

BENDIX REPORT NO. MM-66-15

FINAL REPORT
DEVELOPMENT OF A MATHEMATICAL ANALYSIS
FOR PREDICTING THE DYNAMIC BEHAVIOR
OF THE APOLLO COMMAND MODULE
DURING EARTH LANDING

NASA CONTRACT NAS 9-4511
WITH BENDIX PRODUCTS AEROSPACE DIVISION

PREPARED UNDER DIRECTION OF
R. J. BLACK

MAY 1966

BY
THE BENDIX CORPORATION
BENDIX PRODUCTS AEROSPACE DIVISION
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SOUTH BEND, INDIANA 46620

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FOREWORD

This document constitutes the final report and computer program documentation for the work accomplished between July 7, 1965 and May 16, 1966 by the Bendix Products Aerospace Division under NASA contract NAS 9-4511 entitled "Development of a Mathematical Analysis for Predicting the Dynamic Behavior of the APOLLO Command Module during Earth Landing". Technical Director for this effort was R. J. Black. R. A. Price was Project Administrative Engineer, and R. E. Schmidt was Administrative Coordinator between NASA/MSC and Bendix.

In addition to the Technical Director, the following personnel contributed significantly to the preparation of this report: Mr. W. D. Chambers, Dr. J. C. Gibson, Dr. F. Kobayashi (University of Notre Dame), Mr. D. A. Kobb, Mr. F. P. Mackrill, Mr. H. K. Winters, and Mr. J. Y. Woo.

The assistance throughout the program of Mr. D. L. Brown, NASA/MSC Technical Representative, is acknowledged. His critical review of various aspects of the program was very helpful to the progress of the study.

TABLE OF CONTENTS

<u>Section</u>	<u>Page</u>
FOREWORD	i/ii
I INTRODUCTION	1-1
II COMPUTER PROGRAM	2-1
2.1 Purpose	2-1
2.2 Usage Instructions	2-1
2.2.1 Input Data Format	2-2
2.2.2 Program Options	2-4
2.2.3 Run Stops	2-6
2.2.4 Stacked Run Provisions	2-6
Subroutine (01) Main Program APOLLO	2-21
Subroutine INPUT (02).	2-25
Subroutine INIT (03)	2-37
Subroutine HSAREA (04).	2-53
Subroutine CAPAR (05)	2-57
Subroutine MASTER (06)	2-59
Subroutine DPFAD (07)	2-63
Subroutine ACCEL (08)	2-65
Subroutine GEOM (09)	2-75
Subroutine STROKE (10).	2-77
Subroutine HSSOIL (11)	2-85
Subroutine CASOIL (12)	2-95
Subroutine OUTPUT (13)	2-99
Subroutine Main Program RECT (14)	2-107
Subroutine INTEG (15).	2-111
Subroutine (16)	2-115
Subroutine Bumper (17)	2-119
Subroutine PARA (18)	2-123
TRIAL RUN	2-125
III DERIVATION OF EQUATIONS OF MOTION	3-1
3.1 Introduction	3-1
3.2 Coordinate Systems and Kinematical Transformatives	3-1

TABLE OF CONTENTS (Continued)

<u>Section</u>	<u>Page</u>
3.3 Equation of Motion	3-7
3.3.1 Translational Motion of Capsule	3-7
3.3.2 Translational Motion of Couch System	3-9
3.3.3 Translational Motion of Heat Shield	3-10
3.3.4 Angular Motion of Capsule	3-11
3.3.5 Angular Motion of Couch System	3-13
3.3.6 Angular Motion of Heat Shield System	3-15
3.4 Shock Absorber Forces	3-17
3.4.1 Shock Strut Forces	3-17
3.4.2 Bumper Forces Couch Y-Y Struts	3-24
3.5 Ground Contact Forces	3-27
3.5.1 Heat Shield Ground Contact Forces	3-27
3.5.2 Forces Due to Capsule/Soil Contact	3-53
3.6 Parachute Force	3-65
3.7 Retrorocket Forces	3-67
3.8 Stability Angle Calculation	3-69
3.9 Energy Balance Calculation	3-73
 IV ANALYSIS OF SOIL INTERACTION	 4-1
4.1 Soil Identification Tests	4-1
4.1.1 The Triaxial Tests of Soil Samples	4-2
4.1.2 Penetrometer	4-2
4.1.3 Atterburg Liquid and Plastic Limits Indices	4-3
4.1.4 Specific Gravity Tests	4-3
4.1.5 Proctor Compaction Tests	4-3
4.1.6 Tests to Determine the Elastic Modulus of Soils	4-3
4.2 Soil Bed Preparation	4-4
4.3 Summary of Soil Properties	4-6
4.3.1 Silica Sand	4-6
4.3.2 Air-Floated Clay	4-7
4.4 Oblique Impact Soil Tester	4-7
4.5 Instrumentation of the Oblique Impact Soil Tester	4-9
4.6 Test Procedure	4-10
4.6.1 Static Tests	4-10
4.6.2 Dynamic Impact Tests	4-10
4.7 Test Results	4-11
4.8 Analysis of the Test Results	4-15
 V MODEL TEST PROGRAM AND COMPARISON OF EXPERIMENTAL AND ANALYTICAL RESULTS	 5-1
5.1 General Description	5-1
5.2 Body and Heat Shield	5-2
5.3 Shock Struts	5-3
5.4 Crushable Skin	5-3

TABLE OF CONTENTS (Continued)

<u>Section</u>		<u>Page</u>
5.5	Instrumentation	5-4
5.6	Drop Test Equipment	5-6
5.7	Comparison of Experimental and Analytical Results	5-8

LIST OF ILLUSTRATIONS

<u>Figure</u>	<u>Title</u>	<u>Page</u>
2-1	Program Flow Diagram	2-8
3-1	Eulerian Body Coordinate Systems	3-3
3-2	Space Fixed Coordinate System	3-4
3-3	Nomenclature Associated with Moments Action on Capsule System	3-12
3-4	Nomenclature Associated with Moments Acting on Capsule System	3-14
3-5	Nomenclature Associated with Moments Acting on Heat Shield System	3-16
4-1	Triaxial Soil Test Equipment	4-24
4-2	Schematic of Triaxial Test Cell	4-25
4-3	Density, Moisture and Compaction Relationship	4-26
4-4	Density, Moisture and Compaction Relationship	4-27
4-5	Compaction Test	4-28
4-6	Triaxial Compression Test	4-29
4-7	Grain Size Distribution	4-30
4-8	Triaxial Compression Test	4-31
4-9	Oblique Impact Soil Tester	4-32
4-10	Oblique Impact Soil Tester	4-33
4-11	Instrumented Footpad Schematic	4-34
4-12	Static Pressure Test	4-35
4-13	Static Penetration Test	4-36
4-14	Wave Formation of Static Penetration	4-37
4-15	Vertical Force Versus Time	4-38
4-16	Vertical Force Versus Time	4-39
4-17	Vertical Force Versus Time on Sand	4-40
4-18	Vertical Force Versus Time on Sand	4-41
4-19	Vertical Force Versus Time on Sand	4-42
4-20	Vertical Force Versus Time Oblique Impact Test	4-43
4-21	Horizontal Force Versus Time on Sand	4-44
4-22	Horizontal Force Versus Time on Sand	4-45
4-23	Horizontal Force Versus Time on Sand	4-46
4-24	Horizontal Force Versus Time on Sand	4-47
4-25	Displacement Versus Time on Sand	4-48
4-26	Displacement Versus Time on Sand	4-49

LIST OF ILLUSTRATIONS (Continued)

Figure	Title	Page
4-27	Displacement Versus Time on Sand	4-50
4-28	Displacement Versus Time on Sand	4-51
4-29	Displacement Versus Time on Sand	4-52
4-30	Vertical Force Versus Time on Clay	4-53
4-31	Vertical Force Versus Time on Clay	4-54
4-32	Vertical Force Versus Time on Clay	4-55
4-33	Vertical Force Versus Time on Clay	4-56
4-34	Vertical Force Versus Time on Clay	4-57
4-35	Vertical Force Versus Time on Soft Clay	4-58
4-36	Vertical Force Versus Time	4-59
4-37	Horizontal Force Versus Time on Clay	4-60
4-38	Horizontal Force Versus Time on Clay	4-61
4-39	Horizontal Force Versus Time on Clay	4-62
4-40	Horizontal Force Versus Time on Clay	4-63
4-41	Displacement Versus Time on Clay	4-64
4-42	Displacement Versus Time on Clay	4-65
4-43	Displacement Versus Time on Clay	4-66
4-44	Displacement Versus Time on Clay	4-67
4-45	Displacement Versus Time on Clay	4-68
4-46	Displacement Versus Time on Clay (Soft)	4-69
4-47	Vertical Force Versus Time	4-70
4-48	Penetration Versus Time	4-71
4-49	Vertical Force Versus Time	4-72
4-50	Vertical Force Versus Time	4-73
4-51	Vertical Force Versus Time	4-74
4-52	Vertical Force Versus Time	4-75
4-52A	Dynamic Impact on Clay	4-76
4-52B	Soil Wedge Beneath Footpad after Impact Test	4-76
4-53	Mathematical Model of Footpad and Soil Relationship	4-77
4-54	Static Penetration Test Sand	4-78
4-55	$f(\gamma)$ Versus γ for Sand	4-79
4-56	Static Penetration Test Clay	4-80
4-57	$f(\gamma)$ Versus γ for Clay	4-81
4-58	General Interpretation of Force Versus Clay Relationship	4-82
4-59	Wedge Velocity Versus Time Relationship	4-83
4-60	Dynamic Force Versus V^2 Sand	4-84
4-61	Dynamic Force Versus V^2 Sand	4-85
4-62	Dynamic Force Versus V^2 Sand	4-86
4-63	Dynamic Force Versus V^2 Sand	4-87
4-64	Dynamic Force Versus V^2 Sand	4-88
4-65	Dynamic Force Versus V^2 for Soft Clay	4-89
4-66	Dynamic Force Versus V^2 for Clay	4-90
4-67	Dynamic Force Versus V^2 for Clay	4-91
4-68	Dynamic Force Versus V^2 for Clay	4-92
4-69	Dynamic Force Versus V^2 for Clay	4-93

LIST OF ILLUSTRATIONS (Continued)

<u>Figure</u>	<u>Title</u>	<u>Page</u>
4-70	Dynamic Force Versus V^2 for Clay	4-94
4-71	$K\phi_c$ Versus γ for Sand Density 109 lb./cu. ft.	4-95
4-72	$K\phi_c$ Versus γ for Sand Density 117 lb./cu. ft.	4-96
4-73	Relationship of μ to γ , Time and δ	4-97
5-1	Salt Mandrel	5-10
5-2	Early Stage of Winding	5-10
5-3	Final Stage of Winding	5-10
5-4	Wound Model Form	5-11
5-5	Rough Model Forms Ready for Machining	5-11
5-6	APOLLO Shock Strut Showing Friction Device and Stroke Measuring Mechanism	5-12
5-7	Crush Versus Load Test Curve for APOLLO Crushable Skin	5-13
5-8	Wiper Assembly for Stroke Mechanism	5-14
5-9	Accelerometer Locations on APOLLO Model Body	5-15
5-10	Accelerometer Locations on APOLLO Model Couch	5-16
5-11	Disassembled APOLLO Model	5-17
5-12	APOLLO Model Showing Internal Parts	5-18
5-13	Assembled APOLLO Model Without Crushable Skin	5-19
5-14	APOLLO Model	5-20
5-15	Drop Test Soil Pit for APOLLO Test Program	5-21
5-16	Method of Marking Contact Area on Hard Surface Drop	5-21
5-17	Marked Contact Area on Heat Shield for a Hard Surface Drop.	5-22
5-18	Outline of Contact Area on Heat Shield for a Soil Drop	5-22
5-19	Model Impact Clay Soil	5-23
5-20	Imprint of Model Heat Shield in Clay after Drop	5-23
5-21	Assembly Drawing Showing Shock Strut Locations	5-24
5-22	Drop 1 AR	5-25
5-23	Drop 7 A	5-26
5-24	Instrumentation Used on APOLLO Model Drop Tests	5-27
5-25	Run No. 1 Accelerometer - G	5-28
5-26	Run No. 1 Accelerometer - F	5-29
5-27	Comparison of Computer and Experimental Capsule Accelerations of APOLLO Command Module Test Module	5-30
5-28	Comparison of Computer and Experimental Capsule Accelerations of APOLLO Command Module Test Model	5-31
5-29	Comparison of Computer and Experimental Capsule Accelerations of APOLLO Command Module Test Model	5-32
5-30	Comparison of Computer and Experimental Capsule Accelerations of APOLLO Command Module Test Model	5-33
5-31	Comparison of Computer and Experimental Couch Acceleration of APOLLO Command Module Test Model - Body Fixed Vertical Accelerometer (X) of Couch Center of Gravity	5-34

LIST OF ILLUSTRATIONS (Continued)

<u>Figure</u>	<u>Title</u>	<u>Page</u>
5-32	Run No. 2 Accelerometer - F	5-35
5-33	Run No. 2 Accelerometer - G	5-36
5-34	Run No. 3 Accelerometer - F	5-37
5-35	Run No. 3 Accelerometer - G	5-38
5-36	Run No. 4 Accelerometer - F	5-39
5-37	Run No. 4 Accelerometer - G	5-40
5-38	Run No. 5 Accelerometer - F	5-41
5-39	Run No. 5 Accelerometer - G	5-42
5-40	Run No. 6 Accelerometer - F	5-43
5-41	Run No. 6 Accelerometer - G	5-44
5-42	Run No. 7A Accelerometer - F & G	5-45
5-43	Run No. 8 Accelerometer - F	5-46
5-44	Run No. 8 Accelerometer - G	5-47
5-45	Run No. 8 Accelerometer - M	5-48
5-46	Run No. 8 Accelerometer - J	5-49
5-47	Run No. 9 Accelerometer - F	5-50
5-48	Run No. 9 Accelerometer - G	5-51
5-49	Run No. 10 Accelerometer - F	5-52
5-50	Run No. 10 Accelerometer - C	5-53
5-51	Run No. 10 Accelerometer - G	5-54
5-52	Run No. 11 Accelerometer - G	5-55
5-53	Run No. 11 Accelerometer - F	5-56
5-54	Run No. 11R Accelerometer - G	5-57
5-55	Run No. 11R Accelerometer - F	5-58
5-56	Run No. 12 Accelerometer - G	5-59
5-57	Run No. 12 Accelerometer - F	5-60
5-58	Run No. 12 Accelerometer - M	5-61
5-59	Run No. 12 Accelerometer - C	5-62

LIST OF TABLES

<u>Table</u>	<u>Title</u>	<u>Page</u>
2-1	Program Variables	2-9
2-2	Input Data Card Format	2-17

SECTION I

INTRODUCTION

The following report describes the development and features of a computerized mathematical analysis of the Apollo Command Module for Earth Landing Studies. The computer program is designed to allow study of a wide variety of shock attenuation systems of the astronaut's couch and the capsule proper. Basically, a three-mass approach is used which allows the study of systems involving a shock-mounted, deployed heat shield. Change of an input "flag" and adjustment of input data allows the study of a non-deployed heat shield system as well. The elasto-plastic characteristics of the heat shield and capsule surface are included in the analysis. General three-dimensional landings on arbitrarily shaped surfaces can be covered. Hard surface and earth soil landings can be treated. A wedge theory of soil elasto-plastic deformation is used to define the reaction force between the crushable surface of the module and the deformed soil surface. The soil is dealt with as an independent degree of freedom of the system with the motion of the soil wedge being a function of the reactive forces at the module-soil surface interface and the dynamic subsurface resistive forces acting on the soil wedge.

In addition to these features, parachute force effects and retrorocket systems for the command module may be studied using the program.

A variety of landings, both planar and nonplanar, on hard surfaces, clay and silica sand were used to obtain experimental verification of the computer program. These landings were made with a specially designed model approximating a 1/5 scale version of the Apollo Command Module. The features of the model (and test program) were designed to provide non-trivial input data for the computer program so that verification, if achieved, would not be restricted to a specialized version of the vehicle. The model included a deployed heat shield mounted on eight shock struts, an astronaut's couch suspended on

six shock struts, and a crushable surface on both the heat shield and capsule. All 14 shock struts were instrumented for both instantaneous load and stroke. The general six-degree-of-freedom motions of the capsule and the couch were recorded by twelve appropriately mounted accelerometers.

Due to the large number of transducers contained within the model, not all data from all transducers were recorded for each drop. This required, in some cases, that the load versus stroke characteristics of a particular shock strut had to be inferred from their performance in other drop tests in which their characteristics were recorded. Nevertheless, correlations achieved between model drop test accelerations and those predicted by the computer program were excellent for both the hard surface and soil landings. The best correlation was achieved on those drops for which all pertinent load-stroke shock strut characteristics were recorded - indicating that the program, with proper input data, was an accurate simulation of the earth-landing dynamics of a vehicle in the command module category.

The computer program itself, which represents the major output of this study, is given in terms of a general outline, input parameter definitions, Fortran variable definitions, usage instructions, subroutine block diagrams, a complete Fortran IV listing of the program, and a sample run input-output listing. All of the latter is contained in Section II of this report.

The mathematical analysis upon which the computer is based is covered in Section III of this report. The relationship between variables and parameters defined in the analysis section and those given in the computer program may be obtained by reference to the parameter and Fortran variable definitions given in Section II.

The development of procedures for dealing with the soil forces which occur when the heat shield or capsule surface impact the surface, was an important part of the analysis of the landing dynamics problem. To treat this facet of the problem adequately and accurately it was found necessary to design a special soil impact test machine which provided data for static and dynamic soil-wedge resistive forces as a function of the instantaneous angle between the contact area velocity vector and the soil surface normal. The

description of the soils, the soil impact test machine, test results obtained and the analysis of the soil test results, are given in Section IV of this report.

Section V of this report covers the test results obtained with the command module model. Model and drop test equipment are described, the drop test program is discussed, and the comparisons of couch and capsule accelerations with those obtained with the computer program are presented for all of the drop tests carried out. Conclusions based on the analyses of the correlation of these results are also presented in Section V.

SECTION II

COMPUTER PROGRAM

2.1 PURPOSE

This section describes the computer program written for the purpose of predicting the dynamic behavior of the Apollo Command Module during earth landing. A general flow diagram of the program is shown in Figure 2-1. Major variables used in the program are defined in Table 2-1. Intermediate variables defined and used solely within a given subroutine were not included in this list, since in most cases they are adequately defined by comment cards in the subroutine listing.

Usage instructions are outlined next, giving input data description and card format, program options, run stop information, and a description of the stacked run provision. This is followed by a complete listing of the program including subroutine flow diagrams, and a sample run showing program input and output.

2.2 USAGE INSTRUCTIONS

The following paragraphs will describe the input data format required for running the program, the various options provided within the program, built in run stops, and the method to be used in making stacked runs. These instructions, along with the program variable list previously presented and the sample run shown later in this section, should be sufficient to enable runs to be made and useful results obtained without requiring an intimate knowledge of the equations and relationships used in the program. Although it is believed that the program fulfills its intended purpose as written, it should be pointed out that a major portion of the relationships used in the program are completely general and can in most cases be easily altered to provide the type of input and/or output desired. This built-in flexibility should prove extremely useful in the design of a complex system such as the Apollo Command Module.

2.2.1 Input Data Format

The input data card format is shown in Table 2-3. Columns 1 thru 7 are reserved for card identification such as the name of the first variable on the card, and may be left blank if desired. Columns 8 thru 10 contain the card number, which must be right justified. Input data is placed in floating point form in columns 11-20, 21-30, 31-40, 41-50, 51-60, and 61-70, in the sequence shown in Table 2-3. The data need not be right justified, but must be contained entirely within the field of 10 columns provided.

A major portion of the input position data is relative to a zero reference coordinate system. This zero reference system may be positioned at any point in the body or space which is convenient for the definition of input parameters. The zero reference system is parallel with the space fixed coordinate system, regardless of the origin location chosen. Input parameters which are specified relative to the zero reference system are transformed to the appropriate body coordinate system in the initialization portion of the computer program.

Input data which must be specified in the body coordinate system are as follows. Couch end hardpoints of couch struts (XJ30(i), YJ30(i), ZJ30(i), couch accelerometers (CCH(1,i), CCH(2,i), CCH(3,i)), and bumper bearing pad position (XB13, YB13, ZB13 and XB23, YB23, ZB23) must be given in the couch coordinate system located at the couch c.g. Heat shield end hardpoints of the shield struts (XM20(i), YM20(i), ZM20(i), and distance from the heat shield c.g. to the geometric center (HSCG20) are to be specified in the heat shield coordinate system. Retrorocket triggering sensor (DYNGUS) free end position (ALTX, ALTY, ALTZ) must be given in the capsule coordinate system.

Shock strut load vs. stroke tables are given in cards 37 thru 48. FC(1,n) applies to shield struts 1 thru 8, FC(2,n) to couch struts 1 and 2, and FC(3,n) to couch struts 4 thru 6. The stroke-load tables are modified for each strut by the coefficients on cards 43 thru 48. The coefficients allow for the possibility of a unique stroke-load characteristic for each strut as well as different load levels in the compressive and tensile directions. Strut spring rate is computed within the program based upon the first stroke-load point in the table and the applicable coefficient.

The load vs. stroke table assumed to apply to both bumpers No. 1 and No. 2 is given in cards 55 and 56. The first point in this table cannot be (0,0). The pressure vs. deflection table for the capsule surface appears in cards 61 thru 67. The entire capsule surface is assumed to have this characteristic. Although a total of 21 points on the curve are provided for, a smaller number may be used by setting JJMAX equal to the number of points in the table.

Cards 68 and 69 contain a table for providing a variation of soil static bearing force and dynamic force with angle of impact. Since $AGMA = 1$, $BGMA = 1$ for $GMA = 0$ is assumed, the first input point is the appropriate values for a positive value of GMA. The number of points on the static bearing strength vs. deflection table (cards 71 thru 73) can be varied up to a maximum of 9 points by specifying the number of points, NAA, on card 70. The value of CMU on card 70 allows for a variation of coefficient of friction with angle of impact for real soil runs. For this case, coefficient of friction is equal to $GNDMU + CMU * GMA$, where GMA is the angle of impact computed during the run. For rigid surface runs, the coefficient of friction is simply GNDMU.

Cards 81 thru 100 provide a unique 6 point pressure vs. deflection table for each of a maximum of 10 rings of elements on the heat shield surface. In addition, cards 101 thru 103 allow any element j of any ring i to be separately specified for the purpose of providing an area of different characteristic to the shield surface. Cards 101 thru 103 can be repeated as many times as is required to yield the desired variation of load-deflection over the shield surface. A different pressure vs. deflection characteristic for each of 200 shield elements is possible using this technique.

Card number 120 defines the increment size and range of an arbitrary rough surface. The surface exists over a rectangular area defined by the points (YMIN, ZMIN), (YMIN, ZMIN + NZ*DEZ), (YMIN + NY*DEY, ZMIN + NZ*DEZ), and (YMIN + NY*DEY, ZMIN) in the space fixed coordinate system. The variation in X (departure from the planar surface $X = 0$) over this area is specified in cards 121 thru 137. A 10 x 10 array is provided for, but any smaller number may be used. Values of X are specified in the following sequence: X(YMIN, ZMIN), X(YMIN, ZMIN + DEZ), ,

$X(YMIN, ZMIN + NZ*DEZ), X(YMIN + DEY, ZMIN), \dots, X(YMIN + NY*DEY, ZMIN), \dots, X(YMIN + NY*DEY, ZMIN + NZ*DEZ)$. The maximum positive value of X in the table must also appear as XPMAX on card 27. The rough surface provision only applies to a rigid surface landing condition, $IS = 0$.

2.2.2 Program Options

A wide variety of options may be exercised with the program by setting flags in the input data. These options will be discussed in the order of their appearance in the input data cards.

Altitude at Zero Time. Normal program operation involves positioning the vehicle in contact with the ground surface with the X axis of the space fixed coordinate system going thru the capsule c.g. The run is then started with the vehicle in contact with the surface. If desired, the vehicle can be raised off the surface at zero time to study the effect of parachutes, retrorockets, etc. on the landing dynamics. This, is accomplished by specifying the desired value for XØRIG on card 2, which is the distance from the ground plane to the heat shield surface.

Parachute. A parachute force is computed and applied to the capsule until the X coordinate of the capsule c.g. becomes less than PHITE specified on card 21. A large value for PHITE will eliminate the parachute force throughout the computer run.

Print/Tape. IP and IT on card 25 specify the output printer and tape units desired. As currently programmed, the input and output summary pages appear on unit IP and the detailed output appears on IT. If an output printer is specified for both IP and IT, the entire output will be printed.

Surface Type. The value of IS on card 25 determines the type of surface to be used in the run. $IS = 0$ specifies a rigid surface and $IS = 1$ specifies a real soil of the type described by the parameters on cards 68 thru 73.

Number of Struts. The number of couch struts is specified by JK and the number of shield struts is specified by LM, both appearing on card 25. As currently programmed, the number of couch struts is limited to a maximum of 6 (plus bumpers) and the number of shield struts to a maximum of 8.

Hydraulic Damping. Provision is made for any type of shock strut with damping proportional to the square of the velocity. Such damping is incorporated for a value of 1 for JKDAMP in the case of couch struts and LMDAMP for the shield struts. The damping coefficient is VISJK and VISLM for the couch and shield struts respectively.

Time Considerations. Time interval, maximum problem time, and print time interval are specified by DT, TMAX, and DTP on card 28. Run serial number is also specified here as ISERNØ, and is printed on the output summary page.

Accelerometers. The outputs of up to twelve accelerometers located on the couch and capsule may be calculated during the run. This data is provided for IACCEL = 1 on card 28. Although body x, y, and z accelerations are computed for each accelerometer, space is provided for only twelve columns of acceleration vs. time print out. The twelve functions printed of the 36 available may be altered by minor changes in the OUTPUT subroutine.

Heat Shield. The heat shield may be either deployed, NØHS = 0, or not deployed, NØHS = 1. For NØHS = 1, capsule and heat shield masses and moments of inertia are combined, resulting in a two mass dynamic system.

Shock Strut Type. Two types of strut return stroke are available. IRET on card 29 having a value of 0 incorporates a free return, with only friction acting on the strut between tensile and compressive sections of crushed honeycomb. IRET of 1 gives a ratchet type of strut return.

Integration Method. Several methods of integration are available within the program. Card 30 contains parameters for integration by either (1) Constant interval Runge-Kutta, KA1 = -1, (2) Variable interval Adams-Moulton, KA1 = 0, or (3) Constant interval

Adams-Moulton, $KA1 = 1$. This integration procedure was derived from the MSC MASTER Subroutine, and is used in conjunction with the APOLLO main program (XQT APOLLO). The MSC documentation of this subroutine by J. L. Raney should be consulted for a complete description of the methods used. A rectangular integration procedure is also available in the Apollo Earth Landing Dynamics program. This procedure is employed through the use of the RECT main program (XQT RECT).

Retrorockets. Retrorocket force is deleted for $NRR = 0$ on card 49 and zero thrust on cards 104 thru 115.

Bumpers. The bumpers may be eliminated from the vehicle configuration by specifying a negative bumper length, BLNG, on card 49.

Planar Surface. The landing surface is considered to be planar for $NZ = 0$ and/or $NY = 0$ on card 120. Although a planar surface exists for positive values of NY and NZ if X is zero on cards 121 thru 137, this method should not be used since the consideration of a "rough surface" results in increased running time.

2.2.3 Run Stops

As currently written, the run will automatically stop for three conditions: (1) Maximum problem time, TMAX, has been reached, (2) a couch strut has exceeded its maximum stroke by 5 percent, and (3) a shield strut has exceeded its maximum allowable stroke by 5 percent. The reason for stopping the run is printed on the output summary page. Other criteria such as capsule instability, maximum allowable acceleration exceeded, or heat shield striking capsule could be easily installed as run stops. This is accomplished by setting IPRINT = 1 when the stop criteria has been met, and setting the ISTOP flag to choose the correct format in OUTPUT to describe the reason for stopping the run.

2.2.4 Stacked Run Provision

Data may be stacked for multiple runs thru the following procedure. A complete set of data must be supplied for the first run. Data for the first run is followed by a blank

card and the cards containing data which is to be changed for the second run. If a single parameter is changed, other parameters on that card must be punched in or they will be read as zeros. This procedure is repeated until a data deck for the desired numbers of runs has been compiled. The input summary printout contains a complete listing of data for each run and lists the change cards read in for each run. Output summary pages are sequenced according to run number in the stack.

APOLLO COMMAND MODULE EARTH LANDING ANALYSIS
GENERAL ORGANIZATION AND FUNCTION OF PROGRAM SUBROUTINES

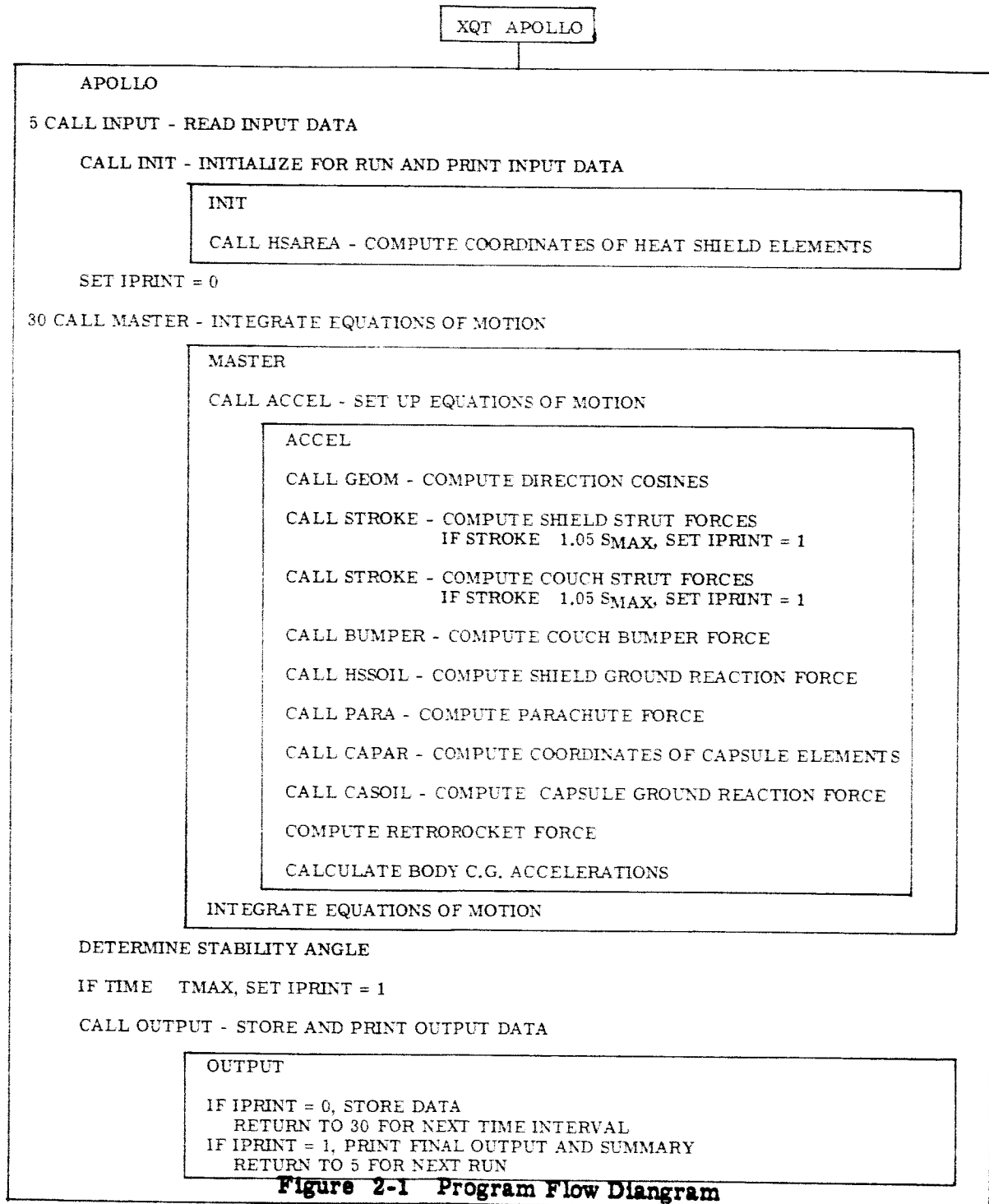


Figure 2-1 Program Flow Diagram

TABLE 2-1 PROGRAM VARIABLES

VARIABLE	SUBROUTINES	DEFINITION
A (10)	3,4,11	Function of normal to shield surface at ring i.
AA (9)	2,3,11	*Soil bearing strength, $F_g / \pi r^3 \gamma$
AA 1 (3,6)	8,13	Acceleration at capsule accelerometer locations - ft./sec. ²
AA 3 (3,6)	8,13	Acceleration at couch accelerometer locations - ft./sec. ²
ACEL	1,5,12	Area of capsule surface elements - ft. ²
ACX	3,8,15	Couch c.g. acceleration along fixed x axis, ft./sec. ²
ACX3	8	Couch c.g. acceleration along couch x axis
ACY	3,8,15	Couch c.g. acceleration along fixed y axis
ACY3	8	Couch c.g. acceleration along couch y axis
ACZ	3,8,15	Couch c.g. acceleration along fixed z axis
ACZ3	8	Couch c.g. acceleration along couch z axis
AEL	4,11,13	Area of heat shield surface elements - ft. ²
AGMA(5)	2,11	*Variation of soil bearing strength with angle of impact
ALT X	2,3,8	*X coordinate of retrorocket altitude sensor - CAP.C.S.
ALT Y	2,3,8	*Y coordinate of retrorocket altitude sensor - CAP.C.S.
ALT Z	2,3,8	*Z coordinate of retrorocket altitude sensor - CAP.C.S.
APX1	3,18	X coordinate of parachute attach point - CAP.C.S.
APX10	2,3	*X coordinate of parachute attach point - Z.R.C.S.
APY1	3,18	Y coordinate of parachute attach point - CAP.C.S.
APY10	2,3	*Y coordinate of parachute attach point - Z.R.C.S.
APZ1	3,18	Z coordinate of parachute attach point - CAP.C.S.
APZ10	2,3	*Z coordinate of parachute attach point - Z.R.C.S.
AREA	3,8,11,13	Heat shield ground contact area, ft. ²
AREAM	3,11,13	Maximum heat shield ground contact area
ASX	3,8,15	Heat shield c.g. acceleration along fixed x axis, ft. sec. ²
ASXZ	8	Heat shield c.g. acceleration along shield x axis
ASY	3,8,15	Heat shield c.g. acceleration along fixed y axis
ASYZ	8	Heat shield c.g. acceleration along shield y axis
ASZ	3,8,15	Heat shield c.g. acceleration along fixed z axis
ASZ2	8	Heat shield c.g. acceleration along shield z axis
AX	3,8,15	Capsule c.g. acceleration along fixed x axis, ft. sec. ²
AX1	8	Capsule c.g. acceleration along capsule x axis
AY	3,8,15	Capsule c.g. acceleration along fixed y axis
AY1	8	Capsule c.g. acceleration along capsule y axis
AZ	3,8,15	Capsule c.g. acceleration along fixed z axis
AZ1	8	Capsule c.g. acceleration along capsule z axis
A2	2,3,6	*Upper bound of single step error in variable step Adams-Moulton mode integration
A3	2,3,6	*Lower bound of single step error in variable step Adams-Moulton mode integration
A4	2,3,6	*Lower bound of Δt in variable step Adams-Moulton mode integration
A5	2,3,6	*Upper bound of Δt in variable step Adams-Moulton mode integration
A7	2,3,6	*Reduction factor for Δt in variable step Adams-Moulton mode integration
BB (9)	1,2,3,11	*Penetration for soil bearing strength, δ / r
BDEF(6)	2,3,17	*Deflection point in bumper stroke-load table, ft.
BFOR(6)	2,3,17	*Force in bumper stroke-load table, lb.
BGMA(5)	2,11	*Variation of soil dynamic force with angle of impact
BLNG	2,3,17	*Maximum stroke for bumpers 1 and 2, ft.
BMPNRG	3,13,17	Energy absorbed by couch bumpers, ft.-lb.
BST1MX	3,17	Maximum stroke of bumper 1
BST2MX	3,17	Maximum stroke of bumper 2
CAP(3,6)	2,3,8	*Coordinates of capsule accelerometers - Z.R.C.S., ft.
CAPDEF(21)	2,3,12	*Deflection in capsule surface deflection - load table, ft.
CAPFOR(21)	2,3,12	*Pressure in capsule surface deflection - load table, lb. ft. ²
CAPM	3,8,13	Capsule mass used in capsule acceleration equations
CAPMO	2,3	*Capsule mass, slugs
CAREA	3,8,12,13	Capsule ground contact area, ft. ²
CAREAM	3,12,13	Maximum capsule ground contact area
CCH(3,6)	2,3,8	*Coordinates of couch accelerometers - CCH.C.S., ft.
CCHM	2,3,8,13	*Mass of astronauts couch, slugs
CCXX	3,8	Coefficient in couch angular acceleration equation
CCXY	3,8	Coefficient in couch angular acceleration equation
CCXZ	3,8	Coefficient in couch angular acceleration equation
CCYX	3,8	Coefficient in couch angular acceleration equation
CCYY	3,8	Coefficient in couch angular acceleration equation
CCYZ	3,8	Coefficient in couch angular acceleration equation

TABLE 2-1 PROGRAM VARIABLES (CONT.)

VARIABLE	SUBROUTINES	DEFINITION
CCZX	3.8	Coefficient in couch angular acceleration equation
CCZY	3.8	Coefficient in couch angular acceleration equation
CCZZ	3	Coefficient in couch angular acceleration equation
CHJK(6)	3.8	Compressive spring rate of couch struts, lb. ft.
CHKT(6)	3.8	Tensile spring rate of couch struts, lb. ft.
CHLM(8)	3.8	Compressive spring rate of shield struts, lb. ft.
CHLMT(8)	3.8	Tensile spring rate of shield struts, lb. ft.
CKPH1C	2.3, 11	*Dimensionless soil resistance factor (K ϕ C)
CMU	2.11	*Variation of coefficient of friction with angle of impact ($\mu = \mu_0 + \text{CMU} \cdot \gamma$)
COEF(2,8)	2.3, 10	*Compressive side variation of strut from stroke-load table
COEFT(2,8)	2.3, 10	*Tensile side variation of strut from stroke-load table
CRRX(6)	3.8	Constant in retrorocket moment equation
CRRY(6)	3.8	Constant in retrorocket moment equation
CRRZ(6)	3.8	Constant in retrorocket moment equation
CTJK	3.8	Couch strut bottoming spring rate, lb. ft.
CTJKO	2.3	*Couch strut bottoming spring rate, lb. ft.
CTLM	3.8	Shield strut bottoming spring rate, lb. ft.
CTLMO	2.3	*Shield strut bottoming spring rate, lb. ft.
CXVELO	3.13	Couch x velocity in F.C.S., ft. sec. (initial)
CXX	3.8	Coefficient in capsule angular acceleration equation
CXY	3.8	Coefficient in capsule angular acceleration equation
CXZ	3.8	Coefficient in capsule angular acceleration equation
CYVELO	3.13	Couch y velocity in F.C.S., ft. sec. (initial)
CYY	3.8	Coefficient in capsule angular acceleration equation
CYZ	3.8	Coefficient in capsule angular acceleration equation
CZVELO	3.13	Couch z velocity in F.C.S., ft. sec. (initial)
CZX	3.8	Coefficient in capsule angular acceleration equation
CZY	3.8	Coefficient in capsule angular acceleration equation
CZZ	3.8	Coefficient in capsule angular acceleration equation
DC11	8.9, 10, 17	Direction cosines relating couch and fixed coordinate systems
DC12	8.9, 10, 17	Direction cosines relating couch and fixed coordinate systems
DC13	8.9, 10, 17	Direction cosines relating couch and fixed coordinate systems
DC21	8.9, 10, 17	Direction cosines relating couch and fixed coordinate systems
DC22	8.9, 10, 17	Direction cosines relating couch and fixed coordinate systems
DC23	8.9, 10, 17	Direction cosines relating couch and fixed coordinate systems
DC31	8.9, 10, 17	Direction cosines relating couch and fixed coordinate systems
DC32	8.9, 10, 17	Direction cosines relating couch and fixed coordinate systems
DC33	8.9, 10, 17	Direction cosines relating couch and fixed coordinate systems
DEFL(10, 50, 6)	2.3, 11, 13	*Deflection in heat shield surface deflection - load table, ft.
DELMAX(12, 55)	3.12	Maximum deflection of capsule element 1.
DEY	2.3	*Increment in y for rough surface definition, ft.
DEZ	2.3	*Increment in z for rough surface definition, ft.
DMAX(10, 50)	3, 11, 13	Maximum deflection of heat shield element 1.
DS11	8.9, 10, 11	Direction cosines relating heat shield and fixed coordinate systems
DS12	8.9, 10, 11	Direction cosines relating heat shield and fixed coordinate systems
DS13	8.9, 10, 11	Direction cosines relating heat shield and fixed coordinate systems
DS21	8.9, 10, 11	Direction cosines relating heat shield and fixed coordinate systems
DS22	8.9, 10, 11	Direction cosines relating heat shield and fixed coordinate systems
DS23	8.9, 10, 11	Direction cosines relating heat shield and fixed coordinate systems
DS31	8.9, 10, 11	Direction cosines relating heat shield and fixed coordinate systems
DS32	8.9, 10, 11	Direction cosines relating heat shield and fixed coordinate systems
DS33	8.9, 10, 11	Direction cosines relating heat shield and fixed coordinate systems
DT	2.3, 8, 10, 11, 15, 14, 18	*Time interval for fixed interval Runge-Kutta and Adams-Moulton integration, sec.
DTP	1.2, 3, 14	*Print time interval, sec.
DUM5(961)	8, 13	Positions, velocities, and accelerations for integration subroutine
D11	1.3, 8, 9, 10, 18, 12	Direction cosines relating capsule and fixed coordinate systems
D12	1.3, 8, 9, 10, 18, 17, 12	Direction cosines relating capsule and fixed coordinate systems
D13	1.3, 8, 9, 10, 18, 12	Direction cosines relating capsule and fixed coordinate systems
D21	1.3, 8, 9, 10, 18, 12	Direction cosines relating capsule and fixed coordinate systems
D22	1.3, 8, 9, 10, 18, 17, 12	Direction cosines relating capsule and fixed coordinate systems
D23	1.3, 8, 9, 10, 18, 12	Direction cosines relating capsule and fixed coordinate systems
D31	3, 8, 9, 10, 18, 12	Direction cosines relating capsule and fixed coordinate systems
D32	3, 8, 9, 10, 18, 17, 12	Direction cosines relating capsule and fixed coordinate systems
D33	3, 8, 9, 10, 18, 12	Direction cosines relating capsule and fixed coordinate systems

TABLE 2-1 PROGRAM VARIABLES (CONT.)

VARIABLE	SUBROUTINES	DEFINITION
ENGKE	3,13	Initial kinetic energy of system, ft.-lb.
ENGKEF	3,13	Final kinetic energy of system, ft.-lb.
ENGPE	3,13	Change in potential energy during run, ft.-lb.
ENGTOT	3,13	Energy absorbed during run, ft.-lb.
ETA	2,3,5,12	*Half-angle of capsule conic section, radians
EX(10)	3,4,11	x coordinates of heat shield surface elements - H.S.C.S., ft.
EY(10,50)	3,4,11	y coordinates of heat shield surface elements - H.S.C.S., ft.
EZ(10,50)	3,4,11	z coordinates of heat shield surface elements - H.S.C.S., ft.
FAKE(100)	2,3	Δx array for rough surface calculations, ft.
FBX	8,17	Bumper force on capsule - x direction - F.C.S., lb.
FBY	8,17	Bumper force on capsule - y direction - F.C.S., lb.
FBZ	8,17	Bumper force on capsule - z direction - F.C.S., lb.
FC(3,6)	2,3,10	*Force in strut load-deflection table, lb.
FCGX	3,8,12	Ground reaction force on capsule - x direction - F.C.S., lb.
FCGY	3,8,12	Ground reaction force on capsule - y direction - F.C.S., lb.
FCGZ	3,8,12	Ground reaction force on capsule - z direction - F.C.S., lb.
FFC(8)	8,10	Strut compressive side friction force, lb.
FFJK(6)	2,3,8	*Couch strut compressive side friction force, lb.
FFJKT(6)	2,3,8	*Couch strut tensile side friction force, lb.
FFLM(8)	2,3,8	*Shield strut compressive side friction force, lb.
FFLMT(8)	2,3,8	*Shield strut tensile side friction force, lb.
FFT(8)	8,10	Strut tensile side friction force, lb.
FHCQ(8)	8,10	Strut load due to honeycomb, lb.
FORCE (10,50,6)	2,3,11,13	*Pressure in heat shield surface deflection - load table, lb. ft. ²
FORJK(6)	3,8,10	Current couch strut force, lb.
FORLM(8)	3,8,10	Current shield strut force, lb.
FORP(8)	8,10	Strut force during previous time interval, lb.
FPPX	8,18	Force on capsule due to parachute - x direction F.C.S., lb.
FPPY	8,18	Force on capsule due to parachute - y direction F.C.S., lb.
FPPZ	8,18	Force on capsule due to parachute - z direction F.C.S., lb.
FPXO	2,3	*Parachute force - x direction F.C.S., lb.
FPYO	2,3	*Parachute force - y direction F.C.S., lb.
FPZO	2,3	*Parachute force - z direction F.C.S., lb.
FSGX	3,8,11,13	Ground reaction force on shield - x direction - F.C.S., lb.
FSGY	3,8,11	Ground reaction force on shield - y direction - F.C.S., lb.
FSGZ	3,8,11	Ground reaction force on shield - z direction - F.C.S., lb.
GMA(5)	2,11	*Angle of impact in AGMA(5), BGMA(5) vs. GMA(5) table
GNDMU	2,3,11,12	*Coefficient of friction between vehicle and soil, $\gamma = 0$
HC	2,3	*Height of apex of capsule conic section - Z.R.C.S., ft.
HGX1	2,3	*x coordinate of couch c.g. - Z.R.C.S., ft.
HGY1	2,3	*y coordinate of couch c.g. - Z.R.C.S., ft.
HGZ1	2,3	*z coordinate of couch c.g. - Z.R.C.S., ft.
HEATA	2,3,4,8,11	*Minor radius of shield spheroidal surface, ft.
HEATB	1,2,3,4,5,8,11,12	*Major radius of shield spheroidal surface, ft.
HSCG2	1,3,4,8,11	Position of shield geometric center relative to shield c.g. - H.S.C.S., ft.
HSCG20	2,3	*Position of shield geometric center relative to shield c.g. - H.S.C.S., ft.
HSDM	3,8,13	Heat shield mass used in shield acceleration equations
HSDMO	2,3	*Heat shield mass, slugs
HSX1	1,3	x coordinate of heat shield c.g. - CAP.C.S., ft.
HSX10	2,3	*x coordinate of heat shield c.g. - Z.R.C.S., ft.
HSY1	1,2,3,5	*y coordinate of heat shield c.g. - Z.R.C.S., ft.
HSZ1	1,2,3,5	*z coordinate of heat shield c.g. - Z.R.C.S., ft.
IACCEL	2,3,8,13	*Accelerometer output flag, : = 1, print : = 0, don't print
IC	3,13,10	Number of bottomed out couch strut
IP	1,2,3,4,5,11,12,13	*Output printer unit number for summary output
IPARA	3,8	Parachute flag : = 0, connected : = 1, parachute cut
IPRINT	1,3,10,13,14	Output print flag : = 1, print final summary : = 0, store data and continue
IREAL	1,6,8,10,11,15,18,17	Integration trial number flag : = 0, intermediate steps : = 1, final step
IRET	2,3,10	*Strut type flag : = 1, ratchet : = 0, free return
IRUNNO	1,13,14	Stacked run number flag, first run = 0.
IS	2,3,11,13,15	*Surface type flag : = 1, real soil : = 0, rigid surface
ISERNO	2,3,13	*Series number of run
ISS	3,10,13	Number of bottomed out shield strut
ISTOP	1,10,13,14	Run stop flag : = 1, max. time : = 2, excessive accel : = 3, couch strut bottomed : = 4, shields strut bottomed; = 5, shield struck capsule.

TABLE 2-1 PROGRAM VARIABLES (CONT.)		
VARIABLE	SUBROUTINE	
IT	2,3,13	*Output tape unit number for detailed output No. 1
JJMAX	2,3,12	*Maximum number of pressure vs. deflection points for capsule surface
JK	2,3,8	*Number of couch struts
JKDAMP	2,3,8	*V ² damping (1) no V ² damping (0) flag for couch struts
JKLM	8,10	Stroke routine flag : = 0, couch struts ; = 1, shield struts
K	3,4,6,10,11,12,13	Number of rings on shield surface subdivision
KA1	2,3,6	*Integration method flag : KA1 < 0, fixed Δt R-K; KA1 = 0, variable Δt A-M; KA1 > 0, fixed Δt A-M
LM	2,3,8	*Number of shield struts
LMDAMP	2,3,8	*V ² damping (1) no V ² damping (0) flag for shield struts
L1	3,13	Data storage flag; print for L1 ≥ 50
M	5,12	Number of rings in capsule surface subdivision
MAP	1,6,14	Integration routine internal flag
N	8,10	Number of struts flag for stroke
N(12)	5,12	Number of elements in capsule ring i
NAA	2,3,11	*Number of points in AA(9) vs BB(9) table
NI(10)	3,4,11,13	Number of elements in shield ring i
NN	1,6,14	Number of variables flag for integration subroutine
NOHS	2,3,8	*Heat shield flag : = 1, not deployed ; = 0, deployed
NORING (10)	3,13	Number of elements bottomed out in shield ring i
NRR	2,3,8	*Number of retrorockets used
NS	8,10	Strut stroke-load table flag : = 1, shield struts ; = 0, couch struts
NY	2,3,8,11	*Number of y increments in rough surface table
NZ	2,3,8,11	*Number of z increments in rough surface table
ODEL (10)	3,13	Amount of permanent deformation in shield ring i
OECS	3,13	Fraction of energy absorbed by couch struts
OEGND	3,13	Fraction of energy absorbed by capsule surface
OESGND	3,13	Fraction of energy absorbed by shield surface
OESOIL	3,13	Fraction of energy absorbed by soil and ground friction
OESS	3,13	Fraction of energy absorbed by shield struts
OFCMAX(6)	3,10,13	Maximum couch strut compressive load, lb.
OFCMIN(6)	3,10,13	Maximum couch strut tensile load, lb.
OFRAC	3,13	Fraction of energy absorbed by all elements considered
OFSMAX(8)	3,10,13	Maximum shield strut compressive load, lb.
OFSMIN(8)	3,10,13	Maximum shield strut tensile load, lb.
OLCB(6)	3,13	Maximum couch strut tensile stroke relative to initial length, ft.
OLCL(6)	3,13	Maximum couch strut compressive stroke relative to initial length, ft.
OLCMAX(6)	3,8,13	Maximum couch strut tensile stroke, ft.
OLCMIN(6)	3,8,13	Maximum couch strut compressive stroke, ft.
OLSB(8)	3,13	Maximum shield strut tensile stroke relative to initial length, ft.
OLSL(8)	3,13	Maximum shield strut compressive stroke relative to initial length, ft.
OLSMAX(8)	3,8,13	Maximum shield strut tensile stroke, ft.
OLSMIN(8)	3,8,13	Maximum shield strut compressive stroke, ft.
OMACX(7)	3,8,13	Maximum acceleration in x direction of couch accelerometers - CCH.C.S., ft. sec. ²
OMACY(7)	3,8,13	Maximum acceleration in y direction of couch accelerometers - CCH.C.S., ft. sec. ²
OMACZ(7)	3,8,13	Maximum acceleration in z direction of couch accelerometers - CCH.C.S., ft. sec. ²
OMAX(7)	3,8,13	Maximum acceleration in x direction of capsule accelerometers - CAP.C.S., ft. sec. ²
OMAY(7)	3,8,13	Maximum acceleration in y direction of capsule accelerometers - CAP.C.S., ft. sec. ²
OMAZ(7)	3,8,13	Maximum acceleration in z direction of capsule accelerometers - CAP.C.S., ft. sec. ²
PHI	3,13	Angular rotation of CAP.C.S. about X axis of F.C.S., rad.
PH1C	3,13	Angular rotation of CCH.C.S. about X axis of F.C.S., rad.
PH1O	2	*Angular rotation of CAP.C.S. about X axis of F.C.S., rad. (initial)
PH1S	3,13	Angular rotation of H.S.C.S. about X axis of F.C.S., rad.
PH1TE	2,3,8	*Parachute cut-off height - F.C.S., ft.
PK	2,3,18	*Parachute cord spring rate, lb. ft.
PKWEE(10,50)	3,11	Crush distance for shield surface, ft.
PLGNOF	2,3,18	*Unstrained parachute line length, ft.
PREV	3,8,12	Previous capsule ground contact area, ft. ²
PSI	3,13	Angular rotation of CAP.C.S. about Z axis of F.C.S., rad.
PH1C	3,13	Angular rotation of CCH.C.S. about Z axis of F.C.S., rad.
PS1O	2	*Angular rotation of CAP.C.S. about Z axis of F.C.S., rad. (initial)
PS1S	3,13	Angular rotation of H.S.C.S. about Z axis of F.C.S., rad.
PVEL(8)	8,10	Strut velocity during previous time interval, ft. sec.
PXVEL	3,18	Parachute velocity - x direction F.C.S., ft. sec.
PXVELO	2,3	*Parachute velocity - x direction F.C.S., ft. sec.
PYVEL	3,18	Parachute velocity - y direction F.C.S., ft. sec.

TABLE 2-1 PROGRAM VARIABLES (CONT.)

VARIABLE	SUBROUTINES	DEFINITION
PYVELO	2,3	*Parachute velocity - y direction F.C.S., ft./sec.
PZVEL	3,18	Parachute velocity - z direction F.C.S., ft./sec.
PZVELO	2,3	*Parachute velocity - z direction F.C.S., ft./sec.
Q	2,3,4	*Nominal number of shield surface elements (max. of 200)
QC	2,3,5	*Nominal number of capsule surface elements (max. of 200)
QCH(8)	8,10	Strut spring rate - compressive side, lb./ft.
QCHT(8)	8	Strut spring rate - tensile side, lb./ft.
QDAMP	8,10	V ² damping flag : = 1, V ² damping : = 0, No V ² damping
QFC(8)	10	Strut force due to honeycomb, lb.
QFF	10	Friction force coefficient
QFX	8,10	Strut force on capsule in x direction - F.C.S., lb.
QFY	8,10	Strut force on capsule in y direction - F.C.S., lb.
QFZ	8,10	Strut force on capsule in z direction - F.C.S., lb.
QKT	3,8,10,11	Strut bottoming spring rate, lb./ft.
QRGX	8,10	x coordinate of shield or couch c.g. for strut length calculation - F.C.S., ft.
QRGY	8,10	y coordinate of shield or couch c.g. for strut length calculation - F.C.S., ft.
QRGZ	8,10	z coordinate of shield or couch c.g. for strut length calculation - F.C.S., ft.
QRYVEL	1	Capsule y direction velocity - F.C.S., ft./sec.
QRZVEL	1	Capsule z direction velocity - F.C.S., ft./sec.
QSD(8)	8,10	Strut stroke-load profile positioning parameter
QSH	8,10	Allowable strut stroke in compressive direction, ft.
QSHI	8,10	Allowable strut stroke in tensile direction
QSQP(8)	8,10	Strut length during previous time interval, ft.
QSR(8)	8,10	Strut stroke-load profile positioning parameter
QSX(8)	3,8,10	x coordinate of strut shield or couch end hardpoint - H.S.C.S. or CCH.C.S., ft.
QSY(8)	3,8,10	y coordinate of strut shield or couch end hardpoint - H.S.C.S. or CCH.C.S., ft.
QSZ(8)	3,8,10	z coordinate of strut shield or couch end hardpoint - H.S.C.S. or CCH.C.S., ft.
QTCX3	8,10	Couch moment about x axis due to struts - CCH.C.S., ft.-lb.
QTCY3	8,10	Couch moment about y axis due to struts - CCH.C.S., ft.-lb.
QTCZ3	8,10	Couch moment about z axis due to struts - CCH.C.S., ft.-lb.
QTSX2	8,10	Shield moment about x axis due to struts - H.S.C.S., ft.-lb.
QTSY2	8,10	Shield moment about y axis due to struts - H.S.C.S., ft.-lb.
QTSZ2	8,10	Shield moment about z axis due to struts - H.S.C.S., ft.-lb.
QTX1	8,10	Capsule moment about x axis due to struts - CAP.C.S., ft.-lb.
QTY1	8,10	Capsule moment about y axis due to struts - CAP.C.S., ft.-lb.
QTZ1	8,10	Capsule moment about z axis due to struts - CAP.C.S., ft.-lb.
QVGX	8,10	Velocity of shield or couch c.g. - x direction, F.C.S., ft./sec.
QVGY	8,10	Velocity of shield or couch c.g. - y direction, F.C.S., ft./sec.
QVGZ	8,10	Velocity of shield or couch c.g. - z direction, F.C.S., ft./sec.
QVIS	8,10	VISLM or VISJK
QWGX	8,10	Angular velocity of shield or couch about x axis, rad./sec.
QWGY	8,10	Angular velocity of shield or couch about y axis, rad./sec.
QWGZ	8,10	Angular velocity of shield or couch about z axis, rad./sec.
QX(8)	8,10	x coordinate of strut capsule end hardpoint - CAP.C.S., ft.
QY(8)	8,10	y coordinate of strut capsule end hardpoint - CAP.C.S., ft.
QZ(8)	8,10	z coordinate of strut capsule end hardpoint - CAP.C.S., ft.
RCX	3,13	x coordinate of couch c.g. - F.C.S., ft.
RCXO	3,13	x coordinate of couch c.g. - F.C.S., ft. (initial)
RCXVEL	3,13	x velocity of couch c.g. - F.C.S., ft./sec.
RCY	3,13	y coordinate of couch c.g. - F.C.S., ft.
RCYO	3	y coordinate of couch c.g. - F.C.S., ft. (initial)
RCYVEL	3,13	y velocity of couch c.g. - F.C.S., ft./sec.
RCZ	3,13	z coordinate of couch c.g. - F.C.S., ft.
RCZO	3,13	z coordinate of couch c.g. - F.C.S., ft. (initial)
RCZVEL	3,13	z velocity of couch c.g. - F.C.S., ft./sec.
RHO(10)	4,11	Radius of heat shield surface element ring i
RPX	3,18	x coordinate of parachute - F.C.S., ft.
RPY	3,18	y coordinate of parachute - F.C.S., ft.
RPZ	3,18	z coordinate of parachute - F.C.S., ft.
RRNRG	3,8,13	Energy imparted by retrorocket, ft.-lb.
RRX1(6)	3,8	*x coordinate of retrorocket attach point - Z.R.C.S., ft.
RRX10(6)	2,3	x coordinate of retrorocket attach point - CAP.C.S., ft.
RRX2(6)	2,3	*x coordinate of retrorocket direction point - Z.R.C.S., ft.
RRY1(6)	3,8	*y coordinate of retrorocket attach point - Z.R.C.S., ft.

TABLE 2-1 PROGRAM VARIABLES (CONT.)		
VARIABLE	SUBROUTINE	
RRY10(6)	2,3	y coordinate of retrorocket attach point - CAP.C.S., ft.
RRY2(6)	2,3	*y coordinate of retrorocket direction point - Z.R.C.S., ft.
RRZ1(6)	3,8	*z coordinate of retrorocket attach point - Z.R.C.S., ft.
RRZ10(6)	2,3	z coordinate of retrorocket attach point - CAP.C.S., ft.
RRZ2(6)	2,3	*z coordinate of retrorocket direction point - Z.R.C.S., ft.
RSURF(3,11,11)	3,11	X,Y,Z array describing rough surface - F.C.S., ft.
RSX	3,13	x coordinate of heat shield c.g. - F.C.S., ft.
RSXO	3,13	x coordinate of heat shield c.g. - F.C.S., ft. (initial)
RSXVEL	3,13	x velocity of heat shield c.g. - F.C.S., ft./sec.
RSY	3,13	y coordinate of heat shield c.g. - F.C.S., ft.
RSYO	3	y coordinate of heat shield c.g. - F.C.S., ft. (initial)
RSYVEL	3,13	y velocity of heat shield c.g. - F.C.S., ft./sec.
RSZ	3,13	z coordinate of heat shield c.g. - F.C.S., ft.
RSZO	3,13	z coordinate of heat shield c.g. - F.C.S., ft. (initial)
RSZVEL	3,13	z velocity of heat shield c.g. - F.C.S., ft./sec.
RX(1)	3,12,13	x coordinate of capsule c.g. - F.C.S., ft.
RXO(1)	3,13	x coordinate of capsule c.g. - F.C.S., ft. (initial)
RXVEL	3,12,13	x velocity of capsule c.g. - F.C.S., ft./sec.
RXVELO	2,13	*x velocity of capsule c.g. - F.C.S., ft./sec. (initial)
RY	3,13	y coordinate of capsule c.g. - F.C.S., ft.
RYO	3	y coordinate of capsule c.g. - F.C.S., ft. (initial)
RYVEL	3,12,13	y velocity of capsule c.g. - F.C.S., ft./sec.
RYVELO	2,13	*y velocity of capsule c.g. - F.C.S., ft./sec. (initial)
RZ	3,13	z coordinate of capsule c.g. - F.C.S., ft.
RZO	3,13	z coordinate of capsule c.g. - F.C.S., ft. (initial)
RZVEL	3,12,13	z velocity of capsule c.g. - F.C.S., ft./sec.
RZVELO	2,13	*z velocity of capsule c.g. - F.C.S., ft./sec. (initial)
SACC	8,11,15	Acceleration of soil mass - F.C.S. ft./sec. ²
SDJK(6)	3,8	QSD(8) for couch struts
SDLM(8)	3,8	QSD(8) for shield struts
SHCJK	2,3,8	*Allowable compressive stroke of couch struts, ft.
SHCJKT	2,3,8	*Allowable tensile stroke of couch struts, ft.
SHCLM	2,3,8	*Allowable compressive stroke of shield struts, ft.
SHCLMT	2,3,8	*Allowable tensile stroke of shield struts, ft.
SLDEL	8,11,15	Displacement of soil mass - F.C.S., ft.
SLGTH(3,6)	2,3,10	*Stroke in strut load-stroke table, ft.
SLJK(6)	3,8,13	Couch strut length, ft.
SLJKO(6)	3,8,13	Initial couch strut length, ft.
SLLM(8)	3,8,13	Shield strut length, ft.
SLLMO(8)	3,8,13	Initial shield strut length, ft.
SLPHI	2,3,11	Soil angle of internal friction (ϕ)
SLRHO	2,3,11	Soil mass density, slugs ft. ³
SO(8)	8,10	Initial strut length, ft.
SOILE	2,3,11	Soil modulus of elasticity, lb./ft. ²
SPACE	3,6	Time interval set by MASTER, initially = DT.
SQ(8)	8,10	Strut length, ft.
SRJK(6)	3,8	QSR(8) for couch struts
SRLM(8)	3,8	QSR(8) for shield struts
SUMCR	3,13,11	Energy absorbed by shield surface, ft.-lb.
SVEL	8,11,15	Velocity of soil mass, ft./sec.
SXVELO	3,13	Initial velocity of heat shield - x direction, F.C.S., ft./sec.
SYVELO	3,13	Initial velocity of heat shield - y direction, F.C.S., ft./sec.
SZVELO	3,13	Initial velocity of heat shield - z direction, F.C.S., ft./sec.
T(1000)	3,6	Variables for integration procedure
TBCX	8,17	Moment about couch x axis due to bumpers - CCH.C.S., ft.-lb.
TBCY	8,17	Moment about couch y axis due to bumpers - CCH.C.S., ft.-lb.
TBCZ	8,17	Moment about couch z axis due to bumpers - CCH.C.S., ft.-lb.
TBX	8,17	Moment about capsule x axis due to bumpers - CAP.C.S., ft.-lb.
TBY	8,17	Moment about capsule y axis due to bumpers - CAP.C.S., ft.-lb.
TBZ	8,17	Moment about capsule z axis due to bumpers - CAP.C.S., ft.-lb.
TCGX1	3,8,12	Moment about capsule x axis due to capsule ground contact - CAP.C.S., ft.-lb.
TCGY1	3,8,12	Moment about capsule y axis due to capsule ground contact - CAP.C.S., ft.-lb.
TCGZ1	3,8,12	Moment about capsule z axis due to capsule ground contact - CAP.C.S., ft.-lb.
TCSQ(6)	3,10,13	Energy absorbed by friction in couch struts, ft.-lb.
TESOIL	3,11,13	Energy absorbed by soil including surface friction, ft.-lb.
THRR(6,10)	2,3,8	*Thrust in retrorocket thrust vs. time table, lb.

TABLE 2-1 PROGRAM VARIABLES (CONT.)

