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SEPARATION CHARACTERISTICS OF THE SUU-51/B
FROM THE F-4C AIRCRAFT

Janis Kukainis

ARO, Inc.

July 1971

PROPULSION WIND TUNNEL FACILITY
ARNOLD ENGINEERING DEVELOPMENT CENTER
AIR FORCE SYSTEMS COMMAND
ARNOLD AIR FORCE STATION, TENNESSEE

NOTICES

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FROM THE F-4C AIRCRAFT

Janis Kukainis
ARO, Inc.

FOREWORD

The work reported herein was sponsored by the Air Force Armament Development and Test Center (ADTC/DLGD), Air Force Systems Command (AFSC), under Program Element 64724F, Project 1120, Task 07.

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 April 12 to 16, 1971, under ARO Project No. PC0138. The manuscript was submitted for publication on May 26, 1971.

This technical report has been reviewed and is approved.

George F. Garey
Lt Colonel, USAF
AF Representative, PWT
Directorate of Test

Joseph R. Henry
Colonel, USAF
Director of Test

ABSTRACT

'A wind tunnel test was conducted using 0.05-scale models to study the separation characteristics of the SUU-51/B from the F-4C aircraft. The separation trajectories were initiated from the left-wing inboard pylon station utilizing the Triple Ejection Rack and from the centerline pylon utilizing the Multiple Ejection Rack. The flight conditions simulated were Mach numbers from 0.66 to 0.90 at an altitude of 5000 ft. Parent aircraft dive angles of 0, 30, and 45 deg were simulated.

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dtd 24 may 74

CONTENTS

APPENDIXES

I. ILLUSTRATIONS

Figure

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_m Store pitching-moment coefficient, referenced to the store center of gravity (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, $dC_n/d(rb/2V_\infty)$

FS   Aircraft fuselage station, in., model scale

F_Z MER/TER ejector force, lb

H   Pressure altitude, ft

I_{xx} Full-scale moment of inertia about the store X_B axis, slug-ft^2

I_{xz} Full-scale product of inertia, X_B-Z_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_∞ Free-stream static pressure, psfa

q Store angular velocity about the Y_B axis, radians/sec

q_∞ Free-stream dynamic pressure, $0.7\, p_\infty M_\infty^2$, psf

r Store angular velocity about the Z_B axis, radians/sec

S Store reference area, ft², 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

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

Z_E Ejector stroke length, ft, full scale

a Parent-aircraft or store 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

$\overline{\theta}$ Simulated parent-aircraft climb angle. Angle between the flight direction and the earth horizontal, deg, positive for increasing altitude

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.

SECTION I
INTRODUCTION

This investigation was conducted in the Aerodynamic Wind Tunnel (4T) of the Propulsion Wind Tunnel Facility to obtain captive-trajectory store-separation data for the SUU-51/B store when released from various F-4C inboard and centerline multiple carriage configurations. Separation trajectories with the folded-fin configuration were initiated from the launch positions with simulated ejector forces acting on the store. If a trajectory was of sufficient length to reach the position where the fins could be deployed, the open-fin configuration was used to obtain additional data, initiating from the chosen store location along the original trajectory. The criterion for fin deployment was a clearance of at least 1.5 ft between the rack and the aft end of the store.

To simulate the separation trajectories, 0.05-scale models of the F-4C and the store were employed. The store models were attached to the Captive Trajectory System (CTS) in the 4T wind tunnel. Flight conditions simulated were Mach numbers from 0.66 to 0.90, an altitude of 5000 ft, and parent-aircraft angles of attack from 2.2 to 0.5 deg in level flight. At most test conditions, parent-aircraft dive angles of 30 and 45 deg were also simulated.

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 0.2 to 1.3. At all Mach numbers, the stagnation pressure can be varied from 200 to 3400 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 degreees 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

The test articles were 0.05-scale models of the F-4C parent aircraft and the SUU-51/B store. A sketch showing the basic dimensions of the F-4C parent model is shown in Fig. 3. For this test, only the left wing and fuselage centerline of the F-4C were equipped for store separation. Details and dimensions of the pylons are shown in Fig. 4. The surfaces of the fuselage centerline and wing inboard pylons are inclined at a 2.5- and 1.0-deg nose-down angle, respectively, with respect to the aircraft waterline.

The Triple Ejection Rack (TER) and Multiple Ejection Rack (MER) were mounted on the inboard and centerline pylons, respectively, and matched to the 30-in. suspension lugs of the pylons. Details and dimensions of the TER and MER are shown in Figs. 5 and 6, respectively.

Details and dimensions of the SUU-51/B store model are shown in Figs. 7, 8, and 9. A dimensional sketch of the 370-gal dummy fuel tank is shown in Fig. 10. A schematic of the TER and MER store stations and orientation is given in Fig. 11, and the weapons loading configurations for which trajectory data were obtained are shown in Fig. 12.

2.3 INSTRUMENTATION

A five-component, internal strain-gage balance was used to obtain the force and moment data on the SUU-51/B model. Translational and angular positions of the store model were obtained from the CTS analog outputs. An angular position indicator on the main pitch sector was used to determine the parent-model angle of attack. The MER and TER were instrumented with a touch wire at each station which aided in the positioning of the sting-mounted store model at the launch position on the rack. The system was also electrically connected to automatically stop the CTS movement if the store model or sting contacted the rack or the aircraft-model surface.

<div align="center">

SECTION III
TEST DESCRIPTION

</div>

3.1 TEST CONDITIONS

Separation trajectory data were obtained at Mach numbers from 0.66 to 0.90. Tunnel dynamic pressure was 500 psf at all Mach numbers, and tunnel stagnation temperature was maintained near 100°F.

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[1] Test Facilities Handbook (Eighth Edition). "Propulsion Wind Tunnel Facility, Vol. 5." Arnold Engineering Development Center, December 1969 (AD864636).

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 TRAJECTORY DATA ACQUISITION

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 redone 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 function for the SUU-51/B store is presented in Fig. 13. 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

The trajectory data are subject to error from several sources including tunnel conditions, balance measurements, extrapolation tolerances allowed in the predicted coefficients, computer inputs, and CTS positioning control. Maximum error in the CTS position control was ±0.05 in. for the translational settings and ±0.15 deg for angular displacement settings in pitch and yaw. Extrapolation tolerances were ±0.10 for each of the aerodynamic coefficients. The maximum uncertainties in the full-scale position data caused by the balance precision limitations are given in Table II.

The estimated uncertainty in setting Mach number was no greater than ±0.003, and the uncertainty in parent-model angle of attack was estimated to be ±0.1 deg.

SECTION IV
RESULTS AND DISCUSSION

4.1 GENERAL

All trajectories obtained were for use in the determination of safe-separation envelopes of the SUU-51/B from the F-4C aircraft. No attempt will be made in this report to establish these envelopes or to qualify the store as safe or unsafe for aircraft separation. The trajectory data are presented as obtained from the wind tunnel along with comments regarding the aerodynamics of the store in the aircraft flow field.

Data taken during this test consisted of ejector-separated trajectories simulating release from multiple carriage positions on the left and right wing inboard and centerline positions of the F-4C aircraft. Trajectories from the right wing were simulated by launching from the left wing with a reversed (1, 3, and 2) TER ejection sequence. Data showing the linear and angular displacements of the store relative to the mate position on the racks or pylons are presented as functions of full-scale trajectory time in Figs. 14 through 22. Positive X, Y, and Z displacements (as seen by the pilot) are forward, to the right (inboard), and down, respectively. Positive changes in pitch and yaw (as seen by the pilot) are nose up and nose right (inboard), respectively.

Open fin data were obtained for the SUU-51/B. The point of attachment of the 1.5-ft-long lanyard which deployed the fins is shown in Fig. 8. A listing of trajectories for which open fin data were obtained and the time in the trajectory at which the fins were deployed is given in Table III.

4.2 SUU-51/B TRAJECTORIES

Nine wing loading configurations of the SUU-51/B were tested. Most of the trajectories obtained were terminated because of CTS rig limitations before the model

fins could be deployed. Data are compared on the basis of aircraft dive angle. It can be seen that trajectories for a particular configuration at a particular test condition varied very little with aircraft dive angle. Generally, it can be seen that the store Z-displacement was greater for the simulated level flight than for the 30- and 45-deg dive angle trajectories because of the greater gravity-force component in level flight. For all configurations, the store exhibited initial negative pitch and yaw motions. At some test conditions the store yaw or pitch rate was so rapid that, in combination with small Z-displacement, the model contacted the TER or MER surface and stopped the trajectory after a very short time.

As seen by the data presented in Table III, only trajectories obtained at the lowest Mach numbers reached fin deployment distance. The data for these trajectories show that fin deployment resulted in both pitch and yaw recovery in the motion of the store.

APPENDIXES
I. ILLUSTRATIONS
II. TABLES

MANUAL
INPUTS

OPERATIONAL
AMPLIFIER

CONTROLLER

THESE COMPONENTS
LOCATED INSIDE TUNNEL

STORE SEPARATION
DRIVE SYSTEM

FEEDBACK

POSITION
INDICATOR

BALANCE

FORCES
& MOMENTS

RAYTHEON
520
COMPUTER

SIGNAL
CONDITIONING

DIGITAL TO
ANALOG
CONVERTER

MULTI-DEVICE
CONTROLLER

ANALOG TO
DIGITAL
CONVERTERS &
COMMUTATOR

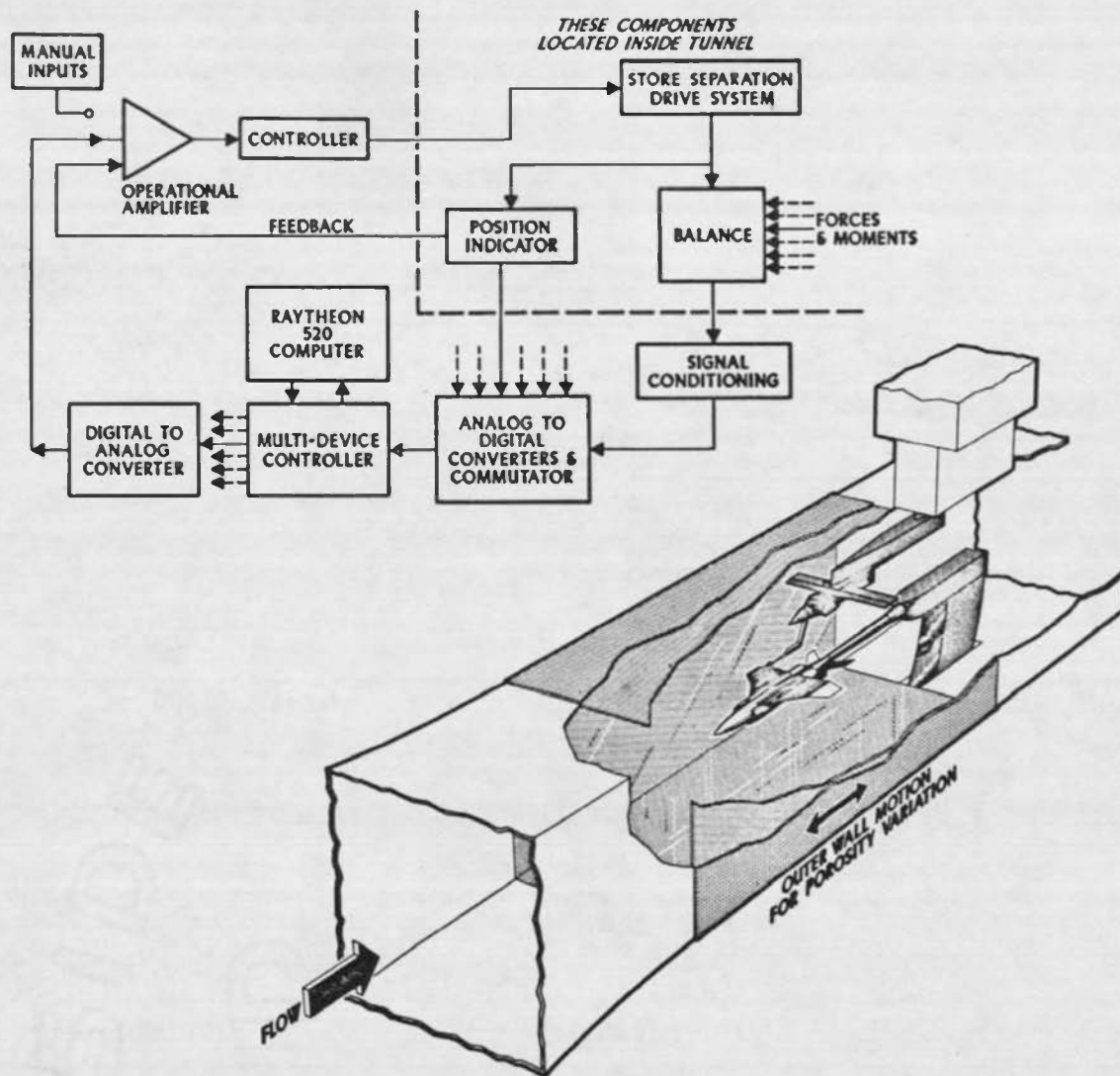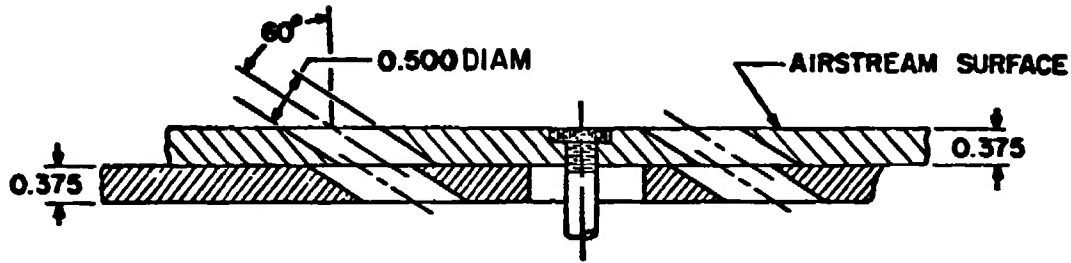OUTER WALL MOTION
FOR POROSITY VARIATION

FLOW

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

60°

0.500 DIAM

AIRSTREAM SURFACE

0.375

0.375

TYPICAL PERFORATED WALL CROSS SECTION

NOTE: TUNNEL STATIONS AND DIMENSIONS ARE IN INCHES

SOLID AREAS

PERFORATED WALLS (10 % MAXIMUM OPEN AREA)

CTS STING SUPPORT

F-4 MODEL

STORE

MAIN SUPPORT

FLOW EXPANSION REGION

STA. 0.0

STA. 36.0

STA. 87.9

STA. 105.1
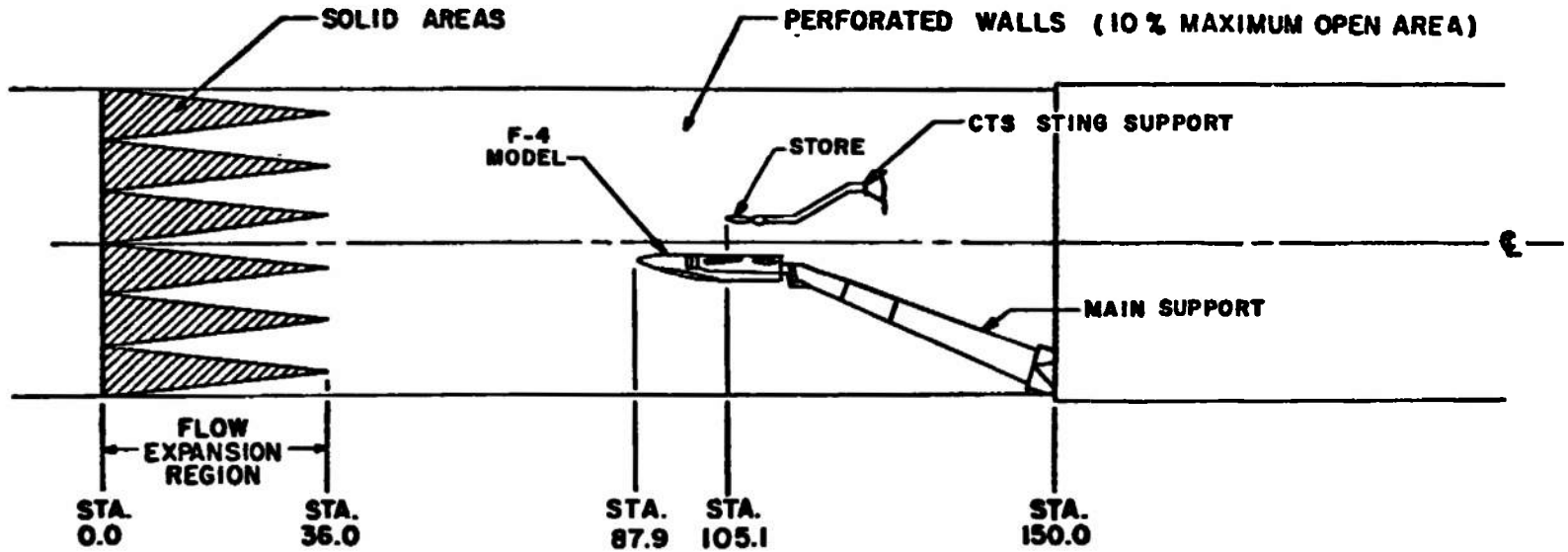
STA. 150.0

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

FRONT VIEW

WL 4.00

WL 0.00

12°

7.5°

FS - 1.355

FS 24.525

SIDE VIEW

BL 11.56

FS - 1.355

FS 11.548

FS 16.050

BL 6.73

BL 4.08

FS 15.666

BL 0.00

ALL DIMENSIONS IN INCHES

BOTTOM VIEW
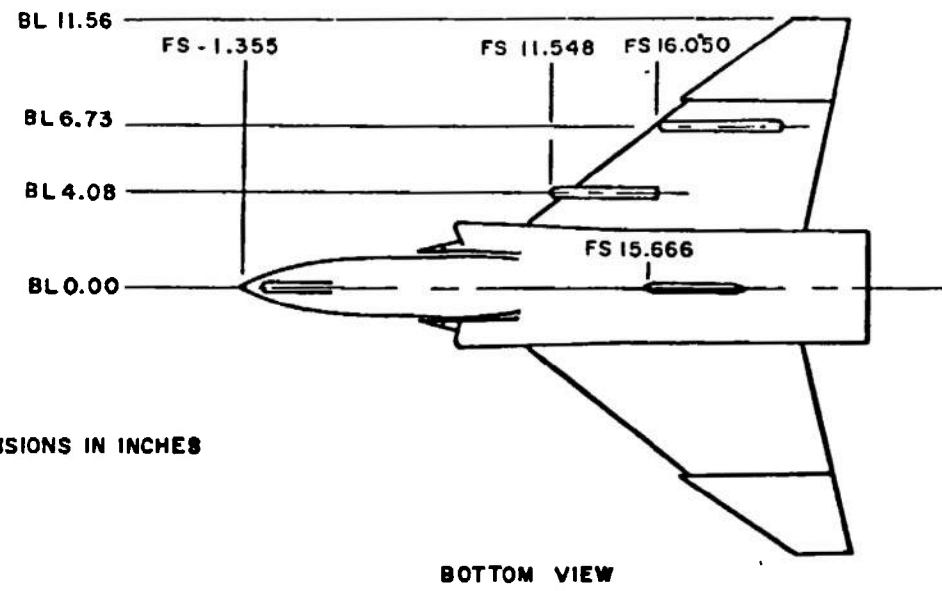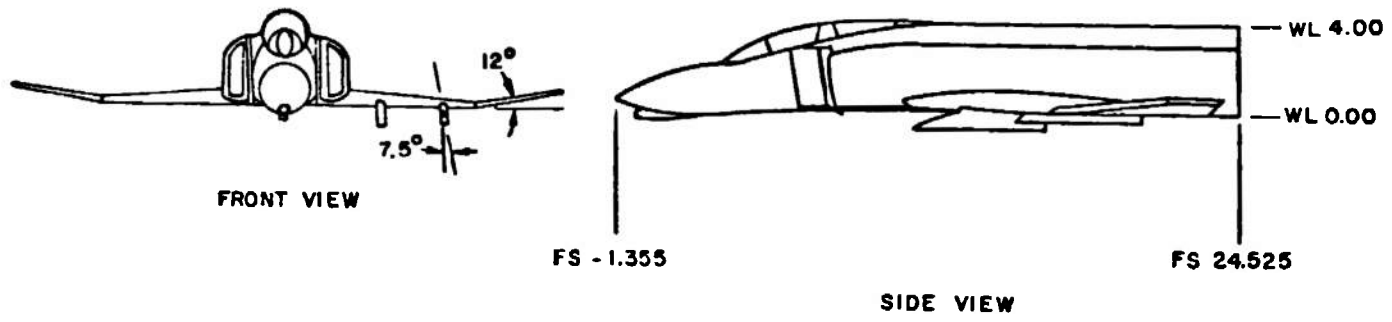
Fig. 3 Sketch of the F-4C Parent-Aircraft Model
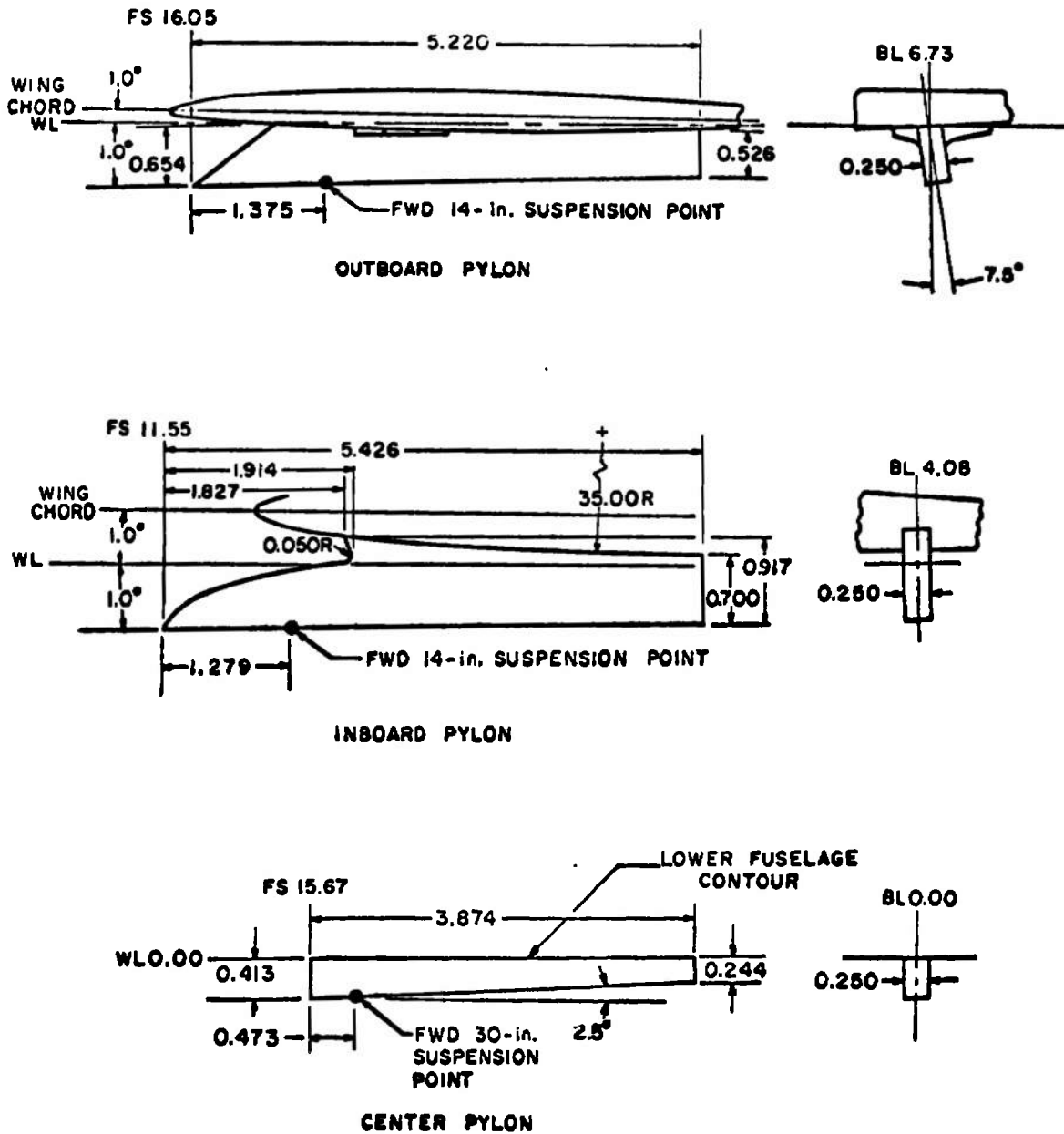
Fig. 4 Details and Dimensions of the F-4C Pylon Models

