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TANK TESTS OF A 1/8-SIZE DYNAMIC MODEL OF THE
PB2Y-3 AIRPLANE WITH SIMULATED JET MOTORS -
NACA MODELS 131J, 131J-1, AND 131J-2

By Joe W. Bell and Robert F. Havens

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

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MEMORANDUM REPORT

for the

Bureau of Aeronautics, Navy Department

TANK TESTS OF A 1/8-SIZE DYNAMIC MODEL OF THE

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INTRODUCTION

The present investigation was undertaken for the purpose of determining the effect of jet motors upon the stability of the PB2Y-3 airplane at a gross load of 76,000 pounds. The request for tests on the powered dynamic model of the PB2Y-3 airplane with jets installed in the rear step was made by the Bureau of Aeronautics, Navy Department, on December 29, 1942.

The Consolidated Aircraft Corporation was represented during the tests of models 131J and 131J-1 by Mr. H. E. Brooke. The program for the tests and the methods used were discussed with Captain Diehl of the Bureau of Aeronautics during his visits to the Laboratory before and during the tests.

The tests were made in NACA tank no. 1 during February and March 1943.

DESCRIPTION OF MODEL

The basic model used in the tests was designated NACA model 131. Models numbers 131J, 131J-1, and 131J-2 were used as designations for the same basic model incorporating different configurations of simulated jet motors. Model 131 was the 1/8-size dynamic model of the PB2Y-3 airplane used in several previous investigations in the tank. It was built in accordance with specifications given in reference 1. The propeller blades were set at 8° at 75-percent radius and were rotated at a speed of 6200 rpm to develop the scale thrust of the PB2Y-3 airplane with engines of 1200 horsepower each. The general arrangement of the model is shown in figure 1.

Three air nozzles were used to simulate the jet motors. These nozzles were of the convergent-divergent type and had diameters of 0.158 inch at the throat and 0.208 inch at the exit. Three arrangements of jets were investigated. Designations and descriptions of these arrangements are listed as follows:

Model 131J - Three nozzles located in the center plane of the stern post and directed parallel to the base plane of the hull (see fig. 2)

Model 131J-1 - Same as model 131J except that the longitudinal axes of the nozzles were directed down 15° with respect to the base plane of the hull (see fig. 2)

Model 131J-2 - Three nozzles in a common horizontal plane with one located on the center line at the stern post and one protruding from either side of the afterbody between stations 6.1 and 6.2 and directed outward at an angle of 7° ; the thrust axes of all three nozzles were directed in a plane parallel to the base plane of the hull (see fig. 3)

The arrangement of jets used in 131J and 131J-1 was designed at the Laboratory before definite drawings of jet motors or their arrangements had been furnished by the contractor. These installations were made simple, and an effort was made to keep the exit of the nozzles flush with the surface of the hull. The arrangement used in model 131J-2 was taken from a drawing of the installation in the full-size airplane which was furnished by the contractor. This installation included cylinders that are to be provided outside the jet motor to serve as shields and means for support of the jet motors in the airplane. Photographs of the installation of nozzles of models 131J and 131J-2 are shown in figure 4.

During the greater part of the tests the step of the model was not ventilated. Ventilation ducts, however, were provided for a part of the tests of model 131J-2. The ducts used in the tests are shown in figure 5. The area and the location of the ducts approximated those of the production installation in the airplane. Existing ducts in the model were used for convenience and therefore were not identical scale models of the full-size ducts.

The pitching moment of inertia of model 131J-2 was found to be 15.9 slug-feet² with the model ballasted to balance at 28-percent mean aerodynamic chord. The moments of inertia of models 131J and 131J-1 were not determined but should have been about the same as that of model 131J-2.

APPARATUS AND PROCEDURE

The tests were conducted in NACA tank no. 1 which is described in detail in reference 2. The model was towed under the main carriage where the airspeed was approximately 5 percent greater than the water speed. The usual method of investigating the stable range of the locations of the center of gravity was used in the tests. This method consists of making accelerated runs and recording the trim of the model and amplitude of porpoising at sufficient intervals to give curves of trim against speed for simulated take-off runs. The acceleration used in the tests was approximately 1 foot

per second per second. Tests without power, with full power of the engines, and with full power of the engines and jets were included in the investigation. Tests without power were made with the propellers in place and free to windmill. When the propellers were operated, the power was turned on at a speed of approximately 15 feet per second to avoid damage from spray at lower speeds. The jets were usually put in operation at the beginning of the run.

The gross load of the model was 148 pounds corresponding to 76,000 pounds full size.

Compressed air was supplied to the nozzles from two high-pressure air cylinders from the towing carriage. A rubber hose of 3/8-inch inside diameter was used to transmit the air to the model. The hose entered the model at the upper surface of the wing near the center of gravity. The restraint in rise and trim applied by the hose was found to be negligible.

The thrust resulting from operation of the nozzles was investigated by placing each manifold and nozzle assembly on a platform scale and taking readings of the scale with and without the nozzles in operation. In this investigation the air was supplied to the manifold through the same assembly of hose and tubing and at the same pressure that was to be used in the tests of the model. The thrust of the

nozzles was found to be 11 pounds for models 131J and 131J-1 and 9.5 pounds for model 131J-2, corresponding to full-size thrusts of 5600 pounds and 4900 pounds, respectively. The reduced thrust of the nozzles in model 131J-2 was probably caused by pressure losses in the manifold. The air was supplied to the manifold at a pressure of 175 pounds per square inch gage in both cases.

RESULTS AND DISCUSSION

Model 131J

The air nozzles of model 131J were located in the plane of symmetry of the hull at the stern post and were directed parallel to the base line of the hull. During the tests of this configuration the flaps were set at 40° and increased chord elevators were used. The chord and the area of these elevators were 20 percent greater than the corresponding scale dimensions of the airplane. Tests were made without power, with full power of the engines, and with full power of the engines and jets. Curves of variations of trim with speed for all of the conditions of the tests of model 131J are shown in figure 6. The effect of engine power was to reduce the trim of the model throughout the runs. The effectiveness of the elevators was very greatly increased by the use of power, but, even so, the trim with full-up elevators and full power did not become as high at speeds below

40 feet per second (66 knots full size) as that with full-up elevators and no power. The effect of the operation of the jets was to increase the trim at all speeds beyond the hump and to decrease the trim at the hump. This change in trim at the hump was opposite from that which would have been expected to result from the thrust moment of the jets and is believed to have resulted from a change in pressure under the tail extension of the model.

Cross plots showing the variation of the maximum amplitude of porpoising with location of the center of gravity are given in figure 7. The stable range of the location of the center of gravity, considering 2° as the maximum allowable amplitude of porpoising, was as follows:

<u>Condition</u>		<u>Forward limit,</u>	<u>Aft limit,</u>
<u>Engine power</u>	<u>Jet power</u>	<u>percent M.A.C.</u>	<u>percent M.A.C.</u>
Zero	Off	26	31
Full	Off	34	33
Full	On	29	32

With power and without the jets in operation, the model was unstable at all locations of the center of gravity. The lower trims resulting from the use of power caused the forward limit, obtained with neutral elevators, to change from 26-percent mean aerodynamic chord to 34-percent mean aerodynamic

chord but only caused the after limit, obtained with elevators at -25° , to change from 31-percent mean aerodynamic chord to 33-percent mean aerodynamic chord. These limits were based on an allowable amplitude of 2° and at every location of the center of gravity the amplitude of porpoising was at least 1° .

The stability of the model was improved somewhat by the operation of the jets. This improvement was effected by the positive trimming moment of the thrust of the jets, which caused higher trims above hump speed and thereby changed the forward limit by 5-percent mean aerodynamic chord. The range of stable locations of the center of gravity, based on an allowable amplitude of 2° , was 29-percent mean aerodynamic chord to 32-percent mean aerodynamic chord, but the model was not completely stable at any position of the center of gravity. The results of the operation of the jets were not as conclusive as they might have been if the model, when tested with full engine power, had been stable without the operation of the jets.

