Rotary Balance Data for a Typical Single-Engine General Aviation Design for an Angle-of-Attack Range of 8° to 90°

II - High-Wing Model A

William Mulcay and Robert Rose

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SUMMARY

Aerodynamic characteristics obtained in a rotational flow environment utilizing a rotary balance located in the Langley spin tunnel are presented in plotted form for a 1/5-scale, single-engine, high-wing, general aviation airplane model. The configurations tested included various tail designs and fuselage shapes. Data are presented without analysis for an angle-of-attack range of 80° to 90° and clockwise and counter-clockwise rotations covering an $\frac{\alpha}{2\nu}$ range from 0 to 0.85.

INTRODUCTION

The NASA Langley Research Center has initiated a broad general aviation stall/spin research program which includes spin-tunnel and free-flight radio control model tests, as well as full-scale flight tests for a number of configurations typical of light, general aviation airplanes. To support this effort, rotary balance wind tunnel force tests covering these same configurations will be conducted to establish a data base for analysis of model and full-scale flight results, and to develop design charts for desirable stall/spin characteristics.

A 1/5-scale, single-engine, general aviation airplane model, referred to as model A, having a high-wing location was tested in a rotational flow environment utilizing a rotary balance located in the Langley spin tunnel. This report presents the data obtained for various tail designs and fuselage shapes. Data for model A having a low-wing location are presented in reference 1.
SYMBOLS

The units for physical quantities used herein are presented in the International System of Units (SI) and U.S. Customary Units. The measurements were made in the U.S. Customary Units; equivalent dimensions were determined by using the conversion factors given in reference 2.

- \( b \) - wing span, m (ft)
- \( c \) - mean aerodynamic chord, cm (in.)
- \( C_L \) - lift-force coefficient, \( \frac{\text{Lift force}}{qS} \)
- \( C_N \) - normal-force coefficient, \( \frac{\text{Normal force}}{qS} \)
- \( C_A \) - axial-force coefficient, \( \frac{\text{Axial force}}{qS} \)
- \( C_Y \) - side-force coefficient, \( \frac{\text{Side force}}{qS} \)
- \( C_\ell \) - rolling moment coefficient, \( \frac{\text{Rolling moment}}{qSb} \)
- \( C_m \) - pitching-moment coefficient, \( \frac{\text{Pitching moment}}{qS\bar{c}} \)
- \( C_n \) - yawing-moment coefficient, \( \frac{\text{Yawing moment}}{qSb} \)
- \( q \) - free-stream dynamic pressure, N/m\(^2\) (lb/ft\(^2\))
- \( S \) - wing area, m\(^2\) (ft\(^2\))
- \( V \) - free-stream velocity, m/sec (ft/sec)
- \( \alpha \) - angle of attack, deg
- \( \beta \) - angle of sideslip, deg
- \( \Omega \) - angular velocity about spin axis, rad/sec
- \( \Omega_b \) - spin coefficient, positive for clockwise spin
- \( \frac{2\Omega}{V} \) - spin coefficient
- \( \delta_a \) - aileron deflection, positive when right aileron is down
  \( \left( \delta_a^{\text{right}} - \delta_a^{\text{left}} \right)/2, \) deg
- \( \delta_e \) - elevator deflection, positive when trailing edge is down, deg
 Testing Equipment

A rotary balance measures the forces and moments acting on an airplane while subjected to rotational flow conditions; the background for this apparatus is discussed in reference 3. A photograph and sketch of the rotary balance apparatus installed in the Langley spin tunnel are shown in figures 1 and 2, respectively. The rotating portion of the balance system, mounted on a horizontal supporting boom which is hinged at the wall, is moved from the wall to the center of the tunnel by cables. The rotary arm of the balance system, which rotates about a vertical axis, is attached to the outer end of the horizontal supporting boom and is driven by a drive shaft through couplings and gears.

