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SEPARATION TRAJECTORIES FOR THE SUU-51B/B STORE FROM THE F-4C AIRCRAFT

Willard E. Summers

ARO, Inc.

June 1972

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FOREWORD

The work reported herein was sponsored by the Air Force Armament Laboratory (AFATL/DLGC/Maj W. A. Miller), Air Force Systems Command (AFSC), under Program Element 64724F.

The test results presented were obtained by ARO, Inc. (a subsidiary of Sverdrup & Parcel and Associates, Inc.), contract operator of the Arnold Engineering Development Center (AEDC), AFSC, Arnold Air Force Station, Tennessee, under Contract F40600-72-C-0003. The test was conducted from March 27 through 30 and April 13 and 14, 1972, under ARO Project No. PC0246. The manuscript was submitted for publication on May 5, 1972.

This technical report has been reviewed and is approved.

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ABSTRACT

Separation trajectory data were obtained to investigate some possible ways to reduce the nose-down pitch of the SUU-51B/B store during separation from the Triple Ejection Rack (TER) on the F-4C aircraft. Data were obtained to assess the influence on the store separation characteristics resulting from (1) changing the store mass properties (ballasting), (2) modifying the TER geometry to represent removal of the nose fairing, (3) changing the store carriage location on the TER, (4) modifying the store nose geometry, and (5) applying dual ejector forces to the store during separation. Separation trajectories were obtained for release from the TER on the inboard pylon at Mach numbers from 0.66 to 1.1 for level flight at 5000-ft altitude. In addition to the trajectory data, force and moment data were obtained on the SUU-51B/B to assess the influence on store loads of (1) changes in store position relative to the rack, and (2) the modified nose geometry. Results of the test show that the dual ejector forces were most effective in reducing the store nose-down pitch. Separation of the ballasted store from the modified TER produced the best results of all combinations using the single ejector. To assess the influence of the modified TER on separation characteristics of another store, trajectory data were obtained for the M-117 bomb from the number 1 TER position. These data showed a slightly reduced nose-down pitch at Mach numbers from 0.5 to 0.9.

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NOMENCLATURE

BL	Aircraft buttock line from plane of symmetry, in., model scale
b	Store reference dimension, ft full scale
C_A	Store axial-force coefficient, axial force/$q_\infty S$
C_ℓ	Store rolling-moment coefficient, rolling moment/$q_\infty Sb$
C_{ℓ_p}	Store roll-damping derivative, $dC_\ell/d(pb/2V_\infty)$
C_m	Store pitching-moment coefficient, referenced to the store cg, pitching moment/$q_\infty Sb$
C_{m_q}	Store pitch-damping derivative, $dC_m/d(qb/2V_\infty)$

C_n	Store yawing-moment coefficient, referenced to the store cg, yawing moment/$q_\infty Sb$
C_{n_r}	Store yaw-damping derivative, $dC_n/d(rb/2V_\infty)$
D	Full-scale store diameter, ft
FS	Aircraft fuselage station, in., model scale
F_Z	TER ejector force, lb (single ejector or total force for dual ejectors)
F_{Z_1}	TER forward ejector force, lb } dual ejectors
F_{Z_2}	TER aft ejector force, lb } dual ejectors
H	Pressure altitude, ft
I_{xx}	Full-scale moment of inertia about the store X_B axis, slug-ft^2
I_{yy}	Full-scale moment of inertia about the store Y_B axis, slug-ft^2
I_{zz}	Full-scale moment of inertia about the store Z_B axis, slug-ft^2
M_∞	Free-stream Mach number
$\overline{m}$	Full-scale store mass, slugs
p	Store angular velocity about the X_B axis, radians/sec
p_∞	Free-stream static pressure, psfa
q	Store angular velocity about the Y_B axis, radians/sec
q_∞	Free-stream dynamic pressure, psf
r	Store angular velocity about the Z_B axis, radians/sec
S	Store reference area, ft^2, full scale
t	Real trajectory time from initiation of trajectory, sec
V_∞	Free-stream velocity, ft/sec
WL	Aircraft waterline from reference horizontal plane, in., model scale
X	Separation distance of the store cg parallel to the flight axis system X_F direction, ft, full scale measured from the prelaunch position

X_{cg} — Full-scale cg location, ft from nose of store

X_L — Ejector piston location relative to the store cg, positive forward of store cg, ft, full scale (single ejector)

X_{L_1} — Forward ejector piston location relative to the store cg, positive forward of store cg, ft, full scale (dual ejector)

X_{L_2} — Aft ejector piston location relative to the store cg, positive forward of store cg, ft, full scale (dual ejector)

Y — Separation distance of the store cg parallel to the flight axis system Y_F direction, ft, full scale measured from the prelaunch position

Z — Separation distance of the store cg parallel to the flight-axis system Z_F direction, ft, full scale measured from the prelaunch position

ZE — Ejector stroke length, ft, full scale

α — Parent-aircraft model angle of attack relative to the free-stream velocity vector, deg

θ — Angle between the store longitudinal axis and its projection in the X_F-Y_F plane, positive when store nose is raised as seen by pilot, deg

ψ — Angle between the projection of the store longitudinal axis in the X_F-Y_F plane and the X_F axis, positive when the store nose is to the right as seen by the pilot, deg

FLIGHT-AXIS SYSTEM COORDINATES

Directions

X_F — Parallel to the free-stream wind vector, positive direction is forward as seen by the pilot

Y_F — Perpendicular to the X_F and Z_F directions, positive direction is to the right as seen by the pilot

Z_F — In the aircraft plane of symmetry, perpendicular to the free-stream wind vector, positive direction is downward

The flight-axis system origin is coincident with the aircraft cg and remains fixed with respect to the parent aircraft during store separation. The X_F, Y_F, and Z_F coordinate axes do not rotate with respect to the initial flight direction and attitude.

STORE BODY-AXIS SYSTEM COORDINATES

Directions

X_B Parallel to the store longitudinal axis, positive direction is upstream in the prelaunch position

Y_B Perpendicular to the store longitudinal axis, and parallel to the flight-axis system X_F-Y_F plane when the store is at zero roll angle, positive direction is to the right looking upstream when the store is at zero yaw and roll angles

Z_B Perpendicular to both the X_B and Y_B axes, positive direction is downward as seen by the pilot when the store is at zero pitch and roll angles.

The store body-axis system origin is coincident with the store cg and moves with the store during separation from the parent airplane. The X_B, Y_B, and Z_B coordinate axes rotate with the store in pitch, yaw, and roll so that mass moments of inertia about the three axes are not time-varying quantities.

PYLON-AXIS SYSTEM COORDINATES

Directions

X_P Parallel to the store longitudinal axis in the prelaunch carriage position, positive direction is forward as seen by the pilot

Y_P Perpendicular to the X_P axis and parallel to the flight-axis system X_F-Y_F plane, positive direction is to the right as seen by the pilot

Z_P Perpendicular to both the X_P and Y_P axes, positive direction is downward

The pylon-axis system origin is coincident with the store cg in the prelaunch carriage position. The axes are rotated with respect to the flight-axis system by the prelaunch yaw and pitch angles of the store. Both the origin and the direction of the coordinate axes remain fixed with respect to the flight-axis system throughout the trajectory.

SECTION I
INTRODUCTION

Previous tests to determine the separation characteristics of the SUU-51B/B have indicated that the store experienced a rapid nose-down pitch during the initial part of the trajectory. The store is carried on the Triple Ejection Rack (TER) with the tail fins folded, and the fins are deployed, by use of a lanyard, shortly after the store leaves the rack. For separation from the number 1 TER position, the nose-down pitch rate was of sufficient magnitude to prevent the store from recovering in pitch (after the fins were deployed) before the open fins on the separating store contacted the rack or adjacent-shoulder-station stores. This condition increased in severity as the flight Mach number approached 0.9.

The purpose of this test was to investigate some possible ways to reduce the store nose-down pitch during the initial part of the separation by changes in (1) store mass properties (ballasting), (2) TER configurations, (3) location of the store on the rack, (4) store nose geometry, and (5) rack ejector forces. Trajectories were obtained to assess the influence of each change singly and combinations of two or more of the changes. Separation trajectory data were also obtained for the M-117 bomb to assess the influence of the modified TER geometry on the M-117 separation characteristics. In addition to the trajectory data, force and moment data were obtained on the standard SUU-51B/B in the presence of the TER, and free-stream stability data were obtained for the model with the modified nose geometry.

Testing was accomplished in the Aerodynamic Wind Tunnel (4T) of the Propulsion Wind Tunnel Facility using 0.05-scale models of the F-4C aircraft and the stores. The F-4C model was mounted on the main tunnel support system and the store models were mounted on the Captive Trajectory Support (CTS). Separation trajectories were obtained from the TER on the wing inboard pylon of the F-4C at conditions simulating level flight at Mach numbers from 0.5 to 1.1 at 5000-ft altitude.

SECTION II
APPARATUS

2.1 TEST FACILITY

The Aerodynamic Wind Tunnel (4T) is a closed-loop, continuous flow, variable-density tunnel in which the Mach number can be varied from 0.1 to 1.3. At all Mach numbers, the stagnation pressure can be varied from 300 to 3700 psfa. The test section is 4 ft square and 12.5 ft long with perforated, variable porosity (0.5- to 10-percent open) walls. It is completely enclosed in a plenum chamber from which the air can be evacuated, allowing part of the tunnel airflow to be removed through the perforated walls of the test section.

For store separation testing, two separate and independent support systems are used to support the models. The parent aircraft model is inverted in the test section and supported by an offset sting attached to the main pitch sector. The store model is supported by the CTS which extends down from the tunnel top wall and provides store movement (six degrees of freedom) independent of the parent-aircraft model. An isometric drawing of a typical store separation installation is shown in Fig. 1 (Appendix I).

Also shown in Fig. 1 is a block diagram of the computer control loop used during captive trajectory testing. The analog system and the digital computer work as an integrated unit and, utilizing required input information, control the store movement during a trajectory. Store positioning is accomplished by use of six individual d-c electric motors. Maximum translational travel of the CTS is ±15 in. from the tunnel centerline in the lateral and vertical directions and 36 in. in the axial direction. Maximum angular displacements are ±45 deg in pitch and yaw and ±360 deg in roll. A more complete description of the test facility can be found in the Test Facilities Handbook.[1] A schematic showing the test section details and the location of the models in the tunnel is shown in Fig. 2.

2.2 TEST ARTICLES

Models used during the test were 0.05-scale models of the SUU-51B/B store, M-117 store, and F-4C aircraft (including pylons, racks, and wing-mounted fuel tanks). A sketch of the F-4C model showing basic dimensions and locations of the wing pylon stations is presented in Fig. 3. Details and dimensions of the inboard pylon are shown in Fig. 4. Details of the dummy 370-gal fuel tank and pylon, which were installed on the outboard wing stations, are shown in Fig. 5. Two TER-model configurations were used during the test. One model represented the actual TER-9/A configuration, and the other model (modified) represented the TER-9/A with the nose fairing removed. Details and dimensions of the TER models are presented in Fig. 6, and photographs of the TER models are shown in Fig. 7. With the TER installed on the wing inboard pylon, the store is oriented at a 1-deg nose-down attitude with respect to the aircraft waterline when in the carriage position.

Details and dimensions of the SUU-51B/B and M-117 stores are presented in Figs. 8 and 9, respectively. The SUU-51B/B fin geometry shown represents the closed-fin configuration used during carriage. The tail fins for the M-117 represent the MAU-103A/B configuration.

The F-4C aircraft model was inverted in the tunnel and attached by an offset sting to the main sting-support system. Store models were mounted on an internal strain-gage balance that was attached to the CTS system. A photograph showing a typical CTS test installation in the tunnel is shown in Fig. 10.

2.3 INSTRUMENTATION

A five-component internal strain-gage balance was used during the tests with the SUU-51B/B (standard nose geometry) and M-117 stores, and a six-component internal strain-gage balance was used during the tests of the SUU-51B/B with the modified nose

[1] Test Facilities Handbook (Ninth Edition). "Propulsion Wind Tunnel Facility, Vol. 4." Arnold Engineering Development Center, July 1971.

geometry. Translational and angular positions of the store models were obtained from the CTS analog outputs. The aircraft angle of attack was set using the main sting support and readout system. The TER models were instrumented with spring-loaded plungers (touch wires) which were electrically connected to give a visual indication on the control console when the store contacted the touch wire at the carriage position. The CTS system was also electrically connected to automatically stop the CTS movement if the store model or CTS contacted the aircraft model, aircraft support sting, or the test section walls.

SECTION III
TEST DESCRIPTION

3.1 TEST CONDITIONS

Separation trajectory data were obtained at Mach numbers from 0.5 to 1.1. Tunnel dynamic pressure was constant at 500 psf for all Mach numbers, and tunnel stagnation temperature was maintained near 100°F.

Tunnel conditions were held constant at the desired Mach number and stagnation pressure while data for each trajectory were obtained. The trajectories were terminated when the store or sting contacted the parent-aircraft model or when a CTS limit was reached.

3.2 DATA ACQUISITION

3.2.1 Force and Moment Data

Store force and moment data were obtained in the following manner. After tunnel conditions were established, the store was manually positioned at the carriage position on the TER. Operational control of the CTS was then switched to the digital computer, which controlled the store movements through commands to the CTS. Data were obtained at preselected store positions which were programmed in the computer.

3.2.2 Trajectory Data

To obtain a trajectory, test conditions were established in the tunnel and the parent model was positioned at the desired angle of attack. The store model was then oriented to a position corresponding to the store carriage location. After the store was set at the desired initial position, operational control of the CTS was switched to the digital computer which controlled the store movement during the trajectory through commands to the CTS analog system (see block diagram, Fig. 1). Data from the wind tunnel, consisting of measured model forces and moments, wind tunnel operating conditions, and CTS rig positions, were input to the digital computer for use in the full-scale trajectory calculations.

The digital computer was programmed to solve the six-degree-of-freedom equations to calculate the angular and linear displacements of the store relative to the parent aircraft pylon. In general, the program involves using the last two successive measured values of each static aerodynamic coefficient to predict the magnitude of the coefficients over the next time interval of the trajectory. These predicted values are used to calculate the new position and attitude of the store at the end of the time interval. The CTS is then commanded to move the store model to this new position and the aerodynamic loads are measured. If these new measurements agree with the predicted values, the process is continued over another time interval of the same magnitude. If the measured and predicted values do not agree within the desired precision, the calculation is repeated over a time interval one-half the previous value. This process is repeated until a complete trajectory has been obtained.

In applying the wind tunnel data to the calculations of the full-scale store trajectories, the measured forces and moments are reduced to coefficient form and then applied with proper full-scale store dimensions and flight dynamic pressure. Dynamic pressure was calculated using a flight velocity equal to the free-stream velocity component plus the components of store velocity relative to the aircraft, and a density corresponding to the simulated altitude.

The initial portion of each launch trajectory incorporated simulated ejector forces in addition to the measured aerodynamic forces acting on the store. The ejector force functions for the stores are presented in Fig. 11. The ejector force was considered to act perpendicular to the rack mounting surface. The locations of the applied ejector forces and other full-scale store parameters used in the trajectory calculations are listed in Table I (Appendix II).

3.3 CORRECTIONS

Balance, sting, and support deflections caused by the aerodynamic loads on the store models were accounted for in the data reduction program to calculate the true store-model angles. Corrections were also made for model weight tares to calculate the net aerodynamic forces on the store model.

3.4 PRECISION OF DATA

Uncertainties in the store force and moment data were calculated taking into consideration probable inaccuracies in the balance measurements and tunnel conditions. Bias errors were assumed to be negligible. The estimated uncertainties in the force and moment coefficients, based on a 95-percent confidence level are:

ΔC_N	ΔC_Y	ΔC_A	ΔC_m	ΔC_n
±0.008	±0.008	±0.01	±0.02	±0.02

The trajectory data are subject to error resulting from uncertainties in tunnel conditions, balance measurements, extrapolation tolerances, and CTS positioning control. Maximum error in the CTS position control was ±0.05 in. for translational settings and ±0.15 deg for angular displacements in pitch and yaw. Extrapolation tolerances were ±0.1 for all aerodynamic coefficients. Based on a 95-percent confidence level, and again ignoring bias errors, the uncertainties in the full-scale trajectory data resulting from balance inaccuracies are:

Time, sec	ΔX	ΔY	ΔZ	Δθ	Δψ
0.1	±0.004	±0.004	±0.002	±0.1	±0.1
0.2	±0.01	±0.01	±0.01	±0.4	±0.4

A few separation trajectories, which were terminated early in the trajectory (at approximately 0.1 sec) because of store-to-store contact, were repeated during the test. A review of the data for these repeat runs for both the SUU-51B/B and M-117 stores indicates that the differences in the repeat data were about one-half the uncertainty values quoted at t = 0.1 sec.

Estimated uncertainty in setting Mach number was ±0.003, and the uncertainty in aircraft-model angle of attack was estimated to be ±0.1 deg.

SECTION IV
RESULTS AND DISCUSSION

4.1 GENERAL

Data taken during the test consisted of (1) force and moment data on the SUU-51B/B with standard nose geometry while near the carriage position on the TER, (2) free-stream stability data for the SUU-51B/B with the modified nose geometry, and (3) separation trajectory data for the SUU-51B/B (standard and modified nose geometries) and M-117 stores.

Force and moment data are presented to show the variation of the aerodynamic coefficients with changes in store cg position relative to the cg position at carriage. Linear displacements for the force and moment data are measured in the pylon-axis coordinates. The free-stream stability data are presented to show the aerodynamic coefficient changes with changes in store pitch angle.

The store separation trajectory data are presented in flight-axis-system coordinates showing the linear displacements of the store cg and the store angular displacements relative to the cg location at the carriage position as a function of full-scale trajectory time. Positive X, Y, and Z displacements (as seen by the pilot) are forward, to the right, and down, respectively. Positive changes in θ and ψ (as seen by the pilot) are store nose up and to the right, respectively. Ejector force functions can be identified from Fig. 11, and other full-scale store parameters used in the trajectory calculations are shown in Table I.

All separation trajectories were initiated from the TER on the inboard pylon of the right wing. For all testing, the 370-gal fuel tanks were installed on the outboard wing stations, and a standard TER with store models at TER position numbers 2 and 3 was installed on the left wing inboard pylon. Identification of the various configurations tested at the right wing inboard pylon is shown in Fig. 12.

Termination of the trajectories was generally a result of the store-support sting contacting the aircraft wing or the CTS reaching a travel limit. In some cases, as noted, termination of the trajectories resulted from the fins of the separating store contacting the rack or shoulder-station stores.

4.2 FORCE AND MOMENT DATA

The force and moment data presented in Fig. 13 show the variations in C_N. C_m, and C_A with changes in X_P/D and Z_P/D for the standard store cg location. There is a considerable Mach number effect indicated for all three coefficients, but the data show that the store should be moved aft of the standard carriage positions to reduce the nose-down aerodynamic pitching moment. However, the total moment acting on the store during the initial part of the trajectory consists of the aerodynamic moment plus the moment applied by the ejector force. Since the SUU-51B/B cg is forward of the ejector foot at the standard carriage position, aft movement of the store would effectively increase the nose-down moment (with ejector location fixed) resulting from the ejector force. Thus, the advantage of the reduction in nose-down aerodynamic moment may be lost as a result of the ejector moment changes when the store moves aft.

4.3 FREE-STREAM DATA

Free-stream stability data for the SUU-51B/B with modified nose geometry are presented in Fig. 14. The data indicate that the store is neutrally stable at small pitch angles for all Mach numbers.

4.4 SEPARATION TRAJECTORY DATA

Data showing the trajectories for the standard SUU-51B/B with dual ejector forces applied during separation from the standard TER are presented in Fig. 15. By varying the force distribution between the two ejectors, it was possible to overcome the store nose-down aerodynamic moment and achieve nose-up pitch during the trajectory. Also, the larger total force of the dual-ejector forced the store away from the carriage position at a faster rate than the single ejector (discussed later). This is advantageous when considering the problem of store fin clearance during separation.

