RESEARCH MEMORANDUM

for the

Civil Aeronautics Administration, Department of Commerce

ESTIMATED FLYING QUALITIES OF THE
MARTIN MODEL 202 AIRPLANE

By

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A conference on the Martin model 202 flying qualities estimations was held on January 20, 1947 with representatives of the Glenn L. Martin Company and the Civil Aeronautics Administration. At this time, it was learned that the positive range of the adjustable stabilizer on the prototype airplane had been changed from 4.4° to 2.5°. In addition, the maximum up and down elevator angles were increased by 5°. These changes should substantially improve the marginal elevator control problem in the landing condition at the foremost center-of-gravity position.

It was also learned that the Martin Company estimated the wing dihedral to be increased by about $\frac{10}{4}$° in level flight as a result of structural deformation. No account was taken of the deformation in the analysis, therefore, it would be expected that the adverse dihedral effect cited will be somewhat alleviated.
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SUMMARY

The flying qualities of the Martin model 202 airplane have been estimated chiefly from the results of tests of an 0.0875-scale complete model with power made in the Wright Brothers tunnel at the Massachusetts Institute of Technology and from partial span wing and isolated vertical tail tests made in the Georgia Tech Nine-Foot Tunnel. These estimated handling qualities have been compared with existing Army-Navy and CAA requirements for stability and control.

The results of the analysis indicate that the Martin model 202 airplane will possess satisfactory handling qualities in all respects except possibly in the following:

The amount of elevator control available for landing or maneuvering in the landing condition is either marginal or insufficient when using the adjustable stabilizer linked to the flaps. Moreover, indications are that the longitudinal trim changes will be neither large nor appreciably worse with a fixed stabilizer than with the contemplated arrangement utilizing the adjustable stabilizer in an attempt to reduce the magnitude of the trim changes caused by flap deflection.

The available rudder control will probably enable landings to be made in cross winds at 90° to the path of only 11 percent of the stalling velocity for some conditions. This condition could probably be improved considerably; chiefly by using somewhat less than full flap deflection.

Considerable negative dihedral effect is probable in the landing and approach conditions which could make the airplane difficult if not dangerous to fly.
The aileron forces in abrupt rolls at cruising speeds are somewhat higher than the desired limits. Moreover, at the lower speeds the aileron forces are undesirably low or overbalanced. No change in the linkage arrangement of the linked-balancing tab would be likely to improve the control forces for one condition without having a detrimental effect on the other. However, it is shown that a spring-tab arrangement can be devised to provide reasonably satisfactory characteristics for all conditions.

INTRODUCTION

At the request of the Civil Aeronautics Administration, Department of Commerce, an estimate was made of the handling qualities of the Martin model 202 transport. This analysis was desired by the CAA as an advance indication of the flight characteristics to be anticipated for the prototype airplane. Availability of such knowledge was believed important from the standpoint of safety, facility in planning the flight-test program and subsequently in expediting the tests themselves.

It was originally planned to base the estimations on the results of complete model tests to be made in one of the Langley 7- by 10-foot tunnels. However, a rather extensive investigation by the Martin Company of a complete model of the Martin model 202 had already been made at the Wright Brothers tunnel at M.I.T. (See references 1 to 4.) In addition, detailed isolated vertical tail tests and tests of a partial span wing to obtain aileron characteristics had been made at the Georgia Tech nine-foot tunnel. (See references 5 and 6.) Therefore, although the investigations did not cover all of the points desired for a complete estimation of handling qualities, the time-saving element prompted the decision to use these data which were already available.

COEFFICIENTS AND SYMBOLS

The following coefficients and symbols appear in the text and figures:

\( C_h \) hinge-moment coefficient of a control surface \( (H/qb c^2) \)

\( C_{h\alpha_t} \) rate of change of hinge-moment coefficient with tail angle of attack


\( C_{h\delta} \) rate of change of hinge-moment coefficient with control-surface deflection

\( C_{h\delta t} \) rate of change of control-surface hinge-moment coefficient with tab deflection

\( C_L \) lift coefficient \( (\text{Lift}/qS) \)

\( T_c' \) effective thrust coefficient \( \left( \frac{\text{effective thrust}}{qS} \right) \)

\( \delta \) control-surface deflection with respect to chord line, degrees

\( i_t \) stabilizer setting with respect to wing root chord line, degrees; positive when trailing edge is down

\( \alpha \) angle of attack of wing root chord, degrees

\( \alpha_t \) angle of attack of tail surface, degrees

\( \beta \) sideslip angle, degrees

\( g \) acceleration due to gravity \( (32.2 \text{ feet per second}) \)

\( V_i \) indicated airspeed \( \left( 0.964 \sqrt{\frac{W/S}{\rho C_L}} \right) \), miles per hour

\( n_p \) neutral-point location, percent mean aerodynamic chord

\( V_{SL} \) stalling speed in the landing condition, power off, miles per hour

\( V_{SG} \) stalling speed in the glide condition, power off, miles per hour

\( V_{Sp} \) stalling speed in the climb condition, 75 percent normal rated power, miles per hour

\( V_{SA} \) stalling speed in the approach condition, 45 percent normal rated power, miles per hour

\( V_p \) design maneuvering speed (see reference 7)

\( V \) true airspeed, feet per second
\( \frac{pb}{2V} \) wing-tip helix angle, radians

\( F_p \) rudder pedal force, pounds

\( F_w \) elevator or aileron wheel force, pounds

\( S_w \) wheel deflection, degrees

\( p \) rolling velocity, radians per second

\( H \) hinge moment of a control surface, pound-feet

\( q \) dynamic pressure \((\rho V^2/2)\), pounds per square foot

\( b \) wing span, feet

\( b' \) (with subscripts) span of a control surface, feet

\( c \) root-mean-square chord of a control surface behind hinge line, feet

\( W \) airplane gross weight, pounds

\( S \) wing area, square feet

\( \rho \) mass density of air, slugs per cubic foot

\( \rho_o \) mass density of air at sea level (0.002378 slug per cubic foot)

Subscripts:

- \( e \) elevator
- \( r \) rudder
- \( a \) aileron
- \( f \) landing flap
- \( e_{bt} \) elevator linked balance tab
- \( e_{tt} \) elevator trim tab
- \( r_{st} \) rudder spring tab
The Martin model 202 airplane is an all-metal, low-wing, twin-engine monoplane with full cantilever wing and tail surfaces. A three-view drawing of the airplane is presented in figure 1. Among the design features are a fully retractable tricycle type landing gear with steerable nose wheel, double-slotted flaps interconnected by mechanical means to an adjustable stabilizer for the purpose of minimizing trim changes when the flaps are lowered or raised and a vane-type (Van Zelm) aileron (see fig. 1) for which a smaller aileron can be used than is customary to obtain the same maximum rolling effectiveness, thus permitting the flap span to be increased.