A test model is mounted on a strain gauge balance which is affixed to the bottom of the rotary balance apparatus. Controls located outside the tunnel are used to activate motors on the rig which position the model to the desired attitude. The angle-of-attack range of the rig is 8 to 90 degrees and the sideslip angle range is ±15 degrees. The spin radius and the lateral displacement motors allow the operator to position the moment center of the balance on the spin axis or at a specific distance...
from the spin axis. This is done for each combination of angle of attack and sideslip angle. The general practice is to mount the moment center of the balance at the cg location about which the aerodynamic moments are desired. Electrical current from the balance, and to the motors on the rig, is conducted through slip-rings located at the rig head. Examples of how the rig is positioned for different angle of attack and sideslip angles are shown in figures 2a and 2b, respectively.

The model can be rotated up to 90 rpm in either direction. By using different rotational speeds and a specific airflow in the tunnel, the motions of a steady spinning airplane can be simulated. The aerodynamic forces and moments can then be measured for values of $\frac{\Omega b}{2v}$, including the case of $\frac{\Omega b}{2v} = 0$, where static aerodynamic forces and moments can be obtained.

A NASA six-component strain gauge balance is mounted inside the model and measures the normal, lateral and longitudinal forces and the yawing, rolling and pitching moments acting about the model body axis. The interactions that exist between the six components are available from balance calibration tests and are accounted for after the balance voltages are converted to forces and moments.

The data acquisition, reduction and presentation system for the rotary balance set-up is composed of a 12-channel scanner/voltmeter, a mini-computer and a plotter. With this equipment, on-line digital print-out and/or graphical plots of data are possible.
TEST PROCEDURES

Rotary aerodynamic data are obtained in two steps. The first step is to record the inertial forces and moments (tares) acting on the model at different attitudes and rotational speeds. To accomplish this, a covered bird-cage like structure is mounted to the upper rig which encloses the model without touching it. In this manner, the air immediately surrounding the model is rotated with it. As the rig is rotated at the desired attitude and rate, the inertial forces and moments generated by the model are measured and stored on magnetic tape for later use.

The second step in the data-gathering process is to measure aerodynamic and inertial forces at different attitudes and rotational speeds for a selected tunnel velocity with, of course, the cage structure removed. The tares are subtracted from these values, and the remaining aerodynamic forces and moments are then converted to coefficient form and stored on magnetic tape.

MODEL

A 1/5-scale fiberglass/foam/plywood model of a configuration considered to be a typical high-wing, single-engine, light general aviation airplane was tested in the present study. A three-view drawing of this model is shown in figure 3, dimensional characteristics of the model are presented in Table I, and a photograph of the model installed on the rotary balance located in the Langley spin tunnel is presented in figure 1.

The model was fabricated such that various tail configurations could be tested as well as fuselage modifications. The
two tail configurations tested involved different locations of the horizontal tail as shown in figure 4. The fuselage shape modifications tested are shown in figure 5.

TEST CONDITIONS

The tests were conducted in the spin tunnel at a tunnel velocity of 7.62 m/sec (25 ft/sec) which corresponds to a Reynolds number of 128,000 based on the model mean aerodynamic chord. Unless noted otherwise in Table II, all the configurations were tested through an angle-of-attack range of 8 to 90° at a zero sideslip angle with the spin axis passing through the full-scale airplane cg location of .255c for angles of attack above 30°. For angles of attack below 35°, the spin axis was set 76.2cm (30 in.) forward of the cg. Consequently, data was obtained for both a 0 and 76.2cm (30 in.) spin radius at angles of attack of 30 and 35°. At each spin attitude, measurements were obtained for nominal $\frac{\rho b}{2V}$ values of .1, .2, .3, .4, .45, .55, .65, .75 and .85 in both clockwise and counter-clockwise directions, as well as for $\frac{\rho b}{2V} = 0$ (static value).

