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# RESEARCH MEMORANDUM

TIME HISTORIES OF HORIZONTAL-TAIL LOADS AND DEFORMATIONS

ON A JET-POWERED BOMBER AIRPLANE DURING WIND-UP

TURNS AT 15,000 FEET AND 22,500 FEET

By William A. McGowan and Bernard Wiener

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TO: NATIONAL ADVISORY COMMITTEE  
FOR AERONAUTICS

WASHINGTON  
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## TIME HISTORIES OF HORIZONTAL-TAIL LOADS AND DEFORMATIONS

ON A JET-POWERED BOMBER AIRPLANE DURING WIND-UP

TURNS AT 15,000 FEET AND 22,500 FEET

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## SUMMARY

Time histories are presented of horizontal-tail and elevator loads and deformations on a jet-powered bomber airplane during wind-up turns at pressure altitudes of 15,000 feet and 22,500 feet. The normal accelerations experienced varied from 0.91g to 2.88g at Mach numbers from 0.31 to 0.75. The maximum horizontal-tail and elevator loads measured were approximately 8,000 pounds and 600 pounds, respectively. Elevator and stabilizer twists were small.

## INTRODUCTION

The NACA is currently conducting a flight investigation to determine the loads and deformations on a jet-bomber type of airplane. For this investigation a B-45A airplane has been instrumented with strain-gage bridges for the measurements of the loads on the horizontal tail, the vertical tail, and the wing and with additional instruments for the measurements of twist which occurs in the elevators, the stabilizers, and the fuselage due to aerodynamic and inertia loads.

Time histories of aerodynamic loads and deformations for the B-45A airplane during level flight, aileron rolls, pull-ups, and turns have been presented in references 1 to 3. This paper presents time histories of horizontal-tail loads, elevator loads, and stabilizer and elevator twists measured during wind-up turns at pressure altitudes of 22,500 feet and 15,000 feet.

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## INSTRUMENTATION

A three-view drawing of the test airplane, with approximate locations of strain-gage bridges and deflection-measuring devices, is given in figure 1.

Standard NACA recording instruments were used to measure airspeed, altitude, rolling, pitching, and yawing velocities, sideslip angle, control forces and positions, and accelerations. Three-component accelerometers were mounted at the airplane center of gravity and the approximate quarter-chord station of the horizontal tail at the airplane center line. Accelerometers were also mounted at the tip and midsemispan of each horizontal stabilizer to measure normal accelerations.

Two booms, one at each wing tip, extending approximately one local chord length ahead of the leading edge contained the airspeed head and sideslip-angle transmitter. The results of a flight calibration of the airspeed system for position error and an analysis of available data for a similar installation indicated a Mach number error of less than  $\pm 0.01$  throughout the test range.

Electrical resistance strain-gage bridges were mounted on each spar near the root on both sides of the horizontal tail to measure shear and bending moment. Strain-gage bridges were also mounted on the elevator torque tube and hinge brackets to measure torque and total load, respectively.

Twist bars were installed in the horizontal stabilizers to measure stabilizer twist at the tip and midsemispan stations with respect to the stabilizer root. Control-position transmitters were installed at the tip and root of the elevators and electrically wired to measure elevator twist relative to the stabilizer. The elevators have a built-in twist of  $1.2^\circ$  trailing edge up at the tip, distributed parabolically from the root. This value was obtained by a different method than that used in reference 2 (where the built-in twist was given as  $1.0^\circ$  and  $1.5^\circ$  trailing edge up right and left, respectively) and is considered a more accurate representation of the built-in elevator twist. The positions of the rudder, ailerons, elevators, and elevator trim tabs were measured at the inboard ends by control-position transmitters.

The output from the strain-gage bridges and twist-measuring devices was recorded on two 18-channel oscillographs. A 0.1-second time pulse was used to correlate the records of all recording instruments.

## RESULTS

Aerodynamic loads and twists were determined for the horizontal stabilizers and elevators of the B-45A airplane during 11 power-on wind-up turns. The aerodynamic loads and twists in addition to the elevator angle, airplane normal-force coefficient, and normal acceleration at the center of gravity were plotted in time-history form and are presented in figures 2 to 12. A summary of pertinent flight conditions for the runs illustrated in the figures is given in table I. Aerodynamic tail loads were determined by adding the inertia loads to the structural loads measured by the strain-gage bridges. The airplane was trimmed in the clean condition at the start of each run.

The estimated accuracies of the aerodynamic loads, twists, and parameters are as follows:

Center-of-gravity normal acceleration, g units . . . . .	±0.03
Total horizontal-tail aerodynamic load, lb . . . . .	±160
Each elevator aerodynamic load, lb . . . . .	±60
Elevator angle, deg . . . . .	±0.25
Elevator twist (relative to stabilizer), deg . . . . .	±0.07
Stabilizer twist at midsemispan, deg . . . . .	±0.007
Stabilizer twist at tip, deg . . . . .	±0.015
Mach number . . . . .	±0.01

Buffeting was experienced only in the maneuver illustrated in figure 7 and occurred throughout the maneuver. The quantities shown in figure 7 are mean values and do not show the oscillations produced by the buffeting. The right elevator load is not given for runs made at a pressure altitude of 15,000 feet (figs. 8 to 12) because of an instrument failure.

Total tail loads.- The maximum down tail load (fig. 7) occurred at a Mach number of 0.75 at a pressure altitude of 21,800 feet and was approximately 8,300 pounds. The greatest up tail load (fig. 4) was measured at a Mach number of 0.52 at a pressure altitude of 23,000 feet and was about 5,200 pounds.

The total tail load at 1g increased in the down direction with increasing Mach number. At a pressure altitude of approximately 22,500 feet with an airplane normal acceleration of 1g the total tail load varied from 900 pounds acting up at a Mach number of 0.41 to a down load of 8,300 pounds at a Mach number of 0.75 (figs. 2 to 7). At a pressure altitude of approximately 15,000 feet with an airplane normal acceleration of 1g the total tail load varied from 1,200 pounds acting up at a Mach number of 0.31 to a down load of 1,600 pounds at a Mach number of 0.47 (figs. 8 to 12).

The total tail load measured during each run increased in the up direction with an increase in the airplane normal-force coefficient.

The tail-load dissymmetry was small in all runs illustrated in the figures.

Elevator loads.- The maximum right and left elevator up loads were 500 pounds and 600 pounds, respectively (fig. 6). These loads were measured at a Mach number of 0.64 at a pressure altitude of 22,800 feet and a normal acceleration of 1g. The maximum down loads for the right and left elevator were approximately 500 pounds and 600 pounds, respectively, (fig. 5) measured at a Mach number of 0.58 and normal acceleration of 2.88g at a pressure altitude of 22,500 feet.

The right elevator had a greater up position than the left elevator with a maximum difference in position of about  $0.8^\circ$ .

There is a relatively high elevator load dissymmetry in figures 2, 3, and 7, the largest dissymmetry being approximately 300 pounds.

Stabilizer and elevator twist.- The stabilizer twist at the mid-semispan and tip increased leading edge up with an increasing up horizontal tail load. The greatest midsemispan twist measured was about  $0.13^\circ$  leading edge up for the right stabilizer (figs. 4 and 5) and  $0.11^\circ$  leading edge down for the left stabilizer (fig. 7). The largest tip twists were approximately  $0.22^\circ$  leading edge up for the right stabilizer (fig. 4) and  $0.33^\circ$  leading edge down for the left stabilizer (fig. 7). In all the maneuvers illustrated the right stabilizer at both the tip and midsemispan was twisted more leading edge up than the left stabilizer.

