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RESEARCH MEMORANDUM

FLIGHT INVESTIGATION OF FLUTTER MODELS WITH

 $\frac{1}{10}$ -SCALE DOUGLAS D-558-2 WING PANELS

By

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FLIGHT INVESTIGATION OF FLUTTER MODELS WITH

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SUMMARY

Flight tests of three rocket-powered models containing $\frac{1}{10}$ -scale Douglas D-558-2 wings as horizontal fins having scaled structural parameters to encompass the stiffness of the full-scale airplane have been conducted to determine whether the possibility of wing flutter due to torsion and bending exists in the full-scale airplane at transonic speeds. A maximum Mach number of approximately 1.54 was attained in the flights.

No wing flutter appeared to be present in the models tested. However, a pitching oscillation of the entire model developed as the model passed through the transonic range.

INTRODUCTION

The Langley Laboratory has conducted a series of flight tests on rocket-powered models containing $\frac{1}{10}$ -scale D-558-2 wings as horizontal fins in order to determine whether wing flexure-torsion flutter might be expected to occur in transonic flight of the D-558-2 airplane. The models were designed and constructed by the El Segundo plant of Douglas Aircraft Company, Inc., and the wings were built to have scaled stiffness parameters to encompass the structural design of the wing panels of the full-scale airplane.

Models having wings with scaled elastic stiffness and weight distribution to yield design flutter speeds lower than, equal to, and higher than the design flutter speeds of the full-scale airplane have been tested and are reported herein.

APPARATUS

Model

The flutter model with $\frac{1}{10}$ -scale Douglas D-558 wing panels is essentially a 5-inch cordite rocket motor to which an instrumented nose, a metallic fuselage fairing, $\frac{1}{10}$ -scale D-558-2 wing panels in the horizontal plane, and simplified vertical stabilizing fins were attached. In addition to being representative of scaled versions of the D-558-2 airplane wing panels, the horizontal wings were so located as to insure stabilization of the model in pitch. These wing panels on the first model, designated "low speed," were designed to be structurally weaker than the stiffness requirements obtained by adding a scale correction to the D-558-2 wing panels. The second model had wing panels designated "true speed" which were designed equal to the scaled stiffness, and the third model, designated "high speed," was designed to have wing panels that were materially stiffer than those of the other models.

A sketch of the models containing "low speed" or "true speed" wing panels and instrumented to obtain wing frequencies is shown in figure 1. The "high speed" model instrumented to record the normal acceleration and angle of attack of the entire model is sketched in figure 2.

Instrumentation

The models were equipped with two-channel telemeters. In the "low speed" and "true speed" models, the wing frequencies were obtained by using the inductance-type frequency pickups that had been built into the wing panels.

In the "high speed" model, the two-channel telemeter was installed to transmit records of the following items within accuracy noted between the parenthesis signs:

- (a) Angle of attack ($\pm 0.6^\circ$)
- (b) Normal acceleration ($\pm 0.2g$)

In order to maintain the symmetry of the model, a dummy canopy was added to the underside of the model.

In flight, the models were tracked by continuous-wave Doppler radar to obtain the velocity. Telemetered data were recorded on film at two radio

receiving stations using recording oscillographs. A radiosonde was released immediately after each firing so that the atmospheric conditions at various altitudes could be obtained.

Launching

The models were launched from a short-length, two-rail launching rack at a 60° launching angle. Photographs of the models on the launching rack are shown in figures 3 and 4.

RESULTS AND DISCUSSION

Prior to the flight-testing of the models, the natural frequencies in torsion and bending of the wing panels were checked by the Langley Physical Research Division. Table I is a listing of the frequencies obtained at the Langley Laboratory, as compared with those given in reference 1. As the base attachment fitting was permanently fastened to the wings, the radius of gyration and the location of the center of gravity of the wing panels could not be determined experimentally and, for this reason, the critical flutter speed (that is, the speed at which wing flutter occurs) could not be estimated. However, from data listed in table I and in reference 1, it appears that the wing panels tested encompass, with scalar corrections, the structural design of the full-scale airplane.

For the tests conducted, the Reynolds number varied from approximately 3×10^6 at a Mach number of 0.64 to a maximum value of 6.7×10^6 at a Mach number of 1.54.

In the initial test ("low speed" winged model) intermittent telemeter operation did not permit the evaluation of the wing vibrations, although it gave assurance that no wing failure occurred. Reduction of the radar data showed that the model attained a maximum Mach number of 1.54, which was slightly higher than the estimated value. Velocity-time plots of the flights of the models reduced from the radar data are shown in figure 5.

From the model containing the "true speed" wings, satisfactory telemeter and velocity records were obtained. The data were reduced and figure 6 is a time history of the flight. As no calibration was made of forces required to deflect the wing pickups, the amplitude of the oscillations recorded could not be evaluated and consequently the magnitude shown on the plot is proportional to that recorded and no units are given. From the record, a low-frequency oscillation of approximately 8 cycles per second was recorded when the model reached a flight Mach number of approximately 0.9 during accelerated flight. This oscillation damped out as the model velocity increased but reappeared during the coasting portion of flight when the

model decelerated to a Mach number of 0.92. A high-frequency oscillation of the order of 120 cycles per second was superimposed on the low-frequency oscillation. Although the instrumentation was designed to record frequency and was not calibrated to measure the magnitude of the oscillation, the high-frequency oscillation seemed to be of small amplitude, while the low-frequency oscillation appeared to be of appreciable magnitude. As the high-frequency oscillation of 120 cycles per second was lower than the natural wing bending frequency, and of negligible amplitude, its existence can be attributed to some condition in the model other than the flutter phenomenon.

