RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Department of the Navy

WIND-TUNNEL INVESTIGATION AT LOW SPEED
OF THE YAWING, PITCHING, AND STATIC STABILITY
CHARACTERISTICS OF A 1/10-SCALE MODEL OF THE
GRUMMAN F9F-9 AIRPLANE

TED No. NACA AD 3109

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS
WASHINGTON
APR 13 1955

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To be returned to the files of the National Advisory Committee for Aeronautics
Washington, D.C.
An experimental investigation has been made in the Langley stability tunnel to determine the low-speed yawing, pitching, and static stability characteristics of a 1/10-scale model of the Grumman F9F-9 airplane. Tests were made to determine the effects of duct-entrance-fairing plugs on the static lateral and longitudinal stability characteristics of the complete model in the clean condition. The remaining tests were concerned with determining tail contributions as well as the effect of duct-entrance-fairing plugs, slats, flaps, and landing gear on the yawing and pitching stability derivatives. These data are presented without analysis in order to expedite distribution.

INTRODUCTION

Previous investigations have indicated that reliable prediction of dynamic flight characteristics over a wide angle-of-attack range requires more accurate estimates of the various aerodynamic parameters than are possible with the use of available procedures. (See refs. 1 and 2, for example.)
The purpose of the present investigation was to determine the yawing and pitching stability derivatives of various clean and landing configurations of a 1/10-scale model of the Grumman F9F-9 airplane. This part of the investigation included determining the tail contributions as well as the effects of slats, flaps, and landing gear. The static lateral and longitudinal stability characteristics of a basic clean configuration were determined in order to provide a basis of comparison with large-scale results from other sources as an aid in evaluating the results of this investigation when applied to the full-scale airplane.

These tests were made at the request of the Bureau of Aeronautics, Department of the Navy, to aid in the development of the Grumman F9F-9 airplane.

SYMBOLS

The data presented herein are in the form of standard NACA coefficients of forces and moments which are referred to the stability system of axes with the origin at the center of gravity. All coefficients are based on the basic wing which has an area of 2.502 square feet as compared with an area of 2.548 square feet for the basic wing plus the leading-edge extension. The positive direction of forces, moments, and angular displacements is shown in figure 1. The coefficients and symbols are defined as follows:

L lift, lb
D drag, lb
Y lateral force, lb
M pitching moment, ft-lb
L' rolling moment, ft-lb
N yawing moment, ft-lb
b span, ft
S area, sq ft
c chord, measured parallel to plane of symmetry, ft

\bar{c} mean aerodynamic chord, \frac{2}{S} \int_{0}^{b/2} c^2 dy, ft
\( y \) spanwise distance from and perpendicular to plane of symmetry, ft

\( q_0 \) free-stream dynamic pressure, \( \rho V^2/2 \), lb/sq ft

\( V \) free-stream velocity, ft/sec

\( \rho \) mass density of air, slugs/cu ft

\( \alpha \) angle of attack of fuselage reference line, deg

\( \theta \) angle of pitch, deg

\( \gamma \) flight-path angle, deg

\( \phi \) angle of roll, deg

\( \beta \) angle of sideslip, deg

\( \psi \) angle of yaw, deg

\( C_L \) lift coefficient, \( L/q_0 S_w \)

\( C_D \) drag coefficient, \( D/q_0 S_w \)

\( C_Y \) lateral-force coefficient, \( Y/q_0 S_w \)

\( C_m \) pitching-moment coefficient, \( M/q_0 S_w C_w \)

\( C_l \) rolling-moment coefficient, \( L'/q_0 S_w b_w \)

\( C_n \) yawing-moment coefficient, \( N/q_0 S_w b_w \)

\( rb/2V \) yawing-angular-velocity parameter, radians

\( r \) yawing angular velocity, \( d\psi/dt \), radians/sec

\( qC/2V \) pitching-angular-velocity parameter, radians

\( q \) pitching angular velocity, \( d\theta/dt \), radians/sec

\( C_{Y\beta} = \frac{\partial C_Y}{\partial \beta} \)
\[ c_{l\beta} = \frac{\partial c_l}{\partial \beta} \]
\[ c_{n\beta} = \frac{\partial c_n}{\partial \beta} \]
\[ c_{Yr} = \frac{\partial c_Y}{\partial \varphi} \]
\[ c_{nr} = \frac{\partial c_n}{\partial \varphi} \]
\[ c_{lr} = \frac{\partial c_l}{\partial \varphi} \]
\[ c_{Lq} = \frac{\partial c_L}{\partial \varphi} \]
\[ c_{Dq} = \frac{\partial c_D}{\partial \varphi} \]
\[ c_{mq} = \frac{\partial c_m}{\partial \varphi} \]

\[ \Delta c_{Yr}, \Delta c_{lr}, \Delta c_{nr}, \] tare increments due to support strut (to be subtracted from basic data)

