RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Department of the Navy

WIND-TUNNEL INVESTIGATION AT LOW SPEED OF THE YAWING STABILITY DERIVATIVES OF A 1/10-SCALE MODEL OF THE DOUGLAS A4D-1 AIRPLANE

TED NO. NACA DE 389

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SUMMARY

An experimental investigation has been made in the Langley stability tunnel to determine the low-speed yawing stability derivatives of a 1/10-scale model of the Douglas A4D-1 airplane. The model was tested in clean and landing configurations with horizontal and vertical tails on and off. The effect of removing the horizontal tail was determined for one of the clean configurations. The effects of external wing stores were determined for one complete clean configuration, for one complete landing configuration, and for one landing configuration with horizontal and vertical tails off. Also included in the investigation were the effects of slats and flaps on the wing-alone derivatives.

These data are presented without analysis in order to expedite distribution.

INTRODUCTION

An important design objective in the development of any airplane is the attainment of acceptable dynamic flight characteristics. Previous experience has indicated that reliable prediction of the dynamic flight characteristics for a wide angle-of-attack range requires more accurate estimates of the various aerodynamic parameters than is 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 stability derivatives of a 1/10-scale model of the Douglas A4D-1 airplane over a wide angle-of-attack range from a series of low-speed tests in the Langley stability tunnel. These tests were made at the request of the Bureau of Aeronautics, Department of the Navy, in order to aid in the development of the Douglas A4D-1 airplane. The results of a previous investigation to determine the static lateral and longitudinal stability characteristics of the same model are given in reference 3.

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. The positive direction of forces, moments, and angular displacements are shown in figure 1. The coefficients and symbols are defined as follows:

\[
\begin{align*}
L & \quad \text{l lift, lb} \\
D & \quad \text{drag, lb} \\
Y & \quad \text{side force, lb} \\
M & \quad \text{pitching moment, ft-lb} \\
L' & \quad \text{rolling moment, ft-lb} \\
N & \quad \text{yawing moment, ft-lb} \\
b & \quad \text{span, ft} \\
S & \quad \text{area, sq ft} \\
c & \quad \text{chord, measured parallel to plane of symmetry, ft} \\
\bar{c} & \quad \text{mean aerodynamic chord, } \frac{2}{S} \int_0^b \int_0^{c_m} c^2 \, dy \\
y & \quad \text{spanwise distance from and perpendicular to plane of symmetry, ft} \\
q & \quad \text{free-stream dynamic pressure, } \rho V^2/2, \text{ lb/sq ft}
\end{align*}
\]
\( V \) \hspace{1cm} \text{free-stream velocity, ft/sec}

\( \rho \) \hspace{1cm} \text{mass density of air, slugs/cu ft}

\( \alpha \) \hspace{1cm} \text{angle of attack of fuselage reference line, deg}

\( \gamma \) \hspace{1cm} \text{flight-path angle, deg}

\( \phi \) \hspace{1cm} \text{angle of roll, deg}

\( \iota_t \) \hspace{1cm} \text{angle of incidence of horizontal tail with respect to fuselage reference line, deg}

\( \delta_r \) \hspace{1cm} \text{flap deflection, deg}

\( \beta \) \hspace{1cm} \text{angle of sideslip, deg}

\( \psi \) \hspace{1cm} \text{angle of yaw, deg}

\( C_Y \) \hspace{1cm} \text{lateral-force coefficient, \( Y/qS_w \)}

\( C_L \) \hspace{1cm} \text{rolling-moment coefficient, \( L'/qS_w b_w \)}

\( C_n \) \hspace{1cm} \text{yawing-moment coefficient, \( N/qS_w b_w \)}

\( rb/2V \) \hspace{1cm} \text{yawing angular-velocity parameter, radians}

\( r \) \hspace{1cm} \text{yawing angular velocity, \( d\psi/dt \), radians/sec}

\[ C_{yr} = \frac{\Delta C_Y}{\Delta \left( \frac{rb}{2V} \right)} \]

\[ C_{lr} = \frac{\Delta C_L}{\Delta \left( \frac{rb}{2V} \right)} \]

\[ C_{nr} = \frac{\Delta C_n}{\Delta \left( \frac{rb}{2V} \right)} \]

\( \Delta C_{yr}, \Delta C_{lr}, \Delta C_{nr} \) \hspace{1cm} \text{tare increments due to support strut (to be subtracted from basic data)}
Subscripts:

\begin{align*}
\text{w} & \quad \text{wing} \\
\text{s} & \quad \text{wing slats, fully opened} \\
\text{f} & \quad \text{split flaps, deflected } 50^\circ \\
\text{c} & \quad \text{closed-landing-gear fairings}
\end{align*}

For convenience, the model components are denoted by the following symbols:

\begin{align*}
\text{W} & \quad \text{wing (when used with subscripts } s \text{ and } f \text{ denote slats open and flaps deflected, respectively)} \\
\text{F} & \quad \text{ducted fuselage (including canopy)} \\
\text{V} & \quad \text{vertical tail} \\
\text{H} & \quad \text{horizontal tail} \\
\text{G} & \quad \text{landing gear down (when used with subscript } c \text{ denotes landing gear up and closed-landing-gear fairings)} \\
\text{E} & \quad \text{two pylon-mounted external stores}
\end{align*}

