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SOME EFFECTS OF EXTERNAL STORES ON THE STATIC STABILITY OF FIGHTER AIRPLANES

by M. Leroy Spearman

Langley Research Center
Hampton, Va. 23365

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • APRIL 1972

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1. Report No. NASA TN D-6775	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle SOME EFFECTS OF EXTERNAL STORES ON THE STATIC STABILITY OF FIGHTER AIRPLANES		5. Report Date April 1972
		6. Performing Organization Code
7. Author(s) M. Leroy Spearman		8. Performing Organization Report No. L-7906
9. Performing Organization Name and Address NASA Langley Research Center Hampton, Va. 23365		10. Work Unit No. 136-63-02-37
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546		13. Type of Report and Period Covered Technical Note
		14. Sponsoring Agency Code
15. Supplementary Notes Presented at the Aircraft/Stores Compatibility Symposium, Dayton, Ohio, December 7-9, 1971.		

16. Abstract

Fighter airplanes may have a seemingly limitless number of external store arrangements. Some practical considerations and some aerodynamic considerations must be taken into account in the arrangements of the external stores. This report points out the nature of the problems concerning the type of store arrangement involved and the type of airplane on which the stores are installed.

17. Key Words (Suggested by Author(s)) External stores Interference effects Fighter airplanes		18. Distribution Statement Unclassified – Unlimited	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 34	22. Price* $3.00

*For sale by the National Technical Information Service, Springfield, Virginia 22151

SOME EFFECTS OF EXTERNAL STORES ON THE STATIC STABILITY OF FIGHTER AIRPLANES

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SUMMARY

Fighter airplanes may have a seemingly limitless number of external store arrangements. Some practical considerations and some aerodynamic considerations must be taken into account in the arrangements of the external stores. This report points out the nature of the problems concerning the type of store arrangement involved and the type of airplane on which the stores are installed as well as some effects of external stores on the static stability of several fighter airplanes. A primary conclusion is that similar types of store arrangements on different types of airplanes may produce different effects on the stability characteristics; this indicates that the effects of stores are more in the "art" stage than in the "science" stage.

INTRODUCTION

Fighter airplanes of today have a seemingly limitless number of external store arrangements. The types and arrangements of external stores are not the same for all airplanes but differ as to the purpose for which the airplane is used. Many problems arise as a result of the type of store arrangement involved and the type of airplane on which the store is installed. The purpose of this report is to point out the nature of the problems and to present some effects of external store arrangements on the static stability characteristics of a straight-wing, a 42° swept-wing, and a 45° swept-wing fighter airplane. The material presented is based on results of wind-tunnel tests with models of the three fighter airplanes. These specific airplanes were chosen as representative of airplane configurations with different wing and tail combinations. The stores included armament, fuel tanks, and rocket packets installed on the body and wing tips and pylon-mounted on the wing.

A bibliography of some research on external store arrangements is included.

SYMBOLS

C_m pitching-moment coefficient

C_L lift coefficient

C_{n_β} directional stability parameter

α angle of attack, deg

M Mach number

RESULTS AND DISCUSSION

Longitudinal Stability Characteristics

Several store arrangements have been investigated on a straight-wing fighter airplane. These stores included fuel tanks and missiles. Detailed results of the studies may be found in references 1 and 2. A typical wing-tip fuel-tank installation for this fighter is shown on a wind-tunnel model in figure 1. The effects of the wing-tip fuel tanks on the static longitudinal stability characteristics at $M = 2$ are shown in figure 2. The wing-tip tanks cause a considerable increase in static longitudinal stability when the horizontal tail is off. This increase in stability is due in part to the pitching-moment characteristics of the store itself and in part to an increase in wing lift provided by the end-plate effect of the store. However, for the complete airplane including the horizontal tail, the tip tanks have relatively little effect on the longitudinal stability. This characteristic is an indication of a compensating loss in tail contribution resulting from dynamic-pressure changes or downwash at the tail induced by the presence of the fuel tanks. The straight-wing wind-tunnel model with a large body-mounted store is shown in figure 3. The effects of the store on the pitching-moment characteristics at $M = 1.8$ are presented in figure 4. A measurable positive increment in pitching moment at zero lift and a slight increase in the longitudinal stability are indicated.

Wind-tunnel studies have been made of a 45° swept-wing fighter with various fuel-tank and missile arrangements (fig. 5). Complete results of these studies are found in reference 3. The stores investigated included large fuel tanks mounted at approximately the midsemispan point under the wing and missiles installed inboard and outboard on the wing. At $M = 2$, the large fuel tanks at the wing midsemispan cause no change in the longitudinal stability with the horizontal tail removed, but a measurable reduction in longitudinal stability does occur with the horizontal tail in place. (See fig. 6.) It would appear from this figure that the decrease in stability is the result of interference of the store on the low horizontal tail.

Several arrangements of fuel tanks and missiles have also been studied on a high-mounted 42° swept-wing airplane. Results of this investigation may be found in reference 4. A unique method of mounting large fuel tanks directly on the sides of the body of this airplane is illustrated in figure 7. Results of the study of the effects of this fuel-tank installation on the longitudinal stability of the 42° swept-wing airplane (ref. 4) indicated that such an arrangement could be used with essentially no effect on the longitudinal stability. Other evidence (unpublished) indicates that fuel tanks may be added to the fuselage of fighter-type airplanes and not only have little effect on the stability characteristics but produce a net reduction in the supersonic wave drag.

The effects of wing-tip-mounted missiles on the straight-wing fighter have also been investigated (refs. 1 and 2). A typical installation for this fighter airplane is shown in figure 8; four missiles are mounted on the wing tips (one over and one under each wing tip). The effects of the wing-tip-mounted missiles on the stability of the straight-wing fighter were similar to the effects of the large fuel tanks mounted on the wing tips, except that the magnitudes of the stability changes were considerably less for the missile installations. The effects of inboard and outboard stores on the 45° swept-wing fighter airplane at $M = 1.6$ are shown in figure 9. The inboard stores mounted under the wing caused a measurable reduction in static longitudinal stability, whereas the outboard store produced essentially no change in longitudinal stability. This effect can apparently be explained by the fact that the inboard stores were slightly larger than the outboard stores and were located somewhat ahead of the moment reference center. The outboard stores (in addition to being smaller) were located close to the moment reference center of the airplane. Semisubmerged body-mounted missiles on a model of the 42° swept-wing fighter are shown in figure 10; the same missiles in the extended position for firing are shown in figure 11. Results obtained in reference 4 indicated that there was essentially no effect on the longitudinal stability when the missiles were in the semisubmerged position or in the extended position, probably because of the proximity of the missiles to the airplane moment reference center.

Lateral-Directional Stability Characteristics

Effects of the wing-tip-mounted missiles on the directional stability of the straight-wing fighter airplane at $M = 2$ are shown in figure 12. Test results indicated that the tip-mounted missiles produced an increase in the lateral force due to sideslip that varied with the missile installation size. In general, the tip-mounted missiles caused no change in directional stability at low angles of attack but with increasing angle of attack above $\alpha = 4^{\circ}$ did cause reductions in directional stability to a measurable degree. The effects of the large body-mounted store are also shown in figure 12. A significant decrease in directional stability is seen throughout the angle-of-attack range since this store was located slightly forward of the airplane center of gravity. Further results presented in reference 1 indicated that tip-mounted stores generally caused a reduction in the effective dihedral since the effect of the tip stores is to increase the lift-curve slope of the wing and thereby increase the rolling moment provided by the wing in sideslip. The large fuselage store caused an increase in side force below the axes of rotation but still produced an increase in positive effective dihedral. This result indicates the probability that the flow field from the body store causes a loss in lift for the trailing wing panel in sideslip and, thus, an increase in the dihedral effect still occurs.

For the 45° swept-wing fighter airplane at $M = 1.6$, the installation of inboard stores resulted in a significant decrease in directional stability throughout the angle-of-attack range (fig. 13). It appears that this adverse effect arises from interference of the store flow field on the vertical tail in addition to the fact that the side force created on the inboard missiles is forward of the airplane center of gravity. The large midsemispan-mounted fuel tanks produced a rather significant increase in directional stability, particularly at angles of attack above about 10° (fig. 13). This effect may be due to the fact that a large part of the increase in side force on the fuel tanks is aft of the airplane center of gravity. Results presented in reference 3 indicated that all the underwing store configurations for the 45° swept-wing fighter, with the exception of the outboard store, caused an increase in positive effective dihedral. This result, again, is apparently caused by a loss in lift on the trailing wing in sideslip due to the store interference flow field.

The effects of the various missile positions on the directional stability of the 42° swept-wing fighter at $M = 1.6$ are shown in figure 14. The body fuel tanks had little influence on either directional stability or effective dihedral (ref. 4). In figure 14 it is seen that semisubmerged missiles and their subsequent extension progressively decreased the directional stability at the lower angles of attack (below $\alpha = 12^{\circ}$). Rocket packets attached to the sides of this fighter fuselage are shown in figure 15. It is interesting to note from reference 4 that the rocket packets, which were in the same position as the semisubmerged missiles, had little effect on the directional stability at any angle of attack.

Tests of a delta-wing aft-tail fighter have indicated some interesting characteristics. This configuration, shown schematically in figure 16, consisted of two relatively large winged missiles pylon-mounted under the wing slightly outboard of the tip of the horizontal tail. The test results (unpublished) indicated that the missiles had no effect on the longitudinal stability. Typical effects of the missiles on the directional stability at $M = 1.6$ are presented in figure 16. A substantial increase in stability was obtained by the addition of the missiles since, with this planform, it was possible to locate the primary lifting surface of the missile aft of the airplane moment center.

CONCLUDING REMARKS

In general, results of studies of the effects of external stores on static stability of fighter airplanes indicate that the installation of various missiles or stores on different types of airplanes is still very much an "art" requiring a systematic series of wind-tunnel tests to provide a measure of the influence of the store installation on the stability characteristics. Apparently, at the present time, no reliable technique is available for adequately predicting the effects on stability of the numerous types of store arrangements possible.

Langley Research Center,
National Aeronautics and Space Administration,
Hampton, Va., March 29, 1972.

REFERENCES

1. Spearman, M. Leroy; and Driver, Cornelius: Longitudinal and Lateral Stability Characteristics of a Low-Aspect-Ratio Unswept-Wing Airplane Model at Mach Numbers of 1.82 and 2.01. NACA RM L56H06, 1957.

2. Robinson, Ross B.: Longitudinal Characteristics of an Unswept-Wing Fighter-Type Model With External Stores at a Mach Number of 1.82 and Some Effects of Horizontal-Tail and Yaw-Damper Deflection on the Sideslip Derivatives. NACA RM L55L26, 1956.

3. Foster, Gerald V.; and Driver, Cornelius: Effects of External Stores on the Static Longitudinal and Lateral Aerodynamic Characteristics of a Model of a 45° Swept-Wing Fighter Airplane at Mach Numbers of 1.61 and 2.01. NACA RM L56F15a, 1956.

4. Church, James D.: Effects of Components and Various Modifications on the Drag and the Static Stability and Control Characteristics of a 42° Swept-Wing Fighter-Airplane Model at Mach Numbers of 1.60 to 2.50. NACA RM L57K01, 1957. (Reprinted 1959.)

BIBLIOGRAPHY

Silvers, H. Norman; and Vogler, Raymond D.: Résumé of Wind-Tunnel Data on the Effect of External Stores on Stability of Models of Military Airplanes. NACA RM L6K08, 1946.

Boddy, Lee E.; and Morrill, Charles P., Jr.: The Aerodynamic Effects of Rockets and Fuel Tanks Mounted Under the Swept-Back Wing of an Airplane Model. NACA RM A7J03, 1948.

