NACA RM L51E17

CONFIDENTIAL

RESEARCH MEMORANDUM

FREE-FLIGHT-TUNNEL INVESTIGATION OF THE DYNAMIC

LATERAL STABILITY AND CONTROL CHARACTERISTICS OF A HIGH-

ASPECT-RATIO BOMBER MODEL WITH SELF-SUPPORTING FREE-

FLOATING FUEL TANKS ATTACHED

TO THE WING TIPS

By Charles V. Bennett and Robert B. Cadman

CLASSIFICATION CHANGED
Langley Aeronautical Laboratory
UNCLASSIFIED   Langley Field, Va.

FOR REFERENCE

NOT TO BE TAKEN FROM THIS ROOM

To _____

By authority of _NACA Res abs_ _____ Date _May 16, 1958_
_+ RN-127_

_am + 6-13-58_

CLASSIFIED DOCUMENT

This document contains classified information affecting the National Defense of the United States within the meaning of the Espionage Act, USC 50:31 and 32. Its transmission or the revelation of its contents in any manner to an unauthorized person is prohibited by law.
Information so classified may be imparted only to persons in the military and naval services of the United States, appropriate civilian officers and employees of the Federal Government who have a legitimate interest therein, and to United States citizens of known loyalty and discretion who of necessity must be informed thereof.

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS
WASHINGTON
August 7, 1951

CONFIDENTIAL

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

FREE-FLIGHT-TUNNEL INVESTIGATION OF THE DYNAMIC

LATERAL STABILITY AND CONTROL CHARACTERISTICS OF A HIGH-

ASPECT-RATIO BOMBER MODEL WITH SELF-SUPPORTING FREE-

FLOATING FUEL TANKS ATTACHED

TO THE WING TIPS

By Charles V. Bennett and Robert B. Cadman

SUMMARY

An experimental investigation has been made in the Langley free-flight tunnel to determine the dynamic lateral stability and control characteristics of a high-aspect-ratio bomber model with self-supporting, free-floating fuel tanks attached to the wing tips. This arrangement represents a configuration in which an auxiliary fuel supply could be efficiently carried without the large increase in wing bending moments normally encountered with fixed wing-tip tanks. Full-span flaps on the lifting surface of the tanks operate automatically in response to the relative bank angle between the bomber and tanks to keep the tanks alined with the bomber wing. The effect of a variation in restoring moment on the flying characteristics of the model was determined in the investigation by varying the gearing ratio (ratio of floating tank flap angle to angle of bank of the tank with respect to the bomber) and the size of the flap.

The results of the investigation showed that the flight behavior of the configuration could be made satisfactory when sufficient restoring moment was supplied. When the restoring moment was insufficient there was considerable flapping of the tanks with respect to the bomber. These flapping motions were most noticeable after a gust or control disturbance and the random disturbances caused by the flapping made it almost impossible for the pilot to maintain smooth wing-level flight.

INTRODUCTION

It has been proposed that the range of bomber airplanes be increased
by the addition of auxiliary fuel supplies in free-floating fuel tanks
hinged to the bomber wing tips. The weight of the auxiliary fuel would
be supported by lifting surfaces on the fuel tanks so that there would
be essentially no increase in wing loading and, because of the increased
aspect ratio, the auxiliary fuel supply probably could be carried more
efficiently in this manner than by any other means. By hinging the fuel
tanks to the wing with freedom in roll the wing bending loads caused by
the aerodynamic and mass forces on the tanks could be minimized.

Investigations have been made in the Langley free-flight tunnel to
determine the lateral stability and control characteristics of various
floating tip configurations. Reference 1 contains the results of an
investigation made to determine the lateral stability and control char-
acteristics of an aspect-ratio-5.06 model having self-supporting, fuel-
carrying panels hinged to the wing tips and reference 2 contains the
results of an investigation of another low-aspect-ratio model with
simplified fighter models attached to the wing tips with one, two, or
three degrees of angular freedom. In order to extend this work to include
higher-aspect-ratio models, the lateral stability and control character-
istics of an aspect-ratio-10.76 model with free-floating fuel tanks
hinged at the tips were determined by an experimental investigation in
the Langley free-flight tunnel. The results of this investigation are
presented herein. The tanks were weighted to simulate a fuel load and
full-span flaps on the lifting surface of the tanks were automatically
operated in response to the relative bank angle between the floating
tanks and the model to keep the tanks alined with the bomber wing. The
investigation consisted of flight tests of the bomber model alone and with
the tanks attached rigidly and with freedom in roll with respect to the
bomber.