Data presented in Fig. 16 show trajectories for the standard and ballasted stores for separation from the standard carriage position, and from a position 4 in. aft of the standard position, using the single ejector. Also shown in this figure is a trajectory obtained from an initial store position 10 in. aft of the standard carriage position with no ejector force. During these trajectories, the TER shoulder-station stores were at the standard carriage positions, and the ejector piston location was considered fixed on the rack. The data show that the rearward store shift produced little effect on the trajectories. Comparison of the data for the standard and ballasted stores shows that the nose-down pitch rate was significantly reduced (about 50 percent) with the ballasted store. Trajectories for the 10-in. rearward shift with no ejector force indicated little change in store pitch motion, although a significant reduction in the store vertical translation is shown. A comparison of the store vertical translations for the dual and single ejectors (Figs. 15 and 16, respectively) shows that the store moved away from the rack more than twice as fast for the dual-ejector store separation.

The strong effect of Mach number on the store pitch motion can be seen in Fig. 17. These data are for the ballasted store from the standard TER and show that the store nose-down pitch motion increases significantly with increasing Mach number.

Figure 18 shows separation data for the standard store from the modified TER at two initial store positions. Here the rearward shift resulted in a larger nose-down pitch rate during the trajectory. the effect of the modified TER geometry, with shoulder station stores at the standard carriage position, can be seen.by comparing data in Figs. 16a and 18. Trajectories from the modified TER (Fig. 18) show less nose-down store pitch, with the difference roughly equivalent to the change indicated previously between the standard and ballasted stores from the standard TER.

All data discussed thus far have been for configurations with the dummy shoulder-station stores at the standard carriage position. Data shown in Fig. 19 are for configurations with all stores shifted 6 in. forward on the TER. The effects of both the TER configuration and store ballast are shown here. With respect to producing minimum nose-down pitch rate, the ballasted store from the modified TER gave the best results. The effect of the 6-in. forward shift of all stores can be seen by comparing data in Figs. 16 and 19. Store nose-down pitch rate is reduced for the forward-shifted stores. This results, at least partially, from the increased nose-up ejector moment resulting from the larger ejector moment arm. Store pitch motion for the ballasted store is roughly equivalent to that obtained for separation using dual ejector force F_c (see Fig. 11b).

Data presented in Fig. 20 show the effect of Mach number on the trajectories for separation from the modified TER. Here again, the strong Mach number influence is evident. Data for the configuration with all stores shifted 10 in. forward on the standard TER are shown in Fig. 21. These data show that the store nose-down pitch rate decreased slightly relative to the 6-in. store shift on the modified TER (Fig. 20a). Trajectory data for the ballasted SUU-51B/B from the modified TER shoulder stations are shown in Fig. 22. The store pitch motion is similar for separation from both stations, and the Mach number influence is similar to that shown for separation from the number 1 TER position.

A comparison of the trajectories obtained with models having either the standard or modified nose geometry is presented in Fig. 23. These data are for separation of the stores from the standard position on the standard TER. The modified nose geometry produced additional nose-down pitch at M_∞ = 0.66 and reduced the nose-down pitch at M_∞ = 0.90. Data presented in Fig. 24 also indicate that the ballasted store with the modified nose geometry shows a improvement with respect to decreased nose-down pitch (compared with Fig. 16b).

Data for the store with standard cg and modified nose geometry, showing the effect of shifting the store aft of the standard carriage position on the modified TER, are shown in Fig. 25. During these trajectories, the ejector force was shifted aft with the store so that the differences shown in the trajectories resulted only from changes in aerodynamic forces and moments. The shoulder stores were installed at the standard position during these tests. These data show that the nose-down pitch rate was reduced as the store was moved aft. Another point of interest here is that the data for the store with modified nose geometry from the standard carriage position are essentially the same as data for separation of the store with standard nose geometry from the standard TER (Fig. 16a). This indicates that the nose-down pitch was increased for separation of the modified store from the modified TER as compared with the standard TER.

To investigate the effect of the modified TER on the separation characteristics of another store, trajectory data were obtained on an M-117 bomb model. Data for these trajectories are presented in Fig. 26. Small differences are shown for data from the two TER configurations, with a tendency for less nose-down pitch motion from the modified TER.

SECTION V
CONCLUSIONS

As a result of this wind tunnel investigation, the following conclusions have been reached:

1. Application of dual ejector forces was most effective in reducing the store nose-down pitch rate during the trajectories with the SUU-51B/B store.

2. The combination of adding ballast to the store nose, modifying the TER geometry, and shifting all three stores 6 in. forward of the standard carriage position on the TER was most effective in reducing the store nose-down pitch rate for trajectories using a single ejector force.

3. The effect on the store separation resulting from modifying the store nose geometry was to decrease the store nose-down pitch rate (relative to trajectories with the standard nose) when separating from the standard TER, and increase the store nose-down pitch rate when separating from the modified TER.

4. A comparison of trajectories for the M-117 bomb from the standard and modified TER showed a slight reduction in store nose-down pitch rate for separation from the modified TER.

APPENDIXES

I. ILLUSTRATIONS

II. TABLE

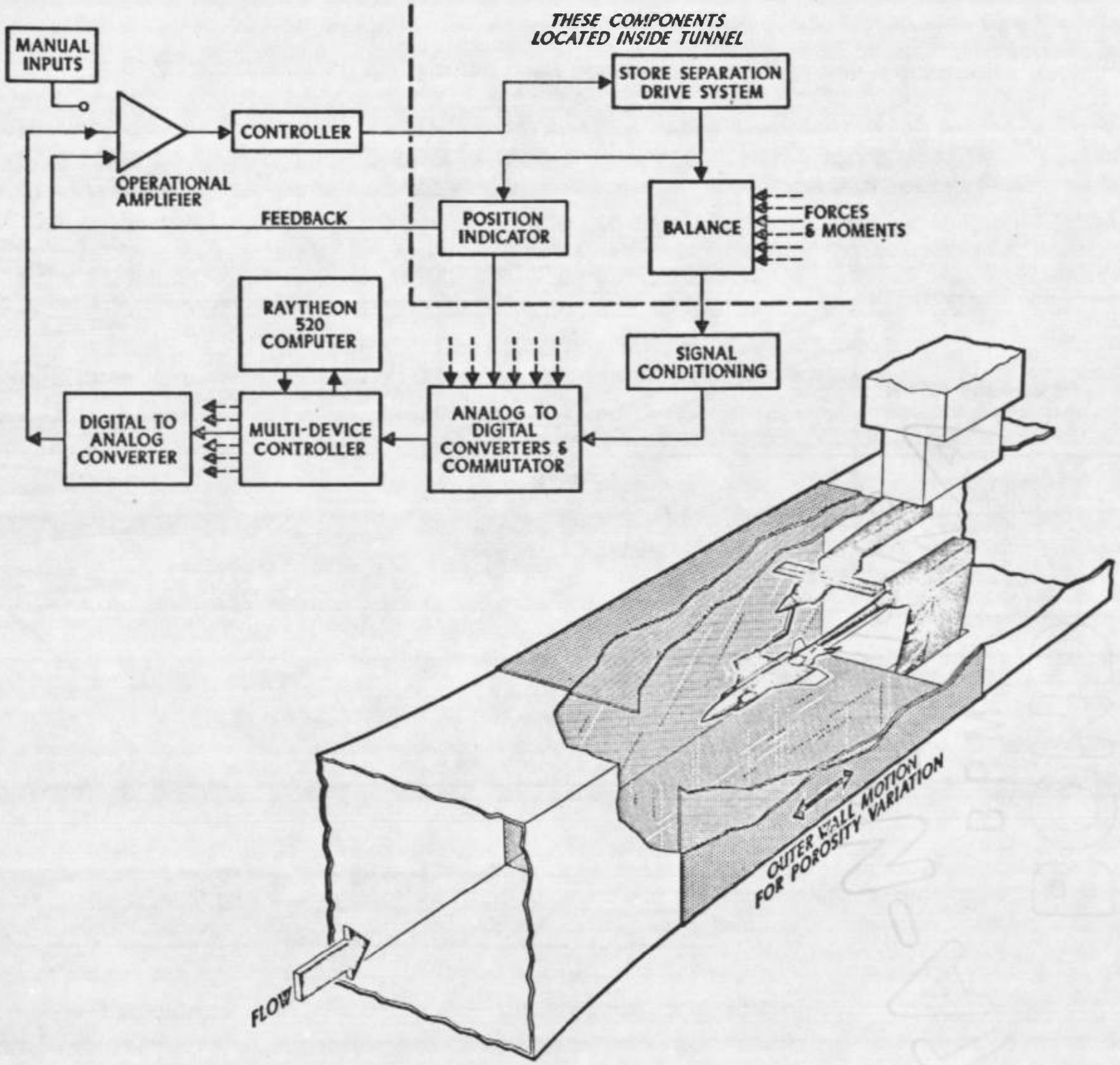


Fig. 1 Isometric Drawing of a Typical Store Separation Installation and a Block Diagram of the Computer Control Loop

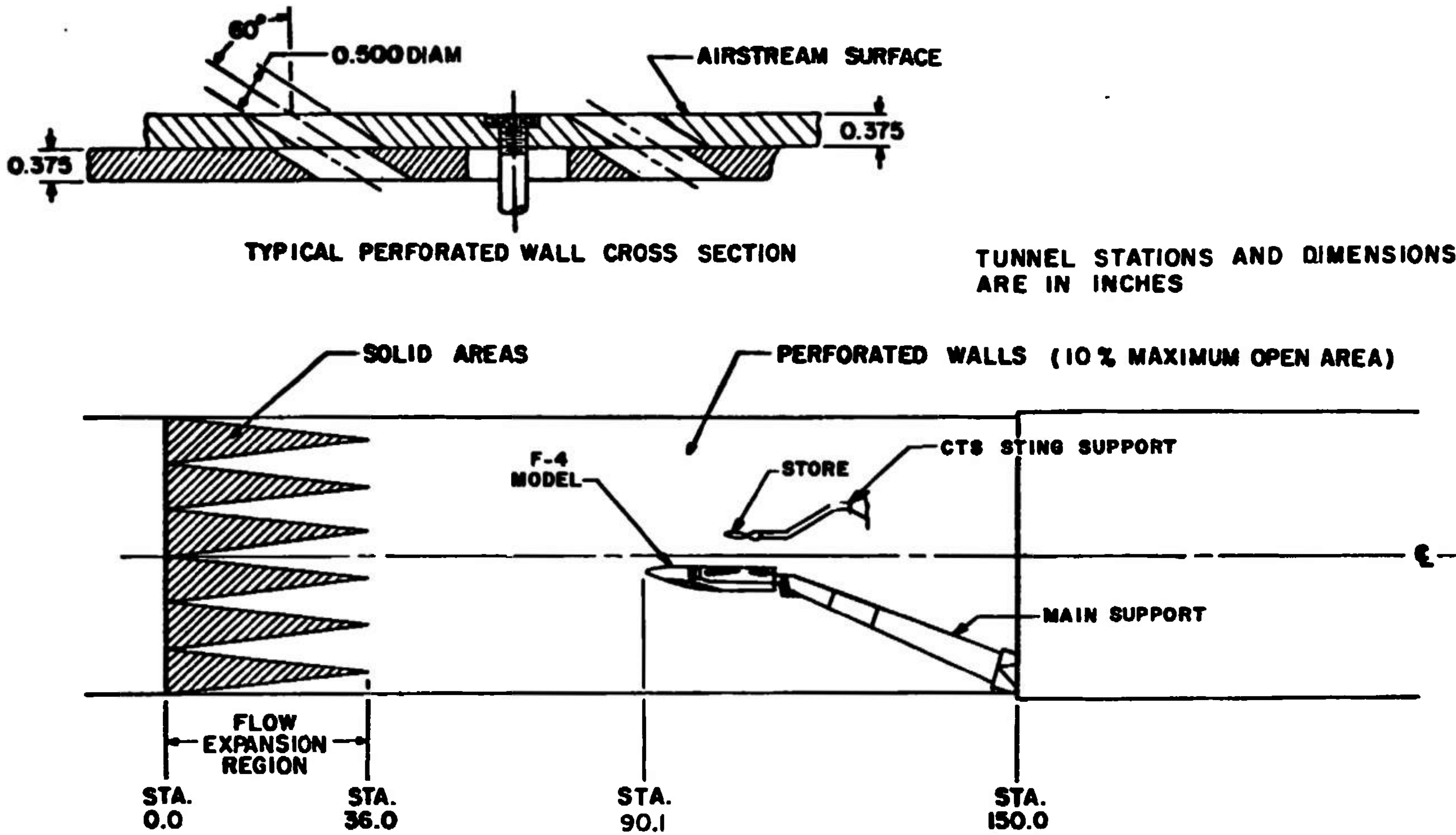


Fig. 2 Schematic of the Tunnel Test Section Showing Model Location

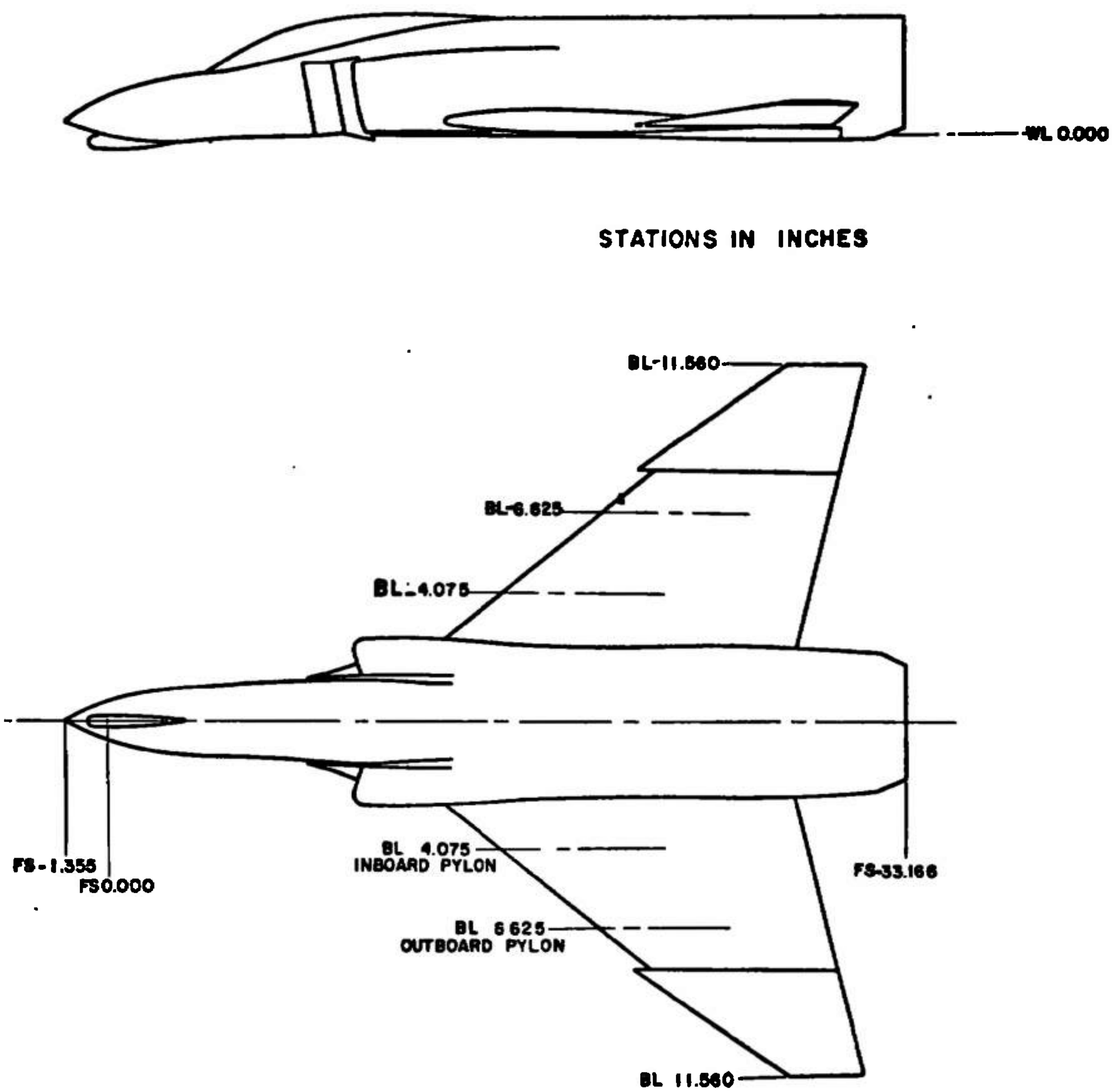
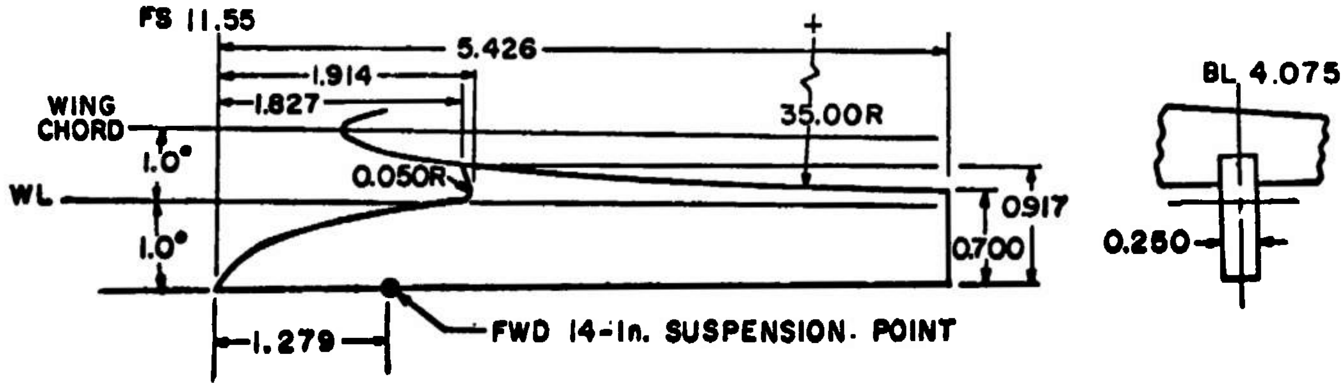
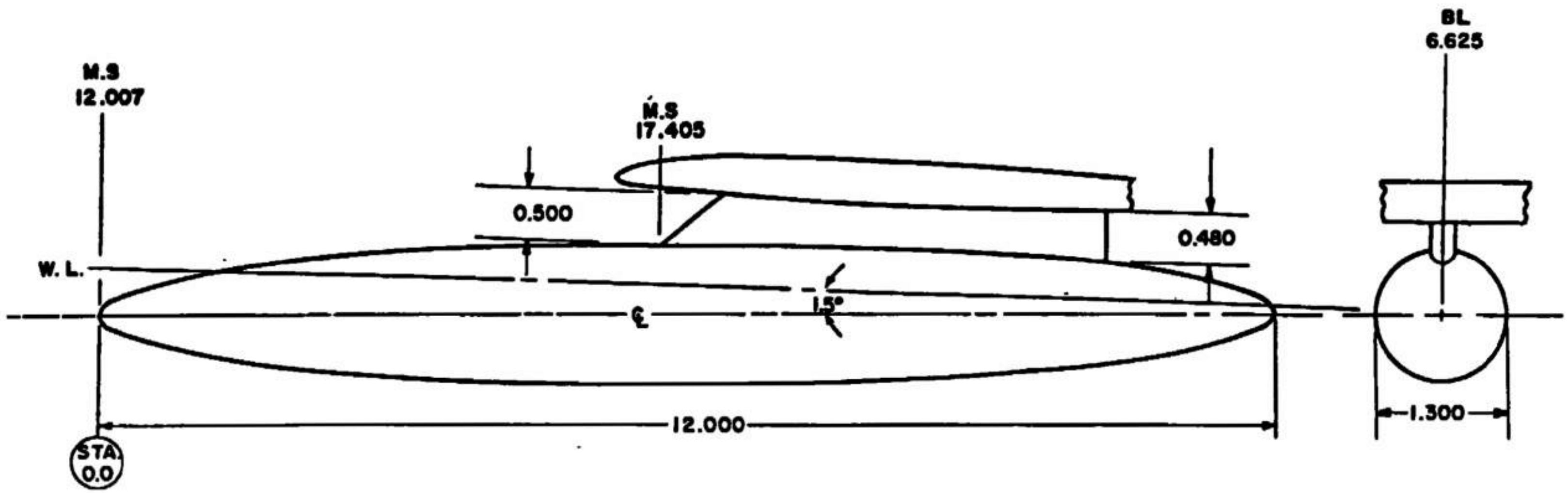