Silvers, H. Norman; and Spreemann, Kenneth P.: Correlation of Wind-Tunnel and Flight Determinations of the Buffet Speed of an Airplane Equipped With External Stores. NACA RM L7E20, 1948.

Silvers, H. Norman; and Spreemann, Kenneth P.: Wind-Tunnel Investigation of a Wing-Fuselage Combination With External Stores. NACA RM L7K20, 1948.

Hart, Roger G.; and Katz, Ellis R.: Flight Investigations at High-Subsonic, Transonic, and Supersonic Speeds To Determine Zero-Lift Drag of Fin-Stabilized Bodies of Revolution Having Fineness Ratios of 12.5, 8.91, and 6.04 and Varying Positions of Maximum Diameter. NACA RM L9I30, 1949.

Silvers, H. Norman; and Spreemann, Kenneth P.: Effect of Airfoil Section and Tip Tanks on the Aerodynamic Characteristics at High Subsonic Speeds of an Unswept Wing of Aspect Ratio 5.16 and Taper Ratio 0.61. NACA RM L9J04, 1949.

Spreemann, Kenneth P.; and Silvers, H. Norman: Experimental Investigation of Various Wing-Mounted External Stores on a Wing-Fuselage Combination Having a Sweptback Wing of Inverse Taper Ratio. NACA RM L9J06, 1950.

Silvers, H. Norman; and Spreemann, Kenneth P.: Experimental Investigation of Various External-Store Configurations on a Model of a Tailless Airplane With a Sweptback Wing. NACA RM L9K25, 1950.

Welsh, Clement J.; and Morrow, John D.: Effect of Wing-Tank Location on the Drag and Trim of a Swept-Wing Model as Measured in Flight at Transonic Speeds. NACA RM L50A19, 1950.

May, Ellery B., Jr.: Investigation of Aerodynamic Effects of an External Store in Combination With 60° Delta and Low-Aspect-Ratio Tapered Wings at a Mach Number of 1.9. NACA RM L50K03, 1951.

Spreemann, Kenneth P.; and Alford, William J., Jr.: Investigation of the Effects of Geometric Changes in an Underwing Pylon-Suspended External-Store Installation on the Aerodynamic Characteristics of a 45° Sweptback Wing at High Subsonic Speeds. NACA RM L50L12, 1951.

Hoffman, Sherwood: Comparison of Zero-Lift Drag Determined by Flight Tests at Transonic Speeds of Pylon, Underslung, and Symmetrically Mounted Nacelles at 40 Percent Semispan of a 45° Sweptback Wing and Body Combination. NACA RM L51D26, 1951.

Pepper, William B., Jr.; and Hoffman, Sherwood: Comparison of Zero-Lift Drags Determined by Flight Tests at Transonic Speeds of Symmetrically Mounted Nacelles in Various Chordwise Positions at the Wing Tip of a 45° Sweptback Wing and Body Combination. NACA RM L51F13, 1951.

Silvers, H. Norman; King, Thomas J., Jr.; and Pasteur, Thomas B., Jr.: Investigation of the Effect of a Nacelle at Various Chordwise and Vertical Positions on the Aerodynamic Characteristics at High Subsonic Speeds of a 45° Sweptback Wing With and Without a Fuselage. NACA RM L51H16, 1951.

Dugan, James C.: External Store Development. Mem. Rep. No. WCNSR-43019-1-1, Wright Air Develop. Center, U.S. Air Force, Aug. 13, 1951.

Tamburello, V.; and Burgan, Elmer: Exploratory Wind-Tunnel Tests of External Stores Mounted in Various Locations on the Wing of a 0.17-Scale Model Jet-Fighter Type Airplane. Rep. C-453 Aero 806, David W. Taylor Model Basin, Navy Dep., Sept. 1951.

Hasel, Lowell E.; and Sevier, John R., Jr.: Aerodynamic Characteristics at Supersonic Speeds of a Series of Wing-Body Combinations Having Cambered Wings With an Aspect Ratio of 3.5 and a Taper Ratio of 0.2 – Effect at $M = 1.60$ of Nacelle Shape and Position on the Aerodynamic Characteristics in Pitch of Two Wing-Body Combinations With 47° Sweptback Wings. NACA RM L51K14a, 1952.

Kremzier, Emil J.; and Dryer, Murray: Aerodynamic Interference Effects on Normal and Axial Force Coefficients of Several Engine-Strut-Body Configurations at Mach Numbers of 1.8 and 2.0. NACA RM E52B21, 1952.

Silvers, H. Norman; and King, Thomas J., Jr.: A Small-Scale Investigation of the Effect of Spanwise and Chordwise Positioning of an Ogive-Cylinder Underwing Nacelle on the High-Speed Aerodynamic Characteristics of a 45° Sweptback Tapered-in-Thickness Wing of Aspect Ratio 6. NACA RM L52J22, 1952.

Hoffman, Sherwood: Transonic Flight Tests To Compare the Zero-Lift Drags of Underslung Nacelles Varied Spanwise on a 45° Sweptback Wing and Body Combination. NACA RM L52D04a, 1952.

Driver, Cornelius: Aerodynamic Characteristics at Supersonic Speeds of a Series of Wing-Body Combinations Having Cambered Wings With an Aspect Ratio of 3.5 and a Taper Ratio of 0.2 – Effect at $M = 2.01$ of Nacelle Shape and Position on the Aerodynamic Characteristics in Pitch of Two Wing-Body Combinations With 47° Sweptback Wings. NACA RM L52F03, 1952.

Scallion, William I.: Low-Speed Investigation of the Effects of Nacelles on the Longitudinal Aerodynamic Characteristics of a 60° Sweptback Delta-Wing—Fuselage Combination With NACA 65A003 Airfoil Sections. NACA RM L52F04, 1952.

Jacobsen, Carl R.: Effects of Systematically Varying the Spanwise and Vertical Location of an External Store on the Aerodynamic Characteristics of an Unswept Tapered Wing of Aspect Ratio 4 at Mach Numbers of 1.41, 1.62, and 1.96. NACA RM L52F13, 1952.

Bielat, Ralph P.; and Harrison, Daniel E.: A Transonic Wind-Tunnel Investigation of the Effects of Nacelle Shape and Position on the Aerodynamic Characteristics of Two 47° Sweptback Wing-Body Configurations. NACA RM L52G02, 1952.

Jacobsen, Carl R.: Effects of the Spanwise, Chordwise, and Vertical Location of an External Store on the Aerodynamic Characteristics of a 60° Delta Wing at Mach Numbers of 1.41, 1.62, and 1.96. NACA RM L52H29, 1952.

Silvers, H. Norman; and King, Thomas J., Jr.: Investigation at High Subsonic Speeds of Bodies Mounted From the Wing of an Unswept-Wing—Fuselage Model, Including Measurements of Body Loads. NACA RM L52J08, 1952.

Smith, Willard G.: 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. NACA RM A52J31, 1953.

Jacobsen, Carl R.: Effects of the Spanwise, Chordwise, and Vertical Location of an External Store on the Aerodynamic Characteristics of a 45° Sweptback Tapered Wing of Aspect Ratio 4 at Mach Numbers of 1.41, 1.62, and 1.96. NACA RM L52J27, 1953.

Jacobsen, Carl R.: Effects of Size of External Stores on the Aerodynamic Characteristics of an Unswept and a 45° Sweptback Wing of Aspect Ratio 4 and a 60° Delta Wing at Mach Numbers of 1.41, 1.62, and 1.96. NACA RM L52K20a, 1953.

Mitcham, Grady L.; and Blanchard, Willard S., Jr.: Low-Lift Drag and Stability Data From Rocket Models of a Modified-Delta-Wing Airplane With and Without External Stores at Mach Numbers From 0.8 to 1.36. NACA RM L53A27, 1953.

Wallskog, Harvey A.; and Hart, Roger G.: Investigation of the Drag of Blunt-Nosed Bodies of Revolution in Free Flight at Mach Numbers From 0.6 to 2.3. NACA RM L53D14a, 1953.

Rainey, Robert W.: Effect of Variations in Reynolds Number on the Aerodynamic Characteristics of Three Bomb or Store Shapes at a Mach Number of 1.62 With and Without Fins. NACA RM L53D27, 1953.

Carmel, Melvin M.; and Fischetti, Thomas L.: A Transonic Wind-Tunnel Investigation of the Effects of Nacelles on the Aerodynamic Characteristics of a Complete Model Configuration. NACA RM L53F22a, 1953.

Mason, Homer P.: Effects of External Store Mounting on the Buffet, Trim, and Drag Characteristics of Rocket-Powered Fuselage and Store Combinations Between Mach Numbers of 0.7 and 1.4. NACA RM L53J22, 1953.

Alexander, S. R.: The Influence of External and Internal Stowage of Sparrow II on the Performance of a Transonic Day Fighter Configuration. NAVAER Rep. No. DR-1484, Bur. Aeronaut., Aug. 1953.

Judd, Joseph H.: Flight Investigation of Engine Nacelles and Wing Vertical Position on the Drag of a Delta-Wing Airplane Configuration From Mach Number 0.8 to 2.0. NACA RM L53L21, 1954.

Silvers, H. Norman; King, Thomas J., Jr.; and Alford, William J., Jr.: Wind-Tunnel Investigation at High Subsonic Speeds of the Effects of Wing-Mounted External Stores on the Loading and Aerodynamic Characteristics in Pitch of a 45° Sweptback Wing Combined With a Fuselage. NACA RM L54A21, 1954.

Alford, William J., Jr.; and Silvers, H. Norman: Investigation at High Subsonic Speeds of Finned and Unfinned Bodies Mounted at Various Locations From the Wings of Unswept- and Swept-Wing—Fuselage Models, Including Measurements of Body Loads. NACA RM L54B18, 1954.

Henning, Allen B.: The Effects of Wing-Mounted External Stores on the Trim, Buffet, and Drag Characteristics of a Rocket-Propelled Model Having a 45° Sweptback Wing. NACA RM L54B19, 1954.

Hoffman, Sherwood; and Wolff, Austin L.: Effect on Drag of Longitudinal Positioning of Half-Submerged and Pylon-Mounted Douglas Aircraft Stores on a Fuselage With and Without Cavities Between Mach Numbers 0.9 and 1.8. NACA RM L54E26, 1954.

Smith, Norman F.: Exploratory Investigation of External Stores on the Aerodynamic Characteristics of a 1/16-Scale Model of the Douglas D-558-II Research Airplane at a Mach Number of 2.01. NACA RM L54F02, 1954.

Mason, Homer P.; and Henning, Allen B.: Effects of Some External-Store Mounting Arrangements and Store Shapes on the Buffet and Drag Characteristics of Wingless Rocket-Powered Models at Mach Numbers From 0.7 to 1.4. NACA RM L54I20a, 1954.

Gapcynski, John P.; and Carlson, Harry W.: A Pressure-Distribution Investigation of the Aerodynamic Characteristics of a Body of Revolution in the Vicinity of a Reflection Plane at Mach Numbers of 1.41 and 2.01. NACA RM L54J29, 1955.

Ballentine, Donald C.: Wind-Tunnel Investigation of a 0.15-Scale Model F3H-2N Airplane Equipped With an Adjustable Leading-Edge Slot and Various External Stores. Aero Rep. 871, David W. Taylor Model Basin, Navy Dep., Oct. 1954.

Alford, William J., Jr.; Silvers, H. Norman; and King, Thomas J., Jr.: Experimental Aerodynamic Forces and Moments at Low Speed of a Missile Model During Simulated Launching From the Midsemispan Location of a 45° Sweptback Wing-Fuselage Combination. NACA RM L54K11a, 1955.

