

UNCLASSIFIED

AD NUMBER

AD912660

LIMITATION CHANGES

TO:

Approved for public release; distribution is unlimited.

FROM:

Distribution authorized to U.S. Gov't. agencies only; Test and Evaluation; JAN 1973. Other requests shall be referred to Air Force Armament Lab., Attn: DLJF, Eglin AFB, FL 32542.

AUTHORITY

AFATL ltr dtd 7 Nov 1975

THIS PAGE IS UNCLASSIFIED

✓
AFATL-TR-73-14

AD0019360

DETERMINATION OF IMPACT PARAMETERS

AVCO SYSTEMS DIVISION
AVCO CORPORATION

TECHNICAL REPORT AFATL-TR-73-14
JANUARY 1973

Distribution limited to U. S. Government agencies only;
this report documents test and evaluation; distribution
limitation applied January 1973 . Other requests for
this document must be referred to the Air Force Armament
Laboratory (DLJF), Eglin Air Force Base, Florida 32542.

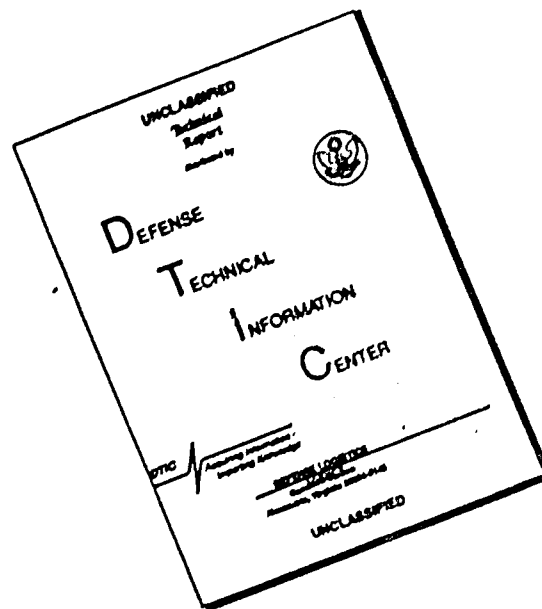
DDC
RECEIVED
AUG 28 1973

AIR FORCE ARMAMENT LABORATORY

AIR FORCE SYSTEMS COMMAND • UNITED STATES AIR FORCE

EGLIN AIR FORCE BASE, FLORIDA

DISCLAIMER NOTICE



THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

Determination Of Impact Parameters

Frank R. Lascher

David Henderson

Sol Feldman

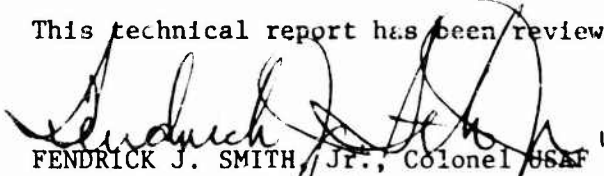
Distribution limited to U. S. Government agencies only; this report documents test and evaluation; distribution limitation applied January 1973 . Other requests for this document must be referred to the Air Force Armament Laboratory (DLJF), Eglin Air Force Base, Florida 32542.

FOREWORD

This program was conducted by Avco Systems Division, Avco Corporation, 201 Lowell Street, Wilmington, Massachusetts 01887, under Contract F08635-72-C-0218 with the Air Force Armament Laboratory, Eglin Air Force Base, Florida, during the period 15 July 1972 to 15 December 1972. Lt William H. McMillian (DLJF) was program manager for the Armament Laboratory.

Avco Program Manager was Mr. Frank R. Lascher, Mr. David Henderson was Technical Program Leader and Mr. Sol Feldman was in charge of the structural response aspects of the program. The Avco report number is AVSD-0169-73-RR.

This technical report has been reviewed and is approved.



FENDRICK J. SMITH, JR., Colonel USAF
Chief, Fuzes and Munition Control
Systems Division

ABSTRACT

This research program was conducted to establish the deceleration environment experienced in the nose and tail fuze wells of the MK82 for bomb impacts into sand targets. The study was conducted for warhead impact velocities of 600, 900, and 1100 ft/sec and impact angles, from the vertical, from 20 to 70 degrees. The contractor's Two-Dimensional Impact and Penetration Computer Program was utilized to establish the time history of the loads applied to the MK82 during the impact and penetration event. This loading environment was then applied to a mathematical structural model of the MK82 to establish the deceleration environments experienced by both fuzes during the penetration event. The results of this analysis indicated that the flexibility characteristics of the warhead have a large influence upon the fuze well deceleration environments and generated deceleration magnification factors as high as 1.8.

Distribution limited to U. S. Government agencies only; this report documents test and evaluation; distribution limitation applied January 1973 . Other requests for this document must be referred to the Air Force Armament Laboratory (DLJF), Eglin Air Force Base, Florida 32542.

TABLE OF CONTENTS

Section	Page
I. INTRODUCTION AND SUMMARY	1
1.1 Introduction	1
1.2 Summary	2
II TECHNICAL DISCUSSION	9
2.1 Introduction	9
2.2 Loading Environments Analysis	11
2.3 MK82 Mathematical Model	28
2.4 Structural Response Analysis	52
III CONCLUSIONS AND RECOMMENDATIONS	67
 APPENDICES	
I 155mm Fuze Environments Program Summary	71
II Two-Dimensional Penetration Computer Code	81
III Program 2947: Structural Response Codes and Integration Routines	97
IV MK82 Fuze Acceleration Impact Environments	103

LIST OF FIGURES

Figure		Page
1	MK82 Basic Configuration Structural Drawing	4
2	MK82 Forward Fuze Axial Acceleration	5
3	MK82 Forward Fuze Lateral Acceleration	6
4	MK82 Aft Fuze Axial Acceleration	7
5	MK82 Aft Fuze Lateral Acceleration	8
6	MK82 Sand Impact Event and Nomenclature	10
7	Velocity Dependence of C_N and C_T - Sand	14
8	Surface or Edge Effects	16
9	Loading Due to Surface Effects	17
10	Unloading Due to Surface Effects	18
11	Typical Impact and Penetration Phenomena	20
12	MK82 Bomb	22
13	Resultant Loading Environment	23
14	Trajectory Data	24
15	Acceleration Environment - Axial	25
16	Acceleration Environment - Lateral	26
17	Trajectory History	27
18	Lumped Parameter System - Axial Model	29
19	Lumped Parameter System - Lateral Model	30
20	Axial Response Forward Fuze $0 < T < 0.15$ ms	54
21	Axial Response Forward Fuze $6.4 < T < 10.4$ ms	55
22	Axial Response Forward Fuze $10 < T < 18$ ms	56
23	Axial Response Forward Fuze $18 < T < 23$ ms	57
24	Axial Response Aft Fuze $0 < T < 1.5$ ms	58

FIGURES (CONCLUDED)

Figure		Page
25	Axial Response Aft Fuze $6.4 < T < 10.4$ ms	59
26	Axial Response Aft Fuze $10 < T < 18$ ms	60
27	Axial Response Aft Fuze $18 < T < 23$ ms	61

LIST OF TABLES

Table	Title	Page
I	Table of Trajectories of the MK82 Mod 1 500-lb Bomb Into a Sand Target	2
II	Distributed Mass Summary - Axial Model MK82 Bomb	31
III	Stiffness Summary - Axial Model	32
IV	Eigen Values - Axial Model	33
V	Normalized Modal Damping Matrix - Axial Model	34
VI	Distributed Mass Summary - Lateral Model MK82 Bomb	42
VII	Stiffness Summary - Lateral Model	43
VIII	Eigen Values - Lateral Model	44
IX	Normalized Modal Damping Matrix - Lateral Model	45
X	Fuze Environment Summary - MK82 Warhead	62
XI	Fuze Mount Design Effects	68

NOMENCLATURE

Symbol	Definition
$X'Y'Z'$	Body fixed coordinate system, i.e., Z' aft along the axis X' Positive, right, perpendicular to the axis of the projectile Y' forms the orthogonal triaxial
dF	elemental force, lbs
η	medium resistance coefficient, psi
ϕ	azimuth position of elemental area dA , (rotation about axis), rad
θ	local 1/2 cone angle, degrees
dA_p	elemental projected area = f (angle of attack α and θ), in. ²
L	local angle of attack, rad
dA	elemental surface area, in. ²
F_f	friction force due to medium resistance
f_c	coefficient of friction
F_N	normal force due to medium resistance
ρ	medium density, slugs/in. ³
ζ	the angle between the local velocity vector and the elemental surface area, rad
V_N	local normal velocity vector, in./sec
$\dot{Z}_L$ and $\dot{X}_L$	local velocity components, in./sec
$\dot{Z}_I$ and $\dot{X}_I$	velocity components in the inertial coordinate system (vehicle center of gravity), in./sec
$S(i)$	axial distance of elemental surface from vehicle C_g , in.
$\dot{\gamma}$	vehicle pitch rate, rad/sec
$r(i)$	radial station of elemental surface area, in.
dM_c	elemental moment about C_g of projectile

SECTION I

INTRODUCTION AND SUMMARY

1.1 INTRODUCTION

To design a fuzeing system for operation in a bomb which will impact and penetrate into a soil, sand, or concrete target, one should be knowledgeable of the high deceleration environment experienced during the impact event in which the fuze will be required to survive and/or function. This is necessary to ensure that the fuze designer has the information necessary to design the fuze structural components and functioning characteristics to perform in and/or survive the deceleration environments associated with the full range of bomb and target impact parameters. In addition, any functional or environmental tests conducted on an existing or developmental system lack meaning unless one can be assured that the environments which are simulated in the tests duplicate the in-use environments in which the unit must function. For these reasons it is desirable that the fuze designer have available to him a series of tables, charts, or graphs which parametrically specify the fuze impact environment as a function of bomb configuration, bomb impact geometry, and target characteristics.

To satisfy this long-term Air Force objective, a series of analytical and experimental programs have been initiated by the Air Force Armament Laboratory (AFATL) to expand the data base in this area and to provide preliminary information for specific impact conditions. This program was conducted to investigate the deceleration environments experienced by the nose and tail fuzes of the MK82 for bomb impacts into sand targets. This was accomplished utilizing the technology developed under Contracts AF 29(601)-7177 and F29601-68-C-0066, sponsored by the Air Force Weapons Laboratory, and serves as a continuation of the effort initiated under Contract F08635-69-C-0193, sponsored by AFATL. Basically, complete histories of the MK82 nose and tail fuze accelerations were determined analytically for a variety of warhead impact conditions into sandy terrain.

1.2 SUMMARY

To obtain the MK82 fuze deceleration environments for warhead impacts into sand targets, a four-part study was conducted. The initial activity consisted of determining the impact loads acting on the MK82 for the impact conditions specified in Table I. This was accomplished utilizing the contractor's two-dimensional Impact and Penetration Computer Code which specified the time history of the forces acting on the MK82 and the resultant warhead deceleration for impacts into the sand target.

TABLE I. TABLE OF TRAJECTORIES OF THE MK82 MOD 1 500-LB.
BOMB INTO A SAND TARGET

Case Number	γ , deg (From Vert.)	V_I	
		Ft/sec	In./sec
1	20	1,100	13,200
2	25	↓	↓
3	30		
4	35		
5	40		
6	45		
7	50		
8	55		
9	60		
10	65		
11	70		
12	20	900	10,800
13	25	↓	↓
14	30		
15	35		
16	40		
17	45		
18	50		
19	55		
20	60		
21	65		
22	70		
23	20	600	1,200
24	25	↓	↓
25	30		
26	35		
27	40		
28	45		
29	50		
30	55		
31	60		
32	65		
33	70		

The second activity consisted of the generation of a dynamic mathematical model of the MK82. The structural layout of the MK82 which was used for this study is shown in Figure 1.

The next phase consisted of determining the structural response of the MK82 nose and tail fuze by applying the loading environment established in Task 1 to the structural model generated in Task 2 and establishing the resultant deceleration environments. A summary of the results, i.e., the peak acceleration environments, is shown in Figures 2 through 5. The axial and transverse accelerations for the forward fuze are shown in Figures 2 and 3, respectively, while the axial and transverse accelerations for the aft fuze are presented in Figures 4 and 5, respectively. These peak levels occur during the first few milliseconds of the penetration event. These early peaks are due to the flexibility of the MK82 bomb and, in most cases, are significantly greater than the rigid body response which reaches a maximum later in the trajectory.

The magnifications of the peak deceleration loads caused by the flexibility of the MK82 were as high as a factor of 1.8. This clearly demonstrates that the flexibility characteristics of the warhead must be considered to establish peak fuze impact decelerations. This magnification factor will be substantially higher for bomb impacts into media which have a higher acoustic impedance than sand. Examples of these media include clay, frozen earth, and concrete.

The results of this program, therefore, provide the fuze designer with detailed information concerning MK82 impact environments. This should not be considered an end in itself, but a first step in the better understanding of fuze loading environments. For this reason, this effort should be expanded to include additional impact media and warheads to provide a more complete data base for the fuze designer.

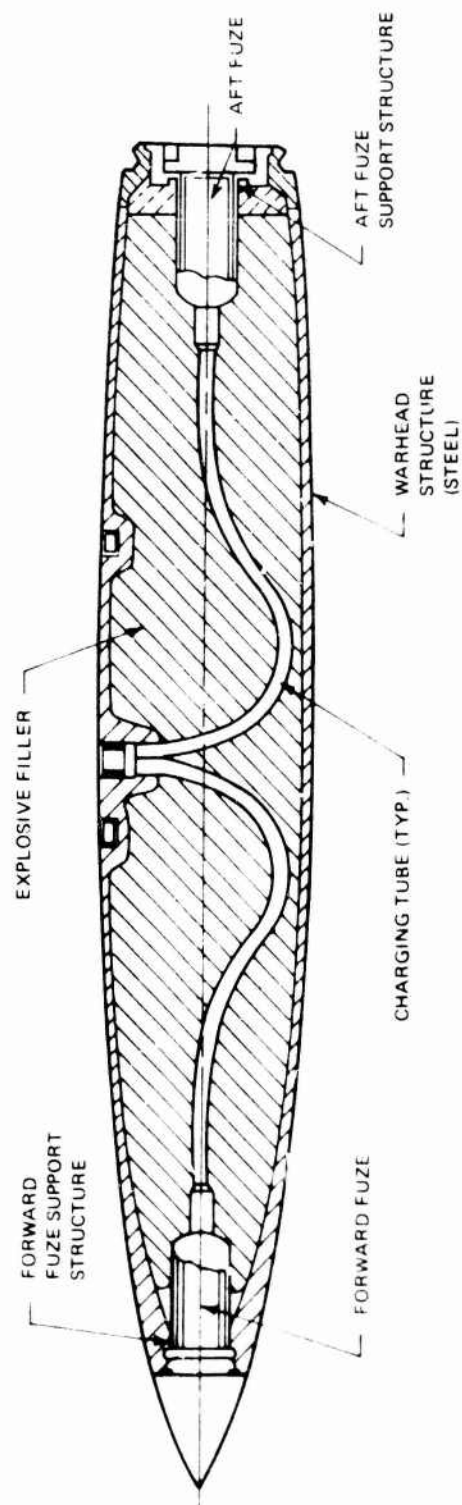


Figure 1 MK82 BASIC CONFIGURATION STRUCTURAL DRAWING

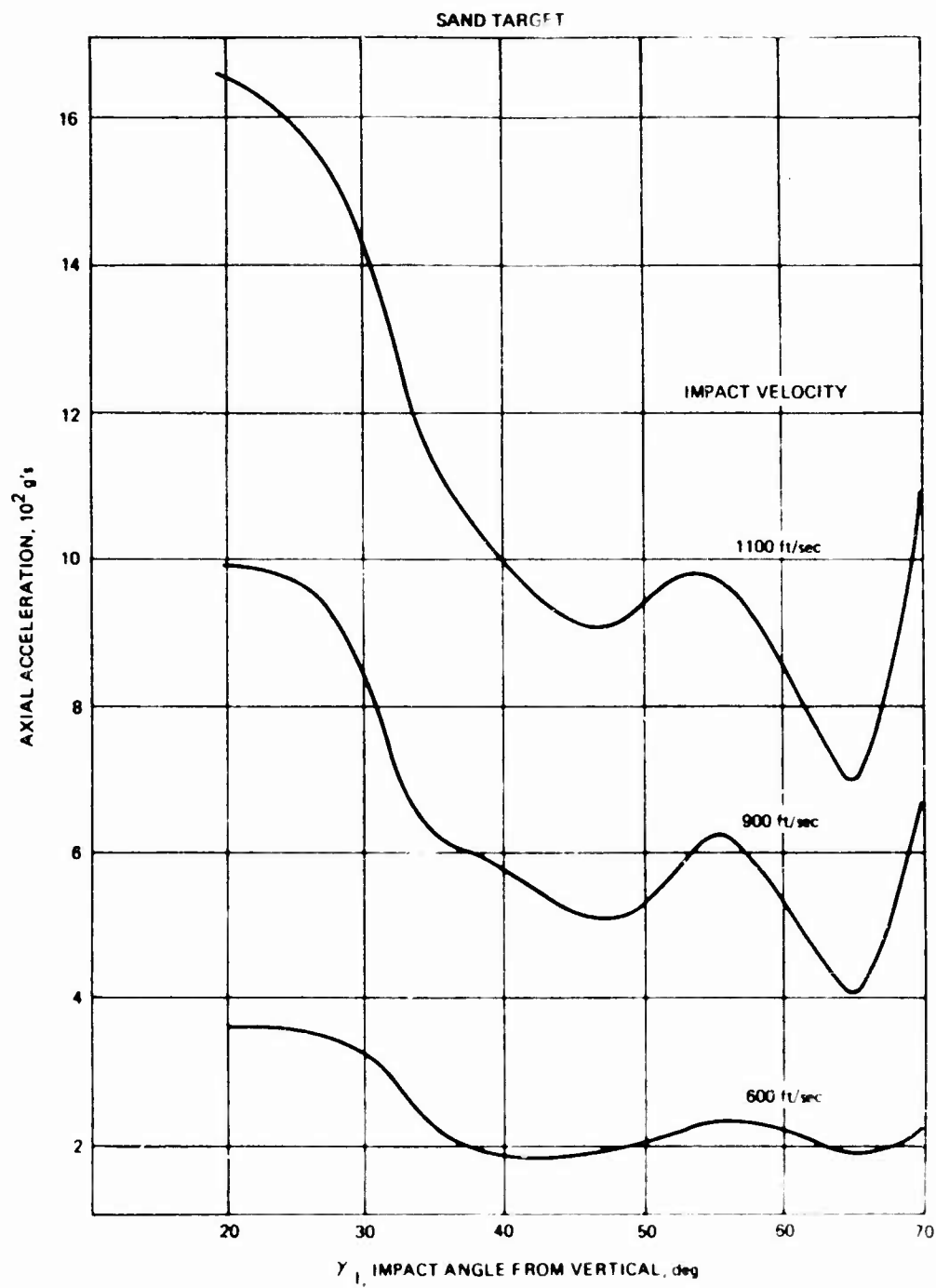


Figure 2 MK82 FORWARD FUZE AXIAL ACCELERATION

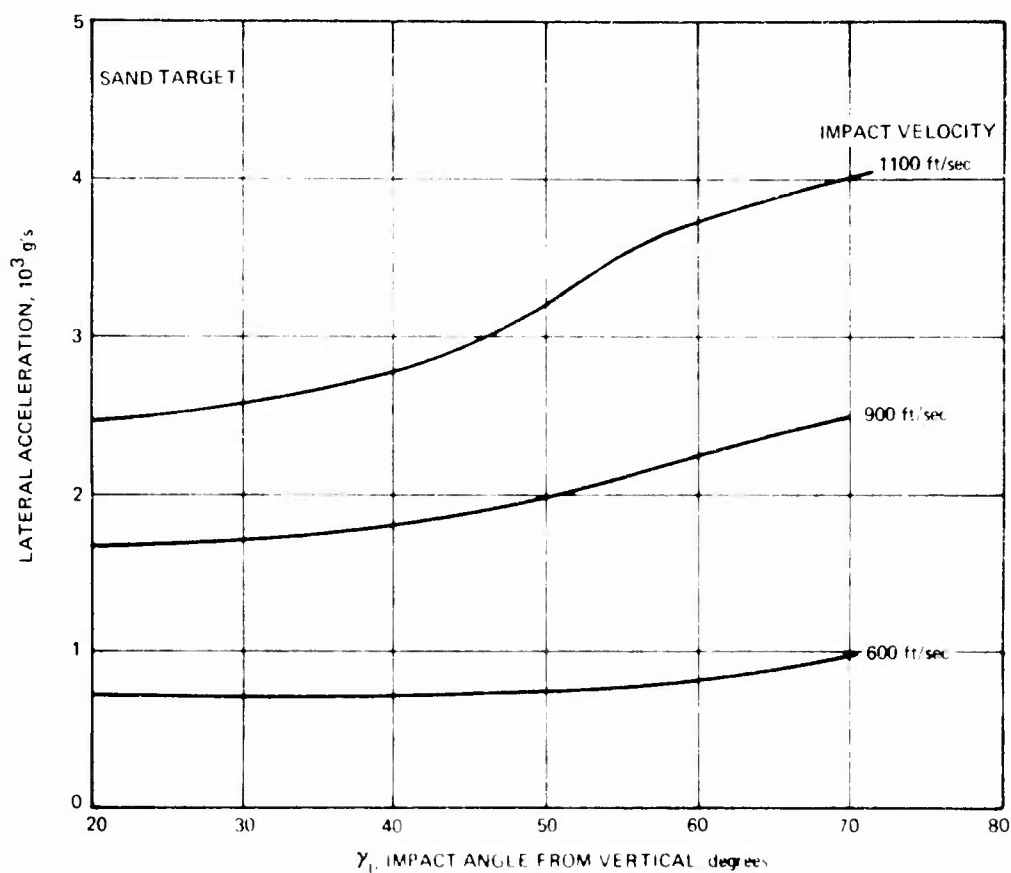


Figure 3 MK82 FORWARD FUZE LATERAL ACCELERATION

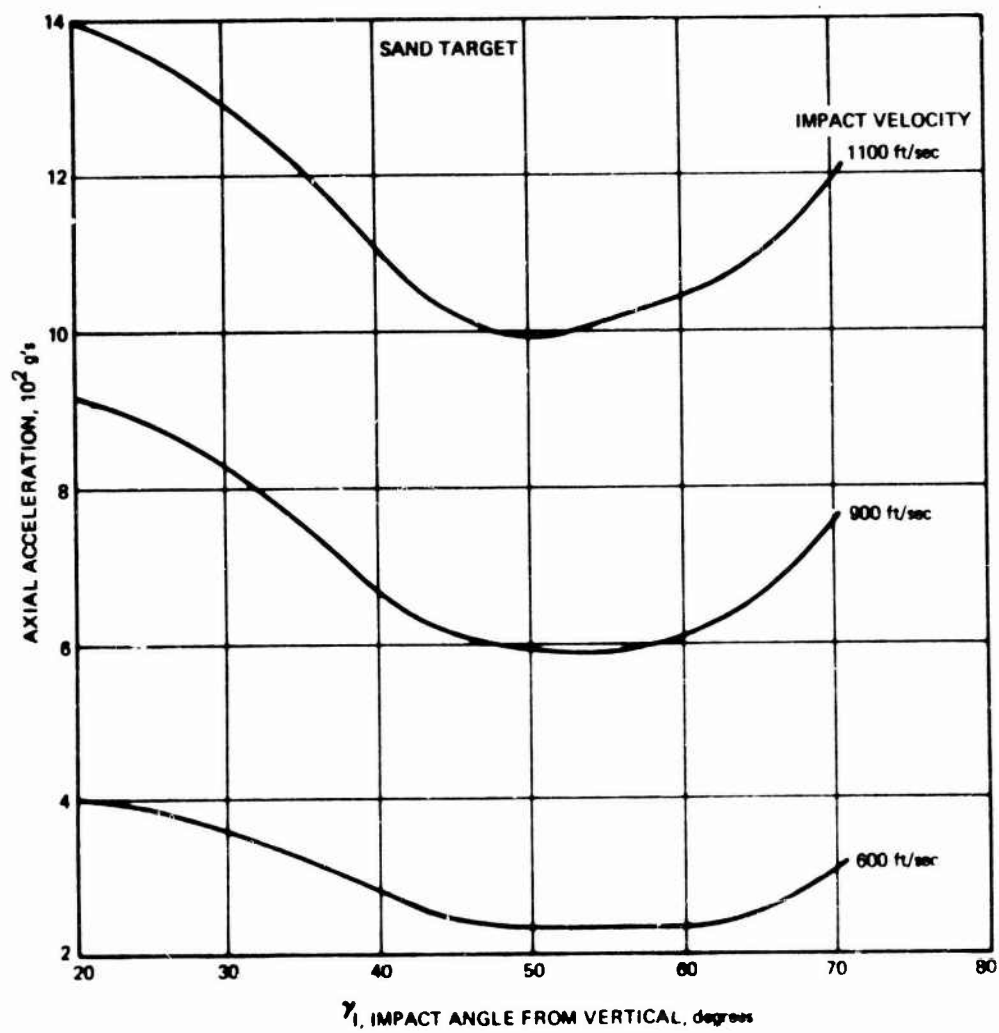


Figure 4 MK82 AFT FUZE AXIAL ACCELERATION

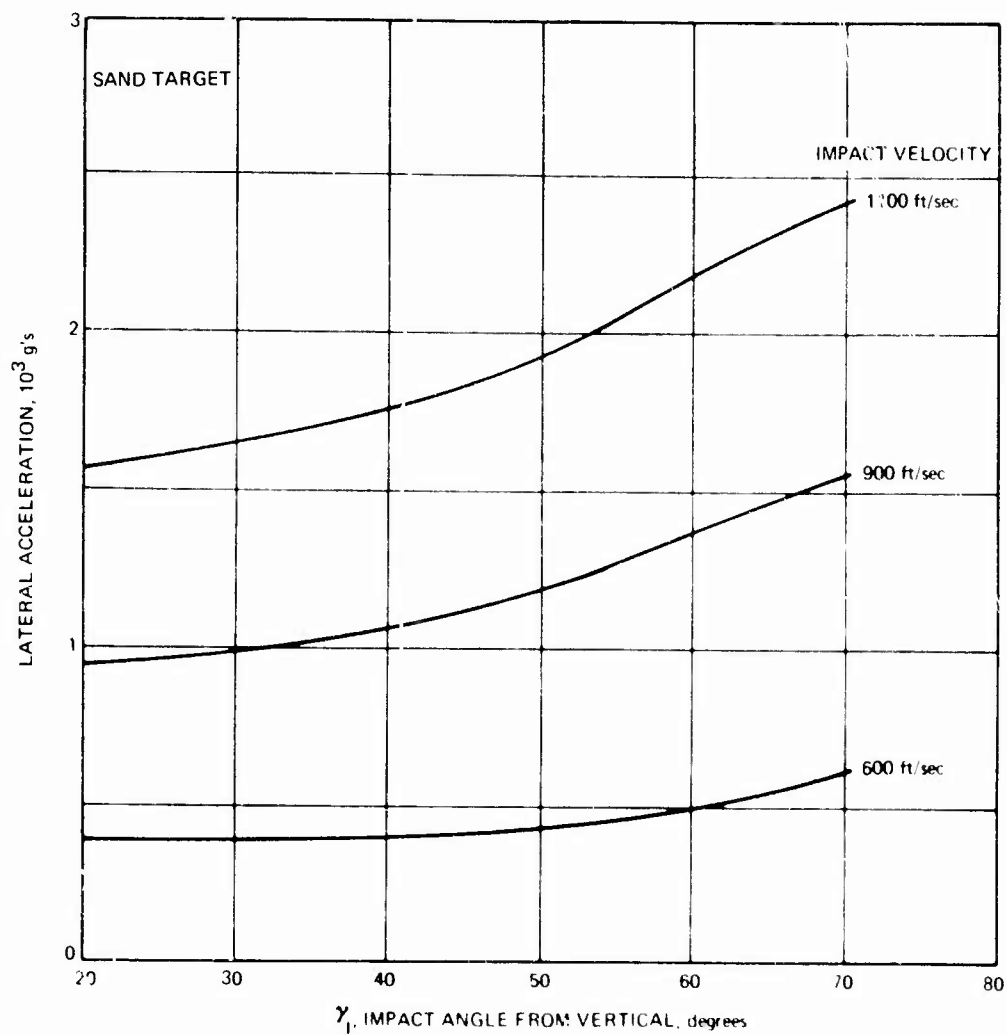


Figure 5 MK82 AFT FUZE LATERAL ACCELERATION

SECTION II

TECHNICAL DISCUSSION

2.1 INTRODUCTION

The objectives of this program were to determine the MK82 bomb fuze acceleration environments due to impacts into sand. This problem is schematically represented in Figure 6. The locations of the forward and aft mounted fuzes are designated. Due to the impact, penetration, and/or ricochet event, transverse and axial accelerations of the fuze systems are experienced as shown. The total accelerations experienced by any station on the warhead is due to the combined elastic plus rigid body accelerations. It was the purpose of this program to determine this total acceleration environment. The environment varies as a function of impact velocity and warhead orientation. The matrix of impact conditions investigated during this study is shown in Table I.

The approach taken to meet the objectives of the program involved the conduct of several tasks. These included

1. Loading Environment Analysis - This study also established the MK82 rigid body response.
2. Generating a dynamic mathematical model of the MK82 configuration.
3. Determining the structural response of the MK82 bomb due to the loading environment established in (1), above.
4. Combining the resulting environments to determine the total acceleration histories of the forward and aft fuze systems.

Each of these study tasks is described in the paragraphs that follow.

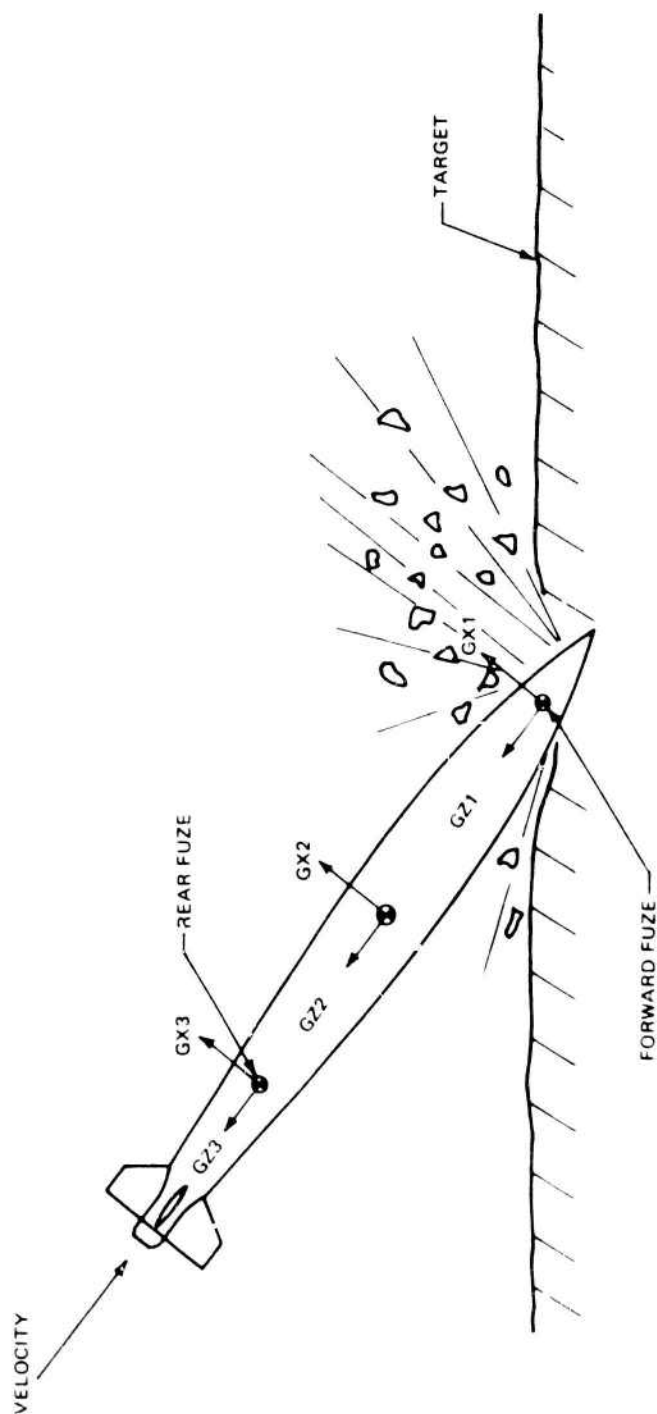


Figure 6 MK82 SAND IMPACT EVENT AND NOMENCLATURE

2.2 LOADING ENVIRONMENTS ANALYSIS

The purpose of the loading environment analysis was to determine the loads acting on the MK82 projectile due to impacts into sand. In view of the fact that the loads are dependent upon the state of the projectile (i.e., its position and velocity relative to the impacted medium), this data, which represents the projectile rigid body response, is determined concurrently with the loading environment.

The capability to perform this type of theoretical analysis with confidence that the predicted loads accurately describe the actual impact environment is due to the contractor's general background in the technological field and, specifically, his participation in the 155mm Fuze Environments Program. The objective of this program was to establish the analytical capability to predict impact environments into sand. This was accomplished, and was verified by test. A summary of that program is included in Appendix I.

The results of that program made available the resistance to penetration force law for sand which is described below.

Dynamic Penetration Force Law for Sand

The basic form of the force law is:

Resistance force = compressibility effects (i.e., shock) +

Medium resistance pressure + medium resistance friction

+ equivalent fluid dynamic normal pressure

+ equivalent shear drag + separation

+ cratering + target surface effects

It is believed that all the pertinent physical phenomena to which a projectile can be subjected during impact into sand are represented above.

The mathematical equivalent expression for the above force law is expressed:

$$dF = dA [\rho cve^{-at} u(t-r) + \eta + C_N kV^2 + C_r kV^2] \\ + \text{Target surface effects}$$

This force law is described in detail in the following paragraphs. Also given are specific values of the governing coefficients.

Medium Resistance Phenomena

Pressure Force

This term is the resistance to penetration associated with the medium characteristics themselves. This term is that resistance necessary to part the medium and allow passage of the projectile, neglecting those forces generated from the inertia of the impacted particles. If the medium were steel or concrete, this resistance would be very high and would be proportional to the failure strength of the material itself.

In the case for sand, this pressure was considered to be relatively small and was found to be on the order of 10 psi near the surface for both sand and soil. Its direction of application is normal to the surface of the projectile, and its magnitude is modified in proportion to the projected cross-sectional area of the elemental area under consideration.

In analytical form, the elemental forces due to the medium resistance pressure are:

$$(dF_x')_m = - \eta \sin \phi \cos \theta dA_p$$

$$(dF_x')_m = - \eta \sin \phi \cos \theta \sin (\theta + \alpha_L \sin \phi) dA$$

and

$$(dF_z')_m = - \eta \sin \theta \sin (\theta + \alpha_L \sin \phi) dA$$

All of the forces shown here and subsequently are resolved from the elemental surface area to the body fixed coordinate system which includes the axial, designated Z' , and the transverse, designated X' .

Friction Force

The medium resistance friction force is defined in the usual way, i.e., its magnitude is equal to the normal force (derived above) times a friction coefficient (f_c), and its direction of application lies in the plane of the elemental surface area.

In analytical form,

$$(F_f) = f_c (F_N)$$

$$(F_N) = \eta dA_p = \eta \sin (\theta + \alpha_L \sin \phi) dA$$

$$(dF_{f_x'}) = - f_c \eta \sin \phi \sin \theta \sin (\theta + \alpha_L \sin \phi) dA$$

$$(dF_{f_z'}) = f_c \eta \cos \theta \sin (\theta + \alpha_L \sin \phi) dA$$

In this instance, f was found to be 0.25. The level of the resulting forces due to this term are, however, relatively insignificant.

Equivalent Fluid Dynamic Resistance Forces

The equivalent fluid dynamic resistance forces are generated from the inertial resistance to motion of the sand particles being impacted by the penetrator. The model used here to represent flow characteristics is the extended Newtonian impact theory. In this theory accommodation coefficients are introduced to account for the nature of the detailed interaction between the sand particle and the body surface.

Of interest here are two of the coefficients C_N , the normal accommodation coefficient, and C_r , the tangential accommodation coefficient. These coefficients are a measure of the proportion of incident normal momentum and tangential momentum that is transferred to the sand particles as a result of collision with the surface of the projectile and therefore are a measure of the amount of momentum imparted to the projectile. This theory postulates that the normal pressure P and shear stress τ at the surface are given by:

$$P = 1/2 C_N \rho V^2 \sin^2 \xi$$

$$\tau = 1/2 C_r \rho V^2 \sin \xi \cos \xi$$

The range of values of these coefficients can be established by considering the fundamental laws of physics. For purely elastic impact of a sand particle where the rebound velocity is equal to the impact velocity, C_N would take on the value of 4.0 while $C_r = 0$. This type of situation, sometimes referred to as completely specular reflection, has no energy loss and consequently establishes the maximum value of C_N and the minimum value of C_r . The other limiting case occurs when $C_N = 2$ and $C_r = 2$. This represents the situation when purely inelastic momentum transfer has taken place and is referred to as "completely diffuse reflection". These boundary conditions on the coefficients modifying the shear and pressure fluid dynamic terms in the force law were recognized and adhered to. The final values of C_N and C_r were found to be within these limits but were also found to be a function of velocity. The curve shown in Figure 7 represents the experimentally determined values for sand of the velocity dependence of C_N and C_r .

The analytical expression used in the two-dimensional simulator for these transverse and axial elemental forces are:

$$(dF_x)_{\text{flow}} = - (P \sin \phi \cos \theta + \tau \cos \xi \cos \phi) dA$$

$$(dF_z)_{\text{flow}} = (P \sin \theta - \tau \sin \xi \cos \theta) dA$$

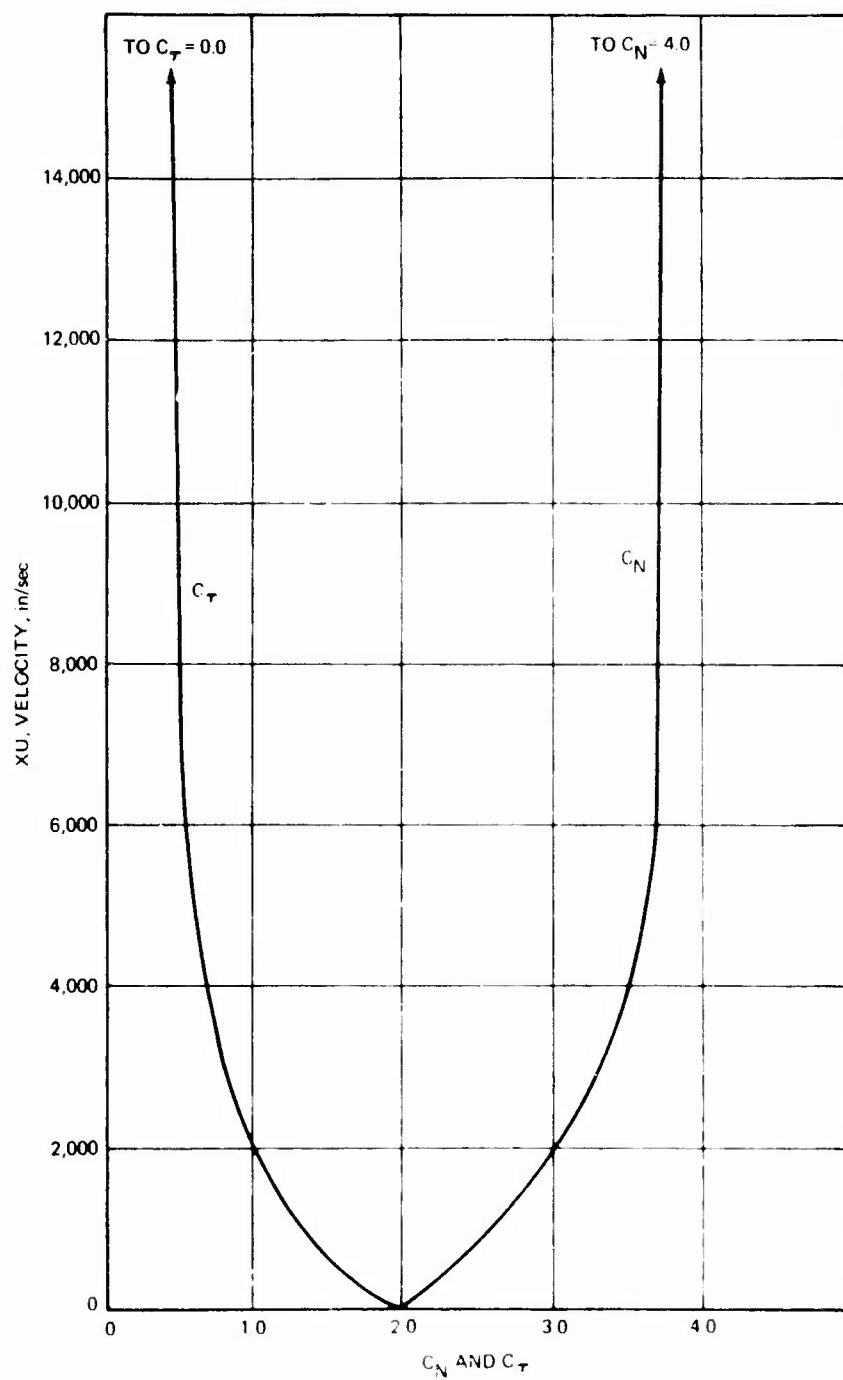


Figure 7 VELOCITY DEPENDENCE OF C_N AND C_T - SAND

Flow Separation Phenomena

Flow separation is a natural phenomenon which simply allows portions of the surface of the projectile to be free of resistance to penetration forces. This occurs whenever the local flow condition is outward from the surface. The parameter which governs whether forces exist is the sign of the local normal velocity vector, V_N .

If the sign is positive, then the flow is inward against the surface, and if negative, the flow is outward from the surface and no forces exist. This phenomenon is handled, therefore, by limiting the integration over the surface of the projectile to those areas where V_N is positive.

For any location on the surface of the projectile,

$$V_N = (-S \theta C \gamma + C \theta S \phi S \gamma) \dot{Z}_L + (S \theta S \gamma + C \theta S \phi C \gamma) \dot{X}_L$$

where

$$\dot{Z}_L = \dot{Z}_I + S(i) \dot{\gamma} \sin \gamma$$

$$\dot{X}_L = \dot{X}_I + \dot{\gamma} S(i) \cos \gamma$$

Values of ϕ are determined when V_N goes to zero. These become integration limits over which resistance to penetration forces can exist.

Target Surface Effects

The phenomenon of target surface effects is shown schematically in Figures 8 and 9. The phenomenon was utilized in the simulations to allow for the lowering of resistance to penetration near the surface of the sand target.

The influence of target surface effects is a function of distance between the projectile and the target surface. This relationship for MK82 impacts into sand is shown in Figure 10. This variation occurs at the surface and down to a depth of 100 inches and allows the upper surface of the projectile to be unloaded with a linear variation of the load to a maximum at the base. VCHIPF is the percentage of unloading and varies as a function of depth as shown.

Resulting Force Law

The analytical expressions for the forces and moments, i.e., the force law, which made up the combination of the above effects is:

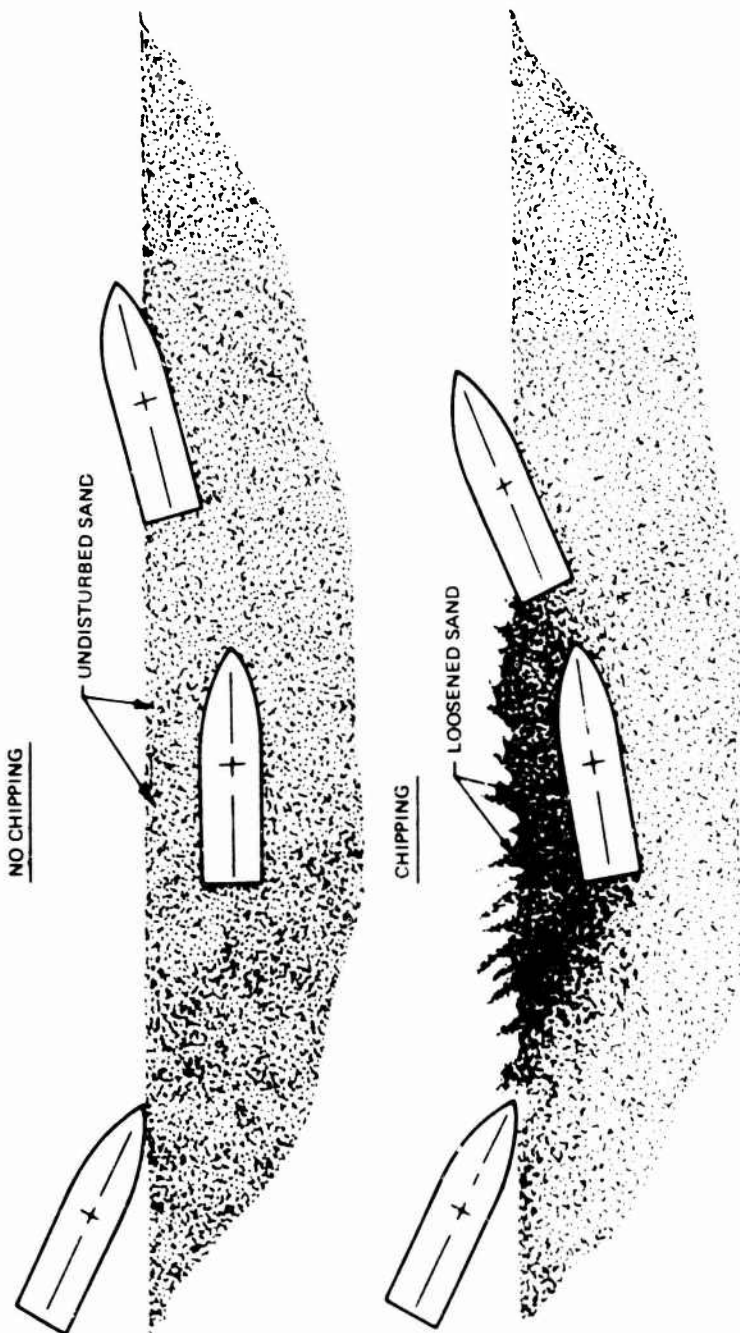


Figure 8 SURFACE OR EDGE EFFECTS

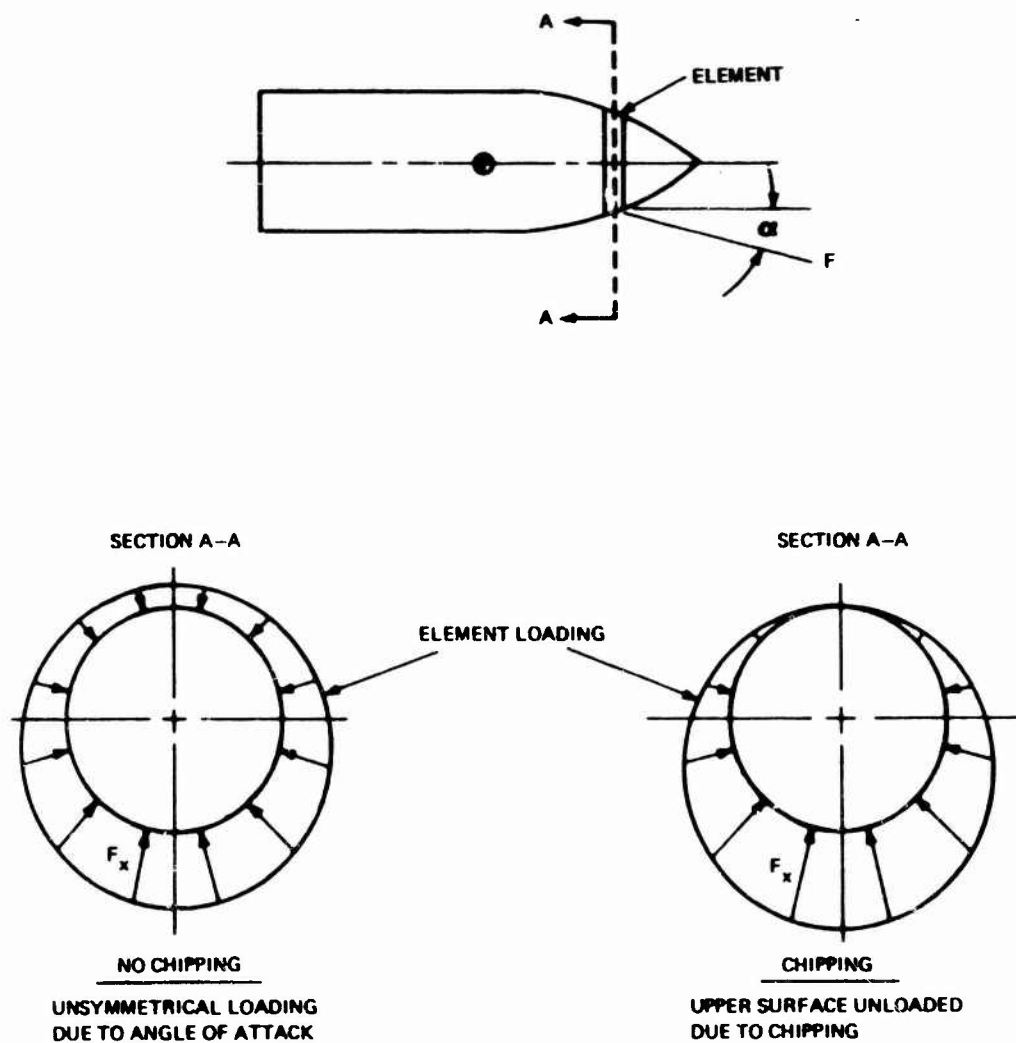


Figure 9 LOADING DUE TO SURFACE EFFECTS

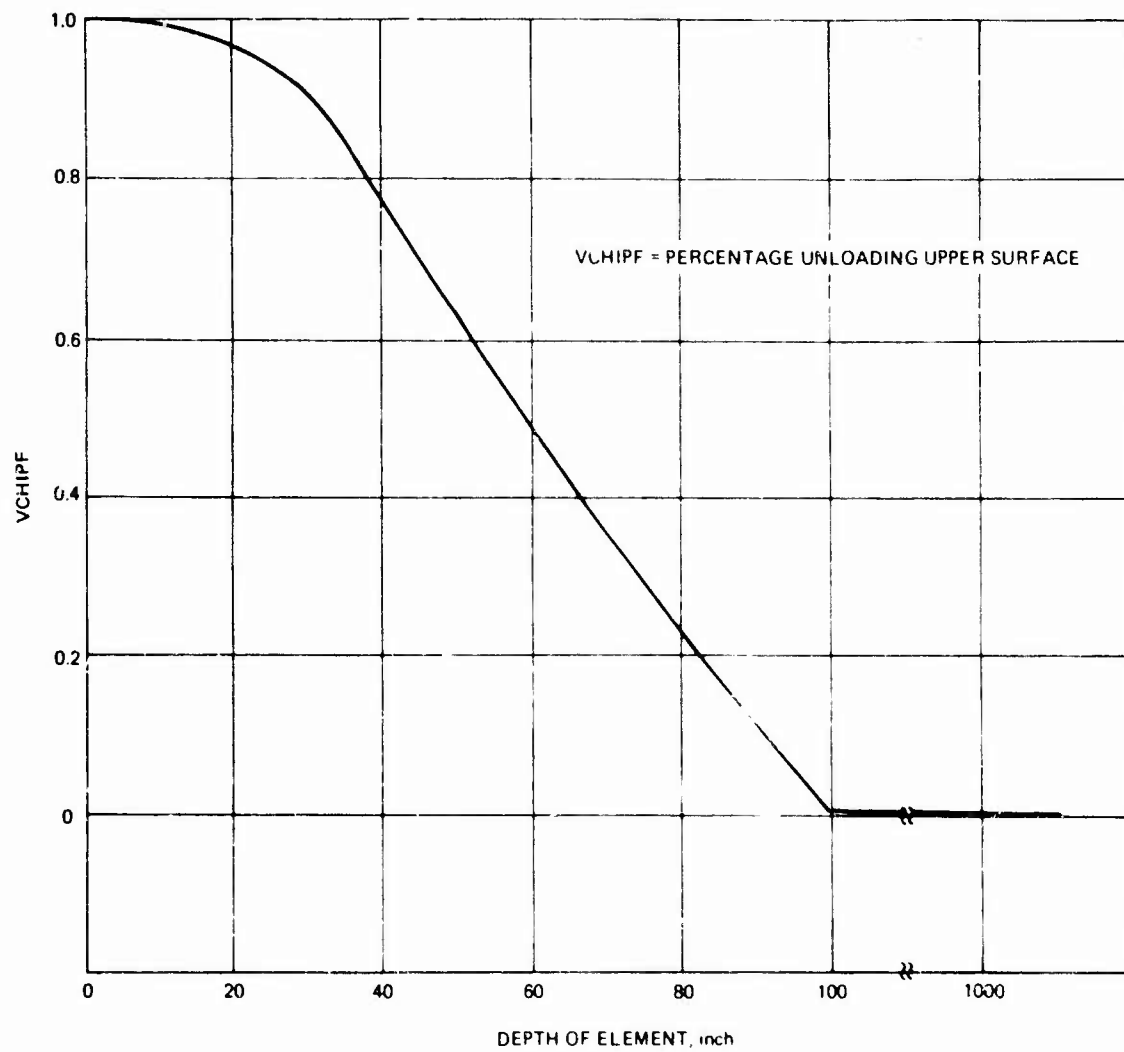


Figure 10 UNLOADING DUE TO SURFACE EFFECTS

For the transverse loads,

$$dF_x' = (dF_x')_m + (dF_x')_f + (dF_x')_{flow}$$

$$\begin{aligned} dF_x' = & - \eta \sin \phi \cos \theta \sin (\theta + \alpha_L \sin \phi) dA \\ & - f_c \sin \phi \sin \theta \sin (\theta + \alpha_L \sin \phi) dA \\ & - (P \sin \phi \cos \theta + r \cos \xi \cos \phi) dA \end{aligned}$$

and for the axial loads,

$$dF_z' = (dF_z')_m + (dF_z')_f + (dF_z')_{flow}$$

$$\begin{aligned} dF_z' = & \eta \sin \theta \sin (\theta + \alpha_L \sin \phi) dA + f_c \cos \theta \sin (\theta + \alpha_L \sin \phi) dA \\ & + (P \sin \theta - r \sin \xi \cos \theta) dA \end{aligned}$$

The moment is determined by establishing the point of application of the above forces. All these forces act at a station measured from the center of gravity of the projectile and at a radius $r(i) \sin \phi$ from the longitudinal axis of the projectile.

$$dM_c = (dF_x') S(i) + (dF_z') r(i) \sin \phi$$

It is apparent that, in view of the fact that the above force law is presented in differential form, a mechanism or tool is needed to integrate these elemental forces over the surface of the projectile and at the same time simulate impact, penetration, and/or ricochet-type phenomena. Such impact phenomena are depicted in Figure 11. From the figure it is also apparent that the rigid body equations of motion must also be solved continuously during the impact event.

The mechanism by which the contractor accomplishes the above tasks is through the use of impact and penetration simulators. The simulator used for the present program is the contractor's 2-Dimensional Impact and Penetration Simulator, i.e., 2-D Code.

Two-dimensional representation of the impact events was considered adequate for the kinds of impact conditions investigated. Basically, the 2-D Code performs all the functions needed to analytically simulate impact-type events. The code:

- Contains the general force law.
- Integrates the forces over the surface of the projectile.
- Solves the rigid body equations of motion.

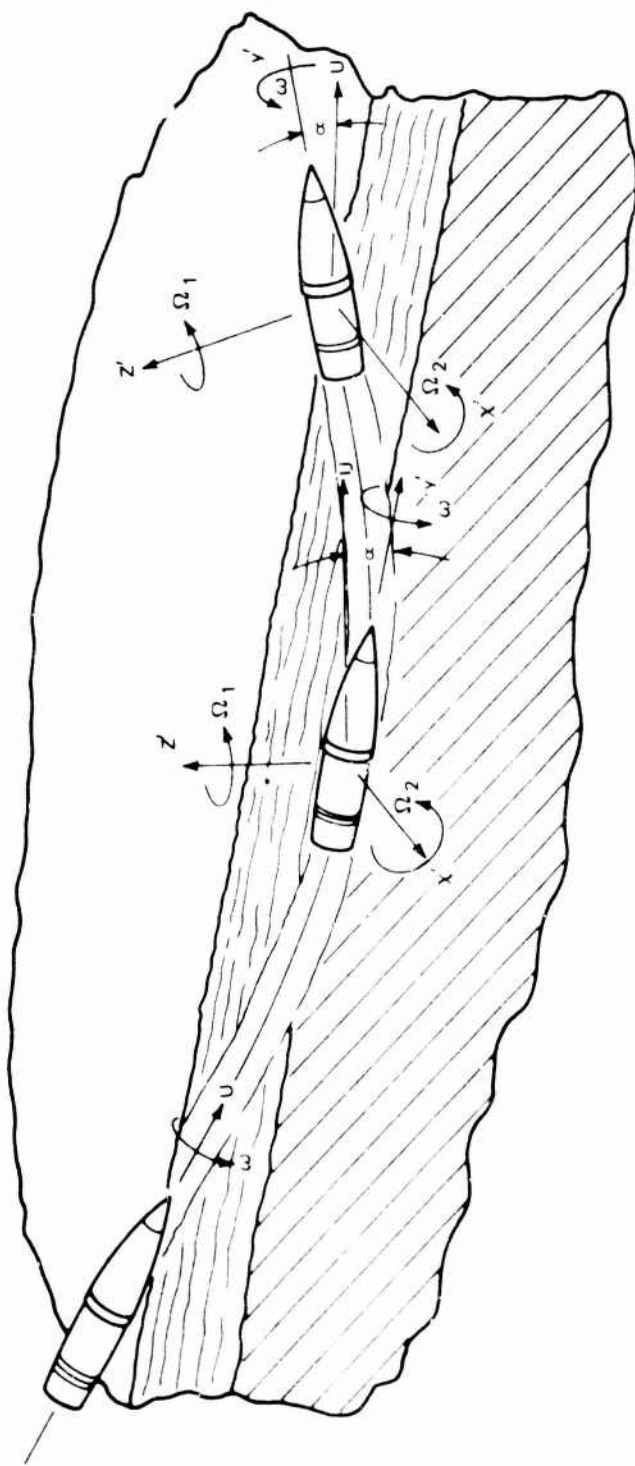


Figure 11 TYPICAL IMPACT AND PENETRATION PHENOMENA

A more detailed description of this code is given in Appendix II; however, an understanding of the 2-D Code's capabilities will be gained through the discussion of its use during this program.

The basic inputs to the 2-D Code included the impact conditions shown in Table I, the force law coefficients described above, the mechanical properties of dry sand, and the MK82 external configuration and its mechanical characteristics. These latter data are summarized in Figure 12. It should be noted that the tail structure is not included in the configurational drawing shown in Figure 12. A basic assumption was made in this regard, i.e., that the tail surface failed early during the penetration event and as a result transmitted little inertial reaction to the rest of the body structure. With this data, a rigid body impact parametric study was conducted. The pertinent results generated by this study included:

1. The loading environments
2. The MK82 rigid body response.

All of this data has been delivered to the Air Force under separate cover. An example of the data format is included here in Figures 13 through 17.

The specific example chosen considers the MK82 impacting sand at a velocity of 1100 fps and at an obliquity angle of 70 degrees measured from the vertical.

The standard output format of the 2-D Code consists of a graphical representation of all pertinent trajectory parameters. Five separate graphs are produced. Figure 13 presents the loading environment, where FZP is the axial resistance to penetration resultant force time history, lb, FXP is the transverse force, lb and MCG is the applied moment acting about the center of gravity of the projectile, in lb. The rotational acceleration is obtained by dividing MCG by the mass moment of inertia of the MK82, i.e., $(MCG/424, \text{rad/sec}^2)$. Figure 14 represents the basic trajectory data of the impact event where X and Z represent linear displacements as a function of time, inches. VEL is the instantaneous velocity, in/sec, GAM is the orientation in degrees as measured from the vertical, and ALPHA is angle of attack, degrees. Figures 15 and 16 show the axial and transverse accelerations, respectively, in g's. GZ1, GZ2, and GZ3, for example, represent the axial g's at the forward fuze well, the center of gravity, and the aft fuze well, respectively. Figure 17 shows a schematic representation of the trajectory.

In addition to the above data, the distributed loading environments history was determined for each of these impact conditions. This data is so voluminous as to be impractical to produce on hard copy. This data was, however, needed to perform subsequent structural response analysis. In view of this, a modification was made to the basic 2-D Code to output the transient distributed loading environment on magnetic tape. The usage of this data will be discussed in subsequent paragraphs.

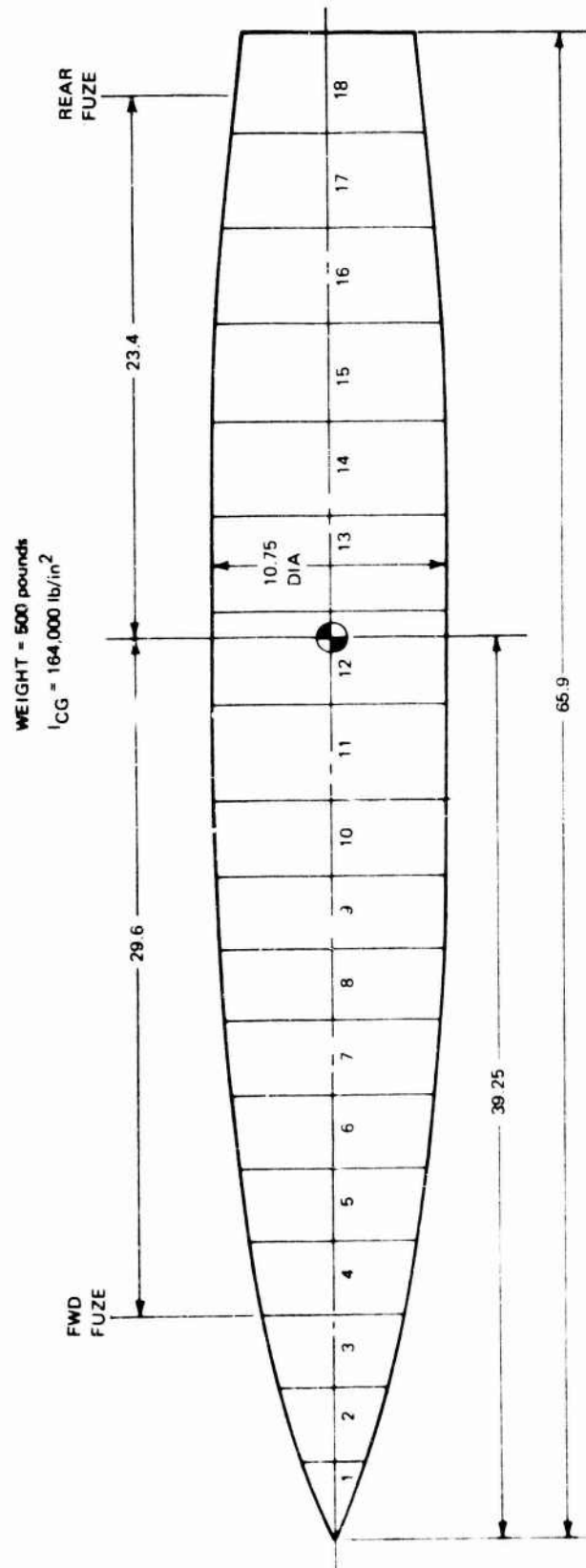


Figure 12 MK82 BOMB

CASE 11 MK82 MOD 1 SAND TARGET

R=0.00 L=95.00 GPM=70.0 VEL=12000. XCG=30.25 XM=500.00

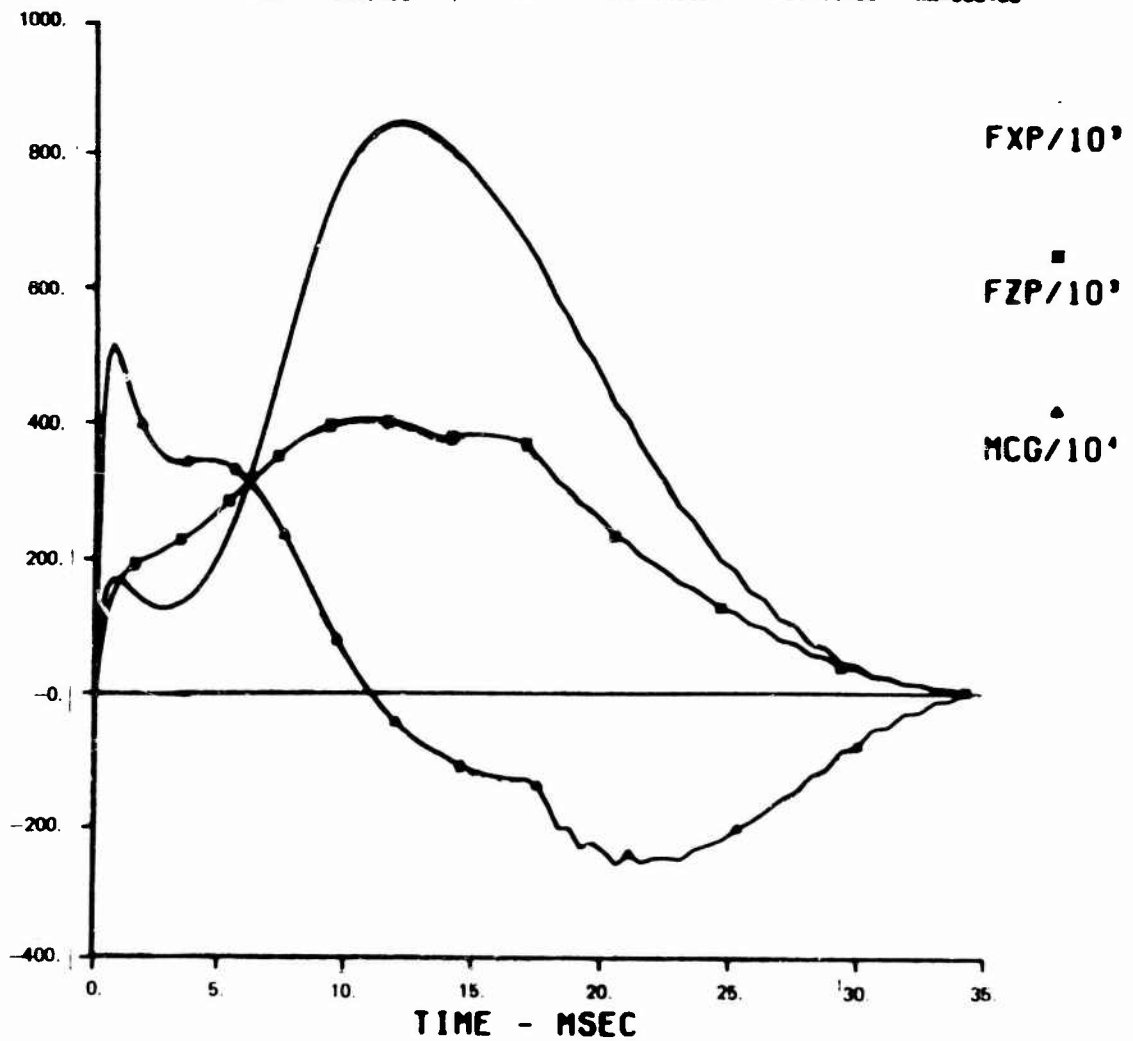


Figure 13 RESULTANT LOADING ENVIRONMENT

CASE 11 MK82 MOD 1 SAND TARGET

R=0.00 L=65.90 OAM=70.0 VEL=13200. XCG=39.25 XM=500.00

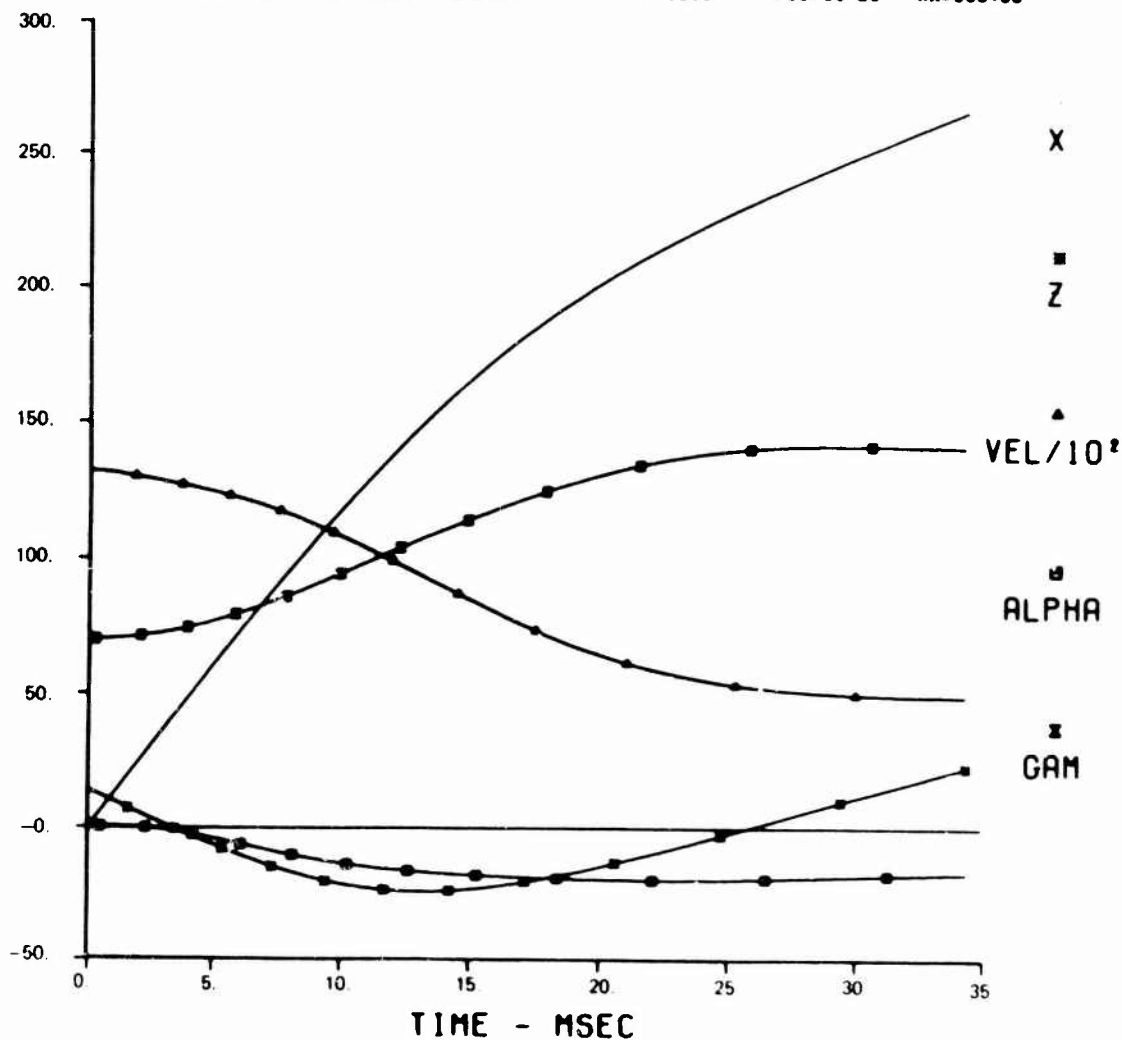


Figure 14 TRAJECTORY DATA

CASE 11 MK82 MOD 1 SAND TARGET

R=0.00 L=05.00 GMM1=70.0 VEL=13000. XCB=30.25 XM=000.00

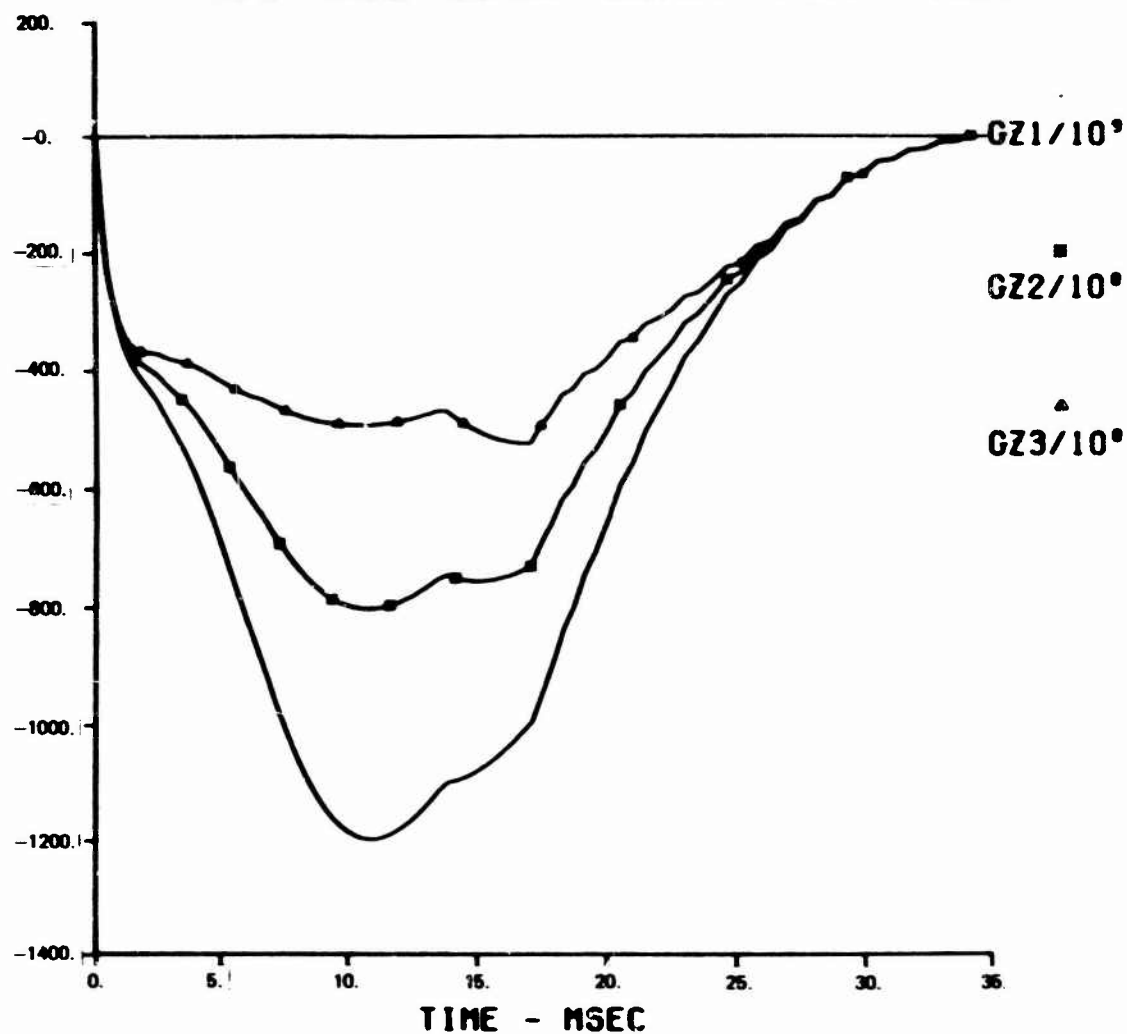


Figure 15 ACCELERATION ENVIRONMENT - AXIAL

CASE 11 MK82 MOD 1 SAND TARGET

R=0.00 L=65.90 GAM=70.0 VEL=13200. XCO=39.25 XM=600.00

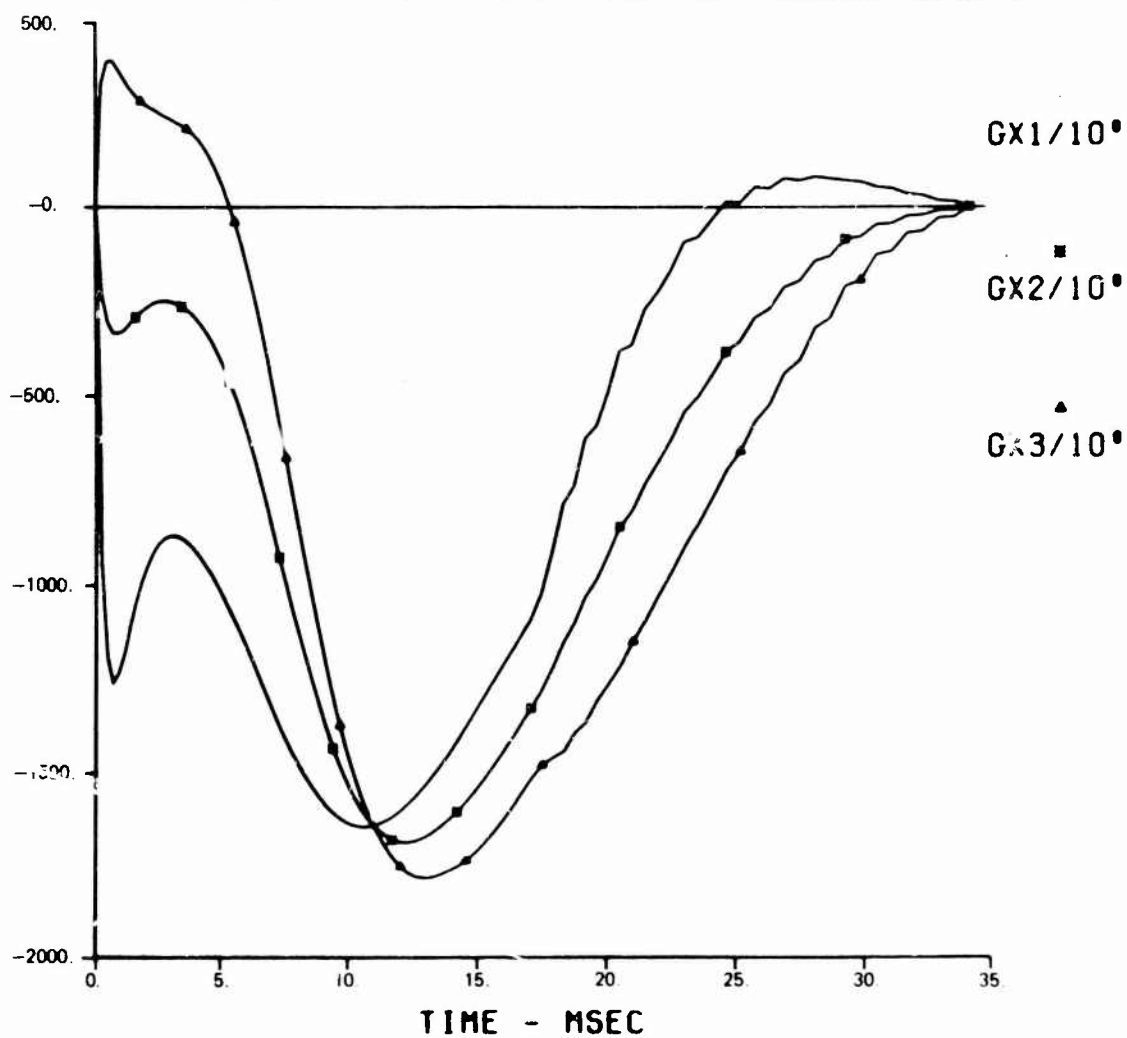


Figure 16 ACCELERATION ENVIRONMENT - LATERAL

CASE 11 MK82 MOD 1 SAND TARGET

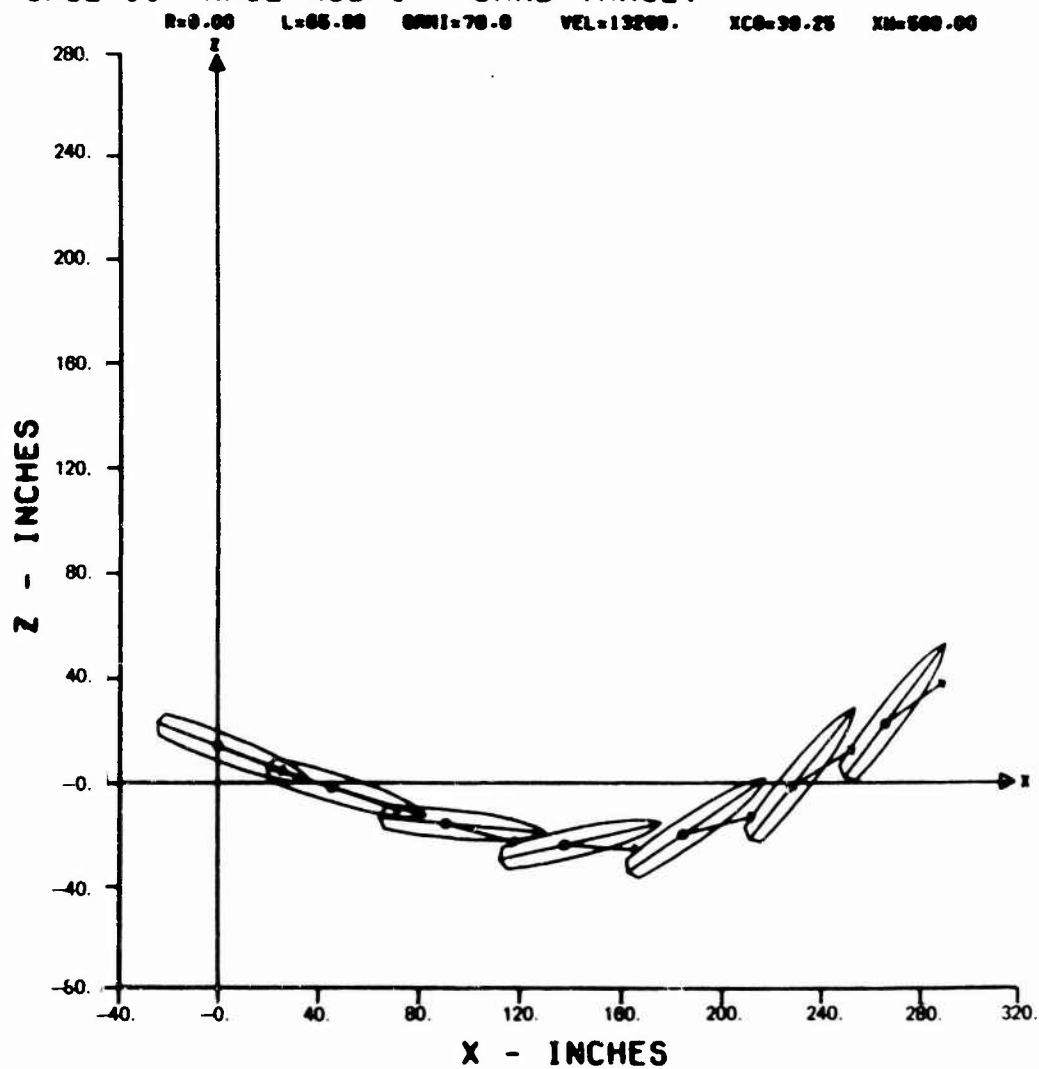


Figure 17 TRAJECTORY HISTORY

2.3 MK82 MATHEMATICAL MODEL

Generating a representative mathematical model of the MK82 bomb involved establishing an equivalent lumped parameter system of the MK82 which included the structure, filler material, and fuze systems. Two models were generated: an axial and a transverse system. These two models were to be analyzed independently in order to determine the orthogonal response motion of each. The system would have to be treated as coupled only if the amplitude of response were relatively large or the rotational rates were sufficiently high to effect the characteristics of the axial and bending stiffness. Neither is the case; consequently, the approach is valid.

The tasks to be accomplished in the generation of a representative dynamic system include:

1. Dividing the system into the appropriate number of elements for both the axial and transverse model.
2. Determining the mass and stiffness matrices for both systems.
3. Determining the eigen values, eigen vectors, and the modal damping matrices.

The basic layout of the MK82 bomb is shown in Figure 1. A complete set of detailed structural drawings was obtained for this configuration and from these drawings the number of degrees of freedom representing the axial and transverse models were selected.

The representative lumped parameter systems selected for this analysis are shown in Figures 18 and 19 for the axial and transverse models, respectively. Only a summary of the pertinent results are contained in this report.

Axial Model

The casing of the projectile is represented by Mass Stations 1 through 18 to be compatible with the 18 distributed load points generated by the 2-D Code. Mass Stations 19 through 24 represent the aft fuze and fuze support system. The fuze itself is No. 23. The forward fuze and structure is represented by Mass Stations 25 and 26, respectively. Connected to the aft end of the forward fuze and the aft fuze is the charging rod shown as Stations 40 through 42 and 37 through 39. The filler material includes Stations 27 through 36.

The mass and stiffness parameters from which the mass and stiffness matrices were developed are shown in Tables II and III. These were input to the contractor's Modal Analysis Program No. 2607 for the purpose of generating the eigen values, vectors, and damping matrices. The eigen values are listed in Table IV.

The eigen vectors were generated in graphical form and are presented in Appendix V.

The normalized modal damping matrix is given in Table V.

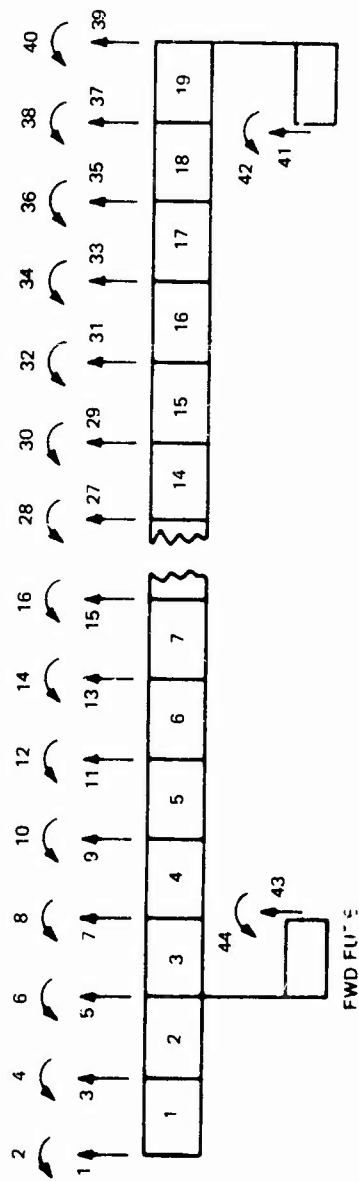


Figure 19 LUMPED PARAMETER SYSTEM - LATERAL MODEL

TABLE II. DISTRIBUTED MASS SUMMARY - AXIAL MODEL MK82 BOMB

1	0.00462	Lb-sec ² /in	22	0.00071	Lb-sec ² /in
2	0.02453		23	0.00112	
3	0.04485		24	0.01645	
4	0.03792		25	0.00071	
5	0.03452		26	0.01645	
6	0.03359		27	0.02324	
7	0.03748		28	0.03924	
8	0.03212		29	0.05068	
9	0.03164		30	0.05913	
10	0.03244		31	0.06196	
11	0.05470		32	0.06196	
12	0.04259		33	0.06196	
13	0.04259		34	0.06171	
14	0.04682		35	0.05827	
15	0.04039		36	0.07018	
16	0.03982		37	0.00026	
17	0.03858		38	0.00044	
18	0.05509		39	0.00059	
19	0.03242		40	0.00026	
20	0.00452		41	0.00044	
21	0.00209	Lb-sec ² /in	42	0.00059	Lb-sec ² /in

TABLE III. STIFFNESS SUMMARY - AXIAL MODEL

($\sim 10^6$ lbs/in)			
K12	53.27	K2123	426.242
K23	127.863	K325	57.520
K34	148.154	K2526	27.969
K45	126.416	K427	5.817
K56	124.100	K2728	7.899
K67	123.462	K2829	10.854
K78	119.417	K2930	13.463
K89	117.059	K3031	14.753
K910	115.798	K3132	14.994
K1011	108.196	K3233	14.994
K1112	95.642	K3334	14.994
K1213	95.642	K3435	14.633
K1314	95.642	K3536	11.219
K1415	89.798		
K1516	87.183	K1137	.00527
K1617	87.148	K3738	.00519
K1718	83.670	K3839	.00548
K1819	410.110	K3924	.288
K1920	10.256		
K2021	87.793	K1140	.00527
K2122	91.486	K4041	.00519
K2224	27.969	K4142	.00548
L1923	2.13	K4226	.228

TABLE IV. EIGEN VALUES - AXIAL MODEL

$(W_n)^2 \sim (\text{Rad/sec})^2$	$f_n \sim \text{cps}$	$(W_n)^2 \sim (\text{Rad/sec})^2$	$f_n \sim \text{cps}$
0	0	12.41232×10^8	5610
5.488218×10^6	373	18.20117×10^8	6793
14.75543×10^6	612	21.45058×10^8	7375
14.79315×10^6	612	29.07477×10^8	8586
40.54191×10^6	1014	38.31534×10^8	9857
49.46260×10^6	1120	47.35595×10^8	10958
49.46884×10^6	1120	49.62745×10^8	11218
76.16817×10^6	1390	57.09199×10^8	12032
1.24803×10^8	1779	66.62120×10^8	12997
2.25971×10^8	2394	74.72805×10^8	13765
2.612074×10^8	2574	82.13839×10^8	14432
3.627731×10^8	3033	87.00827×10^8	14853
4.093918×10^8	3222	1.063044×10^{10}	16417
4.928591×10^8	3535	1.259149×10^{10}	17867
5.122466×10^8	3604	1.373203×10^{10}	18660
5.460110×10^8	3721	1.562515×10^{10}	19905
6.602495×10^8	4092	2.101202×10^{10}	23082
7.531643×10^8	4370	4.630785×10^{10}	34266
7.92457×10^8	4433	18.79096×10^{10}	69026
8.916538×10^8	4755	62.43445×10^{10}	125821
9.496118×10^8	4907	76.40071×10^{10}	139184

TABLE V. NORMALIZED MODAL DAMPING MATRIX-AXIAL MODEL

```

INFLU CARDS READ
DATA* R( 1,1)
LATA* 9.5367030 02 -6.1815070 02 -1.5104840 02 -5.1628370 01 -2.4757230 01
LATA* -1.4771460 01 -1.1116790 01 -6.9309450 00 -5.1724010 00 -4.7556060 00
LATA* -5.5103340 00 -3.5068320 00 -2.5629950 00 -2.8324280 00 -2.1737920 00
LATA* -1.5458100 00 -1.7489750 00 -2.3573460 00 -1.3792720 00 -1.7900090 01
LATA* -8.2220060 02 -2.7738320 02 -4.4073820 02 -6.2868240 01 -2.2731330 00
LATA* -1.9773800 01 -5.5348110 00 -3.6368520 00 -2.0162480 00 -1.5595160 00
LATA* -1.2421690 00 -1.0216510 00 -8.8740850 01 -8.0130640 01 -7.0987800 01
LATA* -8.1862510 01 -7.5238490 03 -8.8295380 03 -2.1009620 02 -8.6293660 03
LATA* -1.9011910 02 -2.6164320 01
DATA* R( 2,1)
LATA* -6.1815070 02 3.6850400 03 -1.9117630 03 -3.7035940 02 -1.5330045 02
LATA* -8.0620400 01 -6.2718940 01 -3.8424950 01 -2.8352720 01 -2.5939860 01
LATA* -2.9768300 01 -1.8667780 01 -1.5854840 01 -1.5162430 01 -1.1618940 01
LATA* -1.0388530 01 -5.3259660 00 -1.2567120 01 -7.3528900 00 -9.5370190 01
LATA* -4.3803810 01 -1.4777140 01 -2.3480940 01 -3.3486100 00 -2.5113980 01
LATA* -1.3062800 02 -3.1811450 01 -1.6521040 01 -1.0810150 01 -8.3704420 00
LATA* -6.6137330 00 -5.4340940 00 -4.7174450 00 -4.2583830 00 -3.7719480 00
LATA* -4.3491870 00 -4.0101140 02 -4.6994050 02 -1.1165780 01 -4.6005680 02
LATA* -1.0193110 01 -1.4897870 00
DATA* R( 3,1)
LATA* -1.5104840 02 -1.5117600 03 7.3062750 03 -2.2043660 03 -4.5155290 02
LATA* -2.0690200 02 -1.3599070 02 -7.5151680 01 -5.6554200 01 -5.0513630 01
LATA* -5.7031430 01 -3.5739180 01 -2.9871080 01 -2.8333180 01 -2.1523000 01
LATA* -1.9274260 01 -1.7272220 01 -2.3228490 01 -1.3588600 01 -1.7597180 00
LATA* -8.0812840 01 -2.7258060 01 -4.3219270 01 -6.1739690 00 -1.0768850 03
LATA* -5.2690290 02 -7.4521420 01 -3.2244110 01 -2.0252910 01 -1.5410440 01
LATA* -1.2182040 01 -9.4821760 00 -8.6529420 00 -7.8043950 00 -6.9096820 00
LATA* -7.9648400 00 -7.4070990 02 -8.6214080 02 -2.6600400 01 -8.5037160 02
LATA* -1.9142870 01 -3.3424010 00
DATA* R( 4,1)
LATA* -5.1628370 01 -3.7039940 02 -2.2043660 03 5.8562620 03 -1.7958750 03
LATA* -3.6540810 02 -1.8074070 02 -9.1601410 01 -6.0145500 01 -5.0603170 01
LATA* -5.4583010 01 -3.3202670 01 -2.7177850 01 -2.5393810 01 -1.9170410 01
LATA* -1.6949690 01 -1.5100100 01 -2.6219340 01 -1.1822820 01 -1.5248440 00
LATA* -6.9999830 01 -2.3601540 01 -3.7524190 01 -5.3390090 00 -2.8946970 01
LATA* -1.5456640 02 -1.5686430 02 -3.3271560 01 -1.8438780 01 -1.3493220 01
LATA* -1.0508100 01 -8.5476150 00 -7.3758480 00 -6.6411100 00 -5.8721450 00
LATA* -6.7638780 00 -6.4384110 02 -7.3564550 02 -1.7760610 01 -7.2293380 02
LATA* -1.4539650 01 -1.8661220 00
DATA* R( 5,1)
LATA* -2.4707230 01 -1.5300450 02 -4.5155290 02 -1.7958750 03 5.3063540 03
LATA* -1.7398360 03 -3.8044130 02 -1.4627010 02 -8.2557340 01 -6.2558510 01
LATA* -6.2455210 01 -3.6100600 01 -2.8502500 01 -2.5941050 01 -1.9212720 01
LATA* -1.6743520 01 -1.4760160 01 -1.9605730 01 -1.1457740 01 -1.4567820 00
LATA* -6.7287530 01 -2.2673720 01 -3.6071380 01 -5.1165840 00 -4.8555350 00
LATA* -7.4730860 01 -5.4389700 01 -2.3093630 01 -1.4663780 01 -1.1290880 01
LATA* -6.0211730 00 -7.4495730 00 -6.4540330 00 -5.8755220 00 -5.2180760 00
LATA* -6.0246260 00 -6.2282360 02 -6.8681740 02 -1.6925860 01 -6.8338860 02
LATA* -1.2119990 01 -1.2131840 00
DATA* R( 6,1)
LATA* -1.4771460 01 -8.6030200 01 -2.0609020 02 -3.6540810 02 -1.7358360 01
LATA* 5.2071230 03 -1.7949930 03 -3.2354380 02 -1.4017900 02 -9.1155670 01
LATA* -8.1383290 01 -4.0947720 01 -3.3099900 01 -2.9117900 01 -2.1043280 01
LATA* -1.8003210 01 -1.5658400 01 -2.0555000 01 -1.2021820 01 -1.5246580 00
LATA* -6.9881120 01 -2.3523210 01 -3.7463260 01 -5.2534750 00 -3.1847140 00
LATA* -4.5938400 01 -3.2427460 01 -1.8206410 01 -1.2660500 01 -1.6180340 01
LATA* -8.3183420 00 -6.9612310 00 -6.1208500 00 -5.5724600 00 -4.9523110 00
LATA* -5.7415460 00 -6.5412990 02 -6.8840370 02 -1.7385850 01 -7.0215880 02
LATA* -1.0949810 01 -8.9035640 01
DATA* R( 7,1)
LATA* -1.1115790 01 -6.2718940 01 -1.3559070 02 -1.8074070 02 -3.8044130 02

```

TABLE V. NORMALIZED MODAL DAMPING MATRIX-AXIAL MODEL (Cont'd)

DATA*	-1.794993D 03	5.374822D 03	-1.734763D 03	-3.543442D 02	-1.746263D 02	*DATA
DATA*	-1.317932D 02	-6.477178D 01	-4.583789D 01	-3.859409D 01	-2.754153D 01	*DATA
DATA*	-2.260662D 01	-1.933526D 01	-2.511413D 01	-1.464210D 01	-1.836025D 03	*DATA
DATA*	-8.406224E-01	-2.826560D-01	-4.506757D-01	-6.337979D 00	-2.116877D 00	*DATA
DATA*	-3.548535D 01	-2.551334D 01	-1.706060D 01	-1.276472D 01	-1.060435D 01	*DATA
DATA*	-8.811953D 00	-7.482164D 00	-6.630477D 00	-4.066856D 00	-5.419245D 03	*DATA
DATA*	-6.283293D 00	-8.020940D-02	-7.544582D-02	-2.064906D-01	-8.446516D-02	*DATA
DATA*	-1.148421D-01	-7.781667D-01				*DATA
DATA*	E(8,1)					*DATA
DATA*	-6.530945D 00	-3.842495D 01	-7.915168D 01	-9.160141D 01	-1.452701D 02	*DATA
DATA*	-3.239438D 02	-1.734763D 03	4.985377D 03	-1.623386D 03	-3.521736D 02	*DATA
DATA*	-1.920131D 02	-8.087185D 01	-5.212734D 01	-4.122574D 01	-2.768157D 01	*DATA
DATA*	-2.243216D 01	-1.876167D 01	-2.396548D 01	-1.395001D 01	-1.724050D 03	*DATA
DATA*	-7.882700D-01	-2.646775E-01	-4.226356D-01	-5.967599D 00	-1.237216D 03	*DATA
DATA*	-2.257156D 01	-1.674248D 01	-1.261216D 01	-9.978590D 00	-8.535555D 00	*DATA
DATA*	-7.230552D 00	-6.191841D 00	-5.526099D 00	-5.079688D 00	-4.550344D 03	*DATA
DATA*	-5.285668D 00	-7.793605D-02	-7.084566D-02	-1.904792D-01	-8.067186D-02	*DATA
DATA*	-9.356858D-02	-5.394954D-01				*DATA
DATA*	E(9,1)					*DATA
DATA*	-5.172401D 00	-2.835272D 01	-5.655420D 01	-6.014550D 01	-8.255734D 01	*DATA
DATA*	-1.401790D 02	-3.543442D 02	-1.623386D 03	4.920441D 03	-1.693485D 03	*DATA
DATA*	-3.993581D 02	-1.293611D 02	-7.282549D 01	-5.294152D 01	-3.355870D 01	*DATA
DATA*	-2.623120D 01	-2.133837D 01	-2.665722D 01	-1.550910D 01	-1.883881D 00	*DATA
DATA*	-8.599265D-01	-2.882476D-01	-4.610934D-01	-6.398092D 00	-8.865269D-01	*DATA
DATA*	-1.712211D 01	-1.315848D 01	-1.089183D 01	-9.038219D 00	-7.933937D 00	*DATA
DATA*	-6.824832D 00	-5.902324D 00	-5.302280D 00	-4.894785D 00	-4.396282D 00	*DATA
DATA*	-5.115555D 00	-9.139237D-02	-7.255617E-02	-2.038020D-01	-9.221420D-02	*DATA
DATA*	-8.847287D-02	-4.380172D-01				*DATA
DATA*	E(10,1)					*DATA
DATA*	-4.765606D 00	-2.590986D 01	-5.051363D 01	-5.060917D 01	-6.255851D 01	*DATA
DATA*	-9.116567D 01	-1.746263D 02	-3.521736D 02	-1.689485D 03	5.229903D 03	*DATA
DATA*	-1.915330D 03	-3.033159D 02	-1.350049D 02	-8.667286D 01	-5.118652D 01	*DATA
DATA*	-3.792980D 01	-2.975184D 01	-3.631373D 01	-2.104242D 01	-2.503899D 03	*DATA
DATA*	-1.140686D 00	-3.815795D-01	-6.116898D-01	-8.413331D 00	-7.935829D-01	*DATA
DATA*	-1.599629D 01	-1.276379D 01	-1.144494D 01	-9.904547D 00	-8.838864D 03	*DATA
DATA*	-7.762276D 00	-6.773888D 00	-6.121927D 00	-5.673693D 00	-5.108282D 03	*DATA
DATA*	-5.653563D 00	-1.347984D-01	-9.083927D-02	-2.442369D-01	-1.359451D-01	*DATA
DATA*	-1.014656D-01	-4.333992D-01				*DATA
DATA*	E(11,1)					*DATA
DATA*	-5.510034D 00	-2.976830D 01	-5.703143D 01	-5.458301D 01	-6.245521D 01	*DATA
DATA*	-8.138329D 01	-1.317932D 02	-1.920131D 02	-3.993581D 02	-1.915330D 03	*DATA
DATA*	5.850865D 03	-1.835720D 03	-4.005195D 02	-2.014534D 02	-1.051768D 02	*DATA
DATA*	-7.211886D 01	-5.375117D 01	-6.312356D 01	-3.644295D 01	-4.217730D 03	*DATA
DATA*	-1.916272D 00	-6.392695D-01	-1.027729D 00	-1.396733D 01	-8.975992D-01	*DATA
DATA*	-1.872240D 01	-1.554034D 01	-1.456442D 01	-1.345674D 01	-1.235370D 01	*DATA
DATA*	-1.091747D 01	-9.608839D 00	-8.733714D 00	-8.124603D 00	-7.331967D 00	*DATA
DATA*	-8.558297D 00	-3.315588D-01	-1.411805D-01	-4.307235D-01	-3.316965D-01	*DATA
DATA*	-1.454199D-01	-5.336597D-01				*DATA
DATA*	E(12,1)					*DATA
DATA*	-3.506832D 00	-1.886728D 01	-3.573918D 01	-3.320267D 01	-3.610060D 01	*DATA
DATA*	-4.394772D 01	-6.477178D 01	-8.087185D 01	-1.293611D 02	-3.333159D 02	*DATA
DATA*	-1.835720D 03	-5.170005D 03	-1.788723D 03	-3.725149D 02	-1.458131D-02	*DATA
DATA*	-8.547621D 01	-5.784714D 01	-6.330837D 01	-3.629932D 01	-4.013880D 03	*DATA
DATA*	-1.815536D 00	-6.629273D-01	-6.734062D-01	-1.297512D 01	-5.631941D-01	*DATA
DATA*	-1.202467D 01	-1.034927D 01	-1.055560D 01	-9.805542D 00	-9.173007D 03	*DATA
DATA*	-8.201863D 00	-7.274915D 00	-6.447146D 00	-6.205070D 00	-5.611850D 03	*DATA
DATA*	-6.559868D 00	-1.495403D-01	-1.119771D-01	-3.888587D-01	-1.492330D-01	*DATA
DATA*	-1.054936E-01	-3.642883D-01				*DATA
DATA*	E(13,1)					*DATA
DATA*	-2.562699D 00	-1.589484D 01	-2.987108D 01	-2.717789D 01	-2.853250D 01	*DATA
DATA*	-3.309990D 01	-4.583789D 01	-5.212734D 01	-7.282549D 01	-1.350049D 02	*DATA
DATA*	-4.009195D 02	-1.704727D 03	5.143305D 03	-1.784249D 03	-3.267081D 02	*DATA
DATA*	-1.465055D 02	-8.587748D 01	-8.512552D 01	-4.832023D 01	-5.045225D 03	*DATA