3.335

2.550

0.920

0.800

A

FWD 30-IN. SUSPENSION POINT

FWD 14-IN. SUSPENSION POINTS

1.320

A

ALL DIMENSIONS IN INCHES

0.326

0.725

0.345

0.130

45°
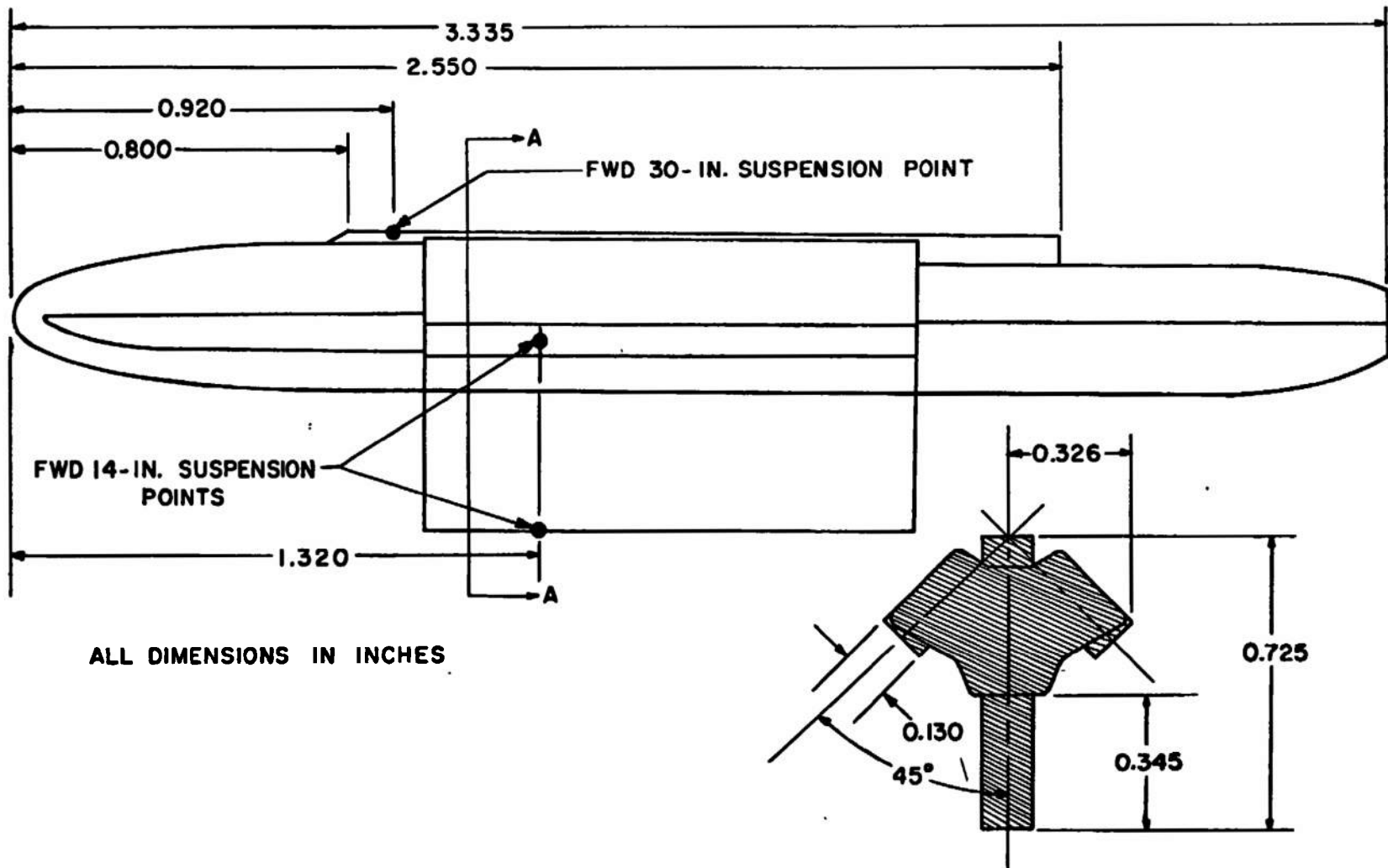
Fig. 5 Details and Dimensions of the TER Model

7.750

6.615

5.735

5.405

3.453

1.915

1.035

B

B

FWD 30-IN.
SUSPENSION POINT

FWD 14-IN.
SUSPENSION POINTS

0.062 R

ALL DIMENSIONS IN INCHES

0.326

0.707

45°

0.345

SECTION B-B
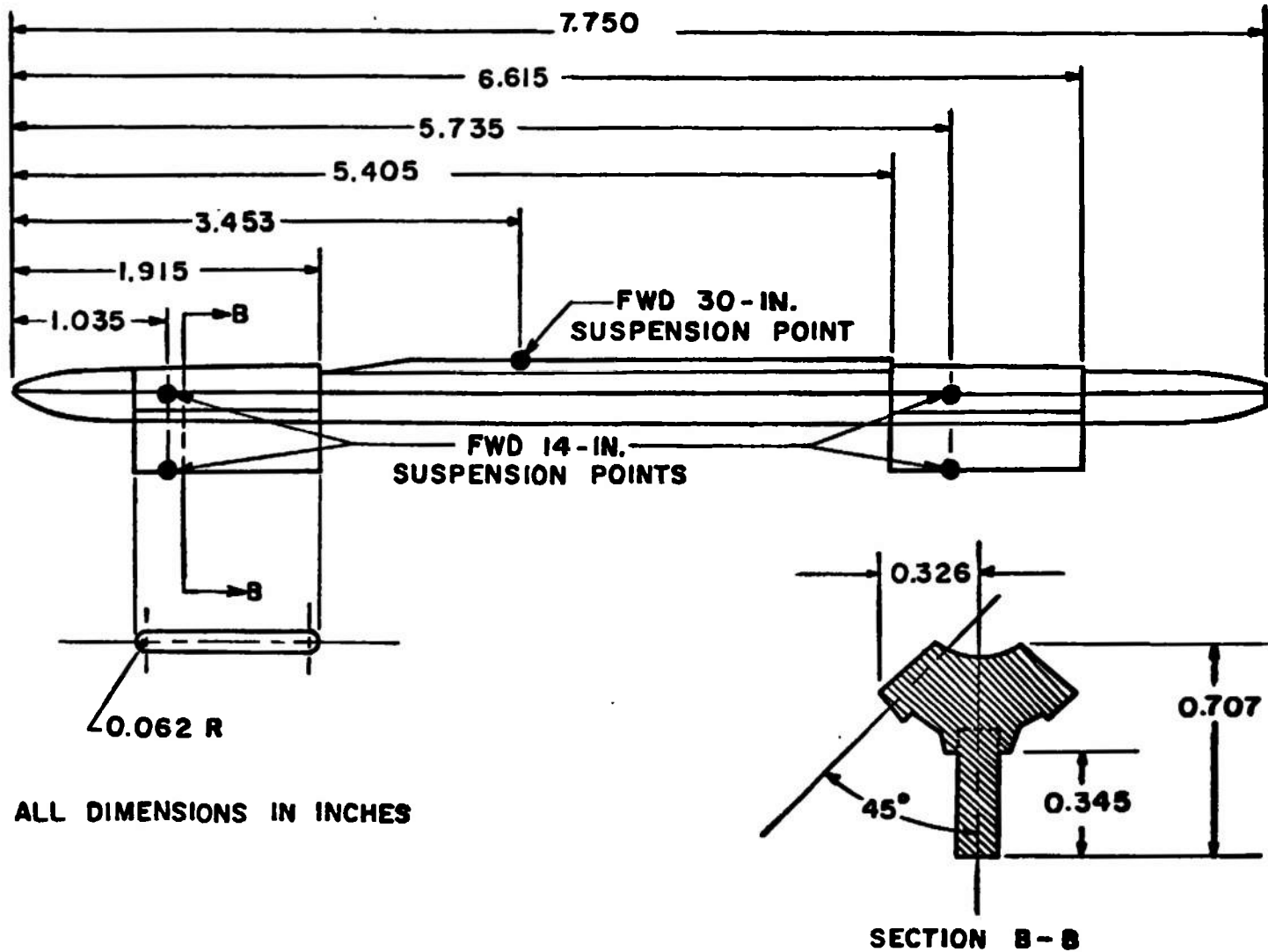
Fig. 6 Details and Dimensions of the MER Model
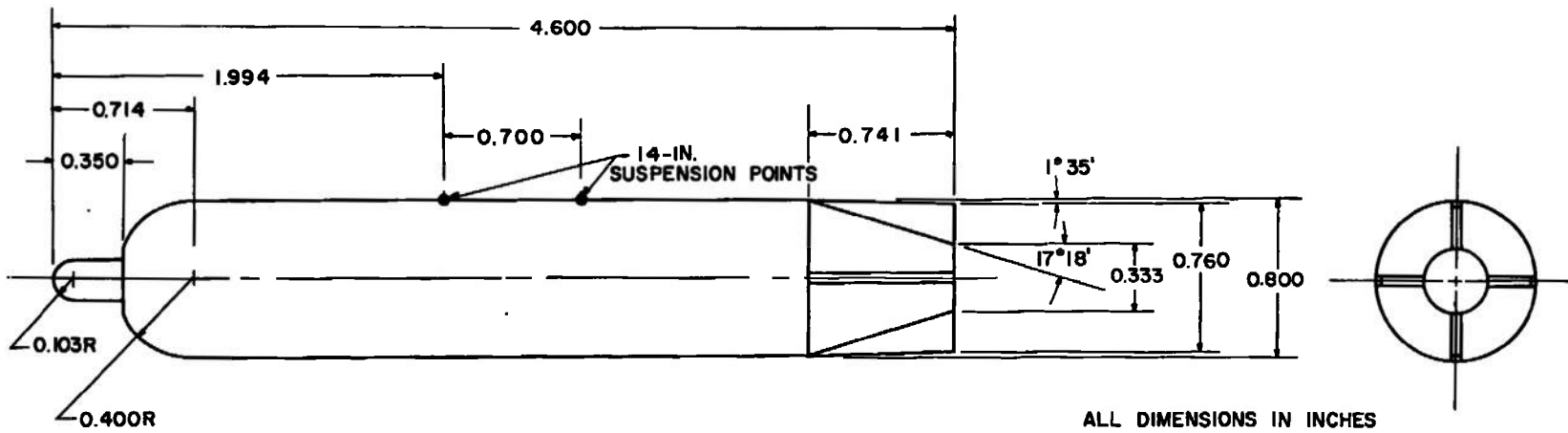
Fig. 7 Details and Dimensions of the Dummy SUU-51/B

ALL DIMENSIONS IN INCHES

FIN DETAIL

LANYARD LOCATION

FINS 4 REQ'D

14 - IN.
SUSPENSION
POINTS

ALL DIMENSIONS IN INCHES

NOTE: 14-IN. SUSPENSION POINTS ARE IN
THE PLANE OF THE VERTICAL FIN.
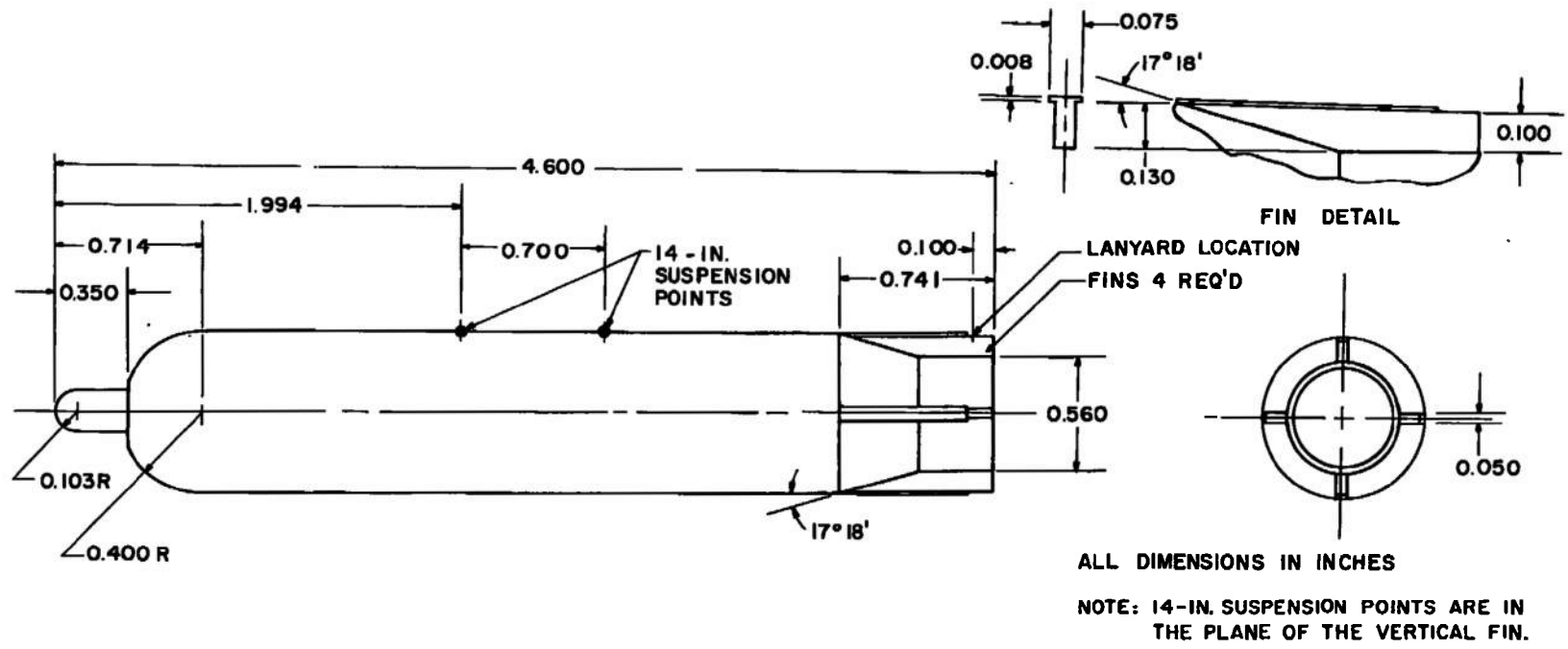
Fig. 8 Details and Dimensions of the Sting-Mounted SUU-51/B with Fins Folded

FIN DETAIL

FINS 4 REQ'D

14 - IN.
SUSPENSION POINTS

ALL DIMENSIONS IN INCHES
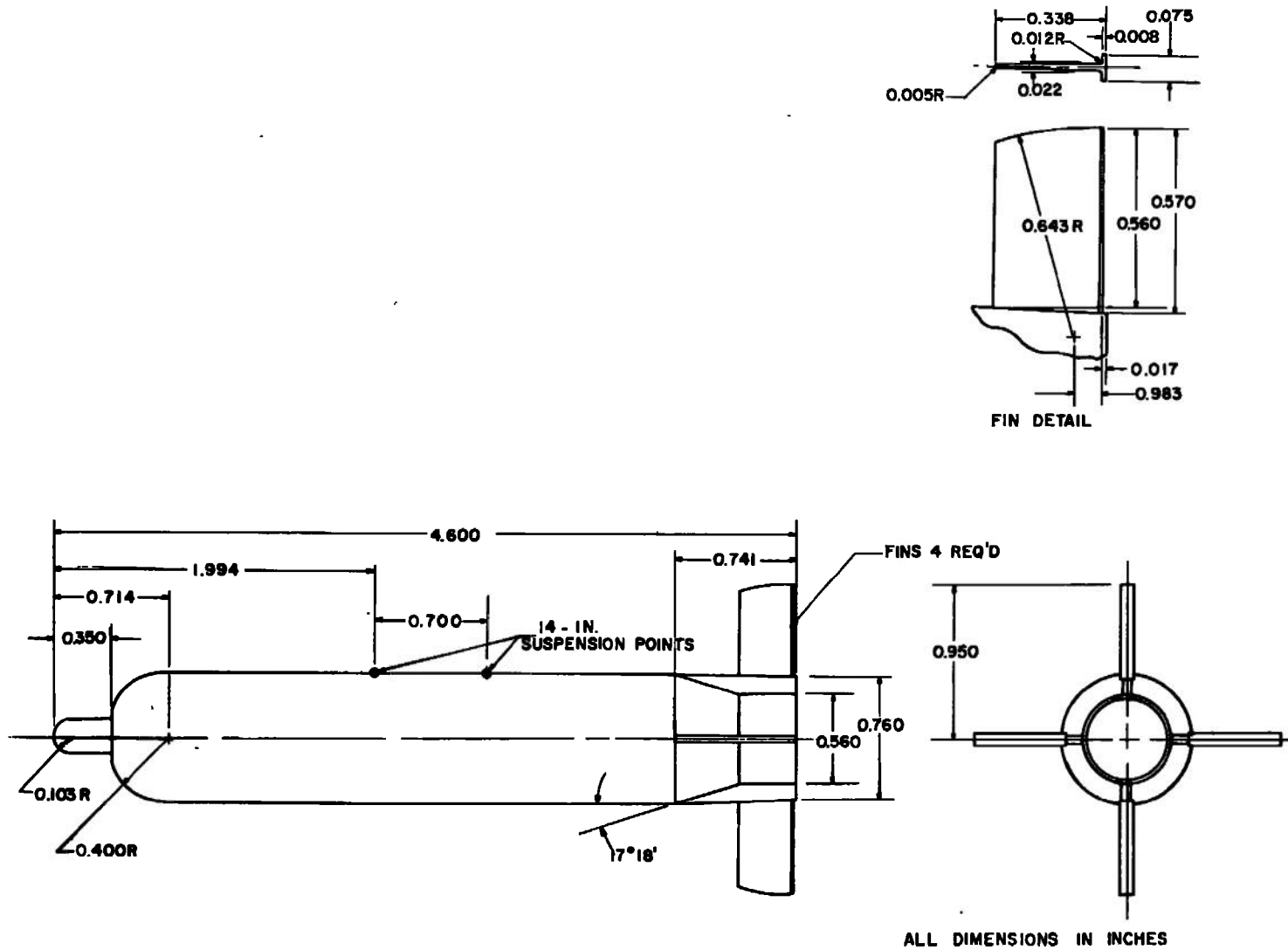
Fig. 9 Details and Dimensions of the Sting-Mounted SUU-51/B with Fins Deployed

FS 10.652

FS 16.050

0.500

WL

ℓ

1.5°

0.480

12.000

BL
6.730

7.5°

1.300

STA
0.0

ALL DIMENSIONS AND MODEL
STATIONS IN INCHES
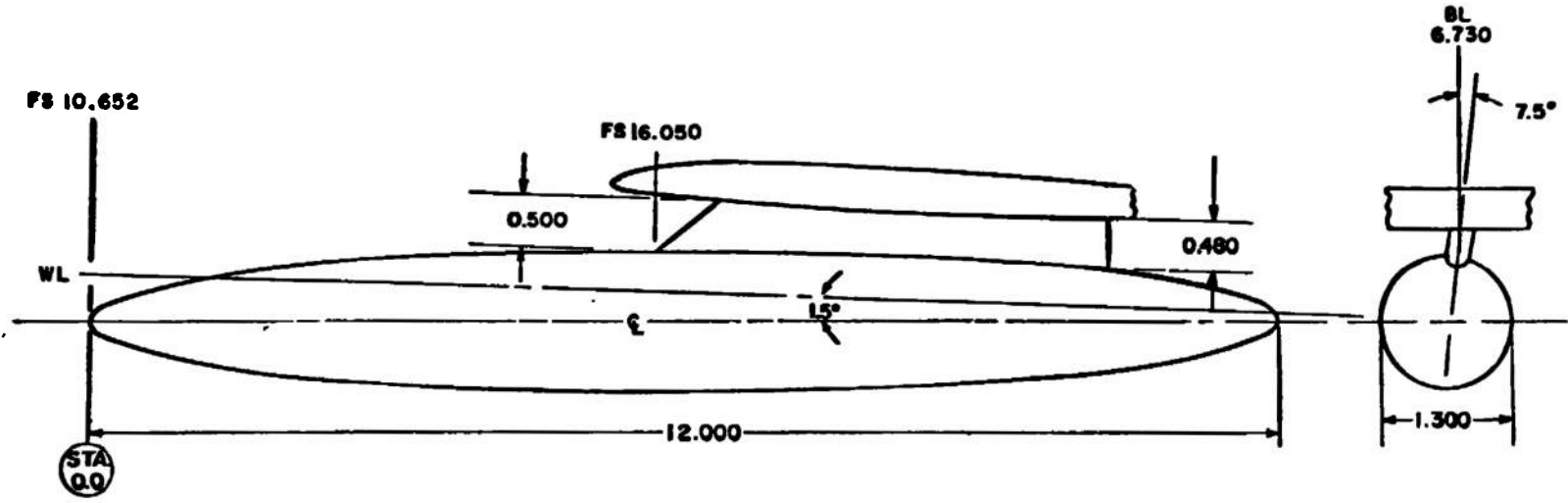
BODY CONTOUR, TYPICAL BOTH ENDS

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. 10 Details and Dimensions of the Dummy 370-gal Fuel Tank

