Sub Library

Inactive

RM A7F19

CONFIDENTIAL

NACA

JUL 24 1947

RESEARCH MEMORANDUM

for the

Civil Aeronautics Administration

STICK-FIXED STABILITY AND CONTROL CHARACTERISTICS OF THE CONSOLIDATED VULTEE MODEL 240 AIRPLANE AS ESTIMATED FROM TESTS OF A 0.092-SCALE POWERED MODEL

By George B. McCullough, James A. Weiberg, and Donald E. Gault

Ames Aeronautical Laboratory
Moffett Field, Calif.

CONTAINS PROPRIETARY INFORMATION

TECHNICAL EDITING WAIVED

FOR REFERENCE

CLASSIFICATION CHANGED
UNCLASSIFIED Inactive

NOT TO BE TAKEN FROM THIS ROOM

J W Crowley per NACA release form 2866 OMM 1-20-55

NACA LIBRARY
LANGLEY AERONAUTICAL LABORATORY
Langley Field, Va.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON

June 27, 1947

CONFIDENTIAL

NASA Technical Library
3 1176 01434 4262

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

for the

Civil Aeronautics Administration

STICK-FIXED STABILITY AND CONTROL CHARACTERISTICS OF THE CONSOLIDATED VULTEE MODEL 240 AIRPLANE AS ESTIMATED FROM TESTS OF A 0.092-SCALE POWERED MODEL

By George B. McCullough, James A. Weiberg,
and Donald E. Gault

SUMMARY

Estimates of the static stick-fixed stability and control characteristics of the Consolidated Vultee model 240 airplane are presented in this report. The estimates are based on tests of a 0.092-scale powered model in the 10-foot wind tunnel of the Guggenheim Aeronautical Laboratory of the California Institute of Technology.

Results of the analysis are evaluated in terms of the Army specifications for stability and control characteristics which are more specific and, in general, equal to or more rigid than the Civil Aeronautics Administration requirements. The stick-fixed stability and control characteristics of the Consolidated Vultee model 240 were found to be satisfactory except for the following:

1. Marginal longitudinal stability in the landing approach (flaps 30°, 50-percent maximum continuous power) with aft center of gravity (31 percent M.A.C.)

2. Marginal rudder control to hold zero sideslip in a climb after take-off with asymmetric power (flaps 30°, left engine inoperative, right engine delivering take-off power) with maximum rudder throw limited to ±18°

3. Marginal dihedral effect with flaps 40° and engines delivering maximum continuous power

INTRODUCTION

In order to facilitate flight tests of the Consolidated Vultee model 240 airplane, estimates of the stick-fixed stability and control characteristics have been made. These estimates were made at the request of the Civil Aeronautics Administration and are based on tests of a 0.092-scale powered model in the GALCIT 10-foot wind tunnel (references 1 and 2). Hinge moments on control surfaces comparable to those on the Consolidated Vultee model 240 were not available; consequently, the stick-free characteristics of the airplane are not presented. The estimated flying qualities are evaluated on the basis of the Army Air Forces specifications for stability and control characteristics of airplanes (reference 3). The generally more specific and rigid nature of these specifications systematizes the discussion and insures compliance with the flying-qualities requirements contained in the Civil Air Regulations (reference 4).

DESCRIPTION OF THE AIRPLANE

The Consolidated Vultee model 240 airplane is a twin-engine low-wing transport of conventional design. It has partial-span Fowler-type flaps and a fully retractable tricycle landing gear. A three-view drawing of the airplane is shown in figure 1, and major dimensions are given in tables I, II, and III. Drawings showing the wing and empennage geometry are presented in figures 2, 3, and 4. The elevators and rudder have straight-sided contour with plain sharp-nose balance. The ailerons are true contour and have an unsealed symmetrical medium-nose balance. All the control surfaces are equipped with spring tabs. The tab dimensions and spring constants are given in table III. The elevator trim tab is also interconnected with the flap operating mechanism to reduce trim changes due to flap operation and reduce control forces in landing. The linkage is such that operation of the flaps produces a trim-tab motion which moves the elevator in a direction tending to hold constant speed. Landing forces are reduced by using the trim tab as a differential servo tab which operates only with relative large up-elevator deflections ($\delta_t = 12^\circ$ down at $\delta_e = 25^\circ$ up).

RESULTS AND DISCUSSION

The paragraph numbering system of reference 3 is retained in the following discussion of the flying qualities of the Consolidated Vultee model 240 airplane to facilitate cross reference to the Army requirements.

The stick-fixed stability and control characteristics only are presented because hinge-moment data for control surfaces comparable to those of the Consolidated Vultee model 240 were not available. It was not considered justifiable to present in this report the results of control-force computations based on section data, since such computations would only be comparable to a preliminary design estimate. The value of such an estimate would be further lessened by the uncertainties introduced by the complex tab arrangements on the airplane.

All control-surface deflections are with tabs undeflected. Symbols and coefficients used throughout the report are defined in the appendix.

Longitudinal Stability and Control

D-2 Static Longitudinal Stability.- The static longitudinal stability (stick fixed) is presented in the form of the variation of elevator deflection with indicated airspeed (fig. 5), and also as the variation of neutral point with lift coefficient (fig. 6) for the following flight conditions:

Condition	Power	Flaps	Gear
Glide	Off	Up	Up
Climb	Rated*	Up	Up
Approach	0.5 Rated	30°	Down
Landing	Off	40°	Down

*Maximum continuous power at sea level.

The estimates are presented for the most forward and most aft center-of-gravity positions of the airplane shown in the following table:

Center-of-gravity position percent M.A.C.	Gross weight (lb)
31	39,000
13	37,143

Figures 5 and 6 indicate that stick-fixed static longitudinal stability will exist for all the required flight conditions within the specified speed ranges. However, in the approach condition with aft center of gravity (0.31 M.A.C.) the stability is low and the airplane becomes unstable at speeds below about 110 miles per hour ($1.2V_{S_A}$), the lower limit of the speed range for which stability is required. Similar instability is shown (fig. 6) for a "balked" landing (maximum continuous power with flaps 40°); however, reference 3 does not require stability for this condition.

It should be pointed out that for the flaps- and gear-up configuration with maximum continuous power the original wind-tunnel data (reference 1) were obtained with an incorrect model power setting to match this condition on the airplane. Consequently, to obtain the curves in figures 5 and 6 for flaps and gear up with maximum continuous power, the data of reference 1 were adjusted using the additional data presented in reference 2 which were obtained in order to determine the effect on stability of this erroneous power setting. The data of reference 2 showed that the model power originally set to match maximum continuous power with flaps and gear up was in error by an amount equivalent to a constant decrement in thrust coefficient T_c of 0.045. Correcting the power setting produced a change in trim of about $0.25C_L$ with little effect on $(dC_m/dC_L)_{\delta_e}$. The effect on stability of this erroneous power setting as shown in figure 7 was small, amounting to approximately 2-percent shift in neutral point. The data presented in figures 5 and 6 have been adjusted for the correct power settings.

D-3.3 Elevator Control Power.- The most critical requirement for elevator control is normally in landing. The sufficiency of the Consolidated Vultee model 240 elevator control for this condition is shown in figure 8 by the variation of elevator deflection with air-speed for the landing configuration (flaps 40°, power off in the presence of the ground). It was necessary to extrapolate the curves in the low-speed range because $C_{L_{max}}$ in the wind tunnel is less than the estimated full-scale value. This figure shows that there is sufficient elevator control (25° maximum up-elevator) to hold the airplane off the ground at speeds down to V_{S_L}. Reference 3 requires elevator control down to only $1.05V_{S_L}$. At $1.05V_{S_L}$ the Consolidated Vultee model 240 will have a margin of 5° up-elevator.

Directional Stability and Control

E-2 Static Directional Stability.- The directional characteristics in steady sideslips were determined for the following conditions of flight and are presented in figure 9:

Condition	Power	Speed (mph)	Gross weight (lb)	Flaps	Gear
Glide	Off	202($1.8V_{S_G}$)	39,000	0°	Up
Climb	Rated[a]	202($1.8V_{S_G}$)	39,000	0°	Up
Landing	Off	117($1.4V_{S_L}$)	37,143	40°	Down
"Balked"[b] landing	Rated[a]	102($1.2V_{S_L}$)	37,143	40°	Down

[a]Maximum continuous power at sea level.

