U.V. Roe.

L.O. 6664A-3 FILE BM49-7-7 PREPARED BY D.G.G. CHECKED BY A.D.W.	NATIONAL AERONAUTICAL ESTABLISHMENT ARNPRIOR, CANADA LABORATORY MEMORANDUM SECTION FLIGHT RESEARCH	NO. FR-16(b) PAGE OF COPY NO 6 DATE 25 Jan. 1954

SECURITY CLASSIFICATION ~~SECRET~~ UNCLASSIFIED

SUBJECT **ESTIMATES OF THE INITIAL PHASE OF THE TRAJECTORY IN THE PITCHING PLANE OF THE VELVET GLOVE MISSILE WHEN LAUNCHED FROM THE CF-100 AIRCRAFT (UNDER-NACELLE POSITION)**

PREPARED BY D. G. Gould

ISSUED TO Internal

THIS MEMORANDUM IS ISSUED TO FURN[ISH INFORMATION] IN ADVANCE OF A REPORT. IT IS PRELIMINA[RY AND] HAS NOT RECEIVED THE CAREFUL EDITING [OF A REPORT. IT] IS SUBJECT TO REVIEW.

AC 2008.1

ESTIMATES OF THE INITIAL PHASE OF THE TRAJECTORY IN THE PITCHING PLANE OF THE VELVET GLOVE MISSILE WHEN LAUNCHED FROM THE CF-100 AIRCRAFT (UNDER-NACELLE POSITION)

SUMMARY

A semi-experimental method of investigating the effects of the flow field induced by the launching aircraft on the trajectory of the Velvet Glove missile has been tried for launches from an under-nacelle position on the CF-100.

The calculations show that the downward displacement of the missile centre of gravity may be very large at low lift coefficients for launchings from the inboard position unless the tip-off distance can be reduced to zero. A zero tip-off distance gives an almost constant vertical displacement of the inboard missile at a distance of 130 ft. from the aircraft over a range of lift coefficients from 0.12 to 0.73. Only one trajectory was computed for a launch from the outboard position at an aircraft lift coefficient of 0.37. The vertical displacement of the missile at a distance of 130 ft. from the aircraft was approximately the same for zero tip-off distance as the launchings from the inboard position.

The amplitude of the initial pitch oscillation was large (about 8°) for all the zero tip-off cases. The missile will complete approximately two complete cycles in pitch oscillation in two seconds so that any initial oscillation should be well damped by the end of the boost period.

1. INTRODUCTION

A semi-experimental method of investigating the effects of aerodynamic interference induced by the launching aircraft on the trajectory of an air launched guided missile was described in Reference 1, where it was applied to launches of the Velvet Glove missile from an under-wing position on the F86E. The method has the advantage over a purely analytical computation that it may be applied to launches from complex three-dimensional bodies whose induced flow fields are difficult, if not impossible, to calculate theoretically.

Two locations for stowing four Velvet Glove missiles on the CF-100 have been proposed. The two positions are shown in a schematic drawing in Figures 1(a) and 1(b). The method described in Reference 1 is particularly useful for predicting the effects of the induced flow field on launches from the under-nacelle position of the CF-100 since the missiles are stowed under the nacelle and under the fuselage-nacelle fillet where the induced flow fields are complex and very difficult to calculate theoretically.

The data from wind tunnel tests and the trajectories computed using this information are given in this memorandum for the inboard under-nacelle missile at three aircraft lift coefficients and for the outboard under-nacelle missile at one aircraft lift coefficient.

2. DESCRIPTION OF FULL SCALE INSTALLATION

Pertinent missile physical and aerodynamic characteristics are given in Reference 1. The pylons used on the CF-100 are the same as those used on the F86E with suitable fairing on the upper portion to adapt them to the CF-100. The distance the missile travels with rear lugs only on the rails has been called the tip-off distance as defined in Reference 1 and may be varied from 3.54 ft. to 0 ft. The minimum travel of the missile with lugs on the rails is 2.0 ft. This corresponds to a tip-off distance of 0 ft.

The location of the missiles in the stowed position relative to the aircraft is given in Figure 1(a). In the stowed position the missile axis is parallel to the fuselage reference line (approximately -1.5° to the aircraft zero-lift axis).

3. METHOD AND SCOPE OF TESTS

The method used was identical to that described in Reference 1. The normal force and pitching moment acting on a missile model were measured with the missile in the vicinity of a 1/10 scale CF-100 model at a number of stations in the pitching plane of the trajectory. The coordinates of the various stations and the missile effective angle of attack and zero-lift pitching moment coefficient are tabulated in Tables 1, 2, 3 and 4 respectively for the inboard under-nacelle missile at aircraft lift coefficients of 0.118, 0.374 and 0.73 and for the outboard under-nacelle missile at an aircraft lift coefficient of 0.374. This information was used in the same manner as in Reference 1 to compute missile trajectories for each of the above cases for tip-off distances of 3.54 ft., 1.77 ft. and 0 ft.

A photograph of the missile and aircraft models in the N.A.E. #3 low speed wind tunnel is shown in Figure 2.

4. NOTATION

The notation used is the same as that of Reference 1, some of which is reproduced here for ready reference.

$\bar{\bar{X}}$ = displacement of the missile centre of gravity in the direction of the launching rails relative to axis fixed in the launching aircraft.

$\bar{X}'$ = horizontal displacement of the missile centre of gravity relative to axis fixed in the launching aircraft, taken equal to $\bar{X}$ in this memorandum.

$\bar{Z}$ = displacement of the missile centre of gravity relative to axis fixed in the launching aircraft, in direction perpendicular to X, positive downward.

$\bar{Z}'$ = vertical displacement of the missile centre of gravity, positive downward.

θ = angular position of missile axis relative to launching rail direction, positive for downward rotation.

θ' = angular position of missile axis relative to horizontal flight path, positive for downward rotation.

$\frac{d\theta}{dt}$ = angular velocity of missile axis in pitch plane, degrees/second, positive for downward rotation.

β' = instantaneous flight path direction relative to horizontal, positive downward.

5. RESULTS AND DISCUSSION

The following flight conditions were chosen for the computed trajectories:

(i) Mach number of launching aircraft = 0.80

Altitude of launching aircraft = 15,000 ft.

Aircraft lift coefficient = 0.118

(ii) Mach number of launching aircraft = 0.70

Altitude of launching aircraft = 35,000 ft.

Aircraft lift coefficient = 0.374

(iii) Mach number of launching aircraft = 0.50

Altitude of launching aircraft = 35,000 ft.

Aircraft lift coefficient = 0.73

Cases (i) and (iii) are the extremes of aircraft lift coefficients in the altitude range from 15,000 to 35,000 ft. over a speed range from M = 0.50 to maximum level speed. In all cases the launching aircraft was assumed to be in steady horizontal flight.

The vertical displacement of the missile centre of gravity, $\bar{Z}'$, the angular rotation of the missile axis relative to the horizontal θ', and the angular velocity of the missile axis in the pitch plane are plotted as functions of distance from the launching aircraft, $\bar{X}$, for cases (i), (ii) and (iii) for the inboard under-nacelle missile in Figures 3(a) to 5(c) and for case (ii) for the outboard under-nacelle missile in Figures 6(a), (b) and (c). In each case calculations were done up to values of X of about 140 ft. and for three tip-off distances, D = 3.54 ft., 1.77 ft. and 0 ft. These curves show in general that a reduction in the tip-off distance is favourable from the point of view of the downward displacement of the missile centre of gravity. Near the end of the computed trajectories $\bar{Z}'$ is reduced to zero or negative values as the tip-off distance is reduced to 0 ft. The effect is especially large for case (i) shown in Figure 3(a) where $\bar{Z}'$ at $\bar{X}$ = 130 ft. is reduced from about 80 ft. at D = 3.54 ft. to 24 ft. at D = 1.77 ft. to -14.5 ft. at D = 0.

The rotation of the missile axis in the pitch plane, θ', has been replotted against time for reach of the above cases in Figures 7, 8, 9 and 10. Plots of the instantaneous flight path direction, β', are also included in the same Figures. The difference between the above two angles at any time ($\theta' - \beta'$) has been taken as a measure of the pitch oscillation of the missile induced by the launching aircraft. The values of $\theta' - \beta'$ are plotted against time for each case in Figures 11, 12, 13 and 14. The first peak in these curves after the missile is free of the flow field induced by the launching aircraft has been taken as the initial pitch oscillation imparted to the missile as it passes through the aircraft flow field. The initial pitch amplitude is plotted against aircraft lift coeffient for D = 3.54 ft., 1.77 ft. and 0 ft. for the inboard under-nacelle missile in Figure 15. Points for the outboard under-nacelle missile at C_L = 0.374 are also included in the Figure for comparison. The curves are of course only approximate since there are only three points for each curve. They do show in a rough manner, however, the effects of aircraft lift coefficient and tip-off distance on the initial pitch oscillation imparted to the missile. The tip-off distance of 3.54 is most favourable at lift coefficients above 0.3 but at lower lift coefficients the initial pitch oscillation becomes very large. At D = 1.77 ft. the initial pitch amplitude increases from about 2^{o} at low lift coefficients to about 6^{o} at higher lift coefficients. At D = 0 the initial amplitude varies from 6 to 8^{o}. These curves show that a tip-off distance of about 1.7 ft. will result in a small initial pitch oscillation over most of the lift coefficient range.

The vertical displacement of the missile centre of gravity at $\bar{X}$ = 130 ft. is plotted against aircraft lift coefficient in Figure 16 for D = 3.54 ft., 1.77 ft., and 0 ft. These curves show that $\bar{Z}'$ at at $\bar{X}$ = 130 ft. is almost constant with varying lift coefficient if the tip-off distance is reduced to 0 ft.

The single point at a lift coefficient of 0.374 for the outboard under-nacelle missile is also very nearly the same as that for the inboard missile.

Zero tip-off distance seems desirable if the vertical displacement of the centre of gravity is to be kept to a minimum at the end of the two second boost period. The initial pitch oscillations are larger for the zero tip-off case than for the 1.77 tip-off case, but since a missile of this type is well damped and since it will have completed about two complete cycles in pitch oscillation by the end of the boost period, the pitch amplitude at the end of boost should be small.

6. CONCLUSIONS

The initial phase of the pitching plane trajectory of the Velvet Glove missile when launched from an under-nacelle position on the CF-100 aircraft has been calculated for three aircraft lift coefficients for the inboard missile position and for one lift coefficient for the outboard missile position.

The calculations show that the downward displacement of the missile centre of gravity may be very large at low lift coefficients for launchings from the inboard under-nacelle position unless the tip-off distance is reduced to zero. A zero tip-off distance gives an almost constant vertical displacement of the centre of gravity at a distance of 130 ft. from the aircraft over a range of aircraft lift coefficients from 0.12 to 0.73 for the inboard under-nacelle position. The vertical displacement of the centre of gravity for the outboard under-nacelle position at the one lift coefficient calculated was approximately the same as that for the inboard missile at zero tip-off distance.

The amplitude of the initial pitch oscillation was large (approximately 8°) for all the zero tip-off cases. Pitching oscillations of the Velvet Glove missile should be well damped, however, so that the amplitude of the pitch oscillation at the end of boost should be small.

REFERENCES

1. GOULD, D. G. Estimates of the initial phase of the trajectory in the pitching plane of the Velvet Glove missile when launched from the F86E.

N.A.E. Lab. memorandum FR6(m).

CF-100 INBOARD UNDER-NACELLE STATION $C_L = 0.118$

TABLE 1

SECRET

STATION	$\bar{X}$	$\bar{Z}$	θ	α_e	C_{M_0}	STATION	$\bar{X}$	$\bar{Z}$	θ	α_e	C_{M_0}
A_0	0	0	0	-5.24	-0.284	B_9	9.29	1.00	0.29	-3.74	0.163
A_2	2.00	0	0	-10.83	-0.001				2.49	-5.85	0.176
A_3	2.83	0.02	0.33	-7.97	-0.254				4.00	-7.34	0.172
		0.14	1.93	-9.80	-0.247	B_{10}	10.54	1.00	0.42	-2.91	0.123
		0.25	3.50	-11.40	-0.242				1.80	-4.80	0.121
A_4	3.66	0.03	0.35	-7.70	-0.171				4.08	-6.47	0.119
		0.14	1.94	-9.31	-0.157	B_{11}	11.79	1.00	0.60	-2.35	0.081
		0.26	3.63	-11.00	-0.155				2.76	-4.31	0.081
A_5	4.50	0.04	0.49	-7.35	-0.071				4.22	-6.16	0.080
		0.19	2.58	-9.64	-0.053	B_{13}	14.29	1.00	0.84	-2.09	0.044
		0.31	4.22	-10.82	-0.052				2.50	-3.82	0.043
A_6	5.54	0.06	0.88	-7.40	0.132				2.94	-5.49	0.039
		0.17	2.34	-9.33	0.145						
		0.31	4.22	-10.64	0.128						
A_7	6.79	0	0.99	-7.09	0.302						
			2.50	-8.86	0.325						
			4.22	-10.41	0.291						
A_8	8.04	0	0.92	-5.54	0.274						
			2.60	-7.30	0.290						
			4.22	-9.23	0.274						
A_9	9.29	0	0.92	-4.53	0.224						
			2.64	-6.44	0.236						
			4.23	-8.24	0.225						
A_{10}	10.54	0	0.92	-3.45	0.149						
			2.50	-5.03	0.151						
			4.23	-7.29	0.144						
A_{11}	11.79	0	0.92	-3.01	0.090						
			2.79	-4.80	0.091						
			4.64	-6.54	0.087						
A_{13}	14.29	0	4.37	-5.87	0.038						