Due to limitations in the instrumentation, the elevator twist at the start of each run could not be determined. The increment in twist due to acceleration was measured, however, and is the quantity presented in the figures.

The elevator twist increased trailing edge down with increasing down elevator loads. The maximum incremental twist measured was  $0.55^\circ$

for the right elevator and  $0.58^\circ$  for the left elevator tip trailing edge down (fig. 6).

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#### REFERENCES

1. Aiken, William S., Jr., and Wiener, Bernard: Time Histories of Horizontal-Tail Loads on a Jet-Powered Bomber Airplane in Four Maneuvers. NACA RM L9H16a, 1949.
2. Cooney, T. V., and McGowan, William A.: Time Histories of Loads and Deformations on a B-45A Airplane in Two Aileron Rolls. NACA RM L9I28a, 1949.
3. Cooney, T. V., and Aiken, William S., Jr.: Time Histories of the Loads and Deformations on the Horizontal Tail of a Jet-Powered Bomber Airplane in Accelerated Maneuvers at 30,000 Feet. NACA RM L50B24a, 1950.

TABLE I  
SUMMARY OF FLIGHT CONDITIONS

Figure number	Airplane weight (lb)	Center-of-gravity position (percent M.A.C.)	Mach number	Elevator-trim-tab position, airplane nose up (deg.)	Power condition (percent maximum rpm)	Center-of-gravity normal-acceleration range (g units)	Pressure altitude (ft)
2	62,700	28.2	0.41	8.5	86	0.99 to 1.67	22,500
3	62,400	28.2	.48	5.8	86	.97 to 2.03	22,300
4	61,600	28.1	.52	4.8	90	.91 to 2.45	23,000
5	60,500	27.9	.58	2.5	92	1.02 to 2.88	22,500
6	59,700	27.8	.64	1.0	95	1.00 to 2.86	22,800
7	58,000	27.6	.75	0.0	100	1.05 to 1.40	21,800
8	55,900	27.4	.31	9.8	80	1.00 to 1.45	15,300
9	56,100	27.4	.32	9.8	80	.93 to 1.46	15,100
10	56,400	27.5	.38	6.5	82	1.02 to 1.86	15,000
11	55,600	27.4	.42	5.5	82	.94 to 2.33	15,000
12	55,300	27.3	.47	3.5	84	.99 to 2.54	14,900

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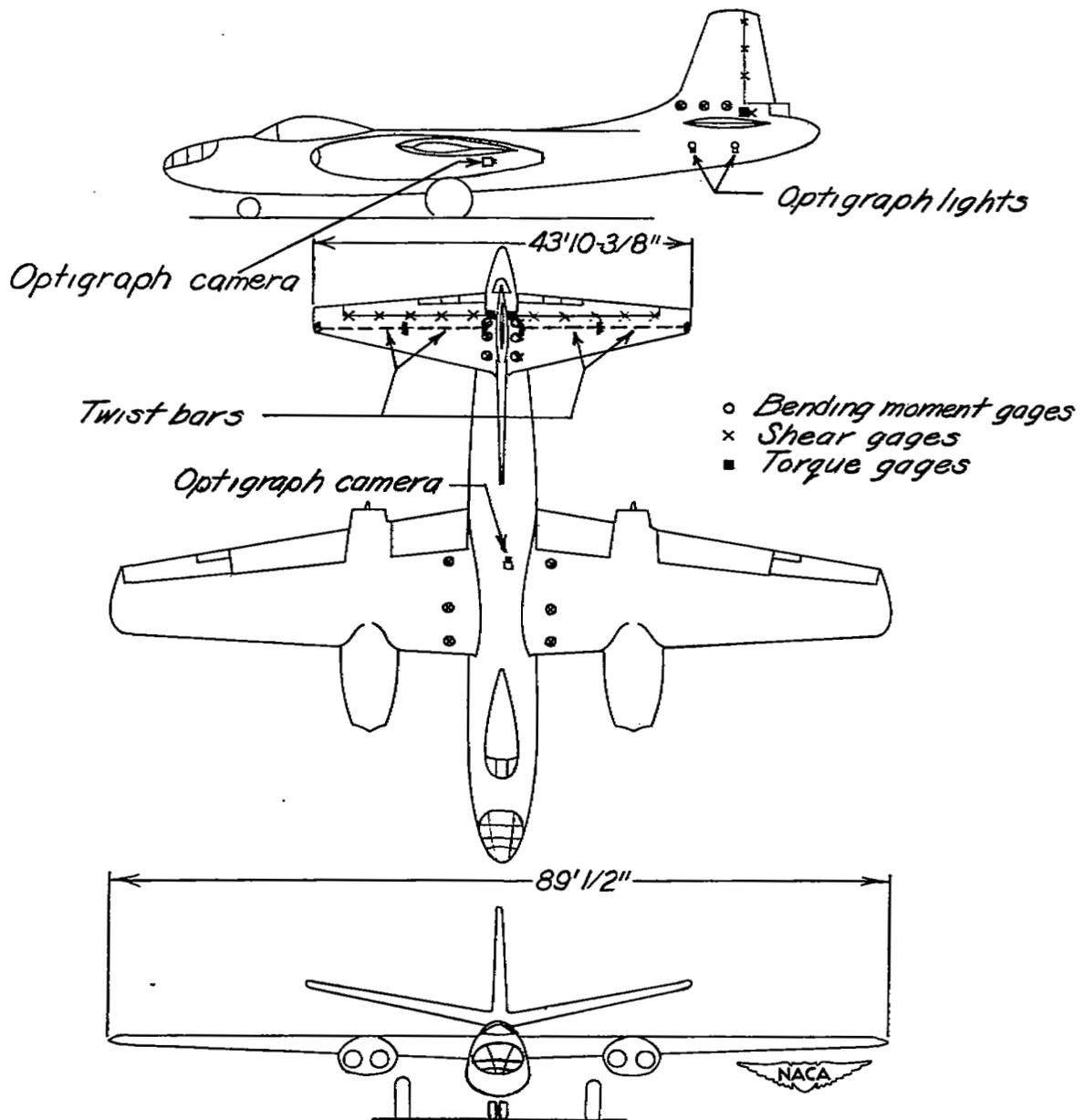


Figure 1.- Three-view drawing of test airplane showing approximate locations of strain-gage bridges and deflection-measuring devices.