Alford, William J., Jr.: Experimental Static Aerodynamic Forces and Moments at Low Speed on a Canard Missile During Simulated Launching From the Midsemispan and Wing-Tip Locations of a 45° Sweptback Wing-Fuselage Combination. NACA RM L55A12, 1955.

Smith, Norman F.; and Carlson, Harry W.: The Origin and Distribution of Supersonic Store Interference From Measurement of Individual Forces on Several Wing-Fuselage-Store Configurations. I.- Swept-Wing Heavy-Bomber Configuration With Large Store (Nacelle). Lift and Drag; Mach Number, 1.61. NACA RM L55A13a, 1955.

Sleeman, William C., Jr.; and Alford, William J., Jr.: Low-Speed Investigation of the Effects of Wing Tanks and Speed Brakes on the Static Stability of a Model Having a 40° Swept Wing. NACA RM L55C17, 1955.

Silvers, H. Norman; and King, Thomas J., Jr.: Investigation at High Subsonic Speeds of the Effects of Various Underwing External-Store Arrangements on the Aerodynamic Characteristics of a 1/16-Scale Model of the Douglas D-558-II Research Airplane. NACA RM L55D11, 1955.

Alford, William J., Jr.; Silvers, H. Norman; and King, Thomas J., Jr.: Experimental Static Aerodynamic Forces and Moments at Low Speed on a Missile Model During Simulated Launching From the 25-Percent-Semispan and Wing-Tip Locations of a 45° Sweptback Wing-Fuselage Combination. NACA RM L55D20, 1955.

Mason, Homer P.: Effects of Wing-Mounted Tank-Type Stores on the Low-Lift Buffeting and Drag of a Swept-Wing Airplane Configuration Between Mach Numbers of 0.8 and 1.3. NACA RM L55D27, 1955.

Smith, Norman F.; and Carlson, Harry W.: The Origin and Distribution of Supersonic Store Interference From Measurement of Individual Forces on Several Wing-Fuselage-Store Configurations. II.- Swept-Wing Heavy-Bomber Configuration With Large Store (Nacelle). Lateral Forces and Pitching Moments; Mach Number, 1.61. NACA RM L55E26a, 1955.

Smith, Norman F.; and Carlson, Harry W.: The Origin and Distribution of Supersonic Store Interference From Measurement of Individual Forces on Several Wing-Fuselage-Store Configurations. III.- Swept-Wing Fighter-Bomber Configuration With Large and Small Stores. Mach Number, 1.61. NACA RM L55H01, 1955.

Kelly, Thomas C.: Transonic Wind-Tunnel Investigation of the Effects of External Stores and Store Position on the Aerodynamic Characteristics of a 1/16-Scale Model of the Douglas D-558-II Research Airplane. NACA RM L55I07, 1955.

Morris, Odell A.: The Origin and Distribution of Supersonic Store Interference From Measurement of Individual Forces on Several Wing-Fuselage-Store Configurations. IV.- Delta-Wing Heavy-Bomber Configuration With Large Store. Mach Number, 1.61. NACA RM L55I27a, 1955.

Hart, Roger G.: Flight Investigation at Mach Numbers From 0.8 to 1.5 To Determine the Effects of Nose Bluntness on the Total Drag of Two Fin-Stabilized Bodies of Revolution. NACA TN 3549, 1955. (Supersedes NACA RM L50I08a.)

Wainwright, John B.; and Rubinstein, Marvin: Report on the Aerodynamic Effects of External Stores on a Wind Tunnel Model XF8U-1 Airplane in the Mach Number Range 0.8 to 1.4. USCEC Rep. 32-1-5, Aerodyn. Test Div., NAMTC, Univ. of Southern California, Apr. 28, 1955.

Carlson, Harry W.; and Geier, Douglas J.: The Origin and Distribution of Supersonic Store Interference From Measurement of Individual Forces on Several Wing-Fuselage-Store Configurations. V.- Swept-Wing Heavy-Bomber Configuration With Large Store (Nacelle). Mach Number 2.01. NACA RM L55K15, 1956.

Smith, Norman F.: The Origin and Distribution of Supersonic Store Interference From Measurement of Individual Forces on Several Wing-Fuselage-Store Configurations. VI.- Swept-Wing Heavy-Bomber Configuration With Stores of Different Sizes and Shapes. NACA RM L55L08, 1956.

Robinson, Ross B.: Longitudinal Characteristics of an Unswept-Wing Fighter-Type Model With External Stores at a Mach Number of 1.82 and Some Effects of Horizontal-Tail and Yaw-Damper Deflection on the Sideslip Derivatives. NACA RM L55L26, 1956.

Hallisy, Joseph M., Jr.; and Kudlacik, Louis: A Transonic Wind-Tunnel Investigation of Store and Horizontal-Tail Loads and Some Effects of Fuselage-Afterbody Modifications on a Swept-Wing Fighter Airplane. NACA RM L56A26, 1956.

Foster, Gerald V.; and Driver, Cornelius: Effects of External Stores on the Static Longitudinal and Lateral Aerodynamic Characteristics of a Model of a 45° Swept-Wing Fighter Airplane at Mach Numbers of 1.61 and 2.01. NACA RM L56F15a, 1956.

Spearman, M. Leroy; and Driver, Cornelius: Longitudinal and Lateral Stability Characteristics of a Low-Aspect-Ratio Unswept-Wing Airplane Model at Mach Numbers of 1.82 and 2.01. NACA RM L56H06, 1957.

Morris, Odell A.: Aerodynamic Forces and Moments on a Large Ogive-Cylinder Store at Various Locations Below the Fuselage Center Line of a Swept-Wing Bomber Configuration at a Mach Number of 1.61. NACA RM L56I25, 1957.

Alford, William J., Jr.; and King, Thomas J., Jr.: Experimental Static Aerodynamic Forces and Moments at High Subsonic Speeds on a Missile Model During Simulated Launching From the Midsemispan Location of a 45° Sweptback Wing-Fuselage-Pylon Combination. NACA RM L56J05, 1957.

Hill, P. R.; and Hoffman, S.: Preliminary Evaluation of the Wing Leading Edge as a Missile-Mounting Location. NACA RM L56J12, 1957.

Geier, Douglas J.; and Carlson, Harry W.: Measurement of Static Forces on Externally Carried Bombs of Fineness Ratios 7.1 and 10.5 in the Flow Field of a Swept-Wing Fighter-Bomber Configuration at a Mach Number of 1.6. NACA RM L56K30, 1957.

Hoffman, Sherwood: Zero-Lift Drag of a Large Fuselage Cavity and a Partially Submerged Store on a 52.5° Sweptback-Wing—Body Configuration as Determined From Free-Flight Tests at Mach Numbers of 0.7 to 1.53. NACA RM L56L21, 1957.

Nugent, Jack: Effect of Wing-Mounted External Stores on the Lift and Drag of the Douglas D-558-II Research Airplane at Transonic Speeds. NACA RM H57E15a, 1957.

Gapcynski, John P.; and Carlson, Harry W.: The Aerodynamic Characteristics of a Body in the Two-Dimensional Flow Field of a Circular-Arc Wing at a Mach Number of 2.01. NACA RM L57E14, 1957.

Polhamus, Edward C.: Effect of Nose Shape on Subsonic Aerodynamic Characteristics of a Body of Revolution Having a Fineness Ratio of 10.94. NACA RM L57F25, 1957.

Pearson, Albin O.: Transonic Investigation of Effects of Spanwise and Chordwise External Store Location and Body Contouring on Aerodynamic Characteristics of 45° Sweptback Wing-Body Configurations. NACA RM L57G17, 1957.

Hoffman, Sherwood: Free-Flight Investigation of the Drag of a Model of a 60° Delta-Wing Bomber With Strut-Mounted Siamese Nacelles and Indented Fuselage at Mach Numbers From 0.80 to 1.35. NACA RM L57G29, 1957.

Church, James D.: Effects of Components and Various Modifications on the Drag and the Static Stability and Control Characteristics of a 42° Swept-Wing Fighter-Airplane Model at Mach Numbers of 1.60 to 2.50. NACA RM L57K01, 1957. (Reprinted 1959.)

Geier, Douglas J.: An Investigation of Supersonic Store Interference in the Vicinity of a 22° Swept-Wing—Fuselage Configuration at Mach Numbers of 1.61 and 2.01. NACA RM L57L18, 1957.

Brindle, C. Carl: Longitudinal Characteristics at Supersonic Speeds of a Winged and a Wingless 0.08-Scale Half Model Sparrow I Missile at Angles of Attack up to 180°. Aero Rep. 931, David W. Taylor Model Basin, Navy Dep., Dec. 1957.

Reese, David E., Jr.: A Wind-Tunnel Investigation of Several Wingless Missile Configurations at Supersonic Speeds. NACA RM A57J22, 1958.

Gnos, A. Vernon; and Kurkowski, Richard L.: Static Longitudinal and Lateral Stability and Control Characteristics of a Model of a Swept-Wing Fighter-Bomber-Type Airplane With a Top Inlet at Mach Numbers From 1.6 to 2.35. NACA RM A57K20, 1958.

Hoffman, Sherwood: Free-Flight Investigation at Mach Numbers From 0.8 to 1.5 of the Effect of a Fuselage Indentation on the Zero-Lift Drag of a 52.5° Sweptback-Wing—Body Configuration With Symmetrically Mounted Stores on the Fuselage. NACA RM L57L04, 1958.

Morris, Odell A.: Effects of External Store-Pylon Configuration and Position on the Aerodynamic Characteristics of a 45° Swept Wing-Fuselage Combination at a Mach Number of 1.61. NACA RM L58C13, 1958.

Oehman, Waldo I.; and Turner, Kenneth L.: Aerodynamic Characteristics of a 45° Swept-Wing Fighter-Airplane Model and Aerodynamic Loads on Adjacent Stores and Missiles at Mach Numbers of 1.57, 1.87, 2.16, and 2.53. NACA RM L58C17, 1958.

Robinson, Robert C.: The Effect of Lower Surface Spoilers on the Transonic Trim Change of a Wind-Tunnel Model of a Fighter Airplane Having a Modified Delta Wing. NASA MEMO 12-27-58A, 1959.

Hoffman, Sherwood: Free-Flight Investigation of the Drag of a 60° Delta-Wing Configuration With Large Stores Mounted Below the Indented Fuselage at Mach Numbers Between 0.8 and 1.6. NASA MEMO 10-9-58L, 1958.

Margolis, Kenneth; Malvestuto, Frank S., Jr.; and Maxie, Peter J., Jr.: Theoretical Calculations of Supersonic Wave Drag at Zero Lift for a Particular Store Arrangement. NACA TN 4120, 1958.

Appich, W. H., Jr.; Oehman, Waldo I.; and Gregory, Donald T.: Aerodynamic Characteristics of Three Versions of a Supersonic Airplane Model With a 45° Sweptback Midwing at Mach Numbers of 1.57 and 2.01. NASA MEMO 12-6-58L, 1959.

Bielat, Ralph P.: A Transonic Wind-Tunnel Investigation of the Performance and of the Static Stability and Control Characteristics of a Model of a Fighter-Type Airplane Which Embodies Partial Body Indentation. NASA MEMO 12-13-58L, 1959.

White, Maurice D.; and Innis, Robert C.: A Flight Investigation of the Low-Speed Handling Qualities of a Tailless Delta-Wing Fighter Airplane. NASA MEMO 4-15-59A, 1959.

Carmel, Melvin M.; and Gregory, Donald T.: Preliminary Investigation of the Static Longitudinal and Lateral Stability Characteristics of a Model of a 45° Swept Wing Airplane at Mach Numbers of 1.59, 1.89, and 2.09. NASA MEMO 3-30-59L, 1959.

Wornom, Dewey E.: Transonic Aerodynamic Characteristics of a 45° Swept-Wing—Fuselage Model With a Finned and Unfinned Body Pylon-Mounted Beneath the Fuselage or Wing, Including Measurements of Body Loads. NASA MEMO 4-20-59L, 1959.