DATA PRESENTATION

Table II identifies the configurations tested and the corresponding appendix figure numbers which present the aerodynamic data. The aerodynamic coefficients vs. $\frac{\rho b}{2V}$ are presented for each configuration in six sequentially numbered figures in the following order: $C_n$, $C_\ell$, $C_m$, $C_N$, $C_Y$ and $C_A$. 

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Each figure, in turn, consists of four pages which present the subject aerodynamic coefficient vs. $\frac{\Omega b}{2V}$ for the following angles of attack and spin radii, unless noted otherwise in Table II.

a) $\alpha = 8, 10, 12, 14, 16$ deg $\quad SR = 76cm$ (30in)
b) $\alpha = 18, 20, 25, 30, 35$ deg $\quad SR = 76cm$ (30in)
c) $\alpha = 30, 35, 40, 45, 50$ deg $\quad SR = 0$
d) $\alpha = 55, 60, 70, 80, 90$ deg $\quad SR = 0$

All the moment data are presented for a cg position of 0.255c.

Lift coefficient as a function of angle of attack for zero rotation rate is presented at the end of the Appendix for several configurations cited in Table II.
REFERENCES


# TABLE I.- DIMENSIONAL CHARACTERISTICS OF THE BASIC MODEL

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall length with tail #4, m (ft)</td>
<td>1.23 (4.05)</td>
</tr>
<tr>
<td><strong>Wing:</strong></td>
<td></td>
</tr>
<tr>
<td>Span, m (ft)</td>
<td>1.46 (4.80)</td>
</tr>
<tr>
<td>Area, m² (ft²)</td>
<td>0.36 (3.87)</td>
</tr>
<tr>
<td>Root chord, cm (in.)</td>
<td>24.54 (9.66)</td>
</tr>
<tr>
<td>Tip chord, cm (in.)</td>
<td>24.54 (9.66)</td>
</tr>
<tr>
<td>Mean aerodynamic chord, cm (in.)</td>
<td>24.54 (9.66)</td>
</tr>
<tr>
<td>Leading edge of ( c ), distance rearward of leading edge of root chord, cm (in.)</td>
<td>0</td>
</tr>
<tr>
<td>Aspect ratio</td>
<td>5.9</td>
</tr>
<tr>
<td>Dihedral, deg</td>
<td>1.5</td>
</tr>
<tr>
<td><strong>Incidence:</strong></td>
<td></td>
</tr>
<tr>
<td>Root, deg</td>
<td>3.5</td>
</tr>
<tr>
<td>Tip, deg</td>
<td>3.5</td>
</tr>
<tr>
<td>Airfoil section</td>
<td>NACA 642-415 modified</td>
</tr>
<tr>
<td><strong>Horizontal tail:</strong></td>
<td></td>
</tr>
<tr>
<td>Span, m (ft)</td>
<td>0.47 (1.53)</td>
</tr>
<tr>
<td>Incidence, deg</td>
<td>-3.0</td>
</tr>
<tr>
<td>Airfoil section</td>
<td>NACA 651-012</td>
</tr>
<tr>
<td><strong>Vertical tail:</strong></td>
<td></td>
</tr>
<tr>
<td>Airfoil section</td>
<td>NACA 651-012</td>
</tr>
</tbody>
</table>
TABLE II.- CONFIGURATIONS TESTED AND FIGURE INDEX
(Unless noted otherwise, all configurations tested through $\alpha=8$ to $90^\circ$ at $\beta=0^\circ$.)