TABLE V. NORMALIZED MODAL DAMPING MATRIX-AXIAL MODEL (Cont'd)

DATA*	-2.2693360	00	-7.4921430	-01	-1.2175050	00	-1.5811170	01	-4.7115570	-01	*DATA
DATA*	-1.0230870	C1	-9.0930200	00	-9.7149280	00	-9.2686510	00	-8.8076700	00	*DATA
DATA*	-7.9528970	00	-7.1005280	00	-6.5168740	00	-6.1015130	00	-5.5264430	00	*DATA
DATA*	-6.4703210	00	-1.1763110	-01	-1.1575790	-01	-4.5759530	-01	-1.1505820	-01	*DATA
DATA*	-9.9812560	-C2	-3.1247710	-01							*DATA
DATA*	E(14,1)										*DATA
DATA*	-2.8324280	00	-1.5162430	01	-2.8333180	01	-2.5393810	01	-2.5941050	01	*DATA
DATA*	-2.9117900	01	-3.8594090	01	-4.1225740	01	-5.2941520	01	-8.6672860	01	*DATA
DATA*	-2.0145340	C2	-3.7251490	02	-1.7842490	C3	5.2446250	03	-1.6394670	03	*DATA
DATA*	-3.5434850	C2	-1.5933580	02	-1.2445280	02	-7.5028980	C1	-7.2466380	00	*DATA
DATA*	-3.2335710	00	-1.0554090	00	-1.7357070	00	-2.1761110	01	-4.4720550	-01	*DATA
DATA*	-9.8324450	00	-8.9862540	00	-9.9675250	00	-9.7190930	00	-5.3566780	00	*DATA
DATA*	-8.5166700	00	-7.6458730	00	-7.6437640	00	-6.6113070	00	-5.9597490	00	*DATA
DATA*	-7.0292270	00	-1.1147420	-01	-1.3326880	-01	-6.0417800	-01	-1.0712530	-01	*DATA
DATA*	-1.0462090	-C1	-3.0755230	-01							*DATA
DATA*	E(15,1)										*DATA
DATA*	-2.1737920	00	-1.1618940	01	-2.1623000	01	-1.9170410	01	-1.9212720	01	*DATA
DATA*	-2.1043280	C1	-2.7041530	01	-2.7081570	C1	-3.3658700	01	-5.1186520	01	*DATA
DATA*	-1.0517680	C2	-1.4561310	02	-3.2670810	C2	-1.6894670	03	4.8253940	03	*DATA
DATA*	-1.5876710	C3	-3.2045770	02	-1.9381890	02	-1.0414480	02	-8.8794400	00	*DATA
DATA*	-3.9118860	00	-1.2659730	00	-2.1011140	00	-2.4687180	01	-3.4146760	-01	*DATA
DATA*	-7.5769660	00	-7.0933690	00	-8.1116470	00	-8.0530720	00	-7.8359730	00	*DATA
DATA*	-7.1826340	00	-6.4782050	00	-5.9872050	00	-5.6316630	00	-5.1176140	00	*DATA
DATA*	-6.0011010	00	-6.7193230	-02	-1.2256340	-C1	-6.5065580	-C1	-6.1971180	-02	*DATA
DATA*	-9.6667570	-C2	-2.4147820	-01							*DATA
DATA*	E(16,1)										*DATA
DATA*	-1.9453100	00	-1.0388530	01	-1.9274260	01	-1.6949690	01	-1.6743520	01	*DATA
DATA*	-1.8003210	C1	-2.2606620	01	-2.2432160	C1	-2.6231200	01	-3.7929800	01	*DATA
DATA*	-7.2118800	C1	-8.5476210	01	-1.4650550	02	-3.5434850	02	-1.5376710	03	*DATA
DATA*	4.7343070	C3	-1.5751980	03	-3.9580510	02	-1.9285080	02	-1.3548640	01	*DATA
DATA*	-5.8504610	00	-1.8589230	00	-3.1457510	00	-3.4142380	01	-3.0449550	-01	*DATA
DATA*	-6.8039130	00	-6.5011780	00	-7.6219740	00	-7.6778970	00	-7.5372810	00	*DATA
DATA*	-6.9481270	00	-6.2909280	00	-5.8296180	00	-5.4932170	00	-4.9974160	00	*DATA
DATA*	-5.8645370	00	-6.0538660	-02	-1.3074550	-C1	-6.2480790	-01	-7.3793760	-02	*DATA
DATA*	-9.2616400	-C2	-2.2008460	-01							*DATA
DATA*	E(17,1)										*DATA
DATA*	-1.7483750	00	-5.3259660	00	-1.7272220	C1	-1.5100100	01	-1.4760160	01	*DATA
DATA*	-1.5658400	01	-1.9335260	01	-1.8761670	01	-2.1336370	C1	-2.9751840	01	*DATA
DATA*	-5.3791170	01	-5.7847140	01	-8.5577480	01	-1.5933580	02	-3.2045770	02	*DATA
DATA*	-1.5751980	C3	4.6616020	03	-1.6036810	C3	-4.8232330	02	-2.3466280	01	*DATA
DATA*	-9.7601470	00	-3.0068680	00	-5.2612350	00	-4.9023070	01	-2.7254540	-01	*DATA
DATA*	-6.1301090	00	-5.9533630	00	-7.1128440	00	-7.2473710	00	-7.1633260	00	*DATA
DATA*	-6.6324350	00	-6.0231070	00	-5.5530050	00	-5.2775800	00	-4.8054510	00	*DATA
DATA*	-5.6425560	00	-7.5057670	-02	-1.3658130	-01	-1.0605340	00	-6.6895680	-02	*DATA
DATA*	-7.7972400	-02	-2.0052380	-01							*DATA
DATA*	E(18,1)										*DATA
DATA*	-2.3573460	00	-1.2567720	01	-2.3228450	C1	-2.0219340	01	-1.9509730	01	*DATA
DATA*	-2.0595000	C1	-2.5114130	01	-2.3965480	01	-2.6697220	01	-3.5313730	01	*DATA
DATA*	-6.3123560	C1	-6.3308370	01	-8.5125520	01	-1.3445280	02	-1.9381890	02	*DATA
DATA*	-3.9580510	C2	-1.6036810	03	7.5586350	C3	-4.8317390	03	-8.4110490	01	*DATA
DATA*	-3.1756870	C1	-9.1745020	00	-1.7334170	01	-1.1660060	C2	-3.6714810	-01	*DATA
DATA*	-8.2771140	00	-8.1419000	00	-9.8700750	00	-1.0143800	01	-1.0078490	01	*DATA
DATA*	-9.3628930	00	-8.5222370	00	-7.9262460	00	-7.4872090	00	-6.8219970	00	*DATA
DATA*	-8.0139780	00	-1.0537520	-01	-2.2201490	-01	-2.1220820	00	-9.0918550	-02	*DATA
DATA*	-1.0912000	-01	-2.7306570	-01							*DATA
DATA*	E(19,1)										*DATA
DATA*	-1.3792720	00	-7.3528900	00	-1.3588000	01	-1.1822820	01	-1.1457740	01	*DATA
DATA*	-1.2021620	C1	-1.4642100	01	-1.3550010	01	-1.5509100	01	-2.1042420	01	*DATA
DATA*	-3.6442950	C1	-3.6299320	01	-4.8320230	01	-7.5028980	01	-1.0414480	02	*DATA
DATA*	-1.5285080	C2	-4.8232330	02	-4.8517390	03	6.3455400	03	-1.3912390	02	*DATA
DATA*	-3.7594410	C1	-9.5244130	00	-2.4669580	01	-8.7031970	01	-2.1477540	-01	*DATA
DATA*	-4.8437300	00	-4.7707070	00	-5.7516560	00	-5.9573880	00	-5.9221250	00	*DATA
DATA*	-5.5035030	00	-5.0105310	00	-4.6608750	00	-4.4031910	00	-4.0122590	00	*DATA

TABLE V. NORMALIZED MODAL DAMPING MATRIX-AXIAL MODEL (Cont'd)

DATA*	-4.7135210	00	-6.214178L	-02	-1.3478110	-01	-1.3959400	00	-5.3245310	-J2	*DATA
DATA*	-6.4684400	-02	-1.5992900	-01							*DATA
DATA*	21, 11										*DATA
DATA*	-1.7903690	-01	-9.5370190	-01	-1.7557180	00	-1.5248440	00	-1.4567820	00	*DATA
DATA*	-1.5246580	00	-1.8360250	00	-1.7240500	00	-1.8838810	00	-2.5338990	00	*DATA
DATA*	-4.2177300	00	-4.0138800	00	-5.0452250	00	-7.2466380	00	-8.8794400	00	*DATA
DATA*	-1.3548640	01	-2.3468280	01	-8.4110490	01	-1.3912590	02	1.1157140	03	*DATA
DATA*	-4.3633600	02	-5.9741150	01	-1.4321530	02	-1.6257800	02	-2.7820350	-J2	*DATA
DATA*	-6.2973440	-01	-6.2975100	-01	-7.7762610	-01	-8.0837140	-01	-8.0891540	-J1	*DATA
DATA*	-7.5503460	-01	-6.8950850	-01	-6.4277350	-01	-6.0812380	-01	-5.5464800	-01	*DATA
DATA*	-6.5199580	-01	-1.0177640	-02	-4.1334920	-02	-1.1516210	00	-7.0176900	-03	*DATA
DATA*	-8.6927850	-03	-2.0975090	-02							*DATA
DATA*	21, 11										*DATA
DATA*	-8.2220660	-02	-4.3803810	-01	-8.6812840	-01	-6.9559830	-01	-6.7287530	-J1	*DATA
DATA*	-6.9881120	-01	-8.4062240	-01	-7.8827000	-01	-8.5992650	-01	-1.1406800	00	*DATA
DATA*	-1.9162720	00	-1.8155360	00	-2.2650360	00	-3.2335710	00	-3.9118860	00	*DATA
DATA*	-5.6504610	00	-9.7601470	00	-3.1756870	01	-3.7594410	01	-4.3633600	02	*DATA
DATA*	1.8195490	03	-2.5277610	02	-8.8843140	02	-1.3269060	02	-1.2776390	-J2	*DATA
DATA*	-2.8930230	-01	-2.8972600	-01	-3.5832370	-01	-3.7285420	-01	-3.7333200	-J1	*DATA
DATA*	-3.4660460	-01	-3.1844020	-01	-2.9651480	-01	-2.8094680	-01	-2.5626330	-J1	*DATA
DATA*	-3.0125800	-01	-4.7990290	-03	-2.0567720	-02	-6.4182820	-01	-3.2229160	-J3	*DATA
DATA*	-4.0093370	-03	-9.6459160	-03							*DATA
DATA*	22, 11										*DATA
DATA*	-2.7739320	-02	-1.4777140	-01	-2.7258060	-01	-2.3601540	-01	-2.2670720	-01	*DATA
DATA*	-2.3523210	-01	-2.8265600	-01	-2.6467750	-01	-2.8824760	-01	-3.8157950	-01	*DATA
DATA*	-6.3926950	-01	-6.0252730	-01	-7.4521430	-01	-1.0594090	00	-1.2659730	00	*DATA
DATA*	-1.8589230	00	-3.0068680	00	-9.1745020	00	-9.5244130	00	-5.9741150	01	*DATA
DATA*	-2.5277010	02	5.6012400	02	-5.8568840	01	-1.5729860	02	-4.3395470	-03	*DATA
DATA*	-9.7617770	-02	-9.7907470	-02	-1.2128910	-01	-1.2633480	-01	-1.2657690	-01	*DATA
DATA*	-1.1824270	-01	-1.0040420	-01	-1.0076630	-01	-9.5354770	-02	-8.6584820	-J2	*DATA
DATA*	-1.0226370	-01	-1.6677240	-03	-7.6207610	-03	-2.8006460	-01	-1.0088630	-J3	*DATA
DATA*	-1.3584410	-03	-3.2575900	-03							*DATA
DATA*	23, 11										*DATA
DATA*	-4.4073820	-02	-2.3480960	-01	-4.3319870	-01	-3.7524190	-01	-3.6371380	-01	*DATA
DATA*	-3.7463260	-01	-4.5067970	-01	-4.2263900	-01	-4.6109340	-01	-6.1158980	-01	*DATA
DATA*	-1.0277290	00	-9.7390620	-01	-1.2175350	00	-1.7357070	00	-2.1011480	00	*DATA
DATA*	-3.1457510	00	-5.2612350	00	-1.7334170	01	-2.4669580	01	-1.4321530	02	*DATA
DATA*	-8.8643140	02	-5.8588840	01	1.2187340	03	-6.5025540	01	-6.8488040	-J3	*DATA
DATA*	-1.5507850	-01	-1.5529540	-01	-1.9265050	-01	-1.9982960	-01	-2.0008010	-J1	*DATA
DATA*	-1.6682450	-01	-1.7065670	-01	-1.5511540	-01	-1.5056110	-01	-1.3733250	-01	*DATA
DATA*	-1.6144500	-01	-2.5652880	-03	-1.0582590	-02	-3.3994170	-01	-1.7275280	-J3	*DATA
DATA*	-2.1487900	-03	-5.1704290	-03							*DATA
DATA*	24, 11										*DATA
DATA*	-6.2868240	-01	-3.3486100	00	-6.1739550	00	-5.3390090	00	-5.1165840	00	*DATA
DATA*	-5.2934750	00	-6.3379790	00	-5.9075190	00	-6.3980920	00	-8.4133310	00	*DATA
DATA*	1.3967330	01	-1.2975120	01	-1.5911170	01	-2.1761110	01	-2.4887180	01	*DATA
DATA*	-3.4142360	01	-4.9023070	01	-1.1660000	02	-8.7031970	01	-1.6257400	02	*DATA
DATA*	-1.3269060	02	-1.5729860	02	-6.5025540	01	9.8713100	02	-9.7617790	-02	*DATA
DATA*	-2.2137000	00	-2.2309670	00	-2.7782450	00	-2.9031780	00	-2.9145750	00	*DATA
DATA*	-2.7262770	00	-2.4934660	00	-2.3268470	00	-2.2029860	00	-2.0101780	00	*DATA
DATA*	-2.3637090	00	-4.1723780	-02	-2.2662660	-01	-1.2721500	01	-2.4792830	-02	*DATA
DATA*	-3.1213460	-02	-7.4078160	-02							*DATA
DATA*	25, 11										*DATA
DATA*	-2.2731330	00	-2.5110980	01	-1.0768850	03	-2.8946970	01	-6.8655350	00	*DATA
DATA*	-3.1847140	00	-2.1168770	00	-1.2372160	00	-8.8652690	-01	-7.9358290	-J1	*DATA
DATA*	-8.9759520	-01	-5.6319410	-01	-4.7115570	-01	-4.4720550	-01	-3.4146760	-01	*DATA
DATA*	-3.0445550	-01	-2.7294540	-01	-3.6714810	-01	-2.1477540	-01	-2.7820350	-J2	*DATA
DATA*	-1.2776390	-02	-4.3095470	-03	-6.8488040	-03	-9.7617790	-02	1.2247380	03	*DATA
DATA*	-6.9255650	01	-1.1525550	00	-5.0804840	-01	-3.2015070	-01	-2.4351920	-01	*DATA
DATA*	-1.5264360	-01	-1.5791440	-01	-1.3651520	-01	-1.2350370	-01	-1.0935240	-J1	*DATA
DATA*	-1.2605660	-01	-1.1709080	-03	-1.3641230	-03	-3.2576790	-03	-1.3537690	-03	*DATA
DATA*	-3.1800740	-03	-7.1235630	-02							*DATA
DATA*	26, 11										*DATA

TABLE V. NORMALIZED MODAL DAMPING MATRIX-AXIAL MODEL (Cont'd)

DATA*	-1.9770800	C1	-1.3062800	O2	-5.2690290	O2	-1.5455640	O2	-7.4730860	J1	*DATA
DATA*	-4.5938400	C1	-3.5485350	O1	-2.2571960	O1	-1.7122110	O1	-1.5996290	O1	*DATA
DATA*	-1.8722400	C1	-1.2024670	O1	-1.0230870	O1	-9.8324450	O0	-7.5769660	JJ	*DATA
DATA*	-6.8039130	O0	-6.1301090	O0	-8.2771140	O0	-4.8437300	O0	-6.2973440	-O1	*DATA
DATA*	-2.8930230	O1	-9.7617770	O2	-1.5507850	O1	-2.2137000	O0	-6.9255650	J1	*DATA
DATA*	1.2708020	O3	-1.7574470	O1	-1.0229650	O1	-6.9819340	O0	-5.4574930	JJ	*DATA
DATA*	-4.3310860	O0	-3.6149760	O0	-3.1458170	O0	-8.4367300	O0	-2.5208410	JJ	*DATA
DATA*	-2.9080420	O0	-2.6457820	O2	-3.1226690	O2	-7.4075880	O2	-3.4587890	-O2	*DATA
DATA*	-1.3686010	O1	-1.0034610	O1							*DATA
DATA*	B(27,1)										*DATA
DATA*	-5.5348110	O0	-3.1811450	O1	-7.4521420	O1	-1.5686430	O2	-5.4389700	J1	*DATA
DATA*	-3.2427460	O1	-2.5513340	O1	-1.6742480	O1	-1.3158480	O1	-1.2763790	O1	*DATA
DATA*	-1.5540340	C1	-1.0349270	O1	-9.0930200	O0	-8.9862540	O0	-7.0933690	JJ	*DATA
DATA*	-6.5011780	O0	-5.9533830	O0	-8.1419000	O0	-4.7707070	O0	-6.2975100	-O1	*DATA
DATA*	-2.8572600	O1	-9.7907470	O2	-1.5529540	O1	-2.2305670	O0	-1.1525550	O0	*DATA
DATA*	-1.7574470	O1	1.0775480	O3	-3.8340160	O2	-7.6041160	O1	-3.3373500	O1	*DATA
DATA*	-1.9220910	O1	-1.2534540	O1	-9.2404120	O0	-7.4542240	O0	-6.1437580	JJ	*DATA
DATA*	-6.7493270	O0	-2.7320360	O2	-3.5117290	O2	-7.5720190	O2	-3.0185210	-O2	*DATA
DATA*	-5.6488220	O2	-5.7639580	O1							*DATA
DATA*	B(28,1)										*DATA
DATA*	-3.0368520	O0	-1.6521040	O1	-3.2344110	O1	-3.3271560	O1	-2.3393630	J1	*DATA
DATA*	-1.8020640	O1	-1.7060600	O1	-1.2612160	O1	-1.0891830	O1	-1.1444940	J1	*DATA
DATA*	-1.4964420	O1	-1.0555600	O1	-9.7149280	O0	-9.9675250	O0	-8.1116470	O0	*DATA
DATA*	-7.6269740	O0	-7.1128440	O0	-9.8700750	O0	-5.7916540	O0	-7.7762610	-O1	*DATA
DATA*	-3.5832370	O1	-1.7128810	O1	-1.9205050	O1	-2.7782450	O0	-5.0804840	-O1	*DATA
DATA*	-1.0229650	O1	-3.8340160	O2	1.5459990	O3	-5.9278760	O2	-1.3181670	-O2	*DATA
DATA*	-5.9557090	O1	-3.4314200	O1	-2.3317140	O1	-1.7788630	O1	-1.4137890	J1	*DATA
DATA*	-1.5150180	O1	-3.5071380	O2	-4.8871930	O2	-9.5754570	O2	-3.8123210	-O2	*DATA
DATA*	-6.8372500	O2	-2.8336020	O1							*DATA
DATA*	B(29,1)										*DATA
DATA*	-2.0162480	O0	-1.0810150	O1	-2.0252910	O1	-1.6438780	O1	-1.4563780	J1	*DATA
DATA*	-1.2388050	O1	-1.2764720	O1	-9.5785900	O0	-9.0382190	O0	-9.9045470	JJ	*DATA
DATA*	-1.3456740	O1	-5.8055420	O0	-9.2686510	O0	-9.7193930	O0	-8.0530720	JJ	*DATA
DATA*	-7.6778970	O0	-7.2473710	O0	-1.0143800	O1	-5.5573880	O0	-8.0837140	-O1	*DATA
DATA*	-3.7285420	O1	-1.2633480	O1	-1.9582960	O1	-2.9031780	O0	-3.2150070	-O1	*DATA
DATA*	-6.9819340	O0	-7.6041160	O1	-5.9278760	O2	1.9677110	O3	-7.4817590	O2	*DATA
DATA*	-1.8122250	O2	-7.2774920	O1	-4.3626950	O1	-3.0911990	O1	-2.3514450	J1	*DATA
DATA*	-2.4456990	O1	-3.7737660	O2	-5.5211550	O2	-1.0105970	O1	-4.0501850	-O2	*DATA
DATA*	-7.1022740	O2	-2.1704980	O1							*DATA
DATA*	B(30,1)										*DATA
DATA*	-1.5555160	O0	-8.3204470	O0	-1.5410440	O1	-1.3453220	O1	-1.1250880	J1	*DATA
DATA*	-1.0180340	O1	-1.0604350	O1	-8.5355550	O0	-7.9339370	O0	-8.8488640	JJ	*DATA
DATA*	-1.2353700	O1	-5.1730070	O0	-8.8076700	O0	-9.3556780	O0	-7.8359730	JJ	*DATA
DATA*	-7.5372810	O0	-7.1633260	O0	-1.0076490	O1	-5.9721250	O0	-8.0551540	-O1	*DATA
DATA*	-3.7333200	O1	-1.2657090	O1	-2.0009010	O1	-2.5145750	O0	-2.4351920	-O1	*DATA
DATA*	-5.4674930	O0	-3.3873500	O1	-1.3181670	O2	-7.4817590	O2	-2.3523270	O3	*DATA
DATA*	-8.2465780	O2	-1.7470280	O2	-8.1209700	O1	-5.0694590	O1	-3.5451750	O1	*DATA
DATA*	-3.5503330	O1	-3.8800490	O2	-5.6528970	O2	-1.0211260	O1	-4.1254770	-O2	*DATA
DATA*	-7.1448340	O2	-1.7772350	O1							*DATA
DATA*	B(31,1)										*DATA
DATA*	-1.2421690	O0	-8.6137330	O0	-1.2132060	O1	-1.0506110	O1	-9.0011730	JJ	*DATA
DATA*	-8.3163620	O0	-8.8319530	O0	-7.2305520	O0	-8.8248320	O0	-7.7022760	JJ	*DATA
DATA*	-1.0917470	O1	-8.2018630	O0	-7.9528970	O0	-8.5168700	O0	-7.1026340	JJ	*DATA
DATA*	-8.9481270	O0	-8.6324350	O0	-9.3628530	O0	-5.5035030	O0	-7.5013400	-O1	*DATA
DATA*	-3.4800460	O1	-1.1824270	O1	-1.8682450	O1	-2.7262770	O0	-1.9264360	-O1	*DATA
DATA*	-4.3810860	O0	-1.9220910	O1	-5.5557090	O1	-1.6124250	O2	-8.0465780	O2	*DATA
DATA*	2.4240120	O3	-8.3448040	O2	-1.7825340	O2	-8.5346120	O1	-5.3378970	O1	*DATA
DATA*	-4.9563230	O1	-3.7010370	O2	-5.6575350	O2	-9.5938220	O2	-3.9059390	-O2	*DATA
DATA*	-6.7141970	O2	-1.4832370	O1							*DATA
DATA*	B(32,1)										*DATA
DATA*	-1.0218510	O0	-5.4340940	O0	-9.9821760	O0	-8.5476150	O0	-7.4459730	JJ	*DATA
DATA*	-8.9612310	O0	-7.4821640	O0	-8.1518410	O0	-5.9023240	O0	-6.7738980	JJ	*DATA
DATA*	-9.6003390	O0	-7.2749150	O0	-7.1005280	O0	-7.6458730	O0	-6.4782050	JJ	*DATA

TABLE V. NORMALIZED MODAL DAMPING MATRIX-AXIAL MODEL (Cont'd)

DATA*	-6.2909280	00	-6.0231070	00	-8.5222370	00	-5.0105310	00	-6.8950850	-01	*DATA
DATA*	-3.1844020	-01	-1.0804290	-01	-1.7065670	-01	-2.4934060	00	-1.5791440	-01	*DATA
CATA*	-3.6149760	00	-1.2534540	01	-3.4314200	01	-7.2774920	01	-1.7470280	02	*DATA
DATA*	-8.3448040	02	-2.4398930	03	-8.3357860	02	-1.8142010	02	-8.7358300	01	*DATA
DATA*	-7.1075170	01	-3.4386460	-02	-5.3715280	-02	-8.8022350	-02	-3.6082340	-02	*DATA
DATA*	-6.1736580	-02	-1.2449730	-01							*DATA
DATA*	B(33,1)										*DATA
DATA*	-8.8740890	-01	-4.7174450	00	-8.6529420	00	-7.3798480	00	-6.4940330	00	*DATA
DATA*	-6.1208500	00	-6.6304770	00	-5.5260950	00	-5.3022800	00	-6.1219270	00	*DATA
DATA*	-8.7337140	00	-6.6471600	00	-6.5168740	00	-7.0437640	00	-5.9872050	00	*DATA
CATA*	-5.8296190	00	-5.5930050	00	-7.5262460	00	-4.6608790	00	-6.4277350	-01	*DATA
DATA*	-2.5691480	-01	-1.0076030	-01	-1.5511940	-01	-2.3268470	00	-1.3591520	-01	*DATA
CATA*	-3.1458170	00	-9.2404120	00	-2.3317140	01	-4.3626990	01	-8.1209670	01	*DATA
DATA*	-1.7825340	02	-8.3357860	02	-2.4359510	03	-8.4180200	02	-1.8590150	02	*DATA
CATA*	-1.1511290	02	-3.2469700	-02	-5.1289220	-02	-8.2330300	-02	-3.3941140	-02	*DATA
DATA*	-5.7885990	-02	-1.0947470	-01							*DATA
CATA*	C(34,1)										*DATA
CATA*	-8.0130640	-01	-4.2583830	00	-7.8043950	00	-6.6411100	00	-5.8795220	00	*DATA
DATA*	-5.5724600	00	-6.0668560	00	-5.0796880	00	-4.8947850	00	-5.6736930	00	*DATA
CATA*	-8.1246030	00	-6.2050700	00	-6.1015130	00	-6.6113070	00	-5.6316630	00	*DATA
DATA*	-5.4932170	00	-5.2775800	00	-7.4872090	00	-4.4031910	00	-6.0812380	-01	*DATA
DATA*	-2.3094680	-01	-9.5354770	-02	-1.5056110	-01	-2.2029860	00	-1.2350370	-01	*DATA
CATA*	-2.8436730	00	-7.4542240	00	-1.7788630	01	-3.0911990	01	-5.6654590	01	*DATA
DATA*	-8.5346120	01	-1.8142010	02	-8.4180200	02	-2.4012400	03	-8.4112210	02	*DATA
DATA*	-2.3008160	02	-3.1042940	-02	-4.9262510	-02	-7.8070950	-02	-3.2324990	-02	*DATA
DATA*	-5.5019340	-02	-9.9591420	-02							*DATA
DATA*	B(35,1)										*DATA
DATA*	-7.0989800	-01	-3.7719480	00	-4.9056820	00	-5.8723450	00	-5.2103760	00	*DATA
DATA*	-4.9623110	00	-5.4192450	00	-4.5503440	00	-4.3962820	00	-5.1082820	00	*DATA
DATA*	-7.3319670	00	-5.6118500	00	-5.5284430	00	-5.9997490	00	-5.1176140	00	*DATA
CATA*	-4.9974160	00	-4.8054510	00	-6.8219970	00	-4.0122590	00	-5.5464800	-01	*DATA
DATA*	-2.5626330	-01	-8.6984820	-02	-1.3733250	-01	-2.0101780	00	-1.0935240	-01	*DATA
CATA*	-2.5208410	00	-6.1437580	00	-1.4137850	01	-2.3514450	01	-3.5951790	01	*DATA
DATA*	-5.3378570	01	-8.7358300	01	-1.8590150	02	-8.4112210	02	-2.1780030	-01	*DATA
CATA*	-8.2735940	02	-2.8501910	-02	-4.5535240	-02	-7.1310720	-02	-2.9614590	-02	*DATA
CATA*	-5.0344660	-02	-8.8615880	-02							*DATA
DATA*	C(36,1)										*DATA
CATA*	-8.1862510	-01	-4.3491870	00	-7.5648400	00	-6.7638780	00	-6.0246260	00	*DATA
DATA*	-5.7419460	00	-6.2832930	00	-5.2856680	00	-5.1155550	00	-5.9535630	00	*DATA
DATA*	-1.5582970	00	-4.5568480	00	-4.4703210	00	-7.0292270	00	-6.0011010	00	*DATA
CATA*	-5.8645370	00	-5.6425560	00	-8.0139780	00	-4.7135210	00	-6.5199580	-01	*DATA
DATA*	-3.0125800	-01	-1.0226370	-01	-1.6144560	-01	-2.3637090	00	-1.2605660	-01	*DATA
CATA*	-2.9080420	00	-6.7493270	00	-1.5150180	01	-2.4496990	01	-3.5903330	01	*DATA
DATA*	-4.9584230	01	-7.1075170	01	-1.1511290	02	-2.3008160	02	-8.2735940	02	*DATA
CATA*	1.4956560	03	-3.3660020	-02	-5.3547570	-02	-8.3910100	-02	-3.4921180	-02	*DATA
DATA*	-5.9318940	-02	-1.0246960	-01							*DATA
DATA*	B(37,1)										*DATA
CATA*	-7.5238490	-03	-4.0101140	-02	-7.4670590	-02	-6.4384110	-02	-6.2282360	-02	*DATA
DATA*	-6.5412990	-02	-8.0209400	-02	-7.7536050	-02	-9.0392370	-02	-1.3479840	-01	*DATA
CATA*	-3.3155880	-01	-1.4956030	-01	-1.1763110	-01	-1.1147420	-01	-8.7193230	-02	*DATA
DATA*	-8.0538660	-02	-7.5097670	-02	-1.0537520	-01	-6.2141780	-02	-1.0177040	-02	*DATA
CATA*	-4.7993290	-03	-1.6687240	-03	-2.5452880	-03	-4.1723780	-02	-1.1709080	-03	*DATA
CATA*	-2.6457820	-02	-2.7320360	-02	-3.5071380	-02	-3.7737660	-02	-3.8806490	-02	*DATA
CATA*	-3.7010370	-02	-3.4386460	-02	-3.2489700	-02	-3.1042940	-02	-2.8501910	-02	*DATA
DATA*	-3.3660020	-02	-3.2153160	00	-9.5458360	-01	-1.6857740	-02	-3.1319570	-04	*DATA
DATA*	-3.9997240	-04	-8.8353350	-04							*DATA
DATA*	C(38,1)										*DATA
CATA*	-8.0395380	-03	-4.6994050	-02	-8.6214080	-02	-7.3564950	-02	-6.8681740	-02	*DATA
DATA*	-6.8840370	-02	-7.9445820	-02	-7.0845660	-02	-7.2996170	-02	-9.0839220	-02	*DATA
CATA*	-1.4118090	-01	-1.1197710	-01	-1.1575790	-01	-1.3326880	-01	-1.2256340	-01	*DATA
CATA*	-1.3074590	-01	-1.3898130	-01	-2.2201490	-01	-1.3478110	-01	-4.1334920	-02	*DATA
CATA*	-2.0567720	-02	-7.6207610	-03	-1.0582560	-02	-2.2602660	-01	-1.2641230	-03	*DATA
CATA*	-3.1326690	-02	-3.5117290	-02	-4.8871920	-02	-5.5211590	-02	-5.8528970	-02	*DATA

TABLE V. NORMALIZED MODAL DAMPING MATRIX-AXIAL MODEL (Concl'd)

CATA*	-5.697539D-02	-5.371628D-02	-5.128922D-02	-4.936251D-02	-4.553524J-J2	*DATA
CATA*	-5.334752D-02	-5.545836D-01	4.135890 D0	-4.129261D-01	-3.988481J-J04	*DATA
CATA*	-5.798696D-C4	-1.088076D-C3				*DATA
CATA*	E(39,1)					*DATA
CATA*	-2.100962D-02	-1.118578D-01	-2.060040D-01	-1.776061D-01	-1.692586D-01	*DATA
CATA*	-1.738985D-C1	-2.064906D-01	-1.904792D-01	-2.038020D-01	-2.642369J-J1	*DATA
CATA*	-4.3J7235D-01	-3.888587D-01	-4.575953D-01	-6.041780D-01	-6.506558J-J1	*DATA
DATA*	-9.248079D-C1	-1.060534D D0	-2.122082D D0	-1.395940D D0	-1.158621D D0	*DATA
CATA*	-6.418282D-C1	-2.800046D-01	-3.395417D-01	-1.272150D C1	-3.257679J-J3	*DATA
CATA*	-7.407588D-02	-7.572019D-02	-9.575457D-02	-1.010597D-01	-1.021126D-01	*DATA
DATA*	-9.593822D-02	-8.802235D-02	-8.233030D-02	-7.807095D-02	-7.131072J-J02	*DATA
DATA*	-8.391010D-C2	-1.685774D-02	-4.125261D-01	2.619209D C1	-8.414982J-J3	*DATA
CATA*	-1.085560D-C3	-2.496883D-03				*DATA
CATA*	B(40,1)					*DATA
CATA*	-8.629366D-C3	-4.600568D-02	-8.503716D-C2	-7.229338D-02	-6.830886J-J2	*DATA
DATA*	-7.021588D-C2	-8.446516D-02	-8.067186D-C2	-9.221420D-02	-1.359451D-J1	*DATA
DATA*	-3.316965D-01	-1.483330D-01	-1.150582D-01	-1.071253D-C1	-8.197118J-J2	*DATA
DATA*	-7.379976D-02	-6.639568D-02	-9.051855D-02	-5.324531D-02	-7.007090J-J03	*DATA
CATA*	-3.222916D-C3	-1.088663D-03	-1.727528D-C3	-2.479283D-02	-1.353769J-J3	*DATA
CATA*	-3.458989D-C2	-3.018521D-02	-2.812321D-02	-4.050185D-02	-4.125477J-J2	*DATA
CATA*	-3.905939D-C2	-3.608234D-02	-3.354114D-02	-3.232499D-02	-2.961459D-02	*DATA
DATA*	-3.492118D-C2	-3.131957D-04	-3.988481D-04	-8.414982D-C4	3.215328J D3	*DATA
CATA*	-9.545292D-01	-1.662324D-02				*DATA
CATA*	E(41,1)					*DATA
CATA*	-1.901191D-C2	-1.019311D-01	-3.514287D-01	-1.453565D-01	-1.211999J-J01	*DATA
CATA*	-1.094961D-01	-1.148421D-01	-9.356858D-02	-8.847287D-02	-1.014850D-J1	*DATA
CATA*	-1.454199D-C1	-1.056936D-01	-9.981256D-02	-1.046209D-01	-8.666797J-J2	*DATA
CATA*	-8.261640D-C2	-7.797240D-02	-1.051200D-01	-6.408440D-C2	-8.692785J-J3	*DATA
DATA*	-4.009337D-03	-1.358441D-03	-2.148790D-03	-3.121346D-02	-3.180074D-J3	*DATA
DATA*	-1.368601D-C1	-5.648822D-02	-6.827250D-02	-7.102274D-02	-7.144834J-J2	*DATA
DATA*	-6.714397D-02	-6.173058D-02	-5.788595D-02	-5.501934D-02	-5.034466D-J2	*DATA
DATA*	-5.931396D-C2	-3.999724D-C4	-5.758696D-04	-1.085660D-03	-9.545292J-J1	*DATA
CATA*	4.136203D D0	-4.105283D-01				*DATA
DATA*	B(42,1)					*DATA
CATA*	-2.618432D-C1	-1.489787D D0	-3.342401D D0	-1.866122D D0	-1.213189J D3	*DATA
CATA*	-8.903564D-01	-7.781667D-01	-5.354954D-01	-4.380172D-01	-4.333992J-J1	*DATA
DATA*	-5.336557D-C1	-3.562883D-01	-3.124771D-01	-3.075523J-J01	-2.414782J-J1	*DATA
CATA*	-2.200846D-C1	-2.005238D-01	-2.730557D-01	-1.599290D-01	-2.097909J-J2	*DATA
CATA*	-9.645916D-C3	-3.257590D-03	-5.170429D-03	-7.407816D-02	-7.123563J-J2	*DATA
CATA*	-1.003461D C1	-3.763958D-01	-2.833602D-J1	-2.170498D-01	-1.737239J-J1	*DATA
CATA*	-1.483237D-C1	-1.244473D-01	-1.054747D-01	-9.959142D-02	-8.661588D-J2	*DATA
CATA*	-1.024696D-C1	-8.835335D-04	-1.066076D-03	-2.496883D-03	-1.662324D-02	*DATA
CATA*	-4.105283D-C1	2.623793D D1				*DATA
CATA*1						*DATA

The model representing the transverse bending characteristic of the MK82 is shown in Figure 19. The forward fuze is represented by Mass Stations 5 and 43, while the aft fuze is designated by Stations 39 and 41. Response information regarding average fuze accelerations can be obtained by averaging the accelerations of the two boundary stations. The mass and stiffness matrices for the lateral model are given in Tables VI and VII. This model was also analyzed to establish its dynamic characteristics, and the eigen values are presented in Table VIII.

The modal damping matrix is shown in Table IX.

TABLE VI. DISTRIBUTED MASS SUMMARY - LATERAL MODEL MK82 BOMB

1	0.000606	22	0.3575
2	0.000987	23	0.09459
3	0.0149	24	1.008
4	0.01876	25	0.09459
5	0.04393	26	1.008
6	0.23747	27	0.09963
7	0.05353	28	1.008
8	0.2629	29	0.09253
9	0.05187	30	1.009
10	0.31023	31	0.08811
11	0.05470	32	0.8880
12	0.3773	33	0.08273
13	0.05997	34	0.7785
14	0.4729	35	0.05808
15	0.06398	36	0.5024
16	0.5539	37	0.02781
17	0.06695	38	0.2641
18	0.6209	39	0.0669
19	0.06990	40	0.478
20	0.6812	41	0.00823
21	0.1000	42	0.1131
		43	0.00823
		44	0.1131

TABLE VII. STIFFNESS SUMMARY - LATERAL MODEL

K MATRIX				
(1, 1)	0.108722320 07	0.174490320 07	-0.169722320 07	0.174490320 07
(2, 2)	0.450319000 07	-0.174490320 07	0.169722320 07	0.450319000 07
(3, 3)	0.148794500 08	0.203915310 08	-0.137922270 08	0.221355240 08
(4, 4)	0.202661240 08	-0.221355240 08	-0.127114800 08	0.2
(5, 5)	0.414166010 08	0.286952170 08	-0.271270110 08	0.355429970 08
(6, 6)	0.621285660 08	-0.435102970 08	-0.423027620 08	0.3
(7, 7)	0.509547750 08	-0.529810650 07	-0.236262540 08	0.382421000 08
(8, 8)	0.118714760 10	-0.382421000 08	-0.531590620 08	0.3
(9, 9)	0.430575370 08	-0.737675790 07	-0.102307220 07	0.339653420 08
(10, 10)	0.167334640 10	-0.308653470 08	-0.773060910 08	0.3
(11, 11)	0.386772730 08	0.115120000 07	-0.216665000 08	0.339165330 08
(12, 12)	0.157121890 10	-0.728166330 08	-0.096749840 08	0.3
(13, 13)	0.409134450 08	0.328131260 08	-0.204660950 08	0.328424160 08
(14, 14)	0.239636600 10	-0.329494440 08	-0.117892000 10	0.3
(15, 15)	0.403505100 08	-0.926324730 06	-0.159835560 08	0.319131220 08
(16, 16)	0.267545790 10	-0.319131220 08	-0.128074210 10	0.3
(17, 17)	0.352342770 08	-0.855220580 08	-0.193507120 08	0.313573930 08
(18, 18)	0.266356020 10	-0.310570930 07	-0.137250720 10	0.3
(19, 19)	0.252657530 08	0.935762420 06	-0.199337400 08	0.313936550 08
(20, 20)	0.307754700 10	-0.319936550 08	-0.150294730 10	0.3
(21, 21)	0.357485900 08	0.106146750 07	-0.158150480 08	0.330551230 08
(22, 22)	0.282537300 10	-0.330551230 08	-0.116193570 10	0.3
(23, 23)	0.316315960 08	0.0	-0.156155400 08	0.330551230 08
(24, 24)	0.266021830 10	-0.330551230 08	-0.118193570 10	0.3
(25, 25)	0.316315960 08	0.0	-0.156155400 08	0.330551230 08
(26, 26)	0.266021830 10	-0.330551230 08	-0.118193570 10	0.3
(27, 27)	0.316315960 08	0.0	-0.156155400 08	0.330551230 08
(28, 28)	0.266021830 10	-0.330551230 08	-0.118193570 10	0.3
(29, 29)	0.307754700 10	-0.319936550 08	-0.150294730 10	0.3
(30, 30)	0.252657530 08	-0.319131220 08	-0.107250500 10	0.312437570 08
(31, 31)	0.252342770 08	-0.107055510 07	-0.144355330 08	0.331702020 08
(32, 32)	0.229405230 10	-0.301702020 08	-0.960840550 08	0.3
(33, 33)	0.286825000 08	-0.393979890 06	-0.122669060 08	0.277752220 08
(34, 34)	0.205780130 10	-0.297742220 08	-0.842656400 08	0.3
(35, 35)	0.300195520 08	-0.124915500 07	-0.231725550 08	0.345270670 08
(36, 36)	0.232548710 10	-0.285270670 08	-0.129010000 10	0.3
(37, 37)	0.111245470 09	0.655064260 08	-0.074730140 08	0.343334220 08
(38, 38)	0.301202300 10	-0.940334020 08	-0.225128610 10	0.3
(39, 39)	0.875534700 08	-0.957734170 08	-0.520663530 08	0.169150660 07
(40, 40)	0.251377800 10	0.169150660 07	-0.493259850 08	
(41, 41)	0.920463320 06	0.169150660 07		
(42, 42)	0.613207010 08			

(5,43) -0.520463523450 06 (5,44) 0.1691506601370107
 (6,43) -0.1691506601370107 (6,44) -0.1691506601370107
 (6,44) -0.49325985064320 08 (7,43) 0.520463523450 06
 (44,44) 0.61320701023370 08

TABLE VIII. EIGEN VALUES - LATERAL MODEL

379	5216
808	5278
1160	5701
1184	6041
1275	6541
1717	6833
2161	7573
2518	8430
2831	9147
2971	9860
3226	10502
3374	10911
3581	11246
3639	12071
3764	12212
3802	12317
3949	13441
4185	14496
4214	15414
4667	17089
4759	21618

TABLE IX. NORMALIZED MODAL DAMPING MATRIX-LATERAL MODEL.

INFLT CARCS HEAD										12.23.12.43	13/25/72
CATA*	9(1,1)										*DATA
CATA*	4.260978D C1	3.493415D 01	-3.278321D 01	2.717586D 01	-7.953458D 00						*DATA
DATA*	2.537141D C1	-2.571362D 00	9.474192D 00	-6.967902D-01	5.272949D 00						*DATA
CATA*	-2.346231C-01	3.161651D 00	-4.047722C-02	2.173282D 00	4.480051D-02						*DATA
DATA*	1.497687D C0	7.492827D-02	1.025233D 00	7.916995D-02	7.050028D-01						*DATA
CATA*	1.502209C-01	5.817145D-01	1.220071E-01	4.157477D-01	1.334136D-01						*DATA
DATA*	2.636266D-01	1.521997D-01	1.781985D-01	1.561559D-01	1.316495D-01						*DATA
CATA*	1.647446C-01	9.235937D-02	1.727567D-01	7.016991D-02	1.354627D-01						*DATA
DATA*	4.239668D-02	6.591731D-02	2.166068D-02	1.796411D-01	3.955821D-02						*DATA
CATA*	1.655039D-C2	5.849510D-03	5.762142D-02	3.906821D 00							*DATA
CATA*	8(2,1)										*DATA
DATA*	3.493415C 01	1.254795D 02	-2.952668D 01	1.052852D 01	-3.35713D 00						*DATA
DATA*	5.391428D 00	-8.155096D-01	1.305233D 00	-2.688048D-01	5.015027D-01						*DATA
CATA*	-1.313569C-01	2.123409D-01	-8.456644D-02	1.075056D-01	-6.067709D-02						*DATA
CATA*	5.801884D-C2	-4.503346D-02	3.367054E-02	-3.436095D-02	2.136541D-02						*DATA
DATA*	-5.708841C-C2	1.736010D-02	-2.623522D-02	1.325445D-02	-2.063771D-02						*DATA
DATA*	9.314417E-C3	-1.790017D-02	6.807965D-03	-1.433784D-02	5.102408D-03						*DATA
CATA*	-1.224949C-C2	3.381721D-03	-1.065696D-02	2.276223D-03	-7.068556D-03						*DATA
DATA*	1.189263C-C3	-3.285417D-03	5.744090E-04	-7.621839D-03	1.013940D-03						*DATA
DATA*	-1.011291D-C3	2.003591D-04	-5.753316D-02	1.282450E-01							*DATA
CATA*	6(3,1)										*DATA
DATA*	-3.278321D 01	-2.592668D 01	7.676271D 02	3.348749D 02	-5.774807D 02						*DATA
DATA*	8.508857D 02	-1.215942D 02	2.653311D 02	-3.541338D 01	1.394700D 02						*DATA
CATA*	-1.426435D C1	8.105278D 01	-6.281019D 00	5.485038D 01	-2.525321D 00						*DATA
CATA*	3.753641D C1	-7.502799D-01	2.568632D 01	3.657490D-02	1.774054D 01						*DATA
CATA*	7.143058D-C1	1.473537D 01	1.614259D 00	1.065512D 01	2.210719D 00						*DATA
CATA*	6.845281D 00	2.829713D 00	4.677167D 00	3.117598D 00	3.473059D 00						*DATA
DATA*	3.440094D 00	2.433921D 00	3.721413D 00	1.838033D 00	3.007434D 00						*DATA
DATA*	1.097409D 00	1.557833D 00	5.665908D-01	4.043411D 00	1.024050D 00						*DATA
CATA*	3.573408D-01	2.523326D-01	-2.565319D 00	8.789148D 01							*DATA
CATA*	8(4,1)										*DATA
DATA*	2.717586D C1	1.052852D 01	3.348749D 02	3.844703D 03	-2.770881D 02						*DATA
DATA*	-1.689067D C3	-4.543623D 01	-1.566656D 02	-1.564238D 01	-4.672236D 01						*DATA
CATA*	-6.914601D 00	-1.810916D 01	-4.038558D 00	-8.837001D 00	-2.562516D 00						*DATA
CATA*	-4.520174D 00	-1.688492D 00	-2.316322D 00	-1.143744D 00	-1.153714D 00						*DATA
CATA*	-1.102271D 00	-6.706834D-01	-7.251861E-01	-2.577089E-01	-5.299556D-01						*DATA
DATA*	-4.023892D-02	-4.294301D-01	4.062446D-02	-3.262686D-01	6.394908D-02						*DATA
DATA*	-2.666201D-C1	5.720934D-02	-2.242375E-01	4.520605D-02	-1.452012D-01						*DATA
DATA*	2.582940D-C2	-6.671609D-02	1.262911D-02	-1.538768D-01	2.277915D-02						*DATA
DATA*	-2.036477D-C2	4.488966D-03	-3.546018D 00	-4.651851D 01							*DATA
CATA*	8(5,1)										*DATA
DATA*	-7.953458D 00	-3.350713D 00	-5.774807D 02	-2.770881D 02	2.134819D 03						*DATA
DATA*	7.274799D 02	-1.171571D 03	1.171258D 03	-2.214638D 02	4.290881D 02						*DATA
DATA*	-8.462778D 01	2.308126D 02	-4.217738D 01	1.530531D 02	-2.251996D 01						*DATA
DATA*	1.048827D 02	-1.237234D 01	7.258523D 01	-6.593250D 00	5.096031D 01						*DATA
DATA*	-4.976922C 00	4.306435D 01	1.547705D-02	3.186617D 01	2.971039D 00						*DATA
DATA*	2.093264D 01	5.401261D 00	1.456005D 01	6.915057D 00	1.092380D 01						*DATA
CATA*	8.251341D 00	7.677648D 00	9.361167D 00	5.779018D 00	7.815069D 00						*DATA
CATA*	3.431070D 00	4.107930D 00	1.766168D 00	1.080243D 01	3.188586D 00						*DATA
CATA*	9.041585C-C1	7.774953D-01	-3.922787D 01	1.540950D 02							*DATA
CATA*	6(6,1)										*DATA
DATA*	2.537141D C1	5.391428D 00	8.508857D 02	-1.689067D 03	7.274799D 02						*DATA
DATA*	2.589117D C4	-9.665430D 02	-7.340343D 03	-2.620281E 02	-1.268767D 03						*DATA
CATA*	-1.092971D C2	-4.189942D 02	-6.151248D 01	-1.890336D 02	-3.829270D 01						*DATA
DATA*	-9.260715D 01	-2.466485D 01	-4.641782D 01	-1.634113D 01	-2.337298D 01						*DATA
DATA*	-1.540389D 01	-1.379634D 01	-1.000609D 01	-5.913118D 00	-7.207138D 00						*DATA
DATA*	-1.649859C 00	-5.756956D 00	2.853941D-02	-4.324062D 00	6.029756D-01						*DATA
CATA*	-3.497666D 00	6.562708E-01	-2.518342D 00	5.569422D-01	-1.879377D 00						*DATA
CATA*	3.287928D-C1	-8.613484D-01	1.648454D-01	-1.985704D 00	2.932681D-01						*DATA
CATA*	-2.617402D-C1	5.769283D-02	-7.035518D 01	-1.428479D 03							*DATA
DATA*	6(7,1)										*DATA
CATA*	-2.571362D C0	-8.155096D-01	-1.215942D 02	-4.543623D 01	-1.171571D 03						*DATA

TABLE IX. NORMALIZED MODAL DAMPING MATRIX-LATERAL MODEL (Cont'd)

DATA*	-9.665430D 02	2.759250D 03	-3.556675D 01	-1.052762D 03	8.578274D 02	*DATA
DATA*	-2.167774D 02	3.051209D 02	-9.655781D 01	1.873813D 02	-5.158541D 01	*DATA
DATA*	1.266971D 02	-2.986361D 01	8.815635D 01	-1.822382D 01	6.274616D 01	*DATA
DATA*	-1.532331D 01	5.379635D 01	-5.953306D 00	4.056712D 01	-7.410884D 01	*DATA
DATA*	2.710349D 01	3.015727D 00	1.907830D 01	5.691389D 00	1.438459D 01	*DATA
DATA*	7.793258D 00	1.009599D 01	9.466618D 00	7.553259D 00	8.273675D 00	*DATA
DATA*	4.452767D 00	4.431252D 00	2.284403D 00	1.184680D 01	4.119399D 00	*DATA
DATA*	9.217223D 01	9.945024D 01	-2.712641D 01	-1.788458D 01		*DATA
DATA*	R(8,1)					*DATA
DATA*	9.474192D 00	1.305233D 00	2.653311D 02	-1.566656D 02	1.171258D 03	*DATA
DATA*	-7.340343D 03	-3.596675D 01	3.564063D 04	-8.776924D 02	-1.039512D 04	*DATA
DATA*	-2.234328D 02	-1.576347D 03	-1.076712D 02	-5.420480D 02	-6.068837D 01	*DATA
DATA*	-2.308604D 02	-3.664693D 01	-1.070519D 02	-2.302812D 01	-5.161654D 01	*DATA
DATA*	-2.066721D 01	-3.007636D 01	-1.307862D 01	-1.350959D 01	-9.108754D 00	*DATA
DATA*	-4.681960D 00	-7.068319D 00	-1.140997D 00	-5.189663D 00	1.911074D 01	*DATA
DATA*	-4.115440D 00	5.776707D 01	-3.381131D 00	5.678848D 01	-2.153588D 00	*DATA
DATA*	3.719357D 01	-5.817588D 01	1.900754D 01	-2.259274D 00	3.396201D 01	*DATA
DATA*	-2.967337D 01	6.707765D 02	-1.265674D 01	-3.095559D 02		*DATA
DATA*	R(9,1)					*DATA
DATA*	-6.567902D 01	-2.698048D 01	-3.541338D 01	-1.564230D 01	-2.214638D 02	*DATA
DATA*	-2.620281D 02	-1.052762D 03	-8.776924D 02	2.596081D 03	-1.941684D 02	*DATA
DATA*	-8.571464D 02	6.745902D 02	-2.005687D 02	2.580096D 02	-8.941304D 01	*DATA
DATA*	1.545940D 02	-4.825101D 01	1.024723D 02	-2.676254D 01	7.121198D 01	*DATA
DATA*	-2.457179D 01	6.020219D 01	-1.156643D 01	4.458877D 01	-4.801629D 00	*DATA
DATA*	2.407310D 01	-3.582340D 01	2.687645D 01	4.019777D 00	1.558486D 01	*DATA
DATA*	5.448360D 00	1.080022D 01	7.437625D 00	7.696022D 00	6.878246D 00	*DATA
DATA*	4.643702D 00	3.772110D 00	2.371180D 00	1.025985D 01	4.259776D 00	*DATA
DATA*	7.231941D 01	1.020678D 00	-1.750387D 01	-2.722004D 01		*DATA
DATA*	R(10,1)					*DATA
DATA*	5.272949D 00	5.015077D 01	1.354700D 02	-4.672236D 01	4.290881D 02	*DATA
DATA*	-1.268767D 03	6.578274D 02	-1.039512D 04	-1.941684D 02	4.255723D 04	*DATA
DATA*	-7.065305D 02	-1.182841D 04	-2.214574D 02	-1.982900D 03	-1.094913D 02	*DATA
DATA*	-6.717040D 02	-6.154940D 01	-2.754964D 02	-3.663746D 01	-1.276436D 02	*DATA
DATA*	-3.174027D 01	-7.270601D 01	-1.523911D 01	-3.333711D 01	-1.305110D 01	*DATA
DATA*	-1.277744D 01	-9.789538D 00	-4.457110D 00	-6.946981D 00	-1.138395D 00	*DATA
DATA*	-5.008231D 00	1.780416D 01	-4.351600D 00	5.262944D 01	-2.732921D 00	*DATA
DATA*	4.050366D 01	-1.238179D 00	2.165674D 01	-2.853629D 00	3.912690D 01	*DATA
DATA*	-3.669080D 01	7.684544D 02	-2.578020D 00	-1.361874D 02		*DATA
DATA*	R(11,1)					*DATA
DATA*	-2.346251D 01	-1.313569D 01	-1.426435D 01	-6.914601D 00	-8.452778D 01	*DATA
DATA*	-1.042971D 02	-2.167774D 02	-2.234328D 02	-8.771484D 02	-7.095305D 02	*DATA
DATA*	2.563320D 03	3.581161D 01	-9.732759D 02	7.908206D 02	-2.077006D 02	*DATA
DATA*	2.946566D 02	-8.619811D 01	1.675555D 02	-4.786285D 01	1.071373D 02	*DATA
DATA*	-3.898190D 01	8.559394D 01	-1.902735D 01	6.113715D 01	-9.455258D 00	*DATA
DATA*	3.920146D 01	-3.747845D 00	2.658673D 01	6.889220D 01	1.431168D 01	*DATA
DATA*	3.744950D 00	1.303494D 01	6.112393D 00	9.351157D 00	6.141236D 00	*DATA
DATA*	5.374881D 00	3.473020D 00	2.725908D 00	9.751822D 00	4.699042D 00	*DATA
DATA*	5.870916D 01	1.158402D 00	-1.201621D 01	-1.035637D 01		*DATA
DATA*	R(12,1)					*DATA
DATA*	3.181051D 00	2.123409D 01	8.109278D 01	-1.810916D 01	2.308126D 02	*DATA
DATA*	-4.189742D 02	3.051209D 02	-1.576347D 03	6.745902D 02	-1.182841D 04	*DATA
DATA*	3.981171D 01	5.090848D 04	-7.566563D 02	-1.565096D 04	-2.338964D 02	*DATA
DATA*	-2.602122D 03	-1.168184D 02	-8.671522D 02	-6.593762D 01	-3.576834D 02	*DATA
DATA*	-5.277089D 01	-1.275009D 02	-3.180704D 01	-8.741186D 01	-2.084856D 01	*DATA
DATA*	-3.486335D 01	-1.505674D 01	-1.371854D 01	-1.045643D 01	-5.114671D 00	*DATA
DATA*	-7.325294D 00	-1.238617D 00	-6.126186D 00	9.351947D 02	-3.778968D 00	*DATA
DATA*	3.434135D 01	-1.055560D 00	2.130484D 01	-3.841017D 00	3.946990D 01	*DATA
DATA*	-4.836381D 01	7.591911D 02	1.455488D 00	-6.724756D 01		*DATA
DATA*	R(13,1)					*DATA
DATA*	-4.047720D 02	-8.458644D 02	-6.281019D 00	-4.035558D 00	-4.217738D 01	*DATA
DATA*	-5.311248D 01	-9.815715D 01	1.076712D 02	-1.009687D 02	-2.116574D 02	*DATA
DATA*	-5.732750D 00	-7.477750D 00	2.742145D 03	-1.007734D 01	-1.008931D 03	*DATA
DATA*	7.906616D 02	-2.210977D 02	0.657339D 02	-5.100108D 01	1.442000D 02	*DATA

TABLE IX. NORMALIZED MODAL DAMPING MATRIX- LATERAL MODEL (Cont'd)

DATA*	-6.6801270	01	1.2358150	02	-3.2086430	01	8.4770370	01	-1.5999410	J1	*DATA
DATA*	5.2967120	C1	-8.8212050	00	3.5153360	01	-2.5276870	00	2.5307150	J1	*DATA
DATA*	1.5464640	00	1.6519820	01	4.6167870	00	1.1652960	01	5.4322130	00	*DATA
CATA*	6.5561680	00	3.2268120	00	3.3021520	00	9.4412530	00	5.9224330	JJ	*DATA
CATA*	4.3841970	-C1	1.3827340	00	-8.9527110	00	-1.4759600	01			*DATA
DATA*	B(14,1)										*DATA
DATA*	2.1732820	00	1.0750560	-01	5.4650380	01	-8.8370010	00	1.5305310	J2	*DATA
DATA*	-1.8903360	C2	1.8738130	02	-5.4204800	02	2.5800960	02	-1.9829000	J3	*DATA
CATA*	7.9082060	C2	-1.5650960	04	-1.0072340	01	6.2210680	04	-7.9673640	J2	*DATA
DATA*	-1.9049750	C4	-2.5702180	02	-3.1325960	03	-1.2554280	02	-1.0420400	J3	*DATA
CATA*	-9.3242750	C1	-5.0822530	02	-5.5010840	01	-2.1842690	C2	-3.4936300	J1	*DATA
DATA*	-8.6174030	01	-2.4456370	01	-3.5050140	01	-1.6472930	01	-1.4412740	J1	*DATA
DATA*	-1.1964560	C1	-4.7329200	00	-9.1258740	00	-1.1478430	00	-5.5381820	J3	*DATA
DATA*	4.1325980	-02	-2.4757240	00	1.2272640	-01	-5.8076340	00	2.5779020	-01	*DATA
DATA*	-6.6768410	-01	4.6431620	-02	3.1839340	00	-3.8837780	01			*DATA
DATA*	B(15,1)										*DATA
CATA*	4.4800510	-C2	-6.0677090	-02	-2.5253210	00	-2.5625160	00	-2.2519960	J1	*DATA
DATA*	-3.8292700	C1	-5.1685410	01	-6.0688370	01	-8.9413040	01	-1.0949130	02	*DATA
DATA*	-2.0770060	C2	-2.3989640	02	-1.0089310	03	-7.9673640	02	2.8225230	03	*DATA
DATA*	-4.1293540	C1	-1.0134270	03	7.8575690	02	-2.1076350	02	2.8225420	J2	*DATA
DATA*	-1.2119350	C2	1.8661330	02	-5.3581180	01	1.1974540	02	-2.8270780	01	*DATA
DATA*	7.2111140	C1	-1.5986840	01	-4.6594660	01	-6.9720750	00	3.2374050	J1	*DATA
DATA*	-1.5048070	C0	2.0895440	01	2.4553040	00	1.4406460	01	4.3098820	03	*DATA
CATA*	7.9525960	C0	2.7926060	00	3.9736850	00	8.7201880	00	7.1091850	J3	*DATA
CATA*	2.3090200	-C1	1.6341580	00	-6.6053780	00	-1.1040630	01			*DATA
DATA*	B(16,1)										*DATA
CATA*	1.4976870	00	5.8018840	-02	3.7536610	01	-4.5201740	00	1.0488270	J2	*DATA
CATA*	-9.2607150	01	1.2660710	02	-2.3086040	02	1.5459400	02	-6.7170400	02	*DATA
CATA*	2.5456480	C2	-2.6021220	03	7.9666190	02	-1.9049750	04	-4.1293540	J1	*DATA
CATA*	7.1134570	04	-8.0001840	02	-2.1360300	04	-2.5413310	02	-3.4882240	03	*DATA
DATA*	-1.6222070	C2	-1.3528280	03	-9.2306810	01	-5.1985190	02	-5.6289620	J1	*DATA
CATA*	-1.9576050	C2	-3.7976370	01	-7.9117210	01	-2.4882190	C1	-3.3575270	J1	*DATA
DATA*	-1.7551940	C1	-1.2189890	01	-1.3052440	01	-4.0505580	00	-7.8040440	00	*DATA
CATA*	-8.2774580	-C1	-3.4711350	00	-1.5222630	-01	-8.2726660	00	-2.5394830	-01	*DATA
CATA*	-8.7503470	-C1	-5.5132970	-02	3.7582540	00	-2.2587530	01			*DATA
DATA*	B(17,1)										*DATA
CATA*	7.4338270	-C2	-4.5033460	-02	-7.5027950	-01	-1.6864920	00	-1.2372340	J1	*DATA
DATA*	-2.4664050	01	-2.9863610	01	-3.6646930	01	-4.8251010	01	-6.1546940	J1	*DATA
DATA*	-8.9198110	01	-1.1881840	J2	-2.1219700	C2	-2.5702180	02	-1.0134270	03	*DATA
CATA*	-8.0001840	C2	2.8593540	03	-3.5768550	01	-1.0075910	C3	7.8616330	J2	*DATA
DATA*	-2.6673500	C2	3.2528290	02	-9.4915850	01	1.8154530	02	-4.6535440	J1	*DATA
DATA*	1.0263440	C2	-2.6444390	01	6.3732270	01	-1.3071910	C1	4.2918510	J1	*DATA
DATA*	-5.5528650	00	2.6726400	01	-3.7735500	-01	1.8068220	01	2.8056440	J3	*DATA
DATA*	9.7496080	C0	2.1976770	00	4.6238900	00	7.6918330	00	6.6330530	J3	*DATA
DATA*	-3.3254920	-C2	1.5388690	00	-4.8115270	00	-8.1122360	00			*DATA
DATA*	B(18,1)										*DATA
DATA*	1.0252330	00	3.3670540	-02	2.5686320	01	-2.3163220	00	7.2565230	J1	*DATA
DATA*	-4.6497820	01	8.8156350	01	-1.0705130	C2	1.0247230	C2	-2.7349640	J2	*DATA
DATA*	1.6755550	C2	-8.6715220	02	2.8573290	C2	-3.1385960	03	7.8575690	J2	*DATA
DATA*	-2.1360300	04	-3.5768950	01	7.7502970	04	-7.7765670	02	-2.3148310	04	*DATA
DATA*	-3.0536830	C2	-4.3169900	03	-1.5509160	02	-1.3042010	03	-5.0870420	J1	*DATA
DATA*	-4.4403450	C2	-5.8484250	01	-1.7221570	02	-3.7162430	01	-7.2814300	J1	*DATA
DATA*	-2.5428810	01	-2.7446270	01	-1.8431500	C1	-1.0176710	01	-1.0968760	J1	*DATA
CATA*	-2.7920810	00	-4.8134900	00	-9.3888020	-01	-1.1715480	01	-1.4827030	J3	*DATA
DATA*	-1.1162560	00	-2.8853040	-01	3.8062200	00	-1.2908280	01			*DATA
DATA*	B(19,1)										*DATA
DATA*	7.9169550	-C2	-3.4360950	-02	3.6574900	-02	-1.1437440	00	-6.9932500	J3	*DATA
DATA*	-1.6341130	C1	-1.8223820	01	-2.3028120	01	-2.8762940	01	-3.6637460	J1	*DATA
DATA*	-4.7862850	C1	-6.5837620	01	-9.1231080	01	-1.2554280	02	-2.1076350	J2	*DATA
DATA*	-2.5413310	C2	-1.0075910	03	-7.7765670	02	2.9497440	03	2.8576360	01	*DATA
DATA*	-1.1762330	C3	8.9744760	02	-2.0382640	02	-1.7261200	02	-8.2383770	01	*DATA
DATA*	1.5864370	C2	-4.3707850	01	9.2575200	01	-2.2179410	01	5.9744120	J1	*DATA
DATA*	-1.1186640	C1	3.6195120	01	-4.1350450	00	2.3521580	01	8.8631870	-01	*DATA

TABLE IX. NORMALIZED MODAL DAMPING MATRIX-LATERAL MODEL (Cont'd)

CATA*	2.636266D-01	9.314417D-03	6.845281D-00	-4.023892D-02	2.093264D-01	*DATA
DATA*	-1.649859D-00	2.710349D-01	-4.681960D-00	2.987310D-01	-1.277744D-01	*DATA
CATA*	3.920146D-01	-3.486335D-01	5.256712D-01	-8.617403D-01	7.211114D-01	*DATA
CATA*	-1.957605D-02	1.026344D-02	-4.440345D-02	1.586437D-02	-1.072072D-03	*DATA
CATA*	3.647118D-02	-3.465353D-03	1.088417D-03	-2.599129D-04	-2.732639D-01	*DATA
CATA*	9.608853D-04	-1.108627D-03	-2.556877D-04	-3.711204D-02	-3.902415D-03	*DATA
CATA*	-1.930816D-02	-1.063333D-02	-1.184028D-02	-3.655492D-02	-6.481241D-01	*DATA
CATA*	-1.102833D-02	-2.763398D-01	-4.038614D-01	-7.895530D-01	-6.477887D-01	*DATA
CATA*	-3.468534D-00	-1.029708D-01	2.707587D-00	-7.310893D-01		*DATA
CATA*	E(27,1)					*DATA
CATA*	1.521957D-01	-1.790017D-02	2.825713D-00	-4.254301D-01	5.431261D-03	*DATA
CATA*	-5.756256D-00	3.015727D-00	-7.068315D-00	-3.582340D-01	-9.789538D-03	*DATA
CATA*	-3.747845D-00	-1.509634D-01	-8.821205D-00	-2.445637D-01	-1.596684D-01	*DATA
CATA*	-3.797637D-01	-2.644439D-01	-5.846425D-01	-4.370765D-01	-9.168046D-01	*DATA
CATA*	-1.048949D-02	-1.713795D-02	-2.370753D-02	-3.740235D-02	-1.117724D-03	*DATA
CATA*	-1.108627D-03	3.083335D-03	-2.662440D-00	-1.120868D-03	1.113888D-03	*DATA
CATA*	-2.359987D-02	3.428928D-02	-1.012241D-02	1.665602D-02	-3.972819D-01	*DATA
CATA*	7.158519D-01	-1.356409D-01	3.156054D-01	-1.796770D-01	5.377628D-01	*DATA
CATA*	-5.250554D-00	9.171072D-00	-3.678217D-01	-2.639177D-00		*DATA
CATA*	E(28,1)					*DATA
CATA*	1.781989D-01	6.807965D-03	4.677167D-00	4.082446D-02	1.456005D-01	*DATA
CATA*	2.853941D-02	1.907830D-01	-1.140997D-00	2.087645D-01	-4.452110D-03	*DATA
CATA*	2.658673D-01	-1.371894D-01	3.515310D-01	-3.505014D-01	4.659466D-01	*DATA
CATA*	-7.911721D-01	6.373227D-01	-1.722157D-02	9.257520D-01	-3.797929D-02	*DATA
CATA*	1.914943D-02	-1.013487D-03	3.554274D-02	-3.819466D-03	1.094987D-03	*DATA
CATA*	-2.596877D-04	-2.863440D-00	9.100480D-04	-1.120284D-03	-2.630116D-04	*DATA
CATA*	-3.700050D-02	-3.561873D-03	-1.950082D-02	-9.887887D-02	-1.034443D-02	*DATA
CATA*	-2.704335D-02	-4.237832D-01	-9.410592D-01	-1.301752D-02	-1.472229D-02	*DATA
CATA*	-3.942923D-00	-2.140137D-01	2.175535D-00	-7.659601D-02		*DATA
CATA*	E(29,1)					*DATA
CATA*	1.561559D-01	-1.433784D-02	3.117590D-00	-3.262686D-01	6.915097D-03	*DATA
CATA*	-4.324062D-00	5.691389D-00	-5.199663D-00	3.015777D-00	-6.996981D-03	*DATA
CATA*	6.889220D-01	-1.045643D-01	-2.527687D-00	-1.647293D-01	-6.972075D-03	*DATA
CATA*	-2.488219D-01	-1.307191D-01	-3.716243D-01	-2.217941D-01	-5.668375D-01	*DATA
CATA*	-5.119012D-01	-9.934921D-01	-9.529541D-01	-1.931482D-02	-2.257455D-02	*DATA
CATA*	-3.711264D-02	-1.120868D-03	-1.120284D-03	2.943884D-03	-8.041106D-03	*DATA
CATA*	-1.052526D-03	1.013568D-03	-2.241554D-02	3.092373D-02	-7.571747D-01	*DATA
CATA*	1.156725D-02	-2.582645D-01	4.775309D-01	-3.998456D-01	7.936239D-01	*DATA
CATA*	-7.507592D-00	1.160252D-01	2.031037D-01	-2.035819D-00		*DATA
CATA*	E(30,1)					*DATA
CATA*	1.316495D-01	5.102408D-03	3.473055D-00	6.394908D-02	1.092380D-01	*DATA
CATA*	6.029756D-01	1.438459D-01	1.911674D-01	1.558486D-01	-1.138395D-00	*DATA
CATA*	1.931168D-01	-5.114671D-00	2.500715D-01	-1.441274D-01	3.237405D-01	*DATA
CATA*	-3.357927D-01	4.291861D-01	-7.281430D-01	5.974412D-01	-1.548263D-02	*DATA
CATA*	1.171087D-02	-3.811526D-02	1.901767D-02	-1.166851D-03	3.658678D-02	*DATA
CATA*	-3.902415D-03	1.113888D-03	-2.630116D-04	-8.041106D-03	9.367535D-04	*DATA
CATA*	-1.086327D-03	-2.395730D-04	-3.771575D-02	-3.308558D-03	-1.755628D-02	*DATA
CATA*	-7.316391D-02	-6.617788D-01	-2.313813D-02	-2.231354D-02	-3.459155D-02	*DATA
CATA*	-3.942016D-00	-4.448002D-01	1.815795D-00	1.752070D-01		*DATA
CATA*	E(31,1)					*DATA
CATA*	1.647446D-01	-1.224949D-02	3.440054D-00	-2.665201D-01	8.251341D-00	*DATA
CATA*	-3.497666D-00	7.793258D-00	-4.115440D-00	5.488360D-00	-5.408231D-00	*DATA
CATA*	3.743755D-00	-7.825298D-00	1.546464D-00	-1.196456D-01	-1.504807D-03	*DATA
CATA*	-1.755194D-01	-5.552865D-00	-2.542881D-01	-1.118664D-01	-3.711145D-01	*DATA
CATA*	-2.714762D-01	-6.319323D-01	-4.834740D-01	-1.148263D-02	-9.487713D-01	*DATA
CATA*	-1.930816D-02	-2.359587D-02	-3.700050D-02	-1.052526D-03	-1.086327D-03	*DATA
CATA*	2.796378D-03	-4.030888D-01	-1.015385D-03	9.791223D-02	-1.784676D-02	*DATA
CATA*	2.355306D-02	-5.362787D-01	8.564454D-01	-8.766814D-01	1.336610D-02	*DATA
CATA*	-1.112858D-01	1.538810D-01	6.338028D-01	-1.677835D-00		*DATA
CATA*	E(32,1)					*DATA
CATA*	9.235937D-02	3.381721D-03	2.433921D-00	5.720934D-02	7.677648D-00	*DATA
CATA*	6.562718D-01	1.009599D-01	5.776707D-01	1.080022D-01	1.780416D-01	*DATA
CATA*	1.303454D-01	-1.236617D-00	1.651982D-01	-4.732520D-00	2.089544D-01	*DATA

TABLE IX. NORMALIZED MODAL DAMPING MATRIX- LATERAL MODEL (Cont'd)

DATA*	-1.2189840	C1	2.6926400	C1	-2.7446270	C1	3.6195128	C1	-5.8463120	J1	*DATA
DATA*	6.8372100	C1	-1.5981310	C2	1.0254990	C2	-3.9304980	C2	1.7280820	C2	*DATA
DATA*	-1.0633420	C3	5.4289280	C2	-3.5618740	C3	1.0135680	C3	-2.3957300	C4	*DATA
DATA*	-4.0306880	C1	6.4132250	C4	-1.0267730	C3	-2.1232160	C4	-3.1141630	C2	*DATA
DATA*	-2.3468840	C3	-4.5855470	C1	-6.0343570	C2	-3.6983530	C2	-8.2037350	C2	*DATA
DATA*	-2.0659000	C0	-8.7418390	C1	1.3750980	C0	2.2589170	-C1			*DATA
DATA*	R(33,1)										*DATA
DATA*	1.7279670	-C1	-1.0656990	-C2	3.7214130	C0	-2.2423750	-C1	5.3611670	C0	*DATA
DATA*	-2.9183420	C0	9.4866180	C0	-3.3811310	C0	7.4376250	C0	-4.3516000	C0	*DATA
DATA*	6.1128930	C0	-6.1261860	C0	4.6167870	C0	-9.1258740	C0	2.4593040	C0	*DATA
DATA*	-1.3052440	C1	-3.7735500	-C1	-1.8431500	C1	-4.1390450	C0	-2.6193150	C1	*DATA
DATA*	-1.3139120	C1	-4.5342380	C1	-2.5564820	C1	-7.5379540	C1	-4.8564670	C1	*DATA
DATA*	-1.1640280	C2	-1.0122410	C2	-1.9900820	C2	-2.3415940	C2	-3.7715790	C2	*DATA
DATA*	-1.0193850	C3	-1.0267730	C3	2.6444960	C3	-1.5940920	C1	-8.7449120	C2	*DATA
DATA*	9.3000990	C2	-1.4117530	C2	1.9156130	C2	-2.2029040	C2	2.5916310	C2	*DATA
DATA*	-1.6782210	C1	1.8616730	C1	5.7586270	-C1	-1.4189770	C0			*DATA
DATA*	R(34,1)										*DATA
DATA*	7.0169910	-C2	2.7762240	-C3	1.8280330	C0	4.5100050	-C2	5.7790180	C0	*DATA
DATA*	5.5694220	-C1	7.1532590	C0	5.8788480	-C1	7.9690200	C0	5.2522440	-C1	*DATA
DATA*	9.3911570	C0	4.3519470	-C2	1.1652960	C1	-1.1476430	C0	1.4406460	C1	*DATA
DATA*	-4.0505580	C0	1.8068220	C1	-1.0176710	C1	3.3521510	C1	-2.2611540	C1	*DATA
DATA*	4.3032710	C1	-2.4335980	C1	6.0817760	C1	-1.4817010	C2	9.5118510	C1	*DATA
DATA*	-3.6594920	C2	1.6656320	C2	-9.8874870	C2	3.0923730	C2	-3.3085580	C3	*DATA
DATA*	4.7512030	C1	-2.1231160	C4	-1.5940700	C1	7.4405680	C4	-9.1178060	C2	*DATA
DATA*	-1.6418220	C4	-1.4819270	C2	-2.1698170	C3	-6.8059210	C2	-2.3343500	C3	*DATA
DATA*	3.2622180	C0	-1.8442990	C2	1.0653810	C0	2.0292800	-C1			*DATA
DATA*	R(35,1)										*DATA
DATA*	1.3666270	-C1	-7.0685560	-C3	3.0074340	C0	-1.4520120	-C1	7.8150690	C0	*DATA
DATA*	-1.8793770	C0	8.2726750	C0	-2.1535880	C0	6.8762460	C0	-2.7329210	C0	*DATA
DATA*	6.1412360	C0	-3.7789680	C0	5.4222130	C0	-5.5361820	C0	4.3093820	C0	*DATA
DATA*	-7.8040440	C0	2.6096460	C0	-1.0868760	C1	8.8631070	-C1	-1.5244130	C1	*DATA
DATA*	-2.4937760	C0	-2.4894160	C1	-8.7234470	C0	-4.2462340	C1	-1.9007820	C1	*DATA
DATA*	-6.4812410	C1	-3.9728190	C1	-1.0344430	C2	-7.5717470	C1	-1.7556280	C2	*DATA
DATA*	-1.7846760	C2	-3.1141630	C2	-8.7449120	C2	-9.1178060	C2	2.5578160	C3	*DATA
DATA*	3.5920170	C1	-7.6534760	C2	5.5809460	C2	-6.2027080	C2	4.7263380	C2	*DATA
DATA*	-2.0708810	C1	8.7479270	C0	9.5082130	-C1	-9.7480700	-C1			*DATA
DATA*	R(36,1)										*DATA
DATA*	4.2196680	-C2	1.1857830	-C3	1.0574050	C0	2.5829400	-C2	3.4310700	C0	*DATA
DATA*	3.2979280	-C1	4.4527870	C0	3.7190570	-C1	4.6437020	C0	4.0568660	-C1	*DATA
DATA*	5.3748810	C0	3.4341350	-C1	6.5551680	C0	4.1325980	-C2	7.9525960	C0	*DATA
DATA*	-8.2774580	-C1	9.7496080	C0	-2.7523810	C0	1.2353520	C1	-6.8539960	C0	*DATA
DATA*	2.1984260	C1	-1.7058060	C1	2.9605670	C1	-4.6632600	C1	4.3848920	C1	*DATA
DATA*	-1.1028330	C2	7.1585190	C1	-2.7043350	C2	1.1567250	C2	-7.3153910	C2	*DATA
DATA*	2.3553060	C2	-2.3468840	C3	8.3000550	C2	-1.6418220	C4	3.9820170	C1	*DATA
DATA*	6.2590210	C4	-3.1047360	C2	-1.6301080	C4	-1.1476340	C3	-7.3078630	C3	*DATA
DATA*	1.3739010	C1	-5.3927190	C2	6.5741420	-C1	1.2246660	-C1			*DATA
DATA*	R(37,1)										*DATA
DATA*	6.9917310	-C2	-3.7854170	-C3	1.5578430	C0	-6.6716090	-C2	4.1079300	C0	*DATA
DATA*	-8.6134840	-C1	4.4312500	C0	-9.8179880	-C1	3.7721100	C0	-1.2381390	C0	*DATA
DATA*	3.4730200	C0	-1.6995980	C3	3.2263120	C0	-2.4757240	C0	2.7926060	C0	*DATA
DATA*	-3.4711350	C0	2.1976770	C0	-4.8134900	C0	1.4479870	C0	-6.7233610	C0	*DATA
DATA*	5.4826310	-C1	-1.0475310	C1	-1.9785940	C0	-1.8469710	C1	-5.9292270	C0	*DATA
DATA*	-2.7633580	C1	-1.1064000	C1	-4.0373320	C1	-2.5816450	C1	-6.6177880	C1	*DATA
DATA*	-5.3627870	C1	-9.8253270	C1	-1.4117530	C2	-1.4815270	C2	-7.6534760	C2	*DATA
DATA*	-3.1047360	C2	3.1497750	C3	8.7023170	C2	-2.1536260	C3	1.6215860	C3	*DATA
DATA*	-1.6155570	C1	3.3446340	-C1	5.1008970	-C1	-4.2707720	-C1			*DATA
DATA*	R(38,1)										*DATA
DATA*	2.1860680	-C2	5.7449360	-C4	5.6899080	-C1	1.2829110	-C2	1.7661680	C0	*DATA
DATA*	1.6484540	-C1	2.0444000	C0	1.9007540	-C1	2.3711880	C0	2.1596740	-C1	*DATA
DATA*	2.7590600	C0	2.1304840	-C1	3.3021520	C0	1.2272640	-C1	3.9736850	C0	*DATA
DATA*	-1.8422430	-C1	4.0278910	C0	-9.3983020	-C1	6.0383170	C0	-2.4998110	C0	*DATA
DATA*	1.0454470	-C1	-6.1750300	C0	1.1542260	C1	-1.7483540	C1	2.0068840	C1	*DATA
DATA*	-4.0306880	C1	3.1550540	C1	-9.4410590	C1	-4.7793090	C1	-2.3138130	C2	*DATA

TABLE IX. NORMALIZED MODAL DAMPING MATRIX- LATERAL MODEL (Concluded)

DATA*	9.5644540	01	-6.0343570	02	1.9196130	02	-2.1698730	03	5.5809460	02	*DATA
DATA*	-1.6301080	04	8.7023170	02	5.8701950	04	-1.8789470	03	-2.7461050	04	*DATA
DATA*	1.8833050	01	-3.9483040	02	3.3556420	01	6.1519020	02			*DATA
DATA*	8(39,1)										*DATA
DATA*	1.7964110	01	-7.6218390	03	4.0434110	00	-1.5387680	01	1.0802430	01	*DATA
DATA*	-1.9857040	00	1.1846800	01	-2.2592740	00	1.0299850	01	-2.8536290	00	*DATA
DATA*	9.7518220	00	-3.9430170	00	9.4412520	00	-5.8076340	00	8.7201880	00	*DATA
DATA*	-8.2725660	00	7.6918330	00	-1.1715480	01	6.4558410	00	-1.6792800	01	*DATA
DATA*	6.4798890	00	-2.8105850	01	1.8572760	00	-4.9797040	01	-4.8404360	01	*DATA
DATA*	-7.8995380	01	-1.7967700	01	-1.3017520	02	-3.9984560	01	-2.2313540	02	*DATA
DATA*	-8.7688140	01	-3.6983530	02	-2.2029040	02	-6.8259210	02	-6.2027080	02	*DATA
DATA*	-1.1476340	03	-2.1538260	03	-1.8769470	03	3.1014900	03	-2.8195380	03	*DATA
DATA*	-4.5687620	01	-2.0462460	02	1.4541780	00	-9.9458110	01			*DATA
DATA*	8(40,1)										*DATA
DATA*	3.9558210	02	1.0139400	03	1.0240500	00	2.2779150	02	3.1885860	00	*DATA
DATA*	2.9326810	01	4.1193990	00	3.3962010	01	4.2697760	00	3.9126900	01	*DATA
DATA*	4.8990420	00	3.4469900	01	5.9224330	00	2.5779020	01	7.1091850	00	*DATA
DATA*	-2.5394830	01	8.6030530	00	-1.4827030	00	1.0725310	01	-4.1529460	00	*DATA
DATA*	1.8744320	01	-1.0400710	01	2.4428550	01	-2.8416030	01	3.4761420	01	*DATA
DATA*	-6.4778870	01	5.3776280	01	-1.4722290	02	7.9062390	01	-3.4591550	02	*DATA
DATA*	1.3366100	02	-8.2037350	02	2.5816310	02	-2.3343500	03	4.7263380	02	*DATA
DATA*	-7.3078630	03	1.6215860	03	-2.7461050	04	-2.8195380	03	5.7203350	04	*DATA
DATA*	7.2207200	01	-1.5362480	03	6.1283550	01	1.0923020	01			*DATA
DATA*	8(41,1)										*DATA
DATA*	1.6550390	02	-1.0112910	03	3.5734080	01	-2.0364770	02	9.0415850	01	*DATA
DATA*	-2.6174020	01	9.2172230	01	-2.9673370	01	7.2319410	01	-3.5590800	01	*DATA
DATA*	5.6709160	01	-4.8363820	01	4.3841970	01	-6.6768410	01	2.3090200	01	*DATA
DATA*	-8.7503470	01	-3.3254520	02	-1.1162560	00	-3.6544790	01	-1.4119780	01	*DATA
DATA*	-1.0952550	00	-2.0527850	00	-1.9457720	00	-2.9095380	00	-3.1959010	00	*DATA
DATA*	-3.4685340	00	-5.2505940	00	-3.9429230	00	-7.5075920	00	-3.9420160	00	*DATA
DATA*	-1.1128980	01	-2.0539000	00	-1.6782210	01	3.2822180	00	-2.0208610	01	*DATA
DATA*	1.3739010	01	-1.6155970	01	1.8633050	01	-4.5687620	01	7.2207200	01	*DATA
DATA*	1.2507470	02	1.1394300	02	1.0317020	01	-1.2667200	01			*DATA
DATA*	8(42,1)										*DATA
DATA*	9.8495100	03	2.0035910	04	2.5233260	01	4.4889660	03	7.7749530	01	*DATA
DATA*	5.7692830	02	9.9450240	01	6.7077650	02	1.0206730	00	7.6845440	02	*DATA
DATA*	1.1584020	00	7.5919110	02	1.3827340	00	4.6431620	02	1.6341580	00	*DATA
DATA*	-5.5132970	02	1.9388690	00	-2.8853040	01	2.3567760	00	-7.5691170	01	*DATA
DATA*	3.9928370	00	-1.8702290	00	4.9242330	00	-4.8401170	00	6.5303910	00	*DATA
DATA*	-1.0297080	01	9.1710720	00	-2.1401370	01	1.1602520	01	-4.4460020	01	*DATA
DATA*	1.5388100	01	-8.7418390	01	1.8616730	01	-1.8442990	02	6.4479270	00	*DATA
DATA*	-3.2927190	02	3.3446340	01	-3.9483040	02	-2.0462460	02	-1.5362480	03	*DATA
DATA*	1.1394300	02	5.1364210	03	1.4651410	01	2.0348100	02			*DATA
DATA*	8(43,1)										*DATA
DATA*	5.7021420	02	-5.7953160	02	-2.5853150	00	-3.5460180	00	-3.9227870	01	*DATA
DATA*	-7.0555380	01	-2.7126410	01	-1.2656740	01	-1.7503870	01	-2.5780200	00	*DATA
DATA*	-1.2016810	01	1.4554880	00	-8.9537110	00	3.1839340	00	-6.6053780	00	*DATA
DATA*	3.7982540	00	-4.8115270	00	3.6062200	00	-3.4997890	00	3.5399780	00	*DATA
DATA*	-3.4599510	00	3.7166270	00	-1.9644850	00	3.4334100	00	-1.0400080	00	*DATA
DATA*	2.7075870	00	-3.6782170	01	2.1755350	00	2.0310370	01	1.8107950	00	*DATA
DATA*	6.3380280	01	1.3790880	00	9.7585270	01	1.0853910	00	9.5082130	01	*DATA
DATA*	6.5741420	01	5.3008970	01	3.3956420	01	1.4541780	00	6.1203550	01	*DATA
DATA*	1.0317020	01	1.4651410	01	1.2425490	02	-1.1789970	02			*DATA
DATA*	8(44,1)										*DATA
DATA*	3.9068210	00	1.2824500	01	8.7891480	01	-4.6518510	01	1.5409500	02	*DATA
DATA*	-1.4284790	03	-1.7884980	01	-3.0585490	02	-2.7220040	01	-1.3519790	02	*DATA
DATA*	-1.9356370	01	-6.7247960	01	-1.4759600	01	-3.8637780	01	-1.1040630	01	*DATA
DATA*	-2.2587530	01	-8.1122360	00	-1.2508260	01	-5.9298700	00	-7.2115070	00	*DATA
DATA*	-6.0615440	00	-4.6752110	00	-4.2015030	00	-2.2340460	00	-3.1819730	00	*DATA
DATA*	-7.3108930	01	-2.6391770	00	-7.6596010	02	-2.0358190	00	1.7520700	01	*DATA
DATA*	-1.6778350	00	2.2589170	01	-1.4169770	00	2.0292800	01	-6.2490700	01	*DATA
DATA*	1.2246660	01	-4.2707720	01	6.1519020	02	-9.9458110	01	1.0923020	01	*DATA
DATA*	-1.2667200	01	2.0348100	02	-1.1789970	02	5.0928070	00			*DATA

2.4 STRUCTURAL RESPONSE ANALYSIS

This phase of the program involved generating the structural response acceleration environments of the two fuzes. This task consequently represents the principal effort conducted necessary to meet the basic study objectives. The two other phases discussed above were preparatory to this final effort in that they provide (1) the loading environment and (2) the dynamic model for subsequent structural response analysis.

Standard modal response analysis techniques were inappropriate for this problem. The reason for this is basically due to the characteristics of the loading environment. It was discontinuous, non-linear, and voluminous in terms of the amount of data necessary to describe the transient axial and transverse time history of loading (for the complete trajectory) for each coordinate of motion and for each impact condition.

The method of analysis utilized to determine the fuze response environments consisted of generating the coupled simultaneous differential equations of motion for each coordinate and solving them directly by numerical integration. The loading environment, which was generated by the 2-D Code, was applied in a digital format on magnetic tape with linear interpolation between data points. A digital loading history was included for each coordinate of lumped parameter system. The set of differential equations in matrix format was of the form:

$$M_N \ddot{X} + K_N X + C_N \dot{X} = F(x, t)$$

where

N = 42 for the axial model

N = 44 for the transverse model (17 translational and 17 rotational coordinates)

M = Mass matrix

K = Stiffness matrix

C = Modal damping matrix

M, K, C = Took on values associated with the axial and transverse models, respectively.

These sets of equations were mechanized for solution and solved by the contractor's Computer Code No. 2947, which incorporates the Adams predictor corrector numerical integration routine. This code and the integration routines are described in Appendix III.

Results

The results of this analysis include the axial and lateral, forward and aft fuze acceleration environments for the full spectrum of impact conditions

presented in Table I. For ease in data utilization and due to the characteristics of the environments, the results are presented in two time regimes, i.e., early during the impact event and later during penetration. The initial impact event excited significant structural response of the MK82 configuration. This early time response resulted in the peak acceleration environments experienced by the fuzes. These accelerations were characterized by high frequency oscillation which rapidly damped out during the subsequent penetration of the projectile. As these oscillations damped out, the rigid body accelerations increased until they reached a peak later in the trajectory. This second peak was, however, in most cases less than the initial high frequency response. In view of the fact that structural response was only present during the initial phase of the impact event, therefore, structural response data is provided only for that initial phase, and subsequent late time environments can be obtained from the rigid body response directly. The above described characteristics are demonstrated by reference to the following example response history. The condition chosen is for the maximum impact velocity at an obliquity of 70 degrees. Figures 15 and 16 present the rigid body response in the axial and lateral directions, respectively, for both fuzes (GZ1, GX1 = forward fuze, GZ3, GX3 = aft fuze).

The peak axial loads for the forward and aft fuze are 1200 and 450 g's, respectively and the peak lateral loads are 1700 and 1800 g's, respectively. These peaks occur at approximately 10 to 15 milliseconds after initial impact.

Figures 20 through 23 are plots of the axial accelerations for the forward fuze, while Figures 24 through 27 are for the aft fuze taking into consideration the flexibility of the warhead structure. Note in Figure 20 the peak early time axial acceleration environment for the forward fuze is 1100 g's and occurs at $t \approx 0.2$ ms. Figures 28 through 30 represent continuations in time for the forward fuze well axial accelerations. The second peak of 830 g's is reached at time ≈ 12 ms. This corresponds to the rigid body peak noted in Figure 15 without centrifugal acceleration coupling. According to Figure 15, this contribution is 400 g's, bringing the total to 1230 g's.

Figure 24 presents the early time axial structural response data for the aft fuze. The peak value is 1200 g's, and the time of occurrence is $t \approx 0.5$ ms. The late time peak occurs at $t \approx 11$ ms and corresponds to the rigid body environment of 830 g's. Again this value is to be corrected by the centrifugal field effects, resulting in an actual acceleration of 430 g's.

Similar data comparisons were made for the lateral case and for different impact conditions. In all cases, the only pertinent structural response occurred during the first few milliseconds of the event and the late time response was essentially due to rigid body effects.

The basic results of the structural response analysis are presented in Appendix IV. Table X delineates the contents of Appendix IV. These results represent direct computer outputs in graphical form, and the data represents the fuze well acceleration environments for the first 1.5 ms of the impact event.

Again for ease in data utilization and interpretation, this information is summarized in Figures 2 through 4. These results are self-explanatory.