Drougge, Georg (With appendix by Sune B. Berndt and Lars O. A. Hilding): An Experimental Investigation of the Interference Between Bodies of Revolution at Transonic Speeds With Special Reference to the Sonic and Supersonic Area Rules. FFA Rep. 83, Aeronaut. Res. Inst. of Sweden, 1959.

Pitts, William C.; and Wiggins, Lyle E.: Axial-Force Reduction by Interference Between Jet and Neighboring Afterbody. NASA TN D-332, 1960.

Pivirotto, Thomas J.: Aerodynamic Test of the 0.16-Scale Model of the Hughes Model 50 Missile. WT 20-355, Jet Propulsion Lab., California Inst. Technol., Aug. 21, 1960.

Brown, A. E.; deLancey, L. M.; and Meeker, R. E.: Studies of the Sidewinder 1C Aeromechanics – Part 1. Aerodynamics. NAVWEPS Rep. 6596, Pt. 1, U.S. Naval Ord. Test Station, Oct. 24, 1960.

Fischetti, Thomas L.; and Eaton, Peter T.: Wind-Tunnel Investigation of the Effects of Externally Installed Missiles on an Aircraft Configuration at High Subsonic Speeds. Aero Rep. 995, David W. Taylor Model Basin, Navy Dep., Dec. 1960.

Luoma, Arvo A.: Transonic Wind-Tunnel Investigation of the Static Longitudinal Stability and Performance Characteristics of a Supersonic Fighter-Bomber Airplane. NASA TM X-513, 1961.

Robinson, Ross B.; and Spearman, M. Leroy: Static Lateral and Directional Stability and Control Characteristics of a 1/40-Scale Model of a 60° Delta Wing Bomber Configuration at a Mach Number of 1.99. NASA TM X-537, 1961.

Bielat, Ralph P.; and Robins, A. Warner: Stability and Control Characteristics at Transonic Speeds of Two Variable-Sweep Airplane Configurations Differing in Wing-Pivot Locations. NASA TM X-559, 1961.

Luoma, Arvo A.: Transonic Wind-Tunnel Investigation of the Static Stability and Control Characteristics of a Supersonic Fighter-Bomber Airplane. NASA TM X-591, 1961.

Brindle, C. Carl: Wind-Tunnel Investigation of the Drag Characteristics of a Pylon-Mounted Missile. Aero Rep. 1010, David W. Taylor Model Basin, Navy Dep., June 1961.

Eaton, Peter T.: Wind-Tunnel Investigation of the Effects of Multiple External Stores on the Longitudinal Aerodynamic Characteristics of the Douglas A4D Airplane. Aero Rep. 1009, David W. Taylor Model Basin, Navy Dep., Sept. 1961.

Brindle, C. Carl: Wind-Tunnel Investigation of External Store Arrangements To Reduce Wave Drag. Aero Rep. 1016, David W. Taylor Model Basin, Navy Dep., Nov. 1961.

Landrum, Emma Jean: Static Lateral and Directional Stability and Control Characteristics of a 1/40-Scale Model of a 60° Delta Wing Bomber Configuration at a Mach Number of 1.61. NASA TM X-748, 1963.

Foster, Gerald V.; and Kyle, Robert G.: Aerodynamic Characteristics of a 1/22-Scale Model of a Fighter Airplane With an Extended Forebody and Other Modifications at Mach Numbers of 1.57 and 2.01. NASA TM X-833, 1963.

Eaton, Peter T.; and Swinney, Charles S.: Incremental Lift and Drag of an External Aircraft Store – Phase I. Test Rep. AL 20, David Taylor Model Basin, Dep. Navy, July 1965.

Shaw, David S.; and Babb, C. Donald: Supersonic Investigation of the Static Stability, Performance, and Control of a Variable-Sweep Tactical Fighter Model – Phase 4. NASA TM X-1143, 1965.

Ferris, James C.: Effects of External Stores on Performance and Stability of a Supersonic Fighter-Bomber Airplane. NASA TM X-1218, 1966.

Ayers, Theodore G.: Transonic Aerodynamic Characteristics of a Variable-Wing-Sweep Tactical Fighter Model – Phase 4. NASA TM X-1237, 1966.

Landrum, Emma Jean: Effect of Nacelle Orientation on the Aerodynamic Characteristics of an Arrow Wing-Body Configuration at Mach Number 2.03. NASA TN D-3284, 1966.

Norris, John D.; and McGhee, Robert J.: Effects of Bluntness on the Subsonic Drag of an Elliptical Forebody. NASA TN D-3388, 1966.

Shaw, David S.; and Wassum, Donald L.: Supersonic Investigation of the Static Stability, Performance, and Control of a Variable-Sweep Tactical Fighter Model – Phase 2. NASA TM X-1046, 1965.

Kyle, Robert G.; and Fuller, Dennis E.: Aerodynamic Characteristics of a Variable-Sweep Strategic Aircraft Model at Mach 2.16. NASA TM X-1169, 1965.

Fuller, Dennis E.; and Shaw, David S.: Supersonic Investigation of the Static Stability, Performance, and Control of a Variable-Sweep Tactical Fighter Model – Phase 6. NASA TM X-1229, 1966.

Fuller, Dennis E.: Supersonic Investigation of the Static Stability, Performance, and Control of a Variable-Sweep Tactical Fighter Model – Phase 7. NASA TM X-1238, 1966.

Campbell, James F.: Stability Characteristics of a Variable-Sweep Lightweight Fighter Configuration With a Keel-Type Fuselage at Mach Numbers From 1.50 to 2.86. NASA TM X-1350, 1967.

Fuller, Dennis E.; and Feryn, Maurice O.: Supersonic Investigation of the Static Stability, Performance, and Control of a Variable-Sweep Tactical Fighter Model. NASA TM X-1377, 1967.

Wassum, Donald L.; and Fuller, Dennis E.: Supersonic Investigation of the Static Stability, Performance, and Control of a Variable-Sweep Tactical Fighter Model – Phase 9. NASA TM X-1399, 1967.

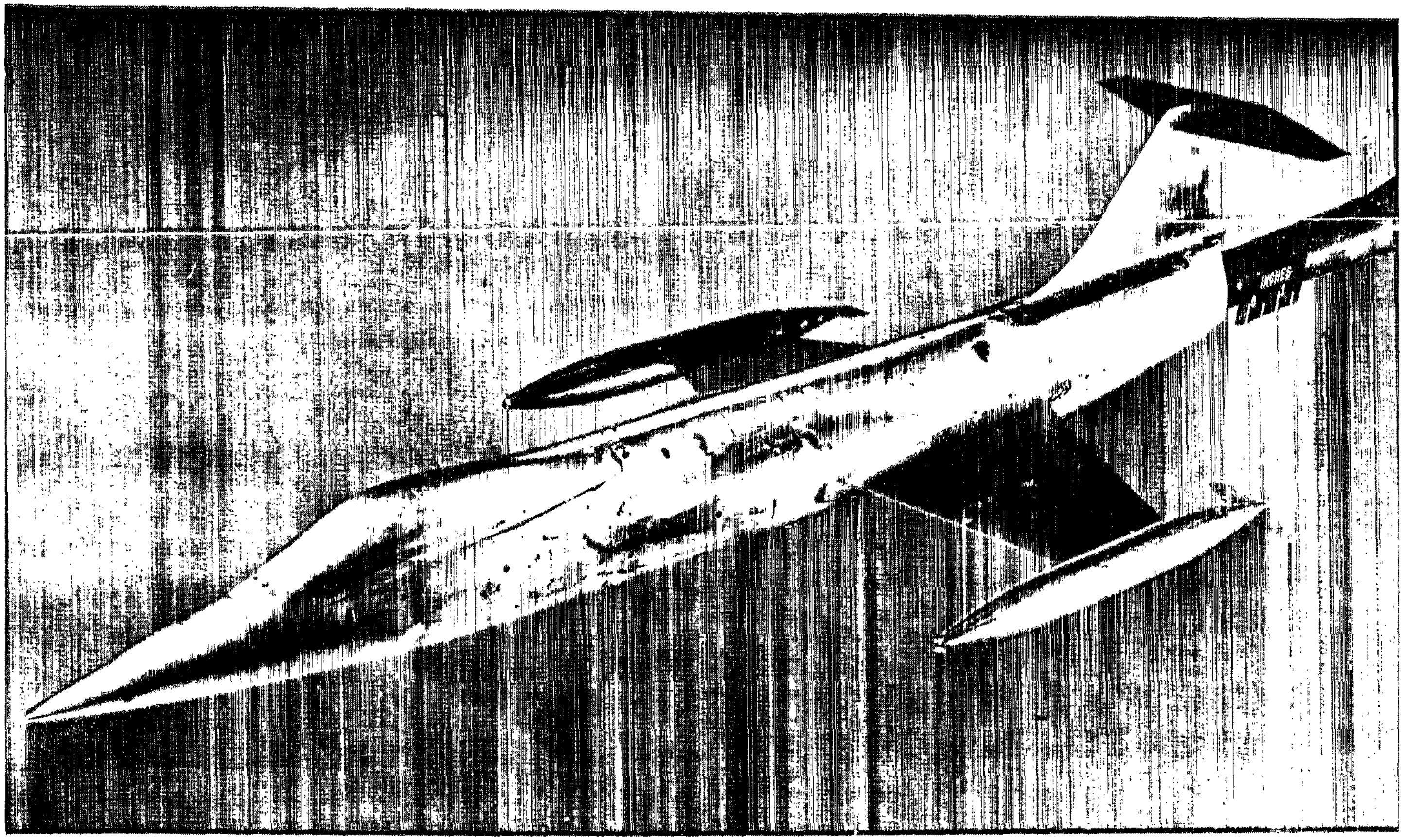
Blair, A. B., Jr.: Effect of Fences, Spoilers, and External Stores on a Variable-Sweep Tactical Fighter Model at Supersonic Speeds. NASA TM X-1725, 1969.

Blair, A. B., Jr.; and Richardson, Celia S.: Effect of Stores on Static Stability, Performance, and Control of a Variable-Sweep Tactical Fighter Bomber Model. NASA TM X-1755, 1969.

Blair, A. B., Jr.: Effect of Stores and Fuselage Modification on Static Stability, Performance, and Control of a Variable-Sweep Tactical Fighter-Bomber Model. NASA TM X-2063, 1970.

Blair, A. B., Jr.: Effect of Stores on Static Stability, Performance, and Control of a Variable-Sweep Tactical Fighter Model. NASA TM X-2064, 1970.

Anon.: Proceedings of the 8th Navy Symposium on Aeroballistics. Vols. 1-5, Naval Weapons Center (China Lake, Calif.), June 1969.



L-72-197

Figure 1.- Model of straight-wing fighter airplane with wing-tip fuel tanks.