[b]The approach condition (flaps 30° 0.5 maximum continuous power) was not investigated because the wind-tunnel tests did not include a determination of the steady sideslip characteristics for this condition.

E-2.1 Rudder-fixed Directional Stability.- Reference to figure 9 shows that directional stability as shown by the variation of rudder deflection with sideslip angle exists for the steady sideslip conditions listed in the preceding table. The variation of rudder angle with angle of sideslip is approximately linear.

E-3.4 Rudder Control Power.- For a multiengine airplane, the critical criterion for rudder control is that the airplane be able to maintain a straight unyawed heading when one engine fails in a climb after take-off. The ability of the Consolidated Vultee model 240 to meet this requirement is shown in figure 10 where the rudder deflection required to hold zero sideslip and the corresponding aileron deflection and angle of bank are given as a function of speed with flaps down 30°, left engine inoperative, and right engine delivering take-off power. This figure shows that 18° of rudder (maximum deflection) is just sufficient to hold zero sideslip down to 110 miles per hour ($1.2V_{S_A}$ with flaps 30°). These computations are for zero tab deflection; consequently, when the tab is deflected to trim, the rudder required to hold zero sideslip will become marginal if maximum rudder throw is limited to 18°.

As was mentioned previously, the data of reference 1 were obtained with an erroneous model power setting to match the power on the airplane. In order to obtain the curves shown in figure 10, the original data were adjusted using the data of reference 2 which were obtained to determine the effects of the error in model power setting. The rudder control thus estimated will be marginal; whereas the original data of reference 1 indicated a margin of 7° of rudder at $1.2V_{S_A}$ as shown by the dashed curves in figure 10.

F-2.1 Static Lateral Stability.- Static lateral stability in steady sideslip as indicated in figure 9 by the variation of aileron deflection with sideslip angle is positive (increase in right aileron with increase in right sideslip and vice versa) for all flight conditions investigated except balked landing (flaps 40°, maximum continuous power) where the stability is marginal to slightly unstable. However, it is not required (reference 3) that a transport-type airplane for which the Consolidated Vultee model 240 is to be used be laterally stable in this flight condition. The basic wind-tunnel data show positive $dC_l/d\psi$ for constant rudder deflection, but the roll due to rudder deflection is sufficient to give a marginal or slightly unstable variation of aileron deflection with sideslip angle in steady sideslips. Steady sideslip characteristics for the normal approach condition (flaps 30°, 0.5 maximum continuous power) are not presented because data for this condition were not obtained in the wind-tunnel tests. However, a comparison of the wind-tunnel data (reference 1) with rudder undeflected for flaps 30° and 40° indicate that the lateral stability in a normal approach will probably be low or marginal.

F-2.3 Variation of Sideforce with Sideslip.- The angle of bank developed in steady sideslips for the power and flap conditions listed in the foregoing table is presented in figure 9. The variation of side force with angle of sideslip for all conditions investigated has a positive slope (increase in right bank with increase in right sideslip, and vice versa), thus satisfying the requirement of reference 3.

F-3.4 Aileron Control Power.- The critical condition for aileron power is the ability of the ailerons to produce the required wing-tip helix angle $pb/2V$ when the airplane is rolled with the rudder locked. Estimates of $pb/2V$ were made for the Consolidated Vultee model 240 based on the GALCIT aileron-effectiveness data (reference 1) converted to full scale by means of factors obtained from comparison of data obtained in the Ames 7- by 10- and 40- by 80-foot wind tunnels. For the high-speed condition (303 mph, flaps up) the estimated value of $pb/2V$ for full aileron deflection is 0.083, and for the low-speed condition ($1.1V_{S_L}$ based on $C_{L_{max}}$ in the wind tunnel, flaps down) the value is 0.076. These are above the required minimum value of 0.07 for this type airplane.

CONCLUSIONS

For the conditions investigated, the Consolidated Vultee model 240 airplane has the following flying characteristics estimated from tests of a 0.092-scale powered model. The flying qualities are evaluated in terms of the Army specifications for stability and control

(reference 3) which are more specific and, in general, equal to or more rigid than the Civil Aeronautics Administration requirements:

1. Static stick-fixed longitudinal stability exists within the speed ranges specified in reference 3 for both flaps up and flaps down for all power conditions for the normal center-of-gravity range of from 13 percent to 31 percent M.A.C. In the approach condition (flaps 30°, 0.5 maximum continuous power) with aft center of gravity (0.31 M.A.C.) the stability is low and the airplane becomes unstable below 110 miles per hour ($1.2V_{S_A}$), the lower limit of the speed range for which stability is required.

2. The elevator control is sufficient to land the airplane at speeds down to V_{S_L} with a margin of 5° elevator at $1.05V_{S_L}$.

3. Directional stability, rudder fixed, is satisfactory.

4. Rudder control is marginal to hold zero sideslip in a climb after take-off with asymmetric power (flaps 30°, left engine inoperative, right engine delivering take-off power) with maximum rudder throw limited to ±18°.

5. Static aileron-fixed lateral stability is adequate except for flaps 40° and engines delivering maximum continuous power where stability is marginal.

6. The side-force characteristics are satisfactory.

7. Aileron control power is sufficient to give a $pb/2V$ rudder locked of 0.083 flaps up and 0.076 flaps down with full aileron deflection.

Ames Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Moffett Field, Calif.

APPENDIX

SYMBOLS AND COEFFICIENTS

The coefficients used are of NACA standard form and are defined as follows:

C_L lift coefficient (L/qS)

C_l rolling-moment coefficient (L'/qSb)

C_m pitching-moment coefficient (M/qSc)

T_c thrust coefficient $(T/\rho V^2 D^2)$

where

b wing span, feet

c wing mean aerodynamic chord, feet

D propeller diameter, feet

L lift, pounds

L' rolling moment, foot-pounds

M pitching moment, foot-pounds

q dynamic pressure $(\frac{1}{2}\rho V^2)$, pounds per square foot

S wing area, square feet

T effective thrust, pounds

V airspeed, feet per second

ρ mass density of air, slugs per cubic foot

All moments are referred to the stability axes and all forces are referred to the wind axes.

The power of the ailerons is expressed as:

$\frac{pb}{2V}$ wing-tip helix angle, radians

where

p rolling velocity, radians per second

Additional symbols used are:

V_i indicated airspeed, miles per hour

V_S airplane stalling speed, miles per hour

V_{S_A} airplane stalling speed in the approach configuration (50-percent normal rated power, flaps 30°, gear down), miles per hour

V_{S_L} airplane stalling speed in the landing configuration (power off, flaps 40°, gear down), miles per hour

V_{S_G} airplane stalling speed in the glide configuration (power off, flaps and gear up), miles per hour

β angle of sideslip, degrees

δ movable surface deflection

φ angle of bank, degrees

ψ angle of yaw ($= -\beta$), degrees

Subscripts

e elevator

r rudder

a aileron

f flap

t tab

REFERENCES

1. Murtaugh, Clyde: Preliminary Report on Wind-Tunnel Tests of a Modified C.092 Scale Powered Model of the Consolidated Vultee (San Diego) Model 240 Airplane. GALCIT Rep. No. 504, Aug. 19, 1946.

2. Murtaugh, Clyde: Preliminary Report on Additional (b) Wind-Tunnel Tests of a Modified 0.092 Scale Model of the Consolidated Vultee (San Diego) Model 240 Airplane. GALCIT Rep. No. 504-B, Nov. 20, 1946.

3. Anon.: Stability and Control Characteristics of Airplanes. No. R-1815-A, Army Air Forces, Apr. 7, 1945.

4. Anon.: Civil Air Regulations, Part 04. Airplane Airworthiness, Transport Categories, Nov. 9, 1945.

TABLE I.– POWER AND LOADING CONDITIONS CONSOLIDATED
VULTEE MODEL 240 AIRPLANE

Engine	Pratt & Whitney R-2800-CA17
Ratings	Bhp/rpm/alt
Maximum continuous	1900/2600/4000
	1700/2600/14,000
Take-off	2400/2800/SL
Reduction gear ratio	0.450
Supercharger	two-speed, single-stage
Propeller[a]	Hamilton Standard 2H17B3-48R
Diameter	13.083 ft
Activity factor	164
Number of blades	three
Loading conditions	
Design	39,000 lb
Landing	37,143 lb
Forward center of gravity	13 percent M.A.C.
Aft center of gravity	31 percent M.A.C.