CF-100 INBOARD UNDER-NACELLE STATION $C_L = 0.374$

TABLE 2

SECRET

STATION	$\bar{X}$	$\bar{Z}$	θ	α_e	C_{M_o}	STATION	$\bar{X}$	$\bar{Z}$	θ	α_e	C_{M_o}
A_0	0	0	0	-4.07	-0.198						
A_2	2.00	0	0	-6.08	-0.242						
A_3	2.83	0	-0.05	-5.36	-0.148						
		0.13	1.82	-6.55	-0.115						
		0.26	3.57	-8.20	-0.122						
A_4	3.66	0	-0.05	-4.00	-0.058						
		0.12	1.69	-5.82	-0.032						
		0.25	3.39	-7.53	-0.027						
A_5	4.50	0	-0.05	-3.27	0.044						
		0.07	1.00	-4.87	0.059						
		0.24	3.30	-6.62	0.080						
A_6	5.54	-0.01	-0.20	-2.47	0.176						
		0.11	1.54	-4.30	0.192						
		0.23	3.15	-6.04	0.223						
A_7	6.79	0	-0.34	-1.50	0.257						
			1.31	-3.32	0.270						
			3.39	-6.45	0.289						
A_8	8.04	0	-0.34	-0.33	0.225						
			1.68	-2.52	0.255						
			3.25	-4.44	0.278						
A_9	9.29	0	-0.16	0.46	0.183						
			1.68	-1.58	0.198						
			3.33	-3.33	0.209						
A_{10}	10.54	0	-0.06	-1.01	0.135						
			1.77	-0.82	0.132						
			3.24	-2.37	0.136						
A_{12}	13.04	0	-0.20	2.06	0.067						

CF-100 INBOARD UNDER-NACELLE STATION $C_L = 0.73$

TABLE 3

SECRET

STATION	$\bar{X}$	$\bar{Z}$	θ	α_e	C_{m_0}
A_0	0	0	0	-2.36	-0.108
A_2	2.00	0	0	-4.05	-0.091
A_3	2.83	0	0	-2.83	0.005
		0.14	1.86	-4.12	0.025
		0.26	3.50	-5.64	0.047
		-0.01	-0.15	-1.54	0.098
A_4	3.66	0.11	1.57	-2.89	0.121
		0.26	3.60	-4.82	0.154
A_5	4.50	-0.01	-0.11	-0.10	0.164
		0.15	2.00	-2.43	0.221
		0.30	4.06	-4.10	0.249
A_6	5.54	0.04	0.55	0.03	0.332
		0.17	2.29	-1.60	0.344
		0.29	4.01	-3.25	0.359
A_7	6.79	0	0.55	1.52	0.419
			2.73	-0.49	0.419
			4.43	-2.16	0.405
A_8	8.04	0	0.42	3.50	0.338
			2.72	1.31	0.326
			4.30	-0.26	0.316
A_9	9.29	0	0.33	4.90	0.255
			2.55	2.84	0.241
			4.24	0.78	0.225
A_{10}	10.54	0	0.42	6.18	0.166
			2.28	4.00	0.152
			4.29	1.90	0.137
A_{11}	11.79	0	0.46	6.80	0.103
			2.87	4.20	0.085
			4.38	2.76	0.071
A_{13}	14.29	0	0.35	7.40	0.053
			2.27	5.13	0.037
			4.47	3.20	0.031

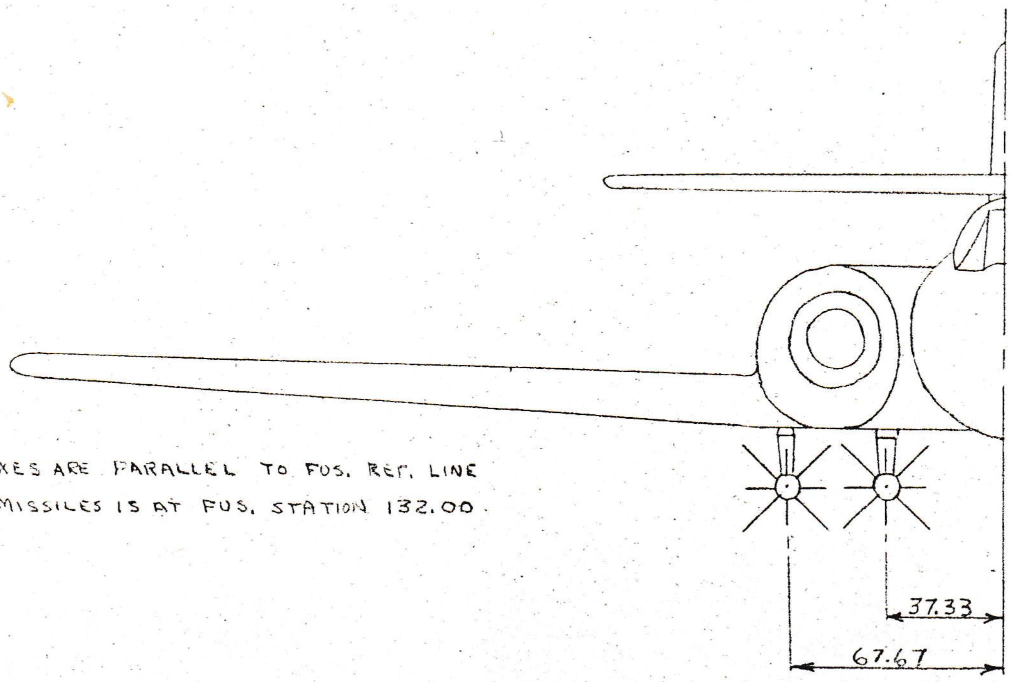
CF-100 OUTBOARD UNDER-NACELLE STATION $C_L = 0.374$

TABLE 4

SECRET

STATION	$\bar{X}$	$\bar{Z}$	θ	α_e	C_{m_0}						
A_0	0	0	0	-0.20	-0.050						
A_2	2.00	0	0	-2.37	-0.073						
A_3	2.83	0	0	-1.58	-0.029						
		0.14	1.88	-3.69	-0.014						
		0.28	3.81	-6.03	0						
A_4	3.66	0.02	0.26	-1.41	0.009						
		0.17	2.28	-3.54	0.029						
		0.27	3.67	-5.12	0.039						
A_5	4.50	0.02	0.30	-1.08	0.052						
		0.16	2.14	-3.14	0.070						
		0.28	3.82	-4.97	0.084						
A_6	5.54	0	-0.06	-0.44	0.144						
		0.16	2.17	-2.57	0.150						
		0.27	3.75	-4.45	0.162						
A_7	6.79	0	0.03	0.13	0.213						
			1.72	-1.75	0.230						
			3.67	-3.47	0.232						
8	8.04	0	-0.07	1.28	0.180						
			1.74	-0.56	0.187						
			3.60	-2.37	0.187						
A_9	9.29	0	0.02	1.98	0.153						
			1.95	0.02	0.152						
			3.65	-1.91	0.156						
A_{10}	10.54	0	-0.06	2.83	0.114						
			1.59	0.87	0.110						
			3.75	-1.06	0.102						
A_{11}	11.79	0	-0.26	3.07	0.080						
			1.89	1.10	0.070						
			3.67	-0.60	0.060						
A_{13}	14.29	0	-0.06	3.12	0.079						
			2.09	1.47	0.072						
			3.38	-0.34	0.064						

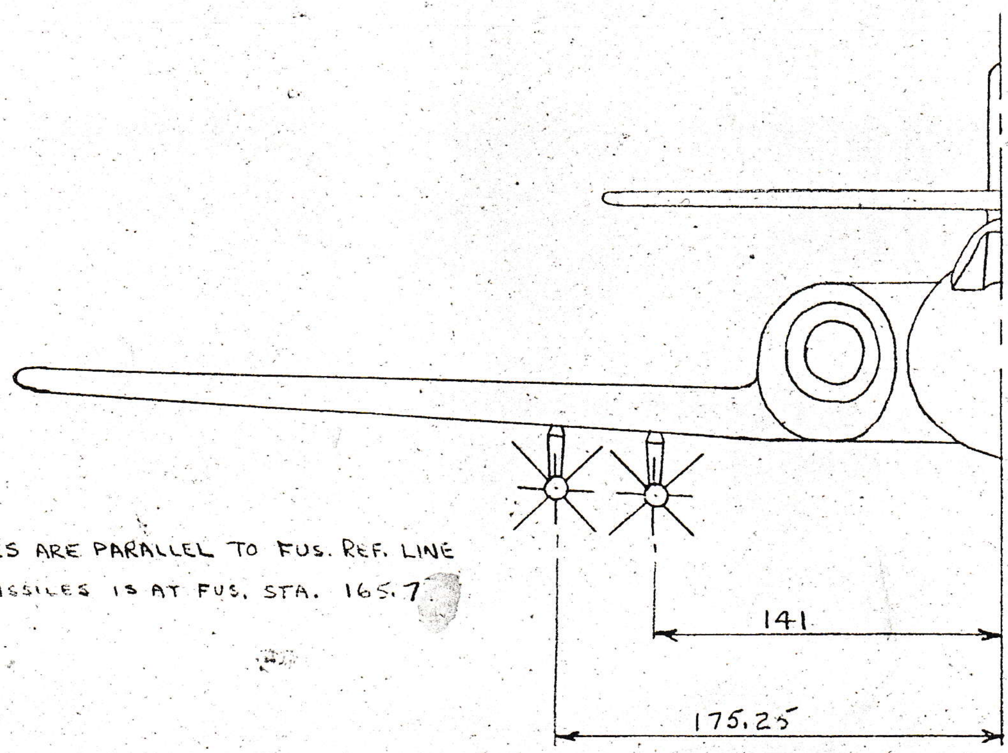
FIG. 1



NOTES:

1. MISSILE AXES ARE PARALLEL TO FUS. REF. LINE
2. NOSE OF MISSILES IS AT FUS. STATION 132.00.

a) UNDER-NACELLE POS'N



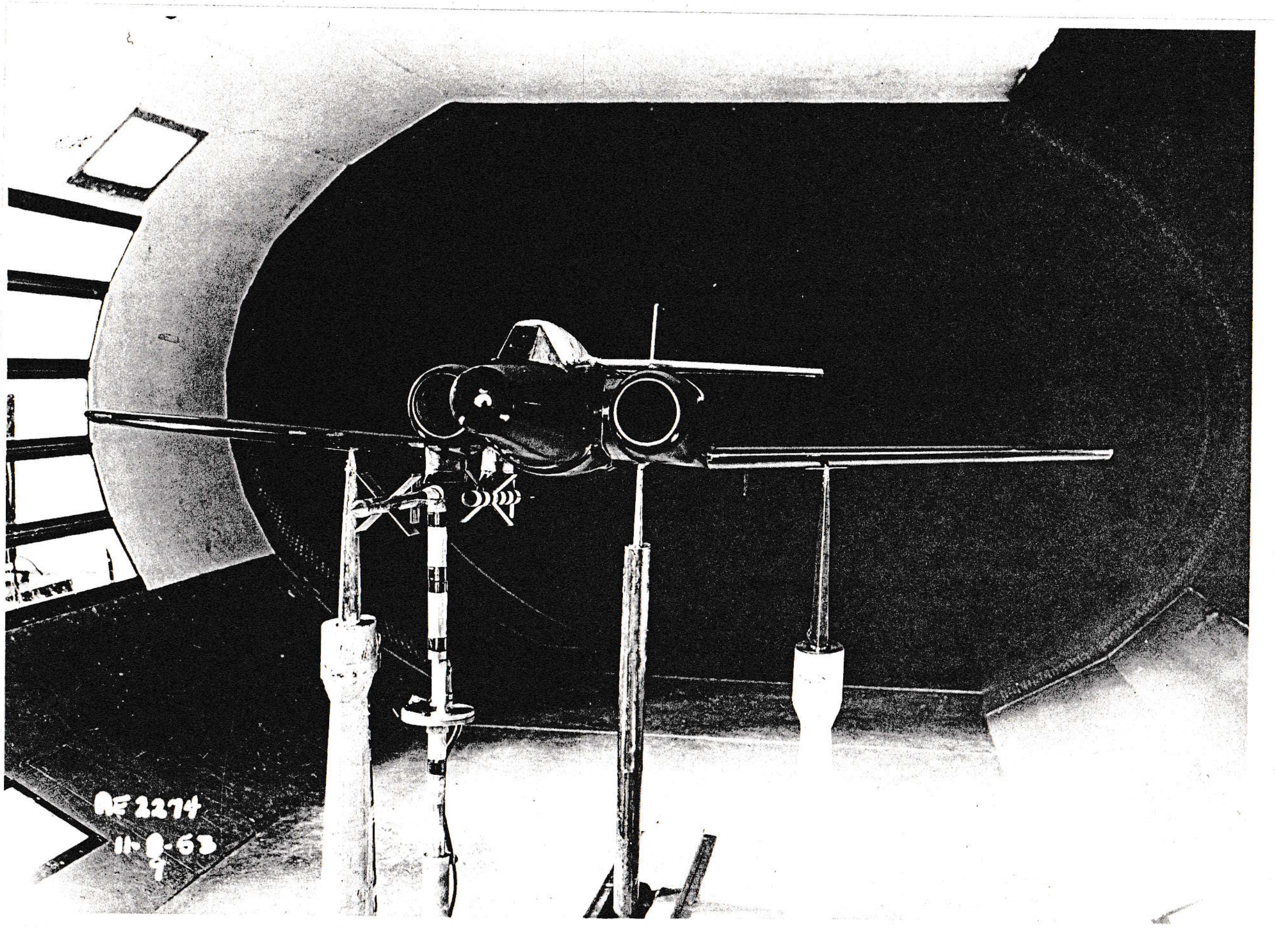
NOTES:

1. MISSILE AXES ARE PARALLEL TO FUS. REF. LINE
2. NOSE OF MISSILES IS AT FUS. STA. 165.7

b) UNDER-WING POS'N

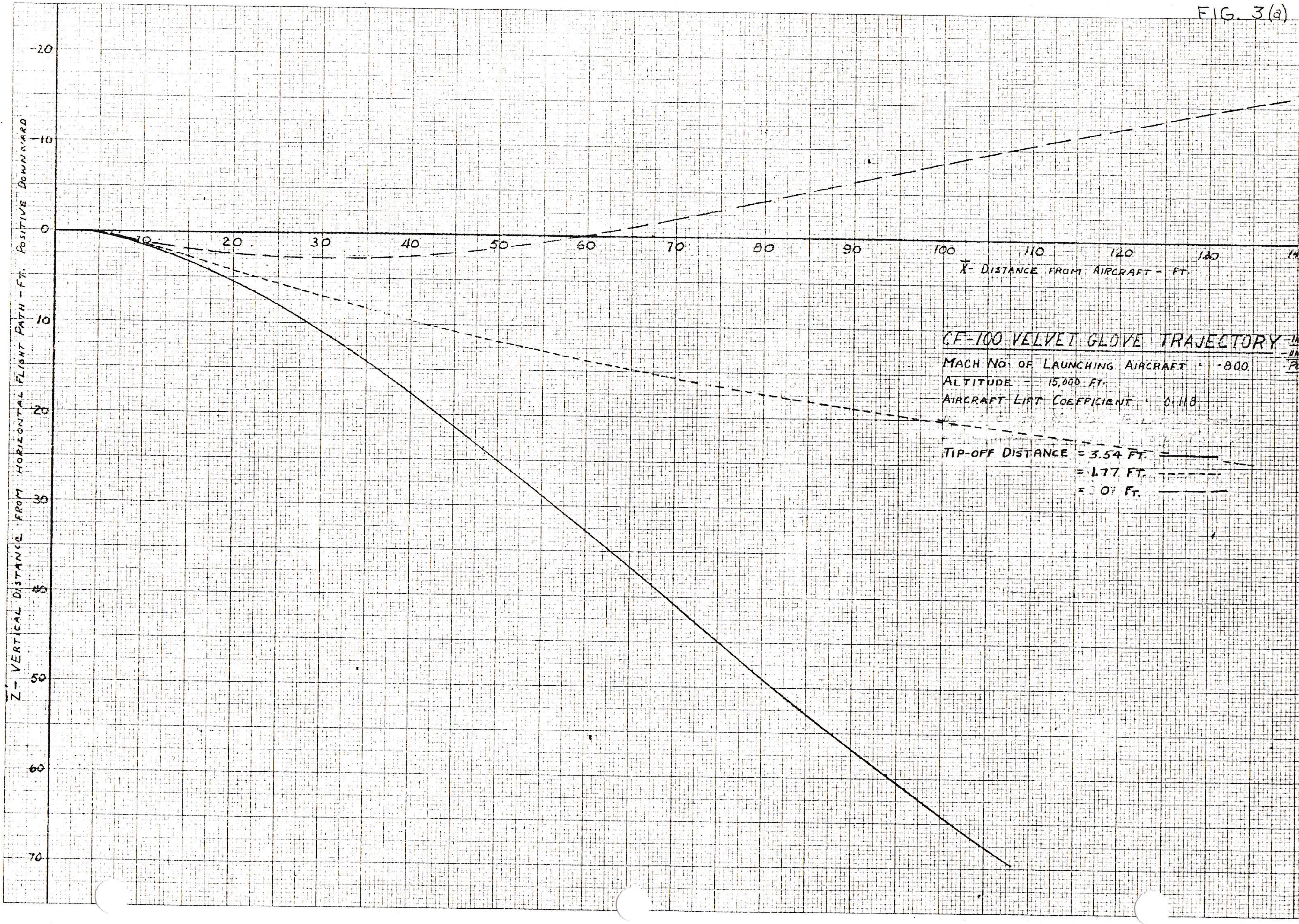
STOWAGE POSITIONS OF VELVET GLOVE MISSILES ON CF-100 AIRCRAFT

FIG. 2

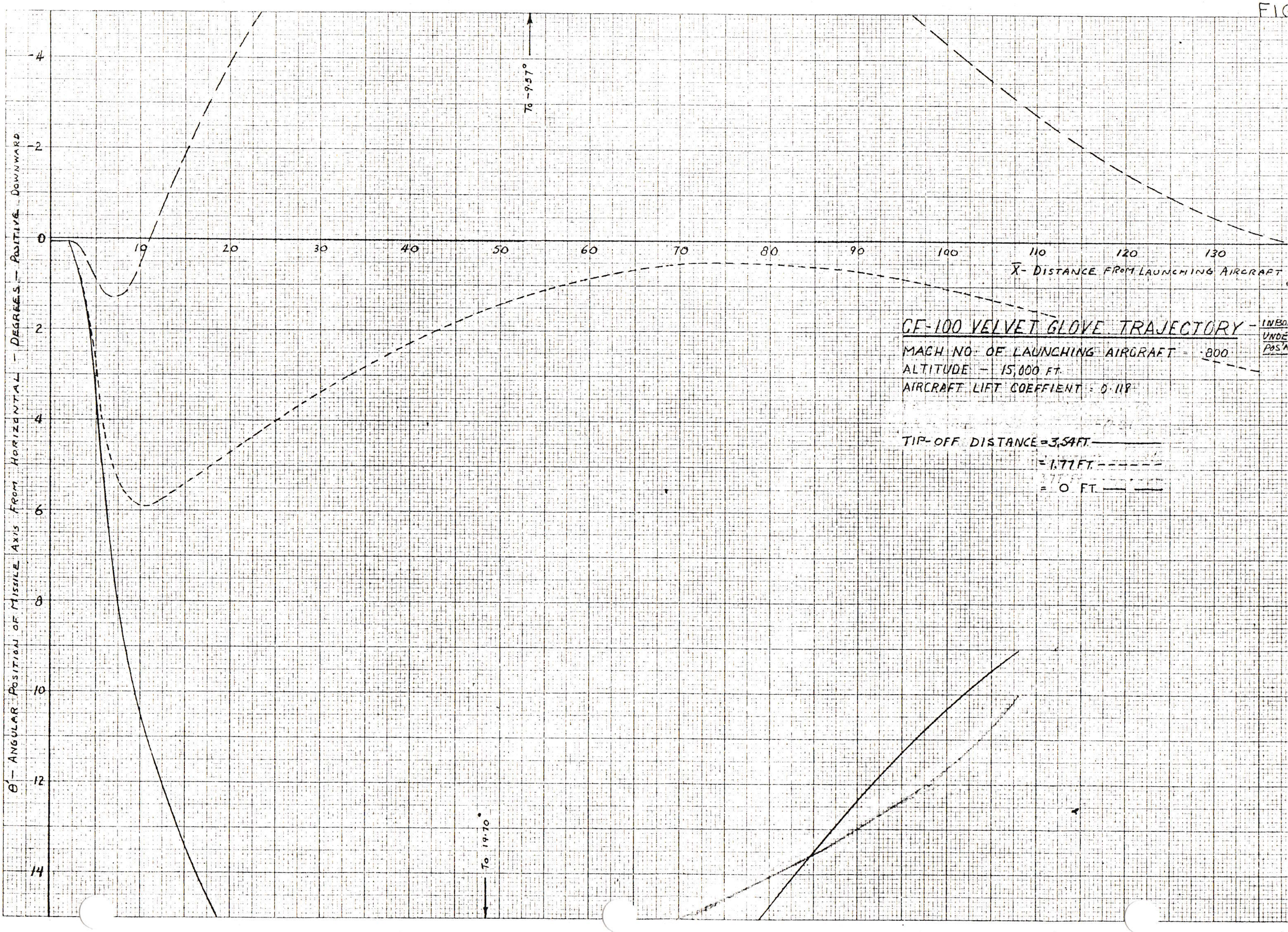


AIRCRAFT AND MISSILE MODELS IN LOW SPEED WIND TUNNEL

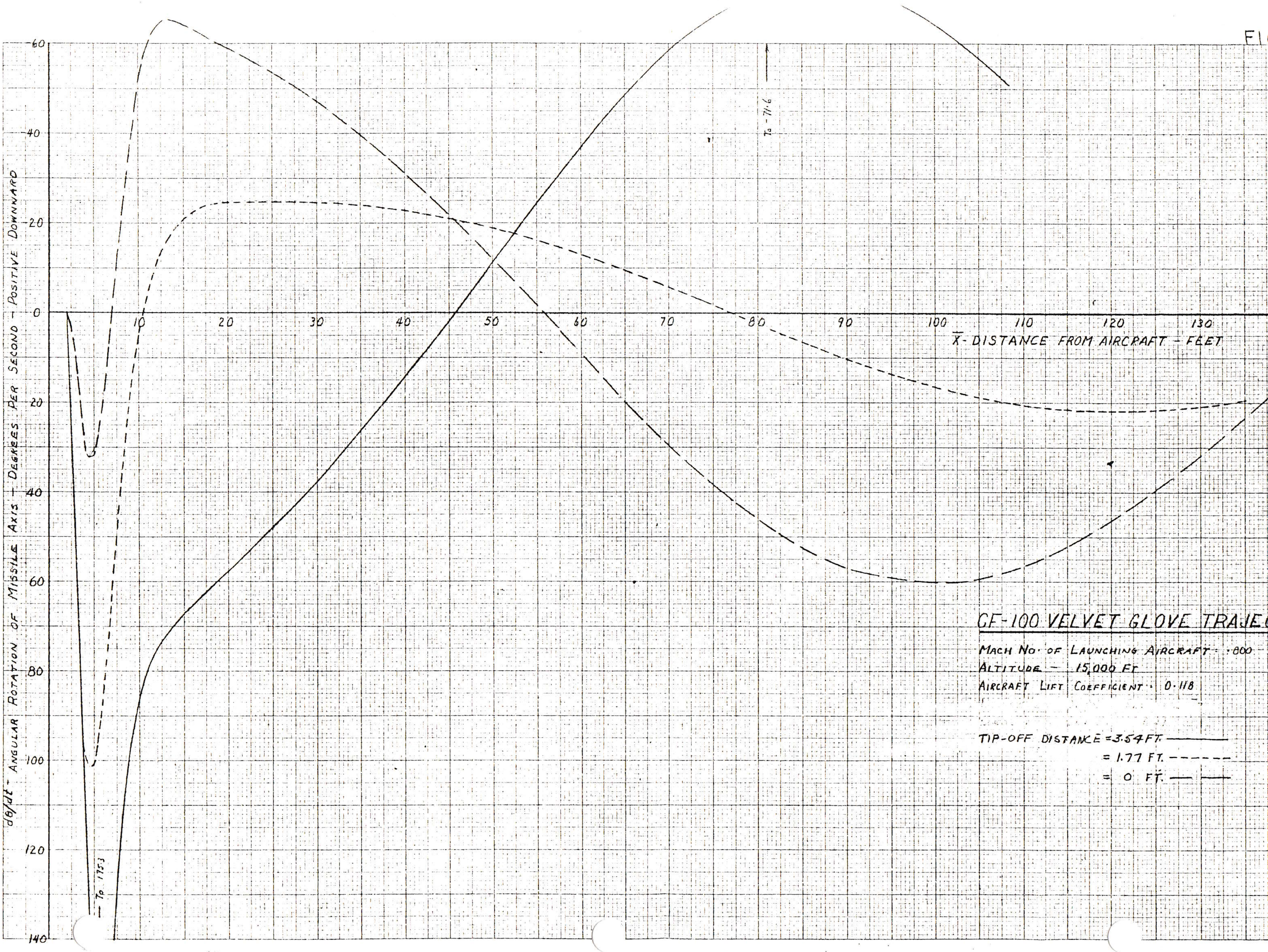
FIG. 3(a)

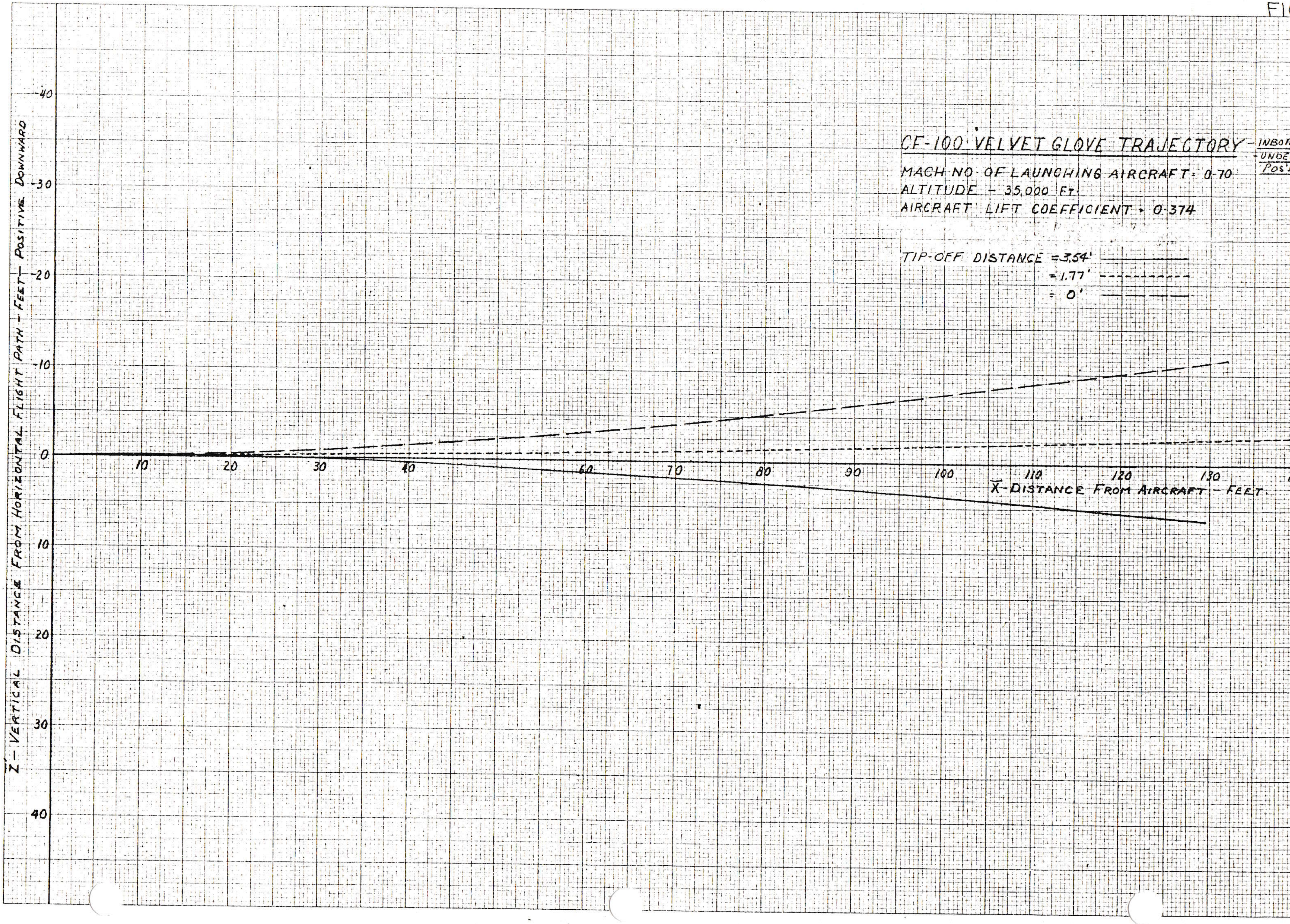


Z - VERTICAL DISTANCE FROM HORIZONTAL FLIGHT PATH - FT. POSITIVE DOWNWARD
-20
-10
0
10
20
30
40
50
60
70
X - DISTANCE FROM AIRCRAFT - FT.
10
20
30
40
50
60
70
80
90
100
110
120
CF-100 VELVET GLOVE TRAJECTORY
MACH No. OF LAUNCHING AIRCRAFT - .800
ALTITUDE - 15,000 FT.
AIRCRAFT LIFT COEFFICIENT - 0.118
TIP-OFF DISTANCE = 3.54 FT.
= 1.77 FT.

