SERVICE REPORT

NACA

Declassified: Authority of NASA
Classification Change Notices No. 43
Dated 2/1/63

RESEARCH MEMORANDUM

for the

DECLASSIFIED: AUTHORITY:

ATS 480
DBRKA TO LEBCH
MEKG DATED 3/2/13/65

U.S. Air Force

STATIC LATERAL AND DIRECTIONAL STABILITY AND CONTROL
CHARACTERISTICS OF A REVISED 1/22-Scale Model
OF THE REPUBLIC F-105 AIRPLANE AT MACH
NUMBERS OF 1.41 AND 2.01

COORD NO. AF-163

By Ross B. Robinson and Gerald V. Foster

Langley Aeronautical Laboratory
Langley Field, Va.

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS
WASHINGTON

NOV 19 1956

CONFIDENTIAL
An investigation has been conducted in the Langley 4- by 4-foot supersonic pressure tunnel at Mach numbers of 1.41 and 2.01 to determine the static lateral and directional stability and control characteristics of a revised 1/22-scale model of the Republic F-105 airplane. This revised configuration, which retained the 45° swept wing of aspect ratio 3.2, supersonic twin wing-root inlets, and horizontal tail of the original model, had a lengthened fuselage with a contoured afterbody, a relocated canopy, a larger vertical tail, and a ventral fin. The effects of various vertical tails and ventral fins, wing-tip fences, a canopy fin, fuselage nose shape, external stores, and deflection of the horizontal tail, spoiler, and rudder were investigated.

The models were tested through an angle-of-attack range from about -6° to 18° at sideslip angles of -5.4°, 0°, and 5.8° and through an angle-of-sideslip range from about -6° to 19° at angles of attack of approximately 0°, 5°, 10°, and 15°. The revised configuration had considerably greater directional stability than the original configuration. Although the directional stability of both complete configurations progressively decreased with increasing Mach number or angle of attack, the onset of directional instability for the revised configuration was delayed to higher Mach numbers or angles of attack. Addition of the wing stores increased the directional stability, whereas the fuselage store, alone or in combination with the wing stores, decreased the directional stability.
INTRODUCTION

At the request of the U. S. Air Force an investigation has been made in the Langley 4- by 4-foot supersonic pressure tunnel to determine the aerodynamic characteristics of a 1/22-scale model of the Republic F-105 airplane at supersonic speeds. The results of the initial phase of this investigation at a Mach number of 2.01 are reported in reference 1. Subsequent modifications to the fuselage and vertical tail were incorporated to reduce the drag and improve the directional stability. The effects of these modifications at Mach numbers of 1.41 and 2.01 and of several arrangements of external stores at a Mach number of 1.41 on the aerodynamic characteristics in pitch are presented in reference 2.

This report contains the static lateral and directional stability and control characteristics of the revised F-105 model at Mach numbers of 1.41 and 2.01. The effects of various vertical tails, a reconnaissance-fighter nose configuration, and the deflection characteristics of several trim and control surfaces are shown at both Mach numbers. The effects of several external-store arrangements and ventral fins are presented for a Mach number of 1.41. For the purpose of comparison, lateral characteristics of a configuration similar to a prototype configuration previously investigated are presented. The tests were made at Reynolds numbers of $0.79 \times 10^6$ and $0.64 \times 10^6$ based on the mean aerodynamic chord, for Mach numbers of 1.41 and 2.01, respectively.

COEFFICIENTS AND SYMBOLS

The data are referred to the stability-axis system (fig. 1) with the moment center located on the fuselage reference line at a longitudinal fuselage station corresponding to the 0.25 mean geometric chord of the wing (fig. 2). The coefficients and symbols are defined as follows:

\[
C_L \quad \text{lift coefficient, } \frac{-F_Z}{qS}
\]

\[
C_X \quad \text{longitudinal-force coefficient (-drag at zero sideslip), } \frac{-F_X}{qS}
\]

\[
C_m \quad \text{pitching-moment coefficient, } \frac{M_Y}{qSc}
\]

\[
C_l \quad \text{rolling-moment coefficient, } \frac{M_X}{qSb}
\]
$C_n$ yawing-moment coefficient, $\frac{M_z}{qSb}$

$C_Y$ side-force coefficient, $\frac{F_Y}{qS}$

$F_Z$ force along Z-axis (-lift)

$F_X$ longitudinal force (-drag at zero sideslip)

$F_Y$ side force

$M_X$ rolling moment

$M_Y$ pitching moment

$M_Z$ yawing moment

$b$ wing span

$\bar{c}$ wing mean geometric chord (mean aerodynamic chord)

$S$ total wing area, including fuselage intercept

$M$ Mach number

$\alpha$ angle of attack, deg

$\beta$ angle of sideslip, deg

$\delta_S$ spoiler deflection, left wing, normal to hinge line, positive when trailing edge moves up, deg

$\delta_r$ rudder deflection, normal to hinge line, positive when trailing edge moves left, deg

$\delta_t$ horizontal-tail incidence angle, measured with respect to fuselage reference line, positive when trailing edge moves down, deg

$\delta_f$ leading-edge flap deflection both flaps normal to hinge line, positive when nose moves down, deg

$\delta_t$ trim-tab deflection, measured from chord line parallel with plane of symmetry, deg

$\delta_{fin}$ canopy-fin deflection, normal to vertical center line, positive when trailing edge moves left, deg

$C_{l\beta} = \frac{\partial C_l}{\partial \beta}$, effective dihedral parameter
\[ C_n = \frac{\partial C}{\partial \alpha}, \text{ directional-stability parameter} \]

\[ C_Y = \frac{\partial C}{\partial \beta}, \text{ side-force parameter} \]

Model designations:

H \hspace{1cm} \text{horizontal tail}

U_1, U_2, U_3, U_4 \hspace{0.5cm} \text{ventral fins (fig. 3(c))}

V_1, V_2, V_3, V_4 \hspace{0.5cm} \text{vertical tails (figs. 3(a) and 3(b))}

MODEL AND APPARATUS

A three-view sketch of the models investigated is presented in figure 2. Details of the various vertical and ventral fins, the control and trim surfaces, wing fences, external-store arrangements, and the RF (reconnaissance-fighter) nose and stores are shown in figure 3. Photographs of the model are presented in figure 4. Geometric characteristics of the model are presented in table I.