Fig. 3 Sketch of the F-4C Aircraft Model



ALL DIMENSIONS IN INCHES

Fig. 4 Details and Dimensions of the Inboard Wing Pylon



MODEL STATIONS AND
DIMENSIONS IN INCHES

BODY CONTOUR, TYPICAL BOTH ENDS

STATION	BODY DIAM	STATION	BODY DIAM
0.000	0.000	2.500	1.116
0.025	0.100	2.750	1.156
0.050	0.144	3.000	1.190
0.150	0.258	3.250	1.218
0.250	0.340	3.500	1.242
0.500	0.498	3.750	1.260
0.750	0.622	4.000	1.274
1.000	0.724	4.250	1.286
1.250	0.812	4.500	1.294
1.500	0.890	4.750	1.298
1.750	0.958	5.000	1.300
2.000	1.016	6.000	1.300
2.250	1.070		

Fig. 5 Details and Dimensions of the Dummy 370-gal Fuel Tank and Pylon

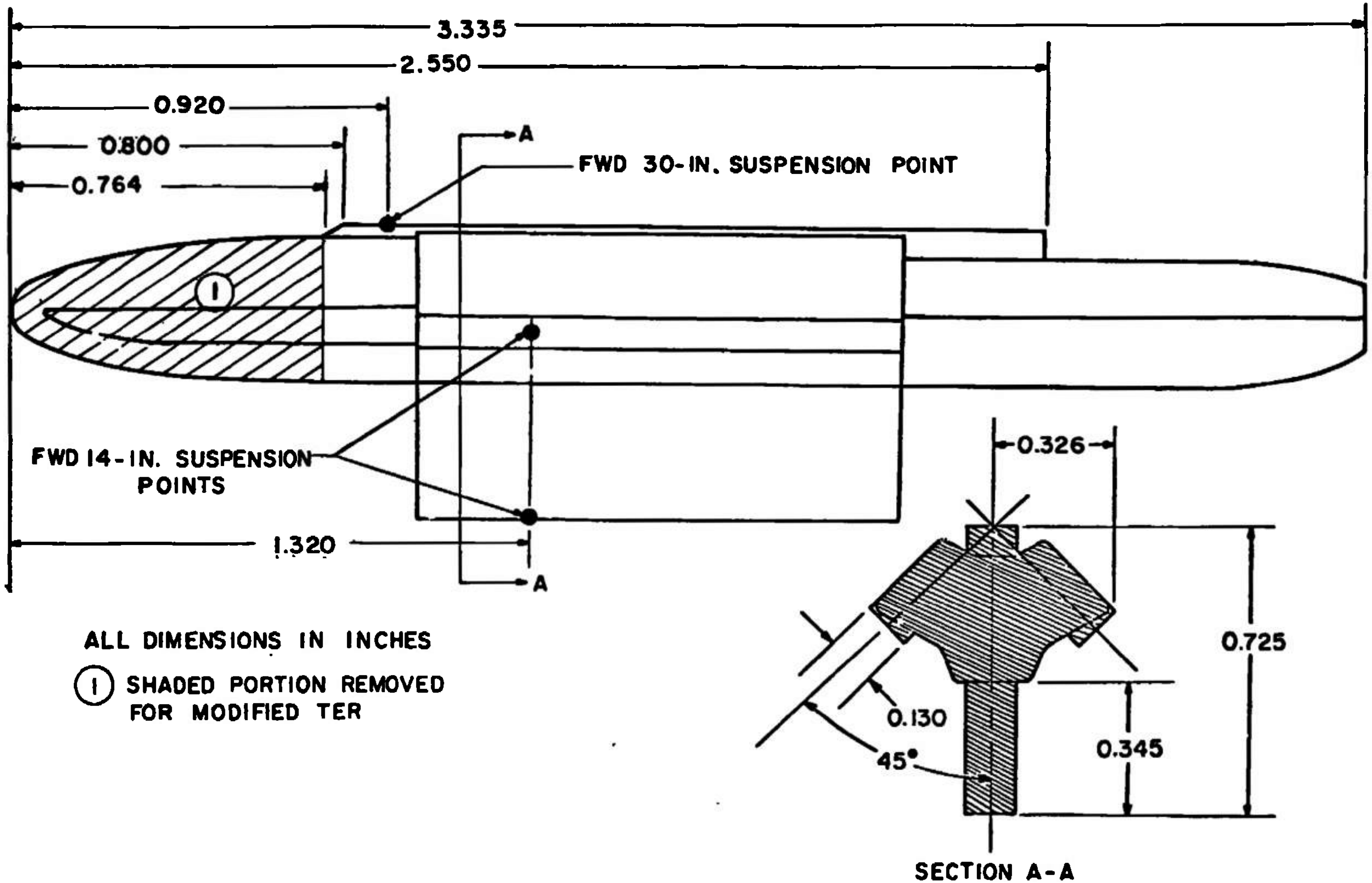
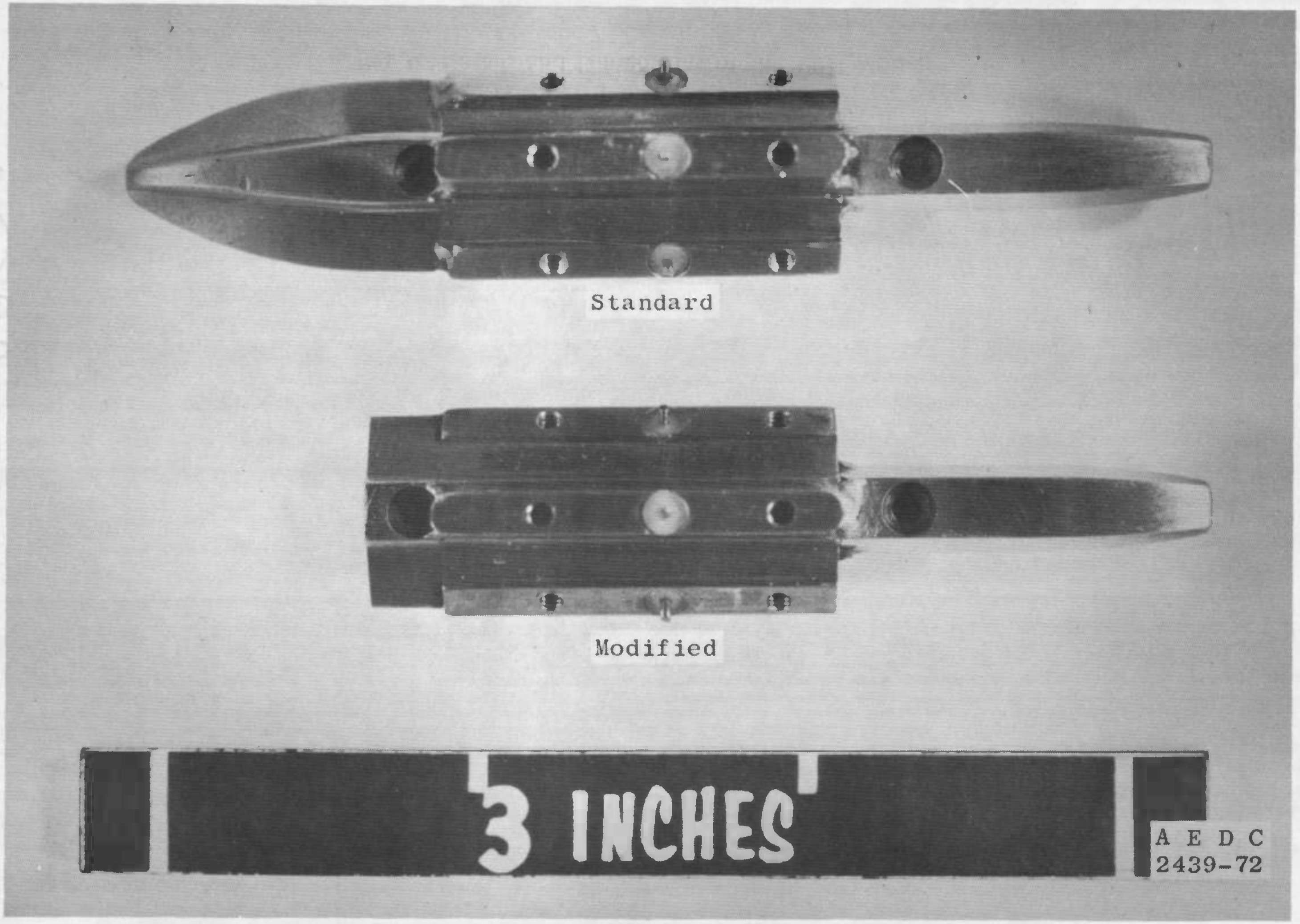
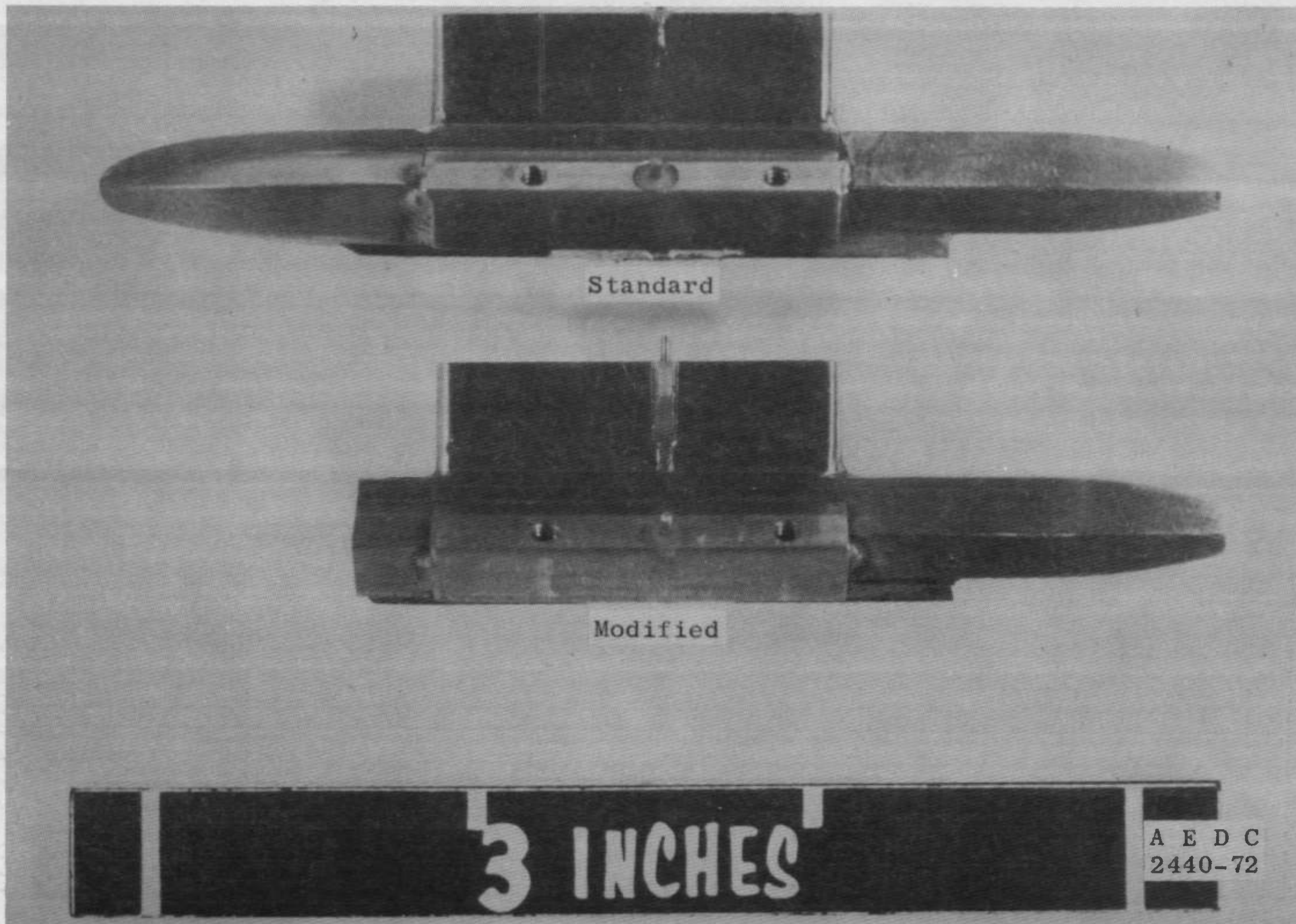


Fig. 6 Details and Dimensions of the TER Models



a. Top View
Fig. 7 Photographs of the TER Models



b. Side View
Fig. 7 Concluded

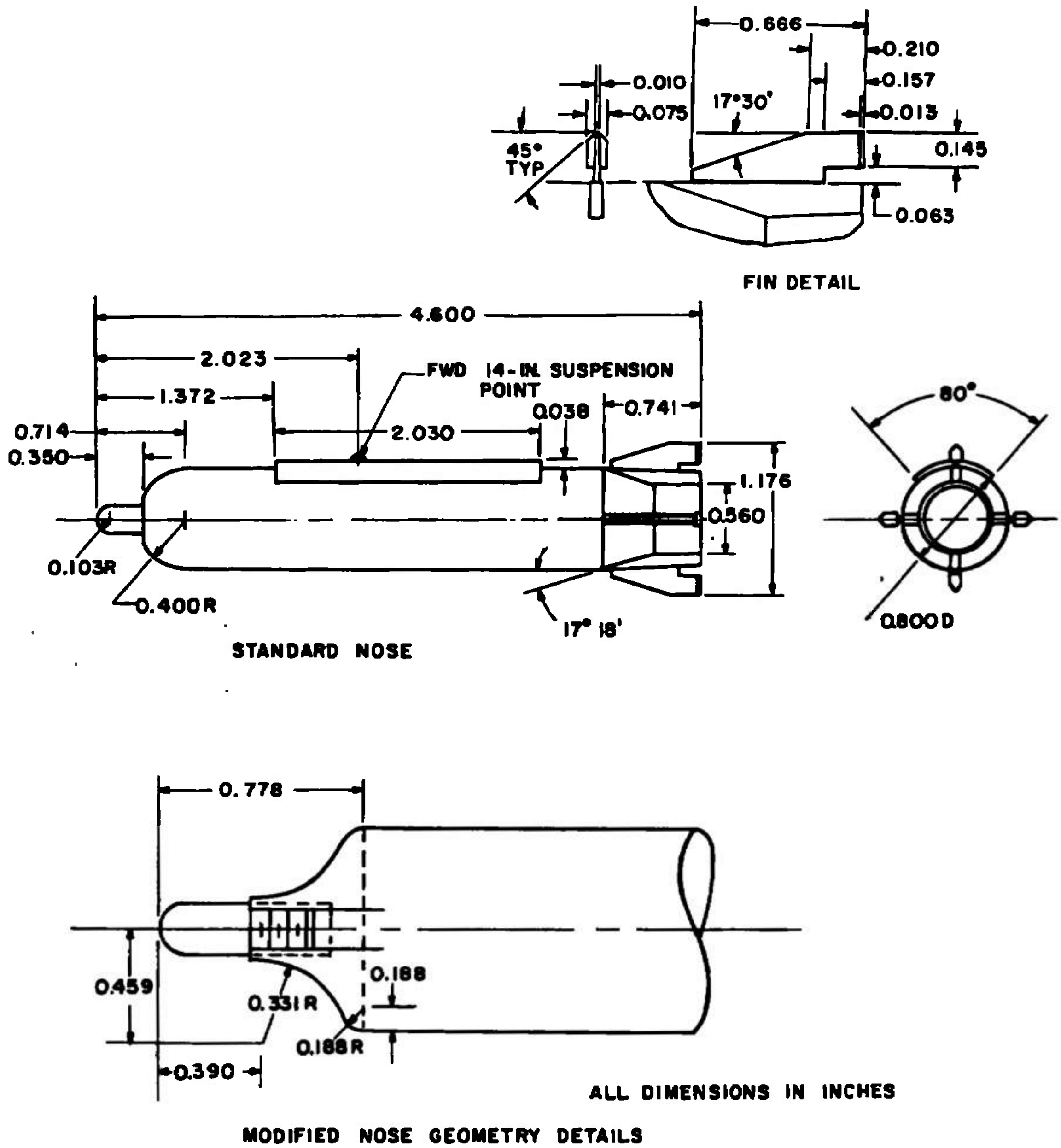
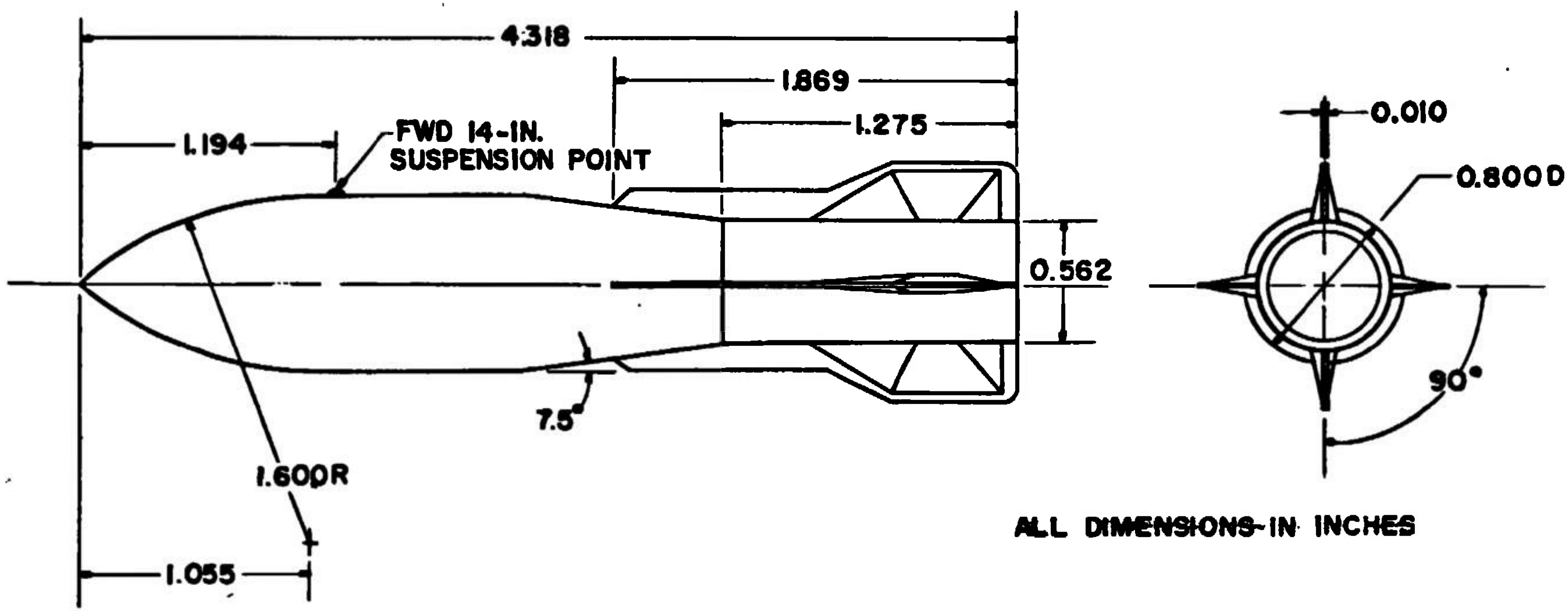
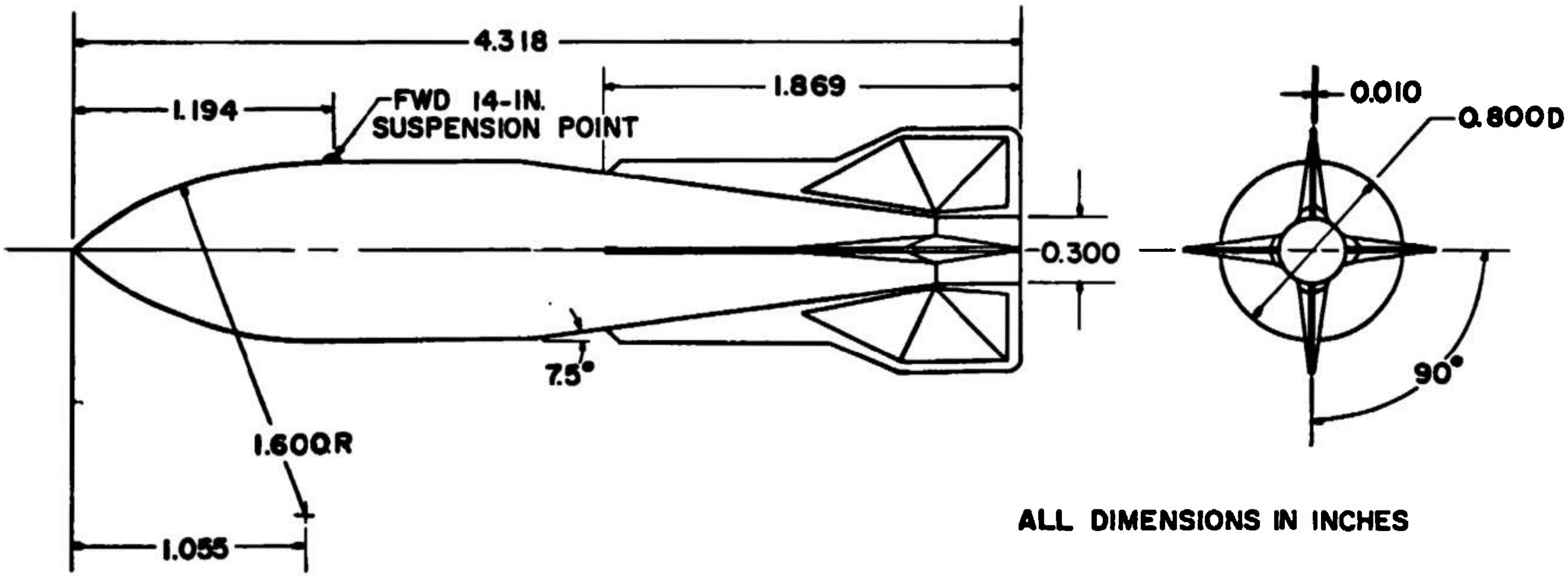