The elevator and rudder can be aerodynamically balanced by an unsealed overhang and either a linked-balance tab or spring tab. The ailerons are aerodynamically balanced by a sealed overhang and a linked-balance tab.

A summary of the physical characteristics of the airplane furnished by the manufacturer is presented in tables I, II, and III.

The complete model tested at M.I.T. was a 0.0875-scale model with power. Details of the model are given in references 1 to 4.
A description of the 0.30-scale vertical tail model and the 0.25-scale partial span wing panel model tested at Georgia Tech can be found in references 5 and 6, respectively.

TESTS AND ANALYSIS

Test conditions: Most of the tests in the Wright Brothers tunnel at M.I.T. were conducted at a dynamic pressure of 16.37 pounds per square foot which corresponded to an airspeed of about 80 miles per hour. The test effective Reynolds number was about 666,000.

The tests in the Georgia Tech wind tunnel of the vertical tail model and of the partial span wing model were made at a dynamic pressure of 25.58 pounds per square foot which corresponded to an airspeed of about 100 miles per hour. The test effective Reynolds numbers were about 3,920,000 and 2,758,000, respectively.

Model configurations and power conditions: The various airplane flight conditions were simulated in the complete model tests by a suitable variation of model configuration and power condition. The conditions referred to repeatedly in this paper are summarized in the following table:

<table>
<thead>
<tr>
<th>Airplane flight condition</th>
<th>Model configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Landing flap</td>
</tr>
<tr>
<td>Gliding</td>
<td>Retracted</td>
</tr>
<tr>
<td>Cruising</td>
<td>Retracted</td>
</tr>
<tr>
<td>Climbing</td>
<td>Retracted</td>
</tr>
<tr>
<td>Approach</td>
<td>35°</td>
</tr>
<tr>
<td>Landing</td>
<td>55°</td>
</tr>
</tbody>
</table>

Methods of Analysis

The Martin model 202 airplane is a commercial transport and hence is required to meet the stability and control requirements of the CAA (reference 7). However, the flying qualities have been analyzed using the latest Army-Navy specifications for stability and control as a guide (reference 8 or 9). This was done primarily
because of the more specific nature of these requirements for
class II airplanes (transport category) as compared to the rather
general coverage of the CAA requirements. Where important dif­
ferences exist between the two sets of specifications which have a
critical bearing on the estimations suitable, reference is made in
the text. It is to be noted that often the conditions for which
model data were obtained did not correspond exactly to those
specified in references 8 or 9. Instances where these differences
have a pertinent bearing will also be brought out in the discussion.

The normal operating weight of the Martin model 202 transport
is around 36,000 pounds \( (W/S = 41.9) \). However, a majority of the
power-on complete model tests were run using a thrust coefficient
variation based on a weight of 29,000 pounds \( (W/S = 33.7) \) and
therefore it was often necessary to base estimates on this latter
weight. All estimates were made for the mean operational or design
center-of-gravity location unless otherwise specified. A weight-
balance summary is given in table IV.

The flying qualities of the airplane have been estimated from
the data reported in references 1 to 6 using methods similar to
those outlined in references 10 to 13. It was assumed that the
control surfaces are mass-balanced, that there is no friction or
stretch in the control system and that there is no fabric distor­
tion. The power-off stalling velocities of the airplane were
based on values of \( C_{L_{\text{max}}} \) which were obtained by extrapolating
the complete model tunnel data.

No hinge-moment data were available from which the control
forces of the elevator could be estimated directly. Values
of \( C_{h\alpha t}(0) \) and \( C_{h\delta}(0.0037q_{t}/q) \) were therefore estimated
utilizing the lifting surface theory of reference 14 and the
results of hinge-moment correlations summarized in reference 15.
The hinge moments were then estimated using the \( q_{t}/q \) calculated
from complete model pitching-moment data. The tab effectiveness
\( (C_{h\delta_{t}} = -0.0047q_{t}/q) \) which was used to determine the effects of a
linked balance tab and trim tab was obtained using the methods
outlined in reference 16. The linkage factor which was used to
convert the surface hinge moment to wheel force was supplied by
the manufacturer and is presented in figure 2.

In instances where only propellers-off data were available,
the effect of the windmilling propellers on stability was estimated
using the methods of reference 17.
The rotary derivatives which were used in estimating the dynamic stability characteristics of the airplane were calculated using the methods of references 18 to 20.

The rudder-control characteristics were computed using both complete model data (transferred to the stability axis) and the results of the isolated vertical tail tests. The angles of attack and tail loads required for trim were obtained from complete model tests. The rudder deflection required for trim and the rudder hinge moments were obtained from the isolated tail tests. It was possible to estimate the approximate effective aspect ratio of the vertical tail using the limited rudder data available from complete model tests. The isolated tail data were then corrected to this aspect ratio. The yawing moment due to the aileron deflection required for steady sideslips was accounted for. Calculations were made for only one of the several possible rudder-balancing arrangements, namely, an unpreloaded spring tab with a spring constant of 12 pounds per degree tab deflection. This spring strength was chosen primarily to provide acceptable forces in the critical asymmetric-power condition. A curve of rudder linkage factor against rudder deflection is presented in figure 3.

The aileron-control estimates were based on the results of the partial span wing tests made at Georgia Tech. The tunnel corrections were computed from reference 21 and it was found that the rolling-moment coefficients presented in reference 6 were about 8 percent too high. This was taken into consideration in the computations. Curves showing the nonlinear linked-balance tab deflections and linkage factor against aileron deflection are presented in figure 4.

