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RESEARCH MEMORANDUM

TIME HISTORIES OF HORIZONTAL-TAIL LOADS ON A JET-POWERED BOMBER AIRPLANE IN FOUR MANEUVERS

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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SUMMARY

Some preliminary results in time-history form are presented for four maneuvers of the first flight in a tail-load investigation on a jet-powered bomber airplane. The results presented are for a constant-power level-flight run from stall to a Mach number of 0.64, a low-speed pull-up to 2.0g, a high-speed pull-up to 1.8g, and a turn to 2.4g.

INTRODUCTION

Numerous investigations have been made for the purpose of correlating tail-load calculations with tail loads measured in flight. Most of these investigations, however, have been made on small, relatively stiff airplanes. The prime purpose of the present investigation is to obtain data on both horizontal and vertical tail loads on a large, high-speed, relatively flexible airplane. A study of tail loads measured by means of strain gages is therefore being conducted by the NACA on a B-45A airplane. These results may be used to check the validity of small-scale tunnel measurements of items such as the aerodynamic center and the zero-lift pitching-moment coefficient of the wing-fuselage combination. The structural deformations of the elevators, stabilizer, and fuselage and their effect on the tail-load distribution are to be studied. The change in stability and control characteristics due to these aeroelastic effects will also be investigated.

The purpose of this paper is to present some immediate results obtained from the first flight which was primarily a pilot-familiarization and instrument-check flight. Time histories are presented showing some quantities important in tail-load investigations for four maneuvers; namely, level flight from stall to a Mach number of approximately 0.64, a low-speed pull-up, a high-speed pull-up, and a turn to about 2.4g.

SYMBOLS

C_{N_A}	airplane normal-force coefficient $\left(\frac{nW}{qS}\right)$
n	airplane normal acceleration at center of gravity, g units
W	airplane gross weight at time of maneuver
q	dynamic pressure
S	wing area
M	Mach number
h_p	pressure altitude

APPARATUS AND TESTS

The test airplane is a standard production model B-45A (No. 7021) supplied to the NACA by the U.S. Air Force for the present investigation. Figure 1 shows a three-view line drawing of the airplane and the approximate locations of the load and deflection-measuring devices.

Electrical strain gages are used to measure shear and bending moments on the wing, horizontal tail, and vertical tail. The gages are located on the main spars at the root of each of the surfaces. The elevator and rudder loads and torques are also measured by means of strain gages located on the hinges for load measurement and on the torque tube for torque measurements.

Twist bars mounted internally in both stabilizers are used to measure the twist at two spanwise stations, midsemispan and tip. These have a linear response to torsional deflections and no response to bending. Elevator twist is measured on both sides by means of control-position transmitters mounted at the root and tip of each elevator which determine the differential deflection between the two stations with respect to the stabilizer.

An optigraph system is used to determine the fuselage bending deflections. The system consists of a continuously recording camera mounted in the fuselage near the rear spar of the wing and small concentrated light sources in the fuselage of stations corresponding to the front and rear spars of the stabilizer.

Standard NACA instruments are used to measure accelerations, airspeed, altitude, rolling, pitching and yawing velocities, angle of drift, and control forces and positions. Normal accelerations are measured at the tip and midsemispan of both stabilizers, and three-component accelerometers measure acceleration at the center of gravity and at the tail. A timer was used to correlate all data from recording instruments.

During the flight, records were taken in a constant-power level-flight run, two pull-ups, three turns, two rolls, and three stalls from level flight. Most runs were made at a pressure altitude of about 15,000 feet and covered a Mach number range approximately from 0.22 to 0.64.

RESULTS AND DISCUSSION

The results presented are for four runs of the first flight, that is, level flight, low-speed pull-up, high-speed pull-up, and turn. These runs were selected because they covered the widest range of important tail-load parameters measured on the first flight. The quantities listed in the following table are shown in time-history form on figures 2 to 5. The table also includes the reading accuracies for the basic measurements.

Center-of-gravity normal acceleration, g units	±0.03
Tail normal acceleration, g units	±0.05
Left and right root-elevator angles, degrees	±0.25
Aerodynamic load on horizontal tail:	
Total, pounds	±160
Left minus right, pounds	±160
Pitching acceleration, radians/sec^2	±0.01
Aerodynamic load:	
On right stabilizer, pounds	±140
On right elevator, pounds	±60
On left stabilizer, pounds	±140
On left elevator, pounds	±60
Right stabilizer twist:	
At tip, degrees	±0.015
At midsemispan, degrees	±0.007
Left stabilizer twist:	
At tip, degrees	±0.015
At midsemispan, degrees	±0.007
Elevator twist, uncorrected for stabilizer twist, left and right, degrees	±0.07
Fuselage bending deflection, inches	±0.03
Mach number	---
Pressure altitude	---
Airplane normal-force coefficient	---

The airspeed system has not yet been calibrated, but estimates of the position error based on similar installations indicate that the Mach number is correct to ±0.02 below the stall.

Figure 2 presents time histories of important tail-load parameters for a level-flight run made with 96-percent engine power with the airplane trimmed in the clean condition for a Mach number of approximately 0.5 at 15,000 feet. This run was actually a gradual descent starting at 13,600 feet with the airplane in a near stalled condition and ending at 8,100 feet with an accompanying increase in Mach number from 0.22 to 0.64. The normal acceleration, airplane normal-force coefficient, and tail-load curves in the region near the stall are mean values and do not show the oscillations present in a stall.