Fig. 8 Details and Dimensions of the SUU-51B/B Store Models

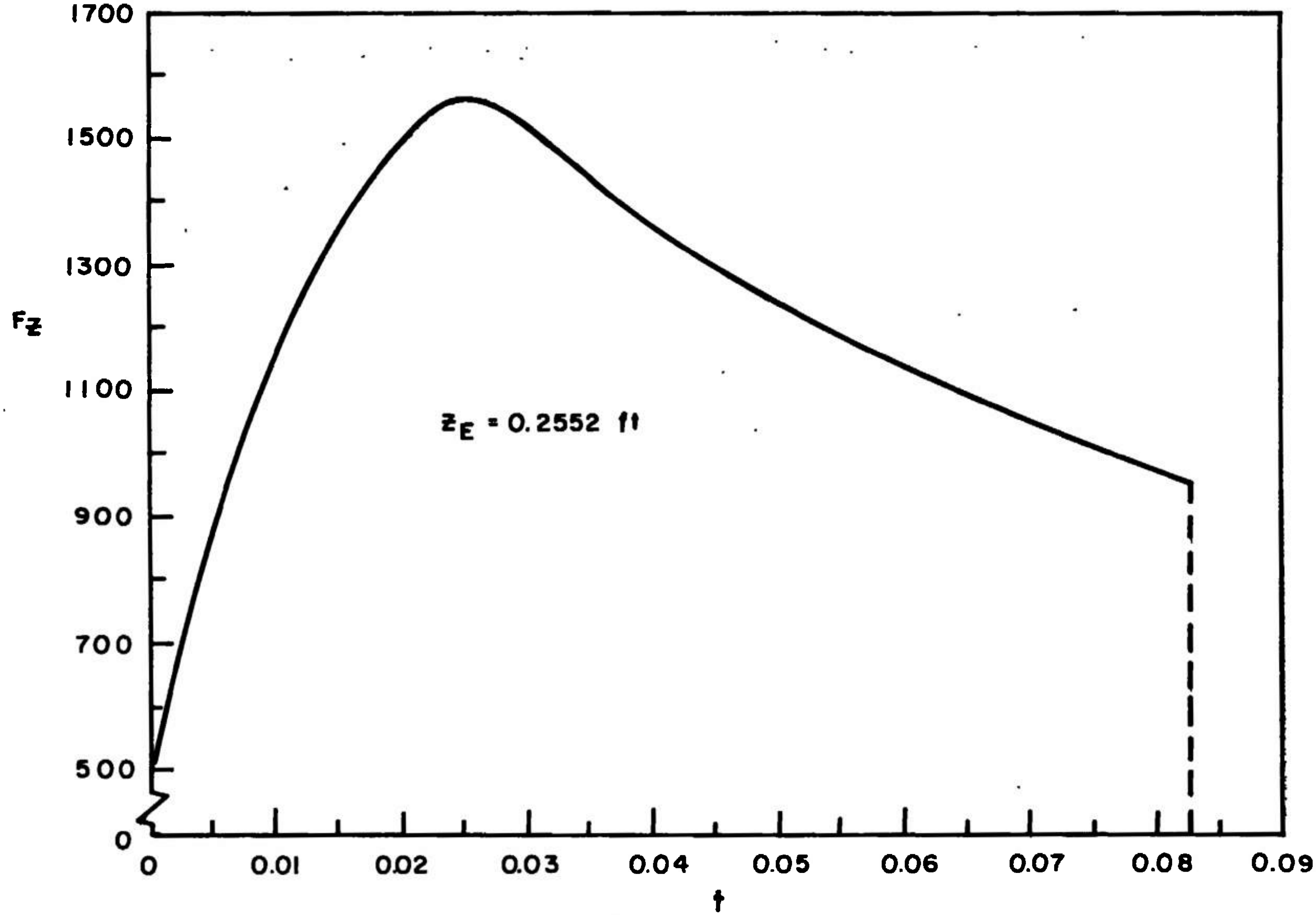


a. Sting-Mounted Model
Fig. 9 Details and Dimensions of the M-117 Store Models



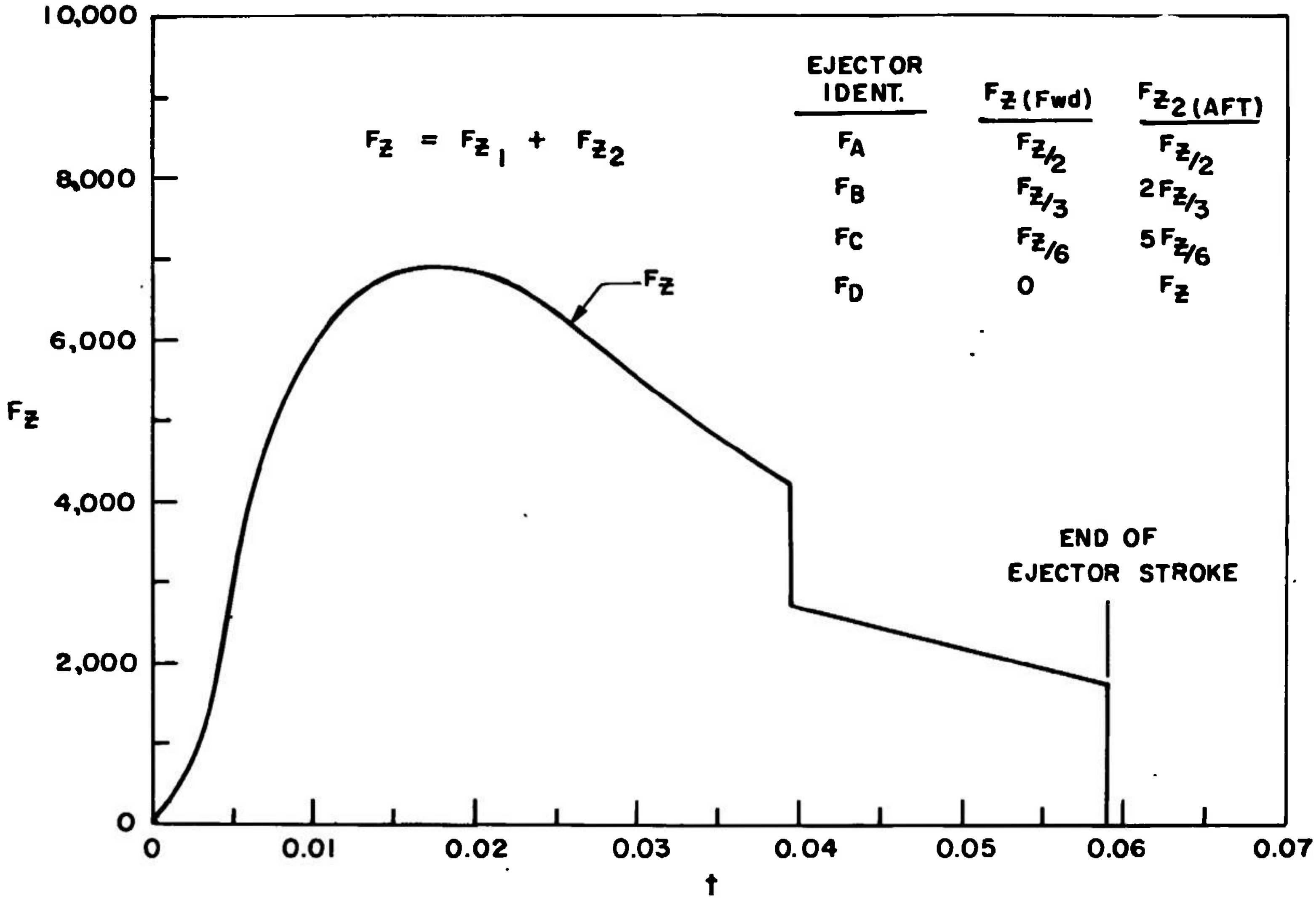
b. Dummy Model
Fig. 9 Concluded

Fig. 10 Photograph Showing a Typical Model Installation for Store Separation Testing

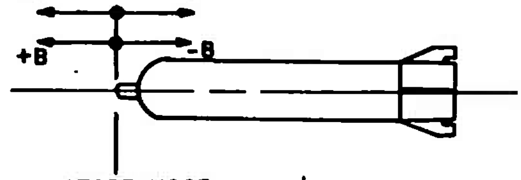


a. Single Ejector

Fig. 11 Ejector Force as a Function of Time for the Store Models

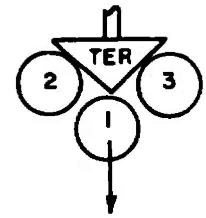


b. Dual Ejector
Fig. 11 Concluded



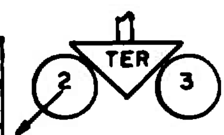
STORE POSITION RELATIVE TO TER

REAR VIEW

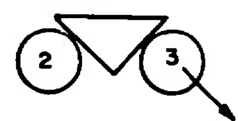


CONFIGURATIONS
1 - 9, 12,16,18 & 19

CONFIG	TEST STORE	TER	TEST STATION	A, in. FULL SCALE	DUMMY STORE POSITIONS	B, in. FULL SCALE
1	SUU-51B/B	STD	1	0	2 & 3	0
2				- 4		
3				-10		
4*				4		
5		MOD		0		
6				- 4		
7		STD		6		6
8		MOD		6		
9		STD		10		10
10		MOD	2	0	3	0
11			3	0	2	0
12	MOD NOSE SUU-51B/B	STD	1	0	2 & 3	0
13		MOD		0		
14				- 16		
15				- 18		
16				- 22		
17		STD	2	0	3	0
18	M-117	STD	1	0	2 & 3	0
19		MOD	1	0	2 & 3	0



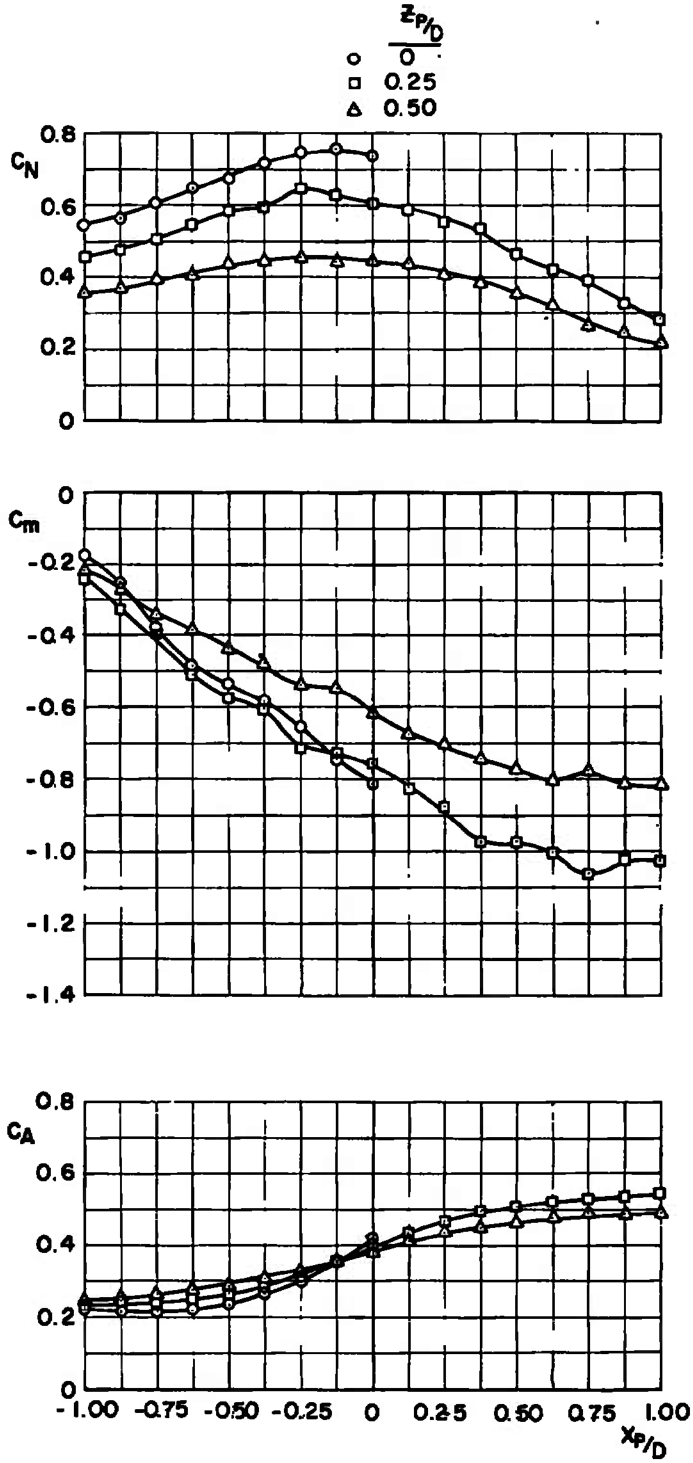
CONFIGURATION 10 AND 17



CONFIGURATION 11

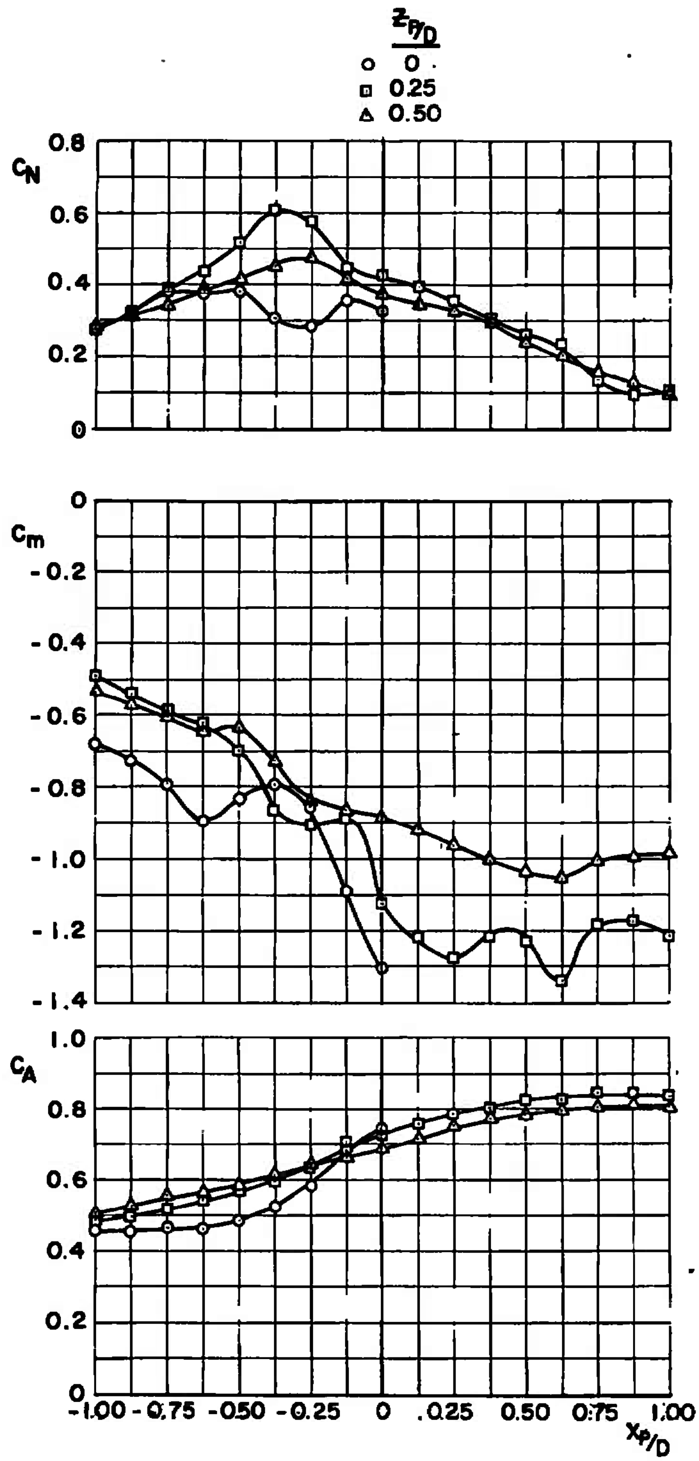
* TEST STORE WAS 4 in. FULL SCALE BELOW THE CARRIAGE POSITION AT t = 0

Fig. 12 Identification of Test Configurations



a. $M_\infty = 0.66$

Fig. 13 Force and Moment Data for the SUU-51B/B Store in the Presence of the Aircraft and TER



b. $M_\infty = 0.90$

Fig. 13 Concluded

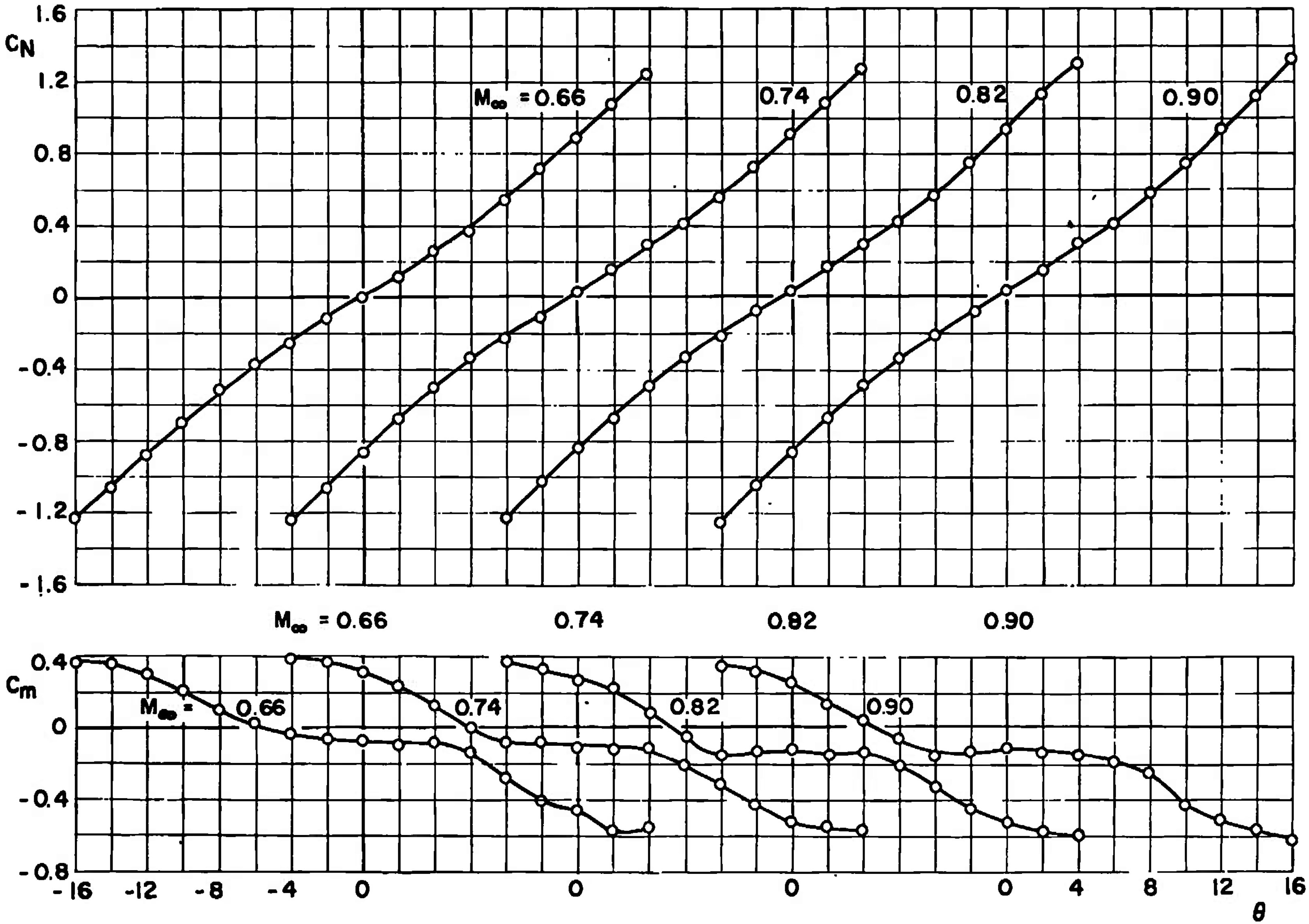


Fig. 14 Free-Stream Stability Data for the SUU-51B/B Store with Modified Nose Geometry

