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RESEARCH MEMORANDUM

for the

Air Materiel Command, Army Air Forces

FORCE TESTS OF THE BOEING XB-47 FULL-SCALE EMPENNAGE
IN THE AMES 40- BY 80-FOOT WIND TUNNEL

By Lynn W. Hunton

Ames Aeronautical Laboratory
Moffett Field, Calif.

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SUMMARY

A wind-tunnel investigation of the Boeing XB-47 full-scale empennage was conducted to provide, prior to flight tests, data required on the effectiveness of the elevator and rudder. The XB-47 airplane is a jet-propelled medium bomber having wing and tail surfaces swept back 35° . The investigation included tests of the effectiveness of the elevator with normal straight sides, with a bulged trailing edge, and with a modified hinge-line gap and tests of the effectiveness of the rudder with a normal straight-sided tab and with a bulged tab.

INTRODUCTION

The Boeing XB-47 airplane is a jet-propelled medium bomber with swept-back wings and tail surfaces. In view of the lack of available flight data on swept control surfaces, the Air Materiel Command requested that tests of the effectiveness of the elevator and rudder be conducted in the Ames 40- by 80-foot wind tunnel prior to the initial flight test of the first experimental bomber. For the investigation the contractor supplied a special model of the tail assembly incorporating the actual tail surfaces from the existing experimental XB-47 airplane.

The results presented herein include the effectiveness of the elevator for a range of attitudes of the horizontal

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stabilizer and the effectiveness of the rudder at various angles of sideslip.

SYMBOLS

The symbols used in this report are defined as follows:

C_L	lift coefficient $\left(\frac{\text{lift}}{qS_H}\right)$
C_Y	side-force coefficient $\left(\frac{\text{side force}}{qS_Y}\right)$
S_H	horizontal-tail area (268 sq ft)
S_Y	vertical-tail area (219.7 sq ft)
q	free-stream dynamic pressure, pounds per square foot
α_u	geometric angle of attack of the fuselage reference line relative to tunnel center line, degrees
α	true angle of attack of the fuselage reference line relative to air stream, degrees
β	angle of sideslip, degrees
δ_e	elevator deflection, degrees
δ_r	rudder deflection, degrees
δ_t	tab deflection, degrees

MODEL

Presented in figure 1 is a three-view drawing of the model. The body, which was of a reinforced steel shell construction, was designed and built by the contractor to simulate the tail cone of the XB-47 airplane. On this body were mounted the actual horizontal and vertical tail surfaces from the first experimental XB-47 airplane. The installation of the model in the tunnel test section is shown in figure 2. Due to the height of the vertical tail, the model had to be mounted

approximately 7 feet below the center line of the air stream in order to obtain the desired angle-of-attack range. Such a deviation from a normal test installation required a special set of support struts as shown in figure 2. Since the drag forces in this investigation were of little importance, no attempt was made to shield these special struts with fairings.

The elevator and rudder were both constant-percent chord (0.3c) with an internal balance panel linkage as shown in figure 3. Both the horizontal and vertical surfaces employed an NACA 65010 airfoil section (measured parallel to wind axis) with cusps removed. The control-surface movement and position indication were effected by electric actuators and selsyns which were installed in the control system. Deflections of the right elevator tab (left tab locked in neutral for all tests) were obtained by locking the tab in various fixed positions. The rudder tab, however, was controllable remotely with an actuator. The modifications tested included a bulged trailing edge and a reduced hinge-line gap on the elevator and a bulged tab on the rudder. Details of these modifications are given with the test results.

TESTS AND RESULTS

The force tests were run at a dynamic pressure of 30 pounds per square foot which corresponds to an airspeed of about 110 miles per hour at standard sea-level conditions (Reynolds numbers of approximately 8×10^6 and 12×10^6 for the horizontal and vertical surfaces, respectively, based on the mean chord). The investigation consisted of two parts: (a) effectiveness tests of the elevator with several different modifications; and (b) effectiveness tests of the rudder at 4 angles of sideslip (-0.3° , -3.4° , -6.3° , and -9.8°) with both a plain and a bulged tab. All force data are presented with reference to the wind axes. A sketch showing the positive directions of the forces is given in figure 4. All data presented as a function of angle of attack α have been corrected for stream angle inclination (0.04° up-flow) and for the influence of the jet boundary as follows:

$$a_T = \delta_w \frac{S_H}{C} C_L 57.3$$

where

δ_w boundary-correction factor (0.11)

S_H horizontal-tail area (268 sq ft)

C cross sectional area of tunnel (2856 sq ft)

All other data obtained at various fixed attitudes of the tail surfaces (horizontal and vertical) are presented herein at the particular geometric angle of attack α_u with no correction for the aforementioned effects. Although the vertical surface tip was rather close to the tunnel wall, no boundary correction has been applied to the measured angle of sideslip β , since no reliable wall correction was available for such an unusual tunnel-model configuration.

Results of the tests of the horizontal tail are presented in figures 5 to 8. Shown in figure 5 for the basic horizontal surface are the lift characteristics as a function, first, of angle of attack for several fixed elevator deflections, and second, of elevator deflection for several fixed angles of attack. It should be noted on this figure that the data for the lift characteristics in pitch of the surface when compared with the other data at equivalent test conditions show a discrepancy amounting to approximately 1.5° of elevator deflection. All data have been thoroughly checked and no explanation can be found. The data of figure 6 show the effect of fixed deflections of the right elevator tab on the effectiveness of the basic elevator. The effectiveness of the elevator with a bulged trailing edge, which extended over approximately 40 percent of the elevator span, is shown in figure 7. Also included in this figure is a sketch showing the location and cross section of the trailing-edge bulge. In figure 8 elevator effectiveness data are shown which were obtained with a modified gap at the elevator hinge line. For this modification, details of which are shown in figure 8, the shroud over the entire span was extended thus reducing the gap opening by as much as 40 percent at some points.

The results of the investigation of the effectiveness of the rudder are presented in figures 9(a) to 9(d) for angles of sideslip of -0.3° , -3.4° , -6.3° , and -9.8° , respectively. At each angle of sideslip, effectiveness data with the rudder tab in several fixed positions were obtained for the basic rudder