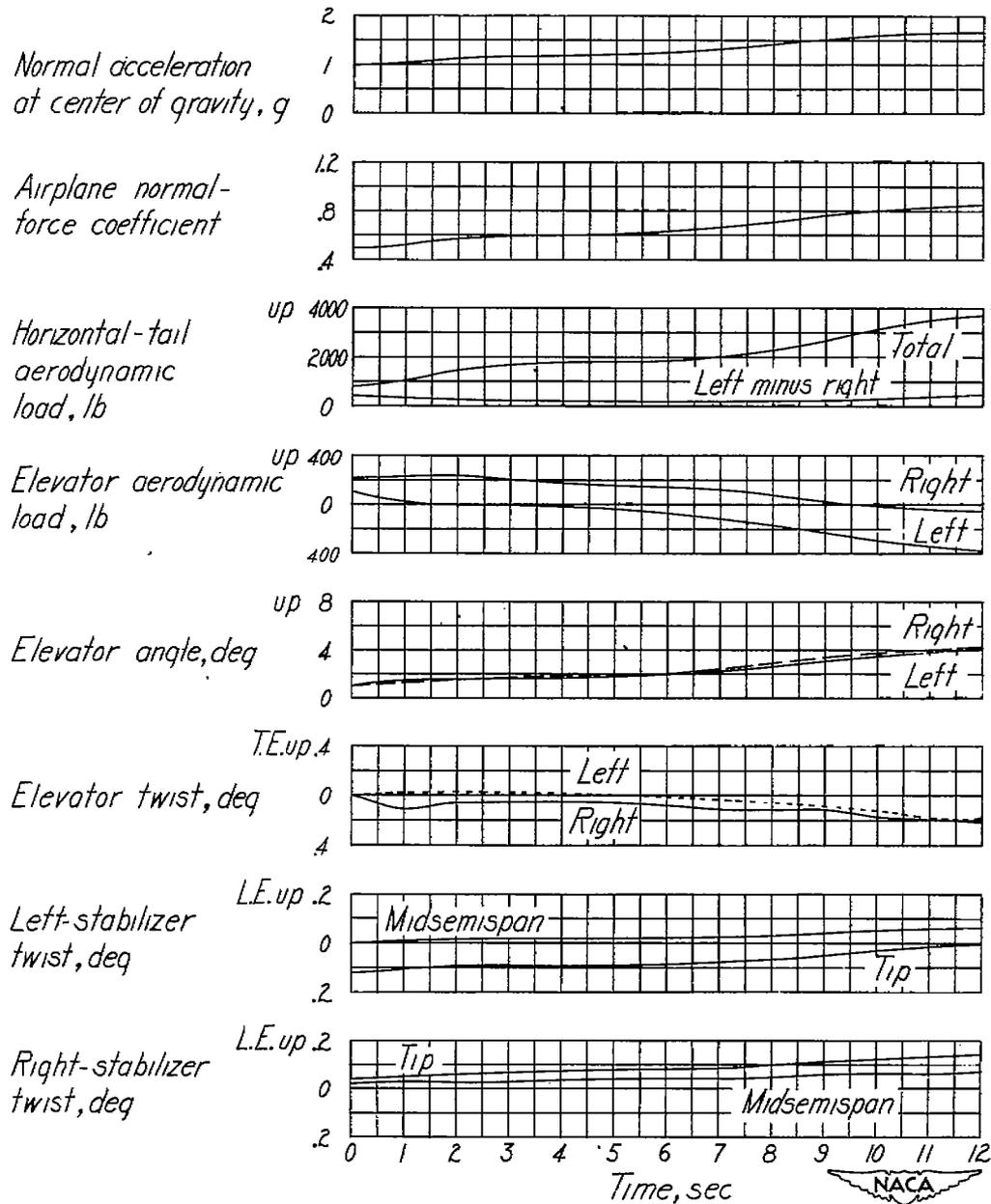


Figure 2.- Time histories of various quantities during a wind-up turn. Pressure altitude, 22,500 feet; Mach number, 0.41; airplane weight, 62,700 pounds; center of gravity is at 28.2 percent mean aerodynamic chord; elevator trim tabs,  $8.5^\circ$  airplane nose up.

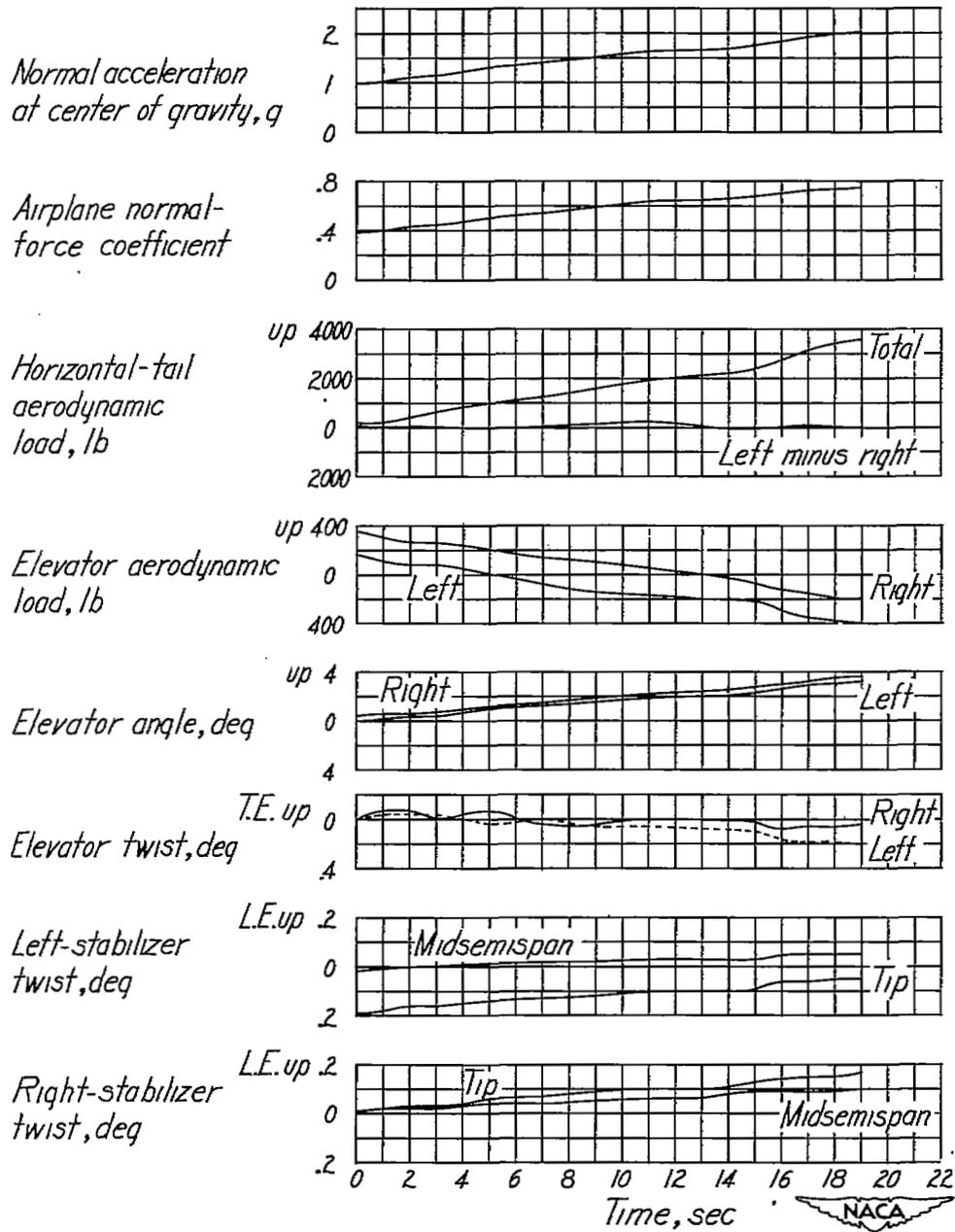


Figure 3.- Time histories of various quantities during a wind-up turn. Pressure altitude, 22,300 feet; Mach number, 0.48; airplane weight, 62,400 pounds; center of gravity is at 28.2 percent mean aerodynamic chord; elevator trim tabs,  $5.8^\circ$  airplane nose up.

