TECHNICAL REPORT
69-15-AD (EK-3841)

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AAI Corporation
COCKEYSVILLE, MARYLAND
formerly Aircraft Armaments, Inc.

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**AIRCRAFT ARMAMENTS, Inc.**

PHASE I REPORT

GROUND SLIDE AIRDROP STUDY

ADDENDUM

TECHNICAL REPORT 69-15-AD (ER-3841)

REPORT NO.

August 1966

DATE

R. C. Wible, Project Engineer

J. E. Foster, Project Manager

AAINC E 138A

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# I. INTRODUCTION

This writing is continuation of the Phase I Report of the Ground Slide Airdrop Study, ER-3841. AAI has performed this study under Contract No. DA-19-129-AMC-337(N) from the U. S. Army Natick Laboratories. The specific object of this report is to present the findings of the Exploratory Test Phase, Phase II, and compare these actual findings to those predicted by the analysis presented in the Study Phase, Phase I. Also included in this report are all changes, deletions, and revisions to be incorporated in the preliminary design specifications of the Phase I report.

The actual findings were acquired from tests performed at Fort Bragg, North Carolina. These tests were conducted by AAI in conjunction with the U. S. Army Field Test Team. The test description and test program is explained in the Report of Exploratory Test Program, ER-4356. Figures 1, 2, 3, 4, and 5 show a typical drop sequence from an actual test. Table 1 lists tests with the associated test conditions.

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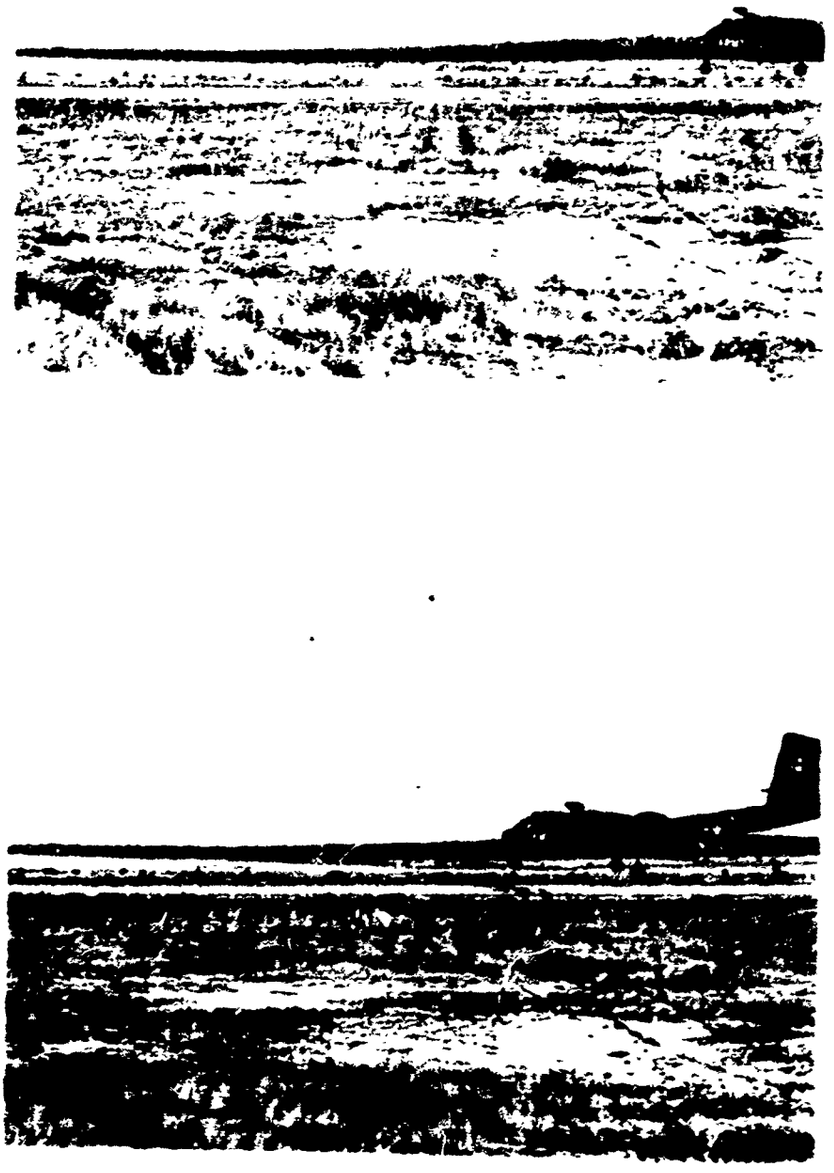

FIGURE 1

FIGURE 2

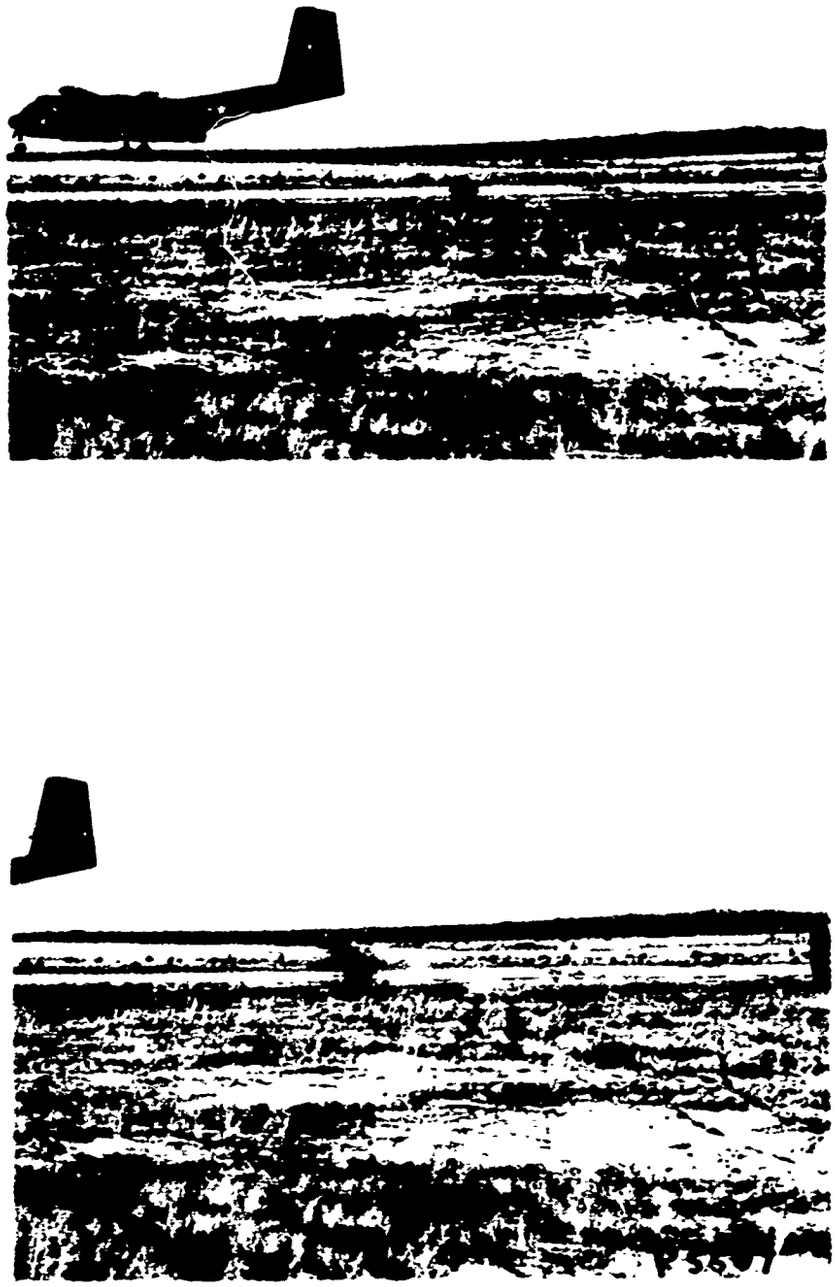

FIGURE 3

FIGURE 4

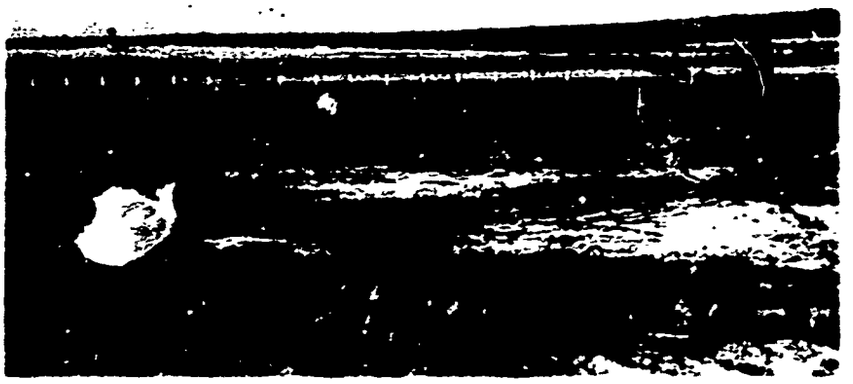

FIGURE 5

AIRCRAFT ARMAMENTS, Inc.

TAB

TEST SC

| Type of Test | Test no. | Ground (hard-smooth)(s) Surface (soft-uneven)(u) | Aircraft Speed (knot) (IAS) | Aircraft Heading (Deg.) Nominal | Platform Length (ft) | Aft Restraint Force (lbs) | Cargo Weight (lbs) | Ring Slot Extraction Chute Size (ft) | Riser Extension Length (ft) |
|---|---|---|---|---|---|---|---|---|---|
| Smooth, hard surface | 1 | S | 90 | 030 | 9 | 4500 | 3950 | 22 | 60 |
| | 2 | S | 90 | 030 | 9 | 4500 | 3950 | 22 | 60 |
| Uneven, soft surface | 3 | U | 85 | 005 | 9 | 4500 | 3950 | 22 | 60 |
| | 4 | U | 85 | 005 | 9 | 4500 | 3950 | 22 | 60 |
| Maximum Extraction Acceleration | 5 | U | 80 | 005 | 9 | 2000 | 1850 | 15 | 60 |
| Minimum Extraction Acceleration | 6 | U | 90 | 005 | 9 | 2000 | 3000 | 15 | 60 |
| Extraction Point Misaligned | 7 | U | 90 | 005 | 9 | 4500 | 3780 | 22 | 60 |
| Extreme C.G. Location | 8 | U | 85 | 005 | 9 | 4500 | 3780 | 22 | 60 |
| Combination of #7 & #8 | 9 | U | 90 | 005 | 9 | 4500 | 3780 | 22 | 60 |
| Extraction Point Misaligned | 10 | U | 85 | 005 | 9 | 4500 | 3780 | 22 | 60 |
| Less Severe #10 | 11 | U | 80 | 005 | 9 | 4500 | 3780 | 22 | 60 |
| Repeat of #1 | 12 | S | 90 | 005 | 9 | 4500 | 3780 | 22 | 60 |
| Extreme Forward End Down Condition | 13 | U | 90 | 005 | 9 | 4500 | 3780 | 22 | 60 |
| Extreme Aft End Down Condition | 14 | U | 100 | 005 | 9 | 4500 | 3780 | 22 | 60 |
| Repeat of #7 | 15 | U | 90 | 005 | 9 | 4500 | 3780 | 22 | 60 |

A

AAI 8178

TABLE 1

TEST SCHEDULE

| Chute Size (ft) | Riser Extension Length (ft) | Extraction Distance (ft) | Extraction Point a Distance (in.) | Extraction Point b Distance (in.) | Extraction Point c Distance (in.) | C.G. d Distance (in.) | C.G. e Distance (in.) | C.G. f Distance (in.) | Cargo Length (ft) | Cargo Height (ft) | Cargo Width (ft) | Wind Velocity (knots) | Wind Heading (Deg.) | Drop Zone Heading (deg.) | Platform(all alum)(A) Type(wood & alum) (W) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 60 | 22 | 54 | 0 | 1.4 | 0 | 0 | 24.3 | 7.5 | 3 | 5 | 8 | 300 | 030 | A |
| | 60 | 22 | 54 | 0 | 1.4 | 0 | 0 | 24.3 | 7.5 | 3 | 5 | 0 | 0 | 030 | A |
| | 60 | 22 | 54 | 0 | 1.4 | 0 | 0 | 24.3 | 7.5 | 3 | 5 | 0 | 180 | 005 | A |
| | 60 | 22 | 54 | 0 | 1.4 | 0 | 0 | 24.3 | 7.5 | 3 | 5 | 5 | 290 | 005 | A |
| | 60 | 22 | 54 | 0 | -1.3 | 0 | 0 | 23.5 | 7.5 | 3.1 | 5 | 8-10 | 230 | 005 | A |
| | 60 | 22 | 54 | 0 | 0 | 0 | 0 | 25.0 | 7.5 | 2.8 | 5 | 4-6 | 80 | 005 | A |
| | 60 | 22 | 54 | 0 | 5.0 | 0 | 0 | 24.0 | 7.5 | 2.3 | 5 | 11-14 | 90 | 005 | W |
| | 60 | 22 | 54 | 0 | 1.0 | 5.0 | 0 | 24.0 | 7.5 | 2.3 | 5 | 10 | 130 | 005 | W |
| | 60 | 22 | 54 | 0 | 7.0 | 5.0 | 0 | 24.0 | 7.5 | 2.3 | 5 | 10 | 190 | 005 | W |
| | 60 | 22 | 54 | 10.25 | 0 | 0 | 0 | 24.0 | 7.5 | 2.3 | 5 | 2 | 265 | 005 | W |
| | 60 | 22 | 54 | 5.00 | 0 | 0 | 0 | 24.0 | 7.5 | 2.3 | 5 | 8-10 | 40 | 005 | W |
| | 60 | 22 | 54 | 0 | 0 | 0 | 0 | 24.0 | 7.5 | 2.3 | 5 | 3-6 | 90 | 005 | W |
| | 60 | 22 | 64 | 0 | 3.0 | 10 | 0 | 24.0 | 7.5 | 2.3 | 5 | 6-9 | 330 | 005 | W |
| | 60 | 22 | 44 | 0 | 9.0 | -10 | 0 | 24.0 | 7.5 | 2.3 | 5 | 7-11 | 310 | 005 | W |
| | 60 | 22 | 54 | 0 | 5.0 | 0 | 0 | 24 | 7.5 | 2.3 | 5 | 3-5 | 190 | 005 | W |

B

## II. PRESENTATION OF RESULTS

### A. General

The results of the test program and the corresponding computer analysis for each test are presented in this section. These results are presented, for ease of handling, in three phases, i.e., Extraction and Tip-off, Descent, and Ground Impact.

In each case the actual test conditions were used as inputs to the computer program and the computed values of velocity, time, distance, etc. are compared with the actual values. In general, the tests values and the computed values are in close agreement. The discrepancies that do occur can be attributed to (1) the inability of the equations of motion to account for all actual happenings such as initial cargo jerk due to restraint strap break and cargo angular acceleration after tip-off induced by aircraft pitching and (2) the inability to select the inputs for the computer with a high degree of accuracy.

Drop No. 2 will not be presented because of camera failure.

### B. Extraction Phase

The time-displacement recorder was used to monitor the relative velocity of the cargo with respect to the aircraft, during the extraction phase. The data obtained was reduced to velocity-versus-time curves. Figures 6 through 19 show plots comparing these actual curves to the curves predicted by the computer analysis. Drop Nos. 1, 4 and 7 are incomplete due to lack of test data.

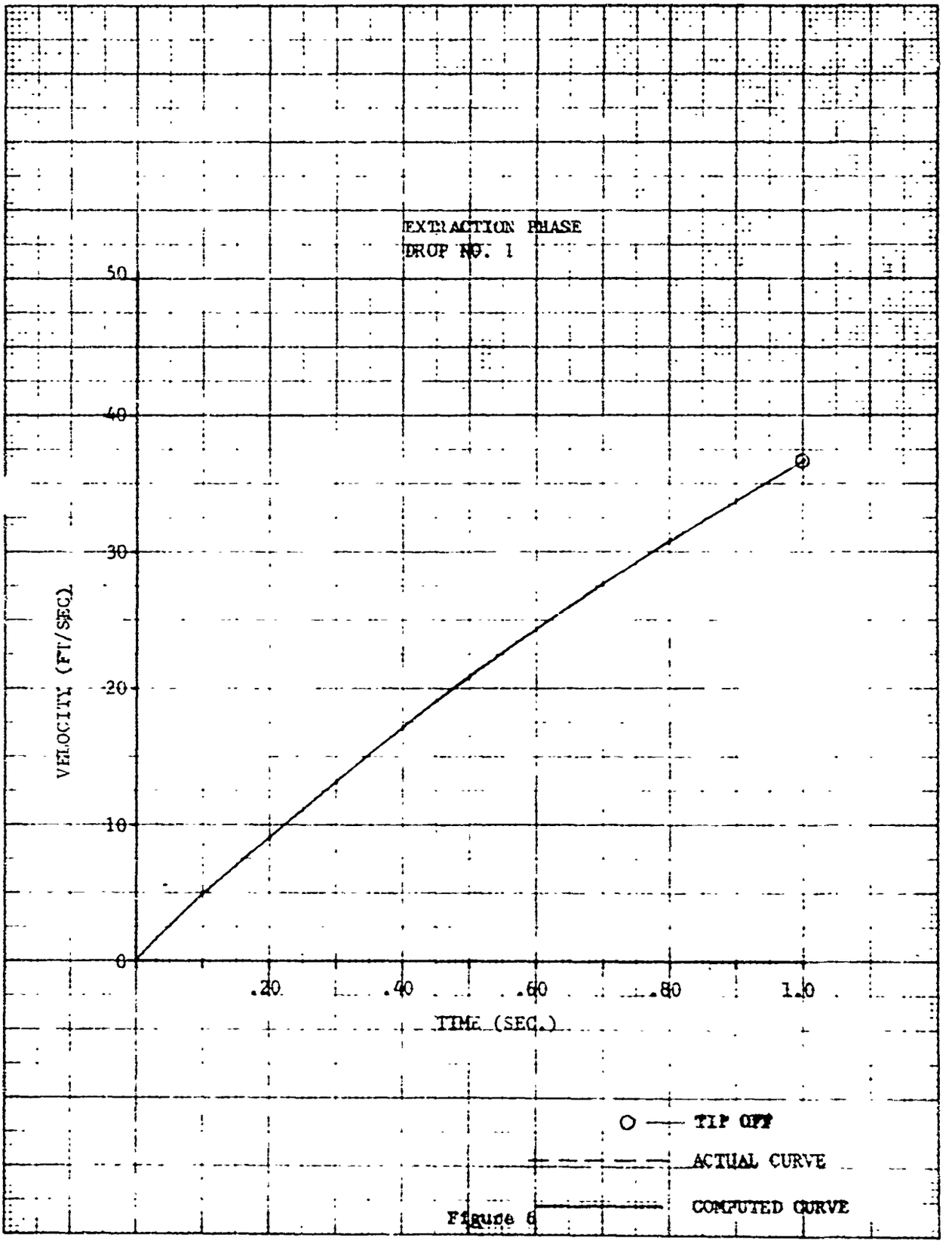
EXTRACTION PHASE
DROP NO. 1
50
40
30
20
10
0
VELOCITY (FT/SEC)
.20
.40
.60
.80
1.0
TIME (SEC.)
TIP OFF
ACTUAL CURVE
COMPUTED CURVE

Figure 6

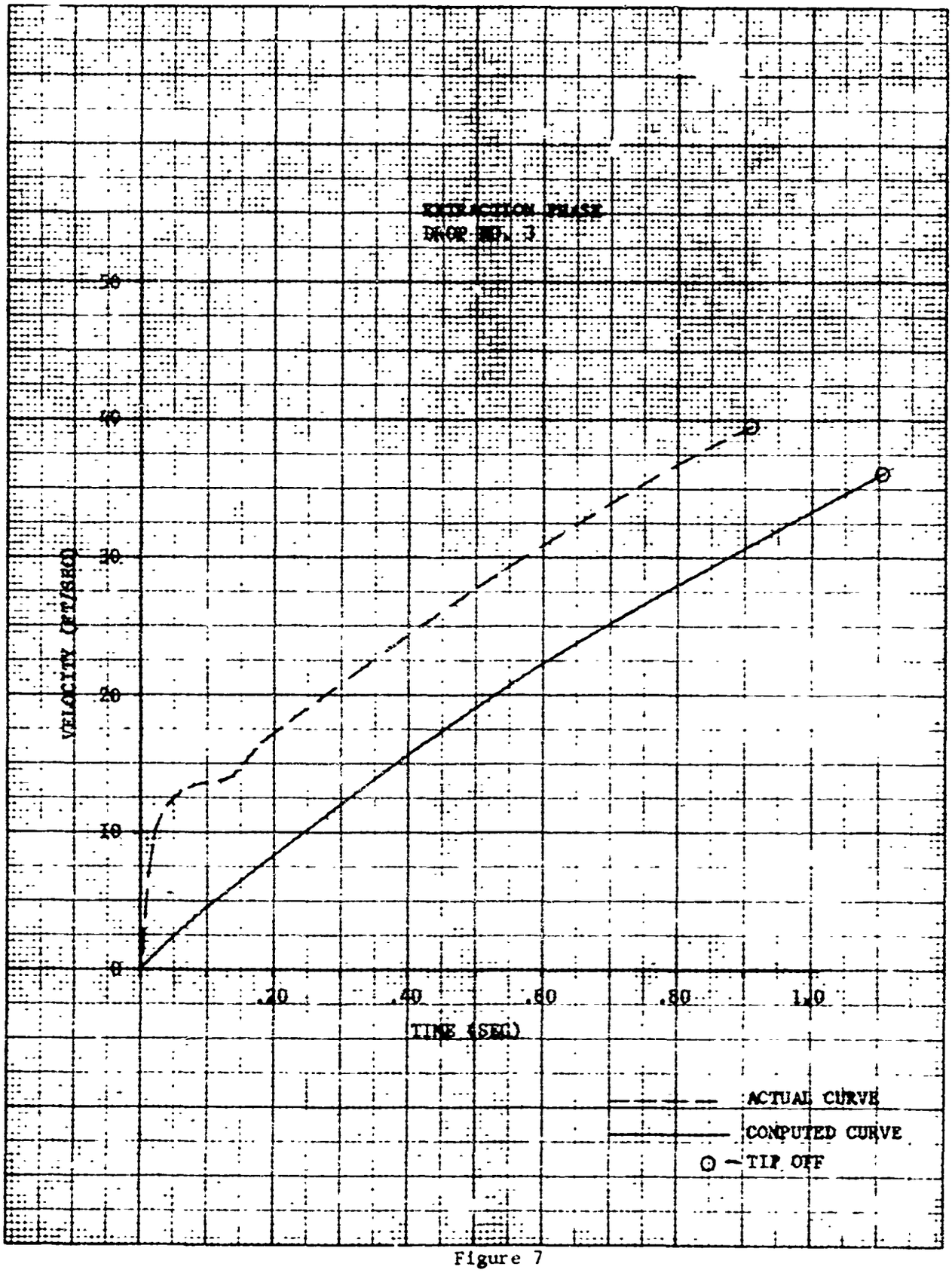
EXTRACTION PHASE
DROP NO. 3
VELOCITY (FT/SEC)
50
40
30
20
10
0
.20
.40
.60
.80
1.0
TIME (SEC)
ACTUAL CURVE
COMPUTED CURVE
TIP OFF

Figure 7

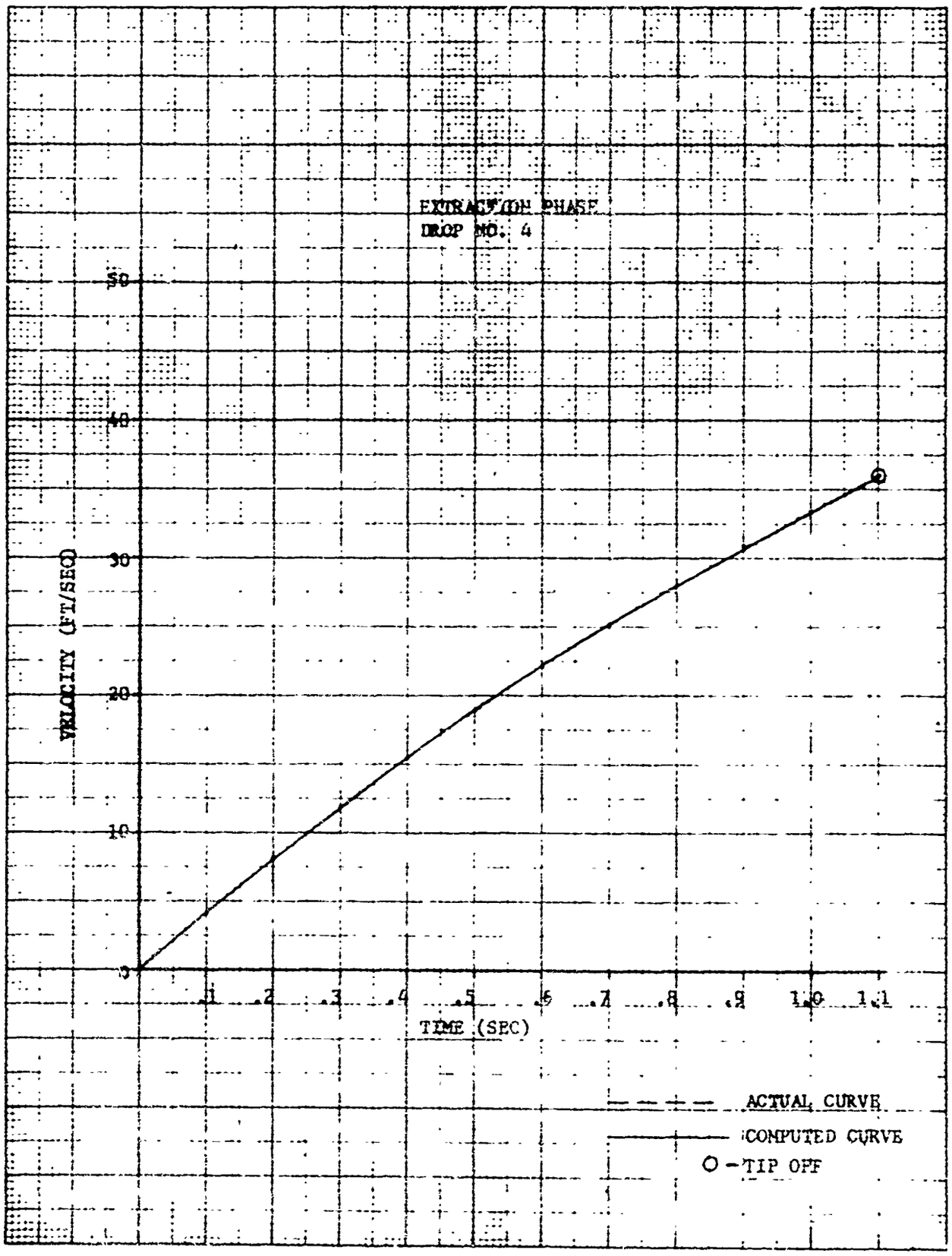
EXTRACTION PHASE
DROP NO. 4
VELOCITY (FT/SEC)
50
40
30
20
10
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
1.1
TIME (SEC)
ACTUAL CURVE
COMPUTED CURVE
O - TIP OFF

Figure 8

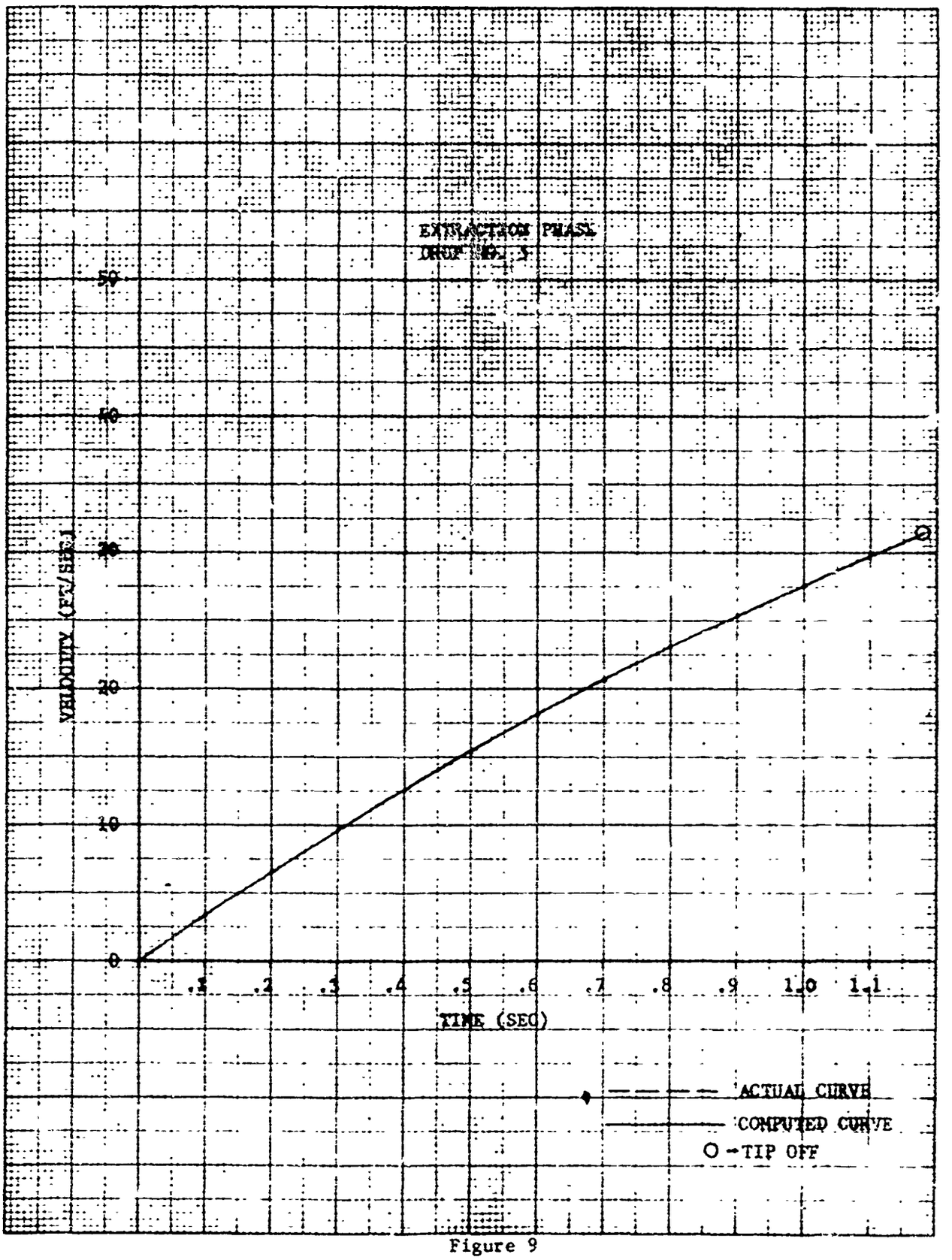
EXTRACTION PHASE
DROP NO. 5
VELOCITY (FT/SEC)
50
40
30
20
10
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
1.1
TIME (SEC)
ACTUAL CURVE
COMPUTED CURVE
O - TIP OFF

Figure 9

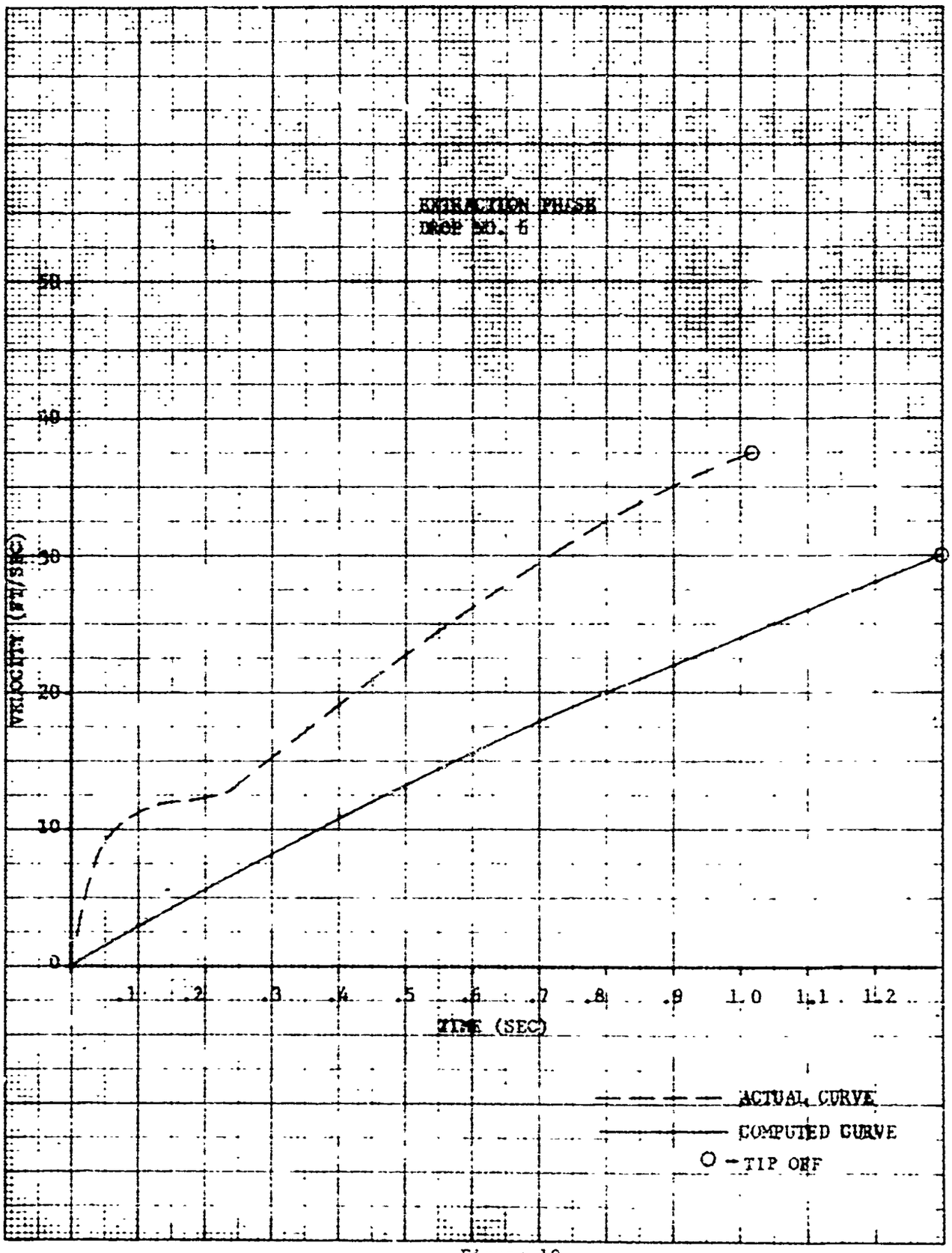
EXTRACTION PHASE
DROP NO. 6
VELOCITY (FT/SEC)
0
10
20
30
40
50
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
1.1
1.2
TIME (SEC)
ACTUAL CURVE
COMPUTED CURVE
TIP OFF

Figure 10

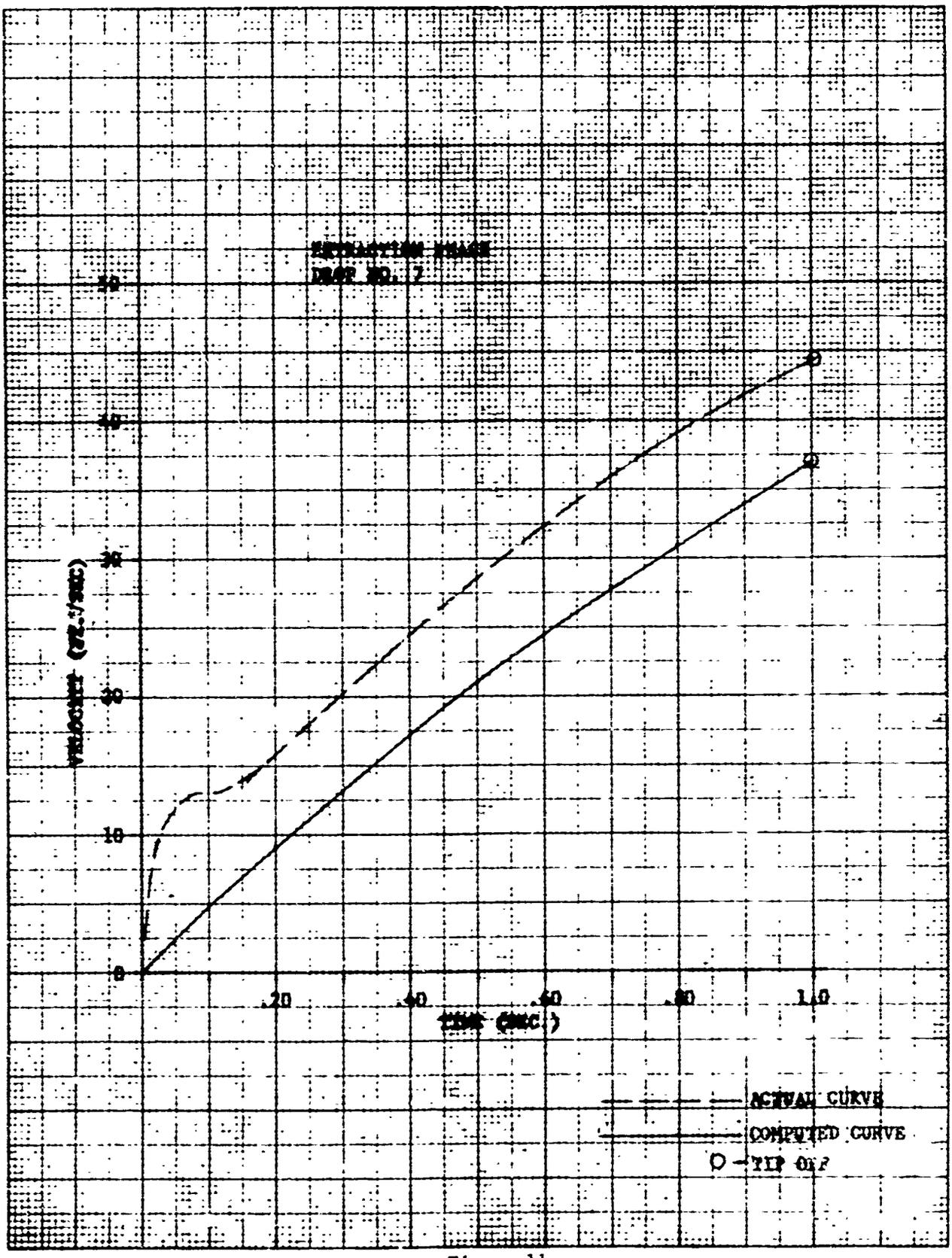
EXTRACTION PHASE
DROP NO. 7
50
40
30
20
10
0
VELOCITY (FT./SEC)
.20
.40
.60
.80
1.0
TIME (SEC.)
ACTUAL CURVE
COMPUTED CURVE
O - TIP OFF

Figure 11

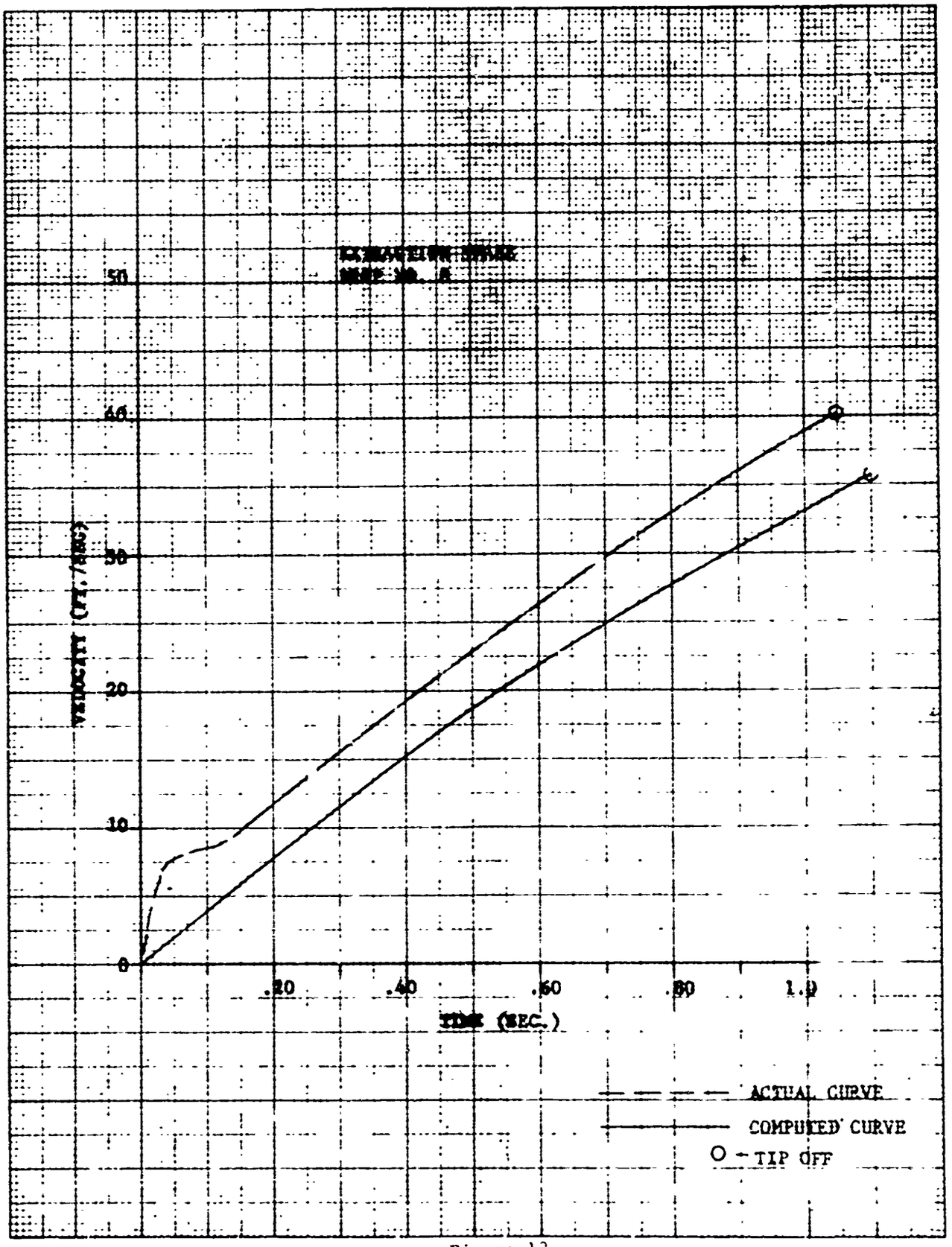
50
40
30
20
10
0
VELOCITY (FT./SEC.)
.20
.40
.60
.80
1.0
TIME (SEC.)
ACTUAL CURVE
COMPUTED CURVE
O - TIP OFF

Figure 12

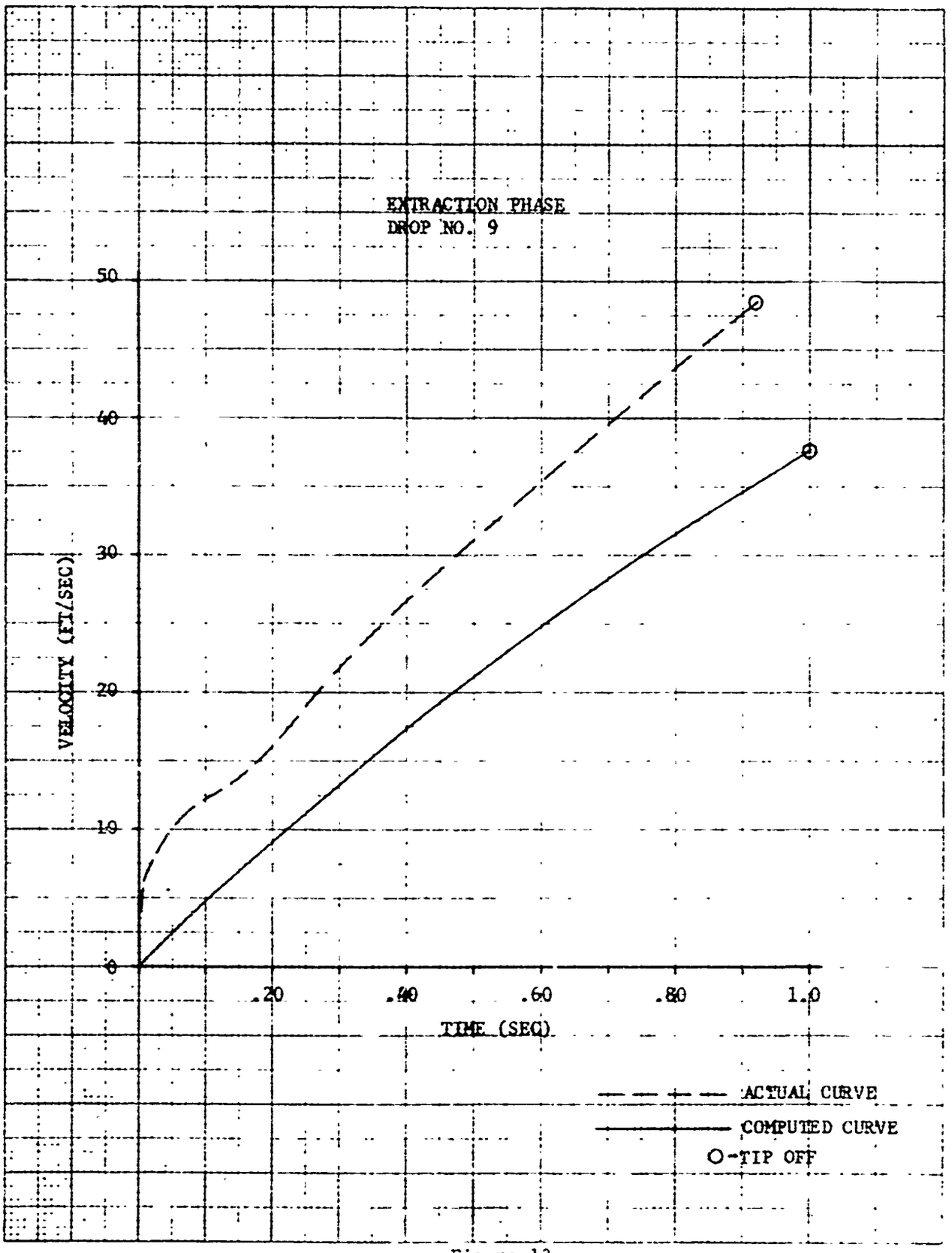
EXTRACTION PHASE
DROP NO. 9
VELOCITY (FT/SEC)
50
40
30
20
10
0
.20
.40
.60
.80
1.0
TIME (SEC)
ACTUAL CURVE
COMPUTED CURVE
O-TIP OFF

Figure 13

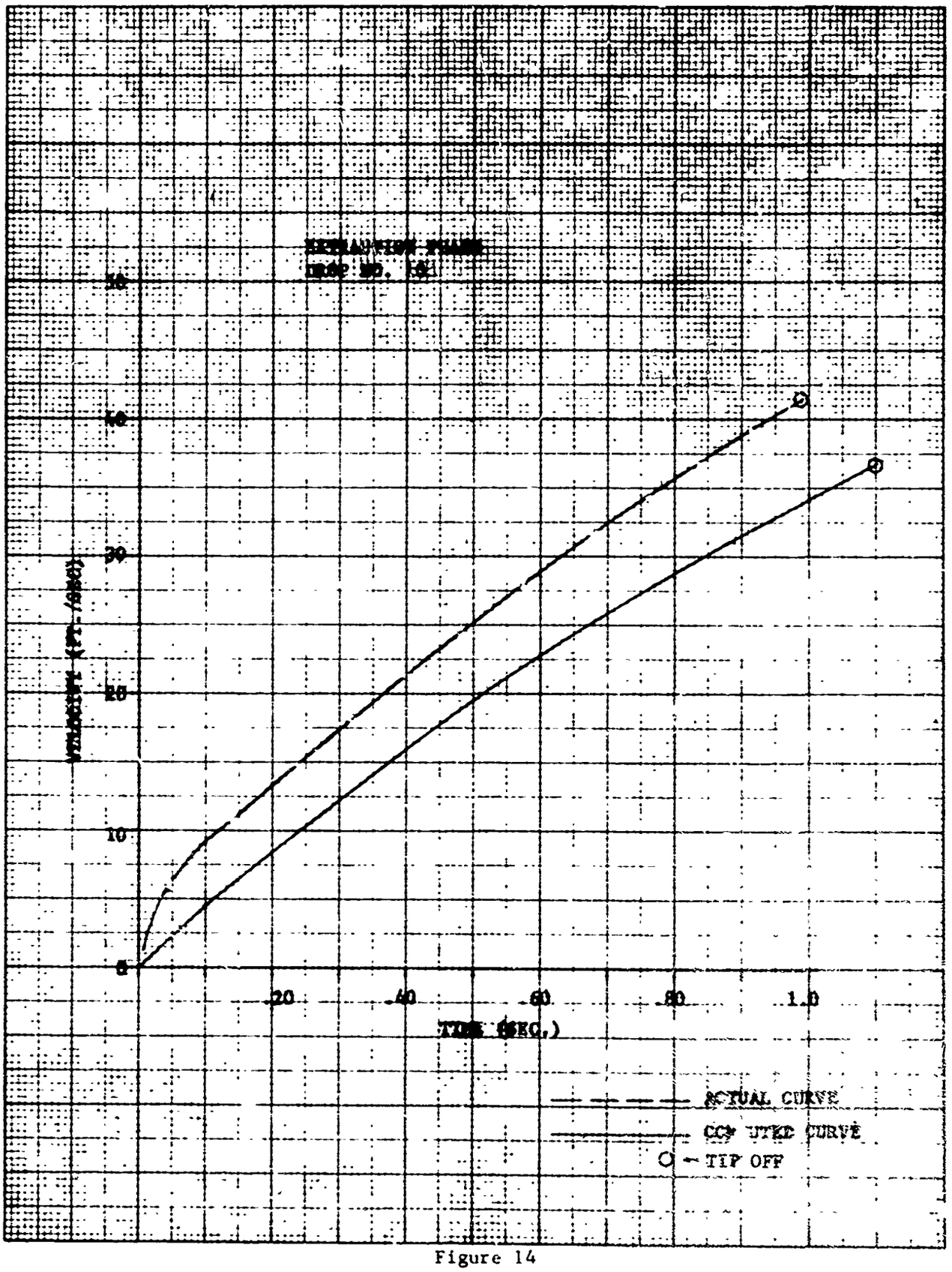


Figure 14

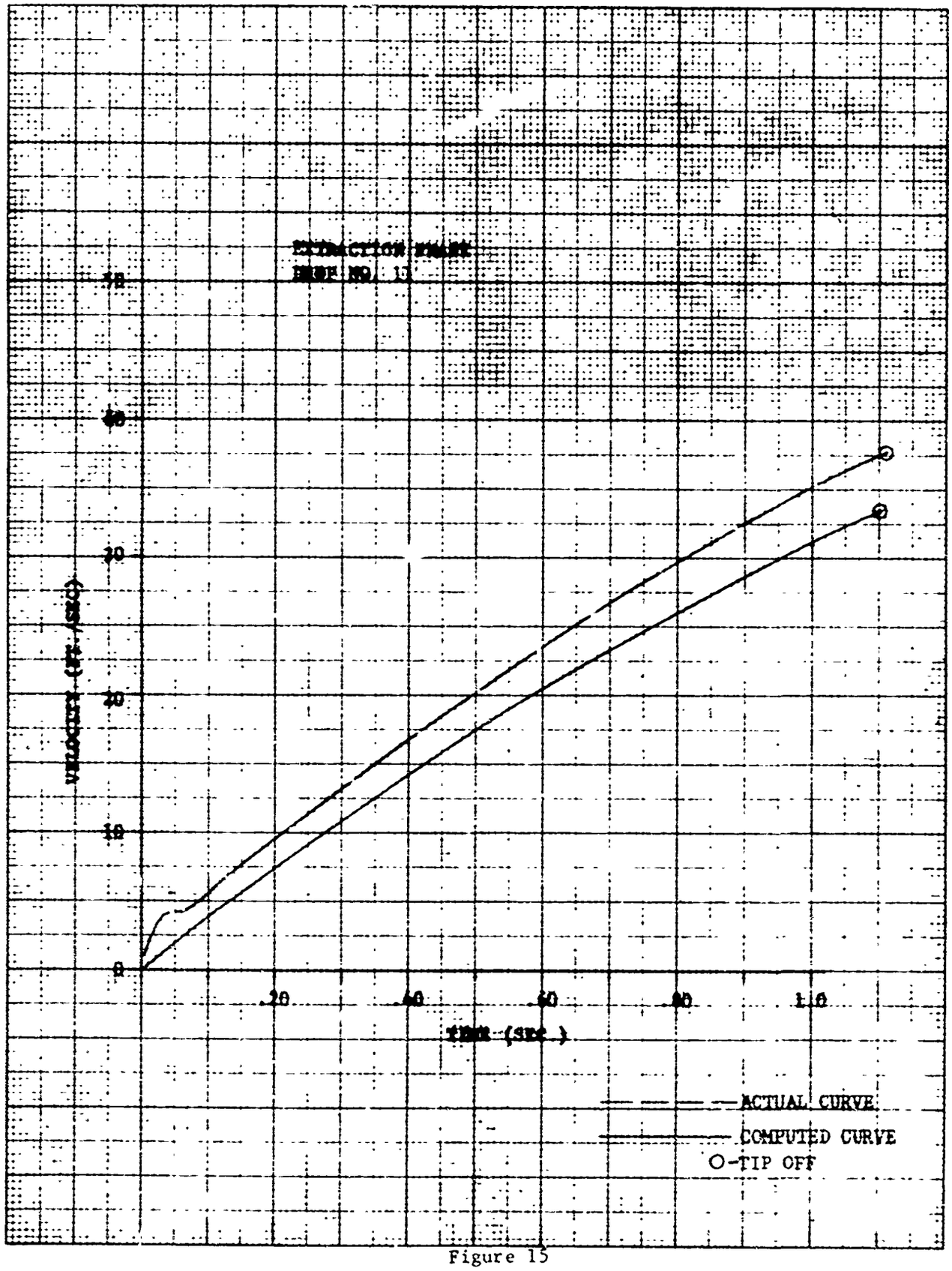
EXTRACTION PHASE
DROP NO. 11
VELOCITY (FT./SEC)
0
10
20
30
40
50
.20
.40
.60
.80
1.0
TIME (SEC.)
ACTUAL CURVE
COMPUTED CURVE
O-TIP OFF