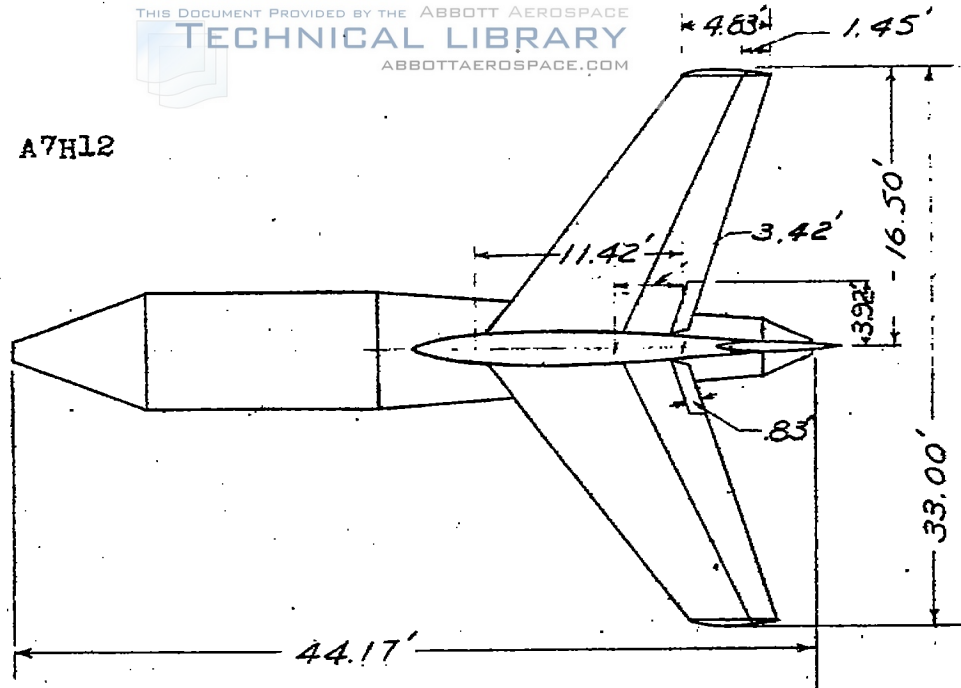
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surface (straight-sided tab) and for the rudder with a bulged tab. A sketch showing a cross-sectional comparison of the straight-sided and the bulged rudder tab is included in figure 9(a). All tests of the rudder were made at an angle of attack of 0° .

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	HORIZ TAIL	VERT. TAIL
AREA	268 SQ.FT.	219.7 SQ.FT.
SPAN	33 FT.	18.67 FT.
SWEEP OF $\frac{1}{4}$	32.8°	35.0°

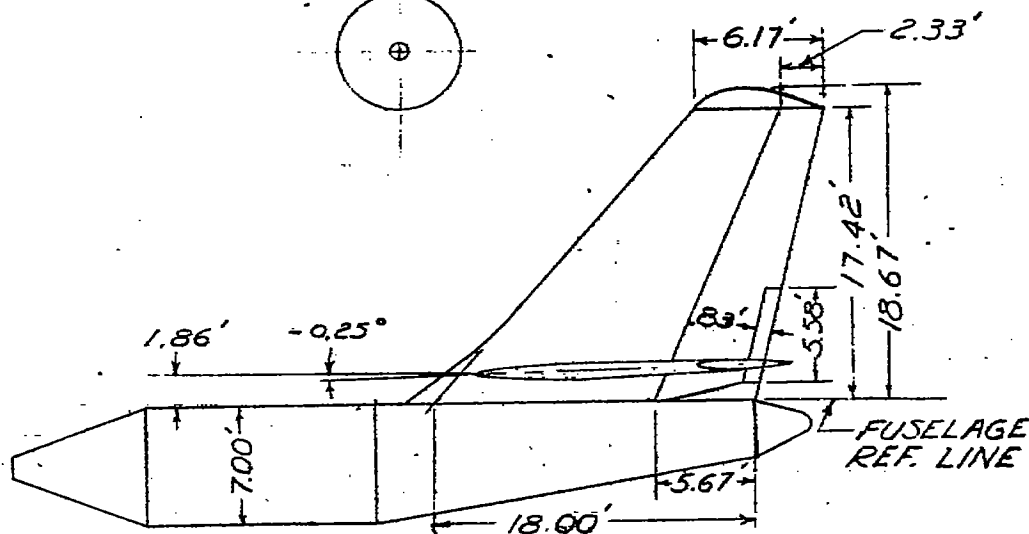
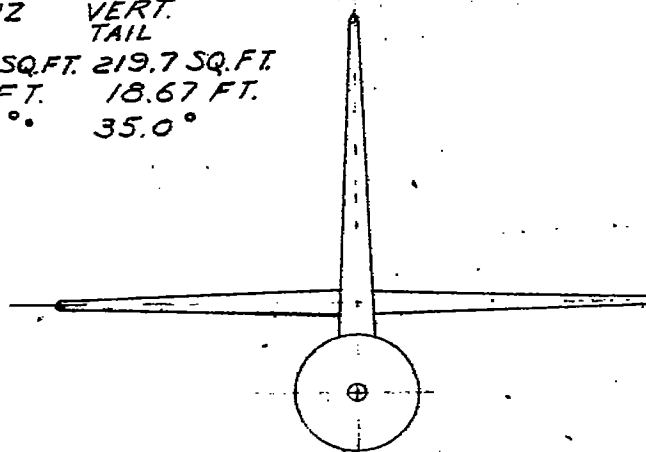
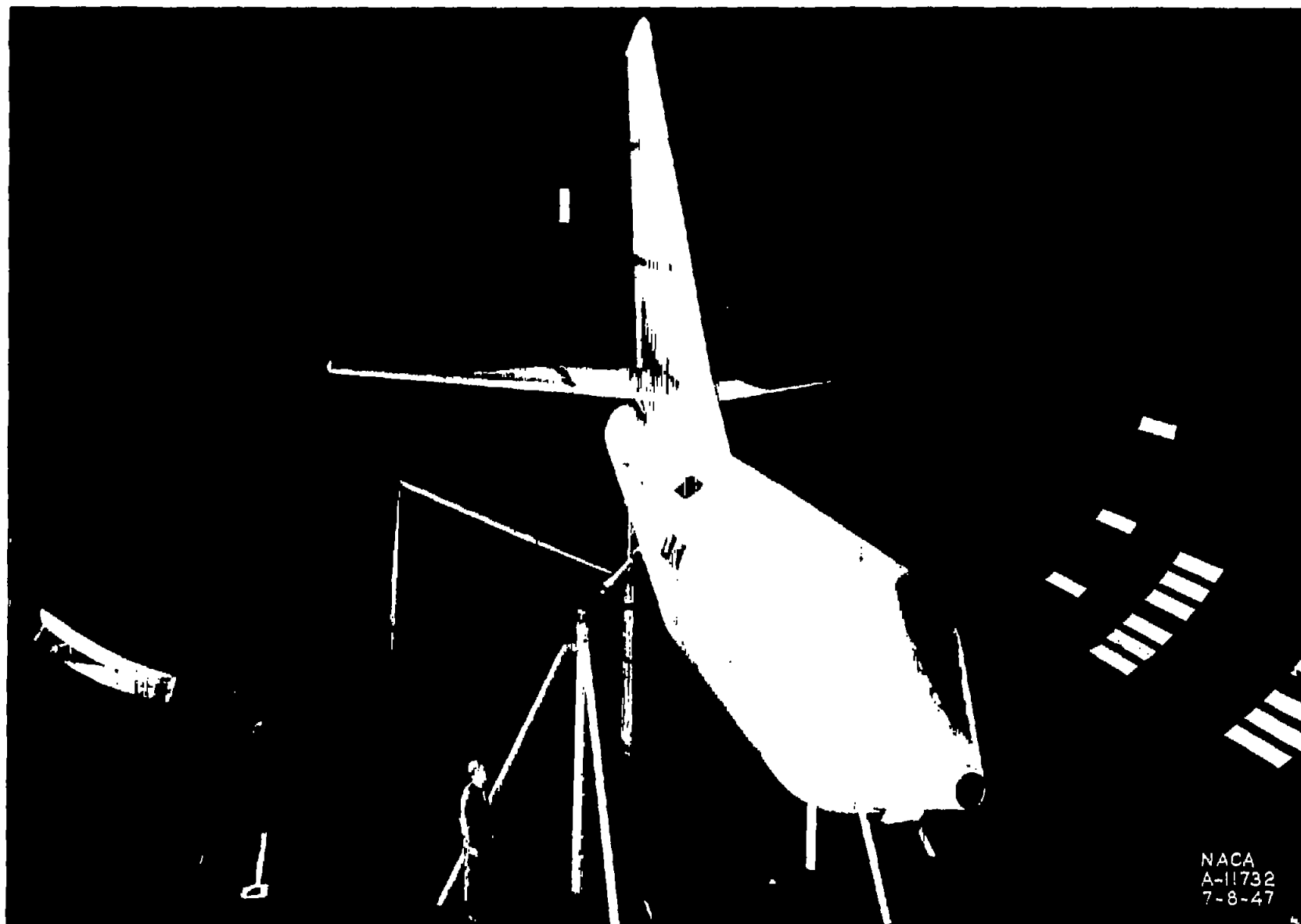


