AD A020052

NPS-55Py75091

NAVAL POSTGRADUATE SCHOOL

Monterey, California

STUDIES OF MOBILITY, AGILITY
AND
SURVIVABILITY IN THE LAND COMBAT ENVIRONMENT

BY

Samuel H. Parry

September 1975

Approved for public release; distribution unlimited.

Prepared for:

U. S. Army Armor Center
Fort Knox, Kentucky 40121

DDC
RECEIVED
FEB 4 1976

NAVAL POSTGRADUATE SCHOOL
Monterey, California

Rear Admiral Isham W. Linder
Superintendent

Jack R. Borsting
Provost

The work reported herein was supported by the U.S. Army Armor Center, Fort Knox, Kentucky.

Reproduction of all or part of this report is authorized.

This report was prepared by:

Samuel H. Parry
Assistant Professor
of Administrative Sciences

Reviewed by:

David A. Schrady, Chairman
Department of Operations Research
and Administrative Sciences

Released by:

R. R. Fossum
Dean of Research

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: NPS-55Py75091

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle): Studies of Mobility, Agility and Survivability in the Land Combat Environment.

5. TYPE OF REPORT & PERIOD COVERED: Final Report, Jul[redacted]—Sep[redacted]75

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s): Samuel H. Parry

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS: Naval Postgraduate School, Monterey, California 99340 Code 55Py

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: [redacted]

11. CONTROLLING OFFICE NAME AND ADDRESS: U.S. Army Armor Center, U.S. Army and Engineer Board, Fort Knox, KY 40121

12. REPORT DATE: Sep[redacted]75

13. NUMBER OF PAGES: 148

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

15. SECURITY CLASS. (of this report)

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

COPY AVAILABLE TO DDC DOES NOT PERMIT FULLY LEGIBLE PRODUCTION

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Tank Mobility	Experimental Design
Tank Ability	Armor Tactics
Tank Survivability	Land Combat Studies

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes the results of research and analysis conducted in two major areas:

(1) The Swedish S-Tank Agility/Survivability (STAGS) test, and
(2) Analysis of apparent acceleration and velocity of a moving target relative to a stationary firer.

Reports on the results of four separate studies conducted for the STAGS Test are given. These reports include the proposed Analytical Plan for analysis

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE S/N 0102-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

251 450

Next page

of the experimental results, Analysis of Variance program and procedures, Mean Value Differential Analysis program and procedures, and String Statistics program and procedures.

The second phase of the report is concerned with the quantification of the effects of mobility and agility on tank survivability. In particular procedures were developed to compute the apparent acceleration and velocity of a target moving at various speeds and accelerations and employing a variety of movement tactics. Complete documentation, including the programs, procedures, and results, are included in this phase of the report.

Finally, data requirements from the STAGS Test to be used in conjunction with the apparent acceleration and velocity analysis are specified.

1. INTRODUCTION

This report describes the results of research and analysis conducted for the U.S. Army Armor and Engineer Board at Fort Knox, Kentucky during July, August, 1975. The research was concentrated in two major areas as follows:

1. The Swedish S-Tank Agility/Survivability Test (STAGS) to be conducted at Fort Knox during the last three months of 1975.

2. Analysis of apparent acceleration and velocity of a moving target relative to a stationary firer.

The total analytical plan for the STAGS test is currently being finalized by Fort Knox. Inputs for this plan were provided by the Training and Doctrine Systems Analysis Activity (TRASANA) and the Armor and Engineer Board, and the writer. The writer was responsible for the Analysis of Variance design and procedures to be used to test statistical hypothesis of the mean values of various factors. This technique is particularly applicable for analyzing the depend variables of lay time, load time, time to fire first and subsequent rounds, acquisition time, and number of rounds fired. The ANOVA will also be used to analyze the horizontal and vertical miss distance dependent variables. TRASANA has responsibility for analyzing the variances of the dependent variables, a particularly important aspect in the study of miss distances. The specific split-plot designs and ANOVA procedures to be used to analyze the field test data are given in Chapter 2.

Specific programs developed to support the STAGS analysis are given in Chapters 3, 4, and 5. In order to test the models developed, a data set was prepared in the same form as the field data will be collected. The actual numbers in the sample data set were made up by two Army officers. Therefore, the sample outputs given in Chapters 3, 4, and 5 are not intended to provide conclusions but to demonstrate the models' capabilities. The analysis of the actual field data will be made by the writer in early 1976 and will be reported in a subsequent Technical Report.

Each of the Chapters 3, 4, and 5 includes a description of the program, a program listing, and a sample output for X and Y miss distances using the sample data set.

The analysis of Variance will utilize the ANOVA package from the Statistical Package for the Social Sciences (SPSS) as discussed in Chapter 3. The Mean Value Differential Analysis (MVDA) program computes the Grand Mean, submeans, and submean differentials for up to a five factor experiment. This program will be used as a supplement to the ANOVA to provide additional insights into the magnitude of mean differences between the various factors in the experiment. The MVDA program is described in Chapter 4.

The String Statistics Program (Chapter 5) was designed to provide initial statistics for experimental data to indicate the basic nature of the data. This program will be expanded in a future contract period to provide

trend analysis and probability plots.

One of the most important questions facing the armor community today is "What is the effect of mobility and agility on tank survivability on the battlefield?" In order to provide a quantification of important facets of this problem, a program was developed to compute the apparent acceleration and velocity of a target moving at various speeds and accelerations and employing a variety of movement tactics. The initial effort (Chapter 6) describes results of targets moving with a flank aspect to the firer vehicle. From this report near far range bands in which apparent acceleration and velocity contribute to the tracking problem are identified. The current status of the research is described in Chapter 7. The program has been expanded to allow target movement in any direction, including sinusoidal and three-dimensional representations. The next phase of research in this area involves the analysis of actual tracking data in conjunction with the target's apparent acceleration and velocity. Data to be collected from the STAGS Test to support this effort is described in Chapter 8.

Based on the efforts conducted to date as documented in this report, additional research proposals are currently being considered by the U.S. Army Armor and Engineer Board. It is anticipated that the results presented herein will serve as the basis for continuing research and analysis of these areas.

2. PROPOSED ANALYTICAL PLAN - ANALYSIS OF VARIANCE

STAGS SURVIVABILITY TEST

The STAGS Test consists of several parts, including vehicle characteristics test, speed and precision of lay, hitting performance, simulated mission firing, human factors evaluation, reliability, maintainability, safety, mobility course evaluation, survivability experiments, and silhouette exposures in stationary positions.

The analysis presented herein will consider only the survivability experiment portion of the STAGS Test.

The survivability experiment will be conducted in two phases as follows:

PHASE I: Yano Range Phase

PART A: Constant Speed Test
PART B: Stop-Start Test
PART C: Evasive Tactics Test

PHASE II: St. Vith Phase

PART A: Intermittent intervisibility discontinuity segments (Routes 1 & 3).

PART B: Three-Tactics Test to measure effects of a moving, partially concealed silhouette on gunner hitting performance (Route 2).

PART C: Concealment Test to measure the effects of selected intervisibility segment length size on gunner hitting performance (Route 4).

PART D: Effects of rapid advance tactics and maximum terrain use tactics on intervisibility segment lengths.

NOTE: Analysis of Variance techniques will be utilized only for the Yano Range Phase of the subtest. Other appropriate techniques such as regression and correlation analyses will be conducted by TRASANA for the St. Vith Phase.

EXPERIMENTAL DESIGN MODEL SELECTION

The purpose of Analysis of Variance (ANOVA) is to test statistical hypotheses of the mean values of various factors (independent variables) as they affect observed values of a specified dependent variable. One of the basic assumptions underlying the linear model is that the variance due to experimental error within each of the treatment populations be homogeneous. Moderate departures from this assumption do not, however, seriously affect the sampling distribution of the resulting F statistic used to test for significant differences between the means of the various treatment levels.

Prior to conducting the ANOVA, appropriate tests (e.g., Hartley, Cochran, or Bartlett test) for homogeneity of variance will be made. If the hypothesis of homogeneity of variance is rejected, appropriate modifications to the F distribution utilized for the test will be made (see Winer, page 206).[1]

Each part of the survivability experiment utilizes five different crews for each of four firer vehicles. Other factors such as target speed, course, tactics, etc., (different for each part) are specified by the experimenter and thus are truly treatment factors.

Several possible designs were considered: full factorial, nested factorial, block design, and split-plot design. The full factorial and block designs were rejected because the crews are "nested" within firer vehicles, since the effects due to crews are restricted to a single level of the firer vehicle factor.

A split-plot design has much in common with a nested (or partially hierarchial) design. The term split-plot comes from agricultural experimentation in which a single level of one treatment is applied to a relatively large plot of ground (the whole plot) but all levels of a second treatment are applied to subplots within the whole plot. The analogy of the survivability experiment with the split-plot concept is illustrated utilizing Phase I - Part A factors.

[1]Winer, B. J., Statistical Principles in Experimental Design, McGraw Hill, 1971.

Each of the twenty crews (selected from the total population of tank crews) are analogous to the whole plots. The four levels of factor F (firer vehicle) are applied to the whole plots (i.e., five crews (whole plots) are assigned to each firer vehicle). The subplots consist of the twelve treatment levels derived from the three courses and four speeds per course. Note that each of the twelve subplots (speed-course treatment levels) are run in <u>every</u> whole plot (20 crews), a requirement for the split-plot design.

The following assumptions are made regarding the split-plot designs used for all of the survivability experiments in Phase I.

1. The firer vehicle factor and all subplot treatment factors are fixed effect factors.

2. The plots (crews) are a random sample from a <u>specified</u> population of plots (crews). Thus, the crew factor is treated as a random effect factor.

<u>NOTE</u>: The implication of considering crews as a random effect factor is that conclusions drawn from the experiment will be relevant to the domain of all crews and not just to the particular ones selected for the experiment. In contrast the implication of considering firer vehicle, course, speed, etc., as fixed effect factors imply that conclusions from the experimental analysis will be relevant to the specific treatment levels of these factors.

A usual requirement in a split-plot design is that the assignment of treatment levels (speed-course) be randomly assigned to the subplots. Since data will be collected simultaneously on the four firer vehicles for each crew, complete randomization within each plot is not possible. The writer's opinion is that this fact will have no real impact on the analysis for the following reasons:

1. The primary reason for randomizing the order in which treatment levels are applied is to eliminate a systematic uncontrolled variation which is especially important if the same subjects can identify patterns in the ordering. This problem is not present in the survivability test since only one replication per crew is conducted and the crews do not know the next treatment level to be presented.

2. Randomization is particularly important in physical science or agriculture experiments where material deterioration, physical attributes, etc., are important considerations. Also, randomization is important when highly accurate measures of the dependent variable are being made (such as in a chemical experiment). These problems are minimal in the survivability experiments.

3. It should be noted that the ordering of the subplot treatment levels will be randomized, but that the same order will be applied to each plot (crew).

4. The survivability experiment represents a situation where the physical considerations of experiment conduct must override. It is important to realize the assumptions made in the design concerning randomization, but the writer feels that very little will be lost in the analysis due to this factor.

The general form of the Analysis of Variance (ANOVA) is given below:

DEFINITIONS

F_i, $i = 1, \ldots, 4$ - Firer vehicles

$C_{m(i)}$, $m = 1, \ldots, 5$ - Crews within firer vehicle, i.

T_j, $j = 1, \ldots, n$ - Treatment levels for the subplots (different for each part of the test).

NOTE: For Phase I, Part A, these are 12 treatment levels made up of 3 courses (flank, oblique, and head-in) each run at 4 speeds (10, 20, 30, 40 MPH).

SOURCE OF VARIATION	DEGREES OF FREEDOM	EXPECTED MEAN SQUARE
BETWEEN PLOTS	19	
F	3	$\sigma^2_\varepsilon + n\,\sigma^2_C + 5n\,\sigma^2_F$
C (within F)	16	$\sigma^2_\varepsilon + n\,\sigma^2_C$

WITHIN PLOTS	20(n-1)	
T	(n-1)	$\sigma_\varepsilon^2 + 20\sigma_T^2 + \sigma_{TC}^2$
F X T	3 n	$\sigma_\varepsilon^2 + 5\sigma_{FT}^2 + \sigma_{TC}^2$
T X C	16(n-1)	$\sigma_\varepsilon^2 + \sigma_{TC}^2$

In the ANOVA presented above, the T X C interaction represents the cross between a fixed and random factor. Because the subplots are not replicated, no degrees of freedom remain for σ_ε^2, the error term.

There has been much discussion concerning the assumptions under which a "mixed" intersection of factors (fixed x random) can be considered as part of the error term (which is assumed to be normally distributed with zero mean and variance σ_ε^2 due to uncontrollable experimental error).

The assumption is made in this design (supported by discussions in Winer) that the T X C source of variation be incorporated as part of σ_ε^2. This assumption will be employed in all designs for the appropriate parts of the survivability test.

It is important to note that the variance due to crew within firer is measured, but that crew interaction with the subplot treatments is considered as part of the experimental error (σ_ε^2).

FACTORS AND PROPOSED DESIGN FOR ANOVA

The following items are described for each part of Phase I of the STAGS Survivability Test in this section:

1. Dependent variables to be measured,
2. Factors (independent variables) in the design,
3. The proposed experimental design model, and

4. Layout of the ANOVA for each part, including the factors, degrees of freedom, expected mean square, and appropriate comments (Attachment 2).

NOTE: A table of definitions for all factors is given in Attachment 1.

PHASE I - PART A

1. Dependent variables to be measured:

   a. Time to lay on targets

   b. Time to fire first rounds

   c. Time between rounds fired

   d. Number of rounds fired

   e. Time to acquire target (gunner's acquisition)

   f. Miss distance (horizontal and vertical) for each round

NOTE: Each dependent variable will essentially constitute a separate ANOVA, but the same design will be used for each. Only one target vehicle is used in I. A.

2. Factors (independent variables) in the design:

   a. Firer (defender) vehicles (F_i, $i = 1, \ldots, 4$)

   b. Crews on firer vehicle (C_j, $j = 1, 5$)[1]

---

[1] The sixth crew run described in STAGS is actually a rerun of an original crew to measure training effect and will be considered in a separate design if, in fact, a sixth crew run is made.

c. Course of target vehicle (D_k, $k = 1,\ldots,3$)

d. Speed of target vehicle (S_ℓ, $\ell = 1,\ldots,4$)

NOTE: There will be 240 data points measured for each dependent variable.

3. Experimental Design

The design for I. A. is a split-plot design as are all designs for Phase I of the survivability experiment. The subplot treatment levels for I. A. (course and speed) will consider the speed factor nested in the course factor. The concept of nesting speed within course considers speed as a function of course, while providing the capability of measuring the course main effect.

$$X_{ijk\ell} = M + F_i + C_{j(i)} + D_k + S_{\ell(k)}$$

$$+ FD_{ik} + FS_{i\ell(k)} + \varepsilon_{(ijk\ell)}$$

NOTE: $\varepsilon_{(ijk\ell)}$, the error term, is actually composed of the interactions of $C_{j(i)}$ with D_k and $S_{\ell(k)}$ as described in a previous section.

PHASE I - PART B

Parts B and C of Phase I are identical except that different tactics are considered. This report presents the designs as two distinct experiments. It may be desirable, however, to consider them as one design with an increased number of treatment levels for Tactics.

1. Dependent variables to be measured (same list as for I. A.)

2. Factors in the design:

a. Firer vehicle (F_i, $i = 1,\ldots,4$)

b. Crews on firer vehicle (C_j, $j = 1,\ldots,5$)

c. Course (direction of travel) (D_k, $k = 1,\ldots,3$)

d. Target vehicles (V_ℓ, $\ell = 1,\ldots,6$)

e. Tactics per segment (T_m, $m = 1,2$)
(acceleration/deceleration time)

There will be 720 data points for each dependent variable.

3. <u>Experimental Design</u>

This design differs from I. A. in the following considerations:

a. Two tactics per segment are considered. These tactics are described by the length of time specified for acceleration/deceleration on each half of the segment, and each half will be treated as a separate trial for purposes of the ANOVA. The tactics are nested within course in the proposed design for the same reason that speed was nested within course in I. A.

b. Six target vehicles are played.

c. Target speed is replaced by the tactic factor described above.

The split-plot design proposed for I. B. is as follows;

$$X_{ijk\ell m} = M + F_i + C_{j(i)} + D_k + V_\ell$$

$$+ T_{m(k)} + FD_{ik} + FV_{i\ell} + FT_{im(k)} + DV_{k\ell}$$

$$+ FDV_{ik\ell} + VT_{\ell m(k)} + FDV_{ik\ell} + FVT_{i\ell m(k)}$$

$$+ \varepsilon_{(ijk\ell m)}$$

PHASE I - PART C

1. Dependent variables to be measured are same as list for I. B.

2. Factors in the design:

   a. Firer vehicle (F_i, $i = 1,\ldots,4$)

   b. Crews on firer vehicle (C_j, $j = 1,\ldots,5$)

   c. Course (D_k, $k = 1,\ldots,3$)

   d. Target vehicle (V_ℓ, $\ell = 1,\ldots,6$)

   e. Evasive tactics (E_m, $m = 1,\ldots,3$)

There will be 1080 data points measured for each dependent variable.

3. Experimental Design

The design for I. C. differs from that for I. B. in that the three levels of evasive tactics replace the two levels of acceleration/deceleration tactics, and tactics are not nested in course.

$$X_{ijk\ell m} = M + F_i + C_{j(i)} + D_k + V_\ell + E_m + FD_{ik} + FV_{i\ell}$$

$$+ FE_{im} + DV_{k\ell} + DE_{km} + VE_{\ell m} + DVE_{k\ell m} + FDV_{ik\ell}$$

$$+ FDE_{ikm} + FVE_{i\ell m} + FDVE_{ik\ell m}$$

$$+ \varepsilon_{(ijk\ell m)}$$

CONSIDERATIONS FOR ANALYSIS

Analyses of the designs are accomplished by running the ANOVA as a full factorial design in a standard computer program (such as SPSS) and manipulate the sum of squares. An example will illustrate the procedure.

Consider two factors, A at 4 levels and B at 5 levels (2 replications). A full factorial design would produce the following:

I. $X_{ijk} = M + A_i + B_j + AB_{ij} + \varepsilon_{k(ij)}$

A_i	: 3 df
B_j	: 4 df
AB_{ij}	: 12 df
$\varepsilon_{k(ij)}$	: 20 df

If B were nested in A, the design is:

II. $X_{ijk} = M + A_i + B_{j(i)} + \varepsilon_{k(ij)}$

A_i	: 3 df
$B_{j(i)}$	: 16 df
$\varepsilon_{k(ij)}$	: 20 df

Sum of squares - equivalence:

Model II		Model I
$SS_{B(A)}$	=	$SS_B + SS_{AB}$

DESIGNS FOR CREW CONSISTENCY

1. For each part of Phase I in the survivability test, a sixth crew trial (which is a duplicate crew from one of the original five for each firer vehicle) is currently proposed.

2. The designs for this analysis are the same as for the primary experiment for each part, except that the degrees of freedom for crews and for error are reduced.

3. Because of the reduction in available degrees of freedom, the power of the fixed effect factor tests is substantially reduced. This presents no real problem, however, since the objective of these designs is to measure the crew difference effect.

EVALUATION OF AIM POINT DEFINITION

In conjunction with Phase I, Part A, it is currently proposed that the Twister vehicle will be run over one course at two speeds without a clearly defined aim point. The design for this run is as follows:

$$X_{ikm} = M + F_i + C_{j(i)} + S_\ell + FS_{i\ell} + \varepsilon_{ikm}$$

One of the original crews will be replicated yielding two data points for each firer vehicle to give a very rough estimate of crew variability.

ATTACHMENT 1

DEFINITION OF FACTORS FOR SURVIVABILITY DESIGNS - PHASE I

FACTOR SYMBOL	PART(s) IN WHICH USED	DEFINITION
F_i, $i=1,\ldots,4$	All	Firer (defender) vehicle
C_j, $j=1,\ldots,5$	All	Crews on firer vehicles
D_k, $k=1,\ldots,3$	All	Course (direction of travel)
S_ℓ, $\ell=1,\ldots,4$	I.A.	Speed (constant) of target vehicle
V_ℓ, $\ell=1,\ldots,6$	I.B., I.C.	Target (attacker) vehicle
T_m, $m=1,2$	I.B.	Tactics per segment (acceleration/deceleration)
E_m, $m=1,\ldots,3$	I.C.	Evasive tactics for target vehicles

ATTACHMENT 2

ANOVA and EMS FOR SURVIVABILITY PORTION OF STAGS TEST

ANOVA FOR PHASE I: PART A - CONSTANT SPEED

DATE - 7/24/75

SOURCE (FACTOR)	df	SS	MS	EMS	F-RATIO	COMMENTS
F_i	3			$\sigma^2_e + 60\sigma^2_F + 12\sigma^2_C$		F, S, D: FIXED EFFECTS C: RANDOM EFFECT
$C_{j(i)}$	16			$\sigma^2_e + 12\sigma^2_C$		F-RATIO FORMULATION: F AGAINST C
D_k	2			$\sigma^2_e + 80\sigma^2_D$		ALL OTHERS AGAINST
$S_{l(k)}$	9			$\sigma^2_e + 20\sigma^2_S$		E.
FD_{ik}	6			$\sigma^2_e + 20\sigma^2_{FD}$		NOTE THE 19 d.f.
$FS_{il(k)}$	27			$\sigma^2_e + 5\sigma^2_{FS}$		OF F & C ARE
$E_{(ijkl)}$	176			σ^2_e		ACTUALLY THE "BETWEEN PLOT" d.f. THE 220 d.f. OF D, S, FD, FS, AND E ARE THE "WITHIN PLOT" d.f.

ANOVA FOR PHASE I : PART B - ACCELERATION / DECELERATION

DATE - 7/24/75

SOURCE (FACTOR)	df	SS	MS	EMS	F-RATIO	COMMENTS
						F, D, V, T : FIXED EFFECTS
F_i	3			$\sigma^2_e + 180\sigma^2_F + 36\sigma^2_C$		C : RANDOM EFFECT
$C_{j(i)}$	16			$\sigma^2_e + 36\sigma^2_C$		
D_k	2			$\sigma^2_e + 240\sigma^2_D$		F-RATIO FORMATION:
V_l	5			$\sigma^2_e + 120\sigma^2_V$		F AGAINST C
$T_{m(k)}$	3			$\sigma^2_e + 120\sigma^2_T$		ALL OTHERS
FD_{ik}	6			$\sigma^2_e + 60\sigma^2_{FD}$		AGAINST $\hat{e}$.
FV_{il}	15			$\sigma^2_e + 30\sigma^2_{FV}$		
$FT_{im(k)}$	9			$\sigma^2_e + 30\sigma^2_{FT}$		
DV_{kl}	10			$\sigma^2_e + 40\sigma^2_{DV}$		
FDV_{ikl}	30			$\sigma^2_e + 10\sigma^2_{FDV}$		
$VT_{lm(k)}$	15			$\sigma^2_e + 20\sigma^2_{VT}$		
FDV_{ikl}	30			$\sigma^2_e + 10\sigma^2_{FDV}$		
$FVT_{ilm(k)}$	45			$\sigma^2_e + 5\sigma^2_{FVT}$		
$E_{(ijklm)}$	530			σ^2_e		

ANOVA FOR PHASE I: PART C - EVASIVE TACTICS

DATE- 7/24/75

SOURCE (FACTOR)	df	SS	MS	EMS	F-RATIO	COMMENTS
						F, D, V, E: FIXED EFFECTS
F_i	3			$\sigma^2_e + 270\sigma^2_F + 54\sigma^2_C$		C: RANDOM EFFECT
$C_{j(i)}$	16			$\sigma^2_e + 54\sigma^2_C$		
D_k	2			$\sigma^2_e + 360\sigma^2_D$		F- RATIO FORMULATION
V_l	5			$\sigma^2_e + 180\sigma^2_V$		F AGAINST C
E_m	2			$\sigma^2_e + 360\sigma^2_E$		ALL OTHERS AGAINST E
FD_{ik}	6			$\sigma^2_e + 90\sigma^2_{FD}$		
FV_{il}	15			$\sigma^2_e + 45\sigma^2_{FV}$		
FE_{im}	6			$\sigma^2_e + 90\sigma^2_{FE}$		
DV_{kl}	10			$\sigma^2_e + 60\sigma^2_{DV}$		
DE_{km}	4			$\sigma^2_e + 120\sigma^2_{DE}$		
FDV_{ikl}	30			$\sigma^2_e + 20\sigma^2_{FDV}$		
FDE_{ikm}	12			$\sigma^2_e + 30\sigma^2_{FDE}$		
VE_{lm}	10			$\sigma^2_e + 60\sigma^2_{VE}$		
FVE_{ilm}	30			$\sigma^2_e + 15\sigma^2_{FVE}$		
DVE_{klm}	20			$\sigma^2_e + 20\sigma^2_{DVE}$		
$FDVE_{iklm}$	60			$\sigma^2_e + 5\sigma^2_{FDVE}$		
$E_{(ijklm)}$	948			σ^2_e		

3. ANALYSIS OF VARIANCE USING STATISTICAL PACKAGE FOR THE SOCIAL SCIENCES (SPSS)

SPSS is a collection of statistical routines to assist in data analysis. The program and sample output given in Attachments 3 and 4, respectively, were run for a sample data deck of X and Y miss distances made up for Phase I - Part A of the STAGS Survivability Test.

The output of the ANOVA in Attachment 4 is for X miss distance. It runs a full factorial on the four factors of firer vehicle, course, speed, and crew. The full factorial analysis is then manipulated into the split-plot design as described in the ANOVA Proposed Analytical Plan section of the STAGS Progress Report by Parry and Selvitelle dated 6 August 1975. A full discussion of the complete SPSS package is given in the following:

Statistical Package for the Social Sciences, Nie, Hull, Jenkins, Steinbrenner, and Bent; 2nd Edition, McGraw Hill, 1975.

NOTE: The SPSS package may be run on the CDC 6500 computer at Fort Leavenworth under Release 6.0.

The point of contact is:

Ms Cindy Parker
AUTOVON: 552-3121/4951

ATTACHMENT 3

SPSS ANOVA PROGRAM LISTING

VOGELBACK COMPUTING CENTER
NORTHWESTERN UNIVERSITY

S P S S - - STATISTICAL PACKAGE FOR THE SOCIAL SCIENCES

VERSION 6.0 -- APRIL 1, 1975

```
RUN NAME          ANOVA FOR STAGS TEST
FILE NAME         XYDEV    ANOVA FOR PHASE 1 PART A
VARIABLE LIST     FIRER, COURSE, SPEED, CREW, XDEV, YDEV
INPUT MEDIUM      CARD
N OF CASES        288
INPUT FORMAT      FIXED (4(1X,F1.0),12X,2F10.0)
```

ACCORDING TO YOUR INPUT FORMAT, VARIABLES ARE TO BE READ AS FOLLOWS

VARIABLE	FORMAT	RECORD	COLUMNS
FIRER	F 1. 0	1	2- 2
COURSE	F 1. 0	1	4- 4
SPEED	F 1. 0	1	6- 6
CREW	F 1. 0	1	8- 8
XDEV	F10. 0	1	21- 30
YDEV	F10. 0	1	31- 40

```
THE INPUT FORMAT PROVIDES FOR   6 VARIABLES.    6 WILL BE READ
IT PROVIDES FOR  1 RECORDS (*CARDS*) PER CASE.  A MAXIMUM OF   40 *COLUMNS* ARE USED ON A RECORD.

                VAR LABELS      FIRER FIRER DEFENDER VEHICLE - 4 LEVELS/
                                COURSE TARGET COURSE -DIRECTION OF HEADING - 3 LEVELS/
                                SPEED TARGET VEHICLE SPEED - 4 LEVELS/
                                CREW   CREW OF FIRER VEHICLE - 6 LEVELS - 6TH IS DUPE OF 5TH/
                                XDEV X-DISTANCE OF ROUND FROM AIM-POINT - MILS/
                                YDEV Y-DISTANCE OF ROUND FROM AIM-POINT - MILS
                VALUE LABELS    FIRER (1) S-TANK (2) M60A1 (3) M60A1E3 (4) TOW-TRACKER/
                                COURSE (1) CONSTANT RANGE (2) OBLIQUE (3) STRAIGHT IN/
                                SPEED (1) 10 MPH (2) 20 MPH (3) 30 MPH (4) 40 MPH/
                                CREW  (1) CREW 1 (2) CREW 2 (3) CREW 3 (4) CREW 4 (5) CREW 5
                COMPUTE         COSPD = COURSE+SPEED+(((COURSE-1)*3)-1)
                COMPUTE         CRWFIR = CREW+FIRER+(((FIRER-1)*4)-1)
                IF              (CREW EQ 6) CRWFIR = FIRER+20
                VAR LABELS      COSPD COURSE-SPEED FACTOR - 12 LEVELS/
                                CRWFIR CREW-FIRER VEHICLE FACTOR - 20 LEVELS/
                ANOVA           XDEV,YDEV BY FIRER(1,4),COURSE(1,3),SPEED(1,4),CREW(1,5)
                OPTIONS         5
                STATISTICS      1,2
                READ INPUT DATA

        133500 CM REQUIRED FOR ANOVA
```

ATTACHMENT 4

SPSS ANOVA OUTPUT EXAMPLE
(Includes Multiple Classification Analysis)

.OVA FOR STAGS TEST

ILE XYDEV (CREATION DATE = 08/12/75) ANOVA FOR PHASE 1 PART A

* * * * * * * * * * A N A L Y S I S O F V A R I A N C E * * * * * * * * * *

	XDEV	X-DISTANCE OF ROUND FROM AIM-POINT - MIL
BY	FIRER	FIRER DEFENDER VEHICLE - 4 LEVELS
	COURSE	TARGET COURSE -DIRECTION OF HEADING - 3
	SPEED	TARGET VEHICLE SPEED - 4 LEVELS
	CREW	CREW OF FIRER VEHICLE - 6 LEVELS - 6TH I

* *

OURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNI OF F
AIN EFFECTS	932.836	12	77.736	13.760	.001
FIRER	797.954	3	265.985	47.083	.00
COURSE	15.570	2	7.785	1.378	.25
SPEED	30.343	3	10.114	1.790	.15
CREW	88.969	4	22.242	3.937	.00
-WAY INTERACTIONS	401.329	53	7.572	1.340	.12
FIRER COURSE	75.610	6	12.602	2.231	.04
FIRER SPEED	55.175	9	6.131	1.085	.38
FIRER CREW	76.612	12	6.384	1.130	.35
COURSE SPEED	18.645	6	3.108	.550	.99
COURSE CREW	63.872	8	7.984	1.413	.20
SPEED CREW	111.414	12	9.285	1.643	.09
-WAY INTERACTIONS	565.795	102	5.547	.982	.99
FIRER COURSE SPEED	92.565	18	5.144	.910	.99
FIRER COURSE CREW	170.351	24	7.098	1.256	.22
FIRER SPEED CREW	167.890	36	4.664	.826	.99
COURSE SPEED CREW	134.969	24	5.624	.995	.94
ESIDUAL	406.751	72	5.649		
OTAL	2306.711	239	9.652		

208 CASES WERE PROCESSED.
48 CASES (16.7 PCT) WERE MISSING.

ANOVA FOR STAGS TEST

FILE XYDEV (CREATION DATE = 08/12/75) ANOVA FOR PHASE 1 PART A

* * * M U L T I P L E C L A S S I F I C A T I O N A N A L Y S I S * * *

	XDEV	X-DISTANCE OF ROUND FROM AIM-POINT - MIL
BY	FIRER	FIRER DEFENDER VEHICLE - 4 LEVELS
	COURSE	TARGET COURSE -DIRECTION OF HEADING - 3
	SPEED	TARGET VEHICLE SPEED - 4 LEVELS
	CREW	CREW OF FIRER VEHICLE - 6 LEVELS - 6TH I

* *

GRAND MEAN = 1.36

VARIABLE + CATEGORY	UNADJUSTED DEV*N	UNADJUSTED ETA	ADJUSTED FOR INDEPENDENTS DEV*N	ADJUSTED FOR INDEPENDENTS BETA	ADJUSTED FOR INDEPENDENTS + COVARIATES DEV*N	ADJUSTED FOR INDEPENDENTS + COVARIATES BETA
FIRER						
1 S-TANK	3.14		3.14			
2 M60A1	-.75		-.75			
3 M60A1E3	-1.28		-1.28			
4 TOW-TRACKER	-1.11		-1.11			
		.59		.59		
COURSE						
1 CONSTANT RANGE	.35		.35			
2 OBLIQUE	-.10		-.10			
3 STRAIGHT IN	-.25		-.25			
		.08		.08		
SPEED						
1 10 MPH	-.57		-.57			
2 20 MPH	.16		.16			
3 30 MPH	.01		.01			
4 40 MPH	.40		.40			
		.11		.11		
CREW						
1 CREW 1	.52		.52			
2 CREW 2	.70		.70			
3 CREW 3	.22		.22			
4 CREW 4	-.69		-.69			
5 CREW 5	-.75		-.75			
		.20		.20		
MULTIPLE R SQUARED				.404		
MULTIPLE R				.636		

4. MEAN VALUE DIFFERENTIAL ANALYSIS

PURPOSE:

To describe and fully document the Mean Value Differential Analysis (MVDA) computer program developed for US Army Armor and Engineer Board.

OVERVIEW:

1. The purpose of the MVDA program is to compute the Grand Mean and submeans (as well as submean differentials from the Grand Mean) of data from an experiment of up to five factors. The current program will handle up to six treatment levels per factor, but this restriction is easily relaxed through modification of the dimension statements.

2. A primary use of the MVDA program is to facilitate the preparation of graphical displays of the treatment level mean value differentials for factor main effects and all interactions up to fourth order (if desired). It is intended as a supplementary program to be used after Analysis of Variance (ANOVA) has indicated the significant factors and interactions of interest.

3. The MVDA program will give significant insights into the particular treatment levels causing the variations leading to significance conclusions in the ANOVA.

COMPUTER PROGRAM AND OUTPUT:

1. The computer program (see Attachment 5) has been written such that all input requirements are documented within the program. It is essential that the user understand FORTRAN Format statements to utilize the program.

2. The program is currently written for IBM FORTRAN in that five and four dimensional arrays are used. In case it becomes necessary to execute the program under a FORTRAN compiler accepting no greater than three dimensional arrays (e.g., CDC FORTRAN) the arrays will require appropriate linearization.

3. The input to MVDA consists of the following:

a. The highest level of interaction terms desired (should be one less than the total number of factors - Card 0010).

b. The number of treatment levels of each factor (assuring that a one (1) is input for unused factors - less than five - Card 0012).

c. Alphabetic description of factors (four letters per factor - Card 0014).

d. Dependent variable data in the formats indicated by Format Cards 1010, 1020, 1030, 1040, 1050.

e. Cases to be run - (see Comment Cards after Card 0052 in the program).

4. The output of the MVDA program is illustrated in Attachment 6 for a sample data deck made up for the Root Sum of Squares (RSS) of X-Y miss distance (meters) for Phase I - Part A of the Survivability subtest of the STAGS experiment (four constant speeds, three courses). The Grand Mean of 4.961 indicates that the overall RSS miss distance was 4.961 meters. The main effect specified as input was firer vehicle (FIRE). Note that Vehicles 1, 2, and 3 were all above the Grand Mean in performance, whereas Vehicle 4 did substantially better (an RSS miss distance of 0.857 which was 4.105 below the Grand Mean, indicated by a minus sign under "Differential from Grand Mean").

To continue the example, note that Firer Vehicle 3 (whose overall RSS miss distance was 7.100) did substantially worse on Course 3 (11.341). Note that the average of 11.341 + 5.952 + 4.006 for Firer Vehicle 3 over all courses equals 7.100, the average over all treatment levels for Firer Vehicle 3.

Continuing the example to the third order interaction terms, note that Firer Vehicle 3 performance on Course 3 was worse at Speeds 1, 3, and 4 than at Speed 2 (although not significantly different). Note that the average of 11.835 + 9.848 + 11.523 + 12.157 is 11.341 (from Firer Vehicle 3, Course 3 in the Second Order Terms table). It should be noted that the data presented in the Third Order Terms is averaged over the five crews on the firer vehicles.

5. Another output of the MVDA program for the same data is given in Attachment 7. Note that the roles of Crews and Speed have been interchanged, giving insight as to how the Crew Factor affects the Firer - Course interaction. For example, Crew 4 did the best overall speeds for Firer Vehicle 3, Course 3; while Crew 1 did the worst (8.521 vs 13.965 under the Submean column).

ATTACHMENT 5

MEAN VALUE DIFFERENTIAL ANALYSIS PROGRAM LISTING

```
C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C
C THIS PROGRAM COMPUTES MEAN VALUE DIFFERENTIALS FROM THE GRAND MEAN
C FOR UP TO 5 FACTORS FOR FIRST, SECOND, THIRD, AND FOURTH ORDER INTERACTIONS
C (SEE KOUT) & MAX 6 LEVELS . THE FOLLOWING INPUT DATA (IN ORDER) IS REQUIRED:
C     (SEE COMMENTS PRECEDING EACH READ STATEMENT)
C
C   1. KOUT (1 CARD)
C
C   2. NUMBER OF LEVELS OF EACH FACTOR (1 CARD)
C
C   3. FACTER(N) (1 CARD)
C
C   4. DEPENDENT VARIABLE VALUES WITH FACTOR LEVEL SUBSCRIPTS
C              (NUMBER OF CARDS = NUMBER OF DATA POINTS)
C         (SAME DATA DECK AS USED FOR SPSS RUNS)
C
C   5. IARD(NN,N) (NN CARDS, WHERE NN= NUMBER OF CASES)
C          (BLANK DATA CARD IS LAST DATA CARD IN THE DATA DECK)
C
C DESIGNED & PROGRAMMED BY PARRY & SELVITELLE - ARMOR BOARD - FT. KNOX
C
C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C
C  DIMENSION OF DV MUST BE CHANGED WITH EACH DATA SET, AS MUST THE
C    FORMAT STATEMENTS FOR 1010,1020,1030,1040,AND 1050.
C
C  ALL OTHER SOURCE STATEMENTS ARE UNCHANGED WITHIN STATED PROGRAM CAPABILITIES.
C
0001        DIMENSION DV(4,3,4,6,1),IARD(50,5),ITOT(5),FACTER(5),FACTOR(5),
           1DVT1(6),DVT2(6,6),DVT3(6,6,6),DVT4(6,6,6,6),IORD(5)
0002        DIMENSION AVT1(6),AVT2(6,6),AVT3(6,6,6),AVT4(6,6,6,6)
C
C   INITIALIZATIONS
C
0003        I=1
0004        J=1
0005        K=1
0006        L=1
0007        M=1
0008        DVTOT=0.
0009        NN=0.
C
C  INPUT STATEMENTS
C
C
C KOUT SPECIFIES THE HIGHEST LEVEL OF INTERACTION TERMS FOR WHICH
C     MEAN VALUE DIFFERENTIALS ARE PRINTED (VALUE = 1,2,3,OR4).
```

```
C
      READ(5,1550)KOUT
 1550 FORMAT(I1)
C
C MUNBER OF LEVELS OF EACH FACTOR (INPUT ONE  FOR UNUSED FACTORS).
C
      READ(5,1000)II,JJ,KK,LL,MM
 1000 FORMAT(5I2)
C
C  ALPHA DESCRIPTION OF FACTORS (MAY OF 4 LETTERS PER FACTOR)
C
      READ(5,1500)(FACTER(N),N=1,5)
 1500 FORMAT(5(A4,1X))
C
C FORMATS 1010,1020,1030,1040,1050 MUST BE ADJUSTED FOR EACH DATA SET.
C
C  ONE FACTOR - DEPENDENT VARIABLE.
C
      NCASES=II*JJ*KK*LL*MM
      IF(JJ.GT.1) GO TO 10
      DO 9 IA=1,NCASES
    9 READ(5,1010) I,DV(I,J,K,L,M)
 1010 FORMAT(I2,18X,F10.0)
      GO TO 30
C
C TWO FACTOR - DEPENDENT VARIABLE
C
   10 IF(KK.GT.1)GOTO15
      DO 11 IZ=1,NCASES
   11 READ(5,1020)I,J,DV(I,J,K,L,M)
 1020 FORMAT(2I2,16X,F10.0)
      GO TO 30
C
C THREE FACTOR - DEPENDENT VARIABLE
C
   15 IF(LL.GT.1)GOTO20
      DO 16 IZ=1,NCASES
   16 READ(5,1030)I,J,K,DV(I,J,K,L,M)
 1030 FORMAT(3I2,14X,F10.0)
      GO TO 30
   20 IF(MM.GT.1)GOTO25
C
C FOUR FACTOR - DEPENDENT VARIABLE
C
      DO 21 IZ=1,NCASES
      READ(5,1040)I,J,K,L,X,Y
 1040 FORMAT(4I2,12X,2F10.0)
      DV(I,J,K,L,M)=SQRT((X*X)+(Y*Y))
```