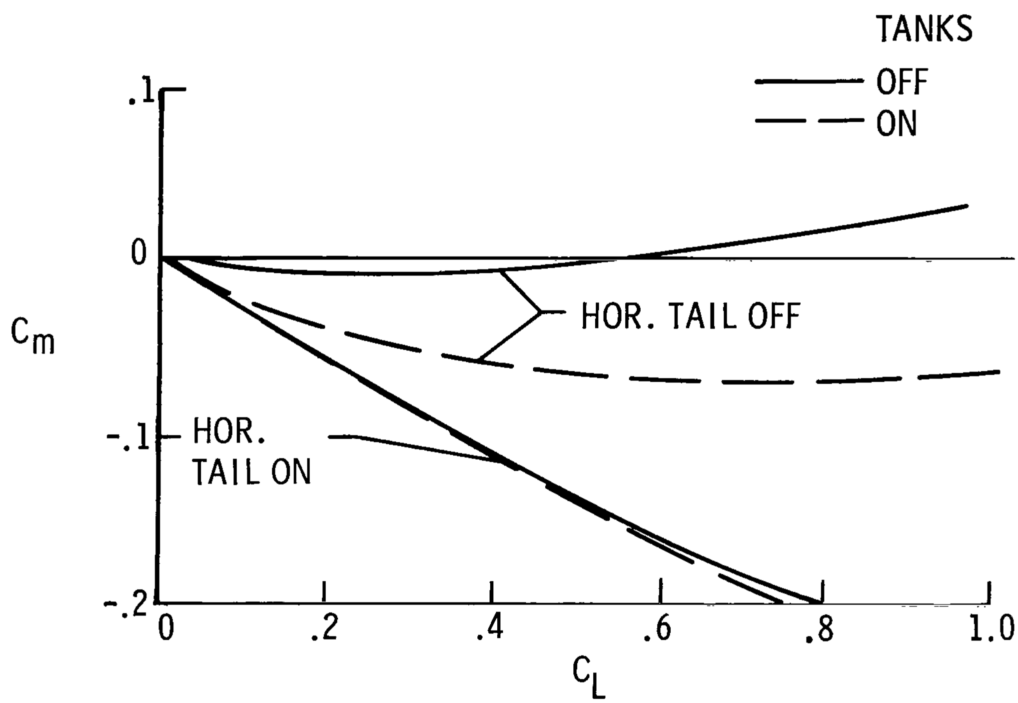


Figure 2.- Effect of wing-tip fuel tanks on longitudinal stability of straight-wing fighter airplane. M = 2.

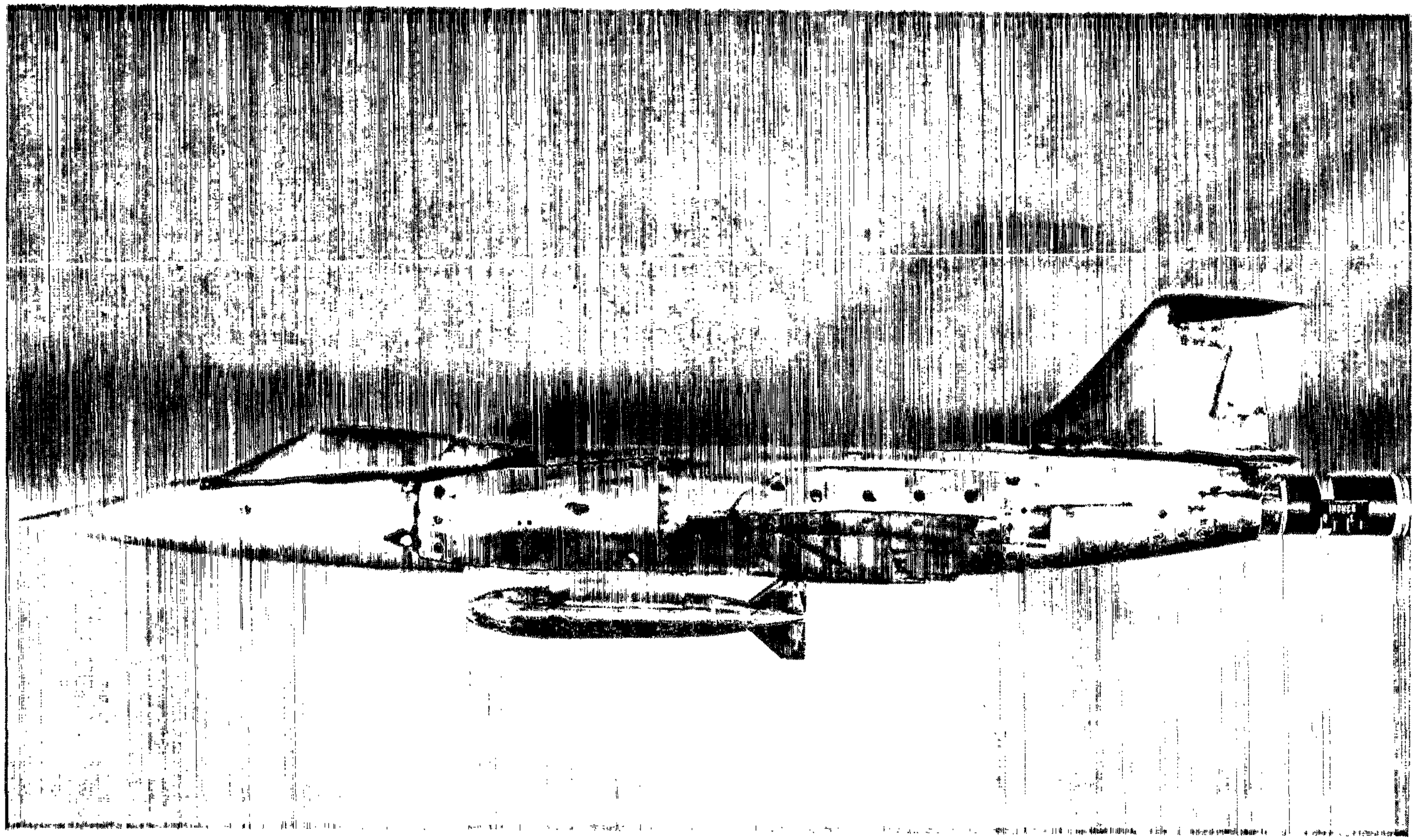


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Figure 3.- Model of straight-wing fighter airplane with body-mounted store.

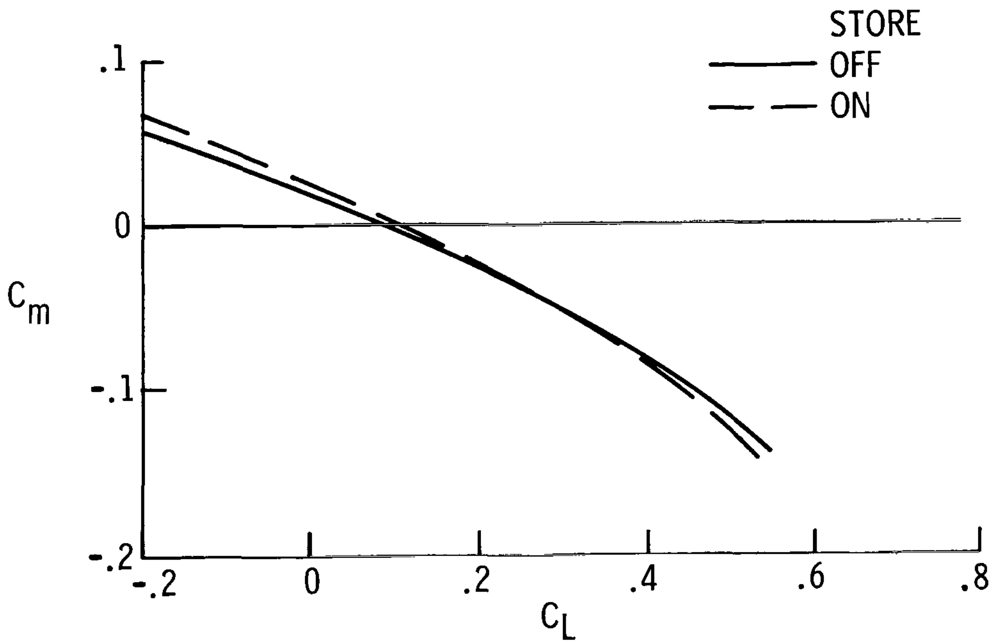

Figure 4.- Effect of body-mounted store on longitudinal stability of straight-wing fighter airplane. M = 1.8.

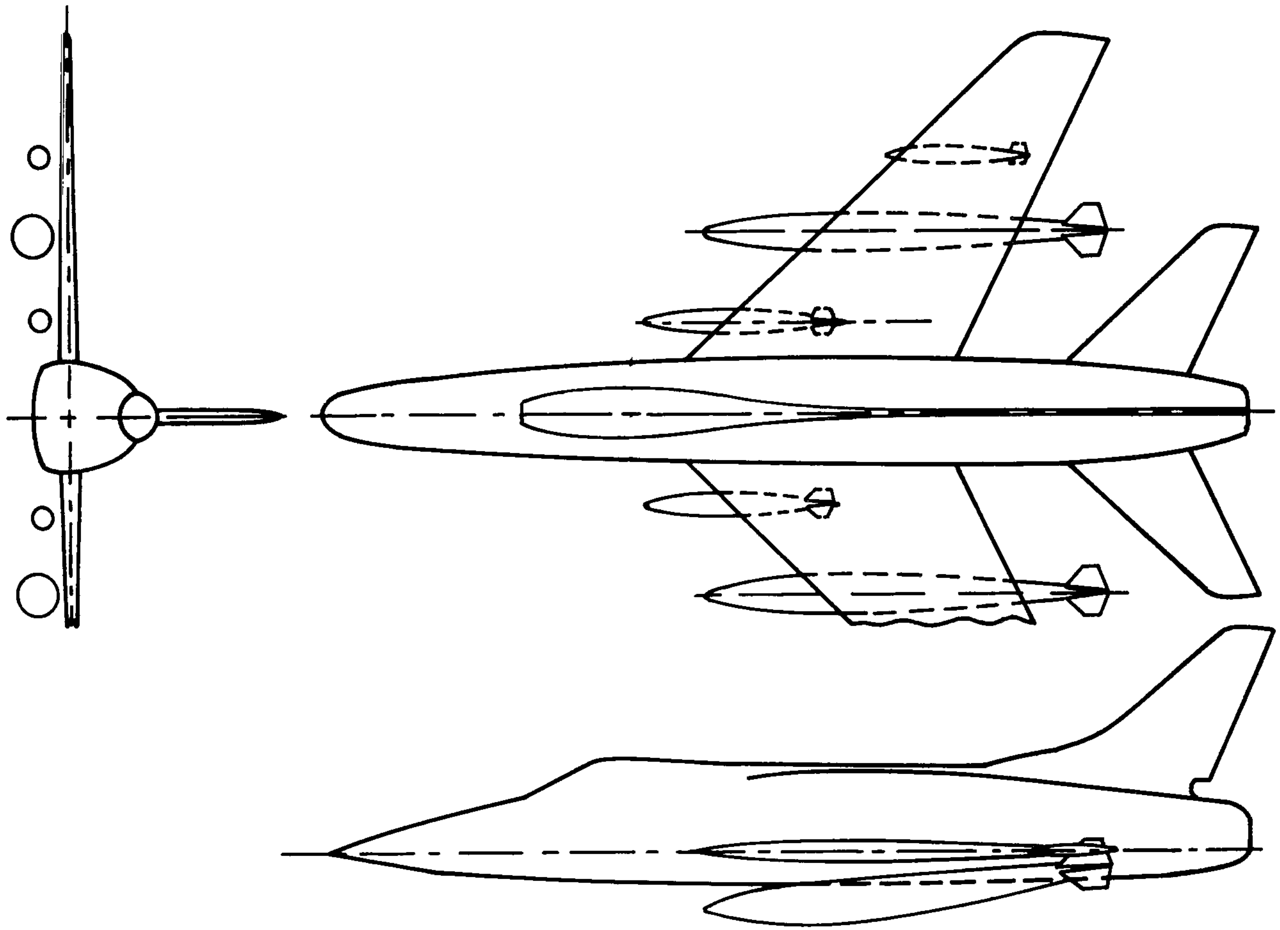

Figure 5.- Location of various stores on model of 45° swept-wing fighter airplane.