VARIABLE	SUBROUTINES	DEFINITION
THTA	3,13	Angular rotation of CAP.C.S. about y axis of F.C.S., rad.
THTAC	3,13	Angular rotation of CCH.C.S. about y axis of F.C.S., rad.
THTAO	2	*Angular rotation of CAP.C.S. about y axis of F.C.S., rad. (initial)
THTAS	3,13	Angular rotation of H.S.C.S. about y axis of F.C.S., rad.
TIME	1,3,8,11,13,14	Problem time, sec.
TMAX	1,2,3,14	*Max problem time, run stops for $TIME \geq TMAX$, Sec.
TOTCCR(6)	3,10,13	Energy absorbed by couch strut crushable elements, ft.-lb.
TOTSCR(8)	3,10,13	Energy absorbed by shield strut crushable elements, ft.-lb.
TP	1,3,14	Print time, sec.
TPPX1	8,18	Moment about capsule x axis due to parachute - CAP.C.S., ft.-lb.
TPPY1	8,18	Moment about capsule y axis due to parachute - CAP.C.S., ft.-lb.
TPPZ1	8,18	Moment about capsule z axis due to parachute - CAP.C.S., ft.-lb.
TSGX	3,8,11	Moment about shield x axis due to ground contact - H.S.C.S., ft.-lb.
TSGY	3,8,11	Moment about shield y axis due to ground contact - H.S.C.S., ft.-lb.
TSGZ	3,8,11	Moment about shield z axis due to ground contact - H.S.C.S., ft.-lb.
TSSQ(8)	3,10,13	Energy absorbed by friction in shield struts, ft.-lb.
TYM(6,10)	2,3,8	*Time in retrorocket thrust vs. time table, sec.
UCXX	2,3,8,13	*Moment of inertia about couch c.g. - XX component, slug - ft. ²
UCXY	2,3,8	*Moment of inertia about couch c.g. - XY component, slug - ft. ²
UCXZ	2,3,8	*Moment of inertia about couch c.g. - XZ component, slug - ft. ²
UCYY	2,3,8,13	*Moment of inertia about couch c.g. - YY component, slug - ft. ²
UCYZ	2,3,8	*Moment of inertia about couch c.g. - YZ component, slug - ft. ²
UCZZ	2,3,8,13	*Moment of inertia about couch c.g. - ZZ component, slug - ft. ²
USXX	2,3, 8,13	*Moment of inertia about heat shield c.g. - XX component, slug - ft. ²
USYY	2,3,8,13	*Moment of inertia about heat shield c.g. - YY component, slug - ft. ²
USZZ	2,3,8,13	*Moment of inertia about heat shield c.g. - ZZ component, slug - ft. ²
UXX	3,8,13	Moment of inertia about capsule c.g. - XX component, slug - ft. ²
UXXO	2,3	*Moment of inertia about capsule c.g. - XX component, slug - ft. ² (initial)
UXY	2,3,8	*Moment of inertia about capsule c.g. - XY component, slug - ft. ²
UXZ	2,3,8	*Moment of inertia about capsule c.g. - XZ component, slug - ft. ²
UYX	3,8,13	Moment of inertia about capsule c.g. - YY component, slug - ft. ²
UYYO	2,3	*Moment of inertia about capsule c.g. - YY component, slug - ft. ² (initial)
UYZ	2,3,8	*Moment of inertia about capsule c.g. - YZ component, slug - ft. ²
UZZ	3,8,13	Moment of inertia about capsule c.g. - ZZ component, slug - ft. ²
UZZO	2,3	*Moment of inertia about capsule c.g. - ZZ component, slug - ft. ² (initial)
VELJK(6)	3,8	Current couch strut stroking velocity, ft. sec.
VELLM(6)	3,8	Current shield strut stroking velocity, ft. sec.
VISJK	2,3,8	*V ² damping coefficient for couch struts
VISLM	2,3,8	*V ² damping coefficient for shield struts
WCX	3,13	Couch angular velocity about the x axis - CCH.C.S., rad. sec.
WCY	3,13	Couch angular velocity about the y axis - CCH.C.S., rad. sec.
WCZ	3,13	Couch angular velocity about the z axis - CCH.C.S., rad. sec.
WDCX	3,8,15	Couch angular acceleration about the x axis - CCH.C.S., rad. sec. ²
WDCY	3,8,15	Couch angular acceleration about the y axis - CCH.C.S., rad. sec. ²
WDCZ	3,8,15	Couch angular acceleration about the z axis - CCH.C.S., rad. sec. ²
WDSX	3,8,15	Shield angular acceleration about the x axis - H.S.C.S., rad. sec. ²
WDSY	3,8,15	Shield angular acceleration about the y axis - H.S.C.S., rad. sec. ²
WDSZ	3,8,15	Shield angular acceleration about the z axis - H.S.C.S., rad. sec. ²
WDX	3,8,15	Capsule angular acceleration about the x axis - CAP.C.S., rad. sec. ²
WDY	3,8,15	Capsule angular acceleration about the y axis - CAP.C.S., rad. sec. ²
WDZ	3,8,15	Capsule angular acceleration about the z axis - CAP.C.S., rad. sec. ²
WSX	3,13	Shield angular velocity about the x axis - H.S.C.S., rad./sec.
WSY	3,13	Shield angular velocity about the y axis - H.S.C.S., rad./sec.
WSZ	3,13	Shield angular velocity about the z axis - H.S.C.S., rad./sec.
WX	3,12,13	Capsule angular velocity about the x axis - CAP.C.S., rad. sec.
WXO	2,13	*Capsule angular velocity about the x axis - CAP.C.S., rad./sec. (initial)
WY	3,12,13	Capsule angular velocity about the y axis - CAP.C.S., rad. sec.
WYO	2,13	*Capsule angular velocity about the y axis - CAP.C.S., rad./sec. (initial)
WZ	3,12,13	Capsule angular velocity about the z axis - CAP.C.S., rad. sec.
WZO	2,13	*Capsule angular velocity about the z axis - CAP.C.S., rad. sec. (initial)
X(12)	5,12	x coordinates of capsule surface elements - CAP.C.S., ft.
XB13	2,3,17	x coordinate of bumper #1 bearing pad - CCH.C.S., ft.
XB23	2,3	x coordinate of bumper #2 bearing pad - CCH.C.S., ft.
XBASE	5,12	x coordinate of base of capsule conic section - CAP.C.S., ft.
XC61	1,2,3,5,8	*x coordinate of capsule c.g. - Z.R.C.S. ft.

TABLE 2-1 PROGRAM VARIABLES (CONCLUDED)

VARIABLE	SUBROUTINES	DEFINITION
XJ3(6)	3,8	x coordinate of couch strut - couch end - CCH.C.S., ft.
XJ30(6)	2	*x coordinate of couch strut - couch end - CCH.C.S., ft.
XK1(6)	3,8	x coordinate of couch strut - capsule end - CAP.C.S., ft.
XK10(6)	2	*x coordinate of couch strut - capsule end - Z.R.C.S., ft.
XL1(8)	3,8	x coordinate of shield strut - capsule end - H.S.C.S., ft.
XL10(8)	2,3	*x coordinate of shield strut - capsule end - Z.R.C.S., ft.
XMAX	2,3,5,12	*x coordinate of top of capsule - Z.R.C.S., ft.
XMIN	2,3,5,12	*x coordinate of capsule shield interface - Z.R.C.S., ft.
XM2(8)	3,8	x coordinate of shield strut - shield end - H.S.C.S., ft.
XM20(8)	2	*x coordinate of shield strut - shield end - H.S.C.S., ft.
XORIG	2,3	Height of shield surface above ground plane at TIME = 0
XPMAX	2,3	*Maximum positive x in rough surface definition, ft.
Y(12,55)	12,5	y coordinates of capsule surface elements - CAP.C.S., ft.
YB13	2,3,17	*y coordinate of bumper #1 bearing pad - CCH.C.S., ft.
YB23	2,3,17	*y coordinate of bumper #2 bearing pad - CCH.C.S., ft.
YCG1	1,2,3,8,5	*y coordinate of capsule c.g. - Z.R.C.S., ft.
YJ3(6)	3,8	y coordinate of couch strut - couch end - CCH.C.S., ft.
YJ30(6)	2	*y coordinate of couch strut - couch end - CCH.C.S., ft.
YK1(6)	3,8	y coordinate of couch strut - capsule end - CAP.C.S., ft.
YK10(6)	2	*y coordinate of couch strut - capsule end - Z.R.C.S., ft.
YL1(8)	3,8	y coordinate of shield strut - capsule end - CAP.C.S.
YL10(8)	2	*y coordinate of shield strut - capsule end - Z.R.C.S., ft.
YMIN	2,3	*Minimum y coordinate of rough surface - F.C.S., ft.
YM2(8)	3,8	y coordinate of shield strut - shield end - H.S.C.S., ft.
YM20(8)	2	*y coordinate of shield strut - shield end - H.S.C.S., ft.
YRP1	3,17	Constant for bumper #1
YRP2	3,17	Constant for bumper #2
Z(12,55)	1,12,5	z coordinates of capsule surface elements - CAP.C.S., ft.
ZB13	2,3,17	*z coordinate of bumper #1 bearing pad - CCH.C.S., ft.
ZB23	2,3,17	*z coordinate of bumper #2 bearing pad - CCH.C.S., ft.
ZCG1	1,2,3,8,5	*z coordinate of capsule c.g. - Z.R.C.S., ft.
ZETA	1,2,3,8,13	*Ground slope, radians
ZJ3(6)	3,8	z coordinate of couch strut - couch end - CCH.C.S., ft.
ZJ30(6)	2	*z coordinate of couch strut - couch end - CCH.C.S., ft.
ZK1(6)	3,8	z coordinate of couch strut - capsule end - CAP.C.S., ft.
ZK10(6)	2	*z coordinate of couch strut - capsule end - Z.R.C.S., ft.
ZL1(8)	3,8	z coordinate of shield strut - capsule end - CAP.C.S., ft.
ZL10(8)	2	*z coordinate of shield strut - capsule end - Z.R.C.S., ft.
ZMIN	2,3	*Minimum z coordinate of rough surface - F.C.S., ft.
ZM2(8)	3,8	z coordinate of shield strut - shield end - H.S.C.S., ft.
ZM20(8)	2	*z coordinate of shield strut - shield end - H.S.C.S., ft.

NOTES:

* Denotes Input Data

F.C.S. - Space Fixed Coordinate System

Z.R.C.S. - Zero Reference Coordinate System

CAP.C.S. - Capsule Coordinate System

CCH.C.S. - Couch Coordinate System

H.S.C.S. - Heat Shield Coordinate System

TABLE 2-2 INPUT DATA CARD FORMAT

Col. 1-7 Ident.	8-11 Card No.	11-20 Data	21-30 Data	31-40 Data	41-50 Data	51-60 Data	61-70 Data
	1	RXVELΦ	RYVELΦ	RZVELΦ	WXΦ	WYΦ	WZΦ
	2	ZETA	CAPMΦ	CCHM	HSDMΦ	XΦRIG	
	3	UXX	UYX	UZZ	UXY	UYZ	UXZ
	4	UCXX	UCYY	UCZZ	UCXY	UCYZ	UCXZ
	5	USXX	USYY	USZZ	PSIΦ	THTAΦ	PHIΦ
	6	HEATA	HEATB	HC	ETA	XMAX	XMIN
	7	XL1Φ(1)	YL1Φ(1)	ZL1Φ(1)	XM2Φ(1)	YM2Φ(1)	ZM2Φ(1)
	8	XL1Φ(2)	YL1Φ(2)	ZL1Φ(2)	XM2Φ(2)	YM2Φ(2)	ZM2Φ(2)
	9	XL1Φ(3)	YL1Φ(3)	ZL1Φ(3)	XM2Φ(3)	YM2Φ(3)	ZM2Φ(3)
	10	XL1Φ(4)	YL1Φ(4)	ZL1Φ(4)	XM2Φ(4)	YM2Φ(4)	ZM2Φ(4)
	11	XL1Φ(5)	YL1Φ(5)	ZL1Φ(5)	XM2Φ(5)	YM2Φ(5)	ZM2Φ(5)
	12	XL1Φ(6)	YL1Φ(6)	ZL1Φ(6)	XM2Φ(6)	YM2Φ(6)	ZM2Φ(6)
	13	XL1Φ(7)	YL1Φ(7)	ZL1Φ(7)	XM2Φ(7)	YM2Φ(7)	ZM2Φ(7)
	14	XL1Φ(8)	YL1Φ(8)	ZL1Φ(8)	XM2Φ(8)	YM2Φ(8)	ZM2Φ(8)
	15	XK1Φ(1)	YK1Φ(1)	ZK1Φ(1)	XJ3Φ(1)	YJ3Φ(1)	ZJ3Φ(1)
	16	XK1Φ(2)	YK1Φ(2)	ZK1Φ(2)	XJ3Φ(2)	YJ3Φ(2)	ZJ3Φ(2)
	17	XK1Φ(3)	YK1Φ(3)	ZK1Φ(3)	XJ3Φ(3)	YJ3Φ(3)	ZJ3Φ(3)
	18	XK1Φ(4)	YK1Φ(4)	ZK1Φ(4)	XJ3Φ(4)	YJ3Φ(4)	ZJ3Φ(4)
	19	XK1Φ(5)	YK1Φ(5)	ZK1Φ(5)	XJ3Φ(5)	YJ3Φ(5)	ZJ3Φ(5)
	20	XK1Φ(6)	YK1Φ(6)	ZK1Φ(6)	XJ3Φ(6)	YJ3Φ(6)	ZJ3Φ(6)
	21	PLGNΦF	PK	FPXΦ	FPYΦ	FPZΦ	PHTE
	22	PXVELΦ	PYVELΦ	PZVELΦ	APX1Φ	APY1Φ	APZ1Φ
	23	XCG1	YCG1	ZCG1			
	24	CTJKΦ	CTLMΦ	SHCJKT	SHCLMT	SHCJK	SHCLM
	25	IP	IT	IS	JK	LM	
	26	HSX1Φ	HSY1	HSZ1	HGX1	HCY1	HCZ1
	27	JKDAMP	LMDAMP	VISJK	VISLM	HSCG2Φ	XPMAX
	28	DT	TMAX	DTP	SERNΦ	IACCEL	NΦHS
	29	IRET	GNDMU		Q	JJMAX	QC
	30	KA1	A2	A3	A4	A5	A7
	31	CAP(1,1)	CAP(1,2)	CAP(1,3)	CAP(1,4)	CAP(1,5)	CAP(1,6)
	32	CAP(2,1)	CAP(2,2)	CAP(2,3)	CAP(2,4)	CAP(2,5)	CAP(2,6)
	33	CAP(3,1)	CAP(3,2)	CAP(3,3)	CAP(3,4)	CAP(3,5)	CAP(3,6)
	34	CCH(1,1)	CCH(1,2)	CCH(1,3)	CCH(1,4)	CCH(1,5)	CCH(1,6)
	35	CCH(2,1)	CCH(2,2)	CCH(2,3)	CCH(2,4)	CCH(2,5)	CCH(2,6)
	36	CCH(3,1)	CCH(3,2)	CCH(3,3)	CCH(3,4)	CCH(3,5)	CCH(3,6)
	37	SLGTH(1,1)	FC(1,1)	SLGTH(1,2)	FC(1,2)	SLGTH(1,3)	FC(1,3)
	38	SLGTH(1,4)	FC(1,4)	SLGTH(1,5)	FC(1,5)	SLGTH(1,6)	FC(1,6)
	39	SLGTH(2,1)	FC(2,1)	SLGTH(2,2)	FC(2,2)	SLGTH(2,3)	FC(2,3)
	40	SLGTH(2,4)	FC(2,4)	SLGTH(2,5)	FC(2,5)	SLGTH(2,6)	FC(2,6)
	41	SLGTH(3,1)	FC(3,1)	SLGTH(3,2)	FC(3,2)	SLGTH(3,3)	FC(3,3)
	42	SLGTH(3,4)	FC(3,4)	SLGTH(3,5)	FC(3,5)	SLGTH(3,6)	FC(3,6)
	43	CΦEF(1,1)	CΦEF(1,2)	CΦEF(1,3)	CΦEF(1,4)	CΦEF(1,5)	CΦEF(1,6)
	44	CΦEF(1,7)	CΦEF(1,8)				
	45	CΦEF(2,1)	CΦEF(2,2)	CΦEF(2,3)	CΦEF(2,4)	CΦEF(2,5)	CΦEF(2,6)
	46	CΦEFT(1,1)	CΦEFT(1,2)	CΦEFT(1,3)	CΦEFT(1,4)	CΦEFT(1,5)	CΦEFT(1,6)
	47	CΦEFT(1,7)	CΦEFT(1,8)				
	48	CΦEFT(2,1)	CΦEFT(2,2)	CΦEFT(2,3)	CΦEFT(2,4)	CΦEFT(2,5)	CΦEFT(2,6)
	49	NRR	ALTZ	ALTY	ALTZ	BLNG	
	50	RRX1(1)	RRY1(1)	RRZ1(1)	RRX2(1)	RRY2(1)	RRZ2(1)
	51	RRX1(2)	RRY1(2)	RRZ1(2)	RRX2(2)	RRY2(2)	RRZ2(2)
	52	RRX1(3)	RRY1(3)	RRZ1(3)	RRX2(3)	RRY2(3)	RRZ2(3)
	53	RRX1(4)	RRY1(4)	RRZ1(4)	RRX2(4)	RRY2(4)	RRZ2(4)
	54	XB13	YB13	ZB13	XB23	YB23	ZB23
	55	BDEF(1)	BΦR(1)	BDEF(2)	BΦR(2)	BDEF(3)	BΦR(3)
	56	BDEF(4)	BΦR(4)	BDEF(5)	BΦR(5)	BDEF(6)	BΦR(6)
	61	CAPDEF(1)	CAPΦR(1)	CAPDEF(2)	CAPΦR(2)	CAPDEF(3)	CAPΦR(3)
	62	CAPDEF(4)	CAPΦR(4)	CAPDEF(5)	CAPΦR(5)	CAPDEF(6)	CAPΦR(6)
	63	CAPDEF(7)	CAPΦR(7)	CAPDEF(8)	CAPΦR(8)	CAPDEF(9)	CAPΦR(9)

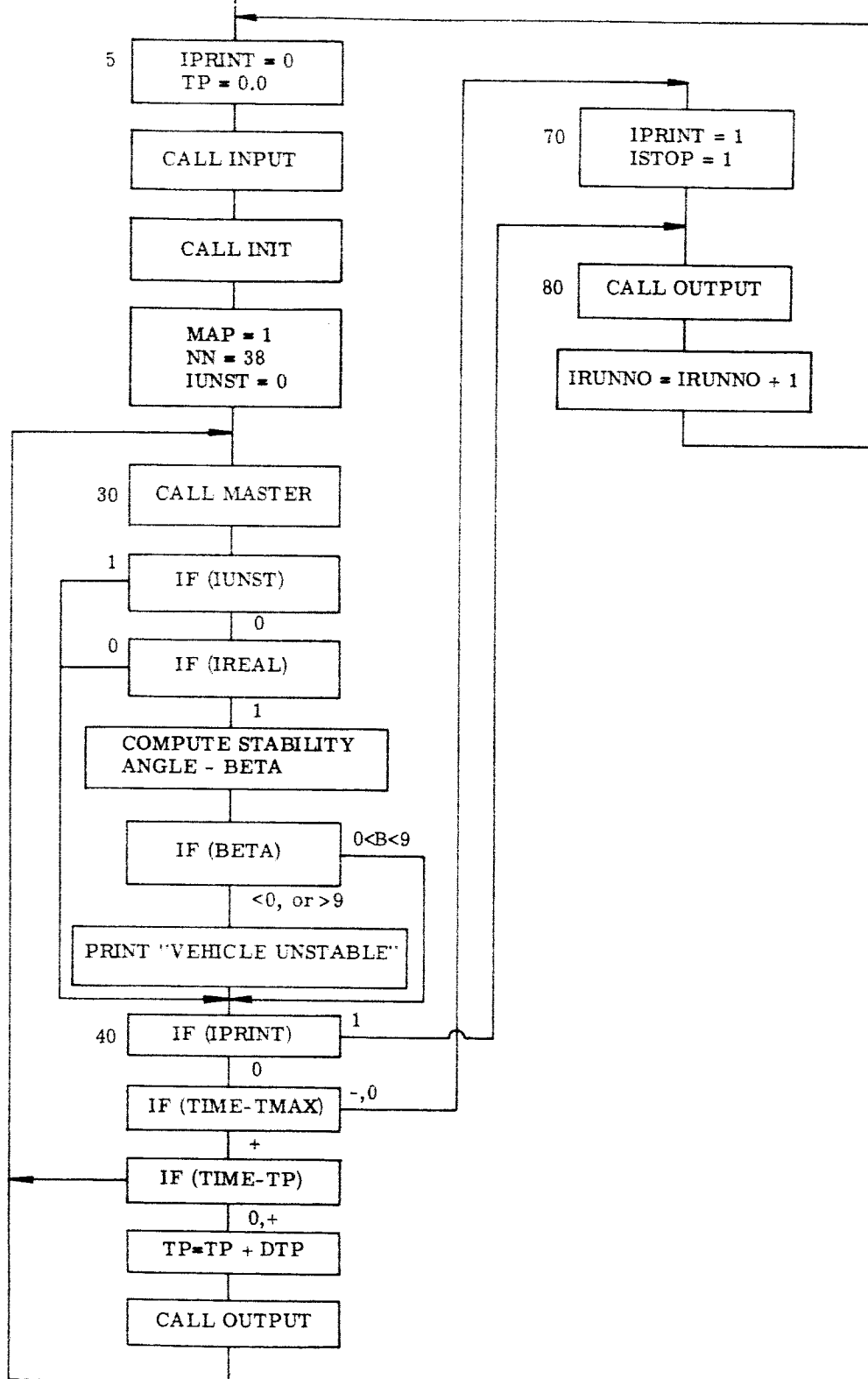
TABLE 2-2 INPUT DATA CARD FORMAT (CONT.)

Col. 1-7 Ident.	8-11 Card No.	11-20 Data	21-30 Data	31-40 Data	41-50 Data	51-60 Data	61-70 Data
	64	CAPDEF(10)	CAPFOR(10)	CAPDEF(11)	CAPFOR(11)	CAPDEF(12)	CAPFOR(12)
	65	CAPDEF(13)	CAPFOR(13)	CAPDEF(14)	CAPFOR(14)	CAPDEF(15)	CAPFOR(15)
	66	CAPDEF(16)	CAPFOR(16)	CAPDEF(17)	CAPFOR(17)	CAPDEF(18)	CAPFOR(18)
	67	CAPDEF(19)	CAPFOR(19)	CAPDEF(20)	CAPFOR(20)	CAPDEF(21)	CAPFOR(21)
	68	GMA(2)	AGMA(2)	BGMA(2)	GMA(3)	AGMA(3)	BGMA(3)
	69	GMA(4)	AGMA(4)	BGMA(4)	GMA(5)	AGMA(5)	BGMA(5)
	70	SLRHØ	SØILE	SLPHI	CKPHIC	NAA	CMU
	71	AA(1)	BB(1)	AA(2)	BB(2)	AA(3)	BB(3)
	72	AA(4)	BB(4)	AA(5)	BB(5)	AA(6)	BB(6)
	73	AA(7)	BB(7)	AA(8)	BB(8)	AA(9)	BB(9)
	74	FFLM(1)	FFLM(2)	FFLM(3)	FFLM(4)	FFLM(5)	FFLM(6)
	75	FFLM(7)	FFLM(8)				
	76	FFJK(1)	FFJK(2)	FFJK(3)	FFJK(4)	FFJK(5)	FFJK(6)
	77	FFLMT(1)	FFLMT(2)	FFLMT(3)	FFLMT(4)	FFLMT(5)	FFLMT(6)
	78	FFLMT(7)	FFLMT(8)				
	79	FFJKT(1)	FFJKT(2)	FFJKT(3)	FFJKT(4)	FFJKT(5)	FFJKT(6)
	81	DEFL(1,J,1)	FØRCE(1,J,1)	DEFL(1,J,2)	FØRCE(1,J,2)	DEFL(1,J,3)	FØRCE(1,J,3)
	82	DEFL(1,J,4)	FØRCE(1,J,4)	DEFL(1,J,5)	FØRCE(1,J,5)	DEFL(1,J,6)	FØRCE(1,J,6)
	83	DEFL(2,J,1)	FØRCE(2,J,1)	DEFL(2,J,2)	FØRCE(2,J,2)	DEFL(2,J,3)	FØRCE(2,J,3)
	84	DEFL(2,J,4)	FØRCE(2,J,4)	DEFL(2,J,5)	FØRCE(2,J,5)	DEFL(2,J,6)	FØRCE(2,J,6)
	85	DEFL(3,J,1)	FØRCE(3,J,1)	DEFL(3,J,2)	FØRCE(3,J,2)	DEFL(3,J,3)	FØRCE(3,J,3)
	86	DEFL(3,J,4)	FØRCE(3,J,4)	DEFL(3,J,5)	FØRCE(3,J,5)	DEFL(3,J,6)	FØRCE(3,J,6)
	87	DEFL(4,J,1)	FØRCE(4,J,1)	DEFL(4,J,2)	FØRCE(4,J,2)	DEFL(4,J,3)	FØRCE(4,J,3)
	88	DEFL(4,J,4)	FØRCE(4,J,4)	DEFL(4,J,5)	FØRCE(4,J,5)	DEFL(4,J,6)	FØRCE(4,J,6)
	89	DEFL(5,J,1)	FØRCE(5,J,1)	DEFL(5,J,2)	FØRCE(5,J,2)	DEFL(5,J,3)	FØRCE(5,J,3)
	90	DEFL(5,J,4)	FØRCE(5,J,4)	DEFL(5,J,5)	FØRCE(5,J,5)	DEFL(5,J,6)	FØRCE(5,J,6)
	91	DEFL(6,J,1)	FØRCE(6,J,1)	DEFL(6,J,2)	FØRCE(6,J,2)	DEFL(6,J,3)	FØRCE(6,J,3)
	92	DEFL(6,J,4)	FØRCE(6,J,4)	DEFL(6,J,5)	FØRCE(6,J,5)	DEFL(6,J,6)	FØRCE(6,J,6)
	93	DEFL(7,J,1)	FØRCE(7,J,1)	DEFL(7,J,2)	FØRCE(7,J,2)	DEFL(7,J,3)	FØRCE(7,J,3)
	94	DEFL(7,J,4)	FØRCE(7,J,4)	DEFL(7,J,5)	FØRCE(7,J,5)	DEFL(7,J,6)	FØRCE(7,J,6)
	95	DEFL(8,J,1)	FØRCE(8,J,1)	DEFL(8,J,2)	FØRCE(8,J,2)	DEFL(8,J,3)	FØRCE(8,J,3)
	96	DEFL(8,J,4)	FØRCE(8,J,4)	DEFL(8,J,5)	FØRCE(8,J,5)	DEFL(8,J,6)	FØRCE(8,J,6)
	97	DEFL(9,J,1)	FØRCE(9,J,1)	DEFL(9,J,2)	FØRCE(9,J,2)	DEFL(9,J,3)	FØRCE(9,J,3)
	98	DEFL(9,J,4)	FØRCE(9,J,4)	DEFL(9,J,5)	FØRCE(9,J,5)	DEFL(9,J,6)	FØRCE(9,J,6)
	99	DEFL(10,J,1)	FØRCE(10,J,1)	DEFL(10,J,2)	FØRCE(10,J,2)	DEFL(10,J,3)	FØRCE(10,J,3)
	100	DEFL(10,J,4)	FØRCE(10,J,4)	DEFL(10,J,5)	FØRCE(10,J,5)	DEFL(10,J,6)	FØRCE(10,J,6)
	101	I	J				
	102	DEFL(I,J,1)	FØRCE(I,J,1)	DEFL(I,J,2)	FØRCE(I,J,2)	DEFL(I,J,3)	FØRCE(I,J,3)
	103	DEFL(I,J,4)	FØRCE(I,J,4)	DEFL(I,J,5)	FØRCE(I,J,5)	DEFL(I,J,6)	FØRCE(I,J,6)
	104	TYM(1,1)	THRR(1,1)	TYM(1,2)	THRR(1,2)	TYM(1,3)	THRR(1,3)
	105	TYM(1,4)	THRR(1,4)	TYM(1,5)	THRR(1,5)	TYM(1,6)	THRR(1,6)
	106	TYM(1,7)	THRR(1,7)	TYM(1,8)	THRR(1,8)	TYM(1,9)	THRR(1,9)
	107	TYM(2,1)	THRR(2,1)	TYM(2,2)	THRR(2,2)	TYM(2,3)	THRR(2,3)
	108	TYM(2,4)	THRR(2,4)	TYM(2,5)	THRR(2,5)	TYM(2,6)	THRR(2,6)
	109	TYM(2,7)	THRR(2,7)	TYM(2,8)	THRR(2,8)	TYM(2,9)	THRR(2,9)
	110	TYM(3,1)	THRR(3,1)	TYM(3,2)	THRR(3,2)	TYM(3,3)	THRR(3,3)
	111	TYM(3,4)	THRR(3,4)	TYM(3,5)	THRR(3,5)	TYM(3,6)	THRR(3,6)
	112	TYM(3,7)	THRR(3,7)	TYM(3,8)	THRR(3,8)	TYM(3,9)	THRR(3,9)
	113	TYM(4,1)	THRR(4,1)	TYM(4,2)	THRR(4,2)	TYM(4,3)	THRR(4,3)
	114	TYM(4,4)	THRR(4,4)	TYM(4,5)	THRR(4,5)	TYM(4,6)	THRR(4,6)
	115	TYM(4,7)	THRR(4,7)	TYM(4,8)	THRR(4,8)	TYM(4,9)	THRR(4,9)
	120	YMIN	DEY	NY	ZMIN	DEZ	NZ
	121	X(Y1,Z1)	X(Y1,Z2)	X(Y1,Z3)	X(Y1,Z4)	X(Y1,Z5)	X(Y1,Z6)
	122	X(Y1,Z7)	X(Y1,Z8)	X(Y1,Z9)	X(Y1,Z10)	X(Y2,Z1)	X(Y2,Z2)
	123	X(Y2,Z3)	X(Y2,Z4)	X(Y2,Z5)	X(Y2,Z6)	X(Y2,Z7)	X(Y2,Z8)

TABLE 2-3 INPUT DATA CARD FORMAT (CONCLUDED)

Col. 1-7 Ident.	8-11 Card No.	11-20 Data	21-30 Data	31-40 Data	41-50 Data	51-60 Data	61-70 Data
	124	X(Y2, Z9)	X(Y2, Z10)	X(Y3, Z1)	X(Y3, Z2)	X(Y3, Z3)	X(Y3, Z4)
	125	X(Y3, Z5)	X(Y3, Z6)	X(Y3, Z7)	X(Y3, Z8)	X(Y3, Z9)	X(Y3, Z10)
	126	X(Y4, Z1)	X(Y4, Z2)	X(Y4, Z3)	X(Y4, Z4)	X(Y4, Z5)	X(Y4, Z6)
	127	X(Y4, Z7)	X(Y4, Z8)	X(Y4, Z9)	X(Y4, Z10)	X(Y5, Z1)	X(Y5, Z2)
	128	X(Y5, Z3)	X(Y5, Z4)	X(Y5, Z5)	X(Y5, Z6)	X(Y5, Z7)	X(Y5, Z8)
	129	X(Y5, Z9)	X(Y5, Z10)	X(Y6, Z1)	X(Y6, Z2)	X(Y6, Z3)	X(Y6, Z4)
	130	X(Y6, Z5)	X(Y6, Z6)	X(Y6, Z7)	X(Y6, Z8)	X(Y6, Z9)	X(Y6, Z10)
	131	X(Y7, Z1)	X(Y7, Z2)	X(Y7, Z3)	X(Y7, Z4)	X(Y7, Z5)	X(Y7, Z6)
	132	X(Y7, Z7)	X(Y7, Z8)	X(Y7, Z9)	X(Y7, Z10)	X(Y8, Z1)	X(Y8, Z2)
	133	X(Y8, Z3)	X(Y8, Z4)	X(Y8, Z5)	X(Y8, Z6)	X(Y8, Z7)	X(Y8, Z8)
	134	X(Y8, Z9)	X(Y8, Z10)	X(Y9, Z1)	X(Y9, Z2)	X(Y9, Z3)	X(Y9, Z4)
	135	X(Y9, Z5)	X(Y9, Z6)	X(Y9, Z7)	X(Y9, Z8)	X(Y9, Z9)	X(Y9, Z10)
	136	X(Y10, Z1)	X(Y10, Z2)	X(Y10, Z3)	X(Y10, Z4)	X(Y10, Z5)	X(Y10, Z6)
	137	X(Y10, Z7)	X(Y10, Z8)	X(Y10, Z9)	X(Y10, Z9)	X(Y10, Z10)	

MAIN PROGRAM - APOLLO (01)



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000001 C
000002 C
000003 C
000004 C
000005 C THIS PROGRAM DESCRIBES THE ACTION OF THE APOLLO COMMAND MODULE &
000006 C ASTRONAUTS COUCH SYSTEM AND PROTECTIVE HEAT SHIELD DURING A
000007 C LANDING ON SOIL
000008 C
000009 C
000010 C
000011 C
000012 C
000013 C COMMON/L1A/RX0(1),RYC,RZC,RXVEL,RXVELC,RZVELC,PSIC,THTAC,PHIC,
000014 C 1XXC,1YYC,1ZC,RCXC,RCYC,RCZC,CXVELC,CYVELC,CZVELC,DUM1(6),RSX0,
000015 C 2RSY0,RSZ0,SVXVELC,SYVELC,SZVELC
000016 C
000017 C COMMON/L1B/XL10(8),YL10(8),ZL10(8),XM20(8),YM20(8),ZM20(8),
000018 C 1XJ30(6),1YJ30(6),1ZJ30(6),XK10(6),YK10(6),ZK10(6),FFXC,FPYC,FPZC,
000019 C 2FXVELC,PYVELC,PZVELC,CHLFC,CHJCO,CTLMO,CTJCO
000020 C
000021 C COMMON/L2/HEATA,HEATE,HSCG2,IP,IS,IT,UXX,UYX,UZZ,UCAX,UCYX,UCZZ,
000022 C 1USXX,USYY,USZZ,FCJK,FCLM,UXY,UYZ,UXZ,UCXY,UCXZ,UCYZ,HC,ETA,PLGNOF,
000023 C 2FK,JK,ILM,HSX1,HGX1,JKDAMP,LMDAMP,VISJK,VISLM
000024 C
000025 C COMMON/L3/RX(1),RY,RZ,RXVEL,RYVEL,RZVEL,PSI,THTA,PHI,WX,WY,WZ,RCX,
000026 C 1RCY,RCZ,RCXVEL,RCYVEL,RCZVEL,PSIC,THTAC,PHIC,WCX,WCY,WZ,RSX,RSY,
000027 C 2RSZ,HSXVEL,RSYVEL,RSZVEL,PSIS,THTAS,PHIS,WSX,WSY,WSZ
000028 C
000029 C COMMON/L3B/AX,AY,AZ,WDX,WLY,WLZ,ACX,ACY,ACZ,WDCX,WDCY,WDCZ,
000030 C 1ASX,ASY,ASZ,WDSX,WDSY,WDSZ
000031 C
000032 C
000033 C COMMON/L5A/DT,TMAX,IFRINT,TF,DTP,ISTOP,IRUNNO,ISERNQ
000034 C
000035 C COMMON/L5B/OLCMAX(6),OLCMIN(6),OLSMAX(6),OLSMIN(6),JC,JS,OLCB(6),
000036 C 1OLCL(6),OLSB(6),OLSL(6),OMACX(7),OMACY(7),OMACZ(7),OMAX(7),
000037 C 2CMAY(7),OMAZ(7),ODEL(10),ENGKE,OECS,ENGPE,OECS,OESEND,OESEIL,
000038 C 3OFFACT,OESEND,ENGKEF,NORING(10),ENGTOT,AX1,AY1,AZ1,ACX3,ACY3,ACZ3,
000039 C 4ASX2,ASY2,ASZ2,L1
000040 C
000041 C COMMON/L5C/ZETA,CAPH,CCHH,HSUM
000042 C
000043 C COMMON/L5D/IC,ISS,OFMAX(6),OFMIN(6),OFMAX(6),OFMIN(6),TSSQ(8),
000044 C 1TCSR(6),TOTSCR(6),TOTCCR(6)
000045 C
000046 C COMMON/L6A/SLJCO(6),SLLMC(8)
000047 C
000048 C COMMON/L6B/XL1(8),YL1(8),ZL1(8),XM2(8),YM2(8),ZM2(8),XJ3(6),
000049 C 1YJ3(6),ZJ3(6),XK1(6),YK1(6),ZK1(6),CXX,CXY,CXZ,CYX,CYY,CYZ,
000050 C 2CZX,CZY,CZZ,CCXX,CCXY,CCXZ,CCYX,CCYY,CCYZ,CCZX,CCZY,CCZZ
000051 C
000052 C COMMON/L7A/QSX(8),QSY(8),QS2(8),QKX,FSGX,FSGY,FSGZ,TSGX,TSGY,TSGZ,
000053 C 1AREA,AREAM
000054 C
000055 C COMMON/L7B/QX(8),QY(8),QZ(8),QSQP(8),QSHT,QFC(8),QCH(8),QSH,
000056 C 1QSF(6),QFF,QVIS,QDAMP,QFX,QFY,QFZ,QTX1,QTY1,QTZ1,JKLM,QTSX2,
000057 C 2QTSY2,QTSZ2,QTCX3,QTCY3,QTCZ3,N,FORP(8),FHCG(8),SO(8),QCHT(8),
000058 C 3QSAT(8),QSD(8),SQ(8),QRGX,QRGY,QRGZ,QVGX,QVGY,QVGZ,QWGX,QWGY,QWGZ
000059 C
000060 C COMMON/L1TB/D11,D12,D13,L21,D22,D23,D31,D32,D33,DS11,DS12,DS13,
000061 C 1DS21,DS22,DS23,DS31,DS32,DS33,DC11,DC12,DC13,DC21,DC22,DC23,
000062 C 2DC31,DC32,DC33
000063 C
000064 C COMMON/L9A/IREAL
000065 C
000066 C COMMON/L9B/SHCJX,SHCJY,SHCLM,SHCLMT,CTJX,CTLM,XCRIG
000067 C
000068 C COMMON/L10/EX(10),EY(10,50),EZ(10,50),NI(10),A(10),CHS,Q,K,
000069 C 1RMC(10),DEFL(10,50,6),FORCE(10,50,6),GNDMU,AEL
000070 C
000071 C COMMON/L11/AA1(3,6),AA3(3,6),CAP(3,6),CCH(3,6),IACCEL
000072 C COMMON/L12/T(1000),SFAC,NN,KA1,A2,A3,A4,A5,A7,MAP
000073 C
000074 C COMMON/L13/SLGTH(3,6),FC(3,6),COEF(2,8),COEFT(2,8),XMAX,XMIN,GC,
000075 C 1NS,FFLM(8),FFLMT(8),FFJX(6),FFJY(6),FFC(8),FFT(8),IRET

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000076      COMMON/L14/PVEL(6)
000077      COI MUN/L15/FCGX,FCGY,FCGZ,TCGX1,TCGY1,TCGZ1,PREV,YCG,ZCG:
000078      1CAFEA,1CAREAM
000079      COMMON/L17/CAPFOR(21),CAPDEF(21),JUMAX
000080      COI MUN/M1/FORUK(6),SLUK(2),CHUKT(6),CHUK(6),SRUKT(6),SRUK(6),
000081      1SLUK(6),VELUK(6),FORLM(6),SLLM(6),CHLMT(6),CHLM(6),SRLMT(6),
000082      2SRLM(6),SDLM(6),VELLN(F),DNAX(10,50),DELMAX(12,55),SACC,SVEL,
000083      3SDEL,FKNEE(10,50)
000084      COI MUN/L19/NOHS,HSY1,HSZ1,ALTZ,ALTY,ALTZ,RRX1(6),RRY1(6),RRZ1(6),
000085      1RRX2(6),RRY2(6),RRZ2(6),HRR,THRR(6,10),TYM(6,10),CFRX(6),CPRY(6),
000086      2CRFZ(6),HCY1,HCZ1
000087      COMMON/L20/XB13,YB13,ZB13,XB23,YB23,ZB23,YRP1,YRP2,BLNG,1BST1MX,
000088      1BST2,X,BMPNRG,BDEF(6),EFCR(6),FBX,FBY,FBZ,TBX,TBY,TBZ,TBCX,TBCY,
000089      2TBCZ,RRNRG
000090      COMMON/L21/FAKE(100),YMIN,DEY,NY,ZMIN,DEZ,NZ,RSURF(3,11,11),XPMAX
000091      COI MUN/L22/PXVEL,PYVEL,PZVEL,APX1,APY1,APZ1,RPX,RPY,RPZ,FPPX,FPPY,
000092      1FPFZ,TPFX1,TPPY1,TPFZ1,AFX10,APY10,APZ10,PHITE,IPAF, XCG1,YCG1,
000093      2ZCC1
000094      COMMON/L23/HSX10,HSCG20,UXXC,UYYC,UZZO,CAPMO,HSDMO,RRX10(6),
000095      1RRY10(6),RRZ10(6)
000096      EQUIVALENCE(TIME,T(39)),(GRYVEL,T(5)),(GRZVEL,T(6))
000097      C
000098      C
000099      5 IF(IINT=0
000100      TP=0.0
000101      C
000102      CALL INPUT
000103      C
000104      CALL INIT
000105      C
000106      HAF=1
000107      NN=30
000108      IUNST=0
000109      C
000110      30 CALL MASTER
000111      C
000112      IF(IUNST.GT. 0) GO TO 40
000113      IF(INEAL)40,40,290
000114      C
000115      290 COSZ=COS(ZETA)
000116      SINZ=SIN(ZETA)
000117      AG=-L11*COSZ+D31*SINZ
000118      EG=-L12*COSZ+D32*SINZ
000119      CG=-L13*COSZ+D33*SINZ
000120      C
000121      COMPUTE VELOCITY VECTOR
000122      IF(ABS(GRYVEL)-0.0001)300,300,310
000123      300 IF(ABS(GRZVEL)-0.0001)380,380,310
000124      310 AV=D21*GRYVEL+D31*GRZVEL
000125      BV=D22*GRYVEL+D32*GRZVEL
000126      CV=D23*GRYVEL+D33*GRZVEL
000127      C
000128      DEFINE STABILITY FLANE
000129      AN=BG*CV-CG*BV
000130      BN=CG*AV-AG*CV
000131      CN=AG*BV-BG*AV
000132      C
000133      DETERMINE STABILITY ANGLE
000134      YOFF=YCG1-HSY1
000135      ZOFF=ZCG1-HSZ1
000136      XR=HSX1+HSCG2-XCG1
000137      IF(BN*BN+CN*CN-0.0001)380,380,315
000138      315 BB=(AN*BN*XR-BN*CN*ZOFF+CN*CN*YOFF)/(BN*BN+CN*CN)
000139      CC=((AN*XR-CN*ZOFF)*(AN*XR-CN*ZOFF)+CN*CN*YOFF*YOFF-CN*CN*HEATB*
000140      1 HEATB)/(BN*BN+CN*CN)
000141      RAD=BB*BB-CC
000142      IF(RAD)370,320,320
000143      320 IF(ABS(BV)-0.0001)321,321,322
000144      321 YK=0.0
000145      GO TO 323
000146      322 YR=-BB+BV*SQRT(RAD)/ABS(BV)
000147      323 IF(ABS(CV)-0.0001)324,324,325
000148      324 ZR=0.0
000149      GO TO 326
000150      325 ZR=(CV/ABS(CV))*SQRT(HEATB*HEATB-(YK+YOFF)*(YK+YOFF))-ZOFF
000151      326 CUSB=(AG*XR+BG*YR+CG*ZR)/SQRT(XR*XR+YR*YR+ZR*ZR)
000152      IF(ABS(AN)-0.0001)340,340,326
000153      326 IF(BG*ZR-CG*YR)330,340,330

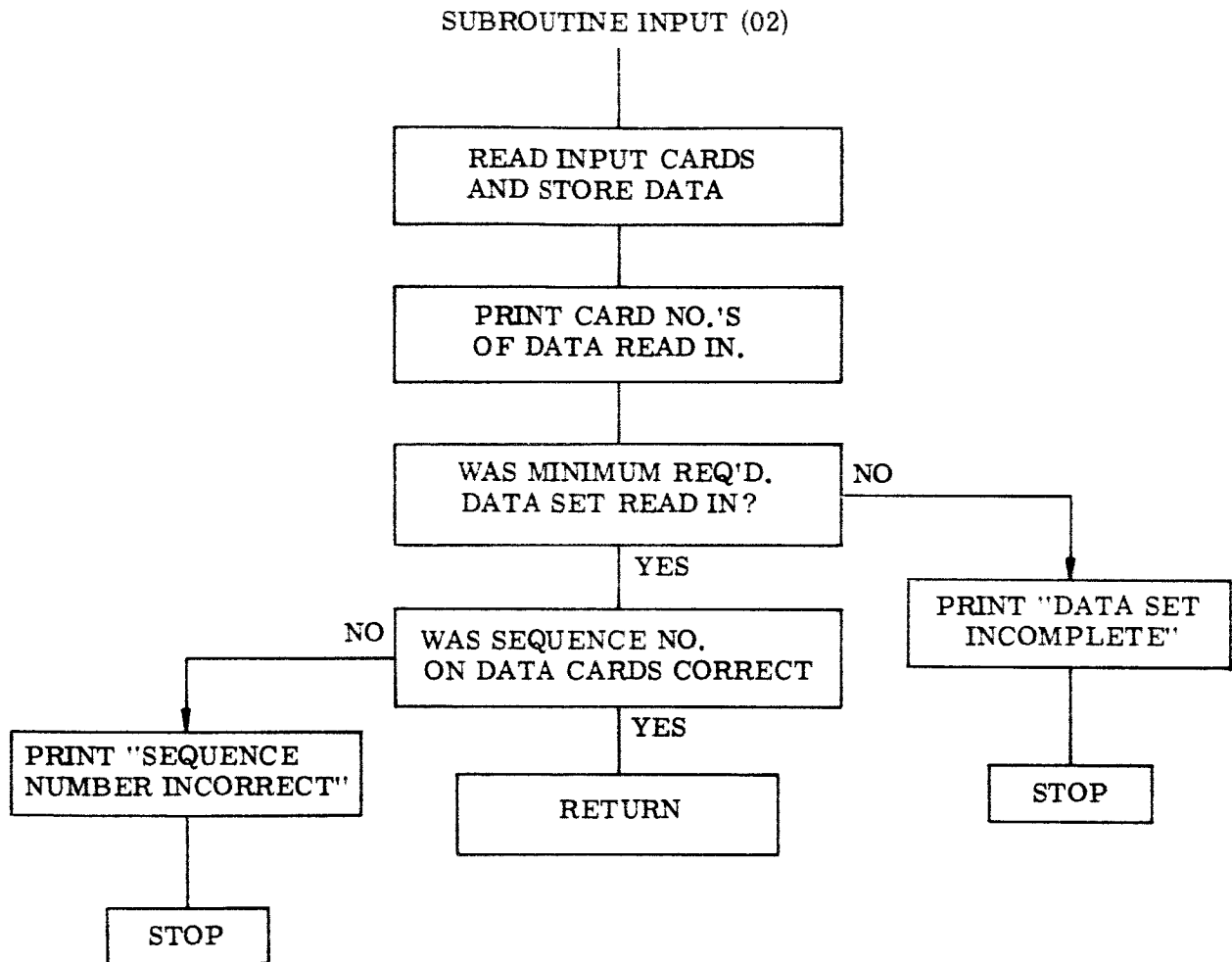
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000151      BETA=ACOS(COSB)*AN*AES(BG*ZR-CG*YR)/(AES(AN)*(EG*ZR-CG*YR))
000152      GO TO 390
000153      340 IF(ABS(BN)-0.0001)355,355,345
000154      345 IF(CG*XR-AG*ZR)350,355,350
000155      350 BETA=ACOS(COSB)*BN*AES(CG*XR-AG*ZR)/(AES(BN)*(CG*XR-AG*ZR))
000156      GO TO 390
000157      355 IF(AG*YR-BG*XR)360,360,360
000158      360 BETA=ACOS(COSB)*CN*AES(AG*YR-BG*XR)/(AES(CN)*(AG*YR-BG*XR))
000159      GO TO 390
000160      370 BETA=10.0
000161      GO TO 390
000162      380 MINR=HEATB-SCRT(YOFF*YOFF+ZOFF*ZOFF)
000163      BETA=ACOS(ABS(XR)/SCRT(XR*XR+MINR*MINR))
000164      390 CONTINUE
000165      IF(BETA .GT. 0 .AND. BETA .LT. 9.0) GO TO 40
000166      IUNST=1
000167      IF(BETA .GT. 9.0) GO TO 35
000168      WRITE(IP,9001) BETA,TIME
000169      GO TO 40
000170      35 WRITE(IP,9002)TIME
000171      40 IF(IPRINT .GT. 0) GO TO 60
000172      C
000173      IPRINT=0
000174      C
000175      IF(TIME .GT. TMAX) GO TO 70
000176      IF(TIME .LT. TP) GO TO 30
000177      TP=TF+DTF
000178      C
000179      CALL OUTPUT
000180      C
000181      GO TO 30
000182      C
000183      70 IPRINT=1
000184      ISTOP=1
000185      80 CALL OUTPUT
000186      IRLN0=IRUNNC+1
000187      GO TO 5
000188      9001 FORMAT(1H1//////////,29H VEHICLE IS UNSTABLE. BETA = ,F10.5,24H TI
000189      ME WHEN THIS OCCURS =,F10.5)
000190      9002 FORMAT(1H1//////////,36H VEHICLE IS UNSTABLE IN A ROLL MODE.,24H T
000191      ME WHEN THIS OCCURS =,F10.5)
000192      ENCL

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000001      SUBROUTINE INPUT
000002      C
000003      C      THIS SUBROUTINE READS THE INPUT DATA FROM SEQUENCED DATA CARDS.
000004      C
000005      C      THE DATA CARDS MUST BE PREPARED IN THE FOLLOWING FORMAT .
000006      C
000007      C      DATA CARD FORMAT
000008      C COLUMN 1-6      7-10      11-20      21-30      31-40      41-50      51-60      61-70
000009      C VARIABLE      CARD      DATA      DATA      DATA      DATA      DATA
000010      C NAME      SEQUENCE
000011      C OR I.D.      RT,JUST.
000012      C
000013      COMMON/L1A/RX0(1),RY0,RZ0,RXVEL0,RYVEL0,RZVEL0,PS10,THTAC,PHIC,
000014      1XX0,1YY0,1WZ0,RCX0,RCY0,RCZ0,CXVEL0,CYVEL0,CZVEL0,DUM1(6),RSX0,
000015      2RSY0,RSZ0, SXVEL0,SYVEL0,SZVEL0
000016      C
000017      COMMON/L1B/XL10(6),YL10(6),ZL10(6),XM20(6),YM20(6),ZM20(6),
000018      1XJ30(6),YJ30(6),ZJ30(6),XK10(6),YK10(6),ZK10(6),FFX0,FFY0,FPZ0,
000019      2FXVEL0,PYVEL0,PZVEL0,CHLMO,CHJKO,CTLMO,CTJKO
000020      COMMON/L2/HEATA,HEATE,HSCG2,IP,IS,IT,UXX,UYX,UZZ,UCXX,UCYY,UCZZ,
000021      1USXX,USYY,USZZ,FCUK,FCLM,UXY,UYZ,UXZ,UCXY,UCXZ,UCYZ,HC,ETA,PLGNOF,
000022      2FK,JK,LM,HSX1,HGX1,JKDAMP,LNDAMP,VISJK,VISLM
000023      COMMON/L5A/DT,THAX,IFRINT,TF,DTP,ISTOP,IRUNNO,ISERN0
000024      COMMON/L5B/OLCMAX(6),OLCMIN(6),OLSMAX(6),OLSMIN(6),JC,JS,OLCB(6),
000025      1OLCL(6),OLSB(6),OLSL(6),OMACX(7),OMACY(7),OMACZ(7),OMAX(7),
000026      2CMAY(7),OMAZ(7),ODEL(10),ENGKE,OECS,ENGPE,CESS,OESEND,OESEIL,
000027      3CFRACT,CEGND,ENGKEF,NORING(10),ENGTOT,AX1,AY1,AZ1,ACX3,ACY3,ACZ3,
000028      4ASX2,ASY2,ASZ2,L1
000029      COMMON/L5C/ZETA,CAPH,CCH,HSUM
000030      COMMON/L9B/SHCJ,SHCJKT,SHCLM,SHCLMT,CTJK,CTLM,XORIG
000031      COMMON/L10/EX(10),EY(10,50),EZ(10,50),NI(10),A(10),CHS,Q,K,
000032      1RHC(10),DEFL(10,50,6),FORCE(10,50,6),GNDMU,AEL
000033      COMMON/L11/AA1(3,6),AA3(3,6),CAP(3,6),CCH(3,6),IACCEL
000034      COMMON/L12/T(1000),SPACE,NN,KA1,A2,A3,A4,A5,A7,MAP
000035      COMMON/L13/SLGTH(3,6),FC(3,6),COEF(2,6),COEFT(2,6),XMAX,XMIN,GC,
000036      1NS,FFLM(6),FFLMT(6),FFJK(6),FFJKT(6),FFC(6),FFT(6),IRET
000037      COMMON/L17/CAPFOR(21),CAPDEF(21),JJMAX
000038      COMMON/L18/SLRMO,SOILE,SLFHI,CKPHIC,NAA,AA(9),BB(9),TESOIL,
000039      1GMA(5),AGMA(5),BGMA(5),CHU,SUMCR
000040      C
000041      COMMON/M1/FORJK(6),SLJK(6),CHJKT(6),CHJK(6),SRJKT(6),SRJK(6),
000042      1SDJK(6),VELJK(6),FORLM(6),SLLM(6),CHLMT(6),CHLM(6),SRLMT(6),
000043      2SRLM(6),SOLM(6),VELLM(6),LMAX(10,50),DELMAX(12,55),SACC,SVEL,
000044      3SLEEL,PKNEE(10,50)
000045      COMMON/L19/NCHS,HSY1,HSZ1,ALT,ALTY,ALTZ,RRX1(6),RRY1(6),RRZ1(6),
000046      1RRX2(6),RRY2(6),RRZ2(6),KRR,THRR(6,10),TYM(6,10),CRRX(6),CRRY(6),
000047      2CRFZ(6),HCY1,HCZ1
000048      COMMON/L20/XB13,YB13,ZB13,XB23,YB23,ZB23,YRP1,YRP2,BLNG,BST1MX,
000049      1BST2MX,BMPNRG,BDEF(6),BFCR(6),FBX,FBY,FBZ,TBX,TBY,TBZ,TBCX,TBCY,
000050      2TBCZ,RRNRG
000051      COMMON/L21/FAKE(100),YMIN,DEY,NY,ZMIN,DEZ,NZ,RSURF(3,11,11),XPMAX
000052      COMMON/L22/PXVEL,PYVEL,PZVEL,APX1,APY1,APZ1,RPX,RPY,RPZ,FPPX,FPPY,
000053      1FPZ,TFPX1,TFPY1,TFPZ1,AFX10,APY10,APZ10,PHITE,IPARA,XCG1,YCG1,
000054      2ZCG1
000055      COMMON/L23/HSX10,HSCG20,UXX0,UYX0,UZZ0,CAPMO,HSOMO,RRX10(6),
000056      1RRY10(6),RRZ10(6)
000057      DIMENSION DUMMY(6),MMMM(150),ITEST(150)
000058      C
000059      DATA (ITEST(I),I=1,150)/150*0/,JTEST(0)/
000060      C
000061      C
000062      C
000063      MM=0
000064      C
000065      1000 READ(5,9001)MMM,(DUMMY(I),I=1,6)
000066      C
000067      IF(MMM.LT. 0) GO TO 400
000068      IF(MMM.EG. 0) GO TO 200
000069      MM=MM+1
000070      ITEST(MM)=1
000071      C
000072      MMM(MM)=MMM
000073      IF(MMM.GT. 67 .AND. MMM.LT. 80) GO TO 500

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000074      IF(MMM .GT. 60 .AND. MMM .LT. 68) GO TO 61
000075      IF(MMM .GT. 30 .AND. MMM .LT. 34) GO TO 31
000076      IF(MMM .GT. 33 .AND. MMM .LT. 37) GO TO 32
000077      IF(MMM .EQ. 120) GO TO 120
000078      IF(MMM .GT. 120 .AND. MMM .LT. 138) GO TO 121
000079      IF(MMM .GT. 60 .AND. MMM .LT. 116) GO TO 600
000080      IF(MMM .GT. 56) GO TO 300
000081
000082      C
000083      GO TO (1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,
000084      23,24,25,26,27,28,29,30,300,300,300,300,300,300,37,38,39,40,41,
000085      242,43,44,45,46,47,48,49,50,51,52,53,54,55,56),MMM
000086      500 M2=MMM-67
000087      GO TO (68,69,70,71,71,71,74,75,76,77,78,79),M2
000088      600 M1=MMM-80
000089      GO TO (81,82,81,82,81,82,81,82,81,82,81,82,81,82,81,
000090      162,101,102,103,104,105,106,107,108,109,110,111,112,113,114,115),
000091      2M1
000092      C
000093      1 RXVELC=DUMMY(1)
000094      KYVELC=DUMMY(2)
000095      KZVELC=DUMMY(3)
000096      WXC=DUMMY(4)
000097      WYC=DUMMY(5)
000098      WZC=DUMMY(6)
000099      GO TO 1000
000100      C
000101      2 ZETA=DUMMY(1)
000102      CAFMC=DUMMY(2)
000103      CCFMC=DUMMY(3)
000104      HSEMC=DUMMY(4)
000105      XCFIS=DUMMY(5)
000106      GO TO 1000
000107      C
000108      3 UX10=DUMMY(1)
000109      UY10=DUMMY(2)
000110      UZ10=DUMMY(3)
000111      UAX=DUMMY(4)
000112      UXZ=DUMMY(5)
000113      UYZ=DUMMY(6)
000114      GO TO 1000
000115      C
000116      4 UCXX=DUMMY(1)
000117      UCYY=DUMMY(2)
000118      UCZZ=DUMMY(3)
000119      UCXY=DUMMY(4)
000120      UCXZ=DUMMY(5)
000121      UCYZ=DUMMY(6)
000122      GO TO 1000
000123      C
000124      5 USAX=DUMMY(1)
000125      USYY=DUMMY(2)
000126      USZZ=DUMMY(3)
000127      FS10=DUMMY(4)
000128      TH10=DUMMY(5)
000129      FH10=DUMMY(6)
000130      GO TO 1000
000131      C
000132      6 FEATA=DUMMY(1)
000133      HEATE=DUMMY(2)
000134      HC=DUMMY(3)
000135      ETA=DUMMY(4)
000136      XMAX=DUMMY(5)
000137      XMIN=DUMMY(6)
000138      GO TO 1000
000139      C
000140      7 XL10(1)=DUMMY(1)
000141      YL10(1)=DUMMY(2)
000142      ZL10(1)=DUMMY(3)
000143      XM20(1)=DUMMY(4)
000144      YM20(1)=DUMMY(5)
000145      ZM20(1)=DUMMY(6)
000146      GO TO 1000
000147      C
000148      8 XL10(2)=DUMMY(1)
000149      YL10(2)=DUMMY(2)

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000149      ZL10(2)=DUMMY(3)
000150      XM20(2)=DUMMY(4)
000151      YM20(2)=DUMMY(5)
000152      ZM20(2)=DUMMY(6)
000153      GO TO 1000
000154      C
000155      9  XL10(3)=DUMMY(1)
000156      YL10(3)=DUMMY(2)
000157      ZL10(3)=DUMMY(3)
000158      XM20(3)=DUMMY(4)
000159      YM20(3)=DUMMY(5)
000160      ZM20(3)=DUMMY(6)
000161      GO TO 1000
000162      C
000163      10 XL10(4)=DUMMY(1)
000164      YL10(4)=DUMMY(2)
000165      ZL10(4)=DUMMY(3)
000166      XM20(4)=DUMMY(4)
000167      YM20(4)=DUMMY(5)
000168      ZM20(4)=DUMMY(6)
000169      GO TO 1000
000170      C
000171      11 XL10(5)=DUMMY(1)
000172      YL10(5)=DUMMY(2)
000173      ZL10(5)=DUMMY(3)
000174      XM20(5)=DUMMY(4)
000175      YM20(5)=DUMMY(5)
000176      ZM20(5)=DUMMY(6)
000177      GO TO 1000
000178      C
000179      12 XL10(6)=DUMMY(1)
000180      YL10(6)=DUMMY(2)
000181      ZL10(6)=DUMMY(3)
000182      XM20(6)=DUMMY(4)
000183      YM20(6)=DUMMY(5)
000184      ZM20(6)=DUMMY(6)
000185      GO TO 1000
000186      C
000187      13 XL10(7)=DUMMY(1)
000188      YL10(7)=DUMMY(2)
000189      ZL10(7)=DUMMY(3)
000190      XM20(7)=DUMMY(4)
000191      YM20(7)=DUMMY(5)
000192      ZM20(7)=DUMMY(6)
000193      GO TO 1000
000194      14 XL10(8)=DUMMY(1)
000195      YL10(8)=DUMMY(2)
000196      ZL10(8)=DUMMY(3)
000197      XM20(8)=DUMMY(4)
000198      YM20(8)=DUMMY(5)
000199      ZM20(8)=DUMMY(6)
000200      GO TO 1000
000201      C
000202      15 XK10(1)=DUMMY(1)
000203      YK10(1)=DUMMY(2)
000204      ZK10(1)=DUMMY(3)
000205      XJ30(1)=DUMMY(4)
000206      YJ30(1)=DUMMY(5)
000207      ZJ30(1)=DUMMY(6)
000208      GO TO 1000
000209      C
000210      16 XK10(2)=DUMMY(1)
000211      YK10(2)=DUMMY(2)
000212      ZK10(2)=DUMMY(3)
000213      XJ30(2)=DUMMY(4)
000214      YJ30(2)=DUMMY(5)
000215      ZJ30(2)=DUMMY(6)
000216      GO TO 1000
000217      C
000218      17 XK10(3)=DUMMY(1)
000219      YK10(3)=DUMMY(2)
000220      ZK10(3)=DUMMY(3)
000221      XJ30(3)=DUMMY(4)
000222      YJ30(3)=DUMMY(5)
000223      ZJ30(3)=DUMMY(6)

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000224      GO TO 1000
000225      C
000226      18 XK10(4)=DUMMY(1)
000227      YK10(4)=DUMMY(2)
000228      ZK10(4)=DUMMY(3)
000229      XJ30(4)=DUMMY(4)
000230      YJ30(4)=DUMMY(5)
000231      ZJ30(4)=DUMMY(6)
000232      GO TO 1000
000233      C
000234      19 XK10(5)=DUMMY(1)
000235      YK10(5)=DUMMY(2)
000236      ZK10(5)=DUMMY(3)
000237      XJ30(5)=DUMMY(4)
000238      YJ30(5)=DUMMY(5)
000239      ZJ30(5)=DUMMY(6)
000240      GO TO 1000
000241      C
000242      20 XK10(6)=DUMMY(1)
000243      YK10(6)=DUMMY(2)
000244      ZK10(6)=DUMMY(3)
000245      XJ30(6)=DUMMY(4)
000246      YJ30(6)=DUMMY(5)
000247      ZJ30(6)=DUMMY(6)
000248      GO TO 1000
000249      C
000250      21 FLGNCF=DUMMY(1)
000251      FK=DUMMY(2)
000252      FXO=DUMMY(3)
000253      FPO=DUMMY(4)
000254      FPZ=DUMMY(5)
000255      FHITL=DUMMY(6)
000256      GO TO 1000
000257      C
000258      22 FXVELC=DUMMY(1)
000259      FYVELC=DUMMY(2)
000260      FZVELC=DUMMY(3)
000261      APX1C=DUMMY(4)
000262      APY1C=DUMMY(5)
000263      APZ1C=DUMMY(6)
000264      GO TO 1000
000265      C
000266      23 XCC1=DUMMY(1)
000267      YCC1=DUMMY(2)
000268      ZCC1=DUMMY(3)
000269      GO TO 1000
000270      C
000271      24 CTXK=DUMMY(1)
000272      CTLMC=DUMMY(2)
000273      SHCJKT=DUMMY(3)
000274      SHCLNT=DUMMY(4)
000275      SHCJKB=DUMMY(5)
000276      SHCLMB=DUMMY(6)
000277      GO TO 1000
000278      C
000279      25 IP=DUMMY(1)
000280      IT=DUMMY(2)
000281      IS=DUMMY(3)
000282      JK=DUMMY(4)
000283      LM=DUMMY(5)
000284      GO TO 1000
000285      C
000286      26 HSA1C=DUMMY(1)
000287      HSY1=DUMMY(2)
000288      HSZ1=DUMMY(3)
000289      HXA1=DUMMY(4)
000290      HCY1=DUMMY(5)
000291      HCZ1=DUMMY(6)
000292      GO TO 1000
000293      C
000294      27 JK[AMP=DUMMY(1)
000295      LMC[AMP=DUMMY(2)
000296      VISJK=DUMMY(3)
000297      VISLM=DUMMY(4)
000298      HSCG20=DUMMY(5)