APPARATUS AND MODELS

The tests of the present investigation were made in the 6- by 6-foot test section of the Langley stability tunnel in which curved flight is simulated by curving the airstream about a stationary model (ref. 4). 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 Douglas A4D-1 airplane. Pertinent geometric characteristics of the model are given in figure 2 and table I. Photographs of one of the landing configurations are presented in figure 3. The wing, ducted fuselage, tail surfaces, and external wing stores were constructed primarily of laminated mahogany, although the wing and tail surfaces were built up from a 1/4-inch-thick aluminum-alloy core which provided additional stiffness and metal trailing edges. The plain split flaps and landing-gear doors were made from 1/16-inch thick aluminum sheet and the landing
gear struts were made from brass tubing. The wing leading-edge slats were cast from brass and simulated either a fully opened or fully closed slat position.

TESTS

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 0.99 x 10^6 based on the wing mean aerodynamic chord of 1.08 feet. The angle-of-attack range for all tests was from approximately -4° to 28°. Tests were made at values of rb/2V of 0, -0.029, -0.061, and -0.080. The various model configurations investigated are shown in table II.

CORRECTIONS

Approximate corrections for jet-boundary effects were applied to the angle of attack by the methods of reference 5. Blockage corrections were determined and applied to the dynamic pressure by the methods of reference 6. These data are not corrected for the effects of the support strut since these effects were determined for only one complete clean configuration and one complete landing configuration. The tares for these two configurations are presented and if applied are to be subtracted from the basic data.

PRESENTATION OF RESULTS

The results of this investigation are presented in figures 4 to 8. 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 III. These data are presented without analysis in order to expedite distribution.

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JKS
REFERENCES


### TABLE I. - GEOMETRIC CHARACTERISTICS

**Wing:**
- Aspect ratio ........................................ 2.91
- Taper ratio ........................................... 0.226
- Quarter-chord sweep angle, deg 33.21
- Dihedral angle (trailing edge), deg 2.670
- Geometric twist, deg 0
- Incidence at root chord (parallel to fuselage reference line), deg 0
- Airfoil section (parallel to fuselage reference line)
  - Root ........................................... Modified NACA 0008
  - Tip ........................................... Modified NACA 0005
- Chord (parallel to fuselage reference line), ft
  - Root ........................................... 1.550
  - Tip ........................................... 0.350
- Area, sq ft ........................................ 2.600
- Span, ft ........................................... 2.750
- Mean aerodynamic chord, ft 1.080

**Horizontal tail:**
- Aspect ratio ........................................ 2.80
- Taper ratio ........................................... 0.225
- Quarter-chord sweep angle, deg 34.37
- Dihedral angle, deg 0
- Airfoil section (parallel to fuselage reference line)
  - Root ........................................... Modified NACA 0007
  - Tip ........................................... Modified NACA 0004
- Chord (parallel to fuselage reference line), ft
  - Root ........................................... 0.667
  - Tip ........................................... 0.350
- Area, sq ft ........................................ 0.499
- Span, ft ........................................... 1.153
- Mean aerodynamic chord, ft 0.466
- Tail length (distance from center of gravity to 8/4 of tail), ft 1.607

**Vertical tail:**
- Aspect ratio ........................................ 1.24
- Taper ratio ........................................... 0.195
- Quarter-chord sweep angle, deg 42.00
- Airfoil section (parallel to fuselage reference line)
  - Root ........................................... Modified NACA 0007
  - Tip ........................................... Modified NACA 0004
- Chord (parallel to fuselage reference line), ft
  - Root (measured 1.96 in. above fuselage reference line) 1.069
  - Tip ........................................... 0.208
- Area, sq ft ........................................ 0.499
- Span, ft ........................................... 0.750
- Mean aerodynamic chord, ft 0.758
- Tail length (distance from center of gravity to 8/4 of tail), ft 1.420

**Fuselage:**
- Maximum width, ft ................................ 0.533
- Maximum depth, ft ................................ 0.500
- Length, ft ........................................ 3.703
- Cross-sectional area of duct, sq ft
  - Inlet (both sides) 0.0343
  - Exit ........................................... 0.0179

**Lift increasing devices:**

- **Wing flaps:**
  - Type ........................................... Split
  - Maximum deflection, deg 90
  - Actual span (one side), ft 0.592
  - Chord (parallel to fuselage reference line), ft 0.208

- **Wing leading-edge slats:**
  - Slat rotation about hinge line for fully opened position, deg 22
  - Actual span (perpendicular to fuselage reference line) (one side), ft 0.750
  - Chord (parallel to fuselage reference line), ft 0.181
  - Root ........................................... 0.087
### TABLE II. - MODEL CONFIGURATIONS INVESTIGATED