On the basis of the results of the first two flight tests, it was concluded that no flexure-torsion wing flutter would occur throughout the speed range tested. It should not, however, be assumed that the flutter problem can be dismissed, as tests conducted and reported in reference 2 indicate that the possibility of flexure-aileron flutter still exists.

As no additional flutter tests appeared to be necessary, the third model, containing "high speed" wing panels for maximum wing rigidity, was flown to investigate the low-frequency oscillation that appeared to be present. The data reduced from the records obtained from the flight of the model are shown in figure 7 as plots of the normal-force coefficient, angle of attack, and Mach number variation with flight time. In the flight, the usual short-period oscillation of the airframe at take-off appears to be damping out when this pitching oscillation is again excited as the model approaches a Mach number of 0.85. The maximum normal acceleration during that portion of flight was $\pm 1.75g$ where "g" is the acceleration due to gravity (that is, 32.2 ft/sec^2). During decelerated flight the maximum normal acceleration was $\pm 2g$. In figure 7 the plot of the variation of the normal-force coefficient C_N with time, evaluated from the normal accelerations recorded, is based on the exposed wing area. From information reported in reference 3 and from unpublished results of rocket-powered flight tests of a 0.13-scale model of the D-558-2, it appears that the pitching oscillation occurs near the force break of the model. In accelerated flight the normal acceleration and angle-of-attack oscillations are in phase but the magnitude of the normal acceleration appears to bear little relation to the amplitude of the pitching oscillation. During deceleration a similar condition occurred but superimposed on this 7-cycle-per-second oscillation of the angle of attack and normal acceleration was a 2-cycle-per-second angle-of-attack oscillation that did not appear to have any effect on the normal acceleration.

The 7-cycle-per-second oscillation is believed to be the usual short-period oscillation of the airframe. The cause of the 2-cycle-per-second oscillation of the angle of attack is unknown.

CONCLUSIONS

No flexure-torsion wing flutter appeared to be present in the models flight-tested to a maximum Mach number of 1.54. However, a pitching oscillation of the entire model developed as the model passed through the transonic range.

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REFERENCES

1. Moore, M. E.: Design of $\frac{1}{10}$ -Scale Wing Flutter Model of D-558 Phase II Airplane. Rep. No. ES-20972, Douglas Aircraft Co., Inc., Nov. 14, 1947.
2. Angle, Ellwyn E., and Lundstrom, Reginald R.: Flight and Wind-Tunnel Investigation to Determine the Aileron Vibration Characteristics of $\frac{1}{4}$ -Scale Wing Panels of the Douglas D-558-2 Research Airplane. NACA RM No. L8H09, 1948.
3. Wright, John B., and Loving, Donald L.: High-Speed Wind-Tunnel Tests of a $\frac{1}{16}$ -Scale Model of the D-558 Research Airplane. Lift and Drag Characteristics of the D-558-1 and Various Wing and Tail Configurations. NACA RM No. L6J09, 1947.

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TABLE I
WING PARAMETERS

Mode	Wing panel, frequency (cps)					
	Low speed		True speed		High speed	
	Panel A ₁	Panel A ₂	Panel A ₃	Panel A ₄	Panel A ₅	Panel A ₆
Model:						
1st bending (NACA)	80	78	145	137	157	136
(Douglas)	85	84	158	158	170	163
2nd bending (NACA)	400	338	660	600	-----	-----
(Douglas)	-----	-----	-----	-----	-----	-----
Torsion (NACA)	238	217	365	404	472	419
(Douglas)	107	105	420	420	590	590
Scaled from model:						
1st bending (NACA)	8	7.8	14.5	13.7	15.7	13.6
(Douglas)	8.5	8.4	15.8	15.8	17.0	16.3
Torsion (NACA)	23.8	21.7	36.5	40.4	47.2	41.9
(Douglas)	10.7	10.5	42.0	42.0	59.0	59.0
Full-scale wing:						
1st bending	15					
Torsion	41.5					