Figure 15

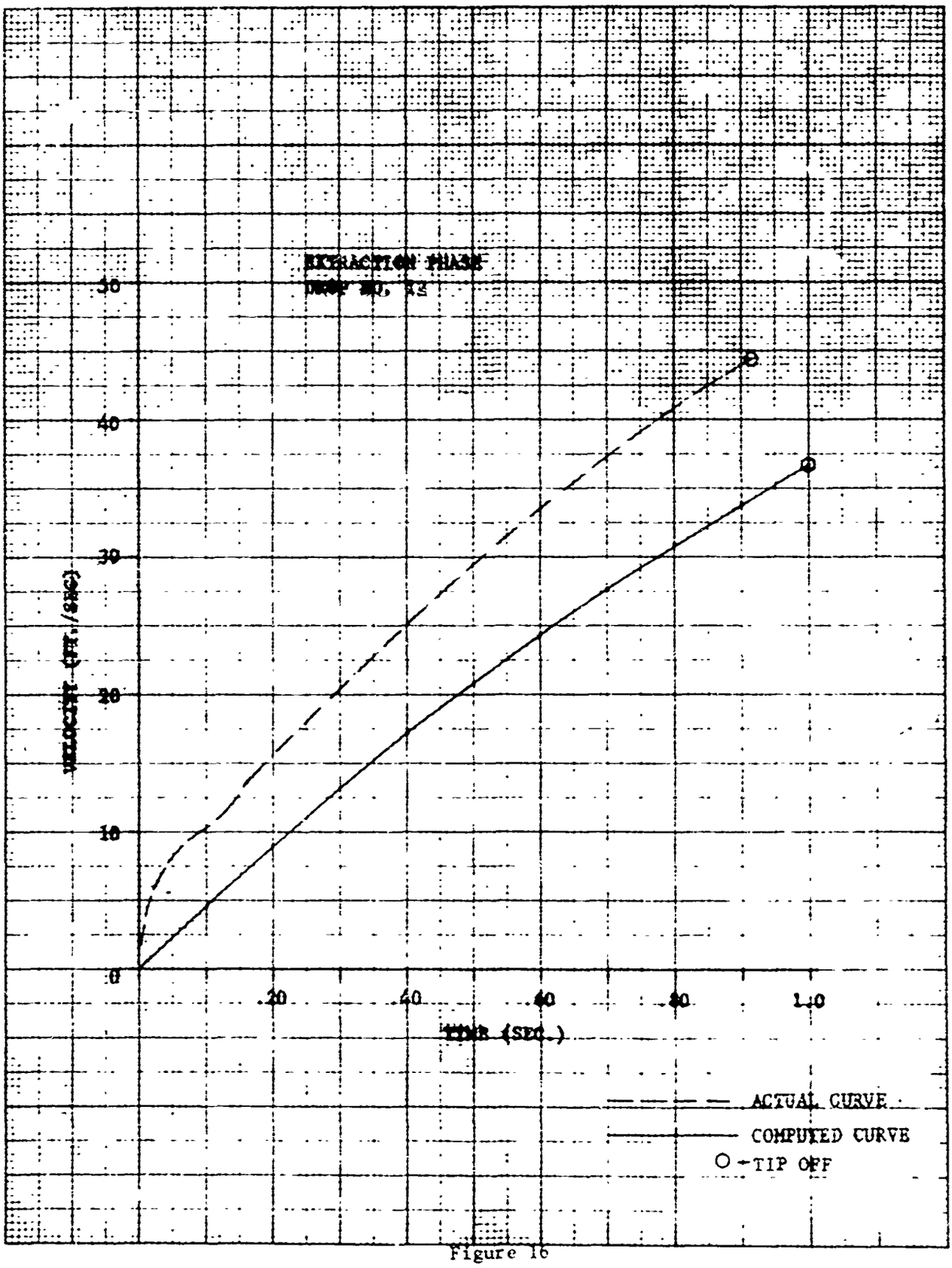
EXTRACTION PHASE
DROP NO. 43
VELOCITY (FT./SEC)
50
40
30
20
10
0
.20
.40
.60
.80
1.0
TIME (SEC.)
ACTUAL CURVE
COMPUTED CURVE
O - TIP OFF

Figure 16

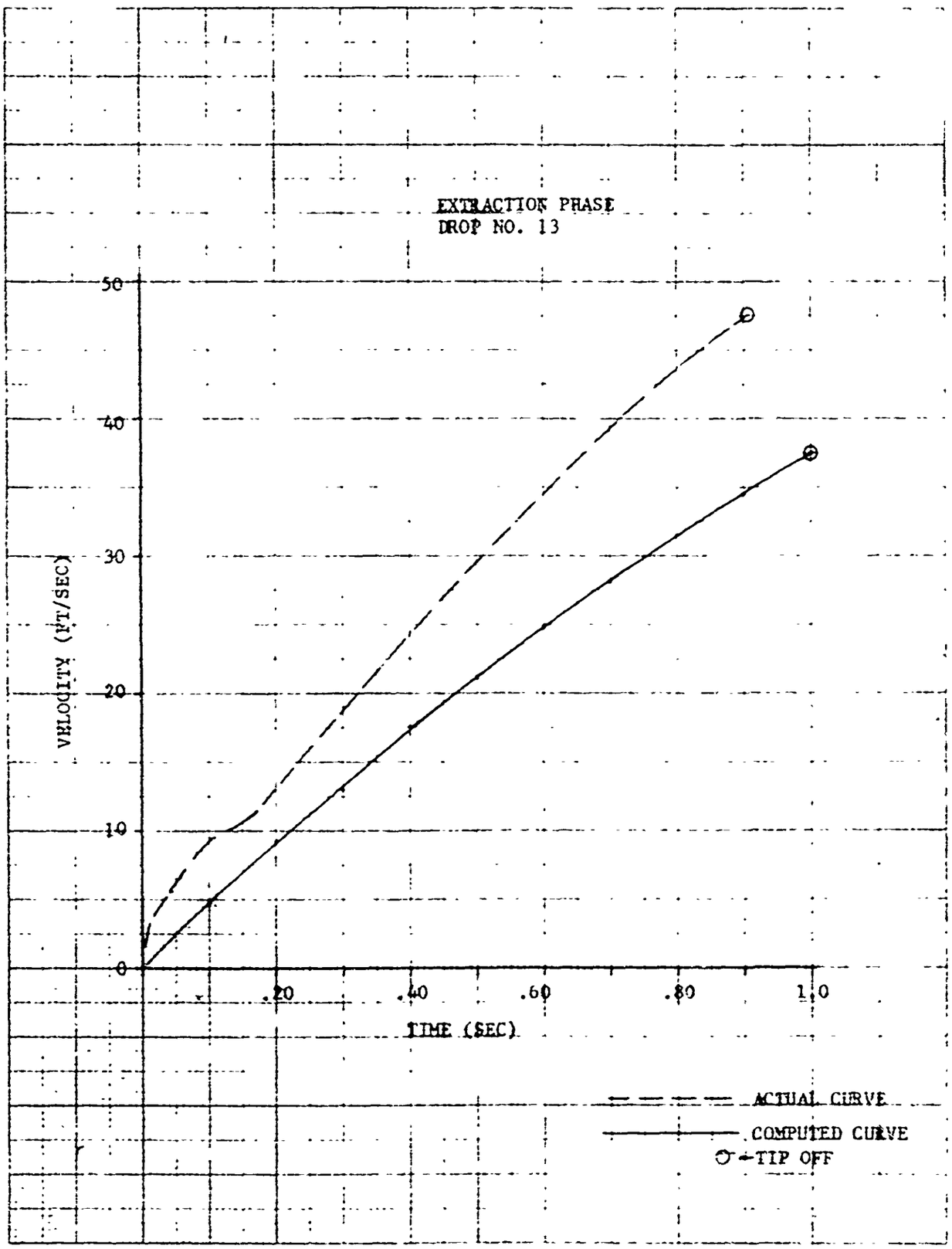
EXTRACTION PHASE
DROP NO. 13
50
40
30
20
10
0
VELOCITY (FT/SEC)
.20
.40
.60
.80
1.0
TIME (SEC)
ACTUAL CURVE
COMPUTED CURVE
TIP OFF

Figure 17

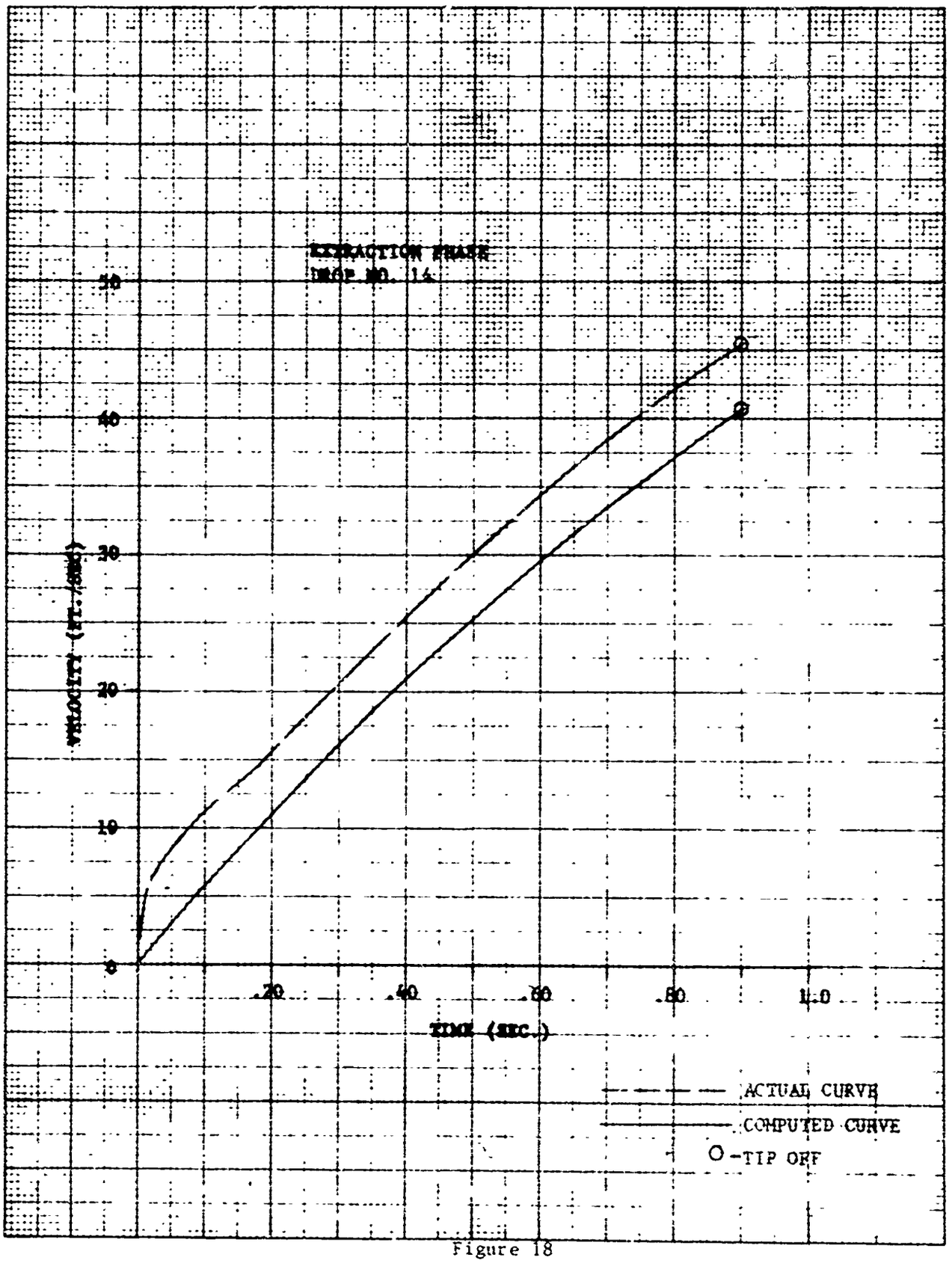
EXTRACTION PHASE
DROP NO. 14
VELOCITY (FT./SEC.)
50
40
30
20
10
0
.20
.40
.60
.80
1.0
TIME (SEC.)
ACTUAL CURVE
COMPUTED CURVE
O-TIP OFF

Figure 18

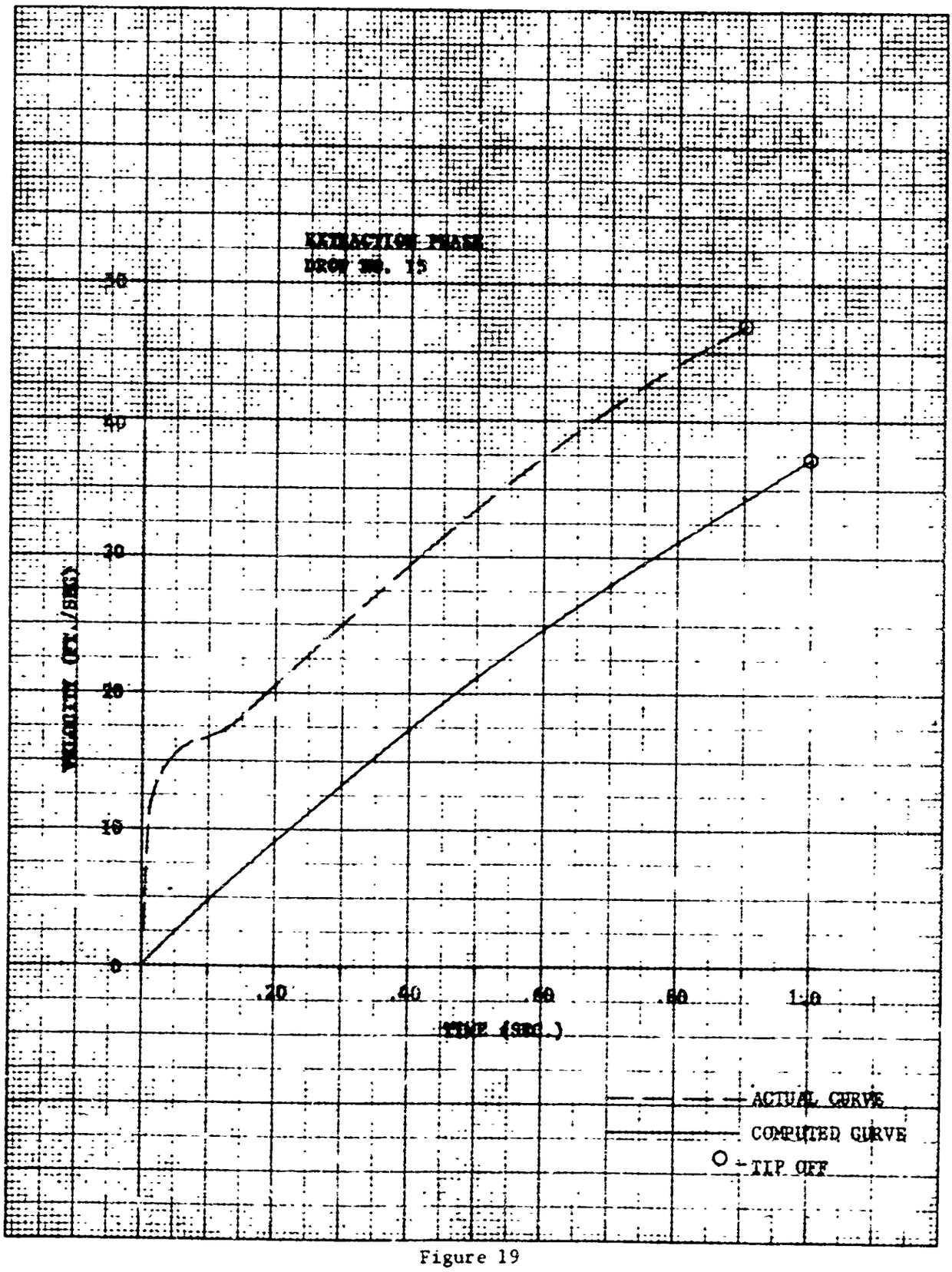
EXTRACTION PHASE
DROP NO. 15
50
40
30
20
10
0
VELOCITY (FT./SEC.)
.20
.40
.60
.80
1.0
TIME (SEC.)
ACTUAL CURVE
COMPUTED CURVE
TIP OFF

Figure 19

As can be seen, the slopes of these curves are quite similar which indicates the actual "g" loads are close to the predicted, however, the amplitudes for a given time are noticeably different. This is one of the cases indicated earlier when the equations of motion are not capable of predicting actual occurrences. The computer equations assume a rigid non-flexible member between the load and the parachute; thus, theoretically, the load is subjected to the exact force-time output of the parachute which decays proportionally to the decay of the $V^2$ term. This results in a velocity-time curve which is relatively smooth as shown in the figures. However, in the real case the connecting member, being nylon webbing, is quite flexible and can store some energy prior to load movement. Therefore, at load movement, which is some predetermined time during the inflation period, the load is subjected to force levels for a short time that are higher than predicted. This gives a cargo jerk which results in an initial steep slope on the velocity-time curve with a larger amplitude than would be obtained for the theoretical case.

C. Descent Phase

Cargo motion during the descent phase was recorded by high-speed motion picture cameras. The film was then reduced using a motion analyzer to various useful curves. Plots were made of each individual test showing the actual curve and the curve predicted by the computer. All curves start at the beginning of the descent phase and run to ground impact. Figures 20 through 33 present the plots of cargo altitude versus horizontal travel. Plots of Drops No. 1, 3, 8 and 11 are incomplete due to the inability to acquire sufficient film data.

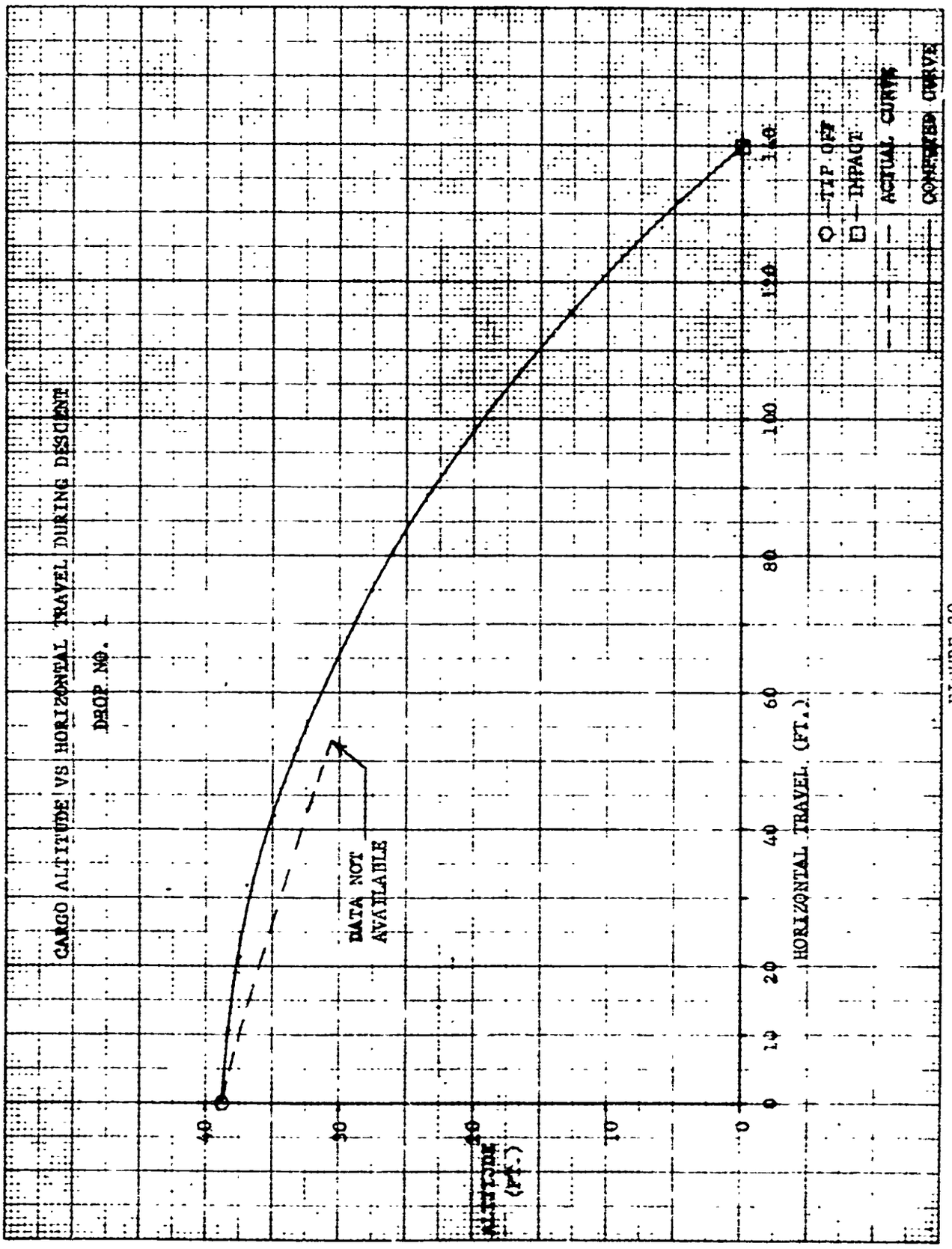
CARGO ALTITUDE VS HORIZONTAL TRAVEL DURING DESCENT
DROP NO. 1
DATA NOT AVAILABLE
ALTITUDE (FT.)
HORIZONTAL TRAVEL (FT.)
0
10
20
30
40
60
80
100
120
140
TIP OFF
IMPACT
ACTUAL CURVE
COMPUTED CURVE

FIGURE 20

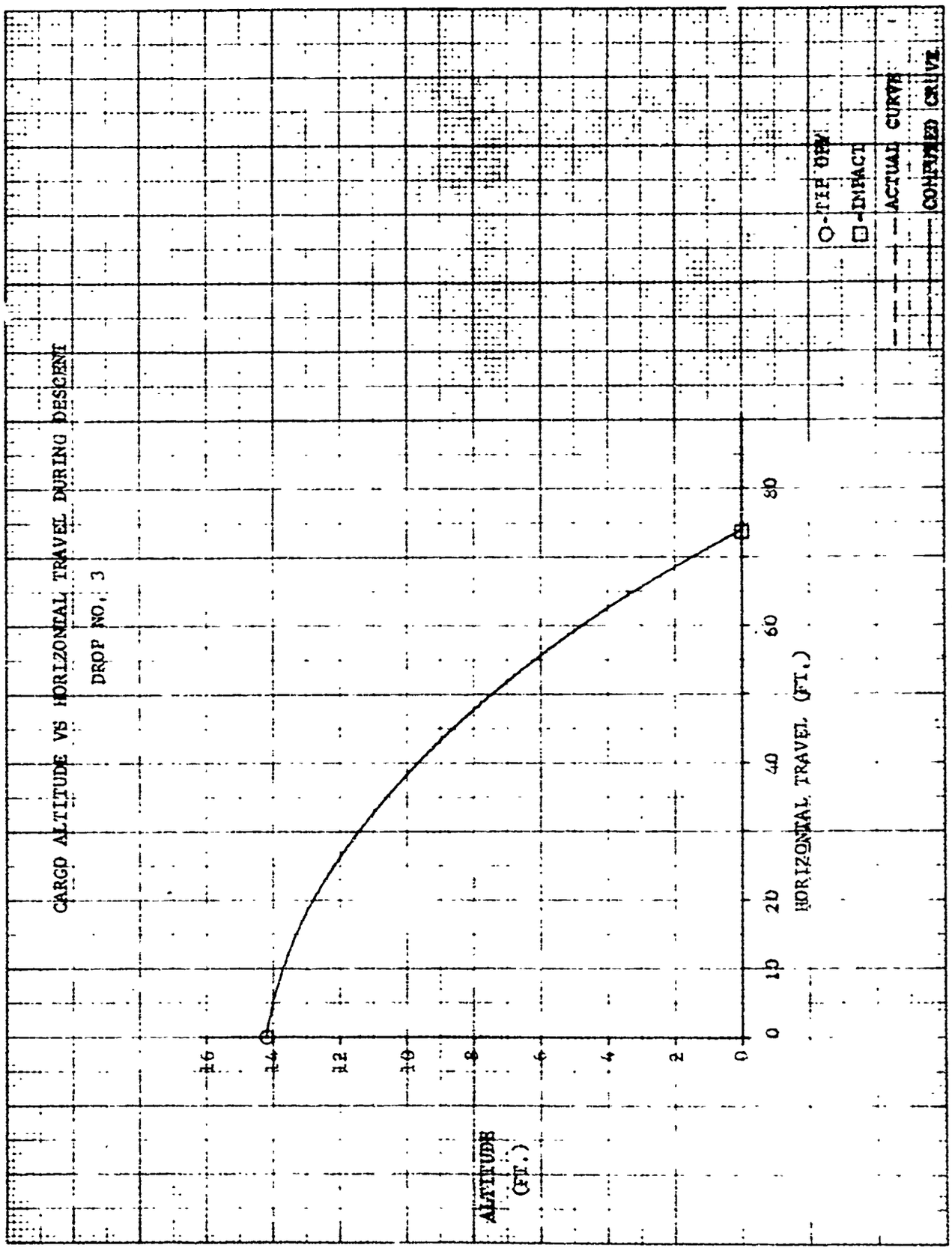
CARGO ALTITUDE VS HORIZONTAL TRAVEL DURING DESCENT
DROP NO. 3
ALTITUDE (FT.)
16
14
12
10
8
6
4
2
0
HORIZONTAL TRAVEL (FT.)
0
20
40
60
80
O-TIP OFF
□-IMPACT
ACTUAL CURVE
CONFIRMED CURVE

FIGURE 21

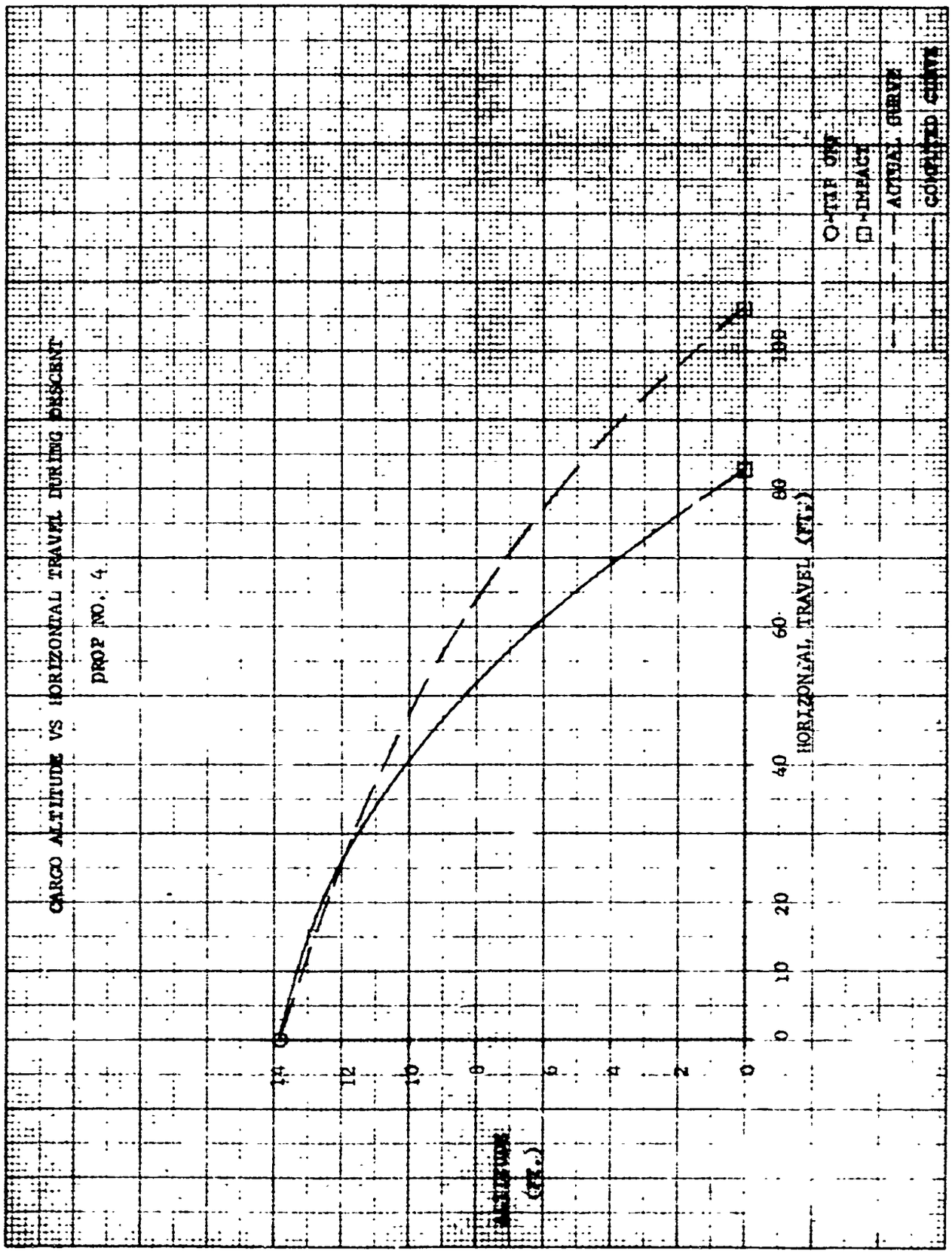
CARGO ALTITUDE VS HORIZONTAL TRAVEL DURING DESCENT
DROP NO. 4
ALTITUDE (FT.)
14
12
10
8
6
4
2
0
0
10
20
40
60
80
100
HORIZONTAL TRAVEL (FT.)
TIP OFF
IMPACT
ACTUAL CURVE
COMPUTED CURVE

FIGURE 22

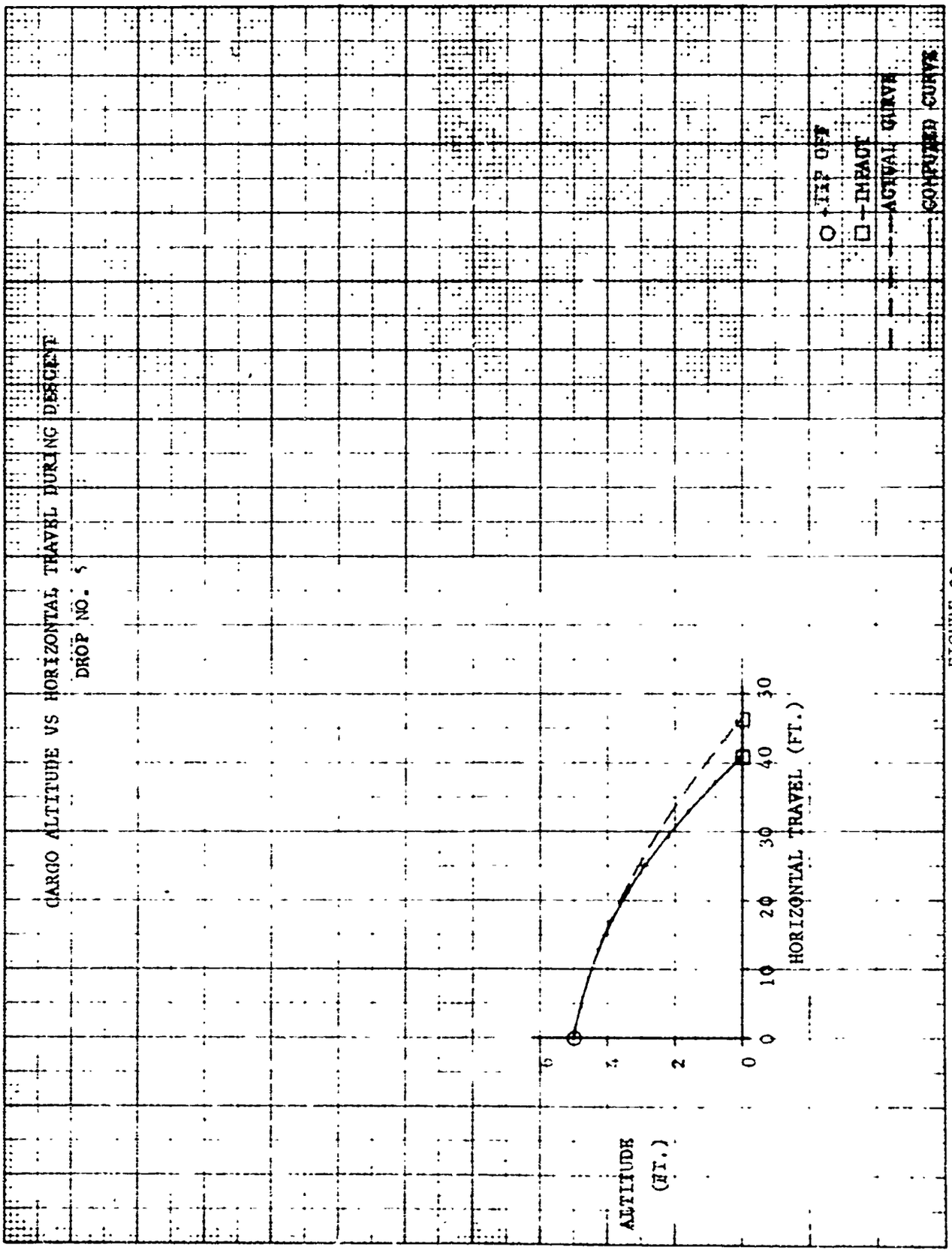
CARGO ALTITUDE VS HORIZONTAL TRAVEL DURING DESCENT
DROP NO. 5
ALTITUDE (FT.)
6
4
2
0
0
10
20
30
40
30
HORIZONTAL TRAVEL (FT.)
TIP OFF
IMPACT
ACTUAL CURVE
COMPUTED CURVE

FIGURE 23

AIRCRAFT ARMAMENTS, Inc.

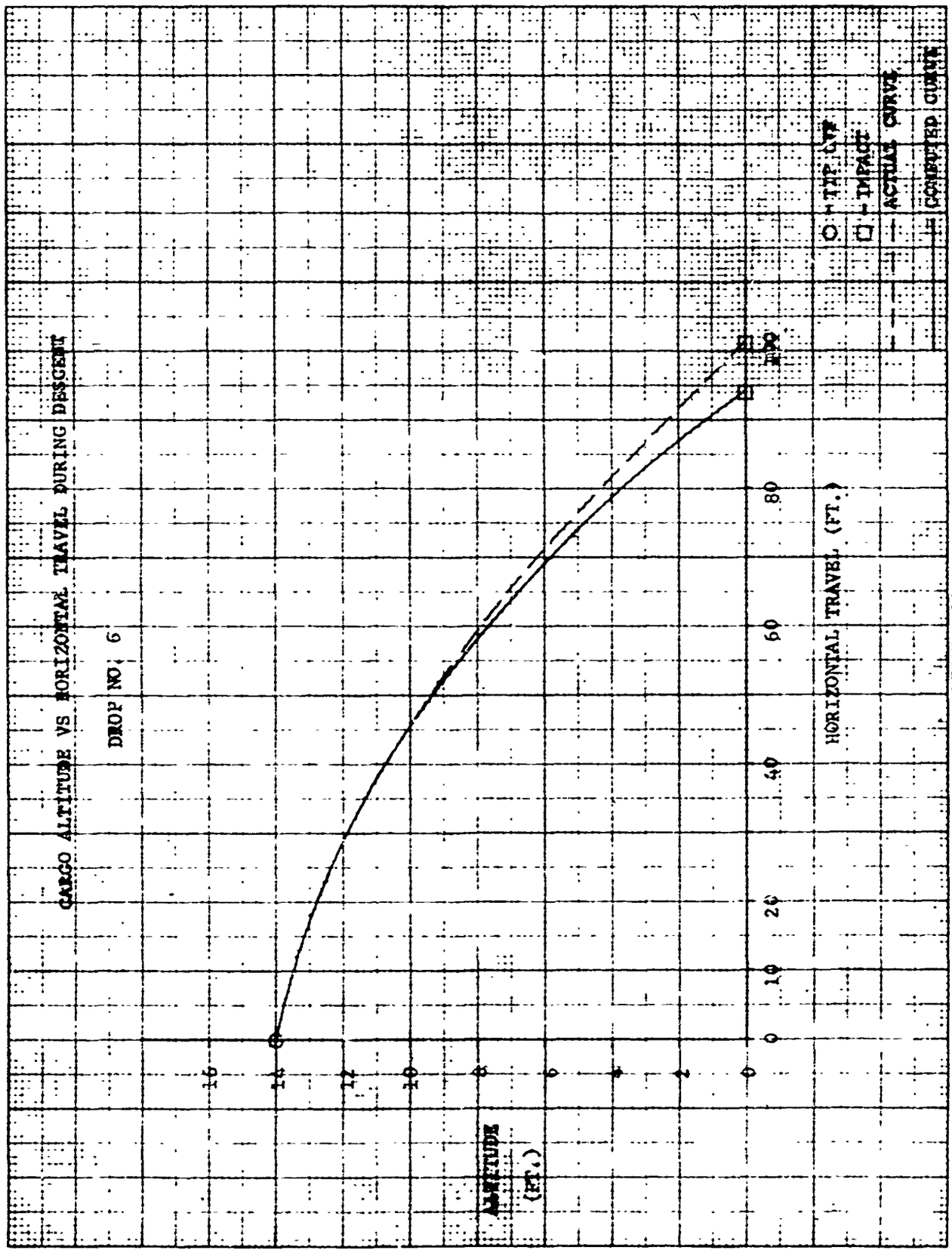


FIGURE 24

AIRCRAFT ARMAMENTS, Inc.

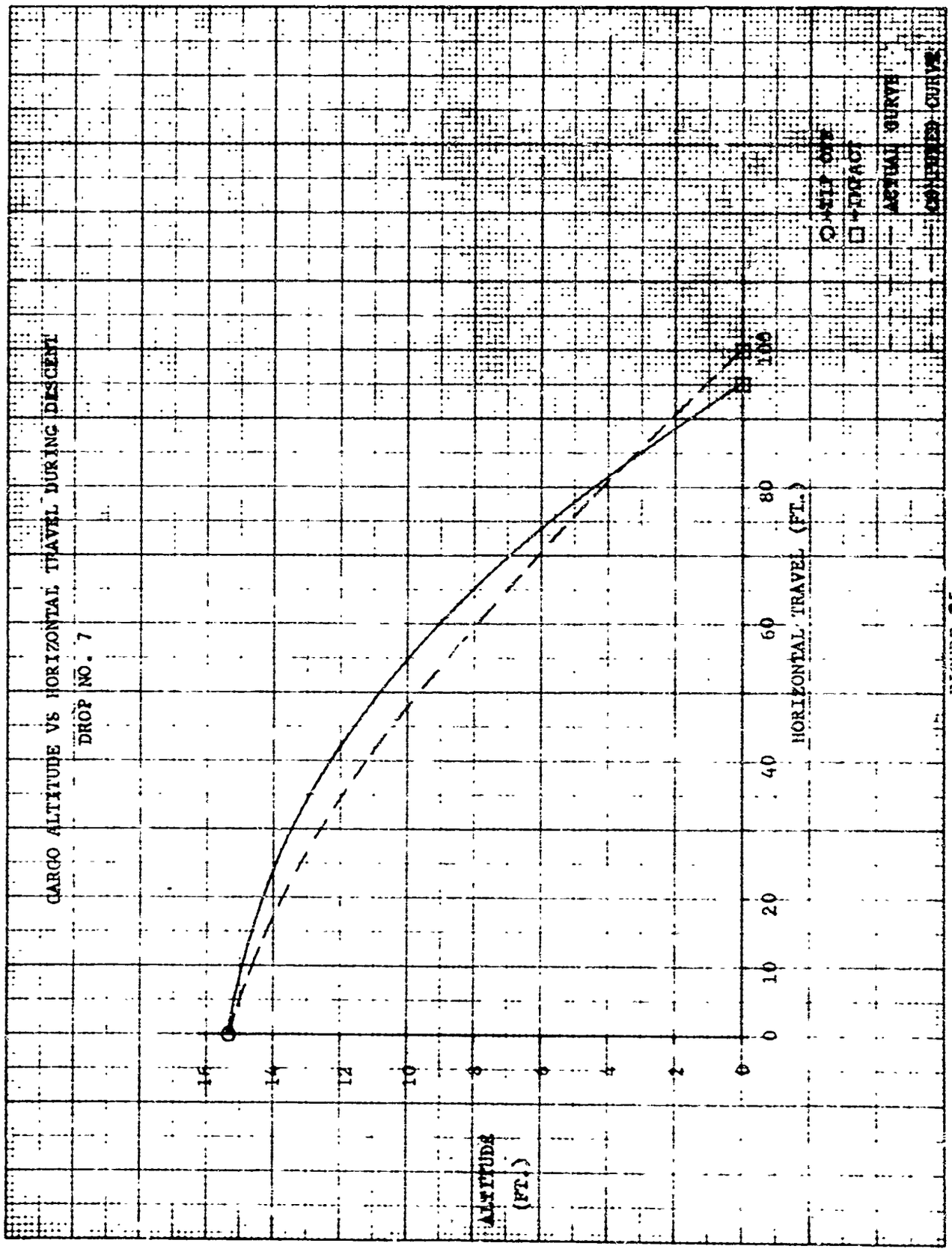


FIGURE 25

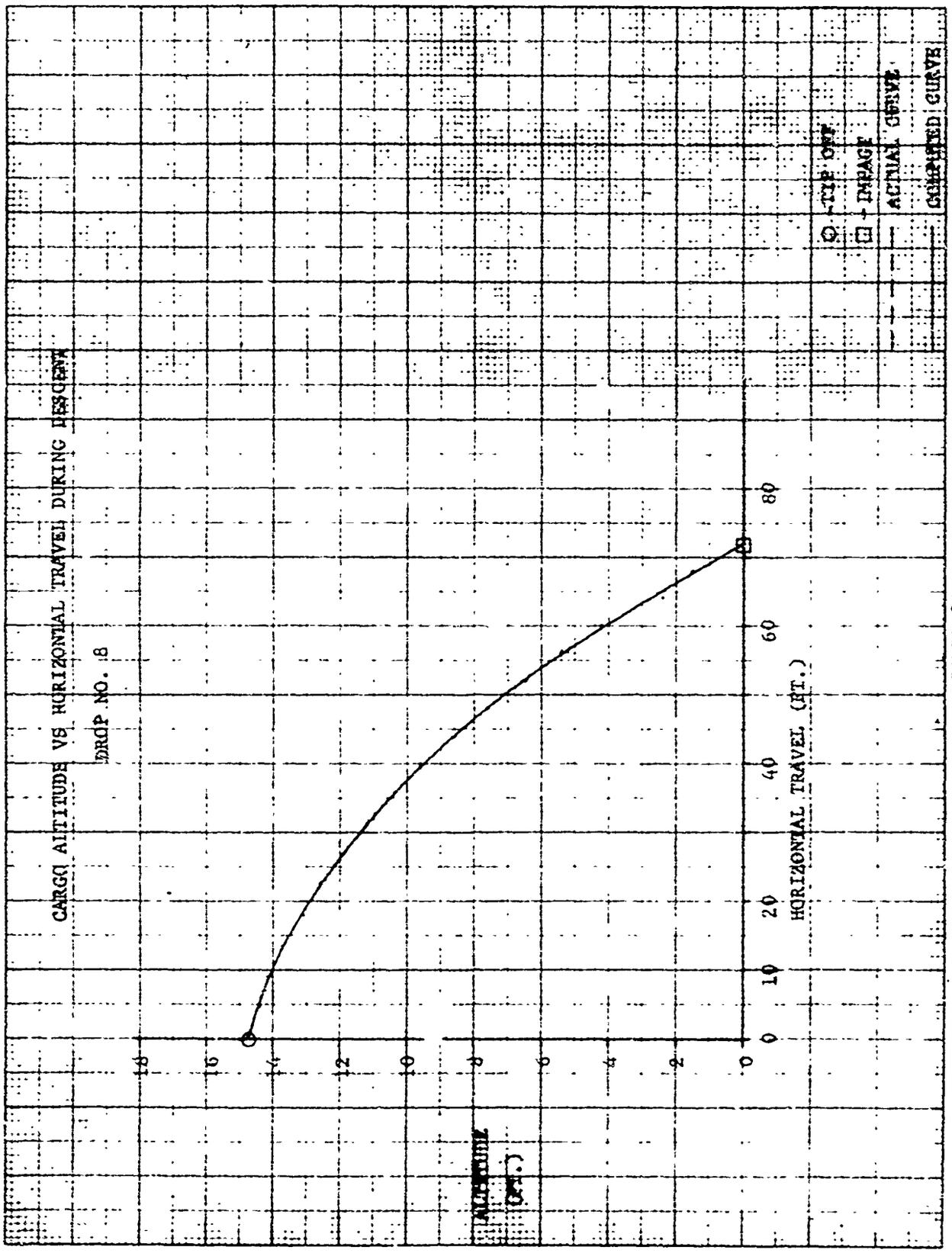
CARGO ALTITUDE VS HORIZONTAL TRAVEL DURING DESCENT
DROP NO. 8
ALTITUDE (FT.)
HORIZONTAL TRAVEL (FT.)
0
2
4
6
8
10
12
14
16
18
0
10
20
40
60
80
- TIP OFF
- IMPACT
ACTUAL CURVE
COMPUTED CURVE

FIGURE 26

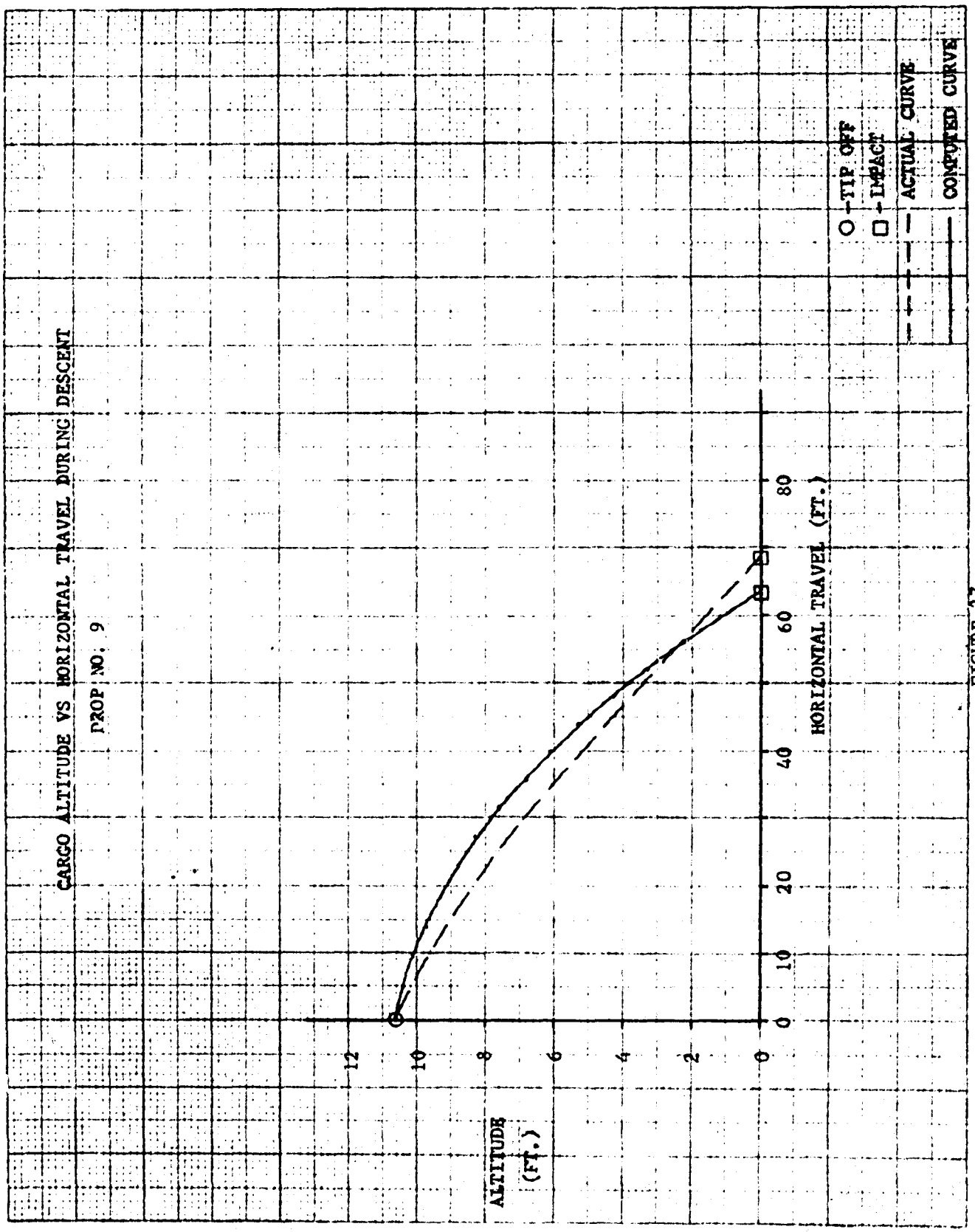
CARGO ALTITUDE VS HORIZONTAL TRAVEL DURING DESCENT
PROP NO. 9
ALTITUDE (FT.)
12
10
8
6
4
2
0
0
10
20
40
60
80
HORIZONTAL TRAVEL (FT.)
O - TIP OFF
□ - IMPACT
ACTUAL CURVE
COMPUTED CURVE

FIGURE 27

AIRCRAFT ARMAMENTS, Inc.

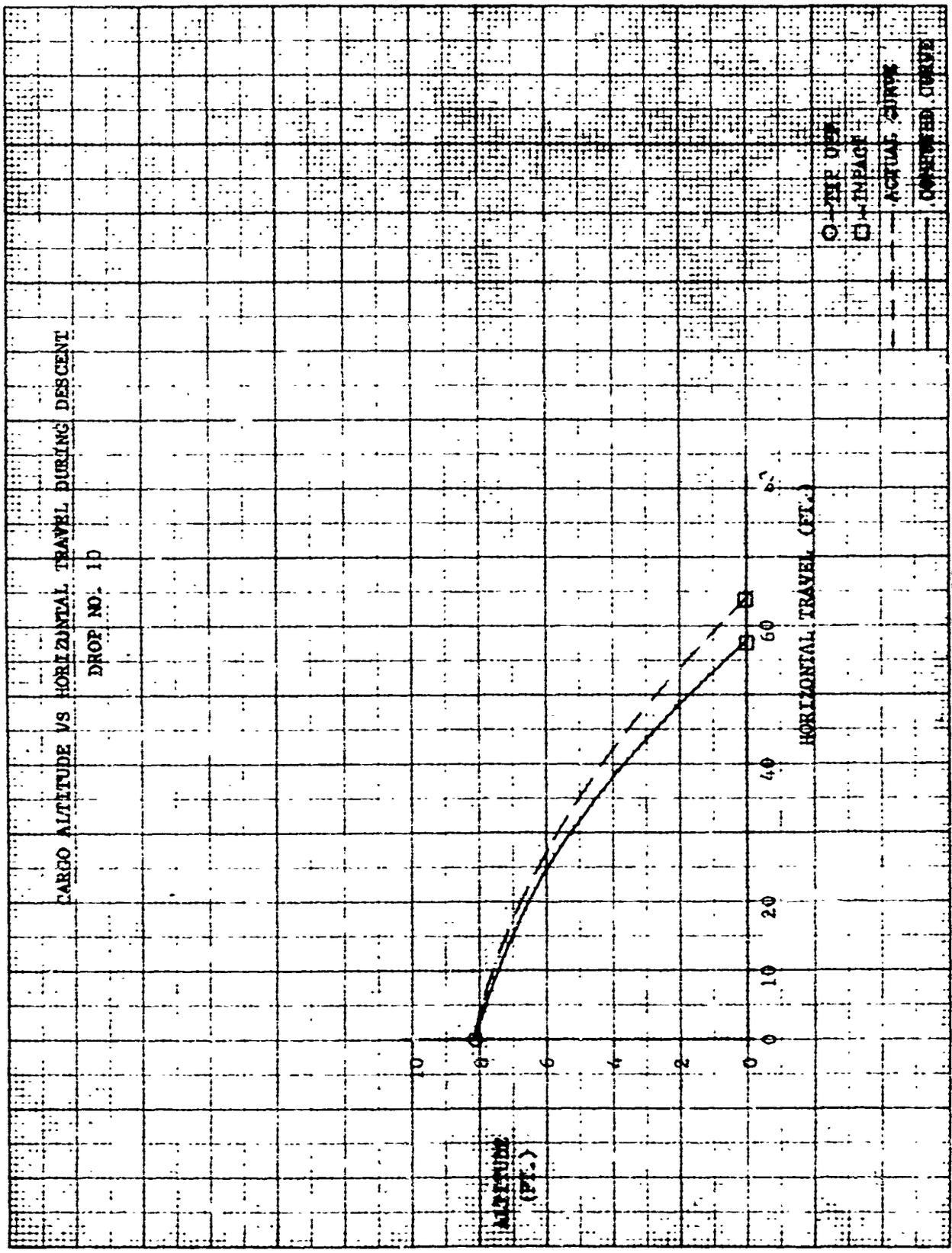


FIGURE 28

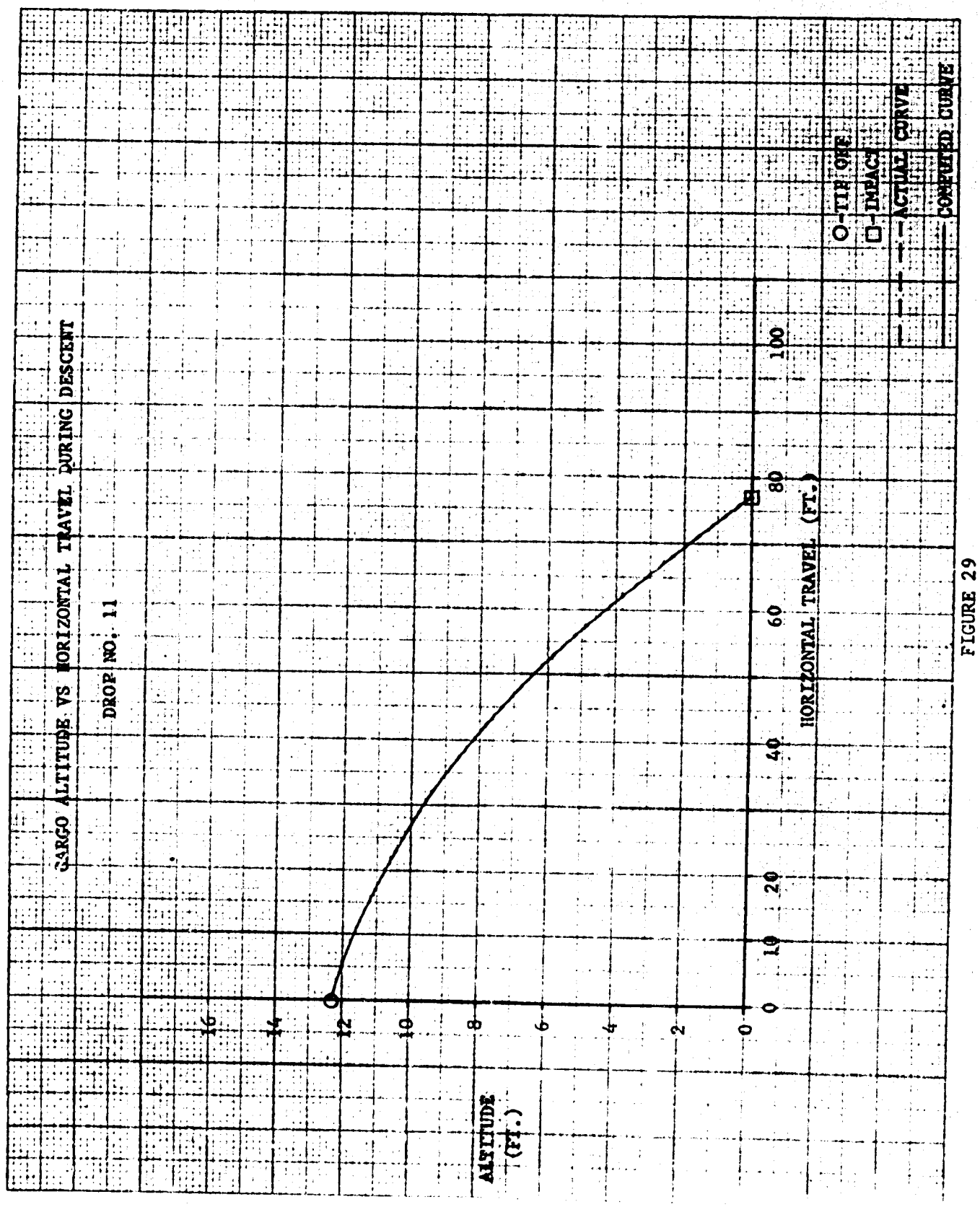
CARGO ALTITUDE VS HORIZONTAL TRAVEL DURING DESCENT
DROP NO. 11
ALTITUDE (FT.)
16
14
12
10
8
6
4
2
0
0
10
20
40
60
80
100
HORIZONTAL TRAVEL (FT.)
O-TIP OFF
□-IMPACT
ACTUAL CURVE
COMPUTED CURVE

FIGURE 29

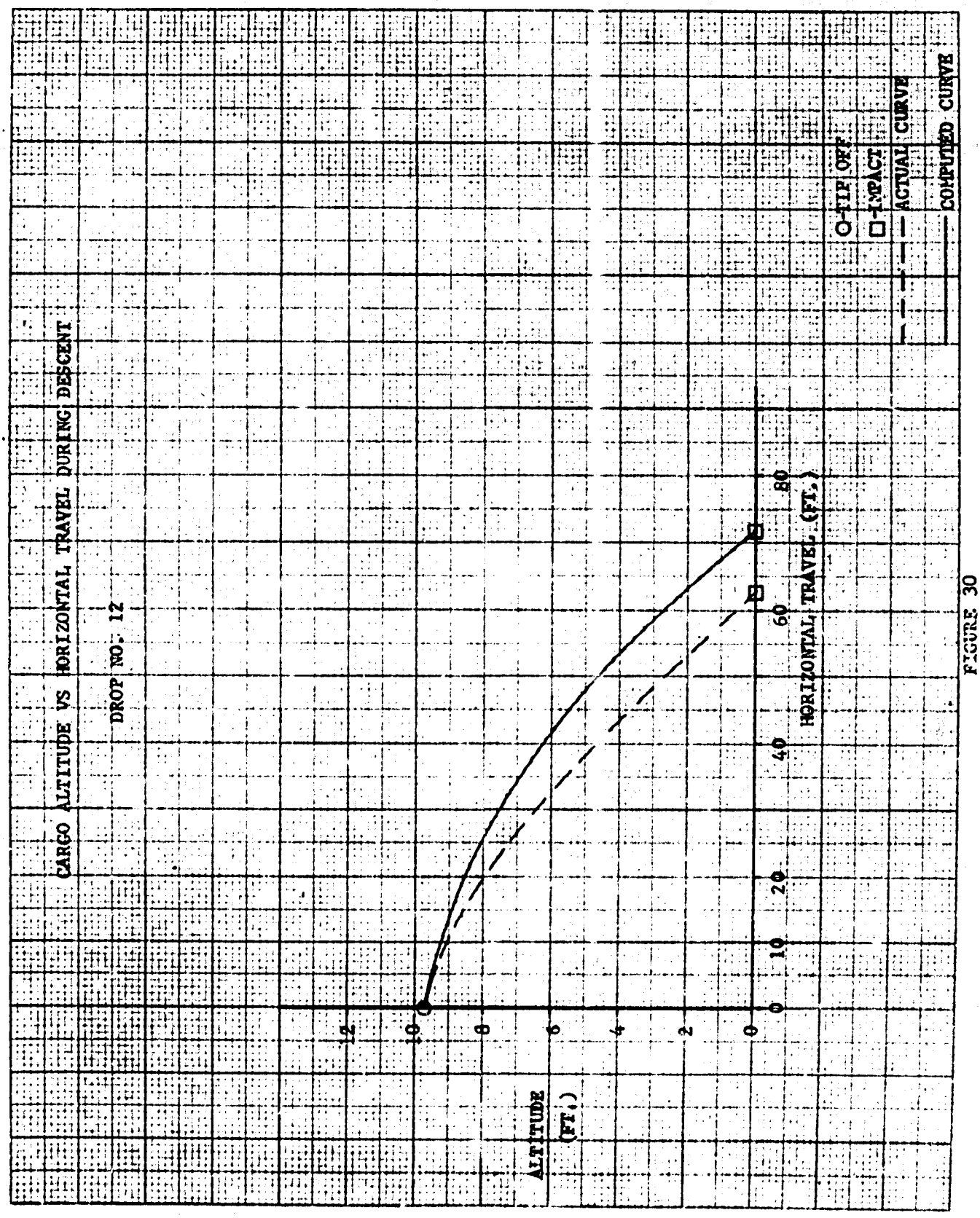
CARGO ALTITUDE VS HORIZONTAL TRAVEL DURING DESCENT
DROP NO. 12
ALTITUDE (FT.)
12
10
8
6
4
2
0
0
10
20
40
60
80
HORIZONTAL TRAVEL (FT.)
O-TIP OFF
□-IMPACT
ACTUAL CURVE
COMPUTED CURVE

FIGURE 30

AIRCRAFT ARMAMENTS, Inc.