Model 131J-1

Model 131J was altered to form model 131J-1 by directing the nozzles down 15° with respect to the base line of the hull. The angle of 15° was selected because that angle would make the projected axes, and therefore the theoretical line of

thrust of jets, pass approximately through the center of gravity of the model. With this type of installation the thrust of the jet motors may be assumed to have little effect on the trim of the model; therefore, in this configuration the changes in trim resulting from the operation of the jets may be attributed to the changes in flow and pressure caused by the action of the air after it had been exhausted from the nozzle. Except for the change of the direction of the jets, the conditions of the tests were identical with those of the tests of model 131J. Inasmuch as the exterior of the model was identical with that of model 131J, the tests without the jets in operation were not repeated.

The curves of variation of trim with speed for model 131J-1 are shown in figure 8. These curves may be compared with similar curves in figure 6 to determine the effect of directing the jets downward. Comparison of these curves shows that directing the jets down 15° reduced the trim of the model during most of the take-off run. Comparison with the curves for model 131J with engine power but without jet power (fig. 6) shows that the operation of the jets when directed down 15° reduced the trim at the hump but had little effect upon the trim at higher speeds.

Curves of variation of maximum amplitude of porpoising with position of the center of gravity for model 131J-1 are shown in figure 9(d). Similar curves for model 131J with engine power and with engine and jet power are repeated in figure 9 for comparison. Comparison of figure 9(d) with figure 9(b) shows that the operation of the jets of model 131J-1 caused little change in the stable range of locations of the center of gravity. Comparison of figure 9(d) with figure 9(c) shows that the effect of directing the jets down 15° was to move the forward limit aft by about 6-percent mean aerodynamic chord and to move the aft limit aft by about 2-percent mean aerodynamic chord.

Model 131J-2

Model 131J-2 differed from model 131J in that two of the air nozzles had been moved from the stern post to the sides at the afterbody and directed outward at angles of 7° with respect to the center plane of the hull. The three nozzles were located in a common plane parallel to the base plane of the hull and had their thrust axes directed in this same plane.

Tests of model 131J-2 were made at two conditions:

- (a) Without ventilation of the step, extended chord elevators, flaps 40° , elevators deflected 0° for determination of forward limit, and -25° for determination of aft limit

- (b) With-ventilation ducts as shown in figure 5, scale elevators, flaps 20° , elevators deflected 0° for determination of forward limit, -20° for determination of aft limit

Condition (a) formed a part of the original investigation initiated with the tests of model 131J; condition (b) was included to determine the effects of jets by comparison with the results of tests reported in reference 3. The tests reported in reference 3 were made at a later date than the tests of models 131J and 131J-1 and included aerodynamic tests which resulted in the use of different test conditions to approximate more nearly the operation of the full-size airplane.

Model 131J-2 without ventilation, flaps 40° , extended chord elevators. - Curves of variation of trim with speed are given in figure 10. These curves are comparable with similar curves for model 131J in figure 6. Trims of model 131J-2 are substantially in agreement with those of model 131J except at the hump where the trim was slightly higher than that for model 131J with jets in operation but not quite as high as that for model 131J without the jets in operation. This difference in trim may be attributed to the fact that two of the jets were directed outward and the changes in flow and pressure under the tail extension of the

model were not as great as they had been with all three jets in the center plane of the model.

Curves of variation of maximum amplitude of porpoising with location of the center of gravity for model 131J-2 are shown in figure 11(c). Similar curves for model 131J without the jets in operation are shown in figure 11(a) and with jets in operation in figure 11(b). Comparison of figure 11(b) with figure 11(c) shows that the results of the tests of model 131J-2 were substantially in agreement with the results of tests of model 131J.

Because of the close agreement between the results of the tests of models 131J-2 and 131J, it was believed that the effect of inclining the jets of model 131J-2 would have been about the same as had been found by inclining the jets of model 131J to form model 131J-1.

Model 131J-2 with ventilation, flaps 20°, scale elevators. - The curves of variation of trim with speed for model 131J-2 with these conditions are shown in figure 3. These may be compared with similar curves of model 131 (without jets) in reference 3. The effects of operation of the jets in this condition were found to be substantially the same as had been found in the same model with other test conditions and in the tests of model 131J. The trim was increased by operation of jets at high speeds and decreased slightly by

operation of the jets at hump speed. Curves of variation of maximum amplitude of porpoising with location of the center of gravity for model 131J-2 with ventilation and with flaps 20° are given in figure 13(b). Similar curves for model 131 without jets are reproduced in figure 13(a) for comparison. Comparison of these curves shows that both the forward and aft limits of stable locations of the center of gravity were shifted approximately 5-percent mean aerodynamic chord by the operation of jets. This change in forward limit was about the same as had been observed in the tests without ventilation, but the change in after limit was much greater than observed without ventilation.

CONCLUSIONS

1. The effect of the operation of three jets located in the plane of symmetry at the stern post and directed parallel to the base line of the hull (model 131J) was to reduce the trim at the hump and to increase the trim at speeds above the hump. The increased trim at speeds above the hump resulted in a forward movement of the range of stable locations of the center of gravity.

2. Except for the reduction in the trim at the hump, the effect of jets upon the trim of the model was almost eliminated by directing the jets down 15° relative to the base line of the hull (model 131J-1). When the jets were

directed down at this angle, their line of thrust passed approximately through the center of gravity of the model.

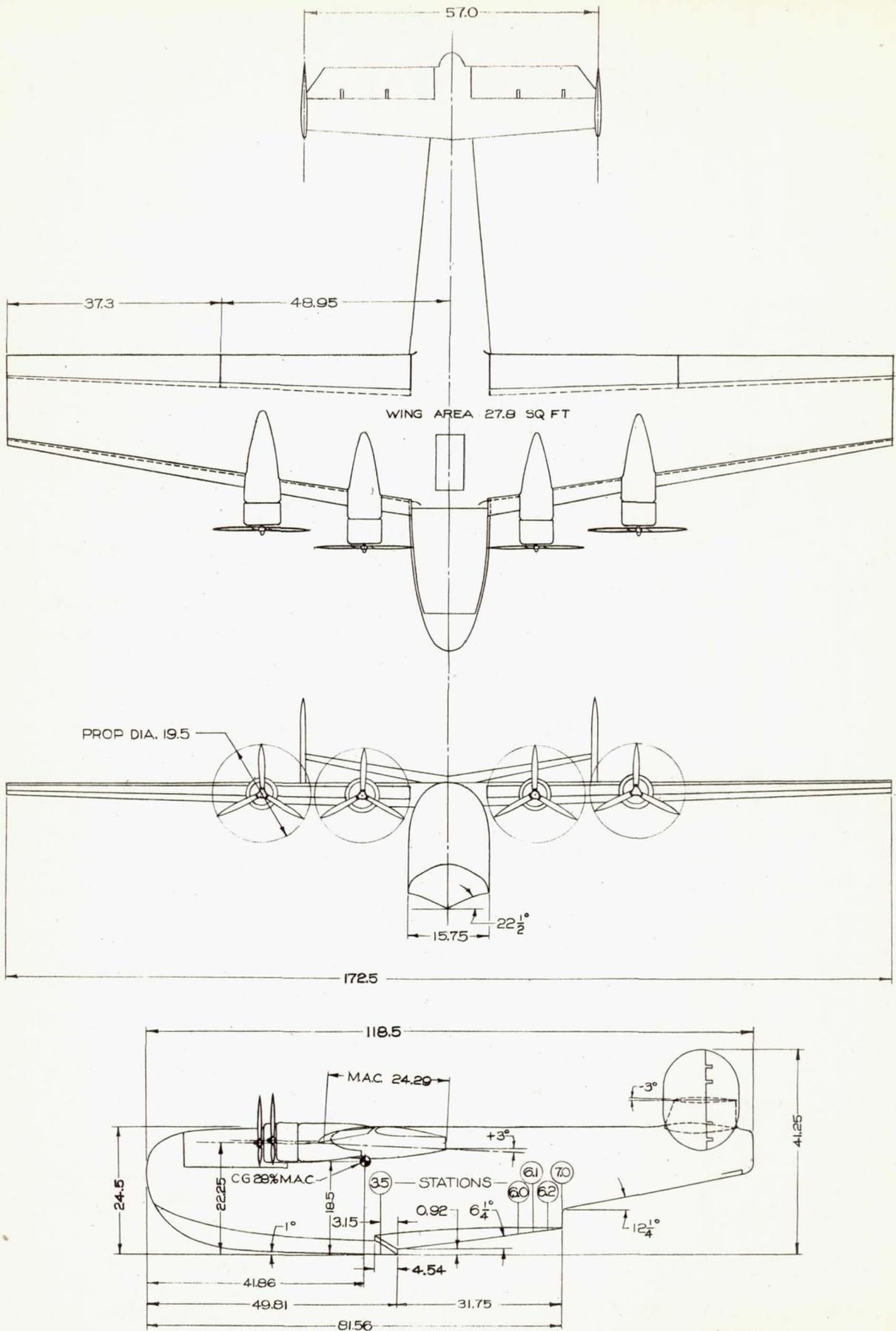
3. Changing the location of two of the jets from the plane of symmetry to the sides of the afterbody and directing them outward 7° relative to the plane of symmetry (model 131J-2) caused no significant effect upon the results of the operation of the jets.