The maximum airplane normal-force coefficient is approximately 1.15. The total horizontal-tail load changes from 3000 pounds up at low Mach number to 9700 pounds down at the highest Mach number. On figure 2 it is seen that the elevator loads increase with speed, the maximum occurring on the left elevator at the value of 1200 pounds. The stabilizers reach a maximum down load of 5900 pounds per side. The stabilizer twists a relatively small amount, about 0.3°, but the twist of the elevator reaches a value of 2.5° trailing edge up on the right side. The effect of this flexibility is seen by considering that at time 130 seconds, if a linear variation of twist from tip to root is assumed, a theoretically rigid elevator would be required to be deflected 1.25° up from the present position to trim the airplane at the conditions existing.

The fuselage-bending-deflection curve follows the horizontal-tail-load curve changing from 0.15 inch up at low speed to 0.66 inch down at high speed. With the associated change in the aerodynamic tail load of 12,700 pounds, the stiffness of the fuselage at the tail under loads applied at the tail is therefore roughly 16,000 pounds per inch.

Figure 3 presents results for a pull-up to approximately 2.0g at a Mach number of 0.4. The maneuver was made at a pressure altitude of about 16,000 feet. The airplane was in the clean condition with a gross weight of 61,800 pounds and the center of gravity at 28.33 percent mean aerodynamic chord. The tail load per g for this run is roughly 3580 pounds as derived from figure 3. The maximum pitching acceleration is about 0.3 radian per second per second with an elevator rate of 23° per second.

Figure 4 presents results for a high-speed pull-up made at a pressure altitude of about 13,000 feet and a Mach number of 0.65. The airplane was in the clean condition and weighed 61,300 pounds with the center of gravity at 28.31 percent mean aerodynamic chord. An acceleration of approximately 1.8g was reached. The maximum down horizontal-tail load is about 8900 pounds while the tail load per g is about 4000 pounds.

Figure 5 presents results for a turn at a pressure altitude of 15,000 feet and a Mach number of 0.59. The airplane gross weight for this run was 61,200 pounds with the center of gravity at 28.30 percent mean aerodynamic chord. A maximum normal acceleration of about 2.4g was reached with a normal-force coefficient of approximately 0.43. An increment of 4000 pounds on the horizontal tail is experienced, yielding a tail load per g of about 2900 pounds.

From figures 2 to 5 it is seen that the elevator loads for all maneuvers are relatively low with a maximum up load of 1200 pounds encountered on the left elevator in the level-flight run. A down load of 600 pounds is the maximum down elevator load and is present in the low-speed pull-up. The static test loads which were supported on the elevators without failure were 6000 pounds up and 4000 pounds down. A maximum up load of 1600 pounds and a down load of 5900 pounds are experienced on the stabilizers. The stabilizer was statically loaded without failure to 15,000 pounds up and 22,000 down. The loads encountered on the horizontal tail during the four runs presented were well below static test loads which were supported without failure.

The stabilizer twists are found to be relatively small, maximum twist being 0.32° leading-edge down at the right stabilizer tip during the high-speed pull-up. The maximum elevator twist occurs on the right elevator during the level-flight run. The difference in the left and right elevator twist may be attributed to the difference in built-in twist of the elevators, 1.5° up at the tip on the left and 1° up at the tip on the right. The fuselage-bending-deflection curves have the same general shape as the horizontal-tail-load curves for all maneuvers. This deflection is a function of both the aerodynamic tail load and the product of fuselage mass and acceleration distributions. The amount of twist of the stabilizer and elevator and the bending of the fuselage under the small loads measured indicates the importance of considering aeroelastic effects upon the tail-load distribution and the stability and control characteristics.

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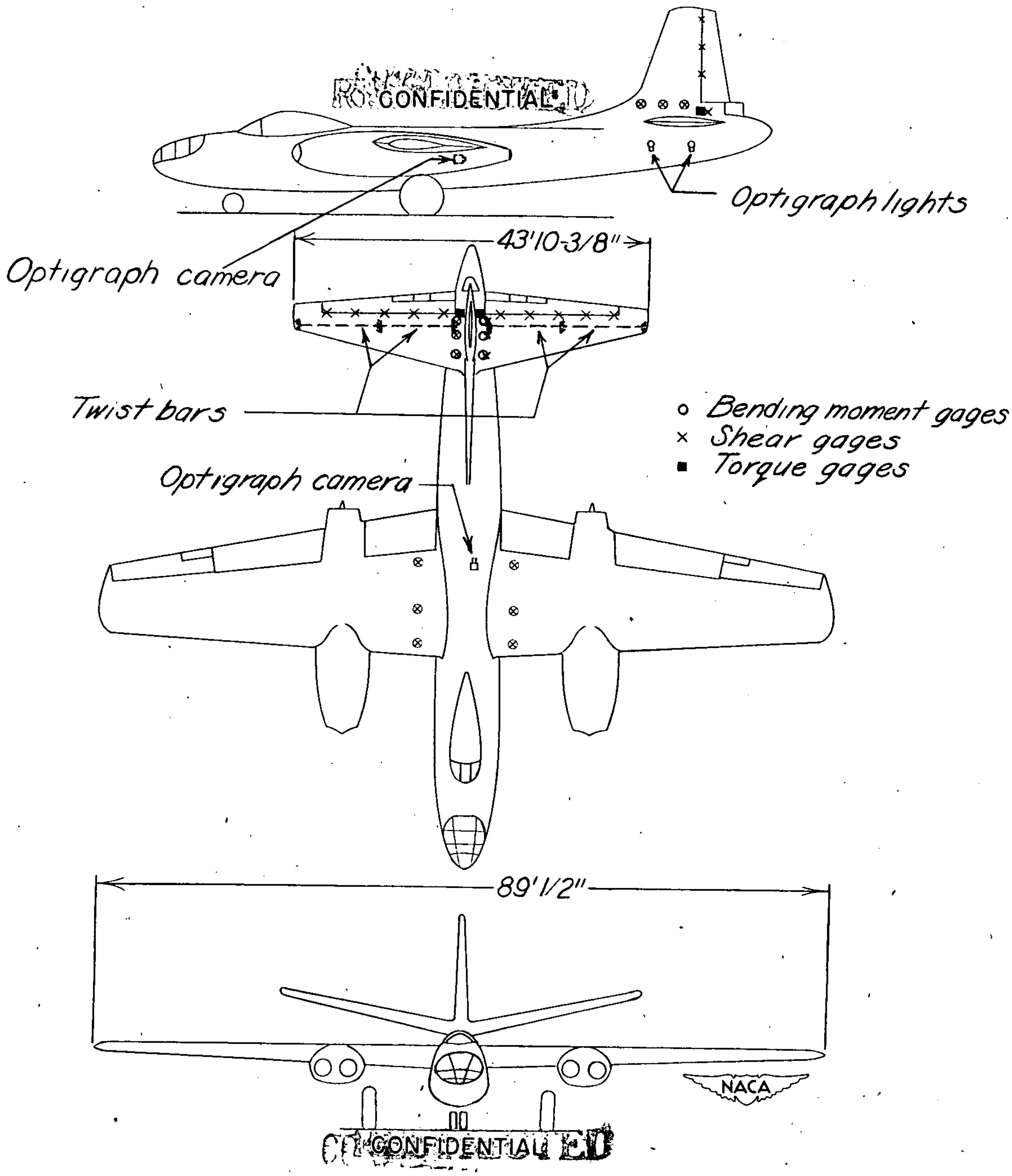