Subscripts:
- \( w \) wing
- \( L \) left
- \( R \) right

For convenience, the model components are denoted by the following symbols:
- \( W \) wing
- \( B \) fuselage
V 
vertical tail

H 
horizontal tail (used with subscript 0 or -10 to denote horizontal-tail incidence)

Z 
wing fences

P 
duct-entrance-fairing plugs

G 
landing gear extended

G' 
landing gear extended, nose-gear doors off

F 
flaps deflected (used with subscripts 20, 30, or 40 to denote flap deflection in degrees with respect to wing chord line)

S 
slats extended

$\delta$ 
flaperon deflected (used with superscript 5 to denote flaperon deflection in degrees with respect to local upper surface of wing)

**APPARATUS AND MODEL**

The tests of the present investigation were made in the 6- by 6-foot curved-flow test section of the Langley stability tunnel in which curved flight is simulated by curving the airstream about a stationary model (ref. 3). Forces and moments on the model were obtained with the model mounted on a single strut support which was in turn fastened to a conventional six-component balance system.

The model used in this investigation was a 1/10-scale model of the Grumman F9F-9 airplane and was supplied to the NACA by the Grumman Aircraft Engineering Corporation. Pertinent geometric characteristics of the model are given in figure 2 and table I. Lateral control on this airplane is provided by flap-type spoiler controls called flaperons (see fig. 2(b)). The left and right flaperons are deflected independently of one another to give left and right rolls, respectively. A symmetrical flaperon deflection of $5^0$, $\delta_{LR}$, corresponds to the neutral flaperon position for all flaps-extended configurations. Photographs of the model are presented in figures 3 and 4. No provisions were made for internal flow; however, removable duct-entrance-fairing plugs were provided so that any interference effects from this area could be determined.
All the tests were made at a dynamic pressure of 24.9 pounds per square foot which corresponds to a Mach number of about 0.13 and a Reynolds number of $0.756 \times 10^6$ based on the wing mean aerodynamic chord of 0.82 foot. The angle-of-attack range for all tests was from approximately $-4^\circ$ to $20^\circ$. The test variables are summarized in the following table:

<table>
<thead>
<tr>
<th>Test</th>
<th>$\beta$, deg</th>
<th>$RB/2V$, radians</th>
<th>$C_\alpha/2V$, radians</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static longitudinal</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Static lateral</td>
<td>$\pm 5$</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Yawing</td>
<td>0</td>
<td>0, $-0.0329$, $-0.0696$, $-0.0917$</td>
<td>0</td>
</tr>
<tr>
<td>Pitching</td>
<td>0</td>
<td>0</td>
<td>0.0085, 0.0180, 0.0238</td>
</tr>
</tbody>
</table>

**CORRECTIONS**

Approximate corrections for jet-boundary effects were applied to the angle of attack and drag coefficient by the methods of reference 4. Horizontal-tail-on pitching-moment coefficients were corrected by the methods of reference 5. Blockage corrections were determined by the methods of reference 6 and were applied to the drag coefficient and the dynamic pressure. These data are not corrected for the effects of the support strut since these effects were determined for only the yawing derivatives of the complete landing configuration. These tares are presented and, if applied, are to be subtracted from the basic data.

**PRESENTATION OF RESULTS**

The static lateral and longitudinal stability characteristics are presented in figures 5 and 6, the yawing stability characteristics are presented in figures 7 to 11, and the pitching stability characteristics are presented in figures 12 and 13. For convenience in locating desired information, a summary of the configurations investigated as well as the
figures that give data for these configurations is given in table II. These data are presented without analysis in order to expedite distribution.