APPARATUS AND TESTS

The investigation was conducted in the Langley free-flight tunnel
which is described in reference 3. A sketch of the model with the free-
floating wing tanks attached is shown in figure 1. The dimensional and
mass characteristics of the bomber model and free-floating tanks are
given in table I. All tests were made at a dynamic pressure of approx-
imately 4.25 pounds per square foot which corresponds to a lift coeffi-
cient of 0.88 for the bomber alone. A slat (fig. 1) was installed on the
bomber model wing to delay premature wing-tip stalling which was attributed
to the low scale (Reynolds number of approximately 55,000) at which the

tests were conducted. The lifting surfaces of the free-floating tanks
were equipped with full-span flaps of 20 percent chord. The flap effec-
tiveness was increased for some tests by adding 3/16- and 3/8-inch exten-
sions to the trailing edge of the full-span flaps. These extensions
increased the chord of the flaps by 56 and 112 percent, respectively.

The free-floating tanks were attached to the bomber by means of a
hinge which provided freedom in roll of the tanks with respect to the
bomber. The weight of the tanks was adjusted so that they tended to
remain alined with the bomber. The wing loading of the weighted tanks
was approximately equal to the wing loading of the bomber. (See table I.)

A mechanical linkage (see fig. 2) was installed on the floating tanks
to deflect the full-span flaps of the tanks in response to the relative
bank angle between the bomber and tanks. With this linkage on the model,
gearing ratios (ratio of tank flap angle to bank angle of tank with
respect to the bomber) of 3.33 and 4.75 were obtained. Cushioning
springs were installed in the linkage system to permit the tanks to roll
with respect to the bomber after the maximum flap deflection of the tanks
was reached. The purpose of the linked flaps was to minimize the rolling
motion of the tanks relative to the bomber by producing aerodynamic
forces on the tanks which tended to keep them alined with the bomber.
For instance, as a tank rotated up, the flap went up and the lift on
the tank was reduced, and, therefore the tank tended to return to its
trimmed position.

The restoring moments about the rolling hinge produced by the
linked flaps are shown in figure 3. The maximum flap deflection of $\pm 40^\circ$
produced a restoring moment of 0.045 foot pounds. Increasing the flap
chord by 56 and 112 percent increased the aerodynamic moment by 15 and
29 percent. The vertical portion of the restoring moment curves (fig. 3)
represents the preload in the cushioning springs that must be overcome
before the tanks can bank to an angle greater than that which corresponds
to 40° flap deflection. After the preload is overcome the tanks can
reach higher angles by compressing the cushioning springs. The restoring
moments provided by compression of the springs are shown by the constant
slope above the vertical portion of the curve. The maximum angle of
bank that could be reached by the tanks (springs fully compressed) was
approximately 32°.

Flight tests were made of the bomber alone and of the bomber with
the tanks attached rigidly and with freedom in roll. In the flight tests
made with the tanks attached with freedom in roll with respect to the
bomber, the pilot paid particular attention to the flapping of the tanks
(rolling motion of the tanks with respect to the bomber) and to the
effects of this flapping on the general flight behavior of the coupled
configuration. In addition, the flapping motions of the tanks were

determined quantitatively from motion-picture records taken with a
camera located to the rear of the tunnel test section.

RESULTS AND DISCUSSION

The flight behavior of the bomber alone was considered represent-
ative of that of an airplane having good stability and control character-
istics. The general flight behavior of the bomber with the tanks attached
rigidly (which was used as a basis for comparison with that of the bomber
with the tanks attached with freedom in roll) was less satisfactory than
that of the bomber alone because of the slower response to aileron
control and because of the decreased lateral stability. The rolling in
response to a given aileron control was slower than that of the bomber
alone because of the increased rolling inertia and the increased damping
in roll. The decreased lateral stability apparently resulted from the
increased rolling and yawing inertia. These results are similar to
those reported in references 1 and 2.