FIGURE 1.- THREE-VIEW DRAWING OF THE BOEING XB-47
 EMPENNAGE MODEL.



(a) Three-quarter front view.

Figure 2.- Views of the Boeing XB-47 empennage model in
the Ames 40- by 80-foot wind tunnel.

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FIGURE 3-47

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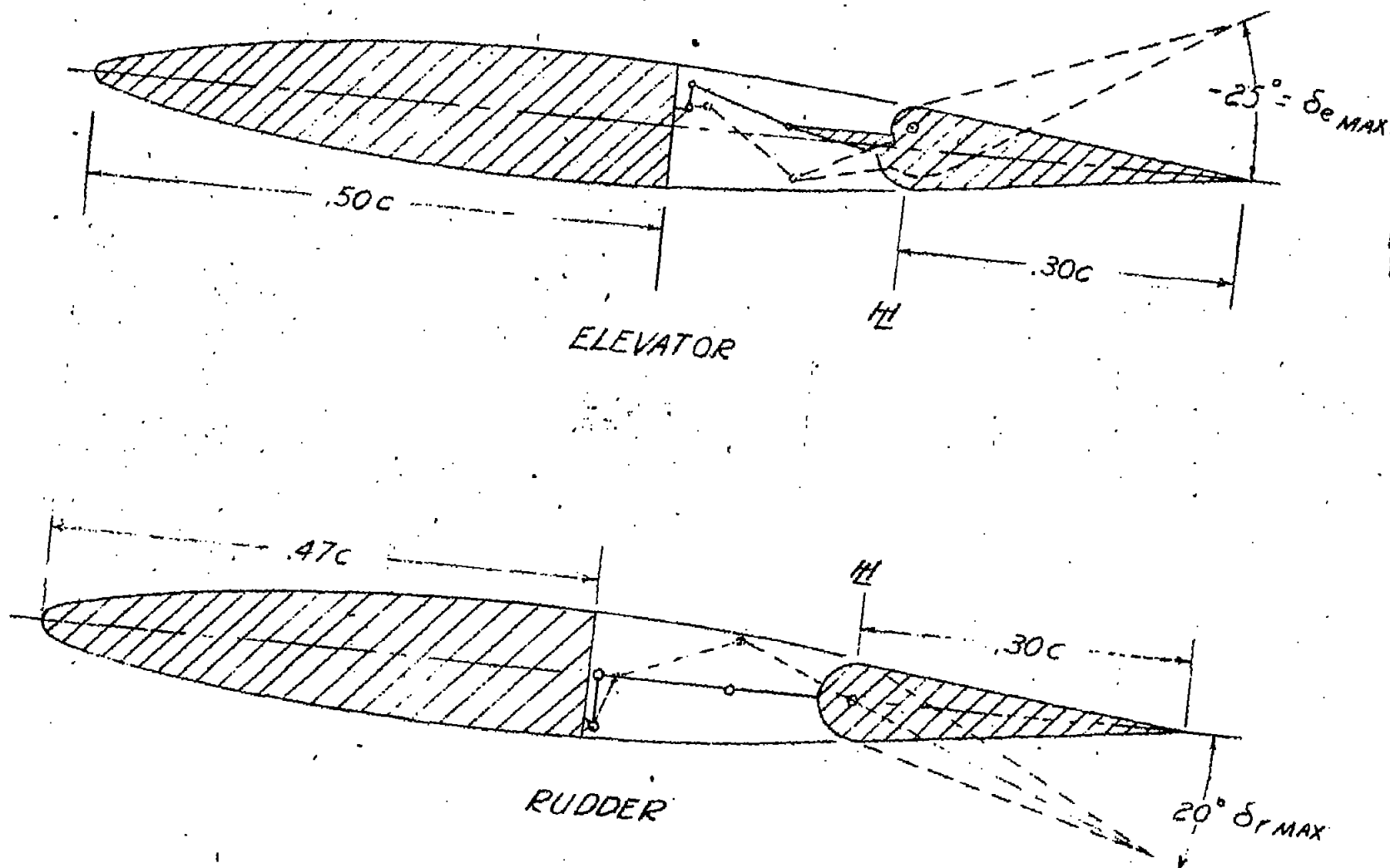
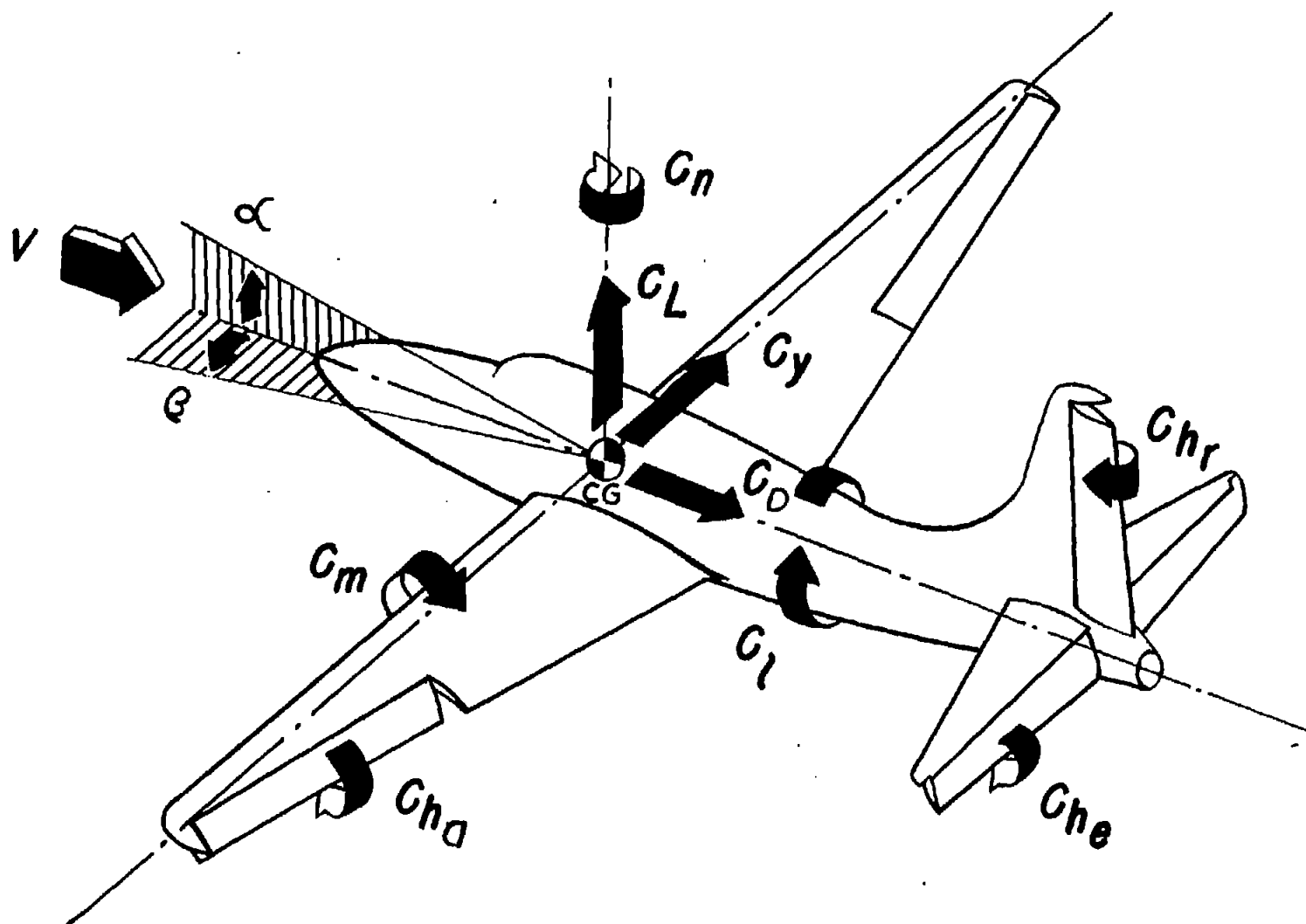