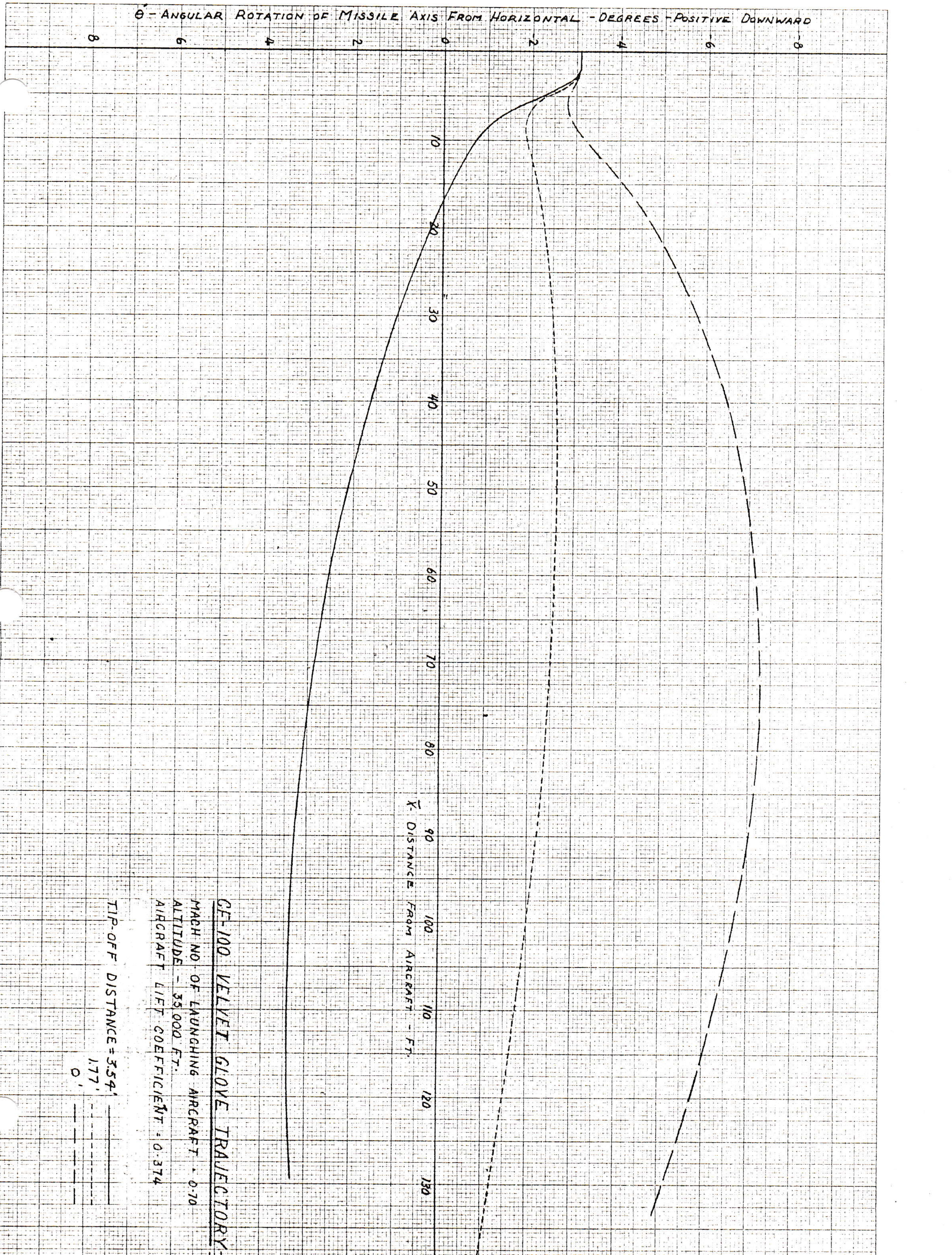


θ' – ANGULAR POSITION OF MISSILE AXIS FROM HORIZONTAL – DEGREES – POSITIVE DOWNWARD
X̄ – DISTANCE FROM LAUNCHING AIRCRAFT
-4
-2
0
2
4
6
8
10
12
14
10
20
30
40
50
60
70
80
90
100
110
120
130
To -9.57°
To 19.70°
CF-100 VELVET GLOVE TRAJECTORY –
MACH NO. OF LAUNCHING AIRCRAFT = .800
ALTITUDE – 15,000 FT.
AIRCRAFT LIFT COEFFIENT = 0.118
TIP-OFF DISTANCE = 3.54 FT.
= 1.77 FT.
= 0 FT.

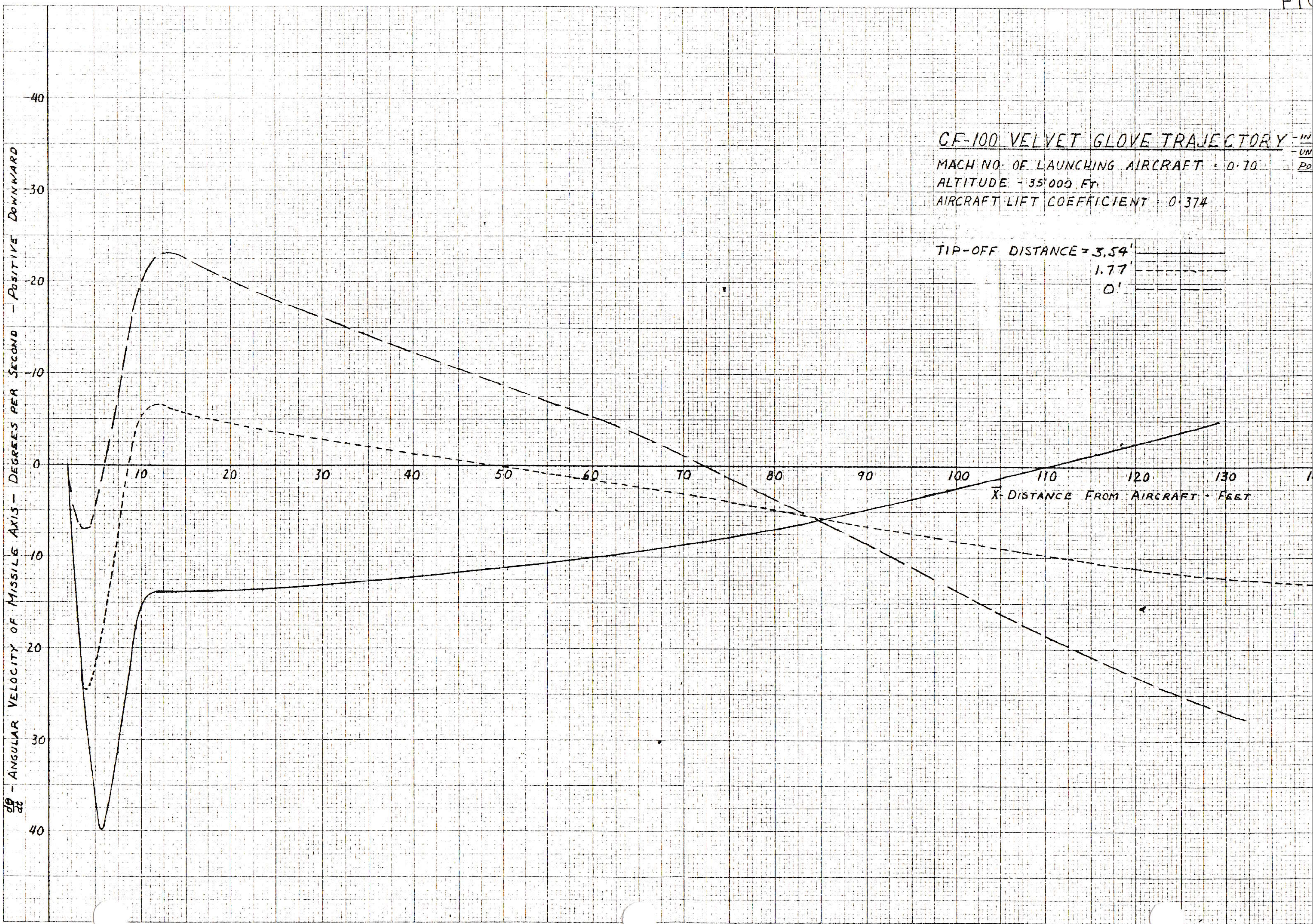

dθ/dt - ANGULAR ROTATION OF MISSILE AXIS - DEGREES PER SECOND - POSITIVE DOWNWARD
X̄ - DISTANCE FROM AIRCRAFT - FEET
To - 71·6
To 175·3
CF-100 VELVET GLOVE TRAJE
MACH No. OF LAUNCHING AIRCRAFT : ·800
ALTITUDE - 15,000 FT
AIRCRAFT LIFT COEFFICIENT : 0·118
TIP-OFF DISTANCE = 3.54 FT.
= 1.77 FT.
= 0 FT.
FI

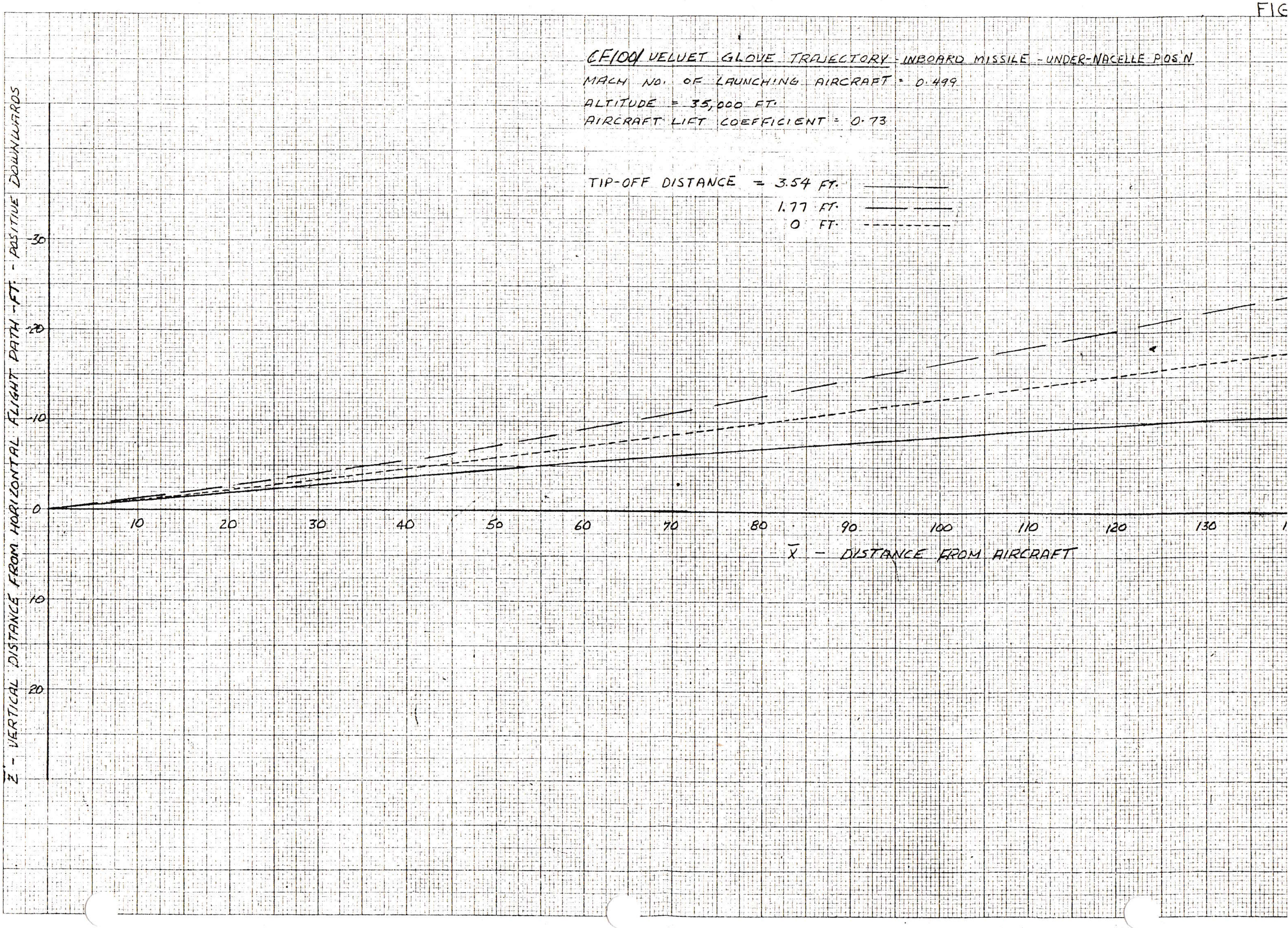


CF-100 VELVET GLOVE TRAJECTORY
MACH NO. OF LAUNCHING AIRCRAFT = 0.70
ALTITUDE – 35,000 FT.
AIRCRAFT LIFT COEFFICIENT = 0.374
TIP-OFF DISTANCE = 3.54'
= 1.77'
= 0'
Z – VERTICAL DISTANCE FROM HORIZONTAL FLIGHT PATH – FEET – POSITIVE DOWNWARD
-40
-30
-20
-10
0
10
20
30
40
10
20
30
40
60
70
80
90
100
110
120
130
X-DISTANCE FROM AIRCRAFT – FEET



θ - ANGULAR ROTATION OF MISSILE AXIS FROM HORIZONTAL - DEGREES - POSITIVE DOWNWARD
8
6
4
2
0
2
4
6
8
10
20
30
40
50
60
70
80
90
100
110
120
130
X̄ DISTANCE FROM AIRCRAFT - FT.
CF-100 VELVET GLOVE TRAJECTORY
MACH NO. OF LAUNCHING AIRCRAFT - 0.70
ALTITUDE - 35,000 FT.
AIRCRAFT LIFT COEFFICIENT - 0.374
TIP-OFF DISTANCE = 3.54'
1.77'
0'