COPY AVAILABLE TO DDC DOES NOT PERMIT FULLY LEGIBLE PRODUCTION

```
0037          21 CONTINUE
0038             GOTO30
          C
          C FIVE FACTOR - DEPENDENT VARIABLE
          C
0039        25   DO 26 IZ=1,NCASES
0040        26   READ(5,1050)I,J,K,L,M,DV(I,J,K,L,M)
0041      1050 FORMAT(5I2,10X,F10.0)
0042        30   CONTINUE
          C
          C  TEMPORARY CARDS FOLLOW TO NOT CONSIDER SIXTH CREW
          C
0043             LL=LL-1
0044             NCASES=II*JJ*KK*LL*MM
          C
          C
          C  COMPUTE GRAND MEAN
0045             DO 50 I=1,II
0046             DO 50 J=1,JJ
0047             DO 50 K=1,KK
0048             DO 50 L=1,LL
0049             DO 50 M=1,MM
0050        50   DVTOT = DVTOT + DV(I,J,K,L,M)
0051             GM=DVTOT/NCASES
0052       100 CONTINUE
          C
          C IARD SPECIFIES THE PRIORITY LEVEL FOR EACH FACTOR AS INPUT TO DV ARRAY.
          C    FORM IS IARD(NN,N) WHERE NN IS CASE NUMBER SUBSCRIPT (MAX OF 50 CASES).
          C    N IS POSITION OF FACTOR IN ORIGINAL DV INPUT.
          C    IARD VALUE IS POSITION OF NTH FACTOR FOR CURRENT CASE.
          C  *EG-IF FACTOR 3 IN DV IS TO BE FIRST FACTOR (TO GET ITS M.V.D. MAIN EFFECT,
          C    INPUT 3 FOR IARD(NN,1).
          C    NOTE: ALL FIVE POSITIONS MUST BE COMPLETED, EVEN IF LESS THAN 5 FACTORS
          C    ARE BEING RUN - PUT IN BLANK DATA CARD AFTER LAST CASE.
          C
0053             NN=NN+1
0054             READ(5,1100)(IARD(NN,N),N=1,5)
0055      1100 FORMAT(5(1X,I1))
0056             DO 105 N=1,5
0057       105 IORD(N)=IARD(NN,N)
0058             IF(IORD(1).EQ.0)GOTO900
0059             DO 110 N=1,5
0060             IF(IORD(N).EQ.1)ITOT(N)=II
0061             IF(IORD(N).EQ.2)ITOT(N)=JJ
0062             IF(IORD(N).EQ.3)ITOT(N)=KK
0063             IF(IORD(N).EQ.4)ITOT(N)=LL
0064             IF(IORD(N).EQ.5)ITOT(N)=MM
0065       110 CONTINUE
```

```
      DO 114 N=1,5
      DO 114 NC=1,5
  114 IF(IORD(N).EQ.NC)FACTOR(N)=FACTER(NC)
      IIT=ITOT(1)
      JJT=ITOT(2)
      KKT=ITOT(3)
      LLT=ITOT(4)
      MMT=ITOT(5)
C COMPUTE DIFFERENTIALS
      DO 120 IW=1,IIT
      AVT1(IW)=0.
      DVT1(IW)=0.
      DO 120 JW=1,JJT
      AVT2(IW,JW)=0.
      DVT2(IW,JW)=0.
      DO 120 KW=1,KKT
      AVT3(IW,JW,KW)=0.
      DVT3(IW,JW,KW)=0.
      DO 120 LW=1,LLT
      AVT4(IW,JW,KW,LW)=0.
  120 DVT4(IW,JW,KW,LW)=0.
      DO 350 IT=1,IIT
      IF(IORD(1).EQ.1)IB=IT
      IF(IORD(1).EQ.2)JB=IT
      IF(IORD(1).EQ.3)KB=IT
      IF(IORD(1).EQ.4)LB=IT
      IF(IORD(1).EQ.5)MB=IT
      DO 300 JT=1,JJT
      IF(IORD(2).EQ.1)IB=JT
      IF(IORD(2).EQ.2)JB=JT
      IF(IORD(2).EQ.3)KB=JT
      IF(IORD(2).EQ.4)LB=JT
      IF(IORD(2).EQ.5)MB=JT
      DO 250 KT=1,KKT
      IF(IORD(3).EQ.1)IB=KT
      IF(IORD(3).EQ.2)JB=KT
      IF(IORD(3).EQ.3)KB=KT
      IF(IORD(3).EQ.4)LB=KT
      IF(IORD(3).EQ.5)MB=KT
      DO 200 LT=1,LLT
      IF(IORD(4).EQ.1)IB=LT
      IF(IORD(4).EQ.2)JB=LT
      IF(IORD(4).EQ.3)KB=LT
      IF(IORD(4).EQ.4)LB=LT
      IF(IORD(4).EQ.5)MB=LT
      DO 150 MT=1,MMT
      IF(IORD(5).EQ.1)IB=MT
      IF(IORD(5).EQ.2)JB=MT
```

```
      IF(IORD(5).EQ.3)KB=MT
      IF(IORD(5).EQ.4)LB=MT
      IF(IORD(5).EQ.5)MB=MT
      DVT4(IT,JT,KT,LT)=DVT4(IT,JT,KT,LT) + DV(IB,JB,KB,LB,MB)
  150 CONTINUE
      DVT3(IT,JT,KT)=DVT3(IT,JT,KT)+DVT4(IT,JT,KT,LT)
      AVT4(IT,JT,KT,LT)=     (DVT4(IT,JT,KT,LT)/MMT) - GM
      DVT4(IT,JT,KT,LT)=DVT4(IT,JT,KT,LT)/MMT
  200 CONTINUE
      DVT2(IT,JT)=DVT2(IT,JT)+DVT3(IT,JT,KT)
      AVT3(IT,JT,KT)=     (DVT3(IT,JT,KT)/(LLT*MMT)) - GM
      DVT3(IT,JT,KT)=DVT3(IT,JT,KT)/(LLT*MMT)
  250 CONTINUE
      DVT1(IT)=DVT1(IT)+DVT2(IT,JT)
      AVT2(IT,JT)=     (DVT2(IT,JT)/(KKT*LLT*MMT)) - GM
      DVT2(IT,JT)=DVT2(IT,JT)/(KKT*LLT*MMT)
  300 CONTINUE
      AVT1(IT)=     (DVT1(IT)/(JJT*KKT*LLT*MMT)) - GM
      DVT1(IT)=DVT1(IT)/(JJT*KKT*LLT*MMT)
  350 CONTINUE
      WRITE(6,2000)(FACTOR(N),N=1,5)
 2000 FORMAT(1H1,10X,'ANALYSIS OF ORDERED FACTORS--',5(2X,A4))
      WRITE(6,2010)GM,FACTOR(1)
 2010 FORMAT(//7X,'GRAND MEAN = ',F10.3,///1X,'MAIN EFFECT FACTOR--',
     12X,A4//3X,'LEVEL',3X,'DIFFERENTIAL FROM GRAND MEAN',
     25X,'SUB-MEAN',/1X)
      DO 500 IC=1,IIT
      WRITE(6,2020)IC,AVT1(IC),DVT1(IC)
 2020 FORMAT(4X,I2,11X,F10.3,12X,F10.3)
  500 CONTINUE
      IF(KOUT.LE.1)GOTO850
      WRITE(6,2030)(FACTOR(N),N=1,2)
 2030 FORMAT(//1X,'SECOND ORDER TERMS--',2(2X,A4)//4X,'LEVEL',7X,'LEVEL'
     1,6X,'DIFFERENTIAL',/2X,'(FACTOR 1)  (FACTOR 2)',3X,
     2'FROM GRAND MEAN',5X,'SUB-MEAN',/1X)
      DO 510 IC=1,IIT
      DO 510 JC=1,JJT
      WRITE(6,2040)IC,JC,AVT2(IC,JC),DVT2(IC,JC)
 2040 FORMAT(5X,I2,10X,I2,10X,F10.3,5X,F10.3)
  510 CONTINUE
      IF(KOUT.LE.2)GOTO850
      WRITE(6,2050)(FACTOR(N),N=1,3)
 2050 FORMAT(//1X,'THIRD ORDER TERMS--',3(2X,A4)//4X,'LEVEL',7X,
     1'LEVEL',7X,'LEVEL',6X,'DIFFERENTIAL'/2X,'(FACTOR 1)',2X,
     2'(FACTOR 2)  (FACTOR 3)  FROM GRAND MEAN',5X,'SUB-MEAN',/1X)
      DO 520 IC=1,IIT
      DO 520 JC=1,JJT
      DO 520 KC=1,KKT
```

```
      WRITE(6,2060)IC,JC,KC,AVT3(IC,JC,KC),DVT3(IC,JC,KC)
 2060 FORMAT(5X,I2,10X,I2,10X,I2,10X,F10.3,5X,F10.3)
  520 CONTINUE
      IF(KOUT.LE.3)GOTO850
      WRITE(6,2070)(FACTOR(N),N=1,4)
 2070 FORMAT(//1X,'FOURTH ORDER TERMS--',4(2X,A4)//4X,'LEVEL',7X,
     1'LEVEL',7X,'LEVEL',7X,'LEVEL',6X,'DIFFERENTIAL'/2X,'(FACTOR 1)',
     22X,'(FACTOR 2)',2X,'(FACTOR 3)',2X,'(FACTOR 4)',2X,
     3'FROM GRAND MEAN',5X,'SUB-MEAN',/1X)
      DO 530 IC=1,IIT
      DO 530 JC=1,JJT
      DO 530 KC=1,KKT
      DO 530 LC=1,LLT
      WRITE(6,2080)IC,JC,KC,LC,AVT4(IC,JC,KC,LC),DVT4(IC,JC,KC,LC)
 2080 FORMAT(5X,4(I2,10X),F10.3,5X,F10.3)
  530 CONTINUE
  850 CONTINUE
      GOTO100
  900 STOP
      END
```

ATTACHMENT 6

MEAN VALUE DIFFERENTIAL ANALYSIS OUTPUT EXAMPLE

FIRER - COURSE - SPEED - CREW

ANALYSIS OF ORDERED FACTORS-- FIRE CRSE SPED CREW

GRAND MEAN = 4.961

MAIN EFFECT FACTOR-- FIRE

LEVEL	DIFFERENTIAL FROM GRAND MEAN	SUB-MEAN
1	1.199	6.160
2	0.768	5.729
3	2.138	7.100
4	-4.105	0.857

SECOND ORDER TERMS-- FIRE CRSE

LEVEL (FACTOR 1)	LEVEL (FACTOR 2)	DIFFERENTIAL FROM GRAND MEAN	SUB-MEAN
1	1	1.489	6.450
1	2	-0.456	4.505
1	3	2.564	7.525
2	1	-1.443	3.519
2	2	-0.279	4.683
2	3	4.025	8.987
3	1	-0.955	4.006
3	2	0.991	5.952
3	3	6.379	11.341
4	1	-4.007	0.955
4	2	-4.108	0.854
4	3	-4.200	0.762

COPY AVAILABLE TO DDC DOES NOT PERMIT FULLY LEGIBLE PRODUCTION

THIRD ORDER TERMS-- FIRE CRSE SPED

LEVEL (FACTOR 1)	LEVEL (FACTOR 2)	LEVEL (FACTOR 3)	DIFFERENTIAL FROM GRAND MEAN	SUB-MEAN
1	1	1	-1.313	3.648
1	1	2	1.111	6.073
1	1	3	1.952	6.913
1	1	4	4.205	9.166
1	2	1	-3.140	1.821
1	2	2	0.074	5.035
1	2	3	0.848	5.809
1	2	4	0.394	5.355
1	3	1	1.327	6.288
1	3	2	3.317	8.278
1	3	3	2.969	7.930
1	3	4	2.643	7.604
2	1	1	-3.334	1.628
2	1	2	-2.186	2.776
2	1	3	-1.038	3.923
2	1	4	0.787	5.748
2	2	1	-1.738	3.224
2	2	2	-1.297	3.664
2	2	3	-0.281	4.680
2	2	4	2.200	7.162
2	3	1	0.709	5.670
2	3	2	1.050	6.012
2	3	3	5.720	10.682
2	3	4	8.622	13.584
3	1	1	-1.387	3.575
3	1	2	-1.562	3.400
3	1	3	-1.332	3.629
3	1	4	0.459	5.420
3	2	1	0.105	5.066
3	2	2	0.853	5.815
3	2	3	1.547	6.508
3	2	4	1.459	6.420
3	3	1	6.873	11.835
3	3	2	4.886	9.848
3	3	3	6.562	11.523
3	3	4	7.195	12.157
4	1	1	-4.732	0.230
4	1	2	-4.319	0.642
4	1	3	-3.731	1.230
4	1	4	-3.244	1.717
4	2	1	-4.615	0.346
4	2	2	-3.952	1.010
4	2	3	-3.842	1.119
4	2	4	-4.022	0.939
4	3	1	-4.625	0.336
4	3	2	-4.237	0.725
4	3	3	-4.150	0.812
4	3	4	-3.787	1.175

ATTACHMENT 7

MEAN VALUE DIFFERENTIAL ANALYSIS OUTPUT EXAMPLE

FIRER - COURSE - CREW - SPEED

ANALYSIS OF ORDERED FACTORS-- FIRE CRSE CREW SPED

GRAND MEAN = 4.961

MAIN EFFECT FACTOR-- FIRE

LEVEL	DIFFERENTIAL FROM GRAND MEAN	SUB-MEAN
1	1.199	6.160
2	0.768	5.729
3	2.138	7.100
4	-4.105	0.857

SECOND ORDER TERMS-- FIRE CRSE

LEVEL (FACTOR 1)	LEVEL (FACTOR 2)	DIFFERENTIAL FROM GRAND MEAN	SUB-MEAN
1	1	1.489	6.450
1	2	-0.456	4.505
1	3	2.564	7.525
2	1	-1.443	3.519
2	2	-0.279	4.683
2	3	4.025	8.987
3	1	-0.955	4.006
3	2	0.991	5.952
3	3	6.379	11.341
4	1	-4.007	0.955
4	2	-4.108	0.854
4	3	-4.200	0.762

THIRD ORDER TERMS-- FIRE CRSE CREW

LEVEL (FACTOR 1)	LEVEL (FACTOR 2)	LEVEL (FACTOR 3)	DIFFERENTIAL FROM GRAND MEAN	SUB-MEAN
1	1	1	2.432	7.394
1	1	2	0.485	5.446
1	1	3	2.292	7.254
1	1	4	0.690	5.651
1	1	5	1.544	6.506
1	2	1	-0.017	4.945
1	2	2	-1.081	3.880
1	2	3	-0.395	4.566
1	2	4	-1.056	3.905
1	2	5	0.268	5.230
1	3	1	4.054	9.016
1	3	2	4.934	9.895
1	3	3	2.408	7.370
1	3	4	0.477	5.438
1	3	5	0.946	5.907
2	1	1	-0.782	4.180
2	1	2	-1.618	3.343
2	1	3	-0.730	4.232
2	1	4	-2.226	2.735
2	1	5	-1.858	3.103
2	2	1	0.735	5.696

COPY AVAILABLE TO DDC DOES NOT PERMIT FULLY LEGIBLE PRODUCTION

THIRD ORDER TERMS-- [illegible] (CONT)

2	2	2	-0.134	4.827
2	2	3	-0.174	4.787
2	2	4	-0.239	4.722
2	2	5	-1.581	3.380
2	3	1	6.855	11.817
2	3	2	3.943	8.904
2	3	3	3.506	8.467
2	3	4	2.494	7.455
2	3	5	3.330	8.291
3	1	1	-1.492	3.469
3	1	2	-1.790	3.172
3	1	3	-1.600	3.361
3	1	4	-0.941	4.021
3	1	5	1.066	6.007
3	2	1	1.146	6.108
3	2	2	1.939	6.901
3	2	3	1.408	6.370
3	2	4	-0.126	4.836
3	2	5	0.587	5.548
3	3	1	9.003	13.965
3	3	2	6.505	11.466
3	3	3	6.404	11.366
3	3	4	3.560	8.521
3	3	5	6.424	11.385
4	1	1	-3.958	1.003
4	1	2	-4.222	0.739
4	1	3	-4.174	0.788
4	1	4	-3.795	1.167
4	1	5	-3.884	1.077
4	2	1	-4.317	0.644
4	2	2	-4.050	0.912
4	2	3	-3.946	1.016
4	2	4	-4.066	0.895
4	2	5	-4.160	0.801
4	3	1	-4.087	0.874
4	3	2	-4.352	0.609
4	3	3	-4.196	0.766
4	3	4	-4.133	0.828
4	3	5	-4.229	0.733

THIS PAGE IS BEST QUALITY PRACTICABLE
COPY AVAILABLE TO DDC DOES NOT PERMIT FULLY LEGIBLE PRODUCTION

5. STRING STATISTICS PROGRAM

The computer program listed in Attachment 8 accepts as input a string of numbers (positive or negative) and a single number, ASPLIT. The string of numbers is divided into two groups as follows:

Group 1: All input numbers less than ASPLIT.

Group 2: All input numbers greater than or equal to ASPLIT.

The output of the program (see Attachment 9) consists of the mean, variance, and standard deviation of the total string, absolute value of numbers in the total string, Group 1, and Group 2. In addition, a counter is provided of the number in each category.

The primary usefulness of the program for USAARENBD is to provide initial insights into the nature of data gathered from an experiment. The sample output in Attachment 9 represents 288 data points on X-miss distance example deck. The value of ASPLIT was 0 for the example.

NOTE: The program is currently written in FC AN formatted for the CDC 6000 series computer.

ATTACHMENT 8

STRING STATISTICS PROGRAM LISTING

```
      PROGRAM STRSTA (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)

      PROGRAM STRING-STATICTICS

THIS PROGRAM ACCEPTS AS INPUT A STRING OF REAL NUMBERS (UP TO 2000-CURRENTLY
      (ADJUST 1000 FORMAT IN ACCORDANCE WITH DATA LOCATION ON CARD).
  THE STRING IS DIVIDED INTO TWO GROUPS:
   ASPLIT = THE BASE NUMBER USED FOR THE SPLIT.
   GROUP 1 ARE ALL NUMBERS LESS THAN ASPLIT.
   GROUP 2 ARE ALL NUMBERS GREATER THAN OR EQUAL TO ASPLIT.

  OUTPUT IS AS FOLLOWS:

  1. MEAN,VARIANCE,STANDARD DEVIATION,AND TOTAL NUMBER    FOR GROUP 1.
  2. SAME AS 1. FOR GROUP 2.
  3. SAME AS 1. FOR OVERALL INPUT STRING.
  4. SAME AS 1. FOR ABSOLUTE VALUE OF INPUT STRING.


  WRITTEN BY SAM PARRY, ARMOR BOARD, FORT KNOX, 28 JULY 1975


      DIMENSION AIN(2000)

  INITIALIZATIONS.

      I=1
      ATOT=0.
      ATSQ=0.
      POSTOT=0.
      POSSQ=0.
      NPOS=0
      NNEG=0
      BNEGT=0.
      BNEGSQ=0.
      ABSTOT=0.

  INPUT STRING- LAST DATA CARD MUST BE 999999999.

      READ(5,1050)ASPLIT
 1050 FORMAT(F10.0)
   50 CONTINUE
      READ(5,1000)AIN(I)
 1000 FORMAT(20X,F10.0)
      IF(AIN(I).EQ.999999999.)GOTO500
      ATOT=ATOT + AIN(I)
      ATSQ=ATSQ + (AIN(I)**2)
      ABSTOT=ABSTOT + ABS(AIN(I))
      IF(AIN(I).LT.ASPLIT)GOTO100
      POSTOT=POSTOT + AIN(I)
      POSSQ=POSSQ + (AIN(I)**2)
      NPOS=NPOS + 1
      I=I+1
      GOTO50
  100 CONTINUE
      BNEGT=BNEGT + AIN(I)
      BNEGSQ=BNEGSQ + (AIN(I)**2)
```

COPY AVAILABLE TO DDC DOES NOT PERMIT FULLY LEGIBLE PRODUCTION

```
      NNEG=NNEG + 1
      I=I+1
      GOTO50
  500 CONTINUE
      I=I-1
      AMEAN=ATOT/I
      AVAR=(ATSQ/I) - (AMEAN**2)
      PPMEAN=POSTOT/NPOS
      PPVAR=(POSSQ/NPOS) - (PPMEAN**2)
      BNMEAN=BNEGT/NNEG
      BNVAR=(BNEGSQ/NNEG) - (BNMEAN**2)
      ABSMN=ABSTOT/I
      ABSVAR=(ATSQ/I) - (ABSMN**2)
      ASTD=SQRT(AVAR)
      PPSTD=SQRT(PPVAR)
      BNSTD=SQRT(BNVAR)
      ABSSTD=SQRT(ABSVAR)
      WRITE(6,2000)ASPLIT
 2000 FORMAT(1H1,20X,"MEAN-VARIANCE ANALYSIS OF INPUT STRING",
     *5X,"ASPLIT = ",F12.4,////20X,
     1"NO. OF CASES        MEAN        VARIANCE    STANDARD DEVIATION")
      WRITE(6,2100)I,AMEAN,AVAR,ASTD
 2100 FORMAT(/1X,"TOTAL STRING",11X,I4,8X,3(E12.4,1X))
      WRITE(6,2050)I,ABSMN,ABSVAR,ABSSTD
 2050 FORMAT(/1X,"ABS. VALUE-TOTAL", 7X,I4,8X,3(E12.4,1X))
      WRITE(6,2300)NNEG,BNMEAN,BNVAR,BNSTD
 2300 FORMAT(/1X,"GROUP 1  NUMBERS",[illegible],8X,3(E12.4,1X))
      WRITE(6,2200)NPOS,PPMEAN,PPVAR,PPSTD
 2200 FORMAT(/1X,"GROUP 2  NUMBERS",[illegible]4,8X,3(E12.4,1X))
      STOP
      END
```

ATTACHMENT 9

STRING STATISTICS OUTPUT EXAMPLE

MEAN-VARIANCE ANALYSIS OF INPUT STRING ASPLIT = 0.0000

	NO. OF CASES	MEAN	VARIANCE	STANDARD DEVIATION
TOTAL STRING	288	.1247E+01	.8255E+01	.2873E+01
ABS. VALUE-TOTAL	288	.2361E+01	.4144E+01	.2036E+01
GROUP 1 NUMBERS	87	-.1976E+01	.2161E+01	.1470E+01
GROUP 2 NUMBERS	201	.2559E+01	.4844E+01	.2201E+01

6. ANALYSIS OF APPARENT ACCELERATION AND APPARENT VELOCITY OF A MOVING TARGET (Part I)

1. PROBLEM DEFINITION:

Determine the sensitivity of apparent acceleration to the tracking vehicle in near and far range cases for a moving target vehicle.

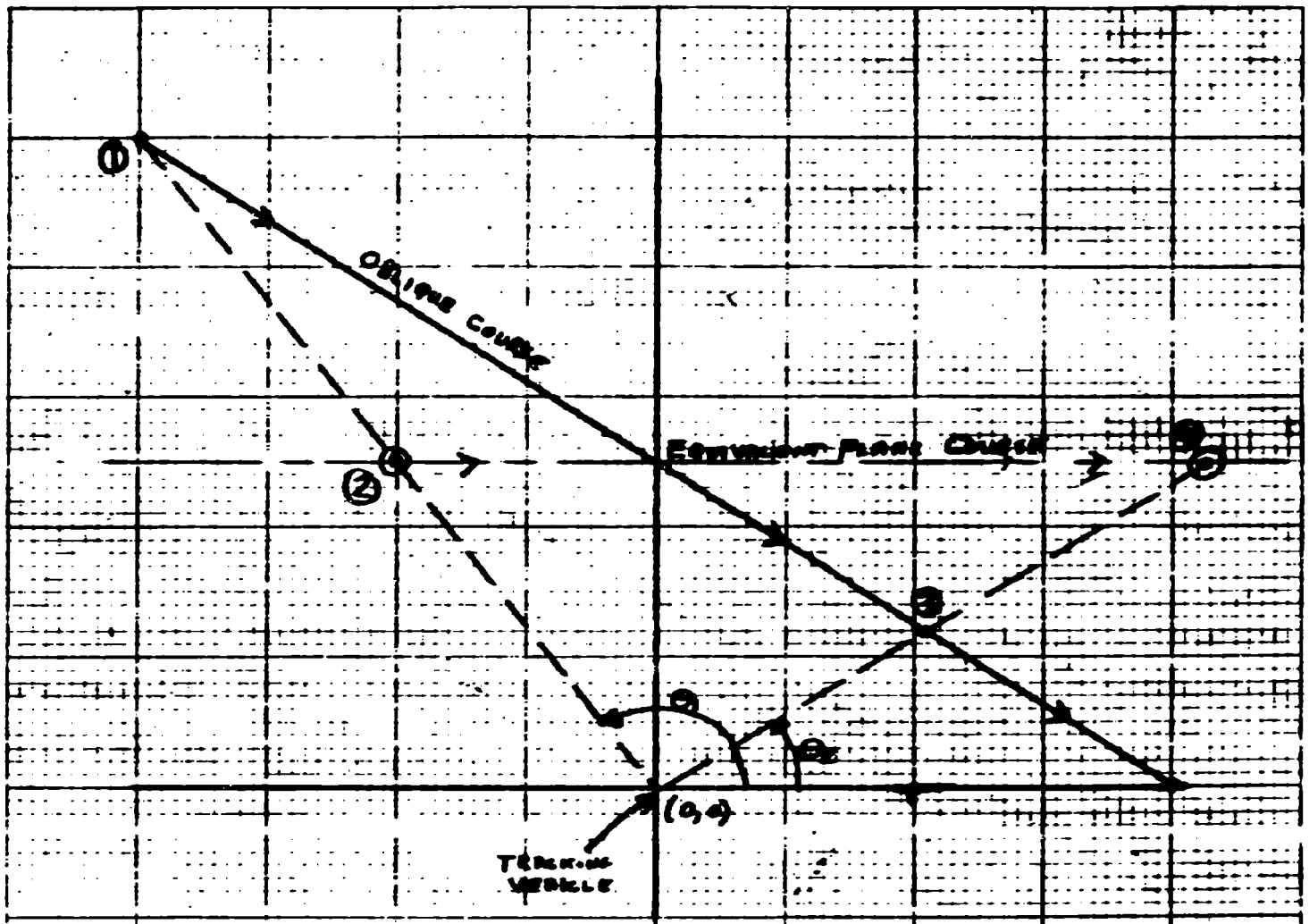
2. APPROACH TO THE PROBLEM:

a. An analytical formulation of the problem was investigated. An attempt was made to express θ, the angle from the tracking vehicle to the target, in Polar coordinate form as a function of the target's acceleration, initial position, and time given in Cartesian (X, Y) coordinate form. The second derivative of θ with respect to time is the apparent acceleration (expressed in radians/second squared) of the target relative to the tracking vehicle.

This approach yielded a rather "messy" formulation of the apparent acceleration, one which would require additional work to solve.

b. The approach used to generate the results was to design a computer program which generates the value of θ, $\Delta\theta$, and Δ_θ for "small" time increments along the path of a moving target. The current program is capable of generating results for any target movement speed, acceleration, deceleration combinations at any specified Y-range from the tracking vehicle and any specified starting point in the X-direction.

NOTE: The program represents all target vehicles as moving with a constant Y-distance from the tracking vehicle (flank). Other target vehicle movement directions (such as oblique, sinusodial, etc.) can be represented by determining the equivalent values of θ for the crossing course and adjusting the speeds and acceleration inputs appropriately. An example of the equivalence is shown in Figure 1. Note that by appropriate inputs of acceleration and starting position on the crossing course, the oblique course is exactly represented as it relates to apparent acceleration of the target vehicle. Obviously, other hit probability considerations regarding agility and direction of movement are not considered in this analysis.



EQUIVALENCE OF OBLIQUE AND PLANE COURSE IN
IN APPARENT ACCELERATION
FIGURE 1

3. ANALYSIS OF THE PROBLEM

Apparent acceleration and apparent velocity analyses conducted to date are presented in Exhibits 1 thru 12 attached. These cases are briefly described below.

a. Exhibits 1 thru 4 describe the apparent acceleration (apparent velocity described in Exhibits 1A thru 4A) for an acceleration in the X direction of one meter/second^2. Each exhibit presents the results of apparent acceleration (velocity) versus time for five ranges (500, 1000, 2000, 3000, and 4000 meters in the Y direction) for a specified target starting point.

Four target starting points form the basis for each exhibit:

1) Start to the extreme left of the tracking vehicle,

2) Start such that the target vehicle crosses X = 0 at the mid-point of his movement,

3) Start at X = 0 and move right,

4) Start to the extreme right of the tracking vehicle.

NOTE: Each of the runs made for Exhibits 1 thru 8 was terminated when the target vehicle reached a maximum velocity, VMAX, specified by input to the program for each case.

b. Exhibits 5 thru 8 present apparent acceleration results analogous to Exhibits 1 thru 4 except that the target vehicle is accelerating in the X direction at two meters/second^2. (No apparent speed curves are presented for these cases).

c. Exhibit 9 presents a description of apparent acceleration versus time for three accelerations of the target vehicle (one, two, and four meters per second^2) at a Y-range of 3000 meters.

d. Exhibit 10 presents an analogous description to Exhibit 9 for a Y-range of 1000 meters.

e. Exhibits 11 (for apparent acceleration) and 12 (for apparent velocity) present the acceleration (or velocity) versus time for the following cases at a Y-range of 2000 meters and a crossing target pattern analogous to Exhibit 2:

(1) Accelerate at two meters/second^2 from an initial velocity of zero to 32 meters/second and maintain a 32 meter/second constant velocity for the duration of the 50 second run;

(2) Start at and maintain a constant velocity of 25 meters/second for the 50 second run;

(3) Start at an initial velocity of 10 meters/second, accelerating at 2 meters/second for 5 seconds, then decelerating at 2 meters/second for 5 seconds, and continuing this pattern for 50 seconds.

4. CONCLUSIONS

a. No attempt has been made by the writers to draw any conclusions from the analyses presented herein.

b. Additional analyses will require specifications of the interaction of apparent acceleration and velocity of the target vehicle to the tracking vehicle with other factors contributing to probability of hit (and ultimately to survivability) of the target vehicle.

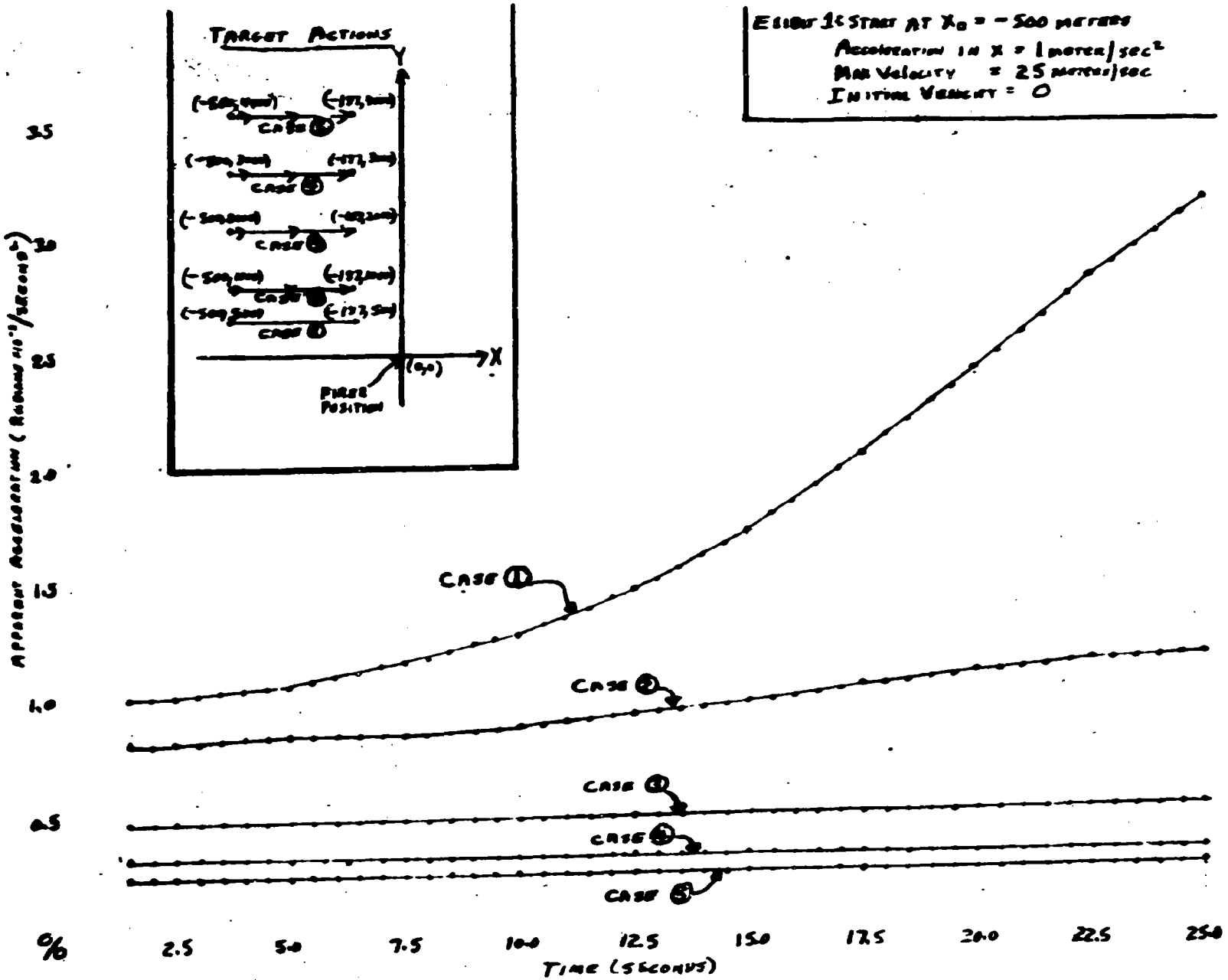


Exhibit 1c Start at X_0 = −500 meters
Acceleration in X = 1 meter/sec²
Max Velocity = 25 meters/sec
Initial Velocity = 0
Target Actions
Y
X
(0,0)
Fire Position
Case 1
Case 2
Case 3
Case 4
Case 5
Apparent Acceleration (Radians ×10⁻³/Second²)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
%
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0
Time (Seconds)

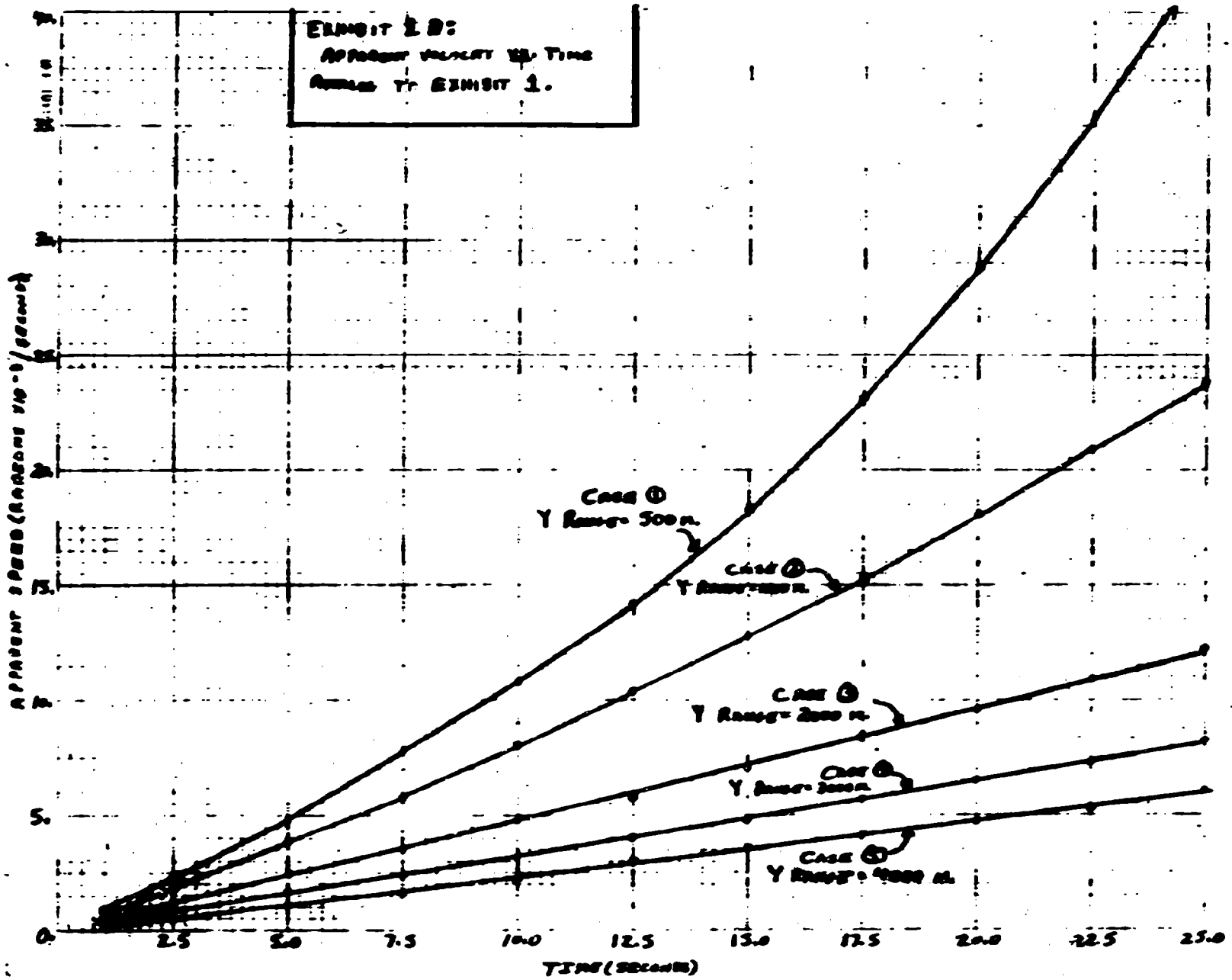


EXHIBIT 1 B:
APPARENT VELOCITY VS. TIME
ANALOG TO EXHIBIT 1.
CASE ①
Y RANGE = 500 M.
CASE ②
CASE ③
CASE ④
CASE ⑤
APPARENT SPEED (RADIANS X10⁻³/SECOND)
TIME (SECONDS)
0.
5.
10.
15.
20.
25.
30.
35.
40.
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0

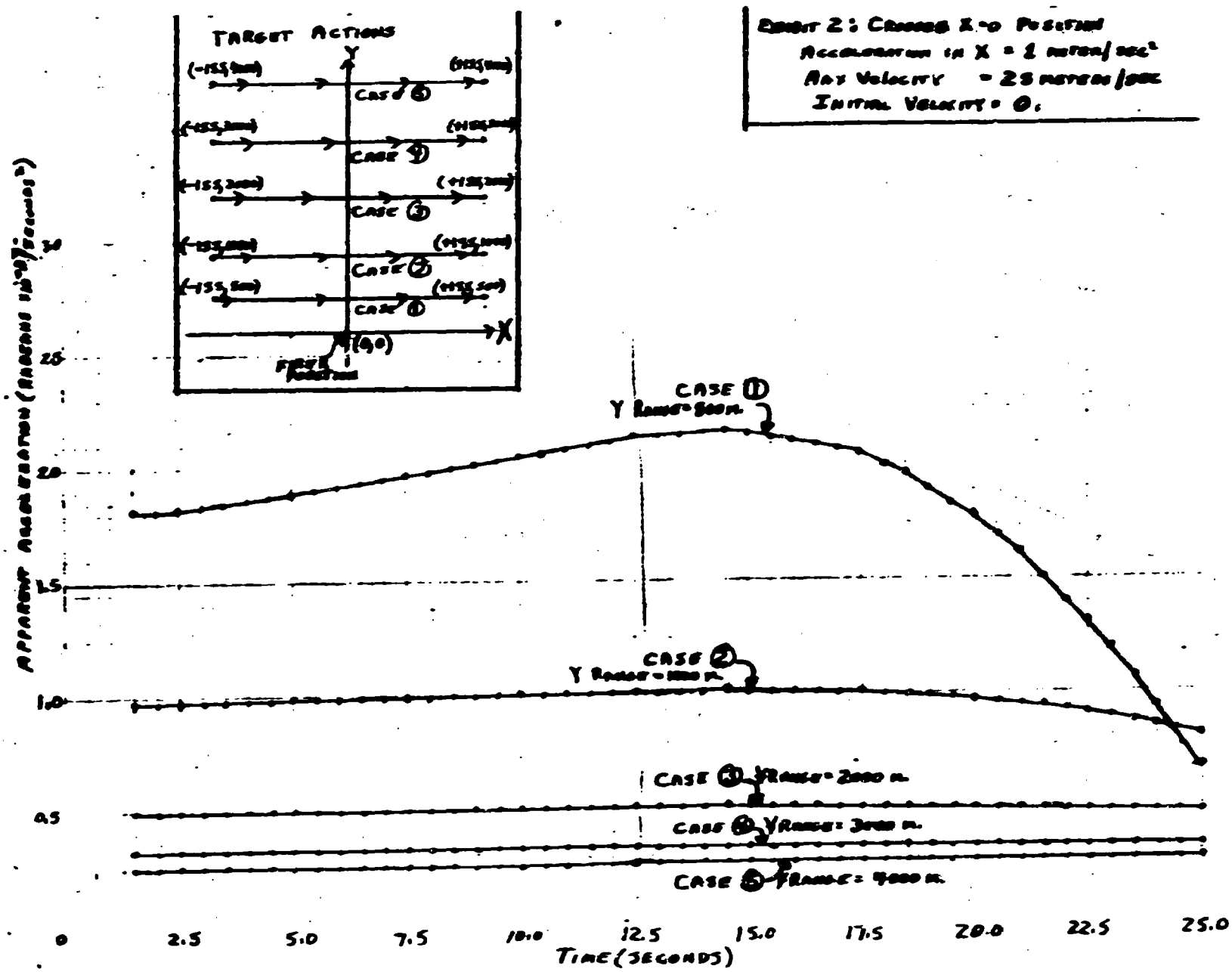


EXHIBIT 2: CROSSING X-0 POSITION
ACCELERATION IN X = 1 METER/SEC²
MAX VELOCITY = 25 METERS/SEC
INITIAL VELOCITY = 0.

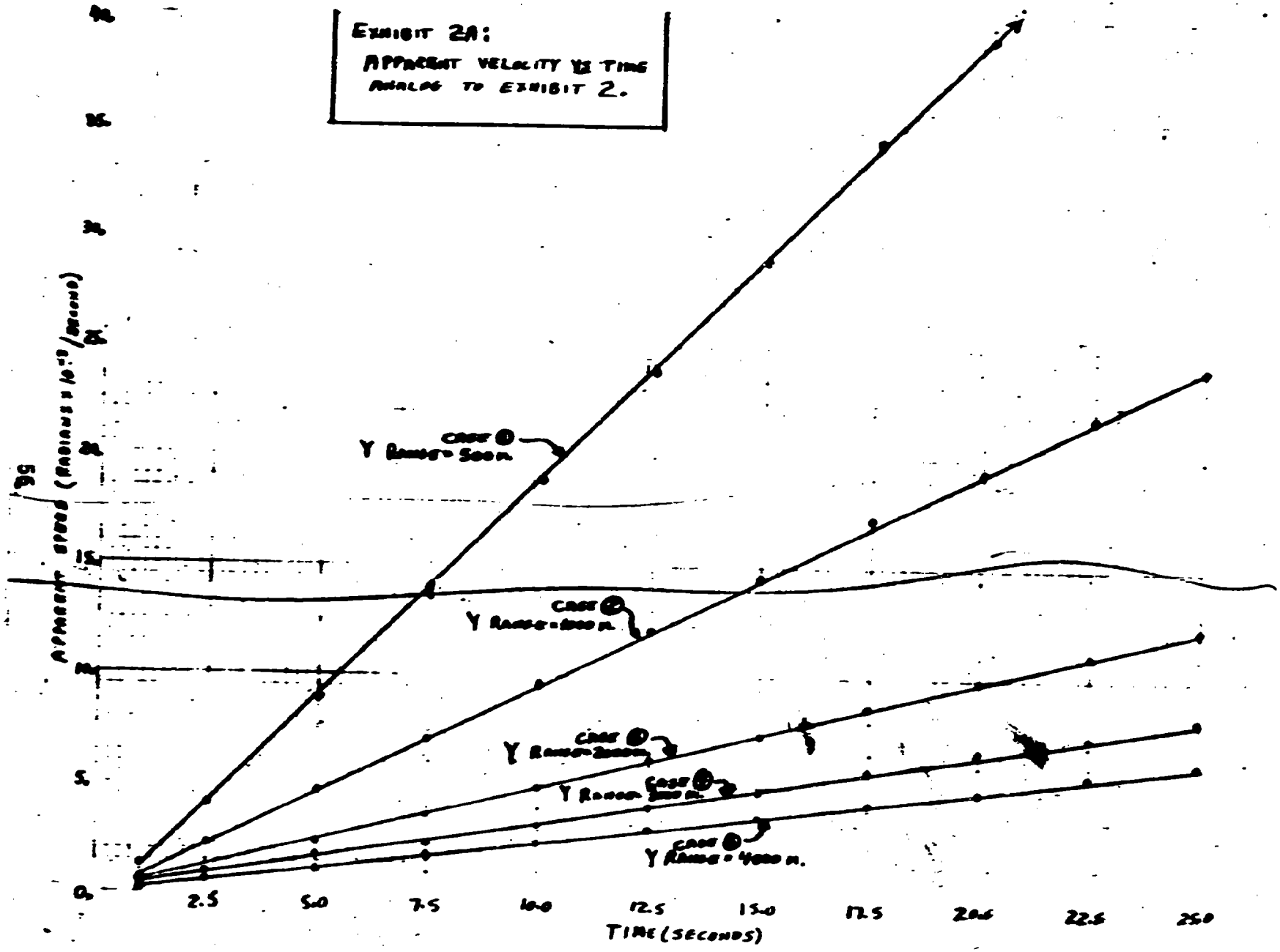


EXHIBIT 2A:
APPARENT VELOCITY VS TIME
ANALOG TO EXHIBIT 2.
APPARENT SPEED (RADIANS x 10^-3/SECOND)
TIME (SECONDS)
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0
0
5
10
15
20
25
30
35
40
Y RANGE = 500 M.
Y RANGE = 1000 M.
Y RANGE = 4000 M.