Figure 1.- Three-view drawing of test airplane showing approximate locations of strain-gage bridges and deflection measuring devices.

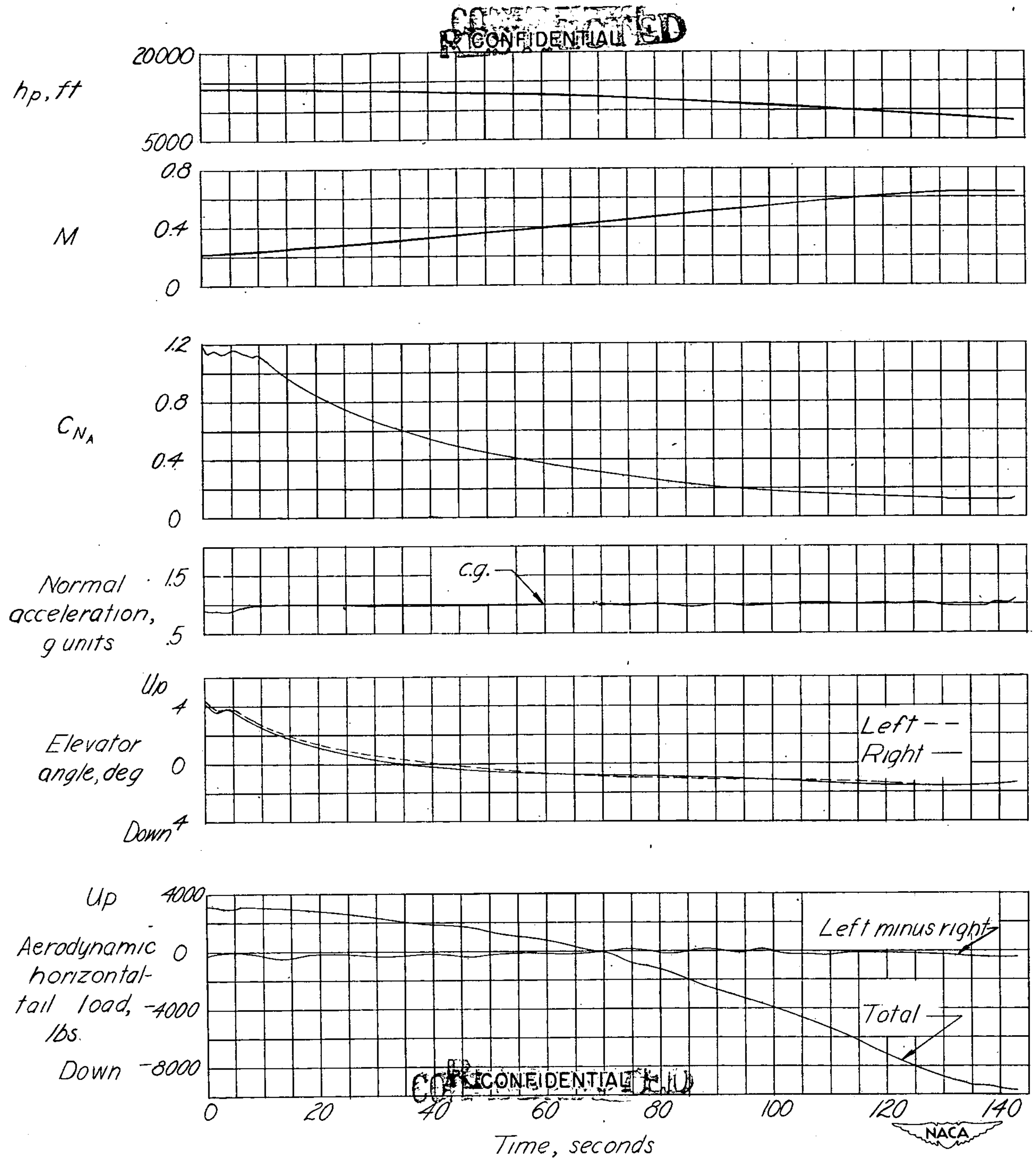