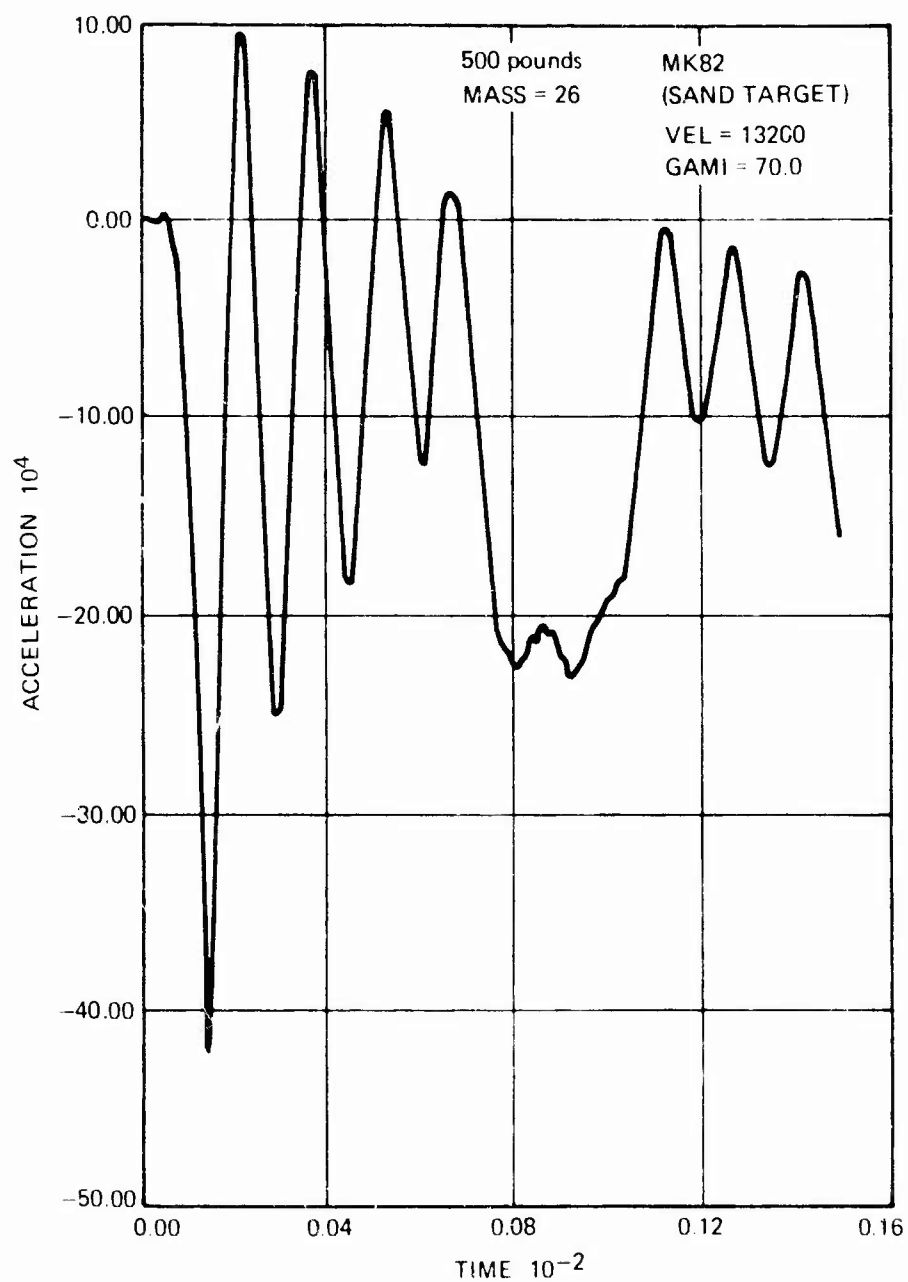


Figure 20 AXIAL RESPONSE FORWARD FUZE $0 < T < 0.15$ ms

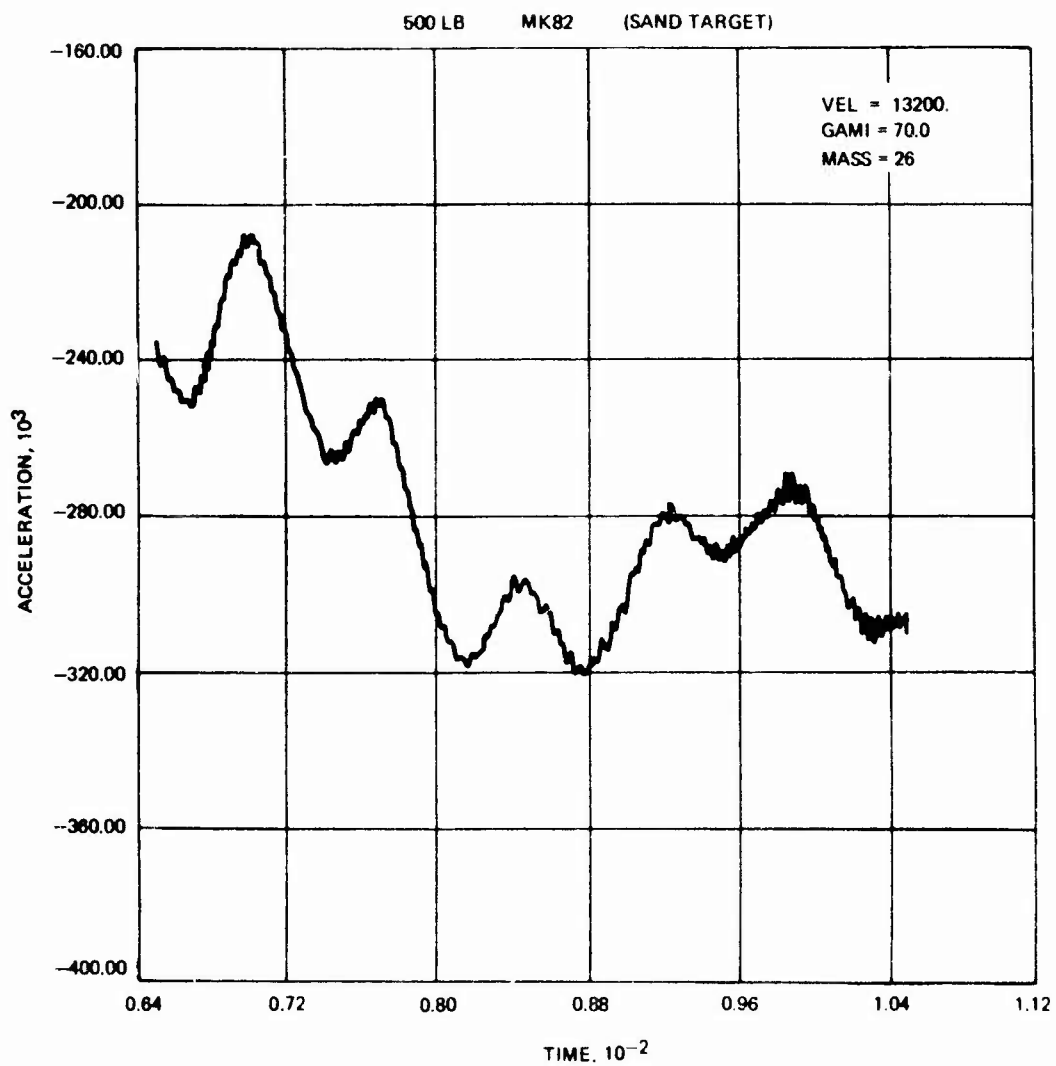


Figure 21 AXIAL RESPONSE FORWARD FUZE $6.4 < T < 10.4$ ms

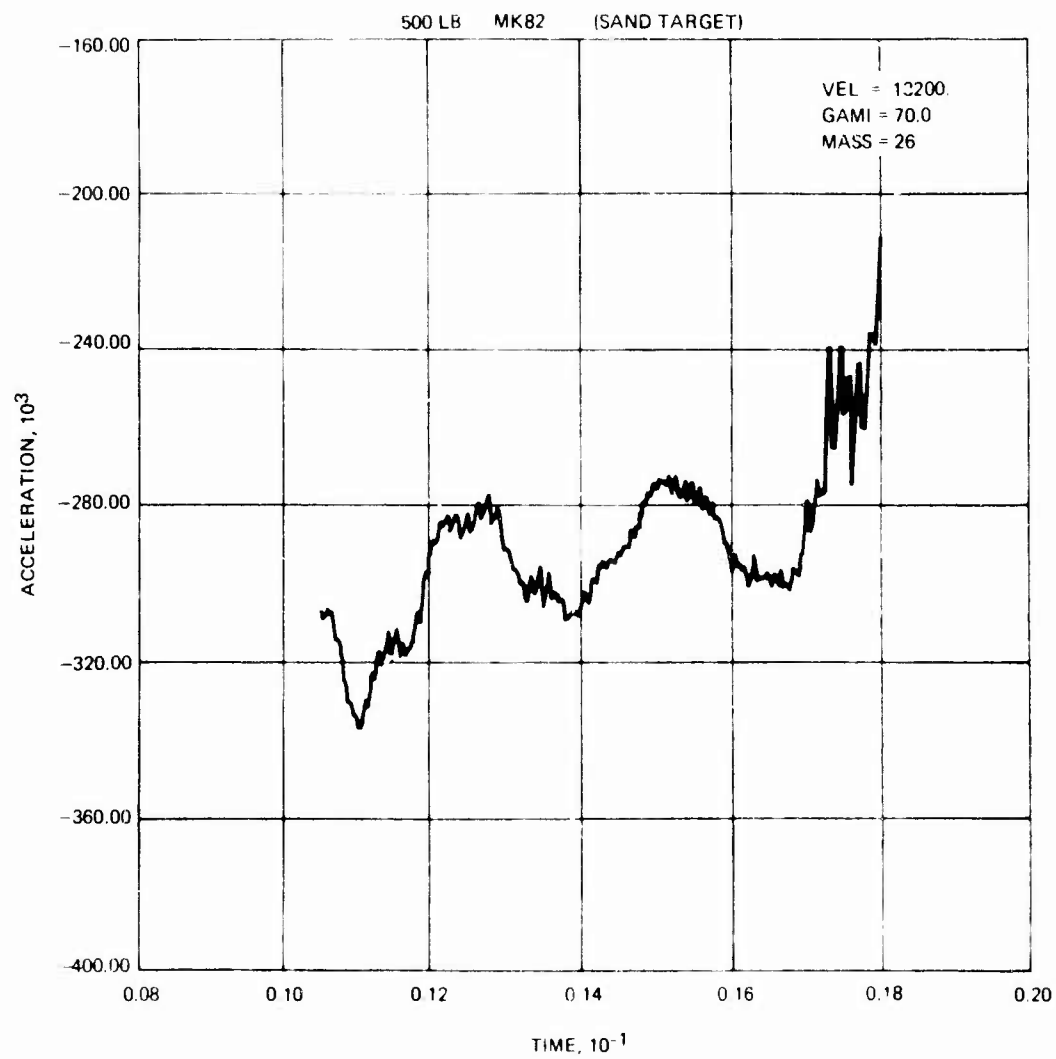


Figure 22 AXIAL RESPONSE FORWARD FUZE $10 < T < 18$ ms

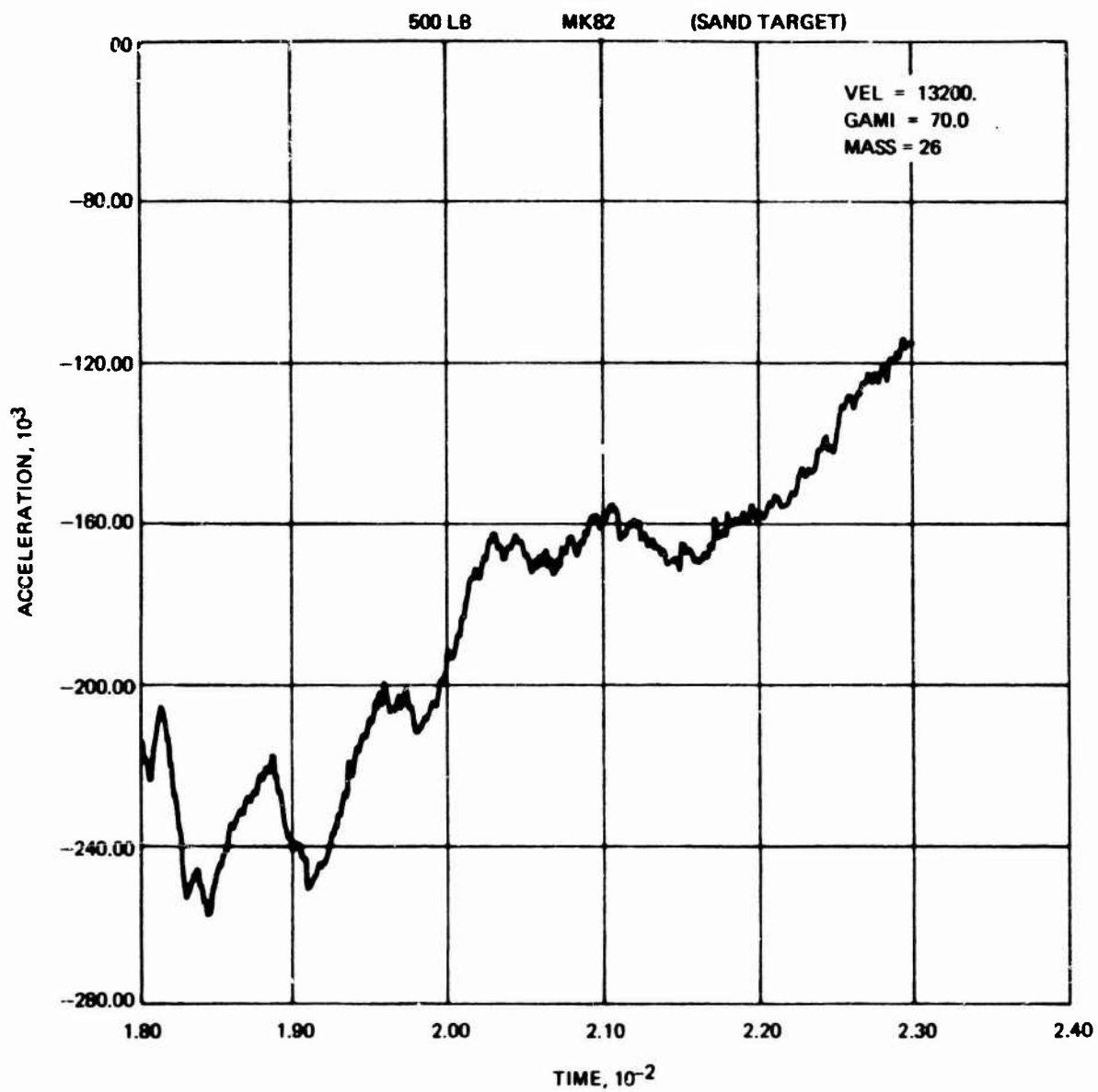


Figure 23 AXIAL RESPONSE FORWARD FUZE $18 < T < 23$ ms

500 LB MK82 (SAND TARGET)

VEL=13200.

GAMI=70.0

MASS= 24

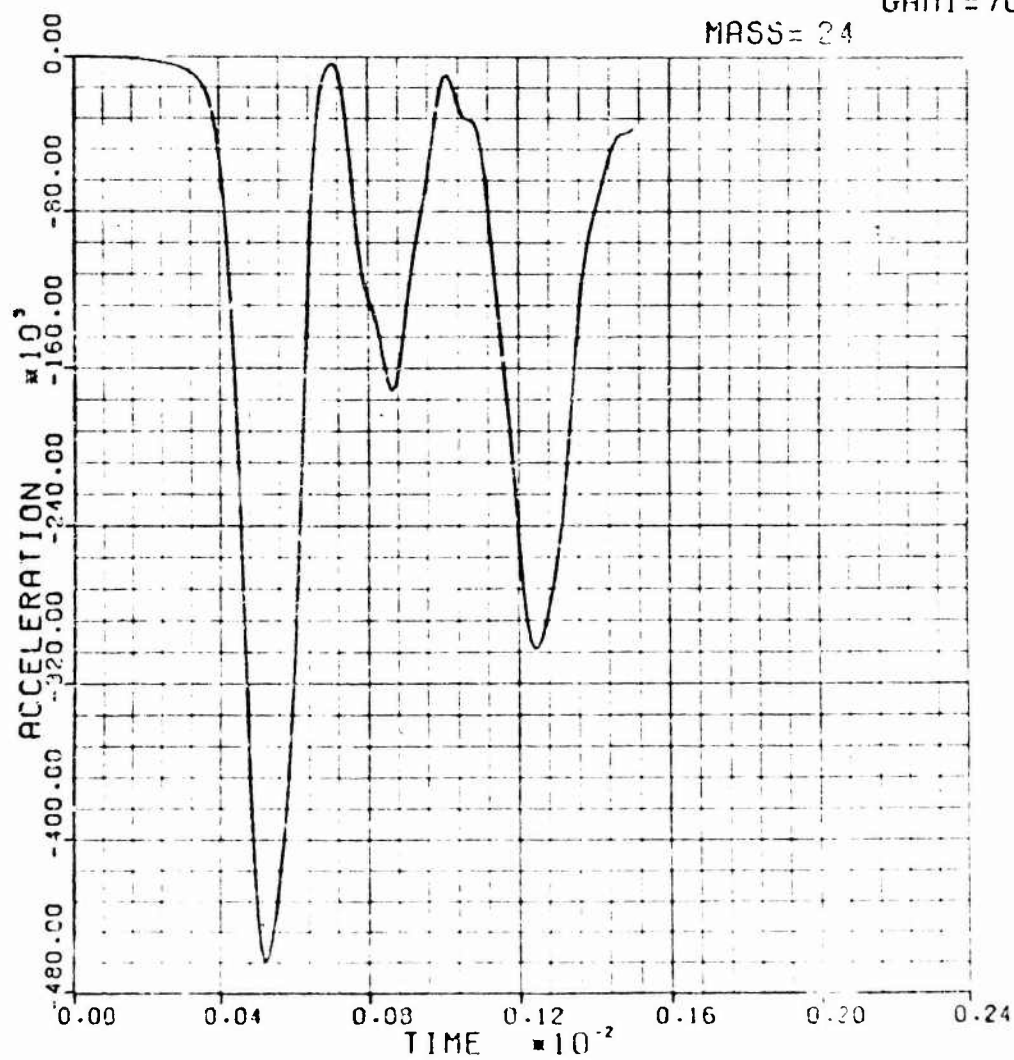


Figure 24 AXIAL RESPONSE AFT FUZE 0 T < 15 ms

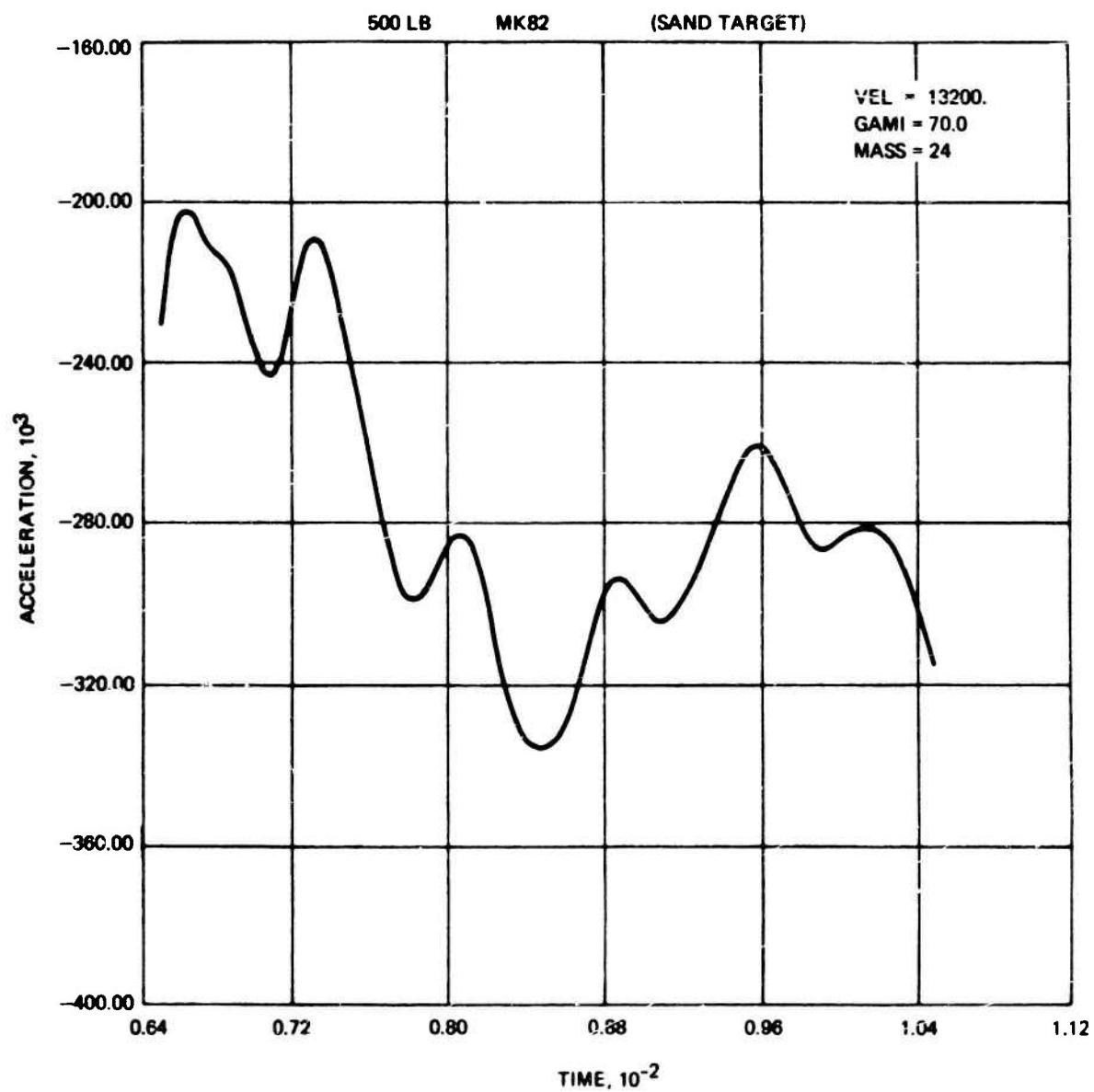


Figure 25 AXIAL RESPONSE AFT FUZE $6.4 < T < 10.4$ ms

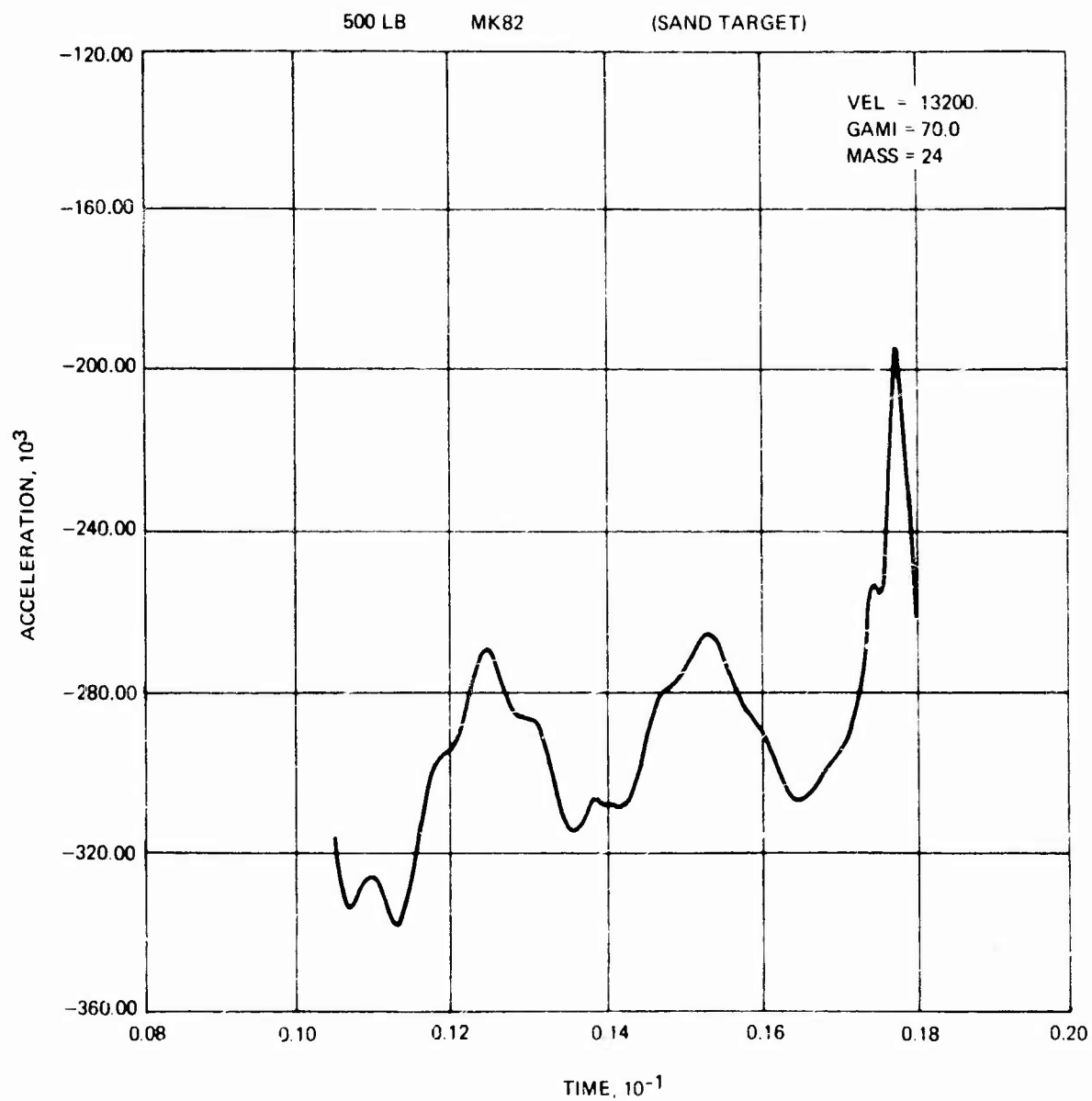


Figure 26 AXIAL RESPONSE AFT FUZE $10 < T < 18$ ms

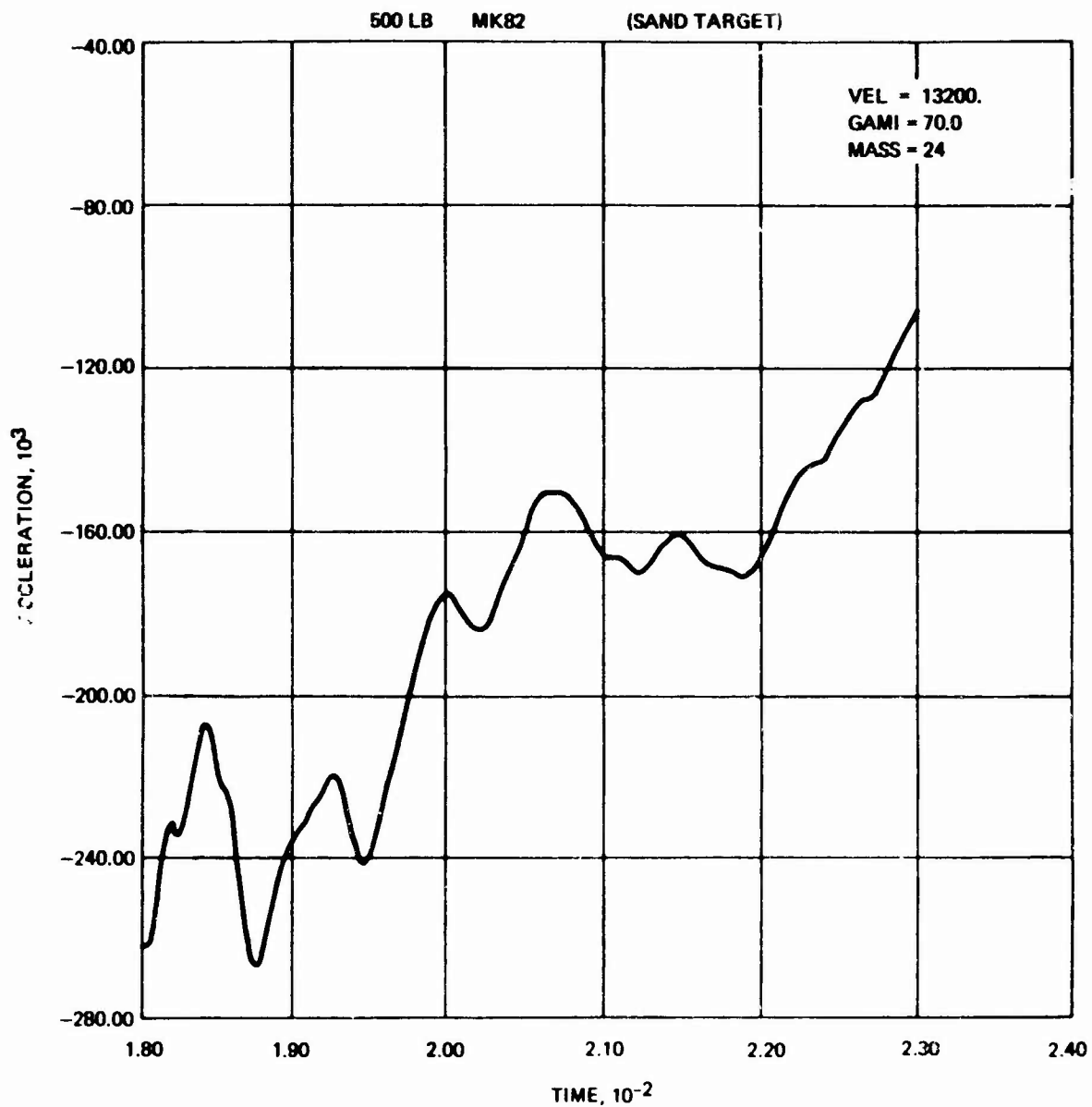


Figure 27 AXIAL RESPONSE AFT FUZE 18 < T < 23 ms

TABLE X. FUZE ENVIRONMENT SUMMARY- MK82 WARHEAD

(Axial Response)

Sand Impacts

Time Regime 0.0 - 1.5 Milliseconds

Impact Conditions		Station	Response Data
γ ~deg	V ~In./sec		
20	13,200	26 - Forward Fuze	Acceleration
25			
30			
35			
40			
45			
55			
60			
65			
70			
20	13,200	26 - Forward Fuze	
25		24 - Aft Fuze	
30			
35			
40			
45			
55			
60			
65			
70			
20	10,800	26 - Forward Fuze	
25			
35			
40			
45			
55			
65			
70			
20		26 - Forward Fuze	
25		24 - Aft Fuze	
35			
40			
45			
55			
65			
70	10,800	24 - Aft Fuze	Acceleration

TABLE X. FUZE ENVIRONMENT SUMMARY-MK82 WARHEAD (Cont'd)

Impact Conditions		Station	Response Data
γ ~deg	V ~In./sec		
20	7,200	26 - Forward Fuze	Acceleration
25		↓	
30		↓	
35		↓	
40		↓	
45		↓	
55		↓	
60		↓	
65		↓	
70		↓	
20	7,200	26 - Forward Fuze	Acceleration
25		↓	
30		↓	
35		↓	
45		↓	
55		↓	
65		↓	
70		↓	
20	13,200	5 - Forward End of Forward Fuze	Acceleration
35		↓	
45		↓	
55		↓	
65		↓	
70		↓	
20	13,200	43 - Aft End of Forward Fuze	Acceleration
35		↓	
45		↓	
55		↓	
65		↓	
70		↓	
20	13,200	41 - Forward End of Aft Fuze	Acceleration
35		↓	
45		↓	
55		↓	
65		↓	
70		↓	

TABLE X. FUZE ENVIRONMENT SUMMARY-MK82 WARHEAD (Cont'd)

Impact Conditions		Station	Response Data
γ ~deg	V ~In./sec		
20	13,200	39 - Aft End of Aft Fuze	Acceleration
35	↓	↓	
45			
55	↓		
65		39 - Aft End of Aft Fuze	
70	13,200		
20	10,800	5 - Forward End of Forward Fuze	
25	↓	↓	
35			
45			
55			
65		5 - Forward End of Forward Fuze	
70			
20		43 - Aft End of Forward Fuze	
25		↓	
35			
45			
55			
65		43 - Aft End of Forward Fuze	
70			
20		41 - Forward End of Aft Fuze	
25		↓	
35			
45			
55			
65		41 - Forward End of Aft Fuze	
70			
20		39 - Aft End of Aft Fuze	
25		↓	
35			
45			
55			
65		39 - Aft End of Aft Fuze	
70	10,800		
20	7,200	5 - Forward End of Forward Fuze	Acceleration
25	↓	↓	
35			
45			
55			
65		5 - Forward End of Forward Fuze	
70	7,200		

TABLE X. FUZE ENVIRONMENT SUMMARY-MK82 WARHEAD (Concl'd)

Impact Conditions		Station	Response Data
γ ~deg	V ~In./sec		
20	7,200 ↓	43 - Aft End of Forward Fuze	Acceleration ↓
25			
35			
45			
55			
65		43 - Aft End of Forward Fuze	
70			
20		41 - Forward End of Aft Fuze	
25			
35			
45			
55			
65		41 - Forward End of Aft Fuze	
70			
20	7,200 ↓	39 - Aft End of Aft Fuze	Acceleration ↓
25			
35			
45			
55			
65		39 - Aft End of Aft Fuze	
70			

SECTION III

CONCLUSIONS AND RECOMMENDATIONS

The objectives of this program were to establish the fuze environments due to MK82 impacts into sand. These objectives were accomplished, and the information contained herein represents the specification of MK82 fuze impact environments data related to sand impacts.

Some care should be used in using and interpreting this data for fuze system functioning investigations. There are two distinct regimes of peak accelerations: early time and late time. The early time is characterized by high frequency oscillations and, in some cases, acceleration direction reversals (of the same order) are experienced. The late time peaks are associated with rigid body response and are characteristically low frequency, i.e., on the order of total penetration duration. The point to be made is that fuze functioning reactions may be sensitive to the two types of acceleration environments, and this should be taken into consideration during fuze functioning investigations.

One of the significant results of this study program was the fact that the effects of projectile flexibilities were significant for sand impact situations. For most impact cases investigated, early time structural response accelerations were significantly higher than peak rigid body acceleration levels. The implication of this result is that for impacts into other target media, which generally will be more resistant to penetration than sand, much higher magnification of acceleration environments due to structural response effects will occur. Magnification factors of five or greater are expected, and this will undoubtedly have a significant effect upon certain fuze systems.

Another interesting and, in some cases, significant result of the study was related to the fuze system mount design. During the modeling analysis, particular attention was given to the mechanical interface design details between the fuze and the main shell structure.

During subsequent structural response analysis, it was determined that, due to the characteristics of these designs, the loading environments transmitted to the fuzes were, in some instances, attenuated and in others they were magnified.

For example, with reference to Table XI below, loading magnification occurred for the aft fuze in both the axial and lateral directions, where attenuation occurred for the forward fuze in both directions. Also, in both cases, magnification was on the order of 30 percent while attenuation was approximately down by 20 percent.

Fuze mount designs which capitalize on this kind of behavior should be considered. It may be possible to develop fuze mount designs which are more sensitive to graze-type impact conditions while desensitizing axial environments. The result would be a more efficient compatible system for broader impact environment utilization.

TABLE XI. FUZE MOUNT DESIGN EFFECTS

V = 1100 = 70° Fuze	Loading Direction	Fuze Peak Acceleration	Nearest Main Structure Acceleration	Ratio
		g's	g's	
Fwd.	Axial	1100	1550	0.71
	Lateral	4000	4900	0.82
Aft	Axial	1200	930	1.3
	Lateral	2600	1940	1.34

Prior to the development of the technology utilized in this program (i.e., the capability to determine well-defined impact loading environments), only crude estimates could be made concerning the accelerations experienced by fuze systems. In the past, it was pointless to perform detailed structural response analysis because of the uncertainties associated with the applied loading environments.

In view of the above, and because of the several significant findings determined during the conduct of this program, the following additional study areas are suggested:

1. Fuze Environments for Other Target Media

Sand is one of the so-called soft targets. There are, however, other targets which may be softer (i.e., wherein lower acceleration environments are experienced by the fuze systems). These include snow, jungle canopy, and terrain representative of marshy areas. There are also much harder targets such as steel armor, concrete, frozen earth, clay, etc. Some of these targets are of more interest than others for reasons of present applications and present performance results. System upgrading, however, may make it essential to know the impact environment into these additional media.

Programs structured to determine fuze environments for additional media would be of two types. These include:

- a. Efforts similar to the present program conducted for sand, i.e., strictly analytical.
- b. Programs which consist of both testing and analysis. Some of the above mentioned media have not been categorized relative to their ballistic resistance to penetration, and this would be required prior to the parametric study for establishing fuze environments.

2. MK82 Structural Integrity Evaluation

For proximity, air burst, or point contact (superquick) modes of operation, impact structural integrity of the MK82 bomb is of no particular interest. The munition is initiated prior to catastrophic structural failure. For delay mode or zero g sensing missions, structural integrity must be maintained in order to insure proper functioning. Structural failure or excessive structural response accelerations or deformation can be directly responsible for duds, low order functioning, or improper initiation timing.

The purpose of a study structured to evaluate the structural integrity of the MK82 warhead would be to establish the bounds of impact conditions and impact media for which structural integrity was maintained. This information could be used directly to determine:

- a. MK82 bomb operating regimes (intact impact), impact conditions, and target spectrum.
- b. Delay mode fuze settings to result in optimum yields.
- c. Design specification for delay mode fuze systems.
- d. Structural design upgrading specification (if required).

3. Impact Environments Analysis for Other Warheads

The present program and the above recommended study areas were geared to the MK82 warhead. These same studies which include fuze environments specification and structural integrity evaluation can be conducted for other warhead configurations, such as MK84, M117, M118, HSM, Bullpup, 2.75-inch rocket, and other similar types.

APPENDIX I

155MM FUZE ENVIRONMENTS PROGRAM SUMMARY

The 155mm Fuze Environments Program, Contract No. DAAA21-71-C-0517, was conducted by the contractor for Picatinny Arsenal to establish the forces acting on the 155mm projectile for impacts into sand and soil targets to develop a Three-Dimensional Impact and Penetration Computer Code for simulation of the terminal impact event. This activity was successfully completed in September 1972.

The two principal objectives of the Phase I activity were:

1. Develop a resistance-to-penetration-force law for projectile impacts into sand and soil targets.
2. Develop a Three-Dimensional Impact and Penetration Computer Program.

The first objective was satisfied by an analytical and experimental program which resulted in verified force laws for projectile impacts into sand and soil targets. This activity was conducted over the first five months of the program. The second effort, which resulted in the successful development of the computer code, was conducted over a seven-month period.

The technical approach utilized to develop the sand and soil penetration force laws consisted of the conduct of two test programs. In the first one, both spinning and non-spinning 20mm projectiles were impacted into sand and soil targets. In the second test program, full-caliber 155mm projectiles were impacted into sand targets. In both test programs, the targets were instrumented with velocity grids and yaw cards positioned along the trajectory of the projectile, both in and out of the target. These were used to monitor the projectile position and orientation time histories during the penetration event. In addition, flash x-ray was also utilized to monitor the impact event for the 20mm tests. These tests were conducted for a variety of impact angles and obliquities to ensure that the final force law was applicable across the entire range of impact variables.

Typical analytical prediction versus test trajectories are shown in Figures I-1 through I-6. The dotted lines represent the test data while the solid line and the projectile drawings are generated by the 2-D Code graphical output routines. It is evident from the figures that excellent agreement is obtained between theory and test.

The results of the non-spinning 20mm tests were then analyzed and simulated using the contractor's Two-Dimensional Impact and Penetration Computer Code. This code, which simulates the impact and penetration of a non-spinning projectile into a target medium, utilizes a general resistance to penetration force. The analysis was conducted by parametrically varying the force law coefficients and target surface effects, such as chipping and cratering, until all the test results were successfully simulated. Since the test simulations

were conducted for various velocities and obliquities, this demonstrated the satisfactory performance of the sand and soil force laws over the impact velocity and angle range of interest.

Once the development of the force law was successfully completed, the development of the Three-Dimensional (6-degree-of-freedom) Impact and Penetration Computer Code was begun. The development of this computer code resulted in an analytical tool with the capability to simulate the three-dimensional motion and forces acting upon a spinning projectile impacting into sand and soil. Upon completion of the 3-D Code, it was used to simulate the spinning 20mm tests and the full-scale 155mm sand impact tests. The results of this analysis indicated that the code was functioning properly, and it could be used to simulate and analyze 6-degree-of-freedom sand impact and penetration events.

This program was successful in accomplishing all of the study and testing objectives. The most noteworthy accomplishments include:

- (1) Successful test program - The testing and instrumentation procedures were more than adequate to provide the required trajectory/time history data.
- (2) 3-D Code development - The computer program was generated, is operational, and simulates three-dimensional motion of a projectile impacting, penetrating, and/or ricocheting into sand or soil targets.
- (3) Determination of projectile impact loading environments and resulting trajectories through analytical simulation - Both the 20mm non-spinning and the spinning 20mm and 155mm impact test conditions have been analytically simulated with the 2- and 3-D Codes, respectively. The results of these simulations are the applied resistance to penetration loading environments which the projectile experiences during the penetration event.

The overall results of the program involve a significant advancement in the state-of-the-art of impact environment technology. This program has resulted in the demonstrated ability to determine impact environments through analytical simulation.

20 MM PROJ - SAND TARGET

R=0.30

L=2.04

GRNI=30.5

VEL=7800.

KCO=1.55

XM=0.21

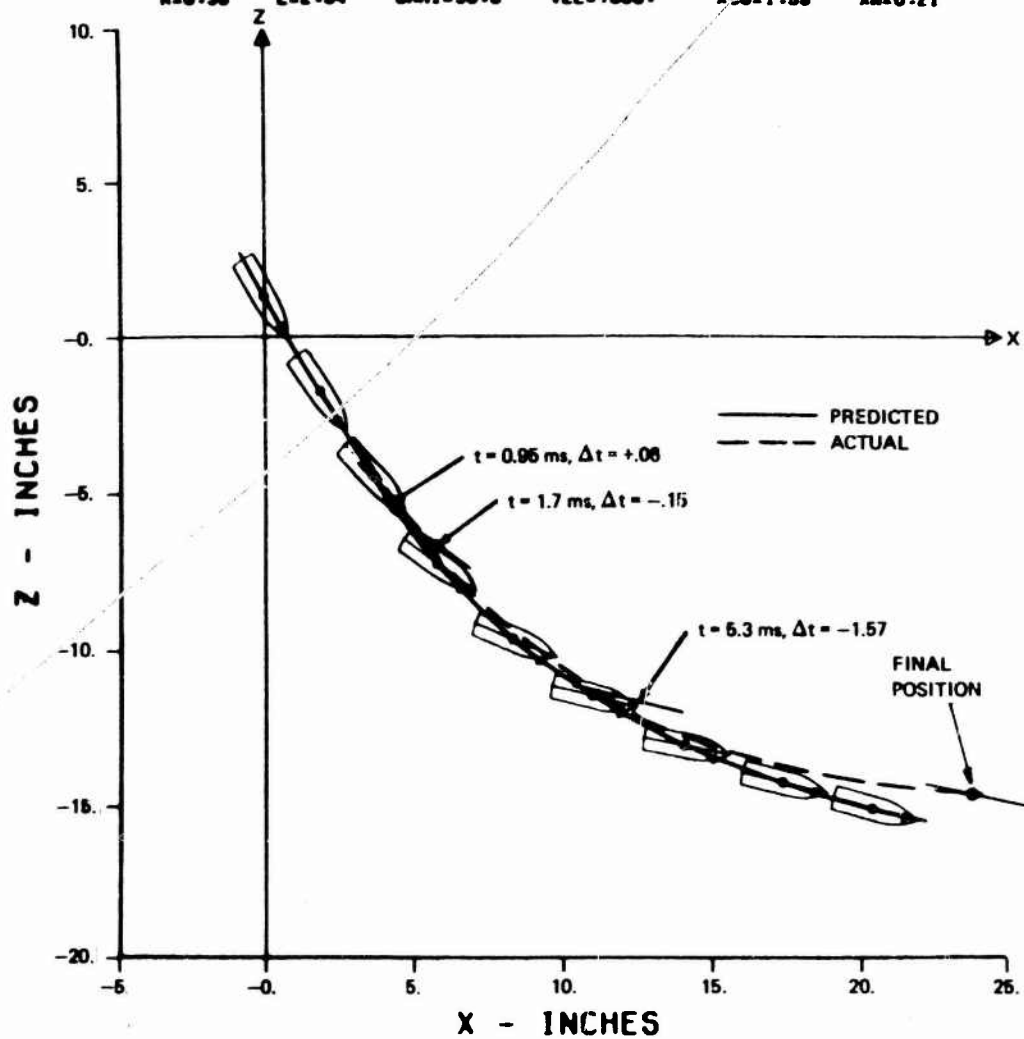


Figure I-1 SIMULATION RESULTS - TEST 8

20 MM PROJ - SAND TARGET

TEST 19

R=0.99

L=2.94

GAMI=68.0

VEL=8484.

XCG=1.55

XM=0.21

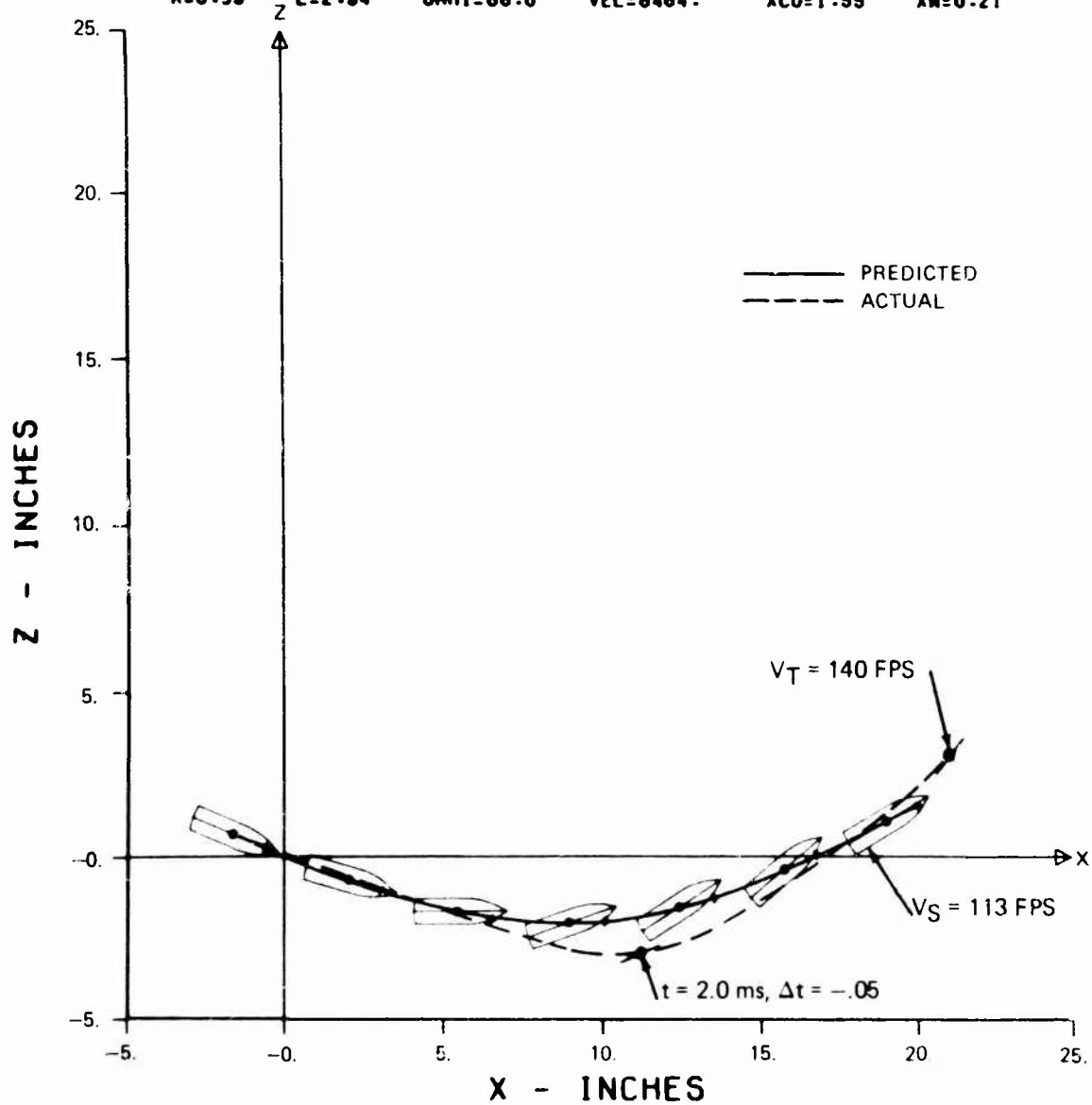


Figure 1-2 SIMULATION RESULTS - TEST 19

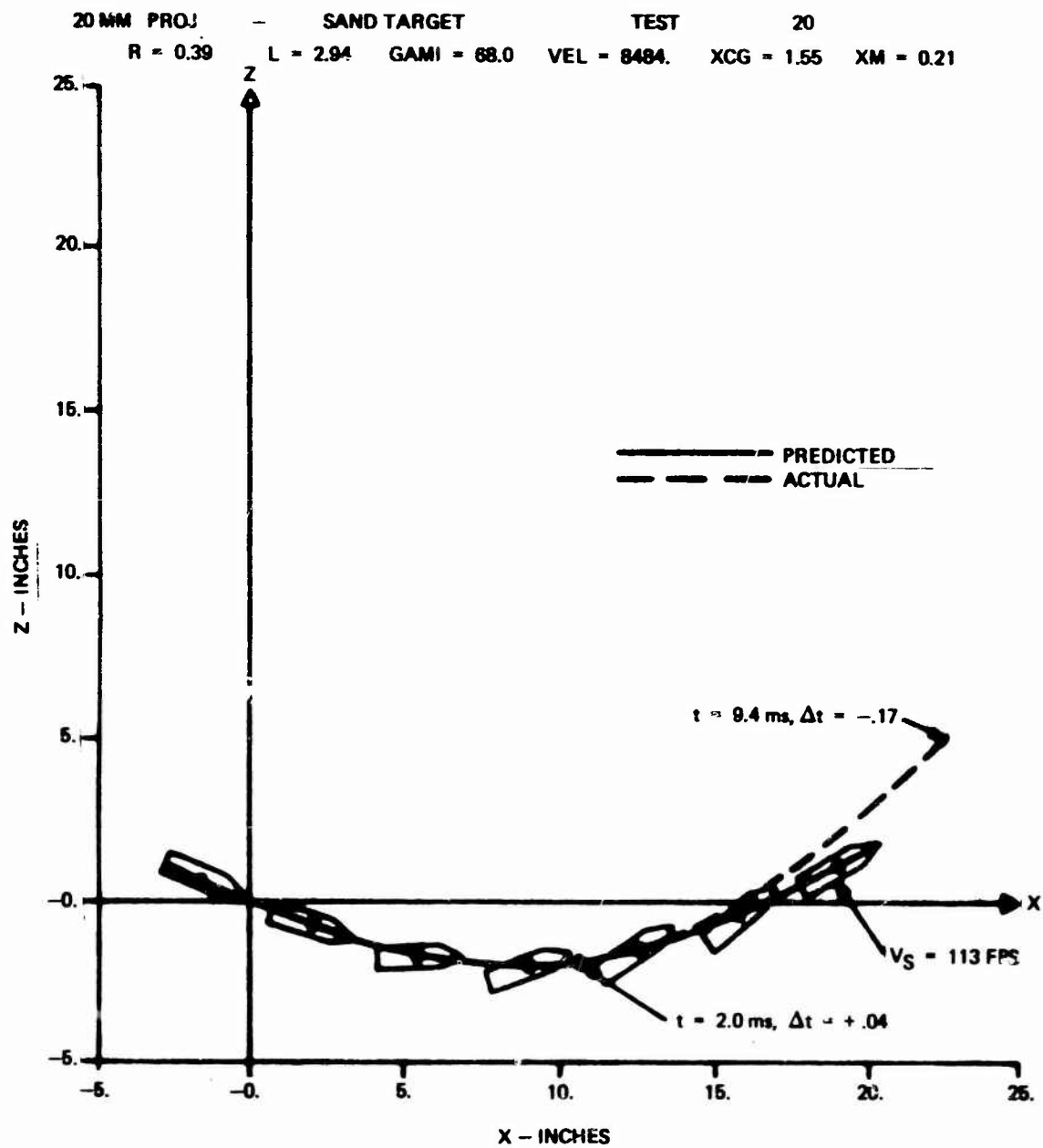


Figure I-3 SIMULATION RESULTS - TEST 20

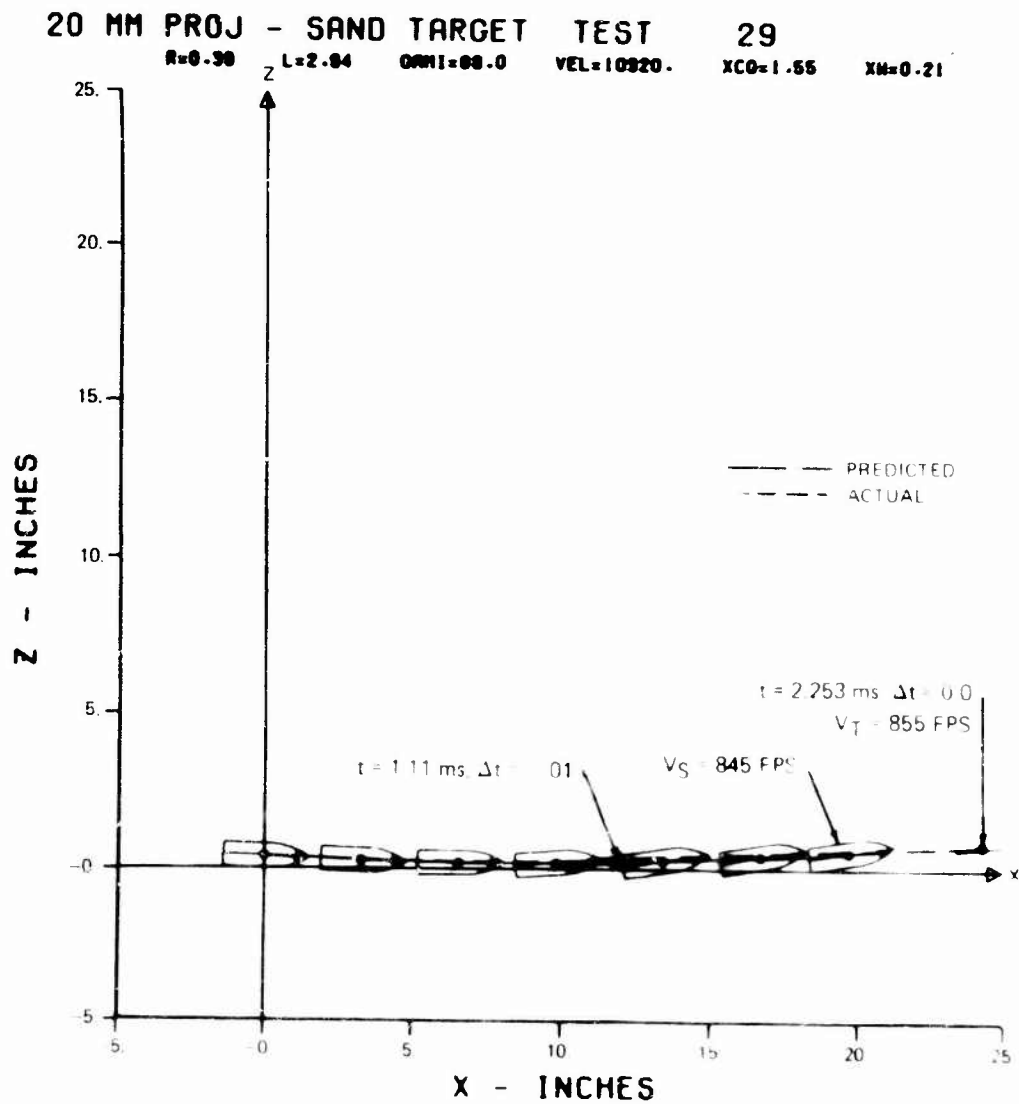


Figure 1-4 SIMULATION RESULTS - TEST 29

20 MM PROJ - SOIL TARGET TEST 40

R=0.00

L=2.04

GRNI=00.0

VCL=0.

MC0=1.05

XM=0.21

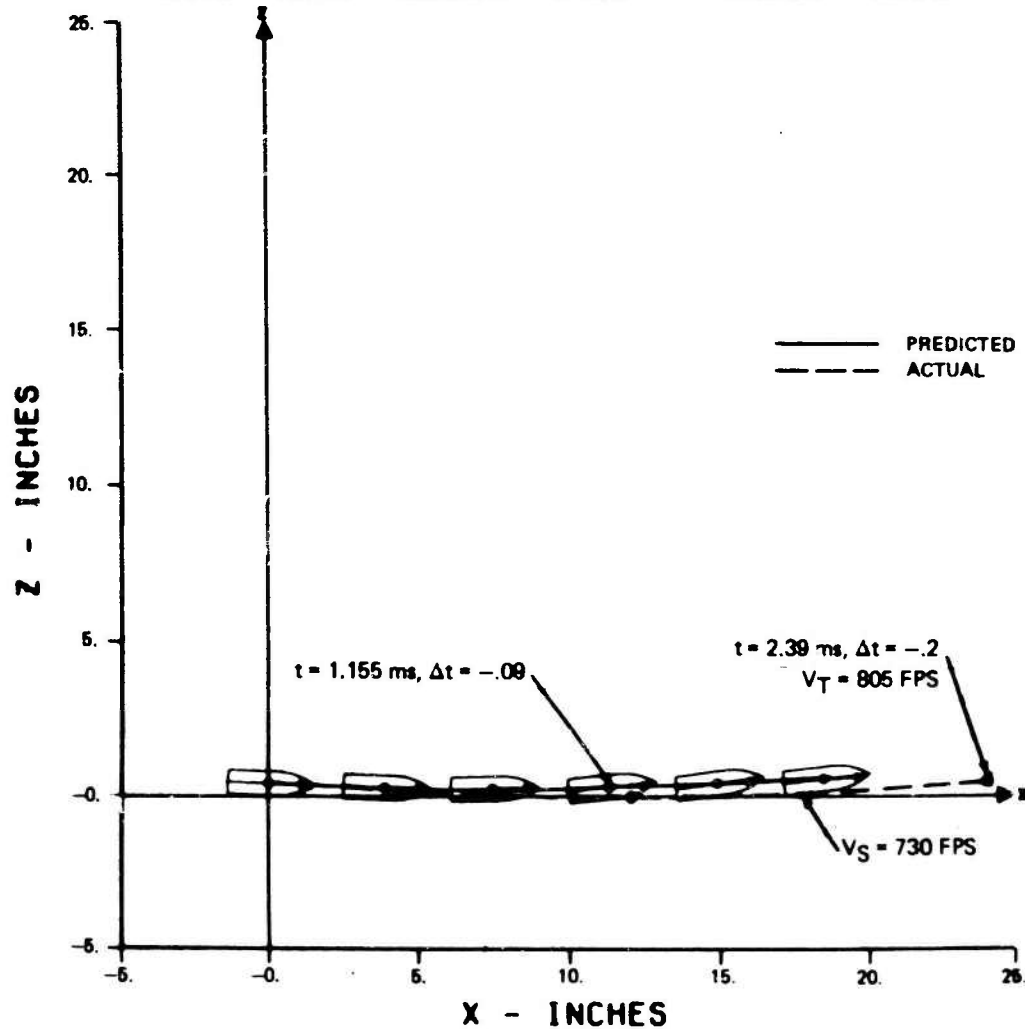


Figure I-5 SIMULATION RESULTS - TEST 40

20 MM PROJ - SOIL TARGET TEST 44
 $R=0.39$ $L=2.84$ $QAM1=68.0$ $VEL=0.$ $XCO=1.55$ $XM=0.21$

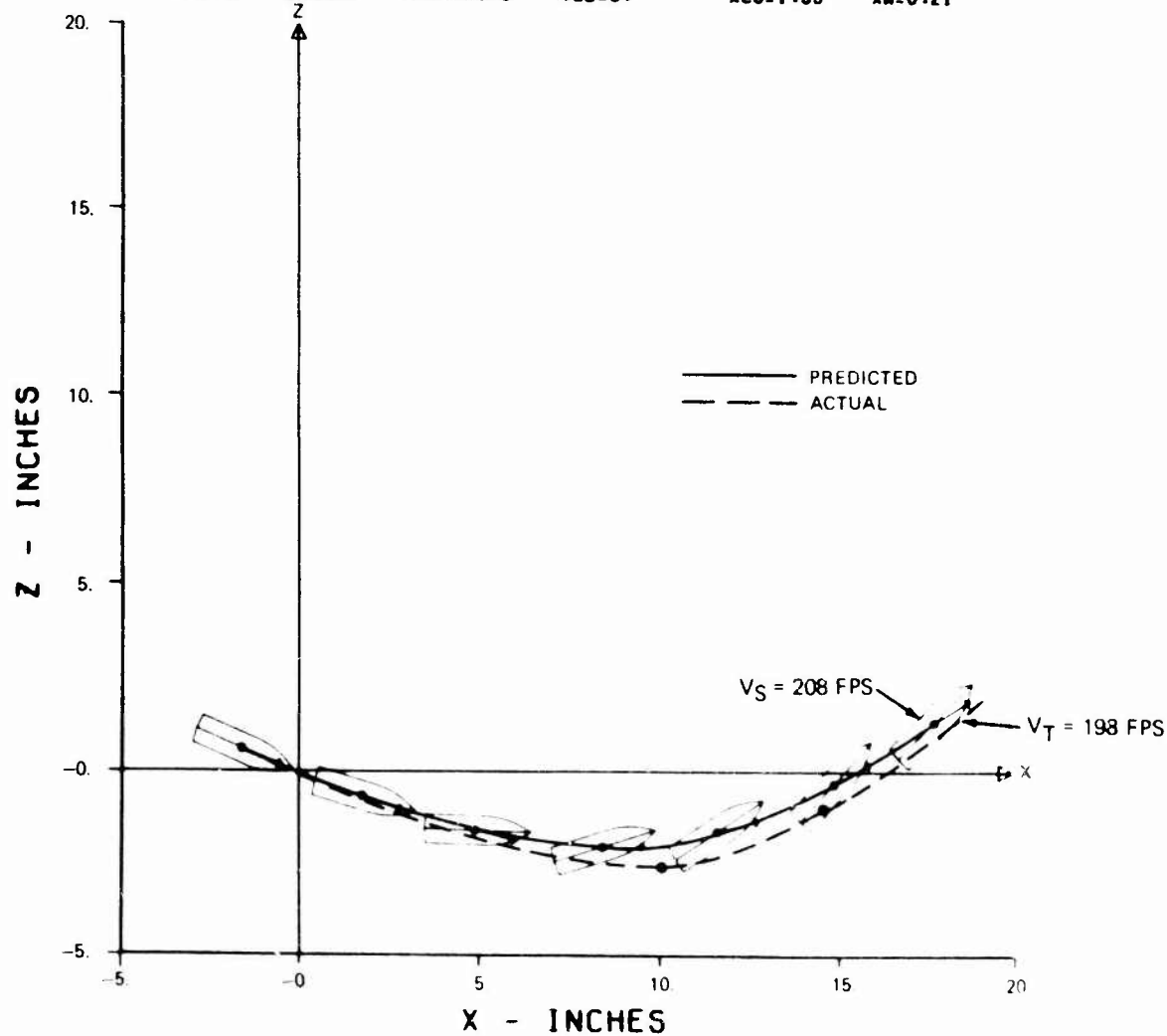


Figure 1-6 SIMULATION RESULTS - TEST 44

APPENDIX II

TWO-DIMENSIONAL PENETRATION COMPUTER CODE

INTRODUCTION

Figure II-1 depicts the general situation of an arbitrarily shaped projectile undergoing penetration into a resisting non-homogeneous media. Any analytical procedure which is developed for the purpose of predicting the trajectory and/or the loading distribution acting on the projectile during penetration must take into consideration all the pertinent conditions which influence those parameters. The obvious ones shown in Figure II-1 are:

1. Arbitrarily shaped projectile
2. Unsymmetrical and discontinuous loading due to
 - a. non-homogeneous material
 - b. discontinuous changes in material properties
 - c. angle of attack
 - d. flow separation and reattachment
 - e. angular velocity
 - f. instability
3. Obliquity

It is intended here to describe an approach and the analyses conducted for the purpose of generating a 2-dimensional impact and penetration simulator which solves the general penetration problem.

DISCUSSION

Most of the previous work on penetration has been concerned with normal impacts and homogeneous resisting media.

Due to symmetry, this impacting situation immediately eliminates a majority of the penetration complexities, namely asymmetrical loadings. Poncelet's equation (see Equation II-1) for predicting the axial loads acting on a projectile during normal impacts and penetration, through many different types of materials, has been demonstrated to be reasonably reliable.

$$F/A = \eta + CV^2 \quad (II-1)$$

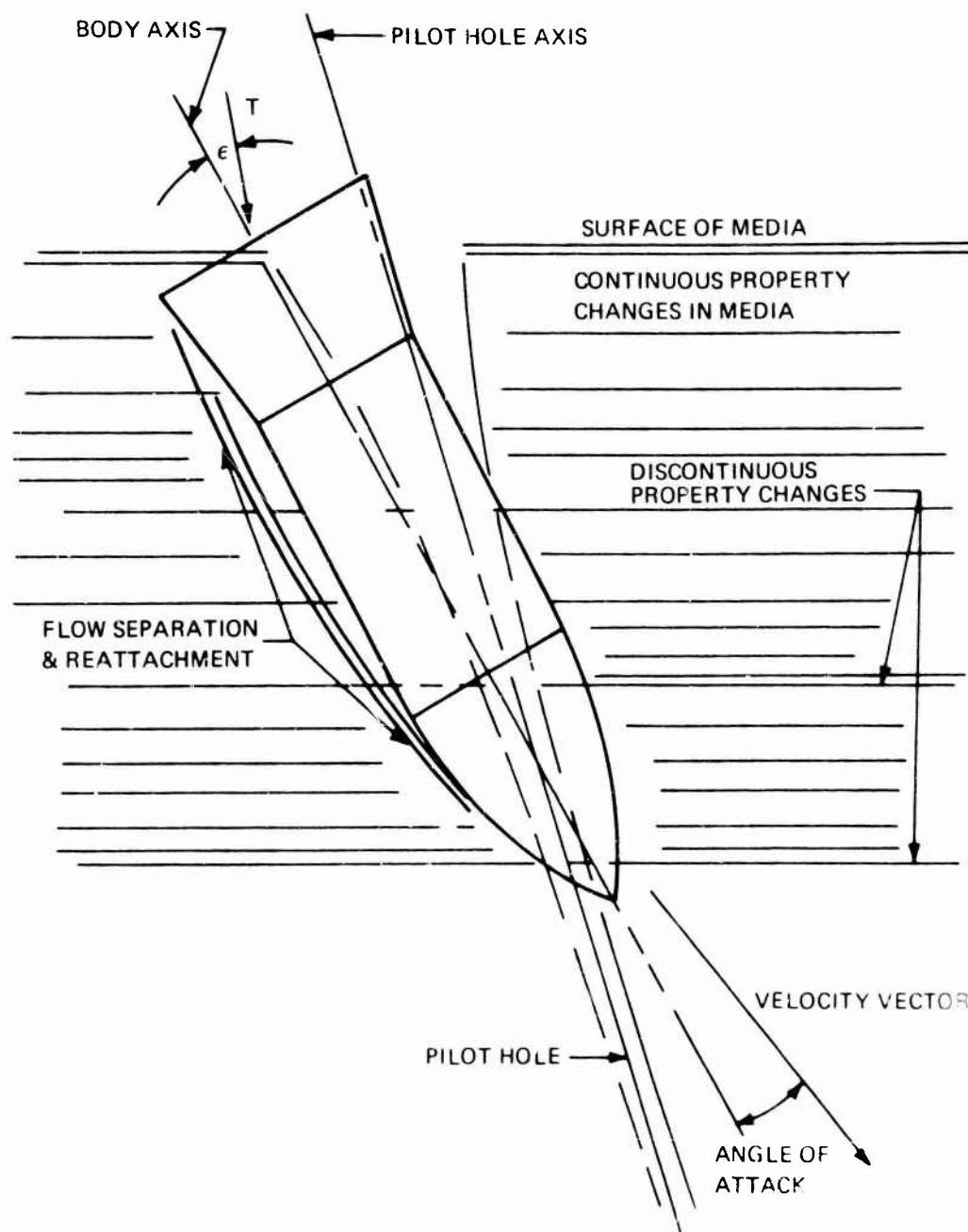


Figure II-1 GENERAL PENETRATION SITUATION

Several improvements have been suggested by investigators such as Allen, Mayfield and Morrison (Reference II-1) who determined that the relationships:

$$F/A = CV^2 \text{ for } V_0 > V > V_c$$

and

$$F/A = \eta + CV^2 \text{ for } V_c > V > 0$$

where

V_0 = impact velocity

V_c = critical velocity (apparently associated with the speed of sound in the media)

fit the data generated from a series of sand penetration tests better than Poncelet's. Figure II-2 presents some typical data that they generated which supports their contention. However, the difference between the above analytical representation and a modified version of Poncelet's, the power series in V (see Equation II-2) appears to be negligible.

$$F/A = \eta + BV + CV^2 \quad (\text{II-2})$$

These theories, however, are concerned primarily with predicting the resultant axial force acting on a projectile. The axial force, however, is only one component of the forces acting upon an elemental area. The other components, because of symmetry (in the case of normal impact), cancel one another.

It is also considerably easier to determine experimentally the axial acceleration and/or penetration depth of a projectile than to determine the pressure distribution, for example, around the surface of a projectile. Hence, less effort has been expended toward the understanding of these other force components.

The resistance to penetration force law to be incorporated in the 2-D simulator will be general in form, i.e.,

$$\frac{dF}{dA} = \text{Impact shock (compressibility effect)} + \dots + \text{etc.}$$

The necessity of being able to define the forces acting on an individual element becomes apparent when considering other than normal impacts and penetrations. Oblique and angle-of-attack impacts or penetrations through non-homogeneous materials will result in non-cancellation of transverse forces, and the projectile will undergo two- or three-dimensional motion. For the penetration projectile designer, these transverse loads will mean combined axial and bending stresses and therefore a different emphasis on structural design. For the systems engineer, the curvilinear trajectories will mean more complex target analysis and projectile shape optimization.

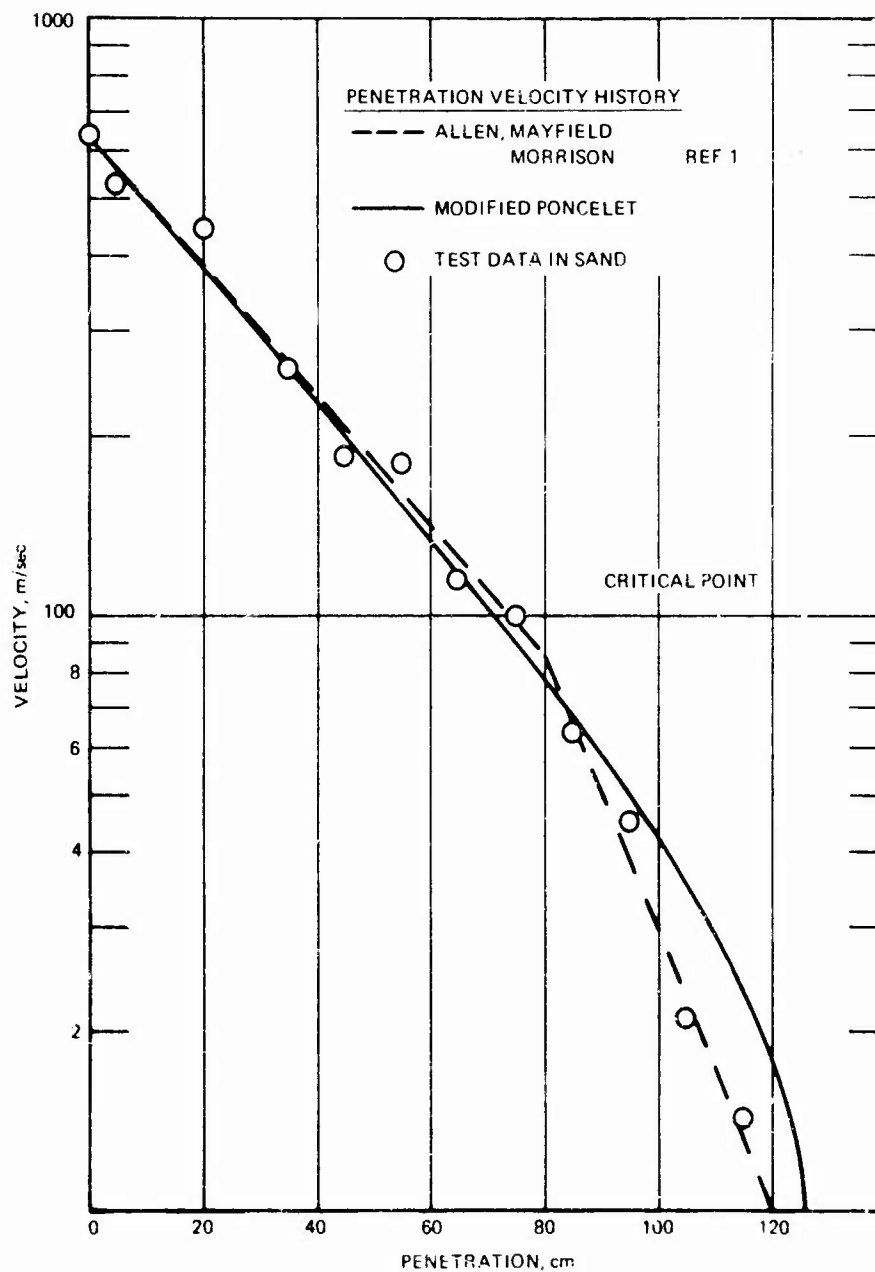


Figure II-2 PENETRATION VELOCITY HISTORY

In order to investigate these phenomena, the 2-D impact and penetration simulator has been developed. The code is used to predict:

1. The trajectory during penetration in a non-homogeneous media, i.e.,
 - a. Linear changes of material properties with depth.
 - b. Discontinuities of material properties at discrete depths.
2. The loading distribution over the entire surface area of the projectile.
3. The above phenomena for any body of revolution.
4. Flow separation and reattachment (The stability of a penetrating projectile can largely depend upon this characteristic.)

BASIC APPROACH

The complexity of the discontinuous loads and the desirability of determining the loading distribution acting on the projectile has led to the approach of dividing the projectile into elemental lengths and considering each length individually during penetration. The equations of motion are integrated numerically. The elemental lengths are fixed and can be represented by a truncated cone; consequently, the loading distribution around the truncated cone can be found by integrating the force law with respect to ϕ (the azimuth position of an elemental area dA) alone. The force on an elemental area dA is a defined function by the general force law. Discontinuous changes influence the loads acting on the position of the elemental length at each instant of time, solving the geometry of the position, thus determining the various limits on ϕ (representing location of the discontinuous changes) and performing multiple integrations of the force law. The total forces acting on the elemental length are determined by summing these results, and the total forces and moments acting on the projectile are the sum of the incremental forces and moments. This procedure is further defined in the subsequent section on the analysis.

ANALYSIS

Nomenclature

- | | |
|-------------|---|
| γ | angular position of projectile longitudinal axis relative to the inertial z-axis |
| $\theta(i)$ | incremental half-cone angle |
| ϕ | angular position of elemental area dA about z' axis ($\phi = 0$ along y') |
| η | is the theoretical structural resistance force required to pull a body through the resisting media; it acts in the direction of the velocity vector |
| B | a frictional coefficient (included for completeness) acting in the direction of the velocity vector |

U	velocity vector
C_p	terradyamic pressure coefficient
C_r	terradyamic shear coefficient
P	terradyamic pressure acting normal to the surface area
r	terradyamic shear force acting along the projected velocity vector in the plane of the elemental area
ψ	angle between the velocity vector U and the plane of the elemental area dA
q	dynamic pressure $1/2 \rho U^2$
α	angle of attack
$r(i)$	radius of elemental length
dL	elemental length
V_N	normal velocity component
ρ	density of resisting media (a function of depth)
M_{cg}	moment acting (on projectile) around the center of gravity
T	thrust
ϵ	thrust misalignment
w	projectile weight
β	rotation of inertial coordinate system from vertical
ω	projectile angular rate
N_e	number of elements

Coordinate System

A set of inertial coordinates x , y , and z are used to reference the motion and displacement of the projectile. The z -axis is normal to, and points away from, the plane of the media to be penetrated. The x -axis is parallel to the plane of the media, and the y -axis forms the orthogonal triad. The origin is located at the initial position of the center of gravity of the projectile (see Figure II-3).

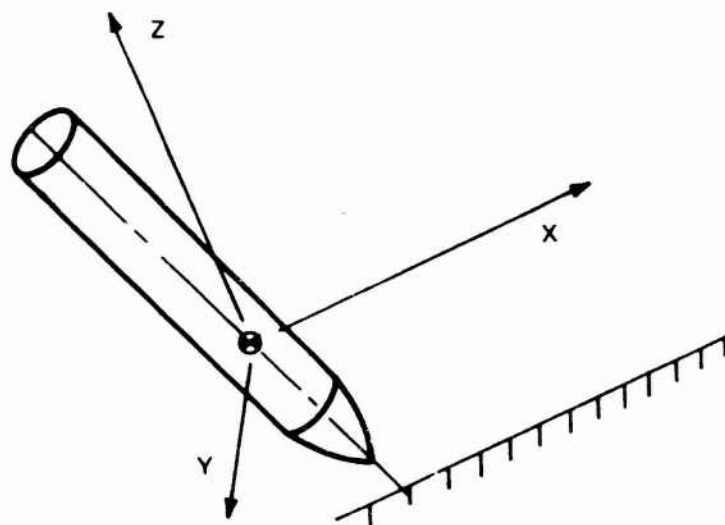


Figure II-3 INERTIAL COORDINATE SYSTEM

A body fixed set of coordinates x' , y' , and z' is used to orient the forces and moments acting on the body, and as only two-dimensional motion is considered, it is obtained in this use by a rotation γ about the y -axis (see Figure II-4).

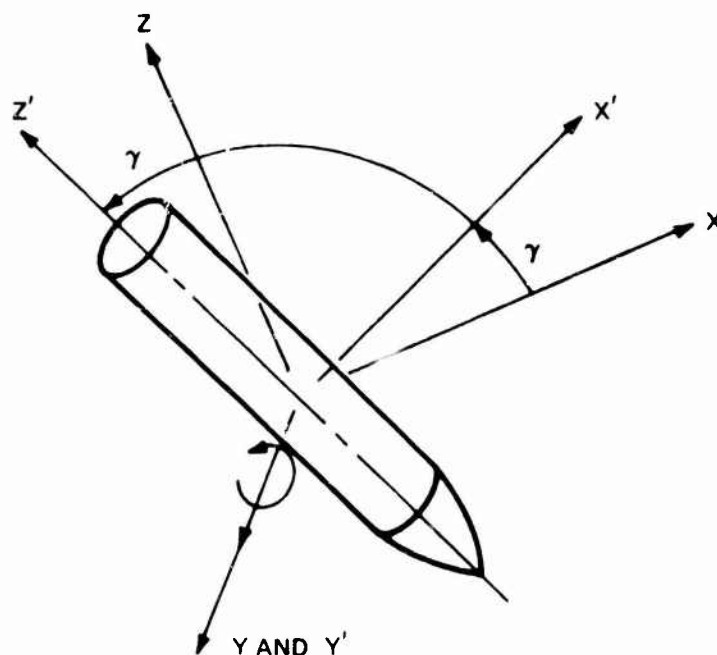


Figure II-4 BODY FIXED COORDINATE SYSTEM

The z' axis is directed aft along the longitudinal axis of the projectile, and the x' axis is in the plane of motion.

A third coordinate system is needed in which the elemental forces acting on the body are derived. This set, x''' , y''' , and z''' , is obtained by two more rotations: ϕ , the azimuth position of an elemental area dA measured around the z' axis, and θ , the elemental half-cone angle of dA measured about the x'' axis as shown in Figure II-5.

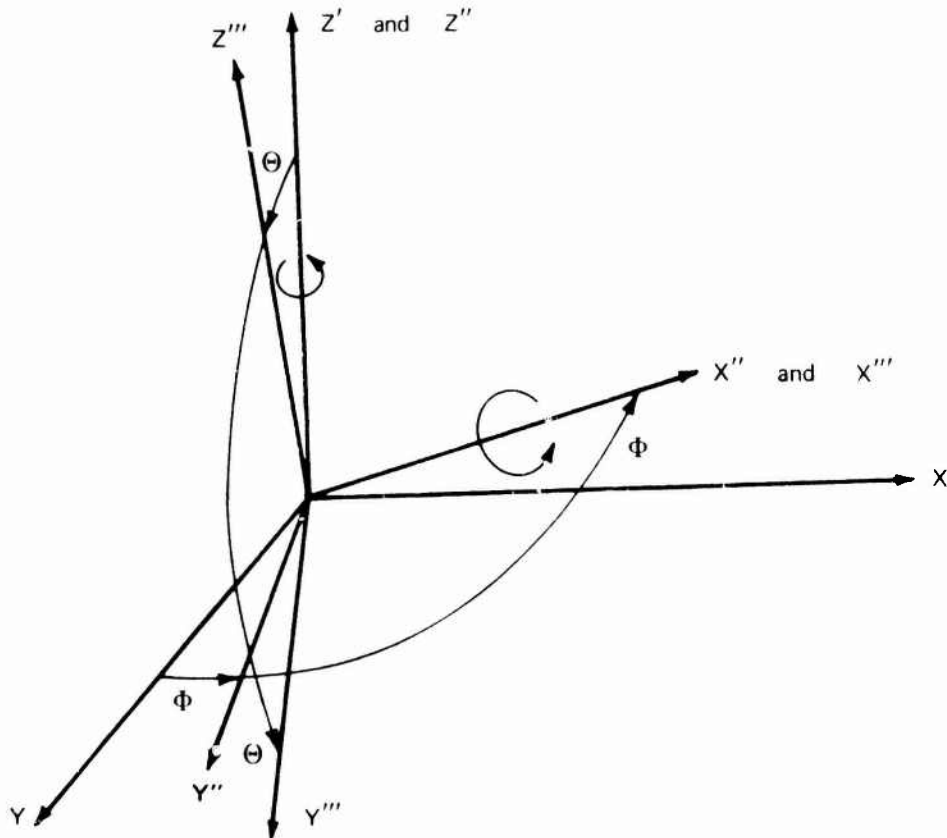


Figure II-5 ELEMENTAL FORCE COORDINATE SYSTEM

The y''' axis, therefore, is an axis normal to the elemental area dA while the x''' and z''' axes lie in the plane of the element.

The transformation matrix between the inertial set and the elemental set is:

$$\begin{vmatrix} z''' \\ x''' \\ y''' \end{vmatrix} = \begin{vmatrix} C\theta C\phi + S\theta S\phi S\gamma - C\theta S\gamma + S\theta S\phi C\gamma S\theta C\phi \\ C\phi S\gamma & C\phi C\gamma & -S\phi \\ -S\theta C\gamma + C\theta S\phi S\gamma & S\theta S\gamma + C\theta S\phi C\gamma C\theta C\phi \end{vmatrix} \begin{vmatrix} z \\ x \\ y \end{vmatrix} \quad (\text{II-3})$$

where the C's and S's represent cosines and sines, respectively.

Force Law

The forces acting upon an elemental surface area are:

$$dF/dA = \eta \leftrightarrow BU \leftrightarrow CU^2 \quad (II-4)$$

$$dF = \eta dA_p \leftrightarrow BU dA_p \leftrightarrow dP \leftrightarrow dr \quad (II-5)$$

where:

$$dP = C_p \sin^2 \psi q dA$$

$$d = C_r \sin \psi \cos \psi q dA$$

as derived in Reference II-3.

In the body frame, the transverse force function is:

$$dF_x' = \eta \sin \alpha dA_p + BU \sin \alpha dA_p \quad (II-6)$$

$$dP \sin \phi \cos \theta + dr \cos \xi \cos \phi$$

and the axial force function is:

$$dF_z' = \eta \cos \alpha dA_p + BU \cos \alpha dA_p - dP \sin \theta + dr \sin \xi \cos \theta \quad (II-7)$$

or

$$dF_x' = \sum_{i=1}^4 dF_x' (i) \quad (II-8)$$

$$dF_z' = \sum_{i=1}^4 dF_z' (i) \quad (II-9)$$

In view of the approach to divide the projectile into elemental lengths, the elemental area is:

$$dA = r(i) dL / \cos \theta (i) d\phi \quad (II-10)$$

the projected area (on a plane perpendicular to the velocity vector) is:

$$dA = dA \sin (\theta \alpha \sin \phi) \quad (II-11)$$

Normally, penetration where large angles of attack are produced are of no interest; therefore assuming small results in:

$$dF_x'(1) = \eta (\sin \phi + \cos \theta \sin \phi a) \sin a \, dA \quad (II-12)$$

Substituting and performing the indicated integration with respect to ϕ gives

$$F_x'(1) = A x_1 (\phi_2 - \phi_1) - B x_1 (\cos \phi_2 - \cos \phi_1) \quad (II-13)$$

where $A x_1$ and $B x_1$ are functions of η , r , ΔL , θ , and a and projectile geometry.

Similarly:

$$F_x'(2) = U [A x_2 (\phi_2 - \phi_1) - B x_2 (\cos \phi_2 - \cos \phi_1)] \quad (II-14)$$

The terms $F_x'(3)$ and $F_x'(4)$ contain ρ and ψ , both functions of ϕ .

$$dF_x'(3) = C_p \sin^2 \psi \, 1/2 \rho U^2 \, dA \quad (II-15)$$

but

$$U^2 \sin^2 \psi = V_N^2 = (\dot{y}''')^2$$

and from Eq. II-1

$$V_N = (S\phi S\gamma - C\phi\gamma S\phi) \dot{z} + (-S\phi S\gamma + C\theta C\gamma S\phi) \dot{x} \quad (II-16)$$

and assuming ρ is a linear variation with depth leads to:

$$\rho = A_p + B_p \sin \phi \quad (II-17)$$

where A_p and B_p are functions of the projectile geometry and γ .

Substituting and performing the indicated operations results in:

$$\begin{aligned} F_x'(3) = & F \cos \theta \left\{ -A_p (\cos \phi_2 - \cos \phi_1) \right. \\ & + B_p \left[\frac{\phi_2 - \phi_1}{2} - \frac{\sin^2 \phi_2 - \sin^2 \phi_1}{4} \right] \\ & + C_p [\cos \phi_1 - \cos \phi_2 + (\cos^3 \phi_2 - \cos^3 \phi_1)^{1/3}] \\ & + D_p \left[\frac{3(\phi_2 - \phi_1)}{8} - \frac{3}{16} (\sin \phi_2 - \sin \phi_1) \right] \\ & \left. - 1/4 (\sin^3 \phi_2 \cos \phi_2 - \sin^3 \phi_1 \cos \phi_1) \right\} \end{aligned} \quad (II-18)$$

where the coefficients are again functions of C_p , r , ΔL , θ , α , $\dot{z}$, $\dot{x}$, ω , C_r and projectile geometry.

$$dF_x'(4) = C_r \sin \psi \cos \psi \frac{1}{2} \rho U^2 \cos \xi \cos \phi dA \quad (II-19)$$

but

$$\cos \xi = \frac{\dot{x}'''}{U \cos \psi}$$

and

$$U \sin \psi = V_N = \dot{y}'''$$

$$\dot{x}''' = C_\phi S_\gamma \dot{z} + C_\phi C_\gamma \dot{x}$$

Substituting and integrating leads to a form similar to Eq. (II-18) but with different coefficients. In the same manner, the expression for $F_z(i)$ can be obtained.

For each force term, the integration limits $\phi(i)$'s are obtained as a function of:

1. Discontinuities in the resisting media.
2. Pilot hole geometry and location.
3. Where the normal velocity component V_N goes to zero (see Figure II-6).

The total force acting on each element of length is then the sum of the forces for each set of integration limits, while the resultant forces acting on the projectile is the sum of the forces acting on each element.

In the inertial coordinate system:

$$F_x = - \sum_{n=1}^{N_e} F_z'(n) \sin \gamma + \sum_{n=1}^{N_e} F_x'(n) \cos \gamma + W \sin \beta + T \sin \epsilon \cos \gamma \quad (II-20)$$

$$F_z = \sum_{n=1}^{N_e} F_z'(n) \cos \gamma + \sum_{n=1}^{N_e} F_x'(n) \sin \gamma + W \cos \beta + T \cos \epsilon \sin \gamma \quad (II-21)$$

$$M_{cg} = \sum_{n=1}^{N_e} [s(n) \cdot F_x'(n)] + T \sin \epsilon \cdot d \quad (II-22)$$

The equations of motion:

$$M\ddot{x} = F_x$$

$$M\ddot{z} = F_z$$

$$I\ddot{\gamma} = M_{cg}$$

are numerically integrated.

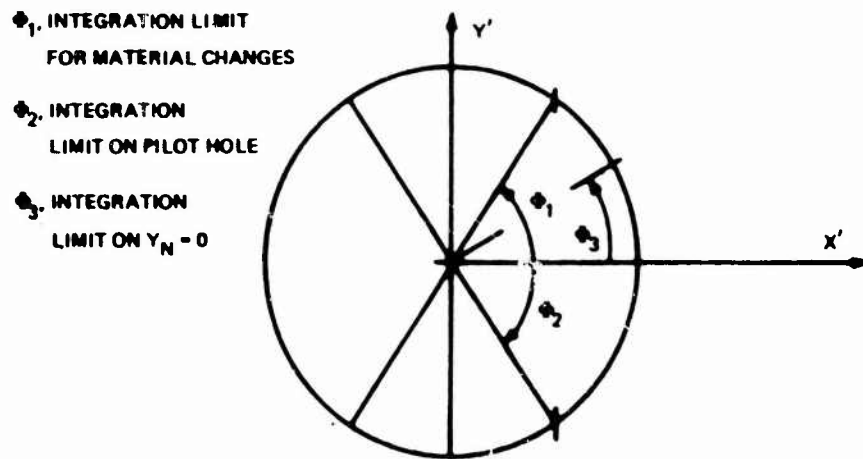
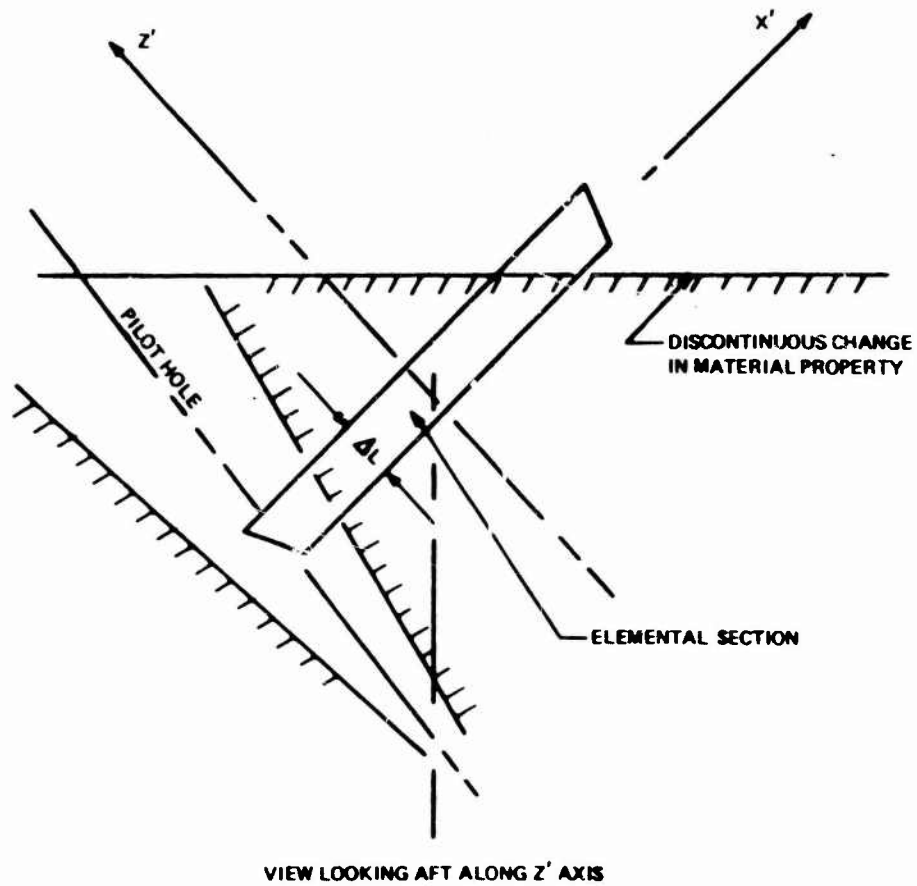


Figure II-6 INTEGRATION LIMIT DETERMINATION

REFERENCES

- II-1. Allen, W. A., Mayfield, E. B. and Morrison, H. L., "The Dynamics of Projectile Penetration in Sand", NAVORD 4980, U. S. Naval Ordnance Test Station (China Lake, California), December 7, 1955.
- II-2. RP/V Program Terradynamics Report, January 31, 1964, Avco/RAD (S).
- II-3. Hayes, W. D., Probstein, R. F., "Hypersonic Flow Theory", 1959, pg. 404.

APPENDIX III

PROGRAM 2947: STRUCTURAL RESPONSE CODES AND INTEGRATION ROUTINES

Program 2607

The dynamic models of complex structures can be formulated by finite element and/or lumped parameter techniques. The resultant equations of equilibrium of motion are second order simultaneous, differential equations in generalized coordinates.

A digital computer program has been written to compute the eigen values, eigen vectors, and modal damping matrix of the system (up to 150 degrees of freedom) and is registered in the Avco Mathematics Department under the code designation 2607. The eigen value and eigen vector routine used is a modified Householder-Givens routine (designated as the HOUSE routine).

Modal analysis is an important technique for computing the transient and steady state dynamic responses for any linear physical system. In its application to matrix methods of structural mechanics, where the mathematical model of a continuous structure can be formulated as the assembly of discrete elements, with its stiffness matrix (K) and mass matrix (M) computed by the finite element displacement method, the resulting linear system is

$$(M)(\ddot{x}) + (K)(x) = (F(t)).$$

In the solution of this linear system of second order equations by the modal method, it is very important to compute accurately the eigen values and eigen vectors. The main purpose of the Avco/IBM program 2607 is to compute the frequencies and mode shapes, utilizing the best current technique possible.

It has been demonstrated that the finite element method (based upon the principle of minimum potential energy) will yield solutions which converge to the exact solutions when the sizes of the finite elements are progressively reduced. Therefore, a fast routine to compute accurately the eigen values and eigen vectors of a large (n x n) real symmetric matrix associated with the homogeneous system $(M)(\ddot{x}) + (K)(x) = 0$ is highly desirable. Based upon past experiences and comparisons made with Avco Computer Program 1384 series and the FAMOUS Program of MIT, the most satisfactory routine based upon a modified Givens-Householder method has been chosen as the basic routine for Avco Computer Program 2607.

Upon determination of the eigen values, vectors and generalized damping matrix, the linear decoupled equations of modal motion could be solved under conditions of an applied generalized forcing function. This approach, however, presumes linearity which is generally not the case for projectile impact problems. For this situation, the above produced modal damping matrix is used and the coupled non-linear equations of motion are solved with the use of Program 1520 described in the next paragraph.

Program 2947

Dynamic analysis of missile structures (DAMS) is a program to solve numerically the generalized coordinate system of second-order, ordinary linear or nonlinear differential equations in the frequency range of structural models. The program was designed primarily to calculate transient responses of missile structures but may be used for other mechanical or electrical systems.

The system of equations to be solved is:

$$a_{11}\ddot{x}_1 + \dots + a_{1n}\ddot{x}_n + b_{11}\dot{x}_1 + \dots + b_{1n}\dot{x}_n + c_{11}x_1 + \dots + c_{1n}x_n = f_1(t, x_1, \dots, x_n, \dot{x}_1, \dots, \dot{x}_n)$$

.....

$$a_{n1}\ddot{x}_1 + \dots + a_{nn}\ddot{x}_n + b_{n1}\dot{x}_1 + \dots + b_{nn}\dot{x}_n + c_{n1}x_1 + \dots + c_{nn}x_n = f_n(t, x_1, \dots, x_n, \dot{x}_1, \dots, \dot{x}_n)$$

where a_{ij} , b_{ij} , c_{ij} are constants, the x_i 's are the coordinates of the system, and the f_i 's are arbitrary single-valued functions (linear or nonlinear).
Written in the matrix form of:

$$A\ddot{X} + B\dot{X} + CX = F(T, X, \dot{X})$$

where

$$A = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & . \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ a_{n1} & . & . & a_{nn} \end{bmatrix} \quad B = \begin{bmatrix} b_{11} & b_{12} & \dots & b_{1n} \\ b_{21} & . & . & . \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ b_{n1} & . & . & b_{nn} \end{bmatrix} \quad C = \begin{bmatrix} c_{11} & c_{12} & \dots & c_{1n} \\ c_{21} & . & . & . \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ c_{n1} & . & . & c_{nn} \end{bmatrix}$$

$$X = \begin{bmatrix} X_1 \\ X_2 \\ \cdot \\ \cdot \\ X_n \end{bmatrix}, \quad \dot{X} = \begin{bmatrix} \dot{X}_1 \\ \dot{X}_2 \\ \cdot \\ \cdot \\ \dot{X}_n \end{bmatrix}, \quad \ddot{X} = \begin{bmatrix} \ddot{X}_1 \\ \ddot{X}_2 \\ \cdot \\ \cdot \\ \ddot{X}_n \end{bmatrix}, \quad F = \begin{bmatrix} f_1 \\ f_2 \\ \cdot \\ \cdot \\ f_n \end{bmatrix}$$

The unique features of DAMS are the flexibility of analytically describing the forcing function; the specification of additional user-desired calculation and outputs by the users' own subroutines, and the graphical outputs that consist of displacement, velocity, acceleration, forcing function, and any user-specified function. As a minimum, the user only needs to specify the forcing function and other pertinent quantities peculiar to the differential equations. The outputs for this minimum input will be displacement, velocity, acceleration, and forcing function at each time step.

DDM4RK - INITIAL VALUE INTEGRATION ROUTINE

Solutions to initial value ordinary differential equations are frequently required in the work currently being done at the contractor facility. The method most often used is the fourth order Adams predictor-corrector technique as implemented in our library subroutine ADM4RK.

Method

A system of ordinary differential equations is numerically solved using an Adams predictor-corrector method. The predictor is an estimate of the function based on the value of the function at the last point and the values of the derivative at the last four points. The corrector is an estimate of the function based on the value of the function at the last point and the values of the derivative at the predictor and the last three points. The difference between the predictor and corrector is a measure of the error at a given step and this fact is used to vary the interval of integration for optimum performance.

APPENDIX IV
MK82 FUZE ACCELERATION
IMPACT ENVIRONMENT

TABLE IV-I. FUZE ENVIRONMENT SUMMARY MED2 WARHEAD

(Axial Response)

Sand Impacts

Time Regime 0.0 - 1.5 Milliseconds

Impact Conditions		Station	Response Data
γ ~deg	v ~In./sec		
20	13,200	26 - Forward Fuze	Acceleration
25			
30			
35			
40			
45			
55			
60			
65			
70			
20		26 - Forward Fuze	
25		24 - Aft Fuze	
30			
35			
40			
45			
55			
60			
65			
70	13,200	24 - Aft Fuze	
20	10,800	26 - Forward Fuze	
25			
35			
40			
45			
55			
65			
70			
20		26 - Forward Fuze	
25		24 - Aft Fuze	
35			
40			
45			
55			
65			
70			
20		26 - Forward Fuze	
25		24 - Aft Fuze	
35			
40			
45			
55			
65			
70	10,800	24 - Aft Fuze	Acceleration

TABLE IV-I. FUZE ENVIRONMENT SUMMARY MK82 WARHEAD (Cont'd)

Impact Conditions		Station	Response Data
γ ~deg	V ~In./sec		
20	7,200	26 - Forward Fuze	Acceleration
25			
30			
35			
40			
45			
55			
60			
65			
70			
20	7,200	26 - Forward Fuze	Acceleration
25		24 - Aft Fuze	
30			
35			
45			
55			
65			
70			
20	13,200	5 - Forward End of Forward Fuze	Acceleration
35			
45			
55			
65			
70			
20	13,200	43 - Aft End of Forward Fuze	Acceleration
35			
45			
55			
65			
70			
20	13,200	41 - Forward End of Aft Fuze	Acceleration
35			
45			
55			
65			
70			

TABLE IV-I. FUZE ENVIRONMENT SUMMARY MK82 WARHEAD (Cont'd)

Impact Conditions		Station	Response Data
γ ~deg	V ~In./sec		
20	13,200	39 - Aft End of Aft Fuze	Acceleration
35	↓	↓	
45			
55	↓		
65		39 - Aft End of Aft Fuze	
70	13,200		
20	10,800	5 - Forward End of Forward Fuze	
25	↓	↓	
35			
45			
55		5 - Forward End of Forward Fuze	
65			
70		43 - Aft End of Forward Fuze	
20		↓	
25		43 - Aft End of Forward Fuze	
35			
45		41 - Forward End of Aft Fuze	
55		↓	
65		41 - Forward End of Aft Fuze	
70		39 - Aft End of Aft Fuze	
20		↓	
25			
35			
45			
55		39 - Aft End of Aft Fuze	
65	10,800		
70		5 - Forward End of Forward Fuze	Acceleration
20	7,200	↓	
25			
35			
45			
55		5 - Forward End of Forward Fuze	
65	↓		
70	7,200		

TABLE IV-I. FUZE ENVIRONMENT SUMMARY MK82 WARHEAD (Concl'd)

Impact Conditions		Station	Response Data
γ ~deg	V ~In./sec		
20	7,200 ↓	43 - Aft End of Forward Fuze	Acceleration ↓
25			
35			
45			
55			
65		43 - Aft End of Forward Fuze	
70			
20		41 - Forward End of Aft Fuze	
25			
35			
45			
55			
65		41 - Forward End of Aft Fuze	
70			
20	↓ 7,200	39 - Aft End of Aft Fuze	↓ Acceleration
25			
35			
45			
55			
65		39 - Aft End of Aft Fuze	
70			

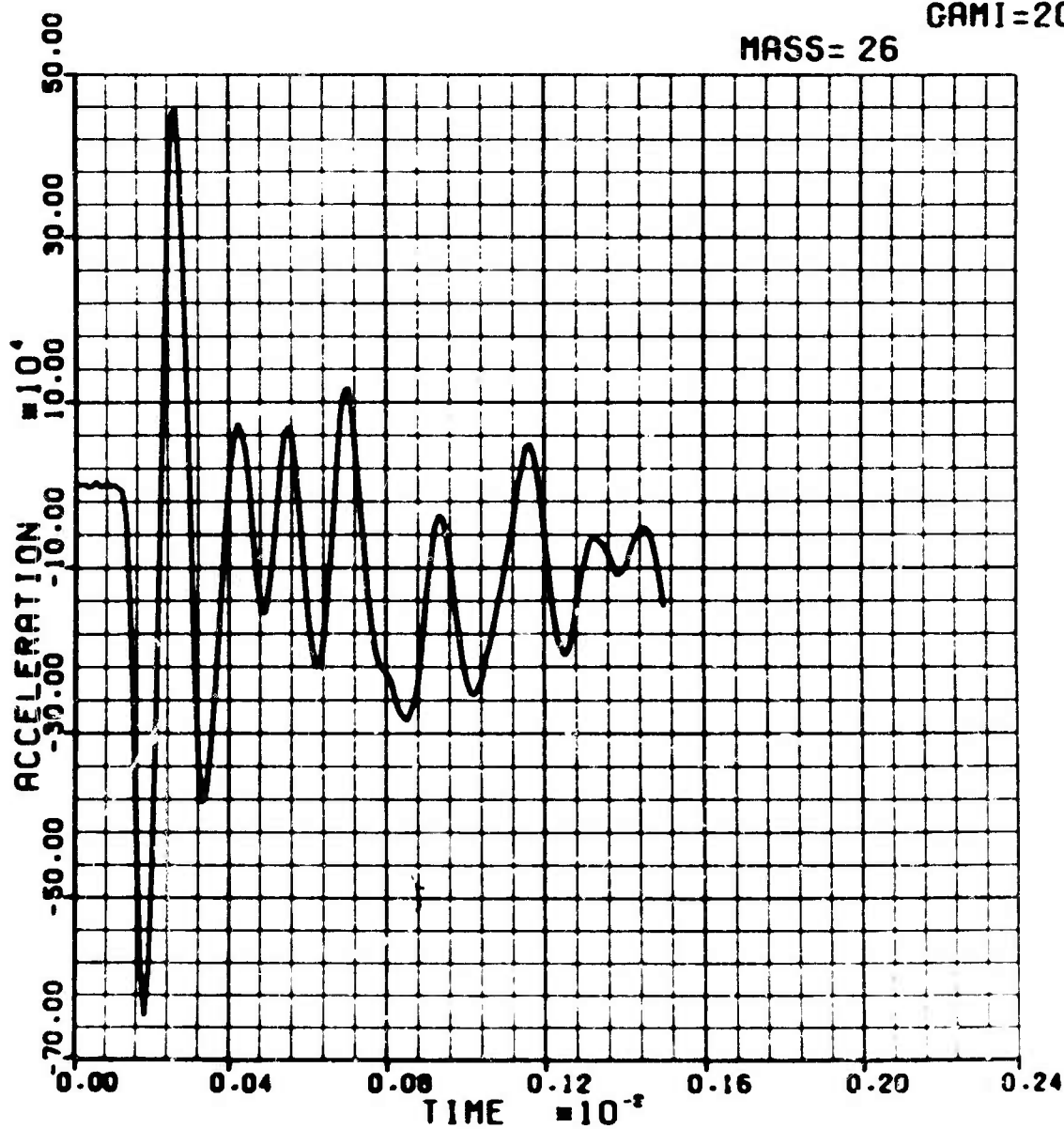
MK82 (AXIAL)

SAND TARGET

VEL=13200.