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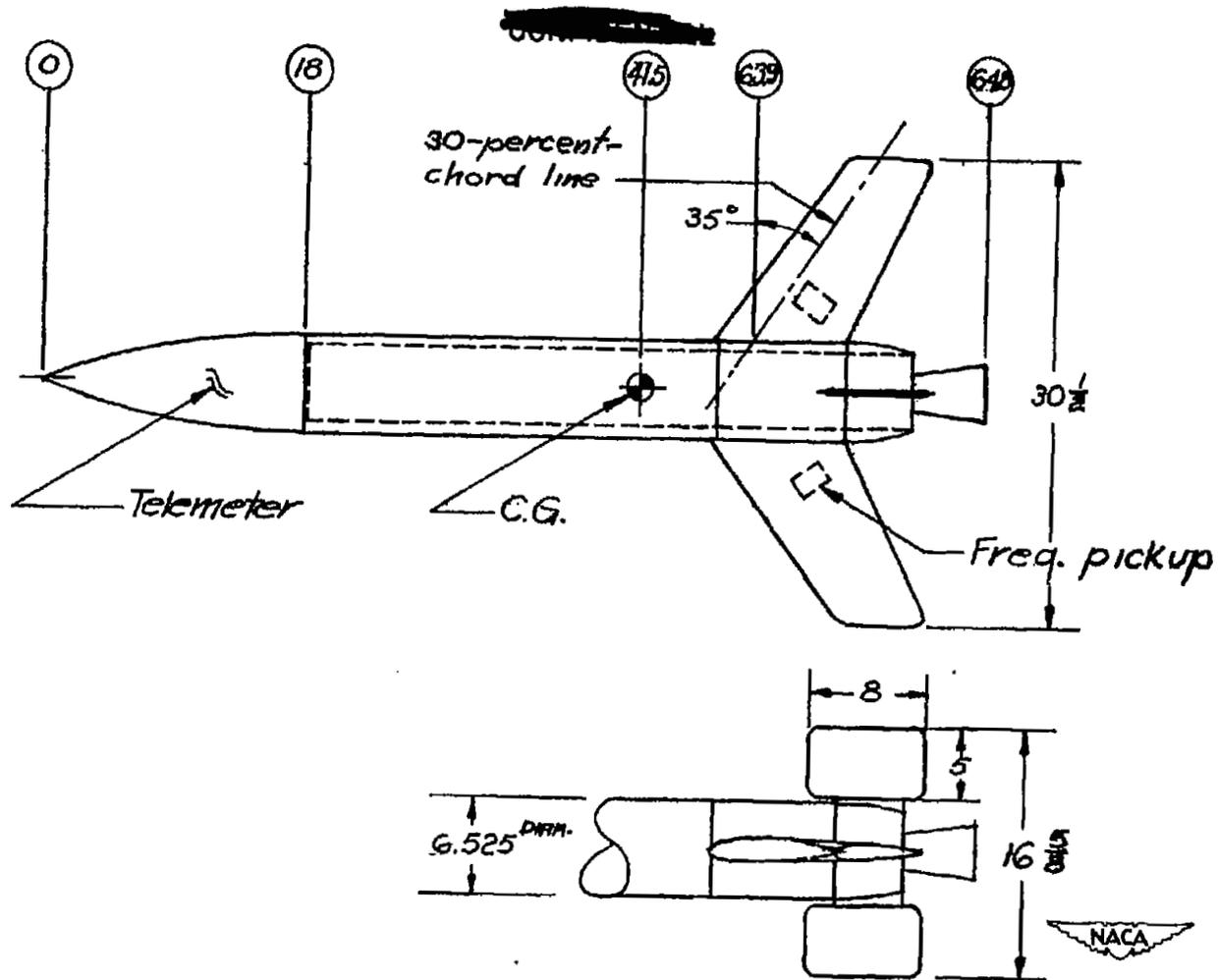


Figure 1.- Sketch of flutter model having "low speed" and "true speed" $\frac{1}{10}$ -scale D-558-2 wing panels.
All dimensions are in inches.