ESTIMATED FLYING QUALITIES

The Army-Navy requirements are divided into four main sections in references 8 or 9, namely:

D - Longitudinal Stability and Control  
E - Directional Stability and Control  
F - Lateral Stability and Control  
G - Stalling Characteristics

The items in the present paper are numbered to correspond with the requirements of references 8 or 9. Whenever a particular requirement was of such nature that an analysis was not deemed feasible using the available wind-tunnel data, it has been omitted.
The Martin model 202 transport falls into the category of class II aircraft in references 8 or 9.

Section D - Longitudinal Stability and Control

D-2 Static longitudinal stability.- The airplane will possess positive static longitudinal stability, elevator fixed, throughout the center-of-gravity range for all required flight conditions. (See fig. 5.) It should be noted that the neutral point curve for 75 percent normal-rated power \((W/S = 33.7 \text{ pounds per square foot})\) actually is equivalent to approximately normal-rated power for the much more frequently encountered condition of \(W/S = 41.9 \text{ pounds per square foot}\). Inasmuch as the estimated value of \(c_{\text{ht}} = 0\), the elevator-free neutral points should be identical with the elevator-fixed neutral points. It should also be noted, however, that in order to obtain satisfactory maneuvering gradients for an airplane of this size and speed, the elevator must be fairly closely balanced (obtained through the use of a linked balancing tab in this instance) and small changes in the hinge-moment parameters (from either nonlinearity, manufacturing dissimilarities or slight errors in the estimations) might easily cause the elevator-free neutral point to shift by 5 percent mean aerodynamic chord or more. This would most likely cause difficulties in the climbing condition (fig. 5) for in this condition the elevator-fixed static margin is a minimum while the tail contribution is considerable. The use of a spring tab would largely reduce the effects of any small changes in the control hinge moments on the stability because of the automatic compensation to these changes (repeatability) which are an inherent characteristic of spring-tab systems.

Application to CAA requirements.- The CAA requires elevator-free stability specifically in the cruising, climbing, approach and landing conditions. However, the requirements either are the same or somewhat less severe than those of D-2 so that the preceding discussion is applicable. The CAA also concerns itself with the stability becoming so great that excessive control forces will be encountered in steady flight. However, generally if the elevator balance is designed to give satisfactory control-force gradients in turning flight and control forces in landing, then satisfactory characteristics will also be obtained in steady flight conditions.

D-3 Elevator control power.- (1) It will be possible to obtain steady flight over the entire speed range for most of the required conditions. (See fig. 6.) The elevator control for stalling the airplane in the landing condition (at the foremost center of gravity),
however, becomes marginal with the contemplated flap full down stabilizer setting of 4.4°. If the cruising stabilizer setting (-1.6°) were used, ample elevator would be available. (See fig. 6(c).)

(2) It should be no problem to obtain the positive limit load factor or maximum lift coefficient in a turn in cruising flight conditions with the present elevator control (fig. 7). For turns in the landing condition (t = 4.4°), however, the elevator available would probably be insufficient to perform the required maneuver at the foremost center of gravity through most of the speed range in view of the aforementioned marginal control for stalling in steady flight in this same condition.

(3) The amount of elevator estimated (from tests in the presence of a groundboard) to be required to hold the airplane off the ground at a speed of 1.05V_{SL} (88 miles per hour, W/S = 41.9) for various arrangements is shown in table V.

It may be seen that the elevator control appears marginal for landing at the foremost center of gravity for the contemplated prototype stabilizer setting of 4.4°. (Maximum available up elevator is 30°.) With the stabilizer set at -1.6° there is unquestionably sufficient elevator for landing throughout the center-of-gravity range.

(5) Often a critical requirement for the adequacy of elevator control is the ability of the control surface to raise the nose wheel during a take off at a speed of 80 percent of V_{SL} with the center of gravity most forward. No data were available, however, with which to estimate the take-off characteristics.

D-4 Elevator control forces. - (1) and (2) Estimated characteristics in steady turning flight were computed for the most forward center-of-gravity location at sea level (a measure of the maximum gradient) and with the center of gravity at the most rearward location for an altitude of 10,000 feet (a measure of the minimum gradient). For each of these conditions, computations were made for the balance tab locked and a linked-balance-tab ratio of 0.4 lag (a linkage variation from 0.3 lead to 0.8 lag is provided for on the prototype airplane).

For all conditions investigated changes in normal acceleration will be approximately proportional to the change in pilot applied control force. (See fig. 7.)

The gradients of elevator control force in steady turns at 270 miles per hour, as estimated from data obtained with the model
in the cruising configuration, are much too high in the tab locked condition. Satisfactory gradients (between 20 and 55 pounds per $g$, references 8 or 9) are indicated, however, with a linked balance tab ratio of 0.4 lag. Again, it must be stressed that minor changes in $C_{\Delta t}$ and $C_{\Delta e}$ could considerably change the estimated characteristics. To illustrate this point computations were made to determine the effect of having slightly different hinge-moment parameters than were estimated. It was assumed that $C_{\Delta t}$ and $C_{\Delta e}$ were changed by 0.0005 and $C_{\Delta e}$ was changed by -0.0005. Then, in a turn at 270 miles per hour at sea level at the foremost center of gravity the gradient is increased by about 27 pounds per $g$ for the linked-balance-tab ratio of 0.4 lag. On the other hand, if a spring tab system were resorted to, an increase of only 4 pounds per $g$ would be attained using a spring constant of 8 pounds per degree tab deflection. Thus if a linked-balance-tab arrangement can not be found which will be satisfactory for all conditions, a suitable spring tab or geared spring-tab system would probably furnish a satisfactory solution.

(6) The control forces required to hold the airplane off the ground at $1.05V_{SL}$ for two possible stabilizer settings and balance arrangements with the airplane initially trimmed at $1.4V_{SL}$ away from the ground are illustrated in table V. It is seen that with a 0.4-lag balance tab the use of either the fixed or adjustable stabilizer would result in a wheel force less than the limiting 50 pounds.

