RESEARCH MEMORANDUM

WIND-TUNNEL INVESTIGATION AT SUBSONIC AND SUPERSONIC SPEEDS OF A MODEL OF A TAILLESS FIGHTER AIRPLANE EMPLOYING A LOW-ASPECT-RATIO SWEPT-BACK WING - EFFECTS OF EXTERNAL FUEL TANKS AND ROCKET PACKETS ON THE DRAG CHARACTERISTICS

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
WASHINGTON
January 12, 1953
WIND-TUNNEL INVESTIGATION AT SUBSONIC AND SUPERSONIC SPEEDS OF A MODEL OF A TAILLESS FIGHTER AIRPLANE EMPLOYING A LOW-ASPECT-RATIO SWEEP-BACK WING - EFFECTS OF EXTERNAL FUEL TANKS AND ROCKET PACKETS ON THE DRAG CHARACTERISTICS

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SUMMARY

The effects of external fuel tanks and externally mounted rocket packets on the drag characteristics of a model of a tailless fighter airplane are presented in this report. The investigation was conducted through a Mach number range of 0.60 to 0.90 and 1.20 to 1.70 at a constant Reynolds number of 3.2 million. The measured lift, drag, pitching-moment, and rolling-moment coefficients and lift-drag ratios are presented in tabular form and the drag characteristics and lift-drag ratios are also presented in graphic form. In addition, pressure distribution data are tabulated which may be used to determine the influence of the external stores on the wing load distribution at supersonic speeds.

Results of this investigation show that the addition of two external fuel tanks and four faired rocket packets to the model produced drag increments which increased from 30 percent to 50 percent of the drag of the basic model between Mach numbers of 0.60 and 0.90, respectively, while at supersonic Mach numbers this drag increment was approximately 30 percent of the drag of the basic model. Tests of the model fitted with four rocket packets indicate that the drag may be reduced at subsonic speeds by fairing the open rocket packets, but at supersonic speeds the faired packets produced more drag. A small decrease in drag was realized at supersonic speeds, for the model fitted with two fuel tanks and four rocket packets, by mounting the outboard packets and fuel tanks in a more forward chordwise position with respect to the wing.

INTRODUCTION

Knowledge of the increases in drag to be expected from the addition of externally mounted fuel tanks and armament under the wings and fuselage becomes increasingly important as the trend continues toward long-range, high-speed fighter airplanes carrying rocket-propelled armament. An
investigation of the effects of this type of external installation on
the aerodynamic characteristics of a model having a low-aspect-ratio
swept-back wing has been conducted in the Ames 6- by 6-foot supersonic
wind tunnel. The model was fitted with various combinations of under-
the-wing type rocket-packet and fuel-tank installations and tested at
subsonic and supersonic Mach numbers at a constant Reynolds number. Two
chordwise locations of the fuel tanks and rocket packets were investigated
and the rocket packets were tested with the ends of the packets faired
smooth and with the rocket tubes open. The results of this investigation
are presented herein. The results of an investigation of the stability
and control characteristics of this same model conducted in the Ames
6- by 6-foot supersonic wind tunnel are presented in reference 1.

NOTATION

The lift, drag, and pitching-moment coefficients are referred to
the stability axes with the origin at the quarter-chord point of the
mean aerodynamic chord projected to the fuselage center line.
Rolling-moment coefficients are referred to the fuselage longitudinal
axis.

\begin{align*}
b & \quad \text{wing span, feet} \\
c & \quad \text{local wing chord measured parallel to plane of symmetry, feet} \\
c & \quad \text{wing mean aerodynamic chord} \left( \frac{\int_0^{b/2} c^2 dy}{\int_0^{b/2} c \, dy} \right), \text{feet} \\
C_D & \quad \text{drag coefficient} \left( \frac{\text{drag}}{qS} \right) \\
C_D & \quad \text{increment of drag coefficient due to external-store installation}
\quad \text{or fuselage modification based on total wing area} \\
\quad \left( C_{D_{\text{model + store}}} - C_{D_{\text{model}}} \right) \\
C_L & \quad \text{lift coefficient} \left( \frac{\text{lift}}{qS} \right) \\
C_l & \quad \text{rolling-moment coefficient} \left( \frac{\text{rolling moment}}{qSb} \right) \\
C_m & \quad \text{pitching-moment coefficient} \left( \frac{\text{pitching moment}}{qSc} \right) \\
C_P & \quad \text{static pressure coefficient} \left( \frac{P - P_0}{q} \right) \\
L/D & \quad \text{lift-drag ratio}
\end{align*}
(\frac{L}{D})_{\text{max}} \quad \text{maximum lift-drag ratio}