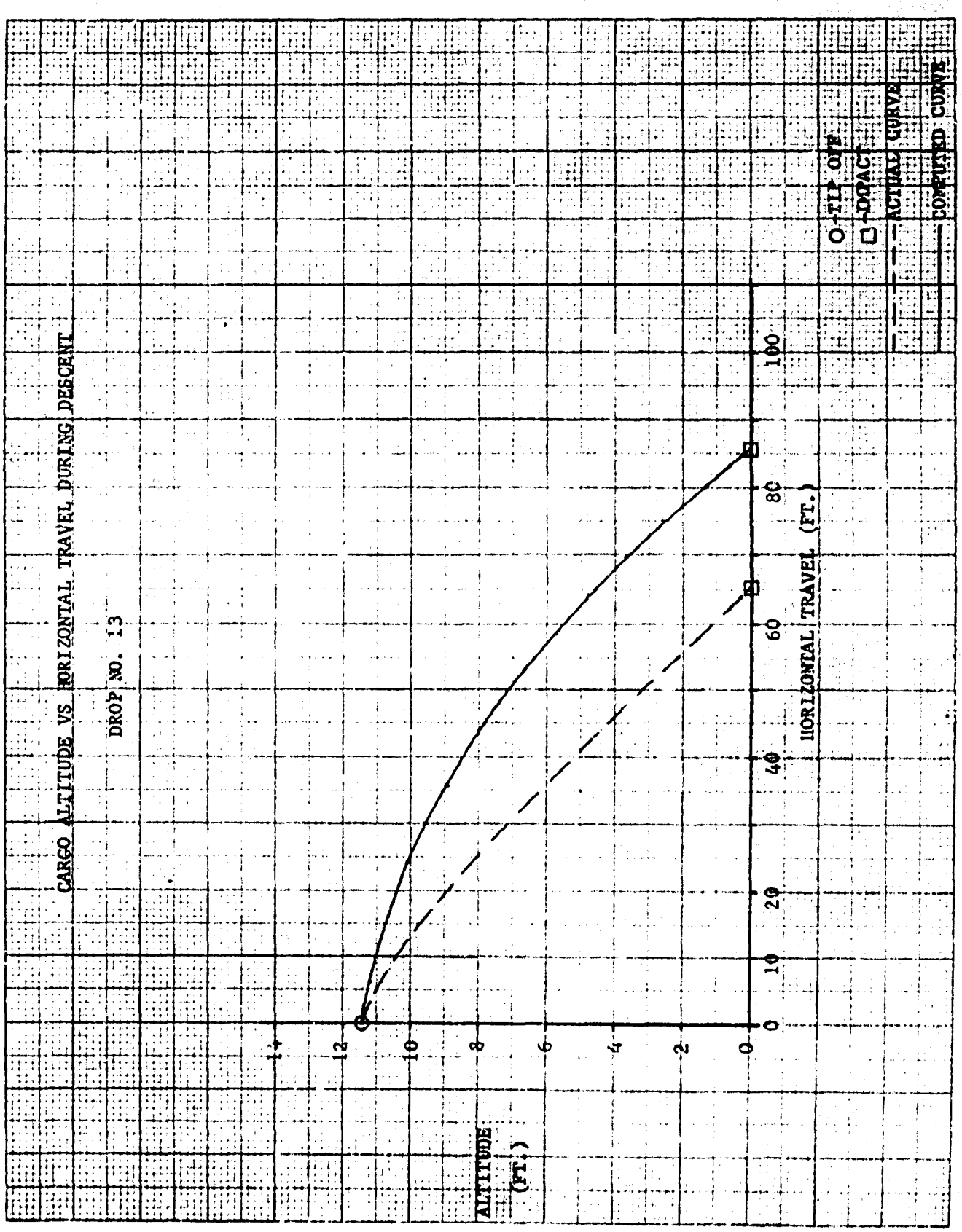


FIGURE 31

AIRCRAFT ARMAMENTS, Inc.

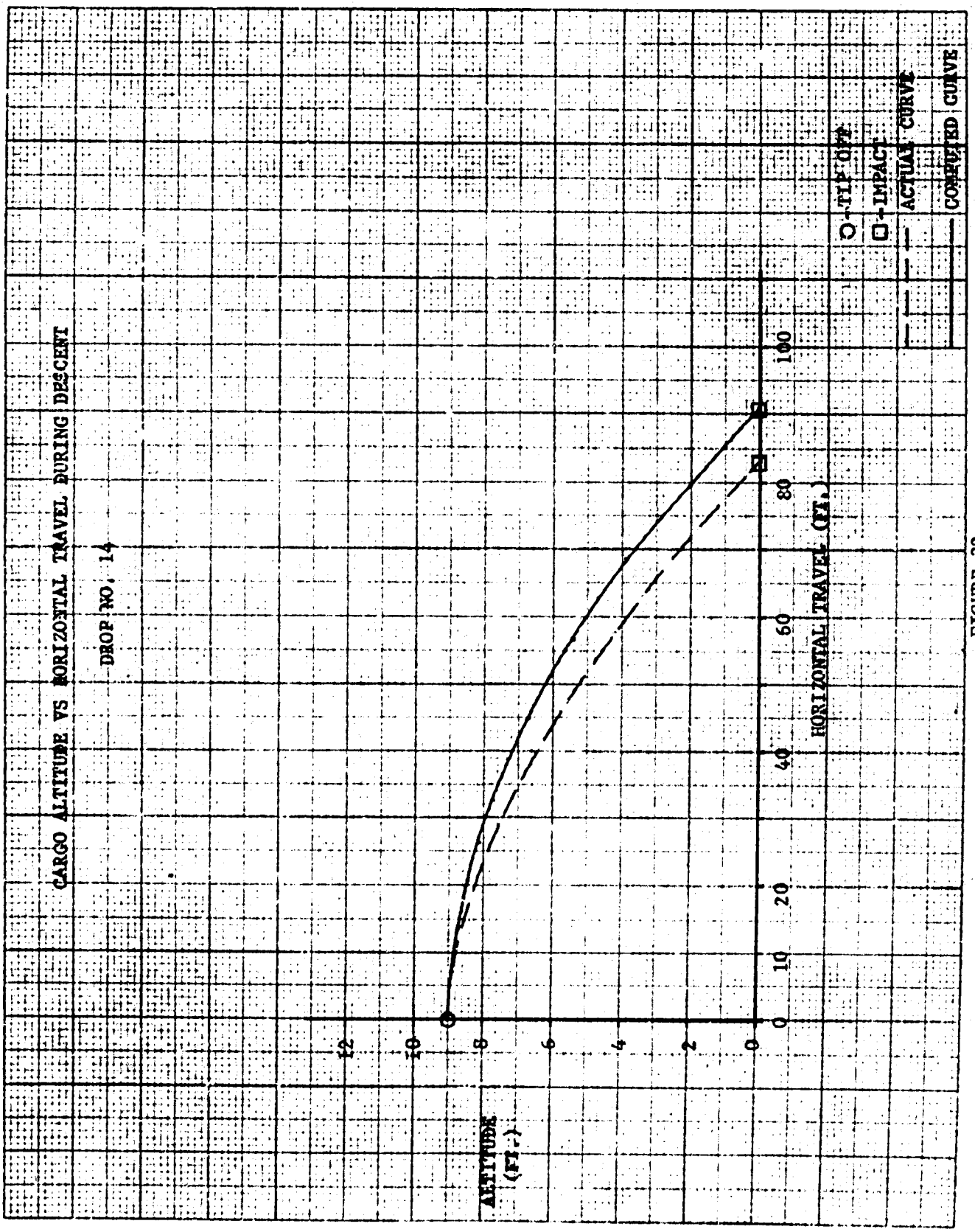


FIGURE 32

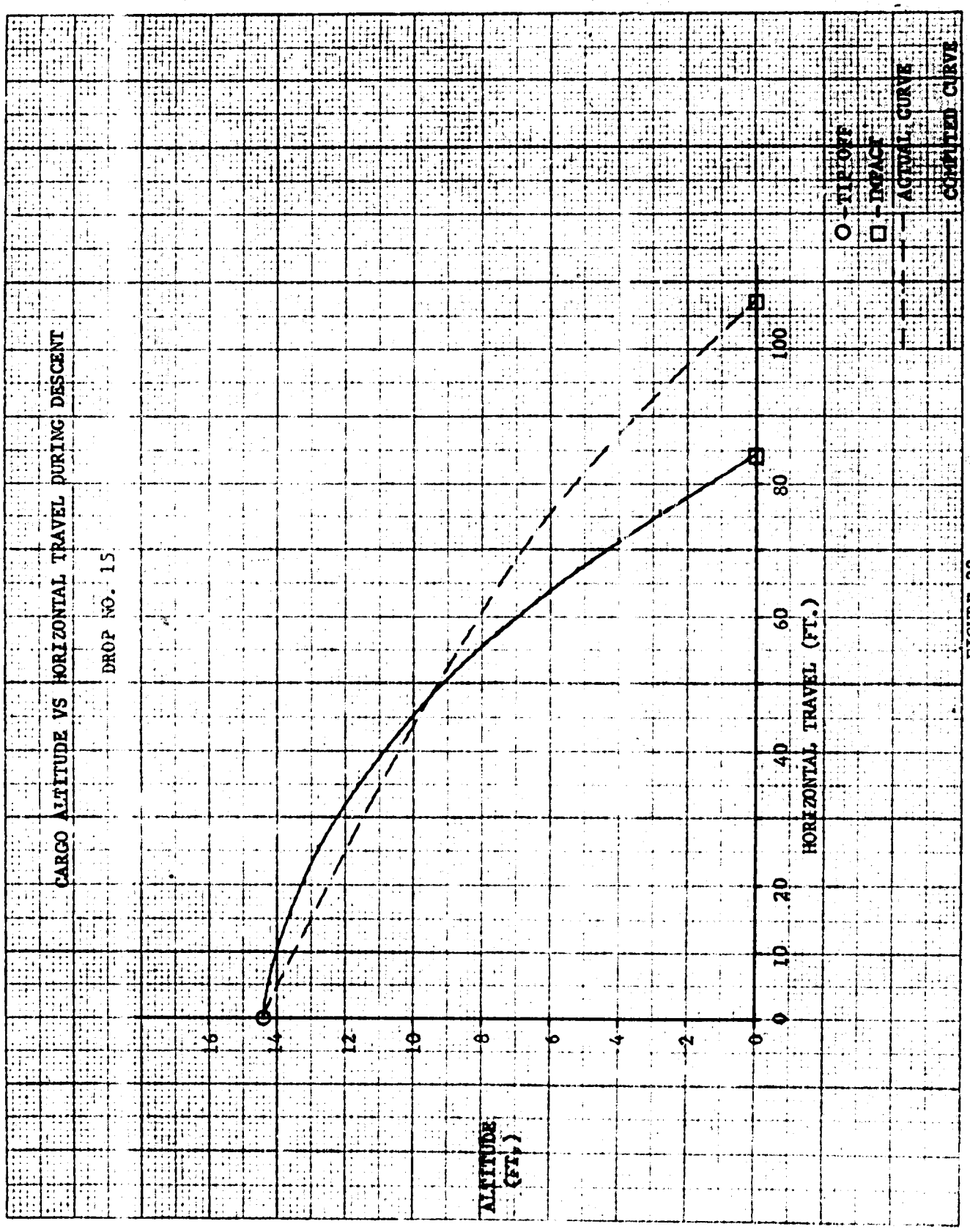
CARGO ALTITUDE VS HORIZONTAL TRAVEL DURING DESCENT
DROP NO. 15
ALTITUDE (FT.)
16
14
12
10
8
6
4
2
0
0
10
20
40
60
80
100
HORIZONTAL TRAVEL (FT.)
O - TIP OFF
□ - IMPACT
— — — ACTUAL CURVE
COMPUTED CURVE

FIGURE 33

A second curve was generated from the data obtained on each test. This curve was a plot of horizontal travel versus descent time. Comparative curves were obtained from the computer analysis and are shown in Figures 34-47. Again Drop No. 1, 3, 8 and 11 are incomplete due to lack of data.

AIRCRAFT ARMAMENTS, Inc.

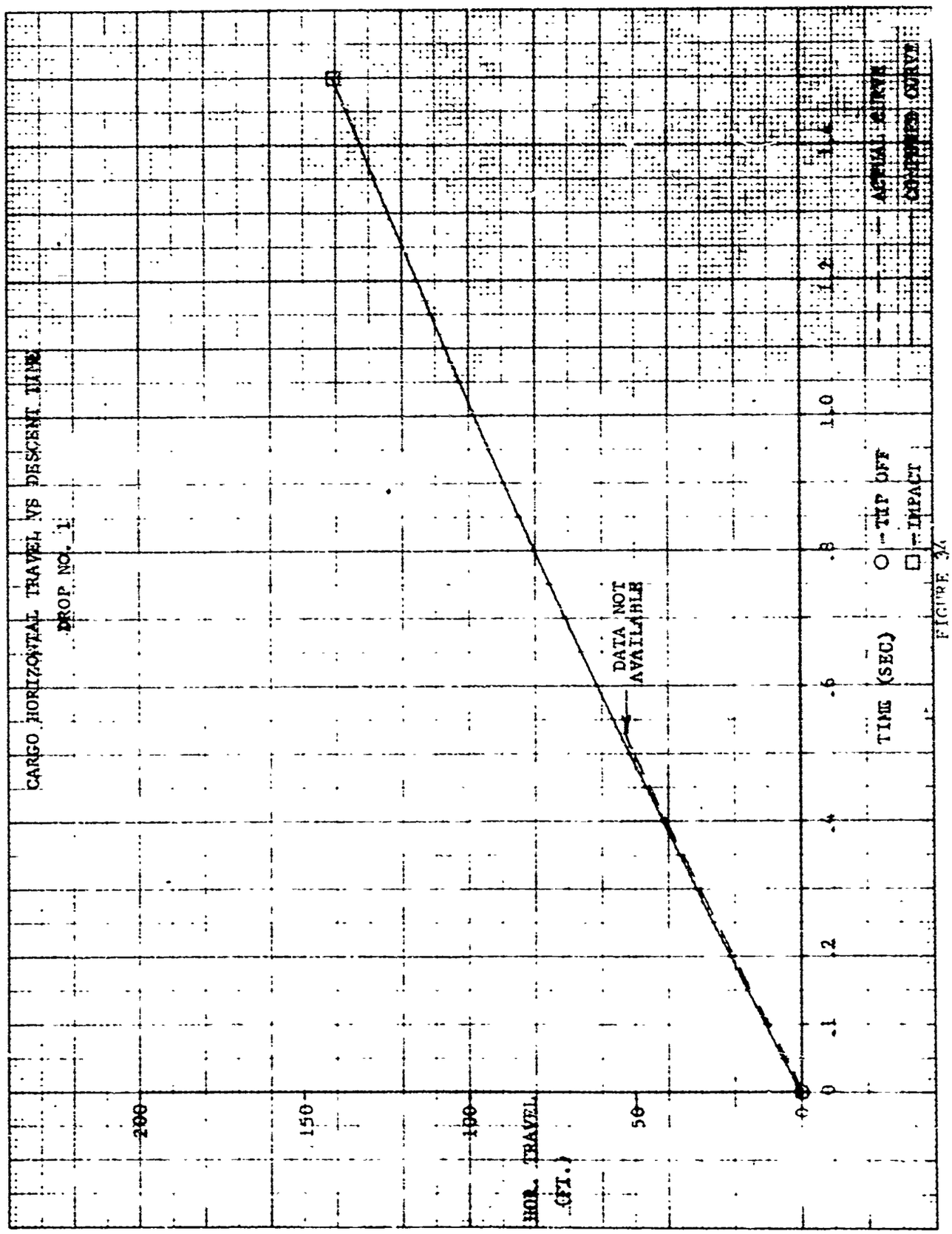


FIGURE 34

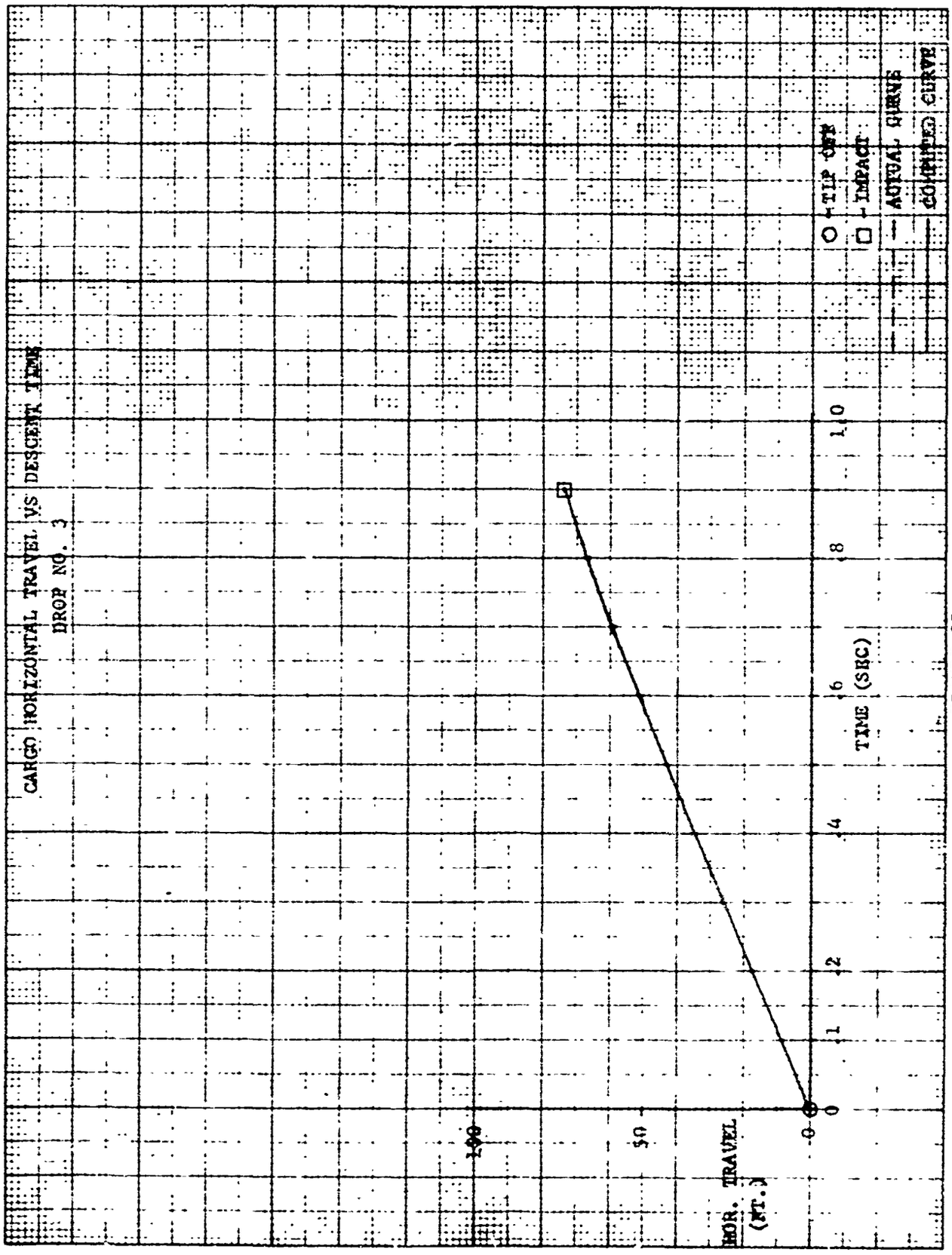
CARGO HORIZONTAL TRAVEL VS DESCENT TIME
DROP NO. 3
HOR. TRAVEL (FT.)
100
50
0
0
1
2
4
6
8
10
TIME (SEC)
TIP OFF
IMPACT
ACTUAL CURVE
COMPUTED CURVE

FIGURE 35

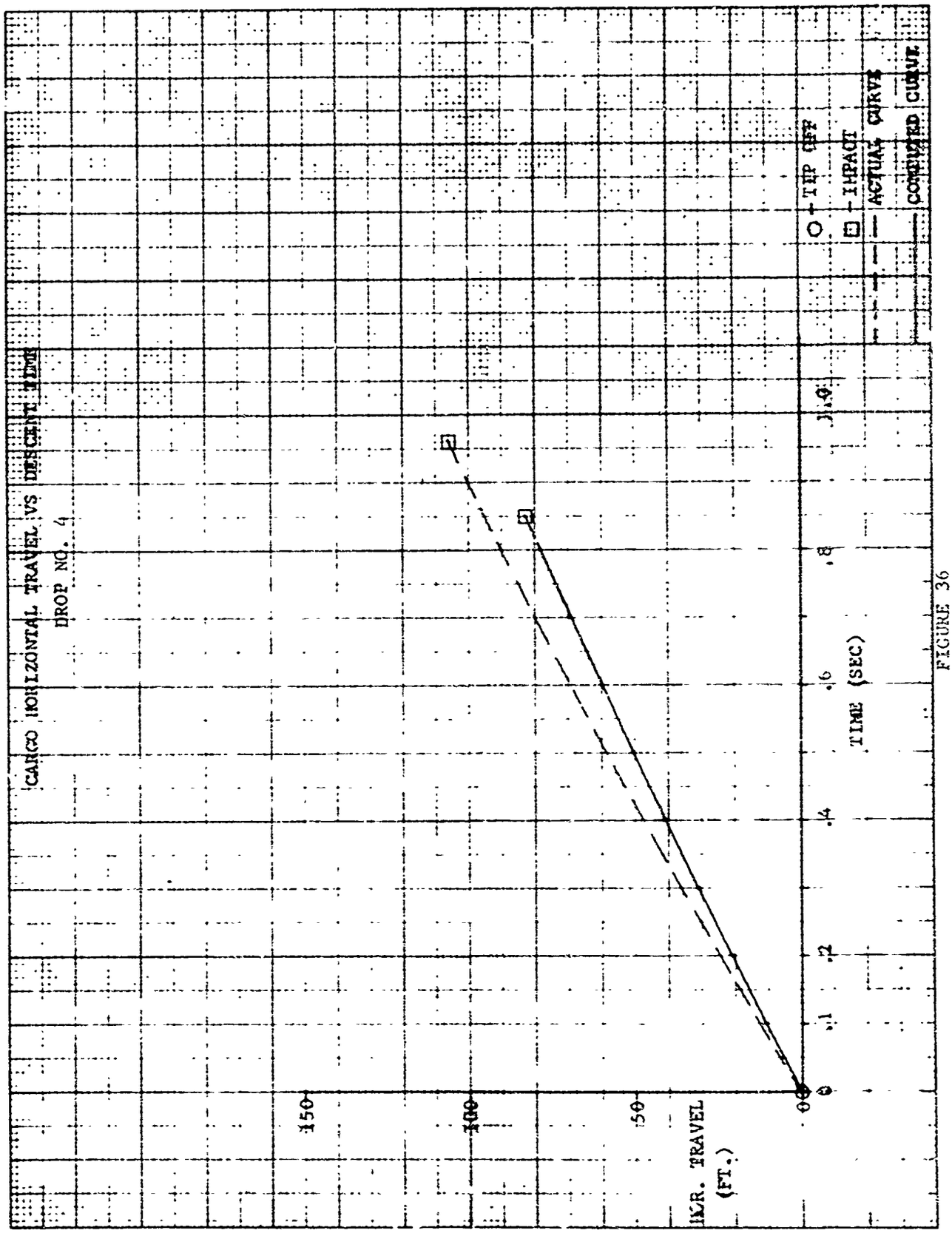
CARGO HORIZONTAL TRAVEL VS DESCENT TIME
DROP NO. 4
150
100
50
0
HOR. TRAVEL (FT.)
0
.1
.2
.4
.6
.8
1.0
TIME (SEC)
TIP OFF
IMPACT
ACTUAL CURVE
COMPUTED CURVE

FIGURE 36

AIRCRAFT ARMAMENTS, Inc.

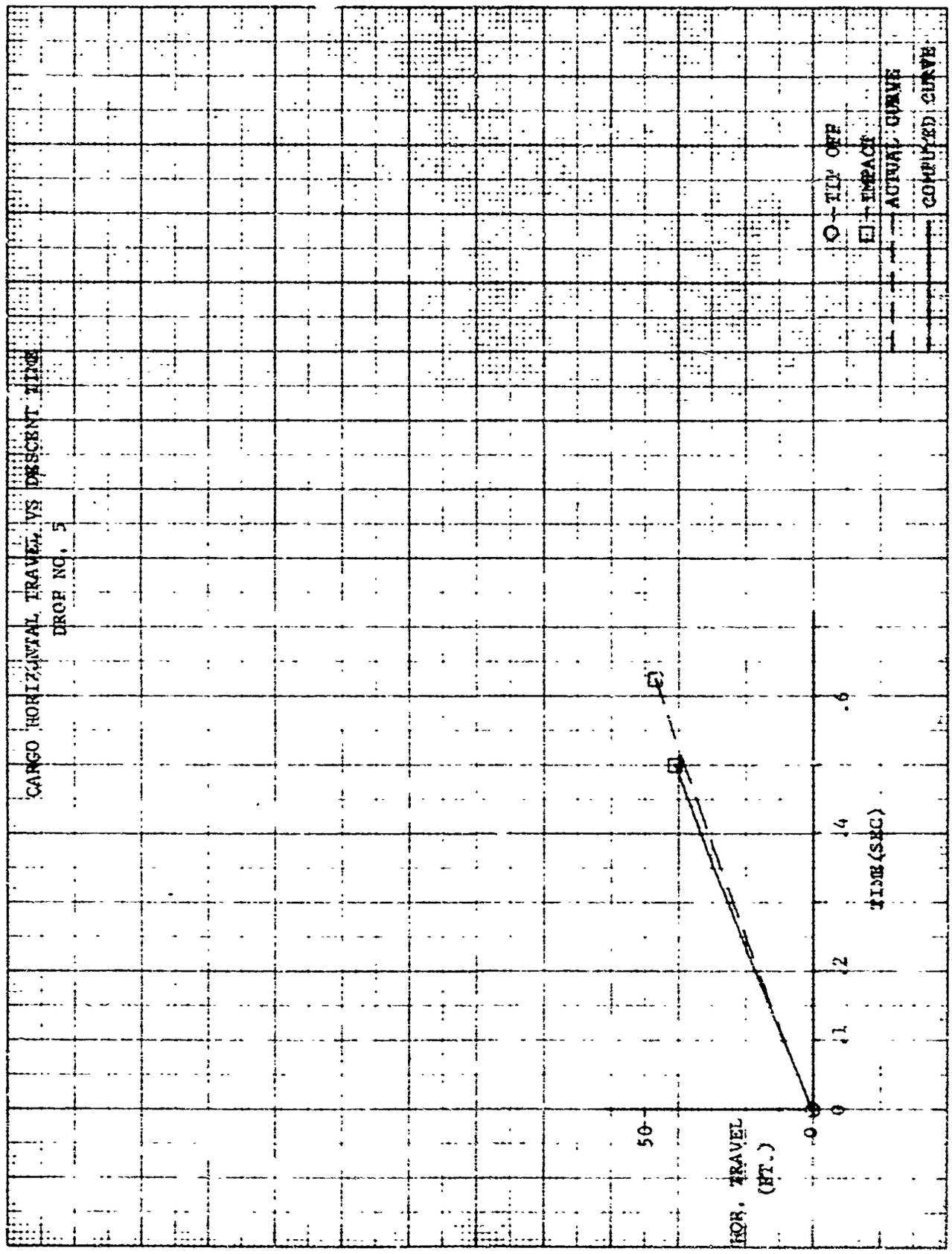


FIGURE 37

AIRCRAFT ARMAMENTS, Inc.

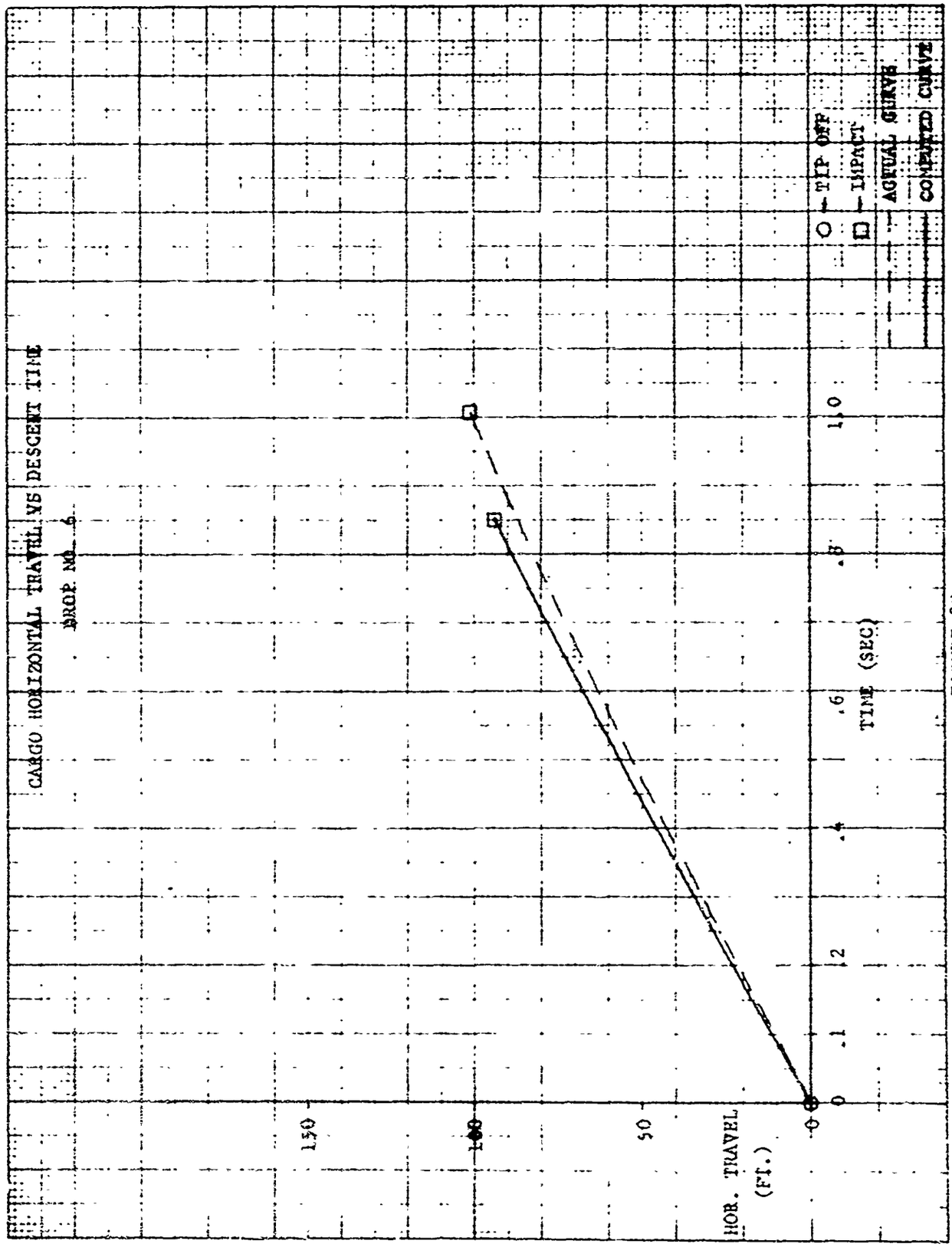


FIGURE 38

AIRCRAFT ARMAMENTS, Inc.

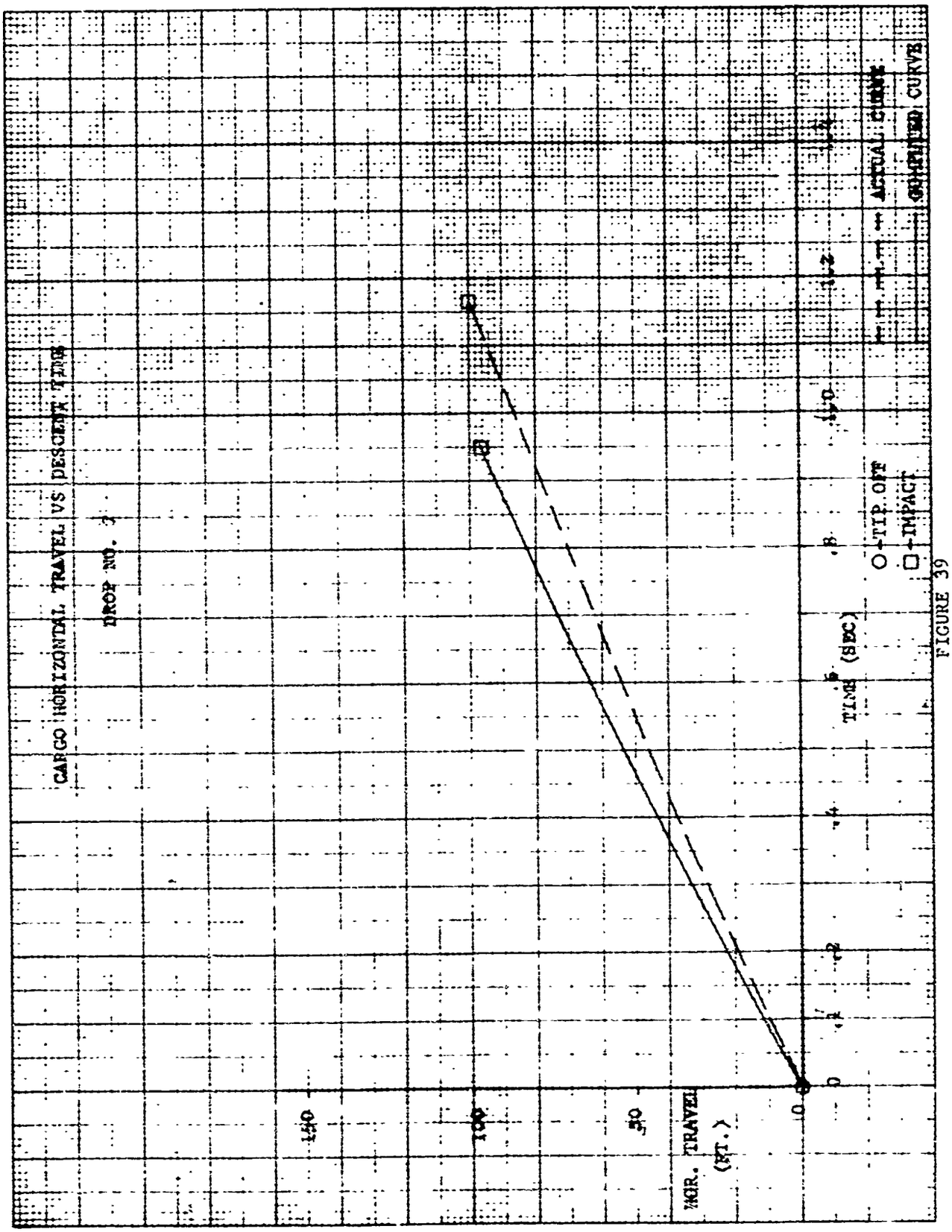


FIGURE 39

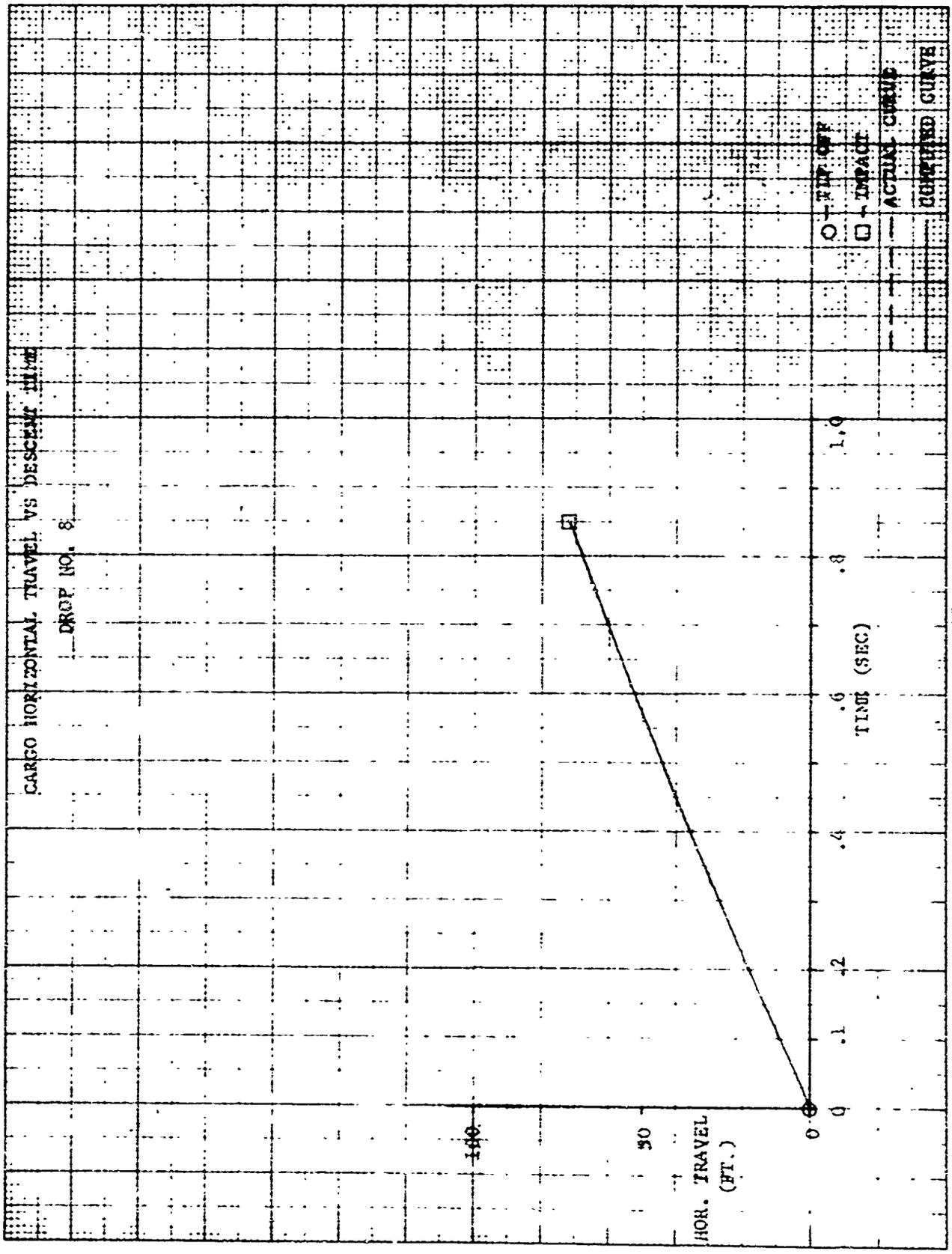
CARGO HORIZONTAL TRAVEL VS DESCENT TIME
DROP NO. 8
HOR. TRAVEL (FT.)
100
50
0
0
.1
.2
.4
.6
.8
1.0
TIME (SEC)
TIP OFF
IMPACT
ACTUAL CURVE
SIMPLIFIED CURVE

FIGURE 40

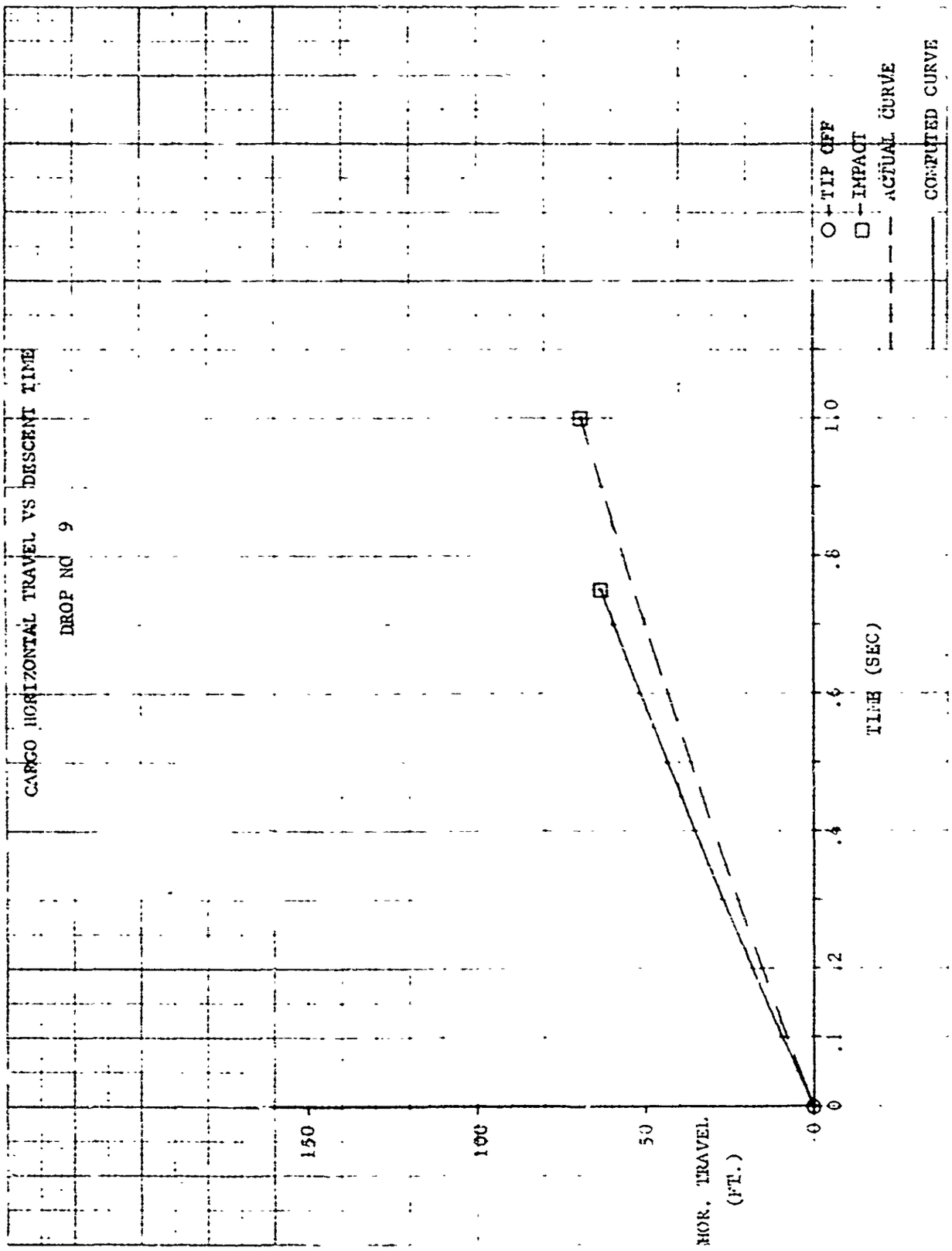
CARGO HORIZONTAL TRAVEL VS DESCENT TIME
DROP NO 9
TIP OFF
IMPACT
ACTUAL CURVE
COMPUTED CURVE
TIME (SEC)
HOR. TRAVEL (FT.)
0
.1
.2
.3
.4
.6
.8
1.0
50
100
150

FIGURE 41

AIRCRAFT ARMAMENTS, Inc.

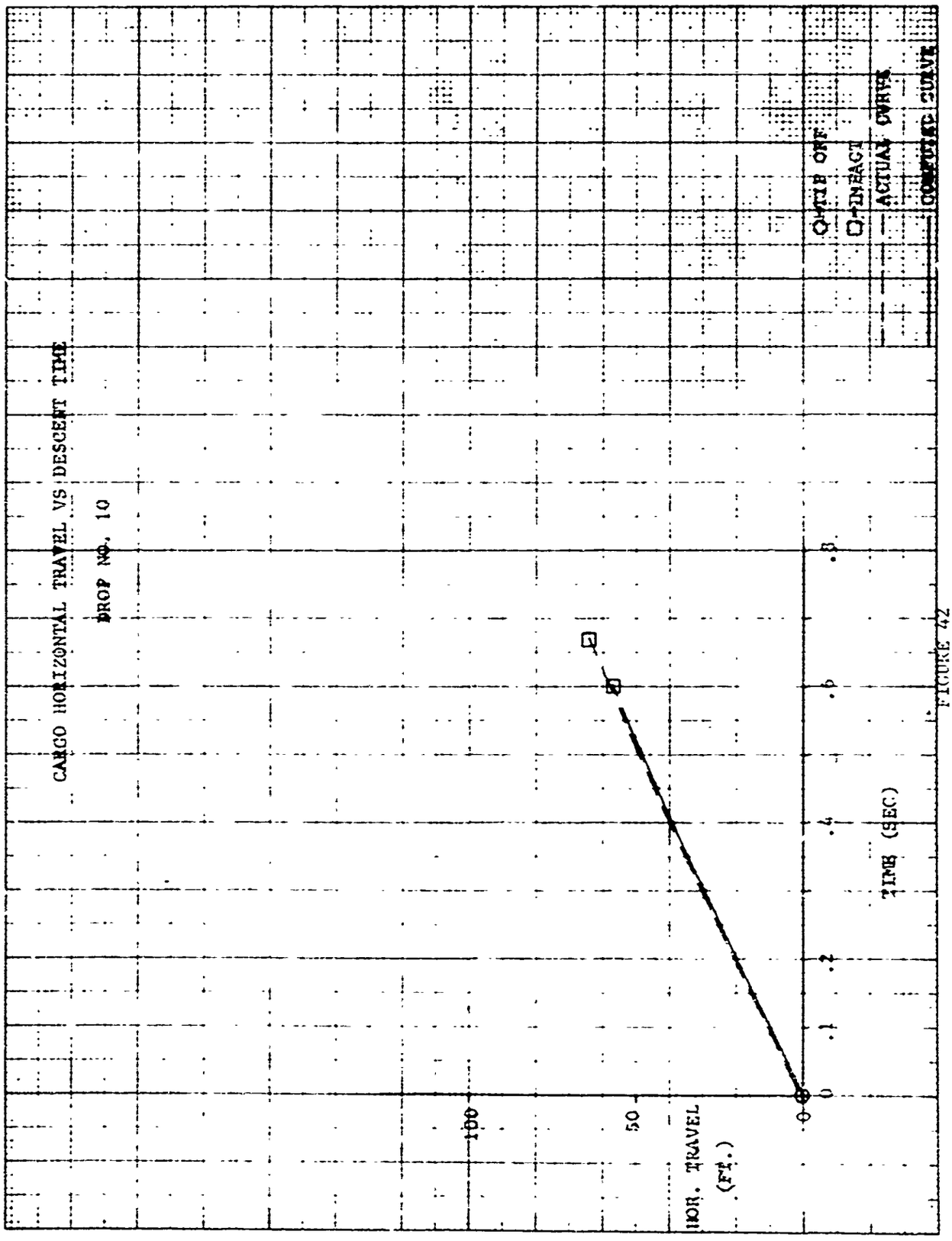


FIGURE 42

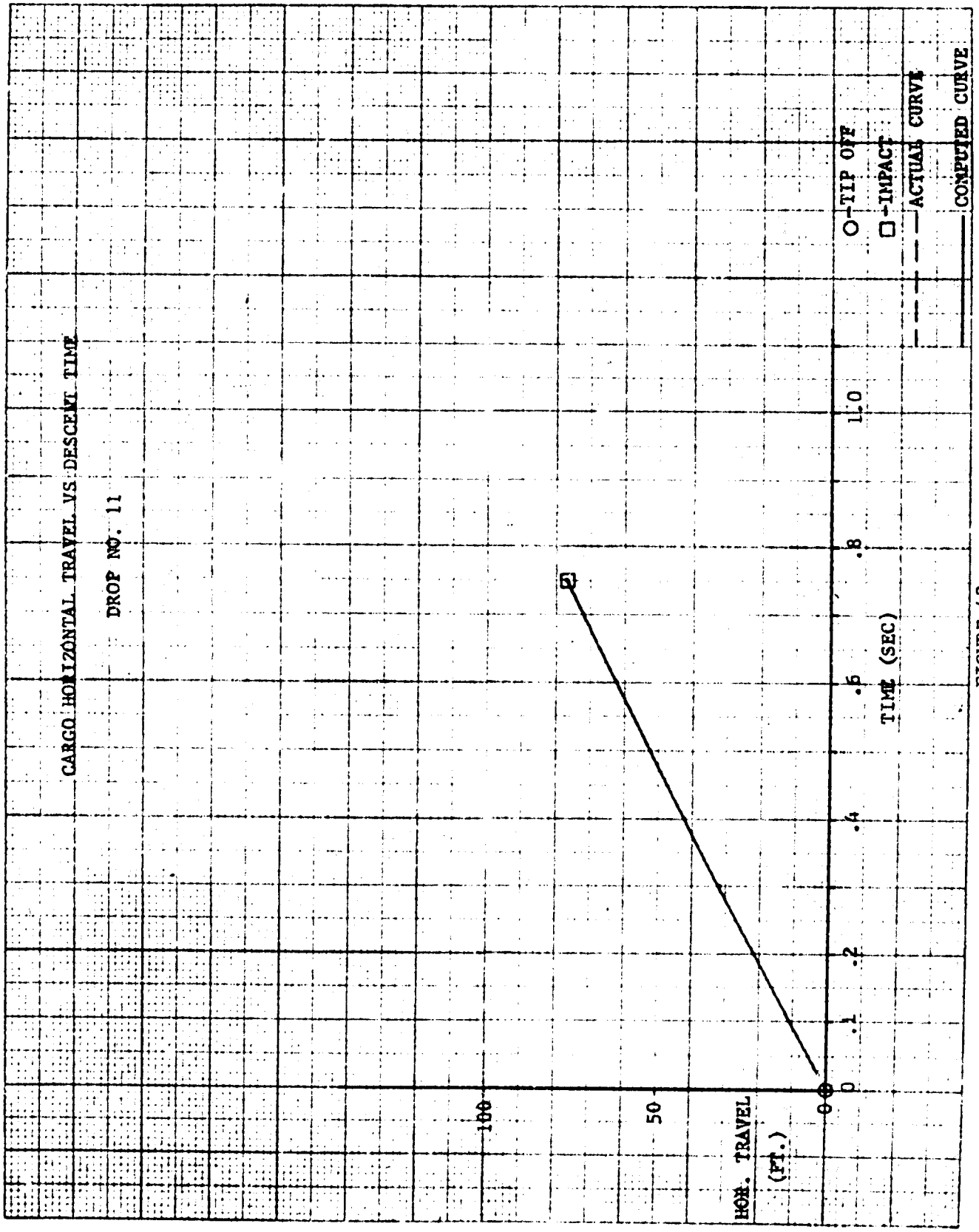
CARGO HORIZONTAL TRAVEL VS DESCENT TIME
DROP NO. 11
HOR. TRAVEL (FT.)
100
50
0
0
.1
.2
.4
.6
.8
1.0
TIME (SEC)
O-TIP OFF
□-IMPACT
ACTUAL CURVE
COMPUTED CURVE

FIGURE 43

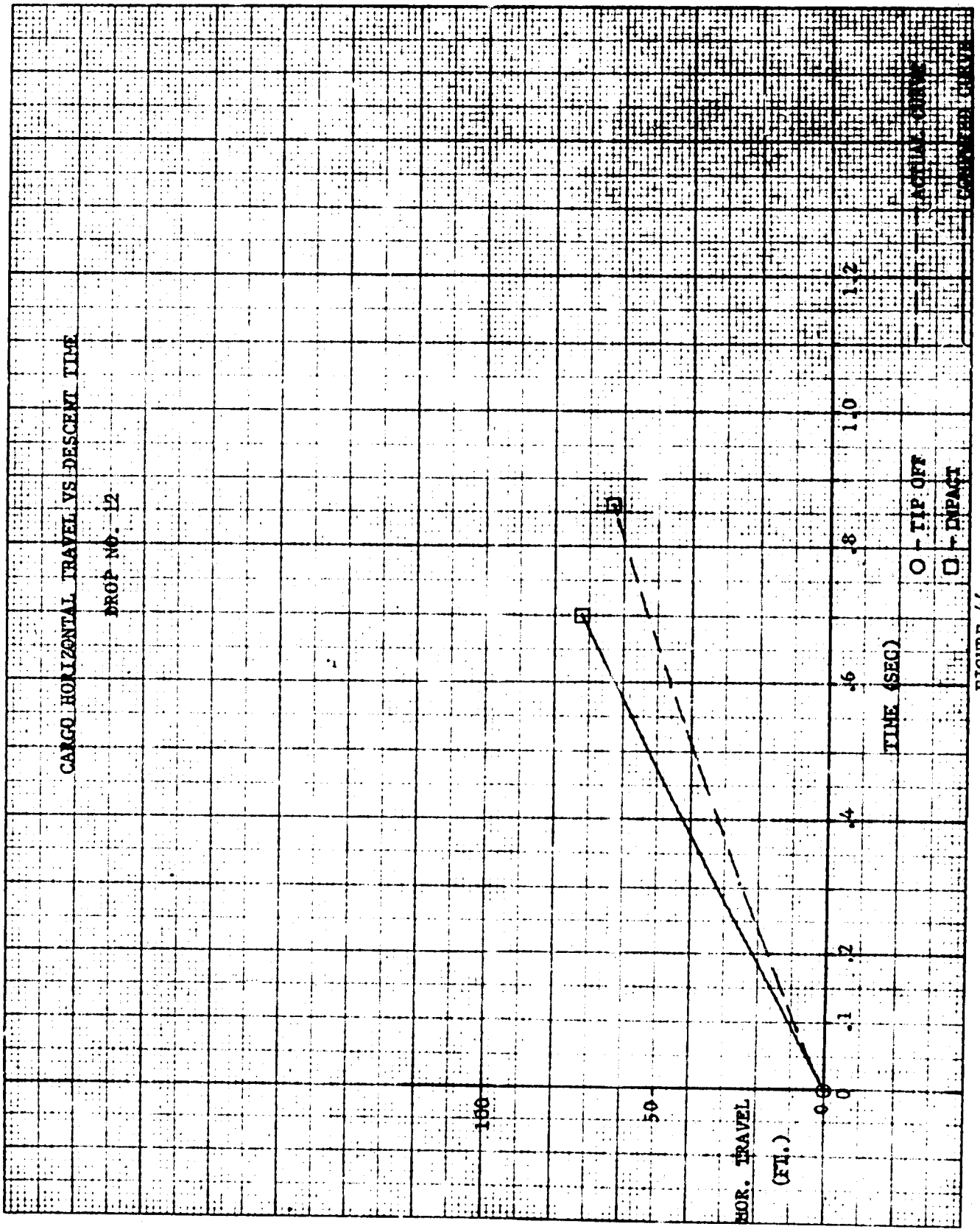
CARGO HORIZONTAL TRAVEL VS DESCENT TIME
DROP NO. 12
HOR. TRAVEL (FT.)
100
50
0
0
.1
.2
.4
.6
.8
1.0
1.2
TIME (SEC)
O - TIP OFF
□ - IMPACT
ACTUAL CURVE
CORRECTED CURVE

FIGURE 44

AIRCRAFT ARMAMENTS, Inc.

