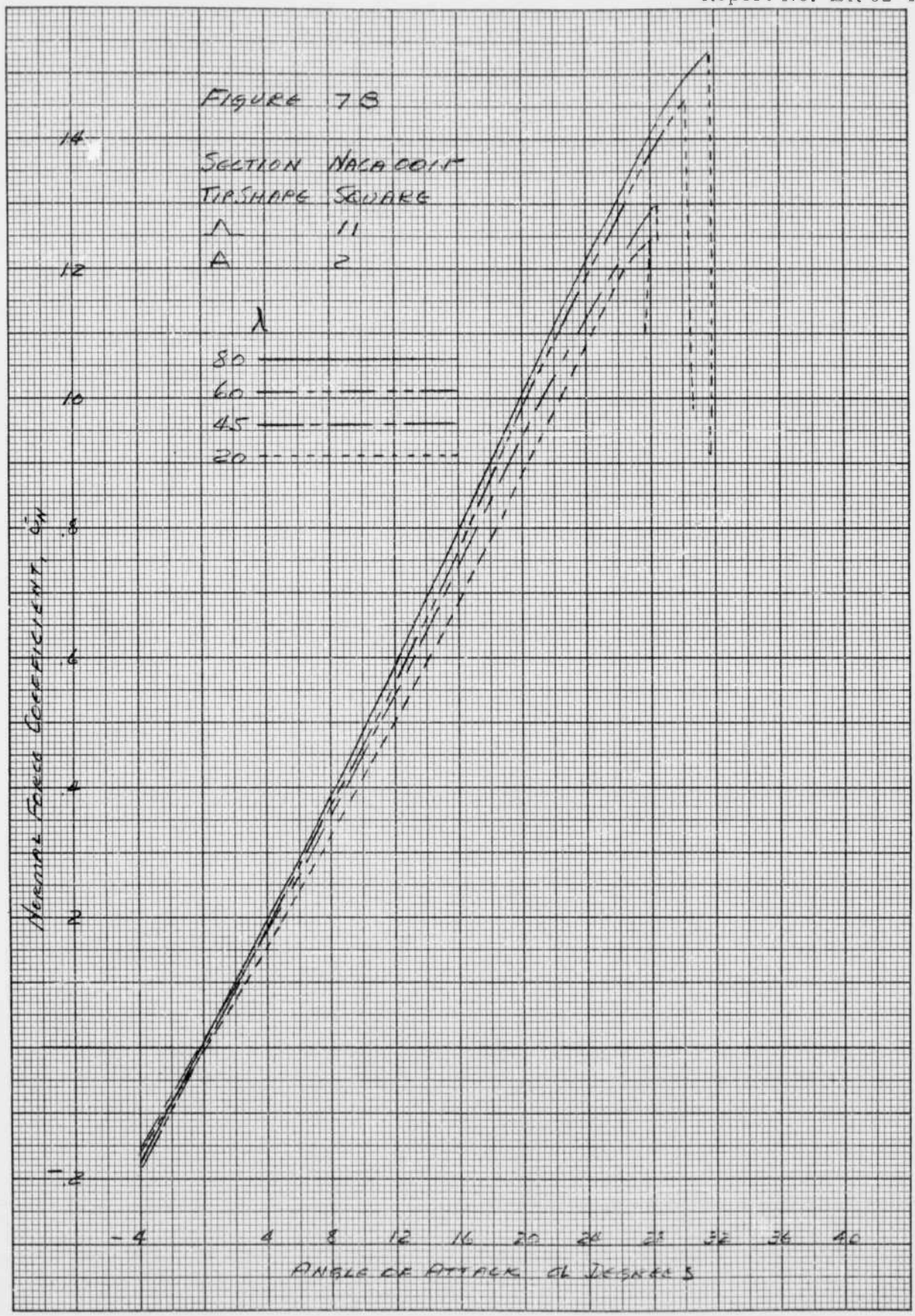


FIGURE 78
SECTION NACA 0015
TIP SHAPE SQUARE
Λ 11
A 2
λ
80
60
45
20
NORMAL FORCE COEFFICIENT, C_N
14
12
10
8
6
4
2
-.2
-4
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α, DEGREES

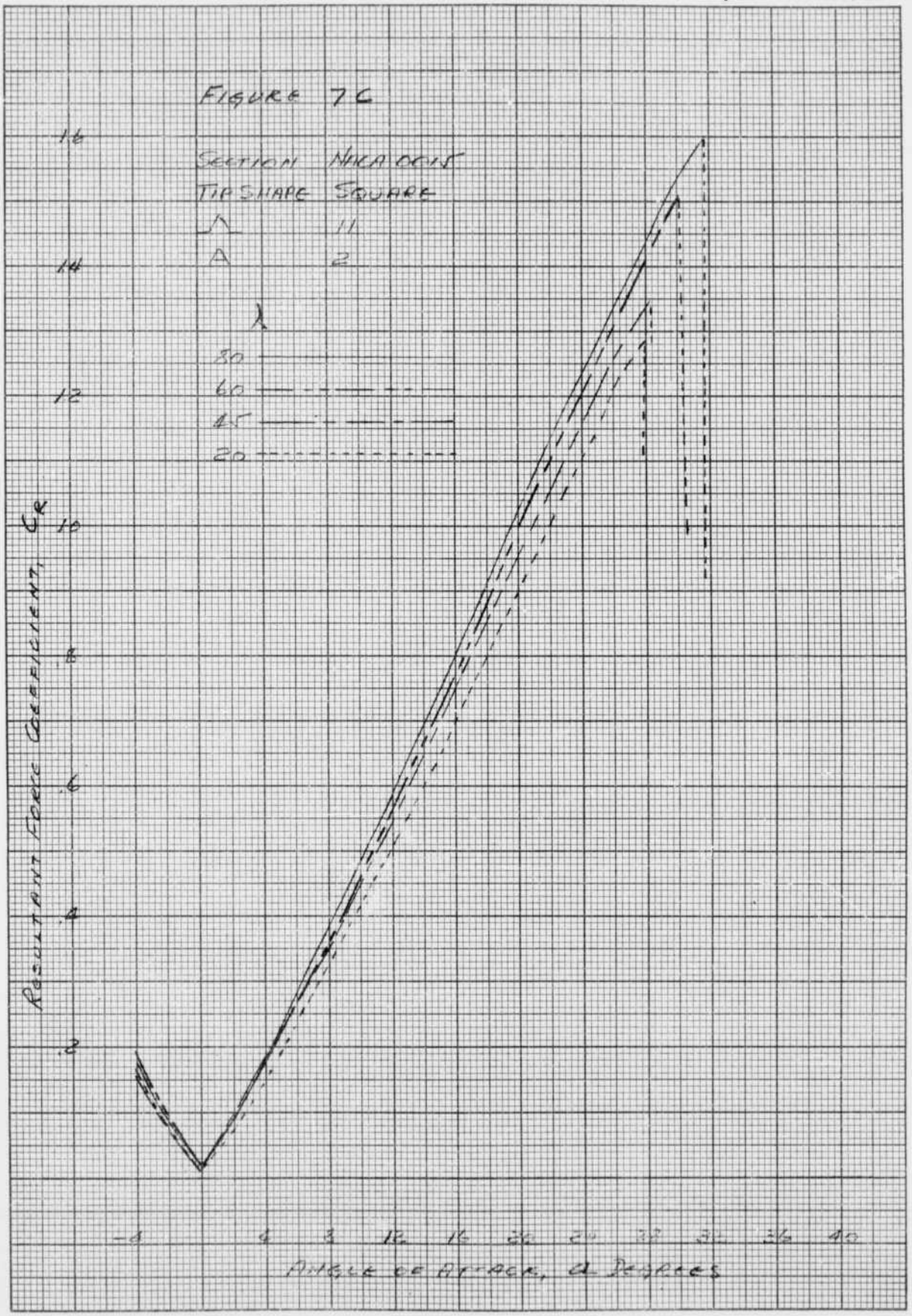


FIGURE 7C
SECTION NACA 0015
TIP SHAPE SQUARE
Λ 11
A 2
λ
30
60
45
20
RESULTANT FORCE COEFFICIENT, CR
16
14
12
10
8
6
4
2
-4
0
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α, DEGREES

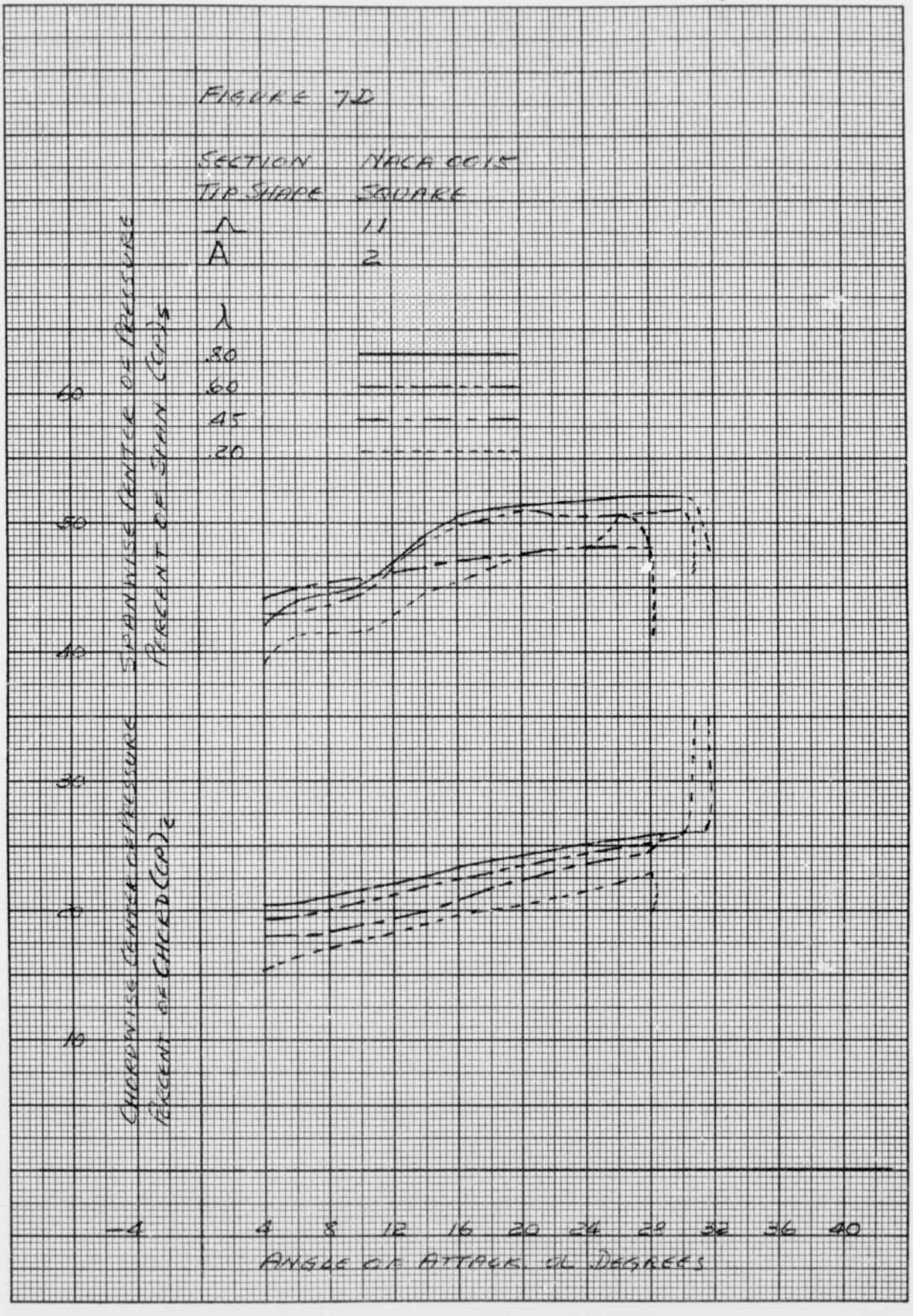


FIGURE 7D
SECTION NACA 66 I 5
TIP SHAPE SQUARE
Λ 11
A 2
λ
.30
.60
.45
.20
CHORDWISE CENTER OF PRESSURE LOCATED AT SUBSONIC SPEEDS
PERCENT OF CHORD (CP)c
60
50
40
30
20
10
-4
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α, DEGREES

FIGURE 8

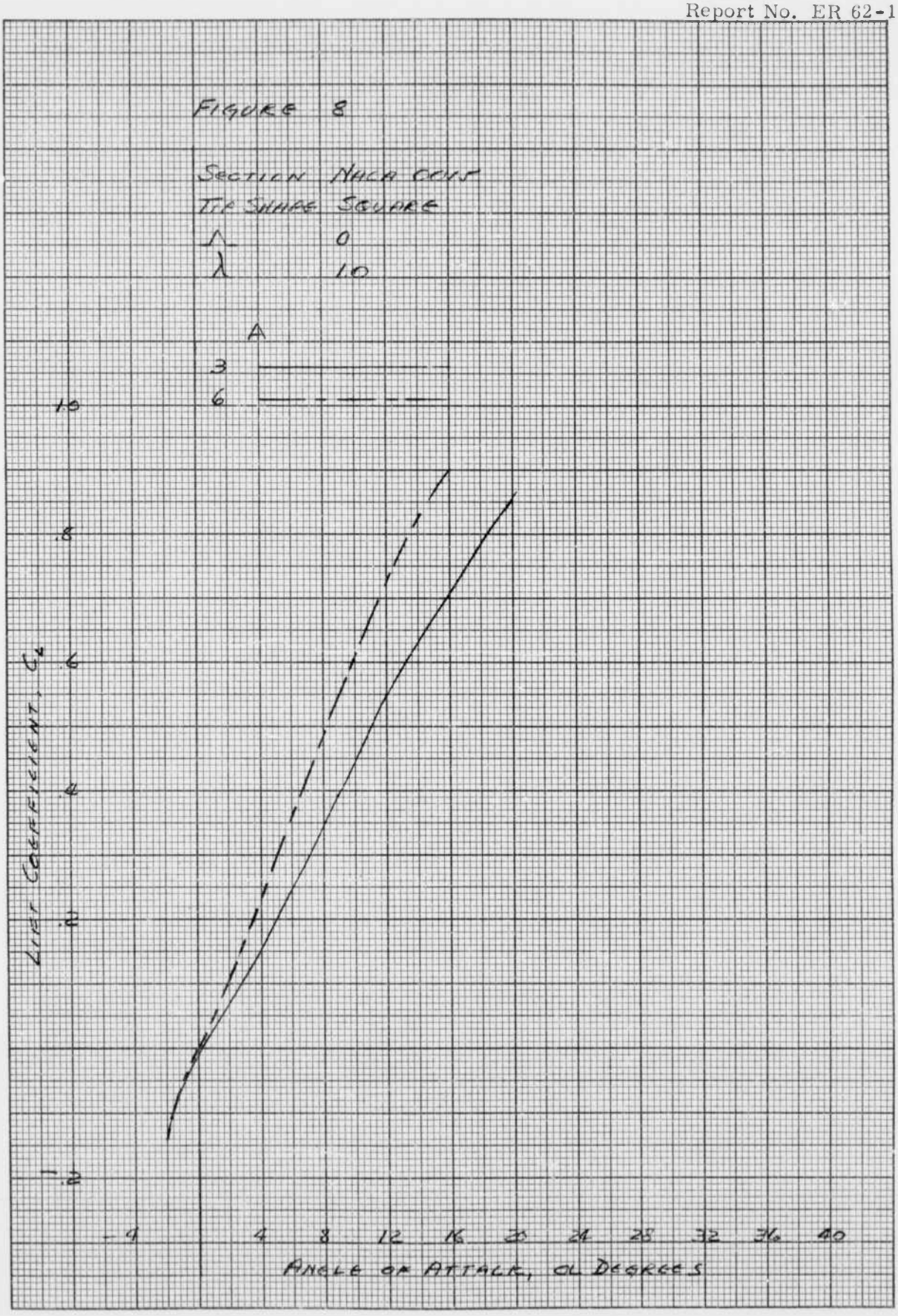
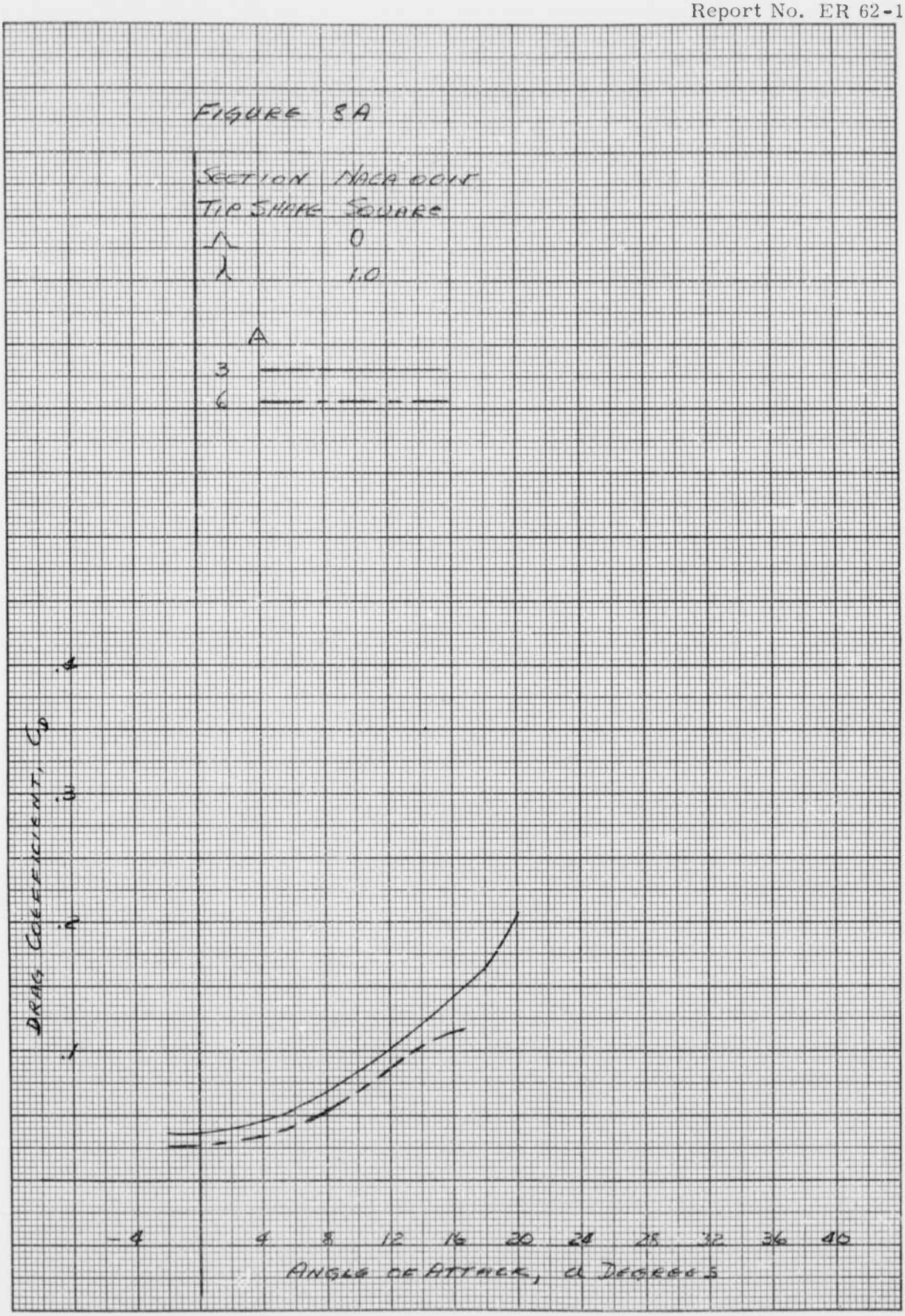

SECTION NACA 0015
TIP SHAPE SQUARE
Λ 0
λ 1.0
A
3
6
1.0
.8
.6
.4
.2
-.2
LIFT COEFFICIENT, C_L
-4
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α, DEGREES

FIGURE 8A

SECTION	NACA 0014
TIP SHAPE	SQUARE
Λ	0
λ	1.0

A
3 ———————
6 — — — — —



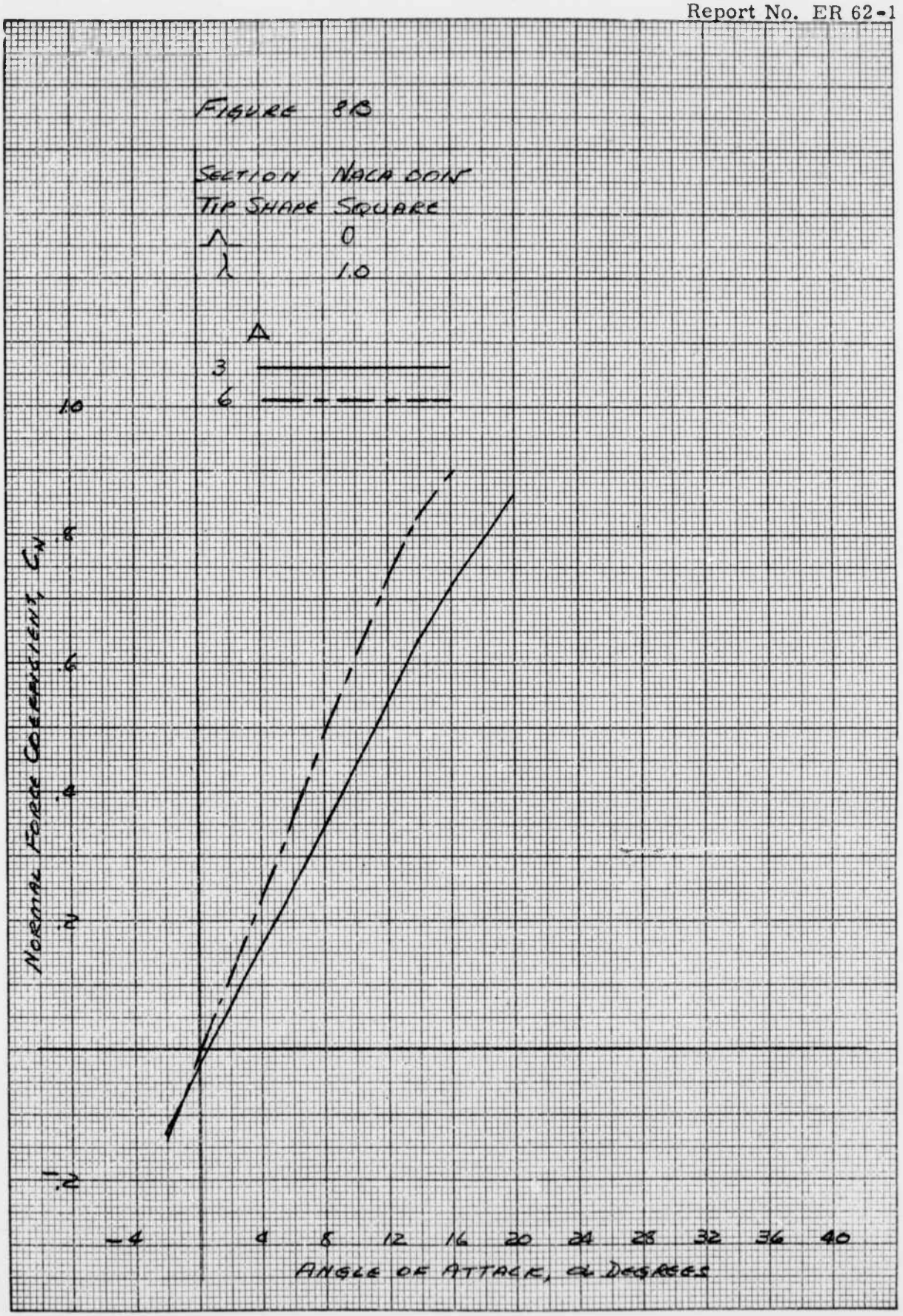


FIGURE 8B
SECTION NACA 0015
TIP SHAPE SQUARE
Λ 0
λ 1.0
A
3
6
1.0
.8
.6
.4
.2
-.2
NORMAL FORCE COEFFICIENT, C_N
-4
0
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α, DEGREES

FIGURE 8C

SECTION NACA 0015
TIP SHAPE SQUARE
Λ 0
λ 1.0

A
3 ———————
6 — — — — —

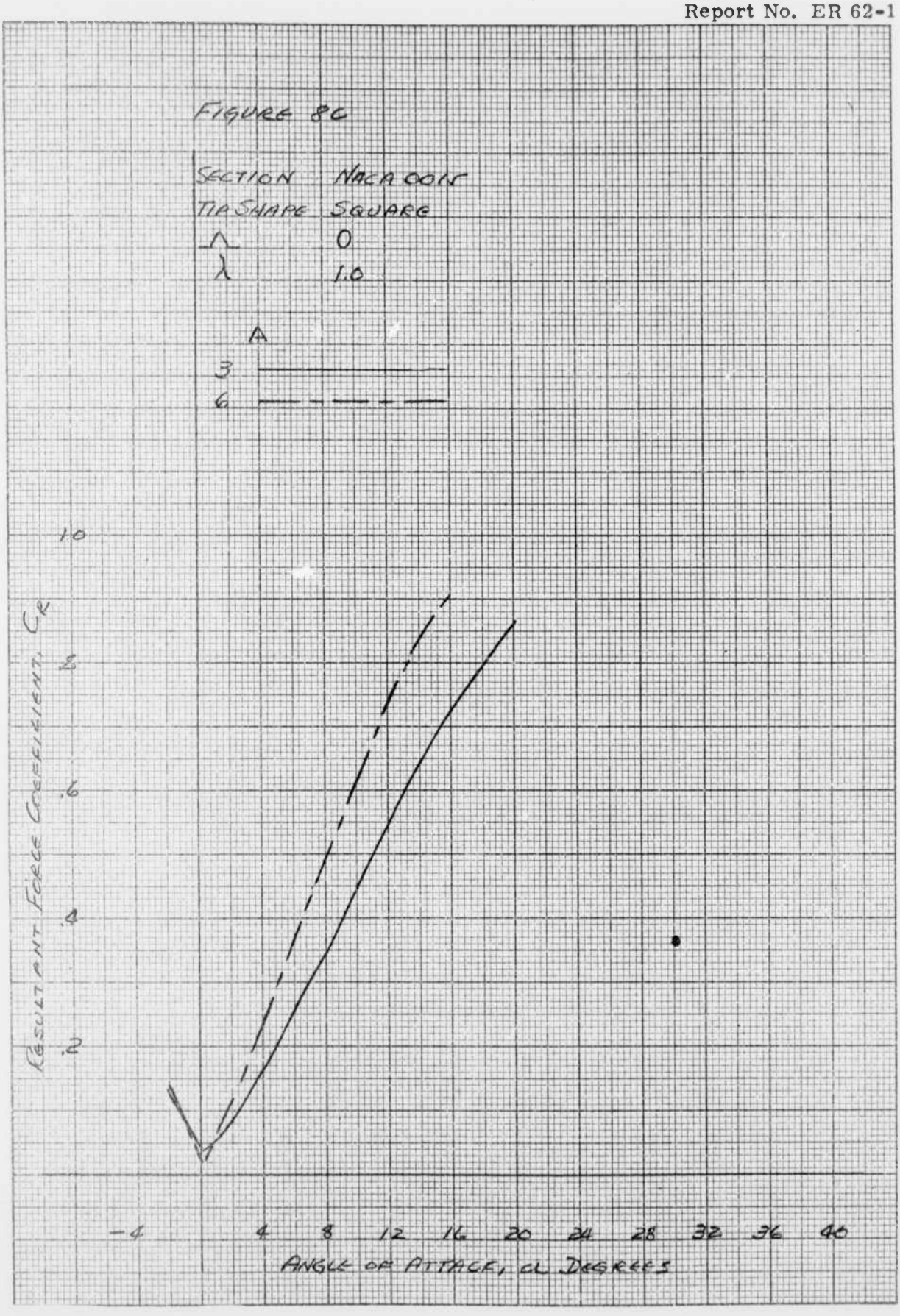
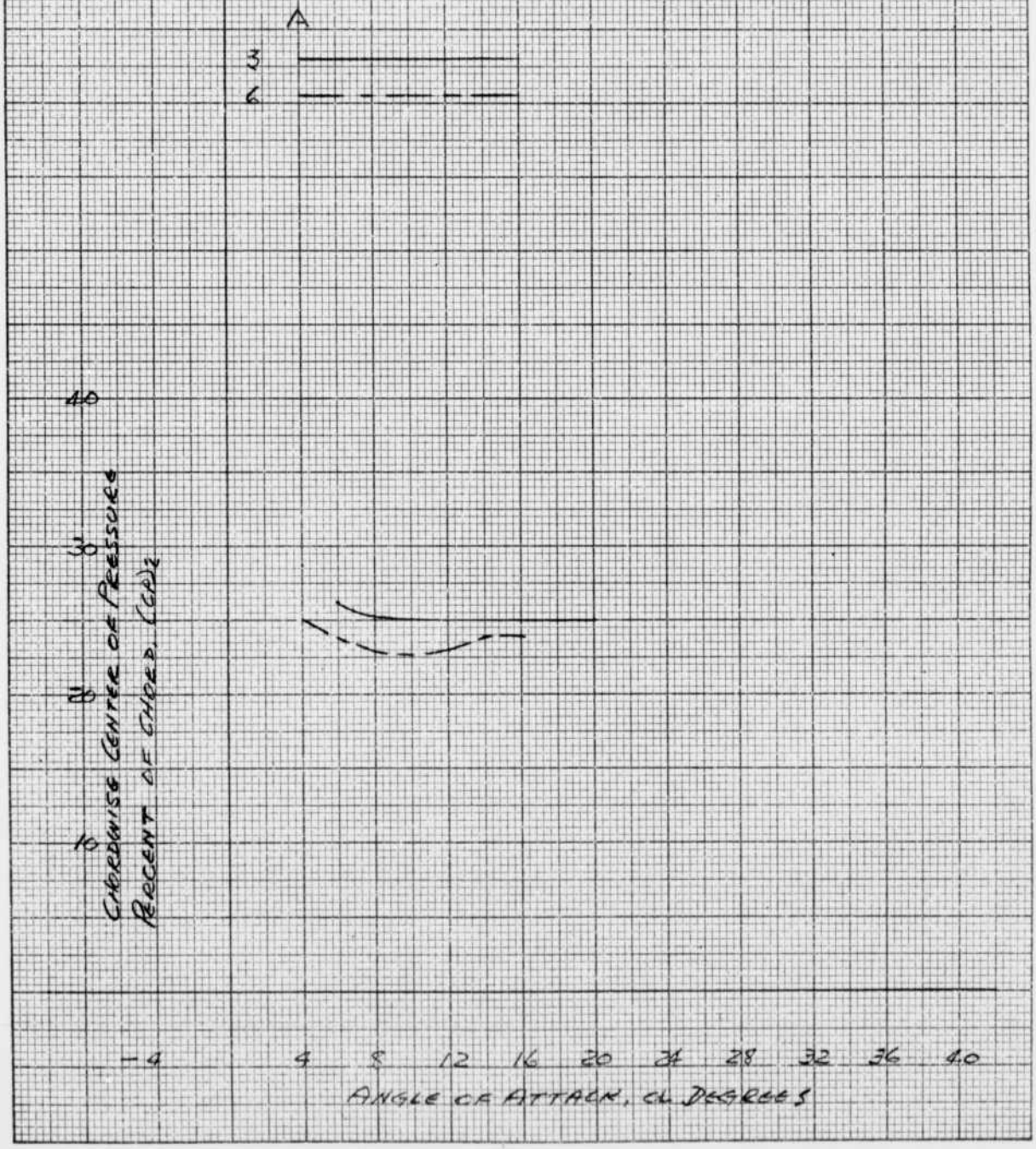


FIGURE 8D

SECTION	NACA 0015
TIP SHAPE	SQUARE
Λ	0
λ	1.0



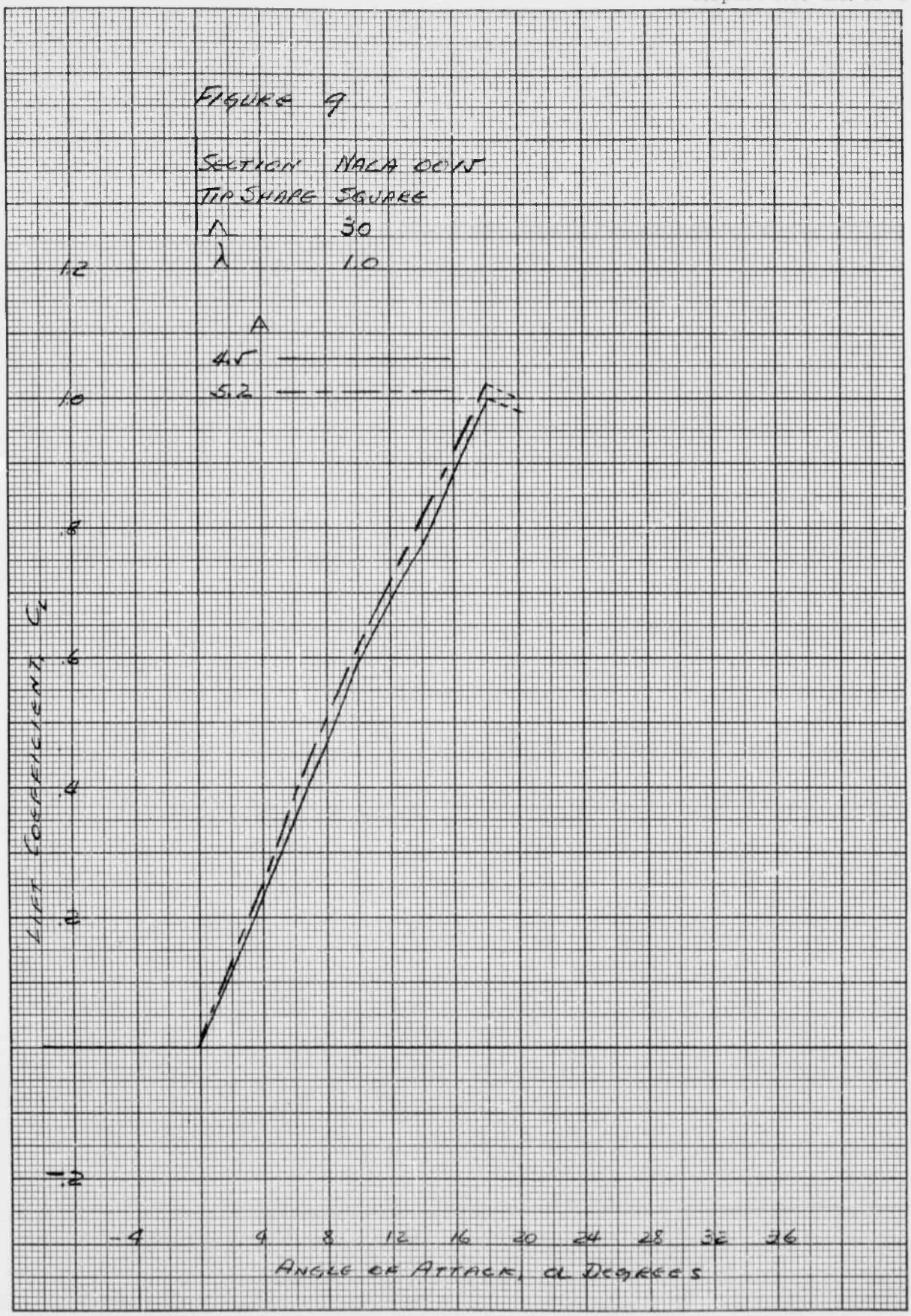
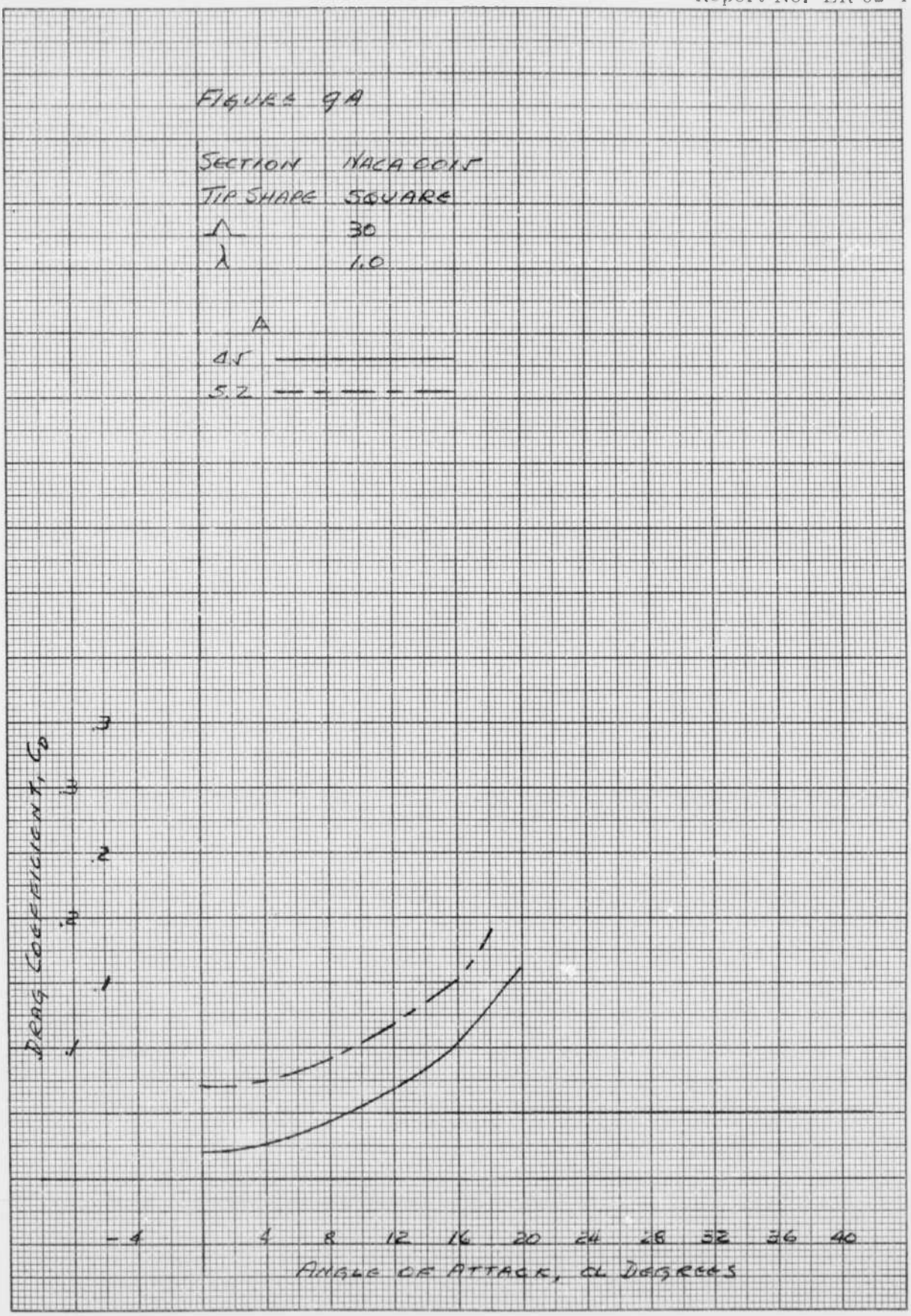


FIGURE 9
SECTION NACA 0015
TIP SHAPE SQUARE
Λ 30
λ 1.0
A
4.5
5.2
1.2
1.0
.8
.6
.4
.2
-.2
LIFT COEFFICIENT, C_L
-4
4
8
12
16
20
24
28
32
36
ANGLE OF ATTACK, α, DEGREES

FIGURE 9A

SECTION	NACA 0015
TIP SHAPE	SQUARE
Λ	30
λ	1.0

A
4.5 ———————
5.2 — - — - —



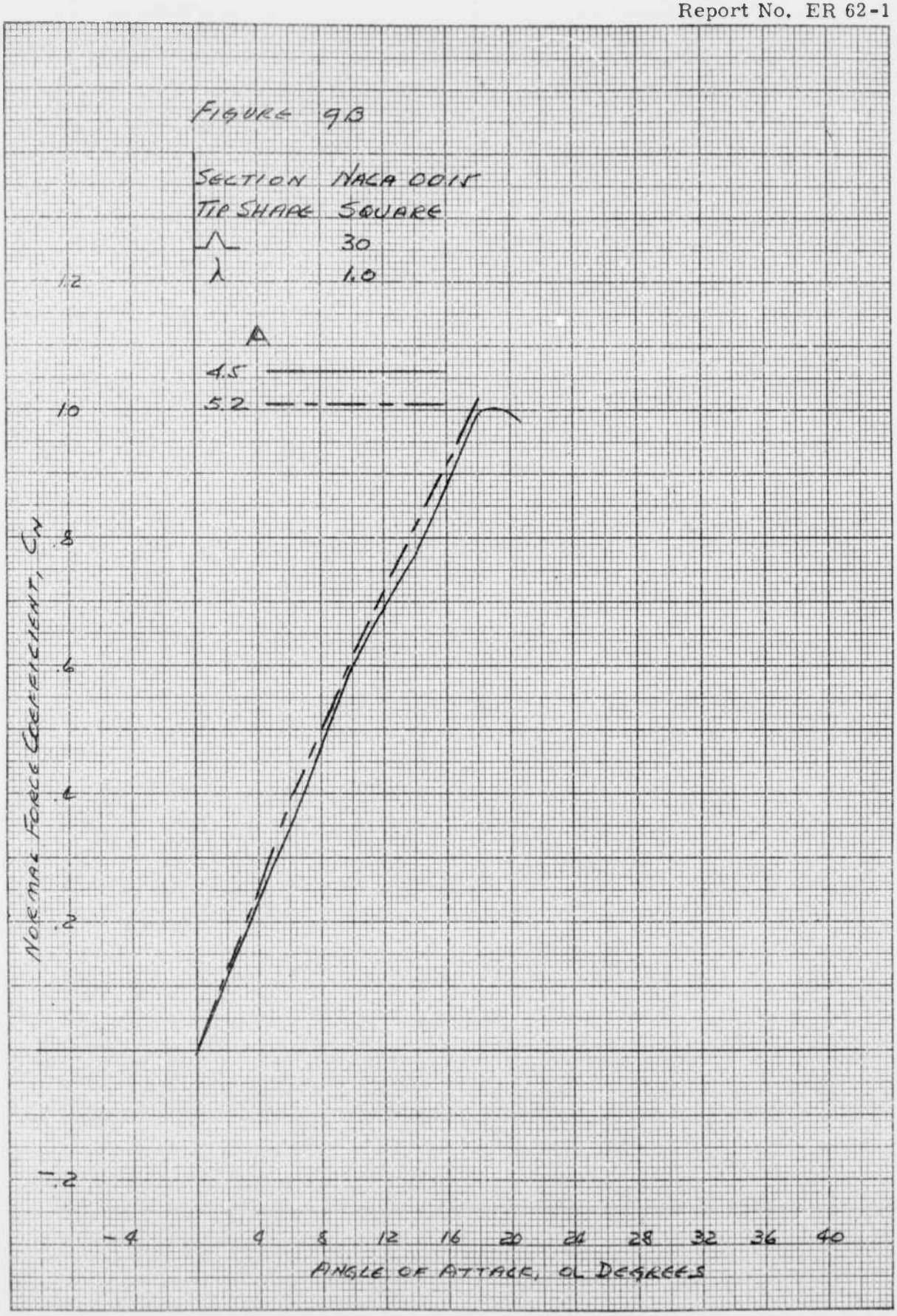


FIGURE 9B
SECTION NACA 0018
TIP SHAPE SQUARE
Λ 30
λ 1.0
A
4.5
5.2
1.2
1.0
.8
.6
.4
.2
-.2
NORMAL FORCE COEFFICIENT, CN
-4
0
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α, DEGREES

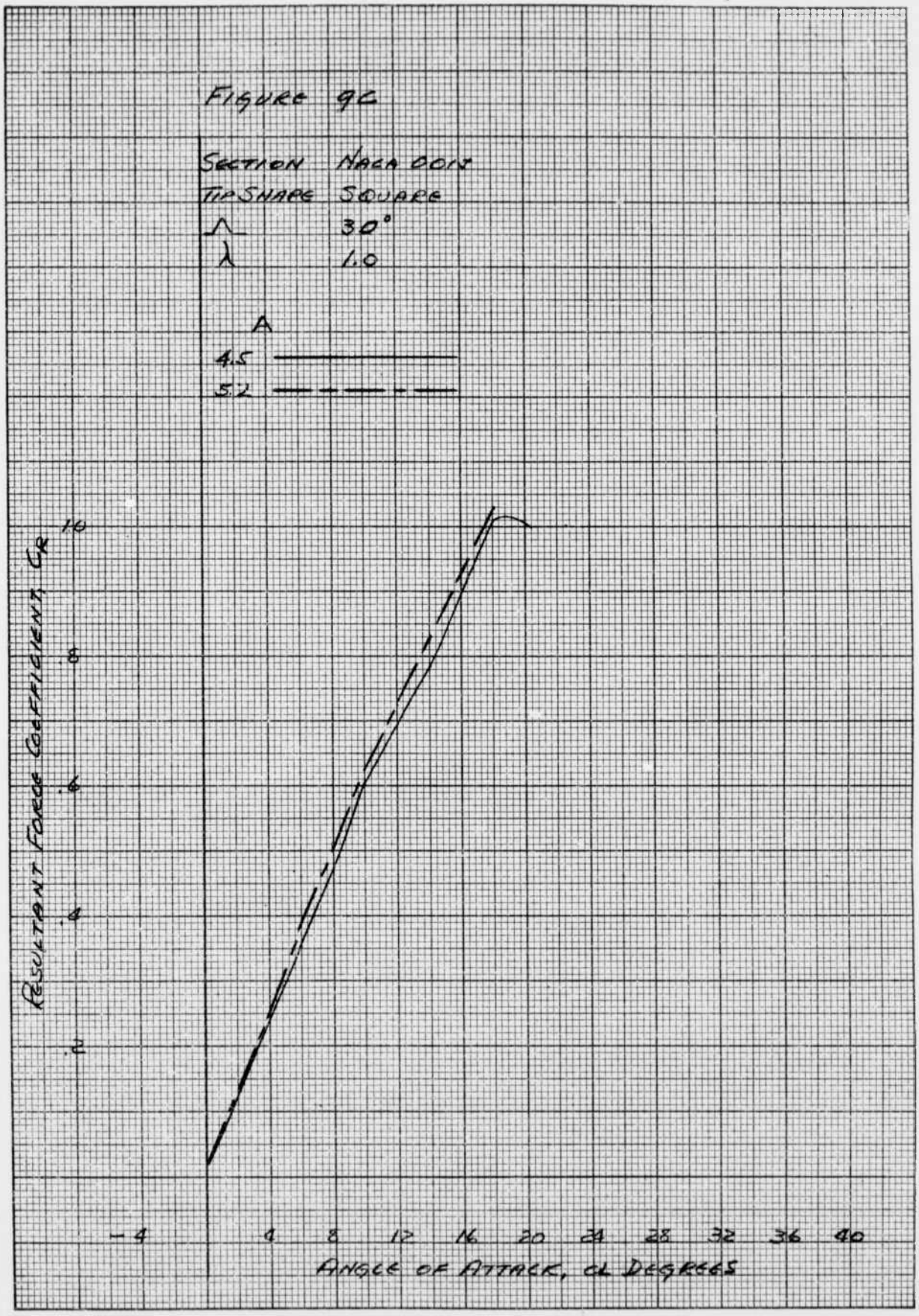
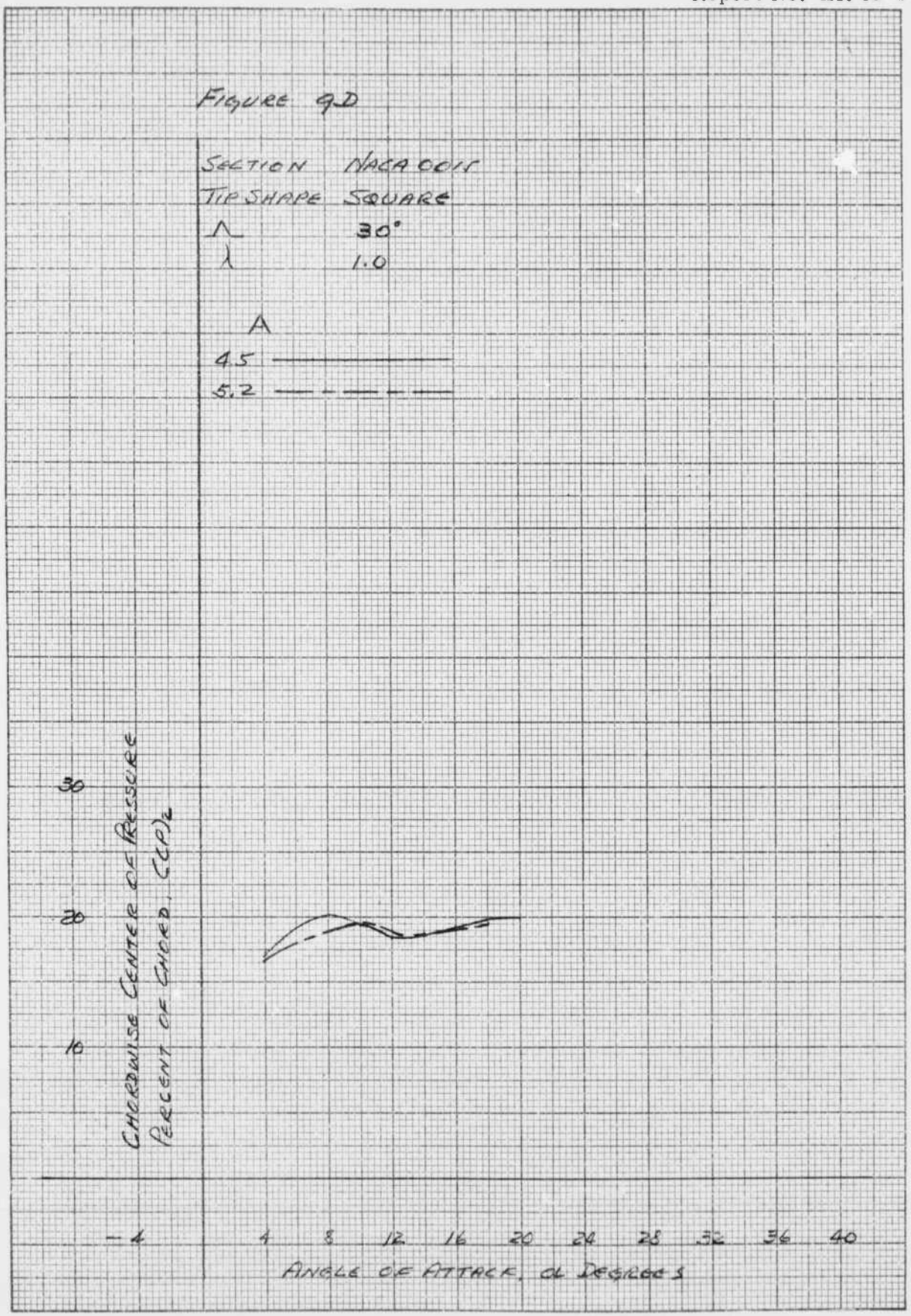


FIGURE 9C
SECTION NACA 0012
TIP SHAPE SQUARE
Λ 30°
λ 1.0
A
4.5
5.2
RESULTANT FORCE COEFFICIENT, CR
1.0
.8
.6
.4
.2
-4
0
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α, DEGREES

Figure 9D


SECTION NACA 0015
TIP SHAPE SQUARE
Λ 30°
λ 1.0
A
4.5
5.2
CHORDWISE CENTER OF PRESSURE
PERCENT OF CHORD, (CP)c
30
20
10
-4
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α, DEGREES

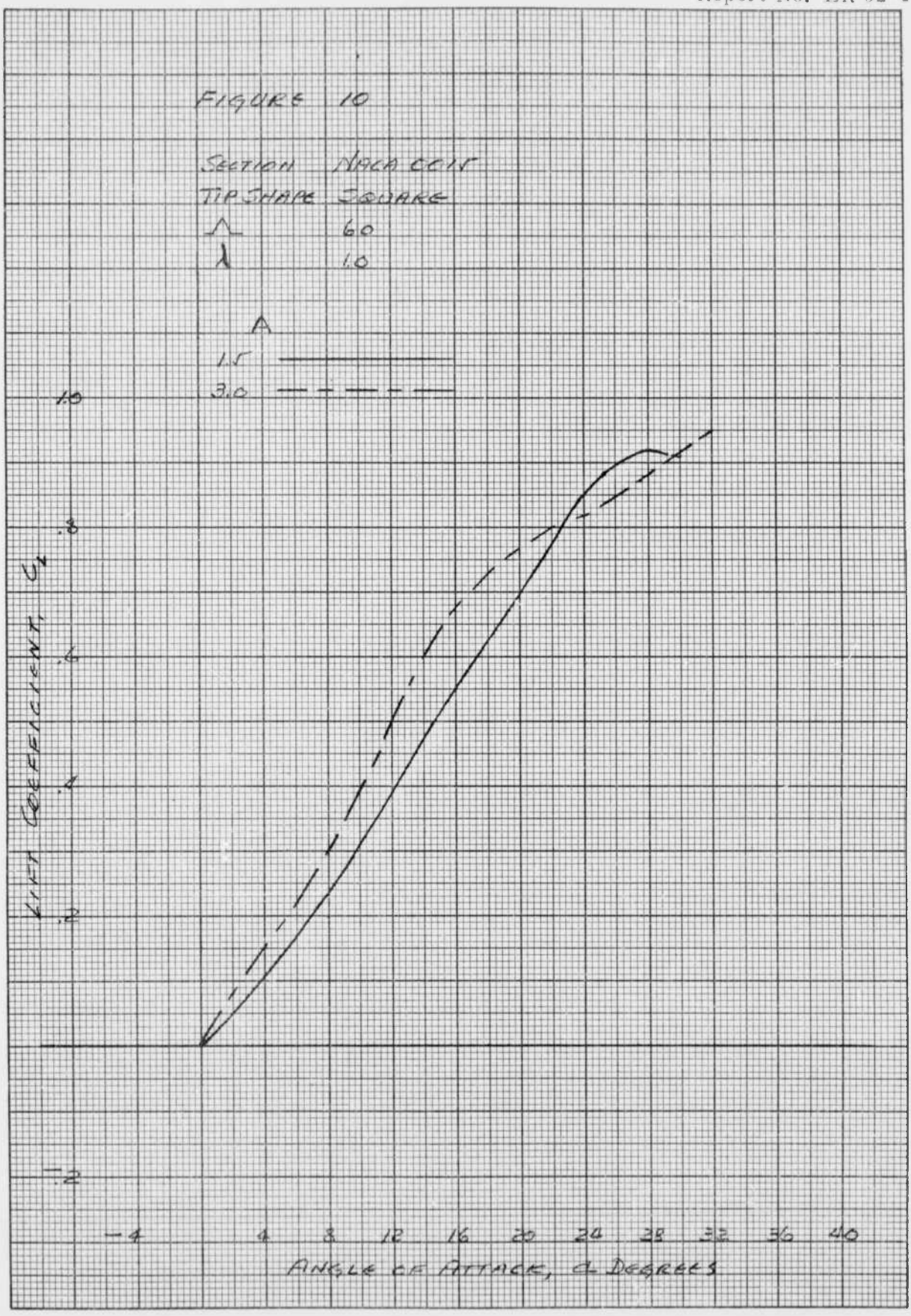


FIGURE 10
SECTION NACA 0015
TIP SHAPE SQUARE
Λ 60
λ 1.0
A
1.5
3.0
1.0
.8
.6
.4
.2
-.2
LIFT COEFFICIENT, C_L
-4
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α DEGREES

FIGURE 16A

SECTION NACA 65A006
TIP SHAPE SQUARE
Λ 60
λ 1.0

A
1.5 ———
3.0 — — — —

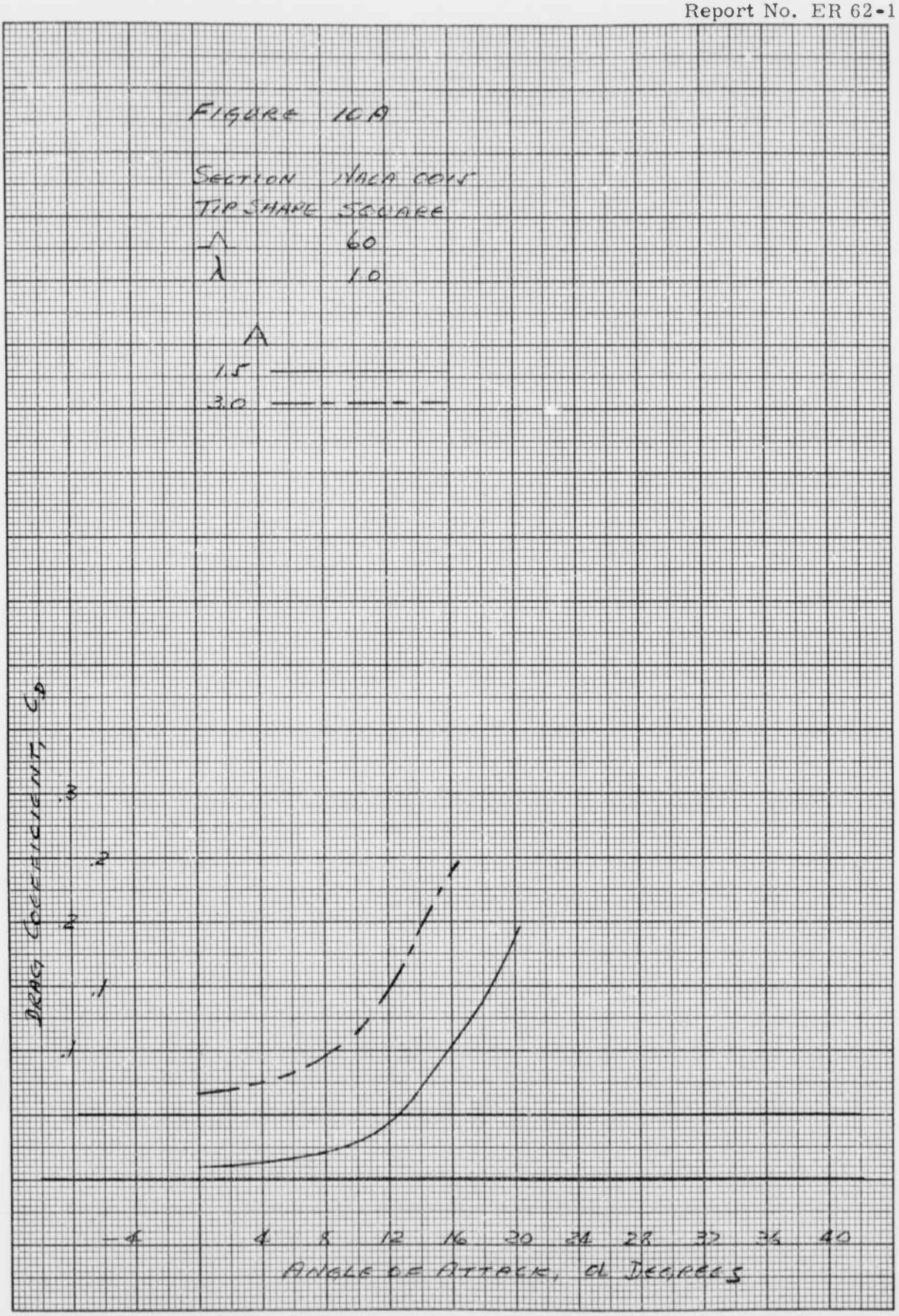


FIGURE 10 B

SECTION NACA 0015
TIP SHAPE SQUARE
Λ 60
λ 1.0

A	
1.5	———
3.0	— - — - —

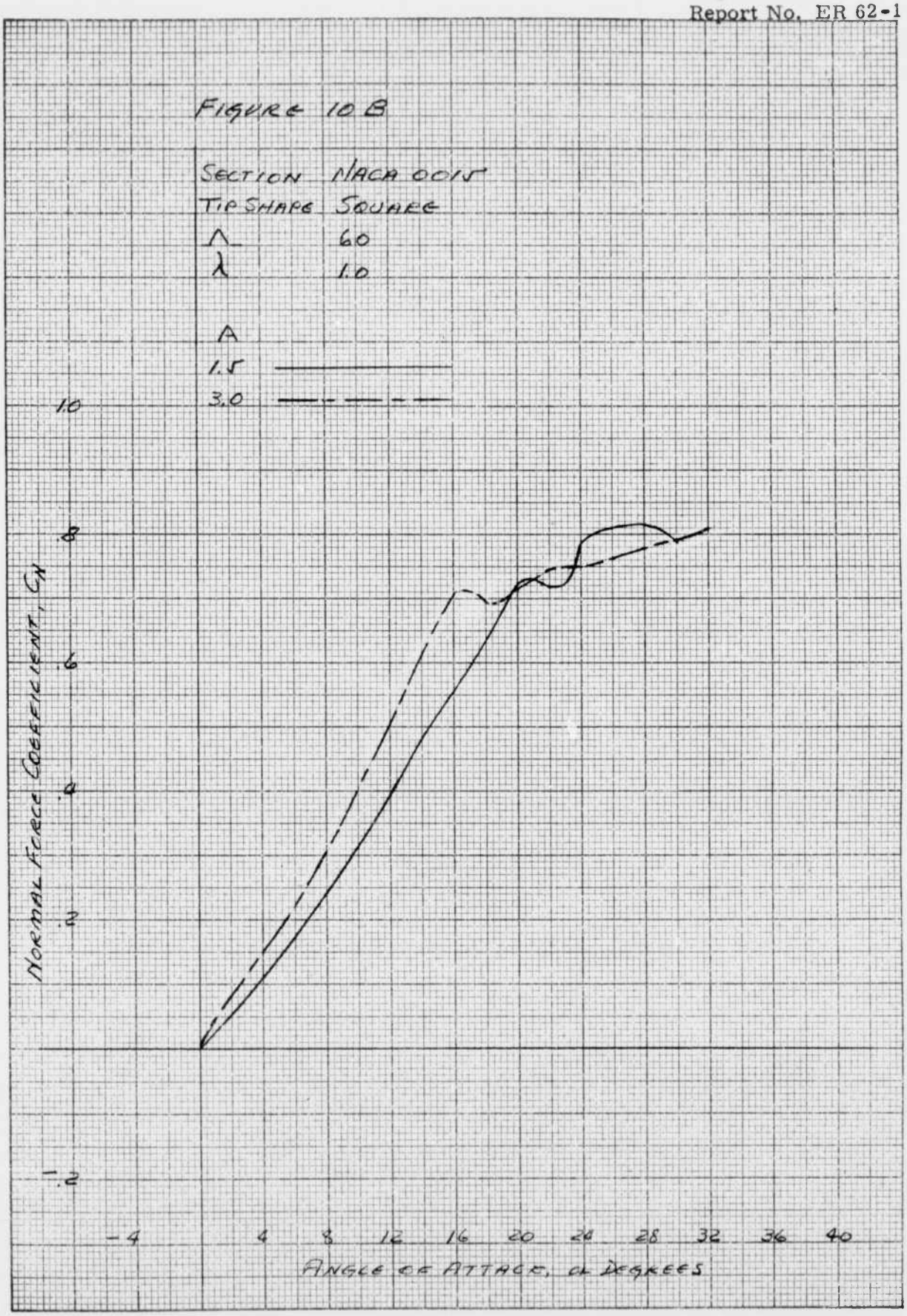


FIGURE 10C

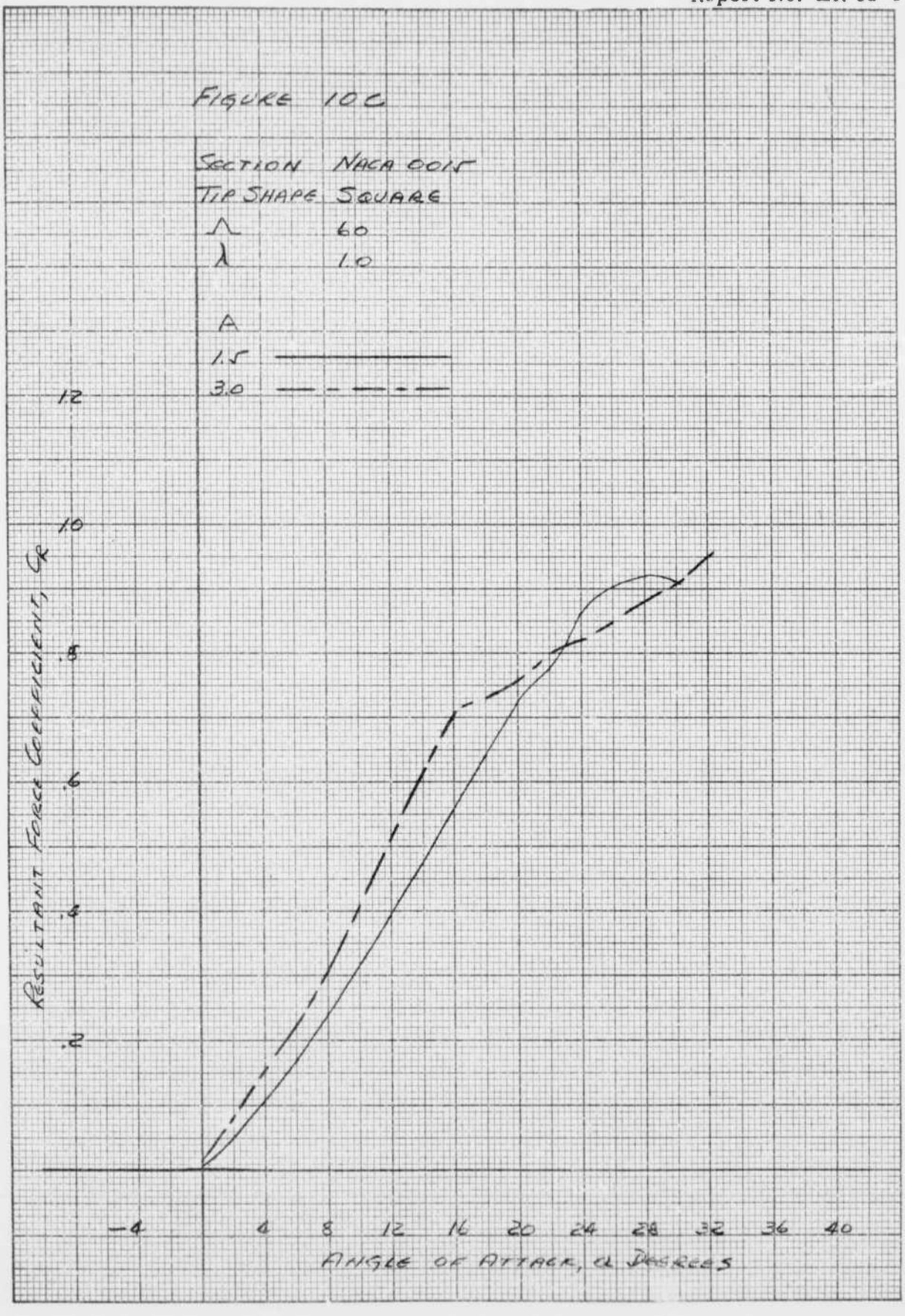
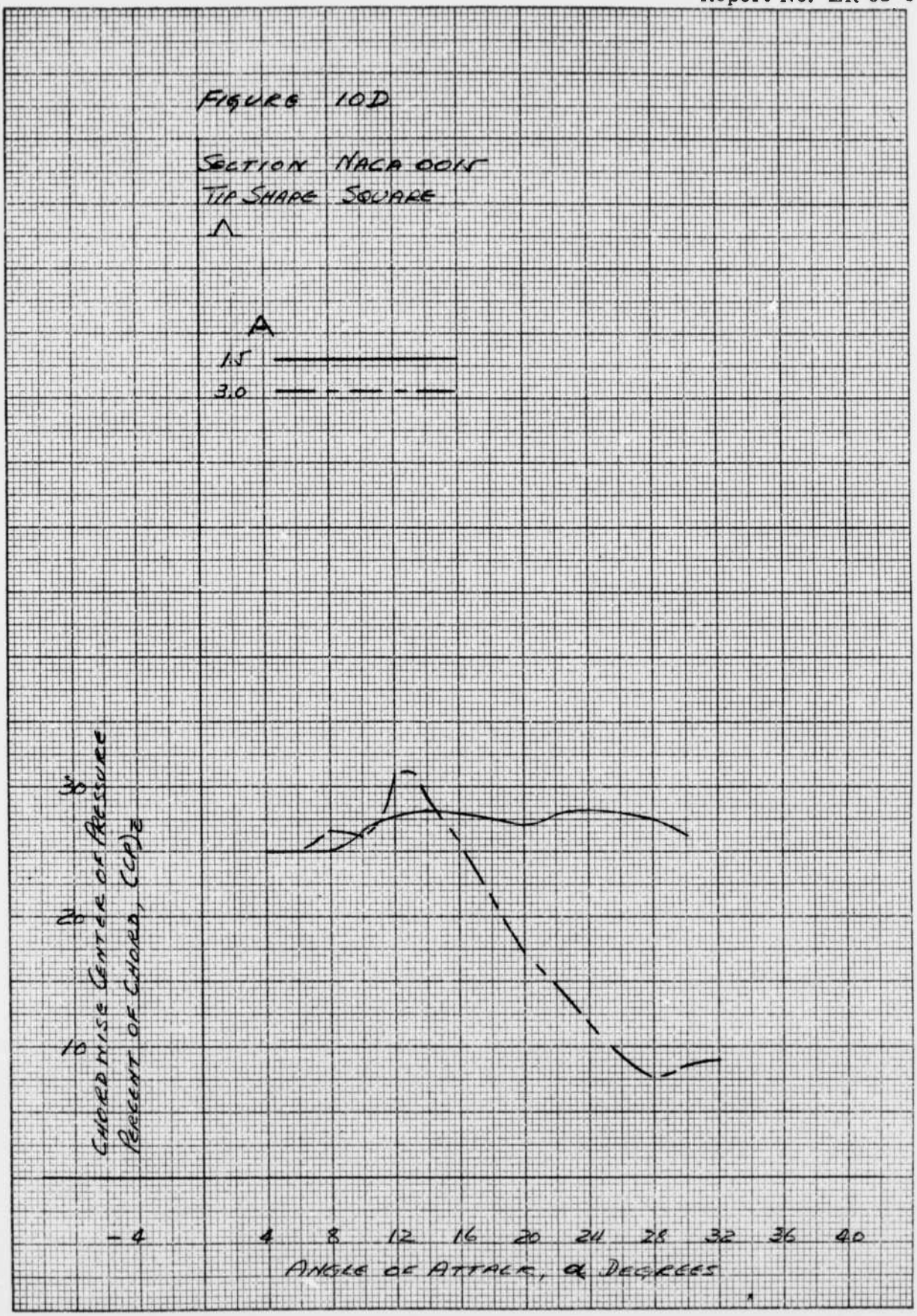

SECTION NACA 0015
TIP SHAPE SQUARE
Λ 60
λ 1.0
A
1.5
3.0
RESULTANT FORCE COEFFICIENTS, CR
1.2
1.0
.8
.6
.4
.2
-4
0
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α, DEGREES

FIGURE 10D

SECTION NACA 0015
TIP SHAPE SQUARE
Λ

A
1.5 ———————
3.0 — - — - —



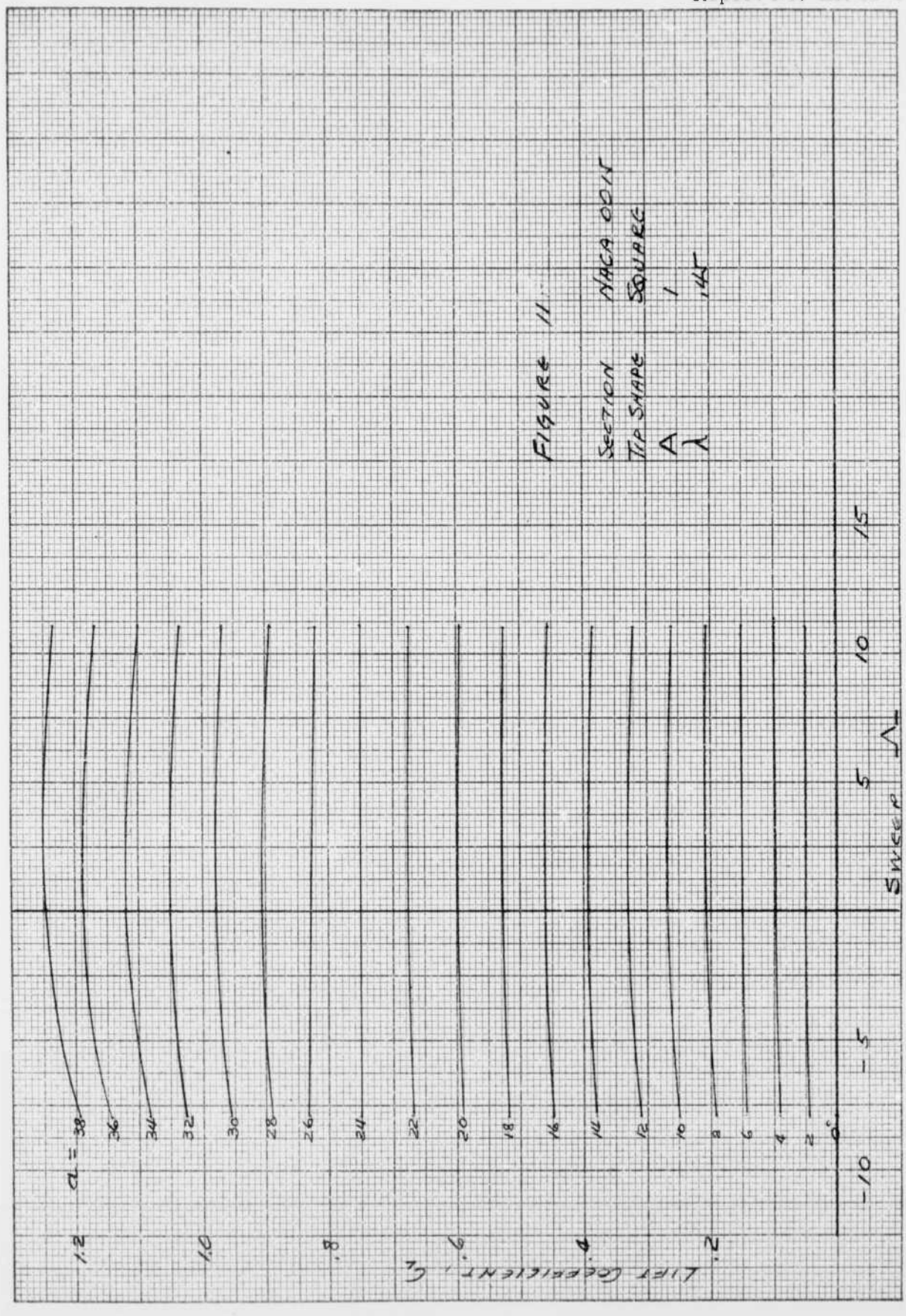


FIGURE 11
SECTION NACA 0015
TIP SHAPE SQUARED
A 1
λ 1.45
LIFT COEFFICIENT, C_L
1.2
1.0
.8
.6
.4
.2
C_L = 38 36 34 32 30 28 26 24 22 20 18 16 14 12 10 8 6 4 2 0°
-10 -5 5 10 15
SWEEP ANGLE, Λ

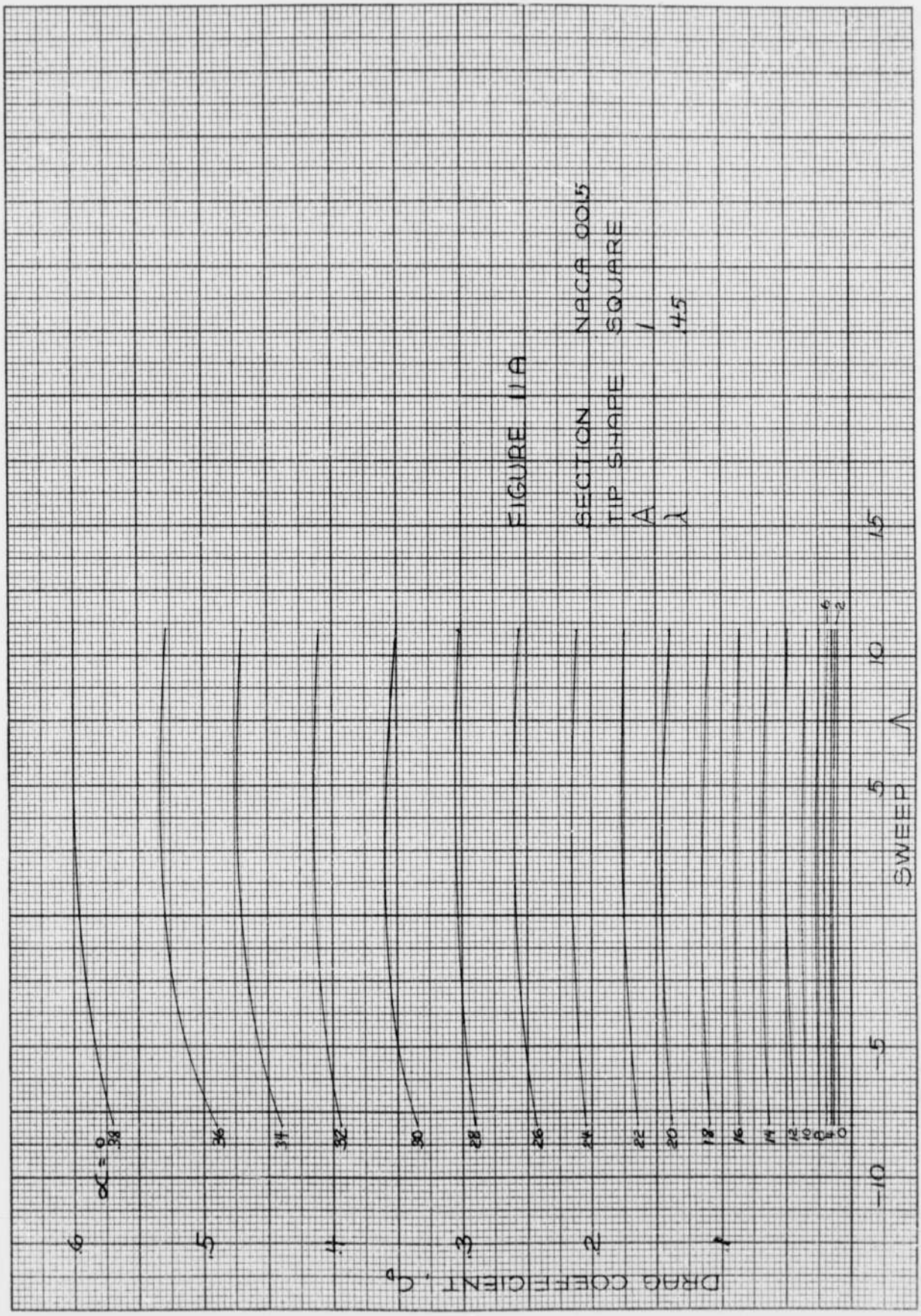


FIGURE 11A
SECTION NACA 0015
TIP SHAPE SQUARE
A 1
λ 4.5
DRAG COEFFICIENT, C_D
SWEEP Λ
15
10
5
-5
-10
α = 0
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
-2

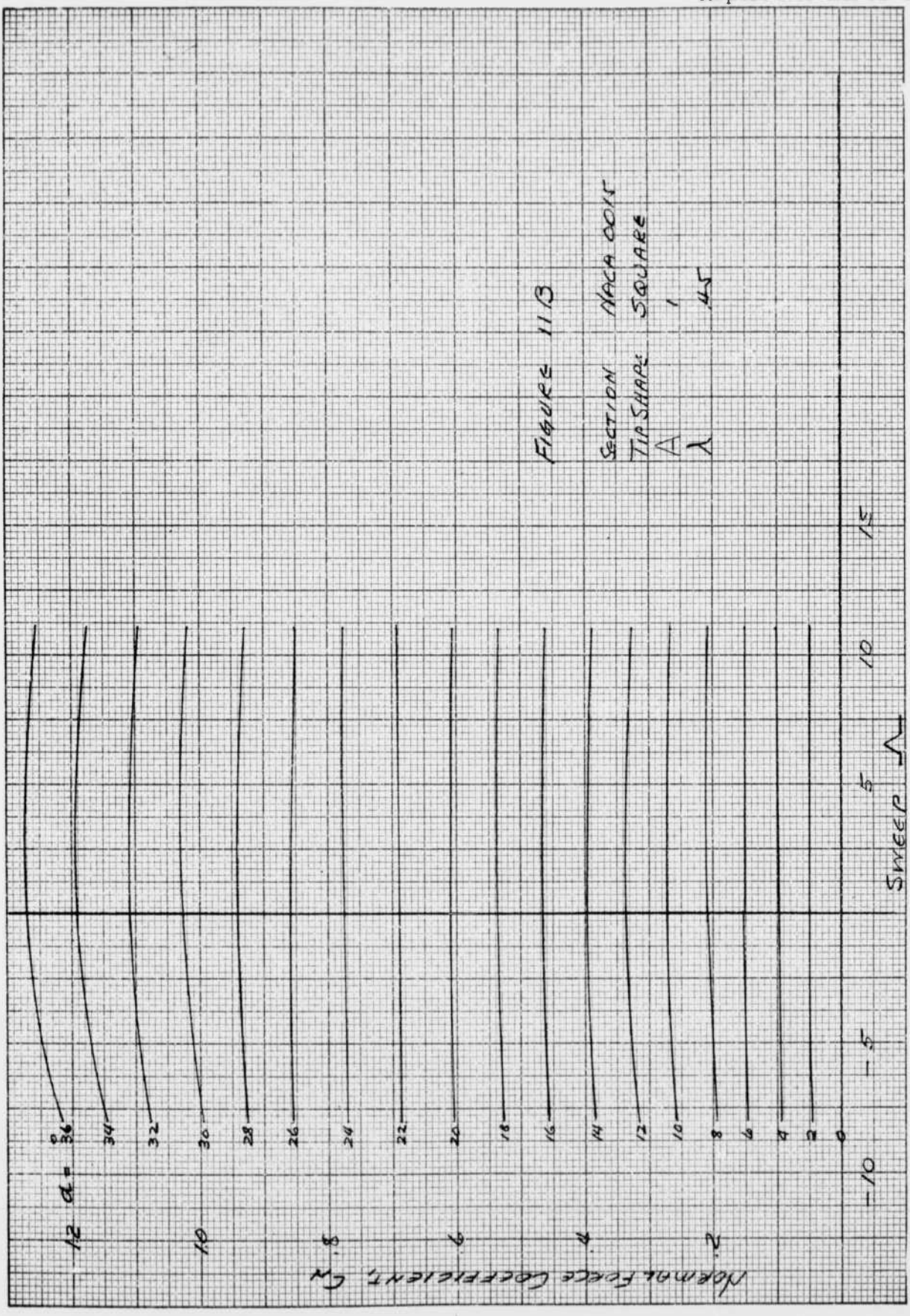


FIGURE 11.3
SECTION NACA 0015
TIP SHAPE: SQUARE
A 1
λ 45
NORMAL FORCE COEFFICIENT, C_N
SWEEP
-10
-5
0
5
10
15
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
α = 36

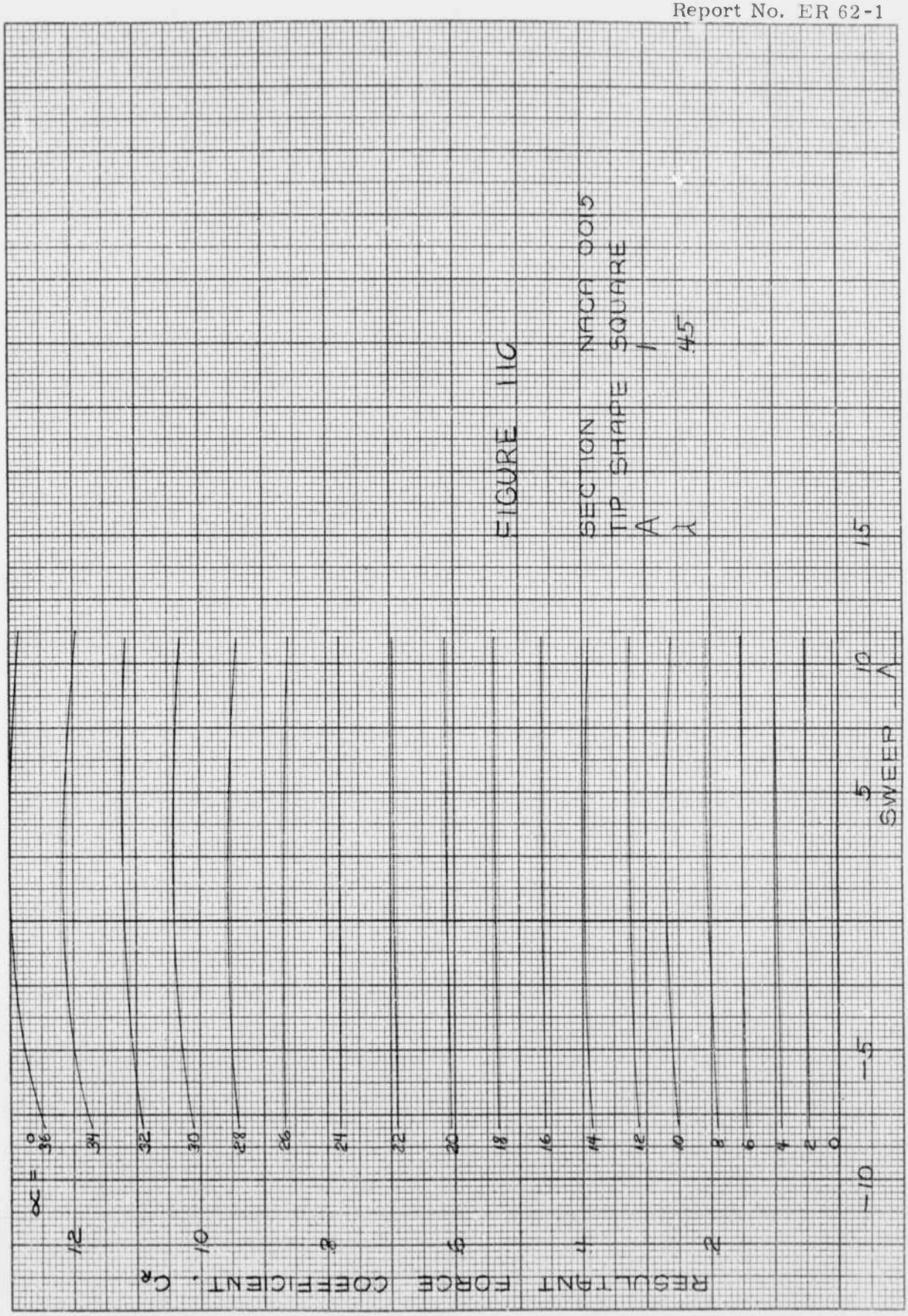


FIGURE 110
SECTION NACA 0015
TIP SHAPE SQUARE
A 1
λ .45
RESULTANT FORCE COEFFICIENT, C_R
SWEEP Λ
-10
-5
0
5
10
15
.2
.1
0
.1
.2
α = 36 34 32 30 28 26 24 22 20 18 16 14 12 10 8 6 4 2 0

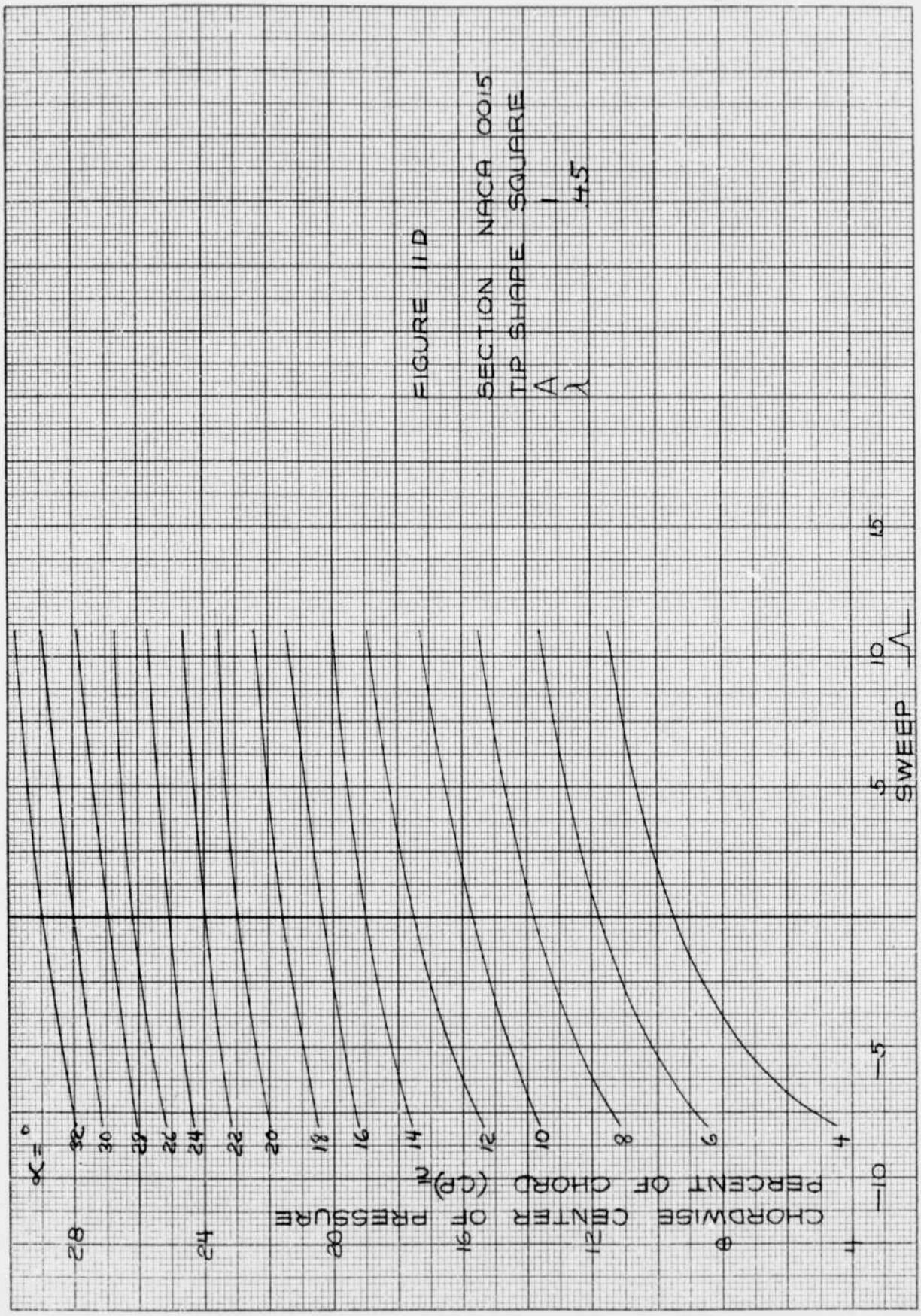


FIGURE 11D
SECTION NACA 0015
TIP SHAPE SQUARE
A
λ
45°
CHORDWISE CENTER OF PRESSURE
PERCENT OF CHORD (CP)M
SWEEP Λ
-10
-5
5
10
15
α = °
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
28
24
20
16
12
8
4

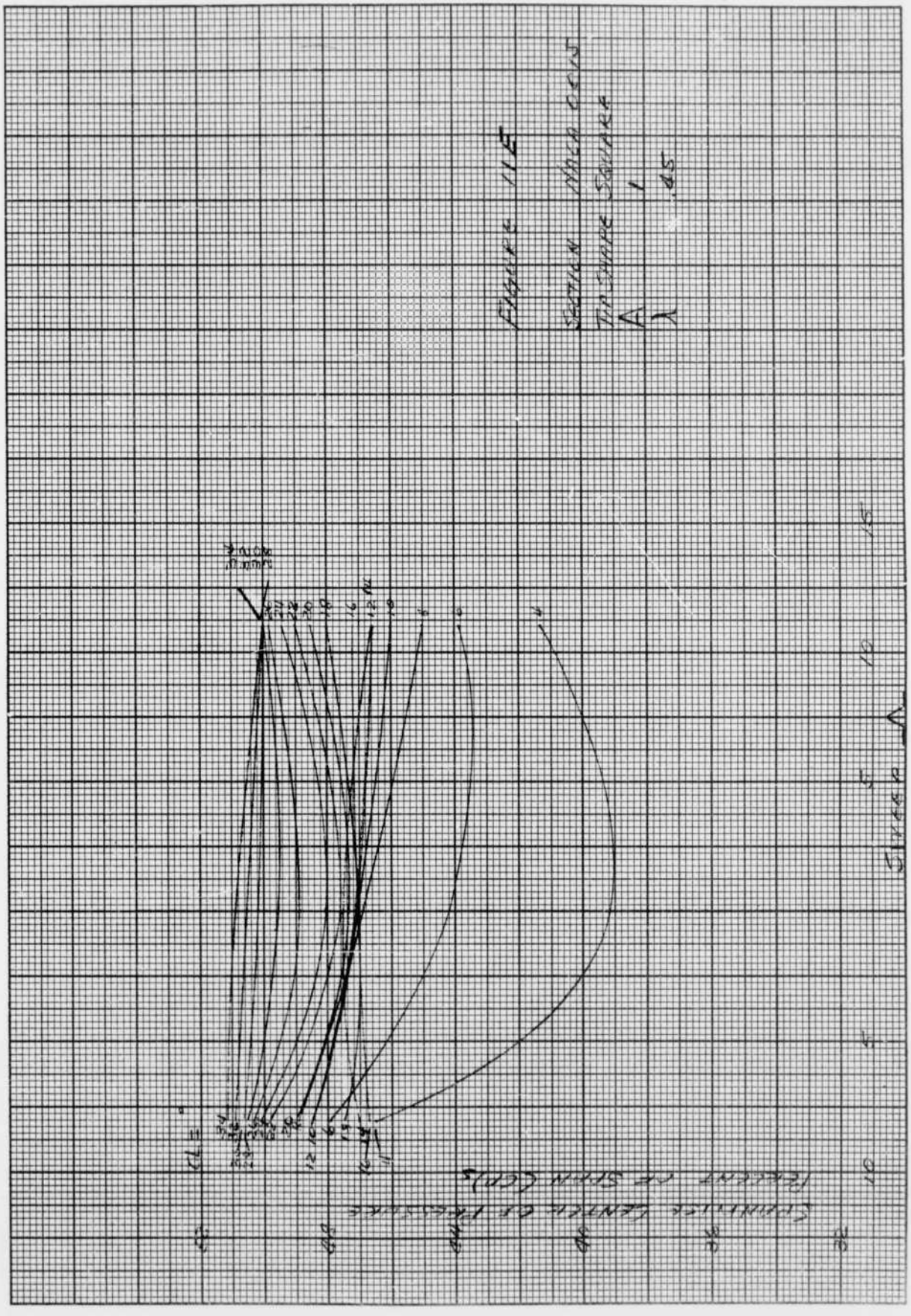


FIGURE 11E
SECTION VIEW
FLYWHEEL SQUARE
1 OF 5
VELOCITY
CENTRIFUGAL FORCE
VELOCITY OF SPIN (CPS)

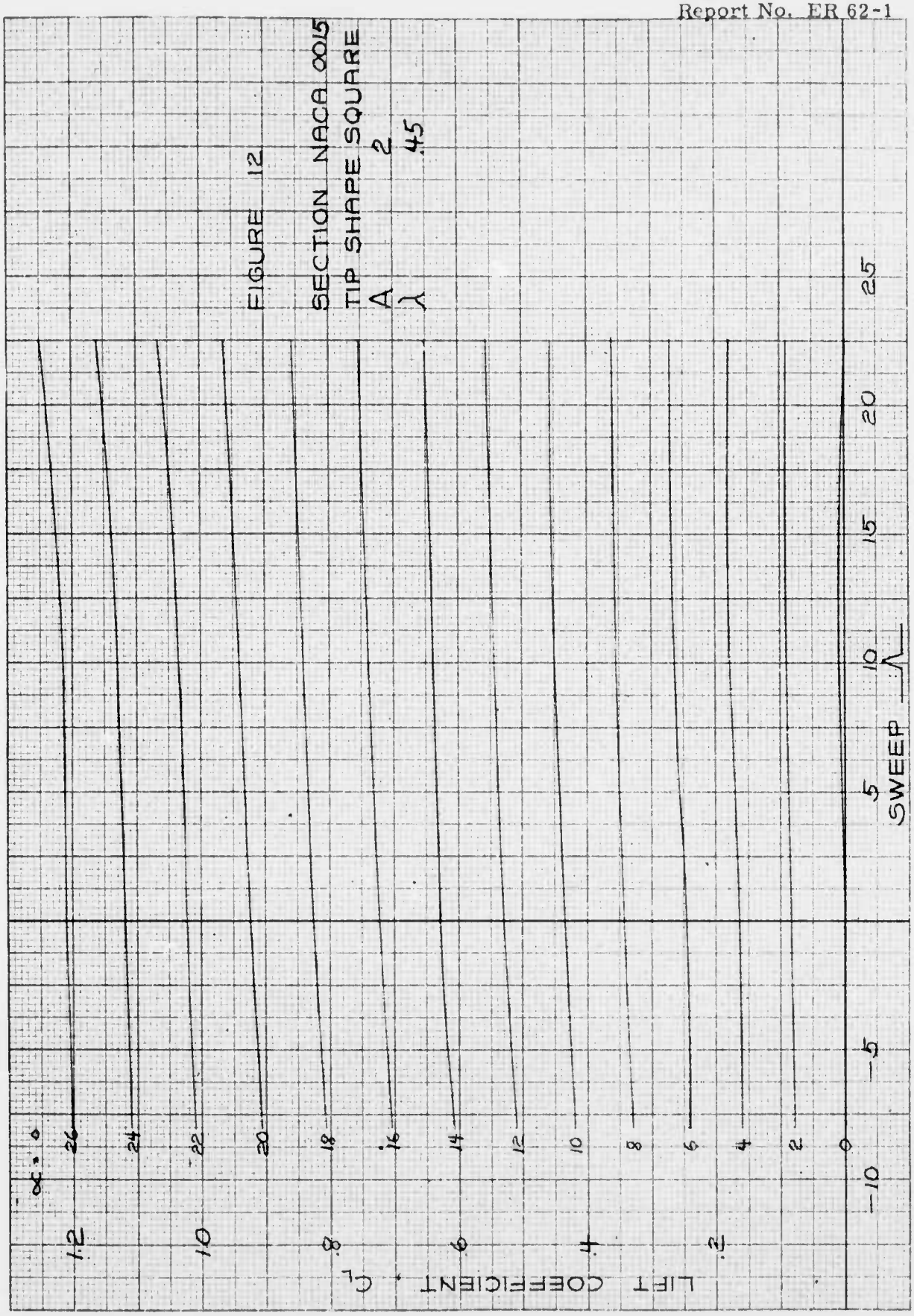


FIGURE 12
SECTION NACA 0015
TIP SHAPE SQUARE
A 2
λ .45
LIFT COEFFICIENT, C_L
SWEEP
α_c, °
1.2
1.0
.8
.6
.4
.2
0
-10
-5
0
5
10
15
20
25
26
24
22
20
18
16
14
12
10
8
6
4
2
0

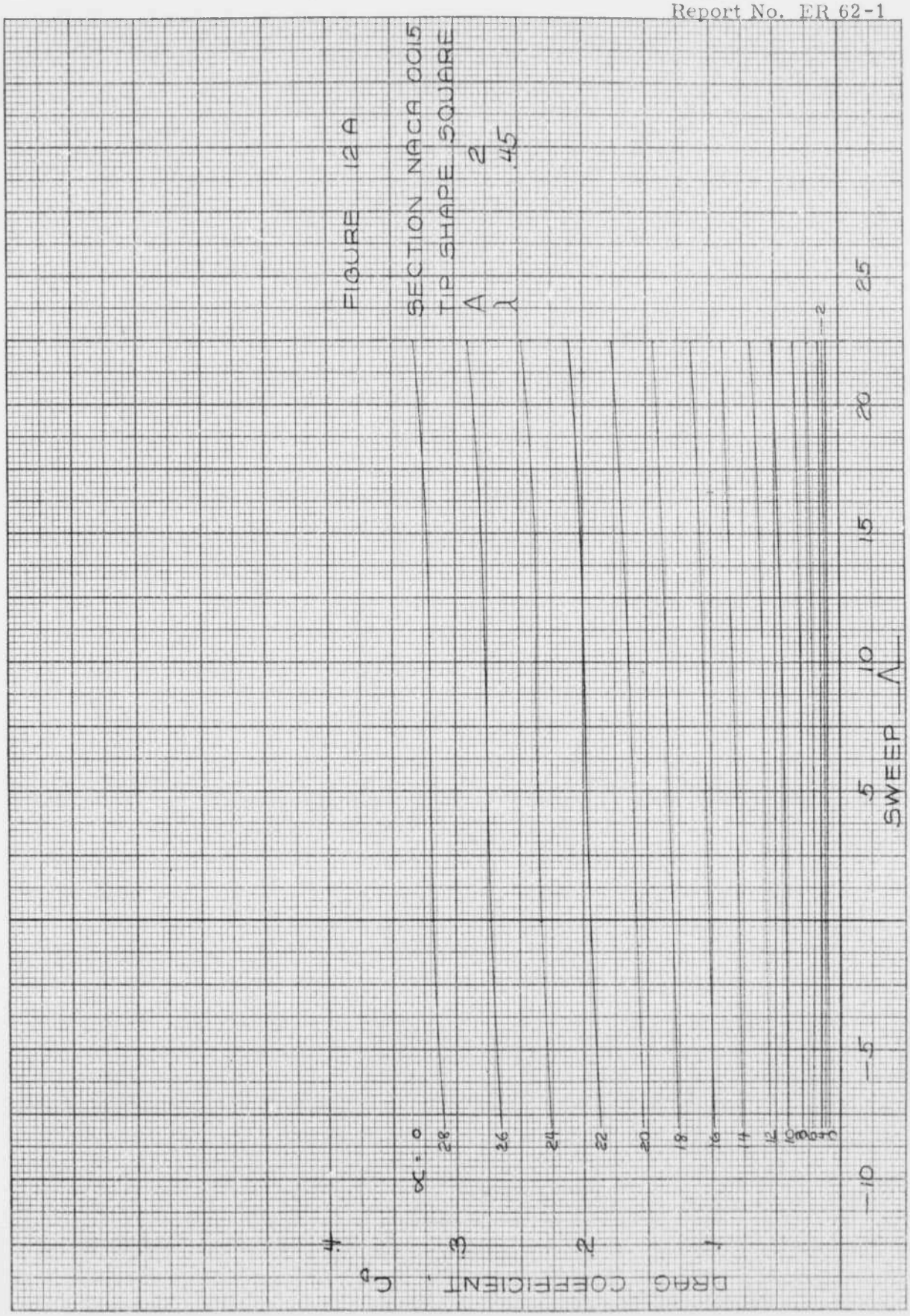


FIGURE 12A
SECTION NACA 0015
TIP SHAPE SQUARE
A 2
λ .45
DRAG COEFFICIENT C_D
SWEEP Λ
4
3
2
1
-10
-5
5
10
15
20
25
α: 0
28
26
24
22
20
18
16
14
12
10
8
6
-2

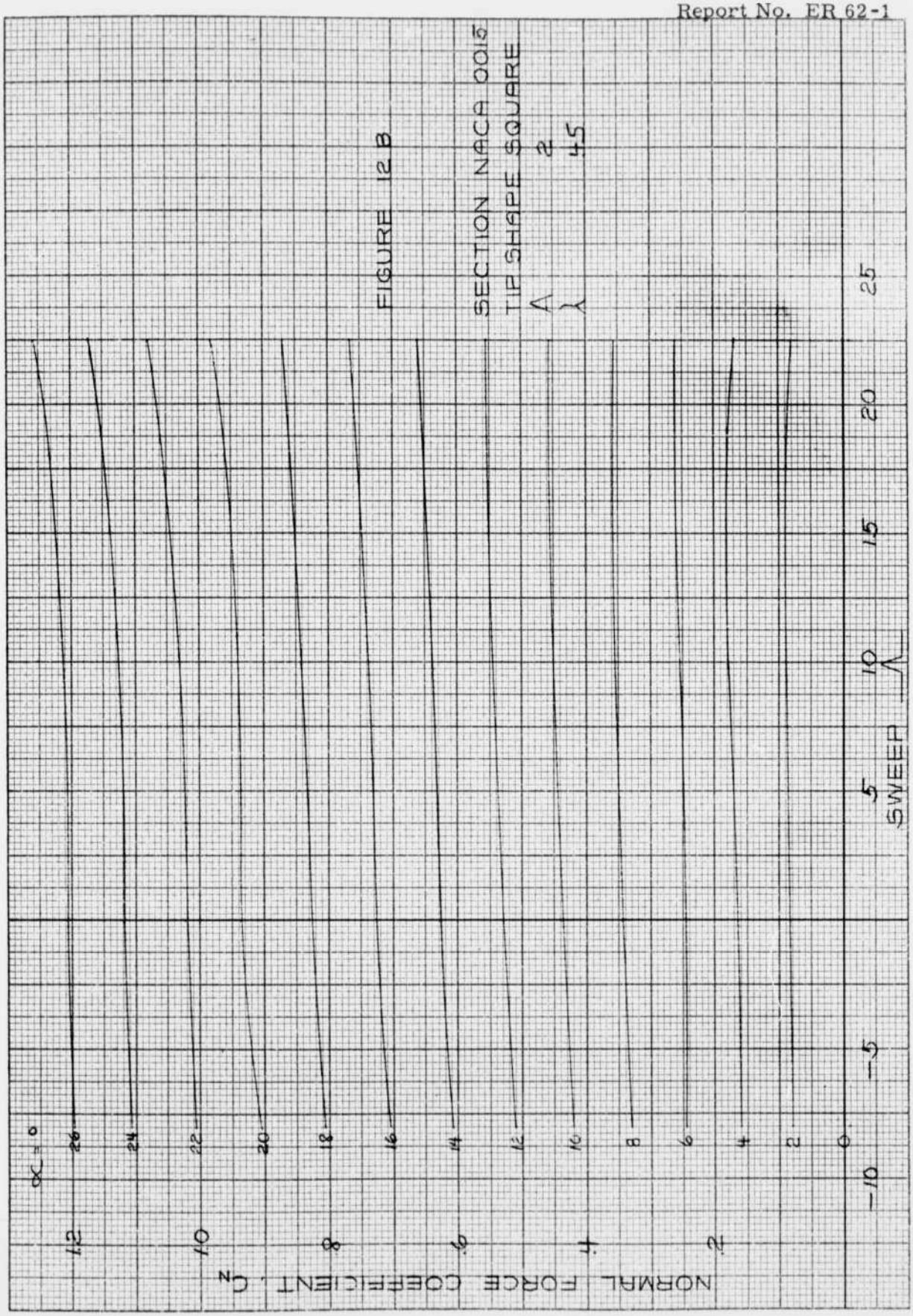


FIGURE 12 B
SECTION NACA 0016
TIP SHAPE SQUARE
Λ
λ
2
45
NORMAL FORCE COEFFICIENT, C_N
SWEEP Λ
$\alpha_c = 0$
-10
-5
0
5
10
15
20
25
2
4
6
8
10
12
14
16
18
20
22
24
26

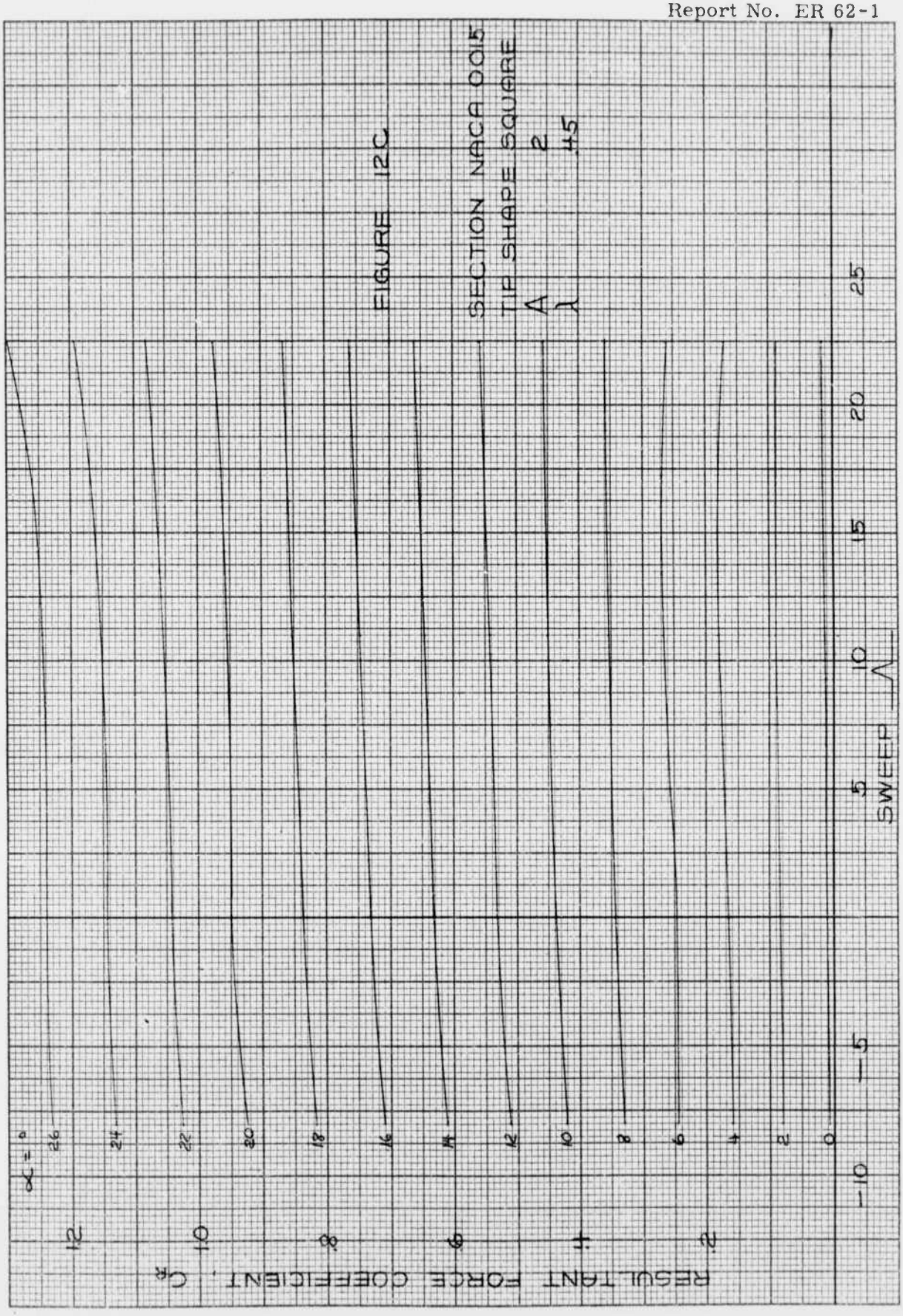


FIGURE 12C
SECTION NACA 0015
TIP SHAPE SQUARE
A 2
λ .45
RESULTANT FORCE COEFFICIENT, C_R
SWEEP Λ
α = °
26
24
22
20
18
16
14
12
10
8
6
4
2
0
-5
-10
5
10
15
20
25

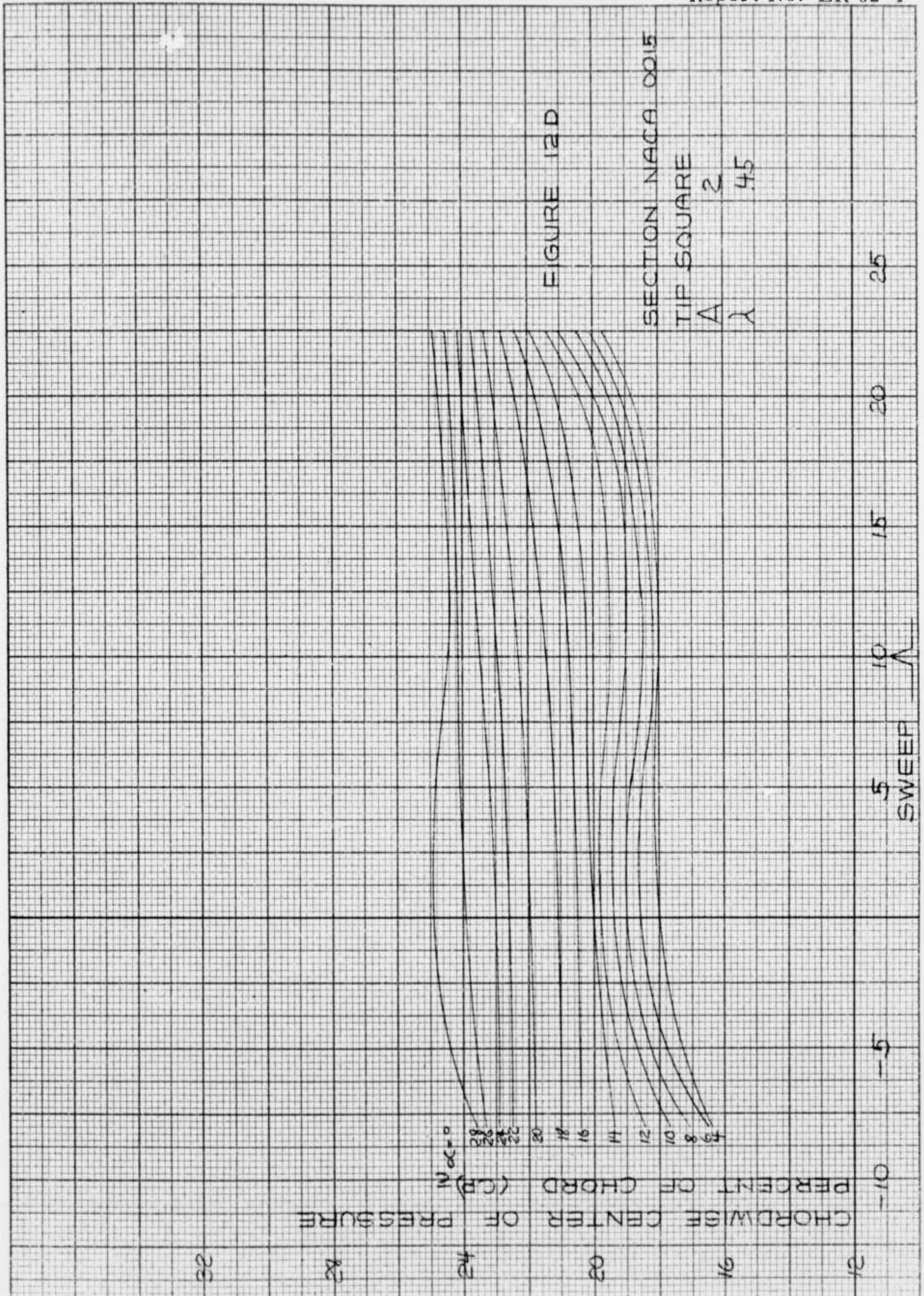


FIGURE 12D
SECTION NACA 0015
TIP SQUARE
A 2
λ 45
SWEEP Λ
-10
-5
5
10
15
20
25
CHORDWISE CENTER OF PRESSURE
PERCENT OF CHORD (CR)
α = 0
28
26
24
22
20
18
16
14
12
10
8
6
4
12
16
20
24
28
32