CF-100 VELVET GLOVE TRAJECTORY
MACH NO. OF LAUNCHING AIRCRAFT : 0.70
ALTITUDE - 35'000 FT.
AIRCRAFT LIFT COEFFICIENT : 0.374
TIP-OFF DISTANCE = 3.54'
1.77'
0'
dθ/dt - ANGULAR VELOCITY OF MISSILE AXIS - DEGREES PER SECOND - POSITIVE DOWNWARD
X̄ - DISTANCE FROM AIRCRAFT - FEET
-40
-30
-20
-10
0
10
20
30
40
10
20
30
40
50
60
70
80
90
100
110
120
130



CF100 VELVET GLOVE TRAJECTORY - INBOARD MISSILE - UNDER-NACELLE POS'N
MACH NO. OF LAUNCHING AIRCRAFT = 0.499
ALTITUDE = 35,000 FT.
AIRCRAFT LIFT COEFFICIENT = 0.73
TIP-OFF DISTANCE = 3.54 FT.
1.77 FT.
0 FT.
Z - VERTICAL DISTANCE FROM HORIZONTAL FLIGHT PATH - FT. - POSITIVE DOWNWARDS
30
20
10
0
10
20
10
20
30
40
50
60
70
80
90
100
110
120
130
X - DISTANCE FROM AIRCRAFT

FIG

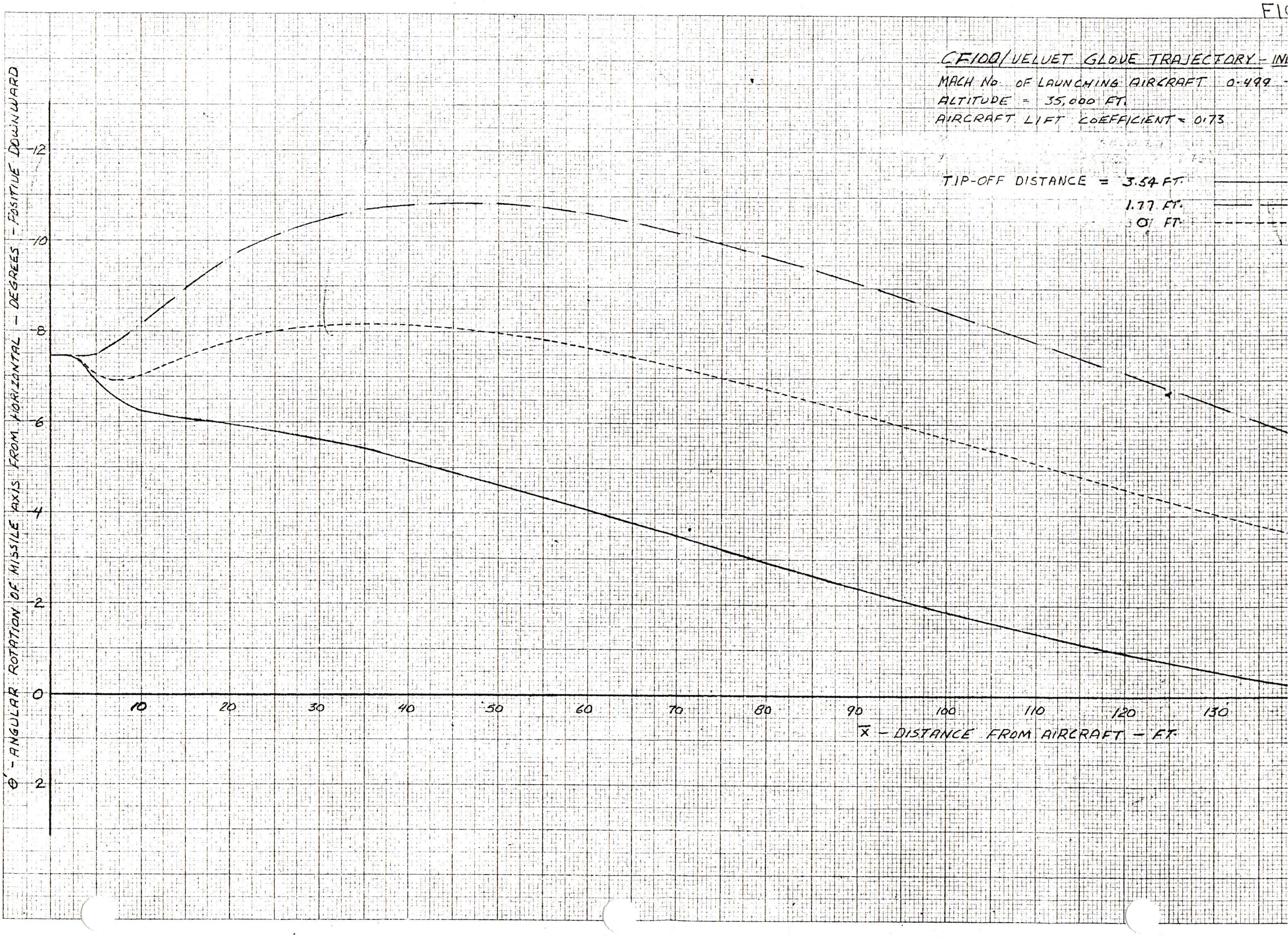
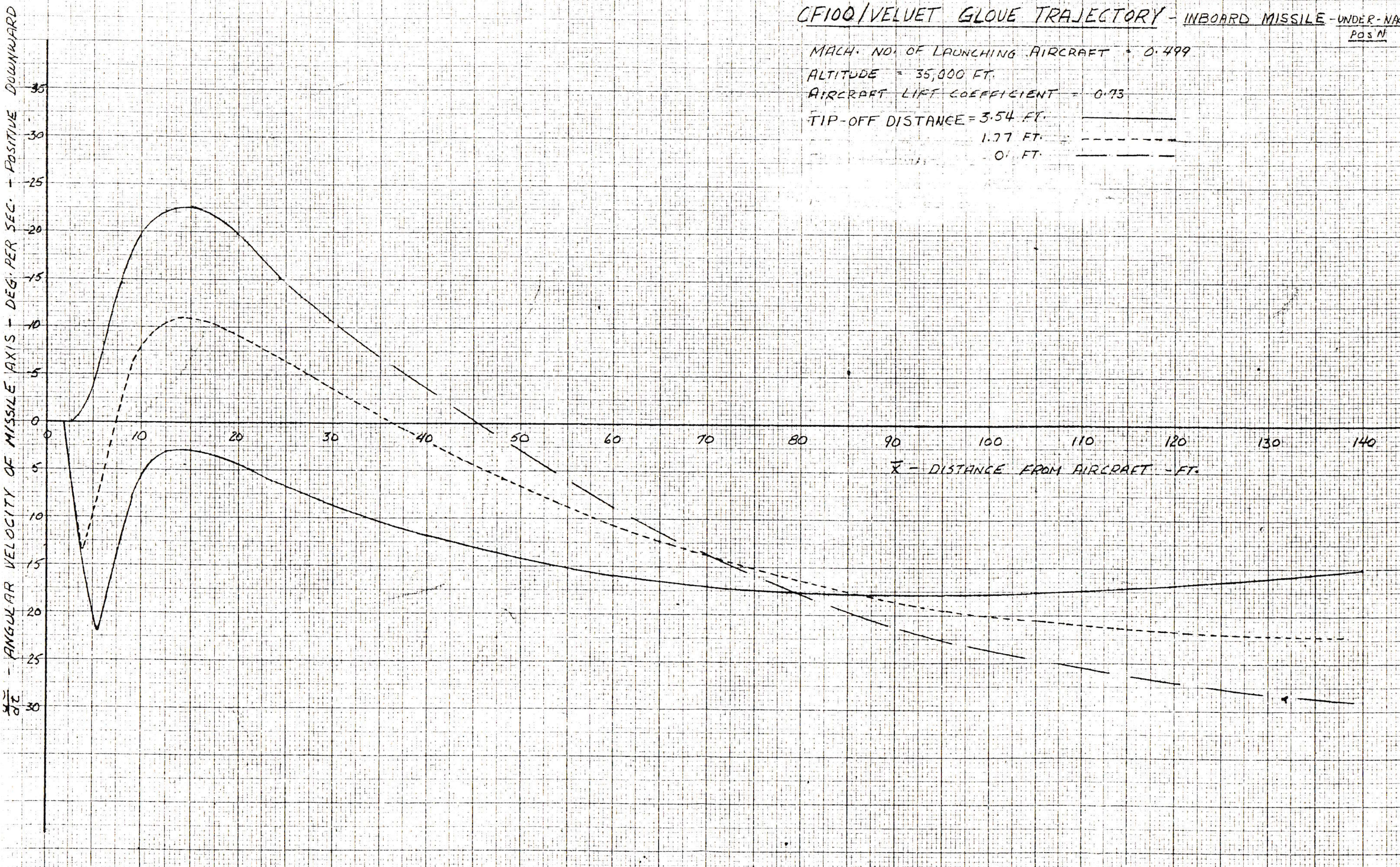
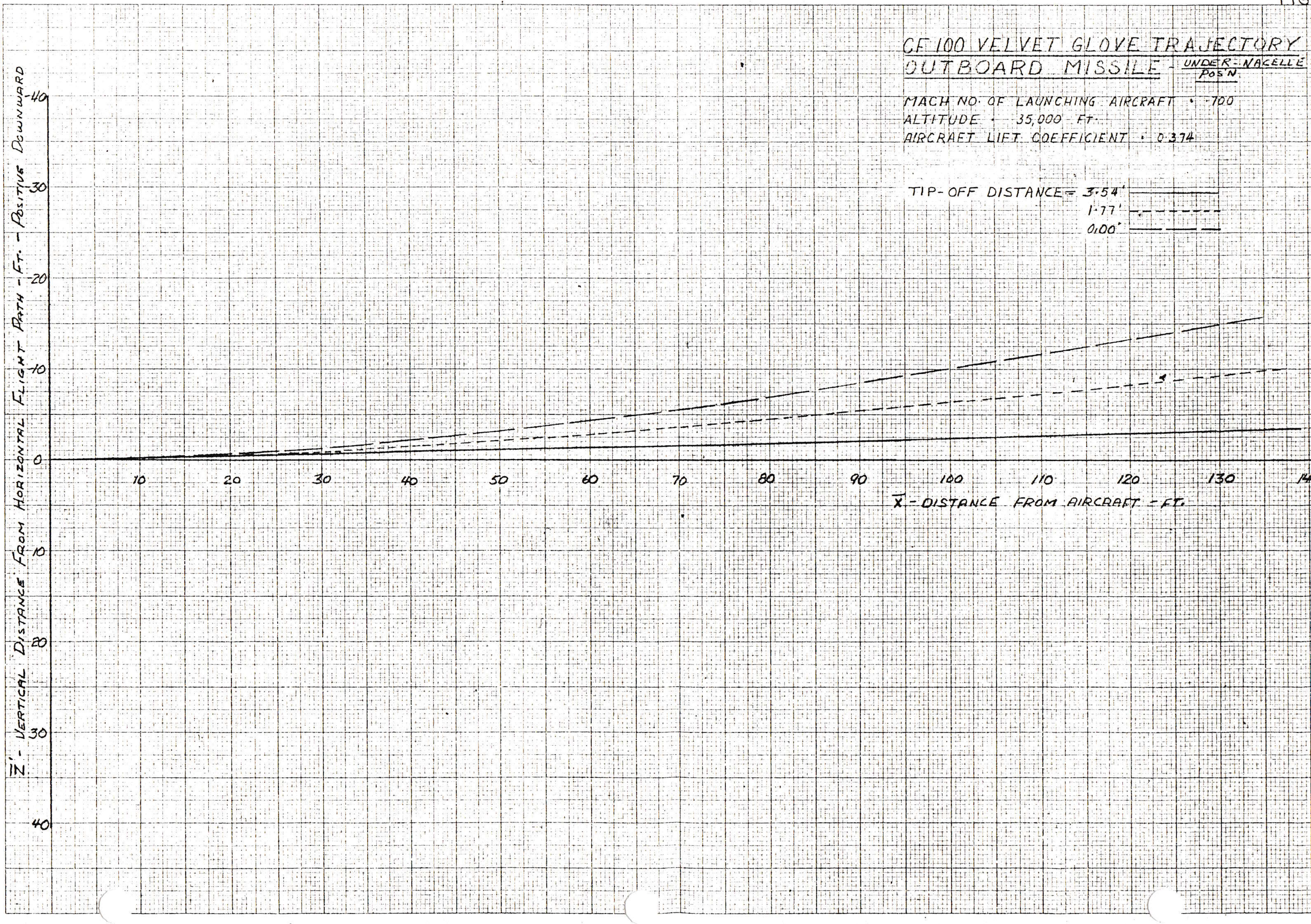

FI
CF100/VELVET GLOVE TRAJECTORY - IN
MACH No. OF LAUNCHING AIRCRAFT 0.499
ALTITUDE = 35,000 FT.
AIRCRAFT LIFT COEFFICIENT = 0.73
TIP-OFF DISTANCE = 3.54 FT.
1.77 FT.
0 FT.
θ' - ANGULAR ROTATION OF MISSILE AXIS FROM HORIZONTAL - DEGREES - POSITIVE DOWNWARD
12
10
8
6
4
2
0
2
10
20
30
40
50
60
70
80
90
100
110
120
130
$\overline{X}$ - DISTANCE FROM AIRCRAFT - FT.