[a]The propellers on the model were made from 1/8-scale models of a three-blade Hamilton Standard 6547A by trimming the blade tips to a diameter of 1.219 feet (13.25 feet full scale) giving an activity factor of 140.

TABLE II.– BASIC DIMENSIONAL DATA OF THE CONSOLIDATED VULTEE MODEL 240 AIRPLANE

Item	Wing	Horizontal tail	Vertical tail
Area (sq ft)	817.19	232.7	125.4[a]
Span (ft)	91.76	36.45	14.10[b]
Aspect ratio	10.3	5.7	1.6
Taper ratio	.333	.333	.305
M.A.C. (ft)	9.72	7.04	9.66
Dihedral	4.83°	0°	– – – –
Incidence[c] (Root chord)	4.0°	0.5	0°
Geometric twist	2.22° at 30.7 percent semispan 4.1 at tip	0°	0°
Root section	63,4–120[d]	65_1–012	65_1–012
Tip section	63,4–515	65_1–012	65_1–012
Percent line straight	61.8	65	65
Tail length (from 0.25 M.A.C. wing to 0.25 M.A.C. tail, ft)	– – – –	35.16	34.91

[a]Area above fuselage including tip fairing, less dorsal.

[b]Less tip fairing.

[c]With respect to fuselage reference line.

[d]63,4–419 at 30.7 percent semispan.

TABLE III.– DIMENSIONAL CHARACTERISTICS OF THE MOVABLE SURFACES OF THE CONSOLIDATED VULTEE MODEL 240 AIRPLANE

Item	Elevators	Rudder	Flaps	Ailerons
Area aft hinge line (sq ft both sides)	59.0	41.0	139.44	43.82
Span (ft one side)	14.20	[a]13.38	27.67	17.40
Root-mean-square chord (ft)	2.16	3.14	2.62 constant	1.26
Hinge-line location (percent chord)	65.0	65.0	---	80.0
Aerodynamic balance (percent of control chord aft of hinge line)	45	45	---	40
Type	Plain sharp nose	Plain sharp nose	Fowler flap	Symmetrical medium nose
Travel	25° up, 15° down	±18°	40° down	±20°
Control tab	One tab on left elevator (see fig. 3)	Inboard end of rudder (see fig. 4)	---	Outboard of trim tab (see fig. 2)
Area (each tab, sq ft)	4.08	3.00	---	1.79
Span (each tab, ft)	6.4	3.62	---	3.88
Root-mean-square chord (ft)	.64	.83	---	--------
Chord (percent of main surface chord aft of hinge line)	25	20	---	25
Control tab spring constant (ft-lb per deg tab deflection)	40	17	---	5(one aileron) 10 (total)
Travel	9° up, 15° down	±12°	---	±10°
Trim tab	One tab on right elevator (see fig. 3)	Outboard of control tab (see fig. 4)	---	Inboard end of aileron (see fig. 2)
Area (each tab, sq ft)	4.08	3.23	---	1.32
Span (each tab, ft)	6.4	5.2	---	3.54
Root-mean-square chord (ft)	.64	.63	---	--------
Chord (percent of main surface chord aft of hinge line)	25	20	---	25
Travel	9° up, 12° down	±9°	---	±10°
Control movement at point of application of pilot effort for full surface deflection, tabs locked (in)[b]	13.9	6.09	---	[c]180°

[a]Less tip fairing. [b]Assuming zero cable stretch. [c]Movement for 14-inch-diameter wheel.

FIGURE LEGENDS

Figure 1.– General arrangement of the Consolidated Vultee Model 240 airplane.

Figure 2.– Wing geometry. Consolidated Vultee Model 240 airplane.

Figure 3.– Horizontal tail geometry. Consolidated Vultee Model 240 airplane.

Figure 4.– Vertical tail geometry. Consolidated Vultee Model 240 airplane.

Figure 5.– Longitudinal characteristics in steady straight flight at sea level. Consolidated Vultee Model 240 airplane. (a) Flaps up.

Figure 5.– Concluded. (b) Flaps down.

Figure 6.– Neutral point variation with lift coefficient. Consolidated Vultee Model 240.

Figure 7.– Effect of incorrect model power setting on longitudinal characteristics. Consolidated Vultee Model 240, flaps and gear up, maximum continuous power.

Figure 8.– Elevator control characteristics in landing. Consolidated Vultee Model 240 airplane, flaps 40° gear down, propellers windmilling, 37,143 lb. g.w.

Figure 9.– Characteristics in steady sideslips. Consolidated Vultee Model 240 airplane. (a) Flaps up, V_i = 202 mph ($1.8V_{S_G}$).

Figure 9.–Concluded. (b) Flaps 40°, gear down.

Figure 10.– Rudder control characteristics in asymmetric power take-off. Consolidated Vultee Model 240 airplane, flaps 30°, gear up, left engine inoperative (propeller windmilling) right engine delivering take-off power, 37,143 lb. g.w.

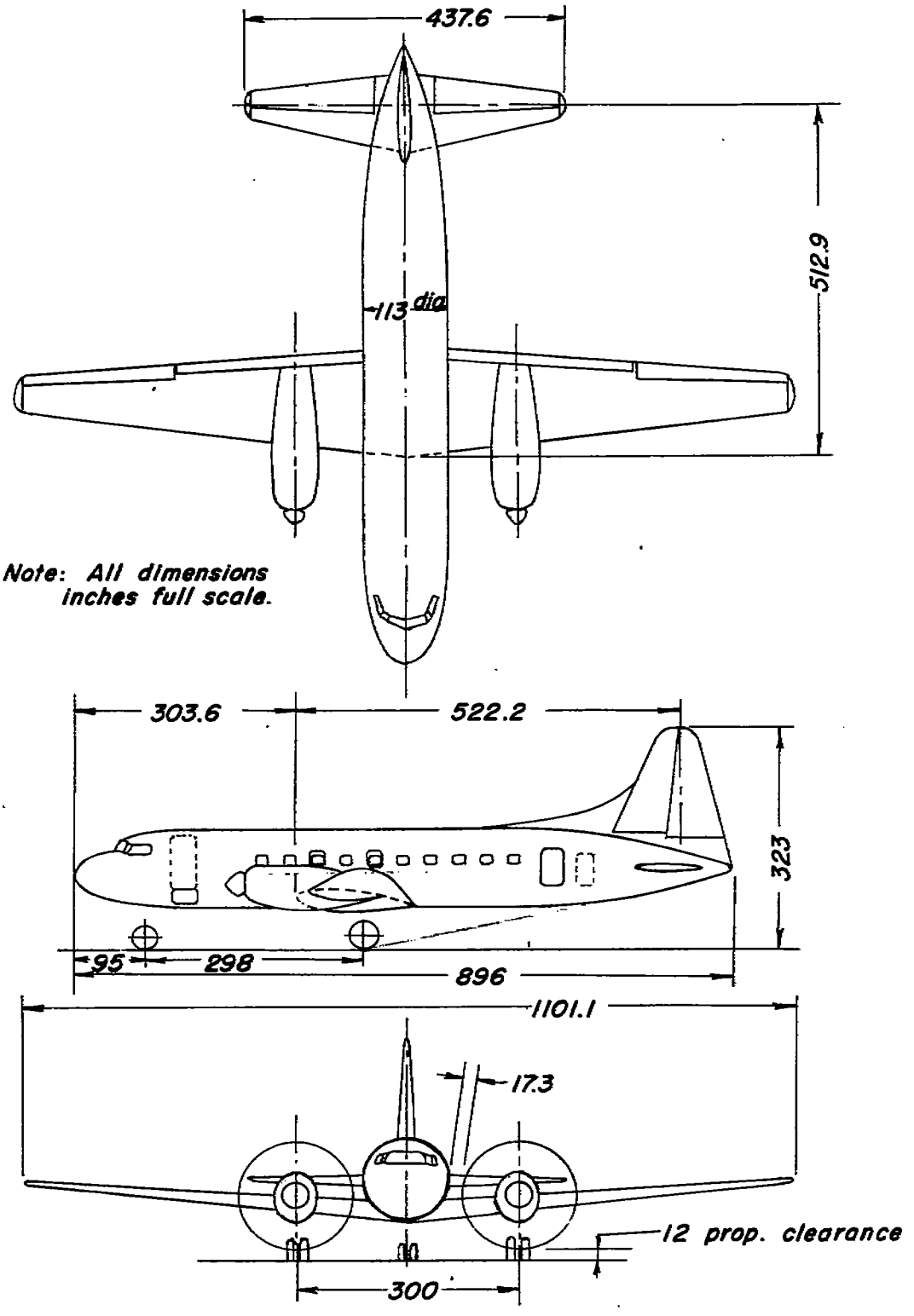


Figure 1.- General arrangement of the Consolidated Vultee Model 240 airplane.