FIGURE 3.- ELEVATOR AND RUDDER BALANCE PANEL LINKAGES

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FIGURE 4.- SIGN CONVENTION FOR THE STANDARD NACA COEFFICIENTS. ALL FORCES, MOMENTS, ANGLES, AND CONTROL SURFACE DEFLECTIONS ARE SHOWN AS POSITIVE.

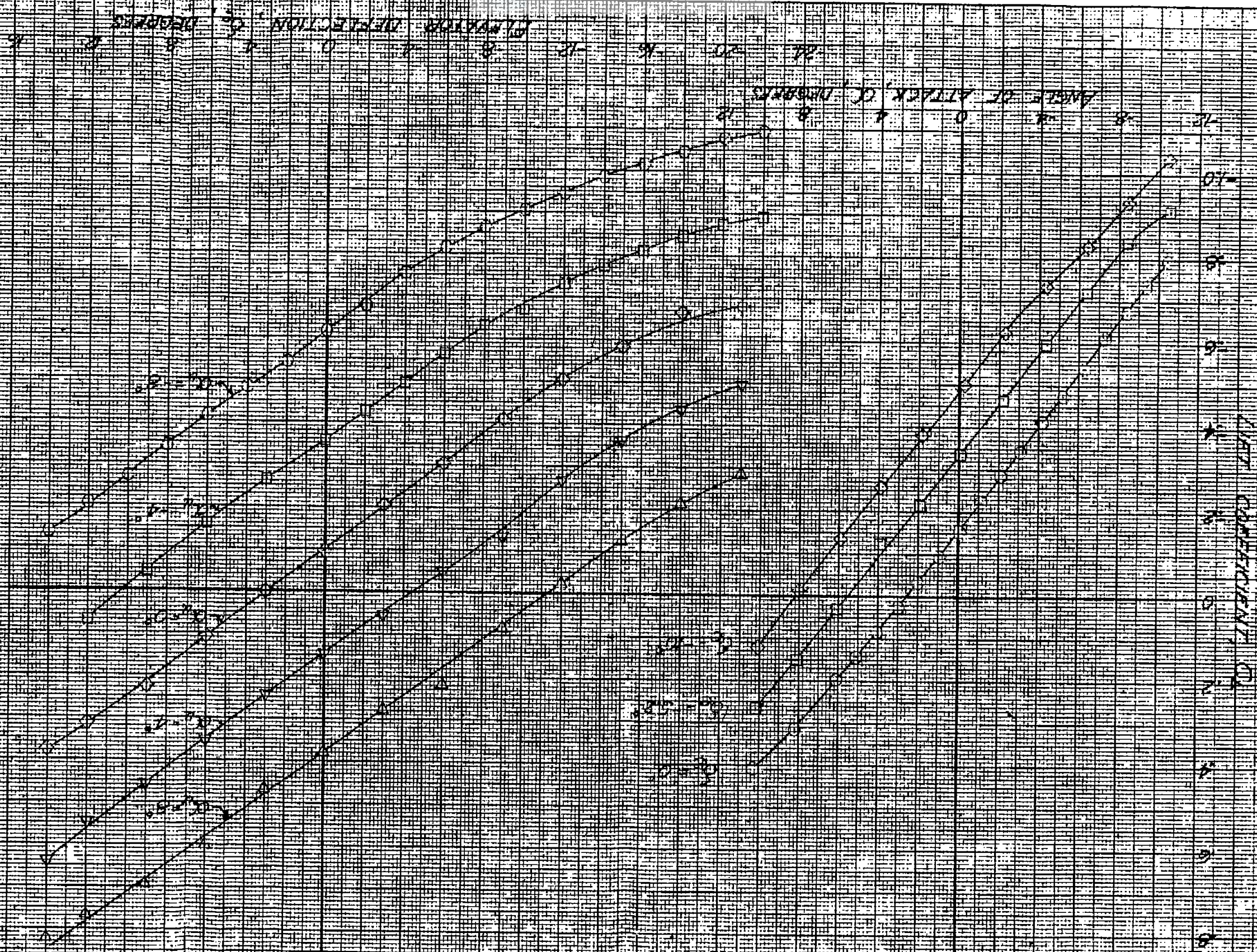


FIGURE 3. LIFT CHARACTERISTICS OF THE BASIC WING-ROOTED SURFACE IN PITCH AND EFFECTIVENESS OF THE ELEVATOR, $\alpha = 0.5^\circ$