D-6 Longitudinal trim changes. - As previously mentioned the Martin model 202 has an adjustable stabilizer linked to the flaps which moves when the flap is changed in a manner which was hoped to minimize the trim changes caused by flap deflection. The following table summarizes the estimated trim changes with a linked adjustable stabilizer as well as for a fixed stabilizer (set for trim in cruising flight). It should be noted that a flap setting of 35° (approach) has been used in estimations requiring a landing setting (55°) because of the insufficiency of the test data at the latter setting. The trim changes on the airplane caused by full flap deflection will therefore probably be somewhat different than the estimations indicate.
<table>
<thead>
<tr>
<th>No.</th>
<th>Speed (mph)</th>
<th>$\delta_t$ (deg)</th>
<th>Gear</th>
<th>$\delta_r$ (deg)</th>
<th>Power</th>
<th>Items changed</th>
<th>Change in control force (lb)</th>
<th>Change in $\delta_e$ for trim (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Tab ratio zero</td>
<td>0.4 lag tab</td>
</tr>
<tr>
<td>1(a)</td>
<td>131</td>
<td>0</td>
<td>Up</td>
<td>-1.6</td>
<td>50%</td>
<td>Flaps 35°, gear down, variable stabilizer ($\delta_t = 2.2°$)</td>
<td>8.7 push</td>
<td>4.3 push</td>
</tr>
<tr>
<td>1(b)</td>
<td>131</td>
<td>0</td>
<td>Up</td>
<td>-1.6</td>
<td>50%</td>
<td>Flaps 35°, gear down, fixed stabilizer</td>
<td>46.0 push</td>
<td>22.1 push</td>
</tr>
<tr>
<td>2</td>
<td>105</td>
<td>35</td>
<td>Down</td>
<td>2.2</td>
<td>50%</td>
<td>Power off</td>
<td>1.7 pull</td>
<td>0.9 pull</td>
</tr>
<tr>
<td>3</td>
<td>273</td>
<td>0</td>
<td>Up</td>
<td>-1.6</td>
<td>N.R.P.</td>
<td>Power off</td>
<td>3.7 push</td>
<td>1.5 push</td>
</tr>
<tr>
<td>4(a)</td>
<td>105</td>
<td>35</td>
<td>Down</td>
<td>2.2</td>
<td>Take-off</td>
<td>Flaps 0°, gear up, variable stabilizer ($\delta_t = -1.6°$)</td>
<td>14.7 push</td>
<td>8.7 push</td>
</tr>
<tr>
<td>4(b)</td>
<td>105</td>
<td>35</td>
<td>Down</td>
<td>-1.6</td>
<td>Take-off</td>
<td>Flaps 0°, gear up, fixed stabilizer</td>
<td>13.6 pull</td>
<td>6.6 pull</td>
</tr>
<tr>
<td>5</td>
<td>105</td>
<td>35</td>
<td>Down</td>
<td>2.2</td>
<td>Power-off</td>
<td>Take-off power</td>
<td>5.2 push</td>
<td>2.5 push</td>
</tr>
</tbody>
</table>

Inspection of the table shows that the use of the 0.4 lag balance tab gives trim changes well under the specified 50-pound limit regardless of whether a linked adjustable or fixed stabilizer is incorporated. It is apparent that the adjustable stabilizer does
not always insure less trim change than a fixed stabilizer (compare conditions 1 and 4). In fact, under certain conditions the changes may be even greater with the adjustable stabilizer. This consideration, the lack of information as to the magnitude of trim changes with the flaps full down and, in addition, the afor-mentioned marginal elevator control associated with the adjustable stabilizer probably would make it of prime interest to check the relative merits of a fixed and adjustable stabilizer on the first flying article.

D-7 Longitudinal trimming device.- (2) The longitudinal trimming device is powerful enough to secure zero elevator control forces over the center-of-gravity range for the specified conditions. (See fig. 8.)

Section E - Directional Stability and Control

E-1 Dynamic stability.- The rudder fixed dynamic stability of the airplane was investigated for a cruising and a gliding flight condition. For the cruising condition \( V_1 = 240 \) miles per hour the airplane will be spirally stable. The oscillatory stability in this condition is such that the period of the oscillation will be about 3 seconds and will damp to \( 1/2 \) amplitude in somewhat less than 1 cycle. In a gliding condition \( V_1 = 141 \) miles per hour, however, the airplane will be spirally unstable. But the spiral mode is such that the divergence will double in about 45 seconds so that the pilot should have no difficulty in controlling it. The period of the oscillation in the gliding condition is about 5 seconds and is also rather heavily damped, the time to damp to half amplitude again being appreciably less than 1 cycle.

E-2 Static directional stability.- (1) The airplane exhibits rudder fixed static directional stability for all flight conditions investigated. (See fig. 9.) It should be noted that the stability is high in the approach condition and particularly high in the landing condition. The angle of sideslip is roughly proportional to the rudder deflection from trim for all conditions.

(2) The critical condition for sideslip caused by rolling is encountered in gliding flight on the Martin Model 202 airplane. When gliding at \( V_1 = 141 \) miles per hour in a \( 45^\circ \) banked turn, the rudder fixed static directional stability is such that the angle of sideslip caused by full aileron deflection is only \( 12.8^\circ \) which is considerably less than the permissible \( 20^\circ \). (See fig. 10.)
(3) The rudder-force characteristics are such that with the rudder free the airplane will always tend to return to the trim condition with the wings level. (See fig. 9.) Although there are no actual force reversals shown, there are tendencies toward overbalance at the larger angles of sideslip. Moreover, overbalance may well occur on the airplane for some of these conditions if the basic limitations of the model hinge-moment data are considered. The data were insufficient, however, to establish whether or not rudder lock would occur at sideslip angles greater than 15° to 20°. If rudder lock is encountered on the airplane at the higher angles of sideslip, it may be desirable to utilize a larger dorsal fin in order to ameliorate the deficiency. As will be pointed out later on in the discussion calculations were made for only a spring tab system. With a linked-balance-tab arrangement or with a combination of the two arrangements even greater tendencies toward overbalancing would be encountered.

(4) The single-engine condition investigated and referred to in this and subsequent sections pertaining to asymmetric power conditions is for a climbing condition at a speed of about 1.2Vs0. The thrust simulated in the right engine (left propeller windmilling) corresponded to about rated power at W/S of 41.9. Although this condition is sometimes more stringent and at other times less stringent than those specified in references 7 to 9, similarity was generally close enough that the one condition investigated could be used throughout. The data were insufficient to establish whether or not the airplane could be balanced directionally in steady straight flight for the aforementioned condition with the rudder free and trim tab neutral. (See fig. 11.)