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000299      XPFAA=DUMMY(6)
000300      GO TO 1000
000301
000302      C      28 DT=DUMMY(1)
000303      TMAX=DUMMY(2)
000304      DTF=DUMMY(3)
000305      ISERNO=DUMMY(4)
000306      IACCEL=DUMMY(5)
000307      NOFS=DUMMY(6)
000308      GO TO 1000
000309
000310      C      29 IRET=DUMMY(1)
000311      GNLMD=DUMMY(2)
000312      G=DUMMY(4)
000313      JUMAX=DUMMY(5)
000314      GC=DUMMY(6)
000315      GO TO 1000
000316
000317      C      30 KA1=DUMMY(1)
000318      A2=DUMMY(2)
000319      A3=DUMMY(3)
000320      A4=DUMMY(4)
000321      A5=DUMMY(5)
000322      A7=DUMMY(6)
000323      GO TO 1000
000324
000325      C      31 M1=MM-30
000326      CAF(M1,1)=DUMMY(1)
000327      CAF(M1,2)=DUMMY(2)
000328      CAF(M1,3)=DUMMY(3)
000329      CAF(M1,4)=DUMMY(4)
000330      CAF(M1,5)=DUMMY(5)
000331      CAF(M1,6)=DUMMY(6)
000332      GO TO 1000
000333
000334      C      32 M1=MM-33
000335      CCH(M1,1)=DUMMY(1)
000336      CCH(M1,2)=DUMMY(2)
000337      CCH(M1,3)=DUMMY(3)
000338      CCH(M1,4)=DUMMY(4)
000339      CCH(M1,5)=DUMMY(5)
000340      CCH(M1,6)=DUMMY(6)
000341      GO TO 1000
000342
000343      C      37 SLGTH(1,1)=DUMMY(1)
000344      FC(1,1)=DUMMY(2)
000345      SLGTH(1,2)=DUMMY(3)
000346      FC(1,2)=DUMMY(4)
000347      SLGTH(1,3)=DUMMY(5)
000348      FC(1,3)=DUMMY(6)
000349      GO TO 1000
000350
000351      C      38 SLGTH(1,4)=DUMMY(1)
000352      FC(1,4)=DUMMY(2)
000353      SLGTH(1,5)=DUMMY(3)
000354      FC(1,5)=DUMMY(4)
000355      SLGTH(1,6)=DUMMY(5)
000356      FC(1,6)=DUMMY(6)
000357      GO TO 1000
000358
000359      C      39 SLGTH(2,1)=DUMMY(1)
000360      FC(2,1)=DUMMY(2)
000361      SLGTH(2,2)=DUMMY(3)
000362      FC(2,2)=DUMMY(4)
000363      SLGTH(2,3)=DUMMY(5)
000364      FC(2,3)=DUMMY(6)
000365      GO TO 1000
000366
000367      C      40 SLGTH(2,4)=DUMMY(1)
000368      FC(2,4)=DUMMY(2)
000369      SLGTH(2,5)=DUMMY(3)
000370      FC(2,5)=DUMMY(4)
000371      SLGTH(2,6)=DUMMY(5)
000372      FC(2,6)=DUMMY(6)
000373      GO TO 1000
000374
000375      C

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000375      41 SLGTH(3,1)=DUMMY(1)
000376      FC(3,1)=DUMMY(2)
000377      SLGTH(3,2)=DUMMY(3)
000378      FC(3,2)=DUMMY(4)
000379      SLGTH(3,3)=DUMMY(5)
000380      FC(3,3)=DUMMY(6)
000381      GO TO 1000
000382      C
000383      42 SLGTH(3,4)=DUMMY(1)
000384      FC(3,4)=DUMMY(2)
000385      SLGTH(3,5)=DUMMY(3)
000386      FC(3,5)=DUMMY(4)
000387      SLGTH(3,6)=DUMMY(5)
000388      FC(3,6)=DUMMY(6)
000389      GO TO 1000
000390      C
000391      43 COEF(1,1)=DUMMY(1)
000392      COEF(1,2)=DUMMY(2)
000393      COEF(1,3)=DUMMY(3)
000394      COEF(1,4)=DUMMY(4)
000395      COEF(1,5)=DUMMY(5)
000396      COEF(1,6)=DUMMY(6)
000397      GO TO 1000
000398      C
000399      44 COEF(1,7)=DUMMY(1)
000400      COEF(1,8)=DUMMY(2)
000401      GO TO 1000
000402      C
000403      45 COEF(2,1)=DUMMY(1)
000404      COEF(2,2)=DUMMY(2)
000405      COEF(2,3)=DUMMY(3)
000406      COEF(2,4)=DUMMY(4)
000407      COEF(2,5)=DUMMY(5)
000408      COEF(2,6)=DUMMY(6)
000409      GO TO 1000
000410      C
000411      46 COEFT(1,1)=DUMMY(1)
000412      COEFT(1,2)=DUMMY(2)
000413      COEFT(1,3)=DUMMY(3)
000414      COEFT(1,4)=DUMMY(4)
000415      COEFT(1,5)=DUMMY(5)
000416      COEFT(1,6)=DUMMY(6)
000417      GO TO 1000
000418      C
000419      47 COEFT(1,7)=DUMMY(1)
000420      COEFT(1,8)=DUMMY(2)
000421      GO TO 1000
000422      C
000423      48 COEFT(2,1)=DUMMY(1)
000424      COEFT(2,2)=DUMMY(2)
000425      COEFT(2,3)=DUMMY(3)
000426      COEFT(2,4)=DUMMY(4)
000427      COEFT(2,5)=DUMMY(5)
000428      COEFT(2,6)=DUMMY(6)
000429      GO TO 1000
000430      C
000431      49 NRK=DUMMY(1)
000432      ALTX=DUMMY(2)
000433      ALTY=DUMMY(3)
000434      ALTZ=DUMMY(4)
000435      BLNG=DUMMY(5)
000436      GO TO 1000
000437      C
000438      50 RXX1C(1)=DUMMY(1)
000439      RRY1C(1)=DUMMY(2)
000440      RRZ1C(1)=DUMMY(3)
000441      RXX2(1)=DUMMY(4)
000442      RRY2(1)=DUMMY(5)
000443      RRZ2(1)=DUMMY(6)
000444      GO TO 1000
000445      C
000446      51 RXX1C(2)=DUMMY(1)
000447      RRY1C(2)=DUMMY(2)
000448      RRZ1C(2)=DUMMY(3)
000449      RXX2(2)=DUMMY(4)

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000450      RRY2(2)=DUMMY(5)
000451      RR22(2)=DUMMY(6)
000452      GO TO 1000
000453      C
000454      52 RRA10(3)=DUMMY(6)
000455      RRY10(3)=DUMMY(2)
000456      RR210(3)=DUMMY(3)
000457      RRA2(3)=DUMMY(4)
000458      RRY2(3)=DUMMY(5)
000459      RR22(3)=DUMMY(6)
000460      GO TO 1000
000461      C
000462      53 RRA10(4)=DUMMY(1)
000463      RRY10(4)=DUMMY(2)
000464      RR210(4)=DUMMY(3)
000465      RRA2(4)=DUMMY(4)
000466      RRY2(4)=DUMMY(5)
000467      RR22(4)=DUMMY(6)
000468      GO TO 1000
000469      C
000470      54 XB13=DUMMY(1)
000471      YB13=DUMMY(2)
000472      ZB13=DUMMY(3)
000473      XB23=DUMMY(4)
000474      YB23=DUMMY(5)
000475      ZB23=DUMMY(6)
000476      GO TO 1000
000477      C
000478      55 EDEF(1)=DUMMY(1)
000479      BFOR(1)=DUMMY(2)
000480      BDEF(2)=DUMMY(3)
000481      EFOR(2)=DUMMY(4)
000482      EDEF(3)=DUMMY(5)
000483      BFOR(3)=DUMMY(6)
000484      GO TO 1000
000485      C
000486      56 BDEF(4)=DUMMY(1)
000487      BFOR(4)=DUMMY(2)
000488      BDEF(5)=DUMMY(3)
000489      BFOR(5)=DUMMY(4)
000490      BDEF(6)=DUMMY(5)
000491      BFOR(6)=DUMMY(6)
000492      GO TO 1000
000493      C
000494      61 M1=MMH-60
000495      CAFDEF(3*M1-2)=DUMMY(1)
000496      CAFFUR(3*M1-2)=DUMMY(2)
000497      CAFDEF(3*M1-1)=DUMMY(3)
000498      CAFFUR(3*M1-1)=DUMMY(4)
000499      CAFDEF(3*M1)=DUMMY(5)
000500      CAFFUR(3*M1)=DUMMY(6)
000501      GO TO 1000
000502      C
000503      68 GMA(2)= DUMMY(1)
000504      AGFA(2)=DUMMY(2)
000505      BGFA(2)=DUMMY(3)
000506      GMA(3)= DUMMY(4)
000507      AGFA(3)=DUMMY(5)
000508      BGFA(3)=DUMMY(6)
000509      GO TO 1000
000510      C
000511      69 GMA(4)= DUMMY(1)
000512      AGFA(4)=DUMMY(2)
000513      BGFA(4)=DUMMY(3)
000514      GMA(5)= DUMMY(4)
000515      AGFA(5)=DUMMY(5)
000516      BGFA(5)=DUMMY(6)
000517      GO TO 1000
000518      C
000519      70 SLRHL=DUMMY(1)
000520      SOLLE=DUMMY(2)

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000521      SLFH1=DUMMY(3)
000522      CKF H10=DUMMY(4)
000523      NAA=DUMMY(5)
000524      CML=DUMMY(6)
000525      GO TO 1000
000526      C
000527      71 AA(3*M2-11)=DUMMY(1)
000528      BB(3*M2-11)=DUMMY(2)
000529      AA(3*M2-10)=DUMMY(3)
000530      BB(3*M2-10)=DUMMY(4)
000531      AA(3*M2-9) =DUMMY(5)
000532      BB(3*M2-9) =DUMMY(6)
000533      GO TO 1000
000534      C
000535      74 FFLM(1)=DUMMY(1)
000536      FFLM(2)=DUMMY(2)
000537      FFLM(3)=DUMMY(3)
000538      FFLM(4)=DUMMY(4)
000539      FFLM(5)=DUMMY(5)
000540      FFLM(6)=DUMMY(6)
000541      GO TO 1000
000542      C
000543      75 FFLM(7)=DUMMY(1)
000544      FFLM(8)=DUMMY(2)
000545      GO TO 1000
000546      C
000547      76 FFJK(1)=DUMMY(1)
000548      FFJK(2)=DUMMY(2)
000549      FFJK(3)=DUMMY(3)
000550      FFJK(4)=DUMMY(4)
000551      FFJK(5)=DUMMY(5)
000552      FFJK(6)=DUMMY(6)
000553      GO TO 1000
000554      C
000555      77 FFLMT(1)=DUMMY(1)
000556      FFLMT(2)=DUMMY(2)
000557      FFLMT(3)=DUMMY(3)
000558      FFLMT(4)=DUMMY(4)
000559      FFLMT(5)=DUMMY(5)
000560      FFLMT(6)=DUMMY(6)
000561      GO TO 1000
000562      C
000563      78 FFLMT(7)=DUMMY(1)
000564      FFLMT(8)=DUMMY(2)
000565      GO TO 1000
000566      C
000567      79 FFJKT(1)=DUMMY(1)
000568      FFJKT(2)=DUMMY(2)
000569      FFJKT(3)=DUMMY(3)
000570      FFJKT(4)=DUMMY(4)
000571      FFJKT(5)=DUMMY(5)
000572      FFJKT(6)=DUMMY(6)
000573      GO TO 1000
000574      C
000575      81 M2=(M1+1)/2
000576      DEFL(M2,1,1)=DUMMY(1)
000577      FORCE(M2,1,1)=DUMMY(2)
000578      DEFL(M2,1,2)=DUMMY(3)
000579      FORCE(M2,1,2)=DUMMY(4)
000580      DEFL(M2,1,3)=DUMMY(5)
000581      FORCE(M2,1,3)=DUMMY(6)
000582      DO 501 I=2,50
000583      DO 501 J=1,3
000584      DEFL(M2,1,J)=DEFL(M2,1,J)
000585      501 FORCE(M2,1,J)=FORCE(M2,1,J)
000586      GO TO 1000
000587      C
000588      82 M2=M1/2
000589      DEFL(M2,1,4)=DUMMY(1)
000590      FORCE(M2,1,4)=DUMMY(2)
000591      DEFL(M2,1,5)=DUMMY(3)
000592      FORCE(M2,1,5)=DUMMY(4)
000593      DEFL(M2,1,6)=DUMMY(5)
000594      FORCE(M2,1,6)=DUMMY(6)
000595      DO 502 I=2,50

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000596          DO 502 J=4,6
000597          DEFL(M2,I,J)=DEFL(M2,I,J)
000598          FORCE(M2,I,J)=FORCE(M2,I,J)
000599          GO TO 1000
000600          101 I=DUMMY(1)
000601              J=DUMMY(2)
000602              GO TO 1000
000603      C
000604          102 DEFL(I,J,1)=DUMMY(1)
000605              FORCE(I,J,1)=DUMMY(2)
000606              DEFL(I,J,2)=DUMMY(3)
000607              FORCE(I,J,2)=DUMMY(4)
000608              DEFL(I,J,3)=DUMMY(5)
000609              FORCE(I,J,3)=DUMMY(6)
000610              GO TO 1000
000611      C
000612          103 DEFL(I,J,4)=DUMMY(1)
000613              FORCE(I,J,4)=DUMMY(2)
000614              DEFL(I,J,5)=DUMMY(3)
000615              FORCE(I,J,5)=DUMMY(4)
000616              DEFL(I,J,6)=DUMMY(5)
000617              FORCE(I,J,6)=DUMMY(6)
000618              GO TO 1000
000619      C
000620          104 TYF(1,1)=DUMMY(1)
000621              THER(1,1)=DUMMY(2)
000622              TYF(1,2)=DUMMY(3)
000623              THER(1,2)=DUMMY(4)
000624              TYF(1,3)=DUMMY(5)
000625              THER(1,3)=DUMMY(6)
000626              GO TO 1000
000627          105 TYF(1,4)=DUMMY(1)
000628              THER(1,4)=DUMMY(2)
000629              TYF(1,5)=DUMMY(3)
000630              THER(1,5)=DUMMY(4)
000631              TYF(1,6)=DUMMY(5)
000632              THER(1,6)=DUMMY(6)
000633              GO TO 1000
000634          106 TYF(1,7)=DUMMY(1)
000635              THER(1,7)=DUMMY(2)
000636              TYF(1,8)=DUMMY(3)
000637              THER(1,8)=DUMMY(4)
000638              TYF(1,9)=DUMMY(5)
000639              THER(1,9)=DUMMY(6)
000640              GO TO 1000
000641          107 TYF(2,1)=DUMMY(1)
000642              THER(2,1)=DUMMY(2)
000643              TYF(2,2)=DUMMY(3)
000644              THER(2,2)=DUMMY(4)
000645              TYF(2,3)=DUMMY(5)
000646              THER(2,3)=DUMMY(6)
000647              GO TO 1000
000648          108 TYF(2,4)=DUMMY(1)
000649              THER(2,4)=DUMMY(2)
000650              TYF(2,5)=DUMMY(3)
000651              THER(2,5)=DUMMY(4)
000652              TYF(2,6)=DUMMY(5)
000653              THER(2,6)=DUMMY(6)
000654              GO TO 1000
000655          109 TYF(2,7)=DUMMY(1)
000656              THER(2,7)=DUMMY(2)
000657              TYF(2,8)=DUMMY(3)
000658              THER(2,8)=DUMMY(4)
000659              TYF(2,9)=DUMMY(5)
000660              THER(2,9)=DUMMY(6)
000661              GO TO 1000
000662          110 TYF(3,1)=DUMMY(1)
000663              THER(3,1)=DUMMY(2)
000664              TYF(3,2)=DUMMY(3)
000665              THER(3,2)=DUMMY(4)
000666              TYF(3,3)=DUMMY(5)
000667              THER(3,3)=DUMMY(6)
000668              GO TO 1000
000669          111 TYF(3,4)=DUMMY(1)
000670              THER(3,4)=DUMMY(2)

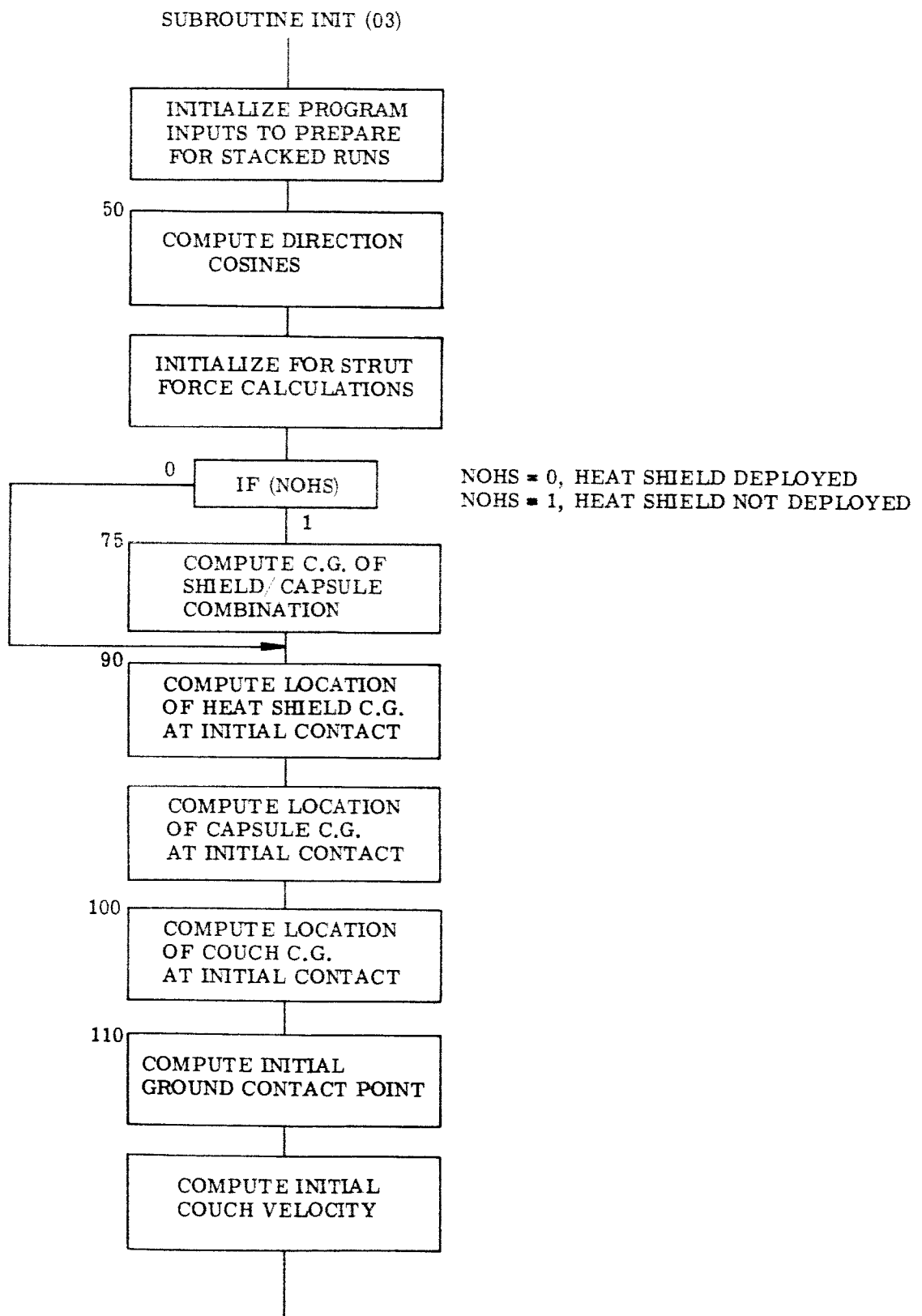
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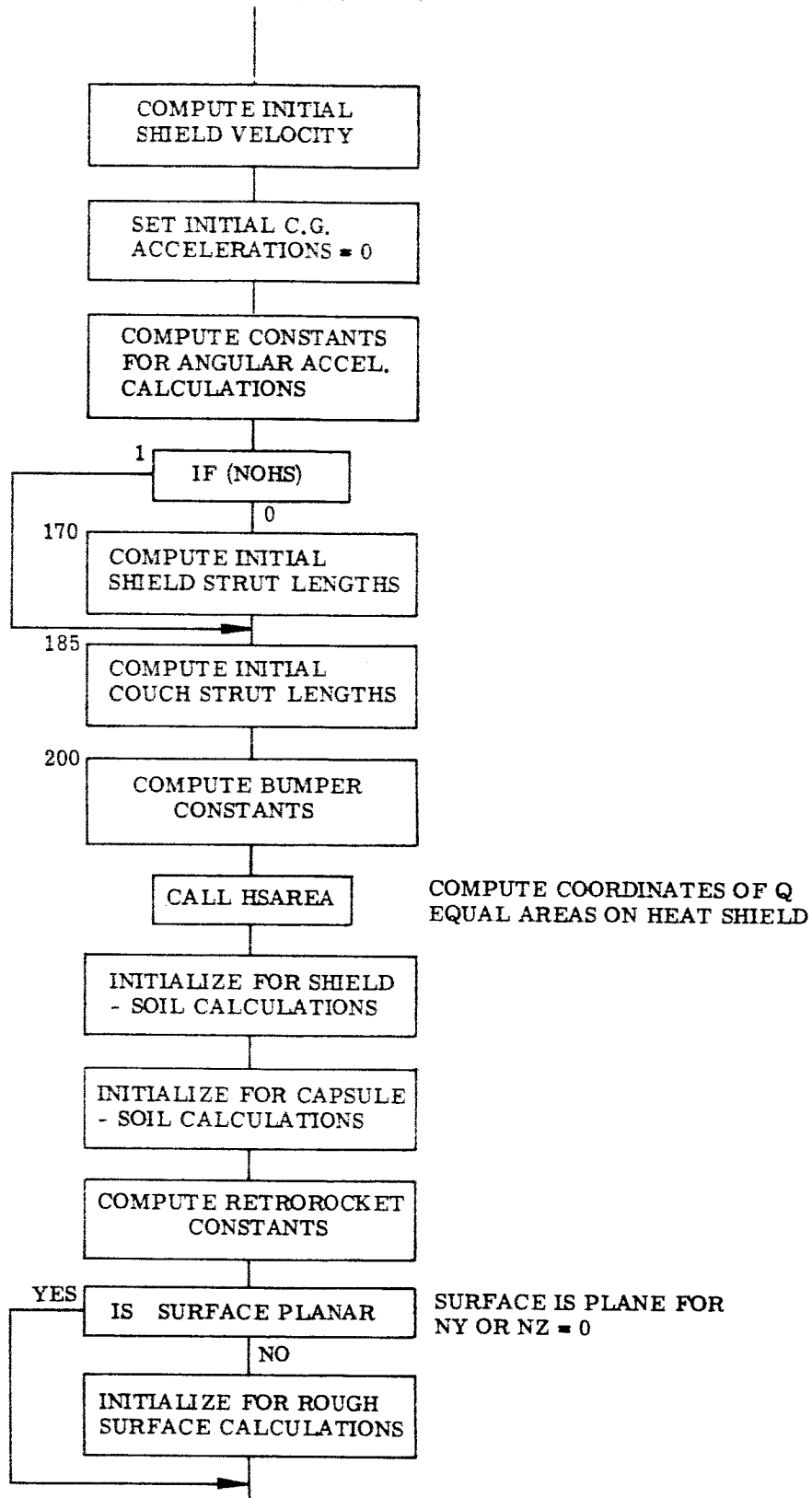
000671      TYR(3,5)=DUMMY(3)
000672      THRR(3,5)=DUMMY(4)
000673      TYR(3,6)=DUMMY(5)
000674      THRR(3,6)=DUMMY(6)
000675      GO TO 1000
000676 112 TYR(3,7)=DUMMY(1)
000677      THRR(3,7)=DUMMY(2)
000678      TYR(3,8)=DUMMY(3)
000679      THRR(3,8)=DUMMY(4)
000680      TYR(3,9)=DUMMY(5)
000681      THRR(3,9)=DUMMY(6)
000682      GO TO 1000
000683 113 TYR(4,1)=DUMMY(1)
000684      THRR(4,1)=DUMMY(2)
000685      TYR(4,2)=DUMMY(3)
000686      THRR(4,2)=DUMMY(4)
000687      TYR(4,3)=DUMMY(5)
000688      THRR(4,3)=DUMMY(6)
000689      GO TO 1000
000690 114 TYR(4,4)=DUMMY(1)
000691      THRR(4,4)=DUMMY(2)
000692      TYR(4,5)=DUMMY(3)
000693      THRR(4,5)=DUMMY(4)
000694      TYR(4,6)=DUMMY(5)
000695      THRR(4,6)=DUMMY(6)
000696      GO TO 1000
000697 115 TYR(4,7)=DUMMY(1)
000698      THRR(4,7)=DUMMY(2)
000699      TYR(4,8)=DUMMY(3)
000700      THRR(4,8)=DUMMY(4)
000701      TYR(4,9)=DUMMY(5)
000702      THRR(4,9)=DUMMY(6)
000703      GO TO 1000
000704 120 YMIN=DUMMY(1)
000705      LEY=DUMMY(2)
000706      NY=DUMMY(3)
000707      ZMIN=DUMMY(4)
000708      LEZ=DUMMY(5)
000709      NZ=DUMMY(6)
000710      GO TO 1000
000711 C
000712 121 M3=MMM-120
000713      FARE(M3*6-5)=DUMMY(1)
000714      FARE(M3*6-4)=DUMMY(2)
000715      FARE(M3*6-3)=DUMMY(3)
000716      FARE(M3*6-2)=DUMMY(4)
000717      FARE(M3*6-1)=DUMMY(5)
000718      FARE(M3*6)=DUMMY(6)
000719      GO TO 1000
000720 C
000721 C TEST IF COMPLETE SET OF INPUT IS PRESENT FIRST TIME PROGRAM IS RUN
000722 200 WRITE(6,9005)
000723      WRITE(6,9003)(MMM(I),I=1,MM)
000724      WRITE(6,9004)
000725      IF(JTEST.GT. 0) GO TO 220
000726      DO 202 I=1,49
000727 202 IF(ITEST(I).LT. 1) GO TO 250
000728      DO 204 I=54,56
000729 204 IF(ITEST(I).LT. 1) GO TO 250
000730      IF(ITEST(61).LT. 1) GO TO 250
000731      DO 206 I=70,71
000732 206 IF(ITEST(I).LT. 1) GO TO 250
000733      DO 208 I=81,82
000734 208 IF(ITEST(I).LT. 1) GO TO 250
000735      IF(ITEST(120).LT. 1) GO TO 250
000736      JTEST=1
000737 220 RETURN
000738 C
000739 250 WRITE(6,9006)I
000740      STCP
000741 C
000742 300 WRITE(6,9005)
000743      WRITE(6,9002)
000744      WRITE(6,9003)(MMM(I),I=1,MM)
000745      STCP

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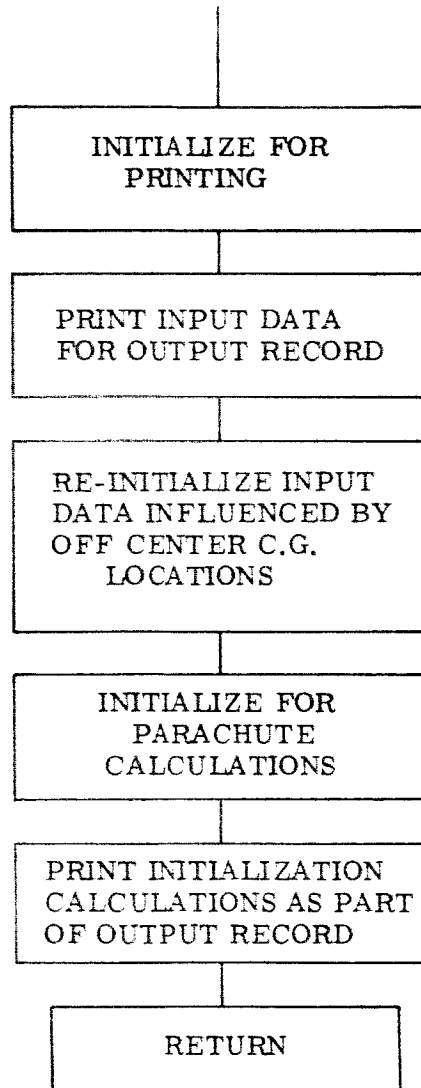
000746	400 STOP
000747	C
000748	9001 FORMAT(7X,I3,6E10.4)
000749	9002 FORMAT(60H INPUT CARD SEQUENCE NUMBER IS INCORRECT. CHECK YOUR
000750	1DATA)
000751	9003 FORMAT(24H NEW CARDS READ THIS RUN,26I4/, (24X,26I4))
000752	9004 FORMAT(1H0)
000753	9005 FORMAT(1H1)
000754	9006 FORMAT(59H ERROR -- ERROR -- INPUT DATA SET IS INCOMPLETE. CARD N
000755	10. 114.48H IS MISSING. INITIAL DATA SET MUST BE COMPLETE.)
000756	C
000757	C
000758	END



SUBROUTINE INIT (03)(CONT.)



SUBROUTINE INIT (03)(CONT.)



ELT INIT.1:660429: 75947

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000001      SUBROUTINE INIT
000002      C
000003      C
000004      C      THIS SUBROUTINE INITIALIZES THE PROGRAM BEFORE EACH RUN -- SETS
000005      C      THE VEHICLE ON THE SURFACE IN THE PROPER ORIENTATION AT TIME T = 0
000006      C      AND PRINTS A SUMMARY OF THE INPUT DATA
000007      C
000008      C
000009      COMMON/L1A/RXC(1),RYC,RZC,RXVEL,RXVELC,RZVELC,PSIC,THTAC,PHIO,
000010      1WXC,WYC,WZC,RCXC,RCYC,RCZC,CXVEL,CYVEL,CZVEL,CUM1(6),RSXO,
000011      2RSYO,RSZO,SVXVELC,SYVELC,SZVELC
000012      COMMON/L1B/XL10(6),YL10(6),ZL10(6),XM20(6),YM20(6),ZM20(6),
000013      1XJ30(6),YJ30(6),ZJ30(6),XK10(6),YK10(6),ZK10(6),FPXO,FPYO,FPZO,
000014      2PXVELC,PYVELC,PZVELC,CHLMC,CHJKO,CTLMO,CTJKO
000015      COMMON/L2/HEATA,HEATB,HSCG2,IP,IS,IT,UXX,UYX,UZZ,UCXX,UCYY,UCZZ,
000016      1USXX,USYY,USZZ,FCUK,FCLM,UXY,UYZ,UXZ,UCXY,UCXZ,UCYZ,HC,ETA,PLGNOF,
000017      2PK,JK,LM,HSX1,HXC1,JKDAMP,LMDAMP,VISJK,VISLM
000018      COMMON/L3/RX(1),RY,RZ,PXVEL,RYVEL,RZVEL,PSI,THTA,PHI,WX,WY,WZ,RCX,
000019      1RCY,RCZ,RCXVEL,RCYVEL,RCZVEL,PSIC,THTAC,PHIC,WCX,WCY,WZ,RSX,RSY,
000020      2RSZ,RSXVEL,RSYVEL,RSZVEL,FSIS,THTAS,PHIS,WSX,WSY,WSZ
000021      COMMON/L3B/AX,AY,AZ,WDX,WLY,WLZ,ACX,ACY,ACZ,WDCX,WDCY,WDCZ,
000022      1ASX,ASY,ASZ,WDSX,WDSY,WDSZ
000023      COMMON/L5A/DT,TMAX,IFRINT,TF,DTP,ISTOP,IRUNNO,ISERNO
000024      COMMON/L5B/OLCMAX(6),OLCMIN(6),OLSMAX(6),OLSMIN(6),JC,JS,OLCB(6),
000025      1OLCL(6),OLSB(6),OLSL(6),OMAX(7),OMACY(7),OMACZ(7),OMAX(7),
000026      2OMAY(7),OMAZ(7),OCEL(10),ENGKE,OEC5,ENGPE,CESS,OESOND,OESOIL,
000027      3OFFALT,DEGND,ENGKEF,NORING(10),ENGTOT,AX1,AY1,AZ1,ACX3,ACY3,ACZ3,
000028      4ASX2,ASY2,ASZ2,L1
000029      COMMON/L5C/ZETA,CAPM,CCH,HSDM
000030      COMMON/L5D/IC,ISS,OFCLMAX(6),OFCLMIN(6),CFSMAX(8),CFSMIN(8),TSSL(8),
000031      1TCSQ(6),TOTSCR(6),TOTCCR(6)
000032      COMMON/L6A/SLUKO(6),SLLMC(6)
000033      COMMON/L6B/XL1(8),YL1(8),ZL1(8),XM2(8),YM2(8),ZM2(8),XJ3(6),
000034      1YJ3(6),ZJ3(6),XK1(6),YK1(6),ZK1(6),CXX,CXY,CXZ,CYX,CYY,CYZ,
000035      2CZXX,CZY,CZZ,CCXX,CCXY,CCXZ,CCYX,CCYY,CCYZ,CCZX,CCZY,CCZZ
000036      COMMON/L7A/QSX(8),GSY(8),GSZ(8),OKT,FSGX,FSGY,FSGZ,TSGX,TSGY,TSGZ,
000037      1AREAM,AREAM
000038      COMMON/L1STB/D11,D12,D13,D21,D22,D23,D31,D32,D33,DS11,DS12,DS13,
000039      1DS21,DS22,DS23,DS31,LS32,LS33,DC11,DC12,DC13,DC21,DC22,DC23,
000040      2DC31,DC32,DC33
000041      C
000042      C
000043      COMMON/L9B/SHCUK,SHCUKT,SHCLM,SHCLMT,CTJK,CTLM,XORIG
000044      COMMON/L10/EX(10),EY(10,50),EZ(10,50),NI(10),A(10),CHS,Q,K,
000045      1RHC(10),DEFL(10,50,6),FORCE(10,50,6),GNDMU,AEL
000046      COMMON/L11/AA1(3,6),AA3(3,6),CAP(3,6),CCH(3,6),IACCEL
000047      COMMON/L12/T(100),SFACE,NK,KA1,A2,A3,A4,A5,A7,MAP
000048      COMMON/L13/SLGTH(3,6),FC(3,6),COEF(2,8),COEFT(2,8),XMAX,XMIN,GC,
000049      1NS,FFLM(8),FFLMT(6),FFUK(6),FFC(8),FFT(8),IRET
000050      COMMON/L14/PVEL(8)
000051      COMMON/L16/FCGX,FCGY,FCGZ,TCGX1,TCGY1,TCGZ1,PREV,YCG,ZCG,
000052      1CAREAM,CAREAM
000053      COMMON/L17/CAPFOR(21),CAPDEF(21),JJMAX
000054      COMMON/L18/SLRHO,SOILE,SLPHI,CKPHIC,NAA,AA(9),BB(9),TESOIL,
000055      1GMA(5),AGMA(5),BGMA(5),CML,SUMCR
000056      COMMON/M1/FORUK(6),SLUK(6),CHUKT(6),CHUK(6),SRUKT(6),SRUK(6),
000057      1SDUK(6),VELUK(6),FORLM(8),SLLM(8),CHLMT(6),CHLM(8),SRLMT(8),
000058      2SRLM(6),SOLM(8),VELLM(8),DMAX(10,50),DELMAX(12,55),SACC,SVEL,
000059      3SLEEL,PKNEE(10,50)
000060      COMMON/L19/NOHS,HSY1,HSZ1,ALTA,ALTY,ALTZ,RRX1(6),RRY1(6),RRZ1(6),
000061      1RRX2(6),RRY2(6),RRZ2(6),RRR,THRR(6,10),TYM(6,10),CRRX(6),CRRY(6),
000062      2CRRZ(6),HCY1,HCZ1
000063      COMMON/L20/XB13,YB13,ZB13,XB23,YB23,ZB23,YRP1,YRP2,BLNG,BST1MX,
000064      1BST2MX,BMPNRG,BDEF(6),BFCR(6),FBX,FBY,FBZ,TBX,TBY,TBZ,TBCX,TBCY,
000065      2TBCZ,RRNRG
000066      COMMON/L21/FAKE(100),YMIN,DEY,NY,ZMIN,DEZ,NZ,RSURF(3,11,11),XPMAX
000067      COMMON/L22/PXVEL,PYVEL,PZVEL,APX1,APY1,APZ1,RPX,RPY,RPZ,FPPX,FPPY,
000068      1FPFZ,TPPX1,TPPY1,TPPZ1,AFX10,APY10,APZ10,PHITE,IPARA,XCG1,YCG1,
000069      2ZCG1
000070      COMMON/L23/HSX10,HSCG20,UXXO,UYXO,UZZO,CAPMO,HSDMO,RRX10(6),
000071      1RRY10(6),RRZ10(6)
000072      C      EQUIVALENCE (TIME,T(39))
000073      C

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000074      C      INITIALIZING THE PROGRAM INPUTS
000075      C
000076      IF (NRK1) 520, 520, 500
000077      500 DO 510 I=1, NRK
000078          KRX1(I)=RRX10(I)
000079          KRY1(I)=RRY10(I)
000080      510 KRZ1(I)=RRZ10(I)
000081      520 HSA1=HSX10
000082          HSG2=HSG20
000083          LXA=LX0
000084          LYY=LY0
000085          LZZ=LZ0
000086          CAFM=CAPM0
000087          HSLM=HSDM0
000088      550 TIME=0.0
000089          KPF=0
000090      C
000091          IF (DTP .LT. DT) DTP=DT
000092      1 DO 5 I=4, 12
000093      5 KX(I)=RX0(I)
000094      10 DO 20 I=1, 84
000095      20 AL1(I)=XL10(I)
000096          FFX=FPX0
000097          FPY=FPY0
000098          FPZ=FPZ0
000099          PXVEL=PXVELO
000100          PYVEL=PYVELO
000101          PZVEL=PZVELO
000102
000103          CTLM=CTLM0
000104          CTJK=CTJK0
000105          PHIS=PHI
000106          PHIC=PHI
000107          PSIS=PSI
000108          PSIC=PSI
000109          THTAL=THTA
000110          THTAS=THTA
000111      C
000112      C      DETERMINE TRIG. CONSTANTS
000113      C
000114      40 COSPSI=COS(PSI)
000115          COSTH=COS(THTA)
000116          COSPHI=COS(PHI)
000117          SINPSI=SIN(PSI)
000118          SINTH=SIN(THTA)
000119          SINPHI=SIN(PHI)
000120      C
000121      C      DIRECTION COSINES
000122      C
000123      50 D11=COSPSI*COSTH
000124          D12=COSPSI*SINTH*SINPHI-SINPSI*COSPHI
000125          D13=SINPSI*SINPHI+COSPSI*SINTH*COSPHI
000126          D21=SINPSI*COSTH
000127          D22=COSPSI*COSPHI+SINPSI*SINTH*SINPHI
000128          D23=SINPSI*SINPHI-COSPSI*SINTH*COSPHI
000129          D31=-SINTH
000130          D32=COSTH*SINPHI
000131          D33=COSTH*COSPHI
000132      C
000133      C      INITIALIZE FOR STRUT FORCE CALCULATIONS
000134      C
000135      DO 60 I=1, JK
000136          TOTCCR(I)=0.0
000137          L=1
000138          IF (I .GT. 2) GO TO 51
000139          IF (SLGTH(2, L) .LT. 0.1E-04) L=2
000140          IF (SLGTH(2, L) .LT. 0.1E-04) GO TO 330
000141          CHJK(I)=FC(2, L)/SLGTH(2, L)*COEF(2, I)
000142          CHJK(I)=FC(2, L)/SLGTH(2, L)*COEF(2, I)
000143          GO TO 52
000144      51 IF (SLGTH(3, L) .LT. 0.1E-04) L=2
000145          IF (SLGTH(3, L) .LT. 0.1E-04) GO TO 330
000146          CHJK(I)=FC(3, L)/SLGTH(3, L)*COEF(2, I)
000147          CHJK(I)=FC(3, L)/SLGTH(3, L)*COEF(2, I)
000148      52 SRJK(I)=0.0

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000149      VELJK(I)=0.0
000150      SDJK(I)=0.0
000151      SRJKT=0.0
000152      60 FORJN(I)=0.0
000153      DO 70 I=1,LM
000154      TOTSLR(I)=0.0
000155      L=1
000156      IF(SLGTH(1,L) .LT. 0.1E-04) L=2
000157      IF(SLGTH(1,L) .LT. 0.1E-04) GO TO 330
000158      CHLM(I)=FC(1,L)/SLGTH(1,L)*COEF(1,I)
000159      CHLMT(I)=FC(1,L)/SLGTH(1,L)*COEF(1,I)
000160      62 SRLM(I)=0.0
000161      VELLN(I)=0.0
000162      SCLM(I)=0.0
000163      SRLMT=0.0
000164      70 FORLM(I)=0.0
000165      C
000166      C      INITIALIZE FOR STRUT LENGTH CALCULATIONS
000167      C
000168      C
000169      C      LOCATION OF HEAT SHIELD C.G. AT INITIAL GROUND CONTACT
000170      C
000171      74 IF(NCHS)90,90,75
000172      C
000173      75 PB=(HSX1-XCG1)*CAPM/(CAPM+HSDM)
000174      FT=PB-(HSX1-XCG1)
000175      HSCG2=HSCG2+PB
000176      UXX=UXX+USXX+(YCG1*YCG1+ZCG1*ZCG1)*(CAPM+HSDM)/4.0
000177      UYY=UYY+CAPH*PT*PT+USYY+HSDM*PB*PB
000178      UZZ=UZZ+CAPH*PT*PT+USZZ+HSDM*PB*PB
000179      CAFM=CAPH+HSDM
000180      HSDM=CAPH
000181      90 RADCAL=SQRT(HEATB*HEATB-(L11*D11*(HEATE*HEATB-HEATA*HEATA)))
000182      RSX=RADCAL-D11*HSCG2+XORIG
000183      RSY=L21*HSX1+D22*HSY1+D23*HSZ1
000184      RSZ=L31*HSX1+D32*HSY1+D33*HSZ1
000185      C
000186      C      LOCATION OF CAPSULE C.G. AT INITIAL GROUND CONTACT
000187      C
000188      RX=RSX-D11*HSX1-D12*HSY1-D13*HSZ1
000189      RY=0.0
000190      RZ=0.0
000191      C
000192      YCG=0.0
000193      ZCG=0.0
000194      C
000195      C      INITIAL LOCATION OF COUCH C.G. AT INITIAL GROUND CONTACT
000196      C
000197      100 RCX=RX+D11*HCX1+D12*HCY1+D13*HCZ1
000198      RCY=L21*HCX1+D22*HCY1+D23*HCZ1
000199      RCZ=L31*HCX1+D32*HCY1+D33*HCZ1
000200      C
000201      C      INITIAL GROUND CONTACT POINT IN COORD SYS. NO.2 (HEAT SHIELD)
000202      C
000203      CONX2=HSCG2-(D11*HEATA*HEATA/RADCAL)
000204      CONY2=-D12*HEATB*HEATB/RADCAL
000205      CONZ2=-D13*HEATB*HEATB/RADCAL
000206      C
000207      C      CONTACT POINT IN FIXED COORD. SYSTEM
000208      C
000209      110 CONX=0.0
000210      CONY=D21*CONX2+D22*CONY2+D23*CONZ2
000211      CONZ=D31*CONX2+D32*CONY2+D33*CONZ2
000212      C
000213      C
000214      C
000215      C
000216      C      INITIAL COUCH VELOCITIES
000217      C
000218      GCX=HCY1*WZ-HCZ1*WY
000219      GCY=HCZ1*WX-HCX1*WZ
000220      GCZ=HCX1*WY-HCY1*WX
000221      RCXVEL=RXVEL-D11*GCX-D12*GCY-D13*GCZ
000222      RCYVEL=RYVEL-D21*GCX-D22*GCY-D23*GCZ
000223      RCZVEL=RZVEL-D31*GCX-D32*GCY-D33*GCZ

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000224      C      WCX=WX
000225      WCY=WY
000226      WCZ=WZ
000227
000228      C      INITIAL HEAT SHIELD VELOCITIES
000229      C
000230      CSX=HSY1*WZ-HSZ1*WY
000231      CSY=HSZ1*WX-HSX1*WZ
000232      CSZ=HSX1*WY-HSY1*WX
000233
000234      C
000235      C
000236      RSXVEL=RXVEL-D11*CSX-D12*CSY-D13*CSZ
000237      C
000238      RSYVEL=RYVEL-D21*CSX-D22*CSY-D23*CSZ
000239      RSZVEL=RZVEL-D31*CSX-D32*CSY-D33*CSZ
000240
000241      C      WSX=WX
000242      WSY=WY
000243      WSZ=WZ
000244
000245      C
000246      C
000247      QSLDEL=0.0
000248      QSVEL=0.0
000249
000250      C
000251      T(1)=RX
000252      T(2)=RY
000253      T(3)=RZ
000254      T(4)=RXVEL
000255      T(5)=RYVEL
000256      T(6)=RZVEL
000257      T(7)=WX
000258      T(8)=WY
000259      T(9)=WZ
000260      T(10)=RCX
000261      T(11)=RCY
000262      T(12)=RCZ
000263      T(13)=RCXVEL
000264      T(14)=RCYVEL
000265      T(15)=RCZVEL
000266      T(16)=WCX
000267      T(17)=WCY
000268      T(18)=WCZ
000269      T(19)=RSX
000270      T(20)=RSY
000271      T(21)=RSZ
000272      T(22)=RSXVEL
000273      T(23)=RSYVEL
000274      T(24)=RSZVEL
000275      T(25)=WSX
000276      T(26)=WSY
000277      T(27)=WSZ
000278      T(28)=PSI
000279      T(29)=THTA
000280      T(30)=PHI
000281      T(31)=PSIC
000282      T(32)=THTAC
000283      T(33)=PHIC
000284      T(34)=PSIS
000285      T(35)=THTAS
000286      T(36)=PHIS
000287      T(37)=QSLDEL
000288      T(38)=QSVEL
000289      SPACE=DT
000290
000291      C
000292      C      INITIAL CAPSULE ACCELERATIONS
000293      C
000294      AX=0.0
000295      AY=0.0
000296      AZ=0.0
000297      WDX=0.0
000298      WDY=0.0
000299      WDZ=0.0

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000299      C
000300      C      INITIAL COUCH ACCELERATIONS
000301      C
000302      150 ACX=0.0
000303      ACY=0.0
000304      ACZ=0.0
000305      WDCX=0.0
000306      WDCY=0.0
000307      WDCZ=0.0
000308      C
000309      C      INITIAL HEAT SHIELD ACCELERATIONS
000310      C
000311      ASX=0.0
000312      ASY=0.0
000313      ASZ=0.0
000314      WDSX=0.0
000315      WDSY=0.0
000316      WDSZ=0.0
000317      C
000318      C      CAPSULE ANGULAR ACCELERATION CONSTANTS
000319      C
000320      U=LXA*UYY*UZZ-2.0*UXY*UYZ+UAX-UXX*UYZ+UYZ-UYY*UXZ+UXZ-UZZ*UXY*UXY
000321      E=1.0/D
000322      CXX=(UYY*UZZ-UYZ*UYZ)*E
000323      CXY=(UYZ+UXZ+UXY*UZZ)*E
000324      CXZ=(UXY*UYZ+UXZ*UYY)*E
000325      CYX=(UXZ*UYZ+UXY*UZZ)*E
000326      CYY=(UXX*UZZ-UXZ*UXZ)*E
000327      CYZ=(UXY*UXZ+UYZ*UXX)*E
000328      CZX=(UXY*UYZ+UXZ*UYY)*E
000329      CZY=(UXZ*UXY+UYZ*UXX)*E
000330      CZZ=(UXX*UYY-UXY*UXY)*E
000331      C
000332      C      COUCH ANGULAR ACCELERATION CONSTANTS
000333      C
000334      D=LCXX*UCYY*UCZZ-2.0*UCXY*UCYZ+UCXZ-UCXX*UCYZ*UCYZ-UCYY*UCXZ*UCXZ-
000335      1 UCZZ*UCXY*UCXY
000336      E=1.0/D
000337      CCXX=(UCYY*UCZZ-UCYZ*UCYZ)*E
000338      CCXY=(UCYZ*UCXZ+UCXY*UCZZ)*E
000339      CCXZ=(UCXY*UCYZ+UCXZ*UCYY)*E
000340      CCYX=(UCXZ*UCYZ+UCXY*UCZZ)*E
000341      CCYY=(UCXX*UCZZ-UCXZ*UCXZ)*E
000342      CCYZ=(UCXY*UCXZ+UCYZ*UCXX)*E
000343      CCZX=(UCXY*UCYZ+UCXZ*UCYY)*E
000344      CCZY=(UCXZ*UCXY+UCYZ*UCXX)*E
000345      CCZZ=(UCXX*UCYY-UCXY*UCXY)*E
000346      C
000347      C
000348      C
000349      C      INITIAL HEAT SHIELD STRUT LENGTHS
000350      C
000351      IF(NCHS)170,170,180
000352      170 DO 140 I=1,LM
000353      SLLM(I)=SQRT((XM2(I)+HSX1-XL1(I))*(XM2(I)+HSX1-XL1(I))+(YM2(I)+
000354      HSY1-YL1(I))*(YM2(I)+HSY1-YL1(I))+(ZM2(I)+HSZ1-ZL1(I))*(ZM2(I)+
000355      HSY1-YL1(I)))
000356      SLLM(I)=SLLM(I)
000357      190 CONTINUE
000358      GO TO 185
000359      180 DO 164 I=1,LM
000360      184 SLLM(I)=0.0
000361      185 DO 200 I=1,JK
000362      SLJK(I)=SQRT((XJ3(I)+HCX1-XK1(I))*(XJ3(I)+HCX1-XK1(I))+(YJ3(I)+
000363      HCY1-YK1(I))*(YJ3(I)+HCY1-YK1(I))+(ZJ3(I)+HCZ1-ZK1(I))*(ZJ3(I)+
000364      HCY1-YK1(I)))
000365      SLJK(I)=SLJK(I)
000366      200 CONTINUE
000367      YRF1=RCY0-RY0+YB13
000368      YRF2=RCY0-RY0+YB23
000369      BST1MX=BDEF(1)
000370      BST2MX=BDEF(1)
000371      BMFNKG=0.0
000372      C
000373      C      CALL SUBROUTINE TO COMPUTE INCREMENTAL AREA INFORMATION ABOUT

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000374 C HEAT SHIELD SURFACE
000375 C
000376 C ENT=CTLM
000377 C
000378 C CALL HSAREA
000379 C
000380 C INITIALIZE FOR HEAT SHIELD - SOIL CALCULATIONS
000381 C
000382 C DO 222 I=1,10
000383 C DO 222 J=1,50
000384 C FKNEE(I,J)=FORCE(I,J+1)
000385 C DMAX(I,J)=0.0
000386 222 CONTINUE
000387 C FSGX=0.0
000388 C FSGY=0.0
000389 C FSGZ=0.0
000390 C TSCX=0.0
000391 C TSGY=0.0
000392 C TSGZ=0.0
000393 C TESOL=0.0
000394 C GMA(1)=0.0
000395 C AGFA(1)=1.0
000396 C EGFA(1)=1.0
000397 C SUPCH=0.0
000398 C
000399 C
000400 C INITIALIZE FOR CAPSULE - SOIL CALCULATIONS
000401 C
000402 C FCGX=0.0
000403 C FCGY=0.0
000404 C FCGZ=0.0
000405 C TCGX1=0.0
000406 C TCGY1=0.0
000407 C TCGZ1=0.0
000408 C CAFEA=0.0
000409 C CAFEAH=0.0
000410 C
000411 C PREV=0.0
000412 C DO 225 I=1,12
000413 C DO 225 J=1,55
000414 225 UELMAX(I,J)=0.0
000415 C
000416 C KETRO=ROCKET MOMENT APPLIED TO CAPSULE IF ROCKETS ARE ON
000417 C
000418 C IKF=0
000419 C IF(NRR .EQ. 0) GO TO 271
000420 C DO 270 I=1,NRR
000421 C KRX=KRX2(I)-KRX1(I)
000422 C KRY=KRY2(I)-KRY1(I)
000423 C KRZ=KRZ2(I)-KRZ1(I)
000424 C RXYZ=SGRT(RRX*KRX+RRY*KRY+RRZ*KRZ)
000425 C CRFX(I)=RRX/RXYZ
000426 C CRKY(I)=RRY/RXYZ
000427 270 CRFZ(I)=RRZ/RXYZ
000428 271 CONTINUE
000429 C KRRG=0.0
000430 C
000431 C
000432 C IF(NY .EQ. 0 .OR. NZ .EQ. 0) GO TO 285
000433 C
000434 C INITIALIZE FOR ROUGH SURFACE
000435 C
000436 C NNY=NY+1
000437 C NNZ=NZ+1
000438 C RSLRF(1:1,NNZ)=0.0
000439 C RSLRF(3:1,1)=ZMIN
000440 C RSLRF(2:1,1)=YMIN
000441 C DO 260 J=1,NNY
000442 C AJ=J
000443 C RSLRF(1:J+1,NNZ)=0.0
000444 C RSLRF(3:J+1,1)=ZMIN
000445 C RSLRF(2:J+1,1)=YMIN+AJ*DEY
000446 C DO 260 K=1,NNZ
000447 C AK=K
000448 C LL=(K-1)*NNY+J

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000449      RSLRF(1,NNY,K)=0.0
000450      RSLRF(1,J,K)=FAKE(LL)
000451      RSLRF(2,J+1,K+1)=YMIN+AJ*DEY
000452      RSLRF(3,J+1,K+1)=ZMIN+AK*DEZ
000453      RSLRF(3,1,K+1)=ZMIN+AK*DEZ
000454      RSLRF(2,1,K+1)=YMIN
000455      280 CONTINUE
000456      285 CONTINUE
000457      C INITIALIZE FOR PRINTING
000458      C
000459      C
000460      DO 250 I=1,10
000461      NGFING(I)=0
000462      250 CDEL(I)=0.0
000463      DO 260 I=1,6
000464      TCSQ(I)=0.0
000465      OFCMAX(I)=0.0
000466      OFCMIN(I)=0.0
000467      OLCMAX(I)=SLJKO(I)
000468      230 OLCMIN(I)=SLJKO(I)
000469      OLCB(I)=0.0
000470      OLCCL(I)=0.0
000471      OMACA(I)=0.0
000472      OMACY(I)=0.0
000473      OMACZ(I)=0.0
000474      OMAX(I)=0.0
000475      OMAY(I)=0.0
000476      260 OMAZ(I)=0.0
000477      DO 240 I=1,8
000478      TSSQ(I)=0.0
000479      OLSB(I)=0.0
000480      OLSL(I)=0.0
000481      OFSMIN(I)=0.0
000482      OFSMAX(I)=0.0
000483      OLSMAX(I)=SLLMO(I)
000484      240 OLSMIN(I)=SLLMO(I)
000485      IC=0
000486      JC=0
000487      ISS=0
000488      JS=0
000489      LI=1
000490      AREA=0.0
000491      AREAN=0.0
000492      FSCX=0.0
000493      IFFINT=0
000494      TP=0.0
000495      ENGKE=0.0
000496      GECS=0.0
000497      ENGPE=0.0
000498      GEES=0.0
000499      CESGND=0.0
000500      OESDIL=0.0
000501      OFFACT=0.0
000502      GEENL=0.0
000503      ENKEF=0.0
000504      ENGTOT=0.0
000505      RXC=RX
000506      RYC=RY
000507      RZC=RZ
000508      RSXO=RSX
000509      RSYO=RSY
000510      RSZO=RSZ
000511      RCXO=RCX
000512      RCO=RCY
000513      RCZO=RCZ
000514      CXVELO=RCXVEL
000515      CYVELO=RCYVEL
000516      CZVELO=RCZVEL
000517      SXVELC=RSXVEL
000518      SYVELO=RSYVEL
000519      SZVELO=RSZVEL
000520      C

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000521 C PRINT INPUT DATA AND INITIALIZATION CALCULATIONS AS PART OF THE
000522 C OUTPUT RECORD
000523 C
000524 WRITE(IP,9100)
000525 WRITE(IP,9028)
000526 WRITE(IP,9001) RXVEL,RYVEL,RZVEL,UX,UY,UZ
000527 WRITE(IP,9002) ZETA,CAPM,CCHM,HSDM,XORIG
000528 WRITE(IP,9003) UXX,UYX,UZZ,UXY,UYZ,UXZ
000529 WRITE(IP,9004) UCXX,UCYY,UCZZ,UCXY,UCXZ,UCYZ
000530 WRITE(IP,9005) USXX,USYY,USZZ,PSI,THTA,FHI
000531 WRITE(IP,9006) HEATA,HEATE,HC,ETA,XMAX,XMIN
000532 WRITE(IP,9007) XL1(1),YL1(1),ZL1(1),XM2(1),YM2(1),ZM2(1)
000533 WRITE(IP,9008) XL1(2),YL1(2),ZL1(2),XM2(2),YM2(2),ZM2(2)
000534 WRITE(IP,9009) XL1(3),YL1(3),ZL1(3),XM2(3),YM2(3),ZM2(3)
000535 WRITE(IP,9010) XL1(4),YL1(4),ZL1(4),XM2(4),YM2(4),ZM2(4)
000536 WRITE(IP,9011) XL1(5),YL1(5),ZL1(5),XM2(5),YM2(5),ZM2(5)
000537 WRITE(IP,9012) XL1(6),YL1(6),ZL1(6),XM2(6),YM2(6),ZM2(6)
000538 WRITE(IP,9013) XL1(7),YL1(7),ZL1(7),XM2(7),YM2(7),ZM2(7)
000539 WRITE(IP,9014) XL1(8),YL1(8),ZL1(8),XM2(8),YM2(8),ZM2(8)
000540 WRITE(IP,9015) XK1(1),YK1(1),ZK1(1),XJ3(1),YJ3(1),ZJ3(1)
000541 WRITE(IP,9016) XK1(2),YK1(2),ZK1(2),XJ3(2),YJ3(2),ZJ3(2)
000542 WRITE(IP,9017) XK1(3),YK1(3),ZK1(3),XJ3(3),YJ3(3),ZJ3(3)
000543 WRITE(IP,9018) XK1(4),YK1(4),ZK1(4),XJ3(4),YJ3(4),ZJ3(4)
000544 WRITE(IP,9019) XK1(5),YK1(5),ZK1(5),XJ3(5),YJ3(5),ZJ3(5)
000545 WRITE(IP,9020) XK1(6),YK1(6),ZK1(6),XJ3(6),YJ3(6),ZJ3(6)
000546 WRITE(IP,9091) PLGN,OF,PK,FPX,FPY,FPZ,FHTE
000547 WRITE(IP,9092) PXVEL,FYVEL,PZVEL,APX10,APY10,APZ10
000548 WRITE(IP,9093) XCG1,YCG1,ZCG1
000549 WRITE(IP,9024) CTJK,CTLM,SHCUKT,SHCLMT,SHCUK,SHCLM
000550 WRITE(IP,9025) IP,IT,IS,JK,LM
000551 WRITE(IP,9026) HXS1,HSY1,HSZ1,HCX1,HCY1,HCZ1
000552 WRITE(IP,9027) JKDAMP,LMDAMP,VISJK,VISLP,HSCG2,XPMAX
000553 WRITE(IP,9042) DT,TMAX,DTF,ISERNO,IACCEL,NOHS
000554 WRITE(IP,9045) IRET,GNDMU,G,JJMAX,DC
000555 WRITE(IP,9049) KA1,A2,A3,A4,A5,A7
000556 WRITE(IP,9050) (CAP(1:I),I=1,6)
000557 WRITE(IP,9052) (CAP(2:I),I=1,6)
000558 WRITE(IP,9053) (CAP(3:I),I=1,6)
000559 WRITE(IP,9054) (CCH(1:I),I=1,6)
000560 WRITE(IP,9055) (CCH(2:I),I=1,6)
000561 WRITE(IP,9056) (CCH(3:I),I=1,6)
000562 WRITE(IP,9057) (SLGTH(1:I),FC(1:I),I=1,3)
000563 WRITE(IP,9058) (SLGTH(1:I),FC(1:I),I=4,6)
000564 WRITE(IP,9059) (SLGTH(2:I),FC(2:I),I=1,3)
000565 WRITE(IP,9060) (SLGTH(2:I),FC(2:I),I=4,6)
000566 WRITE(IP,9061) (SLGTH(3:I),FC(3:I),I=1,3)
000567 WRITE(IP,9062) (SLGTH(3:I),FC(3:I),I=4,6)
000568 310 CONTINUE
000569 WRITE(IP,9063) (COEF(1:I),I=1,6)
000570 WRITE(IP,9064) (COEF(1:I),I=7,8)
000571 WRITE(IP,9065) (COEF(2:I),I=1,6)
000572 WRITE(IP,9066) (COEF(1:I),I=1,6)
000573 WRITE(IP,9067) (COEF(1:I),I=7,8)
000574 WRITE(IP,9068) (COEF(2:I),I=1,6)
000575 WRITE(IP,9074) NKR,ALT,ALTY,ALTZ,BLNG
000576 IF(NKR.LE.0) GO TO 325
000577 WRITE(IP,9076) RRX1(1),RRY1(1),RRZ1(1),RRX2(1),RRY2(1),RRZ2(1)
000578 WRITE(IP,9077) RRX1(2),RRY1(2),RRZ1(2),RRX2(2),RRY2(2),RRZ2(2)
000579 WRITE(IP,9078) RRX1(3),RRY1(3),RRZ1(3),RRX2(3),RRY2(3),RRZ2(3)
000580 WRITE(IP,9079) RRX1(4),RRY1(4),RRZ1(4),RRX2(4),RRY2(4),RRZ2(4)
000581 325 WRITE(IP,9085) XB13,YB13,ZB13,XB23,YB23,ZB23
000582 WRITE(IP,9086) (BDEF(I),BFOR(I),I=1,3)
000583 WRITE(IP,9087) (BDEF(I),BFOR(I),I=4,6)
000584 WRITE(IP,9028)
000585 WRITE(IP,9069) JJMAX
000586 WRITE(IP,9028)
000587 WRITE(IP,9044) (CAPDEF(I),CAPFOR(I),I=1,JJMAX)
000588 WRITE(IP,9028)
000589 WRITE(IP,9097)
000590 WRITE(IP,9098) (GMA(I),AGMA(I),BGMA(I),I=2,3)
000591 WRITE(IP,9099) (GMA(I),AGMA(I),BGMA(I),I=4,5)
000592 WRITE(IP,9070) SLRHO,SOILE,SLPHI,CKPHIC,NAA,CMU
000593 WRITE(IP,9071) (AA(I),BB(I),I=1,3)
000594 WRITE(IP,9072) (AA(I),BB(I),I=4,6)
000595 WRITE(IP,9073) (AA(I),BB(I),I=7,9)

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000596      WRITE(IP,9028)
000597      WRITE(IP,9021)(FFLM(I),I=1,6)
000598      WRITE(IP,9022)(FFLM(I),I=7,6)
000599      WRITE(IP,9023)(FFJK(I),I=1,6)
000600      WRITE(IP,9094)(FFLMT(I),I=1,6)
000601      WRITE(IP,9095)(FFLMT(I),I=7,6)
000602      WRITE(IP,9096)(FFJKT(I),I=1,6)
000603      WRITE(IP,9028)
000604      WRITE(IP,9028)
000605      WRITE (IP,9043)
000606      WRITE(IP,9082)
000607      DO 305 I=1,10
000608      NE=N1(I)
000609      DO 305 J=1,NE
000610      WRITE(IP,9083)I,J,(DEFL(I,J,K),FORCE(I,J,K),K=1,6)
000611 305 CONTINUE
000612      WRITE(IP,9028)
000613      WRITE(IP,9088)
000614      WRITE(IP,9028)
000615      DO 320 J=1,4
000616      WRITE(IP,9080)J,(TYM(J,I),I=1,9)
000617 320 WRITE(IP,9081)J,(THRR(J,I),I=1,9)
000618      WRITE(IP,9089)YMIN,DEY,NY,ZMIN,DEZ,NZ
000619      WRITE(IP,9084) ((RSURF(2,J,K),RSURF(3,J,K),RSURF(1,J,K),J=1,NNY),
000620      IK=1,NNZ)
000621      DO 340 I=1,8
000622      XL1(I)=XL1(I)-XCG1
000623      YL1(I)=YL1(I)-YCG1
000624 340 ZL1(I)=ZL1(I)-ZCG1
000625      DO 345 I=1,6
000626      XK1(I)=XK1(I)-XCG1
000627      YK1(I)=YK1(I)-YCG1
000628 345 ZK1(I)=ZK1(I)-ZCG1
000629      RX=RSX-D11*(HSX1-XCG1)-D12*(HSY1-YCG1)-D13*(HSZ1-ZCG1)
000630      RCX=RX+D11*(HCX1-XCG1)+D12*(HCY1-YCG1)+D13*(HCZ1-ZCG1)
000631      RY=D21*(HCX1-XCG1)+D22*(HCY1-YCG1)+D23*(HCZ1-ZCG1)
000632      RCZ=D31*(HCX1-XCG1)+D32*(HCY1-YCG1)+D33*(HCZ1-ZCG1)
000633 C      RSY=D21*(HSX1-XCG1)+D22*(HSY1-YCG1)+D23*(HSZ1-ZCG1)
000634      RSZ=D31*(HSX1-XCG1)+D32*(HSY1-YCG1)+D33*(HSZ1-ZCG1)
000635      GCX=(HCY1-YCG1)*WX-(HCZ1-ZCG1)*WY
000636      GCY=(HCZ1-ZCG1)*WX-(HCX1-XCG1)*WZ
000637      GCZ=(HCX1-XCG1)*WY-(HCY1-YCG1)*WX
000638      RCXVEL=RXVEL-D11*GCX-D12*GCY-D13*GCZ
000639      RYVEL=RYVEL-D21*GCX-D22*GCY-D23*GCZ
000640      RCZVEL=RZVEL-D31*GCX-D32*GCY-D33*GCZ
000641 C
000642 C      GSX=(HSY1-YCG1)*WZ-(HSZ1-ZCG1)*WY
000643      GSY=(HSZ1-ZCG1)*WX-(HSX1-XCG1)*WZ
000644      GSZ=(HSX1-XCG1)*WY-(HSY1-YCG1)*WX
000645      RSXVEL=RXVEL-D11*GSX-D12*GSY-D13*GSZ
000646      RSYVEL=RYVEL-D21*GSX-D22*GSY-D23*GSZ
000647      RSZVEL=RZVEL-D31*GSX-D32*GSY-D33*GSZ
000648 C
000649 C
000650 C      MAGNITUDE OF PARACHUTE FORCE AND INITIAL LINE LENGTH
000651      APX1=APX10-XCG1
000652      APY1=APY10-YCG1
000653      APZ1=APZ10-ZCG1
000654      APX=D11*APX1+D12*APY1+D13*APZ1+RX
000655      APY=D21*APX1+D22*APY1+D23*APZ1+RY
000656      APZ=D31*APX1+D32*APY1+D33*APZ1+RZ
000657 C
000658      IPARA=0
000659      FP=SQRT(FPX*FPX+FPY*FPY+FPZ*FPZ)
000660      IF(FP.LT. 1.0 .OR. FK.LT. 1.0) GO TO 205
000661      PL=PLGNOF/FP/PK
000662 C
000663 C      INITIAL PARACHUTE POSITION
000664 C
000665 C      UNIT VECTOR COMPONENTS VPX,ETC
000666 C
000667      VPX=(D11*FPX+D12*FPY+D13*FPZ)/FP
000668      VPY=(D21*FPX+D22*FPY+D23*FPZ)/FP
000669      VPZ=(D31*FPX+D32*FPY+D33*FPZ)/FP
000670 C