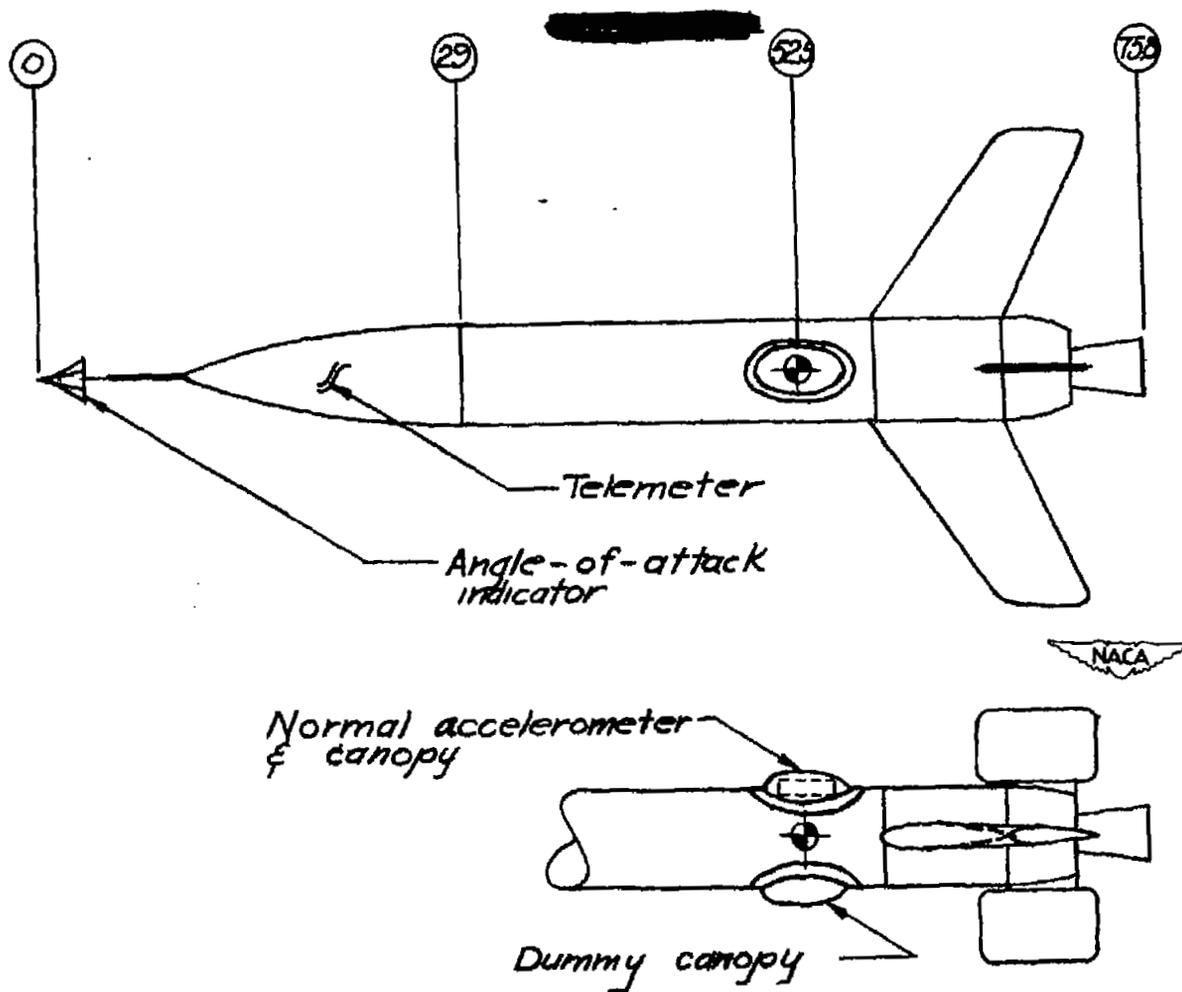


Figure 2.- Sketch of flutter model having "high speed" $\frac{1}{10}$ -scale D-558-2 wing panels showing instrumentation changes.