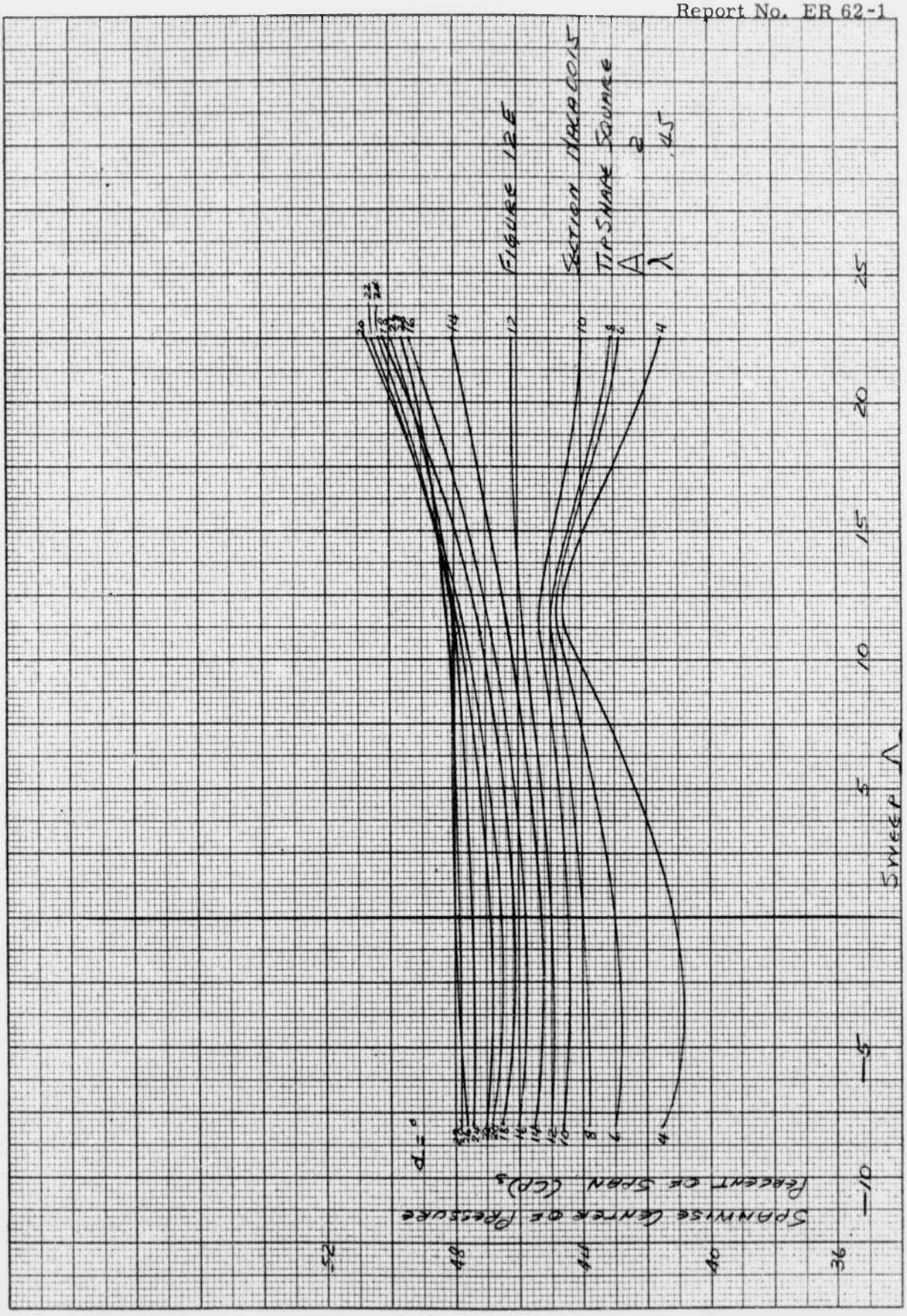


FIGURE 42E
SECTION DATA COILS
TIP SNARE SOURCE
Δ λ 45
2
SWEEP V
SPANWISE CENTRE OF PRESSURE
PERCENT OF SPAN (CP)s
α = °
52
48
44
40
36
10
5
0
5
10
15
20
25

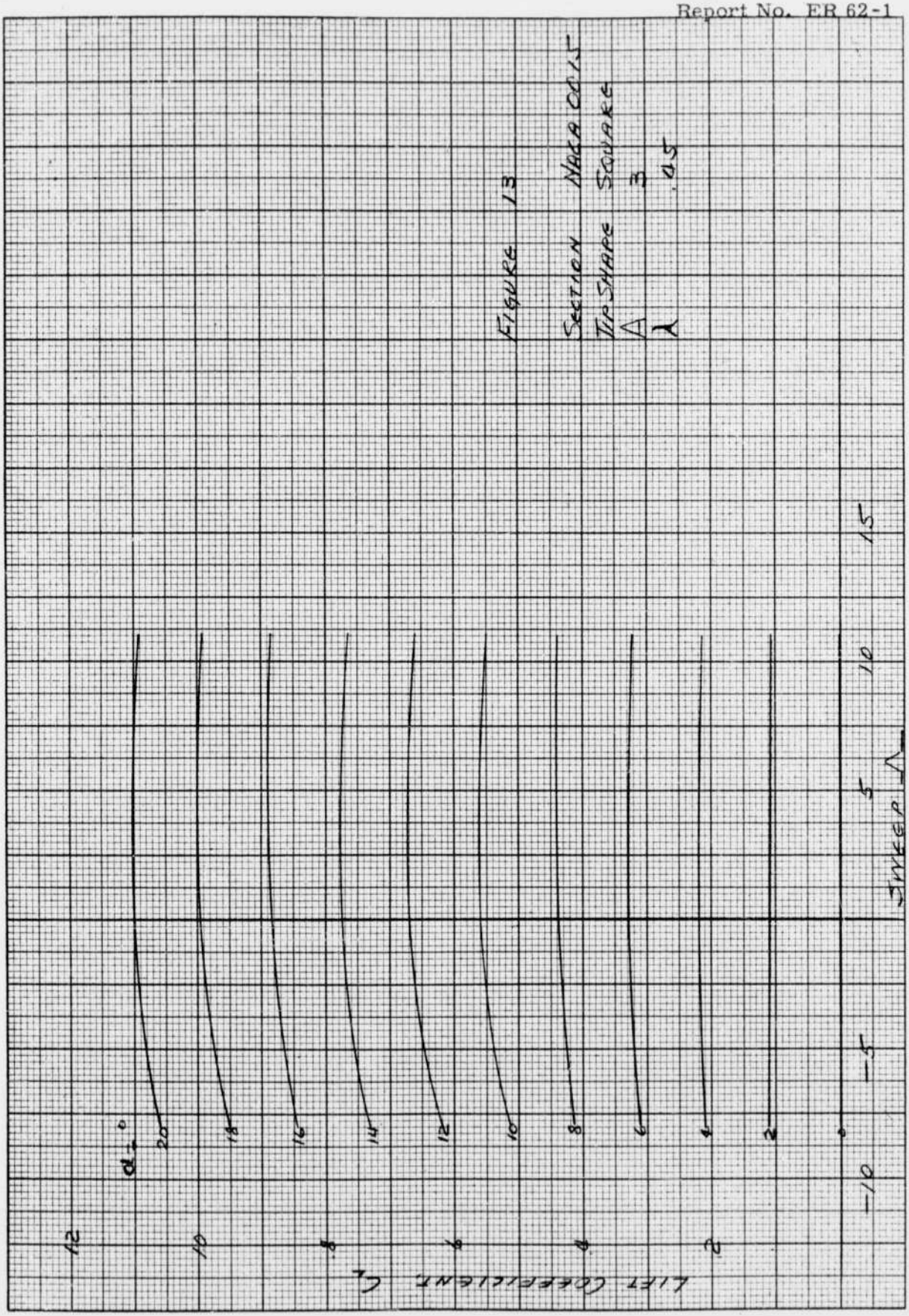
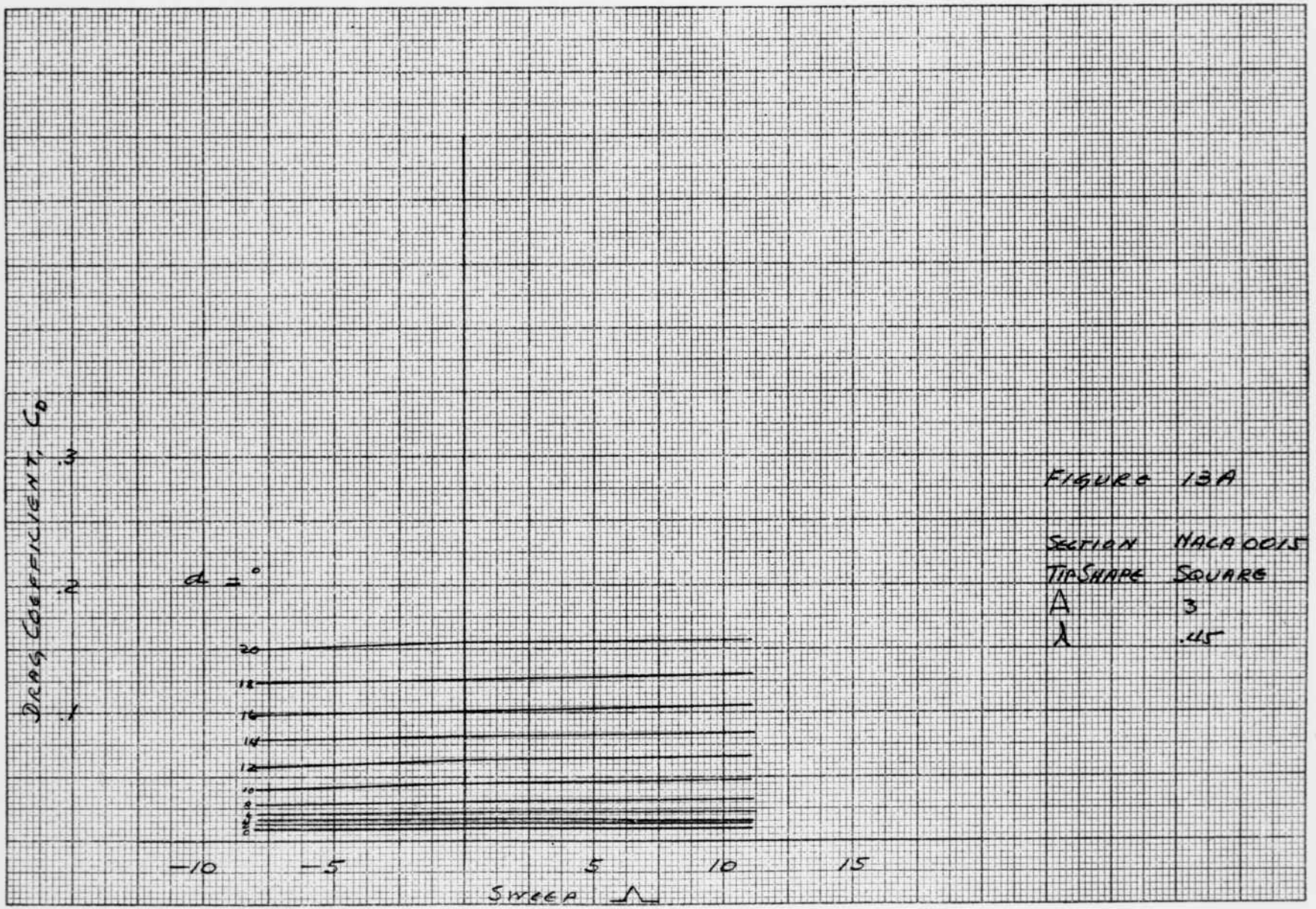


FIGURE 13
SECTION NACA 0015
TIP SHAPE SQUARE
A 3
λ .45
LIFT COEFFICIENT C_L
12
10
8
6
4
2
α_T°
20
18
16
14
12
10
8
6
4
2
0
-10
-5
0
5
10
15
SWEEP Λ


DRAG COEFFICIENT, C_D
.3
.2
.1
α = °
20
18
16
14
12
10
8
DES. α
−10
−5
5
10
15
SWEEP Λ
FIGURE 13A
SECTION NACA 0015
TIP SHAPE SQUARE
A 3
λ .45

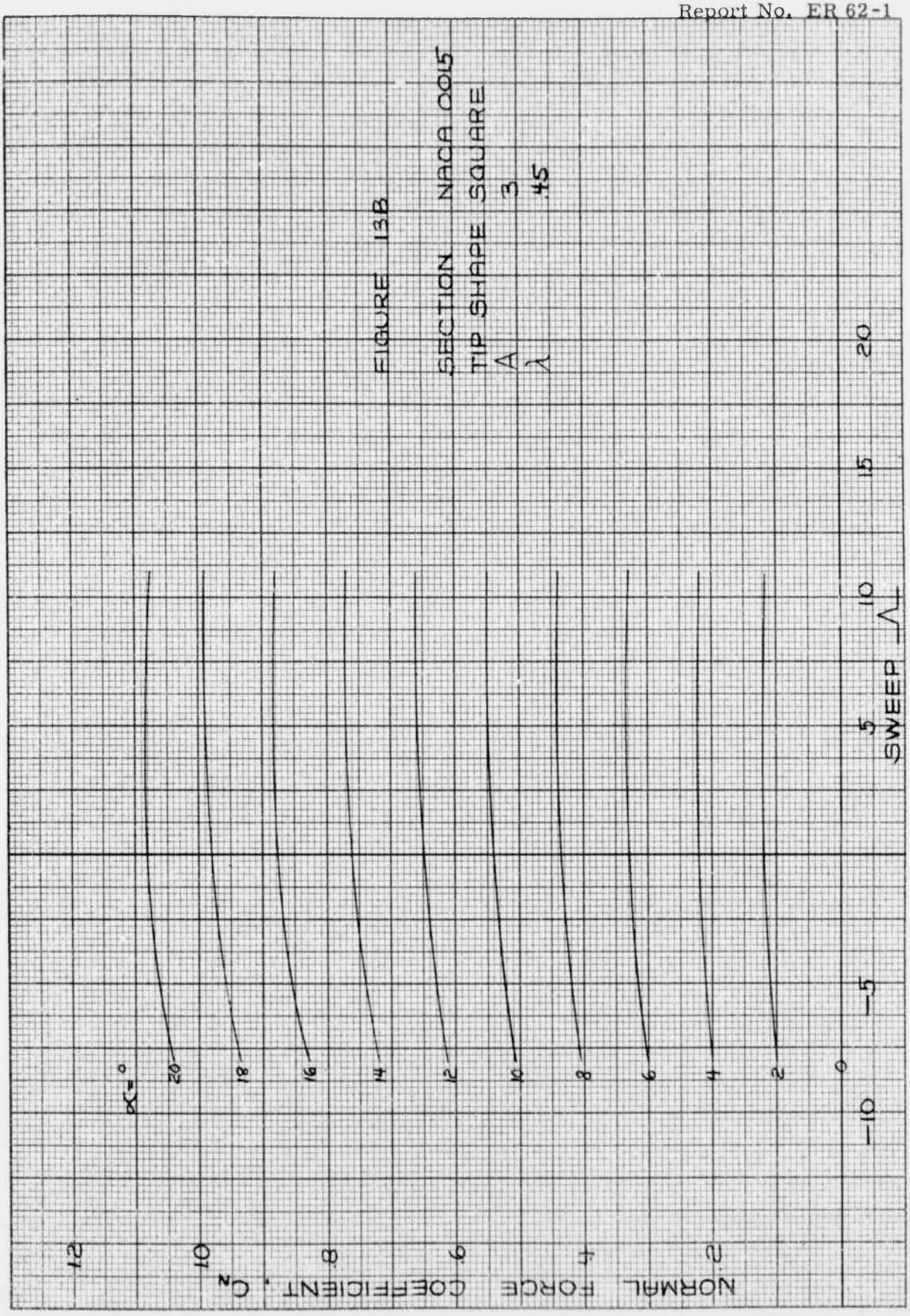


FIGURE 13B
SECTION NACA 0015
TIP SHAPE SQUARE
A 3
λ .45
NORMAL FORCE COEFFICIENT, C_{N_A}
SWEEP $\Lambda_{\frac{1}{4}}$
α = °
20
18
16
14
12
10
8
6
4
2
0
-5
-10
5
10
15
20
.2
.4
.6
.8
1.0
1.2

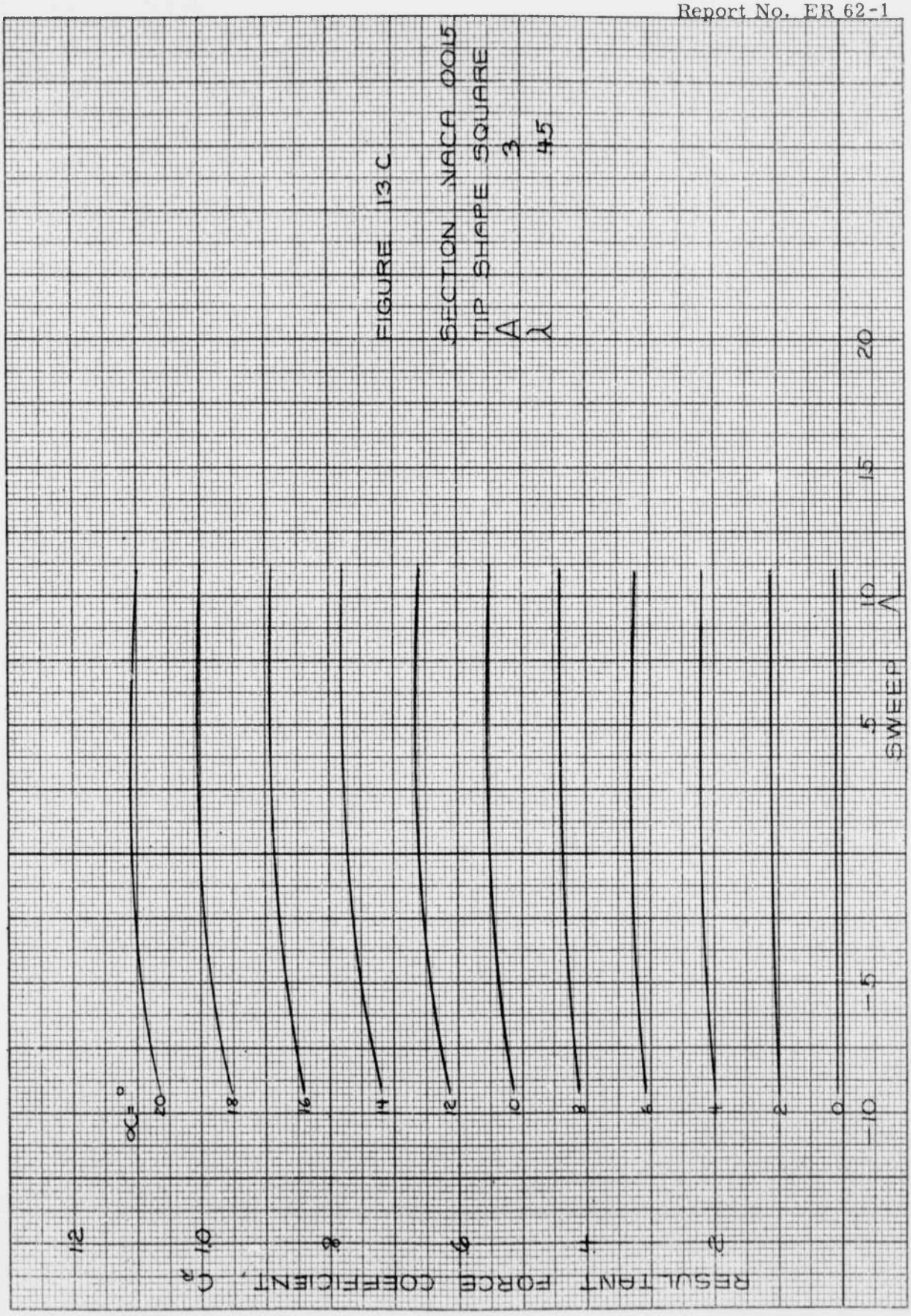


FIGURE 13 C
SECTION NACA 0015
TIP SHAPE SQUARE
A 3
λ 45
RESULTANT FORCE COEFFICIENT C_R
SWEEP Λ
α_c = °
20
18
16
14
12
10
8
6
4
2
0
12
10
8
6
4
2
20
15
10
5
-5
-10

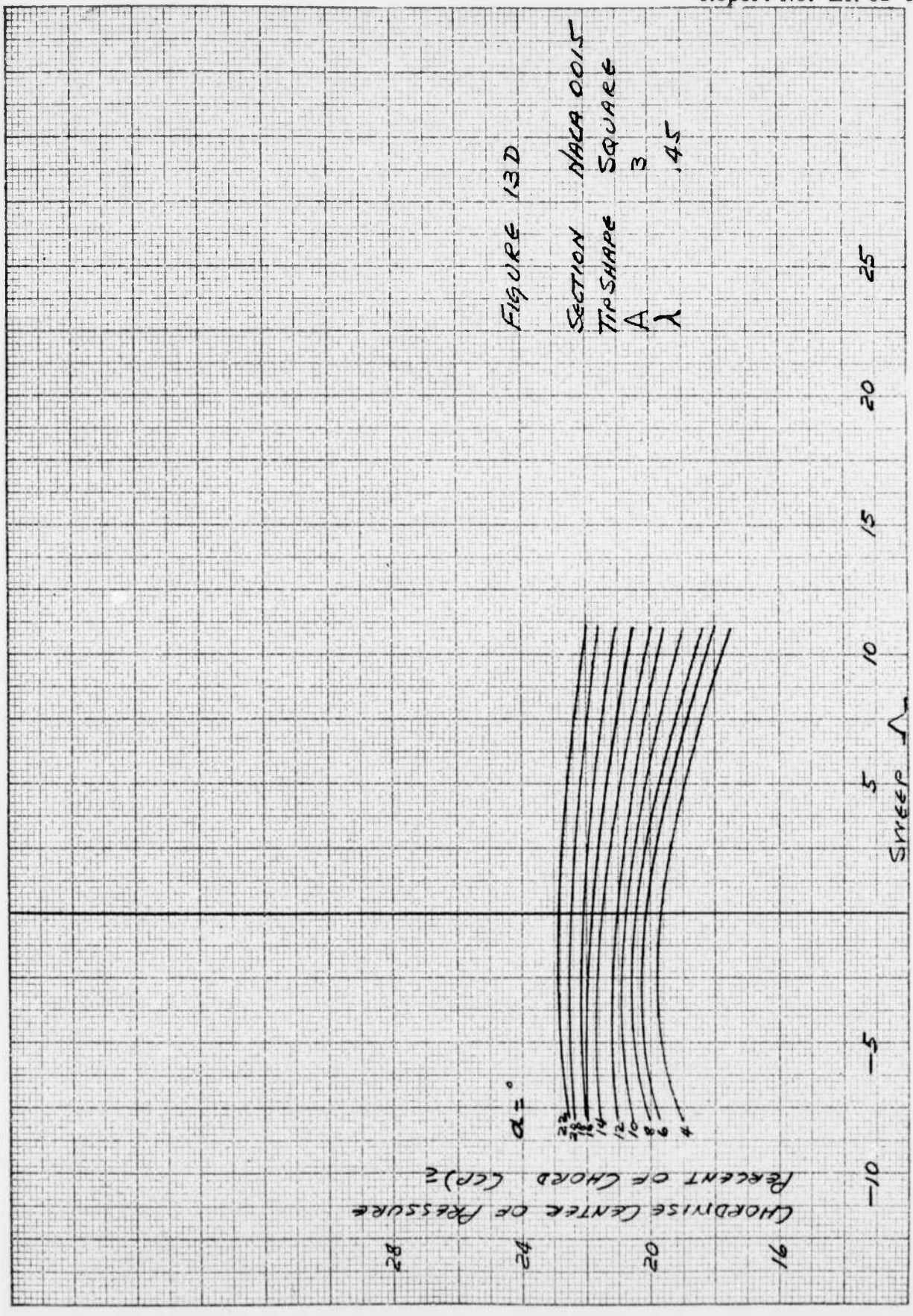
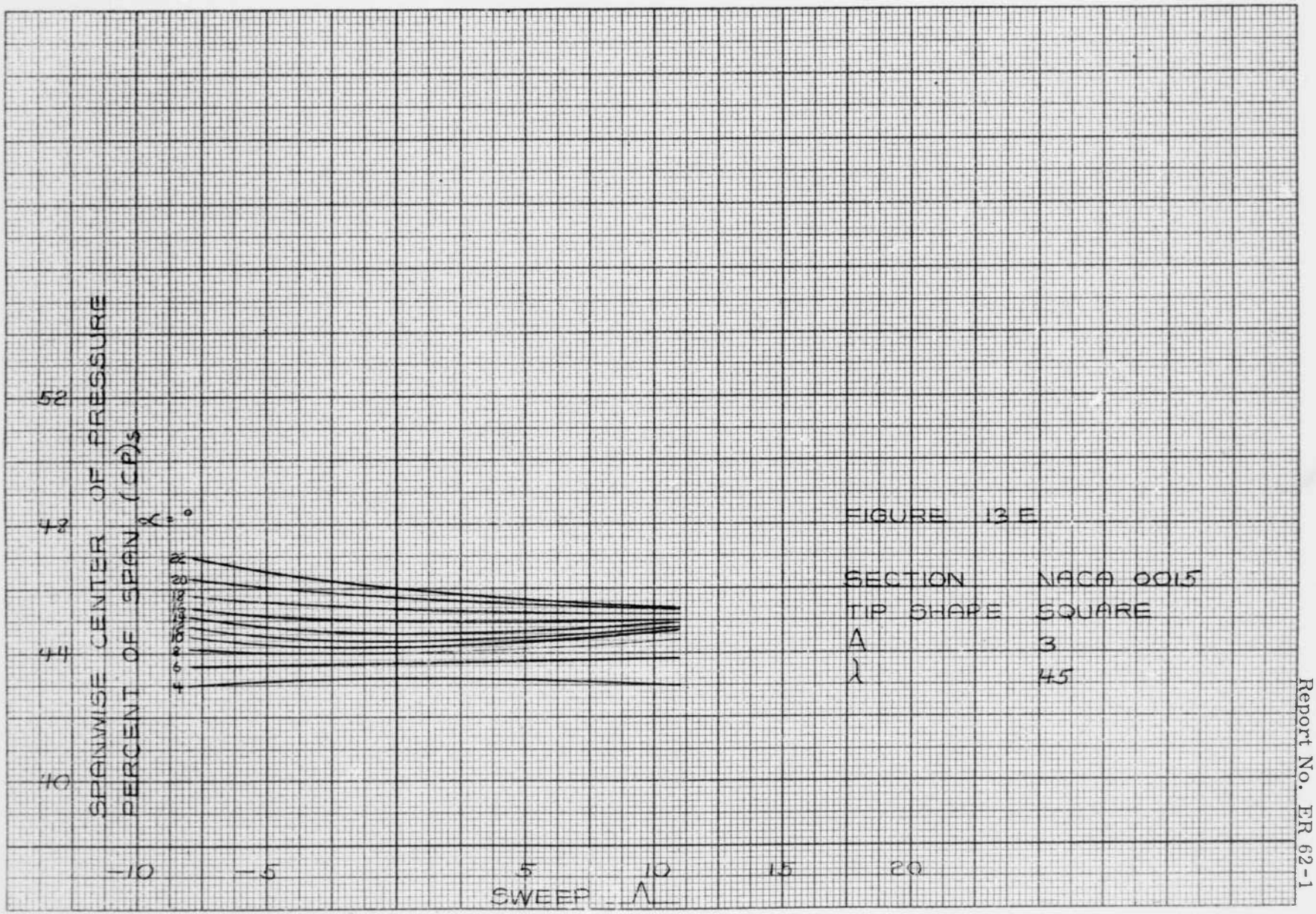


FIGURE 13D
SECTION NACA 0015
TIP SHAPE SQUARE
A 3
λ .45
α = °
22
18
14
12
10
8
6
4
CHORDWISE CENTRE OF PRESSURE
PERCENT OF CHORD (cp)c
28
24
20
16
-10
-5
5
10
15
20
25
SWEEP


SPANWISE CENTER OF PRESSURE
PERCENT OF SPAN (CP)s
52
48
44
40
α°
20
15
10
8
6
4
-10
-5
5
10
15
20
SWEEP Λ
FIGURE 13 E
SECTION NACA 0015
TIP SHAPE SQUARE
Λ 3
λ 45

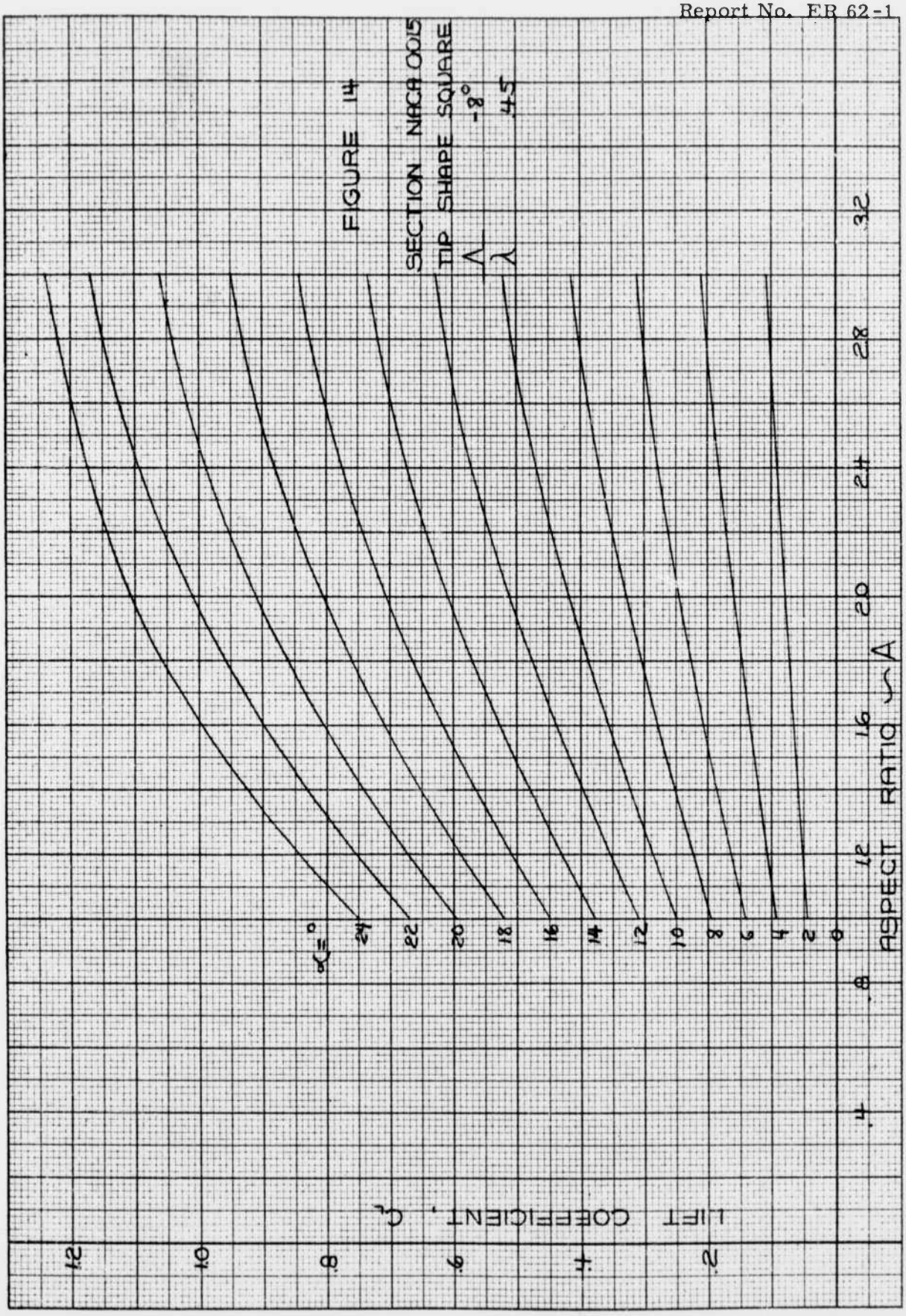


FIGURE 14
SECTION NACA 0015
TIP SHAPE SQUARE
-8°
45
λ
LIFT COEFFICIENT, C_L
ASPECT RATIO A
α = 0°
24
22
20
18
16
14
12
10
8
7
6
4
2
0
4
8
12
16
20
24
28
32
.2
.4
.6
.8
1.0
1.2

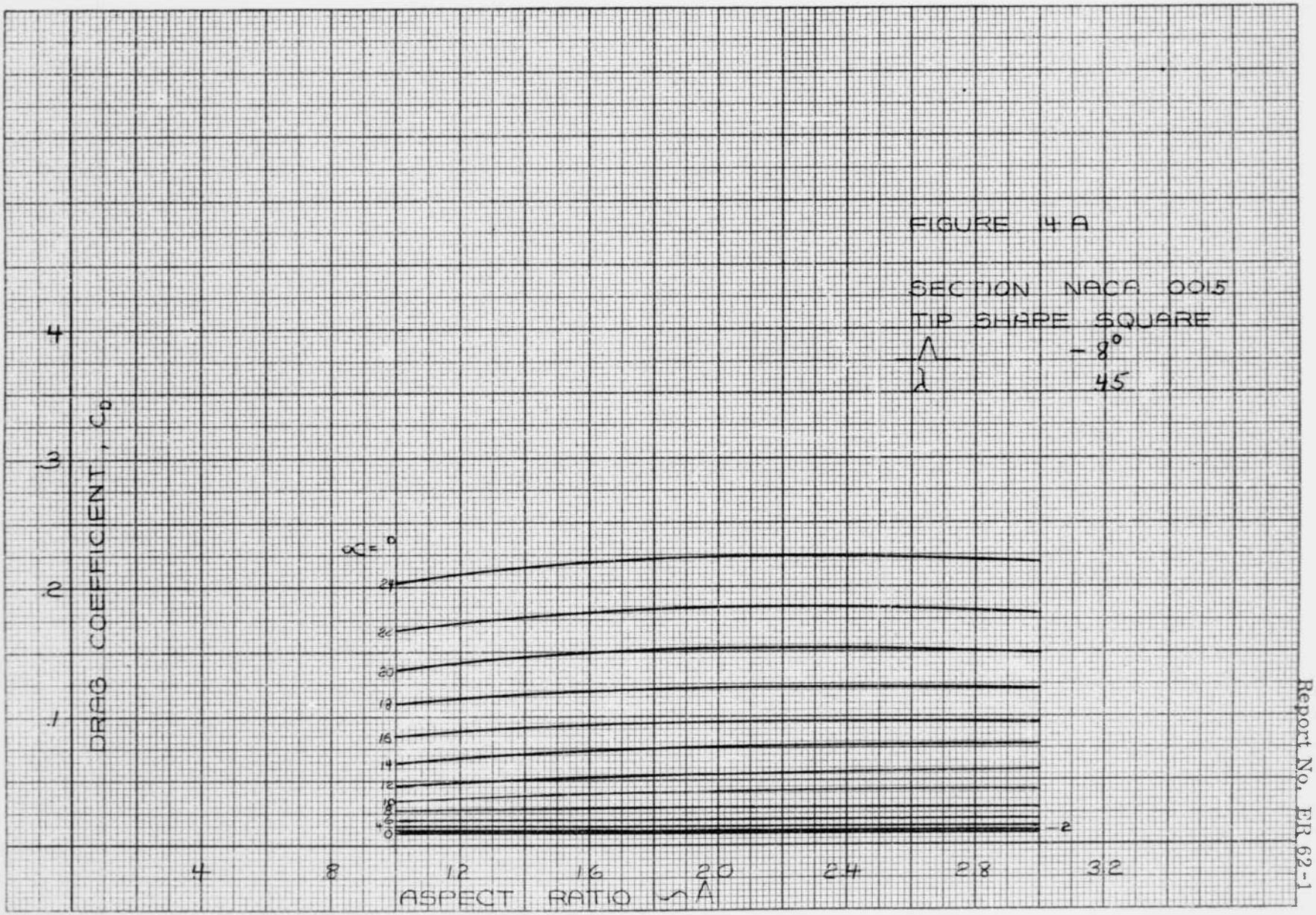


FIGURE 14 A
SECTION NACA 0015
TIP SHAPE SQUARE
Λ
λ
-8°
45
DRAG COEFFICIENT, C_D
ASPECT RATIO A
4
3
2
1
4
8
12
16
20
24
28
32
-2

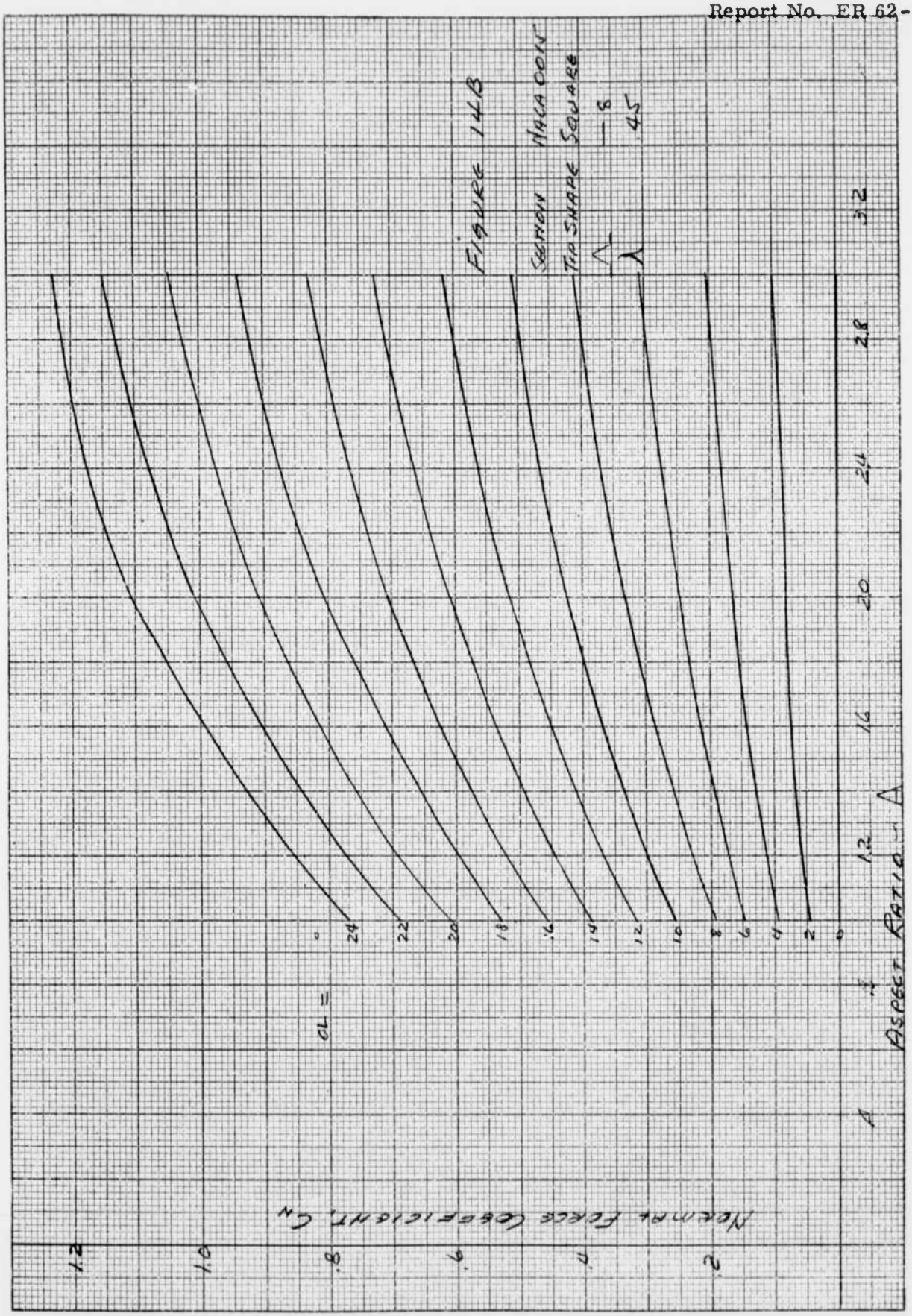


FIGURE 14B
SERMAN NACA 0015
TAPERED SQUARE
Λ
λ
= 8
45
NORMAL FORCE COEFFICIENT C_N
ASPECT RATIO = A
α_L = 0
24
22
20
18
16
14
12
10
8
6
4
2
0
1.2
1.0
.8
.6
.4
.2
4
8
12
16
20
24
28
32

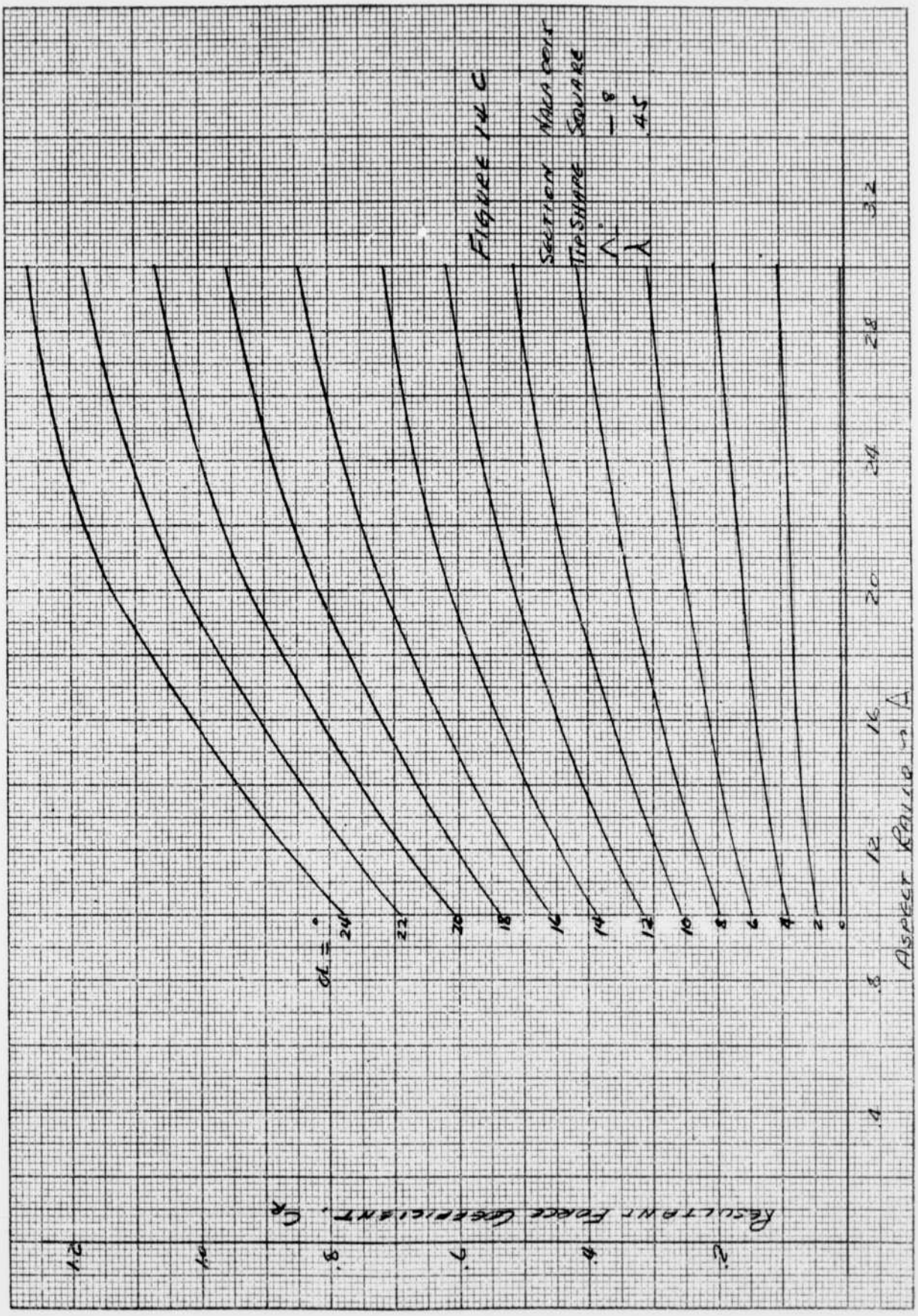
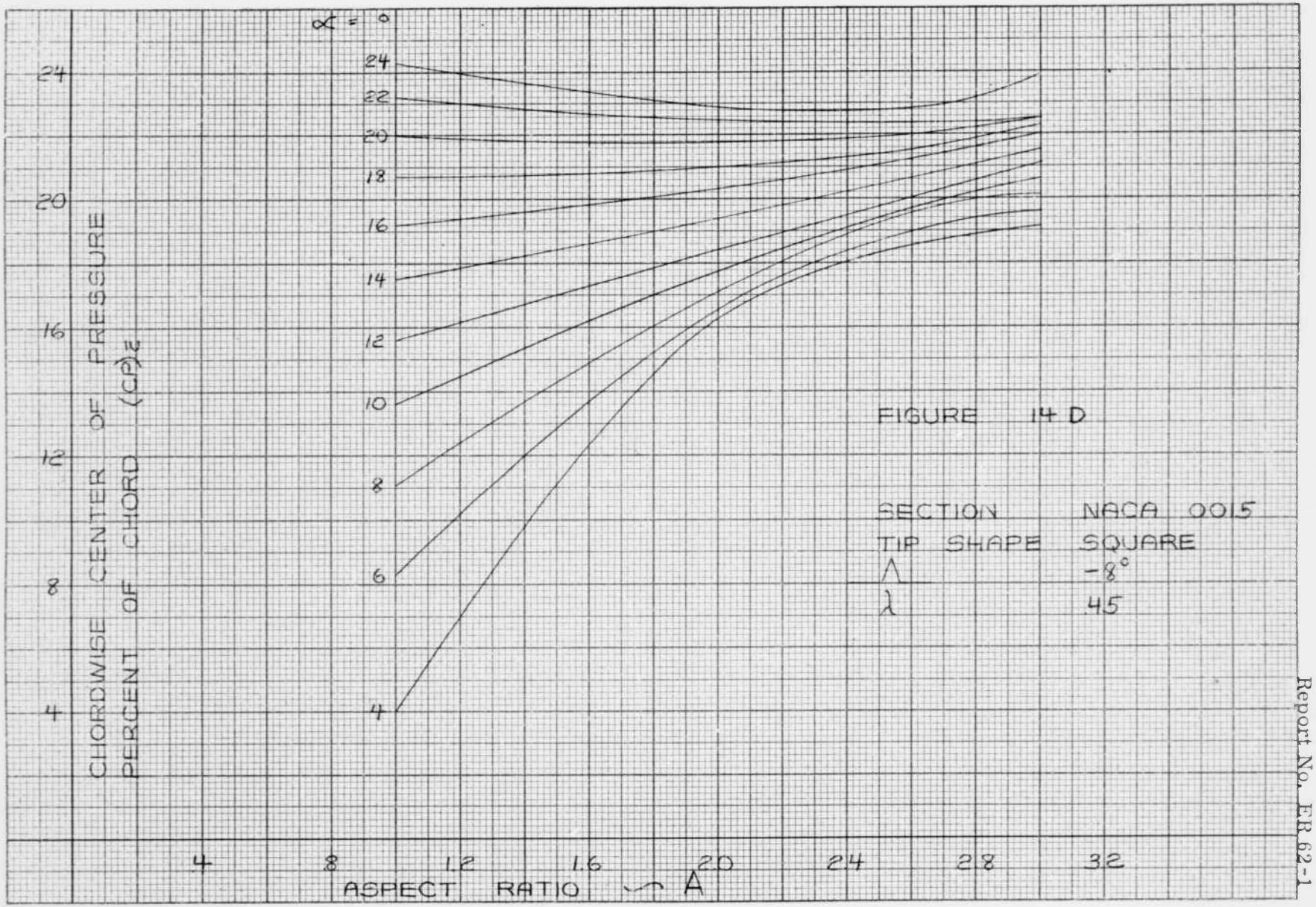


FIGURE 14 C
SECTION NACA 64012
TIP SHAPE SQUARE
Λ°
-8
45
RESULTANT FORCE COEFFICIENT, C_R
ASPECT RATIO Λ
$\alpha_t = 0°$
24
22
20
18
16
14
12
10
8
6
4
2
0
1.2
1.0
.8
.6
.4
.2
4
8
12
16
20
24
28
32


α = 0
24
22
20
18
16
14
12
10
8
6
4
CHORDWISE CENTER OF PRESSURE
PERCENT OF CHORD (cp)/c
24
20
16
12
8
4
4
8
1.2
1.6
2.0
2.4
2.8
3.2
ASPECT RATIO
A
FIGURE 14 D
SECTION NACA 0015
TIP SHAPE SQUARE
Λ -8°
λ .45

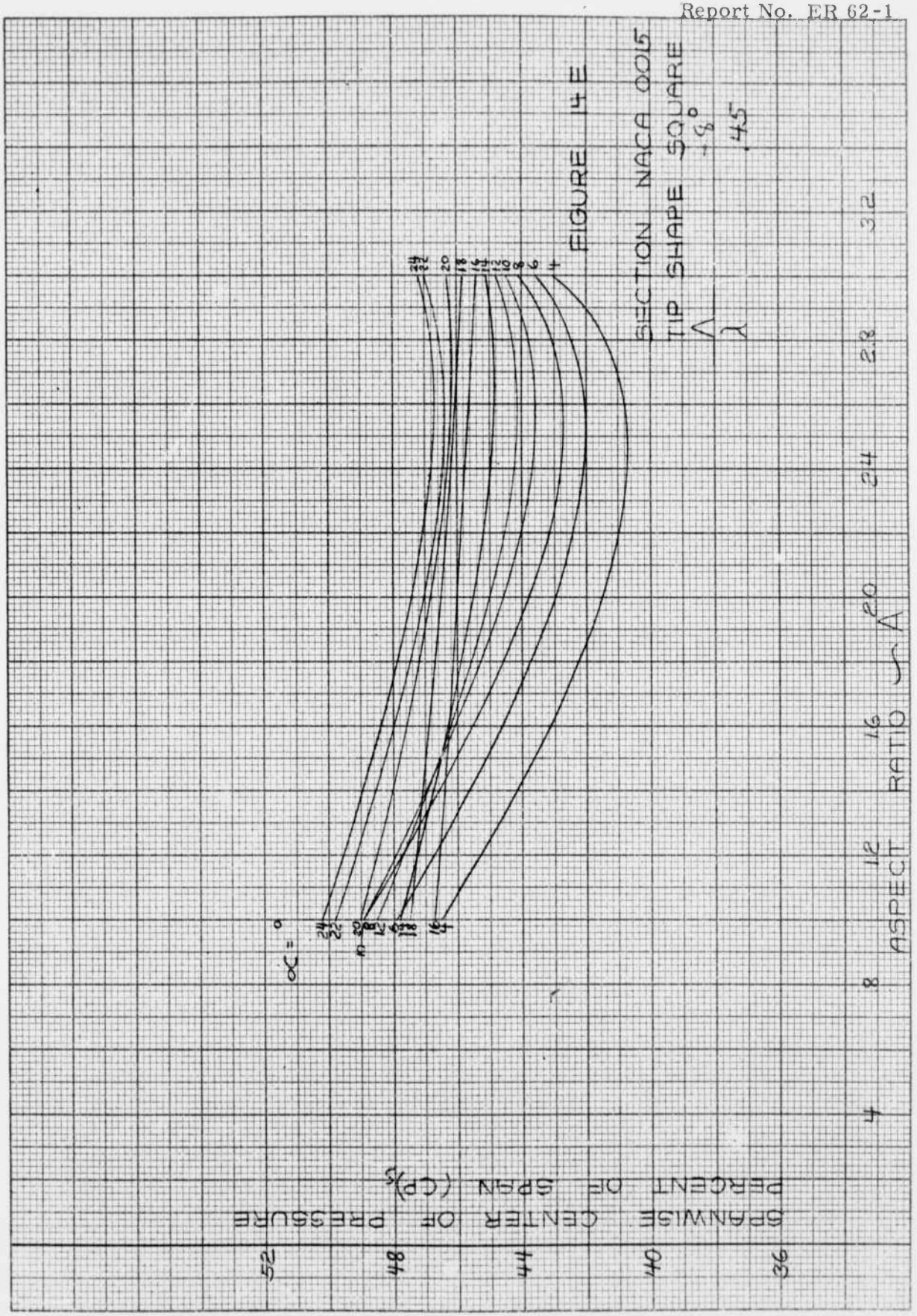


FIGURE 4E
SECTION NACA 0015
TIP SHAPE SQUARE
Λ
λ
+8°
.45
SPANWISE CENTER OF PRESSURE
PERCENT OF SPAN (CP)½
ASPECT RATIO Λ
4
8
12
16
20
24
28
32
36
40
44
48
52
α = 0
24
22
20
18
16
14
12
10
8
6
4

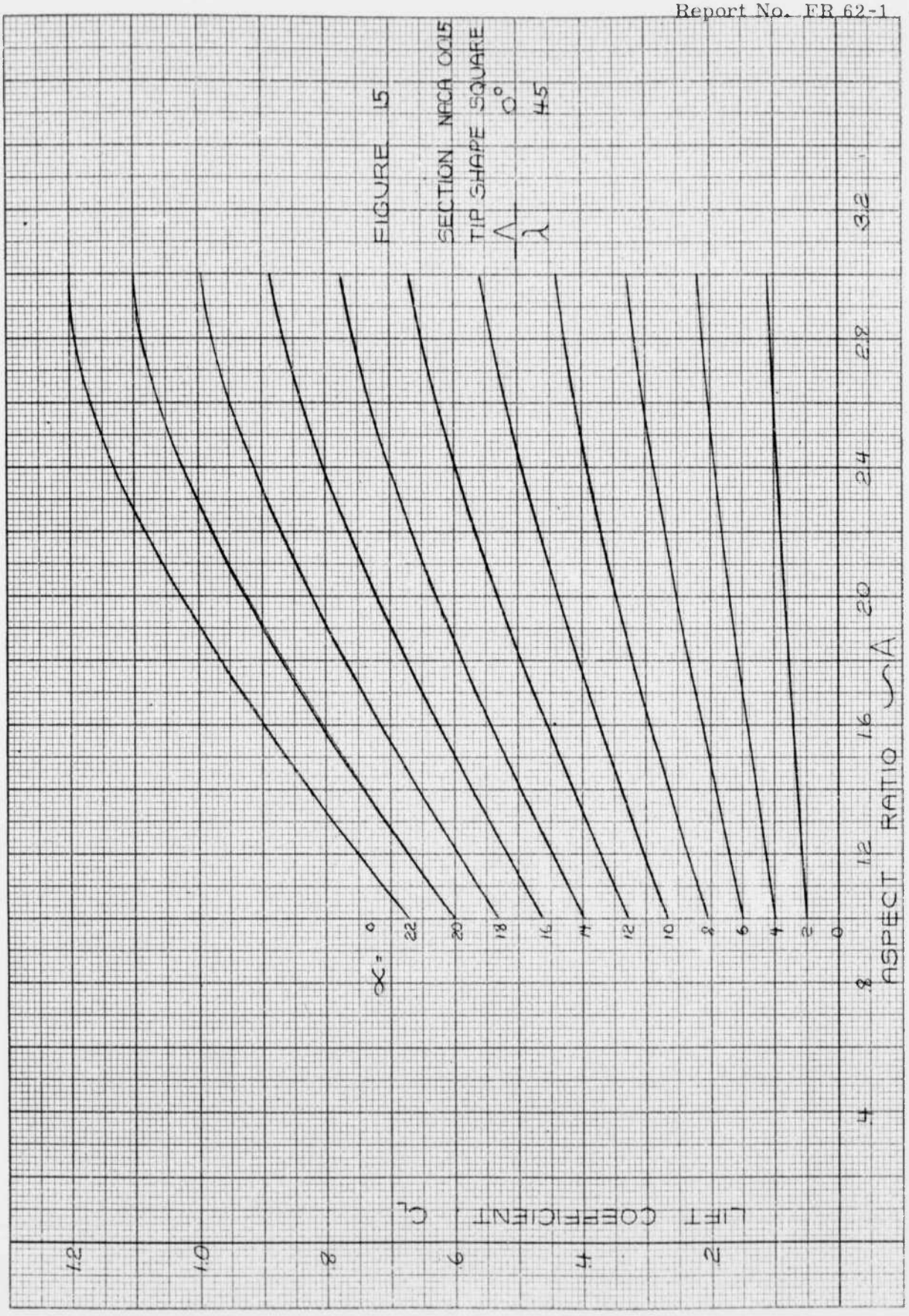


FIGURE 15
SECTION NACA 0015
TIP SHAPE SQUARE
Λ 0°
λ 45
LIFT COEFFICIENT C_L
ASPECT RATIO $\frac{b^2}{A}$
α = 0
22
20
18
16
14
12
10
8
6
4
2
0
1.2
1.0
.8
.6
.4
.2
4
8
12
16
20
24
28
32

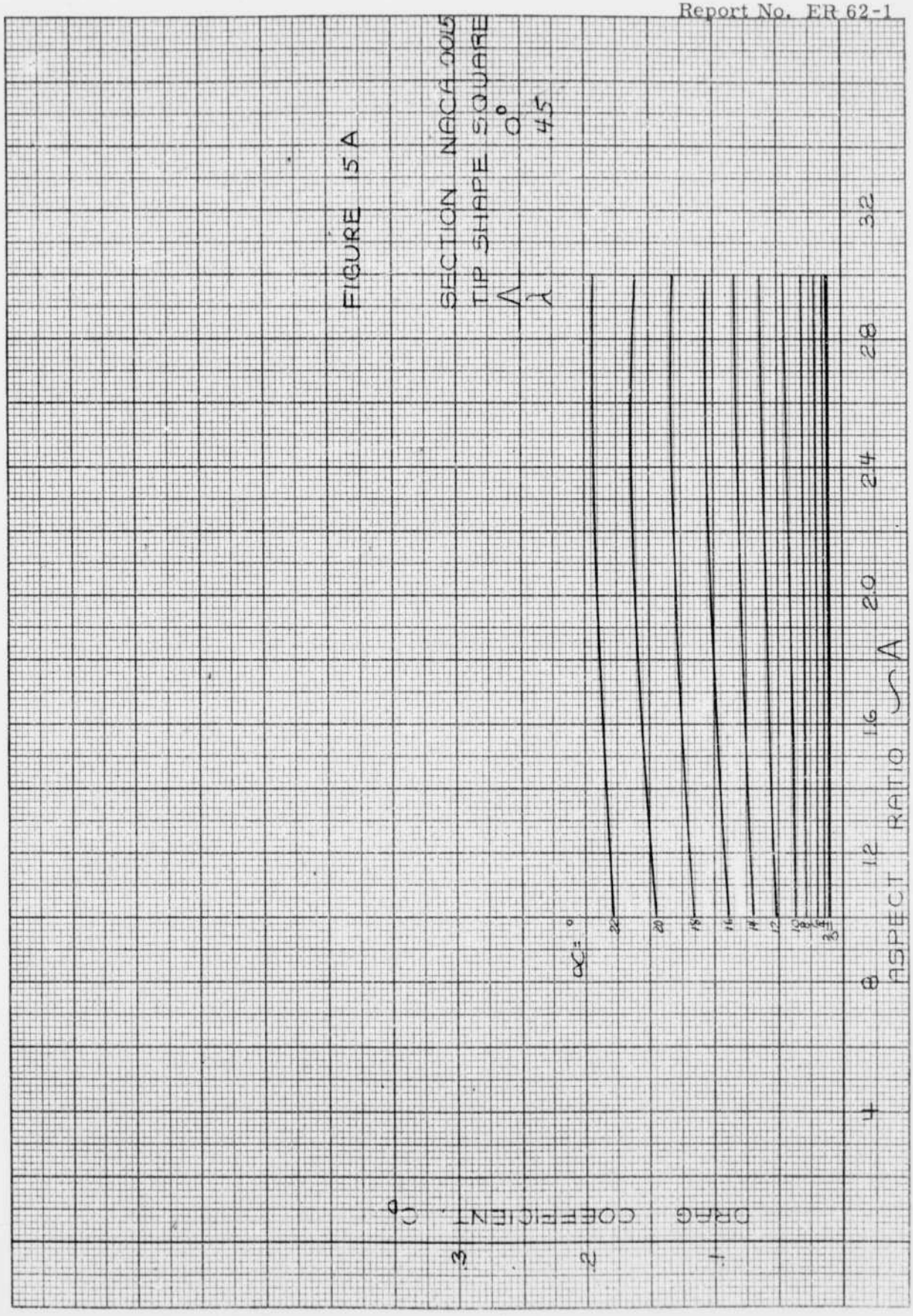


FIGURE 15 A
SECTION NACA 005
TIP SHAPE SQUARE
Λ 0°
λ 45
DRAG COEFFICIENT, C_D
ASPECT RATIO $\frac{b^2}{S}$ A
0
4
8
12
16
20
24
28
32
1
2
3
α°
22
20
18
16
14
12
10
8
6
4
2

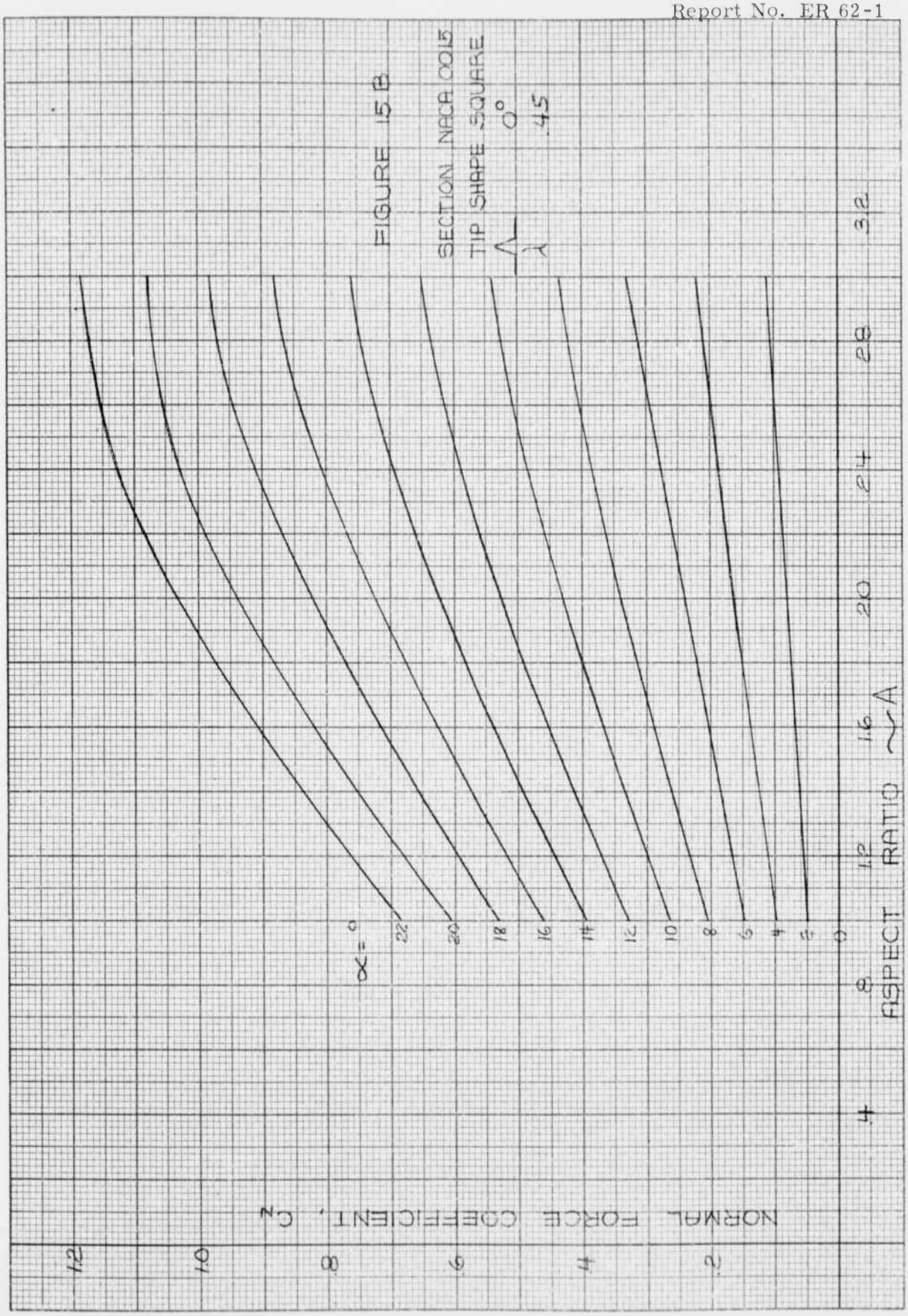


FIGURE 15 B
SECTION NACA 0015
TIP SHAPE SQUARE
0°
45
NORMAL FORCE COEFFICIENT, C_N
ASPECT RATIO $\sim A$
α= 0
22
20
18
16
14
12
10
8
6
4
2
0
4
8
12
16
20
24
28
32
12
10
8
6
4
2

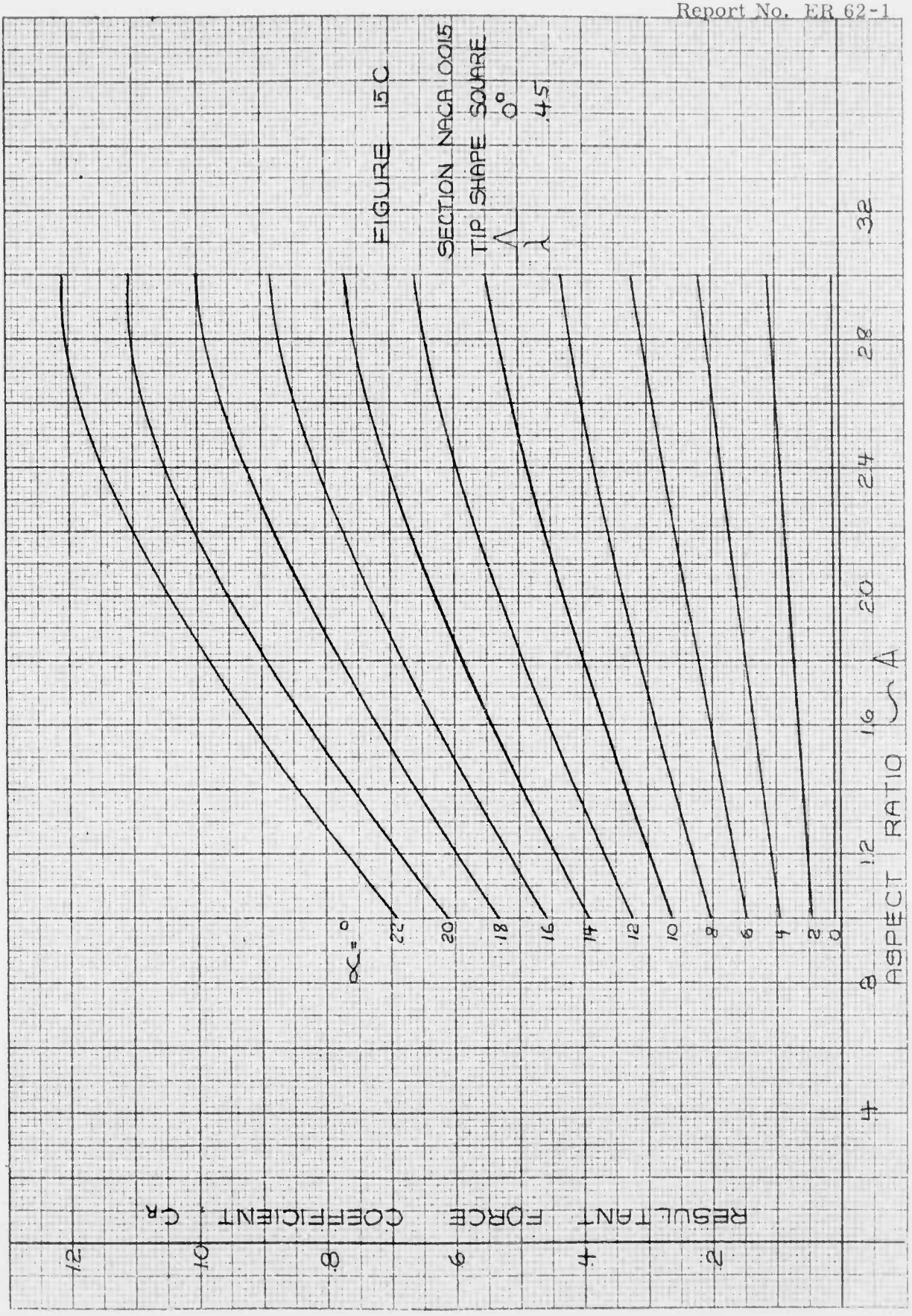
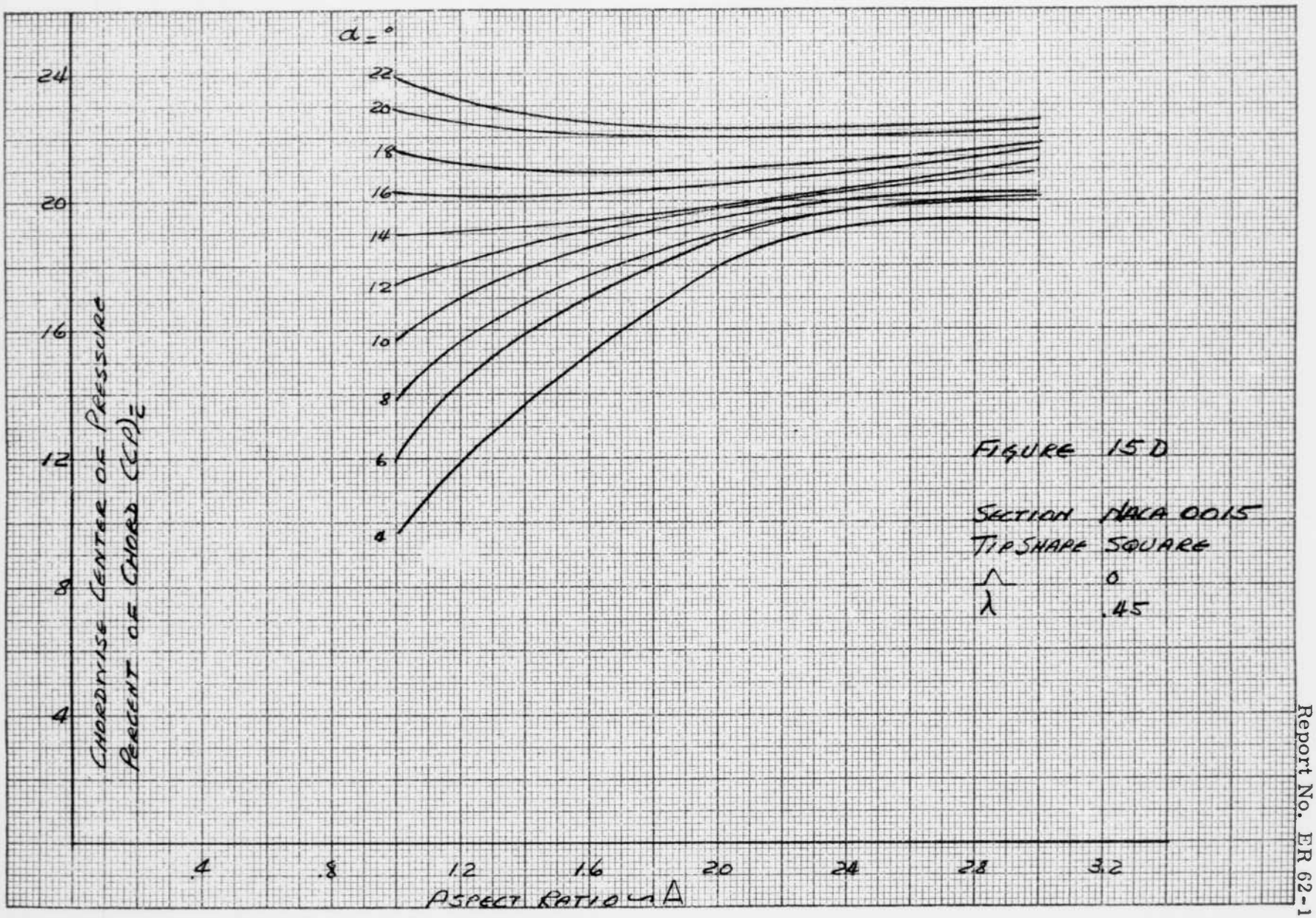


FIGURE 15 C
SECTION NACA 0015
TIP SHAPE SQUARE
0°
45°
RESULTANT FORCE COEFFICIENT C_R
ASPECT RATIO $\frac{b}{c}$
α = °
22
20
18
16
14
12
10
8
6
4
2
0
12
10
8
6
4
2
4
8
12
16
20
24
28
32


α = °
22
20
18
16
14
12
10
8
6
4
24
20
16
12
8
4
CHORDWISE CENTRE OF PRESSURE
PERCENT OF CHORD (CP)c
.4
.8
1.2
1.6
2.0
2.4
2.8
3.2
ASPECT RATIO A
FIGURE 15 D
SECTION NACA 0015
TIP SHAPE SQUARE
Λ 0
λ .45

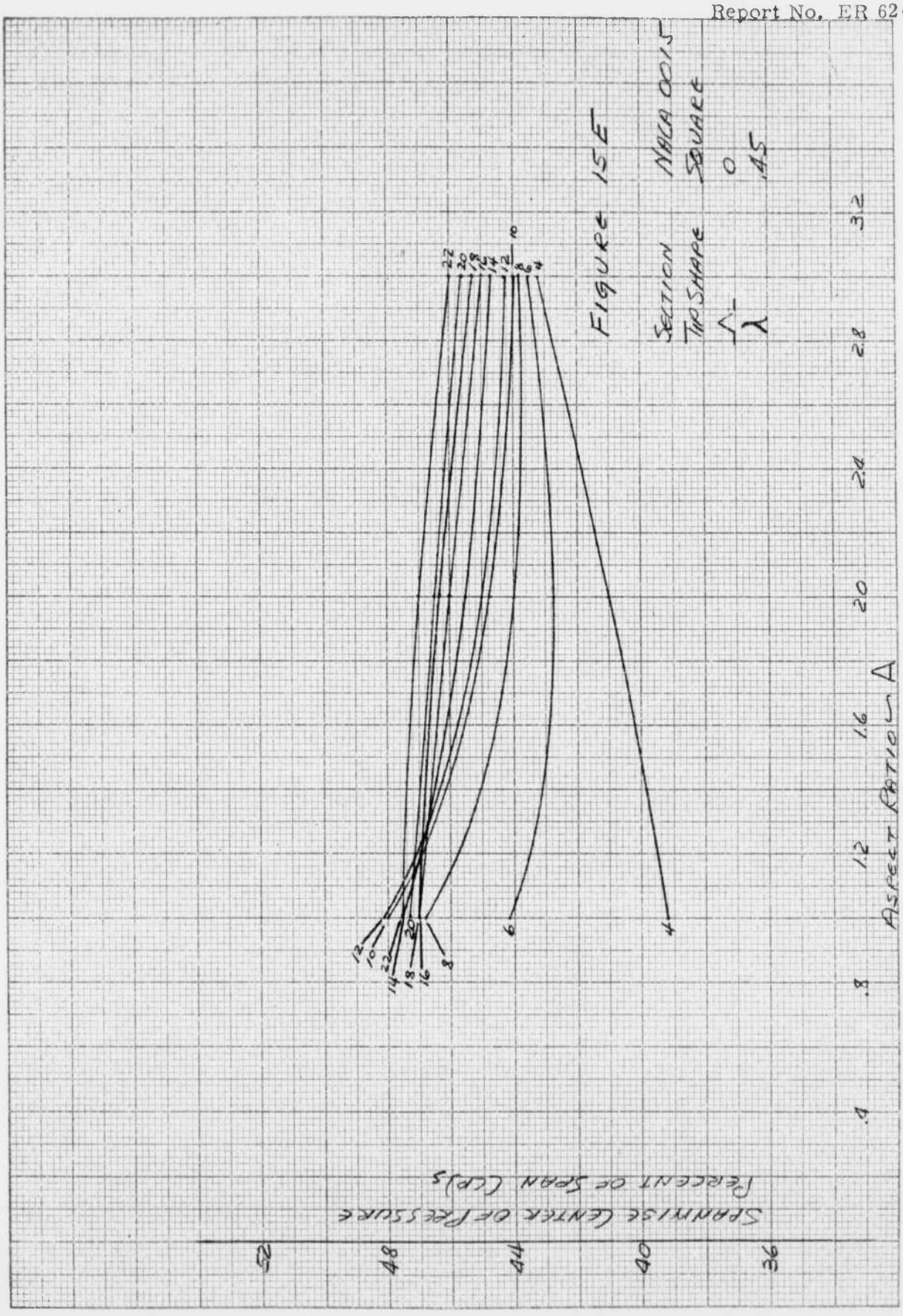


FIGURE 15E
SECTION NACA 0015
TIP SHAPE SQUARE
Λ 0
λ .45
SPANWISE CENTER OF PRESSURE
PERCENT OF SPAN (CP)s
ASPECT RATIO A
52
48
44
40
36
.4
.8
1.2
1.6
2.0
2.8
3.2
22
20
18
16
14
12
10
8
6
4

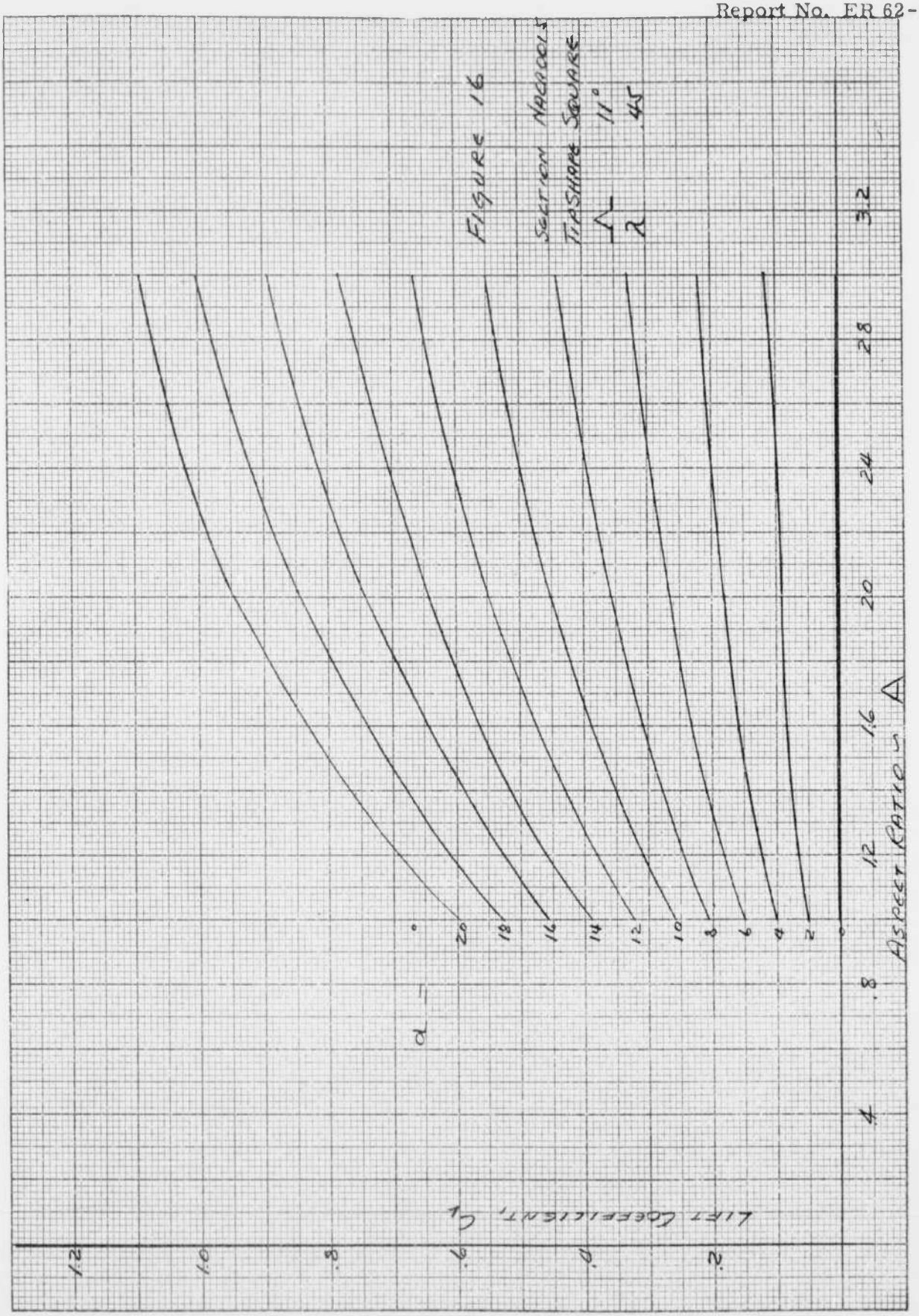


FIGURE 16
SECTION NACA 0012
TIP SHAPE SQUARE
11°
45
ASPECT RATIO Λ
LIFT COEFFICIENT, C_L
α =
0
2
4
6
8
10
12
14
16
18
20
.4
.8
1.2
1.6
2.0
2.4
2.8
3.2
-.2
0.
.2
.4
.6
.8
1.0
1.2

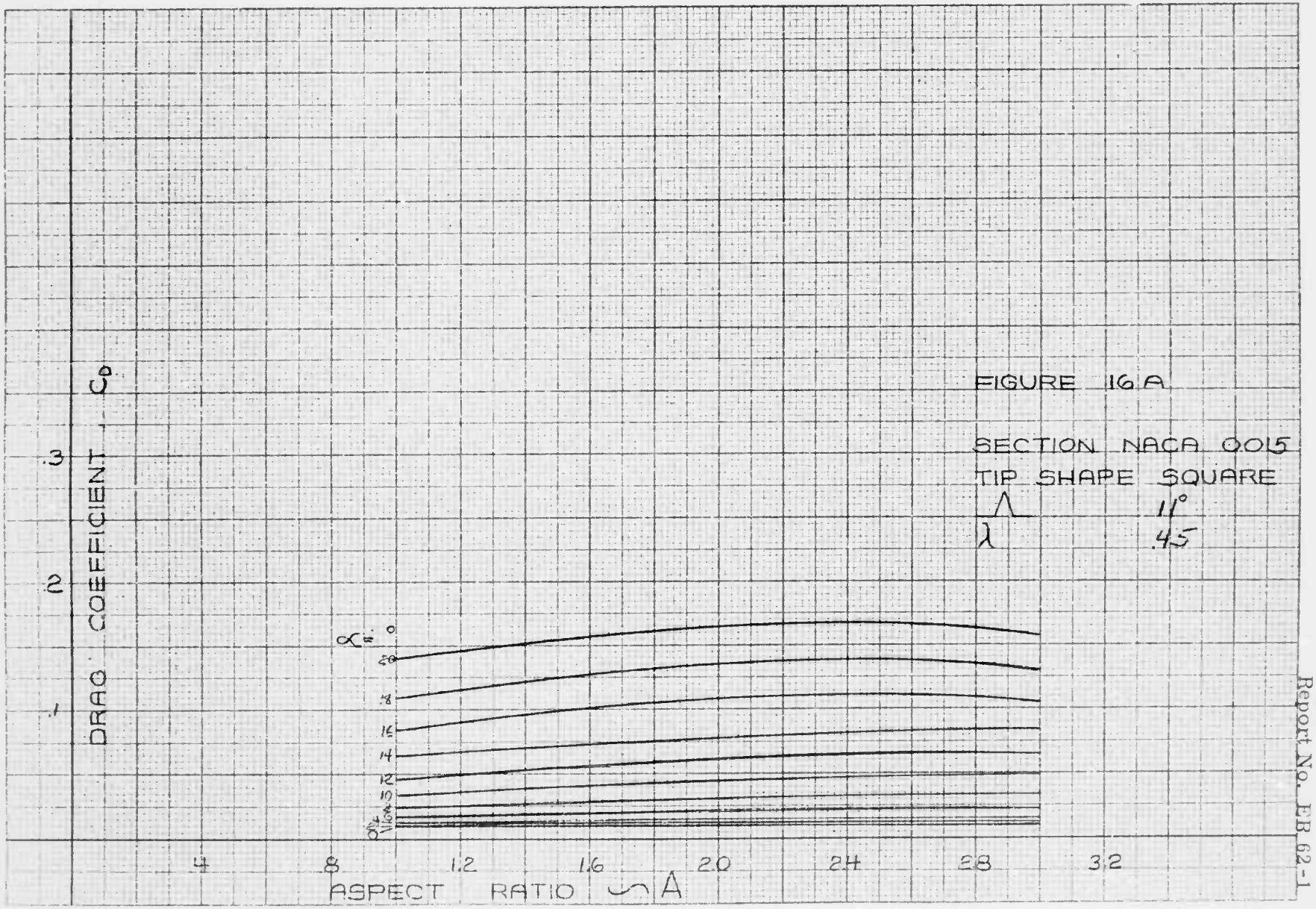


FIGURE 16 A

SECTION NACA 0015
TIP SHAPE SQUARE
Λ 11°
λ .45

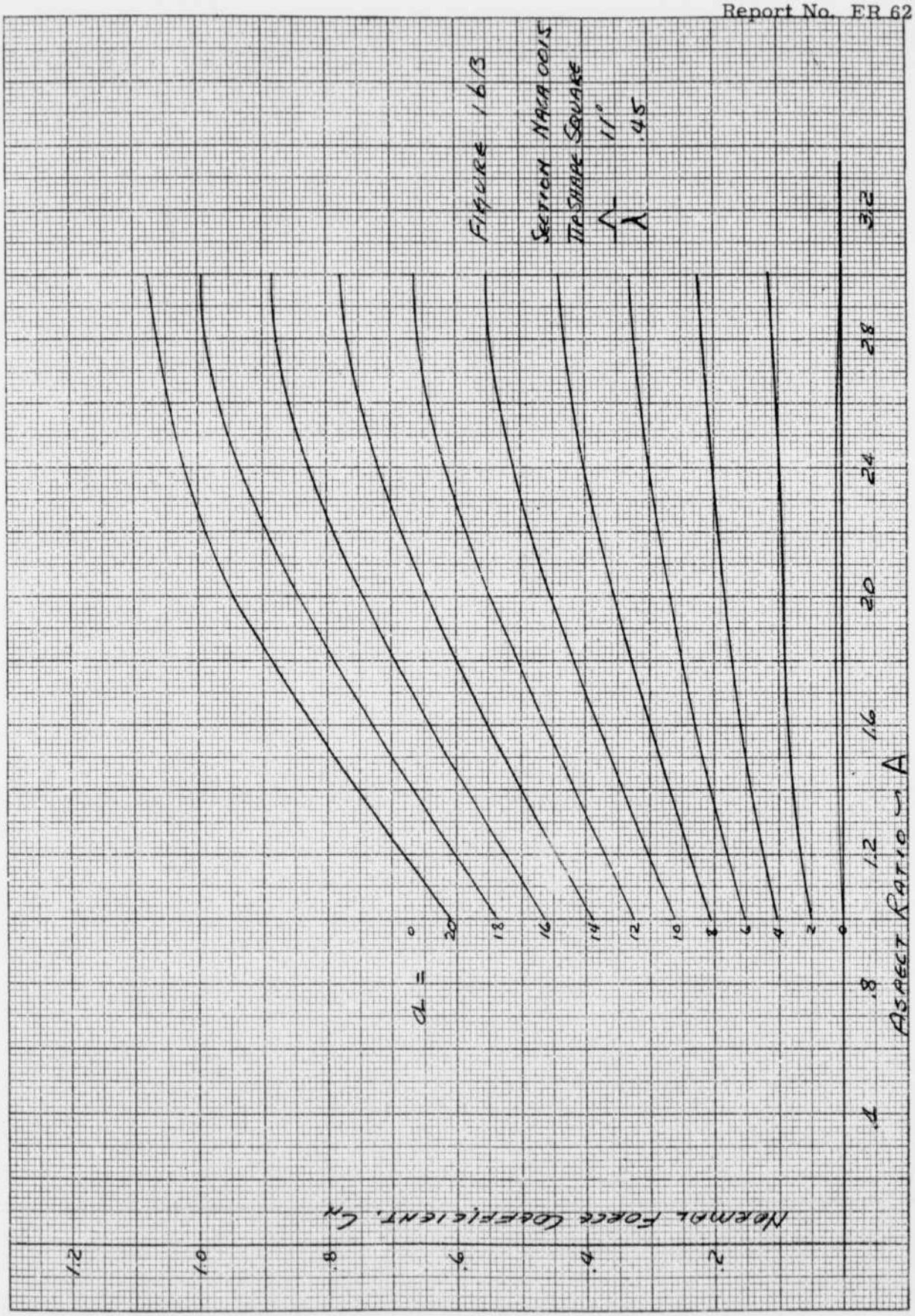


FIGURE 16.13
SECTION NACA 0015
TIP SHAPE SQUARE
Λ
λ
1.1
.45
Normal Force Coefficient, C_N
Aspect Ratio - A
α =
0
2
4
6
8
10
12
14
16
18
20
1.2
1.0
.8
.6
.4
.2
0
4
8
12
16
20
24
28
32

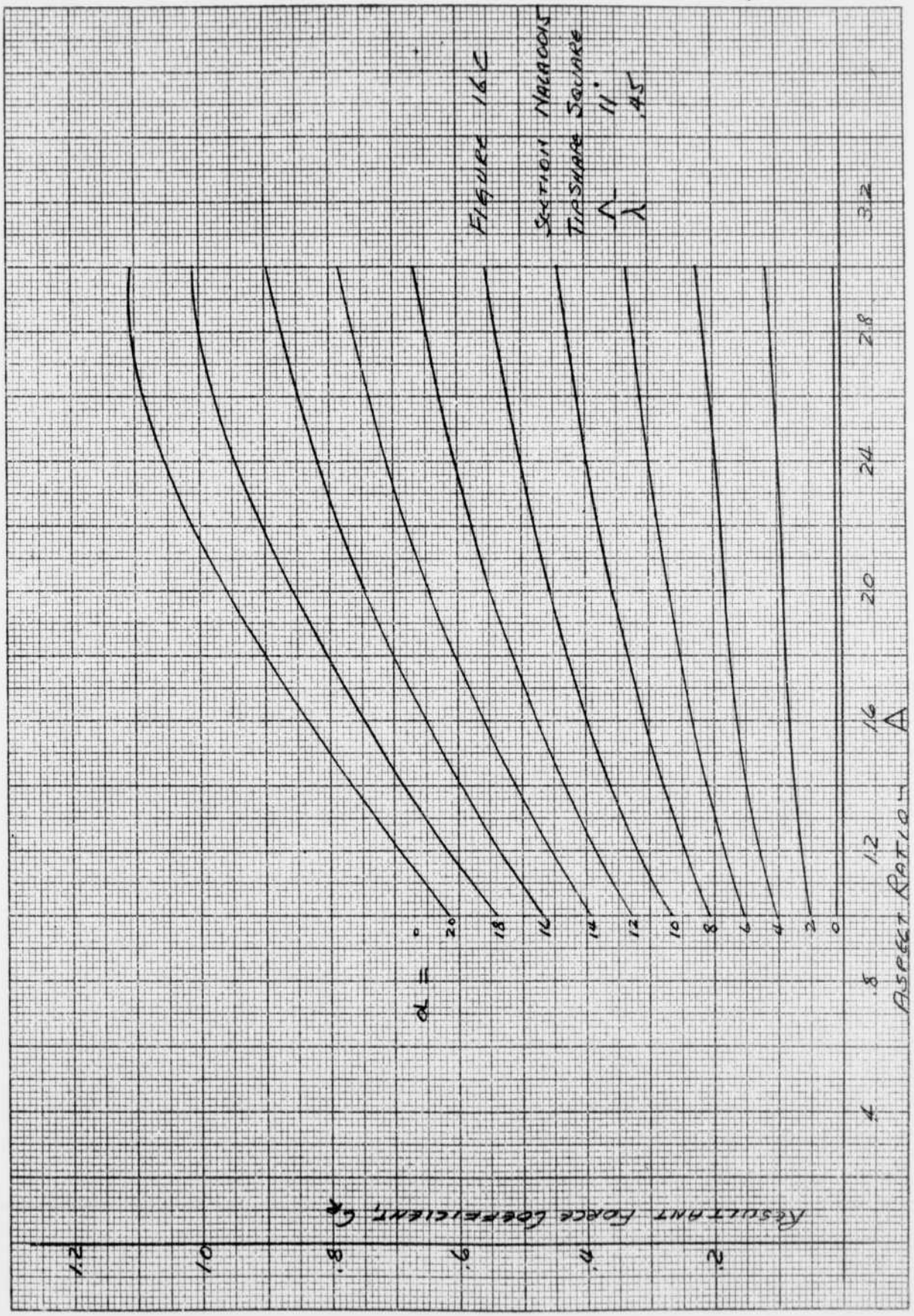
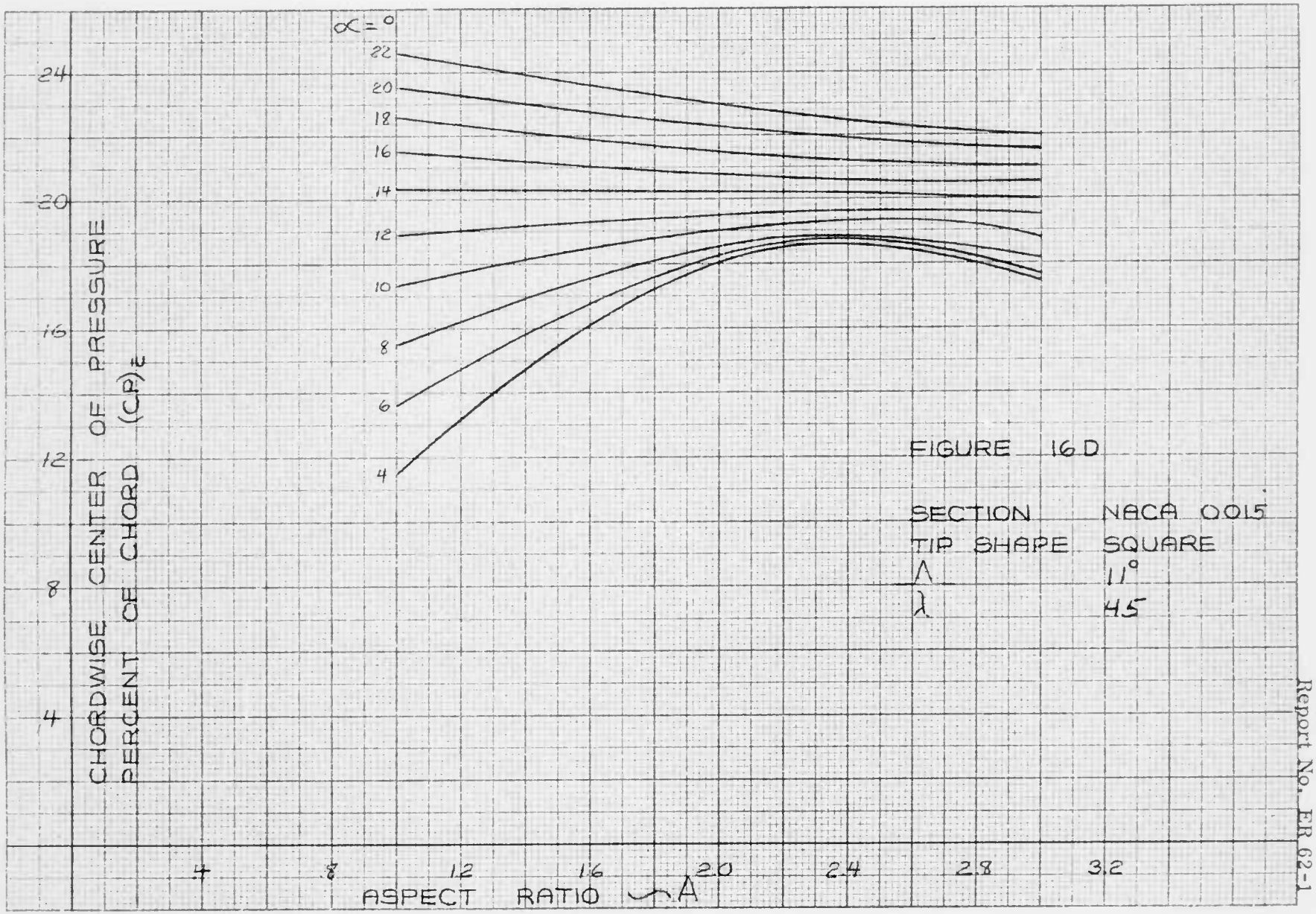
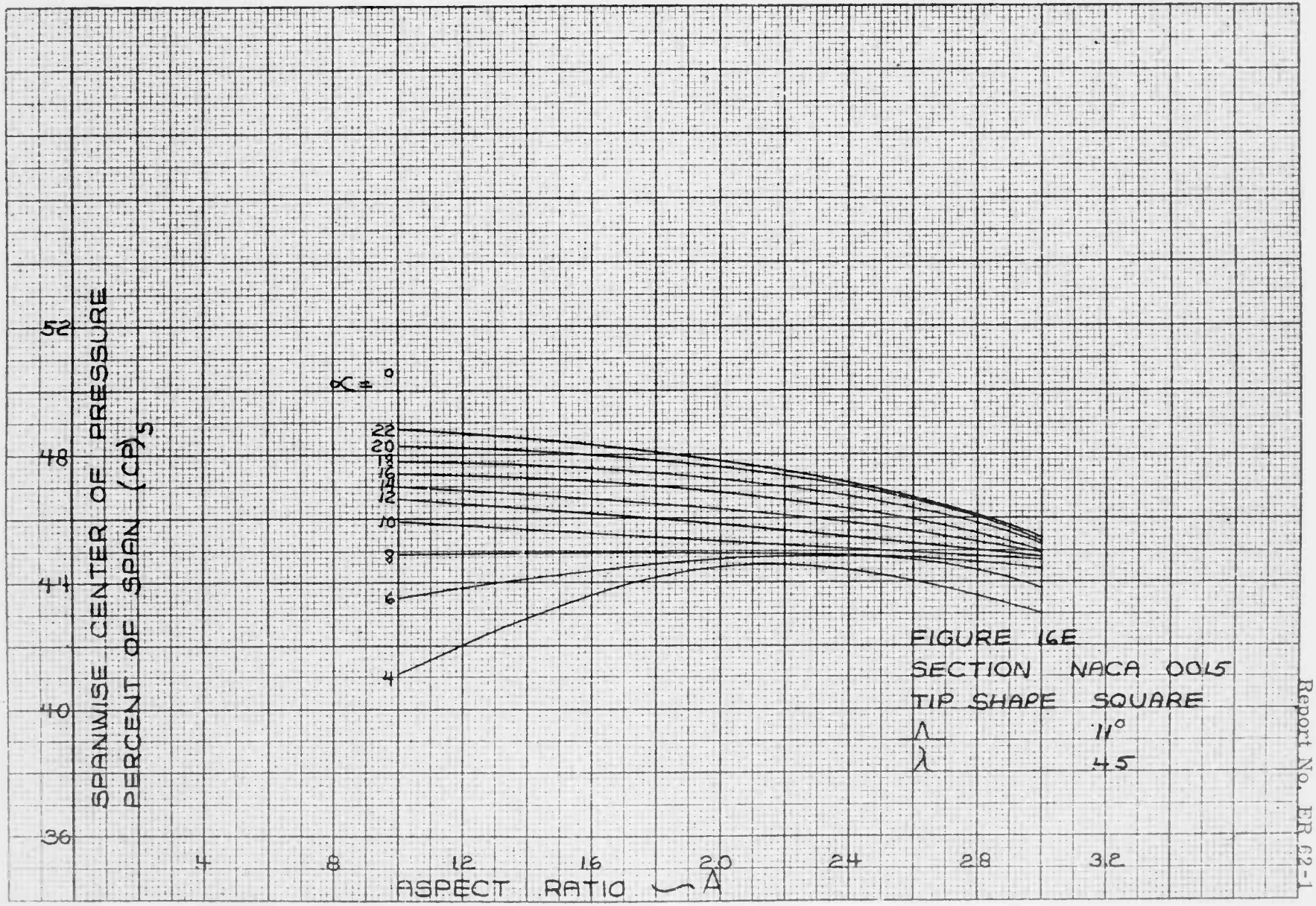


Figure 16C
Section Characteristics Square Tip
λ = 1.0
λ = .45
Resultant Force Coefficient, C_R
Aspect Ratio, A
α = 0
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
0
4
8
12
16
20
24
28
32


α = °
22
20
18
16
14
12
10
8
6
4
24
20
16
12
8
4
CHORDWISE CENTER OF PRESSURE
PERCENT OF CHORD (C.P.)ε
.4
.8
1.2
1.6
2.0
2.4
2.8
3.2
ASPECT RATIO A
FIGURE 16 D
SECTION NACA 0015
TIP SHAPE SQUARE
Λ 11°
λ 45


SPANWISE CENTER OF PRESSURE
PERCENT OF SPAN (CP)s
52
48
44
40
36
α =
22
20
18
16
14
12
10
8
6
4
4
8
12
16
20
24
28
32
ASPECT RATIO A
FIGURE 16E
SECTION NACA 0015
TIP SHAPE SQUARE
Λ 11°
λ 45

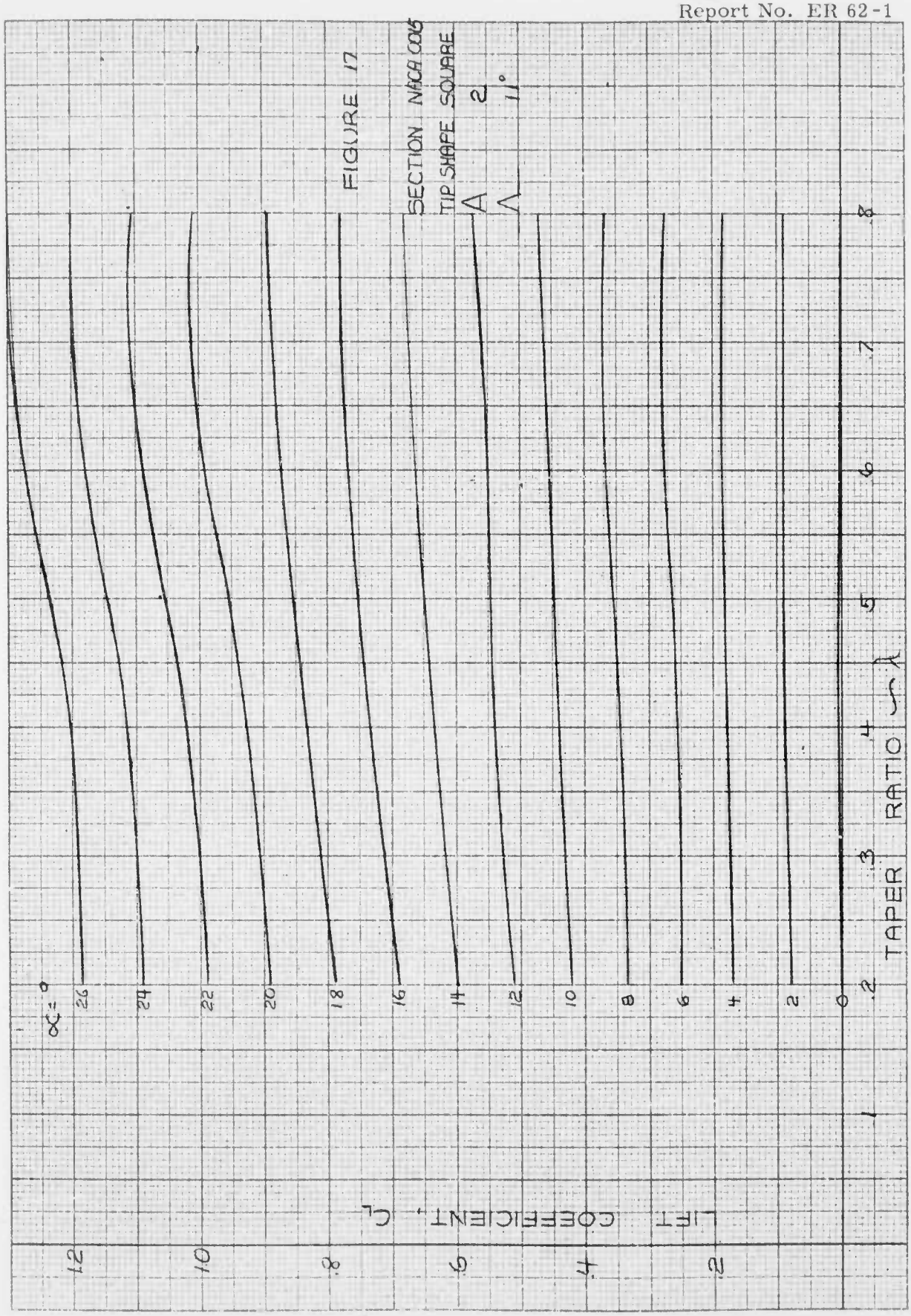


FIGURE 17
SECTION NACA 0005
TIP SHAPE SQUARE
A 2
A 1°
LIFT COEFFICIENT, C_L
TAPER RATIO $\frac{c_t}{c_r}$
$\alpha = 0$
26
24
22
20
18
16
14
12
10
8
6
4
2
0
12
10
8
6
4
2
1
.2
.3
4
5
6
7
8

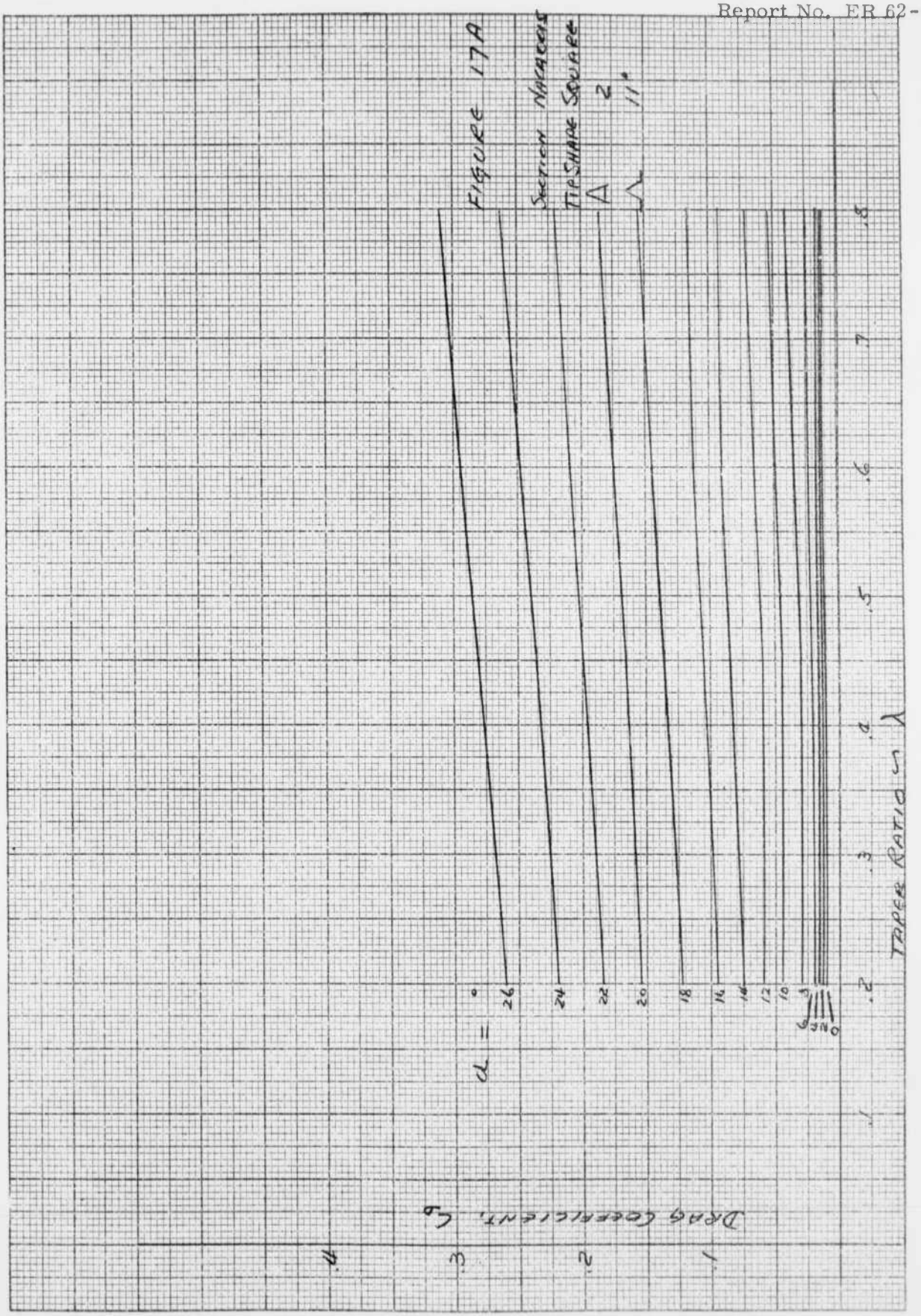


FIGURE 17A
SECTION NACA 65
TIP SHAPE SQUARED
Λ 2°
Λ 11°
DRAG COEFFICIENT, C_D
TAPER RATIO, λ
α = 0°
26
24
22
20
18
14
16
12
10
8
6
4
2
0
.1
.2
.3
.4
.5
.6
.7
.8
1
2
3
4

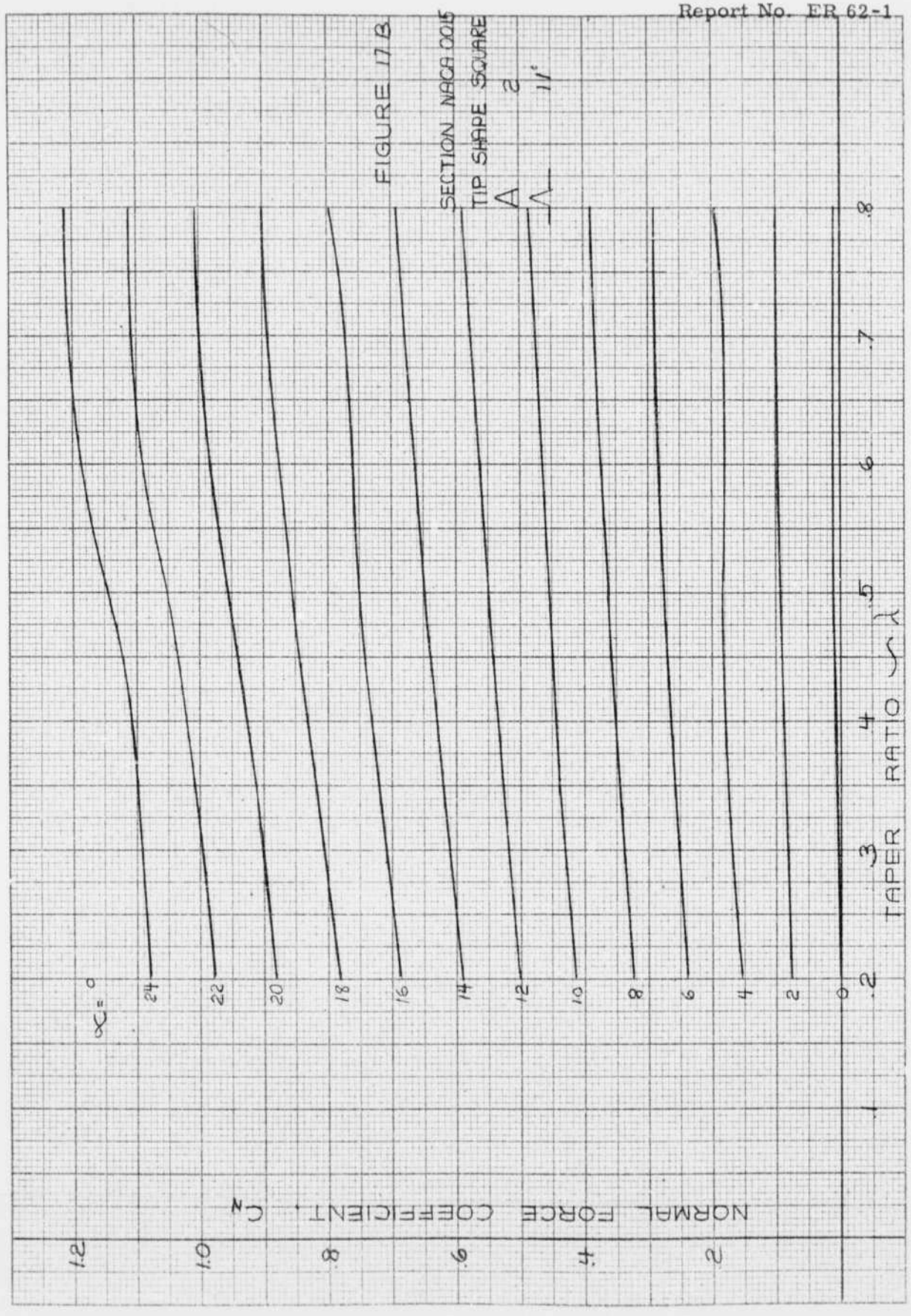


FIGURE 17 B
SECTION NACA 0015
TIP SHAPE SQUARE
A 2
Λ 11°
NORMAL FORCE COEFFICIENT, C_N
TAPER RATIO λ
$\alpha = 0$
24
22
20
18
16
14
12
10
8
6
4
2
0
.2
.3
.4
.5
.6
.7
.8
1
1.2
1.0
.8
.6
.4
.2