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000671      KPX=APX+FL*VPX
000672      KPY=APY+PL*VPY
000673      KPZ=APZ+FL*VPZ
000674      205 CONTINUE
000675      C
000676      C
000677      T(1)=RX
000678      T(2)=RY
000679      T(3)=RZ
000680      T(10)=RCX
000681      T(11)=RCY
000682      T(12)=RCZ
000683      T(13)=RCXVEL
000684      T(14)=RCYVEL
000685      T(15)=RCZVEL
000686      T(19)=RSX
000687      T(20)=RSY
000688      T(21)=RSZ
000689      T(22)=RSXVEL
000690      T(23)=RSYVEL
000691      T(24)=RSZVEL
000692      C
000693      YRF1=RCY-KY+YB13
000694      YRF2=RCY-KY+YB23
000695      C
000696      IF(NNR.EQ.0) GO TO 365
000697      DO 360 I=1,NNR
000698      RRX1(I)=RRX10(I)-XCG1
000699      RRY1(I)=RRY10(I)-YCG1
000700      360 RRZ1(I)=RRZ10(I)-ZCG1
000701      365 CONTINUE
000702      KXC=KX
000703      KYC=KY
000704      KZC=KZ
000705      RSX0=RSX
000706      RSY0=RSY
000707      RSZ0=RSZ
000708      RCX0=RCX
000709      RCY0=RCY
000710      RCZ0=RCZ
000711      CXVELO=RCXVEL
000712      CYVELO=RCYVEL
000713      CZVELO=RCZVEL
000714      SXVELO=RSXVEL
000715      SYVELO=RSYVEL
000716      SZVELO=RSZVEL
000717      WRITE(IP,9028)
000718      WRITE(IP,9029) RX,RY,RZ
000719      WRITE(IP,9030) RCX,RCY,RCZ
000720      WRITE(IP,9031) RSX,RSY,RSZ
000721      WRITE(IP,9032) RXVEL,RYVEL,RZVEL
000722      WRITE(IP,9033) RCXVEL,RCYVEL,RCZVEL
000723      WRITE(IP,9034) RSXVEL,RSYVEL,RSZVEL
000724      WRITE(IP,9035) KPX,KPY,KPZ
000725      WRITE(IP,9036) FP,PL
000726      WRITE(IP,9028)
000727      WRITE(IP,9037)
000728      WRITE(IP,9038) (SLJK(I),I=1,JK)
000729      WRITE(IP,9028)
000730      WRITE(IP,9039)
000731      WRITE(IP,9040) (SLLM(I),I=1,LM)
000732      C
000733      C
000734      C
000735      WRITE(IP,9000)
000736      C
000737      WRITE(IP,9046)
000738      WRITE(IP,9047)EX
000739      WRITE(IP,9047)EY
000740      WRITE(IP,9047)EZ
000741      WRITE(IP,9048)NI
000742      WRITE(IP,9047)A
000743      C
000744      RETURN
000745      330 WRITE(IP,9090)

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000746          STOP
000747
000748          C
000749          9000 FORMAT(1H)
000750          9001 FORMAT(9H RXVEL =,F10.5,9H RYVEL =,F10.5,9H FZVEL =,F10.5,9H WX
000751          1 =,F10.5,9H WY =,F10.5,9H WZ =,F10.5,5H $ 1)
000752          9002 FORMAT(9H ZETA =,F10.5,9H CAPM =,F10.5,9H CCHM =,F10.5,9H HS
000753          1LM =,F10.5,9H XORIG =,F10.5,24H $ 2)
000754          9003 FORMAT(9H UXX =,F10.5,9H UYY =,F10.5,9H LZZ =,F10.5,9H UX
000755          1Y =,F10.5,9H UYZ =,F10.5,9H UXZ =,F10.5,5H $ 3)
000756          9004 FORMAT(9H UCXX =,F10.5,9H UCYY =,F10.5,9H UCZZ =,F10.5,9H UC
000757          1XY =,F10.5,9H UCXZ =,F10.5,9H UCYZ =,F10.5,5H $ 4)
000758          9005 FORMAT(9H USXX =,F10.5,9H USYY =,F10.5,9H LSZZ =,F10.5,9H PS
000759          1I =,F10.5,9H THTA =,F10.5,9H PHI =,F10.5,5H $ 5)
000760          9006 FORMAT(9H HEATA =,F10.5,9H HEATE =,F10.5,9H HC =,F10.5,9H ET
000761          1A =,F10.5,9H XMAX =,F10.5,9H XMN =,F10.5,5H $ 6)
000762          9007 FORMAT(9H XL1(1) =,F10.5,9H YL1(1) =,F10.5,9H ZL1(1) =,F10.5,9H XM
000763          12(1) =,F10.5,9H YM2(1) =,F10.5,9H ZM2(1) =,F10.5,5H $ 7)
000764          9008 FORMAT(9H XL1(2) =,F10.5,9H YL1(2) =,F10.5,9H ZL1(2) =,F10.5,9H XM
000765          12(2) =,F10.5,9H YM2(2) =,F10.5,9H ZM2(2) =,F10.5,5H $ 8)
000766          9009 FORMAT(9H XL1(3) =,F10.5,9H YL1(3) =,F10.5,9H ZL1(3) =,F10.5,9H XM
000767          12(3) =,F10.5,9H YM2(3) =,F10.5,9H ZM2(3) =,F10.5,5H $ 9)
000768          9010 FORMAT(9H XL1(4) =,F10.5,9H YL1(4) =,F10.5,9H ZL1(4) =,F10.5,9H XM
000769          12(4) =,F10.5,9H YM2(4) =,F10.5,9H ZM2(4) =,F10.5,5H $ 10)
000770          9011 FORMAT(9H XL1(5) =,F10.5,9H YL1(5) =,F10.5,9H ZL1(5) =,F10.5,9H XM
000771          12(5) =,F10.5,9H YM2(5) =,F10.5,9H ZM2(5) =,F10.5,5H $ 11)
000772          9012 FORMAT(9H XL1(6) =,F10.5,9H YL1(6) =,F10.5,9H ZL1(6) =,F10.5,9H XM
000773          12(6) =,F10.5,9H YM2(6) =,F10.5,9H ZM2(6) =,F10.5,5H $ 12)
000774          9013 FORMAT(9H XL1(7) =,F10.5,9H YL1(7) =,F10.5,9H ZL1(7) =,F10.5,9H XM
000775          12(7) =,F10.5,9H YM2(7) =,F10.5,9H ZM2(7) =,F10.5,5H $ 13)
000776          9014 FORMAT(9H XL1(8) =,F10.5,9H YL1(8) =,F10.5,9H ZL1(8) =,F10.5,9H XM
000777          12(8) =,F10.5,9H YM2(8) =,F10.5,9H ZM2(8) =,F10.5,5H $ 14)
000778          9015 FORMAT(9H XK1(1) =,F10.5,9H YK1(1) =,F10.5,9H ZK1(1) =,F10.5,9H XU
000779          13(1) =,F10.5,9H YJ3(1) =,F10.5,9H ZJ3(1) =,F10.5,5H $ 15)
000780          9016 FORMAT(9H XK1(2) =,F10.5,9H YK1(2) =,F10.5,9H ZK1(2) =,F10.5,9H XU
000781          13(2) =,F10.5,9H YJ3(2) =,F10.5,9H ZJ3(2) =,F10.5,5H $ 16)
000782          9017 FORMAT(9H XK1(3) =,F10.5,9H YK1(3) =,F10.5,9H ZK1(3) =,F10.5,9H XU
000783          13(3) =,F10.5,9H YJ3(3) =,F10.5,9H ZJ3(3) =,F10.5,5H $ 17)
000784          9018 FORMAT(9H XK1(4) =,F10.5,9H YK1(4) =,F10.5,9H ZK1(4) =,F10.5,9H XU
000785          13(4) =,F10.5,9H YJ3(4) =,F10.5,9H ZJ3(4) =,F10.5,5H $ 18)
000786          9019 FORMAT(9H XK1(5) =,F10.5,9H YK1(5) =,F10.5,9H ZK1(5) =,F10.5,9H XU
000787          13(5) =,F10.5,9H YJ3(5) =,F10.5,9H ZJ3(5) =,F10.5,5H $ 19)
000788          9020 FORMAT(9H XK1(6) =,F10.5,9H YK1(6) =,F10.5,9H ZK1(6) =,F10.5,9H XU
000789          13(6) =,F10.5,9H YJ3(6) =,F10.5,9H ZJ3(6) =,F10.5,5H $ 20)
000790          9021 FORMAT(9H FFLM(1) =,F10.2,9H FFLM(2) =,F10.2,9H FFLM(3) =,F10.2,9H FF
000791          1LM(4) =,F10.2,9H FFLM(5) =,F10.2,9H FFLM(8) =,F10.2,5H $ 74)
000792          9022 FORMAT(9H FFLM(7) =,F10.2,9H FFLM(8) =,F10.2,76X,5H $ 75)
000793          9023 FORMAT(9H FFJK(1) =,F10.2,9H FFJK(2) =,F10.2,9H FFJK(3) =,F10.2,9H FF
000794          1JK(4) =,F10.2,9H FFJK(5) =,F10.2,9H FFJK(6) =,F10.2,9H $ 76)
000795          9024 FORMAT(9H CTJK =,F10.1,9H CTLM =,F10.1,9H SHCJKT =,F10.5,9H SH
000796          1CLMT =,F10.5,9H SHCJN =,F10.5,9H SHCLN =,F10.5,9H $ 24)
000797          9025 FORMAT(9H IP =,F10.9,9H IT =,F10.9,9H IS =,F10.9,9H JK =
000798          1,F10.9,9H LM =,F10.24H $ 25)
000799          9026 FORMAT(9H HSK1 =,F10.5,9H HSY1 =,F10.5,9H HSK2 =,F10.5,9H HC
000800          1A1 =,F10.5,9H HCY1 =,F10.5,9H HCK2 =,F10.5,5H $ 26)
000801          9027 FORMAT(9H UKDAMP =,F10.9,9H LMDAMP =,F10.9,9H VISJK =,F10.5,9H VISLM
000802          1 =,F10.5,9H HSCG2 =,F10.5,9H XPMAX =,F10.5,5H $ 27)
000803          9028 FORMAT(1H)
000804          9029 FORMAT(60H INITIAL CAPSULE C.G. LOCATION
000805          1 X =,F10.5,10H Y =,F10.5,10H Z =,F10.5)
000806          9030 FORMAT(60H INITIAL COUCH C.G. LOCATION
000807          1 X =,F10.5,10H Y =,F10.5,10H Z =,F10.5)
000808          9031 FORMAT(60H INITIAL HEAT SHIELD C.G. LOCATION
000809          1 X =,F10.5,10H Y =,F10.5,10H Z =,F10.5)
000810          9032 FORMAT(60H INITIAL CAPSULE VELOCITY
000811          1 X =,F10.5,10H Y =,F10.5,10H Z =,F10.5)
000812          9033 FORMAT(60H INITIAL COUCH VELOCITY
000813          1 X =,F10.5,10H Y =,F10.5,10H Z =,F10.5)
000814          9034 FORMAT(60H INITIAL HEAT SHIELD VELOCITY
000815          1 X =,F10.5,10H Y =,F10.5,10H Z =,F10.5)
000816          9035 FORMAT(60H INITIAL PARACHUTE C.G. LOCATION
000817          1 X =,F10.5,10H Y =,F10.5,10H Z =,F10.5)
000818          9036 FORMAT(60H INITIAL PARACHUTE FORCE AND CORD LENGTH
000819          1 F =,F10.5,20X,10H LENGTH =,F10.5)
000820          9037 FORMAT(86H COUCH - CAPSULE STRUT NO. 1 2 3
000821          1 4 5 6)

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000821 9036 FORMAT(30H STRUT LENGTH (6F10.5)
000822 9039 FORMAT(105H SHIELD - CAPSULE STRUT NO. 1 2 3
000823 1 4 5 6 7 8)
000824 9040 FORMAT(30H STRUT LENGTH (8F10.5)
000825 9041 FORMAT(6E20.10)
000826 9042 FORMAT(9H DT =,F10.5,9H TMAX =,F10.5,9H DTP =,F10.5,9H SE
000827 1RNC =,I10.9H IACCEL =,I10.9H NOMS =,I10.5H $ 28)
000828 9043 FORMAT(87H TABULATION OF PRESSURE VS DEFL. FOR ELEMENT J OF RING 1
000829 1 ON THE HEAT SHIELD SURFACE. 9H 6 VALUES,15H CARDS 81 - 103)
000830 9044 FORMAT(6E20.5)
000831 9045 FORMAT(9H IRET =,I10.9H GNDMU =,F10.5,19X,9H Q =,F10.5,9H
000832 1JUMAX =,I10.9H QC =,F10.5,5H $ 29)
000833 9046 FORMAT(51H WRITE EX(10),EY(10,70),EZ(10,70),NI(10) AND A(10) )
000834 9047 FORMAT(10E10.4)
000835 9048 FORMAT(10I10)
000836 9049 FORMAT(9H KA1 =,I10.9H A2 =,F10.5,9H A3 =,F10.5,9H A4
000837 1 =,F10.5,9H A5 =,F10.5,9H A7 =,F10.5,5H $ 30)
000838 9050 FORMAT(9H CAP(X,1),F10.5,9H CAP(X,2),F10.5,9H CAP(X,3),F10.5,9H CA
000839 1P(X,4),F10.5,9H CAP(X,5),F10.5,9H CAP(X,6),F10.5,5H $ 31)
000840 9052 FORMAT(9H CAP(Y,1),F10.5,9H CAP(Y,2),F10.5,9H CAP(Y,3),F10.5,9H CA
000841 1P(Y,4),F10.5,9H CAP(Y,5),F10.5,9H CAP(Y,6),F10.5,5H $ 32)
000842 9053 FORMAT(9H CAP(Z,1),F10.5,9H CAP(Z,2),F10.5,9H CAP(Z,3),F10.5,9H CA
000843 1P(Z,4),F10.5,9H CAP(Z,5),F10.5,9H CAP(Z,6),F10.5,5H $ 33)
000844 9054 FORMAT(9H CCH(X,1),F10.5,9H CCH(X,2),F10.5,9H CCH(X,3),F10.5,9H CC
000845 1H(X,4),F10.5,9H CCH(X,5),F10.5,9H CCH(X,6),F10.5,5H $ 34)
000846 9055 FORMAT(9H CCH(Y,1),F10.5,9H CCH(Y,2),F10.5,9H CCH(Y,3),F10.5,9H CC
000847 1H(Y,4),F10.5,9H CCH(Y,5),F10.5,9H CCH(Y,6),F10.5,5H $ 35)
000848 9056 FORMAT(9H CCH(Z,1),F10.5,9H CCH(Z,2),F10.5,9H CCH(Z,3),F10.5,9H CC
000849 1H(Z,4),F10.5,9H CCH(Z,5),F10.5,9H CCH(Z,6),F10.5,5H $ 36)
000850 9057 FORMAT(9H SLGTH1=,F10.5,9H FC(1,1)=,F10.5,9H SLGTH12=,F10.5,9H FC
000851 1(1,2)=,F10.5,9H SLGTH13=,F10.5,9H FC(1,3)=,F10.5,5H $ 37)
000852 9058 FORMAT(9H SLGTH14=,F10.5,9H FC(1,4)=,F10.5,9H SLGTH15=,F10.5,9H FC
000853 1(1,5)=,F10.5,9H SLGTH16=,F10.5,9H FC(1,6)=,F10.5,5H $ 38)
000854 9059 FORMAT(9H SLGTH21=,F10.5,9H FC(2,1)=,F10.5,9H SLGTH22=,F10.5,9H FC
000855 1(2,2)=,F10.5,9H SLGTH23=,F10.5,9H FC(2,3)=,F10.5,5H $ 39)
000856 9060 FORMAT(9H SLGTH24=,F10.5,9H FC(2,4)=,F10.5,9H SLGTH25=,F10.5,9H FC
000857 1(2,5)=,F10.5,9H SLGTH26=,F10.5,9H FC(2,6)=,F10.5,5H $ 40)
000858 9061 FORMAT(9H SLGTH31=,F10.5,9H FC(3,1)=,F10.5,9H SLGTH32=,F10.5,9H FC
000859 1(3,2)=,F10.5,9H SLGTH33=,F10.5,9H FC(3,3)=,F10.5,5H $ 41)
000860 9062 FORMAT(9H SLGTH34=,F10.5,9H FC(3,4)=,F10.5,9H SLGTH35=,F10.5,9H FC
000861 1(3,5)=,F10.5,9H SLGTH36=,F10.5,9H FC(3,6)=,F10.5,5H $ 42)
000862 9063 FORMAT(9H COEF11=,F10.5,9H COEF12=,F10.5,9H COEF13=,F10.5,9H CO
000863 1EF14=,F10.5,9H COEF15=,F10.5,9H COEF16=,F10.5,5H $ 43)
000864 9064 FORMAT(9H COEF17=,F10.5,9H COEF18=,F10.5,76X,5H $ 44)
000865 9065 FORMAT(9H COEF21=,F10.5,9H COEF22=,F10.5,9H COEF23=,F10.5,9H CO
000866 1EF24=,F10.5,9H COEF25=,F10.5,9H COEF26=,F10.5,5H $ 45)
000867 9066 FORMAT(9H COEF21=,F10.5,9H COEF22=,F10.5,9H COEF23=,F10.5,9H CO
000868 1EF24=,F10.5,9H COEF25=,F10.5,9H COEF26=,F10.5,5H $ 46)
000869 9067 FORMAT(9H COEF21=,F10.5,9H COEF22=,F10.5,9H COEF23=,F10.5,9H CO
000870 1EF24=,F10.5,9H COEF25=,F10.5,9H COEF26=,F10.5,5H $ 47)
000871 9068 FORMAT(9H COEF21=,F10.5,9H COEF22=,F10.5,9H COEF23=,F10.5,9H CO
000872 1EF24=,F10.5,9H COEF25=,F10.5,9H COEF26=,F10.5,5H $ 48)
000873 9069 FORMAT(88H TABULATION OF PRESSURE VS DEFL. FOR ALL ELEMENTS ON THE
000874 1 CAPSULE SURFACE. 15,7H VALUES,14H CARDS 61 - 67)
000875 9070 FORMAT(9H SLRHO =,F10.5,9H SOILE =,F10.5,9H SLPHI =,F10.5,9H CK
000876 1PHIC =,F10.5,9H NAA =,I10.9H CMU =,F10.5,5H $ 70)
000877 9071 FORMAT(9H AA(1) =,F10.5,9H BB(1) =,F10.5,9H AA(2) =,F10.5,9H BB
000878 1(2) =,F10.5,9H AA(3) =,F10.5,9H BB(3) =,F10.5,5H $ 71)
000879 9072 FORMAT(9H AA(4) =,F10.5,9H BB(4) =,F10.5,9H AA(5) =,F10.5,9H BB
000880 1(5) =,F10.5,9H AA(6) =,F10.5,9H BB(6) =,F10.5,5H $ 72)
000881 9073 FORMAT(9H AA(7) =,F10.5,9H BB(7) =,F10.5,9H AA(8) =,F10.5,9H BB
000882 1(8) =,F10.5,9H AA(9) =,F10.5,9H BB(9) =,F10.5,5H $ 73)
000883 9074 FORMAT(9H NRR =,I10.9H ALTJ =,F10.5,9H ALTY =,F10.5,9H ALTZ
000884 1 =,F10.5,9H BLNG =,F10.5,19X,5H $ 49)
000885 9076 FORMAT(9H RRX1(1)=,F10.5,9H RRY1(1)=,F10.5,9H RRZ1(1)=,F10.5,9H RR
000886 1X2(1)=,F10.5,9H RRY2(1)=,F10.5,9H RRZ2(1)=,F10.5,5H $ 50)
000887 9077 FORMAT(9H RRX1(2)=,F10.5,9H RRY1(2)=,F10.5,9H RRZ1(2)=,F10.5,9H RR
000888 1X2(2)=,F10.5,9H RRY2(2)=,F10.5,9H RRZ2(2)=,F10.5,5H $ 51)
000889 9078 FORMAT(9H RRX1(3)=,F10.5,9H RRY1(3)=,F10.5,9H RRZ1(3)=,F10.5,9H RR
000890 1X2(3)=,F10.5,9H RRY2(3)=,F10.5,9H RRZ2(3)=,F10.5,5H $ 52)
000891 9079 FORMAT(9H RRX1(4)=,F10.5,9H RRY1(4)=,F10.5,9H RRZ1(4)=,F10.5,9H RR
000892 1X2(4)=,F10.5,9H RRY2(4)=,F10.5,9H RRZ2(4)=,F10.5,5H $ 53)
000893 9080 FORMAT( 7H ROCKET,12,6H TIME ,9F10.4)
000894 9081 FORMAT( 7H ROCKET,12,6H FORCE,9F10.1)
000895 9082 FORMAT(124H 1 J DEFL-1 PRESS-1 DEFL-2 PRESS-2 DEFL-3
1 FRESS-3 DEFL-4 PRESS-4 DEFL-5 PRESS-5 DEFL-6 PRES

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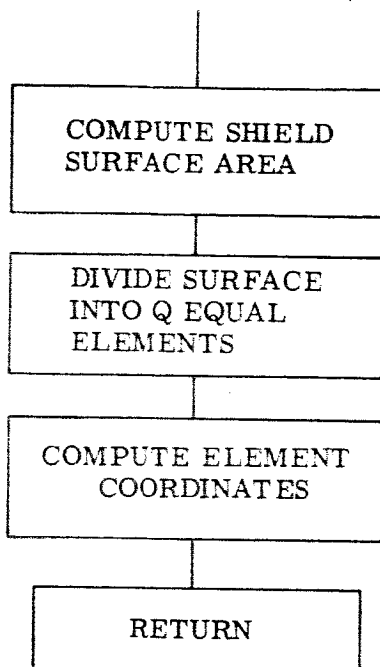
000896      25-e)
000897 9083 FORMAT(13,13,12E10,4)
000898 9084 FORMAT(32HOROUGH SURFACE INPUT INFORMATION//,105H AT VALUES OF Y A
000899     1ND 2 GREATER THAN THOSE TABULATED, REAL SURFACE IS X FT. ABOVE THE
000900     2NOMINAL SMOOTH SURFACE//,97H      Y      Z      X
000901     3      Y      Z      X      Y      Z      X      X//,(3F1
000902     40,3,5X,3F10,3,5X,3F10,3))
000903 9085 FORMAT(9H XB13   =,F10,5,9H YB13   =,F10,5,9H ZB13   =,F10,5,9H XB
000904     123   =,F10,5,9H YB23   =,F10,5,9H ZB23   =,F10,5,5H $ 54)
000905 9086 FORMAT(9H BDEF(1)=,F10,5,9H BFOR(1)=,F10,5,9H EDEF(2)=,F10,5,9H BF
000906     1CR(2)=,F10,5,9H EDEF(3)=,F10,5,9H BFOR(3)=,F10,5,5H $ 55)
000907 9087 FORMAT(9H BDEF(4)=,F10,5,9H BFOR(4)=,F10,5,9H EDEF(5)=,F10,5,9H BF
000908     1CR(5)=,F10,5,9H BDEF(6)=,F10,5,9H BFOR(6)=,F10,5,5H $ 56)
000909 9088 FORMAT(42H THE FOLLOWING INPUT IS ON CARDS 104 - 115)
000910 9089 FORMAT(9HOYMIN   =,F10,5,9H DEY   =,F10,5,9H NY   =,F10,9H ZMIN
000911     1   =,F10,5,9H DEZ   =,F10,5,9H NZ   =,F10,5H $120//,42H THE FOL
000912     2LOWING DATA ARE ON CARDS 121 - 138)
000913 9090 FORMAT(52H STRUT CRUSH FORCE VS DEFLECTION TABLE IS INCORRECT.)
000914 9091 FORMAT(9H PLGNOF =,F10,2,9H PK      =,F10,1,9H FPX      =,F10,2,9H FP
000915     1Y      =,F10,5,9H FPZ      =,F10,5,9H PHITE   =,F10,5,5H $ 21)
000916 9092 FORMAT(9H PXVEL   =,F10,5,9H PYVEL   =,F10,5,9H FZVEL   =,F10,5,9H AP
000917     1X1   =,F10,5,9H APY1   =,F10,5,9H APZ1   =,F10,5,5H $ 22)
000918 9093 FORMAT(9H XCG1    =,F10,5,9H YCG1    =,F10,5,9H ZCG1    =,F10,5,5H $ 5
000919     1H $ 23)
000920 9094 FORMAT(9H FFLMT(1),F10,2,9H FFLMT(2),F10,2,9H FFLMT(3),F10,2,9H FF
000921     1LMT(4),F10,2,9H FFLMT(5),F10,2,9H FFLMT(6),F10,2,5H $ 77)
000922 9095 FORMAT(9H FFLMT(7),F10,2,9H FFLMT(8),F10,2,76X,5H $ 78)
000923 9096 FORMAT(9H FFJKT(1),F10,2,9H FFJKT(2),F10,2,9H FFJKT(3),F10,2,9H FF
000924     1JKT(4),F10,2,9H FFJKT(5),F10,2,9H FFJKT(6),F10,2,5H $ 79)
000925 9097 FORMAT(55H SCIL PARAMETERS      GMA(1)=C.O,AGMA(1)=1.0,BGMA(1)=1.0)
000926 9098 FORMAT(9H GMA(2)   =,F10,5,9H AGMA(2)=,F10,5,9H EGMA(2)=,F10,5,9H GM
000927     1A(3) =,F10,5,9H AGMA(3)=,F10,5,9H BGMA(3)=,F10,5,5H $ 68 )
000928 9099 FORMAT(9H GMA(4)   =,F10,5,9H AGMA(4)=,F10,5,9H EGMA(4)=,F10,5,9H GM
000929     1A(5) =,F10,5,9H AGMA(5)=,F10,5,9H BGMA(5)=,F10,5,5H $ 69 )
000930 9100 FORMAT(65H
000931     1 LISTING )
000932
000933

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C

END

SUBROUTINE HSAREA (04)



ELT HSAREA:1,600308, 34213

```

000001      SUBROUTINE HSAREA
000002      C
000003      C
000004      COMMON/L2/HEATA,HEATB,HSCG2,IP
000005      COMMON/L10/EX(10),EY(10,50),EZ(10,50),NI(10),A(10),CHS,0,K,
000006      1RHC(10),DEFL(10,50,6),FORCE(10,50,6),GNDMU,AEL
000007      C
000008      COMMON/M1/FORJK(6),SLJK(6),CHJK(6),CHJK(6),SRJK(6),SRJK(6),
000009      1SDJK(6),VELJK(6),FORLM(8),SLLM(8),CHLMT(8),CHLM(8),SRLMT(8),
000010      2SRLM(8),SULM(8),VELLM(8),DMAX(10,50),DELMAX(12,55),SACC,SVEL,
000011      3SLEL,PKNLE(10,50)
000012      DIMENSION DETA(10)
000013      C
000014      C      HEAT SHIELD SURFACE AREA
000015      C
000016      C=(SQRT(HEATB*HEATB-HEATA*HEATA)+HEATB)/HEATA
000017      AREA=3.1416*HEATB*HEATB+3.1416*HEATB*HEATA*ALOG(C)/SQRT
000018      1(HEATB*HEATB-HEATA*HEATA)
000019      C      1/4 HEAT SHIELD PERIMETER
000020      D=(HEATB-HEATA)/(HEATB+HEATA)
000021      HSP=3.1416*(HEATA+HEATB)*(1.+(D**2/4.)+(D**4/64.)+(D**6/256.))/4.
000022      ESTDEL=SQRT(AREA/G)
000023      ESTM=(HSP/ESTDEL)-.563
000024      C      NUMBER OF RINGS
000025      K=ESTM+1.
000026      IF(K.GT. 10) GO TO 200
000027      AA=K
000028      DEL=HSP/(AA+.563)
000029      C
000030      C      ELEMENT AREA
000031      C
000032      AEL=DEL*DEL
000033      C
000034      C      CONSTANTS FOR CENTER ELEMENT
000035      C
000036      EY(1,1)=0.0
000037      EZ(1,1)=0.0
000038      EX(1)=HSCG2-HEATA
000039      RHC(1)=0.
000040      A(1)=HEATB*HEATB*HEATA
000041      NI(1)=1
000042      C      DETERMINE PARAMTEERS FOR FIRST RING (I=2)
000043      C
000044      RHC(2)=1.063*DEL
000045      ESTN2=6.2832*RHC(2)/DEL
000046      NI(2)=ESTN2+.5
000047      IF(NI(2).GT. 50) GO TO 200
000048      AB=NI(2)
000049      DETA(2)=6.2832/AB
000050      C
000051      C      BEGIN LOOP TO DETERMINE CONSTANTS FOR REMAINING ELEMENTS
000052      K1=K+1
000053      DO 100 I=2,K1
000054      10 EX(I)=-HEATA*SQRT(1.-RHO(I)*RHO(I))/(HEATB*HEATB)+HSCG2
000055      J=1
000056      20 AC=J-1
000057      BETA=AC*DETA(I)
000058      EY(I,J)=-RHO(I)*SIN(BETA)
000059      EZ(I,J)=RHO(I)*COS(BETA)
000060      A(I)=SQRT(HEATB*HEATB*HEATB*HEATB*(EX(I)-HSCG2)*(EX(I)-HSCG2)
000061      1 +HEATA*HEATA*HEATA*HEATA*RHO(I)*RHO(I))
000062      C
000063      C      TEST FOR LAST ELEMENT IN RING
000064      C
000065      C      IF (J=NI(I))30,40,40
000066      30 J=J+1
000067      GO TO 20
000068      C
000069      C      TEST FOR LAST RING ON HEAT SHIELD
000070      C
000071      40 IF (I=K-1)50,60,60
000072      50 IF (RHO(I)/HEATB-.7)70,80,80
000073      70 L=3

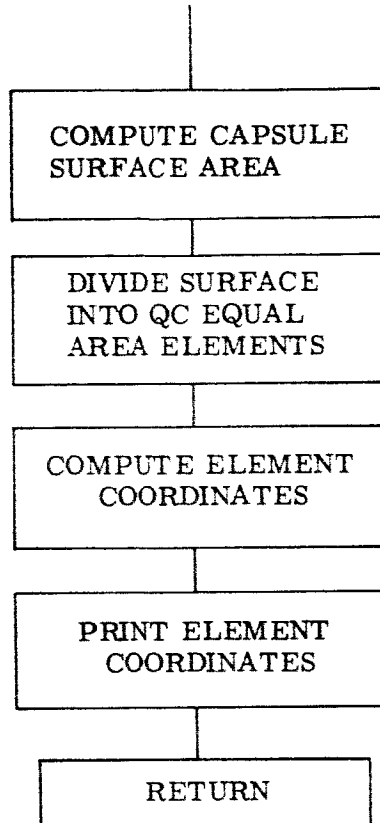
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000074      GO TO 90
000075      80 L=10
000076      90 R=RHC(I)
000077      DO 110 K23=1,L
000078      V=L
000079      DR=DEL*SQRT(HEATE*HEATB-R*R)/(V*SQRT(HEATE*HEATB+(HEATA*HEATA/
000080      1(HEATB*HEATB)-1)*R*R))
000081      110 R=R+DR
000082      ESTNN=6.2832*R/DEL
000083      NI(I+1)=ESTNN+.5
000084      IF(NI(I+1) .GT. 50) GO TO 200
000085      AD=NI(I+1)
000086      DELTA(I+1)=6.2832/AD
000087      100 RHC(I+1)=R
000088      K1=K+1
000089      60 RETURN
000090      200 WRITE(IP,9000)
000091      STOP
000092      9000 FORMAT(52H THE DIMENSIONS (10,70) IN HSAREA HAVE BEEN EXCEEDED)
000093      ENL

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SUBROUTINE CAPAR (05)



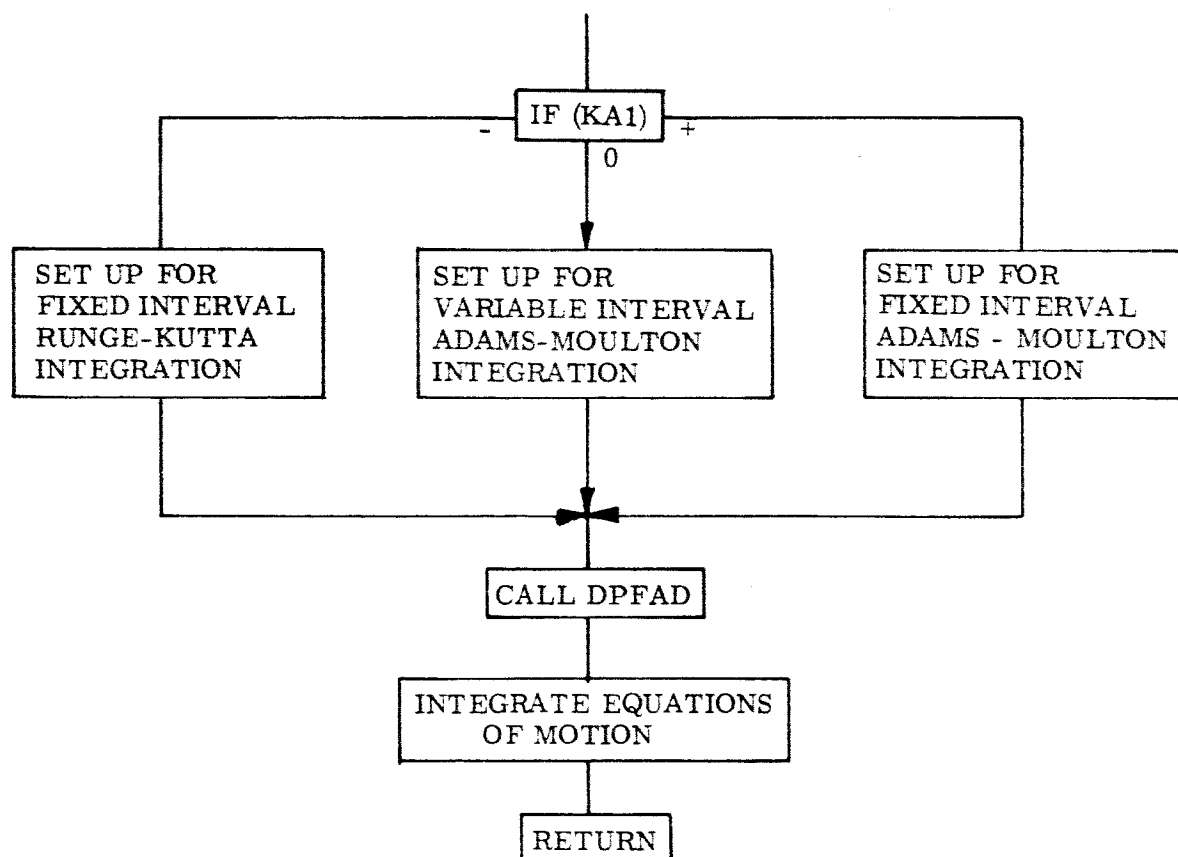
ELT CAPAR,1,660326, 55355

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000001      SUBROUTINE CAPAR
000002      C
000003      C   THIS SUBROUTINE DIVIDES THE SURFACE OF THE CAPSULE INTO
000004      C   APPROXIMATELY QC INCREMENTAL AREAS
000005      C
000006      COMMON/L2/HEATA,HEATE,HSCG2,IP,IS,IT,DEN(17),XV,ETA
000007      COMMON/L13/SLGTH(3,6),FC(3,6),COEF(2,8),COEFT(2,8),XMAX,XMIN,GC,
000008      1NS
000009      COMMON/L15/X(12),Y(12,55),Z(12,55),N(12),M,ACEL,XBASE
000010      COMMON/L16/FCGX,FCGY,FCGZ,TCGX1,TCGY1,TCGZ1,PREV,YCG,ZCG,
000011      1CAREA,CAREAM
000012      COMMON/M1/FORJK(6),SLJK(6),CHJK(6),CHJK(6),SRJK(6),SRJK(6),
000013      1SDJK(6),VELJK(6),FORLM(8),SLLM(8),CHLMT(8),CHLM(8),SRLMT(8),
000014      2SRLM(8),SDLM(8),VELLM(8),LMAX(10,50),DELMAX(12,55),SACC,SVEL,
000015      3SLEL,PKNEE(10,50)
000016      COMMON/L22/PXVEL,PYVEL,PZVEL,APX1,APY1,APZ1,RPX,RPY,RPZ,FPPX,FPPY,
000017      1FPFZ,TPPX1,TPPY1,TPPZ1,APX10,APY10,APZ10,PHITE,IPARA,XCG1,YCG1,
000018      2ZCG1
000019      DIMENSION RHO(12),DBETA(12)
000020      YCG=YCG1
000021      ZCG=ZCG1
000022      C   COMPUTE CAPSULE SURFACE AREA
000023      XBASE=XV-HEATB/COS(ETA)
000024      CAFA=3.1416*HEATB*(2*(XBASE-XMIN)+((XV-XBASE)-(XV-XMAX)*(XV-XMAX)/
000025      1(XV-XBASE))/COS(ETA))
000026      C   COMPUTE CAPSULE 'SLANT HEIGHT'
000027      CAPP=(XMAX-XBASE)/COS(ETA)+XBASE-XMIN
000028      C   COMPUTE ELEMENT AREA
000029      ESTDEL=SQRT(CAPA/GC)
000030      ESTM=CAPP/ESTDEL
000031      M=ESTM+1.
000032      IF(M.GT. 12) GO TO 350
000033      A=M
000034      DEL=CAPP/A
000035      ACEL=DEL*DEL
000036      C   BEGIN LOOP TO DETERMINE ELEMENT COORDINATES
000037      X(1)=XMIN-XCG1+DEL/2.0
000038      XDLM=X(1)+DEL
000039      DO 100 I=2,M
000040      IF(XBASE-XDUM)30,20,20
000041      20 X(1)=XDUM
000042      GO TO 100
000043      30 X(1)=XBASE-(XBASE-XDUM)*COS(ETA)
000044      100 XDLM=XDUM+DEL
000045      DO 201 I=1,M
000046      IF(XBASE-XCG1-X(I))120,110,110
000047      110 RHC(1)=HEATB
000048      GO TO 130
000049      120 RHC(1)=(XV-XCG1-X(I))*SIN(ETA)/COS(ETA)
000050      130 ESTNN=6.2832*RHO(1)/DEL
000051      N(1)=ESTNN+.5
000052      IF(N(1).GT. 53) GO TO 350
000053      C=N(1)
000054      LBETA(1)=6.2832/C
000055      K=N(1)
000056      DO 200 J=1,K
000057      L=J-1
000058      BETA=L*DBETA(1)
000059      Y(I,J)=-RHO(1)*SIN(BETA)-YCG
000060      200 Z(I,J)=RHO(1)*COS(BETA)-ZCG
000061      201 CONTINUE
000062      K=M
000063      DO 210 I=1,K
000064      NN=N(I)
000065      WRITE(6,220) RHO(1),X(I),N(I)
000066      210 WRITE(6,230) (Y(I,J),Z(I,J),J=1,NN)
000067      WRITE(6,240) CAPA,CAPP,ACEL,M
000068      220 FORMAT(2F10.5,110)
000069      230 FORMAT(2F10.5)
000070      240 FORMAT(3F10.5,110)
000071      RETURN
000072      350 WRITE(IP,9000)
000073      9000 FORMAT(52H THE DIMENSIONS (12,55) IN CAREA HAVE BEEN EXCEEDED)
000074      STOP
000075      END

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SUBROUTINE MASTER (06)



ELT MASTER.1:660318. 38488

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000001      SUBROUTINE MASTER
000002  MASTER  PROGRAM TO DO INTEGRATION OF DIFFERENTIAL EQUATIONS
000003      COMMON/L9A/IREAL
000004      COMMON/L12/T(1000),SPACE,NN,KA1,A2,A3,A4,A5,A7,MAP,K
000005      COMMON/M1/FORJK(6),SLJK(6),CHJKT(6),CHJK(6),SRJKT(6),SRJK(6),
000006      1SDJK(6),VELJK(6),FORLM(6),SLLM(6),CHLMT(6),CHLP(6),SRLMT(6),
000007      2SRLM(6),SDLH(6),VELLM(6),DMAX(10,50),DELMAX(12,55),SACC,SVEL,
000008      3SDEL,PKNEE(10,50)
000009      DIMENSION BET(4),SET(4)
000010      DIMENSION PT(9865)
000011      EQUIVALENCE(FORJK(1),PT(1))
000012      DATA SET(1)/1.0/,SET(2)/2.0/,SET(3)/2.0/,SET(4)/1.0/
000013      DATA BET(1)/0.5/,BET(2)/0.5/,BET(3)/1.0/,BET(4)/0.0/
000014      DATA M/1977/
000015      GO TO (502,412,503),MAP
000016      502 N1=NN+1
000017      N2XN1=N1+N1
000018      N3XN1=N2XN1+N1
000019      N4XN1=N3XN1+N1
000020      N5XN1=N4XN1+N1
000021      N6XN1=N5XN1+N1
000022      N7XN1=N3XN1+N4XN1
000023      N9XN1=N7XN1+N2XN1
000024      N10XN1=N5XN1+N5XN1
000025      N12XN1=N10XN1+N2XN1
000026      IF(A7.LT. 0.0000001) A7=0.5
000027      IF(A3.LT. 0.0000001) A3=A2/55.0
000028      DO 1412 I=1,N1
000029      1412 T(I+N2XN1)=0.0
000030      IREAL=1
000031      CALL ACCEL
000032      LL=1
000033      KR = 1
000034      MAP = 2
000035      RETURN
000036      412 DO 415 I=1,KR
000037      LKR=N3XN1*(KR-I+1)
000038      DO 415 J=1,N3XN1
000039      LR=LKR+J
000040      LRJ=LR-N3XN1
000041      415 T(LR)=T(LRJ)
000042      DO 2101 I=1,KK
000043      INDEX=M*(KR-I+1)
000044      DO 2101 J=1,M
000045      INCL=INDEX+J
000046      IND2=IND1+M
000047      2101 PT(IND1)=PT(IND2)
000048      414 MAP = 2
000049      IF(KR.GE.4) GO TO 44
000050      DO 20 I=1,NN
000051      20 T(I+N2XN1)=0.0
000052      K = 1
000053      32 DO 350 I=1,NN
000054      DELY1=SPACE*T(I+N1)
000055      T(I+N2XN1)=T(I+N2XN1)+DELY1*SET(K)
000056      350 T(I)=T(I+N3XN1)+BET(K)*DELY1
000057      IF(K.GE.4) GO TO 37
000058      T(N1)=BET(K)*SPACE+T(N4XN1)
000059      IREAL=0
000060      CALL ACCEL
000061      K = K + 1
000062      GO TO 32
000063      37 DO 40 I=1,NN
000064      CALL DPFAD(T(I+N3XN1),T(I+N5XN1),T(I+N2XN1)/6.0,T(I),T(I+N2XN1))
000065      40 CONTINUE
000066      CALL DPFAD(T(N4XN1),T(N6XN1),SPACE,T(N1),T(N3XN1))
000067      IREAL=1
000068      CALL ACCEL
000069      IF(KA1.LT.0) RETURN
000070      KR = KR + 1
000071      RETURN
000072      44 DO 46 I=1,NN
000073      DEL=SPACE*(55.*T(I+N4XN1)-59.*T(I+N7XN1)+37.*T(I+N10XN1)-9.*T(I+

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000074      1N10XN1+N3XN1)/24.0
000075      46 T(I)=T(I+N3XN1)+DEL
000076      CALL DPFAU(T(N4XN1),T(N6XN1),SPACE,T(N1),T(N3XN1))
000077      IREAL=0
000078      CALL ACCEL
000079      SSE = 0.0
000080      DO 51 I=1,NN
000081      DEL=SPACE*(9.*T(I+N1)+19.*T(I+N4XN1)-5.*T(I+N7XN1)+T(I+N10XN1))/
000082      124.0
000083      YI=T(I+N3XN1) + DEL
000084      IF(KA1.NE.0) GO TO 39
000085      IF (ABS(YI)-1.E-3)103,103,301
000086      103 EPSIL=ABS(-19.0*(YI-T(I))/270.0)
000087      GO TO 307
000088      301 EPSIL=ABS(-19.0*(YI-T(I))/(270.0*YI))
000089      307 IF(SSE .GT. EPSIL) GO TO 302
000090      SSE = EPSIL
000091      302 CALL DPFAU(T(I+N3XN1),T(I+N5XN1),DEL,T(I),T(I+N2XN1))
000092      51 CONTINUE
000093      IREAL=1
000094      CALL ACCEL
000095      IF(KA1.NE.0) GO TO 39
000096      IF(SSE .LT. A2) GO TO 35
000097      IF(ABS(SPACE).GT.A4) GO TO 340
000098      GO TO 39
000099      35 IF(SSE .GT. A3) GO TO 39
000100      IF(ABS(SPACE) .LT. A5) GO TO 360
000101      39 LL = 2
000102      KR = 4
000103      RETURN
000104      340 SPACE = SPACE*A7
000105      GO TO (341,342,1341),LL
000106      1341 DO 1432 I=1,N3XN1
000107      1432 T(I) = T(I+N6XN1)
000108      DO 2104 I=1,M
000109      2104 PT(I)=PT(I+2*M)
000110      GO TO 504
000111      341 DO 501 I=1,N3XN1
000112      501 T(I)=T(I+N12XN1)
000113      DO 2102 I=1,M
000114      2102 PT(I)=PT(I+4*M)
000115      504 NAF=2
000116      LL=1
000117      KR=1
000118      RETURN
000119      342 DO 343 I=1,N3XN1
000120      343 T(I)=T(I+N3XN1)
000121      DO 2103 I=1,M
000122      2103 PT(I)=PT(I+M)
000123      GO TO 504
000124      360 NAF = 3
000125      RETURN
000126      503 DO 362 I=1,N3XN1
000127      T(I+N3XN1)=T(I)
000128      362 T(I+N9XN1)=T(I+N12XN1)
000129      DO 2105 I=1,M
000130      PT(I+M)=PT(I)
000131      2105 PT(I+3*M)=PT(I+4*M)
000132      LL = 3
000133      KR = 3
000134      SPACE = 2.0*SPACE
000135      GO TO 414
000136      ENL

```

SUBROUTINE DPFAD (07)

PERFORM DOUBLE
PRECISION ARITHMETIC
FOR INTEGRATION
SUBROUTINE

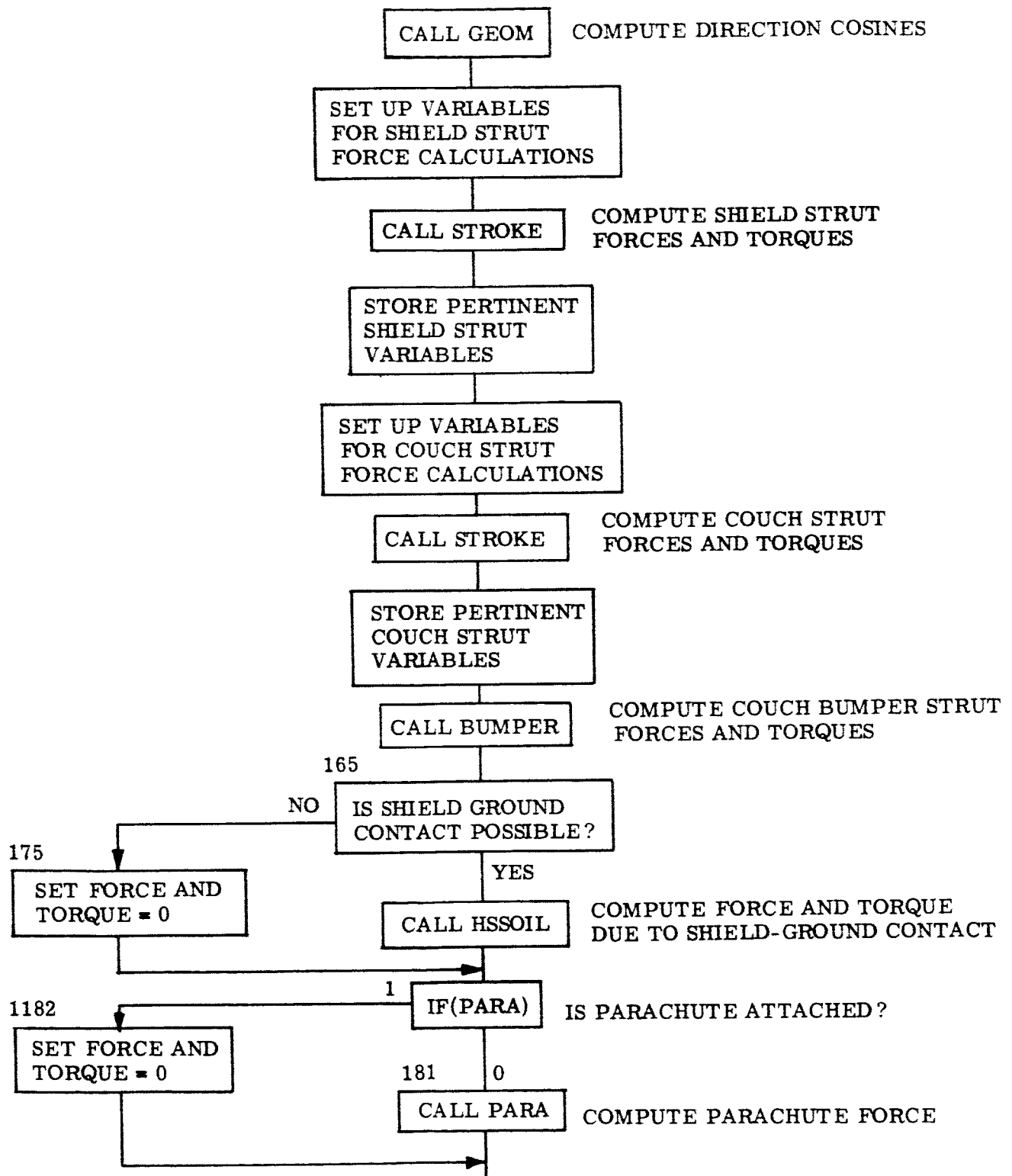
RETURN

-I FOR DPFAD

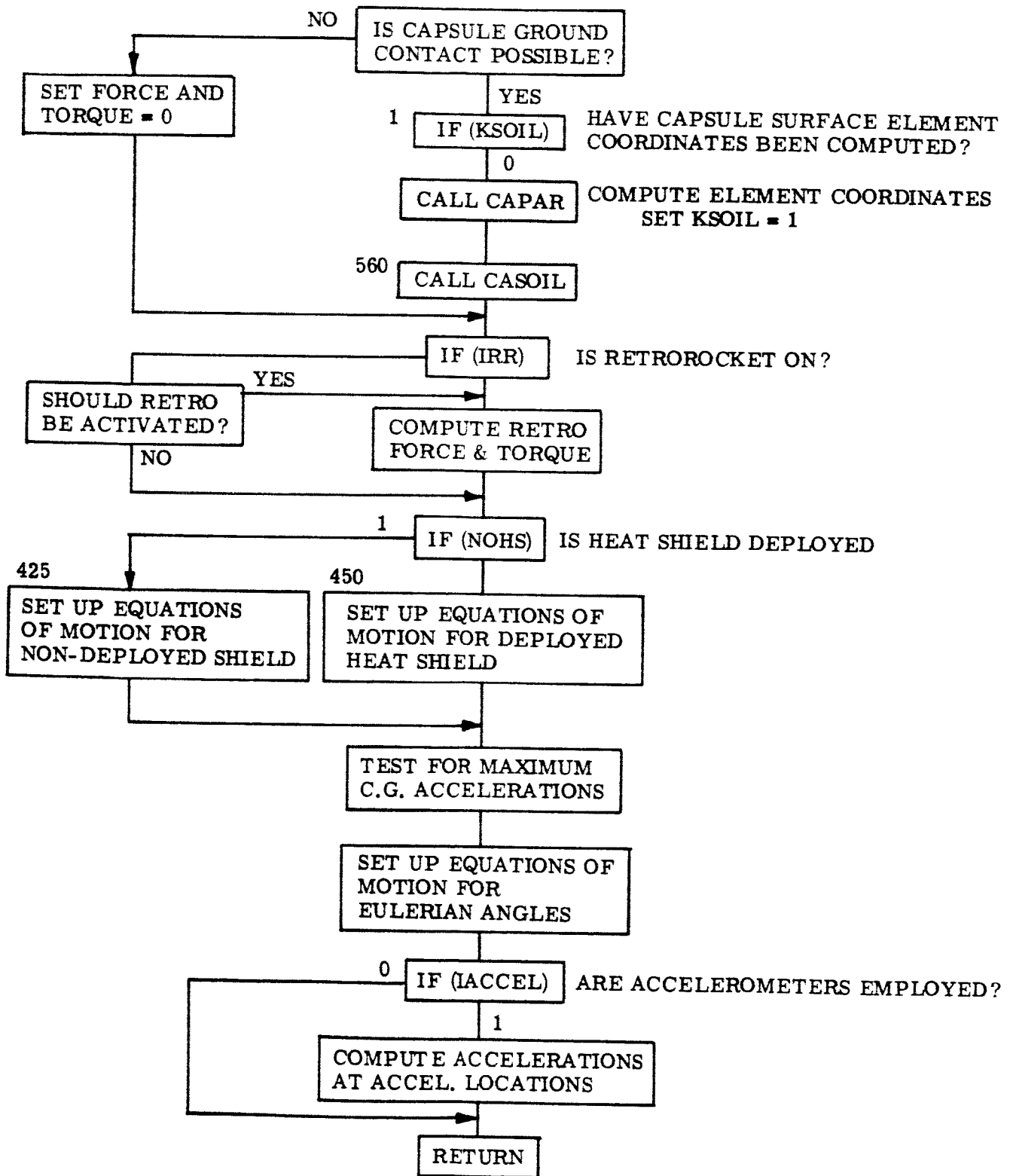
SUBROUTINE DPFAD(AA, BB, CC, DD, EE)
CDPFAD

DOUBLE PRECISION A1, B1, C1
DIMENSION A(6)
EQUIVALENCE (A1, A(1)), (B1, A(3)), (C1, A(5))
DATA A(4)/0.0/
A(1) = AA
A(2) = BB
A(3) = CC
C1 = A1+B1
DD = A(5)
EE = A(6)
RETURN
END

SUBROUTINE ACCEL (08)



SUBROUTINE ACCEL. (08) (Cont.)



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000001      SUBROUTINE ACCEL
000002      C
000003      C
000004      C
000005      C      THIS SUBROUTINE DIRECTS THE DETERMINATION OF SYSTEM ACCELERATIONS
000006      C      FOR ANY GIVEN SET OF COORLINATE DISPLACEMENTS AND VELOCITIES-
000007      C
000008      C
000009      COMMON/L2/HEATA,HEATE,HSCG2,IP,IS,IT,UXX,UYX,UZZ,UCXX,UCYX,UCZZ,
000010      1USXX,USYY,USZZ,FCUK,FCUM,UXY,UYZ,UXZ,UCXY,UCXZ,UCYZ,HC,ETA,PLGNOF,
000011      2FK,JK,LM,HSX1,HCX1,JKDAMP,LKDAMP,VISUK,VISLM
000012      COMMON/L3B/AX,AY,AZ,WDX,WDY,WDZ,ACX,ACY,ACZ,WDCX,WDCY,WDCZ,
000013      1ASX,ASY,ASZ,WDSX,WDSY,WDSZ
000014      COMMON/L5B/OLCMAX(6),OLCMIN(6),OLSMAX(8),OLSMIN(8),JC,JS,OLCB(6),
000015      1OLCL(6),OLSB(8),OLSL(8),OMACX(7),OMACY(7),OMACZ(7),OMAX(7),
000016      2OMAY(7),OMAZ(7),ODEL(10),ENGKE,OECS,ENGPE,DESS,DESGND,DESOIL,
000017      3UFFACT,DEGND,ENGKEF,NORING(10),ENGTOT,AX1,AY1,AZ1,ACX3,ACY3,ACZ3,
000018      4ASX2,ASY2,ASZ2,L1
000019      COMMON/L5C/ZETA,CAPH,CCHH,HSLM
000020      COMMON/L6A/SLJK0(6),SLLMC(8)
000021      COMMON/L6B/XL1(6),YL1(8),ZL1(8),XM2(8),YM2(8),ZM2(8),XJ3(6),
000022      1YJ3(6),ZJ3(6),XK1(6),YK1(6),ZK1(6),CXX,CXY,CXZ,CYX,CYY,CYZ,
000023      2CZX,CZY,CZZ,CCXX,CCXY,CCXZ,CCYX,CCYY,CCYZ,CCZX,CCZY,CCZZ
000024      COMMON/L7A/QSX(6),QSY(8),QSZ(8),QKT,FSGX,FSGY,FSGZ,TSGX,TSGY,TSGZ,
000025      1AREA,AREAM
000026      COMMON/L7B/QX(8),QY(8),QZ(8),QSQP(8),QSHT,QFC(8),QCH(8),QSH,
000027      1QSF(6),QFF,QVIS,QDAMP,QFX,QFY,QFZ,QTX1,QTY1,GTZ1,JKLM,GT SX2,
000028      2GTSY2,GT SZ2,GT CX3,GT CY3,GT CZ3,N,FORP(8),FHCG(8),SO(8),QCHT(8),
000029      3QSF(6),QSD(8),SQ(8),QGRX,QGRY,QGRZ,QVGX,QVGY,QVGZ,QWGX,QWGY,QWGZ
000030      COMMON/LISTB/D11,D12,D13,D21,D22,D23,D31,D32,D33,DS11,DS12,DS13,
000031      1LS21,LS22,LS23,DS31,DS32,DS33,DC11,DC12,DC13,DC21,DC22,DC23,
000032      2LC31,DC32,DC33
000033      COMMON/L9A/IREAL
000034      COMMON/L9B/SHCUK,SHCUKT,SHCLM,SHCLMT,CTJK,CTLM,XORIG
000035      COMMON/L11/AA1(3,6),AA3(3,6),CAP(3,6),CCH(3,6),IACCEL
000036      COMMON/L12/QRX(1),QRY,QRZ,QVX,QVY,QVZ,QWX,QWY,QWZ,
000037      1GRX,GRY,GRZ,QVX,QVY,QVZ,QWX,QWY,QWZ,
000038      2GRSX,GRSY,GRSZ,QV SX,QVSY,QV SZ,QWSX,QWSY,QWSZ,
000039      3GPS1,GTHTA,QPHI,QPSIC,QTHTAC,QPHIC,QPSIS,QTHTAS,QPHIS,QSLDEL,QSVEL
000040      4,TIME,DUM5(961),DT
000041      COMMON/L13/SLGTH(3,6),FC(3,6),COEF(2,8),COEFT(2,8),XMAX,XMIN,QC,
000042      1NS,FFLM(8),FFLMT(8),FFJK(6),FFJKT(6),FFC(8),FFT(8),IRET
000043      COMMON/L14/PVEL(8)
000044      COMMON/L16/FCGX,FCGY,FCGZ,TCGX1,TCGY1,TCGZ1,PREV,YCG,ZCG,
000045      1CAFEA,CAREAM
000046      COMMON/L18/SLRHU,SOILE,SLPHI,CKPHIC,NAA,AA(9),EB(9),TESOIL
000047      COMMON/M1/FORJK(6),SLJK(6),CHUKT(6),CHUK(6),SRJKT(6),SRJK(6),
000048      1SLJK(6),VELJK(6),FORLM(6),SLLM(8),CHLMT(8),CHLM(8),SRLMT(8),
000049      2SRLM(8),SOLM(8),VELLM(8),LMAX(10,50),DELMAX(12,55),SACC,SVEL,
000050      3SLIEL,PKNEE(10,50)
000051      COMMON/L19/NCHS,HSY1,HSZ1,ALT1,ALTY,ALT2,RRX1(6),RRY1(6),RRZ1(6),
000052      1RRX2(6),RRY2(6),RRZ2(6),NRR,THRR(6,10),TYM(6,10),CRRX(6),CRRY(6),
000053      2CRFZ(6),HCY1,HCZ1
000054      COMMON/L20/XB13,YB13,ZB13,XB23,YB23,ZB23,YRP1,YRP2,BLNG,BST1MX,
000055      1BST2MX,BMPNRG,BDEF(6),BFOK(6),FBX,FBY,FBZ,TEX,TBY,TBZ,TBCX,TBCY,
000056      2TBCZ,RRNRG
000057      COMMON/L21/FAKE(100),YMIN,DEY,NY,ZMIN,DEZ,KZ,RSURF(3,11,11),XPMAX
000058      COMMON/L22/PXVEL,PYVEL,PZVEL,APX1,APY1,APZ1,RPX,RPY,RPZ,FPPX,FPPY,
000059      1FPFZ,TPPX1,TPPY1,TPPZ1,APX10,APY10,APZ10,PHITE,IPARA,XCG1,YCG1,
000060      2ZCG1
000061      C
000062      C      DATA G/32.2/,KSOIL/0/
000063      C
000064      C
000065      C      DETERMINE DIRECTION COSINES FOR THE SYSTEM
000066      C
000067      C      CALL GEOM
000068      C
000069      C      SET UP FOR SHIELD STRUT FORCE CALCULATIONS
000070      C
000071      C      IF(NCHS)10,10,95
000072      10 GO 30 I=1,LM
000073      CX(I)=XL1(I)
000074      CY(I)=YL1(I)

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000075      GZ(I)=ZL1(I)
000076      GSA(I)=XF2(I)
000077      GSY(I)=YM2(I)
000078      GSZ(I)=ZM2(I)
000079      SG(I)=SLLM(I)
000080      FOF(I)=FORLM(I)
000081      GCH(I)=CHLMT(I)
000082      GSFT(I)=SRLMT(I)
000083      GSF(I)=SRLM(I)
000084      GSL(I)=SDLM(I)
000085      GSGP(I)=SLLM(I)
000086      PVEL(I)=VELLM(I)
000087      FFC(I)=FFLM(I)
000088      FFT(I)=FFLMT(I)
000089      30 GCH(I)=CHLM(I)
000090      GKT=LTLM
000091      GST=SHCLM
000092      GSFT=SHCLMT
000093      JKLM=1
000094      N=LM
000095      NS=1
000096      GVIS=VISLM
000097      GRGX=GRSX
000098      GRGY=GRSY
000099      GRGZ=GRSZ
000100      GVCX=GVSX
000101      GVGX=GVSX
000102      GVCZ=GVSZ
000103      GWCX=GWSX
000104      GWCY=GWSY
000105      GWCZ=GWSZ
000106      IF (LNDAMP)40,40,50
000107      40 GDAMP=0.0
000108      GO TO 60
000109      50 GDAMP=1.0
000110      60 CONTINUE
000111      C
000112      C      CALCULATE SHIELD STRUT FORCES AND TORQUES
000113      C
000114      C      CALL STROKE
000115      C
000116      C      GO TO 60
000117      C
000118      C      REMEMBER RESULTS
000119      C
000120      60 IF (IKEAL)90,90,70
000121      70 DO 80 I=1,LM
000122      IF (SG(I) .LT. OLSMIN(I)) OLSMIN(I)=SG(I)
000123      IF (SG(I) .GT. OLSMAX(I)) OLSMAX(I)=SG(I)
000124      FORLM(I)=FHCQ(I)
000125      SLLM(I)=SG(I)
000126      CHLM(I)=GCH(I)
000127      CHLMT(I)=GCHT(I)
000128      SRLMT(I)=GSRT(I)
000129      SDLM(I)=GSD(I)
000130      VELLM(I)=PVEL(I)
000131      80 SRLM(I)=GSR(I)
000132      C
000133      90 CONTINUE
000134      C
000135      C      REMEMBER SUM OF FORCES AND TORQUES
000136      C
000137      C      FORCE ON CAPSULE FROM SHIELD (IN FIXED COORD. SYSTEM)
000138      C
000139      FSX=GFX
000140      FSY=GFY
000141      FSZ=GFZ
000142      C
000143      C      TORQUE ON CAPSULE FROM SHIELD
000144      C
000145      TSX=GTAX
000146      TSY=GTAY
000147      TSZ=GTZ
000148      C
000149      C      TORQUE ON SHIELD FROM SHIELD