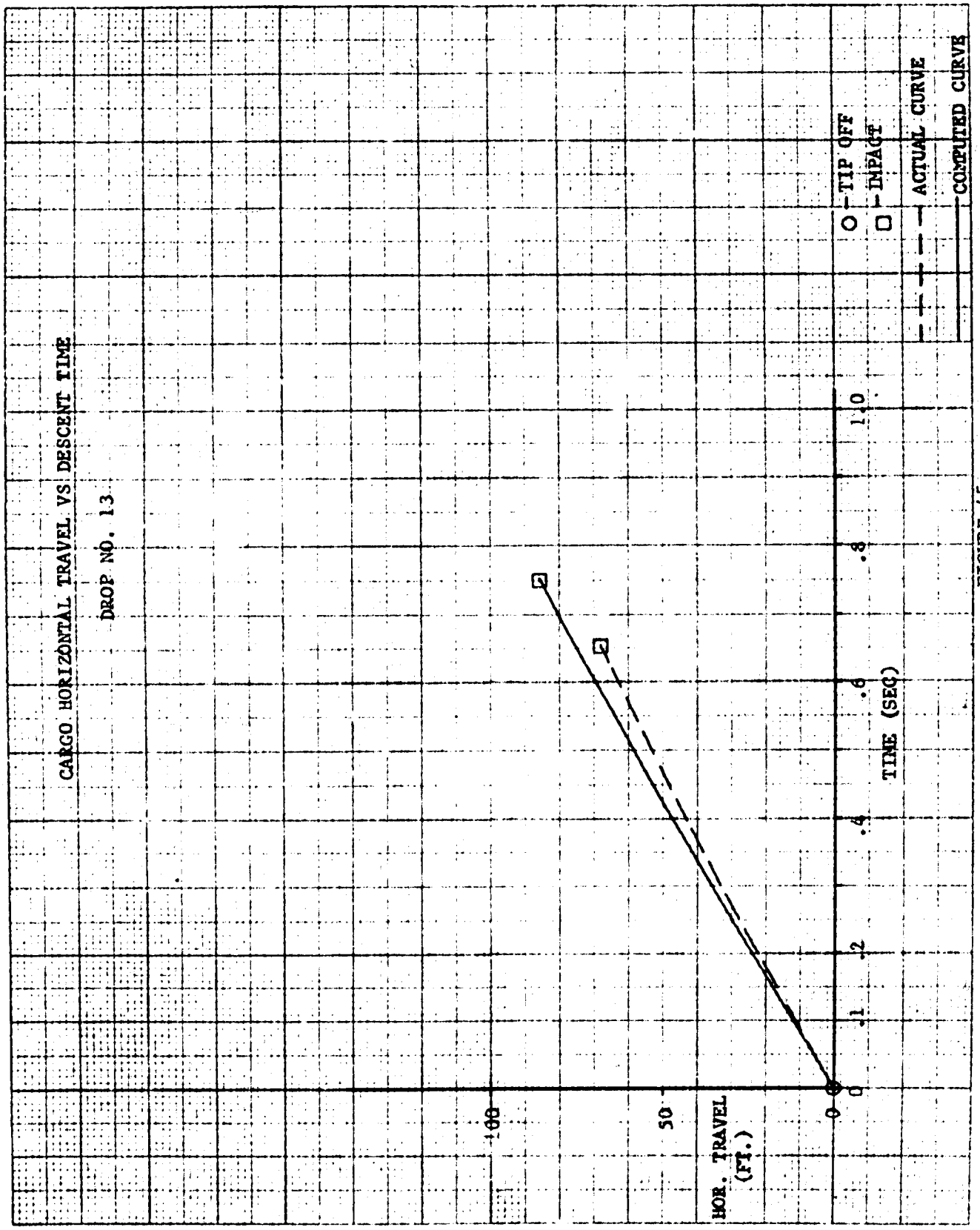


FIGURE 45

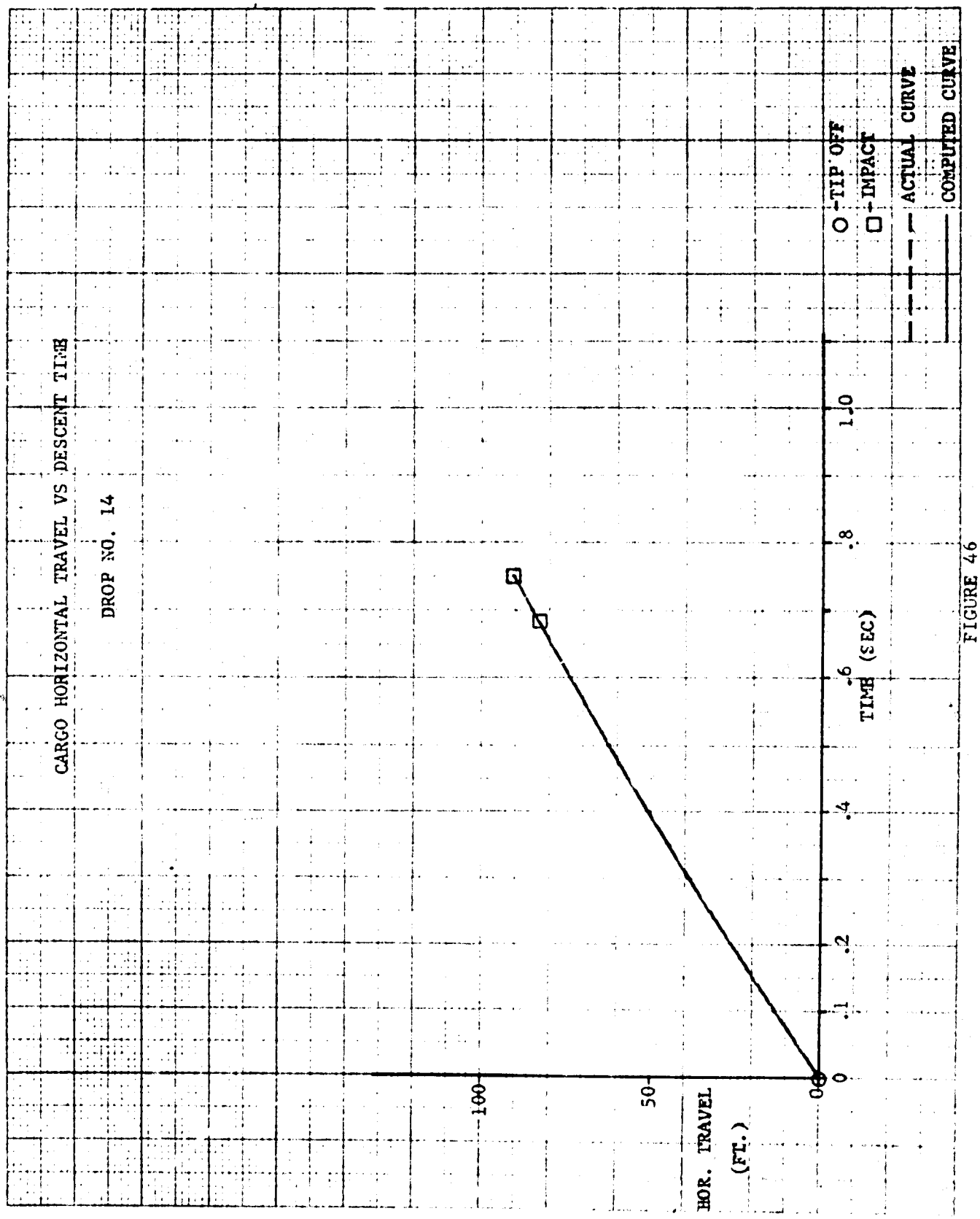
CARGO HORIZONTAL TRAVEL VS DESCENT TIME
DROP NO. 14
HOR. TRAVEL (FT.)
100
50
0
0
.1
.2
.4
.6
.8
1.0
TIME (SEC)
O - TIP OFF
□ - IMPACT
ACTUAL CURVE
COMPUTED CURVE

FIGURE 46

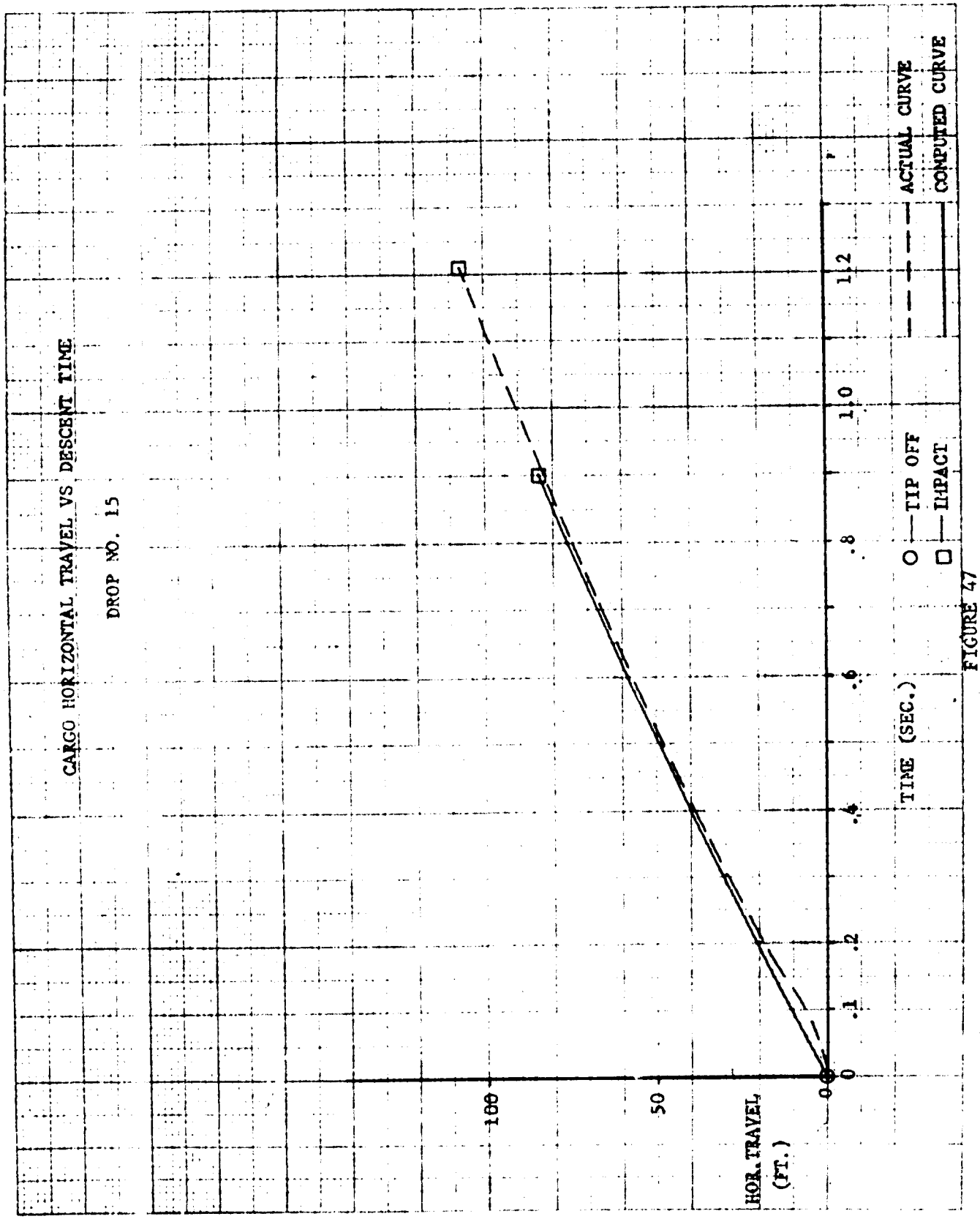
CARGO HORIZONTAL TRAVEL VS DESCENT TIME
DROP NO. 15
HOR. TRAVEL (FT.)
100
50
0
0
.1
.2
.4
.6
.8
1.0
1.2
TIME (SEC.)
TIP OFF
IMPACT
ACTUAL CURVE
COMPUTED CURVE

FIGURE 47

The third plot used in comparing the computer analysis against actual tests is shown below in Figures 48 through 61. These are plots of cargo pitch angle versus descent time. Drops Nos. 1, 3, 8 and 11 are not complete because sufficient data was not acquired from these tests.

In several of the tests, as shown by the curves, the actual cargo pitch angle is quite different from the predicted angle. In the tests the aircraft is pitching, due to turbulence and aircraft instability and this induces some angular acceleration to the cargo. One assumption in the computer equations is that the aircraft does not change pitch angle during extraction.

In figures 76 through 89 cargo pitch angle was plotted versus drop altitude. In these curves the effect of aircraft induced angular acceleration can also be observed.

AIRCRAFT ARMAMENTS, Inc.

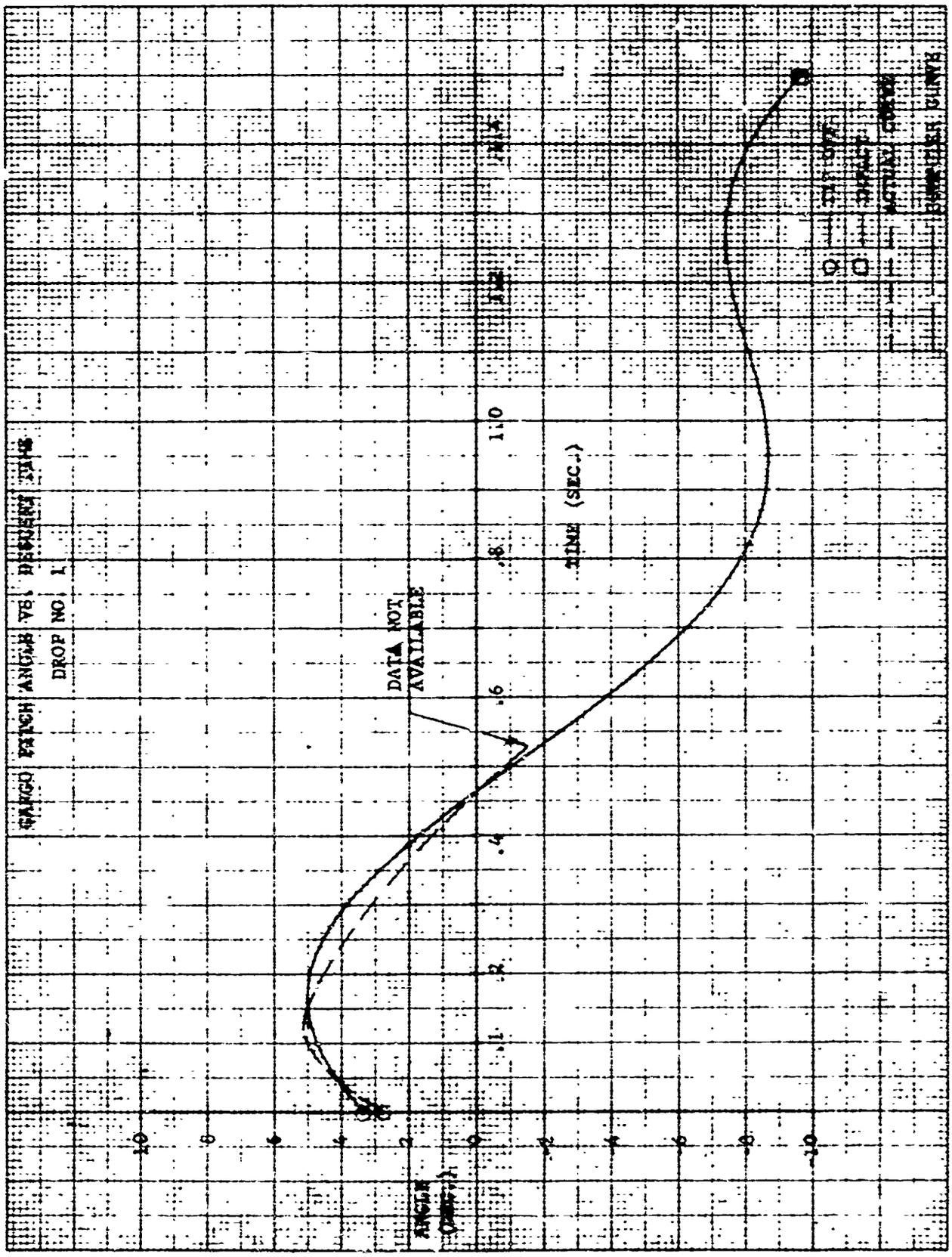


Figure 48

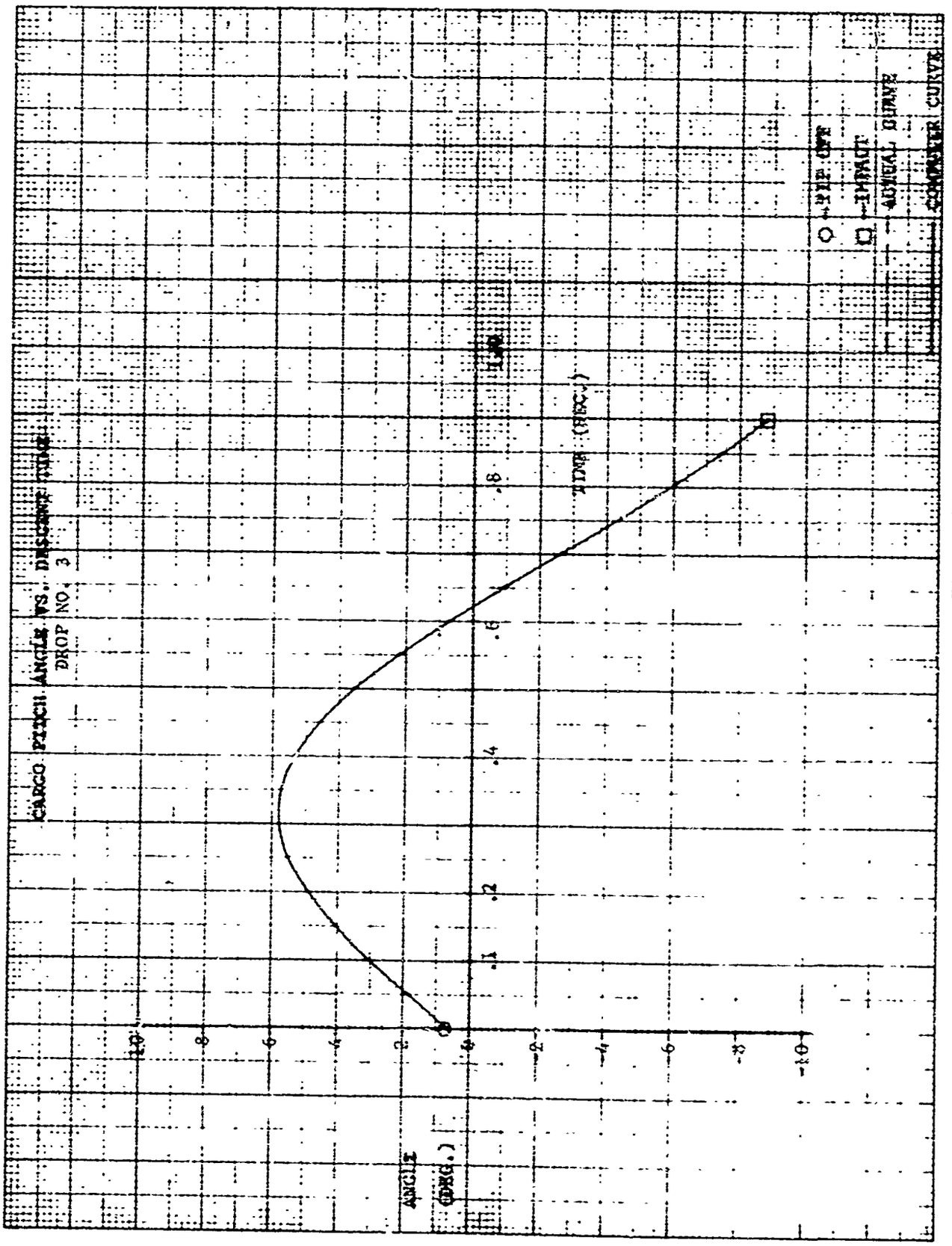
CARGO PITCH ANGLE VS. DESCENT TIME
DROP NO. 3
TIME (SEC.)
ANGLE (DEG.)
.1
.2
.4
.6
.8
1.0
10
8
6
4
2
0
-2
-4
-6
-8
-10
TIP OFF
IMPACT
ACTUAL CURVE
COMPUTER CURVE

Figure 49

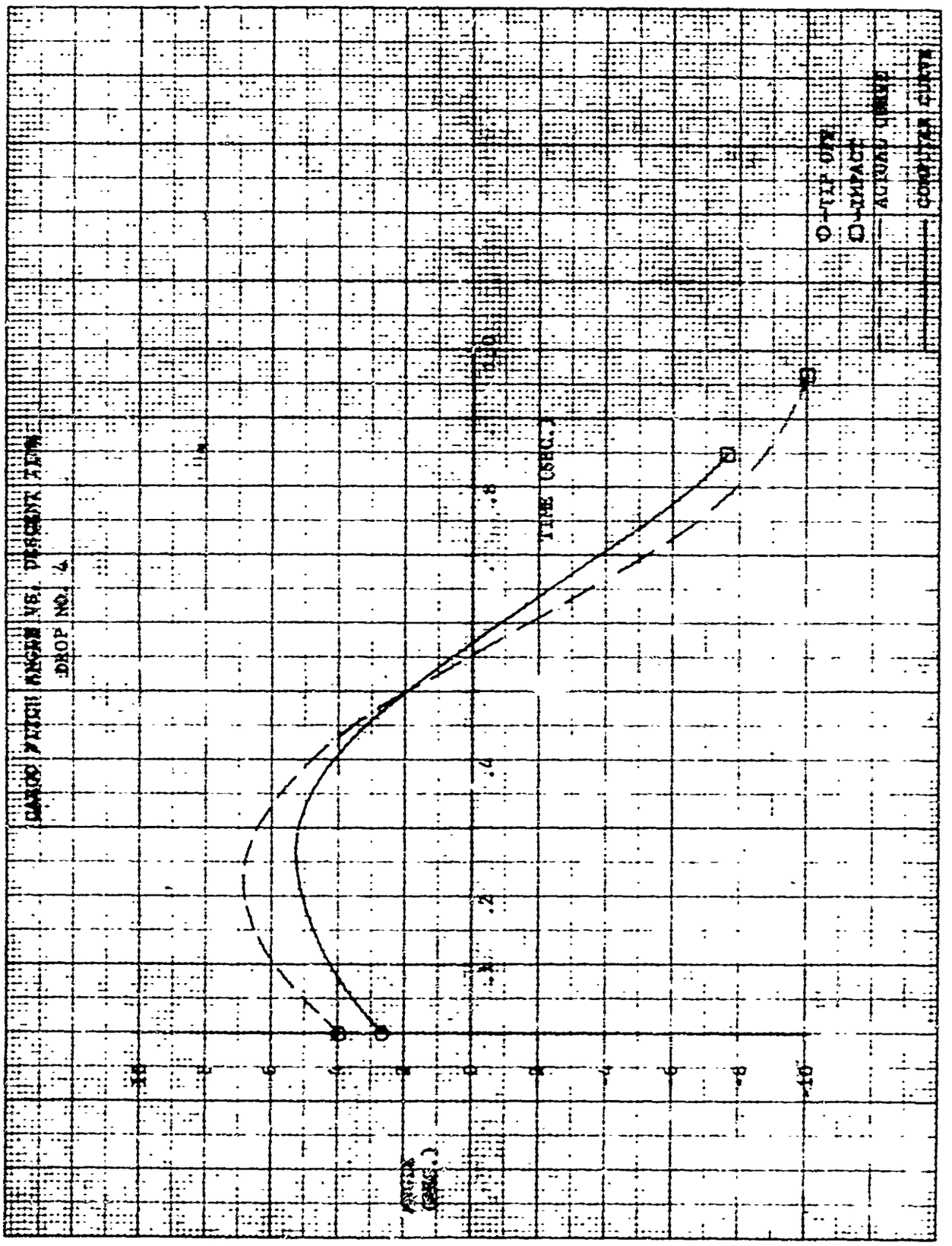
DROP NO. 4
TIME (SEC.)
.2
.4
.8
1.0
-10
-8
-6
-4
-2
0
2
4
6
8
10
O-TIP OFF
□-IMPACT
ACTUAL CURVE
COMPUTER CURVE

Figure 50

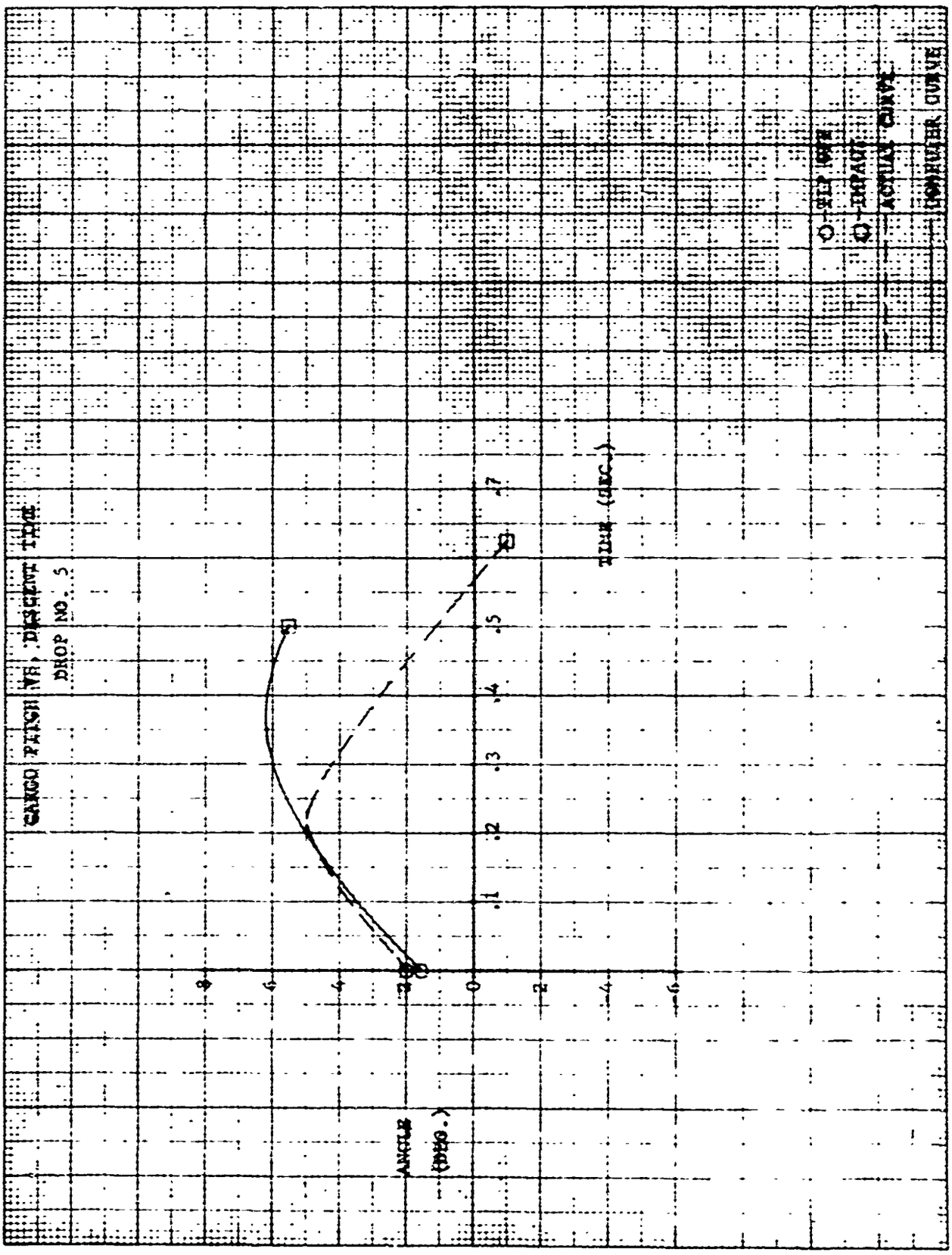
CARGO PITCH VS. DESCENT TIME
DROP NO. 5
ANGLE (DEG.)
TIME (SEC.)
.1
.2
.3
.4
.5
.7
8
6
4
2
0
2
4
6
O-TIP OFF
O-IMPACT
ACTUAL CURVE
COMPUTER CURVE

Figure 51

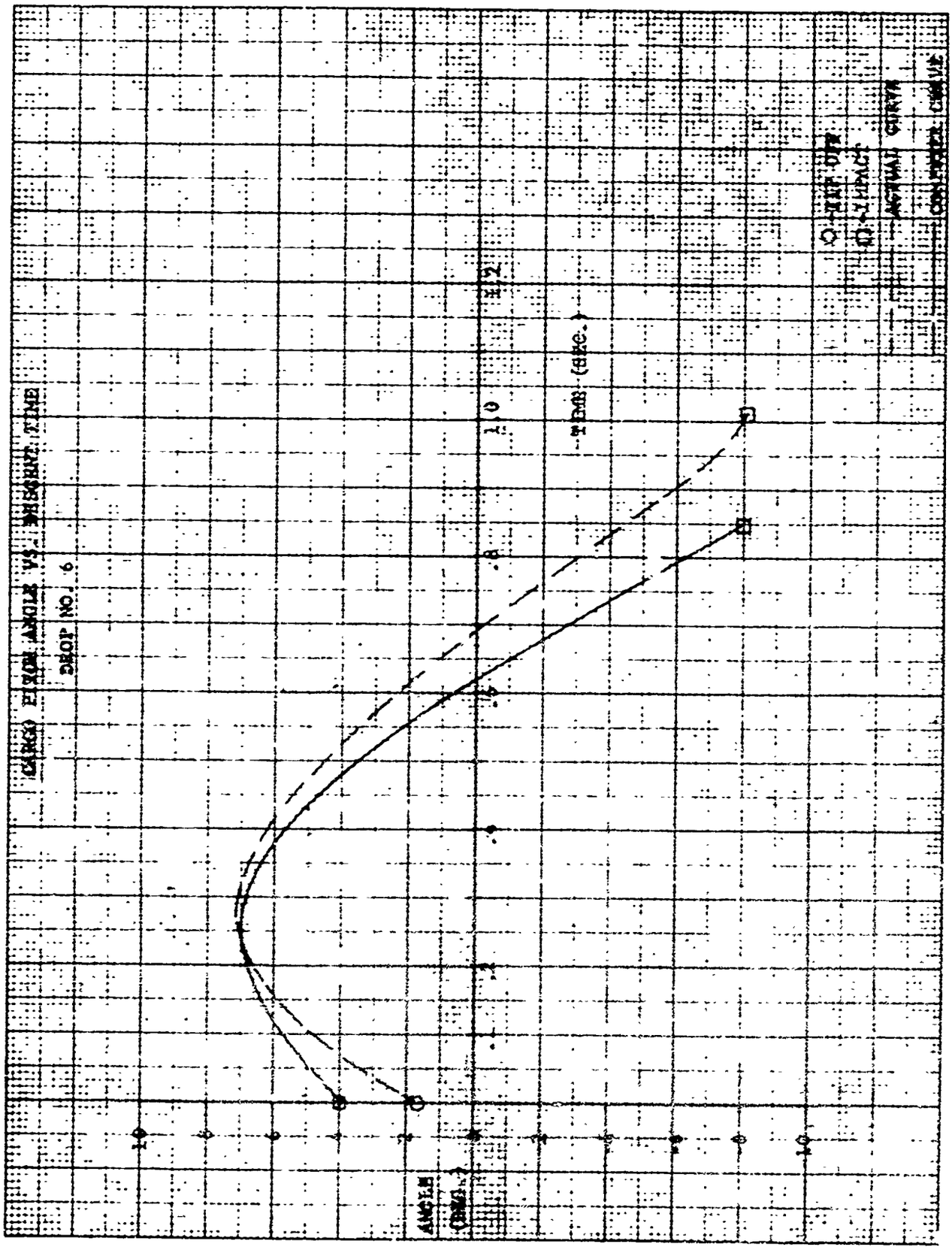
CARGO PITCH ANGLE VS. DESCENT TIME
DROP NO. 6
TIME (SEC.)
ANGLE (DEG.)
ACTUAL CURVE
COMPUTER CURVE

Figure 52

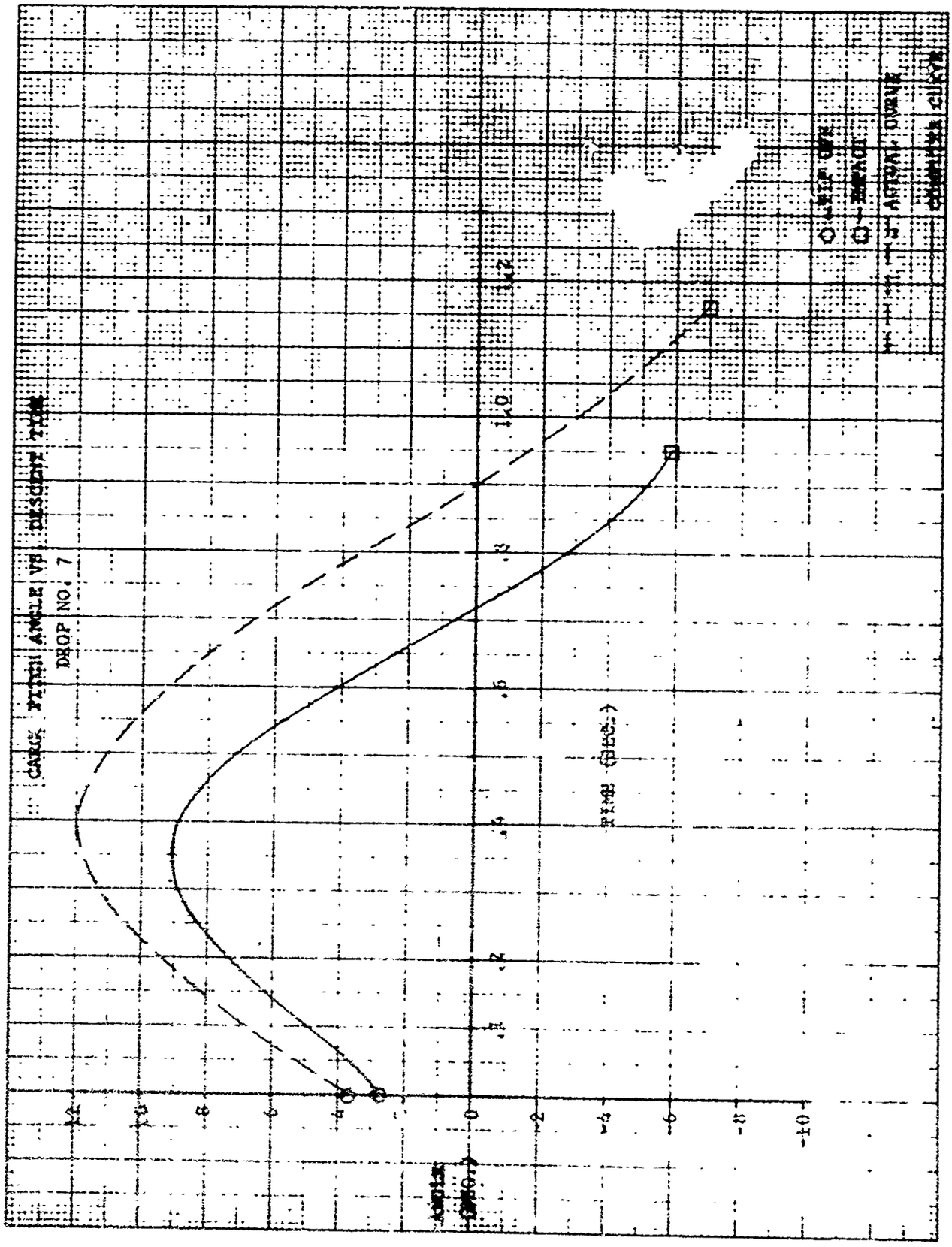
CARGO PITCH ANGLE VS. DESCENT TIME
DROP NO. 7
TIME (SEC.)
ANGLE (DEG.)
ACTUAL CURVE
COMPUTER CURVE

Figure 53

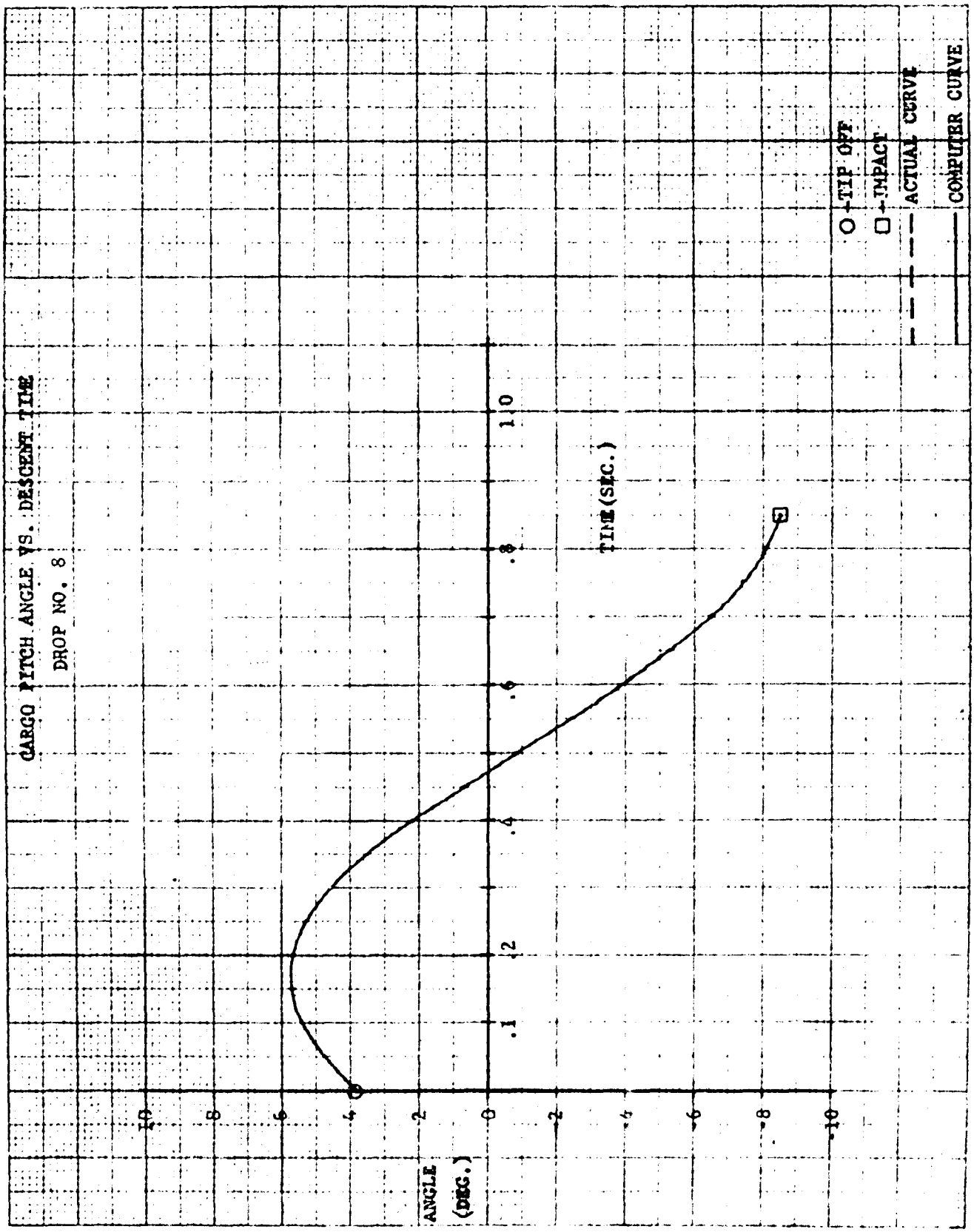
CARGO PITCH ANGLE VS. DESCENT TIME
DROP NO. 8
ANGLE (DEG.)
TIME (SEC.)
10
8
6
4
2
0
-2
-4
-6
-8
-10
.1
.2
.4
.6
.8
1.0
O - TIP OFF
□ - IMPACT
ACTUAL CURVE
COMPUTER CURVE

Figure 54

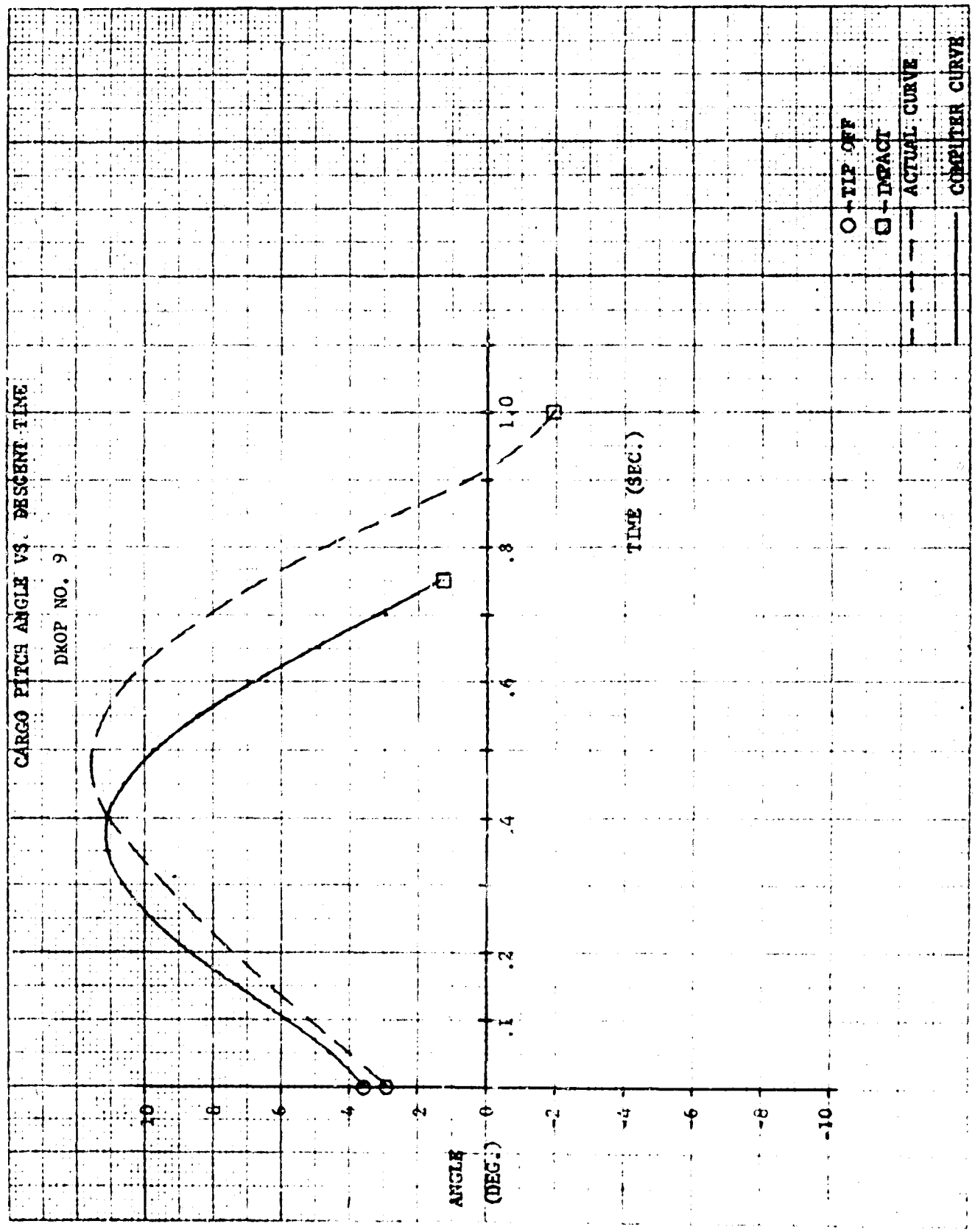
CARGO PITCH ANGLE VS. DESCENT TIME
DROP NO. 9
ANGLE (DEG.)
TIME (SEC.)
10
8
6
4
2
0
-2
-4
-6
-8
-10
.1
.2
.4
.6
.8
1.0
TIP OFF
IMPACT
ACTUAL CURVE
COMPUTER CURVE

Figure 55

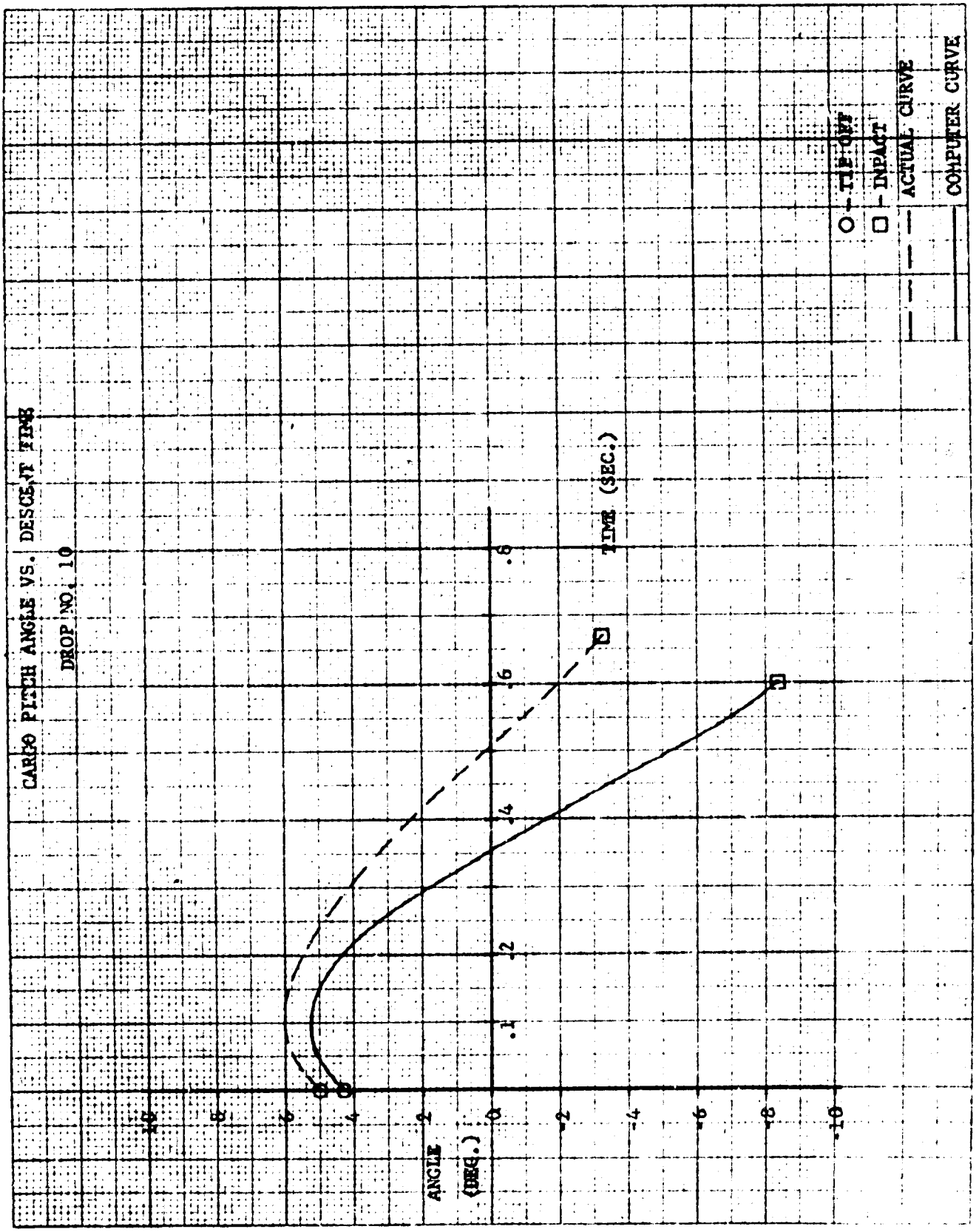
CARGO PITCH ANGLE VS. DESCENT TIME
DROP NO. 10
ANGLE (DEG.)
TIME (SEC.)
.1
.2
.4
.6
.8
10
8
6
4
2
0
-2
-4
-6
-8
-10
○ - TIP-OFF
□ - IMPACT
ACTUAL CURVE
COMPUTER CURVE

Figure 56

AIRCRAFT ARMAMENTS, Inc.

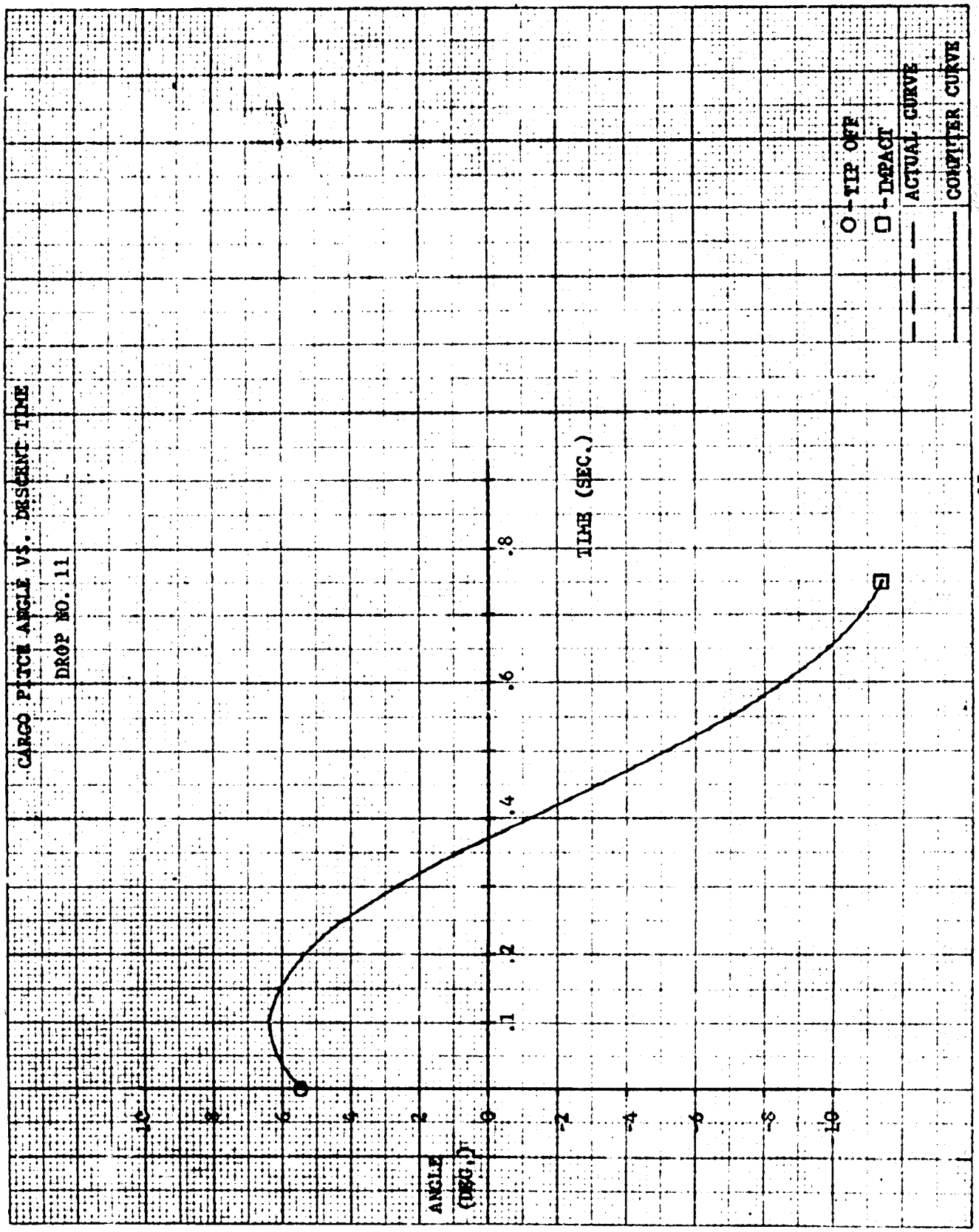


Figure 57

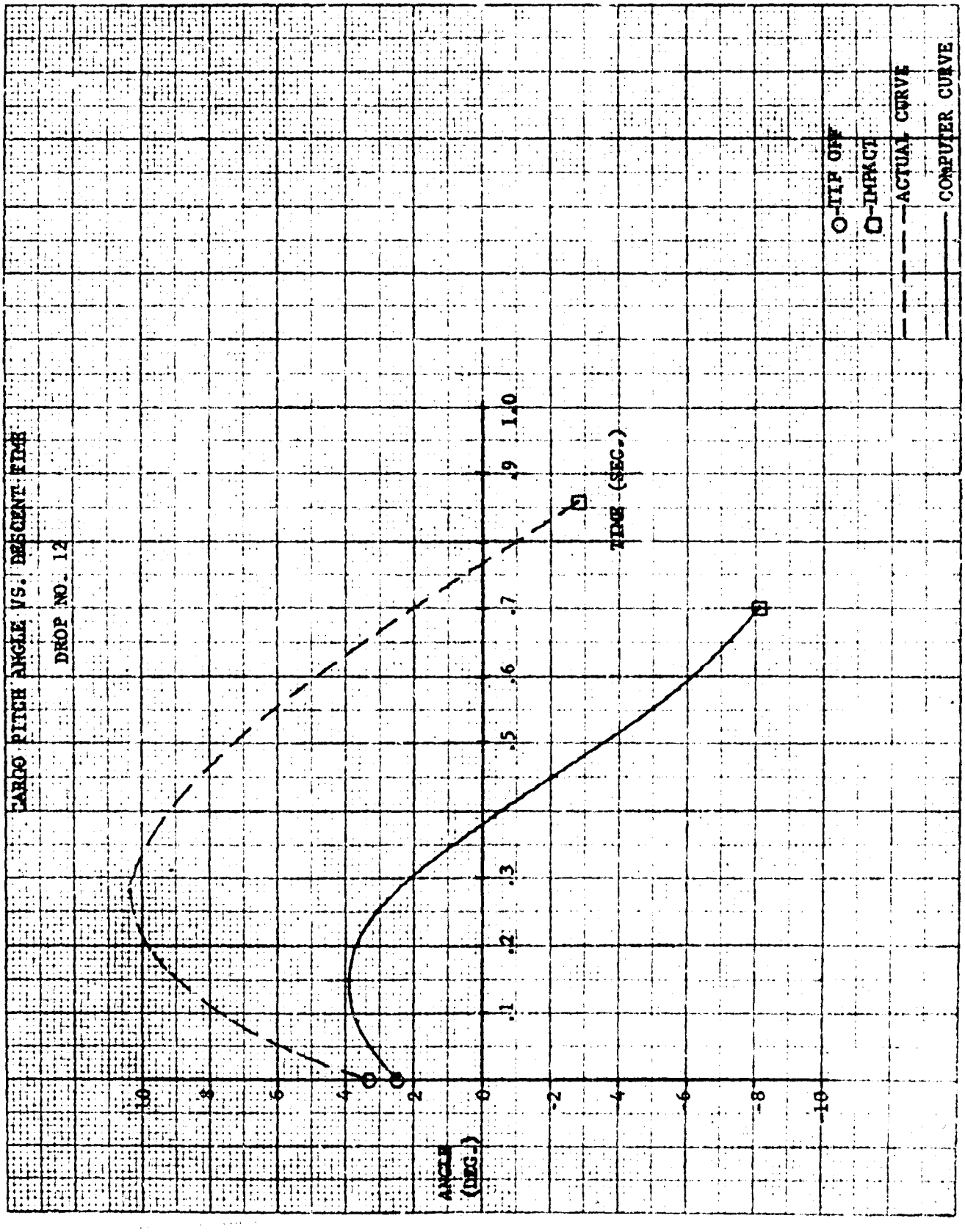
CARGO PITCH ANGLE VS. DESCENT TIME
DROP NO. 12
ANGLE (DEG.)
TIME (SEC.)
10
8
6
4
2
0
-2
-4
-6
-8
-10
.1
.2
.3
.5
.6
.7
.9
1.0
O-TIP OFF
□-IMPACT
ACTUAL CURVE
COMPUTER CURVE

Figure 58

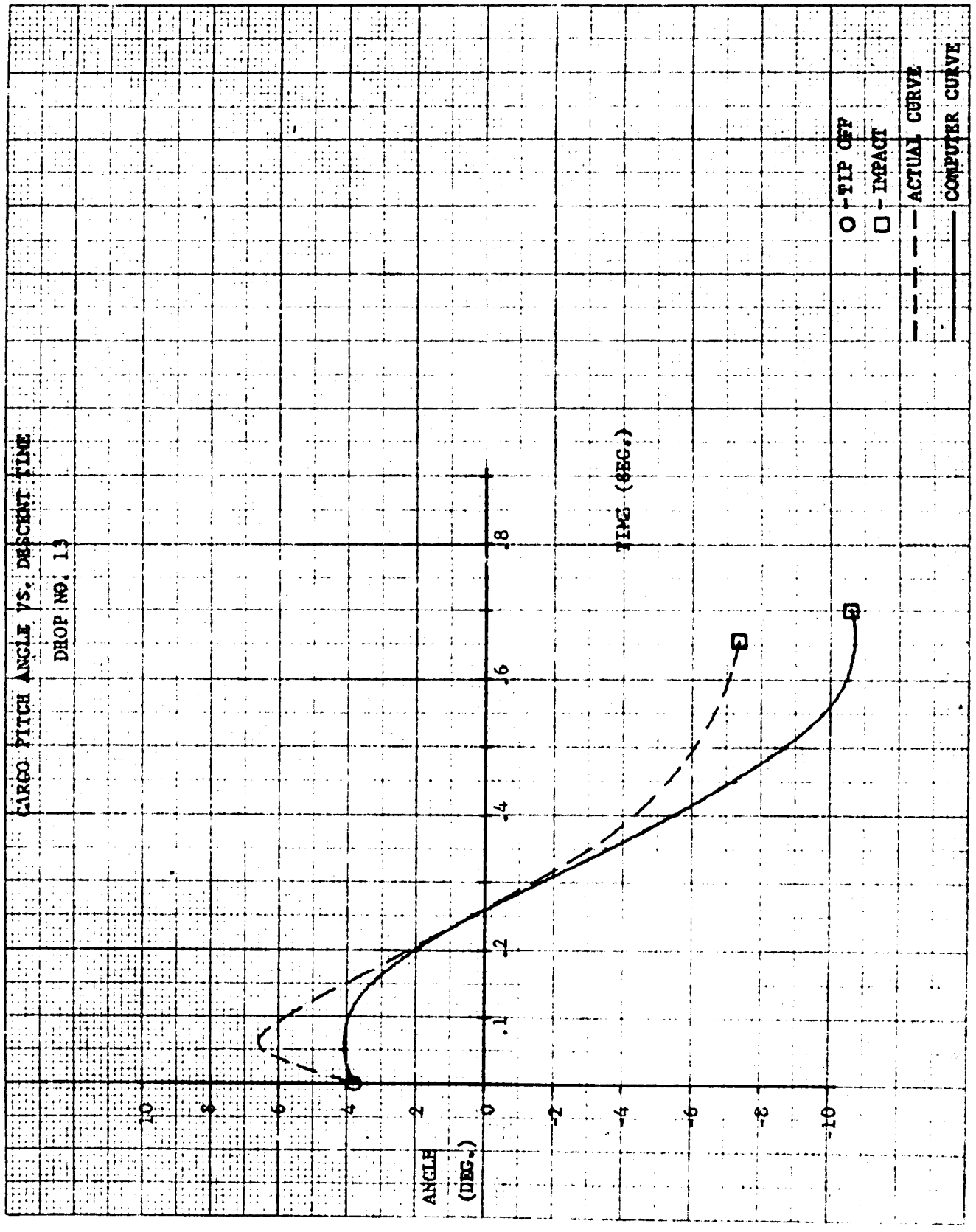
CARGO PITCH ANGLE VS. DESCENT TIME
DROP NO. 13
ANGLE (DEG.)
TIME (SEC.)
10
8
6
4
2
0
-2
-4
-6
-8
-10
.1
.2
.4
.6
.8
O - TIP OFF
□ - IMPACT
ACTUAL CURVE
COMPUTER CURVE

Figure 59

AIRCRAFT ARMAMENTS, Inc.