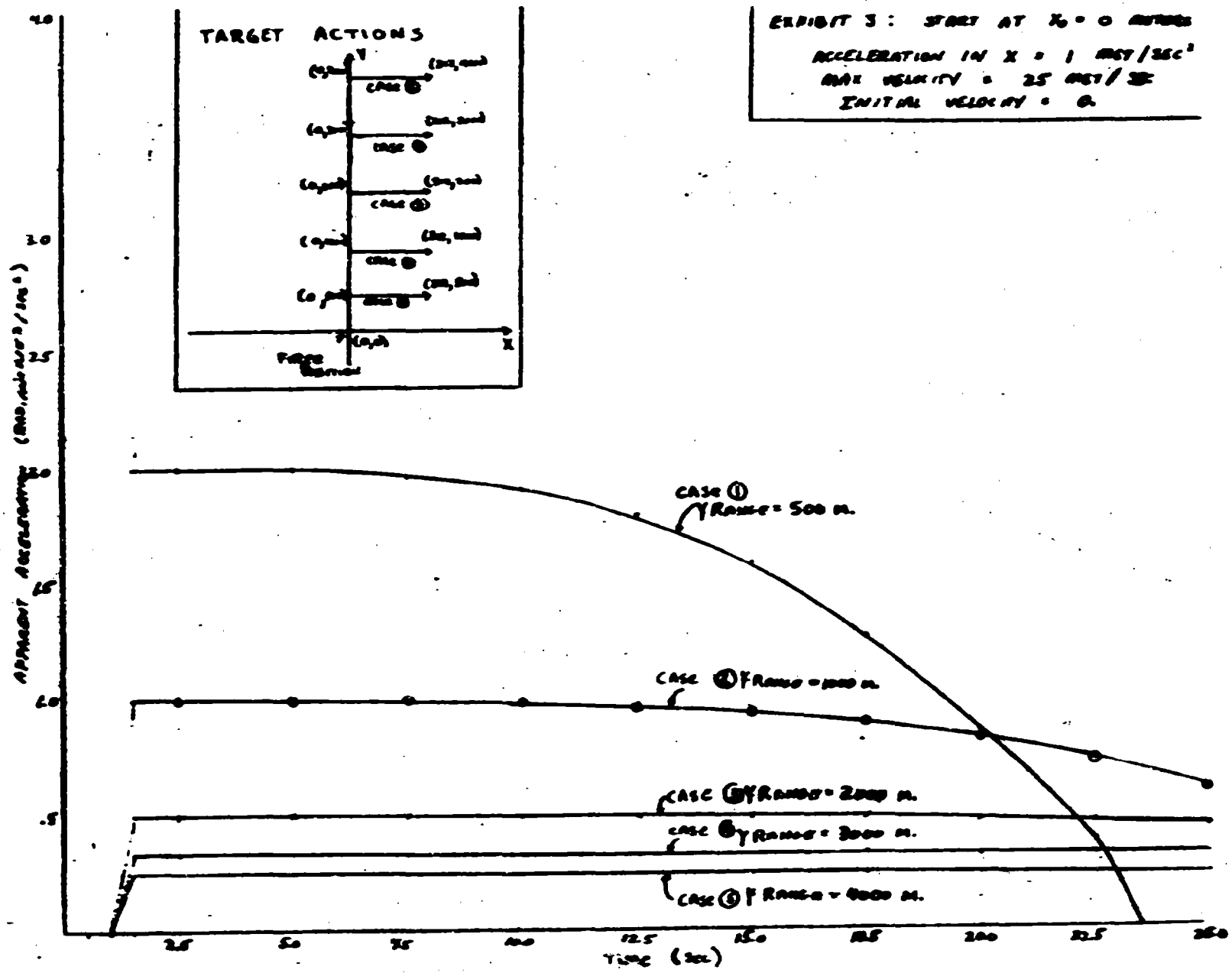


EXHIBIT 3: START AT X_0 = 0 METERS
ACCELERATION IN X = 1 MET/SEC²
MAX VELOCITY = 25 MET/SEC
INITIAL VELOCITY = 0.
TARGET ACTIONS
CASE ①
CASE ②
CASE ③
CASE ④
CASE ⑤
FIRE POSITION
CASE ① Y RANGE = 500 M.
CASE ② Y RANGE = 1000 M.
CASE ③ Y RANGE = 2000 M.
CASE ④ Y RANGE = 3000 M.
CASE ⑤ Y RANGE = 4000 M.
APPARENT ACCELERATION (RADIANS/SEC²)
TIME (SEC)
4.0
3.0
2.5
2.0
1.5
1.0
.5
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0

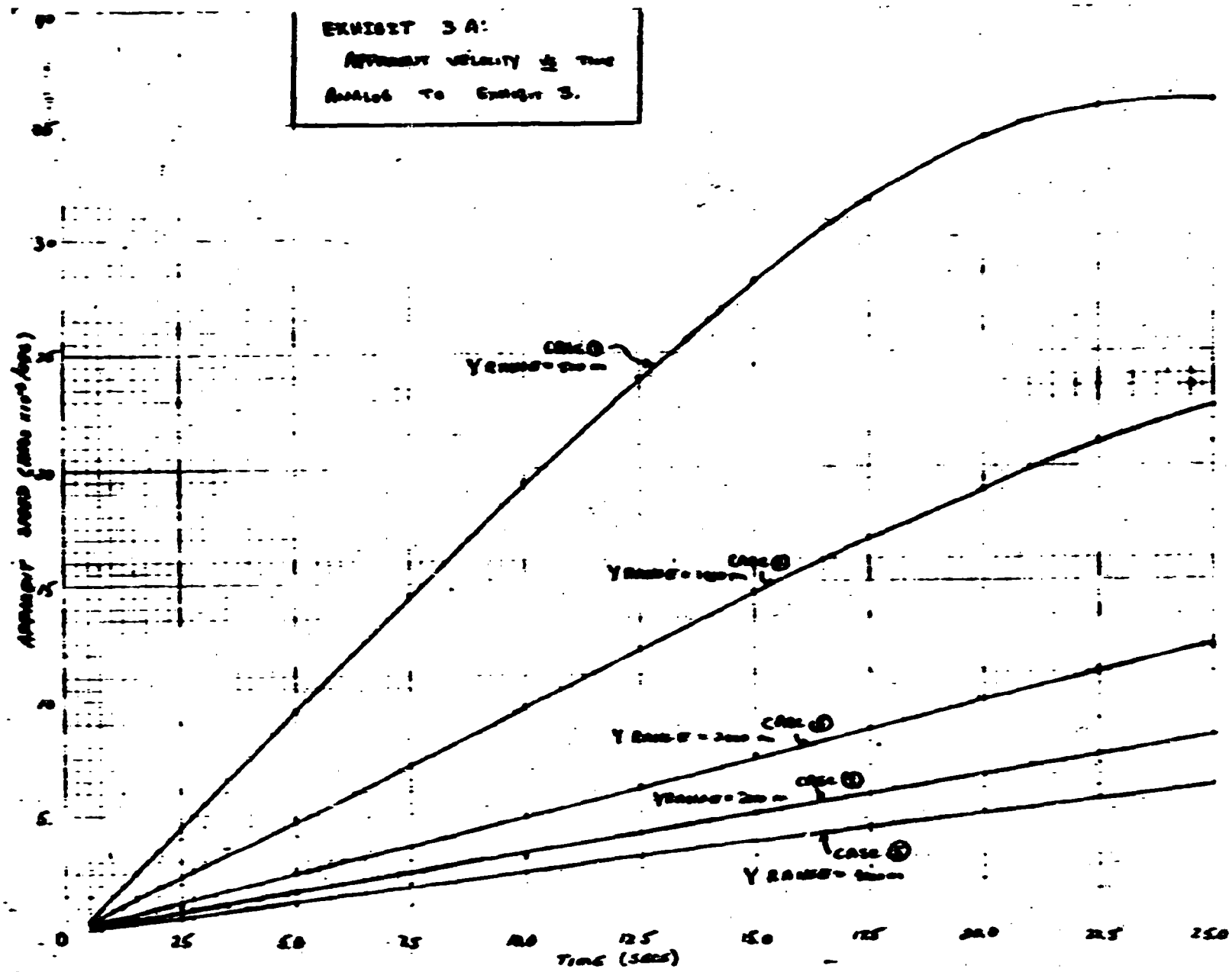


EXHIBIT 3 A:
APPROACH VELOCITY vs TIME
ANALOG TO EXHIBIT 3.
APPROACH SPEED
TIME (SECS)
0
25
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0
5
10
15
20
25
30
35
40
CASE ①
CASE ②
CASE ③
CASE ④
CASE ⑤

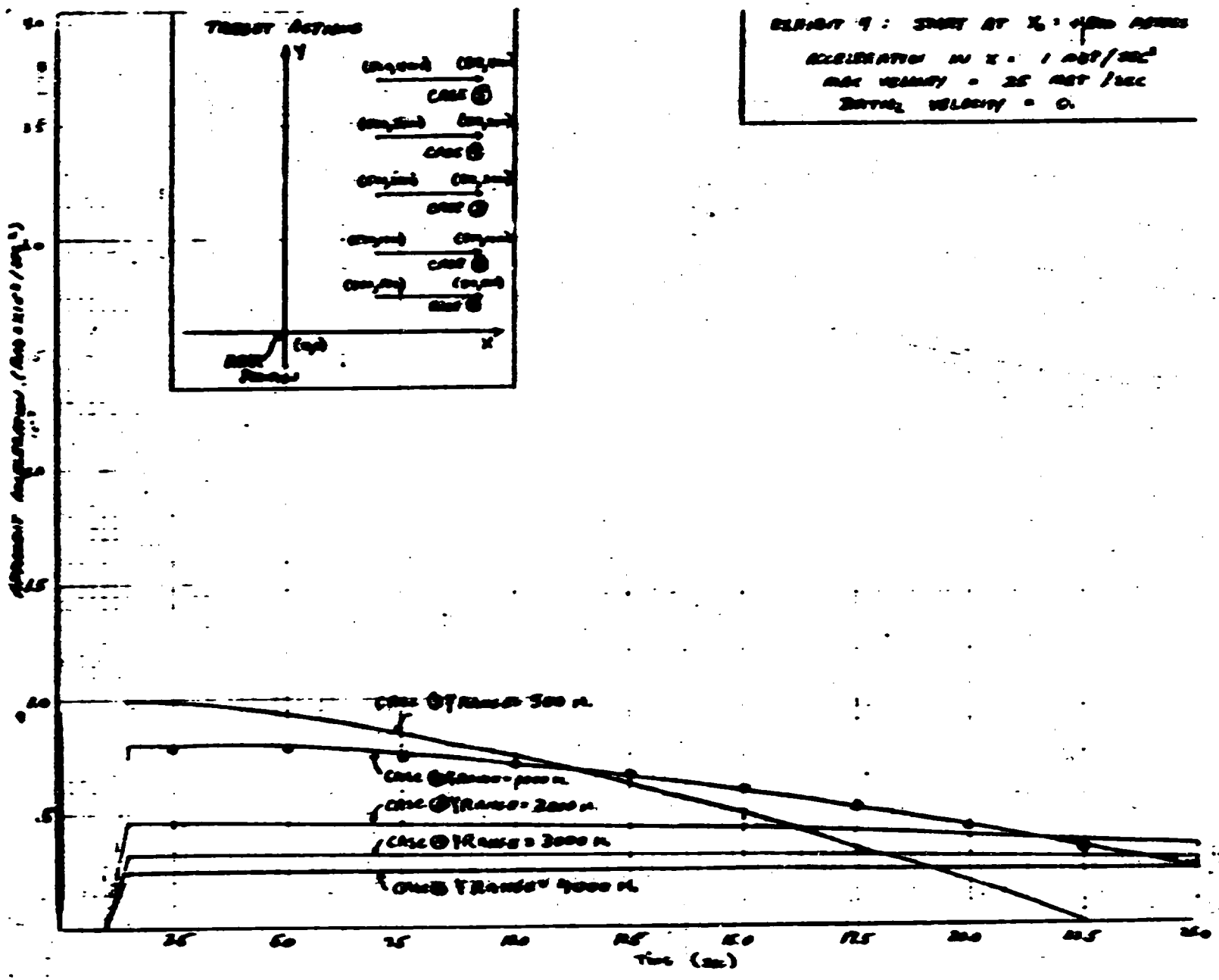


EXHIBIT 9 : START AT X_0 = [illegible] METERS
ACCELERATION IN X = 1 MET/SEC²
MAX VELOCITY = 25 MET/SEC
DIVING_2 VELOCITY = 0.

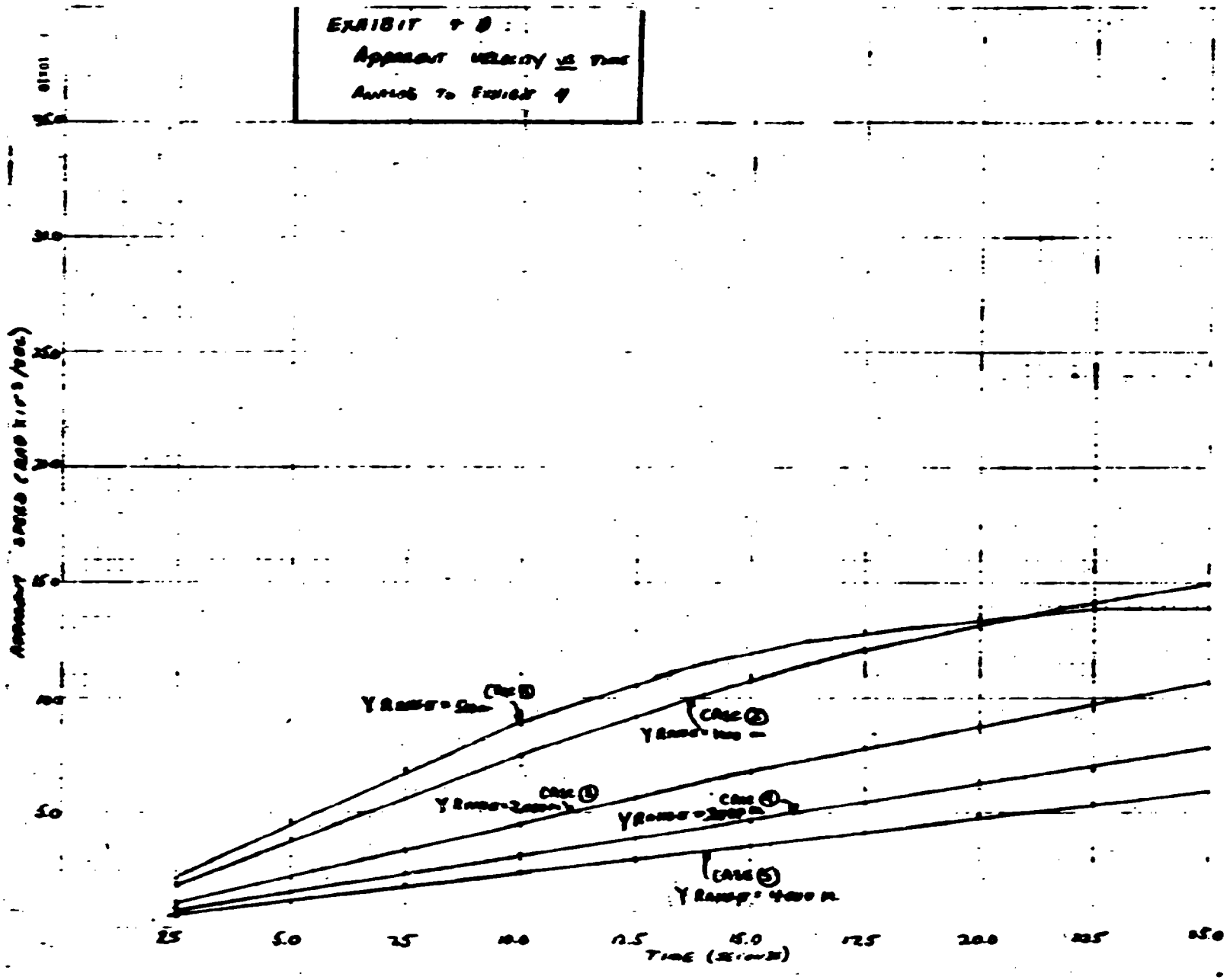


EXHIBIT # 8 :
Apparent velocity vs time
Analog to Exhibit 4
Apparent speed (rad x 10^-3/sec)
Time (seconds)
Y Range = 500 m
Case 1
Case 2
Case 3
Case 4
Case 5
Y Range = 4000 m
5.0
10.0
15.0
20.0
25.0
30.0
35.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0

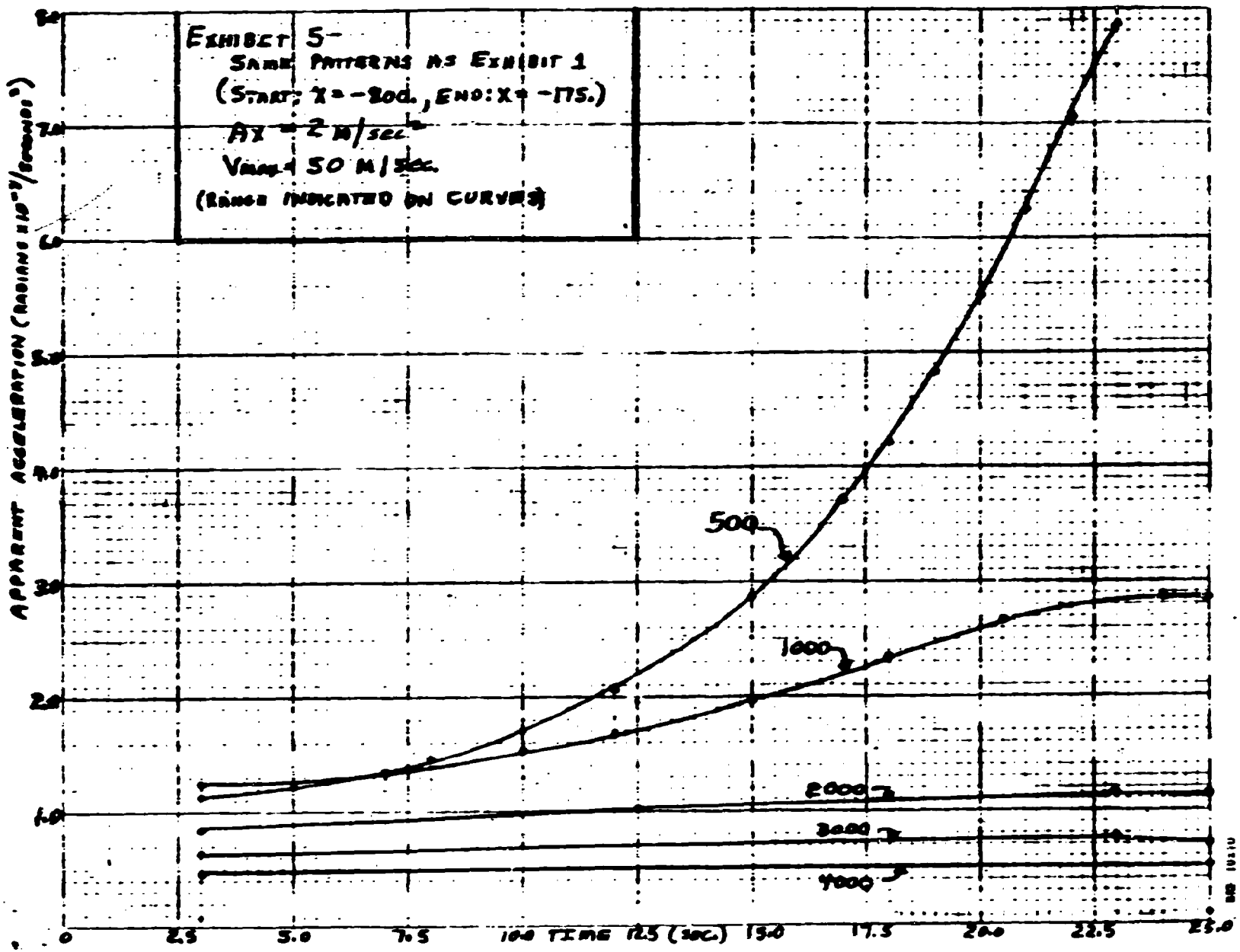
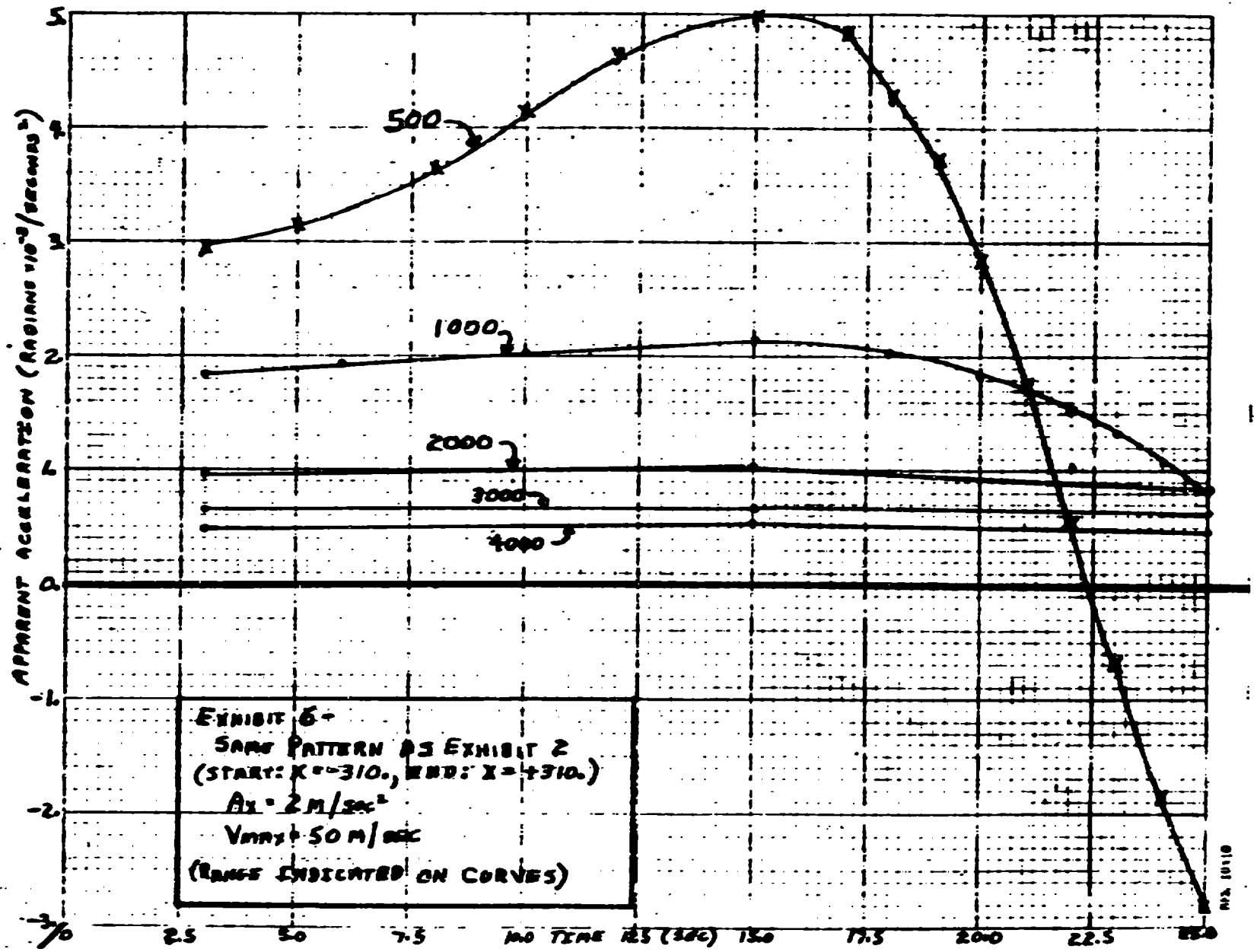
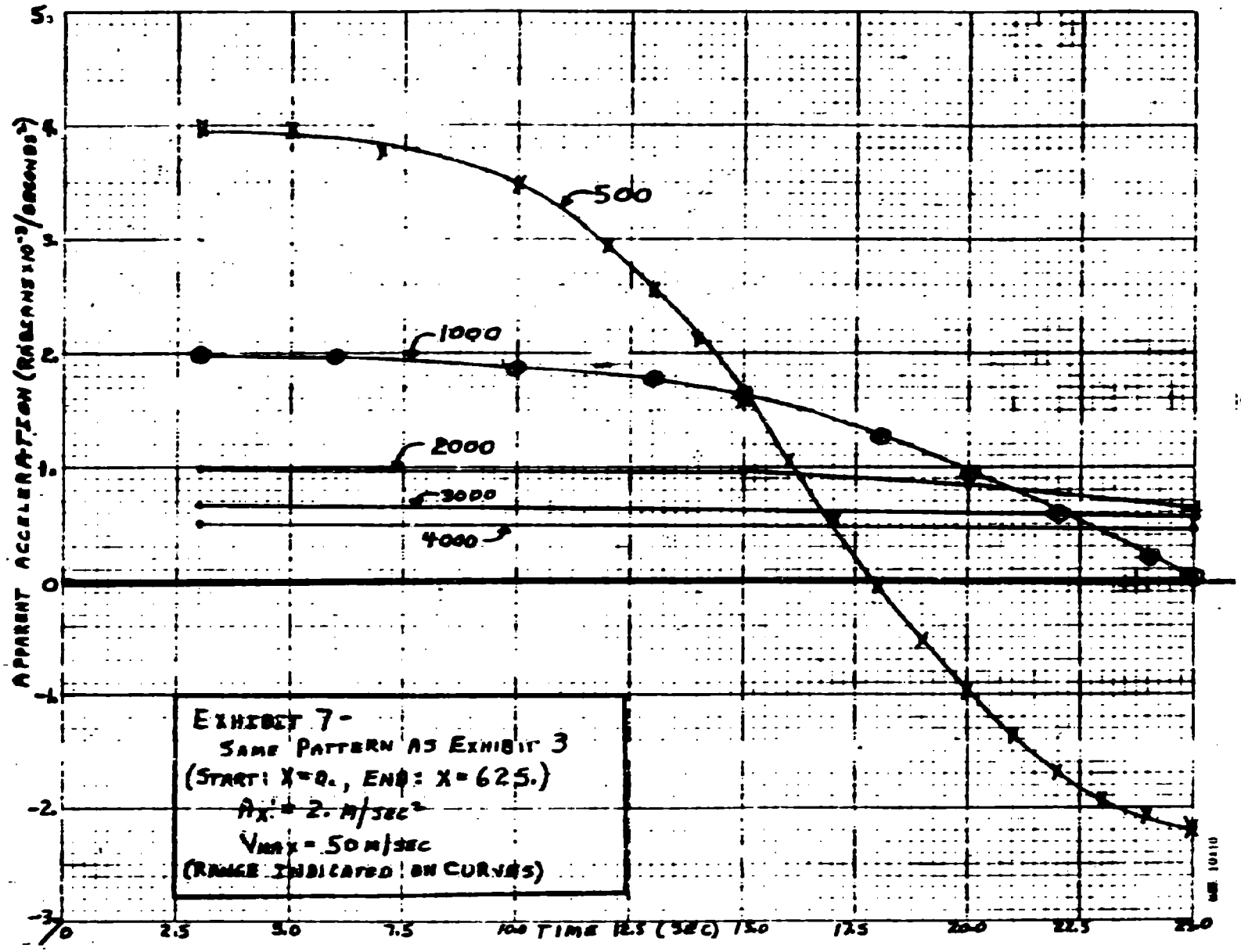
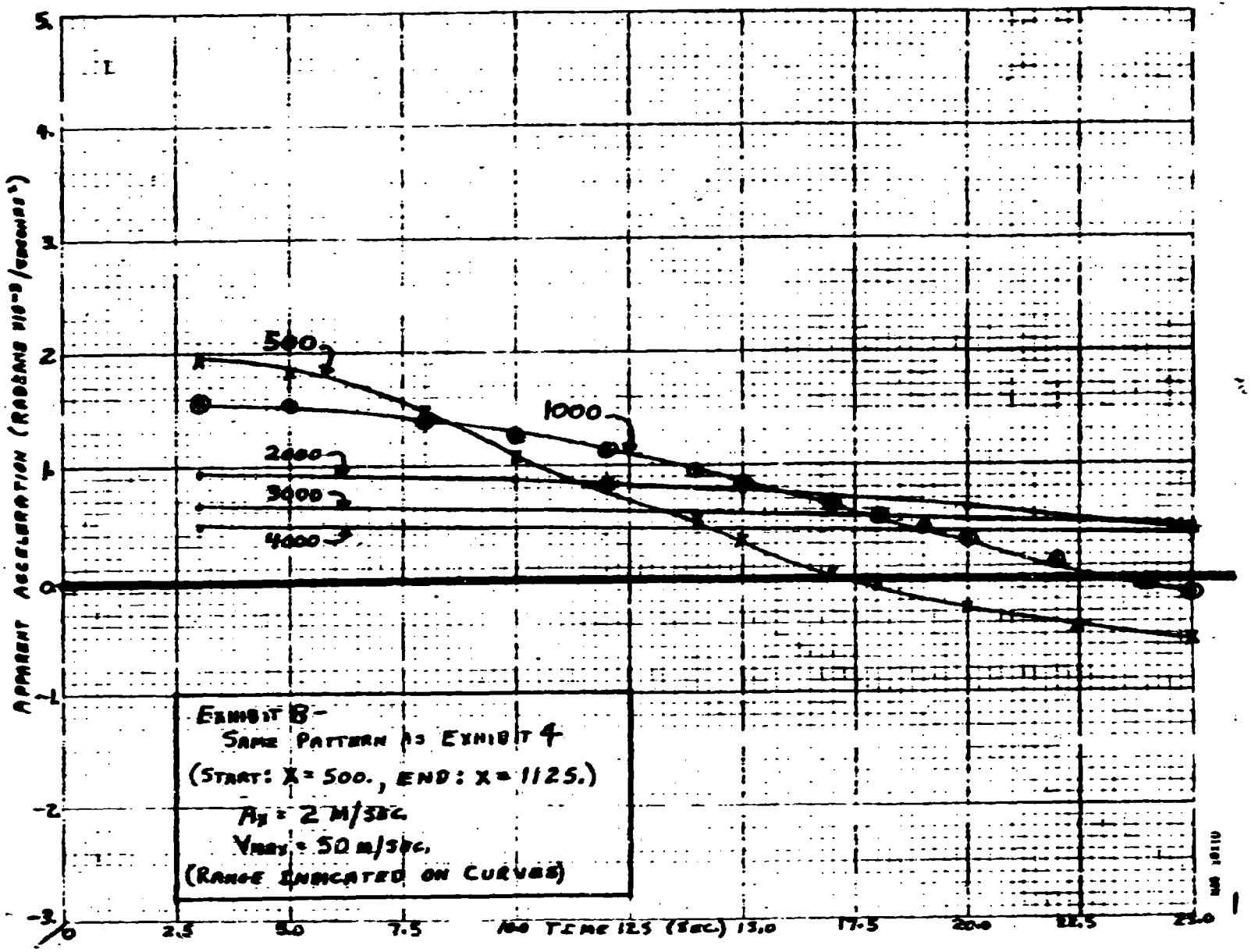


EXHIBIT 5-
SAME PATTERNS AS EXHIBIT 1
(START: X = -200., END: X = -175.)
AX = 2 M/SEC²
VMAX = 50 M/SEC.
(RANGE INDICATED ON CURVES)
APPARENT ACCELERATION (RADIANS ×10⁻⁶/SECONDS²)
TIME (SEC.)
0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
500
1000
2000
3000
4000


APPARENT ACCELERATION (RADIANS x10^-3/SECONDS^2)
5
4
3
2
1
0
-1
-2
-3
500
1000
2000
3000
4000
0
2.5
5.0
7.5
10.0
TIME (SEC)
15.0
17.5
20.0
22.5
25.0
EXHIBIT 6 -
SAME PATTERN AS EXHIBIT 2
(START: X = -310., END: X = +310.)
Ax = 2 M/SEC^2
VMAX = 50 M/SEC
(RANGE INDICATED ON CURVES)


APPARENT ACCELERATION (RADIANS x10^-2/SECONDS^2)
5
4
3
2
1
0
-1
-2
-3
0
2.5
5.0
7.5
10.0
TIME (SEC)
12.5
15.0
17.5
20.0
22.5
25.0
500
1000
2000
3000
4000
EXHIBIT 7 -
SAME PATTERN AS EXHIBIT 3
(START: X=0., END: X=625.)
Ax = 2. M/SEC^2
VMAX = 50 M/SEC
(RANGE INDICATED ON CURVES)


APPARENT ACCELERATION (RADIANS X10^-3/SECONDS^2)
5
4
3
2
1
0
-1
-2
-3
0
2.5
5.0
7.5
10.0 TIME 12.5 (SEC.) 15.0
17.5
20.0
22.5
25.0
500
1000
2000
3000
4000
EXHIBIT 8 -
SAME PATTERN AS EXHIBIT 4
(START: X = 500., END: X = 1125.)
Ay = 2 M/SEC
VMAX = 50 m/sec.
(RANGE INDICATED ON CURVES)

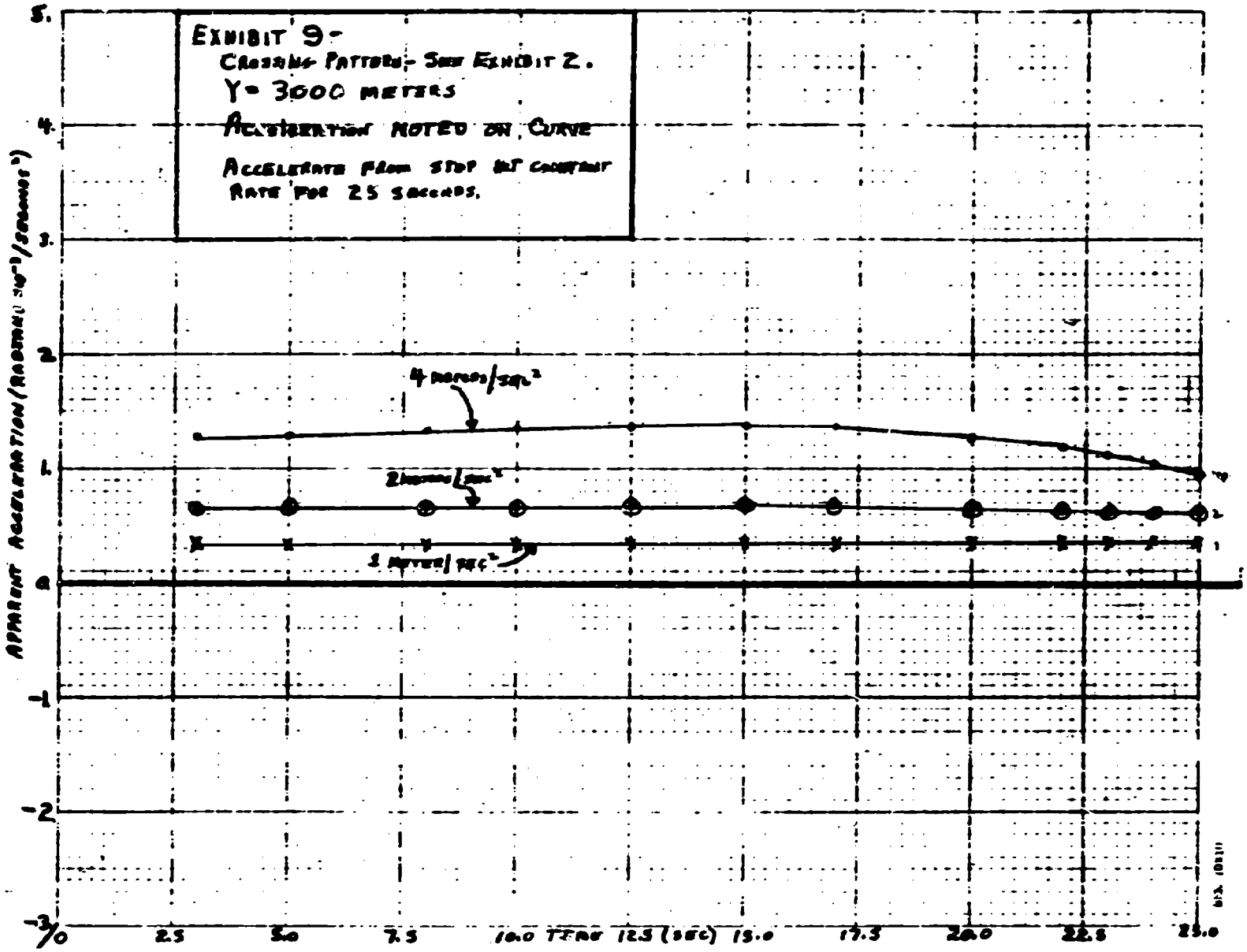
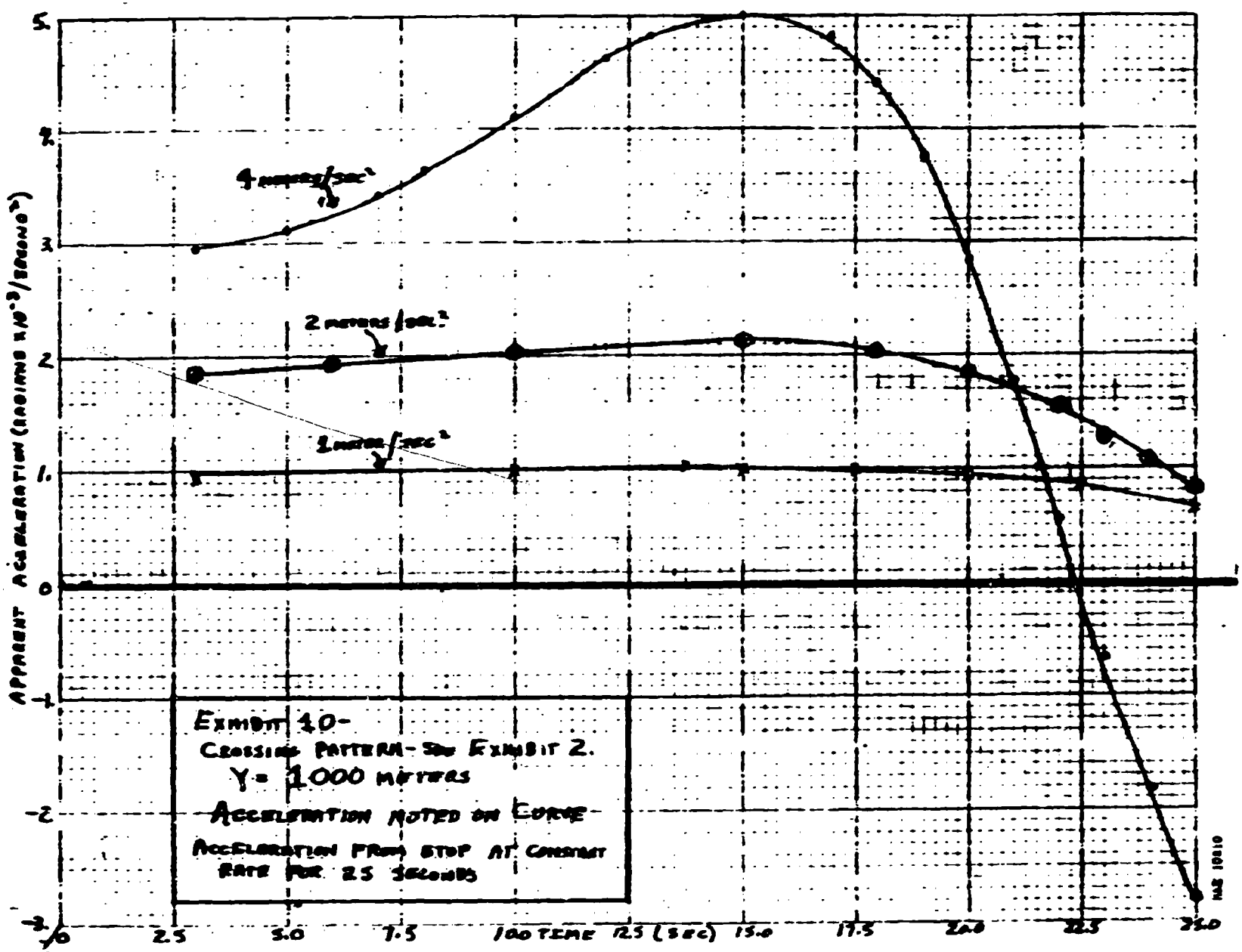


EXHIBIT 9 -
CROSSING PATTERN - SEE EXHIBIT 2.
Y = 3000 METERS
ACCELERATION NOTED ON CURVE
ACCELERATE FROM STOP AT CONSTANT RATE FOR 25 SECONDS.
4 METERS/SEC²
2 METERS/SEC²
1 METER/SEC²
APPARENT ACCELERATION (METERS/SEC²)
5.
4.
3.
2
1.
0
-1
-2
-3
0
2.5
5.0
7.5
10.0 TIME 12.5 (SEC) 15.0
17.5
20.0
22.5
25.0



APPARENT ACCELERATION (RADIANS x10^-3/SECOND^2)
5
4
3
2
1
0
-1
-2
-3
0
2.5
5.0
7.5
10.0 TIME
12.5 (SEC)
15.0
17.5
20.0
22.5
25.0
4 METERS/SEC^2
2 METERS/SEC^2
1 METER/SEC^2
EXHIBIT 10-
CROSSING PATTERN - SEE EXHIBIT 2.
Y = 1000 METERS
ACCELERATION NOTED ON CURVE
ACCELERATION FROM STOP AT CONSTANT RATE FOR 25 SECONDS

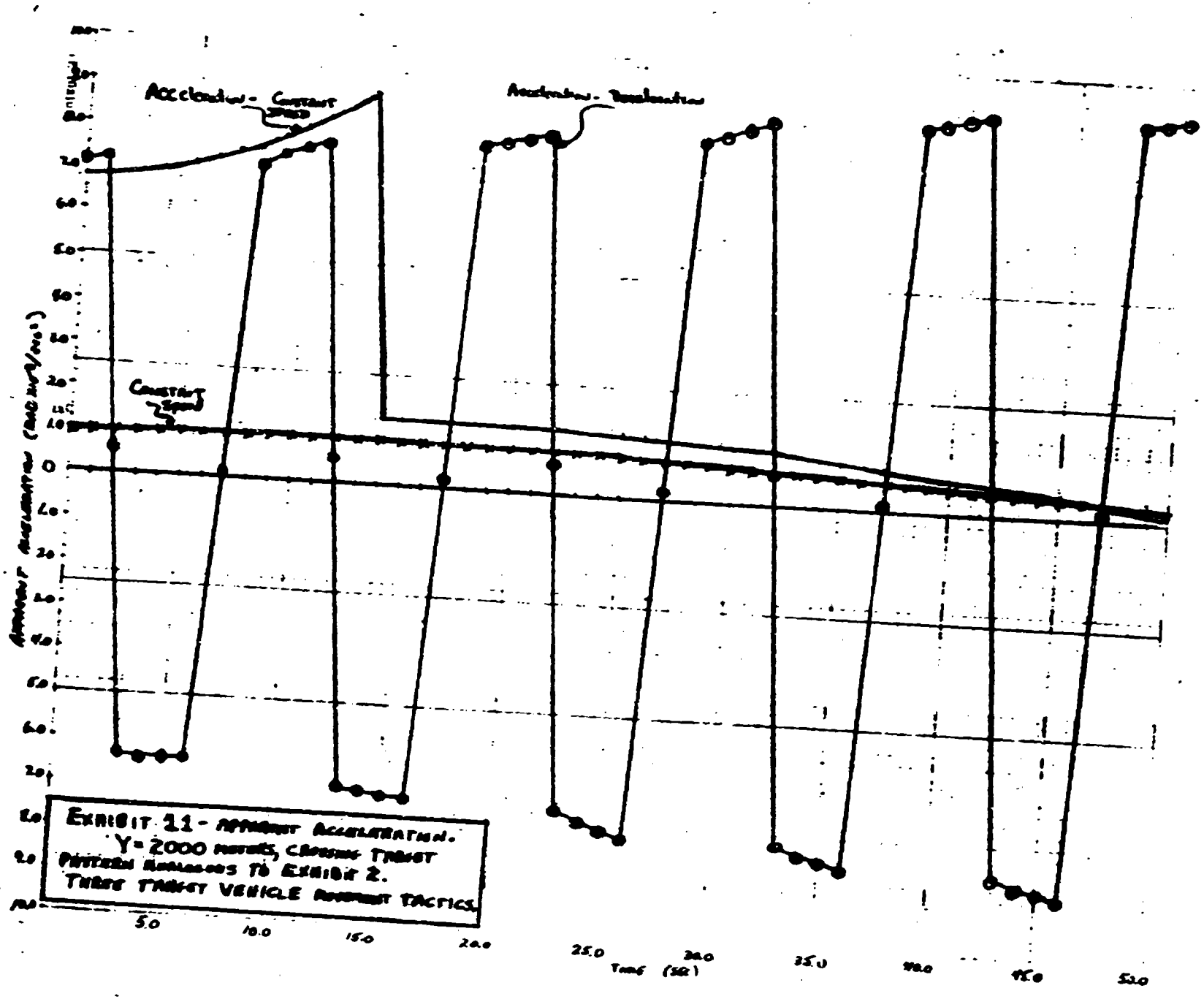


EXHIBIT 11 - APPARENT ACCELERATION.
Y = 2000 METERS, CLOSING TARGET
PATTERN RESPONSES TO EXHIBIT 2.
THREE TARGET VEHICLE EVASIVE TACTICS.