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000150      C
000151      TSX2=QTSX2
000152      TSY2=QTSY2
000153      TSZ2=QTSZ2
000154      C
000155      C      SET UP FOR COUCH STRUT FORCE CALCULATIONS
000156      C
000157      95 DO 100 I=1,JK
000158          LX(I)=XK1(I)
000159          LY(I)=YK1(I)
000160          LZ(I)=ZK1(I)
000161          GSX(I)=XJ3(I)
000162          GSY(I)=YJ3(I)
000163          GSZ(I)=ZJ3(I)
000164          SO(I)=SLJKO(I)
000165          FORF(I)=FORJK(I)
000166          GCHT(I)=CHJKT(I)
000167          GSRT(I)=SRJKT(I)
000168          GSR(I)=SRJK(I)
000169          GSD(I)=SDJK(I)
000170          GSCP(I)=SLJK(I)
000171          PVEL(I)=VELJK(I)
000172          FFC(I)=FFJK(I)
000173          FFT(I)=FFJKT(I)
000174      100 GCH(I)=CHJK(I)
000175          GKT=CTJK
000176          GSH=SHCJK
000177          GSHT=SHCJKT
000178          JKLM=C
000179          N=JK
000180          NS=2
000181          GVIS=VISJK
000182          GRGX=GRCX
000183          GRGY=GRCY
000184          GRGZ=GRCZ
000185          GVGX=GVCX
000186          GVEY=GVCY
000187          GVGZ=GVCZ
000188          GNGX=GNCX
000189          GNGY=GNCY
000190          GNGZ=GNCZ
000191          IF (JKDAMP) 110,110,120
000192      110 GDAMP=0.0
000193          GO TO 130
000194      120 GDAMP=1.0
000195      130 CONTINUE
000196      C
000197      C      CALCULATE COUCH STRUT FORCES AND TORQUES
000198      C
000199      CALL STROKE
000200      GO TO 138
000201      C
000202      C
000203      C      REMEMBER RESULTS
000204      C
000205      138 IF (IREAL) 160,160,140
000206      140 DO 150 I=1,JK
000207          IF (SW(I).LT. OLCMIN(I)) OLCMIN(I)=SQ(I)
000208          IF (SW(I).GT. OLCMAX(I)) OLCMAX(I)=SQ(I)
000209          FORJK(I)=FHCIG(I)
000210          SLJK(I)=SQ(I)
000211          CHJKT(I)=GCHT(I)
000212          CHJK(I)=GCH(I)
000213          SRJKT(I)=GSRT(I)
000214          SDJK(I)=GSD(I)
000215          VELJK(I)=PVEL(I)
000216      150 SRJK(I)=QSR(I)
000217      C
000218      160 CONTINUE
000219      C
000220      C      REMEMBER SUM OF FORCES AND TORQUES
000221      C
000222      C      FORCE ON CAPSULE FROM COUCH (IN FIXED COORD. SYSTEM.)
000223      C
000224      FCX=LFX

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000225      FCY=CFY
000226      FCZ=CFZ
000227      C
000228      C      TORQUE ON CAPSULE FROM COUCH
000229      C
000230      TCX1=GT X1
000231      TCY1=GT Y1
000232      TCZ1=GT Z1
000233      C
000234      C      TORQUE ON COUCH FROM COUCH STRUTS
000235      C
000236      TCX3=GT CX3
000237      TCY3=GT CY3
000238      TCZ3=GT CZ3
000239      C
000240      C
000241      CALL BUMPER
000242      C
000243      C      TOTAL TORQUE ON COUCH
000244      C
000245      TCX3=TCX3+TBCX
000246      TCY3=TCY3+TBCY
000247      TCZ3=TCZ3+TBCZ
000248      C
000249      C
000250      C      INITIALIZE FOR HEAT SHIELD - RIGID SURFACE SUBROUTINE
000251      C
000252      IF(DS11)175,175,165
000253      165 SQR=SQRT(HEATB*HEATB-DS11*DS11*(HEATB*HEATB-HEATA*HEATA))
000254      IF(NY .GT. 0 .AND. NZ .GT. 0) GO TO 170
000255      IF(QHSX-SGR+DS11*HSCG2+0.001)170,170,175
000256      170 CONTINUE
000257      GKT=CTLM
000258      SLCEL=QSLDEL
000259      SVEL=QSVEL
000260      CALL HSSOIL
000261      GO TO 180
000262      175 FSGX=0.0
000263      FSGY=0.0
000264      FSGZ=0.0
000265      TSGX=0.0
000266      TSGY=0.0
000267      TSGZ=0.0
000268      AREA=0.0
000269      180 CONTINUE
000270      C
000271      IF(IFARA .GT. 0 ) GO TO 1182
000272      IF(QHSX-SGR+DS11*HSCG2-PHITE)1182,1182,181
000273      181 CALL PARA
000274      GO TO 183
000275      1182 IPARA=1
000276      FPFY=0.0
000277      FPFY=0.0
000278      FPFZ=0.0
000279      TPFY1=0.0
000280      TPFY1=0.0
000281      TPFZ1=0.0
000282      183 CONTINUE
000283      IF(D11-0.7)500,500,400
000284      C
000285      C      CAPSULE MAY CONTACT THE GROUND: CALCULATE CAPSULE SURFACE AREA
000286      C
000287      500 IF(KSOIL)530,530,560
000288      530 KSOIL=1
000289      CALL CAPAR
000290      560 CALL CASOIL
000291      GO TO 405
000292      400 FCGX=0.0
000293      FCGY=0.0
000294      FCGZ=0.0
000295      TCGX1=0.0
000296      TCGY1=0.0
000297      TCGZ1=0.0
000298      CAKEA=0.0
000299      PRELV=0.0

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000300      C
000301      C      IF (RETRO ON; RETRO ON; RETRO OFF)
000302      C
000303      405 FRXX=0.0
000304      FRRY=0.0
000305      FRRZ=0.0
000306      TRFX=0.0
000307      TRRY=0.0
000308      TRRZ=0.0
000309      IF (IKR) 406, 406, 1409
000310      406 RKTITE=D11*ALT+D12*ALTY+D13*ALTZ-QRX
000311      IF (RKTITE) 407, 407, 408
000312      406 IF (FSGX=0.001) 420, 407, 407
000313      407 IF (IKR) 1408, 1408, 1409
000314      1408 TIMEC=TIME
000315      1409 IRF=1
000316      LG 418 I=1, NRR
000317      J=1
000318      409 IF (TIME-TIMEC-TYM(I, J)) 1412, 411, 410
000319      410 J=J+1
000320      IF (J-10) 409, 411, 411
000321      411 THF=THRR(I, J)
000322      GO TO 413
000323      412 IF (J .GT. 1) GO TO 1413
000324      THF=0.0
000325      GO TO 413
000326      1413 THF=THRR(I, J-1)+(TIME-TIMEC-TYM(I, J-1))*(THRR(I, J)-THRR(I, J-1))/
000327      1*(TYM(I, J)-TYM(I, J-1))
000328      413 FRFX=FRRX+THF*(D11*CRRX(I)+D12*CRRY(I)+D13*CRRZ(I))
000329      FRRY=FRRY+THF*(D21*CRRX(I)+D22*CRRY(I)+D23*CRRZ(I))
000330      FRRZ=FRRZ+THF*(D31*CRRX(I)+D32*CRRY(I)+D33*CRRZ(I))
000331      TRFX=TRRX+THF*(CRRX(I)*RRY1(I)-CRRY(I)*RRZ1(I))
000332      TRRY=TRRY+THF*(CRRX(I)*RRZ1(I)-CRRY(I)*RRX1(I))
000333      418 TRRZ=TRRZ+THF*(CRRY(I)*RRX1(I)-CRRY(I)*RRY1(I))
000334      IF (INEAL) 420, 420, 419
000335      419 RRRRG=RRNRG+(FRFX*GVX+FRRY*GVY+FRRZ*GVZ+TRRX*QBX+FRRY*QBY
000336      1+TRRZ*QBZ)*DT
000337      420 IF (NUMS) 450, 450, 425
000338      425 FGR=1.0/CAPH
000339      AX=(FSGX+FCX+FCGX+FRHX+FBX+FFPX-CAPH*G*COS(ZETA))*PQR
000340      AY=(FSGY+FCY+FCGY+FRRY+FBY+FFPY)*PQR
000341      AZ=(FSGZ+FCZ+FCGZ+FRRZ+FBZ+FFPZ+CAPH*G*SIN(ZETA))*PQR
000342      GO TO 460
000343      C
000344      C      CAPSULE LINEAR ACCELERATION IN THE FIXED COORD. SYSTEM
000345      C
000346      450 FGR=1.0/CAPH
000347      AX=(FSX+FCX+FCGX+FRHX+FBX+FFPX-CAPH*G*COS(ZETA))*PQR
000348      AY=(FSY+FCY+FCGY+FRRY+FBY+FFPY)*PQR
000349      AZ=(FSZ+FCZ+FCGZ+FRRZ+FBZ+FFPZ+CAPH*G*SIN(ZETA))*PQR
000350      C
000351      C      CAPSULE LINEAR ACCELERATION IN THE CAPSULE COORD. SYSTEM
000352      C
000353      460 AX1=D11*AX+D21*AY+D31*AZ
000354      AY1=D12*AX+D22*AY+D32*AZ
000355      AZ1=D13*AX+D23*AY+D33*AZ
000356      C
000357      C      MAXIMUM CAPSULE ACCELERATION
000358      C
000359      IF (ABS(AX1) .GT. ABS(OMAX(1))) OMAX(1)=AX1
000360      IF (ABS(AY1) .GT. ABS(OMAY(1))) OMAY(1)=AY1
000361      IF (ABS(AZ1) .GT. ABS(OMAZ(1))) OMAZ(1)=AZ1
000362      C
000363      C      COUCH LINEAR ACCELERATION IN THE FIXED COORD. SYSTEM
000364      C
000365      FGR=1.0/CCHM
000366      ACX=(-CCHM*G*COS(ZETA)-FCX-FBX)*PQR
000367      ACY=(-FCY-FBY)*PQR
000368      ACZ=(-CCHM*G*SIN(ZETA)-FCZ-FBZ)*PQR
000369      C
000370      C      COUCH LINEAR ACCELERATION IN THE COUCH COORD. SYSTEM
000371      C
000372      ACX3=DC11*ACX+DC21*ACY+DC31*ACZ
000373      ACY3=DC12*ACX+DC22*ACY+DC32*ACZ
000374      ACZ3=DC13*ACX+DC23*ACY+DC33*ACZ

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000375 C
000376 C MAXIMUM COUCH ACCELERATION
000377 C
000378 IF (ABS(ACX3) .GT. ABS(OMACX(1))) OMACX(1)=ACX3
000379 IF (ABS(ACY3) .GT. ABS(OMACY(1))) OMACY(1)=ACY3
000380 IF (ABS(ACZ3) .GT. ABS(OMACZ(1))) OMACZ(1)=ACZ3
000381 C
000382 C HEAT SHIELD LINEAR ACCELERATION
000383 C
000384 IF (NCHS) 470, 470, 480
000385 470 FGR=1.0/HSDM
000386 ASX=(FSGX-FSX-HSDM*G*COS(ZETA))*PQR
000387 ASY=(FSGY-FSY)*PQR
000388 ASZ=(FSGZ-FSZ-HSDM*G*SIN(ZETA))*PQR
000389 C
000390 C
000391 C HEAT SHIELD LINEAR ACCELERATION IN THE HEAT SHIELD COORD. SYSTEM
000392 C
000393 ASX2=DS11*ASX+DS21*ASY+DS31*ASZ
000394 ASY2=DS12*ASX+DS22*ASY+DS32*ASZ
000395 ASZ2=DS13*ASX+DS23*ASY+DS33*ASZ
000396 C CAPSULE TORQUE
000397 TX=TCX1+TSX1+TCGX1+TRRX+TBX
000398 TY=TCY1+TSY1+TCGY1+TRRY+TBY
000399 TZ=TCZ1+TSZ1+TCGZ1+TRRZ+TBZ
000400 GO TO 490
000401 C
000402 480 TX=TCX1+TCGX1+TSGX+TRRX+TBX
000403 TY=TCY1+TCGY1+TSGY+TRRY+TBY
000404 TZ=TCZ1+TCGZ1+TSGZ+TRRZ+TBZ
000405 C
000406 C CAPSULE ANGULAR ACCELERATION
000407 C
000408 490 BX=TX-QWZ*QWX+UAY+QWY*QWZ- (QWZ*QWZ-QWY*QWY)*UYZ-QWY*QWZ*
000409 1 (UZZ-UYY)
000410 BY=TY-QWX*QWY+UYZ+QWY*QWZ+UAY- (QWX*QWX-QWZ*QWZ)*UXZ-QWZ*QWX*
000411 1 (UAX-UZZ)
000412 BZ=TZ-QWY*QWZ+UAX+QWY*QWZ+UYZ- (QWY*QWY-QWX*QWX)*UXY-QWX*QWY*
000413 1 (UYU-UXX)
000414 C
000415 BDX=LXX*BX+CCY*BY+CCZ*BZ
000416 BDY=LYX*BX+CCY*BY+CCZ*BZ
000417 BDZ=LCX*BX+CCY*BY+CCZ*BZ
000418 C
000419 C COUCH ANGULAR ACCELERATIONS
000420 C
000421 BCX=TCX3-QWCZ*QWCX+UCXY+QWCX*QWCY+UCXZ- (QWCZ*QWCZ-QWCY*QWCY)*
000422 1 LCYZ-QWCY*QWCZ*(UCZZ-UYY)
000423 BCY=TCY3-QWCX*QWCY+UCYZ+QWCY*QWCZ+UCXY- (QWCX*QWCX-QWCZ*QWCZ)*
000424 1 LCXZ-QWCZ*QWCX*(UCXX-UZZ)
000425 BCZ=TCZ3-QWCY*QWCZ+UCXZ+QWCX*QWCZ+UCYZ- (QWCY*QWCY-QWCX*QWCX)*
000426 1 LCXY-QWCX*QWCY*(UCYY-UXX)
000427 C
000428 BDCX=CCXX*BCX+CCY*BCY+CCZ*BCZ
000429 BDCY=CCYX*BCX+CCY*BCY+CCZ*BCZ
000430 BDCZ=CCZX*BCX+CCY*BCY+CCZ*BCZ
000431 C
000432 C HEAT SHIELD TORQUE
000433 C
000434 600 TSX=TSGX+TSX2
000435 TSY=TSGY+TSY2
000436 TSZ=TSGZ+TSZ2
000437 C
000438 C HEAT SHIELD ANGULAR ACCELERATION
000439 C
000440 BDSX=TSX/USXX
000441 BDSY=(TSY-QWSZ*QWSX*(USXX-USZZ))/USYY
000442 BDSZ=(TSZ-QWSX*QWSY*(USYY-USXX))/USZZ
000443 C
000444 GO TO 620
000445 620 DUM5(1)=QVX
000446 DUM5(2)=QVY
000447 DUM5(3)=QVZ
000448 DUM5(4)=AX
000449 DUM5(5)=AY

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000450      DUF5(6)=AZ
000451      DUF5(7)=WDX
000452      DUF5(8)=WDY
000453      DUF5(9)=WDZ
000454      DUF5(10)=QVCX
000455      DUF5(11)=QVCY
000456      DUF5(12)=QVCZ
000457      DUF5(13)=ACX
000458      DUF5(14)=ACY
000459      DUF5(15)=ACZ
000460      DUF5(16)=WDCX
000461      DUF5(17)=WDCY
000462      DUF5(18)=WDCZ
000463      DUF5(19)=QVSX
000464      DUF5(20)=QVSY
000465      DUF5(21)=QVSZ
000466      DUF5(22)=ASX
000467      DUF5(23)=ASY
000468      DUF5(24)=ASZ
000469      DUF5(25)=WDSX
000470      DUF5(26)=WDSY
000471      DUF5(27)=WDSZ
000472      IF(ABS(COS(QTHTA))-0.1E-32) 165,185,182
000473      182 DUF5(28)=(QWZ+COS(GPHI)+QWY*SIN(GPHI))/COS(QTHTA)
000474      DUF5(29)=QWY+COS(GPHI)-QWZ*SIN(GPHI)
000475      DUF5(30)=QWX+SIN(QTHTA)/COS(QTHTA)*(QWY*SIN(GPHI)+
000476      16WZ+COS(GPHI))
000477      GO TO 187
000478      C
000479      185 DUF5(28)=0.0
000480      DUF5(29)=QWX
000481      DUF5(30)=SQRT(QWY*QWY+QWZ*QWZ)
000482      C
000483      187 IF(ABS(COS(QHTAC))-0.1E-32) 189,189,188
000484      C
000485      188 DUF5(31)=(QWCZ+COS(GPHIC)+QWCY*SIN(GPHIC))/COS(QHTAC)
000486      DUF5(32)=QWCY+COS(GPHIC)-QWCZ*SIN(GPHIC)
000487      DUF5(33)=QWCX+SIN(QHTAC)/COS(QHTAC)*(QWCY*SIN(GPHIC)+
000488      16WCZ+COS(GPHIC))
000489      GO TO 632
000490      C
000491      189 DUF5(31)=0.0
000492      DUF5(32)=QWCX
000493      DUF5(33)=SQRT(QWCY*QWCY+QWCZ*QWCZ)
000494      C
000495      632 IF(NCHS) 190,190,630
000496      630 DUF5(34)=DUM5(28)
000497      DUF5(35)=DUM5(29)
000498      DUF5(36)=DUM5(30)
000499      DO 631 I=1,9
000500      631 DUM5(I+18)=DUM5(I)
000501      GO TO 200
000502      190 IF(ABS(COS(QHTAS))-0.1E-32) 195,195,191
000503      C
000504      191 DUF5(34)=(QWSZ+COS(GPHIS)+QWSY*SIN(GPHIS))/COS(QHTAS)
000505      DUF5(35)=QWSY+COS(GPHIS)-QWSZ*SIN(GPHIS)
000506      DUF5(36)=QWSX+SIN(QHTAS)/COS(QHTAS)*(QWSY*SIN(GPHIS)+
000507      16WSZ+COS(GPHIS))
000508      GO TO 200
000509      C
000510      195 DUF5(34)=0.0
000511      DUF5(35)=QWSX
000512      DUF5(36)=SQRT(QWSY*QWSY+QWSZ*QWSZ)
000513      200 IF(IACCEL) 300,300,210
000514      210 DO 240 I=1,6
000515      AA1(3,I)=AZ1+WDX*(CAP(2,I)-YCG1)-WDY*(CAP(1,I)-XCG1)-
000516      1(CAP(3,I)-ZCG1)*(QWX*QWX+QWY*QWY+QWZ*QWZ)*((CAP(1,I)-XCG1)*QWX+
000517      2(CAP(2,I)-YCG1)*QWY)
000518      220 AA1(1,I)=AX1+WDY*(CAP(3,I)-ZCG1)-WDZ*(CAP(2,I)-YCG1)-
000519      1(CAP(1,I)-XCG1)*(QWY*QWY+QWZ*QWZ)+QWX*((CAP(3,I)-ZCG1)*QWZ+
000520      2(CAP(2,I)-YCG1)*QWY)

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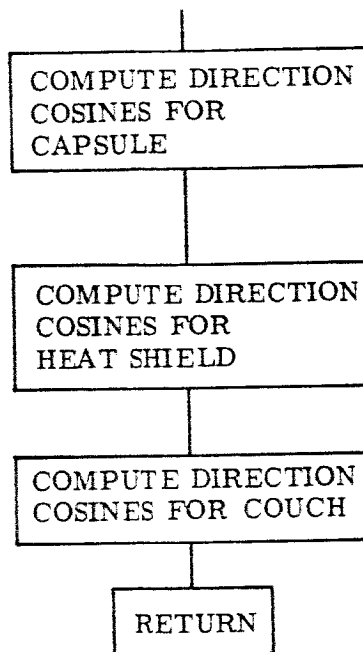