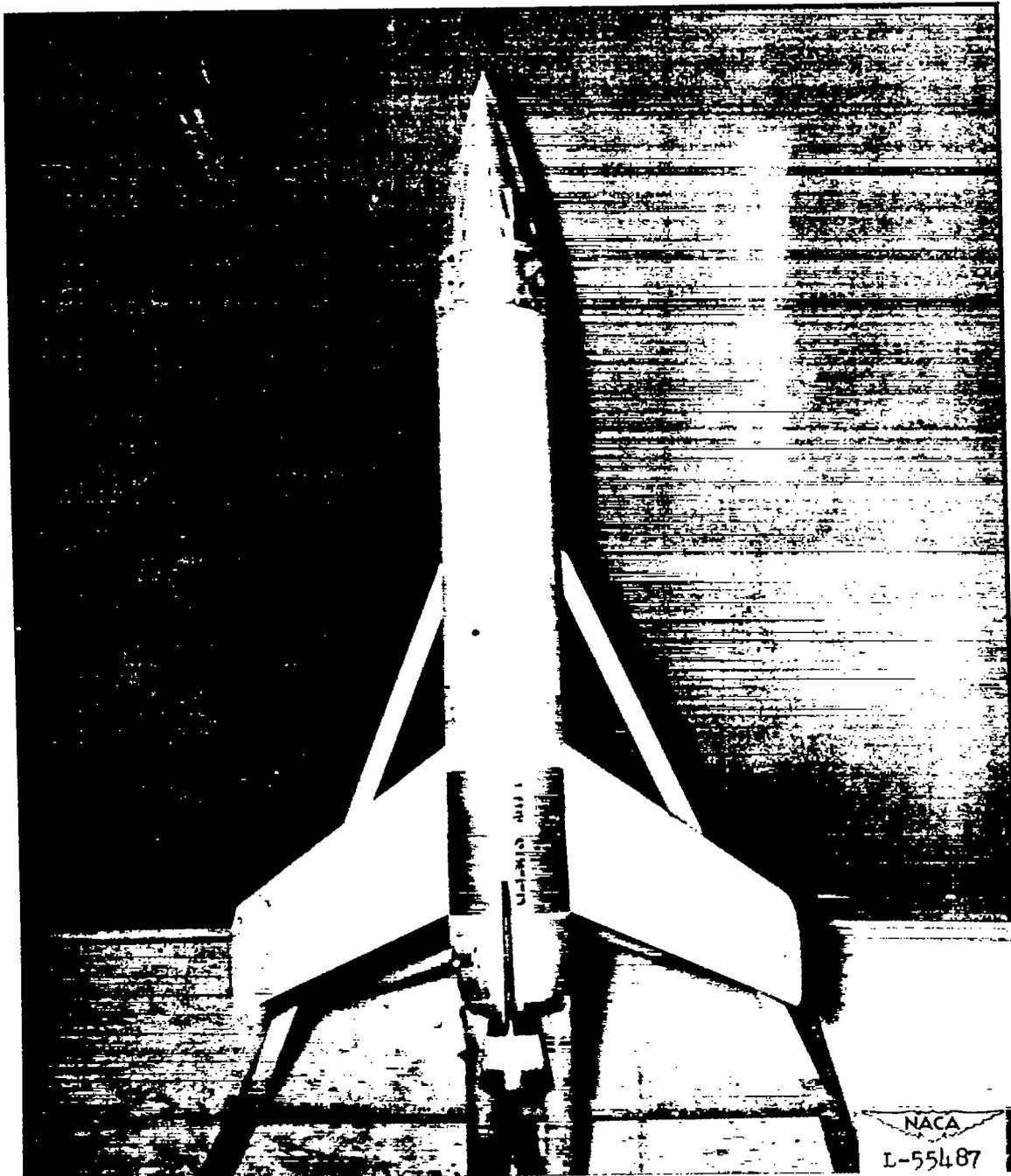


Figure 3.- Photograph of flutter model with "low speed" $\frac{1}{10}$ -scale