M \quad \text{free-stream Mach number}

p \quad \text{local static pressure, pounds per square foot}

P_{\text{o}} \quad \text{free-stream static pressure, pounds per square foot}

q \quad \text{free-stream dynamic pressure, pounds per square foot}

R \quad \text{Reynolds number, based on the mean aerodynamic chord}

S \quad \text{total projected wing area, including area formed by extending leading and trailing edges to plane of symmetry, square feet}

Y \quad \text{spanwise distance from plane of symmetry, feet}

\alpha \quad \text{angle of attack of fuselage longitudinal axis, degrees}

APPARATUS

Wind Tunnel and Equipment

The present investigation was conducted in the Ames 6- by 6-foot supersonic wind tunnel. This is a closed-return, variable-pressure wind tunnel in which the pressure and Mach number can be continuously varied. The stagnation pressure can be varied from 2 to 17 pounds per square inch absolute and the Mach number can be varied from 0.60 to 0.90 and from 1.15 to 2.00. A complete description of the wind tunnel is given in reference 2.

The model was sting mounted with the pitch plane of the model horizontal in the wind tunnel to utilize the most uniform stream conditions. (See reference 2). A four-component electrical strain-gage balance, similar in design to that used in reference 3, was enclosed within the fuselage of the model. The aerodynamic forces and moments were registered by recording-type galvanometers calibrated by applying known loads to the balance.

Model

A model of a high-speed fighter airplane having a low-aspect-ratio, swept-back wing and a swept-back vertical tail but not horizontal tail was used in this investigation (fig. 1). A bubble-type canopy was faired into a dorsal fin which extended back to the vertical tail. Provisions
were made for fairing the vertical tail into the fuselage when the canopy and dorsal fin were removed. The wing had a leading-edge sweep angle of 52.5° and a taper ratio of 0.332 based on the theoretical wing tip. The wing was composed of symmetrical sections in streamwise planes having a thickness of 7.0 percent of the chord at the wing root tapering to 4.5 percent of the chord at the theoretical wing tip.

The model was fitted with inlets housed in wing-body juncture fairings with internal ducts allowing the air to flow through and exhaust at the rear of the fuselage. In this investigation the mass flow of air through the ducts was not adjustable; however, the ducts were constructed so that at supersonic speeds the exit was choked, limiting the inlet Mach number to 0.4. In order to accommodate the annular duct exit and the mounting sting, the boattailing on the model was somewhat less than would be expected on a full-scale airplane.

Rocket packets and fuel tanks were provided, to be attached to the wings in the locations shown in figures 2 and 3. The outboard rocket packets and the fuel tanks were mounted on unswept and swept-forward pylons as shown in figures 2 and 3. The purpose of the swept-forward pylons was to obtain a more forward location of these stores. The rocket packets were tested both with the fore and aft ends of the rocket packet faired smooth and with six holes open through the packet, to simulate conditions before and after firing the rockets.

Provisions were made to measure pressure distribution data at five spanwise stations as shown in figure 4. The location of the orifices on the upper and lower surfaces of the port wing are given in table 1.

TESTS AND PROCEDURE

As a basis for comparison, tests were made of the basic model with canopy and dorsal fin in place and with no external stores installed. Lift, drag, pitching-moment, and rolling-moment data were obtained at Mach numbers of 0.60, 0.80, 0.90, 1.20, 1.35, 1.50, and 1.70 at a constant Reynolds number of 3.2 million, through an angle of attack range of -2° to +8°. Similar data were then obtained at corresponding test conditions for the following model configurations:

1. Basic model fitted with inboard and outboard faired rocket packets mounted on unswept pylons

2. Basic model fitted with inboard and outboard open-tube rocket packets mounted on unswept pylons

3. Basic model fitted with two external fuel tanks mounted on unswept pylons
4. Basic model fitted with inboard and outboard faired rocket packets and two external fuel tanks all mounted on unswept pylons

5. Basic model fitted with outboard faired rocket packets and two external fuel tanks mounted on swept pylons and inboard faired rocket packets mounted on unswept pylons

6. Basic model with canopy and dorsal fin removed (no external stores)

Pressure distribution data were obtained for the basic model and for the model fitted with four faired rocket packets mounted on straight pylons. These tests were conducted at Mach numbers of 1.20, 1.30, and 1.70 at a Reynolds number of 2.0 million. Data were obtained through an angle-of-attack range of $-3^\circ$ to $+12^\circ$ at $2^\circ$ increments for the basic model and $4^\circ$ increments for tests of the model fitted with the rocket packets. A tabulation of the test conditions is presented in table II.