4. The trim at the hump was reduced by the operation of the jets in each of the configurations tested. This reduction in trim was attributed to the action of the air after being exhausted from the jets. This effect caused by the exhaust under the tail extension of the model indicated that even larger effects would result if the jets were located in the main step and permitted to exhaust under the afterbody.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., June 8, 1943.

REFERENCES

1. Brooke, H. E.: Detailed Specification, PB2Y-3 - 1/8 Scale Powered Dynamic Model. Rep. No. ZH-29-008, Consolidated Aircraft Corp., Jan. 1942.
2. Truscott, Starr: The Enlarged N.A.C.A. Tank, and Some of Its Work. NACA TM No. 918, 1939.
3. Bell, Joe W., and Havens, Robert F.: Tank Tests of a 1/8-Size Dynamic Model of the PB2Y-3 Airplane with Increased Power - NACA Model 131. NACA MR, June 9, 1943.



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FIGURE 1.- GENERAL ARRANGEMENT, NACA MODEL 131.

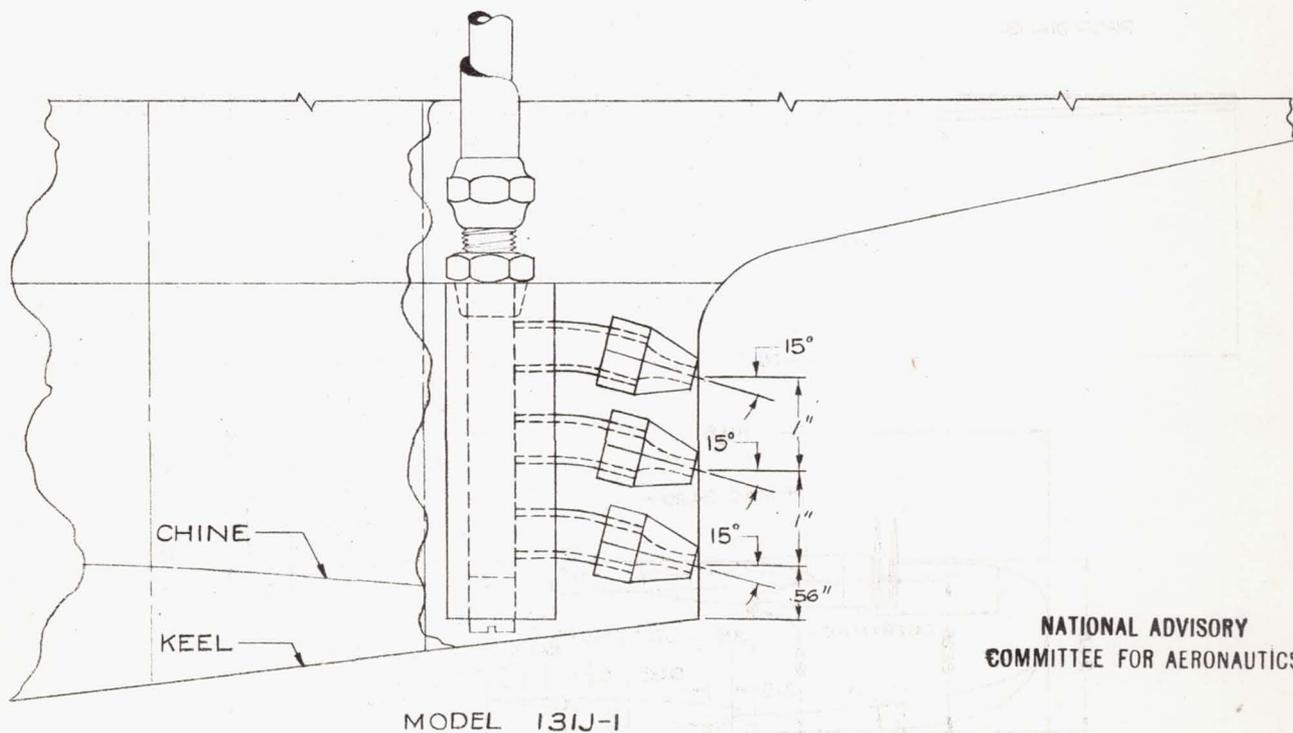
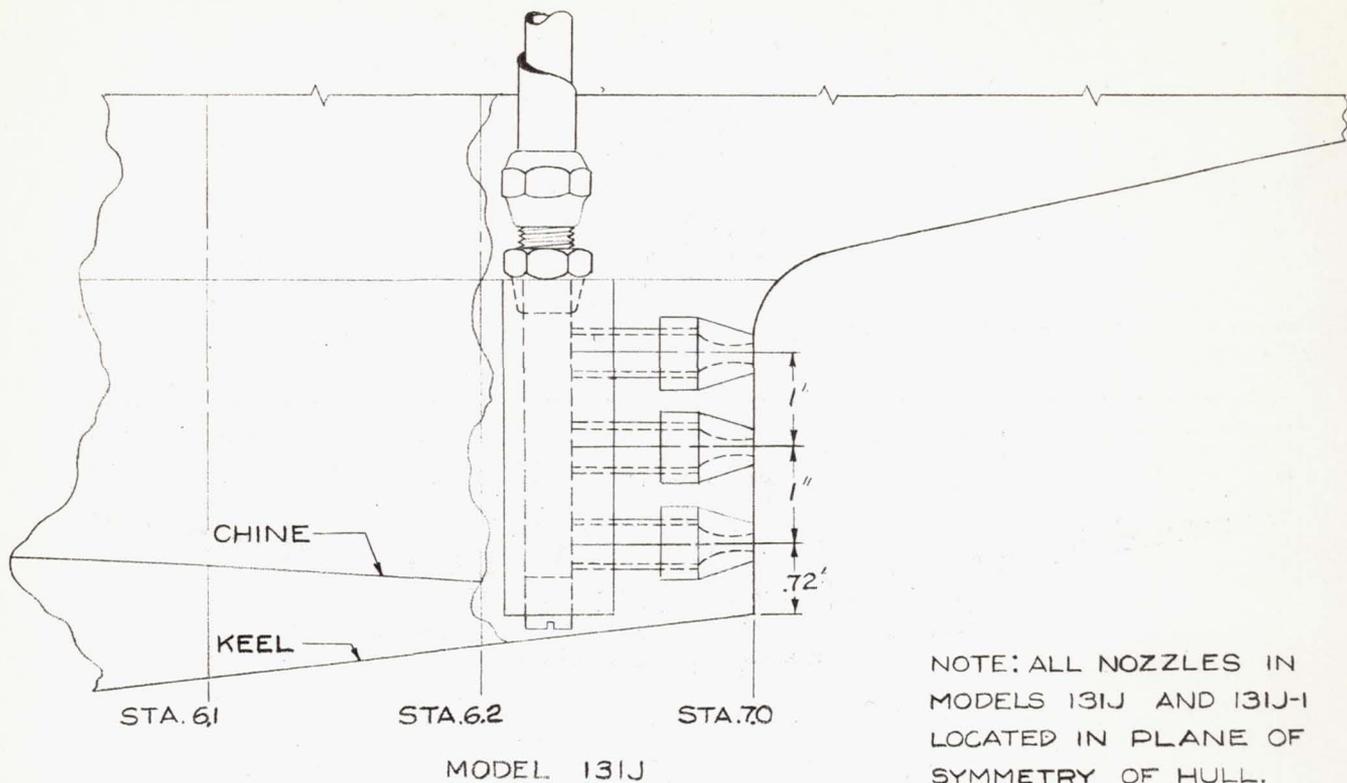
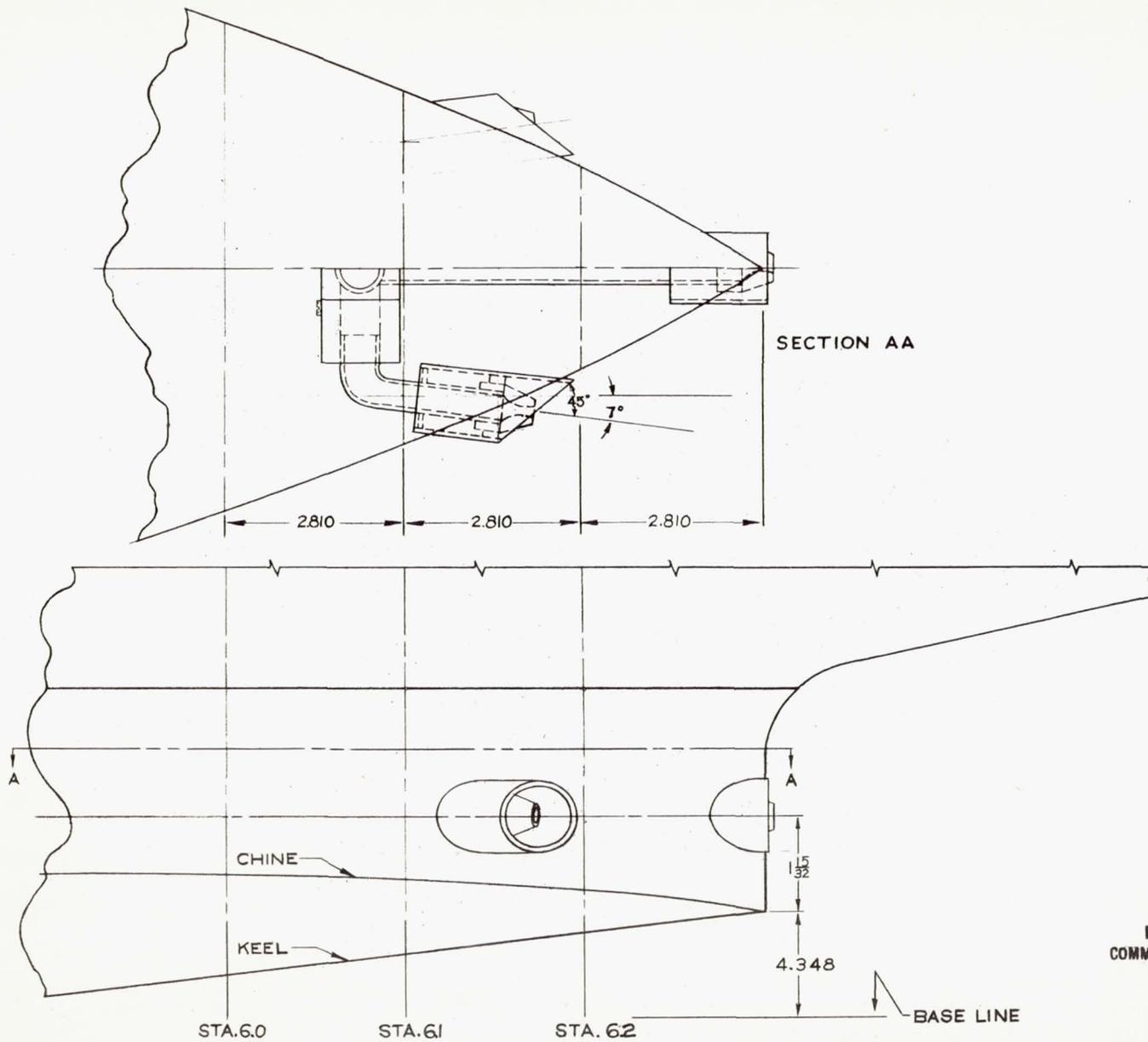
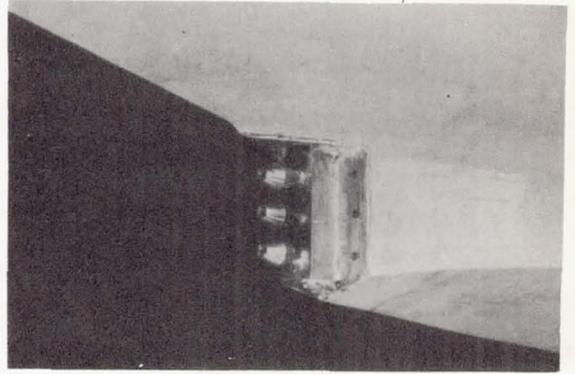
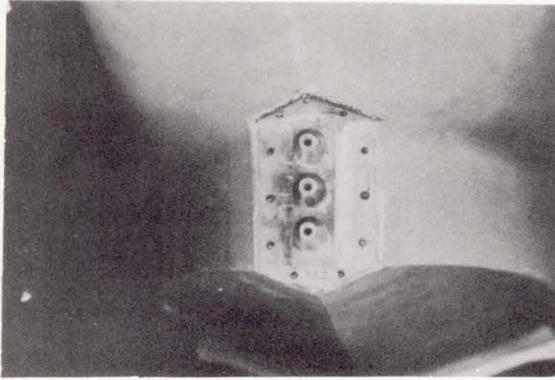


FIGURE 2.- JET INSTALLATION IN AFTERBODY, MODEL 131J AND MODEL 131J-1.

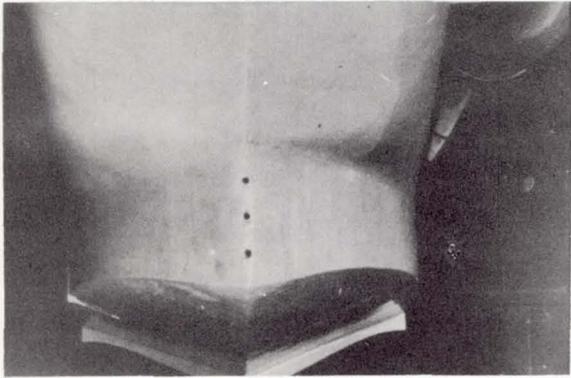


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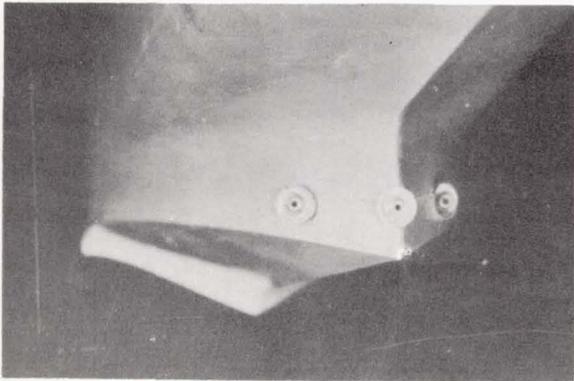
FIGURE 3.- JET INSTALLATION IN AFTERBODY,
MODEL 131J-2.