The rolling motions of the bomber in controlled flight and the
corresponding angles of bank of the floating tanks (measured with
respect to the horizontal) are shown in figures 4 and 5. Since the
film records were read within an accuracy of ±0.5° and no attempt was
made to fair smooth curves through the scatter of points, any abrupt
motion falling within these limits may not represent the actual motions
of the floating tank models. In some cases the floating-tank rolling
motions are displaced from those of the bomber because no attempt was
made to trim the tanks to exactly zero bank with respect to the bomber.
It was also difficult to keep the tanks trimmed so that the flaps were
at 0° deflection when the tanks were at 0° bank. The data of figure 3,
therefore, cannot be used to obtain accurate estimates of the restoring
moments for a given condition. These data can be used, however, to
obtain a general indication of the variation of restoring moment with
tank bank angle for the various gearings used in the tests.

The motions of the bomber and the corresponding motions of the
attached tanks are shown in figure 4 for a gearing ratio of 3.33.
Flights could not be maintained without extensions on the flaps because
of erratic flapping of the tanks and, therefore, no film records were
obtained. The flight records of figures 4(a) and 4(b) are for a gearing
ratio of 3.33 with the flap chord increased 56 and 112 percent, respec-
tively. These records show that the flapping was reduced as the size of
the extension was increased. With the flap chord increased 56 percent
there was considerable flapping of the tanks with respect to the bomber.
These flapping motions, which were most noticeable after a gust or
control disturbance, were very lightly damped and the random disturbances
caused by this erratic flapping of the tanks made it almost impossible

for the pilot to maintain smooth wing-level flight. With the flap chord increased 112 percent, the flapping, although reduced, was still considered objectionable by the pilot.

The flight records for the increased gearing ratio of 4.75 are shown in figure 5. The flight records of figure 5(a) are for a gearing ratio of 4.75 without the flap extension and the records of figure 5(b) and 5(c) were obtained with the flap chord increased 56 and 112 percent, respectively. These records show that the flapping was reduced as the size of the extensions was increased. It was the pilot's opinion that the flight behavior for the condition without the flap extension was comparable to that with a gearing ratio of 3.33 with the flap chord increased 56 percent and that the condition with the flap chord increased 56 percent was comparable to that with a gearing ratio of 3.33 with the flap chord increased 112 percent.

With the gearing ratio of 4.75 and with the 112-percent flap extension, the flying characteristics were considered to be satisfactory and it was the opinion of the pilot that the flight behavior compared favorably with that for the configuration in which the tanks were attached rigidly to the bomber.

CONCLUDING REMARKS

The results of an investigation made in the Langley free-flight tunnel to determine the dynamic lateral stability and control characteristics of a high-aspect-ratio bomber model with free-floating fuel tanks hinged at the tips indicate that the flight behavior of the configuration could be made satisfactory when sufficient restoring moment was supplied. When insufficient restoring moment was supplied there was considerable flapping of the tanks with respect to the bomber. These flapping motions were most noticeable after a gust or control disturbance and the random disturbances caused by this flapping made it almost impossible for the pilot to maintain smooth, wing-level flight.

Langley Aeronautical Laboratory
    National Advisory Committee for Aeronautics
        Langley Field, Va.

REFERENCES

1. Shanks, Robert E., and Grana, David C.: Flight Tests of a Model
   Having Self-Supporting Fuel-Carrying Panels Hinged to the Wing
   Tips. NACA RM L9IO7a, 1949.

2. Bennett, Charles V., and Cadman, Robert B.: Free-Flight-Tunnel
   Investigation of the Dynamic Lateral Stability and Control
   Characteristics of a Tip-to-Tip Bomber-Fighter Coupled Airplane
   Configuration. NACA RM L51A12, 1951.

3. Shortal, Joseph A., and Osterhout, Clayton J.: Preliminary Stability
   and Control Tests on the NACA Free-Flight Wind Tunnel and
   Correlation with Full-Scale Flight Tests. NACA TN 810, 1941.