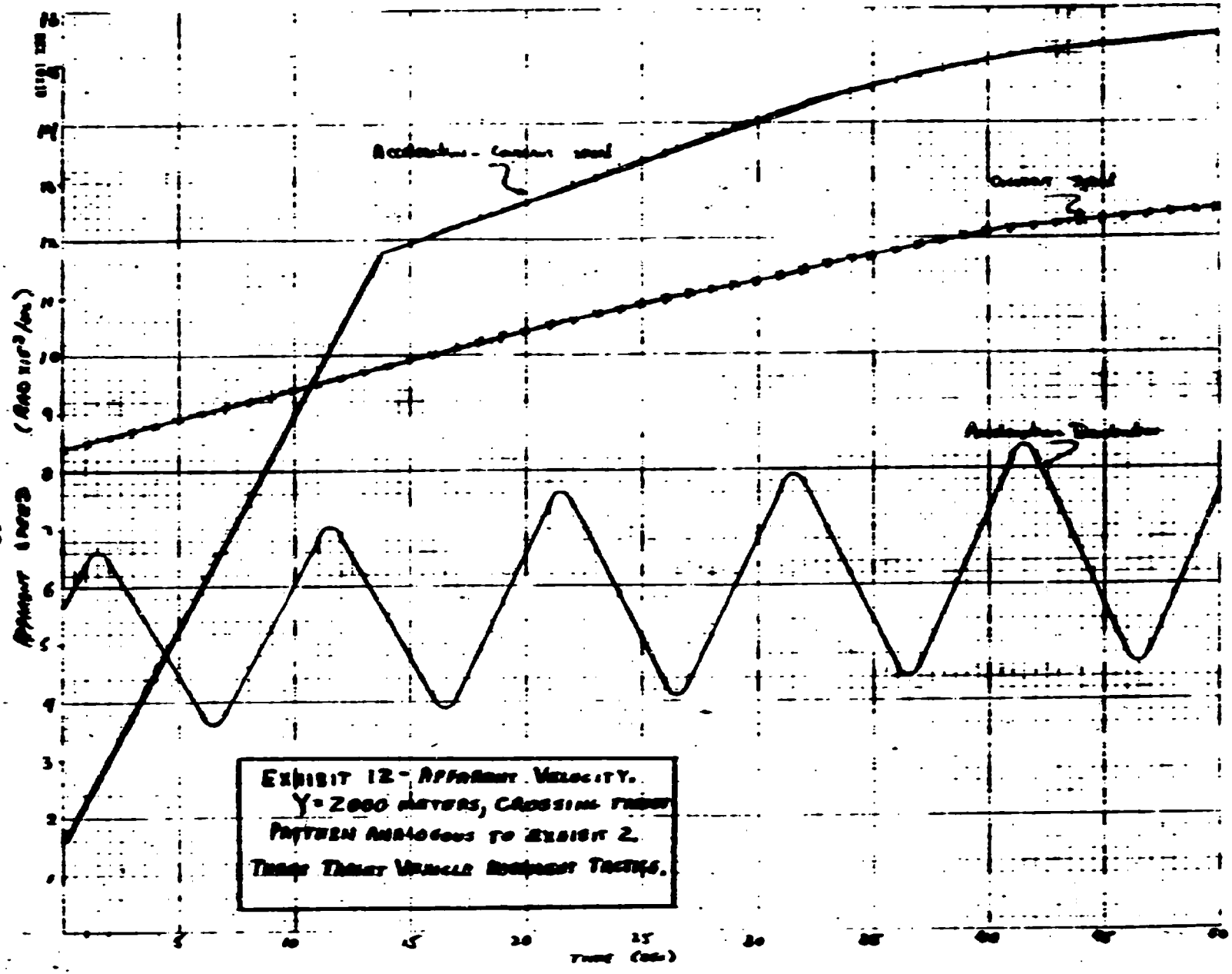


EXHIBIT 12 - APPARENT VELOCITY.
Y = 2000 METERS, CROSSING TARGET
PATTERN ANALOGOUS TO EXHIBIT 2.
THREE TARGET VEHICLE MOVEMENT TACTICS.

7. ANALYSIS OF APPARENT ACCELERATION AND APPARENT VELOCITY OF A MOVING TARGET (Part II)

INTRODUCTION

The analyses presented in this paper represent a substantial extension of the cases considered in the initial report dated 24 July 1975. The current version of the program to compute apparent acceleration and velocity (hereafter referred to as PAPA) is capable of representing a moving target in the following modes (see Section III for a complete description of PAPA).

1. The target may move at any speed, accelerating and decelerating in any specified manner along the movement trace.

2. The target can move along a straight line path in any direction relative to the firer.

3. The target can move along a sinusodial path oriented in any direction, with the capability of changing the amplitude for each full period of the sine wave.

4. The target can move in three dimensions (straight line in the X-Y plane) varying the heighth in any specified manner along the movement trace. This model is well suited to representing aerial vehicle movement.

Over sixty production runs were made for the current study. Only a few selected runs are graphically portrayed in Section II.B. These runs were selected to indicate the magnitude of the differences in apparent acceleration and velocity for various courses, speeds, and tactics. A table indicating all of the production runs made is given in Section II.A.

In general, cases were selected to indicate the effects of target speeds and accelerations for specified courses and movement patterns (Figures 1 - 7 in Section II.B.) Next, cases were selected to indicate the effects of target movement patterns for specified courses and target speeds (Figures 8 - 13 in Section II.B.)

OBSERVATIONS AND CONCLUSIONS

1. As of this time, no actual tracking data has been received, although I should be receiving some in the near future. Note, however, that tracking data (from HEL) is based on constant speed, straight line targets, which present minimal tracking problems relative to apparent acceleration and velocity. In general, I question whether or not tracking data obtained on the ranges for constant speed, straight line targets indicate realistic tracking performance for combat situations.

2. The following observations are made relative to Figures 1 - 7 in Section II.B. (with target speed and acceleration as the variable on each graph).

NOTE: The reader should be careful to note that the vertical scales for each graph differ significantly in many cases.

a. The general shape of the curves are the same for 2,500 and 1,000 meter flank view (as expected). Two primary differences are noted:

(1) The maximum (and minimum) values are 2:1 for 1,000 vs 2,500 meter range, straight line route and 3:1 for sinusodial pattern.

(2) The changes from accelerating to decelerating (and vice versa) are more abrupt for the closer ranges.

NOTE: As always, we are faced with the decision as to what magnitude of change is significant. I am hopeful that the STAGS Test will provide data to shed light on this problem. I have covered this point later and also in my proposal for future work.

b. The sinusodial pattern results in very changeable apparent acceleration curves, even for constant speed targets (see Figures 4A and 5A). The associated apparent velocity curves, especially for the closer range case, would appear to present a severe tracking problem. Note, from Figure 5A, that the target movement pattern (sinusodial) causes large changes in apparent acceleration. The effect of the faster speed compresses the curve, but even M60 speed (Case 2B) may present a significant tracking problem.

c. Consider the head-on case in Figures 6A and 6V. First, note that PAPA determines and prints out each time the turret changes directions (see Figure 6V and the sample output in Section III). It appears to me that the firer would have a very difficult time tracking the faster vehicle, especially considering the frequency with which the turret must pass through the zero point (every 5 seconds against the fast A/D vehicle).

3. The following observations are made relative to Figures 8 - 13 in Section II.B. (with target movement pattern as the variable on each graph).

a. The sinusodial pattern in Figure 8A (2,500 meters - flank for the M60) indicates a somewhat more difficult target to track. We must keep in mind, however, that all of the curves represent tracking required to stay on the target 100 percent of the time. This fact brings up a very important (and unanswered) question: How much degradation in probability of hit results as a function of the percentage of time the tracker is actually laying on the target during the tracking period? Also, when will the gunner cease to track and employ ambush tactics, and what is the resulting degradation in hitting performance?

b. The sinusodial pattern in Figures 10A and 11A indicate the order of magnitude increase in apparent acceleration from a fast target that is maneuvering. This concept is obvious, but the order of magnitude difference was not obvious (at least to the writer).

c. In my opinion, the futility of obtaining tracking data (at least as regards apparent acceleration and velocity) only for constant speed, straight line targets is vividly illustrated in Figures 12A, 12V, 13A, and 13V. Note the impact on apparent acceleration for a target moving in a sinusodial vs straight line pattern for a constant speed target of 15 meters/second.

PROGRAM APPLICATIONS AND FUTURE STUDIES

1. Several future applications for PAPA, especially regarding the STAGS Test data, are proposed in MFR, SAM H. PARRY, 27 August 1975.

2. The program may be useful in determining design characteristics for future turret and fire control systems.

3. The program can be used in conjunction with existing lead angle determination programs to analyze the desired characteristics of a lead computer in the fire control system.

4. The incorporation of intervisibility segment length data would indicate the amount of time (and distance) a tracker would have available for tracking. The appropriate segments of the apparent acceleration and velocity curves could be used to analyze the feasibility of maintaining a reasonable track during the segment.

In my opinion, this paper scarcely scratches the surface of determining the effects of apparent acceleration and velocity on survivability. The one fact that seems apparent, however, is that mobility and agility must have a substantial impact on hitting performance. The utilization of PAPA, in conjunction with actual field data and as a potential tool for tank design analysis, seems to be indicated for future studies.

TABULATION OF COMPUTER RUNS

SECTION II.A

NOTATION FOR CASE NUMBERS - (TACTIC)

Case 1: Straight Line Movement
Case 2: Sinusodial Movement Path
Case 3: Three-Dimensional Movement Path

LETTERS FOLLOWING CASE NUMBERS - (COURSE)

A, AA, AAA: 2500 Meters - Flank View
B, BB, BBB: 1000 Meters - Flank View
C, CC, CCC: Straight-in Route - 1000 Meters Offset from Firer
D, DD, DDD: Straight-in Route - Directly Toward Firer
E, EE, EEE: Oblique Course Relative to Firer

NUMBER OF LETTERS FOLLOWING CASE NUMBERS - (SPEED)

Single Letter: Accelerates at 1 Meter/Second^2, decelerates at 2 Meters/Second^2, with speeds from 2 to 10 Meters/Second (Simulates M60 Tank).

Double Letter: Accelerates at 2 Meters/Second^2, decelerates at 3 Meters/Second^2, with speeds from 5 to 25 Meters/Second (Simulates Highly Mobile and Agile Vehicle).

Triple Letter: Constant Speed of 15 Meters/Second.

CASE 1: STRAIGHT LINE MOVEMENT

Case No.	XI	YI	XF	YF	VI	VMIN	VMAX	AA	AD	TINC
1A	-1000.	2500.	1000.	2500.	3.	2.	10.	1.0	-2.0	1.0
1B	-1000.	1000.	1000.	1000.	3.	2.	10.	1.0	-2.0	1.0
1C	1000.	2000.	1000.	0	3.	2.	10.	1.0	-2.0	1.0
1D	0.	2000.	0.	0.	3.	2.	10.	1.0	-2.0	1.0
1E	-500.	2000.	500.	0.	3.	2.	10.	1.0	-2.0	1.0
1F	-2000	2500	2000	2500	50.	40.	60.	0.	0.	1.
1G	-2000.	1000.	+2000	1000	50	40	60	0.	0.	1.
1H	1000.	4000.	1000.	0.	50.	40.	60.	0.	0.	1.
1I	-1000.	2500	1000.	0.	50.	40.	60.	0.	0.	1.

CASE 1: STRAIGHT LINE MOVEMENT

Case No.	XI	YI	XF	YF	VI	VMIN	VMAX	AA	AD	TINC
1AA	-1000.	2500.	1000.	2500.	6.	5.	25.	2.	-3.	1.
1BB	-1000.	1000.	1000.	1000.	6.	5.	25.	2.	-3.	1.
1CC	1000.	3000.	1000.	0.	6.	5.	25.	2.	-3.	1.
1DD	0.	2000.	0.	0.	6.	5.	25.	2.	-3.	1.
1EE	-1000.	2500.	1000.	0.	6.	5.	25.	2.	-3.	1.
1AAA	-1000.	2500.	1000.	2500.	15.	--	--	0.	0.	1.
1BBB	-1000.	1000.	1000.	1000.	15.	--	--	0.	0.	1.
1CCC	1000.	3000.	1000.	0.	15.	--	--	0.	0.	1.
1DDD	0.	2000.	0.	0.	15.	--	--	0.	0.	1.
1EEE	-1000.	2500.	1000.	0.	15.	--	--	0.	0.	1.

CASE 2: SINUSODIAL MOVEMENT PATH (PART 1)

Case No.	XI	YI	XF	YF	VI	AA	AD	ANGD	ANGA	VMAX	VMIN	IANG
2A	-1000.	2500.	1000.	2500.	3.	1.	-2.	1.047	1.750	10.	2.	24
2B	-1000.	1000.	1000.	1000.	3.	1.	-2.	1.047	1.750	10.	2.	24
2C	1000.	2000.	1000.	0.	3.	1.	-2.	1.047	1.750	10.	2.	24
2D	0.	2000.	0.	0.	3.	1.	-2.	1.047	1.750	10.	2.	24
2E	-500.	2000.	500.	0.	3.	1.	-2.	1.047	1.750	10.	2.	24

CASE 2: SINUSODIAL MOVEMENT PATH (PART 2)

Case No. (Cont)	B	NPER	AMP(1)	AMP(2)	AMP(3)	AMP(4)	AMP(5)	AMP(6)	AMP(7)	AMP(8)	. . .	AMP(15)
2A	75.	15	35.	35.	35.	35.	35.	35.	35.	35.		35.
2B	75.	15	35.	35.	35.	35.	35.	35.	35.	35.		35.
2C	75.	15	35.	35.	35.	35.	35.	35.	35.	35.		35.
2D	75.	15	35.	35.	35.	35.	35.	35.	35.	35.		35.
2E	75.	15	35.	35.	35.	35.	35.	35.	35.	35.		35.

CASE 2: SINUSODIAL MOVEMENT PATH (PART 1)

Case No.	XI	YI	XF	YF	VI	AA	AD	ANGD	ANGA	VMAX	VMIN	IANG
2AA	-1000.	2500.	1000.	2500.	6.	2.	-3.	1.047	1.750	25.	5.	24
2BB	-1000.	1000.	1000.	1000.	6.	2.	-3.	1.047	1.750	25.	5	24
2CC	1000.	3000.	1000.	200.	6.	2.	-3.	1.047	1.750	25.	5	24
2DD	0.	2000.	0.	0.	6.	2.	-3.	1.047	1.750	25.	5	24
2EE	-1000.	2500.	1000.	0.	6.	2.	-3.	1.047	1.750	25.	5	24
2AAA	-1000.	2500.	1000.	2500.	15.	0.	0.	--	--	25.	5	24
2BBB	-1000.	1000.	1000.	1000.	15.	0.	0.	--	--	25.	5	24
2CCC	1000.	3000.	1000.	200.	15.	0.	0.	--	--	25.	5	24
2DDD	0.	2000.	0.	0.	15.	0.	0.	--	--	25.	5	24
2EEE	-1000.	2500.	1000.	0.	15.	0.	0.	--	--	25.	5	24

CASE 2: SINUSOIDAL MOVEMENT PATH (PART 2)

Case No. (Cont)	B	NPER	AMP(1)	AMP(2)	AMP(3)	AMP(4)	AMP(5)	AMP(6)	AMP(7)	AMP(8)	. . .	AMP(15)
2AA	75.	15	35.	35.	35.	35.	35.	35.	35.	35.		35.
2BB	75.	15	35.	35.	35.	35.	35.	35.	35.	35.		35.
2CC	75.	15	35.	35.	35.	35.	35.	35.	35.	35.		35.
2DD	75.	15	35.	35.	35.	35.	35.	35.	35.	35.		35.
2EE	75.	15	35.	35.	35.	35.	35.	35.	35.	35.		35.
2AAA	75.	15	35.	35.	35.	35.	35.	35.	35.	35.		35.
2BBB	75.	15	35.	35.	35.	35.	35.	35.	35.	35.		35.
2CCC	75.	15	35.	35.	35.	35.	35.	35.	35.	35.		35.
2DDD	75.	15	35.	35.	35.	35.	35.	35.	35.	35.		35.
2EEE	75.	15	35.	35.	35.	35.	35.	35.	35.	35.		35.

CASE 3: THREE-DIMENSIONAL MOVEMENT PATH (PART 1)

Case No.	XI	YI	ZI	XF	YF	ZF	VI	VMIN	VMAX	DZINC	MNINC	TINC
3A	-1000.	2500.	5.	1000.	2500.	0.	3.	2.	10.	50.	0	1.0
3B	-1000.	1000.	5.	1000.	1000.	0.	3.	2.	10.	50.	0	1.0
3C	1000.	2000.	5.	1000.	0.	0.	3.	2.	10.	50.	0	1.0
3D	0.	2000.	5.	0.	0.	0.	3.	2.	10.	50.	0	1.0
3E	-500.	2000.	5.	500.	0.	0.	3.	2.	10.	50.	0	1.0
3F	-2000	2500	100.	2000.	2500.	50.	50.	40.	60.	50.	0	1.0
3G	-2000.	1000.	100.	2000.	1000.	50.	50.	40.	60.	50.	0	1.0
3H	1000.	4000.	100.	1000.	0.	50.	50.	40.	60.	50.	0	1.0
3I	-1000.	2500.	100.	1000.	0.	50.	50.	40.	60.	50.	0	1.0

CASE 3: THREE-DIMENSIONAL MOVEMENT PATH (PART 2)

Case No. (cont)	ZH(1)	AC(1)	ZH(2)	AC(2)	ZH(3)	AC(3)	ZH(4)	AC(4)	ZH(5)	AC(5)	ZH(6)	AC(6)	ZH(7)	AC(7)
3A	0.	1.	5.	-2.										
3B	0.	1.	5.	-2.										
3C	0.	1.	5.	-2.										
3D	0.	1.	5.	-2.										
3E	0.	1.	5.	-2.										
3F	50.	0.	100.	0.										
3G	50.	0.	100.	0.										
3H	50.	0.	100.	0.										
3I	50.	0.	100.	0.										

CASE 3: THREE-DIMENSIONAL MOVEMENT PATH (PART 1)

Case No.	XI	YI	ZI	XF	YF	ZF	VI	VMIN	VMAX	DZINC	NNINC	TINC
3AA	-1000.	2500.	5.	1000.	2500.	0.	6.	5.	25.	50.	0	1.0
3BB	-1000.	1000.	5.	1000.	1000.	0.	6.	5.	25.	50.	0	1.0
3CC	1000.	3000.	5.	1000.	0.	0.	6.	5.	25.	50.	0	1.0
3DD	0.	2000.	5.	0.	0.	0.	6.	5.	25.	50.	0	1.0
3EE	-1000.	2000.	5.	1000.	0.	0.	6.	5.	25.	50.	0	1.0
3AAA	-1000.	2500.	5.	1000.	2500.	0.	15.	--	--	50.	0	1.0
3BBB	-1000.	1000.	5.	1000.	1000.	0.	15.	--	--	50.	0	1.0
3CCC	1000.	3000.	5.	1000.	0.	0.	15.	--	--	50.	0	1.0
3DDD	0.	2000.	5.	0.	0.	0.	15.	--	--	50.	0	1.0
3EEE	-1000.	2500.	5.	1000.	0.	0.	15.	--	--	50.	0	1.0

CASE 3: THREE-DIMENSIONAL MOVEMENT PATH (PART 2)

Case No. (cont)	ZH(1)	AC(1)	ZH(2)	AC(2)	ZH(3)	AC(3)	ZH(4)	AC(4)	ZH(5)	AC(5)	ZH(6)	AC(6)	ZH(7)	AC(7)
3AA	0.	2.0	5.	-3.0										
3BB	0.	2.0	5.	-3.0										
3CC	0.	2.0	5.	-3.0										
3DD	0.	2.0	5.	-3.0										
3EE	0.	2.0	5.	-3.0										
3AAA	0.	0.	5.	0.										
3BBB	0.	0.	5.	0.										
3CCC	0.	0.	5.	0.										
3DDD	0.	0.	5.	0.										
3EEE	0.	0.	5.	0.										

APPARENT ACCELERATION AND APPARENT VELOCITY GRAPHS

SECTION II.B

NOTES REGARDING THE GRAPHS

1. Figures 1A, 1V through 7A, 7V, indicate differences due to target speed and acceleration for a specified course and movement pattern.

2. Figures 8A, 8V through 13A, 13V, indicate differences due to target movement pattern for a specified course and target speed, acceleration.

3. All figure numbers ending with "A" are for apparent acceleration and those ending with "V" are for apparent velocity.

4. For apparent velocity curves, positive values indicate turret traversing to the right and negative values indicate turret traversing to the left.

5. Case numbers refer to the table in Section II.A.

6. CAPTION NOTATION ON THE GRAPHS

   a. Target Speeds

      SLOW A/D:
      Acceleration/Deceleration constants are (+1, -2) meters/second^2.
      Minimum and maximum speeds are (2, 10) meters/second.

      FAST A/D:
      Acceleration/Deceleration constants are (+2, -3) meters/second^2.
      Minimum and maximum speeds are (5, 25) meters/second.

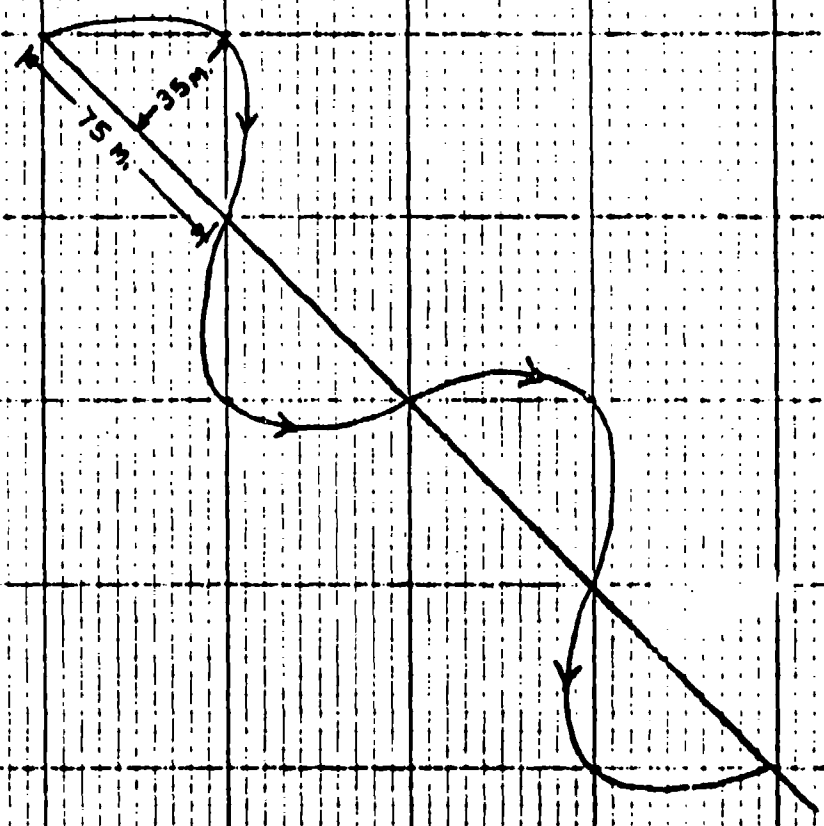
      CONSTANT SPEED:
      No acceleration/deceleration
      Maintains constant speed of 15 meters/second

   b. Movement Pattern:

      STRAIGHT LINE:
      Start and end points of the move as indicated in the caption.

      SINUSODIAL PATTERN: (See diagram on next page)
      Amplitude: 35 meters
      Half period distance: 75 meters

SINUSODIAL MOVEMENT PATTERN



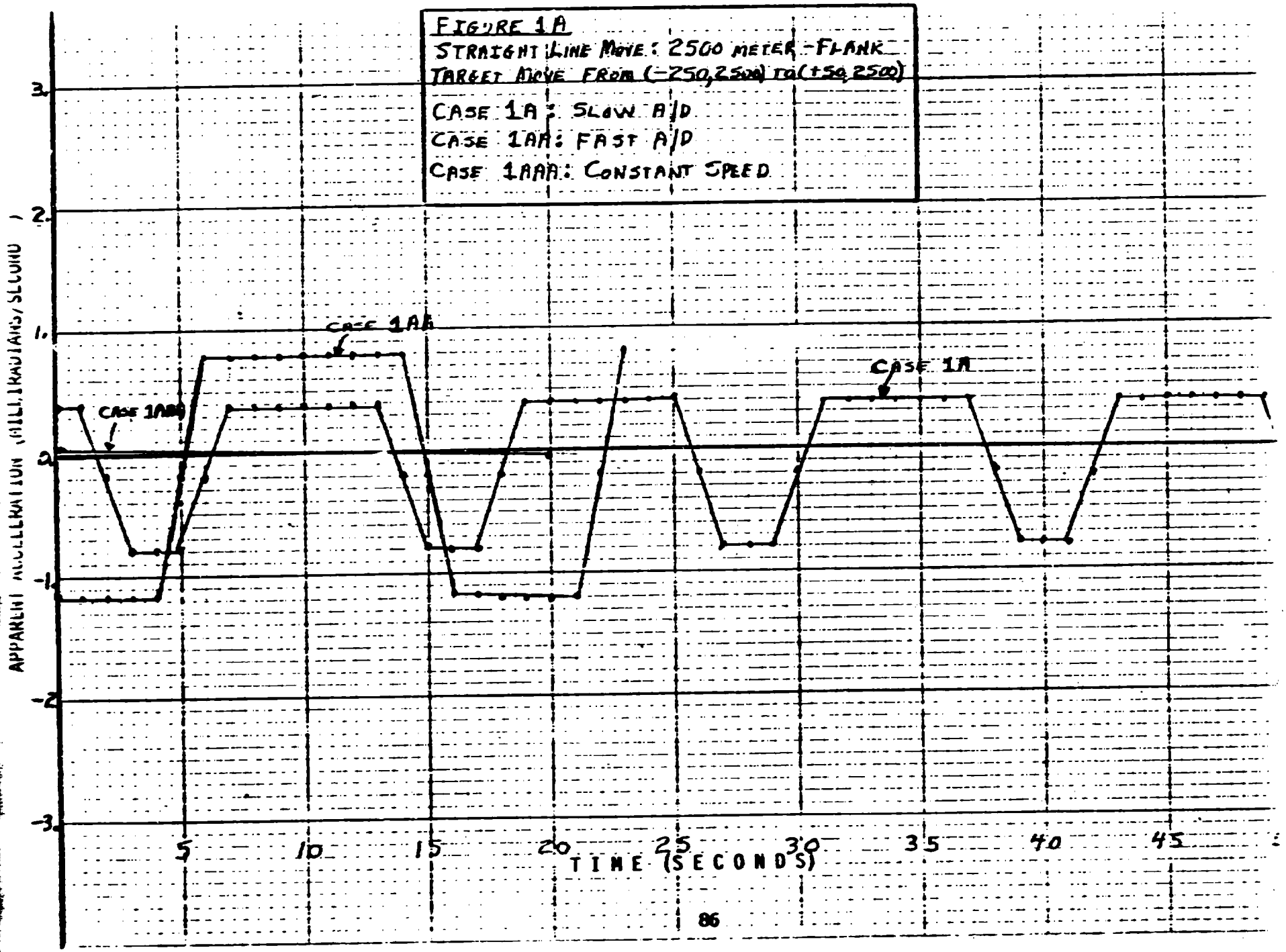


FIGURE 1A
STRAIGHT LINE MOVE: 2500 METER - FLANK
TARGET MOVE FROM (-250,2500) TO (+50,2500)
CASE 1A: SLOW A/D
CASE 1AA: FAST A/D
CASE 1AAA: CONSTANT SPEED
CASE 1AA
CASE 1AAA
CASE 1A
APPARENT ACCELERATION (MILLIRADIANS/SECOND)
3
2
1
0
-1
-2
-3
5
10
15
20
25
30
35
40
45
TIME (SECONDS)

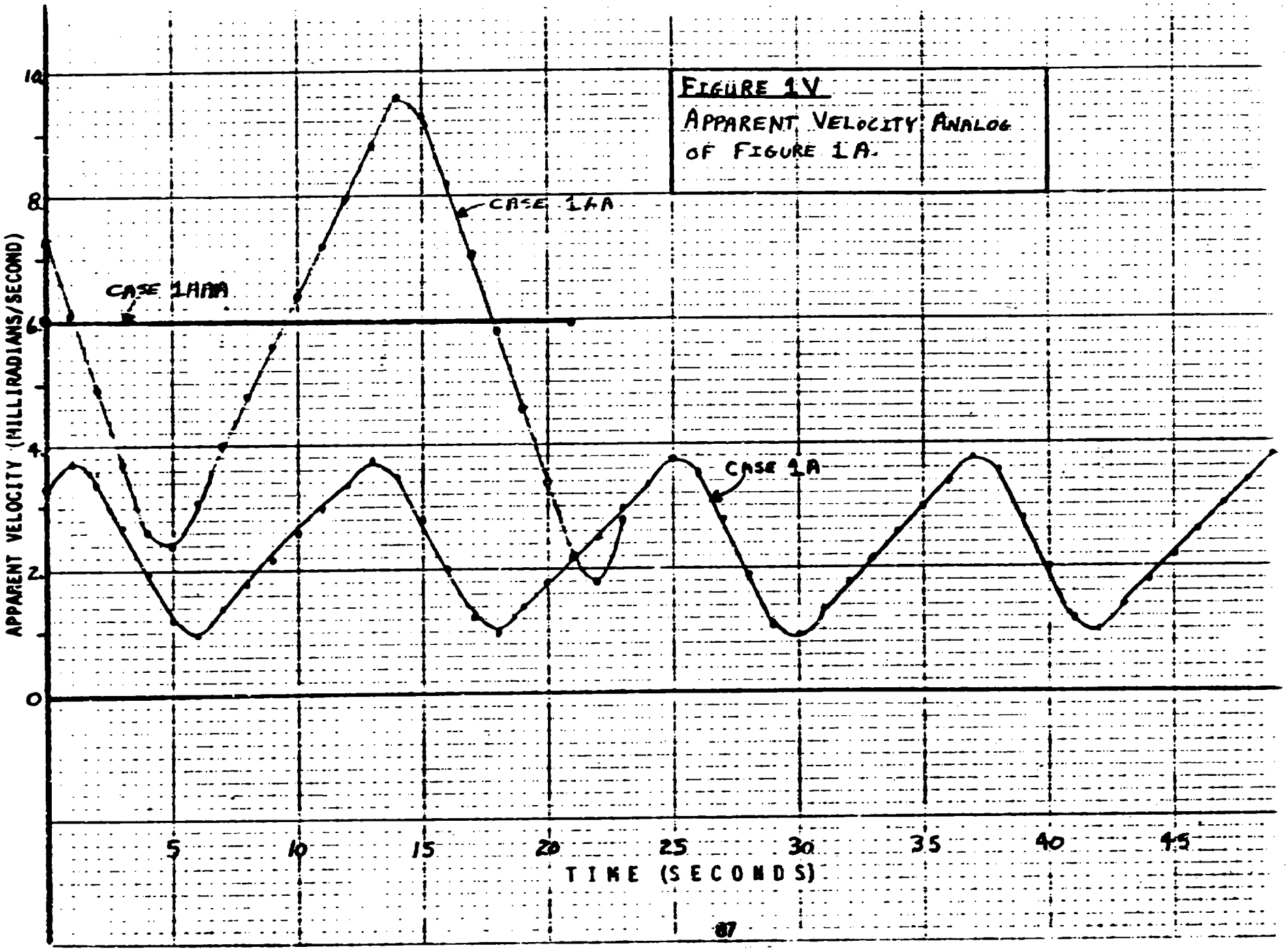


FIGURE 1V
APPARENT VELOCITY ANALOG OF FIGURE 1A.
CASE 1AA
CASE 1AAA
CASE 1A
APPARENT VELOCITY (MILLIRADIANS/SECOND)
0
2
4
6
8
10
5
10
15
20
25
30
35
40
45
TIME (SECONDS)

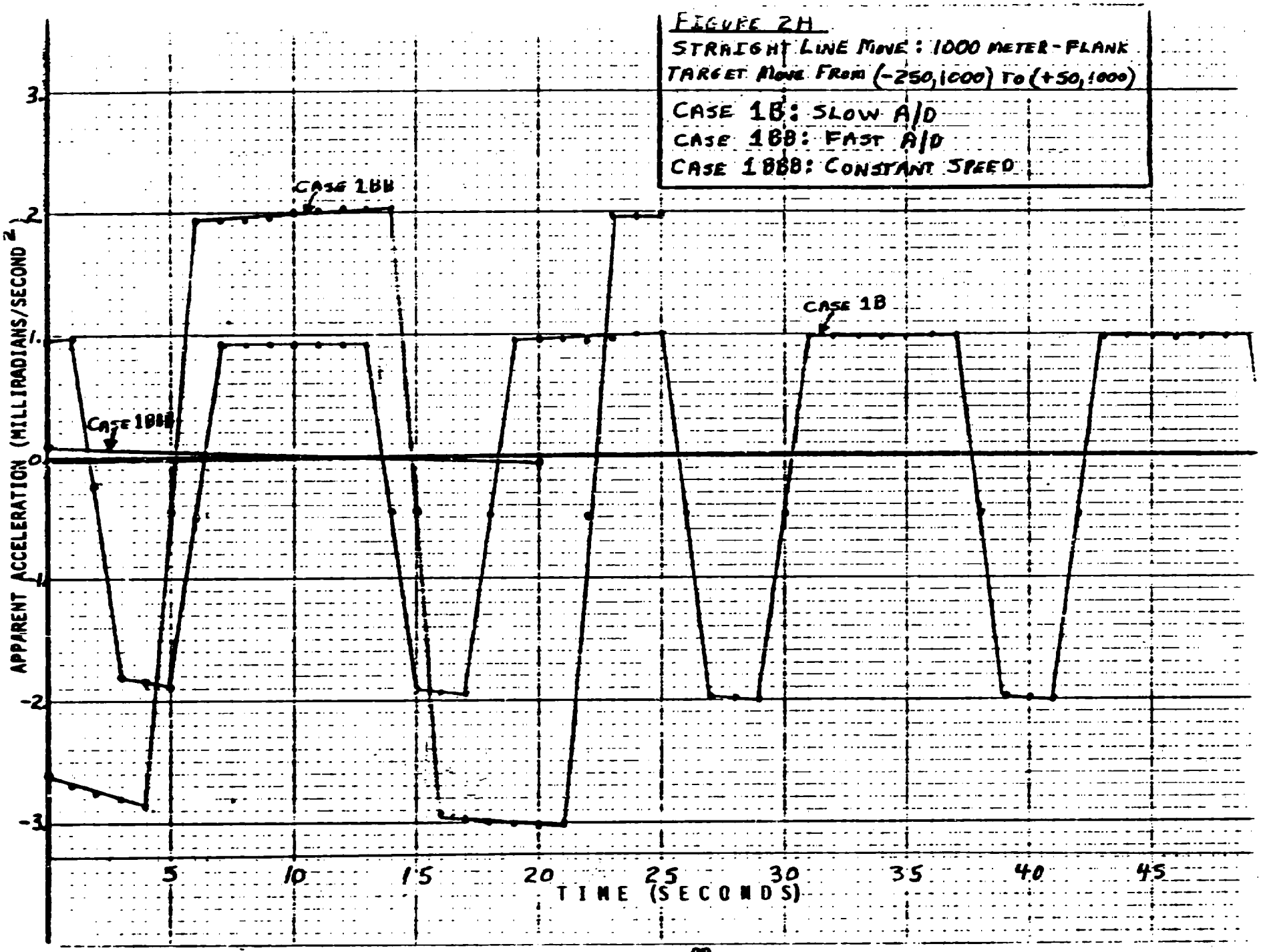


FIGURE 2H
STRAIGHT LINE MOVE: 1000 METER - FLANK
TARGET MOVE FROM (-250,1000) TO (+50,1000)
CASE 1B: SLOW A/D
CASE 1BB: FAST A/D
CASE 1BBB: CONSTANT SPEED
CASE 1BB
CASE 1B
CASE 1BBB
APPARENT ACCELERATION (MILLIRADIANS/SECOND²)
3
2
1
0
-1
-2
-3
5
10
15
20
25
30
35
40
45
TIME (SECONDS)

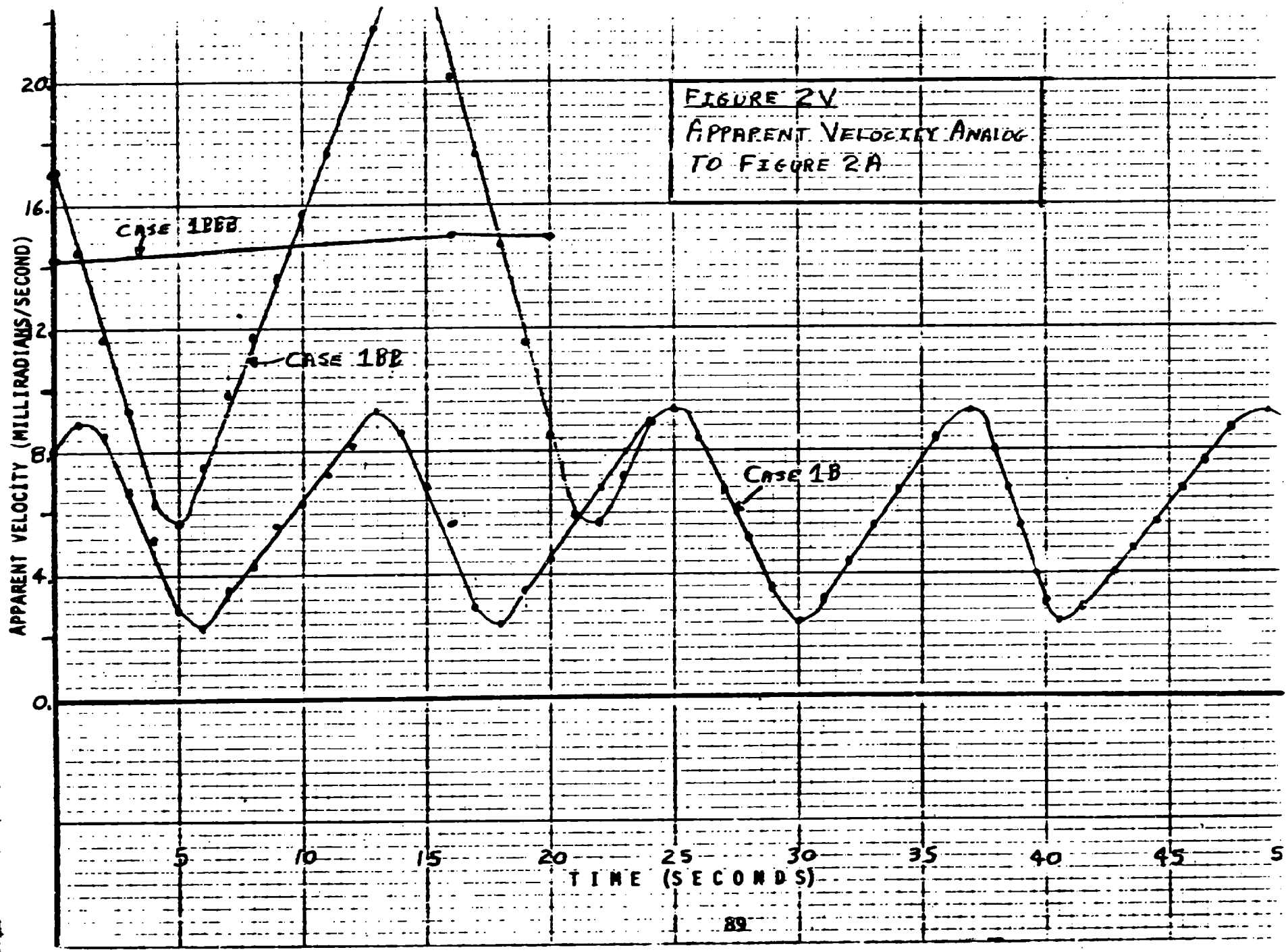


FIGURE 2V
APPARENT VELOCITY ANALOG
TO FIGURE 2A
CASE 1BBB
CASE 1BB
CASE 1B
APPARENT VELOCITY (MILLIRADIANS/SECOND)
20
16.
12
8.
4.
0.
5
10
15
20
25
30
35
40
45
5
TIME (SECONDS)

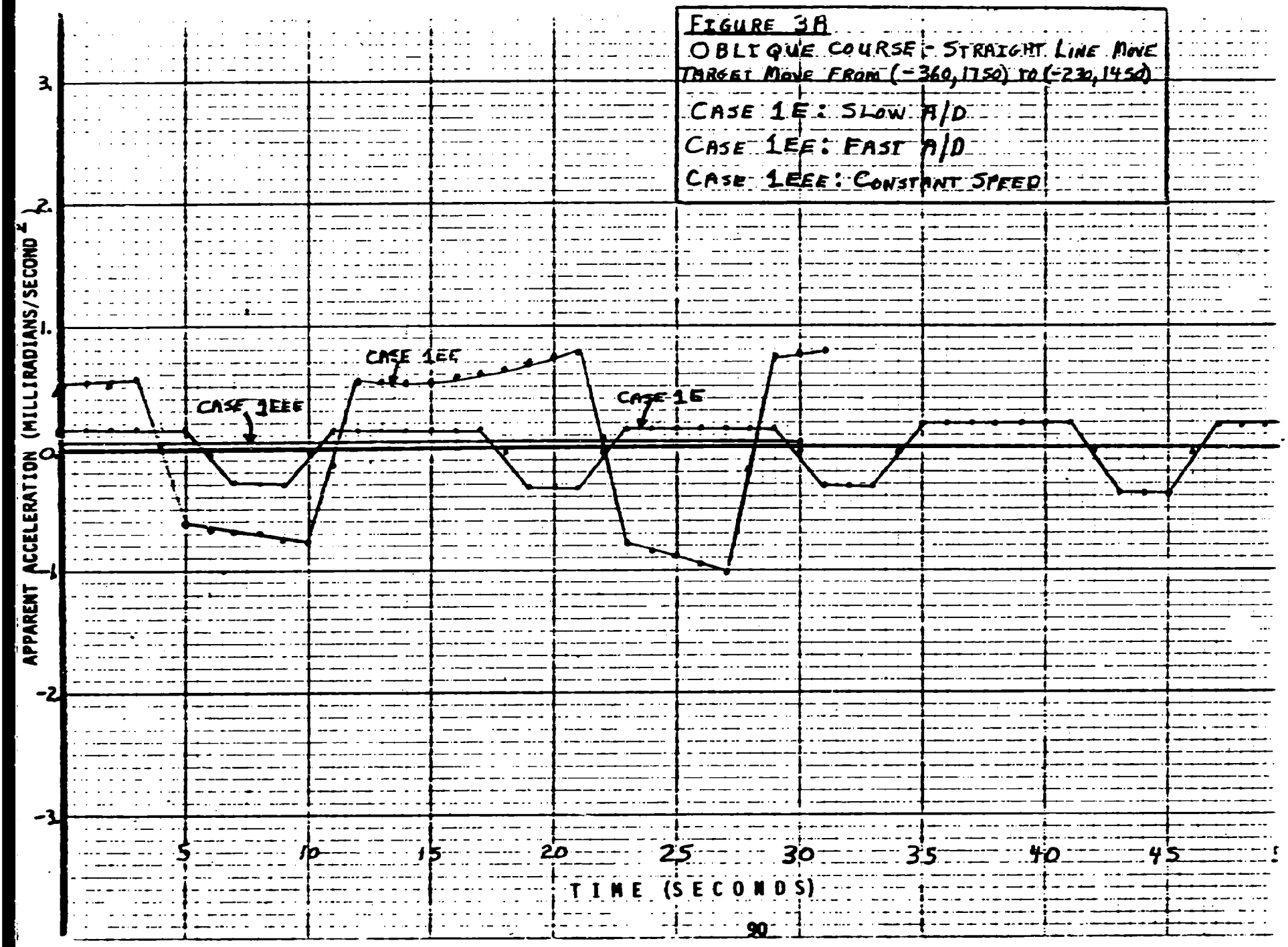


FIGURE 3A
OBLIQUE COURSE - STRAIGHT LINE MOVE
TARGET MOVE FROM (-360,1750) TO (-230,1450)
CASE 1E: SLOW A/D
CASE 1EE: FAST A/D
CASE 1EEE: CONSTANT SPEED
CASE 1EE
CASE 1EEE
CASE 1E
APPARENT ACCELERATION (MILLIRADIANS/SECOND²)
3
2
1
0
-1
-2
-3
5
10
15
20
25
30
35
40
45
TIME (SECONDS)