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REFERENCES


## TABLE I.- GEOMETRIC CHARACTERISTICS OF 1/10-SCALE MODEL OF THE GRUMMAN F9F-9 AIRPLANE

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wing (does not include leading-edge extension):</strong></td>
<td></td>
</tr>
<tr>
<td>Aspect ratio</td>
<td>4.00</td>
</tr>
<tr>
<td>Taper ratio</td>
<td>0.50</td>
</tr>
<tr>
<td>Quarter-chord sweep angle, deg</td>
<td>35.00</td>
</tr>
<tr>
<td>Dihedral angle, deg</td>
<td>-2.50</td>
</tr>
<tr>
<td>Airfoil section at root</td>
<td>Modified NACA 65A006</td>
</tr>
<tr>
<td>Airfoil section at tip</td>
<td>Modified NACA 65A004</td>
</tr>
<tr>
<td>Root chord, ft</td>
<td>1.053</td>
</tr>
<tr>
<td>Tip chord, ft</td>
<td>0.526</td>
</tr>
<tr>
<td>Area, sq ft</td>
<td>2.502</td>
</tr>
<tr>
<td>Span, ft</td>
<td>3.165</td>
</tr>
<tr>
<td>Mean aerodynamic chord, ft</td>
<td>0.820</td>
</tr>
<tr>
<td><strong>Horizontal tail:</strong></td>
<td></td>
</tr>
<tr>
<td>Aspect ratio</td>
<td>3.50</td>
</tr>
<tr>
<td>Taper ratio</td>
<td>0.40</td>
</tr>
<tr>
<td>Quarter-chord sweep angle, deg</td>
<td>35.00</td>
</tr>
<tr>
<td>Airfoil section at root</td>
<td>NACA 65A006</td>
</tr>
<tr>
<td>Airfoil section at tip</td>
<td>NACA 65A004</td>
</tr>
<tr>
<td>Root chord (on fuselage reference line), ft</td>
<td>0.619</td>
</tr>
<tr>
<td>Tip chord, ft</td>
<td>0.248</td>
</tr>
<tr>
<td>Area, sq ft</td>
<td>0.655</td>
</tr>
<tr>
<td>Span, ft</td>
<td>1.519</td>
</tr>
<tr>
<td>Mean aerodynamic chord, ft</td>
<td>0.460</td>
</tr>
<tr>
<td>Tail length (distance from center of gravity to (c/4) of tail), ft</td>
<td>1.26</td>
</tr>
<tr>
<td><strong>Vertical tail:</strong></td>
<td></td>
</tr>
<tr>
<td>Aspect ratio</td>
<td>1.50</td>
</tr>
<tr>
<td>Taper ratio</td>
<td>0.18</td>
</tr>
<tr>
<td>Quarter-chord sweep angle, deg</td>
<td>44.45</td>
</tr>
<tr>
<td>Airfoil section at root</td>
<td>NACA 65A006</td>
</tr>
<tr>
<td>Airfoil section at tip</td>
<td>NACA 65A006</td>
</tr>
<tr>
<td>Root chord (measured 2.70 in. above fuselage reference line), ft</td>
<td>0.875</td>
</tr>
<tr>
<td>Tip chord, ft</td>
<td>0.155</td>
</tr>
<tr>
<td>Area, sq ft</td>
<td>0.479</td>
</tr>
<tr>
<td>Span (measured from 2.70 in. above fuselage reference line), ft</td>
<td>0.775</td>
</tr>
<tr>
<td>Tail length (distance from center of gravity to (c/4) of tail), ft</td>
<td>1.234</td>
</tr>
<tr>
<td>Model configuration</td>
<td>Data</td>
</tr>
<tr>
<td>----------------------</td>
<td>------</td>
</tr>
<tr>
<td>WBZVH&lt;sub&gt;H&lt;sub&gt;0&lt;/sub&gt;, WBZPVH&lt;sub&gt;0&lt;/sub&gt;</td>
<td>Effect of duct-entrance-fairing plugs on clean configuration; $C_L$, $C_D$, and $C_m$ plotted against $\alpha$</td>
</tr>
<tr>
<td>WBZVH&lt;sub&gt;H&lt;sub&gt;0&lt;/sub&gt;, WBZPVH&lt;sub&gt;0&lt;/sub&gt;</td>
<td>Effect of duct-entrance-fairing plugs on clean configuration; $C_{\mu}$, $C_n$, and $C_\beta$ plotted against $\alpha$</td>
</tr>
<tr>
<td>WBZVH&lt;sub&gt;H&lt;sub&gt;0&lt;/sub&gt;, WBZPVH&lt;sub&gt;0&lt;/sub&gt;, WBZPVHO&lt;sub&gt;G&lt;/sub&gt;</td>
<td>Effect of duct-entrance-fairing plugs and landing gear on clean configuration; $C_T$, $C_n$, and $C_\tau$ plotted against $\alpha$</td>
</tr>
<tr>
<td>WBZPVH&lt;sub&gt;0&lt;/sub&gt;, WBZP, WZPF&lt;sub&gt;F&lt;sub&gt;30&lt;/sub&gt;S&lt;sub&gt;5&lt;/sub&gt;L&lt;sub&gt;R&lt;/sub&gt;</td>
<td>Horizontal-tail-vertical-tail contribution for clean and landing configurations; $C_T$, $C_n$, and $C_\tau$ plotted against $\alpha$</td>
</tr>
<tr>
<td>WBZPVH&lt;sub&gt;G&lt;/sub&gt;, WBZPVH&lt;sub&gt;-10^5&lt;/sub&gt;30S&lt;sub&gt;6&lt;/sub&gt;L&lt;sub&gt;R&lt;/sub&gt;</td>
<td>Effect of flaps deflection on landing configurations; $C_T$, $C_n$, and $C_\tau$ plotted against $\alpha$</td>
</tr>
<tr>
<td>WBZPVH&lt;sub&gt;-10^5&lt;/sub&gt;20S&lt;sub&gt;6&lt;/sub&gt;L&lt;sub&gt;R&lt;/sub&gt;</td>
<td>Effect of landing gear and nose-gear doors on landing configuration; $C_T$, $C_n$, and $C_\tau$ plotted against $\alpha$</td>
</tr>
<tr>
<td>WBZPVH&lt;sub&gt;-10^5&lt;/sub&gt;30S&lt;sub&gt;5&lt;/sub&gt;L&lt;sub&gt;R&lt;/sub&gt;</td>
<td>Support-strut tare increments for landing configuration; $\Delta C_T$, $\Delta C_n$, and $\Delta C_\tau$ plotted against $\alpha$</td>
</tr>
<tr>
<td>WBZPVH&lt;sub&gt;-10^5&lt;/sub&gt;30S&lt;sub&gt;5&lt;/sub&gt;L&lt;sub&gt;R&lt;/sub&gt;</td>
<td>Horizontal-tail contribution and the effect of duct-entrance-fairing plugs and landing gear on clean configuration; $C_{lq}$, $C_{dq}$, and $C_{mq}$ plotted against $\alpha$</td>
</tr>
<tr>
<td>WBZPVH&lt;sub&gt;-10^5&lt;/sub&gt;30S&lt;sub&gt;5&lt;/sub&gt;L&lt;sub&gt;R&lt;/sub&gt;</td>
<td>Horizontal-tail contribution and the effect of landing gear on landing configuration; $C_{lq}$, $C_{dq}$, and $C_{mq}$ plotted against $\alpha$</td>
</tr>
</tbody>
</table>
Figure 1.- Stability system of axes. Arrows indicate positive direction of forces, moments, angular displacements, and angular velocities.
(a) General arrangement.