Model 131J without fairing.



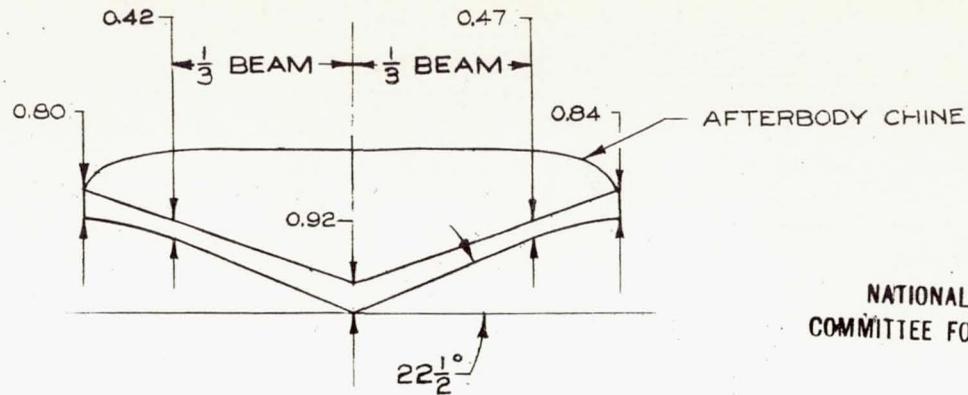
Model 131J as tested.



LMAL 33280 Model 131J-2 as tested.

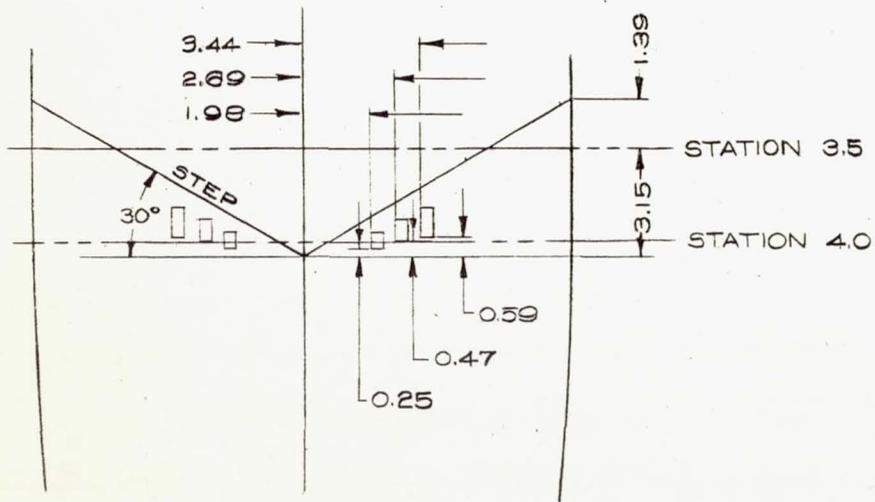
Figure 4.- Photographs of jet installations of NACA models 131J and 131J-2.

ALL DIMENSIONS
IN INCHES



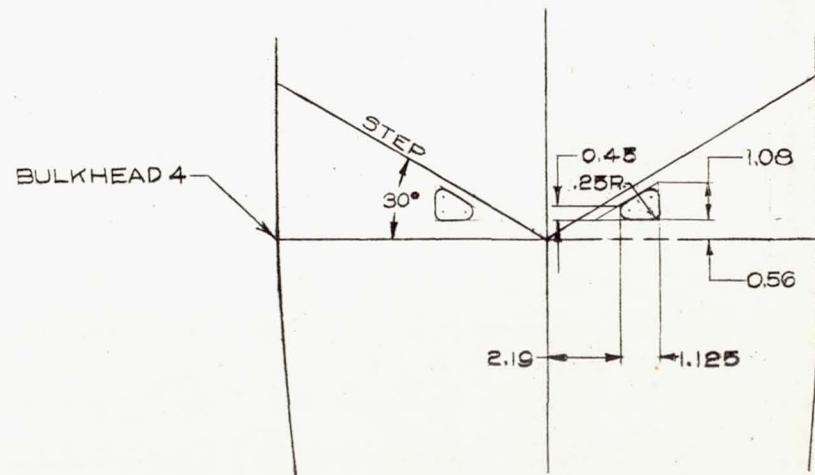
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MODEL STEP PROFILE



MODEL VENTILATION OPENINGS

TOTAL AREA = 1.32 SQ. IN.



PRODUCTION VENTILATION OPENINGS

TOTAL AREA = 1.66 SQ. IN.

FIGURE 5.- MODEL 131 DETAILS OF STEP AND VENTILATION OPENINGS.

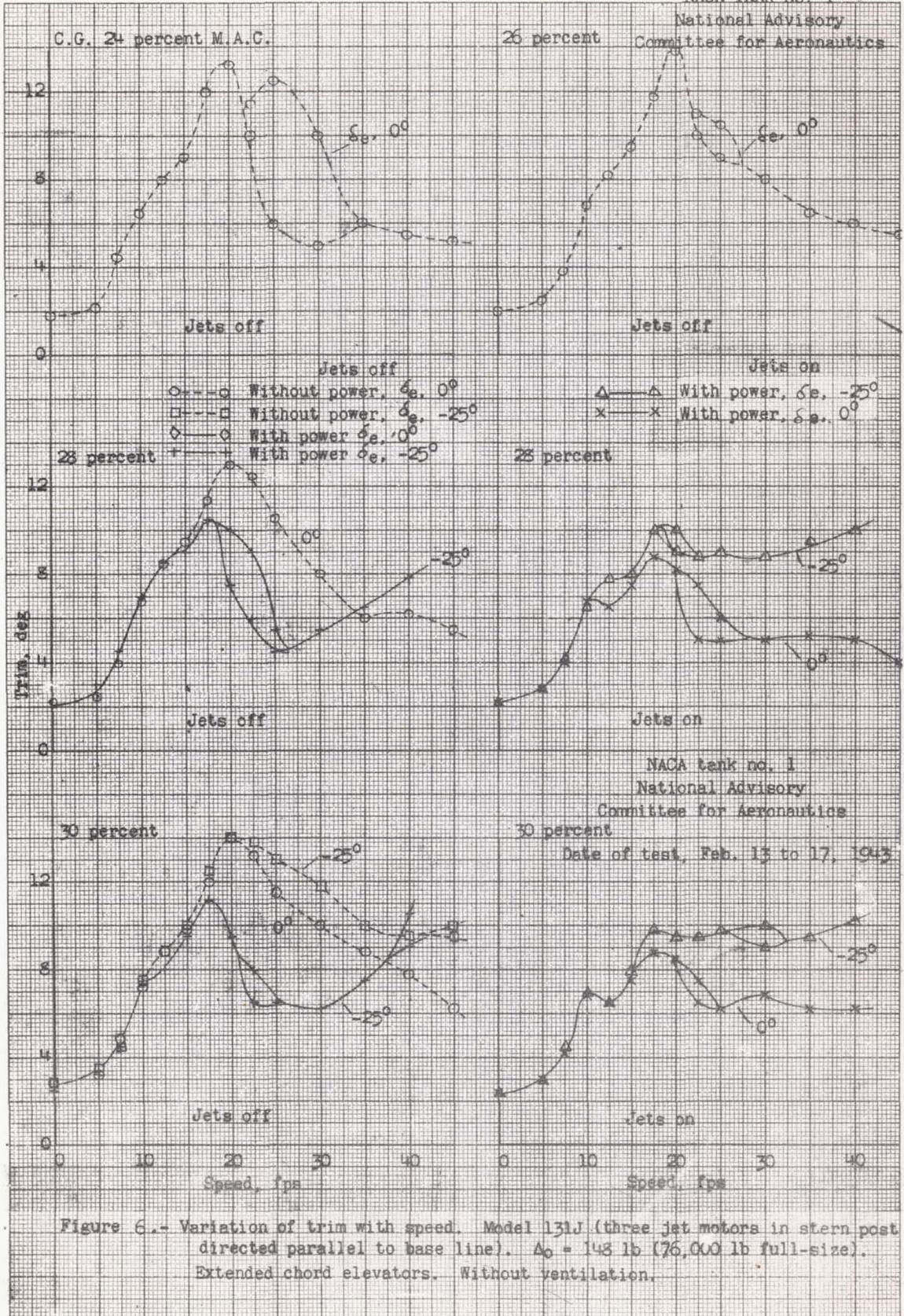


Figure 6.- Variation of trim with speed. Model 131J (three jet motors in stern post directed parallel to base line). $A_0 = 143$ lb (76,000 lb full-size). Extended chord elevators. Without ventilation.