Two model configurations were tested (fig. 2). The original configuration had transonic inlets, a cylindrical afterbody, and a small vertical tail \( (V_0, \text{fig. 3(a)}) \). The revised configuration had supersonic inlets, a longer fuselage with a contoured afterbody, and a larger vertical tail \( (V_1, \text{fig. 3(a)}) \). Both configurations had the same wing, horizontal tail, and ventral fin \( (U_1, \text{fig. 3(c)}) \). It should be noted that none of the configurations of the present investigation correspond exactly to any of the configurations of reference 1.

The model was equipped with a wing having 45° sweepback of the quarter-chord line, an aspect ratio of 3.2, a negative dihedral of 3.5°, and a taper ratio of 0.468. The airfoil sections varied from NACA 65A003.7 at the tips to NACA 65A005.5 just outboard of the inlet (0.38 wing semispan from the plane of symmetry). The wing was positioned slightly above the fuselage reference line (fig. 2). A manually set trim tab for roll control and an upper-surface spoiler were incorporated in the left wing panel (fig. 3(d)). Provision was made for mounting wing fences parallel to the plane of symmetry (fig. 3(g)) on both upper and lower surfaces of both wing panels at 0.95 semispan from the plane of symmetry. Leading-edge flaps (fig. 3(d)) were incorporated in both wing panels.
Both models were equipped with wing root inlets ducted to a single exit at the base of the fuselage. The original model had an inlet designed for transonic speeds, while the revised model inlet was modified for supersonic-speed operation (fig. 2). A small air-bleed port on each side of the fuselage under the wing could be opened to vent the internal duct from each inlet to the tunnel airstream (fig. 2). All tests were made with the jet exit open.

An all-movable, 45° swept horizontal tail was located 0.089 wing semispan below the wing root chord plane. In most cases the horizontal tail was deflected -3°; however, some tests included a horizontal-tail deflection of -16°.

Various vertical tails and ventral fins were provided (figs. 3(a), 3(b), and 3(c)). Only the vertical tail V₁ was equipped with a rudder. Vertical tails V₀ and V₁ were contoured to exact airfoil coordinates (NACA 65A006 at root and NACA 65A004 at tip); whereas, tails V₂, V₃, and V₄ were contoured to approximately the airfoil sections of tails V₀ and V₁. Ventral fins U₂, U₃, and U₄ were made of 1/8-inch sheet metal with the edges beveled. A small triangular canopy fin (fig. 3(f)), which was constructed of 1/8-inch sheet metal with beveled edges, could be located above the moment center, and was employed to alter the flow direction in the region of the vertical tail. Two types of pylon-mounted stores were tested: (1) a large fuselage store with three fins and (2) a smaller store without fins under each wing (fig. 3(h)).

All the control surface and flap deflections were set manually.

Forces and moments on the model were measured by a six-component internal strain-gage balance. Static-pressure orifices at the fuselage base and in the balance enclosure in addition to a total- and static-pressure rake at the exit of the internal duct were used to measure the static-pressure changes and internal flow.

The model was mounted on a sting which could be manually adjusted to provide tests of the model at combined angles of attack and sideslip (fig. 4(c)).
TESTS, CORRECTIONS, AND ACCURACY

Tests

The conditions for the tests were as follows:

Mach number ........................................ 1.41 2.01
Stagnation temperature, °F .......................... 100 100
Stagnation pressure, lb/sq in. abs .................. 5 5
Stagnation dewpoint, °F .............................. -25 -25
Reynolds number, based on c ..................... $0.79 \times 10^6$ $0.64 \times 10^6$

The tests were conducted through an angle-of-attack range from about
-6° to 18° at sideslip angles of -5.4°, 0°, 5.8° and through an angle-of-sideslip range from about -6° to 19° at angles of attack of approximately 0°, 5°, 10°, and 15°.

Corrections and Accuracy

The angles of attack and sideslip were corrected for deflection of
the balance and sting under load. No corrections have been applied to
the data for airstream angularity (less than $\pm 0.1°$ in the horizontal and
vertical plane) or the Mach number variation in the vicinity of the
model ($\pm 0.015$).

Base-pressure measurements were made and the longitudinal-force
coefficients were corrected to correspond to free-stream static pressure
at the base. The internal pressure of the model was measured and
corrections for a buoyant force on the balance were made. Internal drag
was determined from the change in momentum and static pressure from
free-stream conditions to the measured conditions at the duct exit. The
base drag, buoyant force, and internal drag have been subtracted from
the total drag to obtain the net external drag.

The maximum probable errors are estimated in the following table:

<table>
<thead>
<tr>
<th>Probable error in</th>
<th>Mach number</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_L$ ............</td>
<td>$\pm 0.0045$</td>
<td>$\pm 0.0056$</td>
<td>$\pm 0.0011$</td>
<td>$\pm 0.0013$</td>
</tr>
<tr>
<td>$C_X$ (for $C_L = 0$)</td>
<td>$\pm 0.0021$</td>
<td>$\pm 0.0026$</td>
<td>$\pm 0.0002$</td>
<td>$\pm 0.0002$</td>
</tr>
<tr>
<td>$C_m$ ............</td>
<td>$\pm 0.0001$</td>
<td>$\pm 0.0001$</td>
<td>$\pm 0.0001$</td>
<td>$\pm 0.0001$</td>
</tr>
<tr>
<td>$C_Y$ ............</td>
<td>$\pm 0.0012$</td>
<td>$\pm 0.0014$</td>
<td>$\pm 0.0012$</td>
<td>$\pm 0.0014$</td>
</tr>
<tr>
<td>$\alpha$, deg ........</td>
<td>$\pm 0.1$</td>
<td>$\pm 0.1$</td>
<td>$\pm 0.1$</td>
<td>$\pm 0.1$</td>
</tr>
<tr>
<td>$\beta$, deg ........</td>
<td>$\pm 0.1$</td>
<td>$\pm 0.1$</td>
<td>$\pm 0.1$</td>
<td>$\pm 0.1$</td>
</tr>
</tbody>
</table>
PRESENTATION OF RESULTS