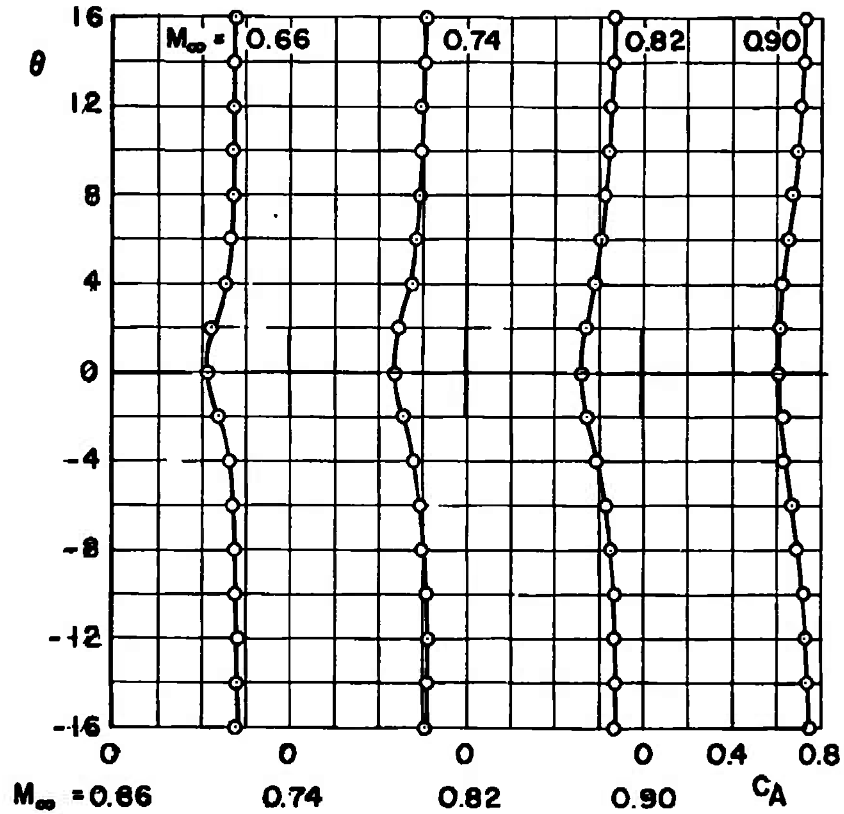


Fig. 14 Concluded

SYMBOL	CONF	M_∞	α	F_z, Fig. 11b
○	1	0.90	0.2	F_A
□	1	0.90	0.2	F_B
△	1	0.90	0.2	F_C
◁	1	0.90	0.2	F_D

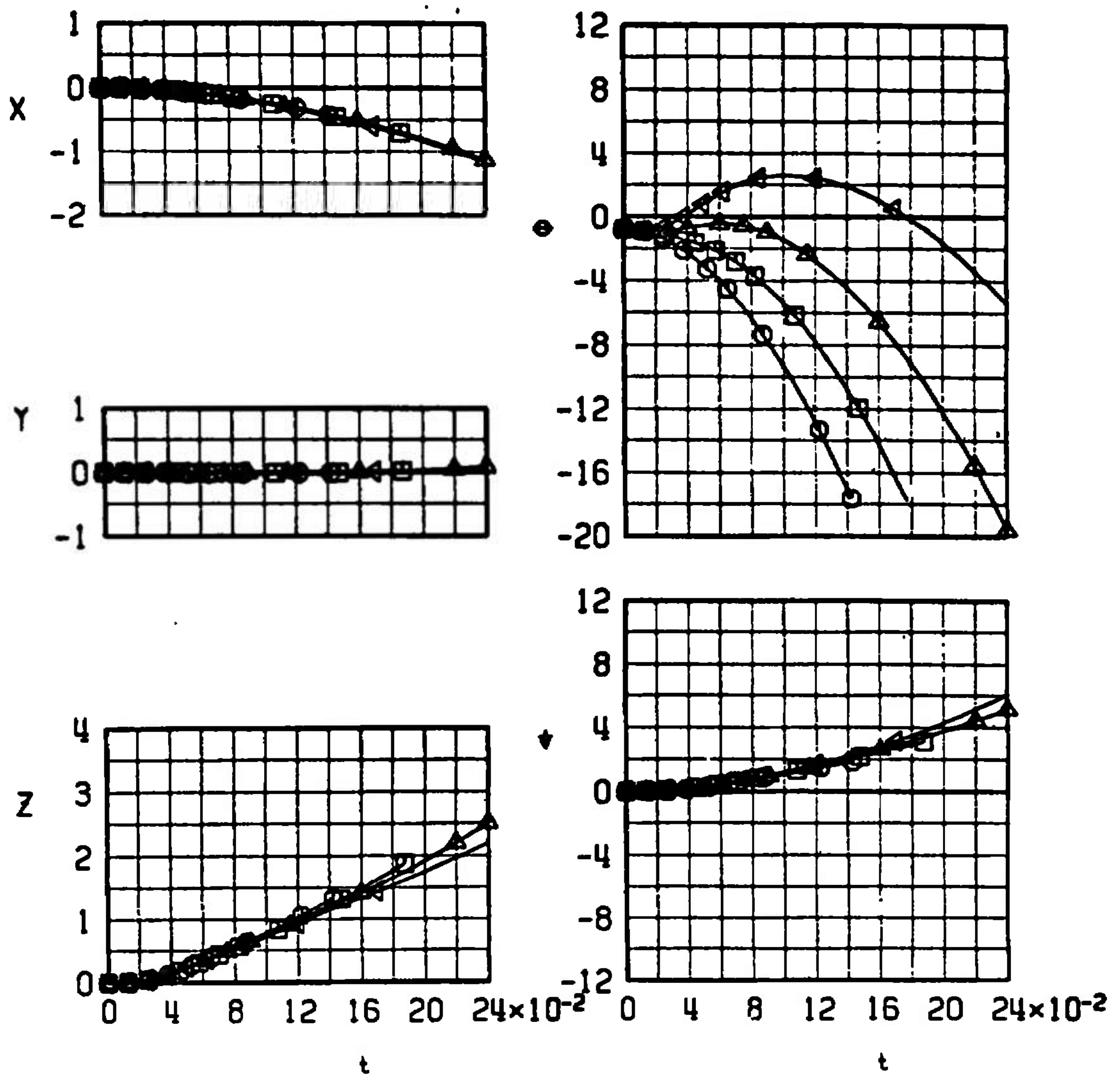
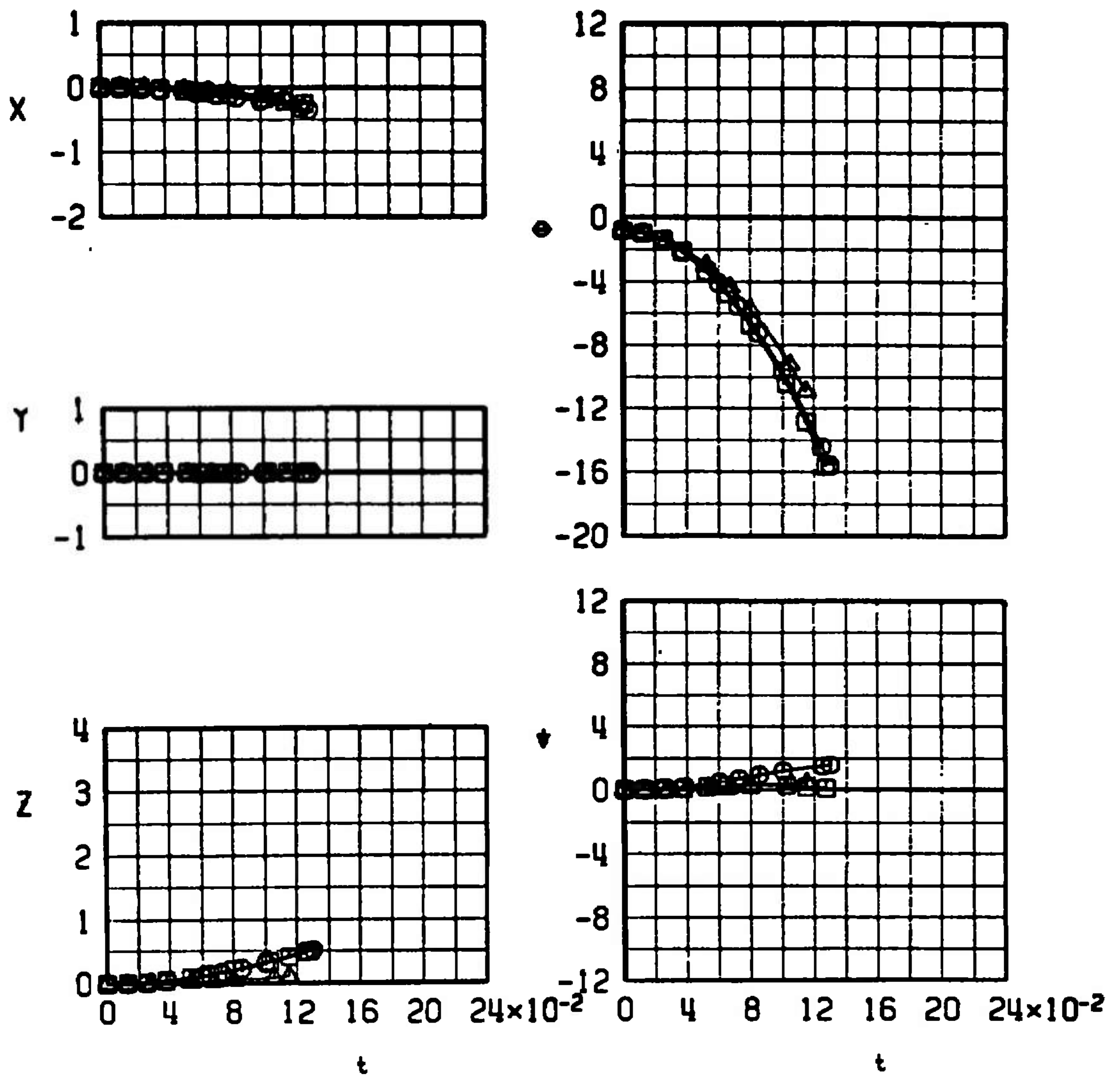


Fig. 15 Trajectory Data for the Standard SUU-51B/B from the Standard TER with Dual Ejector Forces

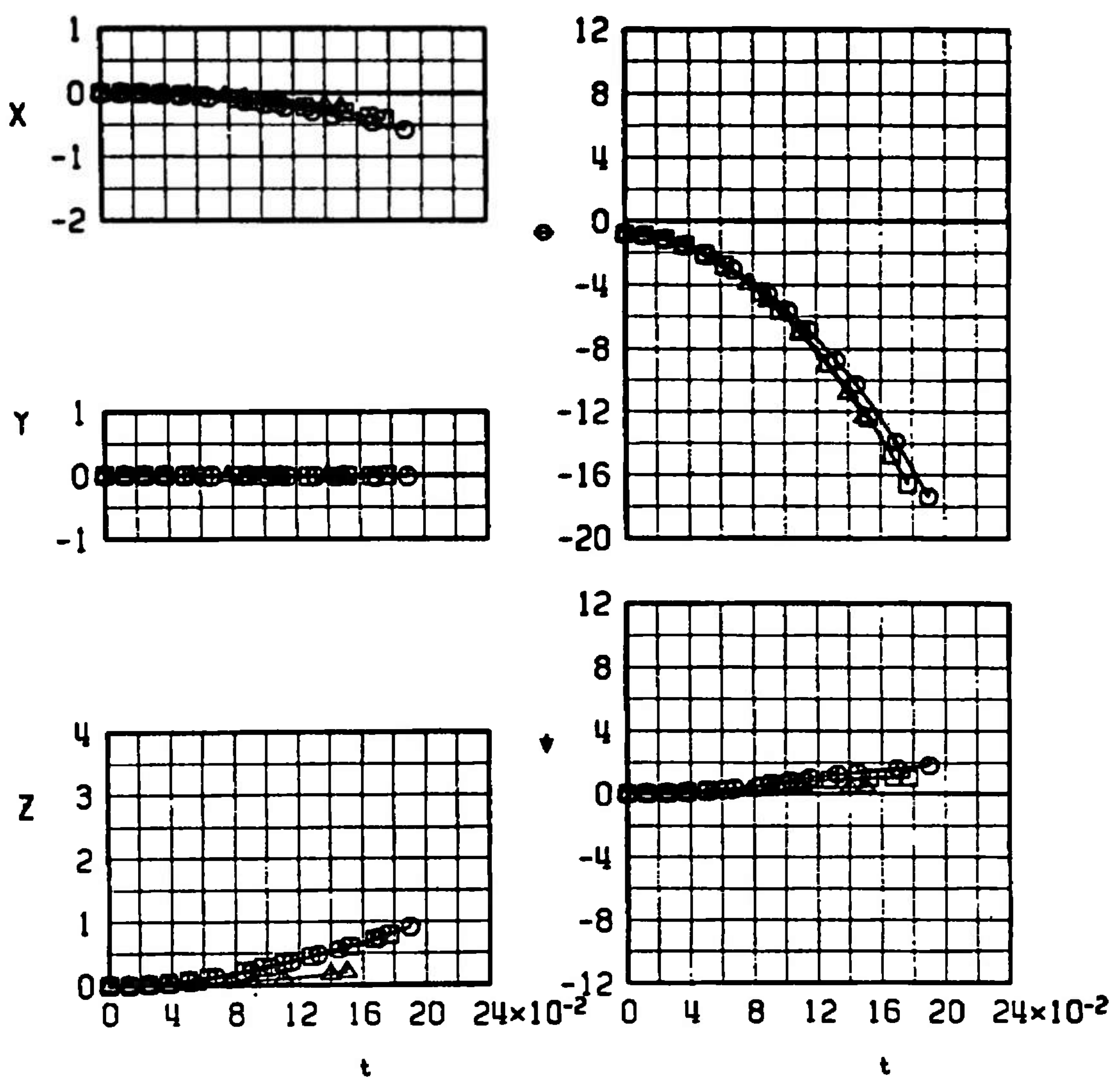
SYMBOL	CONF	M_∞	α	F_Z	X_L
○	1	0.90	0.2	Fig. 11a	-0.211
□	2	0.90	0.2	↓	+0.122
△	3	0.90	0.2	0	—



a. Standard Store

Fig. 16 Trajectory Data for the SUU-51B/B for Changes in Ejector Force and Initial Store Position on the Standard TER

SYMBOL	CONF	M_∞	α	F_Z	X_L
○	1	0.90	0.2	Fig. 11a	-0.541
□	2	0.90	0.2	↓	-0.208
△	3	0.90	0.2	0	—



b. Ballasted Store
Fig. 16 Concluded

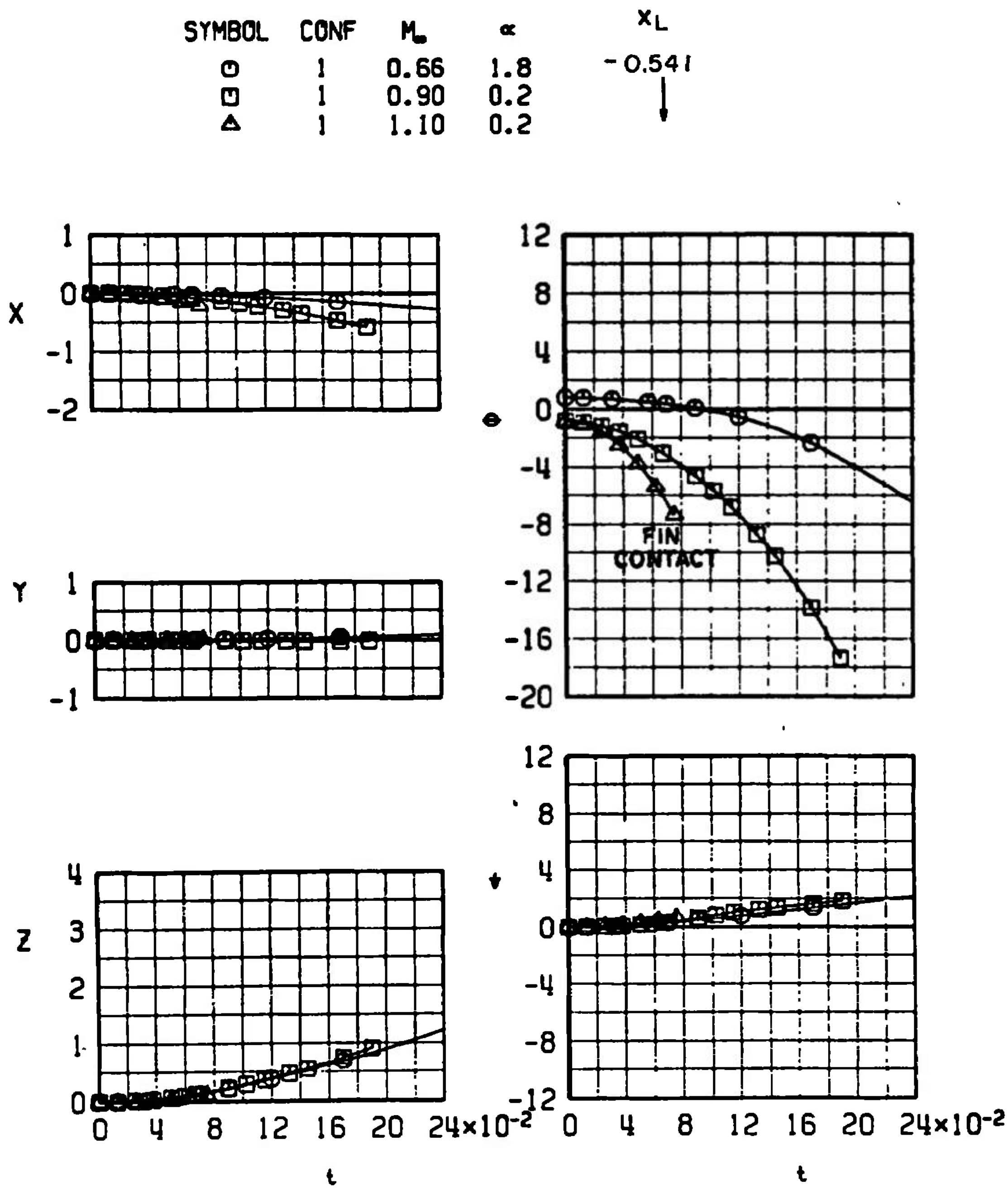


Fig. 17 Trajectory Data for the Ballasted SUU-51B/B from the Standard TER Showing the Effect of Mach Number