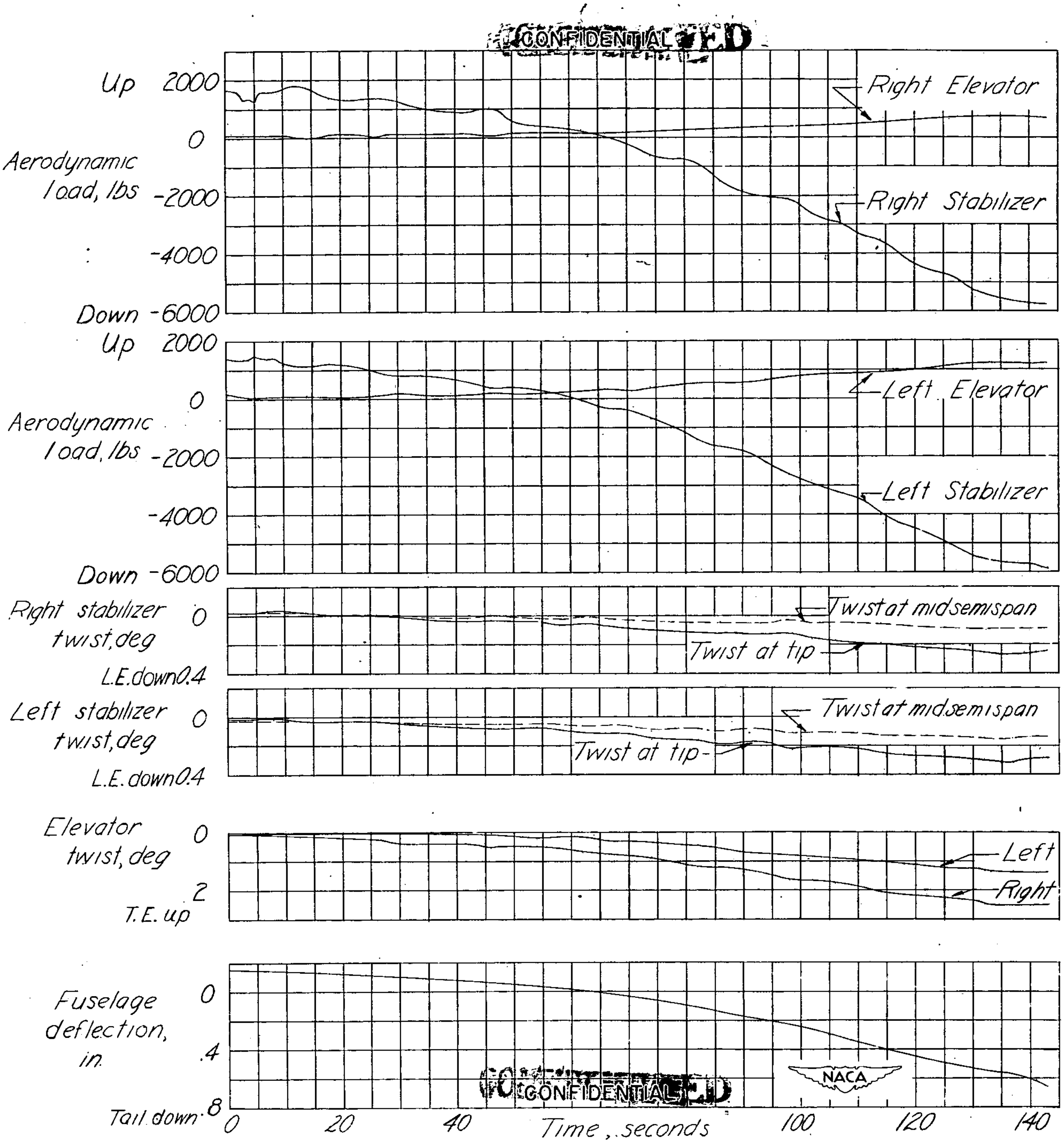


Figure 2.- Time histories of measured quantities during a level-flight run. Airplane weight, 62,000 pounds; center of gravity at 28.34 percent mean aerodynamic chord.