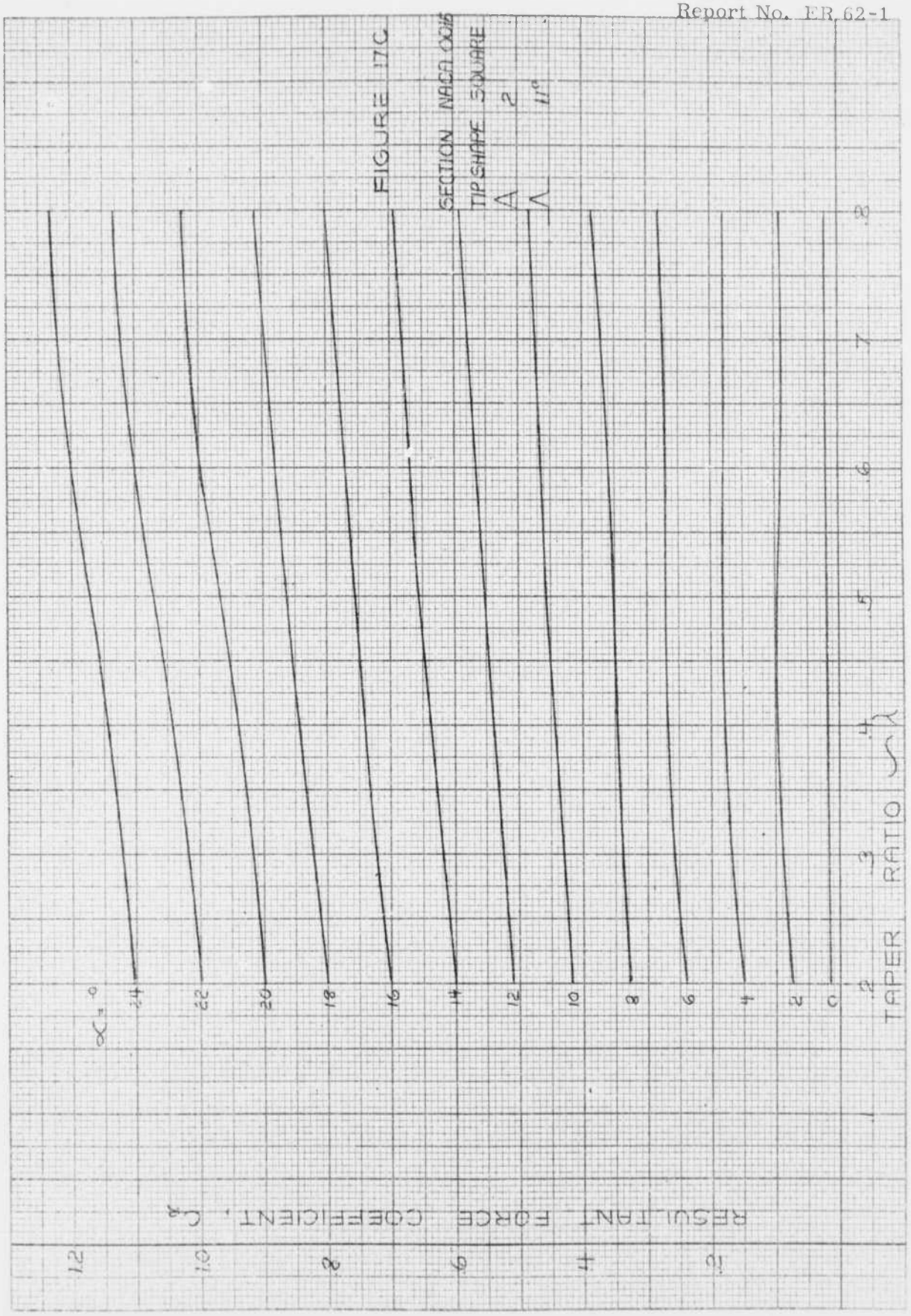


FIGURE 17C
SECTION NACA 0006
TIP SHAPE SQUARE
Λ 2
Λ 11°
RESULTANT FORCE COEFFICIENT, C_R
TAPER RATIO λ
$\alpha = 0°$
24
22
20
18
16
14
12
10
8
6
4
2
0
12
10
8
6
4
2
1
2
3
4
5
6
7
8

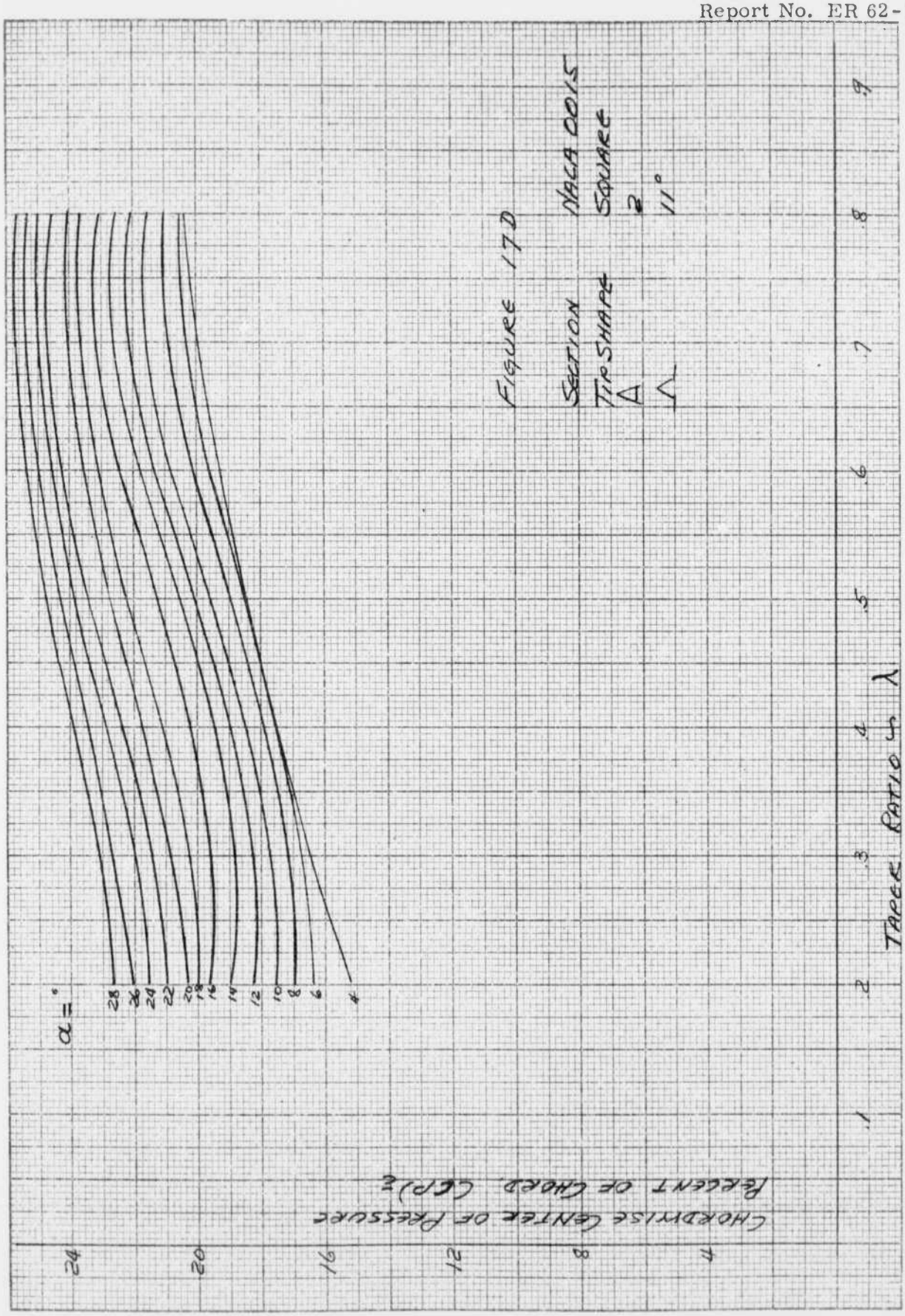


FIGURE 17D
SECTION NACA 0015
TIP SHAPE SQUARE
Λ 2
Λ 11°
TAPER RATIO λ
CHORDWISE CENTER OF PRESSURE
PERCENT OF CHORD (CP)c
α =
28
26
24
22
20
18
16
14
12
10
8
6
4

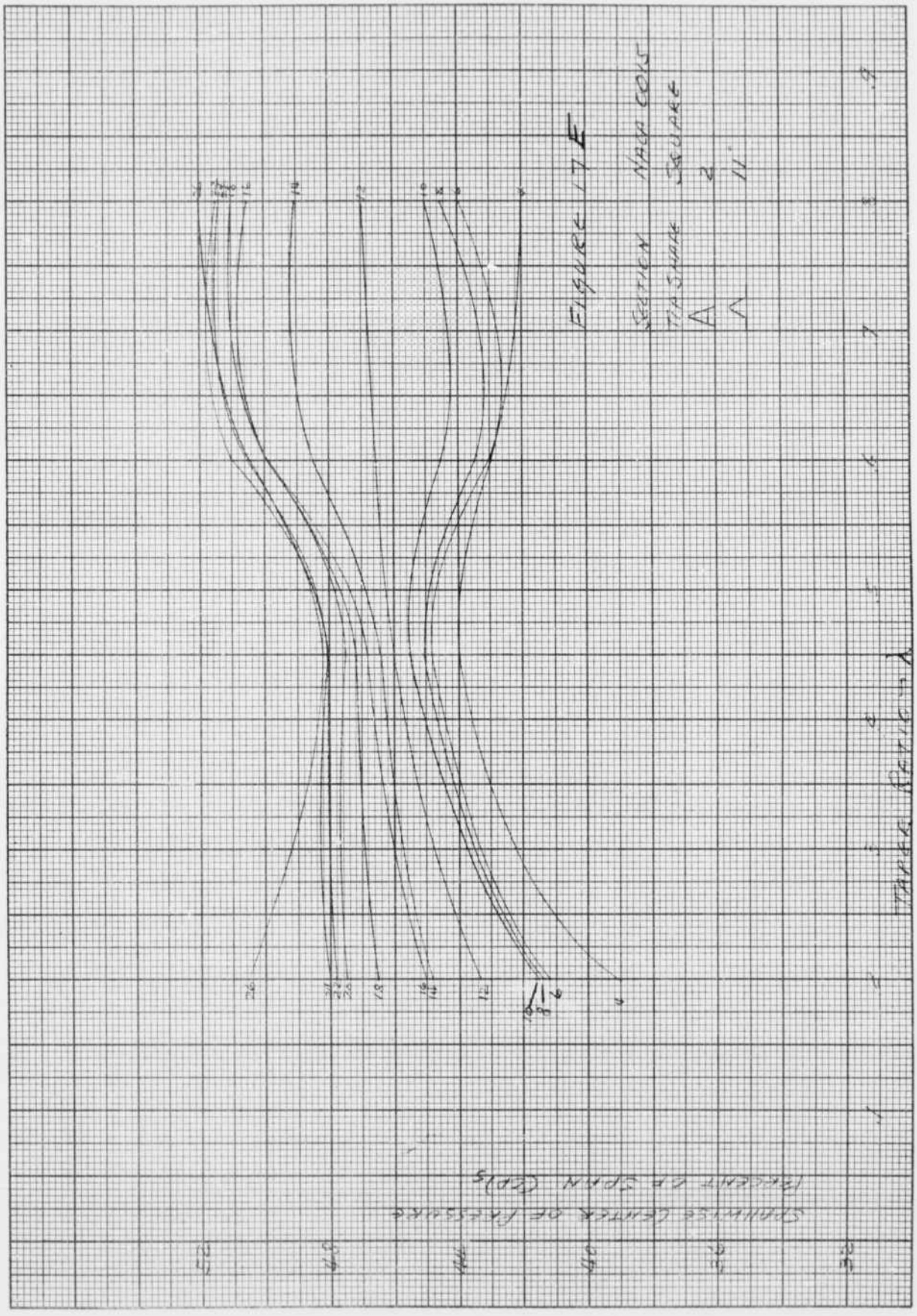


FIGURE 17.4
SECTION NACA 0015
TIP SHAPE SQUARE
AR 2
TAPER RATIO 1
SPANWISE CENTER OF PRESSURE
PERCENT SEMI SPAN (CP)s

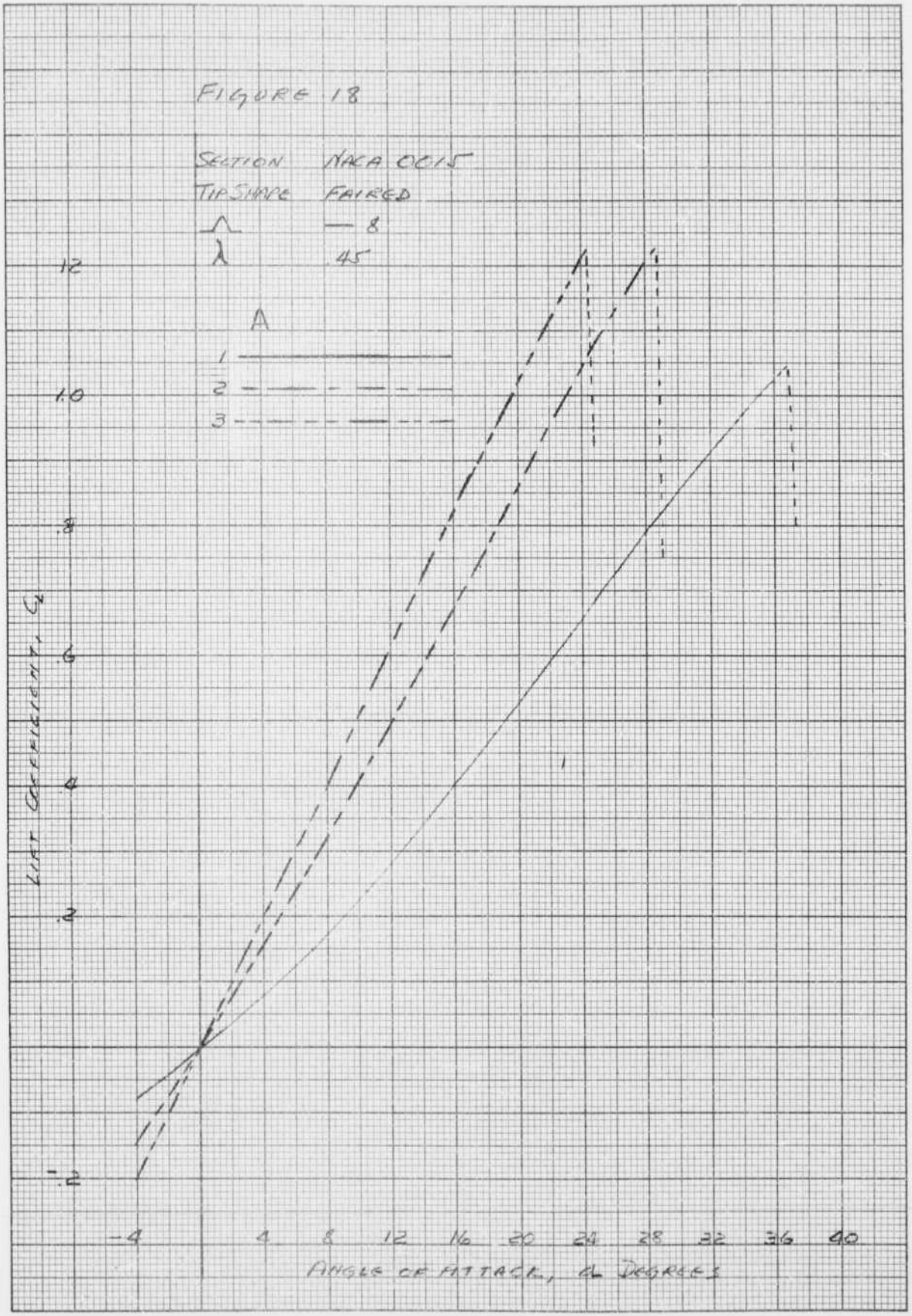


FIGURE 18
SECTION NACA 0015
TIP SHAPE FAIRED
Λ — 8
λ 45
A
1
2
3
12
1.0
.8
.6
.4
.2
-.2
LIFT COEFFICIENT, C_L
-4
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α, DEGREES

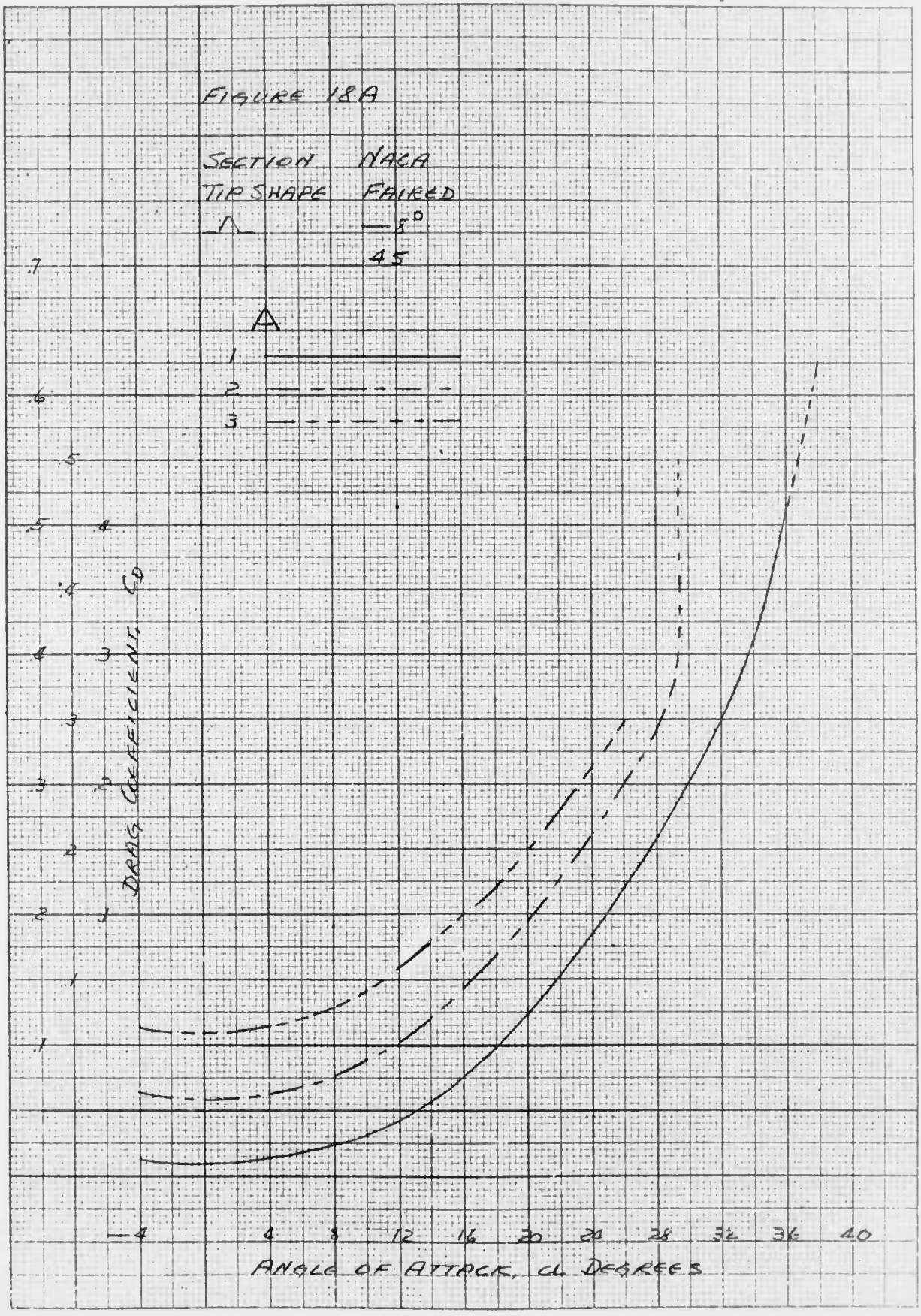


FIGURE 18A
SECTION NACA
TIP SHAPE FAIRED
Λ —5°
45
1
2
3
DRAG COEFFICIENT C_D
.7
.6
.5
.4
.3
.2
.1
5
4
3
2
1
−4
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α DEGREES

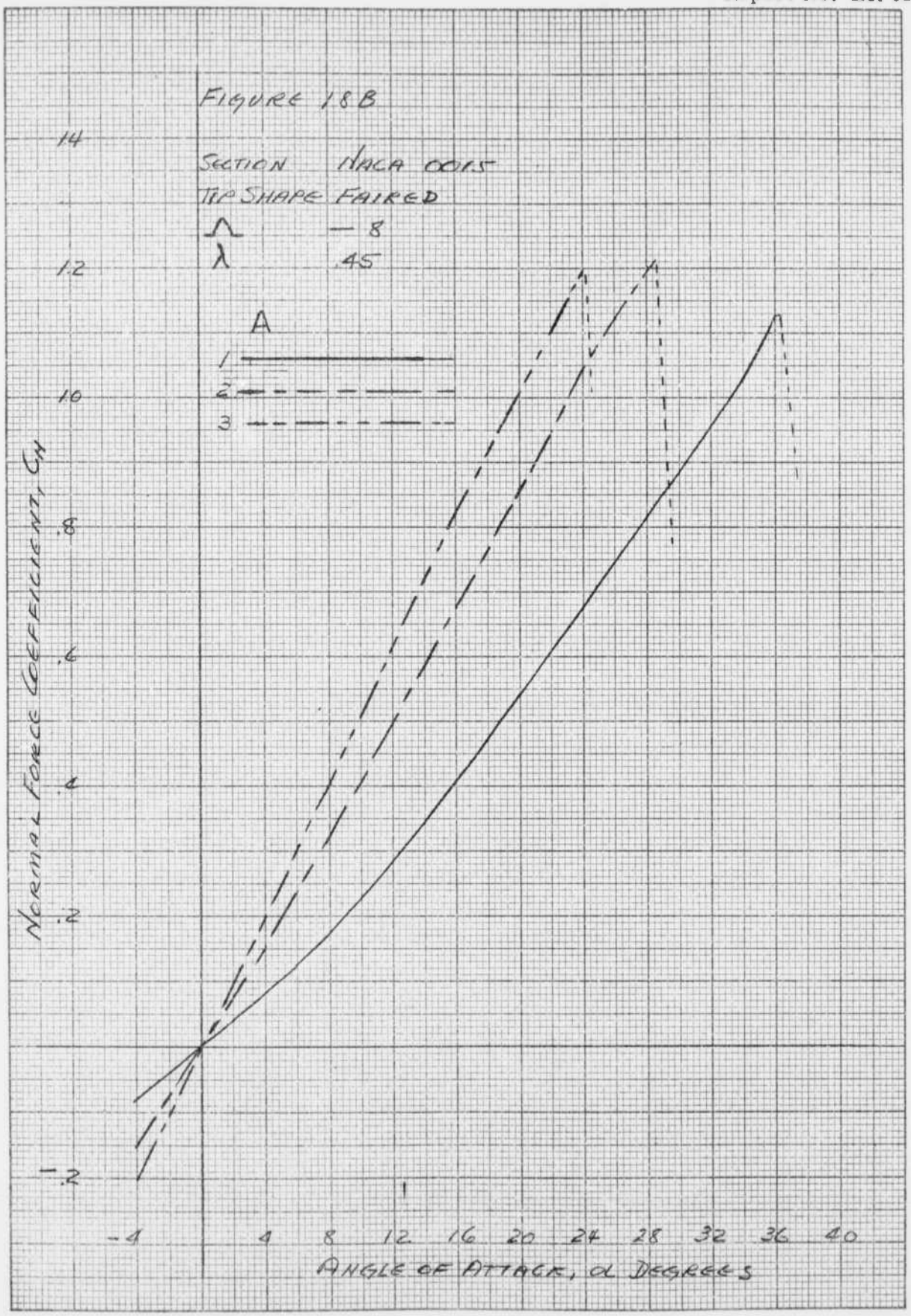


FIGURE 1.8B
SECTION NACA 0015
TIP SHAPE FAIRED
Λ — 8
λ .45
A
1
2
3
1.4
1.2
1.0
.8
.6
.4
.2
-.2
NORMAL FORCE COEFFICIENT, C_N
-4
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α DEGREES

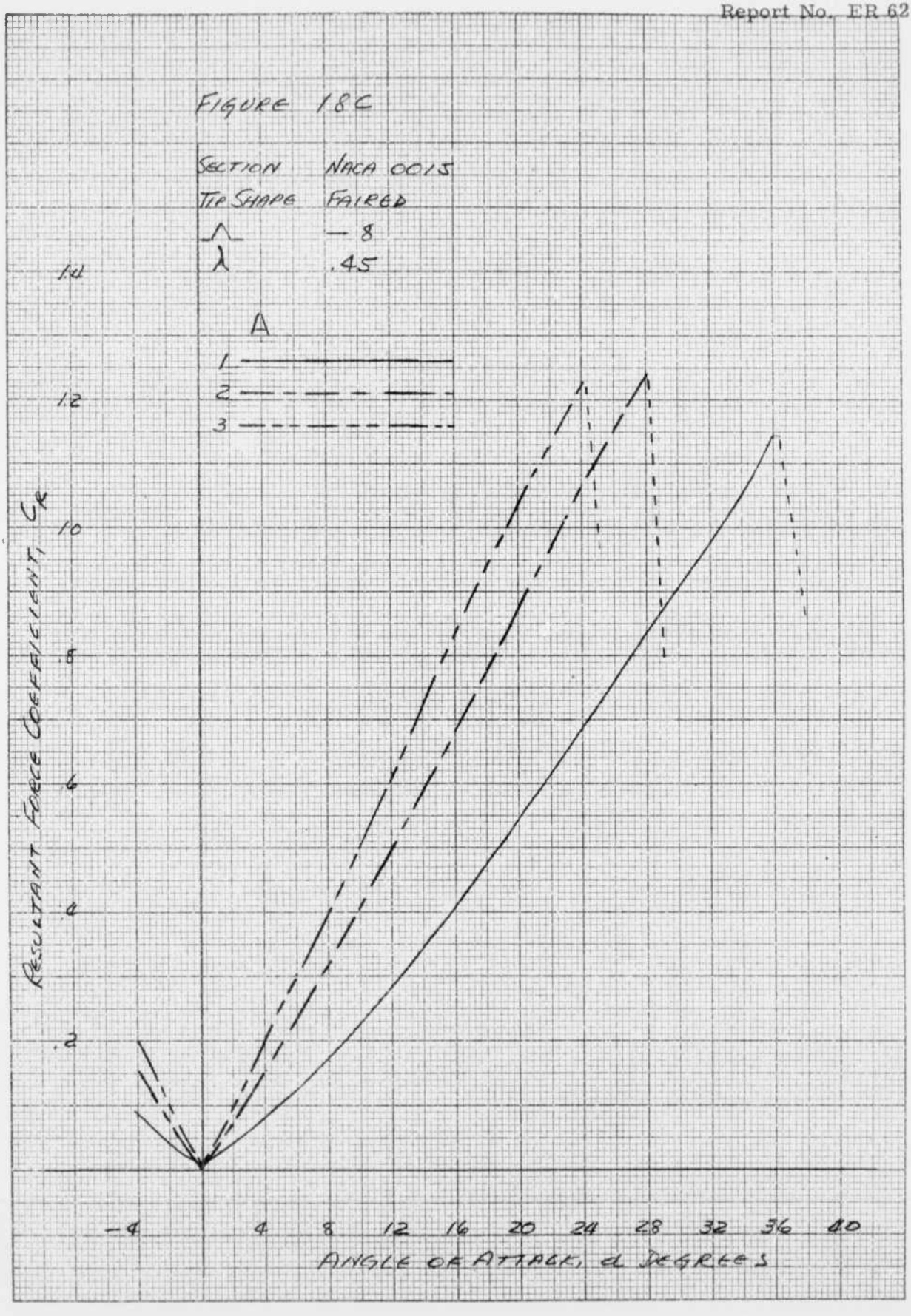


FIGURE 18C
SECTION NACA 0015
TIP SHAPE FAIRED
Λ −8
λ .45
A
1
2
3
1.4
1.2
1.0
.8
.6
.4
.2
RESULTANT FORCE COEFFICIENT, C_R
−4
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α DEGREES

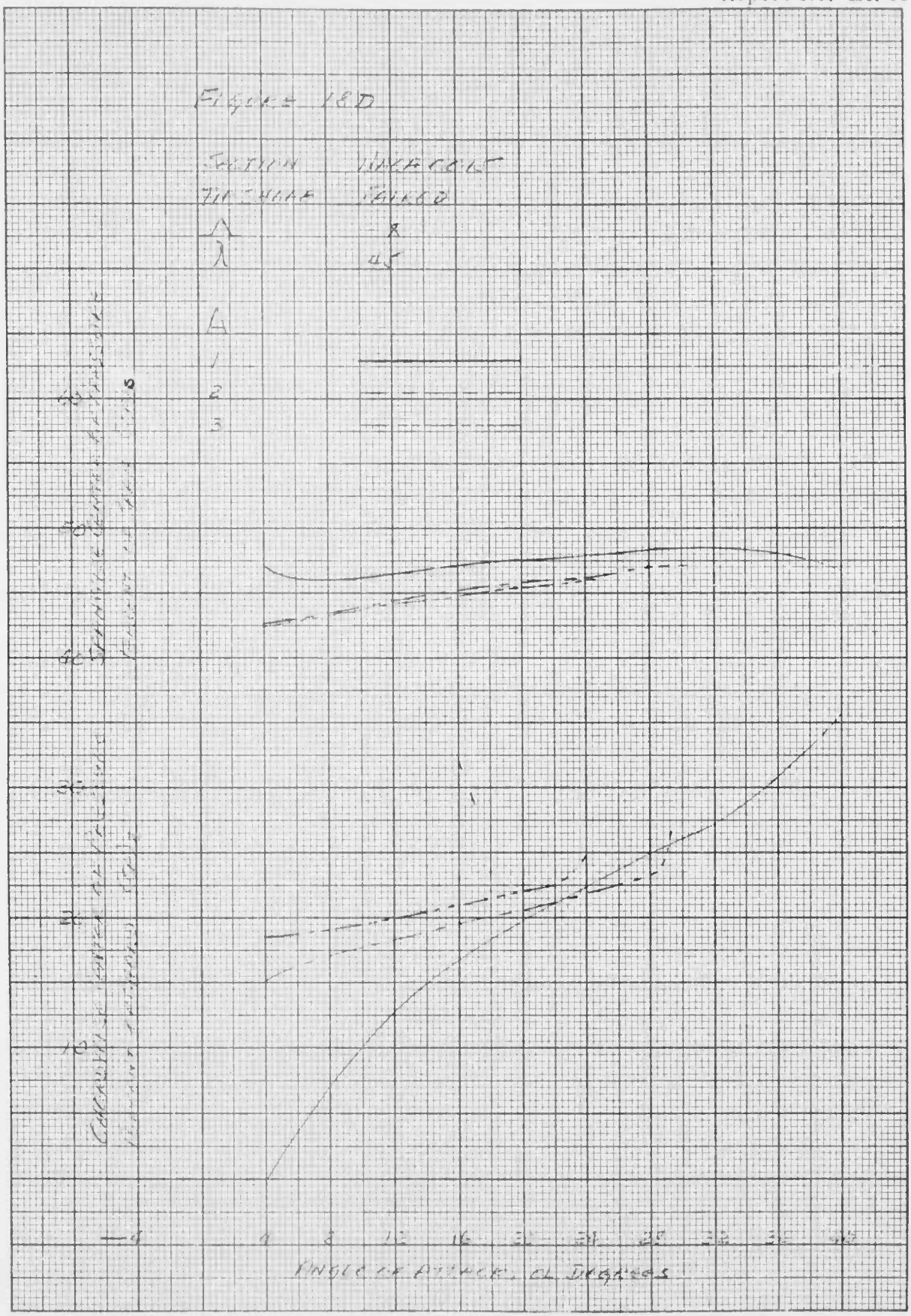


Figure 18D
Section
Fin Name
Index Coil
Used
X
as
1
2
3
Calculated Index Coil Current Ratio
Angle of Attack, Degrees

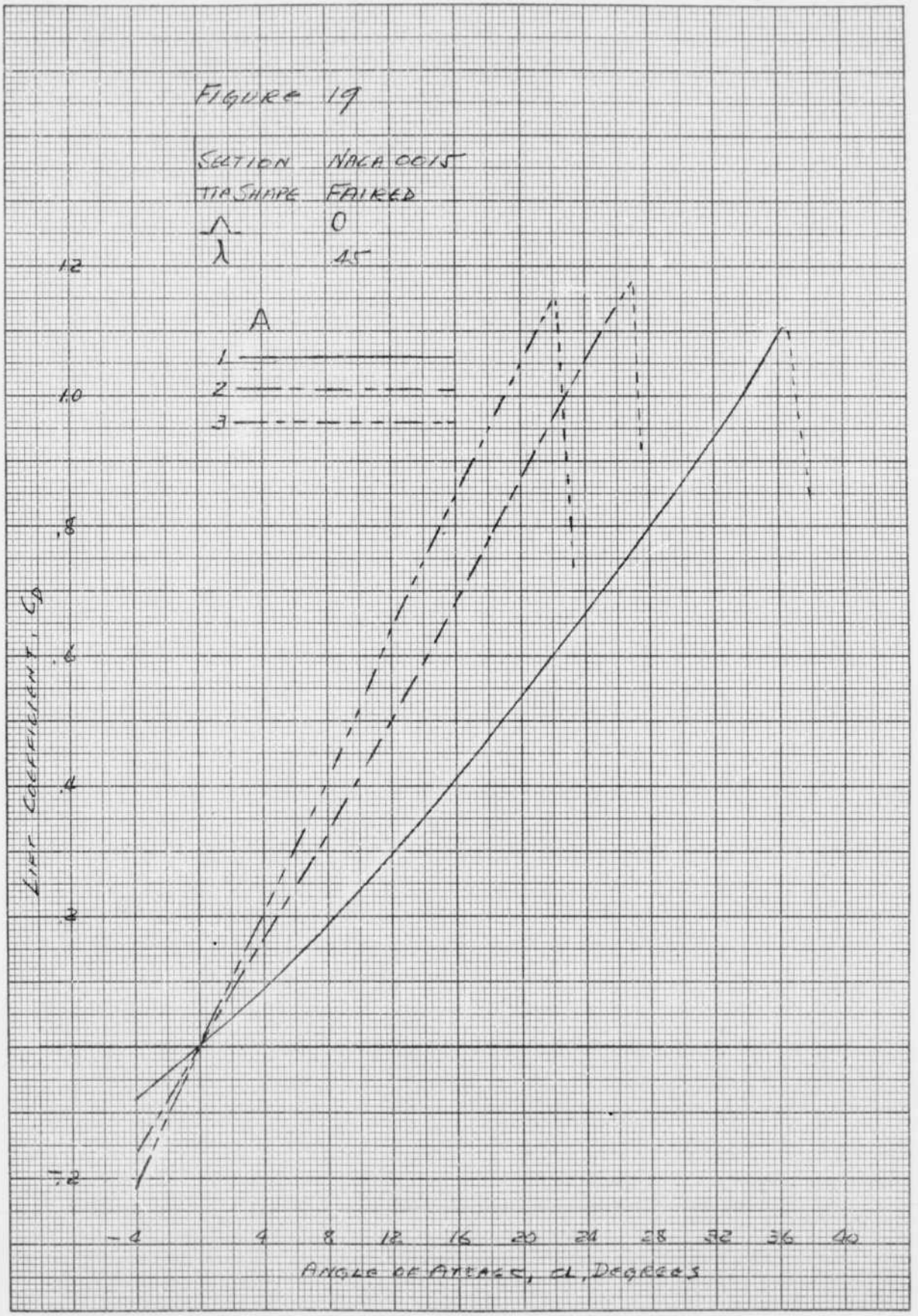


FIGURE 19
SECTION NACA 0015
TIP SHAPE FAILED
Λ 0
λ 15
A
1
2
3
1.2
1.0
.8
.6
.4
.2
-.2
LIFT COEFFICIENT, C_L
-4
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α_L, DEGREES

FIGURE 19A

SECTION NACA 6015
TIP SHAPE FAIRED
Λ 0
λ .45

A
1
2
3

DRAG COEFFICIENT, C_D

.7
.6
.5
.4
.3
.2
.1

-4 0 4 8 12 16 20 24 28 32 36 40

ANGLE OF ATTACK, α_L, DEGREES

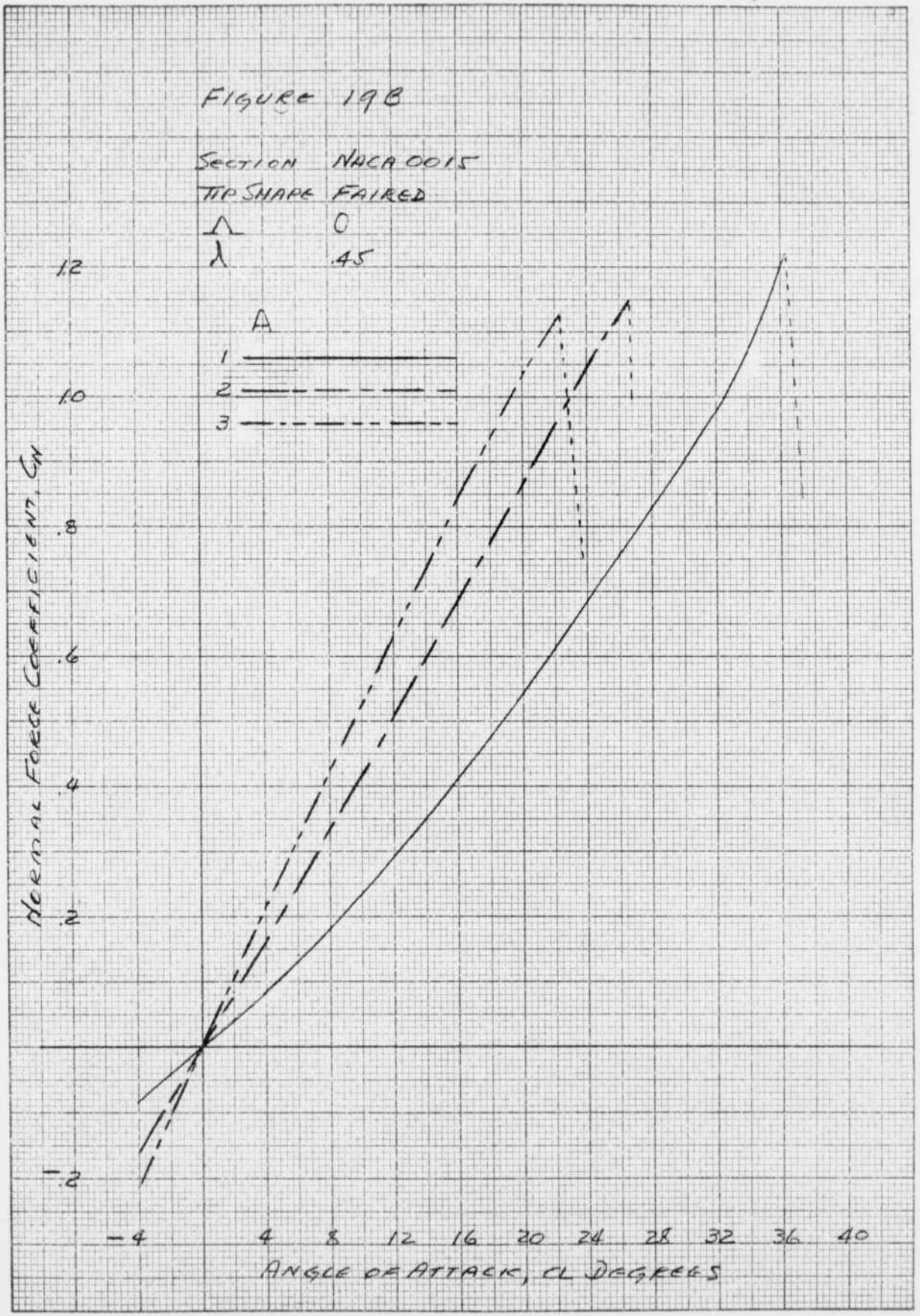


FIGURE 19B
SECTION NACA 0015
TIP SHAPE FAIRED
Λ 0
λ .45
A
1
2
3
1.2
1.0
.8
.6
.4
.2
-.2
NORMAL FORCE COEFFICIENT, CN
-4
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, CL DEGREES

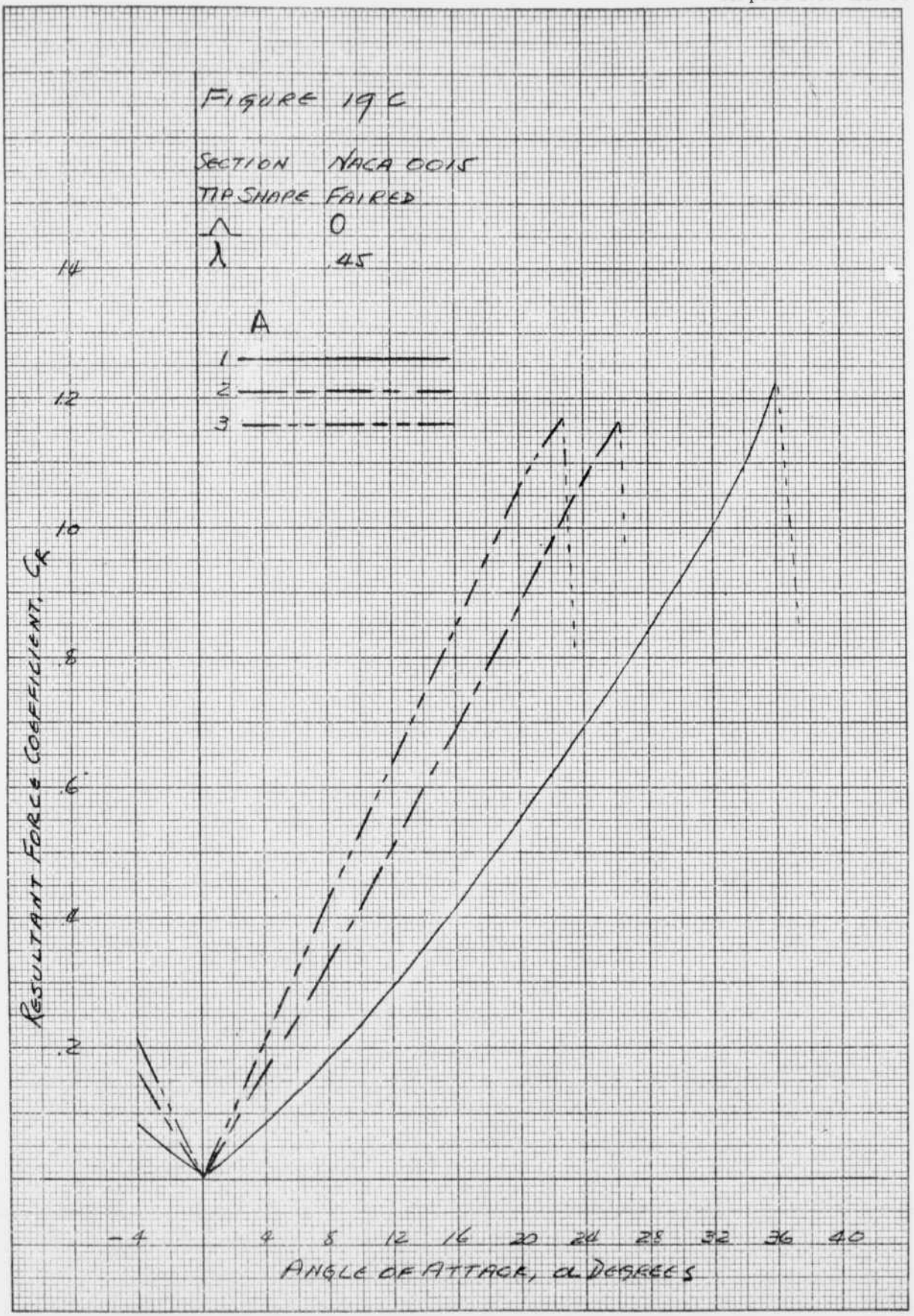


FIGURE 19 C
SECTION NACA 0015
TIP SHAPE FAIRED
Λ 0
λ .45
A
1
2
3
1.4
1.2
1.0
.8
.6
.4
.2
RESULTANT FORCE COEFFICIENT, CR
-4
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α, DEGREES

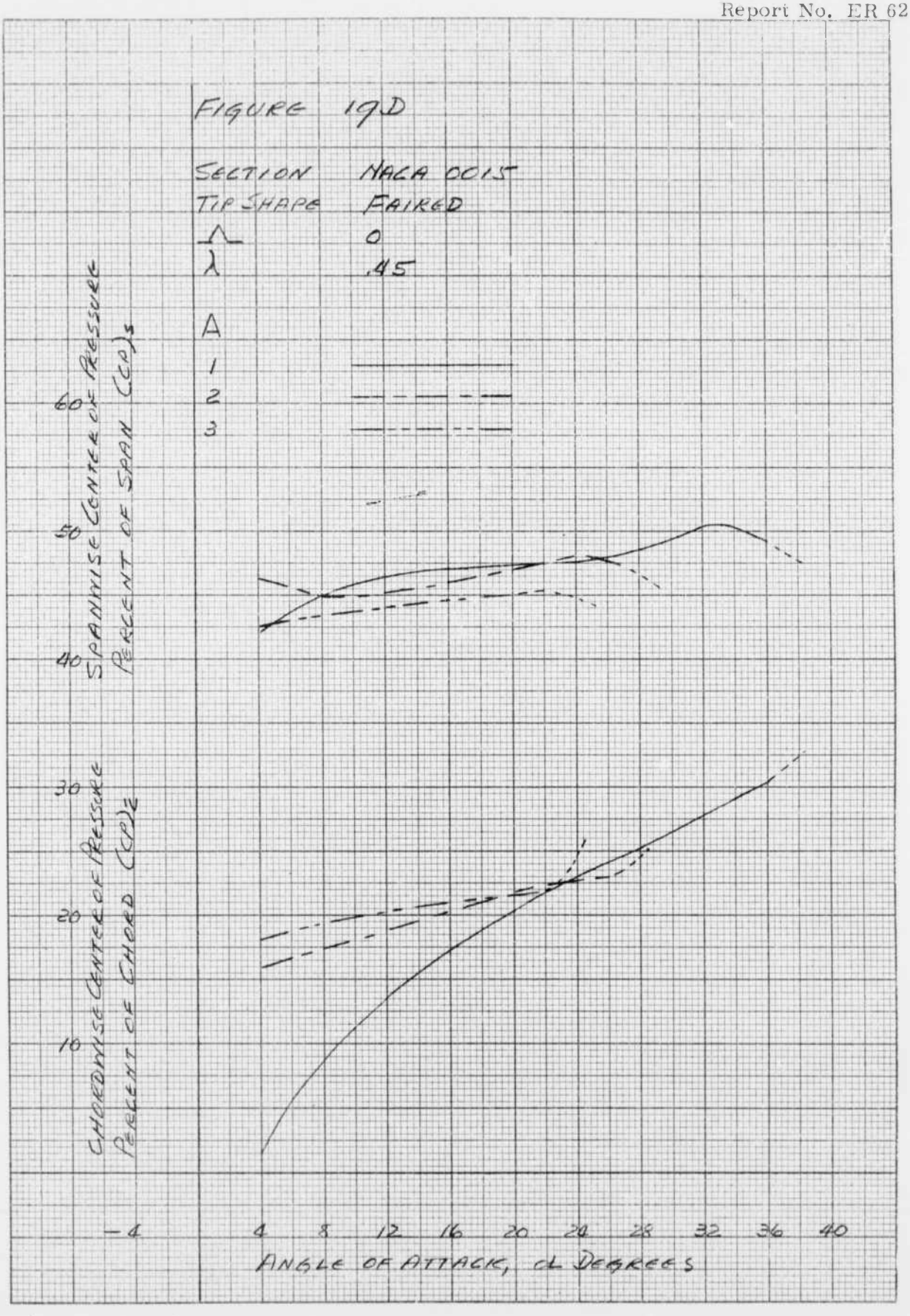


FIGURE 19D
SECTION TIP SHAPE
NACA 0015 FAIRED
Λ 0
λ .45
A
1
2
3
SPANWISE CENTER OF PRESSURE PERCENT OF SPAN (CP)s
CHORDWISE CENTER OF PRESSURE PERCENT OF CHORD (CP)c
60
50
40
30
20
10
-4
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α DEGREES

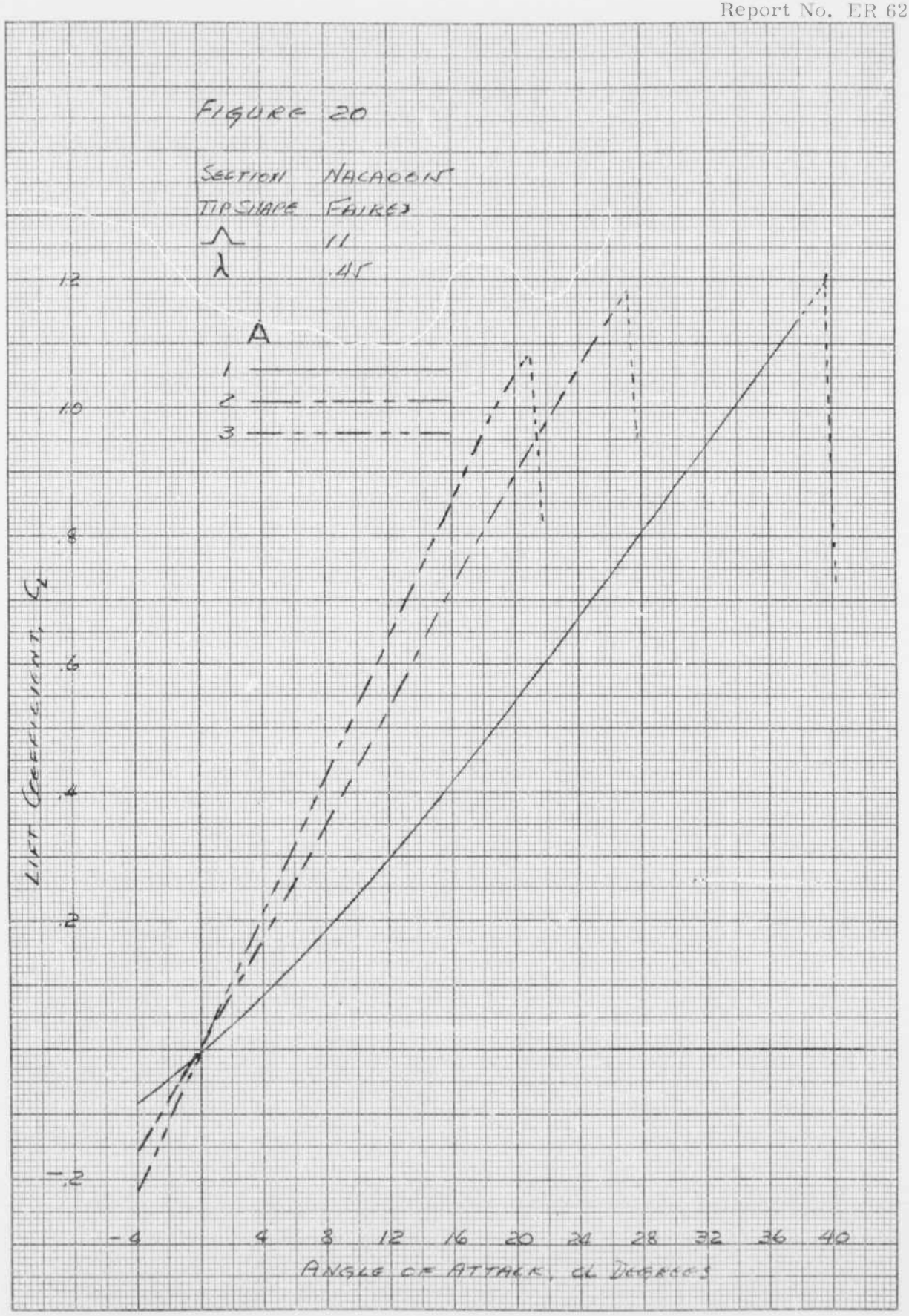


FIGURE 20
SECTION NACA 0015
TIP SHAPE FAIRED
11
.45
A
1
2
3
1.2
1.0
.8
.6
.4
.2
-.2
LIFT COEFFICIENT, C_L
-4
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α, DEGREES

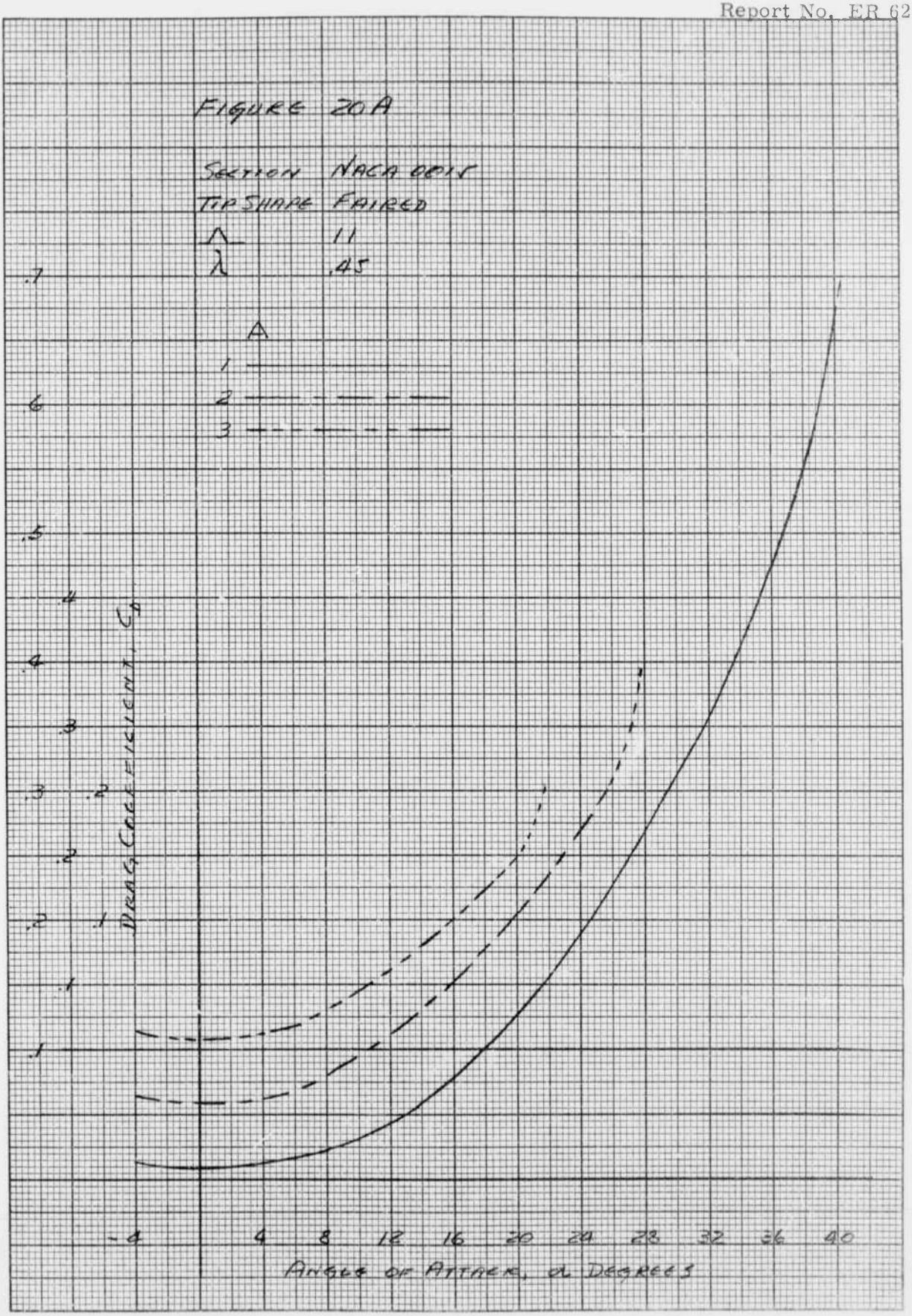


FIGURE 20A
SECTION NACA 0015
TIP SHAPE FAIRED
Λ 11
λ .45
A
1
2
3
DRAG COEFFICIENT, C_D
.7
.6
.5
.4
.3
.2
.1
-4
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α, DEGREES

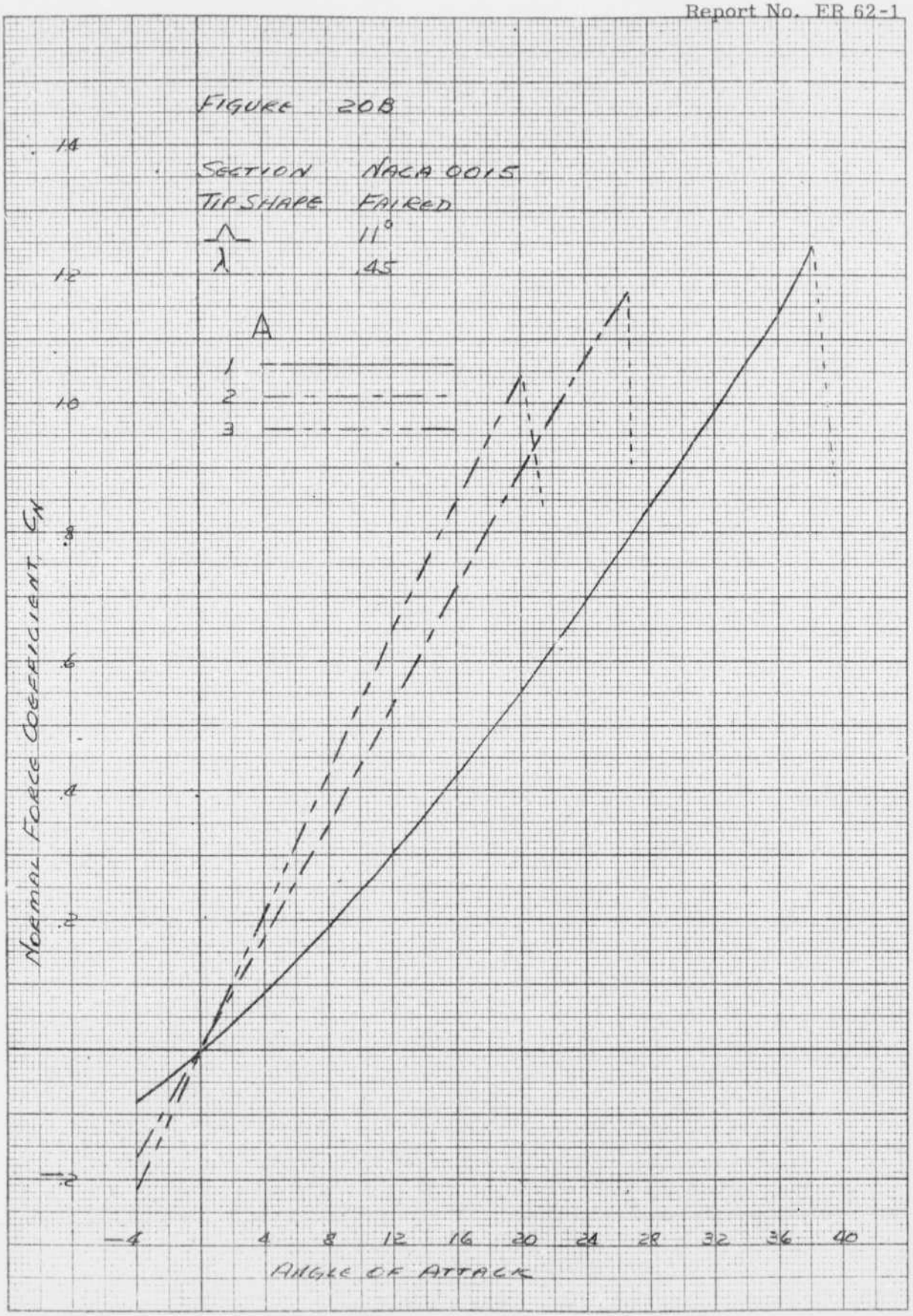


FIGURE 20B
SECTION NACA 0015
TIP SHAPE FAIRED
Λ 11°
λ .45
A
1
2
3
NORMAL FORCE COEFFICIENT, C_N
1.4
1.2
1.0
.8
.6
.4
.2
-.2
-4
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK

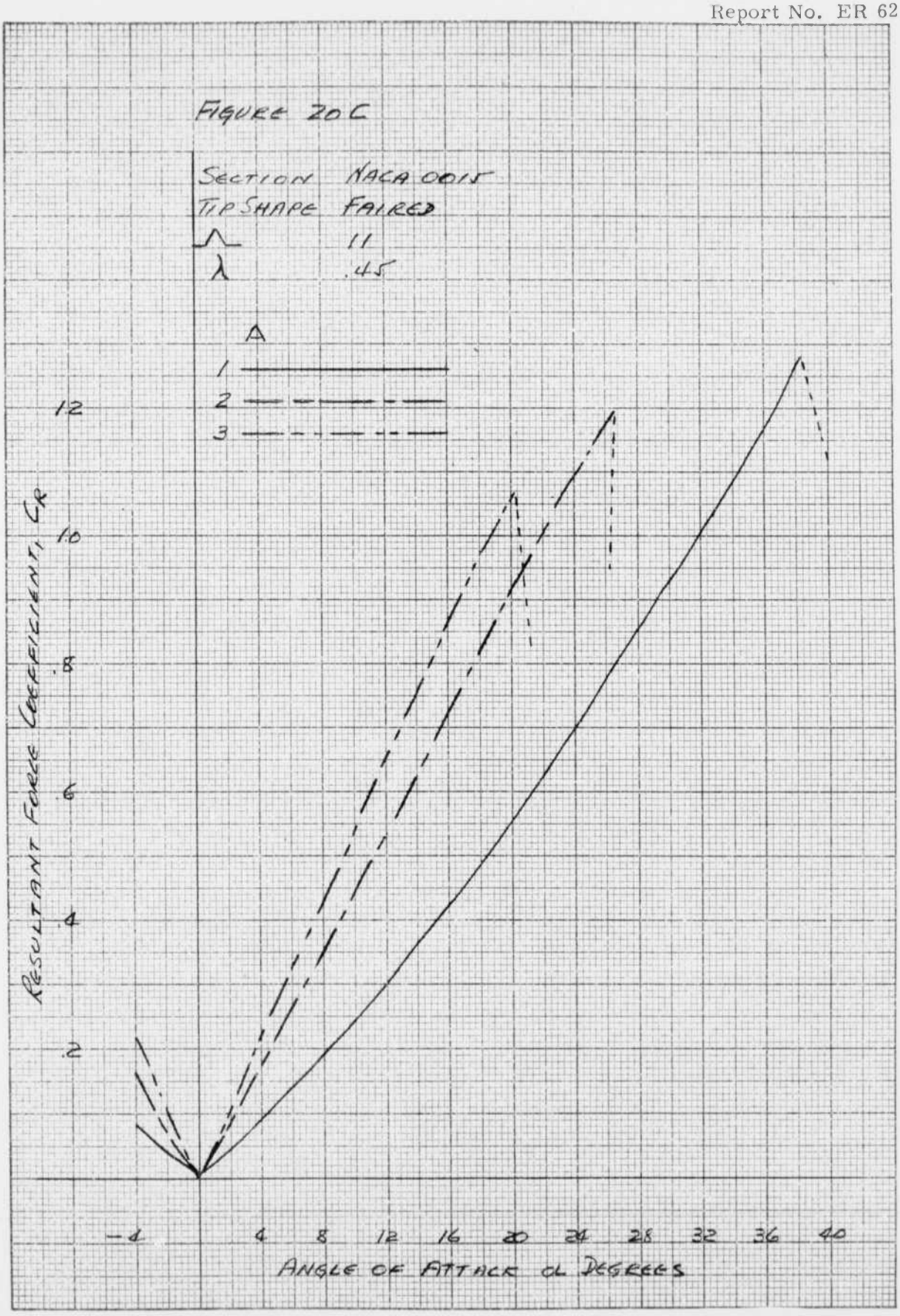


FIGURE 20C
SECTION NACA 0015
TIP SHAPE FAIRED
Λ 11
λ .45
Λ
1
2
3
12
1.0
.8
.6
.4
.2
RESULTANT FORCE COEFFICIENT, CR
-4
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK α DEGREES

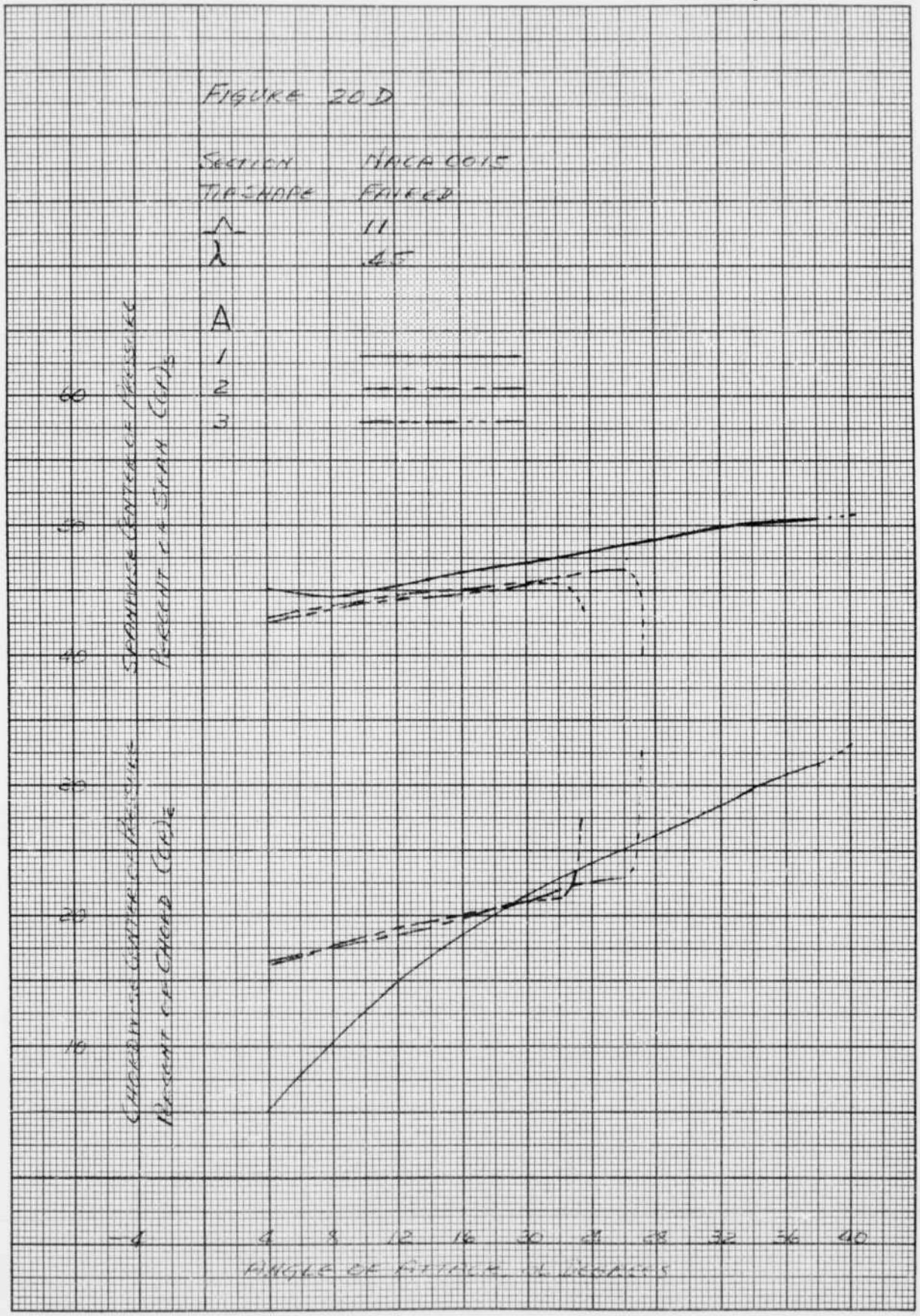


FIGURE 20D
SECTION TAPER
MACH CONE FAIRED
A
1
2
3
60
40
20
0
4
8
12
16
20
24
28
32
36
40

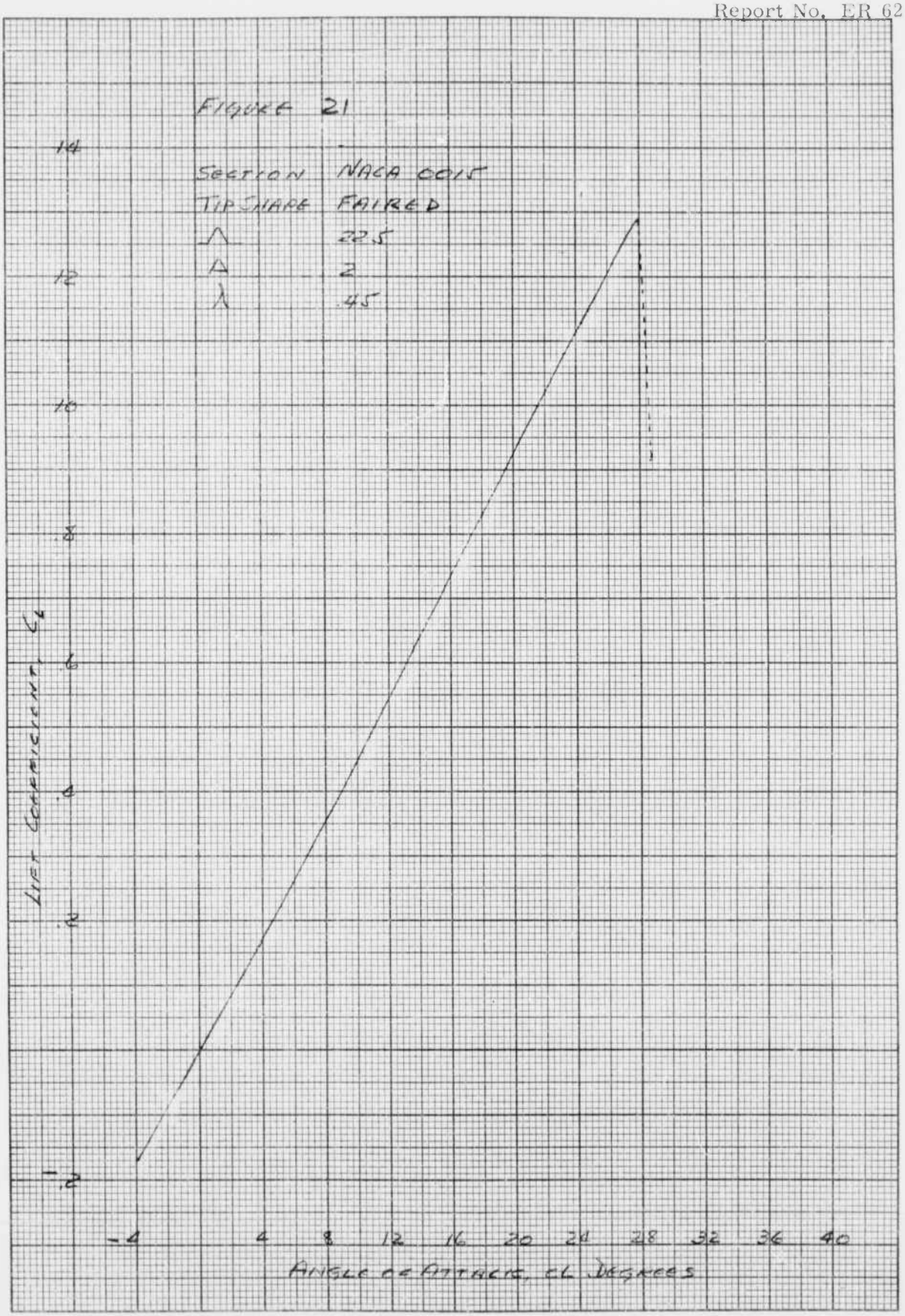
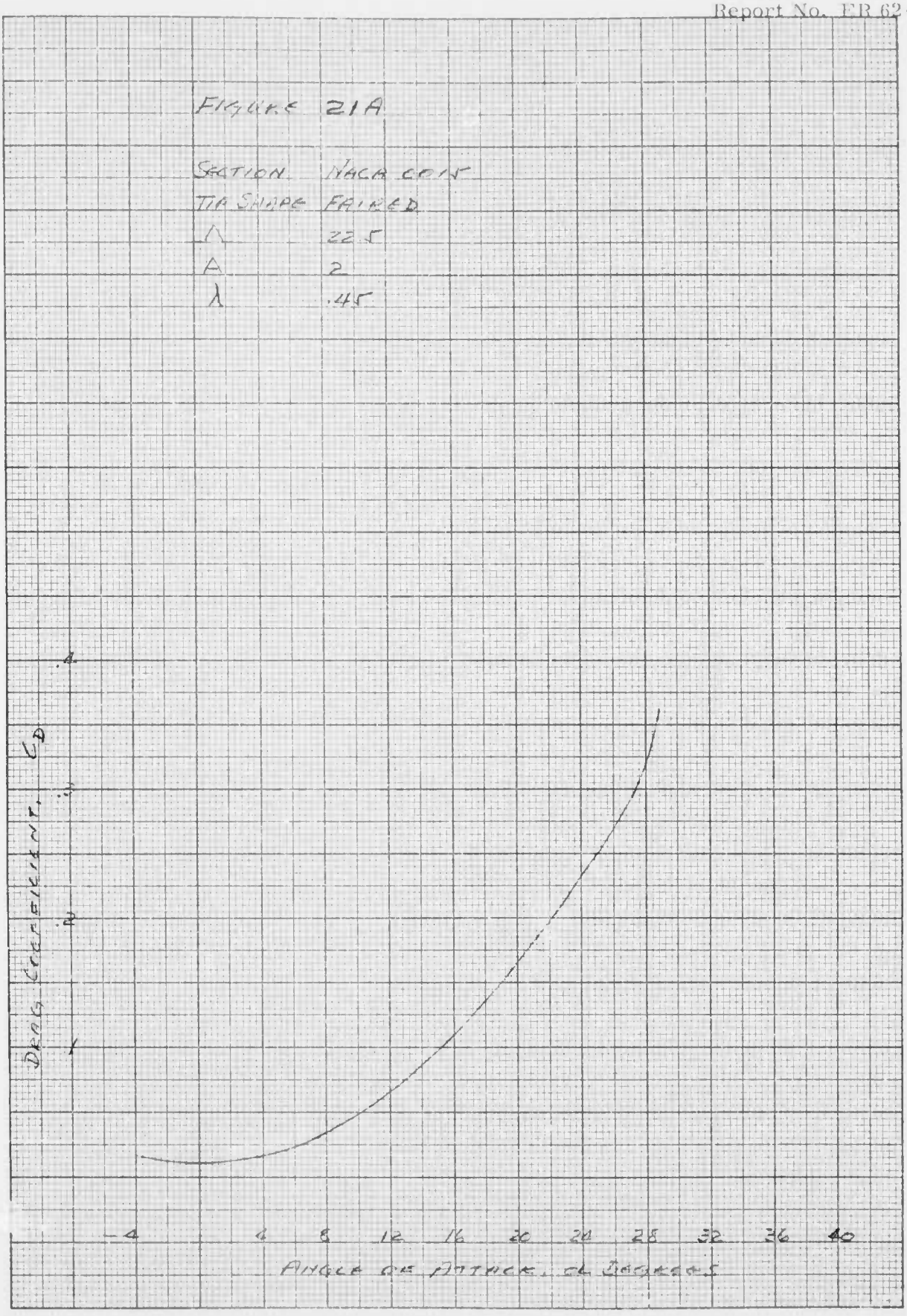


FIGURE 21
SECTION NACA 0015
TIP SHAPE FAIRED
Λ 22.5
A 2
λ .45
14
12
10
.8
.6
.4
.2
-.2
LIFT COEFFICIENT, C_L
-4
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α, DEGREES

FIGURE 21A

STATION NACA 65A
TIP SHAPE FAIRED
Λ 22.5
A 2
λ .45



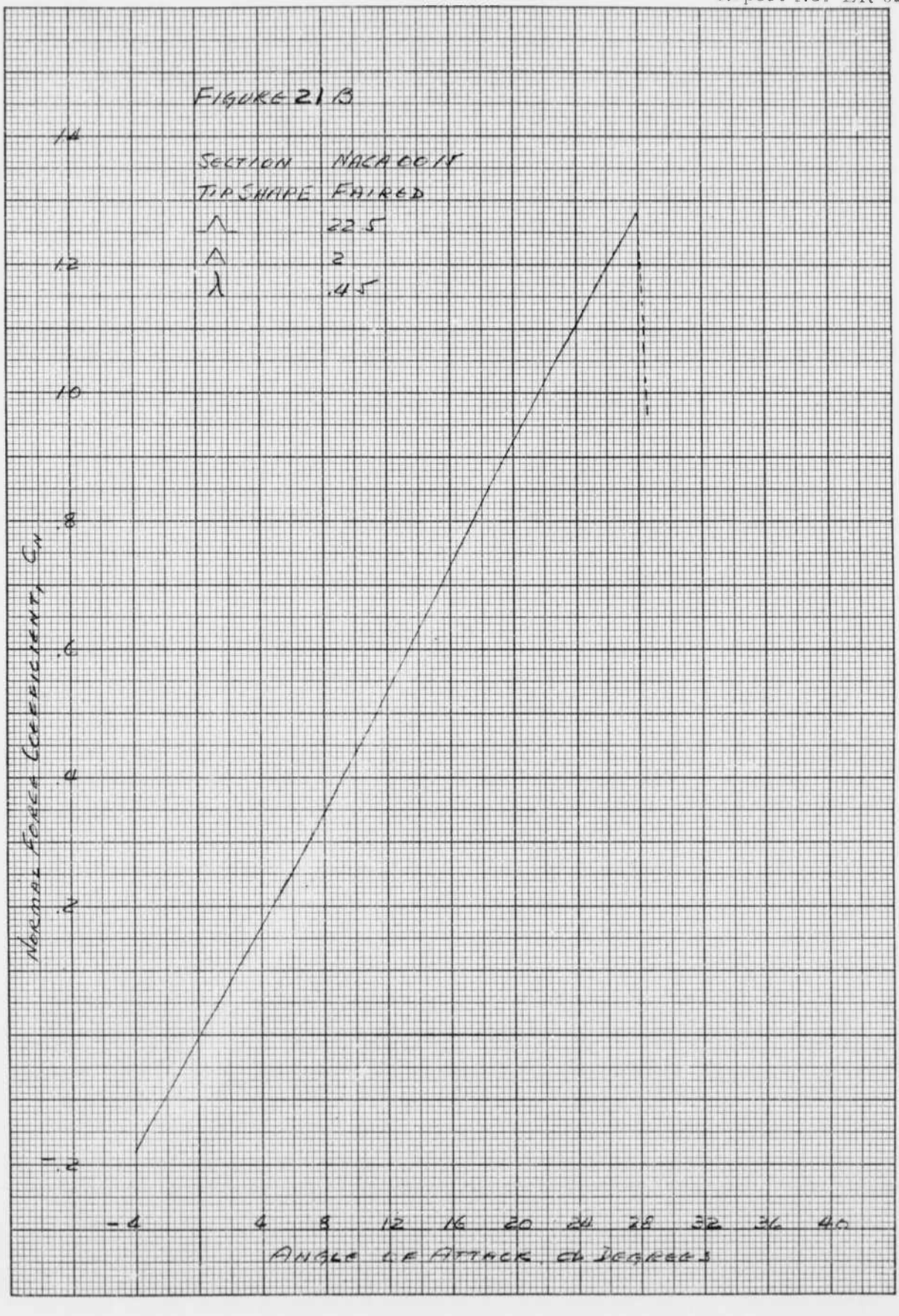


FIGURE 21 B
SECTION NACA 64A
TIP SHAPE FAIRED
Λ 22.5
A 2
λ .45
1.4
1.2
1.0
.8
.6
.4
.2
-.2
NORMAL FORCE COEFFICIENT, C_N
-4
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α DEGREES

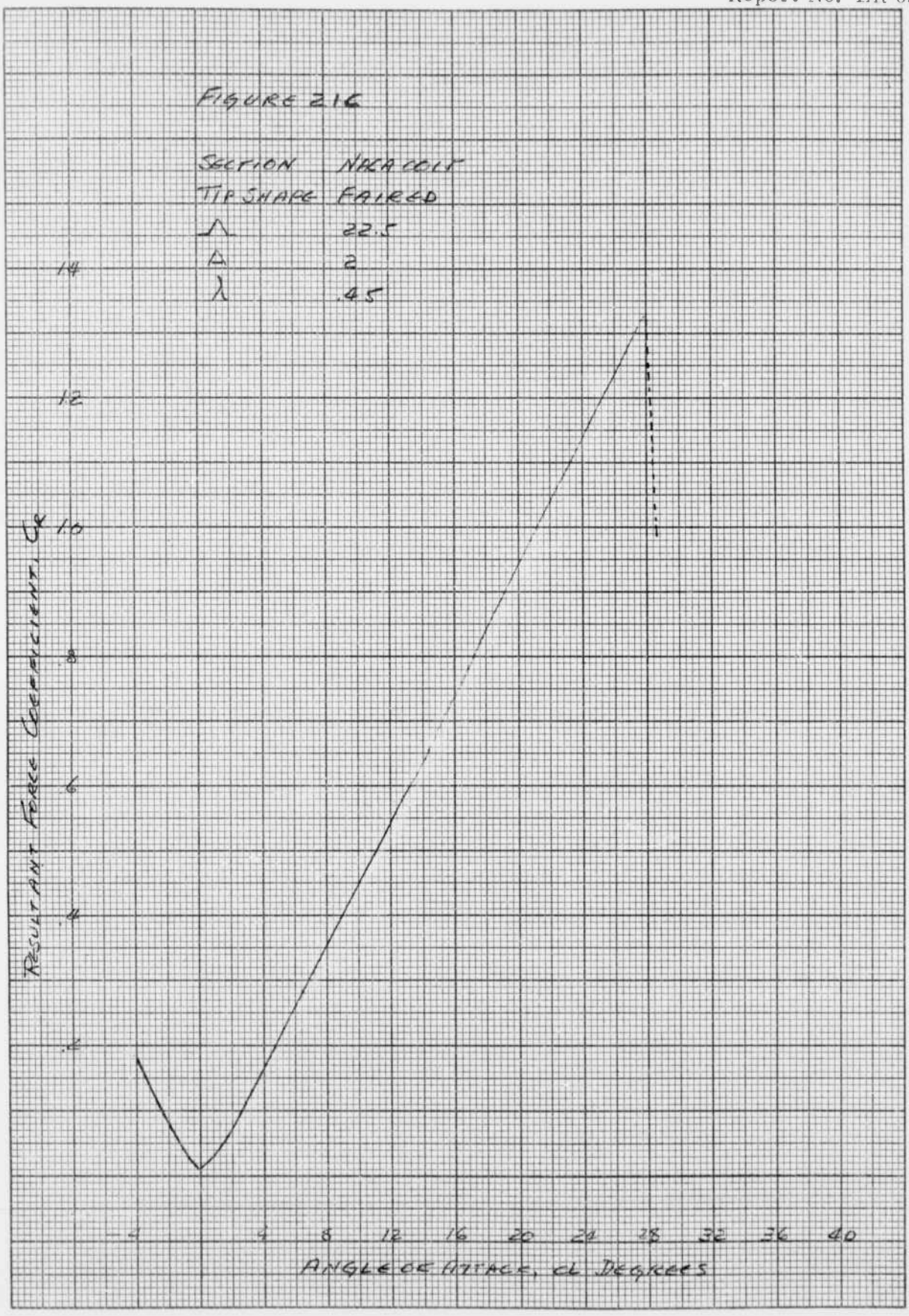
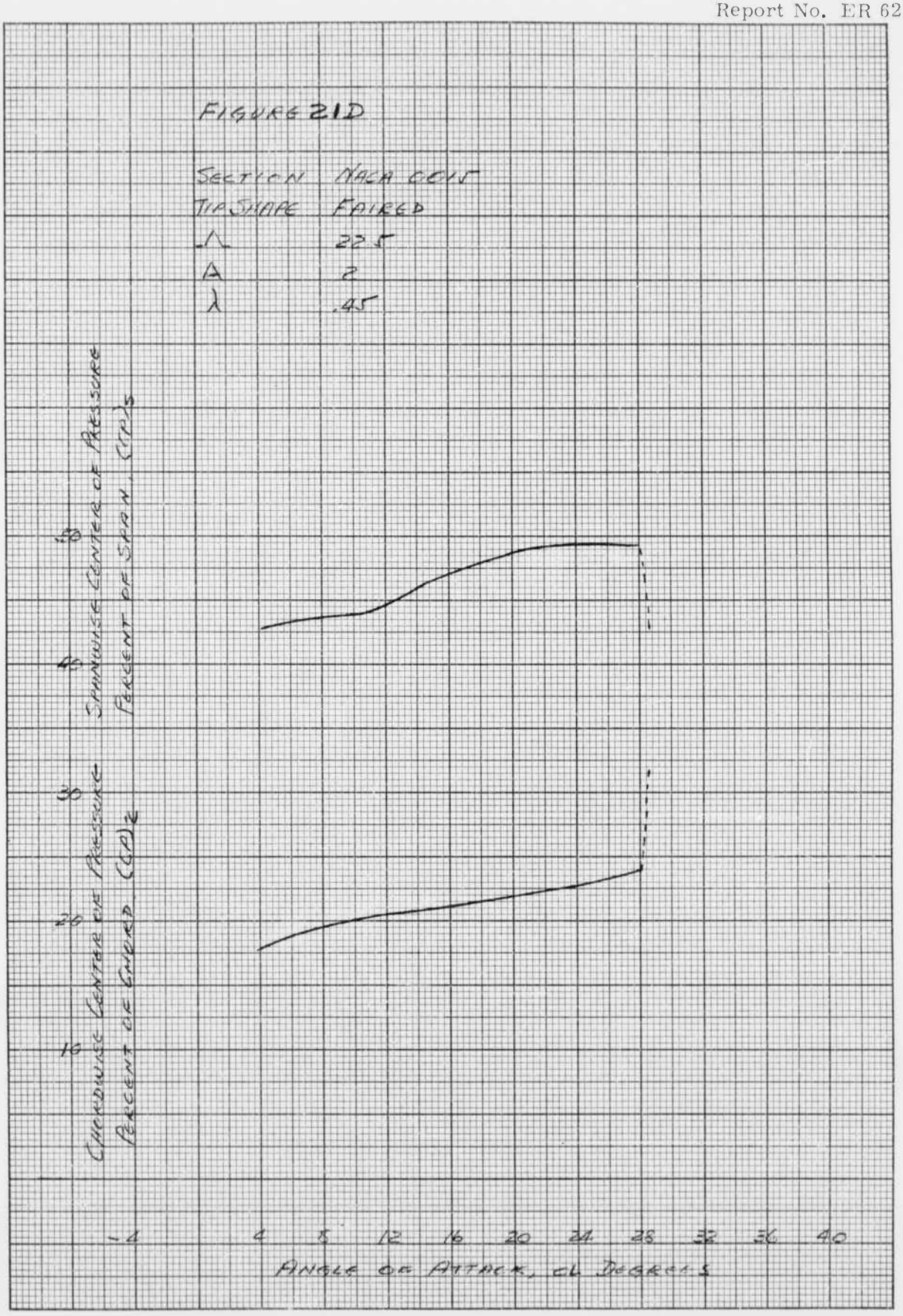


FIGURE 216
SECTION TIP SHAPE
NACA 0012 FAIRED
Λ 22.5
A 2
λ .45
RESULTANT FORCE COEFFICIENT, CR
14
12
10
8
6
4
2
-4
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α, DEGREES

FIGURE 21D

SECTION TIP SHAPE	MACH CONE FAIRED
Λ	22.5
A	2
λ	.45



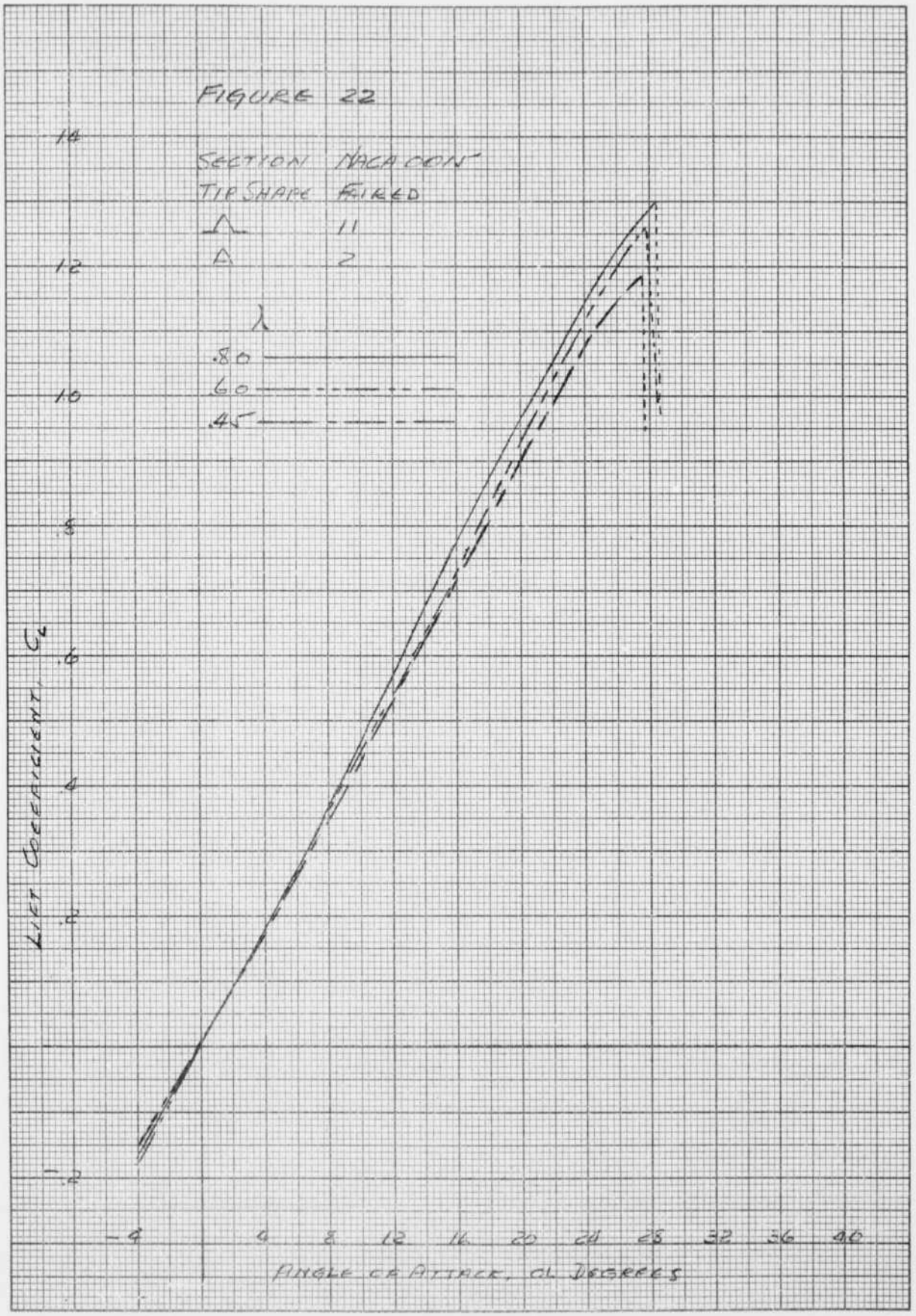
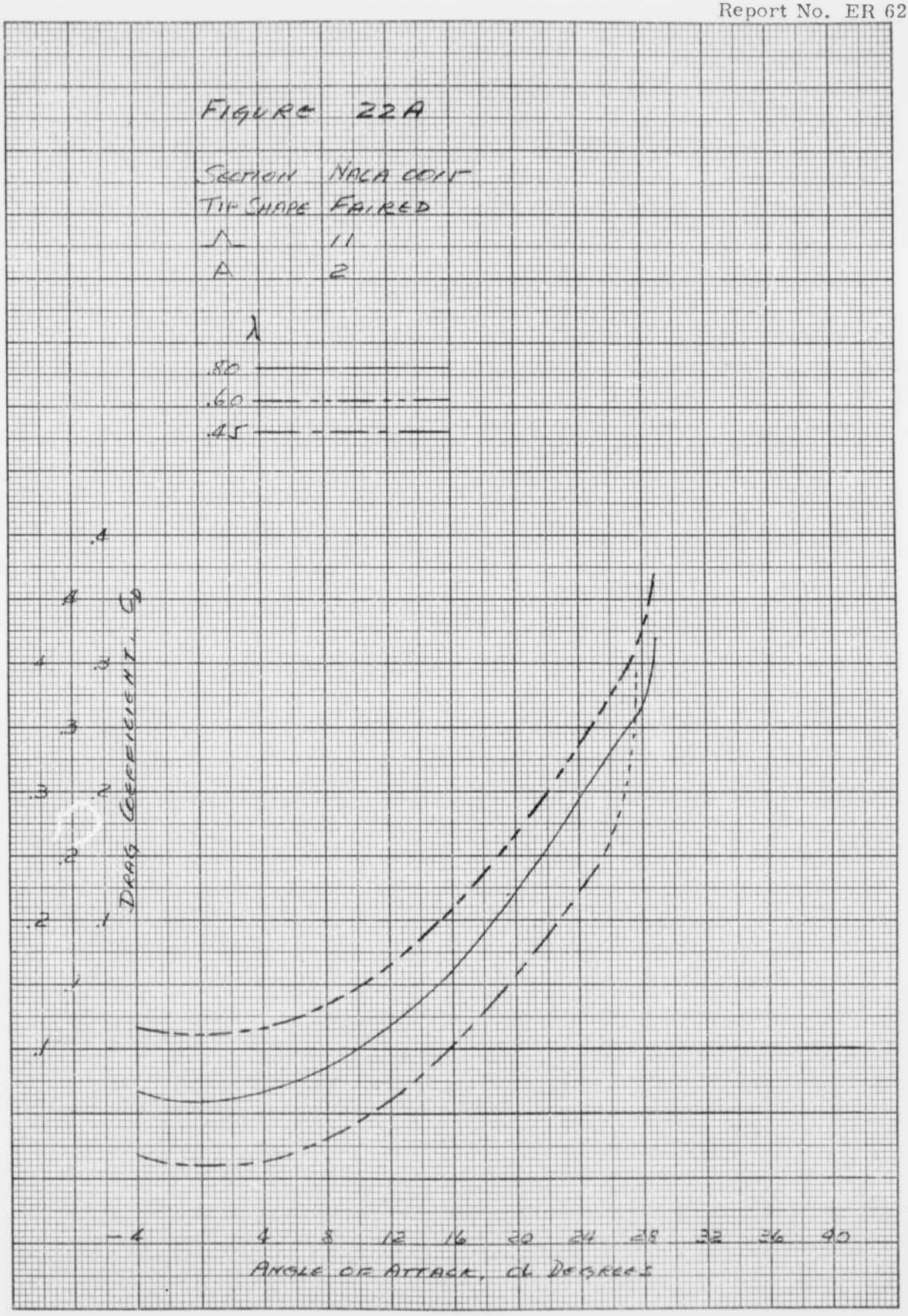


FIGURE 22
SECTION NACA 65A-006
TIP SHAPE FAIRED
11
2
λ
.80
.60
.40
14
12
10
8
6
4
2
-.2
LIFT COEFFICIENT, C_L
-4
0
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α, DEGREES

FIGURE 22A


SECTION NACA 65A-
TIP SHAPE FAIRED
Λ 11
A 2
λ
.80
.60
.45
DRAG COEFFICIENT, C_D
.4
.3
.2
.1
-4
0
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α DEGREES

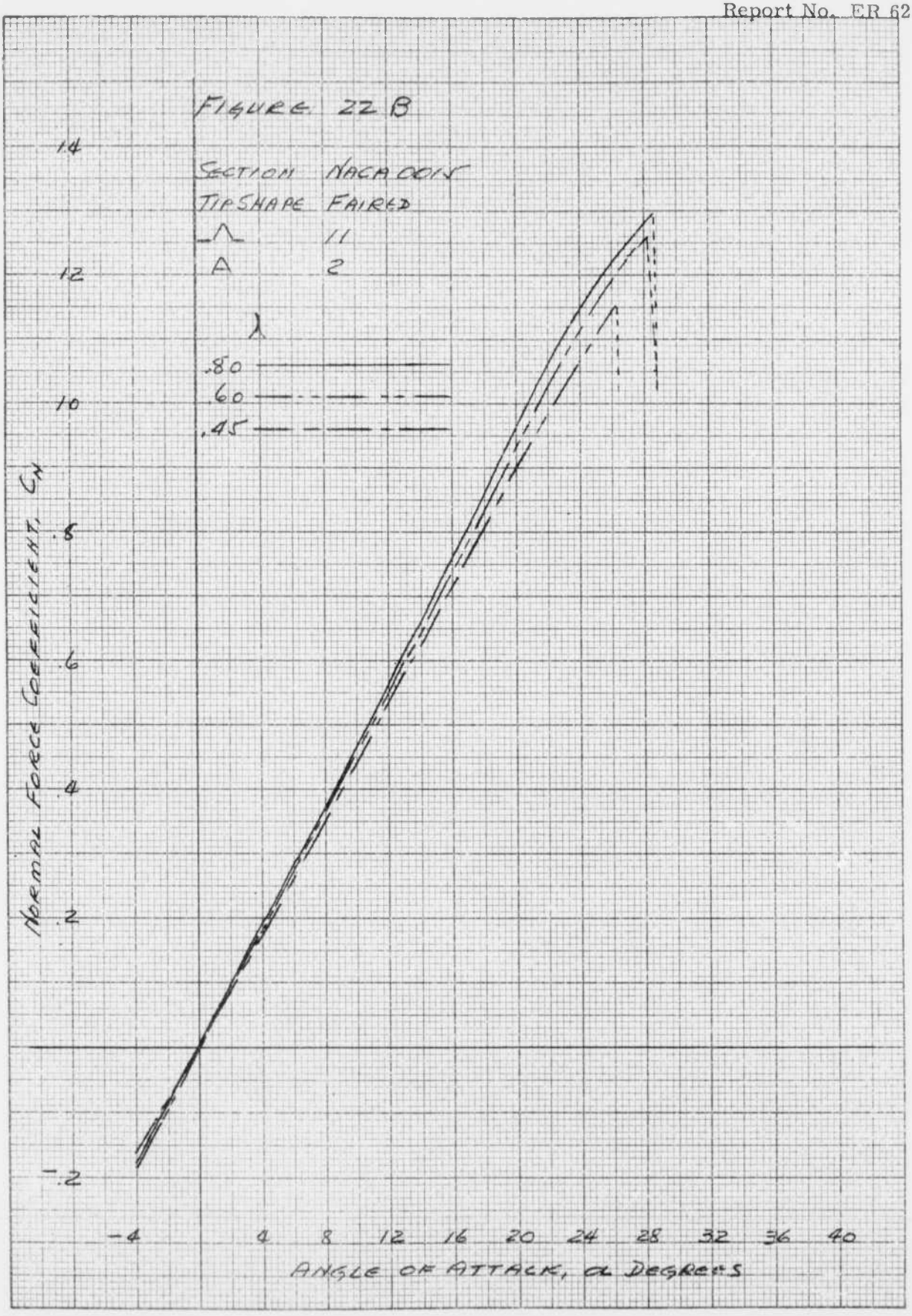


FIGURE 22 B
SECTION NACA 0015
TIP SHAPE FAIRED
Λ 11
A 2
λ
.80
.60
.45
1.4
1.2
1.0
.8
.6
.4
.2
-.2
NORMAL FORCE COEFFICIENT, CN
-4
0
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK, α DEGREES

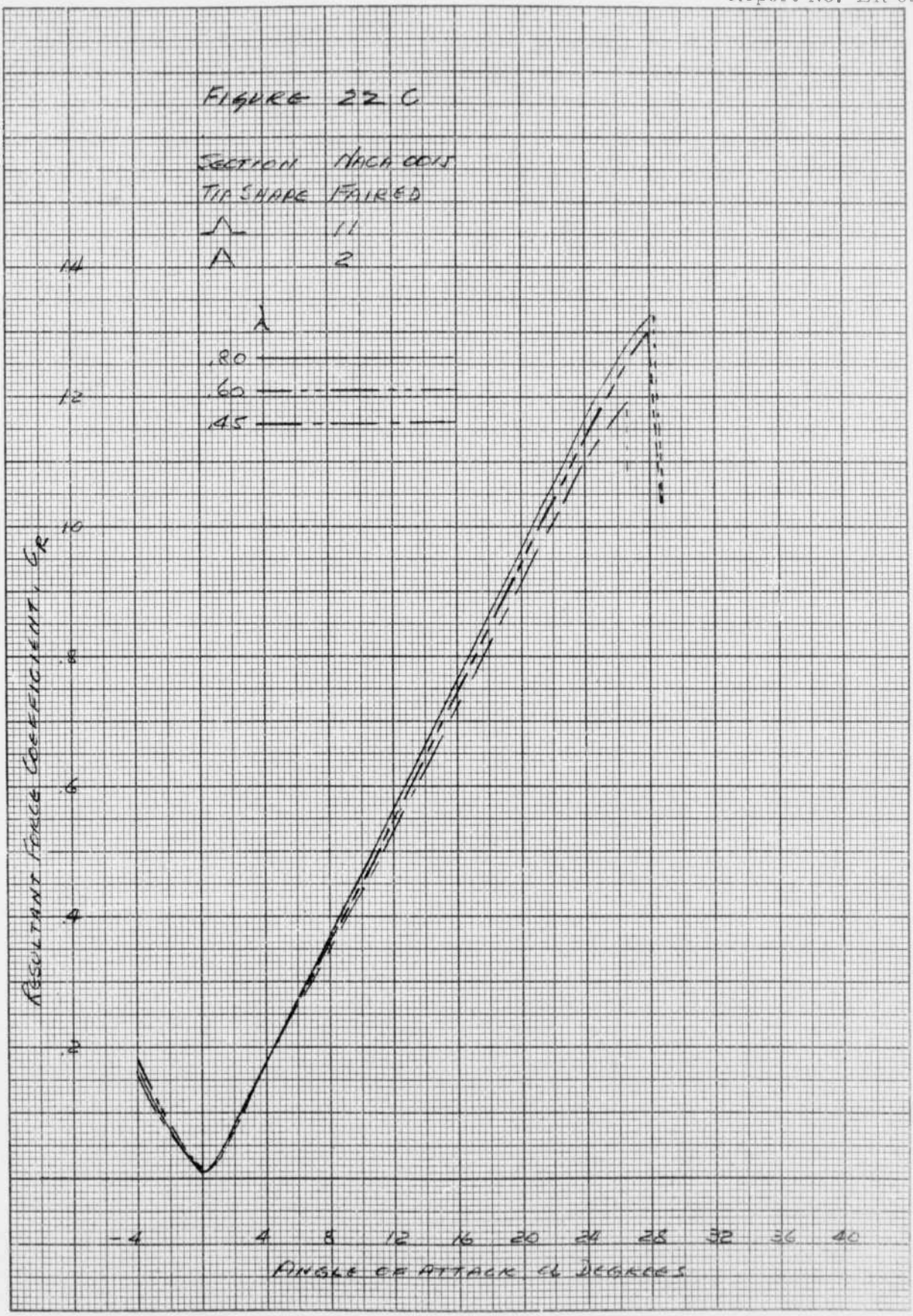


FIGURE 22 C
SECTION NACA 0015
TIP SHAPE FAIRED
Λ 11
A 2
λ
.80
.60
.45
14
12
10
8
6
4
2
RESULTANT FORCE COEFFICIENT, CR
-4
4
8
12
16
20
24
28
32
36
40
ANGLE OF ATTACK IN DEGREES

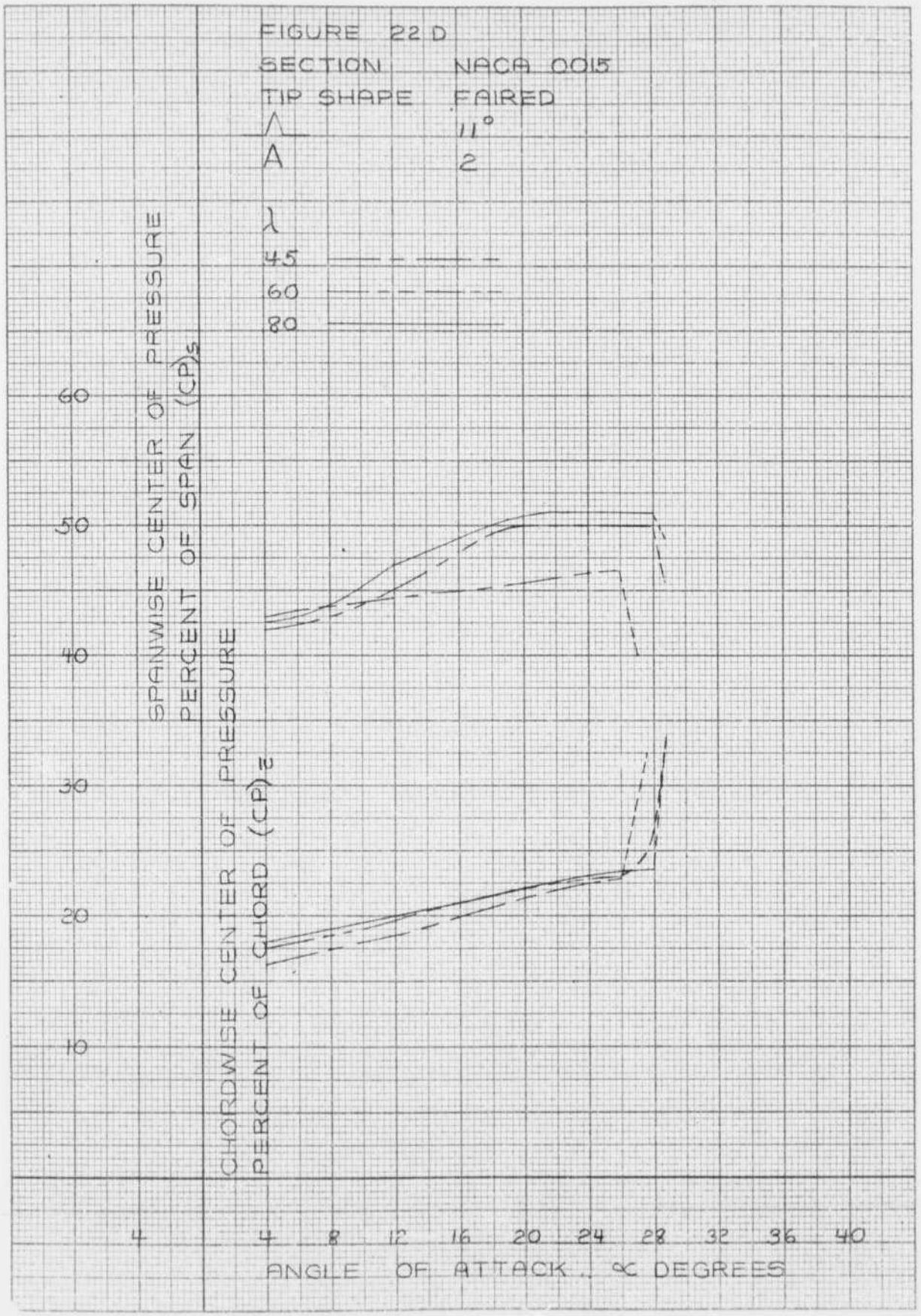


FIGURE 22 D
SECTION NACA 0015
TIP SHAPE FAIRED
Λ 11°
A 2
λ
45
60
80
SPANWISE CENTER OF PRESSURE
PERCENT OF SPAN (CP)s
CHORDWISE CENTER OF PRESSURE
PERCENT OF CHORD (CP)c
60
50
40
30
20
10
4
4 8 12 16 20 24 28 32 36 40
ANGLE OF ATTACK, α DEGREES

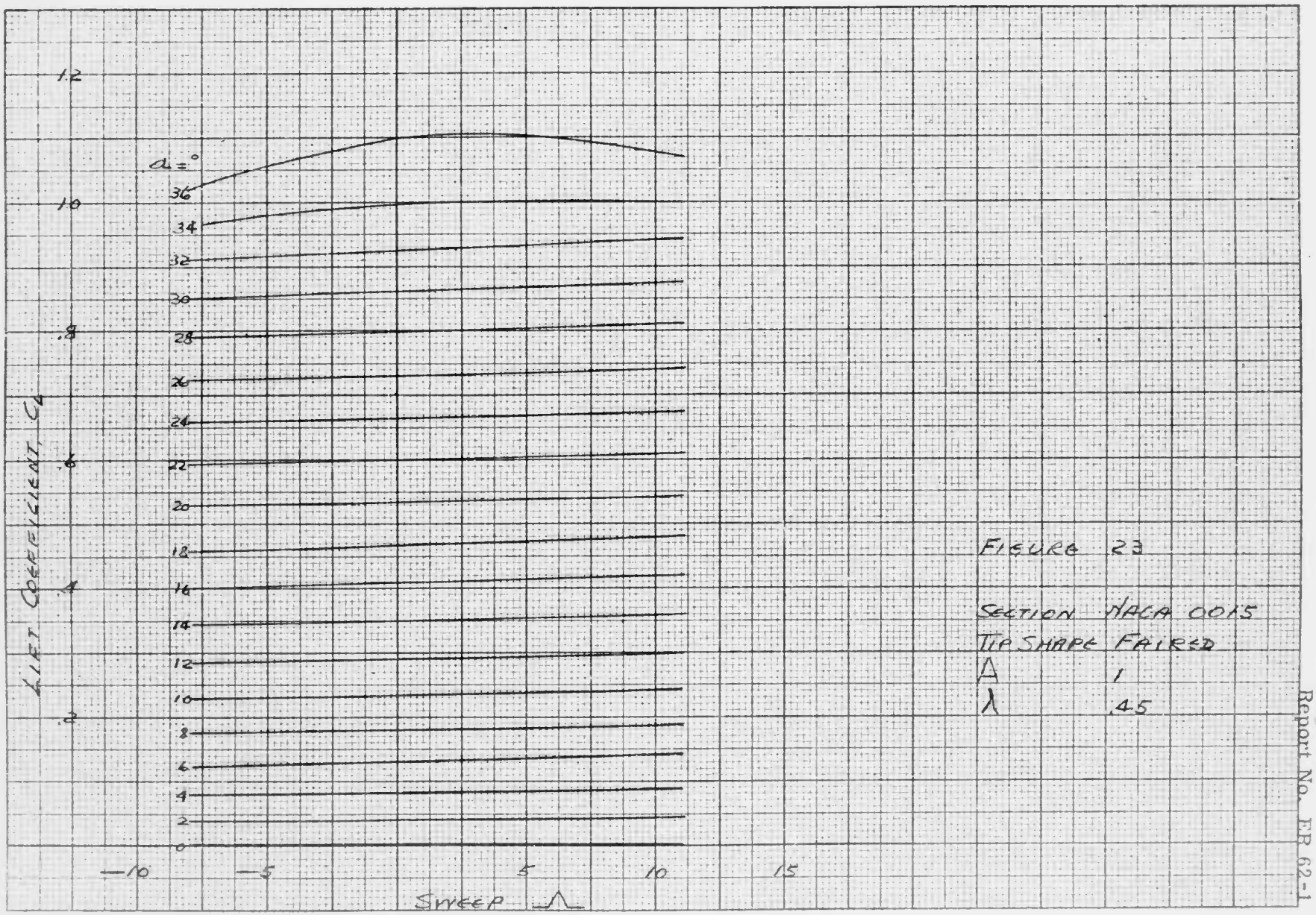


FIGURE 23

SECTION NACA 0015
TIP SHAPE FAIRED
A 1
λ .45

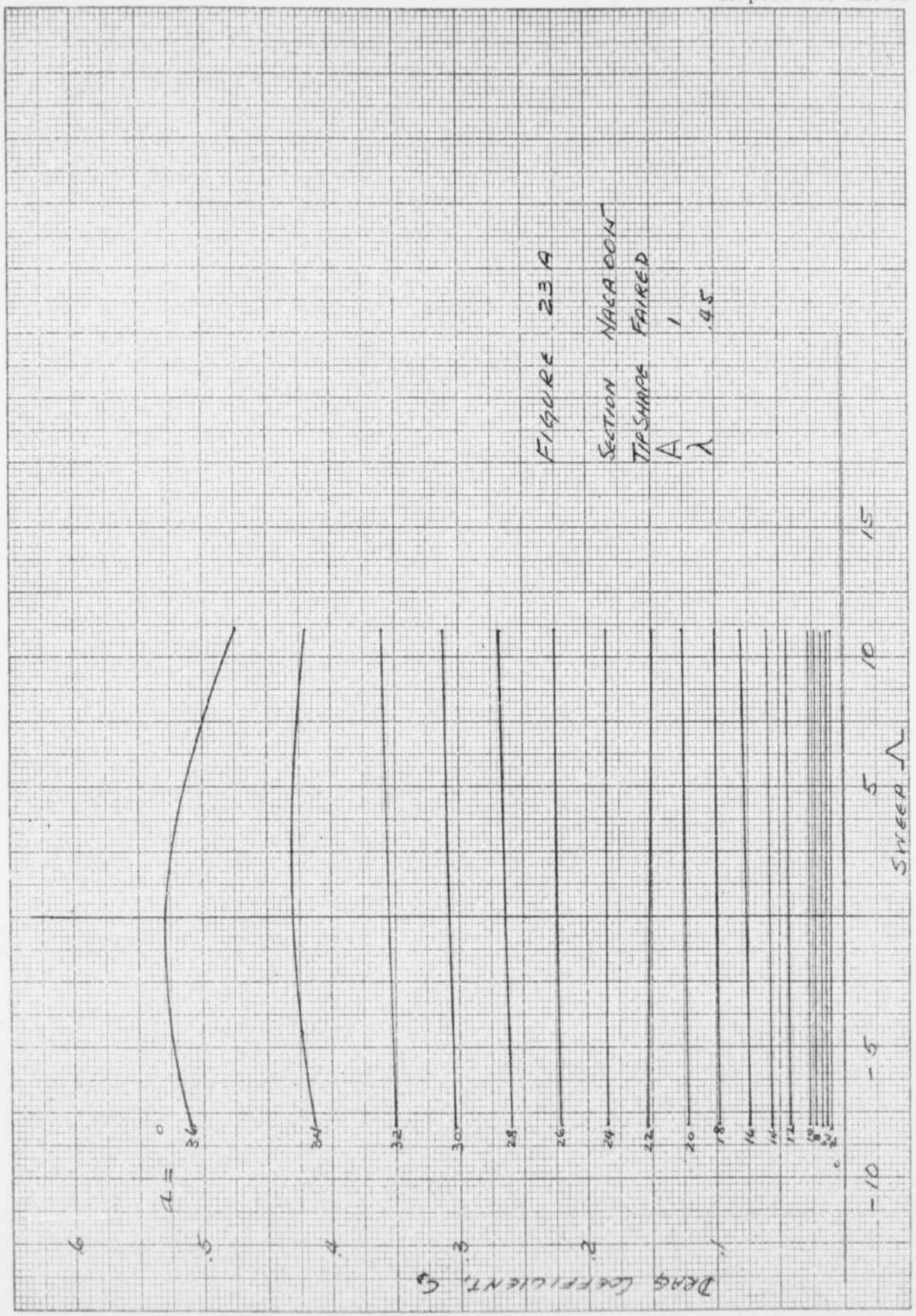


FIGURE 23A
SECTION NACA 0014
TIP SHAPE FAIRED
A 1
λ .45
DRAG COEFFICIENT, C_D
SWEEP Λ
15
10
5
-5
-10
.6
.5
.4
.3
.2
.1
α = 0
36
34
32
30
28
26
24
22
20
18
16
14
12