TABLE I

DIMENSIONAL AND MASS CHARACTERISTICS

	Bomber model	One floating tank model	Coupled configuration
Weight, lb	4.87	0.41	5.69
Wing loading, lb/ft^2	3.74	3.95	3.77
Radius of gyration about longitudinal body axis, spans	0.15	----	[a]0.27
Radius of gyration about vertical body axis, spans	0.21	----	[a]0.30
Wing:			
Airfoil section	Rhode St. Genese-35	Rhode St. Genese-35	----
Span, in.	45.00	9.00	[b]63.80
Area, sq in.	187.20	14.94	217.08
Aspect ratio	10.76	5.42	----
Taper ratio	0.25	1.00	----
Mean aerodynamic chord, in.	4.66	1.66	----
Aileron:			
Area, percent wing area (one aileron)	3.77	----	----
Chord, percent wing chord	30.00	----	----
Span, percent wing span (one aileron).....................	17.92	----	----
Flap:			
Area, percent wing area	----	20.00	----
Chord, percent wing chord	----	20.00	----
Span, percent wing span	----	100.00	----
Fuselage:			
Length, in.	32.60	9.00	----
Diameter, in.	2.50	0.90	----
Fineness ratio (Length/Diameter) ...	13.04	10.00	----
Vertical tail:			
Airfoil section	NACA 0012	----	----
Span, in.	6.31	----	----
Area, percent wing area	13.50	----	----
Aspect ratio	1.58	----	----
Taper ratio	0.33	----	----
Horizontal tail:			
Airfoil section	NACA 0009	----	----
Span, in.	15.00	4.00	----
Area, percent wing area	22.09	21.42	----
Aspect ratio	5.50	5.00	----
Taper ratio........................	0.38	0.60	----
Tail length $\frac{1}{4}$-chord of wing mean aerodynamic chord to rudder hinge line, in.	15.47	----	----

[a]Based on span of bomber.

[b]Includes gap for hinge installation.

.04c

.0373c

.214c

35° Section A—A

Tank roll axis

15.47

A

A

11.71

0.40

0.25 MAC

8.75

9.00

45.00

63.80

6.31

32.60

NACA
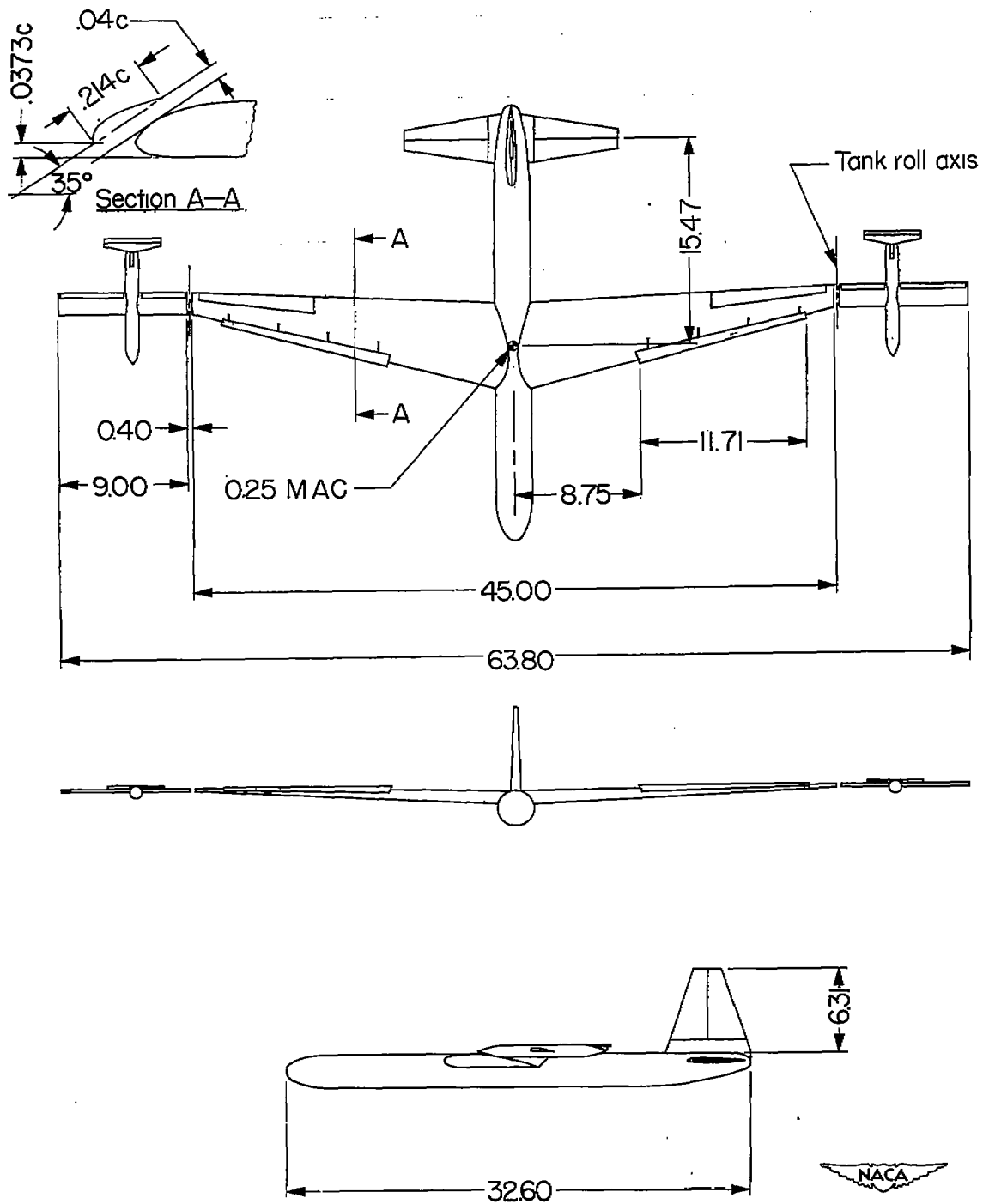
Figure 1.- Three-view sketch of high-aspect-ratio bomber model with free-
floating fuel tanks installed. All dimensions are in inches.