UPSTREAM

UPSTREAM

See Note

TER

MER
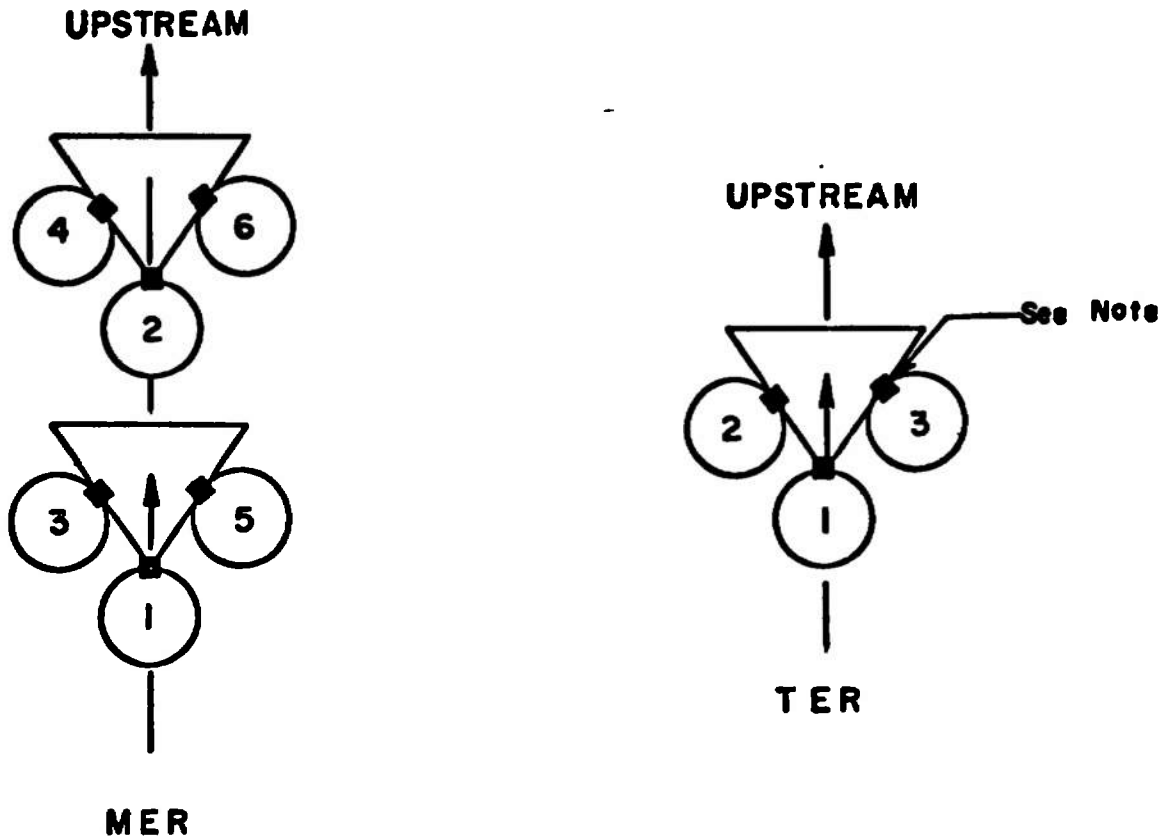
NOTE: The square indicates the orientation of the suspension lugs

TYPE RACK	STATION	ROLL ORIENTATION, deg
MER	1	0
	2	0
	3	45
	4	45
	5	-45
	6	-45
TER	1	0
	2	45
	3	-45

Fig. 11 Schematic of the TER and MER Store Stations and Orientation

CONFIGURATION 1

LEFT WING(TYP)

Ҽ PYLON   INBOARD PYLON (LEFT)

MER STA. 1: EMPTY   TER STA. 1: LAUNCH
MER STA. 2: EMPTY   TER STA. 2: DUMMY
MER STA. 3: DUMMY   TER STA. 3: DUMMY
MER STA. 4: DUMMY
MER STA. 5: DUMMY
MER STA. 6: DUMMY

CONFIGURATION 2

Ҽ PYLON   INBOARD PYLON (LEFT)

MER STA. 1: EMPTY   TER STA. 1: EMPTY
MER STA. 2: EMPTY   TER STA. 2: LAUNCH
MER STA. 3: DUMMY   TER STA. 3: DUMMY
MER STA. 4: DUMMY
MER STA. 5: DUMMY
MER STA. 6: DUMMY

CONFIGURATION 3

Ҽ PYLON   INBOARD PYLON(LEFT)

MER STA. 1: EMPTY   TER STA. 1: EMPTY
MER STA. 2: EMPTY   TER STA. 2: DUMMY
MER STA. 3: DUMMY   TER STA. 3: LAUNCH
MER STA. 4: DUMMY
MER STA. 5: DUMMY
MER STA. 6: DUMMY

CONFIGURATION 4

Ҽ PYLON   INBOARD PYLON (LEFT)

MER STA. 1: EMPTY   TER STA. 1: EMPTY
MER STA. 2: EMPTY   TER STA. 2: EMPTY
MER STA. 3: DUMMY   TER STA. 3: LAUNCH
MER STA. 4: DUMMY
MER STA. 5: DUMMY
MER STA. 6: DUMMY

CONFIGURATION 5

Ҽ PYLON   INBOARD PYLON(LEFT)

MER STA. 1: EMPTY   TER STA. 1: EMPTY
MER STA. 2: EMPTY   TER STA. 2: LAUNCH
MER STA. 3: DUMMY   TER STA. 3: EMPTY
MER STA. 4: DUMMY
MER STA. 5: DUMMY
MER STA. 6: DUMMY

CONFIGURATION 6

Ҽ PYLON   INBOARD PYLON (LEFT)

MER STA. 1: LAUNCH   TER
MER STA. 2: EMPTY
MER STA. 3: DUMMY
MER STA. 4: DUMMY
MER STA. 5: DUMMY
MER STA. 6: DUMMY

CONFIGURATION 7

Ҽ PYLON   INBOARD PYLON (LEFT)

MER STA. 1: EMPTY   TER
MER STA. 2: EMPTY
MER STA. 3: LAUNCH
MER STA. 4: DUMMY
MER STA. 5: DUMMY
MER STA. 6: DUMMY

CONFIGURATION 8

Ҽ PYLON   INBOARD PYLON (LEFT)

MER STA. 1: EMPTY   TER
MER STA. 2: EMPTY
MER STA. 3: EMPTY
MER STA. 4: LAUNCH
MER STA. 5: DUMMY
MER STA. 6: DUMMY

CONFIGURATION 9

Ҽ PYLON   INBOARD PYLON (LEFT)

MER STA. 1: EMPTY   TER
MER STA. 2: EMPTY
MER STA. 3: LAUNCH
MER STA. 4: DUMMY
MER STA. 5: EMPTY
MER STA. 6: EMPTY

NOTE: EMPTY TER ON RIGHT INBOARD PYLON
AND 370 GALLON FUEL TANKS ON OUTBOARD
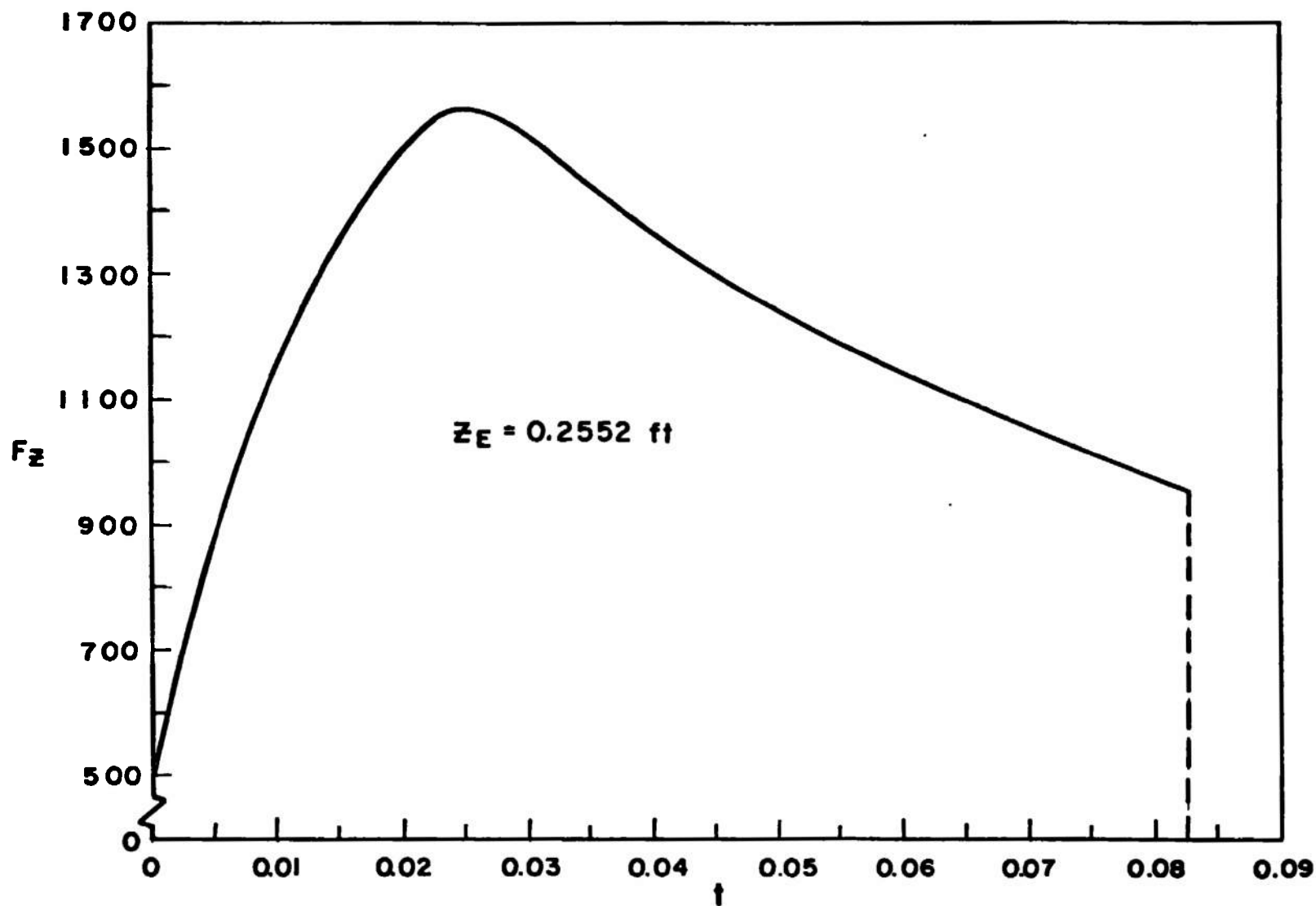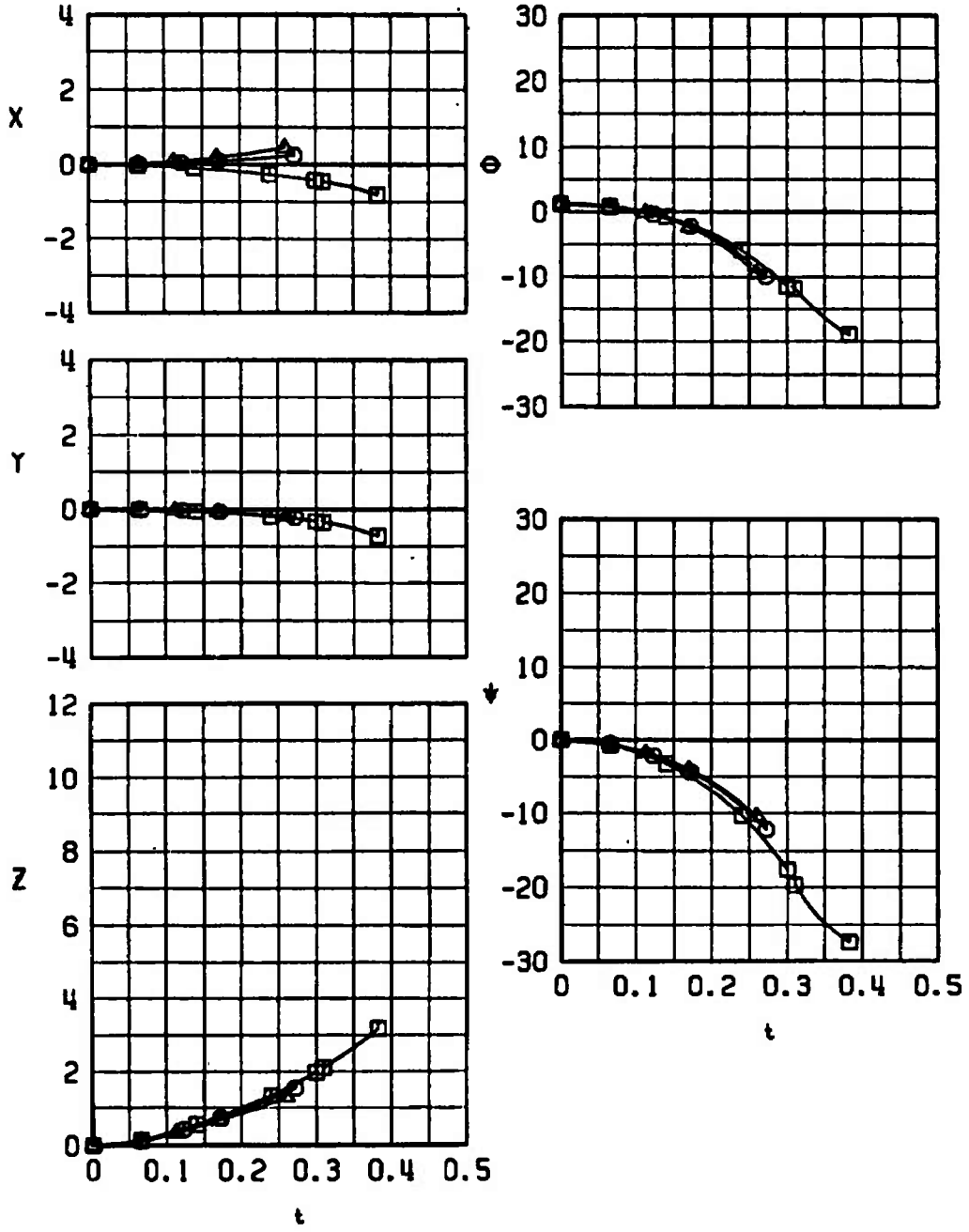PYLONS FOR ALL CONFIGURATIONS TESTED

Fig. 12 F-4C Load Configurations

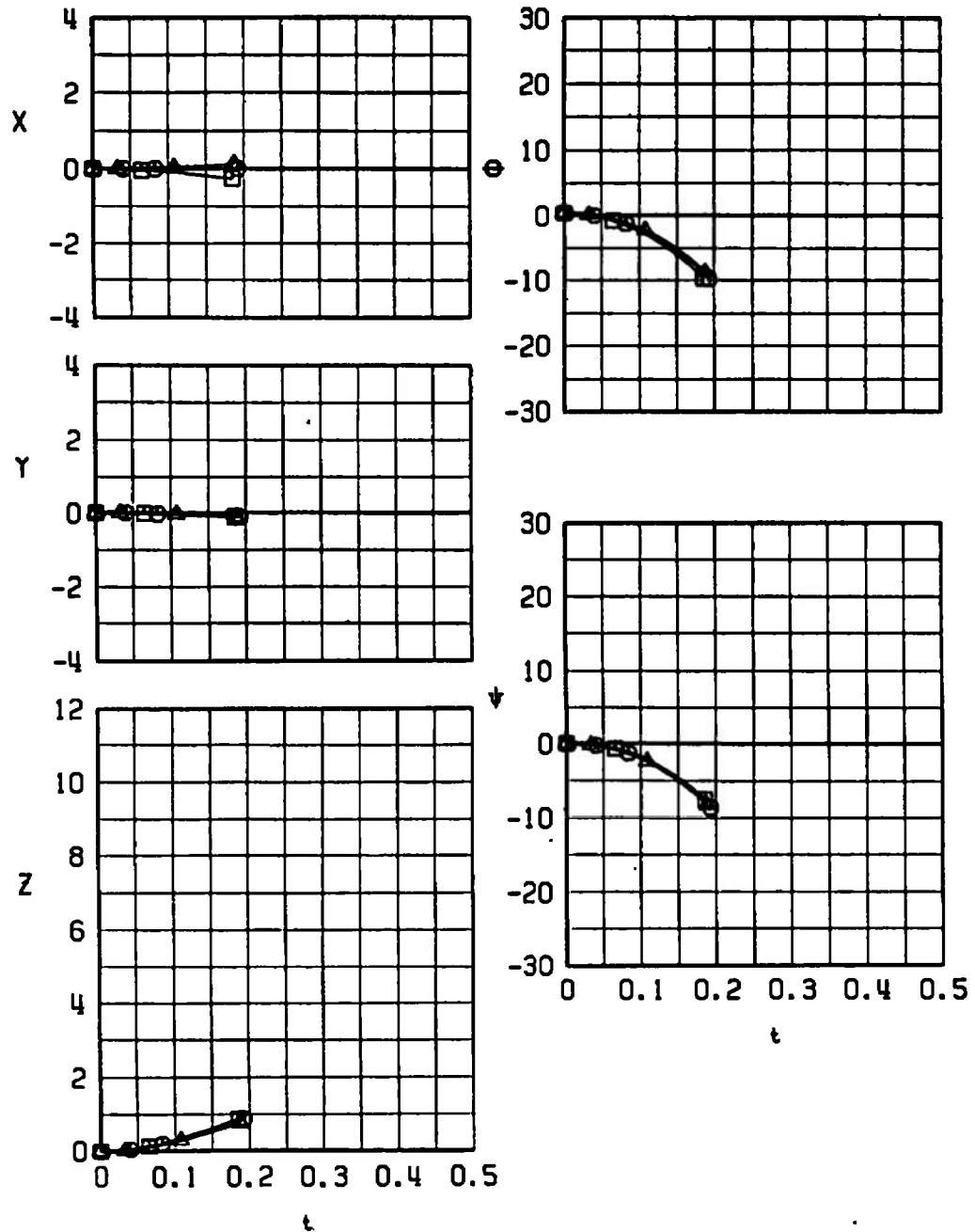Fig. 13 TER and MER Ejector Force Function

SYM	CONF	M_∞	α	$\bar{\theta}$
▣	1	0.66	2.2	0
◑	1	0.66	2.2	-30
△	1	0.66	2.2	-45

a. $M_\infty = 0.66$

Fig. 14 Separation Trajectory Data for Configuration 1

SYM	CONF	M_∞	α	$\bar{\theta}$
⊡	1	0.74	1.4	0
☉	1	0.74	1.4	-30
△	1	0.74	1.4	-45

b. $M_\infty = 0.74$
Fig. 14 Continued

SYM	CONF	M_∞	α	$\bar{\theta}$
⊡	1	0.82	0.8	0
⊙	1	0.82	0.8	-30
△	1	0.82	0.8	-45
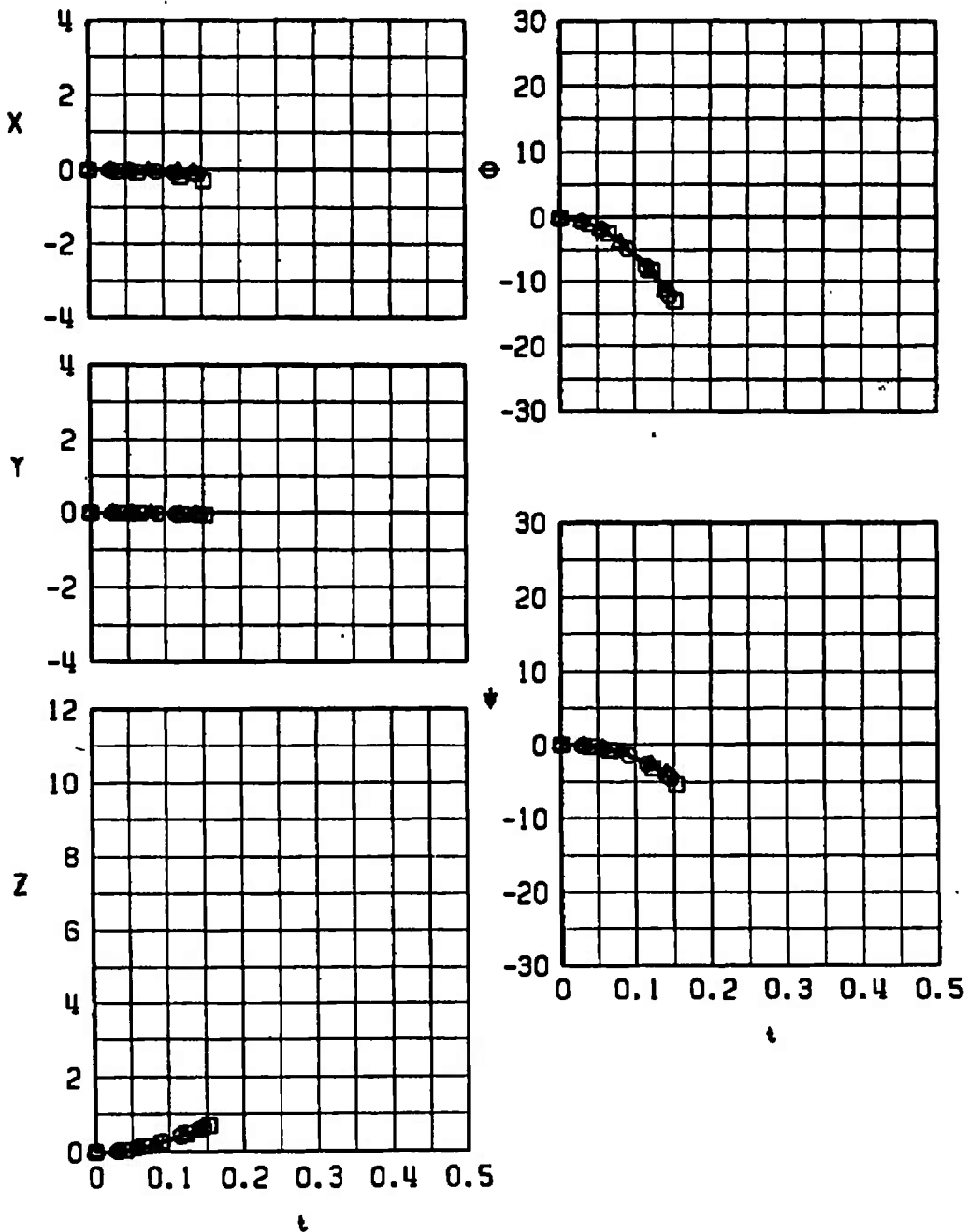
c.　$M_\infty = 0.80$
Fig. 14　Continued