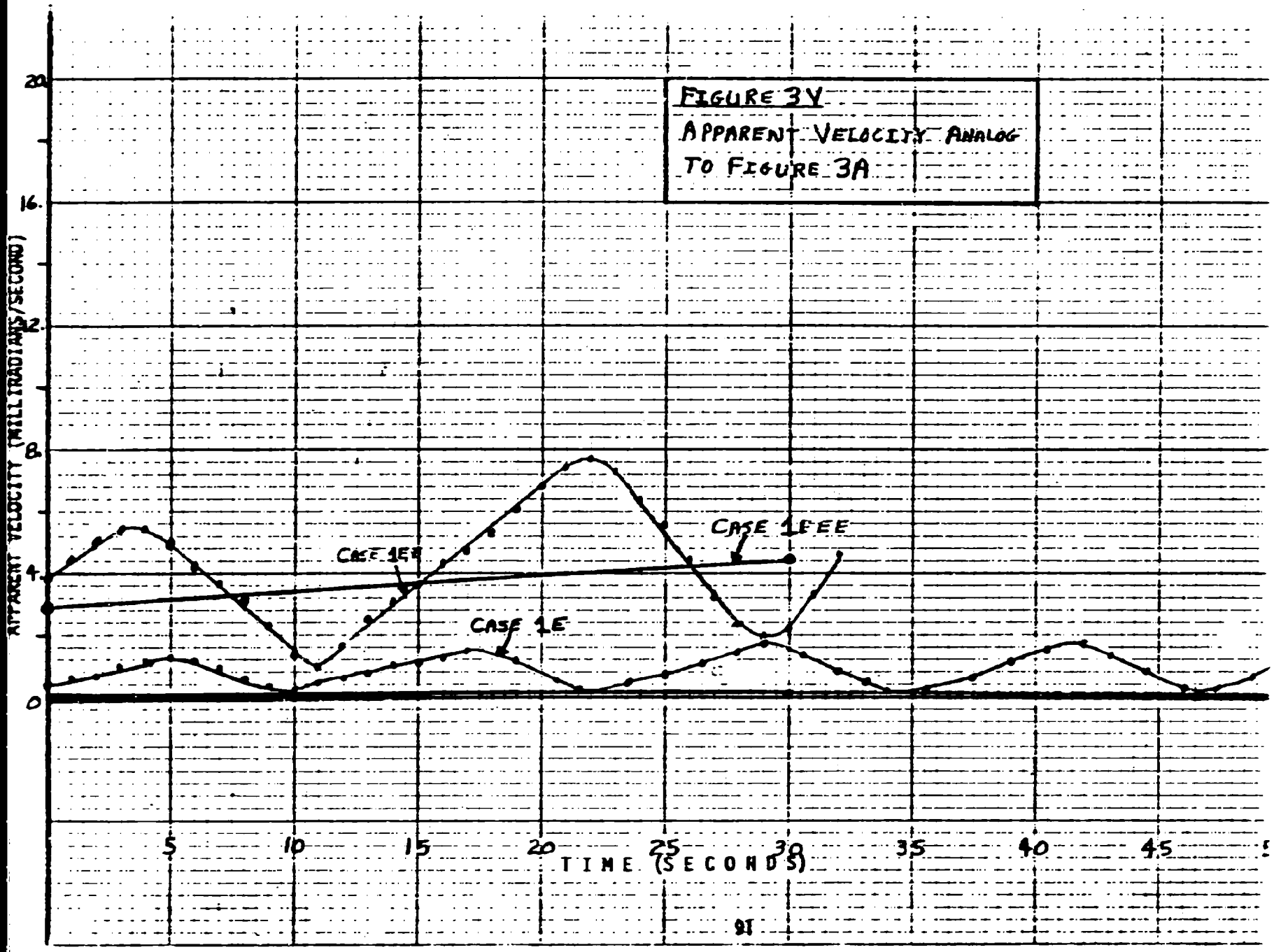


FIGURE 3V
APPARENT VELOCITY ANALOG
TO FIGURE 3A
APPARENT VELOCITY (MILLIRADIANS/SECOND)
20
16.
12.
8.
4.
0
CASE 1EEE
CASE 1EE
CASE 1E
5
10
15
20
25
30
35
40
45
TIME (SECONDS)

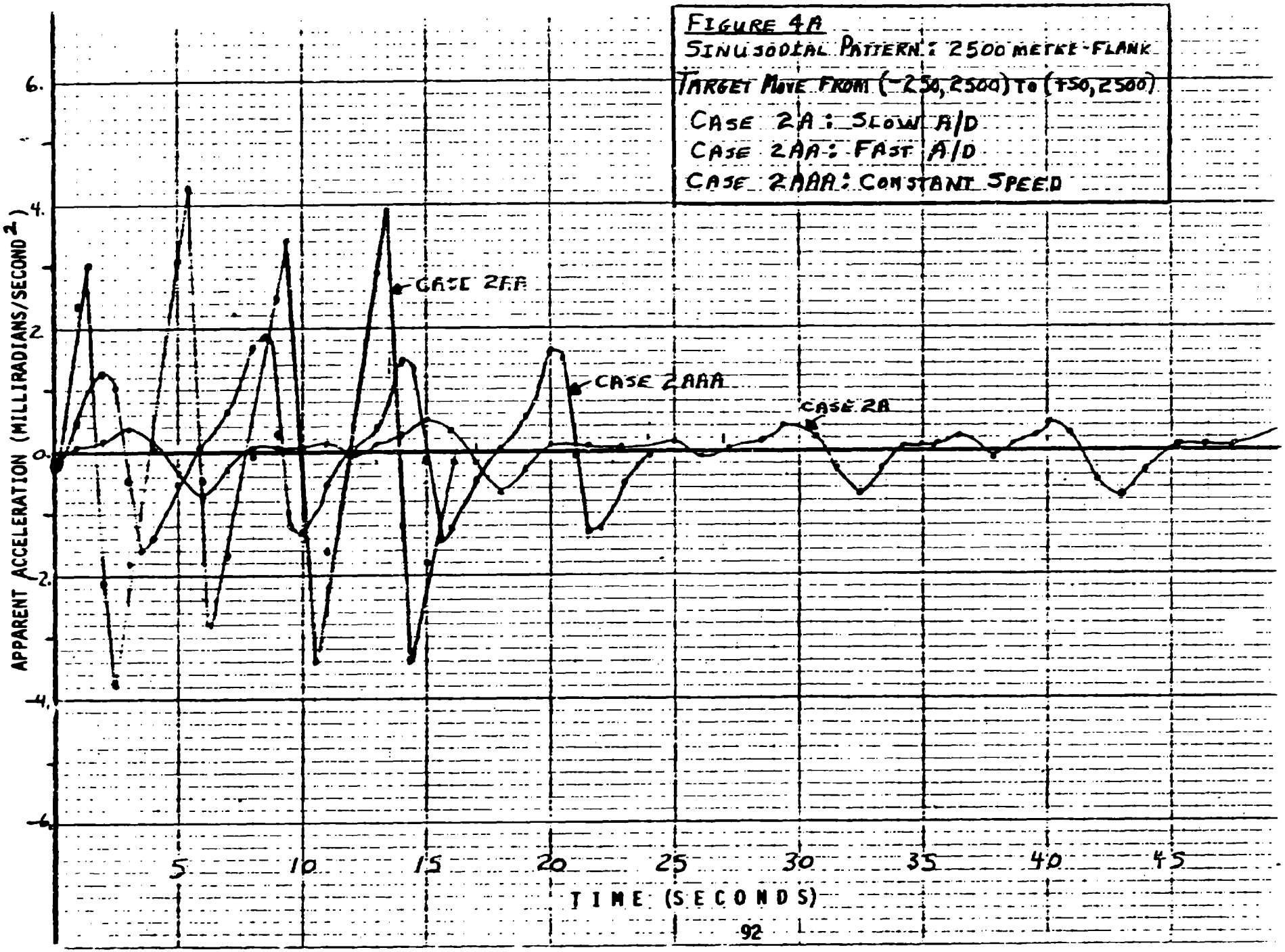


FIGURE 4A
SINUSOIDAL PATTERN: 2500 METRE-FLANK
TARGET MOVE FROM (-250,2500) TO (+50,2500)
CASE 2A: SLOW A/D
CASE 2AA: FAST A/D
CASE 2AAA: CONSTANT SPEED
CASE 2AA
CASE 2AAA
CASE 2A
APPARENT ACCELERATION (MILLIRADIANS/SECOND²)
6.
4.
2
0.
-2.
-4.
-6.
5
10
15
20
25
30
35
40
45
TIME (SECONDS)

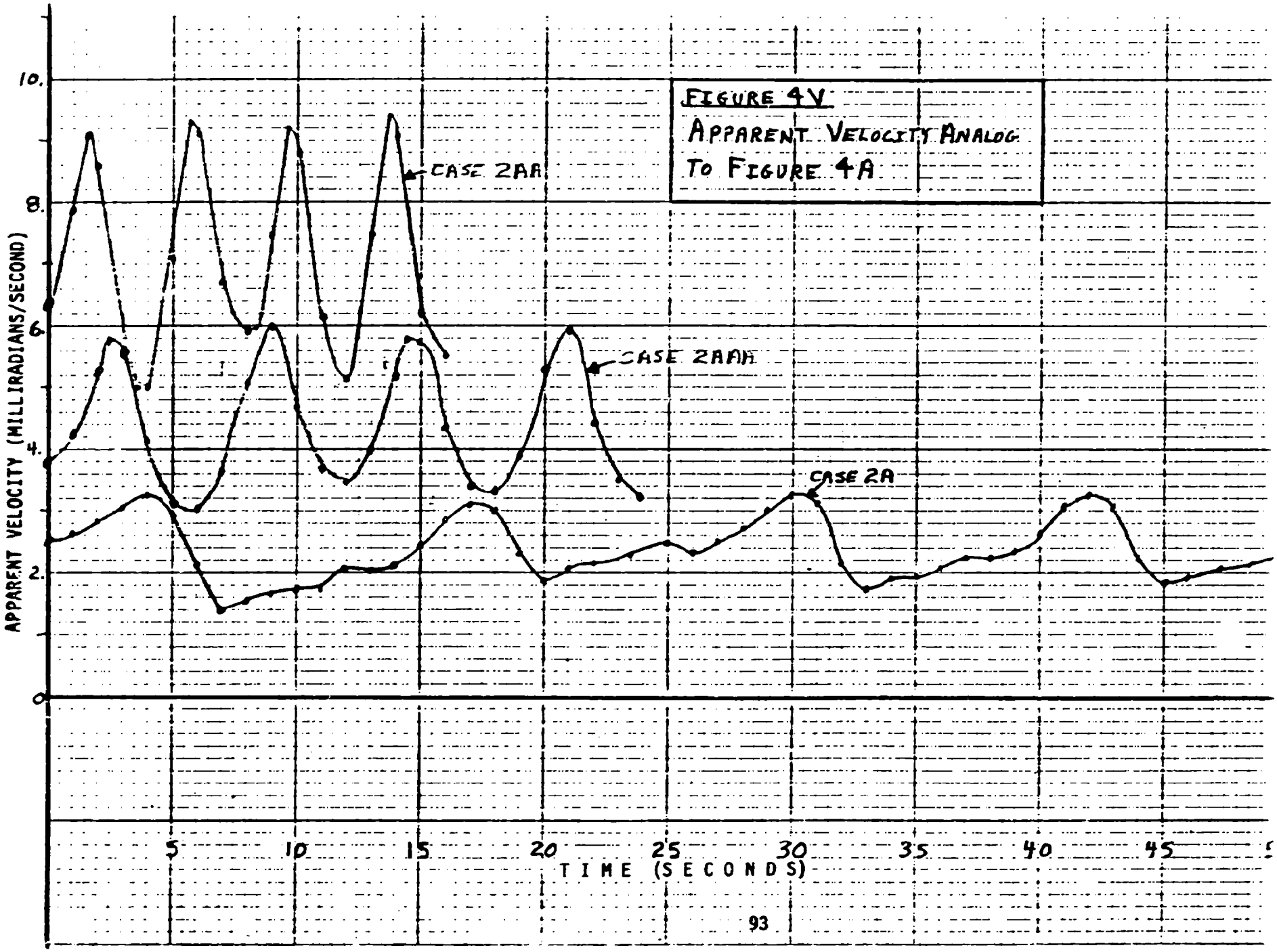


FIGURE 4V
APPARENT VELOCITY ANALOG
TO FIGURE 4A
CASE 2AA
CASE 2AAA
CASE 2A
APPARENT VELOCITY (MILLIRADIANS/SECOND)
10.
8.
6
4.
2.
0
5
10
15
20
25
30
35
40
45
TIME (SECONDS)

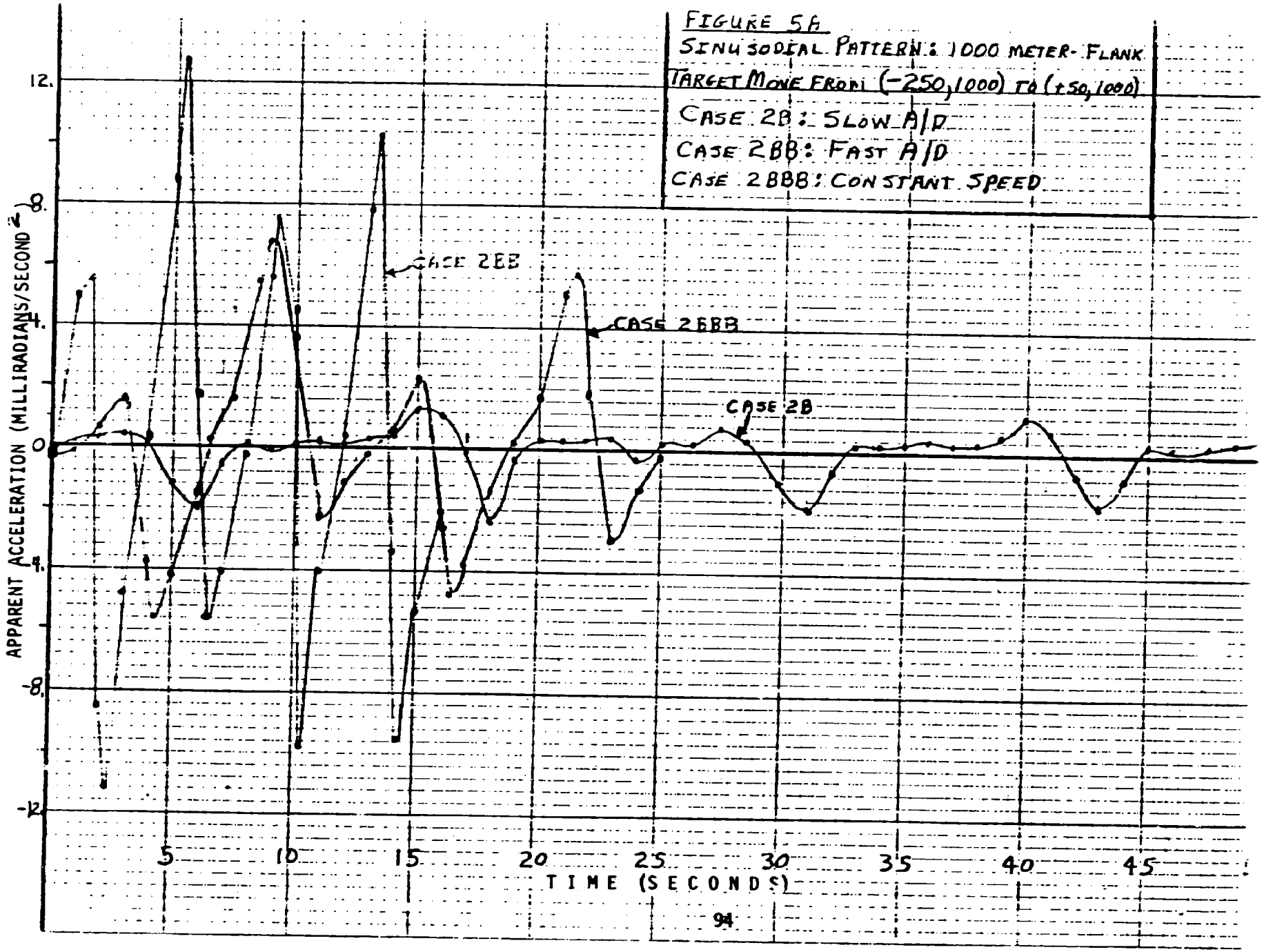


FIGURE 5A
SINUSODIAL PATTERN: 1000 METER- FLANK
TARGET MOVE FROM (-250,1000) TO (+50,1000)
CASE 2B: SLOW A/D
CASE 2BB: FAST A/D
CASE 2BBB: CONSTANT SPEED
CASE 2BB
CASE 2BBB
CASE 2B
APPARENT ACCELERATION (MILLIRADIANS/SECOND²)
12.
8.
4.
0
-4.
-8.
-12
5
10
15
20
25
30
35
40
45
TIME (SECONDS)

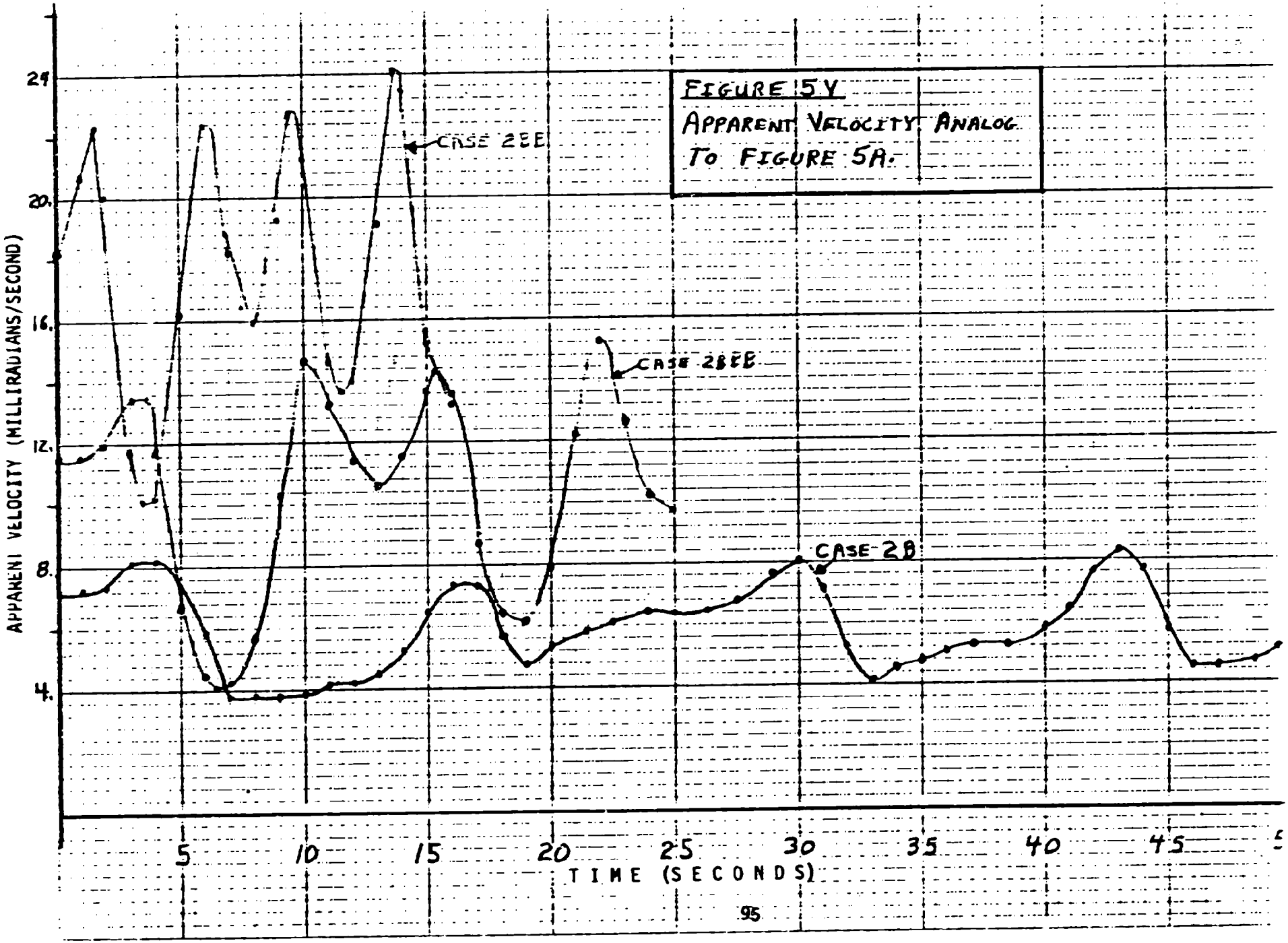


FIGURE 5V
APPARENT VELOCITY ANALOG
TO FIGURE 5A.
CASE 2BE
CASE 2BEB
CASE 2B
APPARENT VELOCITY (MILLIRADIANS/SECOND)
24.
20.
16.
12.
8.
4.
5
10
15
20
25
30
35
40
45
TIME (SECONDS)

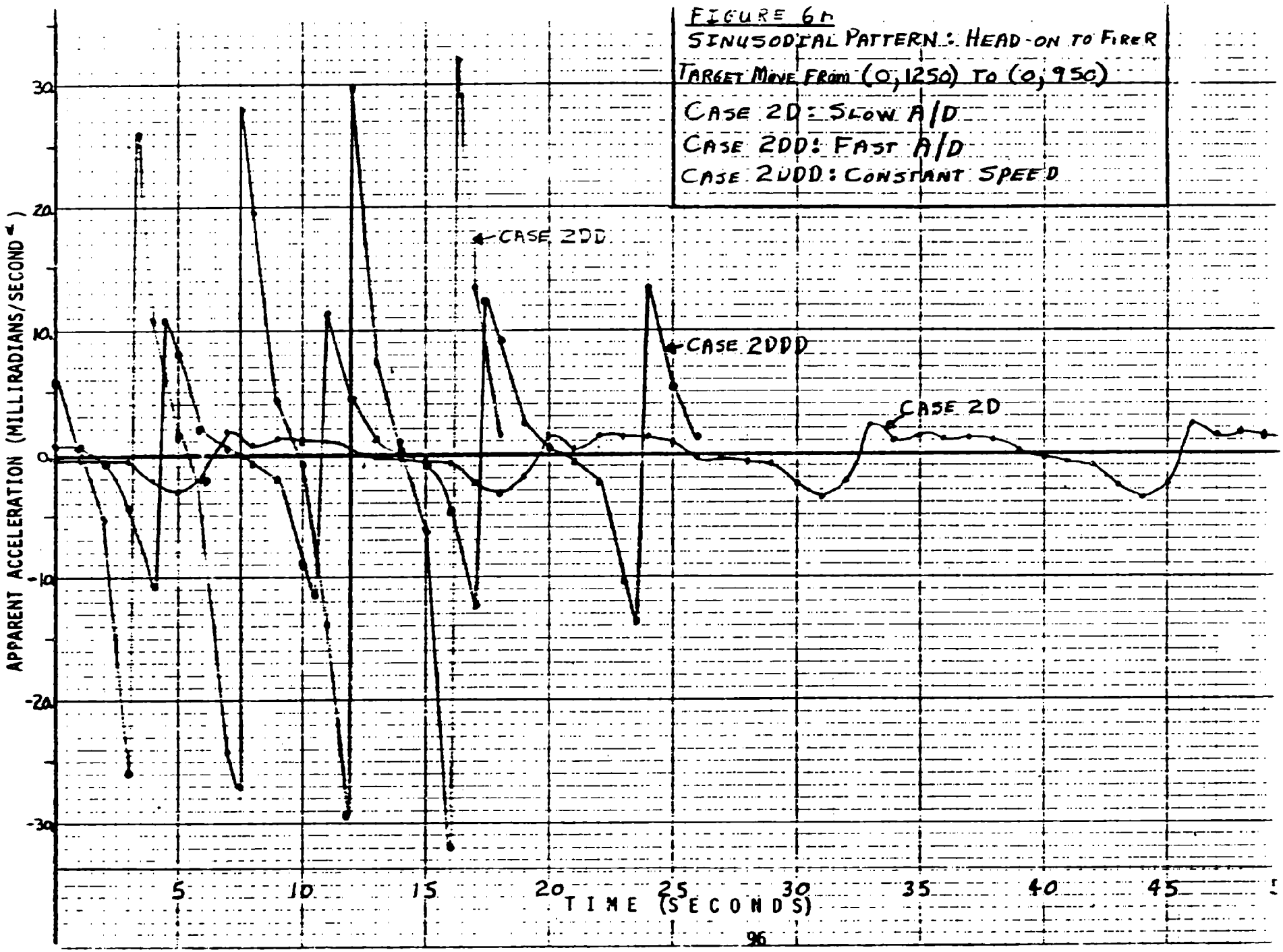


FIGURE 6h
SINUSODIAL PATTERN: HEAD-ON TO FIRER
TARGET MOVE FROM (0,1250) TO (0,950)
CASE 2D: SLOW A/D
CASE 2DD: FAST A/D
CASE 2DDD: CONSTANT SPEED
CASE 2DD
CASE 2DDD
CASE 2D
APPARENT ACCELERATION (MILLIRADIANS/SECOND²)
30
20
10
0
-10
-20
-30
5
10
15
20
25
30
35
40
45
TIME (SECONDS)

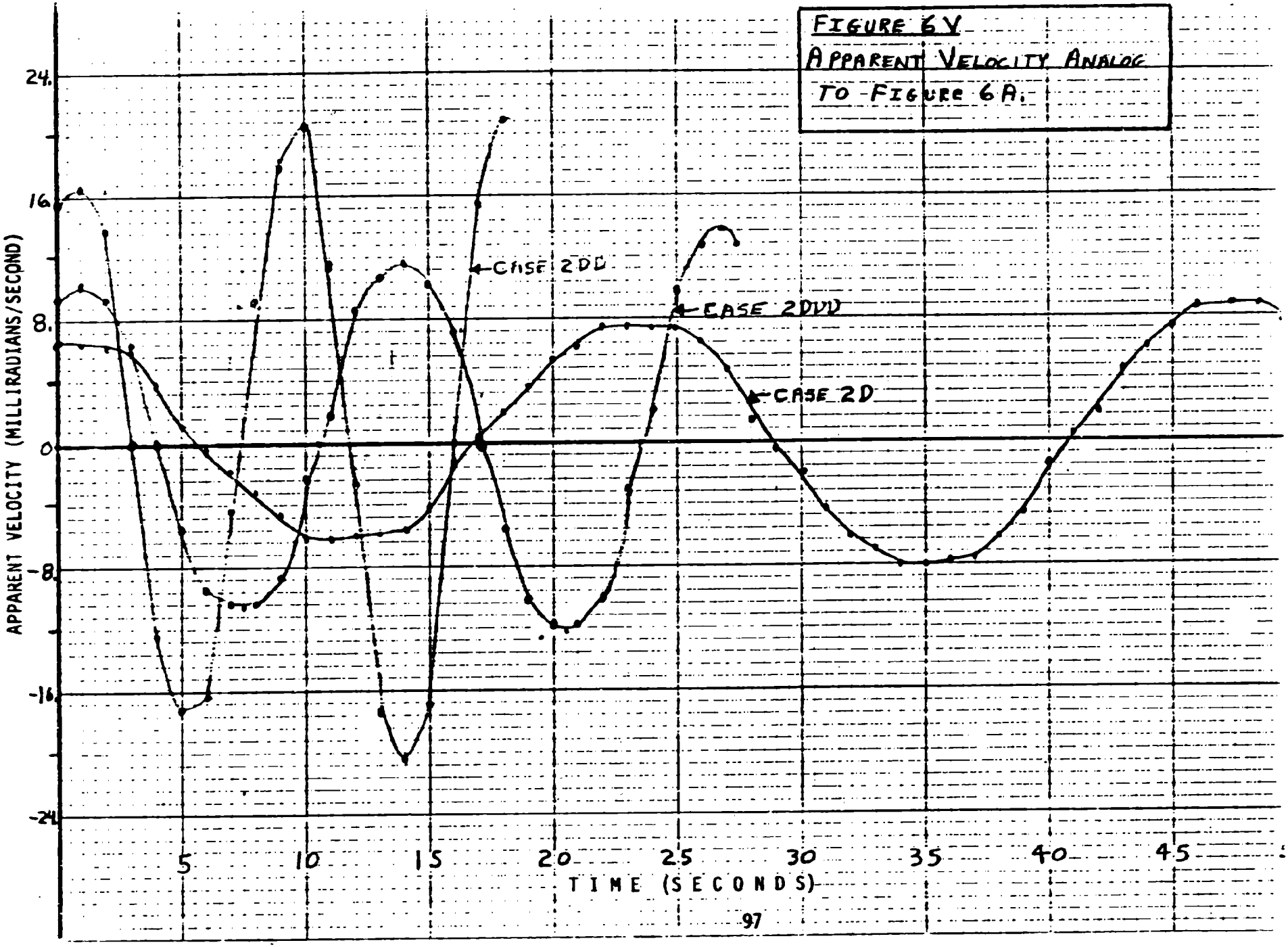


FIGURE 6V
APPARENT VELOCITY ANALOG
TO FIGURE 6A.
CASE 2DD
CASE 2DVD
CASE 2D
APPARENT VELOCITY (MILLIRADIANS/SECOND)
24.
16.
8.
0
-8.
-16.
-24.
5
10
15
20
25
30
35
40
45
TIME (SECONDS)

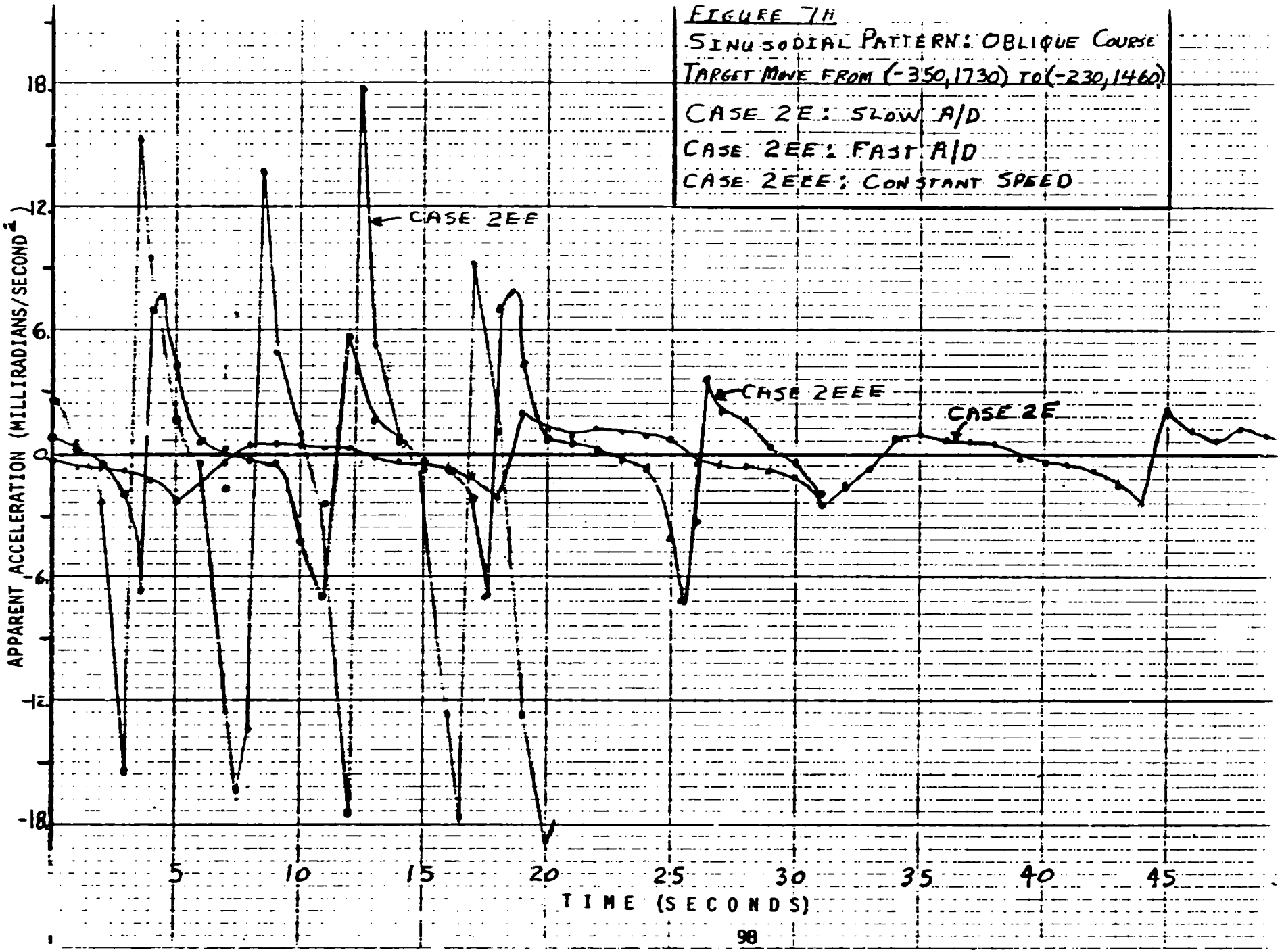


FIGURE 7H
SINUSODIAL PATTERN: OBLIQUE COURSE
TARGET MOVE FROM (-350,1730) TO (-230,1460)
CASE 2E: SLOW A/D
CASE 2EE: FAST A/D
CASE 2EEE: CONSTANT SPEED
CASE 2EE
CASE 2EEE
CASE 2E
APPARENT ACCELERATION (MILLIRADIANS/SECOND²)
18
12
6
0
-6
-12
-18
5
10
15
20
25
30
35
40
45
TIME (SECONDS)

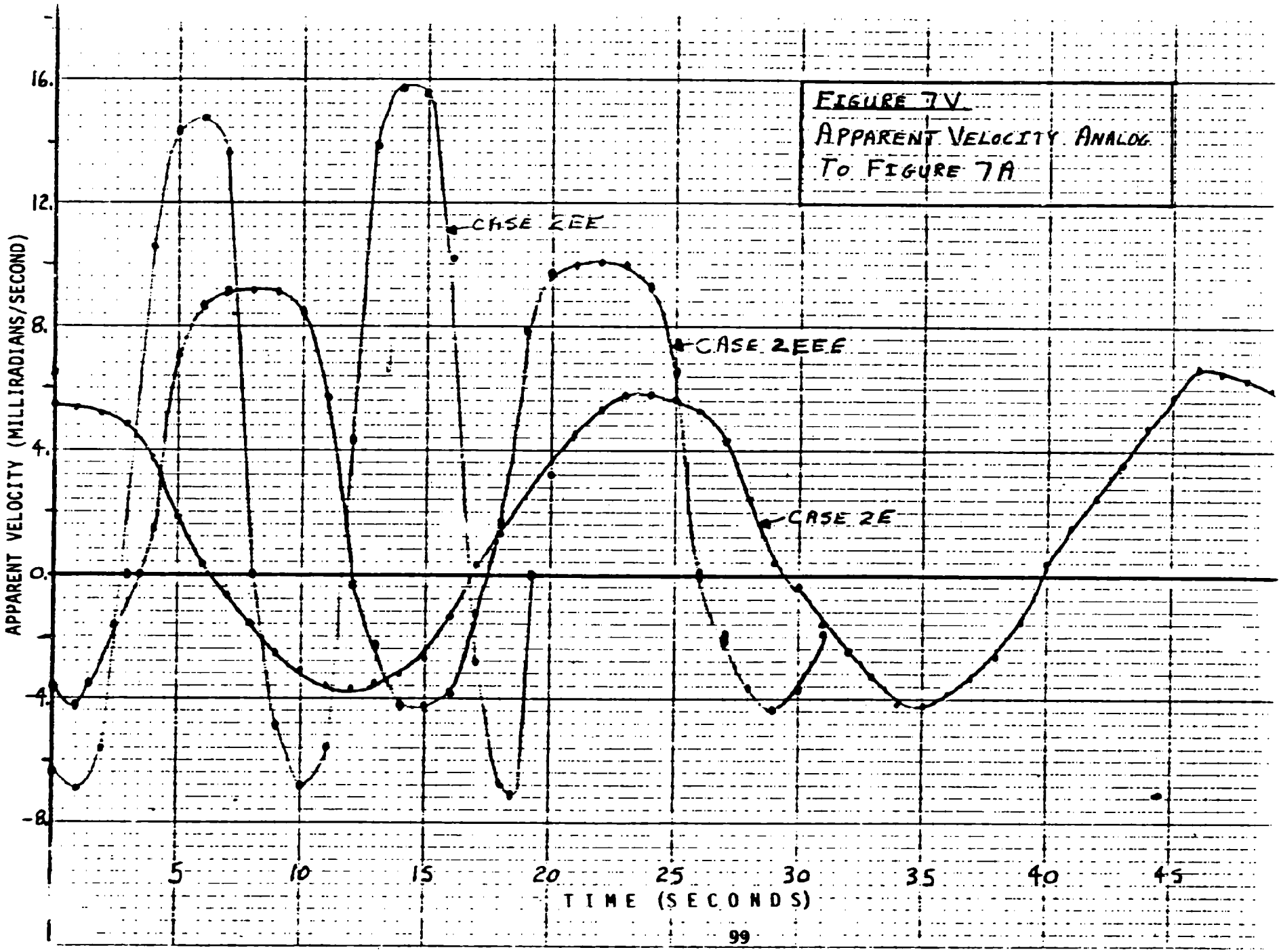


FIGURE 7V
APPARENT VELOCITY ANALOG
TO FIGURE 7A
CASE 2EE
CASE 2EEE
CASE 2E
APPARENT VELOCITY (MILLIRADIANS/SECOND)
16.
12.
8.
4.
0.
-4.
-8.
5
10
15
20
25
30
35
40
45
TIME (SECONDS)

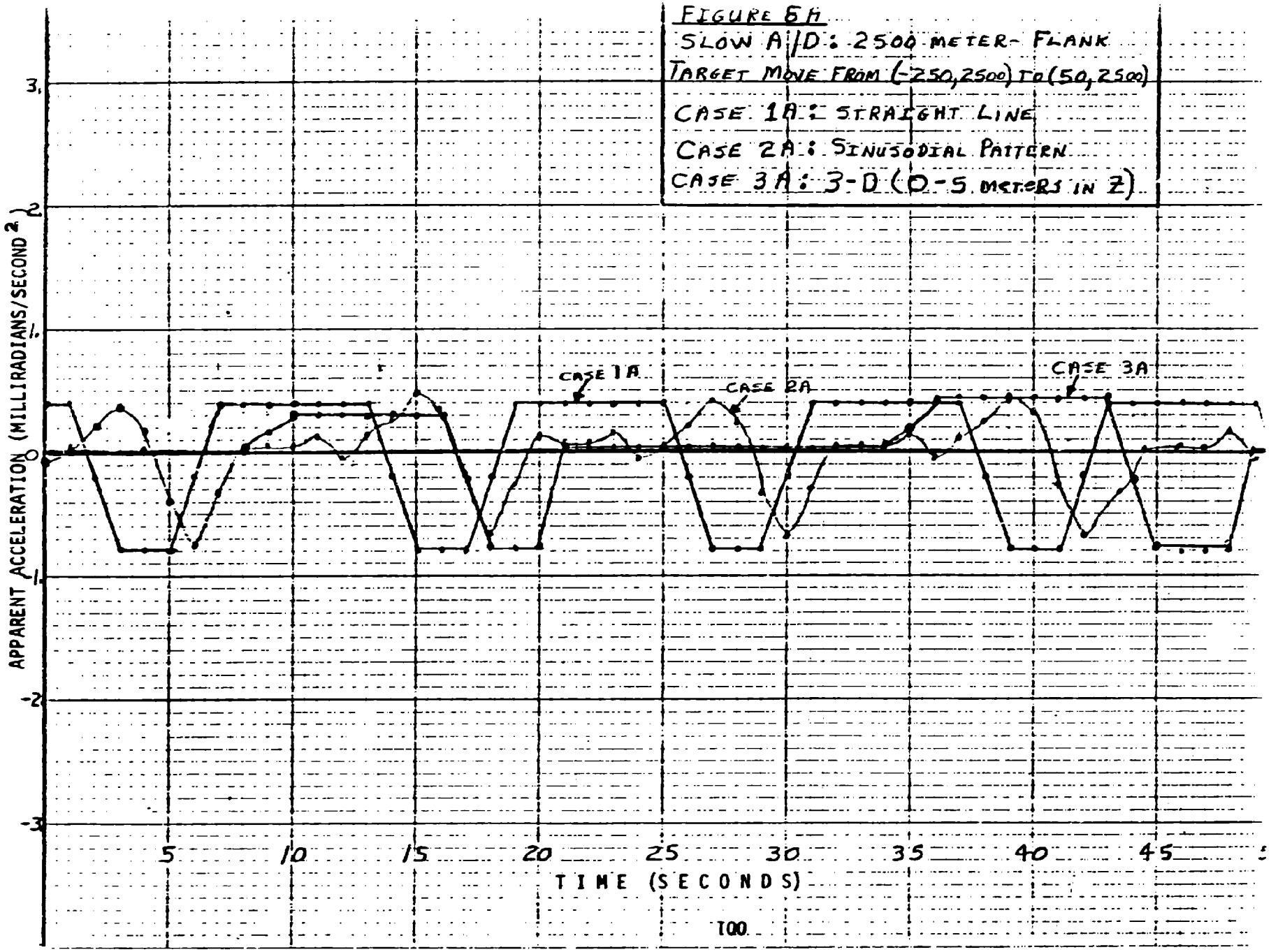


FIGURE 6A
SLOW A/D: 2500 METER- FLANK
TARGET MOVE FROM (-250,2500) TO (50,2500)
CASE 1A: STRAIGHT LINE
CASE 2A: SINUSODIAL PATTERN
CASE 3A: 3-D (0-5 METERS IN Z)
CASE 1A
CASE 2A
CASE 3A
APPARENT ACCELERATION (MILLIRADIANS/SECOND²)
3.
2
1.
0
-1.
-2
-3
5
10
15
20
25
30
35
40
45
TIME (SECONDS)