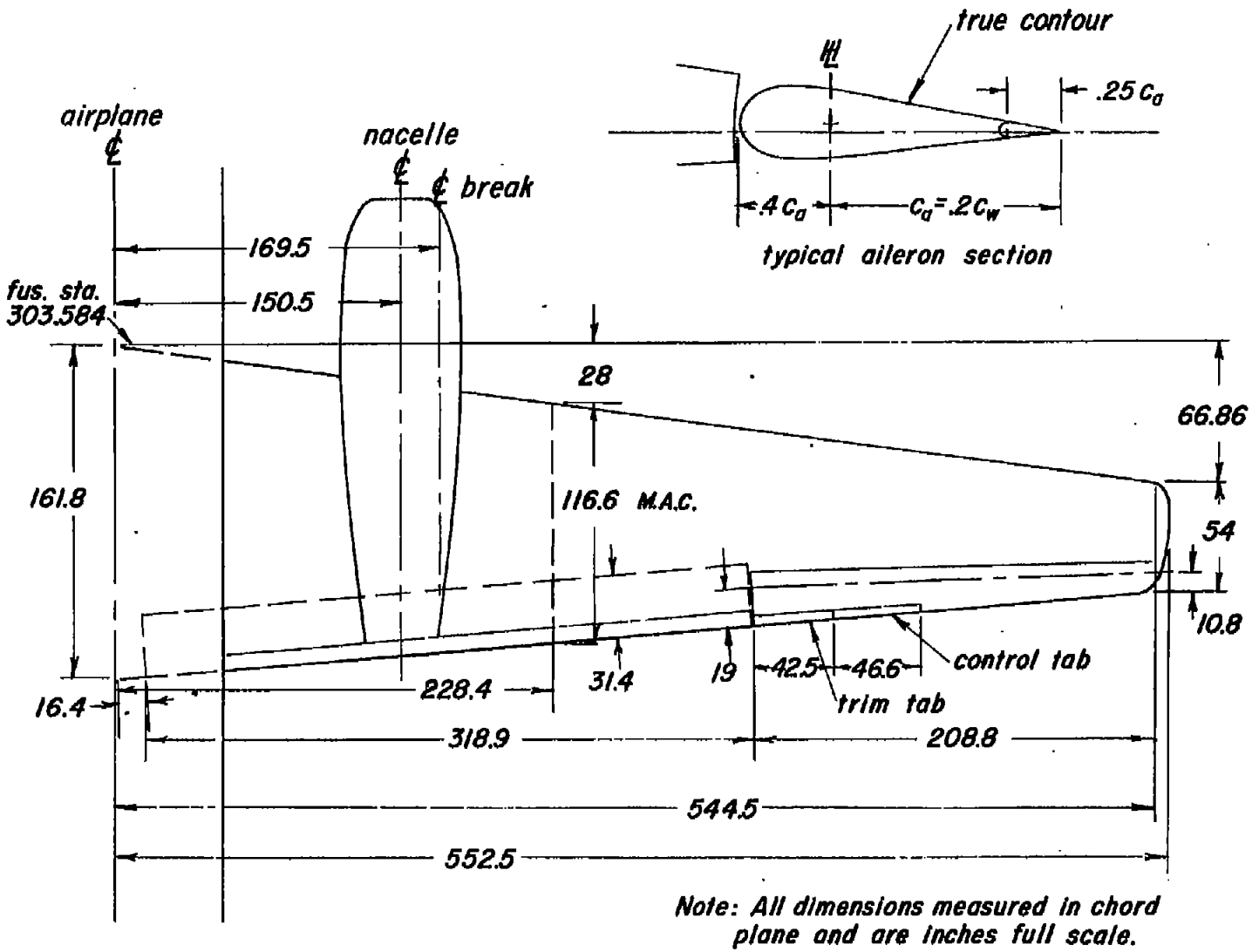


Figure 2.- Wing geometry. Consolidated Vultee Model 240 airplane.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

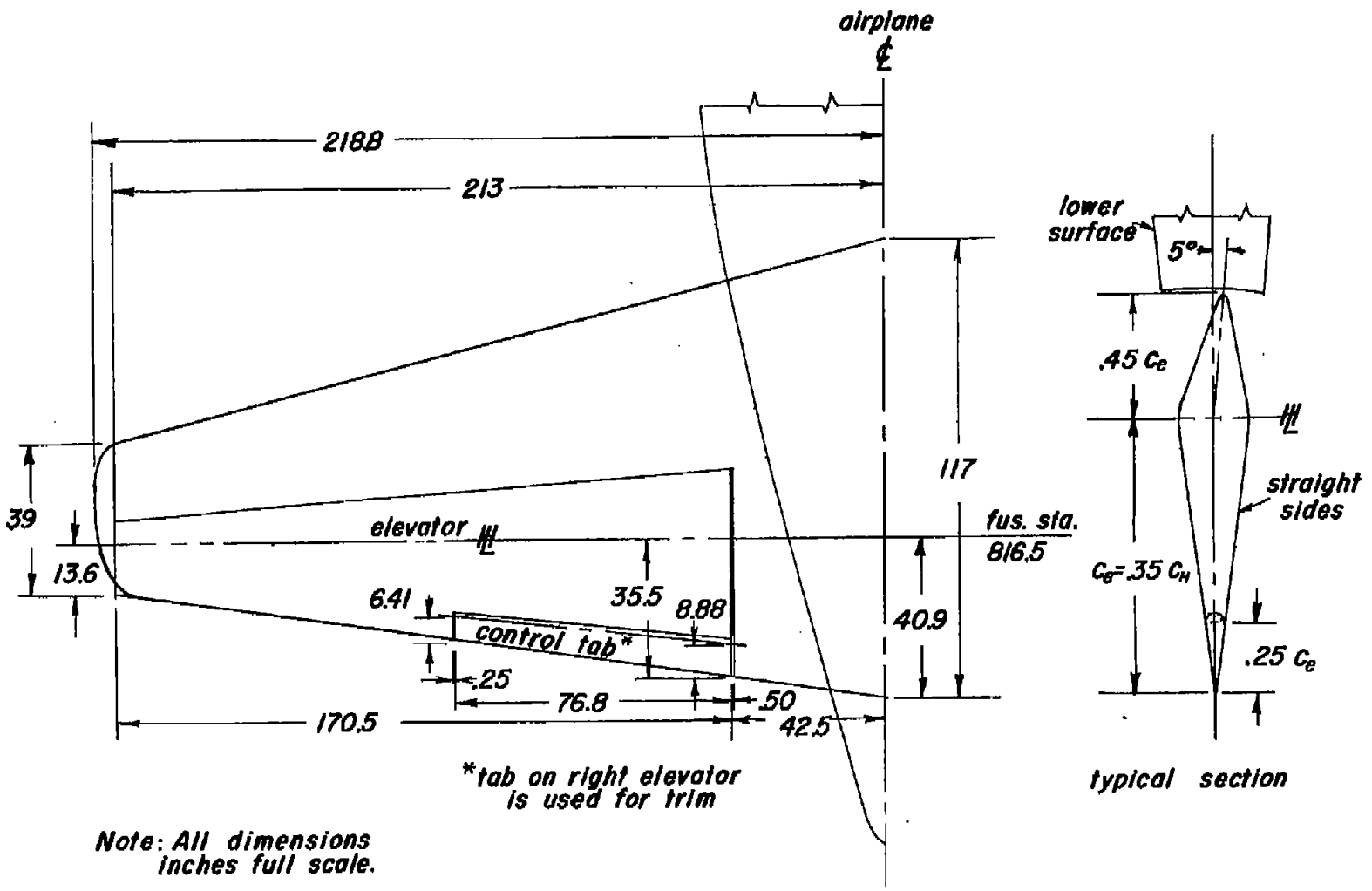


Figure 3.- Horizontal tail geometry. Consolidated Vultee Model 240 airplane.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