SYM	CONF	M_∞	α	$\bar\theta$
▣	1	0.90	0.5	0
◉	1	0.90	0.5	-30
△	1	0.90	0.5	-45
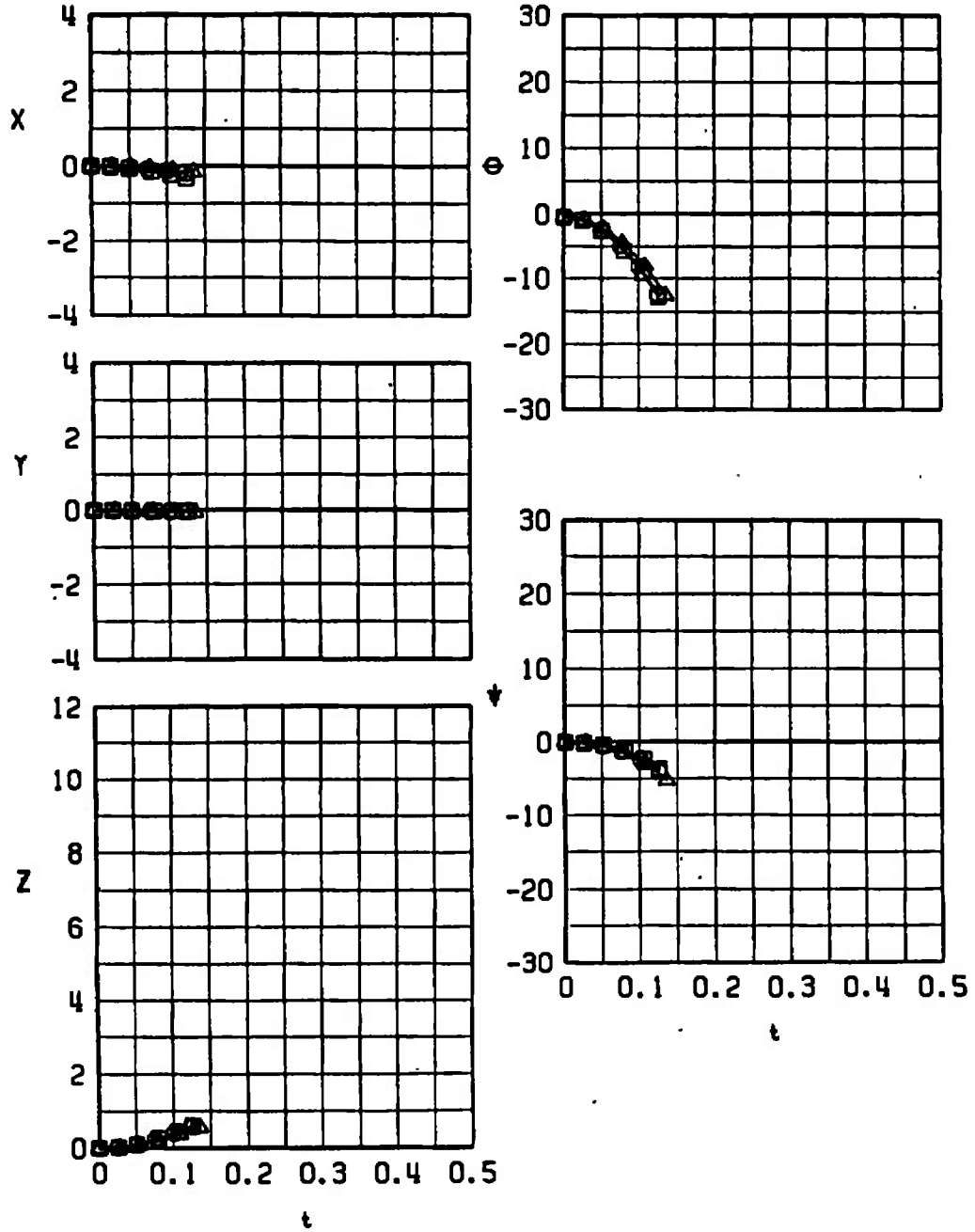
d. $M_\infty = 0.90$
Fig. 14 Concluded

25

SYM	CONF	M_∞	α	$\bar\theta$
⊡	2	0.66	2.2	0
⊙	2	0.66	2.2	-30
△	2	0.66	2.2	-45
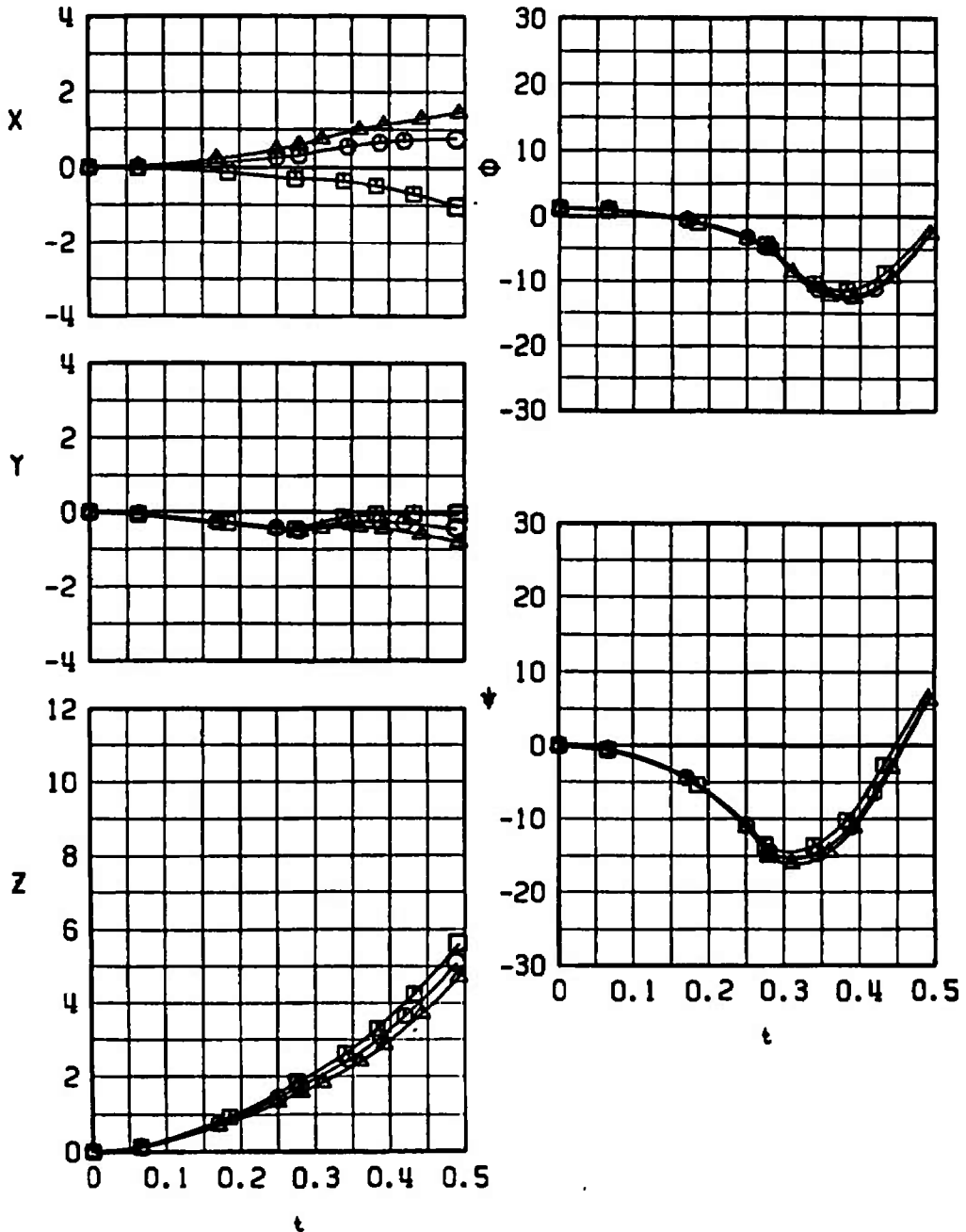
a. $M_\infty = 0.66$

Fig. 15 Separation Trajectory Data for Configuration 2

SYM	CONF	M_∞	α	$\bar{\theta}$
⬚	2	0.74	1.4	0
⊙	2	0.74	1.4	-30
△	2	0.74	1.4	-45
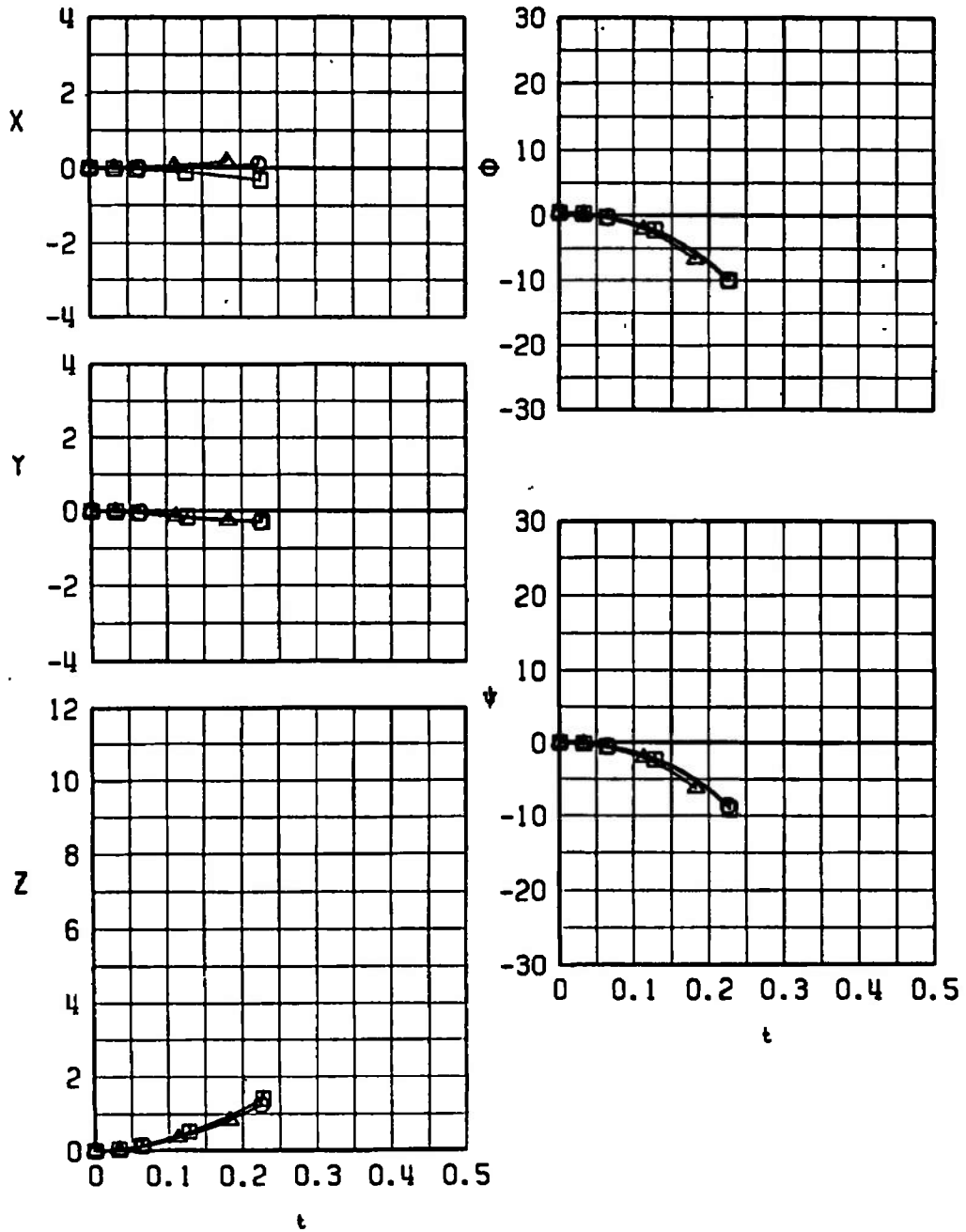
b. $M_\infty = 0.74$
Fig. 15 Continued

27

SYM	CONF	M_∞	α	$\bar{\theta}$
⊡	2	0.82	0.8	0
⊙	2	0.82	0.8	-30
△	2	0.82	0.8	-45
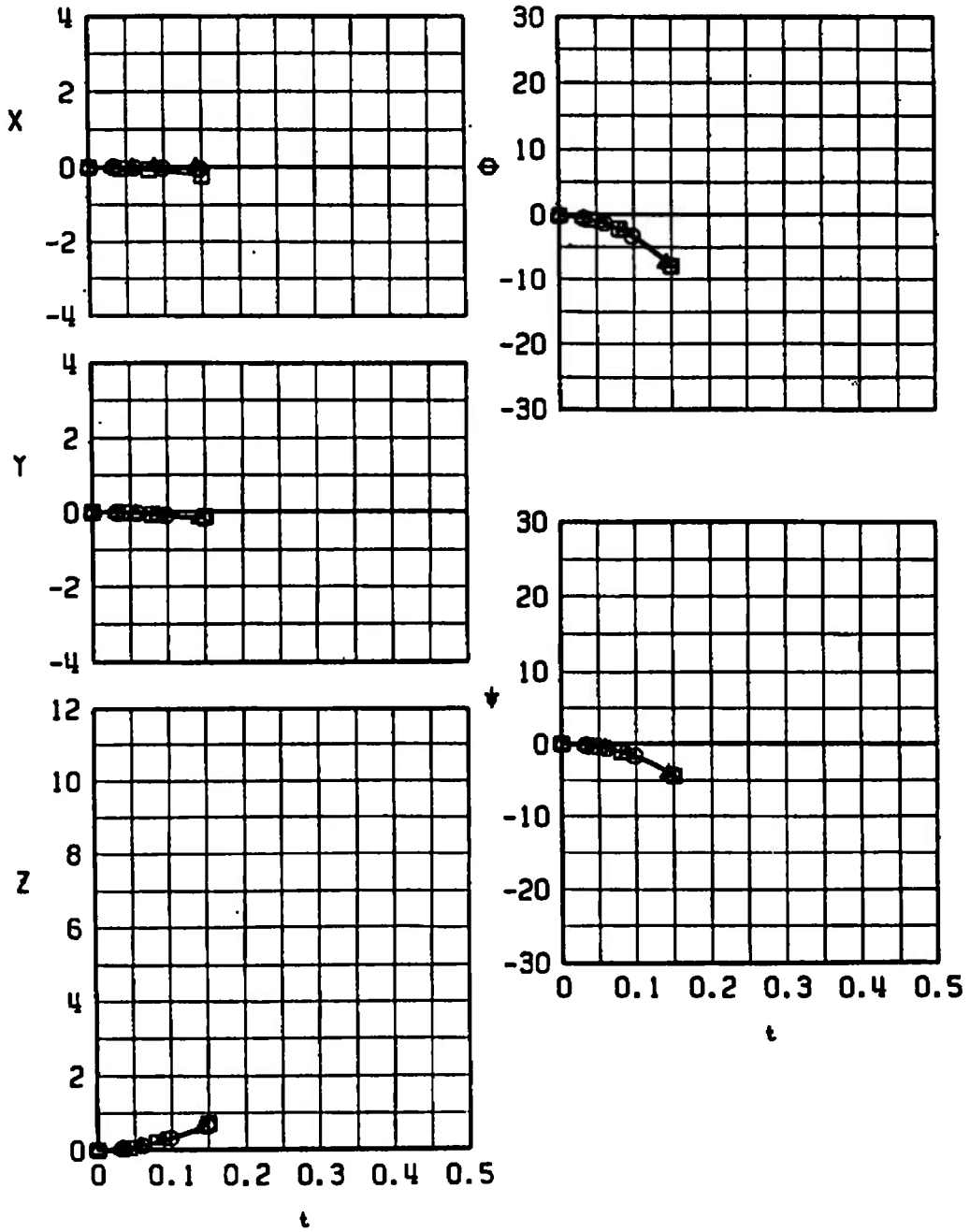
c. $M_\infty = 0.82$
Fig. 15 Continued

SYM	CONF	M_∞	α	$\bar{\theta}$
⊡	2	0.90	0.5	0
⊙	2	0.90	0.5	-30
△	2	0.90	0.5	-45
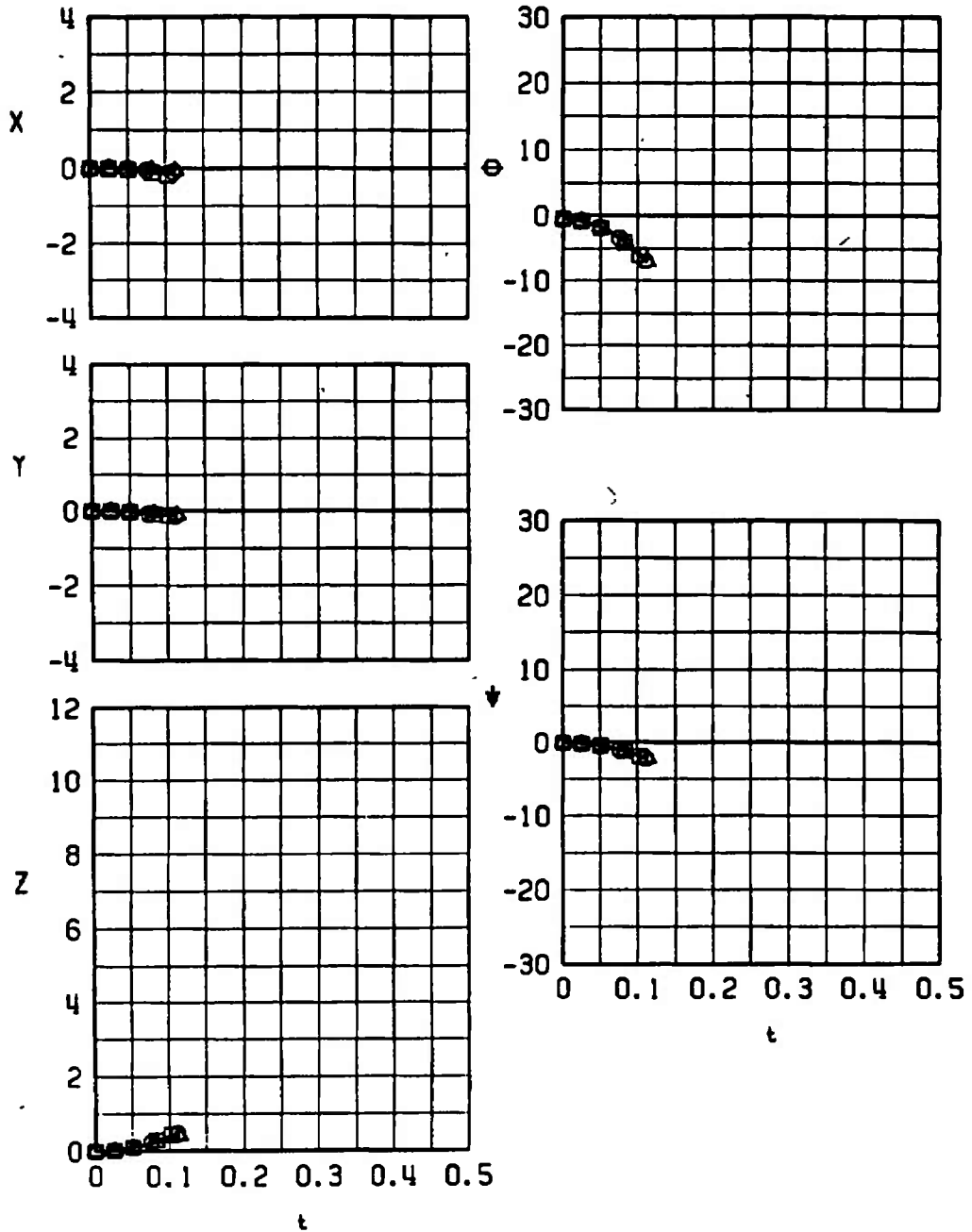
d. $M_\infty = 0.90$
Fig. 15 Concluded
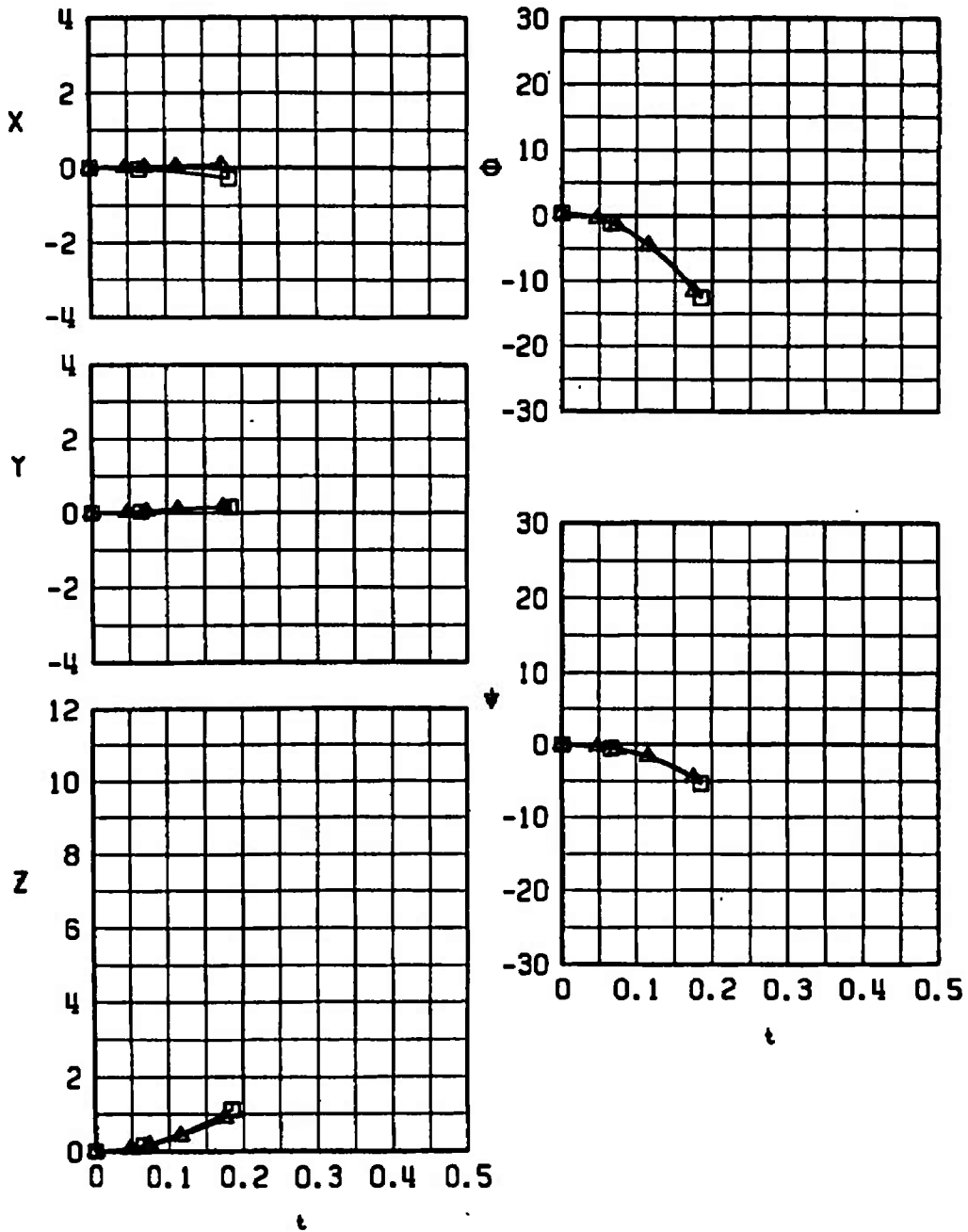
a. $M_\infty = 0.74$