The amount of pitching moment resulting from sideslip although not mentioned in references 8 or 9 is generally considered to be of interest to airline pilots. This airplane will probably meet requirement II-H of reference 22, for it is estimated that, for all conditions shown on figure 9, less than 1° elevator movement is needed to maintain longitudinal trim when the rudder is moved 5° in either direction from its trim position at zero bank.

**E-3 Rudder control power.** - (1) From the conditions investigated and shown in figure 9, it appears safe to assume that the rudder will be sufficiently powerful to trim the airplane in all probable steady symmetric flight conditions with the wings level.

(2) The only complete model yaw data available for the landing condition was at a lift coefficient corresponding to a speed of about 100 miles per hour. Using these data, it is estimated that,
a landing at about 80 miles per hour in a cross-wind at 16 miles per hour (20 percent $V_{SL}$) at 90° to the flight path would require trim to be attainable at $\beta = 12^0$ sideslip. It can be seen, figure 9(e), that only about 60 left and 110 right sideslip can be held with the contemplated maximum rudder deflection ($\pm 25^0$). The trimmable sideslip range could probably be increased by using less than the full down flap setting. (See fig. 9(d).) A slight increase would also be obtainable by increasing the maximum rudder throw to $\pm 30^0$, but the resulting increased severity of rudder lock tendencies might not warrant the change. No data were available with which to estimate the rudder control during take-offs.

(4) For the asymmetric power condition investigated, figure 11, it is seen that about 220 right rudder is needed to hold zero sideslip. Rudder may not be available to meet the actual requirement $E-3-4$, however, inasmuch as full take-off power was not simulated. Moreover, the directional stability would be expected to be somewhat greater with the flaps in the take-off setting ($10^0$ to $15^0$).

**Application to CAA requirements.** - Sufficient rudder control is probably available to execute 200 banked turns with or against the inoperative engine from a steady climb at a speed of $1.4V_{SG}$ with maximum continuous power being applied to the operating engine. For although the thrust coefficient simulated in the model tests analyzed corresponded to only about rated power at $C_L = 1.0$ ($W/S = 41.9$) at the $C_L$ for $1.4V_{SG}$ (about 0.7) the power represented would be even greater than rated power for $W/S = 33.7$.

No data were available for single engine operation in the approach condition, but because of the large directional stability, it is extremely doubtful whether heading changes of $15^0$ against the inoperative engine could be achieved from trim with the wings level.

(5) It is estimated that only about 4.50 of right rudder will be needed to overcome adverse aileron yaw during an abrupt full right aileron roll from a 450 banked turn in the gliding condition at $1.4V_{SG}$.

**E-4 Rudder pedal forces.** - As has been previously mentioned, no particular difficulty is expected to be encountered in obtaining satisfactory control forces because of the wide variety of linkage arrangements and springs of different strengths with which the
prototype airplane can be equipped. As an example calculations using one logical arrangement were made. This arrangement made use of an unpreloaded spring tab with a spring constant of 12 pounds per degree tab deflection.

(1) If the means suggested are used to increase the trimmable sideslip range, it is shown in figures 9(d) and 9(e) that the pedal forces will be considerably less than 180 pounds for the required cross-wind landing. Only about 20 pounds of rudder pedal force will be required to counteract the adverse aileron yaw in condition E-3-5.

(2) The pedal force required to hold zero sideslip in the asymmetric power condition investigated was roughly 120 pounds with the trim tab set for zero pedal force in the symmetric climb condition. (See figs. 9(c) and 11.) The actual pedal force for the required condition would probably be somewhat larger as has been previously pointed out.

E-6 Directional trimming device.- (2) If a spring tab system is used on the rudder, some thought should be given to the use of a separate tab for trimming and balancing purposes. This is advisable because of the possibility of reduced tab effectiveness for balancing when most of the uninstalled lift range of the tab is used up for trimming. Also in spring tab systems the tab hinge moments cause the tab to blow back against the spring requiring extra effort on the part of the pilot in the form of repeated trim jack adjustments. Because this airplane only attains moderately high speeds and has not been designed for violent maneuvering, a combination spring and trim tab might be acceptable.

(3a) The directional trimming device is easily capable of reducing the rudder pedal force to zero in the gliding and climbing flight conditions with the wings level. (See figs. 9(b) and (c).)

(b) About 16.6° left tab (maximum deflection 20°) is necessary to trim in the asymmetric power condition investigated. Inasmuch as in this instance the required condition is slightly less severe, sufficient trim tab should be available to meet it.

Section F - Lateral Stability and Control

F-2 Static lateral stability.- (1) The airplane will probably be laterally statically stable with both fixed or free ailerons in all flap-up conditions. (See figs. 9(a) to 9(c).) However, because of the effects of double-slotted flap deflection, considerable
negative effective dihedral is indicated in the computed approach and landing conditions (figs. 9(d) and 9(e)). The curves of rolling-moment coefficient versus yaw angle for these latter conditions with the rudder fixed at 0° showed either a small amount of stability or neutral stability, but because of the high directional stability present in these conditions and the large change in rolling moment with rudder deflection, the slope of the curve of total aileron deflection for trim against β indicates appreciable instability. It should be remembered that because of the limitations of the available data the flap-down estimates were made at speeds corresponding to angles of attack which would be considerably lower than would be normally used in the approach and landing conditions. At these low angles of attack the flaps were stalled on the model casting some doubt on the applicability of the data to the higher CL range or even the low CL range at the higher Reynolds numbers of the airplane. Nevertheless, unless the rolling- and yawing-moment characteristics are much changed at the larger angles of attack, even the rudder-fixed dihedral effect will be negative because of the greater adverse effect of power in the approach condition and because of the reduced tail contribution to positive dihedral effect at the larger angles of attack in both the approach and landing conditions. If the dihedral effect indicated in figures 9(d) and 9(e) persist on the airplane at the higher lift coefficients, it is believed trouble may be encountered on several scores. In making instrument approaches at fairly low altitudes the pilot brackets a slender range leg, generally using the rudder alone to accomplish this. The rate of spiral divergence would be high and would be continually initiated and aggravated by use of the rudder in obtaining and maintaining headings. In a final landing approach it would be possible to have the rudder fully deflected when attempting to maintain a ground track while trying to raise a wing dropped by a gust. The pb/2V available for leveling the wings in this condition would give rolling velocities far below those now desired by airline pilots.