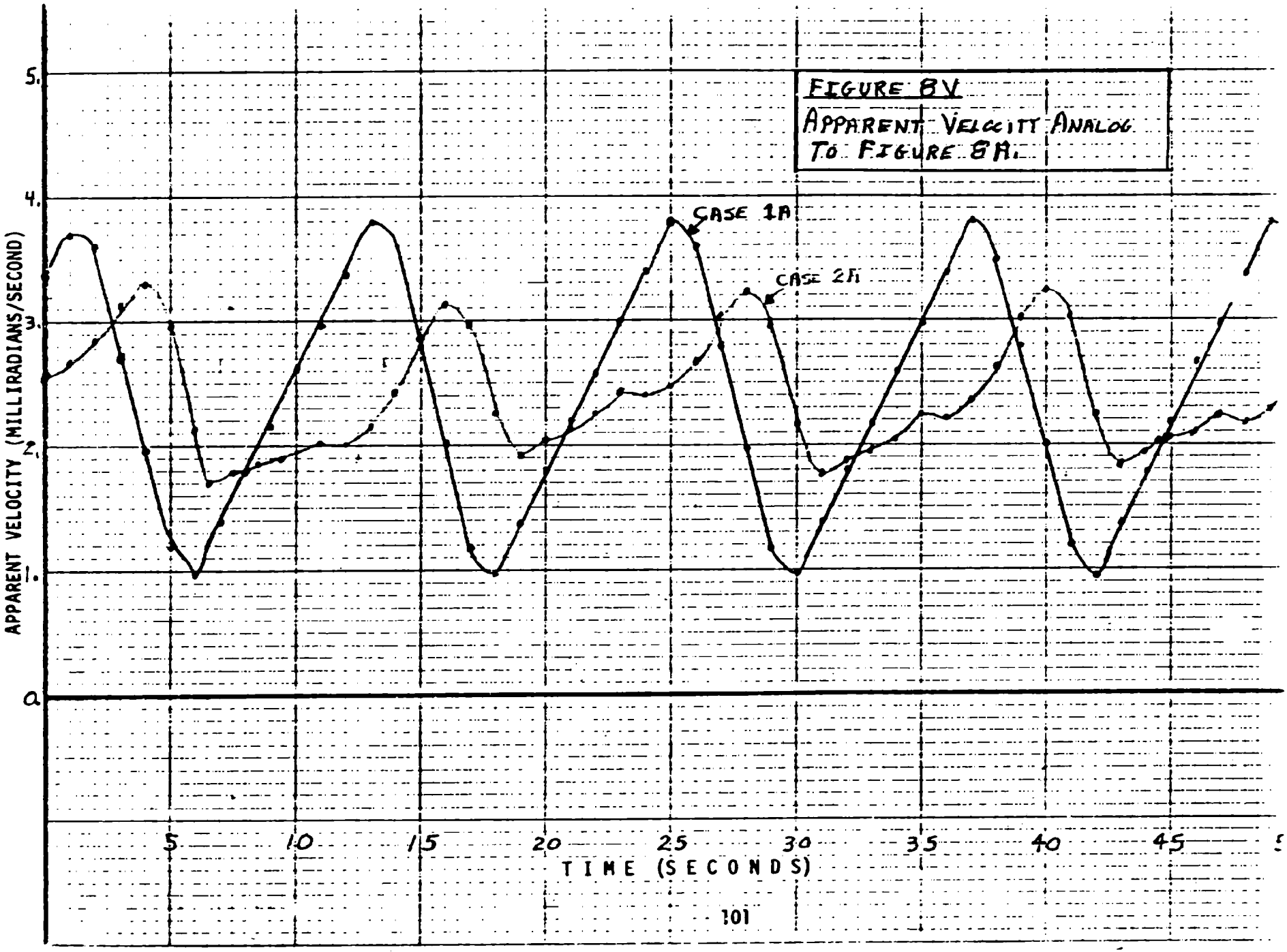


FIGURE 8V
APPARENT VELOCITY ANALOG TO FIGURE 8A.
CASE 1A
CASE 2A
APPARENT VELOCITY (MILLIRADIANS/SECOND)
5.
4.
3.
2.
1.
0.
5
10
15
20
25
30
35
40
45
TIME (SECONDS)

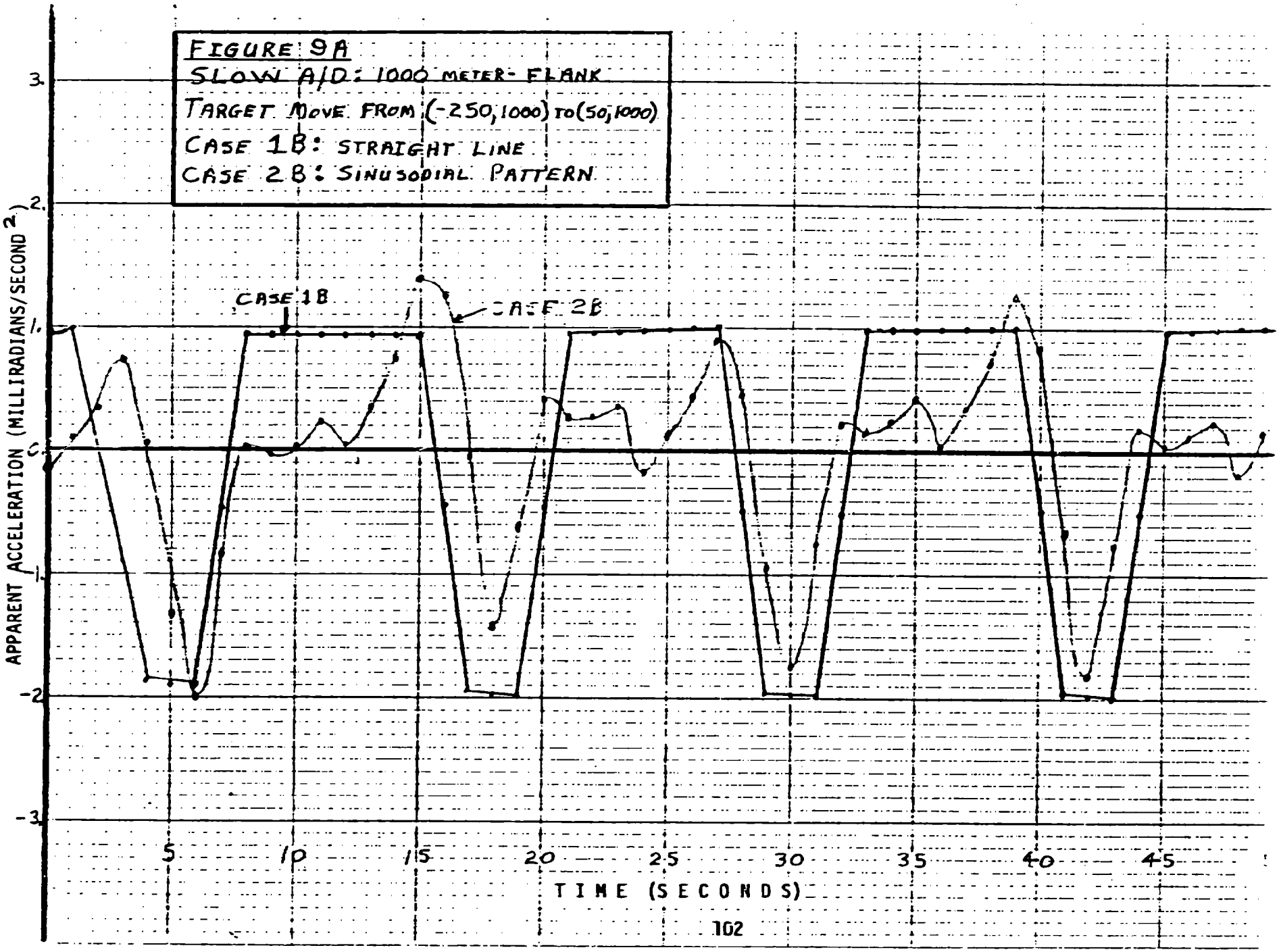


FIGURE 9A
SLOW A/D: 1000 METER- FLANK
TARGET MOVE FROM (-250,1000) TO (50,1000)
CASE 1B: STRAIGHT LINE
CASE 2B: SINUSODIAL PATTERN
CASE 1B
CASE 2B
APPARENT ACCELERATION (MILLIRADIANS/SECOND 2)
3.
2.
1.
0.
-1.
-2
-3
5
10
15
20
25
30
35
40
45
TIME (SECONDS)

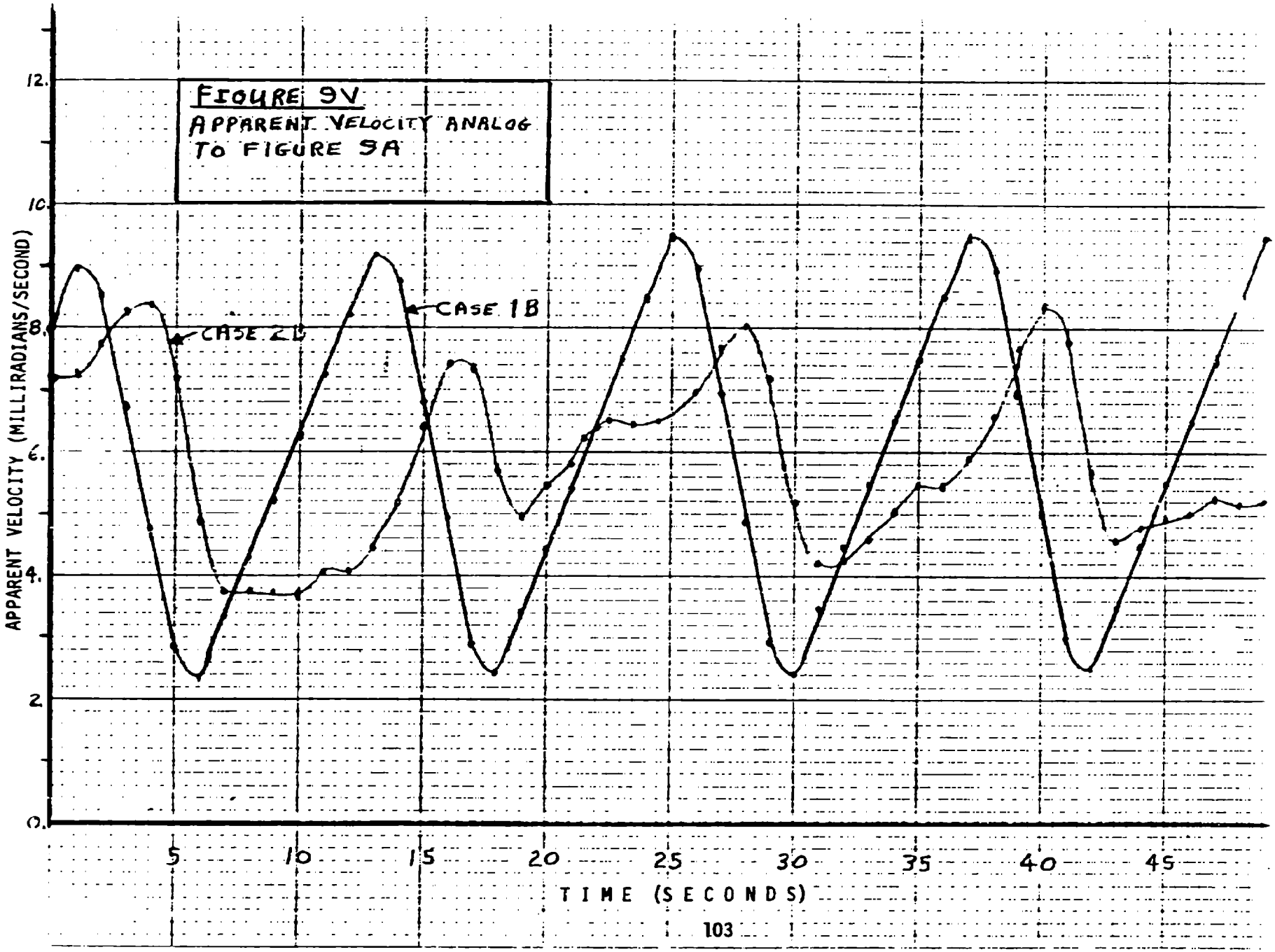


FIGURE 9V
APPARENT VELOCITY ANALOG
TO FIGURE 9A
CASE 1B
CASE 2B
APPARENT VELOCITY (MILLIRADIANS/SECOND)
12.
10.
8.
6.
4.
2
0.
5
10
15
20
25
30
35
40
45
TIME (SECONDS)

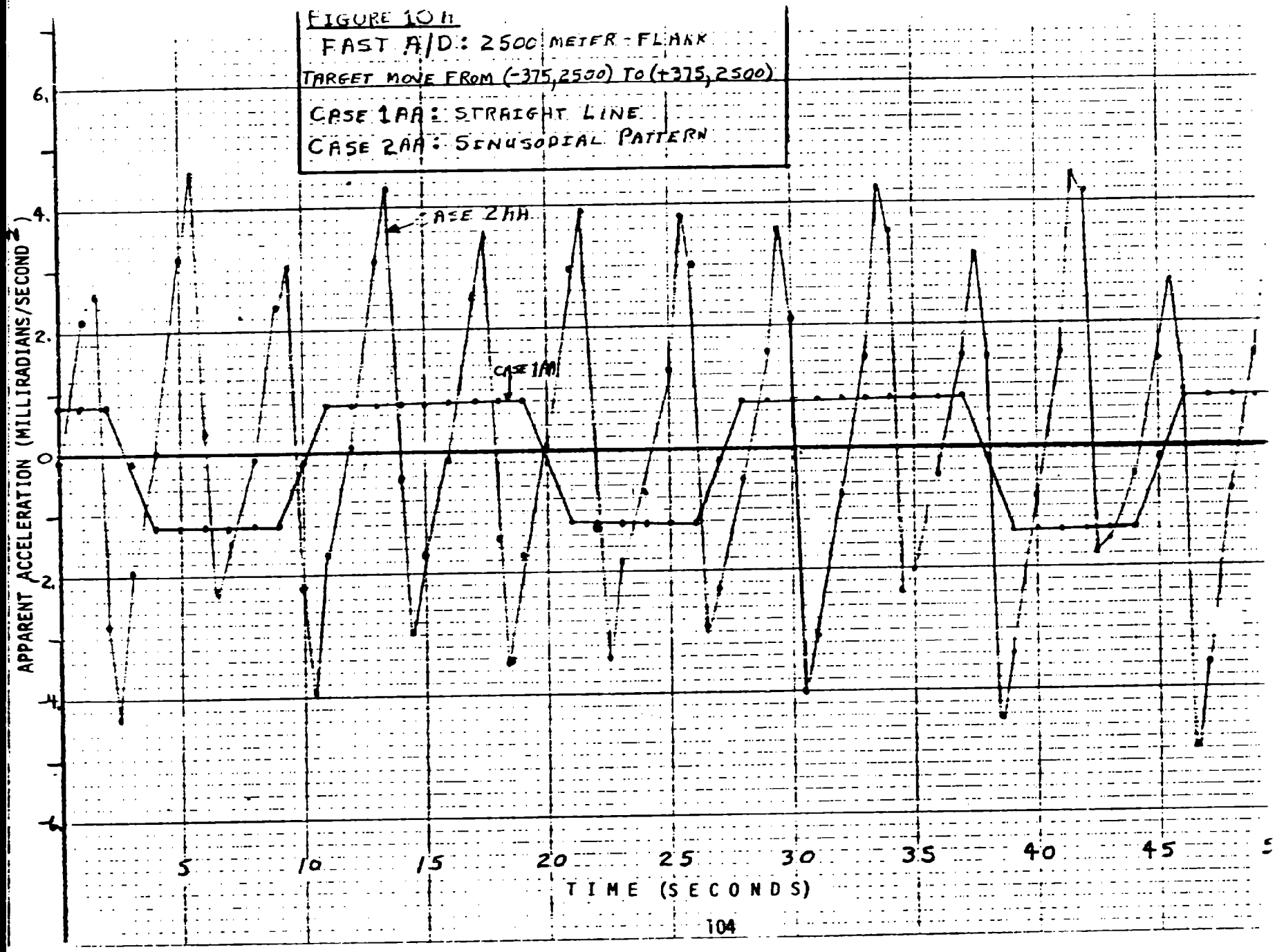


FIGURE 10h
FAST A/D: 2500 METER - FLANK
TARGET MOVE FROM (-375,2500) TO (+375,2500)
CASE 1AA: STRAIGHT LINE
CASE 2AA: SINUSODIAL PATTERN
CASE 2AA
CASE 1AA
APPARENT ACCELERATION (MILLIRADIANS/SECOND²)
6.
4.
2.
0
-2.
-4.
-6.
5
10
15
20
25
30
35
40
45
TIME (SECONDS)

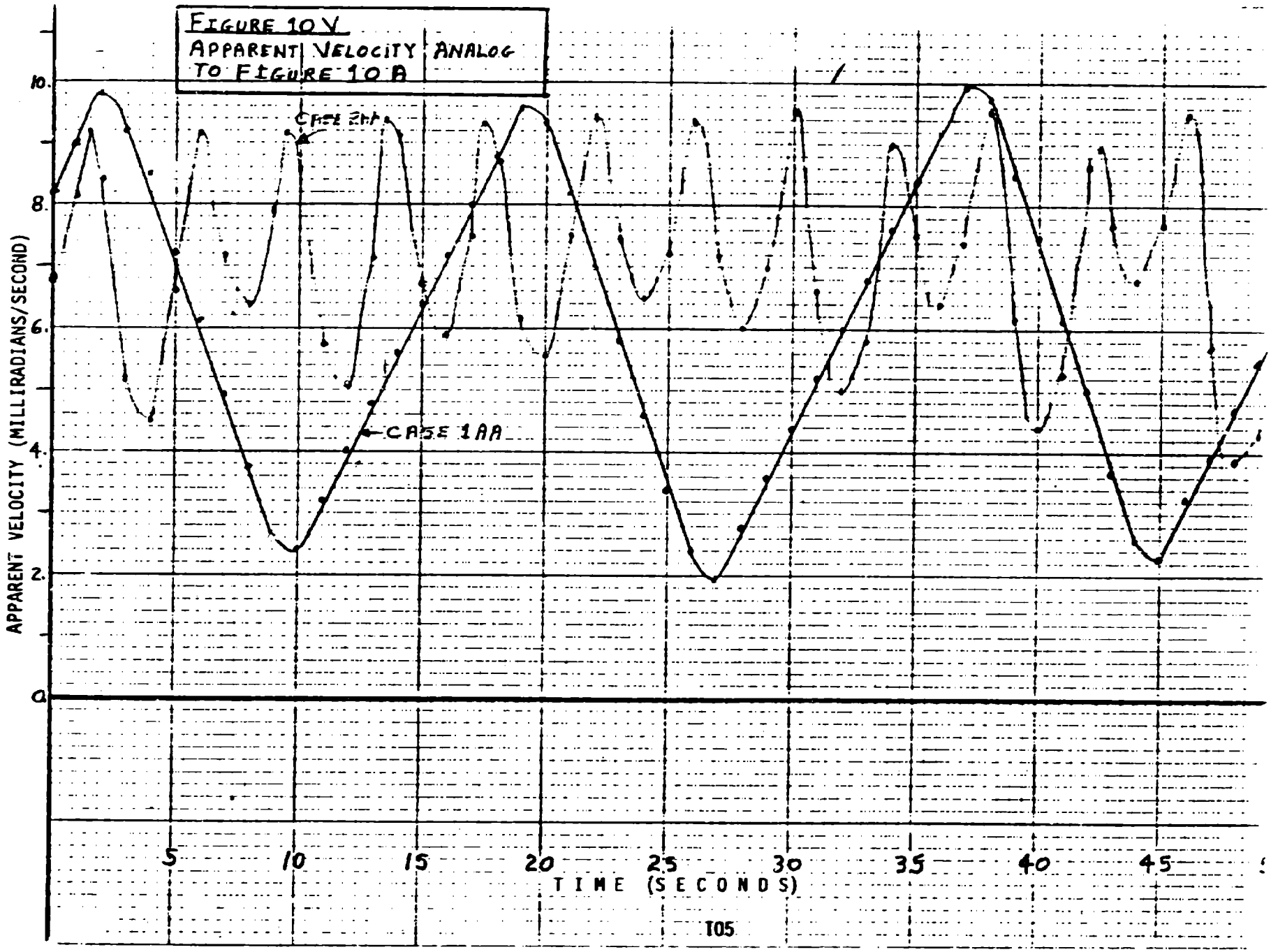


FIGURE 10 V
APPARENT VELOCITY ANALOG
TO FIGURE 10 A
CASE 2AA
CASE 1AA
APPARENT VELOCITY (MILLIRADIANS/SECOND)
10.
8.
6.
4.
2.
0
5
10
15
20
25
30
35
40
45
TIME (SECONDS)

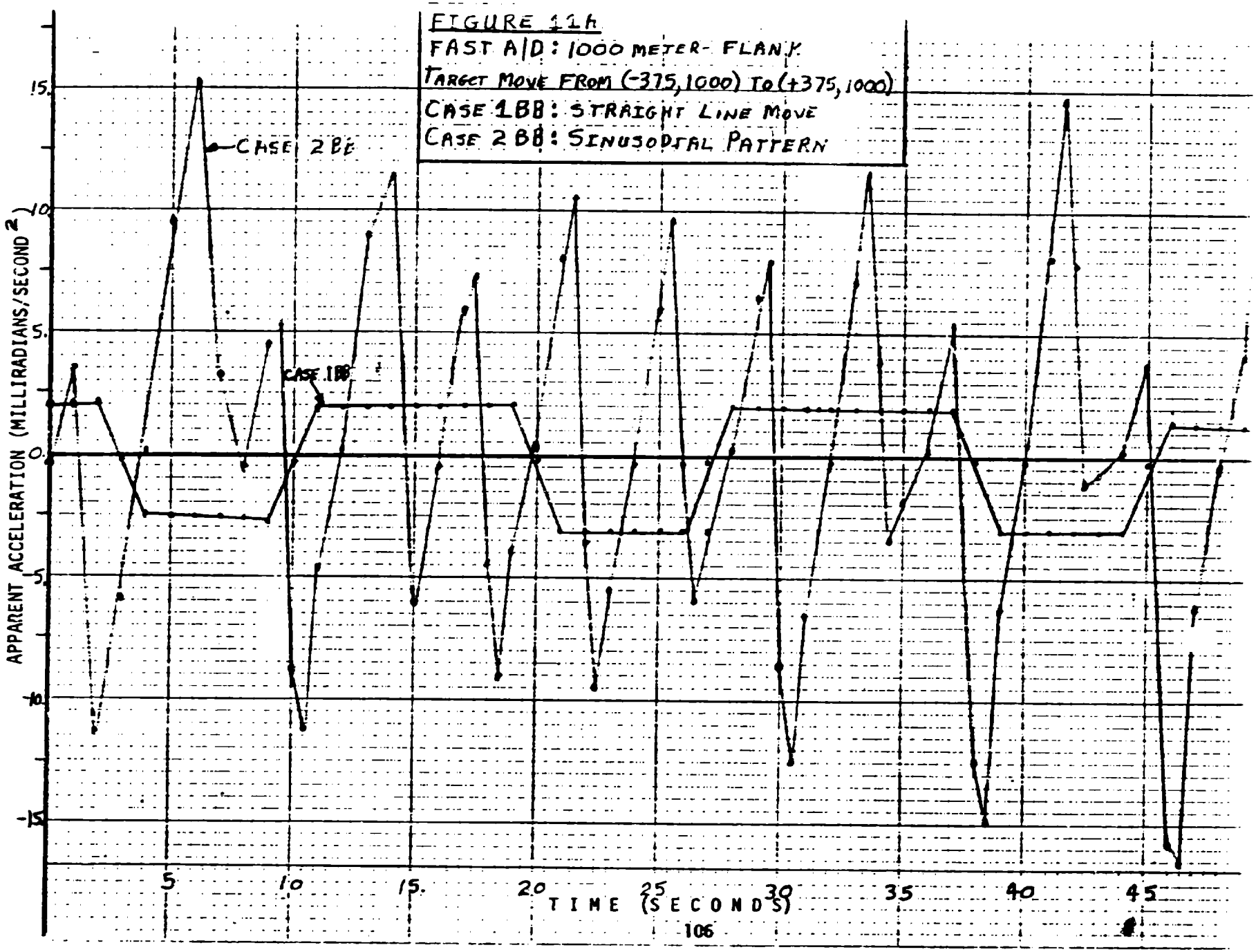


FIGURE 11A
FAST A/D: 1000 METER- FLANK
TARGET MOVE FROM (-375,1000) TO (+375,1000)
CASE 1BB: STRAIGHT LINE MOVE
CASE 2BB: SINUSODIAL PATTERN
CASE 2BB
CASE 1BB
APPARENT ACCELERATION (MILLIRADIANS/SECOND²)
15.
10.
5.
0.
-5.
-10.
-15.
5
10
15.
20
25
30
35
40
45
TIME (SECONDS)

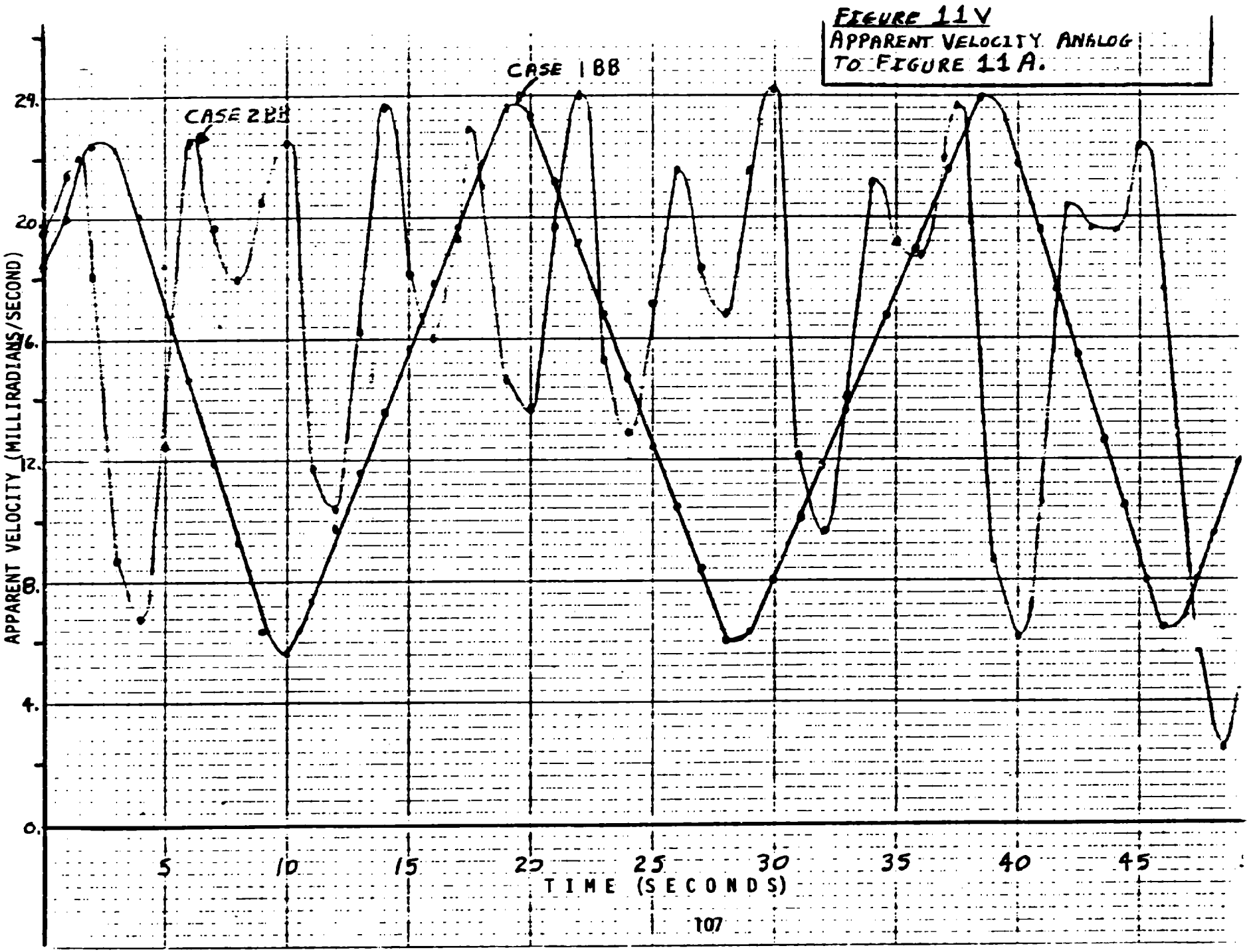


FIGURE 11V
APPARENT VELOCITY ANALOG TO FIGURE 11A.

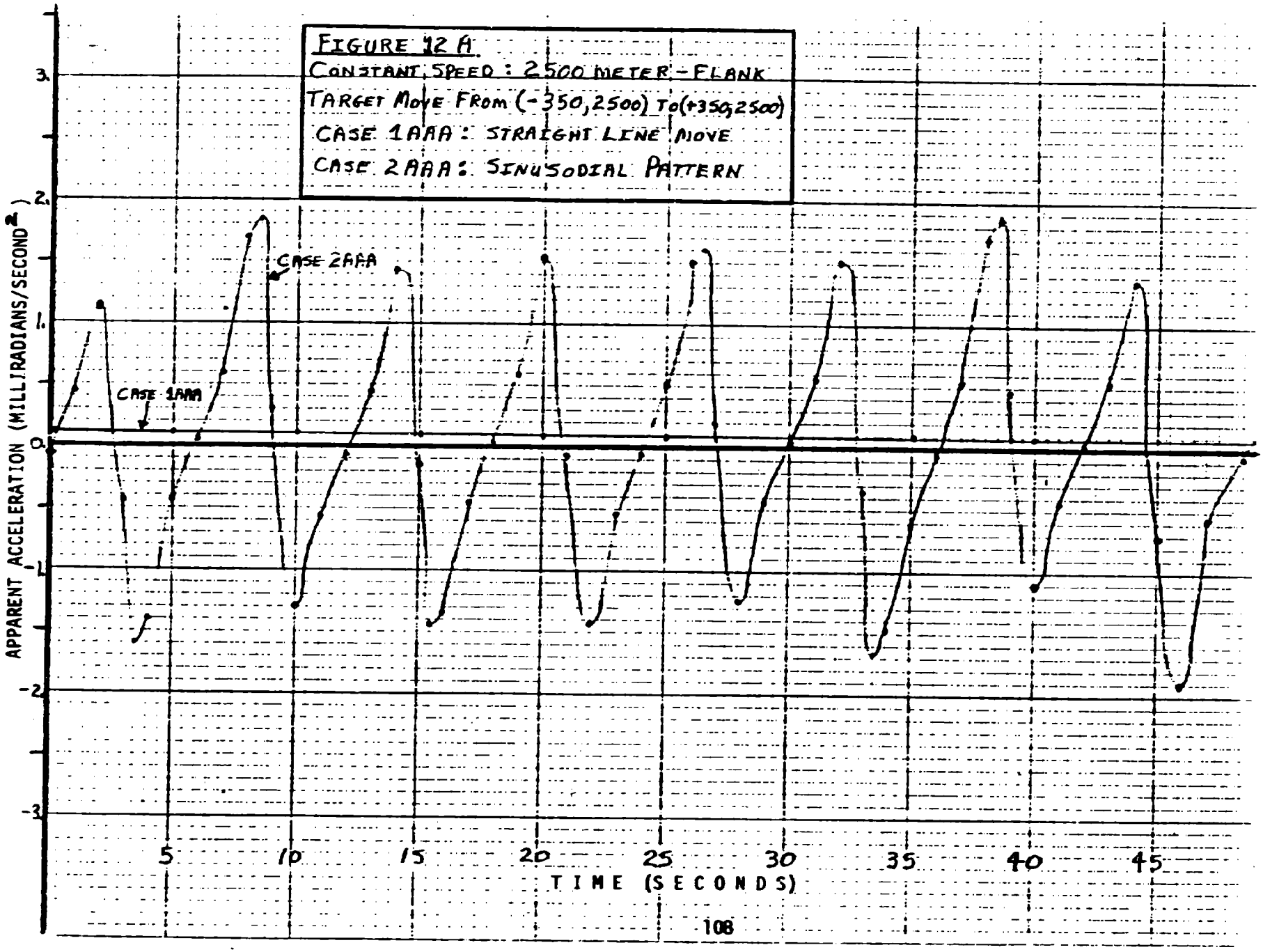


FIGURE 12 A
CONSTANT SPEED : 2500 METER - FLANK
TARGET MOVE FROM (-350,2500) TO (+350,2500)
CASE 1AAA : STRAIGHT LINE MOVE
CASE 2AAA : SINUSODIAL PATTERN
CASE 2AAA
CASE 1AAA
APPARENT ACCELERATION (MILLIRADIANS/SECOND²)
3.
2.
1.
0.
-1.
-2.
-3.
5
10
15
20
25
30
35
40
45
TIME (SECONDS)

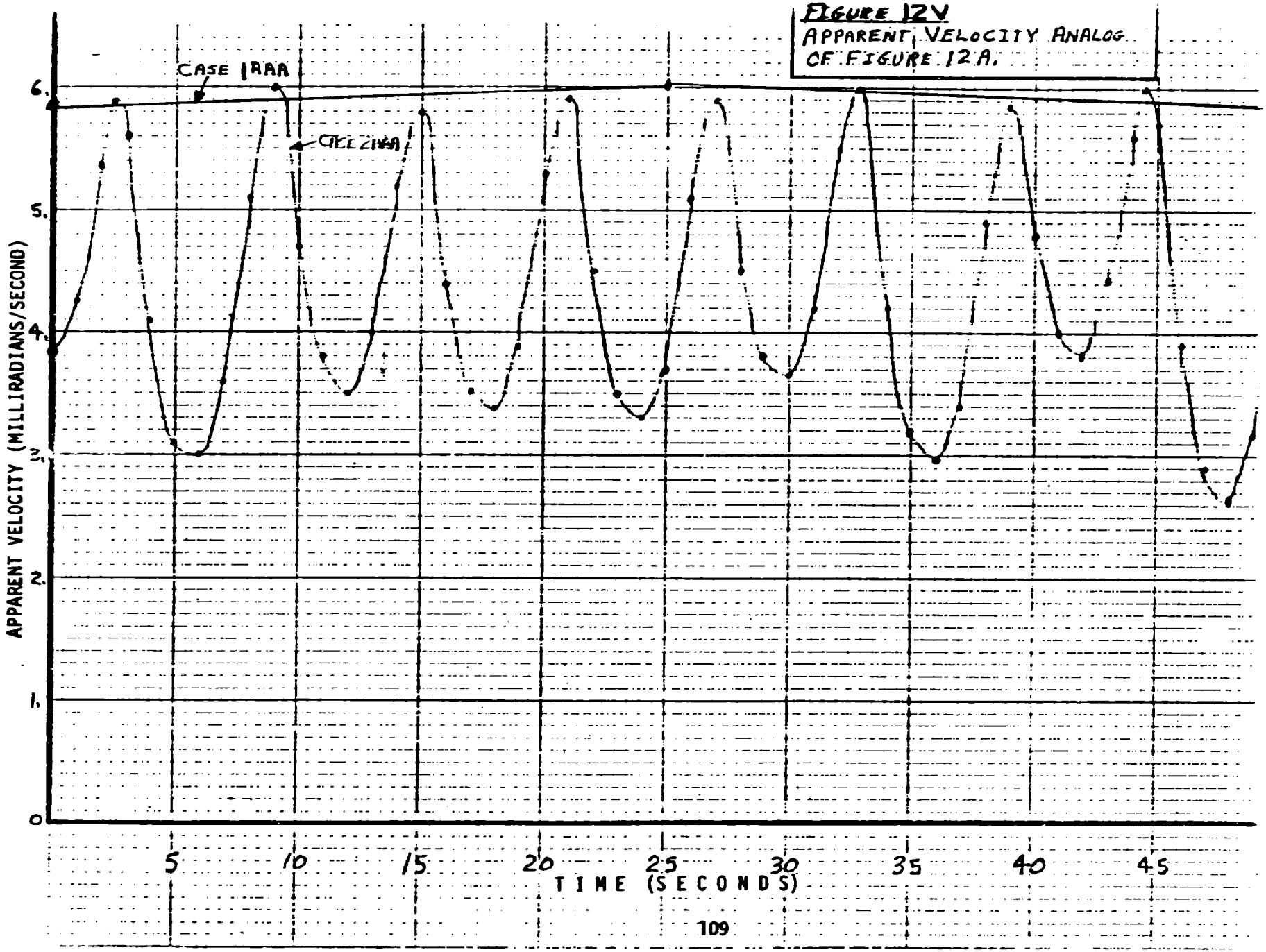


FIGURE 12V
APPARENT VELOCITY ANALOG OF FIGURE 12A.

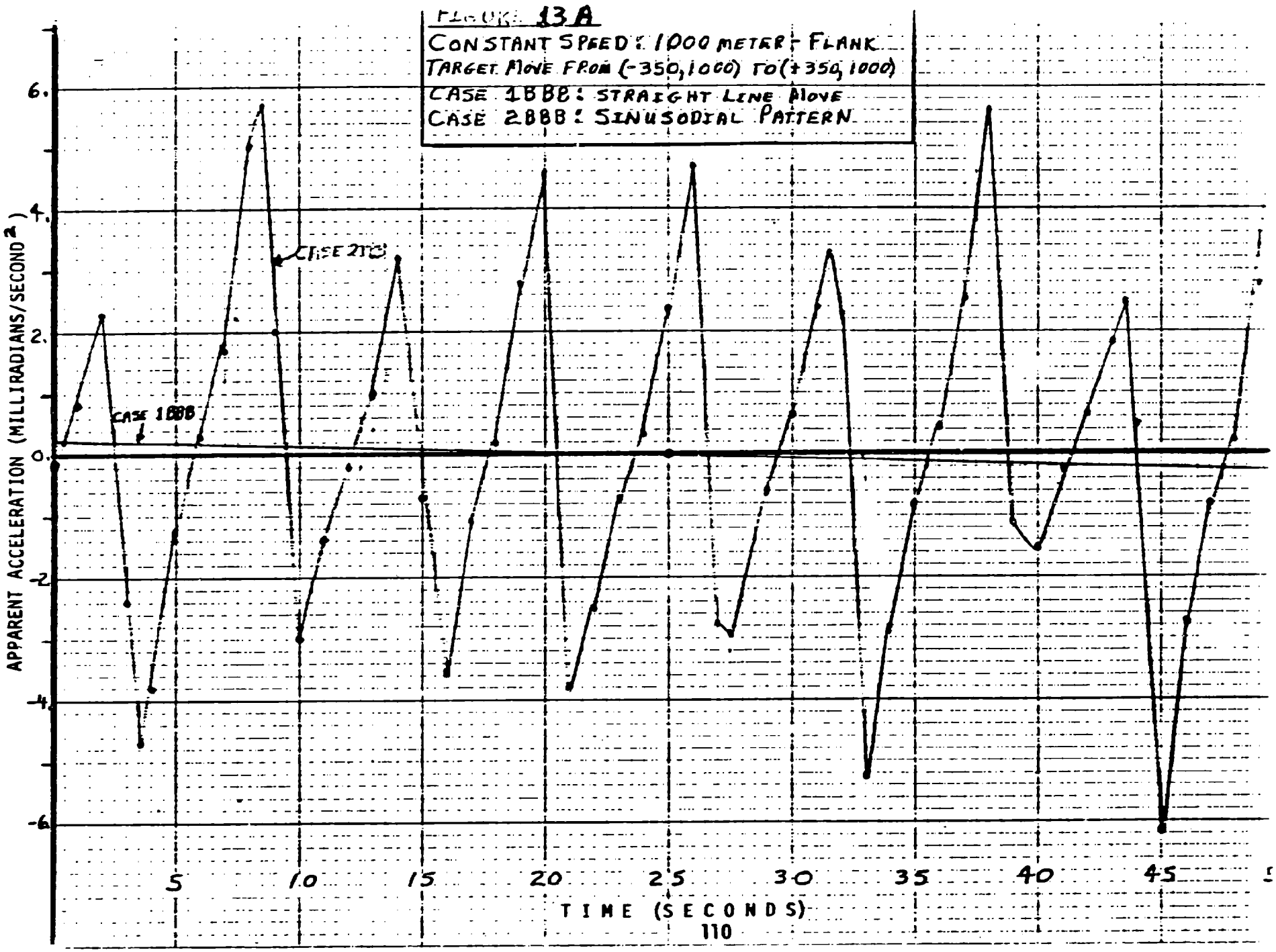


FIGURE 13A
CONSTANT SPEED: 1000 METER - FLANK
TARGET MOVE FROM (-350,1000) TO (+350,1000)
CASE 1BBB: STRAIGHT LINE MOVE
CASE 2BBB: SINUSODIAL PATTERN
CASE 2BBB
CASE 1BBB
APPARENT ACCELERATION (MILLIRADIANS/SECOND²)
6.
4.
2.
0.
-2
-4
-6
5
10
15
20
25
30
35
40
45
TIME (SECONDS)

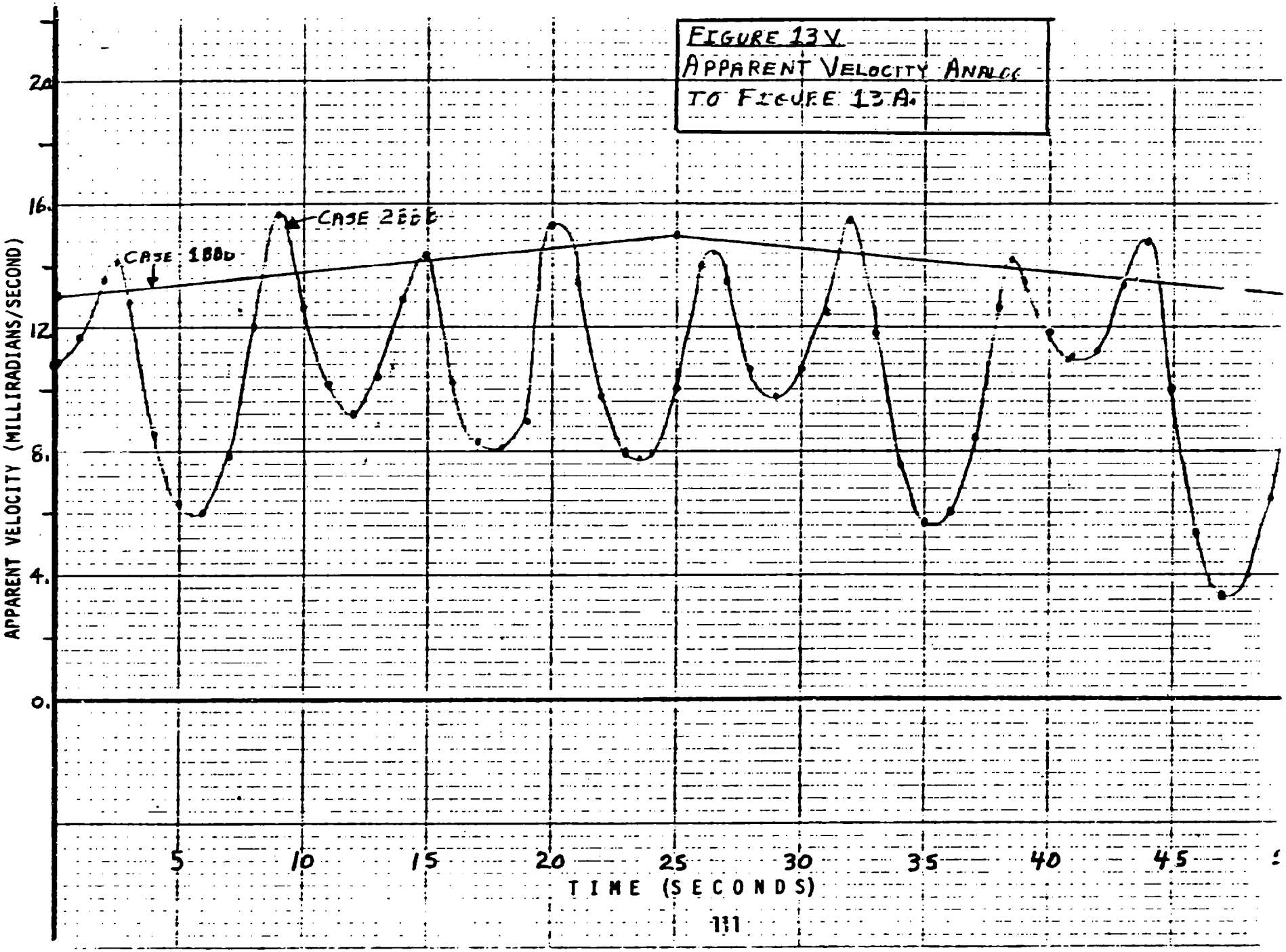


FIGURE 13V
APPARENT VELOCITY ANALOG
TO FIGURE 13A.
CASE 188D
CASE 2EDE
APPARENT VELOCITY (MILLIRADIANS/SECOND)
20.
16.
12
8.
4.
0.
5
10
15
20
25
30
35
40
45
TIME (SECONDS)

SECTION III.