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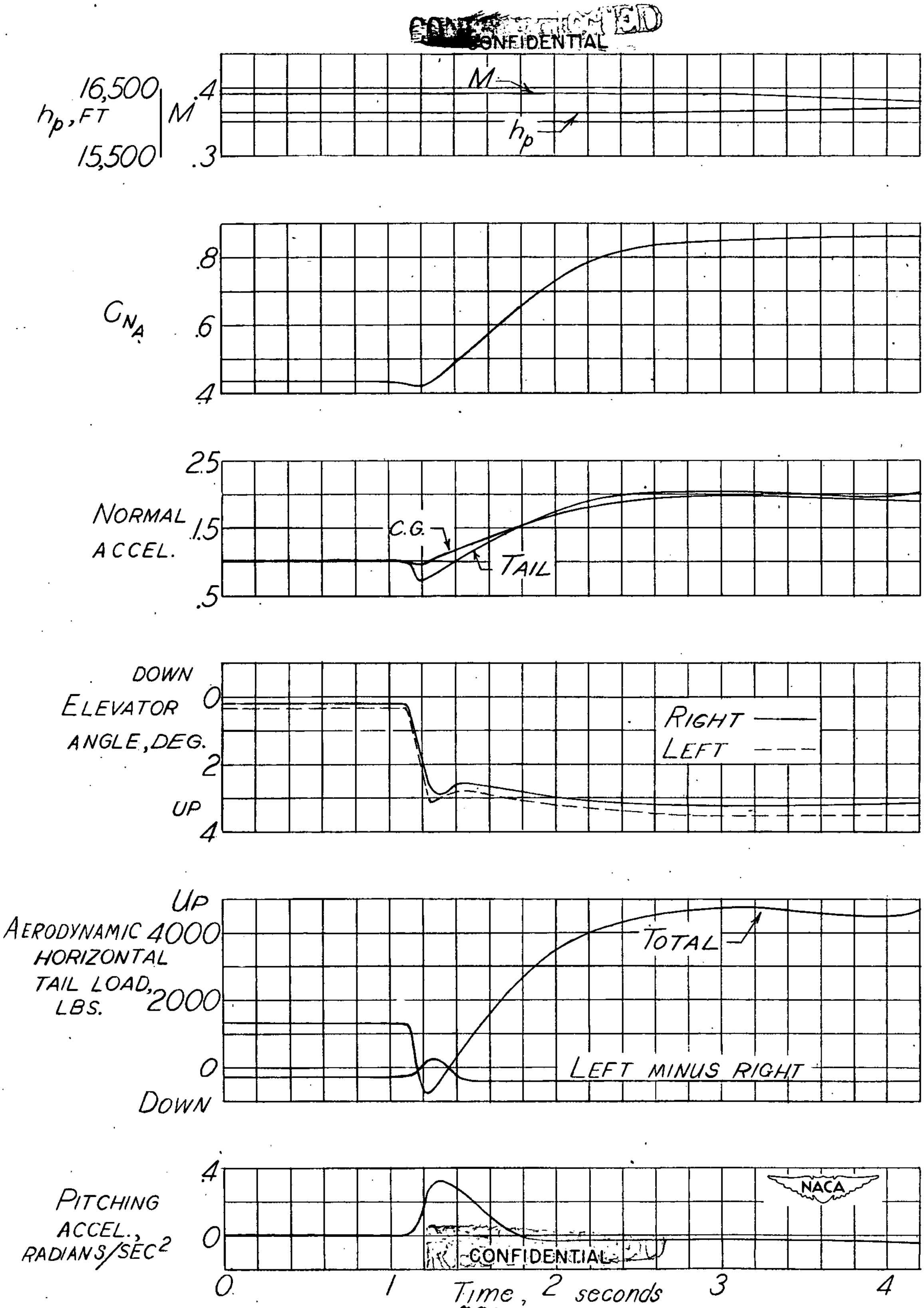
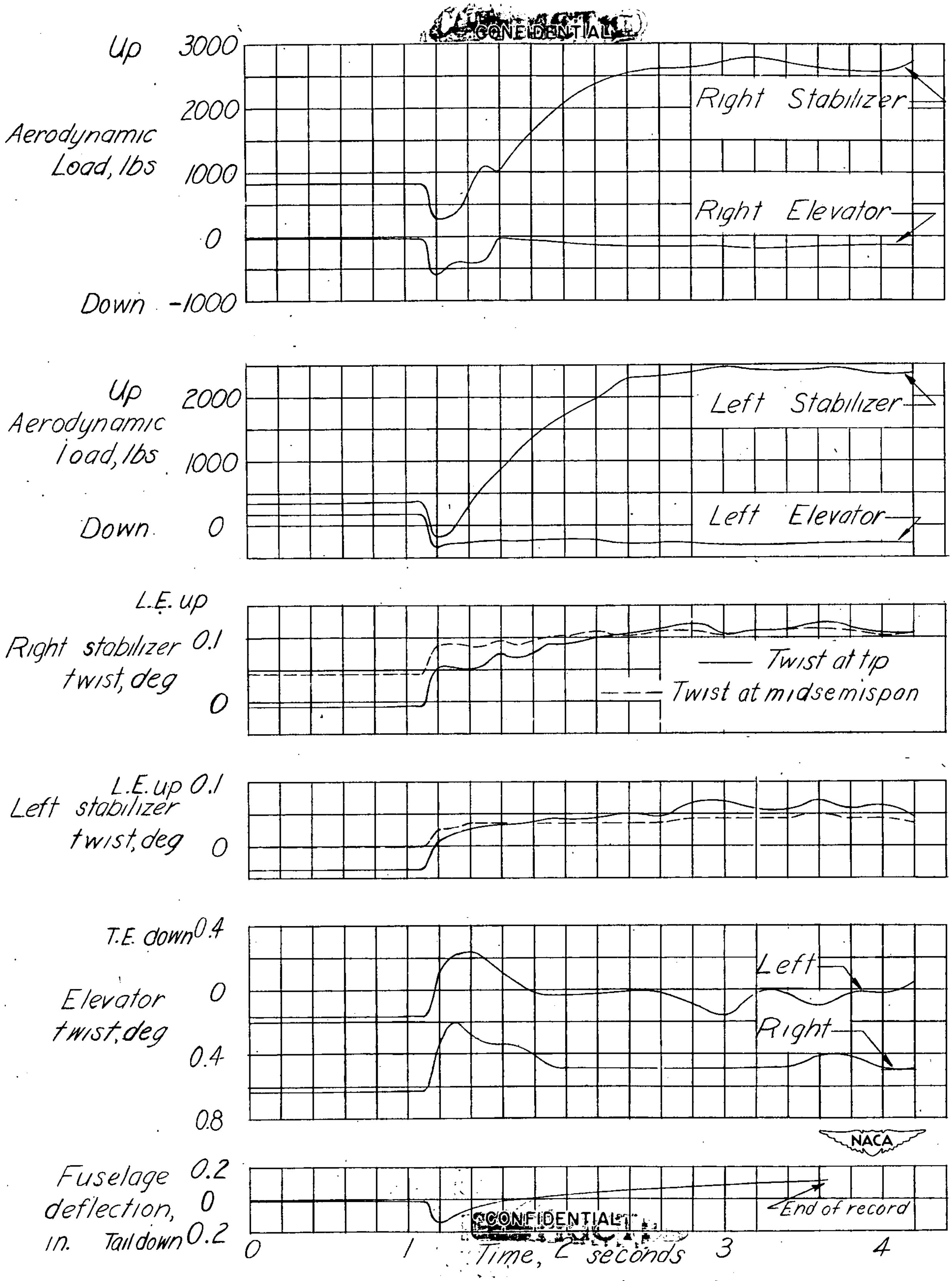