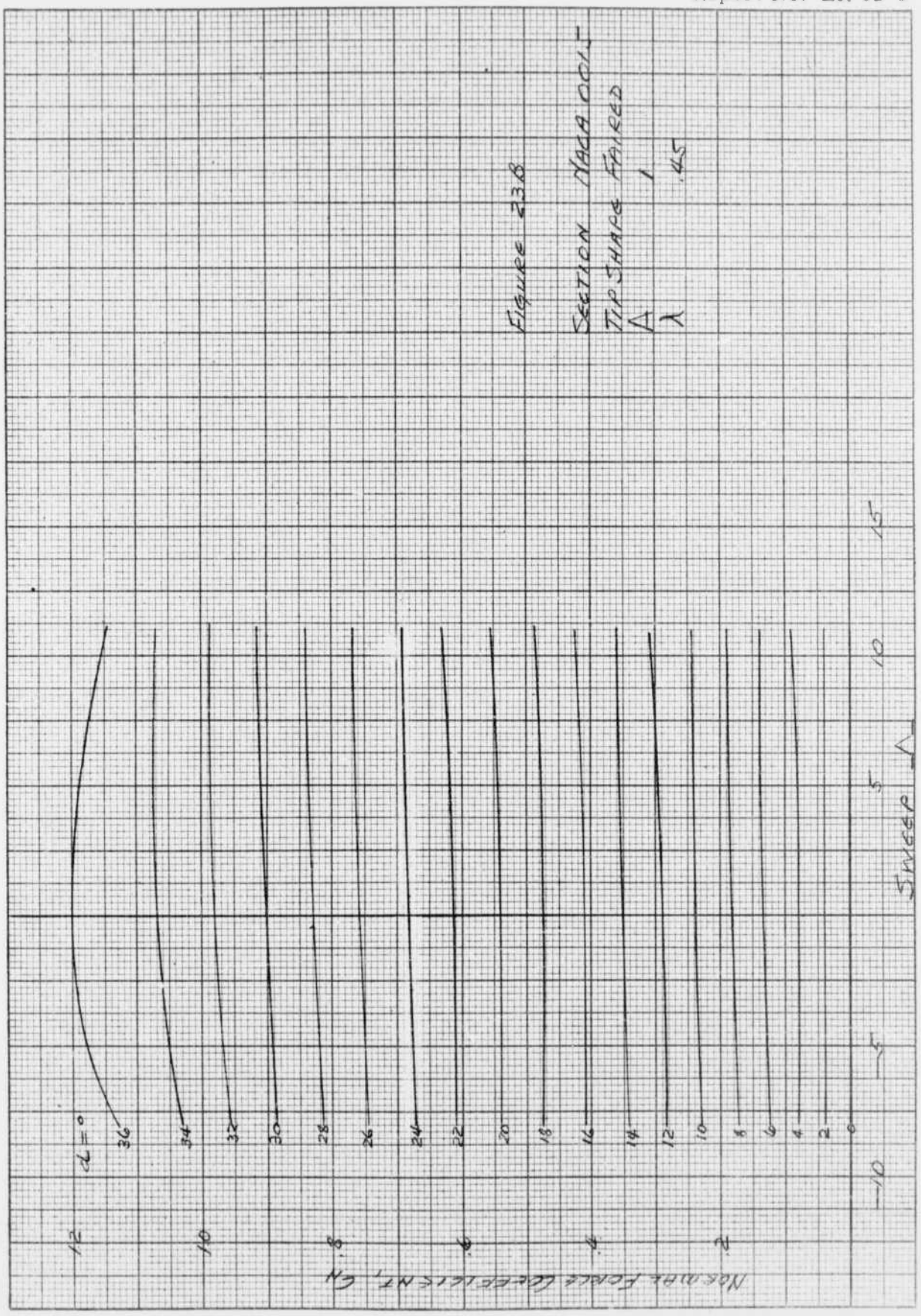


Figure 238
SECTION NACA 0014
TIP SHAPE FAIRED
Δ
λ
1
.45
NORMAL FORCE COEFFICIENT, C_N
12
10
8
6
4
2
$\alpha = 0$
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
-5
-10
15
10
5
SWEEP Λ

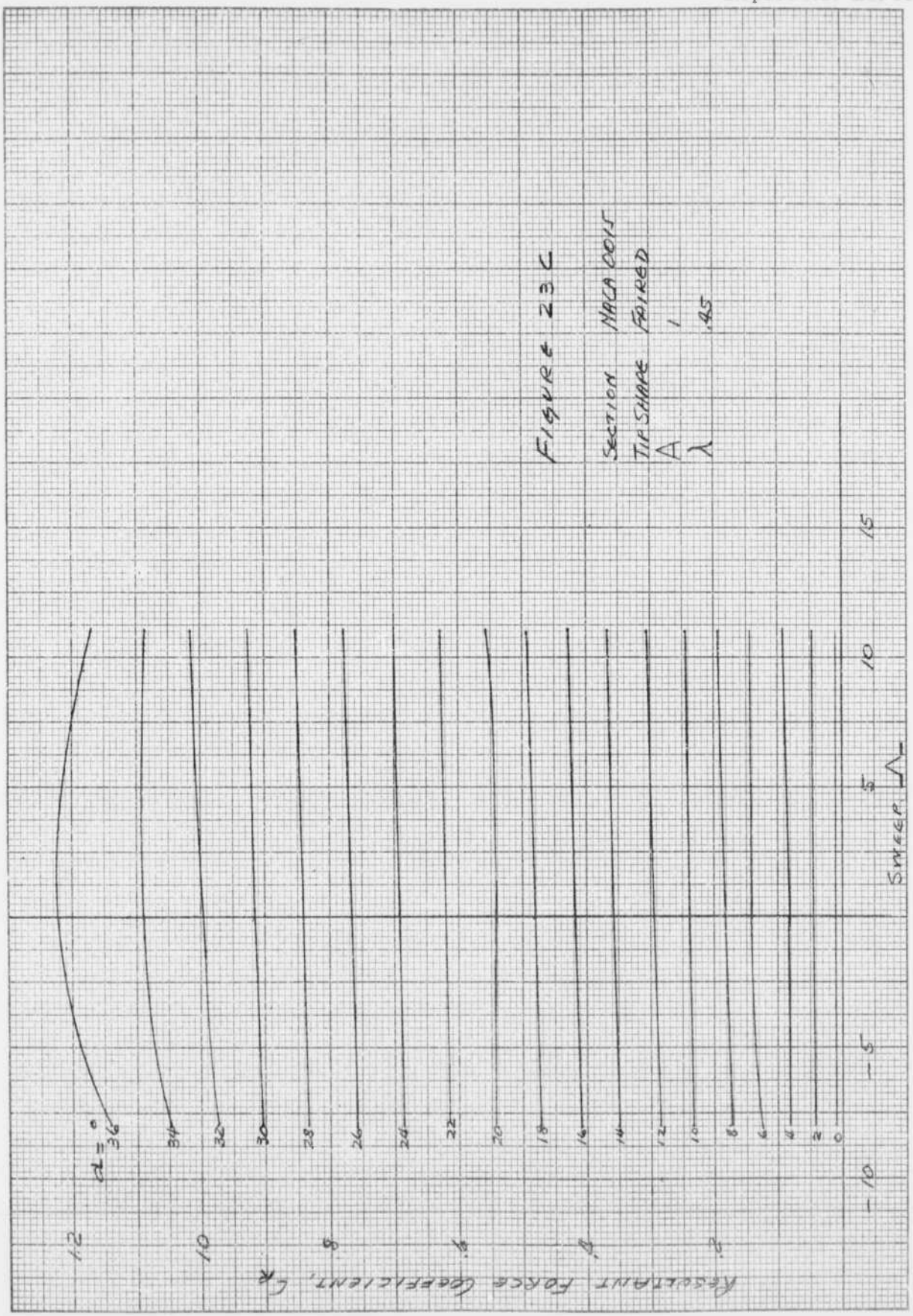


FIGURE 23 C
SECTION NACA 0012
TIP SHAPE SQUARED
A 1
λ .45
RESULTANT FORCE COEFFICIENT, C_R
SWEEP Λ
$\alpha_L = 0°$
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
1.2
1.0
.8
.6
.4
.2
-10
-5
5
10
15

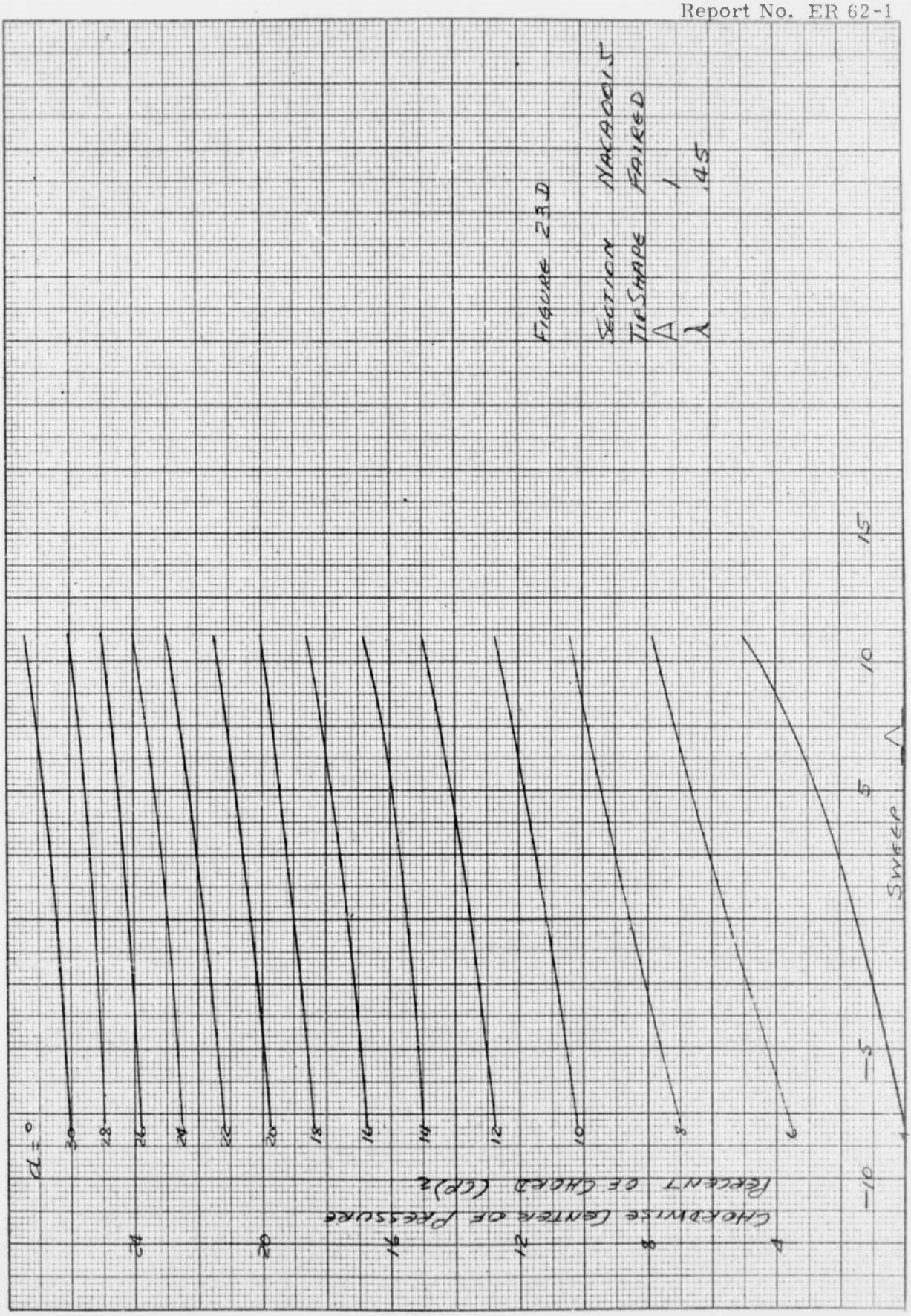


FIGURE 253
SECTION NACA0015
TIP SHAPE FAIRED
Δ 1
λ .45
CHORDWISE CENTER OF PRESSURE
PERCENT OF CHORD (CP)c
SWEEP Λ
-10
-5
0
5
10
15
20
24
16
12
8
4
30
28
26
24
22
20
18
16
14
12
10
8
6
4

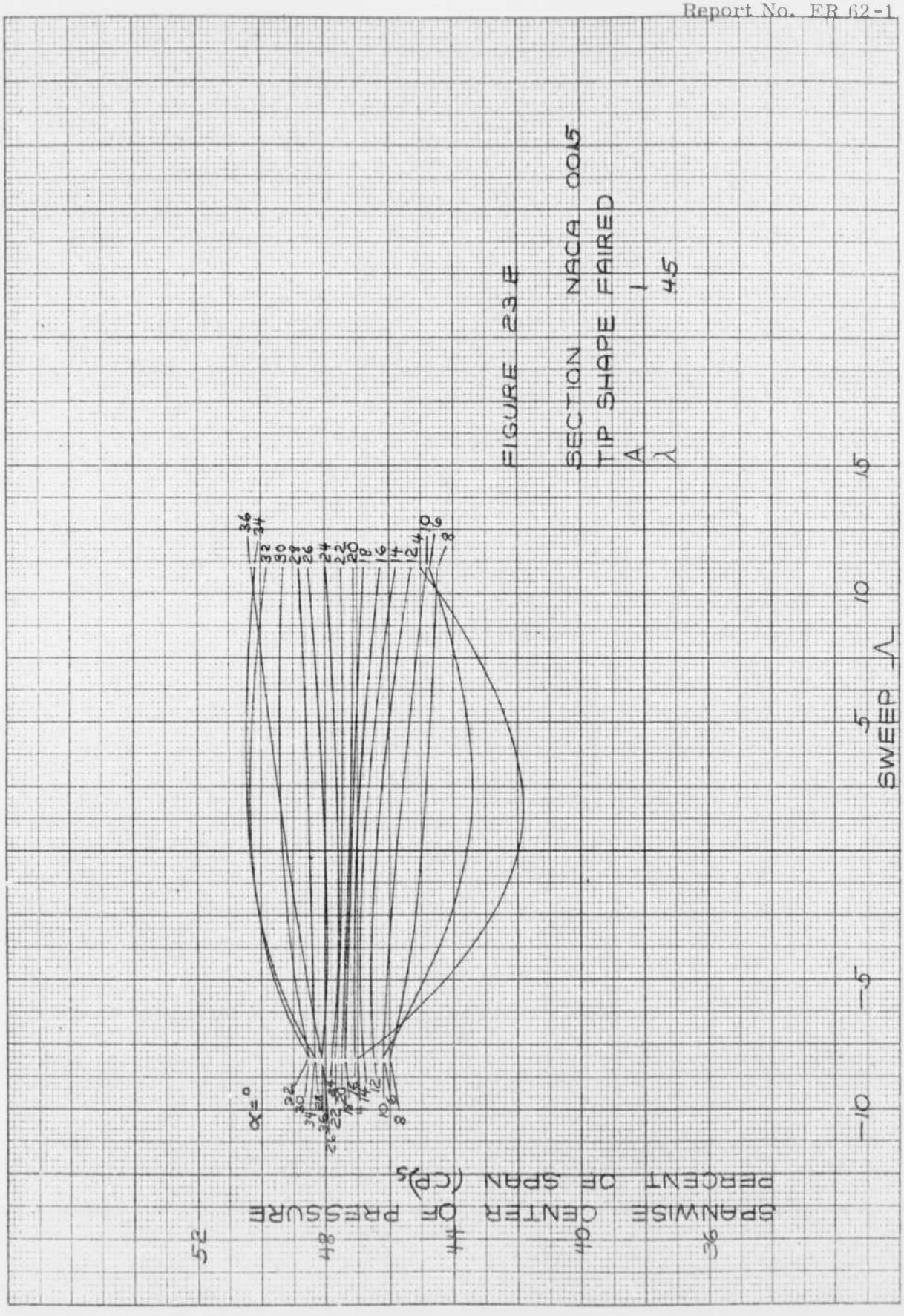


FIGURE 23 E
SECTION NACA 0015
TIP SHAPE FAIRED
A 1
λ 45
SWEEP Λ
15
10
5
-5
-10
SPANWISE CENTER OF PRESSURE
PERCENT OF SPAN (CP)S
52
48
44
40
36
α=0
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8

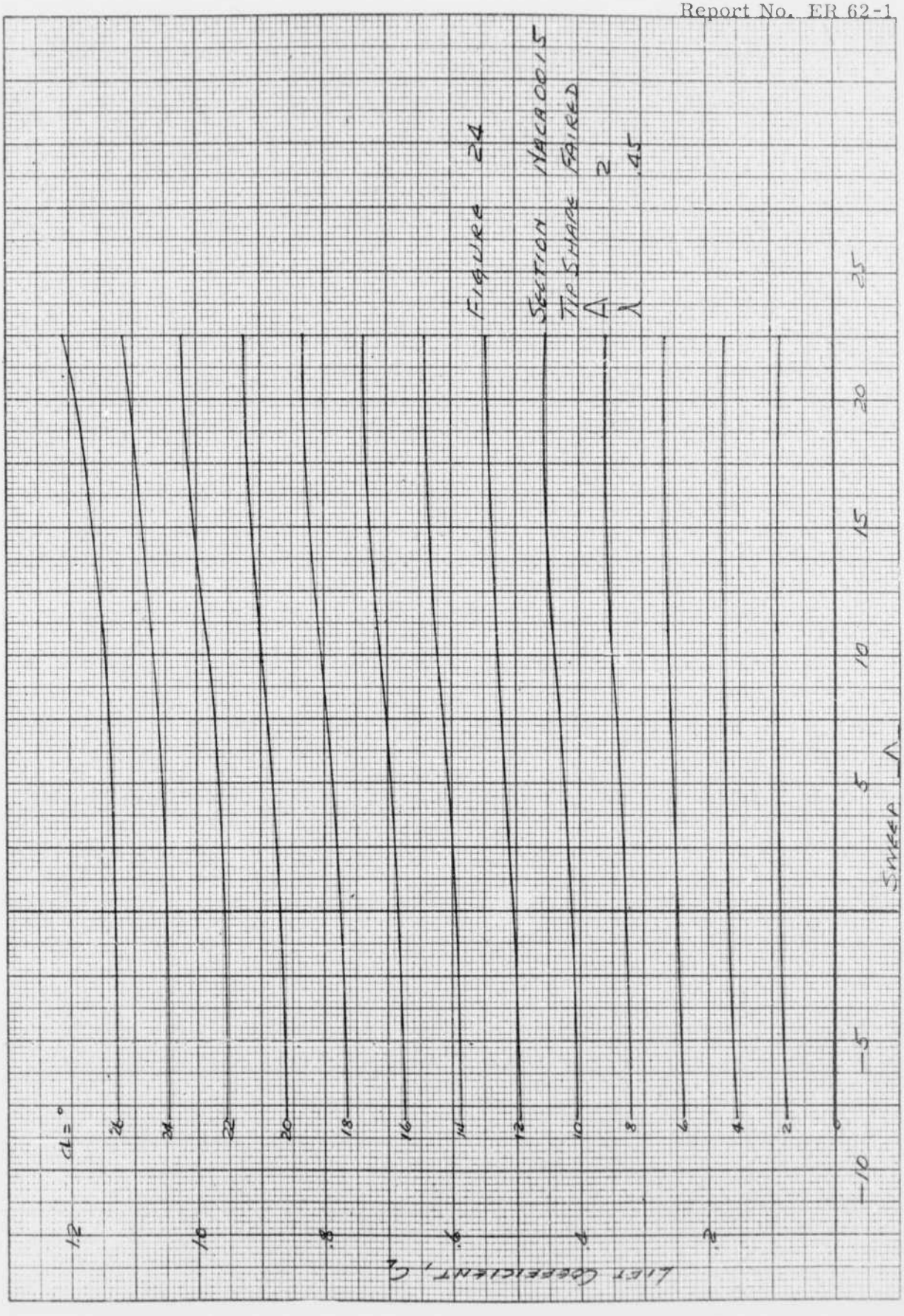


FIGURE 24
SECTION NACA 0015
TIP SHAPE FAIRED
λ 2
Λ 45
SWEEP Λ
LIFT COEFFICIENT, C_L
$C_L = 0$
1.2
1.0
.8
.6
.4
.2
0
26
24
22
20
18
16
14
12
10
8
6
4
2
0
-10
-5
5
10
15
20
25

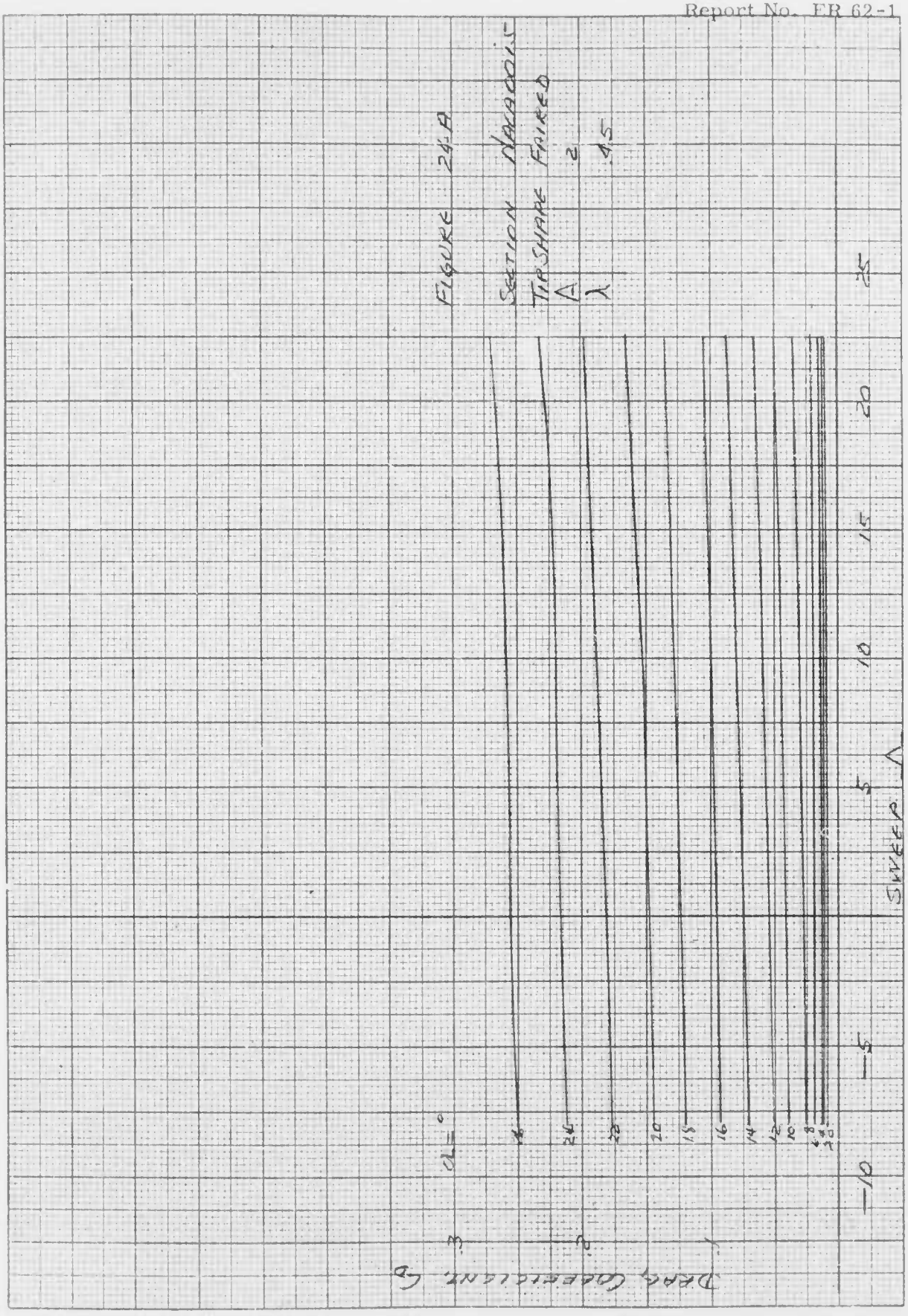


FIGURE 24-B
SECTION NACA 0015
TRAPSHAPE FAIRED
Δ
λ
2
.45
DRAG COEFFICIENT C_D
$\alpha = 0°$
24
22
20
18
16
14
12
10
8
6
4
2
-10
-5
5
10
15
20
25
V SPEEDS

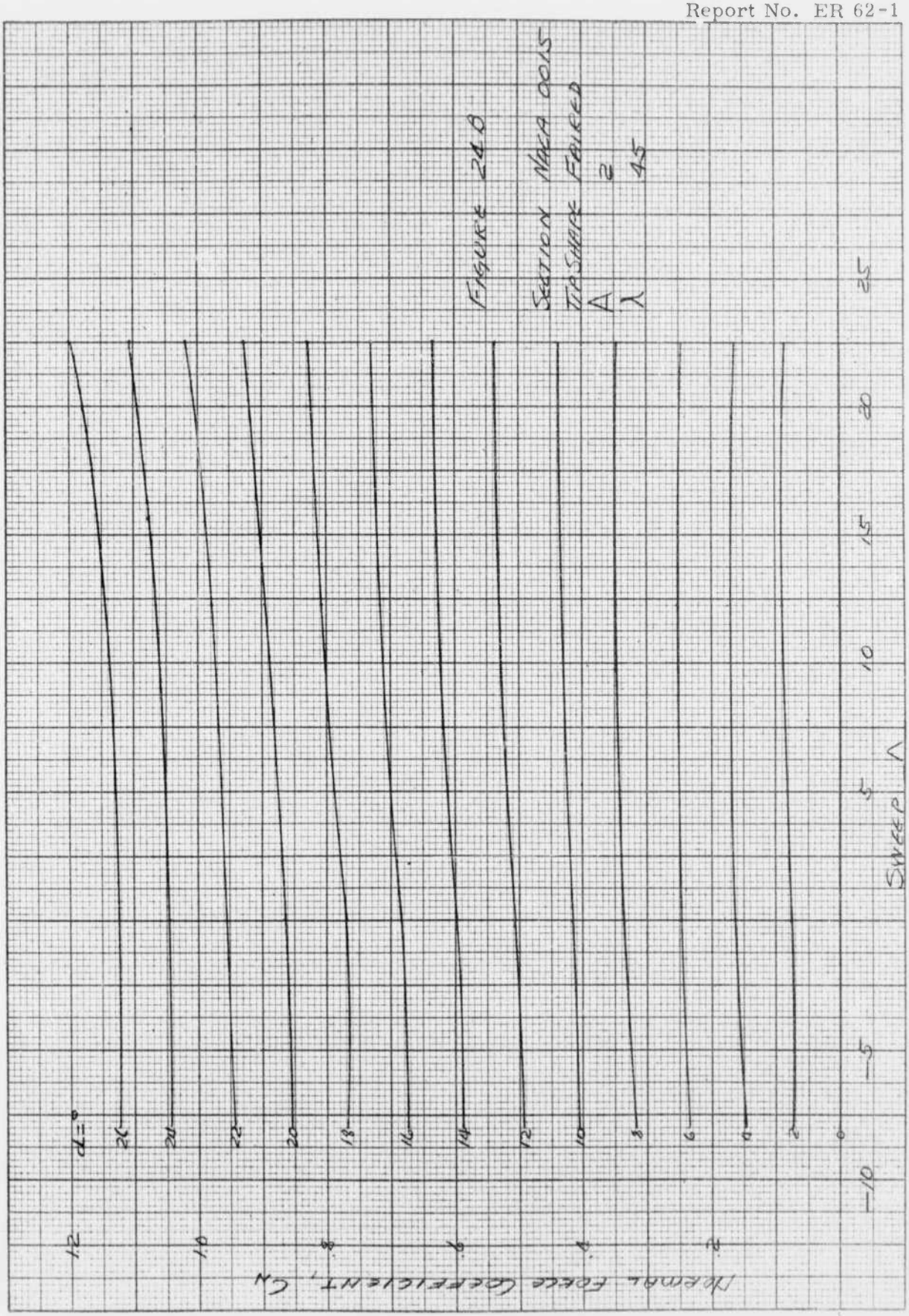


FIGURE 24.0
SECTION NACA 0015
TIP SHAPE FAIRED
A = 2
λ = 45
Sweep, Λ
Normal Force Coefficient, CN
α=
26
24
22
20
18
16
14
12
10
8
6
4
2
0
1.2
1.0
.8
.6
.4
.2
25
20
15
10
5
0
-5
-10

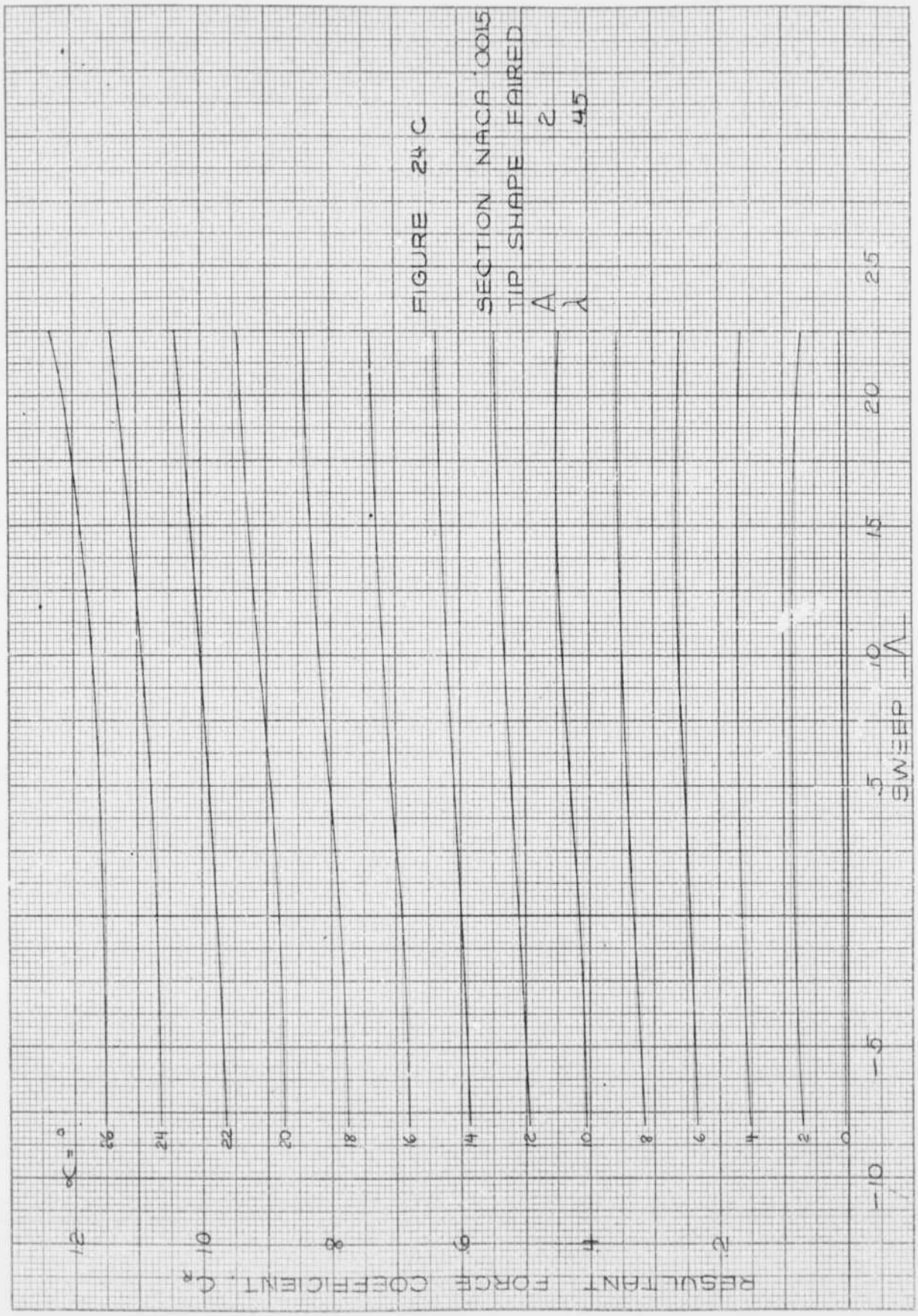


FIGURE 24 C
SECTION NACA 0015
TIP SHAPE FAIRED
A 2
λ 45
RESULTANT FORCE COEFFICIENT, C_R
SWEEP Λ
-10
-5
0
5
10
15
20
25
4
6
8
10
12
14
16
18
20
22
24
26
$\alpha = 0$

Figure 24 D
Section NACA 0015
Type Shape Faired
Δ 2
λ 45
Chordwise Centre of Pressure
Percent of Chord - (cp)c
α = °
36
34
22
20
18
16
14
12
10
8
6
4
28
24
20
16
12
-10
-5
5
10
15
20
25
30
Speed - V

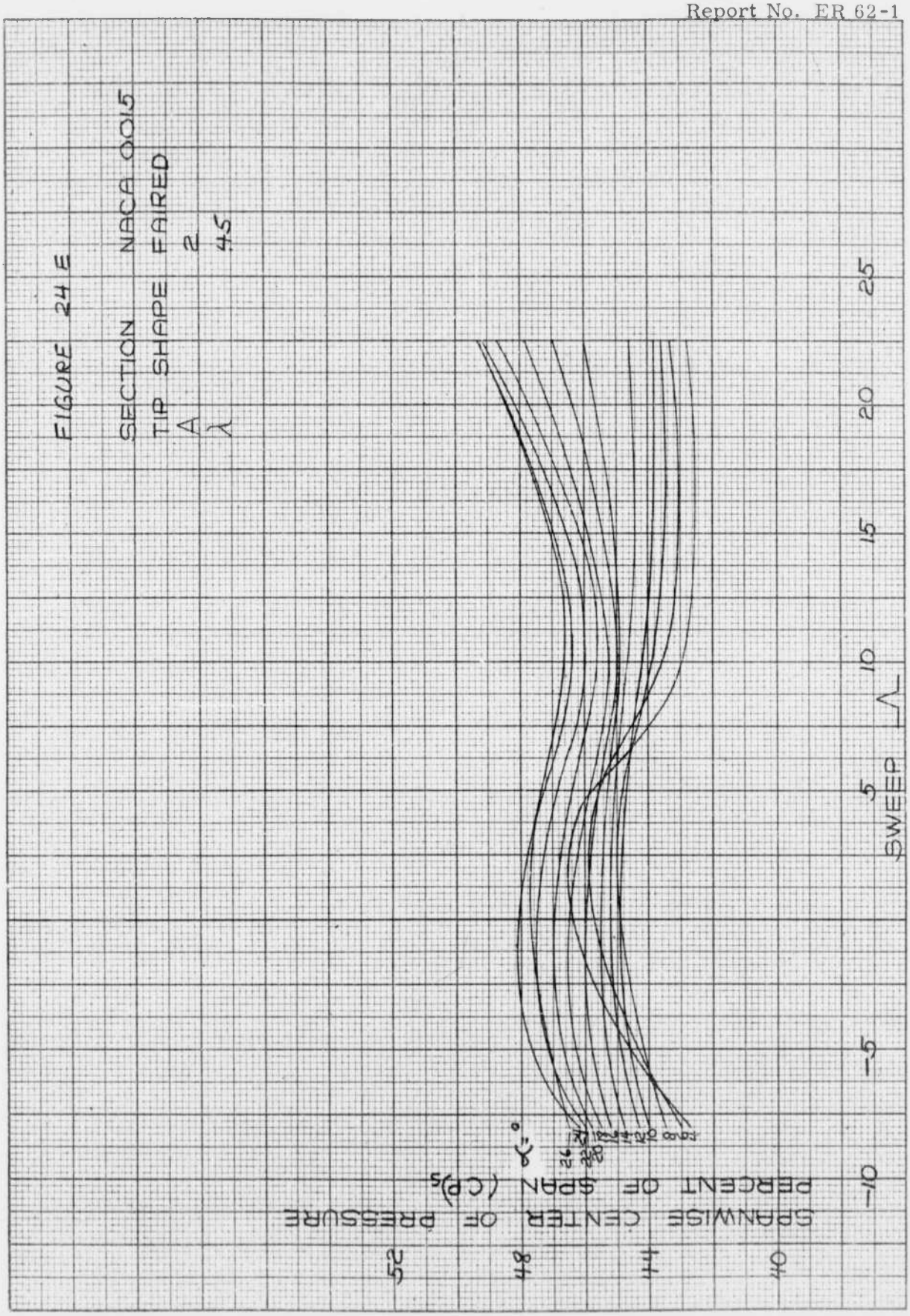


FIGURE 24 E
SECTION NACA 0015
TIP SHAPE FAIRED
A 2
λ 45
SPANWISE CENTER OF PRESSURE
PERCENT OF SPAN (c.p.)s
40
44
48
52
-10
-5
5
10
15
20
25
SWEEP Λ
α°
24
22
20
18
16
14
12
8
6

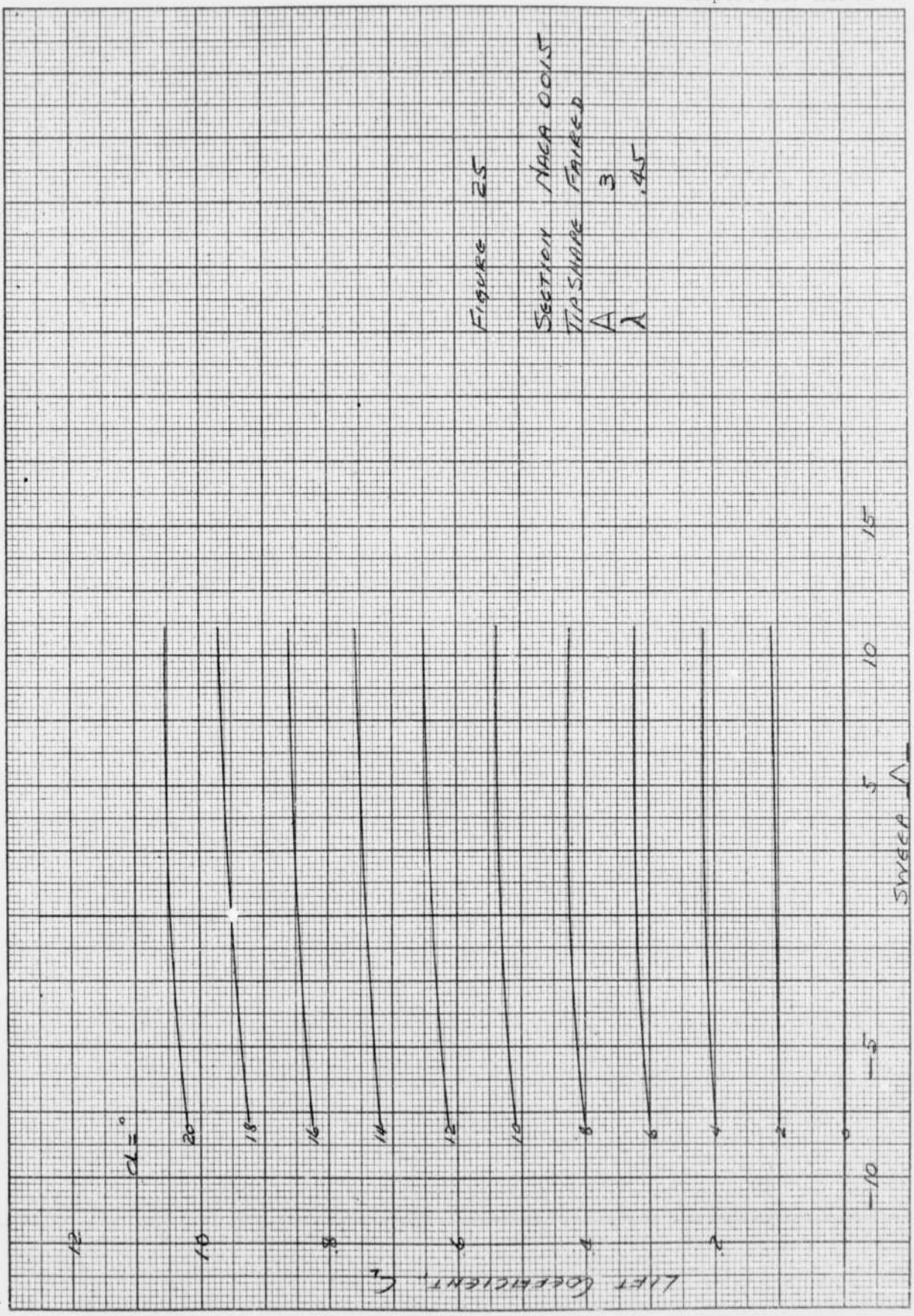


FIGURE 25
SECTION NACA 0015
TIP SHAPE FAIRED
A 3
λ .45
LIFT COEFFICIENT C_L
SWEEP Λ
α = °
20
18
16
14
12
10
8
6
4
2
0
12
10
8
6
4
2
15
10
5
-5
-10

FIGURE 25 A
SECTION NACA 0015
TIP SHAPE FAIRED
A 3
λ 45
DRAG COEFFICIENT, C_D
3
2
1
α = 0
20
18
16
14
12
10
8
6
4
2
-10
-5
5
10
15
SWEEP Λ

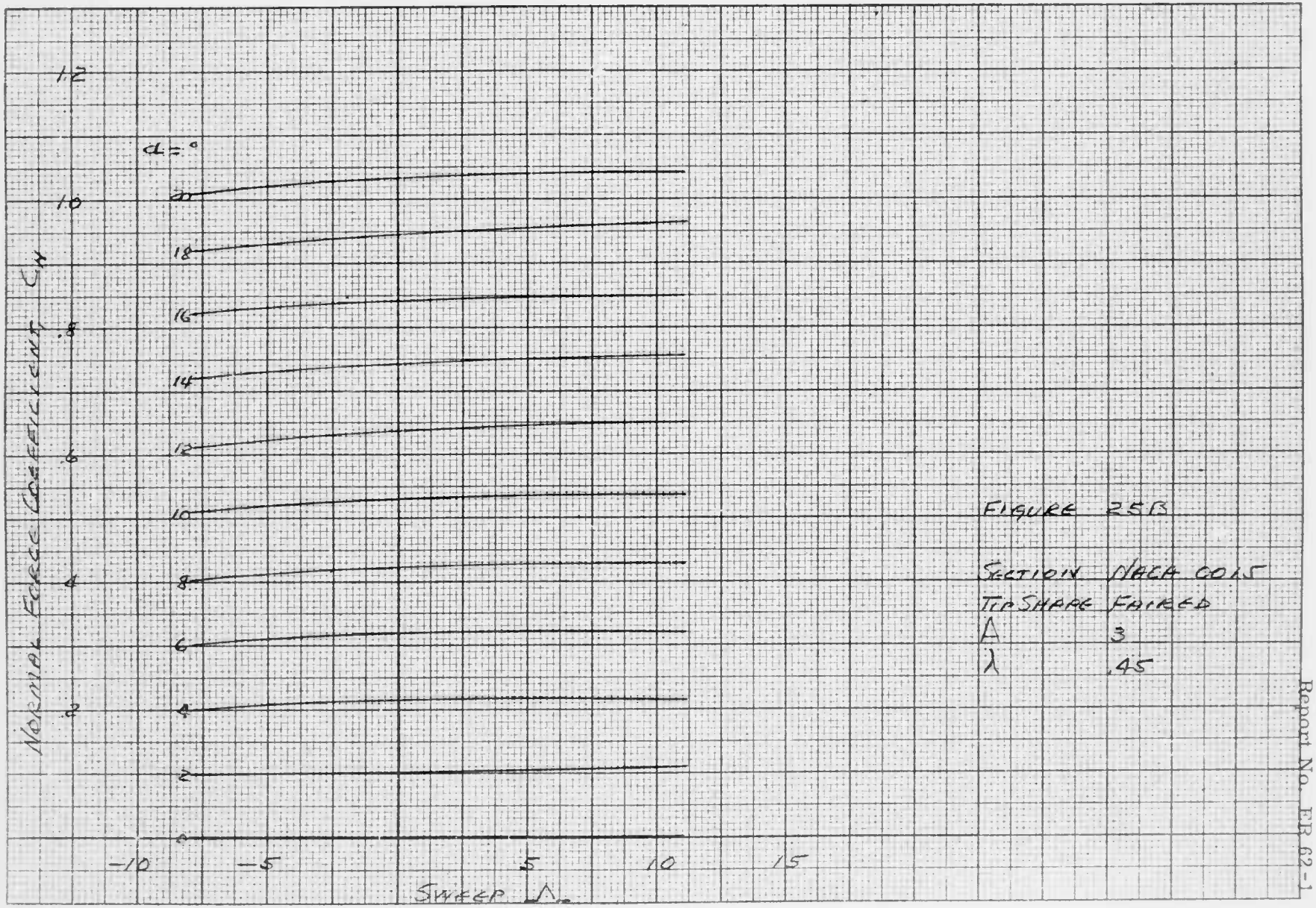


FIGURE 25B

SECTION NACA 0015
TIP SHAPE FAIRED
A 3
λ .45

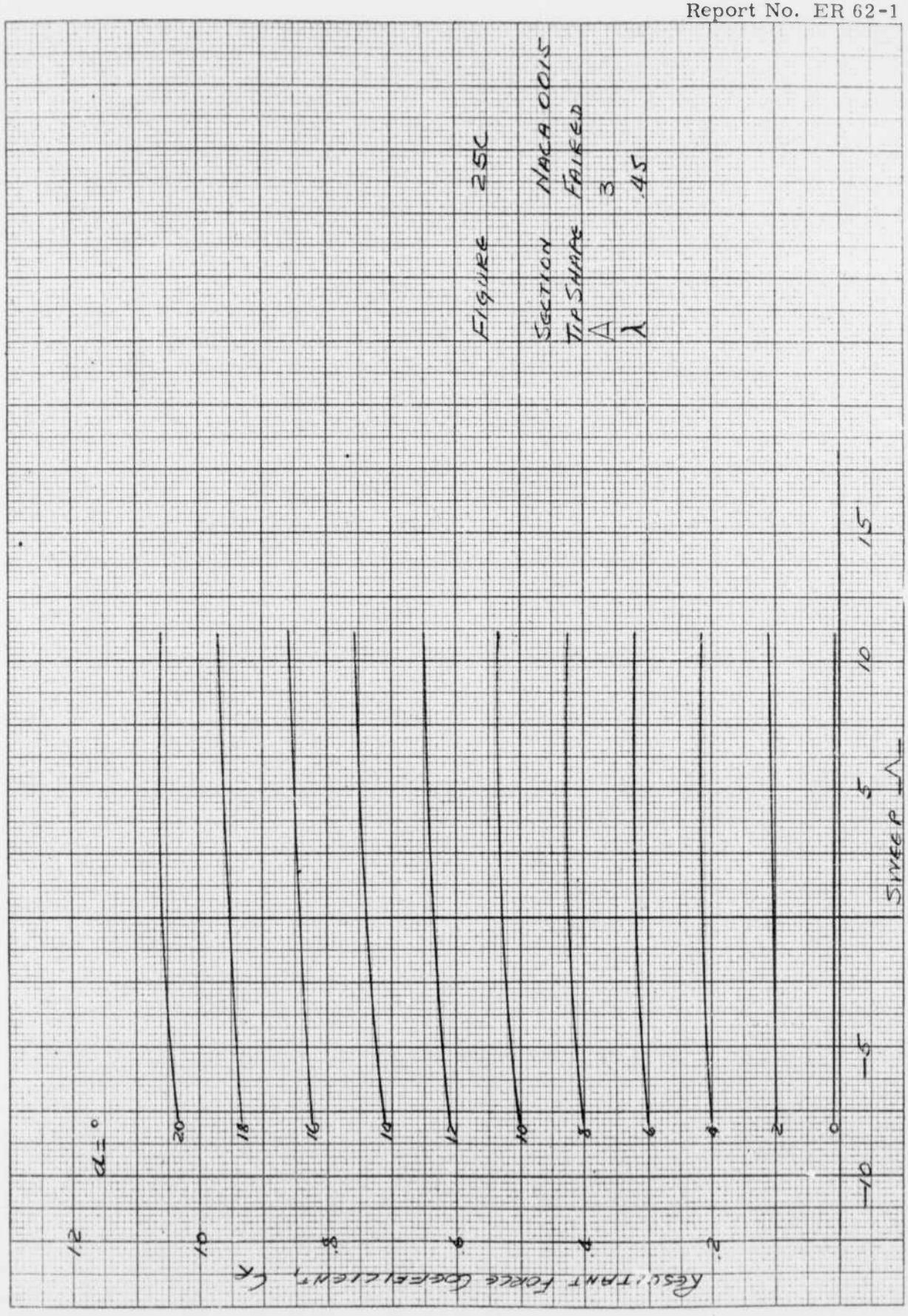


FIGURE 25C
SECTION NACA 0015
TIP SHAPE FAIRED
A 3
λ .45
RESULTANT FORCE COEFFICIENT, C_R
1.2
1.0
.8
.6
.4
.2
α_i = °
20
18
16
14
12
10
8
6
4
2
0
-5
-10
15
10
5
SWEEP $\Lambda_{\frac{1}{4}}$

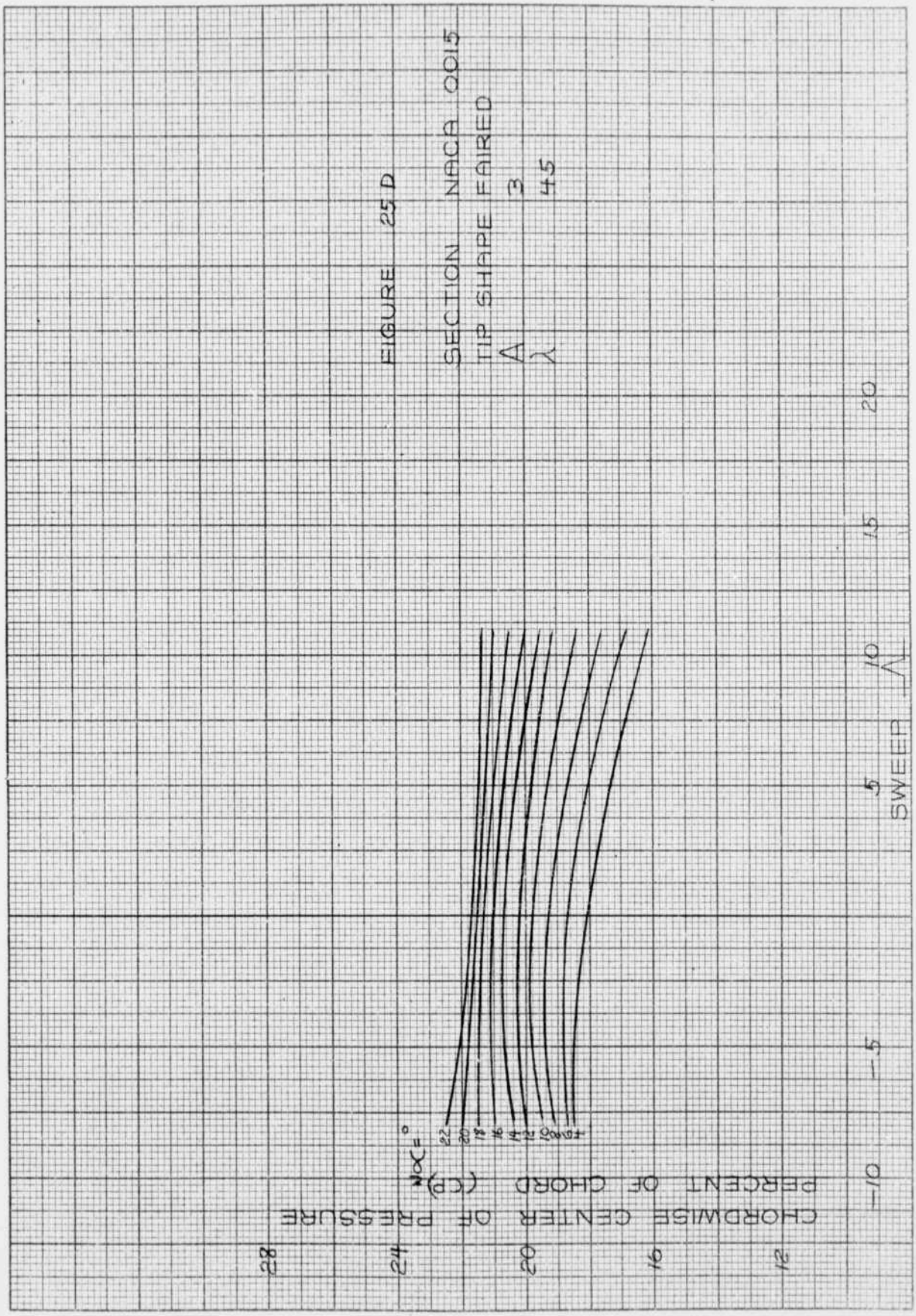


FIGURE 25 D
SECTION NACA 0015
TIP SHAPE FAIRED
A 3
λ 45
SWEEP Λ⊥
20
15
10
5
−5
−10
CHORDWISE CENTER OF PRESSURE
PERCENT OF CHORD (CP)
28
24
20
16
12
α°
22
20
18
16
14
12
10
8
6
4

FIGURE 25 E
SECTION NACA 0015
TIP SHAPE FAIRED
A 3
λ .45
SWEEP Λ.25
-5
-10
-15
-20
SPANWISE CENTER OF PRESSURE
PERCENT OF SPAN (c.p.)
35
40
44
48
52
α = 0
2
4
6
8
10
12
14
16
18
20

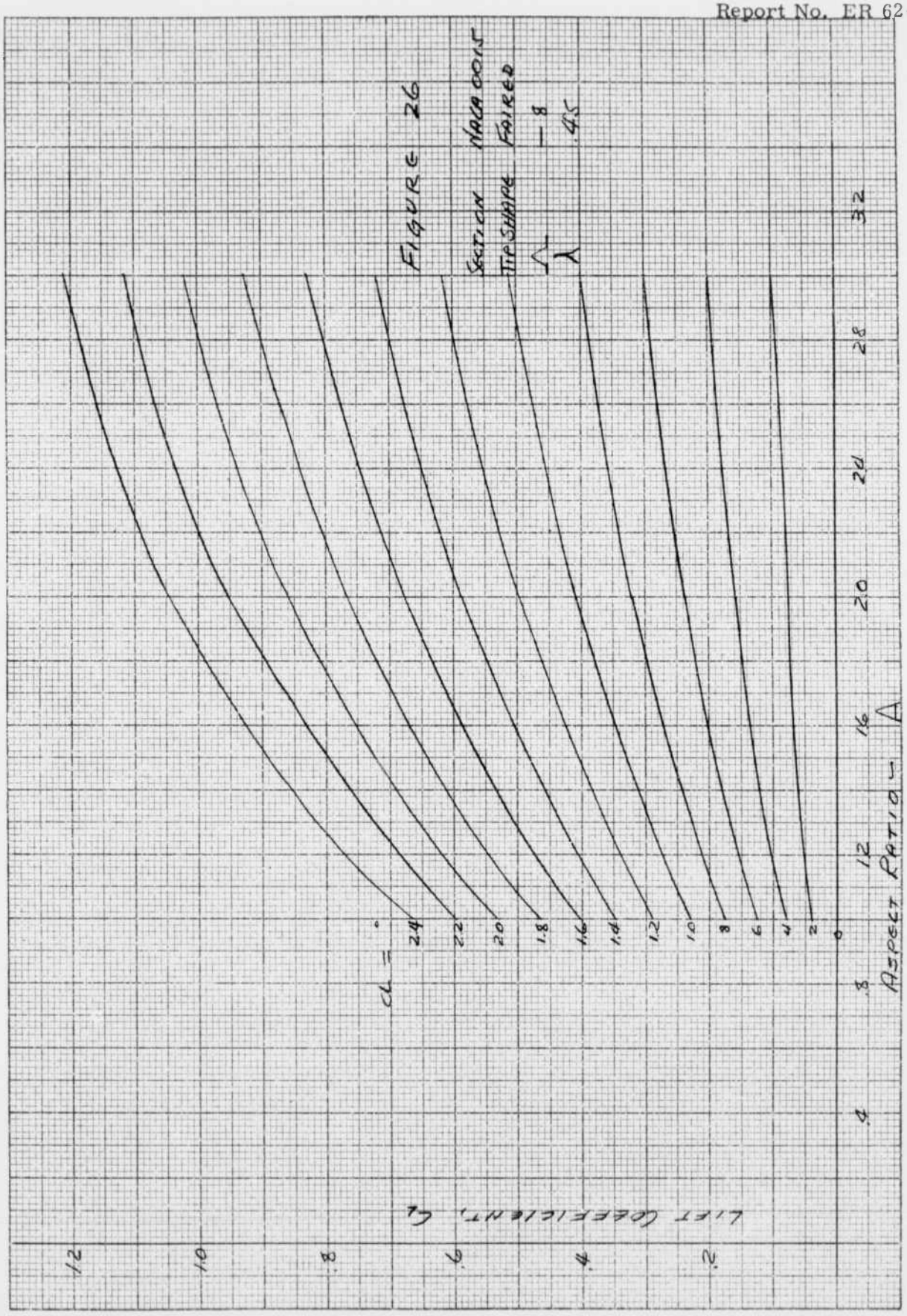


FIGURE 26
SECTION NACA 0015
TIP SHAPE FAIRED
-8
.45
λ
LIFT COEFFICIENT, C_L
ASPECT RATIO - A
C_L = °
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
0
4
8
12
16
20
24
28
32
.2
.4
.6
.8
1.0
1.2

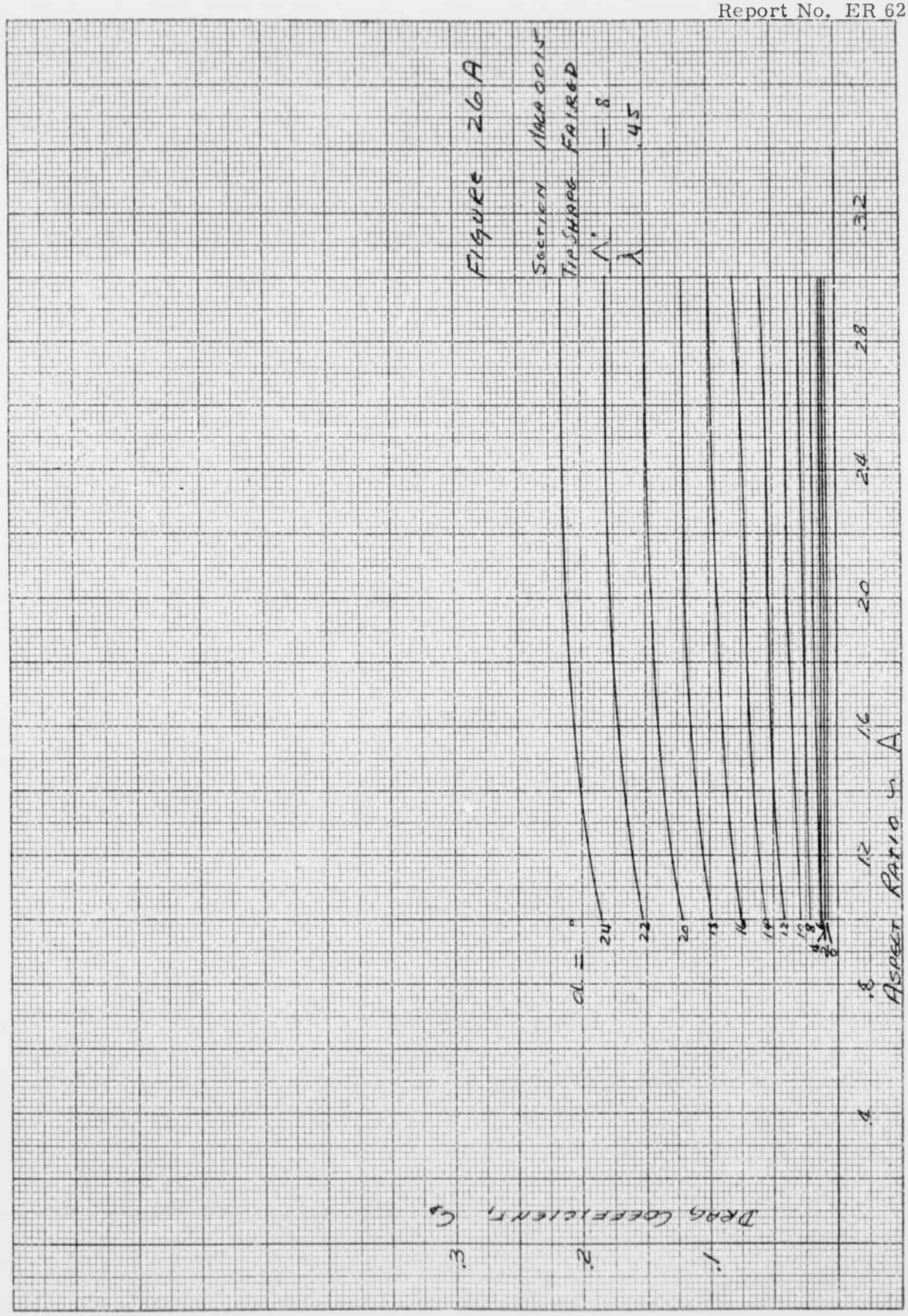


FIGURE 26A
SECTION MACH 0.015
TIP SHARP FAIRED
Λ = 8
λ .45
α = °
24
22
20
18
16
14
12
10
8
6
4
2
0
.4
.8
1.2
1.6
2
2.4
2.8
3.2
ASPECT RATIO A
DRAG COEFFICIENT, C_D

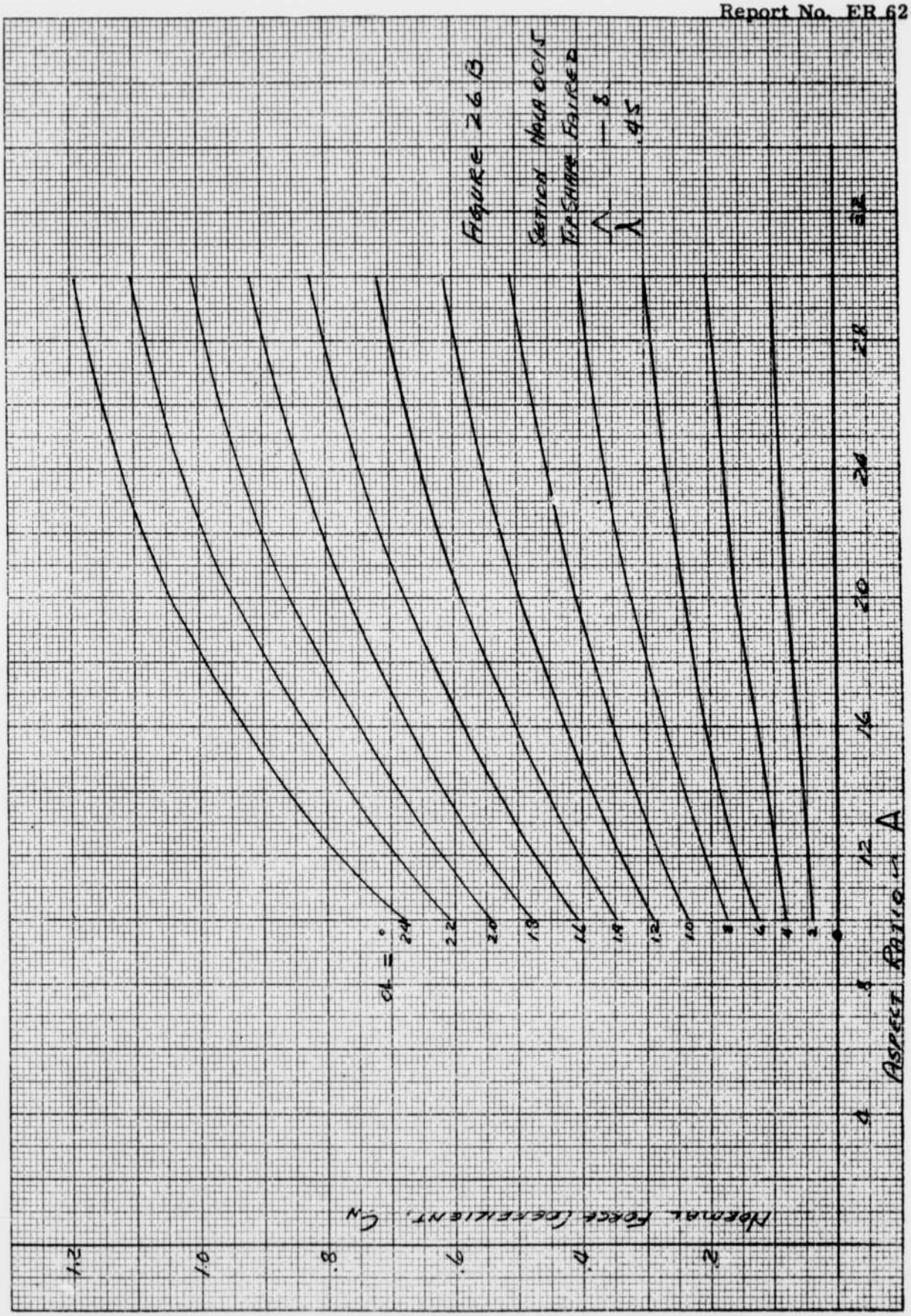


FIGURE 26B
SECTION NACA 0015
FLESHER FAIRED
$\frac{\Lambda}{\lambda} = .45$
$\alpha_t = 0°$
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
NORMAL FORCE COEFFICIENT, C_N
1.2
1.0
.8
.6
.4
.2
4
8
12
16
20
24
28
32
ASPECT RATIO = A

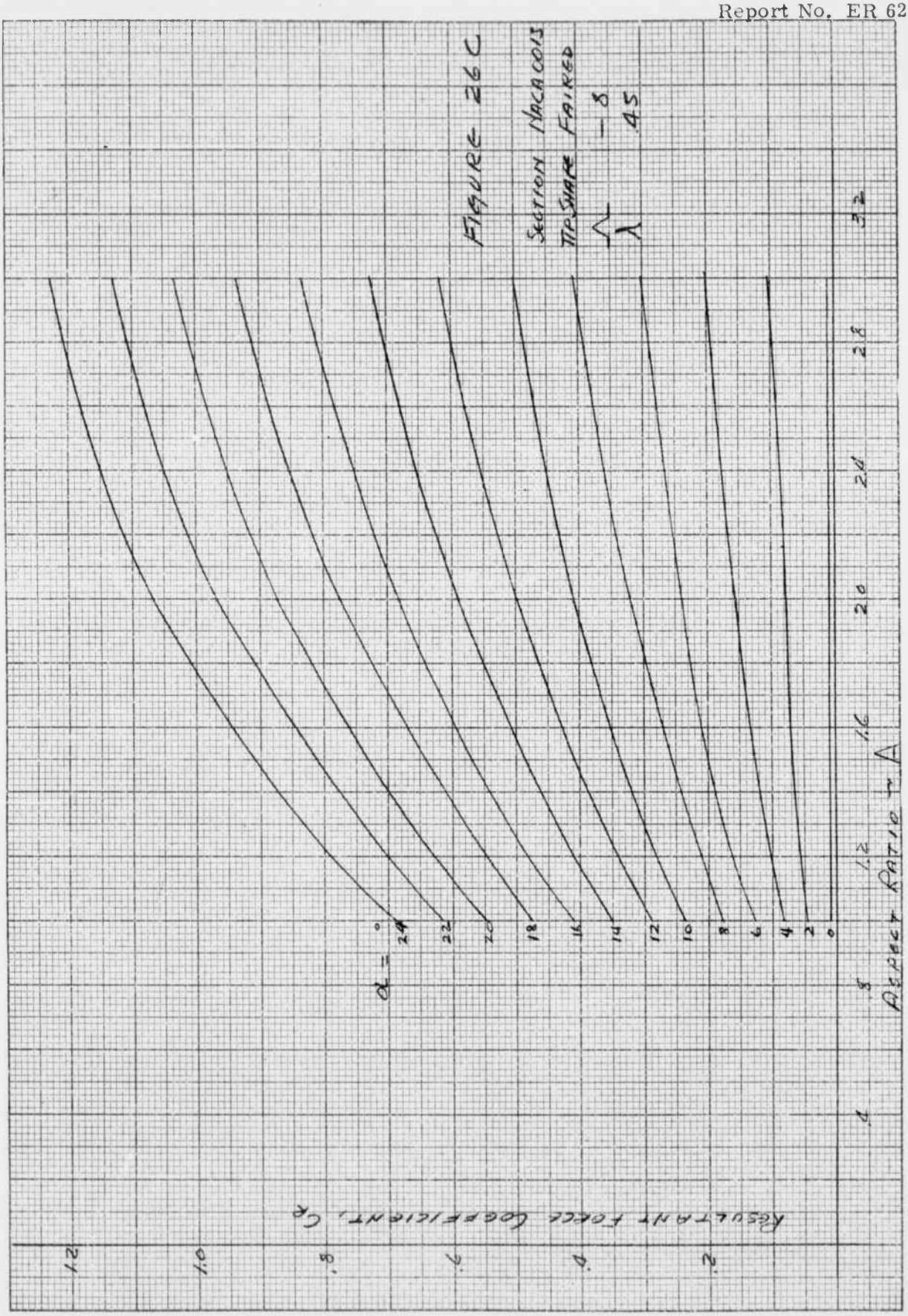


FIGURE 26C
SECTION NACA 0015
TIP SHAPE FAIRED
Λ -.5
λ 45
RESULTANT FORCE COEFFICIENT, C_R
ASPECT RATIO = Λ
α = °
24
22
20
18
16
14
12
10
8
6
4
2
0
1.2
1.0
.8
.6
.4
.2
4
8
12
16
20
24
28
32

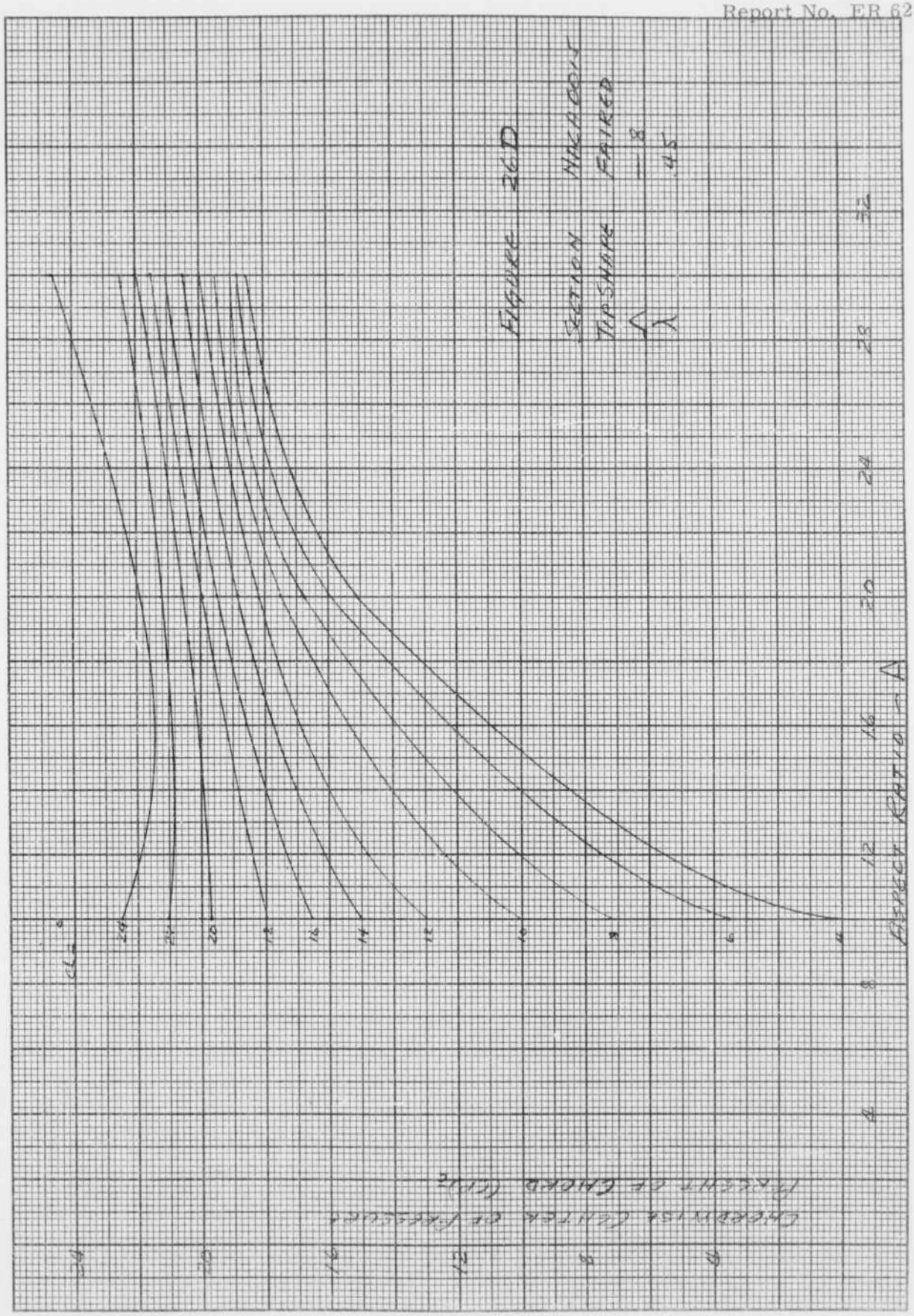


Figure 260
Section Hydrofoil
Top Shape Faired
γ
α
Characteristics of Section at Various Angles of Attack
Lift Coefficient C_L
Drag Coefficient C_D

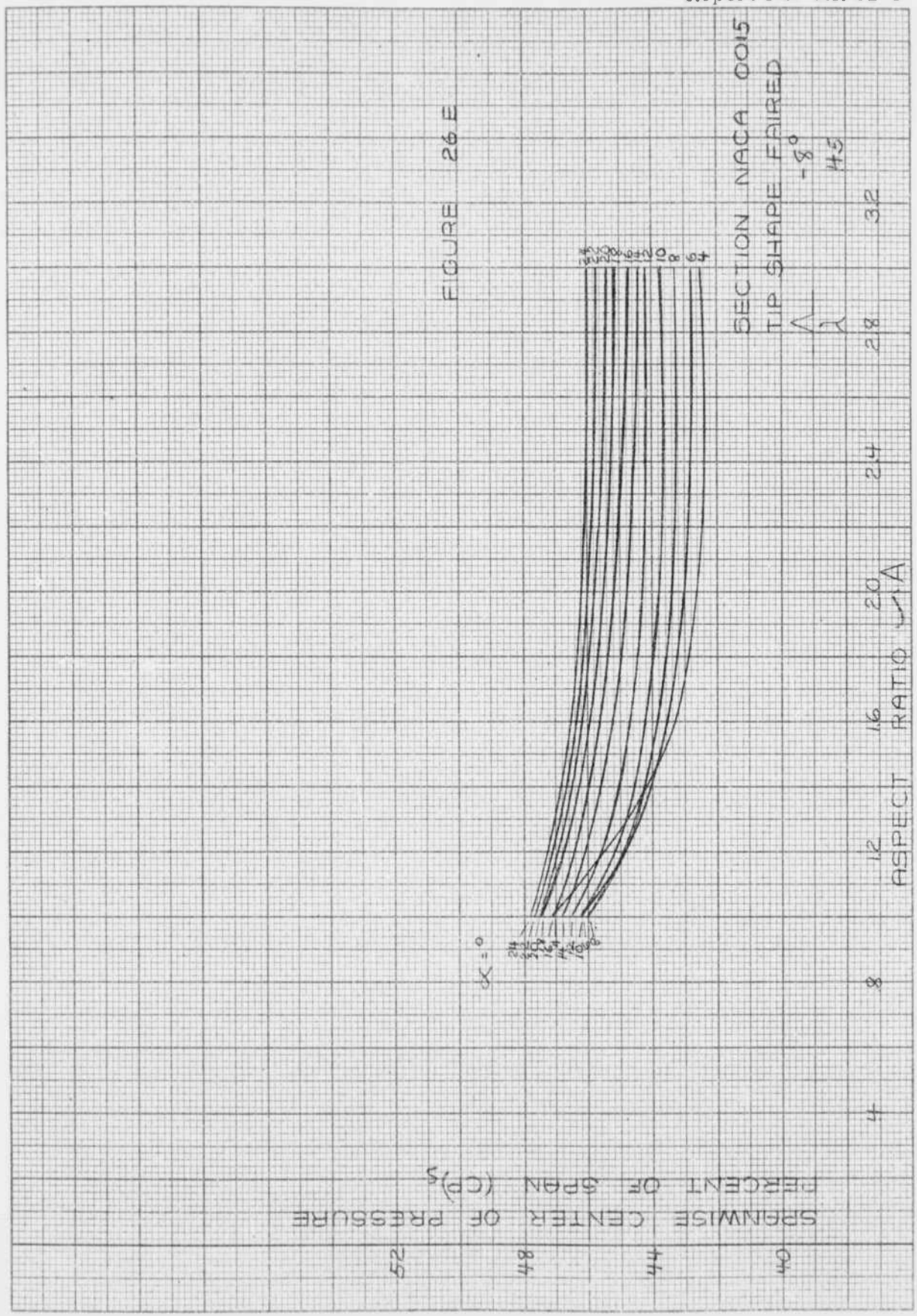


FIGURE 26E
SECTION NACA 0015
TIP SHAPE FAIRED
Λ, γ
45°
-8°
SPANWISE CENTER OF PRESSURE
PERCENT OF SPAN $(CP)_s$
ASPECT RATIO A
4
8
12
16
20
24
28
32
44
48
52
56
$\alpha = 0$

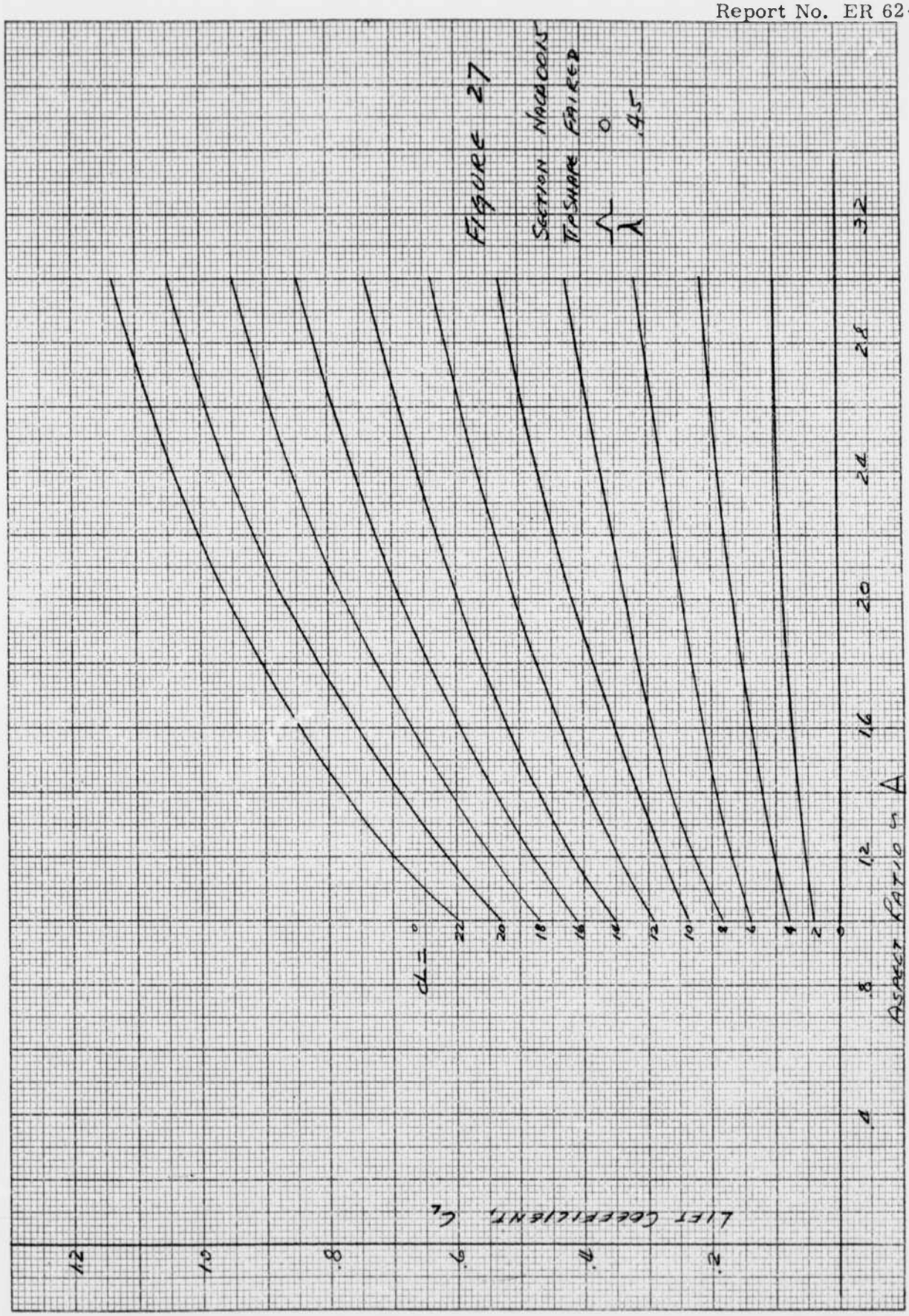


FIGURE 27
SECTION NACA0015
TAPSHAPE FAIRED
Λ 0
λ .45
LIFT COEFFICIENT, C_L
ASPECT RATIO, A
C_L = 0
2
4
6
8
10
12
14
16
18
20
22
.4
.8
1.2
1.6
2.0
2.4
2.8
3.2
.2
.4
.6
.8
1.0
1.2

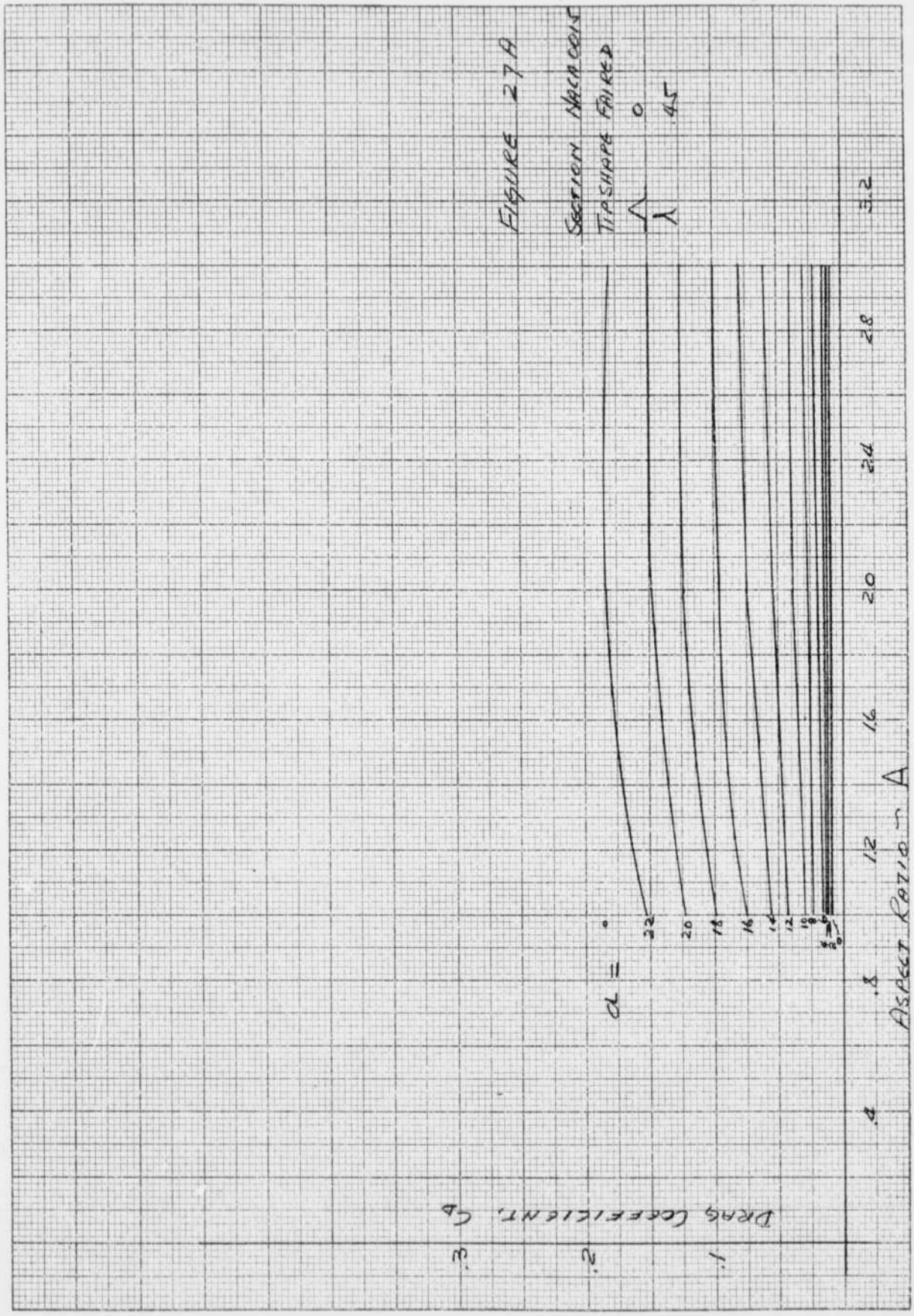


FIGURE 27.A
SECTION NACA 0012
TIP SHAPE FAIRED
Λ 0
λ 45
DRAG COEFFICIENT, C_D
ASPECT RATIO - A
α = 0
22
20
18
16
14
12
10
8
6
4
2
0
.4
.8
1.2
1.6
2.0
2.4
2.8
3.2
1.
2.
3.

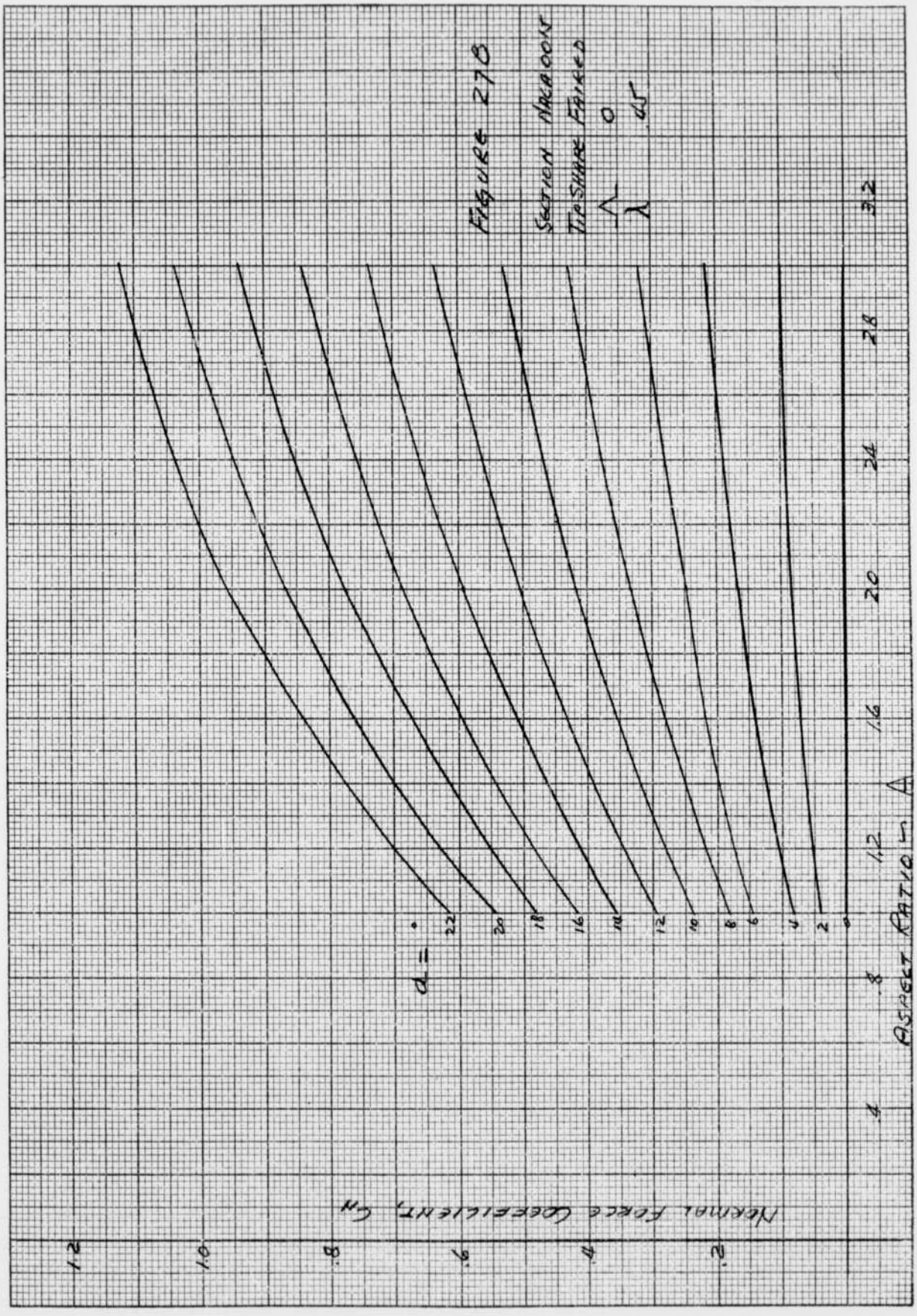


FIGURE 27B
SECTION NORMAL FORCE COEFFICIENT
TIP SHAPE SQUARED
Λ
λ
0
45°
NORMAL FORCE COEFFICIENT, C_N
ASPECT RATIO, A
α = 0
2
4
6
8
10
12
14
16
18
20
22
.4
.8
1.2
1.6
2.0
2.4
2.8
3.2
.2
.4
.6
.8
1.0
1.2

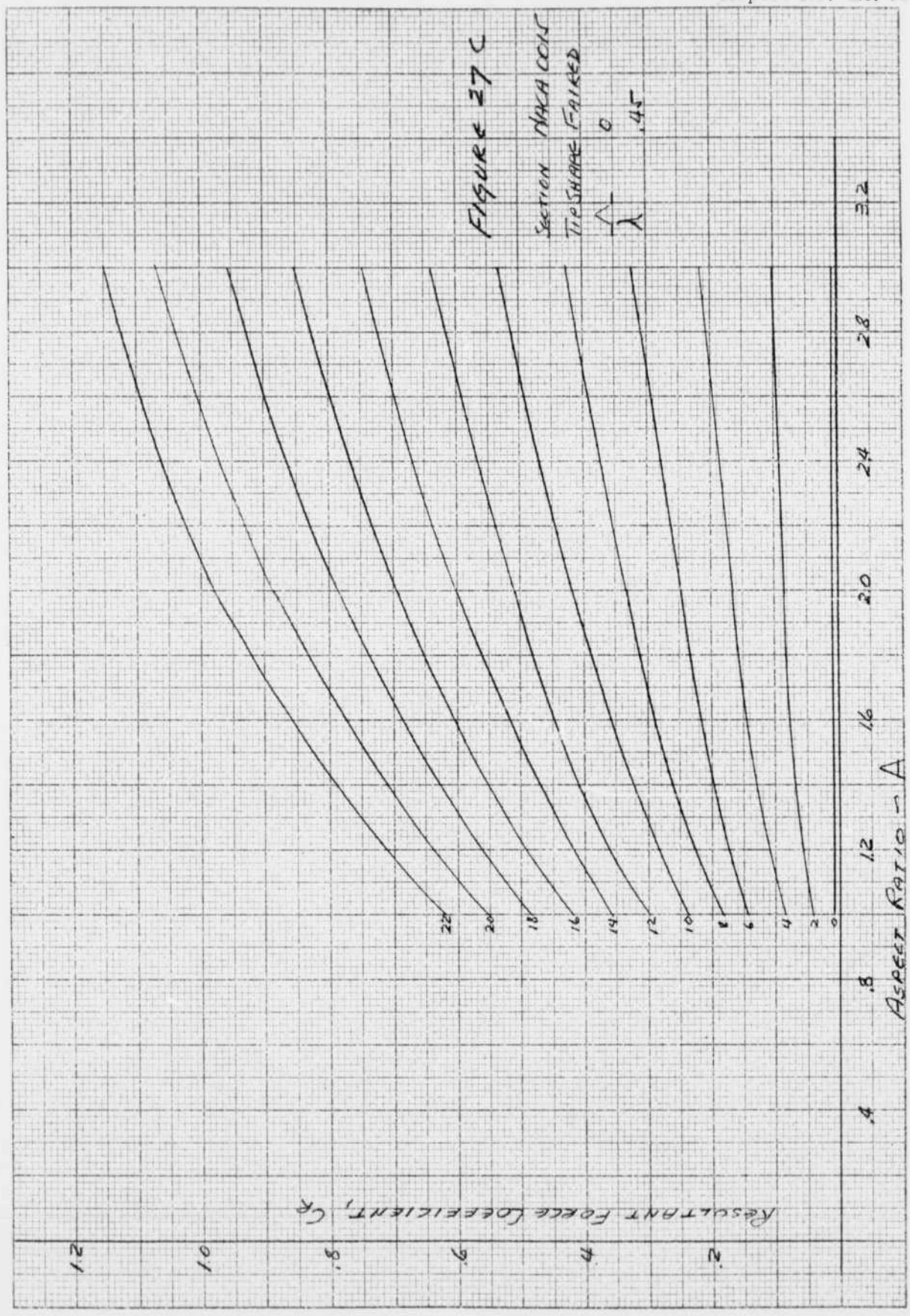


FIGURE 27 C
SECTION NACA 0015
TIP SHAPE FAIRED
Λ 0
λ .45
RESULTANT FORCE COEFFICIENT, C_R
ASPECT RATIO - A
1.2
1.0
.8
.6
.4
.2
.4
.8
1.2
1.6
2.0
2.4
2.8
3.2
22
20
18
16
14
12
10
8
6
4
2
0

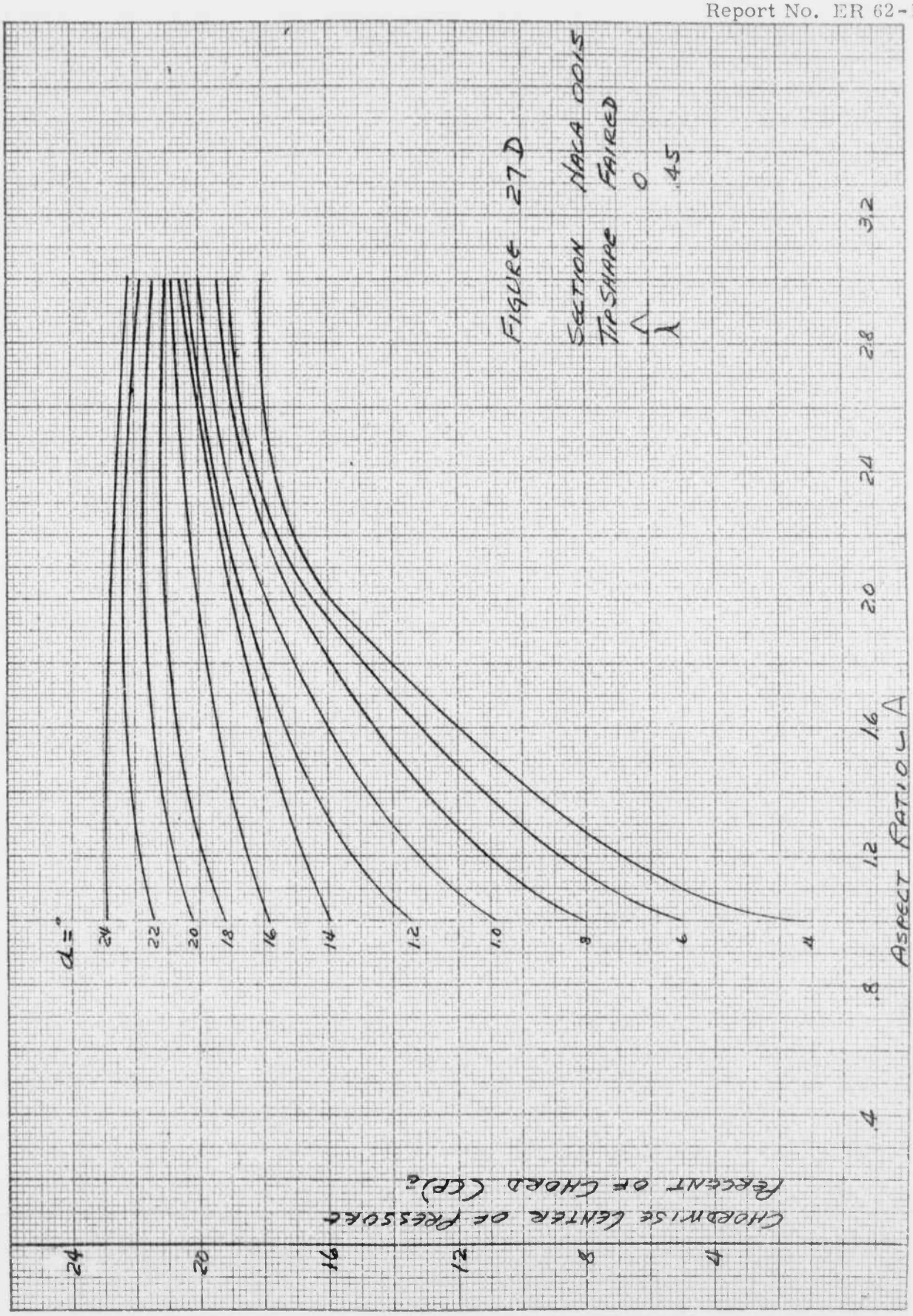


FIGURE 27 D
SECTION NACA 0015
TIP SHAPE FAIRED
Λ
λ
0
.45
CHORDWISE CENTER OF PRESSURE
PERCENT OF CHORD (CP)c
ASPECT RATIO A
α=°
24
22
20
18
16
14
12
10
8
6
4
.4
.8
1.2
1.6
2.0
2.4
2.8
3.2
24
20
16
12
8
4

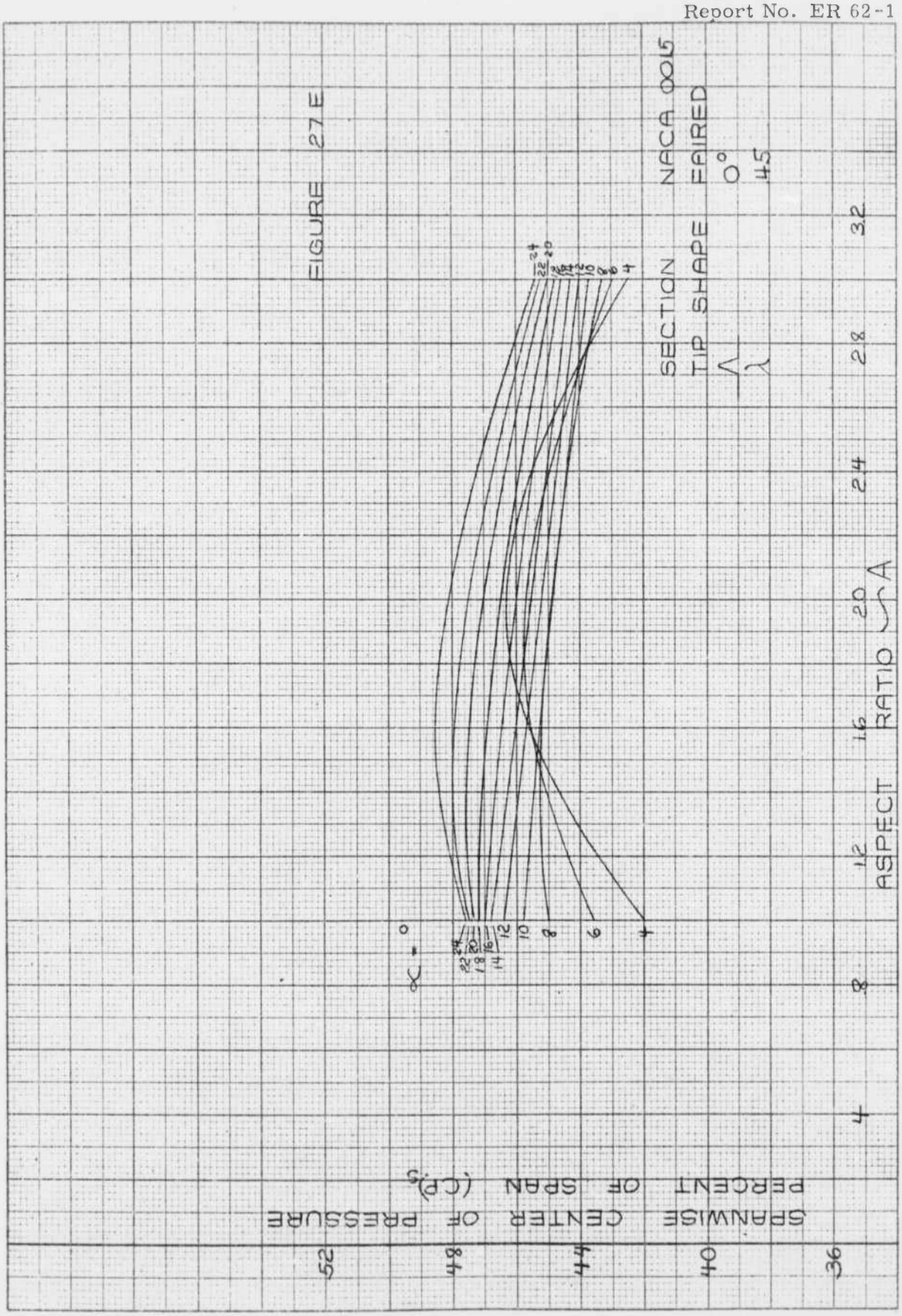


FIGURE 27E
SECTION NACA 0015
TIP SHAPE FAIRED
Λ 0° 45°
λ
SPANWISE CENTER OF PRESSURE
PERCENT OF SPAN (C.P.)
ASPECT RATIO A
α = 0°
4
6
8
10
12
14
16
18
20
22
24
36
40
44
48
52
4
8
12
16
20
24
28
32

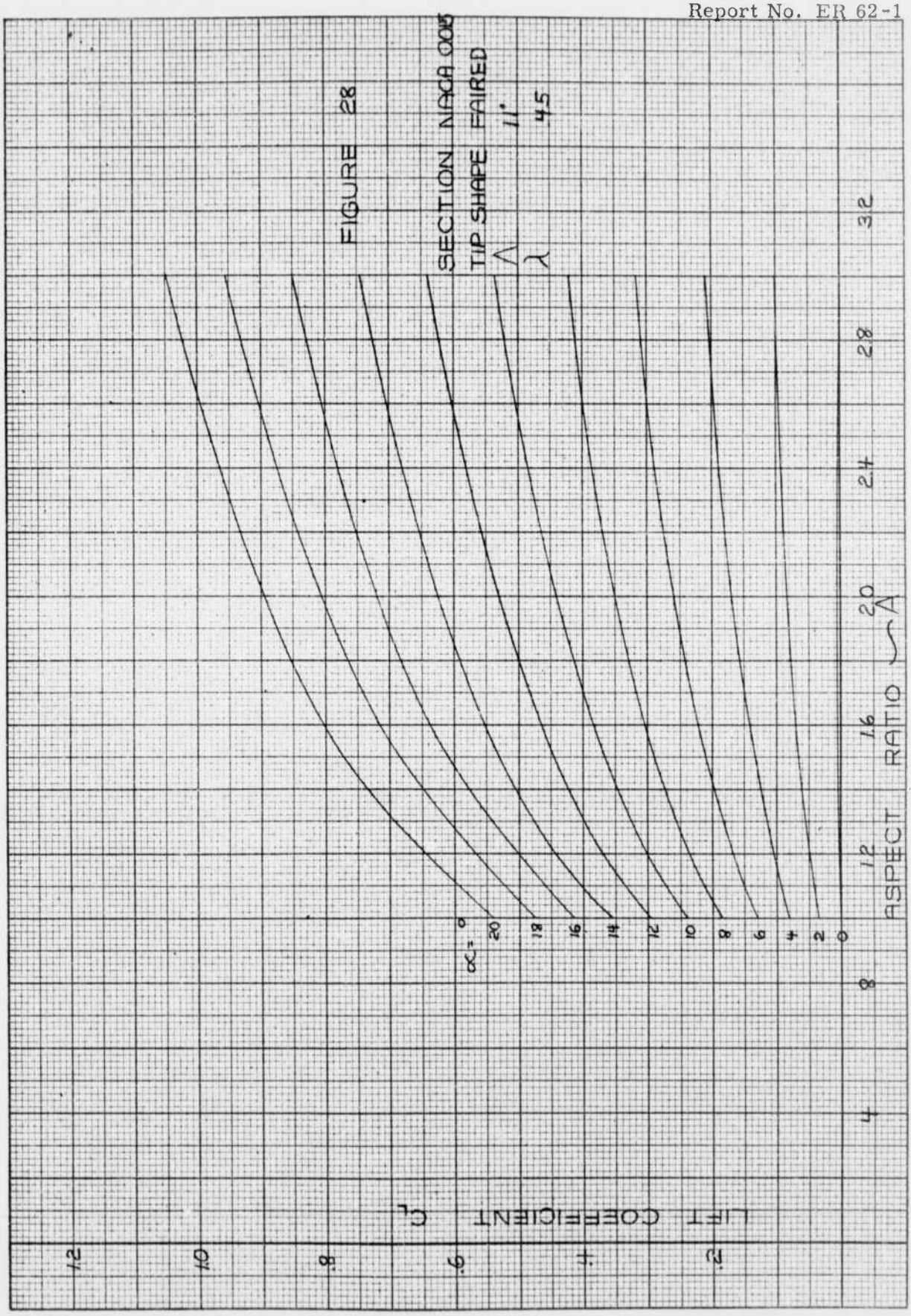


FIGURE 28
SECTION NACA 0005
TIP SHAPE FAIRED
Λ 11°
λ 45
LIFT COEFFICIENT C_L
ASPECT RATIO A
α = 0
20
18
16
14
12
10
8
6
4
2
0
.2
.4
.6
.8
1.0
1.2
4
8
12
16
20
24
28
32

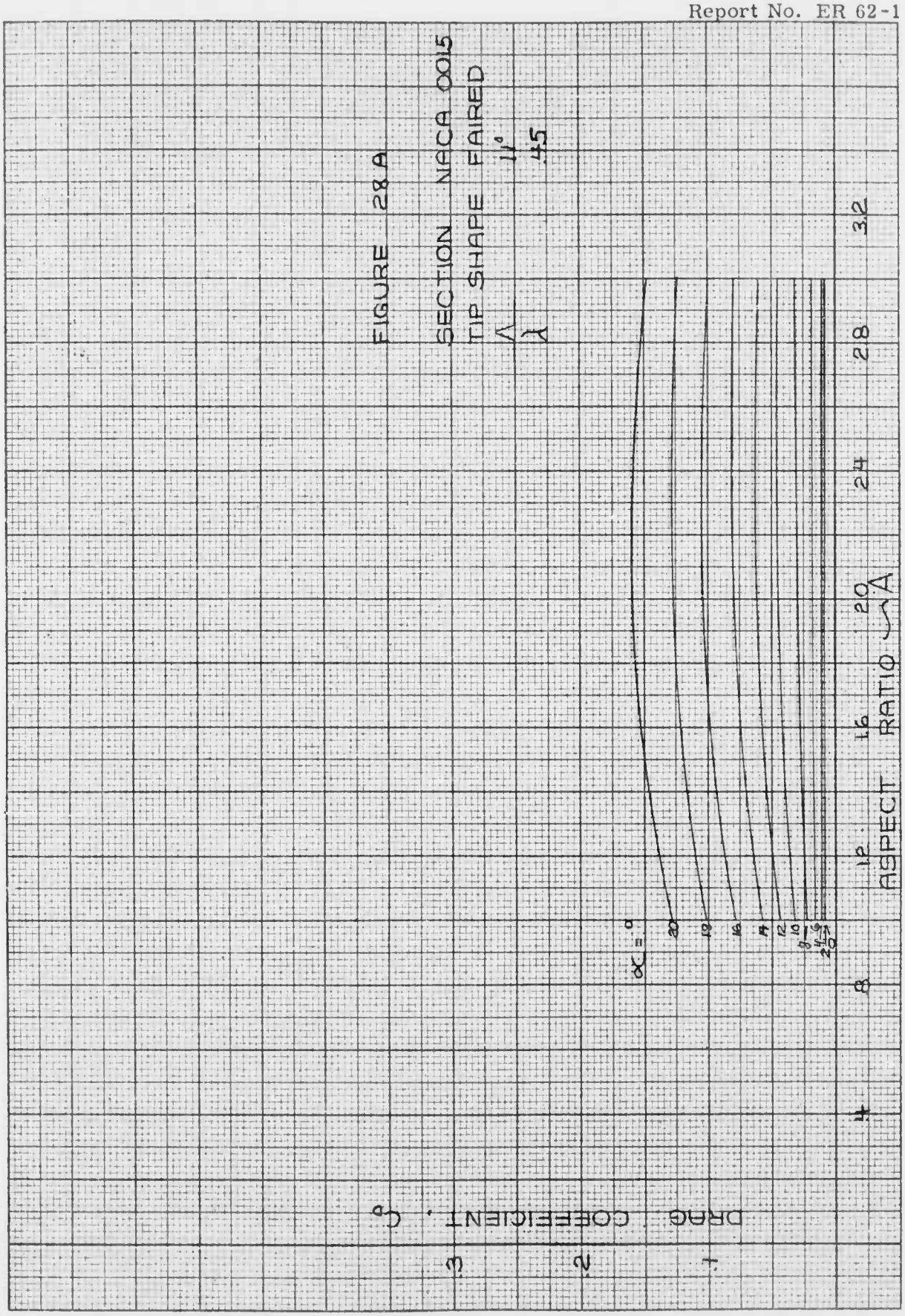


FIGURE 28A
SECTION NACA 0015
TIP SHAPE FAIRED
11°
Λ
λ
45
C_D DRAG COEFFICIENT
ASPECT RATIO A/A
α = 0
20
18
16
14
12
10
8
6
4
2
0
1
2
3
4
8
12
16
20
24
28
32