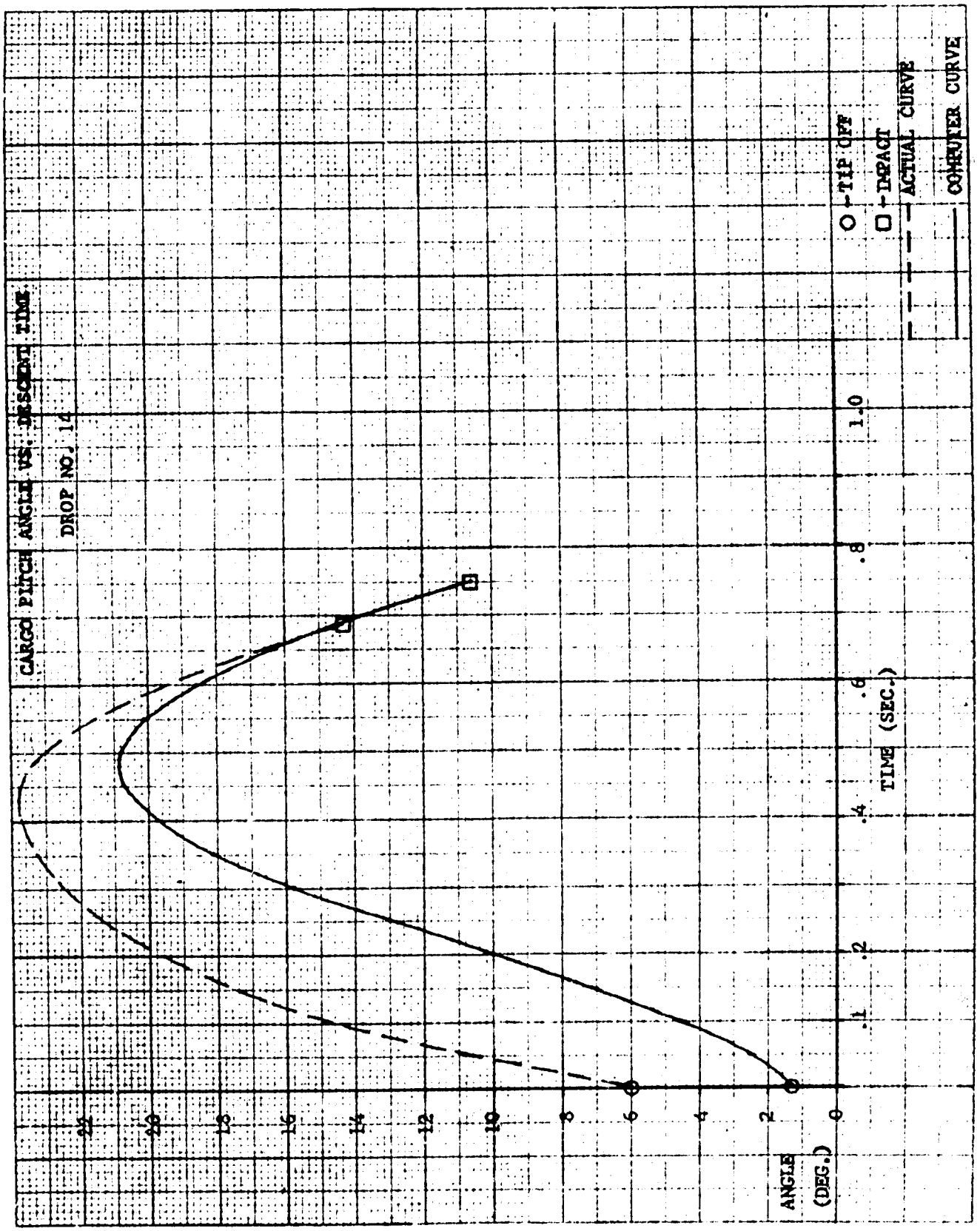


Figure 60

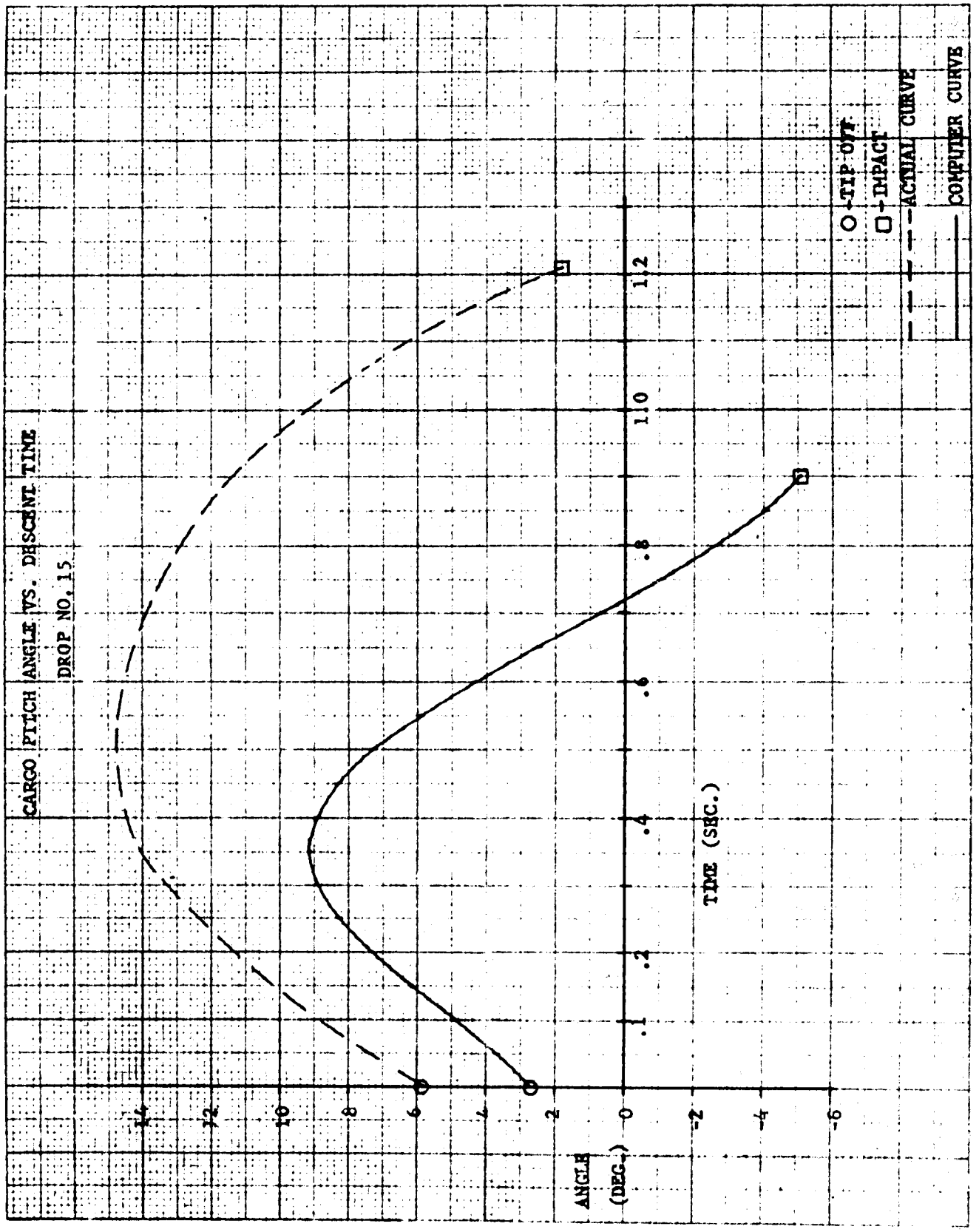
CARGO PITCH ANGLE VS. DESCENT TIME
DROP NO. 15
ANGLE (DEG.)
14
12
10
8
6
4
2
0
-2
-4
-6
TIME (SEC.)
.1
.2
.4
.6
.8
1.0
1.2
TIP OFF
IMPACT
ACTUAL CURVE
COMPUTER CURVE

Figure 61

AIRCRAFT ARMAMENTS, Inc.

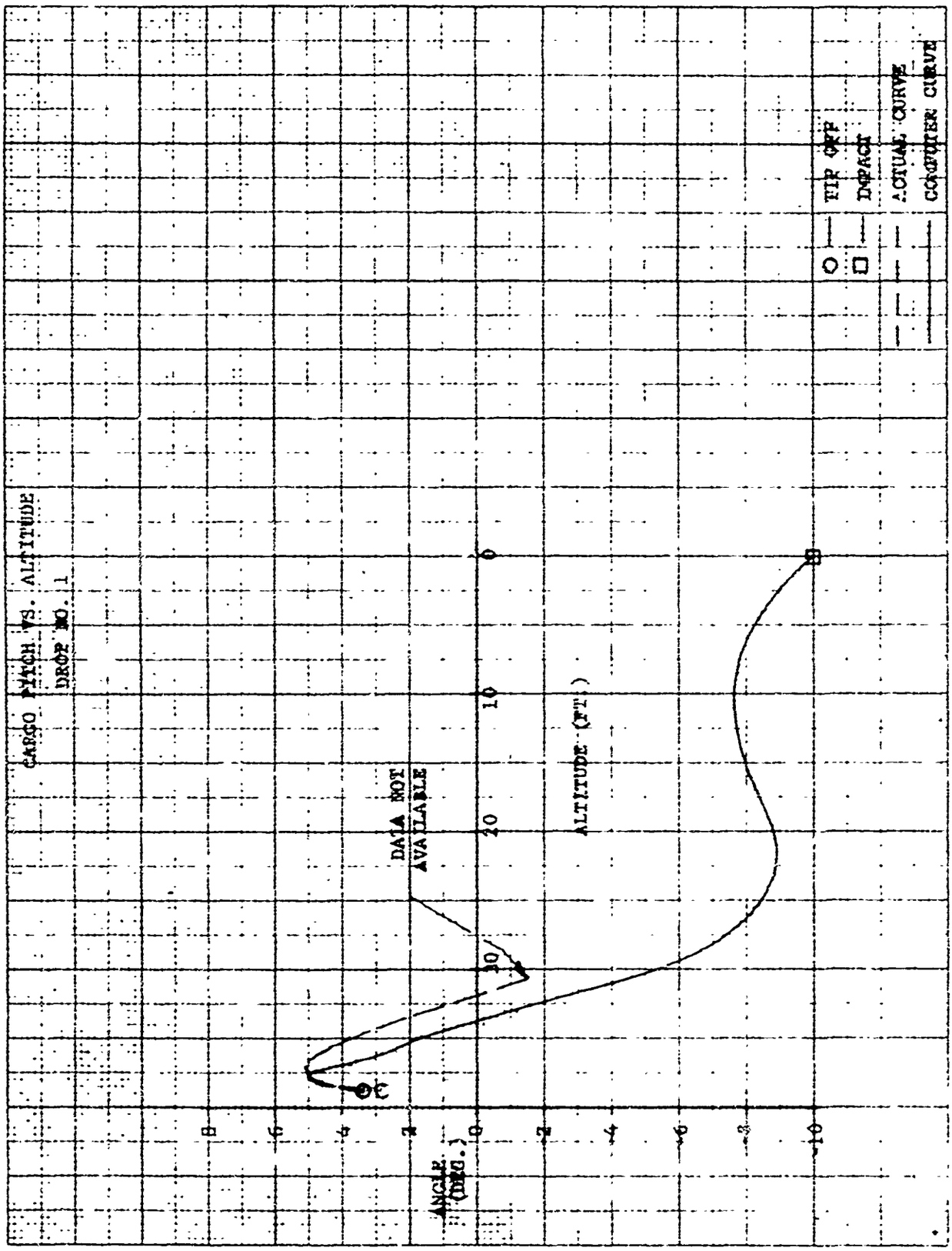


FIGURE 62

AIRCRAFT ARMAMENTS, Inc.

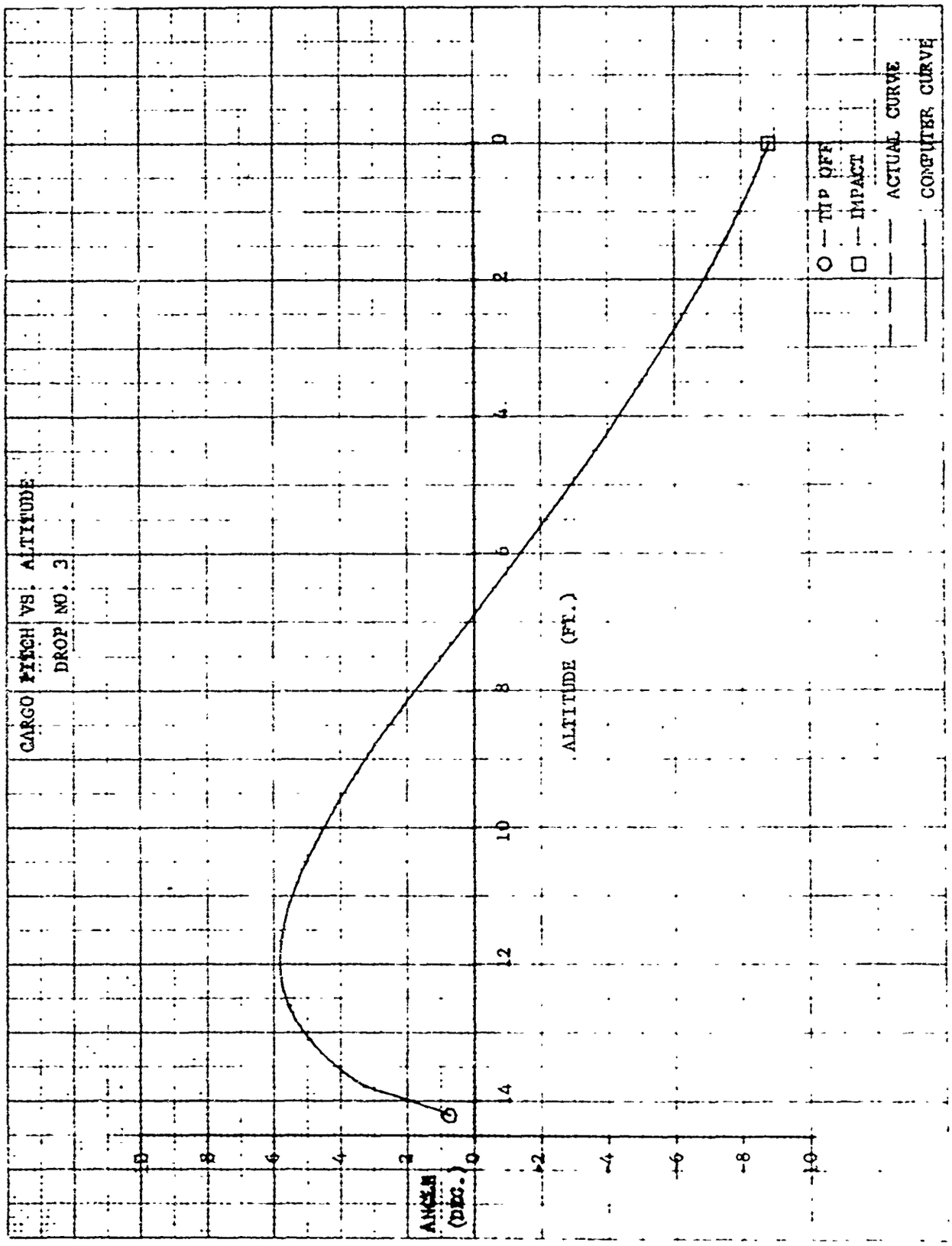


FIGURE 63

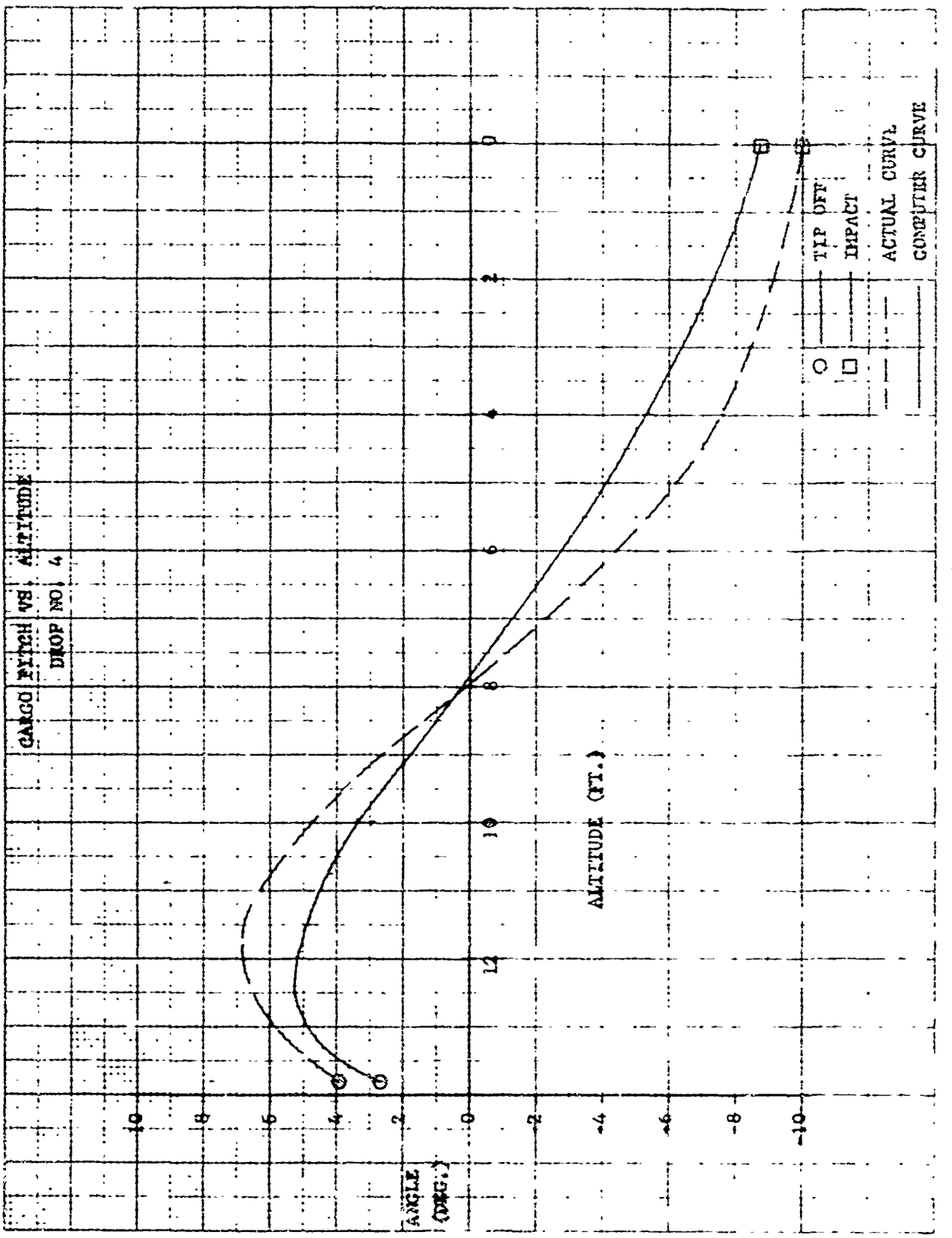
CARGO PITCH VS. ALTITUDE
DROP NO. 4
ANGLE (DEG.)
ALTITUDE (FT.)
10
8
6
4
2
0
-2
-4
-6
-8
-10
0
2
4
6
8
10
12
TIP OFF
IMPACT
ACTUAL CURVE
COMPUTER CURVE

FIGURE 64

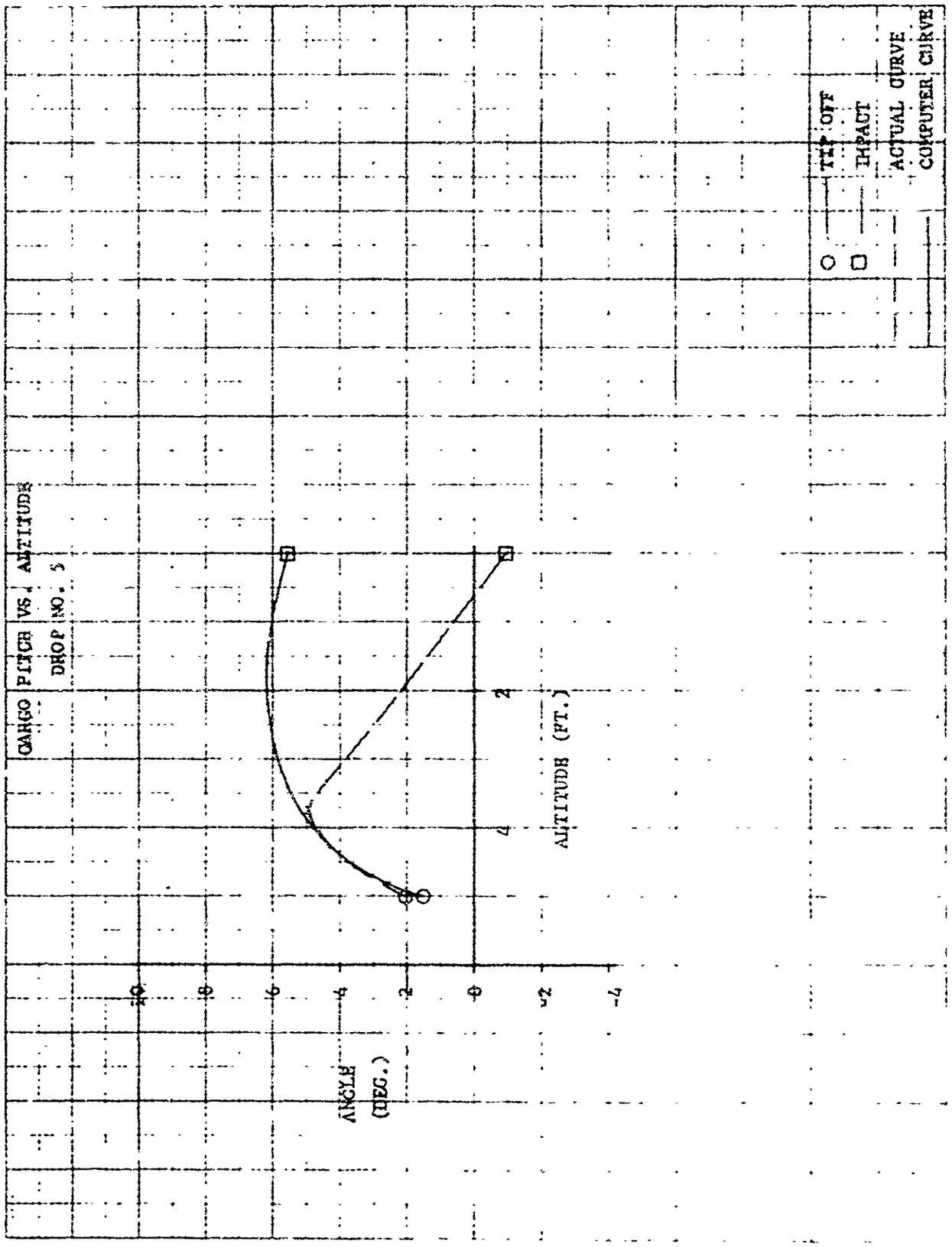
CARGO PITCH VS. ALTITUDE
DROP NO. 5
ANGLE (DEG.)
ALTITUDE (FT.)
TIP OFF
IMPACT
ACTUAL CURVE
COMPUTER CURVE

FIGURE 65

AIRCRAFT ARMAMENTS, Inc.

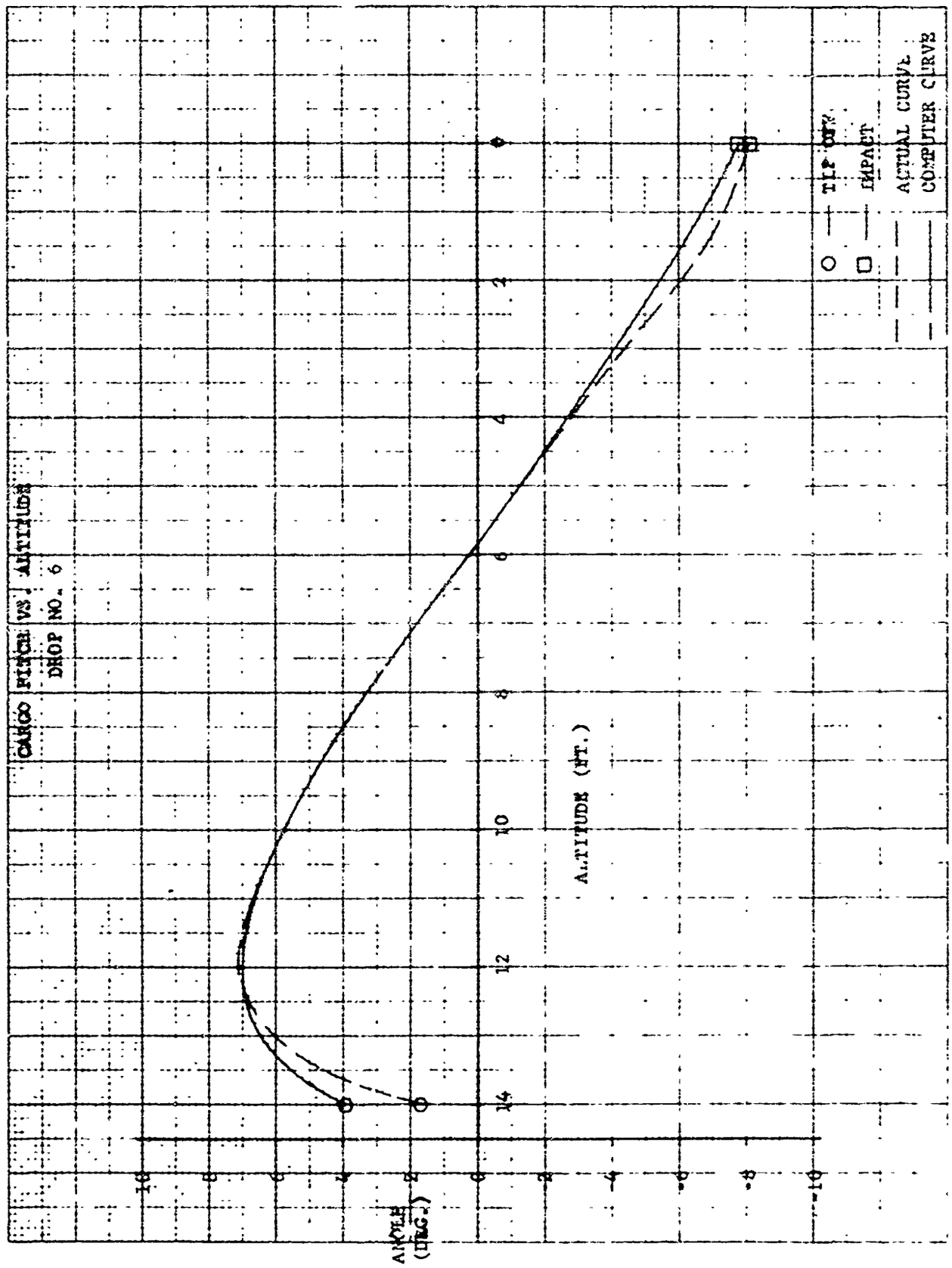


FIGURE 66

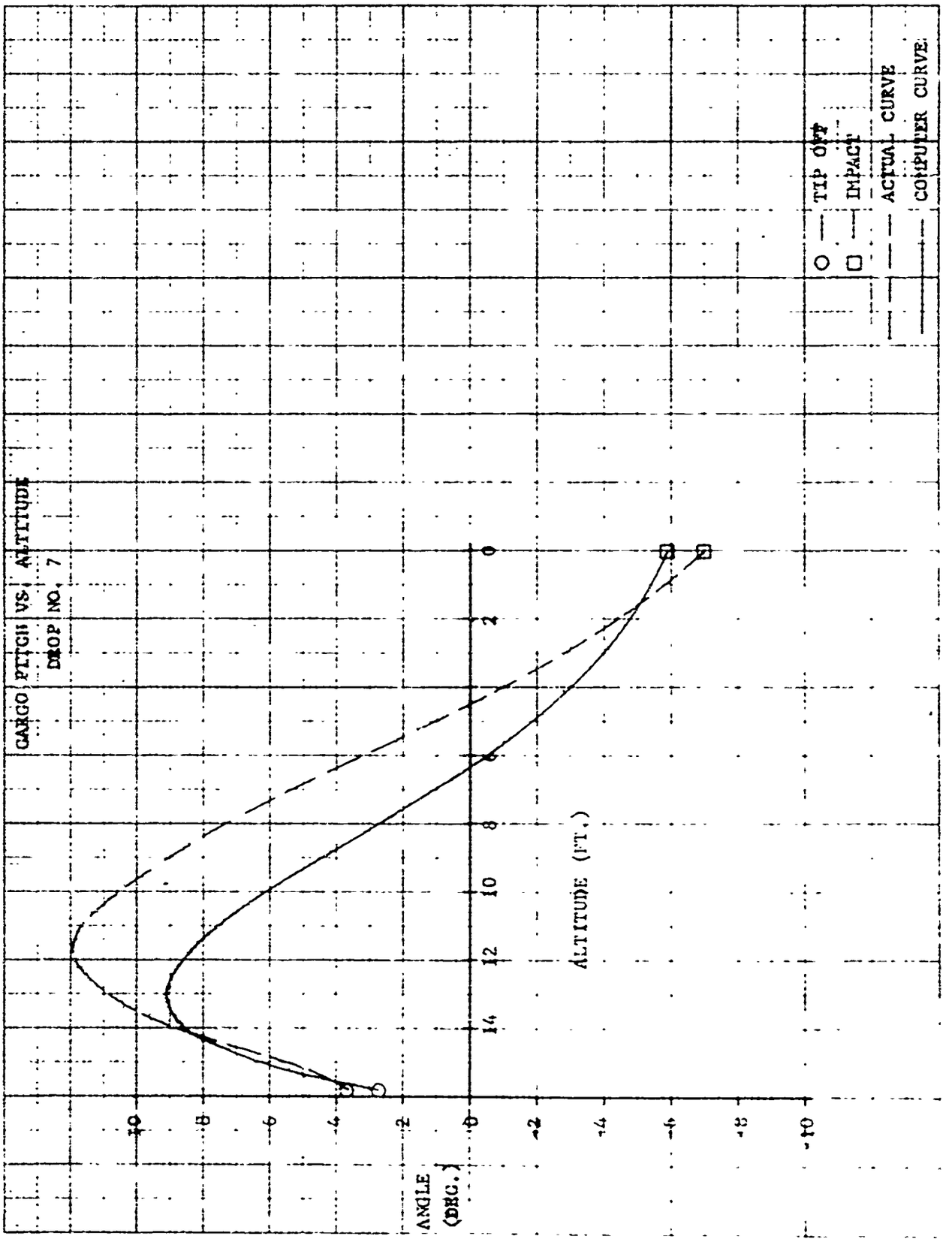
CARGO PITCH VS ALTITUDE
DROP NO. 7
ANGLE (DEG.)
ALTITUDE (FT.)
10
8
6
4
2
0
-2
-4
-6
-8
-10
0
2
4
6
8
10
12
14
TIP OFF
IMPACT
ACTUAL CURVE
COMPUTER CURVE

FIGURE 67

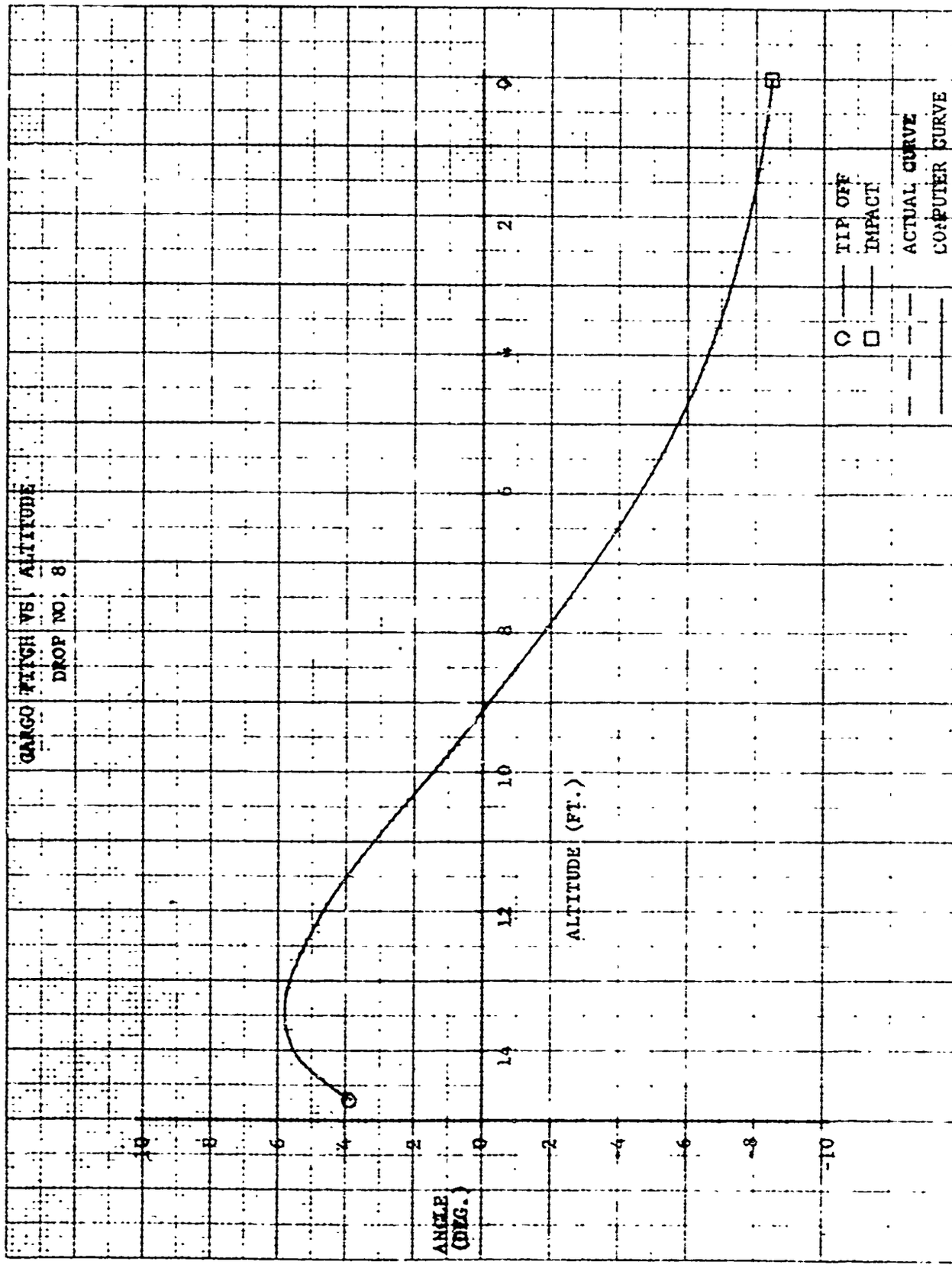
CARGO PITCH VS ALTITUDE
DROP NO. 8
ANGLE (DEG.)
ALTITUDE (FT.)
TIP OFF
IMPACT
ACTUAL CURVE
COMPUTER CURVE

FIGURE 68

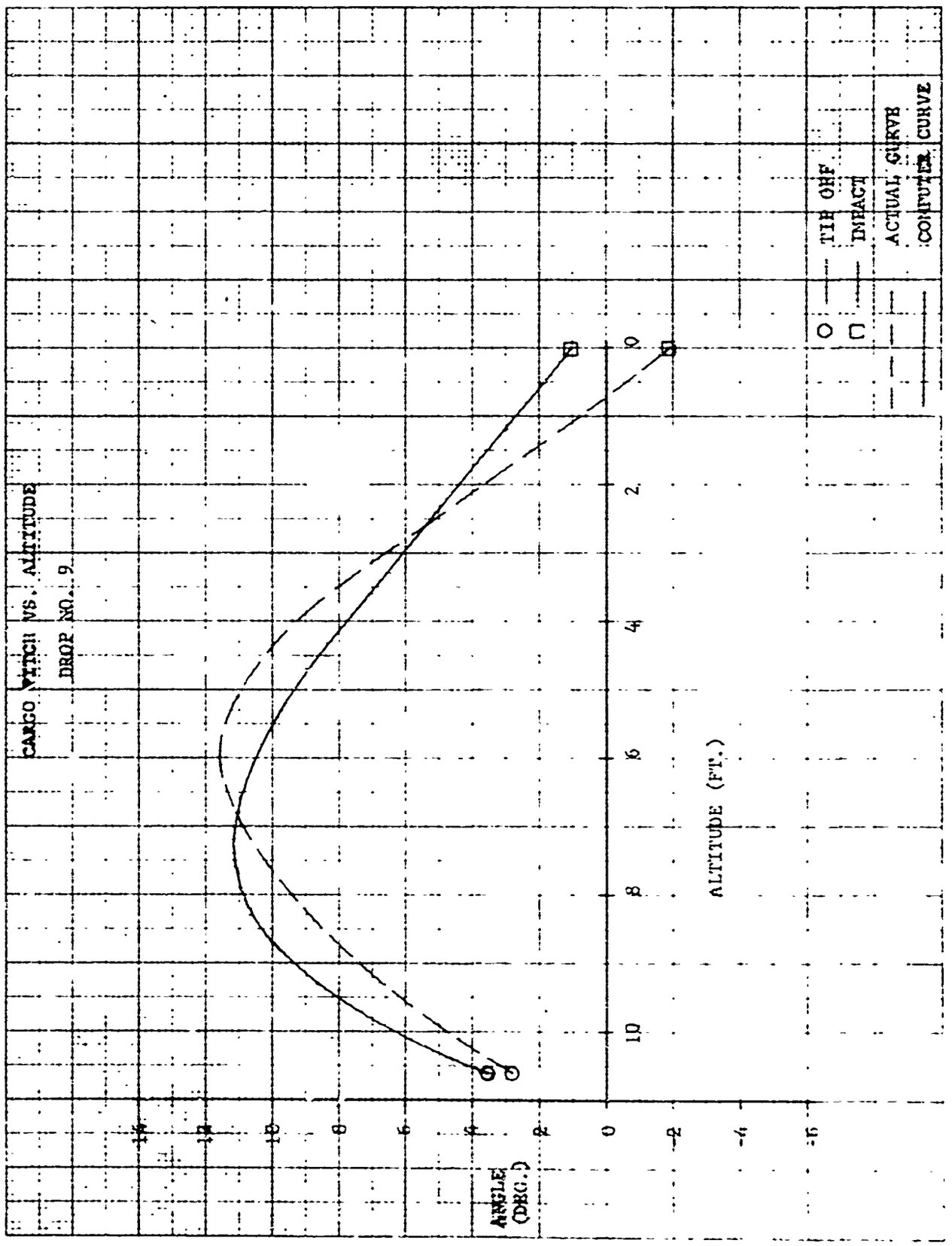
CARGO PITCH VS. ALTITUDE
DROP NO. 9
ANGLE (DEG.)
ALTITUDE (FT.)
TIP OFF
IMPACT
ACTUAL CURVE
COMPUTED CURVE

FIGURE 69

AIRCRAFT ARMAMENTS, Inc.

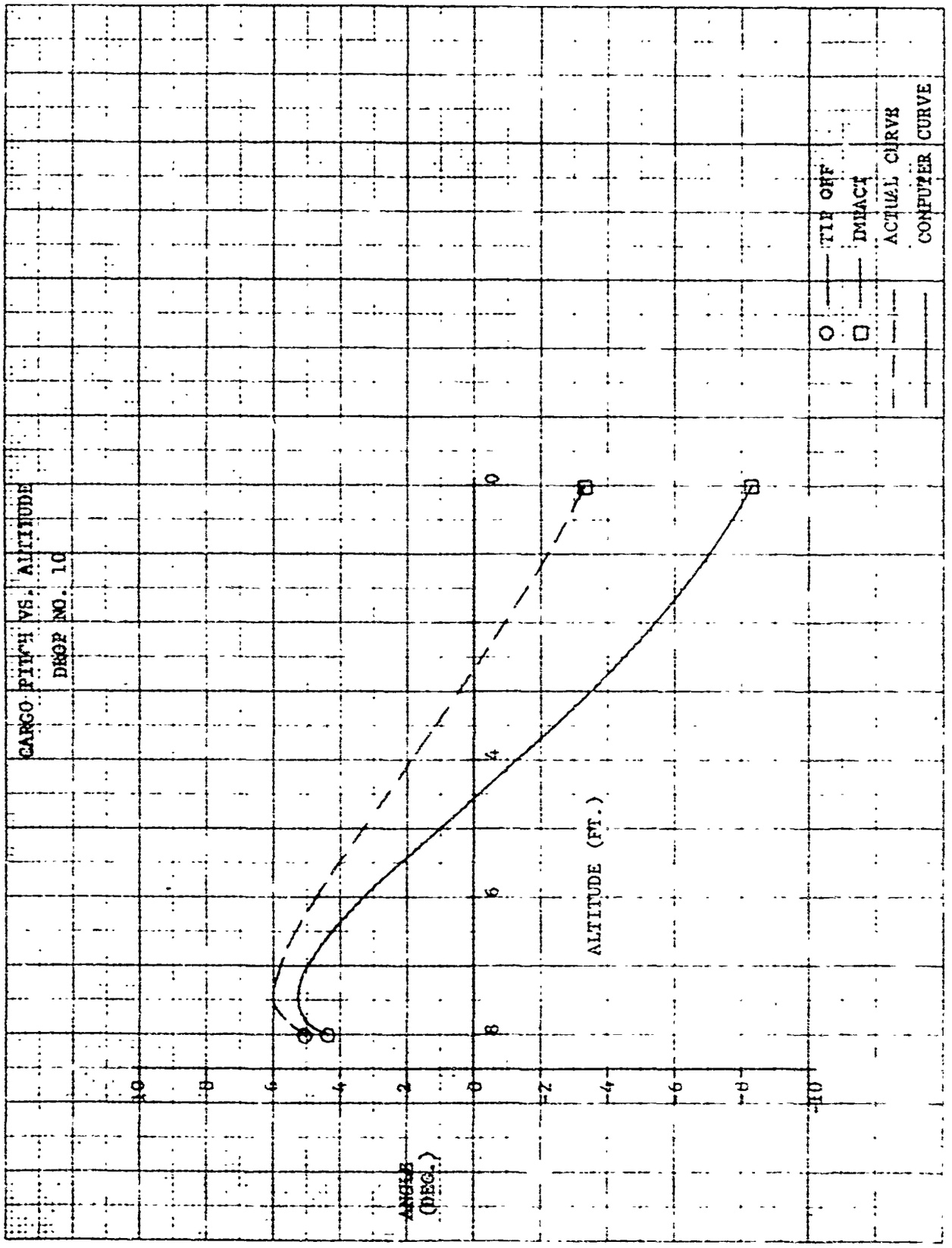


FIGURE 70

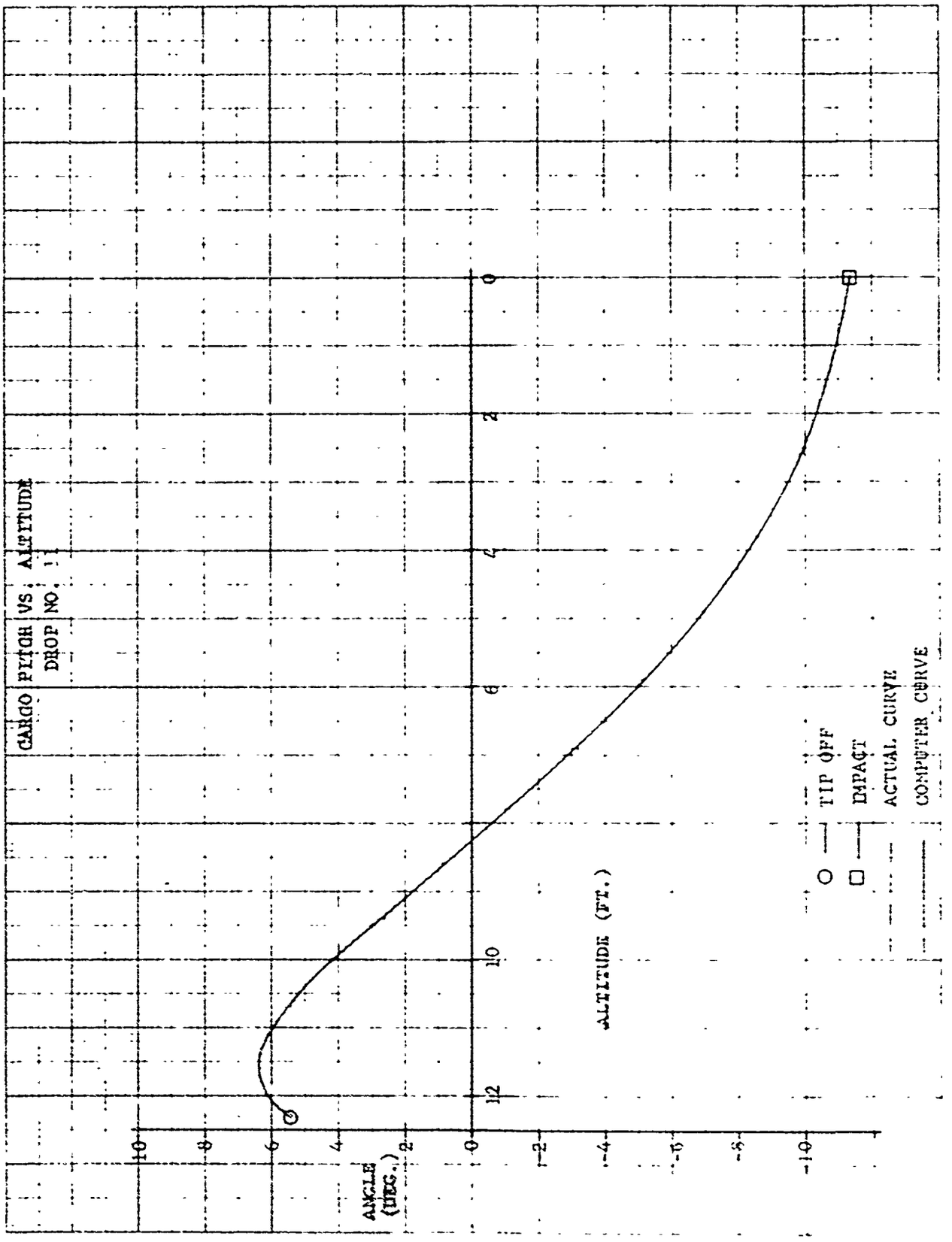
CARGO PITCH VS. ALTITUDE
DROP NO. 11
ANGLE (DEG.)
10
8
6
4
2
0
-2
-4
-6
-8
-10
ALTITUDE (FT.)
0
2
4
6
8
10
12
TIP OFF
IMPACT
ACTUAL CURVE
COMPUTER CURVE

FIGURE 71

AIRCRAFT ARMAMENTS, Inc.

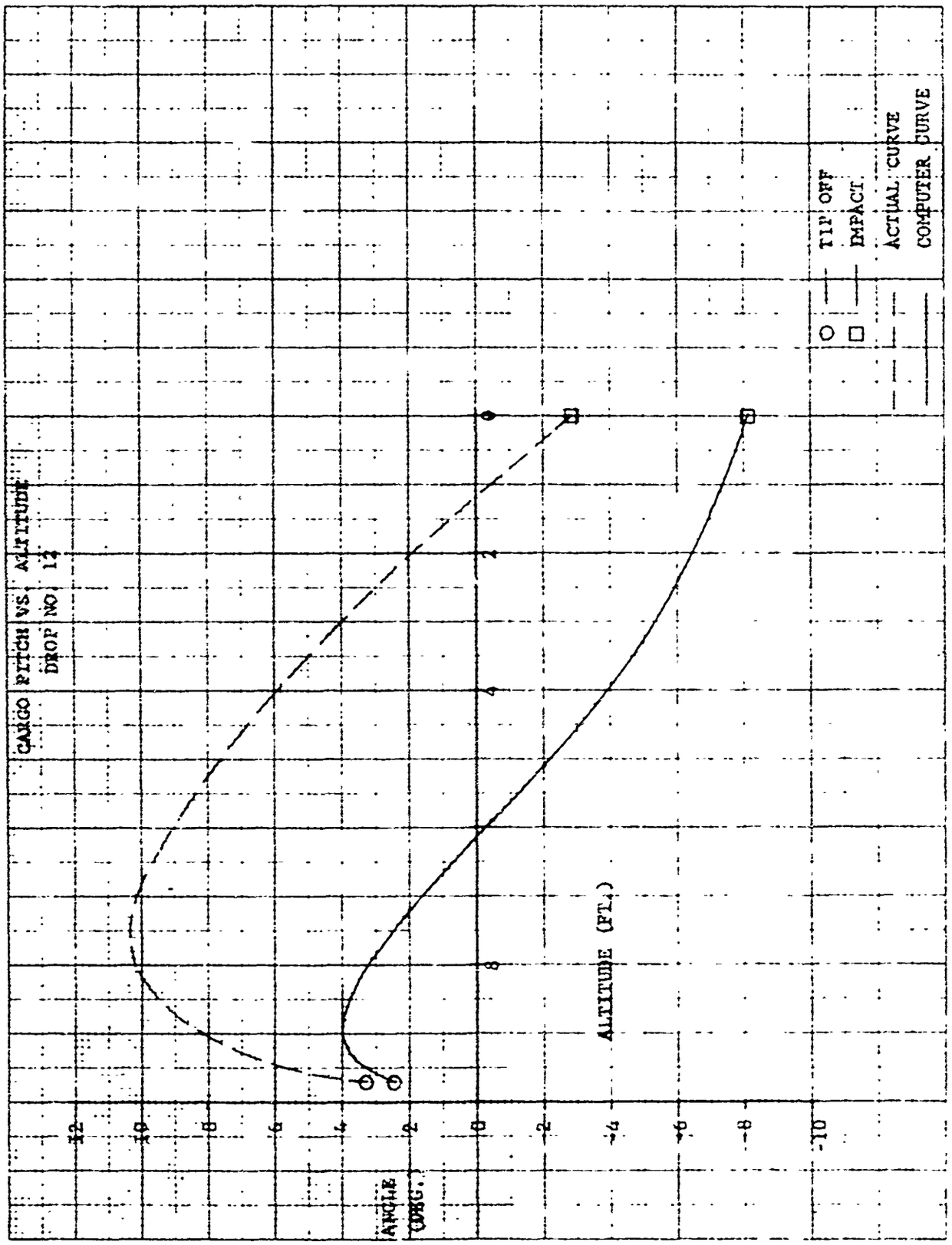


FIGURE 72

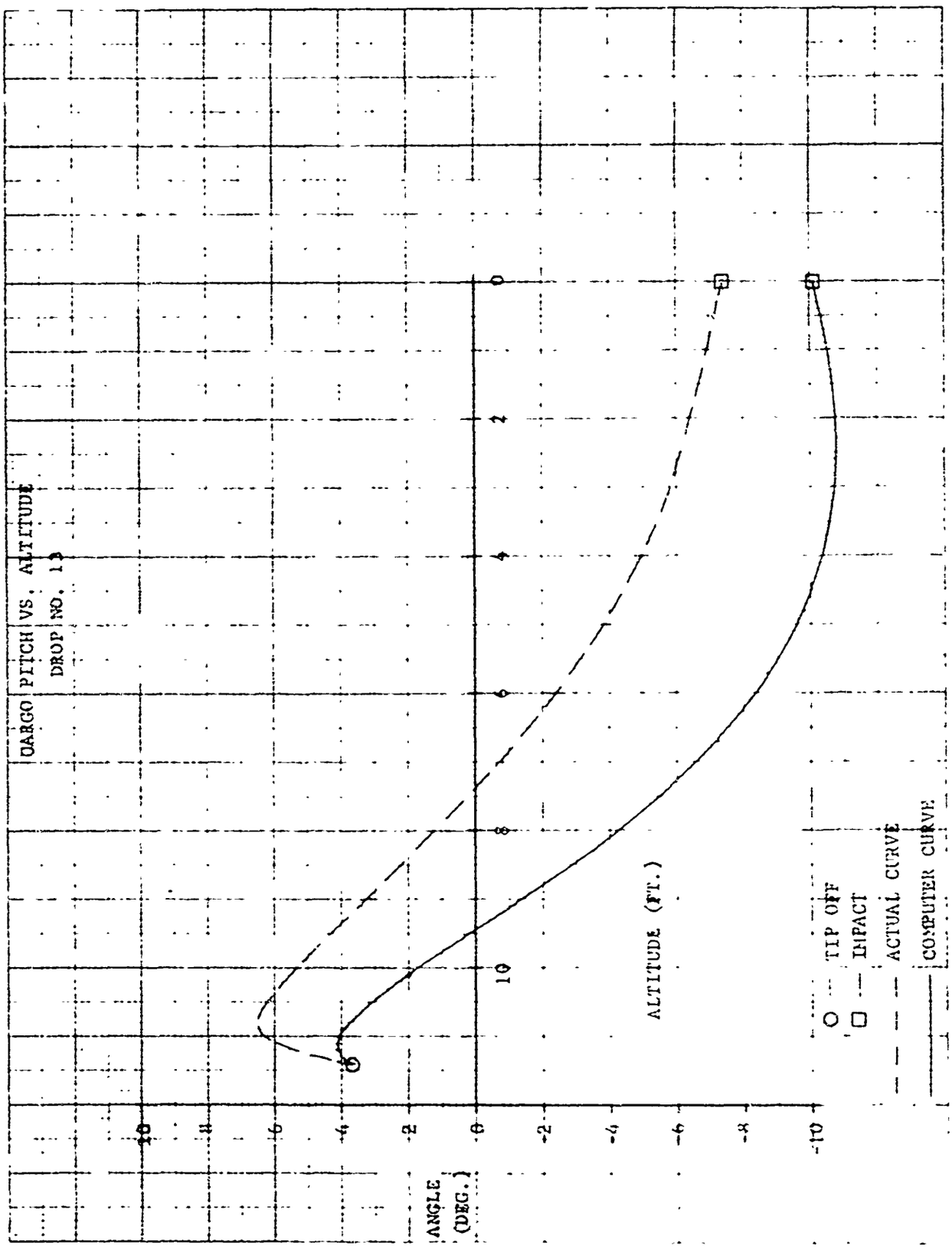
CARGO PITCH VS. ALTITUDE
DROP NO. 13
ANGLE (DEG.)
ALTITUDE (FT.)
TIP OFF
IMPACT
ACTUAL CURVE
COMPUTER CURVE

FIGURE 73

AIRCRAFT ARMAMENTS, Inc.