FIG. 5

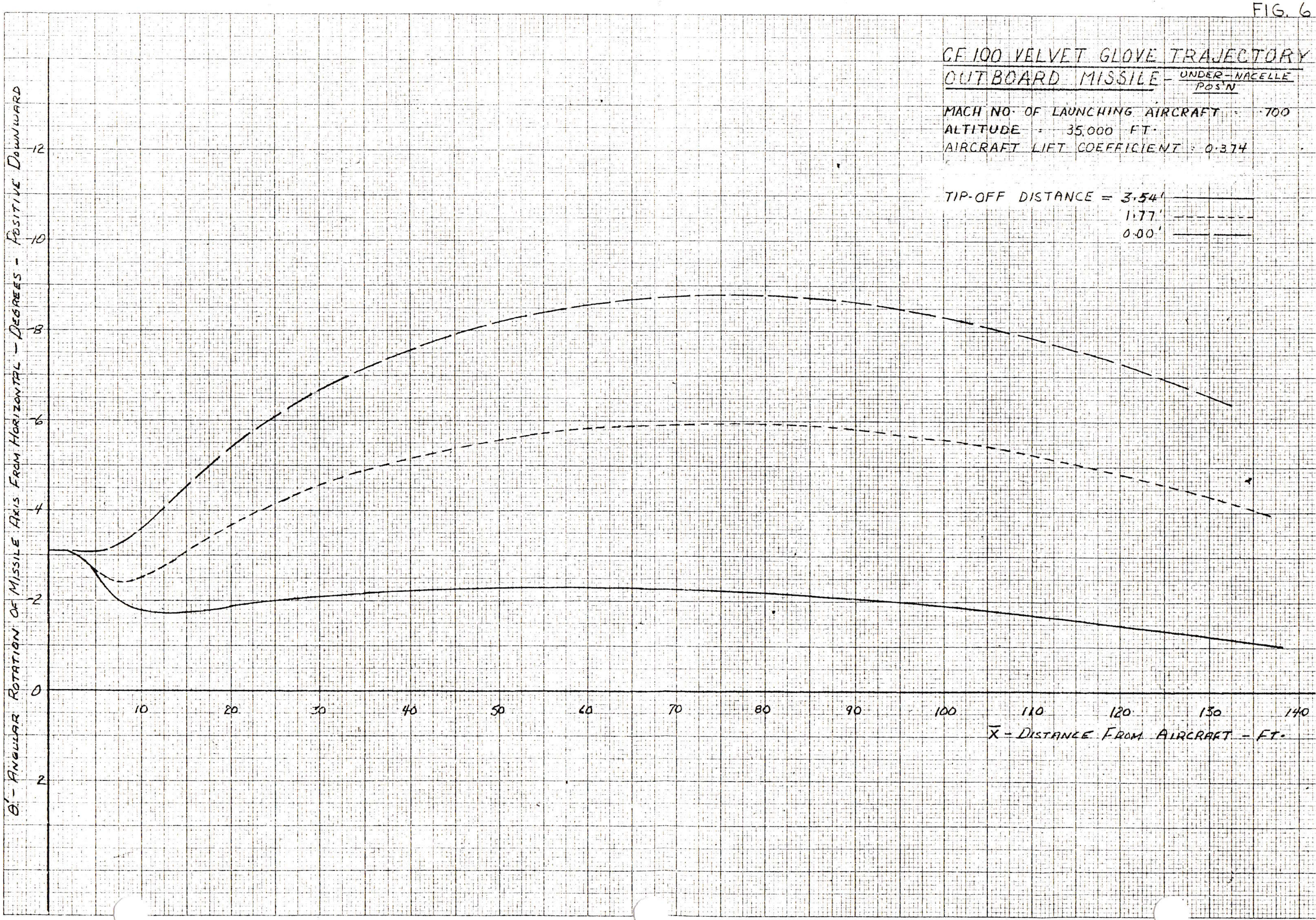


CF100/VELVET GLOVE TRAJECTORY - INBOARD MISSILE - UNDER-NA POS'N
MACH. NO. OF LAUNCHING AIRCRAFT = 0.499
ALTITUDE = 35,000 FT.
AIRCRAFT LIFT COEFFICIENT = 0.73
TIP-OFF DISTANCE = 3.54 FT.
1.77 FT.
0 FT.
- ANGULAR VELOCITY OF MISSILE AXIS - DEG. PER SEC. - POSITIVE DOWNWARD
$\bar{X}$ - DISTANCE FROM AIRCRAFT - FT.


CF 100 VELVET GLOVE TRAJECTORY
OUTBOARD MISSILE - UNDER-NACELLE POS'N.
MACH NO. OF LAUNCHING AIRCRAFT · ·700
ALTITUDE · 35,000 FT.
AIRCRAFT LIFT COEFFICIENT · 0·374
TIP-OFF DISTANCE = 3·54'
1·77'
0.00'
Z̄' - VERTICAL DISTANCE FROM HORIZONTAL FLIGHT PATH - FT. - POSITIVE DOWNWARD
-40
-30
-20
-10
0
10
20
30
40
10
20
30
40
50
60
70
80
90
100
110
120
130
X̄ - DISTANCE FROM AIRCRAFT - FT.

FIG

FIG. 6



CF 100 VELVET GLOVE TRAJECTORY
OUTBOARD MISSILE - UNDER-NACELLE POS'N
MACH NO. OF LAUNCHING AIRCRAFT : .700
ALTITUDE : 35,000 FT.
AIRCRAFT LIFT COEFFICIENT : 0.374
TIP-OFF DISTANCE = 3.54'
1.77'
0.00'
θ' - ANGULAR ROTATION OF MISSILE AXIS FROM HORIZONTAL - DEGREES - POSITIVE DOWNWARD
-12
-10
-8
-6
-4
-2
0
2
10
20
30
40
50
60
70
80
90
100
110
120
130
140
X̄ - DISTANCE FROM AIRCRAFT - FT.

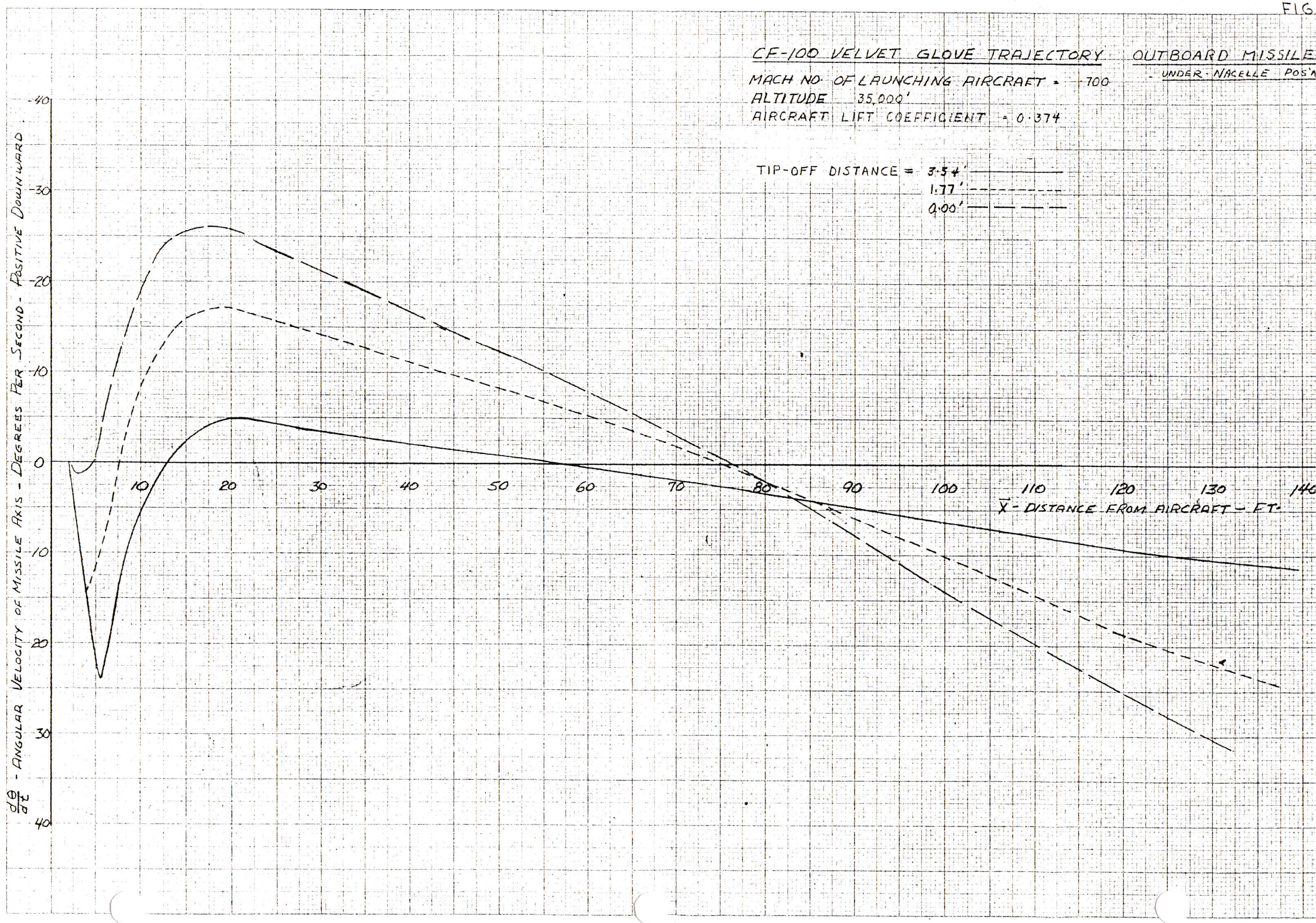


FIG.
CF-100 VELVET GLOVE TRAJECTORY
OUTBOARD MISSILE
- UNDER-NACELLE POS'N
MACH NO. OF LAUNCHING AIRCRAFT = .700
ALTITUDE 35,000'
AIRCRAFT LIFT COEFFICIENT = 0.374
TIP-OFF DISTANCE = 3.54'
1.77'
0.00'
dθ/dt - ANGULAR VELOCITY OF MISSILE AXIS - DEGREES PER SECOND - POSITIVE DOWNWARD.
-40
-30
-20
-10
0
10
20
30
40
10
20
30
40
50
60
70
80
90
100
110
120
130
140
X̄ - DISTANCE FROM AIRCRAFT - FT.