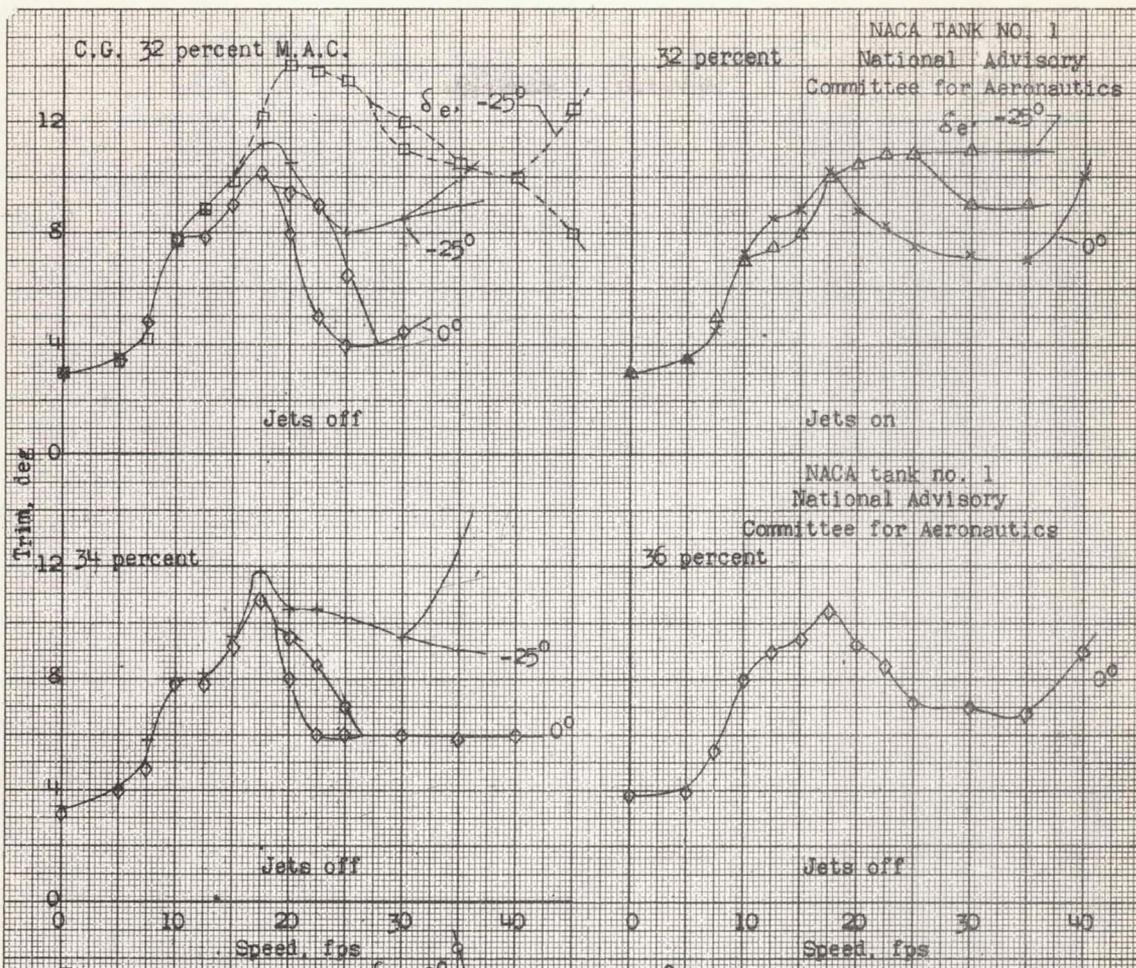


Figure 6.- Concluded.

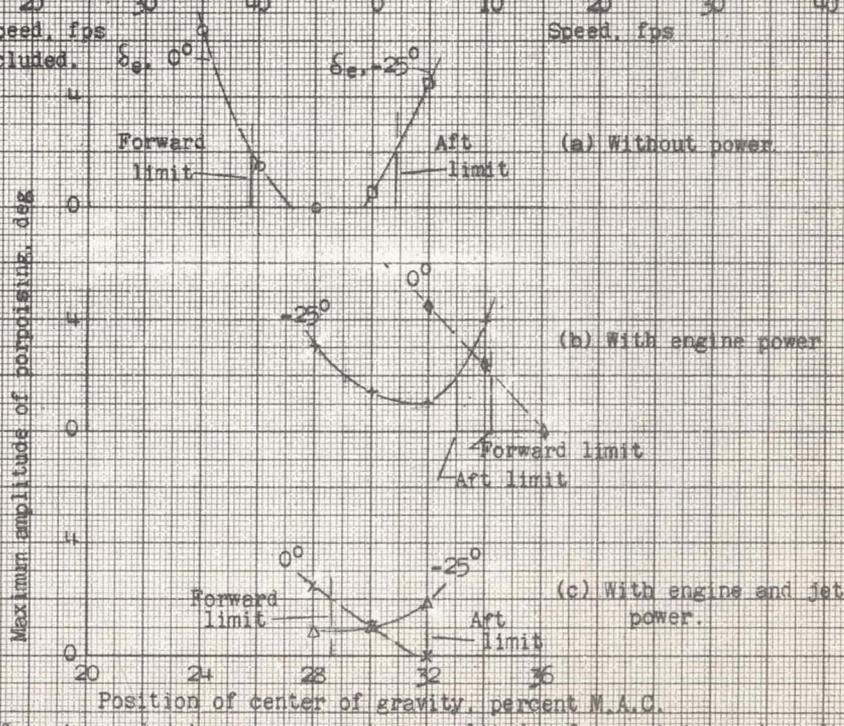


Figure 7.- Effect of engine and jet power on maximum amplitude of porpoising. $A_0 = 148$ lb (76,000 lb full-size). Extended chord elevators. Without ventilation.