An index to the data figures is presented in table II. The basic aerodynamic characteristics in sideslip are presented in figures 5 to 22. The lateral- and directional-control results are shown in figures 23 to 28. Summary figures of the sideslip derivatives are presented in figures 29 to 33 and the spoiler characteristics are summarized in figure 34. All the results are for \( \alpha_t = -3^\circ \) except in figure 16 which contains data for \( \alpha_t = -3^\circ \) and \(-16^\circ\).

DISCUSSION

Static Lateral and Directional Stability

Effect of vertical-tail plan form. - The aerodynamic characteristics in sideslip at several angles of attack for the configuration with various vertical tails as well as with the tail removed are presented in figures 5 and 6 for Mach numbers of 1.41 and 2.01, respectively. The sideslip parameters obtained from these figures are summarized in figure 29.

Increasing the size and aspect ratio of the vertical tail, of course, resulted in an increase in the side force and directional stability as well as an increase in the positive effective dihedral \((-C_{2\beta})\) at both Mach numbers (fig. 29). On the basis of estimated lift-curve slopes for the isolated vertical tails as obtained by the method of reference 3, the changes in side force at \( \alpha = 0^\circ \) are about what should be expected.

The variation of \( C_{np} \) with angle of attack indicates that the tail-off configuration is directionally unstable; however, this instability decreases with increase in angle of attack (fig. 29). For all tail-on configurations, however, a loss in vertical-tail effectiveness is indicated by the rapid decrease in directional stability with increasing angle of attack (configurations having vertical tails \( V_1 \) and \( V_3 \) became unstable above \( \alpha = 140^\circ \)). This opposing trend of increasing stability with the tail off and decreasing stability with the tail on is indicative of a wing-fuselage induced disturbance which is characteristic of configurations having the wing located in a position relatively high with respect to the fuselage crossflow pattern resulting from sideslip. (See ref. 4.) Such arrangements result in a favorable or stabilizing sideway below the center of the wing-body and an adverse sideway above. This disturbance remains essentially in the free-stream direction; hence, with increasing angle of attack the afterbody moves through a stabilizing sideway region into an undisturbed stream while the vertical tail moves down through an adverse sideway region.
The various vertical-tail plan forms investigated included changes not only in area, but also in aspect ratio (with attendant changes in tail lift-curve slope), and in the tail center of pressure (with attendant changes in tail moment arm). The resultant variations in side force and yawing moment with these tails, as previously pointed out, are about as expected at $\alpha = 0^\circ$. While there is little significant difference in the variation of $C_{nB}$ with $\alpha$ for the various tails, it might be of interest to point out that the increment in $C_{nB}$ provided by the extended-chord tail ($V_3$) decreases more rapidly at the highest angle of attack than does that provided by the extended-tip tails ($V_2$ and $V_4$). (See fig. 29.) This trend may result from the fact that most of the added area for the extended-chord tail remains in a region that might be affected by an adverse sidewash from the wing-fuselage disturbance, while that for the extended-tip tails remains above the region of disturbance.

Although the general trends in the sideslip derivatives are the same at both Mach numbers (fig. 29), the lower directional stability at the higher Mach number that results from the decreased vertical-tail lift-curve slope, presents a more critical problem.

Effect of ventral fins.- A comparison of the aerodynamic characteristics in sideslip at several angles of attack for the configuration with the revised vertical tail ($V_1$) both with and without the basic ventral fin ($U_1$) is presented in figures 7 and 8 for Mach numbers of 1.41 and 2.01, respectively.

The ventral fin is effective at both Mach numbers in increasing the side force and yawing moments and, to some extent, reduces the nonlinear variation of $C_n$ with $\beta$. In addition, the ventral fin causes a slight decrease in the rolling-moment variation with sideslip. Ventral fins of various plan forms and sizes were tested at $M = 2.01$ for the model with the revised vertical tail ($V_1$) (fig. 9) and two of the ventral fins were tested for the model with the extended-tip vertical tail ($V_2$) (fig. 10). The sideslip derivatives obtained from these tests are summarized in figures 30 and 31.

As might be expected, progressively increasing the size and aspect ratio of the ventral fin resulted in a progressive increase in the side force and yawing moment (figs. 7 and 8).

Effect of air bleed.- Some tests of the model with tail $V_4$ and fin $U_1$ were made through the angle-of-attack range at constant sideslip angles of $0^\circ$ and $-5.4^\circ$ with the duct air bleed open in order to determine if this opening had any effect on the sideslip characteristics (fig. 11).
Sideslip derivatives obtained from these results are compared in figure 32 with the slopes measured near $\beta = 0^\circ$ from the sideslip tests made for the model without the air bleed and indicate little significant effect of the open air bleed on the sideslip derivatives.

**Effect of wing-tip fences.** - Wing-tip fences were added to the configuration with vertical tail $V_1$ and ventral fin $U_1$ in an attempt to increase the directional stability by providing additional vertical surfaces to the rear of the center of gravity and by reducing the effect of the wing-tip vortices on the vertical tail. The results at $M = 2.01$ (fig. 12) indicate that the addition of the tip end plates increased the side force and yawing moments at $\alpha = 0^\circ$ and $15.4^\circ$ and caused some reduction in the positive effective dihedral at $\alpha = 15.4^\circ$. The addition of the end plates, although helpful, was not sufficient to prevent completely directional instability at the higher angles of attack.