FIG. 7

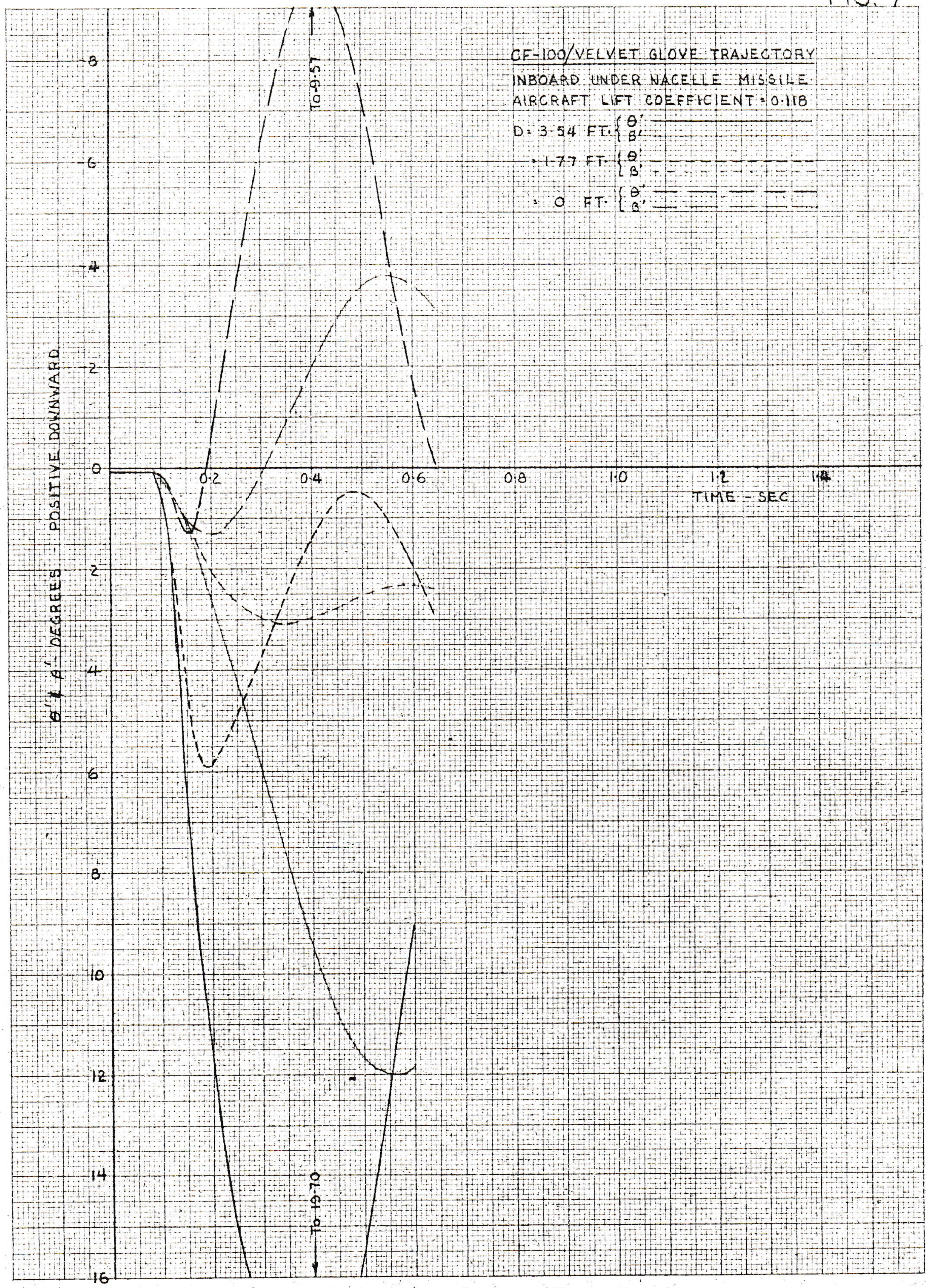
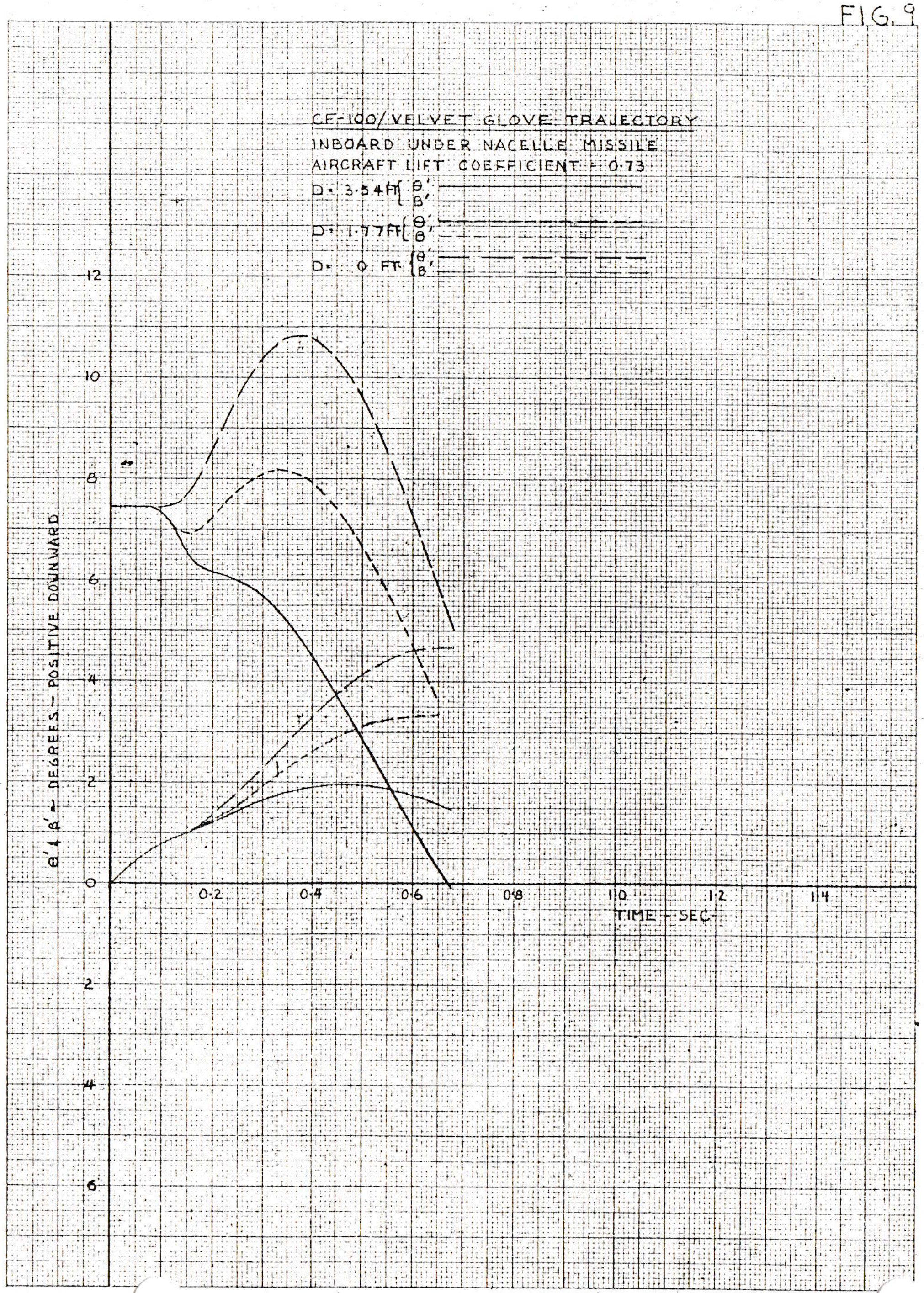
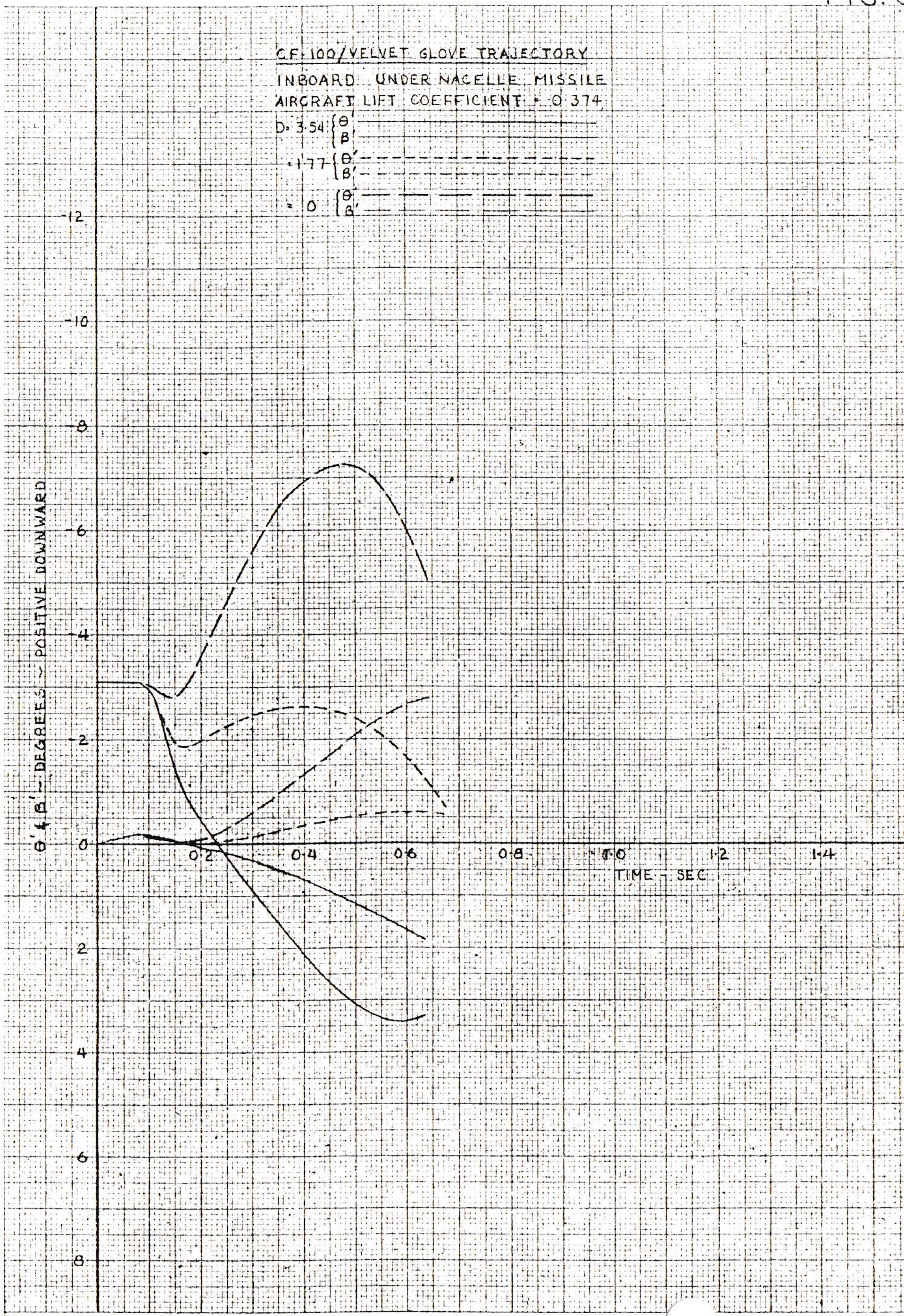

CF-100/VELVET GLOVE TRAJECTORY
INBOARD UNDER NACELLE MISSILE
AIRCRAFT LIFT COEFFICIENT: 0·118
D: 3·54 FT. { θ' β'
= 1·77 FT. { θ' β'
= 0 FT. { θ' β'
To 9·57
To 19·70
θ' & β' DEGREES - POSITIVE DOWNWARD
TIME - SEC
8
6
4
2
0
2
4
6
8
10
12
14
16
0·2
0·4
0·6
0·8
1·0
1·2
1·4

FIG. 9



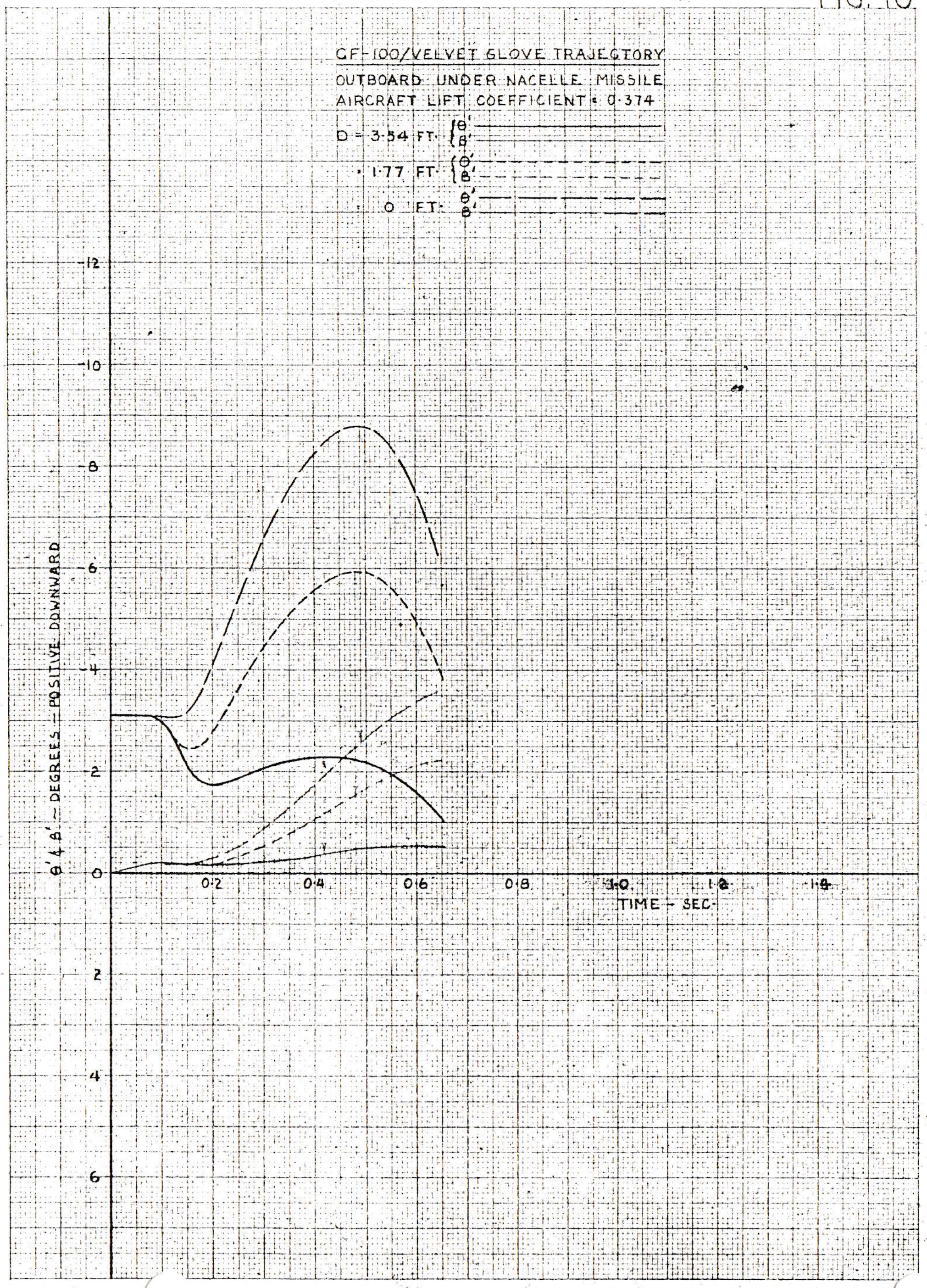
CF-100/VELVET GLOVE TRAJECTORY
INBOARD UNDER NACELLE MISSILE
AIRCRAFT LIFT COEFFICIENT = 0·73
D = 3·54 FT {θ' B'
D = 1·77 FT {θ' B'
D = 0 FT {θ' B'
θ' & B' – DEGREES – POSITIVE DOWNWARD
TIME – SEC

FIG. 8



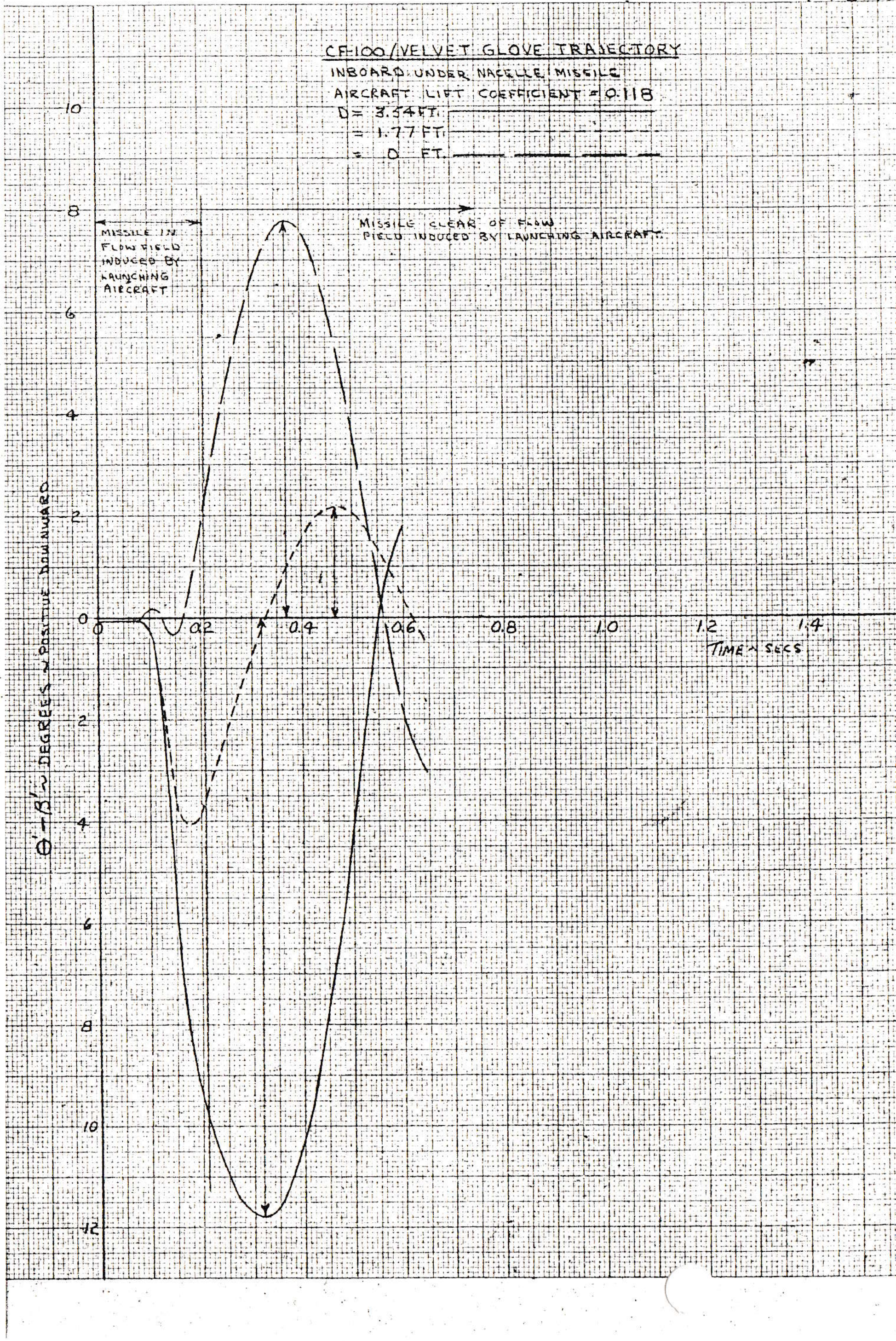
CF-100/VELVET GLOVE TRAJECTORY
INBOARD UNDER NACELLE MISSILE
AIRCRAFT LIFT COEFFICIENT = 0·374
D = 3·54 {θ' B'
= 1·77 {θ' B'
= 0 {θ' B'
θ' & B' – DEGREES – POSITIVE DOWNWARD
TIME – SEC

FIG. 10



CF-100/VELVET GLOVE TRAJECTORY
OUTBOARD UNDER NACELLE MISSILE
AIRCRAFT LIFT COEFFICIENT = 0·374
D = 3·54 FT. θ' β'
1·77 FT. θ' β'
0 FT. θ' β'
θ' & β' – DEGREES – POSITIVE DOWNWARD
TIME – SEC.