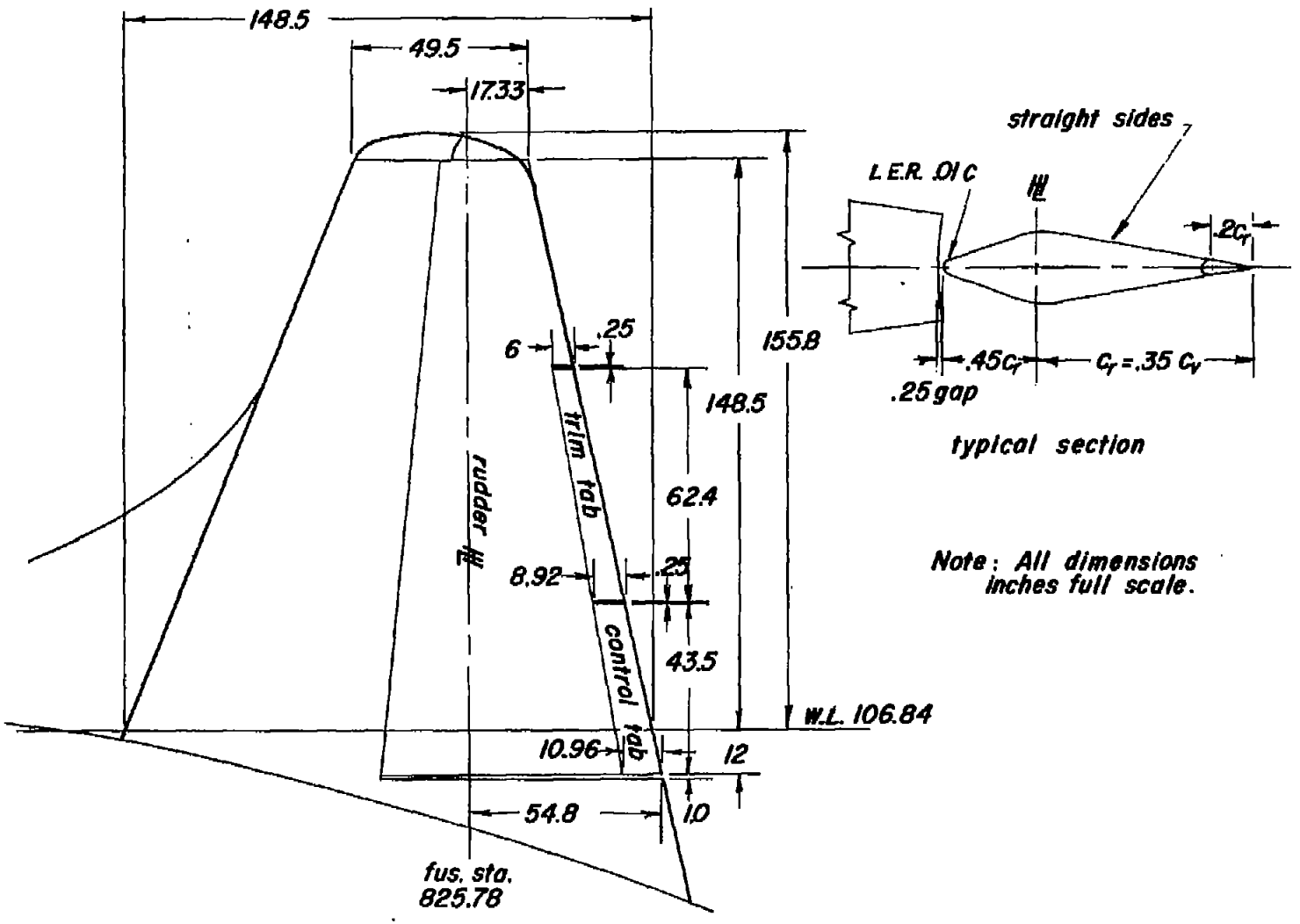
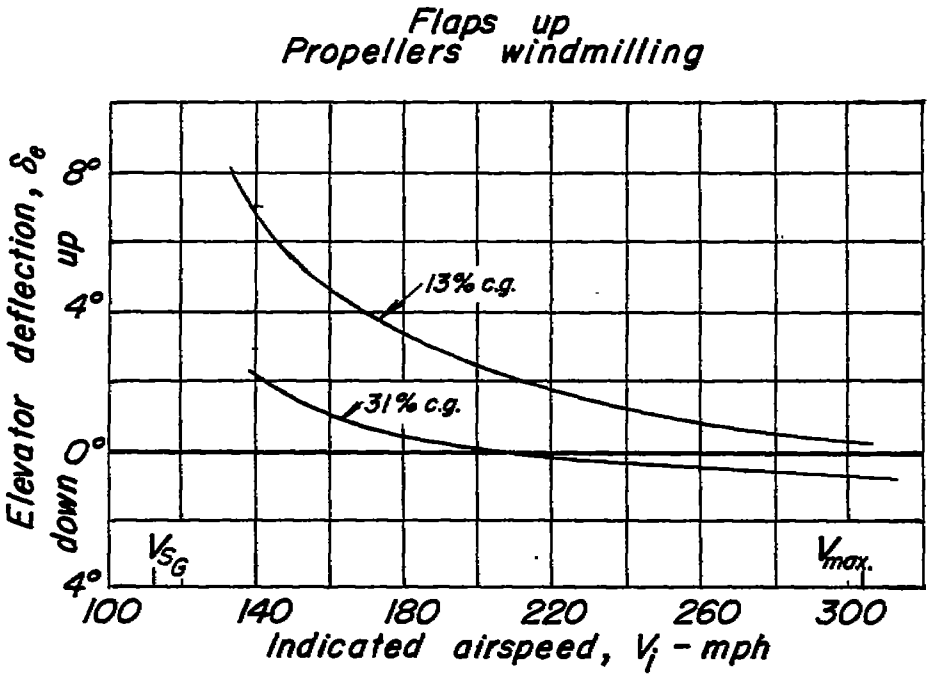
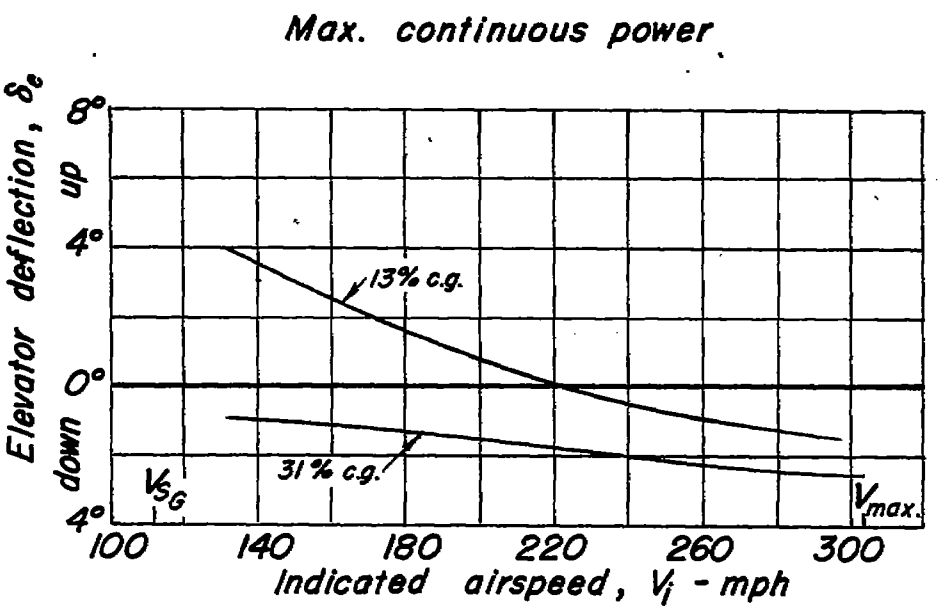


Figure 4. - Vertical tail geometry. Consolidated Vultee Model 240 airplane.