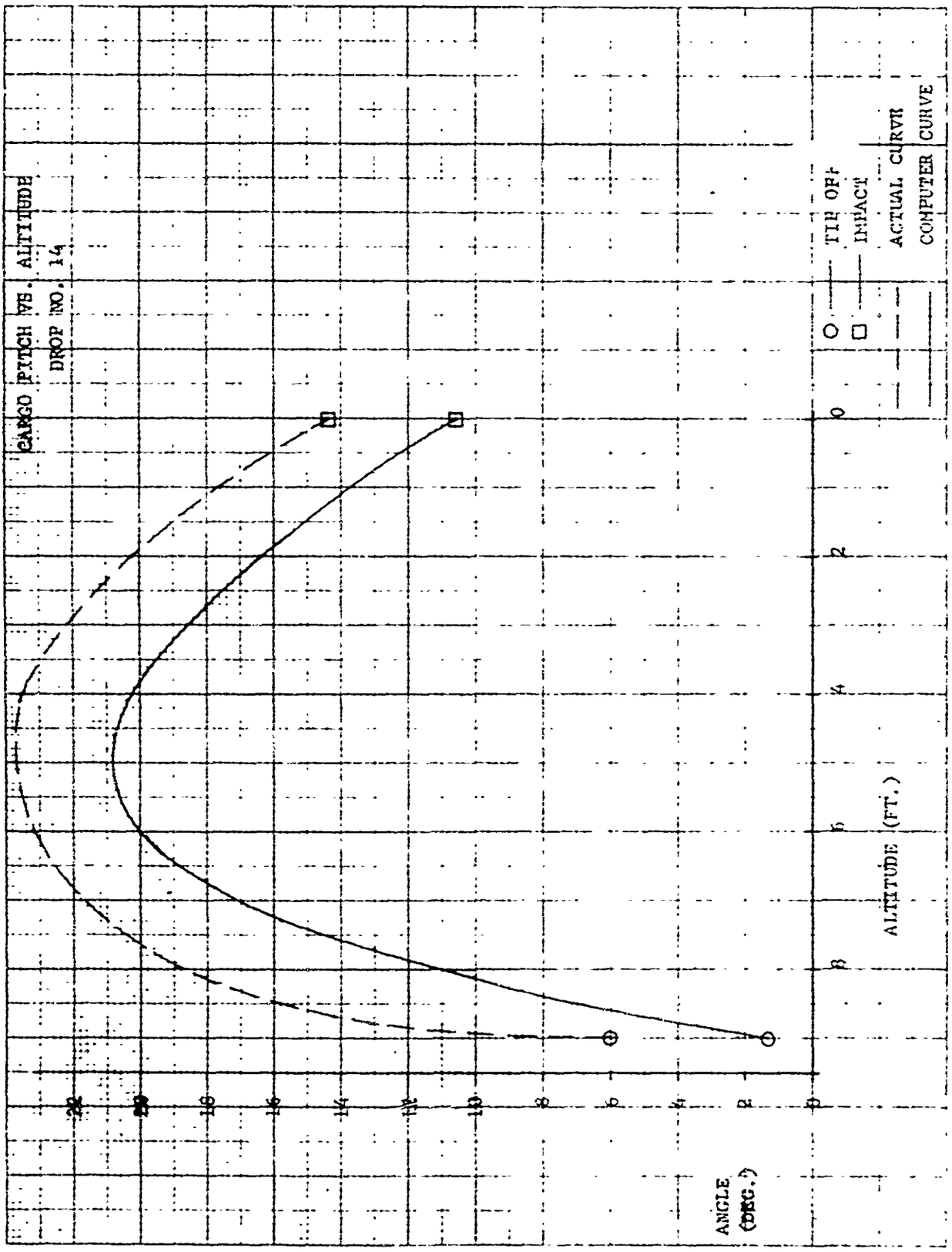


FIGURE 14

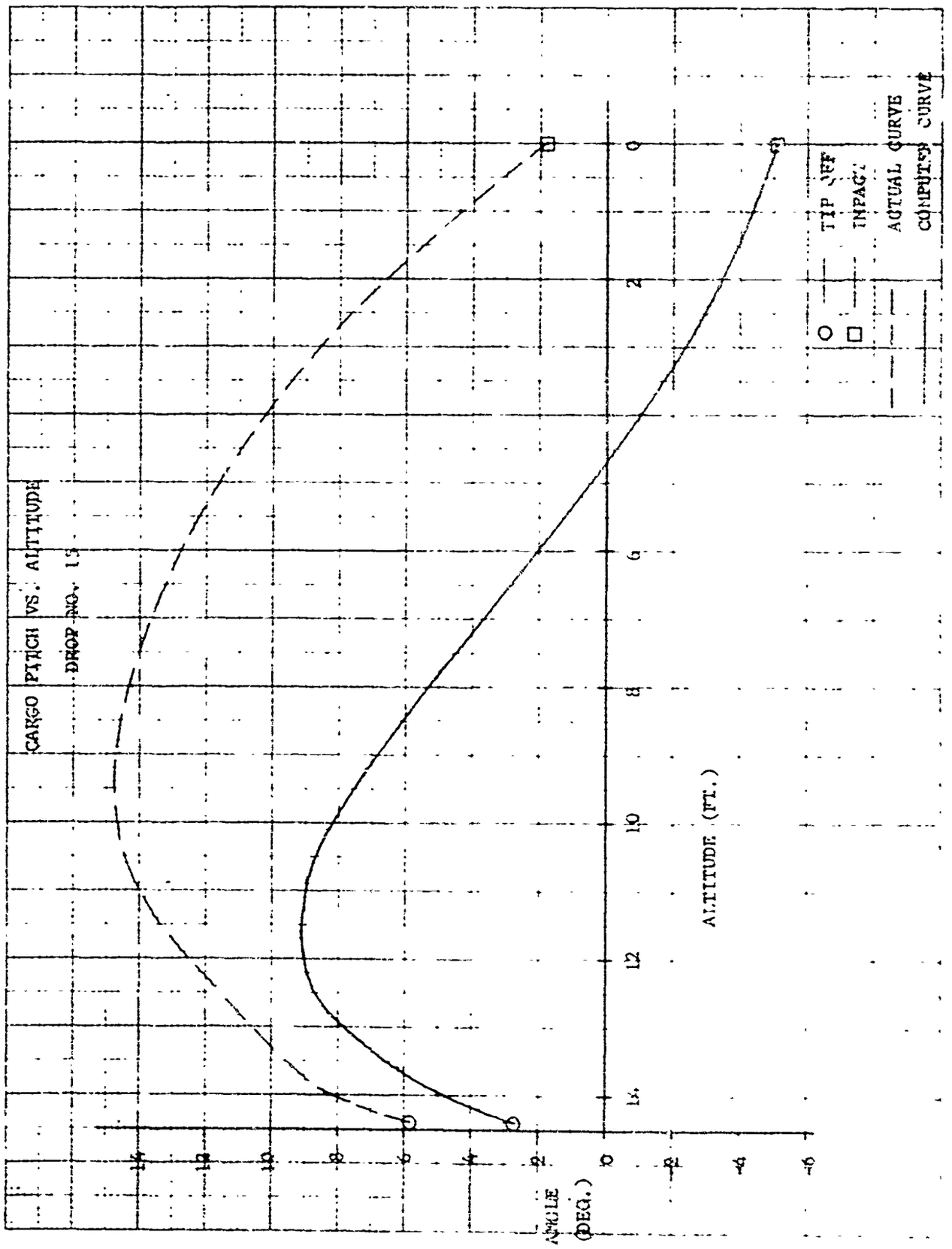
CARGO PITCH VS. ALTITUDE
DROP NO. 15
ANGLE (DEG.)
ALTITUDE (FT.)
TIP OFF
IMPACT
ACTUAL CURVE
COMPUTED CURVE

FIGURE 75

In Figures 76 through 89 plots of predicted cargo horizontal velocity versus descent time are given. Due to the inaccuracies of graphically integrating distance-versus-time data, the actual velocity-versus-time plots are not given since the comparison would be misleading. However, since such close agreement was witnessed between the actual and predicted curves of horizontal travel versus descent time, it can be stated that the actual curves of horizontal velocity versus descent time will be in close agreement with the predicted curves.

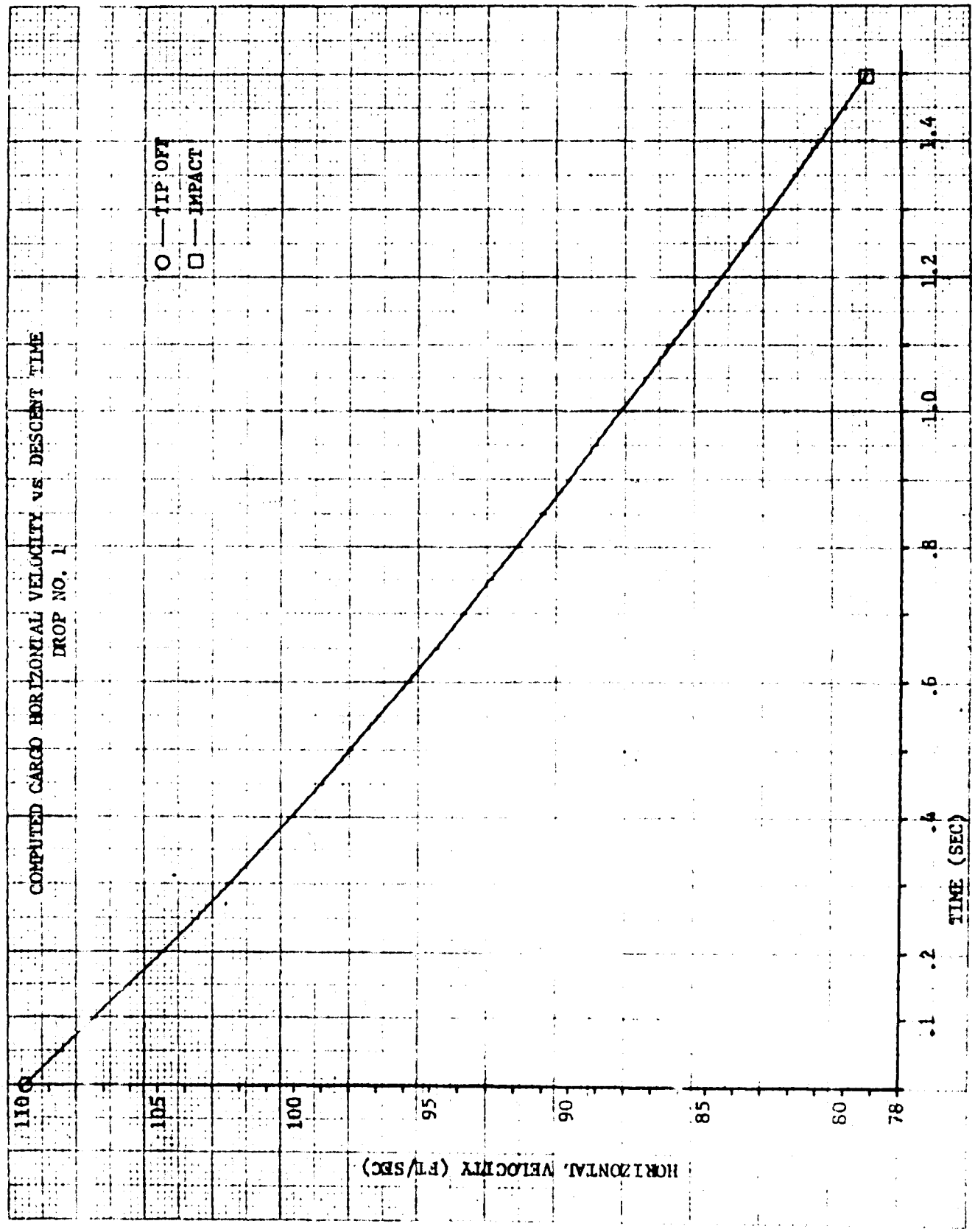
COMPUTED CARGO HORIZONTAL VELOCITY vs DESCENT TIME
DROP NO. 1
O — TIP OFF
□ — IMPACT
HORIZONTAL VELOCITY (FT/SEC)
110
105
100
95
90
85
80
78
TIME (SEC)
.1
.2
.4
.6
.8
1.0
1.2
1.4

Figure 76

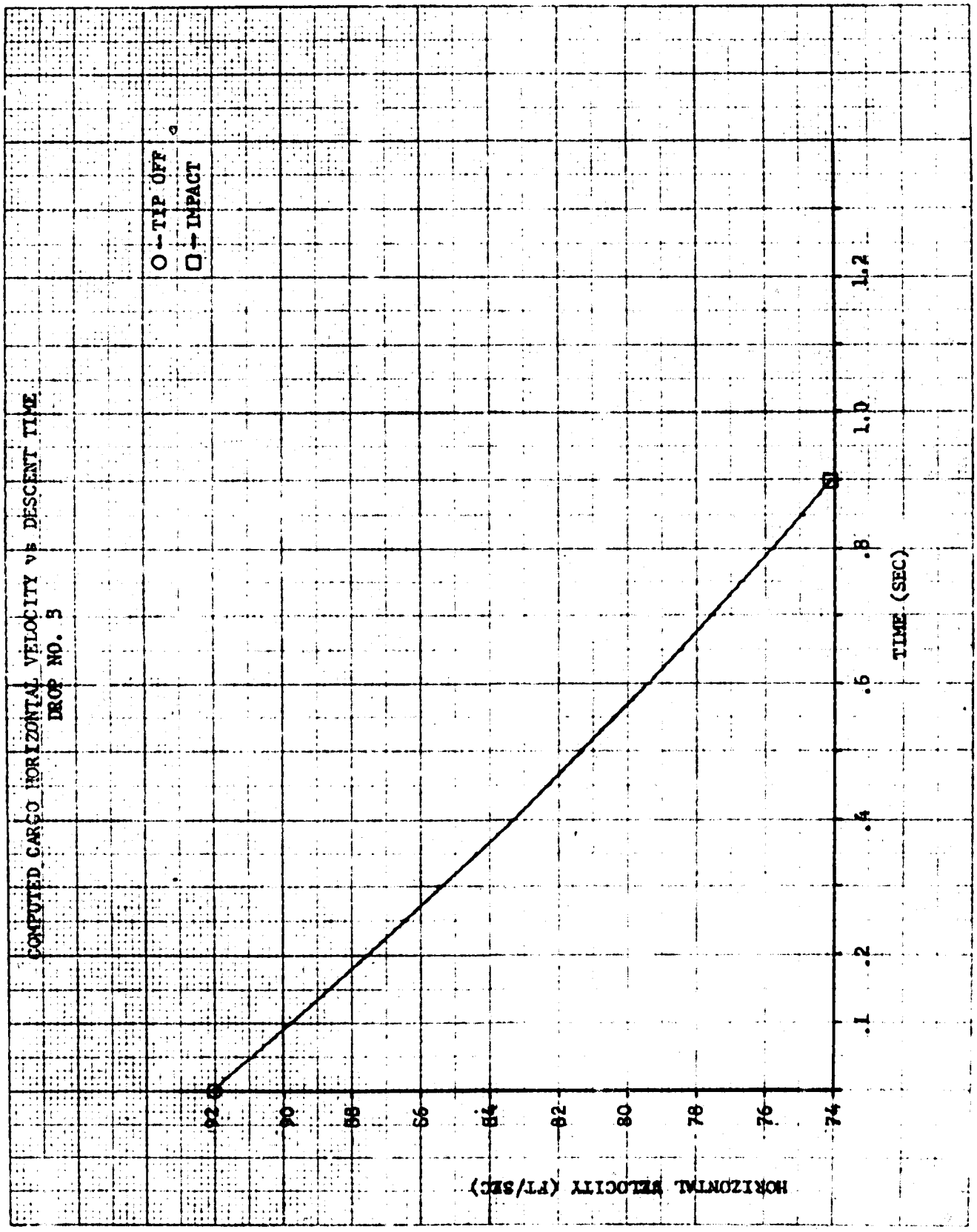
COMPUTED CARGO HORIZONTAL VELOCITY vs DESCENT TIME
DROP NO. 3
O - TIP OFF
□ - IMPACT
HORIZONTAL VELOCITY (FT/SEC)
92
90
88
86
84
82
80
78
76
74
TIME (SEC)
.1
.2
.4
.6
.8
1.0
1.2

Figure 77

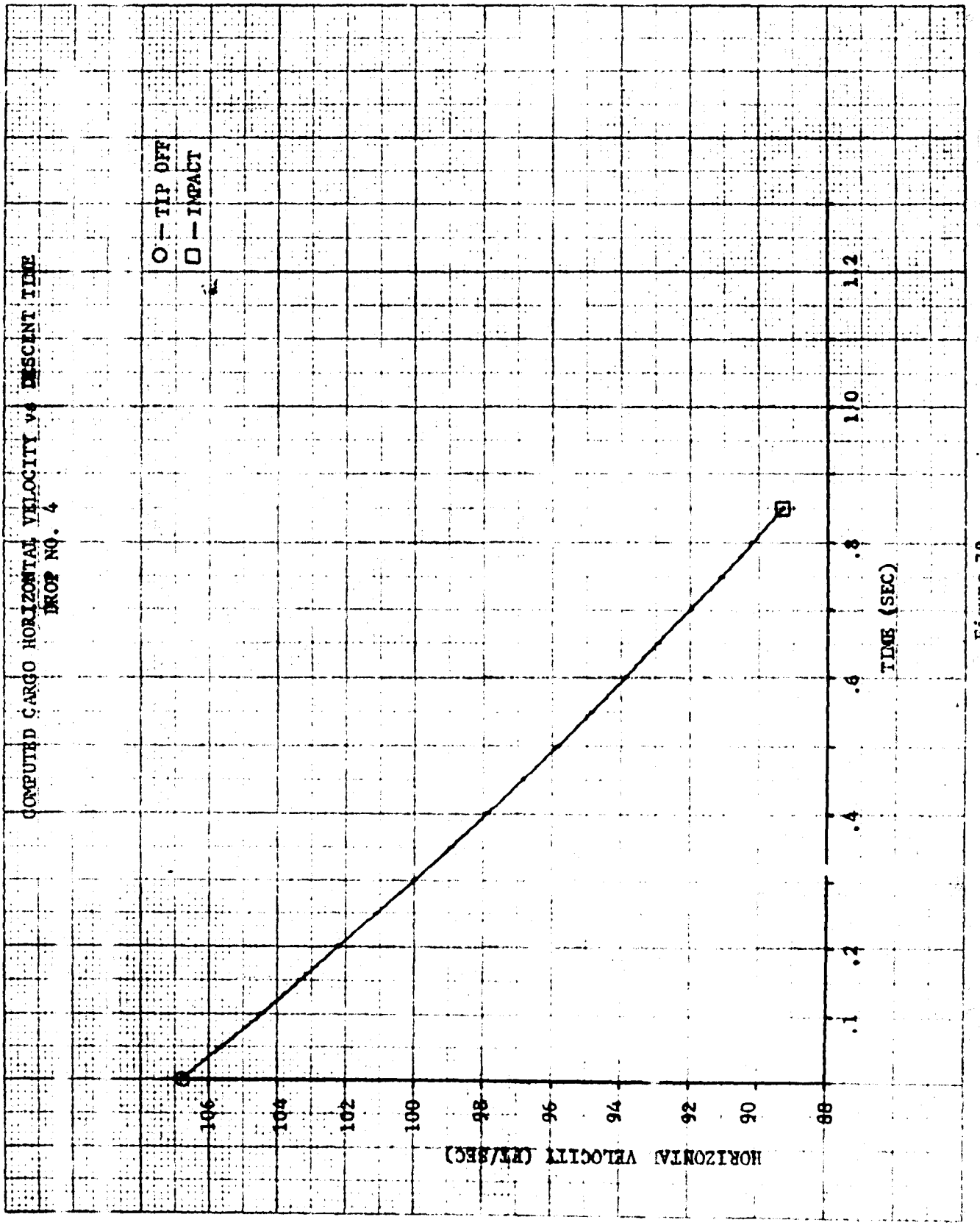
COMPUTED CARGO HORIZONTAL VELOCITY vs DESCENT TIME
DROP NO. 4
O — TIP OFF
□ — IMPACT
HORIZONTAL VELOCITY (FT/SEC)
106
104
102
100
98
96
94
92
90
88
.1
.2
.4
.6
.8
1.0
1.2
TIME (SEC)

Figure 78

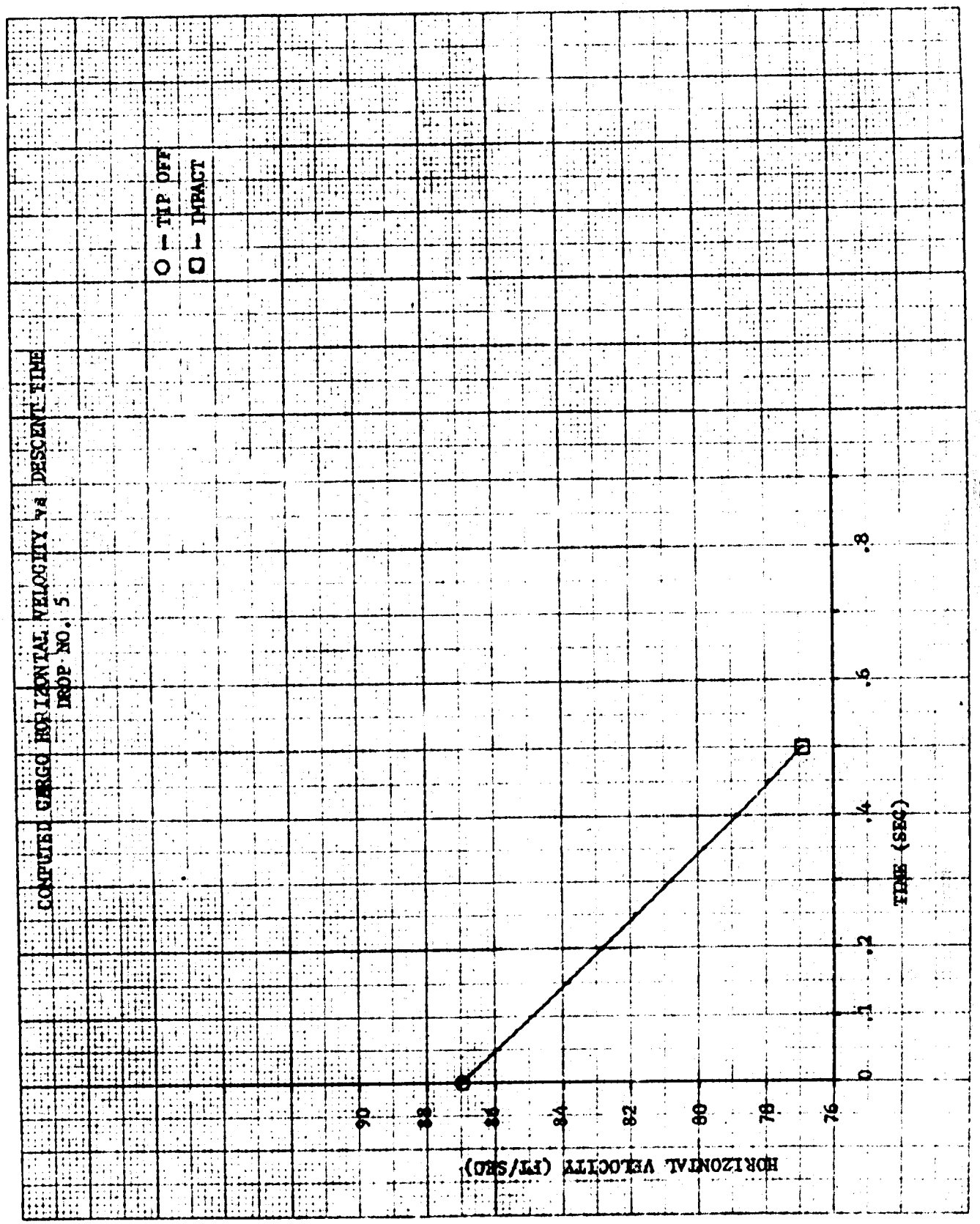
COMPUTED CARGO HORIZONTAL VELOCITY vs DESCENT TIME
DROP NO. 5
O — TIP OFF
□ — IMPACT
HORIZONTAL VELOCITY (FT/SEC)
90
88
86
84
82
80
78
76
0
.1
.2
.4
.6
.8
TIME (SEC)

Figure 79

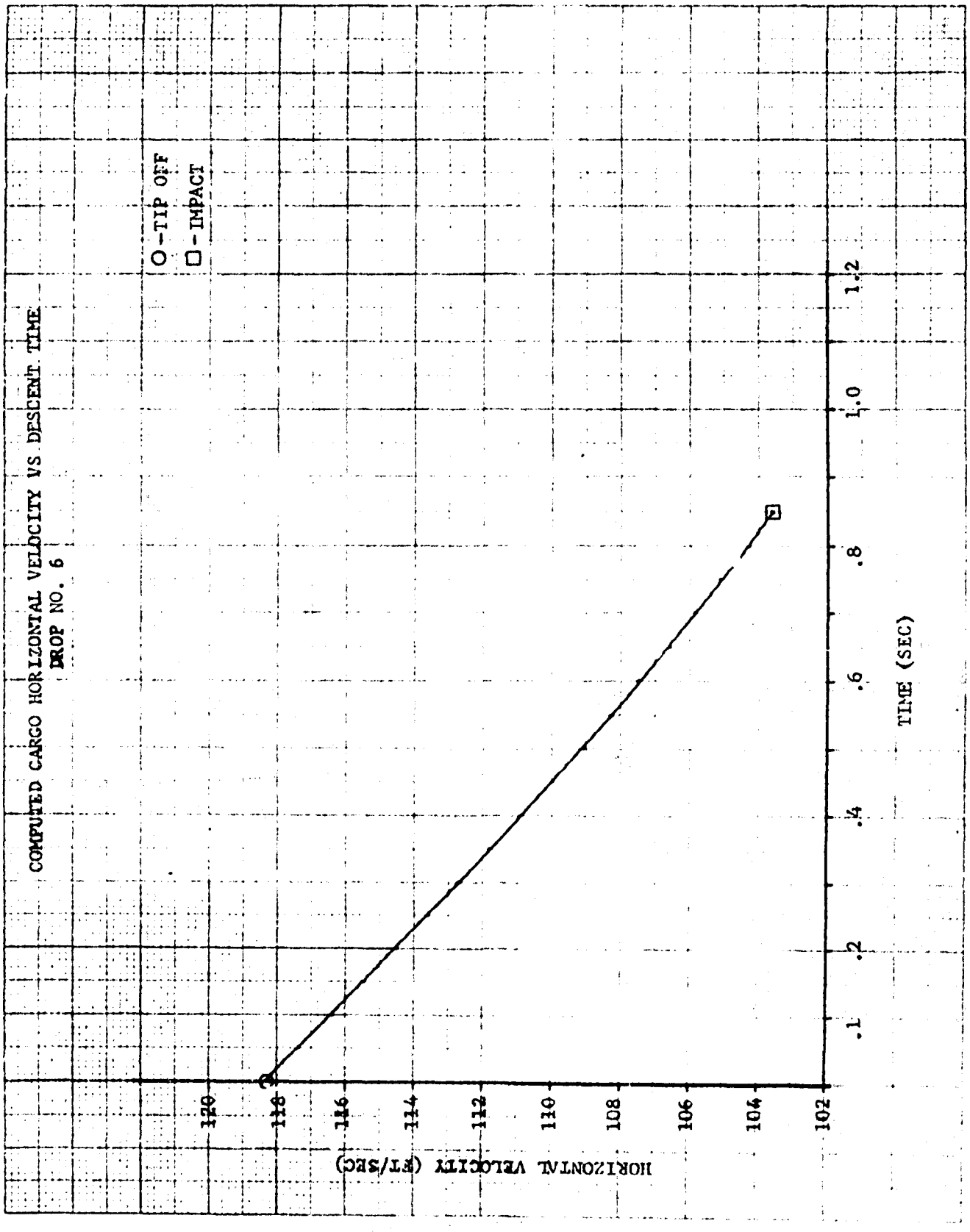
COMPUTED CARGO HORIZONTAL VELOCITY VS DESCENT TIME
DROP NO. 6
O - TIP OFF
□ - IMPACT
HORIZONTAL VELOCITY (FT/SEC)
120
118
116
114
112
110
108
106
104
102
.1
.2
.4
.6
.8
1.0
1.2
TIME (SEC)

Figure 80

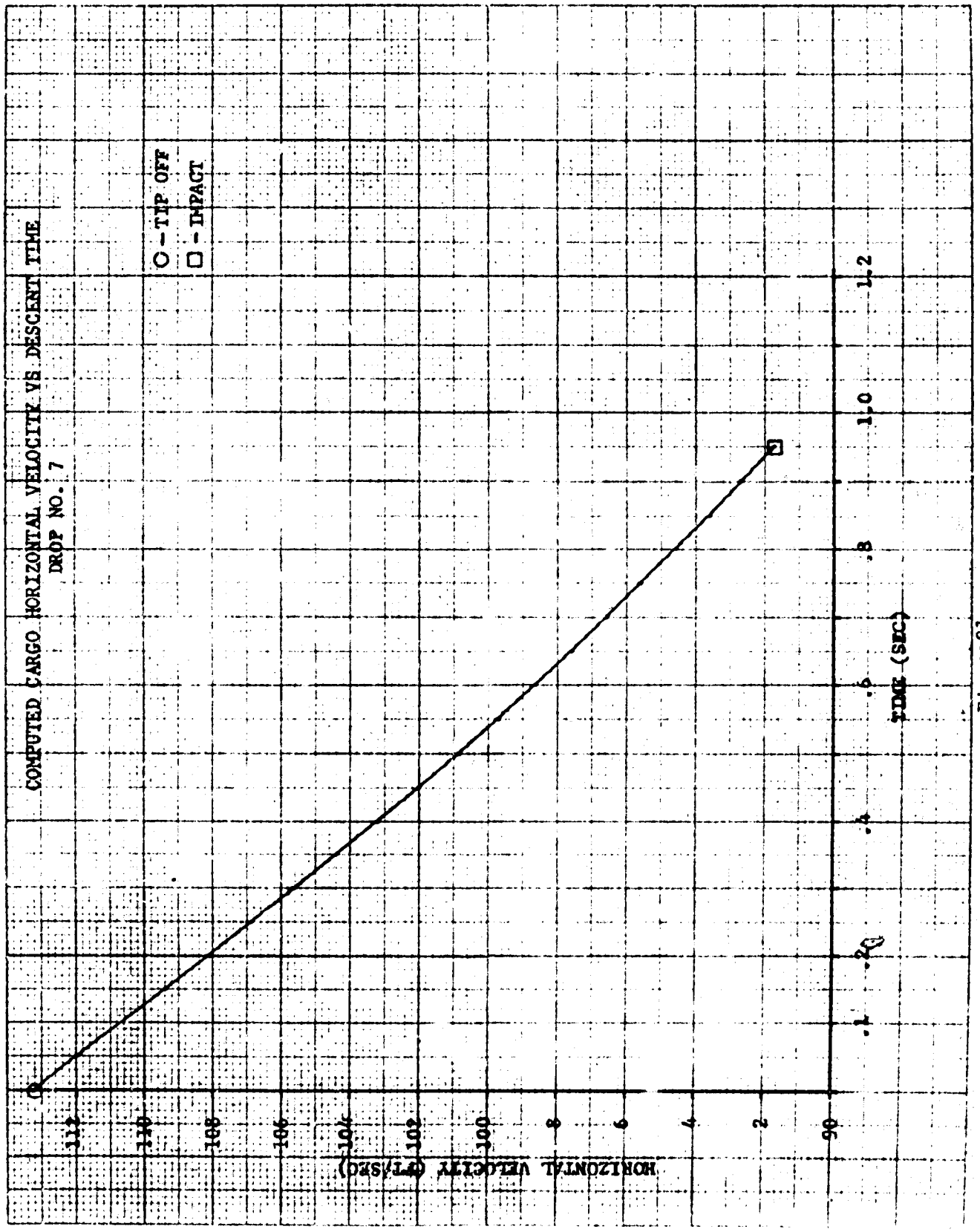
COMPUTED CARGO HORIZONTAL VELOCITY VS DESCENT TIME
DROP NO. 7
O - TIP OFF
□ - IMPACT
HORIZONTAL VELOCITY (FT/SEC)
112
110
108
106
104
102
100
8
6
4
2
90
TIME (SEC)
.2
.4
.6
.8
1.0
1.2

Figure 81

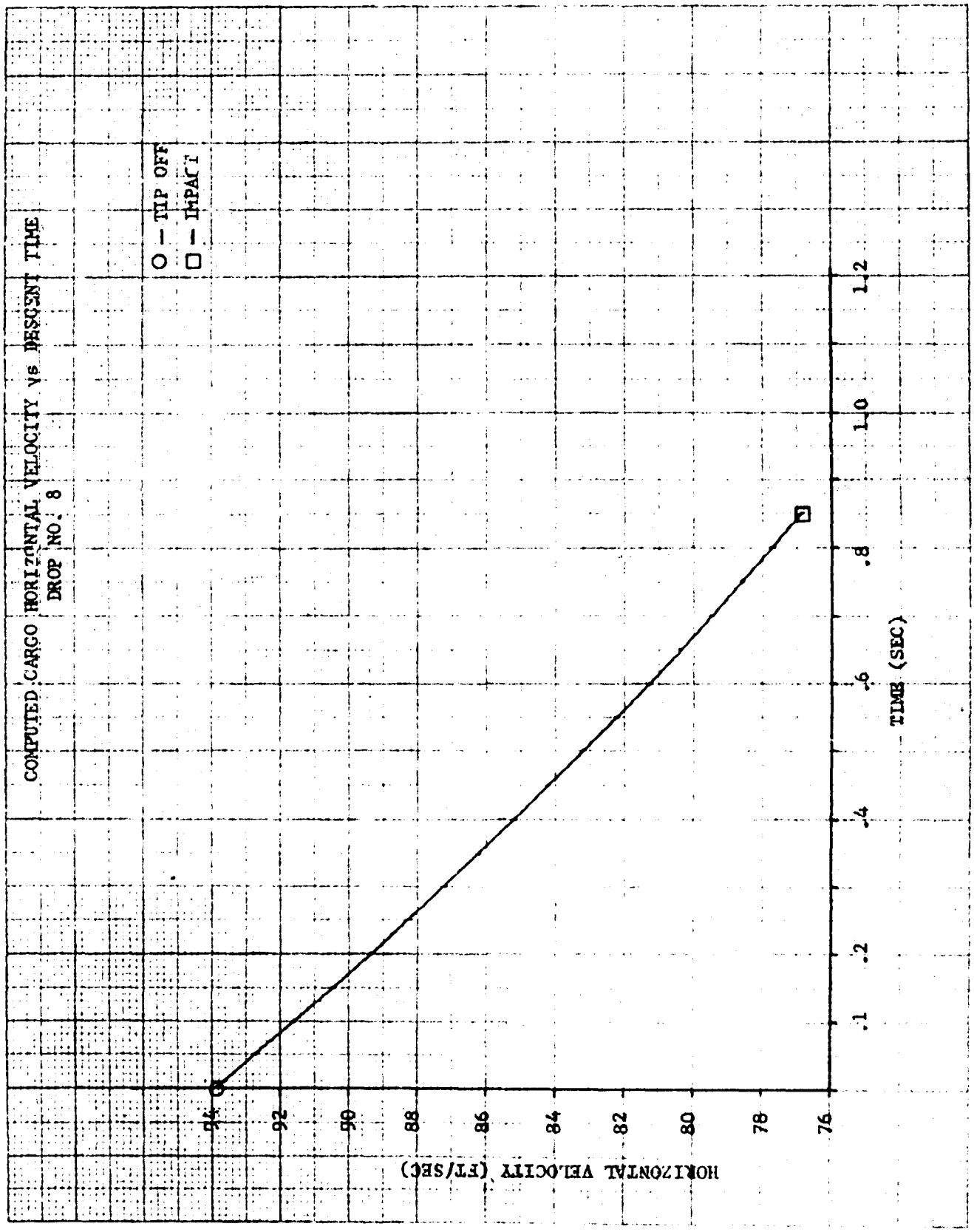
COMPUTED CARGO HORIZONTAL VELOCITY vs DESCENT TIME
DROP NO. 8
O — TIP OFF
□ — IMPACT
HORIZONTAL VELOCITY (FT/SEC)
94
92
90
88
86
84
82
80
78
76
TIME (SEC)
.1
.2
.4
.6
.8
1.0
1.2

Figure 82

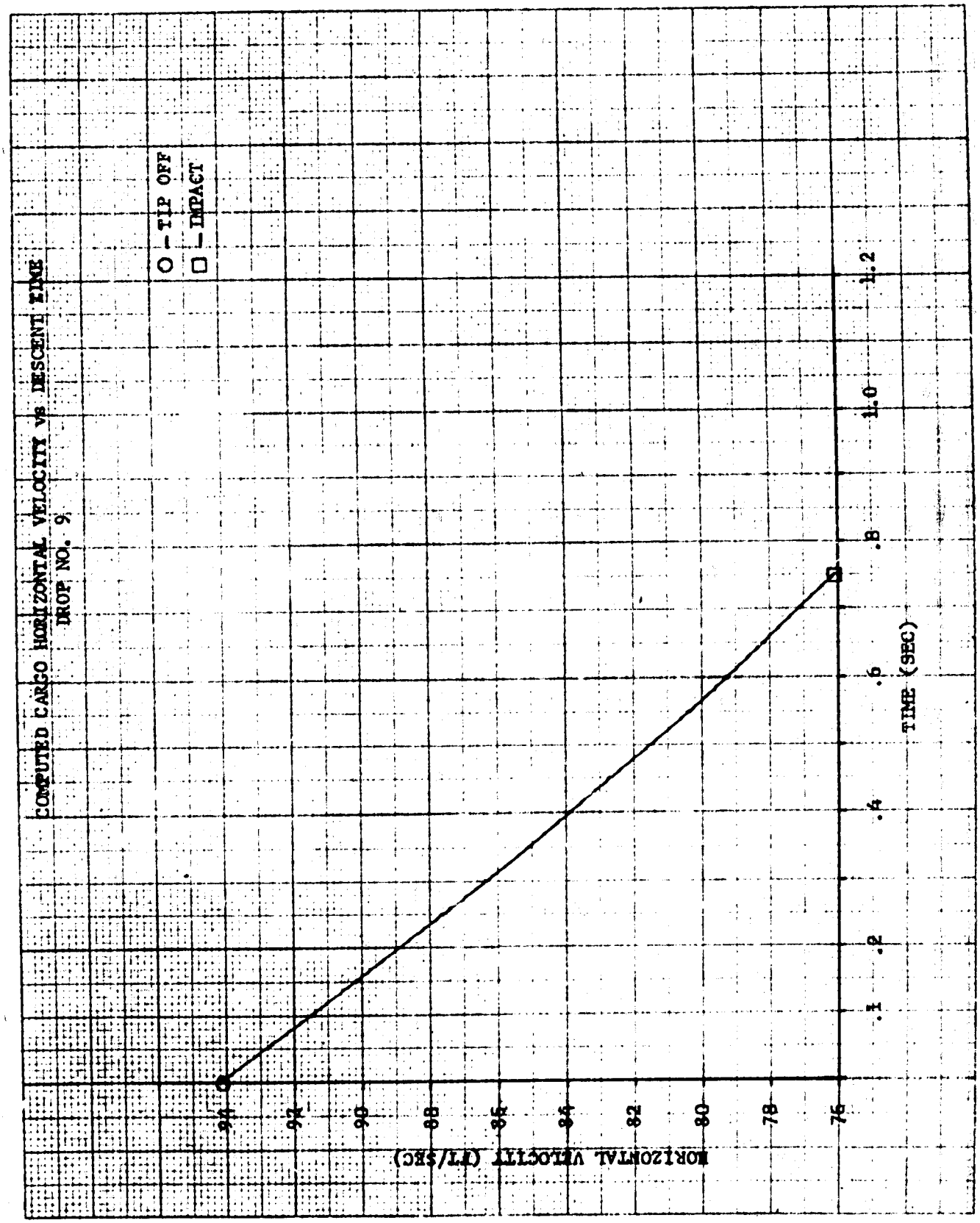
COMPUTED CARGO HORIZONTAL VELOCITY VS DESCENT TIME
DROP NO. 9
O - TIP OFF
□ - IMPACT
HORIZONTAL VELOCITY (FT/SEC)
94
92
90
88
86
84
82
80
78
76
.1
.2
.4
.6
.8
1.0
1.2
TIME (SEC)

Figure 83

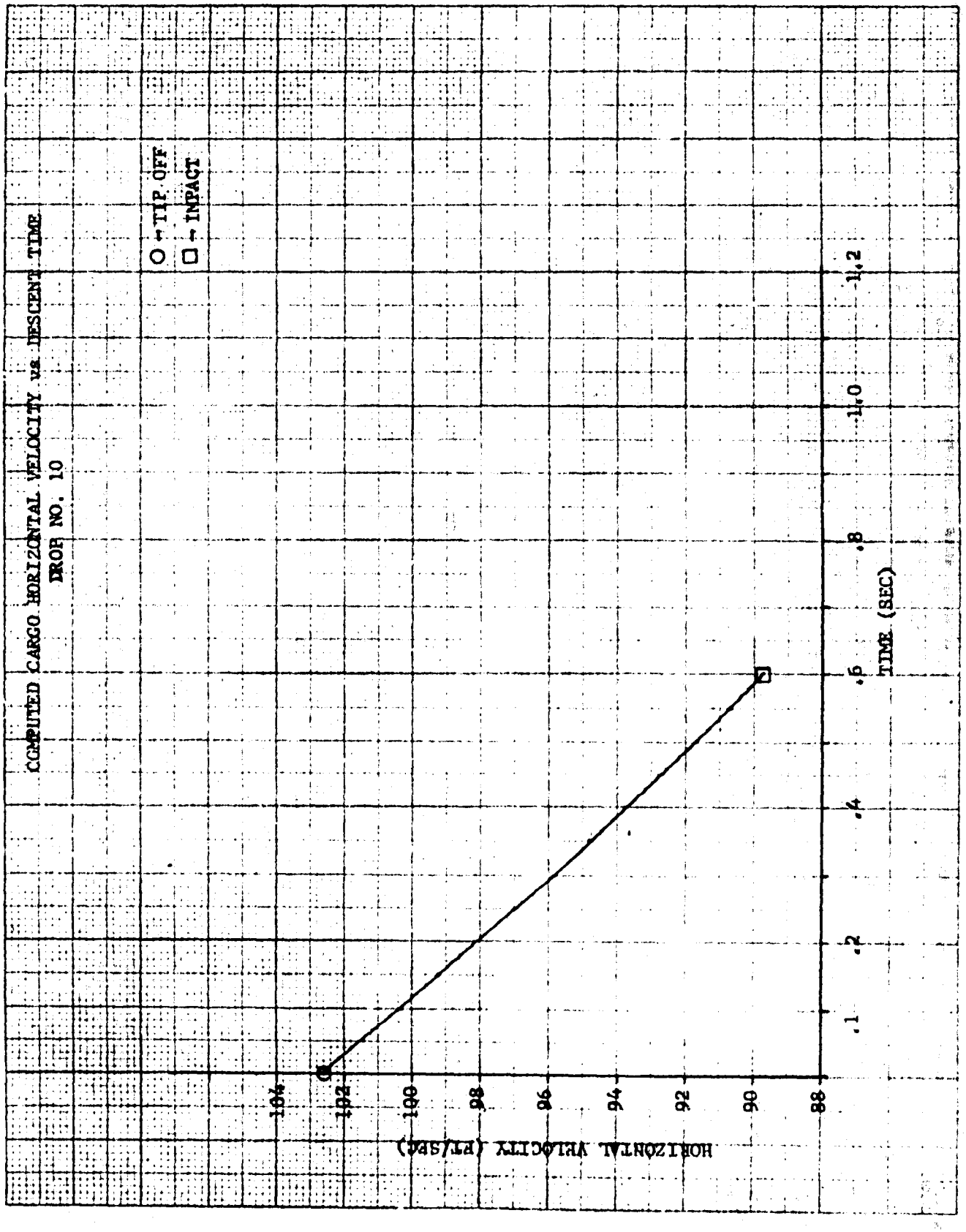
COMPUTED CARGO HORIZONTAL VELOCITY vs DESCENT TIME
DROP NO. 10
O - TIP OFF
□ - IMPACT
HORIZONTAL VELOCITY (FT/SEC)
104
102
100
98
96
94
92
90
88
.1
.2
.4
.6
.8
1.0
1.2
TIME (SEC)

Figure 84

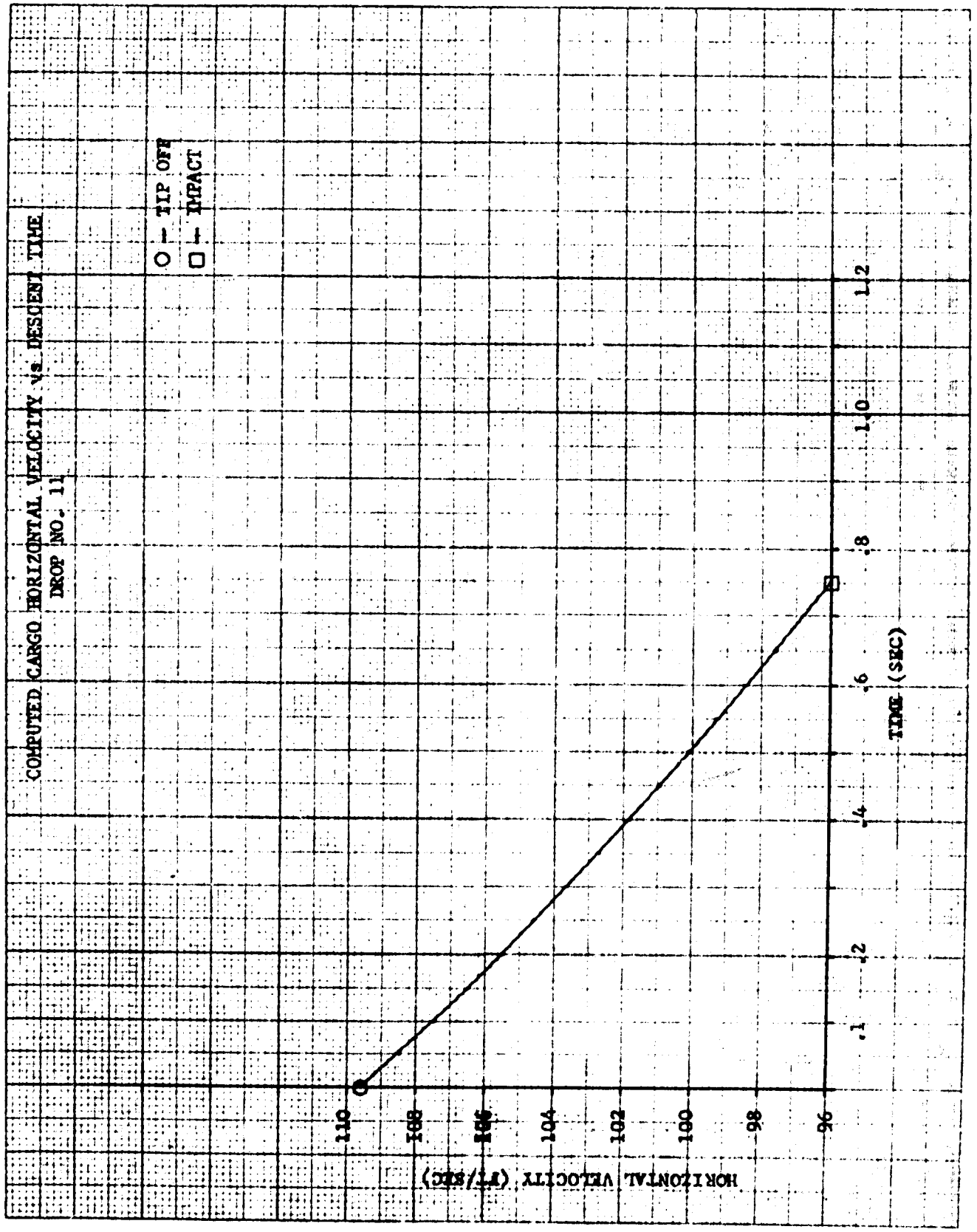
COMPUTED CARGO HORIZONTAL VELOCITY vs DESCENT TIME
DROP NO. 11
O — TIP OFF
□ — IMPACT
HORIZONTAL VELOCITY (FT/SEC)
110
108
106
104
102
100
98
96
TIME (SEC)
.1
.2
.4
.6
.8
1.0
1.2

Figure 85

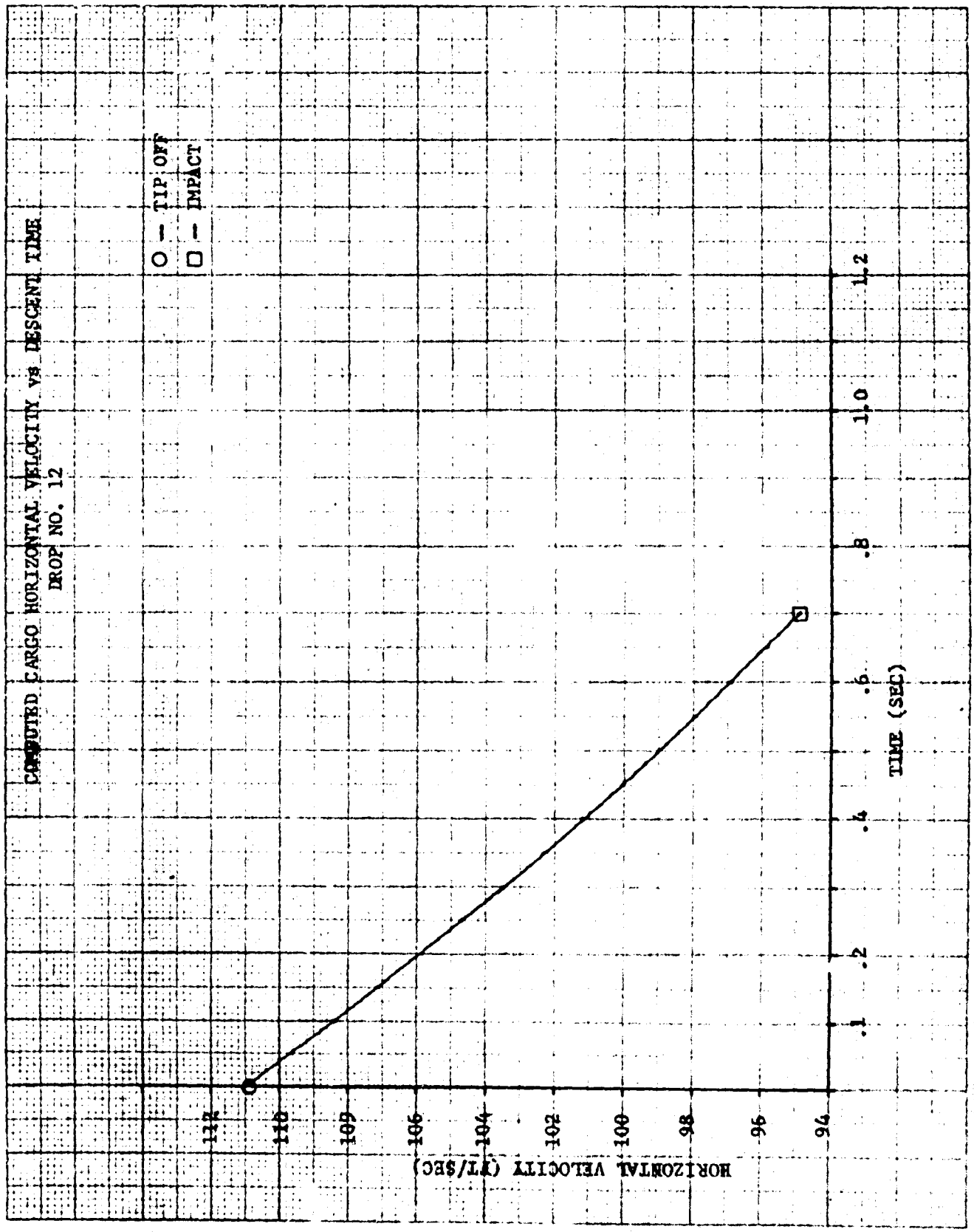
COMPUTED CARGO HORIZONTAL VELOCITY VS DESCENT TIME
DROP NO. 12
O — TIP OFF
□ — IMPACT
HORIZONTAL VELOCITY (FT/SEC)
112
110
108
106
104
102
100
98
96
94
TIME (SEC)
.1
.2
.4
.6
.8
1.0
1.2

Figure 86

AIRCRAFT ARMAMENTS, Inc.