D-558-2 wing panels.



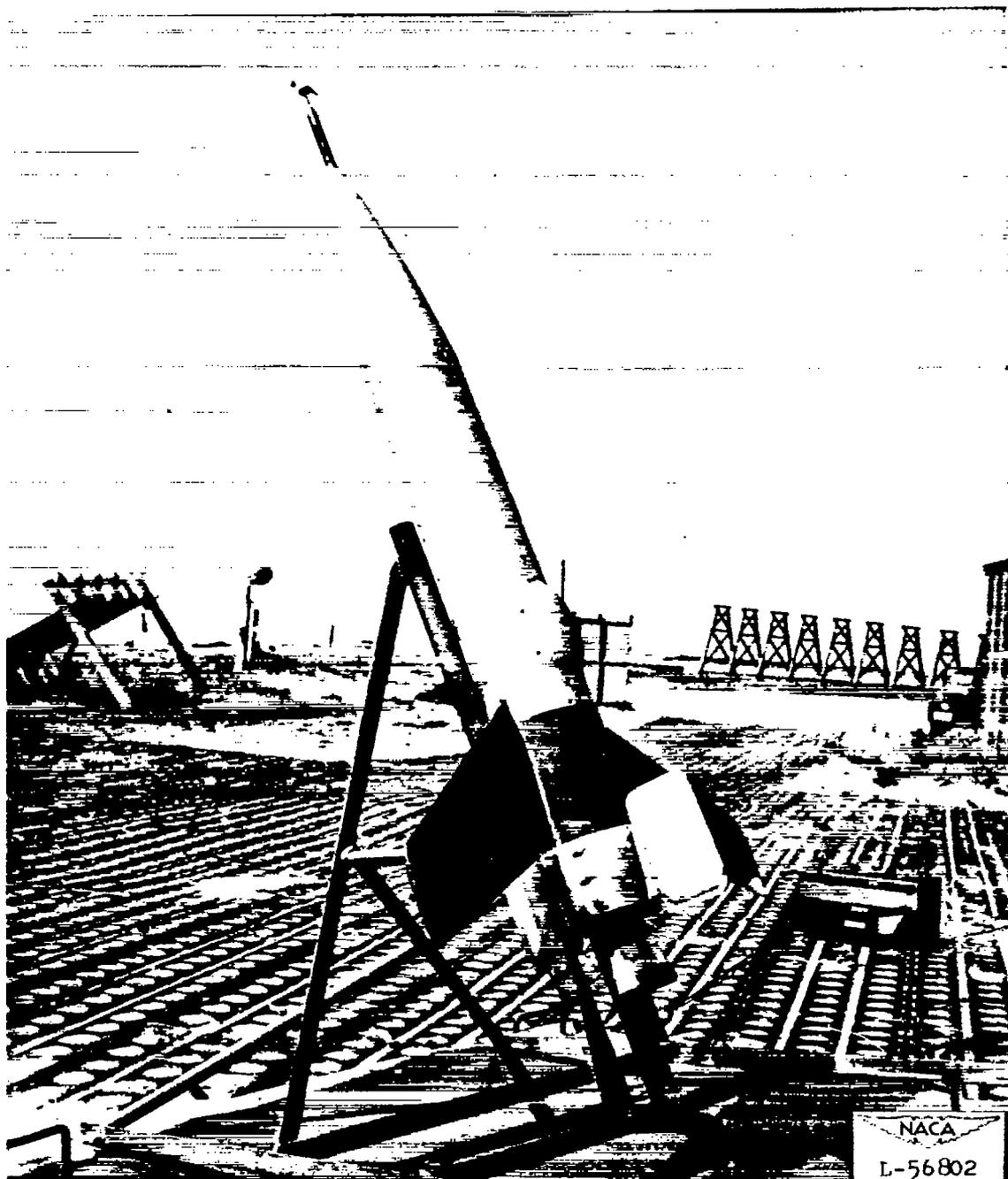
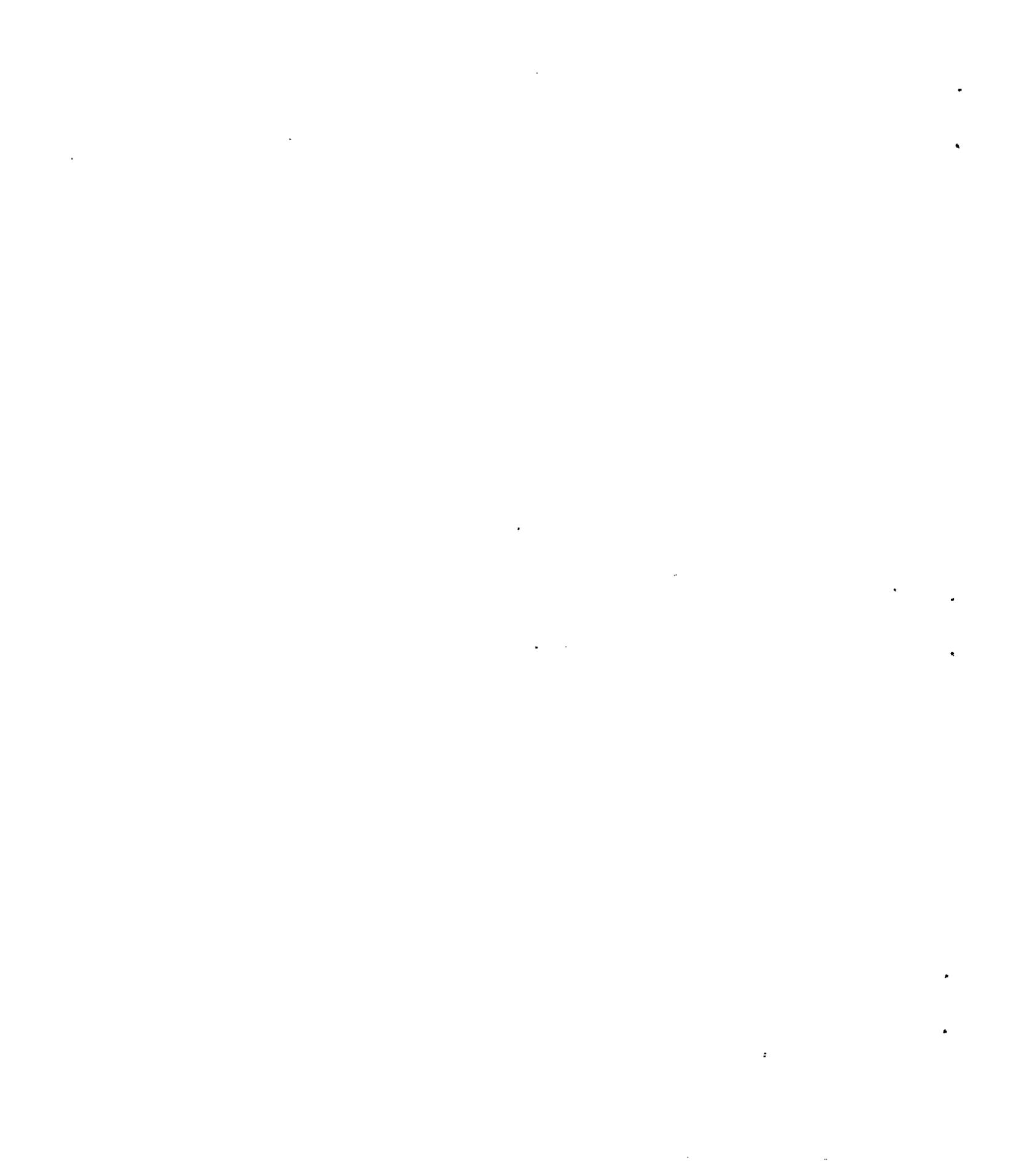