GAMI=20.0

MASS= 26



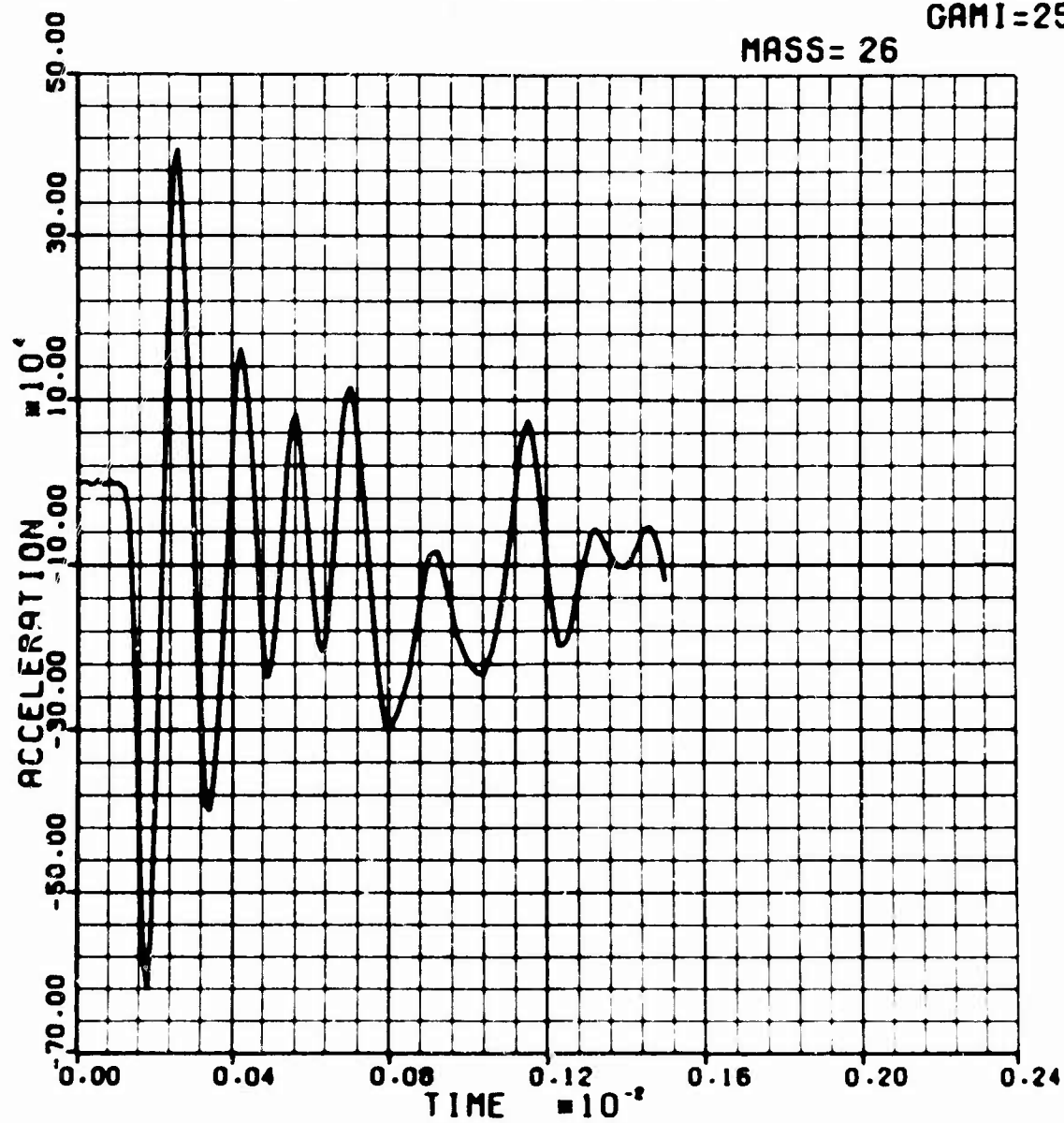
MK82 (AXIAL)

SAND TARGET

VEL=13200.

GAMI=25.0

MASS= 26



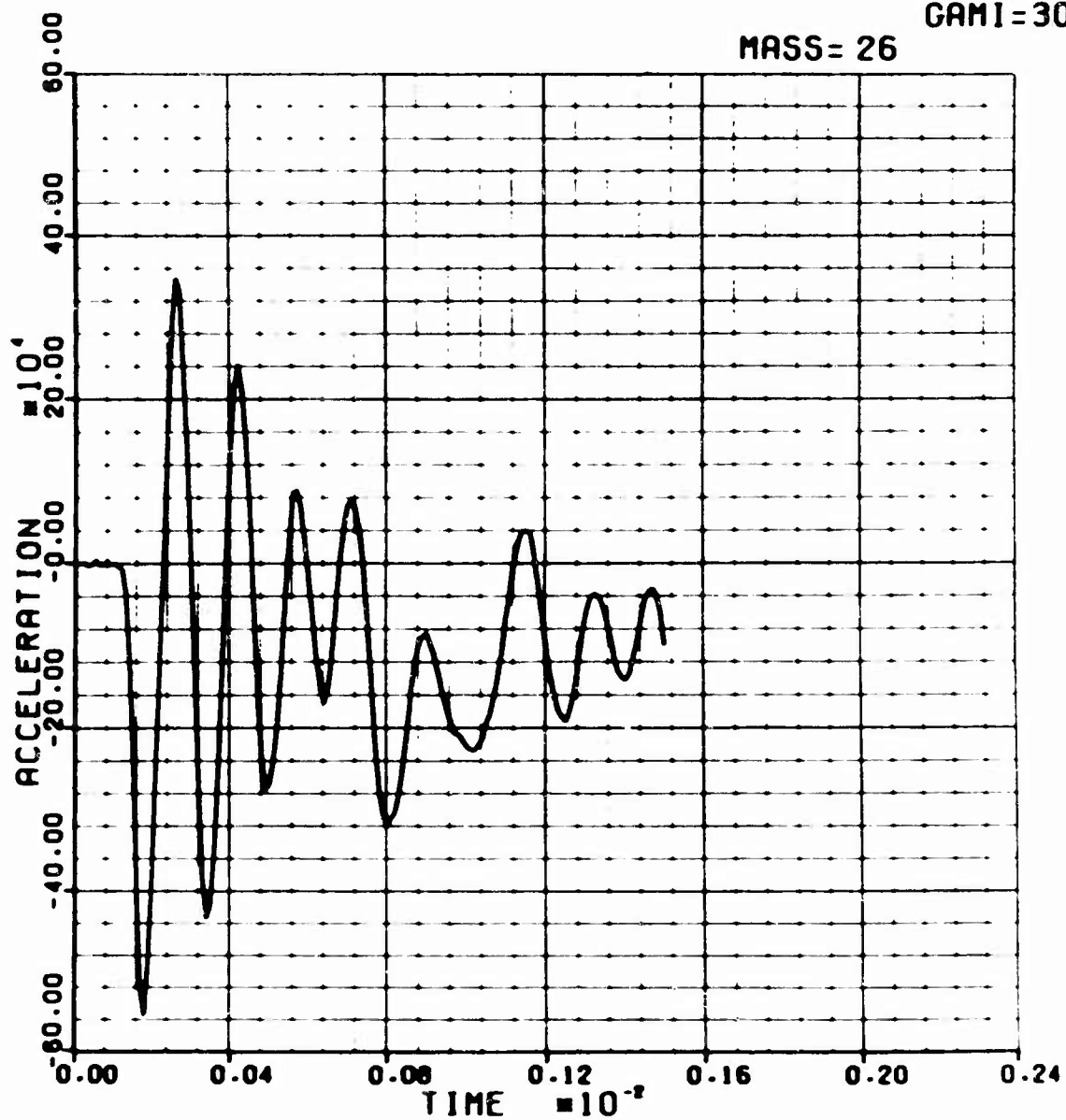
MK82 (AXIAL)

SAND TARGET

VEL=13200.

GAMI=30.0

MASS= 26



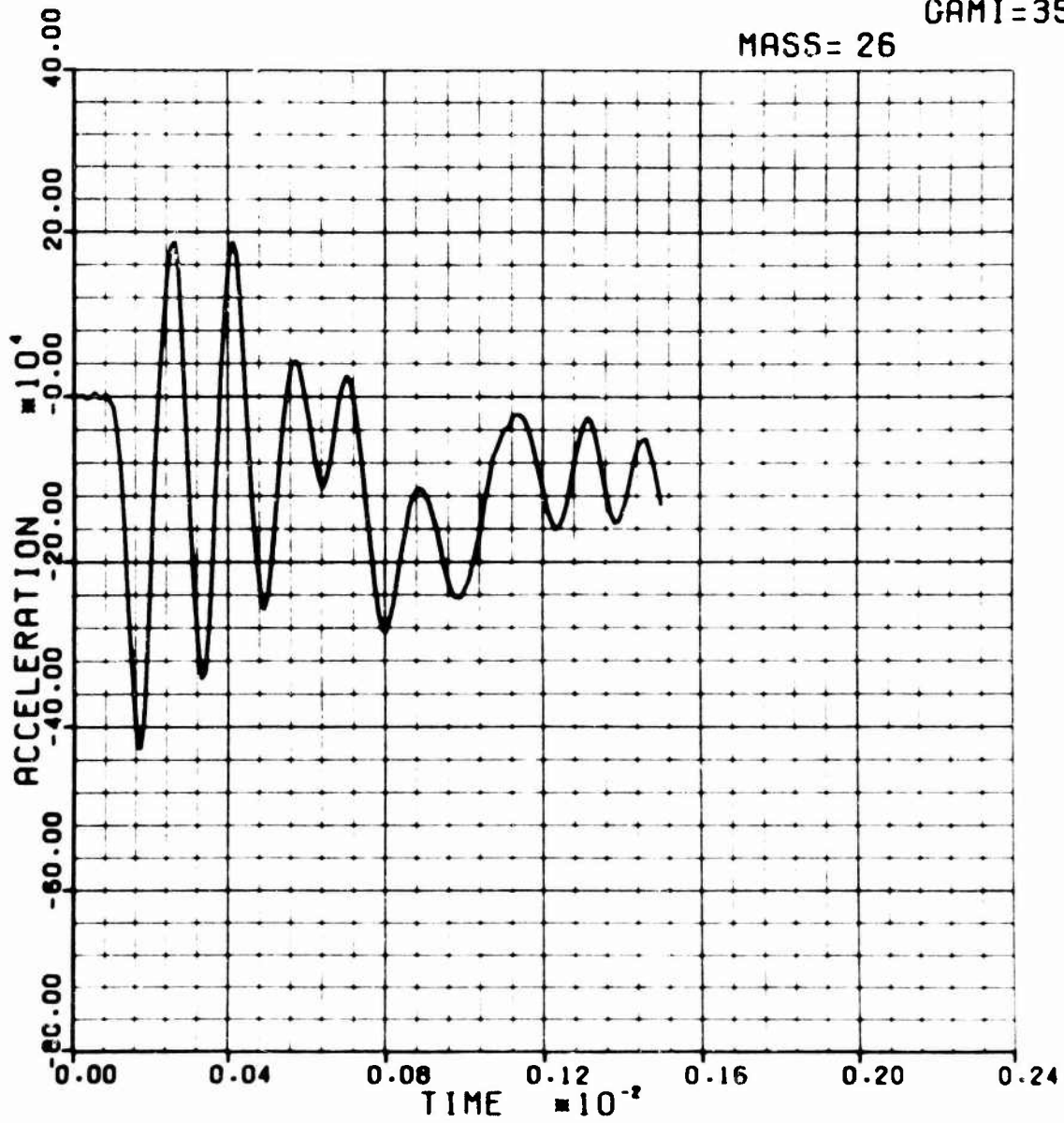
MK82 (AXIAL)

SAND TARGET

VEL=13200.

GAMI=35.0

MASS= 26



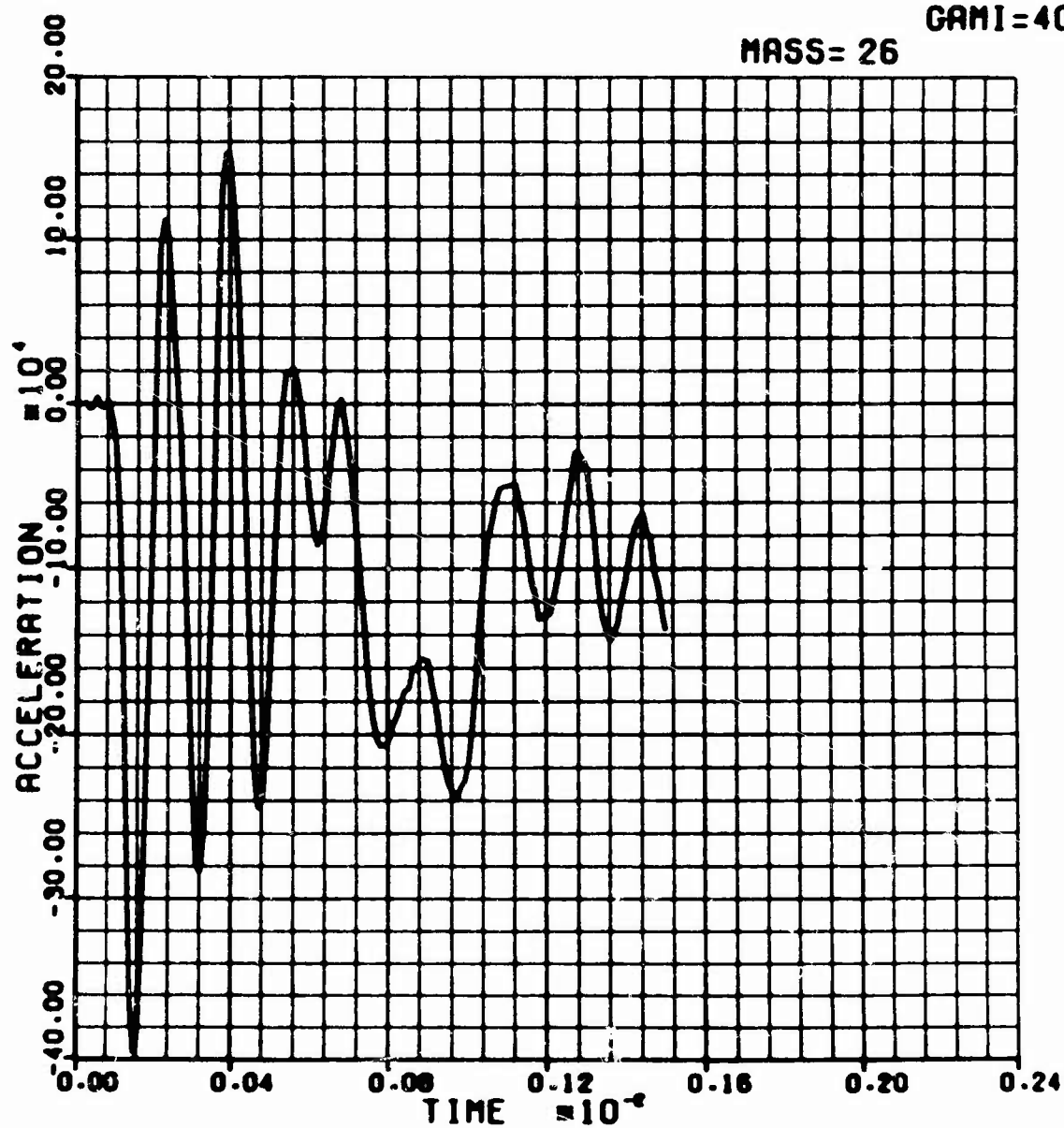
MK82 (AXIAL)

SAND TARGET

VEL=13200.

GAMI=40.0

MASS= 26

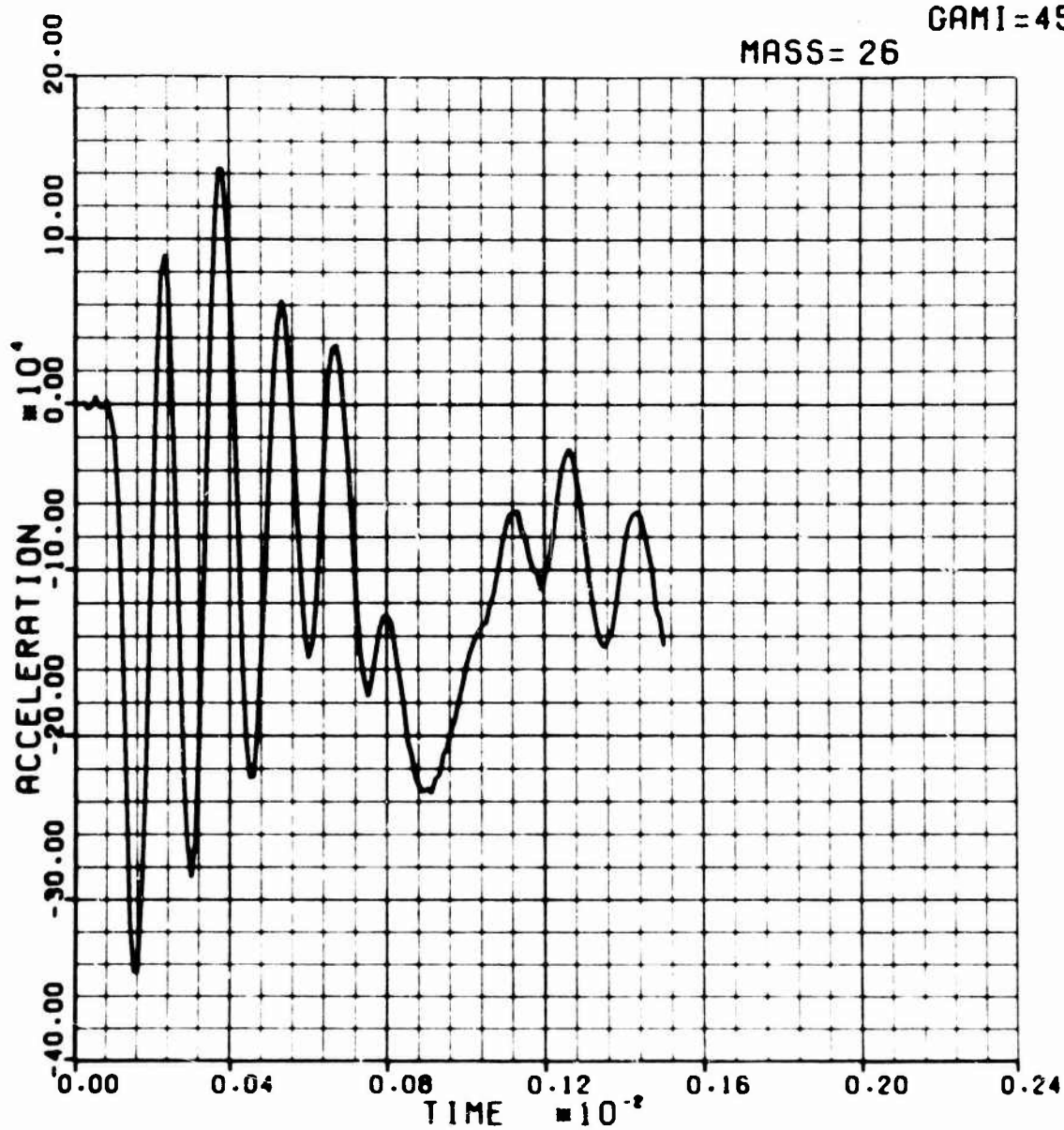


MK82 (AXIAL) SAND TARGET

VEL=13200.

GAMI=45.0

MASS= 26



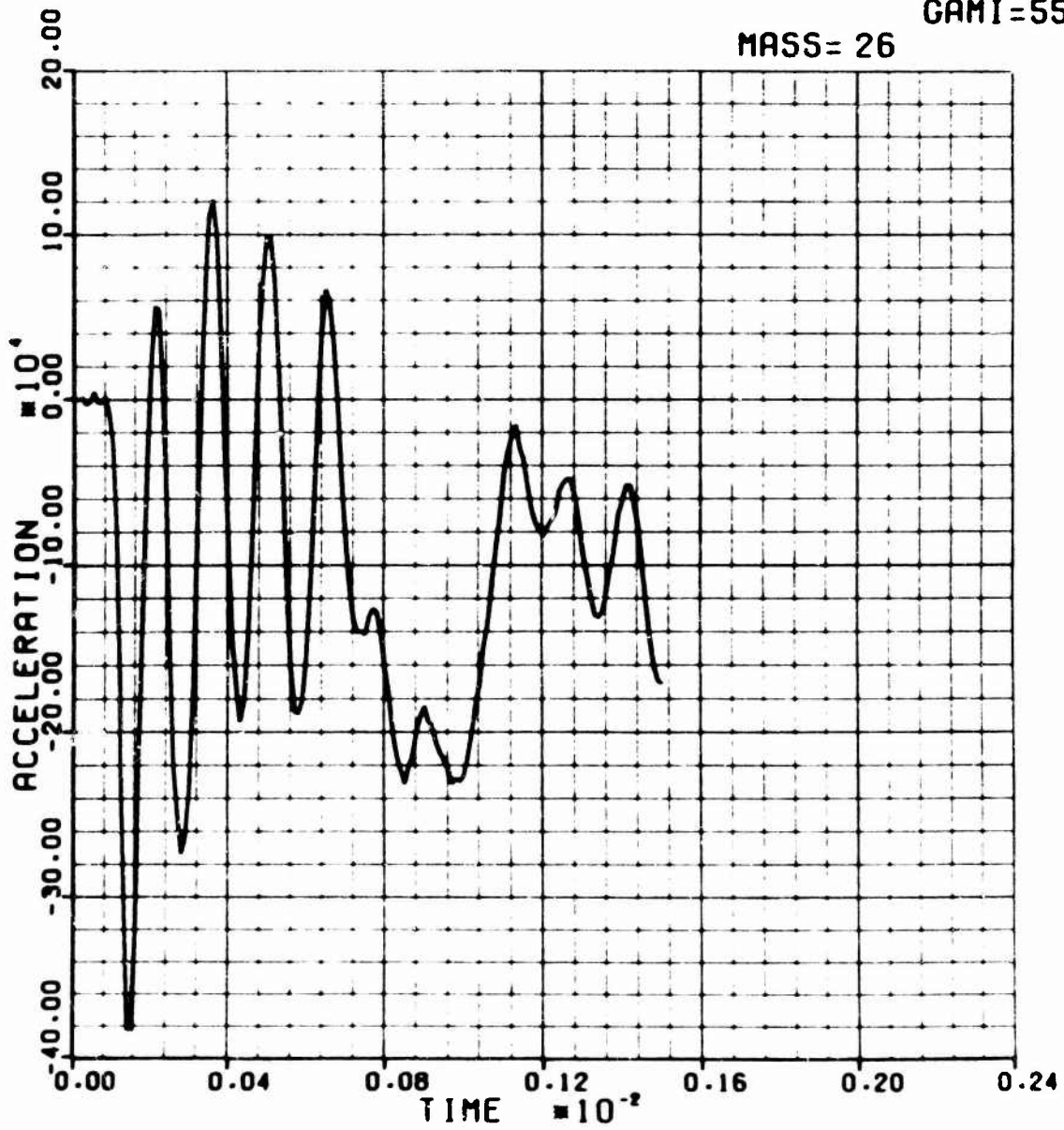
MK82 (AXIAL)

SAND TARGET

VEL=13200.

GAMI=55.0

MASS= 26



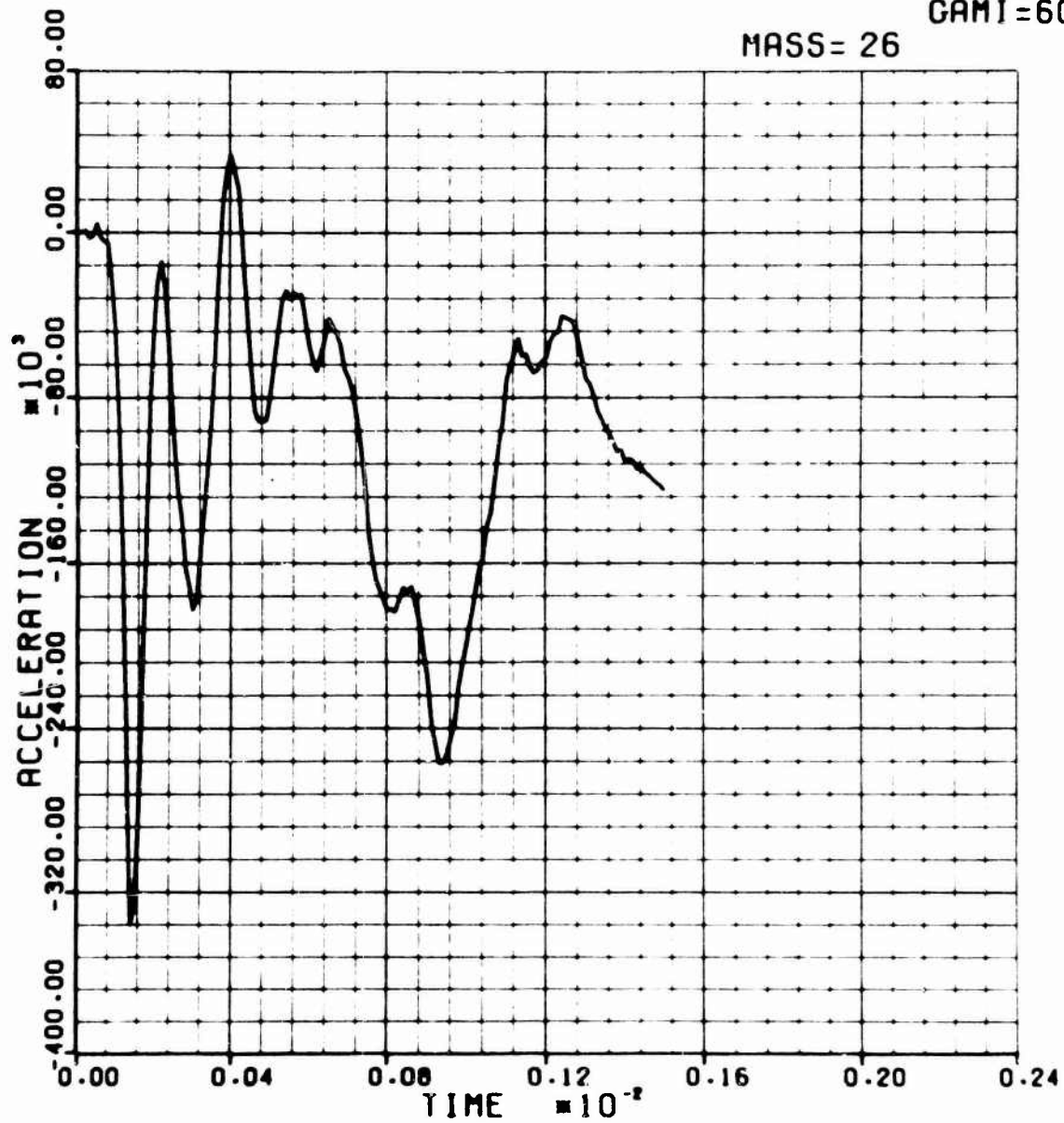
MK82 (AXIAL)

SAND TARGET

VEL=13200.

GAMI=60.0

MASS= 26



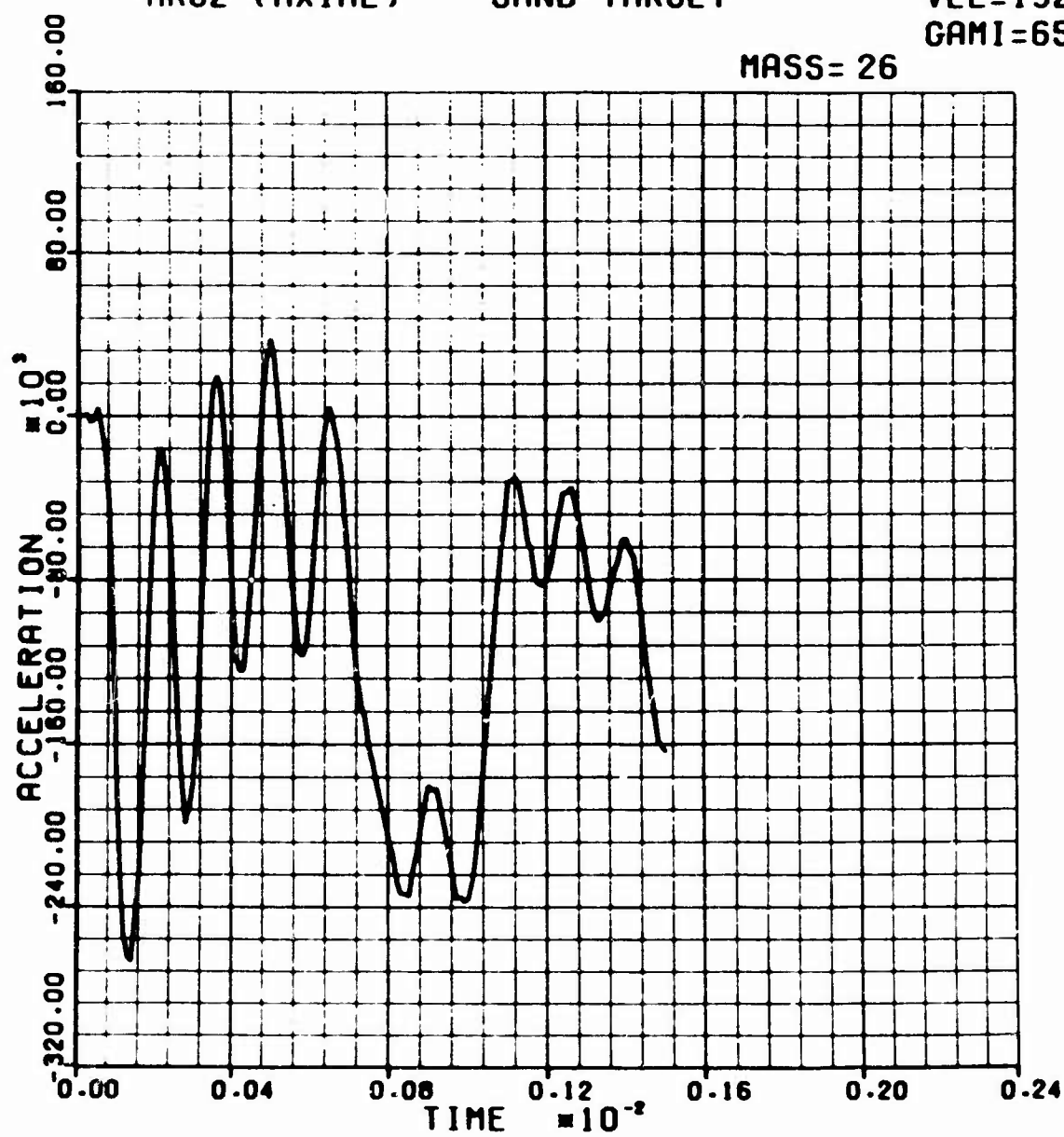
MK82 (AXIAL)

SAND TARGET

VEL=13200.

GAMI=65.0

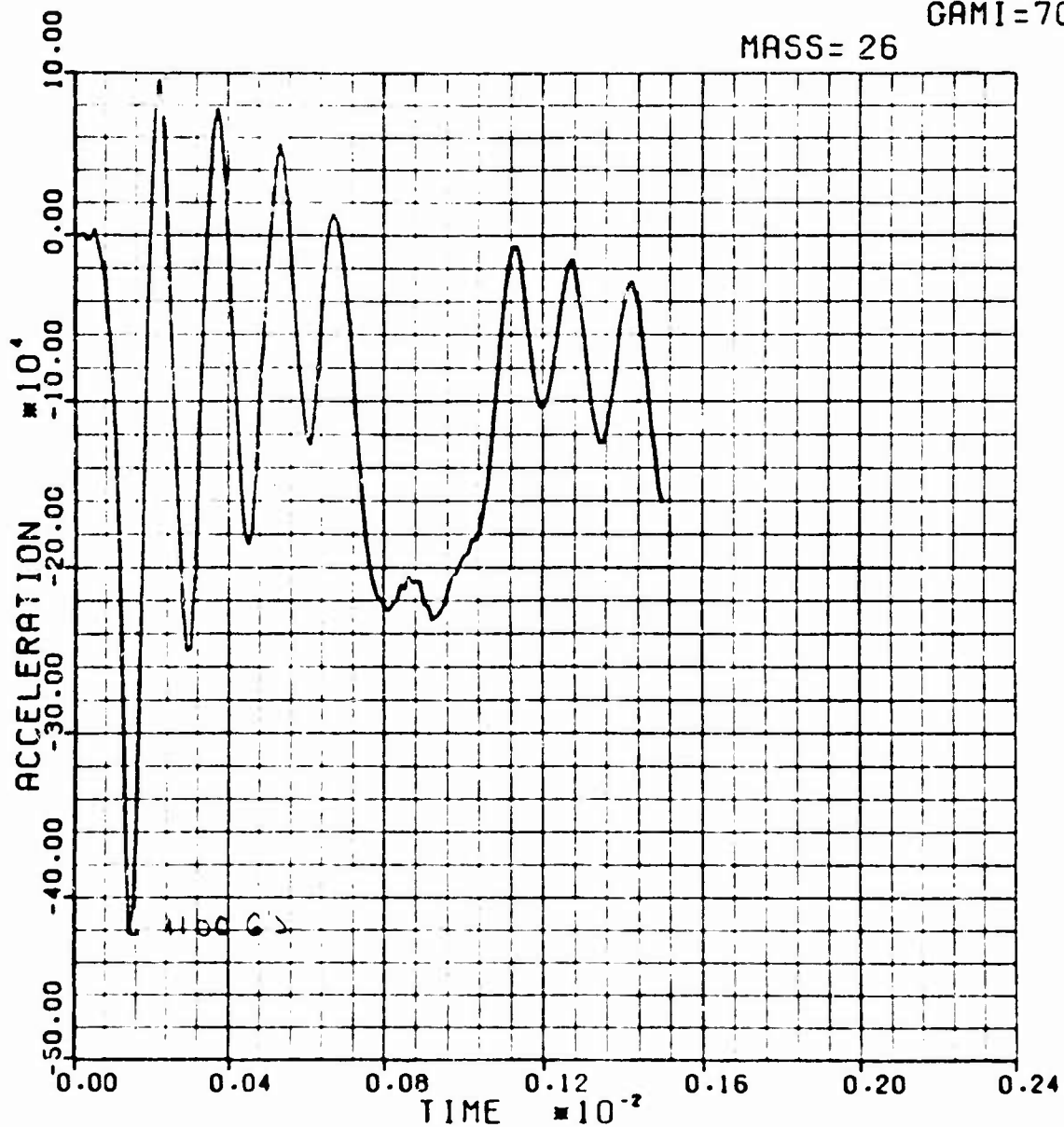
MASS= 26



500 LB MK82 (SAND TARGET)

VEL=13200.
GAMI=70.0

MASS= 26



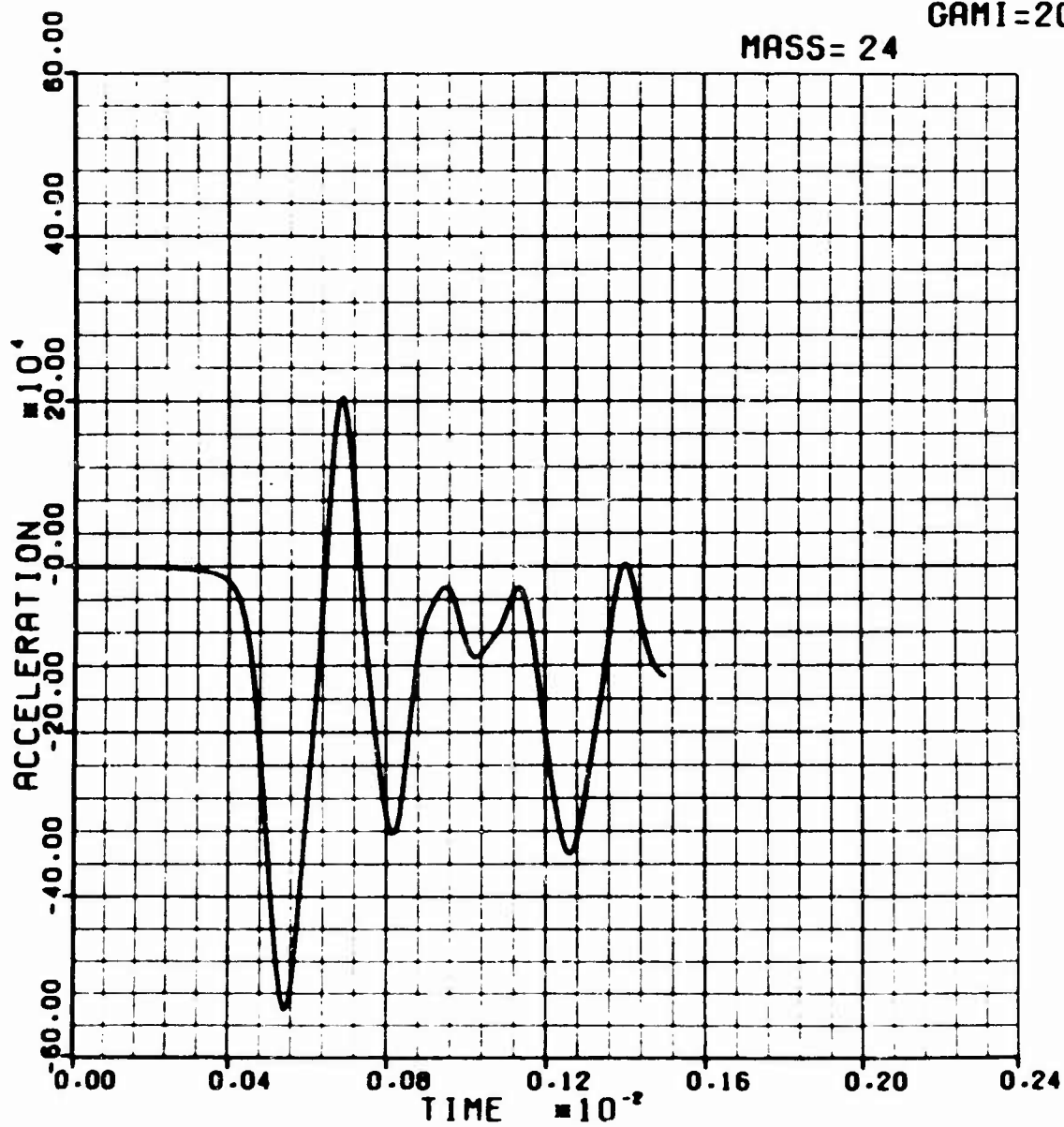
MK82 (AXIAL)

SAND TARGET

VEL=13200.

GAMI=20.0

MASS= 24



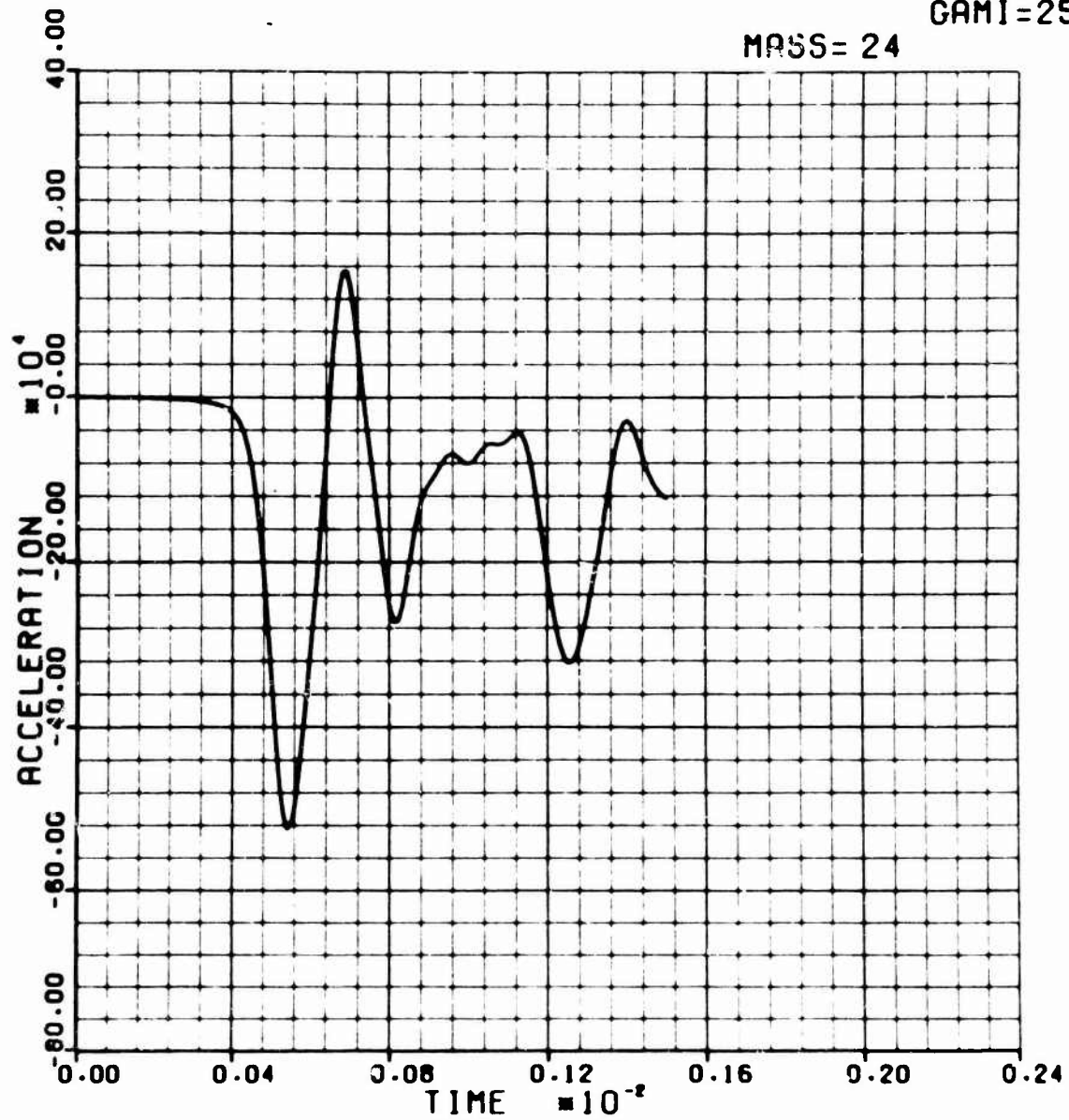
MK82 (AXIAL)

SAND TARGET

VEL=13200.

GAMI=25.0

MASS= 24



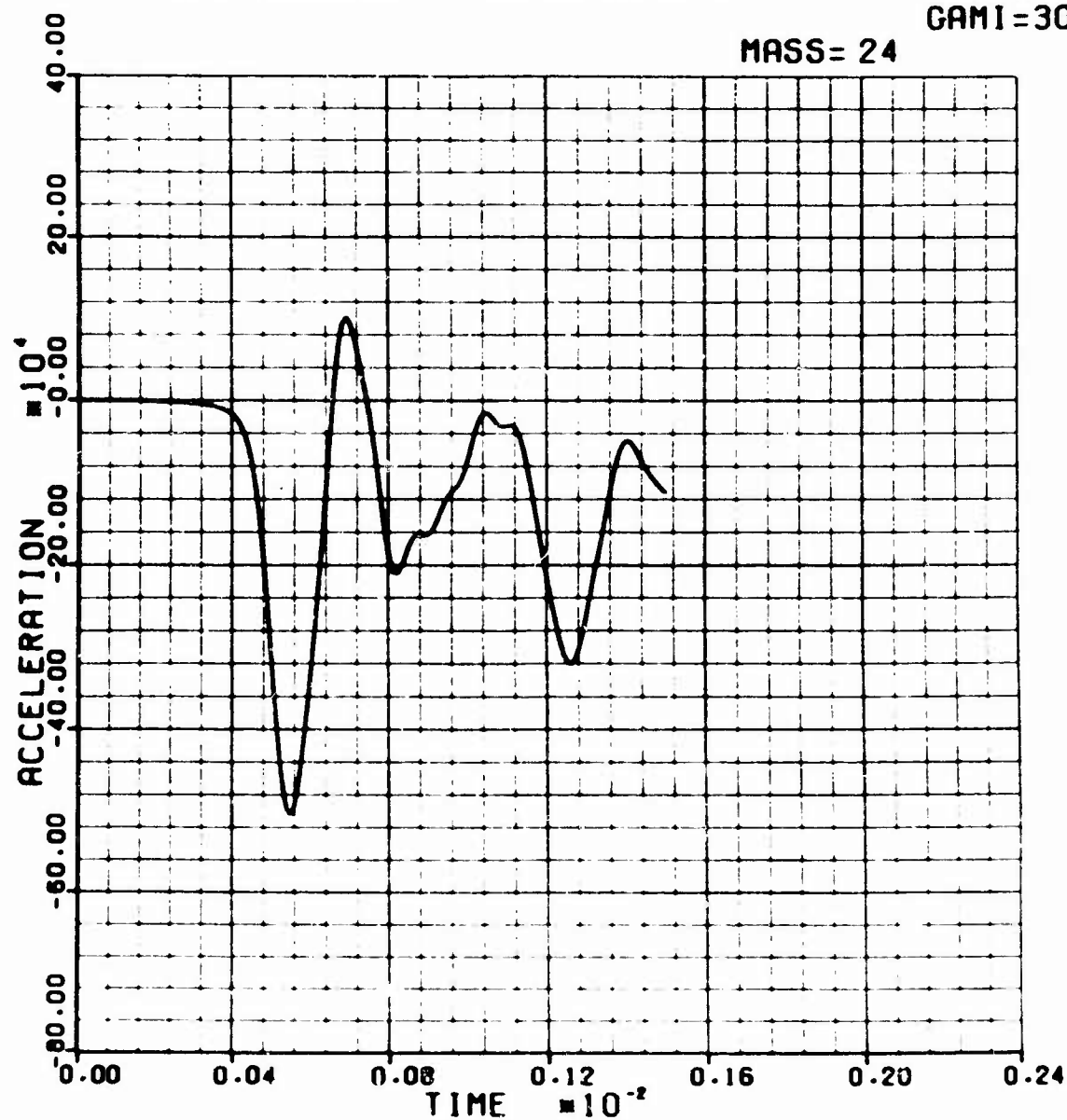
MK82 (AXIAL)

SAND TARGET

VEL=13200.

GAMI=30.0

MASS= 24



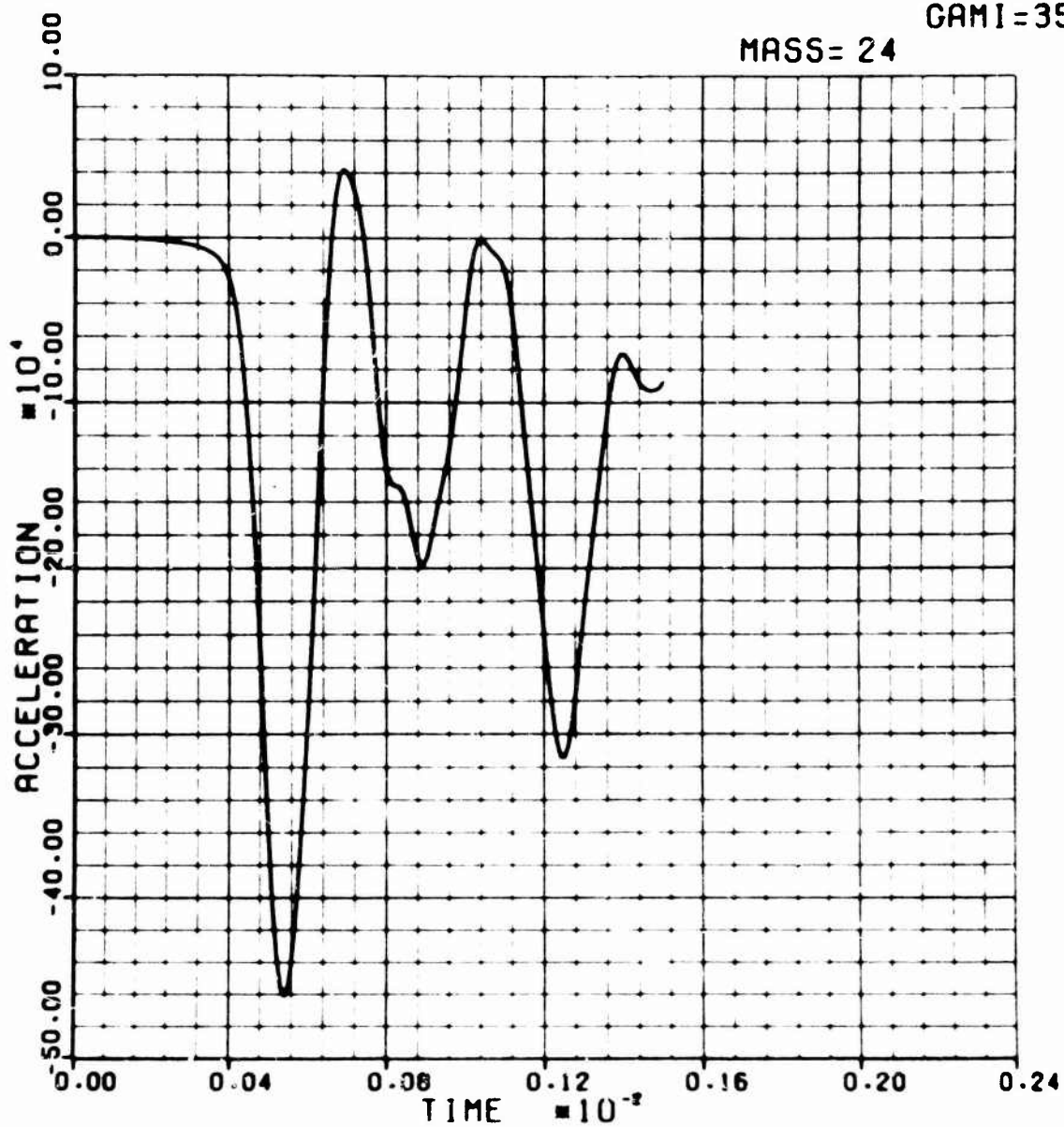
MK82 (AXIAL)

SAND TARGET

VEL=13200.

GAMI=35.0

MASS= 24

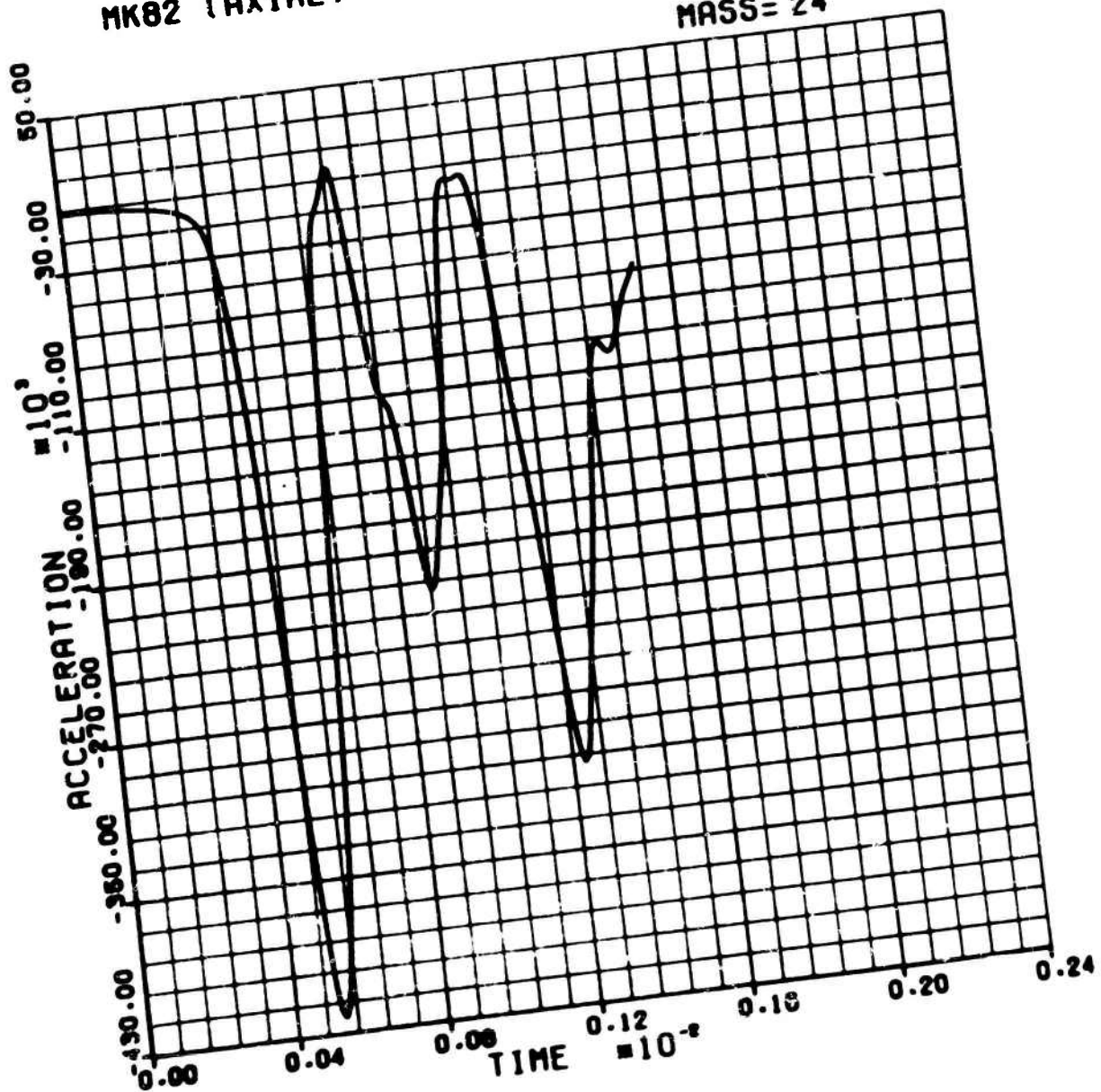


MK82 (AXIAL)

SAND TARGET

VEL=13200.
GAMI=40.0

MASS= 24



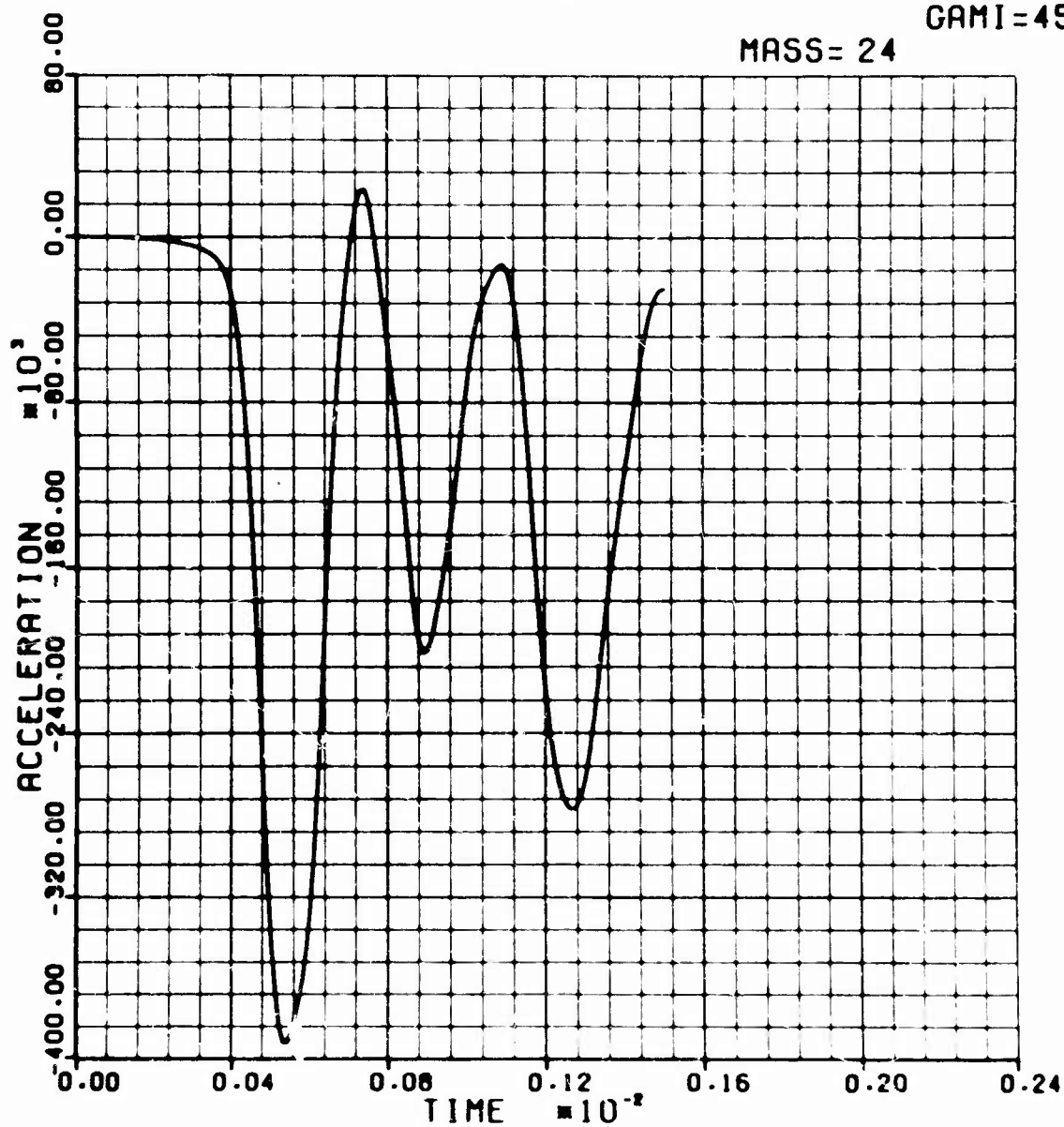
MK82 (AXIAL)

SAND TARGET

VEL=13200.

GAMI=45.0

MASS= 24



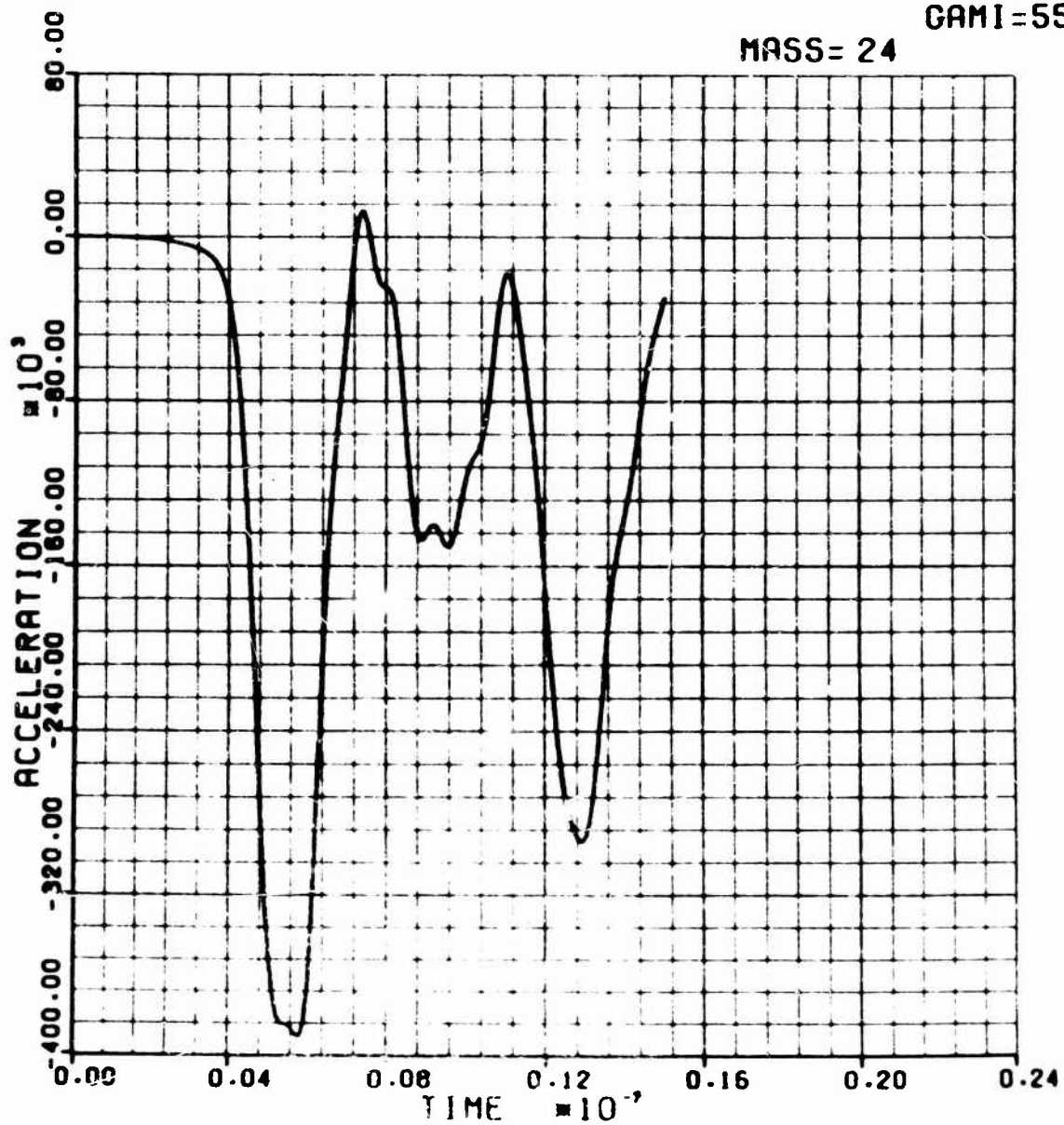
HK82 (AXIAL)

SAND TARGET

VEL=13200.

GAMI=55.0

MASS= 24



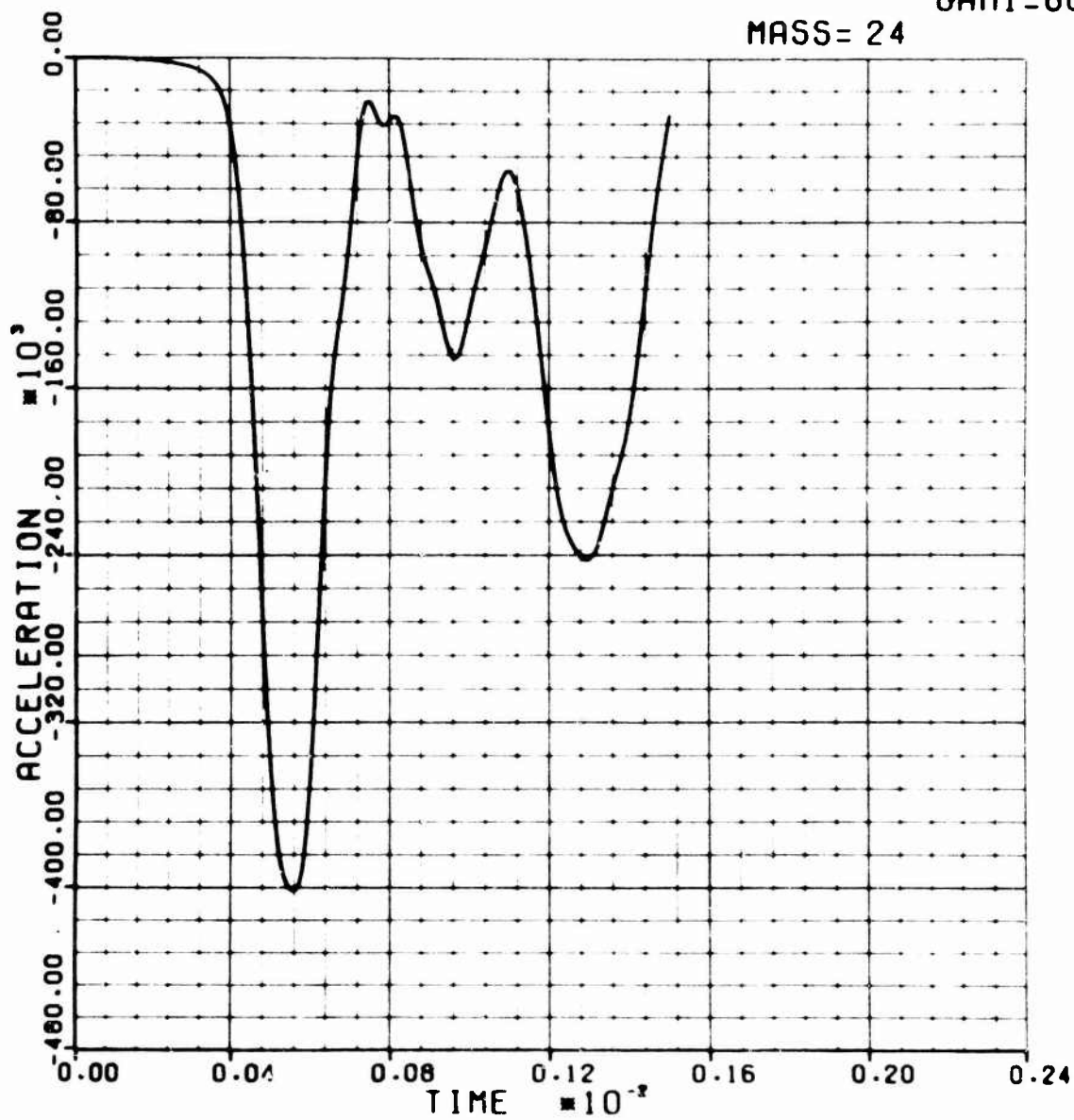
MK82 (AXIAL)

SAND TARGET

VEL=13200.

GAMI=60.0

MASS= 24



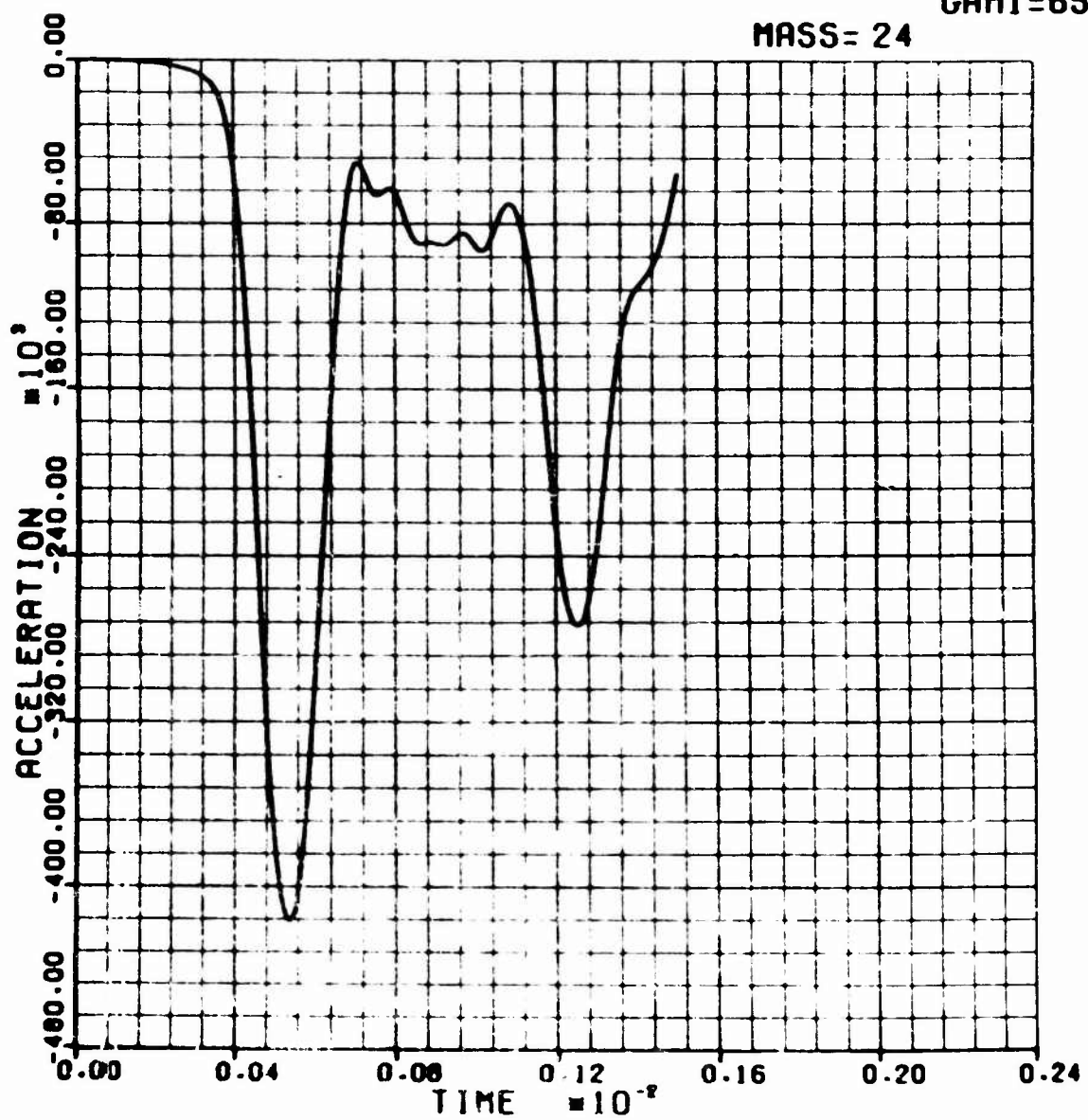
MK82 (AXIAL)

SAND TARGET

VEL=13200.

GAMI=65.0

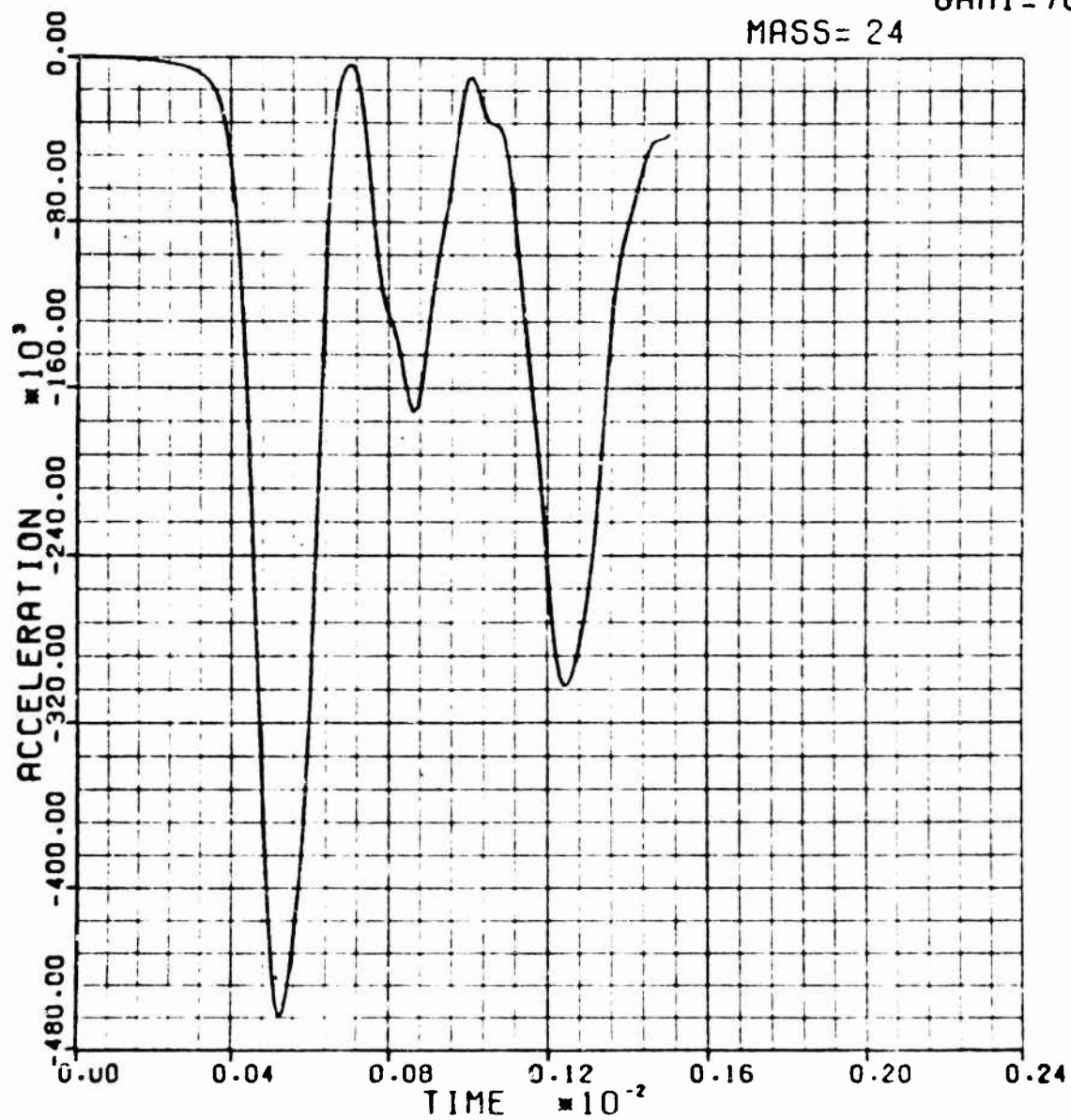
MASS= 24



500 LB MK82 (SAND TARGET)

VEL=13200.
GAMI=70.0

MASS= 24



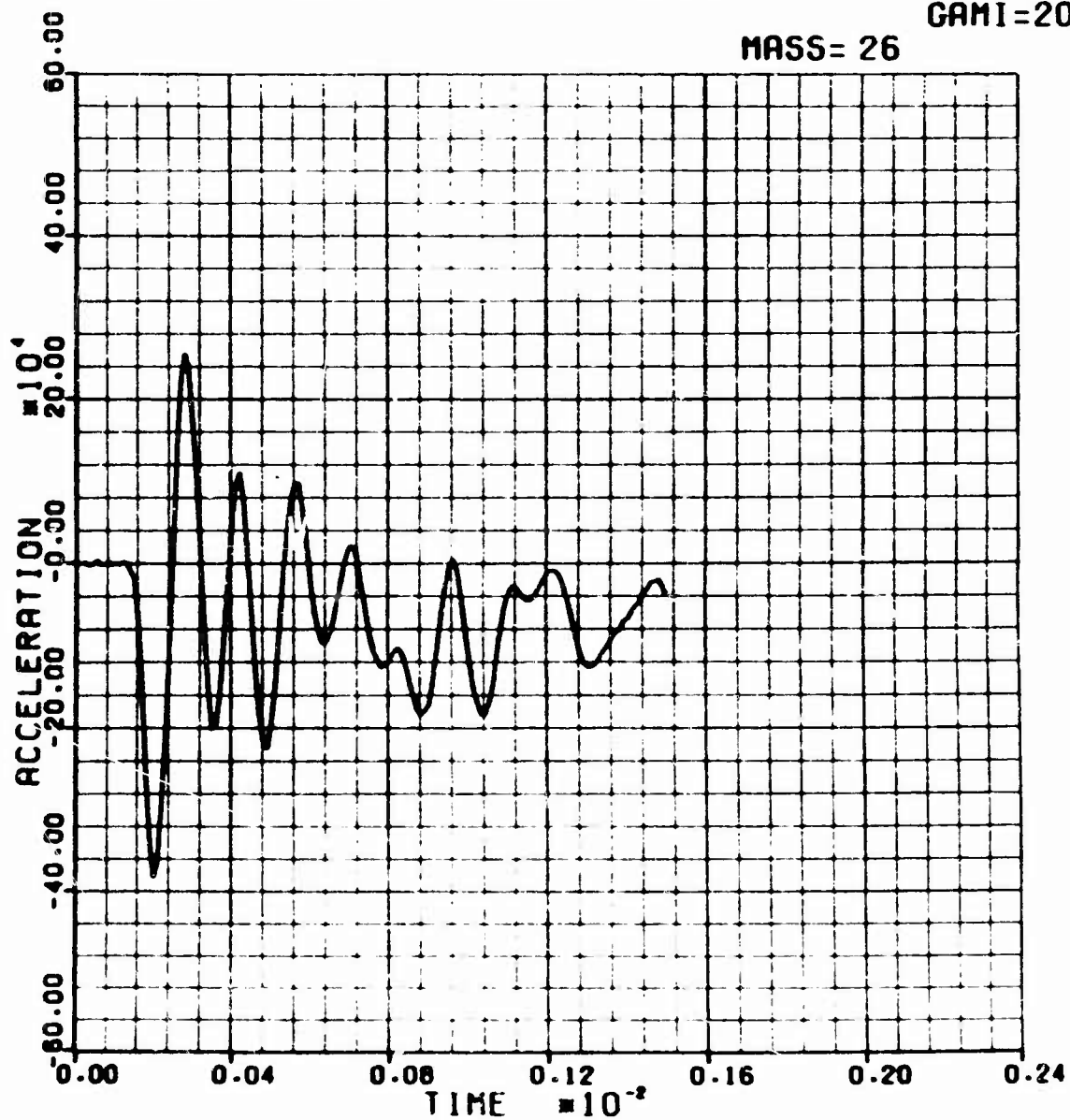
MK82 (AXIAL)

SAND TARGET

VEL=10800.

GAMI=20.0

MASS= 26



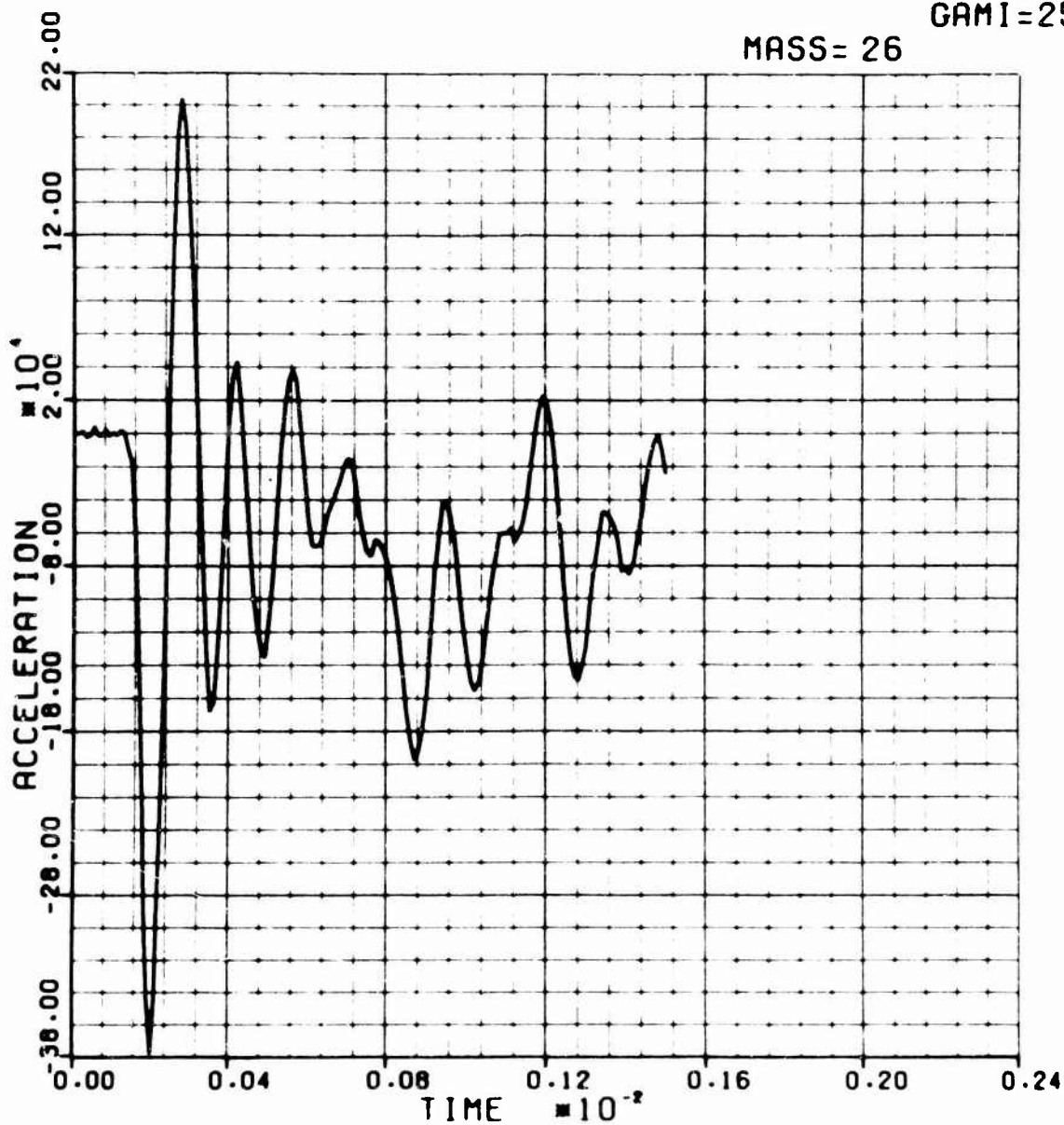
MK82 (AXIAL)

SAND TARGET

VEL=10800.

GAMI=25.0

MASS= 26



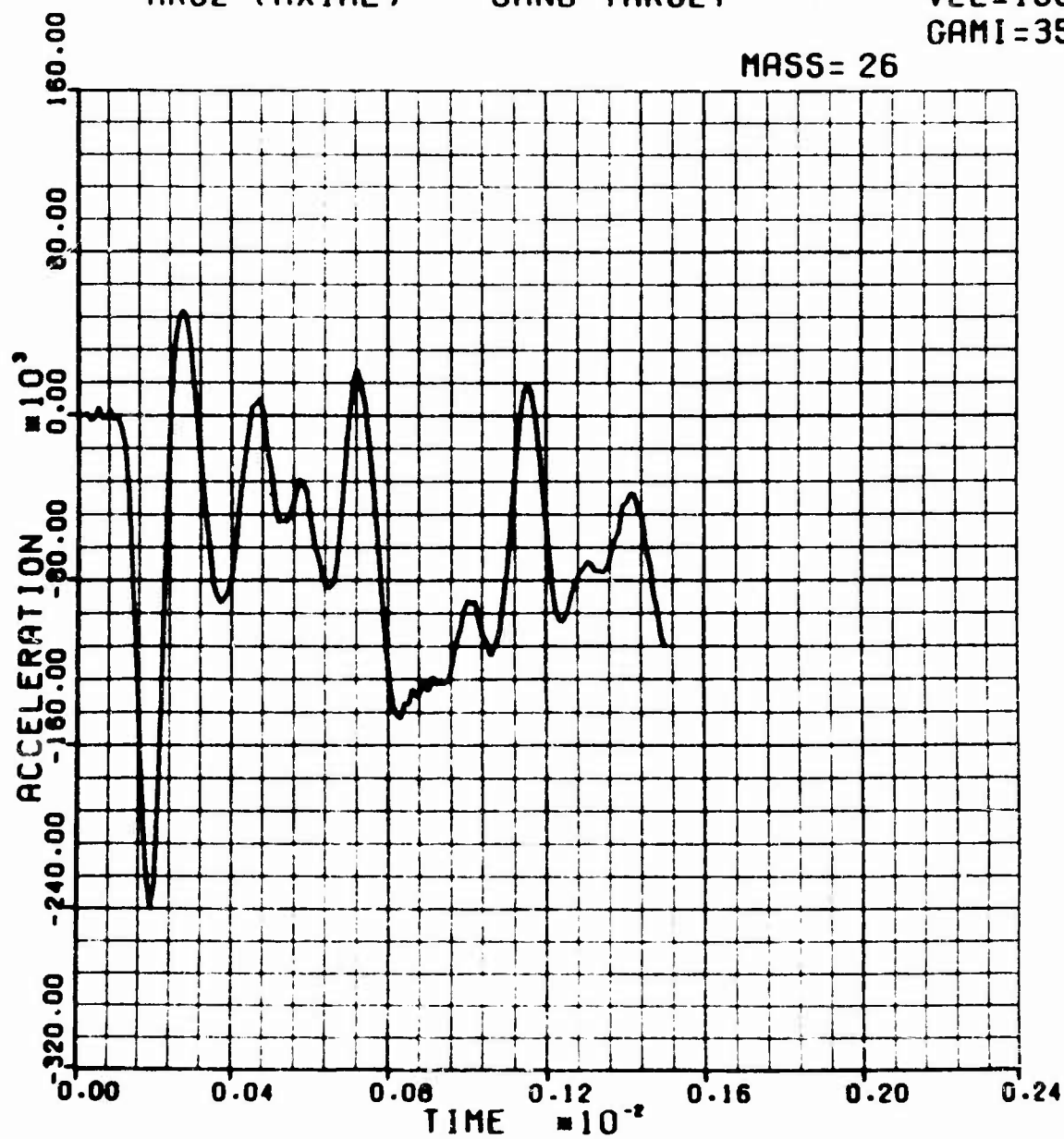
MK82 (AXIAL)

SAND TARGET

VEL=10800.

GAMI=35.0

MASS= 26



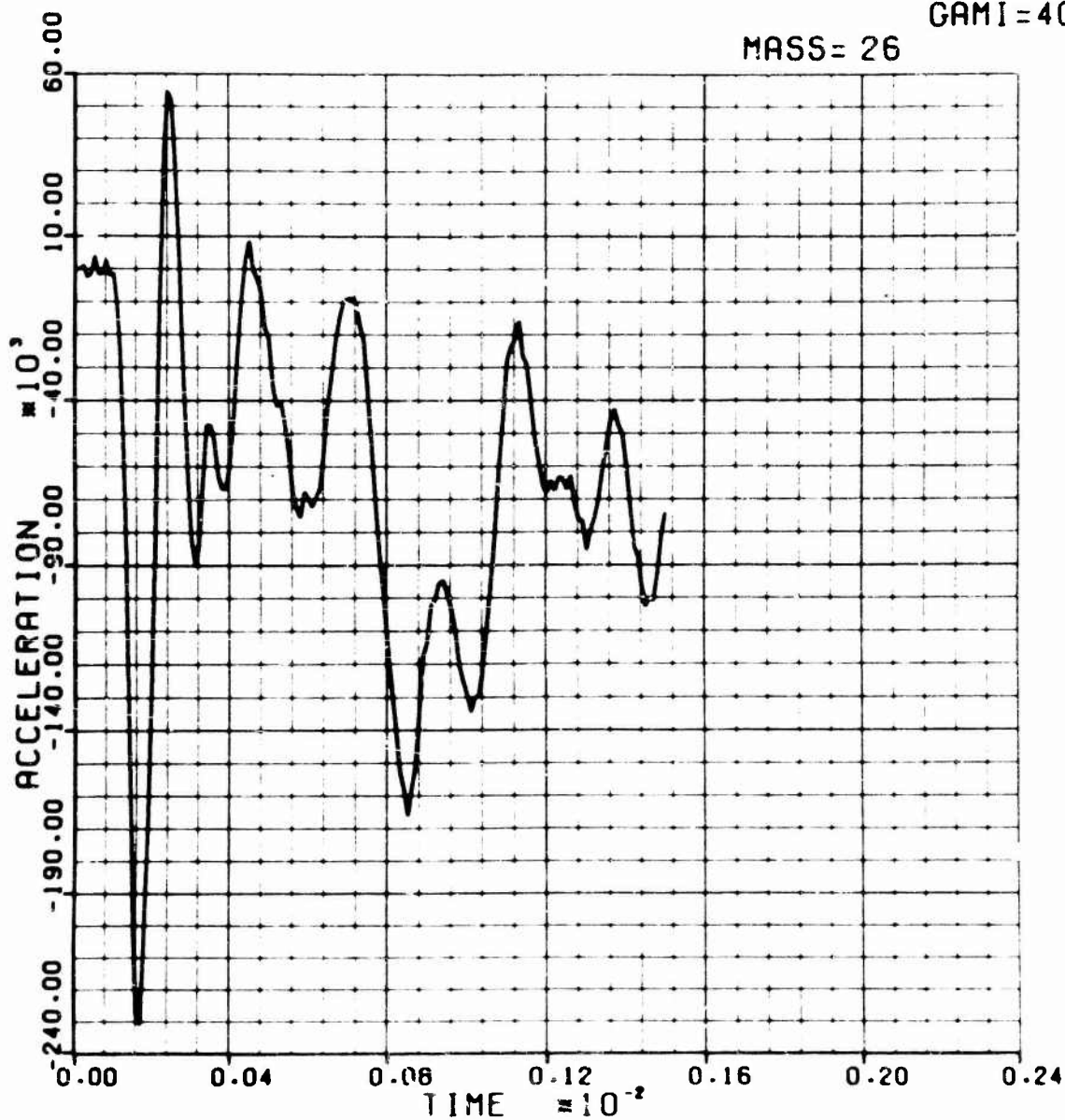
MK82 (AXIAL)

SAND TARGET

VEL=10800.

GAMI=40.0

MASS= 26



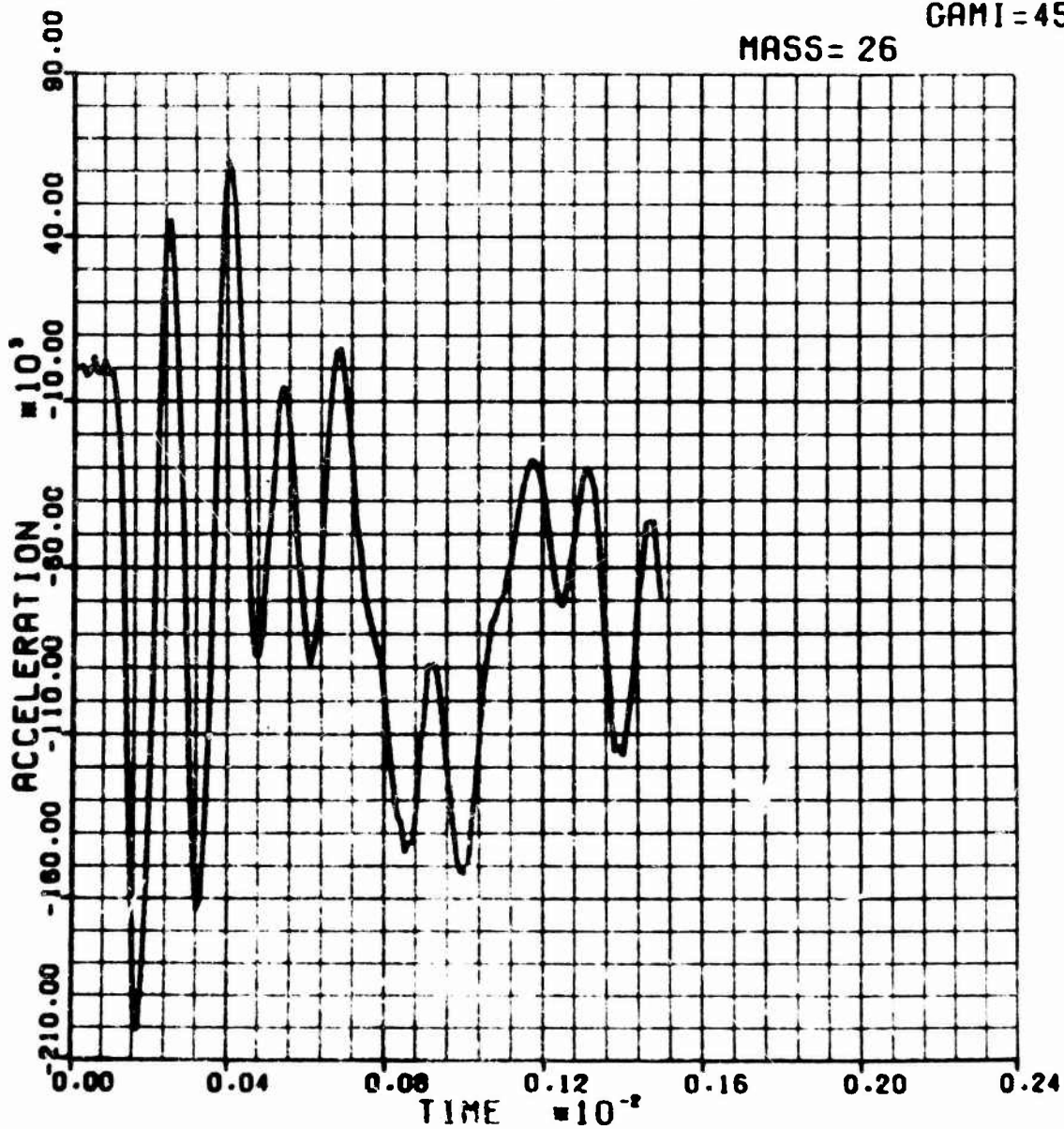
MK82 (AXIAL)

SAND TARGET

VEL=10800.

GAMI=45.0

MASS= 26



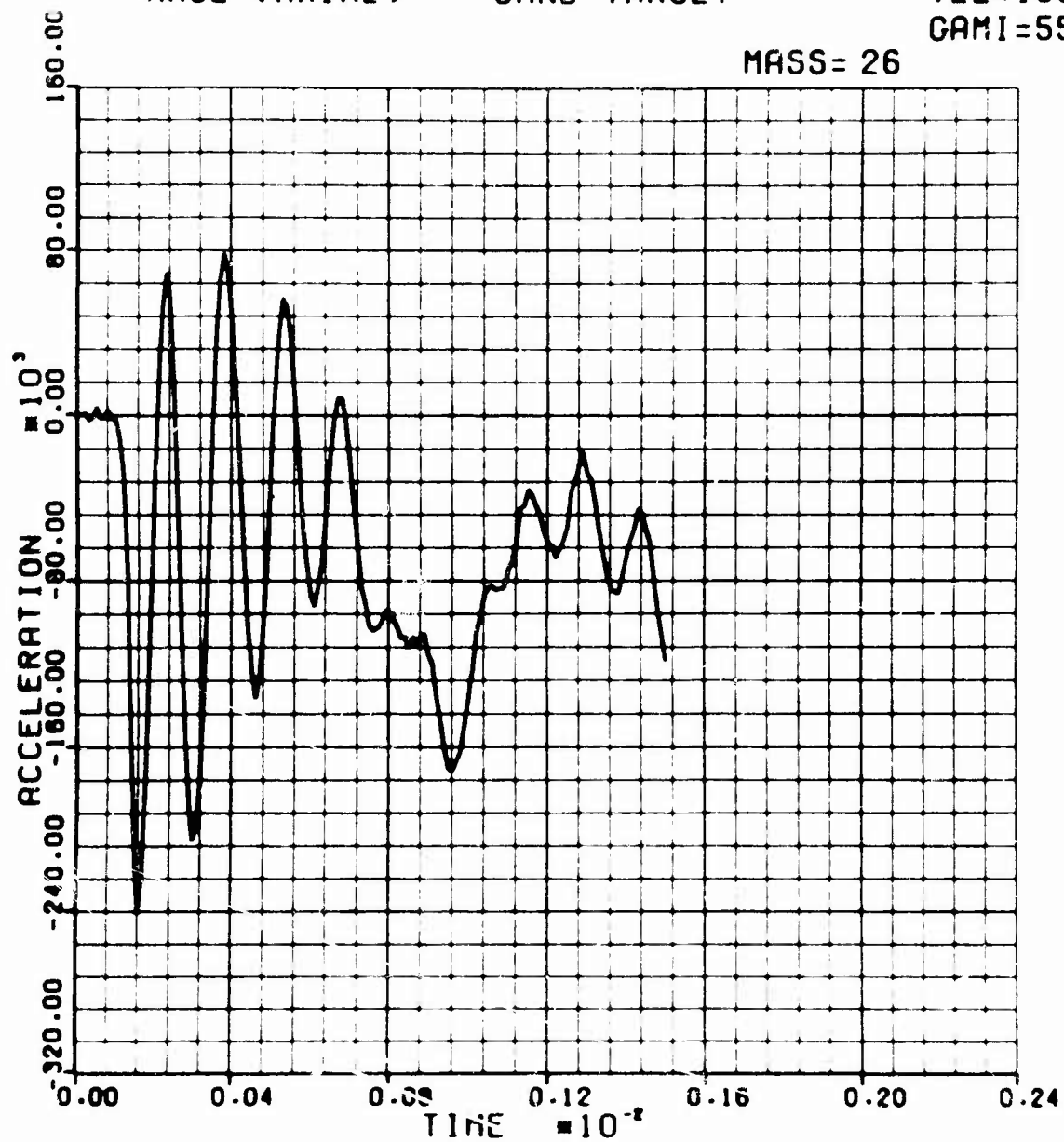
MK82 (AXIAL)

SAND TARGET

VEL=10800.

GAMI=55.0

MASS= 26



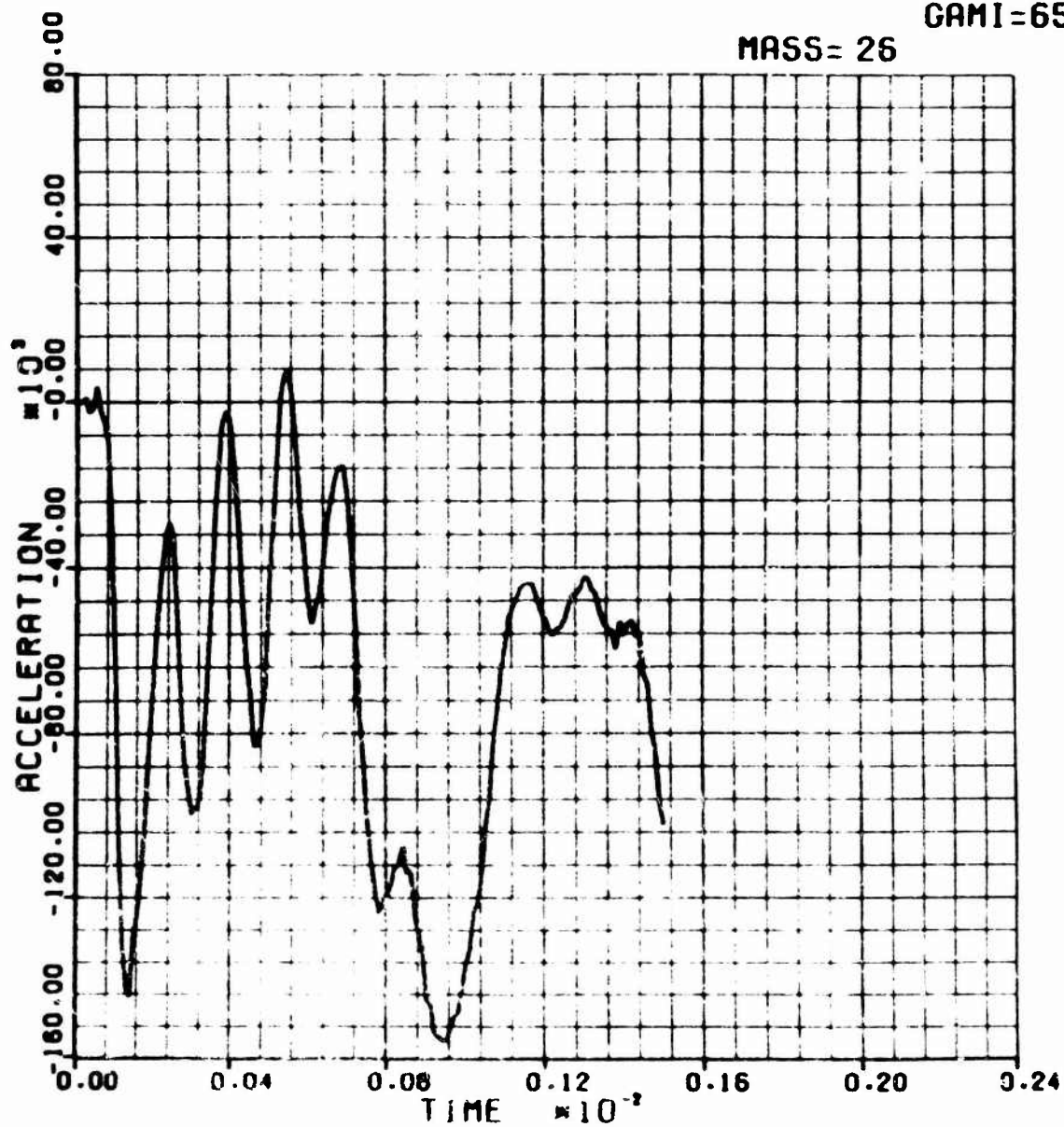
MK82 (AXIAL)

SAND TARGET

VEL=10800.

GAMI=65.0

MASS= 26



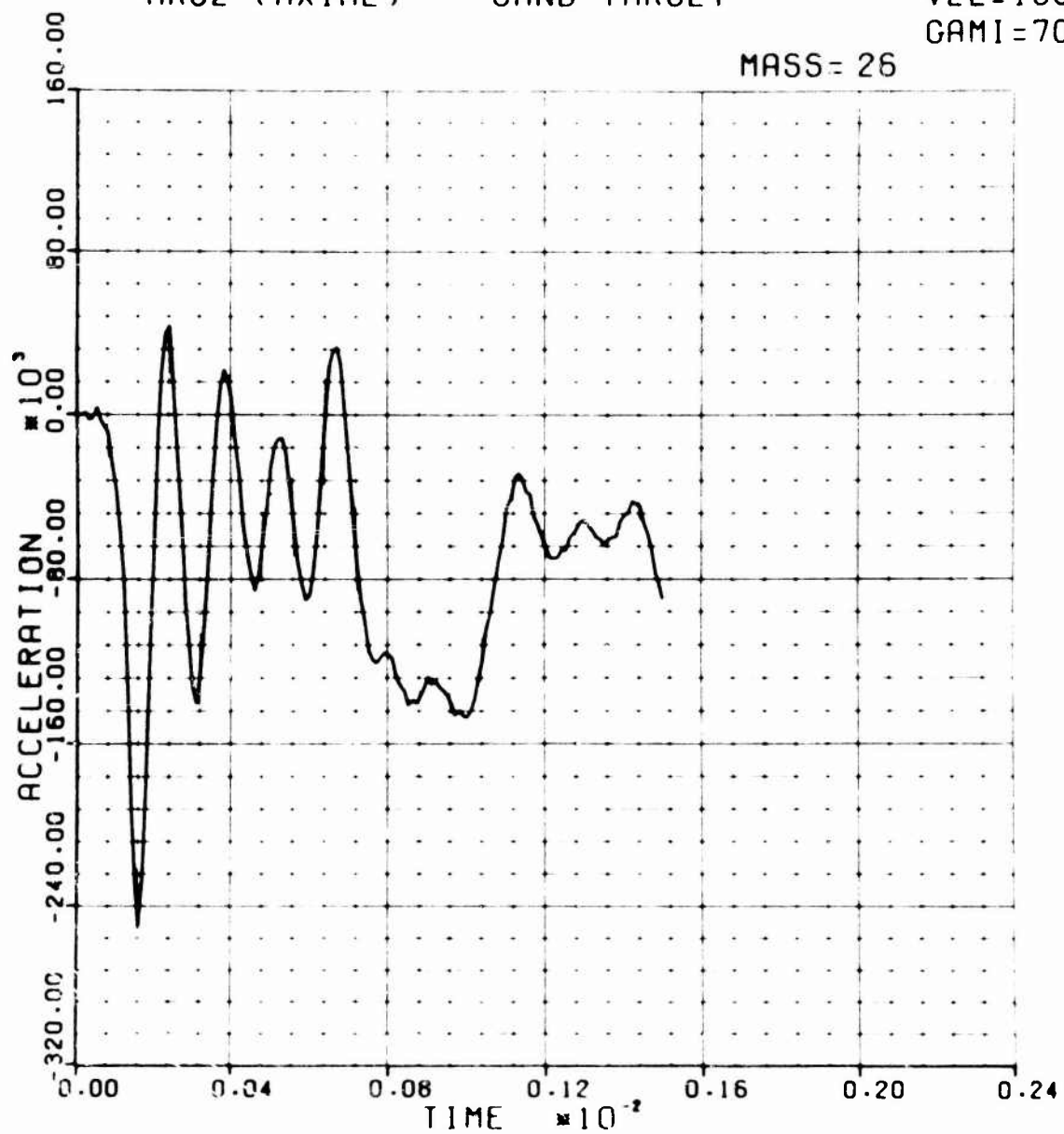
MK82 (AXIAL)

SAND TARGET

VEL=10800.