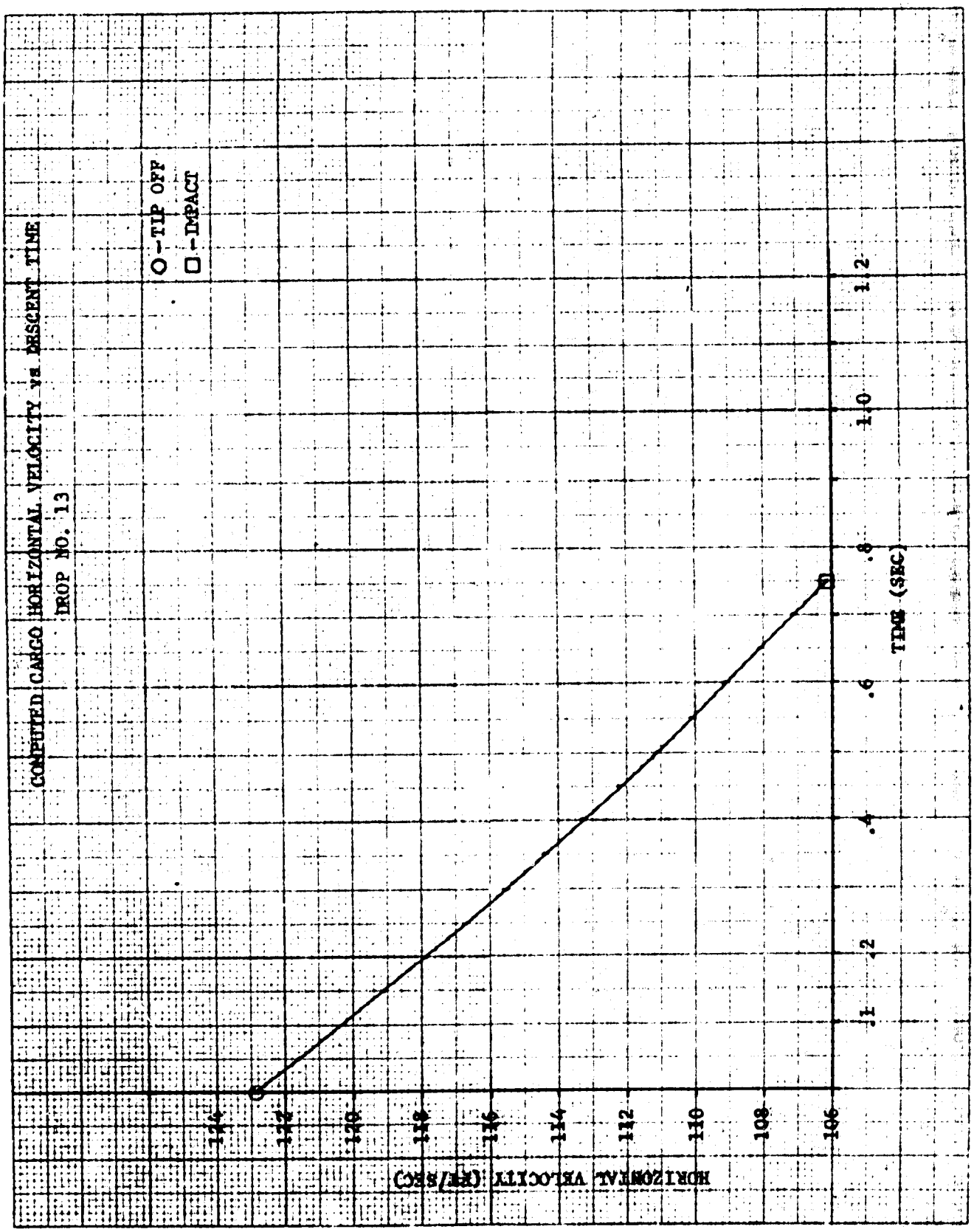


Figure 87

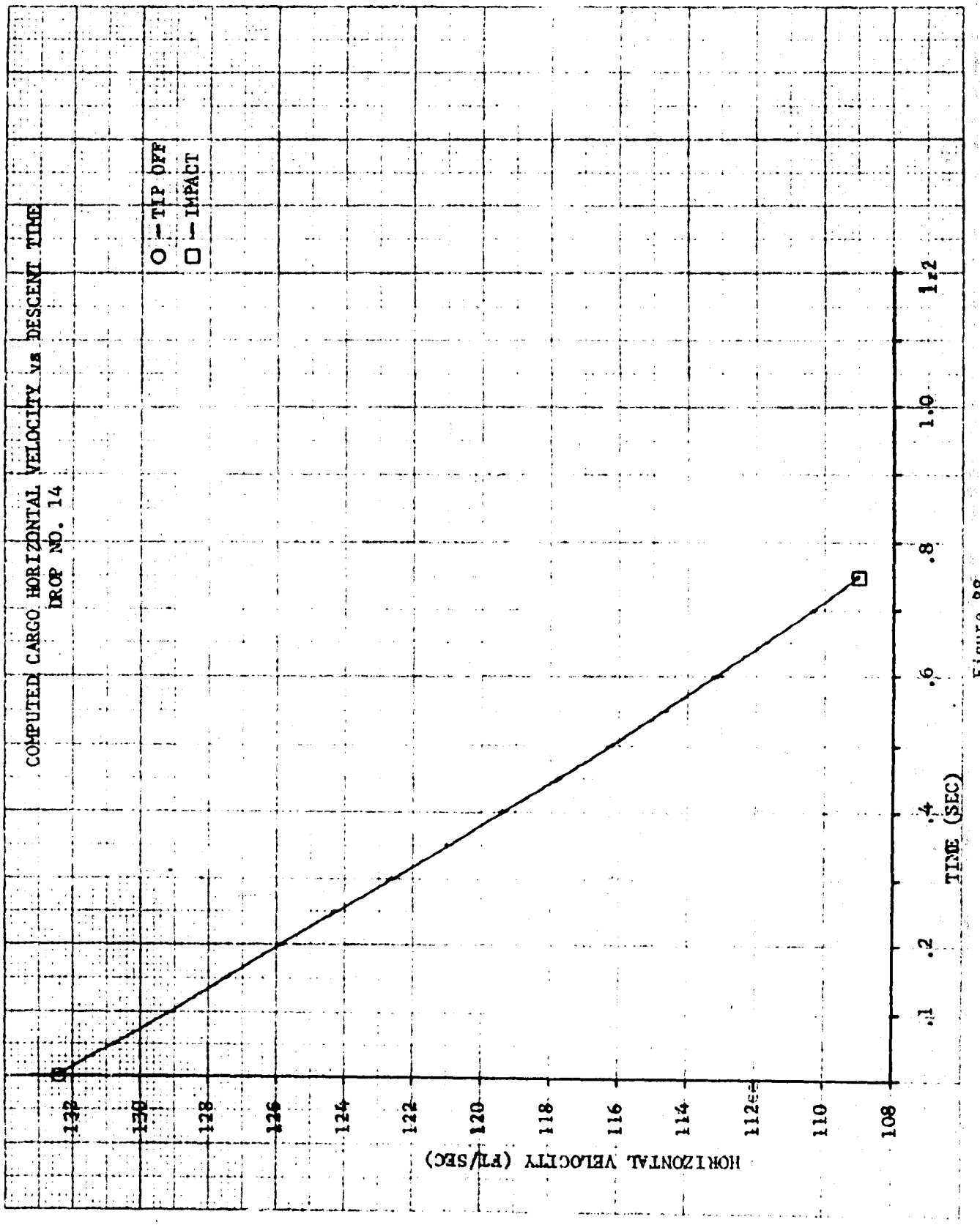
COMPUTED CARGO HORIZONTAL VELOCITY vs DESCENT TIME
DROP NO. 14
O — TIP OFF
□ — IMPACT
HORIZONTAL VELOCITY (FT/SEC)
132
130
128
126
124
122
120
118
116
114
112
110
108
TIME (SEC)
.1
.2
.4
.6
.8
1.0
1.2

Figure 88

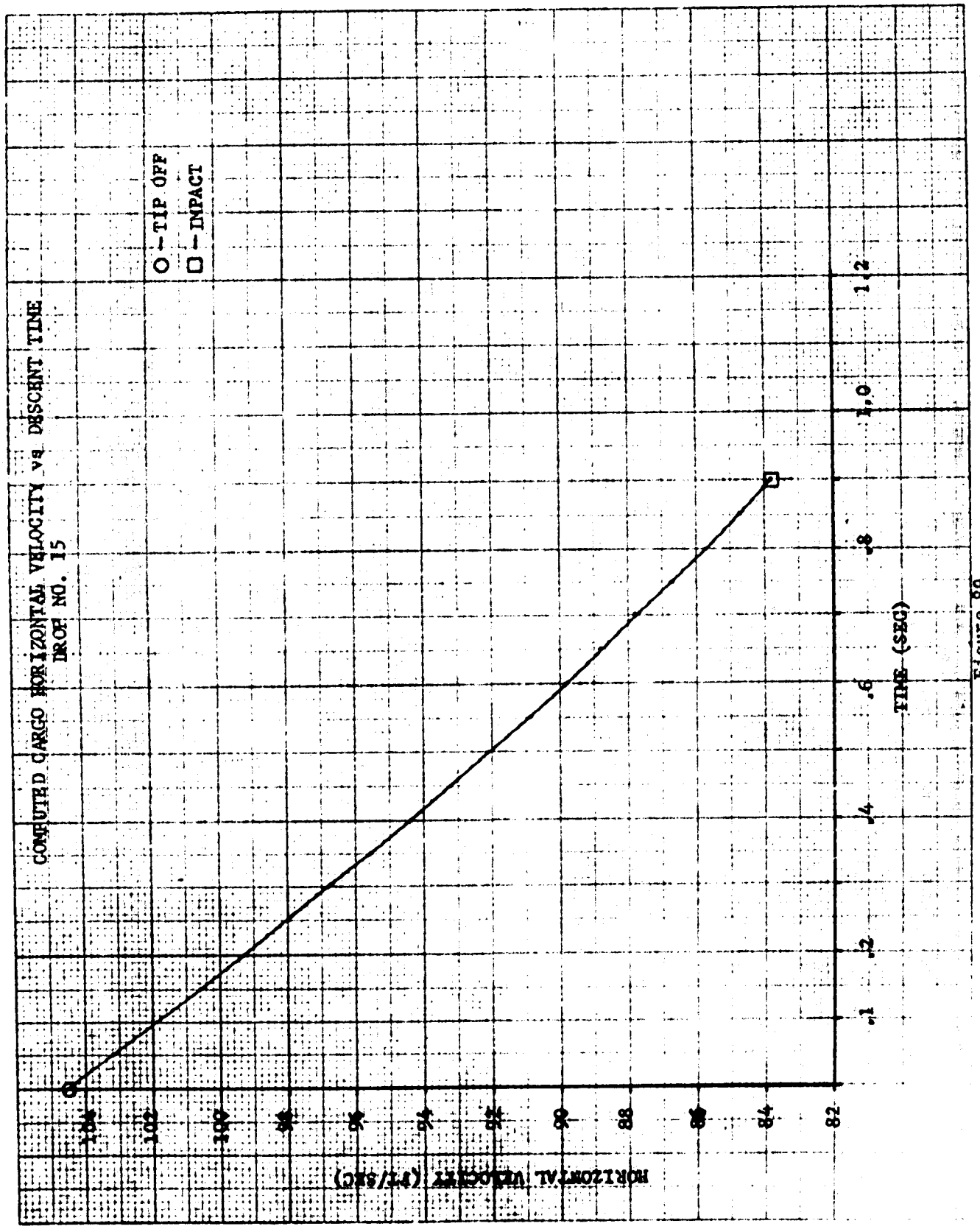
COMPUTED CARGO HORIZONTAL VELOCITY vs DESCENT TIME
DROP NO. 15
O – TIP OFF
□ – IMPACT
HORIZONTAL VELOCITY (FT/SEC)
104
102
100
98
96
94
92
90
88
86
84
82
TIME (SEC)
.1
.2
.4
.6
.8
1.0
1.2

Figure 89

D. Impact Phase

The equations for this phase are much less descriptive of the actual motion than are the equations for the drop phase. Too many variables are not and cannot be considered in the computer program. The slide length seems to be the only method of comparing the computer analysis against the actual occurrence for the impact phase. Below is a tabulation of slide lengths.

| Test No. | Slide Length | |
|---|---|---|
| | Actual | Computer |
| 1. | Load Overturn | 116.8 |
| 3. | 65 | 73.32 |
| 4. | 60 | 102.08 |
| 5. | 80 | 90.67 |
| 6. | 90 | 138.85 |
| 7. | Load Overturn | 105.23 |
| 8. | 72 | 77.07 |
| 9. | 60 | 76.46 |
| 10. | Load Overturn | 104.39 |
| 11. | 90 | 117.65 |
| 12. | 90 | 154.28 |
| 13. | 110 | 131.29 |
| 14. | 110 | 100.61 |
| 15. | 160 | 88.76 |

A value for the coefficient of friction was extremely difficult to select. Below is a list of variables that effect the coefficent of friction.

1. Impact Zone Terrain
2. Impact Zone Vegatation
3. Impact Zone Moisture Content

4. Impact Zone Hardness

5. Impact Zone Material

6. Load Platform Material

7. Load Impact Angle.

The instantaneous value of the coefficient of friction changes all along the slide path in the actual situation. Whereas, the computer assumes the instantaneous coefficient value is equal to the average value. With this though that the exact coefficient of friction value is nearly impossible to obtain, one can say that the two comparative slide lengths are in close agreement.

# III. COMPUTER PROGRAM

## A. General

When the computer program was set up for use on AAI's computer it was necessary to rewrite the program in three distinct separate phases due to the size of AAI's computer. The new program along with its inputs is presented in this section. Also included is a listing of the numerical values of the input as obtained from the test program.

## B. Nomenclature

Presented below is the program input nomenclature. It was felt that clarification was needed as far as defining the coordinate system of each individual computer input.

| Nomenclature | Units | Definition |
|---|---|---|
| $t_o$ | sec | Extraction start time |
| $\zeta_o$ | degrees | Initial yaw angle of cargo in ground fixed frame of reference |
| $r_{x_o}$ | feet | x component of distance from wind fixed frame of reference to cargo c.g. |
| $r_{y_o}$ | feet | y component of distance from wind fixed frame of reference to cargo c.g. |
| $\dot{r}_{x_o}$ | ft/sec | $\frac{d\,r_{x_o}}{dt}$ |
| $\dot{r}_{y_o}$ | ft/sec | $\frac{d\,r_{y_o}}{dt}$ |

| Nomenclature | Units | Definition |
|---|---|---|
| $Ly_o$ | feet | y component from parachute C.G. to extraction point in ground fixed frame of reference. |
| $Lz_o$ | feet | z component from parachute C.G. to extraction point in ground fixed frame of reference. |
| $\dot{Ly}_o$ | ft/sec | $\frac{d\,Ly_o}{dt}$ |
| $\dot{Lz}_o$ | ft/sec | $\frac{d\,Lz_o}{dt}$ |
| $\theta_a$ | degree | Pitch angle of aircraft in ground fixed frame of reference |
| $\phi_a$ | degree | Roll angle of aircraft in ground fixed frame of reference |
| $\psi_a$ | degree | Yaw angle of aircraft in ground fixed frame of reference |
| $r_{ax_o}$ | feet | x distance from ground fixed frame of reference to aircraft C.G. |
| $r_{ay_o}$ | feet | y distance from ground fixed frame of reference to aircraft C.G. |
| $r_{az_o}$ | feet | z distance from ground fixed frame of reference to aircraft C.G. |
| $\Delta t_1$ | second | Time increment for extraction phase |
| $\Delta t_2$ | second | Time increment for tip-off phase |
| $\Delta t_3$ | second | Time increment for descent phase |
| a | feet | x distance from cargo c.g. to extraction point in cargo frame of reference |
| b | feet | y distance from cargo c.g. to extraction point in cargo frame of reference |

| Nomenclature | Units | Definition |
|---|---|---|
| c | feet | z distance from cargo c.g. to extraction point in cargo frame of reference. |
| d | feet | x distance from cargo c.g. to center of the platform floor in cargo frame of reference |
| e | feet | y distance from cargo c.g. to center of the platform floor in cargo frame of reference |
| f | feet | z distance from cargo c.g. to center of the platform floor in cargo frame of reference |
| n | feet | z distance from aircraf c.g. to reaction point in aircraft frame of reference |
| m | slugs | Mass of cargo |
| M | slugs | Mass of parachute |
| $I_{xx}$ | slugs-ft$^2$ | Moment of inertia of the cargo about its x axis |
| $I_{yy}$ | slug-ft$^2$ | Moment of inertia of the cargo about its y axis |
| $I_{zz}$ | slug-ft$^2$ | Moment of inertia of the cargo about its z axis |
| $V_x$ | ft/sec | x component of wind velocity in the ground fixed frame of reference |
| $V_y$ | ft/sec | y component of wind velocity in the ground fixed frame of reference |
| $V_z$ | ft/sec | z component of wind velocity in the ground fixed frame of reference |
| $V_{ax}$ | ft/sec | x component of aircraft velocity in the wind fixed frame of reference |
| $V_{ay}$ | ft/sec | y component of aircraft velocity in the wind fixed frame of reference |

| Nomenclature | Units | Definition |
|---|---|---|
| $V_{az}$ | ft/sec | z component of aircraft velocity in the wind fixed frame of reference |
| $d_e$ | feet | x component from cargo c.g. position, before extraction, to the tip of the aircraft ramp in the aircraft frame of reference. |
| $l_c$ | feet | Half length of platform |
| $K_{L_\alpha}$ | slug/ft. rad. | Slope of the $K_L$ versus $\alpha$ (angle of attack) curve |
| $K_{D_o}$ | slug/ft. | Cargo drag factor with $\alpha = 0$ |
| $K_{D_{\alpha^2}}$ | slug/ft. rad. | Slope of $K_D$ versus $\alpha^2$ curve |
| $Z_{test}$ | feet | Altitude test for descent phase |
| $(C_D A)_o$ | $ft^2$ | Product of drag coefficient and inflated parachute drag area |
| Diam. | ft. | Skirt diameter of inflated parachute |
| $G_N$ | -- | Number of parachutes used |
| $G_F$ | -- | Cluster factor |
| $\rho_o$ | $slug/ft^3$ | Air density at the extraction altitude |

IMPACT PHASE INPUT NOMENCLATURE

| Nomenclature | Units | Definition |
|---|---|---|
| $t_o$ | second | starting time |
| $\Delta t$ | second | time increment for numerical integration |
| $X_o$ | feet | x component of cargo position in ground fixed frame of reference |
| $\dot{X}_o$ | ft/sec | $\left(\frac{dx}{dt}\right)_o$ |
| $\theta_o$ | radians | Pitch angle of cargo in ground fixed frame of reference |
| $\dot{\theta}_o$ | rad/sec | $\left(\frac{d\theta}{dt}\right)_o$ |
| $L_{x_o}$ | feet | X component of parachute line length in ground fixed frame of reference |
| $\dot{L}_{x_o}$ | ft/sec | $\left(\frac{d\,Lx}{dt}\right)_o$ |
| $V_x$ | ft/sec | X component of wind velocity in ground fixed frame of reference |
| $V_z$ | ft/sec | Z component of wind velocity in ground fixed frame of reference |
| ALT | feet | Z component from aircraft C.G. to ground fixed frame of reference |
| $K_{11}$ | feet | X component from cargo C.G. to attachment point of external decelerator in cargo frame of reference |
| $K_{13}$ | feet | Z component from cargo C.G. to attachment point of external decelerator in cargo frame of reference |
| a | feet | X component from cargo C.G. to extraction point on cargo frame of reference |
| c. | feet | Z component from cargo C.G. to extraction point in cargo frame of reference |

| Nomenclature | Units | Definition |
|---|---|---|
| d | feet | X component from cargo C.G. to platform centerline in cargo frame of reference |
| f | feet | Z component from cargo C.G. to platform floor in cargo frame of reference |
| $l_c$ | feet | half length of the platform |
| $I_{yy}$ | slug-ft$^2$ | Moment of inertia of the cargo about its y axis |
| $K_c$ | slug/ft | Parachute draf factor |
| m | slugs | mass of cargo |
| M | slugs | mass of parachute |
| CN | | Case number |
| $\theta_{max}$ | radians | critical pitch angle for which pitch will occur |
| Dia. Chute | feet | inflated parachute diameter |
| $\mu$ | | coefficient of friction |
| $\ell$ | feet | line length |
| $\dot{Z}_o$ | ft/sec | vertical impact velocity |
| $\ddot{X}_o$ | ft/sec$^2$ | $\left(\frac{d^2x}{dt^2}\right)_o$ |
| f | pounds | magnitude of external force |

C. Computer Program and Imputs

Several changes were made in the original computer program. Below is a listing of all four phases of the revised program.

```
00000  *
00000  C      GROUND SLIDE AIR DROP - EXTRACTION PHASE
00000  C
00000  C      PAGE NO.  1
00000  C
00000         COMMON        CN,DELT2,PS0,PSD0,RX0 RYC,RXD0,RYD0,XLYD0,XLZD0,XLZ0,
00000        1XLY0,THD0,TH0,C15,T0,T,RAX0,VAX,RAY0,VAY,RAZ0,VAZ,C13,P20,C26,C3,C
00000        24,C8,C5,C37,C38,XH2,P23,P22,XN,P24,P25,P27,F,XA,C,XB,XJ1,NTBLE,DIA
00000        3M0,NDRD0,CKF,XLM,XJYY,C49,XJ3,XJXX,C50,XJ2,XJZZ,C51,XSM,C39,C12,K,
00000        4ISTEP,IP,IPI,VX,VY,VZ,XLC,D,DELT03,XIPI3,DELT0   ,ZDTEST
00000         EQUIVALENCE (DATA(1),CN)
00000         DIMENSION DATA(73)
00000         DIMENSION A(12,12),YA(12),B(12),TCHUTE(12),DRI(12),XLI(12),XLDI(12
00000        1),XLDDI(12),DRDOI(15),CDRATI(15)
00000         READ 10,T0,PS0,PSD0,RX0,RY0,RXD0,RYD0,XLYD0,XLZD0,XLZ0,XLY0,THA,PH
00000        1A,PSA,RAX0,RAY0,RAZ0,DELT0,XIPI,XA,XB,C,D,E,F,XN,XSM,XLM,XIXX,XIYY
00000        2,XIZZ,VX,VY,VZ,VAX,VAY,VAZ,DE,DELT02,DELT03,XLC,XKLA,XKD0,XKDA,ZDT
00000        3EST,XIPI2,XIPI3,CDA0,DIAM0,GN,GF,CN,RHO
00000     10 FORMAT(8F10.4)
00000         PRINT 4,CN
00000      4 FORMAT(12H1CASE NUMBER,F7.4/17H EXTRACTION PHASE)
00000         PRINT 1,T0,PS0,PSD0,RX0,RY0,RXD0,RYD0,XLYD0,XLZD0,XLZ0,XLY0,THA,PH
00000        1A,PSA,RAX0,RAY0,RAZ0,DELT0,XIPI,XA,XB,C,D,E,F,XN,XSM,XLM,XIXX,XIYY
00000        2,XIZZ,VX,VY,VZ,VAX,VAY,VAZ,DE,DELT02,DELT03,XLC,XKLA,XKD0,XKDA,ZDT
00000        3EST,XIPI2,XIPI3,CDA0,DIAM0,GN,GF,RHO
00000         READ 3000,NTBLE,(TCHUTE(ITBLE),DRI(ITBLE),XLI(ITBLE),XLDI(ITBLE),X
00000        1LDDI(ITBLE),ITBLE=1,NTBLE)
00000   3000 FORMAT(I10/(5F10.5))
00000         PRINT 3001,(TCHUTE(ITBLE),DRI(ITBLE),XLI(ITBLE),XLDI(ITBLE),XLDDI(
00000        1ITBLE),ITBLE=1,NTBLE)
00000  C
00000  C      PAGE NO.  2
00000  C
00000   3001 FORMAT(//41H CHUTE DIAMETER AND LINE LENGTH VARIATION//(10X,5F10.5
00000        1))
00000         READ 4000,NDRD0,(DRDOI(I),CDRATI(I),I=1,NDRD0)
00000   4000 FORMAT(I10/(8F10.4))
00000         PRINT 4001,(DRDOI(I),CDRATI(I),I=1,NDRD0)
00000   4001 FORMAT(//21H (CDA) RATIO VS DR/D0//(10X,2F20.8))
00000      1 FORMAT(//5H INPUT/(4F20.8))
00000         K=12
00000         CKF=RHO  *GN*GF*CDA0/2.
00000         XJXX=XIXX/XLM
00000         XJYY=XIYY/XLM
00000         XJZZ=XIZZ/XLM
00000         C49=XJXX-XJZZ
00000         C50=XJYY-XJZZ
00000  C
00000  C      PAGE NO.  3
00000  C
00000         C51=XJXX-XJYY
00000         XJ1=C49+XJYY
00000         XJ2=C51+XJZZ
00000         XJ3=C51-XJZZ
```

```
      C1=COSF(THA/57.29578)
      C2=SINF(THA/57.29578)
      C3=COSF(PHA/57.29578)
      C4=SINF(PHA/57.29578)
      C5=COSF(PSA/57.29578)
      C6=SINF(PSA/57.29578)
      C7=C6*C1
      C8=C5*C4
      C9=C6*C4
      C10=DE*DE
      C12=XSM*32.16
      C13=1.+XSM/XLM
      C14=XM-F
      C25=PSA/57.29578
      C36=C4*C1
      C37=C6*C3
      C38=C5*C3
      C39=C13*32.16
      P22=C7-C8*C2
      P23=C5*C1+C9*C2
      P24=C5*C2-C9*C1
C
C     PAGE NO.  4
C
      P25=C6*C2+C8*C1
      P26=C3*C2
      P27=C3*C1
      PS0= PS0/57.29578
      T=T0
      DELT2= DELT0/2.
      IPI=XIPI
      IP=IPI
      ISTEP=1
      IK=1
  200 DET2=DELT2
      PS1=PS0
      PSD1=PSD0
      RX1=RX0
      RY1=RY0
      RXD1=RXD0
      RYD1=RYD0
      XLYD1=XLYD0
      XLZD1=XLZD0
      XLZ1=XLZ0
      XLY1=XLY0
  300 TT=T0-T
      RAX1=RAX0+VAX*TT
      RAY1=RAY0+VAY*TT
C
C     PAGE NO.  5
C
      RAZ1=RAZ0+VAZ*TT
      DO 450 I=1,12
      YA(I)=0.
      B(I)=0.
```

```
00000          DO 410 J=1,12
00000     410  A(I,J)=0.
00000          A(4,1)=C13
00000          A(4,4)=1.
00000          A(5,2)=C13
00000          A(5,5)=1.
00000          A(6,3)=C13
00000          A(6,6)=1.
00000          A(8,7)=C4
00000          A(9,1)=P24
00000          A(9,2)=P25
00000          A(9,3)=-P27
00000          A(7,7)=P26
00000          C16=C26-PS0
00000          C17=SINF(C16)
00000          C18=COSF(C16)
00000          C19=C2*C18-C36*C17
00000          C20=SQRTF(1.-C19*C19)
00000          C21=C19/C20
00000          C22=P27/C20
00000          C23=(C2*C17+C36*C18)/C20
00000          RZ0=RAZ1+((RX0-RAX1)*P24+(RY0-RAY1)*P25+C14)/P27
00000    C
00000    C     PAGE NO.  6
00000    C
00000          RZD0=VAZ+((RXD0-VAX)*P24+(RYD0-VAY)*P25)/P27
00000          PH0=ACOSF(C22/SQRTF(C22*C22+C23*C23))
00000          IF(C23)9000,9001,9001
00000     9000 PH0=-PH0
00000     9001 PHD0=-C22*C21*PSD0
00000          TH0=ACOSF(C20/SQRTF(C20*C20+C19*C19))
00000          IF(C19)9002,9003,9003
00000     9002 TH0=-TH0
00000     9003 THD0=C23*PSD0
00000          C24=SINF(PS0)
00000          C25=COSF(PS0)
00000          C27=C25*C23
00000          C28=C24*C23
00000          P1=XA*C19+C*C20
00000          P2=XA*C20-C*C19
00000          P3=P1*C23
00000          P4=P1*C22+XB*C23
00000          P5=P3-XB*C22
00000          C29=P2*C24
00000          C30=P5*C25
00000          C31=P2*C25
00000          C32=P5*C24
00000          C33=2.*P4
00000          C40=C24*C22
00000          C41=C25*C22
00000          C42=P2*P2
00000          C43=PSD0*PSD0
00000          C44=PHD0*PHD0
00000    C
00000    C     PAGE NO.  7
```

```
C
      C45=THD0*THD0
      C46=PHD0*PSD0
      C47=PSD0*THD0
      C48=PHD0*THD0
      C52=2.*P2*C48
      C53=C33*C46
      C54=2.*C47
      P7=C24*C19+C27*C20
      P8=C25*C19-C28*C20
      P11=P1*C25-P2*C28
      P12=P1*C24+P2*C27
      P13=C29-C30
      P14=C31+C32
      P15=C29-P3*C25
      P16=C31+P3*C24
      P18=P1*P1+X8*X8
      P19=(XA*XA+C*C)*C22
      P20=P19+P3*X8
      P21=C33*P4+XJ1
C
C     PAGE NO.  8
C
      DO 3010 I= 2,NTBLE
      IF(TCHUTE(I)-T0) 3010,3011,3011
 3010 CONTINUE
 3011 TFRAC= (T0-TCHUTE(I-1))/(TCHUTE(I)-TCHUTE(I-1))
      DR= DRI(I-1)+(DRI(I)-DRI(I-1))*TFRAC
      DRD0=DR/DIAM0
      XL= XLI(I-1)+(XLI(I)-XLI(I-1))*TFRAC
      XLD= XLDI(I-1)+(XLDI(I)-XLDI(I-1))*TFRAC
      XLDD=XLDDI(I-1)+(XLDDI(I)-XLDDI(I-1))*TFRAC
      XLX0= -SQRTF(XL*XL-XLY0*XLY0-XLZ0*XLZ0)
      XLXD0=(XL*XLD-XLY0*XLYD0-XLZ0*XLZD0)/XLX0
      P37= RXD0+XLXD0-P13*PSD0+P4*C24*PHD0-P11*THD0
      P38= RYD0+XLYD0+P14*PSD0-P4*C25*PHD0-P12*THD0
      P39= RZD0+XLZD0-P5*PHD0+P2*C22*THD0
      DO 4010 I= 2,NDRD0
      IF(DRD0I(I)-DRD0) 4010,4011,4011
 4010 CONTINUE
 4011 CDRAT= CDRATI(I-1)+(CDRATI(I)-CDRATI(I-1))*(DRD0-DRD0I(I-1))/(DRD0
     1I(I)-DRD0I(I-1))
      XKF= CKF*CDRAT
      P40= XKF/XLM*SQRTF(P37*P37+P38*P38+P39*P39)
C
C     PAGE NO.  9
C
      A(1,1)= -P4
      A(1,3)= P14
      A(1,4)= -P4
      A(1,6)= P14
      A(1,7)= P4*P13
      A(1,8)=-C31*P5-C24*(XJYY+P18)
      A(1,9)= C25*(P20+C22*XJYY)-C24*P2*X8
      YA(1)= -P14*32.16+P40*(P4*P37-P14*P39)-P4*P14*C43+C31*P4*C44-(P12*
```

```
      1XB+C26*C22*C49)*C45+C25*P21*C46+(C40*XJ1+C33*P12)*C47+C52*P12-C27*
      2XJ3*C48
       A(2,2)= P4
       A(2,3)= -P13
       A(2,5)= P4
       A(2,6)= -P13
       A(2,7)= P4*P14
       A(2,8)= P2*C32-C25*(P18+XJXX)
       A(2,9)= -C31*XB-P20*C24-C48*XJXX
       YA(2)=P13*32.16+P48*(P13*P39-P4*P38)+P4*P13*C43-C29*P4*C44-(P11*XB
      1+C27*C22*C50)*C45-C24*P21*C46+(C33*P11+C41*XJ1)*C47+C52*P11-C28*XJ
      22*C48
C
C      PAGE NO. 10
C
       A(3,1)= P13
       A(3,2)= -P14
       A(3,4)= P13
       A(3,5)= -P14
       A(3,7)= -C42-P5*P5-XJZZ
       A(3,8)= P2*P4
       A(3,9)= P1*P5+C23*(XJZZ+C42)
       YA(3)=P48*(P14*P38-P13*P37)+(P2*P5-C24*C25*C51)*C44+C22*(P2*XB*C48
      1*C25*C51)*C45+C53*P5-C54*P2*P4*C22+C22*C48*(COSF(2.*P80)*C51-XJZZ-
      22.*C42)
       A(4,7)= -P13
       A(4,8)= P4*C24
       A(4,9)= -P11
       A(5,7)= P14
       A(5,8)= -P4*C25
       A(5,9)= -P12
       A(6,8)= -P5
       A(6,9)= P2*C22
C
C      PAGE NO. 11
C
       A(10,4)= XLX0
       A(10,5)= XLY0
       A(10,6)= XLZ0
       YA(10)= XL*XLDD-XLXD0*XLXD0-XLYD0*XLYD0-XLZD0*XLZD0+XLD*XLD
       A(11,1)=-XSM*XLY0
       A(11,2)=XSM*XLX0
       A(12,1)=XSM*XLZ0
       A(12,3)= -XSM*XLX0
       C34= C22*C3
       C35= C18*C3
       P6= C22*C20
       P28= P22*C24+P23*C25
       P29= P22*C25-P23*C24
       P31= C34*C18+C23*C4
       P32=C23*C35-C22*C4
       P33= RAX1-RX0-P24*XN
       P34= RAY1-RY0-P25*XN
       P35= RAZ1-RZ0+P27*XN
C
```

```
C       PAGE NO. 12
C
        P41= P6/XLM
        P42= P7/XLM
        P43= P8/XLM
        A(1,10)= -P33*P41-P35*P43
        A(1,11)= -P23*P41-P26*P43
        A(1,12)= C37*P41-C4*P43
        A(2,10)= P34*P41+P35*P42
        A(2,11)= P22*P41+P26*P42
        A(2,12)= C38*P41+C4*P42
        A(3,10)= P34*P43-P33*P42
        A(3,11)= P22*P43-P23*P42
        A(3,12)= C38*P43+C37*P42
        A(4,10)= P43
        YA(4)= -P37*P40+P14*C43+C32*C44+P16*C45-C53*C25-P12*C54-C52*C48
        A(5,10)= P42
        YA(5)= -P38*P40+P13*C43-C38*C44+P15*C45-C24*C53+P11*C54+C52*C41
C
C       PAGE NO. 13
C
        A(6,10)= -P41
        YA(6)= -C39-P39*P40+P4*C44+C22*P1*C45+C52*C23
        A(7,8)=P26
        A(7,9)= -C22*P29-C23*P26
        YA(7)= -P29*C46-P28*C22*C47+(P26*C22-P29*C23)*C48
        A(11,10)=P7*XLX0-P8*XLY0
        YA(11)=0.0
        A(12,10)= P6*XLX0+P8*XLZ0
        YA(12)= C12*XLX0
        A(8,8)= -C3*C17
        A(8,9)= -P31
        YA(8)= -C35*C46+C34*C17*C47-P32*C48
        CALL SIMEQ(A,YA,B,R)
C
C       PAGE NO. 14
C
        ISTEP= -ISTEP
        IF(ISTEP)310,900,350
  310   IP= IP+8
        IF(IP-IP8)260,220,220
  220   X= RX0+VX*TT
        Y= RY0+VY*TT
        Z= RZ0+VZ*TT
        XP= X+XLX0+P14
        YP= Y+XLY0+P13
        ZP= Z+XLZ0+P4
        XD= RXD0+VX
        YD= RYD0+VY
        ZD= RZD0+VZ
        TC=SQRTF(XSM*XSM*(B(1)*B(1)+B(2)*B(2)*(B(3)-32.16)*(B(3)-32.16))+B
       1(10)*B(10)+2.*XSM*B(10)*(B(1)*P6+B(2)*P7-(B(3)-32.16)*P8))
        PRINT 2 ,T0,X,Y,Z,XD,YD,ZD,XP,YP,ZP,PS0,PH0,TH0,(B(I),I=1,12)
     20 FORMAT(////4F20.6/ (20X,3F20.6 ))
        PRINT 41,TC
```

```
00000      41 FORMAT(26X,F20.8)
00000         IP=0
00000  C
00000  C      PAGE NO. 15
00000  C
00000     210 C55= B(11)/B(10)
00000         IF(IK)3,3,2
00000       2 C61= C55
00000         C10= (RX0-RAX0+DE)*(RX0-RAX0+DE)
00000         IK= -IK
00000       3 IF(C55*C55-C10)350,212,212
00000     212 PRINT 30,T0
00000      30 FORMAT(///F20.6,24H END OF EXTRACTION PHASE )
00000         XH2=C55
00000         DELT0=DELT02
00000         DELT2=DELT0/2.
00000         ISTEP=1
00000         IPI=XIPI2
00000         IP=IPI
00000  C
00000  C      PREPARE TAPES FOR INPUT TO PHASE II.
00000  C
00000         WRITE TAPE 1,DATA
00000         WRITE TAPE 1,XKLA,XKD0,XKDA
00000         WRITE TAPE 1,(TCHUTE(I),DRI(I),XLI(I),XLDI(I),XLDDI(I),I=1,NTBLE)
00000         WRITE TAPE 1,(DRDOI(I),CDRATI(I),I=1,NDRD0)
00000         STOP
00000     350 RXD0= RXD1+B(1)*DET2
00000         RYD0= RYD1+B(2)*DET2
00000         XLYD0= XLYD1+B(5)*DET2
00000         XLZD0= XLZD1+B(6)*DET2
00000         PSD0= PSD1+B(7)*DET2
00000         RX0= RX1+(RXD1+RXD0)*DET2/2.
00000         RY0= RY1+(RYD1+RYD0)*DET2/2.
00000         XLY0= XLY1+(XLYD1+XLYD0)*DET2/2.
00000         XLZ0= XLZ1+(XLZD1+XLZD0)*DET2/2.
00000         PS0= PS1+(PSD1+PSD0)*DET2/2.
00000         T0= T0+DELT2
00000         DET2= DELT0
00000         IF(ISTEP)300,900,200
00000     900 STOP
00000         END
```

```
00000  C      GROUND SLIDE AIR DROP SYSTEM  TIPOFF PHASE
00000         VELOCF(DA,DB)=DA+DB*DET2
00000         DISPLF(DA,DB,DC)=DA+(DB+DC)*DET2/2.
00000         COMMON        CN,DELT2,PS0,PSD0,RX0,RY0,RXD0,RYD0,XLYD0,XLZD0,XLZ0,
00000        1XLY0,THD0,TH0,C10,T0,T,RAX0,VAX,RAY0,VAY,RAZ0,VAZ,C13,P26,C26,C3,C
00000        24,C6,C5,C37,C36,XH2,P23,P22,XH,P24,P25,P27,F,XA,C,X0,XJ1,NTBLE,DIA
00000        3H0,NDRD0,CKF,XLH,XJYY,C49,XJ3,XJXX,C50,XJ2,XJZZ,C51,X3H,C39,C12,K,
00000        4ISTEP,IP,IPI,VX,VY,VZ,XLC,D,DELT03,XIPI3,DELT8   ,ZDTEST
00000         EQUIVALENCE (DATA(1),CN)
00000         DIMENSION DATA(73)
00000         DIMENSION A(12,12),YA(12),B(12)
00000         DIMENSION TCHUTE(12),DRI(12),XLI(12),XLDI(12),XLDDI(12)
00000         DIMENSION DRDOI(15),CDRATI(15)
00000  C      IF SJ1 IS ON, CASE NUMBER IS READ FROM CARD AND DATA ON PAPER
00000  C         TAPE IS SEARCHED UNTIL THIS CASE NUMBER IS FOUND
00000  C      IF SJ1 IS OFF , THE FIRST SET OF DATA ON THE TAPE IS USED
00000         IF(SENSE SWITCH 1)7000,7100
00000   7000  READ 8000,CCN
00000   8000  FORMAT(F10.0)
00000   7100  READ TAPE 1,DATA
00000         READ TAPE 1,XKLA,XKD0,XKDA
00000          READ TAPE 1,(TCHUTE(I),DRI(I),XLI(I),XLDI(I),XLDDI(I),I=1,NTBLE)
00000          READ TAPE 1,(DRDOI(I),CDRATI(I),I=1,NDRD0)
00000         IF(SENSE SWITCH 1)7200,8002
00000   7200  IF(CCN-CN)7100,8002,7100
00000   8002  PRINT4,CN
00000      4  FORMAT(12H1CASE NUMBER,F7.4/13H TIPOFF PHASE)
00000    200  DET2=DELT2
00000         PS1=PS0
00000         PSD1=PSD0
00000         RX1=RX0
00000         RY1=RY0
00000         RXD1=RXD0
00000         RYD1=RYD0
00000         XLYD1=XLYD0
00000         XLZD1=XLZD0
00000         XLZ1=XLZ0
00000         XLY1=XLY0
00000         THD1=THD0
00000         TH1=TH0
00000    300  TT=T0-T
00000         RAX1=RAX0+VAX*TT
00000         RAY1=RAY0+VAY*TT
00000         RAZ1=RAZ0+VAZ*TT
00000         DO 410 I=1,12
00000         YA(I)=0.
00000         B(I)=0.
00000         DO 410 J=1,12
00000    410  A(I,J)=0.
00000         A(4,1)=C13
00000         A(4,4)=1.
00000         A(5,2)=C13
00000         A(5,5)=1.
00000         A(6,3)=C13
```

```
00000          A(6,6)=1.
00000     440  A(7,7)=P26
00000     450  C16=C26-PS0
00000          C17=SINF(C16)
00000          C18=COSF(C16)
00000          C19=SINF(TH0)
00000          C20=COSF(TH0)
00000          C23=(C3*C3*C17*C18*C19+C4*SQRTF(C20*C20-C3*C3*C17*C17))/(C20*(C3*C
00000         13*C18*C18+C4*C4))
00000          C22=SQRTF(1.-C23*C23)
00000          PH0=ACOSF(C22)
00000          IF(C23)9000,9001,9001
00000     9000 PH0=-PH0
00000     9001 C24=SINF(PS0)
00000          C25=COSF(PS0)
00000          C27=C25*C23
00000          C26=C24*C23
00000          P6=C22*C20
00000          P7=C24*C19+C27*C20
00000          P8=C25*C19-C26*C20
00000          P9=C24*C20-C27*C19
00000          P10=C25*C20+C26*C19
00000          P17=C22*C19
00000          P31=C22*C3*C18+C23*C4
00000          PHD0=((C3*(P10*C6-P9*C5)-P17*C4)*THD0-C3*(P7*C6+P8*C5)*PSD0)/(P31*
00000         1C20)
00000          RZ0=RAZ1-(P8*(RAX1-RX0)+P7*(RAY1-RY0)+XH2*(P8*P23+P7*P22-P6*P26)-X
00000         1N*(P8*P24+P7*P25+P6*P27)+F)/P6
00000          P55=RAX1-RX0-P24*XN+XH2*P23
00000          P56=RAY1-RY0-P25*XN+XH2*P22
00000          P57=RAZ1-RZ0-P27*XN+XH2*P26
00000          P60=P55*C24-P56*C25
00000          P61=P7*P55-P8*P56
00000          P62=C23*C20*P57-P6*P60
00000          P63=P10*P55+P9*P56+P17*P57
00000          RZD0=VAZ-(P8*(VAX-RXD0)+P7*(VAY-RYD0)-PSD0*P61+PHD0*P62+THD0*P63)/
00000         1P6
00000     458  P1=XA*C19+C*C20
00000          P2=XA*C20-C*C19
00000          P3=P1*C23
00000          P4=P1*C22+XB*C23
00000          P5=P3-XB*C22
00000          C29=P2*C24
00000          C30=P5*C25
00000          C31=P2*C25
00000          C32=P5*C24
00000          C33=2.*P4
00000          C40=C24*C22
00000          C41=C25*C22
00000          C42=P2*P2
00000          C43=PSD0*PSD0
00000          C44=PHD0*PHD0
00000          C45=THD0*THD0
00000          C46=PHD0*PSD0
00000          C47=PSD0*THD0
```

```
00000          C48=PHD0*THD0
00000          C52=2.*P2*C48
00000          C53=C33*C46
00000          C54=2.*C47
00000          P7=C24*C19+C27*C20
00000          P8=C25*C19-C28*C20
00000          P11=P1*C25-P2*C28
00000          P12=P1*C24+P2*C27
00000          P13=C29-C30
00000          P14=C31+C32
00000          P15=C29-P3*C25
00000          P16=C31+P3*C24
00000          P18=P1*P1+XB*XB
00000          P19=(XA*XA+C*C)*C22
00000          P20=P19+P3*XB
00000          P21=C33*P4+XJ1
00000          DO 3010 ITBLE=2,NTBLE
00000          IF(TCHUTE(ITBLE)-T0)3010,3011,3011
00000     3010 CONTINUE
00000     3011 TFRAC=(T0-TCHUTE(ITBLE-1))/(TCHUTE(ITBLE)-TCHUTE(ITBLE-1))
00000          DR=DRI(ITBLE-1)+(DRI(ITBLE)-DRI(ITBLE-1))*TFRAC
00000          DRD0=DR/DIAMD
00000          XL=XLI(ITBLE-1)+(XLI(ITBLE)-XLI(ITBLE-1))*TFRAC
00000          XLD=XLDI(ITBLE-1)+(XLDI(ITBLE)-XLDI(ITBLE-1))*TFRAC
00000          XLDD=XLDDI(ITBLE-1)+(XLDDI(ITBLE)-XLDDI(ITBLE-1))*TFRAC
00000          XLX0=-SQRTF(XL*XL-XLY0*XLY0-XLZ0*XLZ0)
00000          XLXD0=(XL*XLD-XLY0*XLYD0-XLZ0*XLZD0)/XLX0
00000          P37=RXD0+XLXD0-P13*PSD0+P4*C24*PHD0-P11*THD0
00000          P38=RYD0+XLYD0+P14*PSD0-P4*C25*PHD0-P12*THD0
00000          P39=RZD0+XLZD0-P5*PHD0+P2*C22*THD0
00000          DO 4010 IDRD0=2,NDRD0
00000          IF(DRD0I(IDRD0)-DRD0)4010,4011,4011
00000     4010 CONTINUE
00000     4011 CDRAT=CDRATI(IDRD0-1)+(CDRATI(IDRD0)-CDRATI(IDRD0-1))*(DRD0-DRD0I(
00000         1IDRD0-1))/(DRD0I(IDRD0)-DRD0I(IDRD0-1))
00000          XKF=CKF*CDRAT
00000          P40=XKF/XLM*SQRTF(P37*P37+P38*P38+P39*P39)
00000          A(1,1)=-P4
00000          A(1,3)=P14
00000          A(1,4)=-P4
00000          A(1,6)=P14
00000          A(1,7)=P4*P13
00000          A(1,8)=-C31*P5-C24*(XJYY+P18)
00000          A(1,9)=C25*(P20+C22*XJYY)-C24*P2*XB
00000          YA(1)=-P14*32.16+P40*(P4*P37-P14*P39)-P4*P14*C43+C31*P4*C44-(P12*X
00000         1B+C28*C22*C49)*C45+C25*P21*C46+(C40*XJ1+C33*P12)*C47+C52*P12-C27*X
00000         2J3*C48
00000          A(2,2)=P4
00000          A(2,3)=-P13
00000          A(2,5)=P4
00000          A(2,6)=-P13
00000          A(2,7)=P4*P14
00000          A(2,8)=P3*C32-C25*(P18+XJXX)
00000          A(2,9)=-C31*XB-P20*C24-C40*XJXX
00000          YA(2)=P13*32.16+P40*(P13*P39-P4*P38)+P4*P13*C43-C29*P4*C44-(P11*XB
```

```
00000        1*C27*C22*C50)*C45-C24*P21*C46+(C33*P11+C41*XJ1)*C47+C52*P11-C28*XJ
00000        22*C48
00000         A(3,1)=P13
00000         A(3,2)=-P14
00000         A(3,4)=P13
00000         A(3,5)=-P14
00000         A(3,7)=-C42-P5*P5-XJZZ
00000         A(3,8)=P2*P4
00000         A(3,9)=P1*P5+C23*(XJZZ+C42)
00000         YA(3)=P40*(P14*P38-P13*P37)*(P2*P5-C24*C25*C51)*C44+C22*(P2*XB+C40
00000        1*C25*C51)*C45+C53*P5-C54*P2*P4*C22+C22*C48*(COSF(2.*PS0)*C51-XJZZ-
00000        22.*C42)
00000         A(4,7)=-P13
00000         A(4,8)=P4*C24
00000         A(4,9)=-P11
00000         A(5,7)=P14
00000         A(5,8)=-P4*C25
00000         A(5,9)=-P12
00000         A(6,8)=-P5
00000         A(6,9)=P2*C22
00000         A(10,4)=XLX0
00000         A(10,5)=XLY0
00000         A(10,6)=XLZ0
00000         YA(10)=XL*XLD0- XLXD0*XLXD0-XLYD0*XLYD0-XLZD0*XLZD0+XLD*XLD
00000         A(11,1)=-XSM*XLY0
00000         A(11,2)=XSM*XLX0
00000         A(12,1)=XSM*XLZ0
00000         A(12,3)=-XSM*XLX0
00000    460  C34=C22*C3
00000         C35=C3*C18
00000         P6=C22*C20
00000         P28=P22*C24+P23*C25
00000         P29=P22*C25-P23*C24
00000         P31=C34*C18+C23*C4
00000         P32=C23*C35-C22*C4
00000         P33=RAX1-RX0-P24*XN
00000         P34=RAY1-RY0-P25*XN
00000         P35=RAZ1-RZ0+P27*XN
00000         P41=P6/XLM
00000         P42=P7/XLM
00000         P43=P8/XLM
00000         A(1,10)=-P33*P41-P35*P43
00000         A(1,11)=-P23*P41-P26*P43
00000         A(1,12)=C37*P41-C4*P43
00000         A(2,10)=P34*P41+P35*P42
00000         A(2,11)=P22*P41+P26*P42
00000         A(2,12)=C38*P41+C4*P42
00000         A(3,10)=P34*P43-P33*P42
00000         A(3,11)=P22*P43-P23*P42
00000         A(3,12)=C37*P42+C38*P43
00000         A(4,10)=P43
00000         YA(4)=-P37*P40+P14*C43+C32*C44+P16*C45-C53*C25-P12*C54-C52*C40
00000         A(5,10)=P42
00000         YA(5)=-P38*P40+P13*C43-C30*C44+P15*C45-C24*C53+P11*C54+C52*C41
00000         A(6,10)=-P41
```

```
00000          YA(6)=-C39-P39*P40+P4*C44+C22*P1*C45+C52*C23
00000          A(7,8)=P28
00000          A(7,9)=-C22*P29-C23*P26
00000          YA(7)=-P29*C46-P28*C22*C47+(P26*C22-P29*C23)*C48
00000          A(11,10)=P7*XLX0-P8*XLY0
00000          YA(11)=0.0
00000          A(12,10)=P6*XLX0+P8*XLZ0
00000          YA(12)=C12*XLX0
00000     470  P9=C24*C20-C27*C19
00000          P10=C25*C20+C28*C19
00000          P17=C22*C19
00000     480  P30=P24*C25+P25*C24
00000          P44=P25*C25-P24*C24
00000          P45=C23*C20
00000          P46=C23*C19
00000          P47=RAX1-RX0
00000          P48=RAY1-RY0
00000          P49=RAZ1-RZ0
00000          P53=C3*(P7*C6+P8*C5)
00000          P54=C4*P17+C3*(P9*C5-P10*C6)
00000          A(7,7)=-P53
00000          A(7,8)=-P31*C20
00000          A(7,9)=-P54
00000          YA(7)=C43*C3*(P6*C6-P7*C5)-C44*P32*C20+C45*((P6*C6-P7*C5)*C3+P6*C4
00000         1)+2.*(C46*P6*C3*C17+C47*C3*(P9*C6+P10*C5)-C48*P31*C19)
00000          A(8,1)=P8
00000          A(8,2)=P7
00000          A(8,3)=-P6
00000          A(8,7)=P61
00000          A(8,8)=-P62
00000          A(8,9)=-P63
00000          YA(8) =-C43*(P6*P55+P7*P56)+C44*(P45*P60+P6*P57)-C45*(P8*P55+P7*P5
00000         16-P6*P57)-2.*((VAX-RXD0)*(PSD0*P7+PHD0*P6*C24-THD0*P10)-(VAY-RYD0)
00000         2*(PSD0*P8+PHD0*P6*C25+THD0*P9)-(VAZ-RZD0)*(PHD0*P45+THD0*P17)+C46*
00000         3P6*(P55*C25+P56*C24)+C47*(P9*P55-P10*P56)-C48*(P17*P60-P46*P57))
00000     670  A(9,10)=XH2
00000          A(9,11)=-1.
00000          GO TO 500
00000     500  CALL SIMEQ(A,YA,B,K)
00000          ISTEP=-ISTEP
00000          IF(ISTEP)310,900,350
00000     310  IP=IP+1
00000          IF(.P-IPI)210,220,220
00000     220  X=RX0+VX*TT
00000          Y=RY0+VY*TT
00000          Z=RZ0+VZ*TT
00000          XP=X+XLX0*P14
00000          YP=Y+XLY0*P13
00000          ZP=Z+XLZ0*P4
00000          XD=RXD0+VX
00000          YD=RYD0+VY
00000          ZD=RZD0+VZ
00000          TC=SQRTF(XSM*XSM*(B(1)*B(1)+B(2)*B(2)+(B(3)-32.16)*(B(3)-32.16))+B
00000         1(10)*B(10)+2.*XSM*B(10)*(B(1)*P8+B(2)*P7-(B(3)-32.16)*P6))
00000          PRINT 20,TO,X,Y,Z,XD,YD,ZD,XP,YP,ZP,PSO,PHO,THO,(B(I),I=1,9)
```

```
00000      20 FORMAT(///4F20.8/ (20X,3F20.8 ))
00000         PRINT 41,TC
00000      41 FORMAT(20X,F20.8)
00000         IP=0
00000      21 PRINT22,(B(I),I=10,12)
00000      22 FORMAT(20X,3F20.8/)
00000     210 GO TO 213
00000     213 IF(B(10))215,215,214
00000     214 C59=B(12)/B(10)
00000         C60=P10*P47+P9*P48+P17*P49+(P10*P23+P9*P22+P17*P26)*XM2+(P17*P27-P
00000        110*P24-P9*P25)*XN+P54*C59
00000         IF(C60-XLC-D)350,215,215
00000     215 PRINT40,T0
00000      40 FORMAT(///F20.8,20H END OF TIPOFF PHASE)
00000         K=K-3
00000         DELT0=DELT03
00000         DELT2=DELT0/2.
00000         DET2=DELT2
00000         ISTEP=1
00000         IPI=XIPI3
00000         IP=IPI
00000   C      PHASE III INPUT TAPE
00000         WRITE TAPE 1, DATA
00000         WRITE TAPE 1,XKLA,XKD0,XKDA,PH0,PHD0,RZD0,RZ0
00000         WRITE TAPE 1,(TCHUTE(I),DRI(I),XLI(I),XLDI(I),XLODI(I),I=1,NTBLE)
00000         WRITE TAPE 1,(DRDOI(I),CDRATI(I),I=1,NDRDO)
00000         GO TO 900
00000     350 RXD0=VELOCF(RXD1,B(1))
00000         RYD0=VELOCF(RYD1,B(2))
00000         XLZD0=VELOCF(XLZD1,B(6))
00000         XLYD0=VELOCF(XLYD1,B(5))
00000         PSD0=VELOCF(PSD1,B(7))
00000         RX0=DISPLF(RX1,RXD1,RXD0)
00000         RY0=DISPLF(RY1,RYD1,RYD0)
00000         XLZ0=DISPLF(XLZ1,XLZD1,XLZD0)
00000         XLY0=DISPLF(XLY1,XLYD1,XLYD0)
00000         PS0=DISPLF(PS1,PSD1,PSD0)
00000         THD0=VELOCF(THD1,B(9))
00000         TH0=DISPLF(TH1,THD1,THD0)
00000     360 T0=T0+DELT2
00000         DET2=DELT0
00000         IF(ISTEP)300,900,200
00000     900 STOP
00000         END
```

```
C       GROUND SLIDE AIR DROP SYSTEM        DESCENT PHASE
        VELOCF(DA,DB)=DA+DB*DET2
        COMMON        CN,DELT2,PSC,PSD0,RX0,RY0,RXD0,RYD0,XLYD0,XLZD0,XLZ0,
       1XLY0,THD0,TH0,C16,T0,T,RAX0,VAX,RAT0,VAY,RAZ0,VAZ,C13,P20,C20,C3,C
       24,C6,C5,C37,C38,XH0,P23,P22,XM,P24,P25,P27,F,XS,C,X0,XJ1,NTBLE,DIA
       3M0,NDRD0,CKF,XLM,XJYY,C40,XJ3,XJXX,C50,XJ2,XJZZ,C51,XSM,C39,C12,K,
       4ISTEP,IP,IPI,VX,VY,VZ,XLC,D,DELTO3,XIP13,DELT0   ,ZDTEST
        EQUIVALENCE (DATA(1),CN)
        DIMENSION DATA(73)
        DISPLF(DA,DB,DC)=DA+(DB+DC)*DET2/2.
        DIMENSION A(12,12),YA(12),B(12)
        DIMENSION TCHUTE(12),DRI(12),XLI(12),XLDI(12),XLDDI(12)
        DIMENSION DRDDI(15),CDRATI(15)
C       IF SJ1 IS ON, CASE NUMBER IS READ FROM CARD AND DATA ON PAPER
C          TAPE IS SEARCHED UNTIL THIS CASE NUMBER IS FOUND
C       IF SJ1 IS OFF , THE FIRST SET OF DATA ON THE TAPE IS USED
        IF(SENSE SWITCH 1)7000,7100
 7000   READ 8000,CCN
 8000   FORMAT(F10.0)
 7100   READ TAPE 1,DATA
        READ TAPE 1 ,XKLA,XKD0,XKDA,PH0,PHD0,RZD0,RZ0
         READ TAPE 1,(TCHUTE(I),DRI(I),XLI(I),XLDI(I),XLDDI(I),I=1,NTBLE)
         READ TAPE 1,(DRDDI(I),CDRATI(I),I=1,NDRD0)
        IF(SENSE SWITCH 1)7200,8002
 7200   IF(CCN-CN)7100,8002,7100
 8002   PRINT4,CN
    4   FORMAT(12H1CASE.NUMBER,F7.4/14H DESCENT PHASE)
C
        NZ= 1
        DO 80 ITBLE= 2,NTBLE
        IF(TCHUTE(ITBLE)-T0) 80,81,81
   80   CONTINUE
   81   TFRAC=(T0-TCHUTE(ITBLE-1))/(TCHUTE(ITBLE)-TCHUTE(ITBLE-1))
        XL=XLI(ITBLE-1)+(XLI(ITBLE)-XLI(ITBLE-1))*TFRAC
        XLD=XLDI(ITBLE-1)+(XLDI(ITBLE)-XLDI(ITBLE-1))*TFRAC
        XLX0= -SQRTF(XL*XL-XLY0*XLY0-XLZ0*XLZ0)
        XLXD0= (XL*XLD-XLY0*XLYD0-XLZ0*XLZD0)/XLX0
C
  200   DET2=DELT2
        PS1=PSC
        PSD1=PSD0
        RX1=RX0
        RY1=RY0
        RXD1=RXD0
        RYD1=RYD0
        XLYD1=XLYD0
        XLZD1=XLZD0
C
        XLXD1= XLXD0
C
        XLZ1=XLZ0
        XLY1=XLY0
C
        XLX1=XLX0
```

```
00000  C
00000     280 TH1=TH0
00000         THD1=THD0
00000         RZD1=RZD0
00000         RZ1=RZ0
00000     290 PHD1=PHD0
00000         PH1=PH0
00000     300 TT=T0-T
00000         RAX1=RAX0+VAX*TT
00000         RAY1=RAY0+VAY*TT
00000         RAZ1=RAZ0+VAZ*TT
00000         DO 410 I=1,12
00000         YA(I)=0.
00000         B(I)=0.
00000         DO 410 J=1,12
00000     410 A(I,J)=0.
00000         A(4,1)=C13
00000         A(4,4)=1.
00000         A(5,2)=C13
00000         A(5,5)=1.
00000         A(6,3)=C13
00000         A(6,6)=1.
00000     450 C16=C20-PS0
00000         C17=SINF(C16)
00000         C18=COSF(C16)
00000     457 C19=SINF(TH0)
00000         C20=COSF(TH0)
00000         C21=C19/C20
00000         C22=COSF(PH0)
00000         C23=SINF(PH0)
00000         C24=SINF(PS0)
00000         C25=COSF(PS0)
00000         C27=C25*C23
00000         C28=C24*C23
00000     458 P1=XA*C19+C*C20
00000         P2=XA*C20-C*C19
00000         P3=P1*C23
00000         P4=P1*C22+XB*C23
00000         P5=P3-XB*C22
00000         C29=P2*C24
00000         C30=P5*C25
00000         C31=P2*C25
00000         C32=P5*C24
00000         C33=2.*P4
00000         C40=C24*C22
00000         C41=C25*C22
00000         C42=P2*P2
00000         C43=PSD0*PSD0
00000         C44=PHD0*PHD0
00000         C45=THD0*THD0
00000         C46=PHD0*PSD0
00000         C47=PSD0*THD0
00000         C48=PHD0*THD0
00000         C52=2.*P2*C48
00000         C53=C33*C40
```

```
00000          C54=2.*C47
00000          P7=C24*C19+C27*C20
00000          P8=C25*C19-C28*C20
00000          P11=P1*C25-P2*C28
00000          P12=P1*C24+P2*C27
00000          P13=C29-C30
00000          P14=C31+C32
00000          P15=C29-P3*C25
00000          P16=C31+P3*C24
00000          P18=P1*P1+X8*X8
00000          P19=(XA*XA+C*C)*C22
00000          P20=P19+P3*X8
00000          P21=C33*P4+XJ1
00000          DO 3010 ITBLE=2,NTBLE
00000          IF(TCHUTE(ITBLE)-T0)3010,3011,3011
00000    3010  CONTINUE
00000    3011  TFRAC=(T0-TCHUTE(ITBLE-1))/(TCHUTE(ITBLE)-TCHUTE(ITBLE-1))
00000          DR=DRI(ITBLE-1)+(DRI(ITBLE)-DRI(ITBLE-1))*TFRAC
00000          DRD0=DR/DIAMO
00000          XL=XLI(ITBLE-1)+(XLI(ITBLE)-XLI(ITBLE-1))*TFRAC
00000          XLD=XLDI(ITBLE-1)+(XLDI(ITBLE)-XLDI(ITBLE-1))*TFRAC
00000          XLDD=XLDDI(ITBLE-1)+(XLDDI(ITBLE)-XLDDI(ITBLE-1))*TFRAC
00000    C
00000          GO TO (1,2) NZ
00000    1     XLX2= -SQRTF(XL*XL-XLY0*XLY0-XLZ0*XLZ0)
00000          IF(XLX2+1.)11,12,12
00000    11    XLX0= XLX2
00000          XLXD0= (XL*XLD-XLY0*XLYD0-XLZ0*XLZD0)/XLX0
00000          GO TO 3
00000    12    NZ= 2
00000          XLXD0= VELOCF(XLXD1,B(4))
00000          XLX0= DISPLF(XLX1,XLXD1,XLXD0)
00000    2     XLZ0=  SQRTF(XL*XL-XLX0*XLX0-XLY0*XLY0)
00000          XLZD0= (XL*XLD-XLY0*XLYD0-XLX0*XLXD0)/XLZ0
00000    3     P37= RXD0+XLXD0-P13*PSD0+P4*C24*PHD0-P11*THD0
00000    C
00000          P38=RYD0+XLYD0+P14*PSD0-P4*C25*PHD0-P12*THD0
00000          P39=RZD0+XLZD0-P5*PHD0+P2*C22*THD0
00000          DO 4010 IDRD0=2,NDRD0
00000          IF(DRD0I(IDRD0)-DRD0)4010,4011,4011
00000    4010  CONTINUE
00000    4011  CDRAT=CDRATI(IDRD0-1)+(CDRATI(IDRD0)-CDRATI(IDRD0-1))*(DRD0-DRD0I(
00000         1IDRD0-1))/(DRD0I(IDRD0)-DRD0I(IDRD0-1))
00000          XKF=CKF*CDRAT
00000          P40=XKF/XLM*SQRTF(P37*P37+P38*P38+P39*P39)
00000          A(1,1)=-P4
00000          A(1,3)=P14
00000          A(1,4)=-P4
00000          A(1,6)=P14
00000          A(1,7)=P4*P1
00000          A(1,8)=-C31*P5-C24*(XJYY+P18)
00000          A(1,9)=C25*(P20+C22*XJYY)-C24*P2*X8
00000          TA(1)=-P14*32.16+P40*(P4*P37-P14*P39)-P4*P14*C43+C31*P4*C44-(P12*X
00000         1B+C28*C22*C49)*C45+C25*P21*C46+(C40*XJ1+C33*P12)*C47+C52*P12-C27*X
00000         2J3*C48
```

```
00000          A(2,2)=P4
00000          A(2,3)=-P13
00000          A(2,5)=P4
00000          A(2,6)=-P13
00000          A(2,7)=P4*P14
00000          A(2,8)=P2*C32-C25*(P18+XJXX)
00000          A(2,9)=-C31*XB-P20*C24-C40*XJXX
00000          YA(2)=P13*32.16+P40*(P13*P39-P4*P38)+P4*P13*C43-C29*P4*C44-(P11*XB
00000         1+C27*C22*C50)*C45-C24*P21*C46+(C33*P11*C41*XJ1)*C47+C52*P11-C28*XJ
00000         22*C48
00000          A(3,1)=P13
00000          A(3,2)=-P14
00000          A(3,4)=P13
00000          A(3,5)=-P14
00000          A(3,7)=-C42-P5*P5-XJZZ
00000          A(3,8)=P2*P4
00000          A(3,9)=P1*P5+C23*(XJZZ+C42)
00000          YA(3)=P40*(P14*P38-P13*P37)+(P2*P5-C24*C25*C51)*C44+C22*(P2*XB+C40
00000         1*C25*C51)*C45+C53*P5-C54*P2*P4*C22+C22*C48*(COSF(2.*P80)*C51-XJZZ-
00000         22.*C42)
00000          A(4,7)=-P13
00000          A(4,8)=P4*C24
00000          A(4,9)=-P11
00000          A(5,7)=P14
00000          A(5,8)=-P4*C25
00000          A(5,9)=-P12
00000          A(6,8)=-P5
00000          A(6,9)=P2*C22
00000          A( 7,4)=XLX0
00000          A( 7,5)=XLY0
00000          A( 7,6)=XLZ0
00000          YA( 7)=XL*XLD0- XLXD0*XLXD0-XLYD0*XLYD0-XLZD0*XLZD0+XLD*XLD
00000          A( 8,2)=XSM*XLZ0
00000          A( 8,3)=-XSM*XLY0
00000          A( 9,1)=A( 8,2)
00000          A( 9,3)=-XSM*XLX0
00000      470 P9=C24*C20-C27*C19
00000          P10=C25*C20+C28*C19
00000          P17=C22*C19
00000          P36=RXD0*RXD0+RYD0*RYD0+RZD0*RZD0
00000          C56=SQRTF(P36)
00000          C57=(P10*RXD0+P9*RYD0+P17*RZD0)/C56
00000          C58=SQRTF(1.-C57*C57)
00000          ALPHA=ACOSF(C57/SQRTF(C57*C57+C58*C58))
00000          IF(C58)9000,9001,9001
00000     9000 ALPHA=-ALPHA
00000     9001 XKL=XKLA*ALPHA
00000          XKD=XKD0+XKDA*ALPHA*ALPHA
00000          YA(4)=-(XKD*P10+XKL*P8)*P36/XLM-P37*P40+P14*C43+C32*C44+P16*C45-C5
00000         13*C25-P12*C54-C52*C40
00000          YA(5)=-(XKD*P9+XKL*P7)*P36/XLM-P38*P40+P13*C43-C30*C44+P15*C45-C24
00000         1*C53+P11*C54+C52*C41
00000          YA(6)=-(XKD*C19-XKL*C20)*P36*C22/XLM-C39-P39*P40 P4*C44+C22*P1*C45
00000         1*C52*C23
00000          YA(8)=P36*(XLY0*C22*(XKD*C19-XKL*C20)-XLZ0*(XKD*P9+XKL*P7))+C12*XL
```

```
00000        1Y0
00000         YA(9)=P36*(XLX0*C22*(XKD*C19-XKL*C20)-XLZ0*(XKD*P10+XKL*P8))+C12*X
00000        1LX0
00000    500 CALL SIMEQ(A,YA,8,K)
00000         ISTEP=-ISTEP
00000         IF(ISTEP)310,900,350
00000    310 IP=IP+1
00000         IF(IP-IPI)210,220,220
00000    210 GO TO 216
00000    220 X=RX0+VX*TT
00000         Y=RY0+VY*TT
00000         Z=RZ0+VZ*TT
00000         XP=X+XLX0+P14
00000         YP=Y+XLY0+P13
00000         ZP=Z+XLZ0+P4
00000         XD=RXD0+VX
00000         YD=RYD0+VY
00000         ZD=RZD0+VZ
00000         TC=SQRTF(XSM*XSM*(B(1)*B(1)+B(2)*B(2)+(B(3)-32.16)*(B(3)-32.16))+(
00000        1XKL*XKL+XKD*XKD)*P36*P36+2.*XSM*P36*(B(1)*(XKL*P8-XKD*P10)+B(2)*(X
00000        2KL*P7-XKD*P9)-(B(3)-32.16)*(XKL*P6+XKD*P17)))
00000         PRINT 20,T0,X,Y,Z,XD,YD,ZD,XP,YP,ZP,PS0,PH0,TH0,(B(I),I=1,9)
00000         PRINT 21,TC
00000     20  FORMAT(///4F20.8/ (20X,3F20.8 ))
00000     21  FORMAT(20X,F20.8)
00000         IP=0
00000         IF(Z -ZDTEST)901,901,350
00000    901 PRINT 50,T0
00000         GO TO 900
00000    216 ZD=RZD0+VZ
00000         IF(Z -ZDTEST)217,217,350
00000    217 PRINT50,T0
00000     50  FORMAT(///F20.8,21H END OF DESCENT PHASE)
00000         GO TO 220
00000    350 RXD0=VELOCF(RXD1,B(1))
00000         RYD0=VELOCF(RYD1,B(2))
00000         XLYD0=VELOCF(XLYD1,B(5))
00000         PSD0=VELOCF(PSD1,B(7))
00000         RX0=DISPLF(RX1,RXD1,RXD0)
00000         RY0=DISPLF(RY1,RYD1,RYD0)
00000         XLY0=DISPLF(XLY1,XLYD1,XLYD0)
00000         PS0=DISPLF(PS1,PSD1,PSD0)
00000    360 PHD0=VELOCF(PHD1,B(8))
00000         PH0=DISPLF(PH1,PHD1,PHD0)
00000    370 THD0=VELOCF(THD1,B(9))
00000         TH0=DISPLF(TH1,THD1,THD0)
00000         RZD0=VELOCF(RZD1,B(3))
00000         RZ0=DISPLF(RZ1,RZD1,RZD0)
00000  C
00000         GO TO (13,14) NZ
00000    13   XLZD0= VELOCF(XLZD1,B(6))
00000         XLZ0= DISPLF(XLZ1,XLZD1,XLZD0)
00000         GO TO 380
00000    14   XLXD0= VELOCF(XLXD1,B(4))
00000         XLX0= DISPLF(XLX1,XLXD1,XLXD0)
```

```
C
  380 T0=T0+DELT2
      DET2=DELT0
      IF(ISTEP)300,900,200
  900 STOP
      END
```

```
00000  *
00000  C     GROUND SLIDE AIRDROP SYSTEM  IMPACT PHASE
00000        VELOCF(DA,DB)=DA+DB*DET2
00000        DISPLF(DA,DB,DC)=DA+(DB+DC)*DET2/2.
00000        COMMON      T0,DELT0,X0,XD0,TH0,THD0,XLX0,XLXD0,VX,VZ,ALT,XK1,XK3,
00000       1XA,XC,D,F,XLC,XIYY,XKF,XSM,XLM,CN,THMAX,DCHUTE,XMU,XL,F1,XIPI,ZD0
00000       2,XD0
00000        EQUIVALENCE (DATA(1),T0)
00000        DIMENSION A(8,8),YA(8),B(8)
00000        DIMENSION DATA(31)
00000        READ 10,DATA
00000     10 FORMAT(8F10.3)
00000        PRINT20,CN
00000     20 FORMAT(12H1CASE NUMBER,F7.4/7H IMPACT)
00000        PRINT 30,DATA
00000     30 FORMAT(//6H INPUT/(8F10.3/))
00000        IF(TH0)50,260,40
00000     40 DX=-XLC+D
00000        GO TO 44
00000     50 DX=XLC+D
00000     44 IK=1
00000     45 DELT2=DELT0/2.
00000        IPI=XIPI
00000        IP=IPI
00000        ISTEP=1
00000     55 ASSIGN 63 TO ICHECK
00000        ASSIGN 65 TO ISKIP
00000        ASSIGN 71 TO IGO
00000     60 C1= SINF(TH0)
00000        C2= COSF(TH0)
00000        P1= XA*C1+XC*C2
00000        P2= XA*C2-XC*C1
00000        P3= XK1*C1+XK3*C2
00000        P4= XK1*C2-XK3*C1
00000        P5= DX*C1+F*C2
00000        P6= DX*C2-F*C1
00000        GO TO ICHECK
00000     63 XLZ0= SQRTF(XL*XL-XLX0*XLX0)
00000        XLZD0= -XLX0*XLXD0/XLZ0
00000        Z0= ALT-P5
00000        ZD0= -P6*THD0
00000        GO TO ISKIP
00000     64 X0= XEA+P6EA-P6
00000        XD0= P5*THD0
00000     65 P7= XD0+XLXD0-P3*THD0-VX
00000        P8= ZD0+XLZD0+P2*THD0-VZ
00000        P9= XKF*SQRTF(P7*P7+P8*P8)/XLM
00000        P10= P7*P9-P2*THD0*TD0
00000        P11= P8*P9-P1*THD0*TD0+32.10
00000        DO 70 I=1,8
00000        YA(I)= 0.0
00000        DO 70 J=1,8
00000     70 A(I,J)= 0.0
00000        A(1,1)=XSM + XLM
```

```
00000          A(1,2)= XLM
00000          GO TO IGO
00000     71   A(1,5)=-XLM * P1
00000          A(1,6)= XMU
00000          YA(1)=  -F1-XLM*P10
00000          A(2,3)= XSM + XLM
00000          A(2,4)= XLM
00000          A(2,5)= XLM * P2
00000          A(2,6)= -1.0
00000          YA(2)=  -XSM*32.16-XLM*P11
00000          A(3,1)=P1
00000          A(3,2)= P1
00000          A(3,3)= -P2
00000          A(3,4)= -P2
00000          A(3,5)= -(XITY/XLM+P1*P1+P2*P2)
00000          A(3,6)= (P3+XMU*P5)/XLM
00000          YA(3)= P2*P11-P1*P10-F1*P3/XLM
00000          A(4,1)= XLZ0
00000          A(4,2)= XLZ0
00000          A(4,3)=-XLX0
00000          A(4,4)= -XLX0
00000          A(4,5)= -P1*XLZ0-P2*XLX0
00000          YA(4)= P11*XLX0-  P9*XLZ0
00000          A(5,2)= XLX0
00000          A(5,4)= XLZ0
00000          YA(5)= -(XLXD0*XLXD0+XLZD0*XLZD0)
00000          A(6,3)= 1.0
00000          A(6,5)= P6
00000          YA(6)= P5*THD0*THD0
00000          IF(ISTEP)320,900,310
00000    310   DELT2=DELT2
00000          X1=X0
00000          XD1=XD0
00000          XLX1=XLX0
00000          XLXD1=XLXD0
00000          TH1=TH0
00000          THD1=THD0
00000          K=6
00000          J=K+1
00000    320   CALL SIMEQ(A,YA,B,K)
00000          ISTEP=-ISTEP
00000          IF(ISTEP)80,900,170
00000     80   IP=IP+1
00000          IF(IP-IPI)120,100,100
00000    100   PRINT110,T0,X0,Z0,TH0,XD0,ZD0,THD0,XLX0,XLZ0,(B(I),I=1,6)
00000    110   FORMAT(///4F20.8/ (20X,3F20.8 ))
00000          IP=0
00000    120   IF(XD0-P5*THD0)220,230,130
00000    130   IF(THOMAX*THOMAX-TH0*TH0)180,180,140
00000    140   IF(IK-2)141,150,141
00000    141   IF((ALT-F)*(ALT-F)-Z0*Z0)240,240,150
00000    150   IF((ALT-Z0-XLZ0-P1)*(ALT-Z0-XLZ0-P1)-DCHUTE*DCHUTE/9.)200,200,170
00000    170   THD0=VELOCF(THD1,B(5))
00000          TH0=DISPLF(TH1,THD1,THD0)
00000   9170   XD0=VELOCF(XD1,B(1))
```

```
00000          XLXD0=VELOCF(XLXD1,B(2))
00000          X0=DISPLF(X1,XD1,XD0)
00000          XLX0=DISPLF(XLX1,XLXD1,XLXD0)
00000          T0=T0+DELT2
00000          DET2=DELT0
00000          IK=0
00000          GO TO 55
00000     180  PRINT190,T0
00000     190  FORMAT(/F20.8,26H CARGO LIKELY TO TURN OVER)
00000     900  STOP
00000     260  PRINT210,T0
00000     210  FORMAT(/F20.8,48H CHUTE IN CONTACT WITH GROUND,IMPACT EDGE MOVING)
00000          GO TO 260
00000     220  PRINT230,T0
00000     230  FORMAT(/F20.8,31H IMPACT EDGE HAS STOPPED MOVING)
00000          GO TO 290
00000     240  IF(DX)250,900,260
00000     250  TH0=0.
00000          IK=2
00000          DX=XLC+D
00000          THD0=-(.3*ZD0/DX)
00000          GO TO 9170
00000     260  PRINT270,T0
00000     270  FORMAT(/F20.8,23H STABLE SURFACE CONTACT)
00000          GO TO 300
00000     260  IP=IP1
00000          ISTEP=1
00000     330  DET2=DELT2
00000          X1=X0
00000          XD1=XD0
00000          XLX1=XLX0
00000          XLXD1=XLXD0
00000          TH1=TH0
00000          THD1=THD0
00000     335  ASSIGN 63 TO ICHECK
00000          ASSIGN 65 TO ISKIP
00000          ASSIGN 72 TO IQO
00000          GO TO 60
00000     72   A(1,5)= -P1 * XLM
00000          A(1,6)= XMU
00000          YA(1)= -F1-P10*XLM
00000          A(2,3)= XSM + XLM
00000          A(2,4)= XLM
00000          A(2,5)= P2 * XLM
00000          A(2,6)= -1.0
00000          A(2,7)= -1.0
00000          YA(2)= -32.16*XSM-P11*XLM
00000          A(3,1)= P1
00000          A(3,2)= P1
00000          A(3,3)= -P2
00000          A(3,4)= -P2
00000          A(3,5)= -(XIYY/XLM+P1*P1+P2*P2)
00000          A(3,6)= (P6+P5*XMU)/XLM
00000          A(3,7)= P2/XLM
00000          YA(3)= P2*P11-P1*P10-F1*P3/XLM
```

```
00000          A(4,1)= XLZ0
00000          A(4,2)= XLZ0
00000          A(4,3)= -XLX0
00000          A(4,4)= - XLX0
00000          A(4,5)= -(P1*XLZ0+P2*XLX0)
00000          A(4,7)= XLX0/XLM
00000          YA(4)= P11*XLX0-P10*XLZ0
00000          A(5,2)= XLX0
00000          A(5,4)= XLZ0
00000          YA(5)= -(XLXD0*XLXD0+XLZD0*XLZD0)
00000          A(6,3)= 1.0
00000          A(6,5)= P6
00000          YA(6)= P5*THD0*THD0
00000          A(7,3)= 1.0
00000          A(7,4)= 1.0
00000          A(7,5)= P2
00000          YA(7)= P1*THD0*THD0
00000          K=7
00000          J=K+1
00000          CALL SIMEQ(A,YA,B,K)
00000          ISTEP=-ISTEP
00000          IF(ISTEP)360,900,435
00000      360 IP=IP+1
00000          IF(IP-IP1)390,370,370
00000      370 PRINT110,T0,X0,Z0,TH0,XD0,ZD0,THD0,XLX0,XLZ0,(B(I),I=1,7)
00000          IP=0
00000      390 IF(XD0-P5*THD0)420,400,410
00000      410 IF(IK-2)411,430,411
00000      411 IF((ALT-F)*(ALT-F)-Z0*Z0)420,420,430
00000      430 IF(THDMAX*THDMAX-THD*THD)180,180,435
00000      435 THD0=VELOCF(THD1,B(5))
00000          TH0=DISPLF(TH1,THD1,THD0)
00000     9435 XD0=VELOCF(XD1,B(1))
00000          XLXD0=VELOCF(XLXD1,B(2))
00000          X0=DISPLF(X1,XD1,XD0)
00000          XLX0=DISPLF(XLX1,XLXD1,XLXD0)
00000          T0=T0+DELT2
00000          DET2=DELT0
00000          IK=0
00000          IF(ISTEP)335,900,330
00000      420 IF(DX)560,900,570
00000      560 TH0=0.
00000          IK=2
00000          DX=XLC+D
00000          THD0=-(.3*200/DX)
00000          GO TO 9435
00000      290 XEA=X0
00000          P6EA=P6
00000      450 IP=IP1
00000          ISTEP=1
00000      460 DET2=DELT2
00000          XLX1=XLX0
00000          XLXD1=XLXD0
00000          TH1=TH0
00000          THD1=THD0
```

```
00000     465 ASSIGN 63 TO ICHECK
00000         ASSIGN 64 TO ISKIP
00000         ASSIGN 73 TO IGO
00000         GO TO 60
00000    73   A(1,5)= -P1 * XLM
00000         A(1,7)= 1.0
00000         YA(1)= -F1-P10*XLM
00000         A(2,3)= XSM * XLM
00000         A(2,4)= XLM
00000         A(2,5)= P2 * XLM
00000         A(2,6)= -1.0
00000         YA(2)= -XSM*32.16-P11*XLM
00000         A(3,1)= P1
00000         A(3,2)= P1
00000         A(3,3)= -P2
00000         A(3,4)= -P2
00000         A(3,5)= -(P1*P1+P2*P2+XIYY/XLM)
00000         A(3,6)= P6/XLM
00000         A(3,7)= P5/XLM
00000         YA(3)= P2*P11-P1*P10-F1*P3/XLM
00000         A(4,1)=XLZ0
00000         A(4,2)= XLZ0
00000         A(4,3)= -XLX0
00000         A(4,4)= -XLX0
00000         A(4,5)= -(P1*XLZ0+P2*XLX0)
00000         YA(4)= P11*XLX0-P10*XLZ0
00000         A(5,2)= XLX0
00000         A(5,4)= XLZ0
00000         YA(5)= -(XLXD0*XLXD0+XLZD0*XLZD0)
00000         A(6,3)= 1.0
00000         A(6,5)= P6
00000         YA(6)= P5*THD0*THD0
00000         A(7,1)= 1.0
00000         A(7,5)= -P5
00000         YA(7)= P6*THD0*THD0
00000         K=7
00000         J=K+1
00000         CALL SIMEQ(A,YA,B,K)
00000         ISTEP=-ISTEP
00000         IF(ISTEP)490,900,535
00000     490 IP=IP+1
00000         IF(IP-IPI)520,500,500
00000     500 PRINT110,T0,X0,Z0,THD,XD0,ZD0,THD0,XLX0,XLZ0,(B(I),I=1,7)
00000         IP=0
00000         IF(IK-2)520,530,520
00000     520 IF((ALT-F)*(ALT-F)-Z0*Z0)540,540,525
00000     525 I ((ALT-Z0-XLZ0-P1)*(ALT-Z0-XLZ0-P1)-DCHUTE*DCHUTE/9.)400,400,530
00000     530 IF(THDMAX*THDMAX-THD*THD)180,180,535
00000     535 THD0=VELOCF(THD1,B(5))
00000         THD=DISPLF(TH1,THD1,THD0)
00000    9535 XLXD0=VELOCF(XLXD1,B(2))
00000         XLX0=DISPLF(XLX1,XLXD1,XLXD0)
00000         T0=T0+DELT2
00000         DELT2=DELT0
00000         IK=0
```

```
00000          IF(ISTEP)465,900,460
00000      540 IF(DX)550,900,260
00000      550 XEA=X0+XLC*2.
00000          P6EA=DX*C2-F*C1
00000          THD=0.
00000          IK=2
00000          DX=XLC+D
00000          THD0= (.3*ZD0/DX)
00000          GO TO 0535
00000      400 PRI' 580,T0
00000      580 FORMAT1/F20.8,48H CHUTE IN CONTACT WITH GROUND,IMPACT PT. STOPPED)
00000          XEA=X0
00000          P6EA=P6
00000      590 IP=IPI
00000          ISTEP=1
00000      600 DET2=DELT2
00000          XLX1=XLX0
00000          XLXD1=XLXD0
00000          TH1=TH0
00000          THD1=THD0
00000      605 ASSIGN 63 TO ICHECK
00000          ASSIGN 61 TO ISKIP
00000          ASSIGN 74 TO IGG
00000          GO TO 60
00000    74    A(1,5)= -P1 * XLM
00000          A(1,7)= 1.0
00000          YA(1)= -F1-P10*XLM
00000          A(2,3)= XSM + XLM
00000          A(2,4)= XLM
00000          A(2,5)= P2 * XLM
00000          A(2,6)= -1.0
00000          A(2,8)= -1.0
00000          YA(2)= -32.16*XSM-P11*XLM
00000          A(3,1)= P1
00000          A(3,2)= P1
00000          A(3,3)= -P2
00000          A(3,4)= -P2
00000          A(3,5)= -(P2*P2+P1*P1+XIYY/XLM)
00000          A(3,6)= P6/XLM
00000          A(3,7)= P5/XLM
00000          A(3,8)= P2/XLM
00000          YA(3)= P2*P11-P1*P10-F1*P3/XLM
00000          A(4,1)= XLZ0
00000          A(4,2)= XLZ0
00000          A(4,3)= -XLX0
00000          A(4,4)= -XLX0
00000          A(4,5)= -(P1*XLZ0+P2*XLX0)
00000          A(4,6)= XLX0/XLM
00000          YA(4)= P11*XLX0-P10*XLZ0
00000          A(5,2)= XLX0
00000          A(5,4)= XLZ0
00000          YA(5)= -(XLXD0*XLXD0+XLZD0*XLZD0)
00000          A(6,3)= 1.0
00000          A(6,5)= P6
00000          YA(6)= P5*THD0*THD0
```

```
00000          A(7,3)= 1.0
00000          A(7,4)= 1.0
00000          A(7,5)= P2
00000          YA(7)= P1*THD0*THD0
00000          A(8,1)= 1.0
00000          A(8,5)= -P5
00000          YA(8)= P6*THD0*THD0
00000          K=8
00000          J=K+1
00000          CALL SIMEQ(A,YA,B,F)
00000          ISTEP=-ISTEP
00000          IF(ISTEP)630,900,700
00000      630 IP=IP+1
00000          IF(IP-IPI)660,640,640
00000      640 PRINT110,T0,X0,Z0,THD,XD0,ZD0,THD0,XLX0,XLZ0,(B(I),I=1,8)
00000          IP=0
00000      660 IF(THDMAX*THDMAX-THD*THD)180,180,670
00000      670 IF(IK-2)671,700,671
00000      671 IF((ALT-F)*(ALT-F)-Z0*Z0)680,680,780
00000      680 IF(DX)690,900,570
00000      690 THD=0.
00000          IK=2
00000          DX=XLC*D
00000          THD0=-(.3*ZD0/DX)
00000          IK=0
00000          GO TO 9700
00000      700 THD0=VELOCF(THD1,B(5))
00000          THD=DISPLF(TH1,THD1,THD0)
00000     9700 XLXD0=VELOCF(XLXD1,B(2))
00000          XLX0=DISPLF(XLX1,XLXD1,XLXD0)
00000          T0=T0+DELT2
00000          DET2=DELT0
00000          IF(ISTEP)605,900,600
00000      300 IP=IPI
00000          ISTEP=1
00000      710 DET2=DELT2
00000          X1=X0
00000          XLX1=XLX0
00000          XD1=XD0
00000          XLXD1=XLXD0
00000      715 P12=XD0+XLXD0-VX
00000          P13=XLZD0-VZ
00000          P14= XKF*SQRTF(P12*P12+P13*P13)/XLM
00000          XLZ0= SQRTF(XL*XL-XLX0*XLX0)
00000          XLZD0=-XLX0*XLXD0/XLZ0
00000          DO 720 I=1,8
00000          YA(I)= 0.0
00000          DO 720 J=1,8
00000      720 A(I,J)= 0.0
00000          A(1,1)= XSA + XLM
00000          A(1,2)= XLM
00000          A(1,4)= XMU
00000          YA(1)= -F1-P12*P14*XLM
00000          A(2,3)= XLM
00000          A(2,4)= -1.0
```

```
00000          YA(2)= -(XSM+XLM)*32.16-P13*P14*XLM
00000          A(3,1)= XC
00000          A(3,2)= XC
00000          A(3,3)= -XA
00000          A(3,4)= XMU*F/XLM
00000          A(3,5)= 1.0/XLM
00000          YA(3)= XA*(32.16+P13*P14)-XC*P12*P14-F*XK3/XLM
00000          A(4,1)= XLZ0
00000          A(4,2)= XLZ0
00000          A(4,3)= -XLX0
00000          YA(4)= XLX0*(32.16+P13*P14)-XLZ0*P12*P14
00000          A(5,2)= XLX0
00000          A(5,3)= XLZ0
00000          YA(5)= -(XLXD0*XLXD0+XLZD0*XLZD0)
00000          K=5
00000          J=K+1
00000          CALL SIMEQ(A,YA,B,K)
00000          ISTEP=-ISTEP
00000          IF(ISTEP)740,900,810
00000      740 IP=IP+1
00000          IF(IP-IPI)770,750,750
00000      750 PRINT110,T0,X0,XLX0,XLZ0,XD0,(B(I),I=1,5)
00000          IP=0
00000      770 IF((ALT-Z0-XLZ0-P1)*(ALT-Z0-XLZ0-P1)-DCHUTE*DCHUTE/9.)570,570,780
00000      780 IF(XD0)790,790,810
00000      790 PRINT800,T0
00000      800 FORMAT(/F20.8,36H IMPACT PHASE SUCCESSFULLY COMPLETED)
00000          STOP
00000      810 XD0=VELOCF(XD1,B(2))
00000          XLXD0=VELOCF(XLXD1,B(2))
00000          X0=DISPLF(X1,XD1,XD0)
00000          XLX0=DISPLF(XLX1,XLXD1,XLXD0)
00000          T0=T0+DELT2
00000          DET2=DELT9
00000          IF(ISTEP)715,900,710
00000      570 PRINT820,T0
00000      820 FORMAT(/F20.8,40H CHUTE IN CONTACT,STABLE SURFACE CONTACT)
00000      830 IP=IPI
00000          ISTEP=1
00000      840 DET2=DELT2
00000          X1=X0
00000          XD1=XD0
00000      845 P12=XD0-VX
00000          P13=-VZ
00000          P14= XKF*SQRTF(P12*P12+P13*P13)/XLM
00000          DO 846 I=1,8
00000          YA(I)= 0.0
00000          DO 846 J=1,8
00000      846 A(I,J)= 0.0
00000          A(1,1)= XSM + XLM
00000          A(1,2)= XMU
00000          A(1,4)= -1.0
00000          YA(1)= -F1-P12*P14*XLM
00000          A(2,2)= -1.0
00000          A(2,4)= -1.0
```

```
00000          YA(2)= -(XSM+XLM)*32.16-P13*P14*XLM
00000          A(3,1)= XC*XLM
00000          A(3,2)= XMU*F
00000          A(3,3)= 1.0
00000          A(3,4)= XA
00000          YA(3)= XLM*XA*(32.16+P13*P14)-XLM*XC*P12*P14-F*XK3
00000          A(4,1)= XLZ0
00000          A(4,4)= XLX0/XLM
00000          YA(4)= XLX0*(32.16+P13*P14)-XLZ0*P12*P14
00000          K=4
00000          J=K+1
00000          CALL SIMEQ(A,YA,B,X)
00000          ISTEP=-ISTEP
00000          IF(ISTEP)850,900,890
00000     850  IP=IP+1
00000          IF(IP-IPI)880,860,860
00000     860  PRINT110,T0,X0,XD0,(B(I),I=1,4)
00000          IP=0
00000     880  IF(XD0)790,790,890
00000     890  XD0=VELOCF(XD1,B(1))
00000          X0=DISPLF(X1,XD1,XD0)
00000          T0=T0+DELT2
00000          DET2=DELT0
00000          IF(ISTEP)845,980,840
00000          END
```