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000521      230 AA1(4:I)=AY1+WDZ*(CAP(1:I)-XCG1)-WDX*(CAP(3:I)-ZCG1)-
000522      1(CAP(2:I)-YCG1)*(GWX*QWX+GWZ*QWZ)+QWY*((CAP(3:I)-ZCG1)*QWZ+
000523      2(CAP(1:I)-XCG1)*QWX)
000524      IF(ABS(AA1(1:I)) .GT. ABS(OMAX(I+1))) OMAX(I+1)=AA1(1:I)
000525      IF(ABS(AA1(2:I)) .GT. ABS(OMAY(I+1))) OMAY(I+1)=AA1(2:I)
000526      IF(ABS(AA1(3:I)) .GT. ABS(OMAZ(I+1))) OMAZ(I+1)=AA1(3:I)
000527      240 CONTINUE
000528      DO 260 I=1,6
000529      AA3(3:I)=ACZ3+WDCX*CCH(2,I)-WDCY*CCH(1,I)-CCH(3,I)*(QWCX*QWCX
000530      1 +QWCY*QWCY)+QWCZ*(CCH(1,I)*QWCX+CCH(2,I)*QWCY)
000531      250 AA3(1:I)=ACX3+WDCY*CCH(3,I)-WDCZ*CCH(2,I)-CCH(1,I)*(QWCY*QWCY
000532      1 +QWCZ*QWCZ)+QWCX*(CCH(2,I)*QWCY+CCH(3,I)*QWCZ)
000533      260 AA3(2:I)=ACY3+WDCZ*CCH(1,I)-WDCX*CCH(3,I)-CCH(2,I)*(QWCX*QWCX
000534      1 +QWCZ*QWCZ)+QWCY*(CCH(1,I)*QWCX+CCH(3,I)*QWCZ)
000535      IF(ABS(AA3(1:I)) .GT. ABS(OMACX(I+1))) OMACX(I+1)=AA3(1:I)
000536      IF(ABS(AA3(2:I)) .GT. ABS(OMACY(I+1))) OMACY(I+1)=AA3(2:I)
000537      IF(ABS(AA3(3:I)) .GT. ABS(OMACZ(I+1))) OMACZ(I+1)=AA3(3:I)
000538      280 CONTINUE
000539      C
000540      300 DUM5(37)=SVEL
000541      DUM5(38)=SACC
000542      RETURN
000543      C
000544      ENL

```

SUBROUTINE GEOM (09)



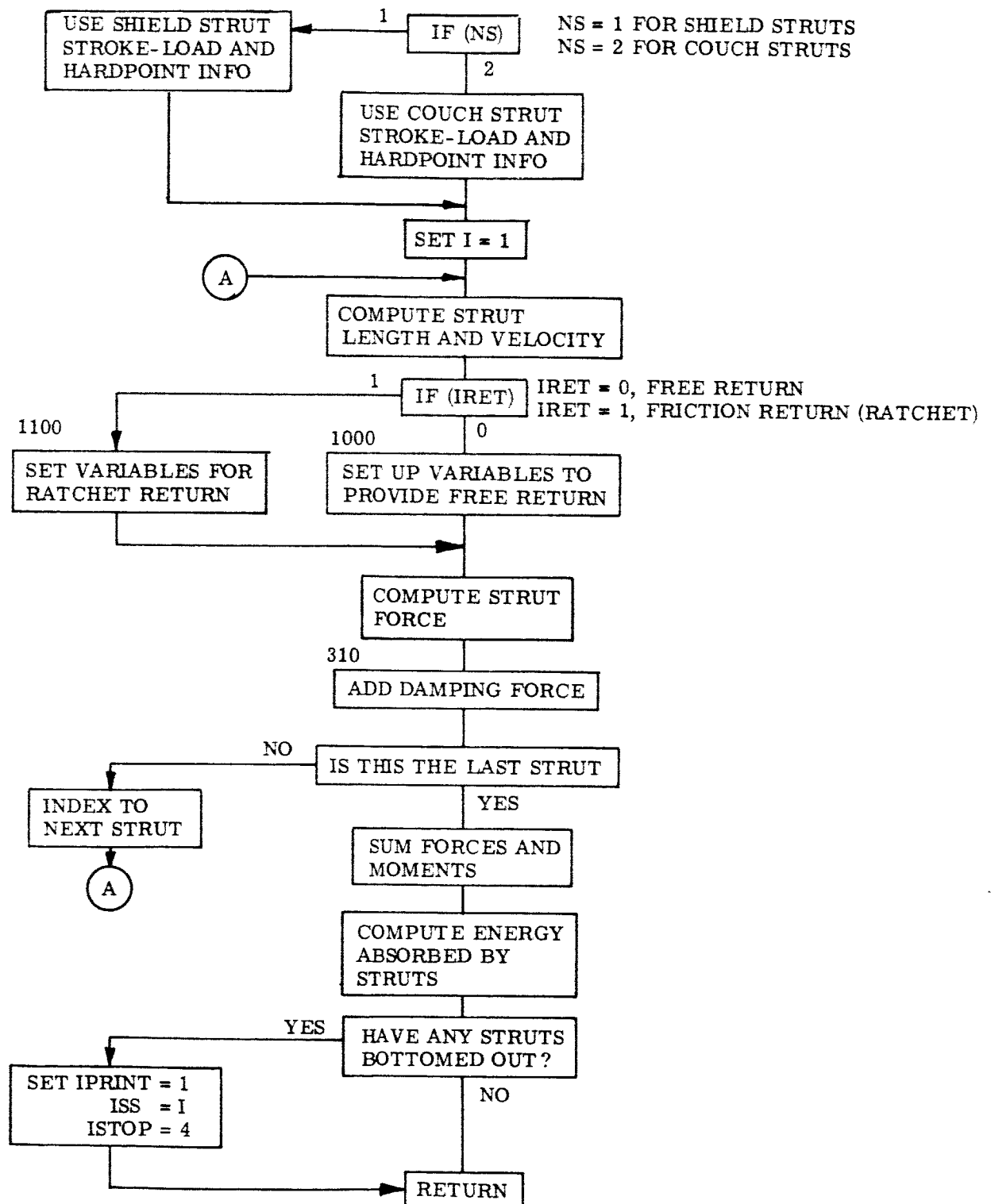
ELT GEUM:1,660306, 34247

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000001      C
000002      SUBROUTINE GEUM
000003      C
000004      C
000005      C      CALCULATE THE DIRECTION COSINES RELATING THE VEHICLE COORD. SYSTEMS
000006      C      TO THE FIXED COORD. SYSTEM
000007      C
000008      COMMON/LIST8/D11,D12,D13,D21,D22,D23,D31,D32,D33,DS11,DS12,DS13,
000009      1DS21,DS22,DS23,DS31,DS32,DS33,DC11,DC12,DC13,DC21,DC22,DC23,
000010      2DC31,DC32,DC33
000011      COMMON/L12/QRX(1),QRY,QRZ,QVX,QVY,QVZ,QWX,QWY,QWZ,
000012      1GRX,GRY,GRZ,QVCX,QVCY,QVCZ,QWCX,QWCY,QWCZ,
000013      2GRSX,GRSY,GRSZ,QVSX,QVSY,QVSZ,QWSX,QWSY,QWSZ,
000014      3GPSI,QHTA,QPHI,QPSIC,QHTAC,QPHIC,QPSIS,QHTAS,QPHIS,QSLDEL,QSVEL
000015      4,TIME,DUM5(961)
000016      C
000017      C
000018      C      CAFSULE
000019      C
000020      C
000021      C
000022      COSP=COS(QPSI)
000023      SINP=SIN(QPSI)
000024      COSPH=COS(QPHI)
000025      SINPH=SIN(QPHI)
000026      COST =COS(QHTA)
000027      SINT =SIN(QHTA)
000028      C
000029      D11= COSP*COST
000030      D12=COSP*SINT*SINPH-SINP*COSPH
000031      D13=SINP*SINPH+COSP*SINT*COSPH
000032      D21=SINP*COST
000033      D22=COSP*COSPH+SINP*SINT*SINPH
000034      D23=SINP*SINPH+COSP*COSPH-COSP*SINPH
000035      D31=-SINT
000036      D32=COST*SINPH
000037      D33=COST*COSPH
000038      C
000039      C      HEAT SHIELD
000040      C
000041      COSPS=COS(QPSIS)
000042      SINPS=SIN(QPSIS)
000043      COSTS=COS(QHTAS)
000044      SINTS=SIN(QHTAS)
000045      COSPHS=COS(QPHIS)
000046      SINPHS=SIN(QPHIS)
000047      C
000048      DS11=COSPS*COSTS
000049      DS12=COSPS*SINTS*SINPHS-SINPS*COSPHS
000050      DS13=SINPS*SINPHS+COSPS*SINTS*COSPHS
000051      DS21=SINPS*COSTS
000052      DS22=COSPS*COSPHS+SINPS*SINTS*SINPHS
000053      DS23=SINPS*SINPHS+COSPS*SINTS*SINPHS
000054      DS31=-SINTS
000055      DS32=COSTS*SINPHS
000056      DS33=COSTS*COSPHS
000057      C
000058      C      COLCH
000059      COSPC=COS(QPSIC)
000060      SINPC=SIN(QPSIC)
000061      COSTC=COS(QHTAC)
000062      SINTC=SIN(QHTAC)
000063      COSPHC=COS(QPHIC)
000064      SINPHC=SIN(QPHIC)
000065      C
000066      DC11=COSPC*COSTC
000067      DC12=COSPC*SINTC*SINPHC-SINPC*COSPHC
000068      DC13=SINPC*SINPHC+COSPC*SINTC*COSPHC
000069      DC21=SINPC*COSTC
000070      DC22=COSPC*COSPHC+SINPC*SINTC*SINPHC
000071      DC23=SINPC*SINPHC+COSPC*SINTC*SINPHC
000072      DC31=-SINTC
000073      DC32=COSTC*SINPHC
000074      DC33=COSTC*COSPHC
000075      C
000076      C
000077      C      END

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SUBROUTINE STROKE (10)



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000001      SUBROUTINE STROKE
000002      C
000003      C      THIS SUBROUTINE DETERMINES THE STRUT STROKE FORCES AS A FUNCTION
000004      C      OF VEHICLE COMPONENT VELOCITIES AND POSITIONS
000005      C
000006      C      STROKE FORCE PROFILE IS EITHER FREE RETURN (IRET=0)
000007      C      OR FRICTION RETURN (IRET=1)
000008      C
000009      COMMON/L5A/DE, TMAX, IPRINT, TP, QTP, ISTOP, IRUNO, ISERIO
000010      COMMON/L5D/IC, ISS, OFCMAX(6), OFCMIN(6), OFSMAX(6), OFSMIN(6), TSSQ(8),
000011      1TCSQ(6), TOTSCR(8), TOTCCR(6)
000012      COMMON/L7A/QSX(8), QSY(8), LSZ(8), QKT, FSGX, FSGY, FSGZ, TSGX, TSGY, TSGZ,
000013      1AREA, AREAM
000014      COMMON/L7B/QX(8), QY(8), QZ(8), QSQP(8), QSHT, QFC(8), QCH(8), QSH,
000015      1QSF(8), QFF, QVIS, QDAMP, QFX, QFY, QFZ, QTX1, QTY1, GTZ1, JKLM, QTSX2,
000016      2GTSY2, CTSZ2, CTCX3, CTCY3, CTCZ3, N, FORP(8), FHCG(8), SO(8), QCHT(8),
000017      3GSKT(8), QSD(8), SQ(8), QRGX, QRGY, QRGZ, QVGX, QVGY, QVEZ, QWGX, QWGY, QWGZ
000018      COMMON/L1TB/D11, D12, D13, D21, D22, D23, D31, D32, D33, DS11, DS12, DS13,
000019      1LS21, DS22, DS23, DS31, LS32, LS33, DC11, DC12, DC13, DC21, CC22, DC23,
000020      2DC31, DC32, DC33
000021      COMMON/L9A/IREAL
000022      COMMON/L12/QRX(1), QRY, QKZ, QVX, QVY, QVZ, QWX, QWY, QWZ,
000023      1GRGX, GRGY, GRGZ, QVCX, QVCY, QVCZ, QWCX, QWCY, QWCZ,
000024      2GRSX, GRSY, QRSZ, QV SX, QVSY, QVSZ, QWSX, QWSY, QWSZ,
000025      3GPS1, GTHTA, QPH1, GPSIC, QHTAL, QPHIC, GFSIS, GTHTAS, QPHIS, QSLDEL, GSVEL
000026      4, TIME, DUM5(961), CT, DM(8), K
000027      COMMON/L13/SLGTH(3,6), FC(3,6), COEF(2,8), COEFT(2,8), XMAX, XMIN, CC,
000028      1NS, FFLA(8), FFLMT(8), FFJK(6), FFJKT(6), FFC(8), FFT(8), IRET
000029      COMMON/L14/PVEL(6)
000030      COMMON/M1/FORJK(6), SLJK(6), CHJKT(6), CHJK(6), SRJKT(6), SRJK(6),
000031      1SDJK(6), VELJK(6), FORLM(8), SLLM(8), CHLMT(8), CHLM(8), SRLMT(8),
000032      2SKLM(8), SCLM(8), VELLM(8), LMAX(10,50), DELMAX(12,55), SACC, SVEL,
000033      3SLEL, PKNEE(10,50)
000034      C
000035      DIMENSION A(8), B(8), C(8), AS(8), BS(8), CS(8), AA(8), BB(8), CC(8),
000036      1AVEL(8), YVELQ(8), ZVELQ(8), XVELSQ(8), YVELSQ(8), ZVELSQ(8), RXQ(8),
000037      2RYG(8), RZQ(8), RSXQ(8), RSYG(8), RSZQ(8), S(8), UVGX(8), UVQY(8),
000038      3UVGZ(8), SVELQ(8), FQG(8), FG(8), FGX(8), FGQY(8), FGZ(8)
000039      DIMENSION TSGX2(8), TSGY2(8), TSGZ2(8), TCGX3(8), TCGY3(8), TCGZ3(8),
000040      1TGX1(8), TGY1(8), TGZ1(8), CRUSH(8), QSF(8), QSFT(8)
000041      C
000042      M1=1
000043      IF(NS.GT. 1) M1=2
000044      IF(NS.EQ. 1) M=1
000045      1 DO 3=0 I=1,N
000046      IF(NS.GT. 1 .AND. I.LE. 2) M=2
000047      IF(NS.GT. 1 .AND. I.GT. 2) M=3
000048      A(I)=QY(I)*QWZ-QZ(I)*QWY
000049      B(I)=QZ(I)*QWX-QX(I)*QWZ
000050      C(I)=QX(I)*QWY-QY(I)*QWX
000051      XVEL(I)=QVX-D11*A(I)-D12*B(I)-D13*C(I)
000052      YVEL(I)=QVY-D21*A(I)-D22*B(I)-D23*C(I)
000053      ZVEL(I)=QVZ-D31*A(I)-D32*B(I)-D33*C(I)
000054      10 AS(I)=QSY(I)*QWGX-QS2(I)*QWGY
000055      BS(I)=QS2(I)*QWGX-QSX(I)*QWGY
000056      CS(I)=QSX(I)*QWGY-QSY(I)*QWGX
000057      RXQ(I)=GRX+D11*QX(I)+D12*QY(I)+D13*QZ(I)
000058      RYG(I)=GRY+D21*QX(I)+D22*QY(I)+D23*QZ(I)
000059      RZQ(I)=GRZ+D31*QX(I)+D32*QY(I)+D33*QZ(I)
000060      IF(NS.GT. 1) GO TO 15
000061      XVELSQ(I)=QVGX-DS11*AS(I)-DS12*BS(I)-DS13*CS(I)
000062      YVELSQ(I)=QVGY-DS21*AS(I)-DS22*BS(I)-DS23*CS(I)
000063      ZVELSQ(I)=QVGZ-DS31*AS(I)-DS32*BS(I)-DS33*CS(I)
000064      RSXQ(I)=GRGX+DS11*QSX(I)+DS12*QSY(I)+DS13*QS2(I)
000065      RSYQ(I)=GRGY+DS21*QSX(I)+DS22*QSY(I)+DS23*QS2(I)
000066      RSZQ(I)=GRGZ+DS31*QSX(I)+DS32*QSY(I)+DS33*QS2(I)
000067      GO TO 16
000068      15 XVELSQ(I)=QVGX-DC11*AS(I)-DC12*BS(I)-DC13*CS(I)
000069      YVELSQ(I)=QVGY-DC21*AS(I)-DC22*BS(I)-DC23*CS(I)
000070      ZVELSQ(I)=QVGZ-DC31*AS(I)-DC32*BS(I)-DC33*CS(I)
000071      RSXQ(I)=GRGX+DC11*QSX(I)+DC12*QSY(I)+DC13*QS2(I)
000072      RSYQ(I)=GRGY+DC21*QSX(I)+DC22*QSY(I)+DC23*QS2(I)
000073      RSZQ(I)=GRGZ+DC31*QSX(I)+DC32*QSY(I)+DC33*QS2(I)

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000074      C
000075      16 IF (INET) 17,17,20
000076      17 QSF(I)=QSD(I)
000077      QSFT(I)=QSR(I)
000078      20 AA(I)=RXQ(I)-RSXQ(I)
000079      BB(I)=RYQ(I)-RSYQ(I)
000080      CC(I)=RZQ(I)-RSZQ(I)
000081      C
000082      S(I)=SQRT(AA(I)*AA(I)+BB(I)*BB(I)+CC(I)*CC(I))
000083      C
000084      UVX(I)=AA(I)/S(I)
000085      UVY(I)=BB(I)/S(I)
000086      UVZ(I)=CC(I)/S(I)
000087      CRUSH(I)=0.0
000088      C
000089      IF (K-3) 22,24,24
000090      22 DDT=DT/2.0
000091      GO TO 30
000092      24 DDT=DT
000093      30 SVLLG(I)=(S(I)-QSGP(I))/DDT
000094      C
000095      C LENGTH OF STRUT (I) DURING THE TIME INTERVAL DT
000096      C
000097      40 SQ(I)=S(I)
000098      C
000099      IF (INET) 1000,1000,1100
000100      1000 IF (SQ(I)-SO(I)) 1010,1050,1030
000101      1010 IF (QSF(I)-(SQ(I)-SO(I))) 1050,1050,1020
000102      1020 QSL(I)=QSF(I)
000103      GO TO 45
000104      1030 IF (QSFT(I)-(SQ(I)-SO(I))) 1040,1050,1050
000105      1040 QSL(I)=QSFT(I)
000106      GO TO 45
000107      1050 FHCQ(I)=0.0
000108      IF (SVLLG(I)) 1055,1060,1070
000109      1055 FDG(I)=1.0
000110      GO TO 300
000111      1060 FDG(I)=0.0
000112      GO TO 300
000113      1070 FDG(I)=-1.0
000114      GO TO 300
000115      C
000116      C IF NEG +STR IS COMP. ,IF ZERO - NO CHANGE ,IF POS - EXTEND.
000117      C
000118      1100 IF (SVLLQ(I)) 41,50,41
000119      41 IF (ABS(SVLLQ(I))*PVEL(I)/SVLLQ(I)) 42,42,45
000120      42 QSL(I)=QSR(I)
000121      GO TO 45
000122      45 IF (SVLLQ(I)) 55,50,140
000123      C
000124      C FORP(I)= PREV.VALUE OF STROKE FORCE. FDG(I)= FRICTION COEF.
000125      C
000126      C
000127      C STRUT IS NOT STROKING
000128      C
000129      50 FHCQ(I)=FORP(I)
000130      FDG(I)=0.0
000131      QSL(I)=QSR(I)
000132      GO TO 300
000133      C
000134      C STRUT IS COMPRESSING
000135      C
000136      55 FDG(I)=1.0
000137      IF (SQ(I)-(SO(I)+QSD(I))) 70,60,65
000138      C
000139      C STRUT HAS NOT CHANGED LENGTH
000140      C
000141      60 FHCQ(I)=0.0
000142      GO TO 300
000143      C
000144      C STRUT IS LONGER THAN ORIGINAL
000145      C
000146      65 IF (SQ(I)-(SO(I)+QSD(I))) 67,67,210
000147      67 FHCQ(I)=-GCH(I)*(SQ(I)-(SO(I)+QSD(I)))
000148      GO TO 300

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000149 C
000150 C STRUT IS SHORTER THAN ORIGINAL
000151 C
000152 70 IF(SL(I)-((SO(I)+QSD(I))-FC(M,I)*COEF(M,I)/QCH(I)))80,80,75
000153 C
000154 C ELASTIC STROKING
000155 C
000156 75 FHCQ(I)=QCH(I)*((SO(I)+QSD(I))-SQ(I))
000157 GO TO 300
000158 C
000159 C PLASTIC CRUSHING OR AGAINST STOP
000160 C
000161 80 IF(SL(I)-(SO(I)+QSH))85,90,90
000162 C
000163 C AGAINST STOP
000164 C
000165 85 STL=(SO(I)+QSH)-SQ(I)
000166 NFLAG=3
000167 GO TO 800
000168 87 GSK(I)=-QSH+QFC(I)*COEF(M,I)/QCH(I)
000169 QSF(I)=QSK(I)
000170 FHCQ(I)=QFC(I)*COEF(M,I)+CKT*((SO(I)+QSD(I))-SQ(I))
000171 GO TO 300
000172 C
000173 C PLASTIC CRUSHING
000174 90 STL=(SO(I)+QSD(I))-SQ(I)
000175 NFLAG=1
000176 GO TO 800
000177 95 GSF(I)=SQ(I)+QFC(I)*COEF(M,I)/QCH(I)-SQ(I)
000178 GSF(I)=QSR(I)
000179 FHCQ(I)=QFC(I)*COEF(M,I)
000180 GO TO 220
000181 C
000182 C
000183 C STRUT IS EXTENDING
000184 C
000185 140 FDL(I)=-1.0
000186 IF(SL(I)-(SO(I)+QSD(I)))150,160,170
000187 C
000188 C STRUT IS SHORTER THAN ORIGINAL
000189 C
000190 150 IF(SL(I)-(SO(I)+QSH))85,155,155
000191 155 FHCQ(I)=QCH(I)*((SO(I)+QSD(I))-SQ(I))
000192 GO TO 300
000193 C
000194 160 FHCQ(I)=0.0
000195 GO TO 300
000196 C
000197 C STRUT IS LONGER THAN ORIGINAL
000198 C
000199 170 IF(SL(I)-((SO(I)+QSD(I))+FC(M,I)*COEF(M,I)/QCH(I)))160,190,190
000200 C
000201 C ELASTIC CRUSHING
000202 C
000203 180 FHCQ(I)=-QCH(I)*(SQ(I)-(SO(I)+QSD(I)))
000204 GO TO 300
000205 C
000206 C PLASTIC STROKING OR AGAINST STOP
000207 C
000208 190 IF(SL(I)-(SO(I)+QSH))200,200,210
000209 C
000210 C PLASTIC CRUSHING
000211 C
000212 200 STL=SQ(I)-(SO(I)+QSD(I))
000213 NFLAG=2
000214 GO TO 800
000215 205 GSF(I)=SQ(I)-QFC(I)*COEF(M,I)/QCH(I)-SQ(I)
000216 GSF(I)=QSR(I)
000217 FHCQ(I)=-QFC(I)*COEF(M,I)
000218 GO TO 220
000219 C
000220 C AGAINST STOP
000221 C
000222 210 STL=SQ(I)-(SO(I)+QSD(I))
000223 NFLAG=4

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000224      GO TO 800
000225      215 QSF(I)=QSHT-QFC(I)*CUEFT(M1+1)/QCH(I)
000226      QSFT(I)=QSR(I)
000227      FHLG(I)=GFC(I)-CUEFT(M1+1)-GRT*(SQ(I)-(SO(I)+QSD(I)))
000228      GO TO 300
000229      220 CRUSH(I)=ABS(SVELQ(I)*DT*FHCQ(I))
000230      300 CONTINUE
000231      IF(INET)1310,1310,1320
000232      1310 QSF(I)=QSFT(I)
000233      QSL(I)=QSF(I)
000234      1320 PVEL(I)=SVELQ(I)
000235      C
000236      C
000237      C      TOTAL STRUT FORCE IS STATIC FORCE (FHCQ(I)) PLUS FRICTION FORCE
000238      C      AND VISCOUS FORCE IF THEY EXIST
000239      C
000240      IF(SL(I)-SO(I))301,302,303
000241      301 GFF=FFC(I)
000242      GO TO 304
000243      302 GFF=U*O
000244      GO TO 304
000245      303 GFF=FFT(I)
000246      304 AVEL=ABS(SVELQ(I))
000247      CFF=1.0
000248      IF(AVEL=O.1)305,305,310
000249      305 CFF=SQRT(AVEL/O.1)
000250      310 FL(I)=FHCQ(I)+FVG(I)*(CFF*GFF+QVIS*AVEL*AVEL*GDAMP)
000251      C
000252      C      FORCE COMPONENTS IN STRUT (I) IN FIXED COORD. SYSTEM
000253      C
000254      FX(I)=FQ(I)*UVGX(I)
000255      FY(I)=FQ(I)*UVGY(I)
000256      320 FZ(I)=FQ(I)*UVGZ(I)
000257      C
000258      C      SUM OF ALL STRUT FORCES ACTING ON CAPSULE FROM SHIELD STRUTS
000259      C      OR COUCH STRUTS
000260      C
000261      GFX=O.0
000262      GFY=O.0
000263      GFZ=O.0
000264      DO 330 I=1,N
000265      GFX=GFX+FX(I)
000266      GFY=GFY+FY(I)
000267      GFZ=GFZ+FZ(I)
000268      C
000269      C      DETERMINE TORQUE ON CAPSULE FROM SHIELD STRUTS OR COUCH
000270      C
000271      TX1(I)=QY(I)*(D13*FLX(I)+D23*FQY(I)+D33*FQZ(I))-QZ(I)*(D12*FLX(I)
000272      1 +D22*FQY(I)+D32*FQZ(I))
000273      TY1(I)=QZ(I)*(D11*FLX(I)+D21*FQY(I)+D31*FQZ(I))-QX(I)*(D13*FLX(I)
000274      1 +D23*FQY(I)+D33*FQZ(I))
000275      330 TQZ1(I)=QX(I)*(D12*FLX(I)+D22*FQY(I)+D32*FQZ(I))-QY(I)*(D11*FLX(I)
000276      1 +D21*FQY(I)+D31*FQZ(I))
000277      C
000278      C      SUM ALL TORQUES ON CAPSULE FROM SHIELD STRUTS OR COUCH STRUTS
000279      GTX1=O.0
000280      GTY1=O.0
000281      GTZ1=O.0
000282      DO 340 I=1,N
000283      GTX1=GTX1+TX1(I)
000284      GTY1=GTY1+TY1(I)
000285      340 GTZ1=GTZ1+TQZ1(I)
000286      C
000287      C
000288      C      IF(JKLM) COUCH STRUTS, COUCH STRUTS ,SHIELD STRUTS
000289      C
000290      C
000291      IF(JKLM)360,360,350
000292      C
000293      350 DO 360 I=1,N
000294      IF(IKEAL)355,355,352
000295      352 IF(FG(I).LT.OFSMIN(I)) OFSMIN(I)=FG(I)
000296      IF(FG(I).GT. OFSMAX(I)) OFSMAX(I)=FG(I)
000297      IF(SL(I)-SO(I))353,353,354
000298      353 GFF=FFC(I)

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000299      GO TO 1355
000300      354 GFF=FFT(I)
000301      1355 TSSQ(I)=TSSQ(I)+ABS(SVELC(I))*GFF*DT/
000302      TOTSCR(I)=TOTSCR(I)+CRUSH(I)
000303      C
000304      C      DETERMINE TORQUE ON SHIELD FROM SHIELD STRUTS
000305      C
000306      355 TSCX2(I)=GSZ(I)*(DS12*FQX(I)+DS22*FCY(I)+DS32*FQZ(I))-GSY(I)*
000307      1 (DS13*FQX(I)+DS23*FCY(I)+DS33*FQZ(I))
000308      TSCY2(I)=GSX(I)*(DS13*FQX(I)+DS23*FCY(I)+DS33*FQZ(I))-GSZ(I)*
000309      1 (DS11*FQX(I)+DS21*FCY(I)+DS31*FQZ(I))
000310      TSCZ2(I)=GSY(I)*(DS11*FQX(I)+DS21*FCY(I)+DS31*FQZ(I))-GSX(I)*
000311      1 (DS12*FQX(I)+DS22*FCY(I)+DS32*FQZ(I))
000312      IF(SW(I) .LT. (SO(I)-1.05*CSH )) GO TO 700
000313      IF(SW(I) .GT. (SO(I)+1.05*CSHT)) GO TO 700
000314      360 CONTINUE
000315      C
000316      C      SUM TORQUES ON SHIELD FROM SHIELD STRUTS
000317      C
000318      C
000319      GTSX2=0.0
000320      GTSY2=0.0
000321      GTSZ2=0.0
000322      C
000323      DO 370 I=1,N
000324      GTSX2=GTSX2+TSCX2(I)
000325      GTSY2=GTSY2+TSCY2(I)
000326      370 GTSZ2=GTSZ2+TSCZ2(I)
000327      C
000328      C
000329      RETURN
000330      C
000331      C
000332      C      DETERMINE TORQUE ON COUCH FROM COUCH STRUTS
000333      C
000334      380 DO 390 I=1,N
000335      C
000336      IF(IREAL)385,385,382
000337      382 IF(FG(I).LT.OFCMIN(I)) OFCMIN(I)=FG(I)
000338      IF(FG(I) .GT. OFCMAX(I)) OFCMAX(I)=FG(I)
000339      IF(SG(I)-SO(I))383,383,384
000340      383 GFF=+FC(I)
000341      GO TO 1365
000342      384 GFF=FFT(I)
000343      1385 TCSQ(I)=TCSQ(I)+ABS(SVELC(I))*GFF*DT/
000344      TOTCCR(I)=TOTCCR(I)+CRUSH(I)
000345      C
000346      385 TCCX3(I)=GSZ(I)*(DC12*FQX(I)+DC22*FCY(I)+DC32*FQZ(I))-GSY(I)*
000347      1 (DC13*FQX(I)+DC23*FCY(I)+DC33*FQZ(I))
000348      TCCY3(I)=GSX(I)*(DC13*FQX(I)+DC23*FCY(I)+DC33*FQZ(I))-GSZ(I)*
000349      1 (DC11*FQX(I)+DC21*FCY(I)+DC31*FQZ(I))
000350      TCCZ3(I)=GSY(I)*(DC11*FQX(I)+DC21*FCY(I)+DC31*FQZ(I))-GSX(I)*
000351      1 (DC12*FQX(I)+DC22*FCY(I)+DC32*FQZ(I))
000352      IF(SG(I) .LT. (SO(I)-1.05*CSH )) GO TO 710
000353      IF(SG(I) .GT. (SO(I)+1.05*CSHT)) GO TO 710
000354      390 CONTINUE
000355      C
000356      C      SUM TORQUES ON COUCH FROM COUCH STRUTS
000357      C
000358      C
000359      GTCX3=0.0
000360      GTCY3=0.0
000361      GTCZ3=0.0
000362      C
000363      DO 400 I=1,N
000364      GTCX3=GTCX3+TCCX3(I)
000365      GTCY3=GTCY3+TCCY3(I)
000366      400 GTCZ3=GTCZ3+TCCZ3(I)
000367      GO TO 600
000368      500 WRITE(6 ,9003)
000369      C
000370      600 CONTINUE
000371      RETURN
000372      700 ISTOP=4
000373      ISS=1
000374      IPRINT=1

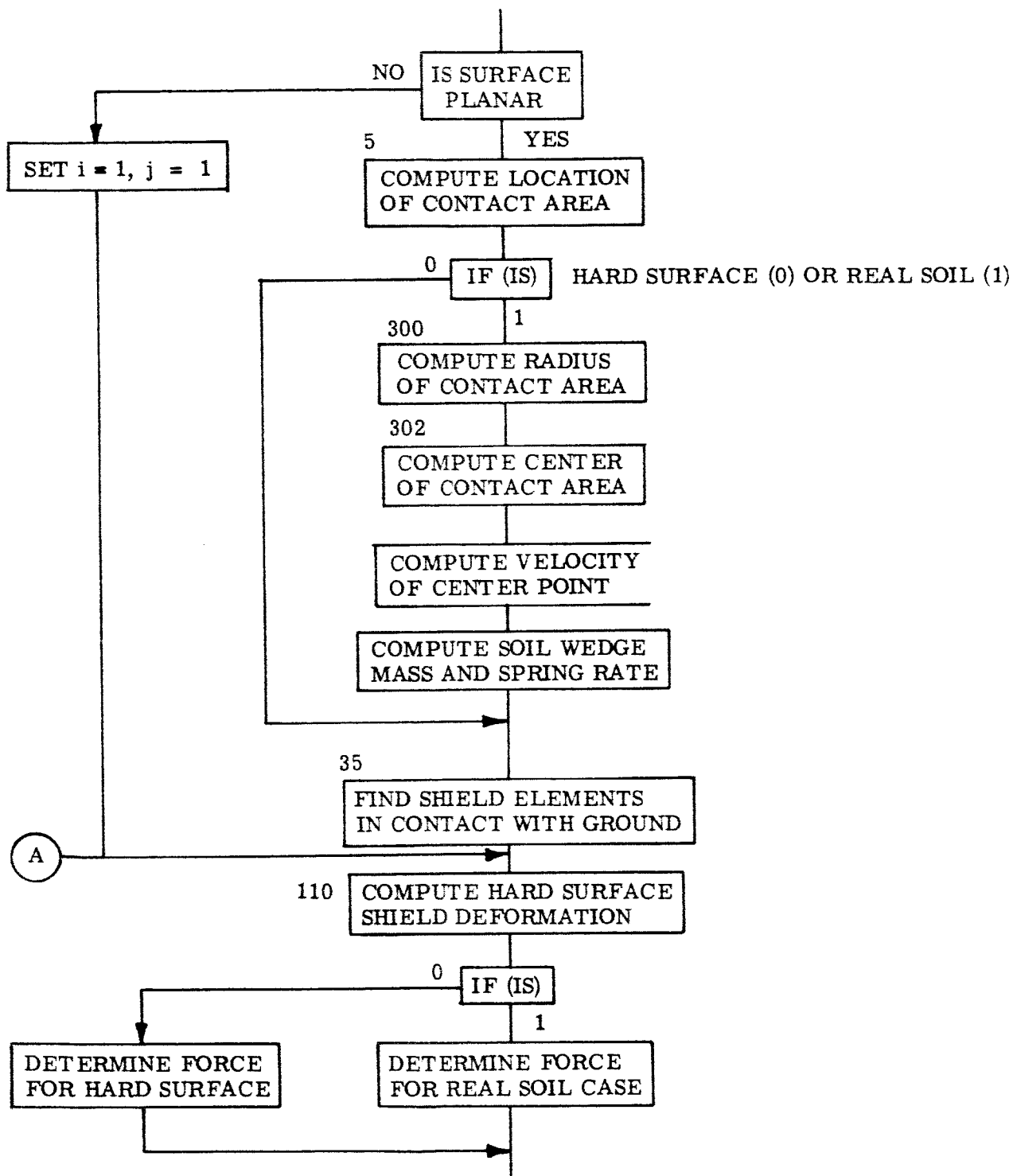
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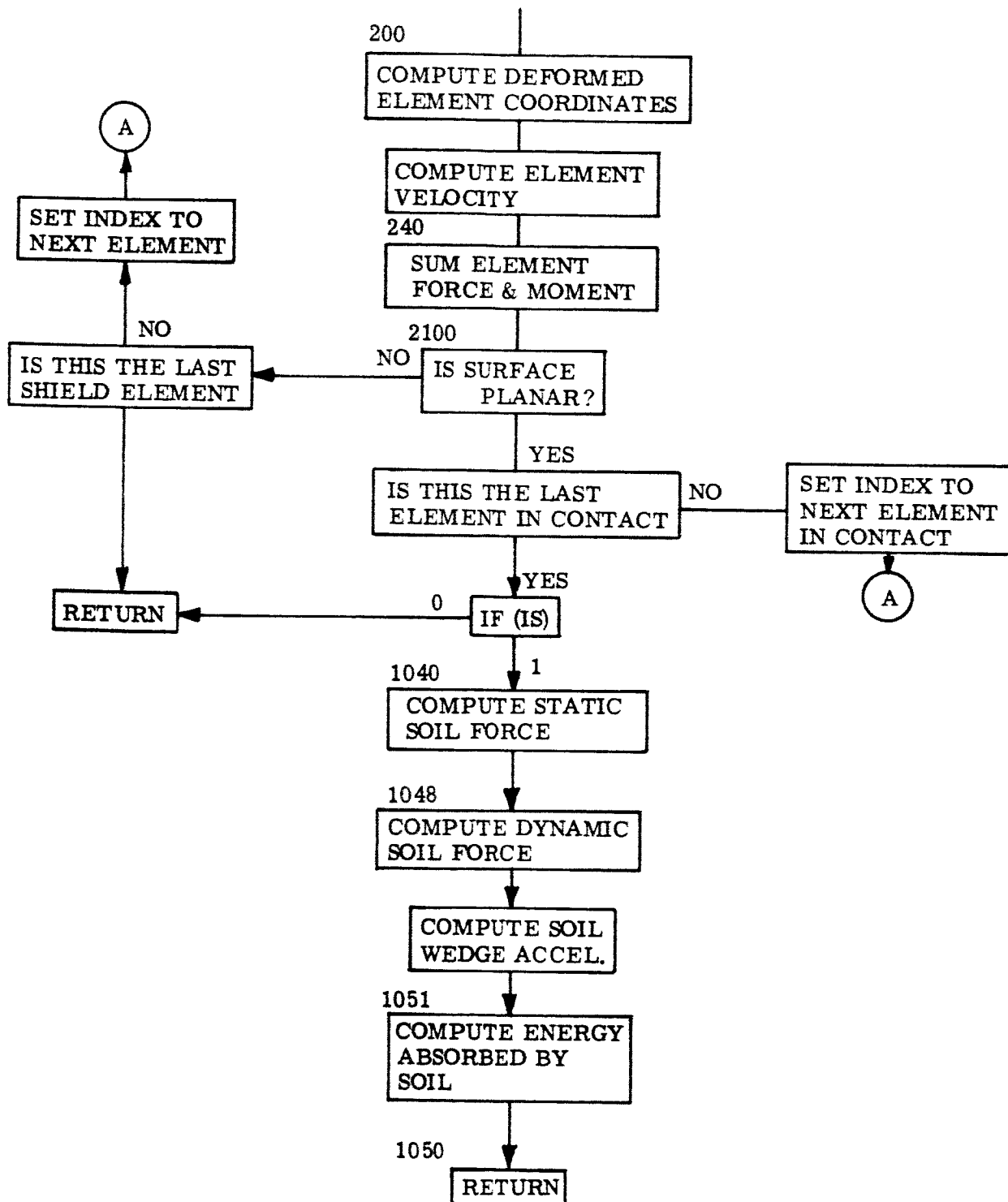
000374      GO TO 360
000375      710  ISTOP=3
000376      IC=1
000377      IPRINT=1
000378      GO TO 390
000379
C
000380      800  J=1
000381      805  IF (SLGTH(M,J)-STL) 810,820,830
000382      810  J=J+1
000383      IF (J .GT. 6) GO TO 850
000384      GO TO 805
000385      820  WFC(I)=FC(M,J)
000386      GO TO (95,205,87,215),NFLAG
000387      830  IF (J .EQ. 1) GO TO 860
000388      WFC(I)=(STL-SLGTH(M,J-1))*(FC(M,J)-FC(M,J-1))/(SLGTH(M,J)-
000389      SLGTH(M,J-1)) +FC(M,J-1)
000390      GO TO (95,205,87,215),NFLAG
000391      850  WFC(I)=FC(M,6)
000392      GO TO (95,205,87,215),NFLAG
000393      860  WFC(I)=FC(M,1)
000394      GO TO (95,205,87,215),NFLAG
000395      9000 FORMAT(3E12.5,I5)
000396      9001 FORMAT(1H0)
000397      9002 FORMAT(10E12.5)
000398      9003 FORMAT(30H ERROR AT LOCATION 230 OR 1130)
000399      9004 FORMAT(110,F10.5)
000400      9005 FORMAT(7F10.5)
000401      ENL

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SUBROUTINE HSSOIL (11)



SUBROUTINE HSSOIL (11)(CONT.)



ELT HSSOIL.1.660505. 41360

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000001      SUBROUTINE HSSOIL
000002      C
000003      C      THIS SUBROUTINE COMPUTES THE GROUND REACTION FORCE FOR A HARD
000004      C      SURFACE (IS=0) OR A REAL SOIL (IS=1)
000005      C
000006      C
000007      COMMON/L2/HEATA,HEATE,HSCG2,IP,IS,IT
000008      COMMON/L5A/DT,TMAX,IFRINT,TF,DTP,ISTOP,IRUNNO,ISERNO
000009      COMMON/L7A/QSX(8),GSY(8),GSZ(8),QKT,FSGX,FSGY,FSGZ,TSGX,TSGY,TSGZ,
000010      1AREA,AREAH
000011      COMMON/L12/D11,D12,D13,D21,D22,D23,D31,D32,D33,DS11,DS12,DS13,
000012      1LS21,DS22,DS23,DS31,DS32,DS33,DC11,DC12,DC13,DC21,DC22,DC23,
000013      2LC31,DC32,DC33
000014      COMMON/L9A/IREAL
000015      COMMON/L10/EX(10),EY(10,50),EZ(10,50),MI(10),A(10),CKK,Q,K,
000016      1RHC(10),DEFL(10,50,6),FORCE(10,50,6),GNDMU,AEL
000017      C
000018      COMMON/L12/QRX(1),QRY,QRZ,QVX,QVY,QVZ,QWX,QWY,QWZ,
000019      1GRCX,GRCY,GRCZ,QVCX,QVCY,QVCZ,QWCX,QWCY,QWCZ,
000020      2GRSX,GRSY,GRSZ,QVSY,QVSY,QVSY,QWSX,QWSY,QWSZ,
000021      3GPSI,QHTA,QPHI,QFSIC,QT-TAC,QPHIC,QPSIS,QHTAS,QPHIS,
000022      4CSLDEL,GSVEL,TIME,CUM5(9E1)
000023      C
000024      COMMON/L16/SLRHC,SOILE,SLPHI,CKPHIC,NAA,AA(9),EB(9),TESOIL,
000025      1GMA(5),AGMA(5),BGMA(5),CML,SUMCR
000026      COMMON/L21/FAKE(100),YMIN,DEY,NY,ZMIN,DEZ,NZ,RSURF(3,11,11),XPPAX
000027      C
000028      COMMON/M1/FORUK(6),SLUK(6),CHUKT(6),CHUK(6),SRUKT(6),SRUK(6),
000029      1SLUK(6),VELUK(6),FORLM(8),SLLM(8),CHLMT(8),CHLM(8),SRLMT(8),
000030      2SRLM(8),SOLM(8),VELLM(8),LMAX(10,50),DELMAX(12,55),SACC,SVEL,
000031      3SLEEL,PKNEE(10,50)
000032      C
000033      DIMENSION DELTA(10,50),P(10,50),DELTOT(10,50)
000034      1WATE=-1
000035      IF(FSGX=0.01)1,2,2
000036      1 1WATE=1
000037      SLEEL=0.0
000038      C
000039      C
000040      C      SET SUMS EQUAL TO ZERO FOR HSSOIL
000041      C
000042      2 FSCX=0.0
000043      FSCY=0.0
000044      FSCZ=0.0
000045      TSCX=0.0
000046      TSCY=0.0
000047      TSCZ=0.0
000048      AREA=0.0
000049      EFFILT=0.0
000050      ESCIL=0.0
000051      FS=0.0
000052      KB=0
000053      1123=0
000054      KS=1
000055      C
000056      C      CALCULATE RADIAL DISTANCE TO GROUND CONTACT AREA
000057      C
000058      C      VARIABLES 'FIX' ARE AN ATTEMPT TO CURE COMPILER ERRORS
000059      FIX=SIN(0.785)
000060      FIX2=SQRT(2.0)
000061      C
000062      R=GRSX+DS11*HSCG2
000063      IF(NY.GT.0.AND.NZ.GT.0)GO TO 2000
000064      DIV=DS12*DS12+DS13*DS13+DS11*DS11*HEATA*HEATA/(HEATB*HEATB)
000065      IF(DS13)3,4,4
000066      3 SS=-1.0
000067      GO TO 5
000068      4 SS=1.0
000069      C
000070      5 RHCP=(-R*SS*SQRT(DS13*DS13+LS12*DS12)+HEATA*DS11*SQRT(DIV
000071      1 -F*K/(HEATB*HEATB)))/DIV
000072      C
000073      RHCN=(-R*SS*SQRT(DS13*DS13+LS12*DS12)-HEATA*DS11*SQRT(DIV

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000074      1 =R/(HEATB*HEATE))/DIV
000075      C
000076      IF (IS) 1500,1500,300
000077      1500 GAF=C*0
000078      GO TO 35
000079      C
000080      C COMPUTE RADIUS OF CONTACT AREA
000081      C
000082      300 RR=SQRT(HEATA*HEATB*(DS12*DS12+DS13*DS13+DS11*DS11*HEATA*HEATA/
000083      1(HEATE*HEATE)-R*R/(HEATB*HEATE)))/(DS12*DS12+DS13*DS13+DS11*DS11
000084      2*HEATA*HEATA/(HEATB*HEATE))**1.5)
000085      IF (RR=0.1E-10) 1050,1050,302
000086      C
000087      C COMPUTE CENTER OF CONTACT AREA
000088      C
000089      302 FZ=(-SS*R*SQRT(DS12*DS12+DS13*DS13))/(DS12*DS12+DS13*DS13+DS11*
000090      1DS11*HEATA*HEATA)/(HEATB*HEATE)
000091      SS12=1.0
000092      SS13=1.0
000093      IF (ABS(DS12)-0.1E-10) 315,315,304
000094      304 IF (DS12) 305,315,310
000095      305 S12=-1.0
000096      GO TO 320
000097      310 S12=1.0
000098      GO TO 320
000099      315 SS12=-1.0
000100      320 IF (ABS(DS13)-0.1E-10) 335,335,322
000101      322 IF (DS13) 325,335,330
000102      325 S13=-1.0
000103      GO TO 340
000104      330 S13=1.0
000105      GO TO 340
000106      335 SS13=-1.0
000107      340 IF (SS12) 345,345,350
000108      345 YC=0.0
000109      ZC=PZ
000110      GO TO 365
000111      350 IF (SS13) 355,355,360
000112      355 ZC=0.0
000113      YC=S12*PZ
000114      GO TO 365
000115      360 YC=S12/S13*SQRT(DS12*DS12/(DS13*DS13+DS12*DS12))*PZ
000116      ZC=DS13/DS12*YC
000117      365 XC=-HEATA*SQRT(1.0-(YC*YC+ZC*ZC)/(HEATB*HEATE))+HSCG2
000118      C
000119      C COMPUTE VELOCITY OF CENTER POINT
000120      C
000121      AQ=Q*SY*ZC-Q*SZ*YC
000122      BQ=Q*SZ*XC-Q*SX*ZC
000123      CQ=Q*SX*YC-Q*SY*XC
000124      VCFX=QV SX+DS11*AQ+DS12*BQ+DS13*CQ
000125      VCFY=QV SY+DS21*AQ+DS22*BQ+DS23*CQ
000126      VCFZ=QV SZ+DS31*AQ+DS32*BQ+DS33*CQ
000127      C
000128      C COMPUTE MASS OF SOIL VOLUME
000129      C
000130      E=(VCPY*VCPY+VCPZ*VCPZ)/(VCFY*VCFY+VCPZ*VCPZ+VCPX*VCPX)
000131      B=SIN(SLPHI)*SIN(SLPHI)
000132      RRR=RR/COS(SLPHI)
000133      C=RRR*RRR
000134      C1=SIN(SLPHI)
000135      C2=COS(SLPHI)
000136      HITE=SQRT(C-RRR*RR)-RRR*(E*C1-SQRT(2.0*E*E*B+C2*C2*E-E*E+1.0))
000137      1/(1.0+E)
000138      29 PWATE=WATE
000139      WATE=3.14159*HITE*SLPHO*RRR*RR/3.0
000140      TGAM=SQRT(VCPY*VCPY+VCPZ*VCPZ)/ABS(VCPX)
000141      GAF=ATAN(TGAM)
000142      CAPEA=0.5*(SQRT(HITE*HITE+(RR+HITE*TGAM)*(RR+HITE*TGAM))+
000143      1 SQRT(HITE*HITE+(RR-HITE*TGAM)*(RR-HITE*TGAM)))
000144      C
000145      C COMPUTE GENERALIZED SPRING RATE FOR SOIL MASS
000146      C
000147      SOILK=2.52*SOILE*RR
000148      32 ELK=SOILK*AEL/(3.14159*RR*RR)

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000149      35 IF(NY .GT. 0 .AND. NZ .GT. 0) GO TO 2000
000150      IF(ABS(RHCP)-ABS(RHON))40,50,50
000151      C
000152      40 F1=ABS(RHCP)
000153      F2=ABS(RHON)
000154      GO TO 6
000155      C
000156      50 F1=ABS(RHON)
000157      F2=ABS(RHCP)
000158      6 IF(RHCP)30,30,10
000159      C
000160      10 IF(RHON)20,20,30
000161      C
000162      20 I=1
000163      J=1
000164      JS=-1
000165      GO TO 80
000166      C
000167      30 I=2
000168      55 IF(RH0(I)-P1)60,60,70
000169      C
000170      60 I=I+1
000171      GO TO 55
000172      C
000173      70 J=1
000174      JS=-1
000175      C
000176      C      IS ELEMENT I,J IN CONTACT WITH THE GROUND
000177      C
000178      80 IF(DS11*EX(I)+DS12*EY(I,J)+DS13*EZ(I,J)+QRSX)90,85,85
000179      85 JS=-1
000180      GO TO 400
000181      C
000182      90 IF(JS)100,110,110
000183      C
000184      100 C=J-1
000185      C=NI(I)
000186      KB=6.2831852*C/D
000187      JS=1
000188      GO TO 110
000189      2000 GRXC=GRSX
000190      IS=0
000191      J=C
000192      I=1
000193      2001 J=J+1
000194      IF(J .LE. NI(I)) GO TO 2005
000195      I=I+1
000196      IF(I .GT. (K+1)) GO TO 2110
000197      J=1
000198      2005 Y=CRSY+DS21*EX(I)+DS22*EY(I,J)+DS32*EZ(I,J)
000199      Z=CRSZ+DS31*EX(I)+DS32*EY(I,J)+DS33*EZ(I,J)
000200      C
000201      IF(Y .LT. RSURF(2,I+1)) .OR. Y .GT. RSURF(2,NY+1,1)) GO TO 2040
000202      IF(Z .LT. RSURF(3,I+1)) .OR. Z .GT. RSURF(3,1,NZ+1)) GO TO 2040
000203      C
000204      IY=0
000205      2020 IY=IY+1
000206      IF(Y .GT. RSURF(2,IY,1)) GO TO 2020
000207      IZ=0
000208      2025 IZ=IZ+1
000209      IF(Z .GT. RSURF(3,I+1,IZ)) GO TO 2025
000210      XP=RSURF(1,IY-1,IZ-1)
000211      IF(IY .EQ. 1 .OR. IZ .EQ. 1) XP=0.0
000212      GO TO 2050
000213      2040 XP=0.0
000214      2050 GRXC=GRSX-XP
000215      110 DELTOT(I,J)=A(I)*(DS11*EX(I)+DS12*EY(I,J)+DS13*EZ(I,J)+QRSX)/
000216      1(HEATB*HEATB+DS11*(EX(I)-HSCG2)+HEATA*HEATA
000217      2*(DS12*EY(I,J)+DS13*EZ(I,J)))
000218      L=1
000219      IF(DEFL(I,J,L) .LT. C.1E-04)L=2
000220      IF(DEFL(I,J,L) .LT. C.1E-04) GO TO 690
000221      CHS=FORCE(I,J,L)/DEFL(I,J,L)
000222      IF(DELTOT(I,J))2090,2090,1111
000223      C

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000224 C IF (HARD SURFACE+HARD SURFACE+REAL SOIL)
000225 C
000226 1111 IF (IS) 111,111,700
000227 C
000228 C REAL SOIL HEAT SHIELD DEFLECTIONS
000229 C
000230 700 IF (PKNEE(I,J)-FORCE(I,J,1)) 702,702,705
000231 702 DELTA(I,J)=ELK*(DELTOT(I,J)+SLDEL)/(AEL*CHS+ELK)
000232 GO TO 708
000233 705 DELTA(I,J)=(AEL*(CHS*DMAX(I,J)-PKNEE(I,J))+ELK*(DELTOT(I,J)
000234 1+SLDEL))/(AEL*CHS+ELK)
000235 708 IF (DELTA(I,J)) 709,710,710
000236 709 F(I,J)=0.0
000237 DELTA(I,J)=0.0
000238 GO TO 200
000239 710 IF (DELTA(I,J)-DMAX(I,J)) 730,730,720
000240 720 DDMAX=DMAX(I,J)
000241 DMAX(I,J)=DELTA(I,J)
000242 IF (DMAX(I,J)-DEFL(I,J,1)) 740,740,780
000243 730 PDMAX=DMAX(I,J)
000244 IF (DMAX(I,J)-DEFL(I,J,1)) 740,740,750
000245 740 DD=DEFL(I,J,1)
000246 GO TO 760
000247 750 DD=DMAX(I,J)
000248 760 P(I,J)=PKNEE(I,J)-CHS*(DD-DELTA(I,J))
000249 IF (P(I,J)) 770,860,880
000250 770 P(I,J)=0.0
000251 GO TO 400
000252 780 LL=0
000253 PS=PKNEE(I,J)
000254 790 LL=DELTOT(I,J)+SLDEL -PS*AEL/ELK
000255 IF (DL .LT. 0.0) GO TO 660
000256 II=1
000257 III=0
000258 IF (DL .GT. DEFL(I,J,III)) II=III
000259 795 IF (DL-DEFL(I,J,II)) 800,810,830
000260 800 FF=(FORCE(I,J,II)-FORCE(I,J,II-1))*(DL-DEFL(I,J,II-1))/
000261 1*(DEFL(I,J,II)-DEFL(I,J,II-1))+FORCE(I,J,II-1)
000262 GO TO 840
000263 810 FF=FORCE(I,J,II)
000264 GO TO 840
000265 820 II=II+1
000266 IF (II-6) 795,795,830
000267 830 FF=FORCE(I,J,6)+GKT*(DL-DEFL(I,J,6))
000268 840 IF (ABS(FF-PS)-0.01*FF) 870,870,850
000269 850 PS=(FF+PS)/2.0
000270 LL=LL+1
000271 IF (LL-20) 790,860,660
000272 860 WRITE(IP,9003) I,FF,PS
000273 870 F(I,J)=FF
000274 PKNEE(I,J)=FF
000275 DMAX(I,J)=DL
000276 880 GO TO 200
000277 C
000278 C HARD SURFACE HEAT SHIELD DEFLECTIONS
000279 C
000280 111 DELTA(I,J)=DELTOT(I,J)
000281 IF (DELTA(I,J)) 660,115,115
000282 115 IF (DELTA(I,J)-DMAX(I,J)) 150,120,120
000283 120 DDMAX=DMAX(I,J)
000284 DMAX(I,J)=DELTA(I,J)
000285 IF (DMAX(I,J)-DEFL(I,J,6)) 125,125,122
000286 122 DMAX(I,J)=DEFL(I,J,6)
000287 C
000288 125 P(I,J)=CHS*DMAX(I,J)
000289 IF (P(I,J)-FORCE(I,J,1)) 200,200,140
000290 C
000291 C
000292 140 IAE=1
000293 GO TO 600
000294 C
000295 145 F(I,J)=FF
000296 GO TO 200
000297 C
000298 150 F(I,J)=CHS*DMAX(I,J)

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000299      PDIMAX=DMAX(I,J)
000300      IF(P(I,J)-FORCE(I,J,1))160,160,170
000301      C
000302      160 F(I,J)=CHS*DELTA(I,J)
000303      GO TO 200
000304      C
000305      170 IAE=L
000306      GO TO 600
000307      C
000308      175 FA=FF-CHS*(DMAX(I,J)-DELTA(I,J))
000309      C
000310      IF(FA)180,180,190
000311      C
000312      180 F(I,J)=0.0
000313      GO TO 400
000314      C
000315      190 F(I,J)=PA
000316      GO TO 200
000317      200 GX=EX(I) * (1.0-DELTA(I,J)*HEATB*HEATB/A(I) )+DELTA(I,J)*
000318      1 HEATE*HEATE*HSCG2/A(I)
000319      COT = 1.0-DELTA(I,J)*HEATA*HEATA/A(I)
000320      GY=EY(I,J)*CON
000321      GZ=EZ(I,J)*CON
000322      C
000323      C THE VELOCITIES OF THE SURFACE AREAS A(I,J) ARE COMPUTED NEXT
000324      C
000325      A1=GZ*CHSY-GY*CHSZ
000326      A2=GX*CHSZ-GZ*CHSX
000327      A3=GY*CHSX-GX*CHSY
000328      C
000329      VX =QV SX+DS11*A1+DS12*A2+DS13*A3
000330      VY =QV SY+DS21*A1+DS22*A2+DS23*A3
000331      VZ =QV SZ+DS31*A1+DS32*A2+DS33*A3
000332      C
000333      IF(VY)210,220,210
000334      220 IF(VZ)210,230,210
000335      210 VBAR=1.0/SORT(VY*VY+VZ*VZ)
000336      IF(1.0/VBAR=0.14)250,250,260
000337      250 CFF=0.5-0.5*CGS(22.2/VBAR)
000338      GO TO 240
000339      260 CFF=1.0
000340      GO TO 240
000341      230 VBAR=1.0
000342      CFF=0.0
000343      C
000344      GO TO 240
000345      2090 FX=0.0
000346      FY=0.0
000347      FZ=0.0
000348      TX2=0.0
000349      TY2=0.0
000350      TZ2=0.0
000351      GO TO 400
000352      240 FX=P(I,J)*AEL
000353      SLTU=GNDML+CHU*GAM
000354      FY=-SLTU*FX*VY*VEAR*CFR
000355      FZ=-SLTU*FX*VZ*VEAR*CFR
000356      EFFRICT=ABS(FY*VY*DT)+ABS(FZ*VZ*DT)+EFRICT
000357      LL=1
000358      IF(DEFL(I,J,LL))1520,1520,1510
000359      1510 GO TO 1530
000360      1520 LL=2
000361      1530 DEL=DMAX(I,J)-DEFL(I,J,LL)
000362      IF(DEL)1540,1540,1534
000363      1534 IF(IREAL)1540,1540,1535
000364      1535 SUPCK=SUMCR+FX*(DMAX(I,J)-PLMAX)
000365      C
000366      C CONVERT FORCE COMPONENTS TO HEAT SHIELD COORD. SYSTEM FOR MOMENT
000367      C CALCULATIONS
000368      C
000369      1540 FX2=DS11*FX+DS21*FY+DS31*FZ
000370      FY2=DS12*FX+DS22*FY+DS32*FZ
000371      FZ2=DS13*FX+DS23*FY+DS33*FZ
000372      C
000373      C THE MOMENT FOR ANY (I,J) SET IS TX2, TY2, TZ2. (I,J) TAKES ON

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000374 C      SUCCSSIVE VALUES FOR ALL THESE STATEMENTS AS THE RESULT OF LOGIC
000375 C      ELSEWHERE IN THIS SUBROUTINE
000376 C
000377 C      TX2=FZ2*GY-FY2*GZ
000378 C      TY2=FX2*GZ-FZ2*GX
000379 C      TZ2=FY2*GX-FX2*GY
000380 C
000381 C      SUB FORCES FROM HEAT SHIELD ELEMENTS FSG IS ZEROED AT START OF SUB
000382 C
000383 C      241 FSCX=FSGX+FX
000384 C      FSCY=FSGY+FY
000385 C      FSCZ=FSGZ+FZ
000386 C
000387 C      TSCX=TSGX+TX2
000388 C      TSGY=TSGY+TY2
000389 C      TSCZ=TSgz+TZ2
000390 C
000391 C      AREA=AREA+AEL
000392 C
000393 C      400 IF(INEAL)402,402,2100
000394 C      402 LMAX(I,J)=PDMAX
000395 C      2100 IF(NY .GT. 0 .AND. NZ .GT. 0) GO TO 2001
000396 C      405 IF(J-NI(I))410,415,415
000397 C      415 IF(KS)417,440,440
000398 C      417 J=1
000399 C      GO TO 80
000400 C      2110 IF(AREA .GT. AREAM) AREAM=AREA
000401 C      GR5X=GR5X0
000402 C      RETURN
000403 C
000404 C      410 IF(KB)430,420,430
000405 C
000406 C      420 J=J+1
000407 C      GO TO 80
000408 C
000409 C      430 IF(JS)440,440,420
000410 C
000411 C      440 IF(I-K-1)450,530,530
000412 C
000413 C      450 I=I+1
000414 C      I123=0
000415 C      IF(RHC(I)-P2)460,530,530
000416 C
000417 C      460 IF(KB)465,520,465
000418 C      465 IF(RHC(I)-P1)680,680,470
000419 C
000420 C      470 IBC=0
000421 C      J=NI(I)+IBC/NI(I-1)
000422 C
000423 C      480 IF(DS11*EX(I) +DS12*EY(I,J)+DS13*EZ(I,J)+GR5X)500,490,490
000424 C
000425 C      500 J=J-1
000426 C      I123=1
000427 C      IF(J)510,510,480
000428 C
000429 C      510 J=NI(I)
000430 C      GO TO 480
000431 C      490 IF(I123)495,495,491
000432 C      491 J=J+1
000433 C      JS=-1
000434 C      KS=-1
000435 C      GO TO 80
000436 C
000437 C      495 J=1
000438 C      JS=-1
000439 C      KB=0
000440 C      KS=1
000441 C      GO TO 80
000442 C
000443 C      520 J=1
000444 C      JS=-1
000445 C      KS=1
000446 C      GO TO 80
000447 C
000448 C      530 IF(AREA .GT. AREAM) AREAM=AREA

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C
C   IF (HARD SURFACE, HARD SURFACE, REAL SOIL)
C
C   IF (IS, 1050, 1050, 940)
C
940 IF (I, WATE) 915, 915, 910
900 SVEL=SVEL*SQRT(PWATE/WATE)
GO TO 915
910 SVEL=0.0
915 IF (SVEL) 920, 1045, 1045
920 I=2
925 IF (GAM-GMA(I)) 941, 937, 930
930 I=I+1
IF (I-5) 925, 925, 935
937 I=I+1
935 AGAM=AGMA(I-1)
EGAM=EGMA(I-1)
GO TO 995
941 AGAM=AGMA(I-1)+(AGMA(I)-AGMA(I-1))*(GAP-GMA(I-1))/
1 (GMA(I)-GMA(I-1))
EGAM=EGMA(I-1)+(EGMA(I)-EGMA(I-1))*(GAM-GMA(I-1))/
1 (GMA(I)-GMA(I-1))
995 BBE=-SLDEL/RR
I=2
1000 IF (BBB-BB(I)) 1030, 1015, 1010
1010 I=I+1
IF (I-NA) 1000, 1000, 1020
1015 I=I+1
1020 AAA=AA(I-1)
GO TO 1040
1030 AAA=AA(I-1)+(AA(I)-AA(I-1))*(BBB-BB(I-1))/(BB(I)-BB(I-1))
1040 FS=AAA*3.1416*RR*RR*RR*SLRHO*32.2
GO TO 1048
1045 SVEL=0.0
GO TO 920
1048 FD=-ABS(SVEL)*CAKEA*SLRHO*CKPHIC*SVEL/2.0
SACC=(AGAM*FS+BGAM*FD-FSGX)/WATE
IF (I, REAL) 1049, 1049, 1051
1049 WATE=PWATE
GO TO 1050
C
1051 ESCIL=ABS((FS+AGAM*FD+BGAM)*SVEL*DT)
C
WRITE(IP, 9004) TIME, SLDEL, SVEL, SACC, FS, FR
WRITE(IP, 9004) DELTOT(1,1), DELTA(1,1), DMAX(1,1), WATE, FSGX, FD
WRITE(IP, 9004) A(1), GRGX, RHON, RHOP, SCILK, QVXS
1050 IF (I, REAL) 1060, 1060, 1055
1055 TESOIL=TESOIL+ESCIL+EFRICT
1060 RETURN
C
C   LINEAR INTERPOLATION IS USED FOR THE DETERMINATION OF PLASTIC
C   CRUSH FORCE ON THE HEAT SHIELD INPUT IS DEFL(II) VS FORCE(II)
C
600 II=1
C
610 IF (DMAX(II, J) .LT. 0.0) GO TO 660
IF (DMAX(II, J) .LT. DEFL(II, J, 1)) GO TO 670
III=3
IF (DMAX(II, J) .GT. DEFL(II, J, III)) III=III
C
615 IF (DMAX(II, J)-DEFL(II, J, III)) 620, 630, 640
C
620 FF=(FORCE(II, J, III)-FORCE(II, J, III-1))*(DMAX(II, J)-DEFL(II, J, III-1))/
1 (DEFL(II, J, III)-DEFL(II, J, III-1))+FORCE(II, J, III-1)
GO TO (145, 175), IAB
C
630 FF=FORCE(II, J, III)
GO TO (145, 175), IAB
C
640 II=II+1
IF (II-6) 615, 615, 650
C

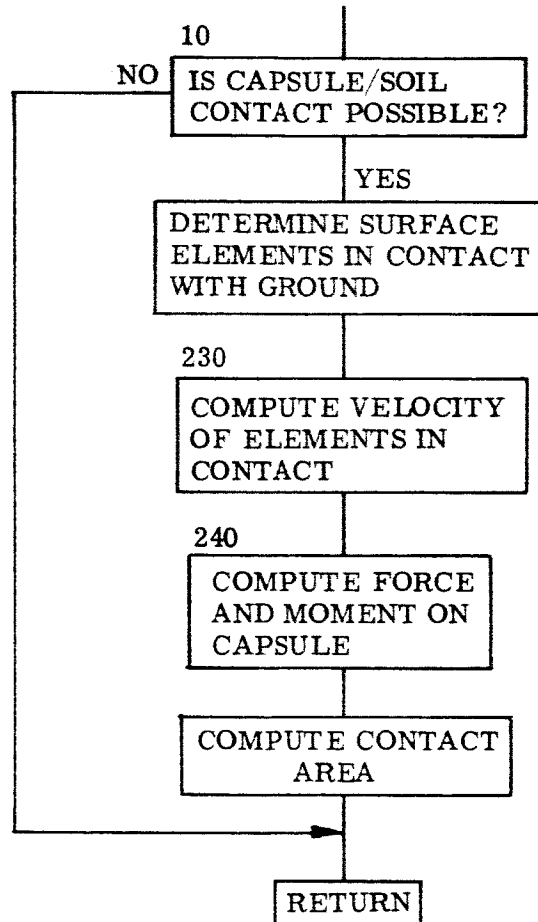
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000521      650 FF=FORCE(I,J,6)+GKT*(DMAX(I,J)-DEFL(I,J,6))
000522      GO TO(145,175),IAB
000523      C
000524      660 WRITE(IP,9000)I,J
000525      STCP
000526      670 WRITE(IP,9001)DMAX(I,J),DEFL(I,J,II)
000527      STCP
000528      680 WRITE(IP,9002)
000529      STCP
000530      690 WRITE(IP,9005)
000531      STCP
000532      9000 FORMAT(7H DELTA(I,I2,1H,I2,34H) LESS THAN 0.0 STOP RUN ON ERROR)
000533      9001 FORMAT(18H ERROR DMAX(I,J) =,F10.5,12H DEFL(II) =,F10.5)
000534      9002 FORMAT(33H ERROR RHO(I) LESS THAN P1 AT 470)
000535      9003 FORMAT(15H ERROR IN RING ,I2, 8H P(I,J)=,F10.5, 4H PS=,F10.5)
000536      9004 FORMAT(6F15.5)
000537      9005 FORMAT(53H HEAT SHIELD CRUSH FORCE VS DEFL. TAELE IS INCORRECT.)
000538      ENL
      3. TOC

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SUBROUTINE CASOIL (12)



ELT CASOIL:1.660404: 51703

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000001      C
000002      C      THIS SUBROUTINE CALCULATES THE CONTACT FORCES BETWEEN THE CAPSULE
000003      C      AND THE GROUND
000004      C
000005      C      SUBROUTINE CASOIL
000006      C
000007      C
000008      C      COMMON/L2/HEATA,HEATE,HSCG2,IP,IS,IT,DEN(17),XV,ETA
000009      C      COMMON/L12B/D11,D12,D13,D21,D22,D23,D31,D32,D33
000010      C      COMMON/L10/EX(10),EY(10,50),EZ(10,50),NI(10),V(10),CKK,QG,K,
000011      C      1RHC(10),DEFL(10,50,6),FORCE(10,50,6),GNDMU,AEL
000012      C      COMMON/L12/RX,RY,RZ,FXVEL,FYVEL,RZVEL,WX,WY,WZ
000013      C      COMMON/L13/SLGTH(3,6),FC(3,6),COEF(2,8),COEFT(2,8),XMAX,XMIN,QC,
000014      C      INS
000015      C      COMMON/L15/X(12),Y(12,55),Z(12,55),NJ(12),N,ACEL,XBASE
000016      C      COMMON/L16/FCGX,FCGY,FCGZ,TCGX1,TCGY1,TCGZ1,PREV,YCG,ZCG,
000017      C      1CAFEA,CAREAM
000018      C      COMMON/L17/CAPFOR(21),CAPDEF(21),JJMAX
000019      C      COMMON/M1/FORJK(6),SLJK(6),CHJK(6),CHJK(6),SRJK(6),SRJK(6),
000020      C      1SDJK(6),VELJK(6),FORLM(8),SLLM(8),CHLMT(8),CHLM(8),SKLMT(8),
000021      C      2SRLM(8),SDLM(8),VELLM(8),DMAX(10,50),DELMAX(12,55),SACC,SVEL,
000022      C      3SLEL,PKNEE(10,50)
000023      C      DIMENSION DELT(12,55)
000024      C
000025      C      L=1
000026      C      IF(CAPDEF(L) .LT. 0.1E-04) L=2
000027      C      IF(CAPDEF(L) .LT. 0.1E-04) GO TO 700
000028      C
000029      C      FCGX=0.0
000030      C      FCGY=0.0
000031      C      FCGZ=0.0
000032      C      TCGX1=0.0
000033      C      TCGY1=0.0
000034      C      TCGZ1=0.0
000035      C      CAFEA=0.0
000036      C      S=SWRT(D12*D12+D13*D13)
000037      C      IF(D11)20,10,10
000038      C
000039      C      10 G=FX+D11*XMIN-D12*YCG-D13*ZCG-HEATB*S
000040      C
000041      C      IF(Q)50,600,600
000042      C
000043      C      20 IF(D11-COS(1.5708+ETA))30,40,40
000044      C
000045      C      30 G=FX+D11*XMAX+HEATB*(XV-XMAX)/(XV-XBASE)=(D12+D13)-D12*YCG-
000046      C      1L13*ZCG
000047      C      IF(Q)60,60,600
000048      C
000049      C      40 G=FX+D11*XBASE-D12*YCG-D13*ZCG-HEATB*S
000050      C      IF(Q)50,600,600
000051      C
000052      C      50 I=1
000053      C      SS=-1
000054      C      GO TO 70
000055      C
000056      C      60 I=N
000057      C      SS=1
000058      C      GO TO 70
000059      C
000060      C      70 J=1
000061      C      JS=-1
000062      C
000063      C      80 IF(RX+D11*X(I) +D12*Y(I,J)+D13*Z(I,J))90,270,270
000064      C
000065      C      90 IF(JS)100,110,110
000066      C
000067      C      100 JB=(J-1)*360/NJ(I)
000068      C      JS=1
000069      C
000070      C      110 IF(X(I) -XBASE)120,120,130
000071      C
000072      C      120 A=C/G
000073      C      C=1.0

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000074      GO TO 140
000075      A=SIN(ETA)
000076      C=COS(ETA)*(XV-ABASE)/(XV-X(I))
000077      C
000078      140 DELT(I,J)=(D11*X(I) :D12*Y(I,J)+D13*Z(I,J)+RX)/(D11+A+C*
000079      1(D12*(Y(I,J)+YCG)/HEATB+D13*(Z(I,J)+ZCG)/HEATB))
000080      C
000081      IF (DELT(I,J)-DELMAX(I,J))160,160,150
000082      150 DELMAX(I,J)=DELT(I,J)
000083      GO TO 210
000084      C
000085      160 IF (DELMAX(I,J)-CAPDEF(L))170,170,175
000086      170 P=CAFFOR(L)/CAPDEF(L)*DELT(I,J)
000087      GO TO 230
000088      C
000089      175 D=DELMAX(I,J)
000090      M3=1
000091      GO TO 500
000092      C
000093      180 F=FMAX-CAPFOR(L)/CAPDEF(L)*(DELMAX(I,J)-DELT(I,J))
000094      IF (F)190,190,200
000095      C
000096      190 F=C-U
000097      GO TO 270
000098      C
000099      200 F=F
000100      GO TO 230
000101      C
000102      210 IF (DELMAX(I,J)-CAPDEF(L))170,170,220
000103      C
000104      C
000105      220 D=DELT(I,J)
000106      M3=2
000107      GO TO 500
000108      C
000109      230 UX=Z(I,J)*WY-Y(I,J)*WZ
000110      UY=X(I) *WZ-Z(I,J)*WX
000111      UZ=Y(I,J)*WX-X(I) *WY
000112      VX=RXVEL+D11*UX+D12*UY+D13*UZ
000113      VY=RYVEL+D21*UX+D22*UY+D23*UZ
000114      VZ=RZVEL+D31*UX+D32*UY+D33*UZ
000115      VBR=SGRT(VY*VY+VZ*VZ)
000116      240 FX=P*ACEL
000117      FY=-GNDMU*FX*VY/VBR
000118      FZ=-GNDMU*FX*VZ/VBR
000119      C
000120      C      CHANGE TO CAPSULE COORDINATES FOR MOMENT CALCULATIONS
000121      C
000122      F1X=L11*FX+D21*FY+D31*FZ
000123      F1Y=L12*FX+D22*FY+D32*FZ
000124      F1Z=L13*FX+D23*FY+D33*FZ
000125      C
000126      C      ELEMENT MOMENT IN CAPSULE COORDINATES
000127      C
000128      250 T1X=F1Z*Y(I,J)-F1Y*Z(I,J)
000129      T1Y=F1X*Z(I,J)-F1Z*X(I)
000130      T1Z=F1Y*X(I) -F1X*Y(I,J)
000131      C
000132      C      SUM FORCES IN FIXED COORDINATE SYSTEM
000133      C
000134      FCGX=FCGX+FX
000135      FCGY=FCGY+FY
000136      FCGZ=FCGZ+FZ
000137      C
000138      C      SUM. CAPSULE TORQUES IN CAPSULE COORDINATE SYSTEM
000139      C
000140      TCGX1=TCGX1+T1X
000141      TCGY1=TCGY1+T1Y
000142      TCGZ1=TCGZ1+T1Z
000143      C
000144      C      SUM. CONTACT AREA
000145      C
000146      CAREA=CAREA+ACEL
000147      C
000148      270 IF (J-NJ(I))280,310,310

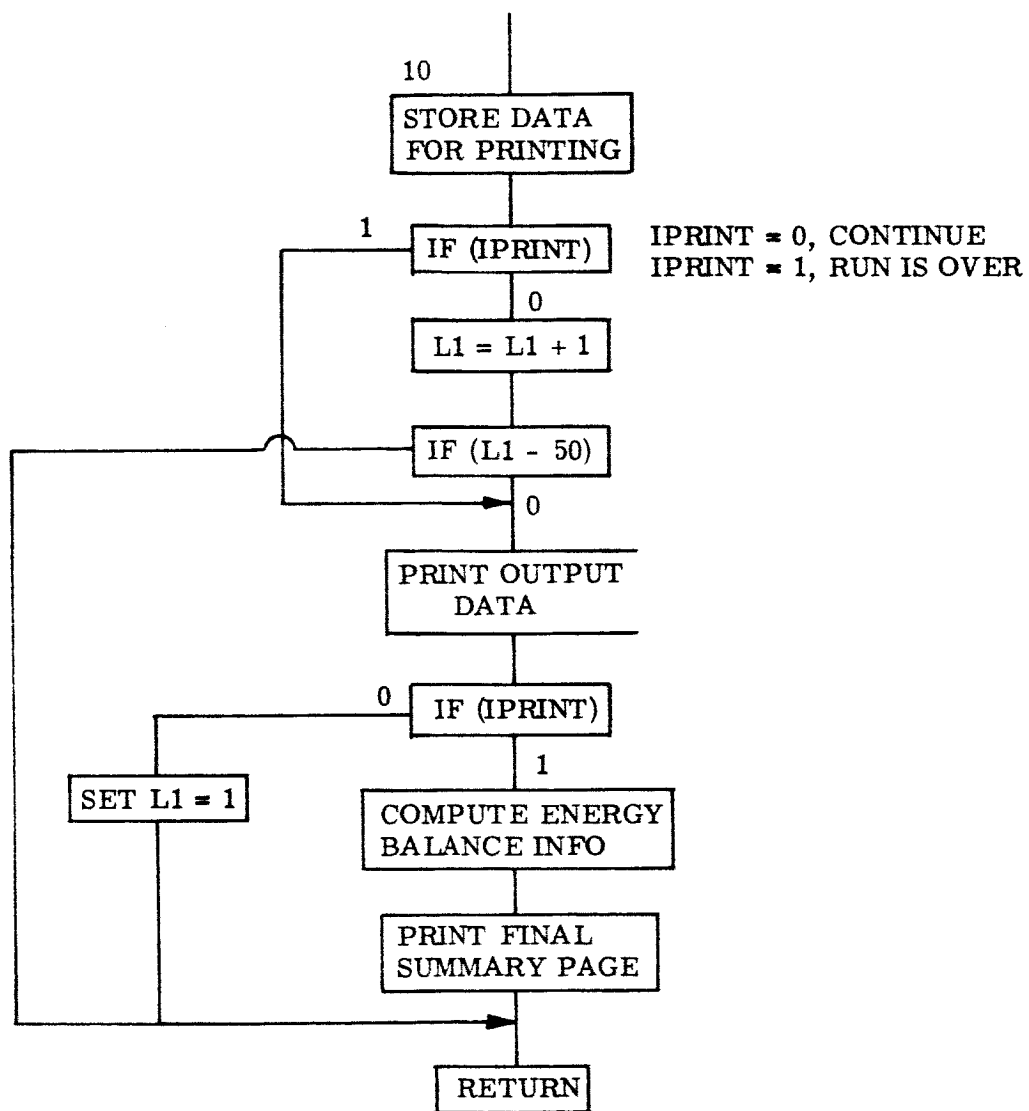
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000149
000150 C 280 IF(JE)290,300,290
000151 C
000152 C 290 IF(JS)300,300,310
000153 C
000154 C 300 J=J+1
000155 JS=-1
000156 GO TO 80
000157 C
000158 C 310 IF(SS)320,330,330
000159 C
000160 C 320 IF(I-N)340,600,600
000161 C
000162 C 330 IF(I-1)600,600,350
000163 C
000164 C 340 IF(ACEL)610,610,345
000165 C 345 IF(I-1,0+(XMIN-XBASE)/SQRT(ACEL))360,360,350
000166 C 350 IF(CAREA-FREV)600,600,360
000167 C
000168 C 360 I=1-SS
000169 FREV=CAREA
000170 J=JB+NJ(I)/360
000171 K=0
000172 C 365 K=K+1
000173 IF(M-NJ(I))370,370,310
000174 C
000175 C 370 IF(RA+D11*X(I) +D12*Y(I,J)+D13*Z(I,J))380,390,390
000176 C
000177 C 380 J=J+1
000178 IF(J)400,400,365
000179 C
000180 C 390 J=J+1
000181 JS=-1
000182 GO TO 80
000183 C 400 J=NJ(I)
000184 GO TO 365
000185 C 500 K=1
000186 C 505 IF(CAPDEF(1)=D)510,520,520
000187 C
000188 C 510 K=K+1
000189 IF(K.GT. JJMAX) GO TO 550
000190 GO TO 505
000191 C 520 PMAX=CAPFOR(K)
000192 GO TO (180,230),M3
000193 C
000194 C 530 IF(K.EQ. 1) GO TO 560
000195 PMAX=(D-CAPDEF(K-1))*(CAPFOR(K)-CAPFOR(K-1))/(CAPDEF(K)-
000196 1CAPDEF(K-1))+CAPFOR(K-1)
000197 GO TO (180,230),M3
000198 C
000199 C 550 PMAX=CAPFOR(JJMAX)
000200 GO TO (180,230),M3
000201 C
000202 C 560 PMAX=CAPFOR(1)
000203 GO TO (180,230),M3
000204 C
000205 C 600 IF(CAREA.GT. CAREAM)CAREAM=CAREA
000206 WRITE(IP,650)RX,G,DELT(1,1),ACEL,D11,CAREA
000207 C 650 FORMAT(6F15.5)
000208 RETURN
000209 C
000210 C 610 WRITE(IP,615)ACEL
000211 C 615 FORMAT(55H STOP, CAPSULE INCREMENTAL AREA LESS THAN ZERO. ACEL =,
000212 IF10.5)
000213 STCP
000214 C 700 WRITE(IP,9001)
000215 STCP
000216 C 9001 FORMAT(54H CAPSULE CRUSH FORCE VS DEFLECTION TABLE IS INCORRECT.)
000217 ENL

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SUBROUTINE OUTPUT (13)



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000001          SUBROUTINE OUTPUT
000002      C
000003      C
000004      C      THIS SUBROUTINE STORES ALL DETAILED DATA FOR PRINTOUT AND PRINTS
000005      C      IT WHEN A FULL PAGE IS AVAILABLE. DETERMINATION OF WHEN A PRINT
000006      C      INTERVAL HAS BEEN REACHED IS LEFT TO THE MAIN EXECUTIVE PROGRAM
000007      C
000008      C
000009      COMMON/L1A/RX0(1),RY0,RZ0,RXVEL0,RYVEL0,RZVEL0,PSIC,THTAC,PHI0,
000010      1MXC,MY0,MZ0,RCX0,RCYC,RCZ0,CXVELO,CYVELO,CZVELO,DUP1(6),RSX0,
000011      2RSY0,RSZ0, SXVELO,SYVEL0,SZVEL0
000012      COMMON/L1B/XL10(8),YL10(8),ZL10(8),XM20(8),YM20(8),ZM20(8),
000013      1XJ30(6),YJ30(6),ZJ30(6),XK10(6),YK10(6),ZK10(6),FFX0,FPYC,FPZ0,
000014      2FXVELO,PYVELO,PZVELO,CHLM0,CHJ0,CTLM0,CTJ0
000015      COMMON/L2/HEATA,HEATB,HSCG2,IP,IS,IT,UXX,UYX,UZZ,UCXX,UCYY,UCZZ,
000016      1LSXX,USYY,USZZ,FCJK,FCLM,UXY,UYZ,UXZ,UCXY,UCXZ,UCYZ,HC,ETA,PLGNOF,
000017      2FK,JK,LM,MSX1,HGX1,JNDAMP,LNDAMP,VISJK,VISLM
000018      COMMON/L5A/DT,THAX,IFRINT,TF,DTP,ISTOP,IRUNNO,ISERAO
000019      COMMON/L5B/OLCMAX(6),OLCIN(6),OLSMAX(8),OLSMIN(8),JC,JS,OLCB(6),
000020      1GLCL(6),OLSB(8),OLSL(8),OMACX(7),OMACY(7),OMACZ(7),OMAX(7),
000021      2OMAY(7),OMAZ(7),ODEL(10),ENGKE,OECS,ENGPE,OEES,OESEND,OEISOIL,
000022      3OFFALT,OEEND,ENGKEF,NORING(10),ENGTOT,AX1,AY1,AZ1,ACX3,ACY3,ACZ3,
000023      4ASX2,ASY2,ASZ2,L1
000024      COMMON/L5C/ZETA,CAPM,CCHM,HSDM
000025      COMMON/L5D/IC,ISS,OFCHAX(6),OFCHIN(6),OFCHMAX(8),OFCHMIN(8),TSSG(8),
000026      1TCSQ(6),TOTSCR(6),TOTCCR(6)
000027      COMMON/L6A/SLJK0(6),SLLM0(6)
000028      COMMON/L7A/QSX(8),QSY(8),QSZ(8),GKT,FSGX,FSGY,FSGZ,TSGX,TSGY,TSGZ,
000029      1AREA,AREAM
000030      COMMON/L9B/SHCUK,SHCUKT,SHCLM,SHCLMT,CTJK,CTLM,XORIG
000031      COMMON/L10/EX(10),EY(10,50),EZ(10,50),NI(10),A(10),CHS,Q,K,
000032      1RHC(10),LEFL(10,50,6),FOFCE(10,50,6),GNDMU,AEL
000033      COMMON/L11/AA1(3,6),AA3(3,6),CAP(3,6),CCH(3,6),IACCEL
000034      COMMON/L12/RX(1),RY,RZ,RXVEL,RYVEL,RZVEL,WX,WY,WZ,
000035      1RCX,RCY,RCZ,RCXVEL,RCYVEL,RCZVEL,WCX,WCY,W CZ,
000036      2RSX,RSY,RSZ,RSXVEL,RSYVEL,RSZVEL,WSX,WSY,WSZ,
000037      3PSI,THTA,PHI,PSIC,THTAC,PHIC,PSIS,THTAS,PHIS,DDD,DDM,TIME,
000038      4DUP5(961)
000039      COMMON/L16/FCGX,FCGY,FCGZ,TCGX1,TCGY1,TCGZ1,PREV,YCG,ZCG,
000040      1CAREM,CAREAM
000041      COMMON/L18/SLRMO,SOILE,SLPHI,CKPHIC,NAA,AA(9),BB(9),TESOIL,
000042      1GMA(5),AGMA(5),BGMA(5),CMU,SUMCR
000043      COMMON/L20/XB13,YB13,ZB13,XB23,YB23,ZB23,YRP1,YRP2,BLNG,BST1MX,
000044      1BST2,X,BMPNRG,BDEF(6),BFCR(6),FBX,FBY,FBZ,TBX,TBY,TBZ,TBCX,TBCY,
000045      2TBCZ,RRNKG
000046      C
000047      COMMON/M1/FORJK(6),SLJK(6),CHJKT(6),CHJK(6),SRJKT(6),SRJK(6),
000048      1SDJK(6),VELJK(6),FORLM(8),SLLM(8),CHLMT(8),CHLM(8),SRLMT(8),
000049      2SRLM(8),SCLM(8),VELL(6),LMAX(10,50),DELMAX(12,55),SACC,SVEL,
000050      3SLEL,PKNEE(10,50)
000051      COMMON/L23/HSX10,HSCG20,LXXC,UYX0,UZZ0,CAPMO,HSDMO,RRX10(6),
000052      1RRY10(6),RRZ10(6)
000053      DIMENSION OX(50),CY(50),OZ(50),ODX(50),ODY(50),ODZ(50),OPSI(50),
000054      1ODFS(50),OTHTA(50),ODTHTA(50),OPHI(50),ODPHI(50),OCX(50),OCY(50),
000055      2OCZ(50),OCDX(50),OCDY(50),OCDZ(50),OCPHI(50),OCDPSI(50),OCTHTA(50),
000056      3OCDTHT(50),OCPHI(50),OCDPHI(50),OSX(50),OSY(50),OSZ(50),TH(50)
000057      DIMENSION OSDX(50),OSDY(50),OSDZ(50),OSPSI(50),OSDFS(50),
000058      1OSTHTA(50),OSDTHT(50),OSPHI(50),OSDPHI(50),OLC1(50),OLC2(50),
000059      2OLC3(50),OLC4(50),OLC5(50),OLC6(50),OLS1(50),OLS2(50),OLS3(50),
000060      3OLS4(50),OLS5(50),OLS6(50),OLS7(50),OLS8(50),OFG(50),OAREA(50),
000061      4GAX(50),OAY(50),OAZ(50),OACX(50),OACY(50),OACZ(50),OASX(50),
000062      5OASY(50),OASZ(50)
000063      DIMENSION OAA1(6,50),OAA3(6,50)
000064      C
000065      C
000066      C
000067      C
000068      C
000069      10 TM(L1)=TIME
000070      OX(L1)=RX
000071      OY(L1)=RY
000072      OZ(L1)=RZ
000073      ODX(L1)=RXVEL

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000074      ODY(L1)=RYVEL
000075      ODZ(L1)=RZVEL
000076      OPSI(L1)=PSI
000077      ODP5I(L1)=WZ
000078      OTHTA(L1)=THTA
000079      ODTHTA(L1)=WY
000080      OPHI(L1)=PHI
000081      ODPHI(L1)=WX
000082      C
000083      C
000084      C
000085      20 OCX(L1)=RCX
000086      OCY(L1)=RCY
000087      OCZ(L1)=RCZ
000088      OCCX(L1)=RCXVEL
000089      OCCY(L1)=RCYVEL
000090      OCCZ(L1)=RCZVEL
000091      OCCPSI(L1)=PSIC
000092      OCCPSI(L1)=WCZ
000093      OCTHTA(L1)=THTAC
000094      OCLTHT(L1)=WCY
000095      OCFHI(L1)=PHIC
000096      OCCPHI(L1)=WCX
000097      C
000098      C
000099      C
000100      30 CSX(L1)=RSX
000101      CSY(L1)=RSY
000102      CSZ(L1)=RSZ
000103      CSLX(L1)=RSXVEL
000104      CSY(L1)=RSYVEL
000105      CSLZ(L1)=RSZVEL
000106      CSFSI(L1)=PSIS
000107      CSLPSI(L1)=WSZ
000108      CSTHTA(L1)=THTAS
000109      CSLTHT(L1)=WSY
000110      CSFHI(L1)=PHIS
000111      CSLPHI(L1)=WSX
000112      C
000113      C
000114      C
000115      40 OLC1(L1)=SLJK(1)-SLJK0(1)
000116      OLC2(L1)=SLJK(2)-SLJK0(2)
000117      OLC3(L1)=SLJK(3)-SLJK0(3)
000118      OLC4(L1)=SLJK(4)-SLJK0(4)
000119      OLC5(L1)=SLJK(5)-SLJK0(5)
000120      OLC6(L1)=SLJK(6)-SLJK0(6)
000121      C
000122      C
000123      C
000124      OLS1(L1)=SLLM(1)-SLLM0(1)
000125      OLS2(L1)=SLLM(2)-SLLM0(2)
000126      OLS3(L1)=SLLM(3)-SLLM0(3)
000127      OLS4(L1)=SLLM(4)-SLLM0(4)
000128      OLS5(L1)=SLLM(5)-SLLM0(5)
000129      OLS6(L1)=SLLM(6)-SLLM0(6)
000130      OLS7(L1)=SLLM(7)-SLLM0(7)
000131      OLS8(L1)=SLLM(8)-SLLM0(8)
000132      C
000133      C
000134      C
000135      50 OAREA(L1)=AREA+CAREA
000136      CFG(L1)=FSGX
000137      OAX(L1)=DUM5(4)
000138      OAY(L1)=DUM5(5)
000139      OAZ(L1)=DUM5(6)
000140      OACX(L1)=DUM5(13)
000141      OACY(L1)=DUM5(14)
000142      OACZ(L1)=DUM5(15)
000143      OASX(L1)=DUM5(22)
000144      OASY(L1)=DUM5(23)
000145      OASZ(L1)=DUM5(24)
000146      C
000147      IF(IACCEL .LE. 0) GO TO 55
000148      C

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000149      C      CAA1(1,L1)=AA1(1,1)
000150      C      CAA1(2,L1)=AA1(1,2)
000151      C      CAA1(3,L1)=AA1(1,3)
000152      C      CAA1(4,L1)=AA1(2,4)
000153      C      CAA1(5,L1)=AA1(2,5)
000154      C      CAA1(6,L1)=AA1(3,6)
000155      C      CAA3(1,L1)=AA3(1,1)
000156      C      CAA3(2,L1)=AA3(1,2)
000157      C      CAA3(3,L1)=AA3(1,3)
000158      C      CAA3(4,L1)=AA3(2,4)
000159      C      CAA3(5,L1)=AA3(2,5)
000160      C      CAA3(6,L1)=AA3(3,6)
000161
000162      C
000163      C
000164      C      IF IPRINT = 0 , CONTINUE .      IF IPRINT = 1 , RUN IS OVER , PRINT
000165      C      FINAL SUMMARY
000166      C
000167      C      55 IF (IPRINT)60,60,70
000168      C
000169      C      60 L1=L1+1
000170      C      IF (L1 .LE. 50) GO TO 230
000171      C
000172      C      IF (L1 .GT. 51) GO TO 250
000173      C      L1=L1-1
000174      C
000175      C
000176      C      70 WRITE (IT,9000)
000177      C      WRITE (IT,9001)
000178      C      WRITE (IT,9002)
000179      C      WRITE (IT,9003) (TM(K),OX(K),CUX(K),OY(K),ODY(K),OZ(K),ODZ(K),
000180      C      1CPSI(K),CPSI(K),CTHTA(K),CDTHTA(K),CPHI(K),CDPHI(K),K=1,L1)
000181      C
000182      C      WRITE (IT,9004)
000183      C      WRITE (IT,9001)
000184      C      WRITE (IT,9002)
000185      C      WRITE (IT,9003) (TM(K),OCX(K),OCDX(K),CCY(K),OCDY(K),OCZ(K),OCDZ(K),
000186      C      1CCFSI(K),COPPSI(K),CCTHTA(K),CDDTHT(K),COPHI(K),CDDPHI(K),K=1,L1)
000187      C
000188      C      WRITE (IT,9005)
000189      C      WRITE (IT,9001)
000190      C      WRITE (IT,9002)
000191      C      WRITE (IT,9003) (TM(K),OSX(K),OSDX(K),OSY(K),OSDY(K),OSZ(K),OSDZ(K),
000192      C      1OSPSI(K),OSDPSI(K),CSTHTA(K),CSDTHT(K),CSPHI(K),CSDPHI(K),K=1,L1)
000193      C
000194      C      WRITE (IT,9007)
000195      C      WRITE (IT,9008)
000196      C      WRITE (IT,9009) (TM(K),OLC1(K),OLC2(K),OLC3(K),OLC4(K),OLC5(K),
000197      C      1OLC6(K),OLC1(K),OLC2(K),OLC3(K),OLC4(K),OLC5(K),OLC6(K),OLC7(K),
000198      C      2OLC8(K),K=1,L1)
000199      C
000200      C      WRITE (IT,9010)
000201      C      WRITE (IT,9011)
000202      C      WRITE (IT,9012)
000203      C      WRITE (IT,9013) (TM(K),OAREA(K),OFG(K),OAX(K),OAY(K),OAZ(K),OACX(K),
000204      C      1OACY(K),OACZ(K),OASX(K),OASY(K),OASZ(K),K=1,L1)
000205      C
000206      C      IF (IACCEL)77,77,75
000207      C      75 WRITE (IT,9052)
000208      C      WRITE (IT,9053)
000209      C      WRITE (IT,9054) ((TM(K), (CAA1(I,K), I=1,6), (CAA3(J,K), J=1,6)), K=1,L1)
000210      C      77 IF (IPRINT)80,60,90
000211      C
000212      C      80 L1=1
000213      C      RETURN
000214      C
000215      C      SET UP FOR FINAL SUMMARY PRINTOUT
000216      C
000217      C      90 WRITE (IP,9014) ISERNO,IRUNNO,RXVELO,RYVELO,RZVELO
000218      C      WRITE (IP,9015) WXO,WYO,WZO
000219      C      IF (IS)100,100,110
000220      C      100 WRITE (IP,9016)
000221      C      GO TO 120
000222      C      110 WRITE (IP,9018)
000223      C      120 WRITE (IP,9017) ZETA

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000224      WRITE(IP,9019)TIME
000225      GO TO(130,140,150,160,170),ISTOP
000226 130  WRITE(IP,9020)
000227      GO TO 180
000228 140  WRITE(IP,9021)
000229      GO TO 180
000230 150  WRITE(IP,9022)IC
000231      GO TO 180
000232 160  WRITE(IP,9023)ISS
000233      GO TO 180
000234 170  WRITE(IP,9024)
000235 180  WRITE(IP,9025)
000236      WRITE(IP,9026)
000237      WRITE(IP,9027)(UFCMIN(I),I=1,6),(OFSTIN(I),I=1,8)
000238      WRITE(IP,9028)(UFCMAX(I),I=1,6),(OFSMAX(I),I=1,8)
000239      WRITE(IP,9029)
000240      CFF=0.0
000241      SFF=0.0
000242      TOTCR=0.0
000243      TOSCR=0.0
000244      CAFM=CAPHG
000245      HSDM=HSDMO
000246      ENCKE=G.5*(CAPH*(RXVELO*RXVELO+RYVELO*RYVELO+RZVELO*RZVELO)
000247      1 +(UAX*WX*WX+UY*WY*WY+UZZ*WZ*WZ)+CCHM*(CXVELO*CXVELO
000248      2 +CYVELO*CYVELO+CZVELO*CZVELO)+(UCX*WX*WX+UCY*WY*WY
000249      3 +LCZ*WZ*WZ)+HSDM*(SXVELO*SXVELO+SYVELO*SYVELO+SZVELO*SZVELO)
000250      4 +(USX*WX*WX+USY*WY*WY+USZ*WZ*WZ))
000251      G=32.2
000252      ENCKE=G*(CAPH*((RXO-RX)*COS(ZETA)-(RZO-RZ)*SIN(ZETA))
000253      1 +CCHM*((RCXO-RCX)*COS(ZETA)-(RCZO-RCZ)*SIN(ZETA))
000254      2 +FSUM*((RSXO-RSX)*COS(ZETA)-(RSZO-RSZ)*SIN(ZETA)))
000255      ENGKEF=G.5*(CAPH*(RXVEL*RXVEL+RYVEL*RYVEL+RZVEL*RZVEL)
000256      1 +(UAX*WX*WX+UY*WY*WY+UZZ*WZ*WZ)+CCHM*(RCXVEL*RCXVEL
000257      2 +RCYVEL*RCYVEL+RCZVEL*RCZVEL)+(UCX*WX*WX+UCY*WY*WY
000258      3 +LCZ*WZ*WZ)+HSDM*(RSXVEL*RSXVEL+RSYVEL*RSYVEL+RSZVEL*RSZVEL)
000259      4 +(USX*WX*WX+USY*WY*WY+USZ*WZ*WZ))
000260      ENGTOT=ENGKE+ENGFE+RRNRG-ENGKEF
000261      DO 191 I=1,6
000262      CFF=CFF+TCSQ(I)
000263      TOTCR=TOTCR+TOTCCR(I)
000264      OLCB(I)=OLCMAX(I)-SLJKO(I)
000265 191  CLCL(I)=SLJKO(I)-OLCMIN(I)
000266      DO 202 I=1,8
000267      SFF=SFF+TSSQ(I)
000268      TOSCR=TOSCR+TOTSCR(I)
000269      OLSB(I)=OLSMAX(I)-SLLMO(I)
000270 202  CLSL(I)=SLLMO(I)-OLSMIN(I)
000271      OECS=(CFF+TOTCR+RRNRG)/ENGTOT
000272      OESS=(SFF+TOSCR)/ENGTOT
000273      OESGND=SUMCR/ENGTOT
000274      OESOIL=TESOIL/ENGTOT
000275      CFFALT=OECS+OESS+OESGND+OEGND+OESOIL
000276      WRITE(IP,9030)(OLCB(I),I=1,6),(OLSB(I),I=1,8)
000277      WRITE(IP,9031)(OLCL(I),I=1,6),(OLSL(I),I=1,8)
000278      WRITE(IP,9032)
000279      WRITE(IP,9033)
000280      WRITE(IP,9034)(OMACX(I),I=1,7)
000281      WRITE(IP,9035)(OMACY(I),I=1,7)
000282      WRITE(IP,9036)(OMACZ(I),I=1,7)
000283      WRITE(IP,9037)
000284      WRITE(IP,9038)(OMAX(I),I=1,7)
000285      WRITE(IP,9039)(OMAY(I),I=1,7)
000286      WRITE(IP,9040)(OMAZ(I),I=1,7)
000287      WRITE(IP,9006)
000288      WRITE(IT,9039)AREAM
000289      WRITE(IP,9006)
000290      WRITE(IP,9040)CAREAM,(NORING(I),I=1,10)
000291      WRITE(IP,9041)(ODEL(I),I=1,10)
000292      WRITE(IP,9042)
000293      WRITE(IP,9043)ENGKE
000294      WRITE(IP,9044)OECS
000295      WRITE(IP,9045)ENGPE,OESS
000296      WRITE(IP,9046)OESGND
000297      WRITE(IP,9047)RRNRG,OEGND
000298      WRITE(IP,9048)OESOIL

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000299      WRITE(IP,9055)ENGKEF
000300      WRITE(IP,9050)OFRACT
000301      WRITE(IP,9049)ENGSTOT
000302      230 RETURN
000303      250 WRITE(IP,9051)LI
000304      STCP
000305      C
000306      C
000307      C
000308      9000 FORMAT(35H1 CAPSULE ORIENTATION INFORMATION)
000309      9001 FORMAT(123H0 TIME X AXIS Y AXIS
000310      1 Z AXIS PSI AXIS THTA AXIS PHI AX
000311      2IS)
000312      9002 FORMAT(126H POS. VEL. POS. VEL. POS. VEL. POS.
000313      1. VEL. POS. VEL. POS. VEL. POS.
000314      2 VEL./.)
000315      9003 FORMAT(F9.6,E9.3,11E10.3)
000316      9004 FORMAT(33H1 COUCH ORIENTATION INFORMATION)
000317      9005 FORMAT(39H1 HEAT SHIELD ORIENTATION INFORMATION)
000318      9006 FORMAT(1H0)
000319      9007 FORMAT(109H1 STROKE OF COUCH STRUTS
000320      1 STROKE OF HEAT SHIELD STRUTS)
000321      9008 FORMAT(123H0 TIME NO. 1 NO. 2 NO. 3 NO. 4 NO. 5 NO. 6
000322      1 NO. 1 NO. 2 NO. 3 NO. 4 NO. 5 NO. 6 NO. 7 NO.
000323      2 B/.)
000324      9009 FORMAT(F9.6,F7.4,5F8.4,F12.4,7F8.4)
000325      9010 FORMAT(105H1 SOIL GROUND ACCELERATIONS ON
000326      1COMPONENT CENTERS OF GRAVITY IN FT./SEC./SEC.)
000327      9011 FORMAT(126H TIME IMPACT REACTION CAPSULE MASS
000328      1 COUCH MASS HEAT SHIELD MASS)
000329      9012 FORMAT(125H AREA FORCE X DIR. Y DIR. Z DIR.
000330      1R. X DIR. Y DIR. Z DIR.
000331      2DIR./.)
000332      9013 FORMAT(F9.6,F7.4,E11.5,F12.4,2F10.4,F14.4,2F10.4,F14.4,2F10.4)
000333      9014 FORMAT(12H1 SERIES NO.,17.9H RUN NO.,14.43H INITIAL CONDITIONS
000334      1 -- LINEAR X VEL.,=F7.2,12H Y VEL.,=F7.2,12H Z VEL.,=F7
000335      2.2)
000336      9015 FORMAT(56X,19H ANGULAR BX VEL.,=F7.2,12H BY VEL.,=F7.2,12H
000337      1 WZ VEL.,=F7.2)
000338      9016 FORMAT(68H0 SURFACE TYPE CRUSHABLE VEHICLE SURFACE RIGID
000339      1SOIL SURFACE)
000340      9017 FORMAT(16H0 GROUND SLOPE =,F9.3)
000341      9018 FORMAT(67H0 SURFACE TYPE CRUSHABLE VEHICLE SURFACE REAL S
000342      1CIL SURFACE)
000343      9019 FORMAT(20H0 TOTAL RUN TIME =,F8.3,22H SEC. STOPPED BECAUSE)
000344      9020 FORMAT(1H+,50X,13H OF MAX. TIME/)
000345      9021 FORMAT(1H+,50X,32H G LOADS EXCEED ALLOWABLE LIMITS/)
000346      9022 FORMAT(1H+,50X,9H STRUT C(,12, 14H) BOTTOMED OUT/)
000347      9023 FORMAT(1H+,50X,9H STRUT S(,12, 14H) BOTTOMED OUT/)
000348      9024 FORMAT(1H+,50X,27H HEAT SHIELD STRUCK CAPSULE/)
000349      9025 FORMAT(32X,23H COUCH - CAPSULE STRUTS,26X,29H HEAT SHIELD - CAPSUL
000350      1E STRUTS)
000351      9026 FORMAT(123H PEAK STRUT FORCES NO.1 NO.2 NO.3 NO.4 NO
000352      1.5 NO.6 NO.1 NO.2 NO.3 NO.4 NO.5 NO.6 NO.7 NO
000353      2.8)
000354      9027 FORMAT(23H TENSION ,6F7.0,F10.0,7F7.0)
000355      9028 FORMAT(23H COMPRESSION ,6F7.0,F10.0,7F7.0)
000356      9029 FORMAT(21H MAX. STRUT STROKE)
000357      9030 FORMAT(23H TENSION ,6F7.3,F10.3,7F7.3)
000358      9031 FORMAT(23H COMPRESSION ,6F7.3,F10.3,7F7.3)
000359      9032 FORMAT(107H0 MAXIMUM ACCELERATIONS C.G. A
000360      1 B C L E F,7X,13HLOCATIO
000361      2NS A-F)
000362      9033 FORMAT(14H COUCH,100X,12HREFER TO CCH)
000363      9034 FORMAT(14X,7H X DIR.,7X,7F12.5,12H AND CAP ON)
000364      9035 FORMAT(14X,7H Y DIR.,7X,7F12.5,15H CAPDS 31 - 36)
000365      9036 FORMAT(14X,7H Z DIR.,7X,7F12.5)
000366      9037 FORMAT(16H CAPSULE)
000367      9038 FORMAT(14X,7H X DIR.,7X,7F12.5)
000368      9039 FORMAT(33H MAXIMUM SHIELD CONTACT AREA =,F8.4,67H SQ.FT. HEAT
000369      1SHIELD SURFACE BACKUP RING 1 2 3 4 5 6 7 8
000370      2 9 10)
000371      9040 FORMAT(33H CAPSULE CONTACT AREA =,F8.4,67H SQ.FT. ,39H EL
000372      1EMENTS PERMANENTLY DEFORMED NO. ,10I4)
000373      9041 FORMAT(81X,7H AMOUNT,10F4.2)

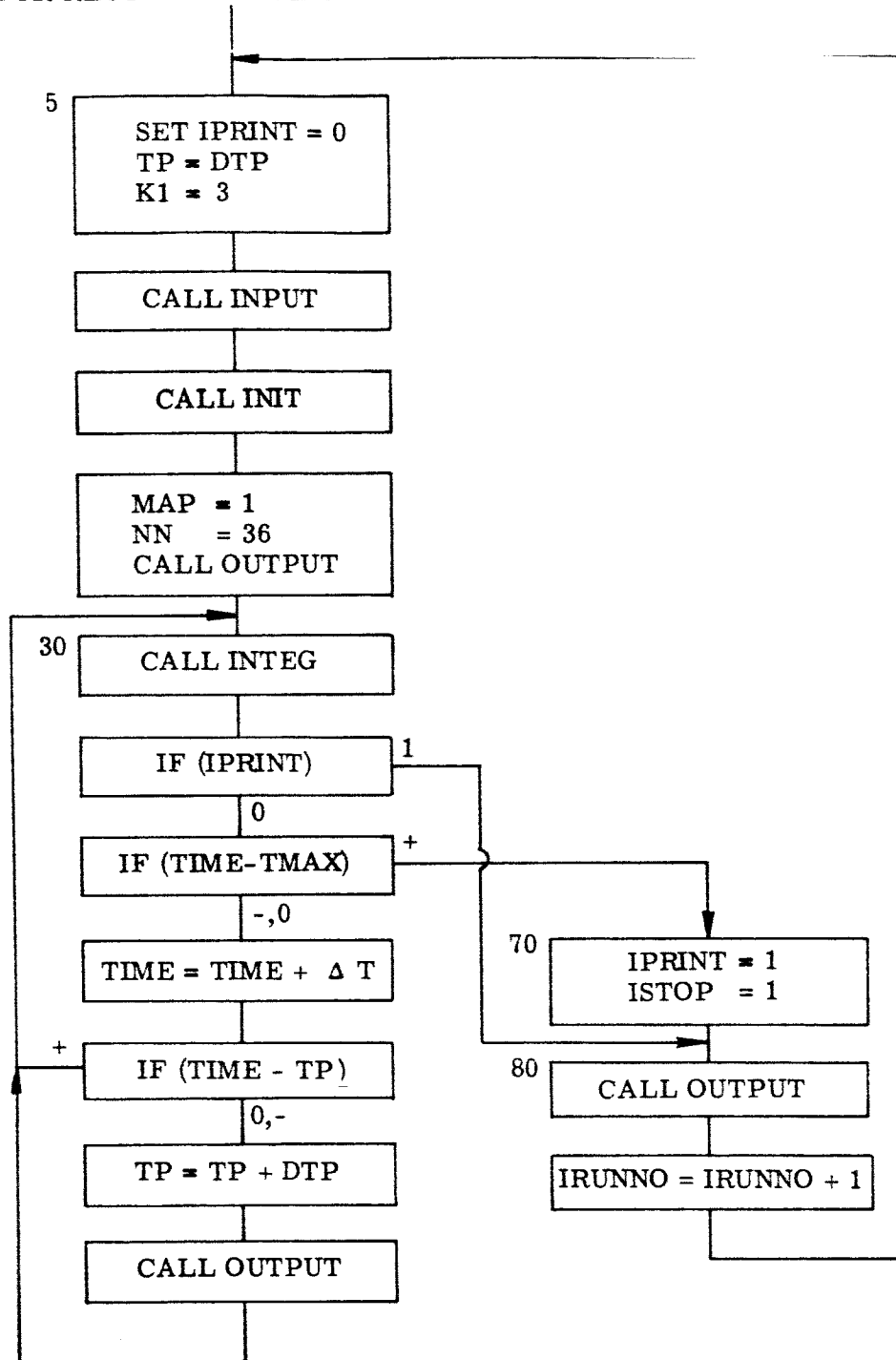
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000374 9042 FORMAT(30H0 ENERGY BALANCE INFORMATION)
000375 9043 FORMAT(44H INITIAL KINETIC ENERGY OF SYSTEM =,F6.1,36H
000376 1 FRACTION OF TOTAL SYSTEM)
000377 9044 FORMAT(62X,48H ENERGY ABSORBED BY COUCH STRUTS =,F7.
000378 13)
000379 9045 FORMAT(44H POTENTIAL ENERGY LOSS TO SYSTEM =,F6.1,34X,24
000380 1H HEAT SHIELD STRUTS =,F7.3)
000381 9046 FORMAT(86X,24H HEAT SHIELD SURFACE =,F7.3)
000382 9047 FORMAT(44H ENERGY ABSORBED BY RETROCKET =,F6.1,34X,24
000383 1H CAPSULE SURFACE =,F7.3)
000384 9048 FORMAT(86X,24H SOIL =,F7.3)
000385 9049 FORMAT(44H TOTAL SYSTEM ENERGY TO BE ABSORBED=,F6.1)
000386 9050 FORMAT(62X,48H FRACTION OF TOTAL SYSTEM ENERGY ABSORBED =,F7.
000387 13)
000388 9051 FORMAT(32H L1 IS LARGER THAN ALLOWED L1 =,I5)
000389 9052 FORMAT(61H1 ACCELEROMETER READINGS FOR CORRELATION WITH THE SCALE
000390 1MODEL/)
000391 9053 FORMAT(127H TIME CAP1(X) CAP2(X) CAP3(X) CAP4(Y) CAP5(
000392 1Y) CAP6(Z) CCH1(X) CCH2(X) CCH3(X) CCH4(Y) CCH5(Y) C
000393 2CH6(Z)//)
000394 9054 FORMAT(F9.6,E9.3,11E10.3)
000395 9055 FORMAT(44H FINAL KINETIC ENERGY OF SYSTEM =,F6.1)
000396 9056 FORMAT(14X,7H Y DIR.,7X,7F12.5)
000397 ENL