Fig. 16 Separation Trajectory Data for Configuration 3

SYM	CONF	M_∞	α	$\bar{\theta}$
⊡	3	0.82	0.8	0
△	3	0.82	0.8	-45
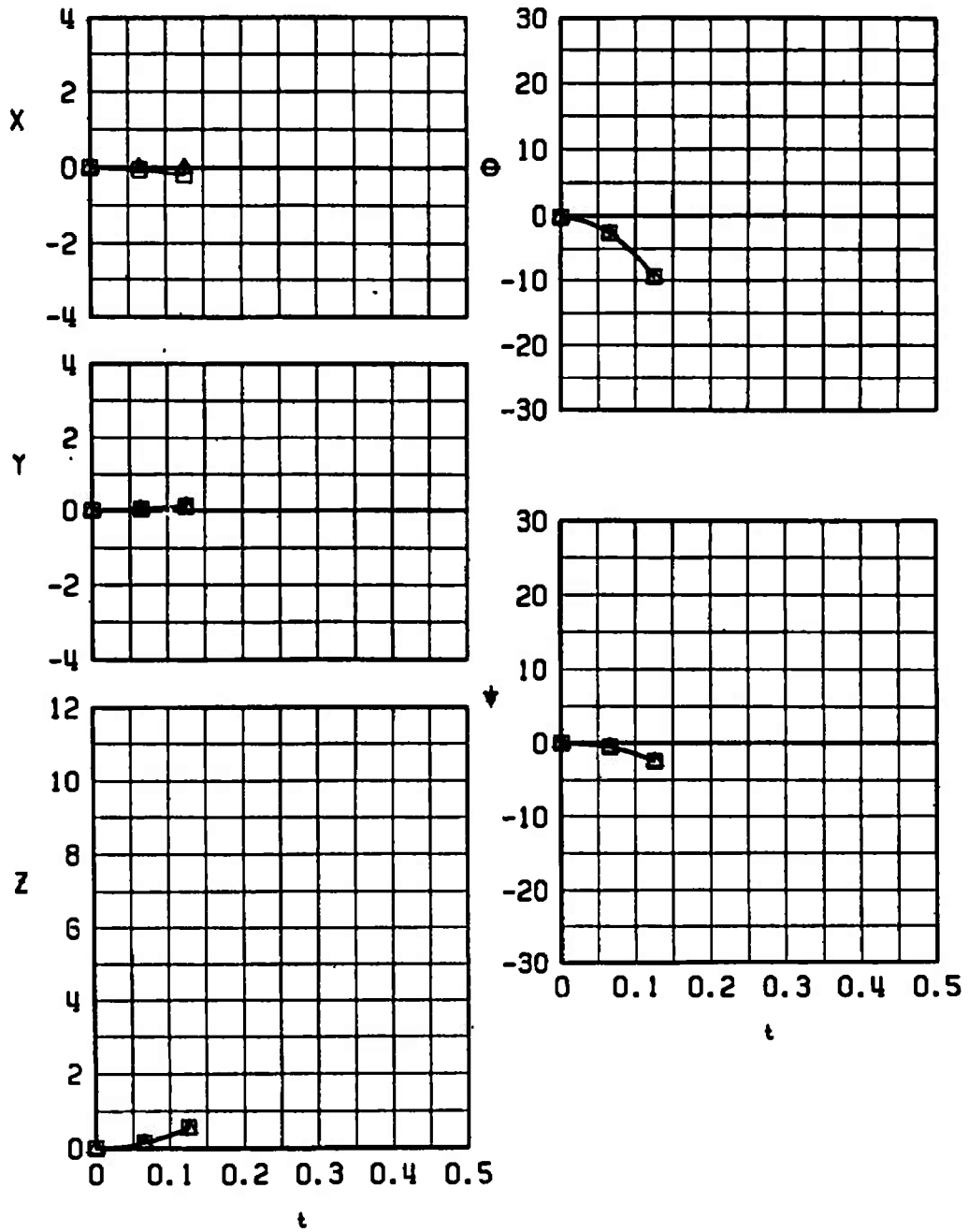
b. $M_\infty = 0.82$
Fig. 16 Continued

31

SYM	CONF	M_∞	α	$\bar{\theta}$
⊡	3	0.90	0.5	0
△	3	0.90	0.5	-45
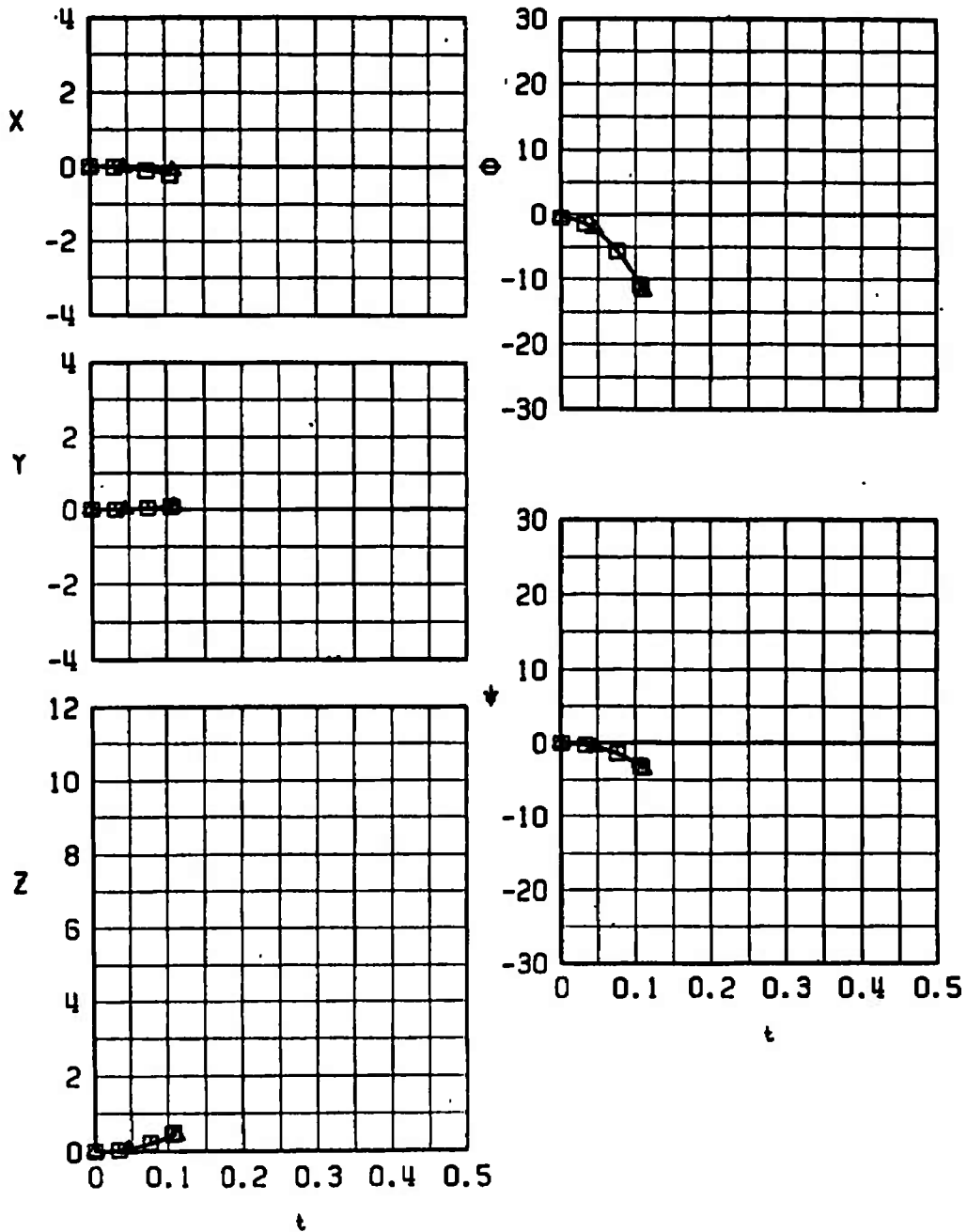
c. $M_\infty = 0.90$
Fig. 16 Concluded

SYM	CONF	M_∞	α	$\bar{\theta}$
▣	4	0.66	2.2	0
⊙	4	0.66	2.2	-30
△	4	0.66	2.2	-45
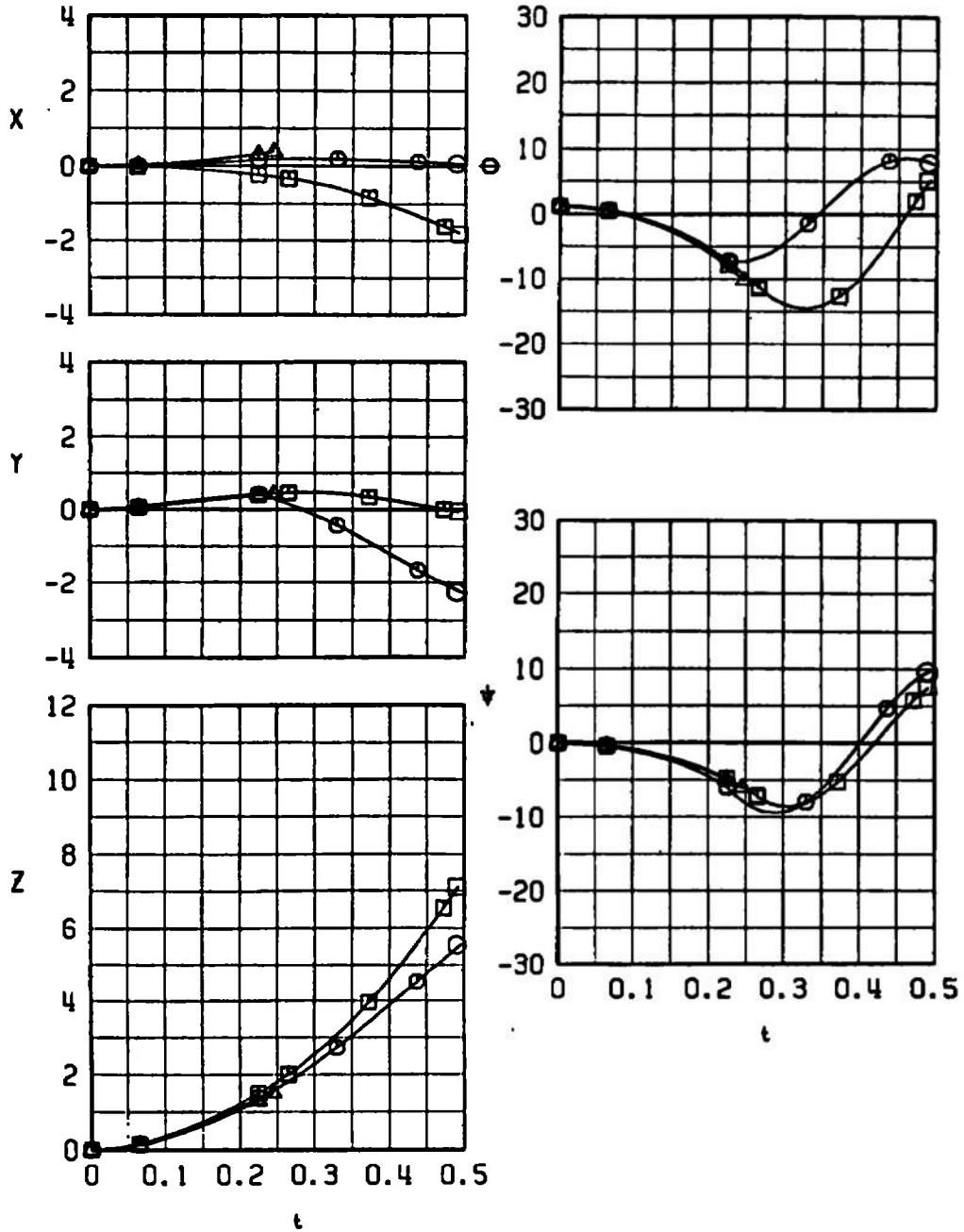
Fig. 17 Separation Trajectory Data for Configuration 4

SYM	CONF	M_∞	$\propto$	$\bar{\theta}$
▢	5	0.66	2.2	0
☉	5	0.66	2.2	-30
△	5	0.66	2.2	-45
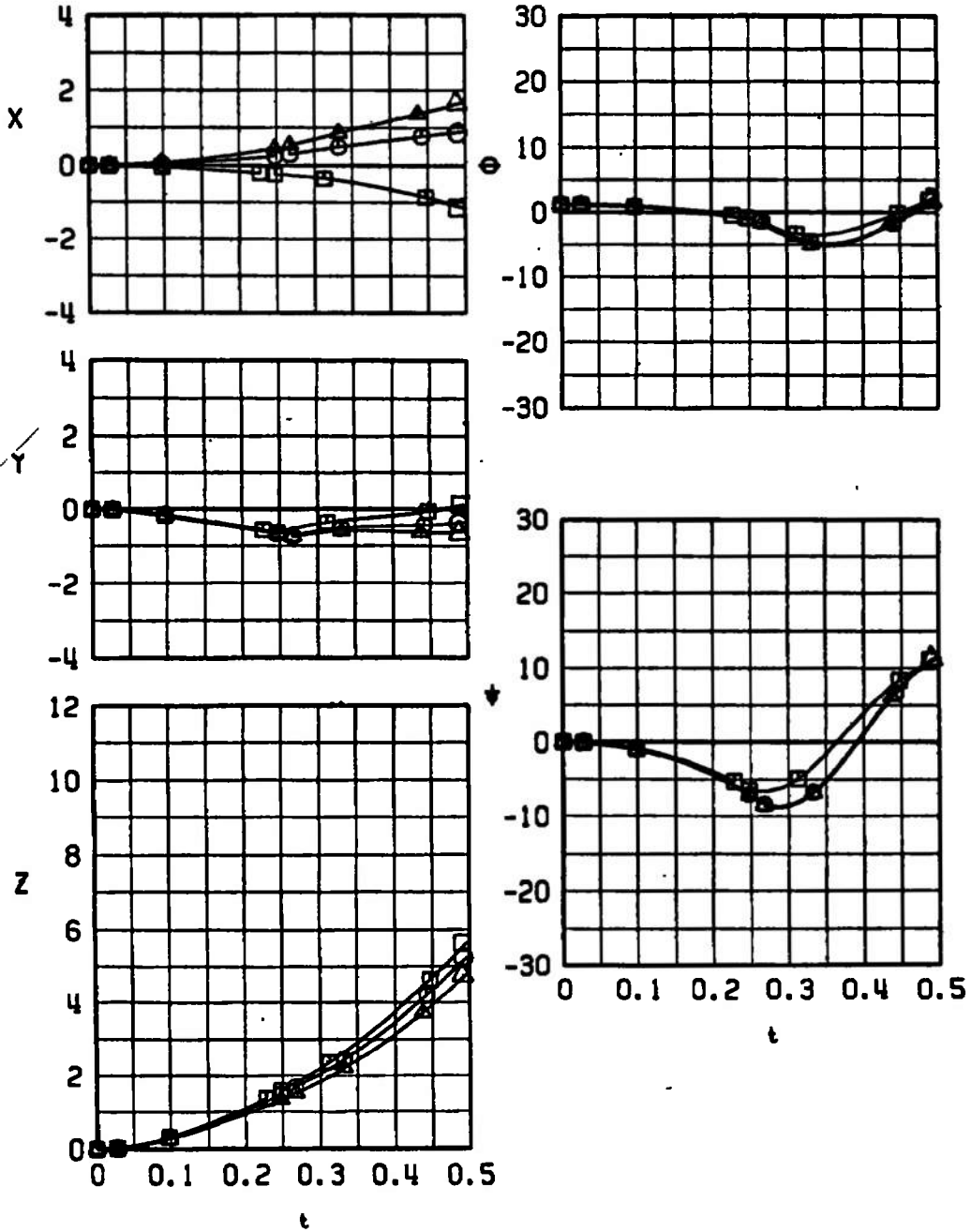
a. M_∞ = 0.66

Fig. 18 Separation Trajectory Data for Configuration 5

SYM	CONF	M_∞	α	$\bar{\theta}$
⊡	5	0.74	1.4	0
⊙	5	0.74	1.4	-30
△	5	0.74	1.4	-45
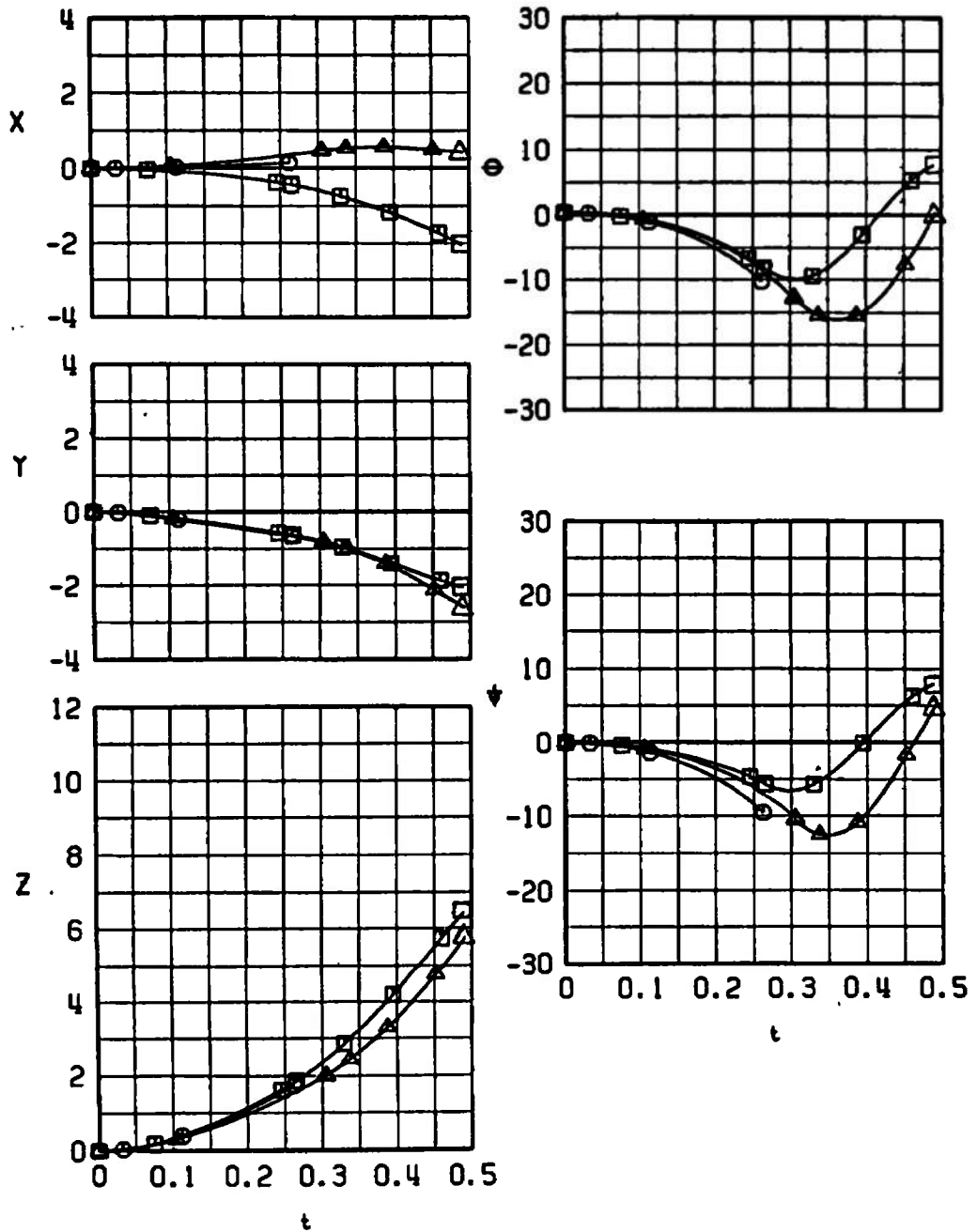
b. $M_\infty = 0.74$