Date of test, Feb. 18 and 19, 1943

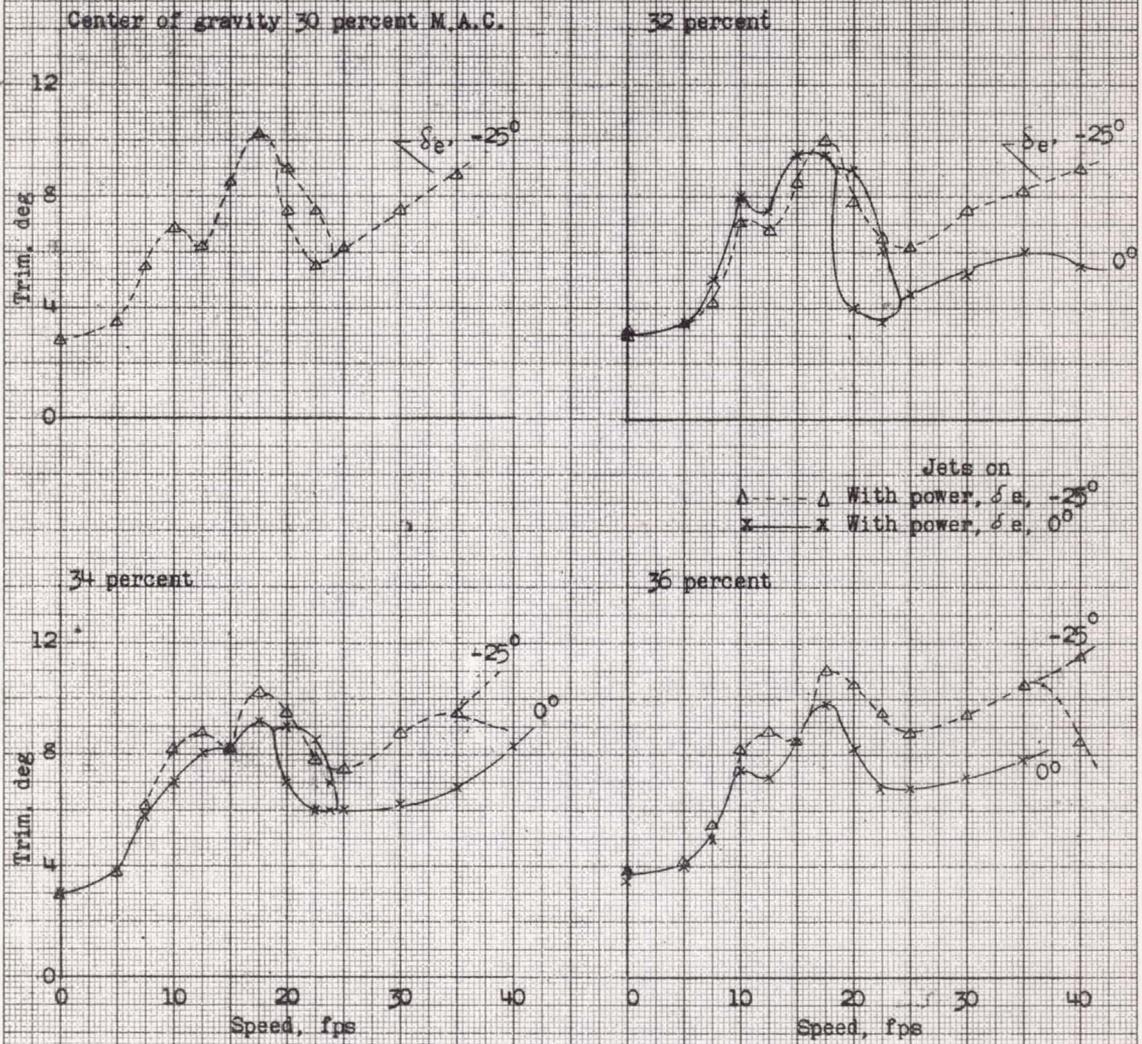


Figure 8. - Variation of trim with speed. Model 131J-1 (three jet motors in stern post directed 15° down relative to base line). $\Delta_0 = 148$ lb (76,000 lb full-size). Extended chord elevators. Without ventilation.

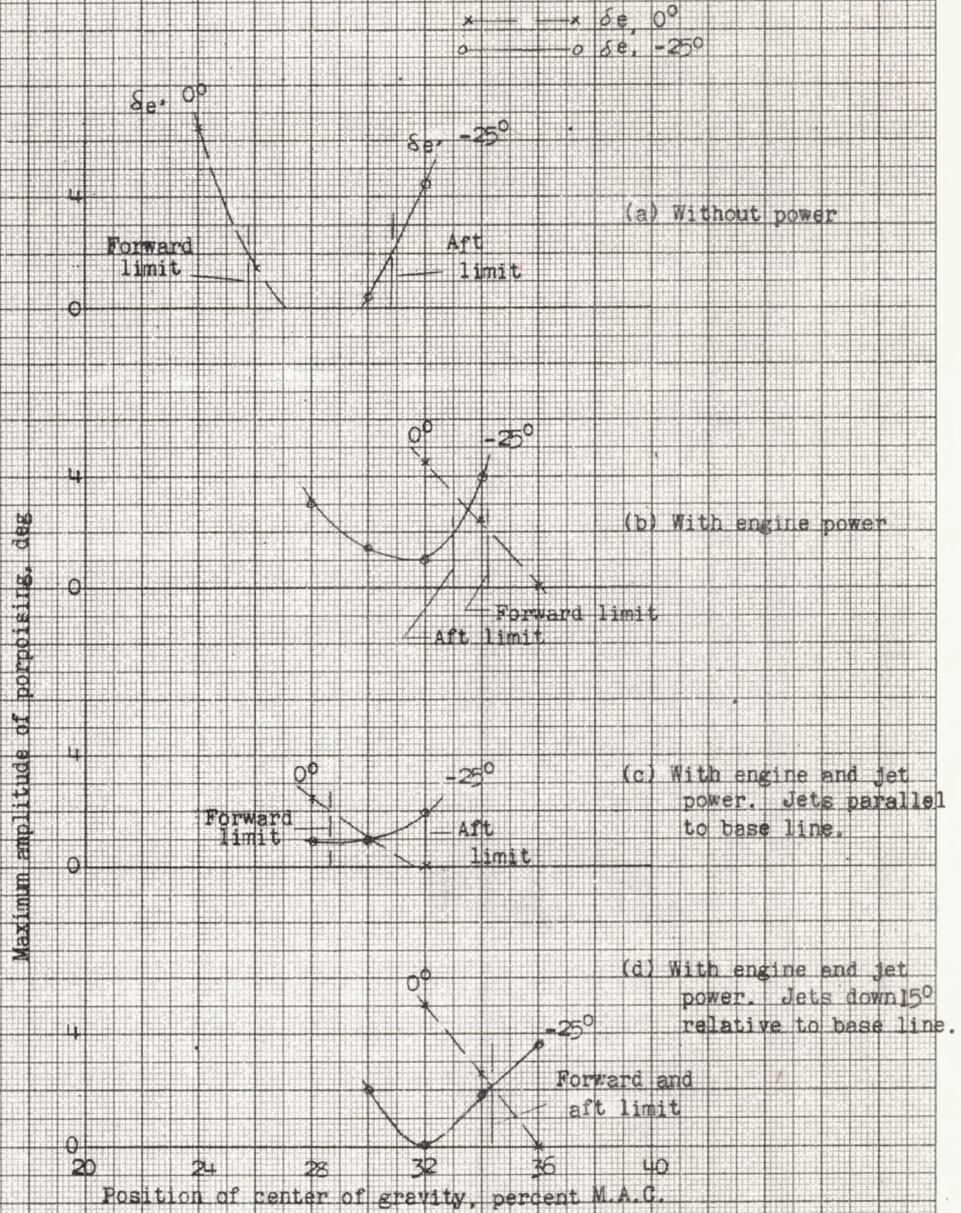
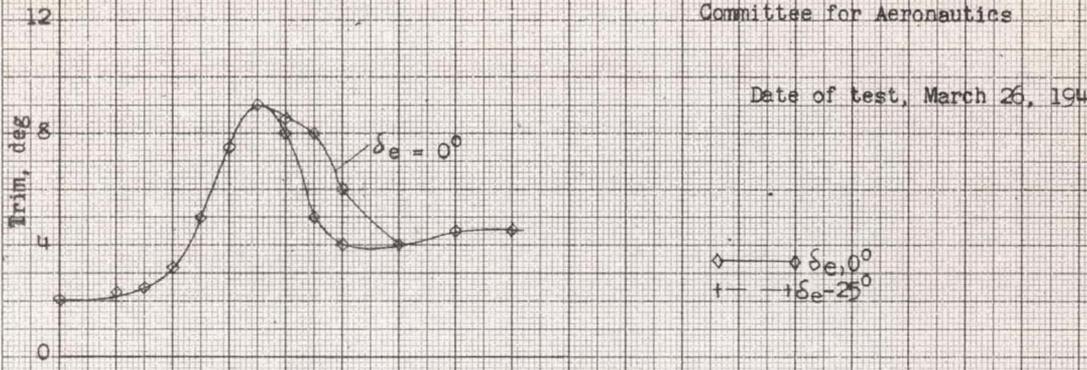


Figure 9.- Effect of engine and jet power on maximum amplitude of porpoising. $\Delta_0 = 148$ lb (76,000 lb full-size).
 Extended chord elevators. Without ventilation.