<table>
<thead>
<tr>
<th>Components</th>
<th>Landing gear</th>
<th>Slats</th>
<th>( \delta_t ), deg</th>
<th>Stores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clean configuration; ( \delta_f = 0^\circ )</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( W_{FGC}VH )</td>
<td>Up</td>
<td>Closed</td>
<td>0</td>
<td>Off</td>
</tr>
<tr>
<td>( W_{FGC}VHE )</td>
<td>Up</td>
<td>Closed</td>
<td>0</td>
<td>On</td>
</tr>
<tr>
<td>( W_{sFGC}VH )</td>
<td>Up</td>
<td>Open</td>
<td>-4</td>
<td>Off</td>
</tr>
<tr>
<td>( W_{FGC}V )</td>
<td>Up</td>
<td>Closed</td>
<td>--</td>
<td>Off</td>
</tr>
<tr>
<td>( W_{FGC} )</td>
<td>Up</td>
<td>Closed</td>
<td>--</td>
<td>Off</td>
</tr>
<tr>
<td>( W_{sFGC} )</td>
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<td>Open</td>
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<td>Off</td>
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<tr>
<td>( W )</td>
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<td>Closed</td>
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<tr>
<td>( W_s )</td>
<td>--</td>
<td>Open</td>
<td>--</td>
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</tr>
<tr>
<td>Landing configuration; ( \delta_f = 50^\circ )</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>( W_f)FGVH</td>
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<td>Closed</td>
<td>-12</td>
<td>Off</td>
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<tr>
<td>( W_{sf})FGVH</td>
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<td>Open</td>
<td>-12</td>
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<tr>
<td>( W_f )</td>
<td>---</td>
<td>Closed</td>
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<td>( W_{sf} )</td>
<td>---</td>
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### TABLE III. - SUMMARY OF MODEL CONFIGURATIONS TESTED AND DATA PRESENTED

<table>
<thead>
<tr>
<th>Model configuration</th>
<th>Data presented</th>
<th>Figure</th>
</tr>
</thead>
<tbody>
<tr>
<td>WFG&lt;sub&gt;c&lt;/sub&gt;VH; ( i_t = 0^\circ ) ( \text{WFGcV} ) ( W_{gsFGcVH}; \ i_t = -4^\circ ) ( W_{fgFGVH}; \ i_t = -12^\circ ) ( W_{sfgFGVH}; \ i_t = -12^\circ )</td>
<td>Effect of high lift devices on complete configurations; ( C_{Yr} ), ( C_{nr} ), and ( C_{lr} ) plotted against ( \alpha )</td>
<td>4</td>
</tr>
<tr>
<td>WFG&lt;sub&gt;c&lt;/sub&gt;VHE; ( i_t = 0^\circ ) ( \text{WsfFGVHE} ); ( i_t = -12^\circ ) ( W_{sfFGE} )</td>
<td>Effect of wing stores on a complete clean configuration, a complete landing configuration, and a landing configuration with tails off; ( C_{Yr} ), ( C_{nr} ), and ( C_{lr} ) plotted against ( \alpha )</td>
<td>5</td>
</tr>
<tr>
<td>WFG&lt;sub&gt;c&lt;/sub&gt; ( \text{WsfFGc} ) ( W_{fgFG} ) ( W_{sfgFG} )</td>
<td>Effect of high lift devices on tail-off configurations; ( C_{Yr} ), ( C_{nr} ), and ( C_{lr} ) plotted against ( \alpha )</td>
<td>6</td>
</tr>
<tr>
<td>W ( \text{Wsf} ) ( W_{fr} ) ( W_{sf} )</td>
<td>Effect of high lift devices on wing alone; ( C_{Yr} ), ( C_{nr} ), and ( C_{lr} ) plotted against ( \alpha )</td>
<td>7</td>
</tr>
<tr>
<td>WFG&lt;sub&gt;c&lt;/sub&gt;VH; ( i_t = 0^\circ ) ( \text{WsfFGVH} ); ( i_t = -12^\circ )</td>
<td>Tare increments due to support strut for complete clean and complete landing configurations; ( \Delta C_{Yr} ), ( \Delta C_{nr} ), and ( \Delta C_{lr} ) plotted against ( \alpha )</td>
<td>8</td>
</tr>
</tbody>
</table>
Figure 1.- Stability system of axes. Arrows indicate positive direction of forces, moments, angular displacements, and angular velocities.
Figure 2. Geometric characteristics of 1/10-scale model of the Douglas A4D-1 airplane.

All dimensions are in inches.
Figure 3.- Photographs of complete model-landing configuration mounted in the curved-flow test section of the Langley stability tunnel. WsFPGVH configuration; \( \theta_t = -12^\circ \).
Figure 4. - Effect of horizontal tail and high lift devices on yawing stability derivatives of complete model.
Figure 5.— Effect of wing stores on yawing stability derivatives of complete model-clean configuration, complete model landing configuration, and landing configuration with horizontal and vertical tails off.
Figure 6. Effect of high lift devices on yawing stability derivatives of horizontal and vertical tail-off configurations.
Figure 7.- Effect of high lift devices on yawing stability derivatives of wing alone.
Figure 8.- Support-strut tare increments $\Delta C_y$, $\Delta C_n$, and $\Delta C_I$ plotted against $\alpha$ for complete model-clean configuration and complete model-landing configuration.