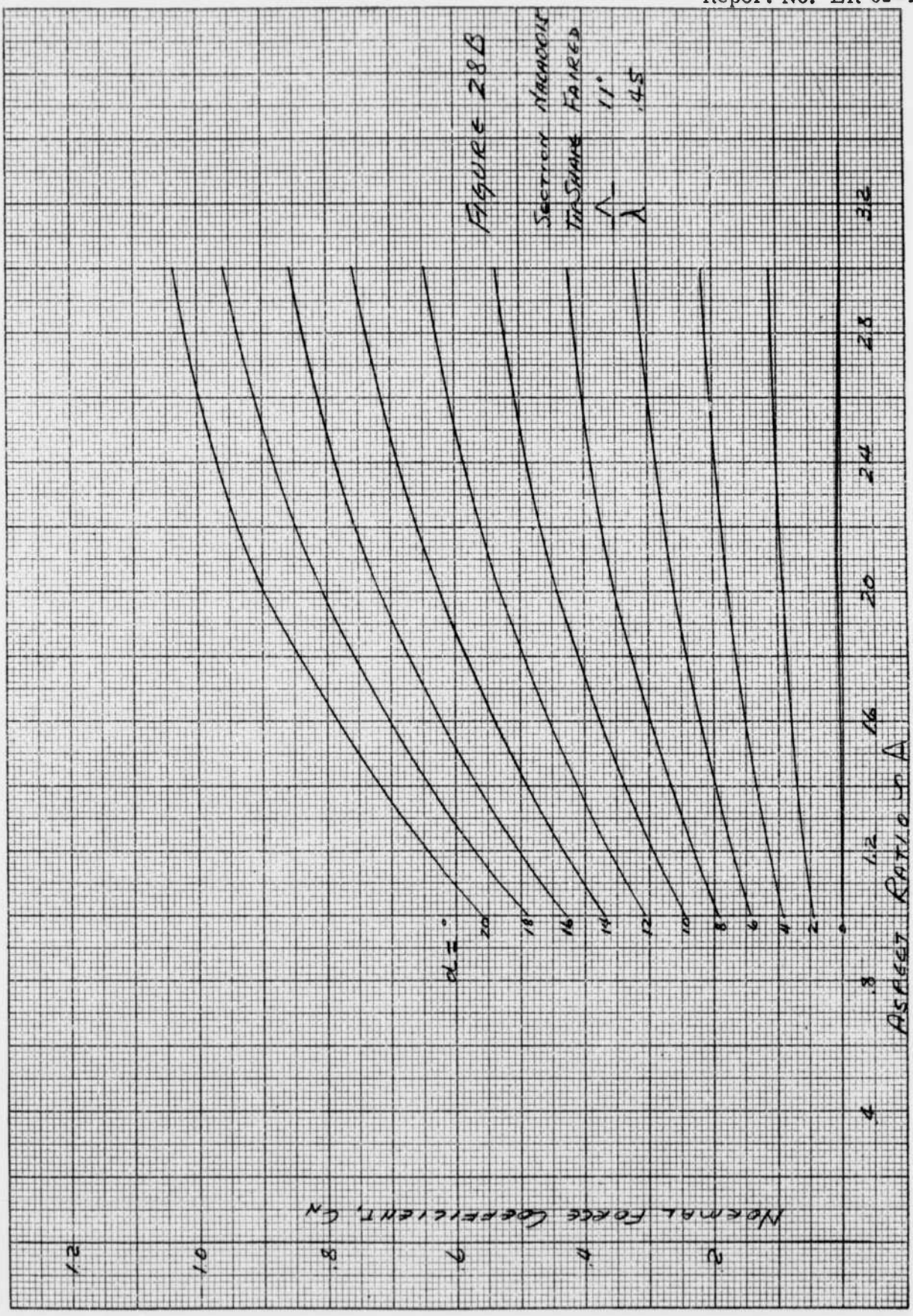
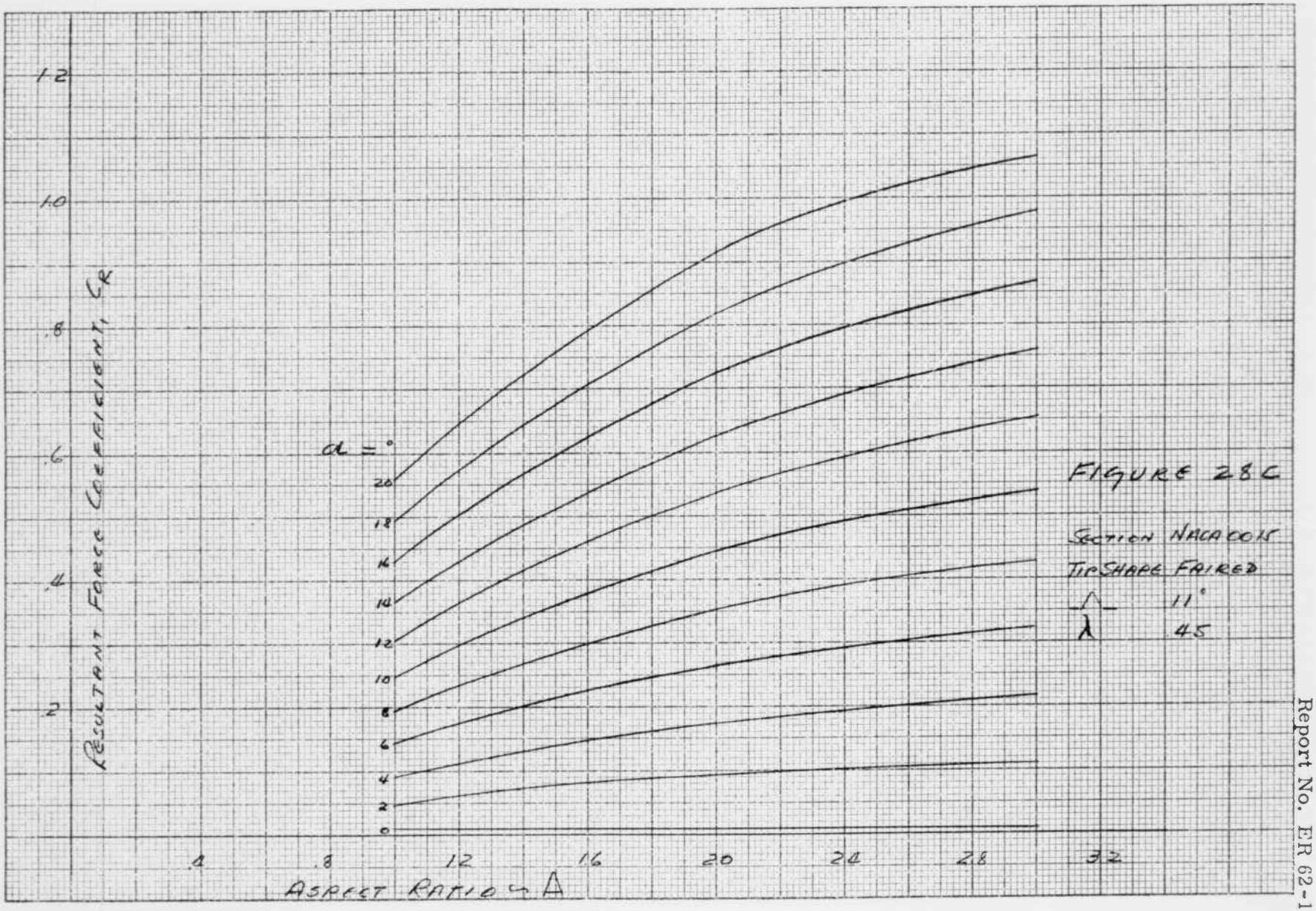


FIGURE 28B
SECTION HARMONIC
THE SAME FAIRED
11°
.45
Λ
λ
NORMAL FORCE COEFFICIENT, CN
ASPECT RATIO OF A
α = °
20
18
16
14
12
10
8
6
4
2
0
1.2
1.0
.8
.6
.4
.2
4
8
12
16
20
24
28
32


RESULTANT FORCE COEFFICIENT, C_R
1.2
1.0
.8
.6
.4
.2
α = °
20
18
16
14
12
10
8
6
4
2
0
.4
.8
1.2
1.6
2.0
2.4
2.8
3.2
ASPECT RATIO = A
FIGURE 28.C
SECTION NACA 0015
TIP SHAPE FAIRED
Λ 11°
λ 45

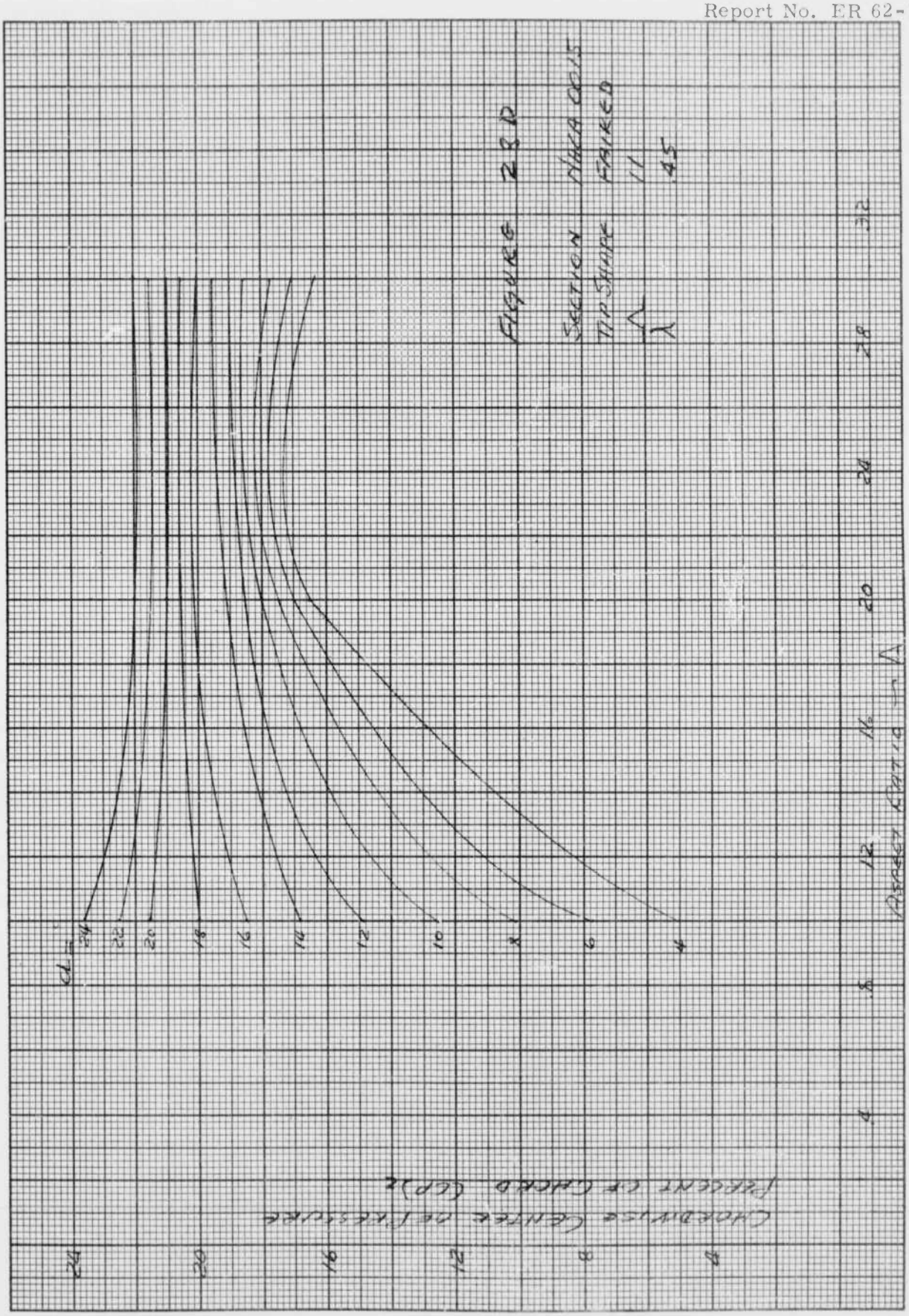


FIGURE 28D
SECTION MACH CONST
MUSHROOM FAIRED
11 45
V
Y
VELOCITY RATIO = V/V∞
CHORDWISE CENTER OF PRESSURE
PERCENT CR CHORD (CP)x

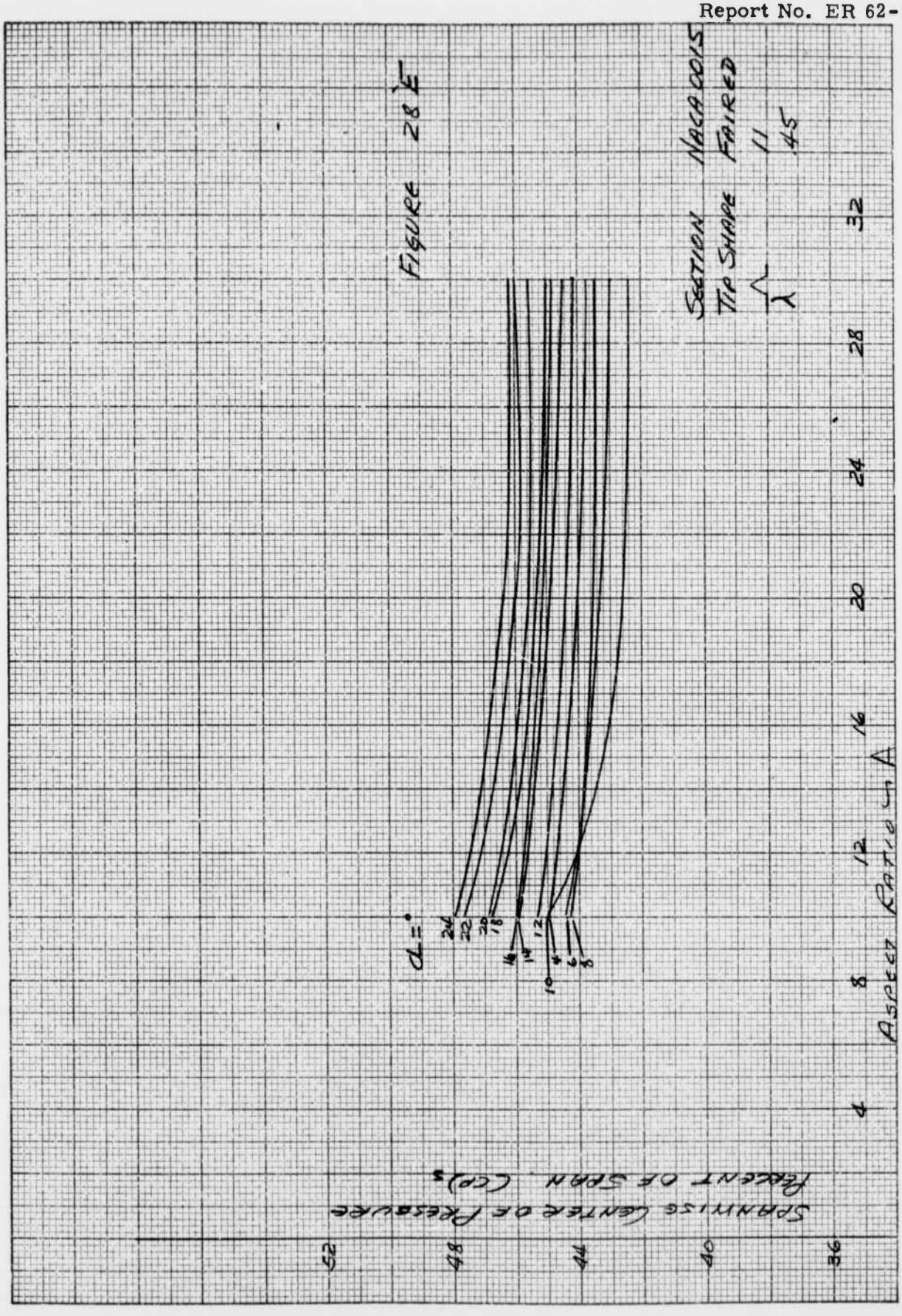


FIGURE 28 E
SECTION NACA 0015
TIP SHAPE FAIRED
λ 1.45
ASPECT RATIO A
SPANWISE CENTER OF PRESSURE
PERCENT OF SPAN (cp)%
α=°
24
22
20
18
16
14
12
10
8
6
4
52
48
44
40
36
32
28
24
20
16
12
8
4

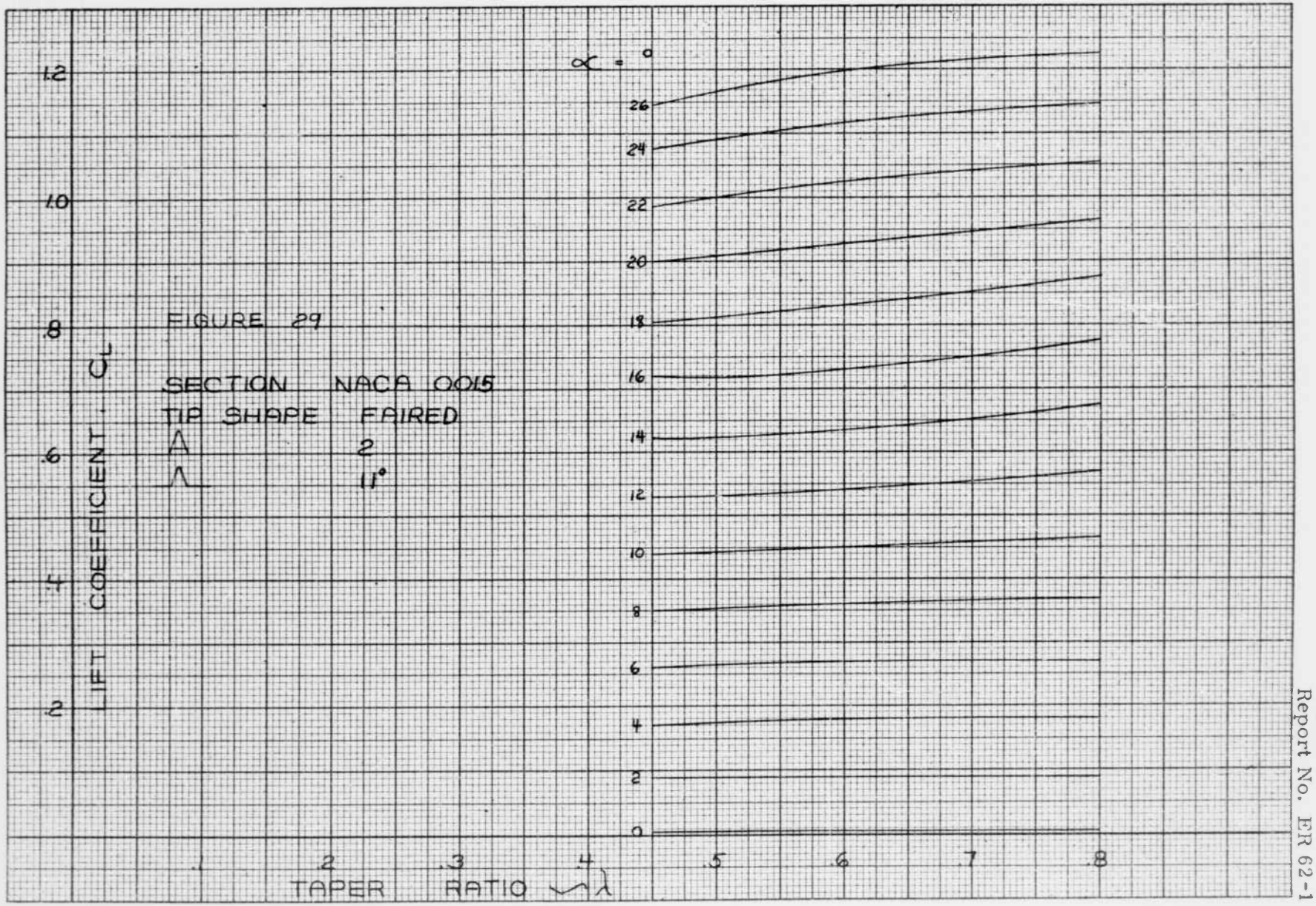


FIGURE 29
SECTION NACA 0015
TIP SHAPE FAIRED
A 2
Λ 11°
LIFT COEFFICIENT C_L
TAPER RATIO λ
α = 0
26
24
22
20
18
16
14
12
10
8
6
4
2
0
1.2
1.0
.8
.6
.4
.2
.1
.2
.3
.4
.5
.6
.7
.8

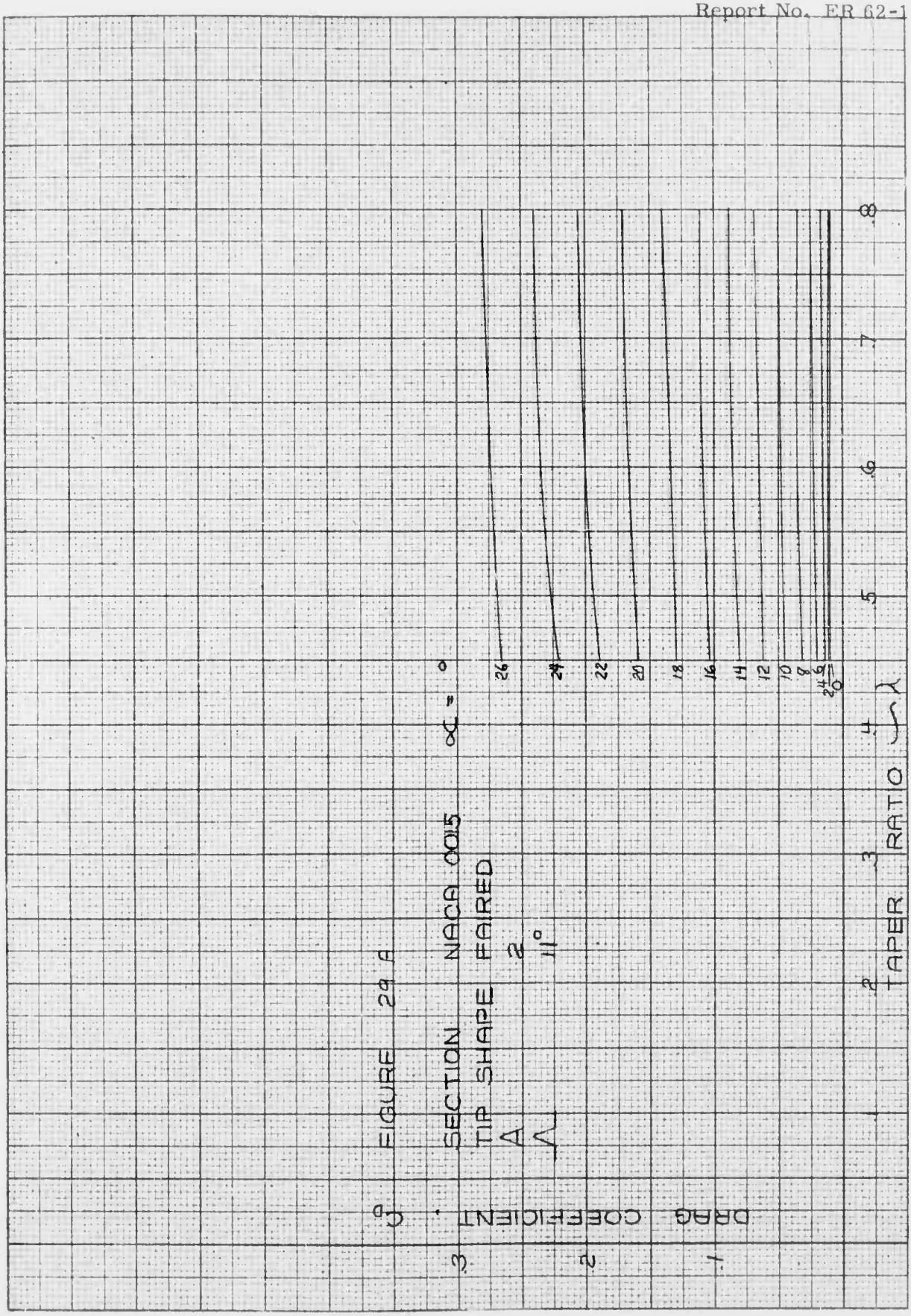

DRAG COEFFICIENT C_D
TAPER RATIO λ
SECTION NACA 0015
TIP SHAPE FAIRED
Λ
α = 0
26
24
22
20
18
16
14
12
10
8
2 4/5
6

FIGURE 29 A

NORMAL FORCE COEFFICIENT, C_N
TAPER RATIO (λ)
α = 0
26
24
22
20
18
16
14
12
10
8
6
4
2
0
SECTION NACA 0015
TIP SHAPE FAIRED
A 2
Λ 11°

FIGURE 29 B

FIGURE 29C
SECTION NACA 0015
TIP SHAPE FAIRED
Λ 2
Δ 11°
RESULTANT FORCE COEFFICIENT, C_R
TAPER RATIO $\frac{\lambda}{4}$
α = 0
26
24
22
20
18
16
14
12
10
8
6
4
2
0
12
10
8
6
4
2
2
3
4
5
6
7
8

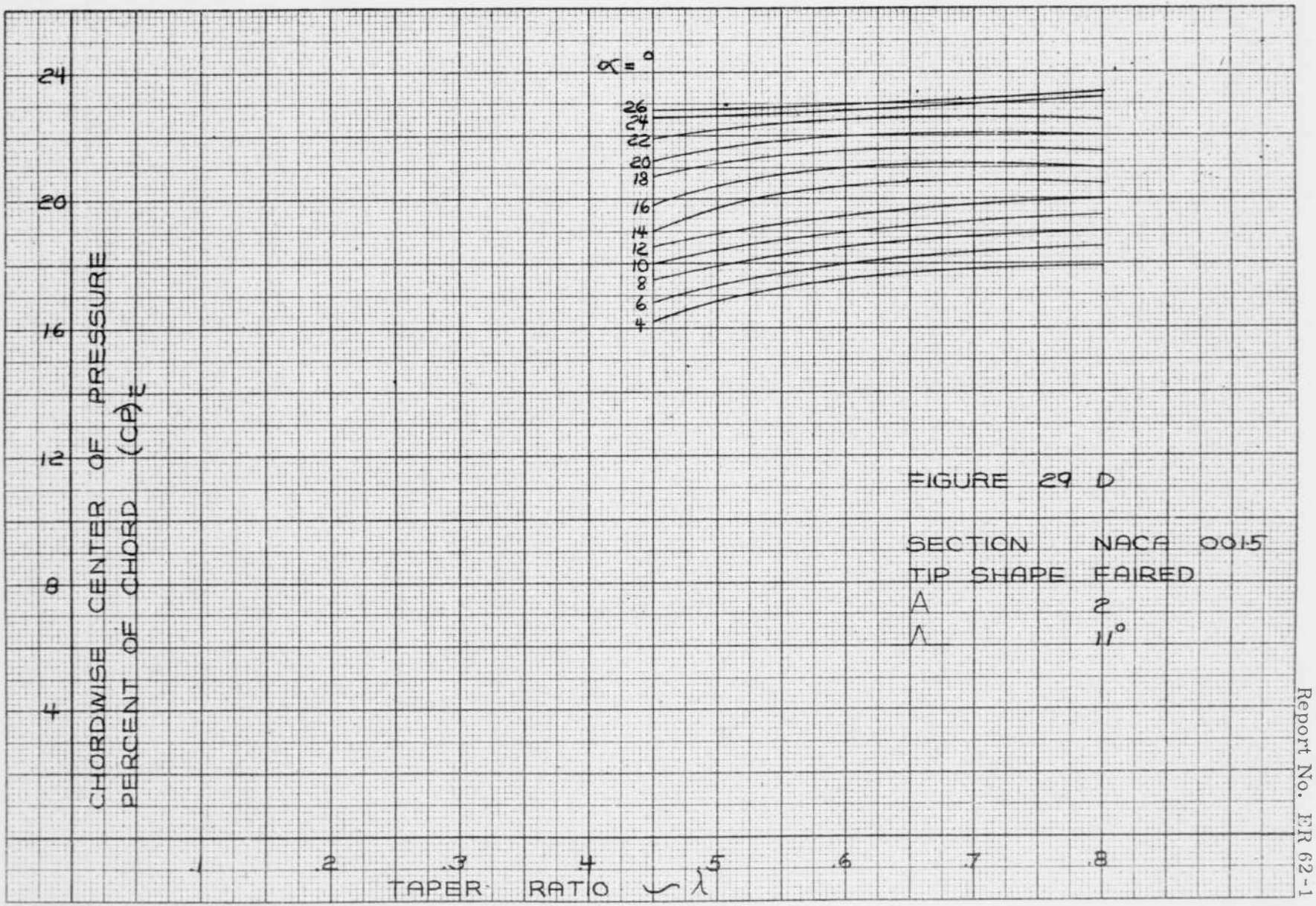

α = °
26
24
22
20
18
16
14
12
10
8
6
4
CHORDWISE CENTER OF PRESSURE
PERCENT OF CHORD (CP)c
24
20
16
12
8
4
.1
.2
.3
.4
.5
.6
.7
.8
TAPER RATIO λ
FIGURE 29 D
SECTION NACA 0015
TIP SHAPE FAIRED
A 2
Λ 11°

FIGURE 29 E
SECTION NACA 0015
TIP SHAPE FAIRED
Λ 11°
λ
TAPER RATIO
SPANWISE PERCENT OF SPAN
CENTER OF PRESSURE (CP)s
α = °
26
34
24
22
20
18
16
14
12
10
8
6
4
1
2
3
4
5
6
7
8
36
40
44
48
52

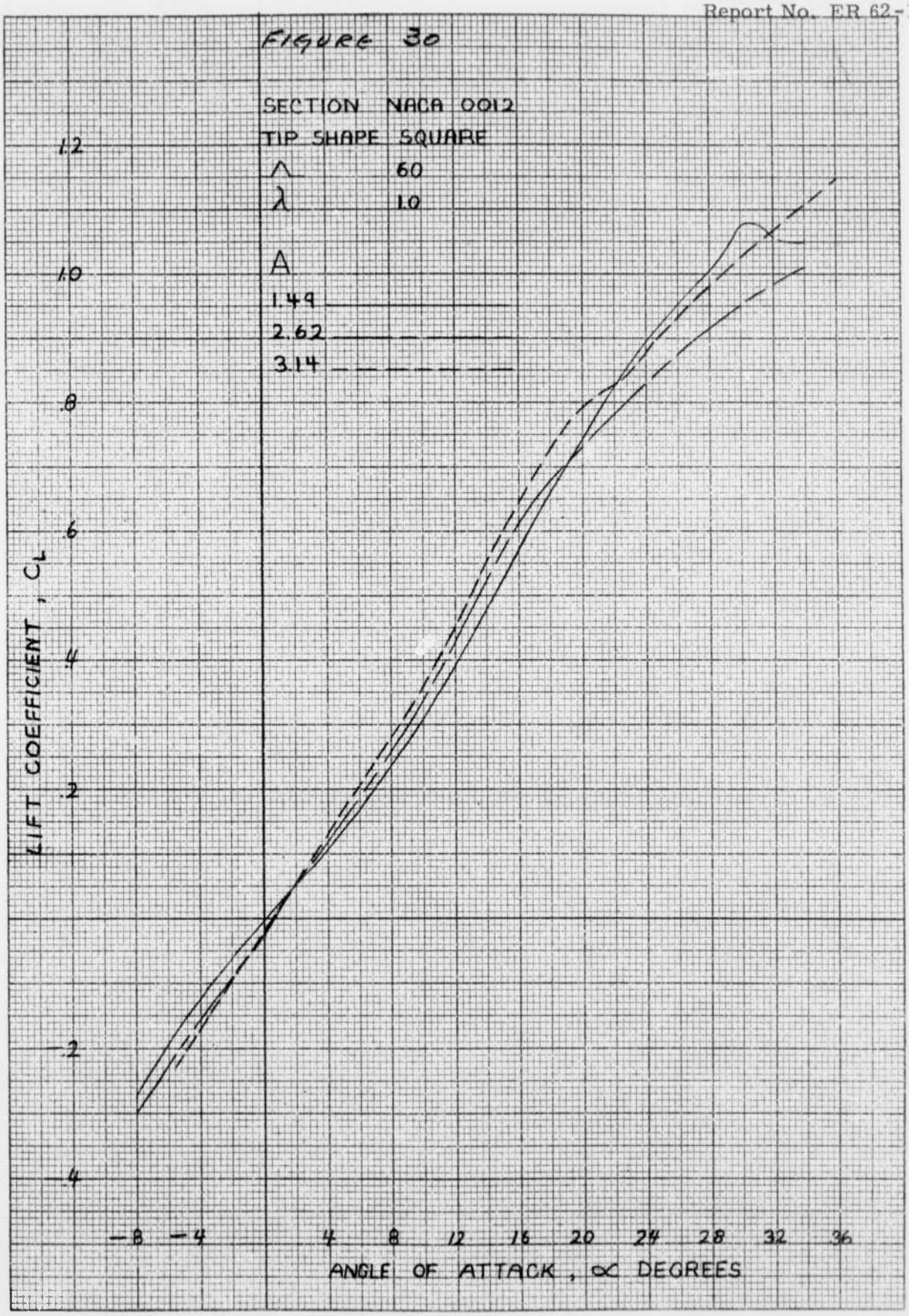


Figure 30
SECTION NACA 0012
TIP SHAPE SQUARE
Λ 60
λ 1.0
A
1.49
2.62
3.14
1.2
1.0
.8
.6
.4
.2
-.2
-.4
LIFT COEFFICIENT, C_L
-8 -4 4 8 12 16 20 24 28 32 36
ANGLE OF ATTACK, ∝ DEGREES

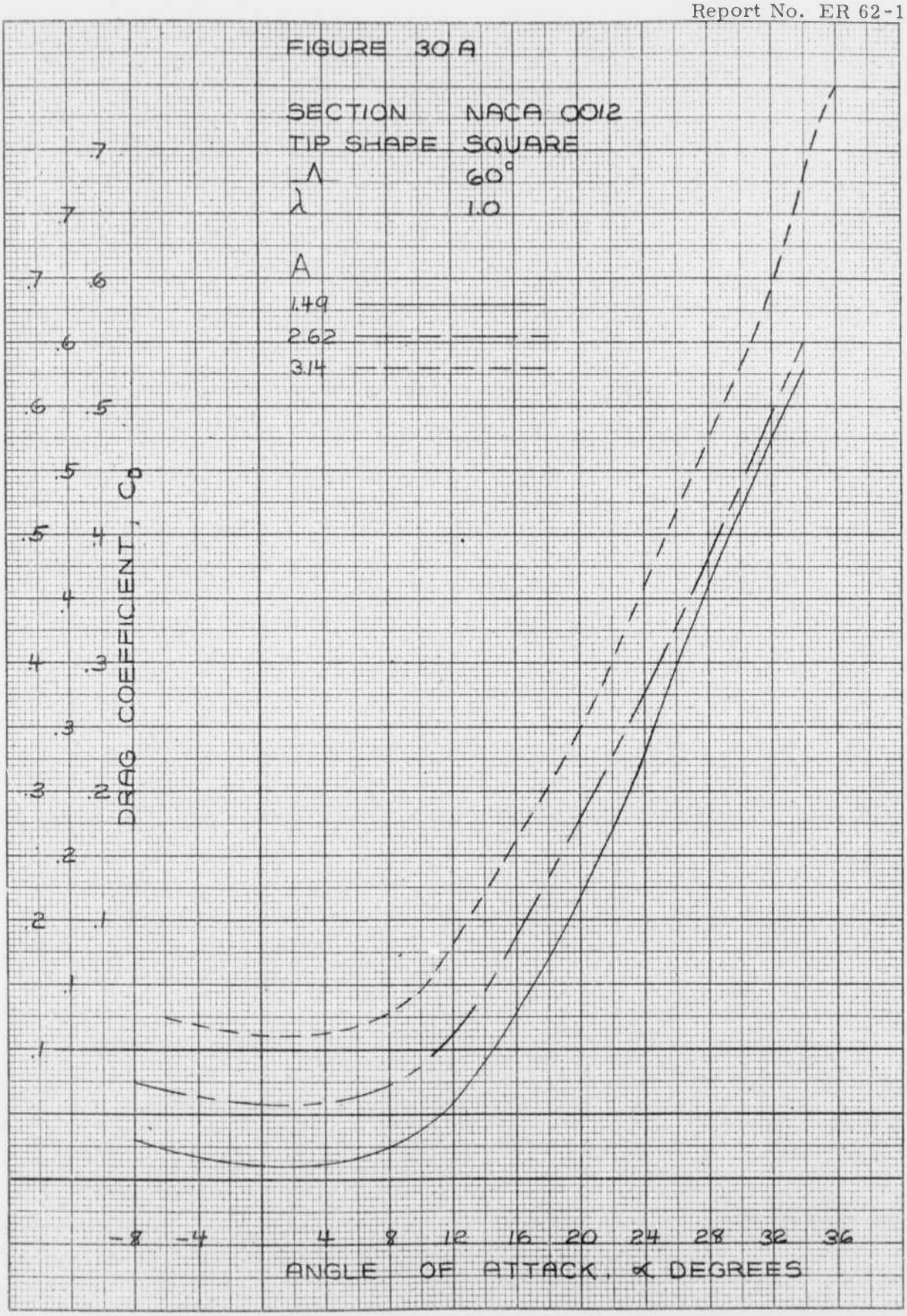


FIGURE 30 A
SECTION NACA 0012
TIP SHAPE SQUARE
Λ 60°
λ 1.0
A
1.49
2.62
3.14
DRAG COEFFICIENT, C_D
.7
.6
.5
.4
.3
.2
.1
-8
-4
4
8
12
16
20
24
28
32
36
ANGLE OF ATTACK, α DEGREES

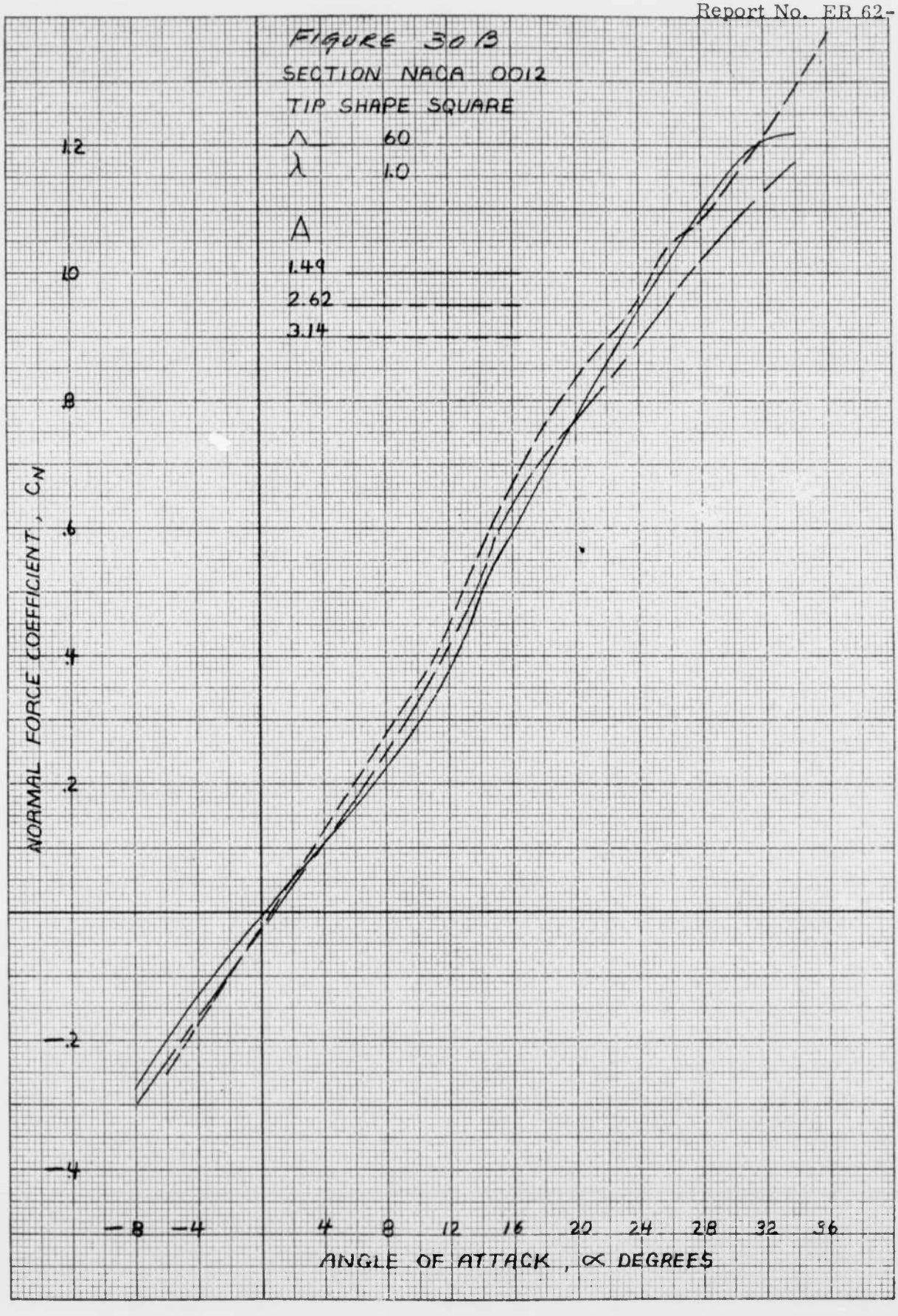


FIGURE 30B
SECTION NACA 0012
TIP SHAPE SQUARE
Λ 60
λ 1.0
A
1.49
2.62
3.14
1.2
1.0
.8
.6
.4
.2
-.2
-.4
NORMAL FORCE COEFFICIENT, C_N
-8
-4
4
8
12
16
20
24
28
32
36
ANGLE OF ATTACK, α DEGREES

FIGURE 30 C

SECTION NACA 0012
TIP SHAPE SQUARE
Λ 60
λ 1.0

A
1.49 ———————
2.62 — — — — —
3.14 — — — — —

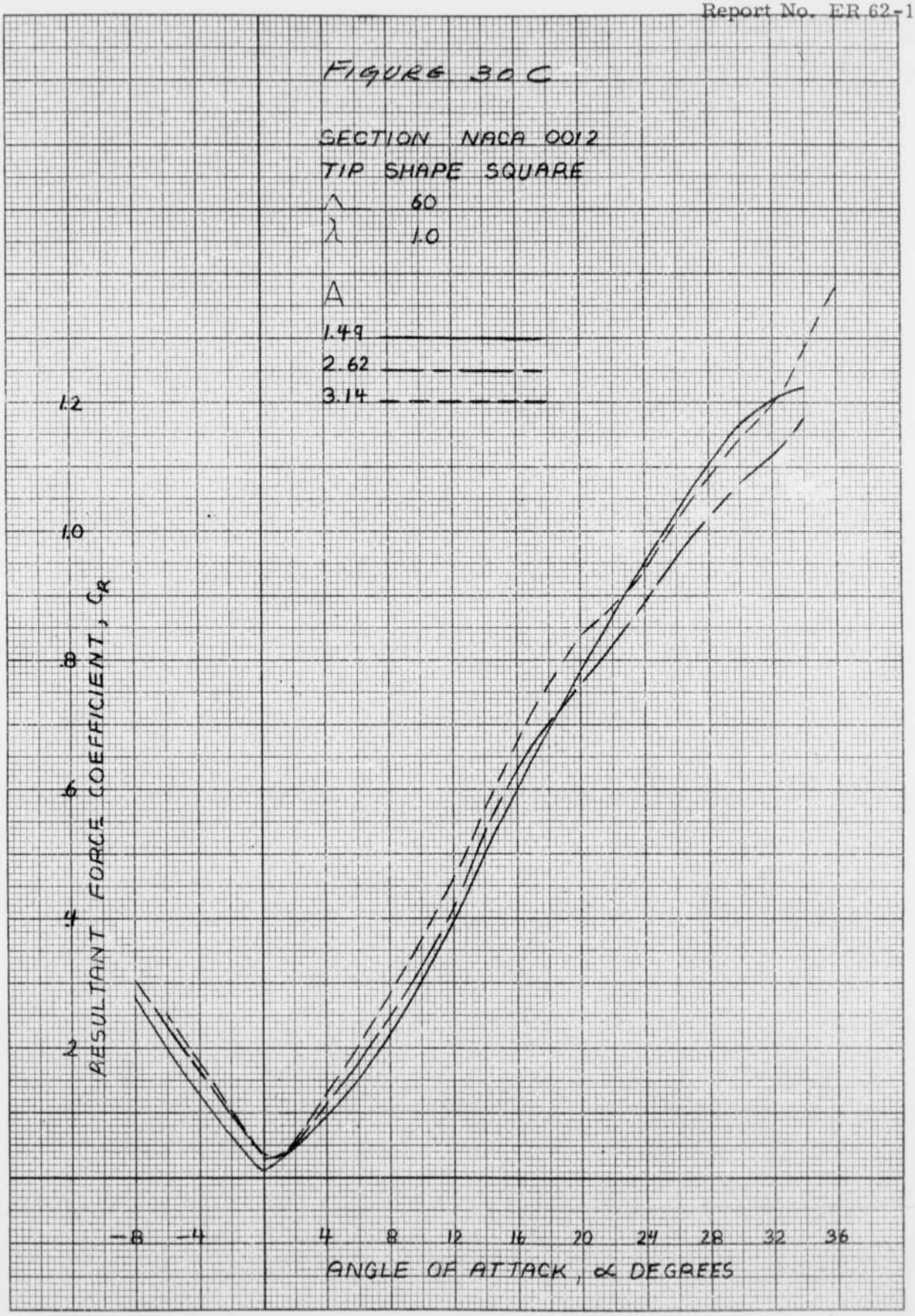
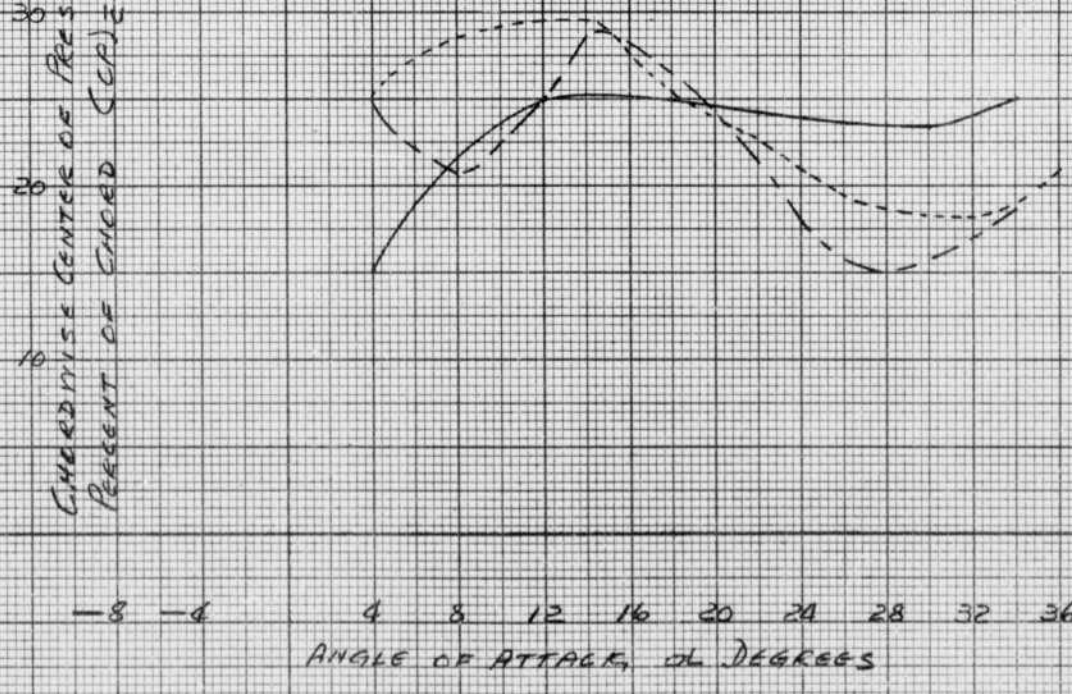


FIGURE 30 D

SECTION	NACA 0012
TIP SHAPE	SQUARE
Λ	60
λ	1.0

A	
1.49	———
2.62	— — — — —
3.14	- - - - - - -



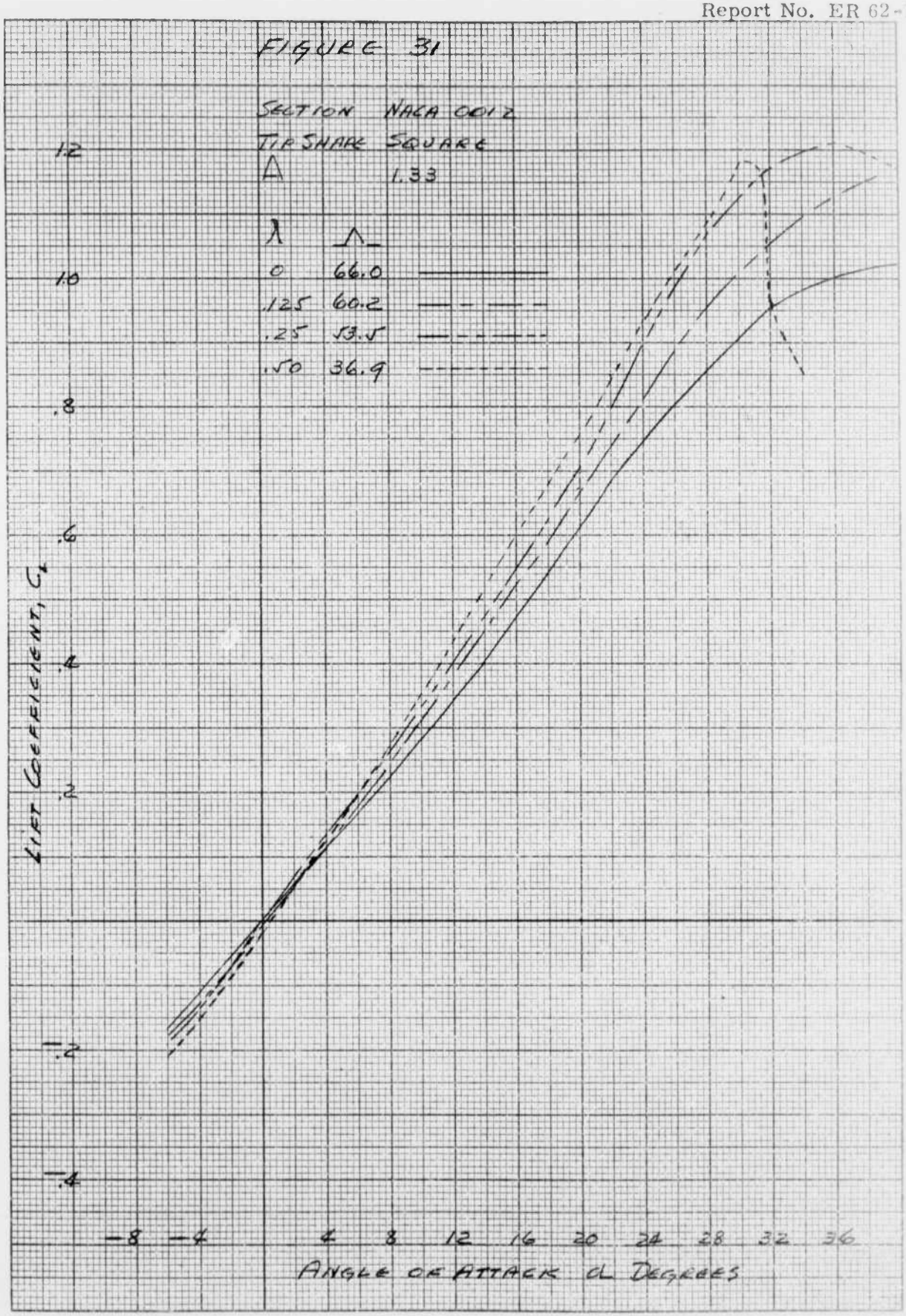


FIGURE 31
SECTION NACA 0012
TIP SHAPE SQUARE
A 1.33
λ Λ
0 66.0
.125 60.2
.25 53.5
.50 36.9
1.2
1.0
.8
.6
.4
.2
-.2
-.4
LIFT COEFFICIENT, C_L
-8 -4 4 8 12 16 20 24 28 32 36
ANGLE OF ATTACK α, DEGREES

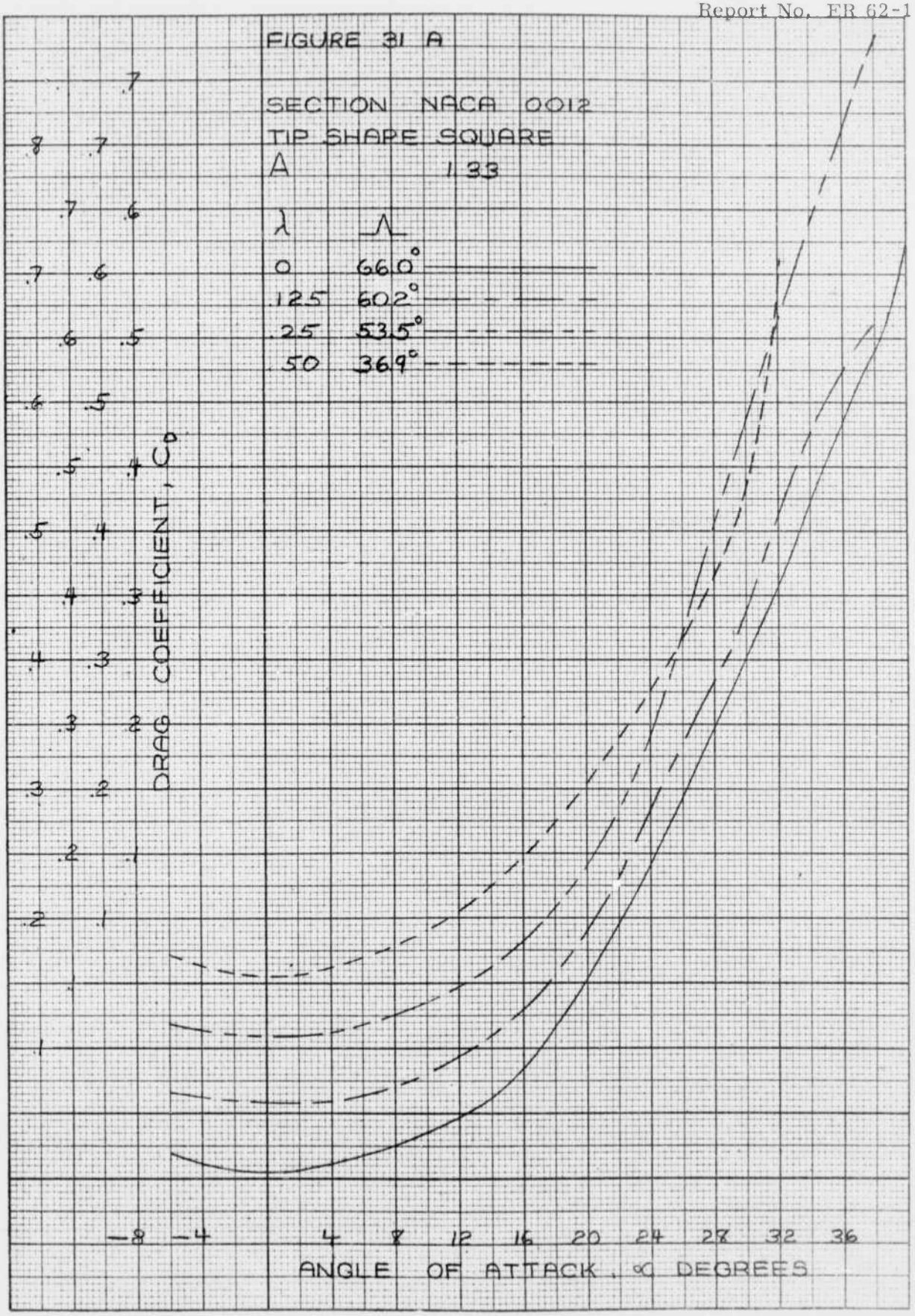


FIGURE 31 A
SECTION NACA 0012
TIP SHAPE SQUARE
A 1.33
λ Λ
0 66.0°
.125 60.2°
.25 53.5°
.50 36.9°
DRAG COEFFICIENT, C_D
ANGLE OF ATTACK, α DEGREES
-8 -4 4 8 12 16 20 24 28 32 36

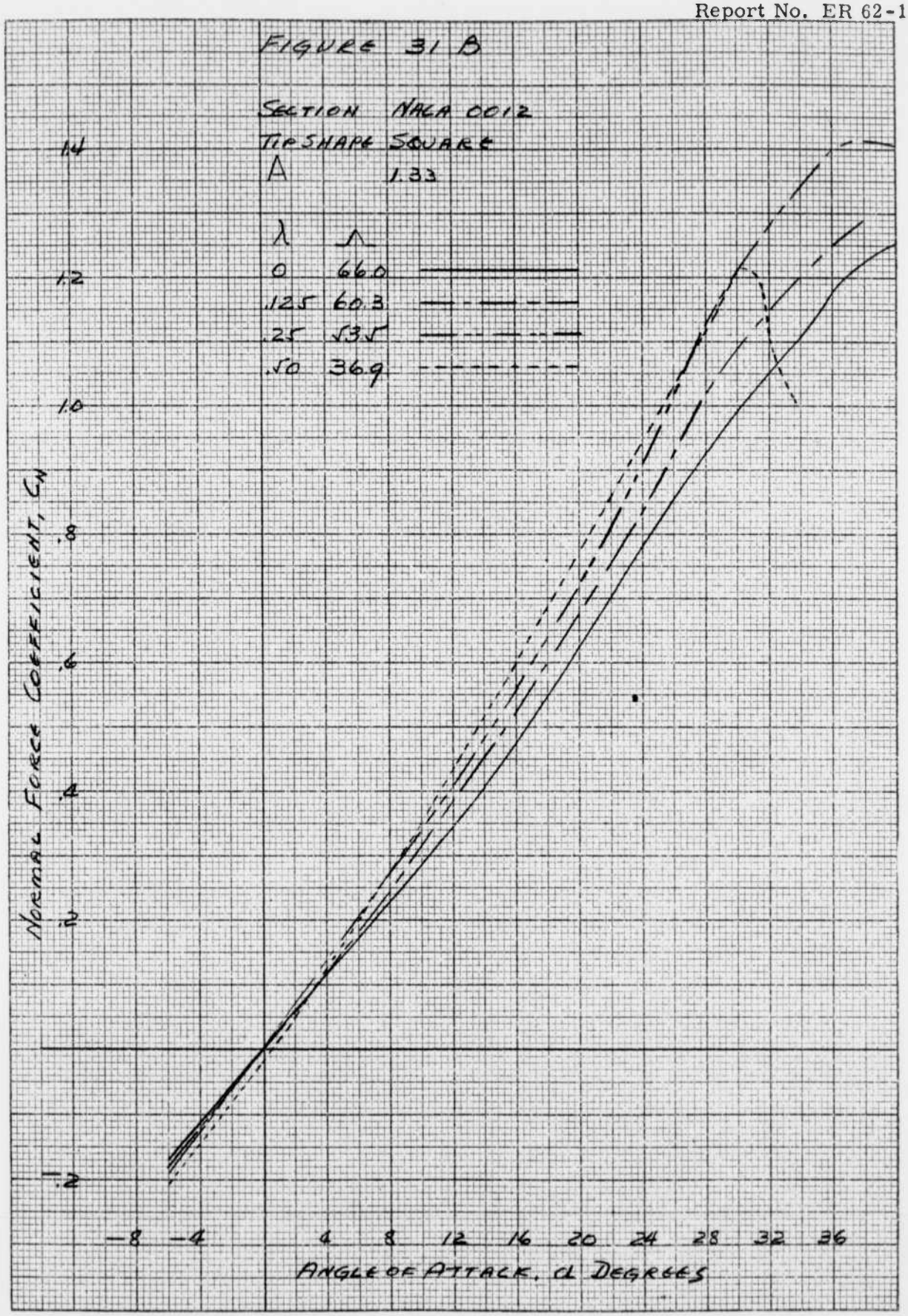


FIGURE 31 B
SECTION NACA 0012
TIP SHAPE SQUARE
A 1.33
λ Λ
0 66.0
.125 60.3
.25 53.5
.50 36.9
1.4
1.2
1.0
.8
.6
.4
.2
-.2
NORMAL FORCE COEFFICIENT, C_N
-8 -4 4 8 12 16 20 24 28 32 36
ANGLE OF ATTACK, α DEGREES

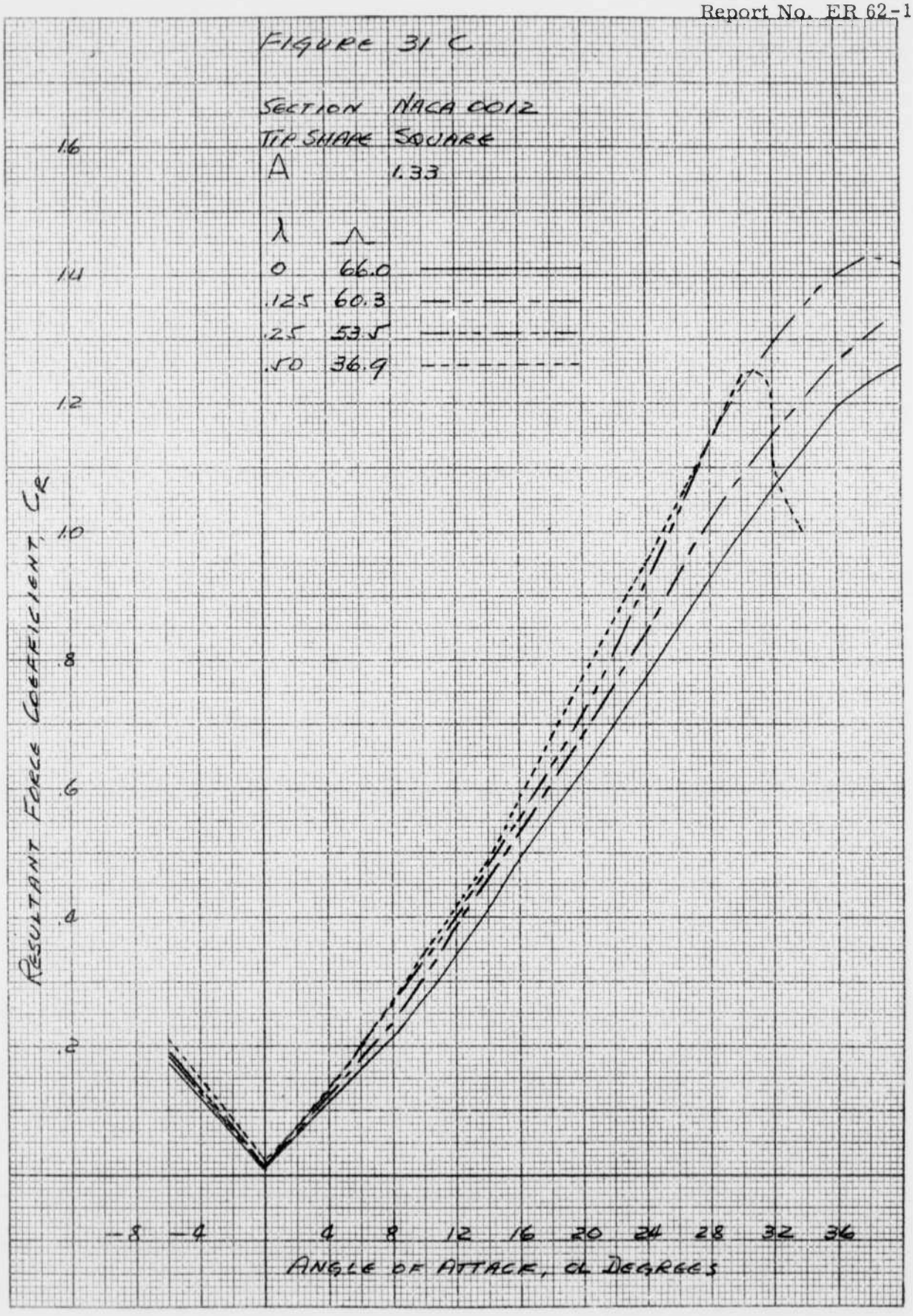


FIGURE 31 C
SECTION NACA 0012
TIP SHAPE SQUARE
A 1.33
λ Λ
0 66.0
.125 60.3
.25 53.5
.50 36.9
RESULTANT FORCE COEFFICIENT, CR
1.6
1.4
1.2
1.0
.8
.6
.4
.2
-8 -4 4 8 12 16 20 24 28 32 36
ANGLE OF ATTACK, αL DEGREES

FIGURE 31 D

SECTION	NACA 0012
TIP SHAPE	SQUARE
A	1.33

λ	Λ	
0	66.0	————
.125	60.2	— - — - —
.25	53.5	— - - — - -
.50	36.9	- - - - - - -

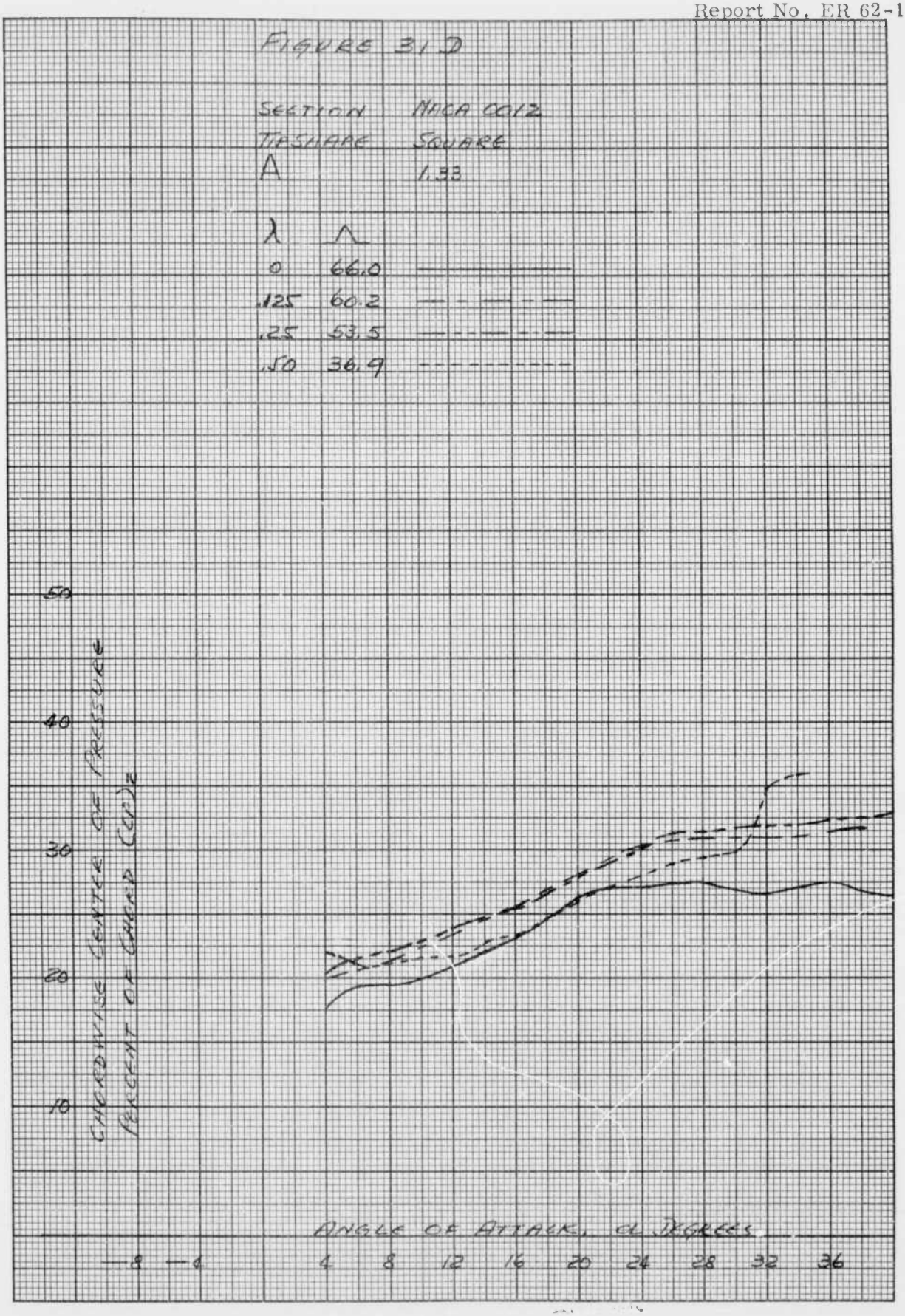
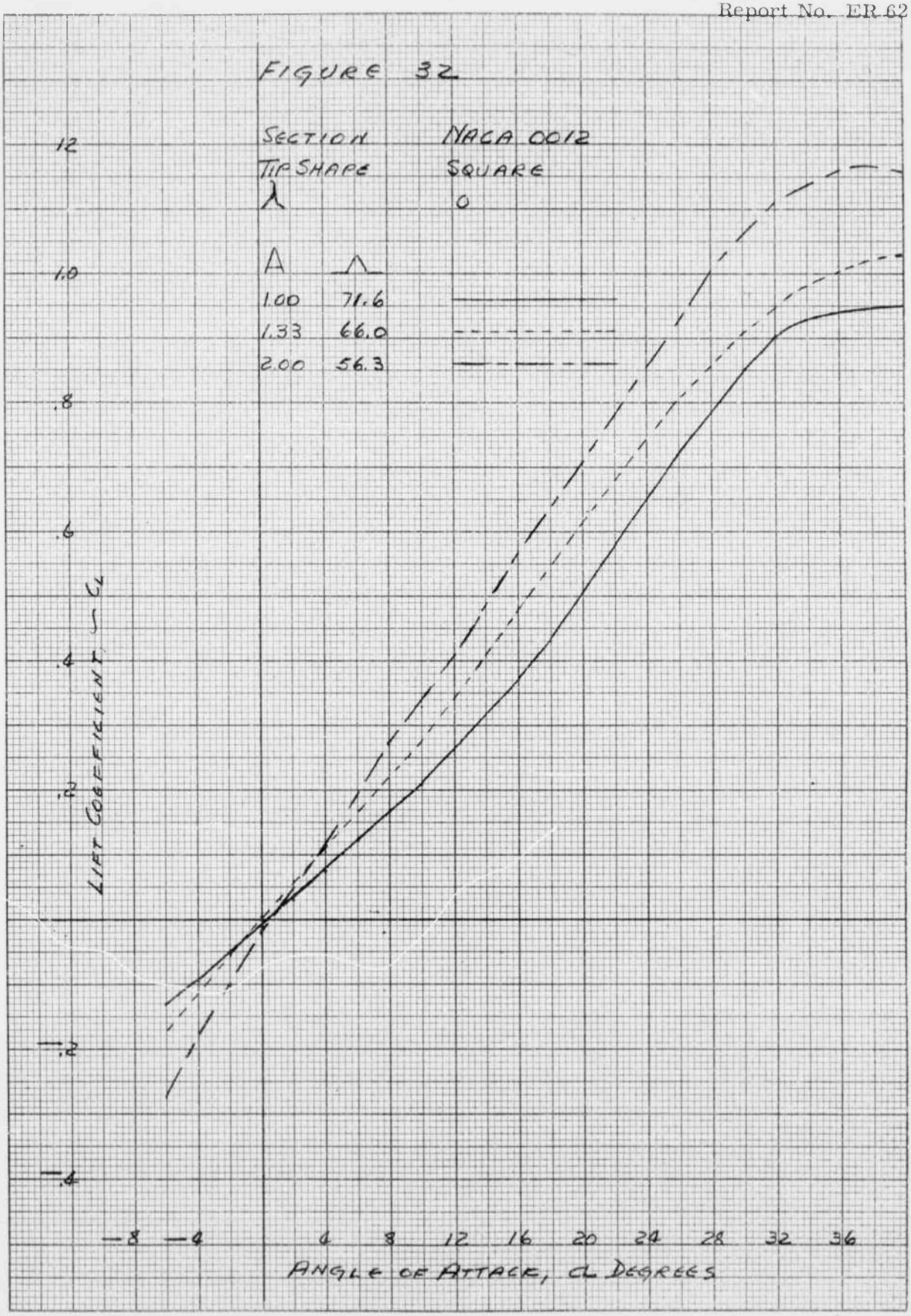


FIGURE 32


SECTION NACA 0012
TIP SHAPE SQUARE
λ 0
A Λ
1.00 71.6
1.33 66.0
2.00 56.3
1.2
1.0
.8
.6
.4
.2
-.2
-.4
LIFT COEFFICIENT — C_L
-8 -4 0 4 8 12 16 20 24 28 32 36
ANGLE OF ATTACK, α_L DEGREES

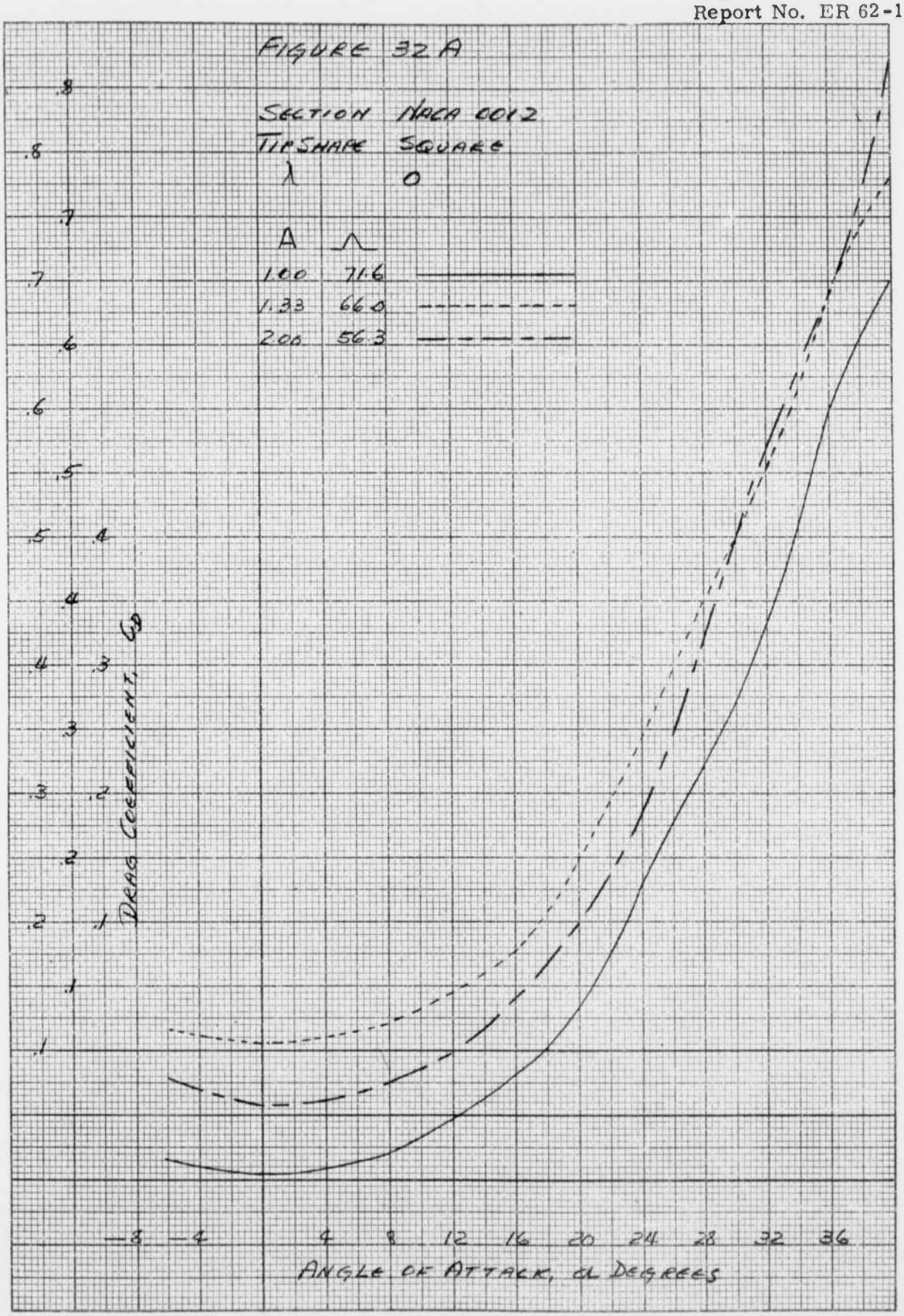


FIGURE 32A
SECTION NACA 0012
TIP SHAPE SQUARE
λ 0
A Λ
1.00 71.6
1.33 66.0
2.00 56.3
DRAG COEFFICIENT, CD
ANGLE OF ATTACK, α, DEGREES
-8 -4 4 8 12 16 20 24 28 32 36

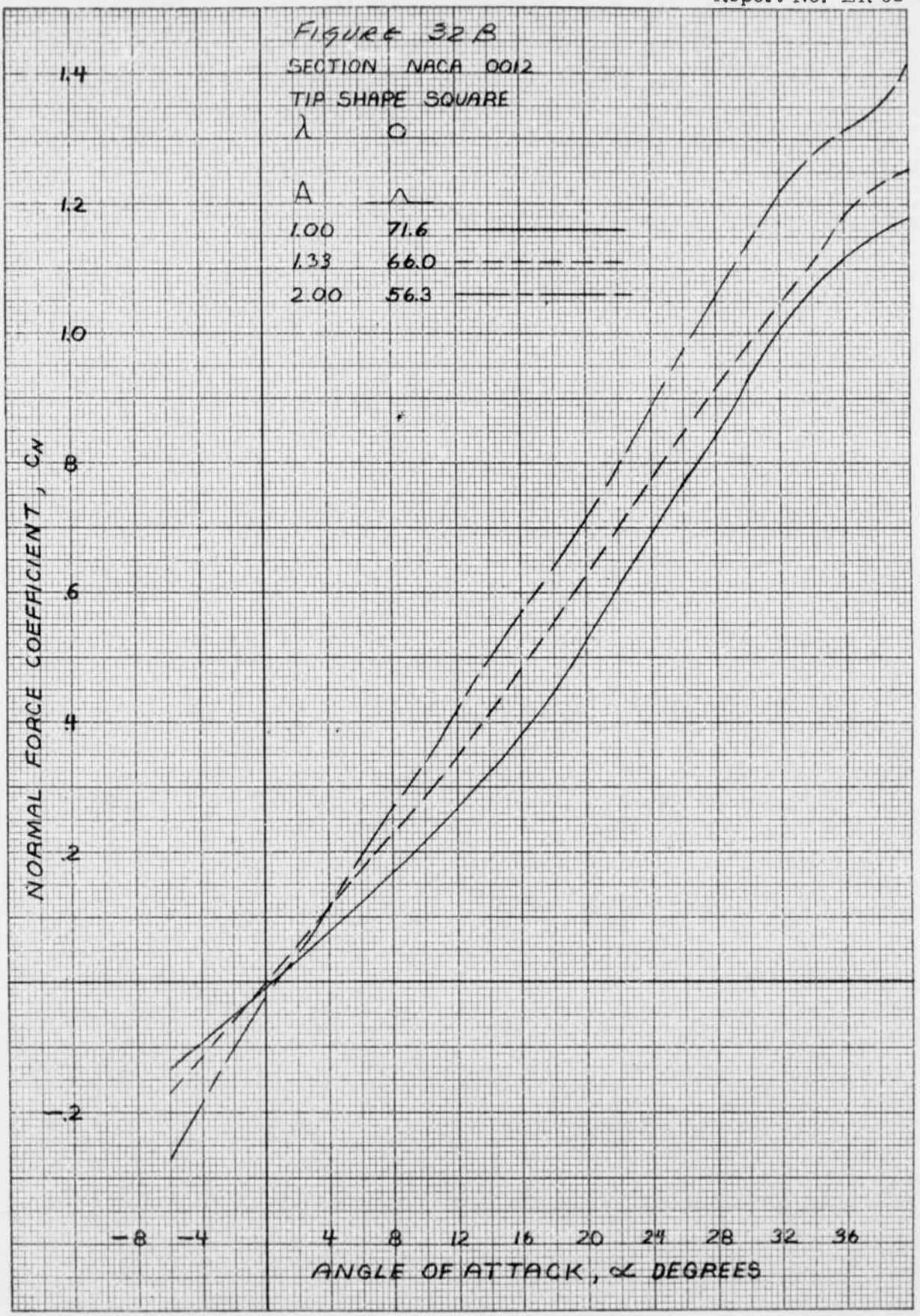


FIGURE 32 B
SECTION NACA 0012
TIP SHAPE SQUARE
λ 0
A Λ
1.00 71.6
1.33 66.0
2.00 56.3
NORMAL FORCE COEFFICIENT, C_N
1.4
1.2
1.0
.8
.6
.4
.2
-.2
-8 -4 4 8 12 16 20 24 28 32 36
ANGLE OF ATTACK, α DEGREES

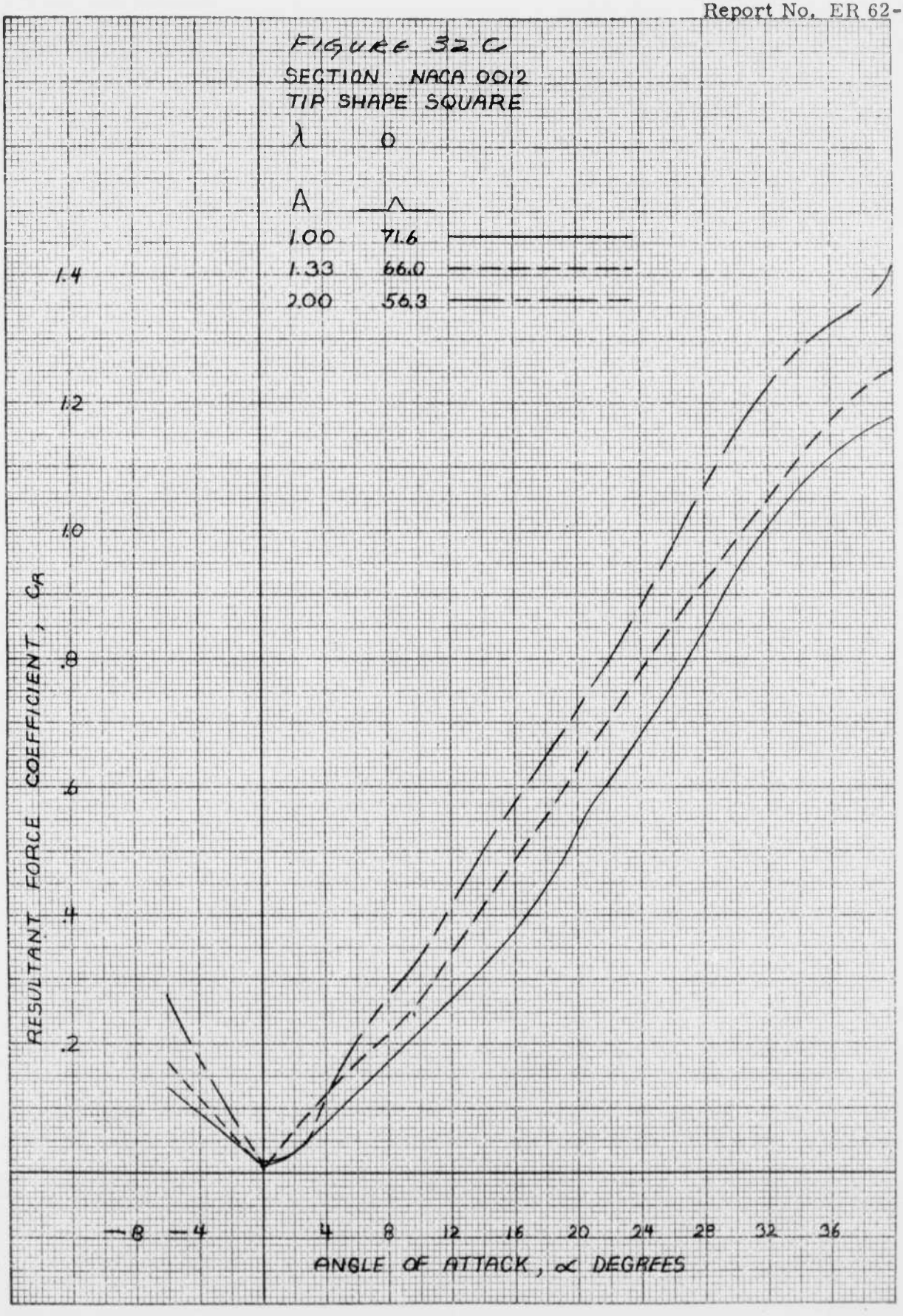
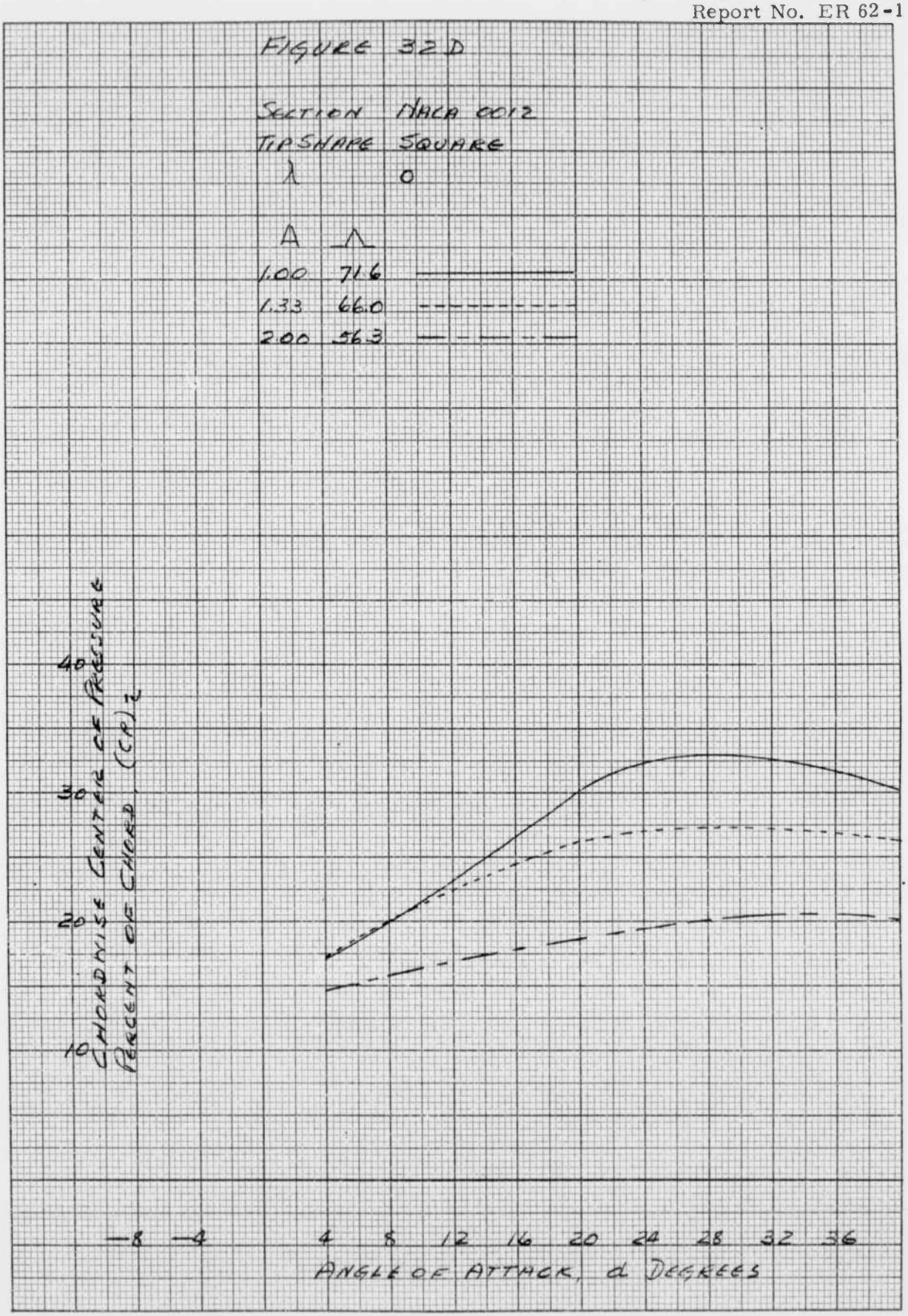


FIGURE 32 C
SECTION NACA 0012
TIP SHAPE SQUARE
λ 0
A Λ
1.00 71.6
1.33 66.0
2.00 56.3
1.4
1.2
1.0
.8
.6
.4
.2
RESULTANT FORCE COEFFICIENT, CR
-8 -4 4 8 12 16 20 24 28 32 36
ANGLE OF ATTACK, α DEGREES

FIGURE 32 D

SECTION NACA 0012
TIP SHAPE SQUARE
λ 0

A	Λ	
1.00	71.6	———
1.33	66.0	- - - - - -
2.00	56.3	— - — - —



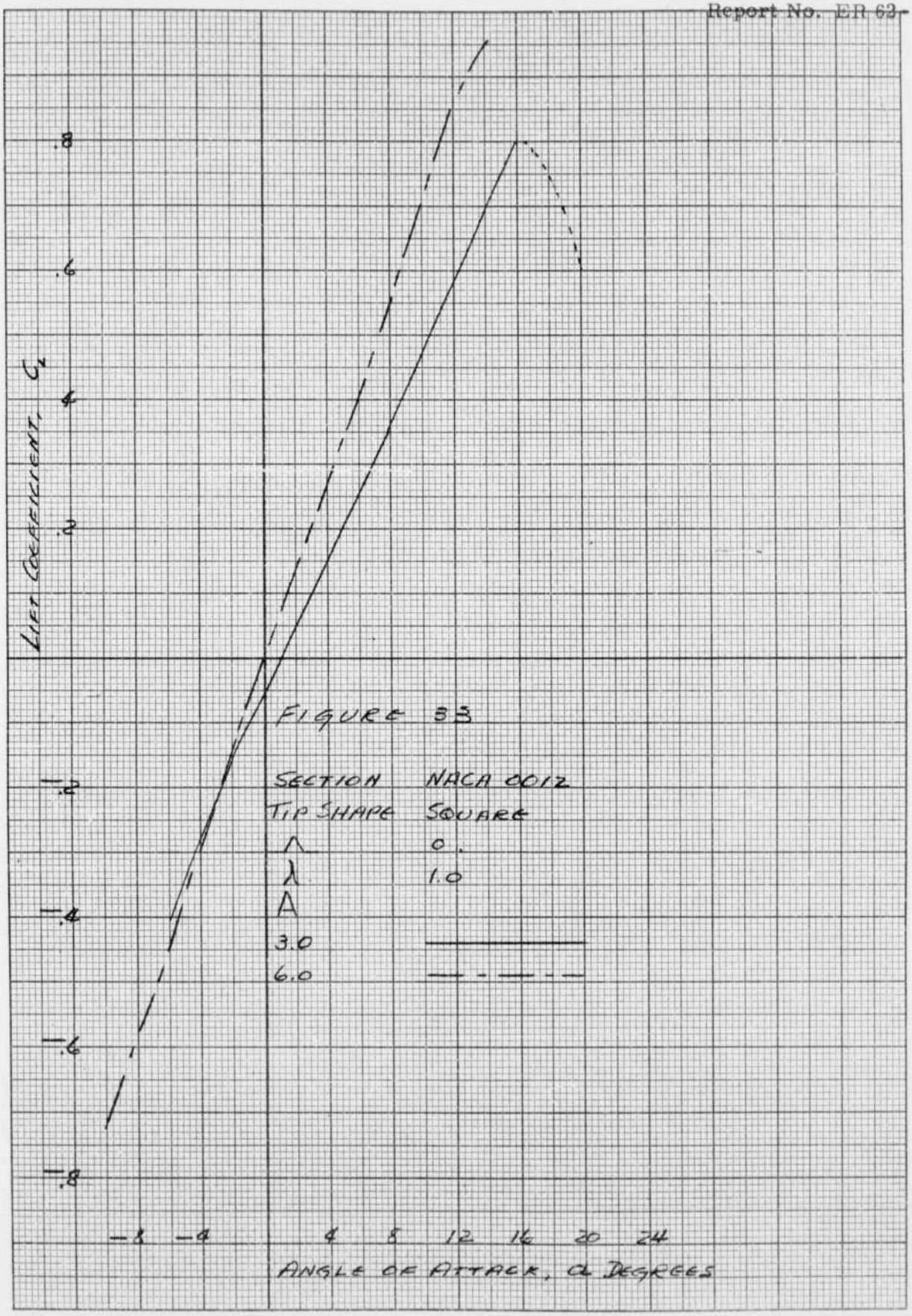
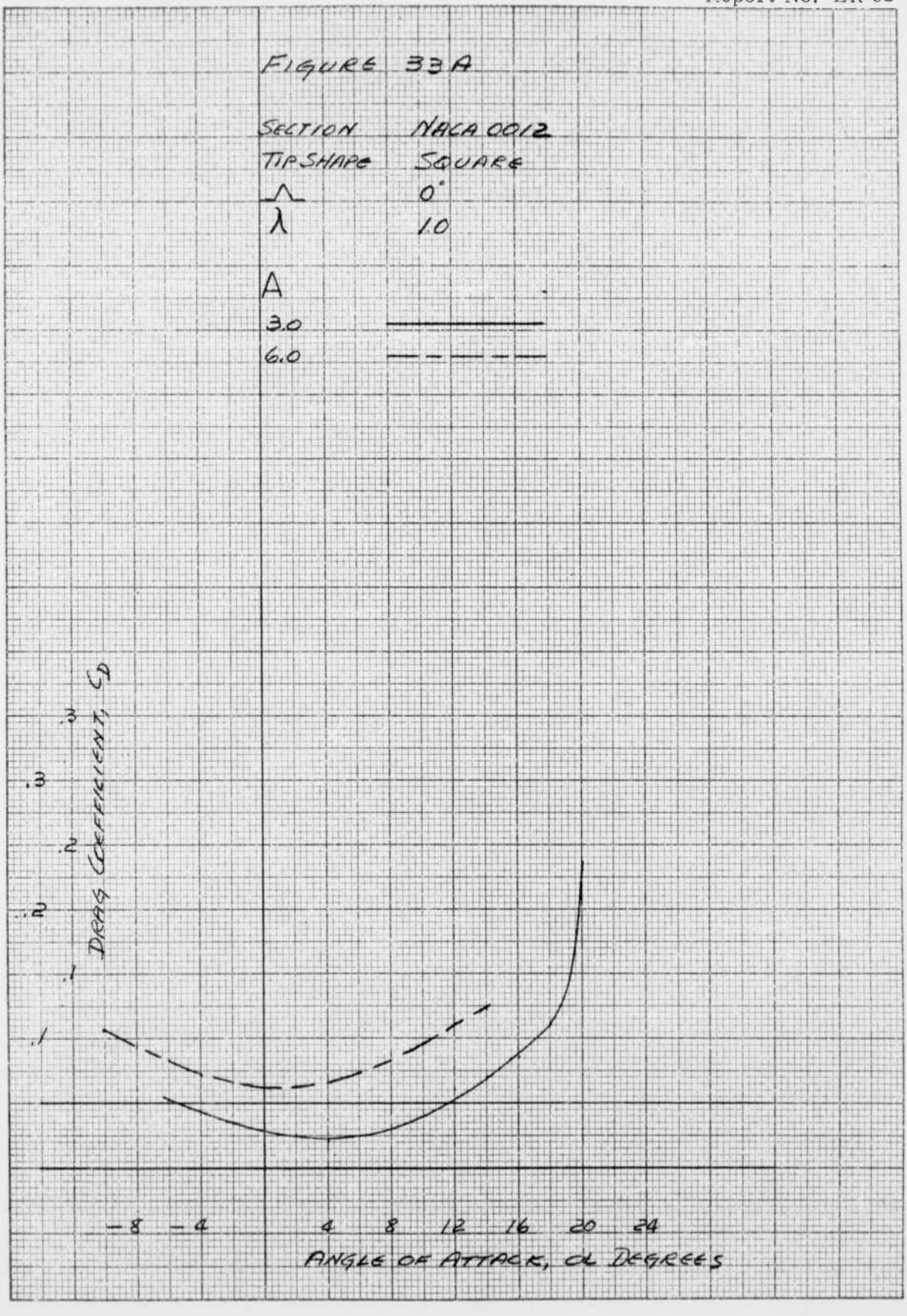

LIFT COEFFICIENT, C_L
.8
.6
.4
.2
-.2
-.4
-.6
-.8
-2
-4
4
8
12
16
20
24
ANGLE OF ATTACK, α DEGREES
SECTION NACA 0012
TIP SHAPE SQUARE
Λ 0.
λ 1.0
A
3.0
6.0

FIGURE 33

FIGURE 33A

SECTION	NACA 0012
TIP SHAPE	SQUARE
Λ	0°
λ	1.0

A
3.0 ———————
6.0 — — — — —



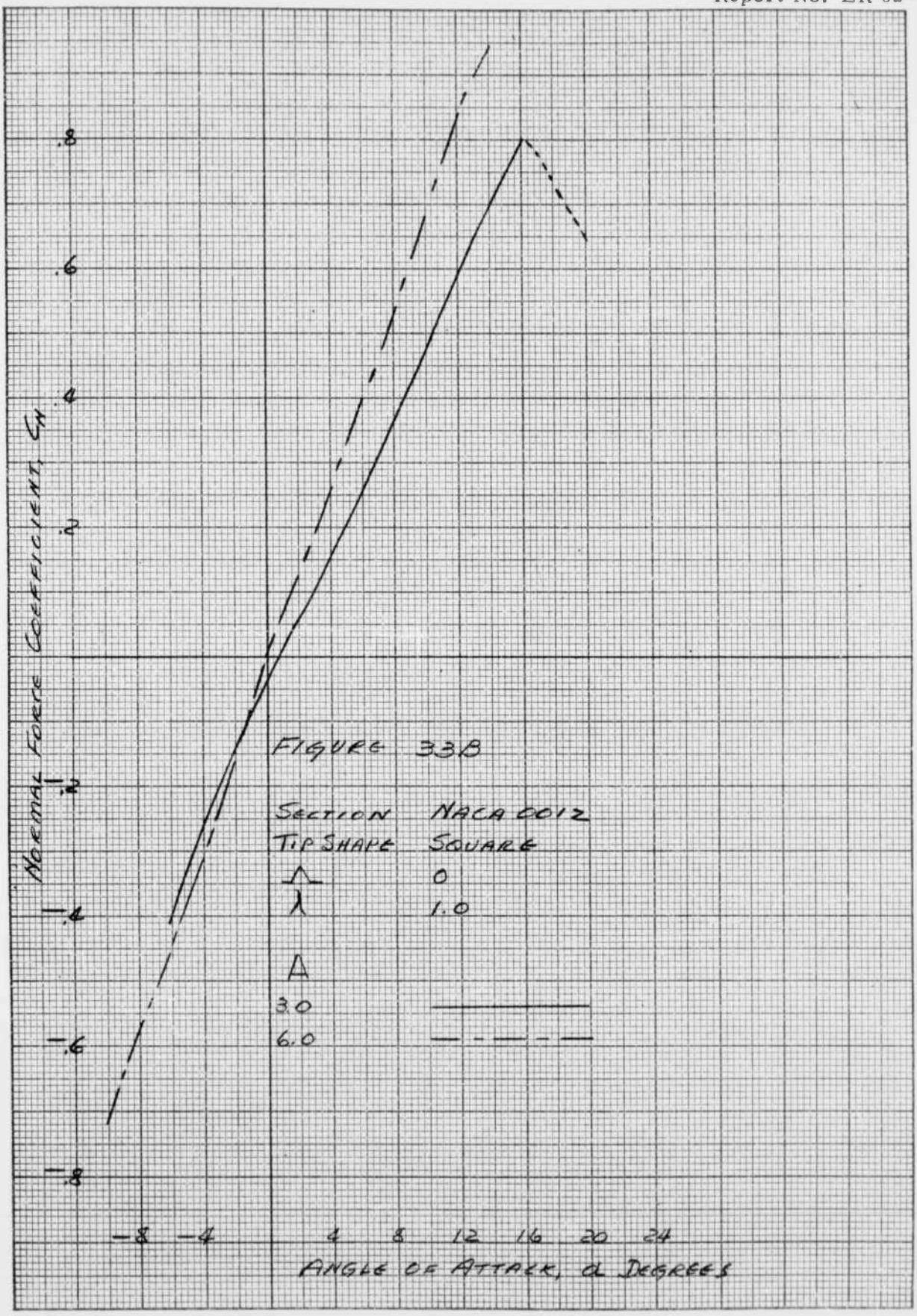

NORMAL FORCE COEFFICIENT, C_N
.8
.6
.4
.2
-.2
-.4
-.6
-.8
-8
-4
4
8
12
16
20
24
ANGLE OF ATTACK, α DEGREES
FIGURE 33B
SECTION NACA 6012
TIP SHAPE SQUARE
Λ 0
λ 1.0
A
3.0
6.0

FIGURE 33C

SECTION NACA 0012
TIP SHAPE SQUARE

Λ	
	0
	1.0

A	
3.0	———
6.0	— - — - —

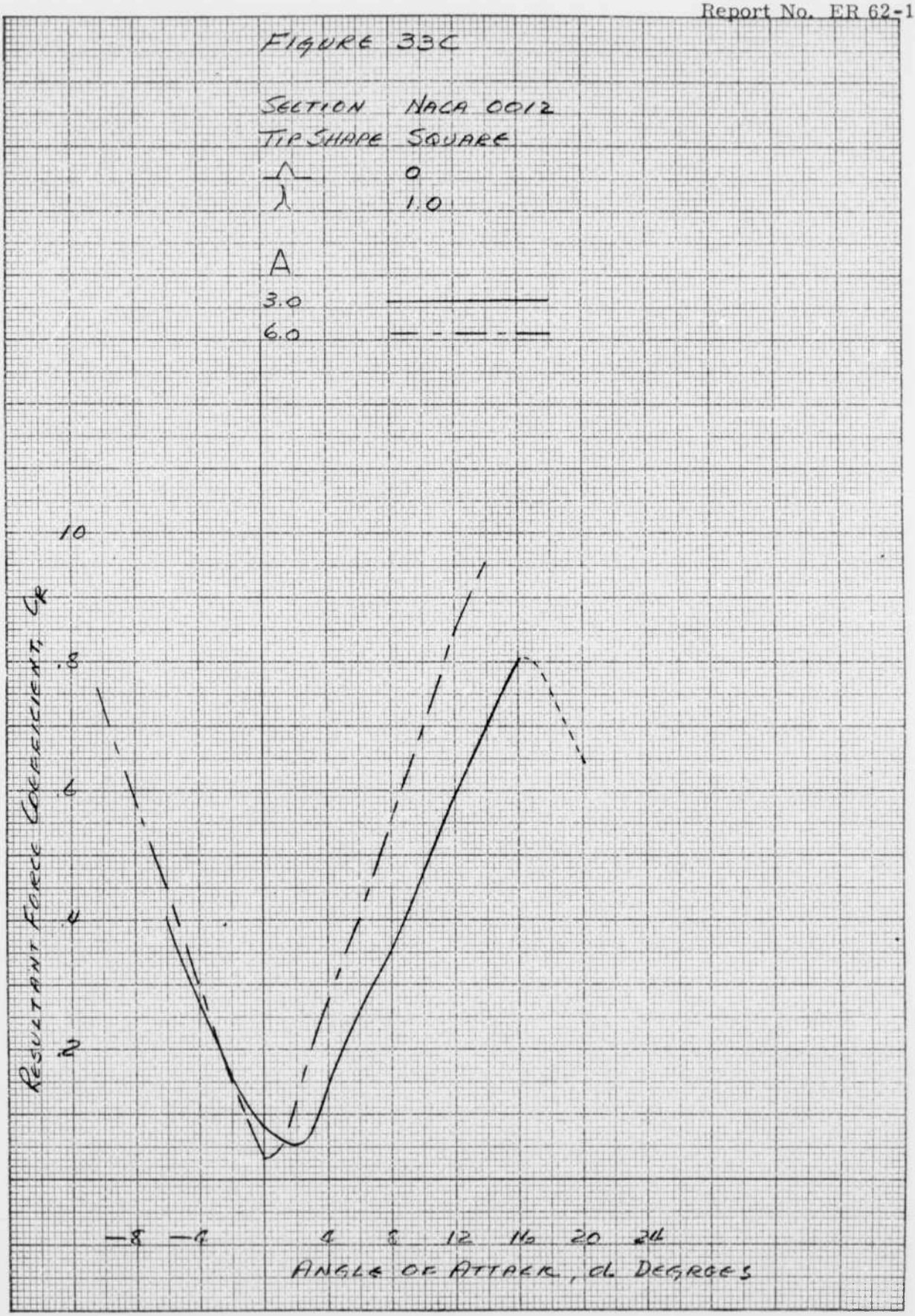
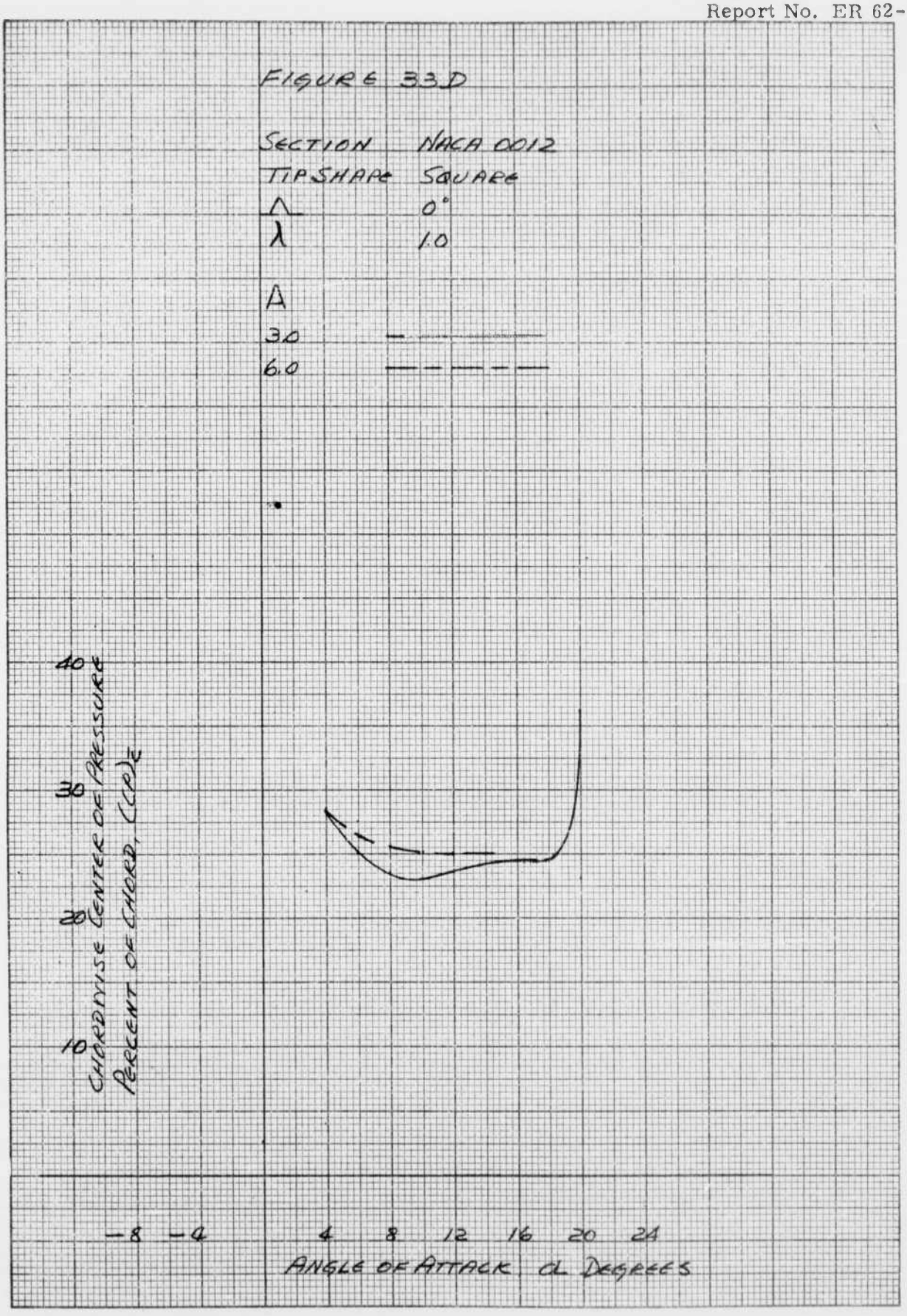


FIGURE 33D

SECTION NACA 0012
TIP SHAPE SQUARE
Λ 0°
λ 1.0

A
3.0 ———————
6.0 — — — — —



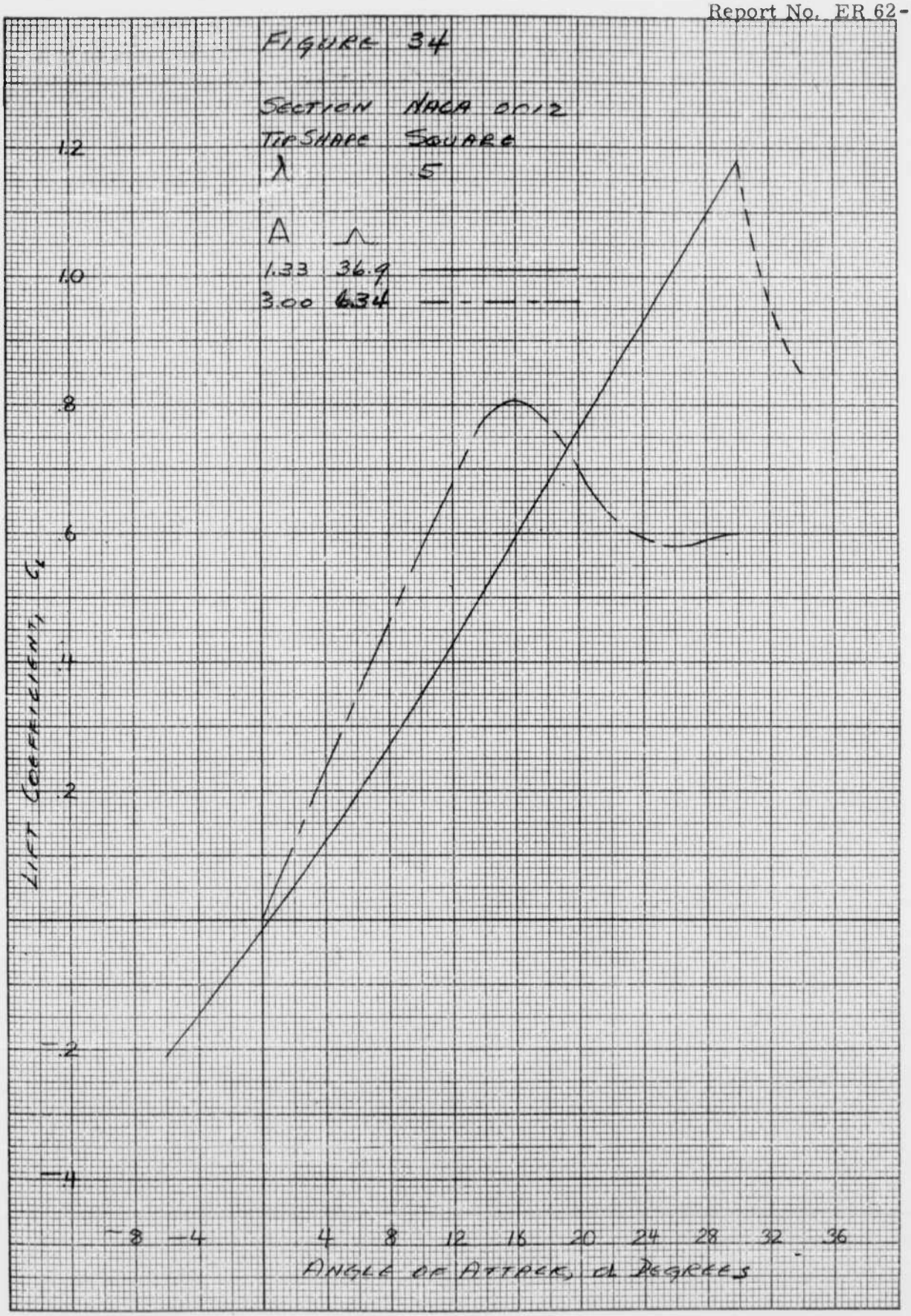


FIGURE 34
SECTION NACA 0012
TIP SHAPE SQUARE
λ .5
A Λ
1.33 36.9
3.00 63.4
1.2
1.0
.8
.6
.4
.2
-.2
-.4
LIFT COEFFICIENT, C_L
-8 -4 4 8 12 16 20 24 28 32 36
ANGLE OF ATTACK, α, DEGREES