Figure 3.- Time histories of measured quantities during a low-speed pull-up. Airplane weight, 61,800 pounds; center of gravity at 28.33 percent mean aerodynamic chord.



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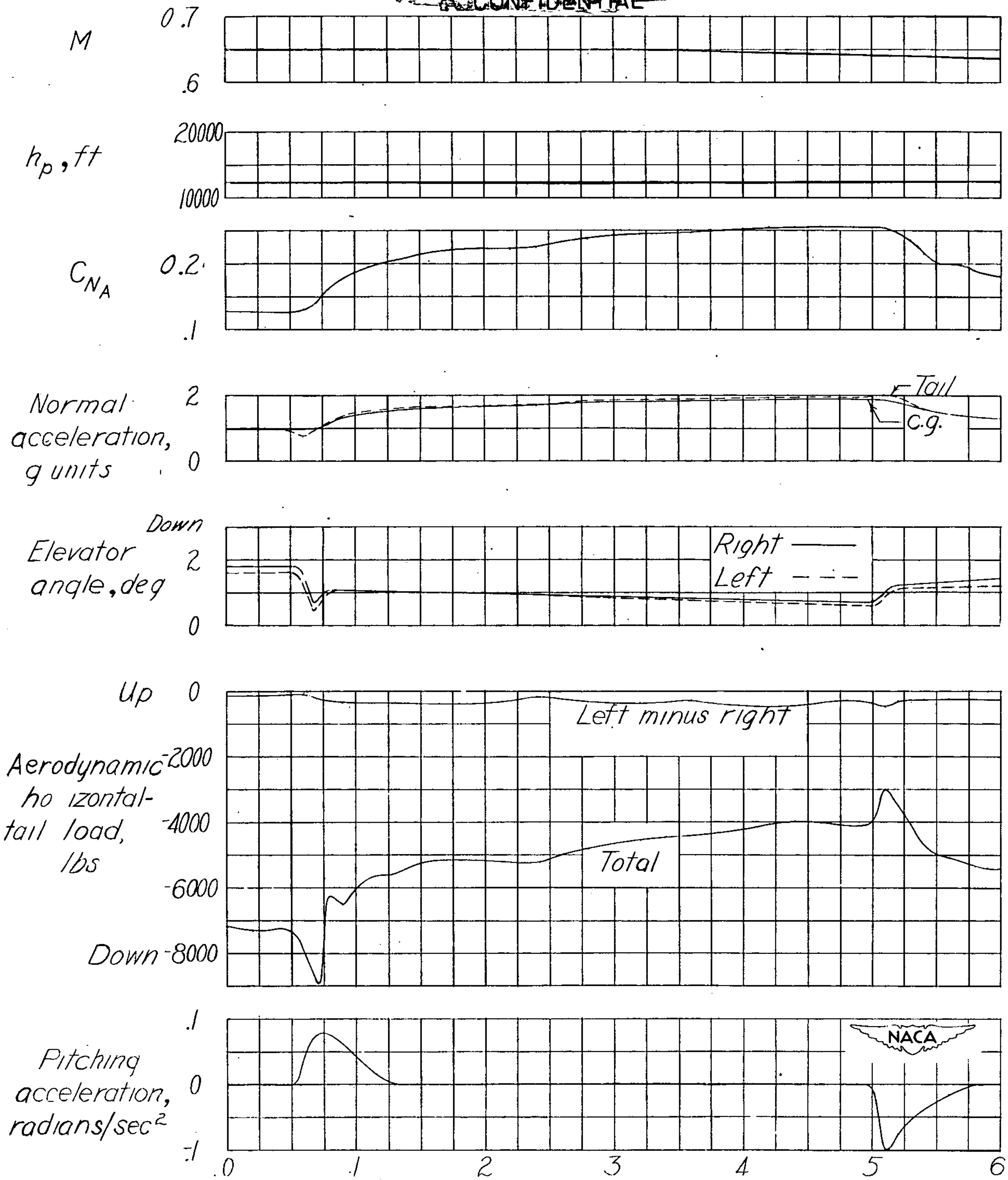

Figure 4.- Time histories of measured quantities during a high-speed pull-up. Airplane weight, 61,300 pounds; center of gravity at 28.31 percent mean aerodynamic chord.