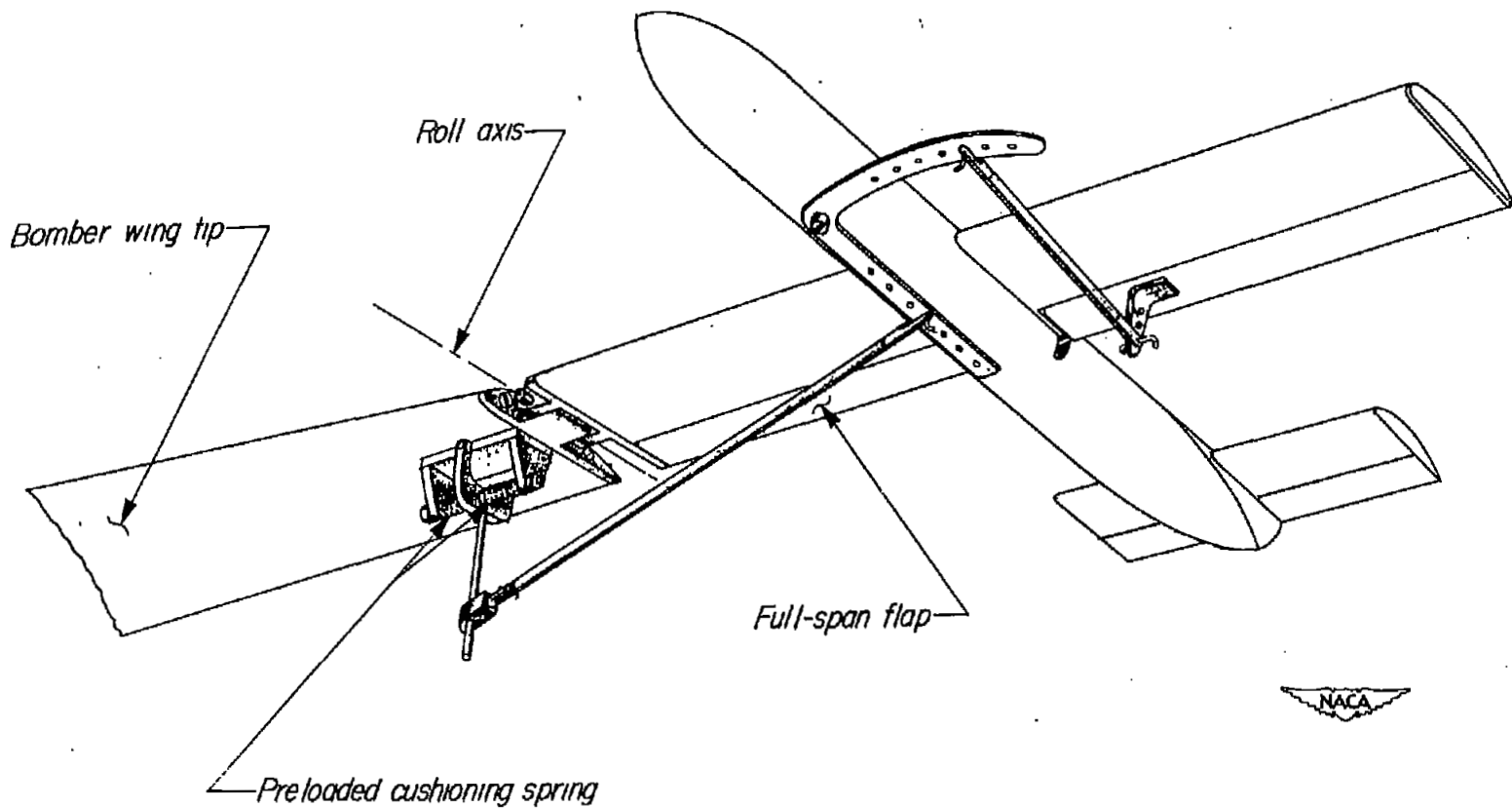Roll axis—

Bomber wing tip—

Full-span flap—

—Preloaded cushioning spring

Figure 2.- Sketch of linkage system used to deflect full-span flaps of