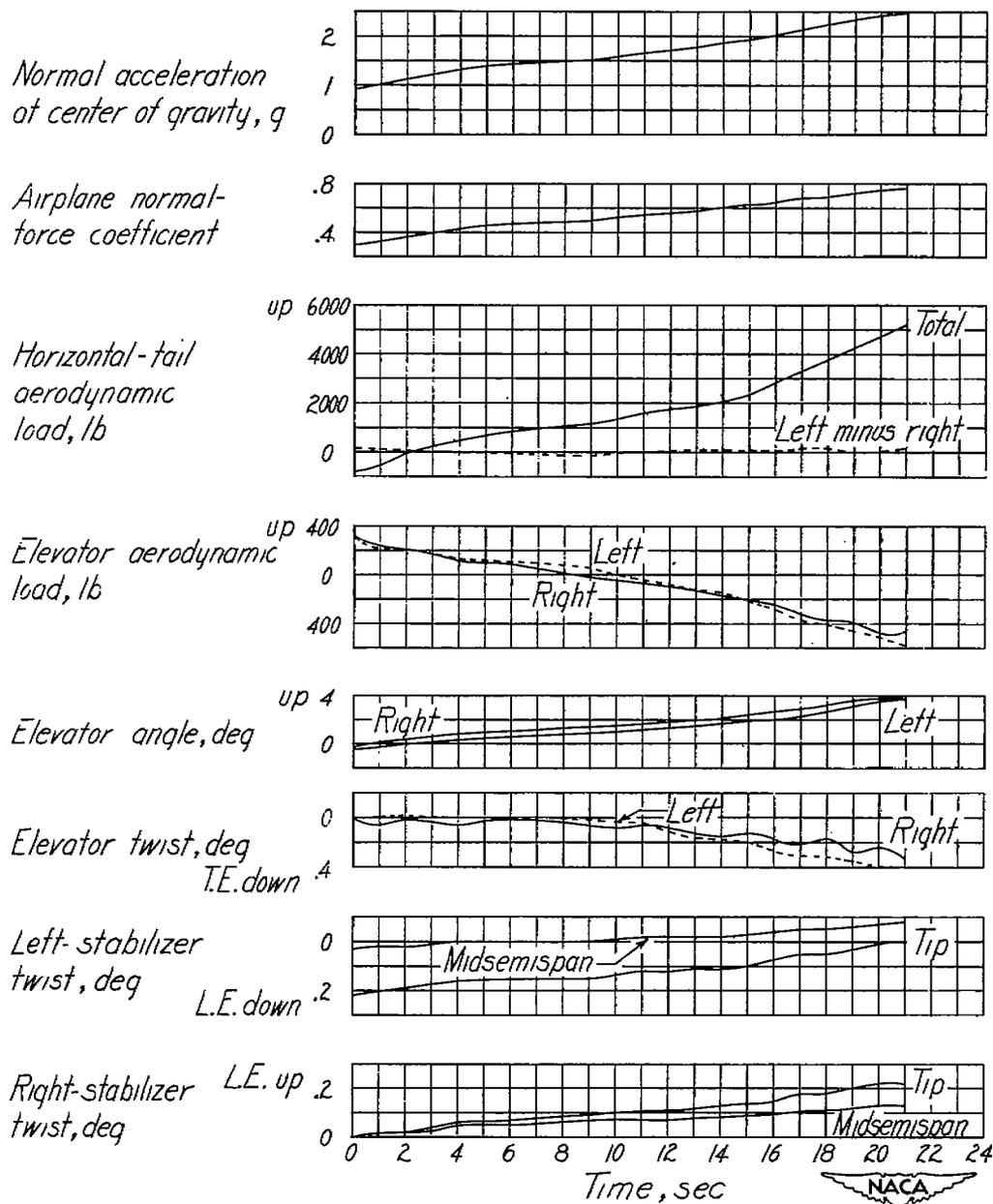


Figure 4.- Time histories of various quantities during a wind-up turn. Pressure altitude, 23,000 feet; Mach number, 0.52; airplane weight, 61,600 pounds; center of gravity is at 28.1 percent mean aerodynamic chord; elevator trim tabs,  $4.8^\circ$  airplane nose up.

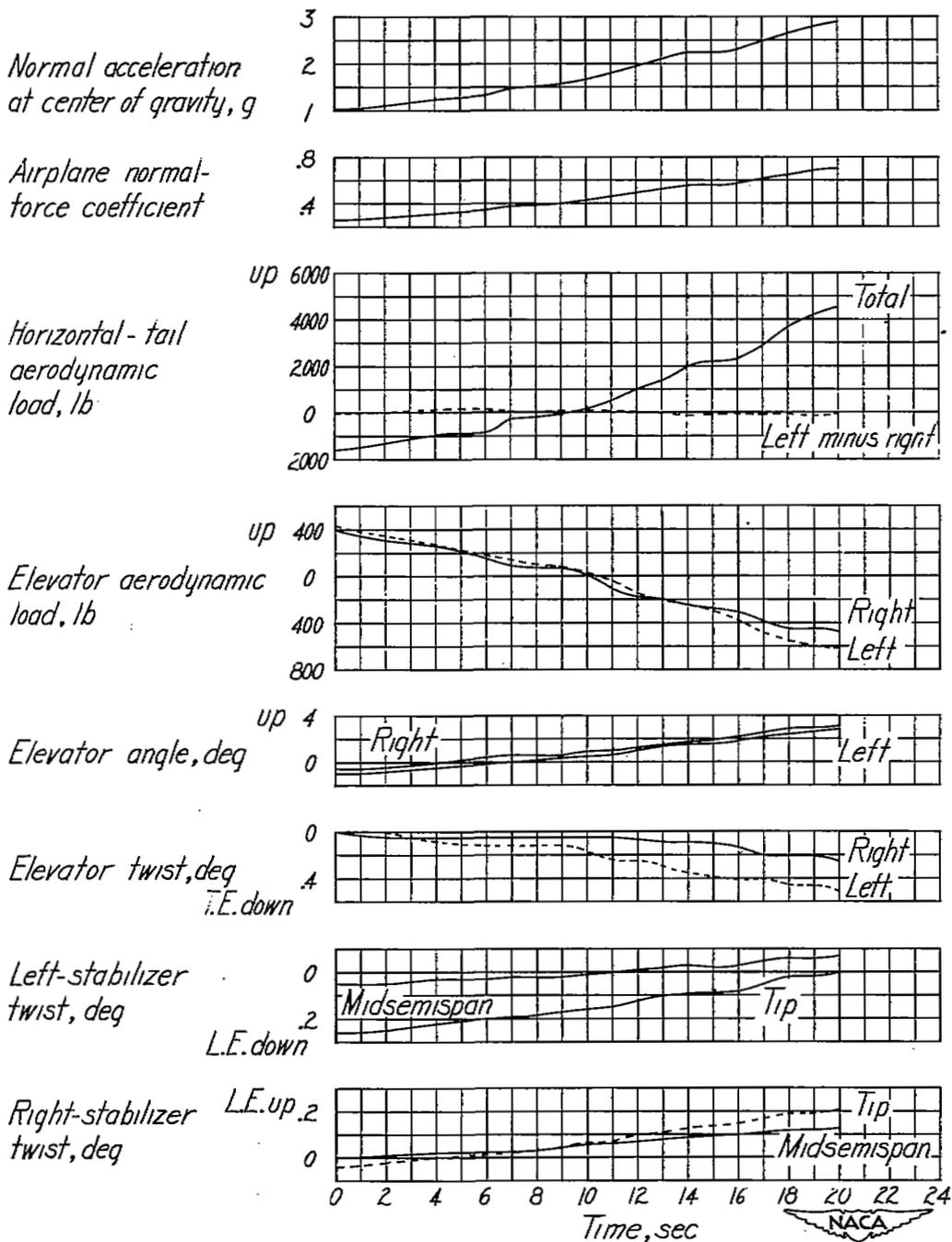


Figure 5.- Time histories of various quantities during a wind-up turn. Pressure altitude, 22,500 feet; Mach number, 0.58; airplane weight, 60,500 pounds; center of gravity is at 27.9 percent mean aerodynamic chord; elevator trim tabs, 2.5° airplane nose up.