**Effect of canopy fin.** - In an effort to find a means to increase the directional stability of the basic configuration (tail $V_1$), some tests were made at $M = 2.01$ with a small movable fin placed longitudinally near the center of moments on the upper surface of the fuselage (fig. 3(f)). The purpose of this fin was to create a stabilizing side-wash at the vertical tail. The results (fig. 13) indicate that the addition of the fin at zero deflection and zero angle of attack caused a slight decrease in directional stability. Since the direct forces on the fin act approximately at the center of moments it is probable that this slight decrease in stability results from the sidewash component of vorticity at the tail resulting from the increase in angle of attack of the fin as the model sideslips. Negative deflections of the fin, as shown by the results, would also be expected to produce a destabilizing moment even at $\beta = 0^\circ$ since such deflections would induce a sidewash velocity component in the positive side-force direction at the vertical tail. The reverse, of course, is true for positive fin deflections.

Such a device as the canopy fin might be used for directional-stability augmentation when linked to a yaw-sensing vane in such a way as to provide positive fin deflections with positive sideslip. A ratio of fin deflection to sideslip angle of about 10 to 1, for example, would double the value of $C_{n\beta}$ at $\alpha = 0^\circ$. At $\alpha = 15.4^\circ$ near $\beta = 0^\circ$ the deflection ratio of 10 to 1 would be sufficient to change the unstable condition of $C_{n\beta}$ to a condition of essentially neutral stability.

**Effect of fuselage nose shape.** - The effect of modifying the nose to represent an RF - or reconnaissance - type of nose is presented in figures 14 and 15 for Mach numbers of 1.41 and 2.01, respectively. There was a small reduction in the yawing-moment coefficients for the complete model with the RF nose at $M = 1.41$ while at $M = 2.01$ the nose change
had essentially no effect on the sideslip characteristics of the wing-fuselage-horizontal-tail configuration.

**Effect of horizontal-tail incidence.** The effect of horizontal-tail deflection on the sideslip characteristics was determined for only two deflections (-30° and -16°) at \( \alpha = 15.4° \) and \( M = 2.01 \) for the configuration with the enlarged vertical tail \( V_4 \) and ventral fin \( U_1 \). These limited results (fig. 16) indicate a slight increase in directional stability and a slight decrease in the effective dihedral. This trend is in agreement with that demonstrated by other configurations having low horizontal tails. (See ref. 5, for example.) At lower Mach numbers, where a greater portion of the fuselage and vertical tail would be in the flow field of the horizontal tail, a larger effect would be expected. Unpublished results from tests conducted in the Langley 4- by 4-foot supersonic pressure tunnel for a similar configuration indicate significant changes in the pressure distribution on the vertical tail due to deflection of a low horizontal tail mounted below the fuselage.

**Effect of leading-edge flap.** The leading-edge flaps deflected 7.5° had only very slight effects on the sideslip characteristics of the basic configuration at \( \alpha = 15.4° \) and \( M = 2.01 \) (fig. 17).

**Effect of external stores.** Some effects of wing and fuselage store installations were determined at \( M = 1.41 \) only. The effects of these stores, both independently and in combination, on the sideslip characteristics of the configuration with the enlarged vertical tail (tail \( V_4 \) and ventral fin \( U_1 \) at \( \alpha = 10.4° \) and 15.7°) are shown in figure 18. The addition of each store arrangement resulted in an increase in the side force. The fuselage store, however, being located slightly forward of the moment reference point, produced a large decrease in the directional stability, whereas the wing stores, being slightly aft of the moment reference point, provided a substantial increase in directional stability. The significance of this effect is most evident at \( \alpha = 15.7° \) where the configuration becomes directionally unstable with the fuselage store while becoming markedly stable with the wing stores. The arrangement having the wing and fuselage stores together results in some decrease in stability with the resultant yawing moments being approximately the summation of the yawing moments for the store arrangements individually.

There is an increase in the positive dihedral effect for the arrangements having the wing stores in spite of the increased side force beneath the roll axis. It is possible that this results from a loss in lift on the trailing wing in sideslip that is induced by the presence of the store. The addition of the fuselage store alone had little effect on the roll characteristics.
Comparison of the effects of the fuselage store on the configurations with and without the vertical tail indicates that for $\alpha = 15.7^\circ$ the decrease in directional stability is somewhat greater with the vertical tail on (fig. 19). It would appear from this effect that the fuselage store had an adverse influence on the vertical-tail effectiveness.

Comparison of original and revised configurations.- A limited investigation was made at $M = 1.41$ to determine the sideslip characteristics of the original configuration. This configuration, in comparison with the revised version, has transonic inlets, no afterbody bump, a shorter nose, more rearward canopy, and a smaller vertical tail. (See fig. 2.) This model, which represents the initial production version of the F-105, was equipped with the small ventral fin $U_1$. A comparison of the sideslip characteristics for this configuration with those for the final revised test model (longer nose, forward canopy, supersonic inlets, bumped afterbody, tail $V_4$, and ventral fin $U_1$) is presented in figure 20 for several angles of attack. The sideslip characteristics are summarized in figure 23. These results indicate that the revised configuration, in comparison with the original configuration, has considerably greater directional stability and more positive effective dihedral. On the basis of estimated lift-curve slopes for the vertical tails, it appears that the differences in the sideslip characteristics of the two configurations are primarily due to the changes in tail plan form.

Lateral and Directional Control

Effects of left-wing spoiler deflection.- The effects of left-wing spoiler deflection on the aerodynamic characteristics in pitch are presented in figures 23 and 24 for Mach numbers of 1.41 and 2.01, respectively. The spoiler characteristics at $\alpha = 0^\circ$ are summarized in figure 34 for both Mach numbers.