Figure 4.— Photograph of flutter model with "high speed" $\frac{1}{10}$ -scale
D-558-2 wing panels.



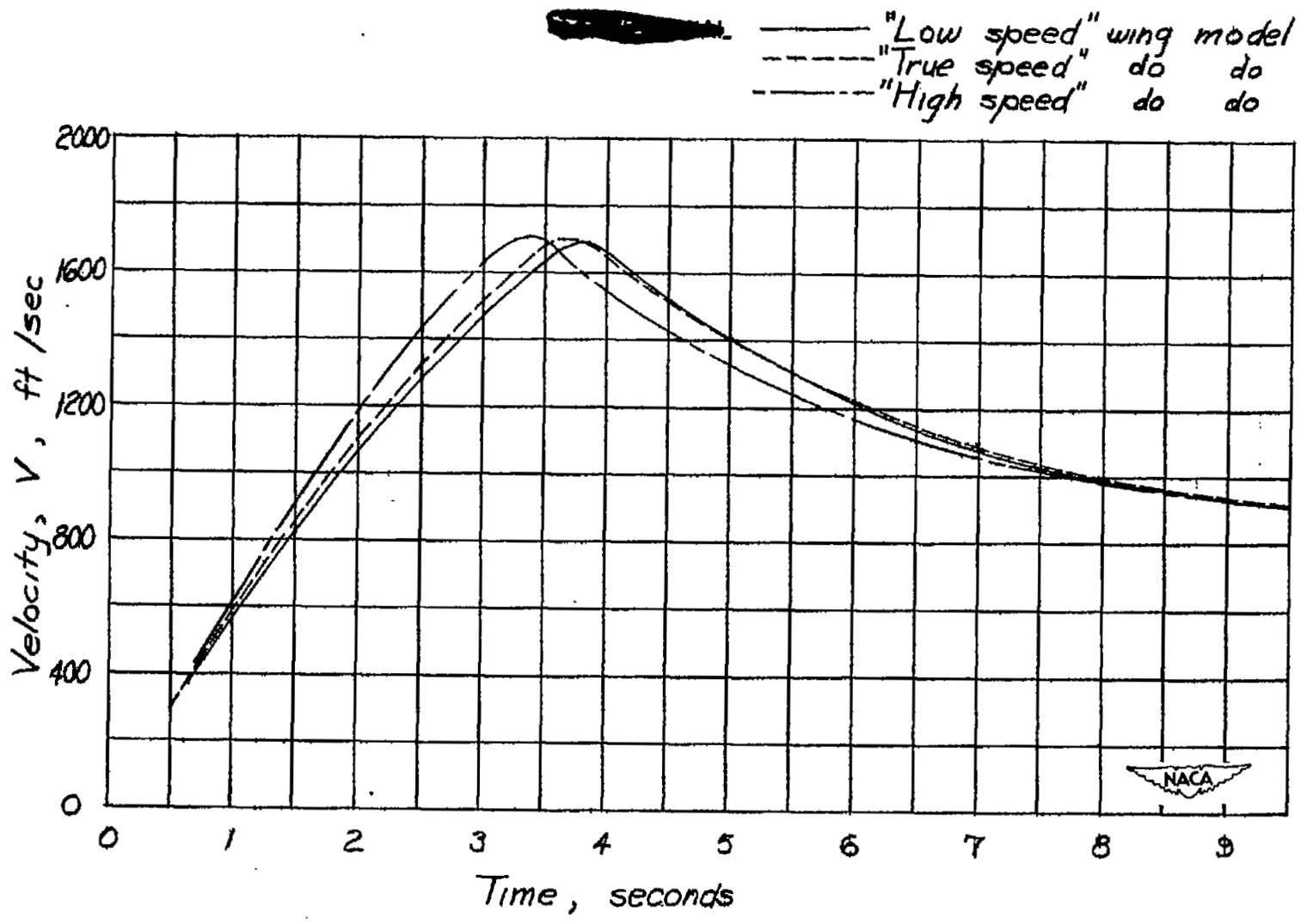


Figure 5.- Velocity variation with time during flight of models.