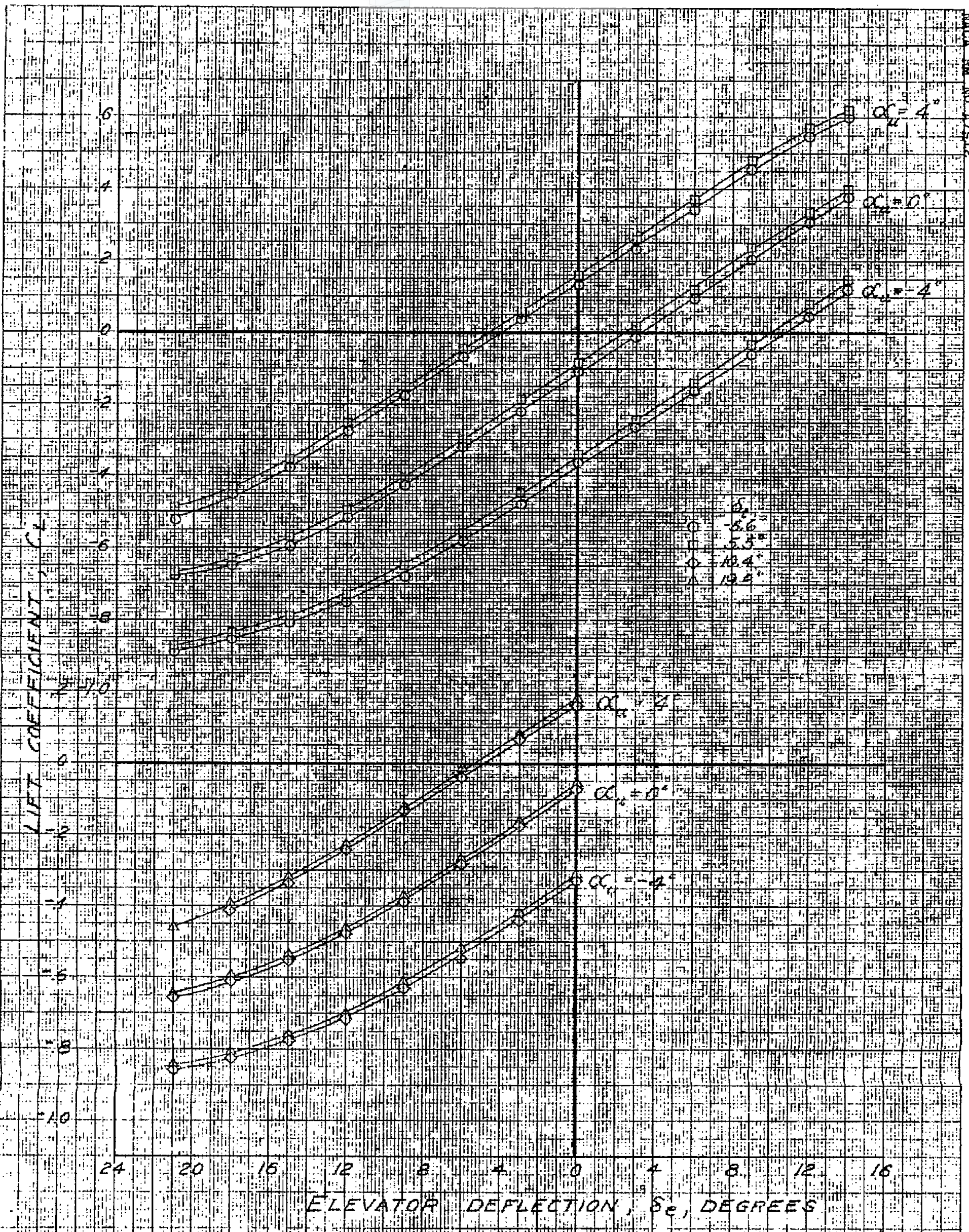


FIGURE 6.- EFFECT OF RIGHT TAB DEFLECTION ON THE EFFECTIVENESS OF THE BASIC ELEVATOR. $\beta = 0.3^\circ$

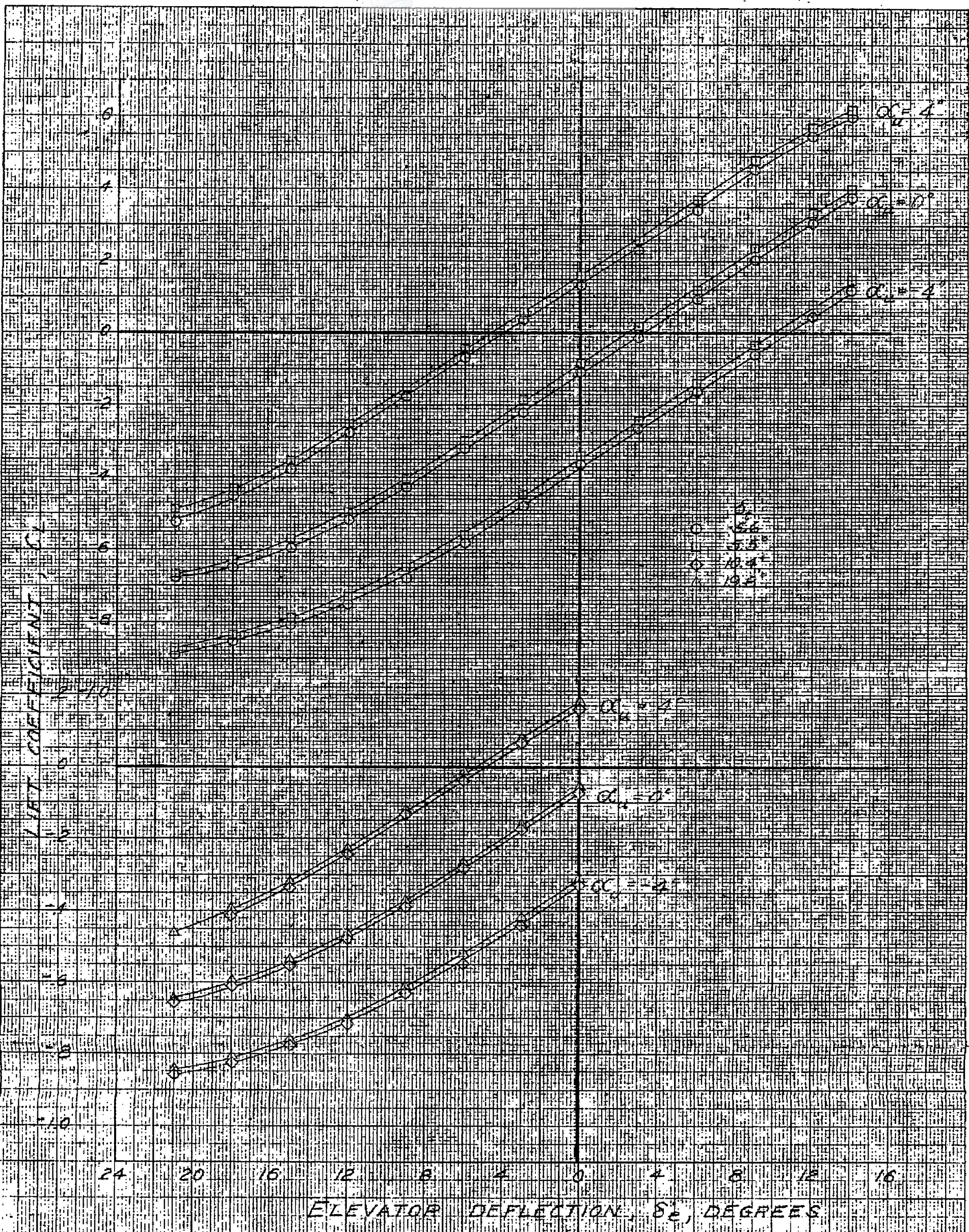


FIGURE 6.- EFFECT OF RIGHT TAB DEFLECTION ON THE EFFECTIVENESS OF THE BASIC ELEVATOR $\delta = 0.3^\circ$