GAMI=70.0

MASS= 26



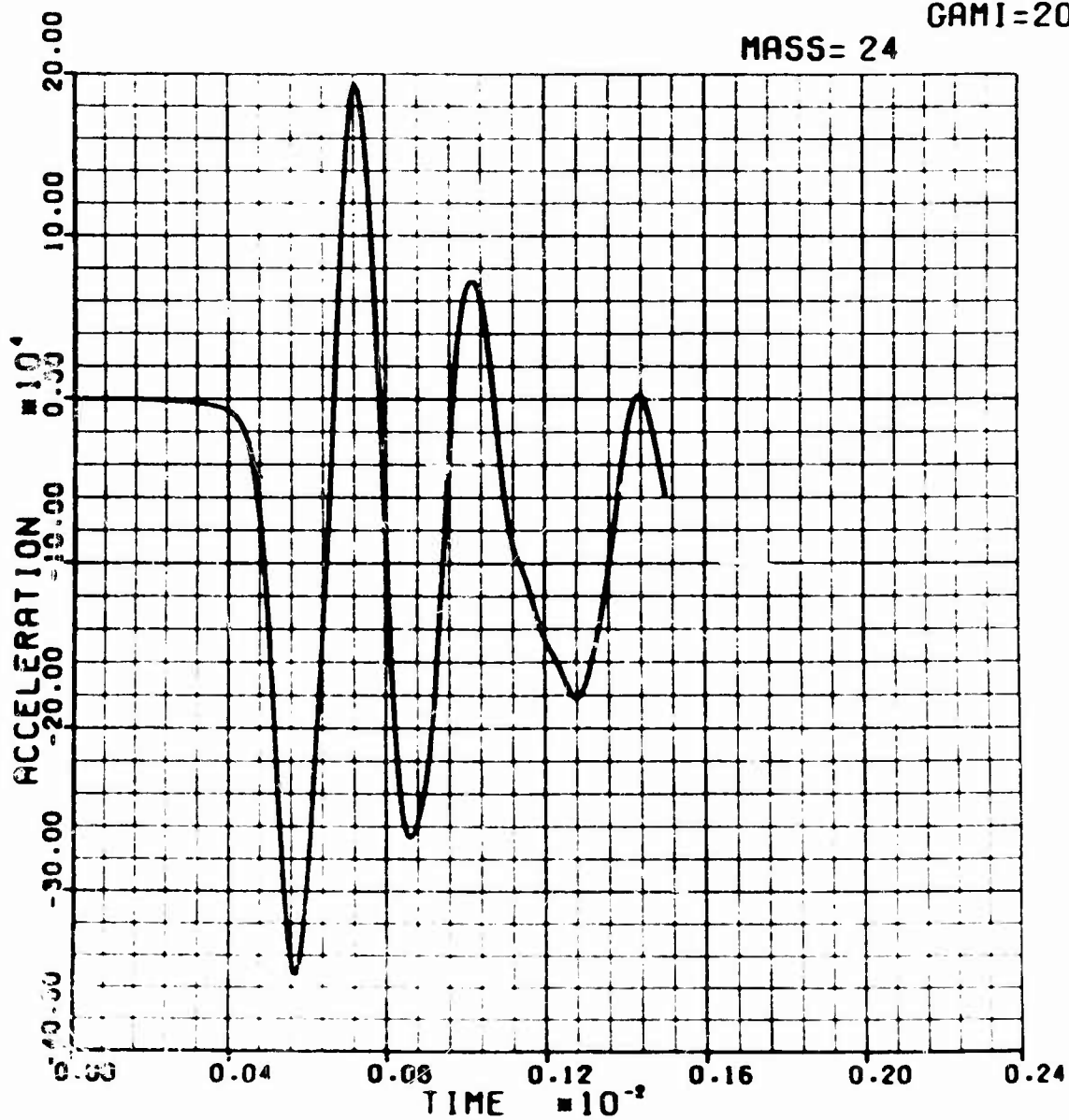
MK82 (AXIAL)

SAND TARGET

VEL=10800.

GAMI=20.0

MASS= 24



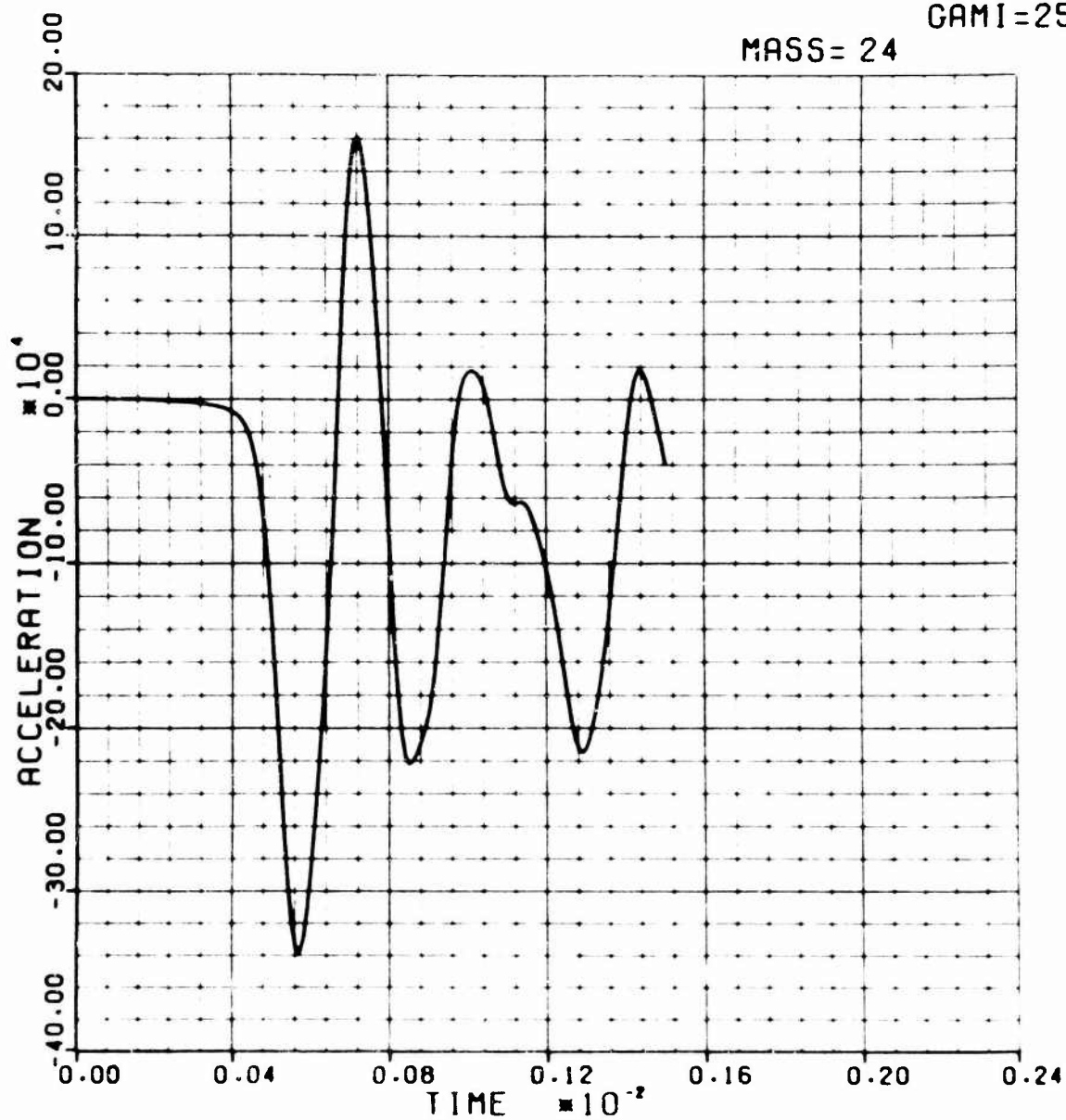
MK82 (AXIAL)

SAND TARGET

VEL=10800.

GAMI=25.0

MASS= 24



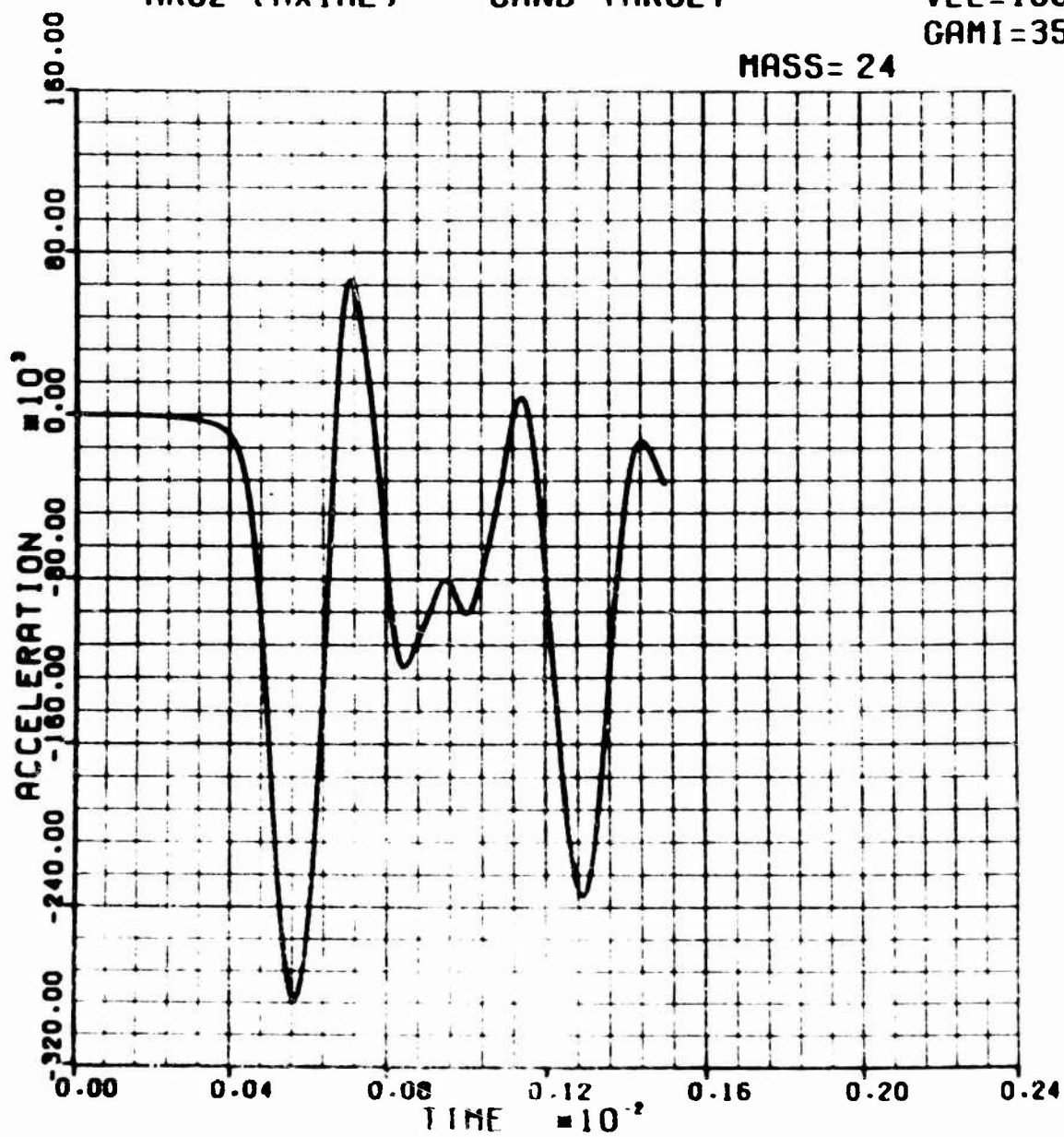
MK82 (AXIAL)

SAND TARGET

VEL=10800.

GAMI=35.0

MASS= 24



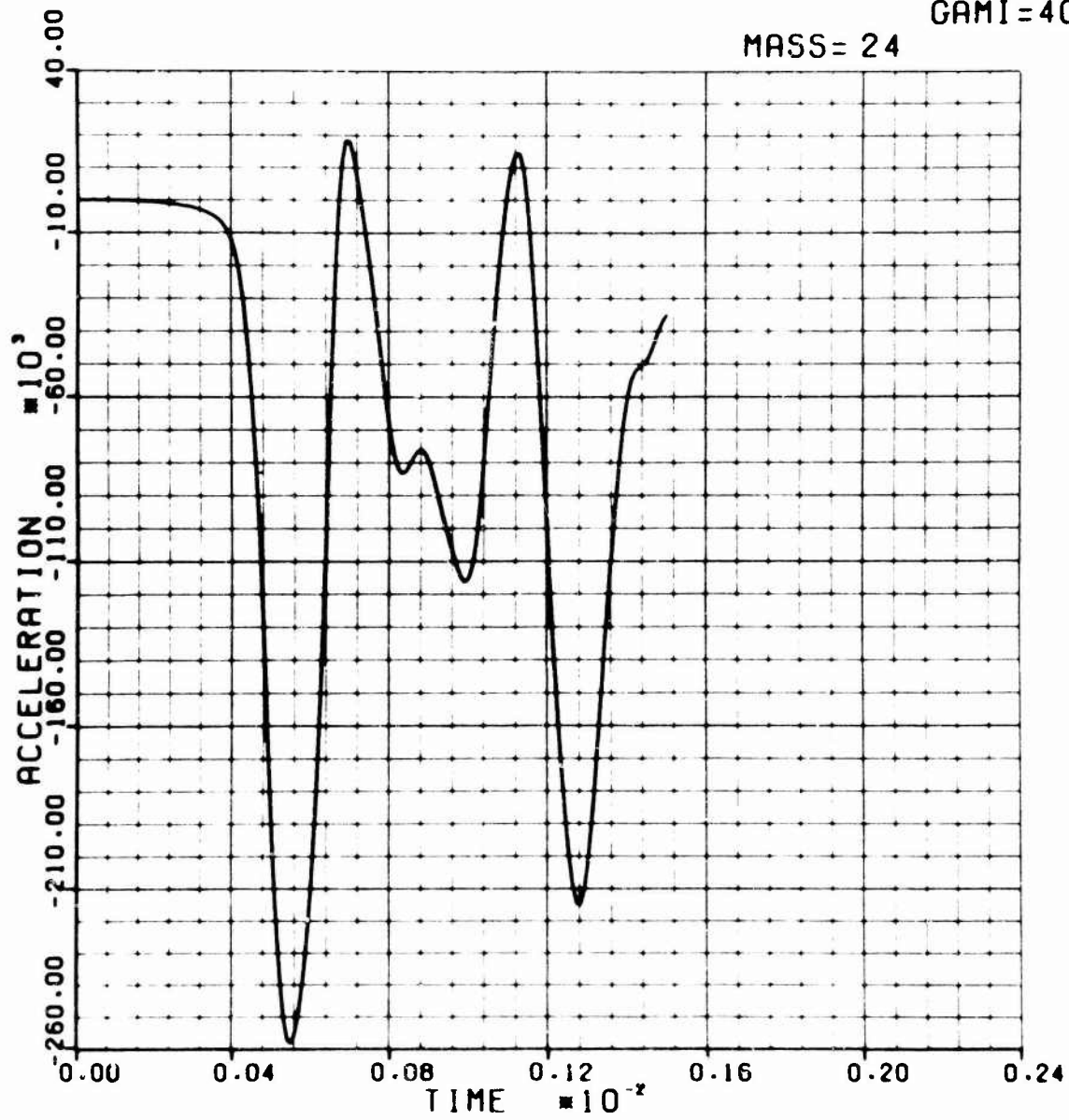
MK82 (AXIAL)

SAND TARGET

VEL=10800.

GAMI=40.0

MASS= 24



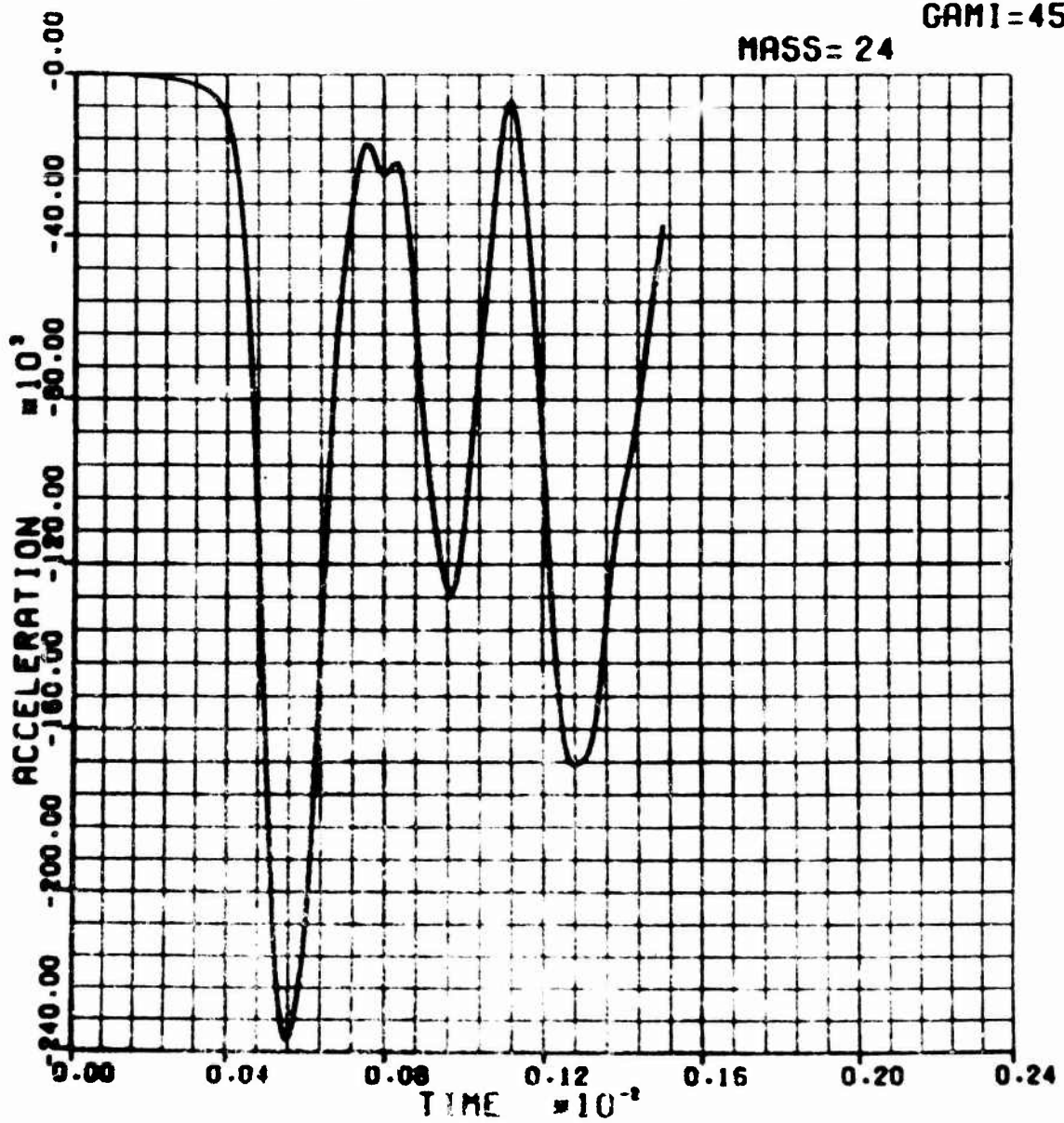
MK82 (AXIAL)

SAND TARGET

VEL=10800.

GAMI=45.0

MASS= 24



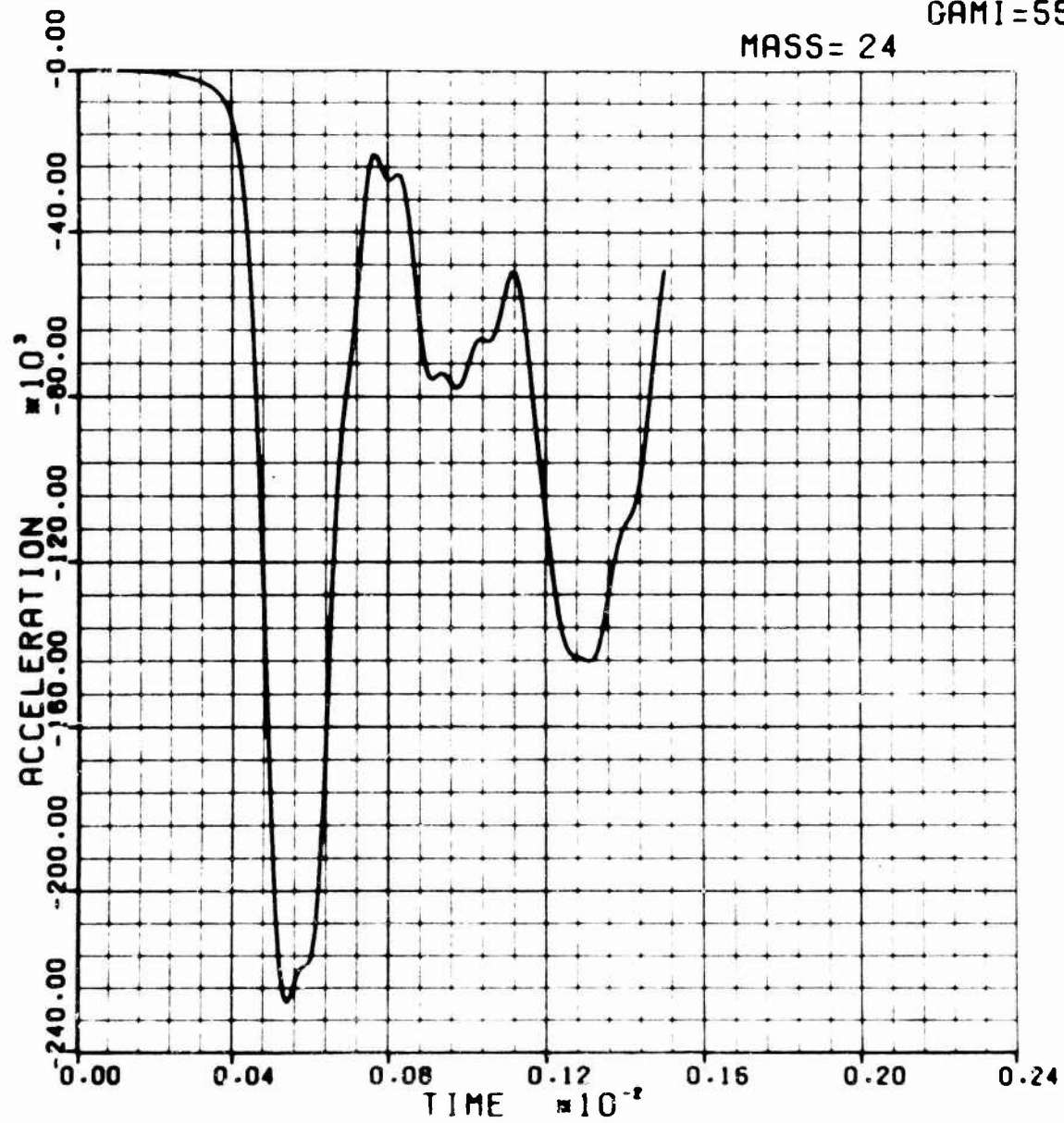
MK82 (AXIAL)

SAND TARGET

VEL=10800.

GAMI=55.0

MASS= 24



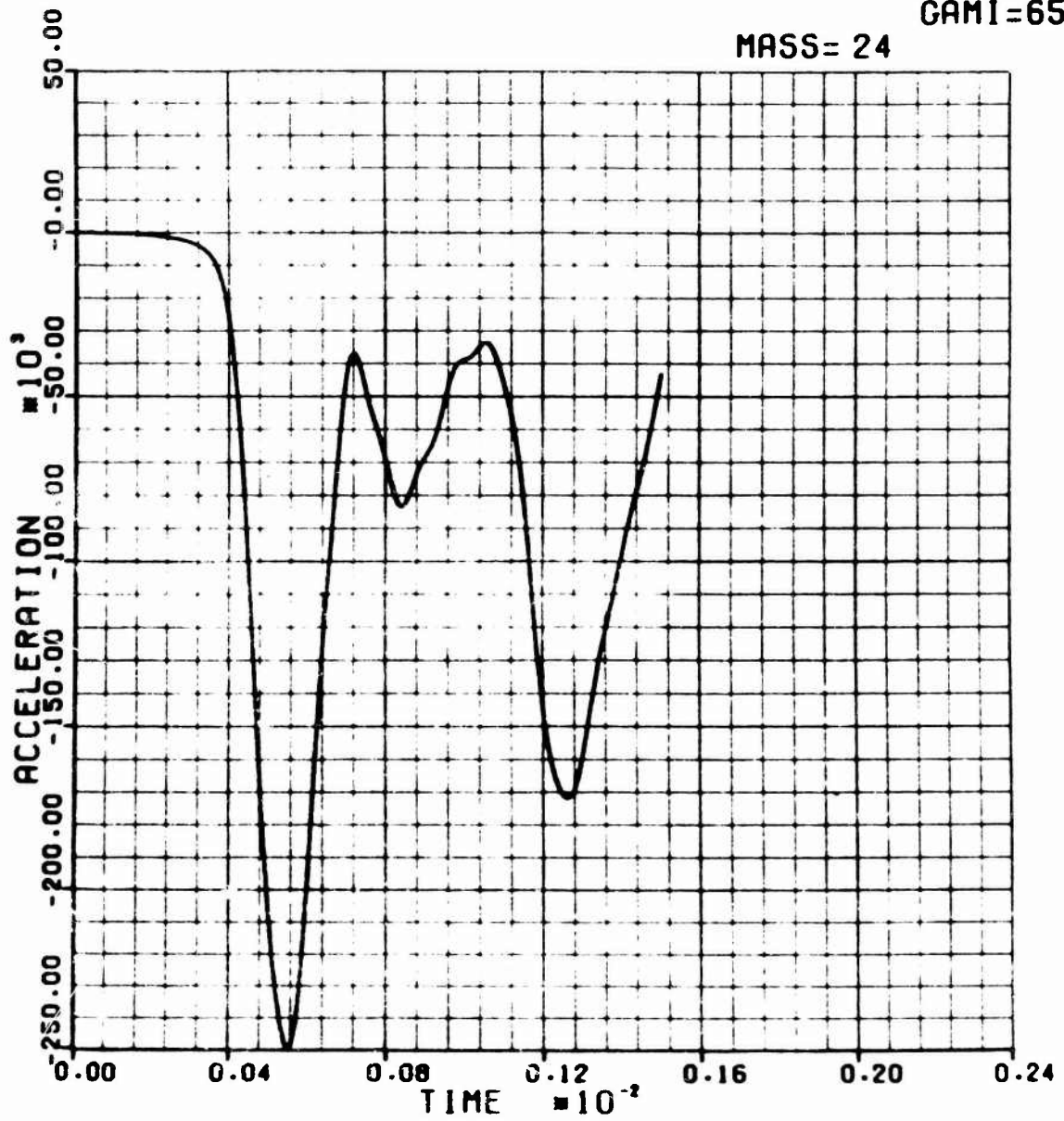
MK82 (AXIAL)

SAND TARGET

VEL=10800.

GAMI=65.0

MASS= 24



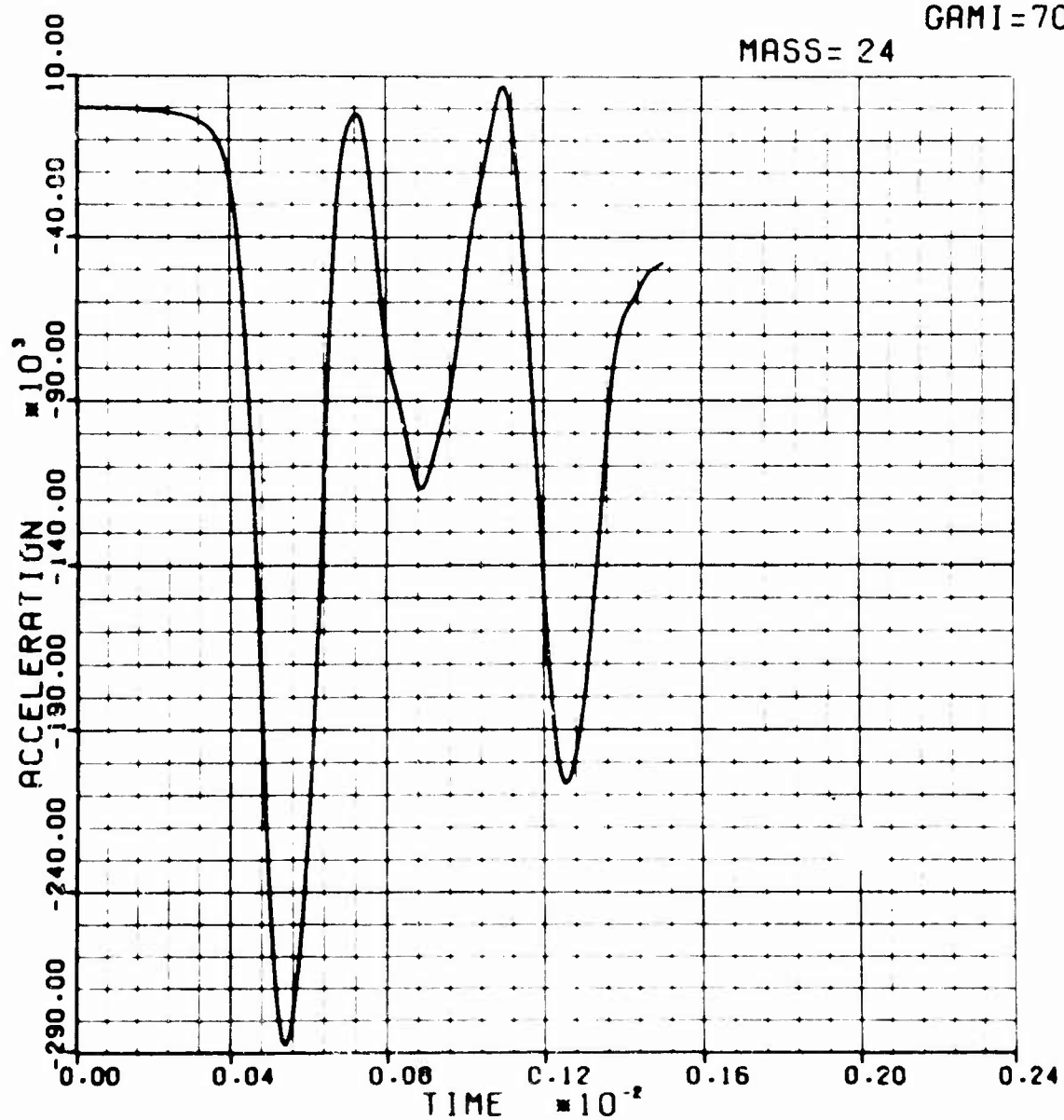
MK82 (AXIAL)

SAND TARGET

VEL=10800.

GAMI=70.0

MASS= 24



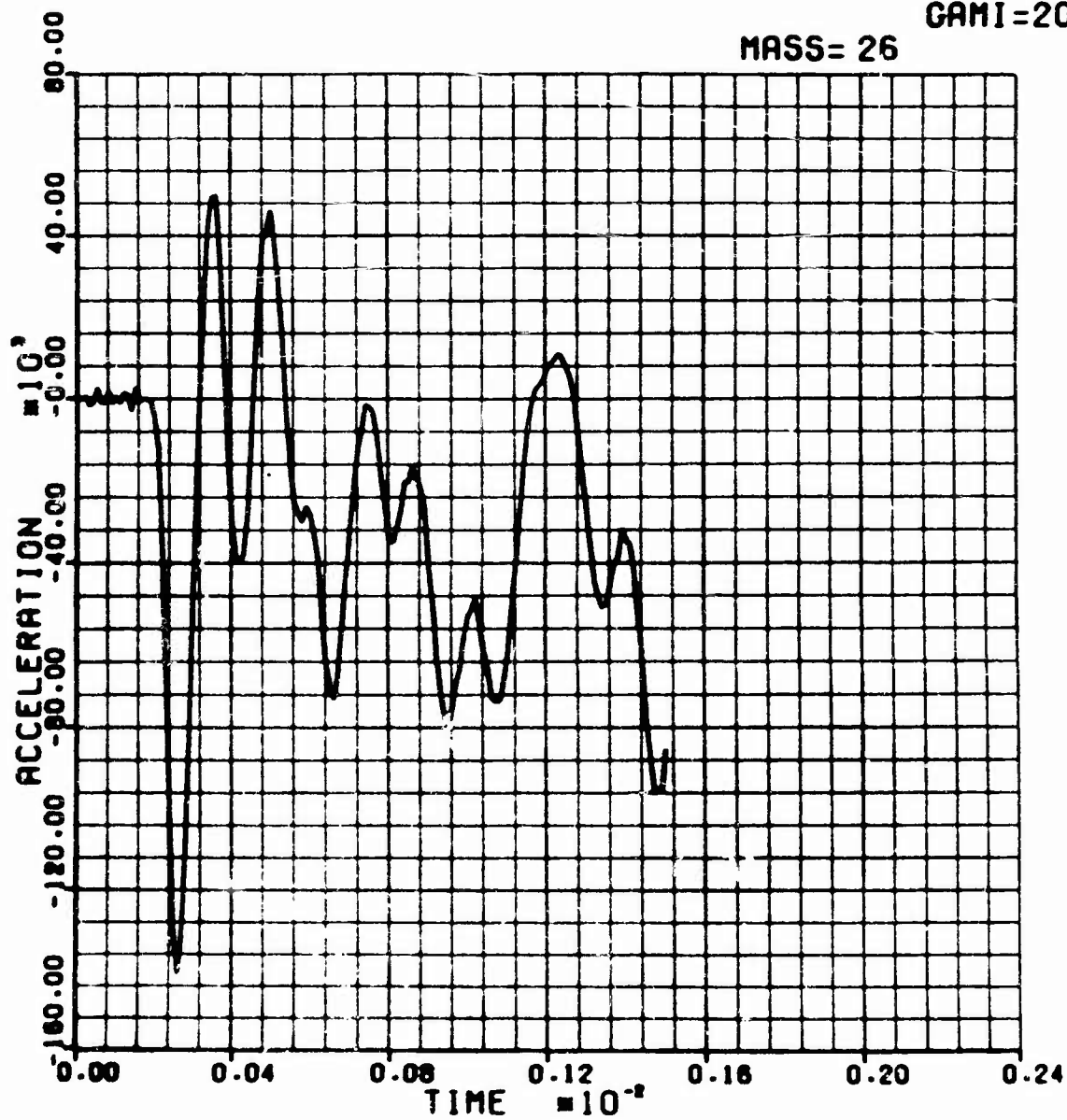
MK82 (AXIAL)

SAND TARGET

VEL= 7200.

GAMI=20.0

MASS= 26



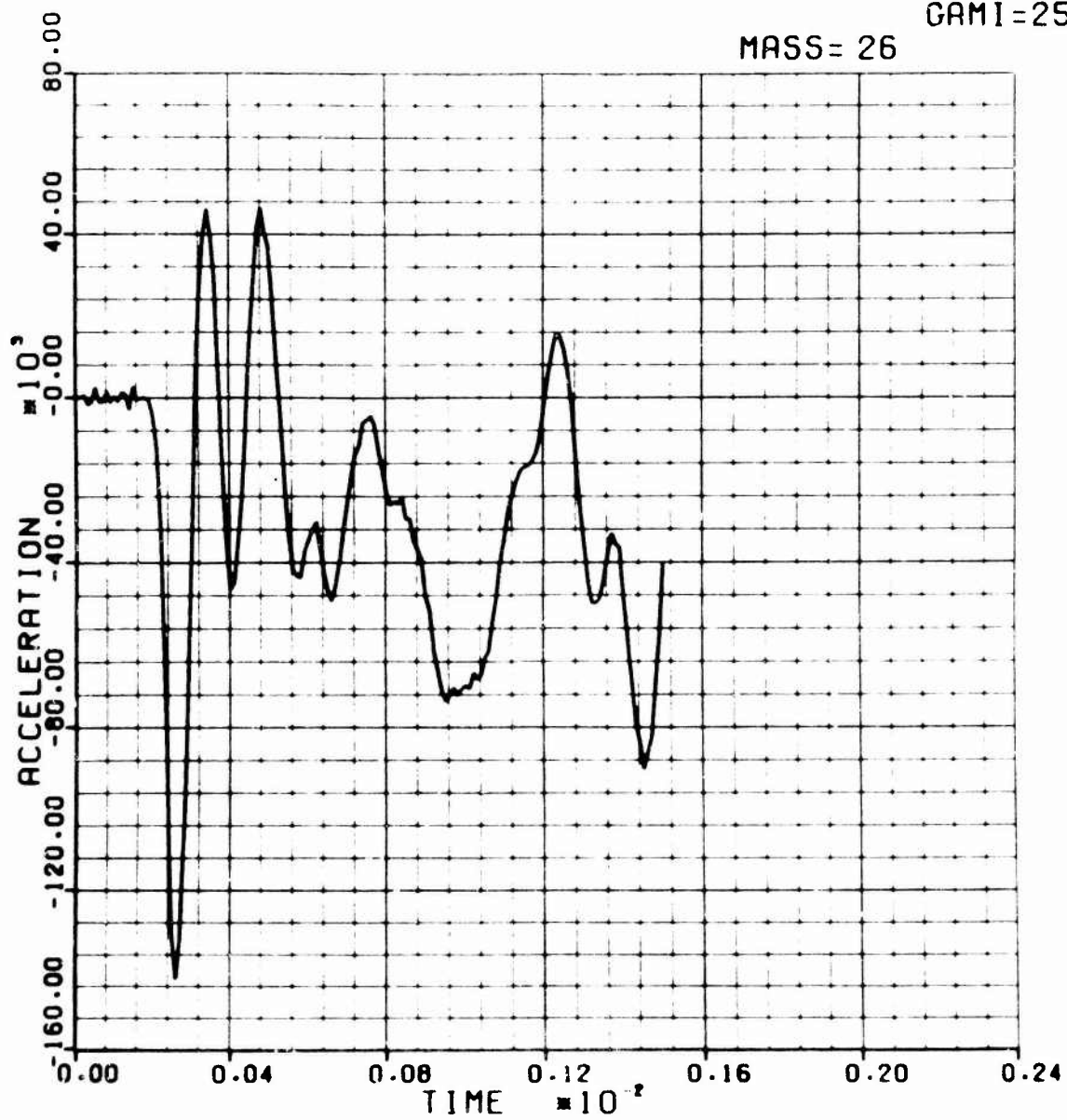
MK82 (AXIAL)

SAND TARGET

VEL= 7200.

GAMI=25.0

MASS= 26



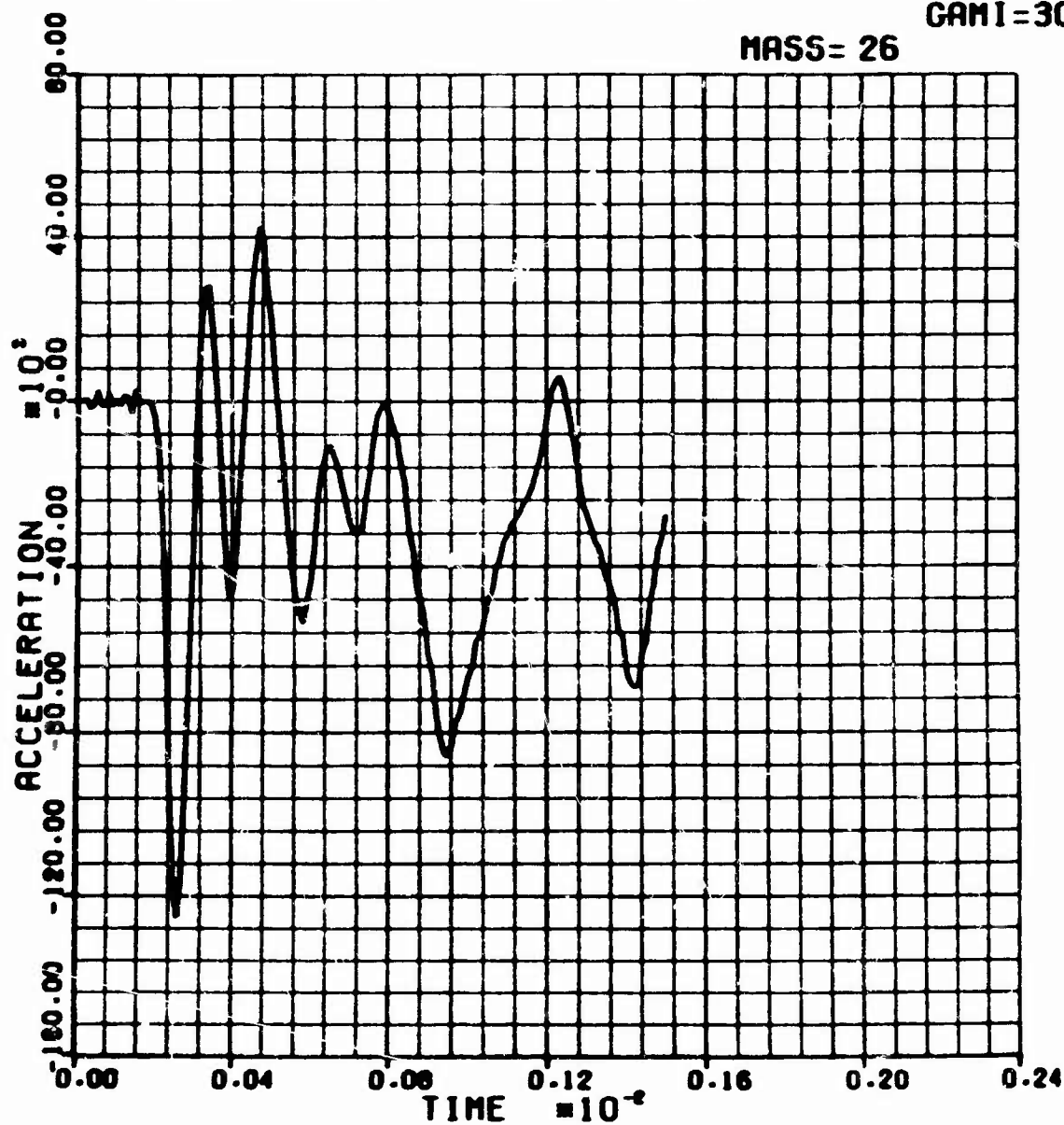
MK82 (AXIAL)

SAND TARGET

VEL= 7200.

GAMI=30.0

MASS= 26



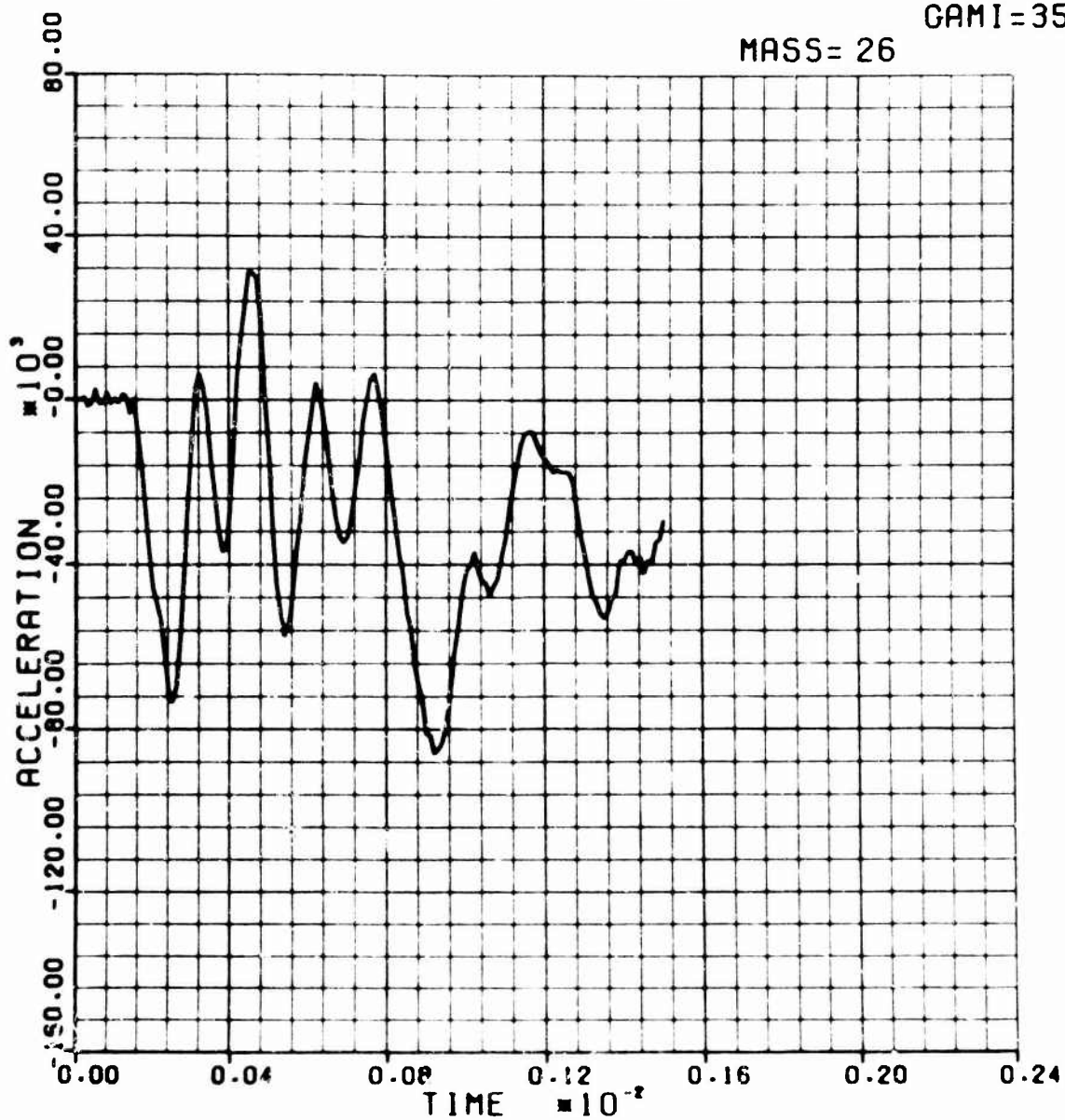
MK82 (AXIAL)

SAND TARGET

VEL= 7200.

GAMI=35.0

MASS= 26



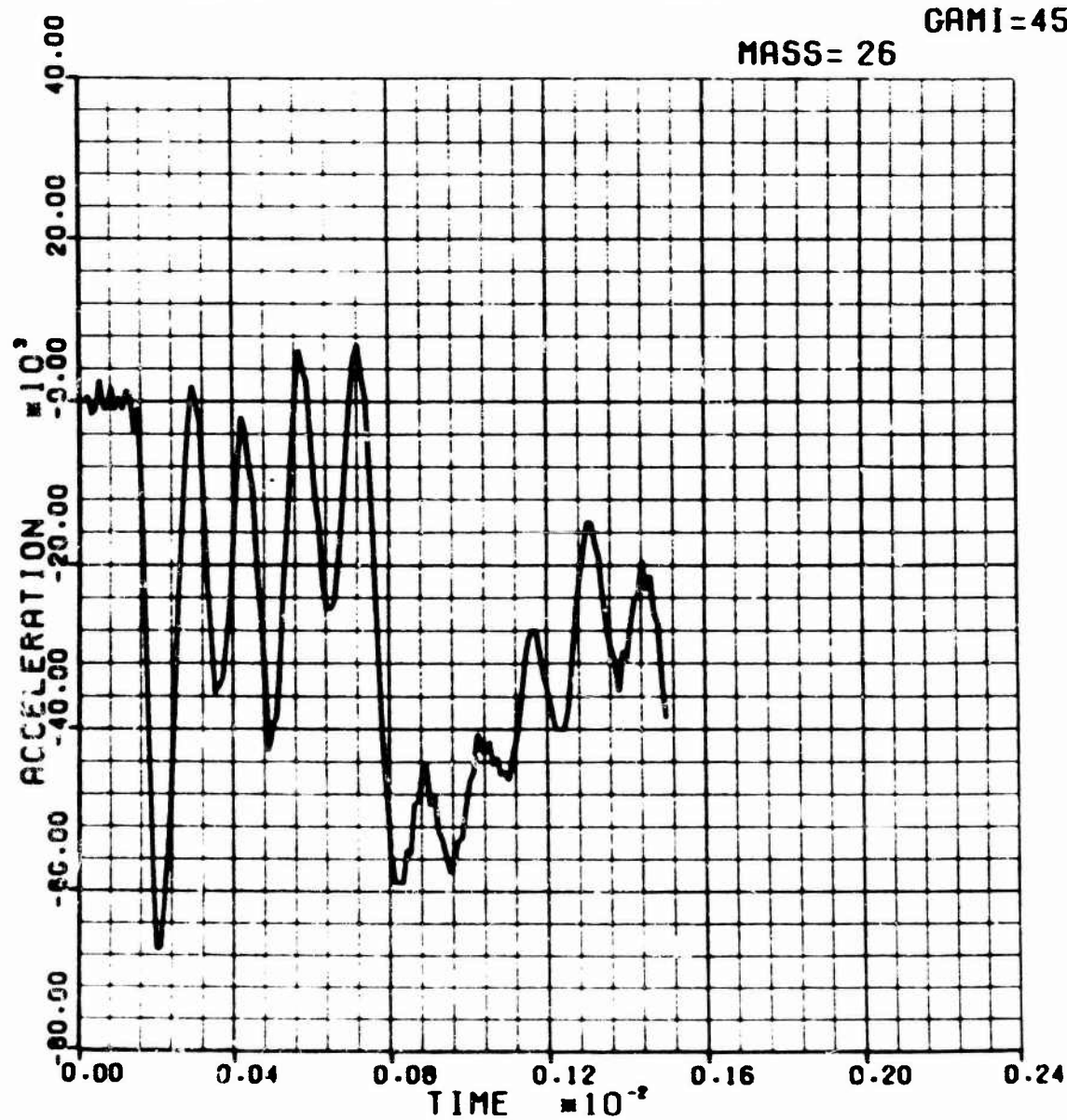
MK82 (AXIAL)

SAND TARGET

VEL= 7200.

GAMI=45.0

MASS= 26



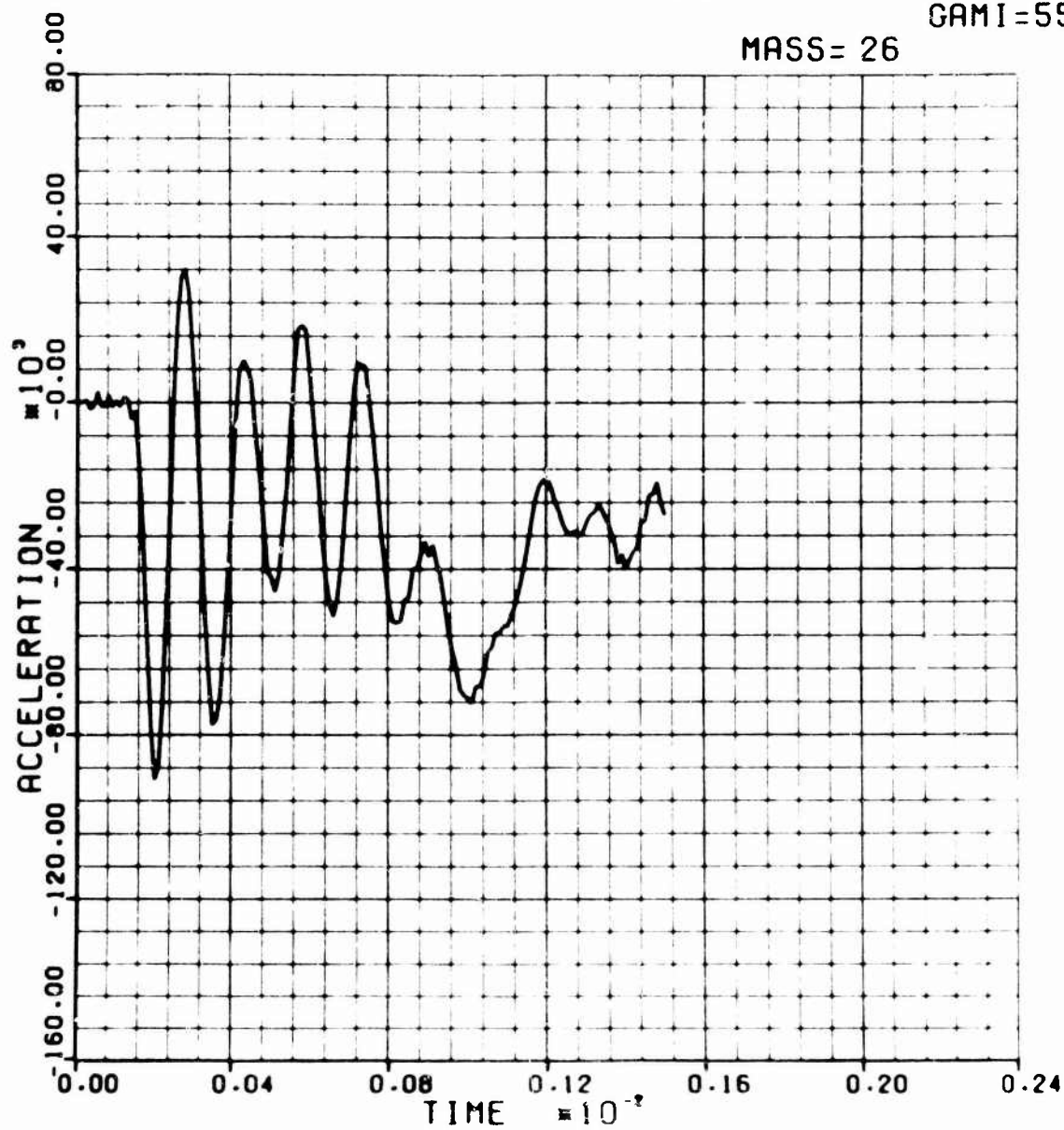
MK82 (AXIAL)

SAND TARGET

VEL= 7200.

GAMI=55.0

MASS= 26



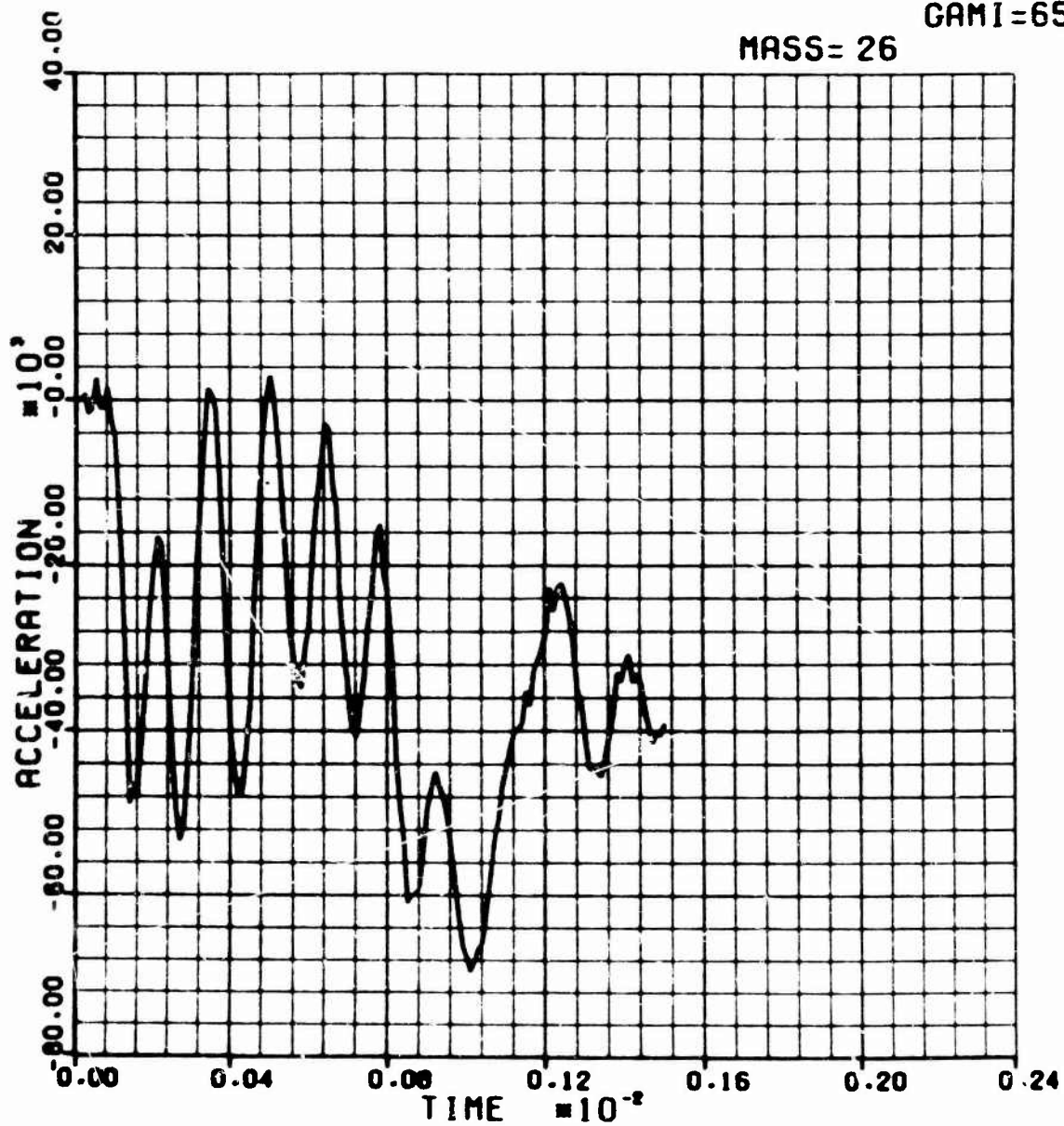
MK82 (AXIAL)

SAND TARGET

VEL= 7200.

GAMI=65.0

MASS= 26



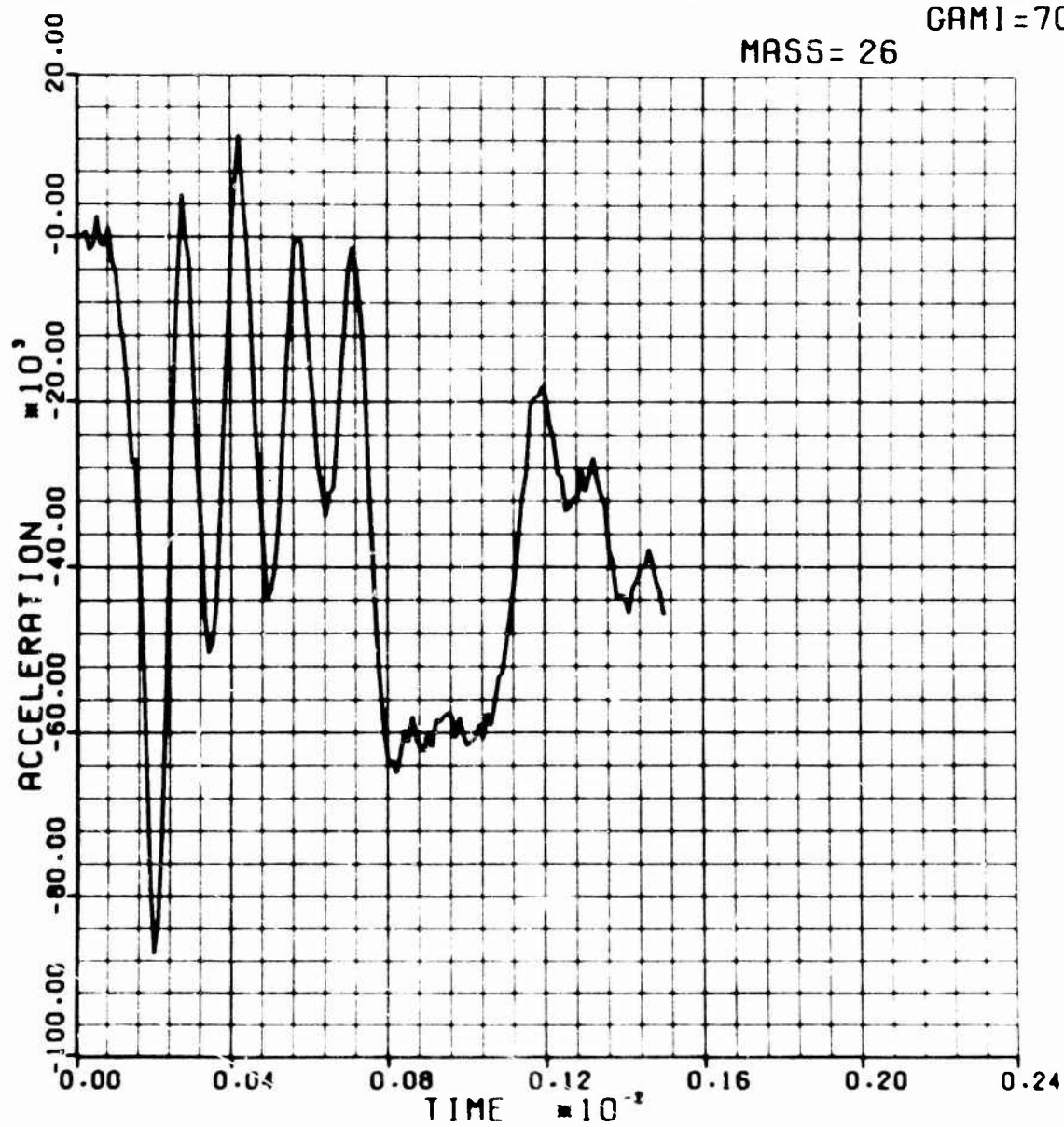
MK82 (AXIAL)

SAND TARGET

VEL= 7200.

GAMI=70.0

MASS= 26



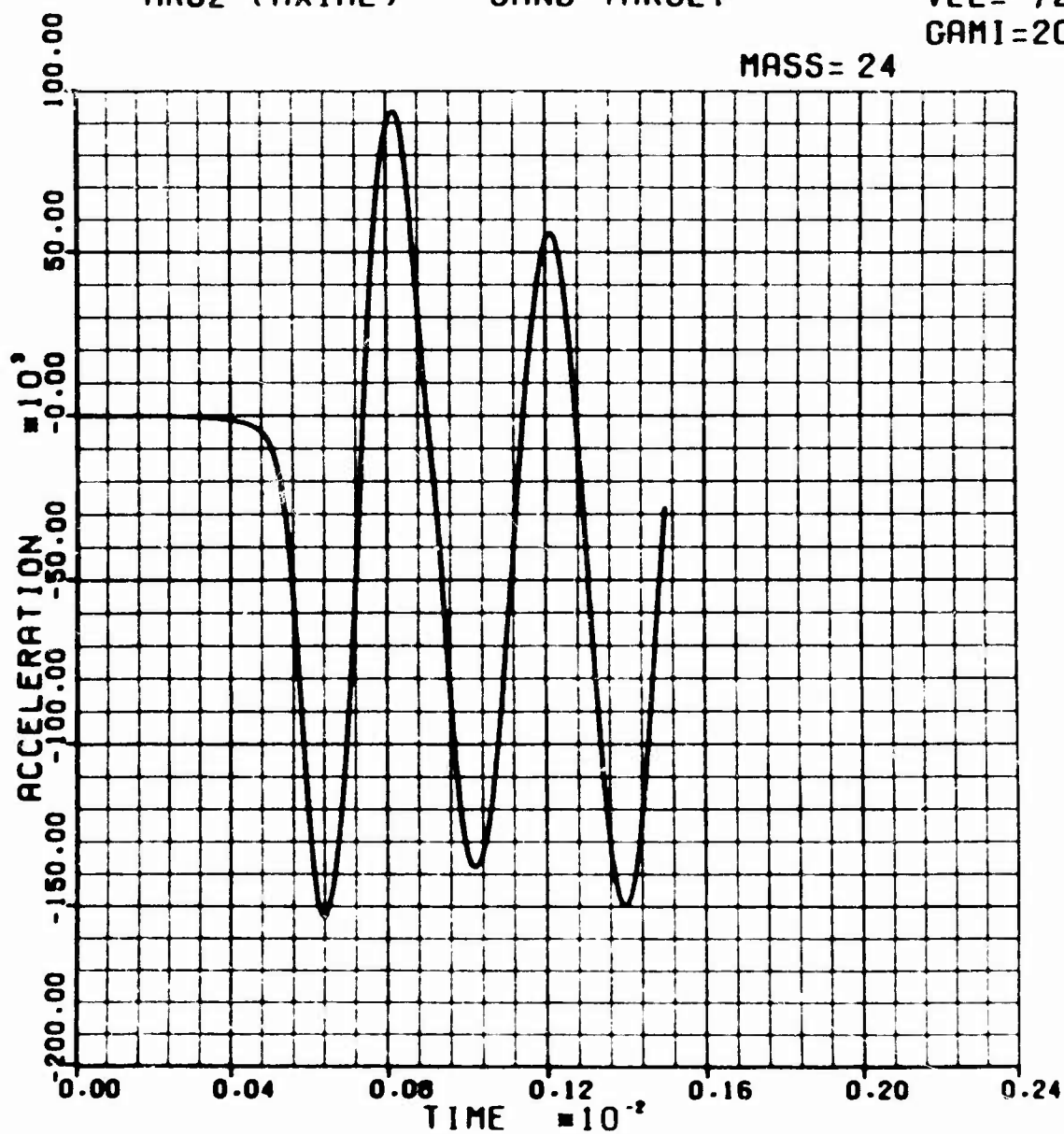
MK82 (AXIAL)

SAND TARGET

VEL= 7200.

GAMI=20.0

MASS= 24



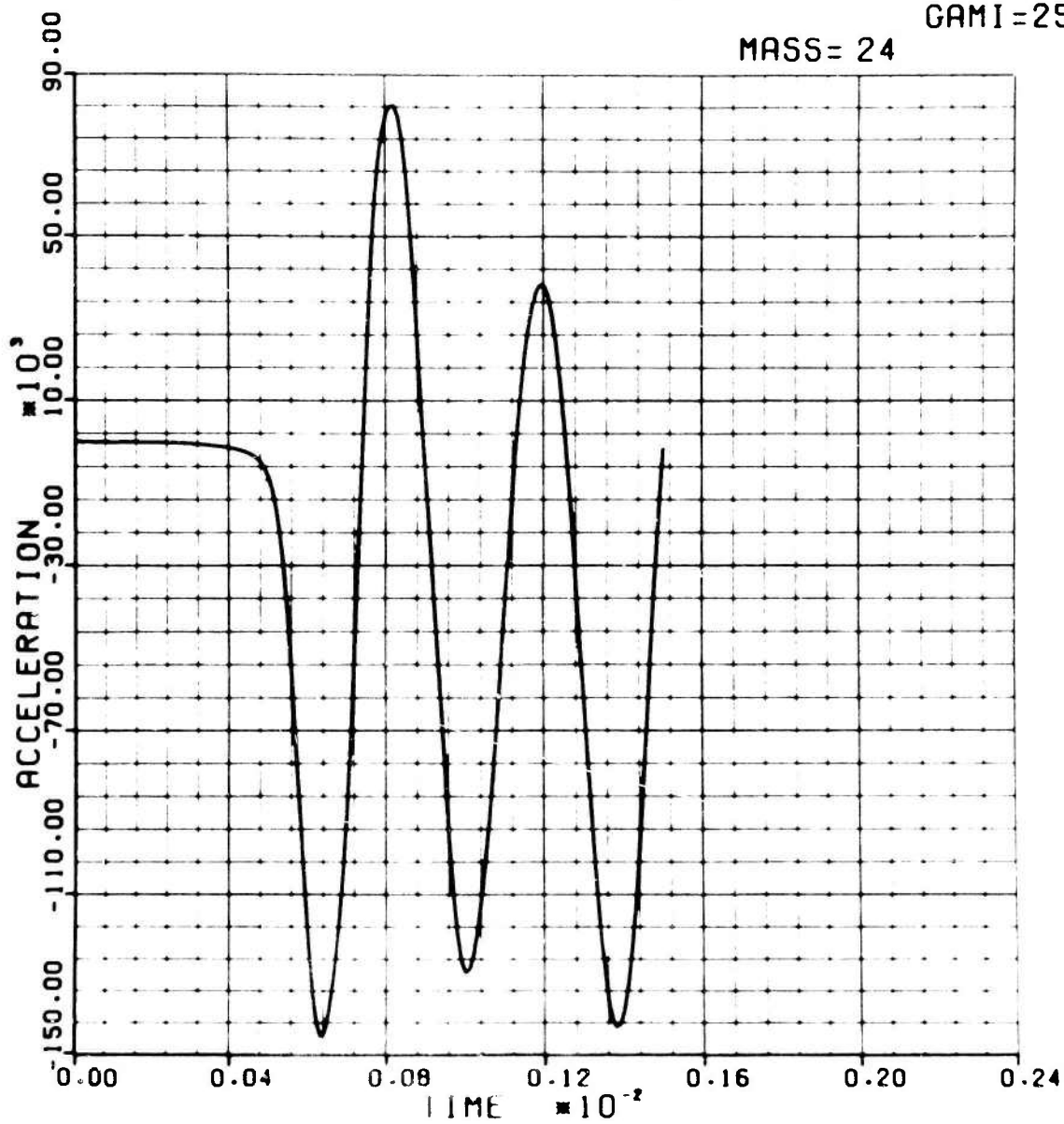
MK82 (AXIAL)

SAND TARGET

VEL = 7200.

GAMI = 25.0

MASS = 24



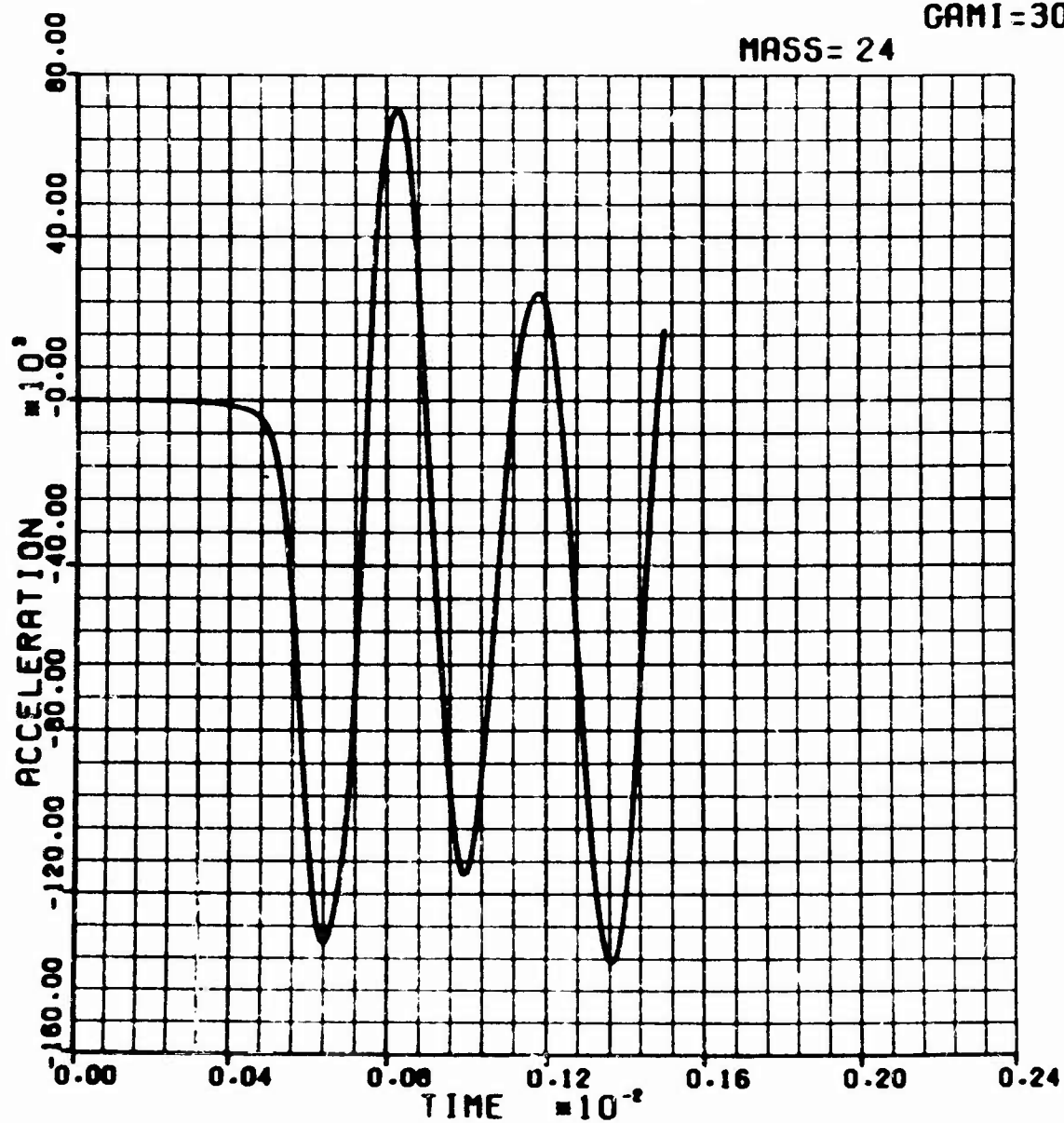
MK82 (AXIAL)

SAND TARGET

VEL= 7200.

GAMI=30.0

MASS= 24



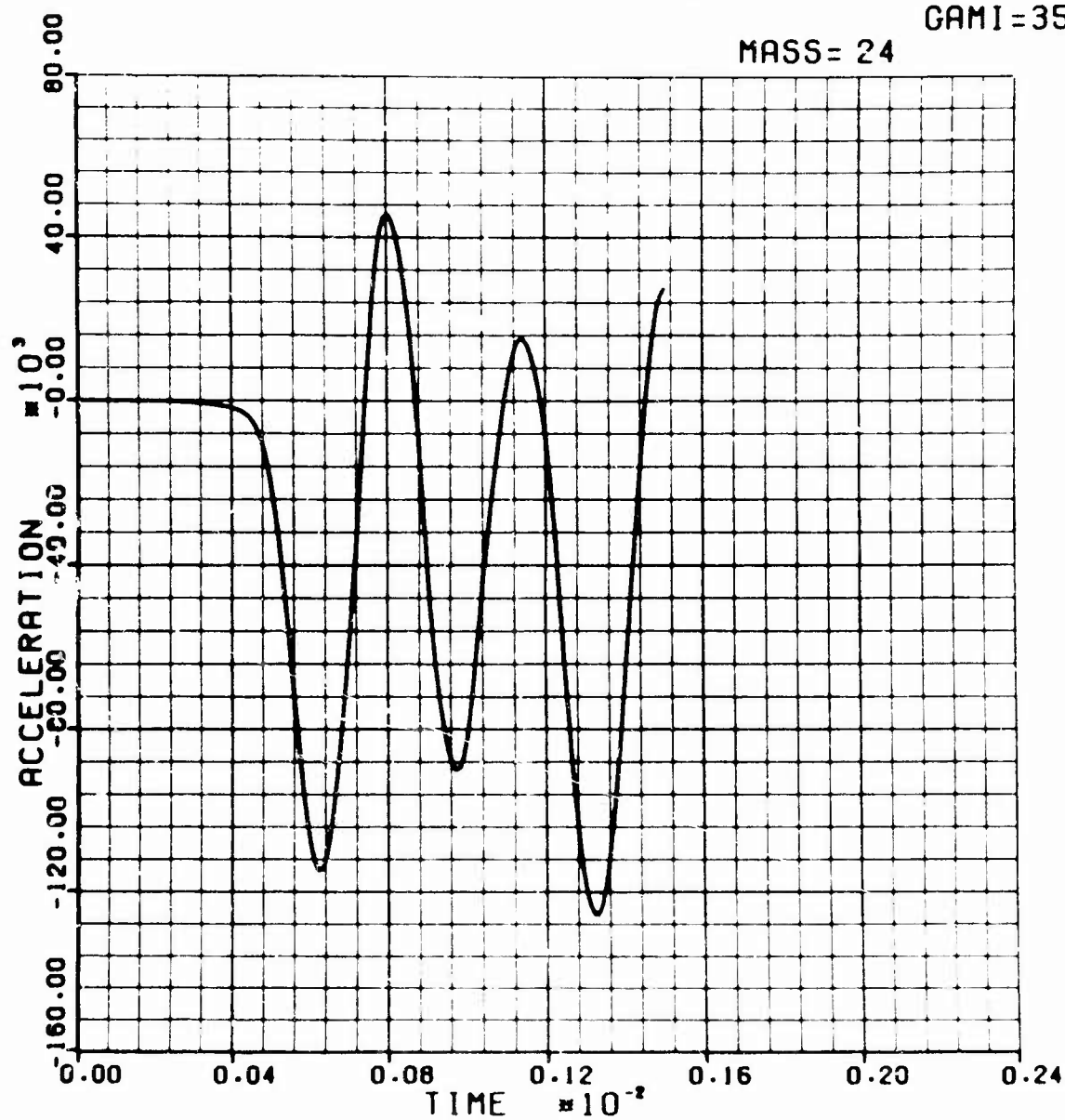
MK82 (AXIAL)

SAND TARGET

VEL= 7200.

GAMI=35.0

MASS= 24



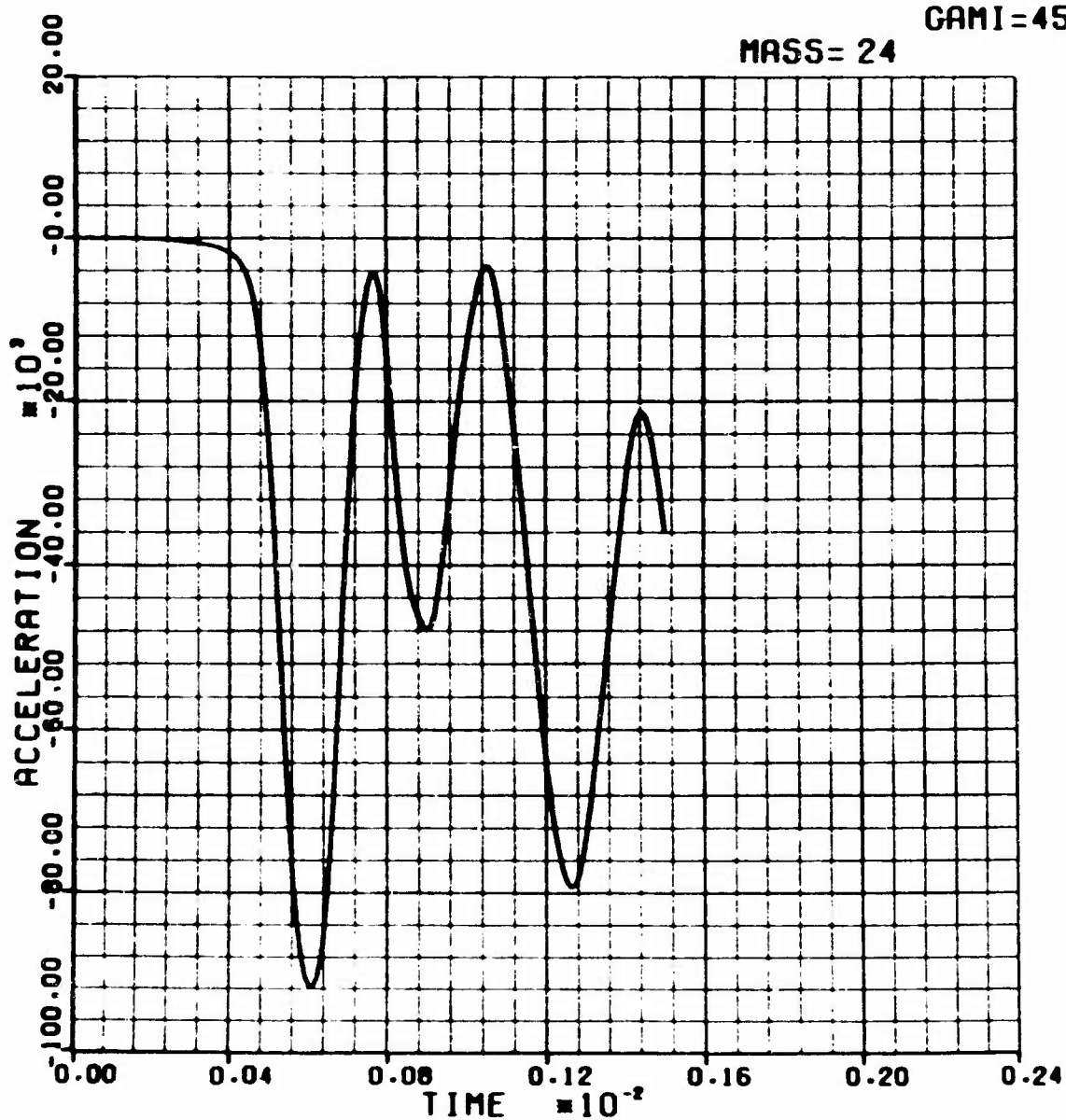
MK82 (AXIAL)

SAND TARGET

VEL= 7200.

GAMI=45.0

MASS= 24



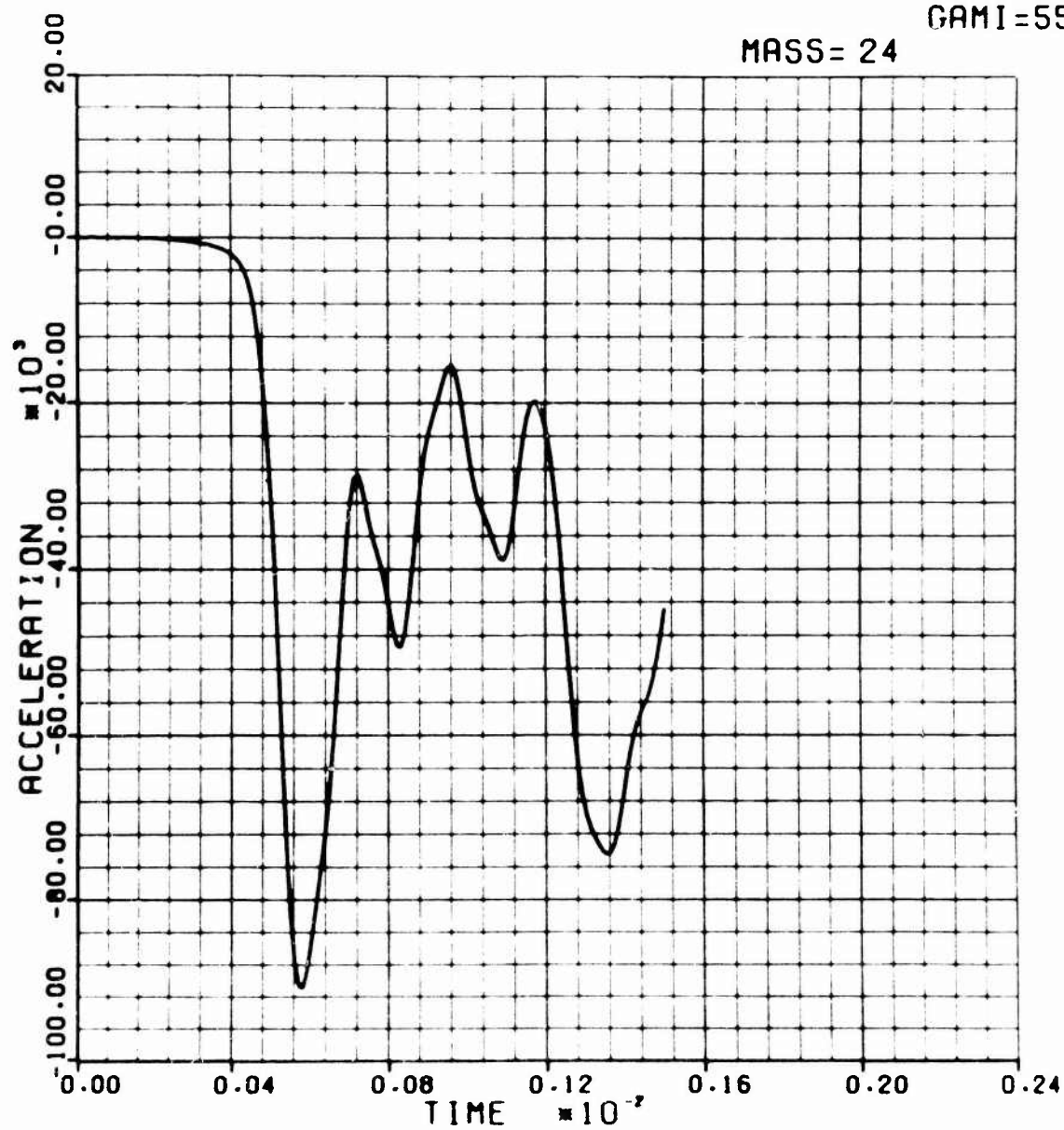
MK82 (AXIAL)

SAND TARGET

VEL= 7200.

GAMI=55.0

MASS= 24



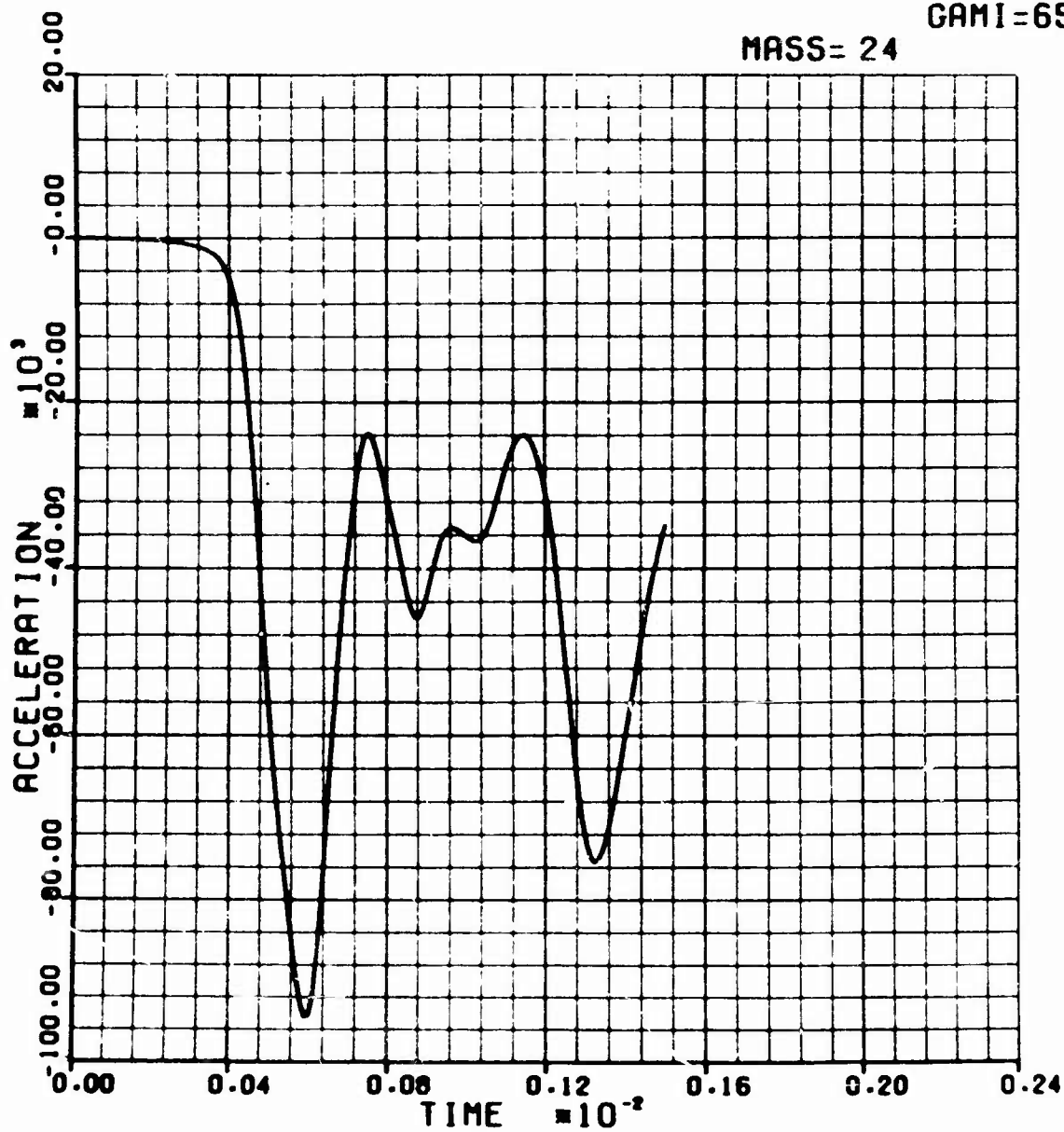
MK82 (AXIAL)

SAND TARGET

VEL= 7200.

GAMI=65.0

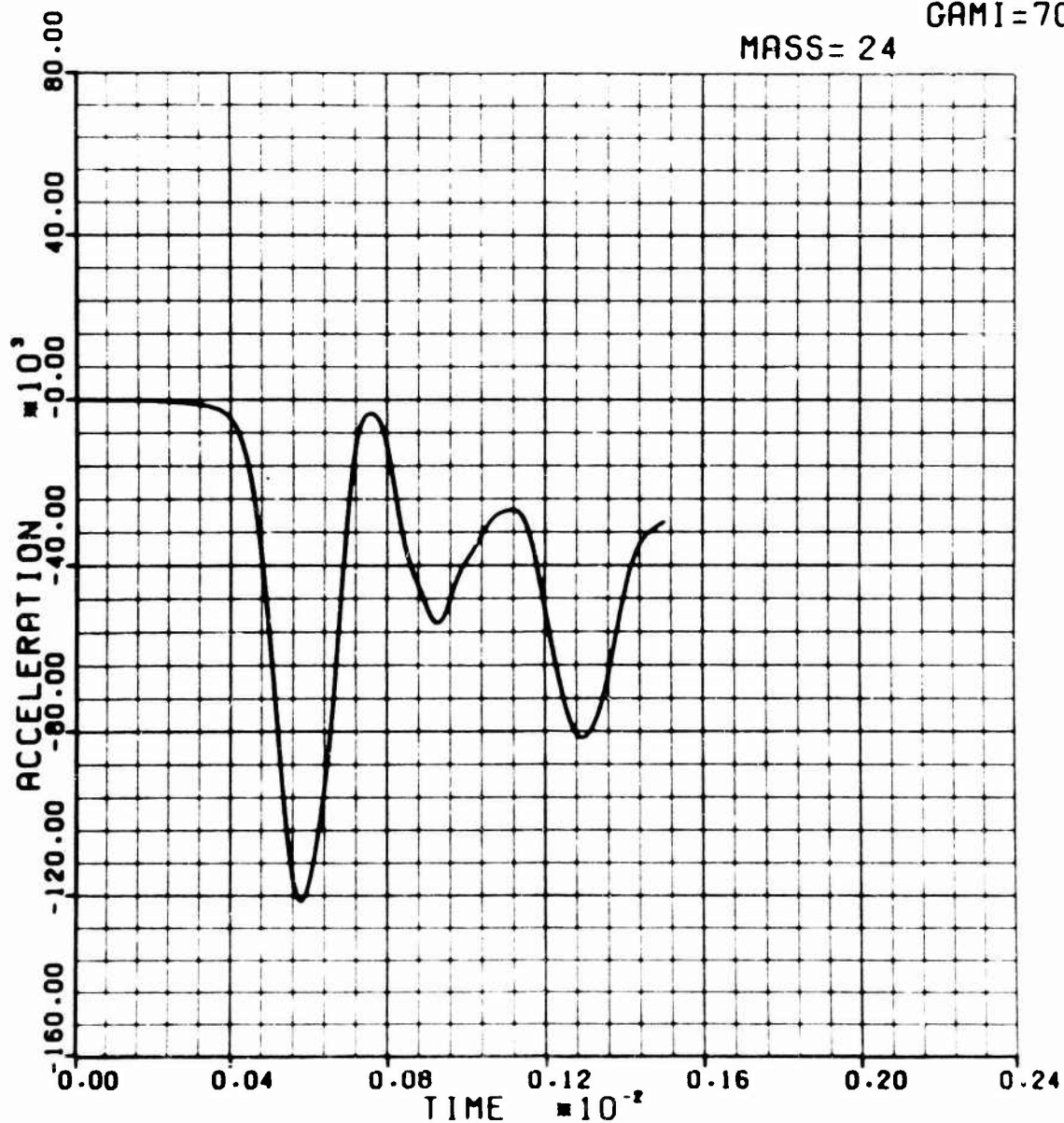
MASS= 24



MK82 (XIRL) SAND TARGET

VEL = 7200.
GAMI = 70.0

MASS = 24



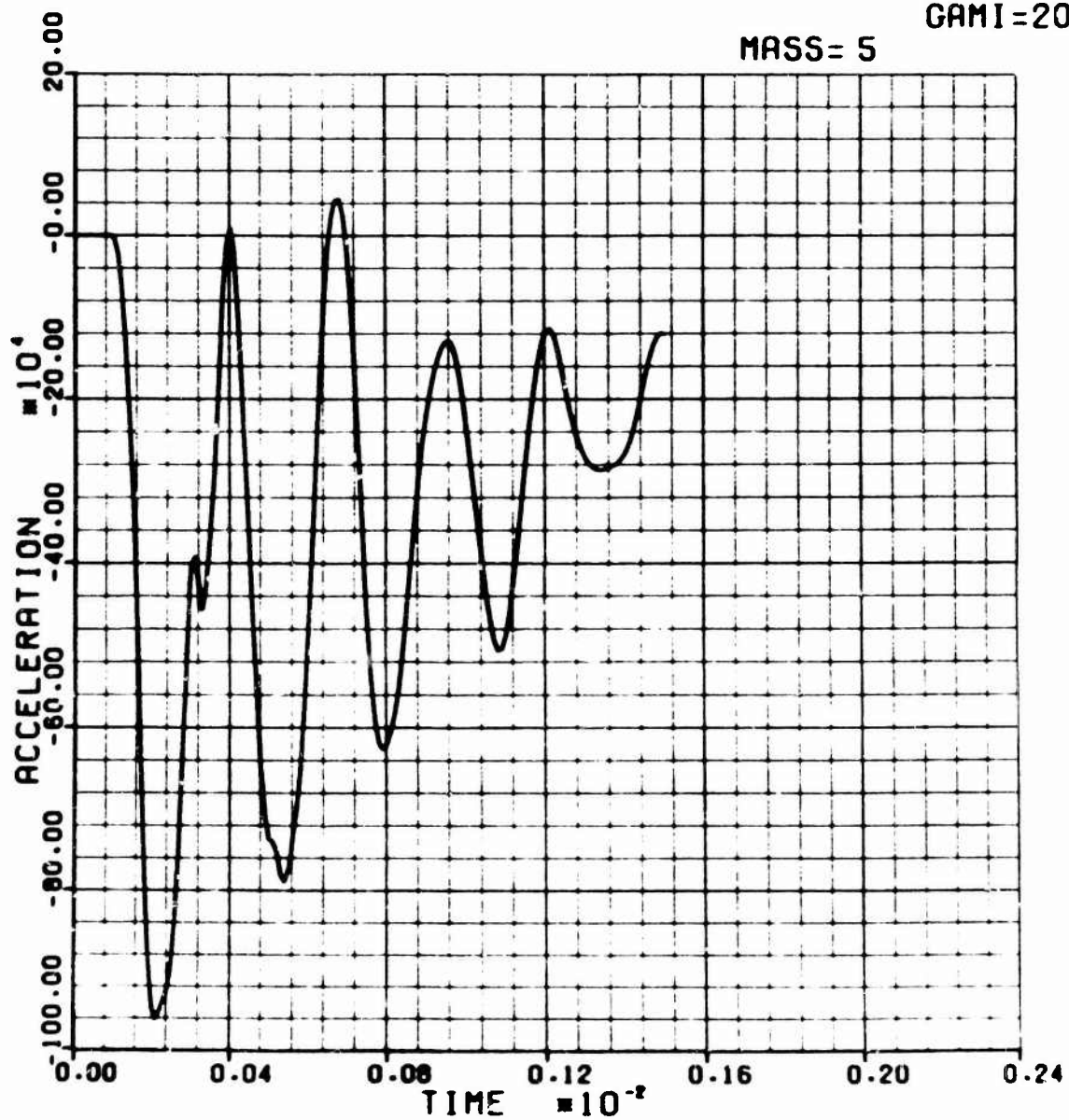
MK82 (LATERAL)

SAND TARGET

VEL=13200.

GAMI=20.0

MASS= 5



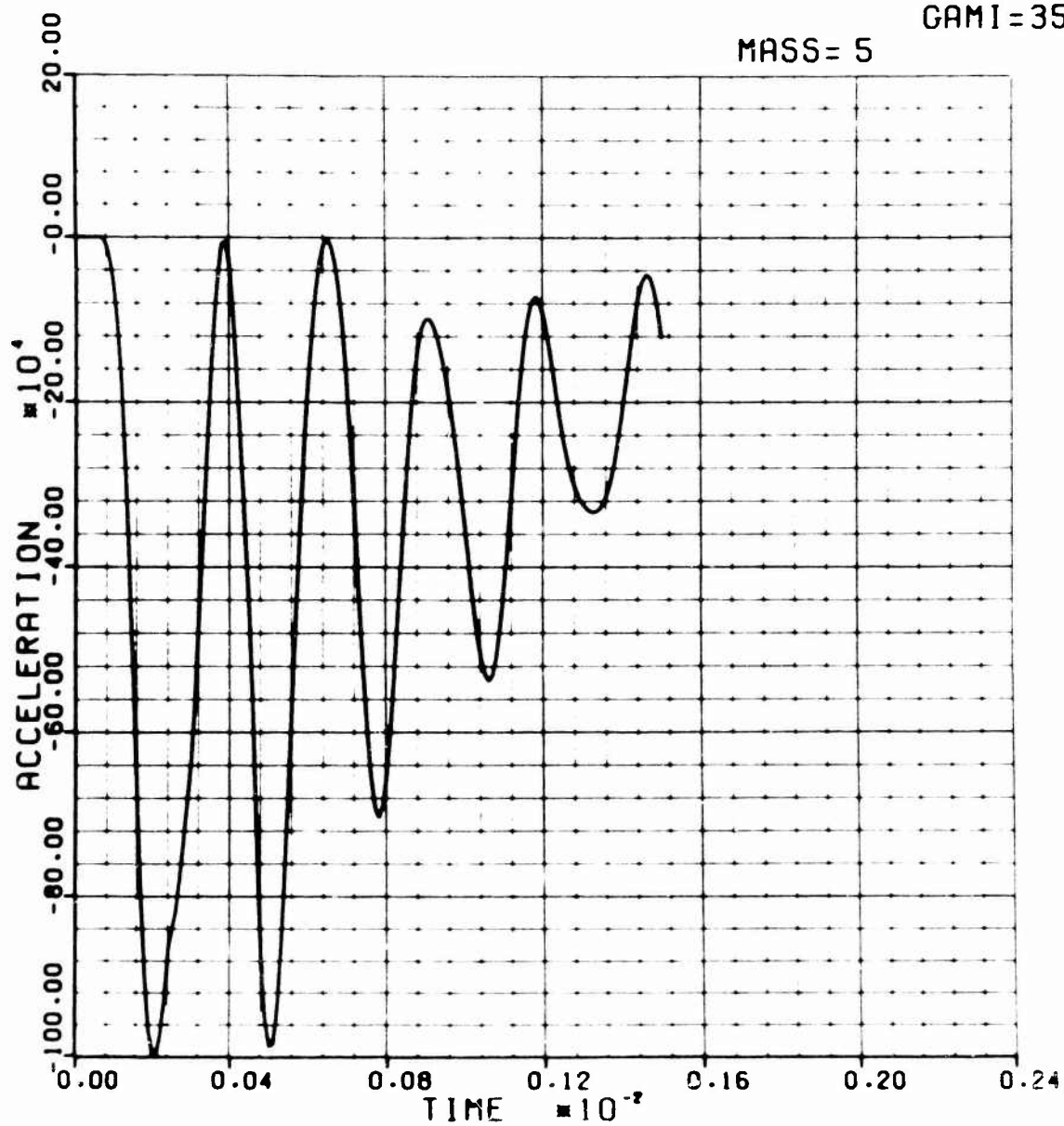
MK82 (LATERAL)

SAND TARGET

VEL=13200.