free-floating tank in response to the relative angle of bank of the
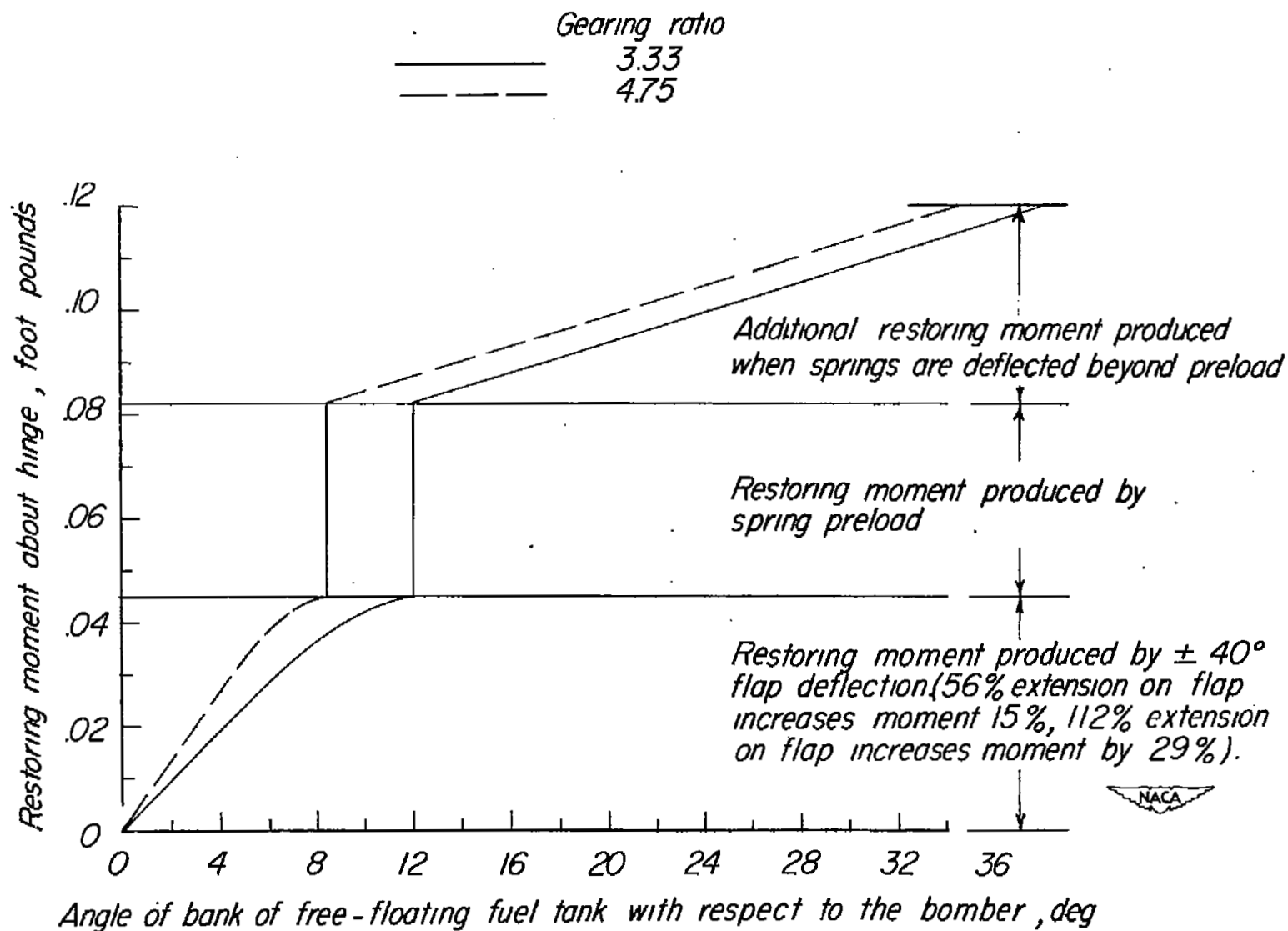tank with respect to the bomber.