The rolling-moment variation with spoiler deflection is somewhat nonlinear - particularly at $M = 1.41$ (fig. 34). The drag increase due to spoiler deflection is fairly large and the resulting yawing moment is, of course, favorable. The rolling effectiveness, in general, decreases quite rapidly with increasing angle of attack at $M = 2.01$ (fig. 24).

The effects of spoiler deflection in sideslip (fig. 25) indicate little change in the static sideslip derivatives and a nearly constant increment of rolling moment due to spoiler deflection.

Lateral trim-tab effectiveness.- A $10^\circ$ downward deflection of a small tab located near the trailing edge of the left-hand wing panel had essentially no effect on the lateral characteristics at $M = 2.01$ (fig. 26).
Effects of rudder deflection.- A 120° deflection of the rudder for the basic configuration \((V_1 U_1)\) produced an essentially constant yawing-moment increment throughout the angle-of-attack range at \(M = 2.01\) (fig. 27). The value of \(C_{n_{0\text{r}}}\) is about -0.00046. The deflected rudder caused a fairly large rolling moment at low angles of attack that decreased with increasing angle of attack.

The increment in yawing moment provided by the positive rudder deflection in constant sideslip (fig. 28) is slightly greater for negative sideslip (rudder against sideslip) than for positive sideslip (rudder with sideslip). This increment in yawing moment decreases quite rapidly with increasing angle of attack because of the decrease in \(C_{n_{0\text{p}}}\).

CONCLUSIONS

The results of an investigation of the static lateral and directional stability characteristics of a revised 1/22-scale model of the Republic F-105 airplane with twin-root supersonic inlets and several variations of various components at Mach numbers of 1.41 and 2.01 indicate that:

1. The directional stability of the complete configuration progressively decreased with increasing Mach number and angle of attack until regions of directional instability occurred as a result of a loss in vertical-tail effectiveness with increasing Mach number and angle of attack and the large unstable yawing moment of the wing-fuselage configuration throughout the angle-of-attack range.

2. Increasing the size and aspect ratio of either the vertical tail or the ventral fin resulted in an increase in the directional stability so that the onset of directional instability was delayed to higher Mach numbers or higher angles of attack. The revised configuration had considerably greater directional stability than the original configuration.

3. A 120° deflection of the rudder produced an essentially constant increment of yawing-moment coefficient of about -0.00046 per degree throughout the angle-of-attack range at a Mach number of 2.01.

4. The addition of the wing stores resulted in an increase in the directional stability, whereas the fuselage store and the combination of fuselage store and wing stores resulted in a decrease in directional stability. The adverse effect of fuselage stores is associated partially with an adverse effect on the stabilizing contribution of the vertical
tail and ventral fin and partly due to destabilizing moments resulting from the forward position of the fuselage store relative to the airplane center of gravity.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., October 16, 1956.

Ross B. Robinson
Aeronautical Research Engineer

Gerald V. Foster
Aeronautical Research Engineer

Approved: John V. Becker
Chief of Compressibility Research Division

jbb
REFERENCES


### TABLE I.- GEOMETRIC CHARACTERISTICS OF MODELS

**Wing:**

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area, including body intercept, sq ft</td>
<td>0.795</td>
</tr>
<tr>
<td>Span, in.</td>
<td>12.10</td>
</tr>
<tr>
<td>Mean geometric chord, in.</td>
<td>6.26</td>
</tr>
<tr>
<td>Aspect ratio</td>
<td>3.2</td>
</tr>
<tr>
<td>Taper ratio</td>
<td>0.668</td>
</tr>
<tr>
<td>Sweep of quarter-chord line, deg</td>
<td>45</td>
</tr>
<tr>
<td>Dihedral, deg</td>
<td>-5.5</td>
</tr>
<tr>
<td>Twist, deg</td>
<td>0</td>
</tr>
<tr>
<td>Incidence, deg</td>
<td>0</td>
</tr>
</tbody>
</table>

**Airfoil sections:**

- At wing station 0.35b/42
- At theoretical tip

**Theoretical root chord at fuselage center line, in.:** 8.18

**Theoretical tip chord, in.:** 3.86

**Horizontal tail:**

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area, including fuselage intercept, sq ft</td>
<td>0.180</td>
</tr>
<tr>
<td>Span, in.</td>
<td>9.10</td>
</tr>
<tr>
<td>Aspect ratio</td>
<td>3.05</td>
</tr>
<tr>
<td>Taper ratio</td>
<td>0.496</td>
</tr>
<tr>
<td>Mean geometric chord, in.</td>
<td>3.12</td>
</tr>
<tr>
<td>Sweep of quarter-chord line, deg</td>
<td>0</td>
</tr>
<tr>
<td>Tail length, 8/7 to 8/7 tail, in.</td>
<td>5</td>
</tr>
</tbody>
</table>

**Airfoil section:**

- Root
- Tip

**Theoretical root chord at fuselage center line, in.:** 2.57

**Theoretical tip chord, in.:** 1.66

**Vertical tails:**

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area, to fuselage center line, sq in.</td>
<td>22.29</td>
</tr>
<tr>
<td>Span, to fuselage center line, in.</td>
<td>9.36</td>
</tr>
<tr>
<td>Aspect ratio</td>
<td>7.95</td>
</tr>
<tr>
<td>Taper ratio</td>
<td>5.96</td>
</tr>
<tr>
<td>Mean geometric chord, in.</td>
<td>7.13</td>
</tr>
<tr>
<td>Sweep of leading edge, deg</td>
<td>0.365</td>
</tr>
<tr>
<td>Radius area, V1 only, sq in.</td>
<td>0.290</td>
</tr>
<tr>
<td>Ratio of area to wing area</td>
<td>0.298</td>
</tr>
</tbody>
</table>