```

MAIN PROGRAM RECT (14)
FOR RECTANGULAR INTEGRATION



ELT RECT.1.660325. 00603

```

000001      C
000002      C
000003      C
000004      C
000005      C   THIS PROGRAM DESCRIBES THE MOTION OF THE AFOLLO COMMAND MODULE *
000006      C   ASTRONAUTS COUCH SYSTEM AND PROTECTIVE HEAT SHIELD DURING A
000007      C   LANDING ON SOIL
000008      C
000009      C
000010      C
000011      C
000012      C
000013      C   COMMON/L1A/RX0(1),RYL,RZC,RXVELO,RYVELO,RZVELO,PSIC,THTAO,PHIG,
000014      C   IXXC,WYC,WZO,RCXO,RCYC,RCZO,CXVELO,CYVELO,CZVELO,DUP1(6),RSXO,
000015      C   ZKSYO,RSZC, SXVELO,SYVELO,SZVELO
000016      C
000017      C   COMMON/L1B/XL10(6),YL10(6),ZL10(6),XM20(6),YM20(6),ZM20(6),
000018      C   1XJ30(6),YJ30(6),ZJ30(6),XK10(6),YK10(6),ZK10(6),FPXO,FPYO,FPZO,
000019      C   2PXVELC,PYVELC,PZVELC,CHLKO,CHJKO,CTLMO,CTJKO
000020      C
000021      C   COMMON/L2/HEATA,HEATE,HSCG2,IP,IS,IT,UXX,UYX,UZZ,LCXX,UCYY,UCZZ,
000022      C   1USXX,USYY,USZZ,FCJK,FCLM,UXY,UYZ,UXZ,UCXY,UCXZ,UCYZ,HC,ETA,PLGNOF,
000023      C   2PK,JK,LM,HXX1,HGX1,JKDAMP,LMDAMP,VISJK,VISLM
000024      C
000025      C
000026      C   COMMON/L3B/AX,AY,AZ,NDX,NEX,NZ,ACX,ACY,ACZ,NDX,NECY,NDCZ,
000027      C   1ASX,ASY,ASZ,NDX,NDY,NDZ
000028      C
000029      C
000030      C   COMMON/L3A/DT,TMAX,IFRINT,TF,UTP,ISTOP,IRUNNG,ISERNO
000031      C
000032      C   COMMON/L5E/OLCMAX(6),OLCMIN(6),OLSMAX(6),OLSMIN(6),JC,JS,OLCB(6),
000033      C   1OLCL(6),OLSB(6),OLSL(6),CMACX(7),OMACY(7),CMACZ(7),OMAX(7),
000034      C   2OMAY(7),OMAZ(7),ODEL(10),ENGKE,DECS,ENPE,CESS,DESEND,DESOIL,
000035      C   3CFFACT,DEGND,ENGKEF,NORING(10),ENGTOT,AX1,AY1,AZ1,ACX3,ACY3,ACZ3,
000036      C   4ASX2,ASY2,ASZ2,L1
000037      C
000038      C   COMMON/L5C/ZETA,CAPH,CCHM,HSDM
000039      C
000040      C   COMMON/L5D/IC,ISS,OFCHMAX(6),OFCHMIN(6),CFSMAX(6),CFSMIN(6),TSSQ(6),
000041      C   1TCSQ(6),TOTSCR(6),TOTCCR(6)
000042      C
000043      C
000044      C   COMMON/L6B/XL1(6),YL1(6),ZL1(6),XM2(6),YM2(6),ZM2(6),XJ3(6),
000045      C   1YJ3(6),ZJ3(6),XK1(6),YK1(6),ZK1(6),CXX,CXY,CXZ,CYX,CYY,CYZ,
000046      C   2CZX,CZY,CZZ,CCXX,CCXY,CCXZ,CCYX,CCYY,CCYZ,CCZX,CCZY,CCZZ
000047      C
000048      C   COMMON/L7A/QSX(8),GSY(8),GSZ(8),QKT,FSGX,FSGY,FSGZ,TSGX,TSGY,TSGZ,
000049      C   1AREA,AREAM
000050      C
000051      C   COMMON/L7B/QX(8),QY(8),QZ(8),QSQF(8),QSHT,QFC(8),QCH(8),QSH,
000052      C   1QSK(8),QFF,QVIS,QDAMP,QFX,QFY,QFZ,QTX1,QTY1,GTZ1,JKLM,QTSX2,
000053      C   2QTSY2,QTSZ2,QTCX3,QTCY3,QTCZ3,N,FORP(6),FHCQ(6),SO(6),QCHT(8),
000054      C   3QSKT(6),QSD(8),SG(8),QRGX,CRGY,CRGZ,CVGX,QVGY,CVGZ,CWGX,CWGY,CWGZ
000055      C
000056      C   COMMON/L1T8/D11,D12,D13,D21,D22,D23,D31,D32,D33,DS11,DS12,DS13,
000057      C   1DS21,DS22,DS23,DS31,DS32,DS33,DC11,DC12,DC13,DC21,DC22,DC23,
000058      C   2DC31,DC32,DC33
000059      C
000060      C   COMMON/L9A/IREAL
000061      C
000062      C   COMMON/L9B/SHCUK,SHCUKT,SHCLM,SHCLMT,CTJK,CTLM,XORIG
000063      C
000064      C   COMMON/L10/EX(10),EY(10,50),EZ(10,50),NI(10),A(10),CHS,Q,K,
000065      C   1HMC(10),DEFL(10,50,6),FORCE(10,50,6),GNDMU,AEL
000066      C
000067      C   COMMON/L11/AA1(3,6),AA3(3,6),CAP(3,6),CCH(3,6),IACCEL
000068      C   COMMON/L12/T(1000),SFAC,NN,KA1,A2,A3,A4,A5,A7,MAP,K1
000069      C
000070      C   COMMON/M1/FORJK(6),SLJK(6),CHJK(6),CHJK(6),SRJK(6),SRJK(6),
000071      C   1SDJK(6),VELJK(6),FORLM(8),SLLM(8),CHLMT(8),CHLM(8),SRLMT(8),
000072      C   2SRLM(8),SDLM(8),VELLM(8),LMAX(10,50),DELMAX(12,55),SACC,SVEL,
000073      C   3SLEL,PKNEE(10,50)

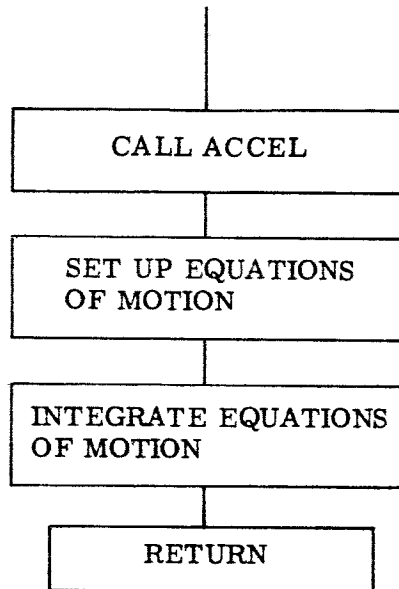
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000074      EQUIVALENCE(TIME,T(39))
000075      C
000076      C
000077      5 IPRINT=0
000078      C
000079      TP=DTP
000080      KI=3
000081      CALL INPUT
000082      C
000083      CALL INIT
000084      C
000085      MAF=1
000086      NN=36
000087      CALL OUTPUT
000088      C
000089      30 CALL INTEG
000090      C
000091      IF(IPRINT .GT. 0) GO TO 80
000092      C
000093      IPRINT=0
000094      C
000095      IF(TIME .GT. TMAX) GO TO 70
000096      C
000097      TIME=TIME+DT
000098      IF(TIME .LT. TP) GO TO 30
000099      TP=TP+DTP
000100      CALL OUTPUT
000101      GO TO 30
000102      C
000103      70 IPRINT=1
000104      ISTOP=1
000105      80 CALL OUTPUT
000106      IRLNNO=IRLNNO+1
000107      GO TO 5
000108      ENL

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SUBROUTINE INTEG (15)



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000001      SUBROUTINE INTEG
000002      C
000003      C
000004      C      THIS IS A RECTANGULAR INTEGRATION TECHNIQUE TO BE USED FOR INITIAL
000005      C      PROGRAM DEBUG ONLY
000006      C
000007      C
000008      COMMON/L2/HEATA,HEATE,HSCG2,IP,IS,IT,UXX,UYX,UZZ,UCXX,UCYY,UCZZ,
000009      1USXX,USYY,USZZ,FCUK,FCUM,UXY,UYZ,UXZ,UCXY,UCXZ,UCYZ,HC,ETA,PLGNOF,
000010      2FK,JK,LM,HX1,HX2,JKDAMP,LMDAMP,VISJK,VISLM
000011      COMMON/L3B/AX,AY,AZ,WDX,WDY,WDZ,ACX,ACY,ACZ,WDCX,WDCY,WDCZ,
000012      1ASX,ASY,ASZ,WDSX,WDSY,WDSZ
000013      COMMON/L5A/DT,TMAX,IFRINT,TF,DTP,ISTOP,IRUNNO,ISERNO
000014      COMMON/L9A/IREAL
000015      COMMON/L12/QRX(1),QRY,QRZ,QVX,QVY,QVZ,QWX,QWY,QWZ,
000016      1GRX,GRY,GRZ,QVCX,QVCY,QVCZ,QWCX,QWCY,QWCZ,
000017      2GRSX,GRSY,GRSZ,QVSY,QVSY,QVSY,QWSX,QWSY,QWSZ,
000018      3QPSI,QHTA,QPHI,QPSIC,QHTAC,QPHIC,QPSIS,QHTAS,QPHIS,QSLDEL,QSVEL
000019      4,TIME,DUM5(961)
000020      C
000021      COMMON/L18/SLRHU,SOILE,SLPHI,CKPHIC,NAA,AA(9),EB(9),TESOIL
000022      COMMON/M1/FORJK(6),SLJK(6),CHJK(6),CHJK(6),SRJK(6),SRJK(6),
000023      1SDJK(6),VELJK(6),FORLM(8),SLLM(8),CHLMT(8),CHLM(8),SRLMT(8),
000024      2SRLM(8),SDLM(8),VELLM(8),DMAX(10,50),DELMAX(12,55),SACC,SVEL,
000025      3SLEEL,PKNEE(10,50)
000026      C
000027      C      SET UP INITIAL CONDITIONS OF HEAT SHIELD SHOCK STRUT FORCES
000028      C
000029      C      VELOCITIES ARE THOSE FROM END OF PREVIOUS TIME INTERVAL
000030      C
000031      C
000032      C
000033      C
000034      30 IREAL=1
000035      60 CALL ACCEL
000036      C
000037      IF(ABS(COS(QHTA))-.01E-32)61,61,51
000038      C
000039      51 QPHI=QPHI+(QWX+SIN(QHTA)/COS(QHTA))*(QWY*SIN(QPHI)+QWZ*COS(QPHI))
000040      1)*DT
000041      QHTA=QHTA+(QWY*COS(QPHI)-QWZ*SIN(QPHI))*DT
000042      QPSI=QPSI+DT*(QWZ+COS(QPHI)+QWY*SIN(QPHI))/COS(QHTA)
000043      GO TO 70
000044      C
000045      61 QPHI=QPHI+DT*SQRT(QWY*QWY+QWZ*QWZ)
000046      QHTA=QHTA+QWX*DT
000047      QPSI=QPSI
000048      C
000049      70 IF(ABS(COS(QHTAC))-.01E-32)90,90,80
000050      C
000051      80 QPHIC=QPHIC+(QWCX+SIN(QHTAC)/COS(QHTAC))*(QWCY*SIN(QPHIC)+
000052      1 QWCZ*COS(QPHIC))*DT
000053      QHTAC=QHTAC+(QWCY*COS(QPHIC)-QWCZ*SIN(QPHIC))*DT
000054      QPSIC=QPSIC+DT*(QWCZ+COS(QPHIC)+QWCY*SIN(QPHIC))/COS(QHTAC)
000055      GO TO 100
000056      C
000057      90 QPHIC=QPHIC+DT*SQRT(QWCY*QWCY+QWCZ*QWCZ)
000058      QHTAC=QHTAC+QWCX*DT
000059      QPSIC=QPSIC
000060      C
000061      100 IF(ABS(COS(QHTAS))-.01E-32)120,120,110
000062      C
000063      110 QPHIS=QPHIS+(QWSX+SIN(QHTAS)/COS(QHTAS))*(QWSY*SIN(QPHIS)+
000064      1 QWSZ*COS(QPHIS))*DT
000065      QHTAS=QHTAS+(QWSY*COS(QPHIS)-QWSZ*SIN(QPHIS))*DT
000066      QPSIS=QPSIS+DT*(QWSZ+COS(QPHIS)+QWSY*SIN(QPHIS))/COS(QHTAS)
000067      GO TO 130
000068      C
000069      120 QPHIS=QPHIS+DT*SQRT(QWSY*QWSY+QWSZ*QWSZ)
000070      QHTAS=QHTAS+QWSX*DT
000071      QPSIS=QPSIS
000072      C
000073      130 CONTINUE

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000074      C      DETERMINE NEW LINEAR VELOCITY AND DISPLACEMENT OF MASS CENTERS
000075      C
000076      GRX=LRX+DT*QVX+DT*DT*AX/2.0
000077      GRY=LCRY+DT*QVY+DT*DT*AY/2.0
000078      GRZ=LRZ+DT*QVZ+DT*DT*AZ/2.0
000079      C
000080      GVX =QVX  +AX*DT
000081      GUY =QVY  +AY*DT
000082      GVZ =QVZ  +AZ*DT
000083      C
000084      GRCX=GRCX+DT*QVCX+DT*DT*ACX/2.0
000085      GRCY=GRCY+DT*QVCY+DT*DT*ACY/2.0
000086      GRCZ=GRCZ+DT*QVCZ+DT*DT*ACZ/2.0
000087      C
000088      GVCX =QVCX  +ACX*DT
000089      GVCY =QVCY  +ACY*DT
000090      GVCZ =QVCZ  +ACZ*DT
000091      C
000092      C
000093      GRSX=GRSX+DT*QVSX+DT*DT*ASX/2.0
000094      GRSY=GRSY+DT*QVSY+DT*DT*ASY/2.0
000095      GRSZ=GRSZ+DT*QVSZ+DT*DT*ASZ/2.0
000096      C
000097      C
000098      GVSX =QVSX  +ASX*DT
000099      GVSY =QVSY  +ASY*DT
000100      GVSZ =QVSZ  +ASZ*DT
000101      C
000102      C      DETERMINE NEW ANGULAR VELOCITY AND DISPLACEMENT OF CAPSULE, COUCH
000103      C      AND HEAT SHIELD
000104      C
000105      GWX=GWX+WDX *DT
000106      GWY=GWY+WDY *DT
000107      GWZ=GWZ+WDX *DT
000108      C
000109      GWCX=GWCX+WDCX*DT
000110      GWCY=GWCY+WDCY*DT
000111      GWCZ=GW CZ+WDCZ*DT
000112      C
000113      GWSX=GWSX+WDSX*DT
000114      GWSY=GWSY+WDSY*DT
000115      GWSZ=GWSZ+WDSZ*DT
000116      C
000117      IF (IS+150,150,140
000118      C
000119      C      DETERMINE NEW VELOCITY AND DISPLACEMENT OF SOIL IN CONTACT
000120      C      WITH HEAT SHIELD
000121      C
000122      140 SLEEL=SLDEL+SVEL*DT+SACC*DT*DT/2.0
000123      SVEL=SVEL+SACC*DT
000124      C
000125      C
000126      150 RETURN
000127      ENL

```

SUBROUTINE (16)

SAME AS APOLLO WITH $250^* \Delta t$ OUTPUT LIMIT.

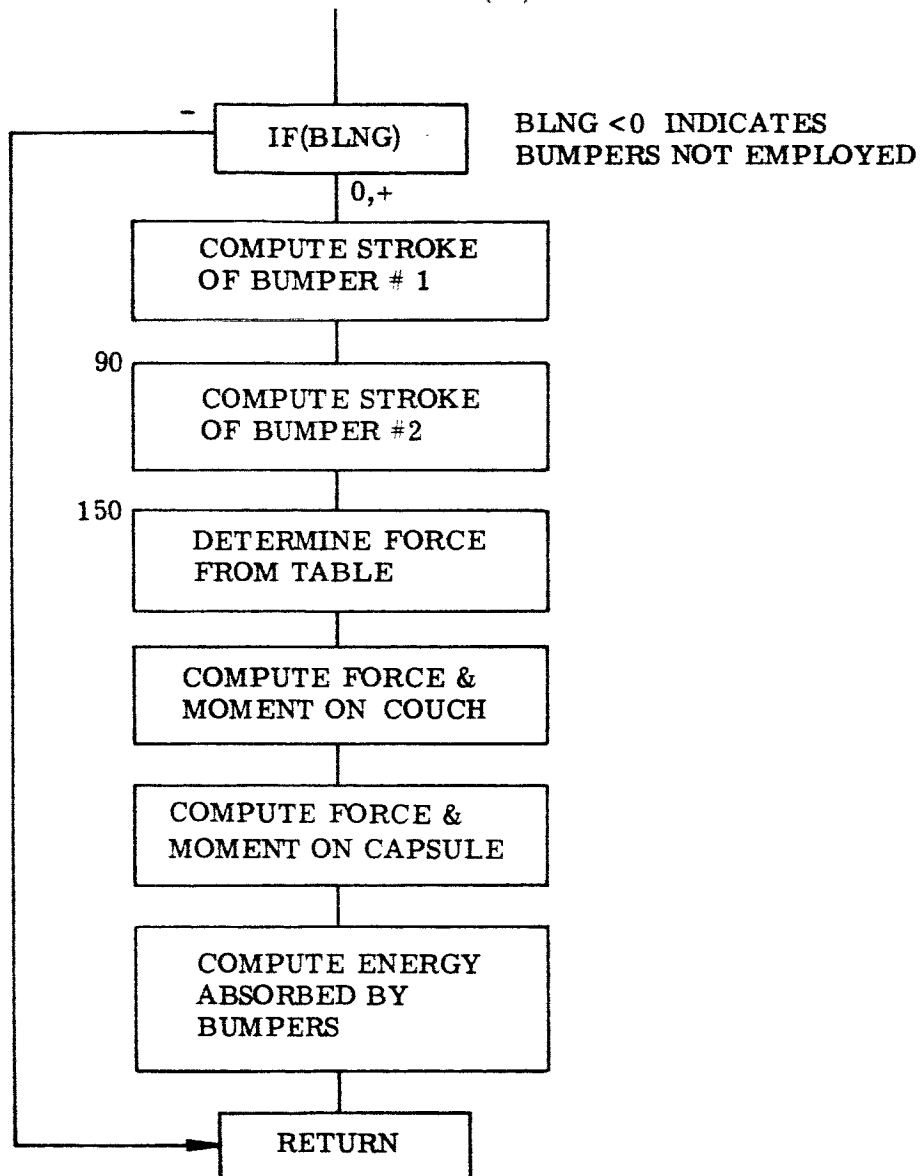
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000001      C
000002      C
000003      C
000004      C
000005      C      THIS PROGRAM DESCRIBES THE MOTION OF THE APOLLO COMMAND MODULE ,
000006      C      ASTRONAUTS COUCH SYSTEM AND PROTECTIVE HEAT SHIELD DURING A
000007      C      LANDING ON SOIL
000008      C
000009      C
000010      C
000011      C
000012      C
000013      C      COMMON/L1A/RX0(1),RYC,RZC,RXVELO,RYVELO,RZVELO,PSIC,THTAQ,PHIC,
000014      C      1WXC,1WY0,1WZ0,RCX0,RCYC,RCZ0,CXVELO,CYVELO,CZVELO,DUM1(6),RSX0,
000015      C      2RSY0,RSZ0, SXVELO,SYVELO,SZVELO
000016      C
000017      C      COMMON/L1B/XL10(6),YL10(6),ZL10(6),XM20(6),YM20(6),ZM20(6),
000018      C      1XJ30(6),1YJ30(6),1ZJ30(6),XK10(6),YK10(6),ZK10(6),FPX0,FPY0,FPZ0,
000019      C      2PXVELO,PYVELO,PZVELO,CHLM0,CHJUK0,CTLM0,CTJUK0
000020      C
000021      C      COMMON/L2/HEATA,HEATE,HSCG2,1P,IS,IT,UXX,UYX,UZZ,UCXX,UCYY,UCZZ,
000022      C      1USXX,USYY,USZZ,FCUK,FCUM,UXY,UYZ,UXZ,UCXY,UCXZ,UCYZ,HC,ETA,PLGNOF,
000023      C      2PK,JK,LM,HSX1,HCX1,JNDAMP,LMDAMP,VISUK,VISLM
000024      C
000025      C
000026      C      COMMON/L3B/AX,AY,AZ,NDX,NLY,NDZ,ACX,ACY,ACZ,WDCX,WDCY,WDCZ,
000027      C      1ASX,ASY,ASZ,NDAX,NDAY,NDZ
000028      C
000029      C
000030      C      COMMON/L5A/DT,TMAX,IFRINT,TF,DTP,ISTOP,IRUNNO,ISERNO
000031      C
000032      C      COMMON/L5B/OLCMAX(6),OLCMIN(6),OLSMAX(6),OLSMIN(6),JC,JS,OLCB(6),
000033      C      1OLCL(6),OLSB(6),OLSL(6),OMACX(6),OMACY(6),OMACZ(6),OMAX(6),
000034      C      2OMAY(6),OMAZ(6),ODEL(10),ENGKE,OECS,ENGPE,OESS,OESGND,OES0IL,
000035      C      3OFFACT,OEGND,ENGKEF,NORING(10),ENGTOT,AX1,AY1,AZ1,ACX3,ACY3,ACZ3,
000036      C      4ASX2,ASY2,ASZ2,LI
000037      C
000038      C      COMMON/L5C/ZETA,CAPM,CCHM,HSDM
000039      C
000040      C      COMMON/L5D/IC,ISS,OFCHMAX(6),OFCHMIN(6),OFCHMAX(6),OFCHMIN(6),TSSG(6),
000041      C      1TCSG(6),TOTSCR(6),TOTCCR(6)
000042      C
000043      C
000044      C      COMMON/L6B/XL1(6),YL1(6),ZL1(6),XM2(6),YM2(6),ZM2(6),XJ3(6),
000045      C      1YJ3(6),ZJ3(6),XK1(6),YK1(6),ZK1(6),CXX,CXY,CXZ,CYX,CYY,CYZ,
000046      C      2CZX,CZY,CZZ,CCXX,CCXY,CCXZ,CCYX,CCYY,CCYZ,CCZX,CCZY,CCZZ
000047      C
000048      C      COMMON/L7A/QSX(6),QSY(6),QSZ(6),QKT,FSGX,FSGY,FSGZ,TSGX,TSGY,TSGZ,
000049      C      1AREA,AREAM
000050      C
000051      C      COMMON/L7B/QX(6),QY(6),QZ(6),QSQP(6),QSHT,QFC(6),QCH(6),QSH,
000052      C      1QSF(6),QFF,QVIS,QDAMP,QFX,QFY,QFZ,QTX1,QTY1,QTZ1,JKLM,CTSX2,
000053      C      2GTSY2,GTSZ2,GTCA3,GTCTY3,GTCTZ3,N,FORP(6),FHCG(6),SO(6),CCHT(6),
000054      C      3GSRF(6),QSD(6),SG(6),QRGX,CRGY,QRGZ,QVEX,QVGY,QVGZ,QWGX,QWGY,QWGZ
000055      C
000056      C      COMMON/L1ST8/D11,D12,D13,D21,D22,D23,D31,D32,D33,DS11,DS12,DS13,
000057      C      1DS21,DS22,DS23,DS31,DS32,DS33,DC11,DC12,DC13,DC21,DC22,DC23,
000058      C      2DC31,DC32,DC33
000059      C
000060      C      COMMON/L9A/IREAL
000061      C
000062      C      COMMON/L9B/SHCJUK,SHCJUKT,SHCLM,SHCLMT,CTJUK,CTLM,XORIG
000063      C
000064      C      COMMON/L10/EX(10),EY(10,50),EZ(10,50),NI(10),A(10),CHS,Q,K,
000065      C      1RHC(10),DEFL(10,50,6),FORCE(10,50,6),GNDMU,AEL
000066      C
000067      C      COMMON/L11/AA1(3,6),AA3(3,6),CAP(3,6),CCH(3,6),IACCEL
000068      C      COMMON/L12/T(1000),SFAC,NN,KA1,A2,A3,A4,A5,A7,MAP
000069      C
000070      C      COMMON/M1/FORJUK(6),SLJUK(6),CHJUK(6),CHJUK(6),SRJUK(6),SRJUK(6),
000071      C      1SDJUK(6),VELJUK(6),FORLM(6),SLLM(6),CHLMT(6),CHLM(6),SRLMT(6),
000072      C      2SKLM(6),SDLM(6),VELLM(6),LMAX(10,50),DELMAX(12,55),SACC,SVEL,
000073      C      3SLEL,PKNEE(10,50)

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000074		EQUIVALENCE(TIME,T(39))
000075	C	
000076	C	
000077		5 IPRINT=0
000078		IOUT=0
000079	C	
000080		CALL INPUT
000081	C	
000082		CALL INIT
000083	C	
000084		MAF=1
000085		NN=30
000086	C	
000087		30 CALL MASTER
000088	C	
000089		IF(IPRINT .GT. 0) GO TO 60
000090	C	
000091		IPRINT=0
000092	C	
000093		IF(TIME .GT. TMAX) GO TO 70
000094	C	
000095		CALL OUTPUT
000096	C	
000097		IOUT=IOUT+1
000098		IF(IOUT-250)30,30,70
000099	C	
000100		70 IPRINT=1
000101		ISTOP=1
000102		80 CALL OUTPUT
000103		IRLNNO=IRUNNO+1
000104		GO TO 5
000105		END

SUBROUTINE BUMPER (17)



ELT BUMPER,1:660429: 37135

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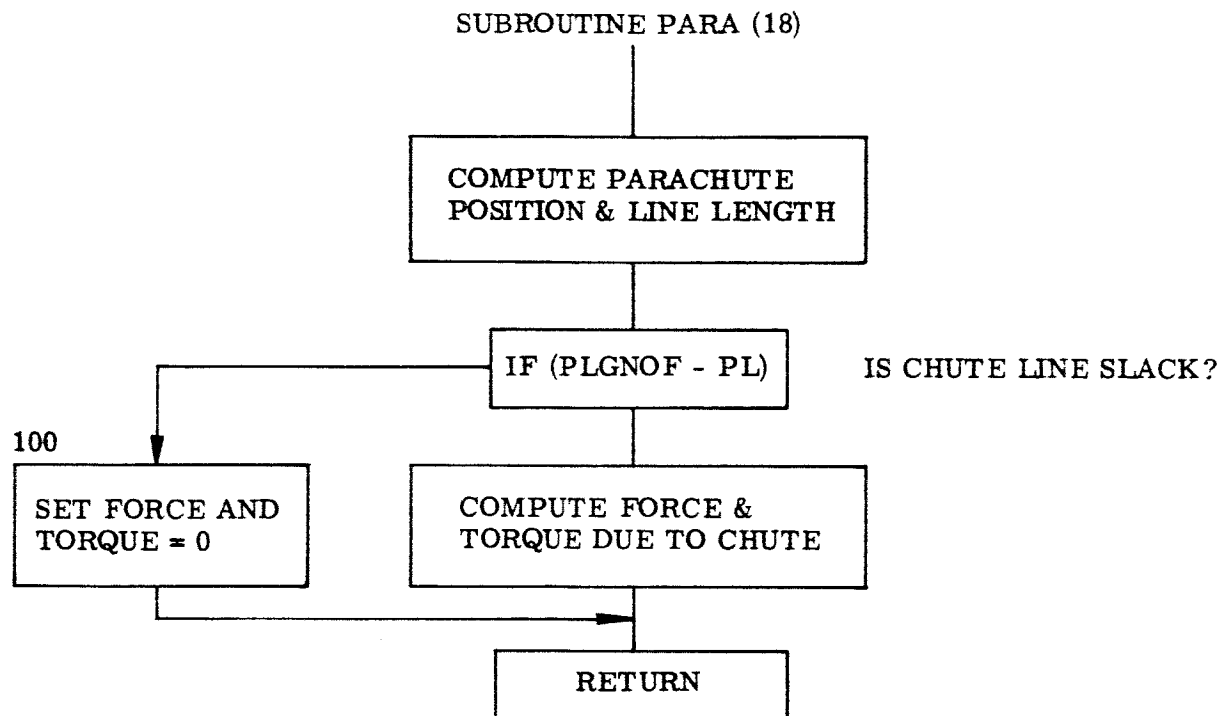
000001      SUBROUTINE BUMPER
000002      C
000003      C      THIS SUBROUTINE COMPUTES THE COUCH Y-Y BUMPER STROKE AND FORCES
000004      C
000005      COMMON/LISTB/D11,D12,D13,L21,D22,D23,D31,D32,D33,DS11,DS12,DS13,
000006      1LS21,DS22,DS23,LS31,LS32,LS33,DC11,DC12,DC13,DC21,DC22,DC23,
000007      2LC31,DC32,DC33
000008      COMMON/L9A/IREAL
000009      COMMON/L12/GRX(1),GRY,GRZ,QVX,QVY,QVZ,QWX,QWY,QWZ,
000010      1GRX,GRY,GRZ,QVX,QVY,QVZ,QWX,QWY,QWZ,
000011      2GRX,GRY,GRZ,QVX,QVY,QVZ,QWX,QWY,QWZ,
000012      3GPSI,GTHTA,QPHI,GPSIC,GTHTAC,QPHIC,QPSIS,QTHTAS,QPHIS,CSLDEL,GSVEL
000013      4,TIME,DUM5(961),DT
000014      COMMON/L20/XB13,YB13,ZB13,XB23,YB23,ZB23,YRP1,YRP2,BLNG,BST1MX,
000015      1BST2MX,BMPNRG,BUEF(6),BFCK(6),FBX,FBY,FBZ,TBX,TBY,TBZ,TBCX,TBCY,
000016      2TBCZ,BRNRG
000017      IF(BLNG.EQ.0) GO TO 300
000018      FBX=0.0
000019      FBY=0.0
000020      FBZ=0.0
000021      TBX=0.0
000022      TBY=0.0
000023      TBZ=0.0
000024      FBCX=0.0
000025      FBCY=0.0
000026      FBCZ=0.0
000027      TBCX=0.0
000028      TBCY=0.0
000029      TBCZ=0.0
000030      C
000031      C      STROKE OF BUMPER NO. 1
000032      C
000033      XB1=GRX+DC11*XB13+DC12*YB13+DC13*ZB13
000034      YB1=GRY+DC21*XB13+DC22*YB13+DC23*ZB13
000035      ZB1=GRZ+DC31*XB13+DC32*YB13+DC33*ZB13
000036      C
000037      C1=-(D12*(GRX+D12*YRP1)+D22*(GRY+D22*YRP1)+D32*(GRZ+D32*YRP1)
000038      1-D12*XB1-D22*YB1-D32*ZB1)/(D12*DC12+D22*DC22+D32*DC32)
000039      C
000040      IF(C1)90,300,40
000041      C
000042      40 BST1=C1
000043      DEF=BST1-BST1MX
000044      IF(DEF)80,50,50
000045      50 NST=1
000046      IF(IREAL)70,70,60
000047      60 BST1MX=BST1
000048      70 DEF=BST1
000049      GO TO 160
000050      C
000051      80 NST=1
000052      GO TO 150
000053      C
000054      C      STROKE OF BUMPER NO. 2
000055      C
000056      90 XB2=GRX+DC11*XB23+DC12*YB23+DC13*ZB23
000057      YB2=GRY+DC21*XB23+DC22*YB23+DC23*ZB23
000058      ZB2=GRZ+DC31*XB23+DC32*YB23+DC33*ZB23
000059      C
000060      C2=(D12*(GRX+D12*YRP2)+D22*(GRY+D22*YRP2)+D32*(GRZ+D32*YRP2)
000061      1-D12*XB2-D22*YB2-D32*ZB2)/(D12*DC12+D22*DC22+D32*DC32)
000062      C
000063      IF(C2)300,300,100
000064      C
000065      100 BST2=C2
000066      DEF=BST2-BST2MX
000067      IF(DEF)140,110,110
000068      110 NST=2
000069      IF(IREAL)130,130,120
000070      120 BST2MX=BST2
000071      130 DEF=BST2
000072      GO TO 160
000073      C

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000074      140 NST=2
000075      GO TO 150
000076      C
000077      150 IF(BDEF(1)+DEF)300,300,155
000078      155 F=(BDEF(1)+DEF)*BFOR(1)/EDEF(1)
000079      GO TO 210
000080      160 I=2
000081      165 IF(DEF-BDEF(I))170,160,190
000082      170 F=(BFOR(I)-BFOR(I-1))*(DEF-BDEF(I-1))/(BDEF(I)-BDEF(I-1))+BFOR(I-1)
000083      1)
000084      IF(IREAL)210,210,250
000085      180 F=EFOR(I)
000086      IF(IREAL)210,210,250
000087      190 I=I+1
000088      IF(I-6)165,165,200
000089      200 F=EFOR(6)+(DEF-BDEF(6))*EFOR(1)/BDEF(1)
000090      GO TO 210
000091      210 IF(NST-1)220,220,240
000092      C      FORCE AND MOMENT ON CAPSULE
000093      220 FBX=L12*F
000094      FBY=L22*F
000095      FBZ=L32*F
000096      C
000097      KBX=C1*DC12+XB1
000098      KBY=C1*DC22+YB1
000099      KBZ=C1*DC32+ZB1
000100      C
000101      230 TFX=FBZ*(GRY-RBY)-FBY*(GRZ-RBZ)
000102      TFY=FBX*(GRZ-RBZ)-FBZ*(GRX-RBX)
000103      TFZ=FBY*(GRX-RBX)-FBX*(GRY-RBY)
000104      C
000105      TBX=-(D11*TFX+D21*TFY+D31*TFZ)
000106      TBY=-(D12*TFX+D22*TFY+D32*TFZ)
000107      TBZ=-(D13*TFX+D23*TFY+D33*TFZ)
000108      C
000109      C      FORCE AND MOMENT ON COUCH
000110      FBCX=-FBX
000111      FBCY=-FBY
000112      FBCZ=-FBZ
000113      C
000114      TFCX=FBCZ*(GRY-RBY)-FBCY*(GRZ-RBZ)
000115      TFCY=FBCX*(GRZ-RBZ)-FBCZ*(GRX-RBX)
000116      TFCZ=FBCY*(GRX-RBX)-FBCX*(GRY-RBY)
000117      C
000118      TBCX=-(DC11*TFCX+DC21*TFY+DC31*TFCZ)
000119      TBCY=-(DC12*TFCX+DC22*TFY+DC32*TFCZ)
000120      TBCZ=-(DC13*TFCX+DC23*TFY+DC33*TFCZ)
000121      GO TO 300
000122      C      FORCE AND MOMENT ON CAPSULE
000123      C
000124      240 FBX=-D12*F
000125      FBY=-D22*F
000126      FBZ=-D32*F
000127      C
000128      KBX=C2*DC12+XB2
000129      KBY=C2*DC22+YB2
000130      KBZ=C2*DC32+ZB2
000131      GO TO 230
000132      250 BMFNKG=BMFPNRG+F*DEF
000133      GO TO 210
000134      C
000135      300 RETURN
000136      END

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ELT PARA,1,660328, 30265

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000001      SUBROUTINE PARA
000002      C
000003      C      THIS SUBROUTINE COMPUTES THE PARACHUTE FORCES APPLIED TO THE
000004      C      CAPSULE
000005      C
000006      COMMON/L2/HEATA,HEATE,HSCG2,IP,IS,IT,UXX,UYX,UZZ,UCXX,UCYY,UCZZ,
000007      1USXX,USYY,USZZ,FCJX,FCLM,UXY,UYZ,UXZ,UCXY,UCXZ,UCYZ,HC,ETA,PLGNOF,
000008      2PK,JK,LM,HSX1,HCX1,JKDAMP,LIDAMP,VISUK,VISLM
000009      COMMON/LISTB/D11,D12,D13,D21,D22,D23,D31,D32,D33,DS11,DS12,DS13,
000010      1DS21,DS22,DS23,DS31,DS32,DS33,DC11,DC12,DC13,DC21,DC22,DC23,
000011      2LC31,DC32,DC33
000012      COMMON/L9A/IREAL
000013      COMMON/L12/QRX(1),CRY,GRZ,GVX,GVY,QVZ,CWX,CWY,CWZ,
000014      1GRCX,GRCY,QRZ,GVCX,GVCY,GVCZ,QWCX,QWCY,QWCZ,
000015      2GRSX,GRSY,QRSZ,GVSX,GVSY,GVSZ,QWSX,QWSY,QWSZ,
000016      3GPSI,GTHTA,QPHI,QPSIC,QTHTAC,QPHIC,QPSIS,QTHTAS,QPHIS,QSLDEL,GSVEL
000017      4,TIME,DUM5(961),DT
000018      COMMON/L22/PXVEL,PYVEL,PZVEL,APX1,APY1,APZ1,RPX,RPY,RPZ,FPPX,FPPY,
000019      1FPFZ,TPPX1,TPPY1,TPPZ1,APX10,APY10,APZ10,PHITE,IPARA,XCG1,YCG1,
000020      2ZCG1
000021      APX=GRX+D11*APX1+D12*APY1+D13*APZ1
000022      APY=GRY+D21*APX1+D22*APY1+D23*APZ1
000023      APZ=GRZ+D31*APX1+D32*APY1+D33*APZ1
000024      RPX=RPX
000025      RPY=RPY
000026      RPZ=RPZ
000027      C
000028      RPX=RPX+PXVEL*DT
000029      RPY=RPY+PYVEL*DT
000030      RPZ=RPZ+PZVEL*DT
000031      FL=SGHT*((APX-RPX)**2+(APY-RPY)**2+(APZ-RPZ)**2)
000032      VFX=(APX-RPX)/PL
000033      VFY=(APY-RPY)/PL
000034      VPZ=(APZ-RPZ)/PL
000035      C
000036      IF (PLGNOF .GT. PL) GO TO 100
000037      FOF=PK*(FL-PLGNOF)
000038      FPFX=VFX*FOR
000039      FPFY=VFY*FOR
000040      FPFZ=VPZ*FOR
000041      C
000042      FPFX1=D11*FPPX+D21*FPFY+D31*FPPZ
000043      FPFY1=D12*FPPX+D22*FPFY+D32*FPPZ
000044      FPFZ1=D13*FPPX+D23*FPFY+D33*FPPZ
000045      TPFX1=FPPZ1*APY1-FPPY1*APZ1
000046      TPFY1=FPPX1*APZ1-FPPZ1*APX1
000047      TPFZ1=FPPY1*APX1-FPPX1*APY1
000048      GO TO 125
000049      C
000050      C
000051      C
000052      100 FPFX=0.0
000053      FPFY=0.0
000054      FPFZ=0.0
000055      TPFX1=0.0
000056      TPFY1=0.0
000057      TPFZ1=0.0
000058      125 IF (IREAL .GT. 0) GO TO 150
000059      C
000060      RPX=RPX0
000061      RPY=RPY0
000062      RPZ=RPZ0
000063      C
000064      150 CONTINUE
000065      C
000066      C
000067      RETURN
000068      END

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NR	ALTA	FLTY	ALTZ	FLRG	NRZ(1)	NRZ(2)	NRZ(3)	NRZ(4)	NRZ(5)	NRZ(6)	NRZ(7)	NRZ(8)	NRZ(9)	NRZ(10)	NRZ(11)	NRZ(12)	NRZ(13)	NRZ(14)	NRZ(15)	NRZ(16)	NRZ(17)	NRZ(18)	NRZ(19)	NRZ(20)	NRZ(21)	NRZ(22)	NRZ(23)	NRZ(24)	NRZ(25)	NRZ(26)	NRZ(27)	NRZ(28)	NRZ(29)	NRZ(30)	NRZ(31)	NRZ(32)	NRZ(33)	NRZ(34)	NRZ(35)	NRZ(36)	NRZ(37)	NRZ(38)	NRZ(39)	NRZ(40)	NRZ(41)	NRZ(42)	NRZ(43)	NRZ(44)	NRZ(45)	NRZ(46)	NRZ(47)	NRZ(48)	NRZ(49)	NRZ(50)	NRZ(51)	NRZ(52)	NRZ(53)	NRZ(54)	NRZ(55)	NRZ(56)	NRZ(57)	NRZ(58)	NRZ(59)	NRZ(60)	NRZ(61)	NRZ(62)	NRZ(63)	NRZ(64)	NRZ(65)	NRZ(66)	NRZ(67)	NRZ(68)	NRZ(69)	NRZ(70)	NRZ(71)	NRZ(72)	NRZ(73)	NRZ(74)	NRZ(75)	NRZ(76)	NRZ(77)	NRZ(78)	NRZ(79)	NRZ(80)	NRZ(81)	NRZ(82)	NRZ(83)	NRZ(84)	NRZ(85)	NRZ(86)	NRZ(87)	NRZ(88)	NRZ(89)	NRZ(90)	NRZ(91)	NRZ(92)	NRZ(93)	NRZ(94)	NRZ(95)	NRZ(96)	NRZ(97)	NRZ(98)	NRZ(99)	NRZ(100)	NRZ(101)	NRZ(102)	NRZ(103)	NRZ(104)	NRZ(105)	NRZ(106)	NRZ(107)	NRZ(108)	NRZ(109)	NRZ(110)	NRZ(111)	NRZ(112)	NRZ(113)	NRZ(114)	NRZ(115)	NRZ(116)	NRZ(117)	NRZ(118)	NRZ(119)	NRZ(120)	NRZ(121)	NRZ(122)	NRZ(123)	NRZ(124)	NRZ(125)	NRZ(126)	NRZ(127)	NRZ(128)	NRZ(129)	NRZ(130)	NRZ(131)	NRZ(132)	NRZ(133)	NRZ(134)	NRZ(135)	NRZ(136)	NRZ(137)	NRZ(138)	NRZ(139)	NRZ(140)	NRZ(141)	NRZ(142)	NRZ(143)	NRZ(144)	NRZ(145)	NRZ(146)	NRZ(147)	NRZ(148)	NRZ(149)	NRZ(150)	NRZ(151)	NRZ(152)	NRZ(153)	NRZ(154)	NRZ(155)	NRZ(156)	NRZ(157)	NRZ(158)	NRZ(159)	NRZ(160)	NRZ(161)	NRZ(162)	NRZ(163)	NRZ(164)	NRZ(165)	NRZ(166)	NRZ(167)	NRZ(168)	NRZ(169)	NRZ(170)	NRZ(171)	NRZ(172)	NRZ(173)	NRZ(174)	NRZ(175)	NRZ(176)	NRZ(177)	NRZ(178)	NRZ(179)	NRZ(180)	NRZ(181)	NRZ(182)	NRZ(183)	NRZ(184)	NRZ(185)	NRZ(186)	NRZ(187)	NRZ(188)	NRZ(189)	NRZ(190)	NRZ(191)	NRZ(192)	NRZ(193)	NRZ(194)	NRZ(195)	NRZ(196)	NRZ(197)	NRZ(198)	NRZ(199)	NRZ(200)	NRZ(201)	NRZ(202)	NRZ(203)	NRZ(204)	NRZ(205)	NRZ(206)	NRZ(207)	NRZ(208)	NRZ(209)	NRZ(210)	NRZ(211)	NRZ(212)	NRZ(213)	NRZ(214)	NRZ(215)	NRZ(216)	NRZ(217)	NRZ(218)	NRZ(219)	NRZ(220)	NRZ(221)	NRZ(222)	NRZ(223)	NRZ(224)	NRZ(225)	NRZ(226)	NRZ(227)	NRZ(228)	NRZ(229)	NRZ(230)	NRZ(231)	NRZ(232)	NRZ(233)	NRZ(234)	NRZ(235)	NRZ(236)	NRZ(237)	NRZ(238)	NRZ(239)	NRZ(240)	NRZ(241)	NRZ(242)	NRZ(243)	NRZ(244)	NRZ(245)	NRZ(246)	NRZ(247)	NRZ(248)	NRZ(249)	NRZ(250)	NRZ(251)	NRZ(252)	NRZ(253)	NRZ(254)	NRZ(255)	NRZ(256)	NRZ(257)	NRZ(258)	NRZ(259)	NRZ(260)	NRZ(261)	NRZ(262)	NRZ(263)	NRZ(264)	NRZ(265)	NRZ(266)	NRZ(267)	NRZ(268)	NRZ(269)	NRZ(270)	NRZ(271)	NRZ(272)	NRZ(273)	NRZ(274)	NRZ(275)	NRZ(276)	NRZ(277)	NRZ(278)	NRZ(279)	NRZ(280)	NRZ(281)	NRZ(282)	NRZ(283)	NRZ(284)	NRZ(285)	NRZ(286)	NRZ(287)	NRZ(288)	NRZ(289)	NRZ(290)	NRZ(291)	NRZ(292)	NRZ(293)	NRZ(294)	NRZ(295)	NRZ(296)	NRZ(297)	NRZ(298)	NRZ(299)	NRZ(300)	NRZ(301)	NRZ(302)	NRZ(303)	NRZ(304)	NRZ(305)	NRZ(306)	NRZ(307)	NRZ(308)	NRZ(309)	NRZ(310)	NRZ(311)	NRZ(312)	NRZ(313)	NRZ(314)	NRZ(315)	NRZ(316)	NRZ(317)	NRZ(318)	NRZ(319)	NRZ(320)	NRZ(321)	NRZ(322)	NRZ(323)	NRZ(324)	NRZ(325)	NRZ(326)	NRZ(327)	NRZ(328)	NRZ(329)	NRZ(330)	NRZ(331)	NRZ(332)	NRZ(333)	NRZ(334)	NRZ(335)	NRZ(336)	NRZ(337)	NRZ(338)	NRZ(339)	NRZ(340)	NRZ(341)	NRZ(342)	NRZ(343)	NRZ(344)	NRZ(345)	NRZ(346)
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TABLEULATION OF PRESSURE VS. DEF. FOR ALL ELEMENTS ON THE CAPSULE SURFACE.

•10000-02	•16830+03	•20000-02	•33600+03	•30000-00	•10000+06
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[illegible]

4.00 FFLM(13)=	4.00 FFLM(31)=	4.00 FFLP(4)=	4.00 FFLM(5)=	4.00 FFLP(6)=	4.00 \$ 74
4.00 FFLM(17)=	4.00				\$ 75
4.00 FFLM(17)=	4.00 FFLM(1)=	4.00 FFLM(3)=	4.00 FFLM(5)=	4.00 FFLM(6)=	\$ 76
4.00 FFLM(17)=	4.00 FFLM(1)=	4.00 FFLM(3)=	4.00 FFLM(5)=	4.00 FFLM(6)=	\$ 77
4.00 FFLM(17)=	4.00 FFLM(1)=	4.00 FFLM(3)=	4.00 FFLM(5)=	4.00 FFLM(6)=	\$ 78
4.00 FFLM(17)=	4.00 FFLM(1)=	4.00 FFLM(3)=	4.00 FFLM(5)=	4.00 FFLM(6)=	\$ 79

[illegible]

9 25 .1000+00 .2000+00 .1100+00 .3000+05 .1200+00 .3500+05 .1300+00 .4000+05 .1400+00 .4500+05
 9 26 .1000+00 .2000+00 .1100+00 .3000+05 .1200+00 .3500+05 .1300+00 .4000+05 .1400+00 .4500+05
 9 27 .1000+00 .2000+00 .1100+00 .3000+05 .1200+00 .3500+05 .1300+00 .4000+05 .1400+00 .4500+05
 9 28 .1000+00 .2000+00 .1100+00 .3000+05 .1200+00 .3500+05 .1300+00 .4000+05 .1400+00 .4500+05
 9 29 .1000+00 .2000+00 .1100+00 .3000+05 .1200+00 .3500+05 .1300+00 .4000+05 .1400+00 .4500+05
 9 30 .1000+00 .2000+00 .1100+00 .3000+05 .1200+00 .3500+05 .1300+00 .4000+05 .1400+00 .4500+05
 9 31 .1000+00 .2000+00 .1100+00 .3000+05 .1200+00 .3500+05 .1300+00 .4000+05 .1400+00 .4500+05
 9 32 .1000+00 .2000+00 .1100+00 .3000+05 .1200+00 .3500+05 .1300+00 .4000+05 .1400+00 .4500+05
 9 33 .1000+00 .2000+00 .1100+00 .3000+05 .1200+00 .3500+05 .1300+00 .4000+05 .1400+00 .4500+05
 9 34 .1000+00 .2000+00 .1100+00 .3000+05 .1200+00 .3500+05 .1300+00 .4000+05 .1400+00 .4500+05
 9 35 .1000+00 .2000+00 .1100+00 .3000+05 .1200+00 .3500+05 .1300+00 .4000+05 .1400+00 .4500+05
 9 36 .1000+00 .2000+00 .1100+00 .3000+05 .1200+00 .3500+05 .1300+00 .4000+05 .1400+00 .4500+05
 9 37 .1000+00 .2000+00 .1100+00 .3000+05 .1200+00 .3500+05 .1300+00 .4000+05 .1400+00 .4500+05
 9 38 .1000+00 .2000+00 .1100+00 .3000+05 .1200+00 .3500+05 .1300+00 .4000+05 .1400+00 .4500+05
 9 39 .1000+00 .2000+00 .1100+00 .3000+05 .1200+00 .3500+05 .1300+00 .4000+05 .1400+00 .4500+05
 9 40 .1000+00 .2000+00 .1100+00 .3000+05 .1200+00 .3500+05 .1300+00 .4000+05 .1400+00 .4500+05
 9 41 .1000+00 .2000+00 .1100+00 .3000+05 .1200+00 .3500+05 .1300+00 .4000+05 .1400+00 .4500+05
 9 42 .1000+00 .2000+00 .1100+00 .3000+05 .1200+00 .3500+05 .1300+00 .4000+05 .1400+00 .4500+05
 9 43 .1000+00 .2000+00 .1100+00 .3000+05 .1200+00 .3500+05 .1300+00 .4000+05 .1400+00 .4500+05
 9 44 .1000+00 .2000+00 .1100+00 .3000+05 .1200+00 .3500+05 .1300+00 .4000+05 .1400+00 .4500+05
 9 45 .1000+00 .2000+00 .1100+00 .3000+05 .1200+00 .3500+05 .1300+00 .4000+05 .1400+00 .4500+05
 9 46 .1000+00 .2000+00 .1100+00 .3000+05 .1200+00 .3500+05 .1300+00 .4000+05 .1400+00 .4500+05
 9 47 .1000+00 .2000+00 .1100+00 .3000+05 .1200+00 .3500+05 .1300+00 .4000+05 .1400+00 .4500+05
 10 1 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000

THE FOLLOWING INPUT IS OF CARLS 104 - 115

ROCKET 1 TIME .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000
 ROCKET 1 FORCE .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000
 ROCKET 2 TIME .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000
 ROCKET 2 FORCE .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000
 ROCKET 3 TIME .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000
 ROCKET 3 FORCE .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000
 ROCKET 4 TIME .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000
 ROCKET 4 FORCE .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000
 YPIN = .5000 DEY = .1500 HY = .0000 DEL = .1500 MZ = .0000

THE FOLLOWING DATA ARE OF CARLS 121 - 136

FLUGH SURFACE INPUT INFORMATION

AT VALUES OF Y AND Z GREATER THAN THOSE TABULATED, REAL SURFACE IS A FT. ABOVE THEORETICAL SMOOTH SURFACE

Y	Z	X	Y	Z	Y	Z	X
.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
INITIAL CAPSULE C.G. LOCATION							
INITIAL COUP C.G. LOCATION							
INITIAL PEAT SHIELD C.G. LOCATION							
INITIAL CAPSULE VELOCITY							
INITIAL COUP VELOCITY							
INITIAL PEAT SHIELD VELOCITY							

INITIAL PARACHUTE C.G. LOCATION									
INITIAL PARACHUTE FORCE AND CORU LENGTH									
COUCH - CAPSULE STRUT NO.									
STRUT LENGTH									
	1	2	3	4	5	6	7	8	
	.64324	.64324	.64325	.64325	.64325	.64325	.64325	.64325	
SHIELD - CAPSULE STRUT NO.									
STRUT LENGTH									
	1	2	3	4	5	6	7	8	
	.62450	.62450	.62450	.62450	.62450	.62450	.62450	.62450	

[illegible]

.73242	.4464	-.51976	.51976	358884.67000	-7.90704
.00500	-.02135	-6.06234	608.30559	1470.23170	.50083
.04063	.01866	-.01866	.67240	1223.62100	297.06960
.73242	.2421	-.56043	.56043	387.43.32000	-6.97610
.00600	-.02292	-5.00652	1256.16850	2080.77840	.59515
.05054	.01621	.01921	.60335	1486.55450	215.18942
.73242	.23244	-.59515	.59515	41039.89000	-6.47205
.00700	-.03124	-3.62699	1475.54680	2657.81920	.62476
.06275	.02006	.02608	.92983	1404.55350	118.46585
.73242	.22533	-.62478	.62478	431397.83000	-5.89019
.00600	-.03413	-2.11087	1536.29800	3130.03620	.64910
.06815	.02139	.02139	1.04246	1576.19540	41.66752
.73242	.22393	-.64910	.64910	448186.48000	-4.81670
.00900	-.03548	-.59009	1491.71180	3429.67400	.66650
.07219	.02485	1.12856	1.12856	1749.51720	3.34512
.73242	.22242	-.66650	.66650	460202.35000	-3.15533
.01000	-.03558	.00600	1403.93470	3529.77690	.67518
.07426	.02396	.02396	1.17316	1882.55350	-0.00000
.73242	.21782	-.67516	.67516	466167.80000	-89056
.01100	-.03556	.00600	1421.38350	3513.37660	.67361
.07368	.02375	.02375	1.16504	1857.26760	-0.00000
.73242	.21620	-.67360	.67360	465111.83000	1.63712
.01200	-.03556	.00600	1561.47000	3368.86570	.66165
.07105	.02346	.02346	1.10413	1664.74100	-0.00000
.73242	.21103	-.66164	.66167	456858.49000	3.96076
.01300	-.03558	.00600	1644.74150	3171.52660	.64024
.06615	.02346	.02346	1.00037	1326.05170	-0.00000
.73242	.22293	-.64024	.64026	442074.37000	5.71421
.01400	-.03556	.00600	2303.87640	2691.08150	.61146
.05952	.01504	.02346	.67153	863.14945	-0.00000
.73242	.22516	-.61145	.61151	422215.96000	6.60272
.01500	-.03558	.00600	2963.74600	2569.34100	.57691
.05330	.01161	.02346	.73954	397.46497	-0.00000
.73242	.23676	-.57867	.57895	395725.21000	6.44975
.01600	-.03558	.00600	3343.10380	2309.78590	.54697
.04726	.00780	.02346	.62375	224.44274	-0.00000
.73242	.24462	-.54691	.54703	377669.66000	5.57846
.01700	-.03558	.00600	3755.28830	2075.26800	.51863
.04225	.00453	.02346	.53173	76.35943	-0.00000
.73242	.24483	-.51855	.51871	358100.43000	4.36994
.01800	-.03558	.00600	4050.04740	1900.97410	.44650
.03856	.00406	.02346	.46653	11.32537	-0.00000
.73242	.25352	-.49639	.49660	342820.20000	2.96639
.01900	-.03558	.00600	4142.01920	1775.75600	.48241
.03631	.00651	.02346	.42792	2.82530	-0.00000
.73242	.25377	-.46246	.46255	333091.35000	1.53323
.02000	.00600	.00600	-4408.96740	-0.00000	.47227
.03474	.02430	.02430	.40152	1794.36620	-0.00000
.73242	.25734	-.47408	.47246	320094.18000	1.61017
.02100	.00600	.00600	-4463.66180	-0.00000	.45696
.03245	.02492	.02346	.26376	1623.78530	-0.00000
.73242	.25663	-.45673	.45723	315535.15000	2.27261
.02200	.00600	.00600	-4422.96530	-0.00000	.43727
.04912	.02119	.02346	.31870	1409.59170	-0.00000
.73242	.26246	-.43565	.43359	301926.65000	2.74224
.02300	.00600	.00600	-4307.33870	-0.00000	.41409
.04647	.01422	.02346	.27066	1105.83040	-0.00000
.73242	.26561	-.44134	.44150	265923.85000	2.95121

02400	00000	-4661.57420	-00000	38883
02326	00000	22209	510.22151	-00000
02344	00000	38934	268442.13000	2.97449
02500	00000	-3627.40190	-00000	36339
04025	00000	18292	603.51626	-00000
02244	00000	36401	450915.47000	-00000
04600	00000	3048.00290	-00000	34022
01770	00000	15011	457.65534	-00000
02742	00000	34098	234916.10000	2.14474
04700	00000	-3140.09400	-00000	32181
01551	00000	12709	399.08227	-00000
02244	00000	32276	222246.15000	1.45339
04800	00000	-3192.60010	-00000	31001
01464	00000	11355	362.52672	-00000
02342	00000	31113	214659.08000	7.1094
02900	00000	-3445.56130	-00000	30584
01425	00000	10456	349.86647	-00000
02342	00000	30719	211174.25000	-03805
03000	00000	-3194.52200	-00000	30939
01459	00000	11289	360.62828	-00000
02242	00000	31091	413629.41000	-70961
03100	00000	-3156.28740	-00000	31632
01545	00000	12294	386.03487	-00000
02244	00000	31980	219791.25000	-1.11587
03200	00000	-3104.61640	-00000	32928
01656	00000	13606	422.41442	-00000
02342	00000	33055	227358.79000	-1.17451
03300	00000	-3058.78130	-00000	33853
01752	00000	14782	452.16035	-00000
02342	00000	33947	233746.05000	-85322
03400	00000	-3068.76160	-00000	34306
01800	00000	15354	474.24725	-00000
02342	00000	34372	238679.20000	-24804
03500	00000	-3044.03890	-00000	34150
01783	00000	15180	462.07559	-00000
02342	00000	34204	235796.26000	40496
03600	00000	-3078.14180	-00000	33454
01710	00000	14271	439.27852	-00000
02342	00000	33519	230992.02000	85617
03700	00000	-3129.03450	-00000	34421
01604	00000	12990	406.48086	-00000
02342	00000	32510	223861.70000	1.05432
03800	00000	-3179.09700	-00000	31311
01454	00000	11701	371.98348	-00000
02342	00000	31421	216196.39000	95201
03900	00000	-3215.43430	-00000	30410
01406	00000	10716	344.63373	-00000
02342	00000	30529	205972.79000	61093
04000	00000	-3242.58770	-00000	29921
01363	00000	10176	330.63870	-00000
02342	00000	30034	204596.74000	28020
04100	00000	-3259.10850	-00000	29781
01350	00000	09157	325.65169	-00000
02342	00000	29883	208629.94000	-03043
04200	00000	-3266.36400	-00000	29607
01352	00000	10001	326.68134	-00000
02342	00000	29897	205613.94000	-00976
04300	00000	-3317.98890	-00000	29791

.01351	.1162	.02398	.09832	326.20946	-.00000
.73242	.7257	-.09709	.09873	205703.61000	.04132
.04400	.00000	.00000	-.3245.17670	-	.25525
.01326	.01045	.02396	.09810	316.33946	-.00000
.73242	.7362	-.09443	.09606	203861.00000	.34946
.04500	.00000	.00000	-.3262.72760	-	.28869
.01267	.01004	.02396	.09171	299.22763	-.00000
.73242	.7341	-.08764	.09054	199335.63000	.71999
.04600	.00000	.00000	-.3261.00490	-	.27819
.01176	.00236	.02396	.01217	269.2247	-.00000
.73242	.00236	-.02773	.02906	192087.26000	.92660
.04700	.00000	.00000	-.3261.17110	-	.28513
.01067	.00659	.02396	.07104	233.0846	-.00000
.73242	.0141	-.06441	.06604	183065.14000	1.08227
.04800	.00000	.00000	-.3241.99600	-	.25104
.00915	.00777	.02396	.06031	195.50983	-.01000
.73242	.08.53	-.02506	.02502	173337.89000	1.04934
.04900	.00000	.00000	-.3147.93830	-	.23737
.00853	.00701	.02396	.05096	160.48000	-.00000
.73242	.08.55	-.023632	.03841	163698.26000	.93152

CAPSULE ORIENTATION INFORMATION

TYPE	X AXIS		Y AXIS		Z AXIS		PSI AXIS		THETA AXIS		PHI AXIS	
	POS.	VEL.	POS.	VEL.	POS.	VEL.	POS.	VEL.	POS.	VEL.	POS.	VEL.
.000000	.146+01	-.120+04	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
.001000	.144+01	-.120+04	.122-16	.12-13	.978-16	.123-11	.000	.000	.000	.000	.000	.000
.002000	.143+01	-.120+04	.245-16	-.206-11	.708-14	.361-10	.000	.000	.000	.000	.000	.000
.003000	.142+01	-.119+04	.146-13	.155-10	.605-10	.963-10	.000	.000	.000	.000	.000	.000
.004000	.141+01	-.118+04	-.172-10	-.219-07	.397-08	-.398-04	.000	.000	.000	.000	.000	.000
.005000	.140+01	-.116+04	.438+09	.944+07	.495+07	.484+04	.000	.000	.000	.000	.000	.000
.006000	.139+01	-.116+04	.137+08	.110+04	.708+07	.993+04	.000	.000	.000	.000	.000	.000
.007000	.138+01	-.952+01	.322+08	.285+05	.180+07	-.212-03	.000	.000	.000	.000	.000	.000
.008000	.137+01	-.879+01	.131+07	.166+04	-.236+06	-.228-03	.000	.000	.000	.000	.000	.000
.009000	.136+01	-.811+01	.421+07	.420+04	-.564+06	-.454-03	.000	.000	.000	.000	.000	.000
.010000	.135+01	-.752+01	.107+06	.872+04	-.114+05	-.717-03	.000	.000	.000	.000	.000	.000
.011000	.134+01	-.696+01	.230+06	.163+03	-.202+05	-.108+04	.000	.000	.000	.000	.000	.000
.012000	.134+01	-.643+01	.449+06	.267+03	-.328+05	-.146-02	.000	.000	.000	.000	.000	.000
.013000	.133+01	-.592+01	.788+06	.416+03	-.496+05	-.193-02	.000	.000	.000	.000	.000	.000
.014000	.132+01	-.544+01	.131+05	.566+03	-.769+05	-.239-02	.000	.000	.000	.000	.000	.000
.015000	.132+01	-.499+01	.200+05	.800+03	-.966+05	-.286-02	.000	.000	.000	.000	.000	.000
.016000	.131+01	-.456+01	.295+05	.162+02	-.127+04	-.330-02	.000	.000	.000	.000	.000	.000
.017000	.131+01	-.415+01	.411+05	.127+02	-.162+04	-.378-02	.000	.000	.000	.000	.000	.000
.018000	.131+01	-.376+01	.563+05	.164+02	-.202+04	-.422-02	.000	.000	.000	.000	.000	.000
.019000	.130+01	-.339+01	.743+05	.201+02	-.247+04	-.476-02	.000	.000	.000	.000	.000	.000
.020000	.130+01	-.302+01	.944+05	.266+02	-.297+04	-.521-02	.000	.000	.000	.000	.000	.000
.021000	.130+01	-.267+01	.116+04	.235+02	-.352+04	-.571-02	.000	.000	.000	.000	.000	.000
.022000	.129+01	-.232+01	.141+04	.248+02	-.410+04	-.605+02	.000	.000	.000	.000	.000	.000
.023000	.129+01	-.199+01	.167+04	.279+02	-.474+04	-.661+02	.000	.000	.000	.000	.000	.000
.024000	.129+01	-.166+01	.196+04	.288+02	-.541+04	-.696+02	.000	.000	.000	.000	.000	.000
.025000	.129+01	-.135+01	.228+04	.311+02	-.615+04	-.757+02	.000	.000	.000	.000	.000	.000
.026000	.129+01	-.104+01	.261+04	.348+02	-.682+04	-.796+02	.000	.000	.000	.000	.000	.000
.027000	.129+01	-.735+00	.296+04	.357+02	-.775+04	-.863+02	.000	.000	.000	.000	.000	.000
.028000	.129+01	-.434+00	.333+04	.375+02	-.864+04	-.912+02	.000	.000	.000	.000	.000	.000
.029000	.129+01	-.135+00	.371+04	.364+02	-.959+04	-.988+02	.000	.000	.000	.000	.000	.000
.030000	.129+01	.123+00	.410+04	.350+02	-.105+03	-.798+02	.000	.000	.000	.000	.000	.000
.031000	.129+01	.303+00	.451+04	.441+02	-.112+03	-.519+02	.000	.000	.000	.000	.000	.000
.032000	.129+01	.375+00	.496+04	.454+02	-.115+03	-.258+02	.000	.000	.000	.000	.000	.000
.033000	.129+01	.349+00	.540+04	.427+02	-.117+03	-.118+02	.000	.000	.000	.000	.000	.000
.034000	.129+01	.194+00	.579+04	.326+02	-.118+03	-.134+02	.000	.000	.000	.000	.000	.000
.035000	.129+01	.462+00	.603+04	.134+02	-.120+03	-.269+02	.000	.000	.000	.000	.000	.000
.036000	.129+01	-.228+01	.602+04	-.145+02	-.124+03	.403+02	.000	.000	.000	.000	.000	.000
.037000	.129+01	.570+00	.579+04	-.295+02	-.128+03	-.290+02	.000	.000	.000	.000	.000	.000
.038000	.129+01	.147+00	.544+04	-.364+02	-.129+03	-.737+03	.000	.000	.000	.000	.000	.000
.039000	.129+01	.375+00	.503+04	-.373+02	-.129+03	.266+02	.000	.000	.000	.000	.000	.000
.040000	.129+01	.611+00	.473+04	-.249+02	-.126+03	.360+02	.000	.000	.000	.000	.000	.000
.041000	.129+01	.765+00	.459+04	-.470+03	-.123+03	.205+02	.000	.000	.000	.000	.000	.000
.042000	.129+01	.841+00	.463+04	.100+02	-.123+03	-.287+02	.000	.000	.000	.000	.000	.000
.043000	.129+01	.836+00	.477+04	.164+02	-.128+03	-.644+02	.000	.000	.000	.000	.000	.000
.044000	.129+01	.763+00	.493+04	.142+02	-.135+03	-.803+02	.000	.000	.000	.000	.000	.000
.045000	.129+01	.721+00	.500+04	-.564+04	-.143+03	-.644+02	.000	.000	.000	.000	.000	.000
.046000	.129+01	.705+00	.495+04	-.698+03	-.147+03	-.237+02	.000	.000	.000	.000	.000	.000
.047000	.129+01	.755+00	.480+04	-.243+02	-.146+03	-.206+02	.000	.000	.000	.000	.000	.000
.048000	.129+01	.840+00	.456+04	-.255+02	-.146+03	.206+02	.000	.000	.000	.000	.000	.000
.049000	.129+01	.923+00	.433+04	-.178+02	-.144+03	.970+03	.000	.000	.000	.000	.000	.000
.050000	.129+01	.923+00	.433+04	-.178+02	-.144+03	.970+03	.000	.000	.000	.000	.000	.000
.051000	.129+01	.923+00	.433+04	-.178+02	-.144+03	.970+03	.000	.000	.000	.000	.000	.000
.052000	.129+01	.923+00	.433+04	-.178+02	-.144+03	.970+03	.000	.000	.000	.000	.000	.000
.053000	.129+01	.923+00	.433+04	-.178+02	-.144+03	.970+03	.000	.000	.000	.000	.000	.000
.054000	.129+01	.923+00	.433+04	-.178+02	-.144+03	.970+03	.000	.000	.000	.000	.000	.000
.055000	.129+01	.923+00	.433+04	-.178+02	-.144+03	.970+03	.000	.000	.000	.000	.000	.000
.056000	.129+01	.923+00	.433+04	-.178+02	-.144+03	.970+03	.000	.000	.000	.000	.000	.000
.057000	.129+01	.923+00	.433+04	-.178+02	-.144+03	.970+03	.000	.000	.000	.000	.000	.000
.058000	.129+01	.923+00	.433+04	-.178+02	-.144+03	.970+03	.000	.000	.000	.000	.000	.000
.059000	.129+01	.923+00	.433+04	-.178+02	-.144+03	.970+03	.000	.000	.000	.000	.000	.000
.060000	.129+01	.923+00	.433+04	-.178+02	-.144+03	.970+03	.000	.000	.000	.000	.000	.000
.061000	.129+01	.923+00	.433+04	-.178+02	-.144+03	.970+03	.000	.000	.000	.000	.000	.000
.062000	.129+01	.923+00	.433+04	-.178+02	-.144+03	.970+03	.000	.000	.000	.000	.000	.000
.063000	.129+01	.923+00	.433+04	-.178+02	-.144+03	.970+03	.000	.000	.000	.000	.000	.000
.064000	.129+01	.923+00	.433+04	-.178+02	-.144+03	.970+03	.000	.000	.000	.000	.000	.000
.065000	.129+01	.923+00	.433+04	-.178+02	-.144+03	.970+03	.000	.000	.000	.000	.000	.000
.066000	.129+01	.923+00	.433+04	-.178+02	-.144+03	.970+03	.000	.000	.000	.000	.000	.000
.067000	.129+01	.923+00	.433+04	-.178+02	-.144+03	.970+03	.000	.000	.000	.000	.000	.000
.068000	.129+01	.923+00	.433+04	-.178+02	-.144+03	.970+03	.000	.000	.000	.000	.000	.000
.069000	.129+01	.923+00	.433+04	-.178+02	-.144+03	.970+03	.000	.000	.000	.000	.000	.000
.070000	.129+01	.923+00	.433+04	-.178+02	-.144+03	.970+03	.000	.000	.000	.000	.000	.000
.071000	.129+01	.923+00	.433+04	-.178+02	-.144+03	.970+03	.000	.000	.000	.000	.000	.000
.072000	.129+01	.923+00	.433+04	-.178+02	-.144+03	.970+03	.000	.000	.000	.000	.000	.000
.073000	.129+01	.923+00	.433+04	-.178+02	-.144+03	.970+03	.000	.000	.000	.000	.000	.000
.074000	.129+01	.923+00	.433+04	-.178+02	-.144+03	.970+03	.000	.000	.000	.000	.000	.000
.075000	.129+01	.923+00	.433+04	-.178+02	-.144+03	.970+03	.000	.000	.000	.000	.000	.000
.076000	.129+01	.923+00	.433+04	-.178+02	-.144+03	.970+03	.000	.000	.000	.000	.000	.000
.077000	.129+01	.923+00	.433+04	-.178+02	-.144+03	.970+03	.000	.000	.000	.000	.000	.000
.078000	.129+01	.923+00	.433+04	-.178+02	-.144+03	.970+03	.000	.000	.000	.000	.000	.000
.079000	.129+01	.923+00	.433+04	-.178+02	-.144+03	.970+03	.000	.000	.000	.000	.000	.000
.080000	.129+01	.923+00	.433+04	-.178+02	-.144+03	.970+03	.000	.000	.000	.000	.000	.000
.081000	.129+01	.923+00	.433+04	-.178+02	-.144+03	.970+03	.000	.000	.000	.000	.000	.000
.082000	.129+01	.923+00	.433+04	-.178+02	-.144+03	.970+03	.000	.000	.000	.000	.000	.000
.083000	.129+01	.923+00	.433+04	-.178+02	-.144+03	.970+03	.000	.000	.000	.000	.000	.000
.084000	.129+01	.923+00	.433+04	-.178+02	-.144+03	.970+03	.000	.000	.000	.000	.000	.000
.085000	.129+01	.923+00	.433+04	-.178+02	-.144+03	.970+03	.000	.000	.000	.000	.000	.000
.086000	.129+01	.923+00	.433+04	-.178+02	-.144+03	.970+03	.000	.000	.000	.000	.000	.000
.087000	.129+01	.923+00	.433+04	-.178+02	-.144+03	.970+03	.000	.000	.000	.000	.000	.000
.088000	.129+01	.923+00	.433+04	-.178+02	-.144+03	.970+03	.000	.000	.000	.000	.000	.000
.089000	.129+01	.923+00	.433+04	-.178+02	-.144+03	.970+03	.000	.000	.000	.000	.000	.000
.090000	.129+01	.923+00	.433+04	-.178+02	-.144+03	.970+03	.000	.000	.000	.000	.000	.000
.091000	.129+01	.923+00	.433+04									

2-138

[illegible]

HEAT SHIELD ORIENTATION INFORMATION.