<table>
<thead>
<tr>
<th>FIGURE NO.</th>
<th>CONFIGURATION</th>
<th>$\delta_e$ deg</th>
<th>$\delta_a$ deg</th>
<th>$\delta_r$ deg</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^a$A1-A6</td>
<td>#4 Horizontal tail</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>$\alpha=30-90^\circ$ only</td>
</tr>
<tr>
<td>A7-A12</td>
<td>with rounded fuselage bottom aft of wing TE</td>
<td></td>
<td></td>
<td></td>
<td>$\alpha=50-90^\circ$ only</td>
</tr>
<tr>
<td>A13-A18</td>
<td>with rounded fuselage bottom aft of engine cowling</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$^a$A19-A24</td>
<td>#3 Horizontal tail</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A25-A30</td>
<td>with rounded fuselage bottom aft of wing TE</td>
<td></td>
<td></td>
<td></td>
<td>$\alpha=30-90^\circ$ only</td>
</tr>
<tr>
<td>A31-A36</td>
<td>with rounded fuselage bottom aft of engine cowling</td>
<td></td>
<td></td>
<td></td>
<td>$\alpha=30-90^\circ$ only</td>
</tr>
</tbody>
</table>

$^a$ $C_L$ vs $\alpha$ presented in figure A37.
Figure 1.- Photograph of 1/5-scale model installed on rotary balance apparatus.
A Slip ring housing
B Drive shaft
C Support boom
D Spin radius offset
  potentiometer
E Counterweight
F Strut
G Angle of attack
  positioning motor

(a) Side view of model.

Figure 2.- Sketch of rotary balance apparatus.
A Slip ring housing
B Spin radius offset
  potentiometer
C Lateral offset
  drive gears
D Lateral offset
  potentiometer
E Strut
F Sideslip angle
  potentiometer
G Sideslip angle
  positioning motor

Spin axis

Velocity vector

(b) Front view of model.

Figure 2.- Concluded.
Figure 3. - Three view drawing of 1/5 scale high-wing general aviation model A. Center of gravity positioned at 0.255C. Dimensions are given in centimeters(inches), model scale.
Figure 4.-Tail configurations tested on model. Dimensions are given in centimeters (inches), model scale.
Figure 5. - Fuselage shape modifications tested on model. Dimensions are given in centimeters (Inches).
Figure A1: Effect of rotation rate and angle of attack on yawing moment coefficient for no. 4 horizontal tail configuration. $\delta = 0^\circ$, $\delta = 5^\circ$, $\delta = 10^\circ$, $\delta = 15^\circ$. $\beta = 0^\circ$. $\gamma = 8^\circ$ to $16^\circ$, $SR = 76cm (30\text{ in})$. 

(a) $\dot{\gamma} = 8^\circ$ to $16^\circ$, $SR = 76cm (30\text{ in})$. 

(b) $2V/\dot{\gamma}$
Figure A1. Continued.
Figure A1. Continued.
(d) $\alpha=55^\circ$ to $90^\circ$, $SR=0$.
Figure A1. Concluded.
Figure A2: Effect of rotation rate and angle of attack on rolling moment coefficient for no. 4 horizontal tail configuration. $\delta_e = 0^\circ$, $\delta_a = 0^\circ$, $\delta_r = 0^\circ$, $\beta = 0^\circ$. 

(a) $q = 8$ to $16$ deg, $SR = 76$ cm ($30$ in).
Figure A2. Continued.

(b) α = 18 to 35 deg, SR = 76 cm (30 in.)
(c) \( \alpha = 30 \text{ to } 50 \text{ deg}, \ SR = 0. \)

Figure A2: Continued.
Figure A3. Effect of rotation rate and angle of attack on pitching moment coefficient for no. 4 horizontal tail configuration. $\delta_e=0^\circ$, $\delta_z=0^\circ$, $\delta_r=0^\circ$. 

(a) $\alpha=8\text{ to }16^\circ$, SR=76cm (30in).
(h) $\alpha=18$ to $35$ deg, $SR=76$ cm (30 in).

Figure A3. Continued.
Figure A3. Continued.
Figure A3. Concluded.
Figure A4: Effect of rotation rate and angle of attack on normal force coefficient for no. 4 horizontal tail configuration. \( \delta_c = 0^\circ, \delta_a = 0^\circ, \delta_e = 0^\circ, \alpha = 0^\circ. \)
Figure A4. Continued.