(2) The small effective dihedral coupled with a rather large directional stability insures that the rolling moment caused by sideslip in a rudder-fixed aileron roll will never be large enough to cause a reversal of rolling velocity because of aileron yaw.

(3) The variation of side force with angle of sideslip will be such that right bank accompanies right steady sideslip and vice versa for all conditions investigated. (See fig. 9.)

F-3 Aileron control power. - (1) There are no differences between the Van Zelm ailerons used on the model 202 and conventional ailerons which would cause the airplane to roll in the wrong direction immediately after an abrupt aileron deflection.
(3) For all conditions investigated, figure 12, the rolling velocity will vary smoothly with aileron deflection and be approximately proportional to the amount of the deflection.

(4) The helix angle obtained with maximum aileron deflection will be approximately equal to or greater than the required \( \frac{p_b}{2V} = 0.070 \) for all conditions except in the gliding flight condition at a speed of 128 miles per hour (fig. 12) where a maximum value of \( \frac{p_b}{2V} = 0.064 \) is obtainable. The values of \( \frac{p_b}{2V} \), however, were obtained from the rolling-moment data of reference 6 and contain an arbitrary correction factor of 20 percent to account for the effects of adverse yaw and wing twist. This correction factor is believed to be conservative inasmuch as the wing twist will probably not be large at the speeds reached and the discussions of E-2-2 and F-2-2 indicate the adverse yaw effects will be rather small on this airplane.

(5) The value of \( p_b \) will probably be considerably greater than 10 feet per second at \( 1.1w_{SL} \) when maximum aileron deflection is used.

(6) Sufficient aileron control is available to secure lateral trim in the asymmetric power flight conditions investigated, about two-thirds of the available aileron being required. (See fig. 11.) Inasmuch as the ailerons remain effective up to full throw, it is probable that requirement F-3-6 could be met for any probable asymmetric power condition likely to be encountered flaps up.

(7) The ailerons are effective enough to obtain a \( \frac{p_b}{2V} \) of 0.05 per 100° of wheel throw up to at least a speed of 240 miles per hour (approximately \( 0.8w_{max} \)). (See fig. 12.)

F-4 Aileron forces. - (1) The aileron control-force characteristics in rolling maneuvers and steady sidslips are not always of sufficient gradient to return the control to trim position when cognisance is taken of the allowable frictional limit of 6 pounds. (See figs. 9 and 12.) In fact, there is actual overbalancing indicated for an abrupt full roll in the gliding flight condition at the lower speed investigated (fig. 12).

(2) The estimated value of \( 0.8w_{max} \) in level flight is approximately 240 miles per hour. At this speed it would require a wheel force of about 150 pounds, (fig. 12) to attain the required \( \frac{p_b}{2V} = 0.07 \). The force is considerably greater than the allowable 80 pounds. Moreover, because of the overbalancing tendencies at the lower speeds, it does not appear feasible to reduce the high-speed force by a change in the linked balance tab deflection rate.
Application to CAA requirements.—Information relative to CAA rolling requirements can be gleaned from the section on strength requirements in reference 7. There it is stated that full aileron deflection is required only up to the design maneuvering speed ($V_p = \text{approximately 170 miles per hour for this airplane}$) and that when the design cruising speed is in excess of $V_p$, the rate of roll required at the design cruising speed be not less than that obtained using full aileron deflection at $V_p$. Assuming a maximum $\frac{p_b}{2V}$ of about 0.07 at $V_p$, it is apparent that only $\frac{p_b}{2V} = \frac{170}{240} \times 0.07 = 0.0495$ will be required at 240 miles per hour. The control force required to obtain this $\frac{p_b}{2V}$ is about 95 pounds, (fig. 12) still over the 80-pound limit, but possibly tolerable. Nevertheless, overbalancing is indicated at lower speeds and thus it was decided to investigate the characteristics with a spring-tab system.

Control forces and $\frac{p_b}{2V}$ were estimated for a spring-tab system with individual unpreloaded spring units with a spring strength of 2 pounds per degree tab deflection at zero aileron deflection. Calculations were made for a spring tab the same size as the present linked tab and for a spring tab of 50 percent increased effectiveness. Both tabs were assumed aerodynamically balanced with a deflection range of $\pm 15^\circ$. The curve of $\delta_a$ versus $\delta_w$ shown in figure 4 was modified so that for the same maximum wheel deflection ($120^\circ$) no reduction in maximum aileron deflection will be obtained when the spring tab is fully deflected. It can be seen, figure 13, that in the gliding condition at $V_1 = 240$ miles per hour the wheel force for a $\frac{p_b}{2V}$ of 0.0495 is reduced to about 60 pounds with the tab of 50 percent increased effectiveness. Moreover, although in the gliding condition at $V_1 = 127$ miles per hour there still exists a slight reduction in control force for increased aileron deflection in the range of total deflections of between $22^\circ$ and $35^\circ$, the objectionable overbalance has been eliminated.

(3) The aileron control force for trim at zero sideslip in the asymmetric power flight condition investigated will be of the order of 20 pounds. This is far less than the limiting 80 pounds. (See fig. 11.)

F-6 Lateral trimming devices.—(3a) The lateral trimming device will be powerful enough to reduce the aileron force to zero in the gliding and climbing conditions at all required speeds. (See figs. 9(b) and (c).)
(3b) Approximately maximum available trim tab (27.5°) will be needed to reduce the aileron control force to zero at zero sideslip for the asymmetric power condition investigated. However, it should also be noted that the specific condition outlined for F-6-3b should also be met inasmuch as it is of less severity than that shown on figure 11.

Section G - Stalling Characteristics

G-2 Stall warning. - Because of differences in scale which will undoubtedly cause the stall characteristics to differ on the airplane and model, the discussion will be of a brief qualitative nature based chiefly on the tuft studies and discussion of reference 3.

Good stall warning will be realized in the landing condition \( (\delta_F = 55^\circ) \) inasmuch as the root section unmistakably stalls first. In the approach condition the stall also begins over the inboard portion of the wing but spreads outboard over the ailerons more than in the landing condition. For the gliding condition \( (\delta_F = 0^\circ) \) the stall started at the inboard trailing edge and gradually spread forward and outward. The addition of power \( (\delta_F = 0^\circ) \) delayed the stall in the nacelle region. For both flap-up conditions, a good portion of the aileron region was stalled before \( C_{L_{\text{max}}} \) was reached.