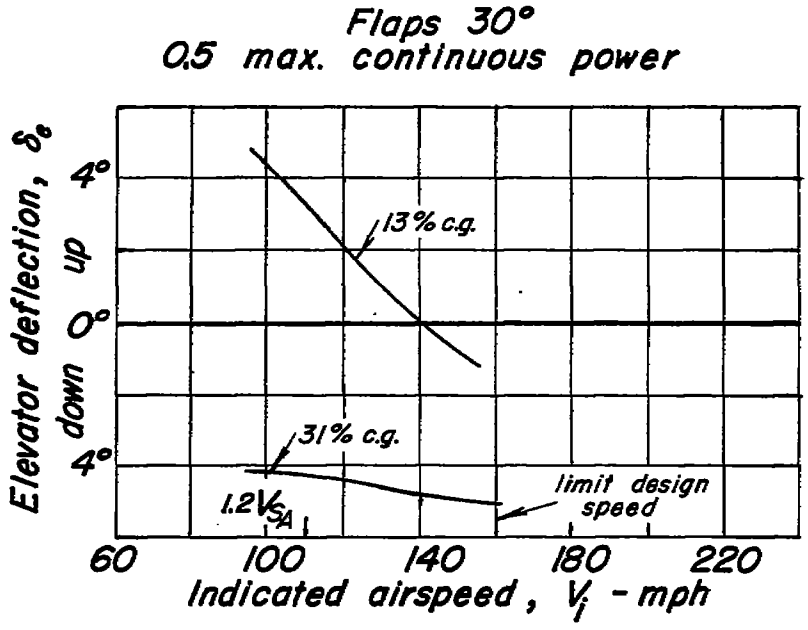
NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

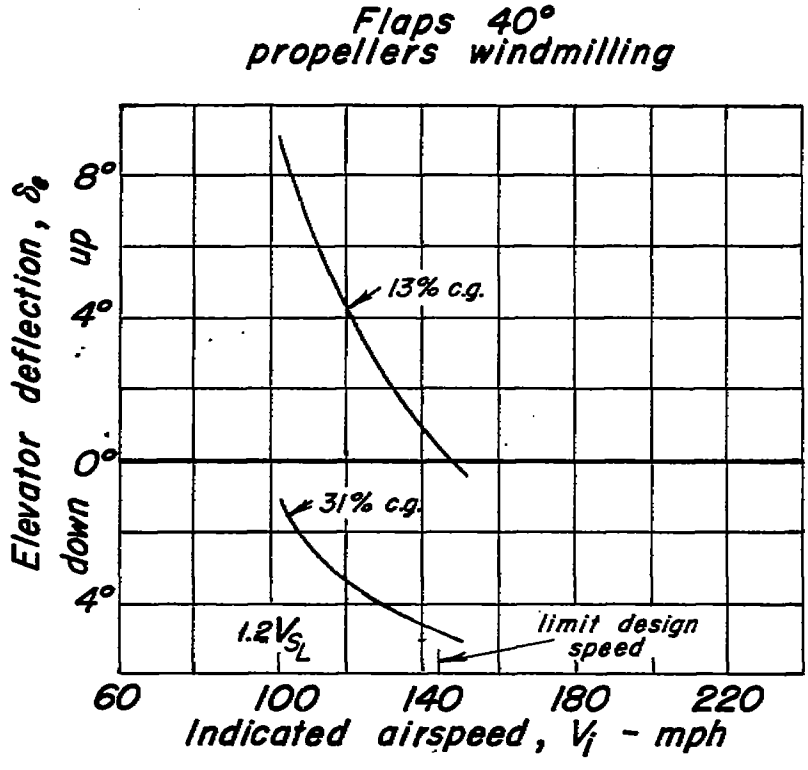




(a) Flaps up

Figure 5.- Longitudinal characteristics in steady straight flight at sea level. Consolidated Vultee Model 240 airplane.





(b) Flaps down.

Figure 5.- Concluded.

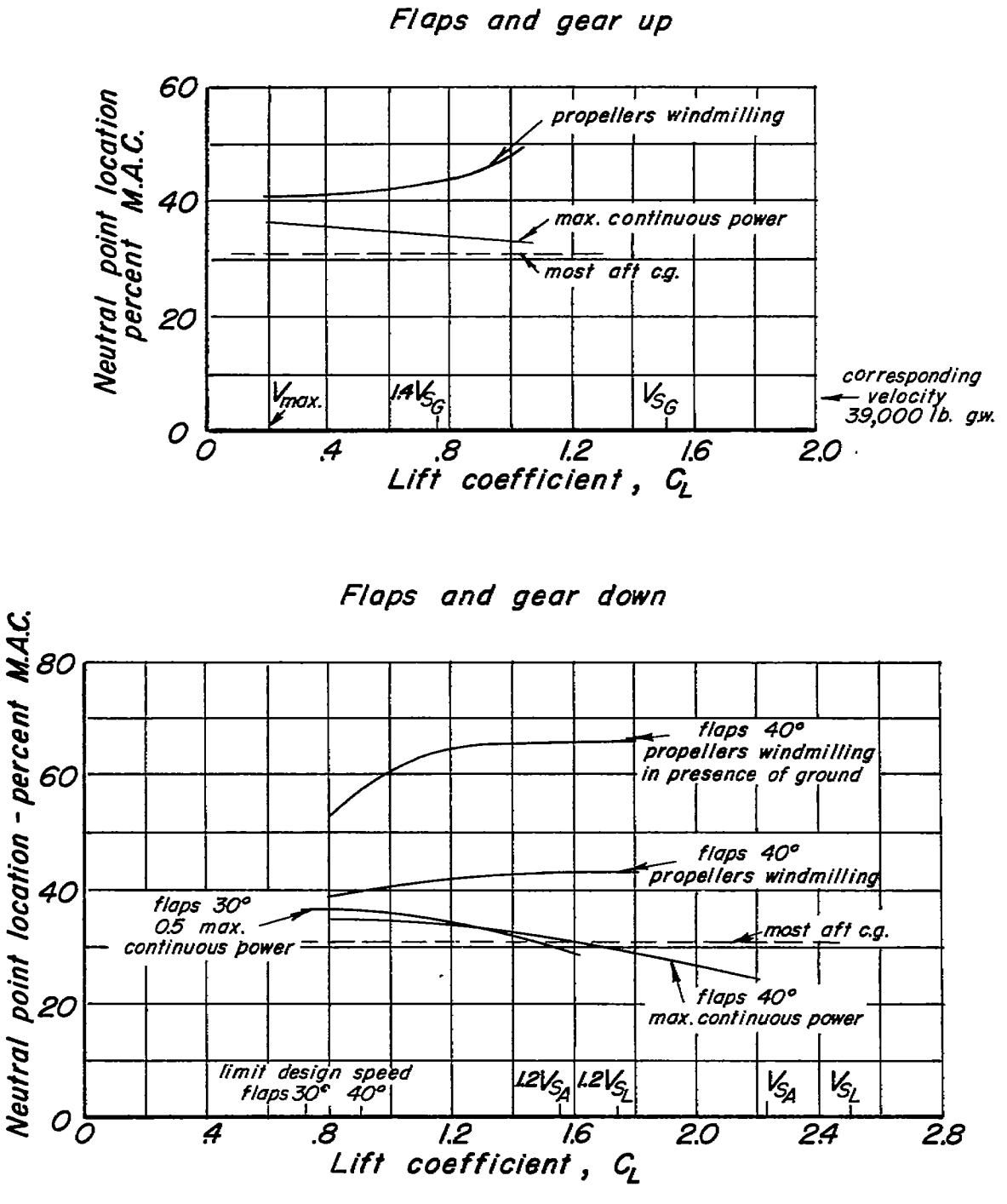
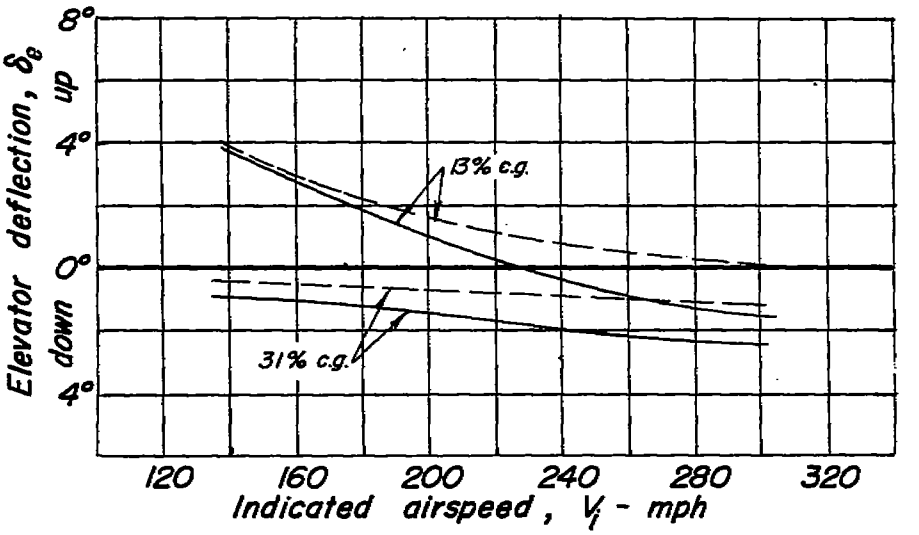


Figure 6.- Neutral point variation with lift coefficient. Consolidated Vultee Model 240.