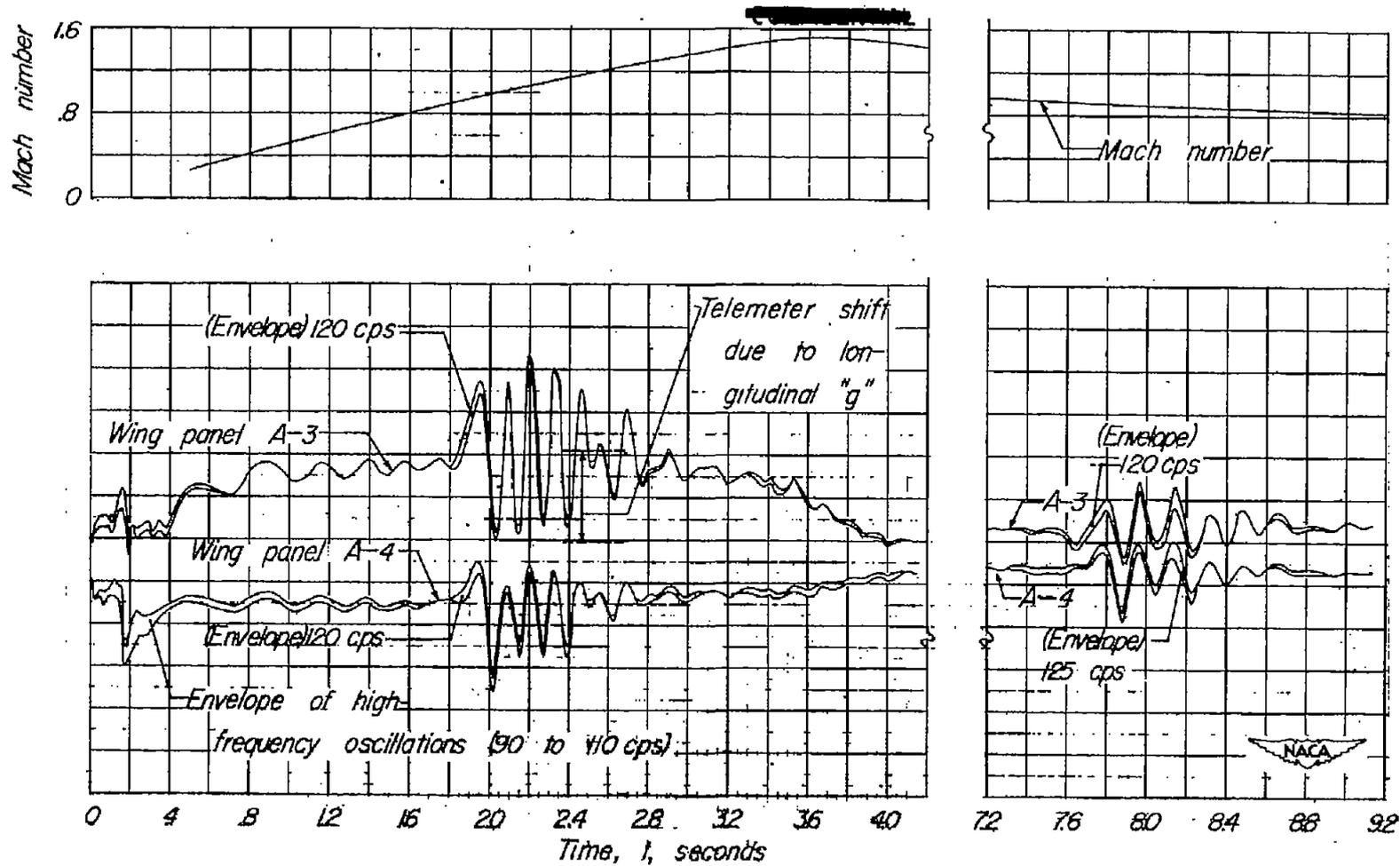


Figure 6.— Time history of flight of flutter model with $\frac{1}{10}$ -scale D-558-2 "true speed" wings.

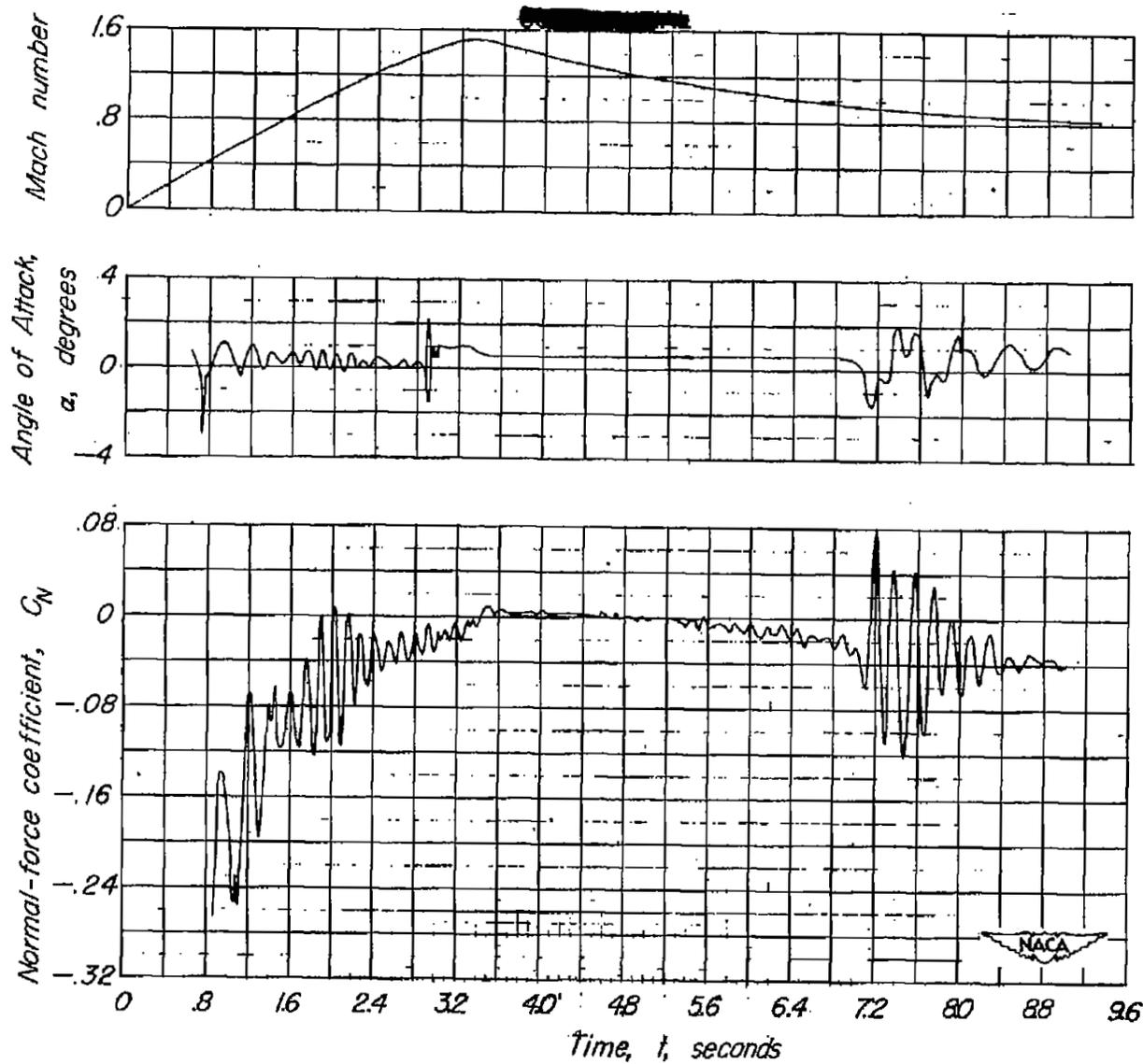


Figure 7.- Time history of flight of flutter model with $\frac{1}{10}$ -scale D-558-2 "high speed" wings.

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