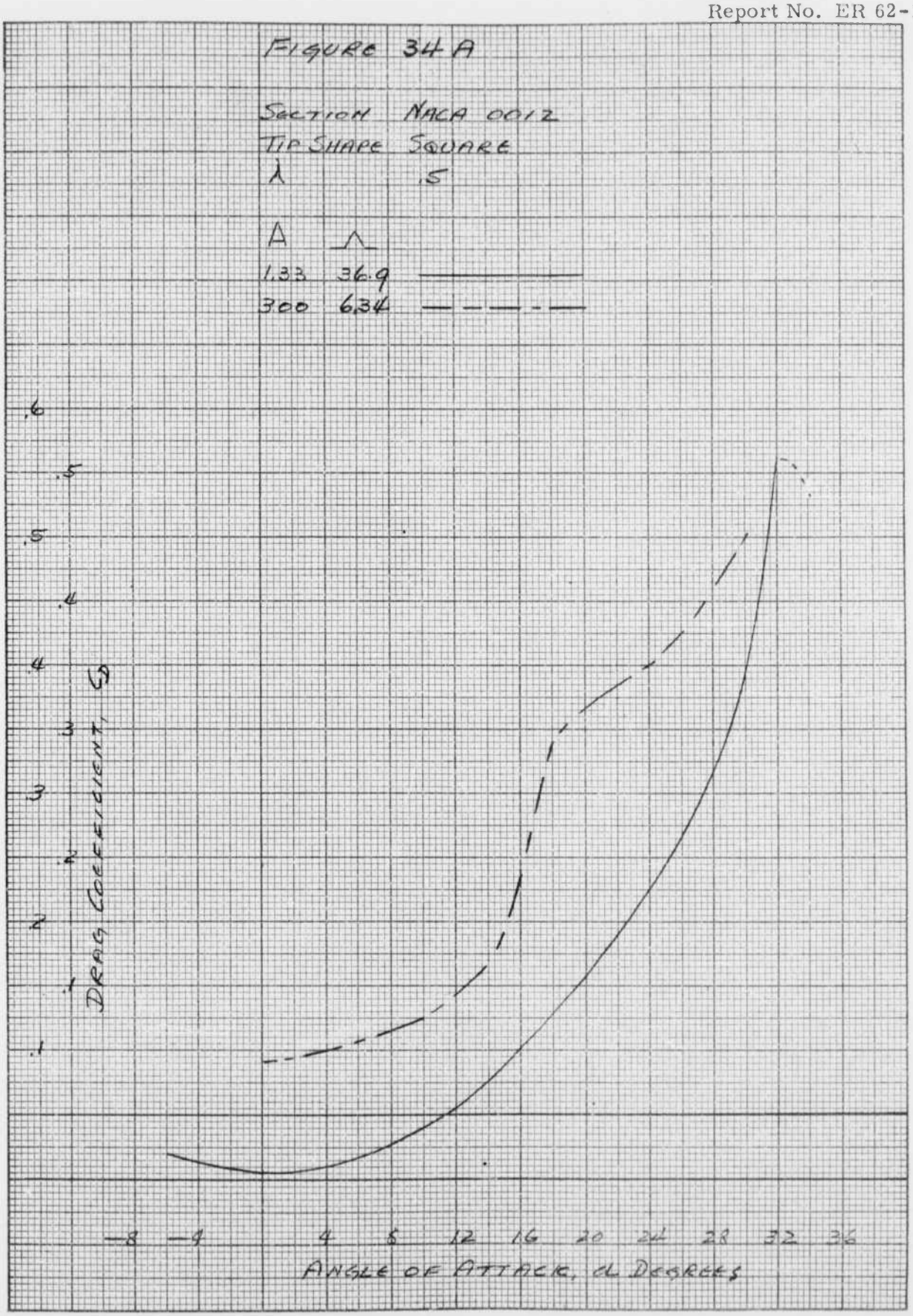
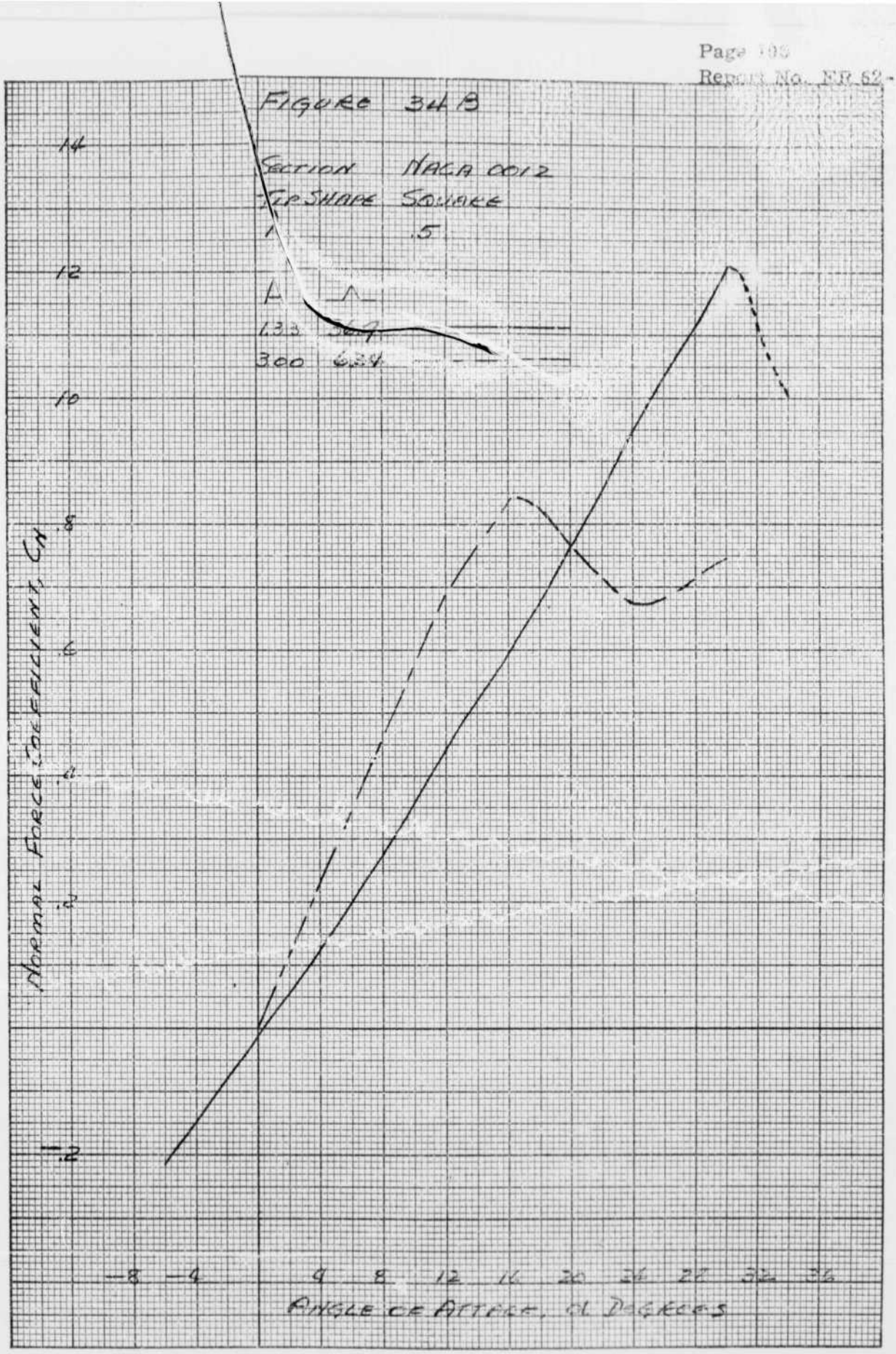


FIGURE 34A
SECTION NACA 0012
TIP SHAPE SQUARE
λ .5
A Λ
1.33 36.9
3.00 6.34
.6
.5
.5
.4
.4
.3
.3
.2
.2
.1
.1
DRAG COEFFICIENT, CD
-8 -4 4 8 12 16 20 24 28 32 36
ANGLE OF ATTACK, α, DEGREES

FIGURE 34B


SECTION NACA 0012
TIP SHAPE SQUARE
1 .5
A
1.33 36.9
3.00 63.4
14
12
10
8
6
4
2
-2
-8 -4 4 8 12 16 20 24 28 32 36
ANGLE OF ATTACK, α, DEGREES
NORMAL FORCE COEFFICIENT, C_N

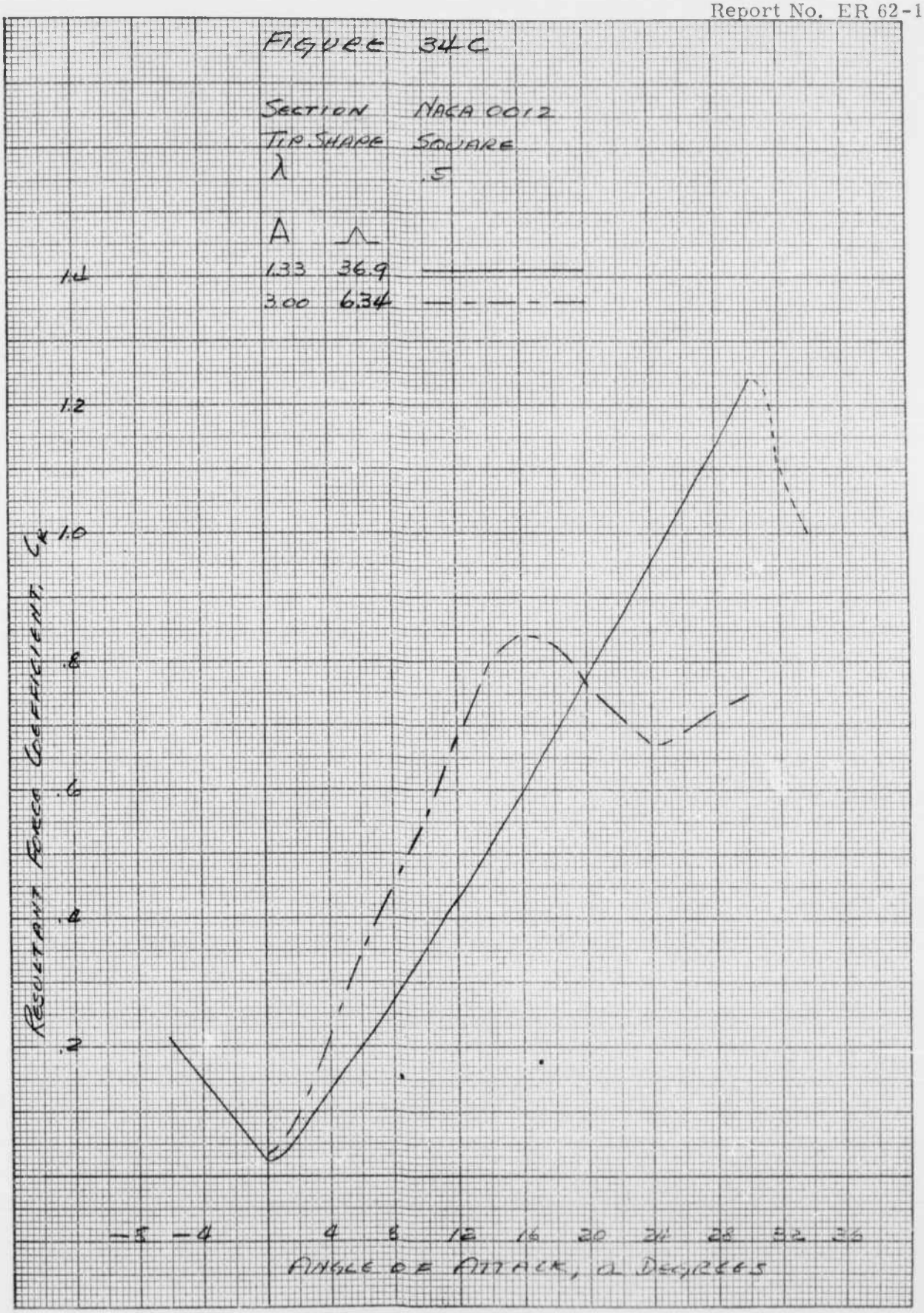
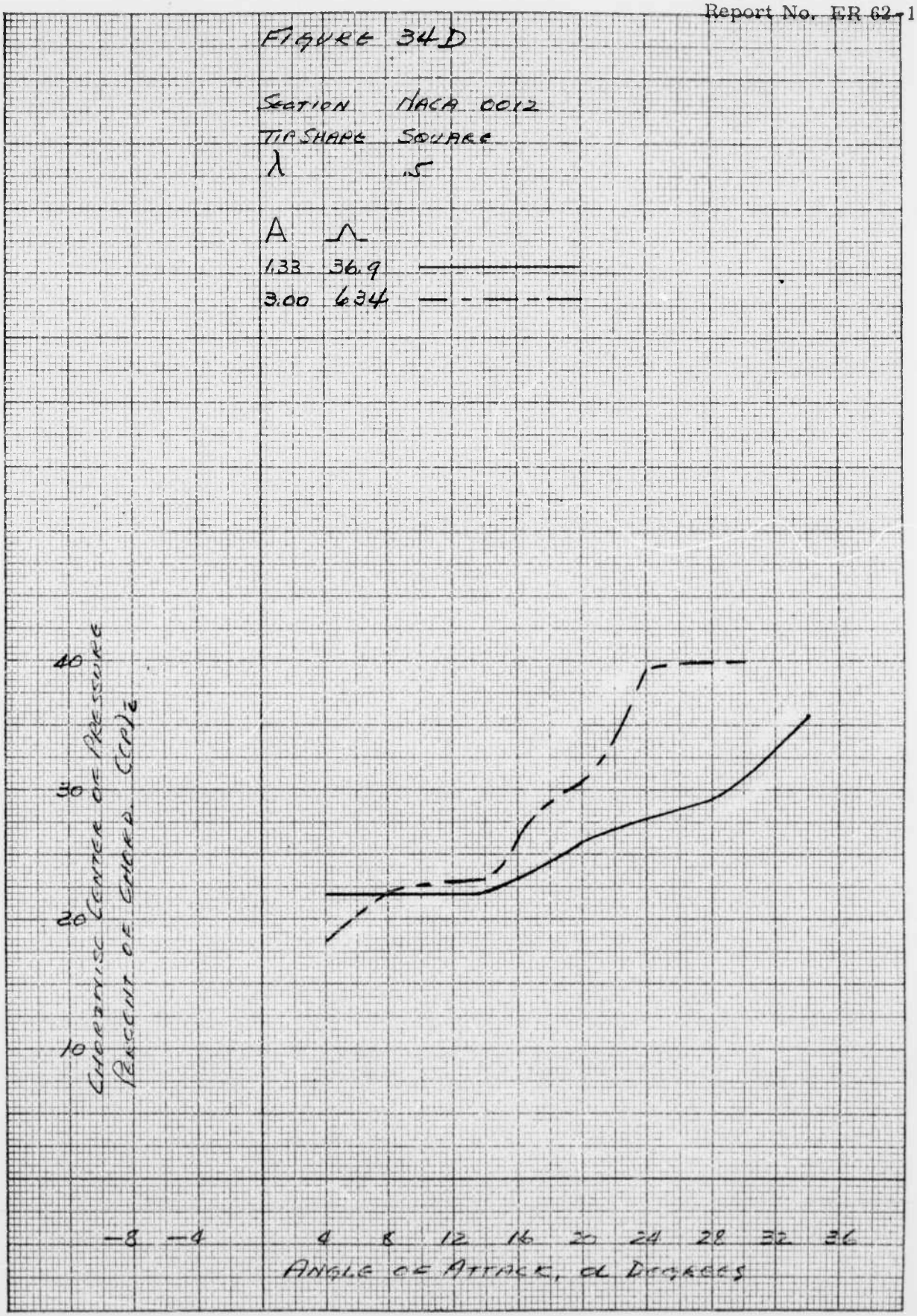


FIGURE 34C
SECTION NACA 0012
TIP SHAPE SQUARE
λ .5
A Λ
1.33 36.9
3.00 6.34
1.4
1.2
1.0
.8
.6
.4
.2
RESULTANT FORCE COEFFICIENT, C_R
-5 -4 4 8 12 16 20 24 28 32 36
ANGLE OF ATTACK, α DEGREES

FIGURE 34D

SECTION NACA 0012
TIP SHAPE SQUARE
λ .5

A	Λ	
1.33	36.9	———
3.00	63.4	— - — - —



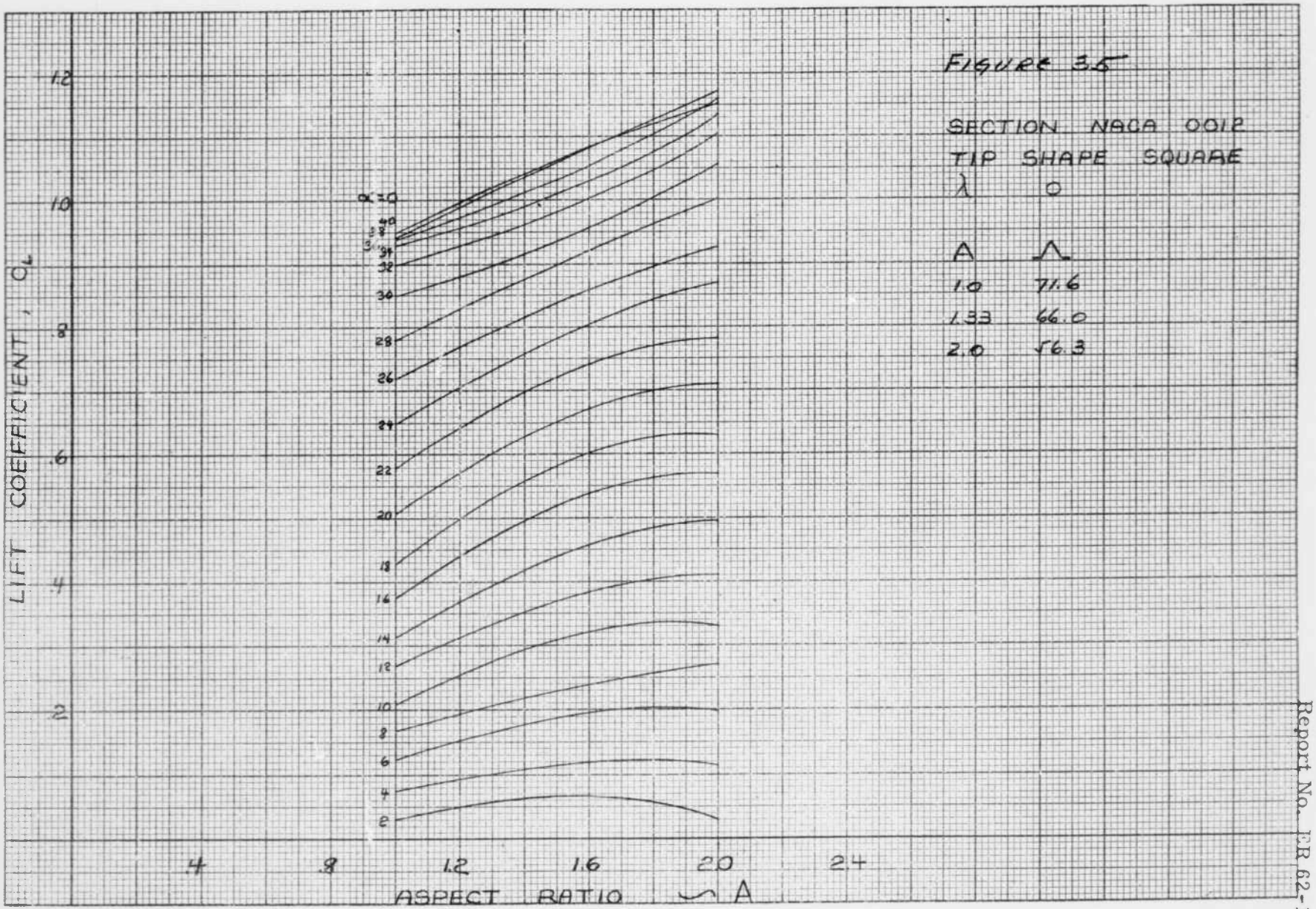


FIGURE 3.5
SECTION NACA 0012
TIP SHAPE SQUARE
λ 0
A Λ
1.0 71.6
1.33 66.0
2.0 56.3
LIFT COEFFICIENT, C_L
ASPECT RATIO A
α=0
.4
.8
1.2
1.6
2.0
2.4
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40

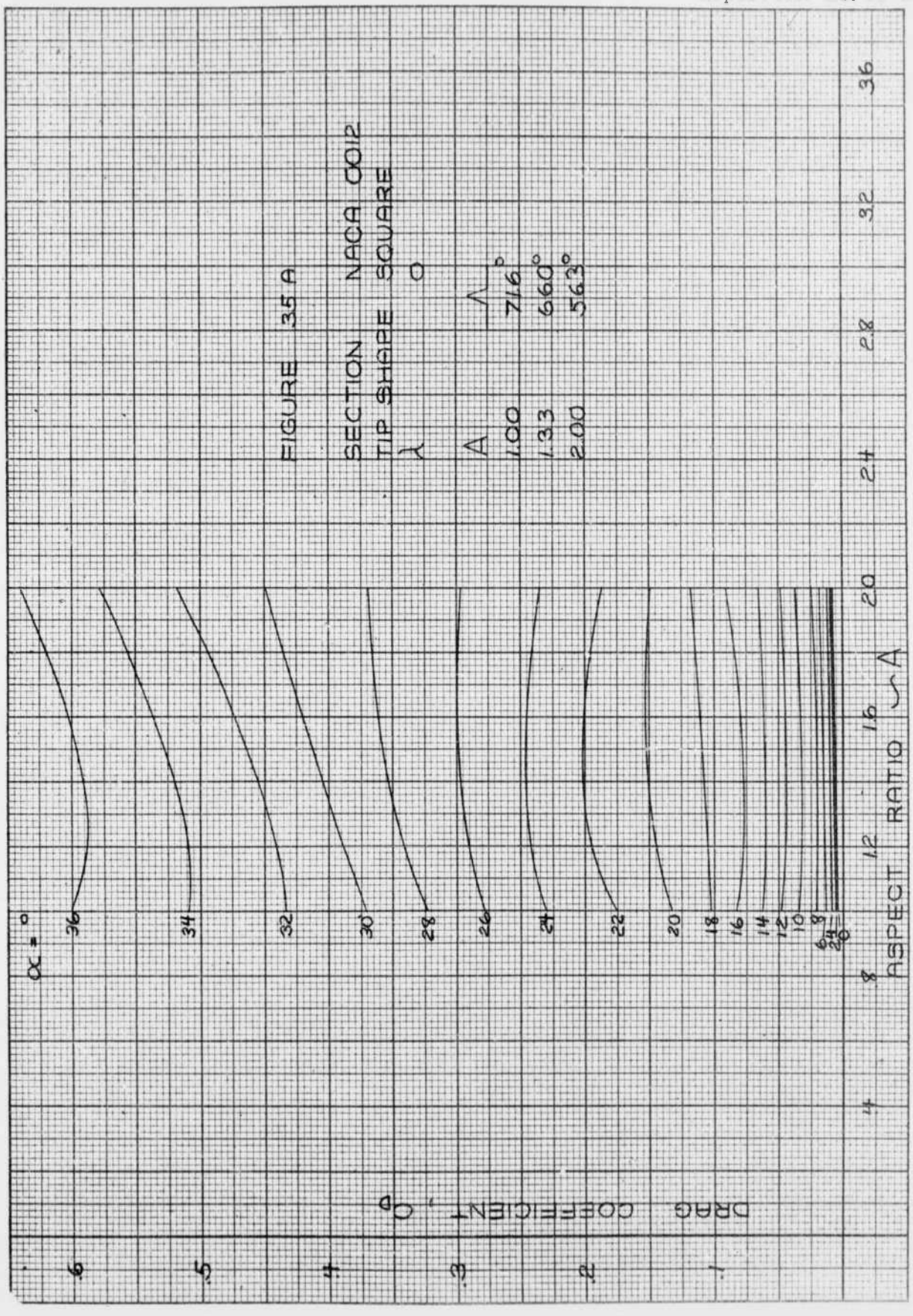


FIGURE 35 A
SECTION NACA 0012
TIP SHAPE SQUARE
λ 0
A Λ
1.00 71.6°
1.33 66.0°
2.00 56.3°
α = 0
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
.6
.5
.4
.3
.2
.1
DRAG COEFFICIENT, C_D
4 8 12 16 20 24 28 32 36
ASPECT RATIO A

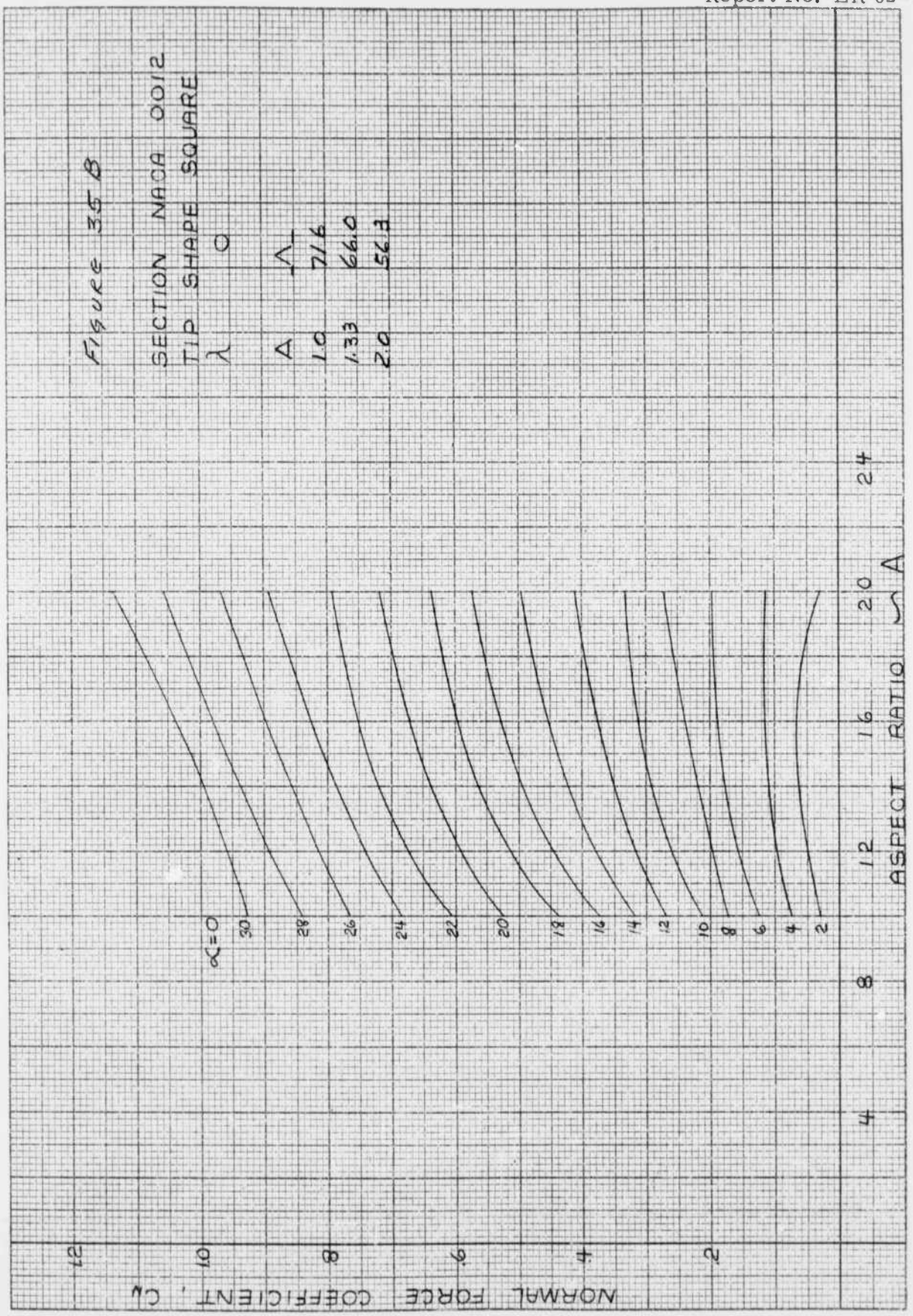


FIGURE 35 B
SECTION NACA 0012
TIP SHAPE SQUARE
λ 0
A Λ
1.0 71.6
1.33 66.0
2.0 56.3
α=0
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
NORMAL FORCE COEFFICIENT, C_N
ASPECT RATIO A
4
8
12
16
20
24

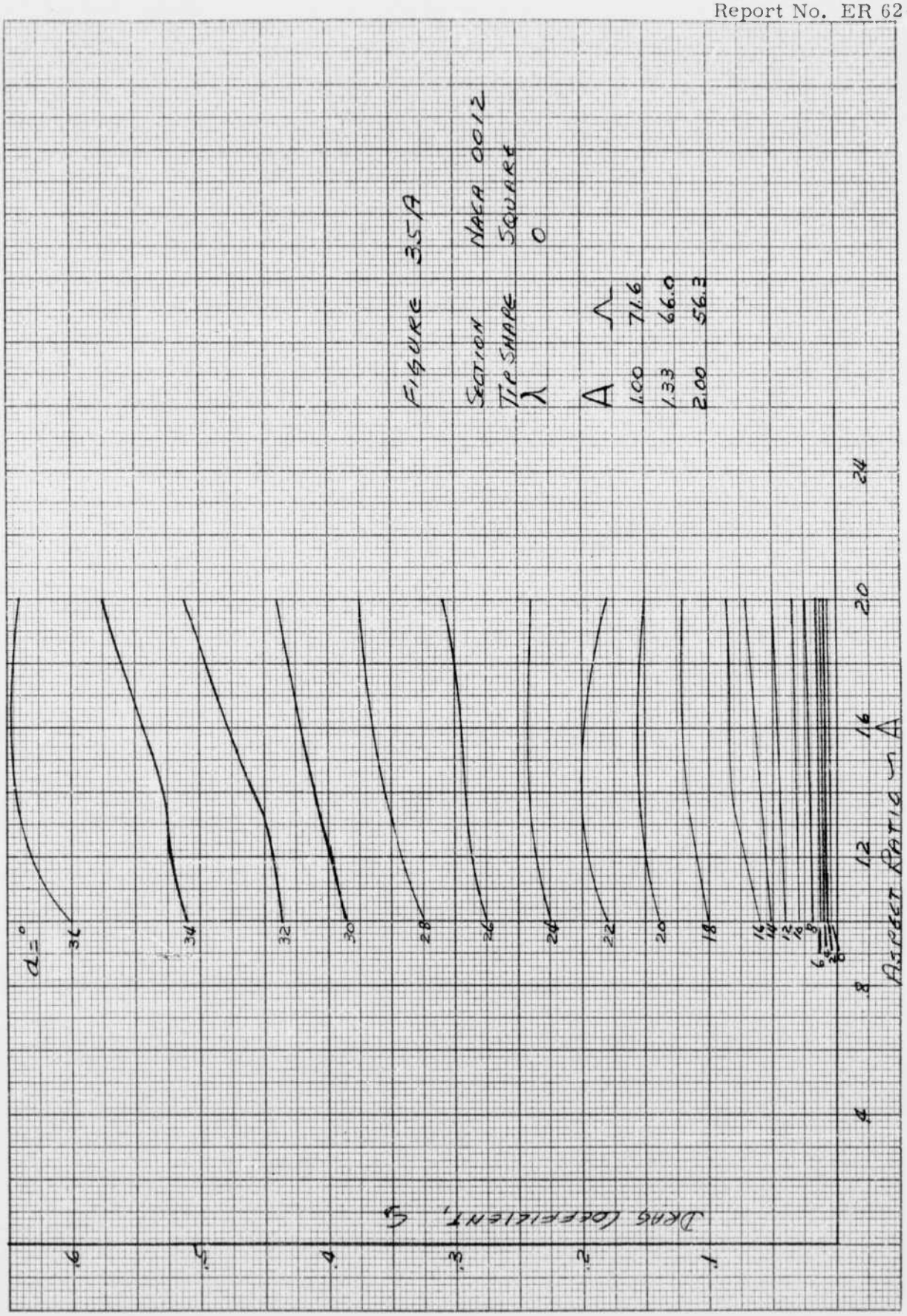


FIGURE 35A
SECTION NACA 0012
TIP SHAPE SQUARE
λ 0
A Λ
1.00 71.6
1.33 66.0
2.00 56.3
DRAG COEFFICIENT, C_D
ASPECT RATIO, A
α = 0
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
.8
1.2
1.6
2.0
2.4
1
2
3
4
5
6

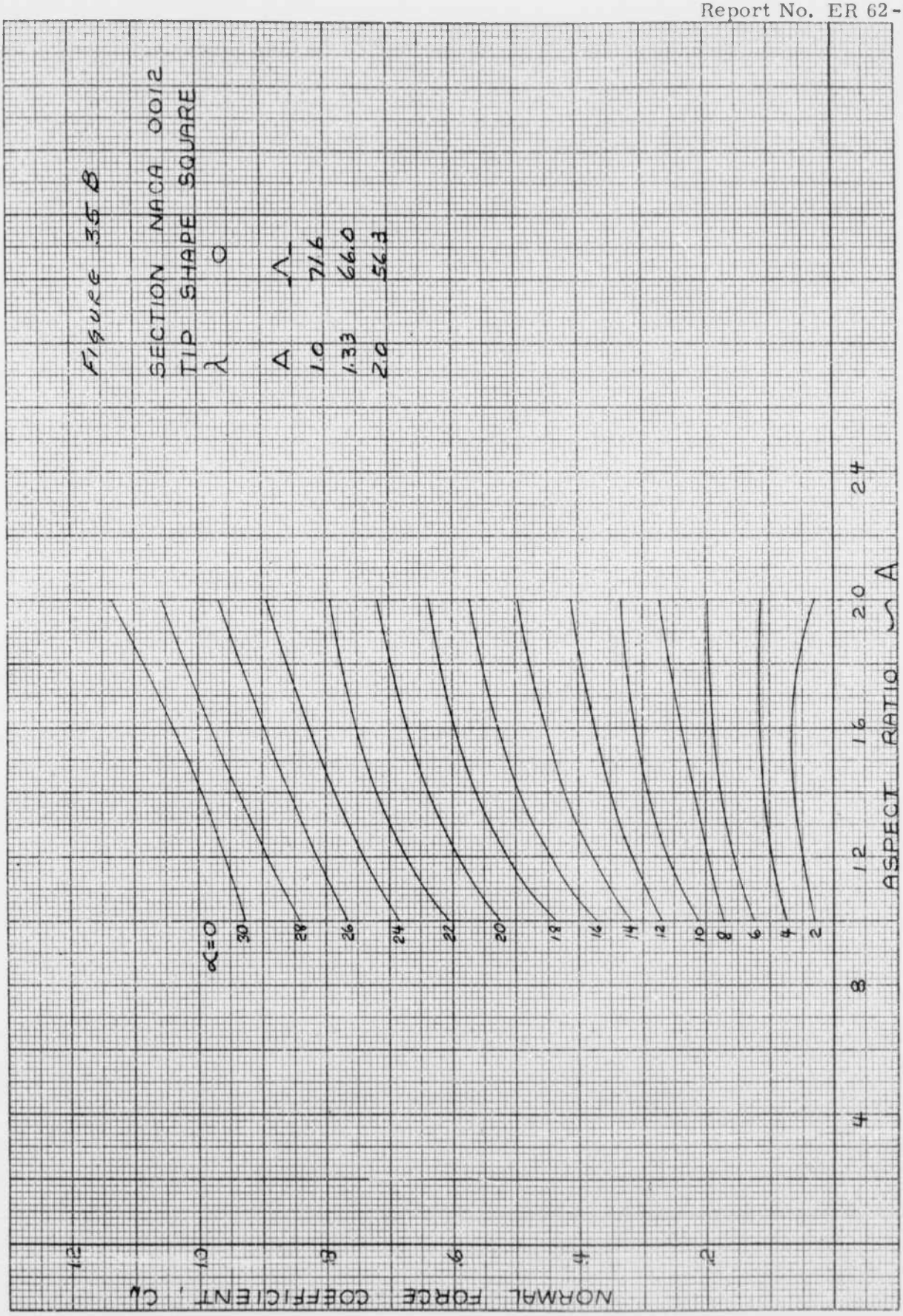


FIGURE 35 B
SECTION NACA 0012
TIP SHAPE SQUARE
λ 0
A Λ
1.0 71.6
1.33 66.0
2.0 56.3
NORMAL FORCE COEFFICIENT, C_{N_α}
ASPECT RATIO A
α=0
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
.2
.4
.6
.8
1.0
1.2
4
8
12
16
20
24

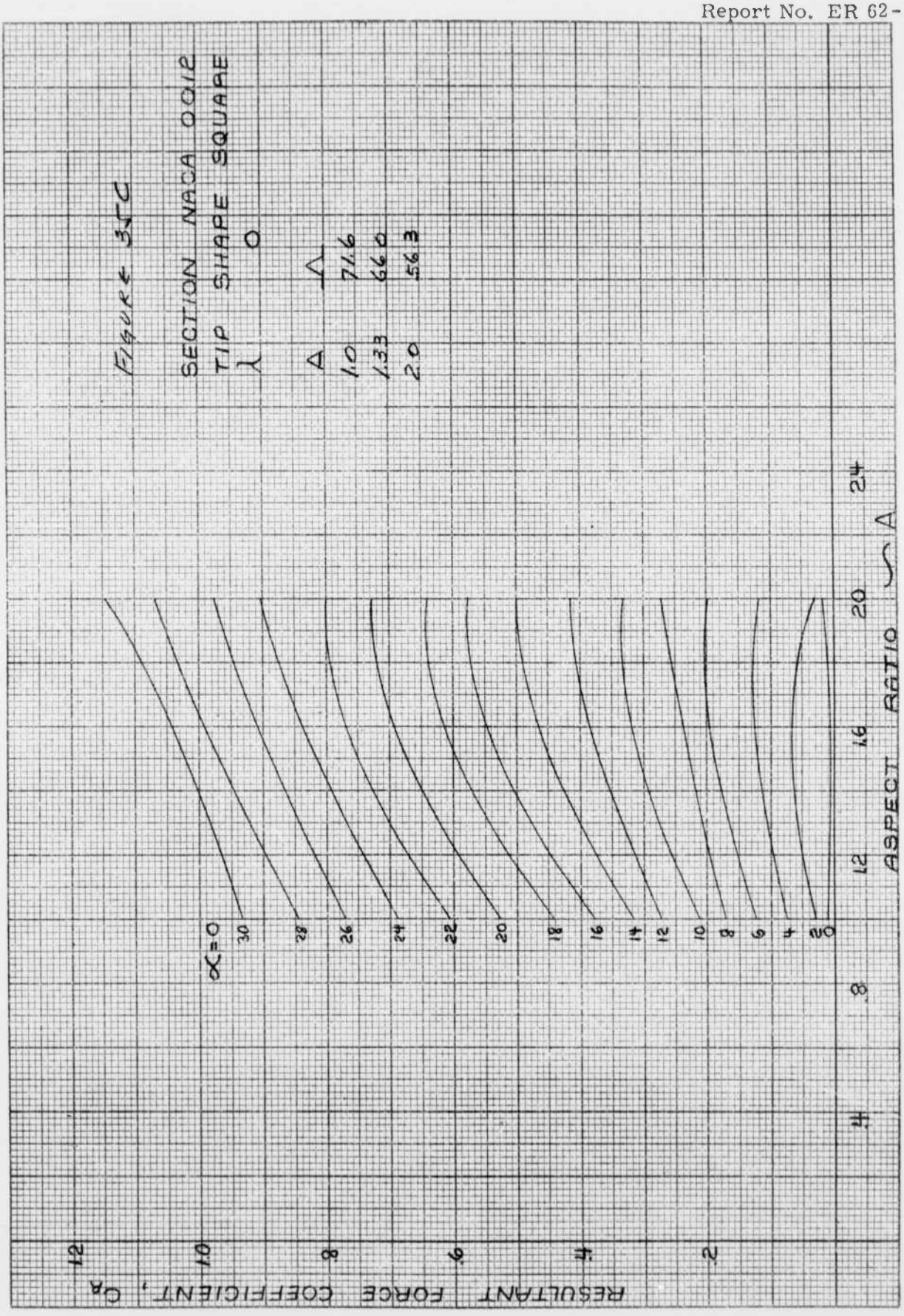


Figure 37C
SECTION NACA 0012
TIP SHAPE SQUARE
λ
0
A Λ
1.0 71.6
1.33 66.0
2.0 56.3
RESULTANT FORCE COEFFICIENT, C_R
ASPECT RATIO A
α=0
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
.4
.8
1.2
1.6
2.0
2.4

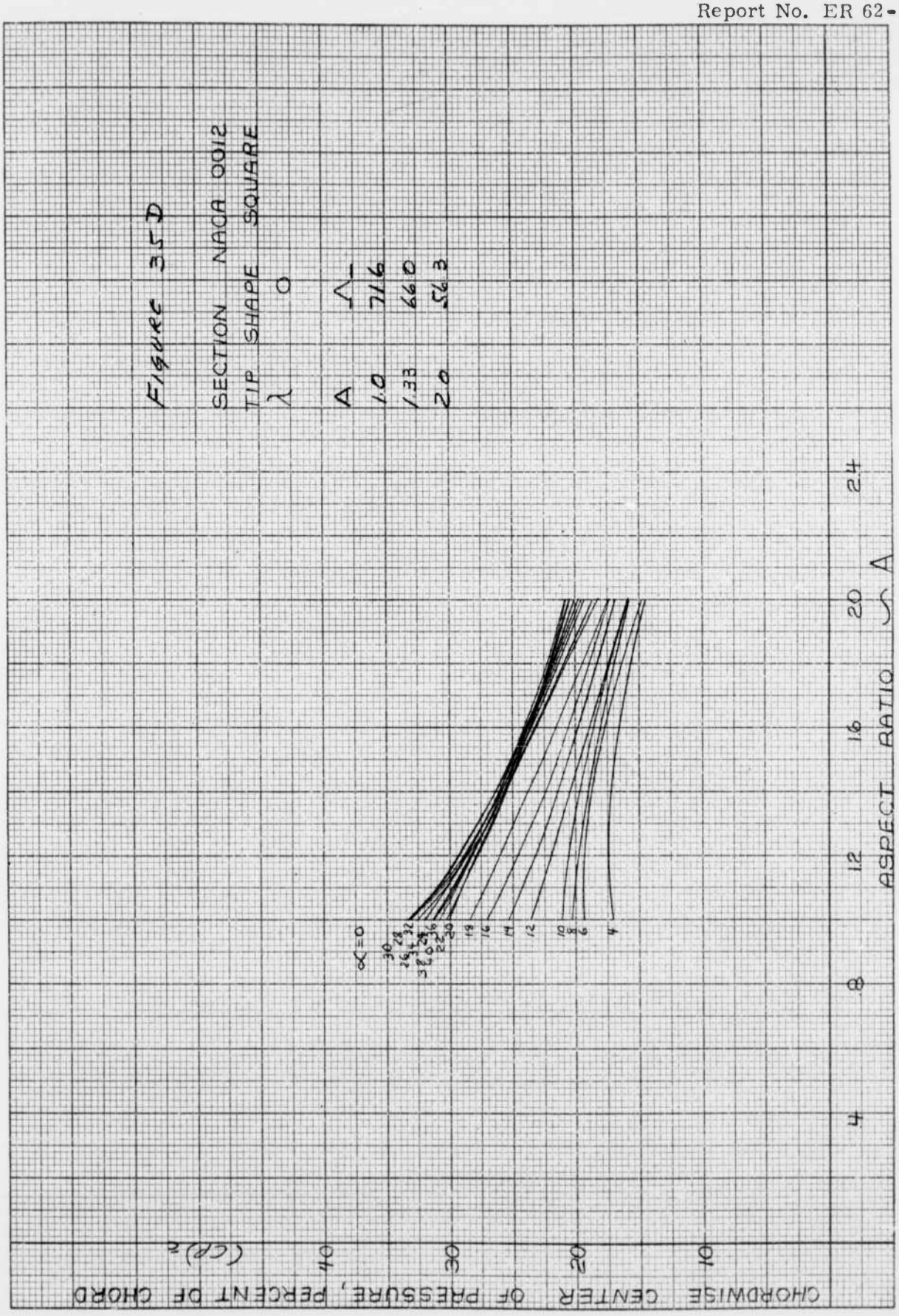


FIGURE 35-D
SECTION NACA 0012
TIP SHAPE SQUARE
λ 0
A Λ
1.0 71.6
1.33 66.0
2.0 54.3
CHORDWISE CENTER OF PRESSURE, PERCENT OF CHORD (cp)c
ASPECT RATIO A
α=0
30
28
26
32
34
36
22
20
18
16
14
12
10
8
6
4

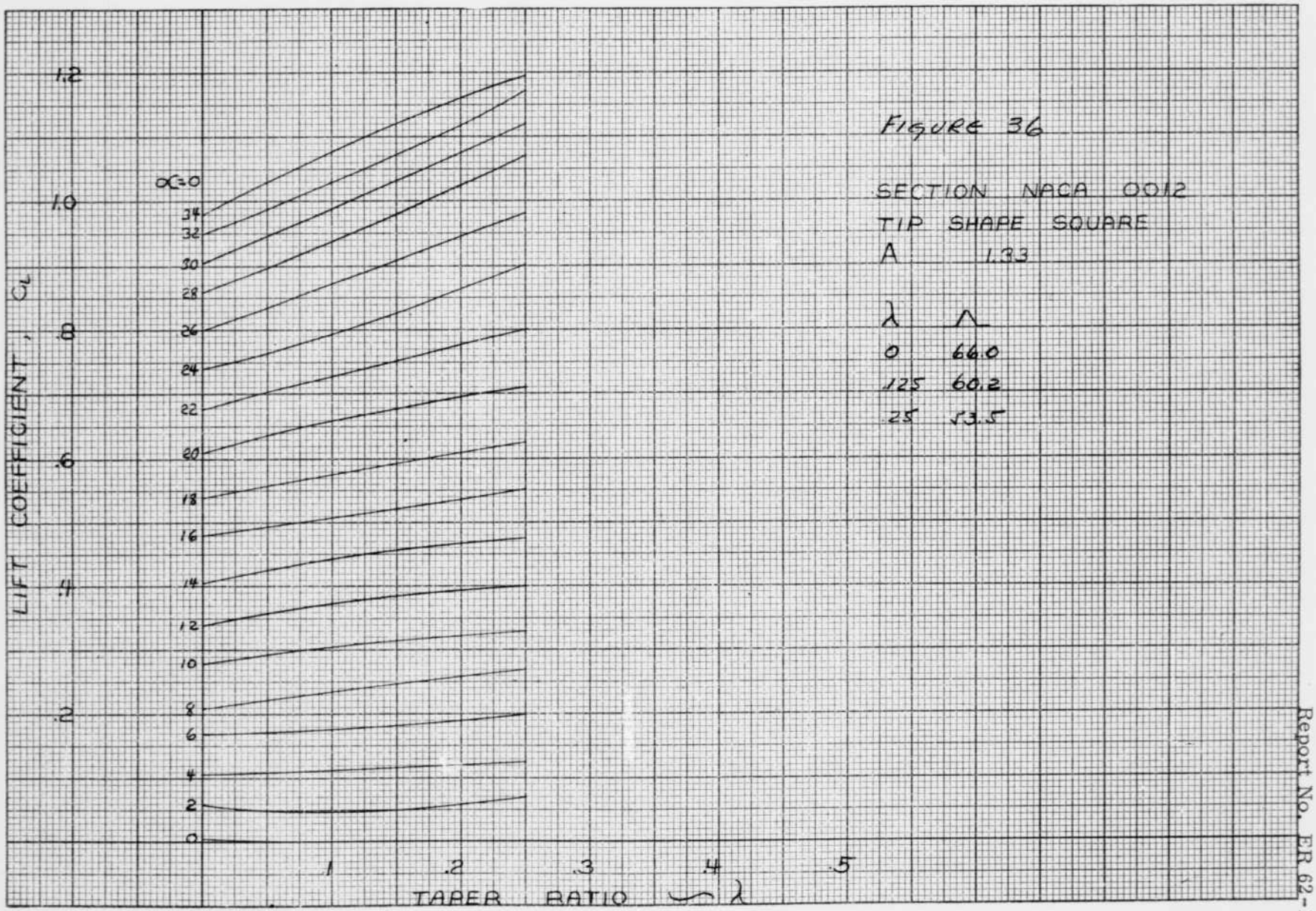


FIGURE 36

SECTION NACA 0012
TIP SHAPE SQUARE
A 1.33

λ	Λ
0	66.0
.125	60.2
.25	53.5

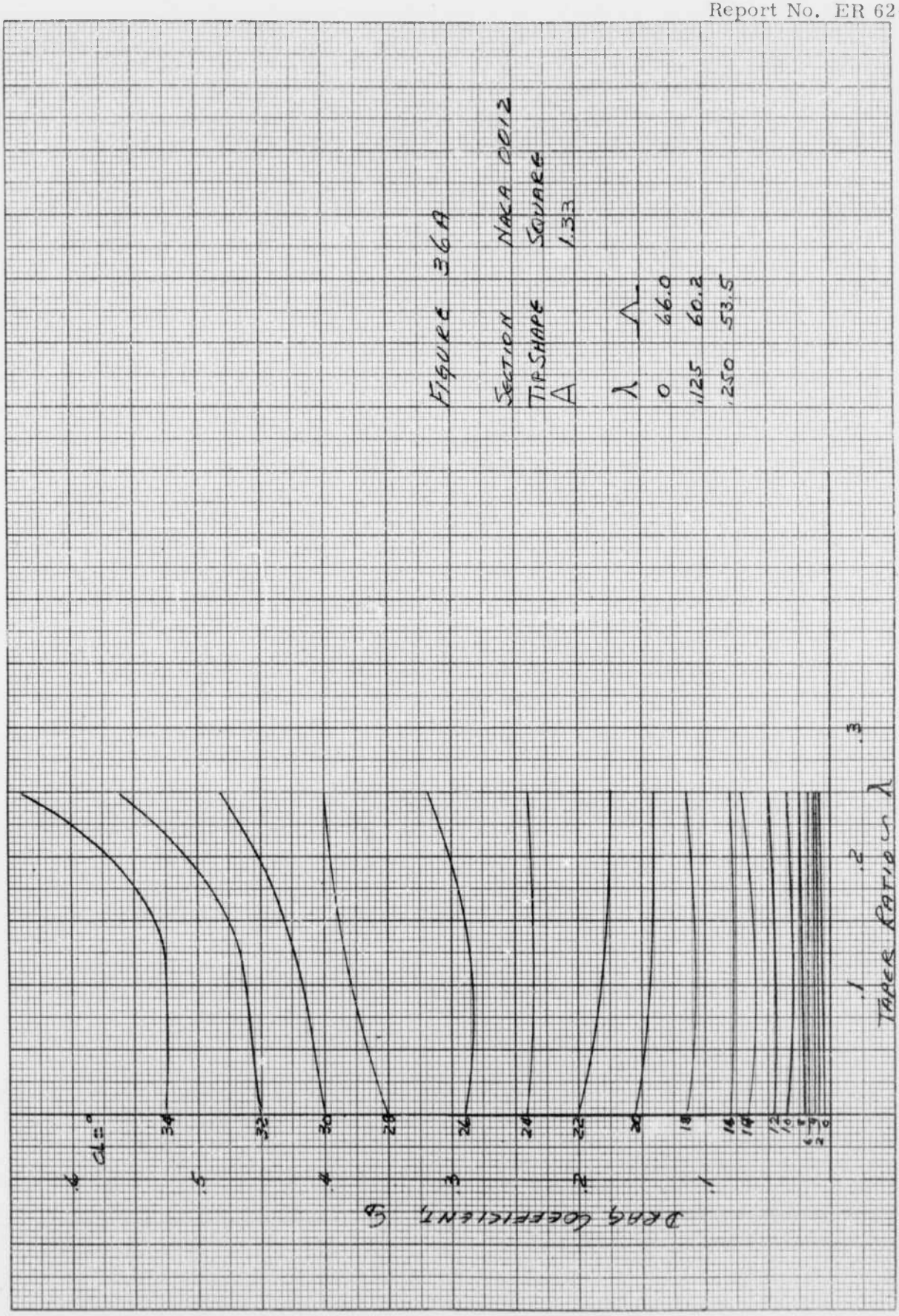


Figure 36A
Section NACA 0012
Tip Shape Square
A 1.33
λ Λ
0 66.0
.125 60.2
.250 53.5
Drag coefficient C_D
Taper Ratio = λ
C_L = 0
.1
.2
.3
1
2
3
4
5
6
18
20
22
24
26
28
30
32
34

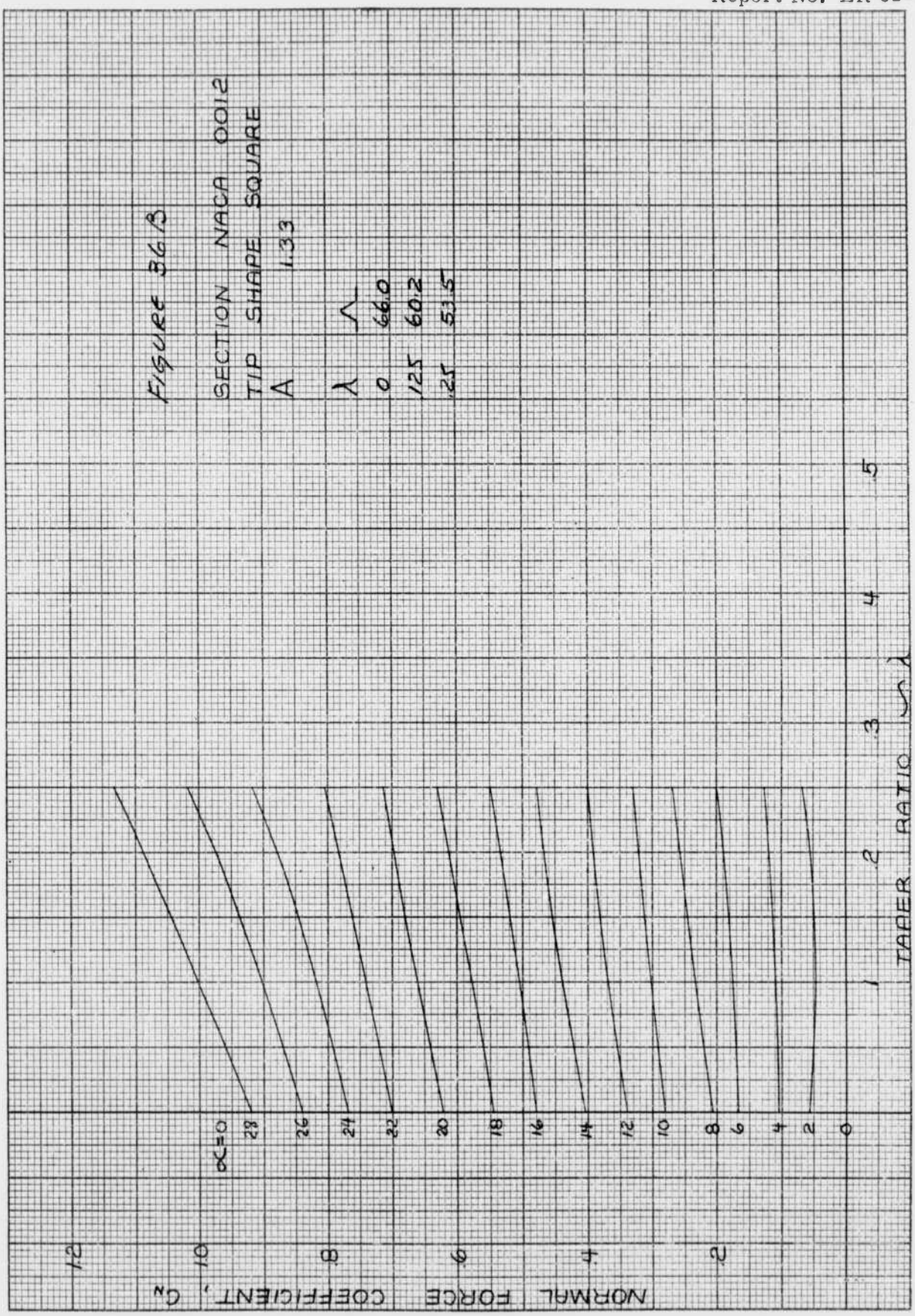


FIGURE 36(3
SECTION NACA 0012
TIP SHAPE SQUARE
A 1.33
λ Λ
0 66.0
.125 60.2
.25 53.5
NORMAL FORCE COEFFICIENT, C_N
TAPER RATIO λ
α=0
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
1.2
1.0
.8
.6
.4
.2
1
2
3
4
5

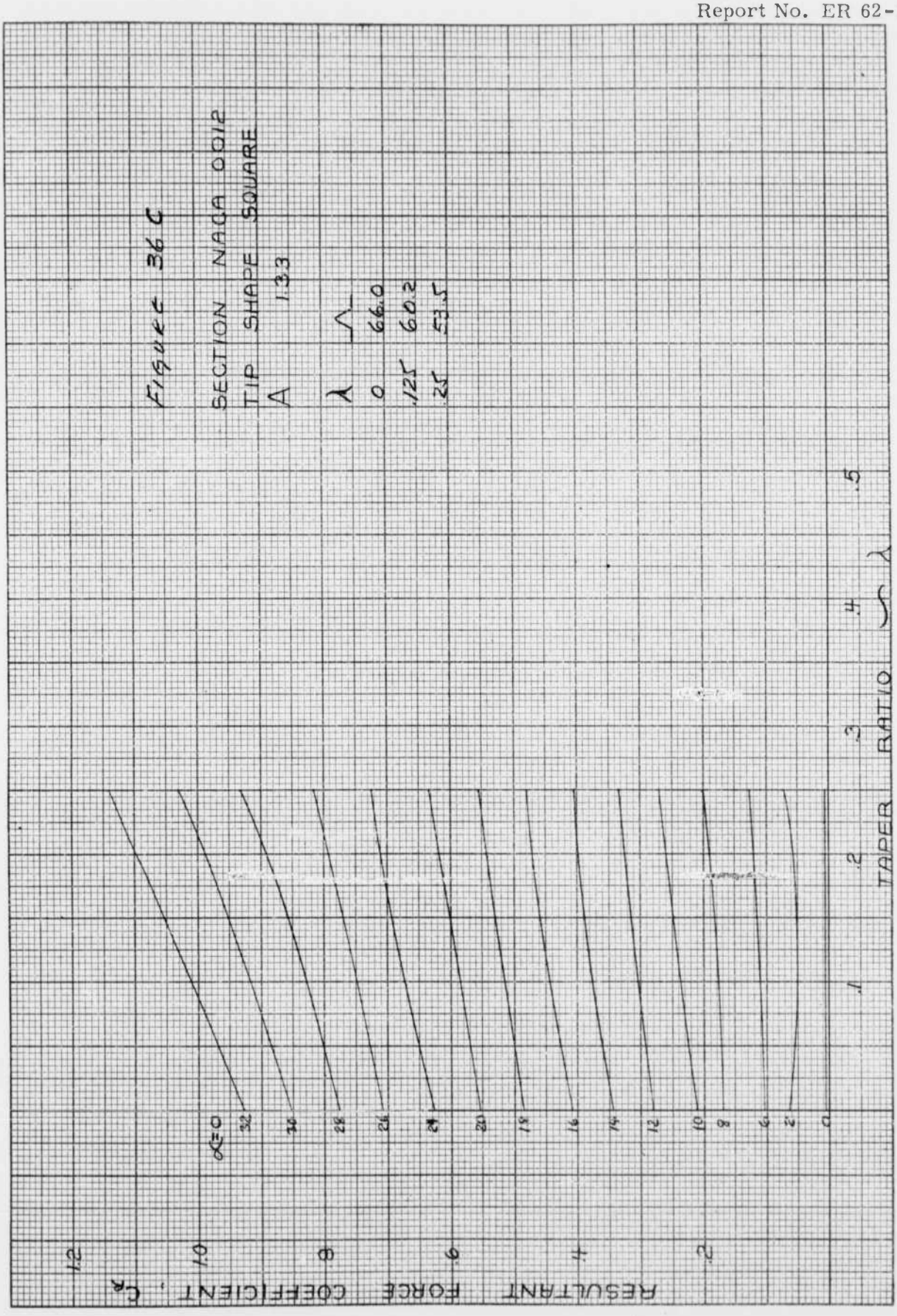


FIGURE 36 C
SECTION NACA 0012
TIP SHAPE SQUARE
A 1.33
λ Λ
0 66.0
.125 60.2
.25 53.5
RESULTANT FORCE COEFFICIENT, C_R
TAPER RATIO λ
1.2
1.0
.8
.6
.4
.2
0
1
.2
.3
.4
.5
α=0
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0

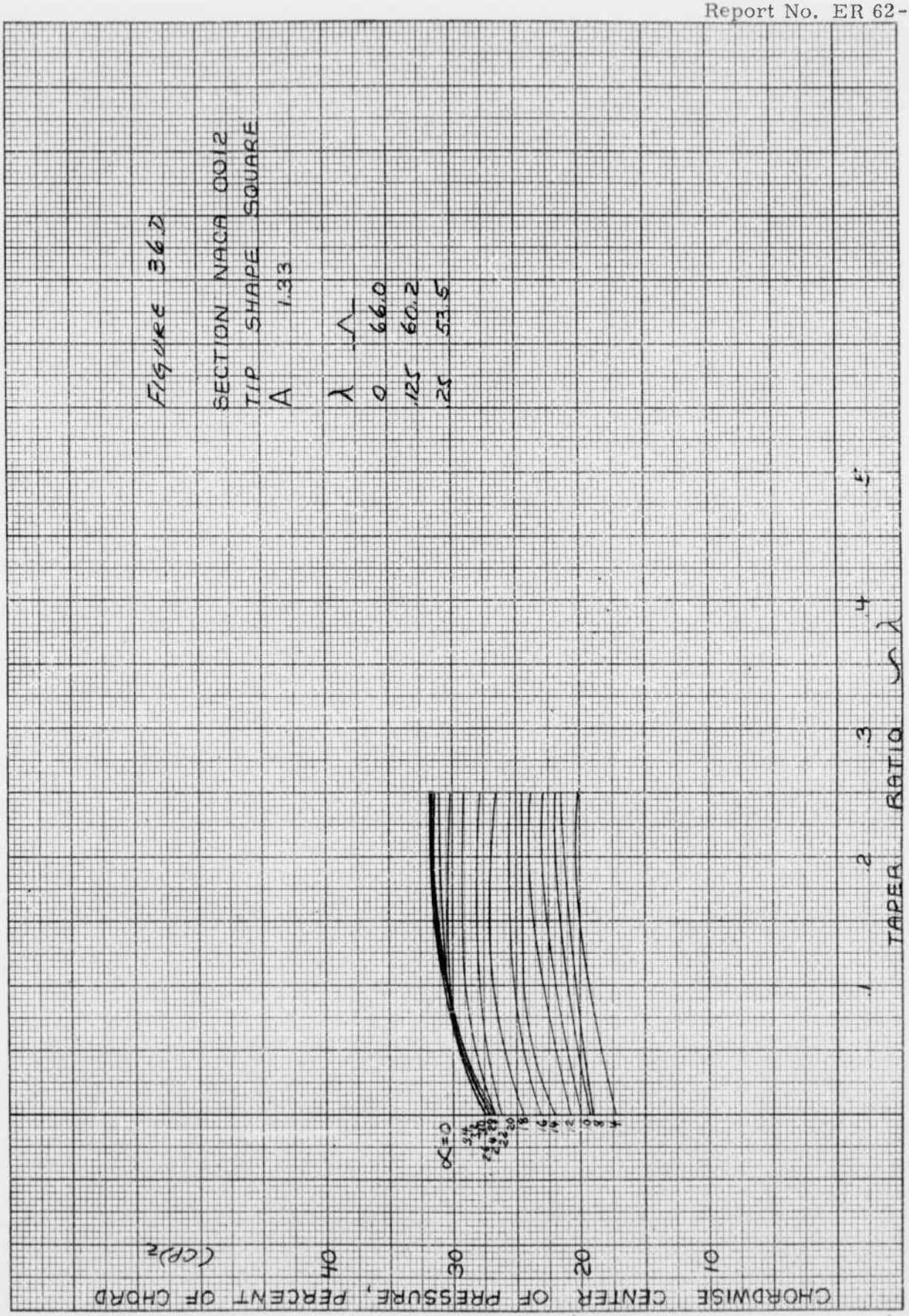


Figure 362
SECTION NACA 0012
TIP SHAPE SQUARE
A 1.33
λ Λ
0 66.0
.125 60.2
.25 53.5
CHORDWISE CENTER OF PRESSURE, PERCENT OF CHORD
(cp)2
10
20
30
40
TAPER RATIO λ
.1
.2
.3
.4
.5
α=0

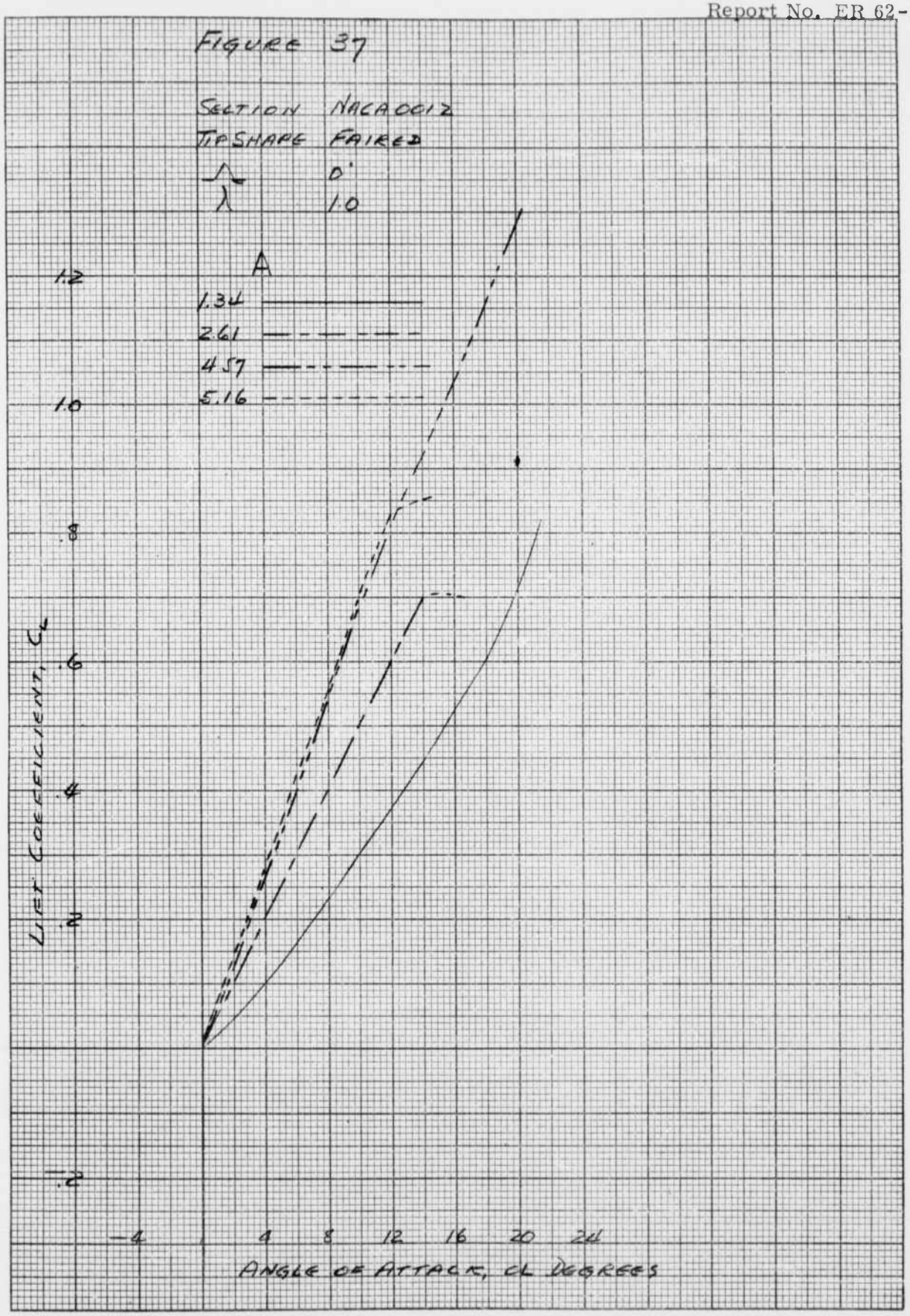


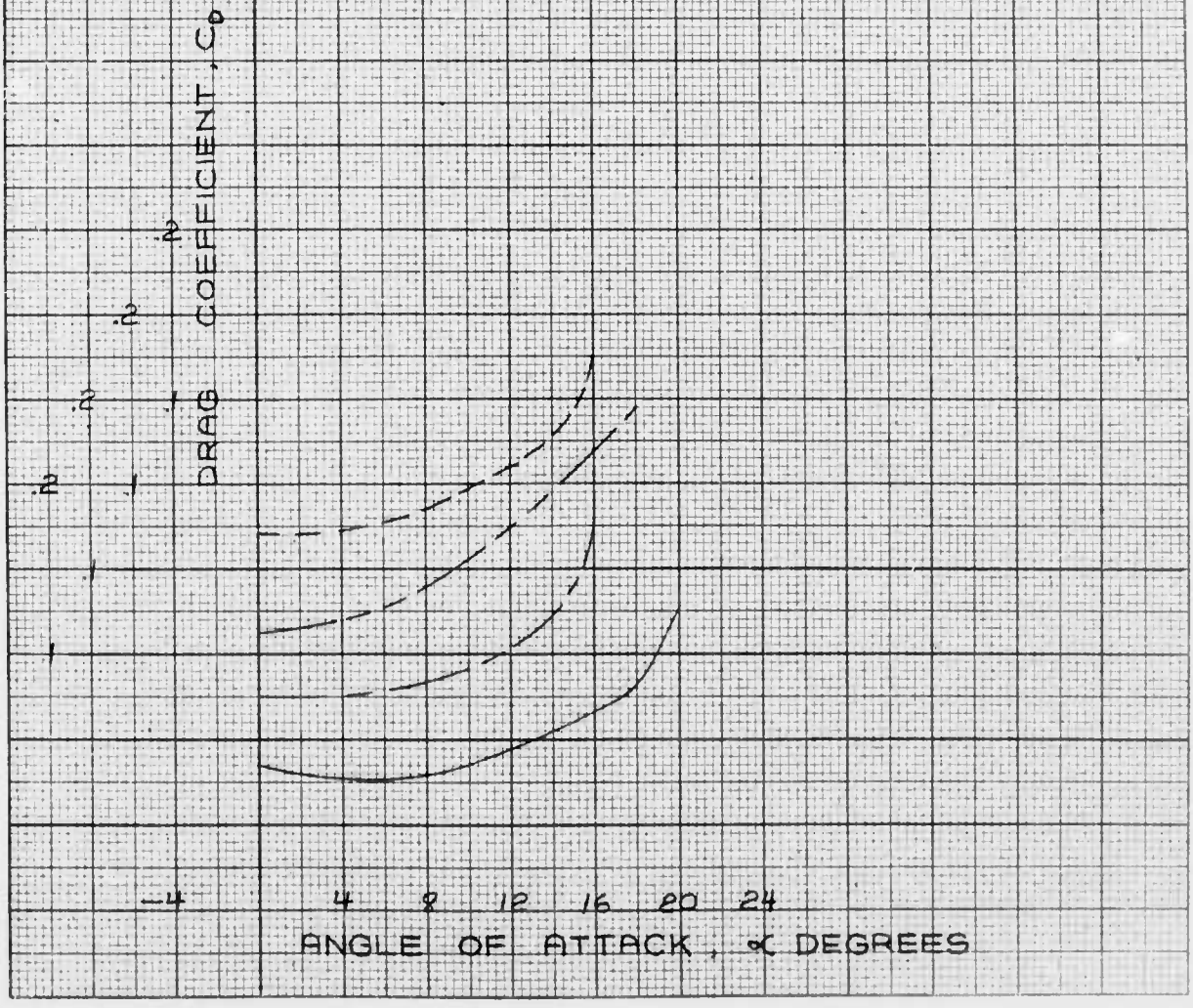
FIGURE 37
SECTION NACA0012
TIP SHAPE FAIRED
Λ 0°
λ 1.0
A
1.34
2.61
4.57
5.16
1.2
1.0
.8
.6
.4
.2
LIFT COEFFICIENT, C_L
-4
4
8
12
16
20
24
ANGLE OF ATTACK, α_L DEGREES

FIGURE 37A

SECTION NACA 0012
TIP SHAPE FAIRED

Λ	λ
0°	1.0

A
1.34
2.61
4.57
5.16



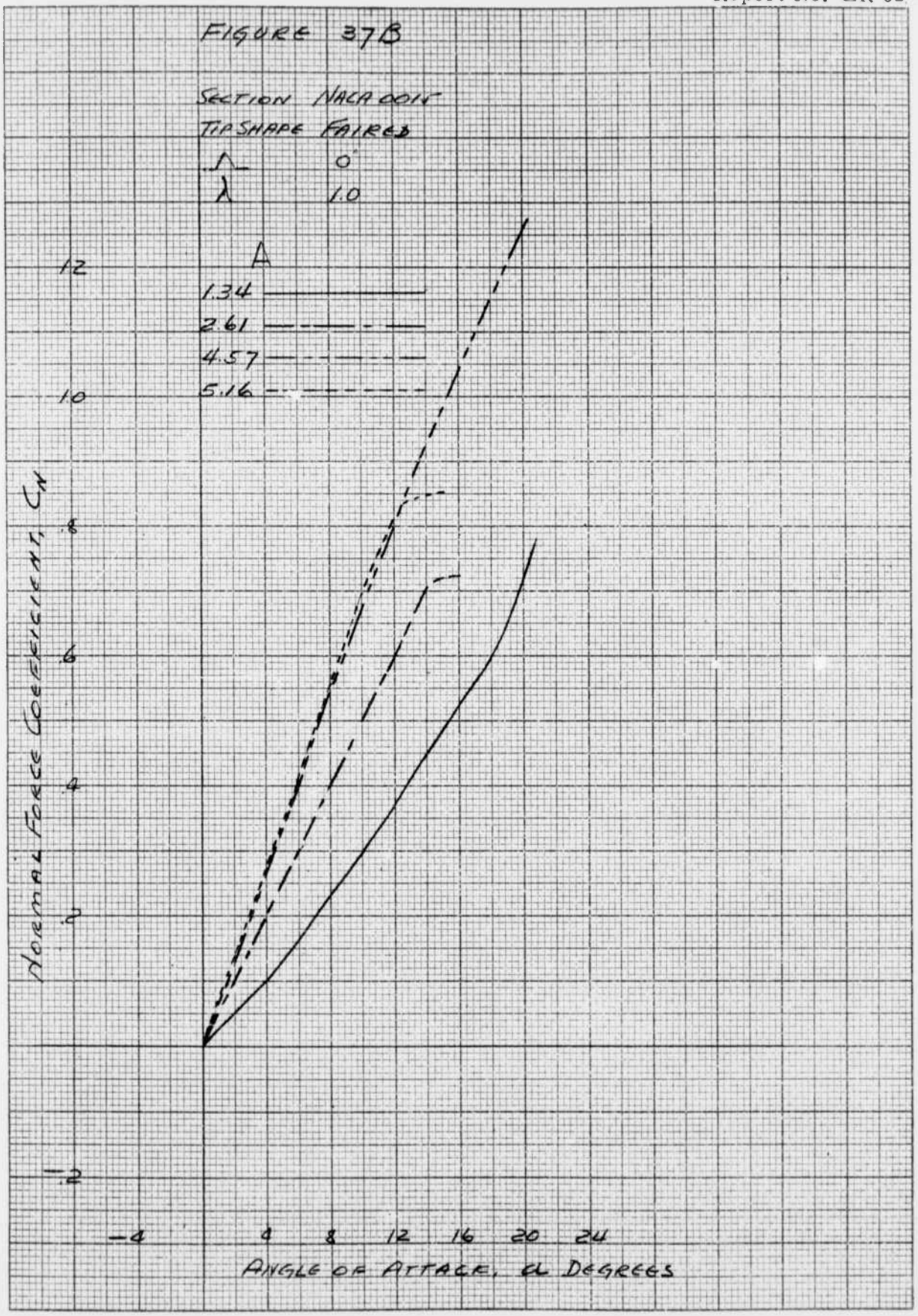


FIGURE 37B
SECTION NACA 0014
TIP SHAPE FAIRED
Λ 0°
λ 1.0
A
1.34
2.61
4.57
5.16
12
10
8
6
4
2
0
-2
-4
4
8
12
16
20
24
NORMAL FORCE COEFFICIENT, C_N
ANGLE OF ATTACK, α, DEGREES

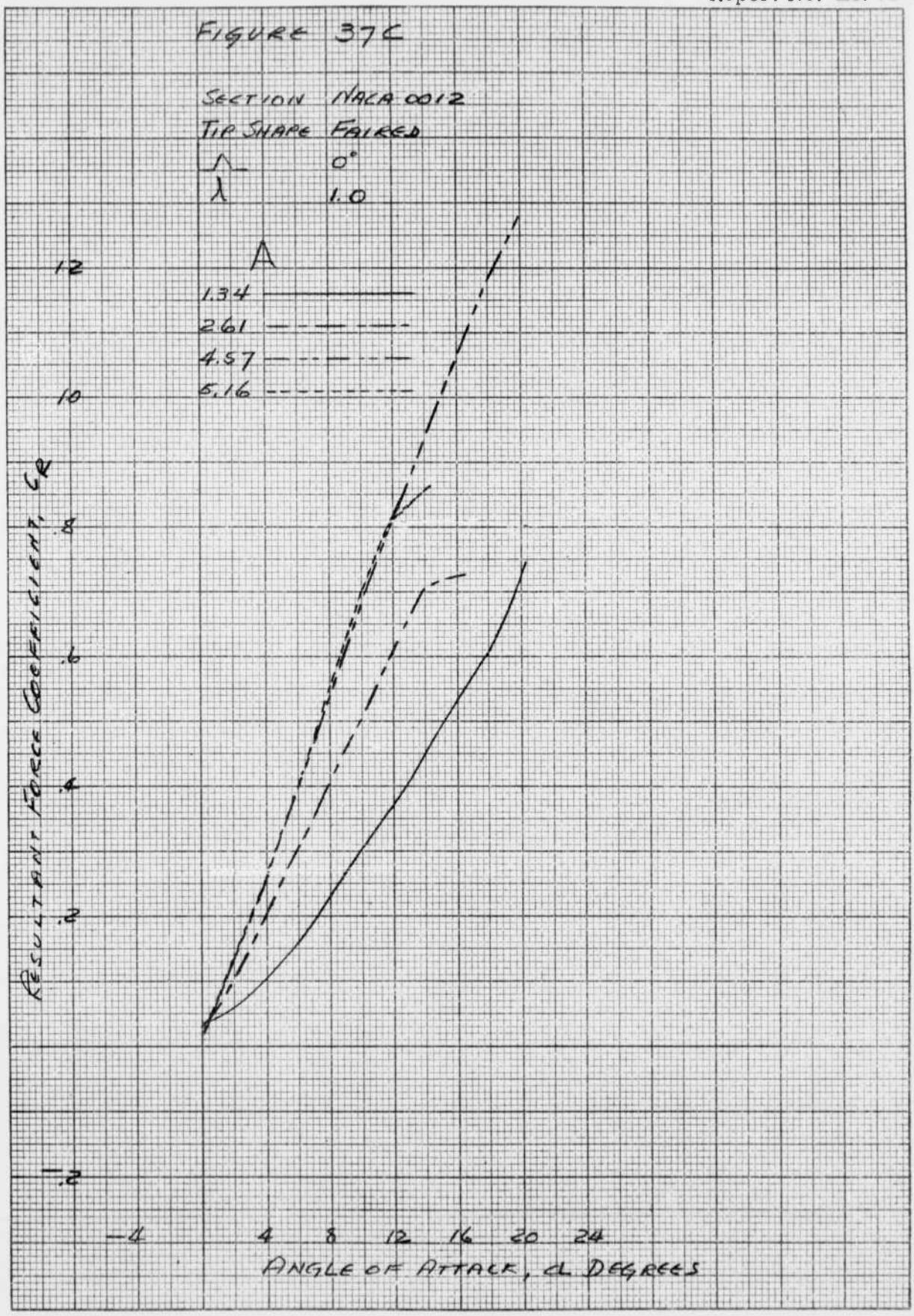


FIGURE 37C
SECTION NACA 0012
TIP SHAPE FAIRED
Λ 0°
λ 1.0
A
1.34
2.61
4.57
5.16
12
10
8
6
4
2
-.2
-4
4
8
12
16
20
24
RESULTANT FORCE COEFFICIENT, CR
ANGLE OF ATTACK, α, DEGREES

FIGURE 37D

SECTION	NACA 0012
TIP SHAPE	FAIRED
Λ	0°
λ	1.0

A	
1.34	———
2.61	— — — —
4.57	— - — - —
5.16	- - - - - -

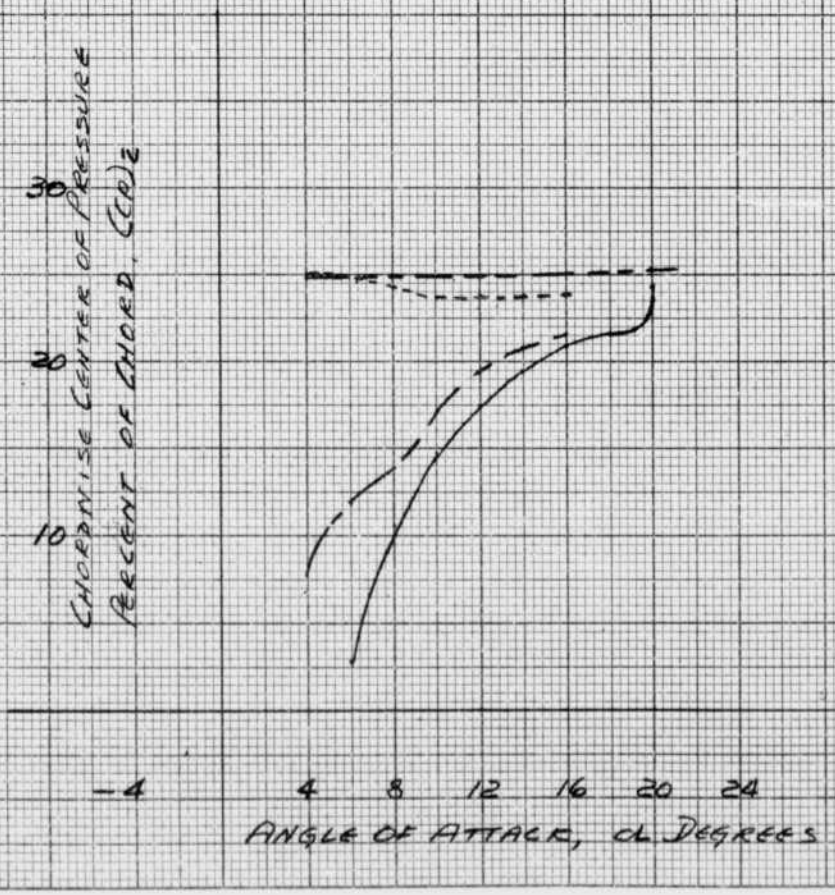


FIGURE 38

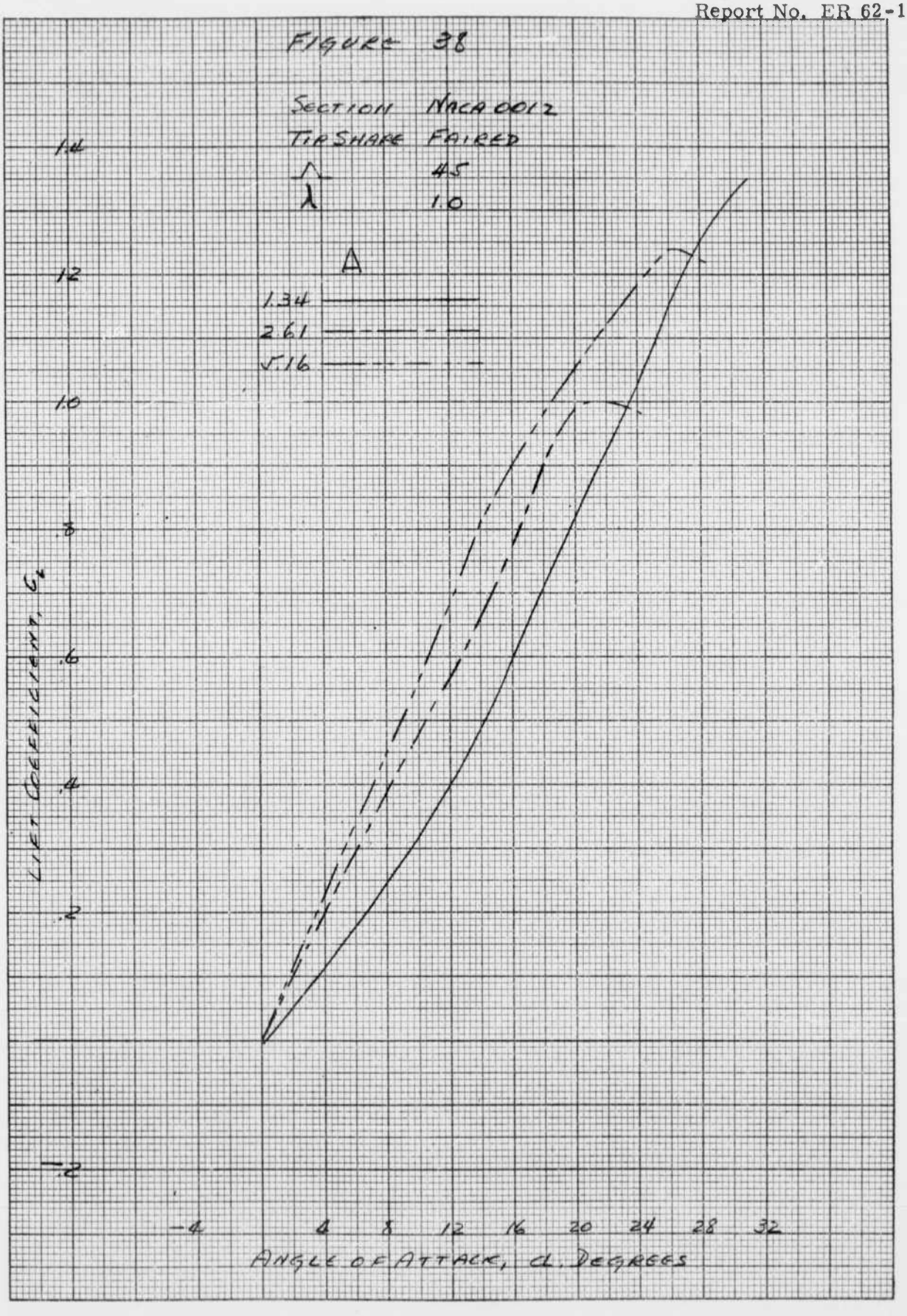
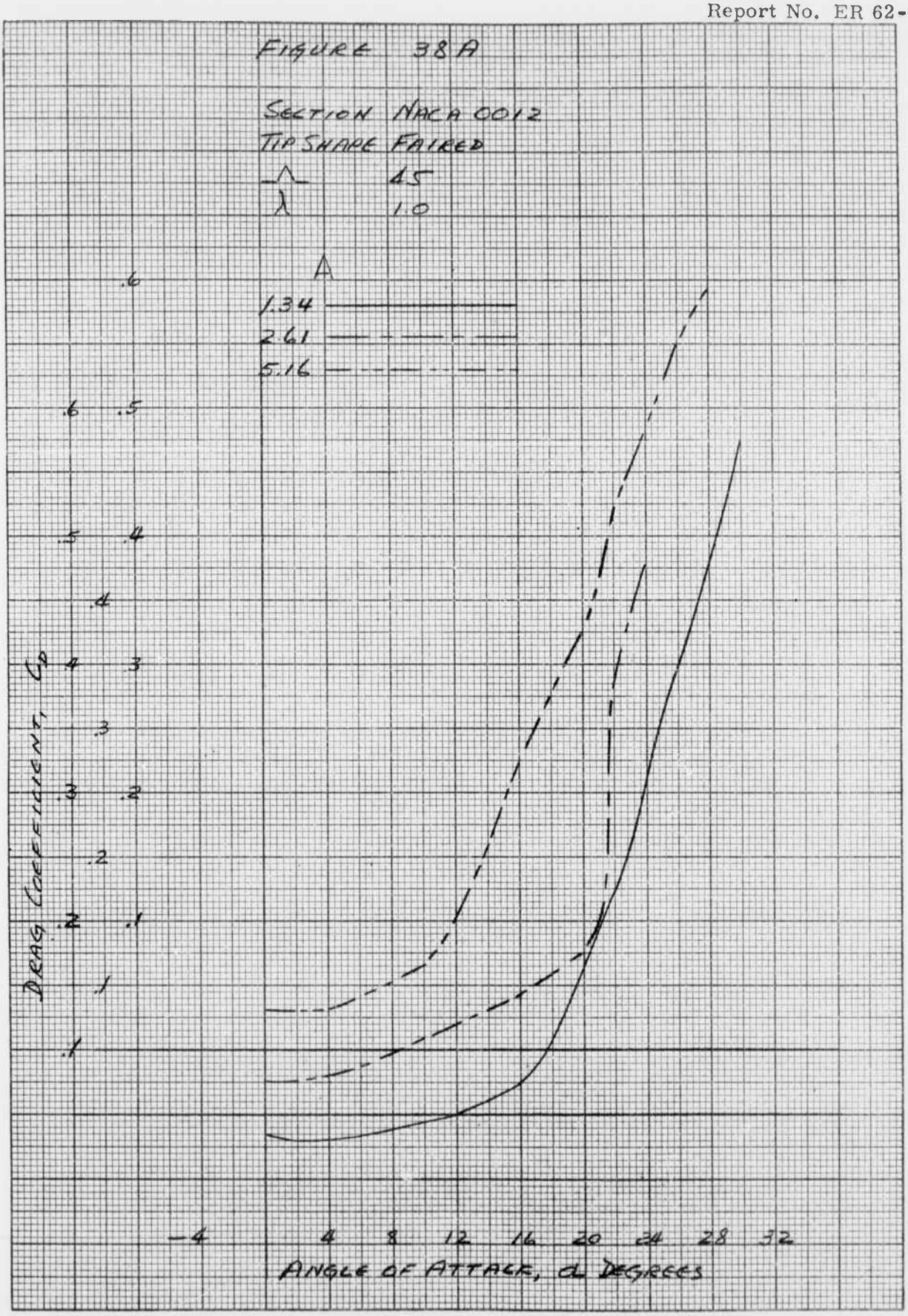

SECTION NACA 0012
TIP SHAPE FAIRED
Λ 45
λ 1.0
A
1.34
2.61
5.16
LIFT COEFFICIENT, C_L
1.4
1.2
1.0
.8
.6
.4
.2
-.2
-4
4
8
12
16
20
24
28
32
ANGLE OF ATTACK, α, DEGREES

FIGURE 38A

SECTION NACA 0012
TIP SHAPE FAIRED
Λ 45
λ 1.0

A
1.34
2.61
5.16



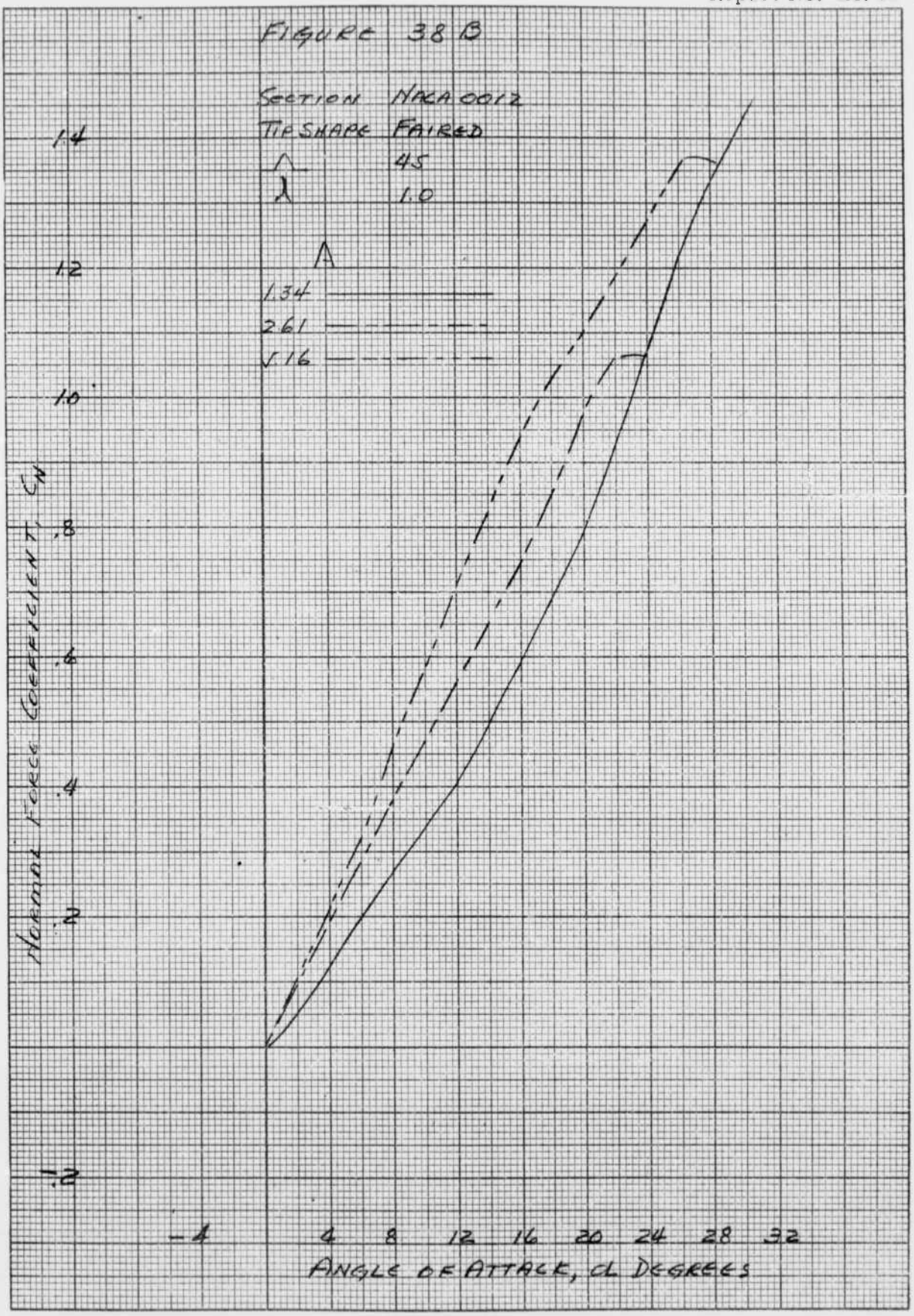


FIGURE 38 B
SECTION NACA 0012
TIP SHAPE FAIRED
Λ 45
λ 1.0
A
1.34
2.61
√16
1.4
1.2
1.0
.8
.6
.4
.2
-.2
NORMAL FORCE COEFFICIENT, CN
-4
4
8
12
16
20
24
28
32
ANGLE OF ATTACK, α, DEGREES

FIGURE 38C

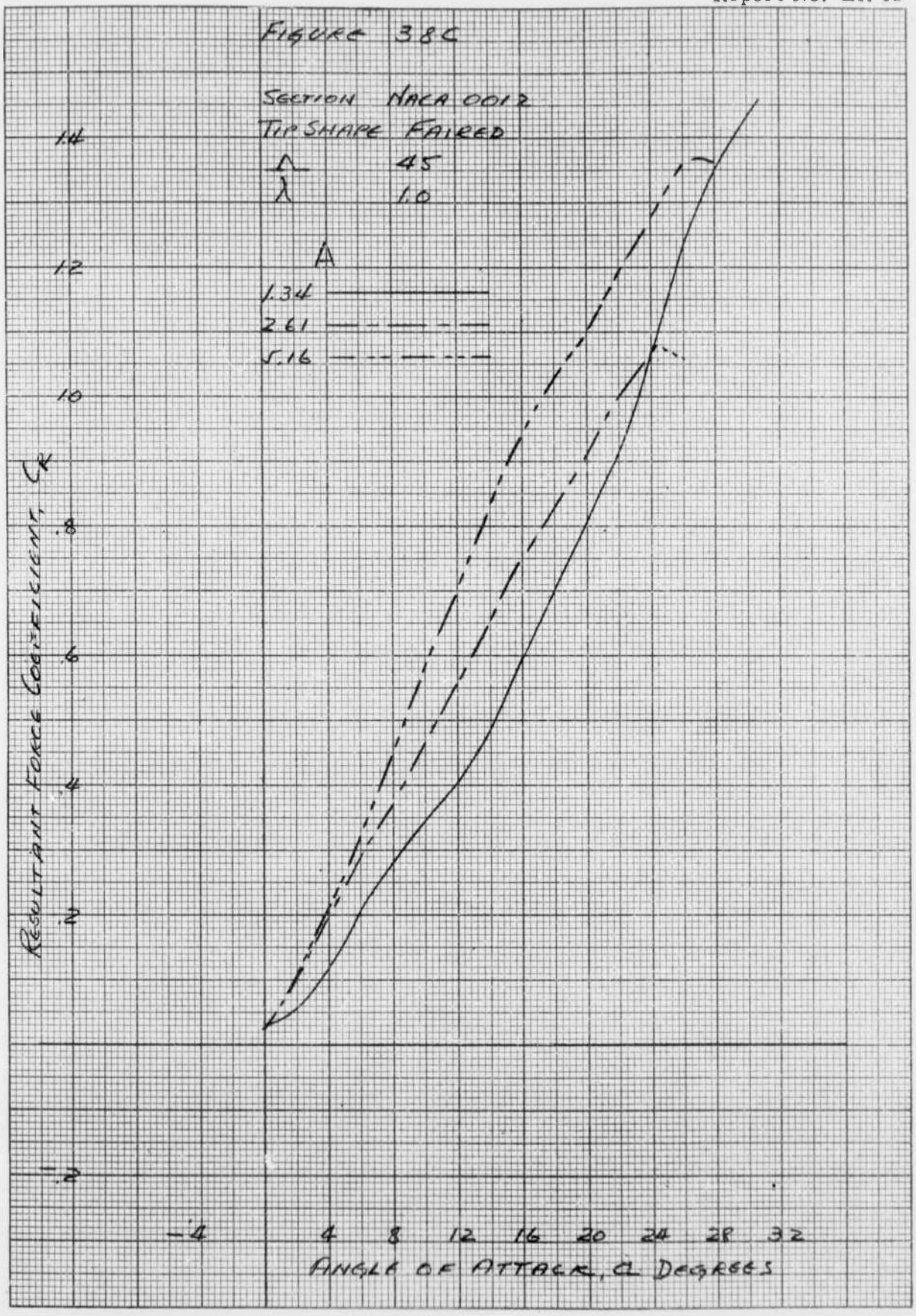
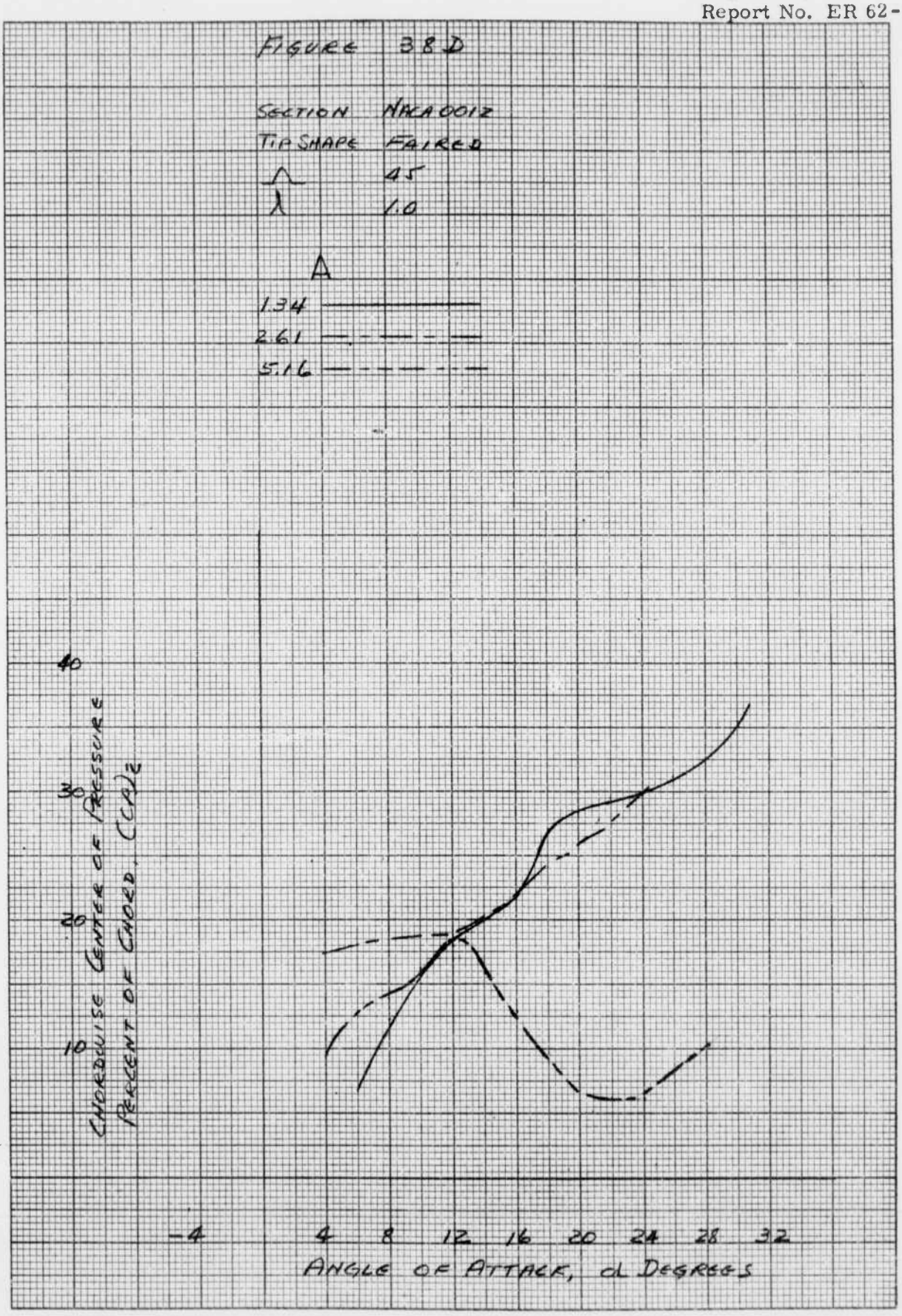

SECTION NACA 0012
TIP SHAPE FAIRED
Λ 45
λ 1.0
A
1.34
2.61
5.16
1.4
1.2
1.0
.8
.6
.4
.2
-.2
-4
4
8
12
16
20
24
28
32
RESULTANT FORCE COEFFICIENT, C_R
ANGLE OF ATTACK, α DEGREES

FIGURE 38D

SECTION NACA0012
TIP SHAPE FAIRED
Λ 45
λ 1.0

A
1.34 ——————
2.61 — . — — . — —
5.16 — — — — — — —



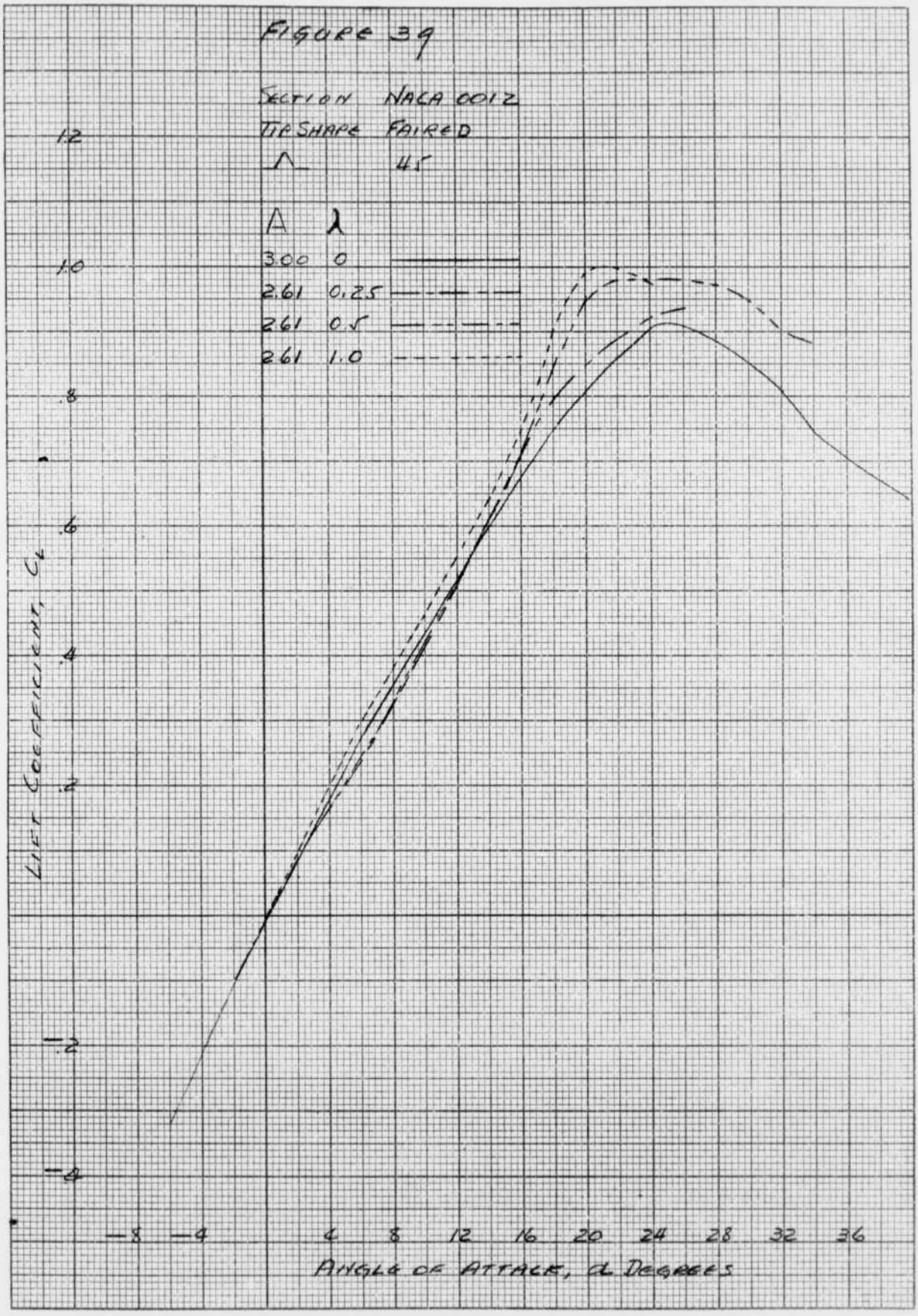
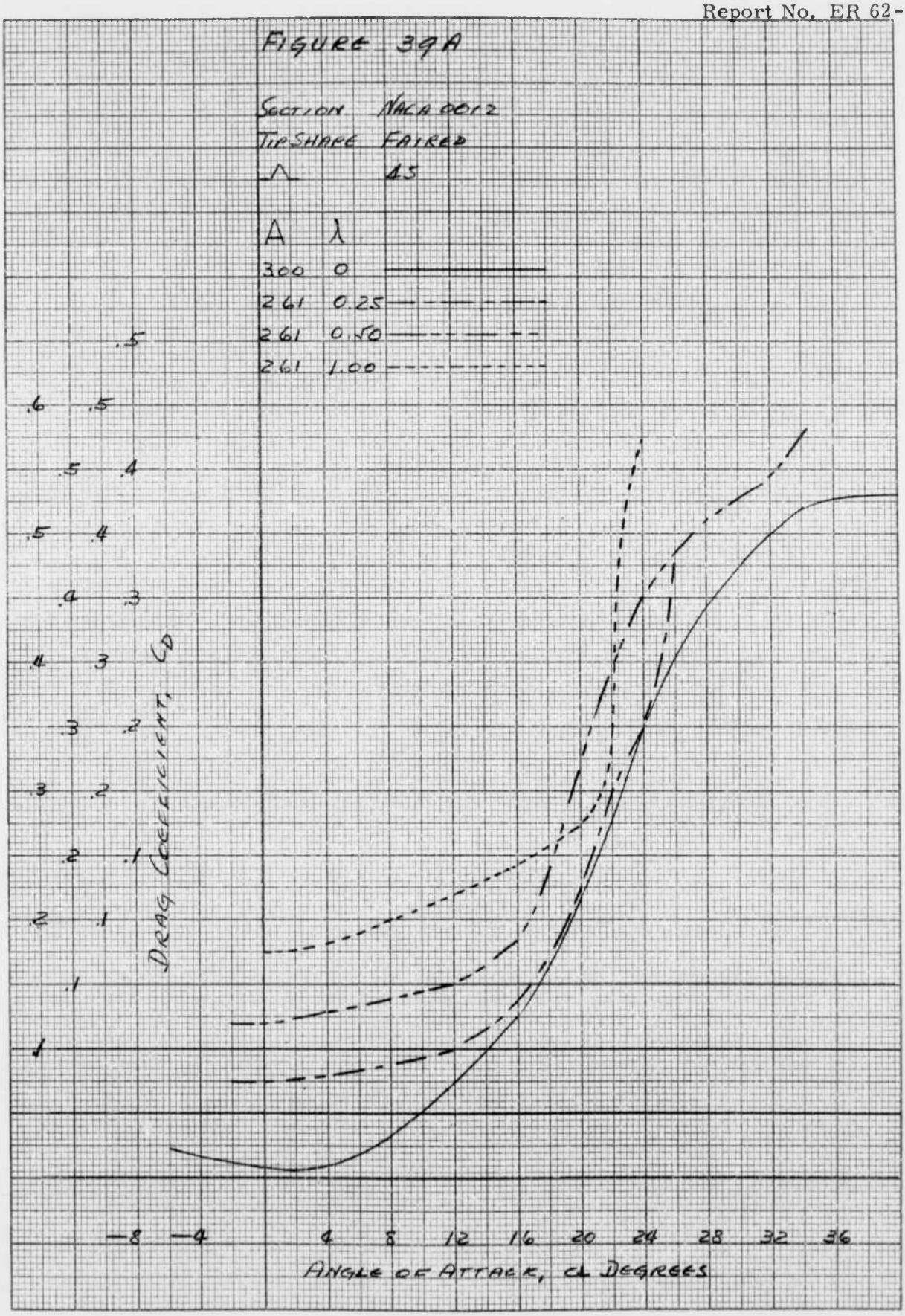


FIGURE 39
SECTION NACA 0012
TIP SHAPE FAIRED
Λ 45
A λ
3.00 0
2.61 0.25
2.61 0.5
2.61 1.0
LIFT COEFFICIENT, C_L
1.2
1.0
.8
.6
.4
.2
-.2
-.4
-8 -4 4 8 12 16 20 24 28 32 36
ANGLE OF ATTACK, α, DEGREES

FIGURE 39A


SECTION NACA 0012
TIP SHAPE FAIRED
Λ 45
A λ
3.00 0
2.61 0.25
2.61 0.50
2.61 1.00
DRAG COEFFICIENT, C_D
.6 .5 .4 .3 .2 .1
.5 .4 .3 .2 .1
.4 .3 .2 .1
.3 .2 .1
.2 .1
.1
-8 -4 4 8 12 16 20 24 28 32 36
ANGLE OF ATTACK, α_L DEGREES

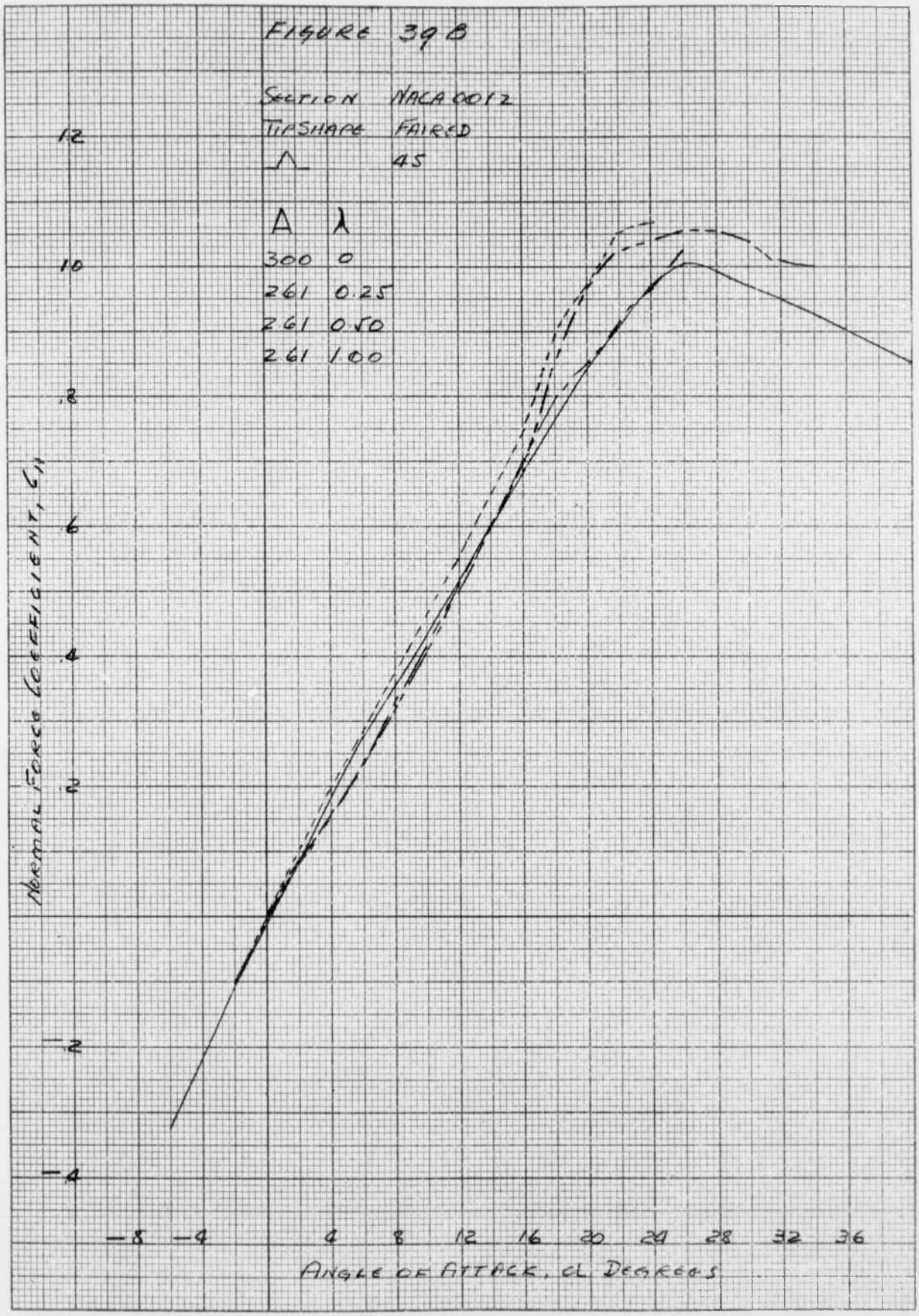


FIGURE 39B
SECTION NACA 0012
TIP SHAPE FAIRED
Λ 45
A λ
3.00 0
2.61 0.25
2.61 0.50
2.61 1.00
NORMAL FORCE COEFFICIENT, C_{N_A}
12
10
8
6
4
2
-2
-4
-8 -4 4 8 12 16 20 24 28 32 36
ANGLE OF ATTACK, α, DEGREES