——original data with incorrect model power setting (GALCIT Rep. 504)
——corrected data (as indicated by GALCIT Rep. 504-B)

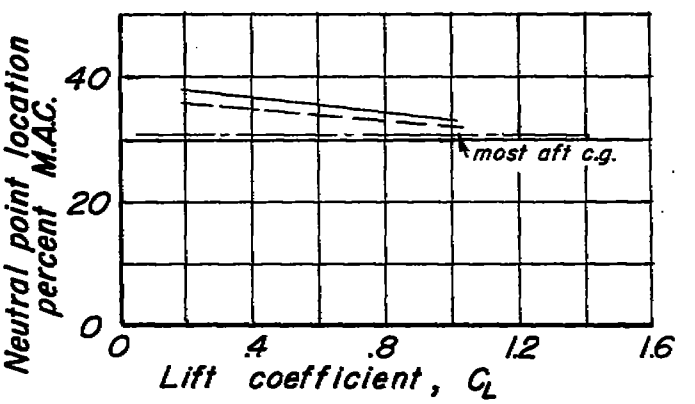


Figure 7.— Effect of incorrect model power setting on longitudinal characteristics. Consolidated Vultee Model 240, flaps and gear up, maximum continuous power.

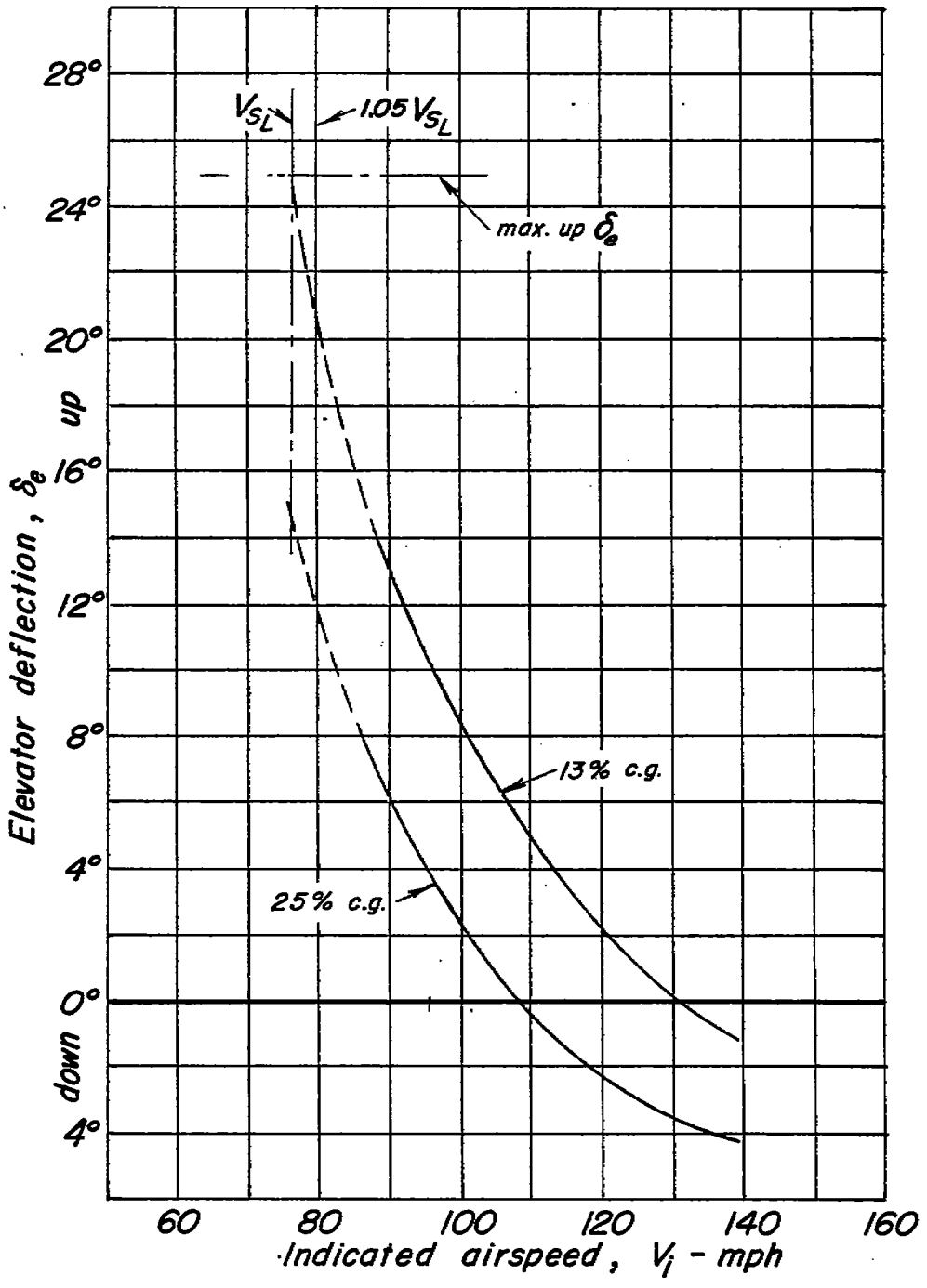
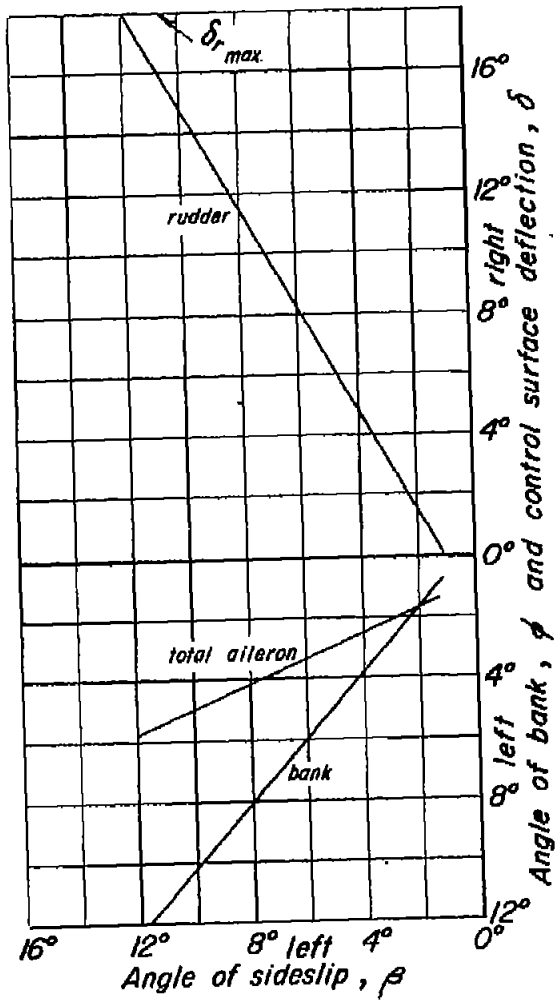
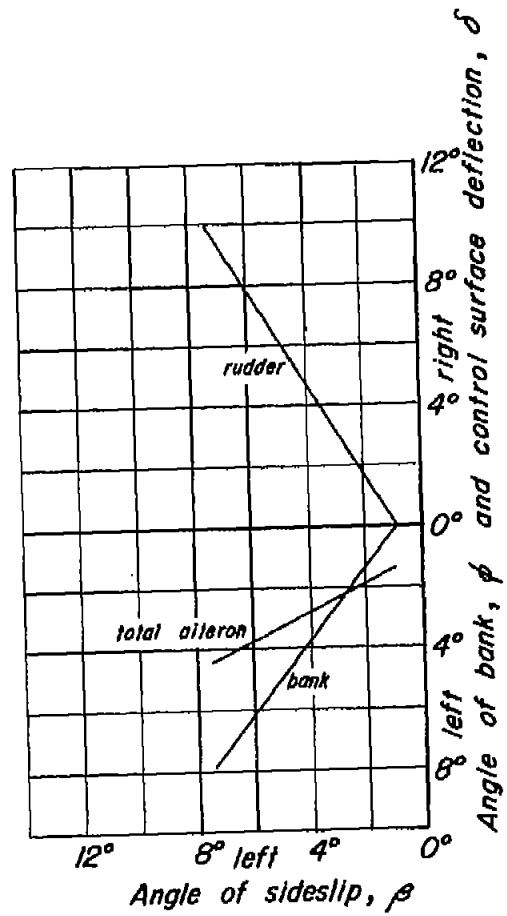


Figure 8.- Elevator control characteristics in landing. Consolidated Vultee Model 240 airplane, flaps 40° gear down, propellers windmilling, 37,143 lb. g.w.