ANGLE OF ATTACK, α , DEGREES
 ELEVATOR DEFLECTION, δ , DEGREES

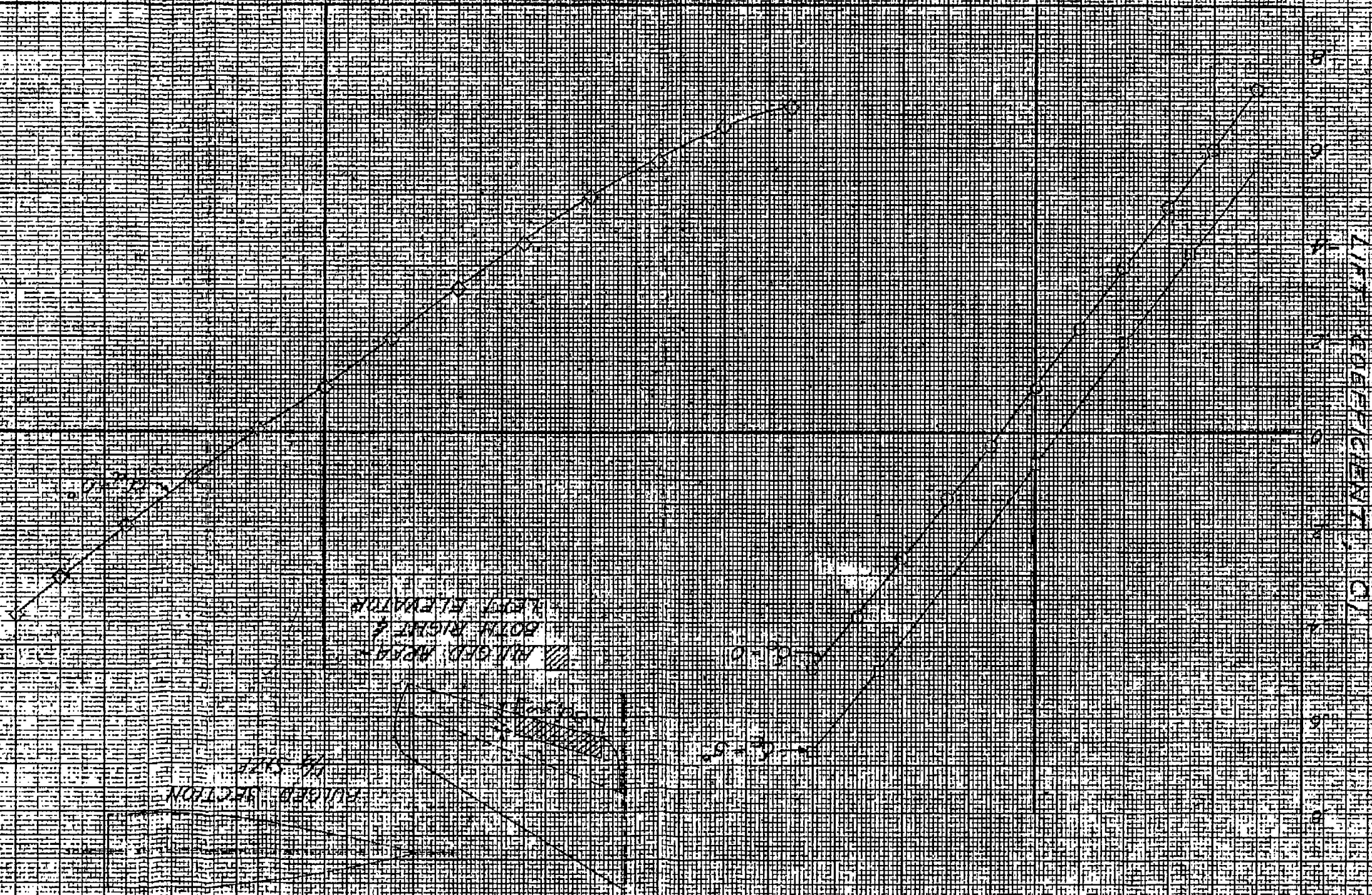


FIGURE 1. LIFT CHARACTERISTICS OF THE HORIZONTAL SURFACE
 IN PITCH AND EFFECTIVENESS OF THE ELEVATOR WITH
 A BULGED TRAILING EDGE, $B = 0.3$