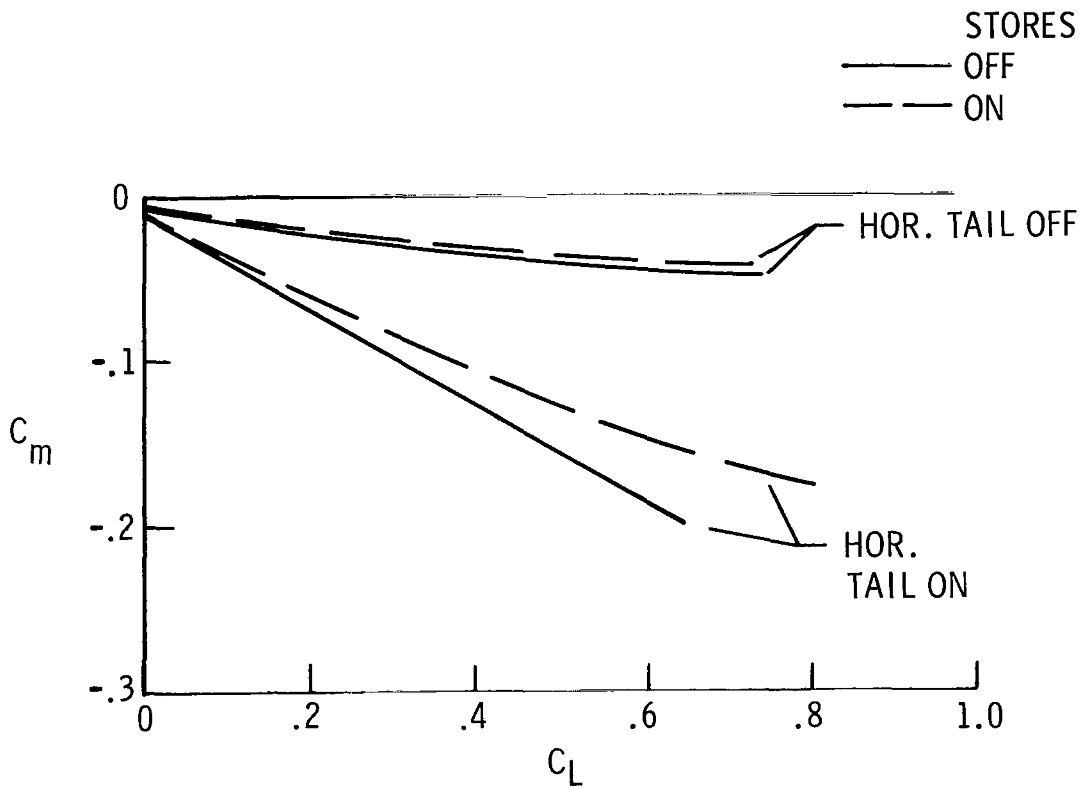

Figure 6.- Effect of large fuel tanks on longitudinal stability of 45° swept-wing fighter airplane. M = 2.

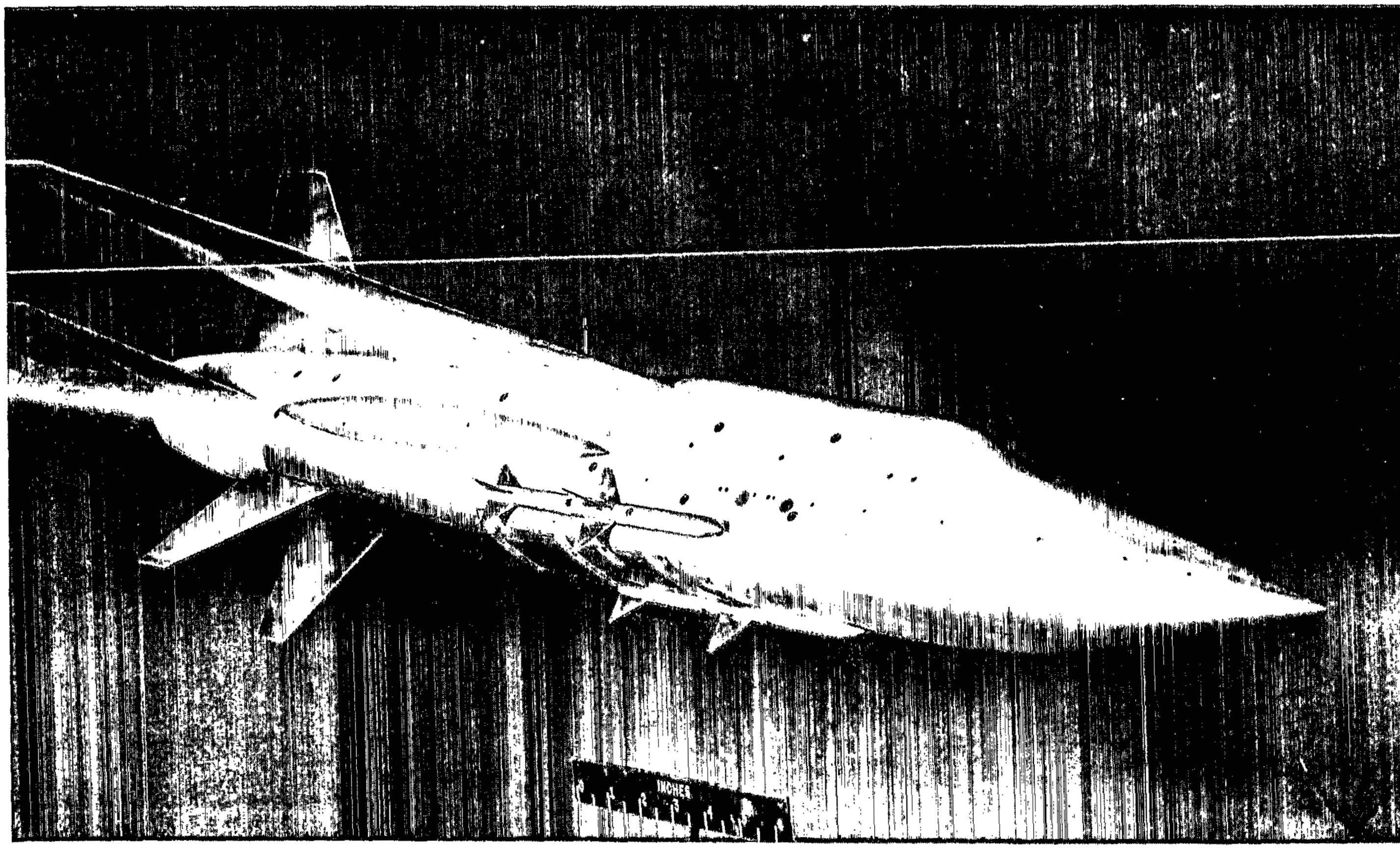

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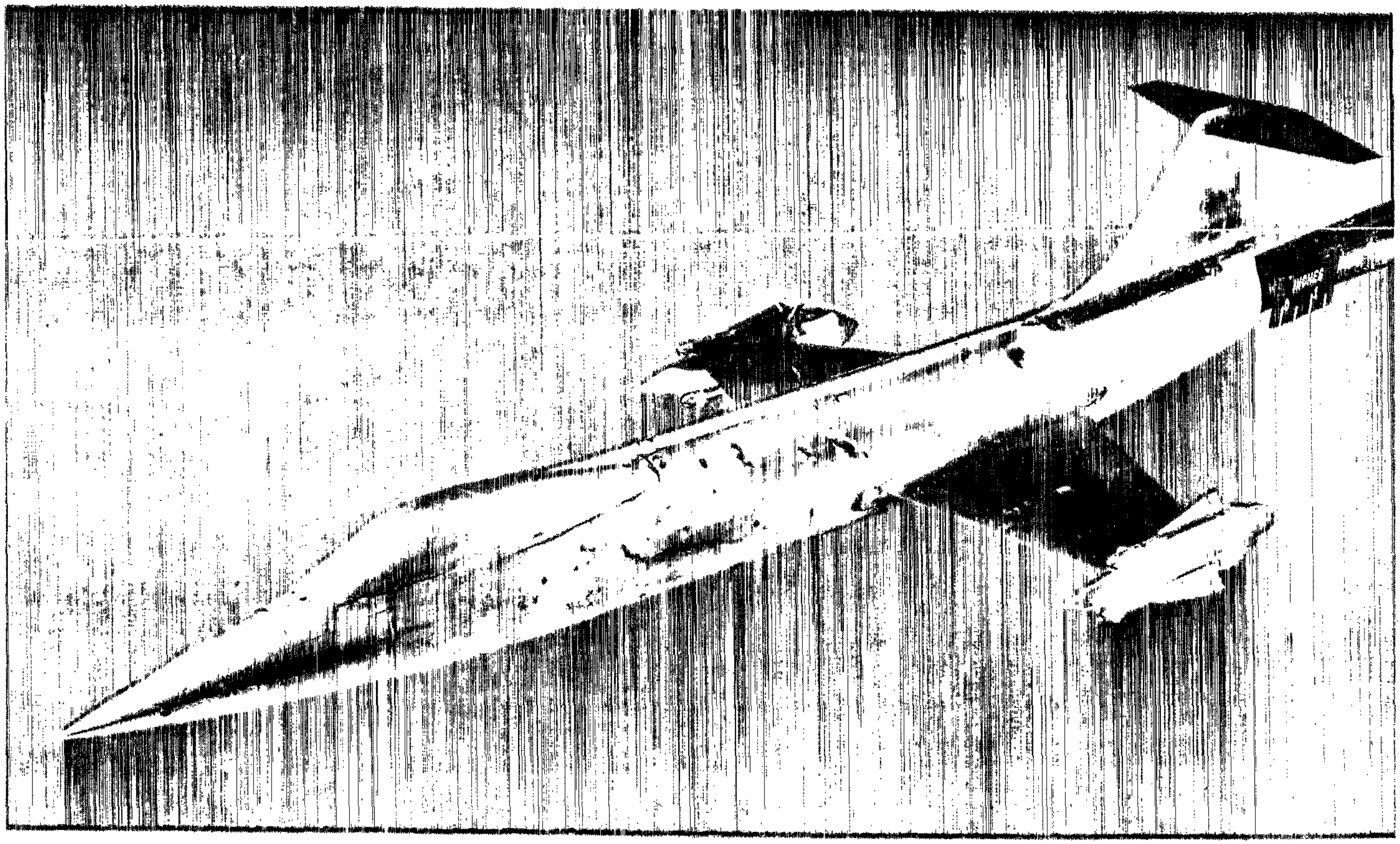
Figure 7.- Model of 42° swept-wing fighter airplane with fuel tanks and missiles.



L-72-200

Figure 8.- Model of straight-wing fighter airplane with wing-tip missiles.