FIG. 11



CF-100/VELVET GLOVE TRAJECTORY
INBOARD UNDER NACELLE MISSILE
AIRCRAFT LIFT COEFFICIENT = 0.118
D = 3.54 FT.
= 1.77 FT.
= 0 FT.
MISSILE IN FLOW FIELD INDUCED BY LAUNCHING AIRCRAFT
MISSILE CLEAR OF FLOW FIELD INDUCED BY LAUNCHING AIRCRAFT
θ' – β' ~ DEGREES ~ POSITIVE DOWNWARD
TIME ~ SECS

FIG. 12

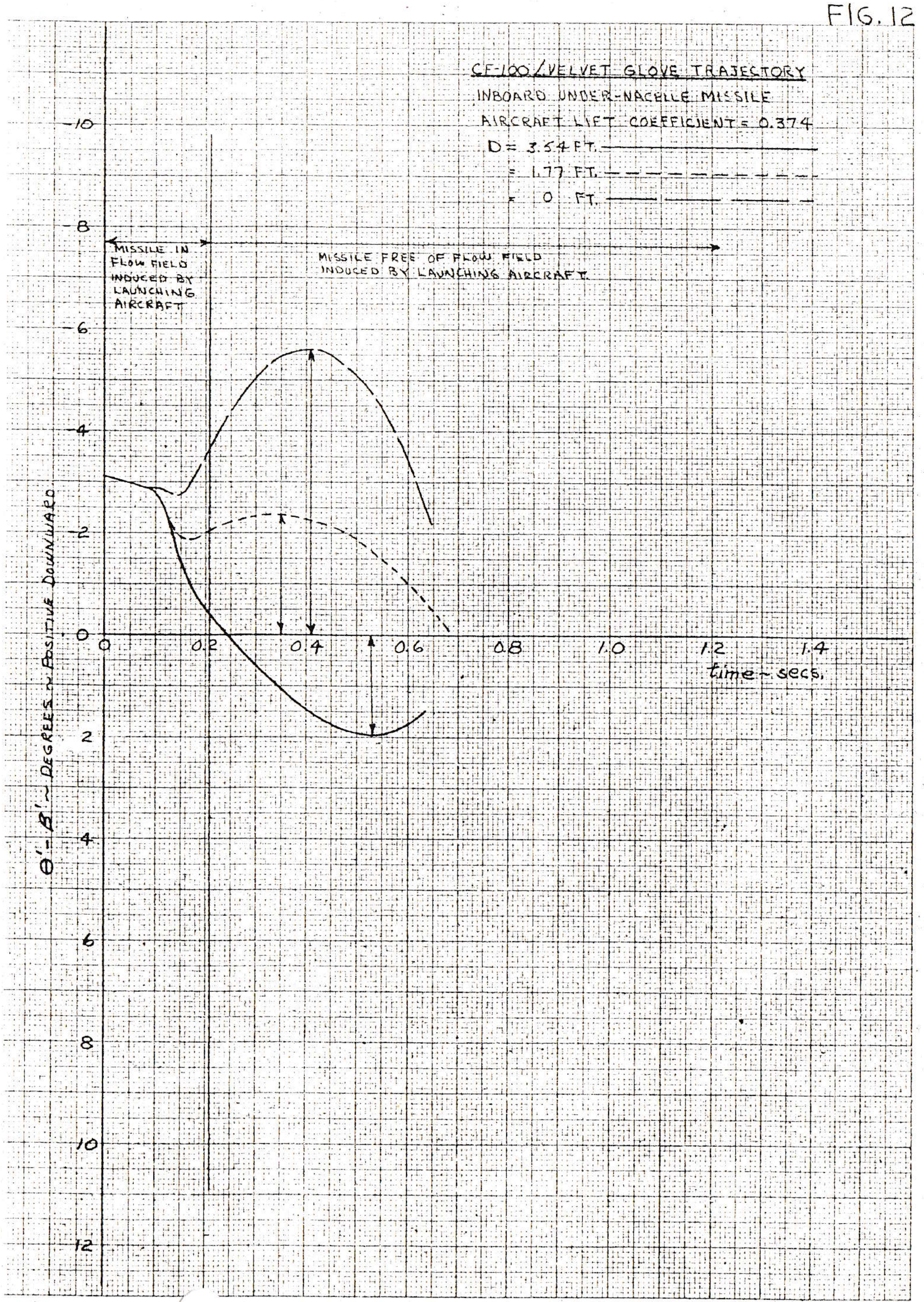
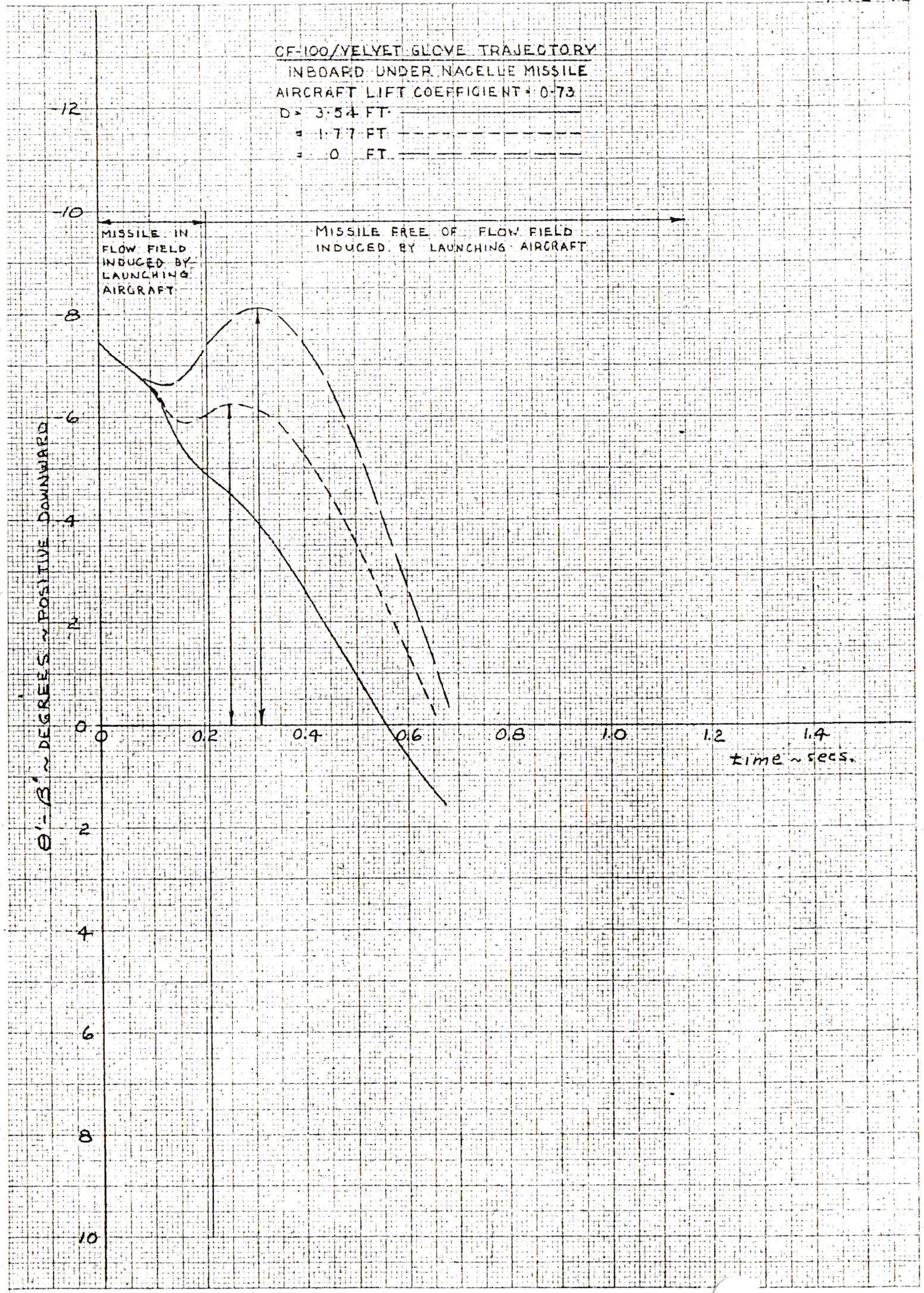

CF-100/VELVET GLOVE TRAJECTORY
INBOARD UNDER-NACELLE MISSILE
AIRCRAFT LIFT COEFFICIENT = 0.374
D = 3.54 FT.
= 1.77 FT.
= 0 FT.
MISSILE IN FLOW FIELD INDUCED BY LAUNCHING AIRCRAFT
MISSILE FREE OF FLOW FIELD INDUCED BY LAUNCHING AIRCRAFT
θ' - β' ~ DEGREES ~ POSITIVE DOWNWARD
time ~ secs.
-10
-8
-6
-4
-2
0
2
4
6
8
10
12
0.2
0.4
0.6
0.8
1.0
1.2
1.4

FIG. 13


CF-100/VELVET GLOVE TRAJECTORY
INBOARD UNDER NACELLE MISSILE
AIRCRAFT LIFT COEFFICIENT = 0.73
D = 3.54 FT.
= 1.77 FT.
= 0 FT.
MISSILE IN FLOW FIELD INDUCED BY LAUNCHING AIRCRAFT
MISSILE FREE OF FLOW FIELD INDUCED BY LAUNCHING AIRCRAFT
θ' - β' ~ DEGREES ~ POSITIVE DOWNWARD
time ~ secs.
-12
-10
-8
-6
-4
-2
0
2
4
6
8
10
0.2
0.4
0.6
0.8
1.0
1.2
1.4

FIGS. 15 & 16

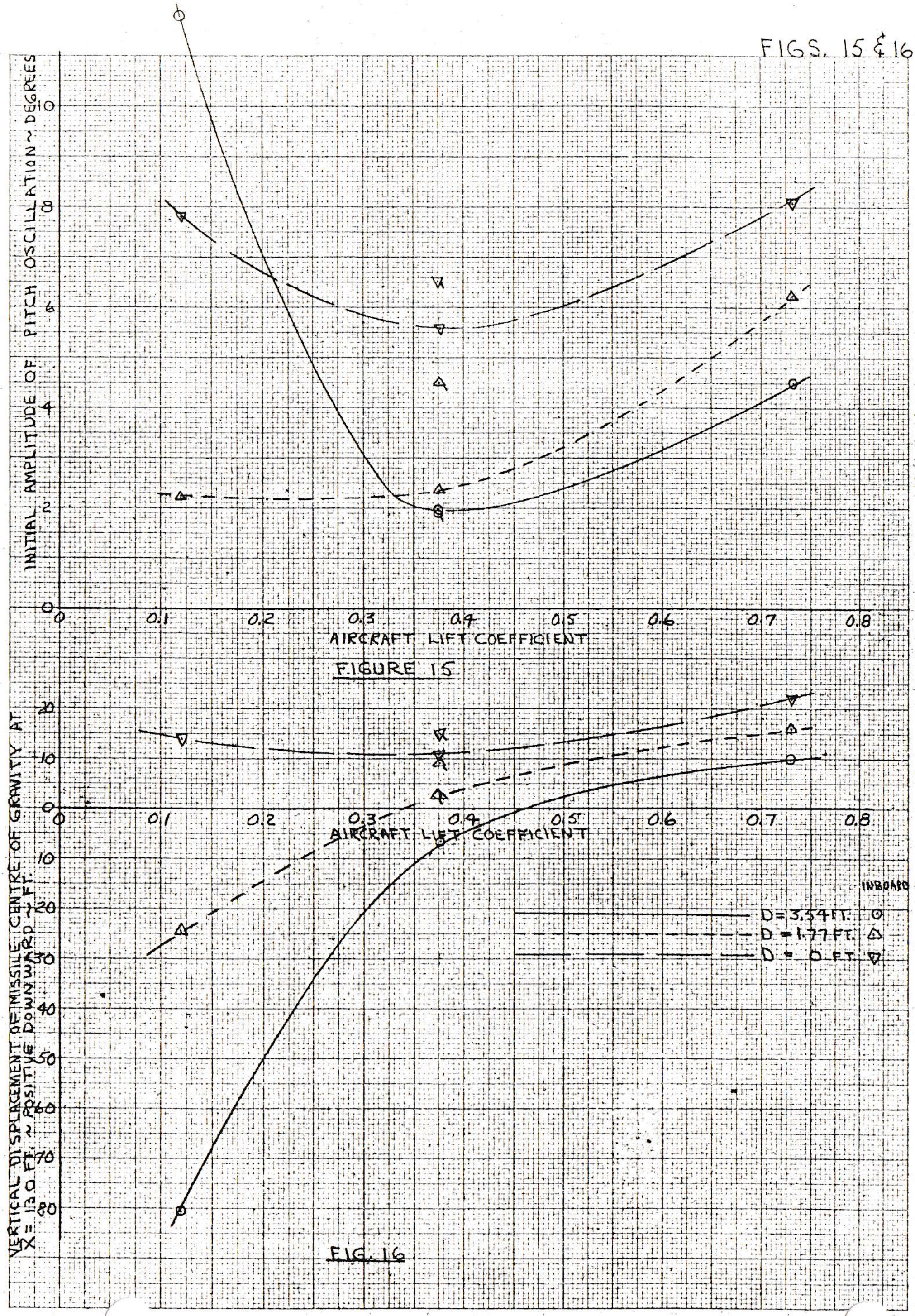


FIGURE 15

FIG. 16

FIG. 14