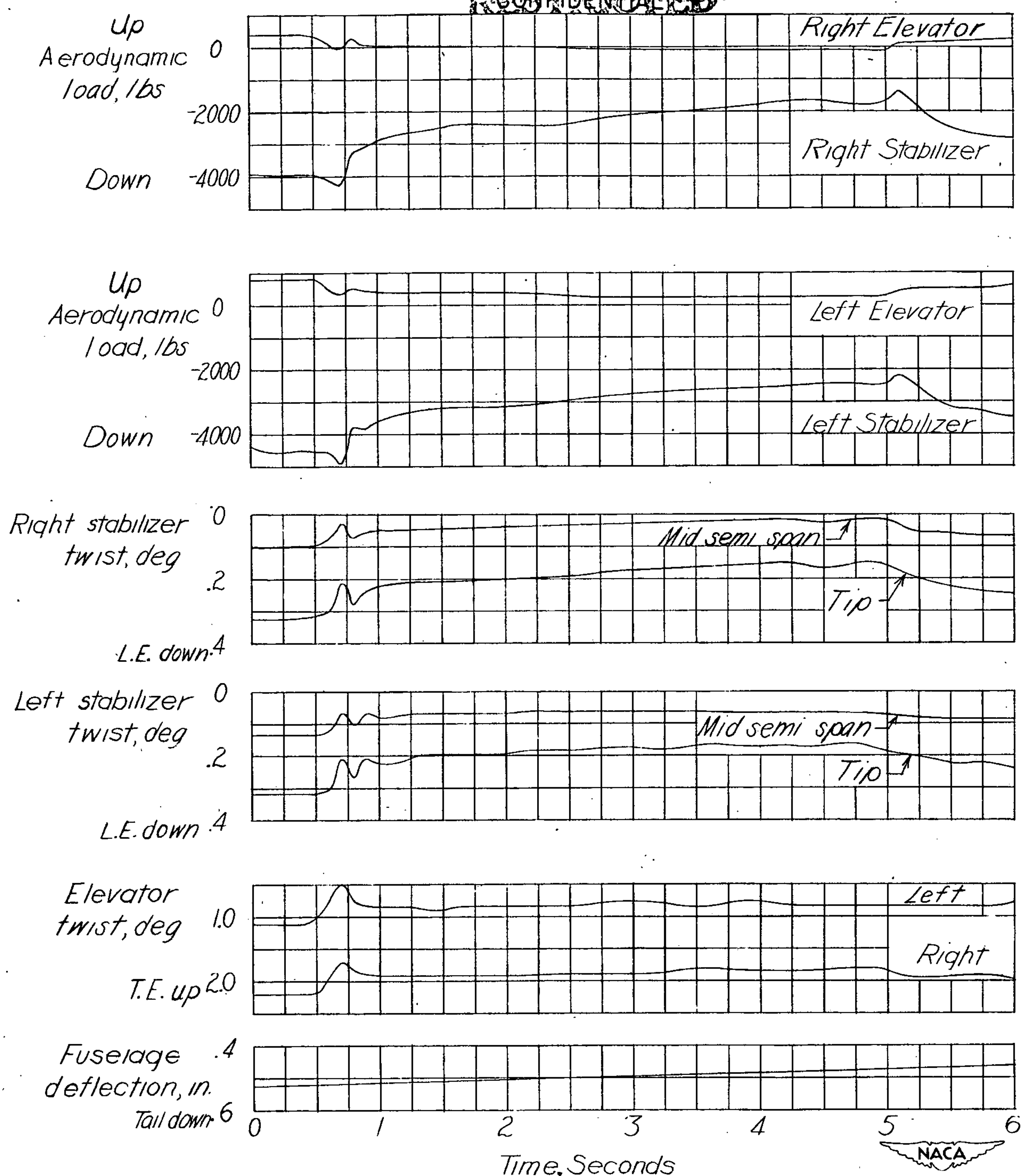

Figure 4.- Concluded.