SYMBOL	CONF	M_∞	α	X_L
○	5	0.90	0.2	-0.211
□	6	0.90	0.2	+0.122

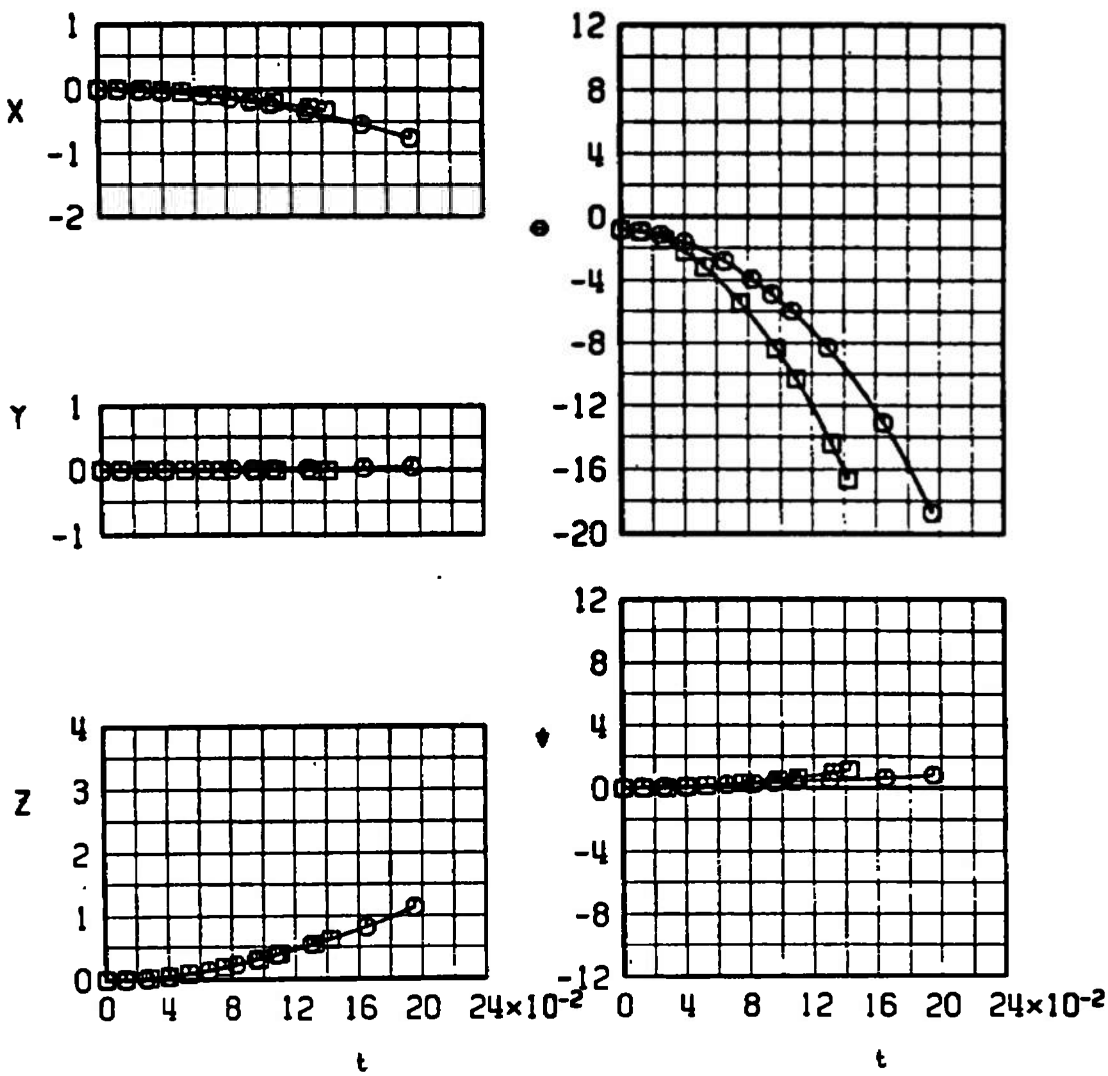


Fig. 18 Trajectory Data for the Standard SUU-51B/B for Changes in Initial Store Position on the Modified TER with Single Ejector

SYMBOL	CONF	M_∞	α	STORE	TER	X_L
○	7	0.90	0.2	STD	STD	-0.711
□	8	0.90	0.2	↓	MOD	↓
●	7	0.90	0.2	BALLAST	STD	-1.041
■	8	0.90	0.2	↓	MOD	↓

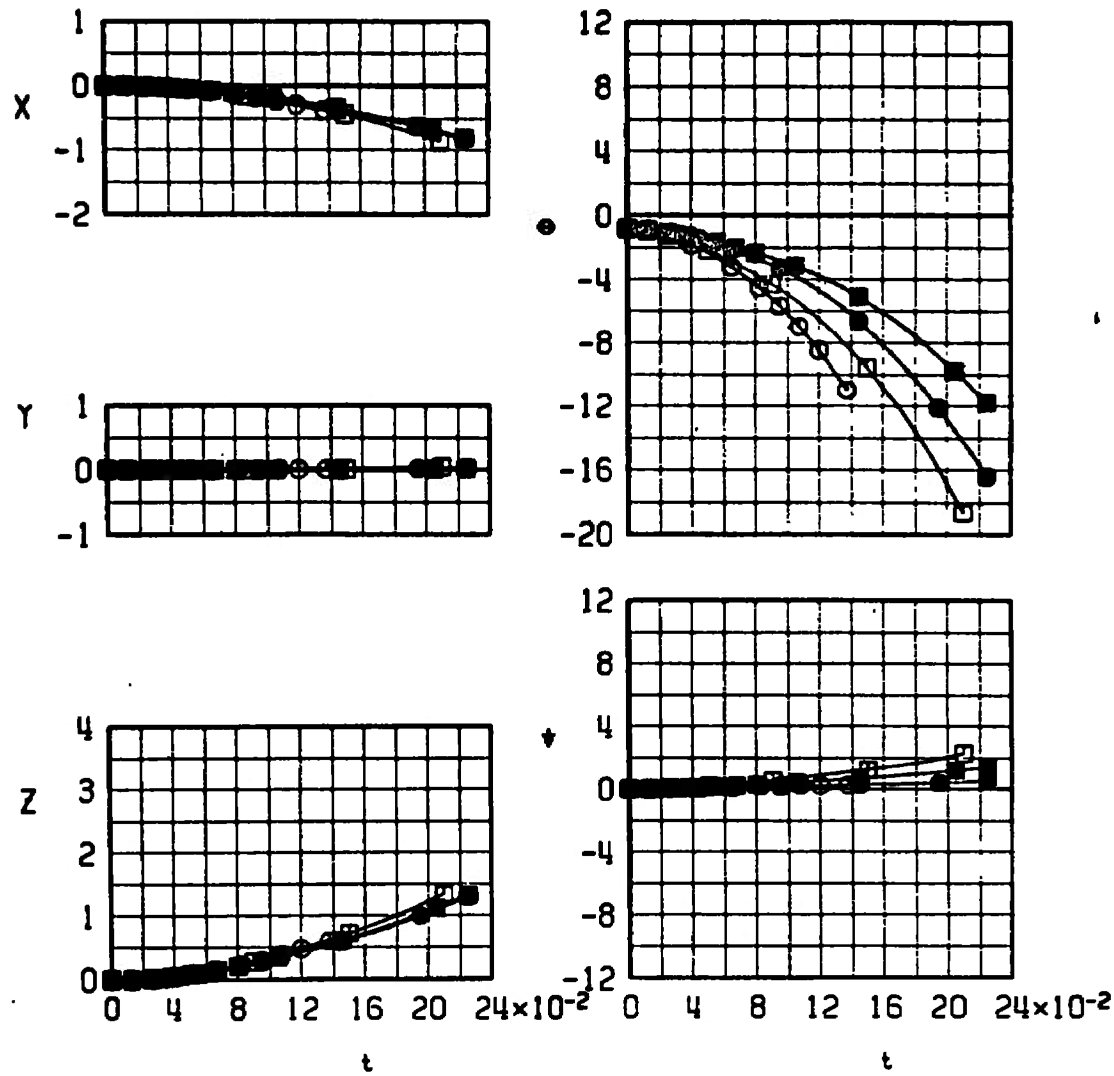
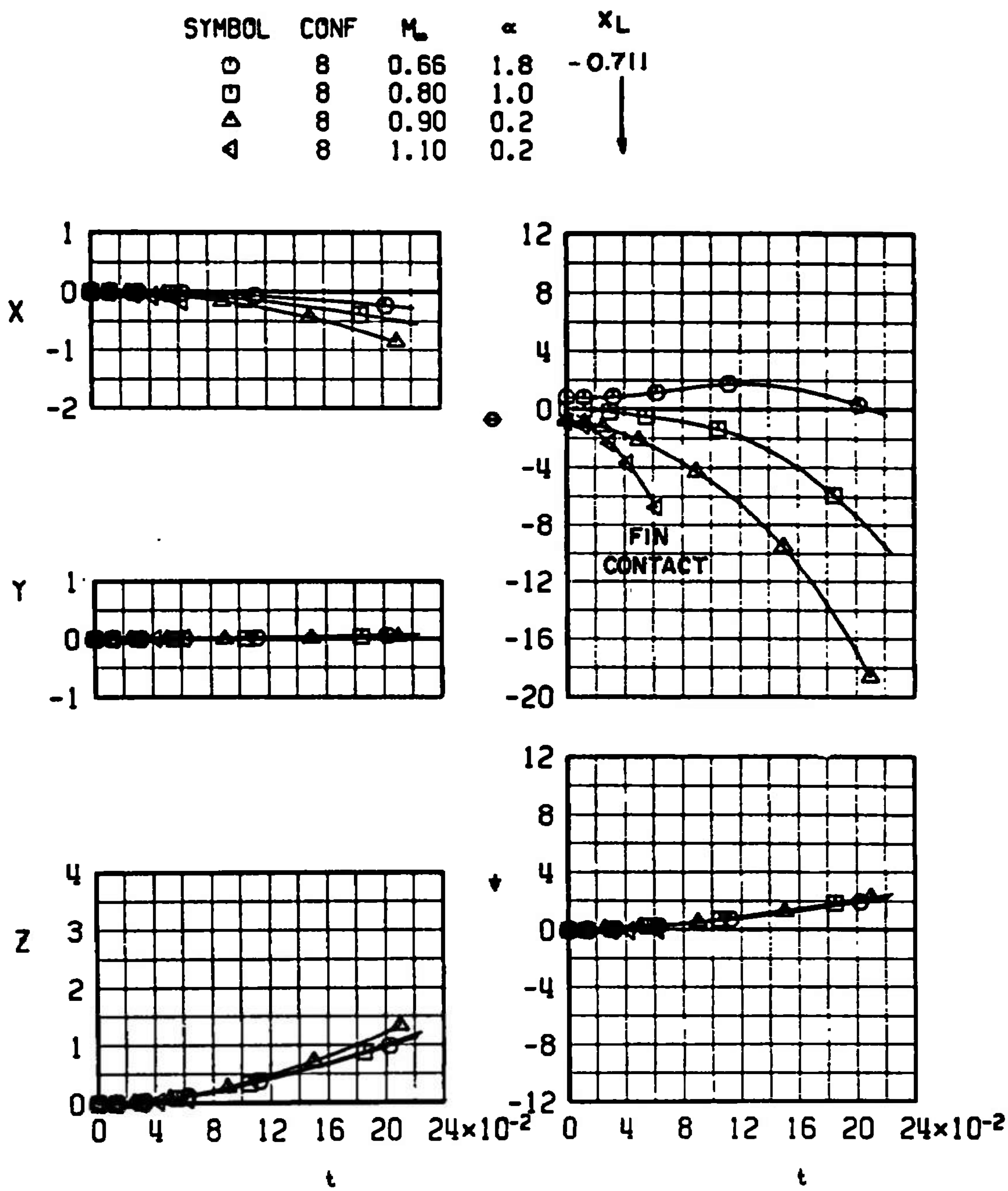
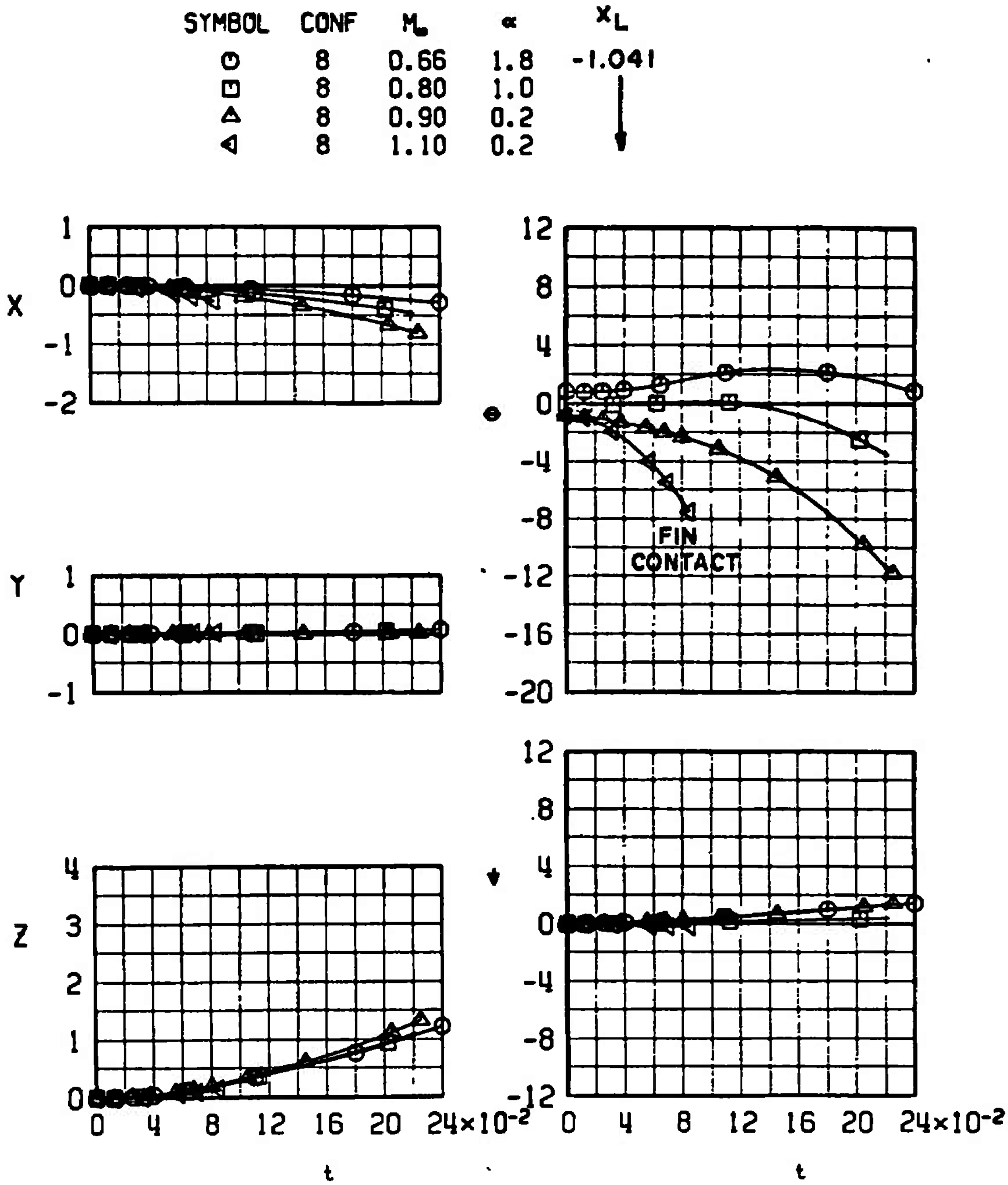


Fig. 19 Trajectory Data Showing the Effect of Store Ballast and TER Geometry with Single Ejector, all Stores Shifted 6 in. Forward



a. Standard Store

Fig. 20 Trajectory Data Showing the Effect of Mach Number for Separation from the Modified TER with Single Ejector, All Stores Shifted 6 in. Forward