\( \alpha = 18^\circ \text{ to } 35^\circ \text{ deg.} \), \( SR = 76 \text{ cm (30 in)} \).
(d) $\alpha = 55$ to 90 deg, SR = 0.

Figure A4: Concluded.
Figure A5. Effect of rotation rate and angle of attack on side-force coefficient for no. 4 horizontal tail configuration. $\delta_e=0^\circ$, $\delta_t=0^\circ$, $\delta_r=0^\circ$. $b/2V$

(a) $\alpha=8$ to $16^\circ$, $SR=76$ cm (30 in).
(d) $\alpha = 55$ to $90$ deg, SR = 0.

Figure A5. Concluded.
Figure A3: Effect of rotation rate and angle of attack on axial-force coefficient for no. 4 horizontal tail configuration, $M_e = 0^\circ$, $M_R = 0^\circ$, $\delta_T = 0^\circ$.

(a) $\alpha = 8^\circ$ to $16^\circ$, $SR = 76$ cm (30 in).
Figure A6. Continued.
Figure A7: Effect of rotation rate and angle of attack on yawing moment coefficient for no. 4 horizontal tail configuration having rounded fuselage bottom aft of wing TE. $\delta_a = 0^\circ$, $\delta_s = 0^\circ$, $\delta_t = 0^\circ$, $\delta_E = 0^\circ$. $\alpha_{deg}$

- $\alpha = 30^\circ$
- $\alpha = 35^\circ$
- $\alpha = 40^\circ$
- $\alpha = 45^\circ$
- $\alpha = 50^\circ$
(b) $\alpha=55$ to 90 deg, SR=0.

Figure A7: Concluded.
Figure A8. Effect of rotation rate and angle of attack on rolling moment coefficient for No. 4 horizontal tail configuration having rounded fuselage bottom aft of wing TE. $\delta_c = 0^\circ$, $\delta_t = 0^\circ$, $\delta_r = 0^\circ$, $\beta = 0^\circ$. $\alpha = 30$ to $50$ deg, $SR = 0$. 
Figure A8-Concluded.
Figure A9. Effect of rotation rate and angle of attack on pitching moment coefficient for no. 4 horizontal tail configuration having rounded fuselage bottom aft of wing TE. \( \delta_e = 0^\circ, \delta_4 = 0^\circ, \delta_\gamma = 0^\circ, \delta_3 = 0^\circ, \theta = 0^\circ \)}
(b) $\alpha=55$ to $90$ deg, SR=0.

Figure A9. Concluded.
Figure A10. Effect of rotation rate and angle of attack on normal force coefficient for no. 4 horizontal tail configuration having rounded fuselage bottom aft of wing TE. $\delta_e = 0^\circ$, $\delta_t = 0^\circ$, $\delta_l = 0^\circ$, $\beta = 0^\circ$. 

(a) $\alpha = 30$ to $50$ deg, $SR = 0$. 

$\Phi b/2V$
(b) $\alpha = 55$ to $90$ deg, $SR = 0$.

Figure A10 - Concluded.
Figure A11. Concluded.
Figure A12. Effect of rotation rate and angle of attack on axial force coefficient for no. 4 horizontal tail configuration having rounded fuselage bottom aft of wing T.E.: \( \delta_c = 0^\circ; \delta_t = 0^\circ; \delta_r = 0^\circ; \delta = 0^\circ \).
(b) $\alpha = 55^\circ \text{to} 90^\circ \text{deg}, \; \text{SR} = 0$.

Figure A12 Continued.
(b) \( \alpha = 55 \text{ to } 90 \deg, \ SR = 0 \).