Figure 3.- Variation of applied restoring moment with angle of bank of free-floating fuel tank with respect to bomber.
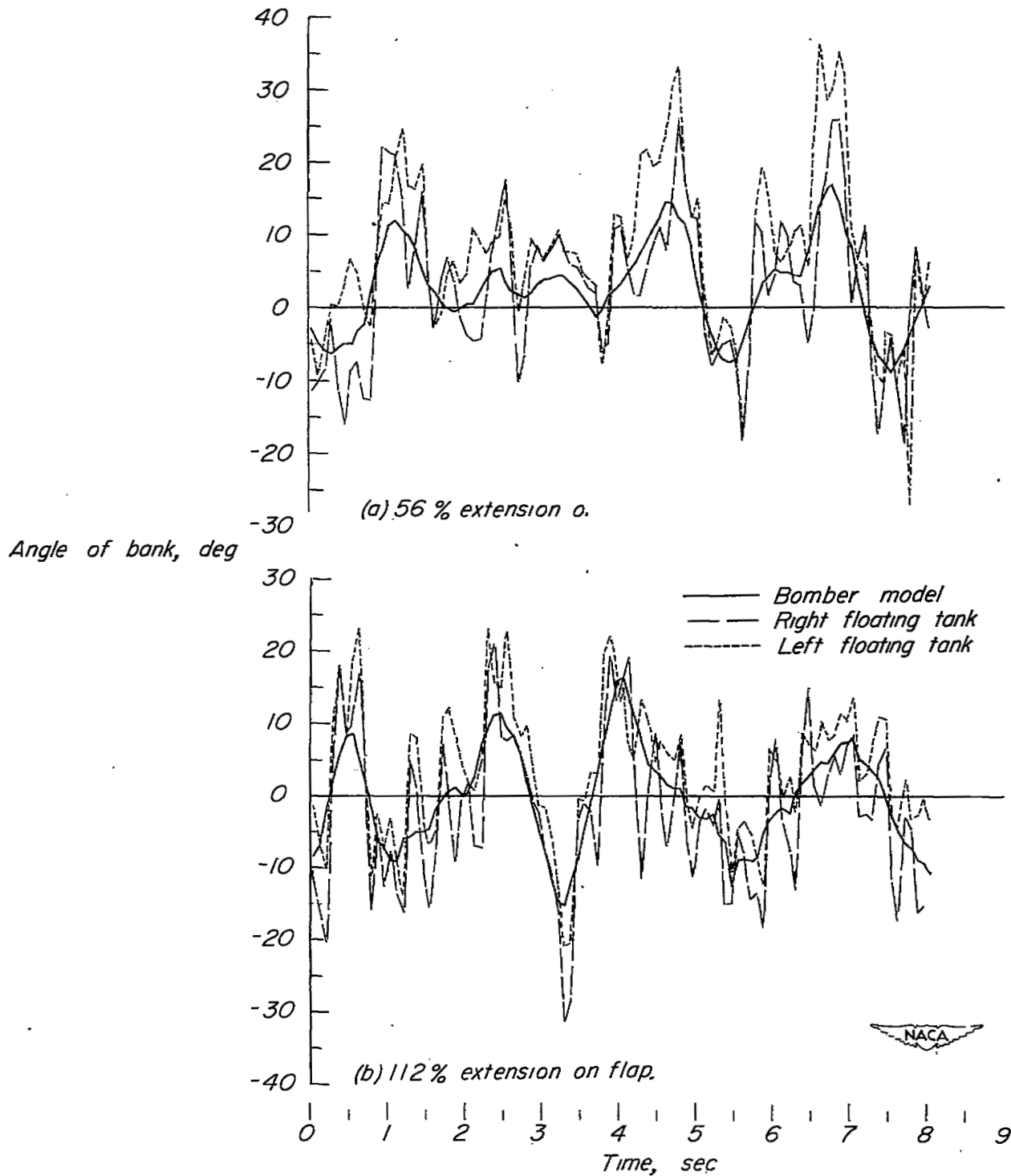
Figure 4.- Rolling motions of bomber and free-floating fuel tanks.
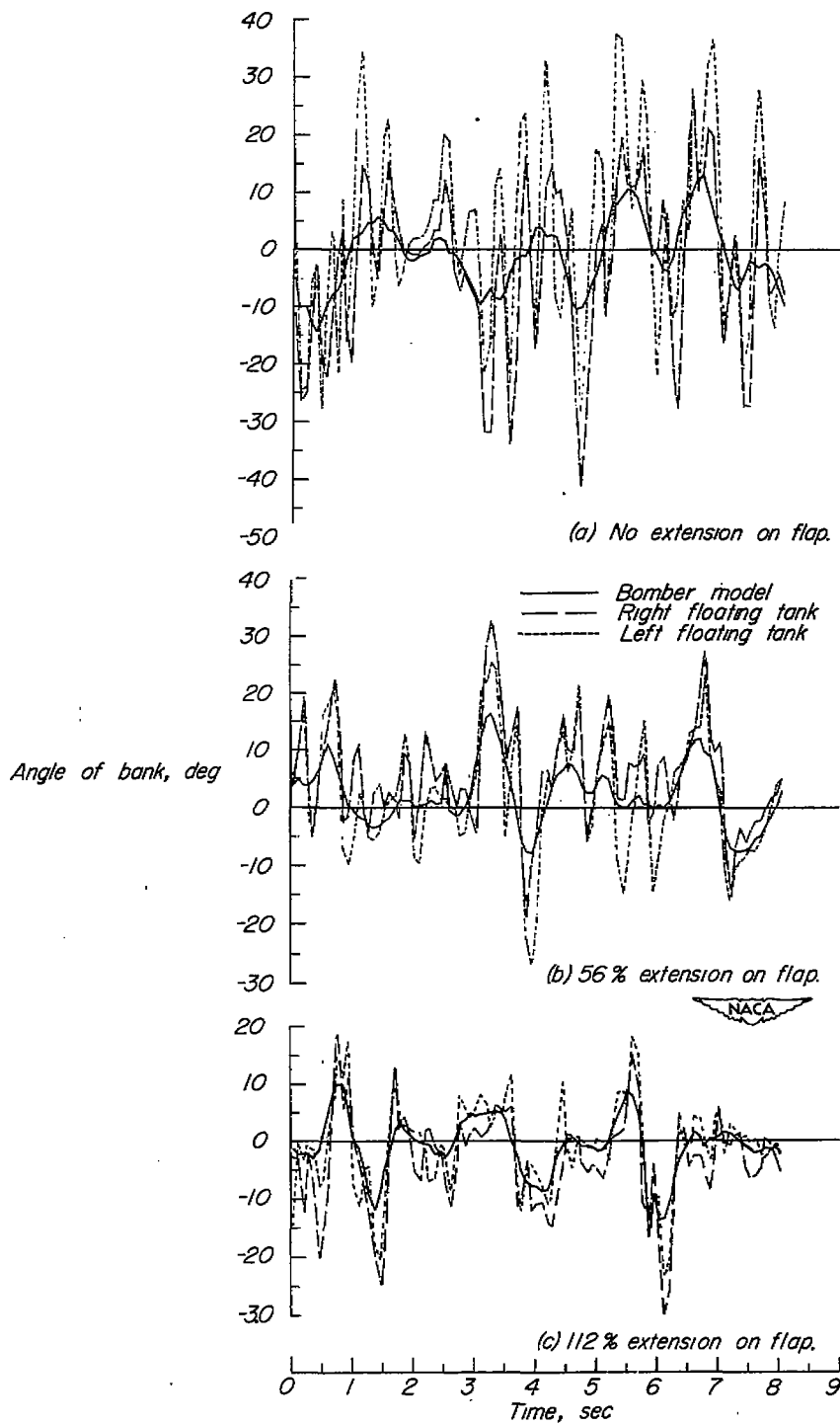Gearing ratio, 3.33.

40
30
20
10
0
-10
-20
-30
-40
-50

(a) No extension on flap.

40
30
20
10
0
-10
-20
-30

Bomber model
Right floating tank
Left floating tank

Angle of bank, deg

(b) 56 % extension on flap.

20
10
0
-10
-20
-30

(c) 112 % extension on flap.

0   1   2   3   4   5   6   7   8   9
Time, sec

Figure 5.- Rolling motions of bomber and free-floating fuel tanks.
Gearing ratio, 4.75.