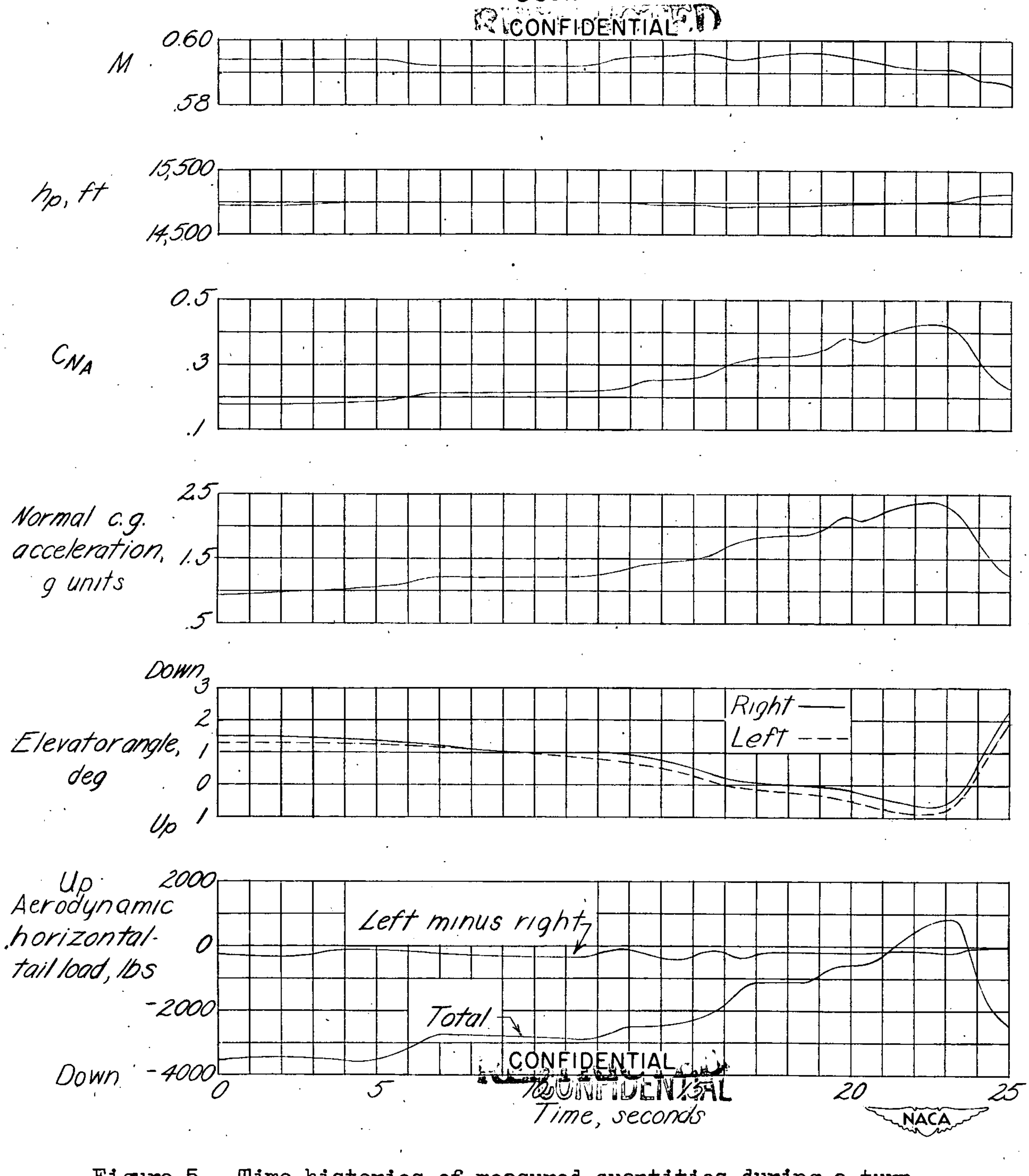

Figure 5.- Time histories of measured quantities during a turn. Airplane weight, 61,200 pounds; center of gravity at 28.30 percent mean aerodynamic chord.

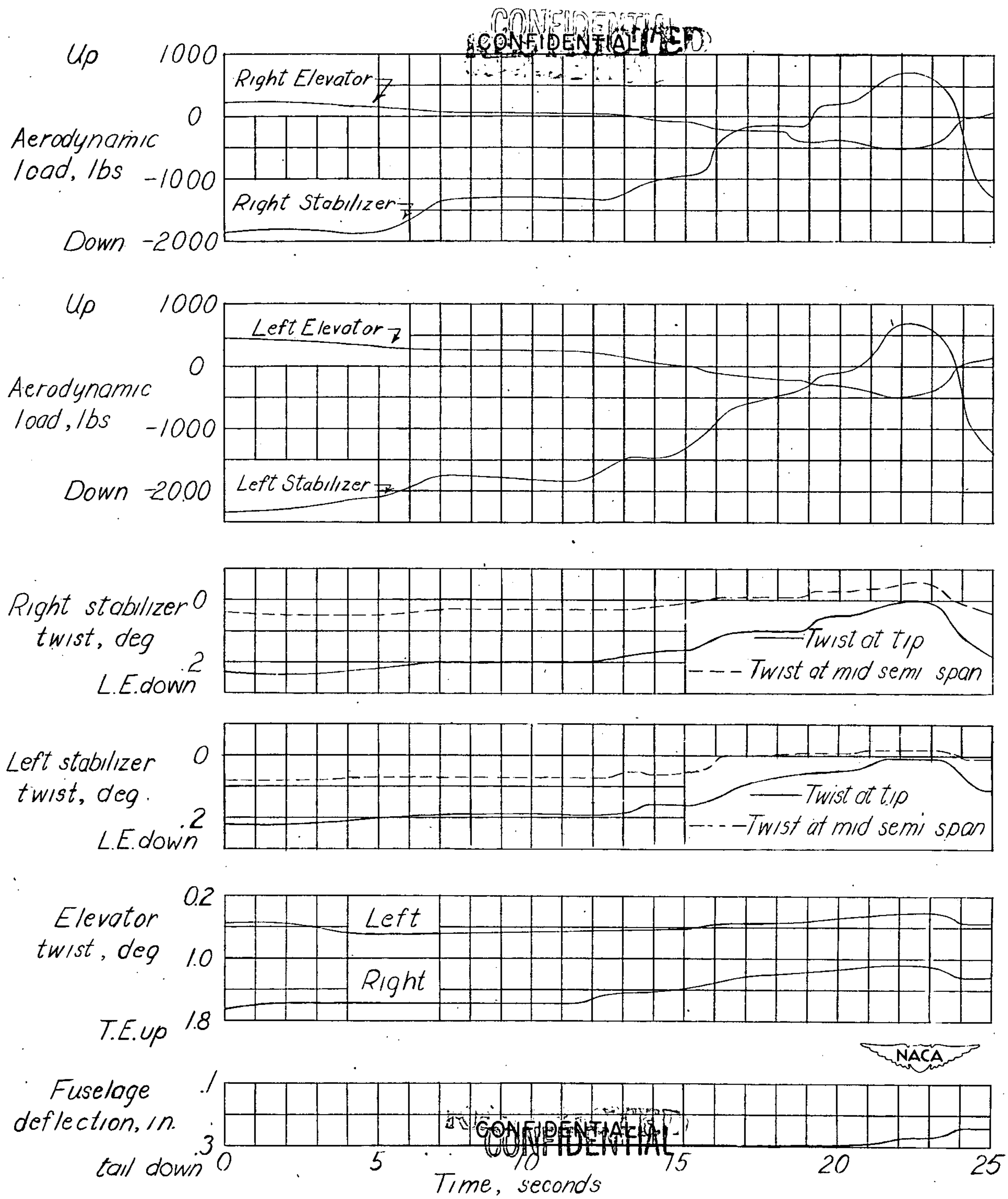

Figure 5.- Concluded.