Figure A13 - Concluded.
Figure A.14. Effect of rotation rate and angle of attack on rolling-moment coefficient for no. 4 horizontal tail configuration having rounded fuselage bottom aft of engine cowling. $\delta_e = 0^\circ$, $\delta_A = 0^\circ$, $\delta_r = 0^\circ$, $\beta = 0^\circ$. 

(a) $\alpha = 5^\circ$ deg, $SR = 0$. 
(b) α=55° to 90° deg, SR=0.
Figure A14. Concluded.
Figure A15: Effect of rotation ratio and angle of attack on pitching-moment coefficient for no. 4 horizontal tail configuration having rounded fuselage bottom left of engine cowling. $\alpha = -50^\circ$, $\delta_e = 0^\circ$, $\delta_a = 0^\circ$, $\delta_r = 0^\circ$. $\phi = 0^\circ.$
Figure A1b. Concluded.
Figure A16: Effect of rotation rate and angle of attack on normal force coefficient for no. 4 horizontal tail configuration having rounded fuselage bottom aft of engine cowling. $\delta_e = 0^\circ$, $\delta_r = 0^\circ$, $\delta_f = 0^\circ$, $\beta = 0^\circ$. 

(a) $\gamma = 50^\circ$, $SR = 0$. 
Figure A17. Effect of rotation rate and angle of attack on side-force coefficient for no. 4 horizontal tail configuration having rounded fuselage bottom aft of engine cowling. $\delta_e = 0^\circ$, $\delta_a = 0^\circ$, $\delta_r = 0^\circ$, $\phi = 0^\circ$. 

(a) $\alpha = 50^\circ$, SR = 0.
(b) $\alpha=55$ to $90$ deg, $SR=0$.

Figure A17-Concluded.
Figure A18 - Effect of rotation rate and angle of attack on axial force coefficient for No. 4 horizontal tail configuration having rounded fuselage bottom aft of engine cowling: $\delta_e = 0^\circ$, $\delta_r = 0^\circ$, $\beta = 0^\circ$. 

(a) $\alpha = 50^\circ$, SR=0.
Figure A19. Effect of rotation rate and angle of attack on yawing-moment coefficient for no. 3 horizontal tail configuration. $\delta_e = 0^\circ$. $\alpha = 8$ to $16$ deg, $SR = 76$ cm (30 in).
\( \alpha, \text{deg} \)

- ○ 18
- □ 20
- ◇ 25
- △ 30
- ▲ 35

(b) \( \alpha = 18 \text{ to } 35 \text{ deg}, \ SR = 76 \text{ cm (30 in).} \)

Figure A19. Continued.
Figure A19 - Continued.
Figure A20. Effect of rotation rate and angle of attack on rolling moment coefficient for no. 3 horizontal tail configuration. $\alpha = 0^\circ; \alpha = 2^\circ; \alpha = 4^\circ; \beta = 0^\circ$. 

- $\alpha = 8$ to $16$ deg. $SR = 76$ cm (30 in).
(b) $\alpha$-13 to 35 deg, SR-76cm (30 in).

Figure A20, Continued.
(d) \(\alpha = 55\) to 90 deg, SR = 0.

Figure A20 Concluded.
Figure A21. Effect of rotation rate and angle of attack on pitching moment coefficient for no. 3 horizontal tail configuration. $\delta_a = 0^\circ$, $\delta_a = 0^\circ$, $\delta_e = 0^\circ$, $\beta = 0^\circ$. $\omega = 8 \text{ to } 15 \text{ deg, } SR = 76 \text{ cm (30 in).}$
Figure A21. Continued.

(b) \( a=18^\circ\text{ to } 35^\circ \text{ deg.} \), \( SR=76\text{ cm}(30\text{ in}) \).
(c) $\alpha = 30$ to 50 deg, $SR = 0$.

Figure A21. Continued.
(d) \( m=55 \text{ to } 90 \text{ deg, } SR=0 \).