Propellers windmilling

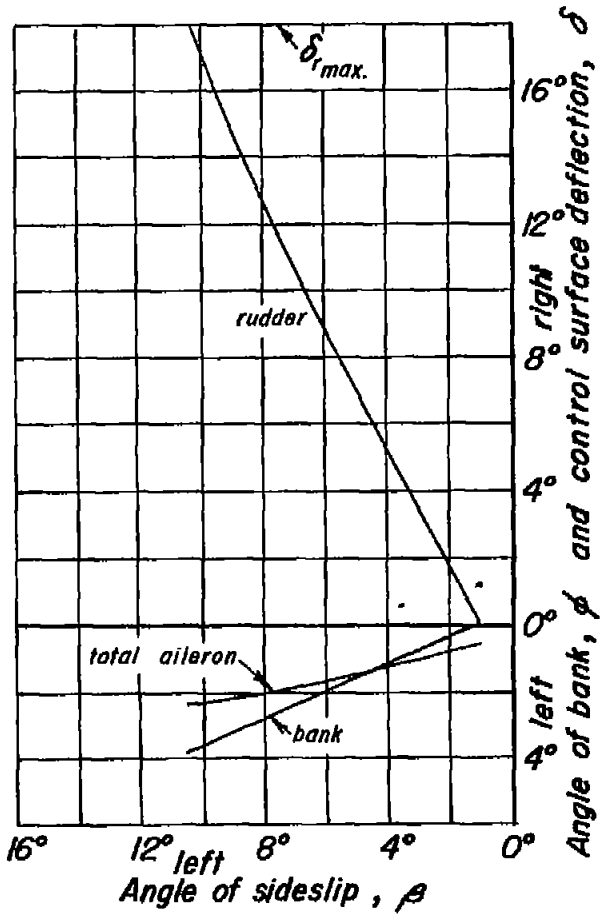


Maximum continuous power

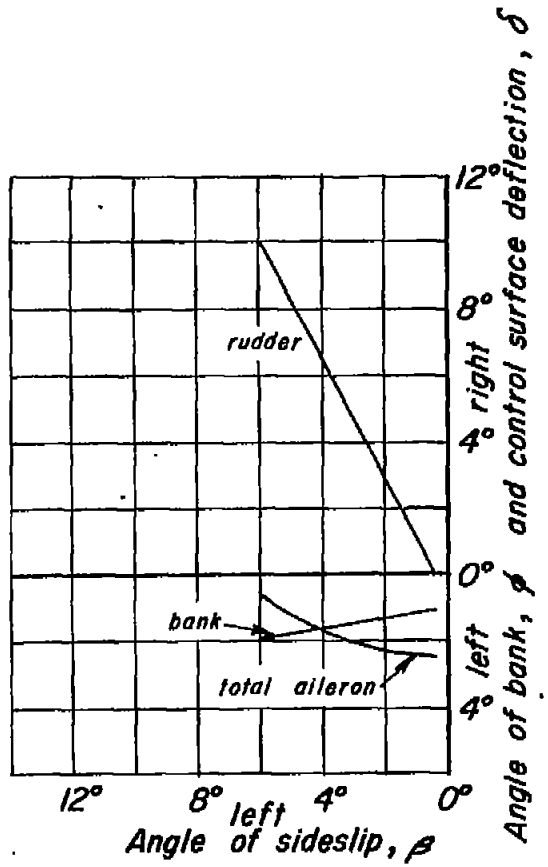
(a) Flaps up, V_i = 202 mph ($1.8V_{S_G}$)

Figure 9.- Characteristics in steady sideslips. Consolidated Vultee Model 240 airplane.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS



Propellers windmilling
V_i = 117 mph ($1.4V_{S_L}$)



Maximum continuous power
V_i = 102 mph ($1.2V_{S_L}$)

(b) Flaps 40°, gear down.

Figure 9. - Concluded.

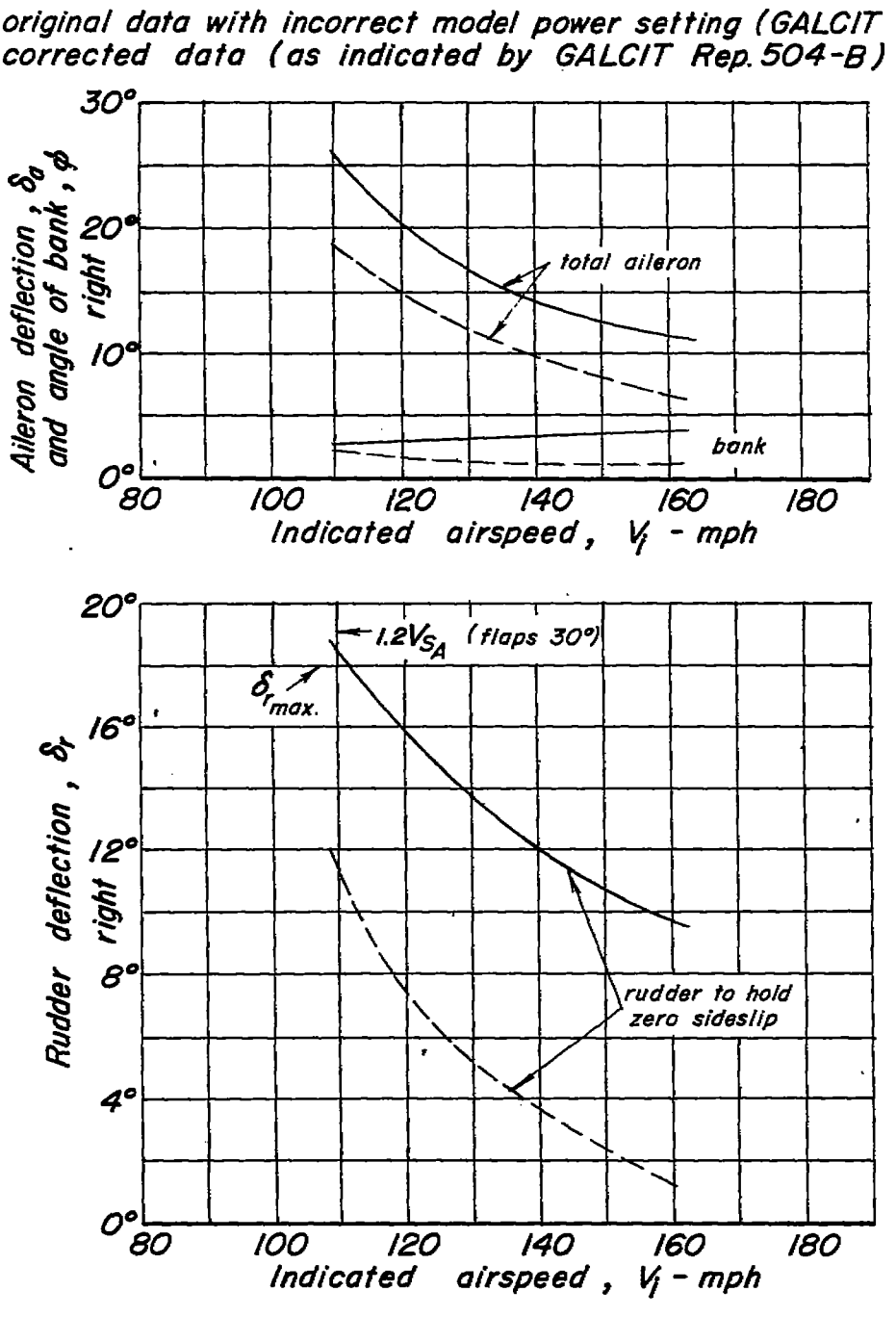


Figure 10.- Rudder control characteristics in asymmetric power take off. Consolidated Vultee Model 240 airplane, flaps 30°, gear up, left engine inoperative (propeller windmilling) right engine delivering take-off power, 37,143 lb. g.w.

NASA Technical Library
3 1176 01434 4262