Reduction of Data

The test data have been reduced to standard NACA coefficient form based on the total projected wing area including the area in the region formed by extending the leading and trailing edges to the plane of symmetry (fig. 1). Factors which could affect the accuracy of these results and the corrections applied are discussed in the following paragraphs.

Angle of attack. - The determination of the actual angle of attack of the model under load required several corrections to be applied to the nominal angle. Corrections, determined from static load calibrations, were applied for the angular deflection of the sting and balance under aerodynamic load and for the angular movement due to structural clearance in the model support and balance. These corrections amounted to from 5 to 10 percent of the nominal angle, depending on the load.

Tunnel-wall interference. - Corrections to the data for the effects of the tunnel walls at subsonic speeds were made by the method of reference 4. These corrections which were added to the data were as follows:

\[
\Delta \alpha = 0.377 C_L \\
\Delta C_D = 0.0066 C_L^2
\]

The reflected bow wave did not intersect the model and so no tunnel-wall corrections were made for supersonic Mach numbers.
The effect of constriction of the flow at subsonic speeds due to the presence of the model was taken into account by the method of reference 5. This correction was calculated for conditions of zero angle of attack and was applied through the angle-of-attack range. At a Mach number of 0.90, this correction amounted to a 1-percent increase in Mach number and dynamic pressure over those values determined from calibrations of the wind tunnel without a model in place.

Support interference. - Results of a wind-tunnel test of a similar model (reference 6) show that the effects of support interference consisted primarily of a change of pressure at the base of the model. In this test the base pressure was measured and corrections were applied to adjust the pressure at the base to free-stream static pressure.\(^1\) The drag values are, therefore, forebody drag coefficients.

Stream variations. - Tests were made at subsonic and supersonic speeds with the model in upright and inverted attitudes. Results of these tests showed no measurable indications of stream angle or stream curvature in the horizontal plane of the wind tunnel. Stream surveys of the Ames 6- by 6-foot supersonic wind tunnel (reference 2) show some curvature in the vertical plane of the wind tunnel, but the results of a subsequent investigation (reference 7) indicate that this curvature has little effect on the longitudinal aerodynamic characteristics of the model when pitched in the horizontal plane.

Internal duct drag. - The model was equipped with twin ducts through which air could flow. However, provisions were not made to vary the mass flow, so a study of the duct drag characteristics was not feasible in this investigation. The drag data presented herein are for the complete model; that is, the drag due to flow through the ducts has not been subtracted from the final drag coefficients.

Precision of Data

The accuracy of the test results, excluding stream effects, is shown by the repeatability of the data. Examination of the results showed the data to repeat with the accuracy shown in the following table:

\(^1\) The base area used in this investigation was the entire base area of the model less the duct exit area.
The precision of the data presented herein is superior to that of the data in reference 1 because these data were obtained for a consecutive series of tests in the wind tunnel and the mounting of the model and balance was unchanged during this investigation.

RESULTS AND DISCUSSION

Only the data pertinent to a study of the effects of external fuel tanks and rocket packets on the drag characteristics of the model are discussed in this report. All the force and moment data obtained from these tests, including lift and rolling-moment coefficients and lift-drag ratio, are presented in table III, however. In addition, experimental static pressure coefficients obtained at Mach numbers of 1.20, 1.30, and 1.70 for the basic model and for the model fitted with four rocket packets are presented in table IV. Comparison of the data from these pressure distribution tests gives an indication of the effects of the rocket-packet installation on the air loads experienced by the model.

The effects of external stores on the drag characteristics of the model are presented in this report as the increments of drag coefficient incurred by the addition of external stores. Figure 5 presents the variation of drag coefficient with lift coefficient for the basic model at Mach numbers of 0.60, 0.80, 0.90, 1.20, 1.35, 1.50, and 1.70. As previously mentioned, the drag coefficients presented in this report include the internal duct drag. The increments of drag coefficient for the various store installations investigated are shown in figure 6 as a function of Mach number for 0 and 0.25 lift coefficients. This figure shows that at subsonic speeds the drag increment resulting from the addition of four rocket packets was somewhat less when the packets were faired, but at supersonic speeds fairing the packets increased the drag. The drag increments for two fuel tanks and four rocket packets, mounted in the aft chordwise location (unswept pylons), varied from approximately 30 percent of the drag of the basic model at a Mach number of 0.60 to 50 percent at
a Mach number of 0.90. For Mach numbers of 1.20 to 1.70 the drag increment for these same external-store configurations was approximately 30 percent of the drag of the basic model. Results of tests of the model with the stores mounted in two chordwise locations showed that the change in chordwise location had no significant effect on the drag at subsonic speeds. At supersonic speeds, however, the drag increment resulting from the addition of two fuel tanks and four rocket packets was somewhat smaller for the forward chordwise location (swept pylons).