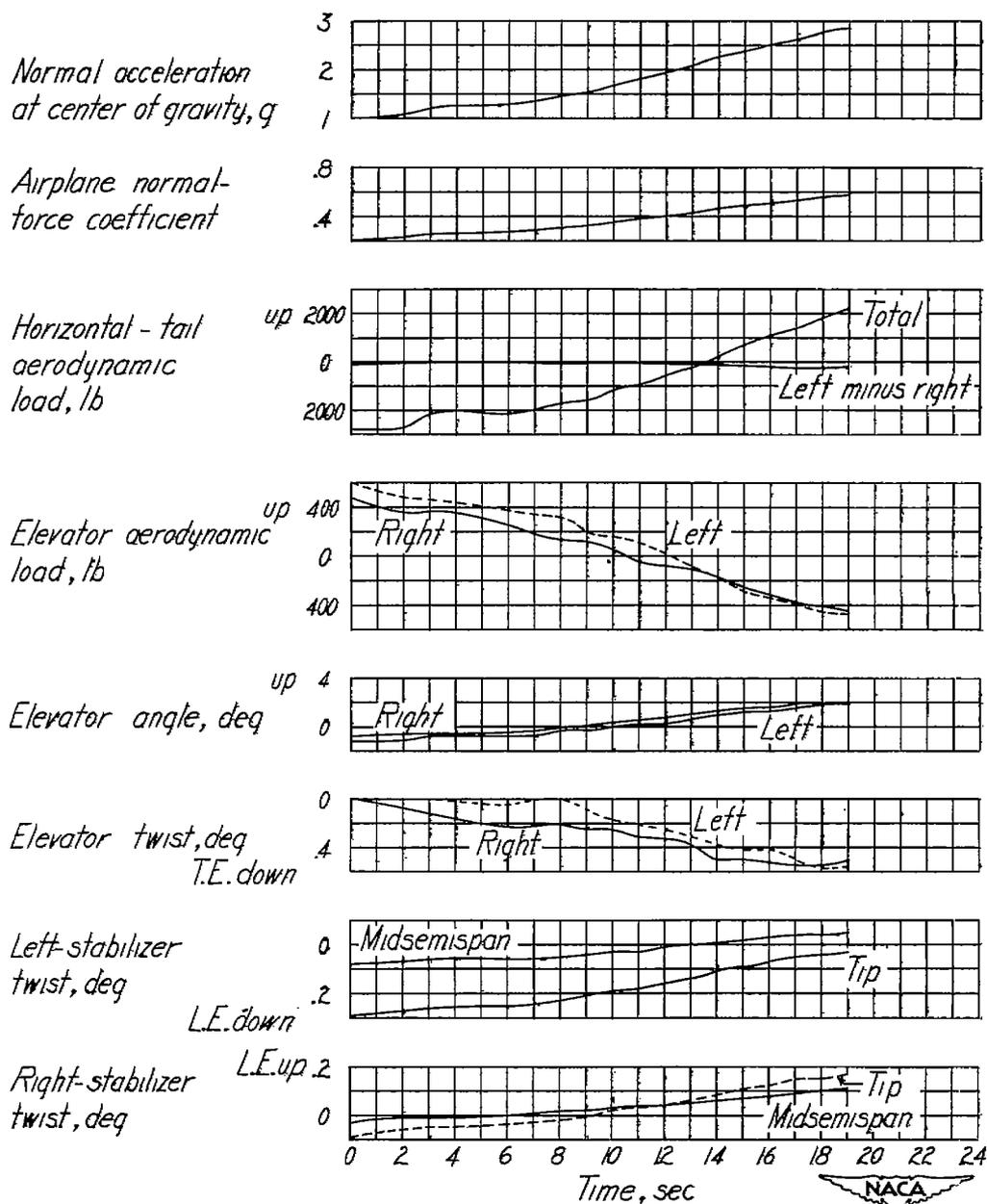


Figure 6.- Time histories of various quantities during a wind-up turn. Pressure altitude, 22,800 feet; Mach number, 0.64; airplane weight, 59,700 pounds; center of gravity is at 27.8 percent mean aerodynamic chord; elevator trim tabs,  $1.0^\circ$  airplane nose up.