FIGURE 39C

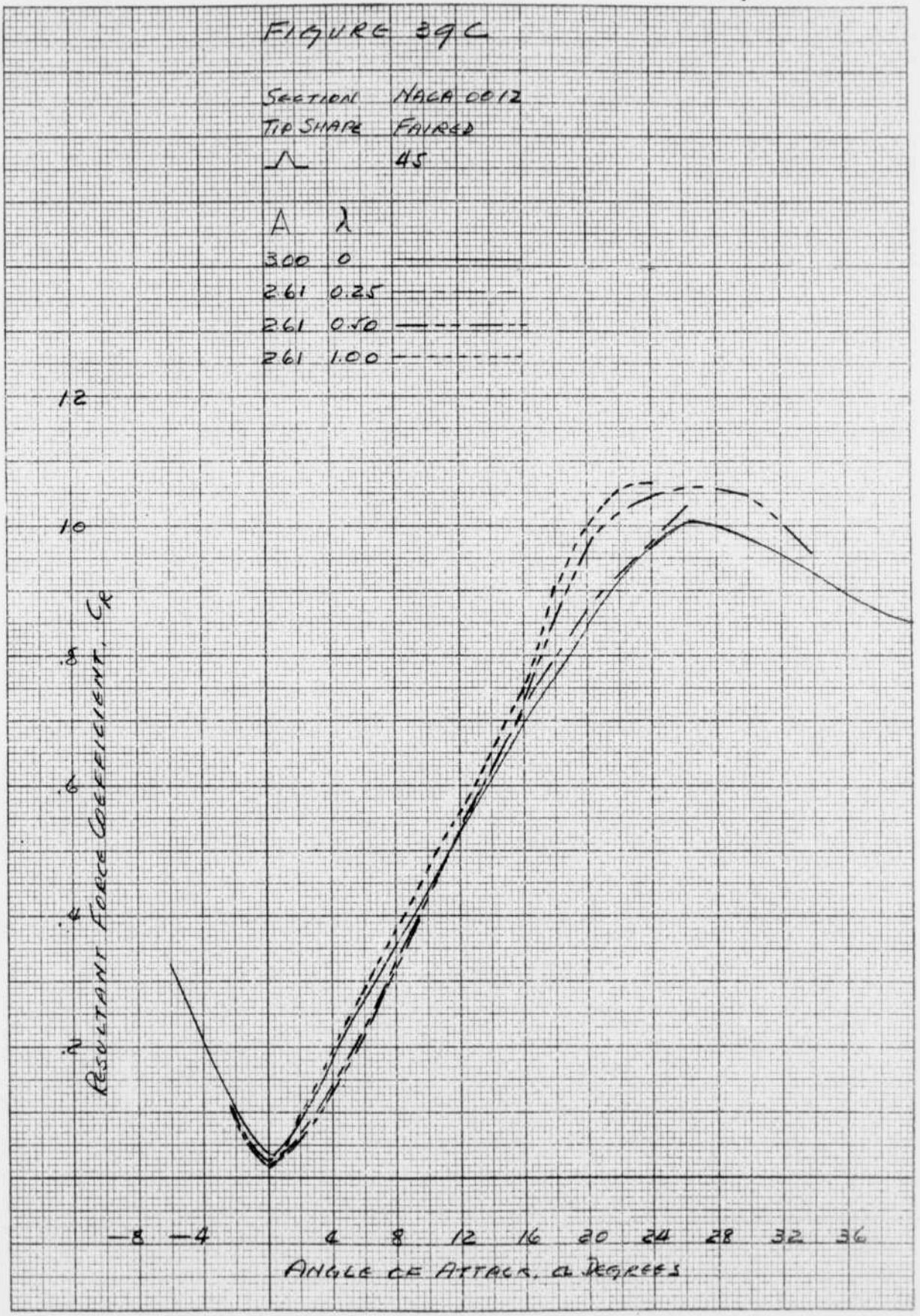

SECTION NACA 0012
TIP SHAPE FAIRED
Λ 45
A λ
3.00 0
2.61 0.25
2.61 0.50
2.61 1.00
1.2
1.0
.8
.6
.4
RESULTANT FORCE COEFFICIENT, C_R
-8 -4 4 8 12 16 20 24 28 32 36
ANGLE OF ATTACK, α DEGREES

FIGURE 39 D

SECTION NACA 0012
TIP SHAPE FAIRED
Λ 45°

A	λ	
3.00	0	———
2.61	0.25	– – –
2.61	0.50	— – —
2.61	1.00	– – –

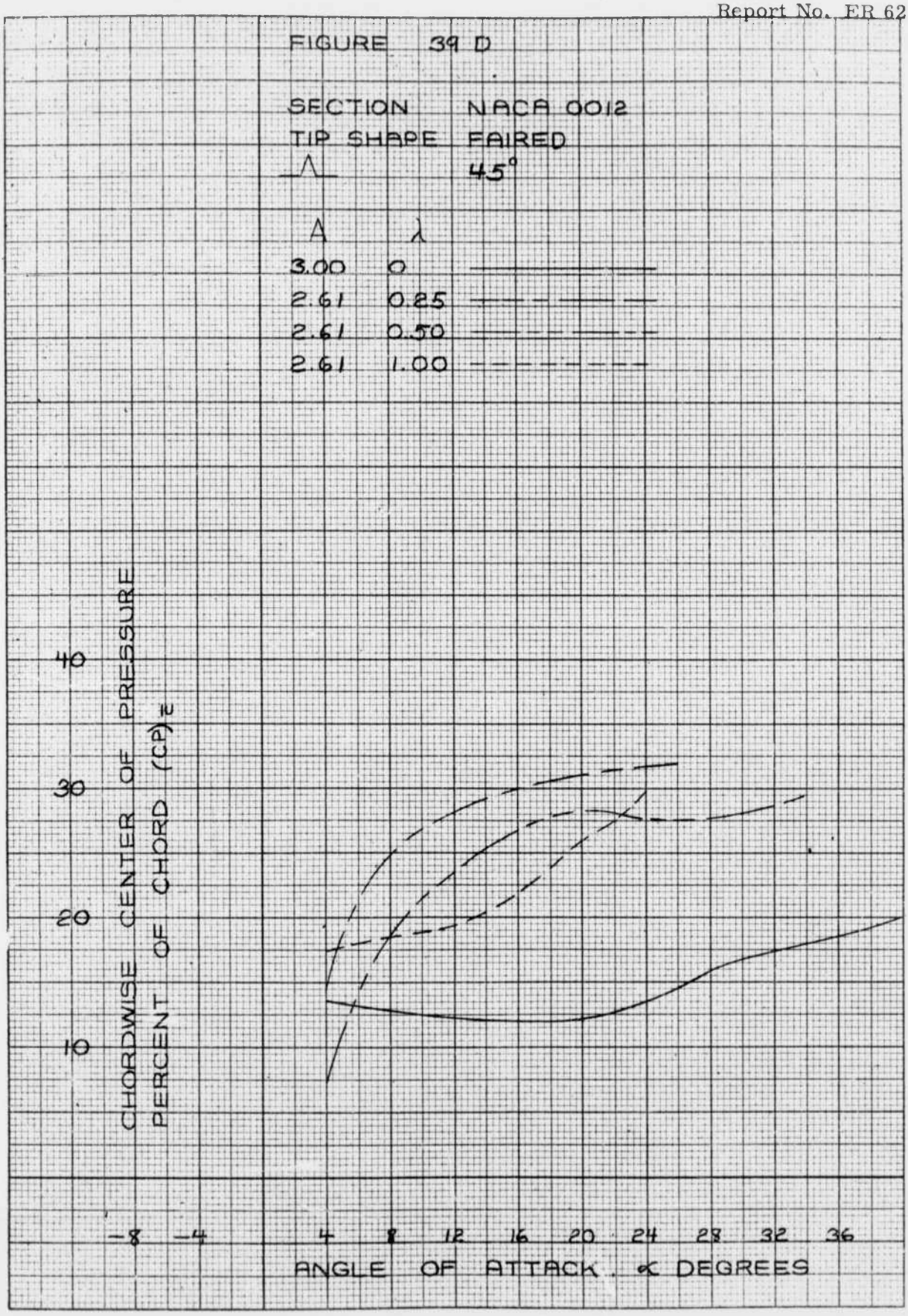
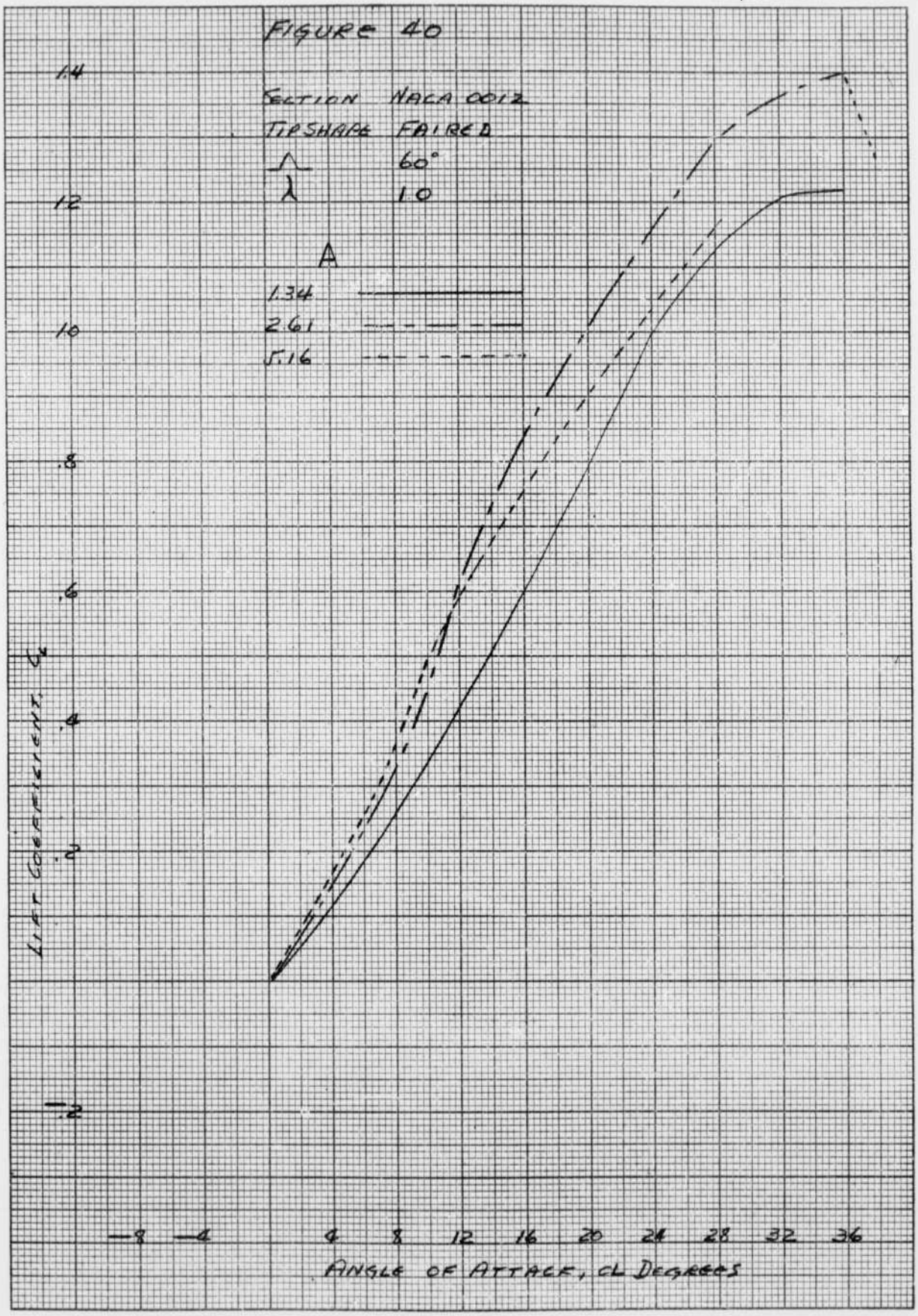


FIGURE 40


SECTION NACA 0012
TIP SHAPE FAIRED
Λ 60°
λ 1.0
A
1.34
2.61
5.16
1.4
1.2
1.0
.8
.6
.4
.2
-.2
LIFT COEFFICIENT, C_L
-8
-4
0
4
8
12
16
20
24
28
32
36
ANGLE OF ATTACK, α DEGREES

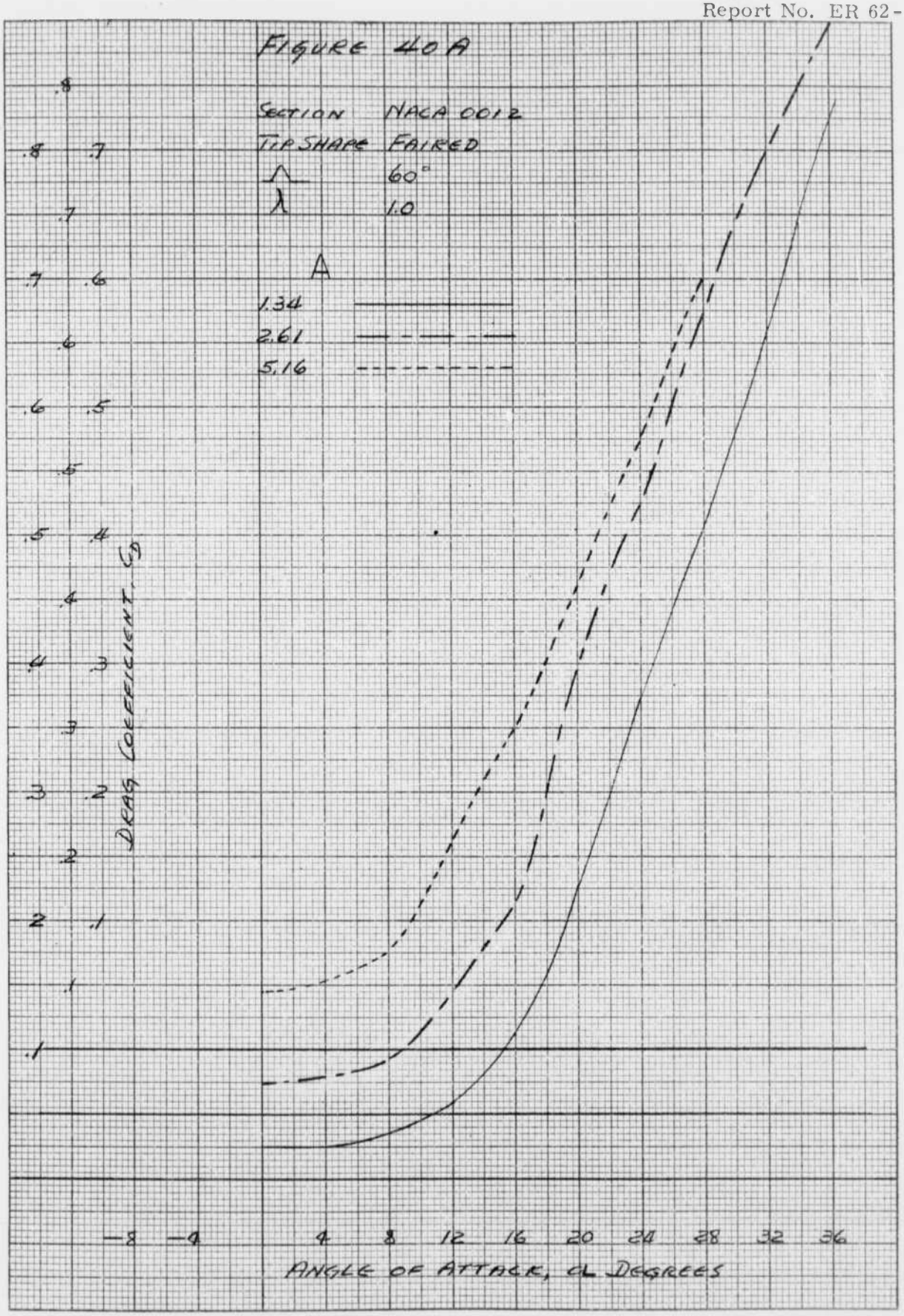


FIGURE 40A
SECTION NACA 0012
TIP SHAPE FAIRED
Λ 60°
λ 1.0
A
1.34
2.61
5.16
DRAG COEFFICIENT, C_D
ANGLE OF ATTACK, α, DEGREES
-8
-4
4
8
12
16
20
24
28
32
36

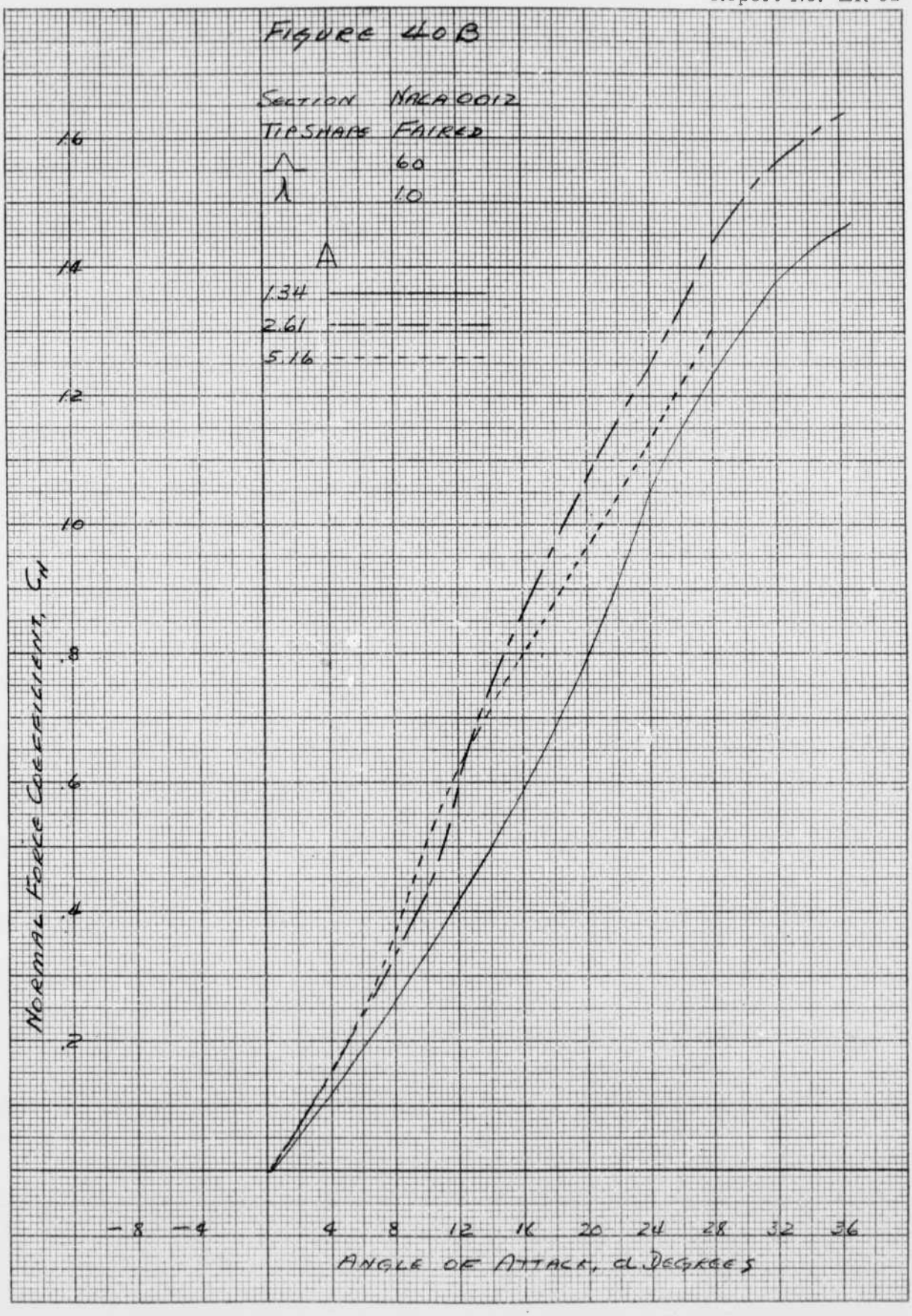


FIGURE 40B
SECTION NACA 0012
TIP SHAPE FAIRED
Λ 60
λ 1.0
A
1.34
2.61
5.16
NORMAL FORCE COEFFICIENT, C_N
1.6
1.4
1.2
1.0
.8
.6
.4
.2
-8
-4
4
8
12
16
20
24
28
32
36
ANGLE OF ATTACK, α, DEGREES

Figure 40 C

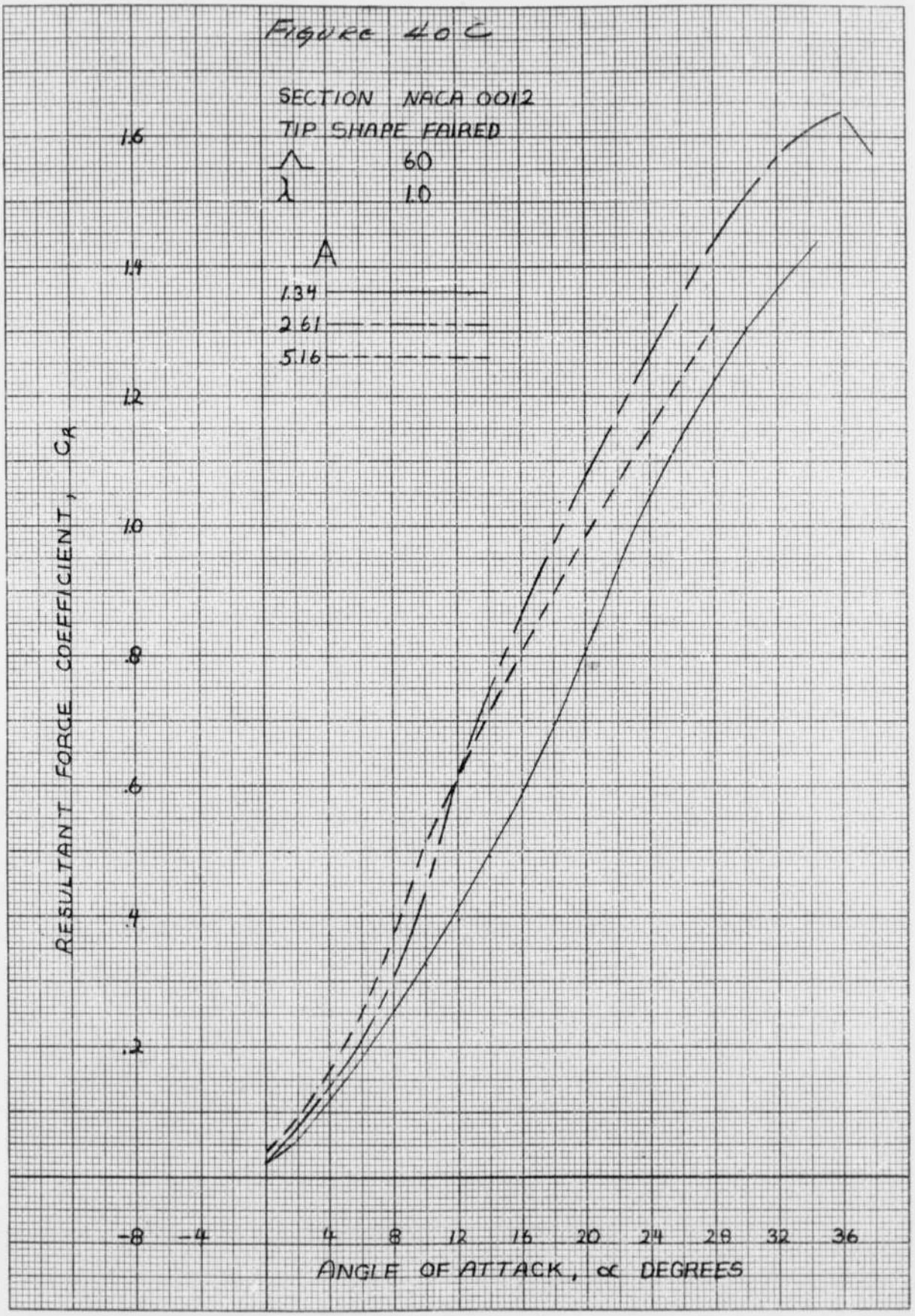
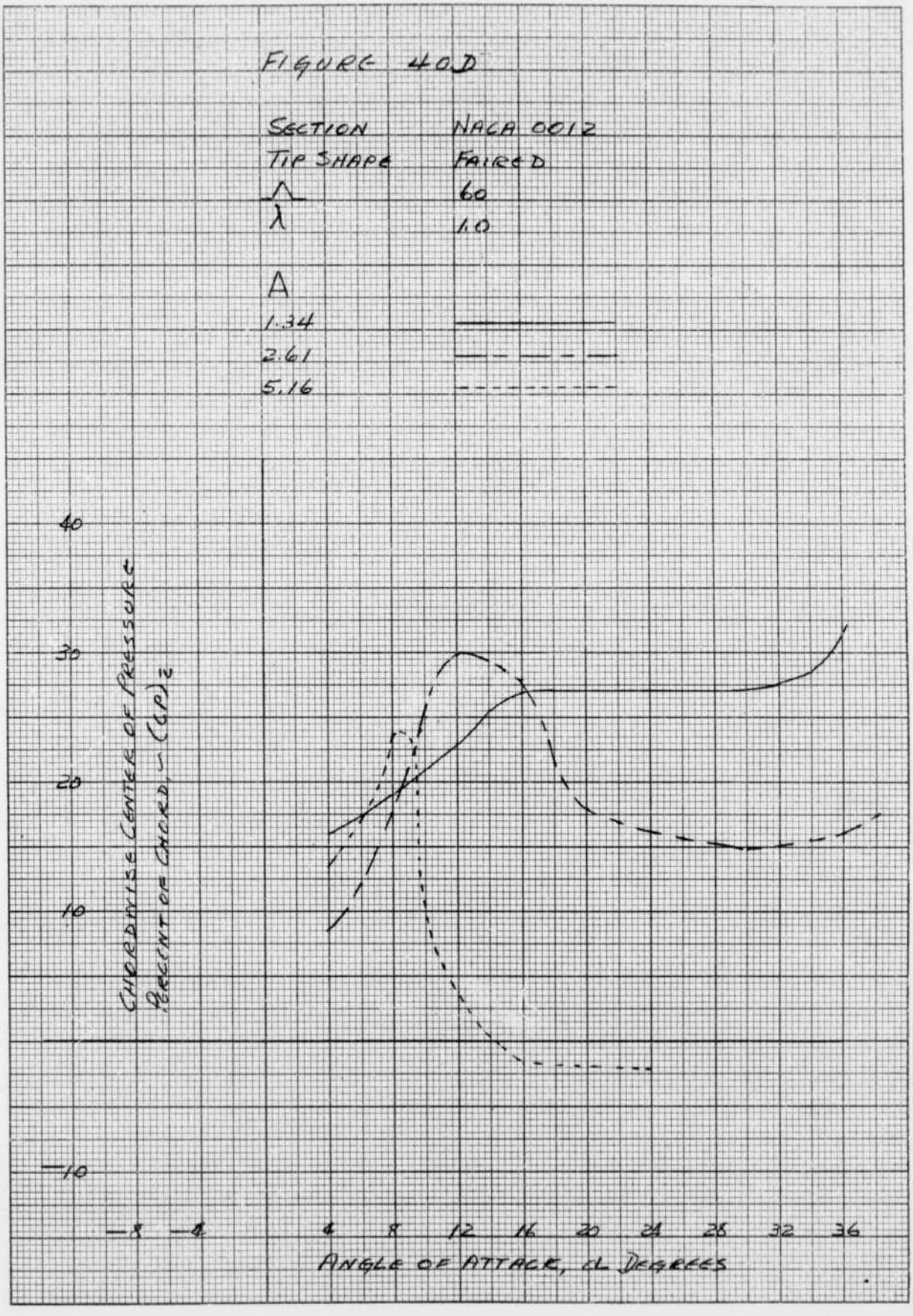
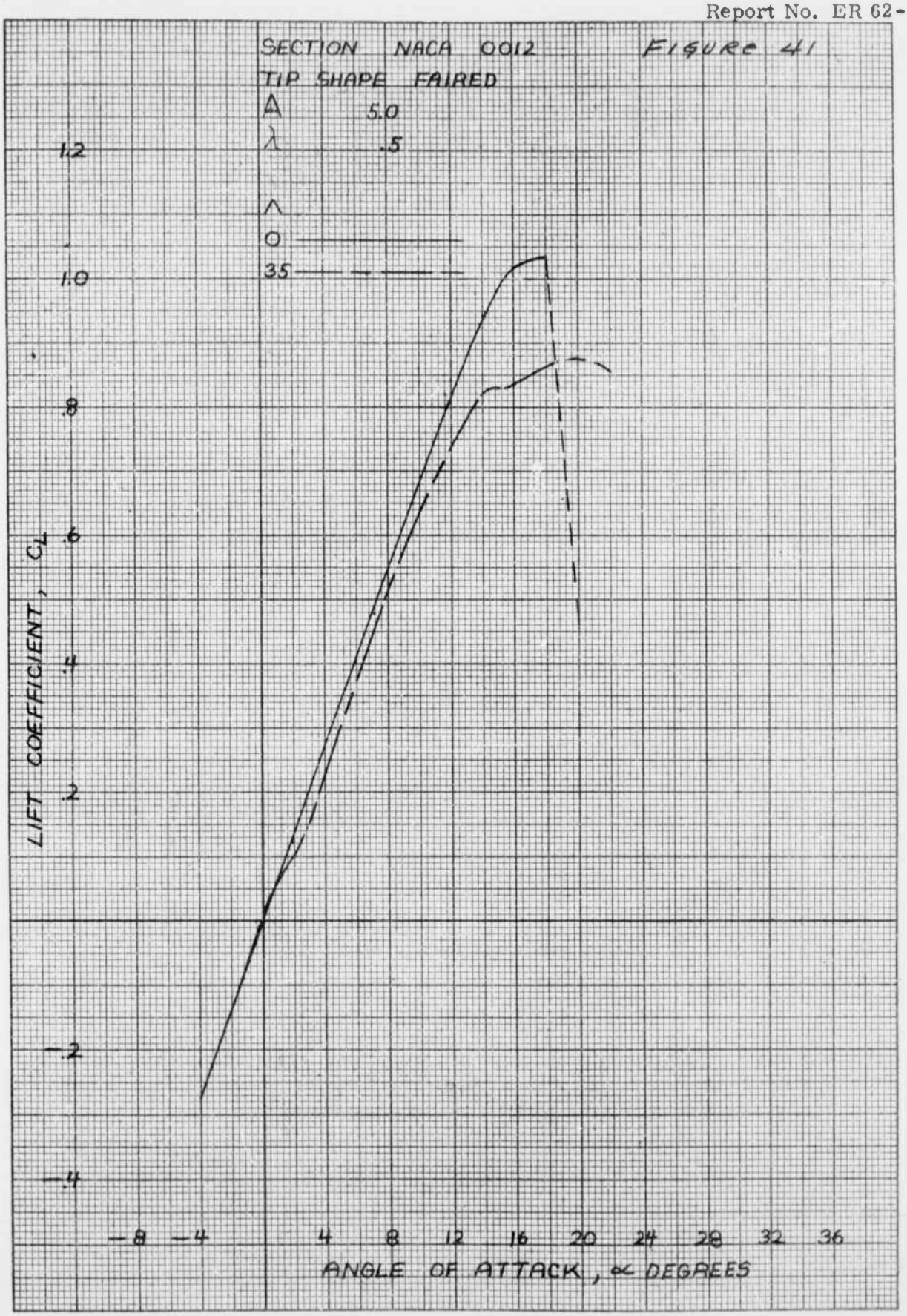

SECTION NACA 0012
TIP SHAPE FAIRED
Λ 60
λ 1.0
A
1.34
2.61
5.16
RESULTANT FORCE COEFFICIENT, C_R
1.6
1.4
1.2
1.0
.8
.6
.4
.2
-8
-4
4
8
12
16
20
24
28
32
36
ANGLE OF ATTACK, α DEGREES

FIGURE 40D


SECTION TIP SHAPE
NACA 0012 FAIRED
Λ
60
λ
1.0
A
1.34
2.61
5.16
CHORDWISE CENTER OF PRESSURE
PERCENT OF CHORD, - (CP)c/4
40
30
20
10
-10
-8
-4
4
8
12
16
20
24
28
32
36
ANGLE OF ATTACK, α, DEGREES


SECTION NACA 0012
TIP SHAPE FAIRED
FIGURE 41
A 5.0
λ .5
Λ
0
35
1.2
1.0
.8
.6
.4
.2
-.4
LIFT COEFFICIENT, C_L
-8
-4
4
8
12
16
20
24
28
32
36
ANGLE OF ATTACK, α DEGREES

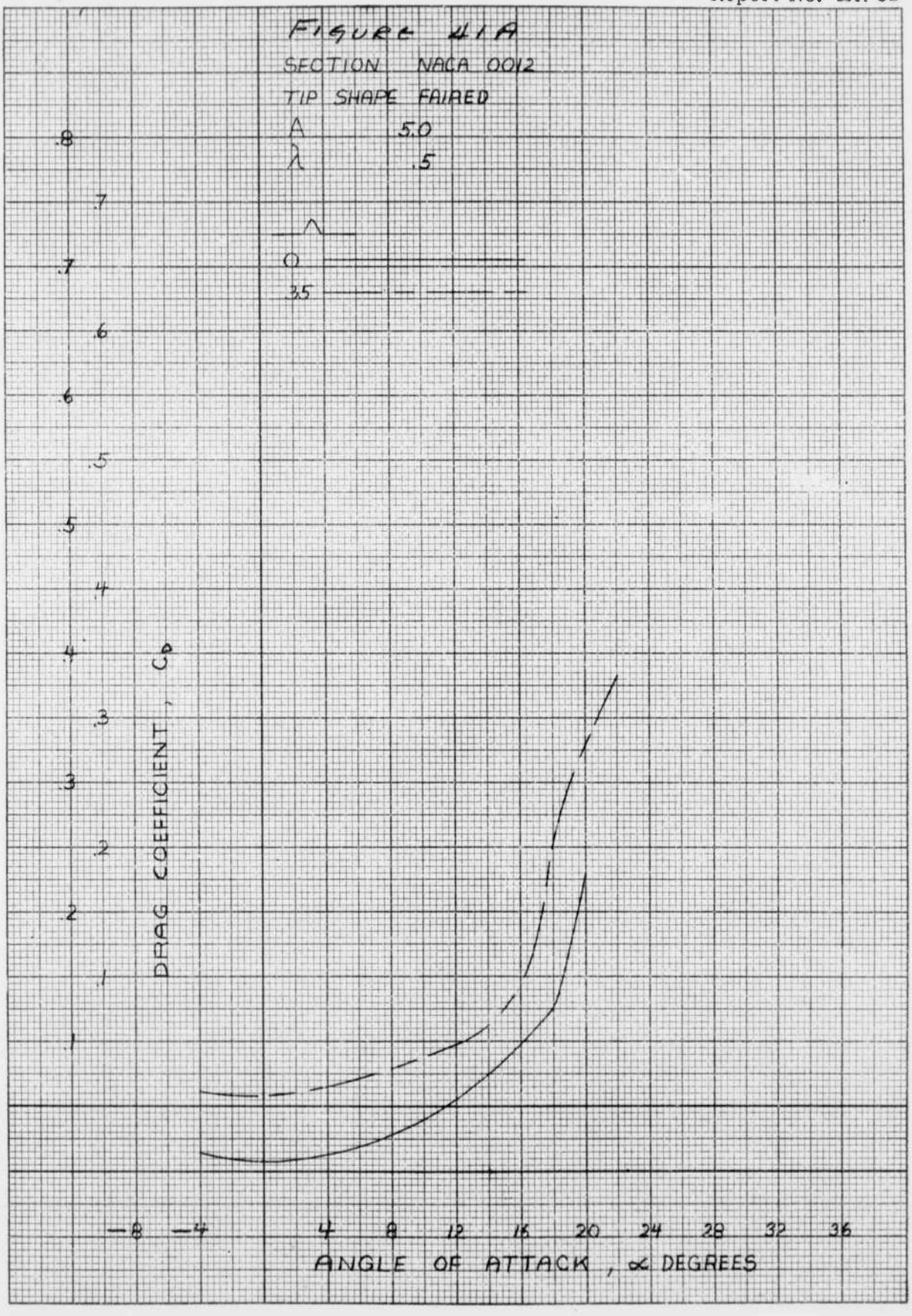


FIGURE 41A
SECTION NACA 0012
TIP SHAPE FAIRED
A 5.0
λ .5
0
35
DRAG COEFFICIENT, C_D
.8
.7
.7
.6
.6
.5
.5
.4
.4
.3
.3
.2
.2
.1
1
-8
-4
4
8
12
16
20
24
28
32
36
ANGLE OF ATTACK, α DEGREES

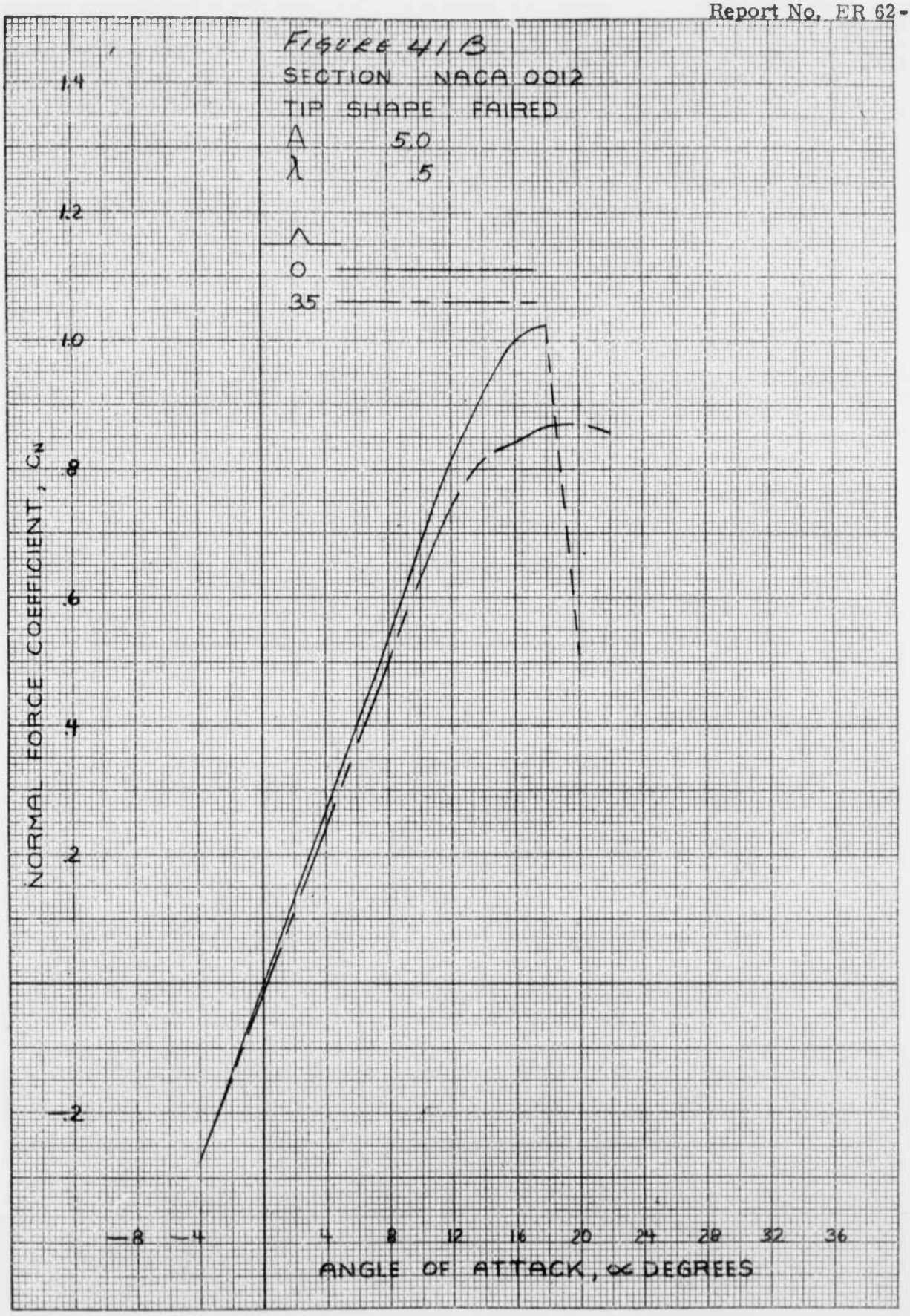


FIGURE 41 B
SECTION NACA 0012
TIP SHAPE FAIRED
A 5.0
λ .5
Λ
0
35
NORMAL FORCE COEFFICIENT, C_N
1.4
1.2
1.0
.8
.6
.4
.2
-.2
-8
-4
4
8
12
16
20
24
28
32
36
ANGLE OF ATTACK, α DEGREES

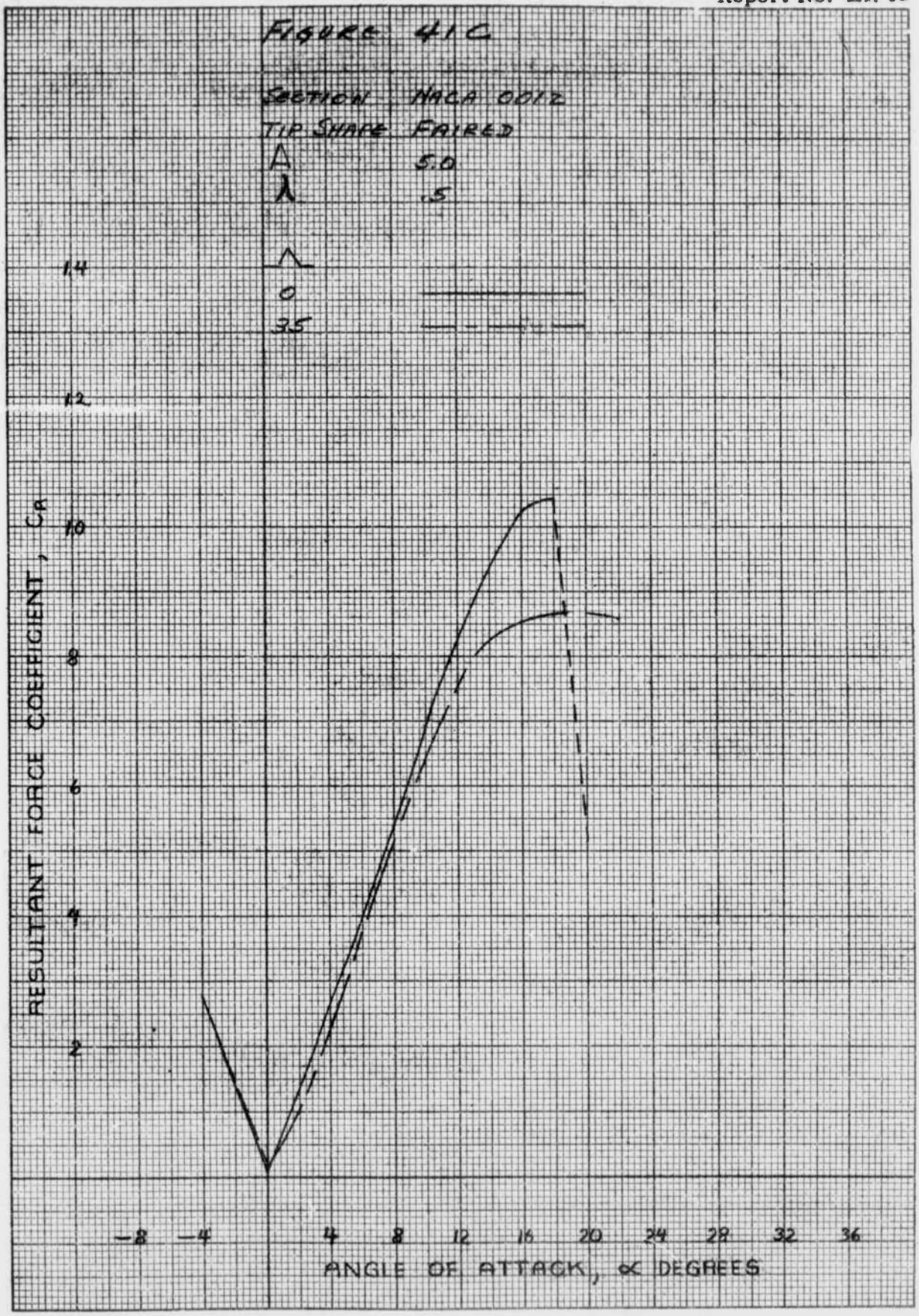
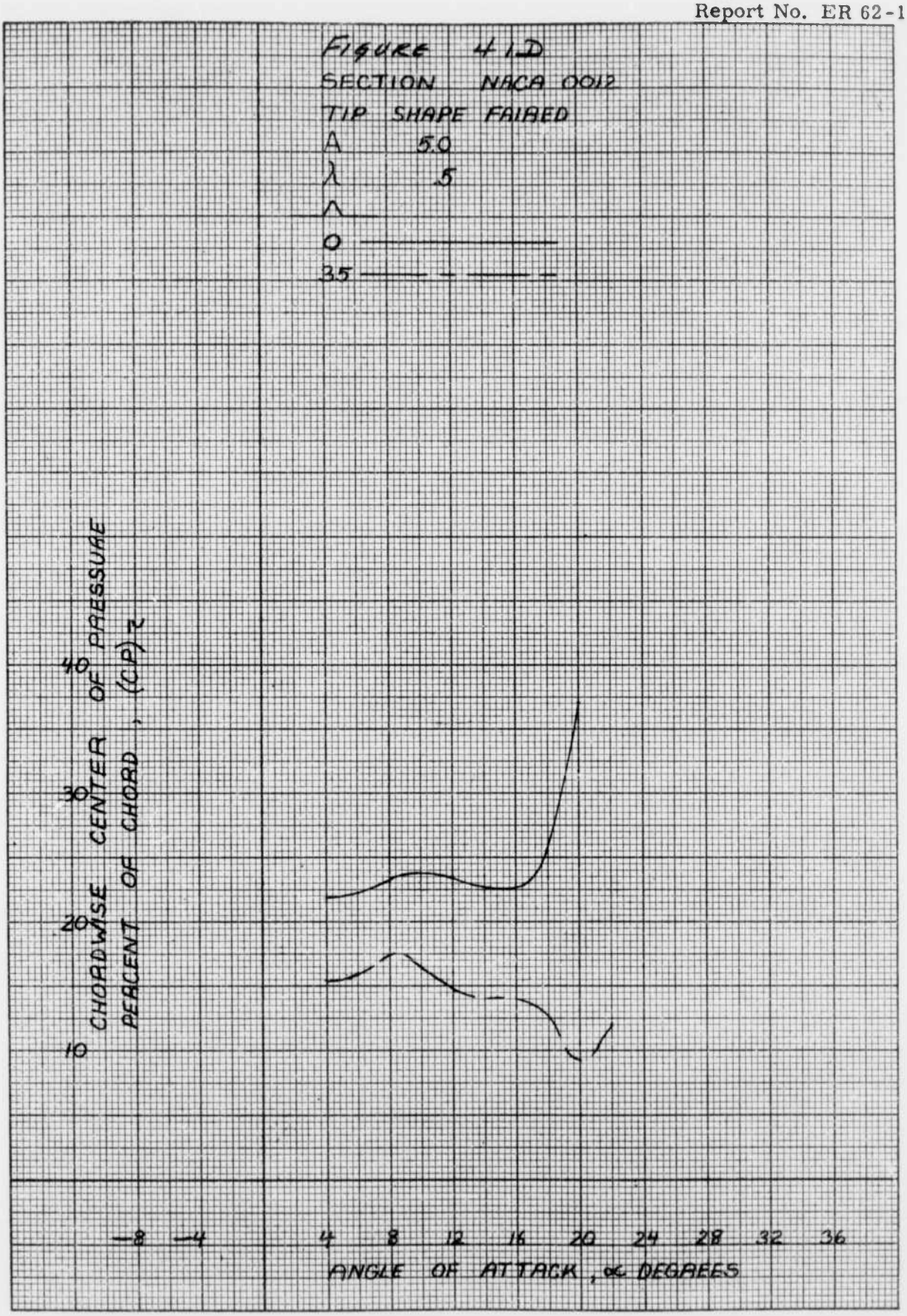


FIGURE 41C
SECTION NACA 0012
TIP SHAPE FAIRED
A 5.0
λ .5
Λ
0
35
1.4
1.2
1.0
.8
.6
.4
.2
RESULTANT FORCE COEFFICIENT, C_R
-8
-4
4
8
12
16
20
24
28
32
36
ANGLE OF ATTACK, α DEGREES

FIGURE 41D
SECTION NACA 0012
TIP SHAPE FAIRED
A 5.0
λ .5
Λ
0 ——————
35 —— - —— -



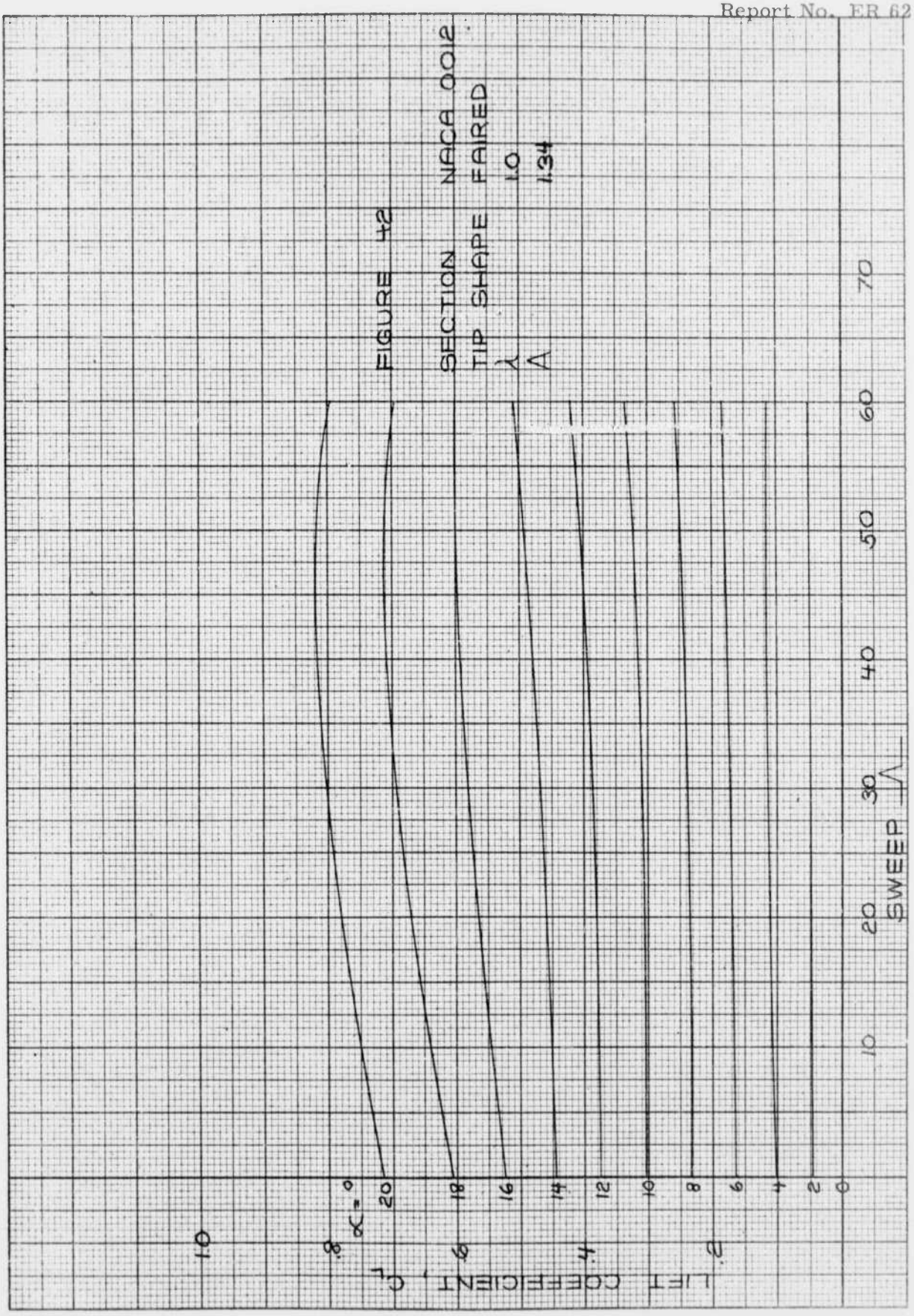


FIGURE 42
SECTION NACA 0012
TIP SHAPE FAIRED
λ 1.0
A 1.34
LIFT COEFFICIENT, C_L
SWEEP Λ
$\alpha = 0°$
0
2
4
6
8
10
12
14
16
18
20
10
20
30
40
50
60
70

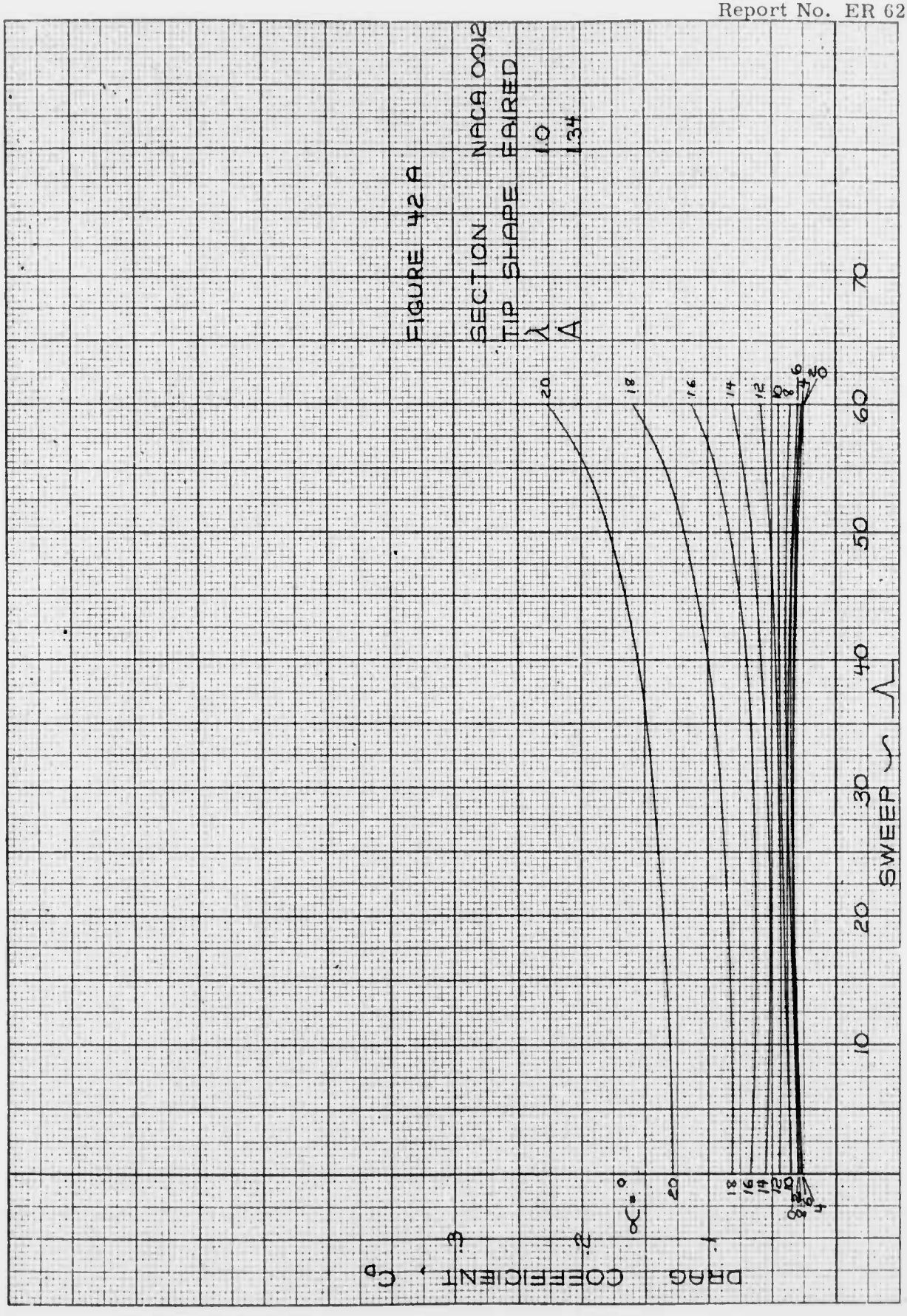

DRAG COEFFICIENT, C_D
SWEEP Λ
0
10
20
30
40
50
60
70
α = 0°
02
18
16
14
12
10
08
06
04
02
00
SECTION NACA 0012
TIP SHAPE FAIRED
λ 1.0
Λ 1.34

FIGURE 42 A

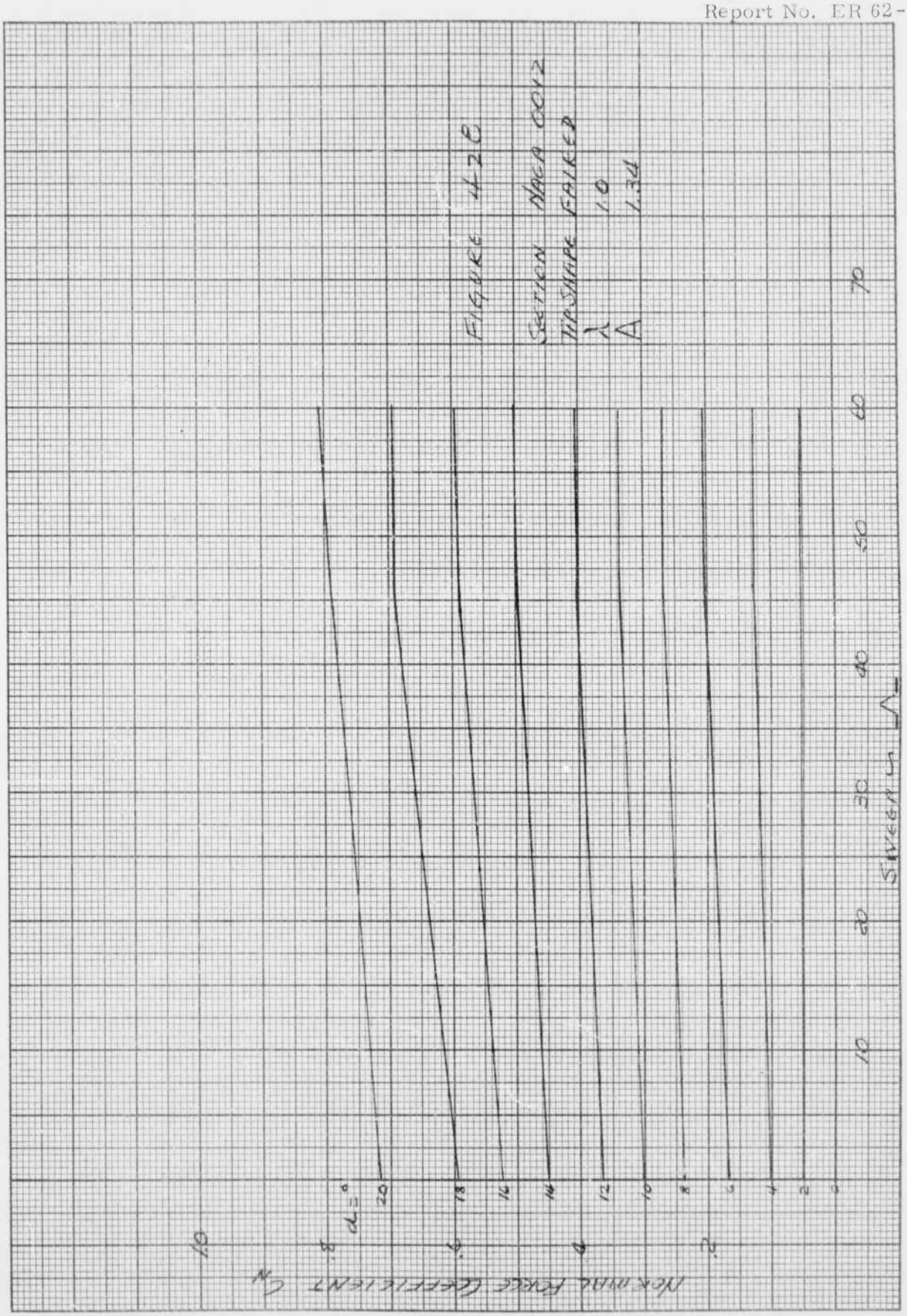


FIGURE 420
SECTION NACA 0012
TAPERED PLANFORM
λ 1.0
A 1.34
Maximum Force Coefficient C_N
α_{TE} = 0°
SWEEP Λ⊥

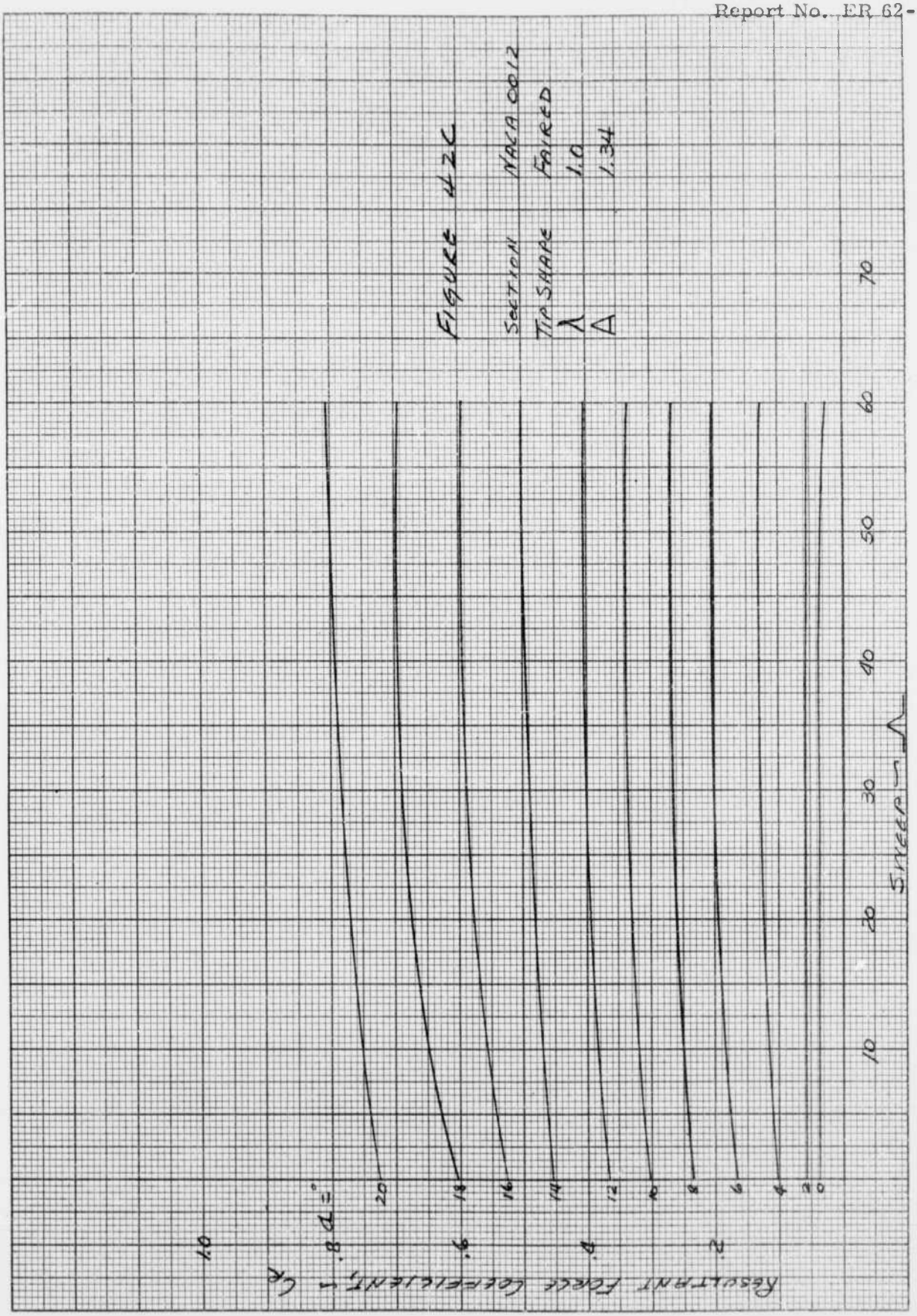


FIGURE 4.2.C
SECTION NACA 0012
TIP SHAPE FAIRED
λ 1.0
A 1.34
SWEEP Λ
ASSOCIATED FLOCK COEFFICIENT, CL
α = 18°
20
18
16
14
12
10
8
6
4
2
0
1.0
.8
.6
.4
.2
10
20
30
40
50
60
70

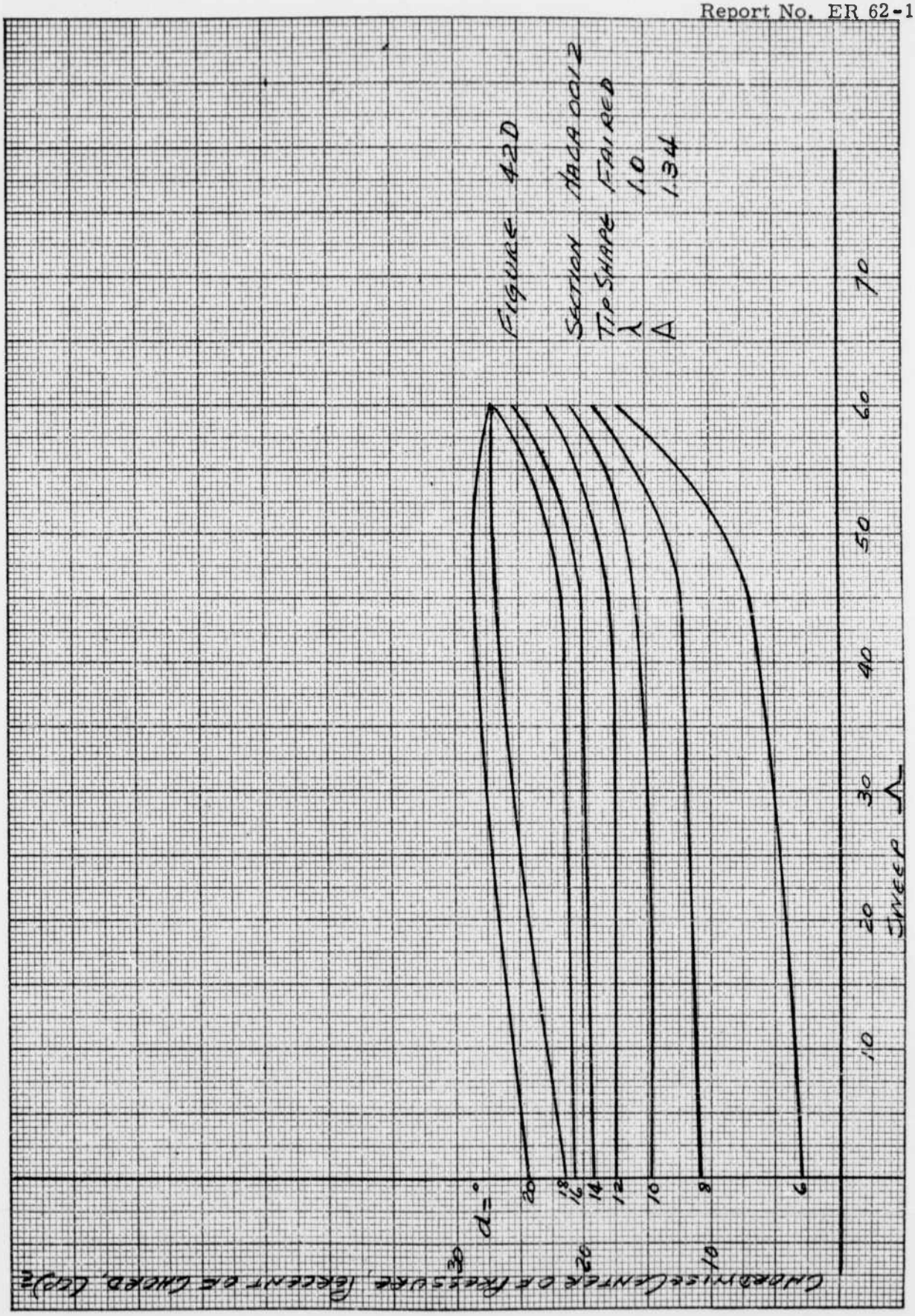


FIGURE 42D
SECTION MACH 0.72
TIP SHAPE FAIRED
λ 1.0
A 1.34
INCREASED
CHORDWISE CENTER OF PRESSURE, PERCENT OF CHORD, (c.p.)z
α = 0°
20
18
16
14
12
10
8
6
10
20
30
40
50
60
70

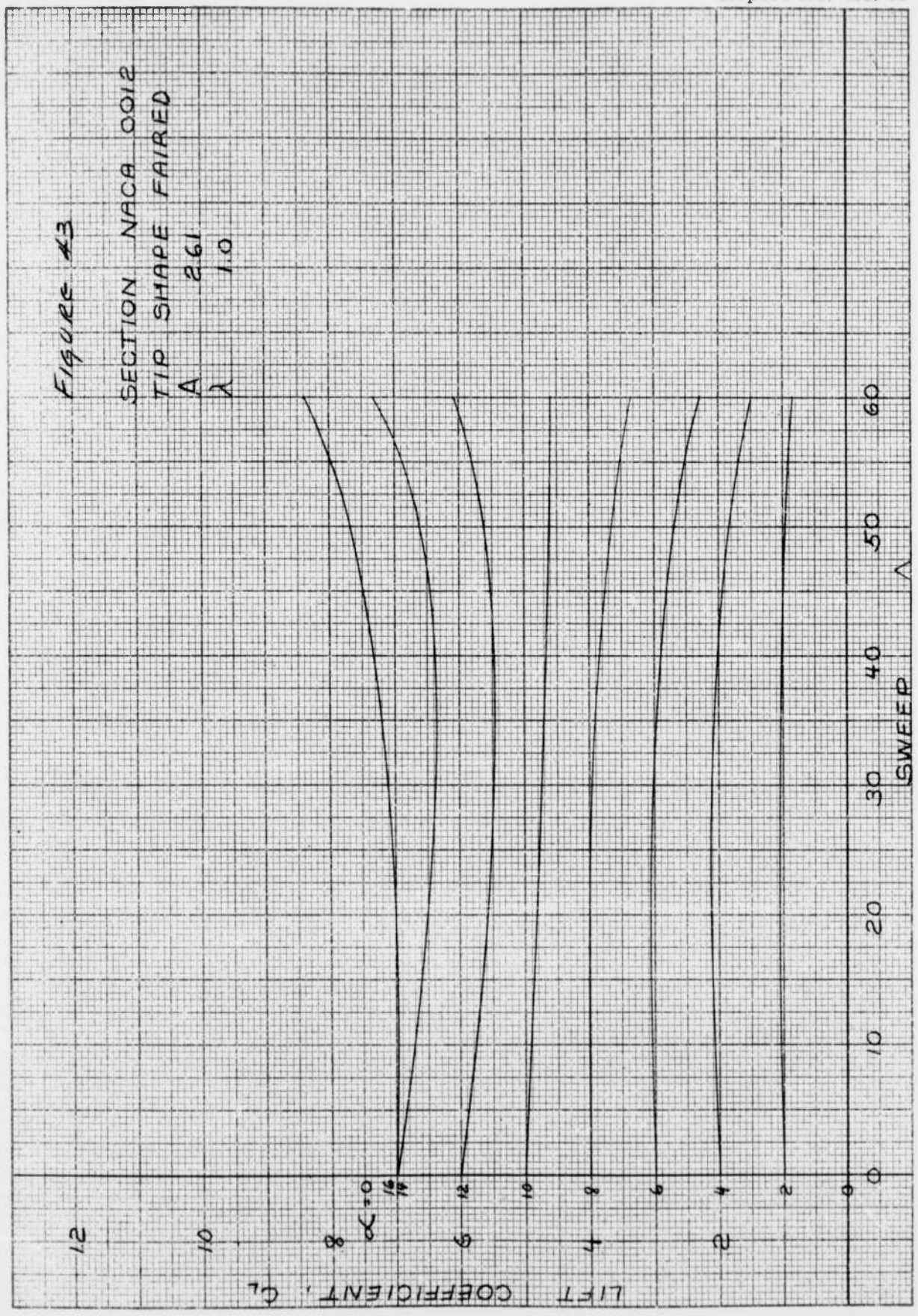


FIGURE #3
SECTION NACA 0012
TIP SHAPE FAIRED
A 2.61
λ 1.0
LIFT COEFFICIENT, C_L
SWEEP Λ
α = 0
16
14
12
10
8
6
4
2
0
0
10
20
30
40
50
60

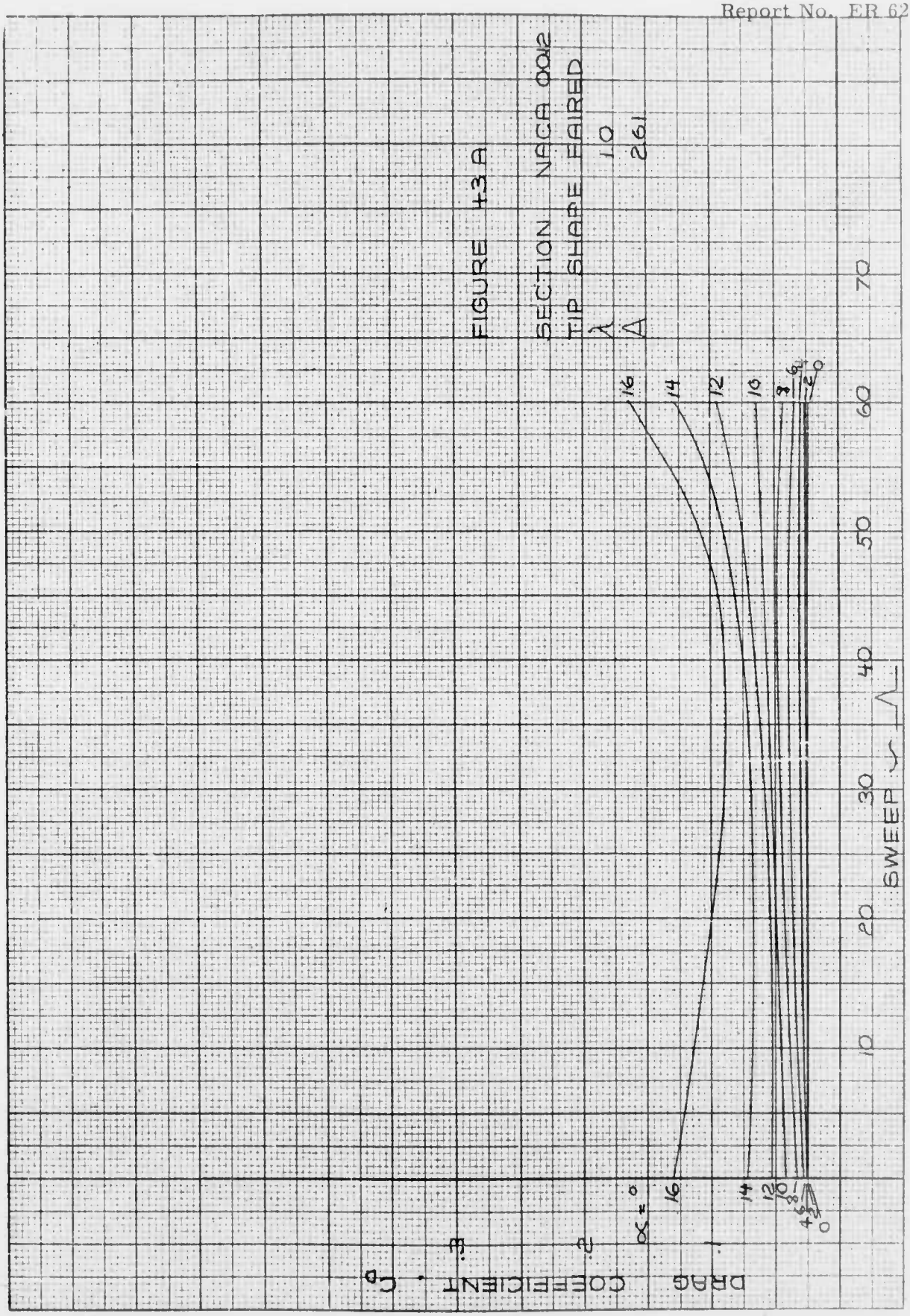


FIGURE 43 A
SECTION NACA 0012
TIP SHAPE FAIRED
λ 1.0
A 2.61
DRAG COEFFICIENT - C_D
$\alpha = 0°$
16
14
12
10
8
6
4
2
0
SWEEP Λ
10
20
30
40
50
60
70

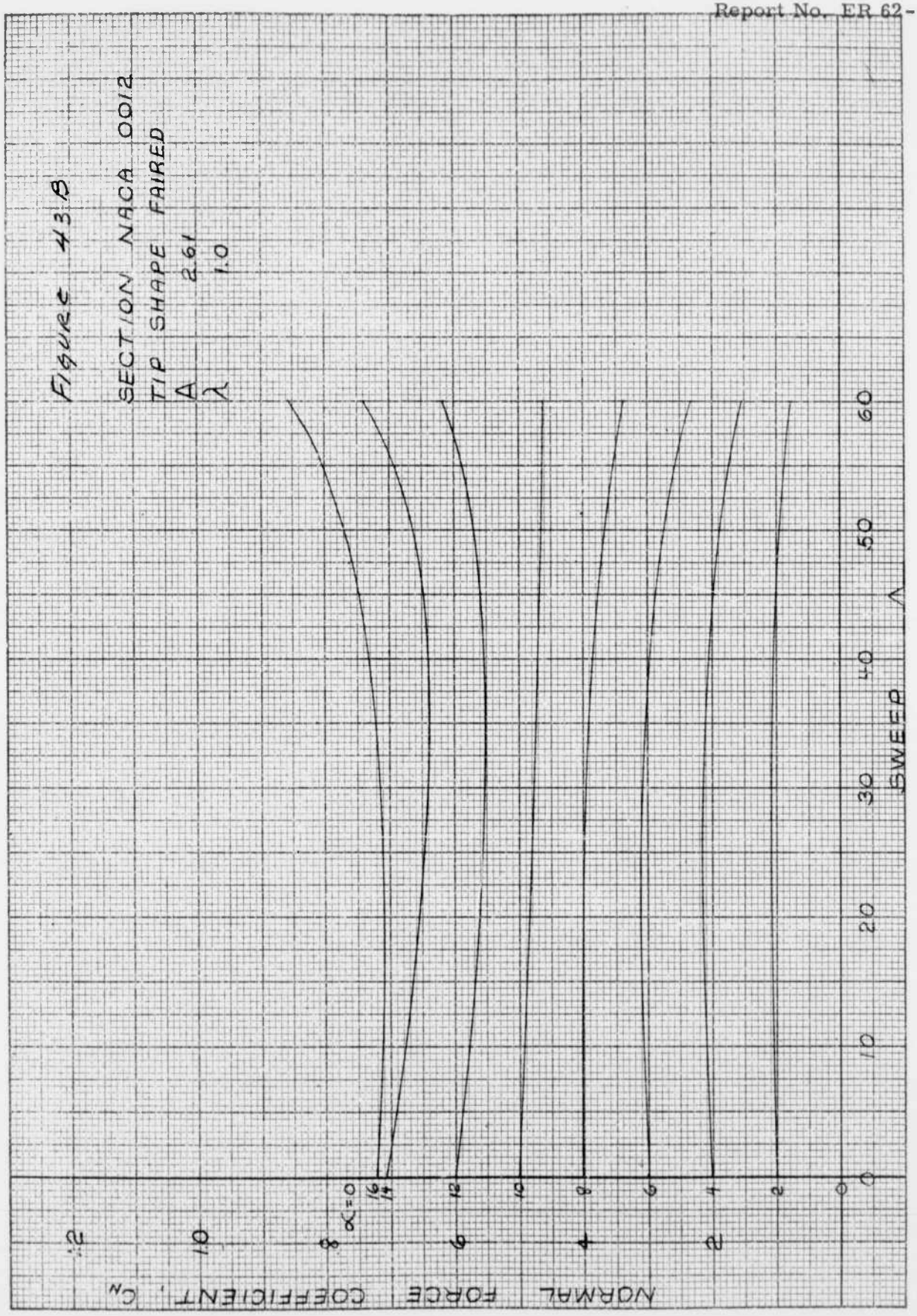


Figure 43 B
SECTION NACA 0012
TIP SHAPE FAIRED
A 2.61
λ 1.0
NORMAL FORCE COEFFICIENT, C_N
SWEEP Λ
α=0
16
14
12
10
8
6
4
2
0
.2
.1
0
10
20
30
40
50
60

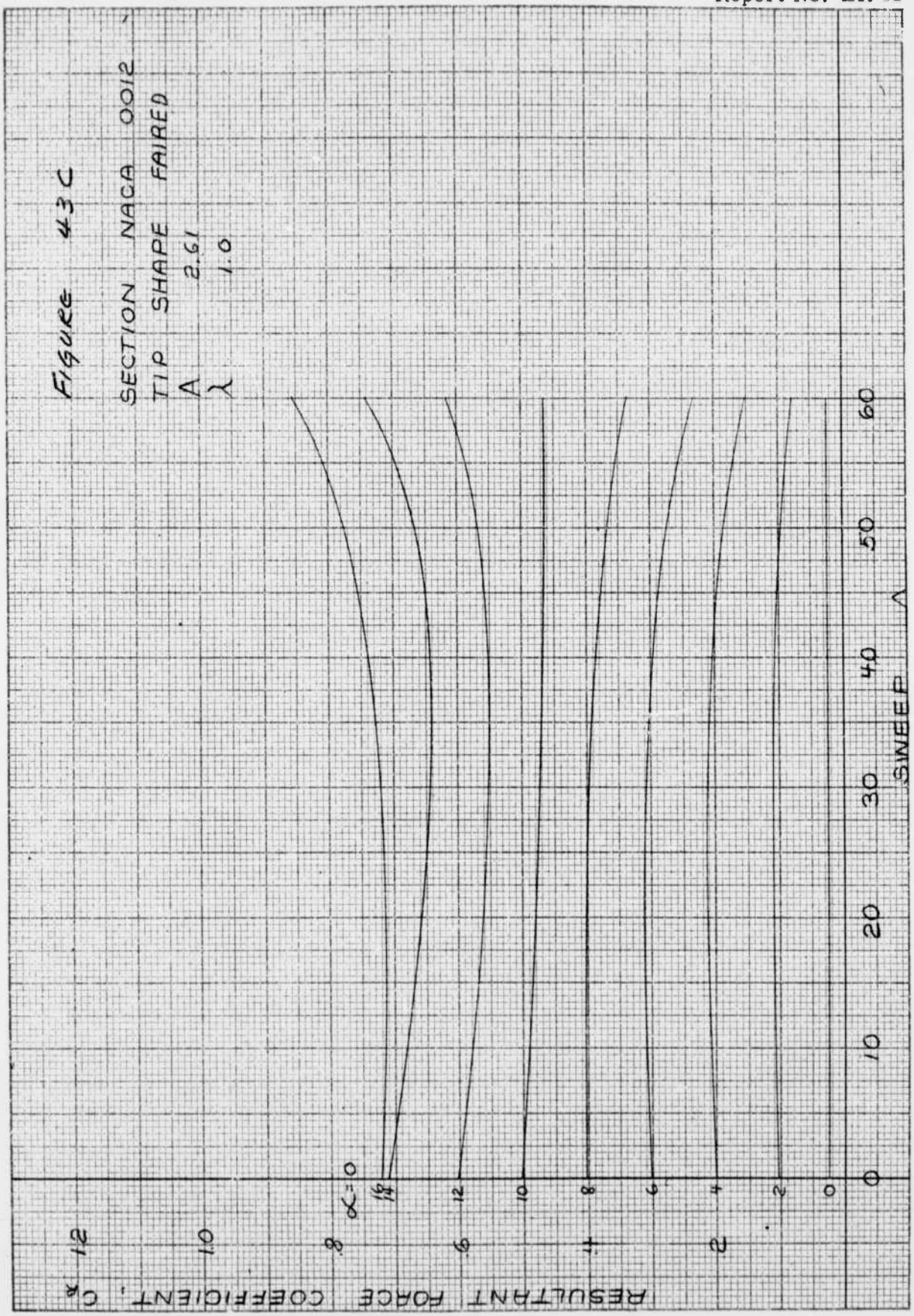


FIGURE 43C
SECTION NACA 0012
TIP SHAPE FAIRED
A 2.61
λ 1.0
RESULTANT FORCE COEFFICIENT, C_R
SWEEP Λ
0
10
20
30
40
50
60
.8
1.0
1.2
2
4
6
8
10
12
14
α=0

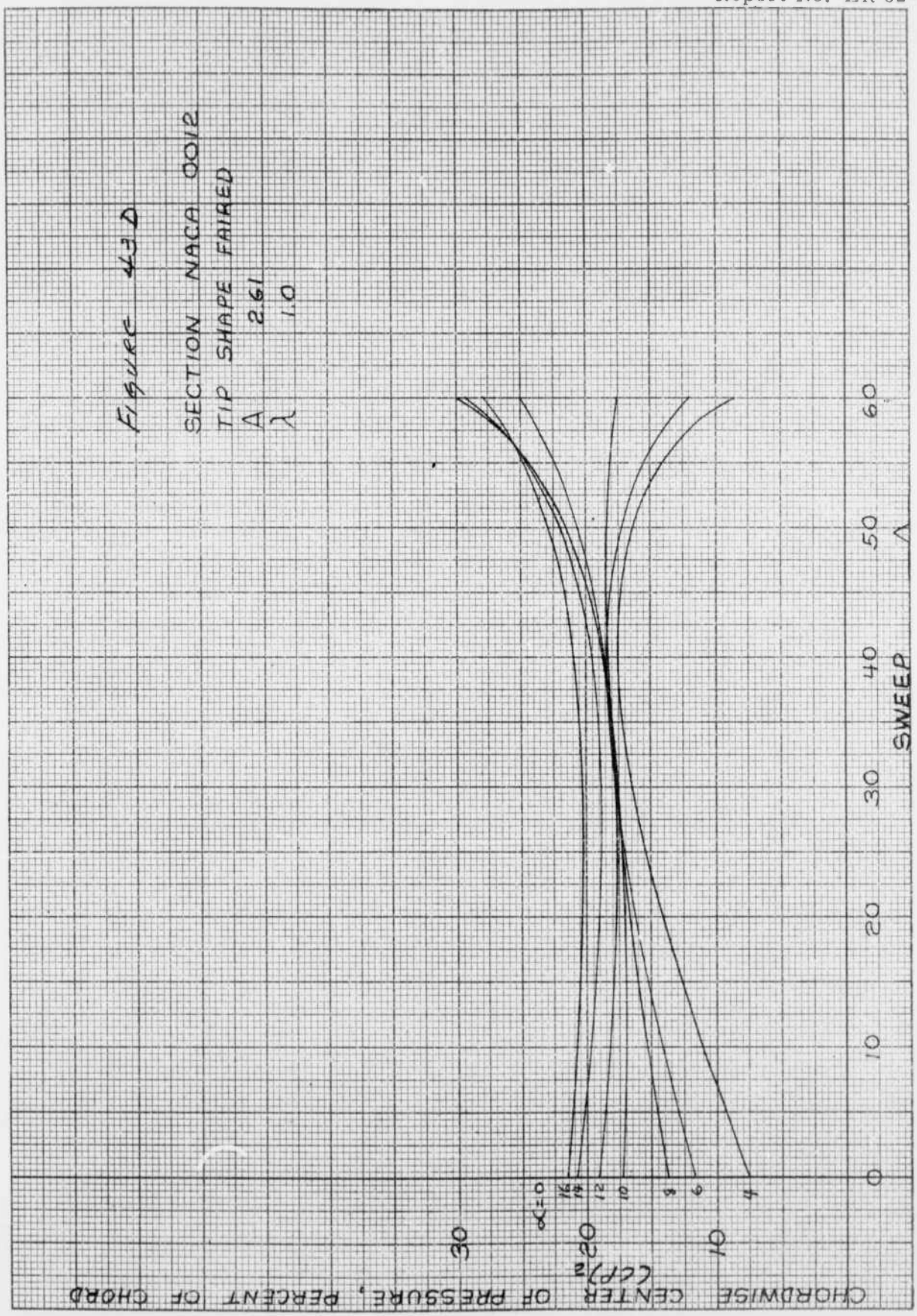


Figure 43 D
SECTION NACA 0012
TIP SHAPE FAIRED
Λ 2.61
λ 1.0
SWEEP Λ
0
10
20
30
40
50
60
CHORDWISE CENTER OF PRESSURE, PERCENT OF CHORD
$(\bar{c}/)_{\frac{1}{2}}$
30
20
10
α=0
16
14
12
10
8
6
4

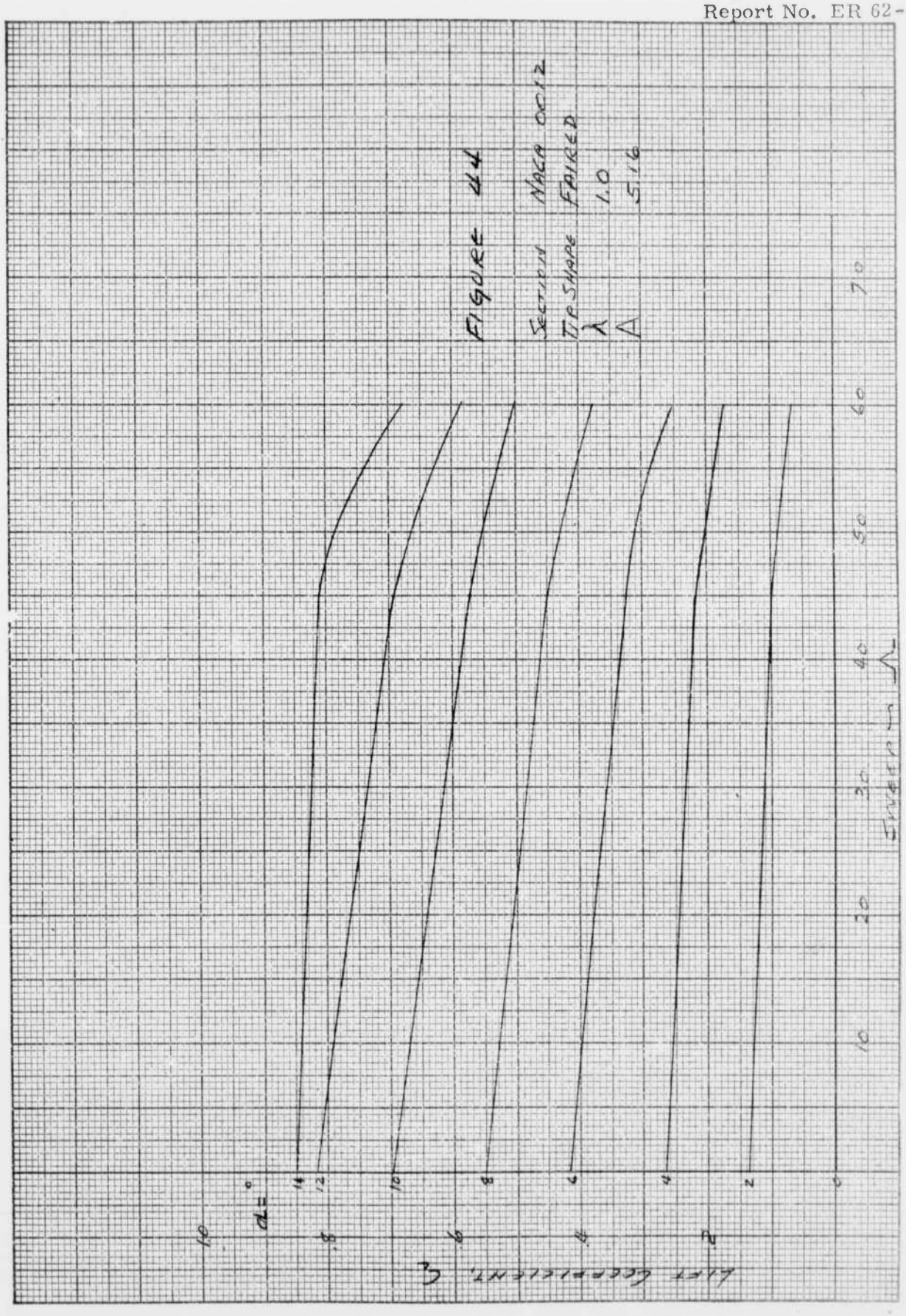


FIGURE 44
SECTION NACA 0012
TIP SHAPE FAIRED
λ 1.0
Δ 51.6
LIFT COEFFICIENT, C_L
ENDURANCE, MINUTES
α = 0°
10
8
6
4
2
0
10
20
30
40
50
60
70

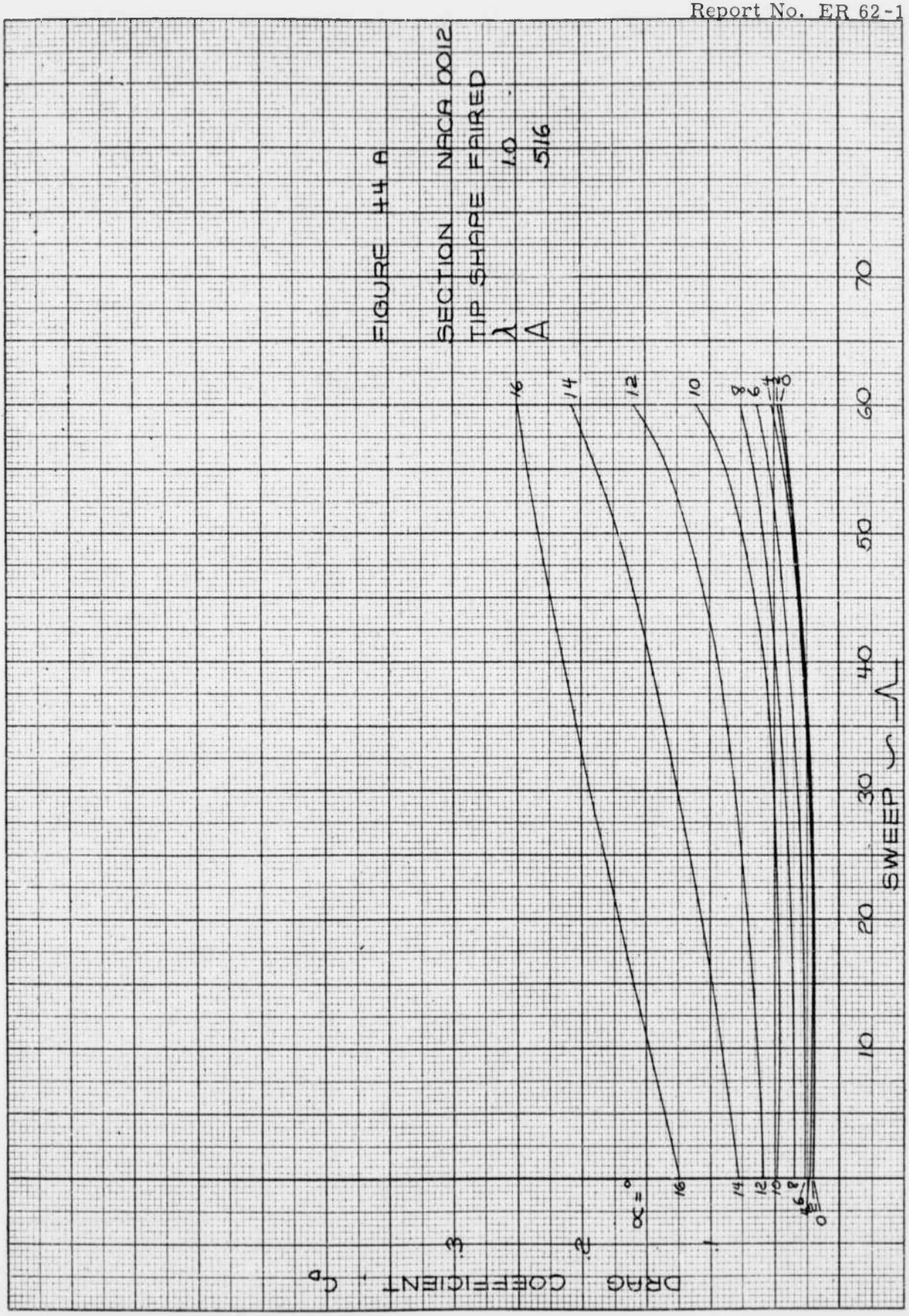


FIGURE 44 A
SECTION NACA 0012
TIP SHAPE FAIRED
λ 1.0
A 5/16
DRAG COEFFICIENT, C_D
SWEEP Λ
α = 0
0
2
4
6
8
10
12
14
16
10
20
30
40
50
60
70

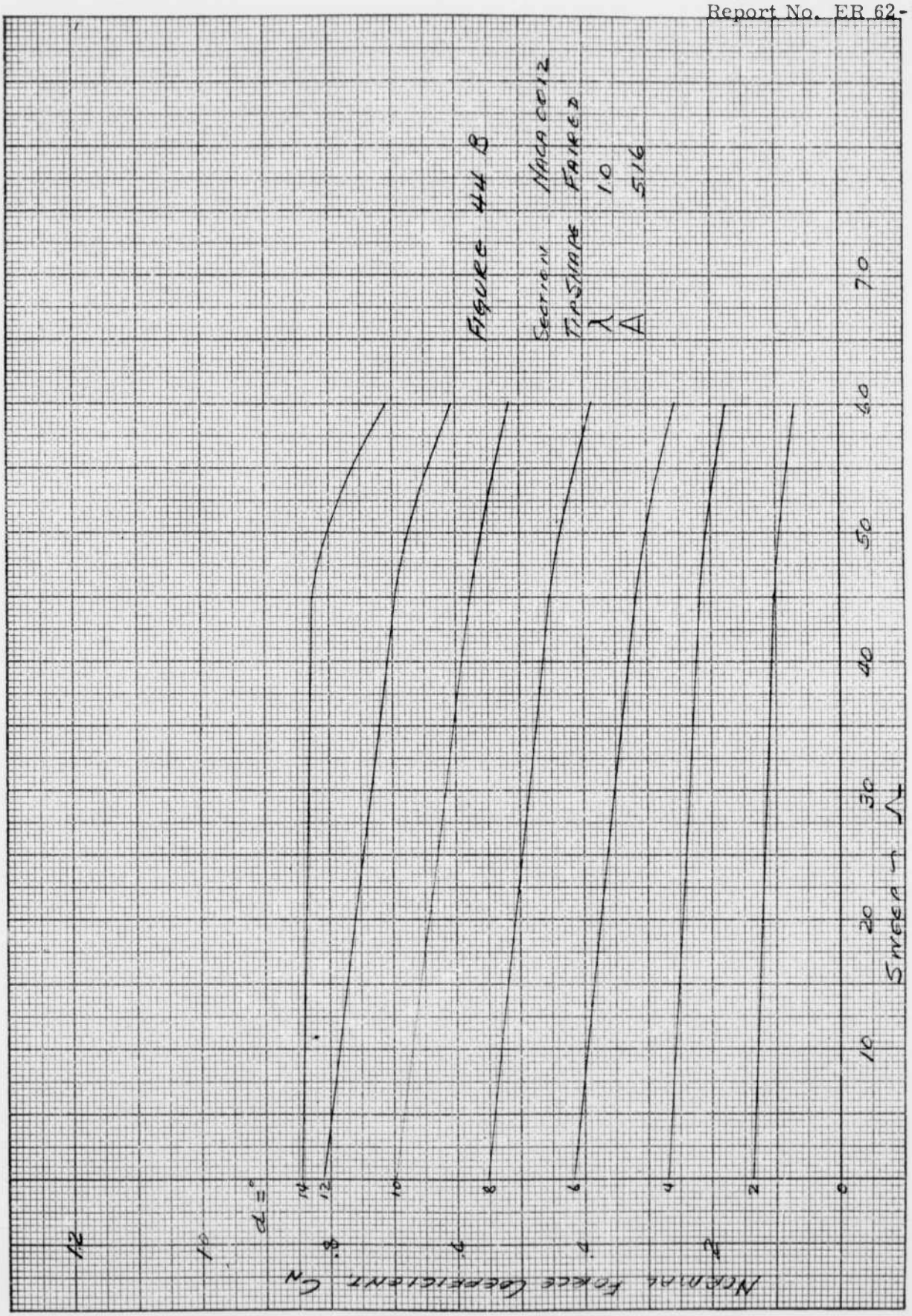


FIGURE 44 B
SECTION NACA 0012
TAPERED
λ 1.0
A 5.16
NORMAL FORCE COEFFICIENT C_N
SWEEP Λ
$\alpha = 0°$
0
2
4
6
8
10
12
14
16
20
30
40
50
60
70

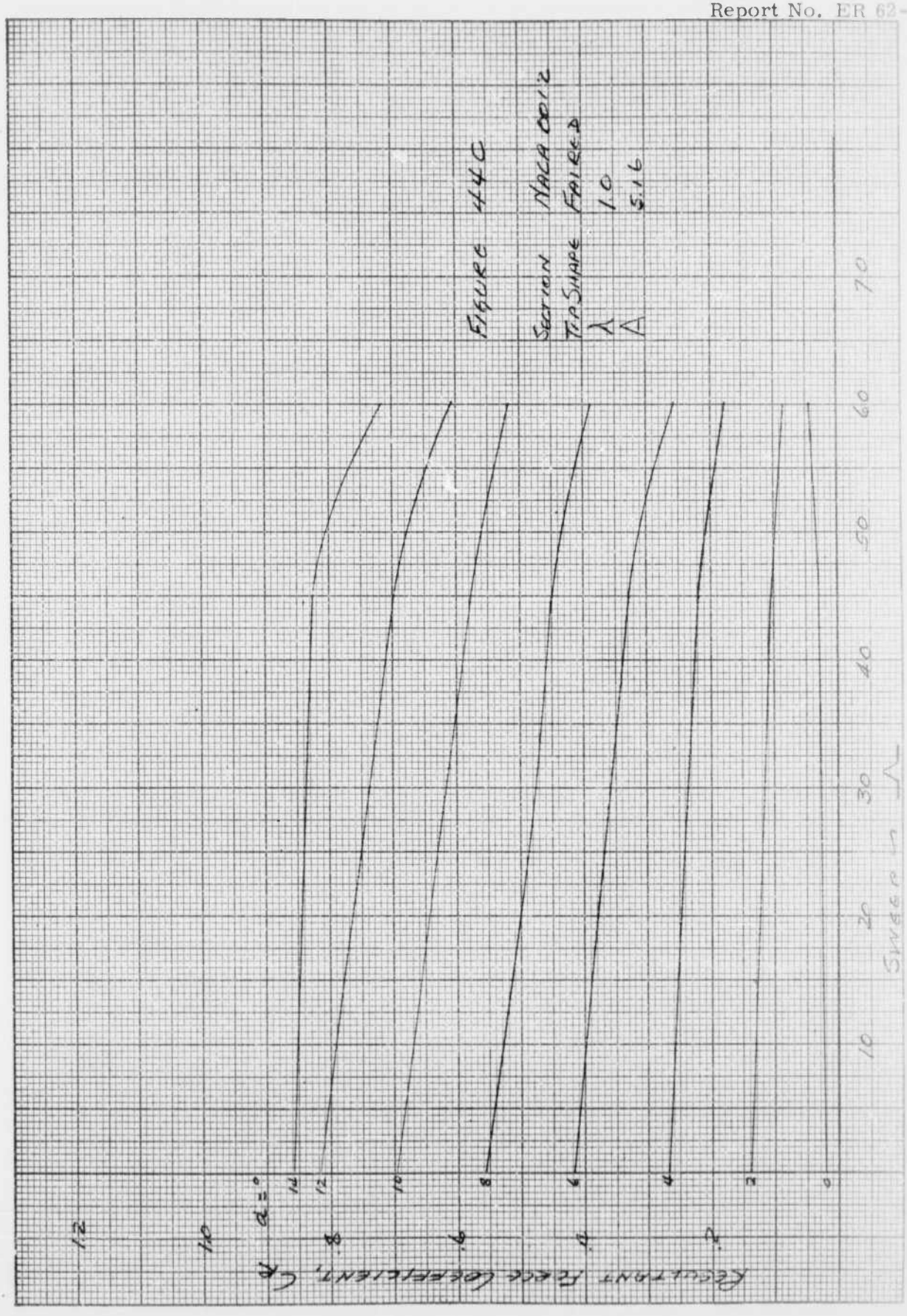


FIGURE 44C
SECTION NACA 0012
TAPERED
λ 1.0
A 5.16
LIFT-CURVE SLOPE, C_{L_α}, PER RADIAN
SWEEP IN DEGREES
0
20
30
40
50
60
70
$\alpha = 0°$
1.2
1.0

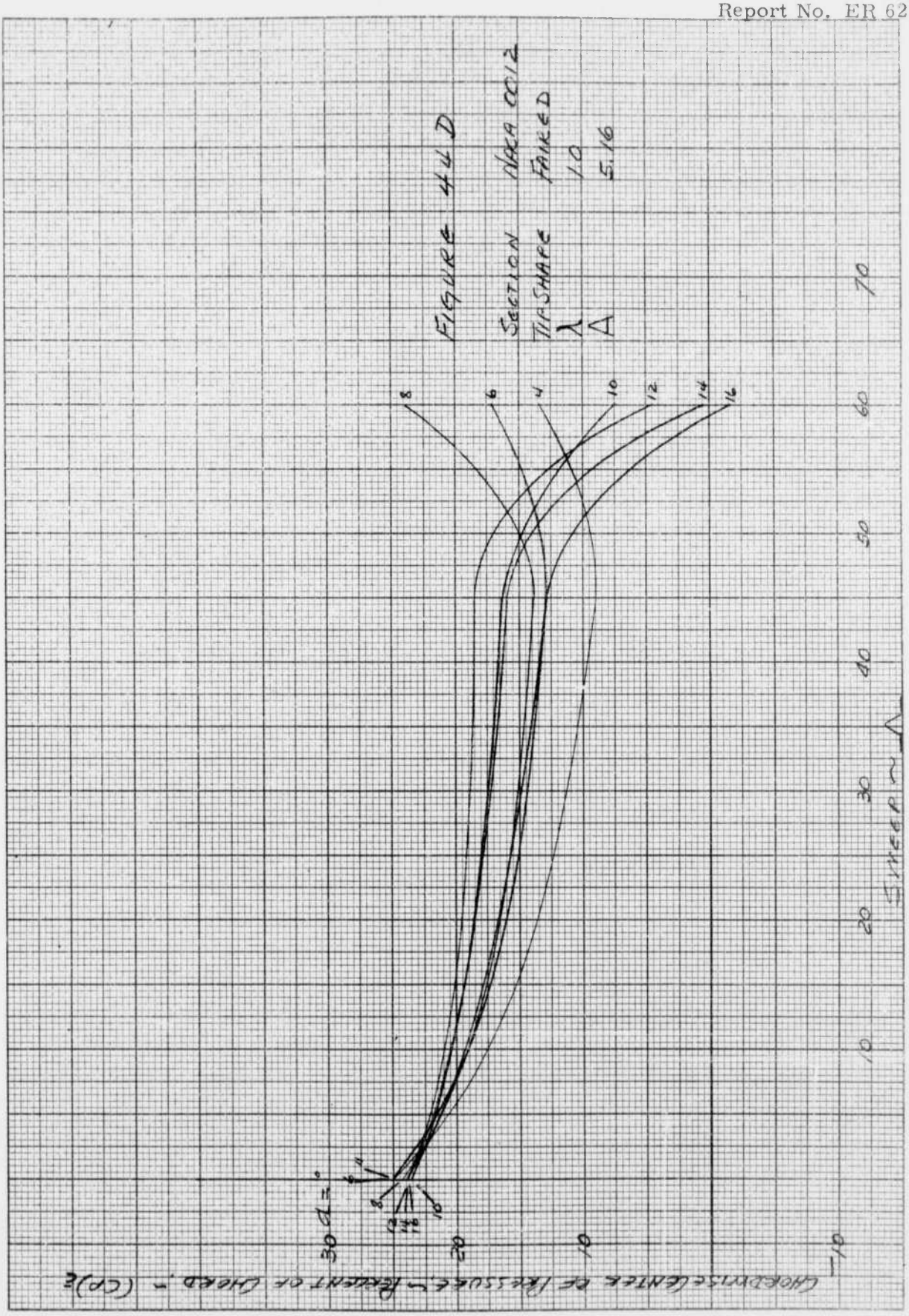


FIGURE 44 D
SECTION NACA 0012
PLAN SHAPE TAPERED
λ 1.0
A 5.16
8
6
4
10
12
14
16
CHORDWISE CENTER OF PRESSURE - PERCENT OF CHORD - (CP)c
-10
0
10
20
30
40
50
60
70
VELOCITY - V

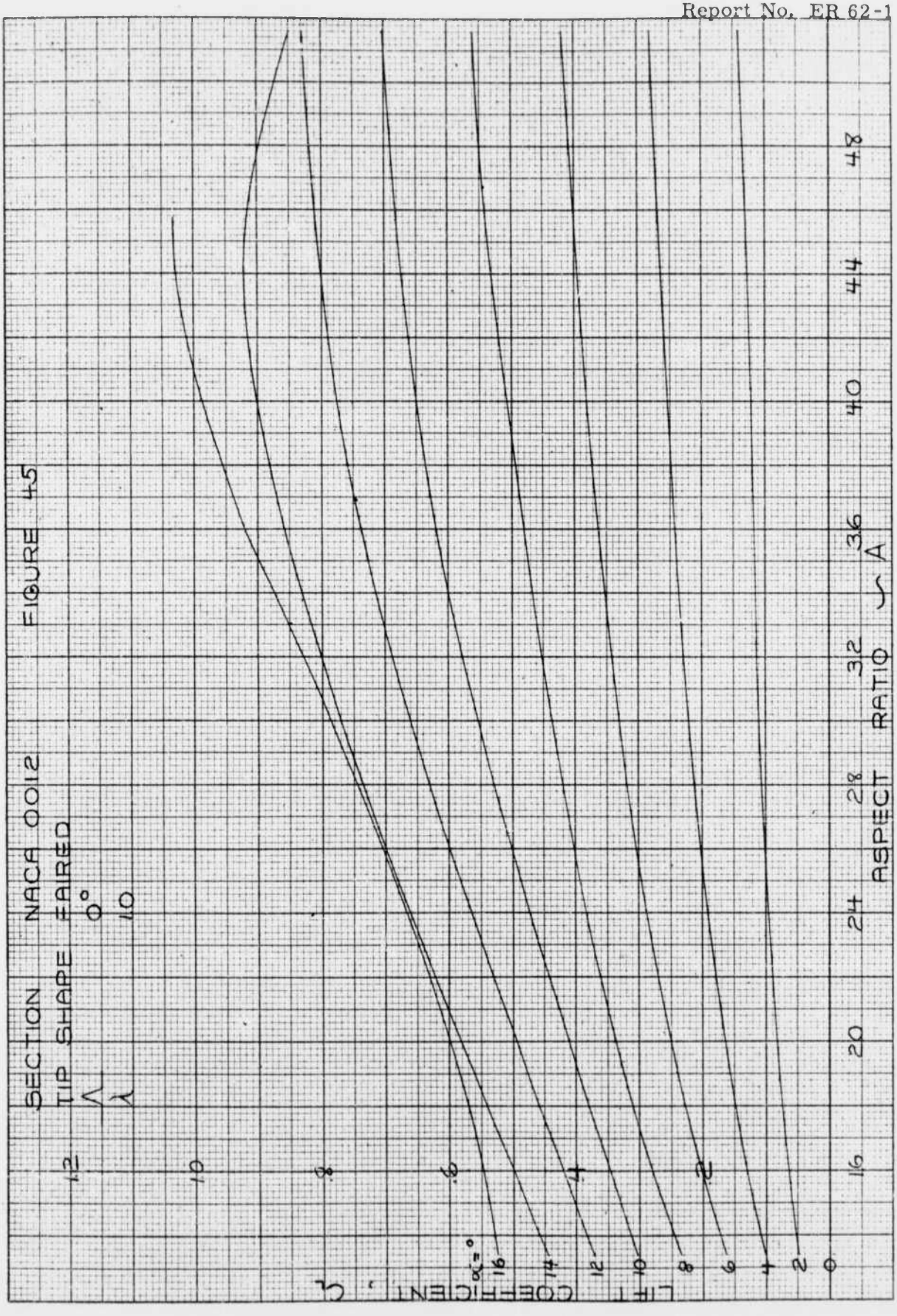
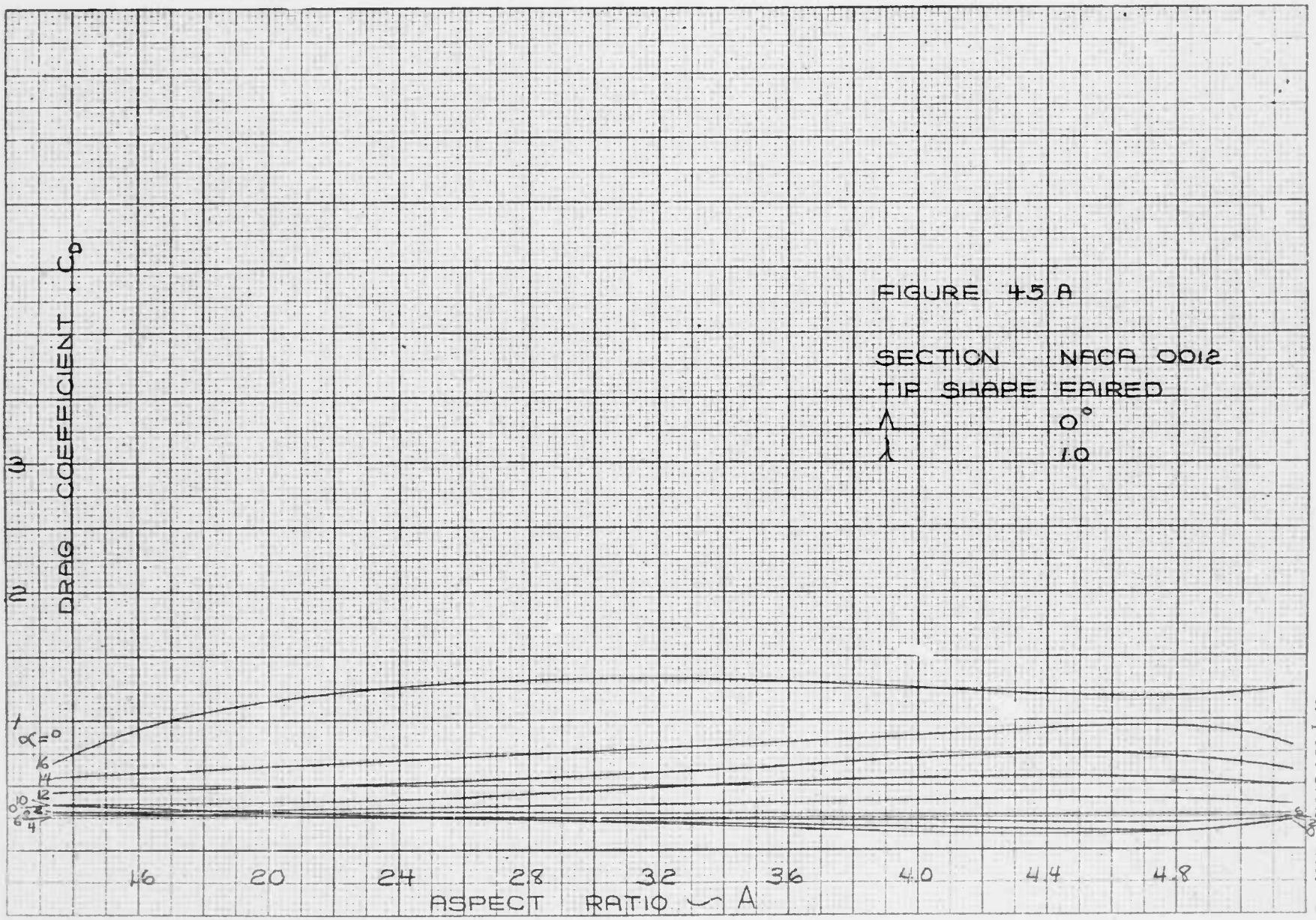