**Ventrals:**

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area, exposed, sq in.</td>
<td>3.38</td>
</tr>
<tr>
<td>V1</td>
<td>7.45</td>
</tr>
<tr>
<td>V2</td>
<td>9.12</td>
</tr>
<tr>
<td>V3</td>
<td>5.53</td>
</tr>
</tbody>
</table>

**Fuselage:**

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length, in.</td>
<td>52.74</td>
</tr>
<tr>
<td>Maximum frontal area, sq ft</td>
<td>35.75</td>
</tr>
<tr>
<td>Maximum frontal area, sq ft</td>
<td>0.053</td>
</tr>
</tbody>
</table>

**Stores:**

**Wing (each):**

- Length, in.                                      | 30.20          |
- Maximum frontal area, sq in.                     | 1.90           |

**Location:**

- Outboard of fuselage center line, in.            | 5.77           |
- Below body center line at fuselage station 21.69 in. | 1.97           |
- Nose of store to fuselage nose, in.              | 37.10          |
- Angle between store center line and fuselage center line, deg | -3.6 |

**Fuselage:**

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length, in.</td>
<td>35.00</td>
</tr>
<tr>
<td>Maximum frontal area, sq in.</td>
<td>3.16</td>
</tr>
</tbody>
</table>

**Location:**

- Below body center line at fuselage station 15.59, in. | 3.63 |
- Nose of store to fuselage nose, in.               | 10.80          |

**Miscellaneous:**

**Canopy fin:**

- Area, sq in.                                     | 1.81           |
- Location of hinge line from fuselage nose, in.   | 19.76          |

**Wing-tip fences:**

- Area each, sq in.                                | 4.60           |
- Location, outboard of fuselage center line, in.  | 9.08           |

**Leading-edge flaps:**

- Area each, sq in.                                | 3.42           |
- Span, fraction of wing semispan                  | 0.56           |
- Location, inboard end, from fuselage center line, in. | 3.73          |

**Spoiler:**

- Area, sq in.                                     | 2.76           |
- Span, fraction of wing semispan                  | 0.20           |
- Location, inboard end, from fuselage center line, in. | 1.82          |

**Trim tab:**

- Area, sq in.                                     | 1.82           |
- Span, fraction of wing semispan                  | 0.29           |
- Location, inboard end, from fuselage center line, in. | 3.65          |
<table>
<thead>
<tr>
<th>Figure</th>
<th>M</th>
<th>Type of data</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>1.41</td>
<td>Basic lateral</td>
<td>Effect of vertical-tail plan form</td>
</tr>
<tr>
<td>6</td>
<td>2.01</td>
<td>Basic lateral</td>
<td>Effect of vertical-tail plan form</td>
</tr>
<tr>
<td>7</td>
<td>1.41</td>
<td>Basic lateral</td>
<td>Effect of ventral fin</td>
</tr>
<tr>
<td>8</td>
<td>2.01</td>
<td>Basic lateral</td>
<td>Effect of ventral fin</td>
</tr>
<tr>
<td>9</td>
<td>2.01</td>
<td>Basic lateral</td>
<td>Effect of ventral-fin plan form</td>
</tr>
<tr>
<td>10</td>
<td>2.01</td>
<td>Basic lateral</td>
<td>Effect of ventral-fin plan form</td>
</tr>
<tr>
<td>11</td>
<td>2.01</td>
<td>Basic lateral</td>
<td>Air bleed open</td>
</tr>
<tr>
<td>12</td>
<td>2.01</td>
<td>Basic lateral</td>
<td>Effect of wing-tip fence</td>
</tr>
<tr>
<td>13</td>
<td>2.01</td>
<td>Basic lateral</td>
<td>Effect of canopy fin</td>
</tr>
<tr>
<td>14</td>
<td>1.41</td>
<td>Basic lateral</td>
<td>Effect of nose modification</td>
</tr>
<tr>
<td>15</td>
<td>2.01</td>
<td>Basic lateral</td>
<td>Effect of nose modification</td>
</tr>
<tr>
<td>16</td>
<td>2.01</td>
<td>Basic lateral</td>
<td>Effect of ...</td>
</tr>
<tr>
<td>17</td>
<td>2.01</td>
<td>Basic lateral</td>
<td>Effect of leading-edge flap</td>
</tr>
<tr>
<td>18</td>
<td>1.41</td>
<td>Basic lateral</td>
<td>Effect of stores</td>
</tr>
<tr>
<td>19</td>
<td>1.41</td>
<td>Basic lateral</td>
<td>Effect of stores</td>
</tr>
<tr>
<td>20</td>
<td>1.41</td>
<td>Basic lateral</td>
<td>Comparison of original and revised configuration</td>
</tr>
<tr>
<td>21</td>
<td>1.41</td>
<td>Basic longitudinal</td>
<td>Effect of vertical-tail plan form</td>
</tr>
<tr>
<td>22</td>
<td>2.01</td>
<td>Basic longitudinal</td>
<td>Effect of vertical-tail plan form</td>
</tr>
<tr>
<td>23</td>
<td>1.41</td>
<td>Basic lateral and longitudinal</td>
<td>Effect of spoiler deflection</td>
</tr>
<tr>
<td>24</td>
<td>2.01</td>
<td>Basic lateral and longitudinal</td>
<td>Effect of spoiler deflection</td>
</tr>
<tr>
<td>25</td>
<td>2.01</td>
<td>Basic lateral</td>
<td>Effect of spoiler</td>
</tr>
<tr>
<td>26</td>
<td>2.01</td>
<td>Basic lateral</td>
<td>Effect of lateral trim-tab deflection</td>
</tr>
<tr>
<td>27</td>
<td>2.01</td>
<td>Basic lateral</td>
<td>Effect of rudder deflection</td>
</tr>
<tr>
<td>28</td>
<td>2.01</td>
<td>Basic lateral</td>
<td>Effect of rudder deflection</td>
</tr>
<tr>
<td>29</td>
<td>1.41</td>
<td>Lateral parameters</td>
<td>Effect of vertical-tail plan form</td>
</tr>
<tr>
<td>30</td>
<td>2.01</td>
<td>Lateral parameters</td>
<td>Effect of ventral-fin plan form</td>
</tr>
<tr>
<td>31</td>
<td>2.01</td>
<td>Lateral parameters</td>
<td>Effect of ventral-fin plan form</td>
</tr>
<tr>
<td>32</td>
<td>1.41</td>
<td>Lateral parameters</td>
<td>Effect of air bleed</td>
</tr>
<tr>
<td>33</td>
<td>1.41</td>
<td>Lateral parameters</td>
<td>Comparison of original and revised configuration</td>
</tr>
<tr>
<td>34</td>
<td>1.41</td>
<td>Basic lateral and longitudinal</td>
<td>Effect of spoiler deflection</td>
</tr>
</tbody>
</table>
Figure 1.- Axis system. Arrows indicate positive directions. Leading-edge-flap, trim-tab, and spoiler deflections positive when trailing edge moves up.
Figure 2.- Sketch of model. Solid line is revised model; dashed line is original model. All dimensions in inches except as noted.
(a) Original and revised vertical tails. Rudder area, 3.60 sq in.