Fig. 18 Continued

SYM	CONF	M∞	α	$\bar{\theta}$
□	5	0.82	0.8	0
◉	5	0.82	0.8	-30
△	5	0.82	0.8	-45
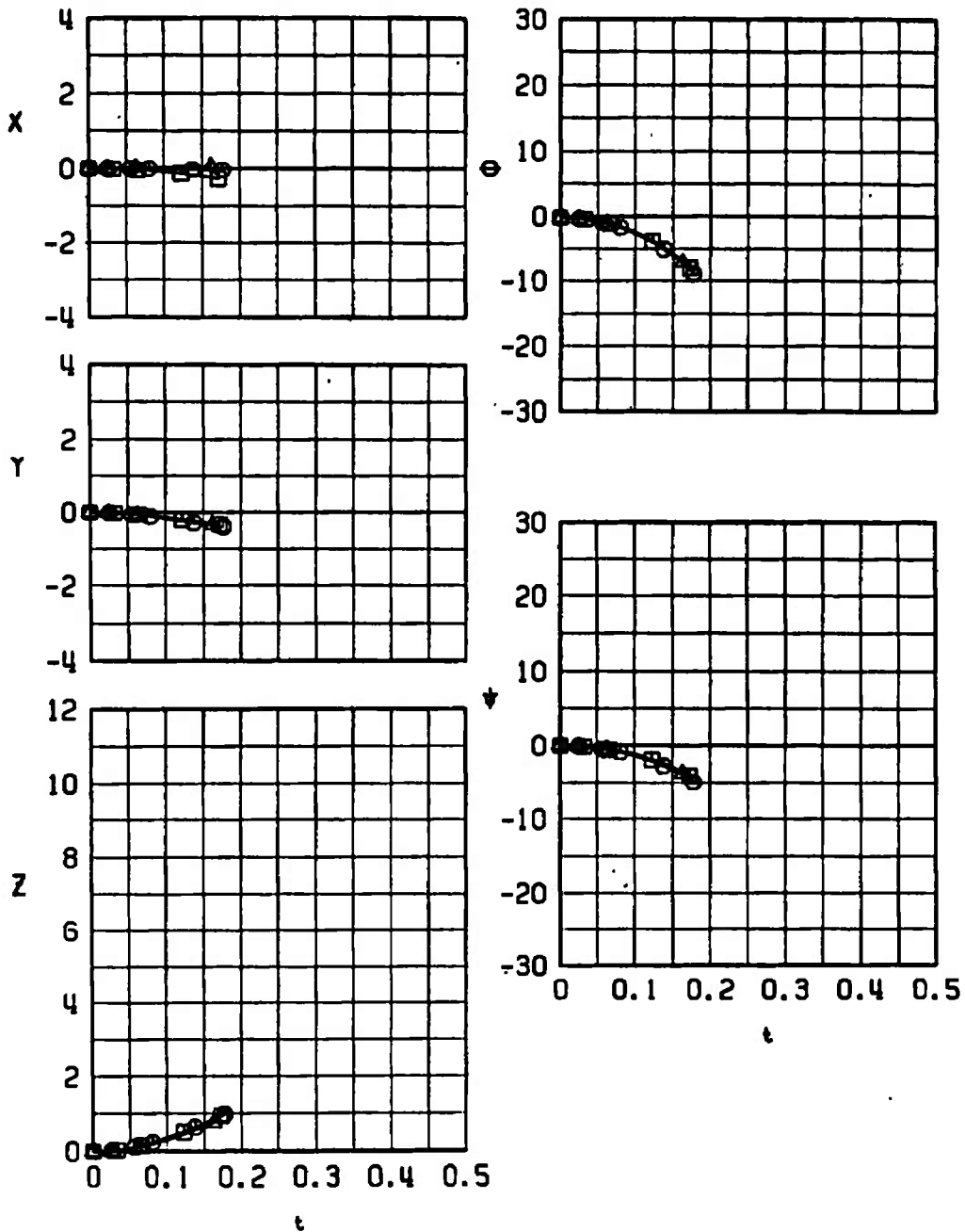
c. $M_\infty = 0.82$
Fig. 18 Continued

SYM	CONF	M_∞	α	$\bar{\theta}$
⊡	5	0.90	0.5	0
⊙	5	0.90	0.5	-30
△	5	0.90	0.5	-45
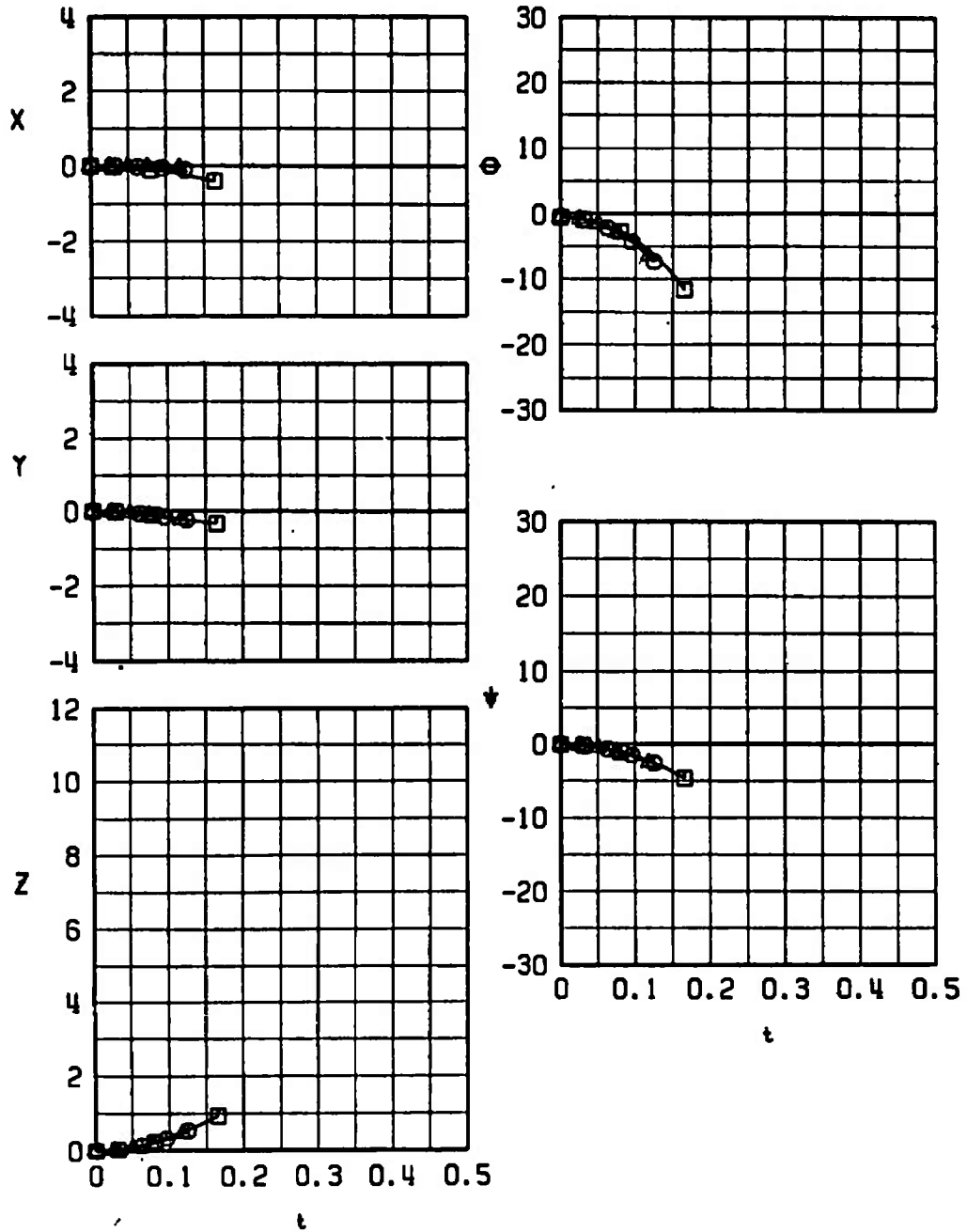
d. $M_\infty = 0.90$
Fig. 18 Concluded

SYM	CONF	M_∞	α	$\bar{\theta}$
▢	6	0.66	2.2	0
◉	6	0.66	2.2	-30
△	6	0.66	2.2	-45
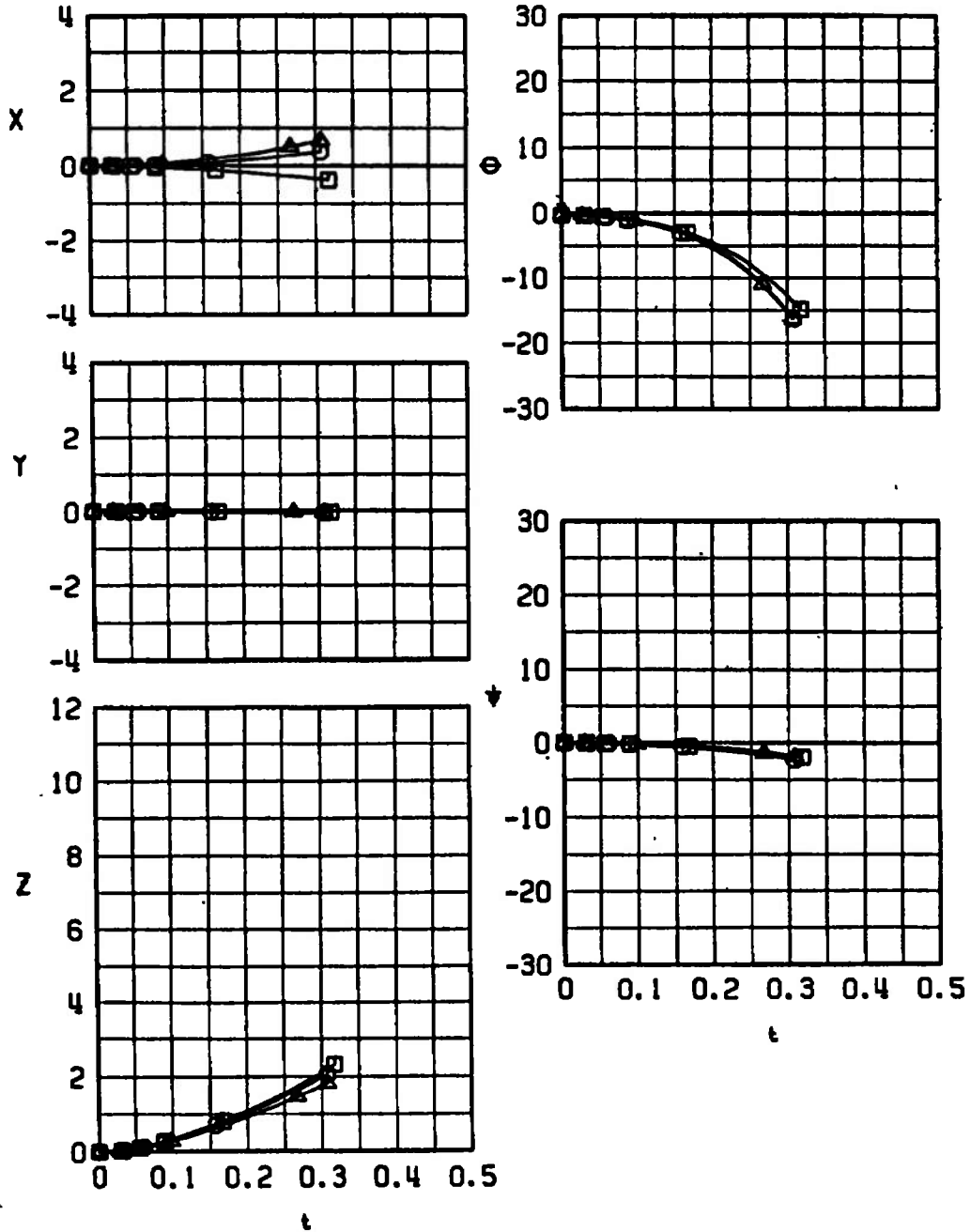
a. $M_\infty = 0.66$

Fig. 19 Separation Trajectory Data for Configuration 6

SYM	CONF	M_∞	α	$\bar\theta$
⊡	6	0.74	1.4	0
⊙	6	0.74	1.4	-30
△	6	0.74	1.4	-45
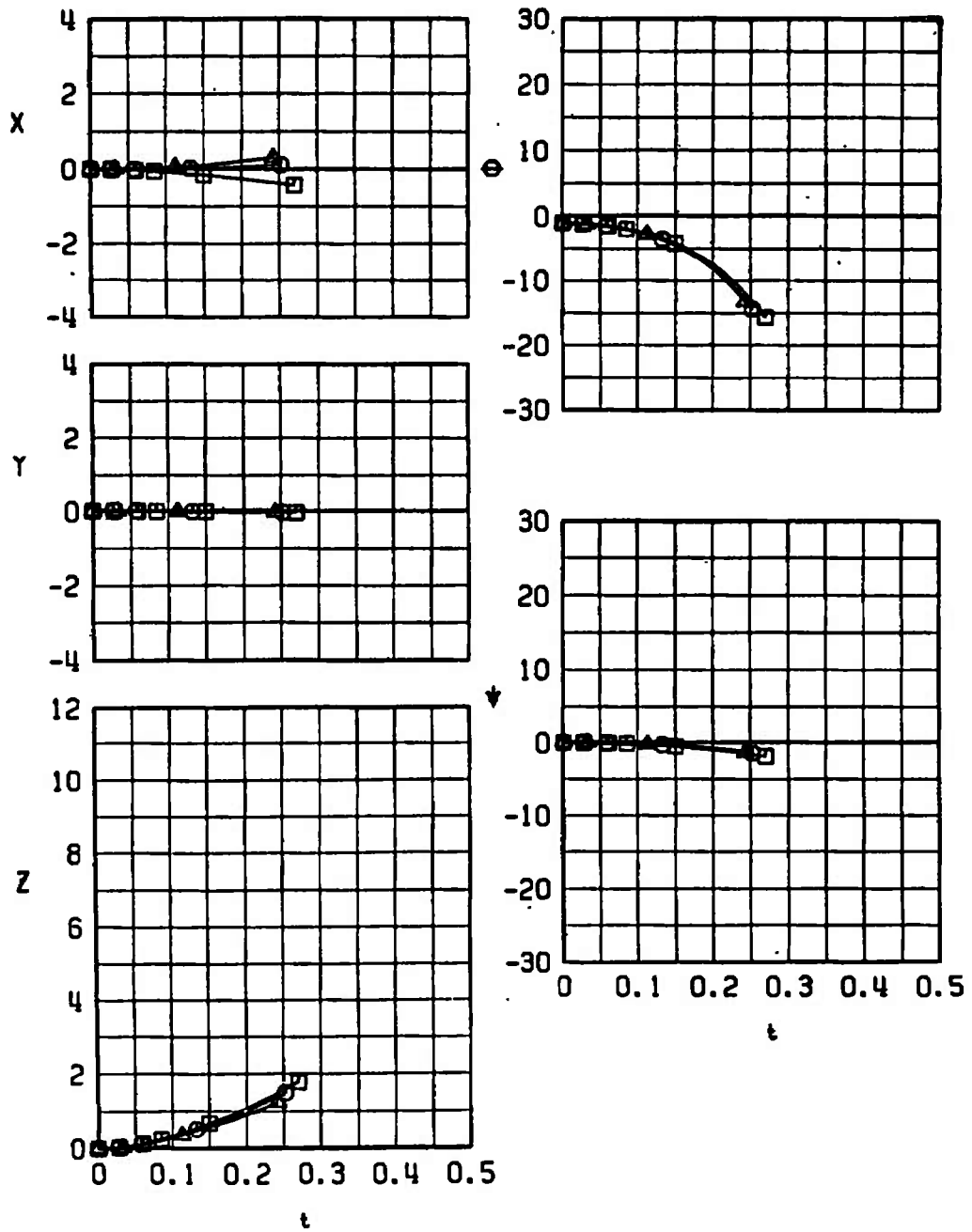
b. $M_\infty = 0.74$

Fig. 19 Continued

SYM	CONF	M_∞	α	$\bar{\theta}$
☐	6	0.82	0.8	0
△	6	0.82	0.8	-45
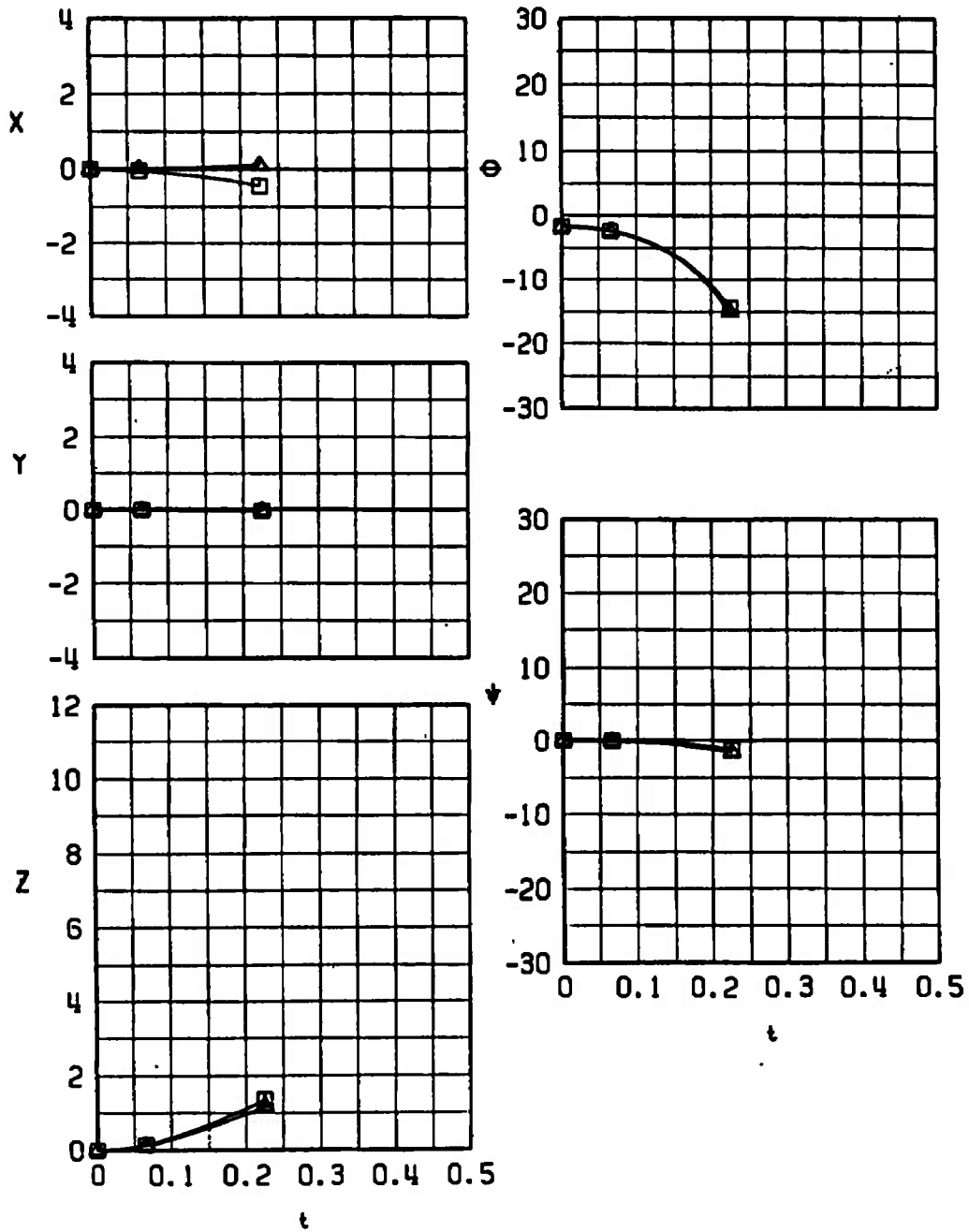
c. $M_\infty = 0.82$
Fig. 19 Continued