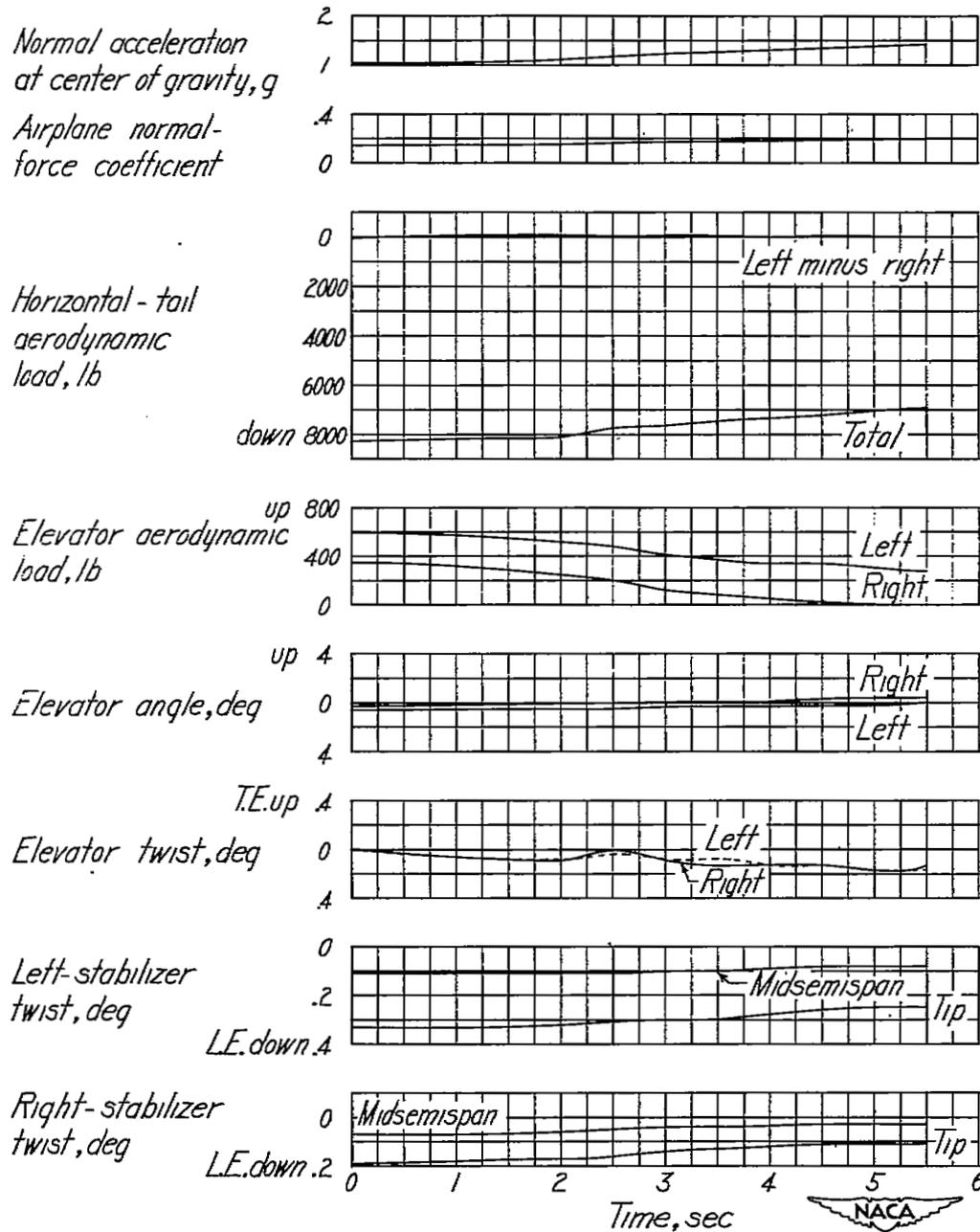


Figure 7.- Time histories of various quantities during a wind-up turn. Pressure altitude, 21,800 feet; Mach number, 0.75; airplane weight, 58,000 pounds; center of gravity is at 27.6 percent mean aerodynamic chord; elevator trim tabs,  $0.0^\circ$  airplane nose up. (Buffeting present throughout.)

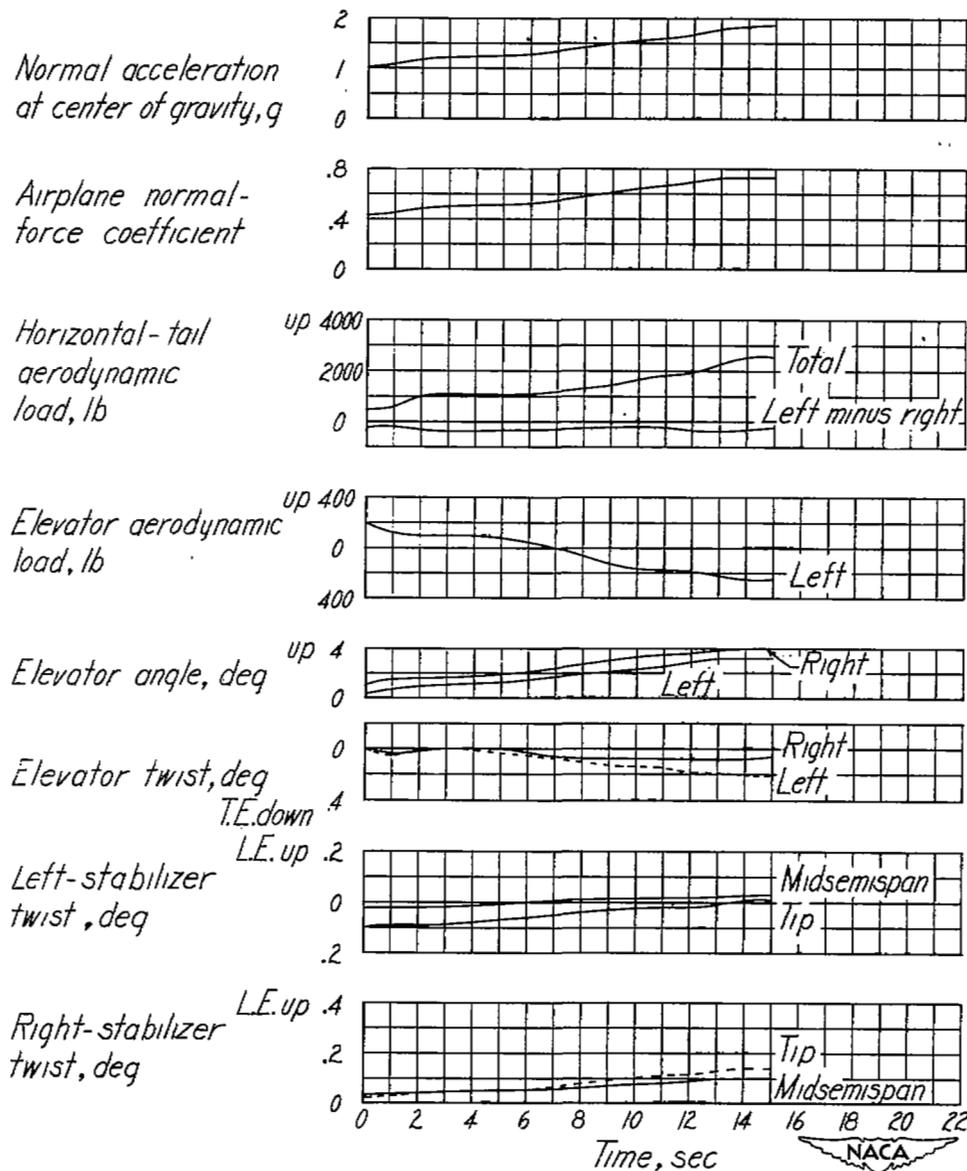


Figure 8.- Time histories of various quantities during a wind-up turn. Pressure altitude, 15,300 feet; Mach number, 0.31; airplane weight, 55,900 pounds; center of gravity is at 27.4 percent mean aerodynamic chord; elevator trim tabs,  $9.8^\circ$  airplane nose up.