Figure A21. Concluded.
Figure A22. Effect of rotation rate and angle of attack on normal force coefficient for no. 3 horizontal tail configuration, $\alpha=0^\circ$, $\delta_t=0^\circ$, $\delta_r=0^\circ$, $\beta=0^\circ$. 

(a) $\alpha=8^\circ$ to $15^\circ$, $SR=76$cm (30in).
Figure A22. Continued.

(b) $\alpha = 18$ to $35$ deg., $SR = 76$ cm (30 in).
Figure A22. Continued.

(c) $\alpha = 30$ to $50 \text{deg}, SR = 0.$
(d) $\alpha = 55$ to $90$ deg, $SR = 0$.

Figure A22. Concluded.
(b) $c=18$ to 35 deg, $SR = 76$ cm (30 in).

Figure A23. Continued.
Figure A23, Continued.
Figure A23, Concluded.
Figure A24: Effect of rotation rate and angle of attack on axial force coefficient for no. 3 horizontal tail configuration. \( \delta_e = 0^\circ, \delta_f = 0^\circ, \delta_r = 0^\circ \). S = 60\text{in}.}

(a) \( \alpha = 8\text{to}15\text{deg}, SR = 76\text{cm (30in)}\).
(d) \( \alpha = 55 \text{ to } 90 \text{ deg}, \ SR = 0 \).

Figure A24. Concluded.
Figure A25. Effect of rotation rate and angle of attack on yawing moment coefficient for No. 3 horizontal tail configuration having rounded fuselage bottom aft of wing TE. \( \alpha = 0^\circ, \quad \delta_e = 0^\circ, \quad \delta_z = 0^\circ, \quad \beta = 0^\circ \).
Figure A25: Concluded.
Figure A.20. Effect of rotation rate and angle of attack on rolling-moment coefficient for no. 3 horizontal tail configuration having rounded fuselage bottom aft of wing. Tk, $\alpha_e = 0^\circ$, $\alpha = 0^\circ$, $\alpha_r = 0^\circ$, $\beta = 0^\circ$. 

(a) $\alpha$ = 30 to 50 deg, SR = 0.
(b) α = 55 to 90 deg, SR = 0.

Figure A26: Concluded.
Figure A.27. Effect of rotation rate and angle of attack on pitching moment coefficient for no. 3 horizontal tail configuration having rounded fuselage bottom aft of wing TR. $\delta_e = 0^\circ$, $\delta_d = 0^\circ$, $\delta_r = 0^\circ$, $\Phi = 0^\circ$. 
Figure A27, Continued.

(b) $\alpha=55$ to $90$ deg, $SR=0$. 
Figure A.28. Effect of rotation rate and angle of attack on normal-force coefficient for no. 3 horizontal tail configuration having rounded fuselage bottom aft of wing. TE. $\alpha = 0^\circ$, $\delta_r = 0^\circ$, $\delta_s = 0^\circ$. $\beta = 0^\circ$. 
(b) $\Theta = 55$ to $90$ deg. $SR = 0$.

Figure A28. Concluded.
Figure A29. Effect of rotation rate and angle of attack on side-force coefficient for no. 3 horizontal tail configuration having rounded fuselage bottom aft of wing. TE, $\alpha = 0^\circ$, $\alpha_i = 0^\circ$, $\beta = 0^\circ$. 
(a) $\alpha = 30$ to $50^\circ$, SR = 0.
Figure A.29. Concluded.
Figure A30. Effect of rotation rate and angle of attack on axial force coefficient for no. 3 horizontal tail configuration having rounded fuselage bottom aft of wing. TR: $\delta_e=0^\circ$, $\delta_a=0^\circ$, $\delta_r=0^\circ$, $\beta=0^\circ$. 

(a) $\alpha$=30 to 50 deg, $SR=0$. 