SYM	CONF	M_∞	α	$\bar{\theta}$
▣	6	0.90	0.5	0
△	6	0.90	0.5	-45
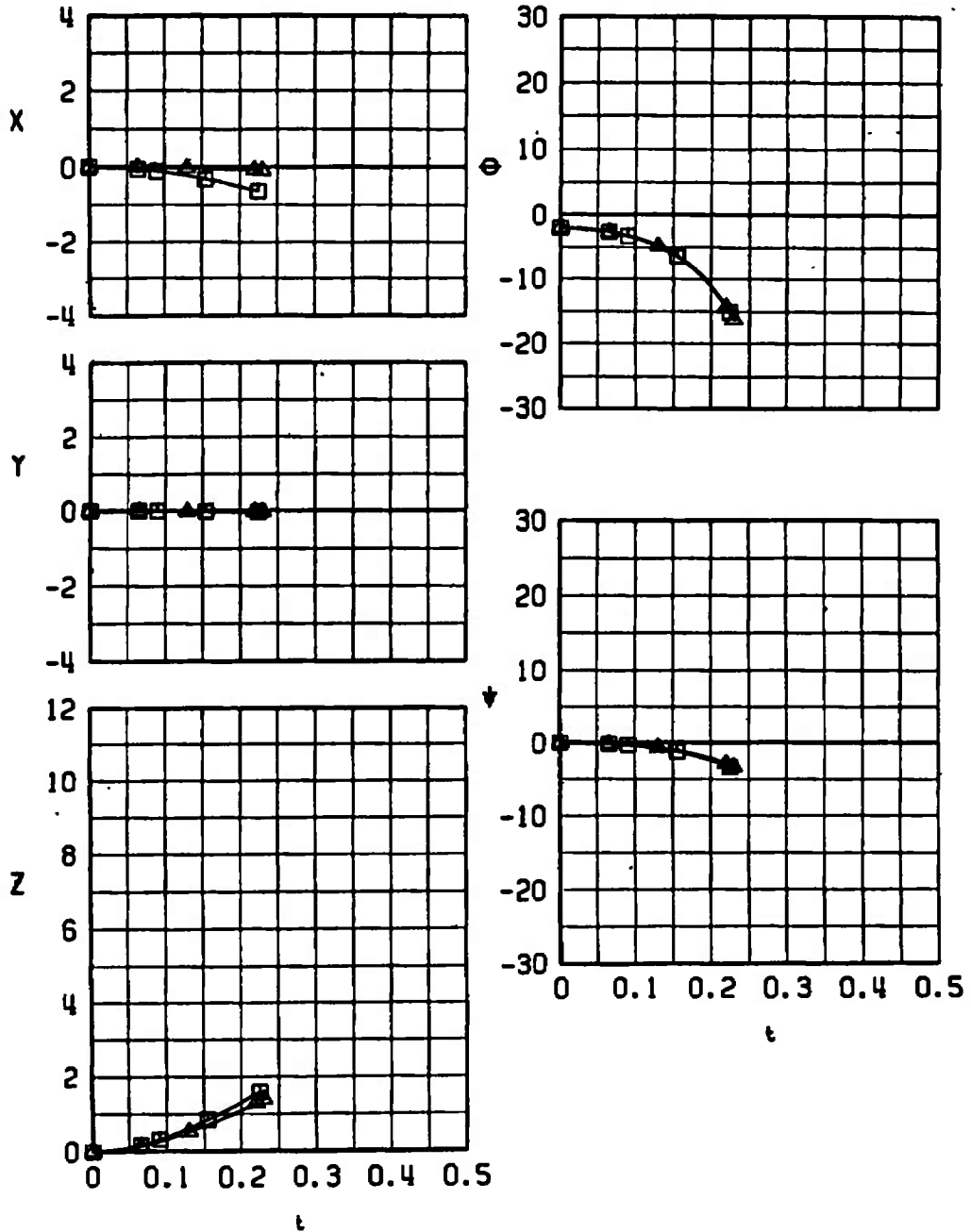
d. $M_\infty = 0.90$
Fig. 19 Concluded

SYM	CONF	M_∞	α	$\bar{\theta}$
▫	7	0.66	2.2	0
△	7	0.66	2.2	-45
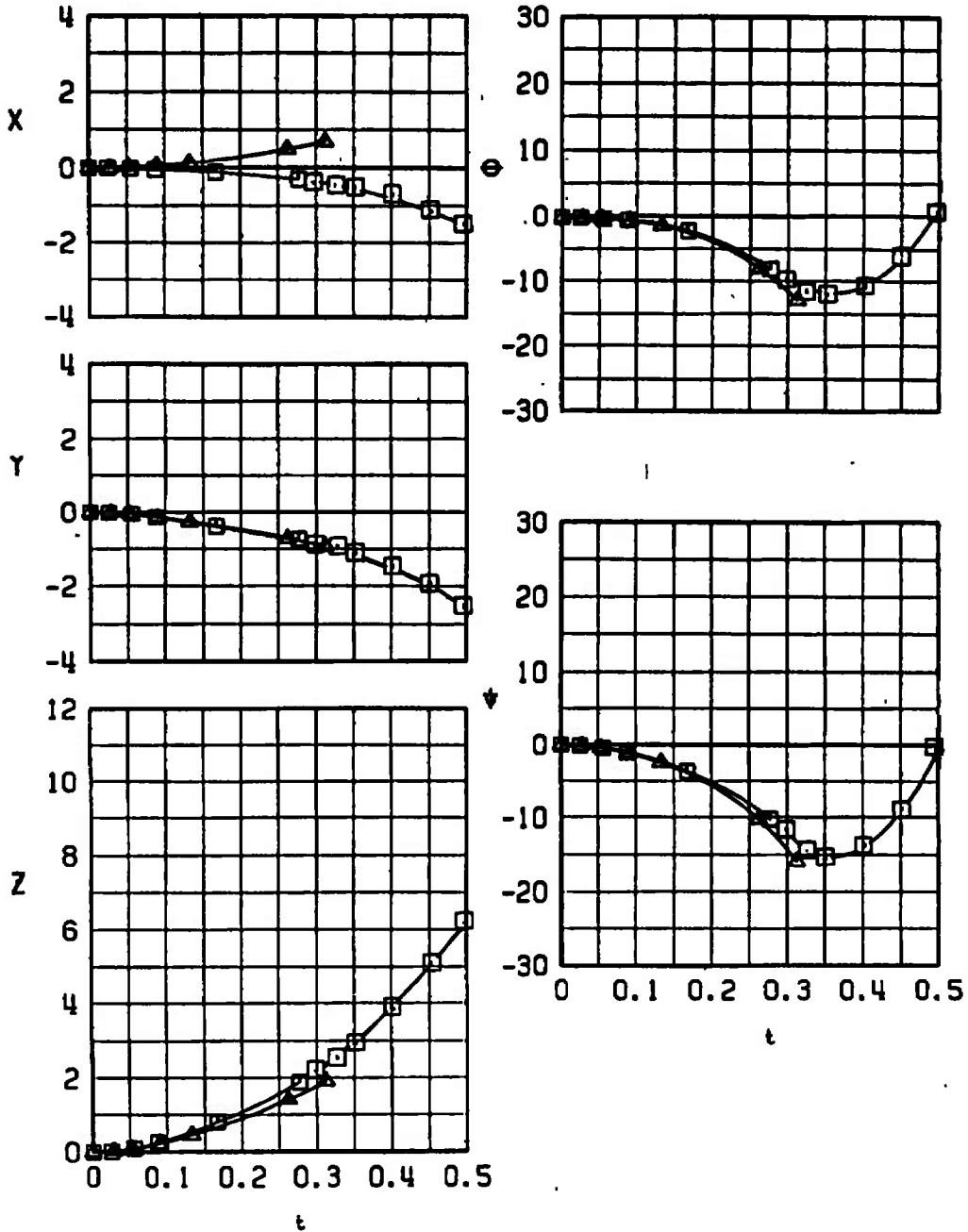
a. $M_\infty = 0.66$

Fig. 20 Separation Trajectory Data for Configuration 7

SYM	CONF	M_∞	α	$\bar{\theta}$
◻	7	0.74	1.4	0
△	7	0.74	1.4	-45
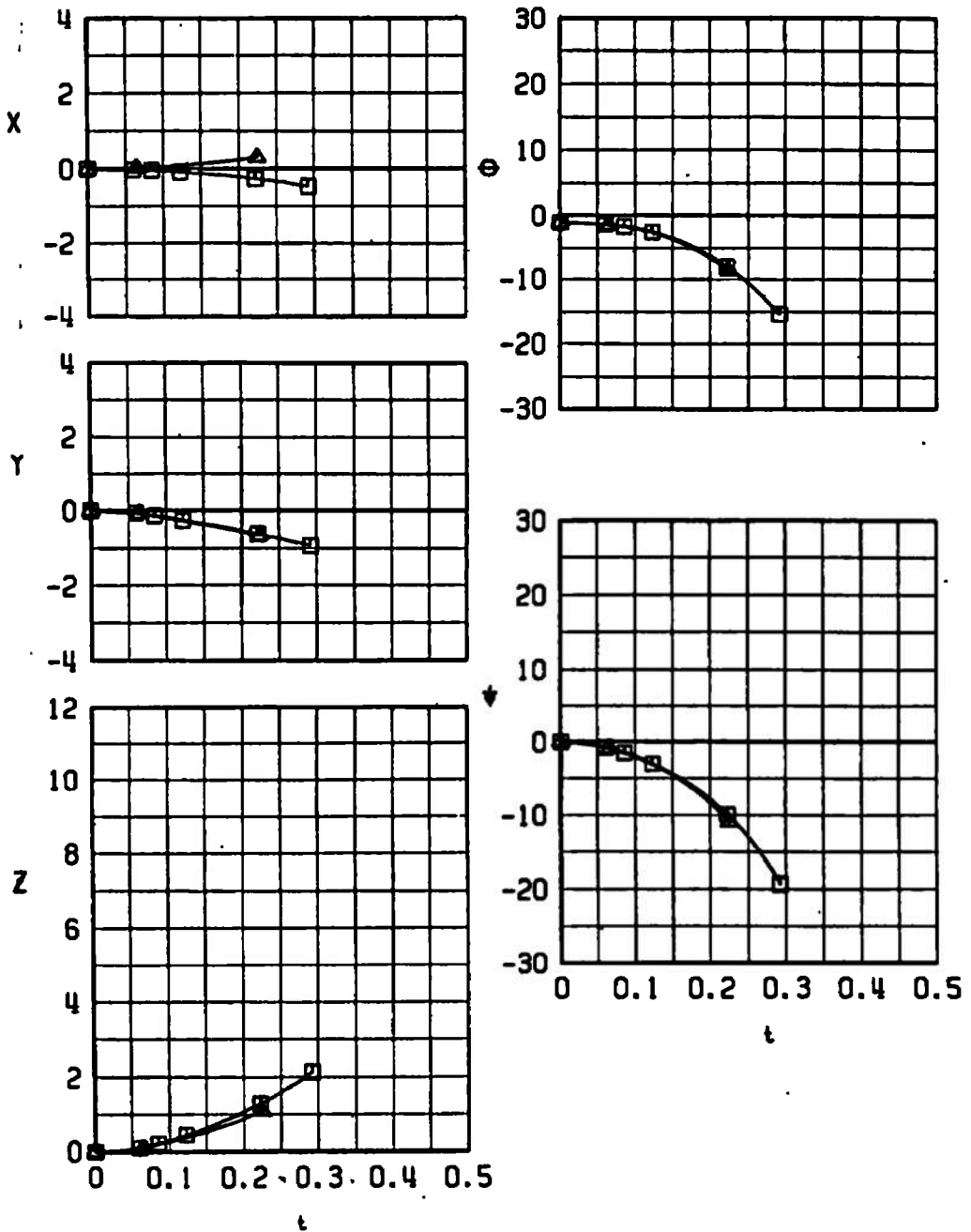
b. M_∞ = 0.74
Fig. 20 Continued

c. $M_\infty = 0.82$
Fig. 20 Continued

SYM	CONF	M_∞	α	$\bar{\theta}$
⊡	7	0.90	0.5	0
△	7	0.90	0.5	-45
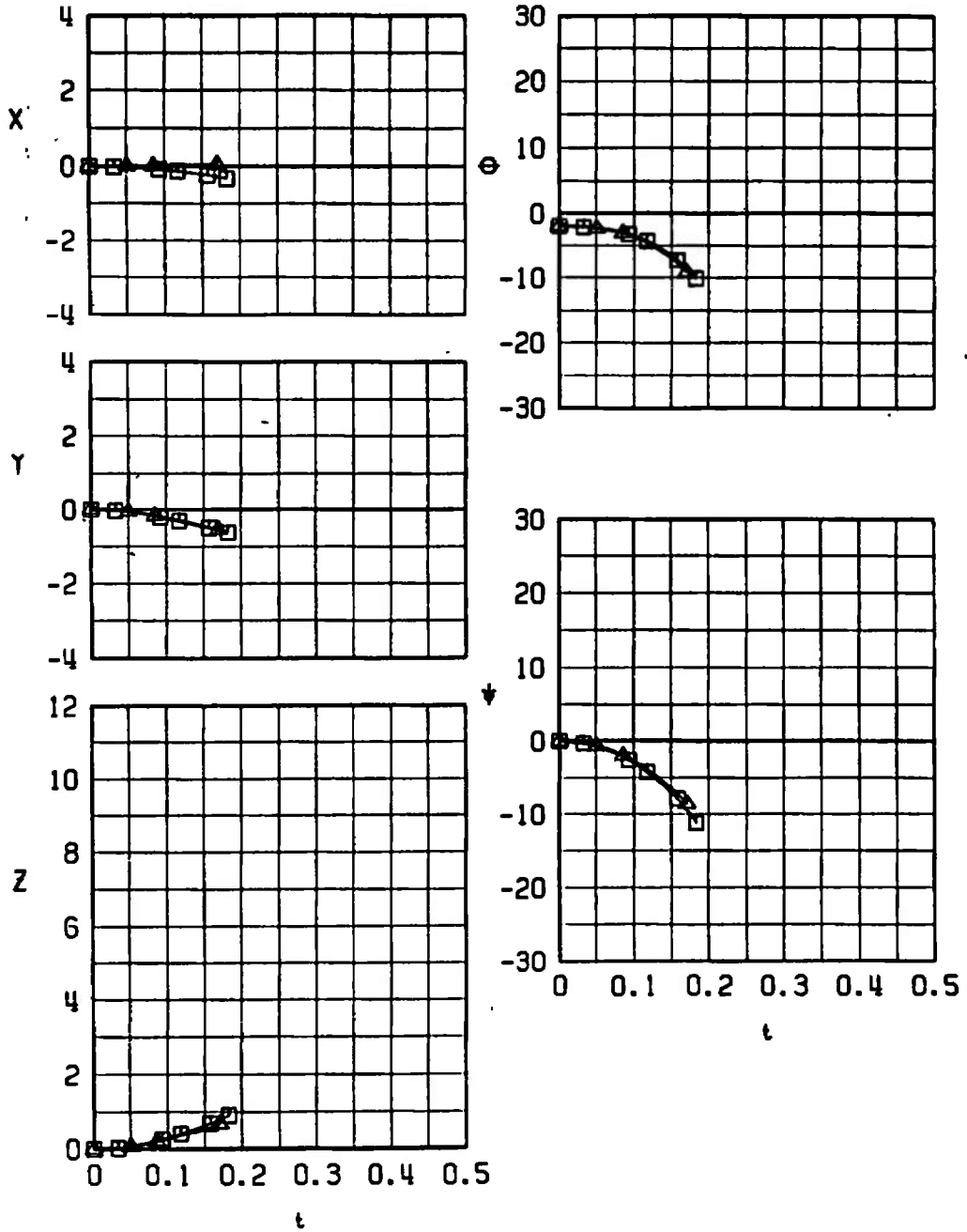
d. $M_\infty = 0.90$
Fig. 20 Concluded

SYM	CONF	M_∞	α	$\bar{\theta}$
⊡	8	0.66	2.2	0
△	8	0.66	2.2	-45
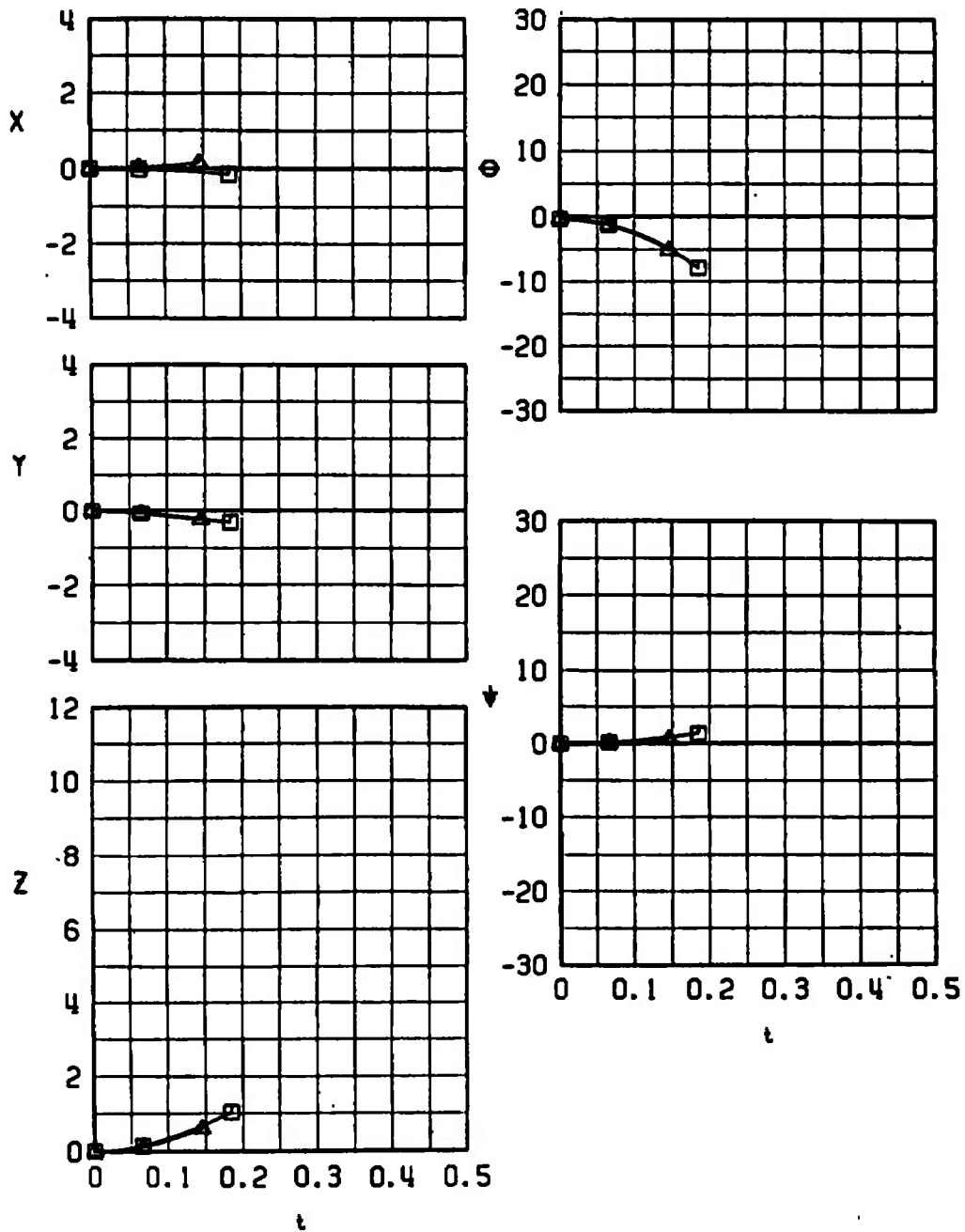
a. $M_\infty = 0.66$

Fig. 21 Separation Trajectory Data for Configuration 8

SYM	CONF	M_∞	α	$\bar{\theta}$
▱	8	0.74	1.4	0
△	8	0.74	1.4	-45
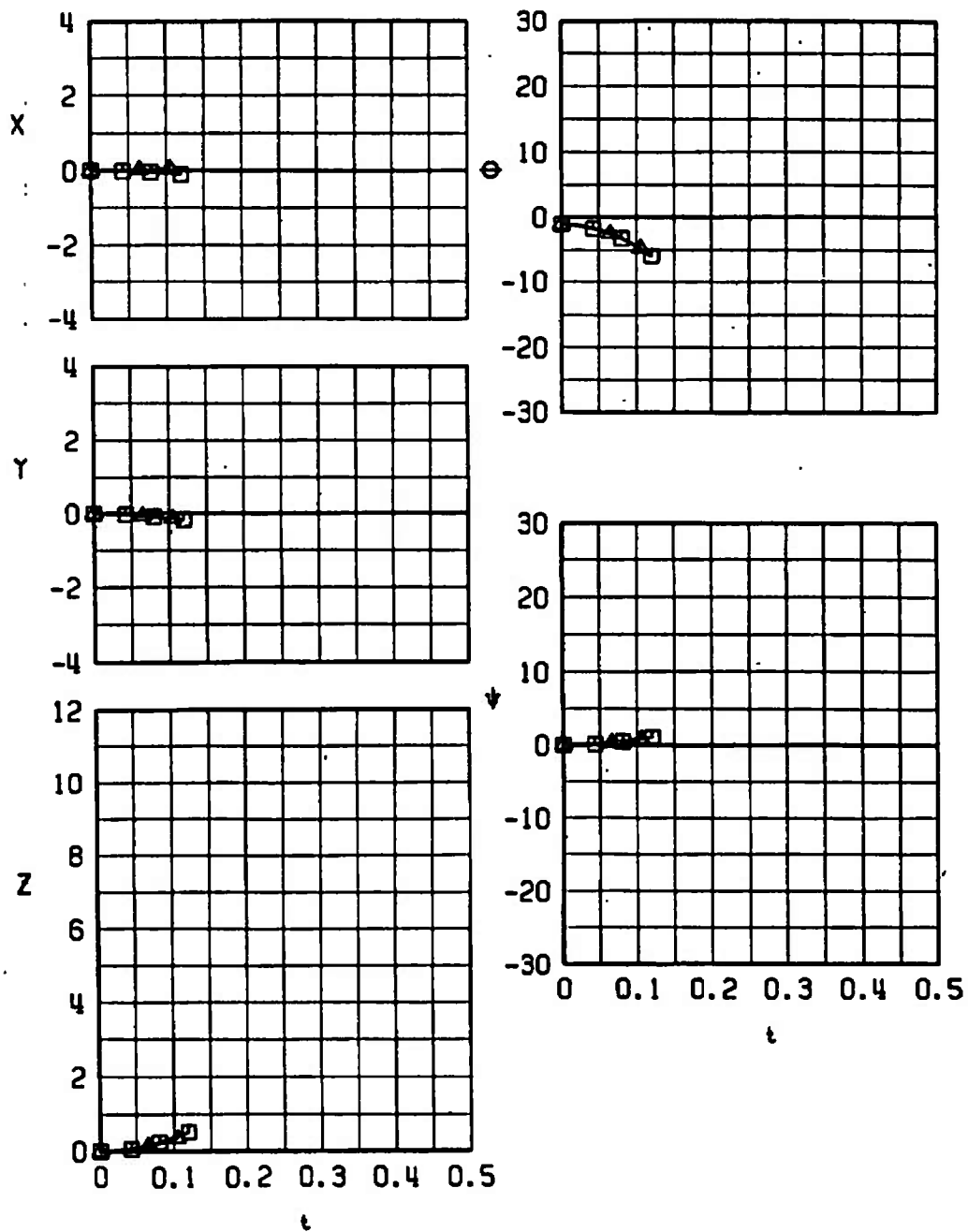
b. $M_\infty = 0.74$