GAMI=35.0

MASS= 5

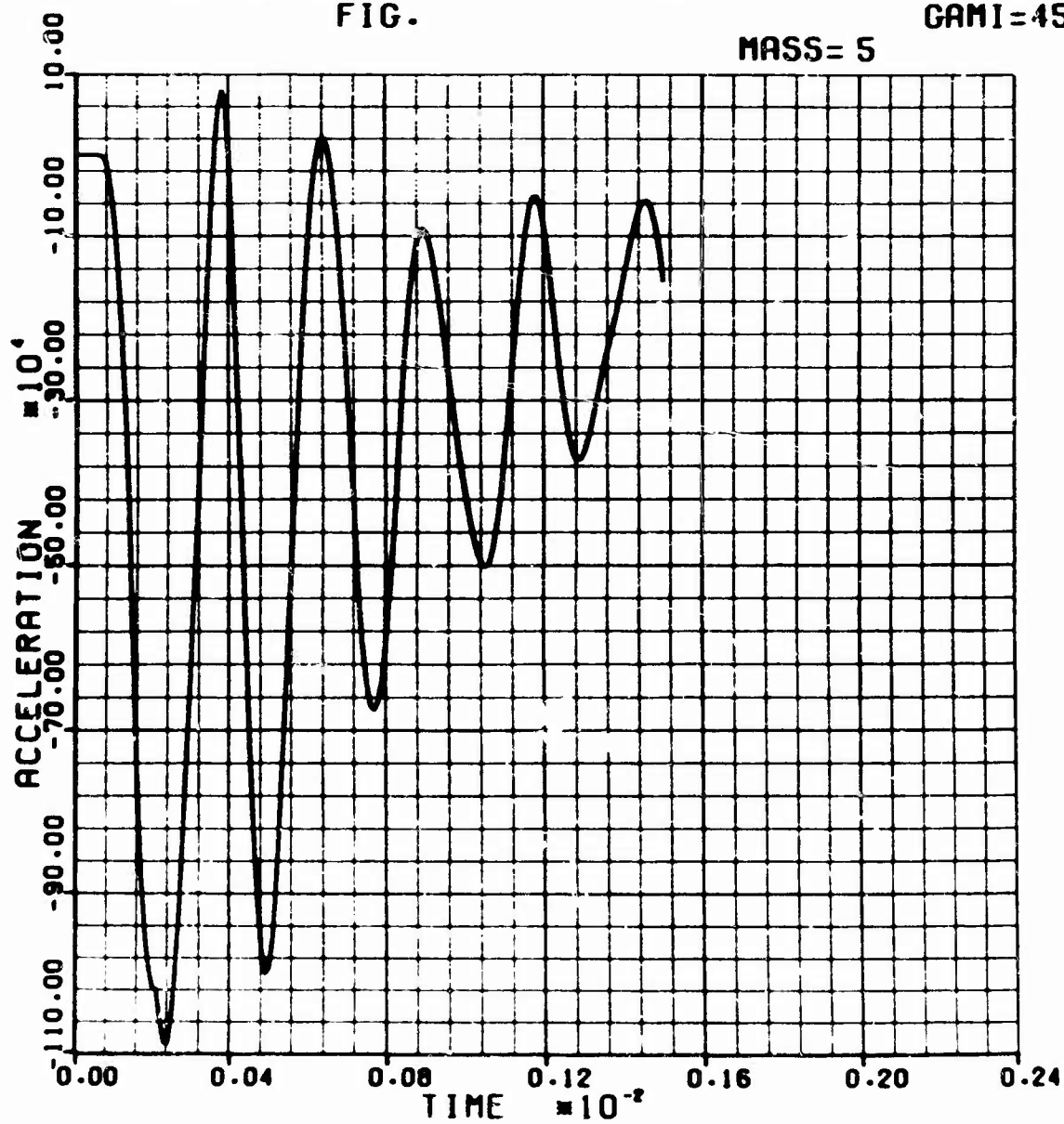


MK82 (LATERAL)
FIG.

SAND TARGET

VEL=13200.
GAMI=45.0

MASS= 5



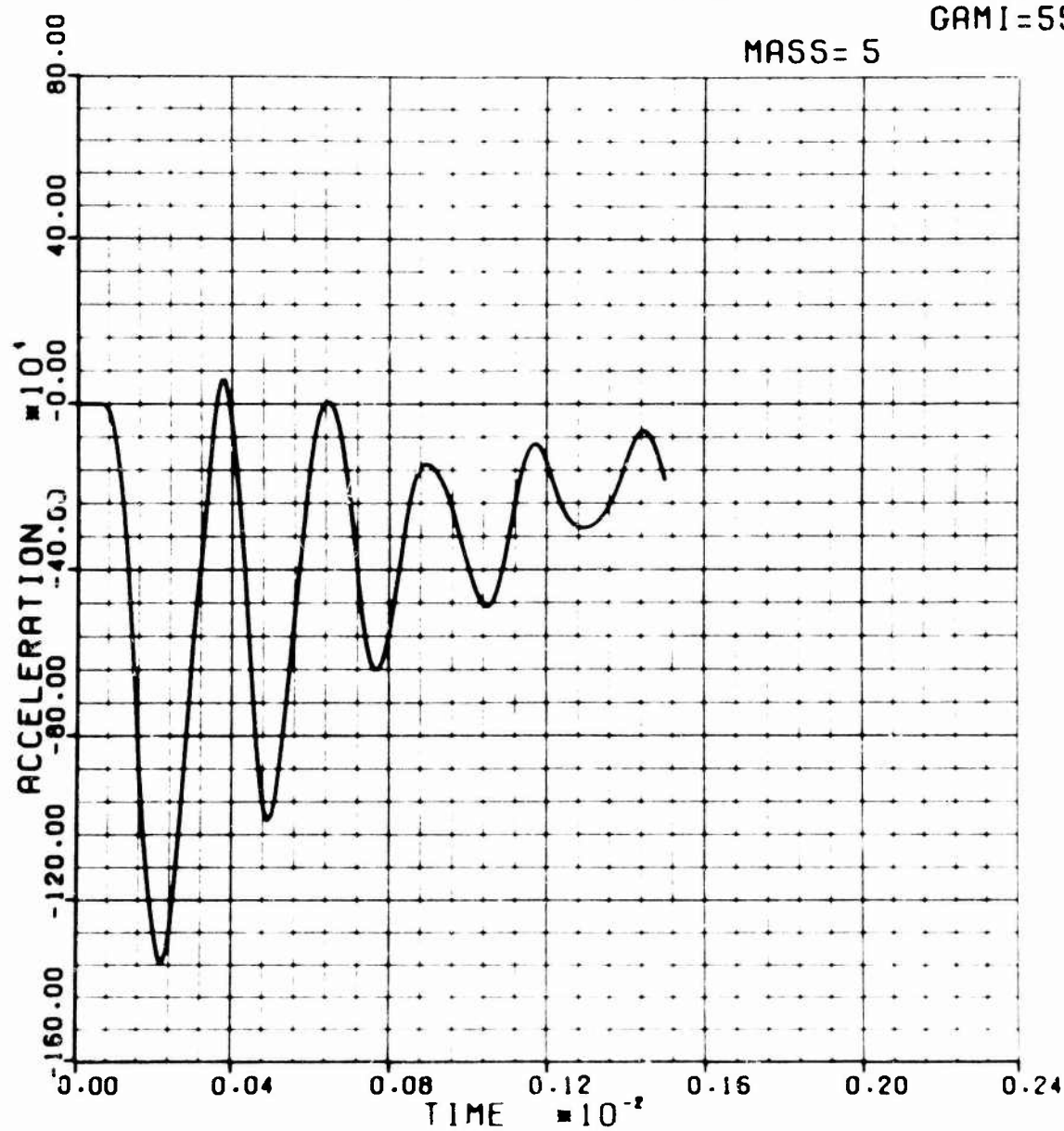
MK82 (LATERAL)

SAND TARGET

VEL=13200.

GAMI=55.0

MASS= 5



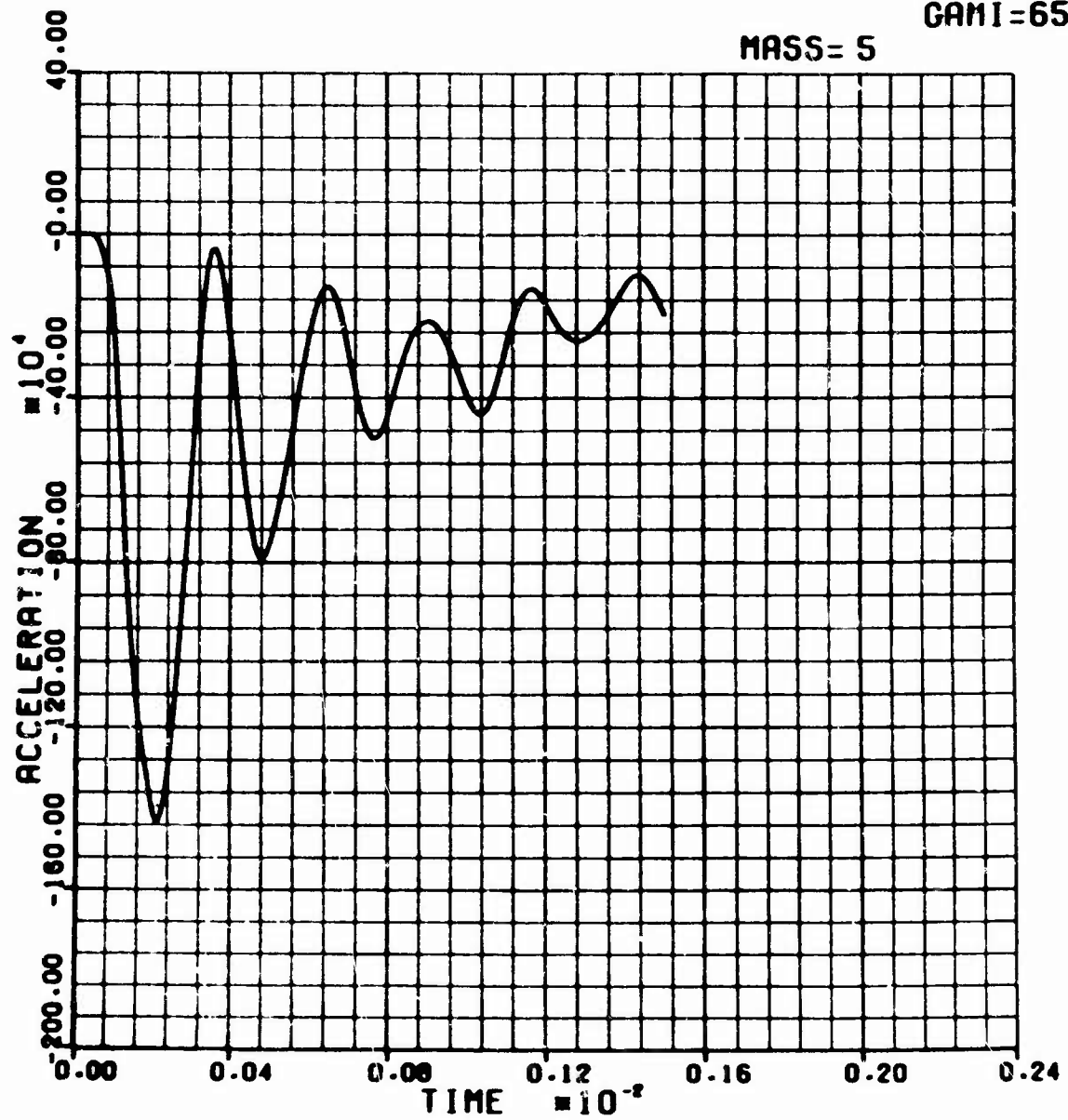
MK82 (LATERAL)

SAND TARGET

VEL=13200.

GAMI=65.0

MASS= 5

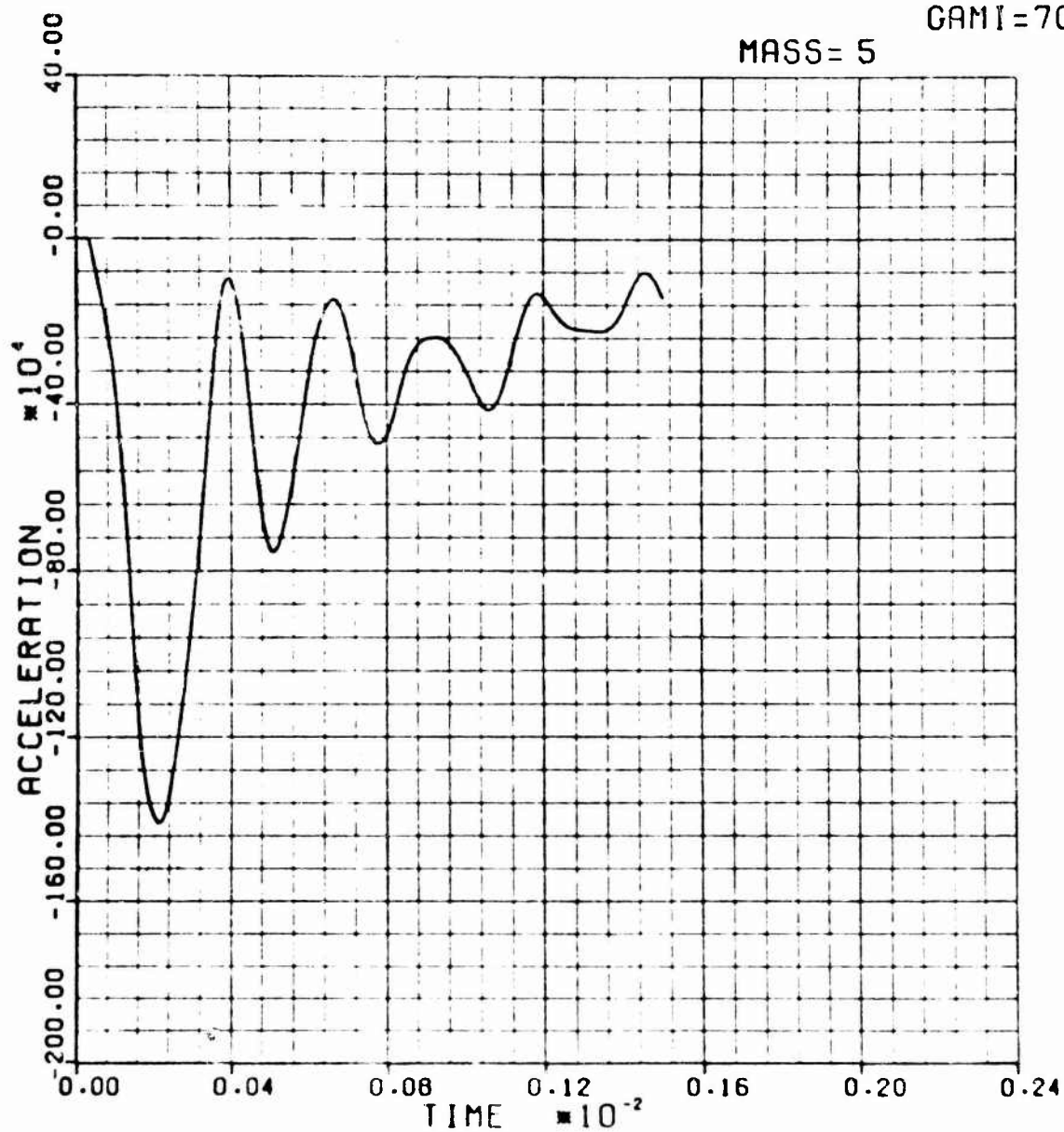


500 LB MK82 (SAND TARGET)

VEL=13200.

GAMI=70.0

MASS= 5



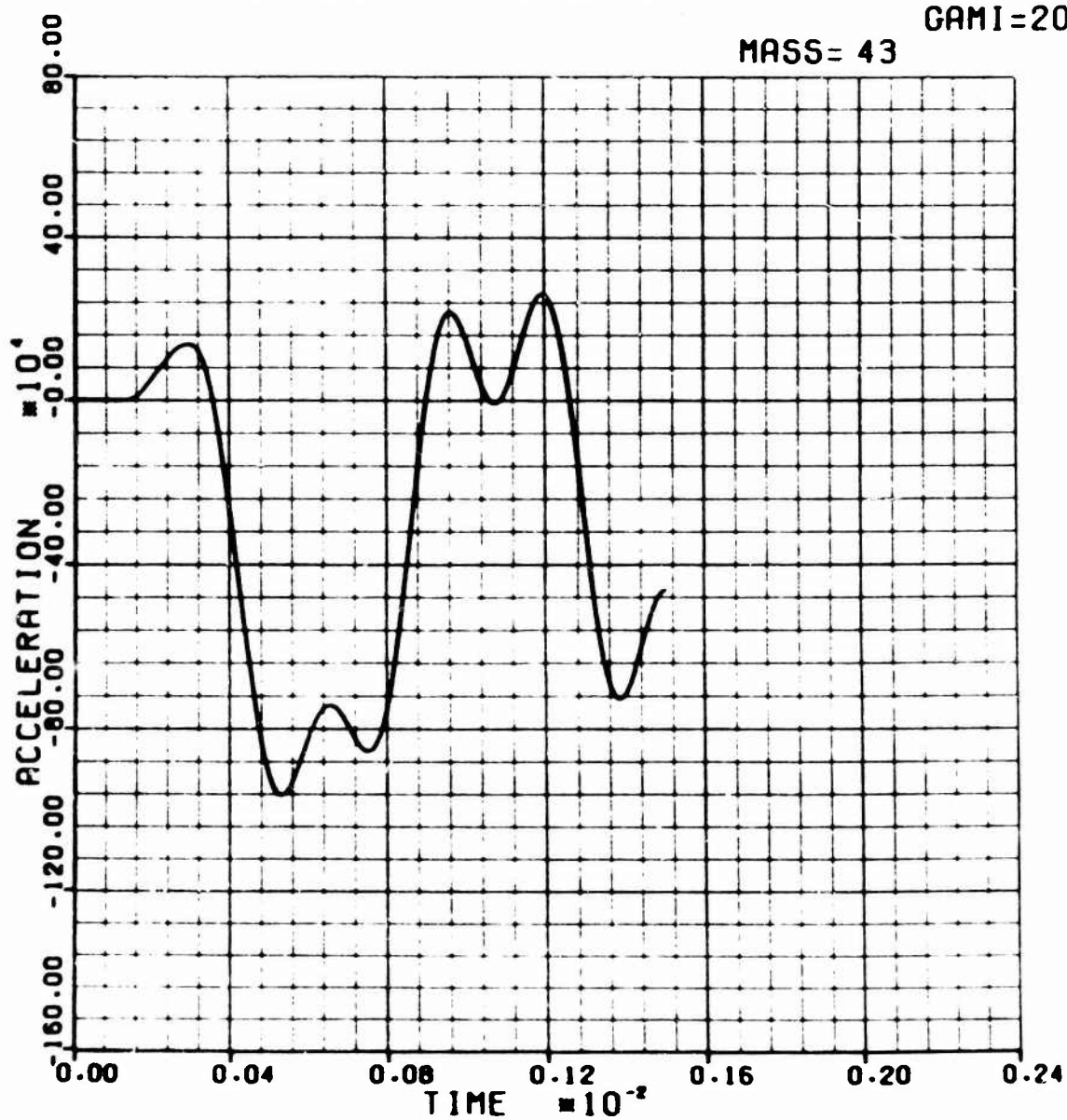
MK82 (LATERAL)

SAND TARGET

VEL=13200.

GAMI=20.0

MASS= 43



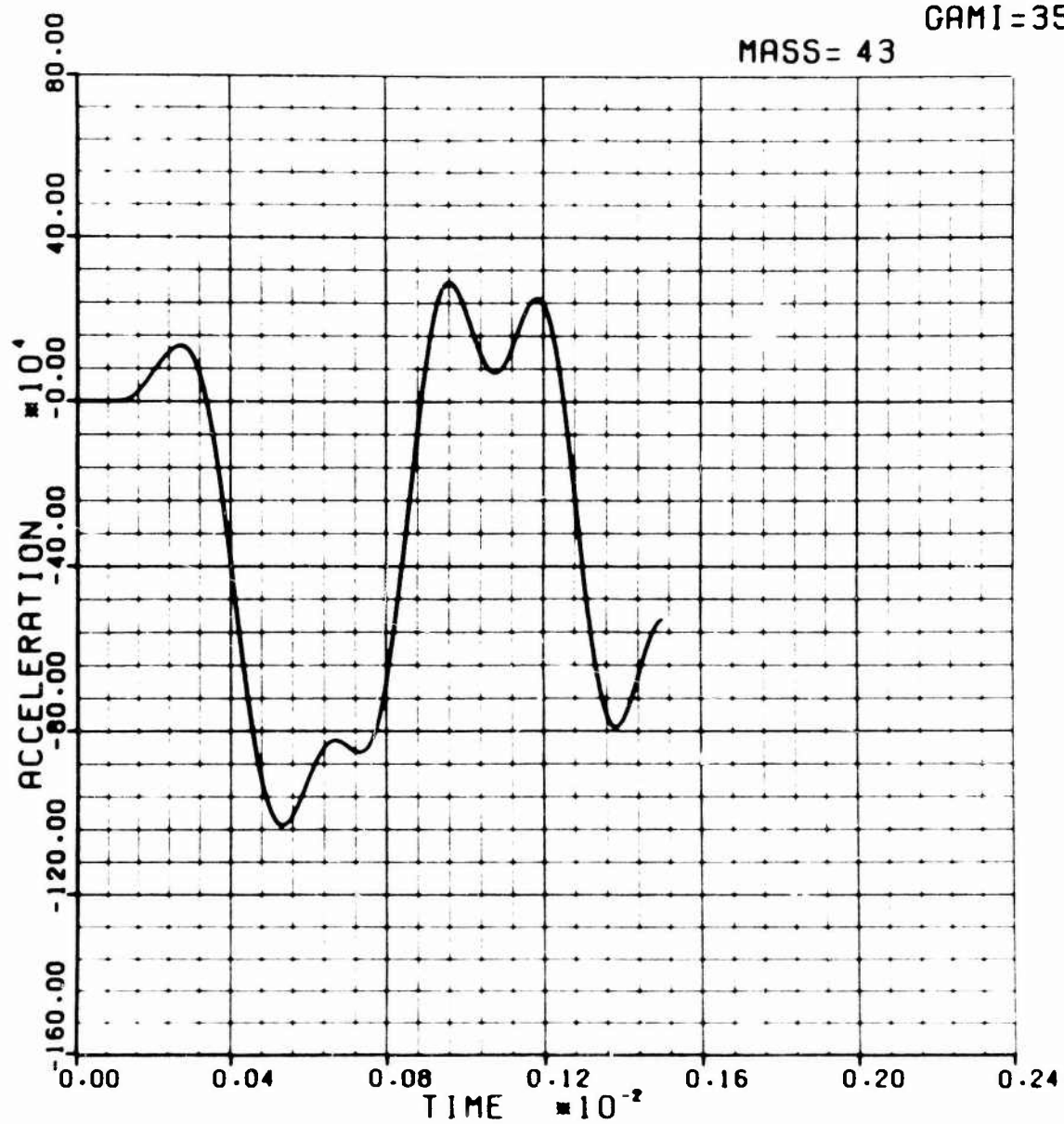
MK82 (LATERAL)

SAND TARGET

VEL=13200.

GAMI=35.0

MASS= 43



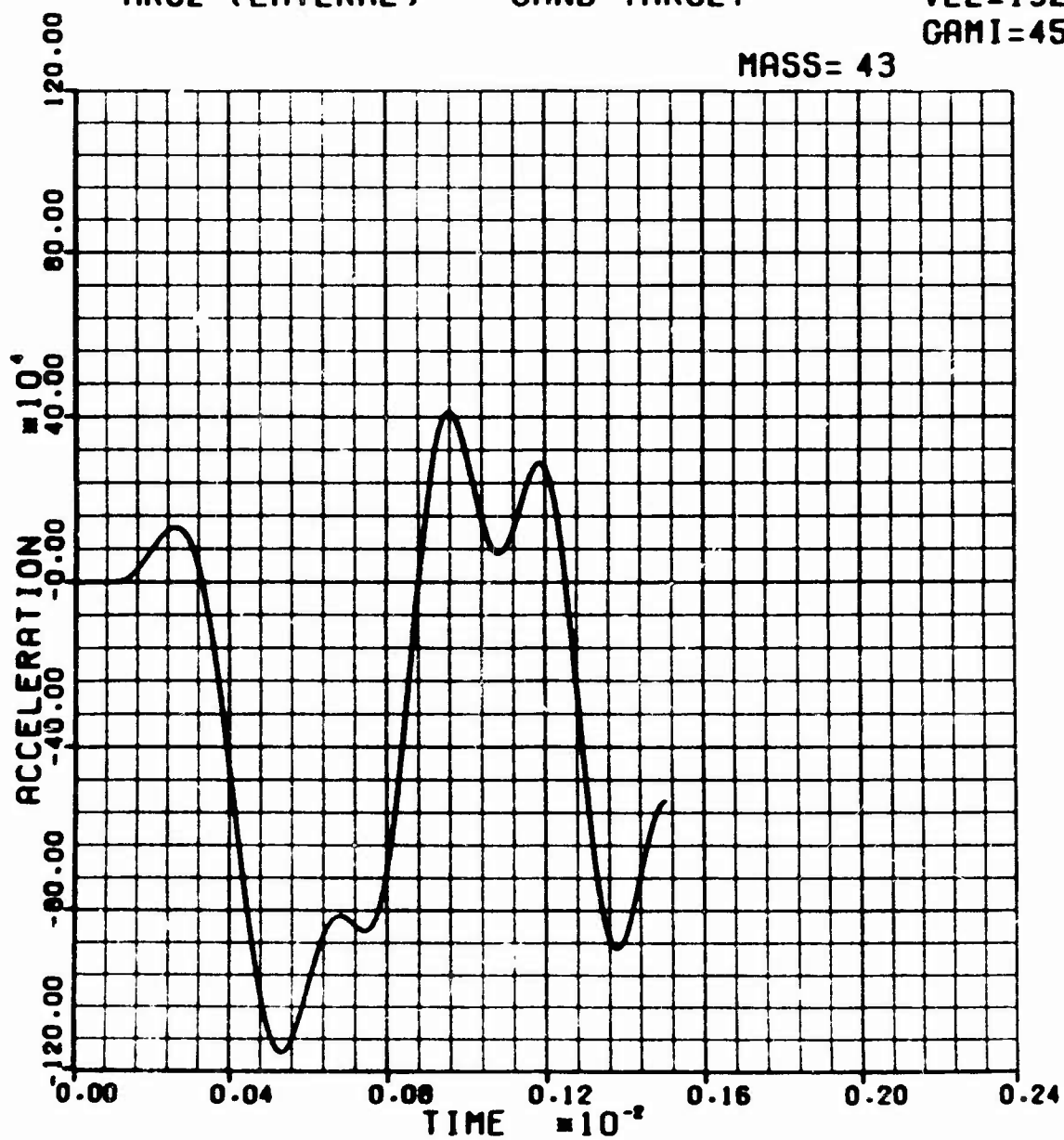
MK82 (LATERAL)

SAND TARGET

VEL=13200.

GAMI=45.0

MASS= 43



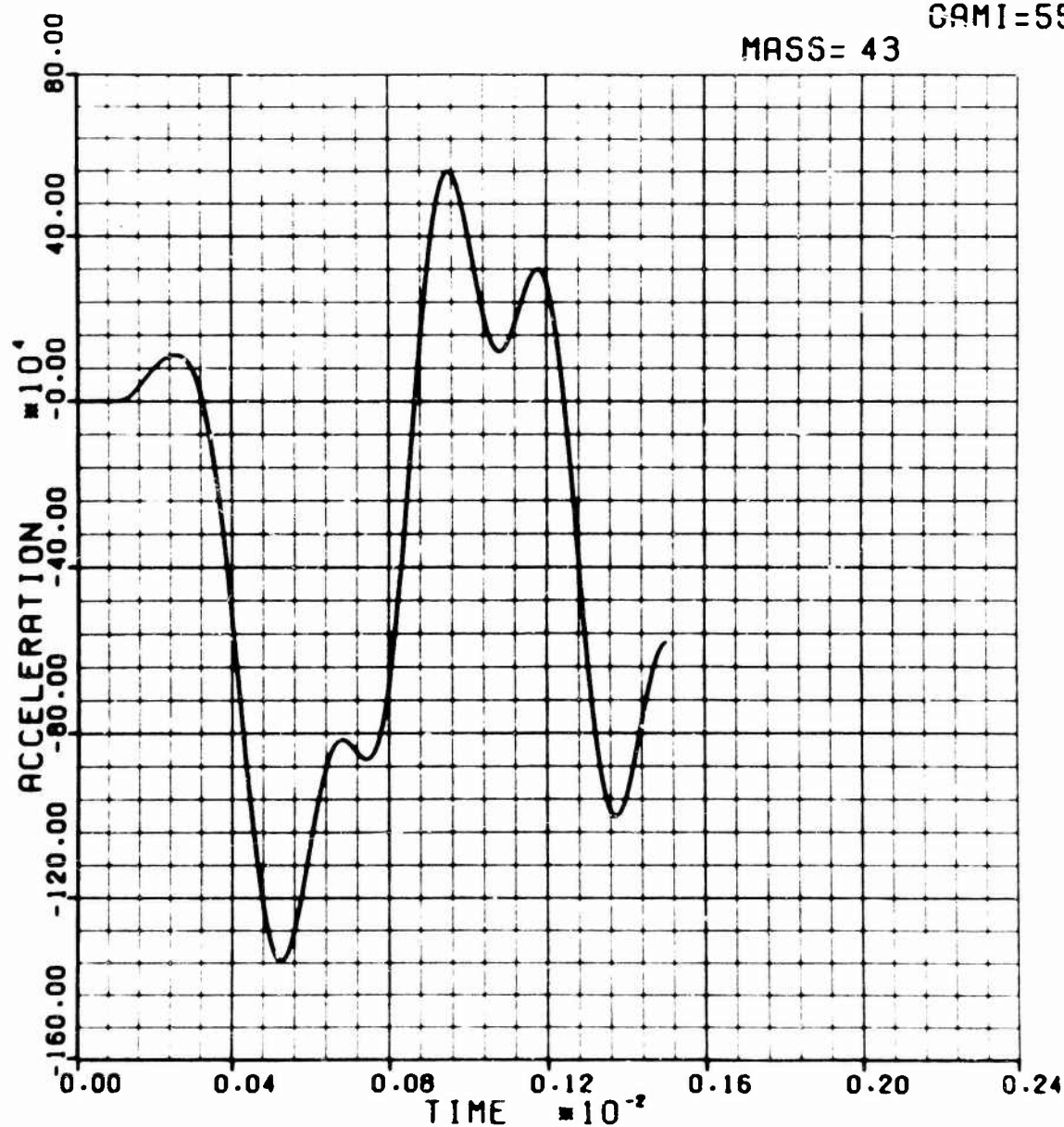
MK82 (LATERAL)

SAND TARGET

VEL=13200.

GAMI=55.0

MASS= 43



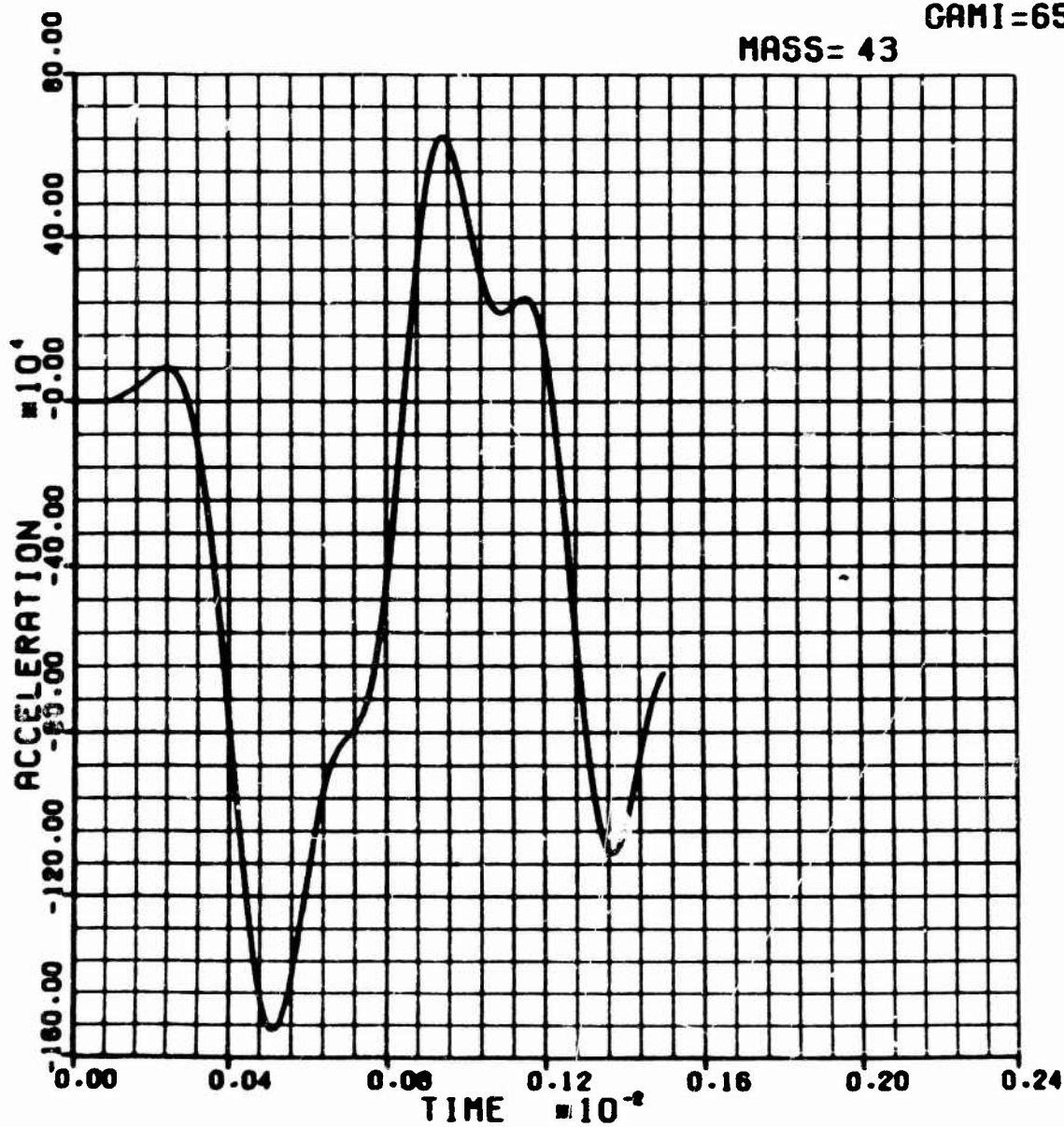
MK82 (LATERAL)

SAND TARGET

VEL=13200.

GAMI=65.0

MASS= 43

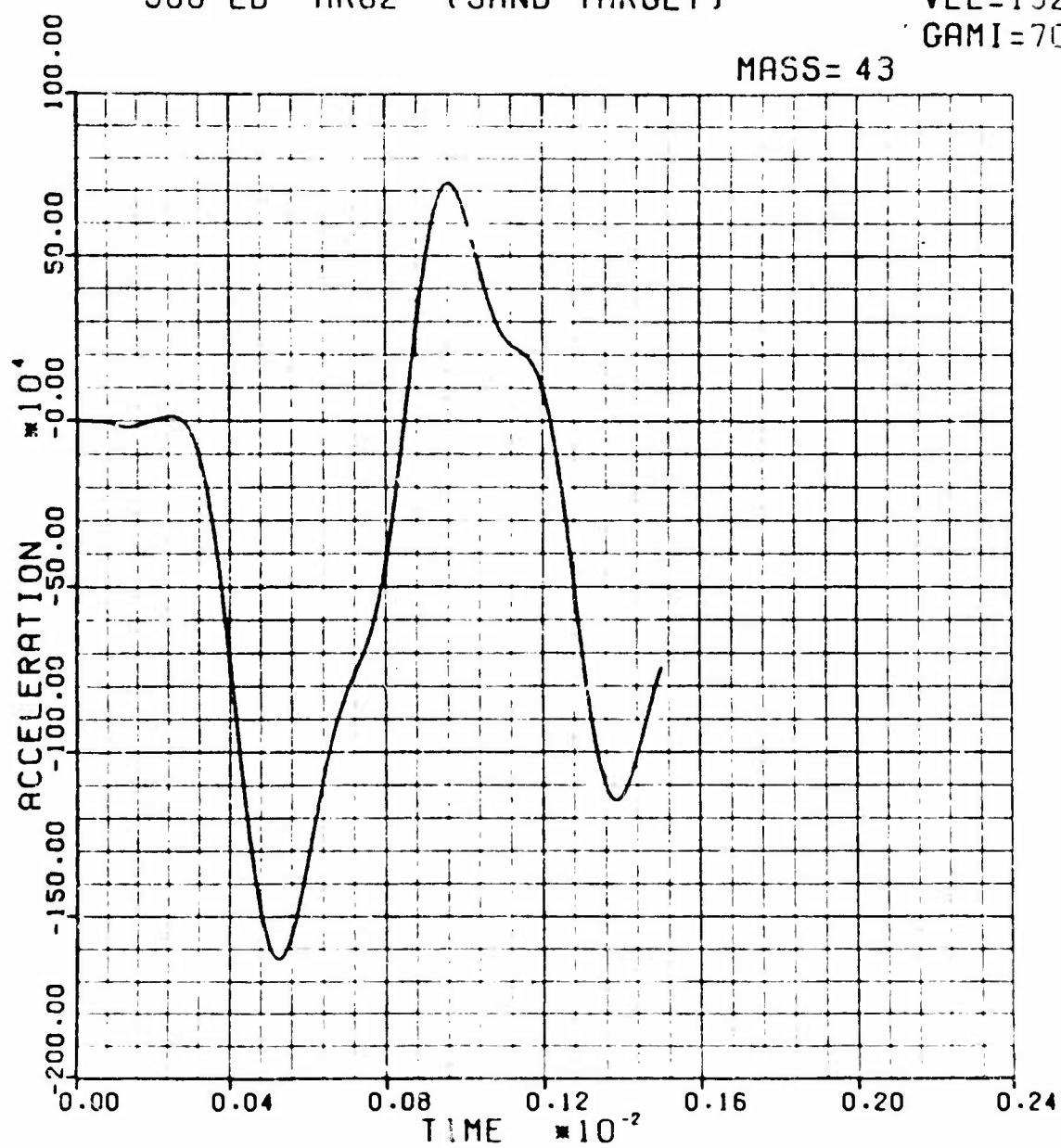


500 LB MK82 (SAND TARGET)

VEL=13200.

GAMI=70.0

MASS= 43



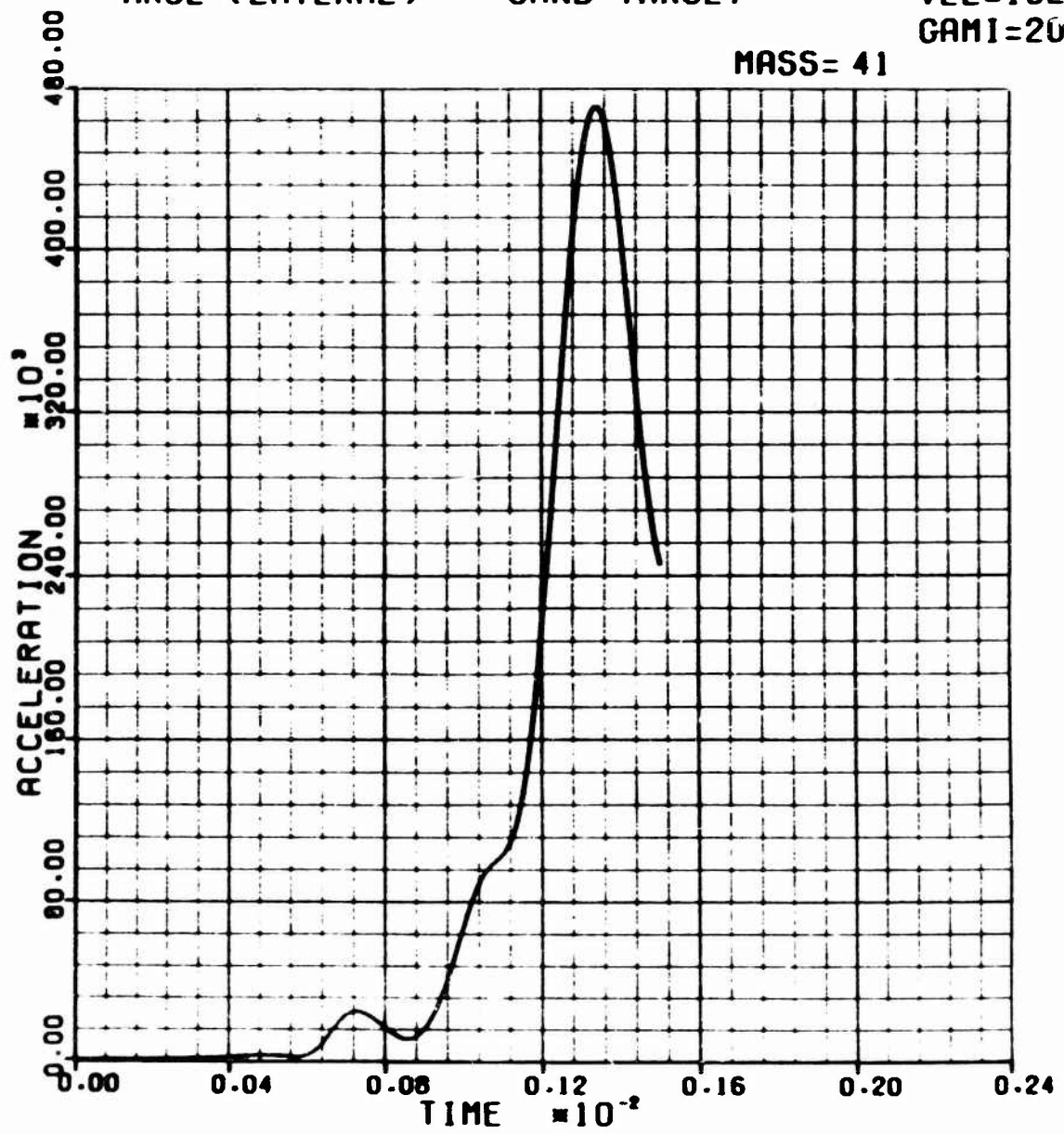
MK82 (LATERAL)

SAND TARGET

VEL=13200.

GAM1=20.0

MASS= 41



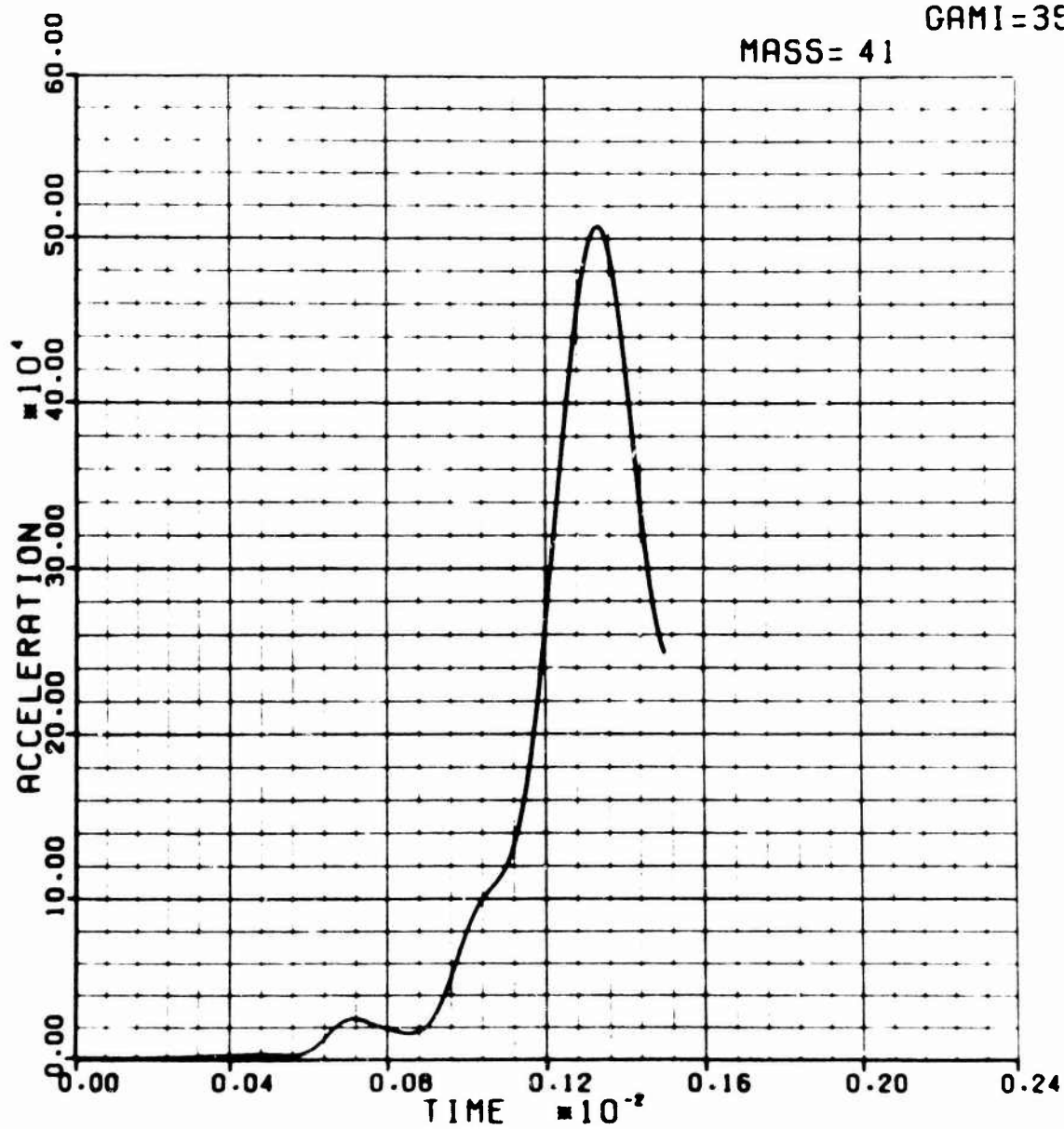
MK82 (LATERAL)

SAND TARGET

VEL=13200.

GAMI=35.0

MASS= 41



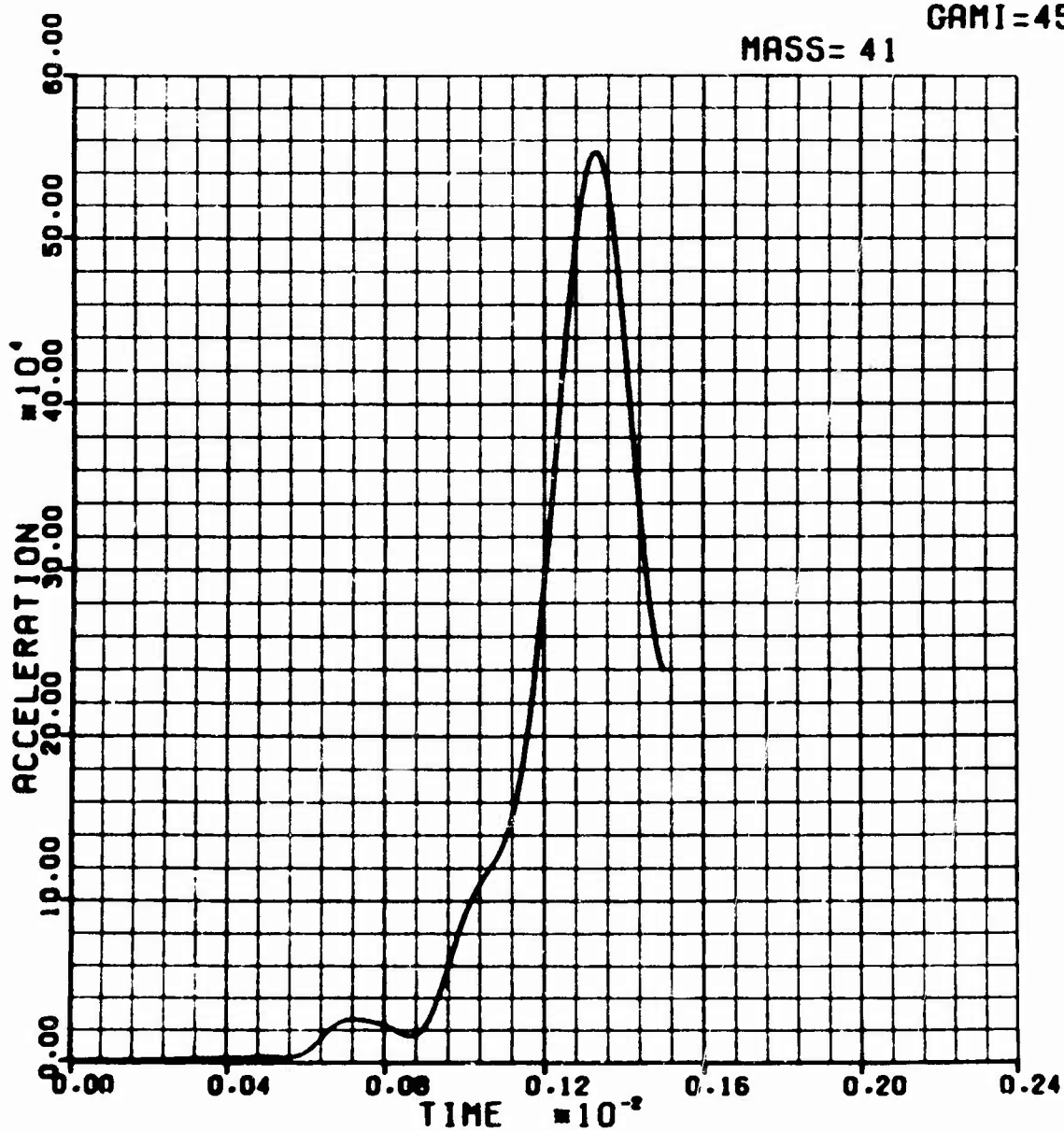
MK82 (LATERAL)

SAND TARGET

VEL=13200.

GAMI=45.0

MASS= 41



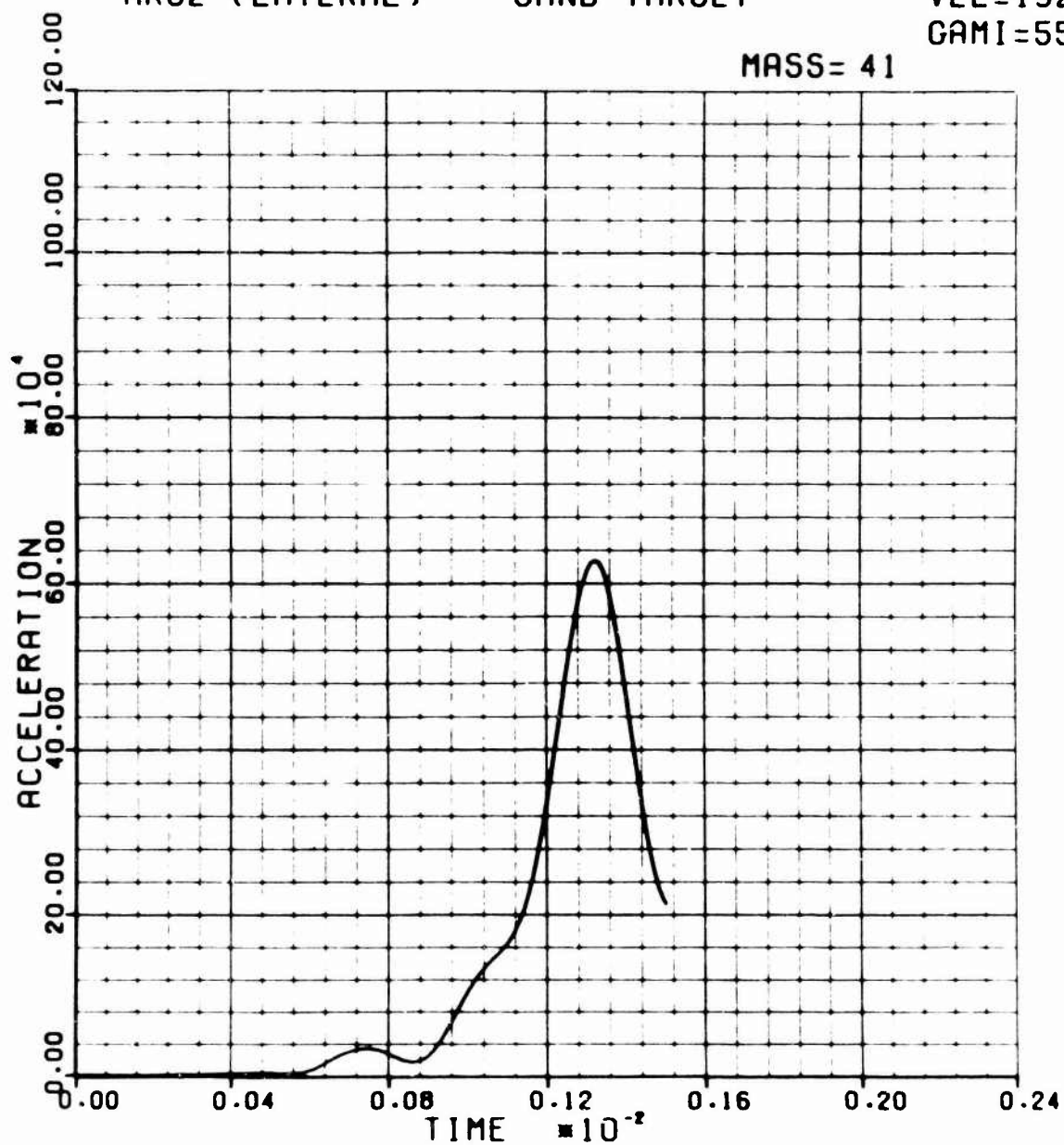
MK82 (LATERAL)

SAND TARGET

VEL=13200.

GAMI=55.0

MASS= 41



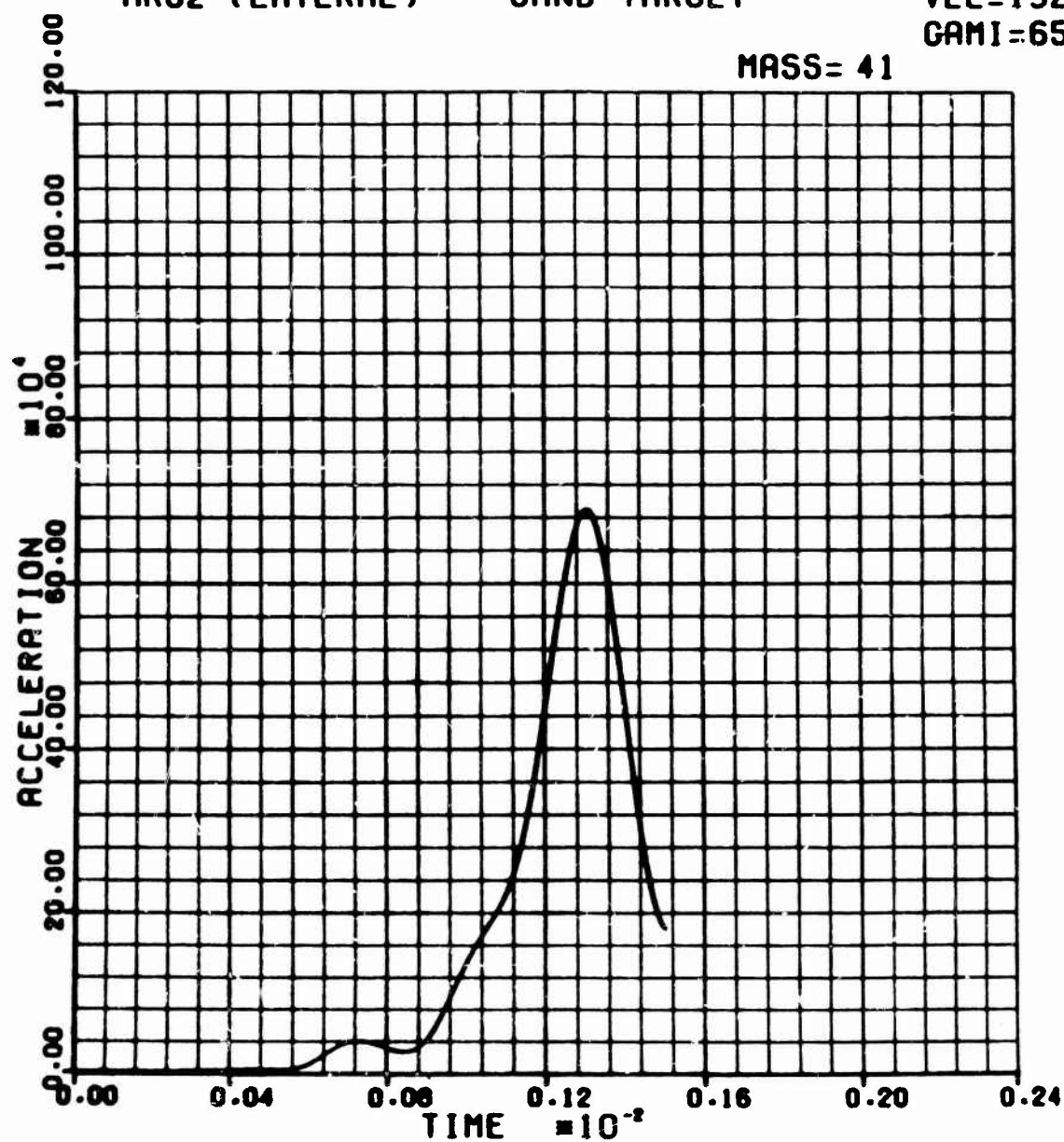
MK82 (LATERAL)

SAND TARGET

VEL=13200.

GAMI=65.0

MASS= 41

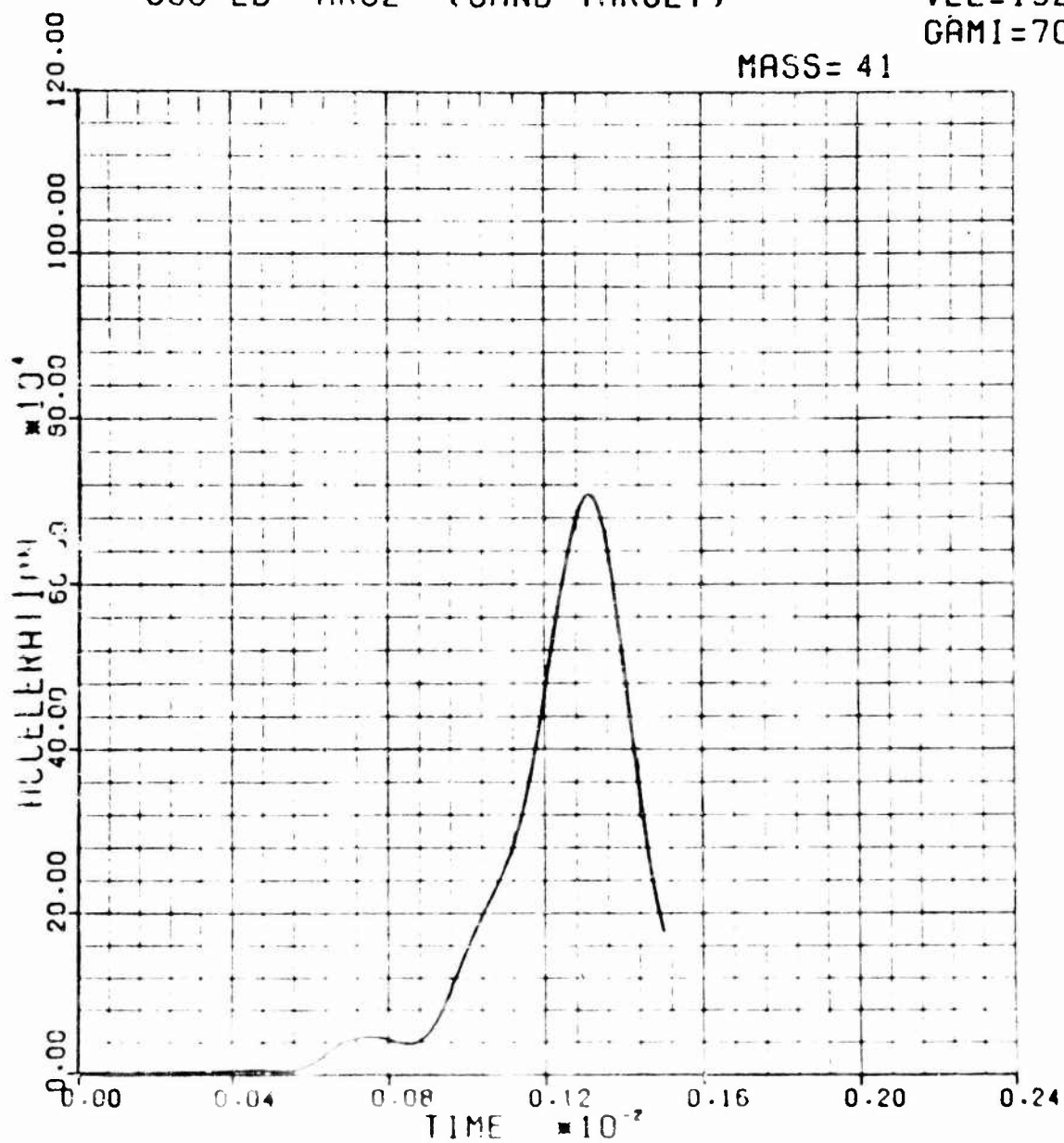


500 LB MK82 (SAND TARGET)

VEL=13200.

GAMI=70.0

MASS= 41



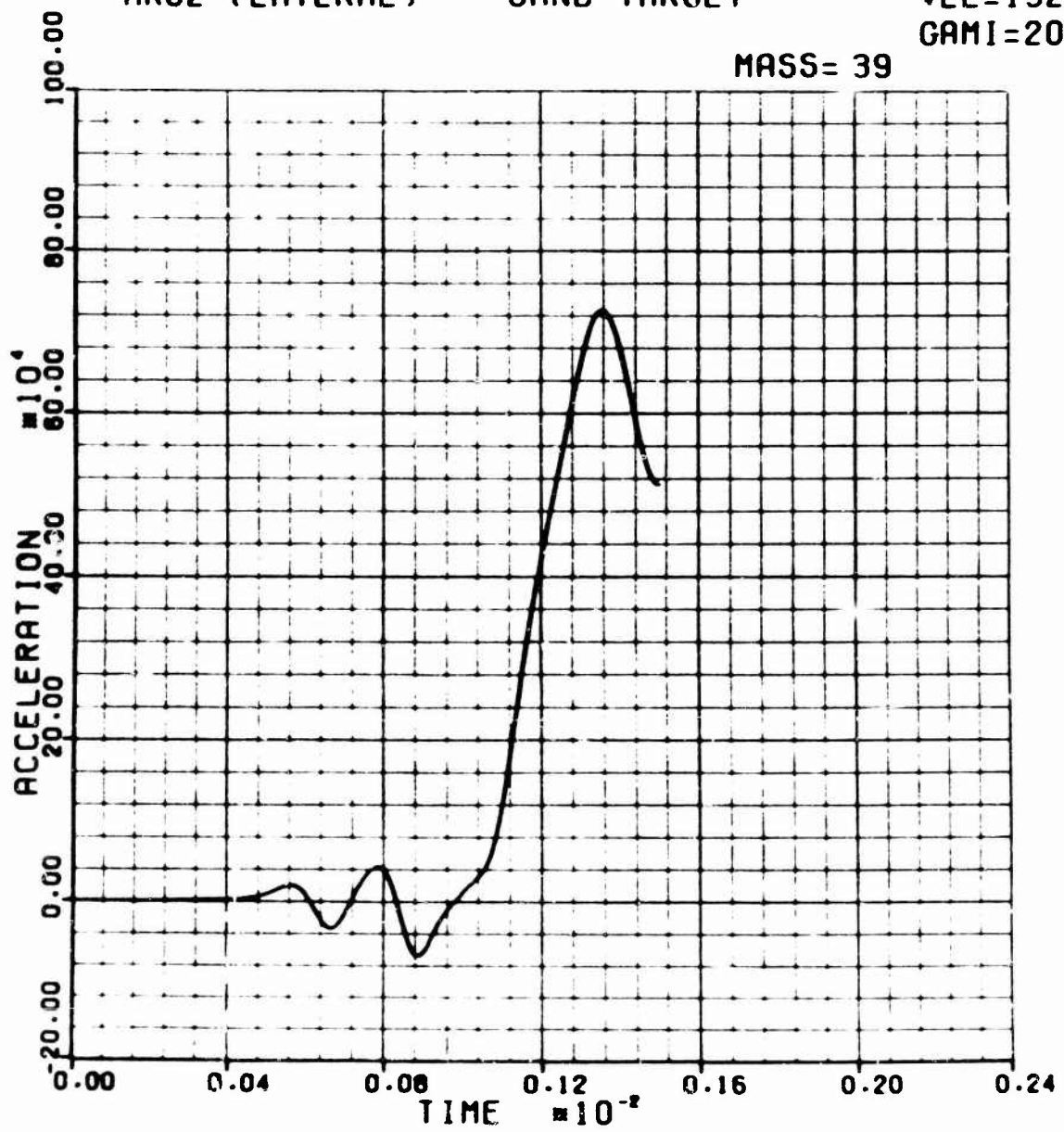
MK82 (LATERAL)

SAND TARGET

VEL=13200.

GAMI=20.0

MASS= 39



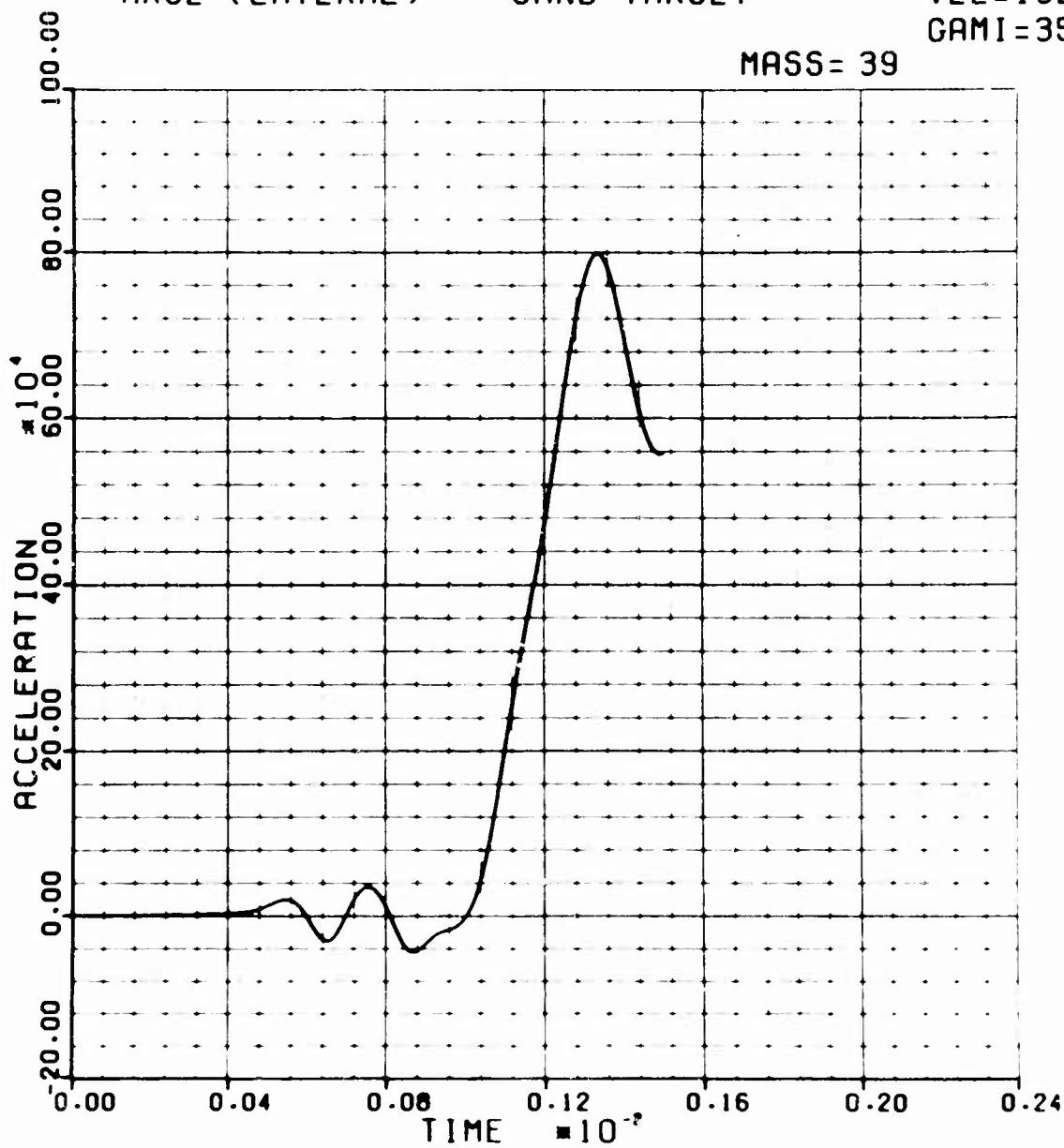
MK82 (LATERAL)

SAND TARGET

VEL=13200.

GAMI=35.0

MASS= 39



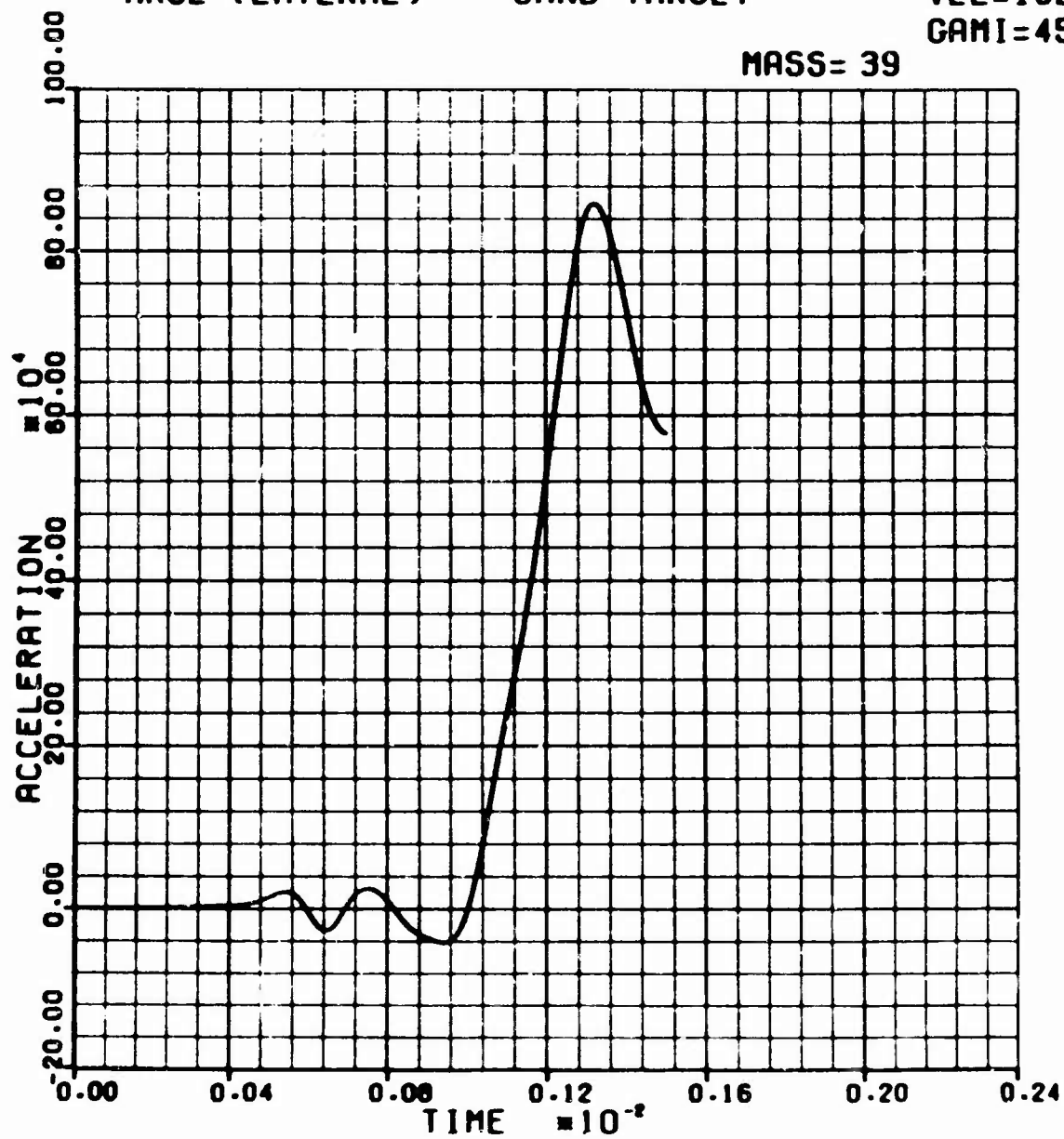
MK82 (LATERAL)

SAND TARGET

VEL=13200.

GAMI=45.0

MASS= 39



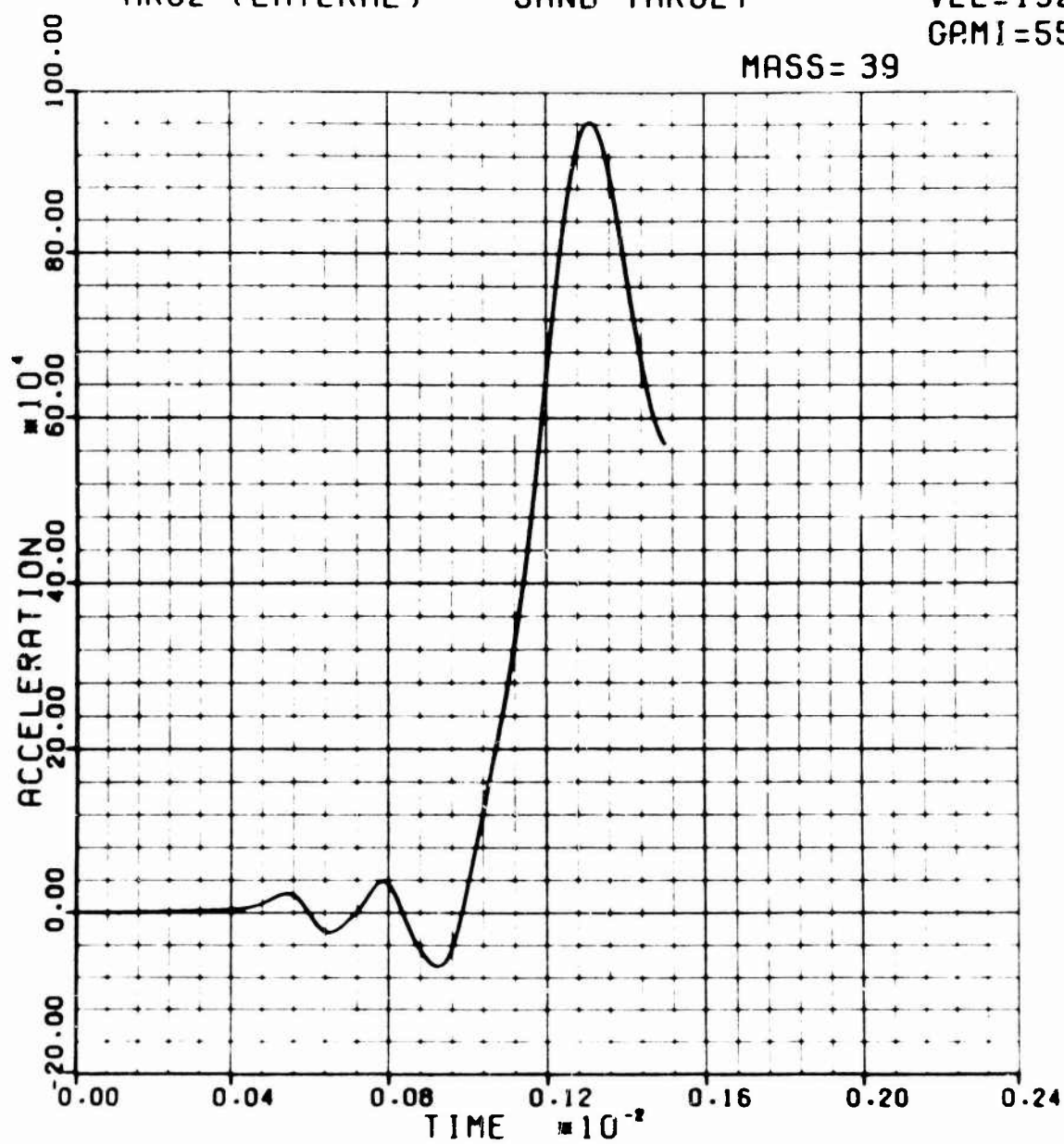
MK82 (LATERAL)

SAND TARGET

VEL=13200.

GPMI=55.0

MASS= 39



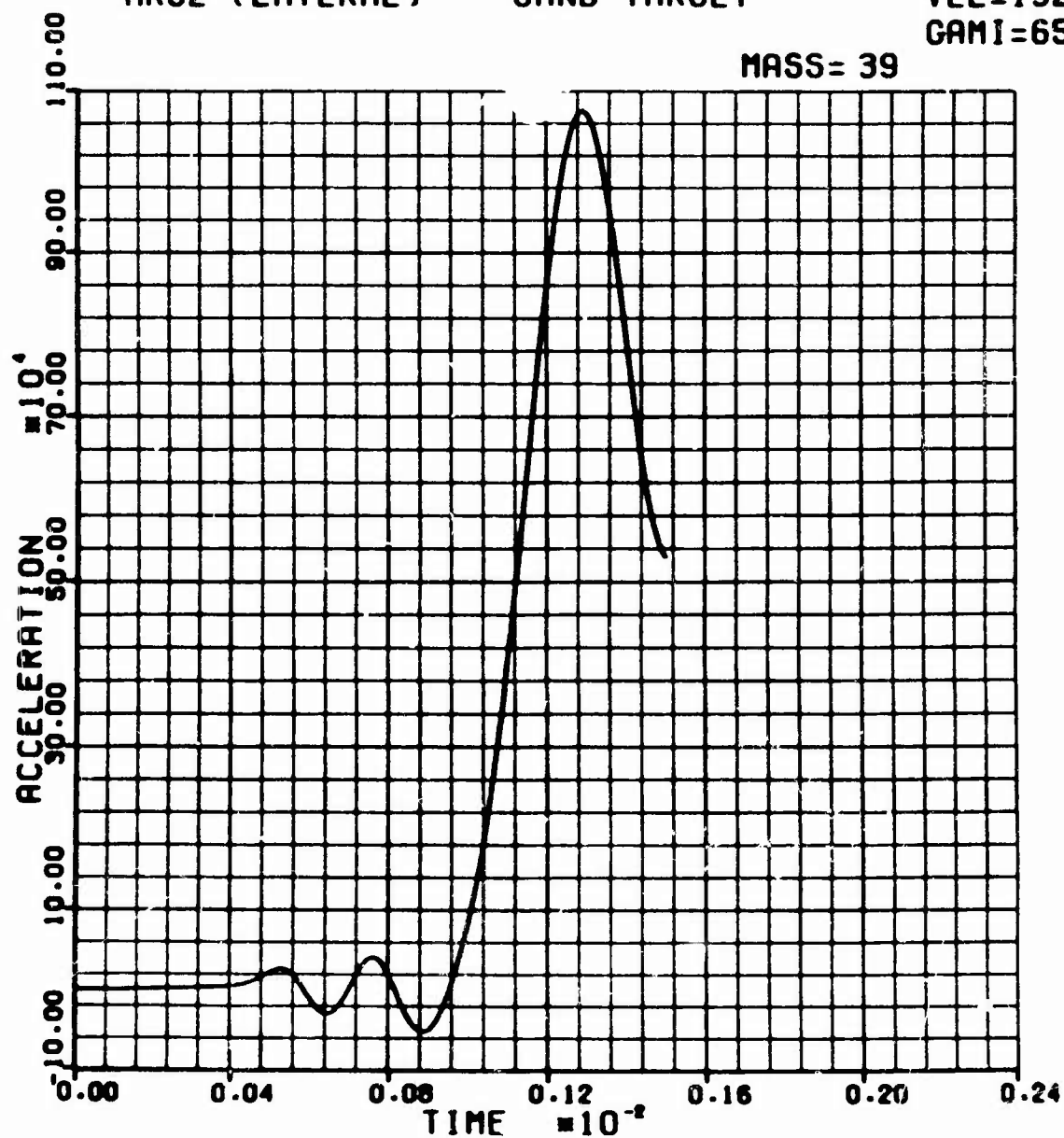
MK82 (LATERAL)

SAND TARGET

VEL=13200.

GAMI=65.0

MASS= 39

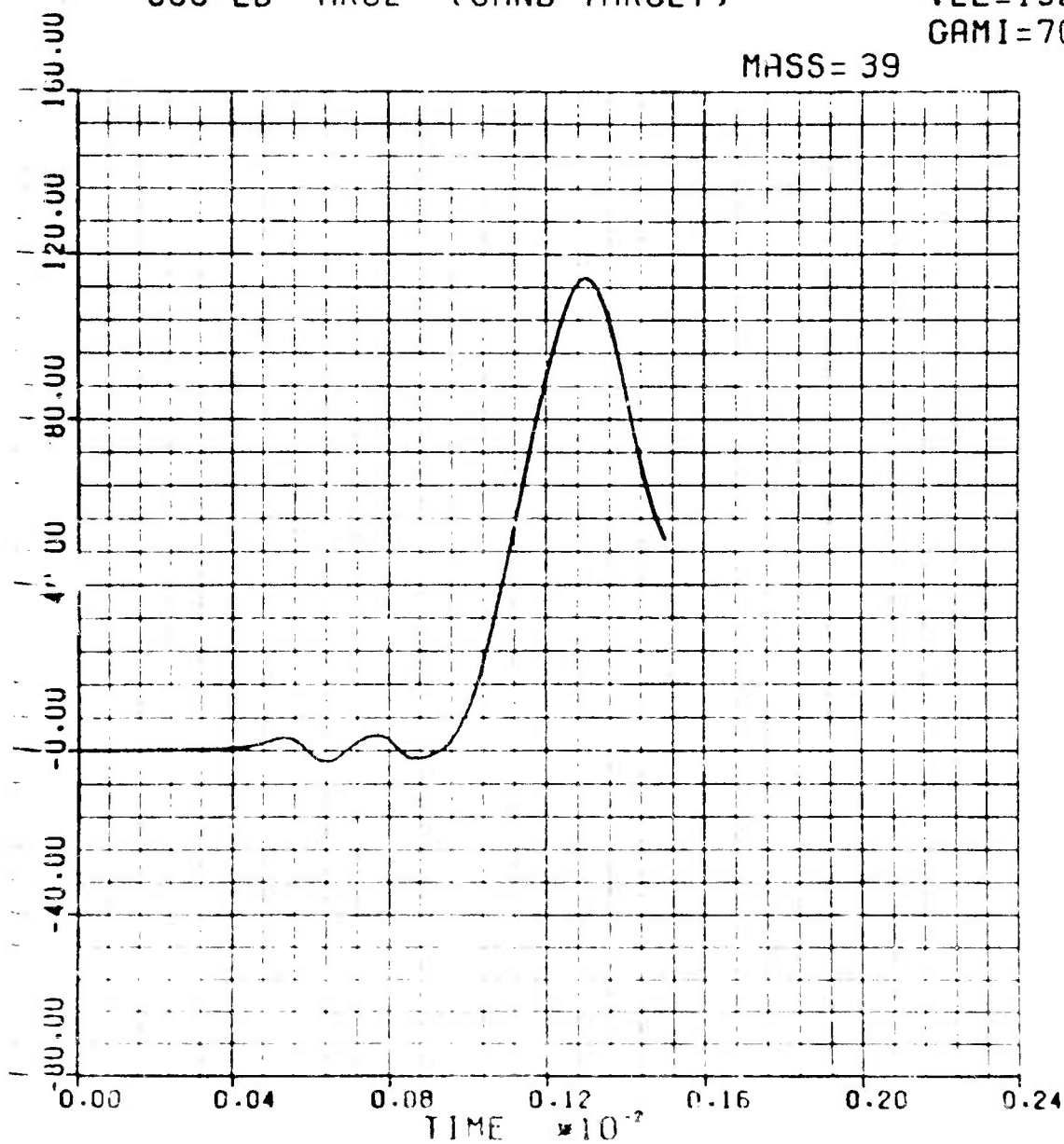


500 LB MK82 (SAND TARGET)

VEL=13200.

GAMI=70.0

MASS= 39



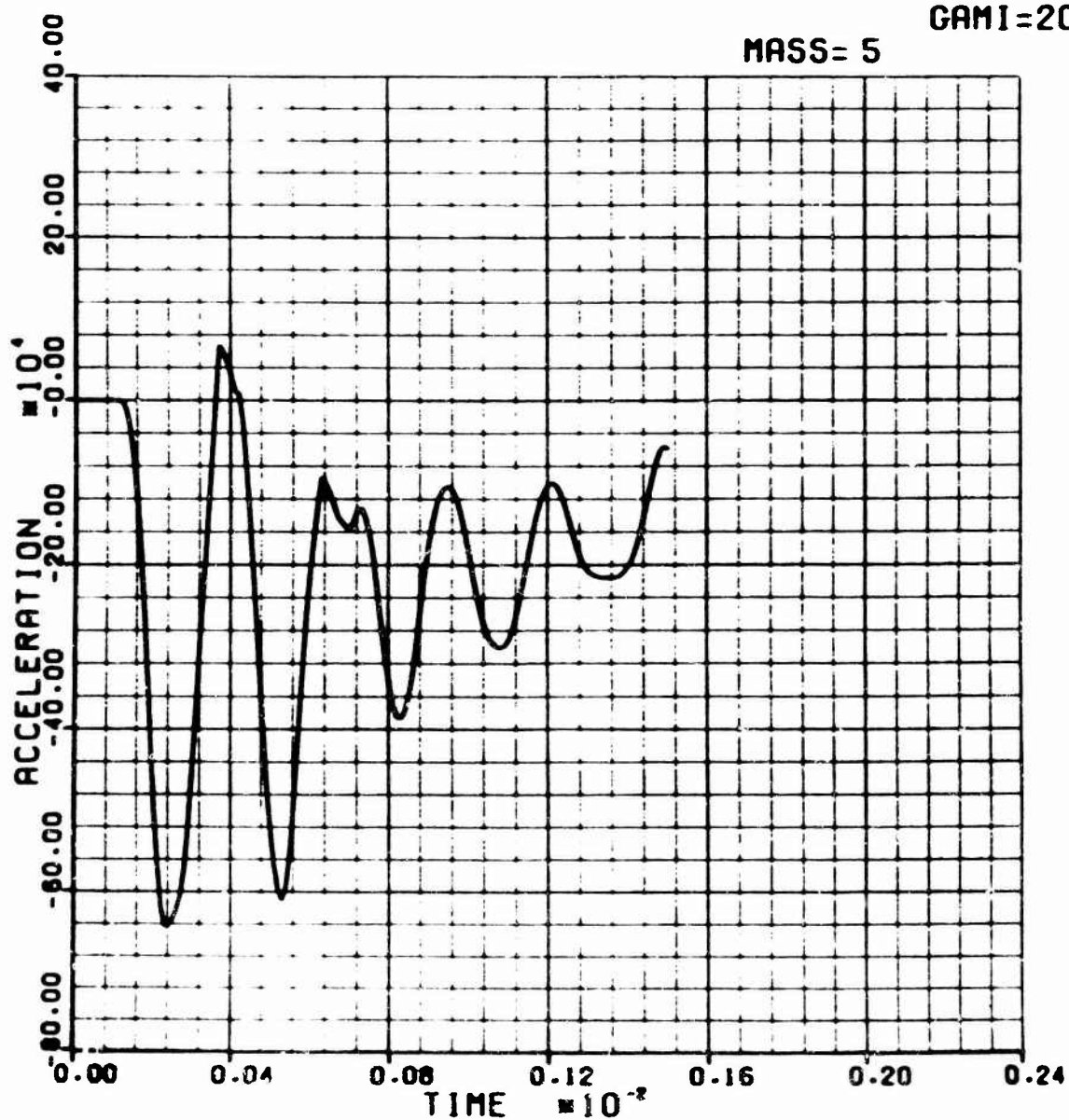
MK82 (LATERAL)

SAND TARGET

VEL=10800.

GAMI=20.0

MASS= 5



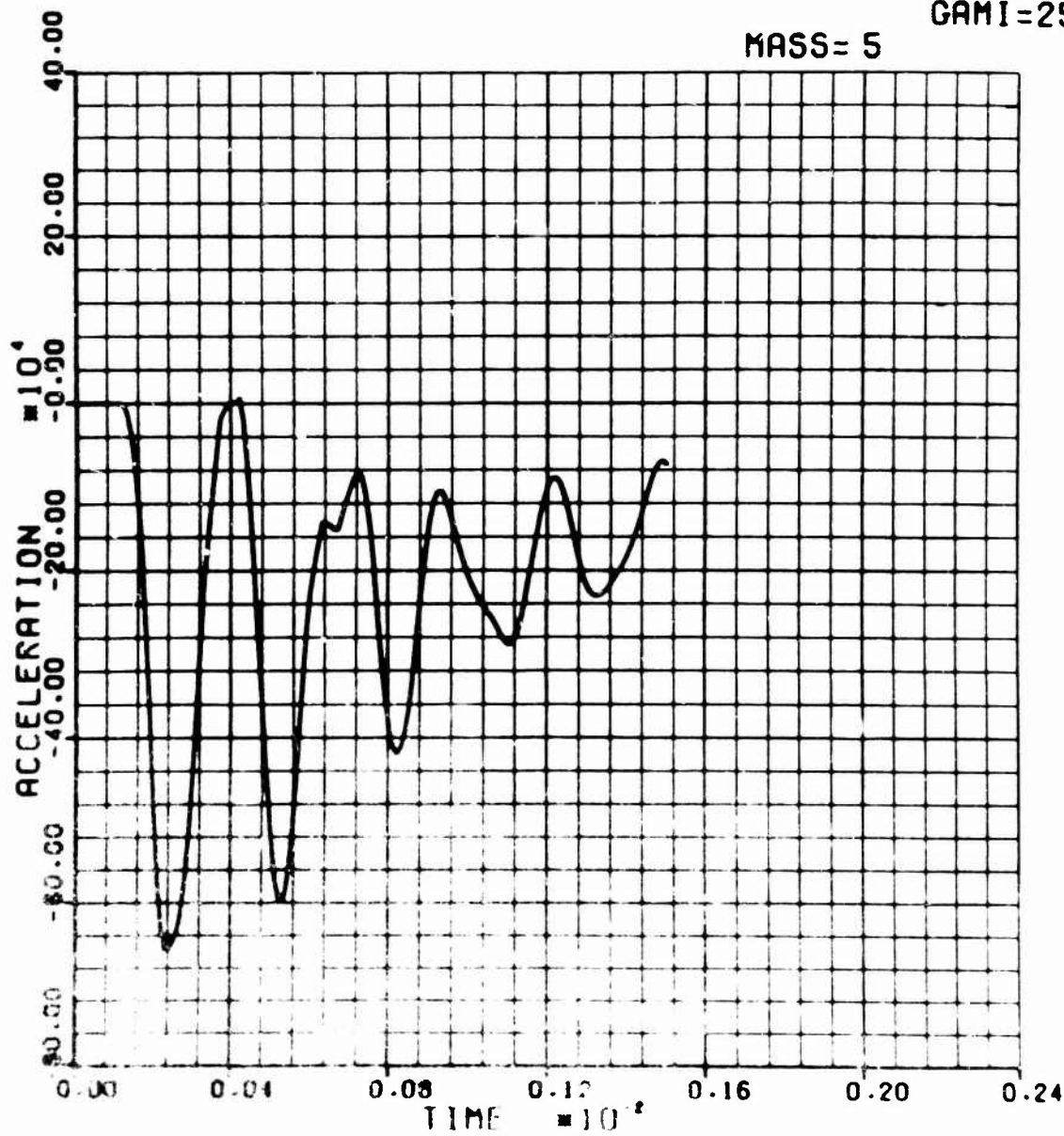
MK82 (LATERAL)

SAND TARGET

VEL=10800.

GAMI=25.0

MASS= 5



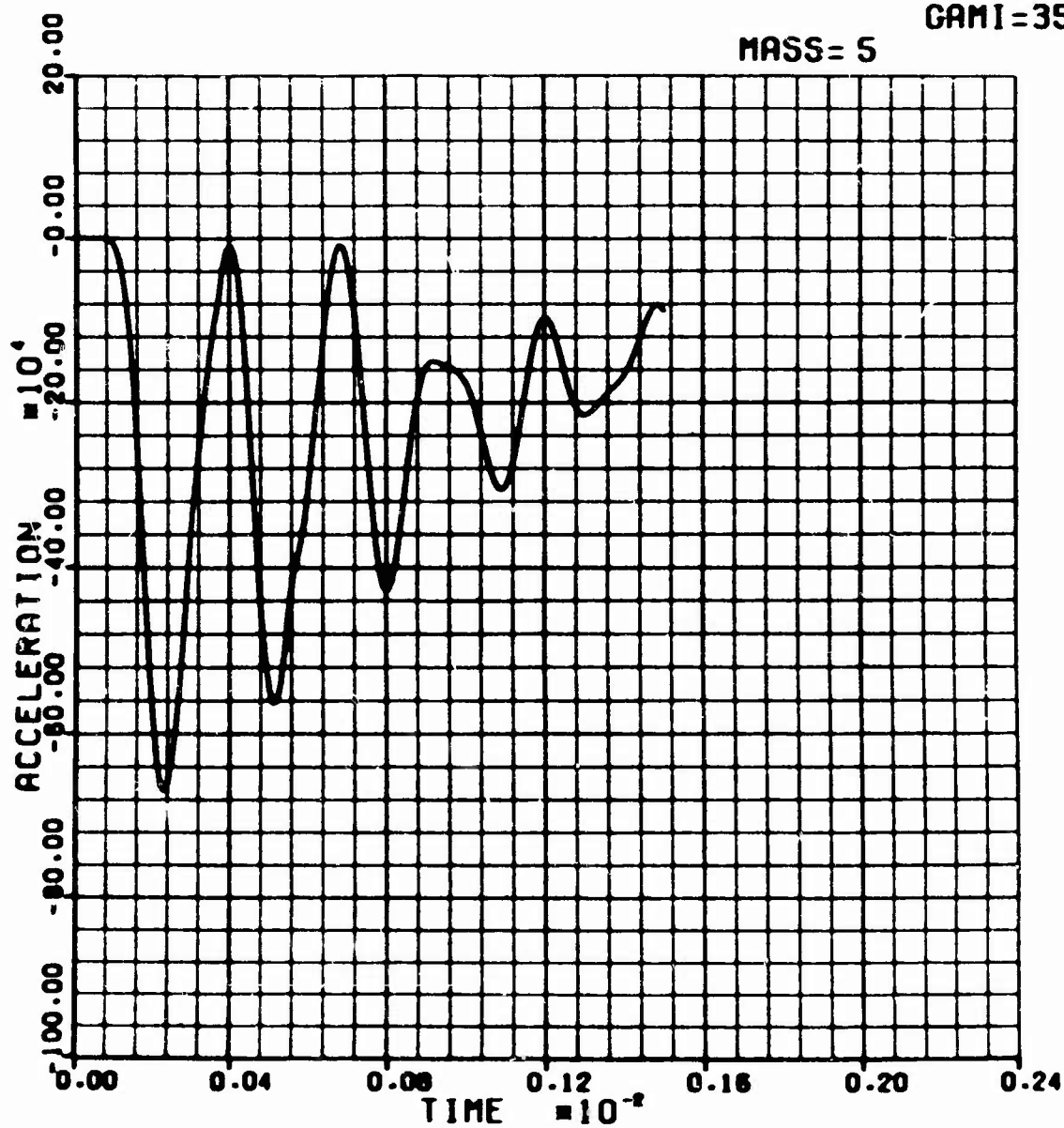
MK82 (LATERAL)

SAND TARGET

VEL=10800.

GAMI=35.0

MASS= 5



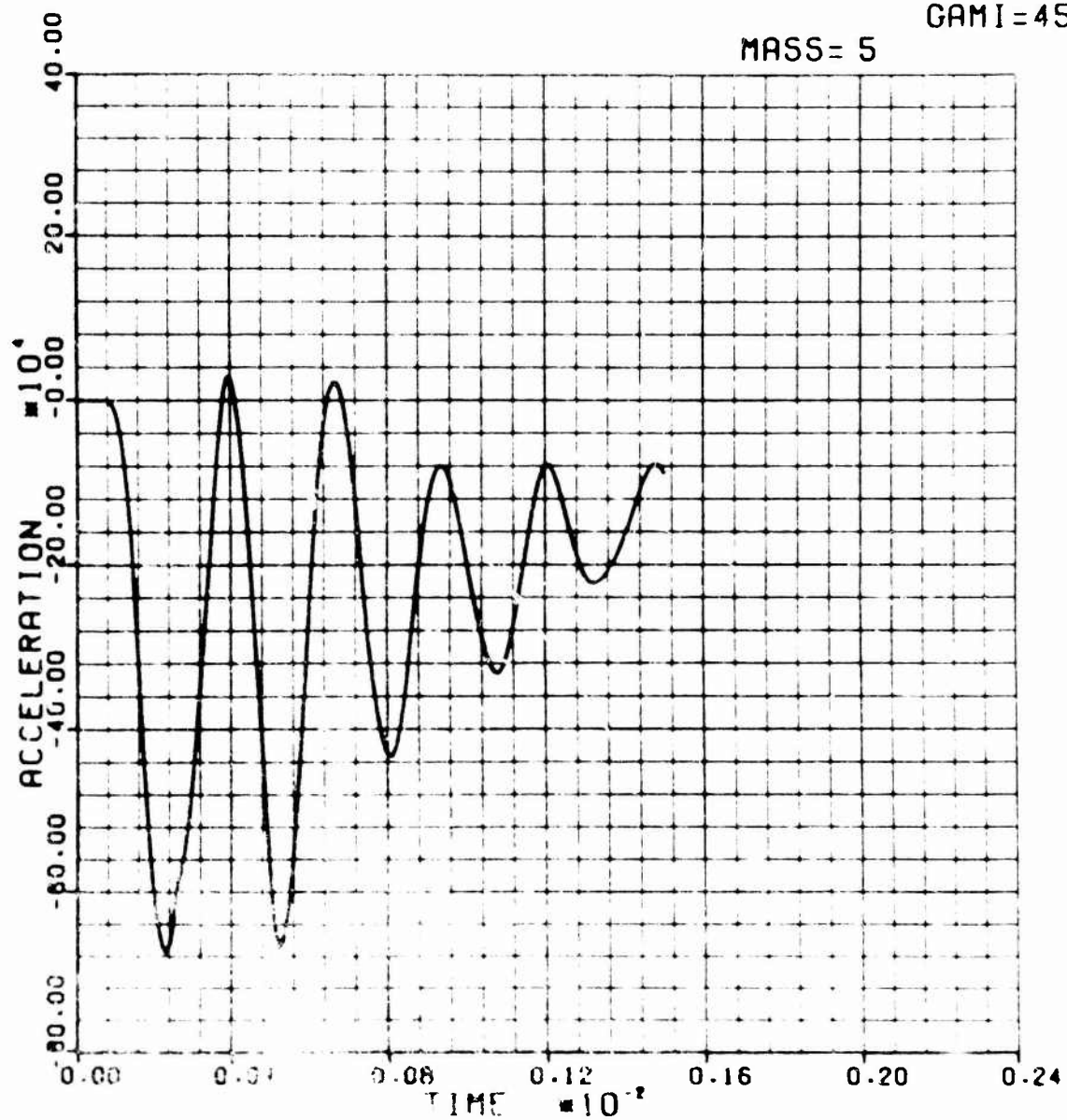
MK82 (LATERAL)

SAND TARGET

VEL=10800.