There generally will be a fairly marked increase in the rearward travel of the control column as stall approaches. (See fig. 6.) This is especially true in the landing condition.

G-3 Prevention of the complete stall. - The tuft sketches showed that a good portion of the ailerons were stalled before \( C_{L_{\text{max}}} \) was reached in the flap-up flight conditions. The data of reference 6, however, indicate that considerable aileron effectiveness exists up to the stall. In the landing condition, the ailerons remained unstalled above the angle of attack for \( C_{L_{\text{max}}} \). As has been shown previously, the available elevator to stall with the stabilizer set in the flap-full-down position was marginal. However, for less positive stabilizer settings in the landing condition and in other conditions it should be possible to prevent or recover from the complete stall by the normal use of the controls when corrective action is taken immediately after the stall warning occurs.

G-4 Differential stalling of the wings. - Any differential stalling on the airplane will depend critically on the amount of
asymmetry in the actual airplane. Model data showed that in flap-down conditions the right wing panel stalled considerably earlier than the left panel. It was also shown, however, that the stall occurred on the inboard portion of the wing so that the rolling or yawing moments incurred would probably be controllable.

CONCLUDING REMARKS

The results of the analysis based on the available wind-tunnel data indicate that the Martin Model 202 airplane will probably possess satisfactory handling qualities in all respects except possibly in the following.

1. The amount of elevator control available for landing or maneuvering in the landing condition is either marginal or insufficient when using the adjustable stabilizer linked to the flaps. Moreover, indications are that the longitudinal trim changes are neither large nor appreciably worse with a fixed stabilizer than with the contemplated arrangement utilizing the adjustable stabilizer in an attempt to reduce the magnitude of the trim changes caused by flap deflection.

2. Indications are that the available rudder control will enable landings to be made in cross winds at 90° to the path of only 11 percent of the stalling velocity for some conditions. This condition could be improved; chiefly by using somewhat less than full flap deflection.

3. Considerable negative effective dihedral is probable in the landing and approach conditions which could make the airplane difficult if not dangerous to fly.

4. The aileron forces in abrupt rolls at cruising speeds are somewhat higher than the desired limits. Moreover, at the lower speeds the aileron forces are undesirably low or overbalanced. No change in the linkage arrangement of the linked balancing tab would be likely to improve the control forces for one condition without having a detrimental effect on the other. However, a spring-tab
arrangement can be designed that will provide reasonably satisfactory characteristics for all conditions.

Langley Memorial Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va.

Approved: Hartley A. Soule
Chief of Stability Research Division

Joseph Weil
Aeronautical Engineer

Margaret F. Spear
Engineering Aide
REFERENCES


### TABLE I

PHYSICAL CHARACTERISTICS OF THE MARTIN MODEL 202 AIRPLANE

<table>
<thead>
<tr>
<th>Type</th>
<th>Commercial transport</th>
</tr>
</thead>
</table>

**Engines**

- **Manufacturer's designation**: Pratt & Whitney R-2800-CA3
- **Normal power**
  - 1700 bhp at 2600 rpm at sea level
  - 1700 bhp at 2600 rpm at 7,000 ft
  - 1450 bhp at 2600 rpm at 18,500 ft
- **Take-off power**: 2100 bhp at 2800 rpm at sea level
- **Supercharger type**: Single stage, two speed
- **Propeller gear ratio**: 0.450

**Propeller**

- **Type**: Hamilton Standard reversible pitch
- **Diameter, ft**: 13.08
- **Blade design**: 2H17B3-48R
- **Number of blades**: 3
- **Activity factor (per blade)**: 168
- **Side-force factor**: 132

**Landing gear**

- **Tricycle (nose-wheel) type**

---

1 Water injection rating of 2400 bhp simulated in all take-off power complete model testing.

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### TABLE II

#### AIRPLANE WING AND TAIL-SURFACE DATA

<table>
<thead>
<tr>
<th></th>
<th>Wing</th>
<th>Horizontal tail</th>
<th>Vertical tail</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Area, sq ft</strong></td>
<td>860</td>
<td>275.1</td>
<td>118.0</td>
</tr>
<tr>
<td><strong>Span, ft</strong></td>
<td>92.75</td>
<td>36.47</td>
<td>14.297</td>
</tr>
<tr>
<td><strong>Aspect ratio</strong></td>
<td>10</td>
<td>4.84</td>
<td>1.732</td>
</tr>
<tr>
<td><strong>Taper ratio</strong></td>
<td>2.75</td>
<td>2.5</td>
<td>2.215</td>
</tr>
<tr>
<td><strong>2Dihedral, deg</strong></td>
<td>3</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td><strong>Sweepback, quarter chord line, deg</strong></td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Root section</strong></td>
<td>W-16 (19 percent) modified</td>
<td>65-013 modified</td>
<td>65-011 modified</td>
</tr>
<tr>
<td><strong>Tip section</strong></td>
<td>W-16 (15 percent) modified</td>
<td>65-010 modified</td>
<td>65-011 modified</td>
</tr>
<tr>
<td><strong>Angle of incidence at root, deg</strong></td>
<td>3 (^3)</td>
<td>from -1.6° to 4.4°</td>
<td>0</td>
</tr>
<tr>
<td><strong>Angle of incidence at break, deg</strong></td>
<td>3 (^3)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><strong>Angle of incidence at tip, deg</strong></td>
<td>3 (^3)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><strong>M.A.C., ft</strong></td>
<td>10.02</td>
<td>8.069</td>
<td>8.767</td>
</tr>
<tr>
<td><strong>Theoretical root chord, ft</strong></td>
<td>13.67</td>
<td>10.833</td>
<td>11.490</td>
</tr>
<tr>
<td><strong>Theoretical tip chord, ft</strong></td>
<td>4.97</td>
<td>4.333</td>
<td>5.186</td>
</tr>
</tbody>
</table>

1. Includes no dorsal fin area.
2. Dihedral measured at quarter chord line.
3. Angle of incidence measured with respect to fuselage base line.
4. Angle of incidence measured with respect to wing chord line.