Figure 2.- Geometric characteristics of 1/10-scale model of the Grumman F9F-9 airplane. All dimensions in inches.
(b) Details of fence, slat, flaps, and flaperon.

Figure 2.- Concluded.
(a) Side view of WBZPVH-10F3085LRG landing configuration.

(b) Side view of WBZVH0 clean configuration.

Figure 3.- Photographs of 1/10-scale model of the Grumman F9F-9 airplane mounted on model support pedestal.
(a) Front view of WBZPVH-10F $-30^\circ$ landing configuration.

(b) Rear view of WBZPVH-10F $-30^\circ$ landing configuration.

Figure 4.- Photographs of 1/10-scale model of the Grumman F9F-9 airplane mounted in the 6- by 6-foot curved-flow test section of the Langley stability tunnel. Pitching-flow test setup.
Figure 5.- Effect of duct-entrance-fairing plugs on the static longitudinal stability characteristics. Slats, flaps, flaperons, and landing gear retracted.
Figure 6.- Effect of duct-entrance-fairing plugs on the static lateral stability characteristics. Slats, flaps, flaperons, and landing gear retracted.
Figure 7. Effect of duct-entrance-fairing plugs and landing gear on the yawing stability characteristics. Slats, flaps, and flaperons retracted.
Figure 8. - Horizontal-tail—vertical-tail contribution and the effect of slats, flaps, and flaperons on the yawing stability characteristics. Landing gear retracted.
Figure 9.- Effect of slats, flaps, and flaperons on the yawing stability characteristics. Landing gear extended.
Figure 10.- Effect of landing gear and nose-gear doors on the yawing stability characteristics. Slats, flaps, and flaperons extended.
Figure 11.- Support-strut tare increments $\Delta C_{Yr}$, $\Delta C_{nr}$, and $\Delta C_{Ir}$ plotted against $\alpha$. Slats, flaps, flaperons, and landing gear extended.
Figure 12.—Horizontal-tail contribution and the effect of duct-entrance-fairing plugs and landing gear on the pitching stability characteristics. Slats, flaps, and flaperons retracted.
Figure 13.— Horizontal-tail contribution and the effect of landing gear on the pitching stability characteristics. Slats, flaps, and flaperons extended.