Table I is a listing of the appropriate input values for the drop phase computer program. Table II is a listing of the input values for the impact phase computer program, some of which are obtained from the results of the drop phase computer run.

AIRCRAFT ARMAMENTS, Inc.

DROP PHASE IMPUTS

| CASE No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $\chi_0$ | 0 | | | | | | | | | | | | | | |
| $\psi_0$ | 0 | | -7. | -12. | -7. | | | | -7. | | -7. | -7. | -7. | | |
| $\psi_0$ | 0 | | | | | | | | | | | | | | |
| $\pi_{x0}$ | 0 | | | | | | | | | | | | | | |
| $\pi_{y0}$ | 0 | | | | | | | | | | | | | | |
| $\dot{x}_{a0}$ | 151.6 | | 142. | 145.05 | 134.6 | 151.7 | 150.4 | 142.8 | 152. | 143.5 | 134.8 | 151.7 | 151.7 | 168.5 | 152 |
| $\dot{y}_{a0}$ | -11.8 | | 1.64 | -8.25 | 10.17 | 8.45 | 23.4 | 14.0 | | -3.295 | 8.05 | 8.31 | -10.4 | -11.43 | |
| $\dot{L}_x$ | 0 | | | | | | | | | | | | | | |
| $\dot{L}_y$ | 0 | | | | | | | | | | | | | | |
| $L_{z0}$ | 0 | | | | | | | | | | | | | | |
| $L_{xc}$ | 6.45 | | -.953 | 4.78 | 5.85 | -4.31 | -12.78 | -8.1 | | 1.80 | -4.95 | -4.54 | 5.675 | 5.62 | |
| $\theta_a$ | 2. | | -1. | 1. | | 2. | 2. | 2. | 3. | 3. | 4. | 1. | 3. | 1. | 2. |
| $\phi_a$ | 0 | | | | | | | | | | | | | | |
| $\psi_a$ | 0 | | -7. | -12 | -7. | | | | -7. | | -7. | -7 | -7. | | |
| $\pi_{axc}$ | 0 | | | | | | | | | | | | | | |
| $\pi_{a\phi_a}$ | 0 | | | | | | | | | | | | | | |
| $\pi_{az_0}$ | 0 | | | | | | | | | | | | | | |
| $\Delta t$ | .01 | | .01 | .01 | .01 | .01 | .01 | .01 | .01 | .01 | .01 | .01 | .01 | .01 | .01 |
| No. CYCLES PRINT OUT | 10. | | 10 | 10. | 10. | 10 | 10. | 10. | 10. | 10. | 10. | 10 | 10 | 10. | 10. |
| $x$ | -5. | | -5. | -5. | -5. | -5. | -5. | -5. | -5. | -5. | -5. | -5. | -5.75 | -4.125 | -5. |
| $\dot{x}$ | 0 | | | | | | | | | .855 | -4.16 | | | | |
| $r$ | .117 | | .117 | .117 | | .08 | 5. | .167 | .666 | | | | -.167 | .833 | .5 |
| $d$ | 0 | | | | | | | .42 | .42 | | | | -.75 | .975 | |
| $\dot{r}$ | 0 | | | | | | | | | | | | | | |
| $f$ | -2.01 | | -2.01 | -2.01 | -1.85 | -2. | -1.92 | -1.92 | -1.92 | -1.92 | -2. | -1.91 | -1.92 | -1.92 | -1.92 |
| $N$ | -2. | | -2. | -2 | -2. | -2 | -2. | -2. | -2. | -2. | -2. | -2. | -2. | -2. | -2 |
| $m$ | 119 | | 119 | 117.5 | 57.5 | 93.1 | 117.5 | 117.5 | 117.5 | 117.5 | 117.5 | 117.5 | 117.5 | 117.5 | 117.5 |
| $N_i$ | 1.09 | | 1.09 | 1.09 | .684 | .682 | 1.09 | 1.09 | 1.09 | 1.09 | 1.09 | 1.09 | 1.09 | 1.09 | 1.09 |
| $I_{xx}$ | 344.4 | | 344.4 | 344.4 | 229.6 | 300.9 | 305.2 | 307.6 | 307.6 | 307.6 | 307.6 | 307.6 | 307.2 | 307.2 | 307.2 |
| $I_{yy}$ | 452.8 | | 452.8 | 452.8 | 434. | 461.4 | 383.5 | 386.5 | 386.5 | 386.5 | 386.5 | 386.5 | 428. | 444.3 | 383.5 |
| $I_{zz}$ | 643. | | 643. | 643. | 508.9 | 585.1 | 571.8 | 573.8 | 573.8 | 573.8 | 573.8 | 573.8 | 638.4 | 664.4 | 511.6 |
| $V_x$ | 0 | | -11.7 | 1.75 | -11.8 | .3 | 3.28 | -9. | -16.9 | -.7 | 12.9 | 1.2 | 13.3 | 7.15 | -.75 |
| $V_y$ | 11.8 | | -1.64 | 8.25 | 10.17 | -8.45 | -23.4 | -14.0 | | 3.29 | -8.05 | -8.31 | 10.4 | 11.4 | |
| $V_z$ | 0 | | | | | | | | | | | | | | |
| $V_{ax}$ | 151.6 | | 142 | 145.05 | 134.6 | 151.7 | 150.4 | 142.8 | 152 | 143.5 | 134.8 | 151.7 | 151.7 | 168.5 | 152. |
| $V_{ay}$ | -11.8 | | 1.64 | -8.26 | -10.17 | 8.45 | 23.4 | 14.0 | | -3.295 | 6.05 | 8.31 | -10.4 | -11.43 | |
| $V_{az}$ | 0 | | | | | | | | | | | | | | |
| $d_z$ | -22.6 | | -22.6 | -22.6 | -22.6 | -22.6 | -22.6 | -22.6 | -22.6 | -22.6 | -22.6 | -22.6 | -22.6 | -22.7 | -22.6 |
| $\Delta t_z$ | .001 | | .001 | .001 | .001 | .001 | .001 | .001 | .001 | .001 | .001 | .001 | .001 | .001 | .001 |
| $\Delta t_z$ | .01 | | .01 | .01 | .01 | .01 | .01 | .01 | .01 | .01 | .01 | .01 | .01 | .01 | .01 |
| $\dot{z}_0$ | 4.83 | | 4.83 | 4.83 | 4.83 | 4.83 | 4.83 | 4.83 | 4.83 | 4.83 | 4.83 | 4.83 | 4.83 | 4.83 | 4.83 |
| $K_{L\alpha}$ | .1175 | | .1175 | .1175 | .1175 | .1175 | .1175 | .1175 | .1175 | .1175 | .1175 | .1175 | .1175 | .1175 | .1175 |
| $K_{D_0}$ | .0121 | | .0121 | .0121 | .0121 | .0121 | .0121 | .0121 | .0121 | .0121 | .0121 | .0121 | .0121 | .0121 | .0121 |
| $K_{D_0\alpha}$ | .153 | | .153 | .153 | .153 | .153 | .140 | .140 | .140 | .140 | .140 | .140 | .140 | .140 | .140 |
| Z TEST | -50. | | -25. | -25. | -25. | -25. | -25. | -25 | -25. | -25. | -25. | -25. | -25. | -25. | -25. |
| II No. CYCLES | 10. | | 10. | 10 | 10. | 10 | 10. | 10 | 10 | 10 | 10 | 10. | 10. | 10 | 10 |
| III No. CYCLES | 5. | | 5. | 5 | 5. | 5. | 5. | 5 | 5. | 5. | 5 | 5. | 5 | 5. | 5. |
| $C_{DA_0}$ | 204. | | 204 | 204. | 92.8 | 92.8 | 204. | 204 | 204. | 204 | 204 | 204 | 204. | 204 | 204 |
| DIAM. | 15.4 | | 15.4 | 15.4 | 10.5 | 10.5 | 15.4 | 15.4 | 15.4 | 15.4 | 15.4 | 15.4 | 15.4 | 15.4 | 15.4 |
| $G_N$ | 1. | | 1. | 1 | 1. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| $G_F$ | 1. | | 1. | 1. | 1. | 1. | 1 | 1. | 1. | 1. | 1. | 1 | 1 | 1 | 1 |
| $\rho_0$ | .0024 | | .0024 | .0024 | .0024 | .0024 | .0024 | .0024 | .0024 | .0024 | .0024 | .0024 | .0024 | .0024 | .0024 |

TABLE I

IMPACT PHASE IMPUTS

| CASE No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $t_o$ | 0.0 | | [illegible] | ← | | | | | | | | | | → | 0.0 |
| $\Delta t$ | .005 | | .005 | ← | | | | | | | | | | → | .005 |
| $X_o$ | 294.3 | | 215.[illegible] | 241.341 | 185.54 | 295.998 | 245.764 | 213.88 | 190.277 | 208.524 | 243.597 | 227.637 | 251.57 | 238.712 | 223.242 |
| $\dot{X}_o$ | 79.481 | | 74.094 | 89.373 | 76.936 | 103.584 | 91.749 | 76.851 | 76.096 | 89.771 | 96.054 | 94.935 | 106.159 | 109.63 | 83.803 |
| $\theta_o$ | -.154 | | -.155 | -.123 | .096 | -.139 | -.103 | -.148 | .018 | -.145 | -.178 | -.142 | -.176 | .184 | -.089 |
| $\dot{\theta}_o$ | -.342 | | -.424 | -.24 | -.179 | -.572 | -.192 | -.1 | -.378 | -.438 | -.135 | -.233 | .216 | -1.123 | -.325 |
| $L_{x_o}$ | -82.981 | | -82.[illegible] | -82.[illegible] | -77.369 | -77.093 | -81.245 | -81.953 | -82.694 | -82.444 | -82.338 | -82.556 | -82.43 | -82.641 | -82.454 |
| $\dot{L}_{x_o}$ | 6.05 | | 2.263 | 1.9 | .36 | 1.9 | 2.39 | 1.18 | 1.25 | .8 | 1.8 | .95 | 1.49 | 2.75 | 2.09 |
| $V_x$ | 0.0 | | -11.7 | [illegible] | -11.3 | .3 | 3.28 | -9. | -16.9 | -.7 | 12.9 | 1.2 | 13.3 | 7.15 | -6.75 |
| $V_z$ | 0.0 | | -1.64 | [illegible] | ← | | | | | | | | | → | 0.0 |
| $A_{LT}$ | -41 | | -16.591 | -[illegible].178 | -7.6 | 17.744 | -19.172 | -18.499 | -14.06 | -12.31 | -17.301 | -13.02 | -14. | -12.35 | -17.72 |
| $K_{11}$ | 0.0 | | 0.0 | ← | | | | | | | | | | → | 0.0 |
| $K_{13}$ | 0.0 | | 0.0 | ← | | | | | | | | | | → | 0.0 |
| $a$ | -5. | | -5. | ← | | | | | | | → | -5. | -5.75 | -4.125 | -5. |
| $c$ | .117 | | .117 | .117 | 0.0 | .08 | .5 | .167 | .666 | 0.0 | ← → | 0.0 | -.167 | .835 | .5 |
| $d$ | 0.0 | | 0.0 | ← | | → | 0.0 | .42 | .42 | 0.0 | ← → | 0.0 | -.75 | .875 | 0.0 |
| $f$ | -2.01 | | -2.01 | -2.01 | -1.85 | -2. | -1.92 | ← | → | -1.92 | -2. | -1.91 | -1.92 | ← → | -1.92 |
| $l_c$ | 4.83 | | 4.83 | ← | | | | | | | | | | → | 4.83 |
| $I_{yy}$ | 452.8 | | 452.8 | 452.8 | 434. | 461.4 | 383.5 | 386.5 | ← | | → | 386.5 | 428. | 444.3 | 383.5 |
| $K_f$ | .123 | | .123 | .123 | .057 | .057 | .123 | ← | | | | | | → | .123 |
| $m$ | 119.5 | | 119.5 | 119.5 | 57.5 | 93.1 | 117.5 | 119.5 | 119.5 | 117.5 | | | | → | 117.5 |
| $M$ | 1.09 | | 1.09 | 1.09 | .684 | .684 | 1.09 | ← | | | | | | → | 1.09 |
| $CN$ | 1.0 | | 3.0 | 4.0 | 5.0 | 6.0 | 7.0 | 8.0 | 9.0 | 10.0 | 11.0 | 12.0 | 13.0 | 14.0 | 15.0 |
| $\theta_{max.}$ | .873 | | .873 | ← | | | | | | | | | | → | .873 |
| DIA. CHUTE | 15.4 | | 15.4 | 15.4 | 10.5 | 10.5 | 15.4 | ← | | | | | | → | 15.4 |
| $U$ | .9 | | 1.35 | ← | | | | | | → | 1.35 | .9 | 1.35 | ← → | 1.35 |
| $L$ | 86.5 | | 83. | 83. | 77.7 | 77.7 | 83. | ← | | | | | | → | 83. |
| $f_i$ | 0.0 | | 0.0 | ← | | | | | | | | | | → | 0.0 |
| No. CYCLES/PRINT OUT | 20 | | 20 | ← | | | | | | | | | | → | 20 |
| $\dot{Z}_o$ | -46.422 | | -28.896 | -28.63 | -17.034 | -28.499 | -30.063 | -29.652 | -24.724 | -21.851 | -27.657 | -24.169 | -26.565 | -22.271 | -28.815 |
| $\ddot{X}_o$ | -17.25 | | -16.814 | -17.38 | -19.192 | -14.828 | -18.61 | -17.123 | -20.285 | -18.809 | -15.693 | -19.545 | -19.34 | -25.768 | -19.045 |

TABLE II

AAINC 2138A

D. Lateral Restraint

It was originally thought that the pilot would fly the aircraft in a crabbed position during a crosswind situation. In this position he would have lined the aircraft up with its velocity vector in the wind fixed frame of reference. The extraction parachute in this case would be directly behind the aircraft, because the parachute always lines up with the aircraft velocity vector in the wind fixed frame of reference. Taking this into consideration, the computer program was written excluding a lateral movement restraint requirement in the extraction phase. Such a restraint, of course, is unnecessary when the extraction parachute is directly behind the load.

Due to the difficulty encountered in trying to maintain a stable attitude while flying the aircraft in a crosswind situation, the actual cases proved to be different. When only a few feet above the ground the pilot was concerned primarily with motion in the direction that would result in ground contact, i.e., pitch angle change and vertical motion; therefore, the aircraft was usually not lined up with the resultant velocity vector. The parachute in this case would not be directly behind the aircraft, but would be off to one side. How extreme the parachute is off to one side depends on the magnitude of the angular difference between the actual aircraft heading vector and the velocity vector of the aircraft in the wind fixed frame of reference. Lack of a lateral restraint in the extraction phase of the computer program will allow the load to exceed the lateral boundaries of the aircraft when acted upon by some side force. The side force in this case is the lateral component of the extraction force produced by the misaligned parachute. In actuality the load cannot exceed the aircraft lateral boundaries; thus an error could be produced in the

computer results without this restraint. To add this restraint requirement to the computer program would mean a major change to the program. It was found that the error this caused could be minimized by forcing certain inputs to be particular values in the tip-off phase. The two inputs that were changed were the yaw angle ($\psi$) and the lateral position vector ($r_y$). These two quantities were given values they would have at tip-off if the load were laterally restrained by the aircraft.

## IV. CONCLUSIONS AND RECOMMENDATIONS

Included in this section are the changes, deletions, and revisions to the Phase I report. Major changes, deletions, and revisions are not necessary due to the close agreement of the results from the computer analysis when compared to the actual occurrence. There are a few minor changes that will further refine the analysis if incorporated. The following changes and revisions should be incorporated in the Phase I Report.

The limits of the extraction point locations with respect to the cargo C.G. in both the vertical and lateral direction should be changed. These changes are as follows: Vertical distance from G.C. to be within + 10 inches and -5 inches. Lateral distance from C.G. to be within ± 5 inches. The lateral limitation was decreased because the cargo could become jammed in the cargo compartment and cause aircraft damage, when the lateral offset distance was too large.

The longitudinal limitation in the location of the C.G. from the center of a 9 foot platform can be changed from ± 6 inches to ± 10 inches. The maximum offset was not found during the testing program but the load did survive with a ± 10 inch offset.

The limitation of the 12 know crosswind is not a product caused by system operation as originally thought. Instead, this limit is influenced mainly by the ability of the pilot to manipulate the aircraft in excessive crosswind. Since the aircraft flies very close to the ground, it is effected by the ground turbulence. This turbulence causes the aircraft to move quite erratically and almost impossible to control. Aircraft dipping and lifting

10 feet is common with ground turbulence caused by a 12 knot wind. Thus, in most cases the pilot will fly the aircraft 20 feet or higher above the ground with a crosswind of 12 knots or more. This drop altitude will cause cargo damage for excessive impact forces.

Sufficient data was not acquired to state whether the limits on the impact angle are maximum. However in test no. 14 the load impacted at a 14° tail down angle with load survival.

As the load descends, it oscillates. For loads that are alike, the oscillations will be identical. Therefore, the impact angle is dependent on the altitude for any load. Further investigation is needed in this area to more closely identify specific load properties with oscillatory motion. This in turn will also increase load survivability.

At this time there have been no tests of multiple load delivery using the ground slide system. It is recommended that efforts be directed in this area to gain this much needed knowledge.

On all except one of these tests, the cargo was restrained to the platform by use of chains. These were used so that the load would not shift at all during the testing. Of course, in an actual air delivery situation regular restraint straps are used. The information acquired from the tests can be applied to an air delivery situation, in that the shifting limitations are described.

A special platform is needed that will resist overturn, withstand the forces excerted upon it at ground impact, and prohibit bending in the longitudinal direction. This platform will basically have a rounded front edge and heavy rails that run longitudinally. The platform used in the test phase had these physical qualities, but it was over designed. During the testing the only part of the platform that seemed to show any failure was the bottom surface. This failure only appears on the platforms that have wooden panels. The design of the new platform should have as its goals: low cost, light weight, bending resistance in rails, and overturn resistance.

Unclassified

Security Classification

## DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

| | |
|---|---|
| 1. ORIGINATING ACTIVITY (Corporate author)<br>AAI Corporation<br>Cockeysville, Maryland | 2a. REPORT SECURITY CLASSIFICATION<br>Unclassified<br>2b. GROUP |

3. REPORT TITLE

**Ground Slide Airdrop Study: Phase I (Addendum)**

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

**Exploratory test**

5. AUTHOR(S) (First name, middle initial, last name)

R.C. Wible
J.E. Foster

| | | |
|---|---|---|
| 6. REPORT DATE<br>August 1966 | 7a. TOTAL NO. OF PAGES<br>140 | 7b. NO. OF REFS |
| 8a. CONTRACT OR GRANT NO.<br>DA19-129-AMC-337(N)<br>b. PROJECT NO.<br>1F121401D195<br>c.<br>d. | 9a. ORIGINATOR'S REPORT NUMBER(S)<br>ER-3841<br>9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)<br>69-15-AD | |

10. DISTRIBUTION STATEMENT

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|---|---|
| 11. SUPPLEMENTARY NOTES<br>**Addendum to technical report, 69- AD, (ER-3841), January 1965, contract No. DA19-129-AMC-337(N), U. S. Army Natick Labs.** | 12. SPONSORING MILITARY ACTIVITY<br>US Army Natick Laboratories<br>Natick, Massachusetts 01760 |

13. ABSTRACT

This report is a continuation of the Phase 1 Report of the Ground Slide Airdrop Study conducted under Contract No. DA19-129-AMC-337(N). The object of the report is to present the findings of the Exploratory Test Phase, Phase II, and to compare the actual findings to those predicted by the Phase I study.

Results of limited flight tests conducted at Ft. Bragg, North Carolina are presented and compared to analytical results which were generated using test conditions as input values. In general, the test values and the computed values are in close agreement.

Also included are all changes, deletions and revisions to be incorporated in the preliminary design specifications of the Phase I report.

Unclassified

Unclassified

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| 14 KEY WORDS | LINK A ROLE | LINK A WT | LINK B ROLE | LINK B WT | LINK C ROLE | LINK C WT |
|---|---|---|---|---|---|---|
| Testing | 8 | | | | | |
| Systems | 9 | | | | | |
| Delivery | 9 | | | | | |
| Air-drop operations | 9 | | | | | |
| Ground slide | 10 | | | | | |