GAMI=45.0

MASS= 5



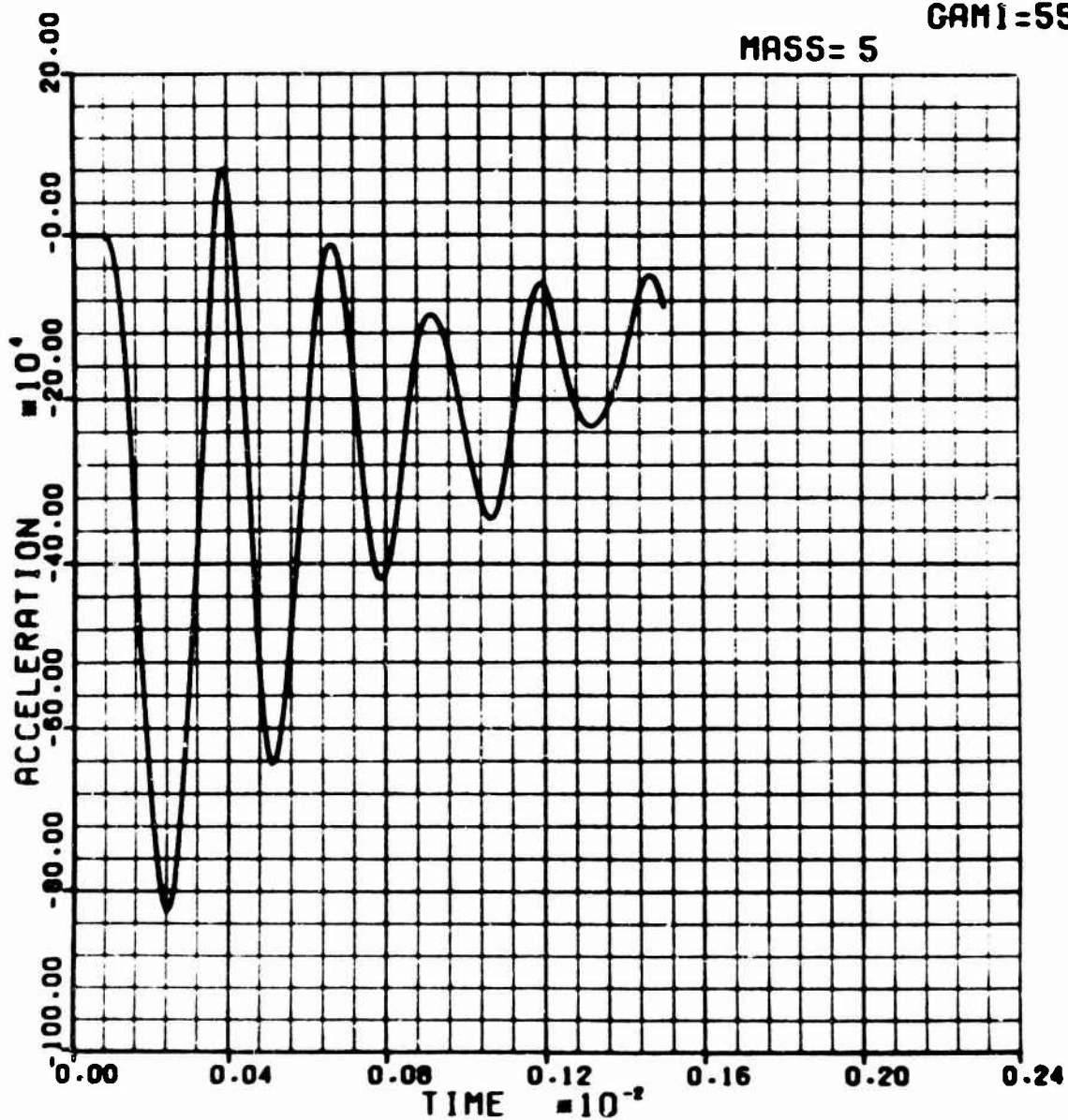
MK82 (LATERAL)

SAND TARGET

VEL=10800.

GAM=55.0

MASS= 5



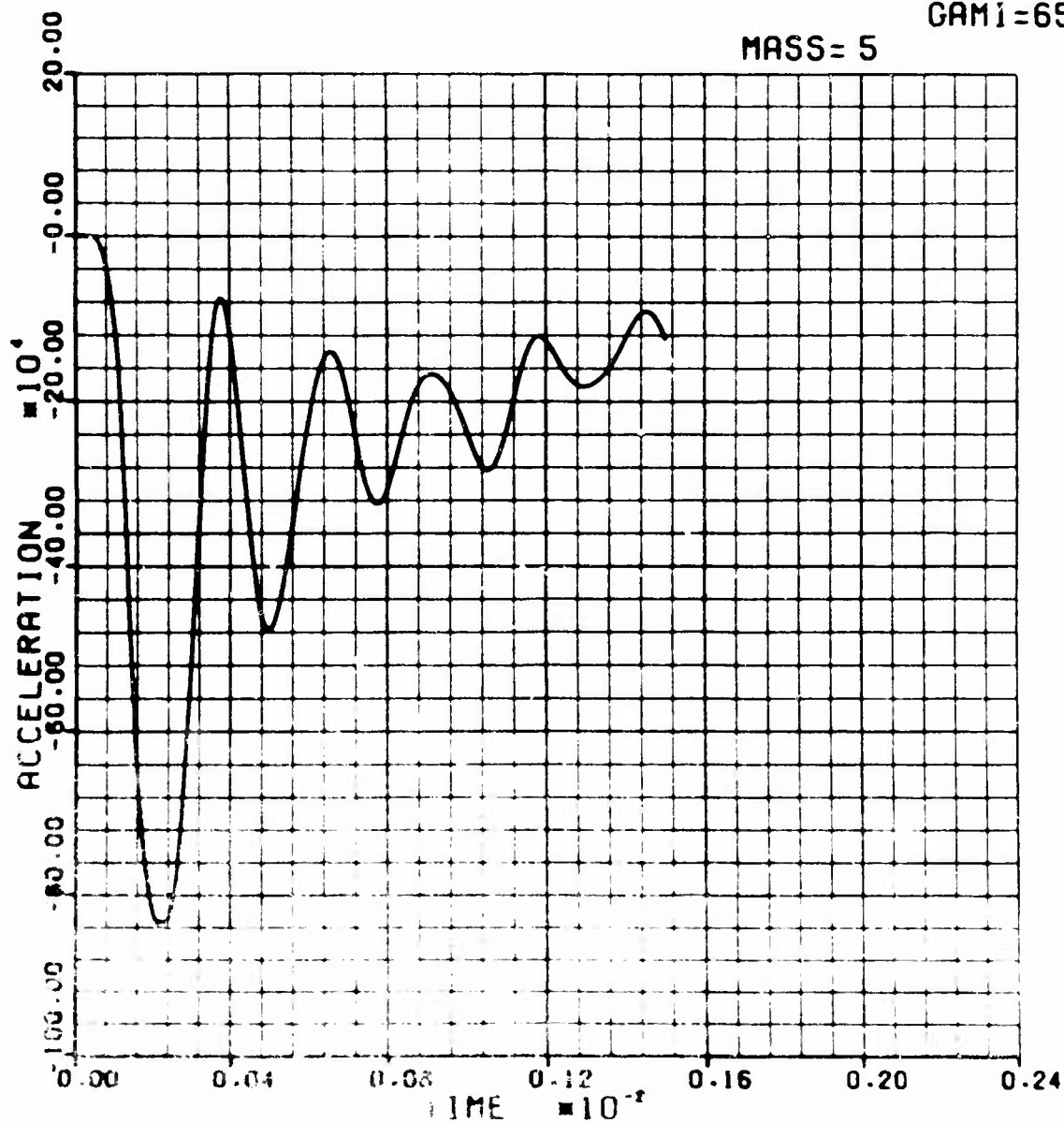
MK82 (LATERAL)

SAND TARGET

VEL=10800.

GAM=65.0

MASS= 5



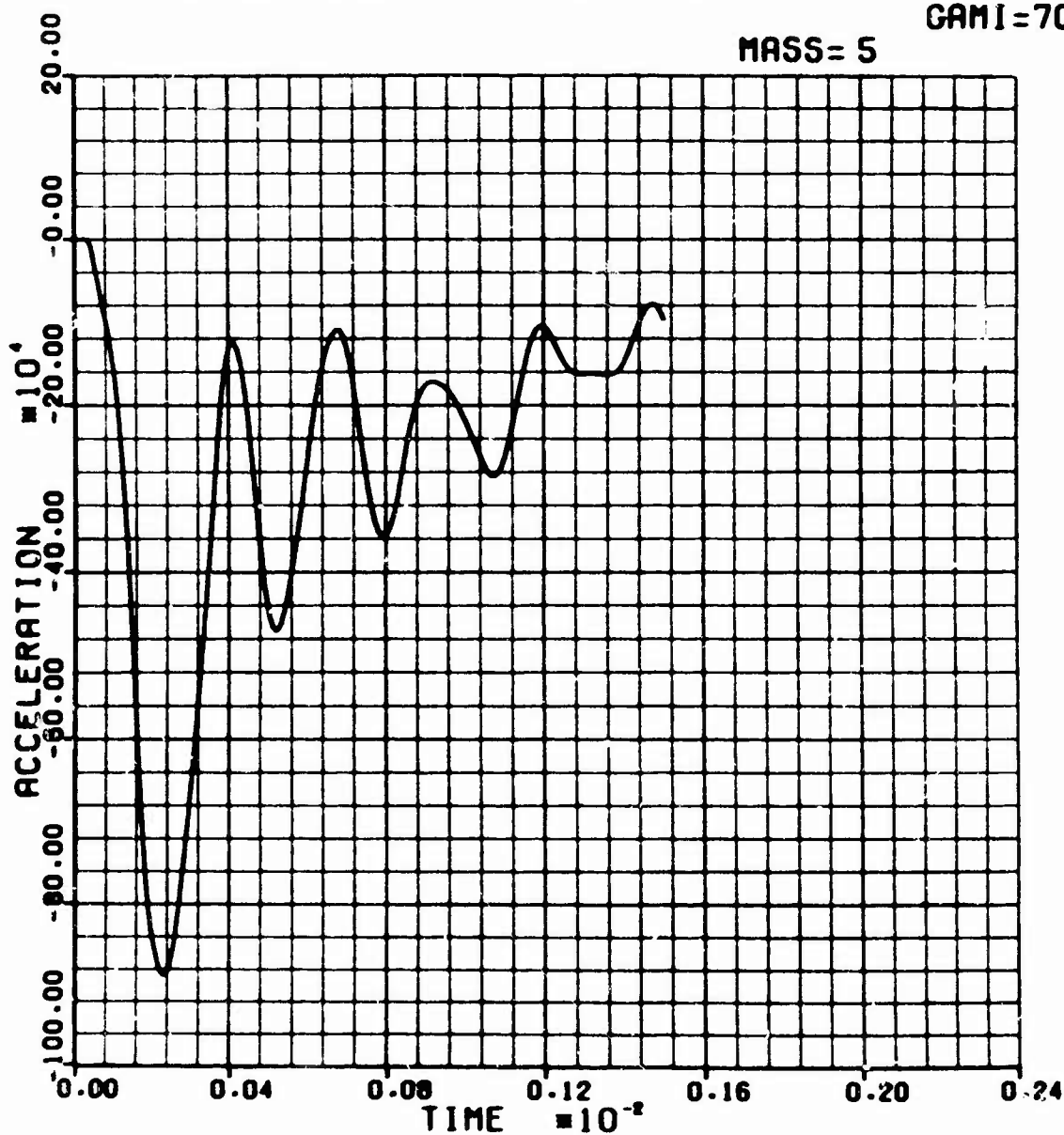
MK82 (LATERAL)

SAND TARGET

VEL=10800.

GAMI=70.0

MASS= 5



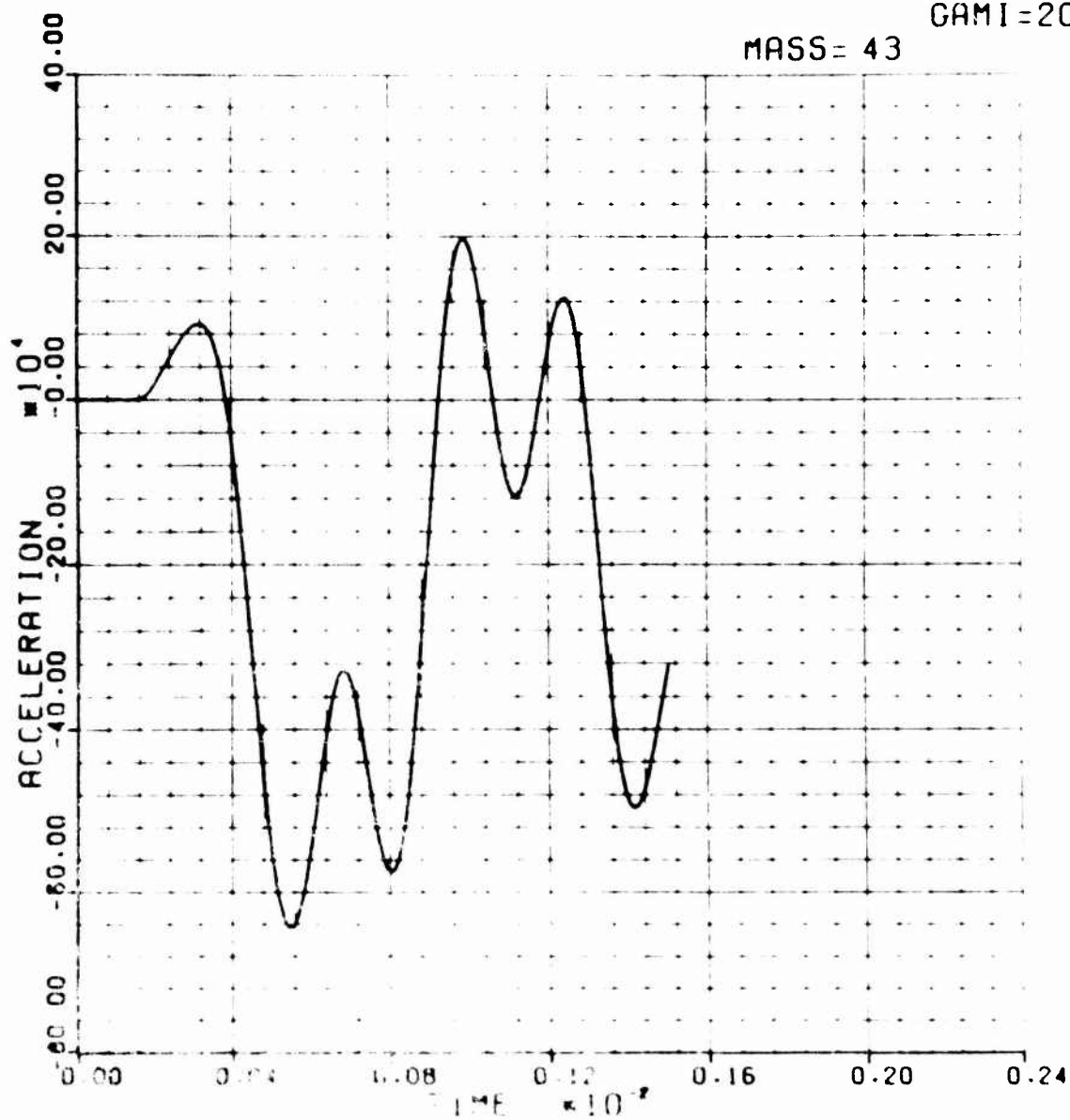
MK82 (LATERAL)

SAND TARGET

VEL=10800.

GAMI=20.0

MASS= 43



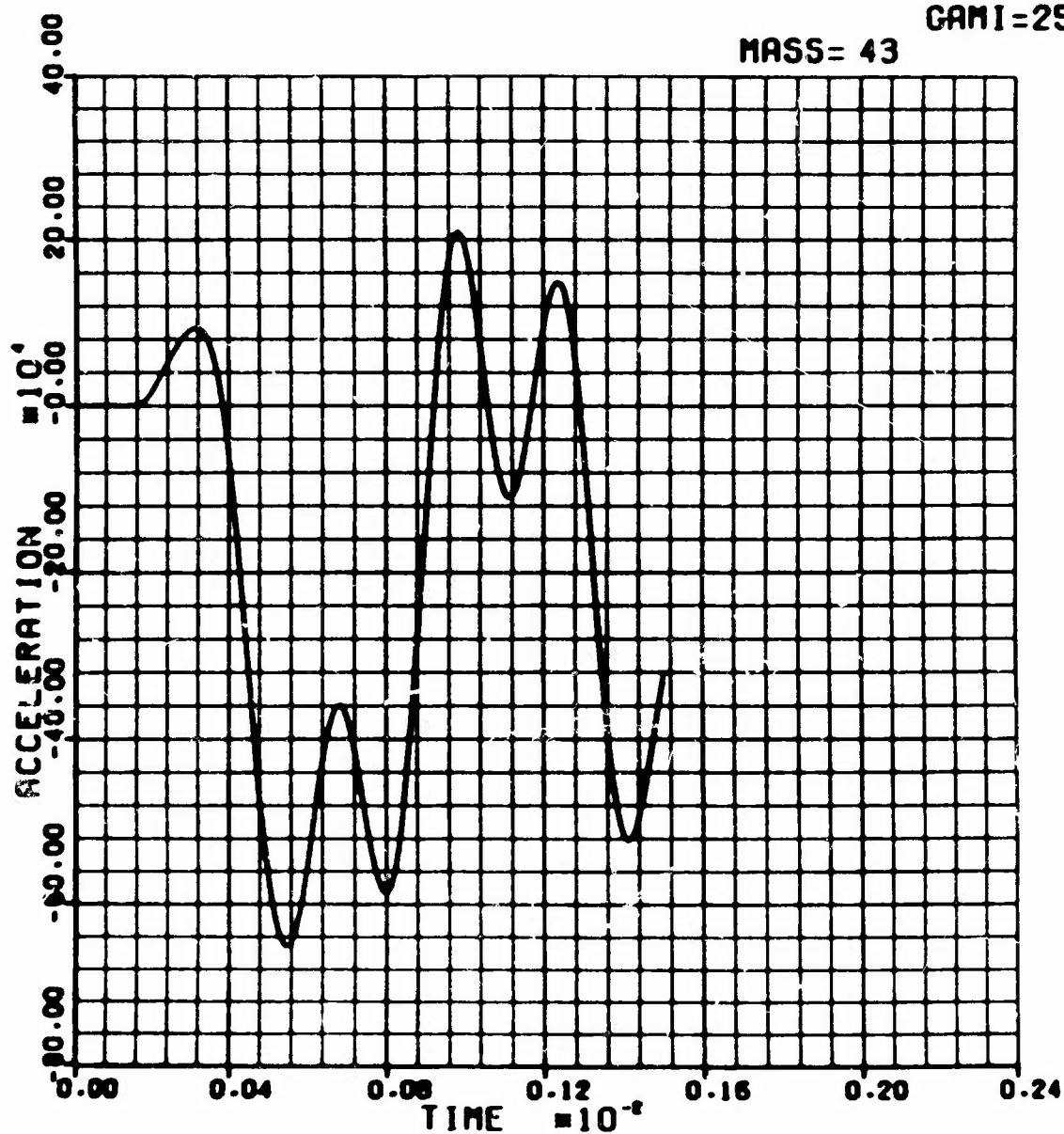
MK82 (LATERAL)

SAND TARGET

VEL=10800.

GAMI=25.0

MASS= 43

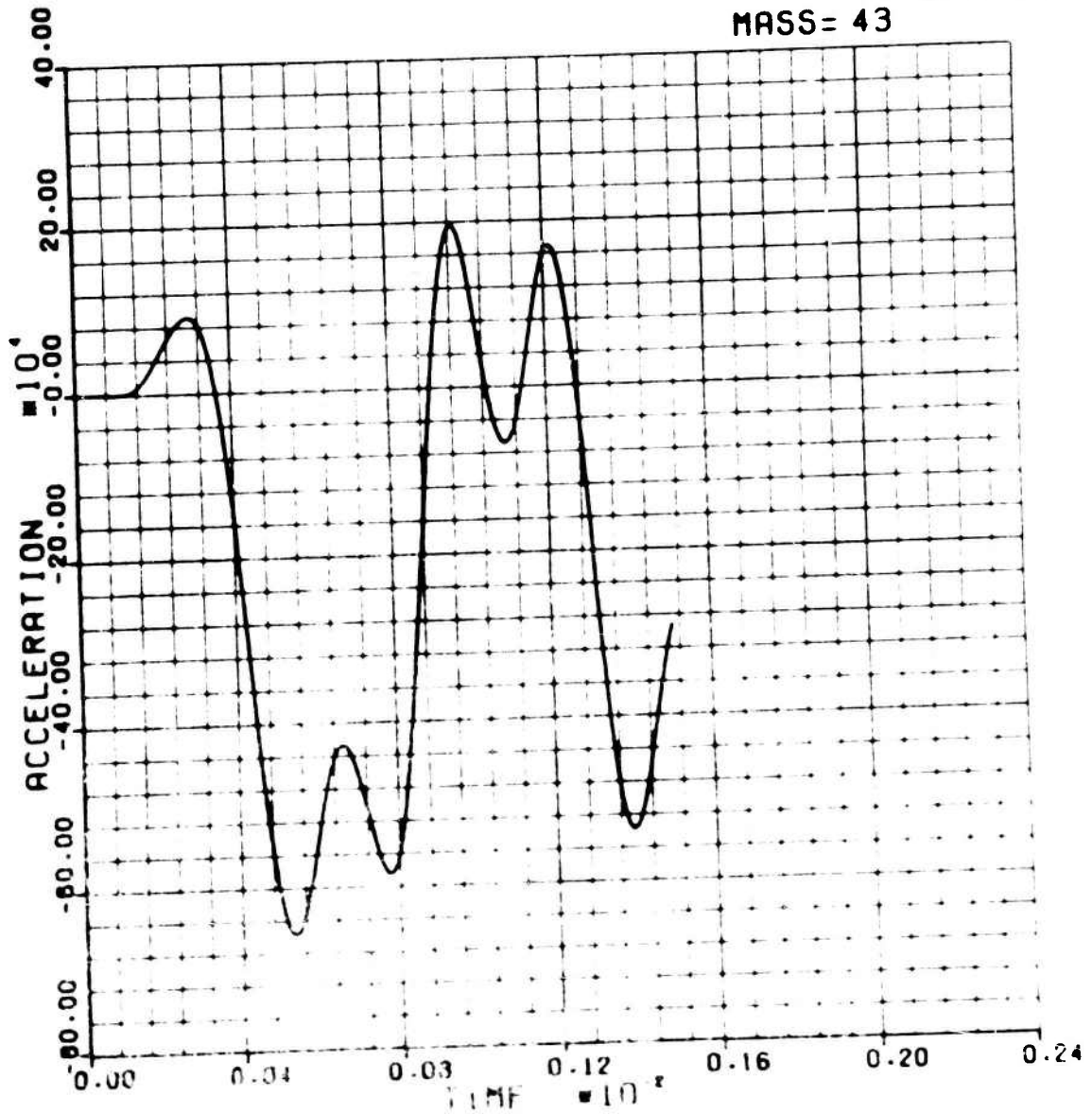


MK82 (LATERAL)

SAND TARGET

VEL=10800.
GAMI=35.0

MASS= 43



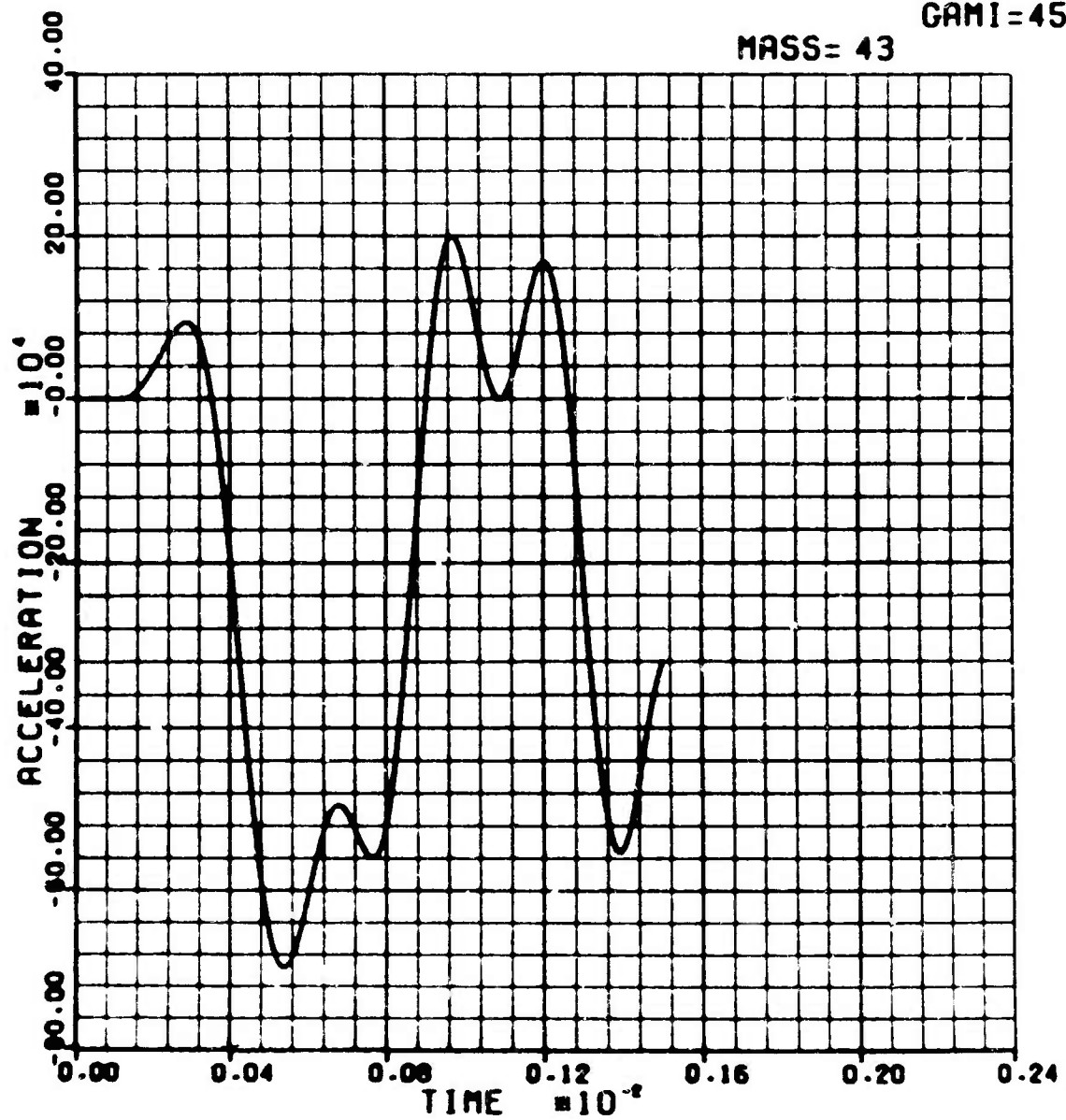
MK82 (LATERAL)

SAND TARGET

VEL=10800.

GAMI=45.0

MASS= 43



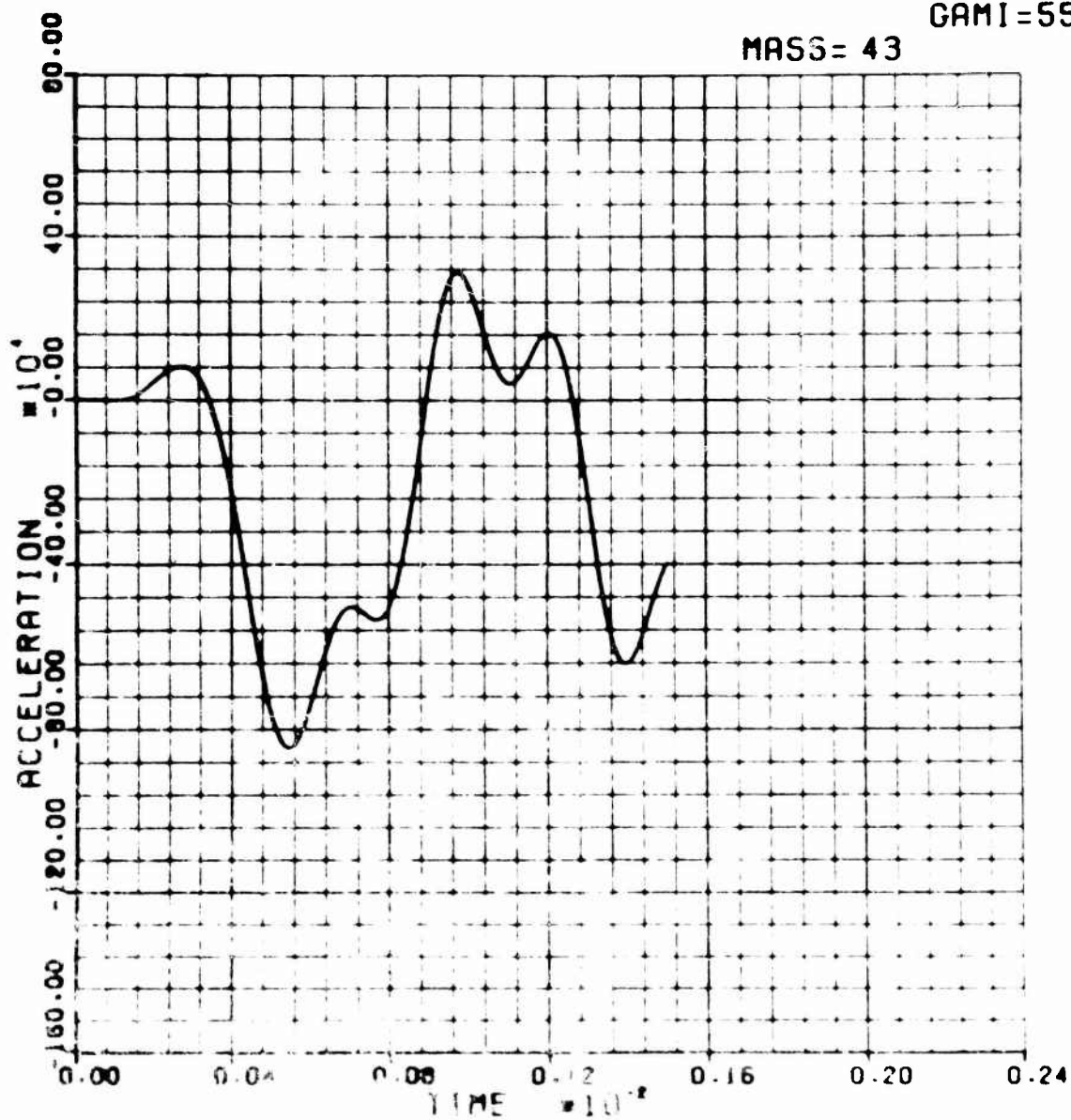
MK82 (LATERAL)

SAND TARGET

VEL=10800.

GAMI=55.0

MASS= 43



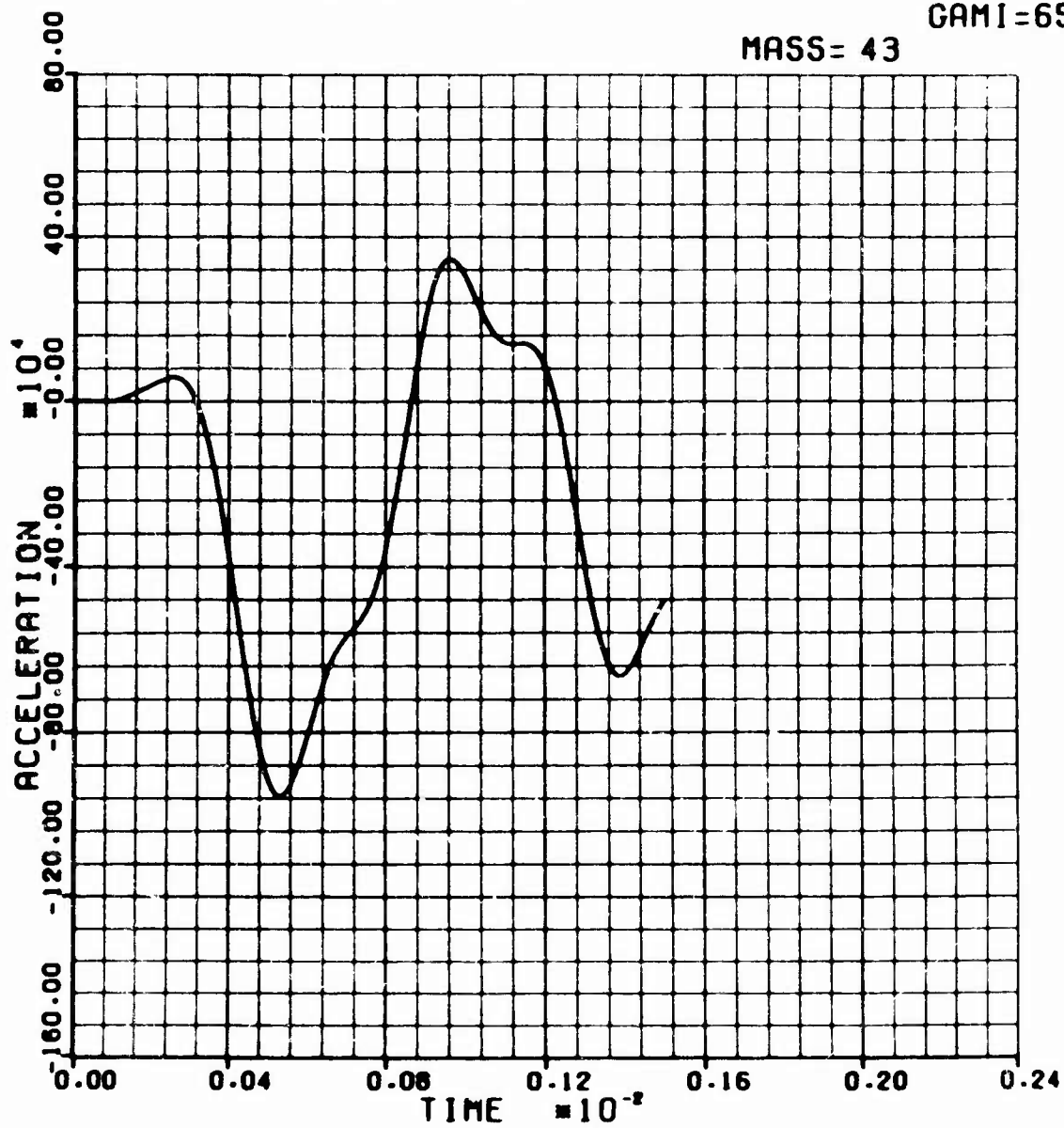
MK82 (LATERAL)

SAND TARGET

VEL=10800.

GAMI=65.0

MASS= 43



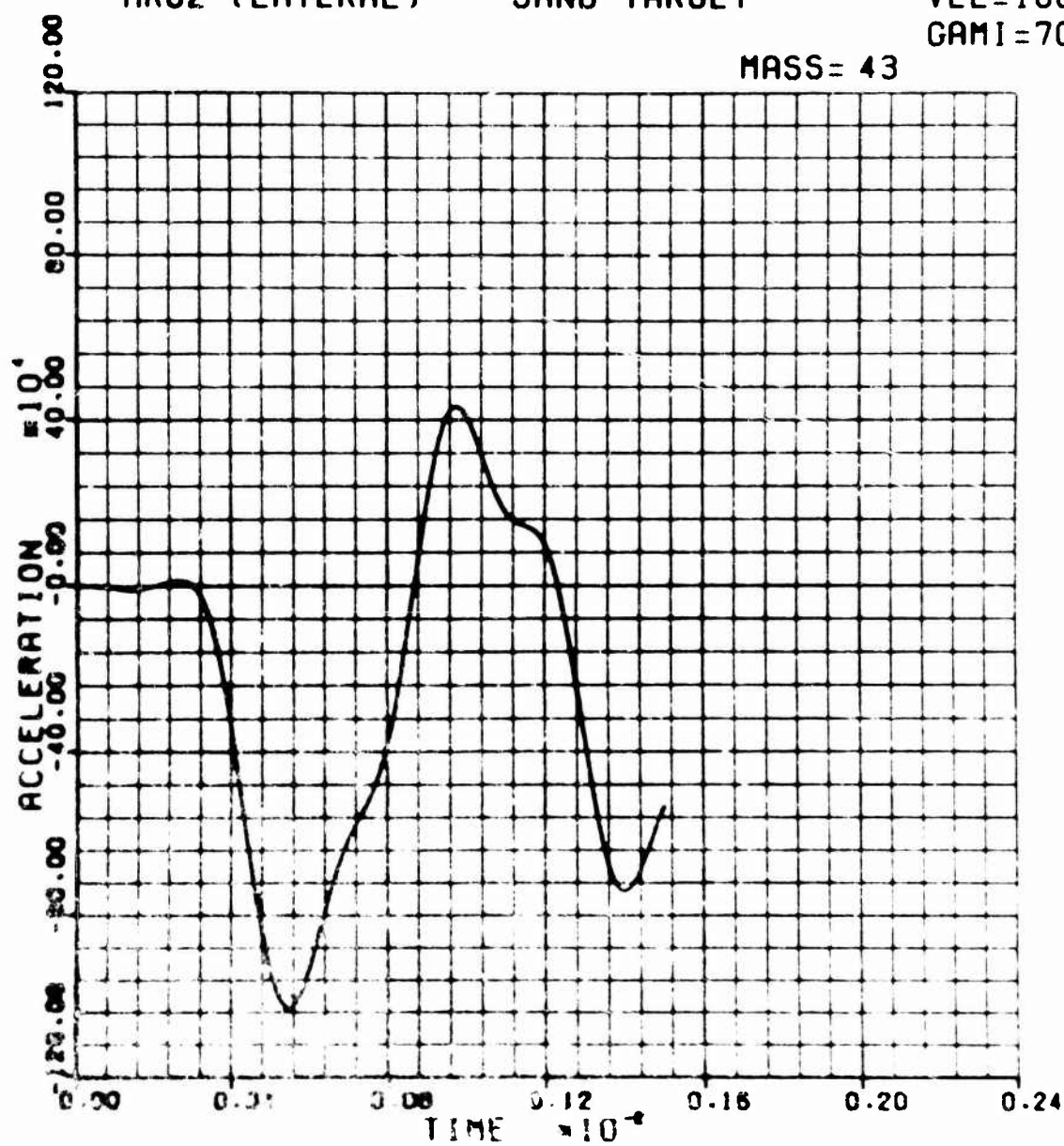
MK82 (LATERAL)

SAND TARGET

VEL=10800

GAMI=70.0

MASS= 43



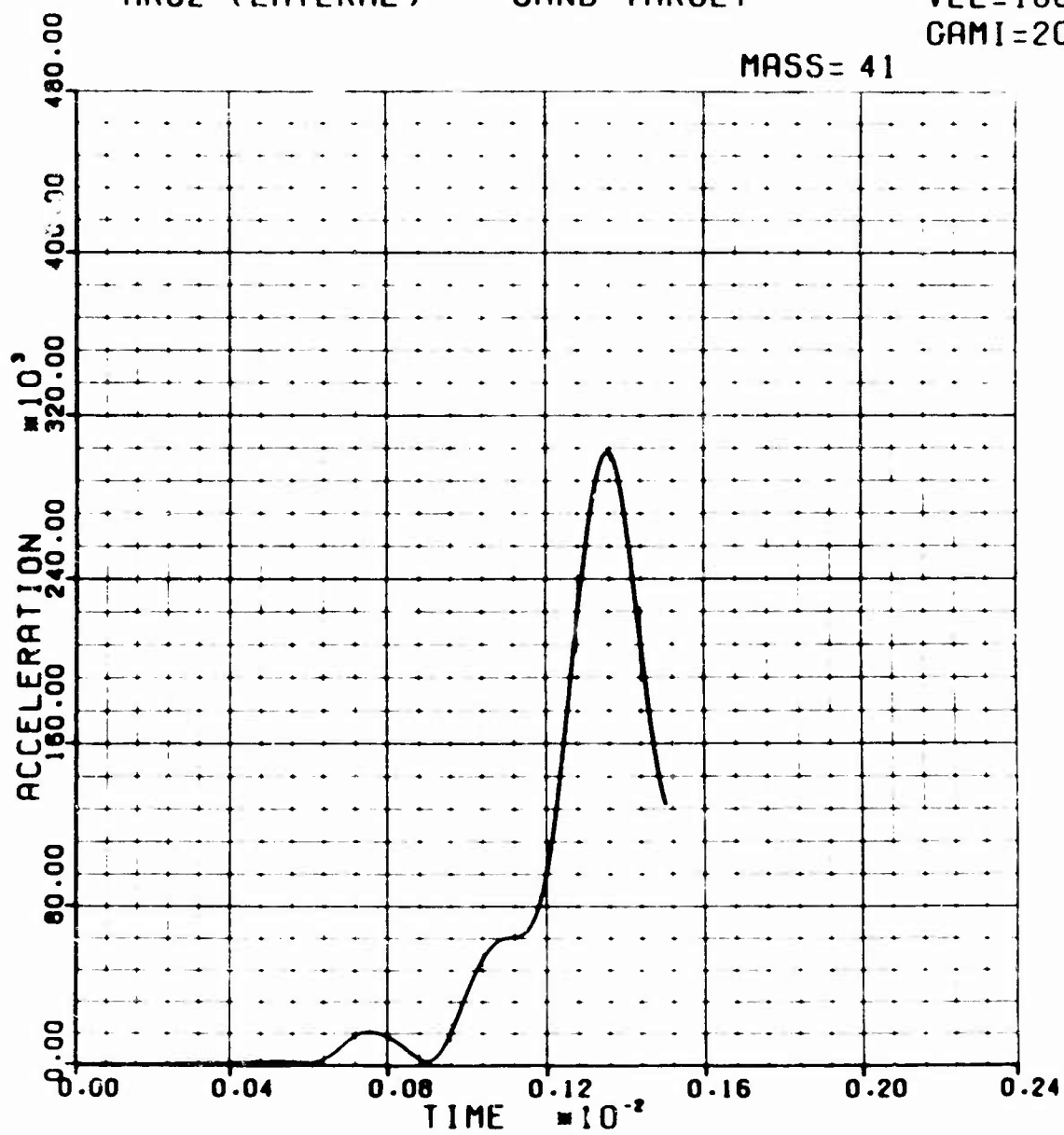
MK82 (LATERAL)

SAND TARGET

VEL=10800.

GAMI=20.0

MASS= 41



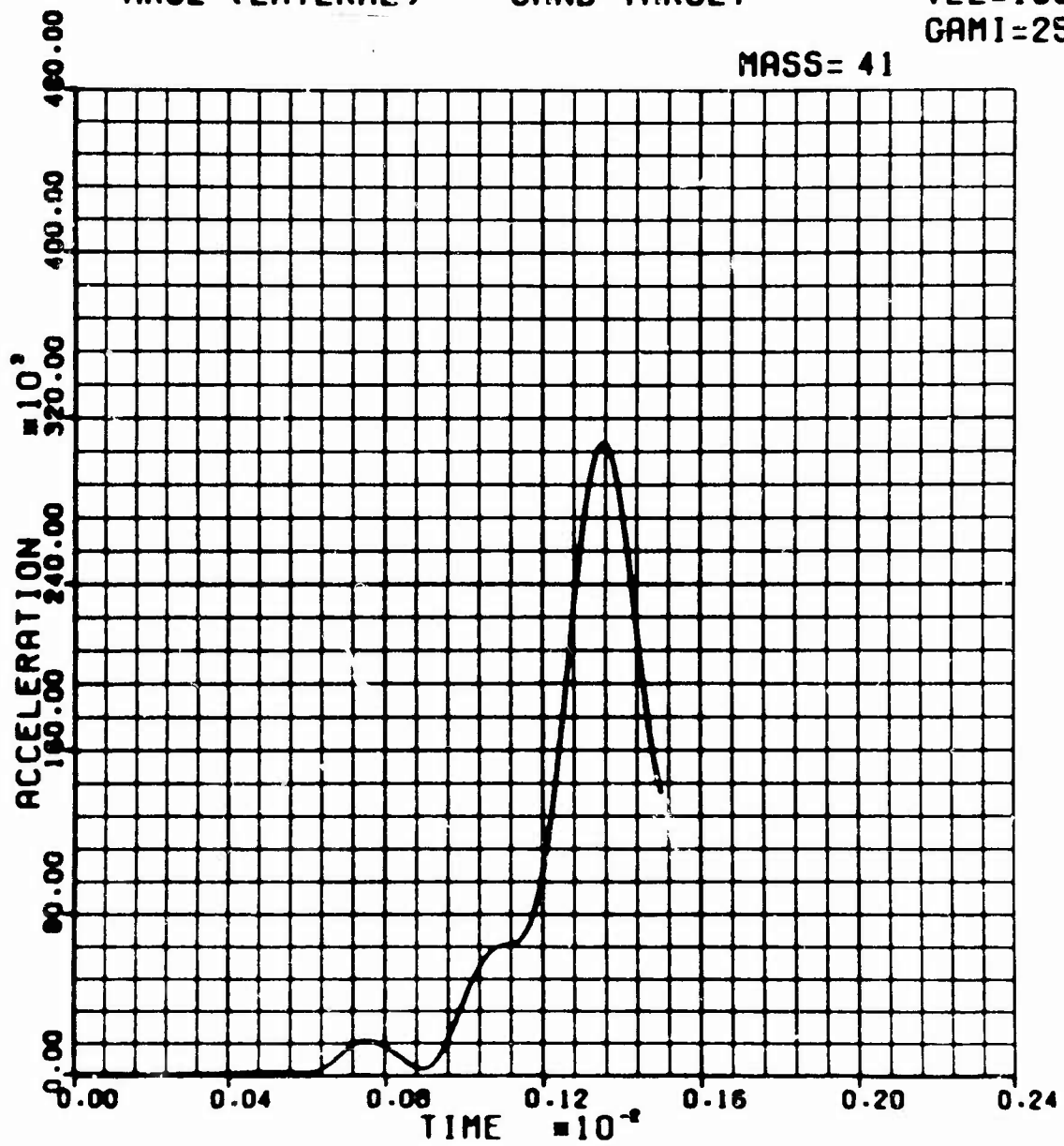
MK82 (LATERAL)

SAND TARGET

VEL=10800.

GAMI=25.0

MASS= 41



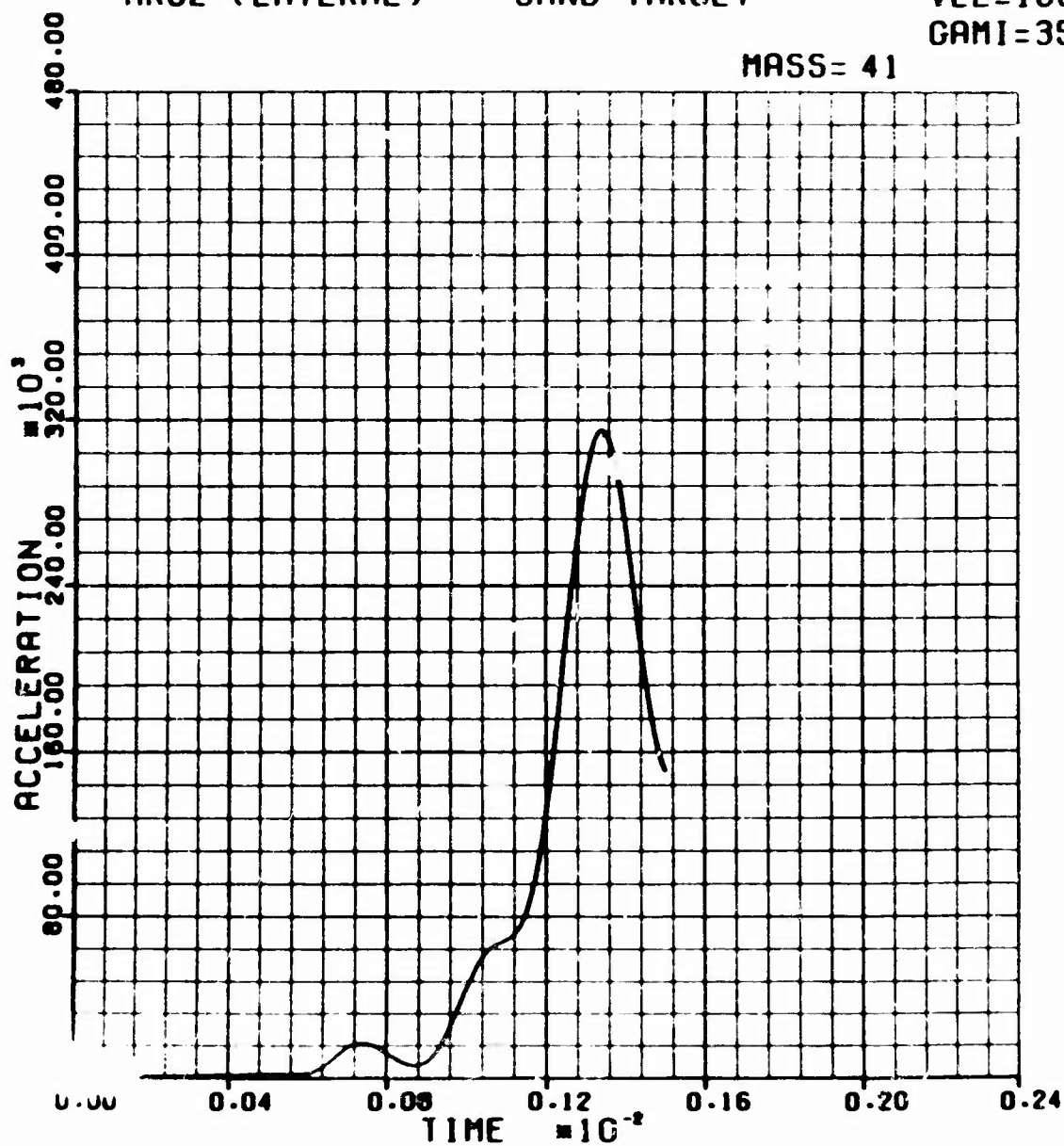
MK82 (LATERAL)

SAND TARGET

VEL=10800.

GAMI=35.0

MASS= 41



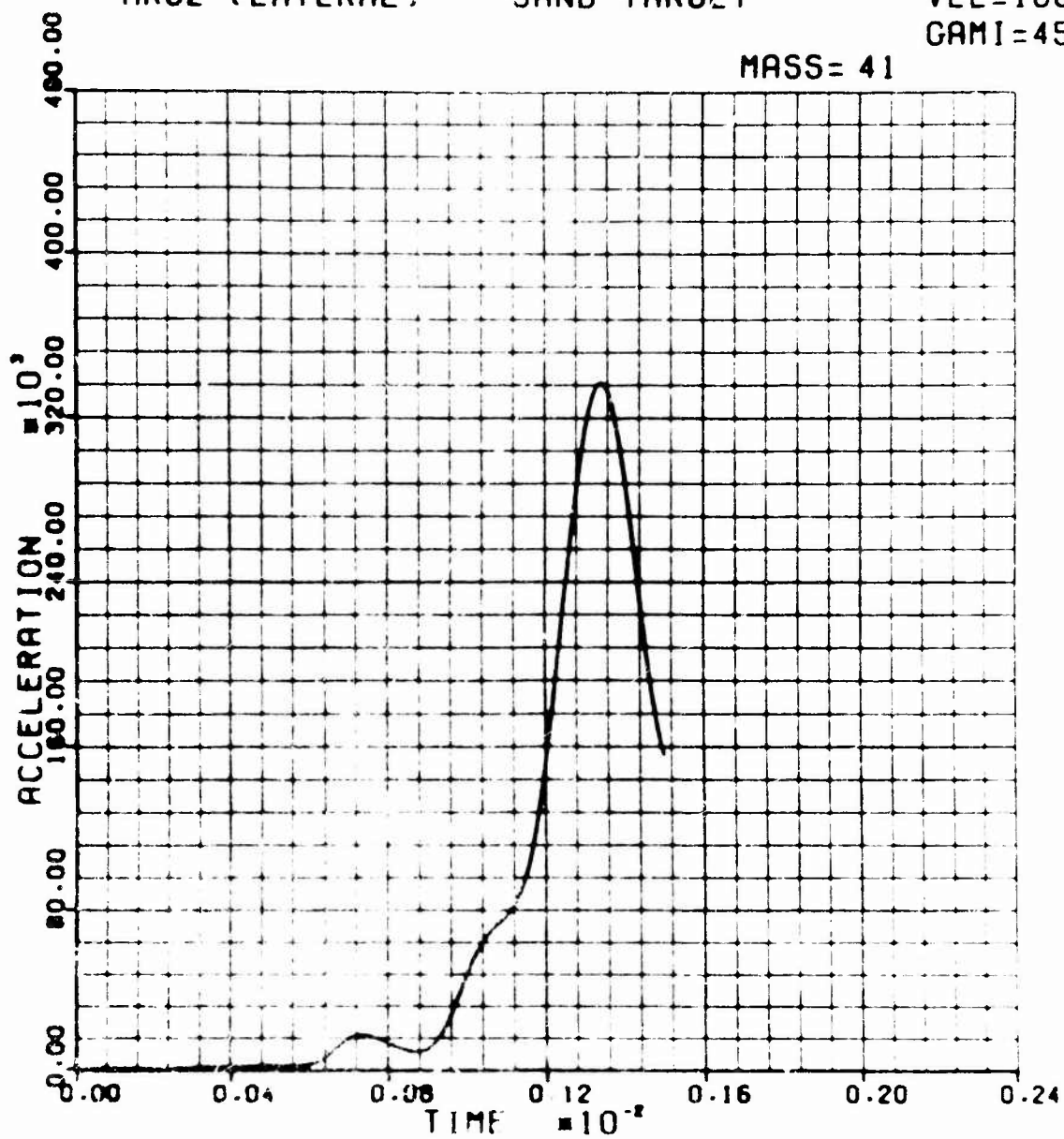
MK82 (LATERAL)

SAND TARGET

VEL=10800.

GAMI=45.0

MASS= 41



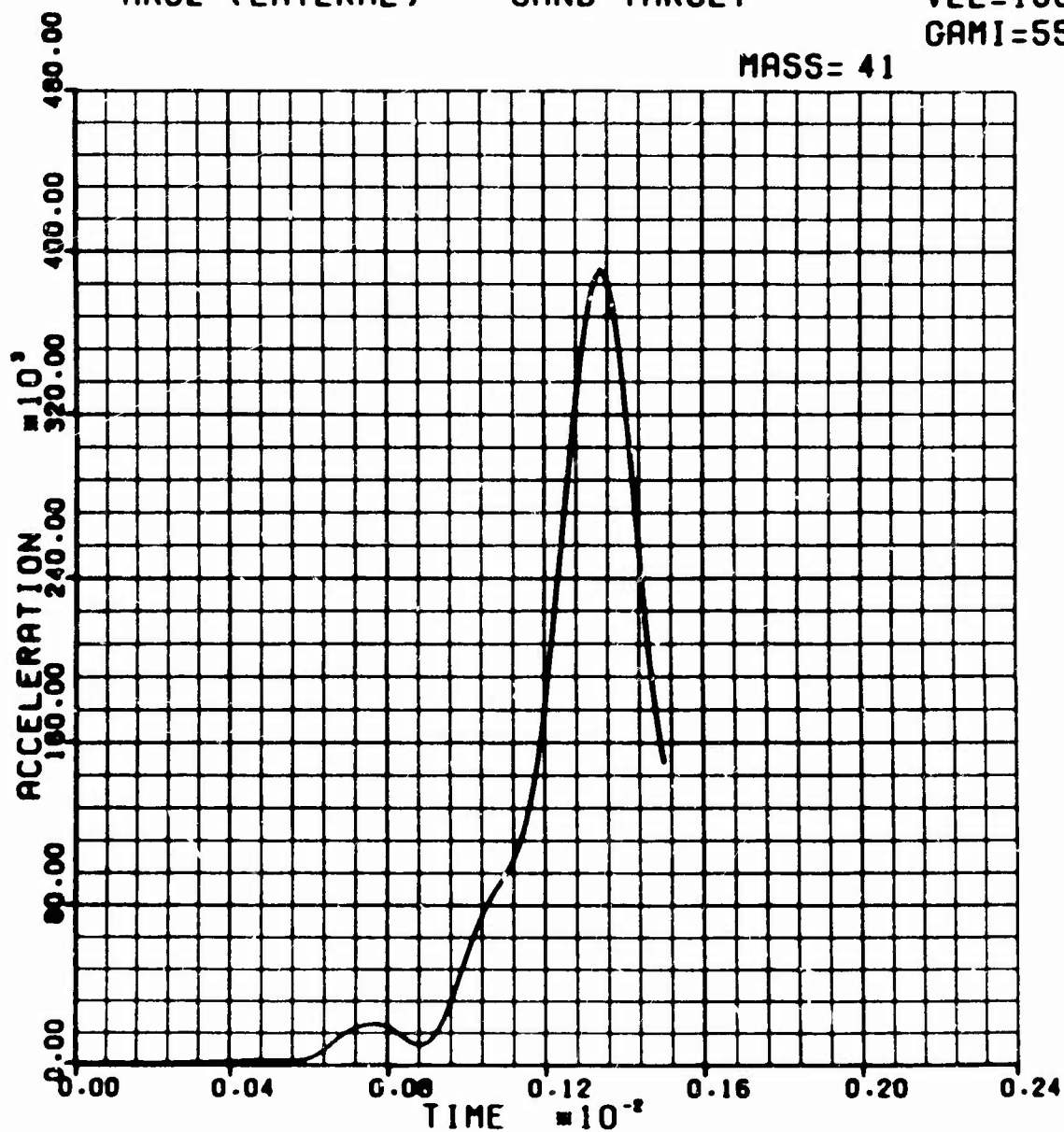
MK82 (LATERAL)

SAND TARGET

VEL=10800.

GAMI=55.0

MASS= 41



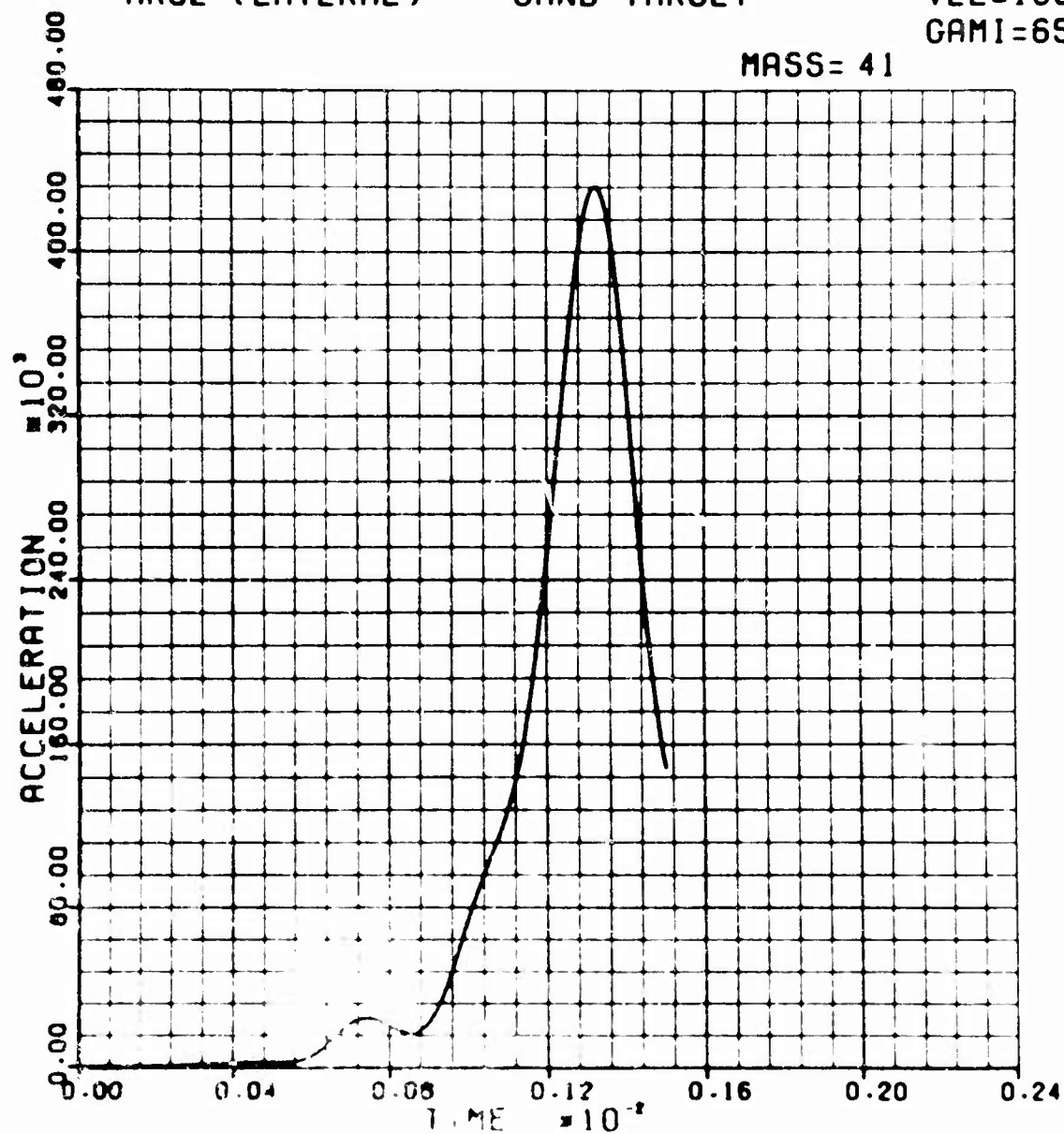
MK82 (LATERAL)

SAND TARGET

VEL=10800.

GAMI=65.0

MASS= 41



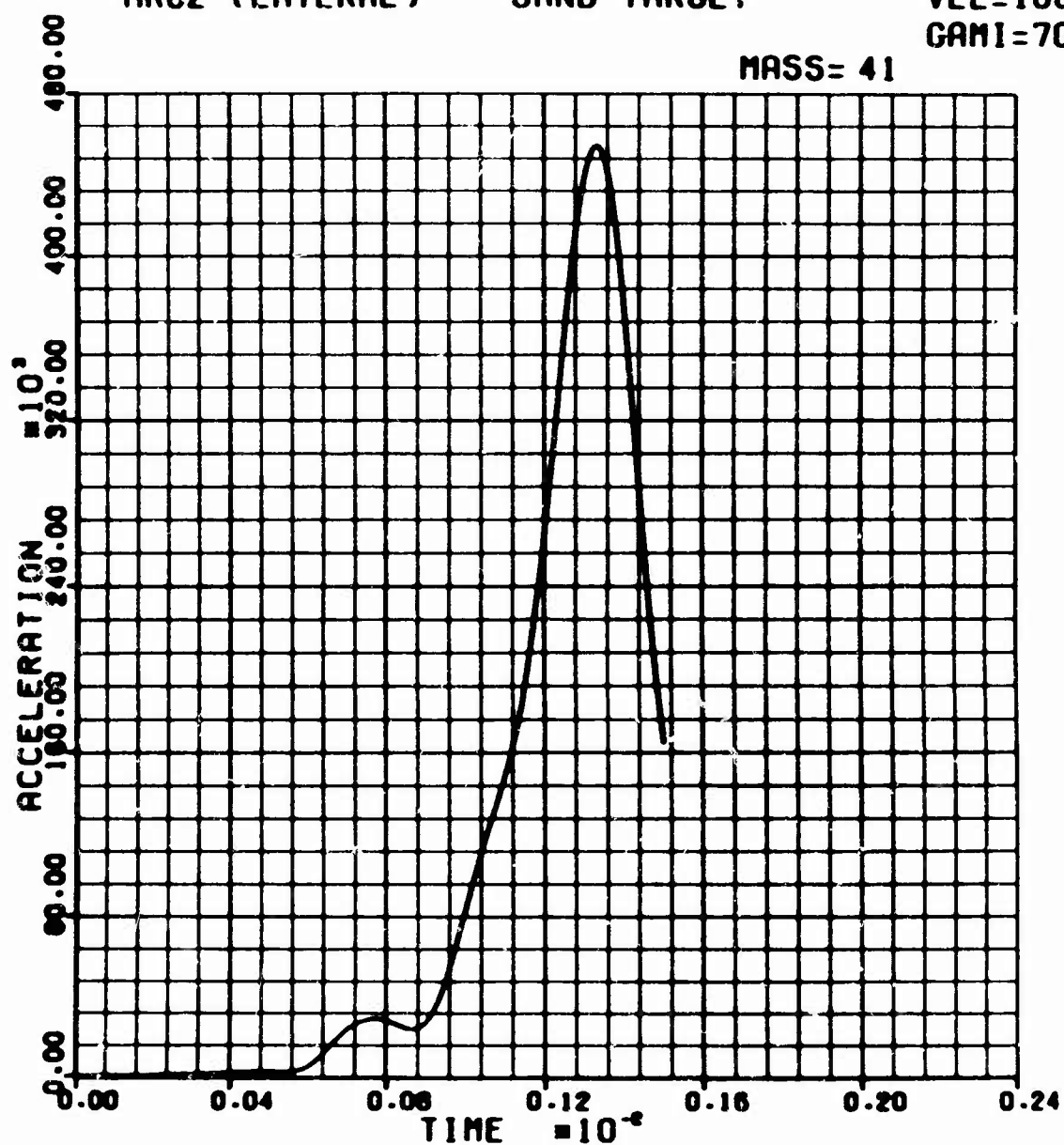
MK82 (LATERAL)

SAND TARGET

VEL=10800.

GAMI=70.0

MASS= 41



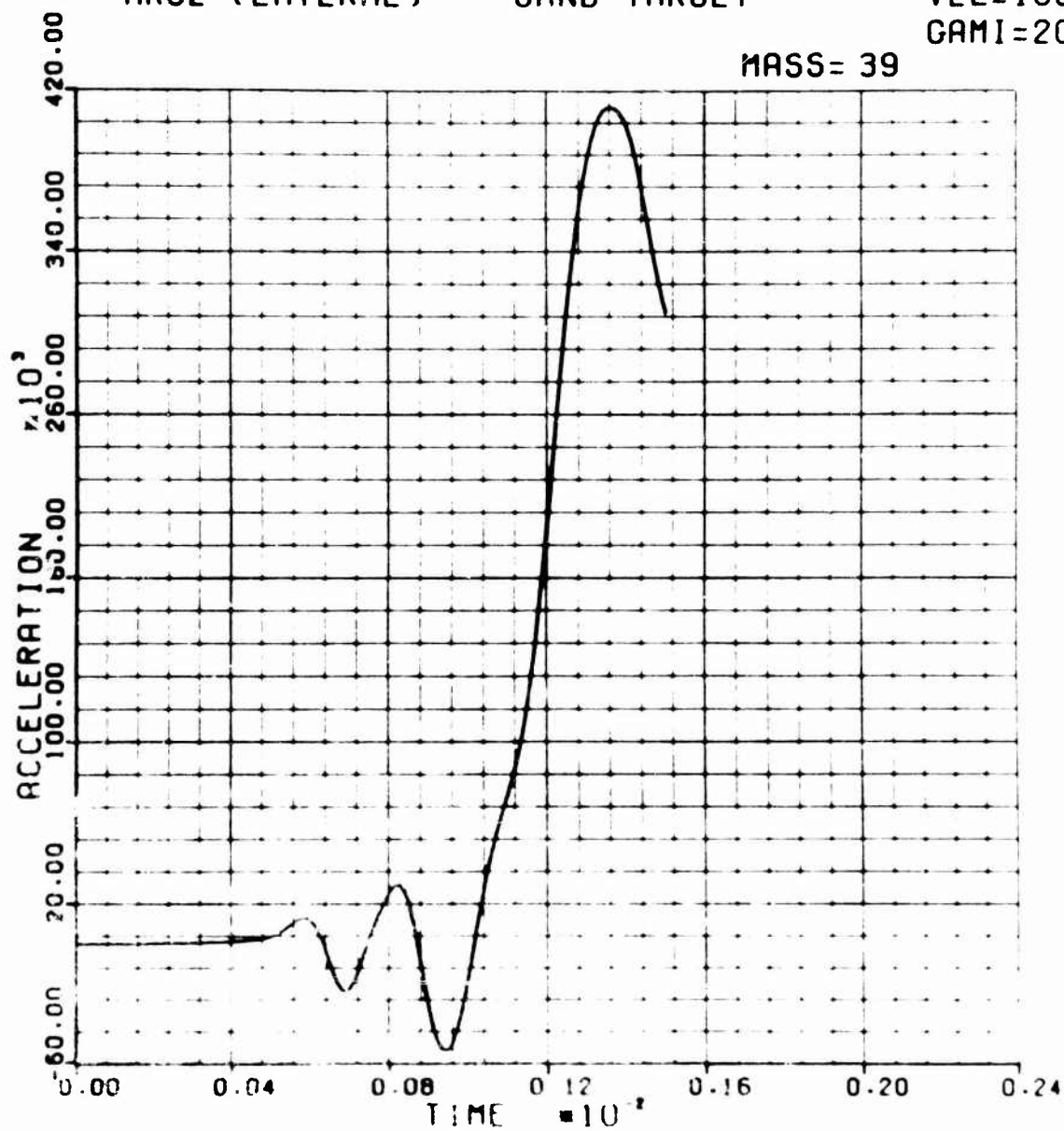
MK82 (LATERAL)

SAND TARGET

VEL=10800.

GAMI=20.0

MASS= 39



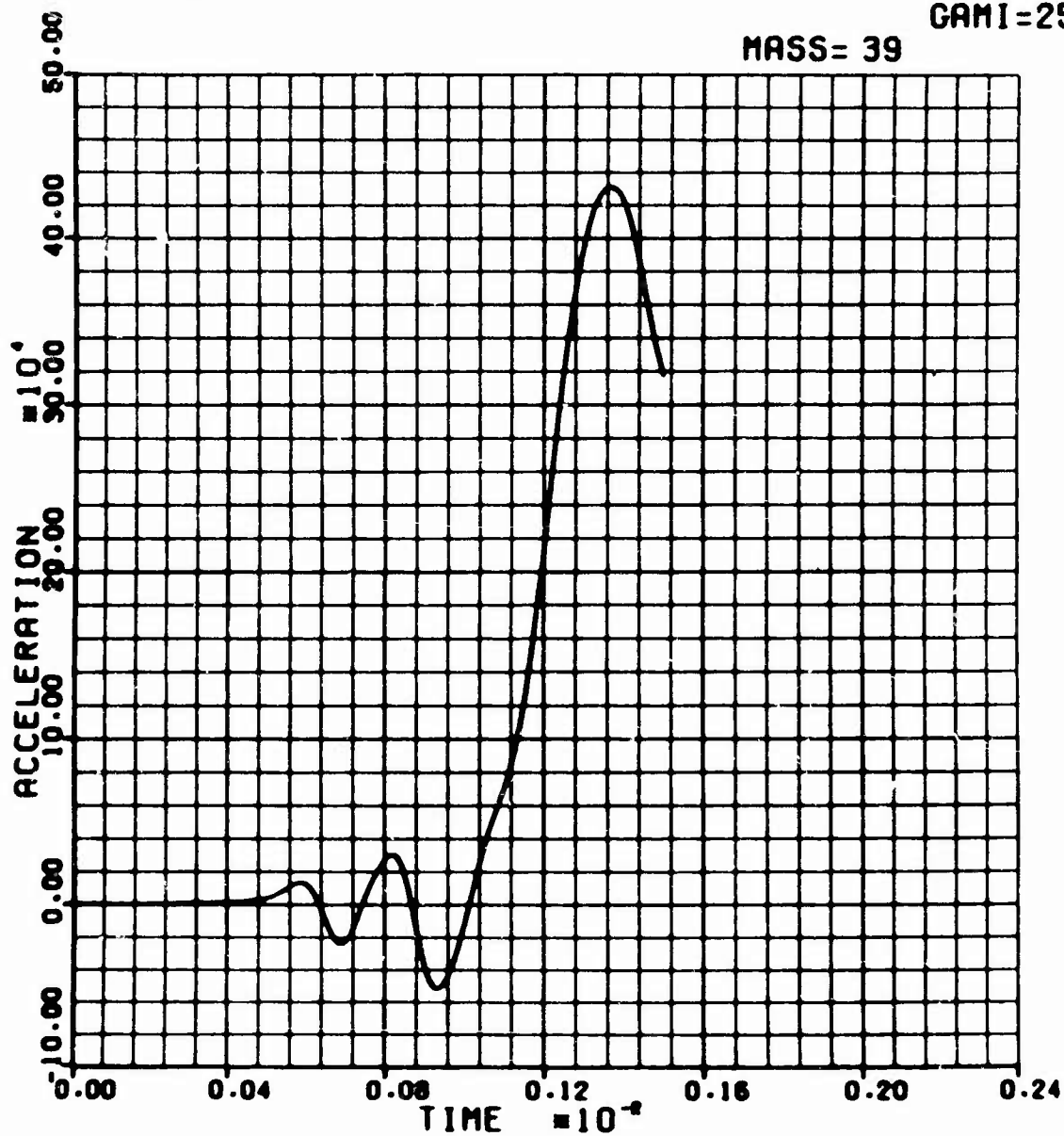
MK82 (LATERAL)

SAND TARGET

VEL=10000.

GAMI=25.0

MASS= 39



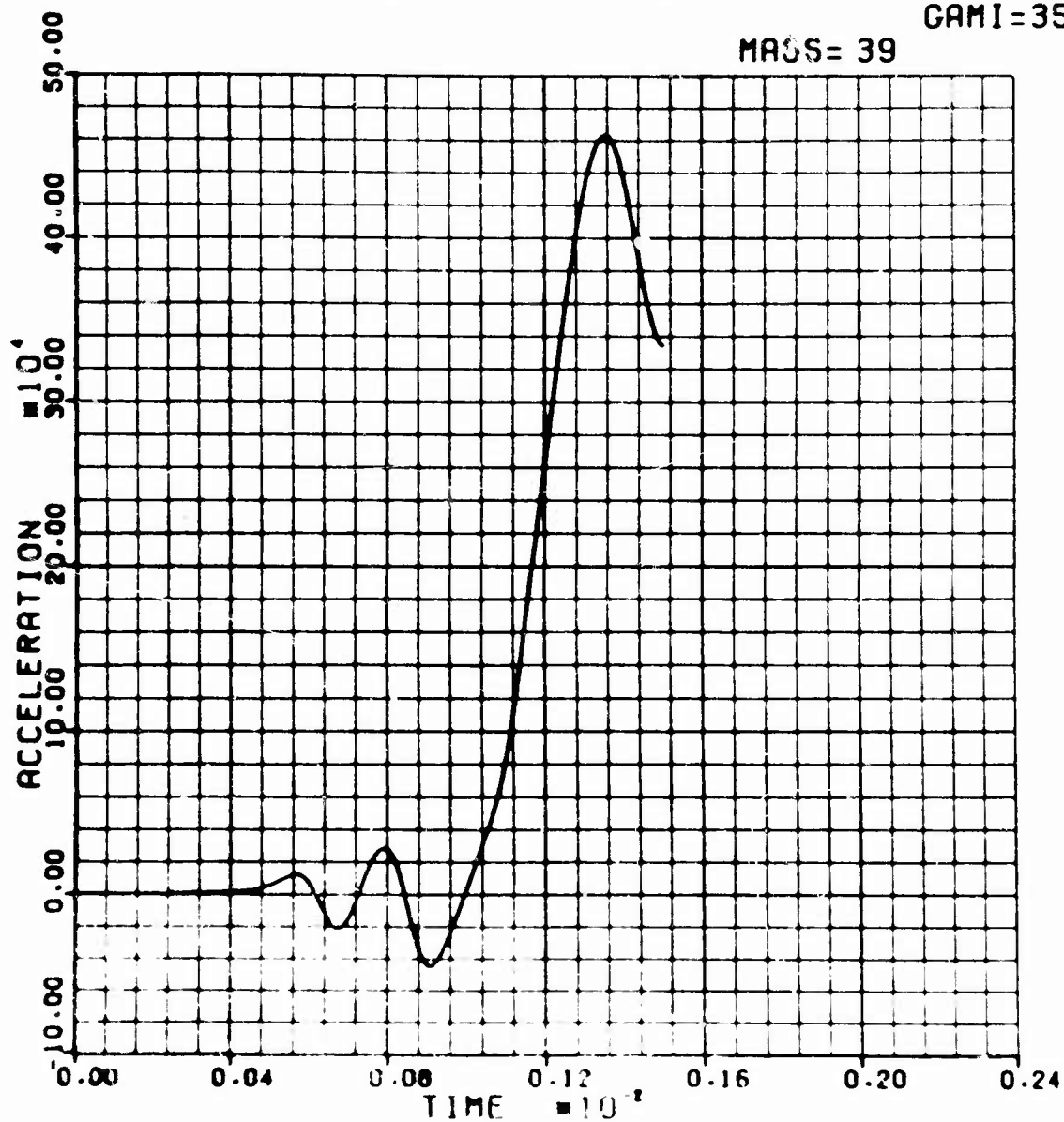
MK82 (LATERAL)

SAND TARGET

VEL=10800.

GAMI=35.0

MASS= 39



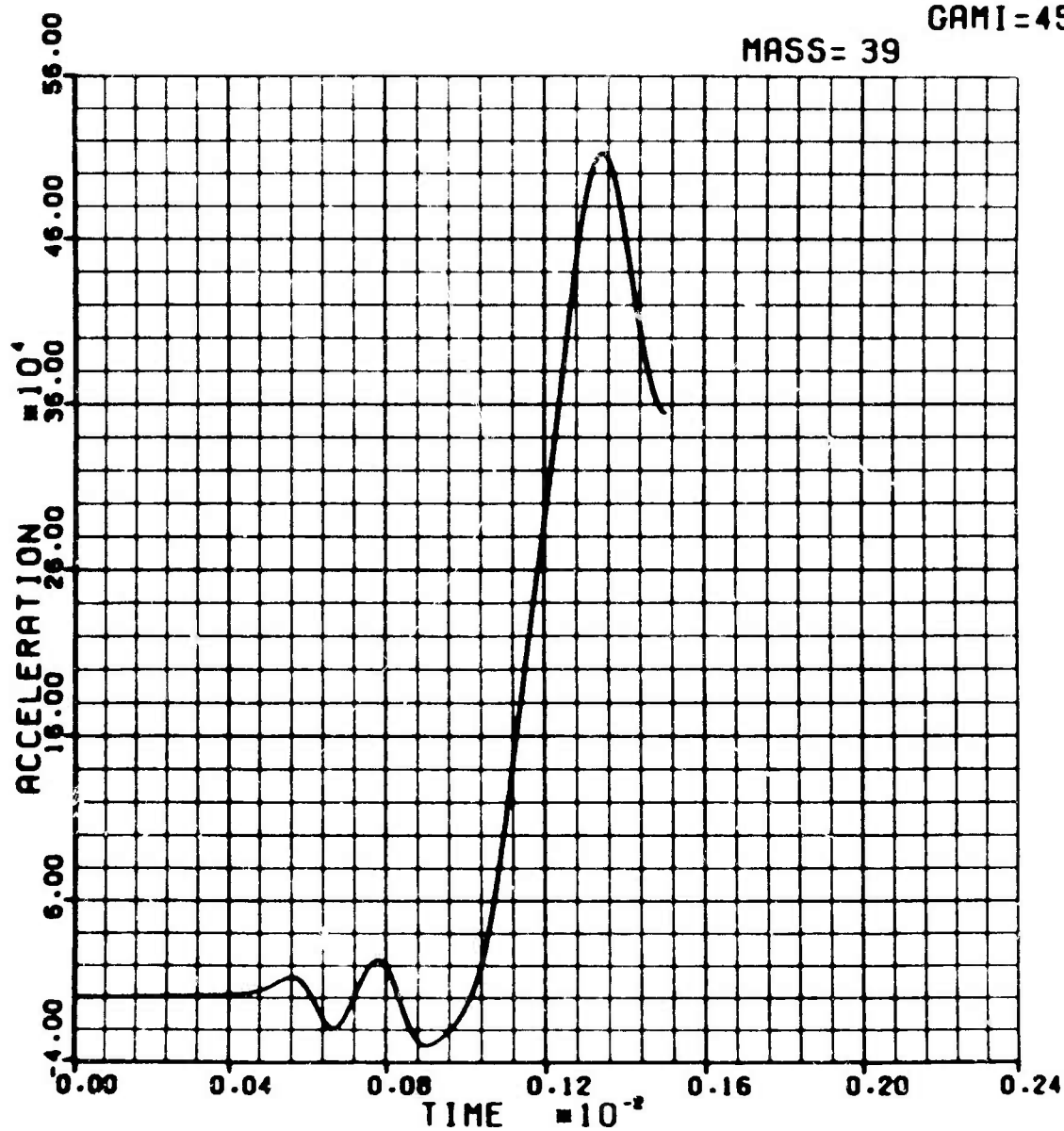
MK82 (LATERAL)

SAND TARGET

VEL=10800.

GAMI=45.0

MASS= 39



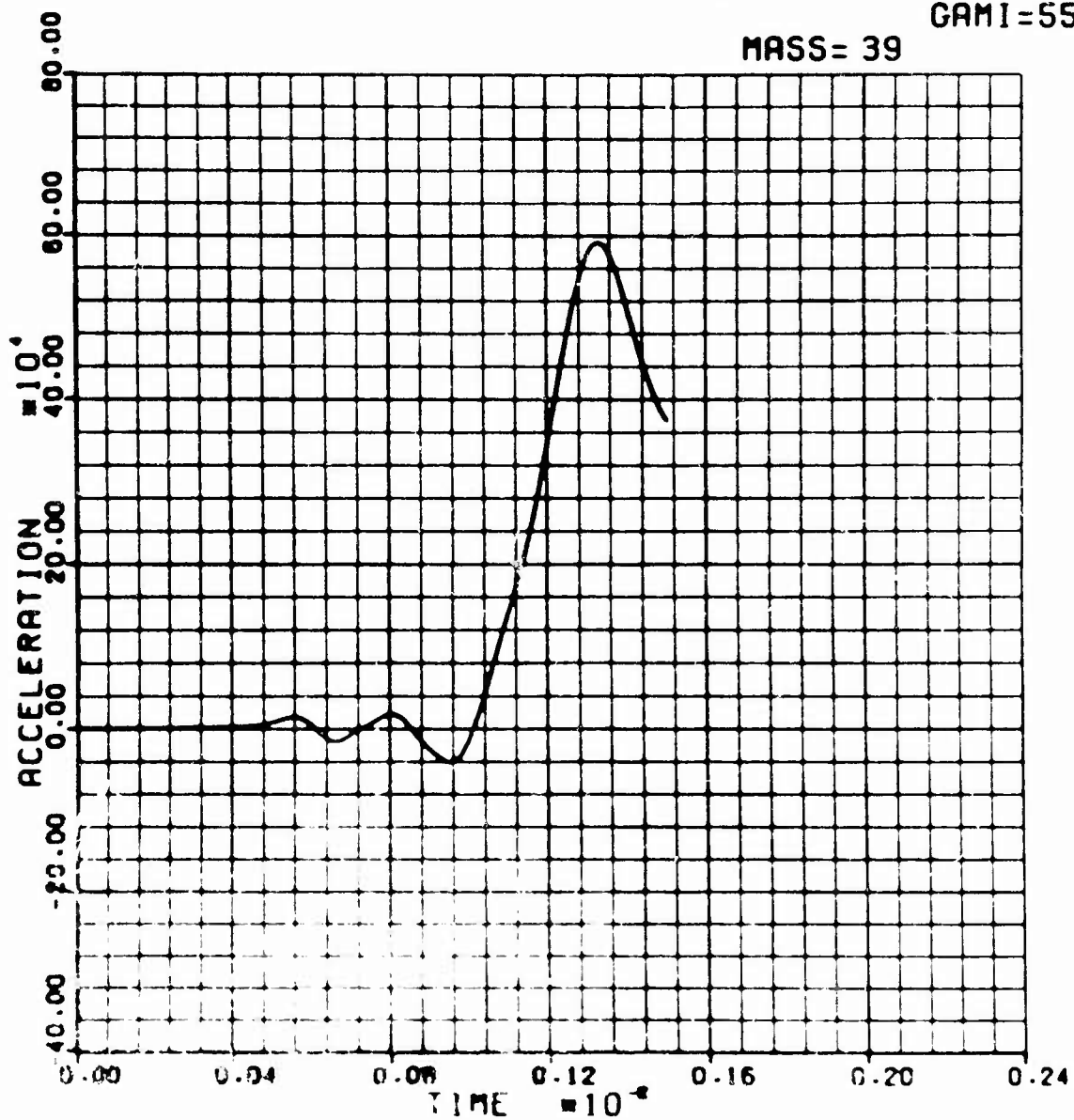
MK82 (LATERAL)

SAND TARGET

VEL=10800.

GAMI=55.0

MASS= 39



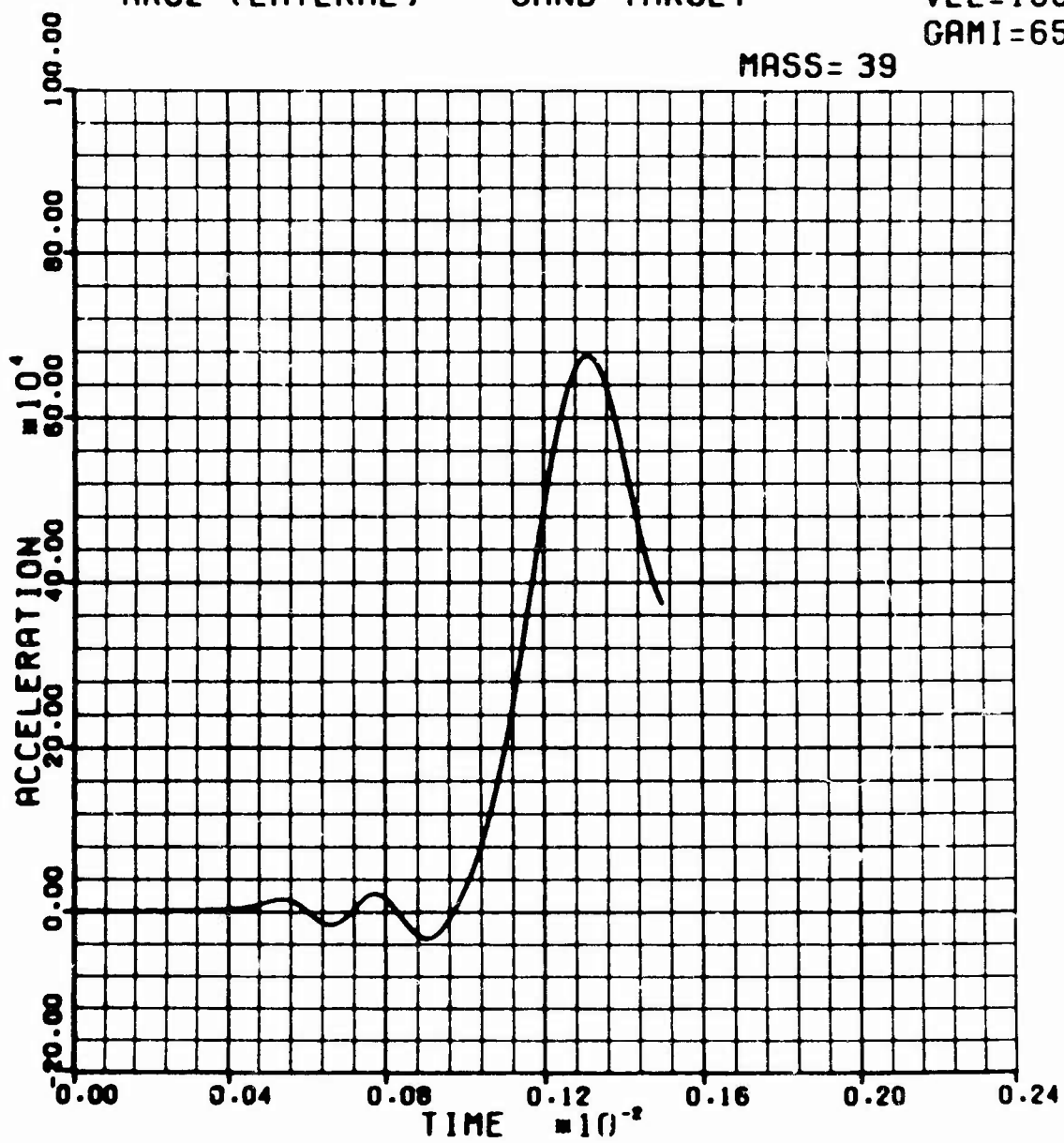
MK82 (LATERAL)

SAND TARGET

VEL=10800.

GAMI=65.0

MASS= 39



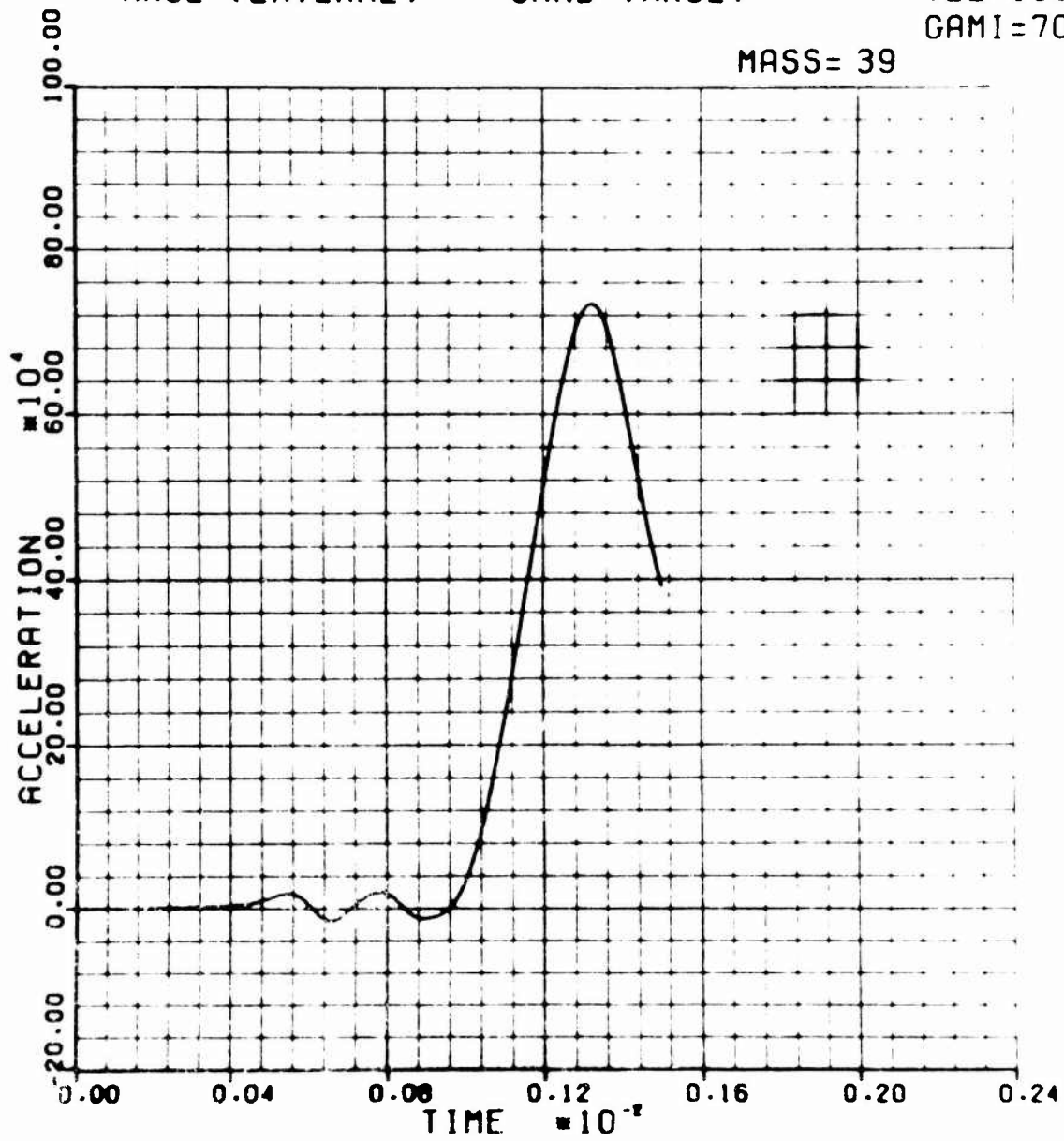
MK82 (LATERAL)

SAND TARGET

VEL=10800.

GAMI=70.0

MASS= 39



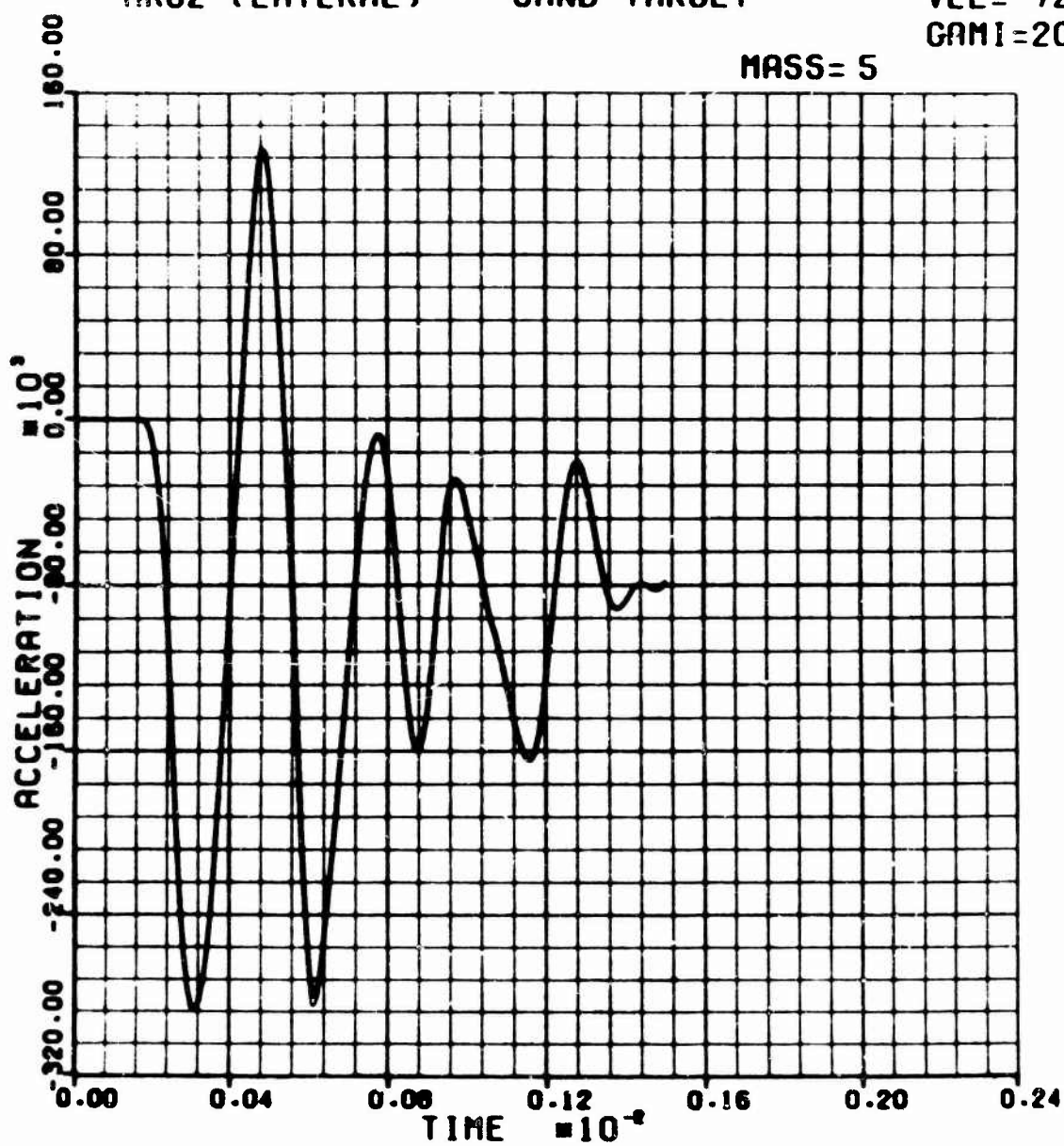
MK82 (LATERAL)

SAND TARGET

VEL= 7200.

GAMI=20.0

MASS= 5



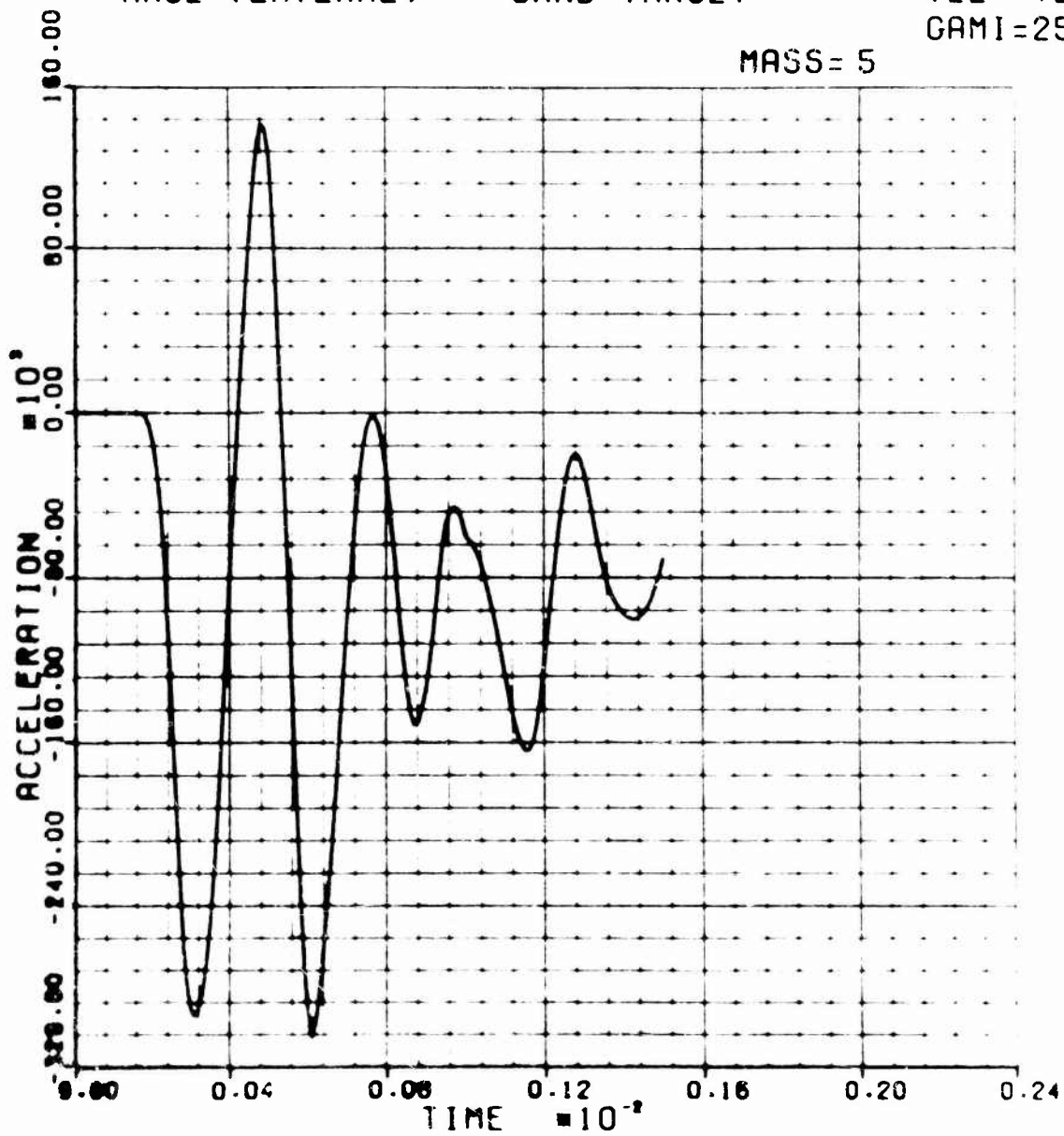
MK82 (LATERAL)

SAND TARGET

VEL= 7200.

GAMI=25.0

MASS= 5



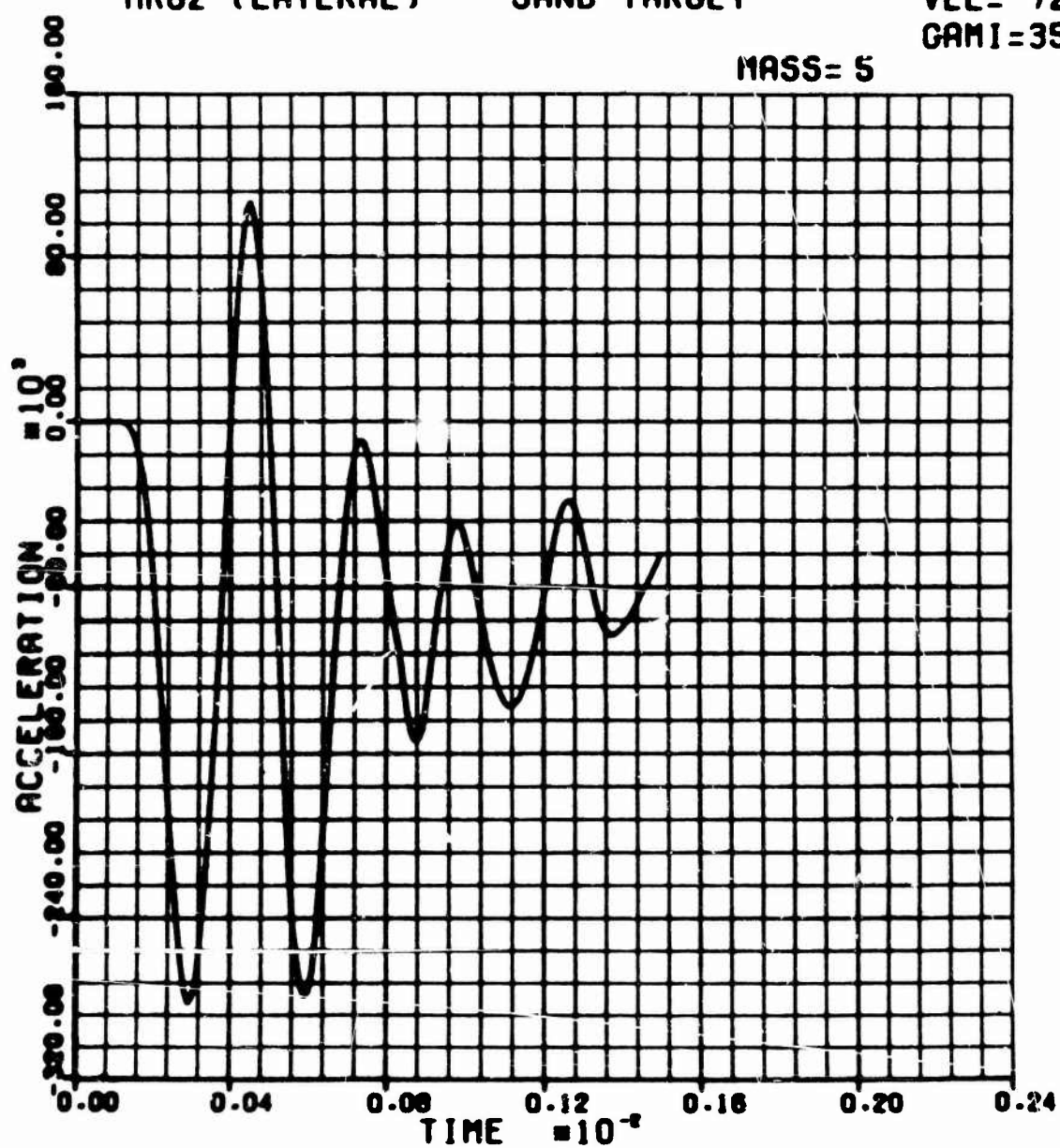
MK82 (LATERAL)

SAND TARGET

VEL= 7200.