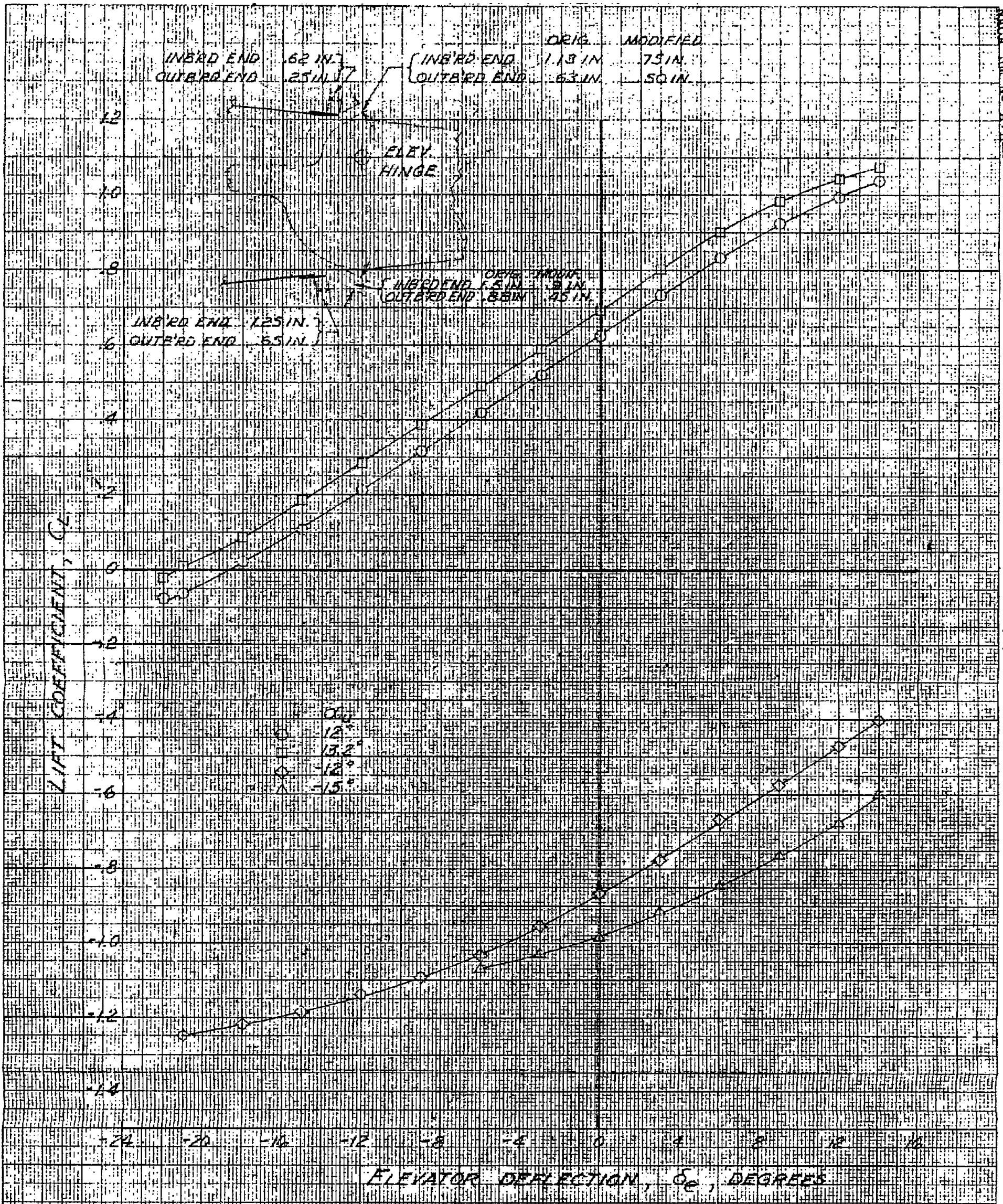
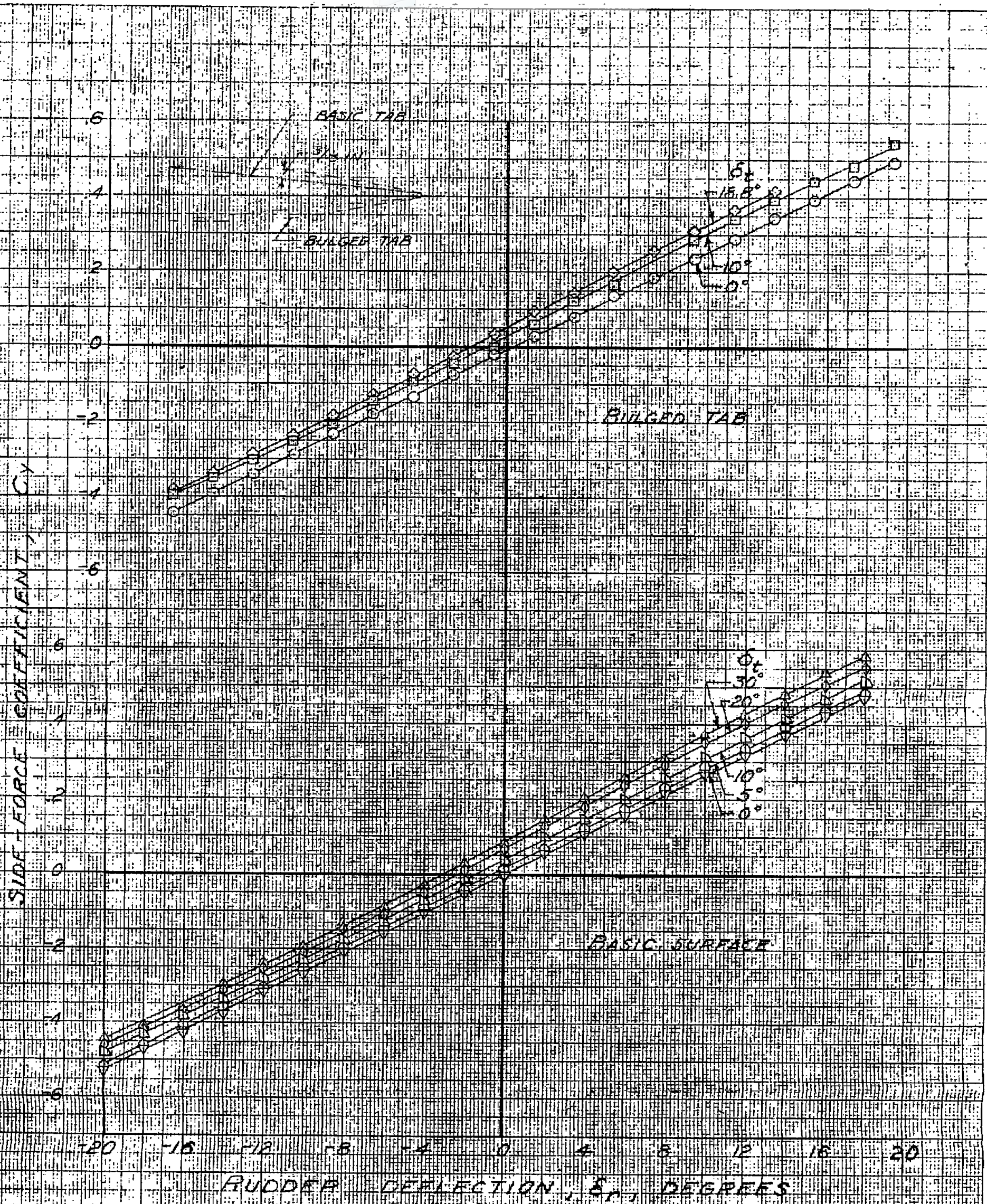
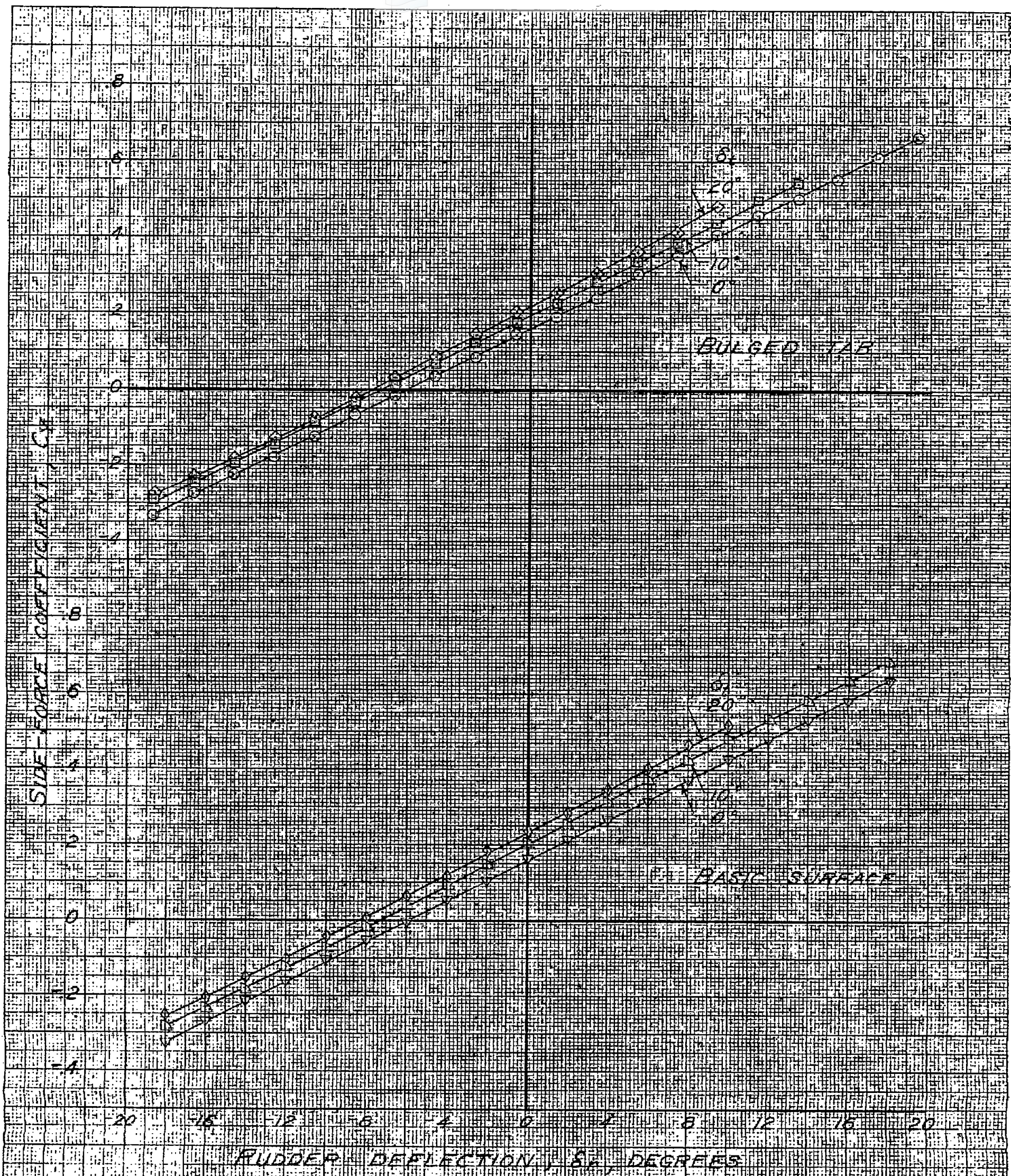