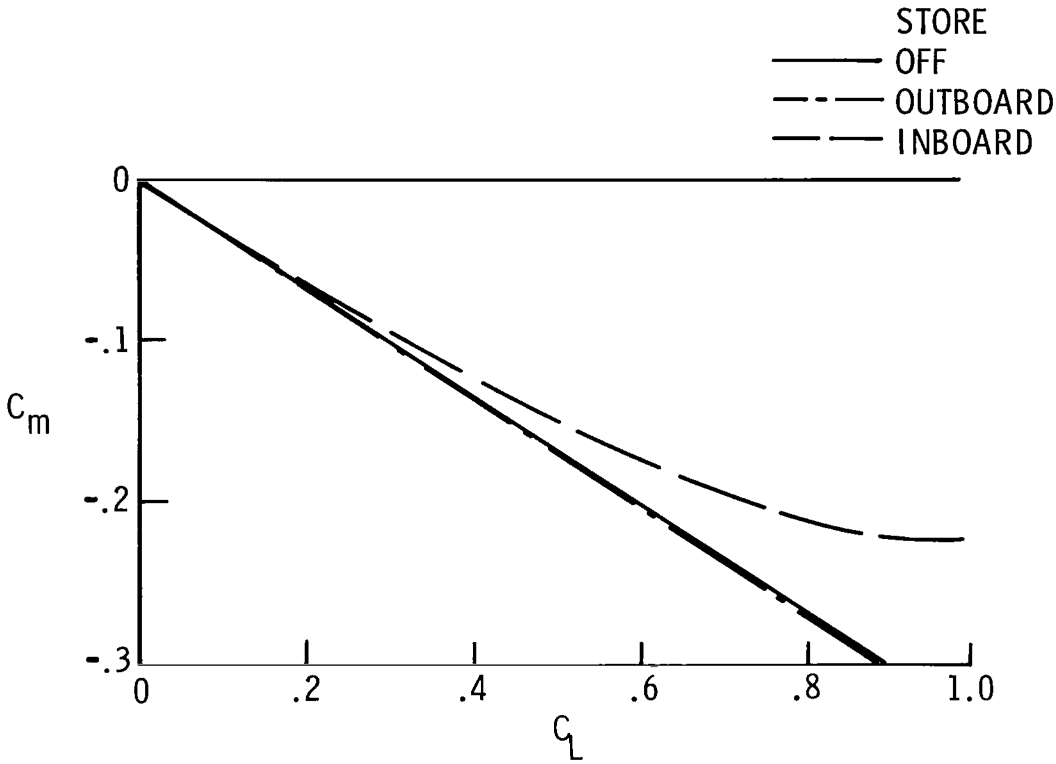


Figure 9.- Effect of inboard and outboard stores on longitudinal stability of 45° swept-wing fighter airplane. M = 1.6.

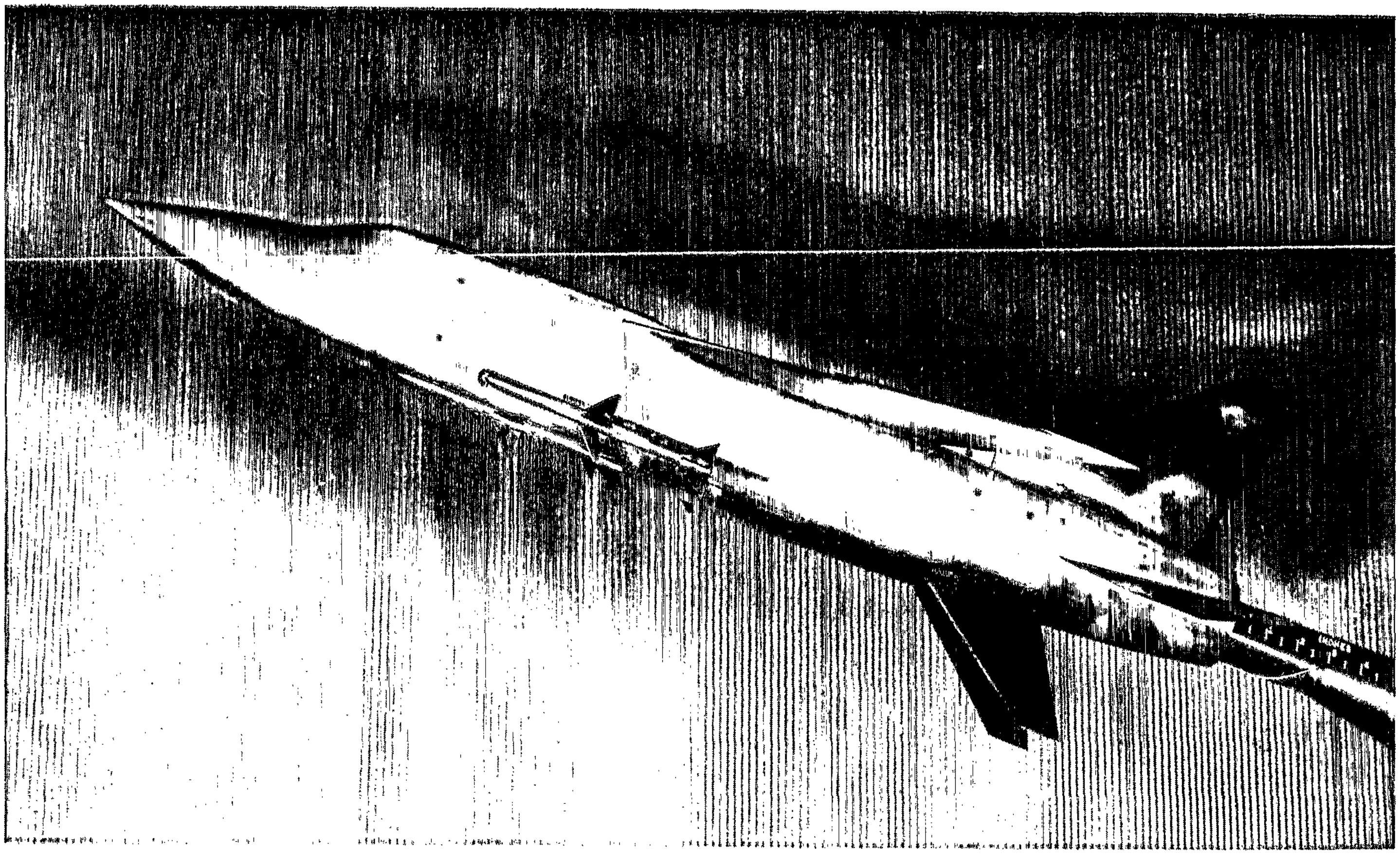


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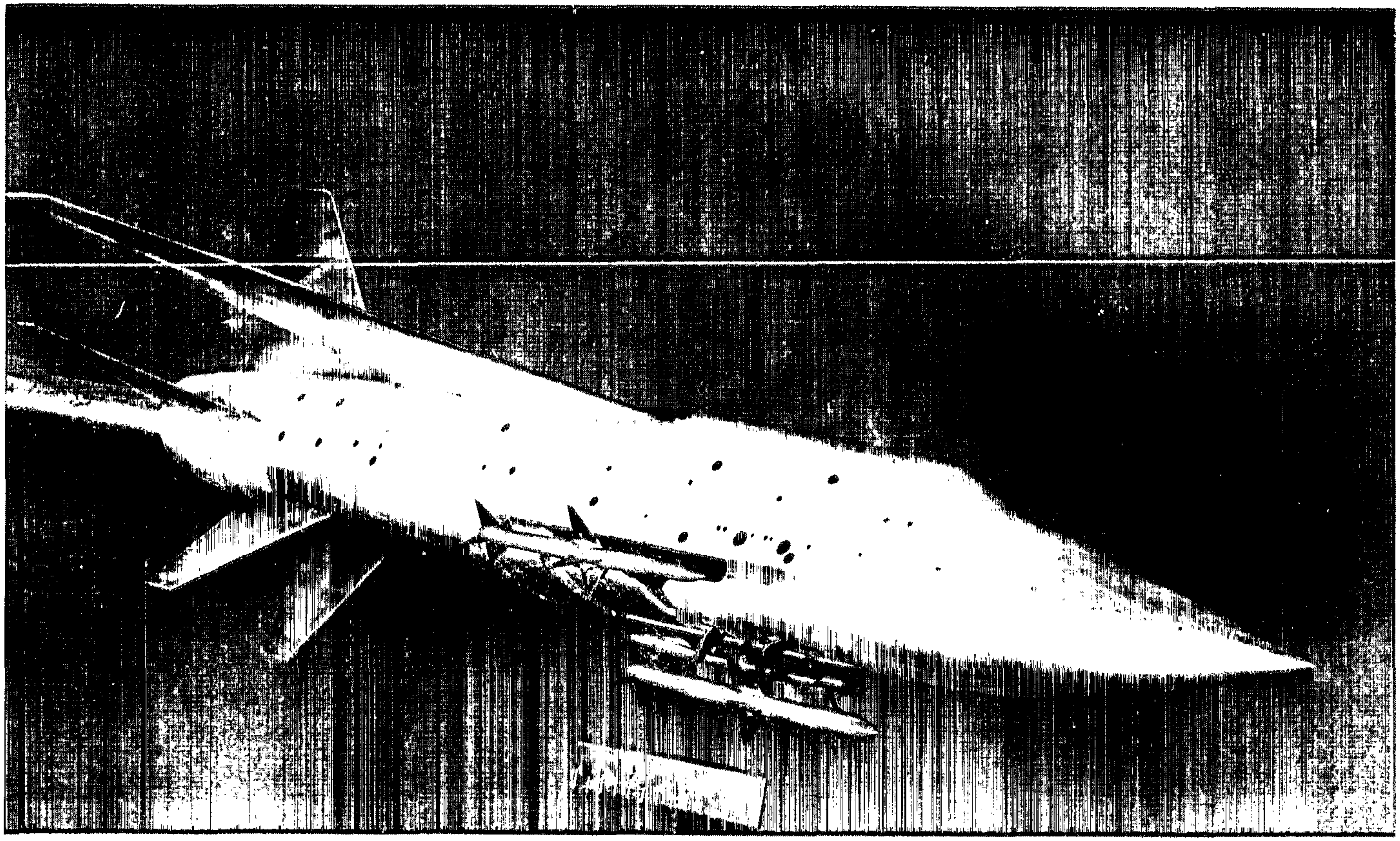
Figure 10.- Model of 42° swept-wing fighter airplane with semisubmerged missiles.



L-72-2402

Figure 11.- Model of 42° swept-wing fighter airplane with missiles extended.

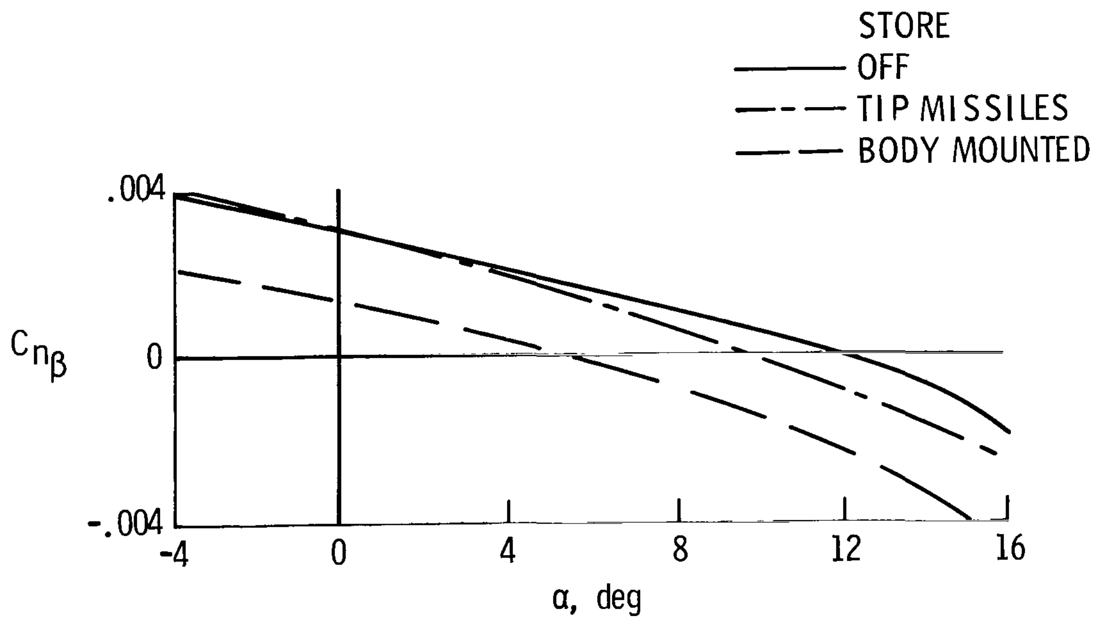


Figure 12.- Effects of stores on directional stability of straight-wing fighter airplane. M = 2.