DESCRIPTION OF LOGIC AND INPUT REQUIREMENTS FOR ANALYSIS OF APPARENT ACCELERATION (PROGRAM PAPA)

The computer program (PAPA) which computes $\Delta\Theta$ (apparent velocity) and $\Delta^2\Theta$ (apparent acceleration), is capable of computing these values for the following cases of target movement. Each case can represent the target

a. at any X-Y starting position with any initial velocity,

b. accelerating/decelerating during the movement trace until reaching specified maximum/minimum velocities or reaching the specified final position.

NOTE: A listing of the program is given in Attachment 10 and a sample output in Attachment 11.

CASE 1 A. Target moving such that Y distance to firer remains constant at any initial (X, Y) position.

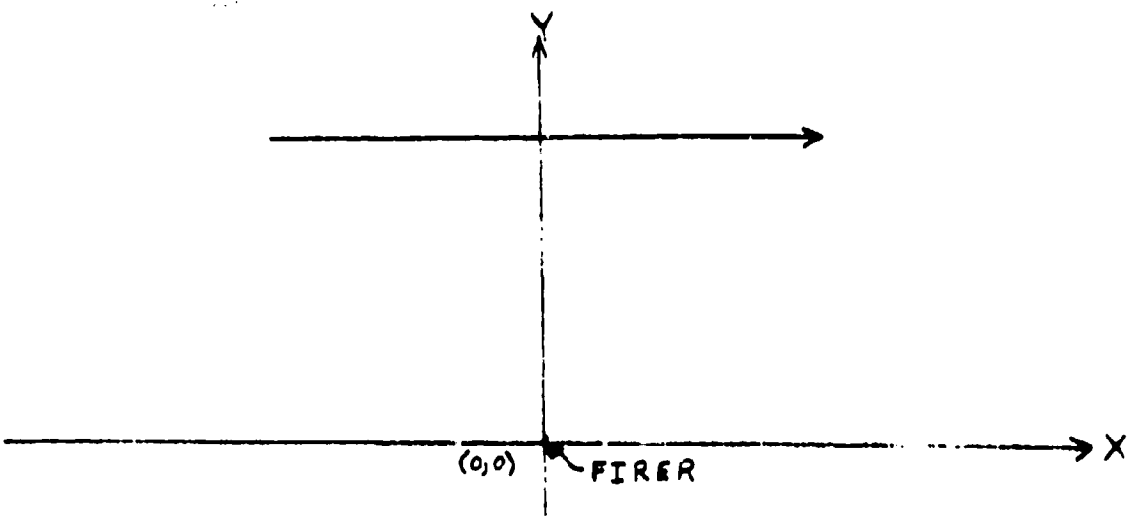


FIGURE 1

CASE 1 B. Additional straight line movement. (Includes oblique - any specified angle).

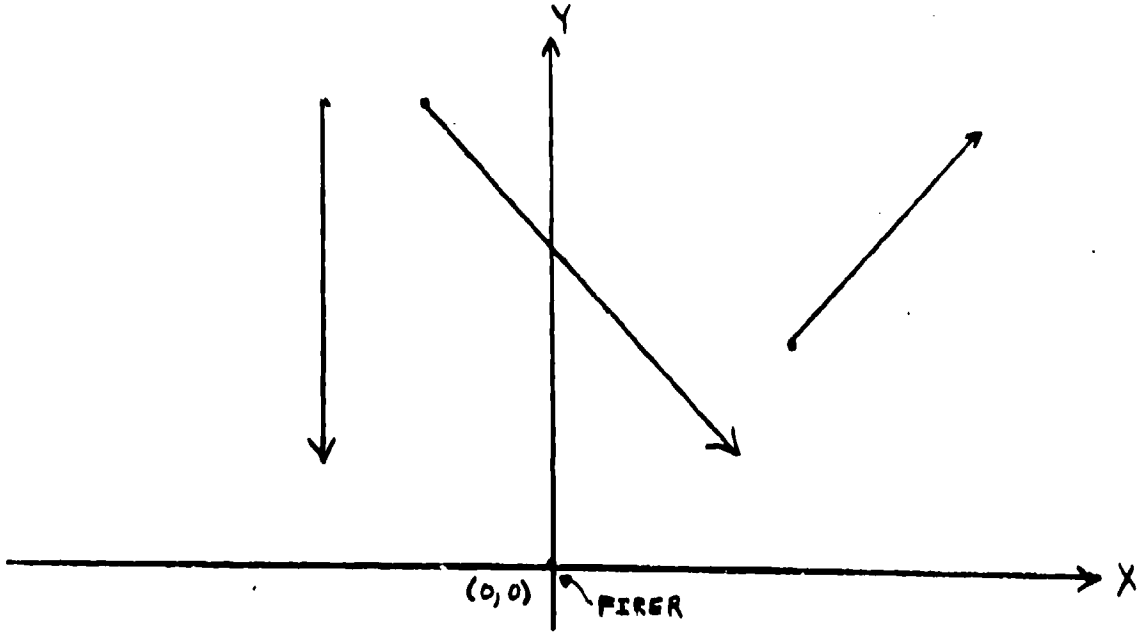


FIGURE 2

CASE 2: Sinusodial movement patterns.

CASE 2 A.

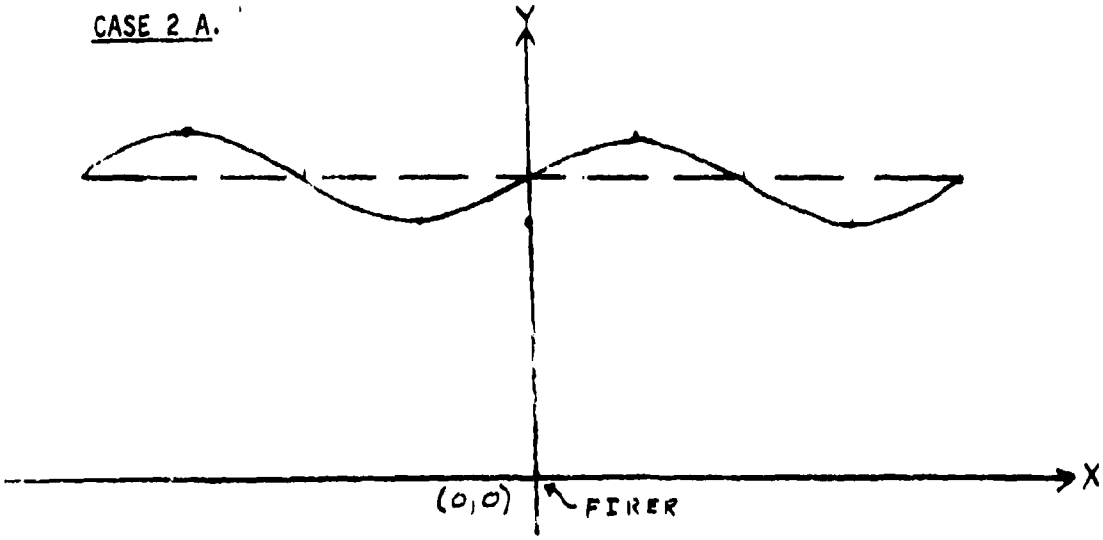


FIGURE 3

CASE 2 B.

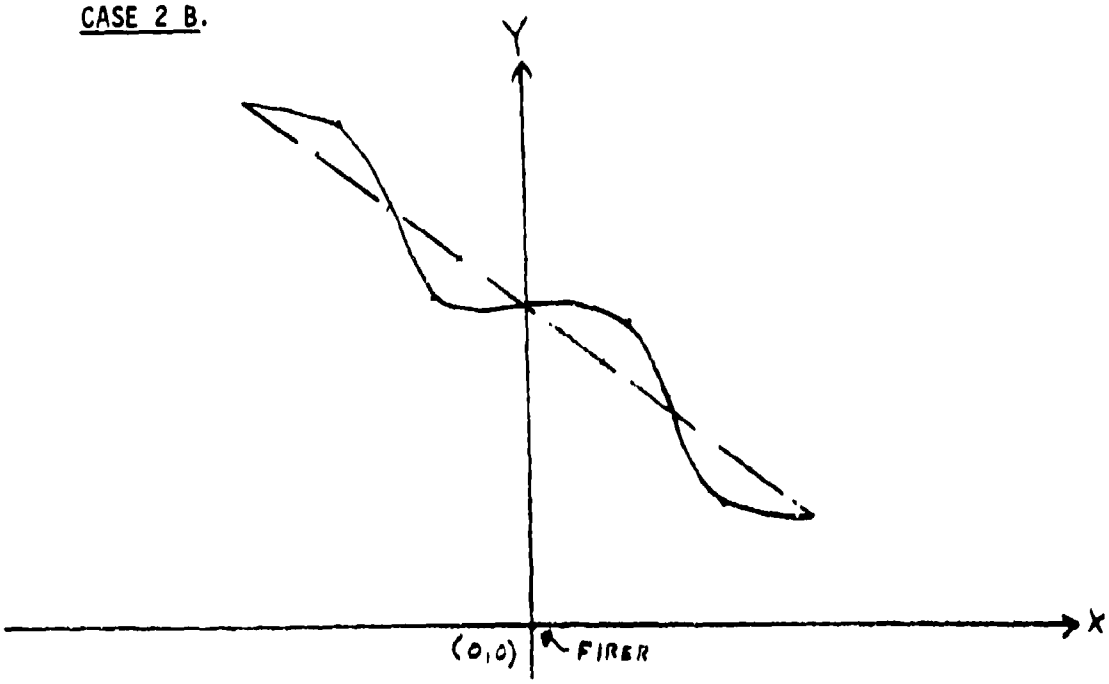
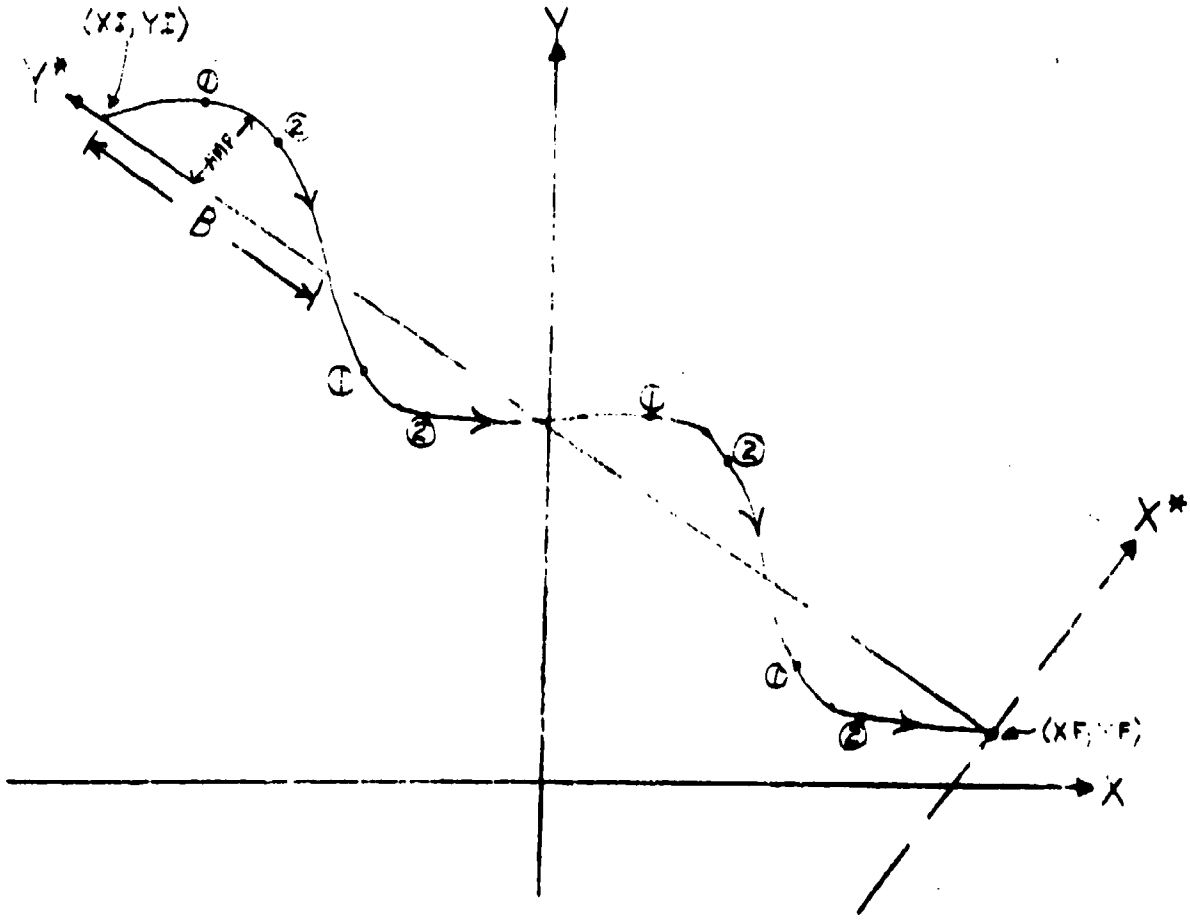


FIGURE 4



EXAMPLE OF SINUSODIAL MOVEMENT

FIGURE 5

EXAMPLE FOR CASE 2

Consider the example in Figure 5.

The equation of the target movement trace is

$$X^* = A \sin (y^*)$$

where

X^* = the X^* coordinate translated to (XF, YF) and rotated such that the sinusodial axis becomes the Y^* axis;

A = amplitude of the sine wave,

y^* = the y^* coordinate of the translated and rotated coordinate system (in radians relative to the sine wave).

The movement path along the sine wave is generated by dividing 2π radians (one full period) into "small" fixed increment angles, represented by y^*. The corresponding rotated and translated coordinate value in meters is noted by Y^*. The shape of the sine wave is determined by inputs of AMP(J), the amplitude for the J^{TH} period, and B, the distance (meters) between each crossing of the Y^* axis (half-period distance).

For each fixed Δy^* interval, the (X^*, Y^*) position on the movement path is computed using a straight line pattern from the previous point on the sine wave. Thus, a piecewise linear movement pattern is fitted to the actual sinusodial pattern, but the values of Θ, $\Delta\Theta$, and $\Delta^2\Theta$ are computed from points on the sine curve. The approximation may be made as close as desired by selecting "small" Δy^* increments.

The inputs required for the straight line, sinusodial, and three-dimensional patterns are given in a subsequent section.

CASE 3 - THREE DIMENSIONAL PATTERN

The three-dimensional movement pattern moves the target on a straight line path in the X-Y plane. The target's movement in the Z direction is controlled through input data (defined in the next section).

In general, the X-Y distance between Z heighth changes is fixed. Note, however, that the heighth at each change point, as well as the acceleration/deceleration between heighth changes, may vary for each segment.

The values of $\Delta\Theta$ and $\Delta^2\Theta$ represent the appropriate rates of change of Θ in three dimensions (as opposed to the change in the X Y plane or the change in the X Y - Z plane only). Thus, $\Delta\Theta$ and $\Delta^2\Theta$ represent the total apparent acceleration and velocity values relative to the tracker.

NOTE: The THREED routine may be utilized to represent an aerial vehicle as well as a ground target movement trace.

INPUT REQUIREMENTS FOR PAPA

A. Straight line movement (Subroutine STRAIT).

1. (XI, YI): the target's initial position (meters).
2. (XF, YF): the target's final position (meters).
3. VI: initial velocity of target at (XI, YI) (meters/second).
4. AA: acceleration (meters/second^2) when target is accelerating.
5. AD: deceleration (meters/second^2) when target is decelerating.
6. (VMIN, VMAX): minimum and maximum velocity of the target during the movement trace.
7. TINC: the time increment used for computation of apparent acceleration and velocity.

B. Sinusodial movement (subroutine SINMOV).

1. (XI, YI): the target's initial position (meters).
2. (XF, YF): the target's final position (meters).
3. AMP(J): the amplitude of the sine wave (meters) for the J<u>TH</u> period.
4. B: the distance (in meters) between each crossing of the Y* axis (see Figure 5).
5. VI: the initial velocity of the target at XI, YI (meters/second).

6. AA: the acceleration (meters/second^2) when target is accelerating.

7. AD: the deceleration (meters/second^2) when target is decelerating.

8. ANGD: the value (in radians (0 - π)) at which the target will begin decelerating (points 1 in Figure 5).

9. ANGA: the value (in radians (0 - π)) at which the target will begin accelerating (points 2 in Figure 5).

NOTE: Values such as ANGD = $\frac{\pi}{3}$ and ANGA = $\frac{\pi}{2}$ might be appropriate, depending on AMP(J), B, and V. These values would begin slowing the target for the turn about two-thirds of the way to the peak of the curve and begin acceleration at the peak of the curve.

10. IANG: the fixed increment for computing target movement (number of increments per 2 π period).

11. NPER: number of periods in the movement pattern.

NOTE: The distance between the inputs

(XI, YI) and (XF, YF) must equal

$$2 \cdot B \cdot NPER.$$

12. (VMIN, VMAX): the minimum and maximum velocity of the target during the movement trace (meters/second).

C. Three-dimensional movement (Subroutine THREED).

1. (XI, YI, ZI): the target's initial position (meters).

2. (XF, YF, ZF): the target's final position (meters).

3. VI: initial velocity of target at (XI, YI) (meters/second).

4. (VMIN, VMAX): minimum and maximum velocity of the target during the movement trace.

5. DZINC: the increment of distance traveled in the X-Y plane at which a new Z heighth of the movement path is specified in ZH(I) (meters).

6. NNINC: the number of DZINC increments in the total movement path (maximum of 200 increments).

<u>NOTE</u>: $$NNINC = \frac{\sqrt{(XF - XI)^2 + (YF - YI)^2}}{DZINC}$$

7. TINC: the time increment used for computation of apparent acceleration and velocity.

8. ZH(I), I = 1,...,NNINC: the Z heighth of the movement path (positive or negative) at the <u>end of</u> the $I^{\underline{TH}}$ increment.

<u>NOTE</u>: Initial heighth is input for ZI.

9. AC(I), I = 1,...,NNINC: the acceleration (or deceleration) when moving from the $(I-1)^{\underline{ST}}$ to the $I^{\underline{TH}}$ point (corresponding to ZH(I)).

<u>NOTE</u>: Care should be taken to assure that reasonable values of AC(I) are specified for up-slopes and down-slopes.

<u>NOTE</u>: If constant oscilations between two heights (and constant accelerations over each increment) are desired, the following inputs are made:

a. Input NNINC = 0

b. Input ZH(1) as the heighth for the end of the first, third, fifth, etc., increments.

c. Input ZH(2) as the heighth for the end of the second, fourth, sixth, etc., increments.

d. Input AC(1) and AC(2) as the appropriate accelerations when moving toward ZH(1) and ZH(2), respectively.

ATTACHMENT 10

PROGRAM PAPA

FORTRAN SOURCE LISTING

```
      PROGRAM PAPA (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
C
C*****************************************************************
C
C  PROGRAM  PAPA
C  APPARENT ACCELERATION AND VELOCITY
C
C  DESIGNED & PROGRAMMED BY SAM H. PARRY, NAVAL POSTGRADUATE SCHOOL
C
C----------**FOR USAARENBD-FORT KNOX---- AUGUST 1975-**
C
C*****************************************************************
C
      DIMENSION AMP(15)
      COMMON    TH(400),THXY2(400),DTH(400),DDTH(400)
   10 CONTINUE
C NCASE=1 -STRAIGHT LINE MOVE, =2 -SINUSODIAL MOVE, 3 = 3D MOVE
      READ(5,900)NCASE
  900 FORMAT(I1)
      IF(NCASE.EQ.0)STOP
      DTH(1)=0.
      DDTH(2)=0.
      DDTH(1)=0.
      IF(NCASE.GT.1)GOTO100
      READ(5,910)XI,YI,XF,YF,VI,VMIN,VMAX,AA,AD,TINC
  910 FORMAT(4F10.0,6F5.0)
      WRITE(6,1500)XI,YI,XF,YF,VI,VMIN,VMAX,AA,AD,TINC
 1500 FORMAT(1H1,20X,"APPARENT ACCELERATION AND VELOCITY ANALYSIS",//,
     *20X,"STRAIGHT LINE TARGET MOVEMENT",///
     115X,"INPUT DATA",///,10X,"INITIAL POSITION (XI,YI)  ",F8.1,1X,
     2F8.1,//10X,"FINAL POSITION (XF,YF)  ",F8.1,1X,F8.1,//10X,
     3"INITIAL SPEED (VI - M/S)  ",F7.1,//10X,
     4"MIN AND MAX SPEED (VMIN,VMAX)  ",F7.1,1X,F7.1,//10X,
     5"ACCELERATION/DECELERATION CONSTANTS (M/SEC SQUARED) -",
     6F7.1,1X,F7.1,//10X,"TIME INCREMENT  ",F7.4)
      WRITE(6,1010)
 1010 FORMAT(///8X,"INCREMENT   XC",8X,"YC",9X,"SPEED",2X,
     *"ACTUAL RANGE",5X,
     1"ANGLE       DANGLE      DDANGLE",/1X)
      CALL STRAIT(XI,YI,XF,YF,VI,VMIN,VMAX,AA,AD,TINC)
      GOTO10
  100 CONTINUE
      IF(NCASE.GT.2)GOTO150
      READ(5,920)XI,YI,XF,YF,VI,VMIN,VMAX,AA,AD,B,ANGD,ANGA,NPER,IANG
  920 FORMAT(4F8.0,8F5.0,2I4)
      READ(5,930)KINC,(AMP(KI),KI=1,KINC)
  930 FORMAT(I5,15F5.0)
      WRITE(6,1600)XI,YI,XF,YF,VI,VMIN,VMAX,AA,AD,ANGD,ANGA,NPER,IANG,B
 1600 FORMAT(1H1,20X,"APPARENT ACCELERATION AND VELOCITY ANALYSIS",//,
     120X,"SINUSODIAL TARGET MOVEMENT",///,
     215X,"INPUT DATA",///10X,"INITIAL POSITION (XI,YI)  ",F8.1,1X,
     3F8.1,//10X,"FINAL POSITION (XF,YF)--",F8.1,1X,F8.1,//10X,
     4"INITIAL SPEED (VI - M/S)  ",F7.1,//10X,
     5"MIN AND MAX SPEED (VMIN,VMAX)  ",F7.1,1X,F7.1,//10X,
     6"ACCELERATION/DECELERATION CONSTANTS (M/SEC SQUARED)  ",
     7F7.1,1X,F7.1,//10X,"DECELERATION POINT IN THE PERIOD(RADIANS)  ",
     8F8.4,//10X,"ACCELERATION POINT IN THE PERIOD(RADIANS)  ",F8.4,//
```

```
      910X,"NUMBER OF PERIODS IN THE MOVE  ",I4,//10X,
     *"NUMBER OF INCREMENTS PER PERIOD",I4,//10X,
     *"HALF-PERIOD DISTANCE  ",F7.1)
      WRITE(6,1012)
 1012 FORMAT(///8X,"INCREMENT   XC",8X,"YC",9X,"SPEED",2X,
     *"ACCELERATION",2X,"TIME",3X,"ACTUAL RANGE",5X,
     1"ANGLE      DANGLE     DDANGLE",/1X)
      CALL SINMOV(AMP,B,XI,YI,VI,AA,AD,ANGD,ANGA,IANG,NPER,XF,YF,
     1VMAX,VMIN)
      GOTO10
  150 CONTINUE
      IF(NCASE.GT.3)STOP
      READ(5,975)XI,YI,ZI,XF,YF,ZF,VI,VMIN,VMAX,DZINC,NNINC,TINC
  975 FORMAT(6F8.0,4F5.0,2X,I5,F5.0)
      CALL THREED(XI,YI,ZI,XF,YF,ZF,VI,VMIN,VMAX,DZINC,NNINC,TINC)
      GOTO10
      END
```

COPY AVAILABLE TO DDC DOES NOT
PERMIT FULLY LEGIBLE PRODUCTION

```
C
C*****************************************************************************
C
      SUBROUTINE STRAIT(XI,YI,XF,YF,VI,VMIN,VMAX,AA,AD,TINC)
      COMMON     TH(400),THXYZ(400),DTH(400),DDTH(400)
      I=1
      AC=AA
      XCL=XI
      YCL=YI
      VFL=VI
      DTRAV=0.
      DTOT=SQRT((XF-XI)**2 +(YF-YI)**2)
      TEMP=(YF-YI)/DTOT
      TAMP=(XF-XI)/DTOT
   50 CONTINUE
      IF(VFL.GE.VMAX)AC=AD
      IF(VFL.LE.VMIN)AC=AA
      IF(DTRAV.GE.DTOT)GOTO200
      XC=(AC*TAMP*(TINC**2))/2. + (VFL*TAMP*TINC) + XCL
      YC=(AC*TEMP*(TINC**2))/2. +(VFL*TEMP*TINC) + YCL
      DTR=SQRT((XC-XCL)**2 +(YC-YCL)**2)
      DTRAV=DTRAV + DTR
      DFT =SQRT((XC*XC) +(YC*YC))
      COSTH=XC/DFT
      VF=AC*TINC + VFL
      IF(ABS(COSTH).GT.1.)GOTO230
      TH(I)=ACOS(COSTH)
      IF(I.LE.1)GOTO100
      DTH(I)=(TH(I)-TH(I-1))/TINC
      DTH(I)=ABS(DTH(I))
      IF(I.LE.2)GOTO100
      DDTH(I)=(DTH(I)-DTH(I-1))/TINC
  100 CONTINUE
      WRITE(6,1200)I,XC,YC,VF,DFT,TH(I),DTH(I),DDTH(I)
 1200 FORMAT(8X,I4,6X,F8.2,2X,F8.2,2X,F7.2,2X,F8.2,2X,3E13.5)
      I=I+1
      IF(I.GT.400)GOTO190
      VFL=VF
      XCL=XC
      YCL=YC
      GOTO50
  190 WRITE(6,1050)
 1050 FORMAT(//10X,"RUN TERMINATED - EXCESSIVE INCREMENTS")
      GOTO250
  200 WRITE(6,1060)
 1060 FORMAT(//10X,"RUN-TERMINATED - REACHED FINAL POSITION")
      GOTO250
  230 WRITE(6,1070)
 1070 FORMAT(//10X,"RUN TERMINATED - COSTH GT 1")
      GOTO250
  250 CONTINUE
      RETURN
      END
```

```
C
C*******************  ************************  ************************
C
      SUBROUTINE SINMOV(AMP,B,XI,YI,VI,AA,AD,ANGD,ANGA,IANG,NPER,XF,YF,
     1VMAX,VMIN)
      COMMON     TH(400),THXYZ(400),DTH(400),DDTH(400)
      DIMENSION AMP(15)
      XCL=XI
      YCL=YI
      VFL=VI
      DTOT=SQRT((YF-YI)**2+(XF-XI)**2)
      TSIN=(XF-XI)/DTOT
      ANGT=ASIN(TSIN)
      TCOS=COS(ANGT)
      DANG=6.283185308/IANG
      DYINC=(2.*B)/IANG
      PII=3.141592654
      AC=AA
      CTIM=0.
      K=1
      DO 200 I=1,NPER
      DO 150 J=1,IANG
      AJ=J
C
C
      XCLRT=((XCL-XF)*TCOS)+(YCL-YF)*TSIN
      YCLRT=((YCL-YF)*TCOS)-(XCL-XF)*TSIN
      YCRT=YCLRT - DYINC
      XCRT= AMP(I)*SIN(    J*DANG)
      DTRAV=SQRT((YCRT-YCLRT)**2-+ (XCRT-XCLRT)**2)
      IF(AC.EQ.0.)GOTO50
      VFLTP=VFL**2
      TUMP=2.*AC*DTRAV
      IF((TUMP.LT.0.).AND.(VFLTP.LT.(ABS(TUMP))))GOTO250
      TIME=(-VFL+SQRT(VFLTP+TUMP))/AC
      IF(TIME.LE.0)GOTO240
      GOTO100
   50 CONTINUE
      IF(VFL.LE.0.)GOTO255
      TIME=DTRAV/VFL
  100 CONTINUE
      XC=(XCRT*TCOS)-(YCRT*TSIN)-+ XF
      YC=(YCRT*TCOS)+(XCRT*TSIN) + YF
      DFT=SQRT((XC*XC)-+ (YC*YC))
      COSTH=XC/DFT
      VF=AC*TIME + VFL
      IF(ABS(COSTH).GT.1)GOTO257
      TH(K)=ACOS(COSTH)
      DTH(K)=(TH(K-1)-TH(K))/TIME
      IF(K.LE.2)GOTO60
      IF(K.LE.1)GOTO60
      IF(((DTH(K).LT.0.).AND.(DTH(K-1).GT.0.)).OR.
     1((DTH(K).GT.0.).AND.(DTH(K-1).LT.0.)))GOTO55
      KPRTST=0
      GOTO58
   55 CONTINUE
      SAVT=DTH(K)
```

COPY AVAILABLE TO DDC DOES NOT PERMIT FULLY LEGIBLE PRODUCTION

```
      ATK=ABS(DTH(K))
      ATKM=ABS(DTH(K-1))
      QTOT=ATK+ATKM
      TTD=ATKM*TIME/QTOT
      TTA=ATK*TIME/QTOT
      DECL=-ATKM/TTD
      ACCL=ATK/TTA
      KPRTST=1
      DDTH(K)=DECL
      TIME=TTD
      DTH(K)=0.
      GOTO60
   58 CONTINUE
      IF(K.LE.2)GOTO60
      DDTH(K)=(ABS(DTH(K))-ABS(DTH(K-1)))/TIME
   60 CONTINUE
      CTIM=CTIM+TIME
      WRITE(6,1210)[illegible],DTH(K),DDTH(K)
 1210 FORMAT(8X,I4,8X,F8.2,8X,F8.2,3X,F7.2,2X,F8.4,3X,F7.1,
     15X,F8.1,5X,3E13.5)
      IF(KPRTST.EQ.0)GOTO70
      TIME=TTA
      CTIM=CTIM+TIME
      DTH(K)=SAVT
      DDTH(K)=ACCL
      WRITE(6,1212)CTIM,DTH(K),DDTH(K)
 1212 FORMAT(8X,"CHANGE IN DIRECTION OF GUN TRAVEL",18X,
     1F7.1,31X,2E13.5)
   70 CONTINUE
      K=K+1
      IF(K.GT.400)GOTO260
      VFL=VF
      XCL=XC
      YCL=YC
      IF (J*DANG.GE.ANGD)AC=AD
      IF (J*DANG.GE.ANGA)AC=AA
      IF(J*DANG.GT.PII+ANGD)AC=AD
      IF(J*DANG.GT.PII+ANGA)AC=AA
      IF((VFL.GE.VMAX).AND.(AC.GT.0.))GOTO130
      GOTO135
  130 VFL=VMAX
      AC=0.
      GOTO150
  135 IF((VFL.LE.VMIN).AND.(AC.LT.0.))GOTO140
      GOTO150
  140 VFL=VMIN
      AC=0.
  150 CONTINUE
       IF(I.EQ.NPER)GOTO200
      WRITE(6,1220)
 1220 FORMAT(/10X,"NEXT PERIOD OF SINE WAVE TARGET MOVEMENT",/1X)
  200 CONTINUE
      GOTO500
  240 WRITE(6,2100)J,I
 2100 FORMAT(//10X,"ERROR - INCREMENT ",I4," PERIOD ",I4," TIME LT 0")
      GOTO500
  250 CONTINUE
```

```
      VFL=VMIN
      AC=0.
      GOTO50
C 250 WRITE(6,2200)J,I
 2200 FORMAT(//10X,"ERROR - INCREMENT ",I4," PERIOD ",I4,
     1" - NEGATIVE UNDER SQUARE ROOT")
  255 WRITE(6,2220)J,I
 2220 FORMAT(//10X,"ERROR - INCREMENT ",I4," PERIOD ",I4,
     1"   VELOCITY NEGATIVE OR ZERO")
      GOTO500
  257 WRITE(6,2230)J,I
 2230 FORMAT(//10X,"ERROR - INCREMENT ",I4," PERIOD ",I4,
     1"   COSTH GT 1")
      GOTO500
  260 WRITE(6,2300)
 2300 FORMAT(//10X,"TOTAL ALLOWED INCREMENTS EXCEEDED")
      GOTO500
  500 CONTINUE
      RETURN
      END
```

COPY AVAILABLE TO DDC DOES NOT
PERMIT FULLY LEGIBLE PRODUCTION

```
C
C*********************************************************************
C
      SUBROUTINE THREED(XI,YI,ZI,XF,YF,ZF,VI,VMIN,VMAX,DZINC,
     1NNINC,TINC)
      COMMON    TH(400),THXYZ(400),DTH(400),DDTH(400)
      DIMENSION ZH(200),AC(200)
      DTOT=SQRT((XF-XI)**2 +(YF-YI)**2)
      XCL=XI
      YCL=YI
      ZCL=ZI
      VFL=VI
      IF(NNINC.EQ.0)GOTO70
      NTCRDS=NNINC/8 + 1
      DO 50 KZ=1,NTCRDS
      KSTART=((KZ-1)*8) +1
      KEND=KZ*8
   50 READ(5,950)(ZH(KJ),AC(KJ),KJ=KSTART,KEND)
  950 FORMAT(16F5.0)
      GOTO80
   70 CONTINUE
      READ(5,950)(ZH(KJ),AC(KJ),KJ=1,2)
      NNINC=DTOT/DZINC
      DO 75 K=1,NNINC,2
      AC(K)=AC(1)
   75 ZH(K)=ZH(1)
      DO 77 K=2,NNINC,2
      AC(K)=AC(2)
   77 ZH(K)=ZH(2)
   80 CONTINUE
      WRITE(6,1700)XI,YI,ZI,XF,YF,ZF,VI,VMIN,VMAX,DZINC,NNINC,TINC
 1700 FORMAT(1H1,20X,"APPARENT ACCELERATION AND VELOCITY ANALYSIS",//,
     120X,"THREE DIMENSIONAL TARGET MOVEMENT",///,15X,"INPUT DATA",///,
     2"INITIAL POSITION (XI,YI,ZI)--",3(1X,F8.1),//10X,
     3"FINAL POSITION (XF,YF,ZF) ",3(1X,F8.1),//10X,
     4"INITIAL, MINIMUM, AND MAXIMUM VELOCITY (M/S) ",3(1X,F7.1),//10X,
     5"LENGTH OF X-Y DISTANCE INCREMENT FOR Z CHANGE ",F8.1,//10X,
     6"NUMBER OF DISTANCE INCREMENTS--",I4,//10X,"TIME INCREMENT",F8.4)
      WRITE(6,1710)
 1710 FORMAT(//30X,"TERRAIN HEIGHTH --ACCELERATION INCREMENTS"//10X,
     1"DIST. INC.  HEIGHTH   ACCELERATION -FROM PREVIOUS TO CURRENT INC"
     2,//1X)
      DO 90 K=1,NNINC
   90 WRITE(6,1720)K,ZH(K),AC(K)
 1720 FORMAT(13X,I3,6X,F7.1,6X,F8.2)
      WRITE(6,1730)
 1730 FORMAT(////1X,"TIME INC.    X          Y          Z",7X,"SPEED",
     12X,"ACCELERATION  ACTUAL RANGE  ANGLE (XY)",3X,
     2"ANGLE (XY-Z)    DANGLE      DDANGLE"/1X)
      DTRAXY=0.
      DTRAV=0.
      I=1
      VFL=VI
      TEMPS=(YF-YI)/DTOT
      TEMPC=(XF-XI)/DTOT
      IF(I.GT.1)GOTO100
      CXYP=XI/(SQRT((XI*XI)+(YI*YI)))
```

```
      CXYZP=(SQRT((XI*XI)+(YI*YI)))/(SQRT((XI*XI)+(YI*YI)+(ZI*ZI)))
      TH(1)=ACOS(CXYP)
      THXYZ(1)=ACOS(CXYZP)
C
C  J = INCREMENT NUMBER FOR ZH(J) AND AC(J)
C
      IF(ZH(1).GE.ZI)NPN=1
      IF(ZH(1).LT.ZI)NPN=2
      DELZ=ZH(1)-ZI
      J=1
      I=I+1
  100 CONTINUE
C
C  SET UP FOR NEW INCREMENT
C
      IF(I.LE.2)GOTO120
      IF(ZCL.GE.ZH(J).AND.NPN.EQ.1)GOTO110
      IF(ZCL.LE.ZH(J).AND.NPN.EQ.2)GOTO110
      GOTO150
  110 CONTINUE
      J=J+1
      IF(J.GT.NNINC)GOTO800
      IF(ZH(J).GE.ZH(J-1))NPN=1
      IF(ZH(J).LE.ZH(J-1))NPN=2
      DELZ=ZH(J)-ZH(J-1)
  120 CONTINUE
      DZTOT=SQRT((DELZ **2) + (DZINC**2))
      ZCOSB=DZINC/DZTOT
      ZSINB=ABS(DELZ)/DZTOT
      ACX=AC(J)*ZCOSB*TEMPC
      ACY=AC(J)*ZCOSB*TEMPS
      ACZ=AC(J)*ZSINB
      GOTO175
  150 CONTINUE
      IF(VFL.GE.VMAX)GOTO155
      GOTO160
  155 VFL=VMAX
      ACX=0.
      ACY=0.
      ACZ=0.
      GOTO175
  160 IF(VFL.LE.VMIN)GOTO165
      GOTO175
  165 VFL=VMIN
      ACX=0.
      ACY=0.
      ACZ=0.
      AC(J)=0.
      AC(J)=0.
  175 VFLX=VFL*ZCOSB*TEMPC
      VFLY=VFL*ZCOSB*TEMPS
      VFLZ=VFL*ZSINB
      XC=(ACX*(TINC**2)/2.) + (VFLX*TINC) + XCL
      YC=(ACY*(TINC**2)/2.) + (VFLY*TINC) + YCL
      TZC=(ACZ*(TINC**2)/2.) + (VFLZ*TINC)
      IF(NPN.EQ.1)ZC=ZCL+TZC
      IF(NPN.EQ.2)ZC=ZCL-TZC
```

COPY AVAILABLE TO DDC DOES NOT PERMIT FULLY LEGIBLE PRODUCTION

```
      DTXY=SQRT((XC-XCL)**2 + (YC-YCL)**2)
      DTR=SQRT((XC-XCL)**2 + (YC-YCL)**2 + (ZC-ZCL)**2)
      DFT=SQRT(XC*XC + YC*YC + ZC*ZC)
      DFTXY=SQRT(XC*XC + YC*YC)
      DTRAV=DTRAV + DTR
      DTRAXY=DTRAXY + DTXY
      CXY=XC/DFTXY
      CXYZ=DFTXY/DFT
      TH(I)=ACOS(CXY)
      THXYZ(I)=ACOS(CXYZ)
      DTH(I)=SQRT(((TH(I)-TH(I-1))**2) +((THXYZ(I)-THXYZ(I-1))**2))
      DTH(I)=ABS(DTH(I)/TINC)
      IF(I.GE.3)DDTH(I)=(DTH(I)-DTH(I-1))/TINC
      VFX=ACX * TINC + VFLX
      VFY=ACY * TINC + VFLY
      VFZ=ACZ * TINC + VFLZ
      VF=SQRT(VFX**2 + VFY**2 + VFZ**2)
      WRITE(6,1800)I,XC,YC,ZC,VF,AC(J),DFT,TH(I),THXYZ(I),DTH(I),DDTH(I)
 1800 FORMAT(5X,I3,2X,F8.1,1X,F8.1,3X,F7.1,4X,F6.1,3X,F7.2,9X,
     1F7.1,3X,4(E13.5))
      I=I+1
      IF(I.GT.400)GOTO810
      VFL=VF
      XCL=XC
      YCL=YC
      ZCL=ZC
      IF(DTRAXY.GE.(DZINC*NNINC))GOTO850
      IF(DTRAXY.GE.DTOT)GOTO850
      GOTO100
  800 WRITE(6,1920)
 1920 FORMAT(///10X,"RUN TERMINATED - EXCESSIVE DISTANCE INCREMENTS")
      GOTO900
  810 WRITE(6,1930)
 1930 FORMAT(///10X,"RUN TERMINATED - EXCESSIVE ANGLE INCREMENTS")
      GOTO900
  850 WRITE(6,1940)
 1940 FORMAT(///10X,"RUN TERMINATED - COMPLETED MOVEMENT TRACE")
  900 CONTINUE
      RETURN
      END
```

ATTACHMENT 11

SAMPLE OUTPUT - PROGRAM PAPA

COPY AVAILABLE TO DDC DOES NOT PERMIT FULLY LEGIBLE PRODUCTION

```
        APPARENT ACCELERATION AND VELOCITY ANALYSIS
       SINUSOIDAL TARGET MOVEMENT

    INPUT DATA

INITIAL POSITION (XI,YI)        0.0    2000.0
FINAL POSITION (XF,YF)        0.0       0.0
INITIAL SPEED (VI - M/S)      15.0
MIN AND MAX SPEED (VMIN,VMAX)       5.0     25.0
ACCELERATION/DECELERATION CONSTANTS (M/SEC SQUARED)       0.0      0.0
DECELERATION POINT IN THE PERIOD(RADIANS)     1.0470
ACCELERATION POINT IN THE PERIOD(RADIANS)     1.7500
NUMBER OF PERIODS IN THE MOVE     15
NUMBER OF INCREMENTS PER PERIOD  24
HALF-PERIOD DISTANCE      75.0
```

INCREMENT	XC	YC	SPEED	ACCELERATION	TIME	ACTUAL RANGE	ANGLE	DANGLE	DDANGLE
1	9.06	1993.75	15.00	0.0000	.7	1993.8	.15663E+01	-.21347E-01	0.
1	17.50	1987.50	15.00	0.0000	1.4	1987.6	.15620E+01	.60657E-02	0.
1	24.75	1981.25	15.00	0.0000	2.1	1981.4	.15593E+01	.57768E-02	-.48412E-03
1	30.31	1975.00	15.00	0.0000	2.6	1975.2	.15555E+01	.51190E-02	-.11793E-02
1	33.81	1968.75	15.00	0.0000	3.1	1969.0	.15536E+01	.38209E-02	-.27189E-02
1	35.00	1962.50	15.00	0.0000	3.5	1962.8	.15530E+01	.15611E-02	-.53275E-02
1	33.81	1956.25	15.00	0.0000	3.8	1956.5	.15535E+01	0.	-.67507E-02
CHANGE IN DIRECTION OF GUN TRAVEL					4.0			-.13025E-02	.67507E-02
1	30.31	1950.00	15.00	0.0000	4.4	1950.2	.15553E+01	-.36386E-02	.48932E-02
1	24.75	1943.75	15.00	0.0000	5.0	1943.9	.15581E+01	-.50397E-02	.25119E-02
1	17.50	1937.50	15.00	0.0000	5.6	1937.6	.15618E+01	-.57983E-02	.11689E-02
1	9.06	1931.25	15.00	0.0000	6.3	1931.3	.15661E+01	-.62002E-02	.57390E-03
1	-.00	1925.00	15.00	0.0000	7.1	1925.0	.15708E+01	-.63930E-02	.26276E-03
1	-9.06	1918.75	15.00	0.0000	7.8	1918.8	.15755E+01	-.64346E-02	.56763E-04
1	-17.50	1912.50	15.00	0.0000	8.5	1912.6	.15799E+01	-.63251E-02	-.15634E-03
1	-24.75	1906.25	15.00	0.0000	9.1	1906.4	.15836E+01	-.60058E-02	-.50051E-03
1	-30.31	1900.00	15.00	0.0000	9.7	1900.2	.15867E+01	-.53239E-02	-.12225E-02
1	-33.81	1893.75	15.00	0.0000	10.2	1894.1	.15886E+01	-.39763E-02	-.28225E-02
1	-35.00	1887.50	15.00	0.0000	10.6	1887.8	.15893E+01	-.16284E-02	-.55353E-02
1	-33.81	1881.25	15.00	0.0000	10.8	1881.6	.15889E+01	0.	-.70186E-02
CHANGE IN DIRECTION OF GUN TRAVEL					11.0			.13488E-02	.70186E-02
1	-30.31	1875.00	15.00	0.0000	11.5	1875.2	.15870E+01	.37793E-02	.50907E-02
1	-24.75	1868.75	15.00	0.0000	12.1	1868.9	.15840E+01	.52382E-02	.26155E-02
1	-17.50	1862.50	15.00	0.0000	12.7	1862.6	.15802E+01	.60291E-02	.12395E-02
1	-9.06	1856.25	15.00	0.0000	13.4	1856.3	.15757E+01	.64489E-02	.59960E-03
1	.00	1850.00	15.00	0.0000	14.1	1850.0	.15708E+01	.66513E-02	.27579E-03