b. Ballasted Store
Fig. 20 Concluded

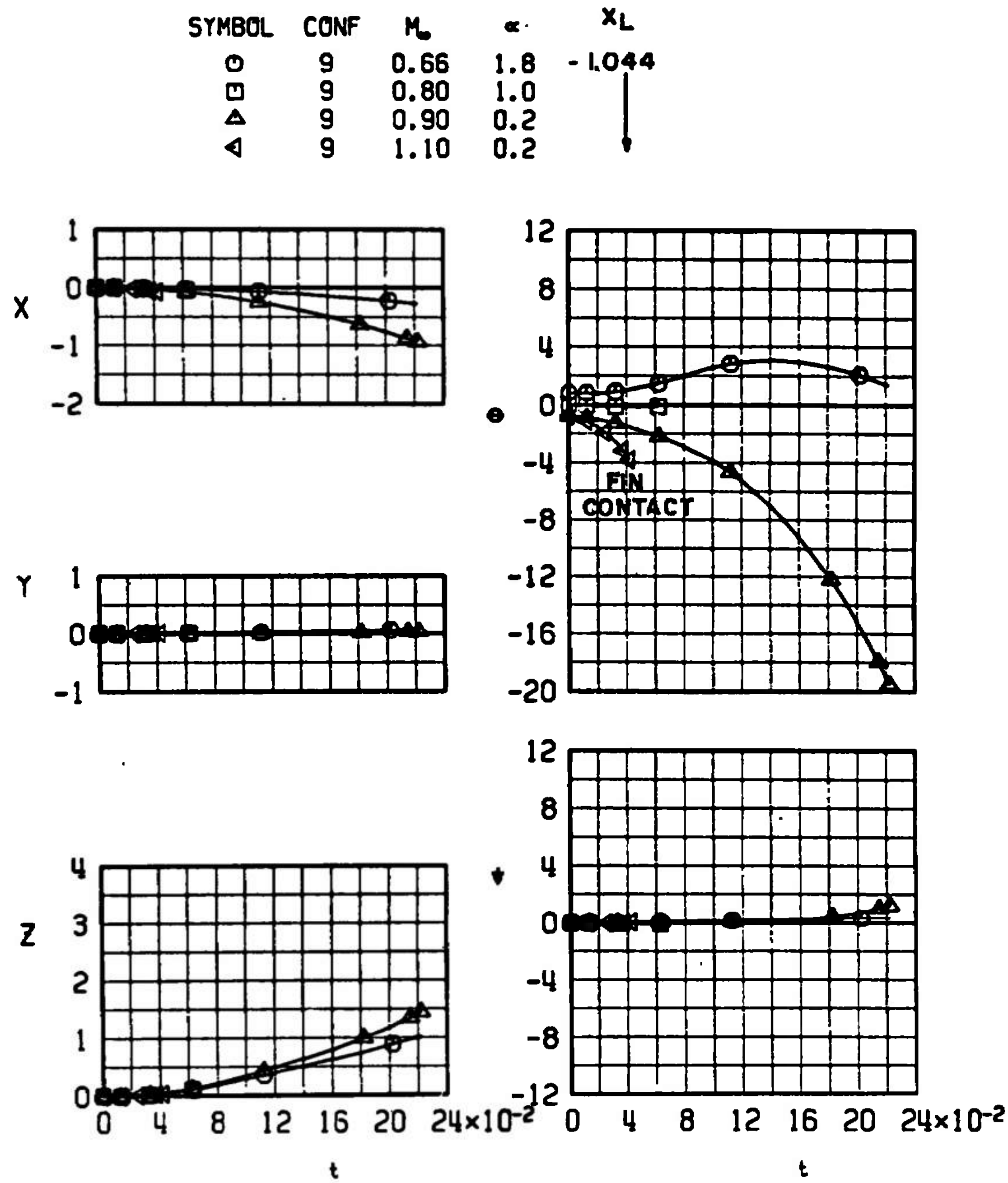
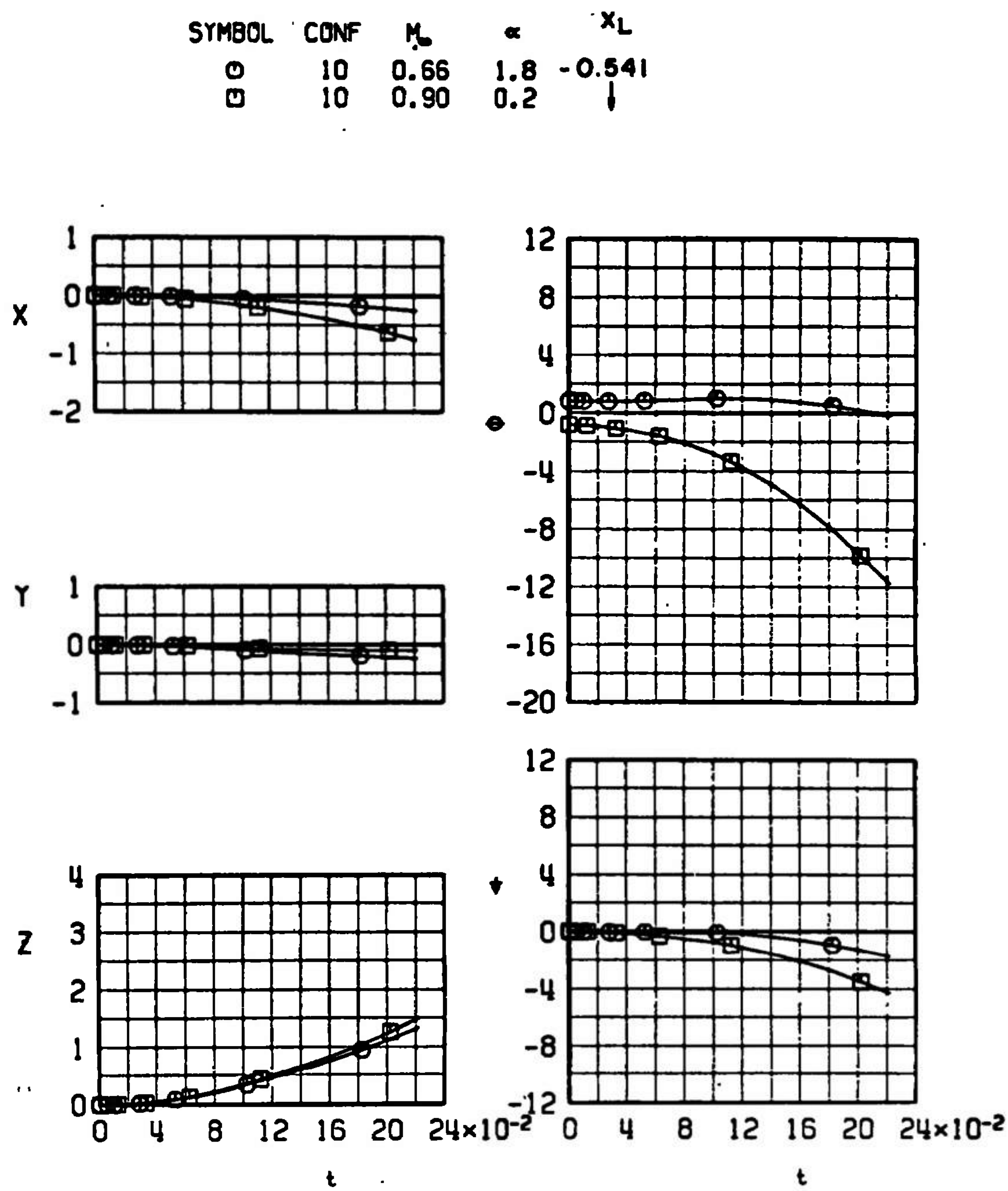
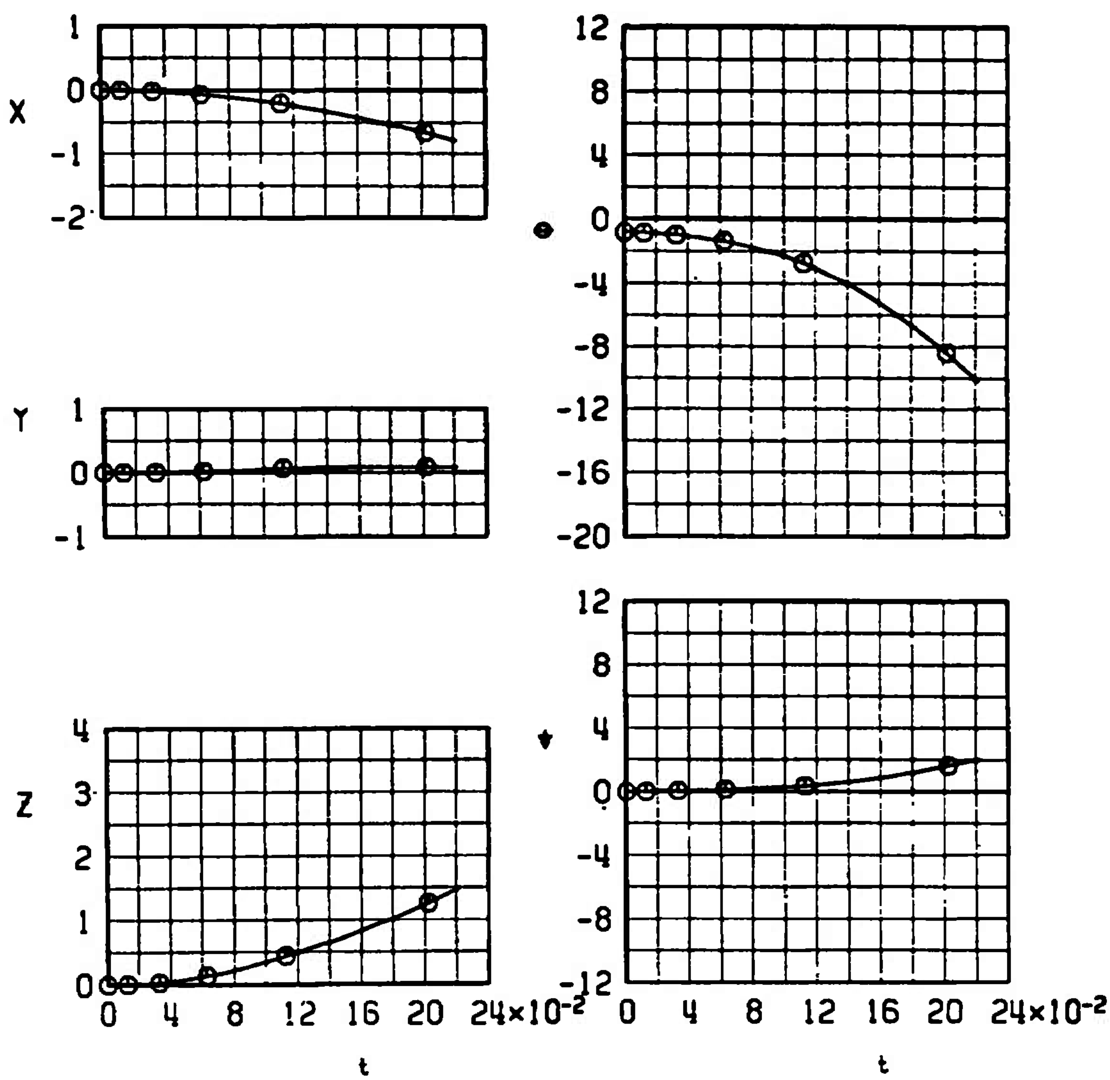


Fig. 21 Trajectory Data for the Standard SUU-51B/B Showing the Effect of Mach Number for Separation from the Standard TER with Single Ejector, All Stores Shifted 10 in. Forward



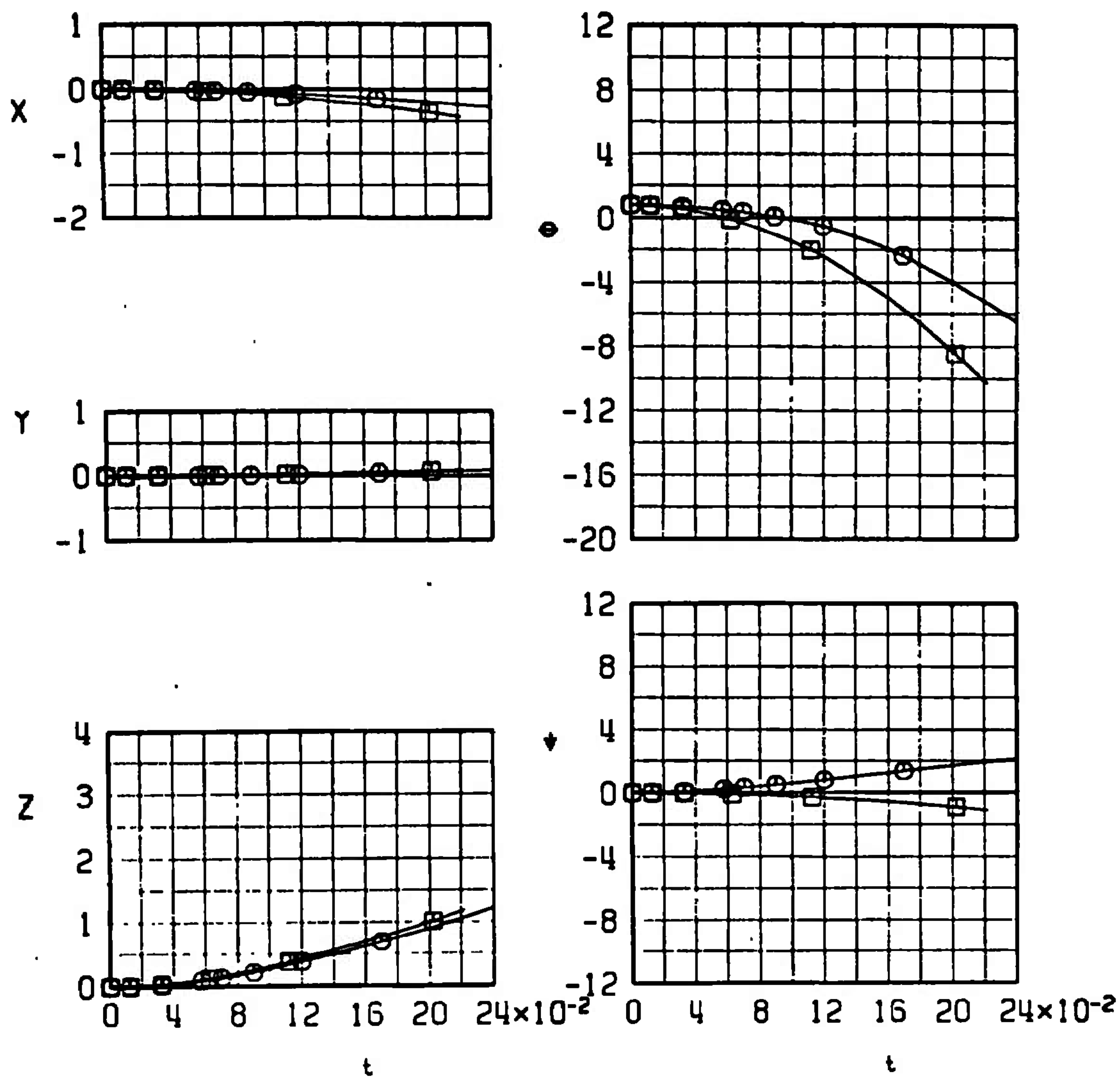
a. From TER Position 2
Fig. 22 Trajectory Data for the Ballasted SUU-51B/B from the Modified TER Shoulder Positions

SYMBOL	CONF	M_∞	α	X_L
⊖	11	0.90	0.2	-0.541



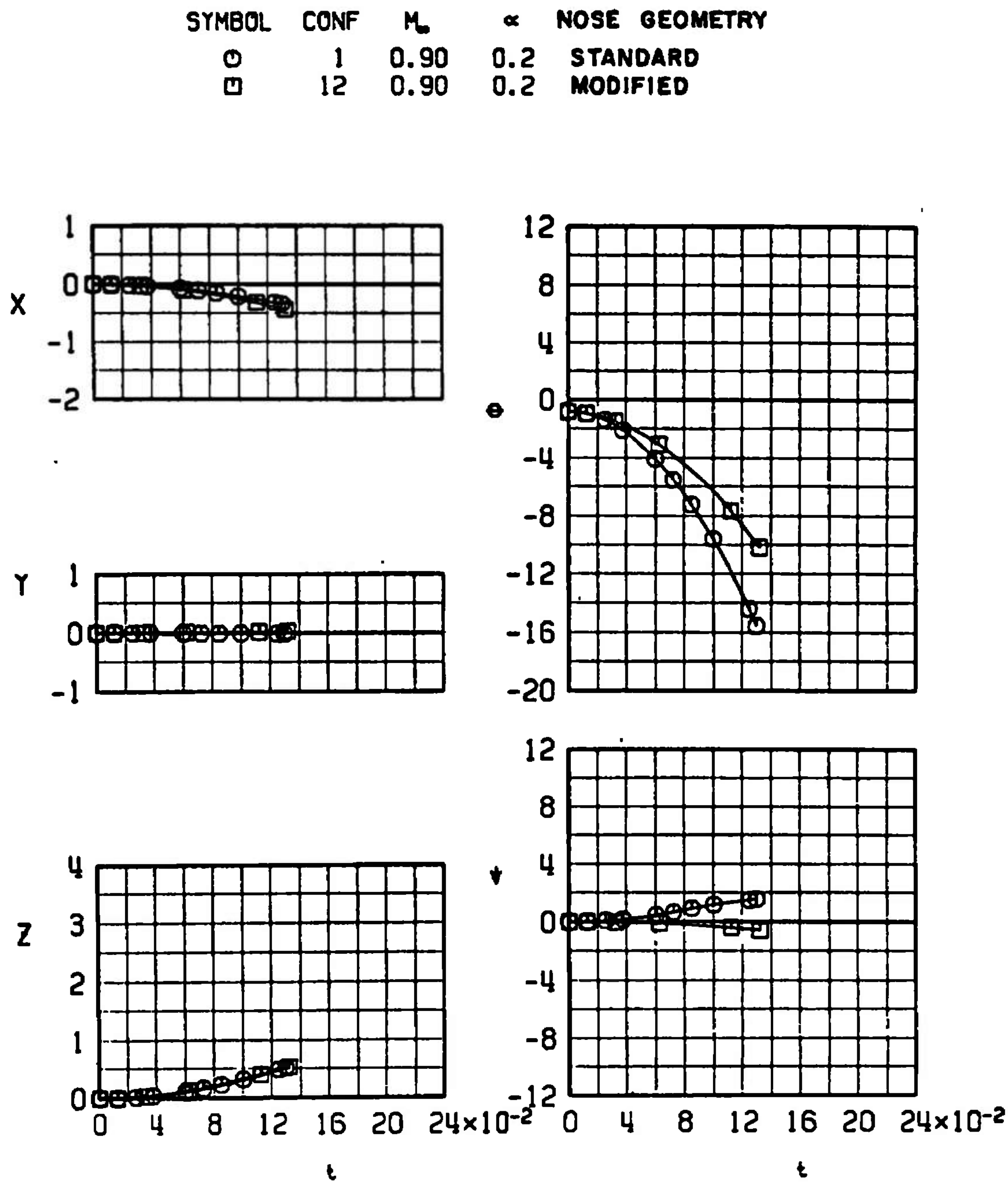
b. From TER Position 3
Fig. 22 Concluded

SYMBOL	CONF	M_∞	α	NOSE GEOMETRY
○	1	0.66	1.8	STANDARD
□	12	0.66	1.8	MODIFIED



a. M_∞ = 0.66

Fig. 23 Effect of Store Nose Geometry on the Store Separation Trajectories from the Standard Carriage Position



b. $M_\infty = 0.90$

Fig. 23 Concluded

SYMBOL	CONF	M_∞	α	STORE cg	X_L
○	12	0.90	0.2	STANDARD	-0.211
□	12	0.90	0.2	BALLASTED	-0.541

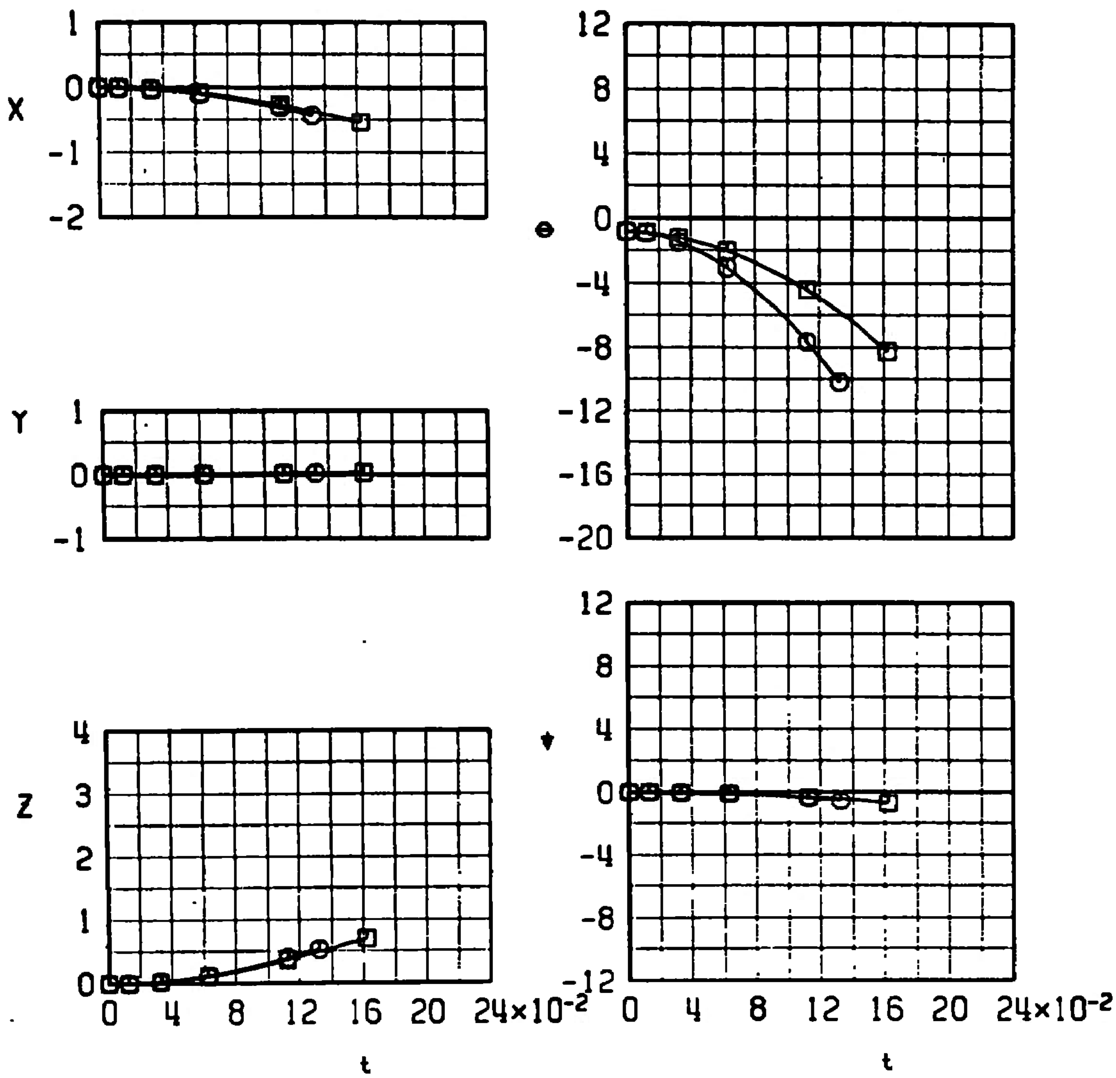


Fig. 24 Trajectory Data for the SUU-51B/B with Modified Nose Geometry, Showing the Effect of Ballast in the Store Nose