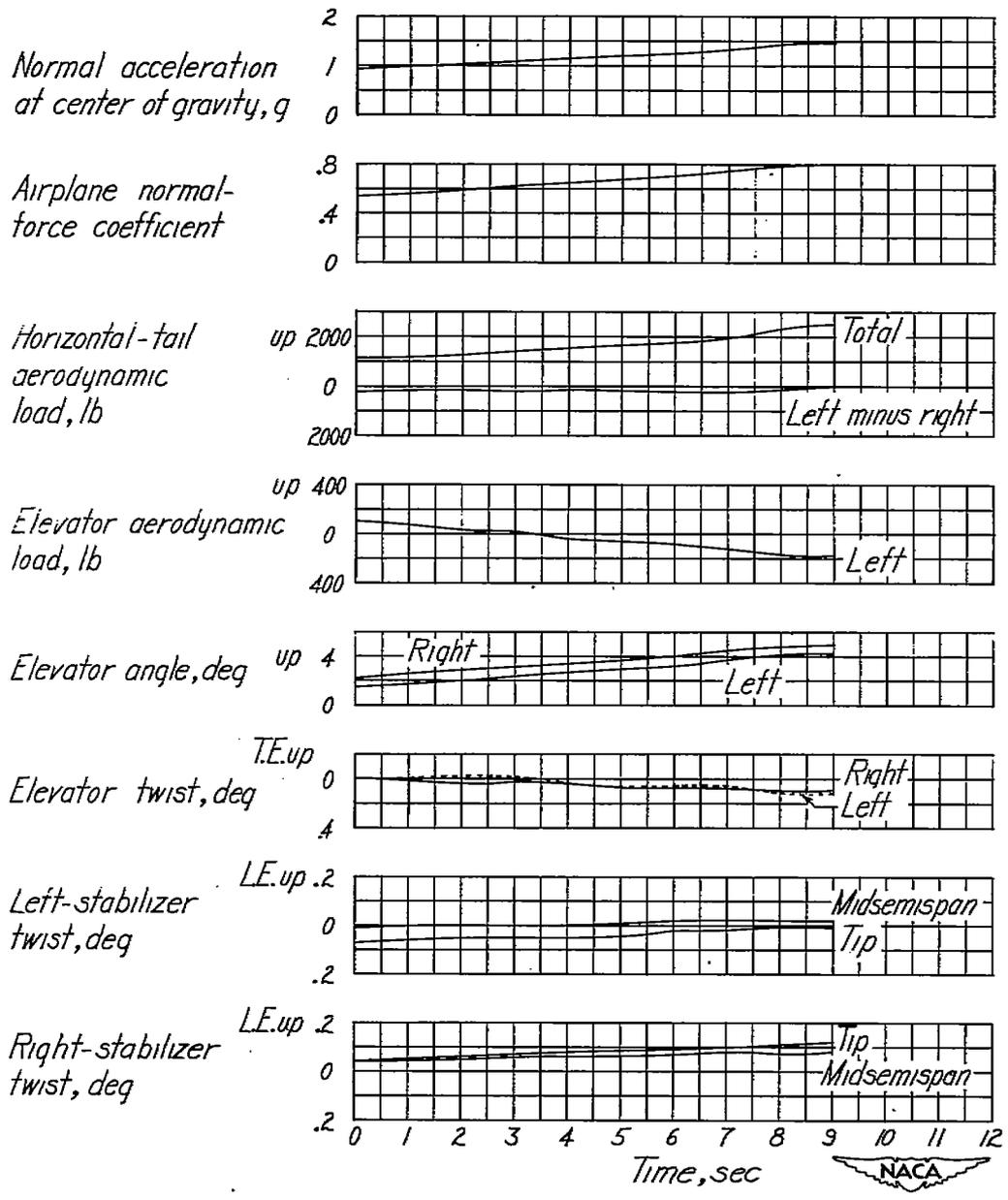


Figure 9.- Time histories of various quantities during a wind-up turn. Pressure altitude, 15,100 feet; Mach number, 0.32; airplane weight, 56,100 pounds; center of gravity is at 27.4 percent mean aerodynamic chord; elevator trim tabs,  $9.8^\circ$  airplane nose up.

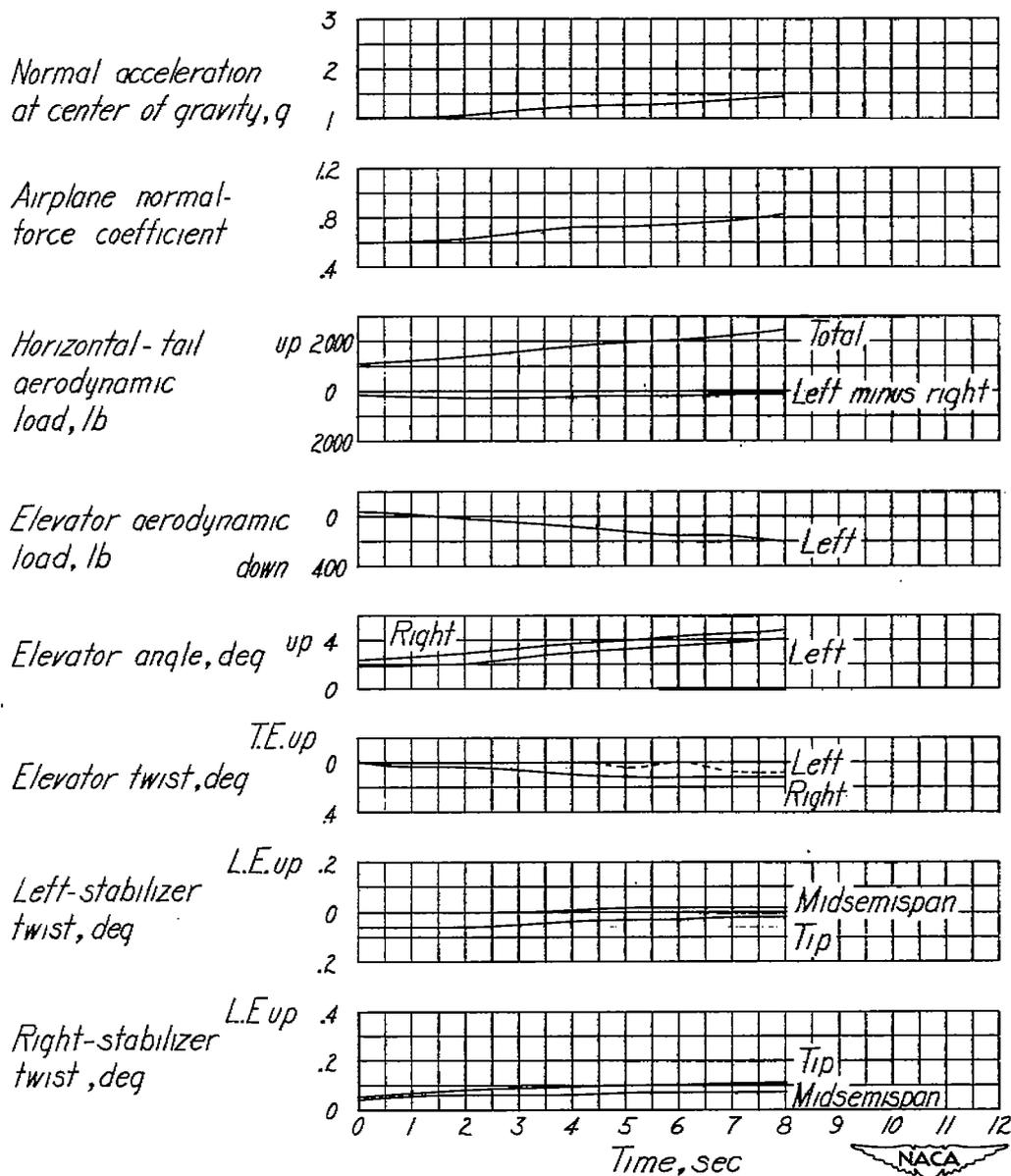


Figure 10.- Time histories of various quantities during a wind-up turn. Pressure altitude, 15,000 feet; Mach number, 0.38; airplane weight, 56,400 pounds; center of gravity is at 27.5 percent mean aerodynamic chord; elevator trim tabs,  $6.5^\circ$  airplane nose up.