Figure 3.- Details of various fins, tails, stores and controls. All dimensions in inches except as noted.
(b) Additional vertical tails.

Figure 3.- Continued.
(c) Ventral fins.

Figure 3. - Continued.
(d) Leading-edge flaps, spoiler, and trim tab.

Figure 3.- Continued.
(e) Noses.

Figure 3. - Continued.
Hinge line, .64 fin chord

Axis through c.g., .70 fin chord

Area = 1.81 sq. in.

(f) Canopy fin.

Total area, 4.60 sq in.

(g) Wing-tip fence, each tip. Wing station 9.08.

Figure 3.- Continued.
(h) Location of external stores.

Figure 3. - Concluded.
(a) Original model.       L-91360

Figure 4.- Photographs of model.
(b) Revised model. Tail \( V_4 \)  

L-88918

Figure 4.- Continued.
(c) Model mounted in tunnel. \( \alpha \approx 15^\circ \).

Figure 4.- Concluded.
Figure 5.- Effect of vertical-tail plan form on aerodynamic characteristics in sideslip. Ventral fin $U_1$; $M = 1.41$; $\iota_t = -3^\circ$.
(b) $\alpha \approx 5.6^\circ$.

Figure 5.- Continued.
(c) \( \alpha \approx 10.4^\circ \).

Figure 5. - Continued.
(d) \( \alpha \approx 15.7^\circ \).

Figure 5.—Concluded.
Figure 6.- Effect of vertical-tail plan form on aerodynamic characteristics in sideslip. Ventral fin \( U_1 \); \( M = 2.01; \ i_t = -3^\circ \).
Figure 6. - Continued.

(b) $\alpha = 5.5^\circ$. 

(a) $\alpha = 5.5^\circ$. 

Diagram with data points and annotations.
Figure 6. - Continued.

(c) $\alpha \approx 10.2^\circ$. 
Figure 6.- Concluded.

(d) $\alpha \approx 15.4^\circ$. 

Figure 6.- Concluded.
Figure 7.- Effect of ventral fin on aerodynamic characteristics in sideslip. $M = 1.41; V_{1}U_{1}; i_{t} = -3^\circ$. 

(a) $\alpha = 0^\circ$. 
(b) \( \alpha = 10.4^\circ \).

Figure 7.- Continued.
(c) \( \alpha \approx 15.7^\circ \).

Figure 7.- Concluded.
Figure 8.- Effect of ventral fin on aerodynamic characteristics in side-slip. $M = 2.01; V_{\perp}U_{\perp}; i_{t} = -3^\circ$. 

(a) $\alpha = 0^\circ$. 
(b) $\alpha \approx 5.5^\circ$.

Figure 8.- Continued.
Figure 8.- Continued.

(c) $\alpha \approx 10.2^\circ$. 

Figure 8.- Continued.
Figure 8.- Concluded.

(d) \( \alpha \approx 15.4^\circ \).
Figure 9.- Effect of ventral-fin plan form on aerodynamic characteristics in sideslip. $M = 2.01$; $V_1$; $i_t = -30^\circ$.
Figure 9. - Continued.

(b) \( \alpha \approx 10.2^\circ \).
(c) $\alpha \approx 15.4^\circ$.

Figure 9. - Concluded.
Figure 10.- Effect of ventral-fin plan form on aerodynamic characteristics in sideslip. $M = 2.01; V_2; \alpha = -3^\circ$. Flagged symbols indicate repeat run.
Figure 10.- Concluded.

(b) \( \alpha = 15.4^\circ \).

Figure 10.- Concluded.
Figure 11.- Effect of angle of attack on sideslip characteristics of model with air bleed open. \( V_t U_1; \ i_t = -3^\circ \).
(b) $M = 2.01$.

Figure 11.- Concluded.
Figure 12. Effect of wing-tip fence on aerodynamic characteristics in sideslip. $M = 2.01; V_{1}U_{1}; \beta_{t} = -3^\circ$.
Figure 12.- Concluded.

(b) $\alpha \approx 15.4^\circ$. 
Figure 13.- Effect of canopy fin on aerodynamic characteristics in side-slip. $M = 2.01; V_1U_1; i_t = -3^\circ$.
(b) \( \alpha \approx 15.4^0 \).

Figure 13. Concluded.
Figure 14. - Effect of nose modification on aerodynamic characteristics in sideslip. $M = 1.41; V_4 U_1; \beta_1 = -3^\circ$. 

(a) $\alpha = 10.4^\circ$. 
(b) $\alpha \approx 15.7^\circ$.

Figure 14.- Concluded.
Figure 15. - Effect of nose modification on aerodynamic characteristics in sideslip. $M = 2.01; V_U; \beta = -3^\circ$.
(b) $\alpha \approx 10.2^\circ$.