Center of gravity, 28 percent M.A.C.

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Date of test, March 26, 1943



c.g. 30 percent

c.g. 32 percent

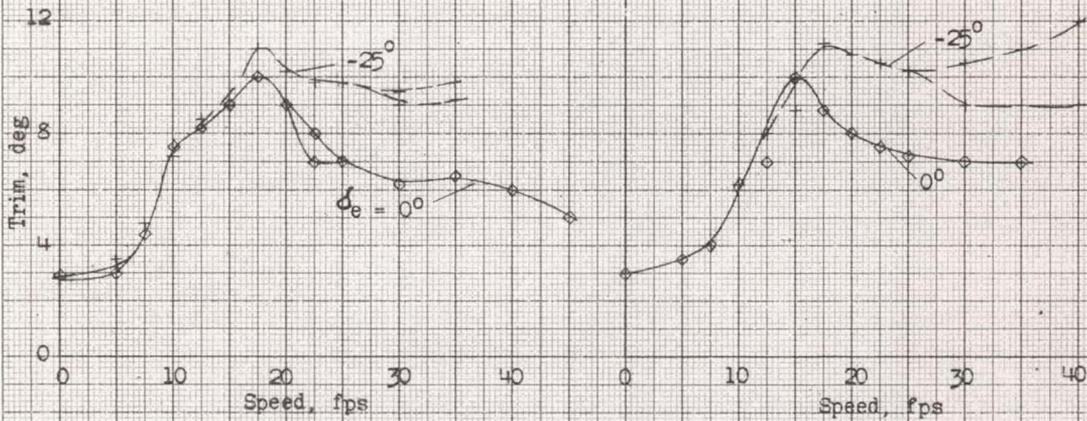
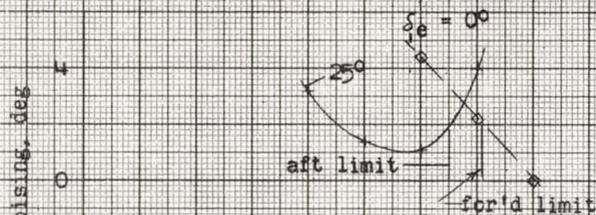
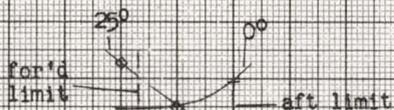


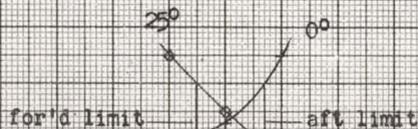
Figure 10.- Variation of trim with speed. Model 131J-2 with jet and engine power. $\Delta_0 = 148$ lb (76,000 lb full size). Flaps 40° . Extended chord elevators. Without ventilation.



(a) Model 131J (3 jets in common vertical plane at stern post) with engine power.



(b) Model 131J with engine and jet power.



(c) Model 131J-2 (1 jet in center plane at stern post, 2 jets in sides of afterbody) with engine and jet power.

Figure 11.- Effect of jet power on maximum amplitude of porpoising. Models 131J and 131J-2. Flaps 40°. Extended chord elevators. $\Delta_0 = 148$ pounds (76,000 pounds, full-size).

Center of gravity, 26 percent M.A.C.

NACA TANK NO. 1
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Date of test, March 26, 1943

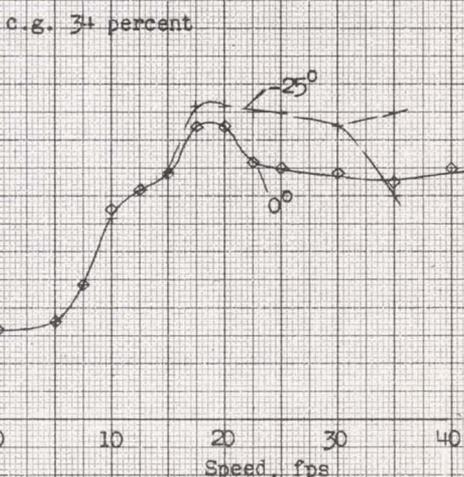
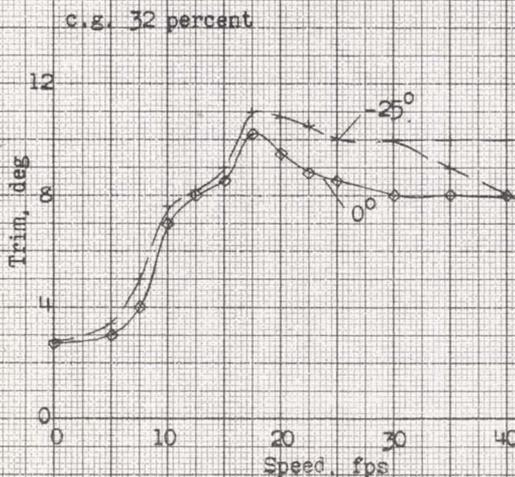
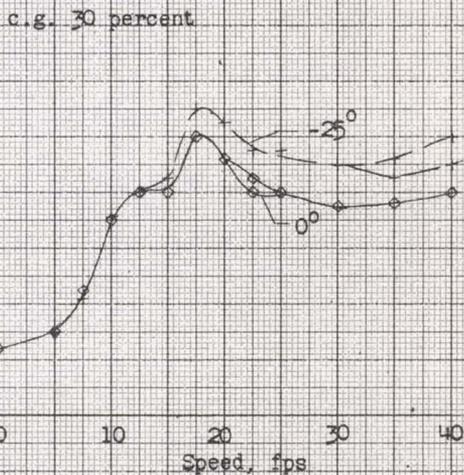
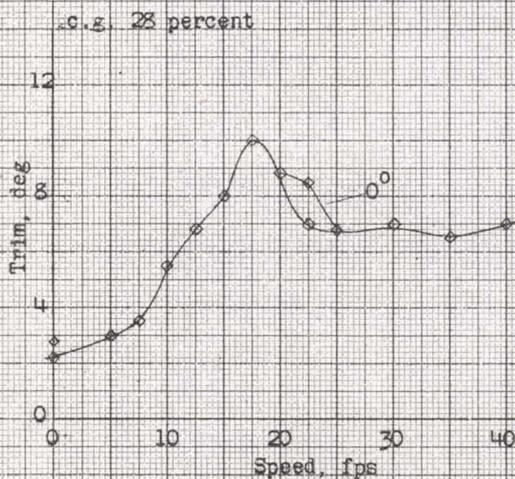
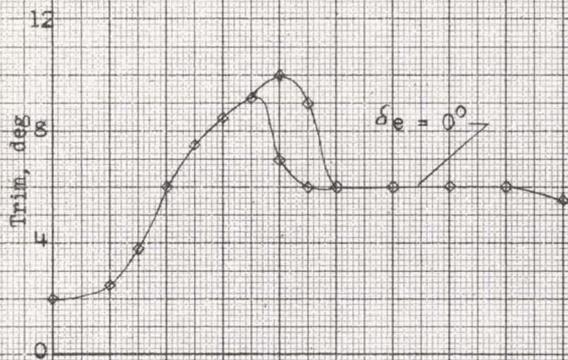


Figure 12.- Variation of trim with speed. Model 131J-2 with jet and engine power. $\Delta_0 = 148$ pounds (76,000 pounds, full-size). Flaps 20° . Scale elevators. With ventilation.