SYMBOL	CONF	M_∞	α	AFT SHIFT, in.
○	13	0.90	0.2	0
□	14	0.90	0.2	16
△	15	0.90	0.2	18
◁	16	0.90	0.2	22

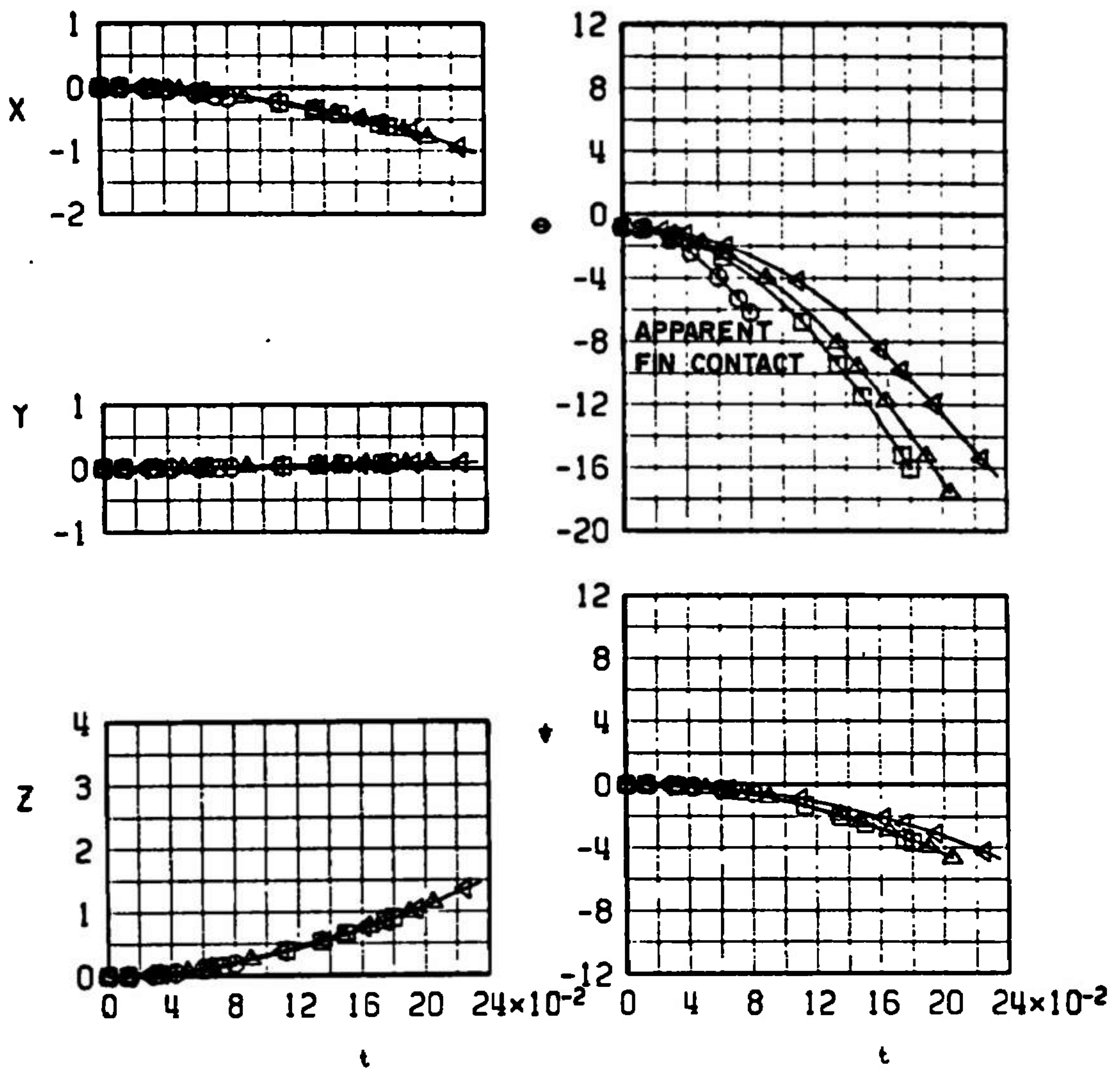
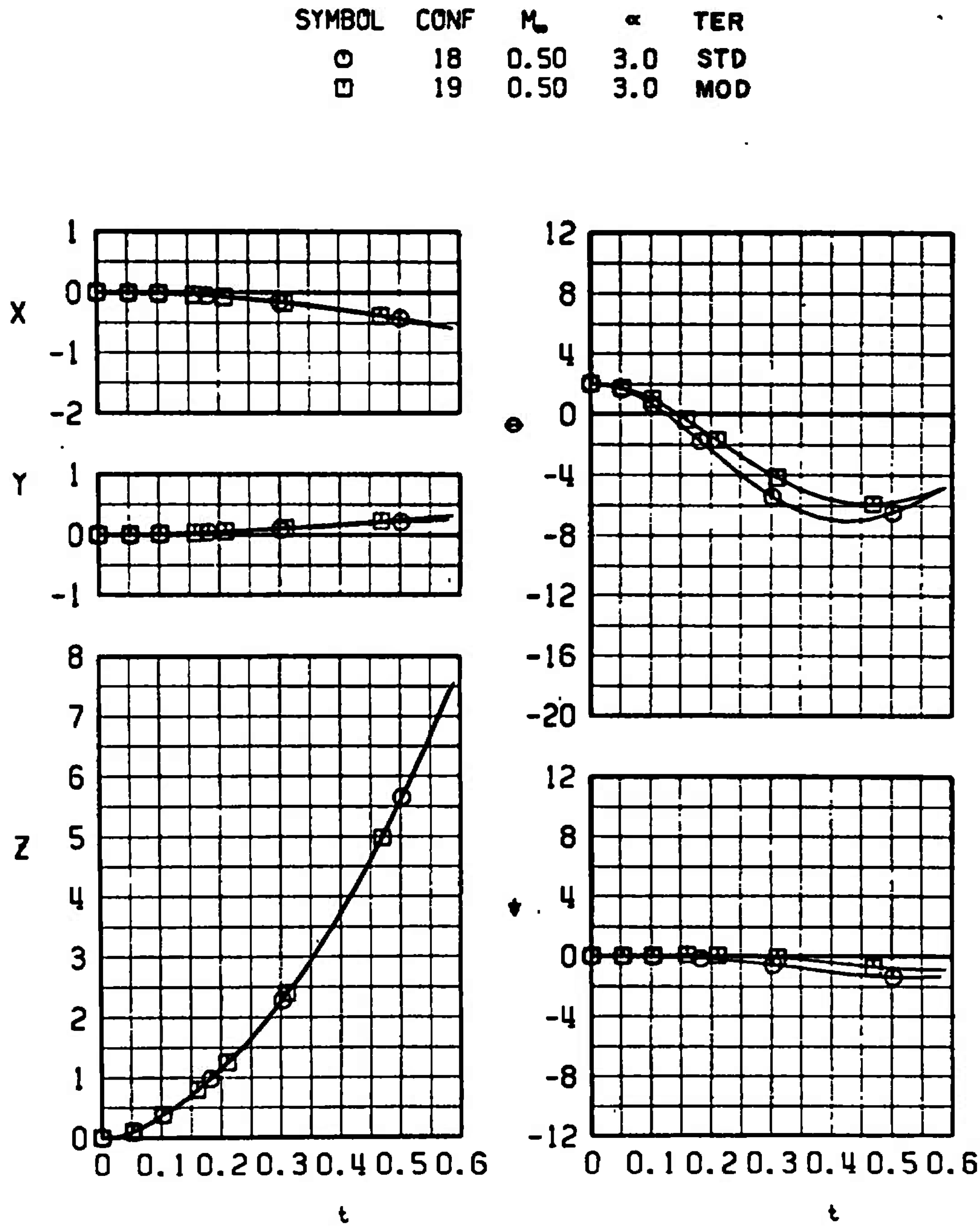
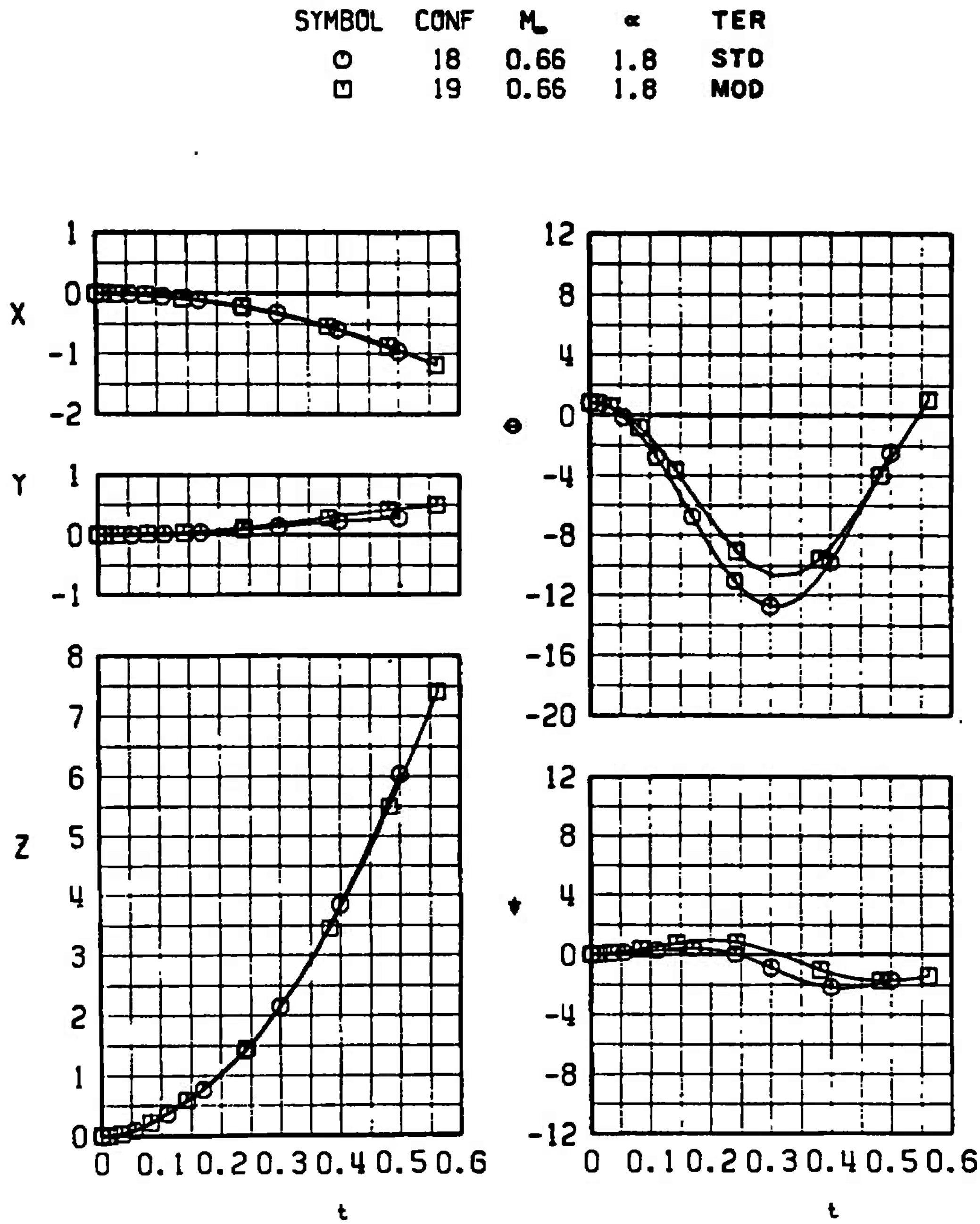


Fig. 25 Trajectory Data for the Modified Nose Geometry Store Showing the Effect of Shifting the Store and Ejector Aft on the Modified TER, X_L = -0.211

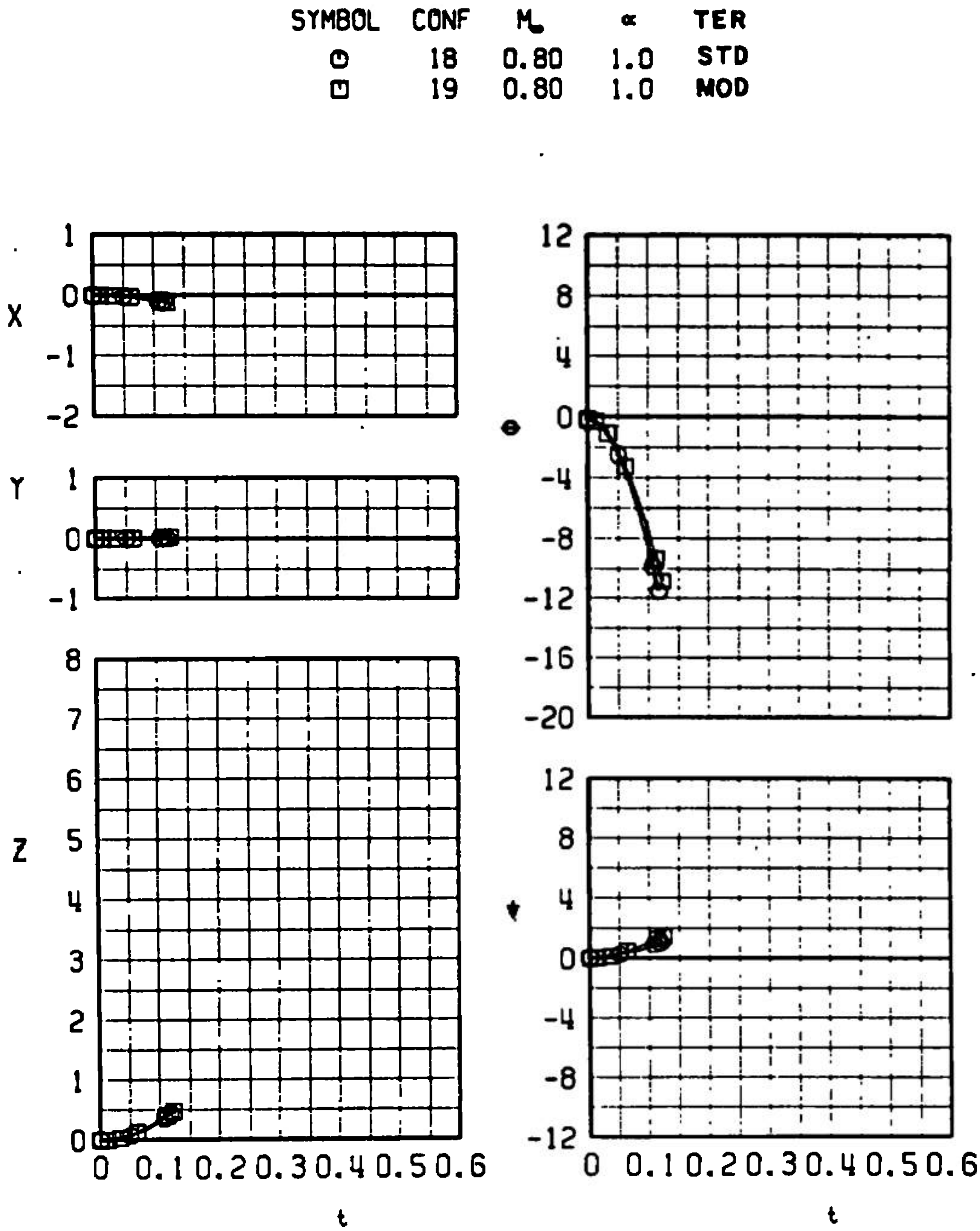


a. $M_\infty = 0.50$

Fig. 26 Trajectory Data for the M-117 Showing the Effect of TER Geometry

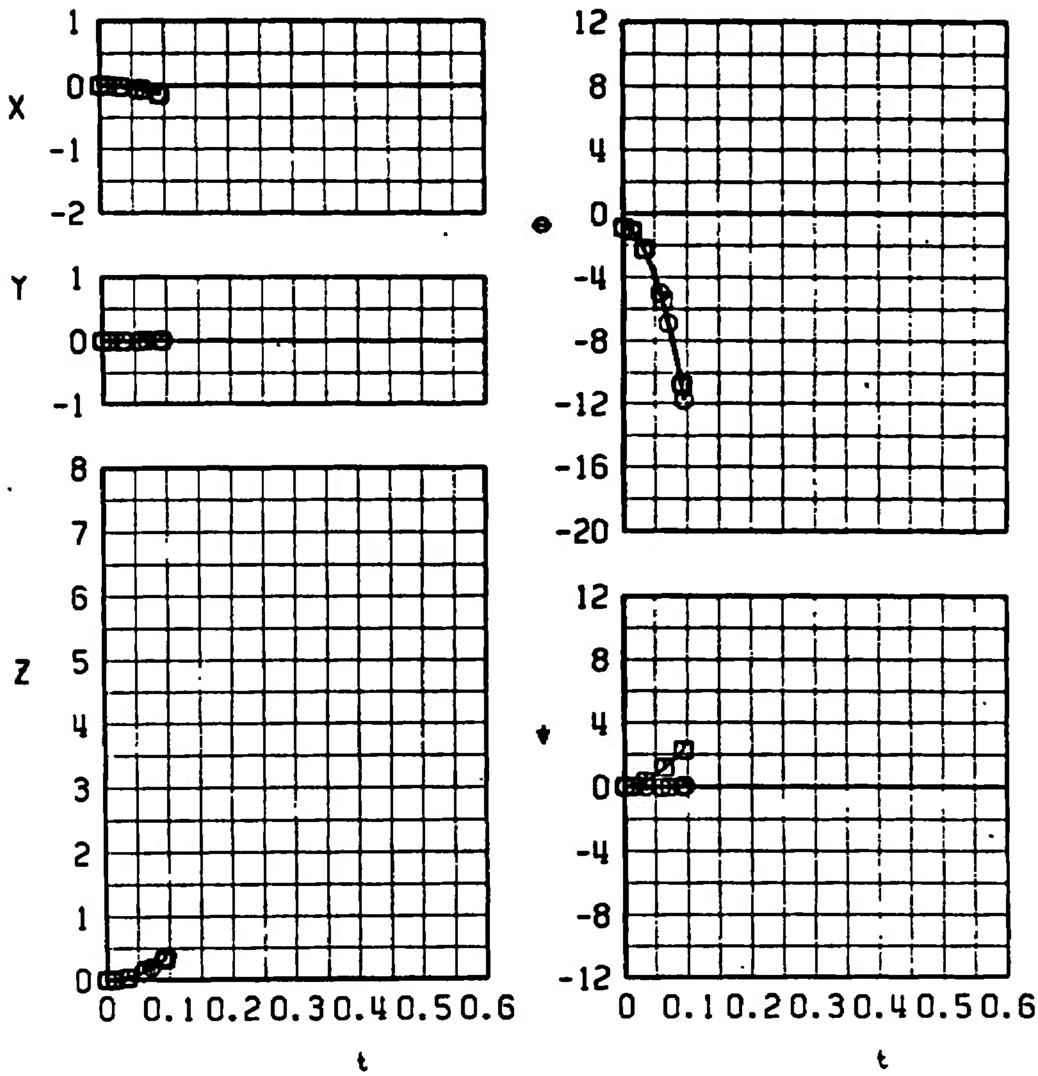


b. $M_\infty = 0.66$
Fig. 26 Continued



c. $M_\infty = 0.80$
Fig. 26 Continued

SYMBOL	CONF	M_∞	α	TER
○	18	0.90	0.2	STD
□	19	0.90	0.2	MOD



d. M_∞ = 0.90

Fig. 26 Concluded

TABLE I
FULL-SCALE STORE PARAMETERS USED IN TRAJECTORY CALCULATIONS

PARAMETER	STORE		
	STANDARD SUU-51B/B	BALLASTED SUU-51B/B	M-117
$\bar{m}$	25.17	29.82	23.31
X_{cg}	3.91	3.58	2.74
Z_{cg}	0.018	0.015	0.000
S	1.396	1.396	1.396
b	1.333	1.333	1.333
I_{YY}	70	109	50
I_{ZZ}	70	109	50
C_{m_q}	-35	-35	-70
C_{n_r}	-35	-35	-70
X_L	-0.211	-0.541	0.000
X_{L_1}	0.810	NA	NA
X_{L_2}	-0.898	NA	NA
Z_E	0.255	0.255	0.255

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Willard E. Summers, ARO, Inc.

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11. SUPPLEMENTARY NOTES	12 SPONSORING MILITARY ACTIVITY
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13 ABSTRACT

Separation trajectory data were obtained to investigate some possible ways to reduce the nose-down pitch of the SUU-51B/B store during separation from the Triple Ejection Rack (TER) on the F-4C aircraft. Data were obtained to assess the influence on the store separation characteristics resulting from (1) changing the store mass properties (ballasting), (2) modifying the TER geometry to represent removal of the nose fairing, (3) changing the store carriage location on the TER, (4) modifying the store nose geometry, and (5) applying dual ejector forces to the store during separation. Separation trajectories were obtained for release from the TER on the inboard pylon at Mach numbers from 0.66 to 1.1 for level flight at 5000-ft altitude. In addition to the trajectory data, force and moment data were obtained on the SUU-51B/B to assess the influence on store loads of (1) changes in store position relative to the rack, and (2) the modified nose geometry. Results of the test show that the dual ejector forces were most effective in reducing the store nose-down pitch. Separation of the ballasted store from the modified TER produced the best results of all combinations using the single ejector.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
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bombs						
scale models						
F-4C aircraft						
aerodynamic characteristics						
angle of attack						
stability						
transonic flow						

AFSC
Arnold AFS Tenn