FIGURE 8- EFFECTIVENESS OF THE ELEVATOR WITH A MODIFIED GAP. $\beta = 0.3^\circ$



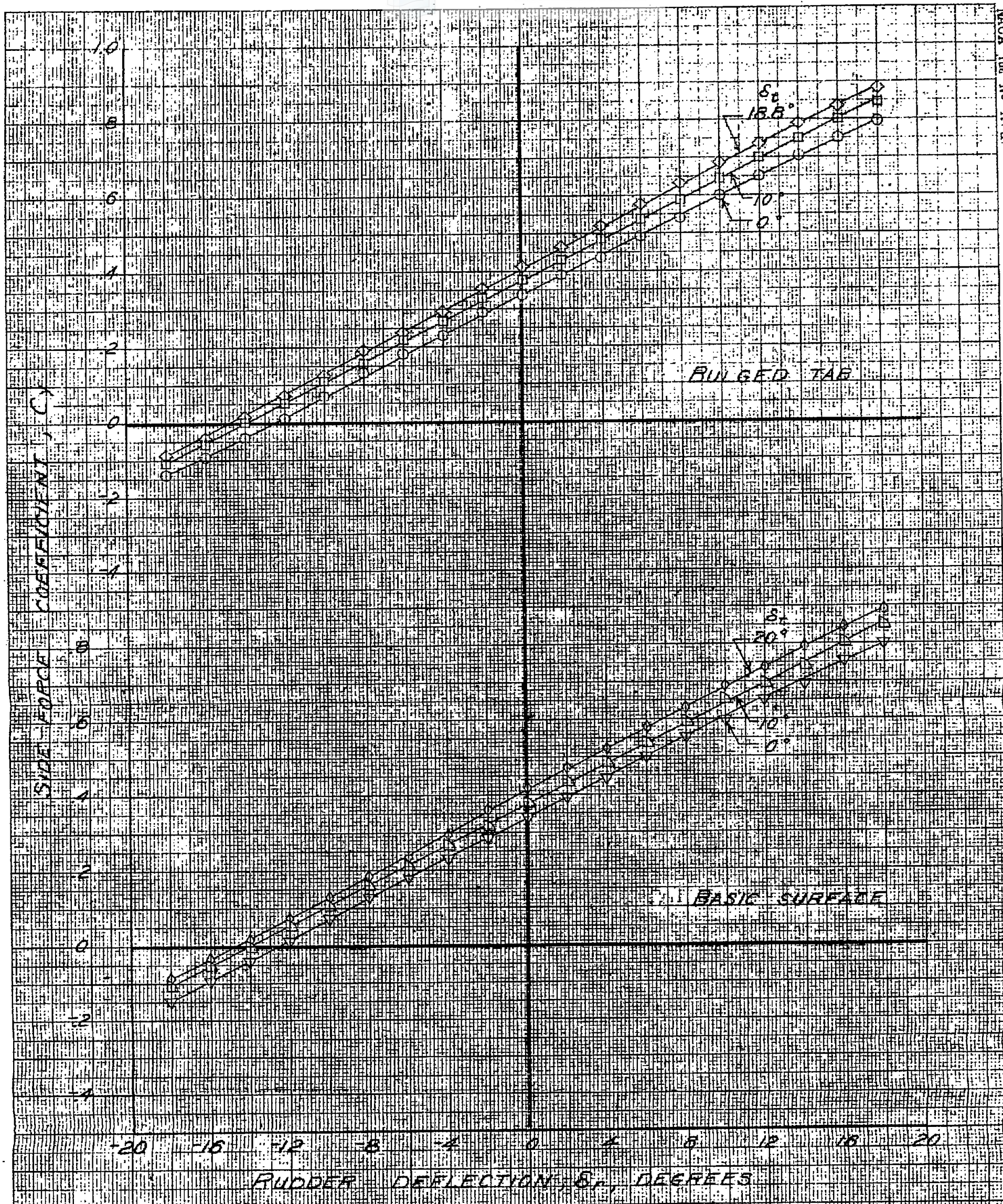
(a) $\alpha = -0.3^\circ$

FIGURE 9. - EFFECTIVENESS OF THE RUDDER WITH THE BASIC TAB AND WITH THE BULGED TAB. $\alpha = 0^\circ$



(b) $\beta, -3.4^\circ$

FIGURE 9 - CONTINUED



(C) $\alpha = 6.3^\circ$

FIGURE 3. CONTINUED



(d) $\beta = 9.8^\circ$

FIGURE 9- CONCLUDED.



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