NEXT PERIOD OF SINE WAVE TARGET MOVEMENT

2	9.06	1843.75	15.00	0.0000	14.9	1843.8	.15659E+01	.66964E-02	.61459E-04
2	17.50	1837.50	15.00	0.0000	15.6	1837.6	.15613E+01	.65842E-02	-.16015E-03
2	24.75	1831.25	15.00	0.0000	16.2	1831.4	.15573E+01	.62537E-02	-.51802E-03
2	30.31	1825.00	15.00	0.0000	16.8	1825.3	.15542E+01	.55459E-02	-.12690E-02
2	33.81	1818.75	15.00	0.0000	17.2	1819.1	.15522E+01	.41449E-02	-.29343E-02
2	35.00	1812.50	15.00	0.0000	17.7	1812.8	.15515E+01	.17017E-02	-.57599E-02
2	33.81	1806.25	15.00	0.0000	17.9	1806.6	.15521E+01	0.	-.73086E-02
CHANGE IN DIRECTION OF GUN TRAVEL					18.1			-.13985E-02	.73086E-02
2	30.31	1800.00	15.00	0.0000	18.6	1800.3	.15540E+01	-.39312E-02	.53048E-02
2	24.75	1793.75	15.00	0.0000	19.1	1793.9	.15570E+01	-.54529E-02	.27280E-02
2	17.50	1787.50	15.00	0.0000	19.8	1787.6	.15610E+01	-.62789E-02	.12946E-02
2	9.06	1781.25	15.00	0.0000	20.5	1781.3	.15657E+01	-.67184E-02	.62768E-03
2	-.00	1775.00	15.00	0.0000	21.2	1775.0	.15708E+01	-.69313E-02	.29013E-03
2	-9.06	1768.75	15.00	0.0000	21.9	1768.8	.15759E+01	-.69803E-02	.66762E-04
2	-17.50	1762.50	15.00	0.0000	22.6	1762.6	.15807E+01	-.66654E-02	-.16406E-03
2	-24.75	1756.25	15.00	0.0000	23.3	1756.4	.15849E+01	-.65229E-02	-.53676E-03
2	-30.31	1750.00	15.00	0.0000	23.8	1750.3	.15881E+01	-.57871E-02	-.13192E-02
2	-33.81	1743.75	15.00	0.0000	24.3	1744.1	.15902E+01	-.43284E-02	-.30553E-02
2	-35.00	1737.50	15.00	0.0000	24.7	1737.9	.15909E+01	-.17818E-02	-.60035E-02
2	-33.81	1731.25	15.00	0.0000	25.0	1731.6	.15903E+01	0.	-.76236E-02
CHANGE IN DIRECTION OF GUN TRAVEL					25.1			.14520E-02	.76236E-02
2	-30.31	1725.00	15.00	0.0000	25.6	1725.3	.15884E+01	.40959E-02	.55378E-02
2	-24.75	1718.75	15.00	0.0000	26.2	1716.9	.15852E+01	.56359E-02	.28506E-02
2	-17.50	1712.50	15.00	0.0000	26.8	1712.6	.15810E+01	.65504E-02	.13548E-02
2	-9.06	1706.25	15.00	0.0000	27.5	1706.3	.15761E+01	.70115E-02	.65849E-03
2	.00	1700.00	15.00	0.0000	28.3	1700.0	.15708E+01	.72360E-02	.30598E-03

NEXT PERIOD OF SINE WAVE TARGET MOVEMENT

3	9.06	1693.75	15.00	0.0000	29.0	1693.8	.15654E+01	.72894E-02	.72783E-04
3	17.50	1687.50	15.00	0.0000	29.7	1687.6	.15604E+01	.71717E-02	-.16805E-02
3	24.75	1681.25	15.00	0.0000	30.3	1681.4	.15561E+01	.68164E-02	-.55686E-03
3	30.31	1675.00	15.00	0.0000	30.9	1675.3	.15527E+01	.60503E-02	-.13735E-02
3	33.81	1668.75	15.00	0.0000	31.4	1669.1	.15505E+01	.45289E-02	-.31866E-02
3	35.00	1662.50	15.00	0.0000	31.8	1662.9	.15497E+01	.18699E-02	-.62685E-02
3	33.81	1656.25	15.00	0.0000	32.0	1656.6	.15504E+01	0.	-.79670E-02
CHANGE IN DIRECTION OF GUN TRAVEL					32.2			-.15096E-02	.79670E-02
3	30.31	1650.00	15.00	0.0000	32.7	1650.3	.15524E+01	-.42749E-02	.57921E-02
3	24.75	1643.75	15.00	0.0000	33.2	1643.9	.15557E+01	-.59398E-02	.29848E-02
3	17.50	1637.50	15.00	0.0000	33.9	1637.6	.15601E+01	-.68464E-02	.14209E-02
3	9.06	1631.25	15.00	0.0000	34.6	1631.3	.15652E+01	-.73312E-02	.69244E-03
3	-.00	1625.00	15.00	0.0000	35.3	1625.0	.15708E+01	-.75687E-02	.32359E-03
3	-9.06	1618.75	15.00	0.0000	36.0	1618.8	.15764E+01	-.76271E-02	.79656E-04
3	-17.50	1612.50	15.00	0.0000	36.7	1612.6	.15816E+01	-.75066E-02	-.17209E-03
3	-24.75	1606.25	15.00	0.0000	37.4	1606.4	.15862E+01	-.71375E-02	-.57946E-03
3	-30.31	1600.00	15.00	0.0000	37.9	1600.3	.15897E+01	-.63386E-02	-.14324E-02
3	-33.81	1593.75	15.00	0.0000	38.4	1594.1	.15920E+01	-.47488E-02	-.33297E-02
3	-35.00	1587.50	15.00	0.0000	38.8	1587.9	.15928E+01	-.19670E-02	-.65581E-02
3	-33.81	1581.25	15.00	0.0000	39.1	1581.6	.15922E+01	0.	-.83427E-02
CHANGE IN DIRECTION OF GUN TRAVEL					39.3			.15718E-02	.83427E-02
3	-30.31	1575.00	15.00	0.0000	39.7	1575.3	.15900E+01	.44703E-02	.60708E-02
3	-24.75	1568.75	15.00	0.0000	40.3	1568.9	.15866E+01	.62173E-02	.31321E-02
3	-17.50	1562.50	15.00	0.0000	40.9	1562.6	.15820E+01	.71704E-02	.14937E-02
3	-9.06	1556.25	15.00	0.0000	41.6	1556.3	.15766E+01	.76816E-02	.73003E-03
3	.00	1550.00	15.00	0.0000	42.4	1550.0	.15708E+01	.79334E-02	.34325E-03

NEXT PERIOD OF SINE WAVE TARGET MOVEMENT

4	9.06	1543.75	15.00	0.0000	43.1	1543.8	.15649E+01	.79976E-02	.87551E-04
4	17.50	1537.50	15.00	0.0000	43.8	1537.6	.15594E+01	.78743E-02	-.17615E-03
4	24.75	1531.25	15.00	0.0000	44.4	1531.4	.15546E+01	.74903E-02	-.60174E-03
4	30.31	1525.00	15.00	0.0000	45.0	1525.3	.15509E+01	.66556E-02	-.14965E-02
4	33.81	1518.75	15.00	0.0000	45.5	1519.1	.15485E+01	.49912E-02	-.34863E-02
4	35.00	1512.50	15.00	0.0000	45.9	1512.9	.15477E+01	.20746E-02	-.68756E-02
4	33.81	1506.25	15.00	0.0000	46.1	1506.6	.15484E+01	0.	-.87556E-02
CHANGE IN DIRECTION OF GUN TRAVEL					46.3			-.16393E-02	.87556E-02
4	30.31	1500.00	15.00	0.0000	46.8	1500.3	.15506E+01	-.46843E-02	.63777E-02
4	24.75	1493.75	15.00	0.0000	47.4	1494.0	.15542E+01	-.65221E-02	.32948E-02
4	17.50	1487.50	15.00	0.0000	48.0	1487.6	.15590E+01	-.75266E-02	.15743E-02
4	9.06	1481.25	15.00	0.0000	48.7	1481.3	.15647E+01	-.80670E-02	.77188E-03
4	-.00	1475.00	15.00	0.0000	49.4	1475.0	.15706E+01	-.83351E-02	.36534E-03
4	-9.06	1468.75	15.00	0.0000	50.2	1468.8	.15770E+01	-.84060E-02	.96681E-04
4	-17.50	1462.50	15.00	0.0000	50.9	1462.6	.15828E+01	-.82799E-02	-.18016E-03
4	-24.75	1456.25	15.00	0.0000	51.5	1456.5	.15878E+01	-.78799E-02	-.62687E-03
4	-30.31	1450.00	15.00	0.0000	52.1	1450.3	.15917E+01	-.70061E-02	-.15666E-02
4	-33.81	1443.75	15.00	0.0000	52.5	1444.1	.15942E+01	-.52595E-02	-.36582E-02
4	-35.00	1437.50	15.00	0.0000	53.0	1437.9	.15951E+01	-.21546E-02	-.72254E-02
4	-33.81	1431.25	15.00	0.0000	53.2	1431.6	.15944E+01	0.	-.92114E-02
CHANGE IN DIRECTION OF GUN TRAVEL					53.4			.17127E-02	.92114E-02
4	-30.31	1425.00	15.00	0.0000	53.9	1425.3	.15921E+01	.49198E-02	.67173E-02
4	-24.75	1418.75	15.00	0.0000	54.4	1419.0	.15882E+01	.66582E-02	.34752E-02
4	-17.50	1412.50	15.00	0.0000	55.1	1412.6	.15832E+01	.79199E-02	.16640E-02
4	-9.06	1406.25	15.00	0.0000	55.8	1406.3	.15772E+01	.84932E-02	.81873E-03
4	.00	1400.00	15.00	0.0000	56.5	1400.0	.15708E+01	.87796E-02	.39032E-03

NEXT PERIOD OF SINE WAVE TARGET MOVEMENT

5	9.06	1393.75	15.00	0.0000	57.2	1393.8	.15643E+01	.88584E-02	.10732E-03
5	17.50	1387.50	15.00	0.0000	57.9	1387.6	.15582E+01	.87295E-02	-.18404E-03
5	24.75	1381.25	15.00	0.0000	58.6	1381.5	.15529E+01	.83121E-02	-.65407E-03
5	30.31	1375.00	15.00	0.0000	59.1	1375.3	.15486E+01	.73955E-02	-.16435E-02
5	33.81	1368.75	15.00	0.0000	59.6	1369.2	.15461E+01	.55583E-02	-.38480E-02
5	35.00	1362.50	15.00	0.0000	60.0	1362.9	.15451E+01	.23291E-02	-.76127E-02
5	33.81	1356.25	15.00	0.0000	60.3	1356.7	.15459E+01	0.	-.97172E-02
CHANGE IN DIRECTION OF GUN TRAVEL					60.5			-.17928E-02	.97172E-02
5	30.31	1350.00	15.00	0.0000	60.9	1350.3	.15483E+01	-.51802E-02	.70950E-02
5	24.75	1343.75	15.00	0.0000	61.5	1344.0	.15524E+01	-.72308E-02	.36765E-02
5	17.50	1337.50	15.00	0.0000	62.1	1337.6	.15577E+01	-.83567E-02	.17645E-02
5	9.06	1331.25	15.00	0.0000	62.8	1331.3	.15640E+01	-.89670E-02	.87154E-03
5	-.00	1325.00	15.00	0.0000	63.6	1325.0	.15708E+01	-.92742E-02	.41877E-03
5	-9.06	1318.75	15.00	0.0000	64.3	1318.8	.15777E+01	-.92621E-02	.11981E-03
5	-17.50	1312.50	15.00	0.0000	65.0	1312.6	.15841E+01	-.92307E-02	-.18766E-03
5	-24.75	1306.25	15.00	0.0000	65.6	1306.5	.15897E+01	-.87946E-02	-.68358E-03
5	-30.31	1300.00	15.00	0.0000	66.2	1300.4	.15941E+01	-.78306E-02	-.17282E-02
5	-33.81	1293.75	15.00	0.0000	66.7	1294.2	.15969E+01	-.58930E-02	-.40584E-02
5	-35.00	1287.50	15.00	0.0000	67.1	1288.0	.15980E+01	-.24810E-02	-.80437E-02
5	-33.81	1281.25	15.00	0.0000	67.3	1281.7	.15972E+01	0.	-.10282E-01
CHANGE IN DIRECTION OF GUN TRAVEL					67.5			.18804E-02	.10282E-01
5	-30.31	1275.00	15.00	0.0000	68.0	1275.4	.15946E+01	.54696E-02	.75176E-02
5	-24.75	1268.75	15.00	0.0000	68.6	1269.0	.15903E+01	.76462E-02	.39024E-02
5	-17.50	1262.50	15.00	0.0000	69.2	1262.6	.15847E+01	.88444E-02	.18779E-02
5	-9.06	1256.25	15.00	0.0000	69.9	1256.3	.15780E+01	.94967E-02	.93149E-03
5	.00	1250.00	15.00	0.0000	70.6	1250.0	.15708E+01	.99279E-02	.45143E-03

NEXT PERIOD OF SINE WAVE TARGET MOVEMENT

6	9.06	1243.75	15.00	0.0000	71.4	1243.8	.15635E+01	.99267E-02	.13462E-03
6	17.50	1237.50	15.00	0.0000	72.1	1237.6	.15567E+01	.97930E-02	-.19085E-03
6	24.75	1231.25	15.00	0.0000	72.7	1231.5	.15507E+01	.93364E-02	-.71566E-03
6	30.31	1225.00	15.00	0.0000	73.3	1225.4	.15461E+01	.83201E-02	-.18220E-02
6	33.81	1218.75	15.00	0.0000	73.7	1219.2	.15431E+01	.62705E-02	-.42930E-02
6	35.00	1212.50	15.00	0.0000	74.2	1213.0	.15419E+01	.26537E-02	-.85263E-02
6	33.81	1206.25	15.00	0.0000	74.4	1206.7	.15428E+01	0.	-.10916E-01
CHANGE IN DIRECTION OF GUN TRAVEL					74.6			-.15766E-02	.10916E-01
6	30.31	1200.00	15.00	0.0000	75.1	1200.4	.15455E+01	-.57931E-02	.79936E-02
6	24.75	1193.75	15.00	0.0000	75.6	1194.0	.15501E+01	-.81122E-02	.41578E-02
6	17.50	1187.50	15.00	0.0000	76.3	1187.6	.15561E+01	-.93926E-02	.20067E-02
6	9.06	1181.25	15.00	0.0000	77.0	1181.3	.15631E+01	-.10093E-01	.10001E-02
6	-.00	1175.00	15.00	0.0000	77.7	1175.0	.15708E+01	-.10452E-01	.48928E-03
6	-9.06	1168.75	15.00	0.0000	78.4	1168.8	.15785E+01	-.10564E-01	.15235E-03
6	-17.50	1162.50	15.00	0.0000	79.1	1162.6	.15858E+01	-.10428E-01	-.19335E-03
6	-24.75	1156.25	15.00	0.0000	79.8	1156.5	.15922E+01	-.99493E-02	-.75060E-03
6	-30.31	1150.00	15.00	0.0000	80.3	1150.4	.15971E+01	-.88748E-02	-.19264E-02
6	-33.81	1143.75	15.00	0.0000	80.8	1144.2	.16003E+01	-.66995E-02	-.45563E-02
6	-35.00	1137.50	15.00	0.0000	81.2	1138.0	.16016E+01	-.28519E-02	-.90705E-02
6	-33.81	1131.25	15.00	0.0000	81.5	1131.8	.16007E+01	0.	-.11633E-01
CHANGE IN DIRECTION OF GUN TRAVEL					81.6			.20826E-02	.11633E-01
6	-30.31	1125.00	15.00	0.0000	82.1	1125.4	.15977E+01	.61570E-02	.85339E-02
6	-24.75	1118.75	15.00	0.0000	82.7	1119.0	.15929E+01	.86385E-02	.44489E-02
6	-17.50	1112.50	15.00	0.0000	83.3	1112.6	.15865E+01	.10013E-01	.21543E-02
6	-9.06	1106.25	15.00	0.0000	84.0	1106.3	.15790E+01	.10769E-01	.10794E-02
6	.00	1100.00	15.00	0.0000	84.8	1100.0	.15708E+01	.11160E-01	.53360E-03

NEXT PERIOD OF SINE WAVE TARGET MOVEMENT

7	9.06	1093.75	15.00	0.0000	85.5	1093.8	.15625E+01	.11288E-01	.17383E-03
7	17.50	1087.50	15.00	0.0000	86.2	1087.6	.15547E+01	.11152E-01	-.19477E-03
7	24.75	1081.25	15.00	0.0000	86.9	1081.5	.15479E+01	.10648E-01	-.78872E-03
7	30.31	1075.00	15.00	0.0000	87.4	1075.4	.15426E+01	.95087E-02	-.20432E-02
7	33.81	1068.75	15.00	0.0000	87.9	1069.3	.15392E+01	.71913E-02	-.48538E-02
7	35.00	1062.50	15.00	0.0000	88.3	1063.1	.15379E+01	.30816E-02	-.96886E-02
7	33.81	1056.25	15.00	0.0000	88.5	1056.8	.15388E+01	0.	-.12451E-01
CHANGE IN DIRECTION OF GUN TRAVEL					88.7			-.21999E-02	.12451E-01
7	30.31	1050.00	15.00	0.0000	89.2	1050.4	.15419E+01	-.65696E-02	.91523E-02
7	24.75	1043.75	15.00	0.0000	89.7	1044.0	.15471E+01	-.92378E-02	.47235E-02
7	17.50	1037.50	15.00	0.0000	90.4	1037.6	.15539E+01	-.10721E-01	.23251E-02
7	9.06	1031.25	15.00	0.0000	91.1	1031.3	.15620E+01	-.11542E-01	.11720E-02
7	-.00	1025.00	15.00	0.0000	91.8	1025.0	.15708E+01	-.11972E-01	.58611E-03
7	-9.06	1018.75	15.00	0.0000	92.5	1018.8	.15797E+01	-.12119E-01	.20020E-03
7	-17.50	1012.50	15.00	0.0000	93.3	1012.7	.15881E+01	-.11983E-01	-.19454E-03
7	-24.75	1006.25	15.00	0.0000	93.9	1006.6	.15954E+01	-.11453E-01	-.83033E-03
7	-30.31	1000.00	15.00	0.0000	94.4	1000.5	.16011E+01	-.10240E-01	-.21747E-02
7	-33.81	993.75	15.00	0.0000	94.9	994.3	.16048E+01	-.77608E-02	-.51925E-02
7	-35.00	987.50	15.00	0.0000	95.3	988.1	.16062E+01	-.33507E-02	-.10397E-01
7	-33.81	981.25	15.00	0.0000	95.6	981.8	.16052E+01	0.	-.13392E-01
CHANGE IN DIRECTION OF GUN TRAVEL					95.8			.23302E-02	.13392E-01
7	-30.31	975.00	15.00	0.0000	96.2	975.5	.16019E+01	.70411E-02	.98671E-02
7	-24.75	968.75	15.00	0.0000	96.8	969.1	.15963E+01	.99262E-02	.51724E-02
7	-17.50	962.50	15.00	0.0000	97.4	962.7	.15890E+01	.11537E-01	.25251E-02
7	-9.06	956.25	15.00	0.0000	98.1	956.3	.15803E+01	.12435E-01	.12815E-02
7	.00	950.00	15.00	0.0000	98.9	950.0	.15708E+01	.12911E-01	.64919E-03

NEXT PERIOD OF SINE WAVE TARGET MOVEMENT

8	9.06	943.75	15.00	0.0000	99.6	943.8	.15612E+01	.13082E-01	.23306E-03
8	17.50	937.50	15.00	0.0000	100.3	937.7	.15521E+01	.12948E-01	-.19179E-03
8	24.75	931.25	15.00	0.0000	101.0	931.6	.15442E+01	.12389E-01	-.87572E-03
8	30.31	925.00	15.00	0.0000	101.5	925.5	.15380E+01	.11093E-01	-.23238E-02
8	33.81	918.75	15.00	0.0000	102.0	919.4	.15340E+01	.84278E-02	-.55817E-02
8	35.00	912.50	15.00	0.0000	102.4	913.2	.15325E+01	.36701E-02	-.11216E-01
8	33.81	906.25	15.00	0.0000	102.7	906.9	.15335E+01	0.	-.14487E-01
CHANGE IN DIRECTION OF GUN TRAVEL					102.8			-.24752E-02	.14487E-01
8	30.31	900.00	15.00	0.0000	103.3	900.5	.15371E+01	-.75850E-02	.10703E-01
8	24.75	893.75	15.00	0.0000	103.9	894.1	.15431E+01	-.10725E-01	.56298E-02
8	17.50	887.50	15.00	0.0000	104.5	887.7	.15511E+01	-.12488E-01	.27622E-02
8	9.06	881.25	15.00	0.0000	105.2	881.3	.15605E+01	-.13477E-01	.14128E-02
8	-.00	875.00	15.00	0.0000	105.9	875.0	.15708E+01	-.14010E-01	.72619E-03
8	-9.06	868.75	15.00	0.0000	106.7	868.8	.15812E+01	-.14211E-01	.27472E-03
8	-17.50	862.50	15.00	0.0000	107.4	862.7	.15911E+01	-.14082E-01	-.16517E-03
8	-24.75	856.25	15.00	0.0000	108.0	856.6	.15997E+01	-.13491E-01	-.92506E-03
8	-30.31	850.00	15.00	0.0000	108.6	850.5	.16064E+01	-.12100E-01	-.24941E-02
8	-33.81	843.75	15.00	0.0000	109.0	844.4	.16108E+01	-.92197E-02	-.60332E-02
8	-35.00	837.50	15.00	0.0000	109.5	838.2	.16126E+01	-.40551E-02	-.12175E-01
8	-33.81	831.25	15.00	0.0000	109.7	831.9	.16114E+01	0.	-.15777E-01
CHANGE IN DIRECTION OF GUN TRAVEL					109.9			.26370E-02	.15777E-01
8	-30.31	825.00	15.00	0.0000	110.4	825.6	.16075E+01	.82193E-02	.11692E-01
8	-24.75	818.75	15.00	0.0000	110.9	819.1	.16010E+01	.11664E-01	.61752E-02
8	-17.50	812.50	15.00	0.0000	111.6	812.7	.15923E+01	.13608E-01	.30476E-02
8	-9.06	806.25	15.00	0.0000	112.3	806.3	.15820E+01	.14710E-01	.15730E-02
8	.00	800.00	15.00	0.0000	113.0	800.0	.15708E+01	.15313E-01	.82196E-03

NEXT PERIOD OF SINE WAVE TARGET MOVEMENT

9	9.06	793.75	15.00	0.0000	113.7	793.8	.15594E+01	.15554E-01	.32864E-03
9	17.50	787.50	15.00	0.0000	114.4	787.7	.15486E+01	.15433E-01	-.17256E-03
9	24.75	781.25	15.00	0.0000	115.1	781.6	.15391E+01	.14809E-01	-.97827E-03
9	30.31	775.00	15.00	0.0000	115.6	775.6	.15317E+01	.13308E-01	-.26901E-02
9	33.81	768.75	15.00	0.0000	116.1	769.5	.15268E+01	.10175E-01	-.65633E-02
9	35.00	762.50	15.00	0.0000	116.5	763.3	.15249E+01	.45279E-02	-.13313E-01
9	33.81	756.25	15.00	0.0000	116.8	757.0	.15261E+01	0.	-.17317E-01
CHANGE IN DIRECTION OF GUN TRAVEL					117.0			-.28176E-02	.17317E-01
9	30.31	750.00	15.00	0.0000	117.4	750.6	.15304E+01	-.89681E-02	.12882E-01
9	24.75	743.75	15.00	0.0000	118.0	744.2	.15375E+01	-.12782E-01	.68368E-02
9	17.50	737.50	15.00	0.0000	118.6	737.7	.15471E+01	-.14950E-01	.33978E-02
9	9.06	731.25	15.00	0.0000	119.3	731.3	.15584E+01	-.16191E-01	.17726E-02
9	-.00	725.00	15.00	0.0000	120.1	725.0	.15708E+01	-.16883E-01	.94379E-03
9	-9.06	718.75	15.00	0.0000	120.8	718.8	.15834E+01	-.17177E-01	.40015E-03
9	-17.50	712.50	15.00	0.0000	121.5	712.7	.15954E+01	-.17072E-01	-.15043E-03
9	-24.75	706.25	15.00	0.0000	122.1	706.7	.16058E+01	-.16411E-01	-.10347E-02
9	-30.31	700.00	15.00	0.0000	122.7	700.7	.16141E+01	-.14784E-01	-.29175E-02
9	-33.81	693.75	15.00	0.0000	123.2	694.6	.16195E+01	-.11349E-01	-.71938E-02
9	-35.00	687.50	15.00	0.0000	123.6	688.4	.16217E+01	-.51211E-02	-.14683E-01
9	-33.81	681.25	15.00	0.0000	123.9	682.1	.16204E+01	0.	-.19188E-01
CHANGE IN DIRECTION OF GUN TRAVEL					124.0			.30183E-02	.19188E-01
9	-30.31	675.00	15.00	0.0000	124.5	675.7	.16157E+01	.98651E-02	.14341E-01
9	-24.75	668.75	15.00	0.0000	125.1	669.2	.16078E+01	.14135E-01	.76557E-02
9	-17.50	662.50	15.00	0.0000	125.7	662.7	.15972E+01	.16584E-01	.36371E-02
9	-9.06	656.25	15.00	0.0000	126.4	656.3	.15846E+01	.18003E-01	.20273E-02
9	.00	650.00	15.00	0.0000	127.1	650.0	.15708E+01	.13813E-01	.11031E-02

NEXT PERIOD OF SINE WAVE TARGET MOVEMENT

10	9.06	643.75	15.00	0.0000	127.9	643.8	.15567E+01	.19178E-01	.49781E-03
10	17.50	637.50	15.00	0.0000	128.6	637.7	.15434E+01	.19099E-01	-.11282E-03
10	24.75	631.25	15.00	0.0000	129.2	631.7	.15316E+01	.18402E-01	-.10923E-02
10	30.31	625.00	15.00	0.0000	129.8	625.7	.15223E+01	.16626E-01	-.31836E-02
10	33.81	618.75	15.00	0.0000	130.2	619.7	.15162E+01	.12828E-01	-.79555E-02
10	35.00	612.50	15.00	0.0000	130.7	613.5	.15137E+01	.58862E-02	-.16365E-01
10	33.81	606.25	15.00	0.0000	130.9	607.2	.15151E+01	0.	-.21511E-01
CHANGE IN DIRECTION OF GUN TRAVEL					131.1			-.32384E-02	.21511E-01
10	30.31	600.00	15.00	0.0000	131.6	600.8	.15203E+01	-.10958E-01	.16169E-01
10	24.75	593.75	15.00	0.0000	132.1	594.3	.15291E+01	-.15808E-01	.66949E-02
10	17.50	587.50	15.00	0.0000	132.8	587.6	.15410E+01	-.18618E-01	.44035E-02
10	9.06	581.25	15.00	0.0000	133.5	581.3	.15552E+01	-.20272E-01	.23626E-02
10	-.00	575.00	15.00	0.0000	134.2	575.0	.15708E+01	-.21240E-01	.13186E-02
10	-9.06	568.75	15.00	0.0000	134.9	568.8	.15867E+01	-.21706E-01	.63612E-03
10	-17.50	562.50	15.00	0.0000	135.6	562.8	.16019E+01	-.21672E-01	-.49038E-04
10	-24.75	556.25	15.00	0.0000	136.3	556.6	.16153E+01	-.20941E-01	-.11462E-02
10	-30.31	550.00	15.00	0.0000	136.8	550.6	.16259E+01	-.18990E-01	-.34968E-02
10	-33.81	543.75	15.00	0.0000	137.3	544.8	.16329E+01	-.14745E-01	-.88926E-02
10	-35.00	537.50	15.00	0.0000	137.7	538.6	.16358E+01	-.69071E-02	-.18476E-01
10	-33.81	531.25	15.00	0.0000	138.0	532.3	.16343E+01	0.	-.24468E-01
CHANGE IN DIRECTION OF GUN TRAVEL					138.1			.34719E-02	.24468E-01
10	-30.31	525.00	15.00	0.0000	138.6	525.9	.16285E+01	.12317E-01	.18527E-01
10	-24.75	518.75	15.00	0.0000	139.2	519.3	.16185E+01	.17926E-01	.10056E-01
10	-17.50	512.50	15.00	0.0000	139.8	512.8	.16049E+01	.21219E-01	.51602E-02
10	-9.06	506.25	15.00	0.0000	140.5	506.3	.15887E+01	.23195E-01	.28219E-02
10	.00	500.00	15.00	0.0000	141.3	500.0	.15708E+01	.24386E-01	.16231E-02

NEXT PERIOD OF SINE WAVE TARGET MOVEMENT

11	9.06	493.75	15.00	0.0000	142.0	493.8	.15525E+01	.25003E-01	.84124E-03
11	17.50	487.50	15.00	0.0000	142.7	487.8	.15349E+01	.25046E-01	.61246E-04
11	24.75	481.25	15.00	0.0000	143.3	481.9	.15194E+01	.24290E-01	-.11848E-02
11	30.31	475.00	15.00	0.0000	143.9	476.0	.15071E+01	.22133E-01	-.38662E-02
11	33.81	468.75	15.00	0.0000	144.4	470.0	.14986E+01	.17325E-01	-.10070E-01
11	35.00	462.50	15.00	0.0000	144.8	463.8	.14953E+01	.83311E-02	-.21204E-01
11	33.81	456.25	15.00	0.0000	145.1	457.5	.14968E+01	0.	-.28357E-01
CHANGE IN DIRECTION OF GUN TRAVEL					145.2			-.36976E-02	.28357E-01
11	30.31	450.00	15.00	0.0000	[illegible]	[illegible]	[illegible]	-.14049E-01	.21680E-01
11	24.75	443.75	15.00	0.0000	[illegible]	[illegible]	[illegible]	-.20693E-01	.11912E-01
11	17.50	437.50	15.00	0.0000	146.9	437.8	.15308E+01	-.24661E-01	.62186E-02
11	9.06	431.25	15.00	0.0000	147.6	431.3	.15496E+01	-.27100E-01	.34842E-02
11	-.00	425.00	15.00	0.0000	148.3	425.0	.15708E+01	-.28625E-01	.20785E-02
11	-9.06	418.75	15.00	0.0000	149.1	418.8	.15924E+01	-.29480E-01	.11643E-02
11	-17.50	412.50	15.00	0.0000	149.8	412.9	.16132E+01	-.29562E-01	.25987E-03
11	-24.75	406.25	15.00	0.0000	150.4	407.0	.16316E+01	-.[illegible]909E-01	-.11799E-02
11	-30.31	400.00	15.00	0.0000	150.9	401.1	.16464E+01	-.26512E-01	-.42962E-02
11	-33.81	393.75	15.00	0.0000	151.4	395.2	.16564E+01	-.20981E-01	-.11585E-01
11	-35.00	387.50	15.00	0.0000	151.8	389.1	.16609E+01	-.10439E-01	-.24853E-01
11	-33.81	381.25	15.00	0.0000	152.2	382.7	.16592E+01	0.	-.33693E-01
CHANGE IN DIRECTION OF GUN TRAVEL					152.3			.38529E-02	.33693E-01
11	-30.31	375.00	15.00	0.0000	152.8	376.2	.16515E+01	.16317E-01	.26105E-01
11	-24.75	368.75	15.00	0.0000	153.3	369.6	.16378E+01	.24453E-01	.14587E-01
11	-17.50	362.50	15.00	0.0000	153.9	362.9	.16190E+01	.29426E-01	.77952E-02
11	-9.06	356.25	15.00	0.0000	154.6	356.4	.15962E+01	.32584E-01	.45097E-02
11	.00	350.00	15.00	0.0000	155.4	350.0	.15708E+01	.34649E-01	.28147E-02

NEXT PERIOD OF SINE WAVE TARGET MOVEMENT

12	9.06	343.75	15.00	0.0000	156.1	343.9	.15444E+01	.35909E-01	.17165E-02
12	17.50	337.50	15.00	0.0000	156.8	338.0	.15190E+01	.36359E-01	.64264E-03
12	24.75	331.25	15.00	0.0000	157.5	332.2	.14962E+01	.35684E-01	-.10574E-02
12	30.31	325.00	15.00	0.0000	158.0	326.4	.14776E+01	.33025E-01	-.47667E-02
12	33.81	318.75	15.00	0.0000	158.5	320.5	.14651E+01	.26542E-01	-.13580E-01
12	35.00	312.50	15.00	0.0000	158.9	314.5	.14593E+01	.13833E-01	-.29961E-01
12	33.81	306.25	15.00	0.0000	159.2	308.1	.14608E+01	0.	-.41441E-01
CHANGE IN DIRECTION OF GUN TRAVEL					159.3			-.37456E-02	.41441E-01
12	30.31	300.00	15.00	0.0000	159.8	301.5	.14701E+01	-.19378E-01	.32742E-01
12	24.75	293.75	15.00	0.0000	160.4	294.6	.14867E+01	-.29837E-01	.18751E-01
12	17.50	287.50	15.00	0.0000	161.0	288.0	.15100E+01	-.36450E-01	.10365E-01
12	9.06	281.25	15.00	0.0000	161.7	281.4	.15386E+01	-.40840E-01	.62697E-02
12	-.00	275.00	15.00	0.0000	162.4	275.0	.15708E+01	-.43884E-01	.41478E-02
12	-9.06	268.75	15.00	0.0000	163.2	268.9	.16045E+01	-.45923E-01	.27799E-02
12	-17.50	262.50	15.00	0.0000	163.9	263.1	.16374E+01	-.46949E-01	.14646E-02
12	-24.75	256.25	15.00	0.0000	164.5	257.4	.16671E+01	-.46568E-01	-.59716E-03
12	-30.31	250.00	15.00	0.0000	165.1	251.8	.16915E+01	-.43697E-01	-.51471E-02
12	-33.81	243.75	15.00	0.0000	165.6	246.1	.17086E+01	-.35948E-01	-.16229E-01
12	-35.00	237.50	15.00	0.0000	166.0	240.1	.17171E+01	-.20033E-01	-.37521E-01
12	-33.81	231.25	15.00	0.0000	166.3	233.7	.17160E+01	0.	-.53614E-01
CHANGE IN DIRECTION OF GUN TRAVEL					166.4			.27099E-02	.53614E-01
12	-30.31	225.00	15.00	0.0000	166.9	227.0	.17047E+01	.23578E-01	.43708E-01
12	-24.75	218.75	15.00	0.0000	167.4	220.1	.16835E+01	.38099E-01	.26035E-01
12	-17.50	212.50	15.00	0.0000	168.1	213.2	.16530E+01	.47785E-01	.15180E-01
12	-9.06	206.25	15.00	0.0000	168.8	206.4	.16147E+01	.54661E-01	.98203E-02
12	.00	200.00	15.00	0.0000	169.5	200.0	.15708E+01	.59623E-01	.70355E-02

NEXT PERIOD OF SINE WAVE TARGET MOVEMENT

13	9.06	193.75	15.00	0.0000	170.2	194.0	.15241E+01	.63678E-01	.52530E-02
13	17.50	187.50	15.00	0.0000	170.9	186.3	.14777E+01	.66184E-01	.35798E-02
13	24.75	181.25	15.00	0.0000	171.6	182.9	.14351E+01	.66829E-01	.10101E-02
13	30.31	175.00	15.00	0.0000	172.1	177.6	.13993E+01	.64180E-01	-.47483E-02
13	33.81	168.75	15.00	0.0000	172.6	172.1	.13731E+01	.54916E-01	-.19404E-01
13	35.00	162.50	15.00	0.0000	173.0	166.2	.13587E+01	.33997E-01	-.49315E-01
13	33.81	156.25	15.00	0.0000	173.5	159.9	.13577E+01	.22137E-02	-.74929E-01
13	30.31	150.00	15.00	0.0000	173.5	153.0	.13714E+01	0.	-.64717E-01
CHANGE IN DIRECTION OF GUN TRAVEL					173.9			-.28685E-01	.64717E-01
13	24.75	143.75	15.00	0.0000	174.5	145.9	.14003E+01	-.51802E-01	.41446E-01
13	17.50	137.50	15.00	0.0000	175.1	138.6	.14442E+01	-.68803E-01	.26644E-01
13	9.06	131.25	15.00	0.0000	175.8	131.6	.15019E+01	-.82379E-01	.19388E-01
13	-.00	125.00	15.00	0.0000	176.6	125.0	.15708E+01	-.93920E-01	.15730E-01
13	-9.06	118.75	15.00	0.0000	177.3	119.1	.16469E+01	-.10377E+00	.13425E-01
13	-17.50	112.50	15.00	0.0000	178.0	113.9	.17251E+01	-.11165E+00	.11261E-01
13	-24.75	106.25	15.00	0.0000	178.6	109.1	.17996E+01	-.11680E+00	.80701E-02
13	-30.31	100.00	15.00	0.0000	179.2	104.5	.18651E+01	-.11736E+00	.98851E-03
13	-33.81	93.75	15.00	0.0000	179.7	99.7	.19169E+01	-.10848E+00	-.18597E-01
13	-35.00	87.50	15.00	0.0000	180.1	94.2	.19513E+01	-.81118E-01	-.64498E-01
13	-33.81	81.25	15.00	0.0000	180.5	88.0	.19651E+01	-.32519E-01	-.11457E+00
13	-30.31	75.00	15.00	0.0000	180.8	80.9	.19549E+01	0.	-.11297E+00
CHANGE IN DIRECTION OF GUN TRAVEL					181.0			.21418E-01	.11297E+00
13	-24.75	68.75	15.00	0.0000	181.6	73.1	.19163E+01	.69088E-01	.65464E-01
13	-17.50	62.50	15.00	0.0000	182.2	64.9	.18436E+01	.11367E+00	.69671E-01
13	-9.06	56.25	15.00	0.0000	182.9	57.0	.17305E+01	.16186E+00	.68619E-01
13	.00	50.00	15.00	0.0000	183.6	50.0	.15708E+01	.21762E+00	.76006E-01

COPY AVAILABLE TO DDC DOES NOT
PERMIT FULLY LEGIBLE PRODUCTION

8. DATA REQUIREMENTS FROM STAGS TEST FOR ANALYSIS OF APPARENT ACCUMULATION AND VELOCITY

COPY AVAILABLE TO DDC DOES NOT PERMIT FULLY LEGIBLE PRODUCTION

OBJECTIVE

To obtain tracking data for stationary firer - moving target cases to be used in conjunction with the program which determines apparent acceleration and velocity for specified target movement patterns, speeds, and accelerations.

DATA REQUIREMENTS

A. Target Vehicle During Movement Trace

1. The actual position of the vehicle as a function of time. Either a continuous trace or discrete values every Δt time units (where $\Delta t \leq 1$ second) will satisfy the requirements.

2. The actual speed and acceleration of the vehicle at the points in time for which position is recorded.

B. Target Tracking Data Relative to Stationary Firer

NOTE: This discussion assumes that gun cameras on the firer vehicles will be utilized for data collection.

1. General approach (independent of subtest).

a. Basic data currently planned consists of various time factors (lay time, time to fire first round, etc.) and "miss distance" for each round (probably in mils).

b. Additional data requirements consist of recording the (X, Y) distance of the point at which the gun is pointing from the actual aim point at Δt increments during

tracking. Depending on the tracking time interval, Δt should be no greater than one second (possibly smaller if a "short" tracking interval exists, i.e., "short" being less than five seconds). In other words, we want to record the same data which will be collected at the time of firing each round for specified time increments during the tracking phase.

C. It is recommended that we define the commencement of tracking (for purposes of film reduction) as that point in time when the target vehicle first appears on the gun camera film. The actual analysis will incorporate the determination of when tracking actually begins.

D. I recommend that during the initial film reduction process, we record tracking data for only a very limited number of cases, so as not to impede the data reduction process for the primary dependent variables of interest. The gun camera and target vehicle data can be utilized at a later time for collection of additional tracking data of interest. Specific recommendations as to those cases for which tracking data should be collected during the initial reduction phase are given in the next section.

2. Specific applicable subtests for tracking data collection

a. Speed and Precision of Lay (stationary firer <u>vs</u> moving target cases)

No initial tracking data collection

b. Survivability subtest

(1) Phase I.A. (Yano: Constant Speed)

Recommend tracking data collection for the following cases (for one crew).

(a) Flank course (20 MPH)

(b) Flank course (40 MPH)

(c) Oblique course (20 MPH)

(d) Oblique course (40 MPH)

Best Available Copy

(2) Phase II.B (Yano: Start-Stop Test)

Recommend tracking data collection for the following cases (for one crew).

(a) Flank course (greatest mobility vehicle)

(b) Flank course (M60A1)

(c) Oblique course (greatest mobility vehicle)

(d) Oblique course (M60A1)

(3) Phase II.C (Yano: Evasive Tactics)

Recommend tracking data collection for the following cases (for one crew).

(a) Flank course - M60A1 - sine wave

(b) Flank course - (greatest mobility vehicle) - sine wave

(c) Oblique course - M60A1 - sine wave

(d) Oblique course - (greatest mobility vehicle) - sine wave

(e) Head-on course - M60A1 - sine wave

(f) Head-on course - (greatest mobility vehicle) - sine wave

<u>NOTE</u>: The program can accept sine waves with varying amplitudes and frequencies during the movement trace. Such a substitution would be acceptable.

(4) St. Vith Phase

No initial tracking data collection

This report has provided a brief outline of the proposed data requirements to utilize STAGS test data in the analysis of apparent acceleration and velocity contributions to the probability of hit and survivability of combat vehicles.

These recommendations are subject to modification based on the actual conduct and results of the STAGS test.

REFERENCES

[1] Nie, et.al., Statistical Package for the Social Sciences, 2nd Edition, McGraw-Hill, 1975.

[2] U.S. Army Armor & Engineer Board, S-Tank Agility/Survivability Test Plan, Fort Knox, Kentucky, July, 1975.

[3] Winer, B. J., Statistical Principles in Experimental Design, McGraw-Hill, 1971.

INITIAL DISTRIBUTION LIST

	No. of Copies
Dean of Research Code 023 Naval Postgraduate School Monterey, California 93940	2
Defense Documentation Center Cameron Station Alexandria, Virginia 22314	12
Defense Logistics Studies Information Exchange (DLSIE) Fort Lee, Virginia 23801	1
Library (Code 0212) Naval Postgraduate School Monterey, California 93940	2
Library (Code 55) Naval Postgraduate School Monterey, California 93940	2
MG D. A. Starry, Commanding General U.S. Army Armor Center Fort Knox, Kentucky 40121	1
U.S. Army Armor and Engineer Board Fort Knox, Kentucky 40121 ATTN: COL Ed Davis, President	10
Director, Human Engineering Lab ATTN: AMXHE (Mr. Andrew Eckles, III) Aberdeen Proving Grounds, Maryland 21005	1
Ballistics Research Laboratory ATTN: AMSL (Dr. C. Masaitis) Aberdeen Proving Grounds, Maryland 21005	1
U.S. Army TRADOC Systems Analysis Activity ATTN: Mr. Roy Reynolds White Sands Missile Range, New Mexico 88002	1
Professor Samuel H. Parry Code 55Py Department of Operations Research and Administrative Sciences Naval Postgraduate School Monterey, California 93940	10