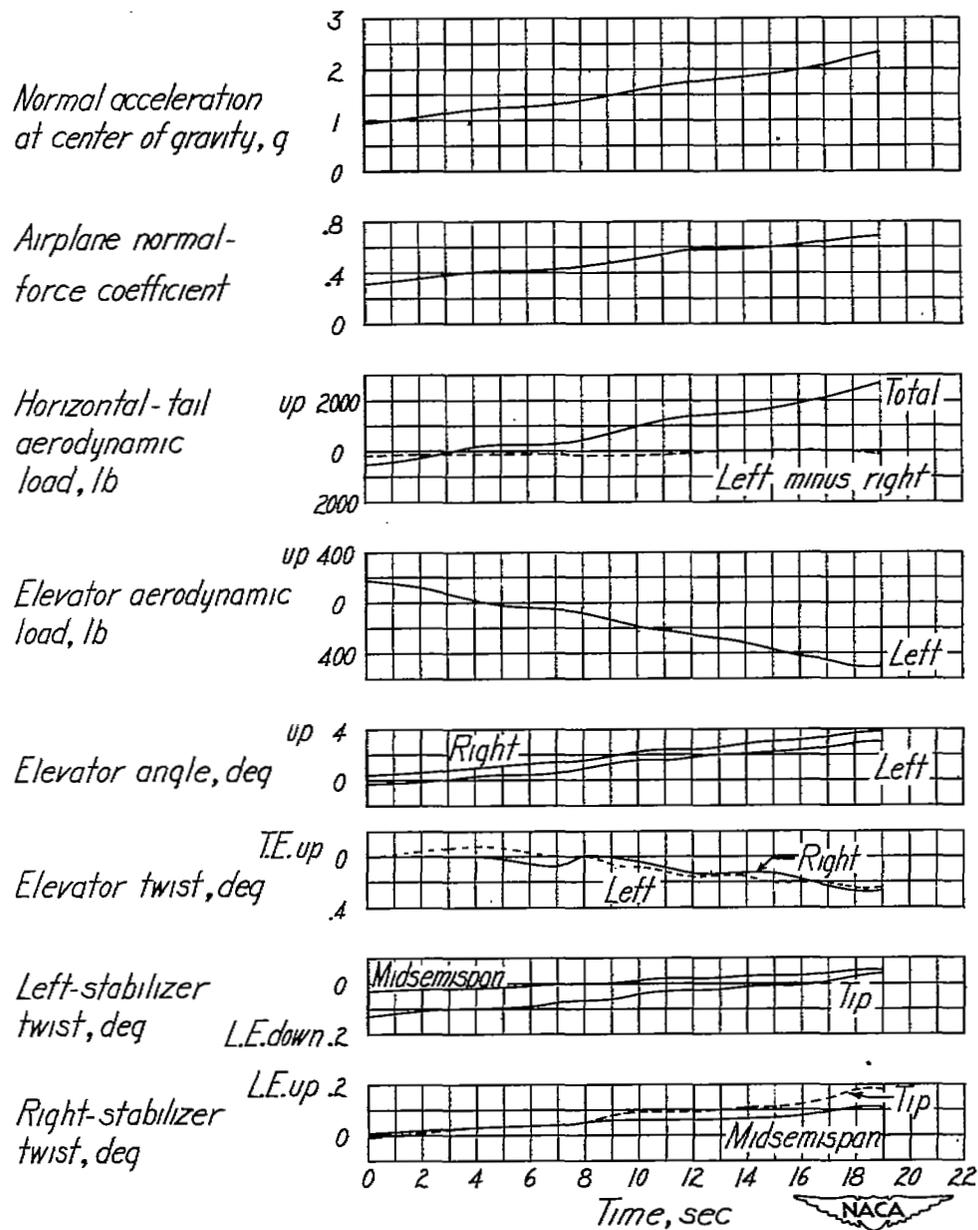


Figure 11.- Time histories of various quantities during a wind-up turn. Pressure altitude, 15,000 feet; Mach number, 0.42; airplane weight, 55,600 pounds; center of gravity is at 27.4 percent mean aerodynamic chord; elevator trim tabs,  $5.5^\circ$  airplane nose up.

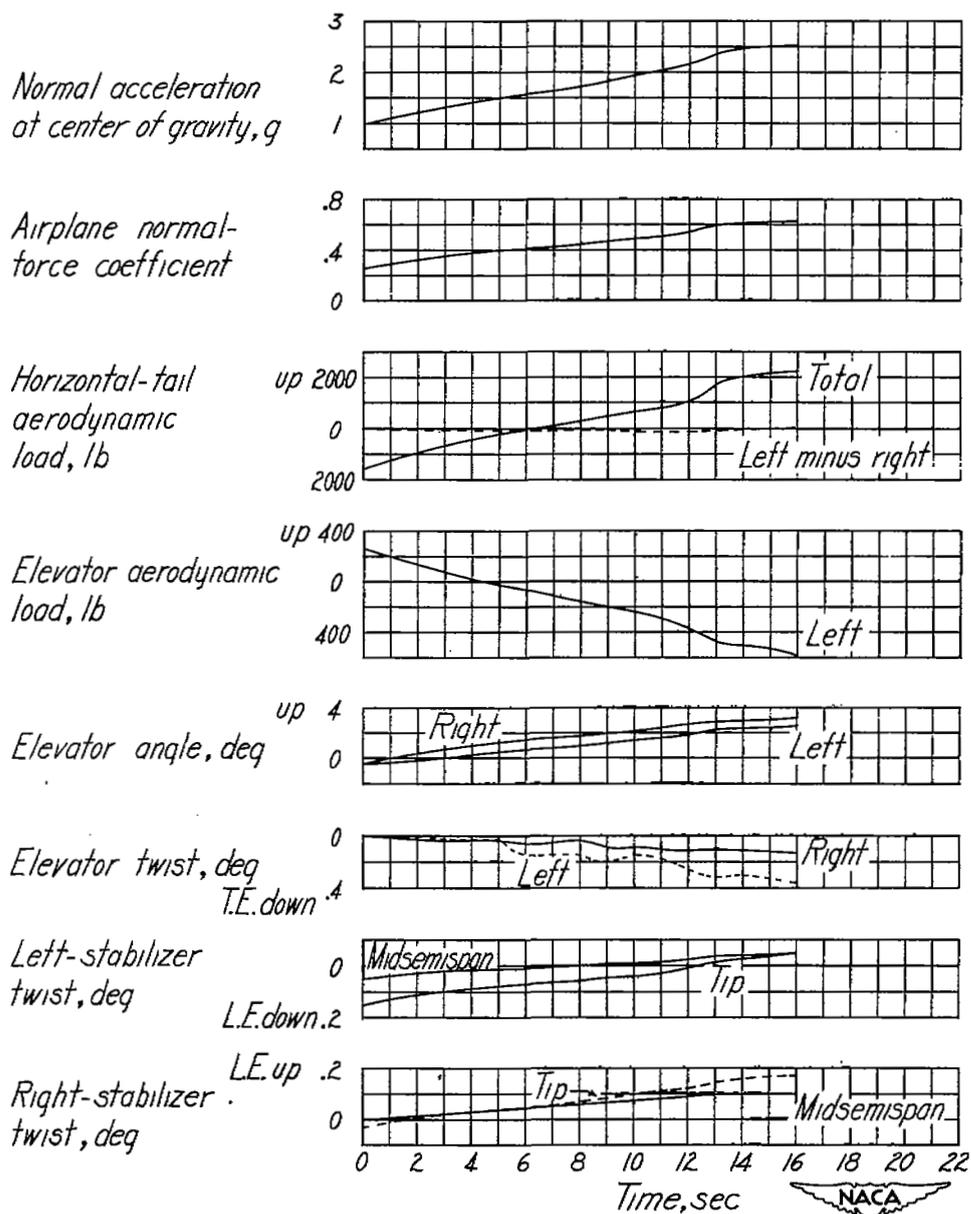


Figure 12.- Time histories of various quantities during a wind-up turn. Pressure altitude, 14,900 feet; Mach number, 0.47; airplane weight, 55,300 pounds; center of gravity is at 27.3 percent mean aerodynamic chord; elevator trim tabs,  $3.5^\circ$  airplane nose up.

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