GAMI=35.0

MASS= 5



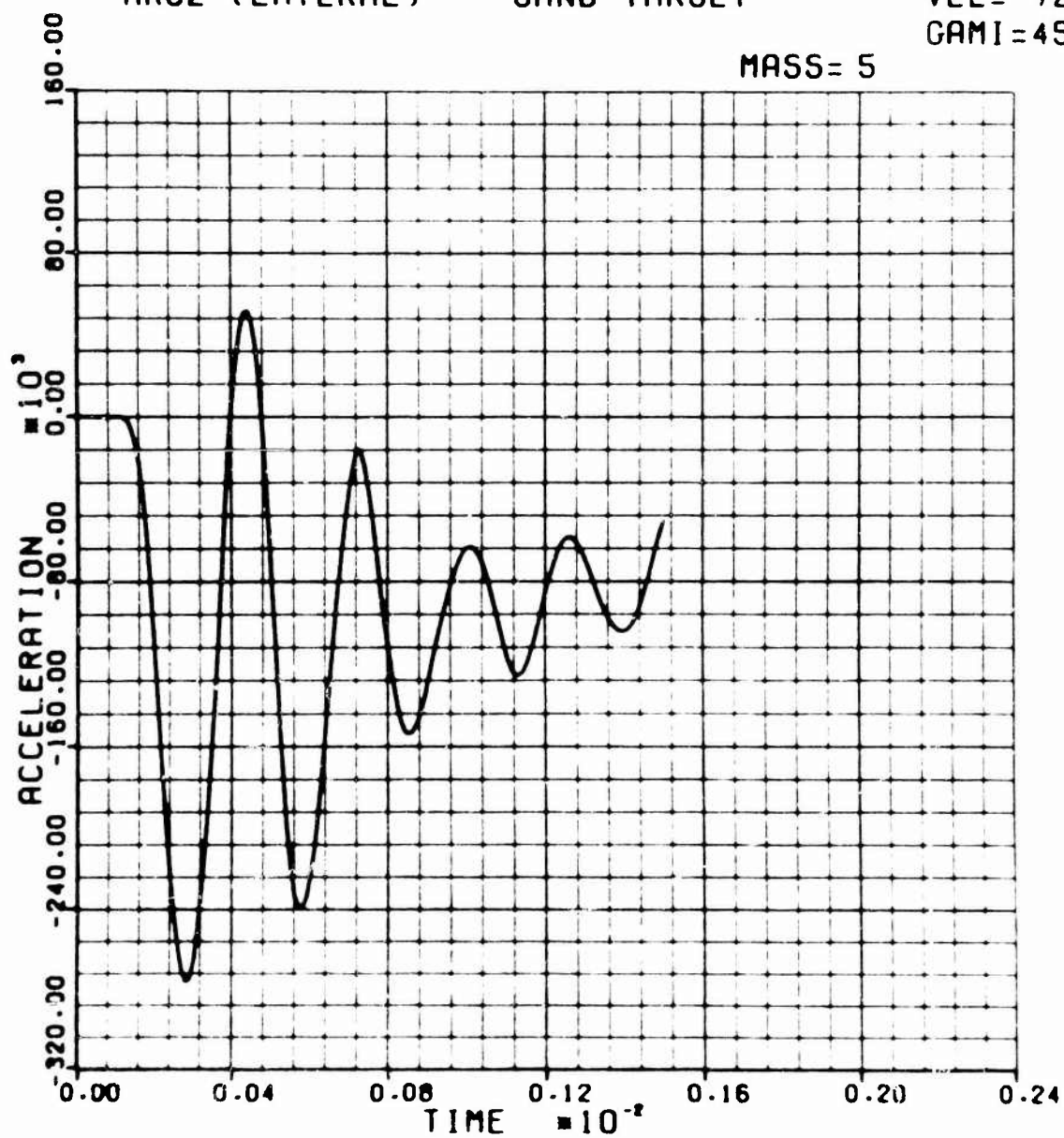
MK82 (LATERAL)

SAND TARGET

VEL= 7200.

GAMI=45.0

MASS= 5



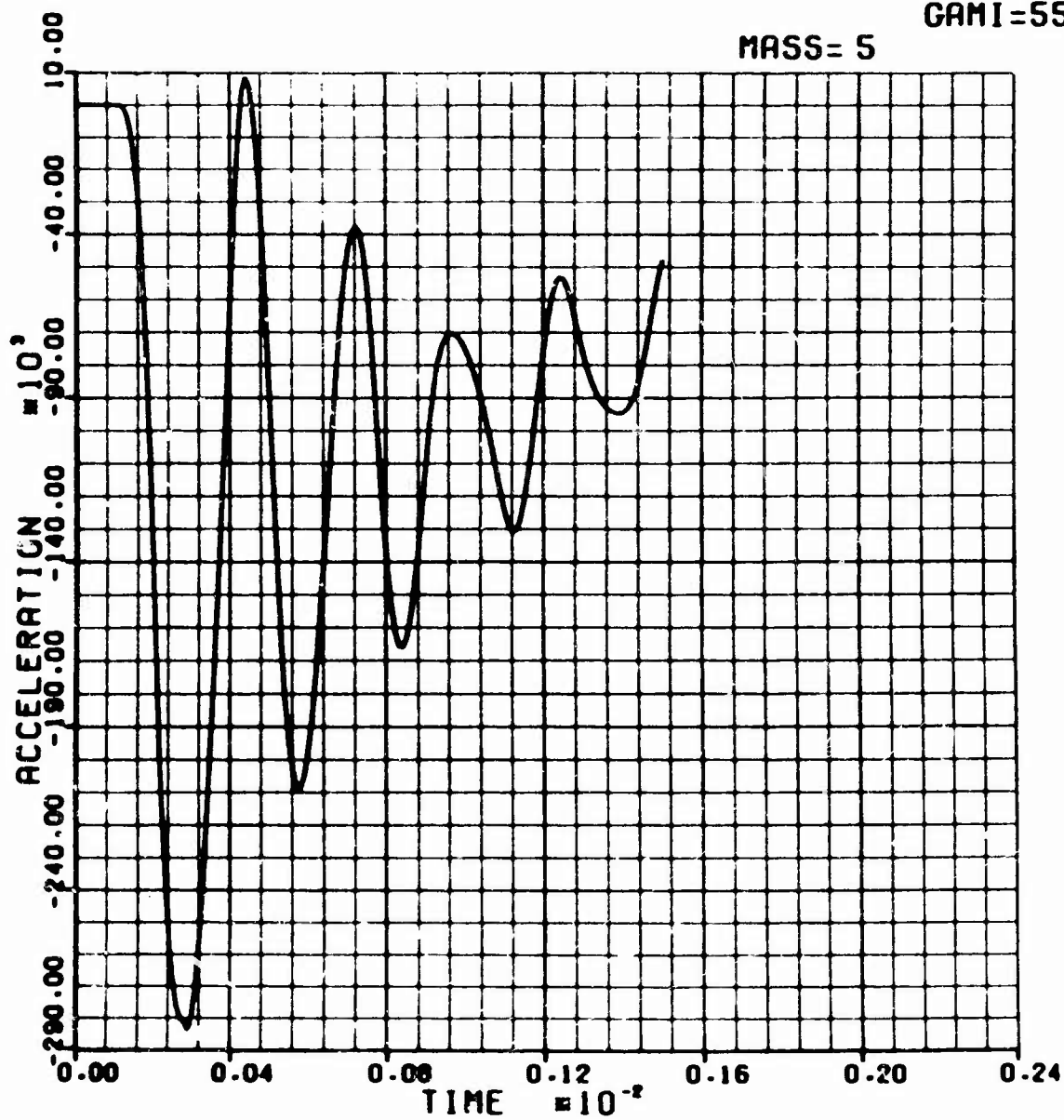
MK82 (LATERAL)

SAND TARGET

VEL= 7200.

GAMI=55.0

MASS= 5



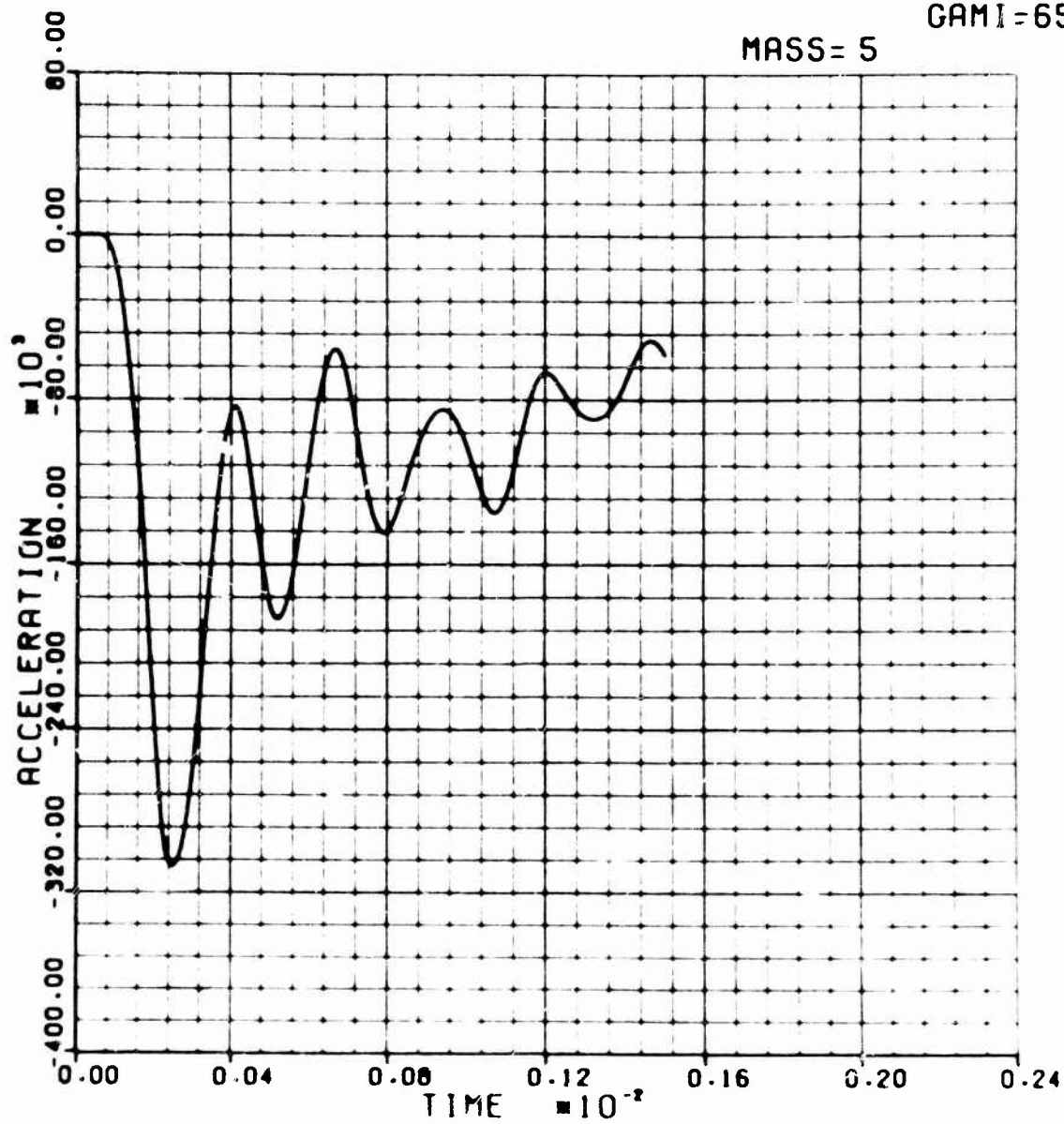
MK82 (LATERAL)

SAND TARGET

VEL= 7200.

GAMI=65.0

MASS= 5



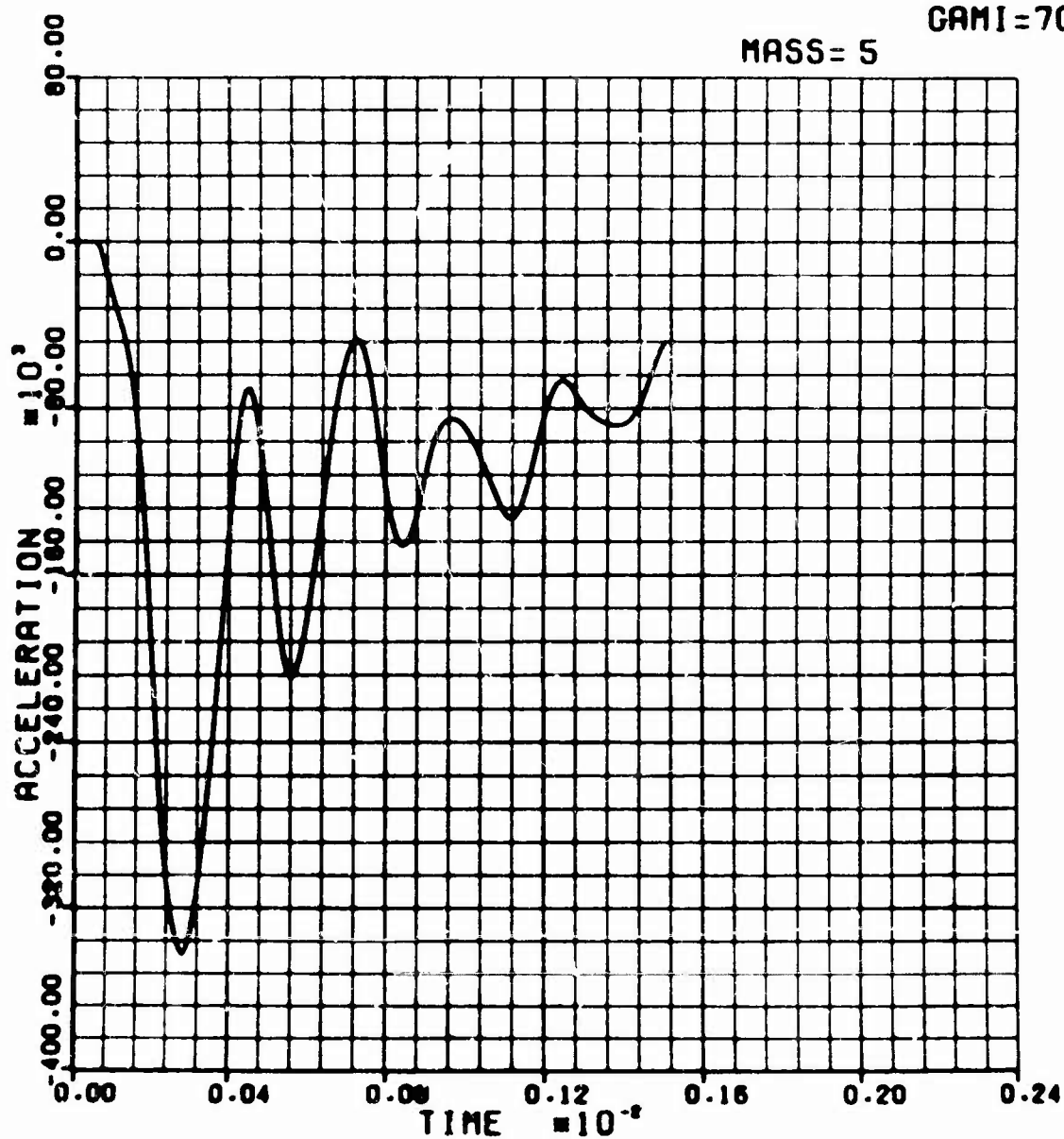
MK82 (LATERAL)

SAND TARGET

VEL= 7200.

GAMI=70.0

MASS= 5



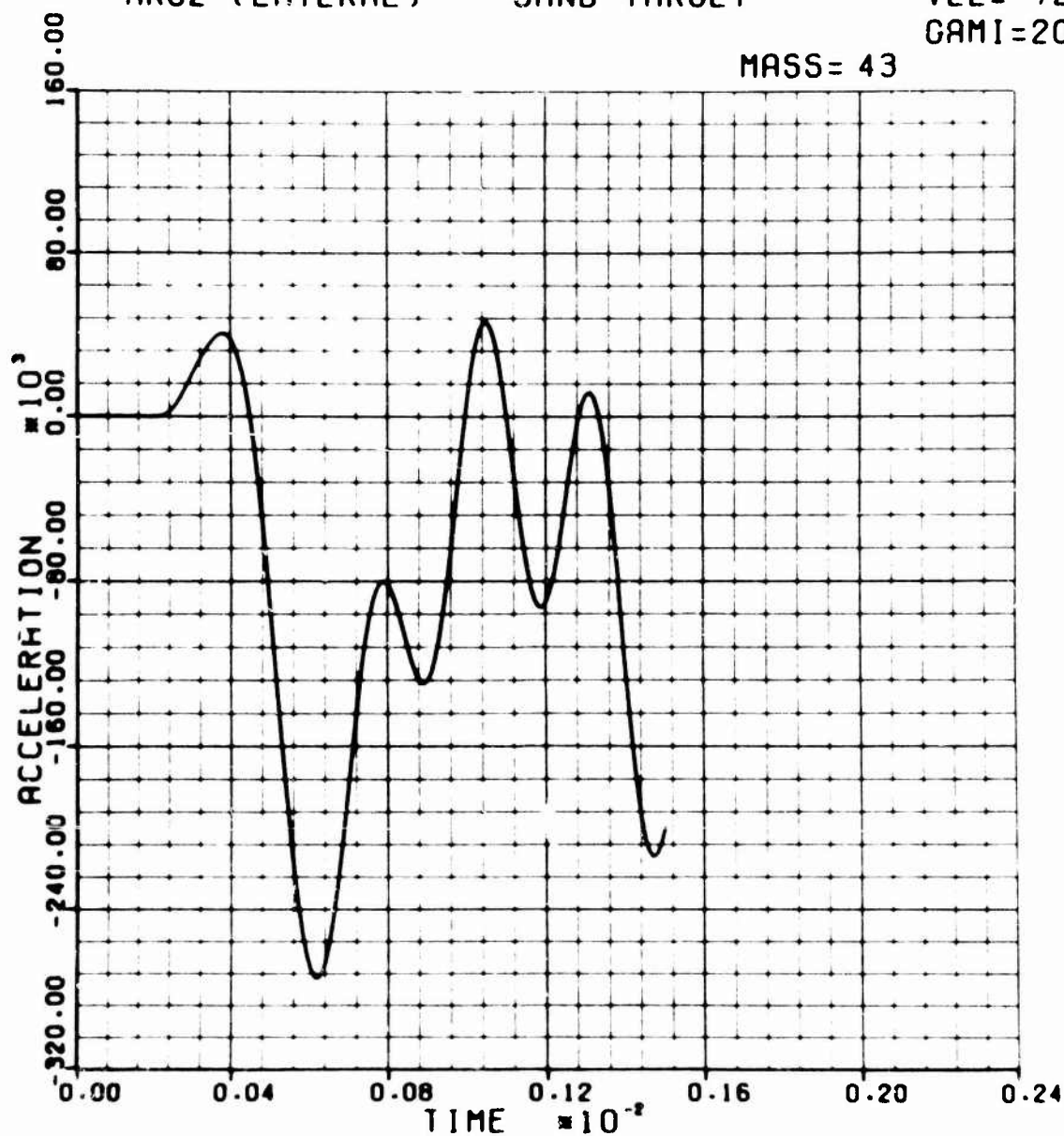
MK82 (LATERAL)

SAND TARGET

VEL= 7200.

GAMI=20.0

MASS= 43



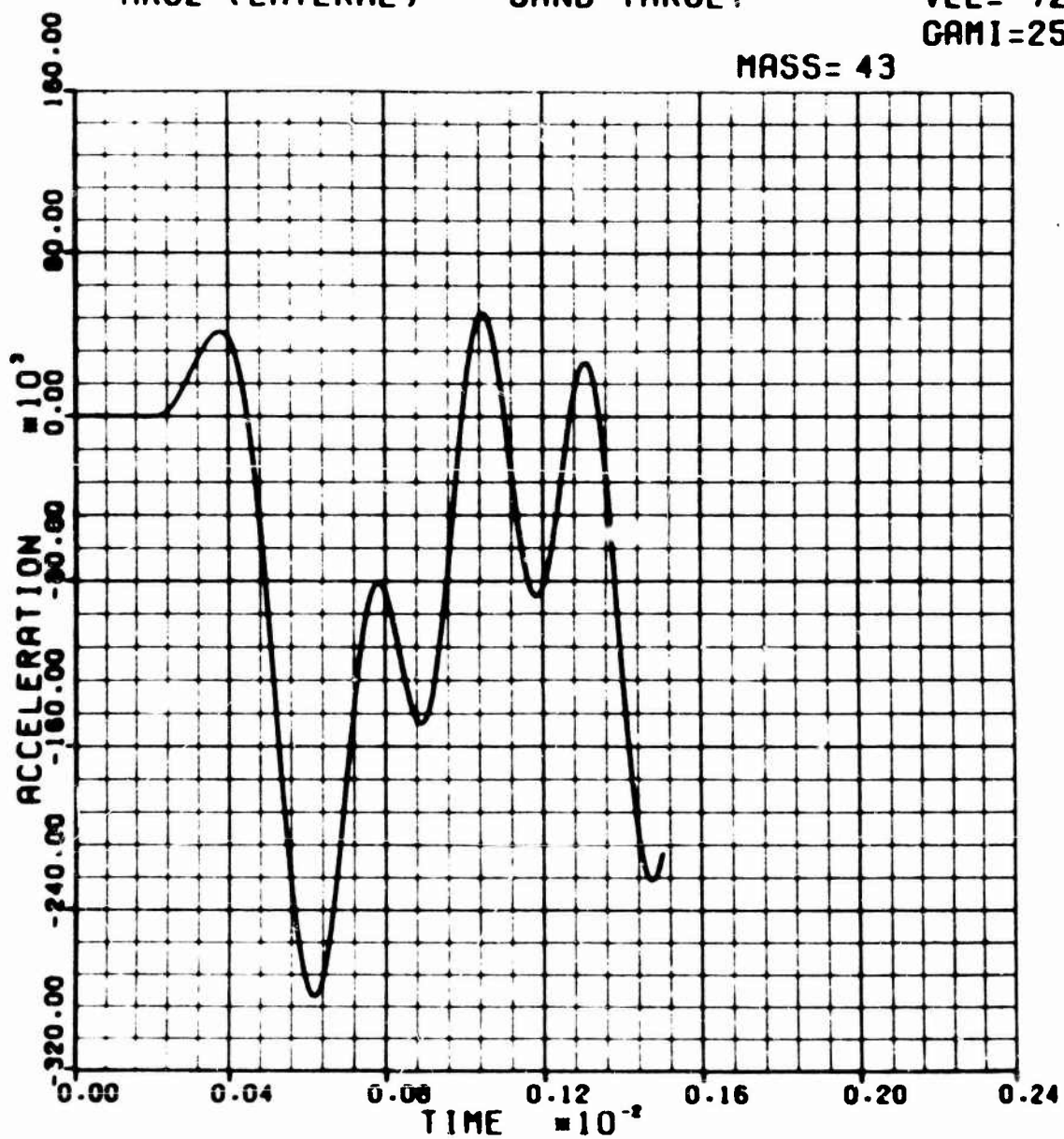
MK82 (LATERAL)

SAND TARGET

VEL= 7200.

GAMI=25.0

MASS= 43



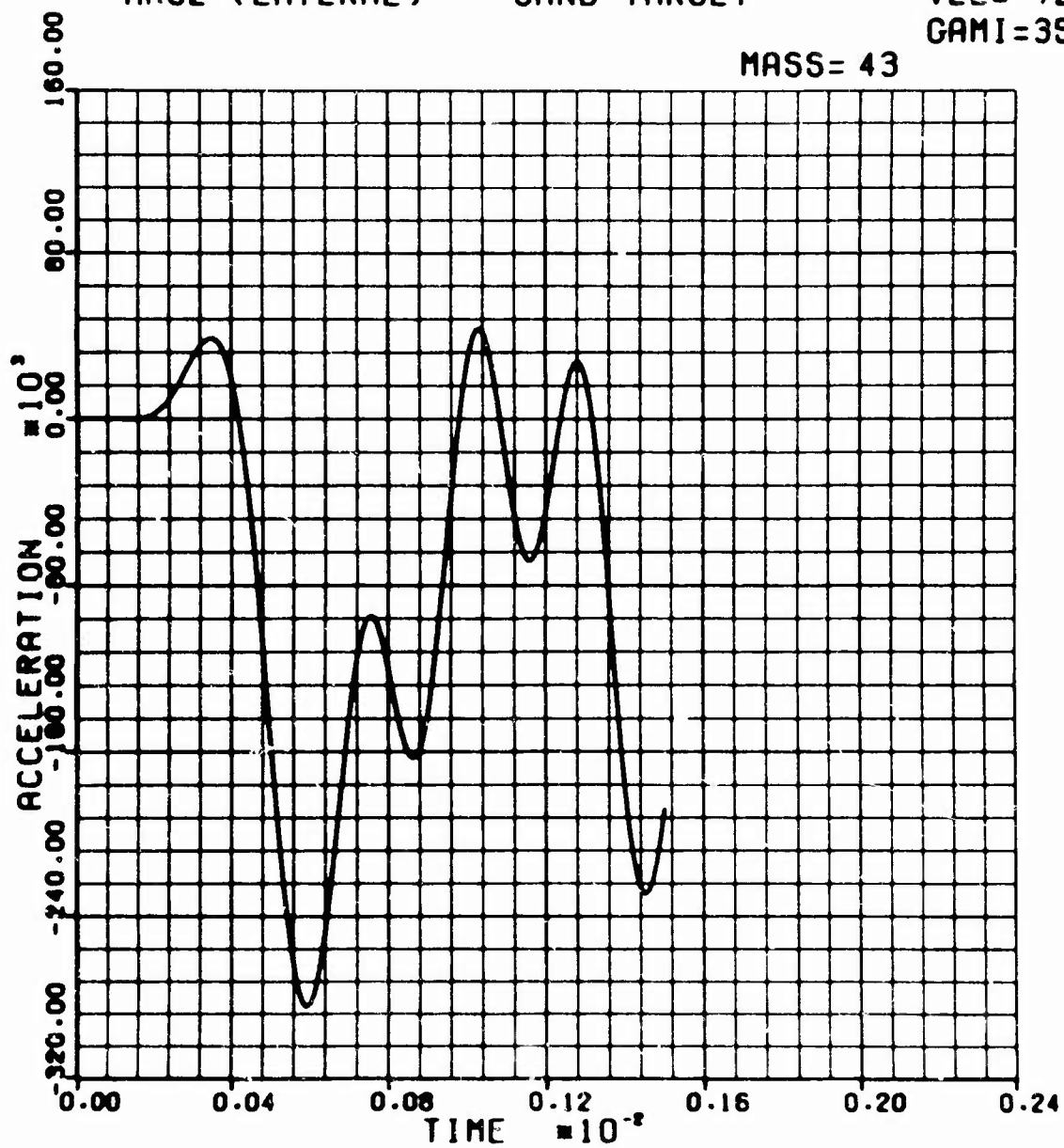
MK82 (LATERAL)

SAND TARGET

VEL= 7200.

GAMI=35.0

MASS= 43



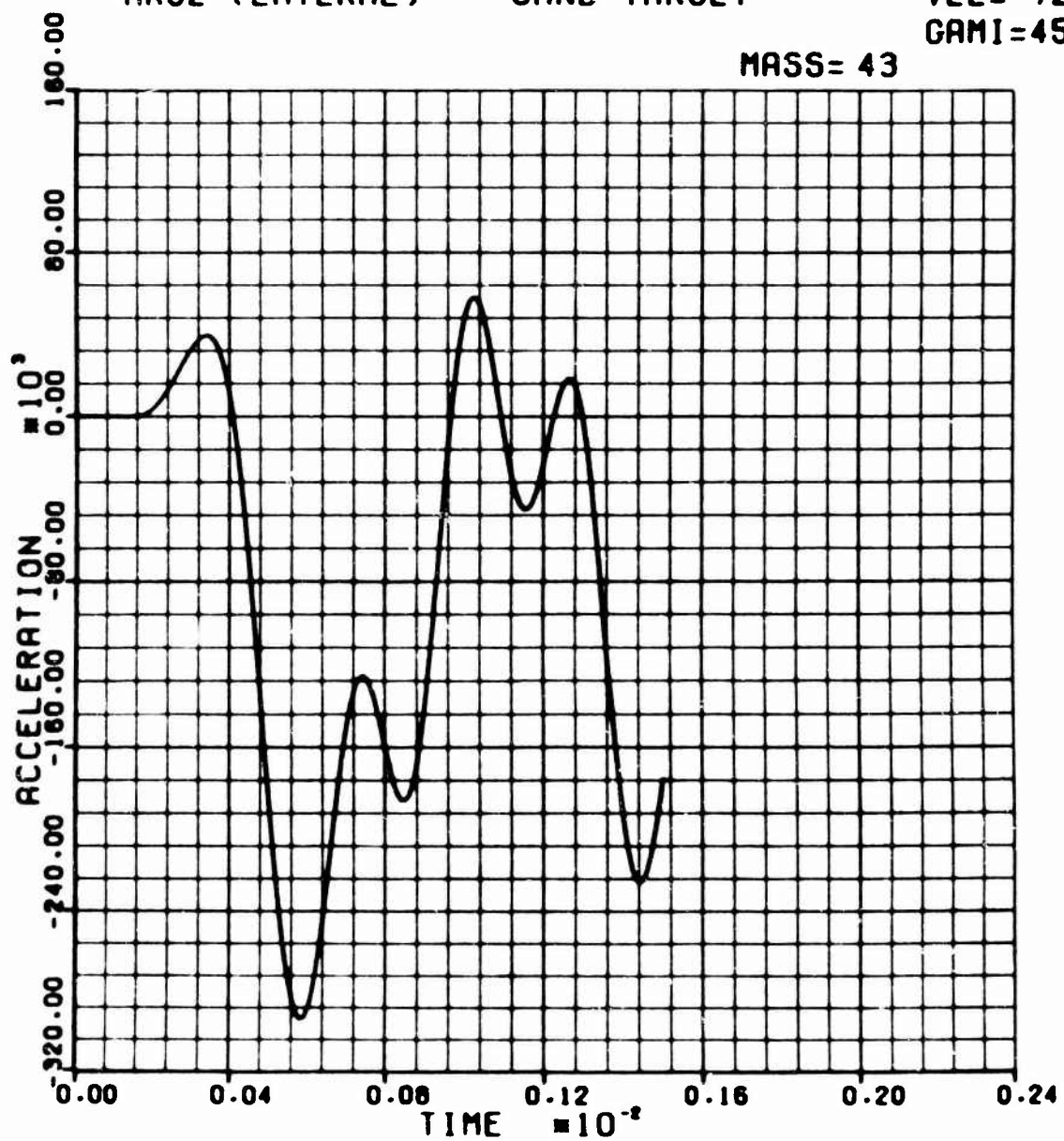
MK82 (LATERAL)

SAND TARGET

VEL= 7200.

GAMI=45.0

MASS= 43



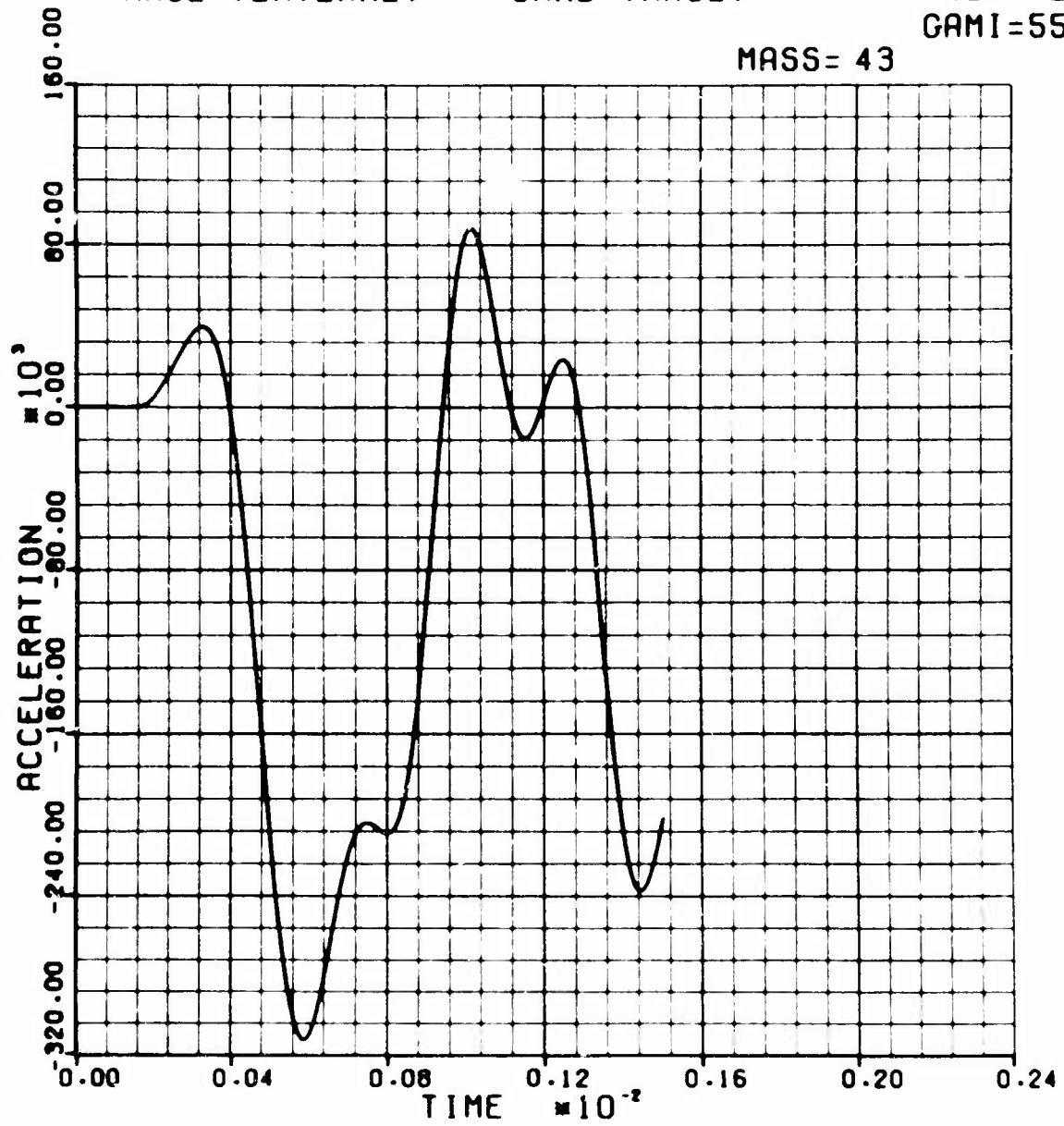
MK82 (LATERAL)

SAND TARGET

VEL= 7200.

GAMI=55.0

MASS= 43



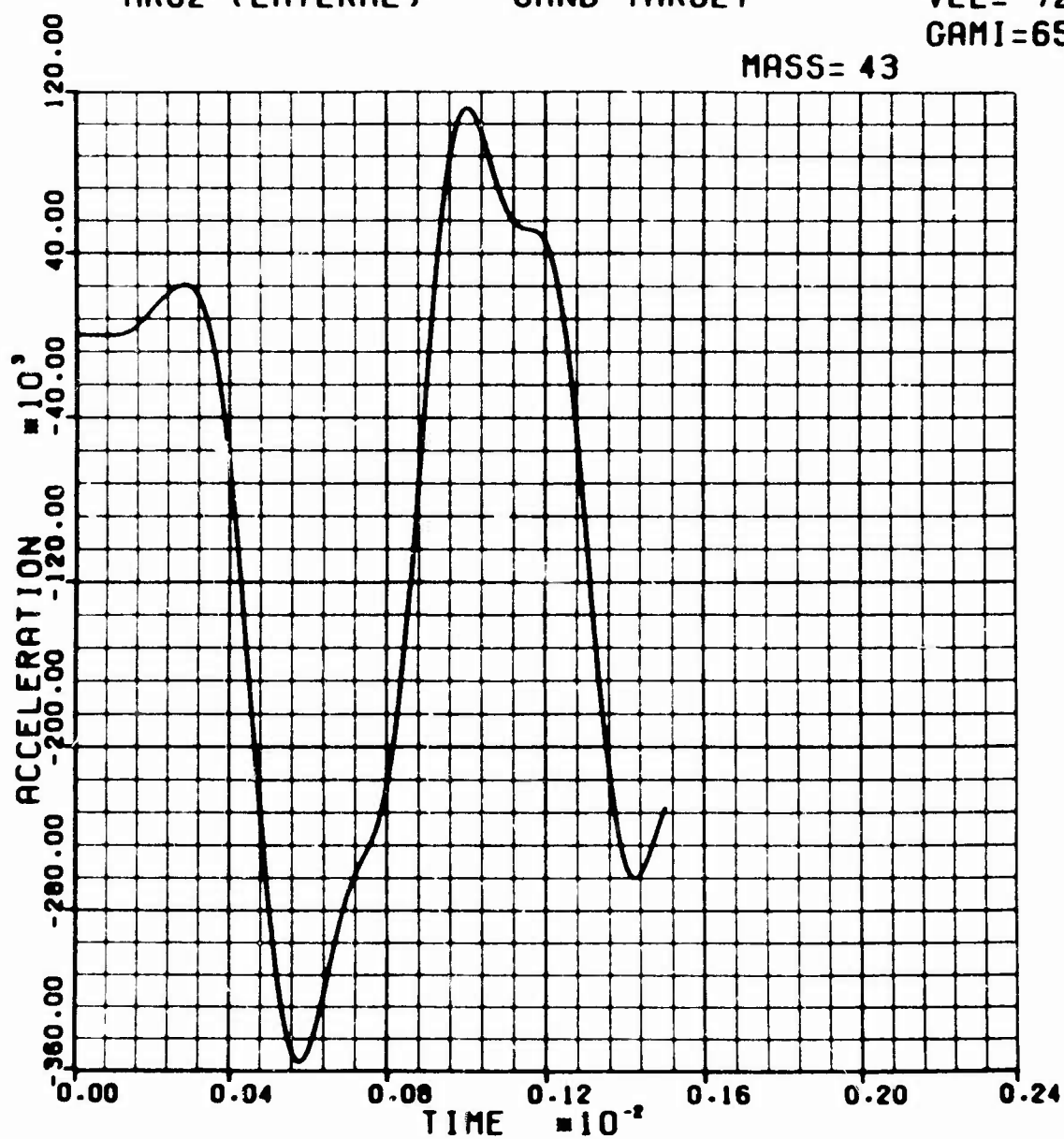
MK82 (LATERAL)

SAND TARGET

VEL= 7200.

GAMI=65.0

MASS= 43



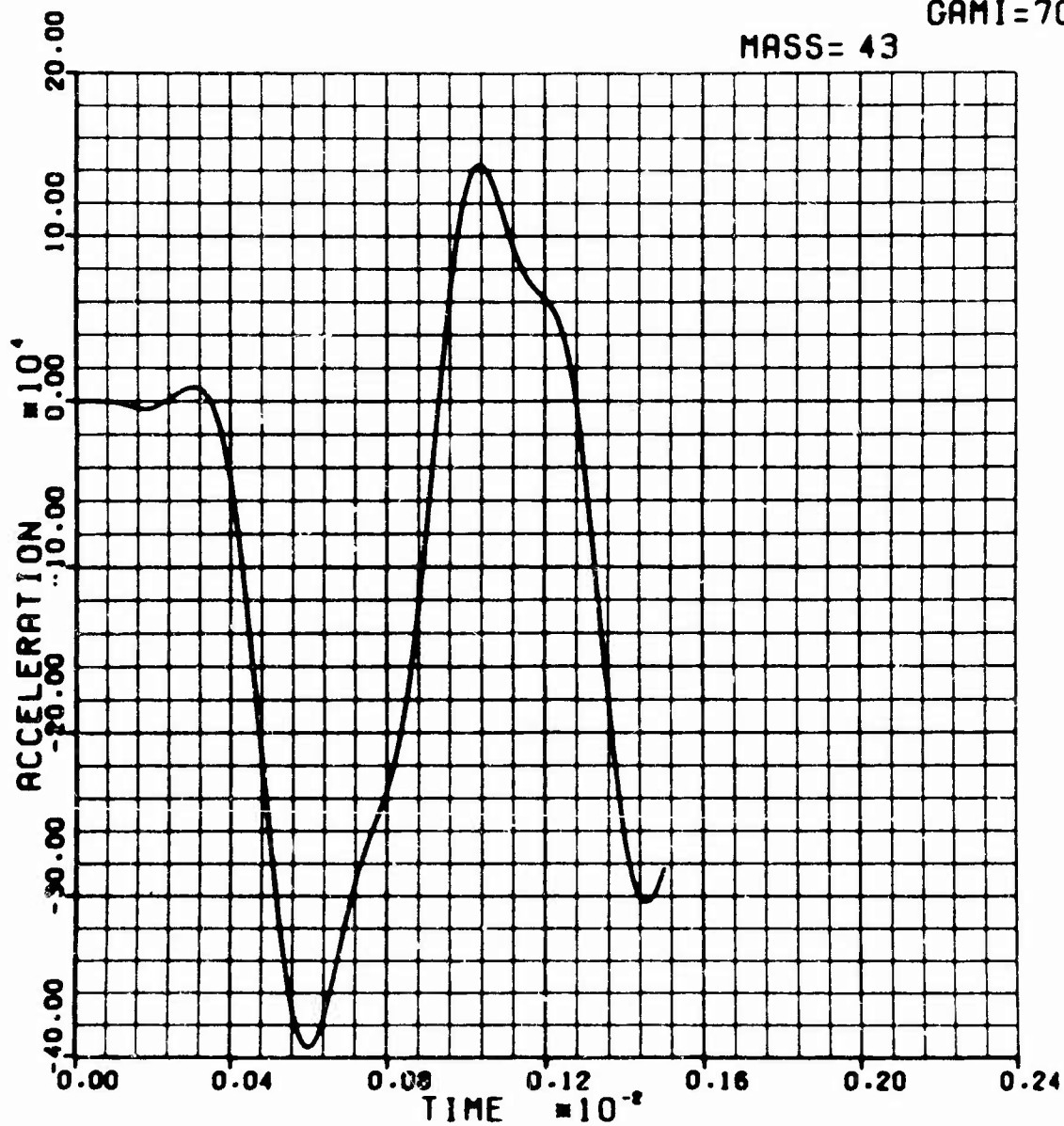
MK82 (LATERAL)

SAND TARGET

VEL= 7200.

GAMI=70.0

MASS= 43



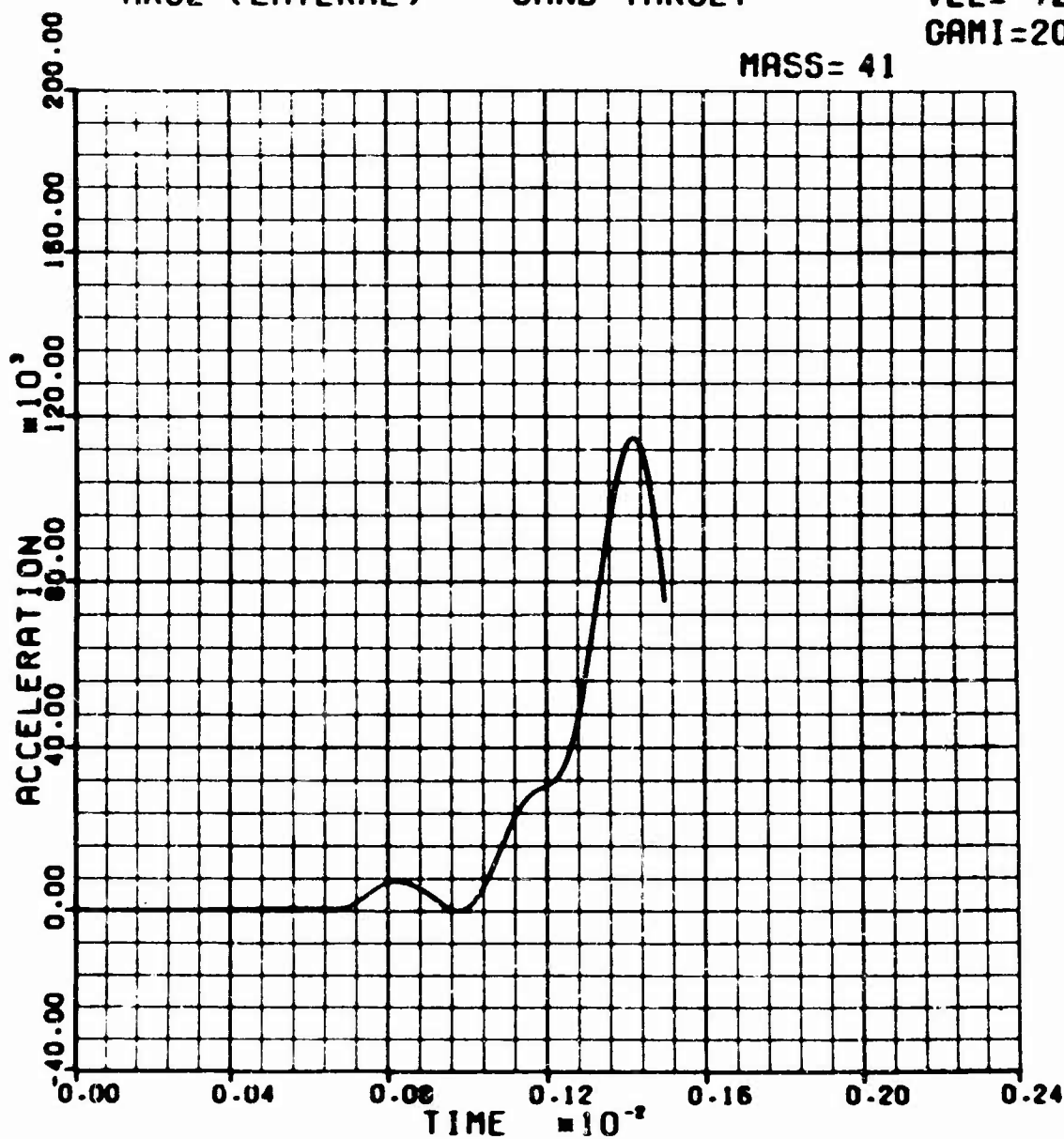
MK82 (LATERAL)

SAND TARGET

VEL= 7200.

GAMI=20.0

MASS= 41



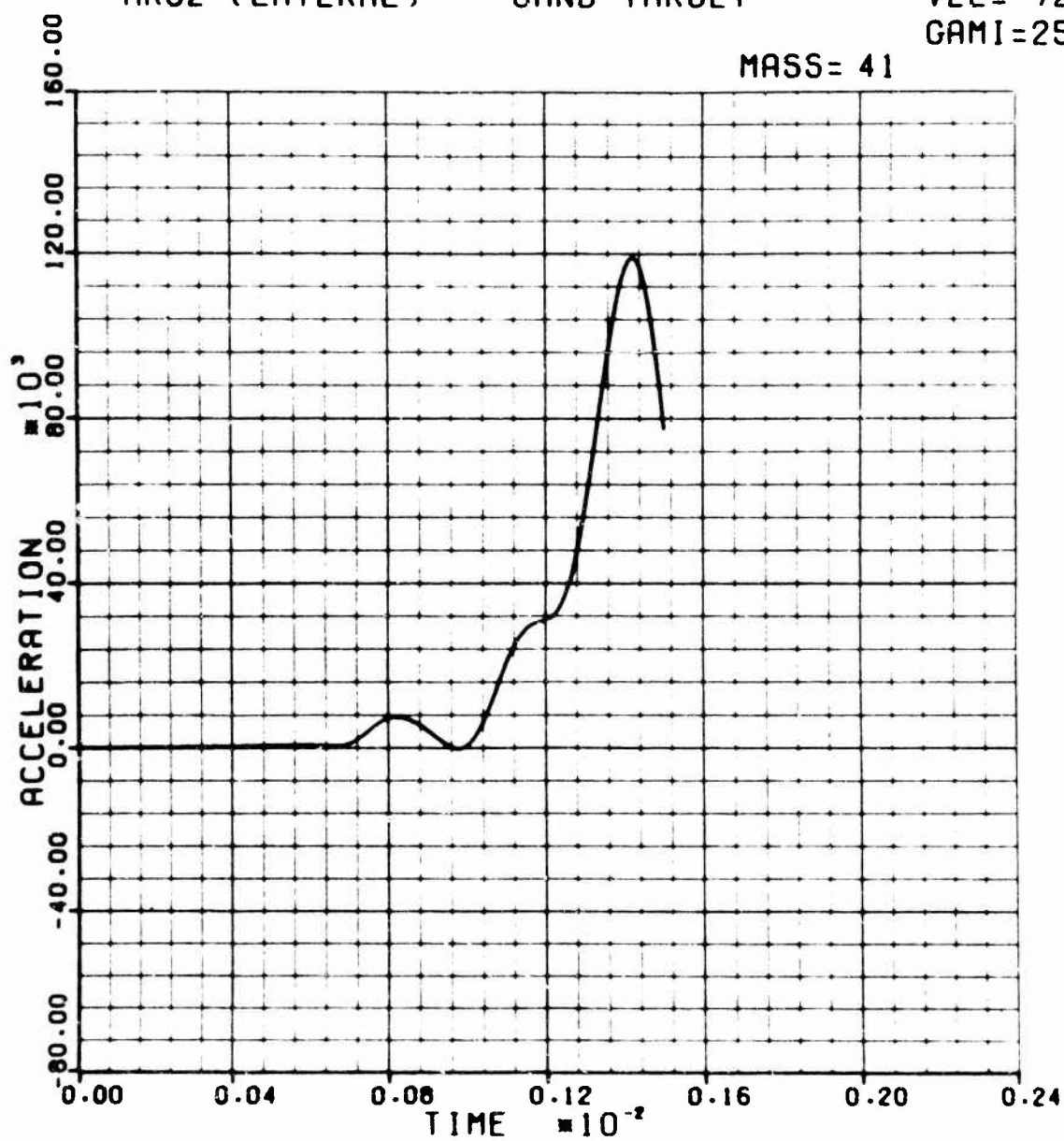
MK82 (LATERAL)

SAND TARGET

VEL = 7200.

GAMI = 25.0

MASS = 41



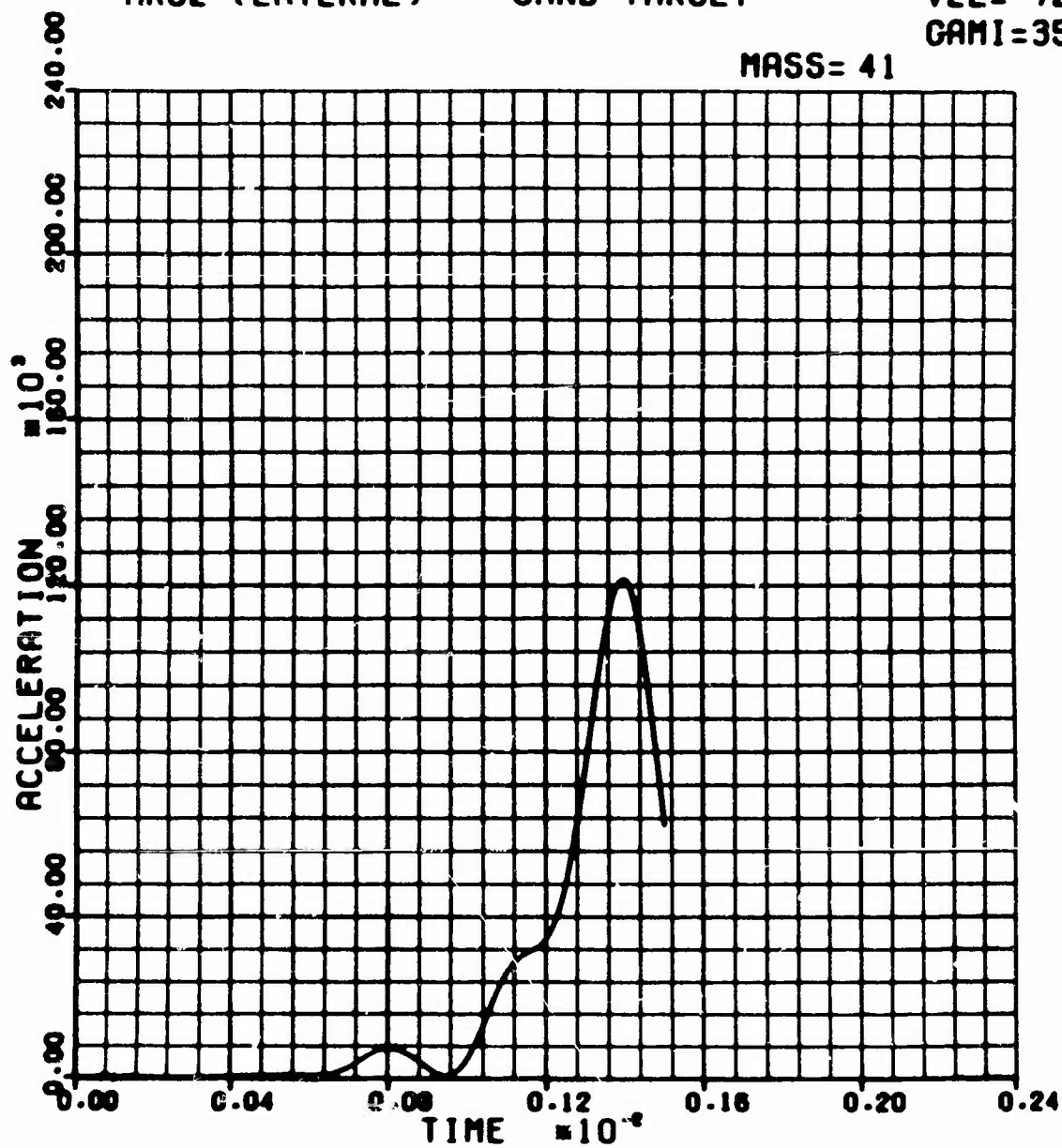
MK82 (LATERAL)

SAND TARGET

VEL= 7200.

GAMI=35.0

MASS= 41



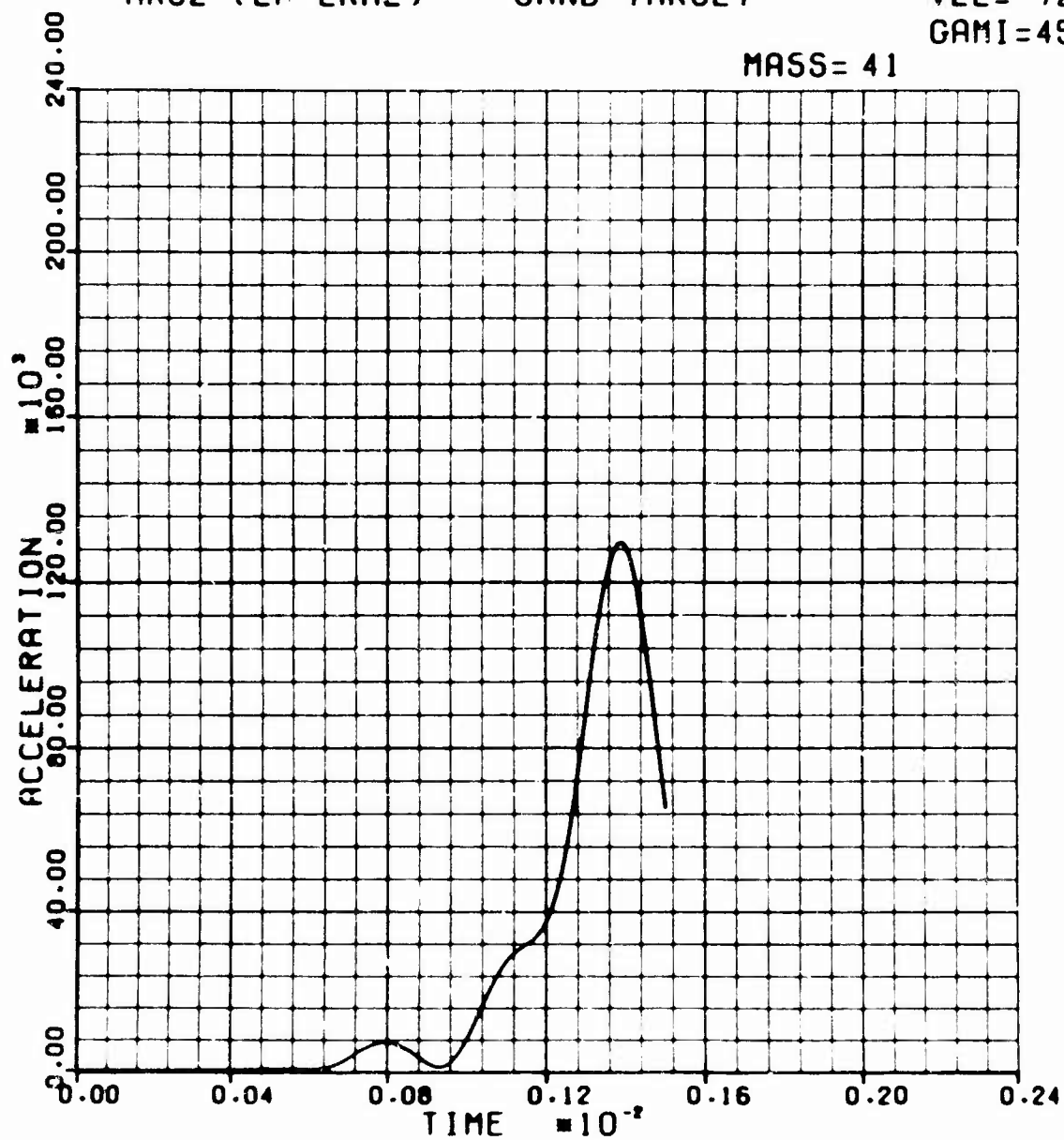
MK82 (LA ERAL)

SAND TARGET

VEL= 7200.

GAMI=45.0

MASS= 41



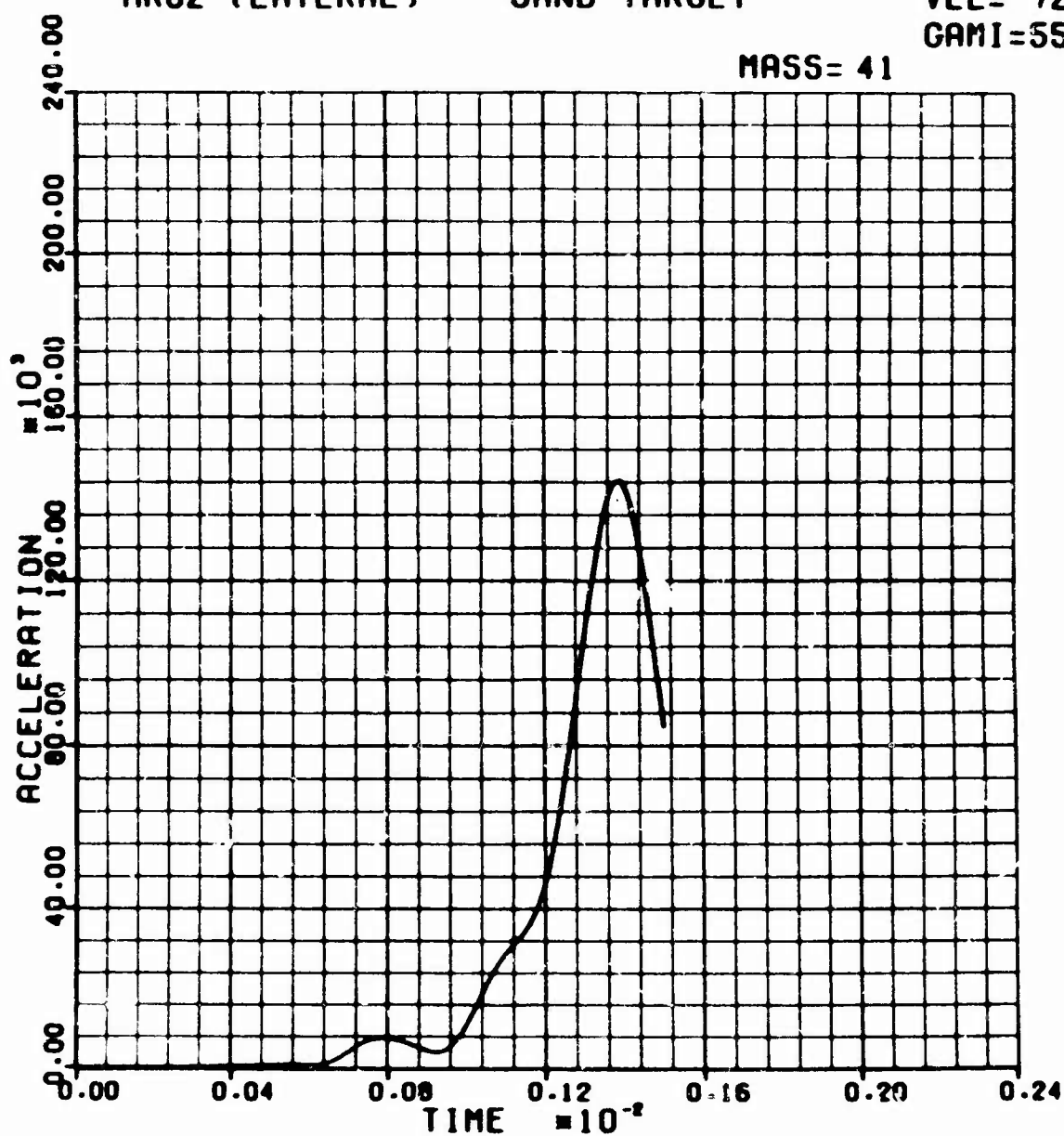
MK82 (LATERAL)

SAND TARGET

VEL= 7200.

GAMI=55.0

MASS= 41



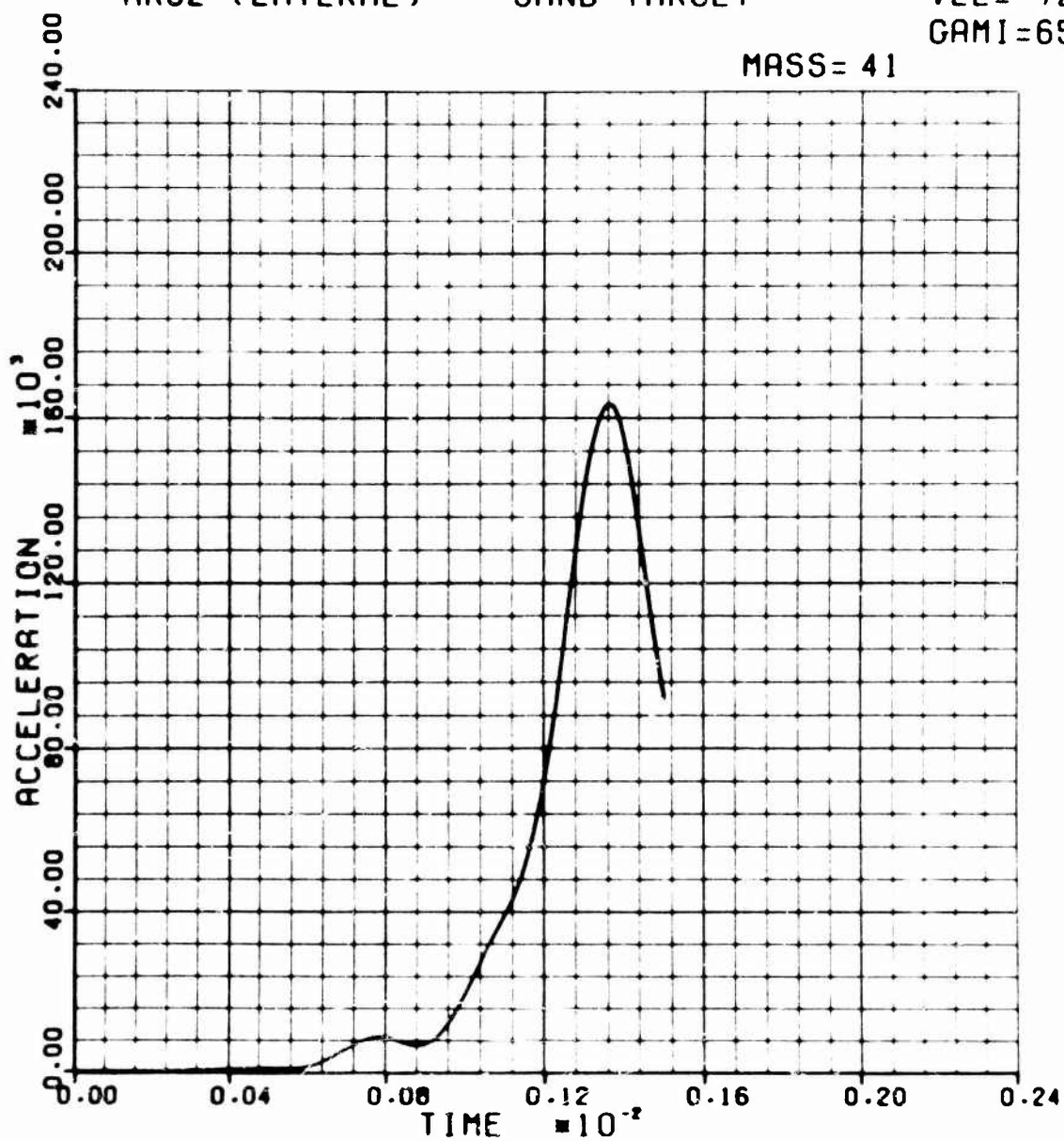
MK82 (LATERAL)

SAND TARGET

VEL= 7200.

GAMI=65.0

MASS= 41



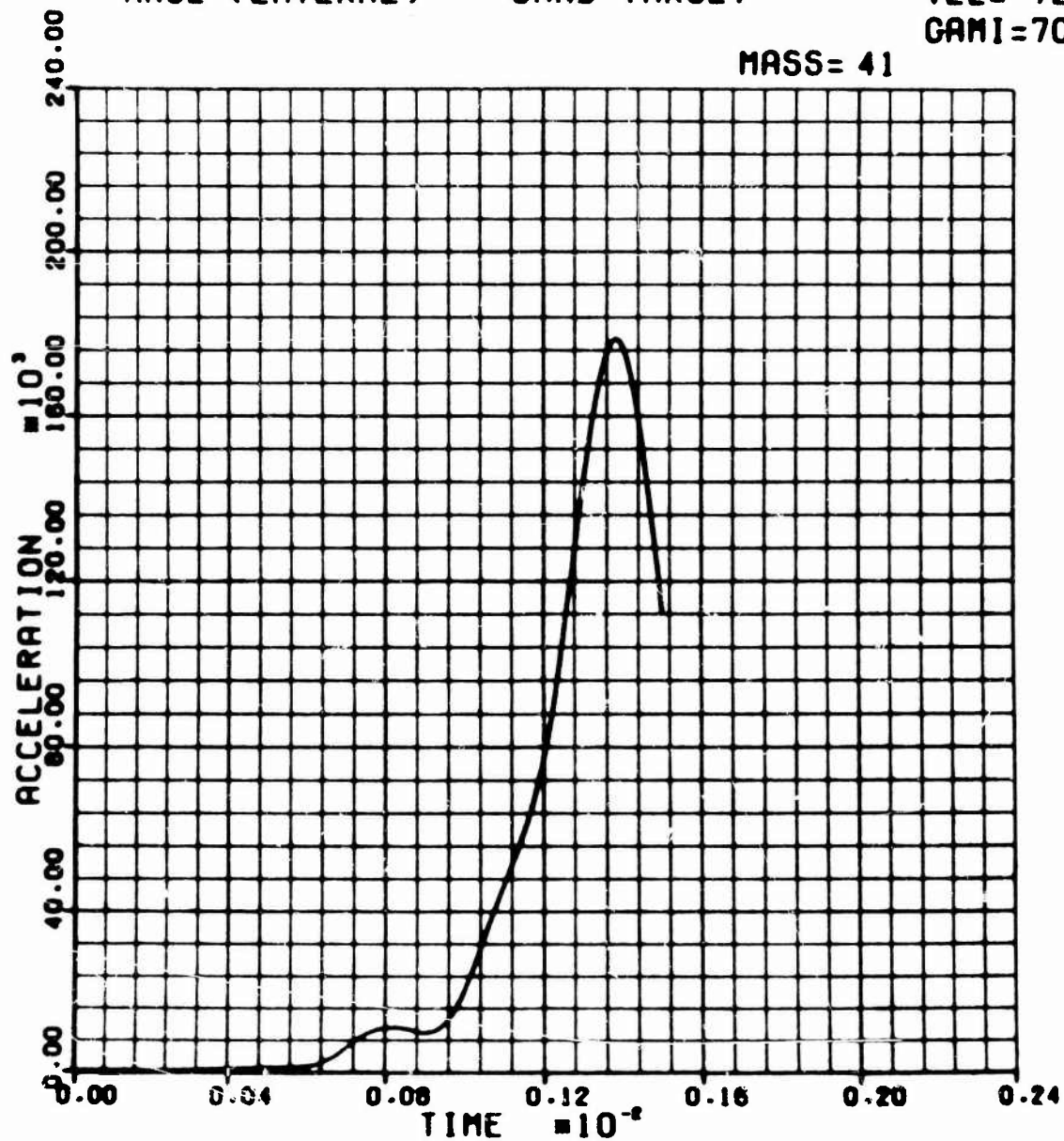
MK82 (LATERAL)

SAND TARGET

VEL= 7200.

GAMI=70.0

MASS= 41



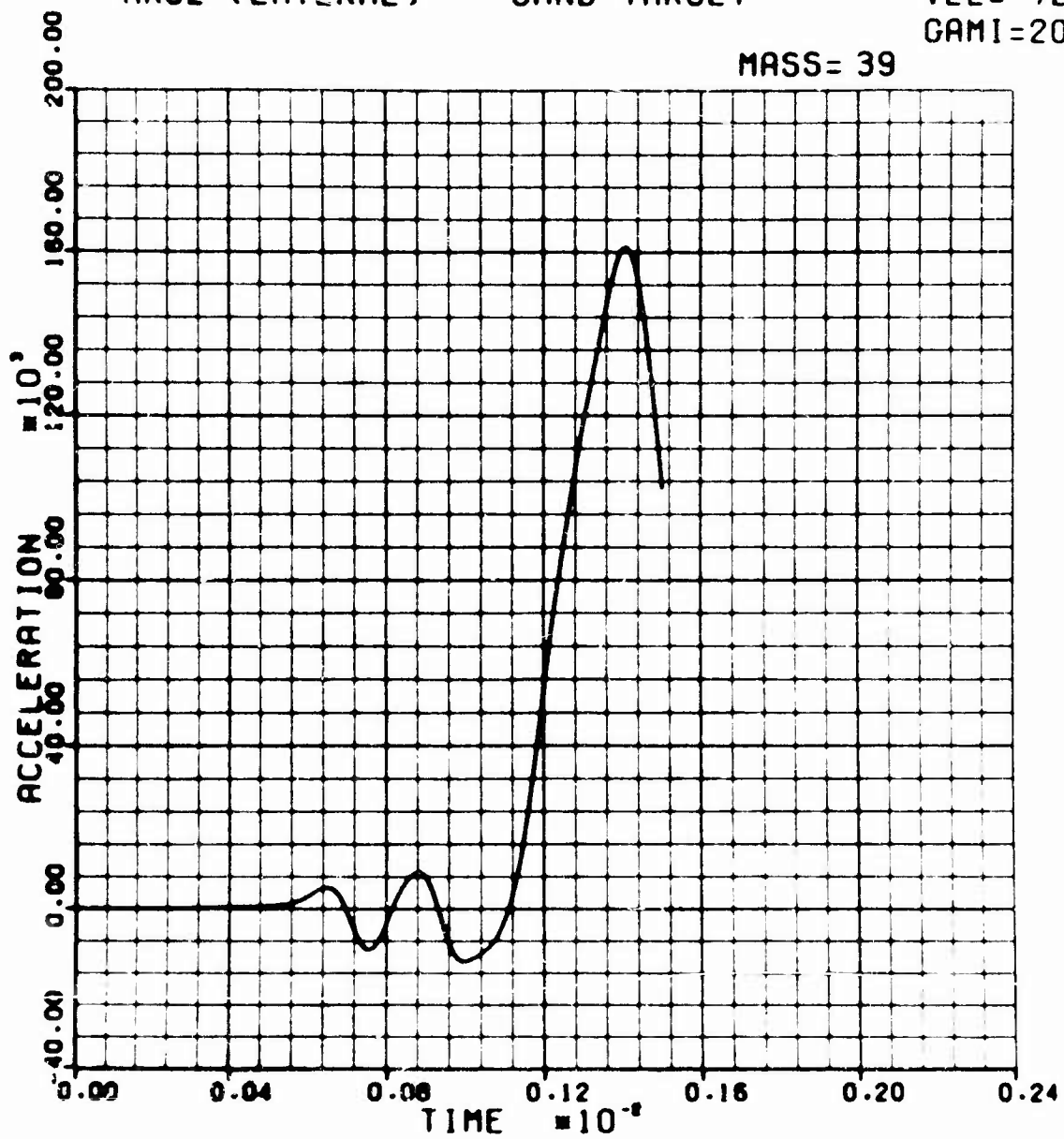
MK82 (LATERAL)

SAND TARGET

VEL= 7200.

GAMI=20.0

MASS= 39



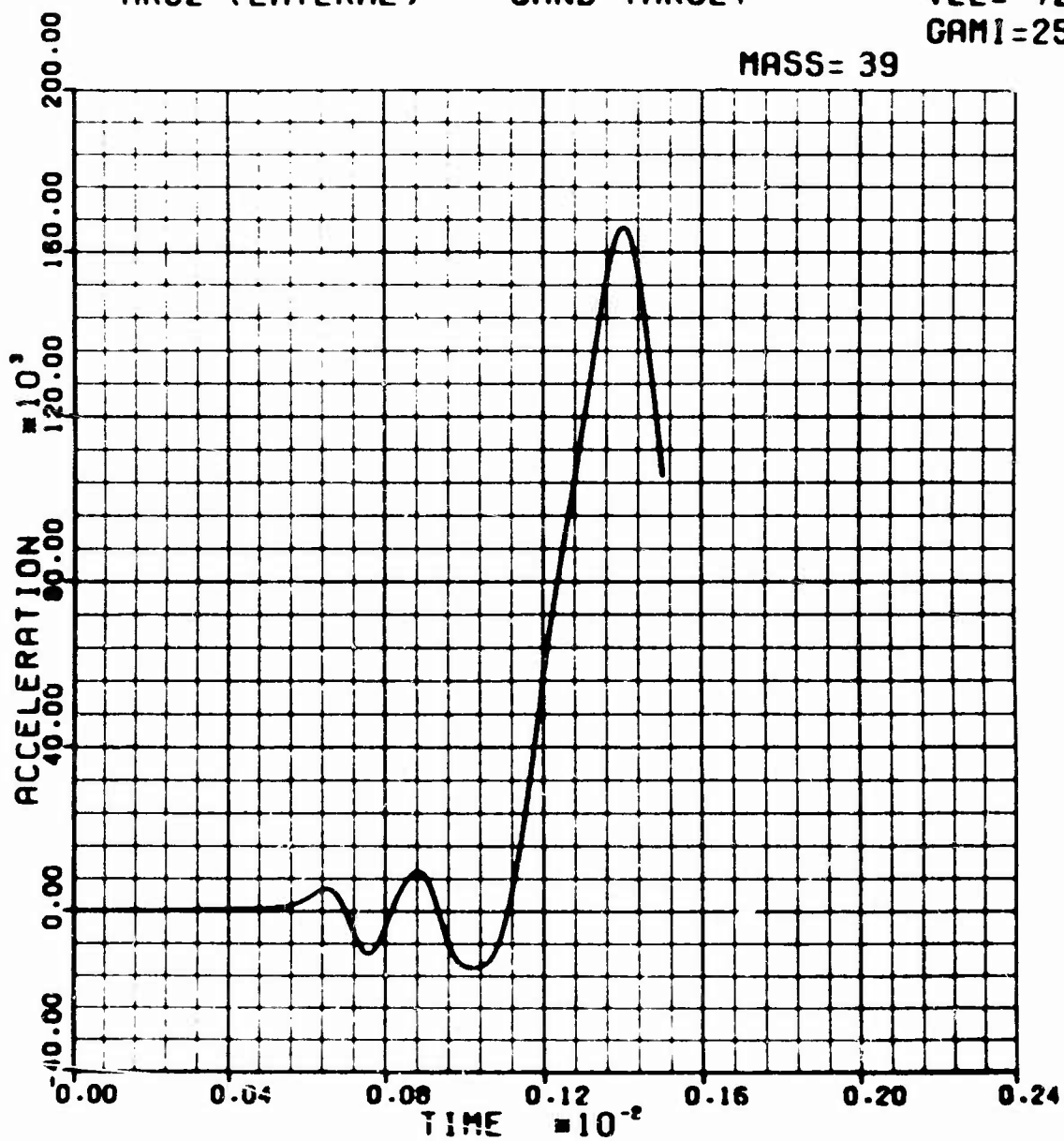
MK82 (LATERAL)

SAND TARGET

VEL= 7200.

GAMI=25.0

MASS= 39



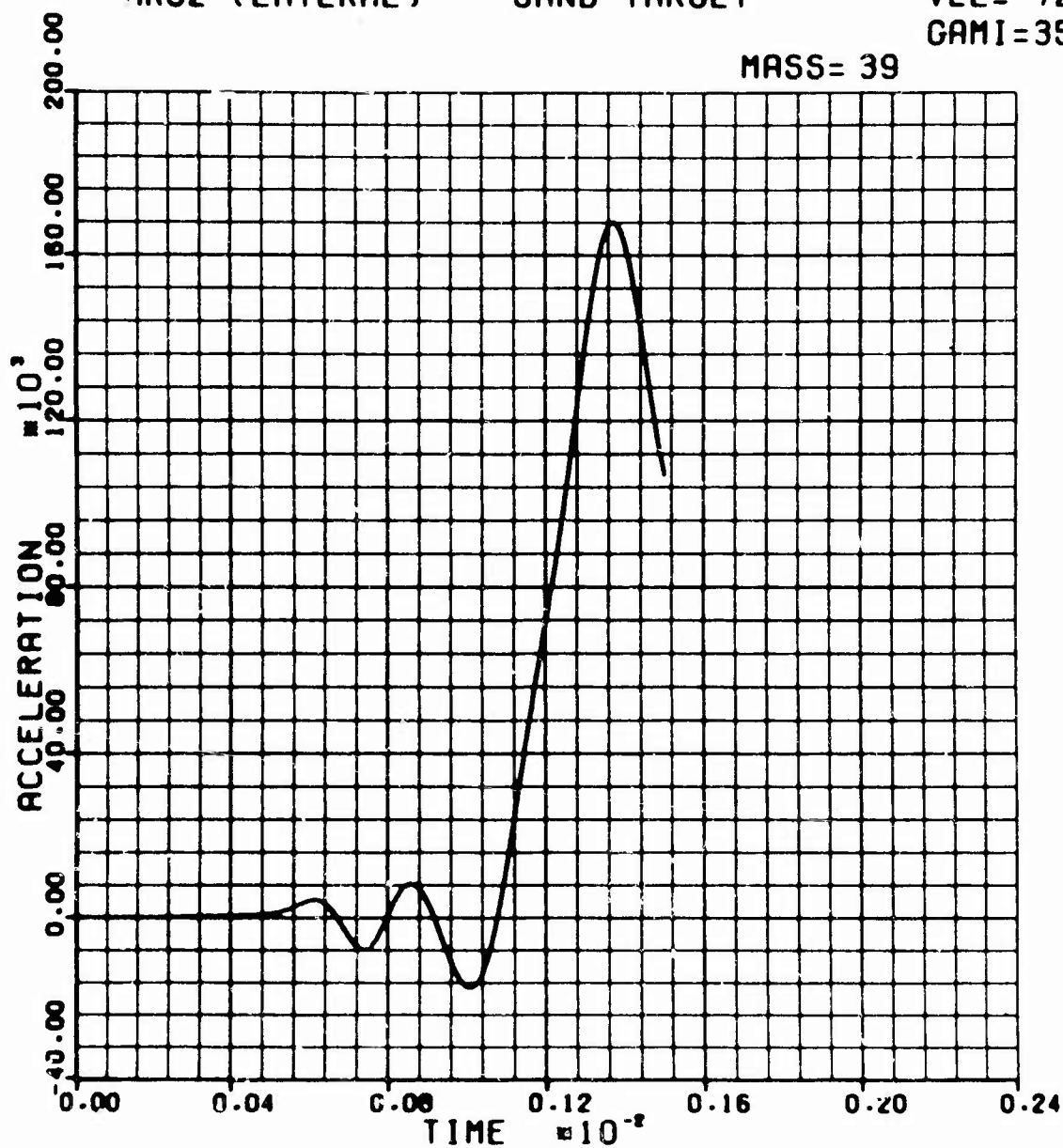
MK82 (LATERAL)

SAND TARGET

VEL= 7200.

GAMI=35.0

MASS= 39



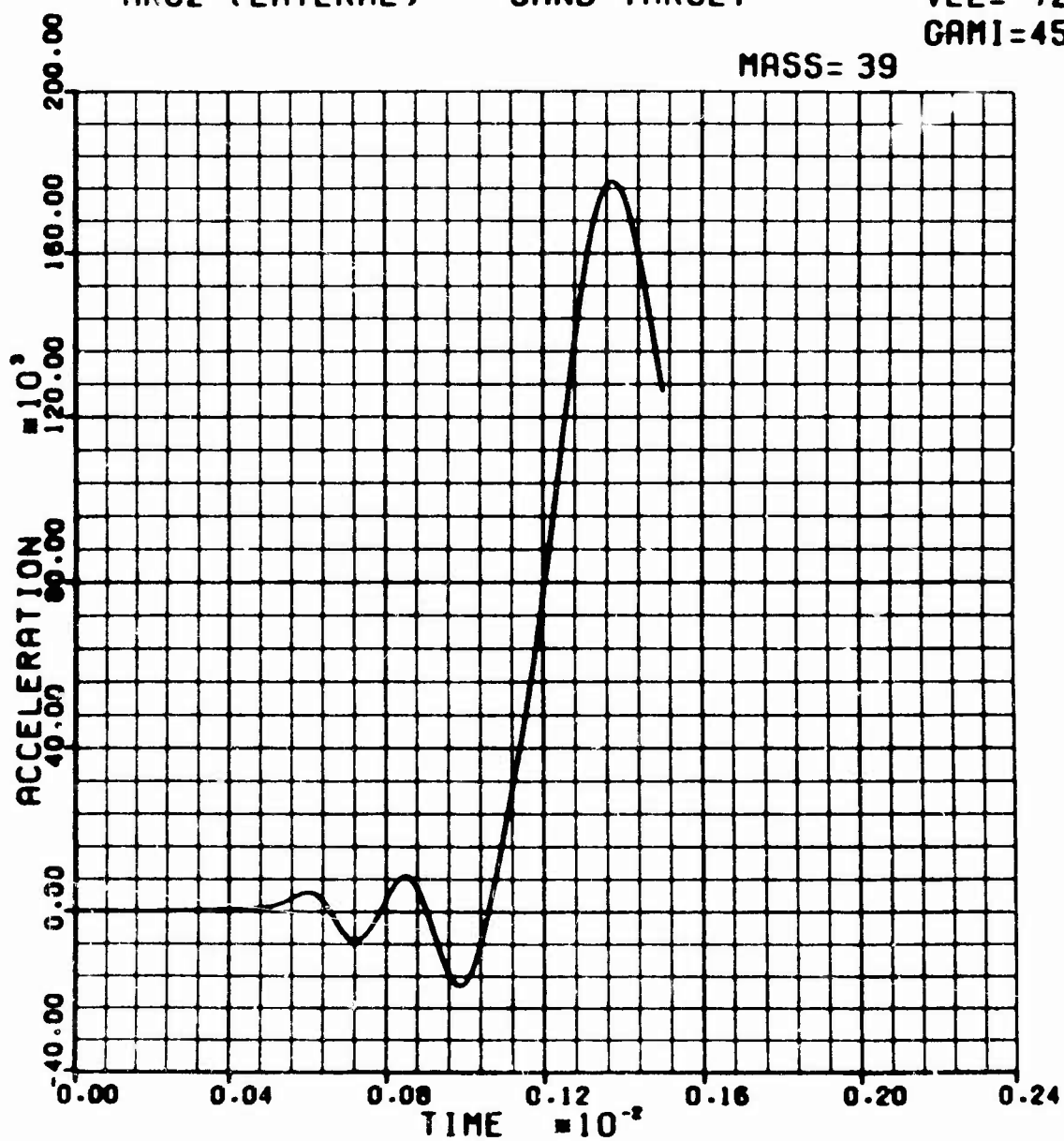
MK82 (LATERAL)

SAND TARGET

VEL= 7200.

GAMI=45.0

MASS= 39

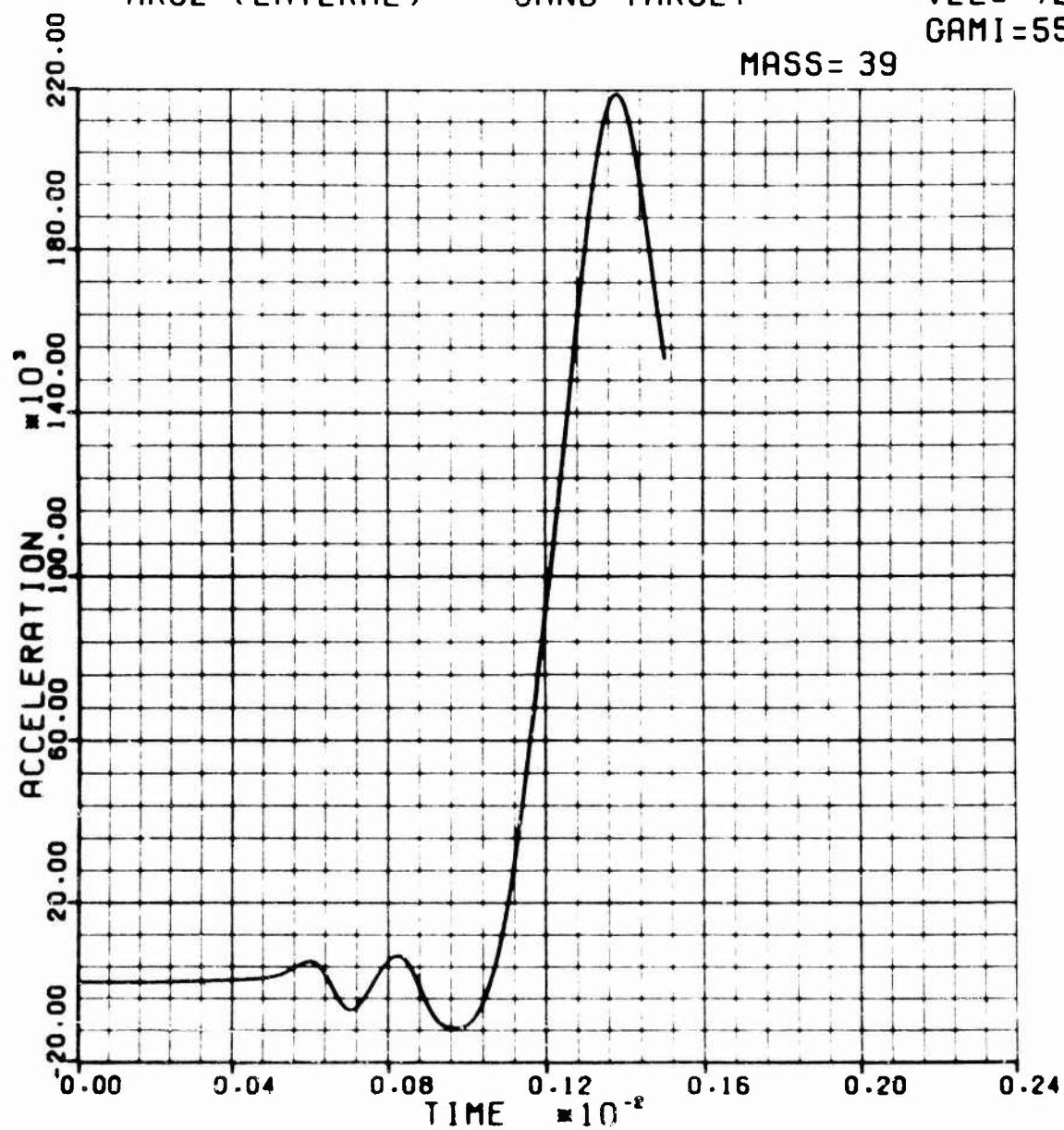


MK82 (LATERAL)

SAND TARGET

VEL= 7200.
GAMI=55.0

MASS= 39



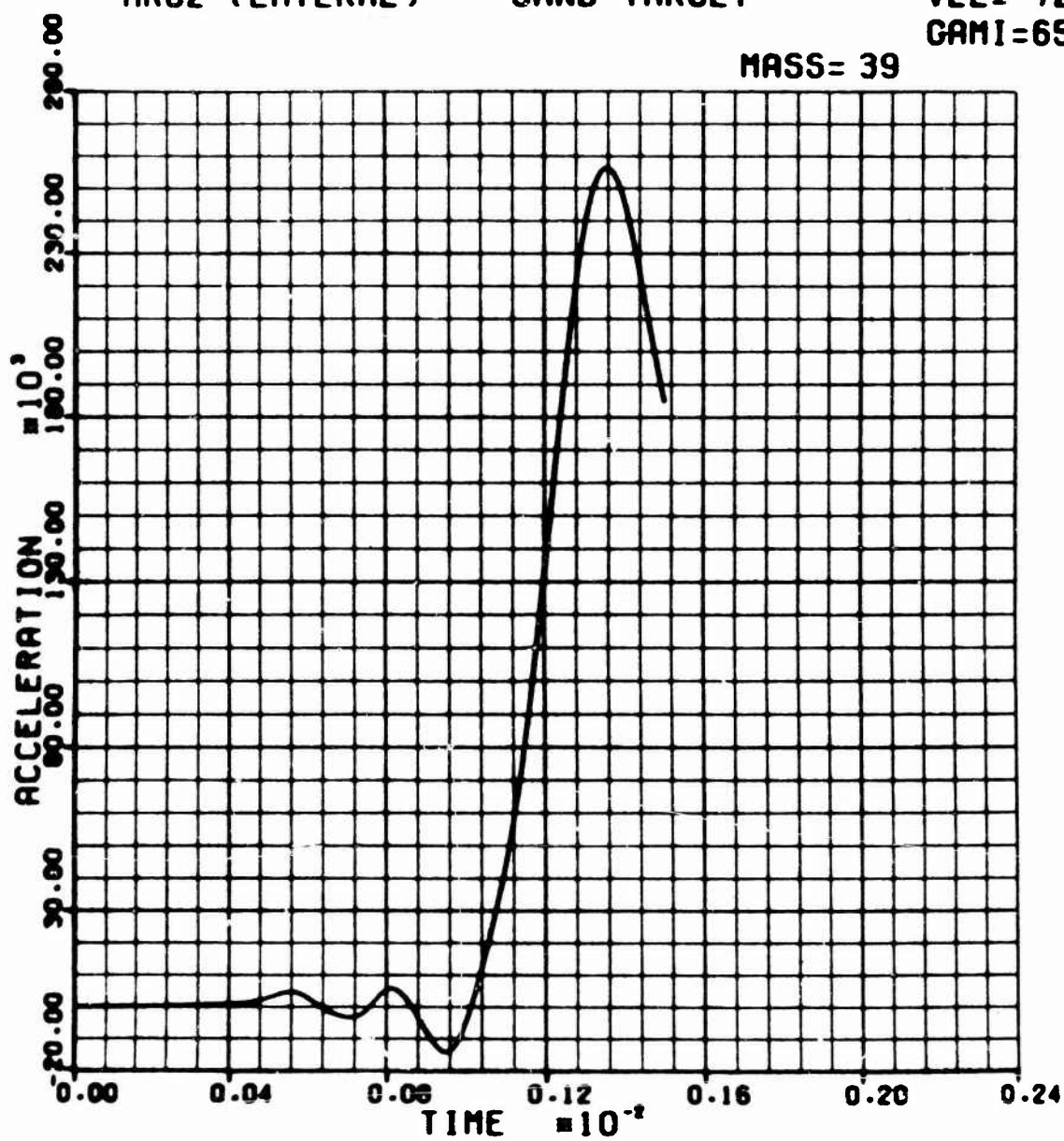
MK82 (LATERAL)

SAND TARGET

VEL= 7200.

GAMI=65.0

MASS= 39



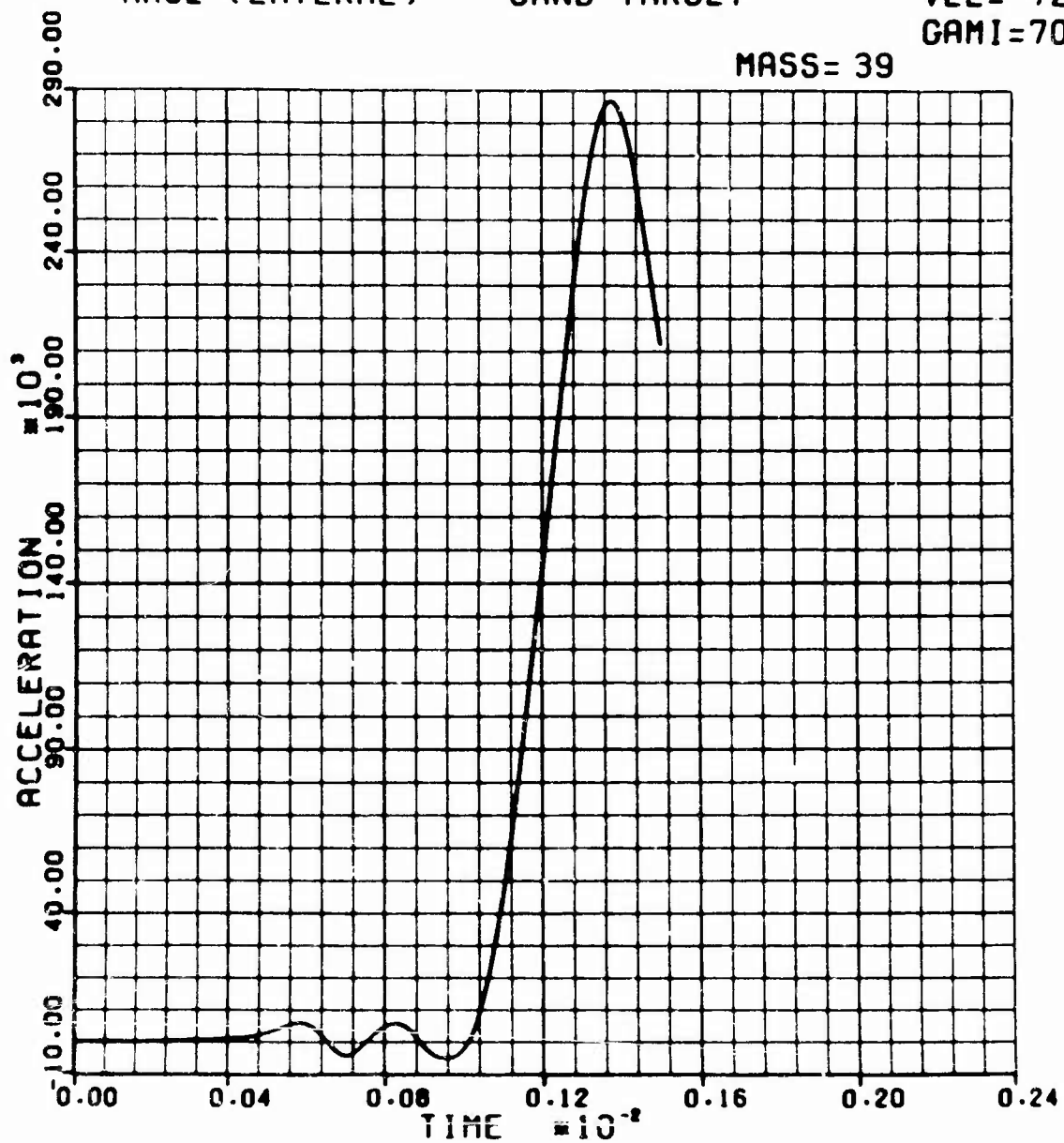
MK82 (LATERAL)

SAND TARGET

VEL= 7200.

GAMI=70.0

MASS= 39



INITIAL DISTRIBUTION

Hq USAF (RDQRM)	2
Hq USAF (SAM1D)	1
Hq USAF (XOXFCM)	1
Hq USAF (RDPA)	1
AFSC (SDMM)	1
ASD (ENYS)	1
AFWL (DOUL)	1
AUL (AUL/LSE-70-239)	1
Redstone Sci Info Ctr (Ch, Doc Sec)	2
USA Aberdeen R&D Ctr (AMXRD-BTL)	2
Frankford Ars (Lib, K2400)	1
Picatinny Ars (SMUPA-TS-T-S)	1
Harry Diamond Lab (AMXDO-DA)	1
USN Ord Lab (Code 730)	2
USNWC (Code 753)	1
DDC	2
CNO (OP-982E)	1
Infrared Info & Anal, Univ of Mich	1
Avco Corp	2
TRADOC/ADTC--DO	1
AFATL/DLOSL	2
AFATL/DL	1
AFATL/DLOU	1
AFATL/DLGZ	1
AFATL/FLJ	1
AFATL/DLW	1
AFATL/DLQ	1

Unclassified

Security Classification		
DOCUMENT CONTROL DATA - R & D		
(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)		
1. ORIGINATING ACTIVITY (Corporate author) Avco Systems Division Avco Corporation 201 Lowell Street, Wilmington, Massachusetts 01887		2a. REPORT SECURITY CLASSIFICATION Unclassified
		2b. GROUP
3. REPORT TITLE DETERMINATION OF IMPACT PARAMETERS		
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Final Report - 15 July 1972 to 15 December 1972		
5. AUTHOR(S) (First name, middle initial, last name) Frank R. Lascher Sol Feldman David Henderson		
6. REPORT DATE January 1973	7a. TOTAL NO. OF PAGES 242	7b. NO. OF REFS
8a. CONTRACT OR GRANT NO. F08635-72-C-0218	8b. ORIGINATOR'S REPORT NUMBER(S) AVSD-0169-73-RR	
9. PROJECT NO. 670D		
c. Task No. 02	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	
4. Work Unit No. 012	AFATL-TR-73-14	
10. DISTRIBUTION STATEMENT DISTRIBUTION LIMITED TO U.S. GOVERNMENT AGENCIES ONLY. THIS REPORT DOCUMENTS TEST AND EVALUATION; DISTRIBUTION LIMITATION APPLIED JANUARY 1973. OTHER REQUESTS FOR THIS DOCUMENT MUST BE REFERRED TO THE AIR FORCE ARMAMENT LABORATORY (DLJF), EGLIN AIR FORCE BASE, FLORIDA 32542.		
11. SUPPLEMENTARY NOTES Available in DDC	12. SPONSORING MILITARY ACTIVITY Air Force Armament Laboratory Air Force Systems Command Eglin Air Force Base, Florida 32542	
13. ABSTRACT This research program was conducted to establish the deceleration environment experienced in the nose and tail fuze wells of the MK82 for bomb impacts into sand targets. The study was conducted for warhead impact velocities of 600, 900, and 1100 ft/sec and impact angles, from the vertical, from 20 to 70 degrees. The contractor's Two-Dimensional Impact and Penetration Computer Program was utilized to establish the time history of the loads applied to the MK82 during the impact and penetration event. This loading environment was then applied to a mathematical structural model of the MK82 to establish the deceleration environments experienced by both fuzes during the penetration event. The results of this analysis indicated that the flexibility characteristics of the warhead have a large influence upon the fuze well deceleration environments and generated deceleration magnification factors as high as 1.8.		

DD FORM 1473
1 NOV 66

Unclassified

Security Classification

Unclassified

Security Classification

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Impact Parameters						
MK82 Mat: Model						
Loading Environments Analysis						
Structural Response Analysis						
155mm Fuze						
MK82 Fuze						
2-Dimensional Impact and Penetration Simulator						

Unclassified

Security Classification