The maximum lift-drag ratios for all the configurations tested are shown in figure 7 as a function of Mach number. These data are for the unbalanced model.

Results of this investigation show that the addition of external stores could appreciably affect the trim drag of the model. This effect is illustrated in figure 8 which shows the variation of pitching-moment coefficient with lift coefficient for the basic model and for the model fitted with two external fuel tanks and four rocket packets. The magnitude of the pitching-moment coefficient at zero lift for the basic model was quite small at all Mach numbers, but the model fitted with external stores showed a significant negative pitching moment at subsonic speeds and a positive pitching moment at supersonic speeds. These pitching moments, associated with the installation of external stores on the model, significantly influence the deflection of the longitudinal control surface required for a specific flight condition. Thus it should be noted that the drag coefficients presented for this investigation are for the unbalanced model and that the total drag for the model balanced with a control device will include an additional drag increment or decrement due to the change in control setting required to counteract the aerodynamic influence of the external store. Pitching-moment characteristics are shown for the model fitted with two fuel tanks and four rocket packets because they exhibit the most pronounced effects of external stores of all the configurations investigated.

CONCLUSIONS

The following conclusions are based on a wind-tunnel investigation of the effects of external fuel tanks and externally mounted rocket packets on the drag characteristics of a model of a tailless fighter airplane:

1. The drag increase resulting from the addition of two external fuel tanks and four faired rocket packets varied from 30 percent of the drag of the basic model at 0.60 Mach number to 50 percent of the drag of the basic model at 0.90 Mach number. At Mach numbers of 1.20 to 1.70, this drag increment was approximately 30 percent of the drag of the basic model.
2. The drag coefficient, at subsonic speeds, for the model fitted with four faired rocket packets was smaller than with four open rocket packets. At supersonic speeds the four faired packets produced greater drag increments than the open packets.

3. The drag coefficients for the model fitted with two fuel tanks and four faired rocket packets were somewhat less, at supersonic speeds, with the outboard rocket packets and fuel tanks in a forward chordwise location. At subsonic speeds the chordwise location caused no significant effect on the drag characteristics.

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REFERENCES


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**Table III - Concluded**
### TABLE IV. EXPERIMENTAL PRESSURE COEFFICIENTS, $C_p$

*(a) Basic model, $M = 1.2$*

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**Note:** Additional data not shown due to truncation.
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**Note:**

This table lists values for various parameters. Each row represents a different set of values for three variables, with the specific values provided in the table.

**Table III - Continued**

---

The table continues with additional rows, each providing a set of values for the parameters.
### Table IV. - Experimental Pressure Coefficients, $C_p$

(a) Basic model, $M = 1.2$

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(Continued on subsequent pages)
TABLE IV.-- CONTINUED
(b) Basic model, $M = 1.3$

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### TABLE IV. - CONTINUED

(c) Basic model, $M = 1.7$

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NACA RM A52J31
### TABLE IV.- CONTINUED

(d) Model with rocket packets, \( M = 1.2 \)

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**TABLE IV.** - CONTINUED
(c) Model with rocket packets, $M = 1.3$

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### Table IV—Concluded

(f) Model with rocket packets, $M = 1.7$

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Note: The table continues with similar entries for different orifice numbers and angles of attack.
Wing area, 1,682 square feet

All dimensions shown in inches unless otherwise noted

Figure 1: Three-view drawing of the model showing the external fuel tanks and rocket packets.
Figure 2.—Details of the external fuel tanks with unswept and swept pylons.
Note: rocket packet shown with open tubes

Unswept pylon

All dimensions shown in inches unless otherwise noted

Swept pylon

(a) Outboard location.

Figure 3.- Details of the rocket packets with unswept and swept pylons.
Model plane of symmetry

Wing reference plane

fuselage contour

1.65

1.76

Section A-A

All dimensions shown in inches unless otherwise noted

10.74 aft of fuselage nose

92°

2°

1.27

1.76

2.04

4.76

center of gravity

(b) Inboard location.

Figure 3. - Concluded.
Figure 4.—Dimensional sketch of the lower surface of the model with rocket packets installed, showing the pressure survey stations.
Figure 5.- Variation of drag coefficient with lift coefficient for the basic model.
Figure 6.- Variation of increment of drag coefficient with Mach number at 0 and 0.25 lift coefficient for the various external store configurations mounted on the model.
Figure 6.—Concluded.
Figure 7.- Variation of the maximum lift-drag ratio with Mach number for the various external store configurations mounted on the model.
Figure 8.—Variation of pitching-moment coefficient with lift coefficient for the basic model and for the model fitted with two external fuel tanks and four faired rocket packets mounted on unswept pylons.