G_A

$\Omega b/2V$
Figure A31: Effect of rotation rate and angle of attack on yawing-moment coefficient for No. 3 horizontal tail configuration having rounded fuselage bottom aft of engine cowling. \( \delta_e = 0^\circ \), \( \delta_a = 0^\circ \), \( \delta_f = 0^\circ \), \( \beta = 0^\circ \).
Figure A32. Effect of rotation rate and angle of attack on rolling moment coefficient for no. 3 horizontal tail configuration having rounded fuselage bottom aft of engine cowling. $\delta_c = 40^\circ$, $\delta_s = 0^\circ$, $\delta_f = 0^\circ$, $\beta = 0^\circ$. 

(a) $\alpha = 30$ to $50$ deg, $SR = 0$. 
Figure A32. Concluded.
Figure A33. Effect of rotation rate and angle of attack on pitching-moment coefficient for no. 3 horizontal tail configuration having rounded fuselage bottom aft of engine cowling. δe = 0°, δx = 0°, δr = 0°, β = 0°.
Figure A33 Concluded.
Figure A.34: Effect of rotation rate and angle of attack on normal force coefficient for no. 3 horizontal tail configuration having rounded fuselage bottom aft of engine cowling. $\delta_{e}=0^\circ$, $\delta_{a}=0^\circ$, $\delta_{r}=0^\circ$, $\delta=0^\circ$. $\Gamma=1.0$. 

(a) $\alpha=30^\circ$ to $50^\circ$ deg, $SR=0$. 

Caption: Figure A.34: Effect of rotation rate and angle of attack on normal force coefficient for no. 3 horizontal tail configuration having rounded fuselage bottom aft of engine cowling. $\delta_{e}=0^\circ$, $\delta_{a}=0^\circ$, $\delta_{r}=0^\circ$, $\delta=0^\circ$. $\Gamma=1.0$. 

(a) $\alpha=30^\circ$ to $50^\circ$ deg, $SR=0$. 

Legend: 

- $\alpha$: Angle of attack (degrees) 
- $\Gamma$: Rotation rate (unknown units) 
- $SR$: Surface roughness (unknown units) 

Graph: 

- Graph showing the relationship between normal force coefficient and rotation rate for various angles of attack.

Notes: 

- The figure illustrates the impact of rotation rate and angle of attack on the normal force coefficient for a specific horizontal tail configuration.

- The graph uses symbols to denote different data points for various conditions.

- The legend provides a key to the symbols and variables used in the graph.
Figure A34. Concluded.
Figure A.35: Effect of rotation rate and angle of attack on side-force coefficient for no. 3 horizontal tail configuration having rounded fuselage bottom aft of engine cowling. $\alpha = 0^\circ$, $\beta = 0^\circ$, $\gamma = 0^\circ$, $\delta = 0^\circ$. (a) $\alpha = 30$ to $50$ deg, $SR = 0$. 
Figure A35. Concluded.
Figure A36. Effect of rotation rate and angle of attack on axial force coefficient for no. 3 horizontal tail configuration having rounded fuselage bottom aft of engine cowling. $\delta_e = 0^\circ$, $\delta_a = 0^\circ$, $\delta_c = 0^\circ$, $\beta = 0^\circ$.  

(a) $\alpha = 30$ to $50$ deg; $SR = 0$. 

$C_A$ vs. $\alpha$, $\theta_b/2V$. 

Grid lines indicate $\alpha$: 30, 35, 40, 45, 50 deg.
Figure A36. Concluded.
Figure A37. Lift coefficient as a function of angle of attack for various tail configurations.
Aerodynamic characteristics obtained in a rotational flow environment utilizing a rotary balance located in the Langley spin tunnel are presented in plotted form for a 1/5-scale, single-engine, high-wing, general aviation airplane model. The configurations tested included various tail designs and fuselage shapes. Data are presented without analysis for an angle-of-attack range of 8° to 90° and clockwise and counter-clockwise rotations covering an $\frac{\Omega_b}{2V}$ range from 0 to 0.85.