Figure 15. - Continued.
Figure 15.- Concluded.

(c) $\alpha \approx 15.4^\circ$. 

NACA RM SL56J30

**CONFIDENTIAL**
Figure 16.- Effect of horizontal-tail incidence on aerodynamic characteristics in sideslip. $\alpha = 15.4^\circ; M = 2.01; V_4 U_1$. 
Figure 17.- Effect of leading-edge-flap deflection on aerodynamic characteristics in sideslip. $\alpha = 15.4^\circ$; $M = 2.01$; $V_1U_1$; $\lambda_t = -3^\circ$. 
Figure 18. - Effect of external stores on aerodynamic characteristics in sideslip. $M = 1.41; V_t U_t; \beta_t = 3^\circ$. 

(a) $\alpha \approx 10.4^\circ$. 

$NACA RM SL56J30$
(b) \( \alpha \approx 15.7^\circ \).

Figure 18.- Concluded.
Figure 19. - Effect of fuselage store on aerodynamic characteristics in sideslip. Tail on and tail off; $\alpha = 15.7^\circ$; $M = 1.41$; $V/u_1$; $I_t = -3^\circ$. 
Figure 20.- Aerodynamic characteristics in sideslip for original and revised configurations. $M = 1.41$; revised configuration with $V_t U_1$; $\alpha_t = -3^\circ$.
(b) \( \alpha \approx 10.4^\circ \).

Figure 20.- Continued.
(c) $\alpha \approx 15.7^\circ$.

Figure 20.- Concluded.
Figure 21. - Variation of $C_L$, $C_X$, and $C_m$ with $\beta$ for various configurations. $M = 1.41; i_t = -3^\circ$. 

(a) $\alpha = 0^\circ$. 
Figure 21.- Continued.

(b) \( \alpha \approx 5.6^\circ \).
Figure 21.- Continued.

(c) $\alpha \approx 10.4^\circ$.

Figure 21.- Continued.
(d) $\alpha \approx 15.7^\circ$.

Figure 21.- Concluded.
Figure 22.- Variation of $C_L$, $C_X$, and $C_m$ with $\beta$ for various configurations. $M = 2.01; \alpha_t = -3^\circ$. 

(a) $\alpha = 0^\circ$. 
(b) $\alpha \approx 5.5^\circ$.

Figure 22. - Continued.
\[ \beta \text{, deg} \]

(c) \( \alpha \approx 10.2^\circ \).

Figure 22.- Continued.
(d) $\alpha \approx 15.4^\circ$.

Figure 22.- Concluded.
(a) Variation of $C_m$, $C_x$, and $\alpha$ with $C_L$.

Figure 23.- Effect of spoiler deflection on aerodynamic characteristics in pitch. $\beta = 0^\circ$; $M = 1.41$; $V_{\text{i}} U_1$; $i_t = -3^\circ$. 
(b) Variation of $C_n$, $C_l$, and $C_Y$ with $\alpha$.

Figure 23.- Concluded.
Figure 24.- Effect of spoiler deflection on aerodynamic characteristics in pitch. $\beta = 0^\circ$; $M = 2.01; V_{4U_1}; i_t = -3^\circ$. 

(a) Variation of $C_m$, $C_x$, and $\alpha$ with $C_L$. 

(b) Variation of $C_n$, $C_l$, and $C_Y$ with $\alpha$.

Figure 24. Concluded.
Figure 25. Effect of spoiler deflection on aerodynamic characteristics in sideslip. $M = 2.01, V_u U_1; \theta_\alpha = -3^\circ$. 

(a) $\alpha = 0^\circ$. 
(b) $\alpha \approx 10.2^\circ$.

Figure 25.- Concluded.
Figure 26. - Effect of trim-tab deflection on lateral characteristics in pitch. \( \beta = 0^\circ; M = 2.01; V_1U_1; \eta_t = -3^\circ \).
Figure 27.- Effect of rudder deflection on lateral characteristics in pitch. $\beta = 0^\circ$; $M = 2.01$; $V_U/U_1$; $\alpha_t = -3^\circ$. 
Figure 28.- Effect of sideslip on the lateral characteristics in pitch with rudder deflected. $\delta_r = 12^\circ$; $M = 2.01$; $V_{1}U_{1}$; $\alpha = 3^\circ$. 
Figure 29. - Variation of sideslip derivatives with angle of attack for various vertical tails. $U_1; \theta_t = -3^\circ$. 

(a) $M = 1.41$. 
(b) $M = 2.01$.

Figure 29.- Concluded.
Figure 30. - Variation of sideslip derivatives with angle of attack for various ventral-fin arrangements. $V_1; i_t = -3^\circ$. 

(a) $M = 1.41$. 
(b) $M = 2.01$.

Figure 30.- Concluded.
Figure 31. - Variation of sideslip derivatives with angle of attack for various ventral fins with tail $V_2$. $M = 2.01$; $\iota = -30^\circ$. 
Figure 32. Variation of sideslip derivatives with angle of attack for open and closed air bleed. $\psi_h$, $\alpha = -30^\circ$. 
Figure 33.- Variation of sideslip derivatives with angle of attack for original and revised configurations. Revised model with $V_4$; $M = 1.41$; $l_t = -3^\circ$. 
Figure 54.- Spoiler control characteristics at $\alpha = \beta = 0^\circ; I_L = 3^\circ$. 
An investigation has been conducted in the Langley 4- by 4-foot supersonic pressure tunnel at a Mach number of 1.41 and 2.01 to determine the lateral and directional stability characteristics of various configurations of a revised 1/22-scale model of the Republic F-105 airplane. The revised configuration had a 45° sweptback wing of aspect ratio 3.2 and twin-root supersonic inlets. The results presented were obtained at combined angles of attack (18° maximum) and sideslip (19° maximum).