Fig. 21 Continued

SYM	CONF	M_∞	α	$\bar{\theta}$
▢	8	0.82	0.8	0
△	8	0.82	0.8	-45

c. M_∞ = 0.82
Fig. 21 Continued

48
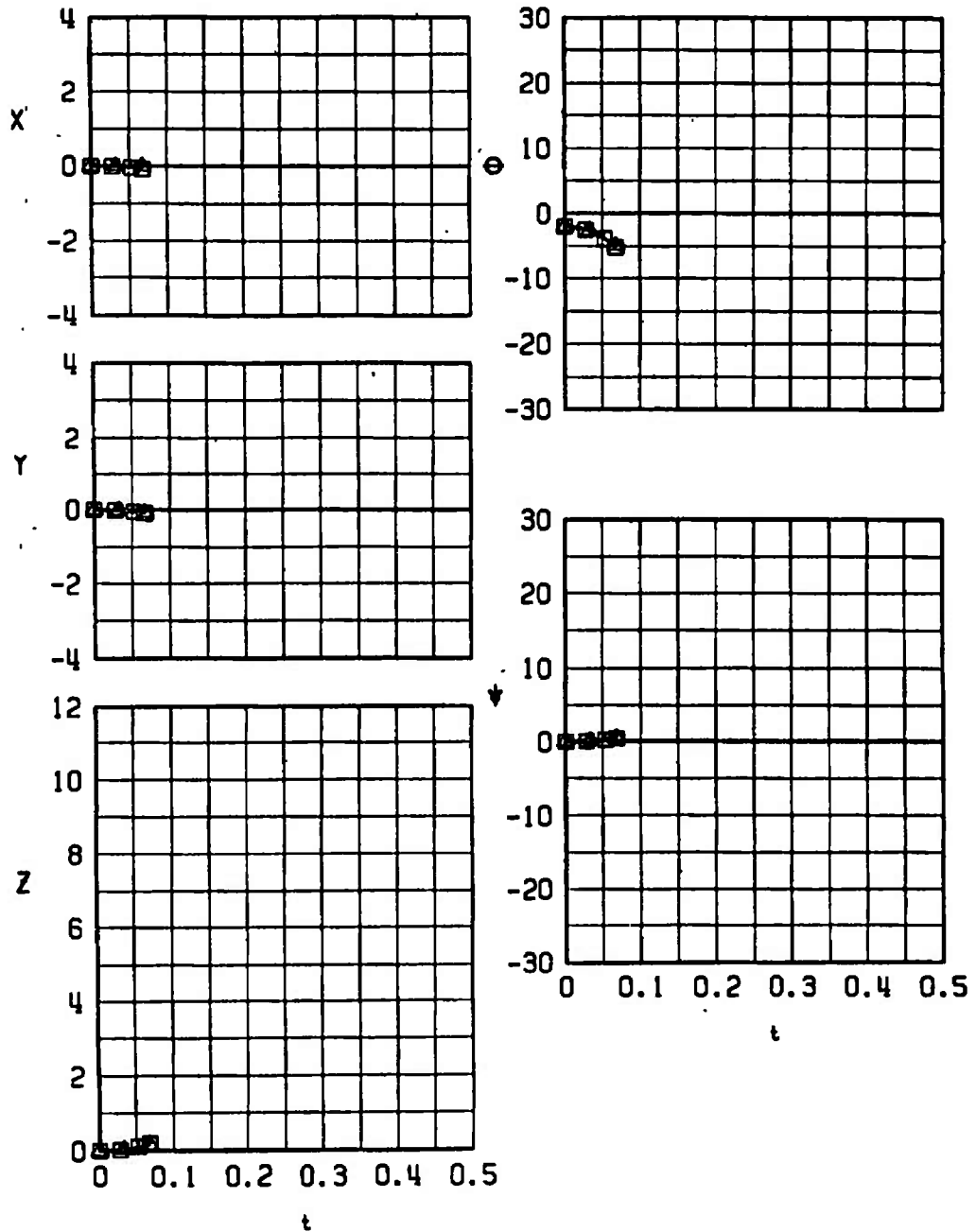
d. $M_\infty = 0.90$
Fig. 21 Concluded
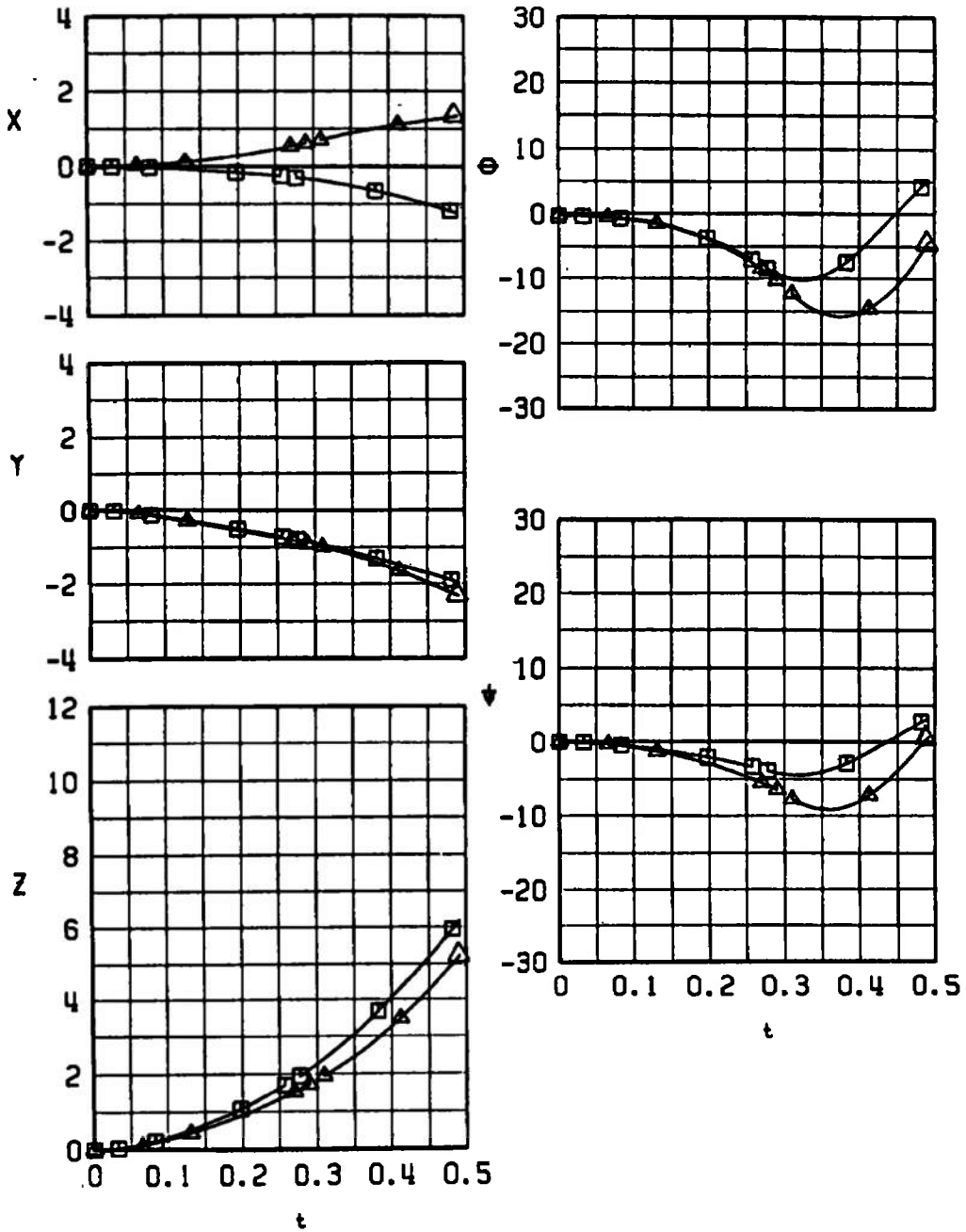
a. $M_\infty = 0.66$

Fig. 22 Separation Trajectory Data for Configuration 9

SYM	CONF	M∞	α	$\bar{\theta}$
▢	9	0.74	1.4	0
△	9	0.74	1.4	-45
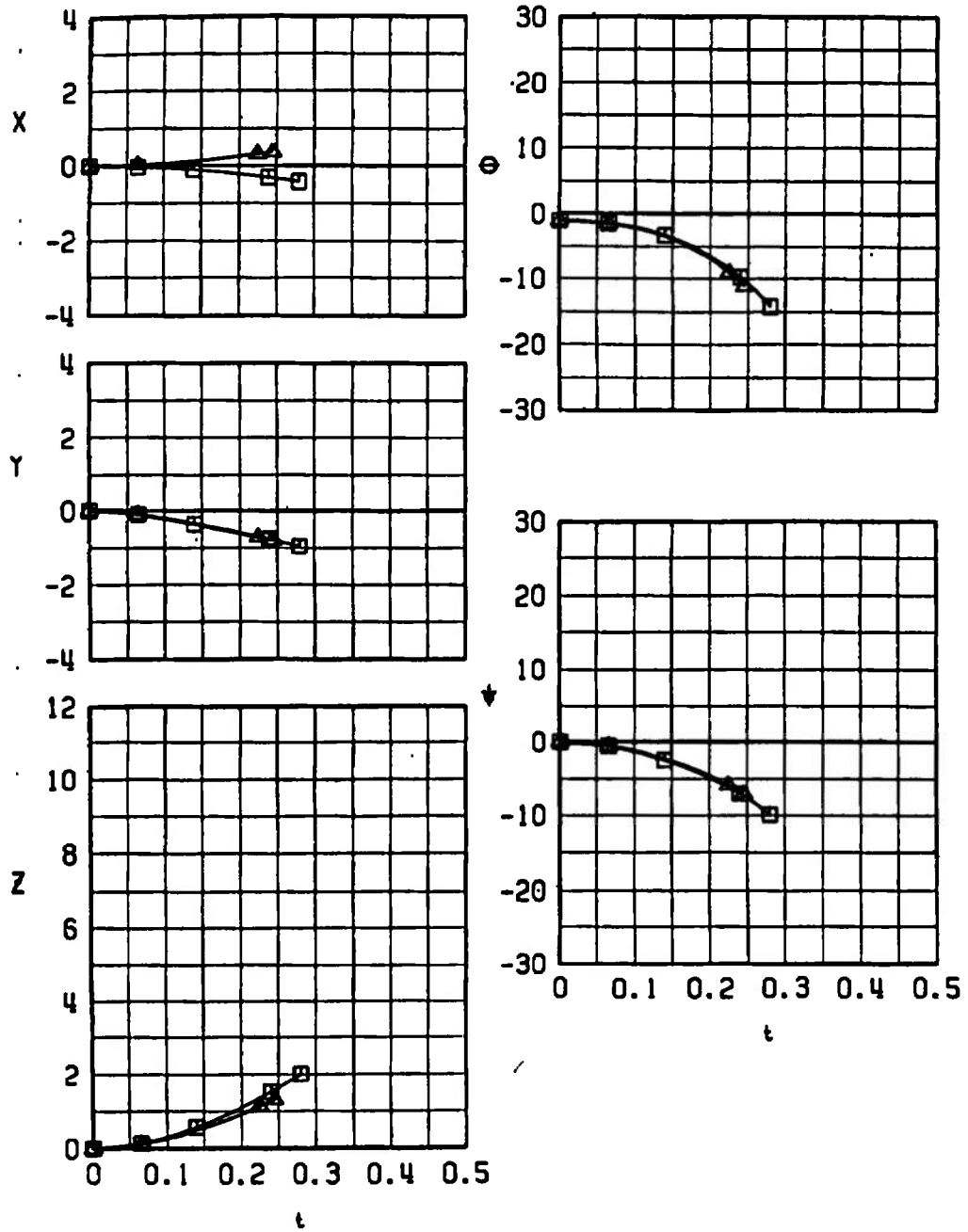
b. M∞ = 0.74
Fig. 22 Continued

51

SYM	CONF	M_∞	α	$\bar{\theta}$
□	9	0.82	0.8	0
△	9	0.82	0.8	-45
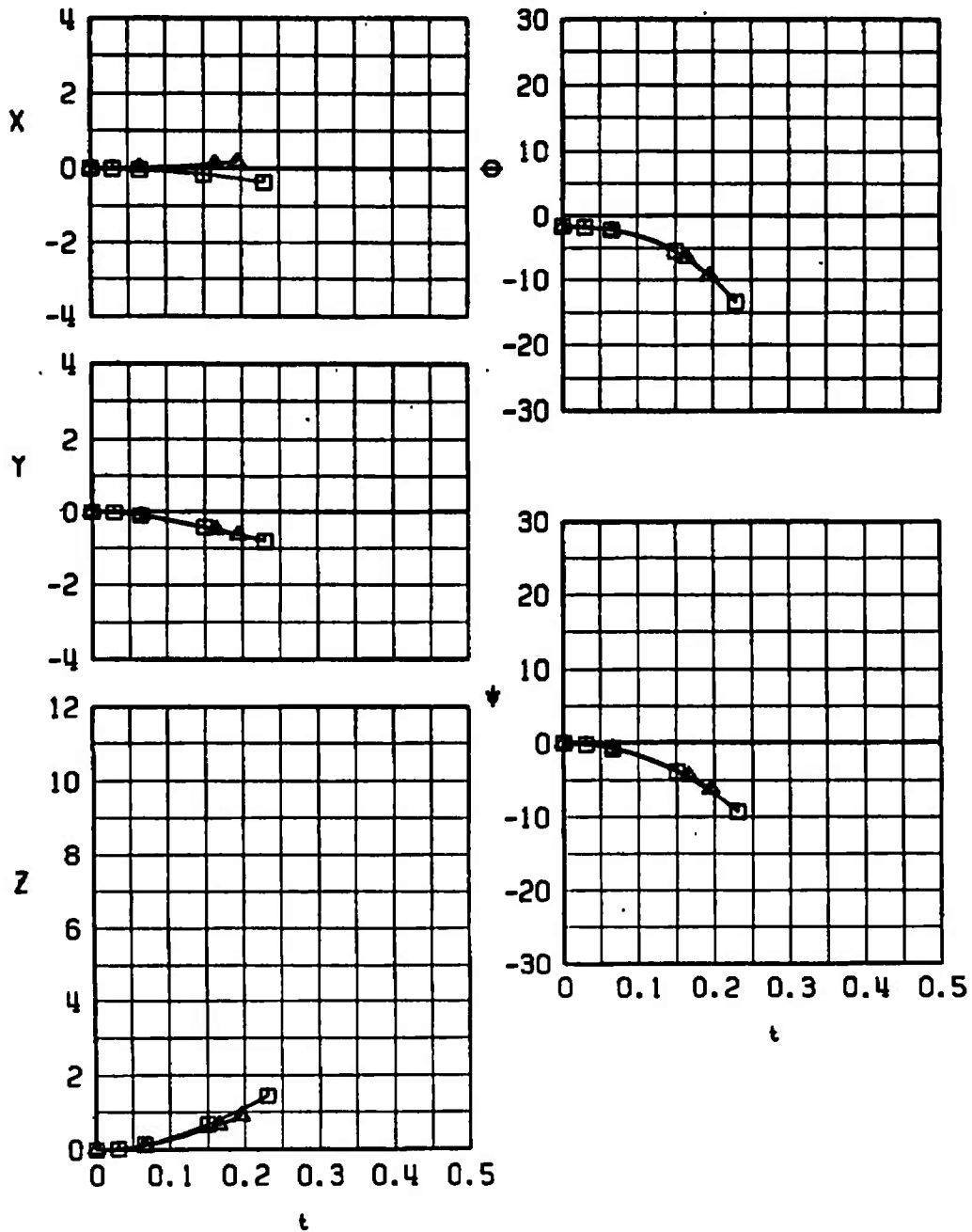
c. $M_\infty = 0.82$

Fig. 22 Continued

52

SYM	CONF	M_∞	α	$\bar{\theta}$
⊡	9	0.90	0.5	0
△	9	0.90	0.5	−45
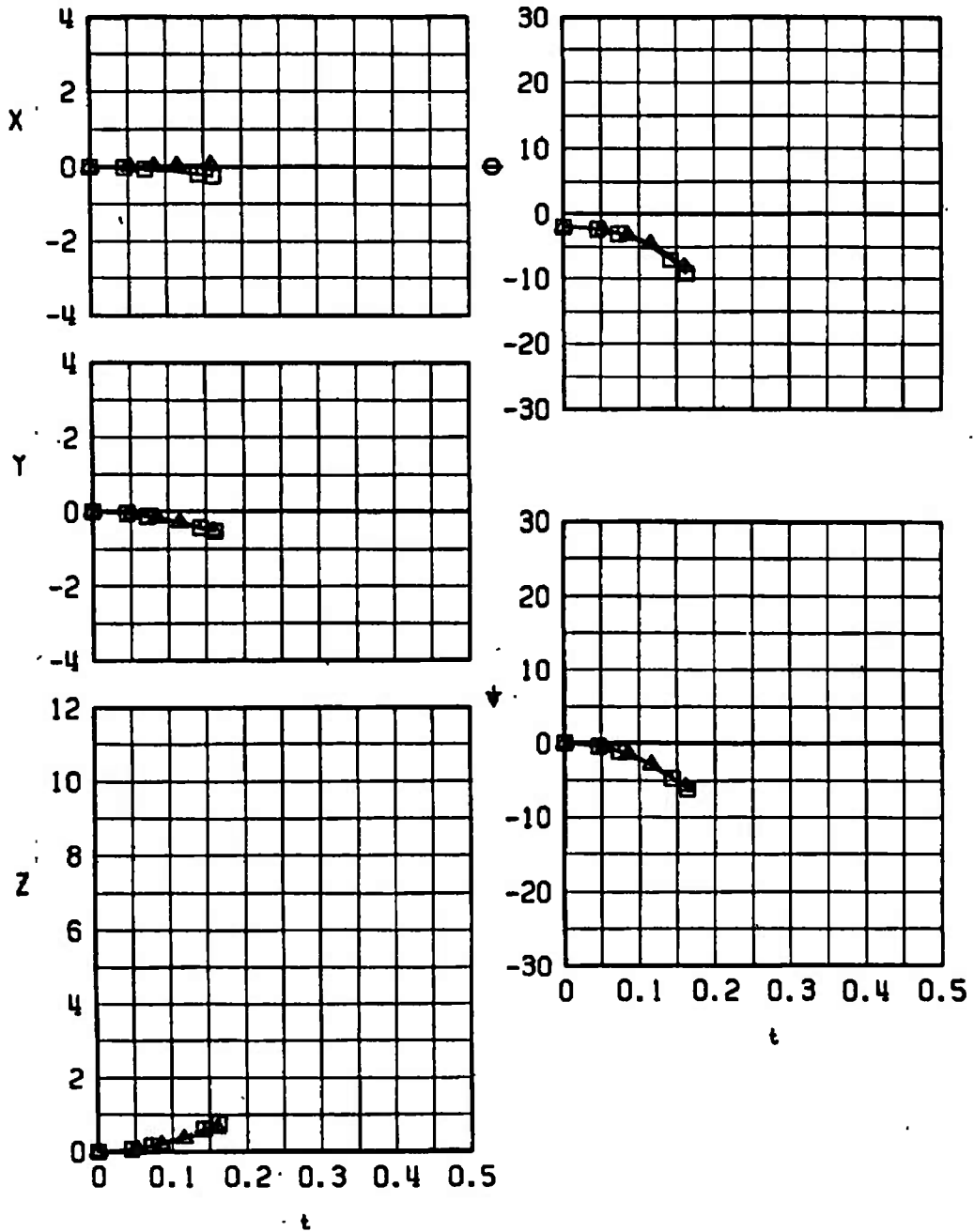
d. $M_\infty = 0.90$
Fig. 22 Concluded

53

TABLE I
FULL-SCALE STORE PARAMETERS USED IN THE TRAJECTORY CALCULATIONS

Parameter	Folded Fin Configuration	Deployed Fin Configuration
Mass, $\bar{m}$, slugs	25.590	25.590
Center-of-gravity location, X_{cg}, ft	4.000	4.000
Ejector piston location, X_L, ft	-0.0785	
Ejector stroke length, Z_F, ft	0.2552	
Distance of the store cg above the store axial centerline, ft	0.0180	0.0180
Store reference area, S, ft^2	1.3963	1.3963
Store reference diameter, b, ft	1.3330	1.3330
Pitch moment of inertia, I_{yy}, slugs-ft^2	71.8170	71.8170
Yaw moment of inertia, I_{zz}, slugs-ft^2	71.5360	71.5360
Product of inertia, I_{xz}, slugs-ft^2	0	0
Pitch damping derivative, C_{m_q}, per radian	-9.0	-60.0
Yaw damping derivative, C_{n_r}, per radian	-9.0	-60.0

TABLE II
MAXIMUM FULL-SCALE POSITION UNCERTAINTIES RESULTING
FROM BALANCE PRECISION LIMITATIONS

M_∞	t, sec	ΔX, ft	ΔY, ft	ΔZ, ft	$\Delta\theta$, deg	$\Delta\psi$, deg
0.66	0.3	0.02	0.02	0.01	0.2	0.3
0.66	0.5	0.05	0.05	0.03	0.5	0.8
0.90	0.3	0.04	0.04	0.02	0.4	0.6
0.90	0.5	0.10	0.10	0.05	1.0	1.6

TABLE III
FIN DEPLOYMENT

Configuration	M_∞	α_p	$\bar{\theta}$	Presented in Figure No.	Time at Which Fins Were Deployed, sec
1	0. 66	2. 2	0	14a	0. 3100
2	0. 66	2. 2	0	15a	0. 2750
2	0. 66	2. 2	-30	15a	0. 2800
2	0. 66	2. 2	-45	15a	0. 2800
4	0. 66	2. 2	0	17	0. 2650
4	0. 66	2. 2	-30	17	0. 2250
5	0. 66	2. 2	0	18a	0. 2475
5	0. 66	2. 2	-30	18a	0. 2675
5	0. 66	2. 2	-45	18a	0. 2675
5	0. 74	1. 4	0	18b	0. 2650
5	0. 74	1. 4	-45	18b	0. 3050
7	0. 66	2. 2	0	20a	0. 2975
9	0. 66	2. 2	0	22a	0. 2775
9	0. 66	2. 2	-45	22a	0. 3100

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13 ABSTRACT

A wind tunnel test was conducted using 0.05-scale models to study the separation characteristics of the SUU-51/B from the F-4C aircraft. The separation trajectories were initiated from the left-wing inboard pylon station utilizing the Triple Ejection Rack and from the centerline pylon utilizing the Multiple Ejection Rack. The flight conditions simulated were Mach numbers from 0.66 to 0.90 at an altitude of 5000 ft. Parent aircraft dive angles of 0, 30, and 45 45 deg were simulated.

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