SECTION NACA 0012
TIP SHAPE FAIRED
Λ 0°
λ 1.0
C_L LIFT COEFFICIENT
α = 20°
16
12
8
4
0
ASPECT RATIO A
0
2
4
6
8
12
16
20
24
28
32
36
40
44
48
1.2
1.0
.8
.6
.4
.2

FIGURE 45


DRAG COEFFICIENT - C_D
FIGURE 45 A
SECTION NACA 0012
TIP SHAPE FAIRED
0°
1.0
α=0
6
14
10
12
0
2
4
6
8
1.6
2.0
2.4
2.8
3.2
3.6
4.0
4.4
4.8
ASPECT RATIO ~ A

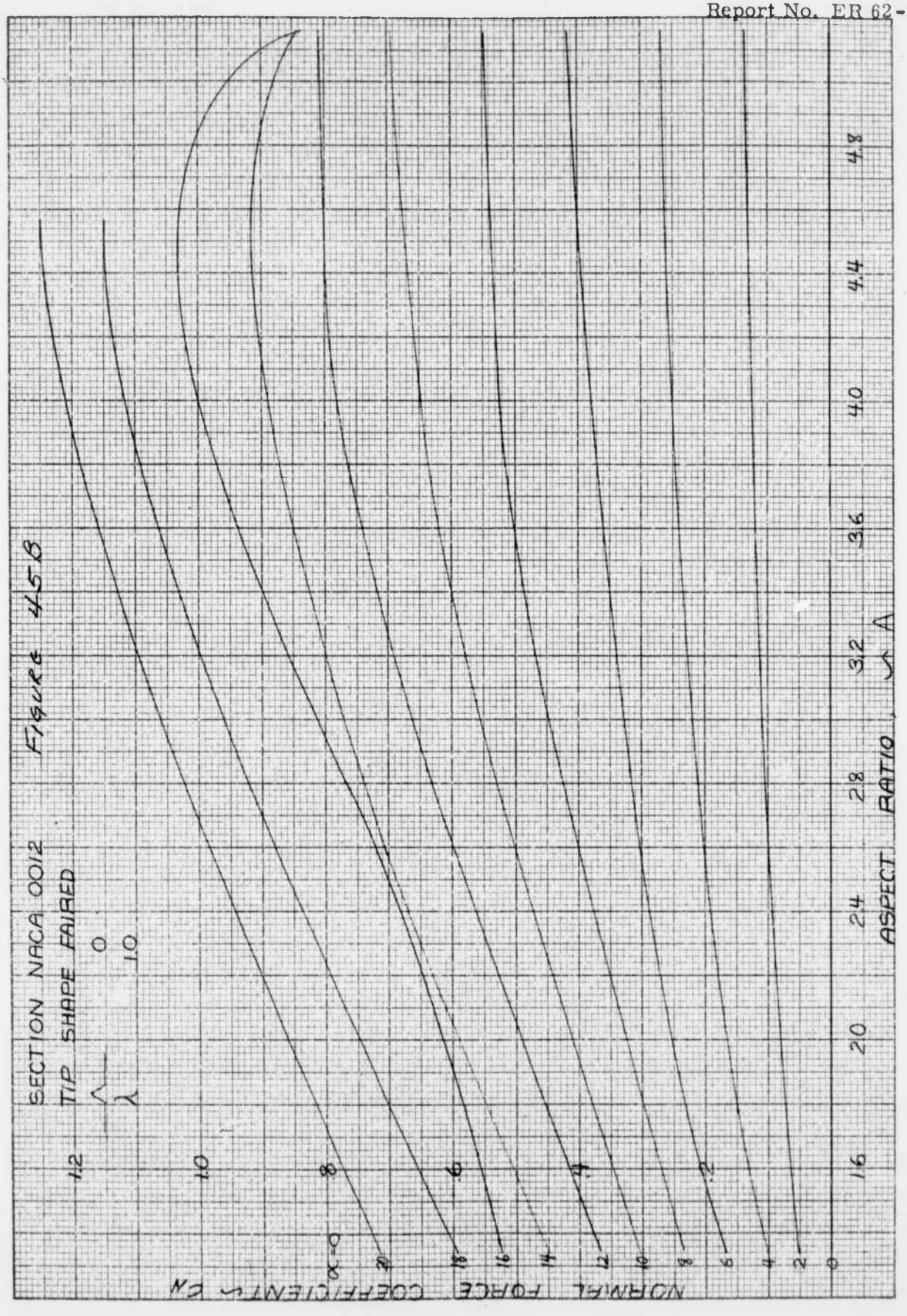


Figure 458
SECTION NACA 0012
TIP SHAPE FAIRED
0
1.0
NORMAL FORCE COEFFICIENTS C_N
ASPECT RATIO, Λ
16
20
24
28
3.2
3.6
4.0
4.4
4.8
0
2
4
6
8
10
12
14
16
18
α=0
2
4
6
8
10
12

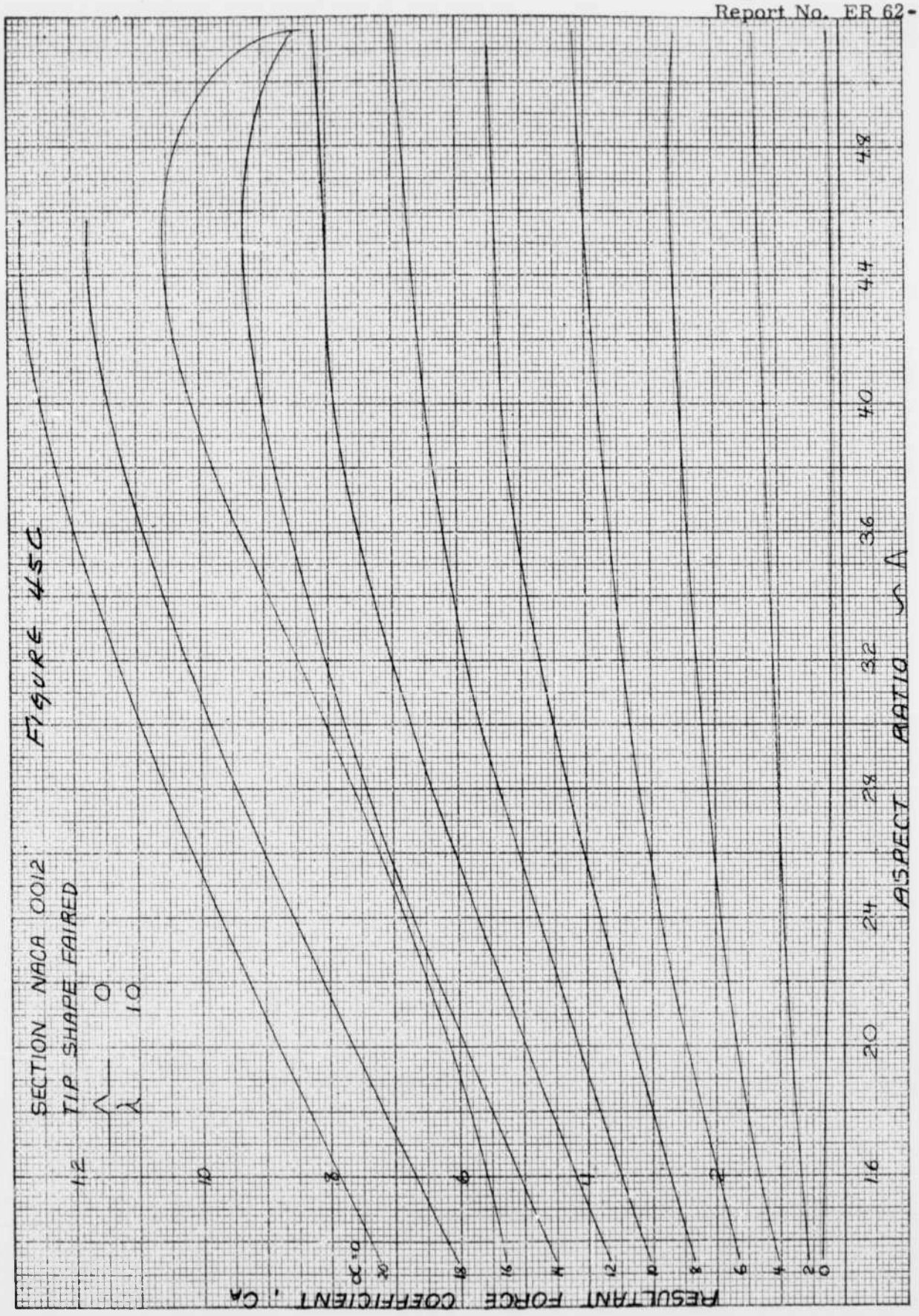


FIGURE 45C
SECTION NACA 0012
TIP SHAPE FAIRED
λ 0
1.0
RESULTANT FORCE COEFFICIENT , CA
ASPECT RATIO A
α = 0
2
4
6
8
10
12
14
16
18
20
0
4
8
12
16
20
24
28
32
36
40
44
48

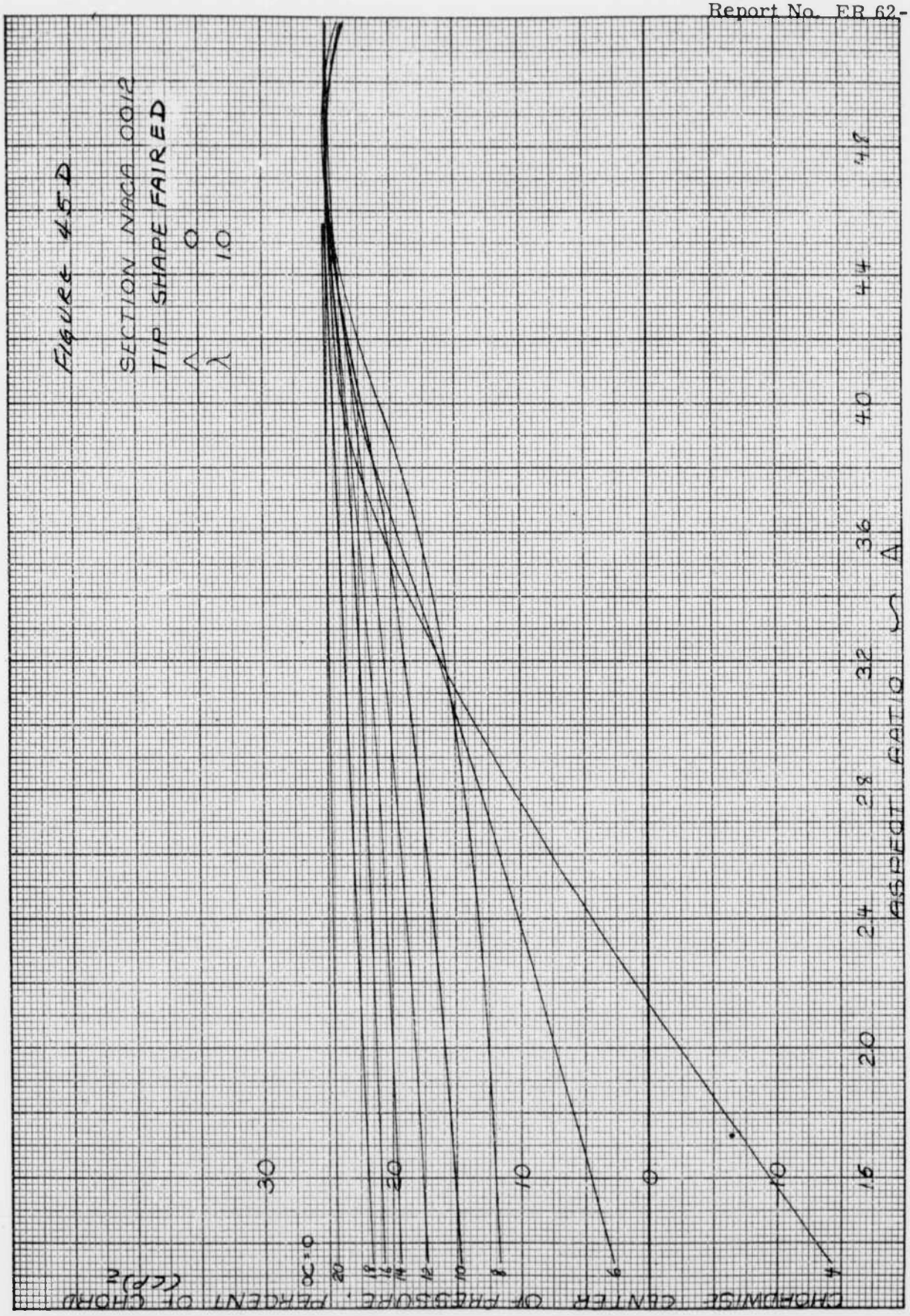


FIGURE 45D
SECTION NACA 0012
TIP SHARE FAIRED
Λ 0
λ 1.0
ASPECT RATIO A
16
20
24
28
32
36
40
44
48
10
0
-10
30
20
10
0
CHORDWISE CENTER OF PRESSURE, PERCENT OF CHORD (cp)c
α 0-3
2
4
6
8
10
12
14

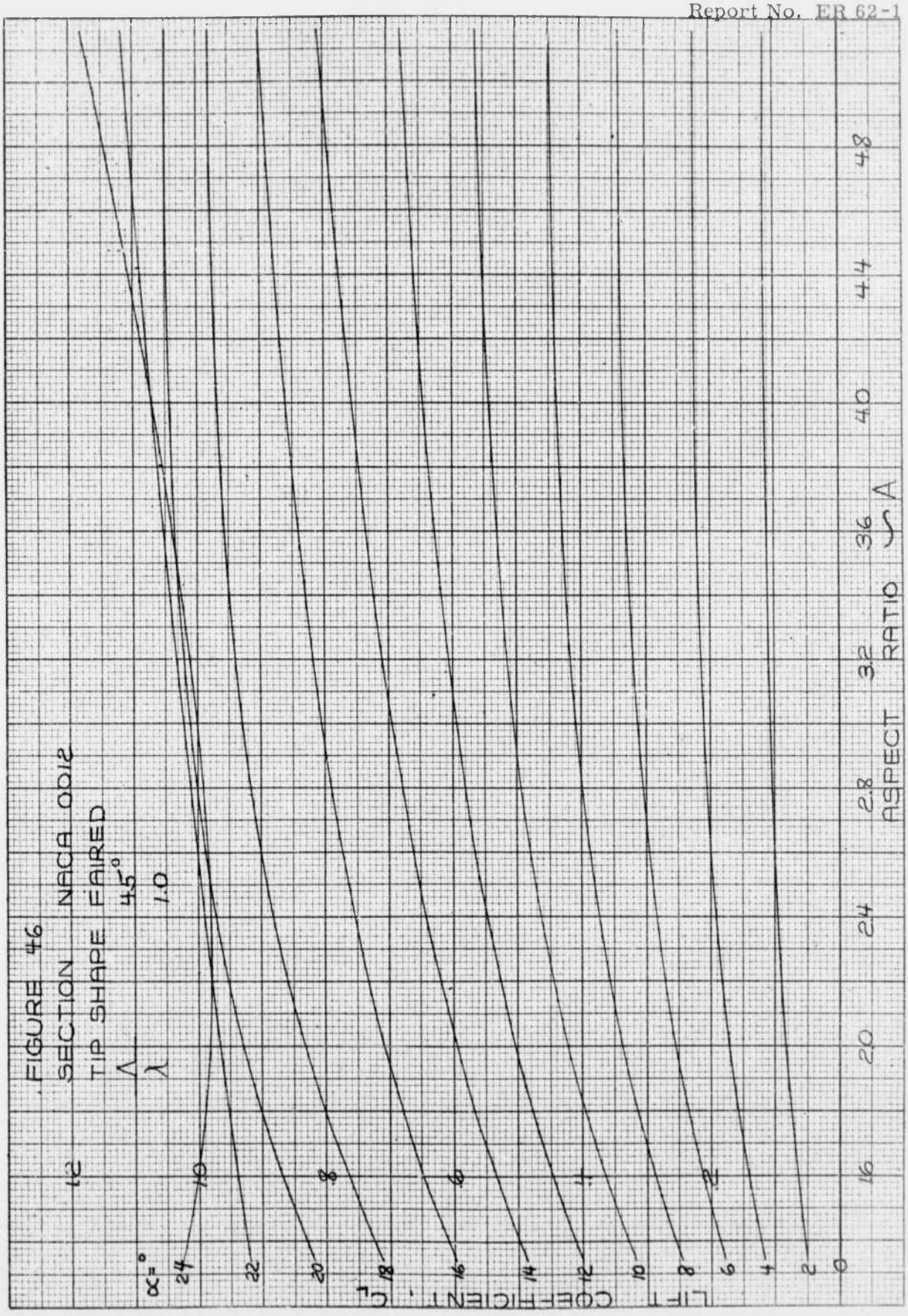


FIGURE 46
SECTION NACA 0012
TIP SHAPE FAIRED
Λ 45°
λ 1.0
t/c
α=°
24
22
20
18
16
14
12
10
8
6
4
2
0
LIFT COEFFICIENT, C_L
0
4
8
12
16
20
24
28
32
36
40
44
48
ASPECT RATIO A

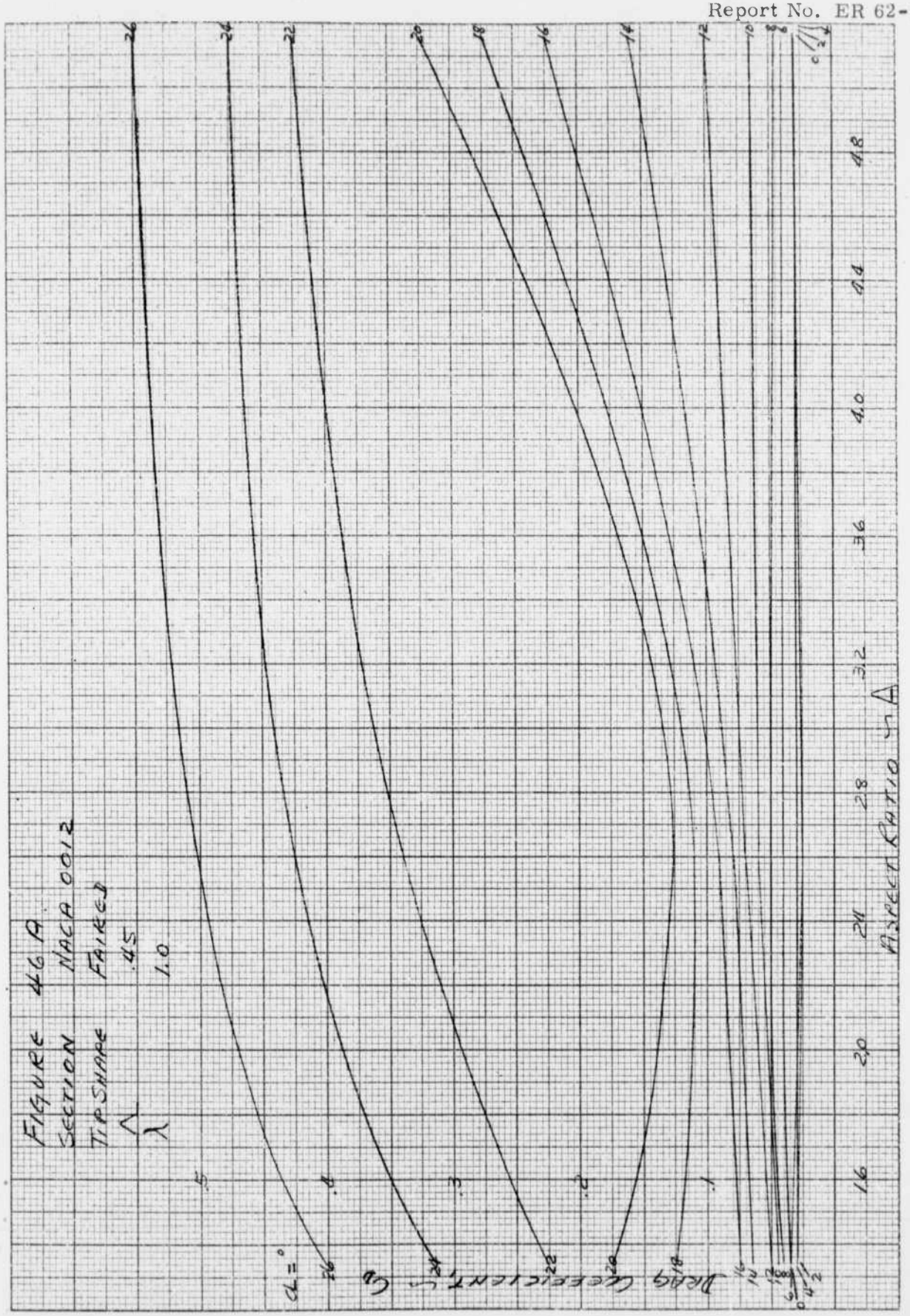


FIGURE 46 A
SECTION NACA 0012
TIP SHAPE FAIRED
Λ .45
λ 1.0
Drag Coefficient C_D
Aspect Ratio A
C_L = 0
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
16
20
24
28
32
36
40
44
48
4.0

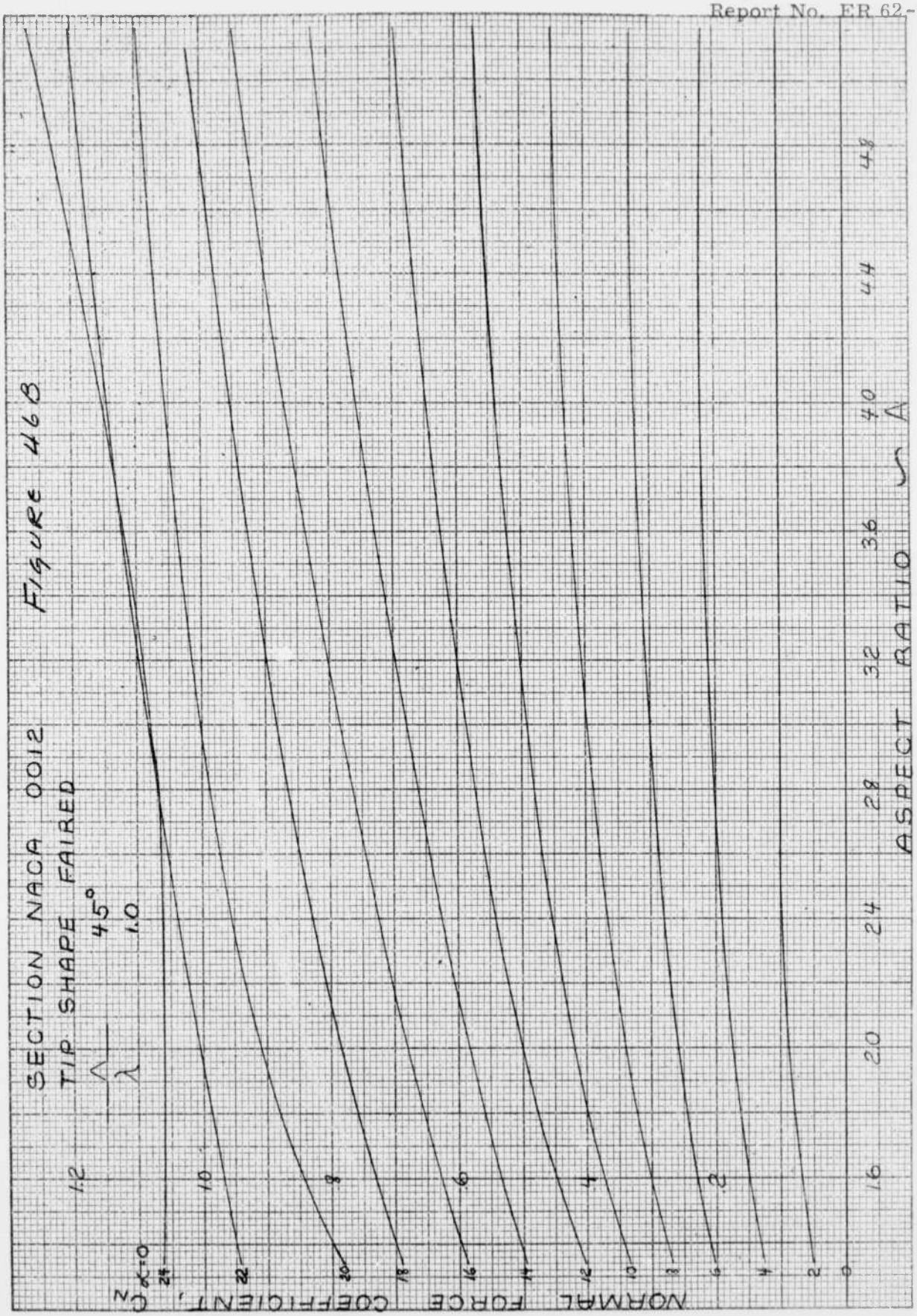

SECTION NACA 0012
TIP SHAPE FAIRED
Λ 45°
λ 1.0
NORMAL FORCE COEFFICIENT, C_{N_α}
ASPECT RATIO A
0
2
4
6
8
10
12
14
16
18
20
22
24
28
32
36
40
44
48
1.2

Figure 46B

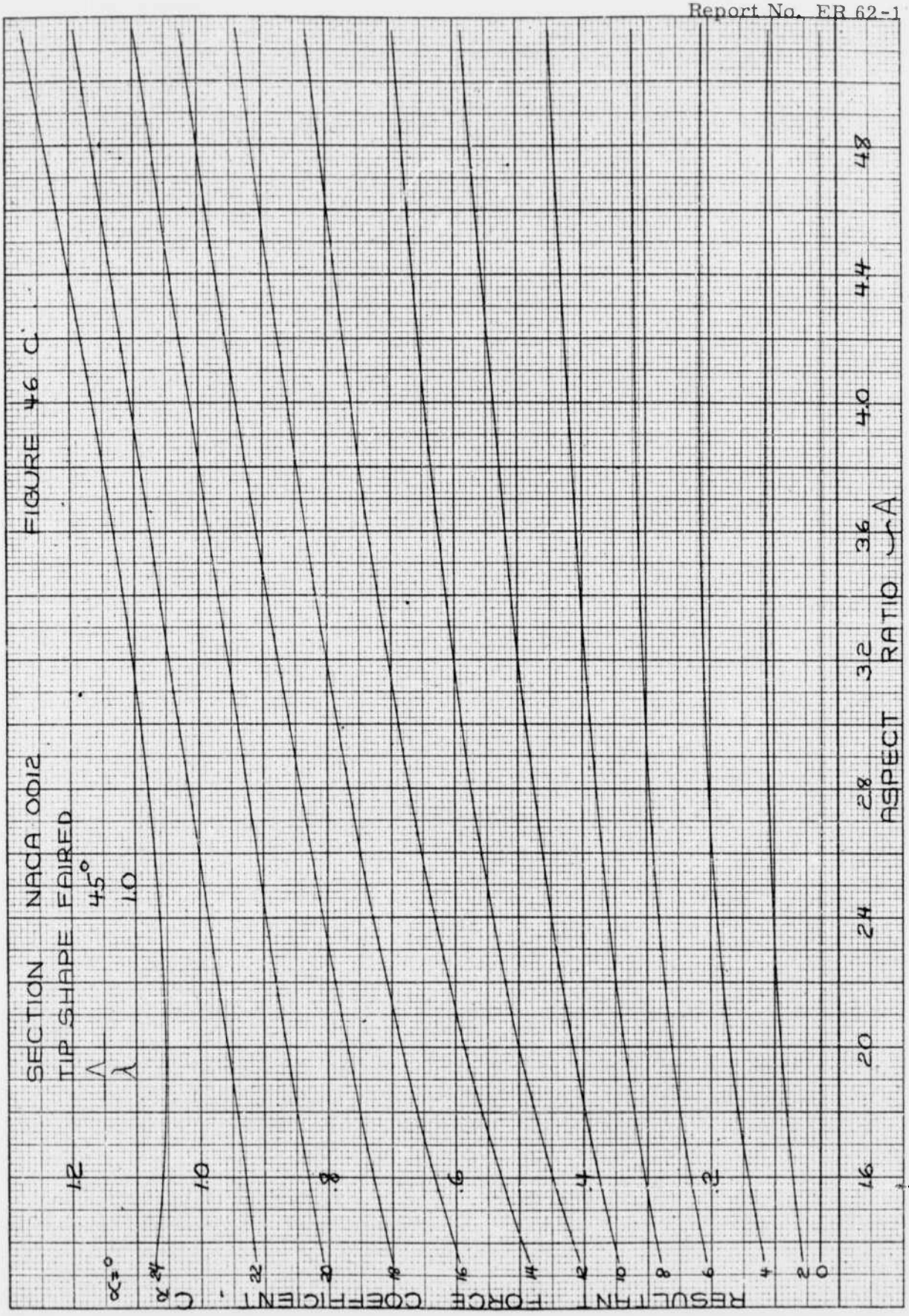


FIGURE 46 C
SECTION NACA 0012
TIP SHAPE FAIRED
Λ 45°
λ 1.0
ASPECT RATIO A
RESULTANT FORCE COEFFICIENT C_R
0
2
4
6
8
10
12
14
16
18
20
22
16
20
24
28
32
36
40
44
48
1.0
.8
.6
.4
.2
α=0°

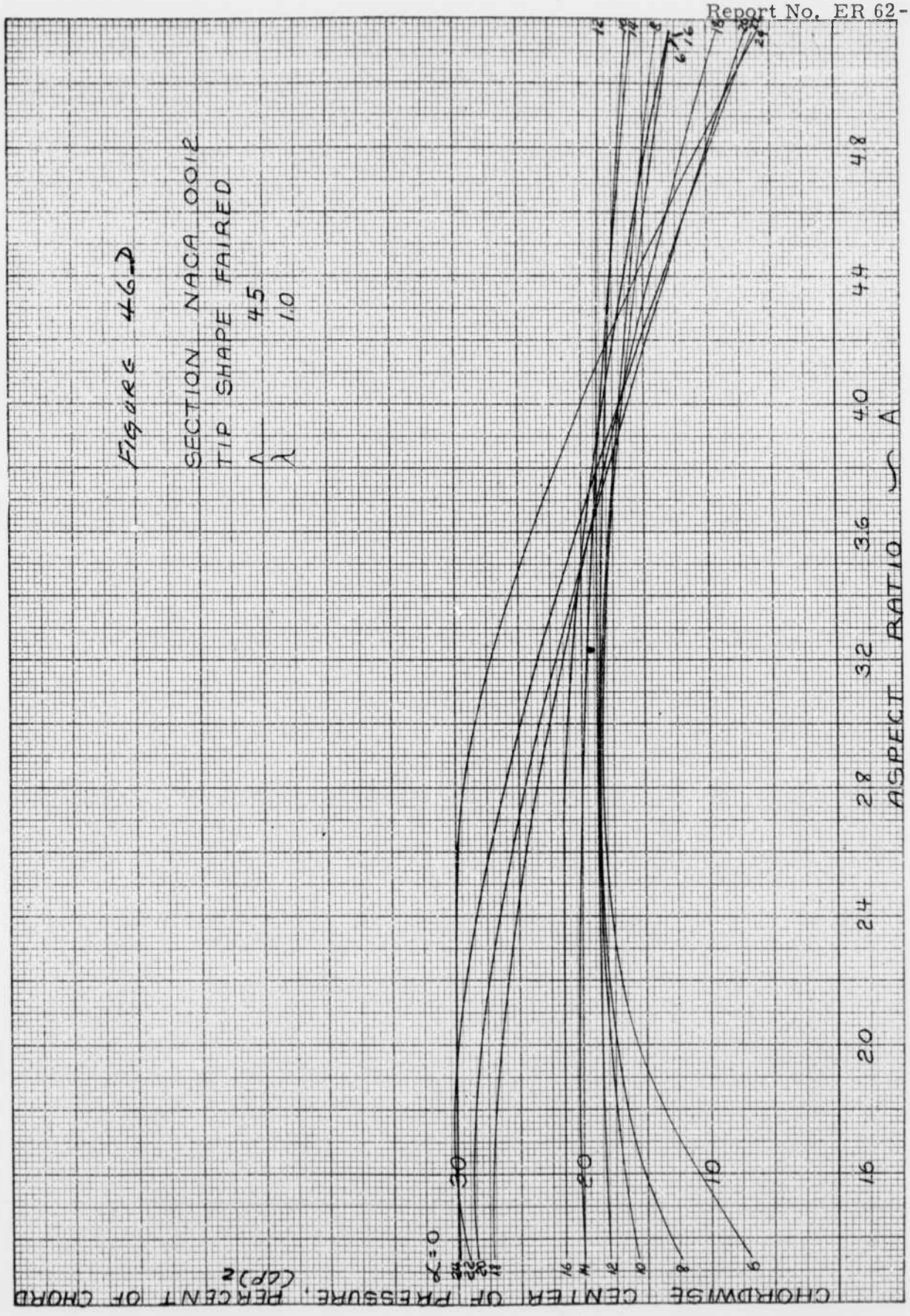


Figure 46-D
SECTION NACA 0012
TIP SHAPE FAIRED
Λ 45
λ 1.0
CHORDWISE CENTER OF PRESSURE, PERCENT OF CHORD
ASPECT RATIO A
16
20
24
28
32
36
40
44
48
10
20
30
α=0
6
8
10
12
14
16
18
20
22
24

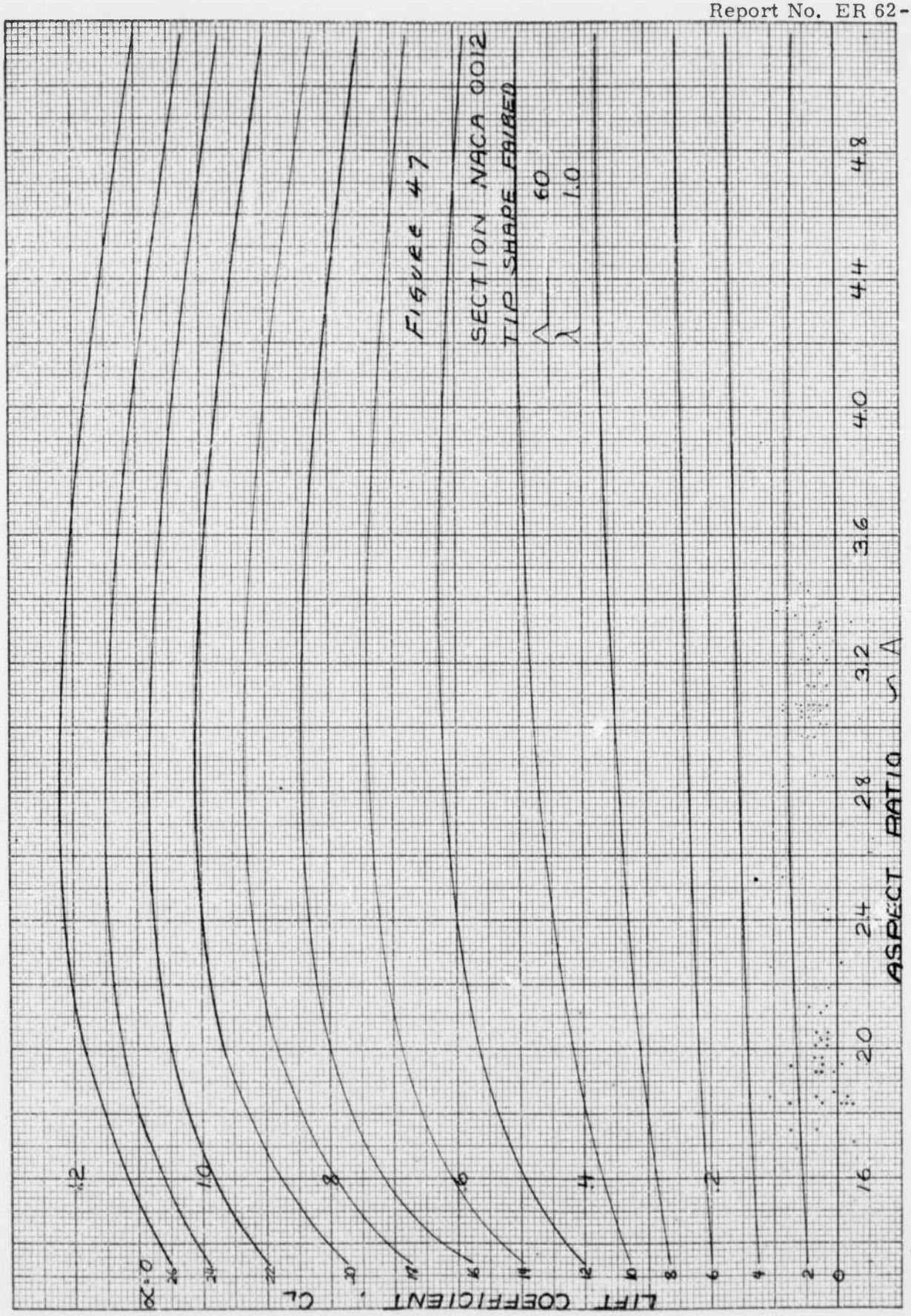


FIGURE 47
SECTION NACA 0012
TIP SHAPE FAIRED
Λ 60
λ 1.0
LIFT COEFFICIENT CL
ASPECT RATIO A
0
2
4
6
8
10
12
16
20
24
28
32
36
40
44
48
α=0
2
4
6
8
10
12
14
16
18
20
22
24
26

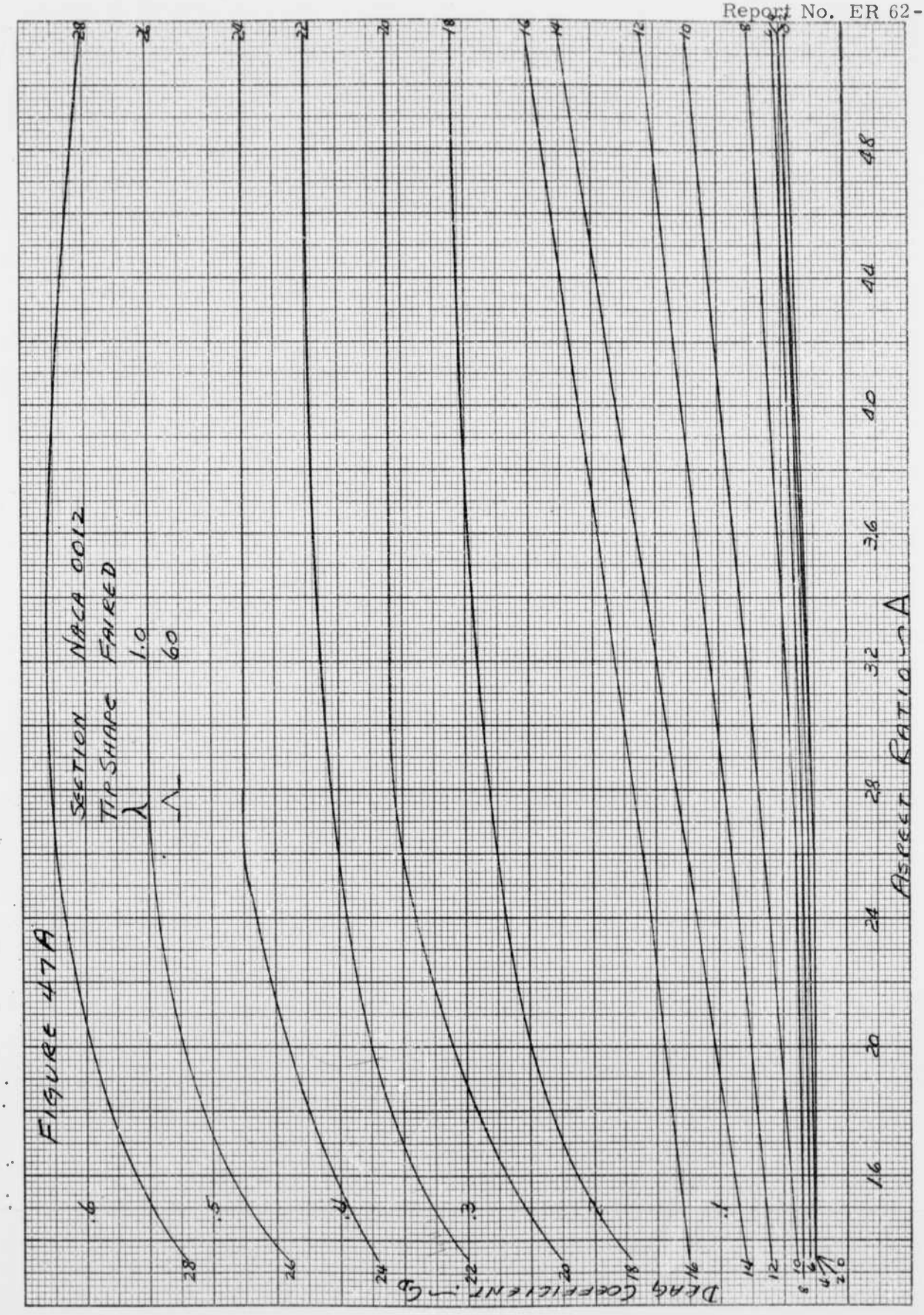


FIGURE 47A
SECTION NACA 0012
TIP SHAPE FAIRED
1.0
60
DRAG COEFFICIENT C_D
ASPECT RATIO A
4
8
12
16
20
24
28
32
36
40
44
48
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3.0

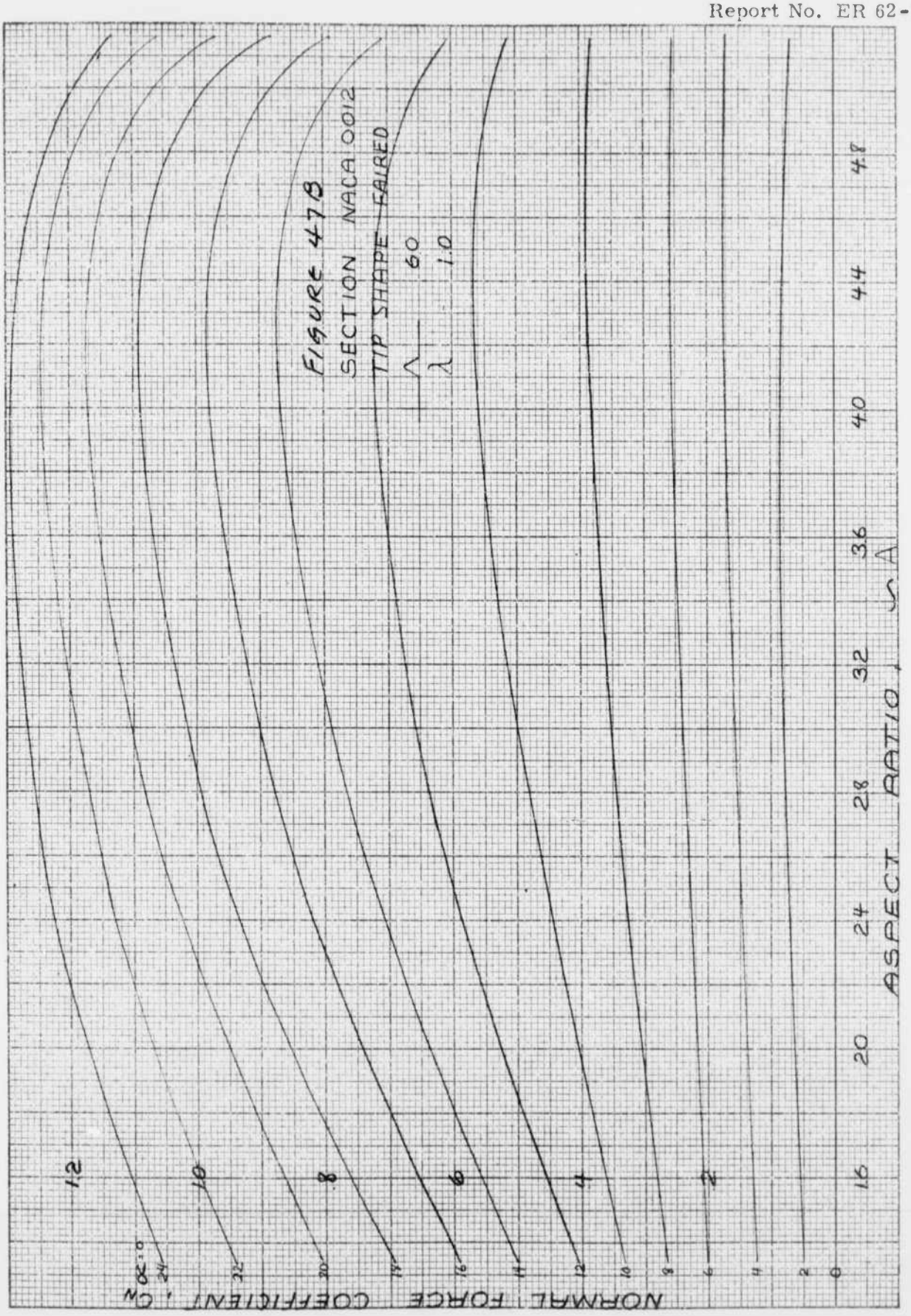


FIGURE 478
SECTION NACA 0012
TIP SHAPE FAIRED
Λ 60
λ 1.0
NORMAL FORCE COEFFICIENT, $C_{N_{\alpha=0}}$
ASPECT RATIO, A
0
2
4
6
8
10
12
16
20
24
28
32
36
40
44
48

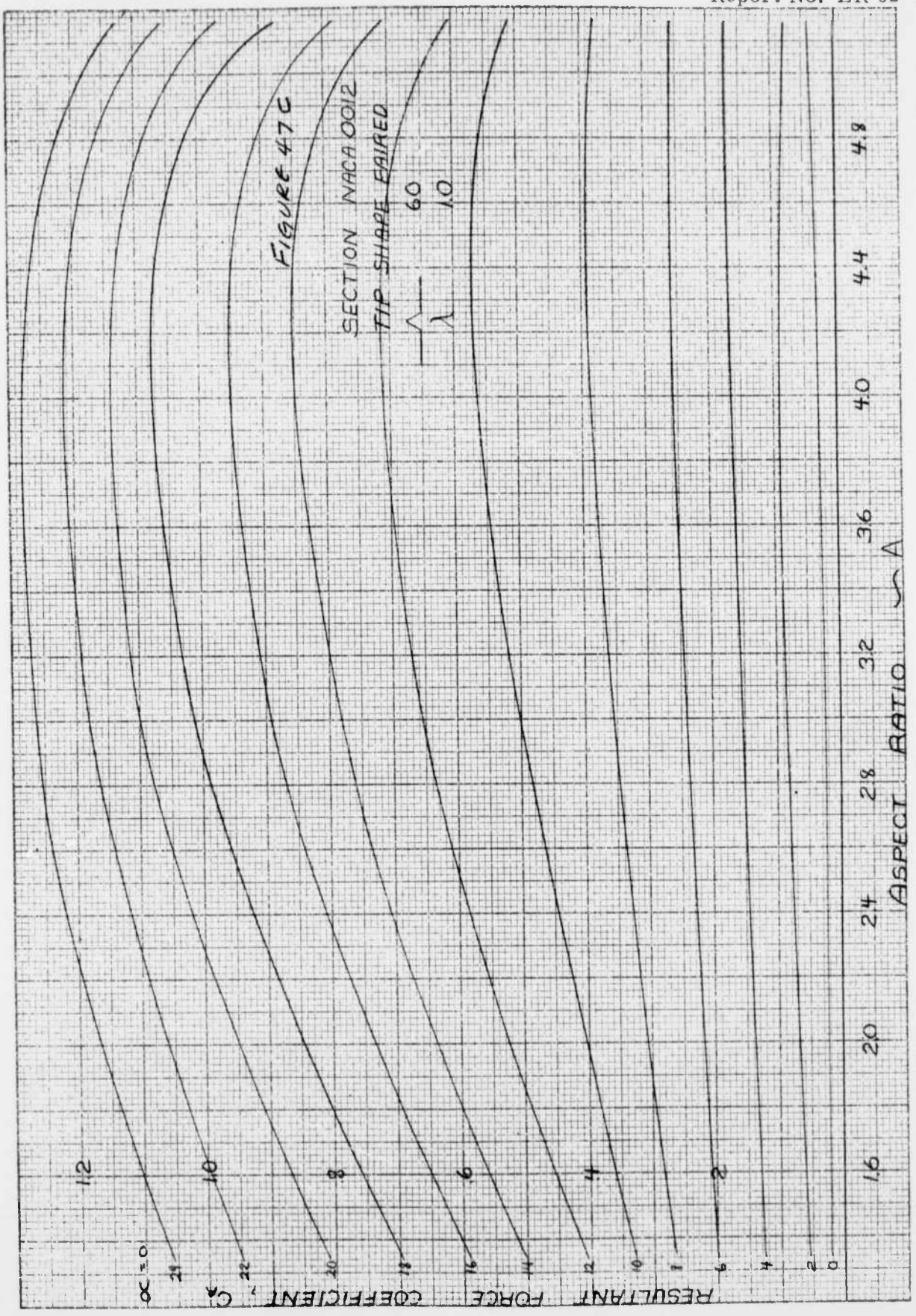


FIGURE 47 C
SECTION NACA 0012
TIP SHAPE FAIRED
λ 1.0 6.0
RESULTANT FORCE COEFFICIENT, C_A
ASPECT RATIO A
1.6
2.0
2.4
2.8
3.2
3.6
4.0
4.4
4.8
0
2
4
6
8
10
12
14
16
18
20
22
24
α = 0

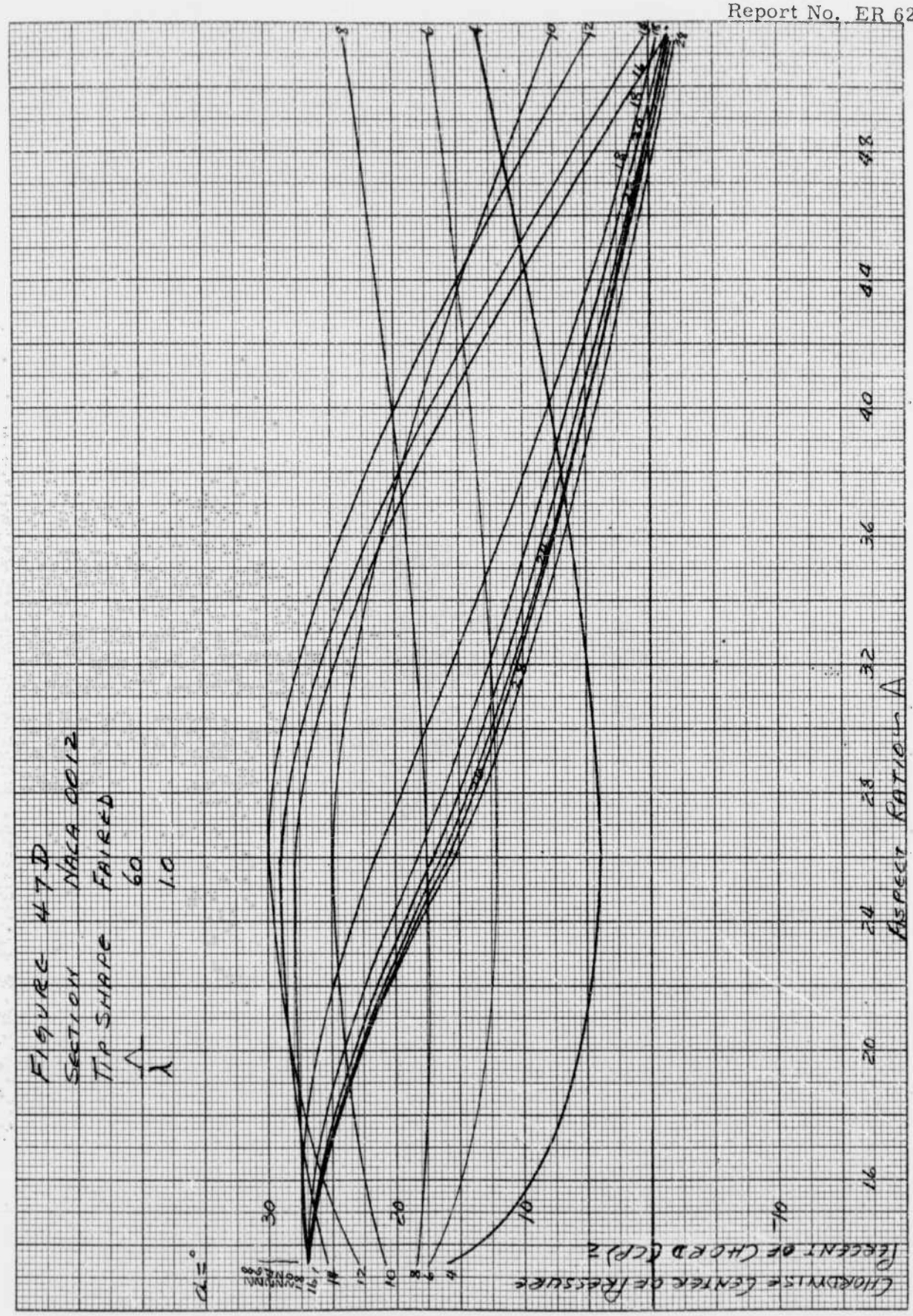


FIGURE 47D
SECTION NACA 0012
TIP SHAPE FAIRED
60
1.0
Λ
λ
ASPECT RATIO, A
CHORDWISE CENTER OF PRESSURE
PERCENT OF CHORD (CP)x
α = °

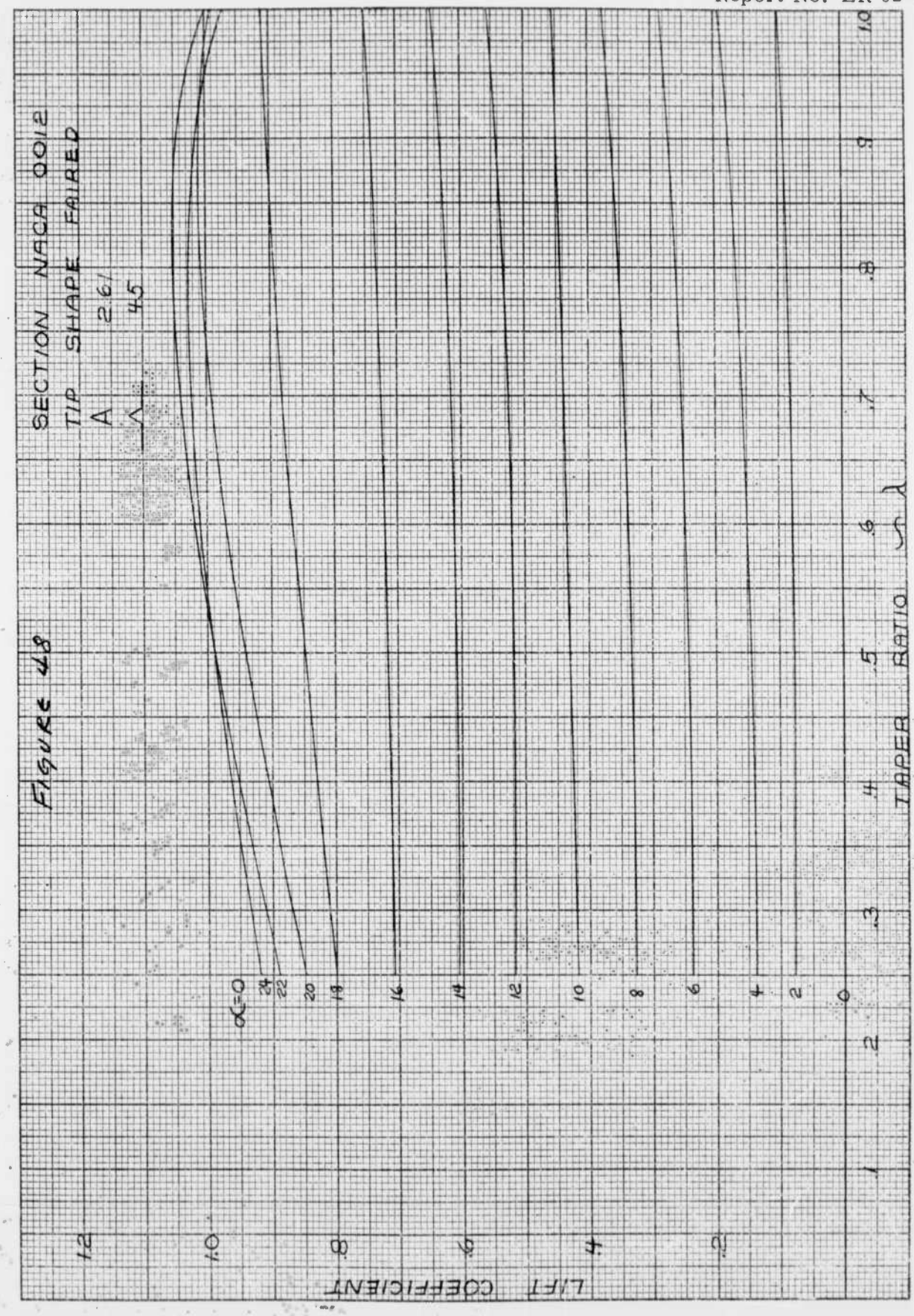

SECTION NACA 0012
TIP SHAPE FAIRED
A 2.67
Λ 45
α=0
24
22
20
18
16
14
12
10
8
6
4
2
0
1.2
1.0
.8
.6
.4
.2
LIFT COEFFICIENT
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
TAPER RATIO λ

FIGURE 48

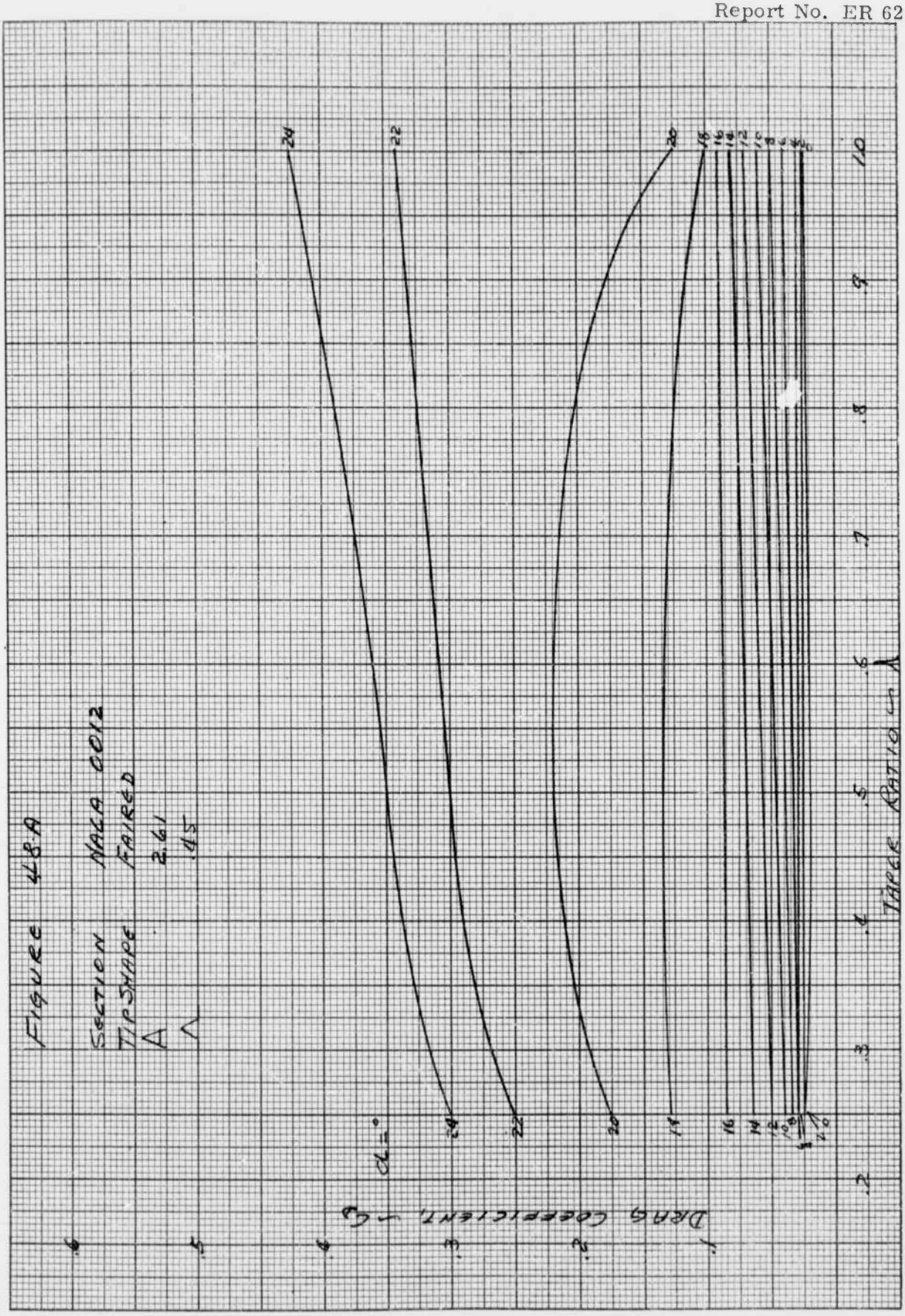


Figure 48A
Section NACA 0012
Tip Shape Faired
Δ 2.61
Λ 45
Drag Coefficient, C_D
Taper Ratio λ
C_L =
24
22
20
18
16
14
12
10
8
6
4
2
0
.2
.3
.4
.5
.6
.7
.8
.9
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6

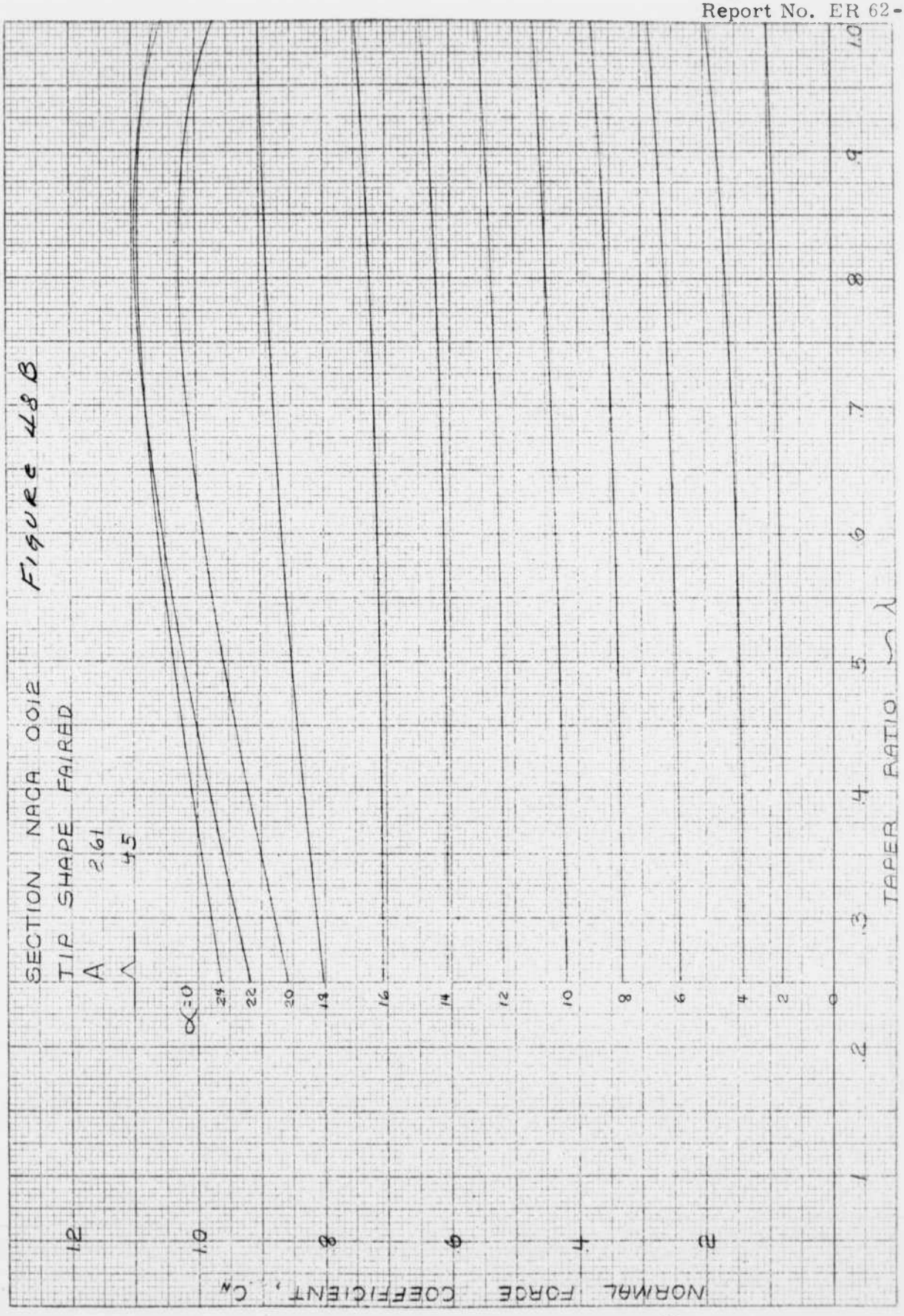

SECTION NACA 0012
TIP SHAPE FAIRED
A 2.61
Λ 45
α=0
24
22
20
18
16
14
12
10
8
6
4
2
0
NORMAL FORCE COEFFICIENT, C_N
TAPER RATIO λ
1.2
1.0
.8
.6
.4
.2
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0

FIGURE 48B

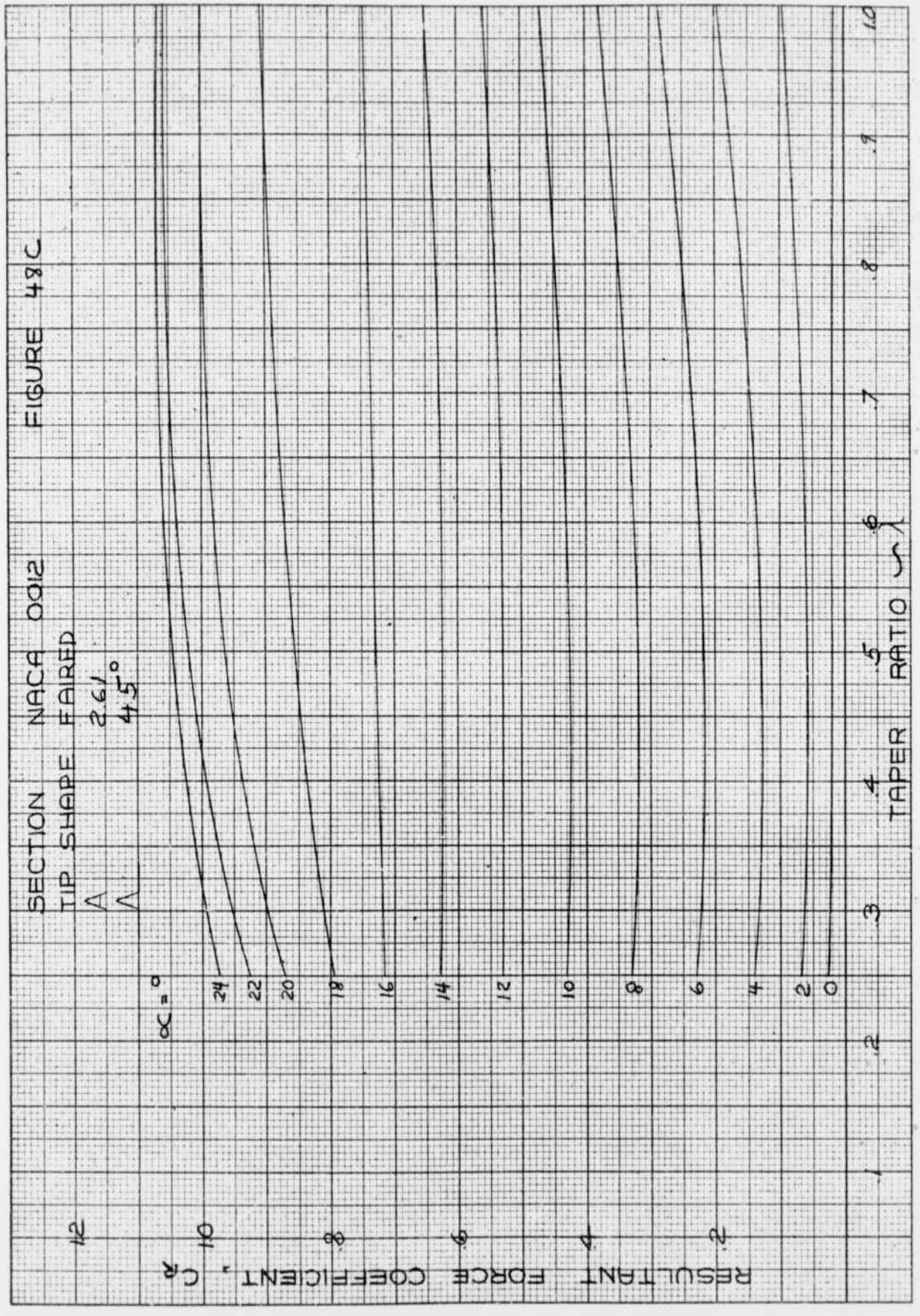


FIGURE 48C
SECTION NACA 0012
TIP SHAPE FAIRED
A 2.61
Λ 45.5°
RESULTANT FORCE COEFFICIENT, C_R
TAPER RATIO λ
α = 0
24
22
20
18
16
14
12
10
8
6
4
2
0
12
10
8
6
4
2
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0

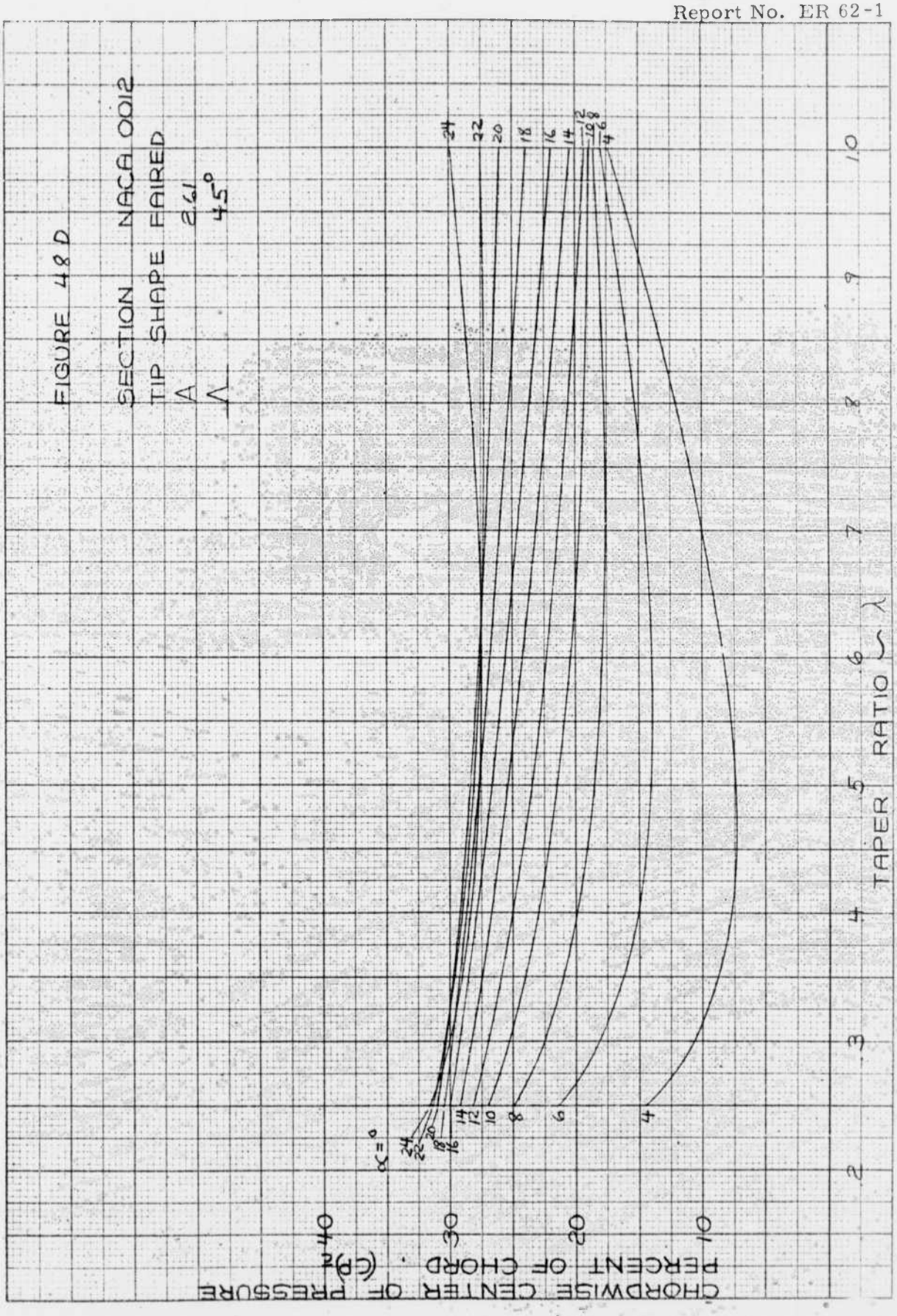


FIGURE 48 D
SECTION NACA 0012
TIP SHAPE FAIRED
A 2.61
Λ 45°
CHORDWISE CENTER OF PRESSURE
PERCENT OF CHORD (CP)
TAPER RATIO λ
α = 0
24
22
20
18
16
14
12
10
8
6
4

FIGURE 4.9

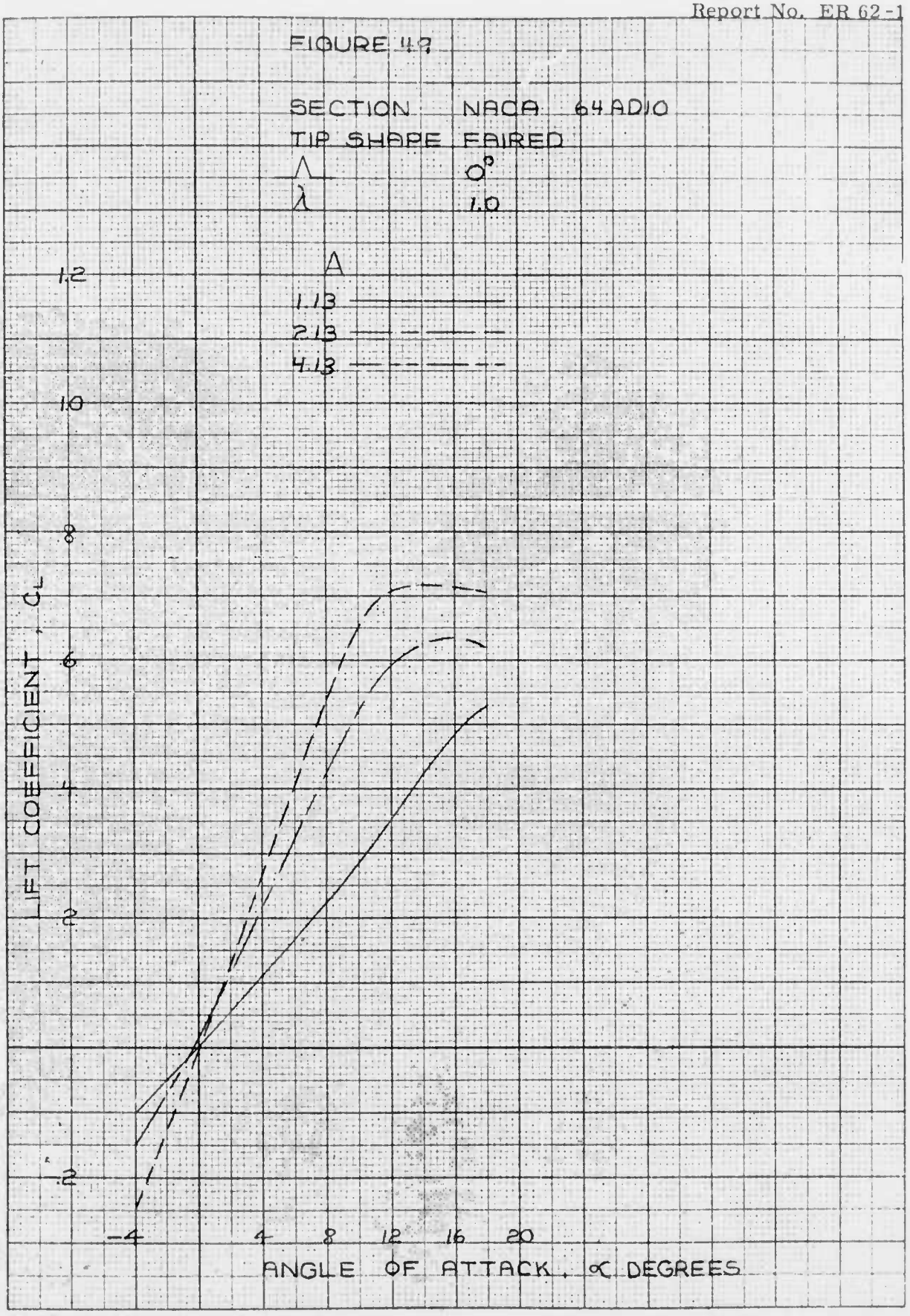
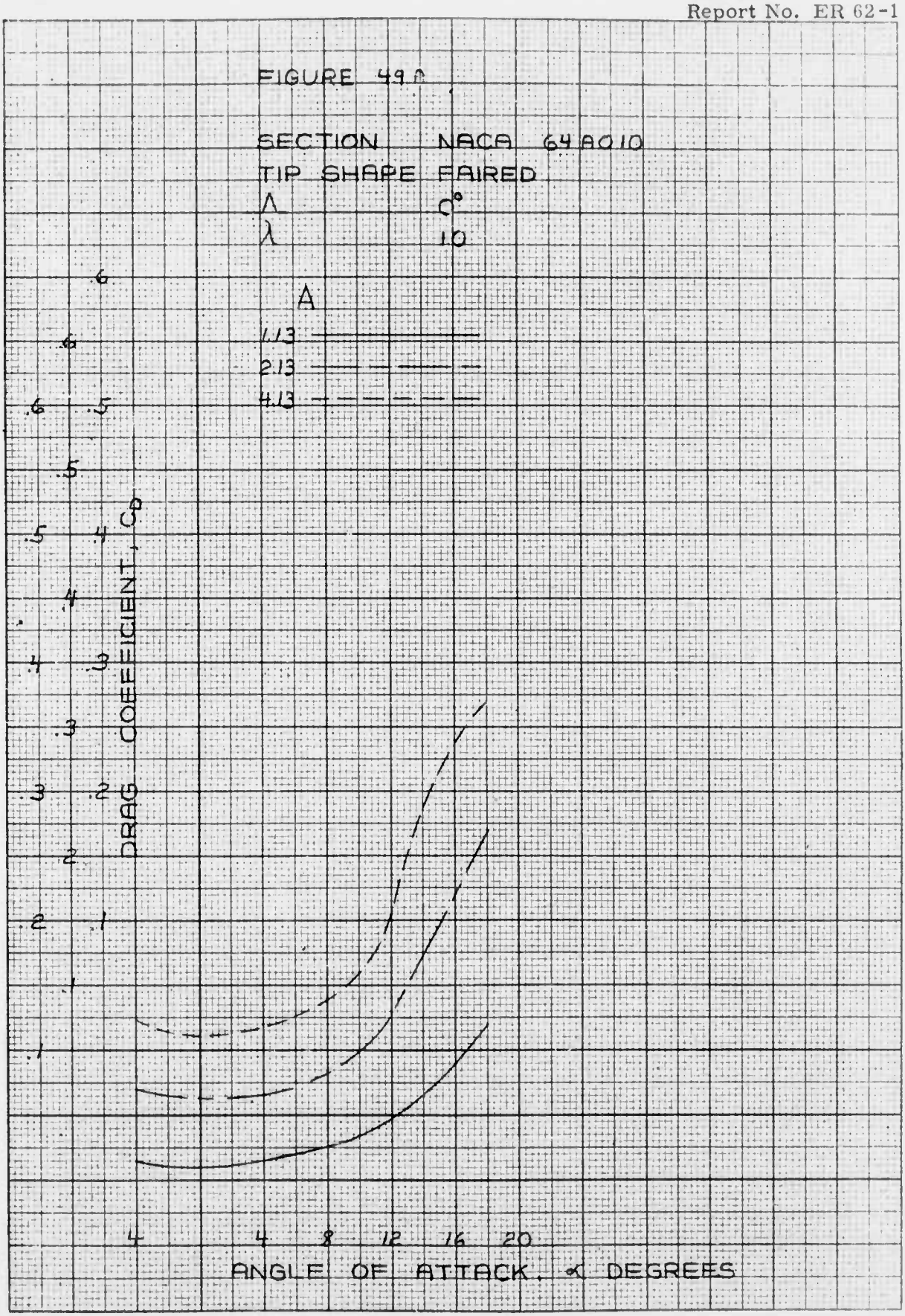

SECTION NACA 64A010
TIP SHAPE FAIRED
Λ 0°
λ 1.0
A
1.13
2.13
4.13
1.2
1.0
.8
.6
.4
.2
-.2
LIFT COEFFICIENT, C_L
-4
4
8
12
16
20
ANGLE OF ATTACK, α DEGREES

FIGURE 49

SECTION NACA 64A010
TIP SHAPE FAIRED
Λ 0°
λ 1.0

A
1.13
2.13
4.13



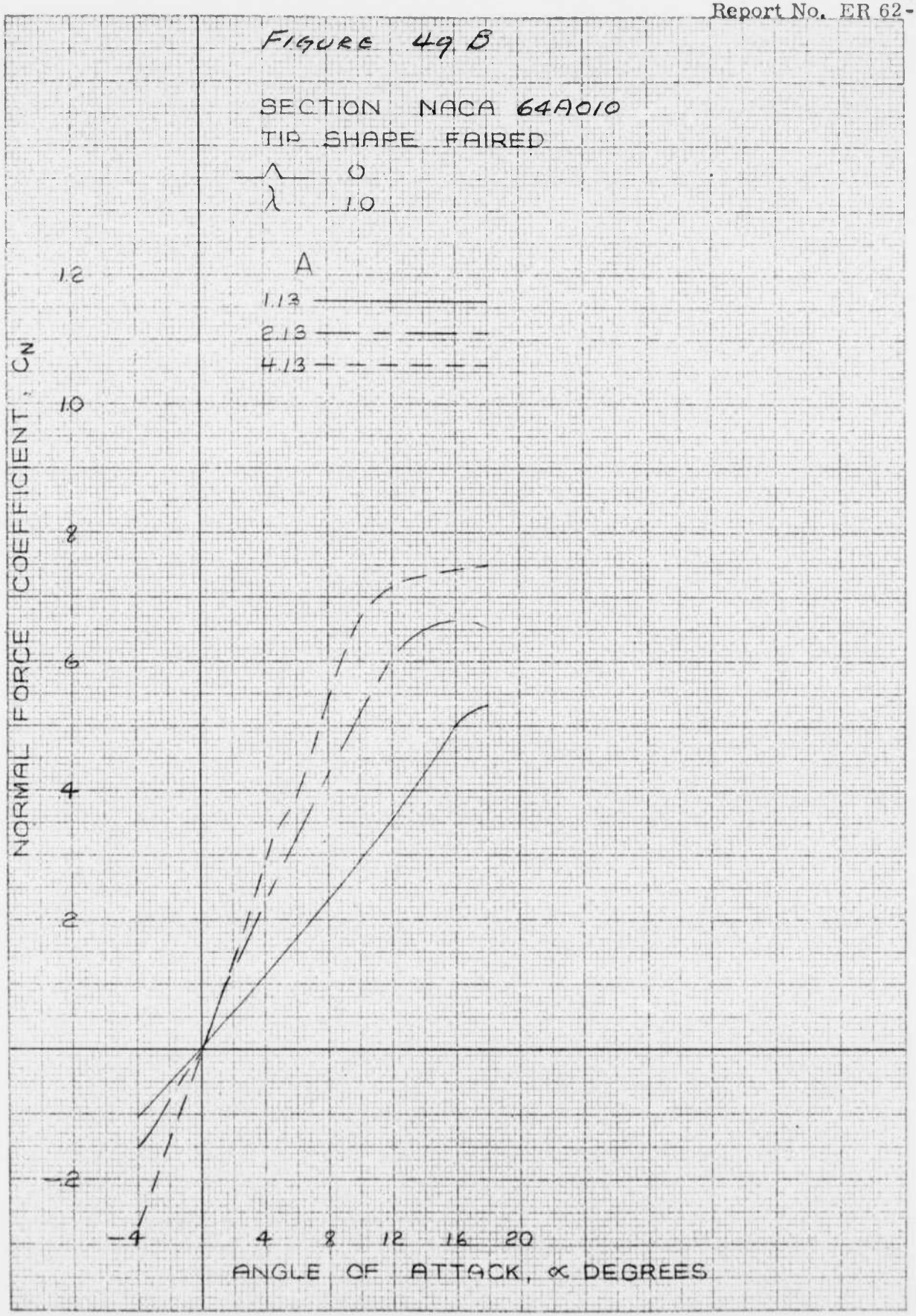


FIGURE 49 B
SECTION NACA 64A010
TIP SHAPE FAIRED
Λ 0
λ 1.0
A
1.13
2.13
4.13
NORMAL FORCE COEFFICIENT, CN
1.2
1.0
.8
.6
.4
.2
-.2
-.4
4
8
12
16
20
ANGLE OF ATTACK, α DEGREES

FIGURE 49C

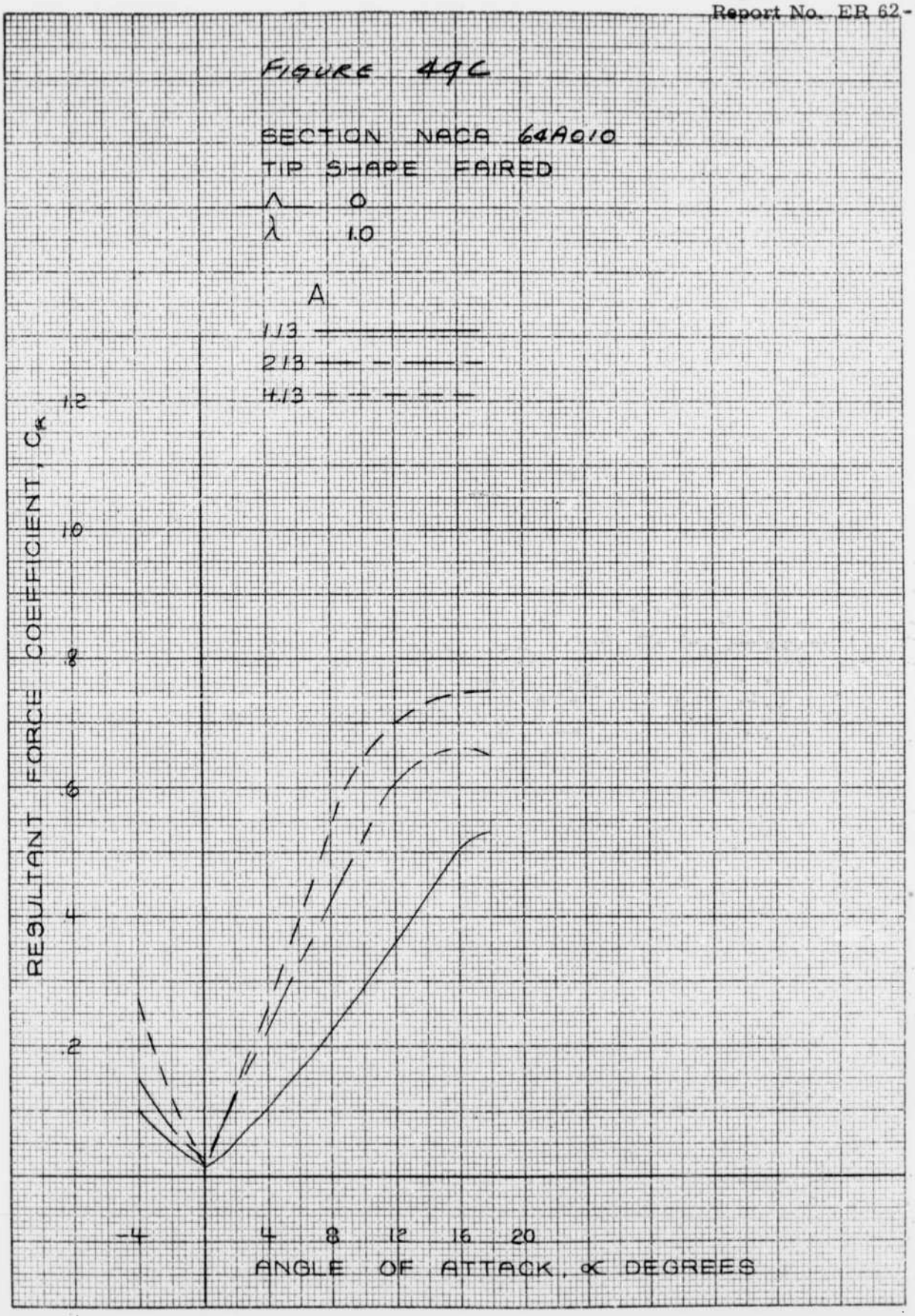
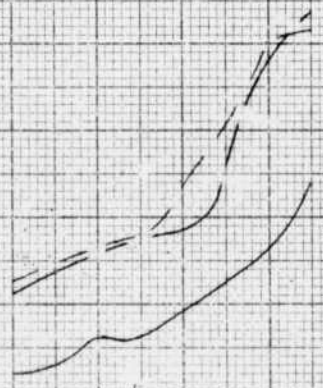

SECTION NACA 64A010
TIP SHAPE FAIRED
Λ 0
λ 1.0
A
1.13
2.13
4.13
RESULTANT FORCE COEFFICIENT, C_R
1.2
1.0
.8
.6
.4
.2
-4
4
8
12
16
20
ANGLE OF ATTACK, α DEGREES

FIGURE 49 D

SECTION NACA 64A010
TIP SHAPE FAIRED

Λ	0
λ	1.0

A
1.13
2.13
4.13



CHORDWISE CENTER OF PRESSURE
PERCENT OF CHORD, (CP)c

30
20
10

-4
4 8 12 16 20
ANGLE OF ATTACK, α DEGREES

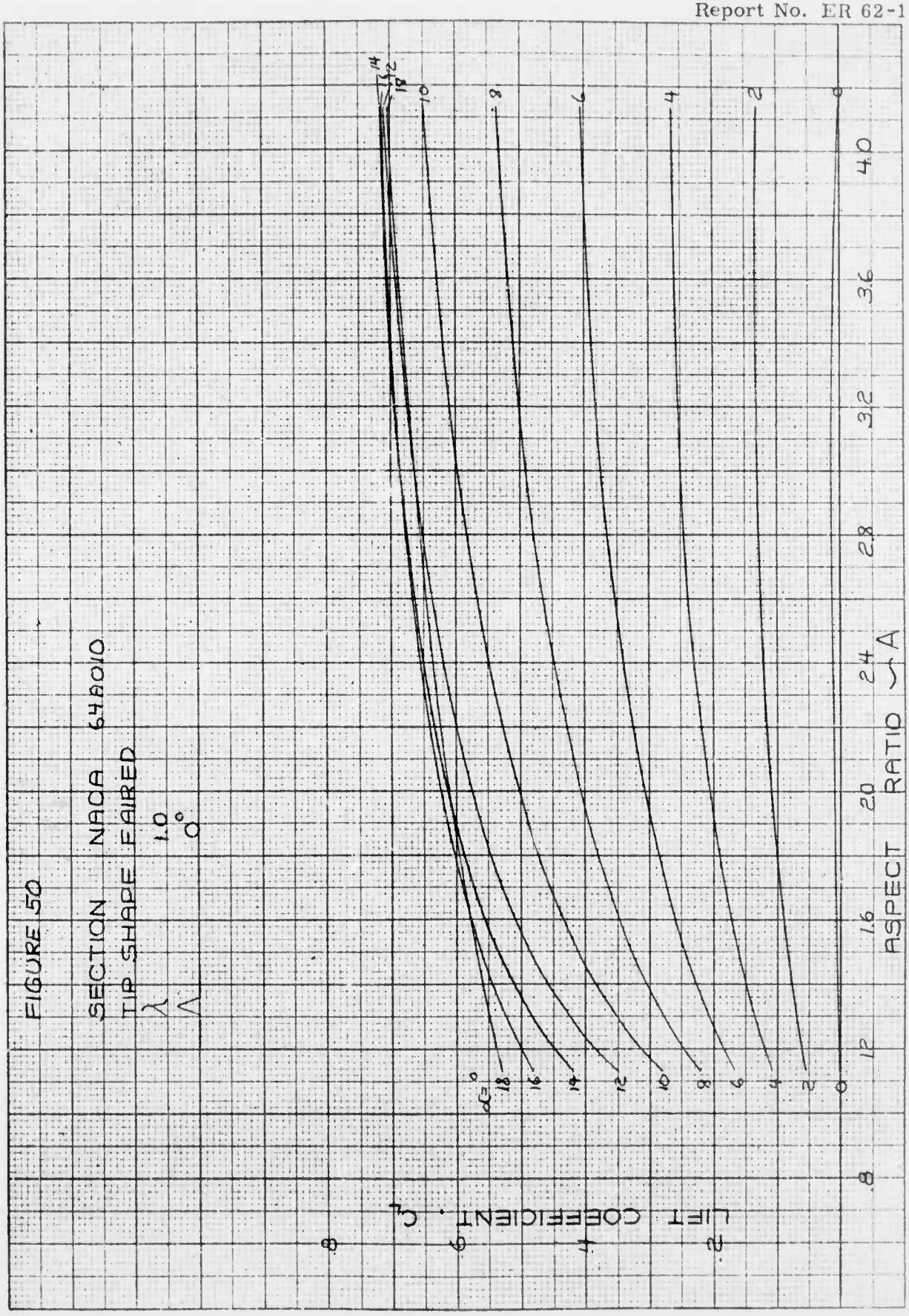

LIFT COEFFICIENT, C_L
ASPECT RATIO, A
0
.4
.8
1.2
1.6
2.0
2.4
2.8
3.2
3.6
4.0
0
2
4
6
8
10
12
14
16
18
α_{ZL}
SECTION NACA 64A010
TIP SHAPE FAIRED
λ 1.0
Λ 0°

FIGURE 50

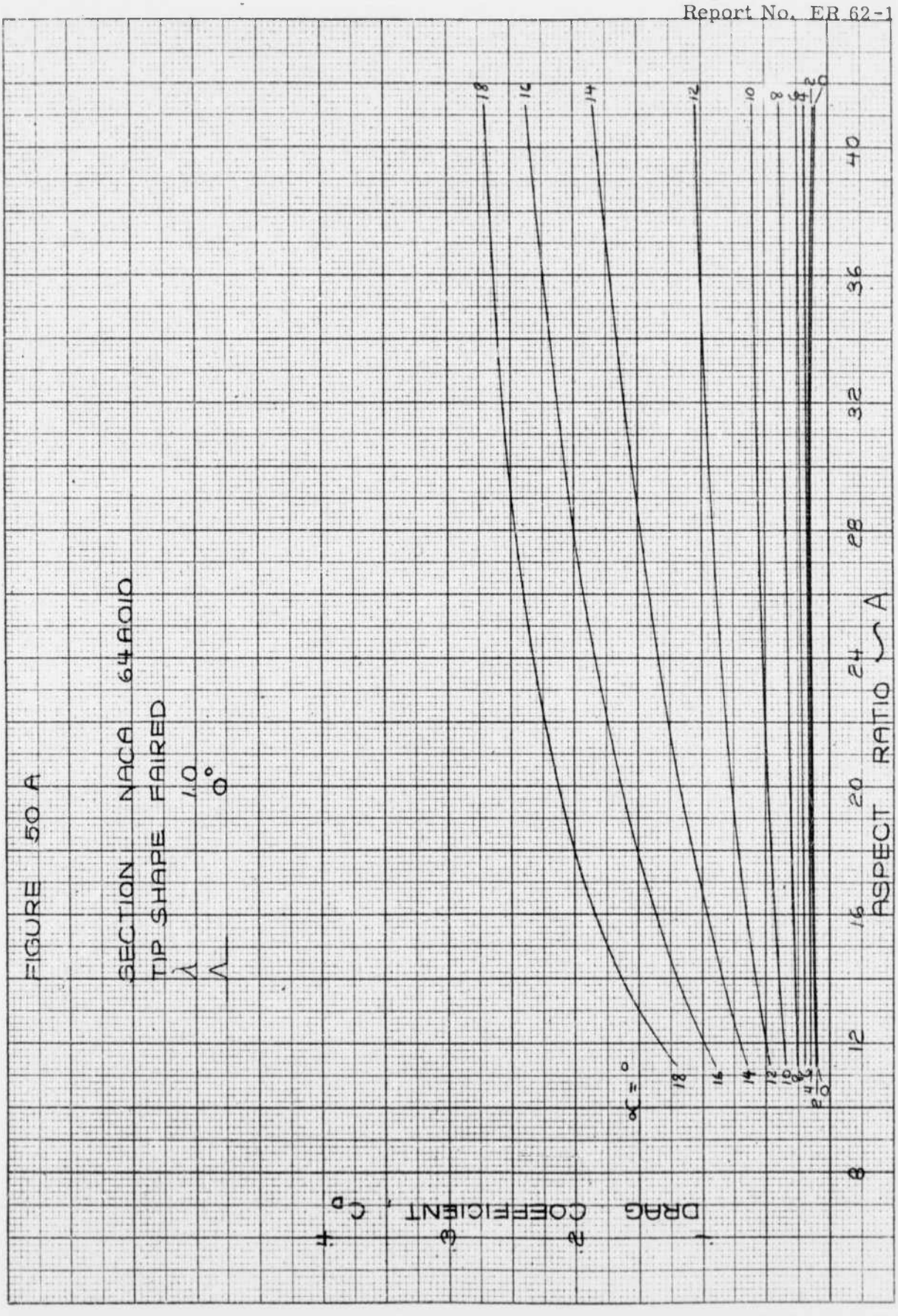


FIGURE 50 A

SECTION NACA 64A010
TIP SHAPE FAIRED
λ 1.0
Λ 0°

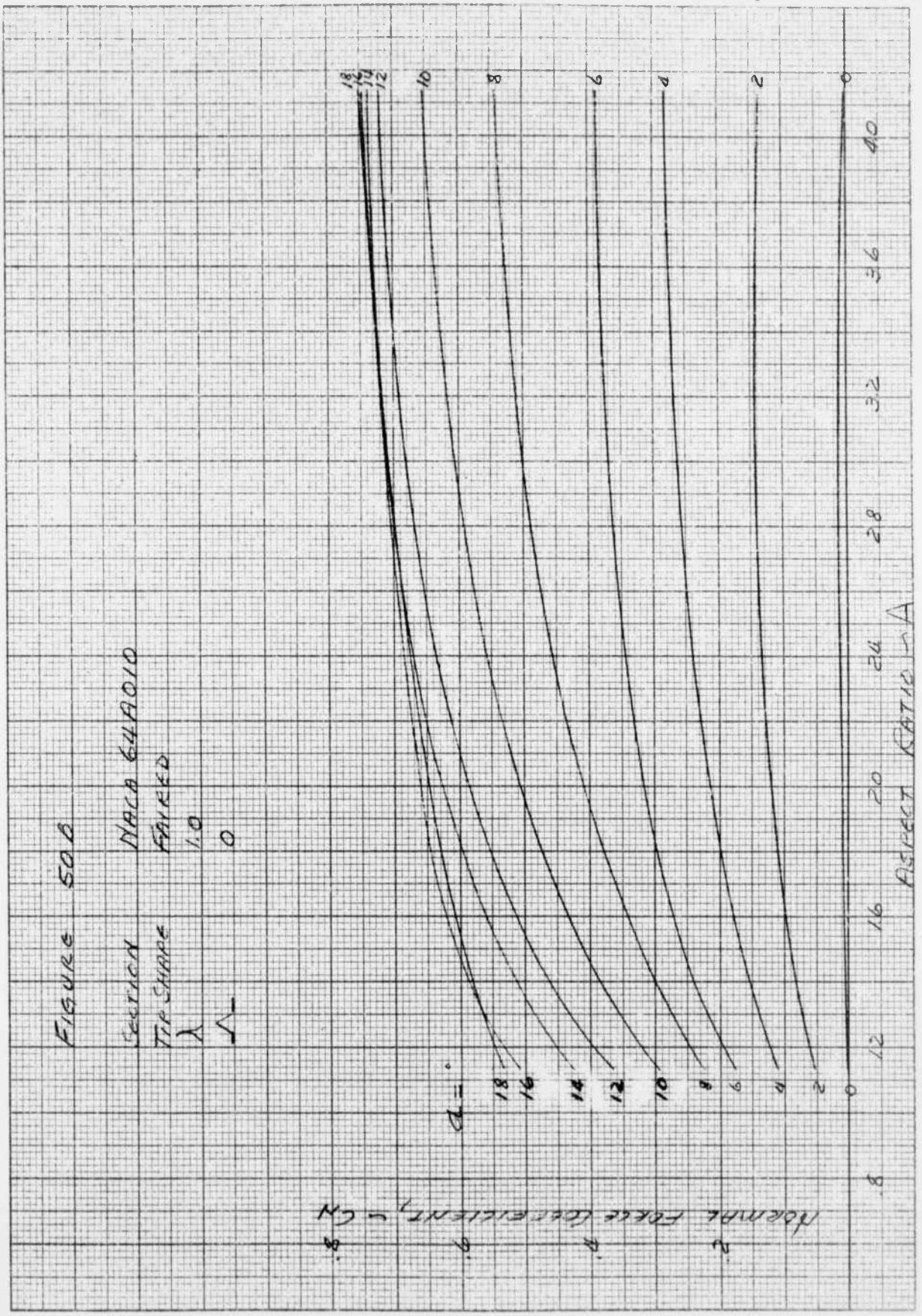


FIGURE 508
SECTION NACA 64A010
TIP SHAPE FAIRED
λ 1.0
Λ 0
NORMAL FORCE COEFFICIENT, C_N
ABSOLUTE ANGLE OF ATTACK, α
C_L = 1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
0
0
4
8
12
16
20
24
28
32
36
40

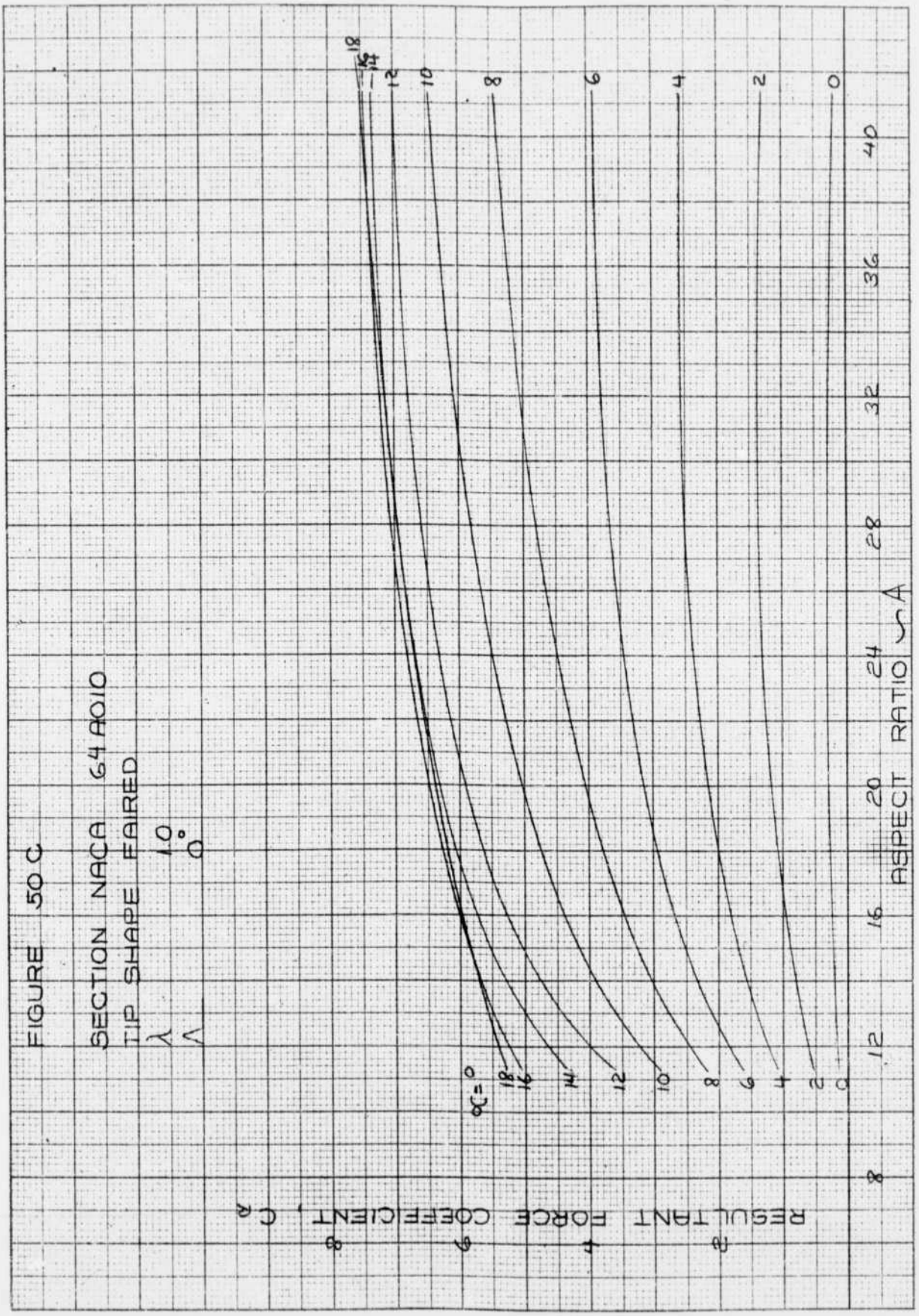


FIGURE 50 C
SECTION NACA 64 A010
TIP SHAPE FAIRED
λ 1.0
Λ 0°
RESULTANT FORCE COEFFICIENT, C_R
ASPECT RATIO A
$\alpha_c = 0$
0
2
4
6
8
10
12
14
16
18
8
12
16
20
24
28
32
36
40

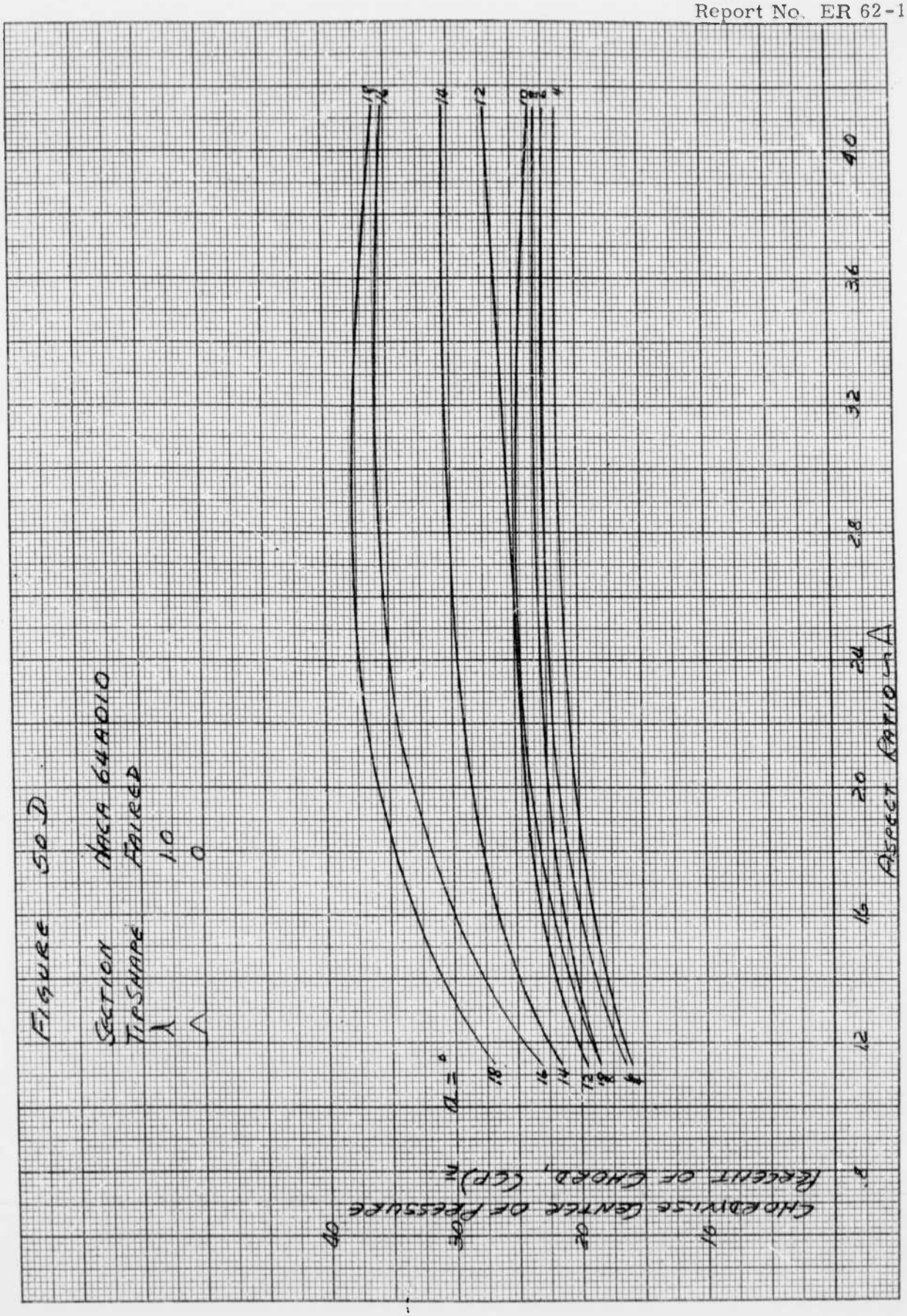


FIGURE 50 D
SECTION NACA 64A010
TIPSHAPE FAIRED
λ 1.0
Λ 0
CHORDWISE CENTER OF PRESSURE
RECENT OF CHORD, (CP)c
ASPECT RATIO A
α = °
18
16
14
12
10
8
4
40
36
32
28
24
20
16
12
8
4
0
10
20
30
40