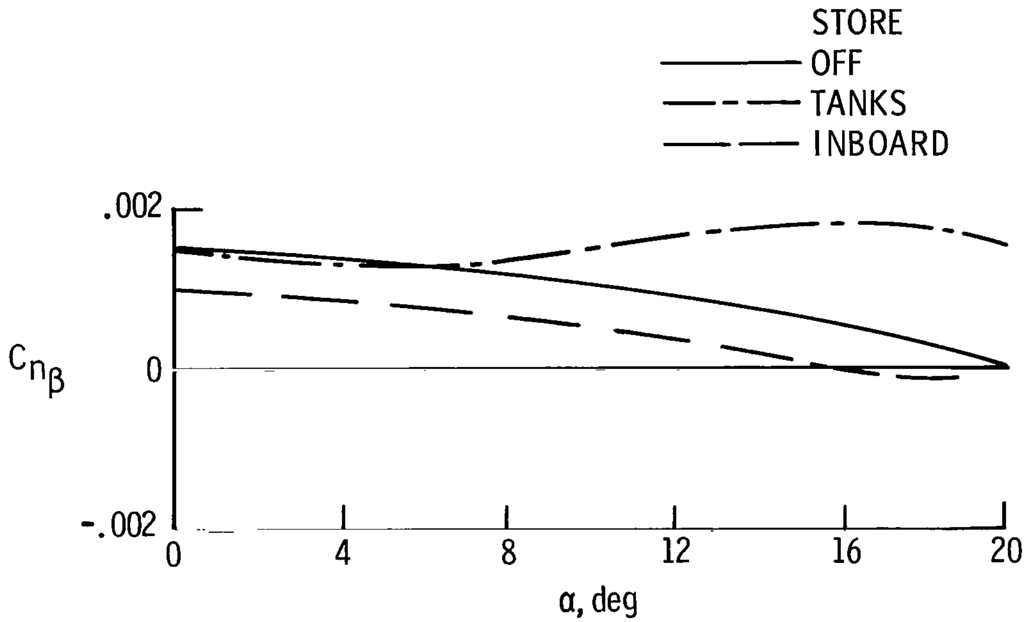


Figure 13.- Effects of stores on directional stability of 45° swept-wing fighter airplane. M = 1.6.

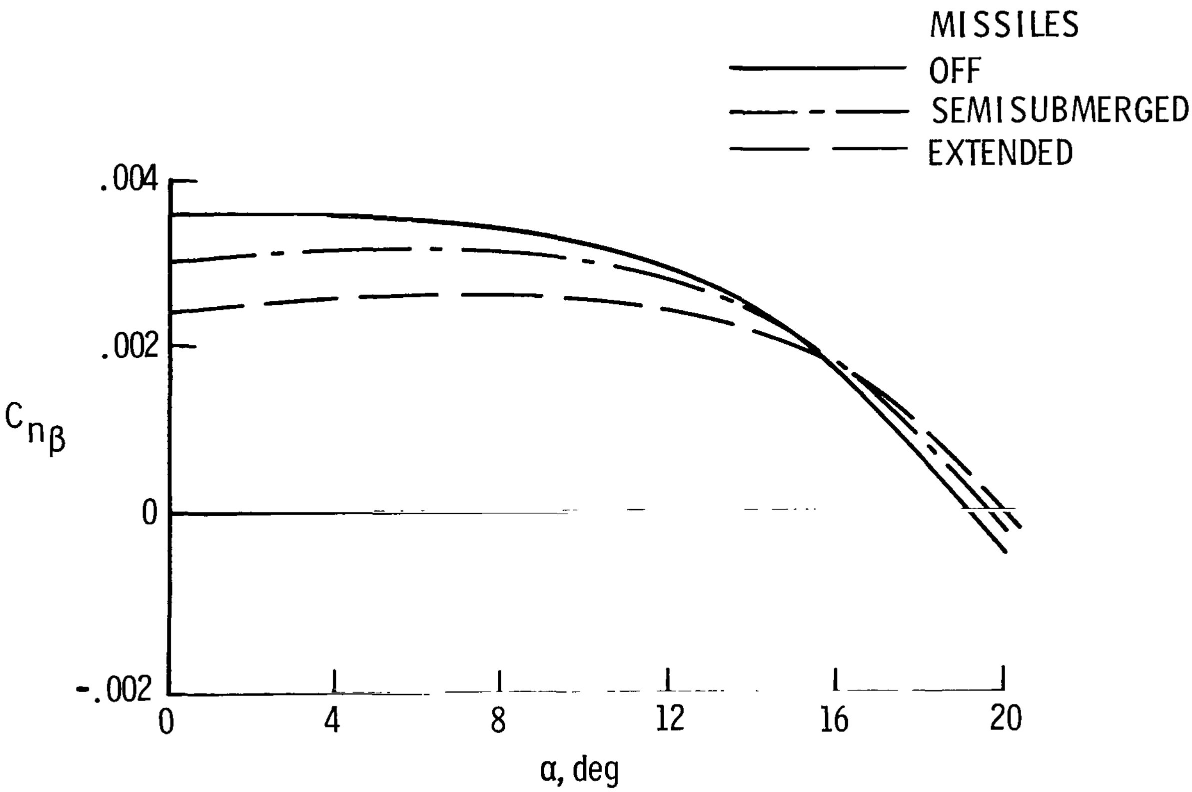
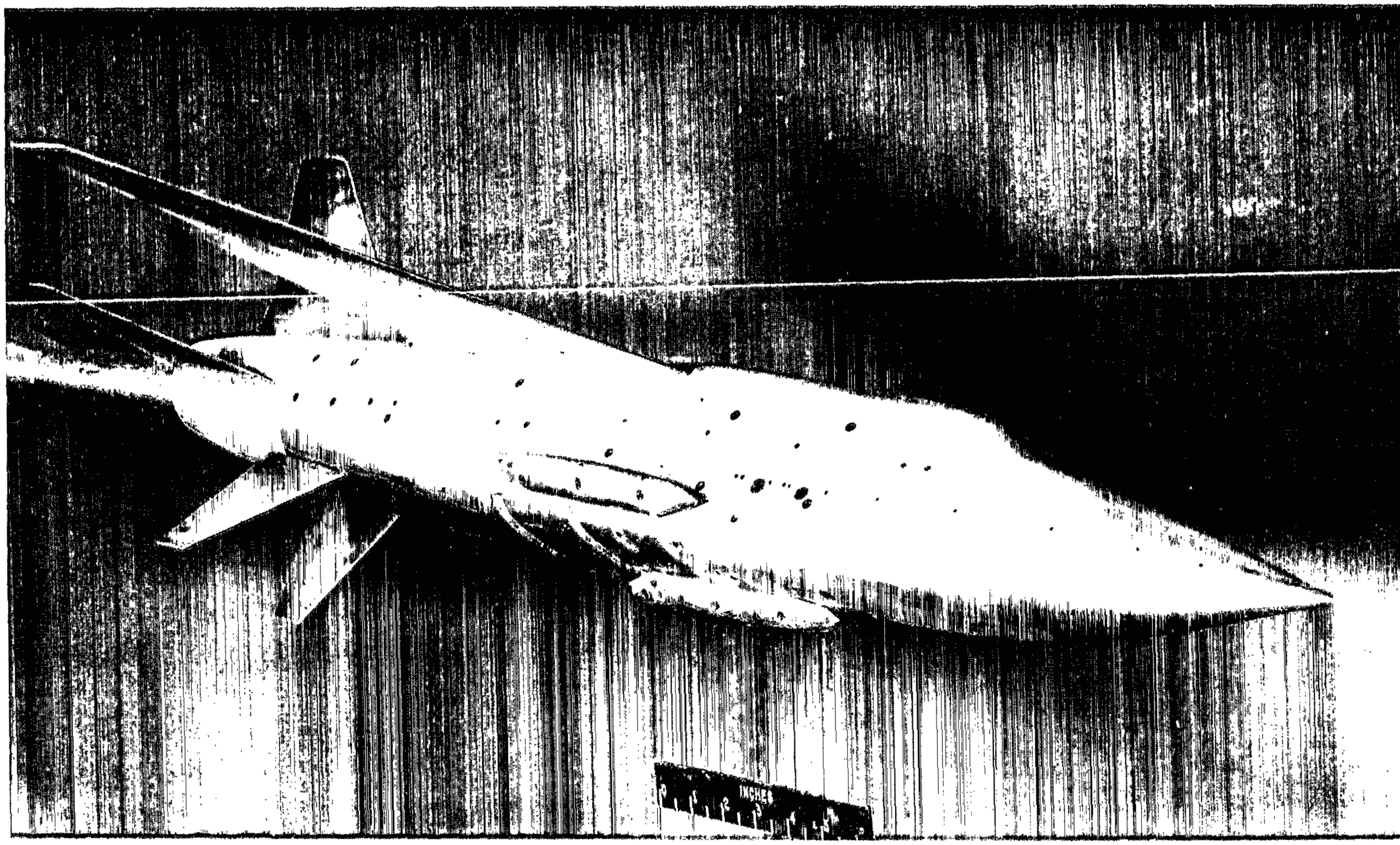


Figure 14.- Effects of missiles on directional stability of 42° swept-wing fighter airplane. M = 1.6.



L-72-2403

Figure 15.- Model of 42° swept-wing fighter airplane with rocket packets.

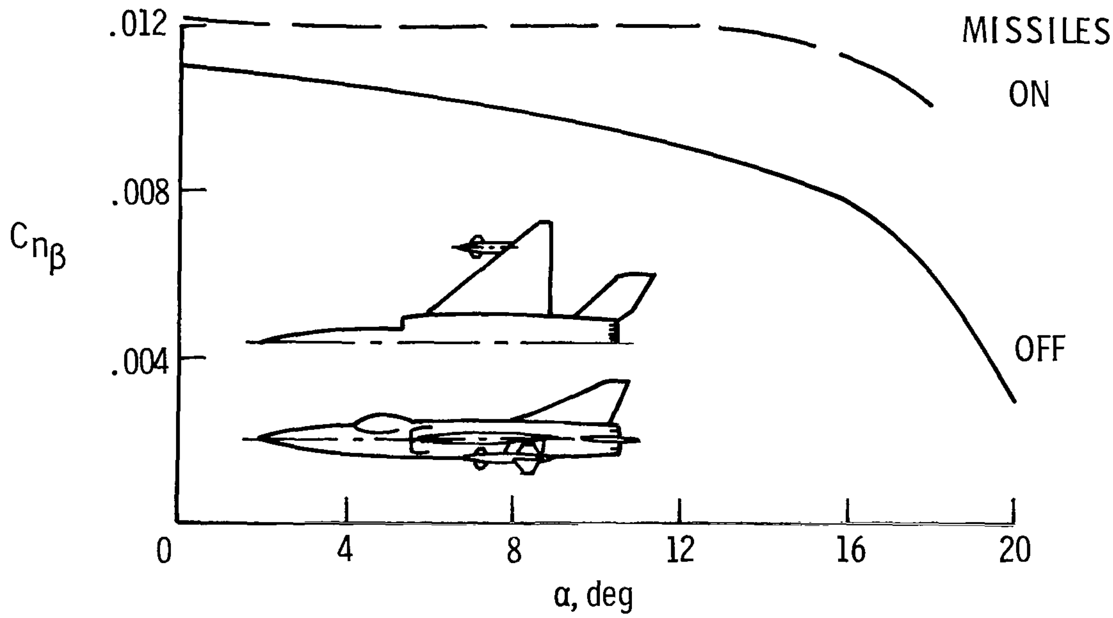


Figure 16.- Effect of missiles on delta-wing fighter airplane. M = 1.6.

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