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TABLE III

AIRPLANE CONTROL-SURFACE DATA

<table>
<thead>
<tr>
<th></th>
<th>Aileron</th>
<th>Elevators</th>
<th>Rudder</th>
<th>Wing Flaps</th>
<th>Fuselage Flaps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent span</td>
<td>12.2%</td>
<td>90%</td>
<td>100%</td>
<td>63.4%</td>
<td>9.9%</td>
</tr>
<tr>
<td>Area, behind hinge line, sq ft</td>
<td>16.6</td>
<td>24.5</td>
<td>39.67%</td>
<td>150%</td>
<td></td>
</tr>
<tr>
<td>Balance area, sq ft</td>
<td>4.32</td>
<td>7.63</td>
<td>15.12%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percent chord behind hinge line</td>
<td>23.0</td>
<td>20.0</td>
<td>34.0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean chord, behind hinge line, ft</td>
<td>1.437</td>
<td>1.50</td>
<td>2.796%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance to 1/4 tail M.A.C. from 1/4 wing M.A.C., ft</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control deflection, deg</td>
<td>30 up 15 down</td>
<td>26 up 16 down</td>
<td>25 right 25 left</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trim-tab area, sq ft</td>
<td>1.33</td>
<td>3.43</td>
<td>15.93%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Span, ft</td>
<td>4</td>
<td>7.1</td>
<td>6.50%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tab deflection, deg</td>
<td>12 up 16 down</td>
<td>±15</td>
<td>±120%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Balance tab area, sq ft</td>
<td>(2)</td>
<td>(2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tab deflection, deg</td>
<td>9 up 12 down</td>
<td>.8 lag .3 lead</td>
<td>±10%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 One side
2 Same tab used for trimming and balancing
3 Flaps up
4 Flaps down (α = 55°)
5 Double slotted flaps
6 Split flaps

Flap deflections, deg (corresponding powers)

For landing ................ 45-55 (power off)
For take-off ................. 10-15 (≥100-2400 hp)
Approach ........................ 30-35 (765 hp)
All other conditions ........... Flaps retracted

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**TABLE IV**

**AIRPLANE WEIGHT-BALANCE SUMMARY**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Gross weight (lb)</th>
<th>Center of gravity, wheels up</th>
<th>Center of gravity, wheels down</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(in. behind fuselage station 0)(^1)</td>
<td>(percent M.A.C.)</td>
</tr>
<tr>
<td>Design</td>
<td>36,000</td>
<td>448</td>
<td>27.4</td>
</tr>
<tr>
<td>Foremost c.g.</td>
<td></td>
<td>434</td>
<td>14.4</td>
</tr>
<tr>
<td>Rearmost c.g.</td>
<td></td>
<td>452</td>
<td>31.0</td>
</tr>
</tbody>
</table>

\(^1\) Fuselage station 0 is 100 inches forward of nose.
TABLE V

LANDING CHARACTERISTICS

\[ V_1 = 1.05V_{CL} = 88 \text{ mph}, \ W/S = 41.9 \]

<table>
<thead>
<tr>
<th>Condition</th>
<th>16 percent c.g. (foremost)</th>
<th>31 percent c.g. (rearmost)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \delta_{\text{t}} ) (deg)</td>
<td>Balance tab</td>
<td>( \delta_{\text{req}} ) (deg)</td>
</tr>
<tr>
<td>4.4</td>
<td>Locked</td>
<td>29 up</td>
</tr>
<tr>
<td>0.4 lag</td>
<td>29 up</td>
<td>3.1 down</td>
</tr>
<tr>
<td>-1.6</td>
<td>Locked</td>
<td>13.3 up</td>
</tr>
<tr>
<td>0.4 lag</td>
<td>13.3 up</td>
<td>1.2 up</td>
</tr>
</tbody>
</table>

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Figure 1.—Three-view drawing of the Martin Model 202 airplane.

Note: All dimensions in feet.

- hinge line seal
- Section A-A

Foremost c.g., 14.4% M.A.C.
Rearmost c.g., 31% M.A.C.

Incidence 3°
Static ground line

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Figure 2.- Variation of elevator linkage factor with elevator deflection on the Martin Model 202 airplane.
Figure 3.- Variation of rudder linkage factor with rudder deflection on the Martin Model 202 airplane. Spring tab locked, no load.
Figure 4. Variation of aileron linkage factor, wheel deflection, and linked balance tab deflection with aileron deflection on the Martin Model 202 airplane.
Figure 5—Estimated elevator-fixed neutral points of the Martin Model 202 airplane. $\frac{W}{S} = 35.7$ lb/sq ft.
Figure 6.- Estimated elevator characteristics of the Martin Model 202 airplane in steady flight. W/S = 33.7 lbs/sq ft.
Figure 7.—Estimated elevator-control characteristics in accelerated flight for the Martin Model 202 airplane. $V/9 = 33.7 \text{ lb/ft}^2$; $V = 270 \text{ mph}$; $\theta = -1.6^\circ$.
Figure 8.—Estimated trim tab deflection required for zero elevator control force on the Martin Model 202 airplane. Linked balance tab deflection 0.1 lag. N/S = 33.7 lb/sq ft.
Fig. 9a

(a) Gliding condition, $V_1 = 127.2$ mph

Figure 9.- Estimated steady sideslip characteristics of the Martin Model 202 airplane. $C_{L} = 0.73$ lbs/sq ft.
Figure 9b

(b) Climbing condition, $V_1 = 101$ mph

Figure 9, continued.
(c) Cruising condition, $V_L = 239$ mph

Figure 9c - Continued.
(d) Approach condition, $V_L = 115$ mph

Figure 9. - Continued.
Figure 9c—Concluded.
Figure 10.—Estimated variation of sideslip angle with time during an abrupt rudder-fixed aileron roll out of a steady 45° banked turn on the Martin Model 202 airplane. Gliding condition, $V_1 = 141$ mph, full right aileron.
Figure 11.- Estimated single-engine characteristics in steady sideslip of the Martin Model 209 airplane. Left propeller windmilling; right engine $T_d = 0.159$, $\alpha_c = 0^\circ$, $V_t = 115$ mph.
Figure 12.— Estimated variation of helix angle, and aileron wheel force with total aileron deflection for various conditions on the Martin Model 202 airplane. \( \frac{V}{S} = 21.86 \) lbs/eq ft.