TIME	X AXIS		Y AXIS		Z AXIS		PSI AXIS		THETA AXIS		PHI AXIS	
	P.C.S.	VEL.	P.O.S.	VEL.	P.O.S.	VEL.	P.C.S.	VEL.	P.O.S.	VEL.	P.O.S.	VEL.
000000	242-00	-126-04	-100	-100	-278-15	-352-11	-100	-110-06	-100	-129-06	-161-07	-126-05
001000	240-00	-118-04	-1348-16	-349-13	-201-13	-100-09	-245-10	-110-06	-550-10	-129-06	-161-07	-126-05
002000	249-00	-110-04	-169-00	-349-11	-201-13	-100-09	-245-10	-110-06	-550-10	-129-06	-161-07	-126-05
003000	258-00	-950-01	-418-13	-469-10	-229-12	-260-09	-417-08	-212-05	-410-08	-537-05	-153-07	-258-07
004000	250-00	-791-01	-488-10	-905-07	-395-10	-348-06	-417-08	-212-05	-130-07	-178-04	-153-07	-258-07
005000	242-00	-698-01	-424-09	-241-07	-212-09	-308-06	-417-08	-212-05	-238-07	-126-04	-153-07	-258-07
006000	229-00	-647-01	-562-09	-348-06	-513-09	-231-05	-429-08	-289-05	-568-07	-035-04	-178-07	-545-05
007000	229-00	-545-01	-513-09	-319-06	-287-08	-350-06	-123-07	-556-05	-108-06	-446-01	-243-07	-765-05
008000	224-00	-442-01	-120-08	-138-04	-602-09	-938-05	-194-07	-852-05	-500-08	-232-03	-307-07	-210-05
009000	220-00	-311-01	-140-08	-178-06	-203-07	-330-04	-226-05	-926-05	-457-06	-754-03	-253-07	-174-04
010000	218-00	-181-00	-154-08	-119-07	-755-07	-719-04	-241-07	-562-05	-167-05	-117-02	-124-07	-592-04
011000	218-00	-164-01	-135-08	-110-06	-149-06	-758-04	-418-07	-507-05	-335-05	-167-02	-915-07	-103-03
012000	221-00	-366-01	-335-09	-166-05	-228-06	-828-04	-448-07	-196-06	-531-05	-218-02	-225-06	-176-03
013000	226-00	-571-01	-223-06	-366-05	-316-06	-944-04	-392-07	-125-04	-771-05	-268-02	-454-06	-262-03
014000	232-00	-660-01	-740-08	-253-05	-419-06	-114-03	-160-07	-361-04	-107-04	-236-02	-607-06	-431-03
015000	239-00	-645-01	-166-07	-118-04	-547-06	-143-03	-341-07	-751-04	-146-04	-433-02	-133-05	-627-03
016000	245-00	-558-01	-319-07	-151-04	-707-06	-160-03	-140-06	-133-03	-196-04	-567-02	-206-05	-876-03
017000	250-00	-439-01	-556-07	-249-04	-911-05	-230-03	-313-06	-217-03	-263-04	-776-02	-310-05	-119-02
018000	254-00	-297-01	-907-07	-419-04	-117-05	-300-03	-356-06	-336-03	-353-04	-102-01	-447-05	-157-02
019000	256-00	-153-01	-141-06	-267-04	-152-05	-362-03	-569-06	-498-03	-470-04	-133-01	-624-05	-202-02
020000	257-00	-161-04	-209-06	-751-04	-197-05	-523-03	-159-05	-701-03	-619-04	-126-01	-654-05	-256-02
021000	262-00	-227-01	-300-06	-103-05	-258-05	-697-03	-241-05	-950-03	-600-04	-401-01	-114-04	-318-02
022000	262-00	-275-01	-417-06	-132-03	-338-05	-910-03	-350-05	-126-02	-102-03	-244-01	-145-04	-390-02
023000	266-00	-299-01	-564-06	-164-03	-442-05	-117-02	-453-05	-163-02	-128-03	-246-01	-192-04	-471-02
024000	269-00	-247-01	-740-06	-241-03	-575-05	-149-02	-675-05	-507-02	-158-03	-335-01	-244-04	-563-02
025000	272-00	-269-01	-966-06	-241-03	-744-05	-166-02	-905-05	-258-02	-194-03	-369-01	-305-04	-666-02
026000	274-00	-215-01	-123-05	-463-03	-955-05	-235-02	-119-04	-316-02	-235-03	-448-01	-377-04	-781-02
027000	276-00	-145-01	-153-05	-323-03	-122-02	-292-02	-155-04	-406-02	-285-03	-351-01	-462-04	-908-02
028000	277-00	-711-01	-188-05	-363-03	-155-04	-367-02	-200-04	-510-02	-346-03	-668-01	-555-04	-105-01
029000	278-00	-256-01	-218-05	-249-03	-203-04	-563-02	-256-04	-614-02	-416-03	-765-01	-471-04	-120-01
030000	277-00	-710-01	-218-05	-130-04	-250-04	-214-02	-309-04	-333-02	-488-03	-192-01	-727-04	-110-01
031000	277-00	-112-01	-251-05	-277-03	-250-04	-214-02	-246-04	-610-02	-460-03	-371-01	-784-04	-101-01
032000	279-00	-117-01	-350-05	-123-02	-208-04	-523-02	-168-04	-158-01	-395-03	-403-01	-983-04	-750-02
033000	279-00	-1853-00	-478-05	-117-02	-142-04	-647-02	-423-06	-191-01	-293-03	-104-00	-104-03	-339-02
034000	274-00	-1246-00	-561-05	-307-03	-904-05	-286-02	-164-04	-134-01	-204-03	-672-01	-105-03	-176-02
035000	274-00	-465-00	-528-05	-109-02	-908-05	-385-02	-241-04	-177-02	-169-03	-162-01	-100-03	-719-02
036000	279-00	-858-00	-531-05	-268-02	-163-04	-101-01	-162-04	-992-02	-202-03	-599-01	-106-04	-120-01
037000	276-00	-105-01	-103-06	-362-02	-282-04	-131-01	-633-05	-146-01	-274-03	-775-01	-766-04	-156-01
038000	277-00	-952-00	-367-05	-382-02	-411-04	-122-01	-743-05	-116-01	-342-03	-509-01	-55-04	-161-01
039000	276-00	-611-00	-736-05	-350-02	-518-04	-910-02	-168-04	-454-02	-358-03	-122-02	-406-04	-191-01
040000	278-00	-200-00	-107-04	-313-02	-395-05	-632-02	-173-04	-615-03	-351-03	-413-01	-219-04	-186-01
041000	279-00	-364-01	-134-04	-241-02	-649-04	-441-02	-150-04	-444-02	-316-03	-413-01	-434-05	-170-01
042000	279-00	-9948-01	-153-04	-162-02	-716-04	-459-02	-100-04	-543-02	-278-03	-343-01	-116-04	-154-01
043000	279-00	-413-01	-170-04	-141-02	-677-04	-660-02	-518-05	-400-02	-254-03	-132-01	-212-04	-153-01
044000	279-00	-349-00	-186-04	-172-02	-771-04	-682-04	-264-05	-373-03	-252-03	-979-01	-881-04	-106-01
045000	276-00	-740-00	-207-04	-211-02	-836-04	-650-02	-430-05	-315-02	-262-03	-615-02	-466-04	-676-02
046000	276-00	-967-00	-225-04	-194-02	-899-04	-669-02	-679-05	-414-02	-265-03	-103-01	-510-04	-801-03
047000	241-00	-106-04	-449-04	-971-04	-759-02	-759-02	-15-04	-776-02	-260-03	-160-01	-497-04	-336-02
048000	270-00	-105-01	-270-04	-105-03	-788-02	-23-04	-23-04	-403-02	-299-03	-260-01	-442-04	-753-02
049000	214-00	-934-00	-288-04	-124-02	-113-03	-660-02	-306-04	-406-02	-318-03	-540-01	-347-04	-107-01

TIME	SOIL IMPACT REACTION AREA	GROUND REACTION FORCE	ACCELERATIONS		ON COMPONENT		CENTERS OF GRAVITY		IN FT./SEC./SEC.		HEAT SHIELD MASS	
			X DIR.	Y DIR.	X DIR.	Y DIR.	X DIR.	Y DIR.	X DIR.	Y DIR.	X DIR.	Y DIR.
.000000	.0000	.00000	-32.2719	.0000	.0000	-32.6106	-.0000	.0000	.0000	-31.7608	-.0000	.0000
.001000	.2502	.24925+03	-8.6985	.0000	-.0000	-34.7887	-.0000	.0000	.0000	496.2993	-.0000	.0000
.002000	.5780	.60117+03	40.5508	.0000	.0000	-12.1645	-.0000	.0000	.0000	1182.6892	-.0000	.0000
.003000	.5780	.10095+04	180.5508	.0000	.0000	25.5758	.0000	.0000	.0000	1735.9416	-.0000	.0000
.004000	1.1009	.11700+04	441.2110	.0000	-.0000	102.0237	.0000	.0000	.0000	1333.0334	.0001	.0004
.005000	1.1009	.12336+04	708.2059	.0000	-.0000	275.7620	.0000	.0000	.0000	599.6706	.0002	.0017
.006000	1.1009	.12866+04	700.6019	.0000	-.0000	566.3985	-.0254	.0000	.0000	432.3989	.0001	.0004
.007000	1.1009	.14040+04	746.7063	.0000	-.0000	486.6390	-.0037	.0000	.0000	600.0784	-.0001	.0005
.008000	1.1009	.15702+04	712.3601	.0000	-.0000	575.6457	.0000	.0000	.0000	1356.8579	-.0001	.0005
.009000	1.1009	.17495+04	639.8272	.0000	-.0000	407.2461	-.0225	.0000	.0000	1573.4088	-.0001	.0005
.010000	1.7689	.18826+04	590.8304	.0000	-.0000	436.0467	-.0224	.0000	.0000	2499.7623	-.0000	.0005
.011000	1.7689	.18573+04	543.2173	.0000	-.0000	434.0393	-.0735	.0000	.0000	2490.6252	-.0000	.0005
.012000	1.1009	.16647+04	521.1443	.0000	-.0000	431.0461	-.0722	.0000	.0000	2095.7287	-.0015	.0093
.013000	1.1009	.13261+04	495.5412	.0000	-.0000	429.7944	-.0349	.0000	.0000	1362.1500	-.0025	.0053
.014000	1.1009	.08315+03	468.0635	.0000	-.0000	427.5971	-.0159	.0000	.0000	365.3518	-.0040	.0036
.015000	1.1009	.39746+03	440.4520	.0000	-.0000	425.2579	-.0252	.0000	.0000	-694.4089	-.0059	.0034
.016000	1.1009	.22444+03	417.3222	.0000	-.0000	422.6372	-.0329	.0000	.0000	-1038.4365	-.0064	.0027
.017000	1.1009	.78354+02	397.3762	.0000	-.0000	420.3617	-.0527	.0000	.0000	-1328.5255	-.0113	.0093
.018000	.5780	.11325+02	361.1904	.0000	-.0000	416.0669	.4331	.0000	.0000	-1440.6449	-.0148	.0001
.019000	.5780	.28253+01	369.0498	.0000	-.0000	415.2596	.3138	.0000	.0000	-1425.1679	-.0169	.0056
.020000	.5780	.17944+04	359.1653	.0000	-.0000	413.1728	-.0742	.0000	.0000	2877.5303	-.0219	.0056
.021000	.5780	.16236+04	348.0650	.0000	-.0000	409.0232	-.0547	.0000	.0000	2502.3675	-.0259	.0056
.022000	.5780	.14098+04	339.1570	.0000	-.0000	400.2504	-.0719	.0000	.0000	2024.1033	-.0297	.0041
.023000	.5780	.11058+04	329.4994	.0000	-.0000	391.0199	-.0351	.0000	.0000	1475.5939	-.0333	.0022
.024000	.5780	.91024+03	320.4265	.0000	-.0000	362.5571	-.0500	.0000	.0000	1296.4285	-.0364	.0097
.025000	.5780	.68352+03	312.4176	.0000	-.0000	374.7056	-.0384	.0000	.0000	335.5302	-.0392	.0045
.026000	.2202	.45766+03	306.0713	.0000	-.0000	366.7115	-.0127	.0000	.0000	-132.7190	-.0411	.0041
.027000	.2202	.39909+03	301.0960	.0000	-.0000	356.1034	-.0601	.0000	.0000	-55.5407	-.0439	.0039
.028000	.2202	.36253+03	299.4956	.0000	-.0000	351.2405	-.0703	.0000	.0000	-32.1582	-.0443	.0036
.029000	.2202	.34987+03	299.4966	.0000	-.0000	343.5763	-.0506	.0000	.0000	-358.2140	-.0476	.0036
.030000	.2202	.36063+03	223.6729	.0000	-.0000	337.1983	-.0280	.0000	.0000	-112.4395	-.0516	.0036
.031000	.2202	.38803+03	134.1675	.0000	-.0000	330.4140	.0012	.0000	.0000	112.0092	-.0579	.0036
.032000	.2202	.42245+03	14.3898	.0000	-.0000	323.5000	.0532	.0000	.0000	639.6634	-.0574	.0036
.033000	.2202	.45216+03	-94.9589	.0000	-.0000	316.7102	1.7674	.0000	.0000	1026.4690	-.0555	.0036
.034000	.5780	.47425+03	-156.5914	.0000	-.0000	311.1295	4.6906	.0000	.0000	127.7925	-.0591	.0036
.035000	.5780	.46208+03	-112.5159	.0000	-.0000	307.0697	8.7900	.0000	.0000	1105.1355	-.0633	.0036
.036000	.2202	.43926+03	-21.7304	.0000	-.0000	202.7877	10.4364	.0000	.0000	651.0624	1.2747	.0036
.037000	.2202	.40645+03	68.3297	.0000	-.0000	100.5735	5.0073	.0000	.0000	517.0047	.0549	.0036
.038000	.2202	.37196+03	195.3209	.0000	-.0000	-53.5279	2.6423	.0000	.0000	191.0014	-.0542	.0036
.039000	.2202	.34463+03	255.2676	.0000	-.0000	-53.5279	-2.3702	.0000	.0000	-17.0625	-.0475	.0036
.040000	.2202	.33004+03	192.4310	.0000	-.0000	46.2515	-8.4714	.0000	.0000	69.6490	-1.1167	.0036
.041000	.2202	.32585+03	120.0964	.0000	-.0000	122.5538	-11.9912	.0000	.0000	222.2643	-.0505	.0036
.042000	.2202	.34668+03	36.2927	.0000	-.0000	193.1906	-4.6003	.0000	.0000	423.1134	-.0490	.0036
.043000	.2202	.32621+03	-37.5146	.0000	-.0000	214.0968	2.6423	.0000	.0000	619.9630	-.0247	.0036
.044000	.2202	.31634+03	-63.1204	.0000	-.0000	105.4299	2.9410	.0000	.0000	736.7884	.0314	.0036
.045000	.2202	.29923+03	-58.5526	.0000	-.0000	14.5538	7.0290	.0000	.0000	730.0092	.0313	.0036
.046000	.2202	.26620+03	-4.4584	.0000	-.0000	-90.0283	5.2616	.0000	.0000	470.0414	.0249	.0036
.047000	.2202	.23305+03	72.5620	.0000	-.0000	-156.4808	4.7339	.0000	.0000	297.2528	.0075	.0036
.048000	.2202	.19551+03	56.5285	.0000	-.0000	-145.4239	1.7465	.0000	.0000	131.8227	-.0045	.0036
.049000	.2202	.16046+03	65.7661	.0000	-.0000	-35.5093	-3.6602	.0000	.0000	16.0419	-.0610	.0036

ACCELEROMETER READINGS FOR CORRELATION WITH THE SCALE MODEL

TYPE	CAP11A)	CAP2(A)	CAP3(A)	CAP4(Y)	CAP5(Y)	CAP6(Z)	CCH1(X)	CCH2(X)	CCH3(X)	CCH4(Y)	CCH5(Y)	CCH6(Z)
000000	-323+02	-323+02	-323+02	-667-01	730-10	-000	-326+02	-326+02	-326+02	000	000	000
000100	-890+01	-890+01	-890+01	-257-00	123-07	-298-08	-326+02	-326+02	-326+02	-235+01	-211-07	-211-07
000200	406+02	406+02	406+02	-462-00	150-07	274-07	-122+02	-122+02	-122+02	-422+01	-189-05	-189-05
000300	181+03	181+03	181+03	-769-00	356-07	402-06	256+02	256+02	256+02	721+01	-375-06	-430-06
000400	441+02	441+02	441+02	-579-00	333-04	-267-01	102+03	102+03	102+03	530+01	-264-05	133-00
000500	768+03	768+03	768+03	-569-00	529-04	-455-00	276+03	276+03	276+03	-636+01	-140-05	228+01
000600	761+03	761+03	761+03	-114-00	505-02	-270-00	568+03	568+03	568+03	-173+01	-254-01	136+01
000700	747+03	747+03	747+03	121+01	677-02	-148-00	487+03	487+03	487+03	110+02	-337-01	709-00
000800	712+03	712+03	712+03	133+01	159-01	-979-01	406+03	406+03	406+03	119+02	-793-01	468-00
000900	640+03	640+03	640+03	102+01	446-01	-237-00	436+03	436+03	436+03	659+01	-223-00	113+01
001000	561+03	561+03	561+03	144+01	654-01	-281-00	434+03	434+03	434+03	122+02	-325-00	139+01
001100	543+03	543+03	543+03	129+01	149-00	-348-00	432+03	432+03	432+03	957+01	-740-00	171+01
001200	521+03	521+03	521+03	171+01	147-00	-369-00	430+03	430+03	430+03	133+02	-720-00	179+01
001300	468+03	468+03	468+03	162+01	272-00	-363-00	428+03	428+03	428+03	168+02	-135+01	172+01
001400	441+03	441+03	441+03	165+01	235-00	-344-00	426+03	426+03	426+03	128+02	-116+01	156+01
001500	417+03	417+03	417+03	159+01	572-00	-358-00	423+03	423+03	423+03	630+01	-284+01	157+01
001600	395+03	395+03	395+03	169+01	472-00	-381-00	420+03	420+03	420+03	700+01	-233+01	163+01
001700	367+03	367+03	367+03	171+01	394-00	-710-00	416+03	416+03	416+03	-977+01	-193+01	316+01
001800	369+03	369+03	369+03	479-00	461-01	-418-00	413+03	413+03	413+03	360+01	312-00	149+01
001900	359+03	359+03	359+03	-270-00	188-00	-347-00	409+03	409+03	409+03	245+00	-750-00	101+01
002000	350+03	350+03	350+03	-220-00	331-00	-219-00	406+03	406+03	406+03	-667+01	-155+01	225-00
002100	344+03	344+03	344+03	-147+01	768-00	-198-00	400+03	400+03	400+03	324+00	-372+01	903+00
002200	331+03	331+03	331+03	131+01	707-00	-198-00	392+03	392+03	392+03	-569-00	-339+01	171-00
002300	324+03	324+03	324+03	638-00	596-00	-363-00	383+03	383+03	383+03	-547+01	-261+01	592-00
002400	312+03	312+03	312+03	305-00	323-00	-197-00	374+03	374+03	374+03	-459+01	-143+01	508-00
002500	307+03	307+03	307+03	-262-00	268-00	-396-00	366+03	366+03	366+03	-944+01	-113+01	310-00
002600	304+03	304+03	304+03	-116-00	229-00	-235-00	358+03	358+03	358+03	-944+01	-261-00	254+00
002700	299+03	299+03	299+03	-390-00	109+00	-462-00	351+03	351+03	351+03	-928+01	-261-00	254+00
002800	297+03	297+03	297+03	-368-00	659-01	-308-00	343+03	343+03	343+03	-121+02	-330-00	102+02
002900	229+03	229+03	229+03	-161+01	289-00	-304+01	336+03	336+03	336+03	-102+02	-114+02	-114+02
003000	224+03	224+03	224+03	-148+01	236-00	-353+01	330+03	330+03	330+03	-102+02	-114+02	-114+02
003100	234+03	234+03	234+03	-306+01	166-01	-204+01	322+03	322+03	322+03	-167+02	-116+02	-116+02
003200	233+02	233+02	233+02	-513+01	572-00	-592-00	316+03	316+03	316+03	-253+02	-170+01	-967+01
003300	232+02	232+02	232+02	-746+01	144+01	-103+01	311+03	311+03	311+03	-334+02	-463+01	-900+01
003400	217+04	217+04	217+04	-672+01	258+01	-256+01	308+03	308+03	308+03	-315+02	-674+01	-760+01
003500	191+02	191+02	191+02	-306+01	118+01	-192+01	303+03	303+03	303+03	-151+02	-104+02	-753+01
003600	195+03	195+03	195+03	734-02	672-00	-293+01	293+03	293+03	293+03	-264+01	-454+01	-116+02
003700	192+03	192+03	192+03	311+01	201+01	-316-00	286+03	286+03	286+03	-264+01	-454+01	-116+02
003800	183+02	183+02	183+02	670+01	249+01	-274+01	280+03	280+03	280+03	-264+01	-454+01	-116+02
003900	175+03	175+03	175+03	410+01	553-00	-273+01	273+03	273+03	273+03	-264+01	-454+01	-116+02
004000	140+03	140+03	140+03	661-00	309-00	-273+01	273+03	273+03	273+03	-264+01	-454+01	-116+02
004100	124+03	124+03	124+03	-112+01	731-00	-395+00	268+03	268+03	268+03	-264+01	-454+01	-116+02
004200	124+03	124+03	124+03	-112+01	731-00	-395+00	268+03	268+03	268+03	-264+01	-454+01	-116+02
004300	124+03	124+03	124+03	-112+01	731-00	-395+00	268+03	268+03	268+03	-264+01	-454+01	-116+02
004400	124+03	124+03	124+03	-112+01	731-00	-395+00	268+03	268+03	268+03	-264+01	-454+01	-116+02
004500	124+03	124+03	124+03	-112+01	731-00	-395+00	268+03	268+03	268+03	-264+01	-454+01	-116+02
004600	124+03	124+03	124+03	-112+01	731-00	-395+00	268+03	268+03	268+03	-264+01	-454+01	-116+02
004700	124+03	124+03	124+03	-112+01	731-00	-395+00	268+03	268+03	268+03	-264+01	-454+01	-116+02
004800	124+03	124+03	124+03	-112+01	731-00	-395+00	268+03	268+03	268+03	-264+01	-454+01	-116+02
004900	124+03	124+03	124+03	-112+01	731-00	-395+00	268+03	268+03	268+03	-264+01	-454+01	-116+02

SERIES NO. 11 RUN NO. 0 INITIAL CONDITIONS -- LINEAR ANGULAR X VEL. = -12.00 Y VEL. = .00 Z VEL. = .00
 SURFACE TYPE CRUSHABLE VEHICLE SURFACE NEAL SOIL SURFACE
 GROUND SLOPE = .000

TOTAL RUN TIME = .045 SEC. STOPPED BECAUSE OF MAX. TIME

PEAK STRUT FORCES
 TENSION NO.1 NO.2 NO.3 NO.4 NO.5 NO.6 NO.7 NO.8
 COMPRESSION -72. -72. -72. -72. -72. -72. -72. -72.
 MAX. STRUT STROKE 16. 16. 16. 16. 16. 16. 16. 16.
 TENSION .056 .056 .056 .056 .056 .056 .056 .056
 COMPRESSION .000 .000 .000 .000 .000 .000 .000 .000

MAXIMUM ACCELERATIONS
 COUCH X DIR. 568.39851 568.39851 568.39851 568.39851 568.39851 568.39851 568.39851 568.39851
 Y DIR. -14.05626 -14.05626 -14.05626 -14.05626 -14.05626 -14.05626 -14.05626 -14.05626
 Z DIR. 46.02883 46.02883 46.02883 46.02883 46.02883 46.02883 46.02883 46.02883
 CAPSULE X DIR. 761.65302 761.65302 761.65302 761.65302 761.65302 761.65302 761.65302 761.65302
 Y DIR. -3.12812 -3.12812 -3.12812 -3.12812 -3.12812 -3.12812 -3.12812 -3.12812
 Z DIR. -5.70530 -5.70530 -5.70530 -5.70530 -5.70530 -5.70530 -5.70530 -5.70530

MAXIMUM SHIELD CONTACT AREA = 1.7869 SQ.FT. HEAT SHIELD SURFACE BACKUP RING 1 2 3 4 5 6 7 8 9 10

CAPSULE CONTACT AREA = .0000 SQ.FT. ELEMENTS PERMANENTLY DEFORMED NO. C C C C C C C C C C
 AMOUNT .00 .00 .00 .00 .00 .00 .00 .00 .00 .00

ENERGY BALANCE INFORMATION
 INITIAL KINETIC ENERGY OF SYSTEM = 133.5
 FRACTION OF TOTAL SYSTEM ENERGY ABSORBED BY
 COUCH STRUTS = .041
 HEAT SHIELD STRUTS = .744
 HEAT SHIELD SURFACE = .000
 CAPSULE SURFACE = .000
 SOIL = .768
 FRACTION OF TOTAL SYSTEM ENERGY ABSORBED = 1.153

SECTION III

DERIVATION OF EQUATIONS OF MOTION

3.1 INTRODUCTION

This portion of the final report is divided into eight sections. The first section defines the coordinate systems used in the analysis. The second section gives the derivation of the equations of motion of the various mass systems making up the command module. The next four sections describe the determination of forces due to shock strut stroking, capsule and heat shield/soil contact, parachute, and retrorocket employment.

The seventh section presents the derivation of equations for determining command module stability angle. The eighth, and final section, describes the energy balance equations which are included in the computer program to give an indication of the accuracy of the solution.

3.2 COORDINATE SYSTEMS AND KINEMATICAL TRANSFORMATIVES

For purposes of this dynamic analysis the command module is considered to be made up of three masses. The first of these is the capsule system which consists of the entire module less the couch system and the deployable heat shield. The second of these is the couch system which consists of the three couches of the astronauts and the astronauts themselves. The couch system is coupled to the capsule system by a series of deformable shock absorbers. The third mass consists of the deployable heat shield which is connected to the aft portion of the capsule by a series of strokable shock absorbers. If the heat shield is not deployed during landing the surface of the heat shield is treated as part of the hull (the outer, plastically deformable surface of the module) and the heat shield itself is treated as part of the capsule system, thus reducing the problem to one of two masses rather than three. For a deployed heat shield the three mass approach is

necessary since it is impossible to obtain an accurate analyses of the stroking of the heat shield shock absorbers by kinematics alone.

Three sets of Eulerian axes are located in the body as shown in Figure 3-1. The first of these (x, y, z) moves with the capsule system with the origin located at the center of gravity of the capsule. The axes are aligned with the geometrical lines of symmetry of the module. The second set of axes (x_c, y_c, z_c) moves with the astronaut couch system and is parallel to the capsule axes system prior to stroking of any elements of the couch shock absorber system. The origins of both of the above mass systems are considered, for generality, to be off of the geometric centerline of the module.

The third set of body axes (x_s, y_s, z_s) moves with the deployable heat shield and is located initially parallel to the previous two sets of axes with its origin at the geometric center of the shield structure.

The angular position of the capsule coordinate systems relative to a fixed coordinate system, described shortly, is determined by three consecutive rotations, ϕ , ψ , and θ as shown in Figure 3-1. To obtain any particular angular orientation, the coordinate system is first rotated through an angle θ about the z axis. Next it is rotated through an angle θ about the y axis which, due to the first rotation is displaced by ψ from its original position. Finally the system is rotated through an angle ϕ about the displaced x axis.

The angular positions of the couch coordinate system and the heat shield coordinate system are defined by the angles ψ_c , θ_c and ϕ_c , and ψ_s , θ_s and ϕ_s respectively. Both use the same conventions as the capsule rotations given above.

A fixed coordinate system is located on the earth's surface as shown in Figure 3-2. X axis of this system is initially perpendicular to the ground surface. The Z axis would correspond to the principle direction of the ground slope and the Y axis would be 90° across the slope.

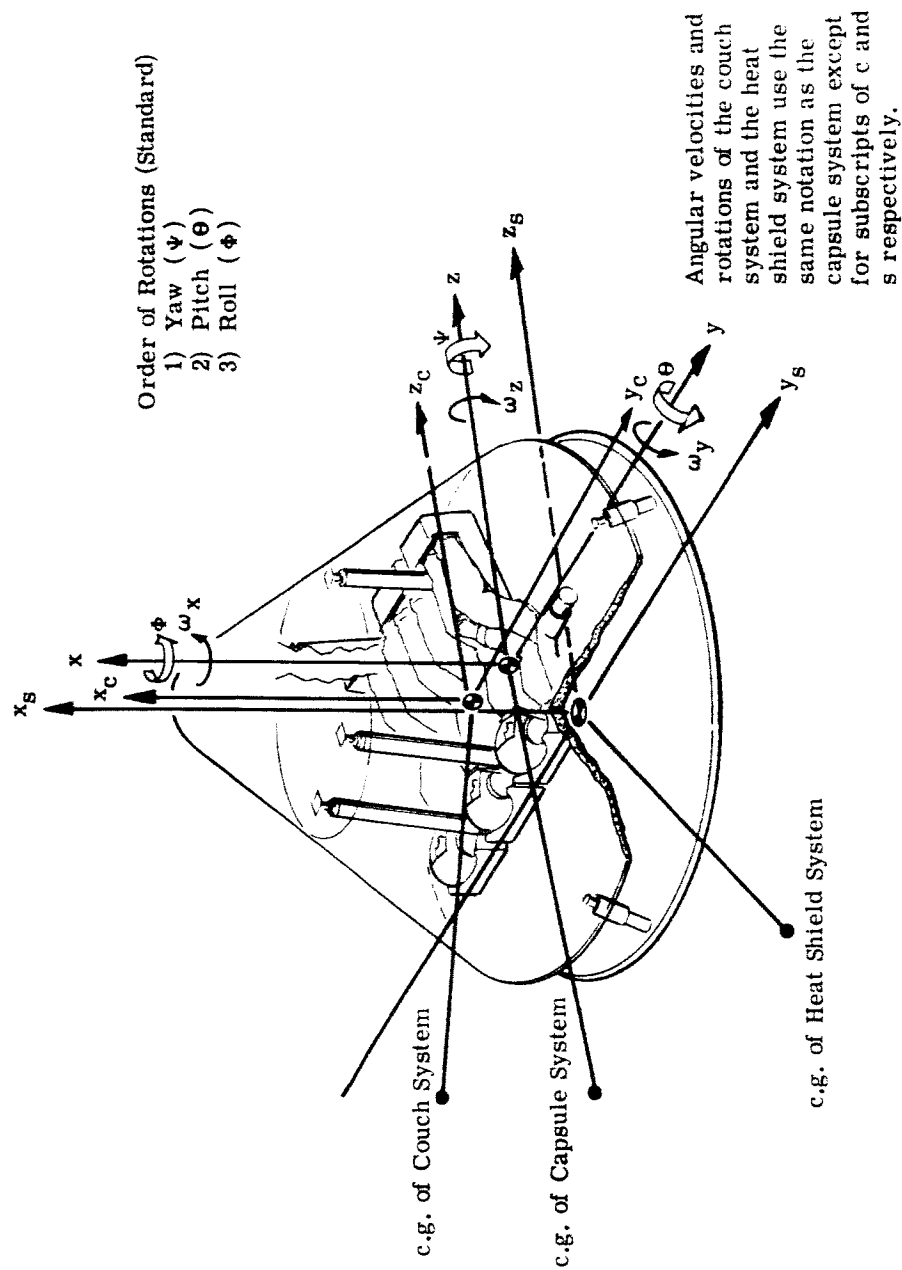


Figure 3-1. Eulerian Body Coordinate Systems

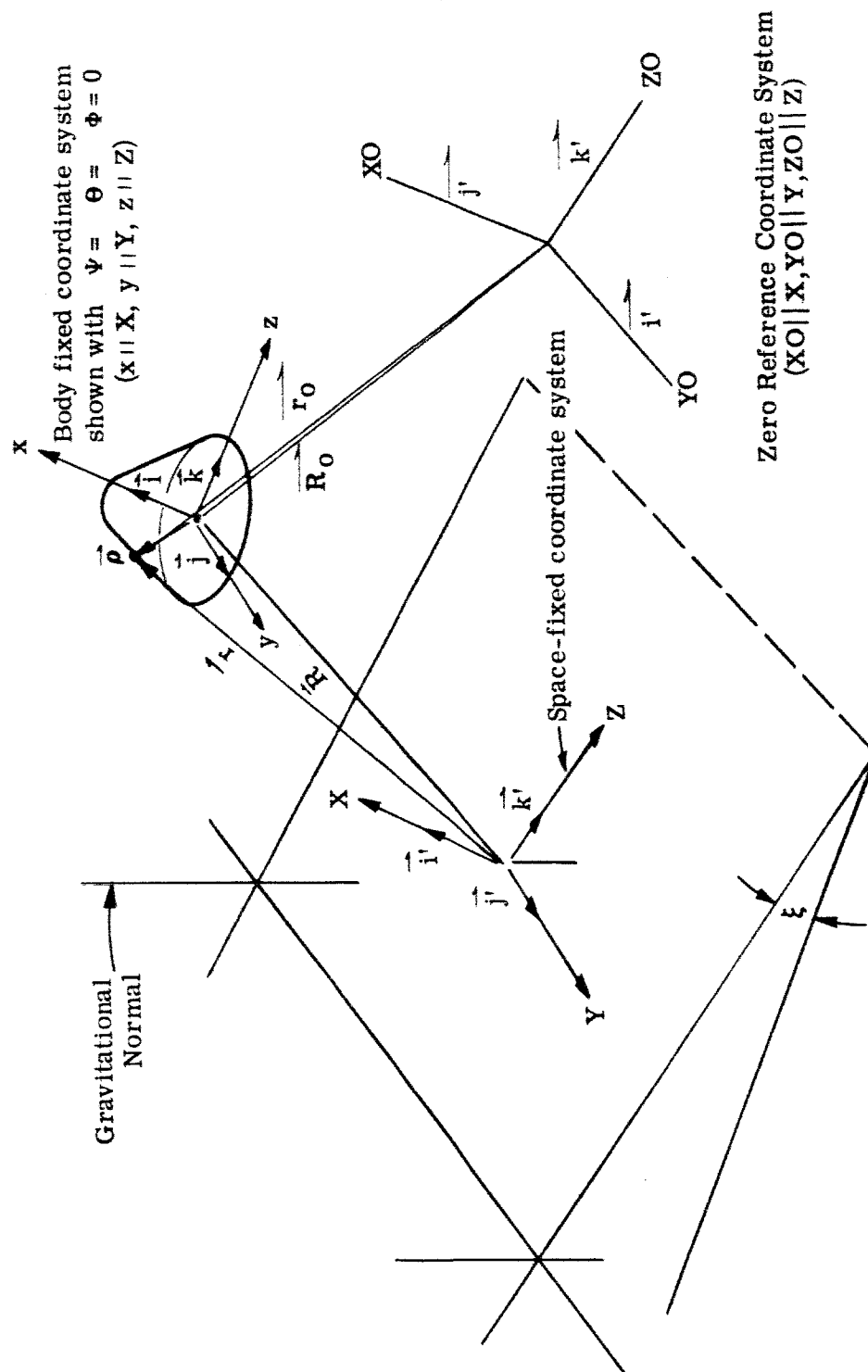


Figure 3-2. Space Fixed Coordinate System

In the analysis of the motion of the command module it will be necessary to transform force and distance vector from the body fixed Eulerian axes (x, y, z) , (x_c, y_c, z_c) and (x_s, y_s, z_s) to the space fixed Newtonian frame (X, Y, Z) . For example, if we know the position of a point on the surface of the hull in terms of a vector $\vec{\rho}$ of the body fixed coordinate system then its absolute position vector $\vec{r}$ is given by

$$\vec{r} = \vec{R} + \vec{\rho} \quad (1)$$

Where

R is a vector in the space fixed system from its origin to the origin of the capsule coordinate system.

But ρ must be redefined in terms of the space fixed coordinate system.

If the scalar components of ρ in the body fixed system are ρ_x, ρ_y, ρ_z , such that

$$\vec{\rho} = \rho_x \vec{i} + \rho_y \vec{j} + \rho_z \vec{k} \quad (2)$$

then the scalar components in the space fixed system $\rho'_x, \rho'_y, \rho'_z$ are given by the following matrix transformation

$$\begin{vmatrix} \rho'_x \\ \rho'_y \\ \rho'_z \end{vmatrix} = \begin{vmatrix} d_{11} & d_{12} & d_{13} \\ d_{21} & d_{22} & d_{23} \\ d_{31} & d_{32} & d_{33} \end{vmatrix} \begin{vmatrix} \rho_x \\ \rho_y \\ \rho_z \end{vmatrix} \quad (3)$$

Where

the quantities d_{11} etc. are direction cosines related to the Euler angles of the body fixed axes as defined in Figure 3-1 by the following equations:

$$\left. \begin{aligned} d_{11} &= \cos \theta \cos \psi \\ d_{12} &= \sin \phi \sin \theta \cos \psi - \cos \phi \sin \psi \\ d_{13} &= \cos \phi \sin \theta \cos \psi + \sin \phi \sin \psi \end{aligned} \right\} \quad (4)$$

$$\begin{aligned}
 d_{21} &= \cos \theta \sin \psi \\
 d_{22} &= \sin \phi \sin \theta \sin \psi + \cos \phi \cos \psi \\
 d_{23} &= \cos \phi \sin \theta \sin \psi - \sin \phi \cos \psi \\
 d_{31} &= -\sin \theta \\
 d_{32} &= \sin \phi \cos \theta \\
 d_{33} &= \cos \phi \cos \theta
 \end{aligned}
 \tag{4}$$

(cont.)

The inverse operation of converting a vector in the space fixed coordinate system to one in the body fixed coordinate system is achieved by the following transformation:

$$\begin{vmatrix} \rho_x \\ \rho_y \\ \rho_z \end{vmatrix} = \begin{vmatrix} d_{11} & d_{21} & d_{31} \\ d_{12} & d_{22} & d_{32} \\ d_{13} & d_{23} & d_{33} \end{vmatrix} \begin{vmatrix} \rho'_x \\ \rho'_y \\ \rho'_z \end{vmatrix}
 \tag{5}$$

In addition to the above transformations we will also require a relationship between the time derivative of the Euler angles and the angular velocity components of the capsule and couch systems in order to determine the change in the Euler angles with time. This relationship is given by:

$$\dot{\phi} = \omega_x + \tan \theta (\omega_y \sin \phi + \omega_z \cos \phi)
 \tag{6}$$

$$\dot{\theta} = \omega_y \cos \phi - \omega_z \sin \phi
 \tag{7}$$

$$\dot{\psi} = \frac{\omega_z \cos \phi + \omega_y \sin \phi}{\cos \theta}
 \tag{8}$$

In addition to the space fixed and three body coordinate systems described above, another system, designated the zero reference coordinate system, is defined for the purpose of simplifying the specification of computer program input data. The zero reference system is parallel to the space-fixed system, but it may be located at any point in space from which command module configuration dimensions can be conveniently specified. Wherever practical, program inputs will be specified relative to the zero reference system rather

than one of the body systems. The inputs are then transformed to the appropriate body system in the initialization portion of the computer program.

With these preliminary kinematical considerations we now proceed to the equations of motion of the system.

3.3 EQUATIONS OF MOTION

3.3.1 Translational Motion of Capsule System

The motion of the center of gravity of the capsule system which is also the origin of the capsule coordinate system is described by the time variation of a vector $\vec{R}$ from the origin of the space fixed coordinate system to the origin of the capsule coordinate system. The components of this vector in the X, Y, Z directions respectively are R_x , R_y , and R_z .

The forces acting on the system are; first, the normal and tangential ground contact forces resulting from the hull-soil interaction, second, the gravitational force due to the weight of the capsule proper, third, the thrust forces from a retro-rocket and frame thrusters used for angular rate reduction, fourth, forces due to shock strut stroking (relative motion between a deployed heat shield and the capsule proper), fifth, shock strut stroking forces caused by relative motion between the couch system and the capsule system, and sixth, forces due to a parachute.

With respect to each of these forces the following definitions and comments are made.

The force vector, F_m , due to the hull-soil interaction at each point of the hull in contact with the soil is divided into three components corresponding to the X, Y, and Z direction of the space fixed coordinate system. The point components are F_{xm} , F_{ym} , and F_{zm} , in which the subscript m is an index corresponding to the particular point on the hull upon which the forces act. A total of M hull points are considered. These forces result from the elasto-plastic deformation of the hull in combination with the rather complex dynamics of the soil structure beneath the total soil contact area of the hull. A subsequent section of this report gives a detailed derivation of this relationship.

The forces due to gravity are simply the vector $-M_0 g \cos \zeta \vec{i}'$ and $M_0 g \sin \zeta \vec{k}'$ in which ζ is the ground slope as defined in Figure 3-2, and M_0 is the mass of the capsule system.

The third set of forces previously mentioned is divided into a retro-rocket force and thrusters for reduction of angular orientation. The retro-rocket force consists of a constant force vector in the capsule coordinate system acting through the command module's center of gravity. The transformed components in the space fixed coordinate system are F_{rx} , F_{ry} , and F_{rz} . The thruster force depends upon the mode of operation of the stabilization system. For symmetric operations, the stabilization system provides only a moment acting about the capsule center of gravity. For non-symmetric operations a net thrust is provided along the x axis of the vehicle. For both cases the operation of the system depends upon ω_z and ω_y exceeding a certain deadband limit in which case the thrusters are turned on to oppose the angular velocities. It is considered that there are L thrusters each having a force vector $\vec{F}_{tl}$ in the body fixed system. For the non-symmetric mode of thruster operation the transformed components of the x body axis thrust are F_{tx} , F_{ty} , and F_{tz} .

With respect to the deployed heat shield shock absorber system, it is considered that there are a total of Q struts end mounted on spherical hinges or their equivalent and located between the capsule system and the interior surface of the heat shield. These may be oriented in any direction. All parameters of each strut (vector position of hard points, stroke load, etc.) are indexed by the subscript q . The vector force output of each shock strut is $\vec{Q}_q$. The components of the individual strut stroke forces in the space fixed coordinate system are Q_{xq} , Q_{yq} , and Q_{zq} .

Forces of the couch shock absorber act along the axis of each strut. It is considered that there are a total of P struts. All parameters of each strut are indexed by the subscript p . The components of the individual strut stroke forces in the space fixed coordinate system are P_{xp} , P_{yp} , P_{zp} .

The effect of a deployed parachute on the landing dynamics is taken into account through the inclusion of a parachute force and resulting moment in the capsule equations of motion.

It is assumed that parachute velocity, line elasticity, and capsule attach point are known for a given landing situation. The force (F_{cht}) and moment ($R_{cht} \times F_{cht}^b$) due to the parachute is then computed for each time interval throughout the landing based upon the relative positions of the parachute and capsule.

The equations of motion for the capsule center of gravity are, therefore,

$$M_O \ddot{R}_x = \sum_{m=1}^M F_{hm} - M_g \cos \zeta + F_{rx} + F_{tx} + \sum_{q=1}^Q Q_{xq} + \sum_{p=1}^P P_{xp} + F_{cht_x} \quad (9)$$

$$M_O \ddot{R}_y = \sum_{m=1}^M F_{ym} + F_{ry} + F_{ty} + \sum_{q=1}^Q Q_{yq} + \sum_{p=1}^P P_{yp} + F_{cht_y} \quad (10)$$

$$M_O \ddot{R}_z = \sum_{m=1}^M F_{zm} + M_g \sin \zeta + F_{rz} + F_{tz} + \sum_{q=1}^Q Q_{zq} + \sum_{p=1}^P P_{zp} + F_{cht_z} \quad (11)$$

3.3.2 Translational Motion of Couch System

Only two sets of forces act on the couch system. The first is the gravitational force having vector components of $-M_c g \cos \zeta \vec{i}'$ and $M_c g \sin \zeta \vec{k}'$. The second is the shock strut stroke forces. These are simply the negative of the shock strut forces acting on the capsule system and therefore, from the previous definition consist of the vector components $-P_{xp} \vec{i}'$, $-P_{yp} \vec{j}'$ and $-P_{zp} \vec{k}'$. The equations of motion for the couch center of gravity are therefore

$$M_c \ddot{R}_{cx} = -M_c g \cos \zeta - \sum_{p=1}^P P_{xp} \quad (12)$$

$$M_c \ddot{R}_{cy} = - \sum_{p=1}^P P_{yp} \quad (13)$$

$$M_c \ddot{R}_{cz} = M_c g \sin \zeta - \sum_{p=1}^P P_{zp} \quad (14)$$

Where

M_c is the mass of couch system and R_{cx} , R_{cy} , and R_{cz} are the scalar components of the vector from the origin of the space fixed coordinate system to the origin of the body-fixed couch coordinate system.

3.3.3 Translation Motion of Heat Shield

Three sets of forces act on the heat shield system. The first is the ground contact force vector resulting from impact of the heat shield with the soil. The second, is the gravitational force, and the third is the reaction from the shock struts between the capsule system and the heat shield system.

The ground contact forces are treated in the same manner as those resulting from the hull-soil interaction. A total of N points on the surface of the heat shield are considered and all parameters associated with each particular point (or, more precisely, each particular area) are indexed by the subscript n . The components of the soil-interaction force vector at a particular point on the surface of the shield are denoted by F_{xn} , F_{yn} , and F_{zn} for the X , Y , and Z directions respectively of the space fixed coordinate system. To avoid confusion of the shield forces with the ground forces acting on the hull of the capsule, the subscript N goes from $M + 1$ to $M + N$ rather than from 1 to N . This also is convenient in studying the case of the undeployed heat shield since all that is necessary is to redefine M as equal to the total number hull point and heat shield points.

The gravitational force is given by the vector $(-M_S g \cos \zeta \vec{i}' + M_S g \sin \zeta \vec{k}')$.

The forces due to stroking of the shock struts between the capsule system and the heat shield are simply the negative of those acting on the capsule from the same source.

(Q_{xq} , Q_{yq} , and Q_{zq}). Thus the equations of motion for translation of the heat shield are

$$M_S \ddot{R}_{Sx} = \sum_{n=M+1}^{M+N} F_{xn} - M_S g \cos \zeta - \sum_{q=1}^Q Q_{xq} \quad (15)$$

$$M_S \ddot{R}_{Sy} = \sum_{n=M+1}^{M+N} F_{yn} - \sum_{q=1}^Q Q_{yq} \quad (16)$$

$$M_S \ddot{R}_{Sz} = \sum_{n=M+1}^{M+N} F_{zn} + M_S g \sin \zeta - \sum_{q=1}^Q Q_{zq} \quad (17)$$

Where

M_s is the mass of the heat shield and R_{sx} , R_{sy} , and R_{sz} are the scalar components of the vector from the origin of the space fixed coordinate system to the origin of the heat shield, body-fixed coordinate system.

3.3.4 Angular Motion of Capsule System

Moments acting on the capsule system result from the previously defined forces $\vec{P}_p$, $\vec{F}_m$, $\vec{Q}_q$ and $\vec{F}_{tl}$. The vectors to the point of reaction of these forces are shown in Figure 3-3 and are $\vec{R}_{cp}$, $\vec{R}_{hm}$, $\vec{R}_{sq}$, and $\vec{R}_{tl}$ respectively. For clarity these forces and distance vector are shown in Figure 3-3. To determine the vector of the total moment acting on the capsule system, it is first necessary to transform $\vec{P}_p$, $\vec{F}_m$, and $\vec{Q}_q$ into the body coordinate system ($\vec{F}_{tl}$ is in the body coordinate system originally) then crossmultiply these vectors by the appropriate length vectors given above. The transformed force vectors will be denoted by the superscript b.

From Equation (5)

$$\vec{P}_p^b = [d] [P_p] \quad (18)$$

and so forth for the $\vec{F}_m^b$ and $\vec{Q}_q^b$.

The total moment is given by

$$M_x \vec{i} + M_y \vec{j} + M_z \vec{k} = \vec{R}_{cp} \times \vec{P}_p^b + \vec{R}_{hm} \times \vec{F}_m^b + \vec{R}_{sq} \times \vec{Q}_q^b + \vec{R}_{tl} \times \vec{F}_{tl} + \vec{R}_{cht} \times \vec{F}_{cht}^b \quad (19)$$

Thus: the total moment acting on the capsule is denoted by three scalar components M_x , M_y , M_z which are considered positive when acting counterclockwise for an observer looking in at the origin along a particular axes (conventional right hand system). From the time derivative of the moment of momentum the following equations for the angular motion are obtained.

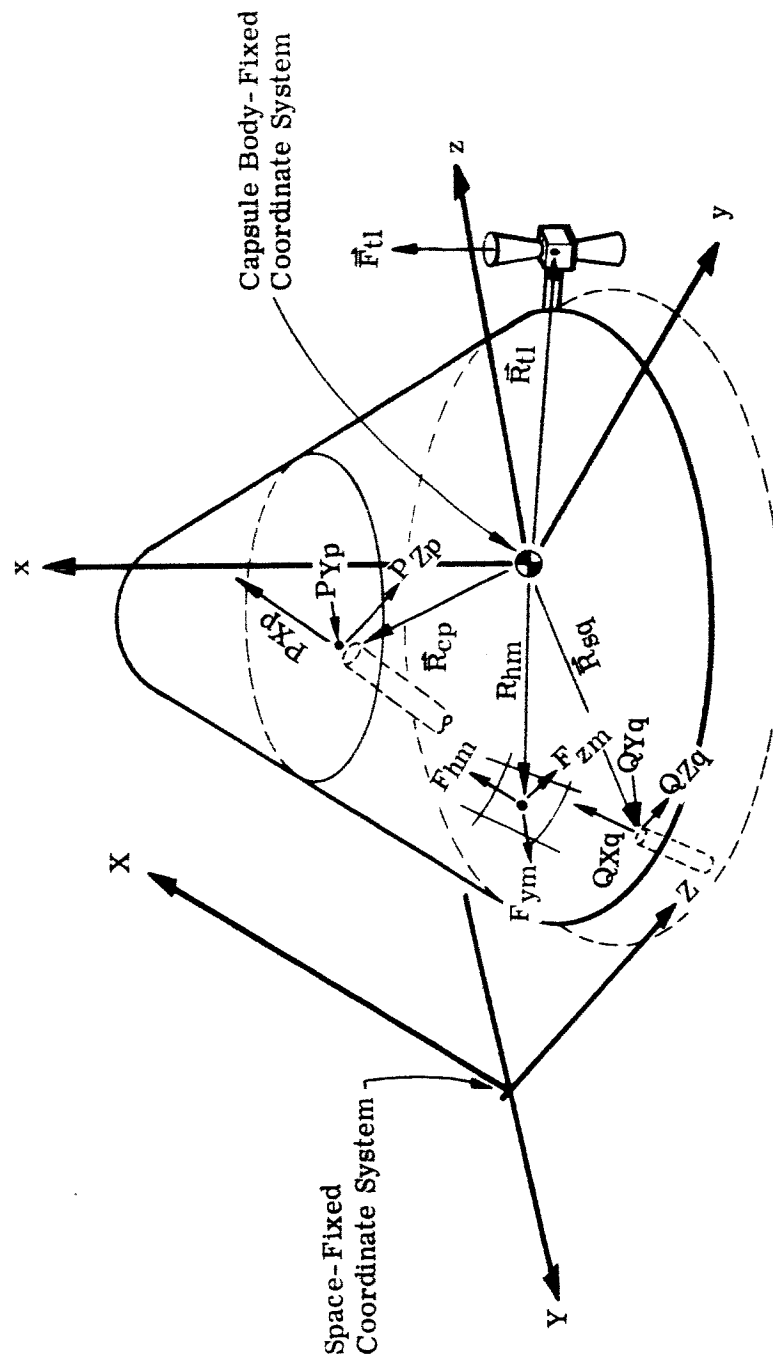


Figure 3-3. Nomenclature Associated with Moments Action on Capsule System

$$\begin{aligned}
M_x = & I_{xx} \dot{\omega}_x + (\omega_z \omega_x - \dot{\omega}_y) I_{xy} - (\dot{\omega}_z + \omega_x \omega_y) I_{zx} \\
& + (\omega_z^2 - \omega_y^2) I_{yz} + \omega_y \omega_z (I_{zz} - I_{yy})
\end{aligned} \tag{20}$$

$$\begin{aligned}
M_y = & I_{yy} \dot{\omega}_y + (\omega_x \omega_y + \dot{\omega}_z) I_{yz} - (\dot{\omega}_x + \omega_y \omega_z) I_{xy} \\
& + (\omega_x^2 - \omega_z^2) I_{zx} + \omega_z \omega_x (I_{xx} - I_{zz})
\end{aligned} \tag{21}$$

$$\begin{aligned}
M_z = & I_{zz} \dot{\omega}_z + (\omega_y \omega_z - \dot{\omega}_x) I_{xz} - (\dot{\omega}_y + \omega_z \omega_x) I_{yz} \\
& + (\omega_y^2 - \omega_x^2) I_{xy} + \omega_x \omega_y (I_{yy} - I_{xx})
\end{aligned} \tag{22}$$

These equations are written in general form (including the products of inertia) since it appears that with the body axes not aligned with the axis of geometric symmetry all products of inertia could exist.

3.3.5 Angular Motion of Couch System

Moments acting on the couch system result from the force output of each of the P shock struts. The vector from the origin of the couch body-fixed coordinate system to the couch hard point of the pth shock strut is denoted by $\vec{L}_{cp}$ as shown in Figure 3-4. The body-fixed transform of $\vec{P}_p$ is given by

$$\vec{P}_p^{cb} = - \begin{bmatrix} d_c \end{bmatrix} \begin{bmatrix} P_p \end{bmatrix} \tag{23}$$

Where

The superscript cb denotes that the vector is in the couch body-fixed coordinate system. The matrix $\begin{bmatrix} d_c \end{bmatrix}$ is analogous to $\begin{bmatrix} d \end{bmatrix}$ as defined by Equation (4) with the exception that it is in terms of the couch rotations. The negative sign is necessary in Equation (23) since the components of P_p were defined as positive when acting on the capsule system which are the negative of those acting on the couch system. The total moment acting on the couch system is given by,

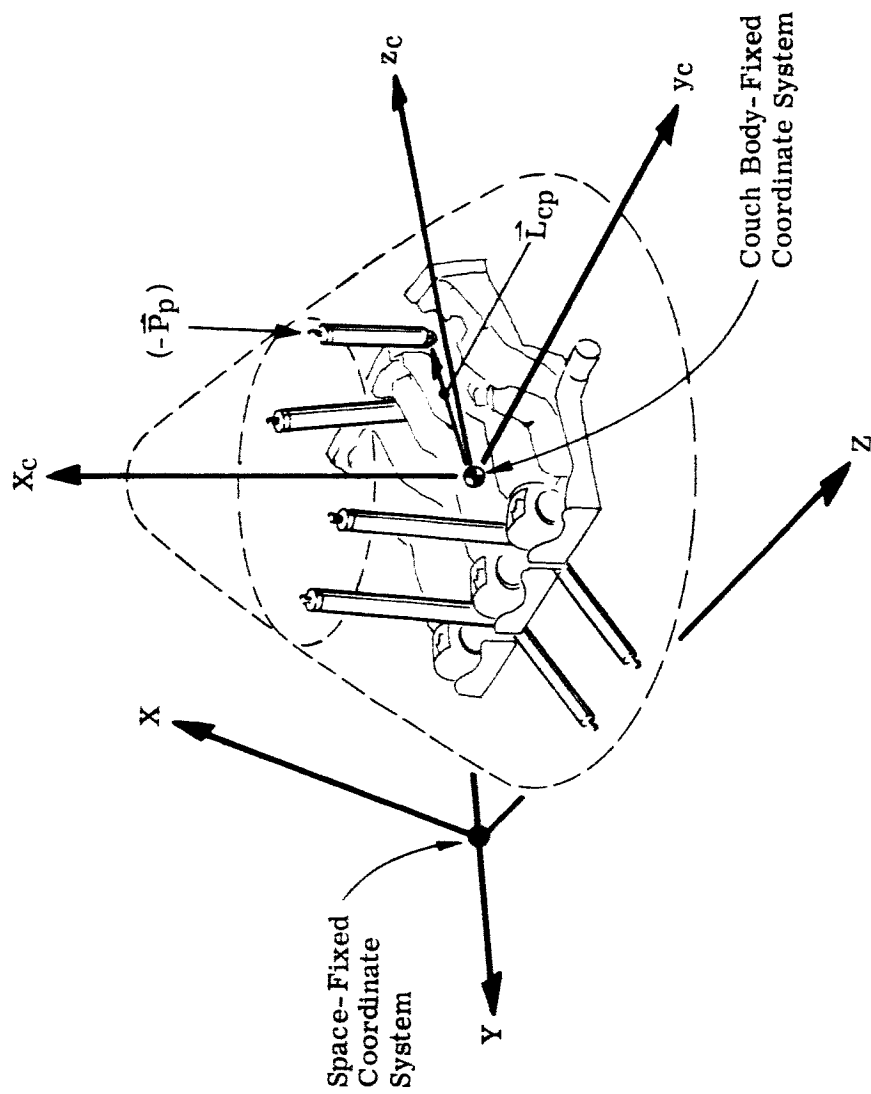


Figure 3-4. Nomenclature Associated with Moments Acting on Capsule System

$$M_{cx}\vec{i} + M_{cy}\vec{j} + M_{cz}\vec{k} = \vec{L}_{cp} \times \vec{P}_p^{cb} \quad (24)$$

Thus the equations of angular motion are,

$$M_{cx} = I_{xx}^c \dot{\omega}_{cx} + (\omega_{cz} \omega_{cx} - \dot{\omega}_{cy}) I_{xy}^c - (\dot{\omega}_{cz} + \omega_{cx} \omega_{cy}) I_{zx}^c \\ + (\omega_{cz}^2 - \omega_{cy}^2) I_{yz}^c + \omega_{cy} \omega_{cz} (I_{zz}^c - I_{yy}^c) \quad (25)$$

$$M_{cy} = I_{yy}^c \dot{\omega}_{cy} + (\omega_{cx} \omega_{cy} - \dot{\omega}_{cz}) I_{yz}^c - (\dot{\omega}_{cx} + \omega_{cy} \omega_{cz}) I_{xy}^c \\ + (\omega_{cx}^2 - \omega_{cz}^2) I_{zx}^c + \omega_{cz} \omega_{cx} (I_{xx}^c - I_{zz}^c) \quad (26)$$

$$M_{cz} = I_{zz}^c \dot{\omega}_{cz} + (\omega_{cy} \omega_{cz} - \dot{\omega}_{cx}) I_{xz}^c - (\dot{\omega}_{cy} + \omega_{cz} \omega_{cx}) I_{yz}^c \\ + (\omega_{cy}^2 + \omega_{cx}^2) I_{xy}^c + \omega_{cx} \omega_{cy} (I_{yy}^c - I_{xx}^c) \quad (27)$$

Again the equations of angular motion are written in general form due to the non-symmetry of the couch system.

3.3.6 Angular Motion of Heat Shield System

Moments acting on the heat shield system result from the shock strut reactions $\vec{Q}_q$ and the ground contact forces $\vec{F}_n$. The appropriate nomenclature for these forces and their moment arm vectors is shown in Figure 3-5. In a manner similar to that previously carried out for the capsule system and the couch system the transformed forces are first determined.

$$\vec{Q}_q^{sb} = - \begin{bmatrix} d_s \end{bmatrix} \begin{bmatrix} Q_q \end{bmatrix} \quad (28)$$

and

$$\vec{F}_n^{sb} = \begin{bmatrix} d_s \end{bmatrix} \begin{bmatrix} \vec{F}_n \end{bmatrix} \quad (29)$$

Thus the total moment acting on the heat shield system is given by

$$M_{sx}\vec{i} + M_{sy}\vec{j} + M_{sz}\vec{k} = \vec{D}_{sq} \times \vec{Q}_q^{sb} + \vec{D}_n \times \vec{F}_n^{sb} \quad (30)$$

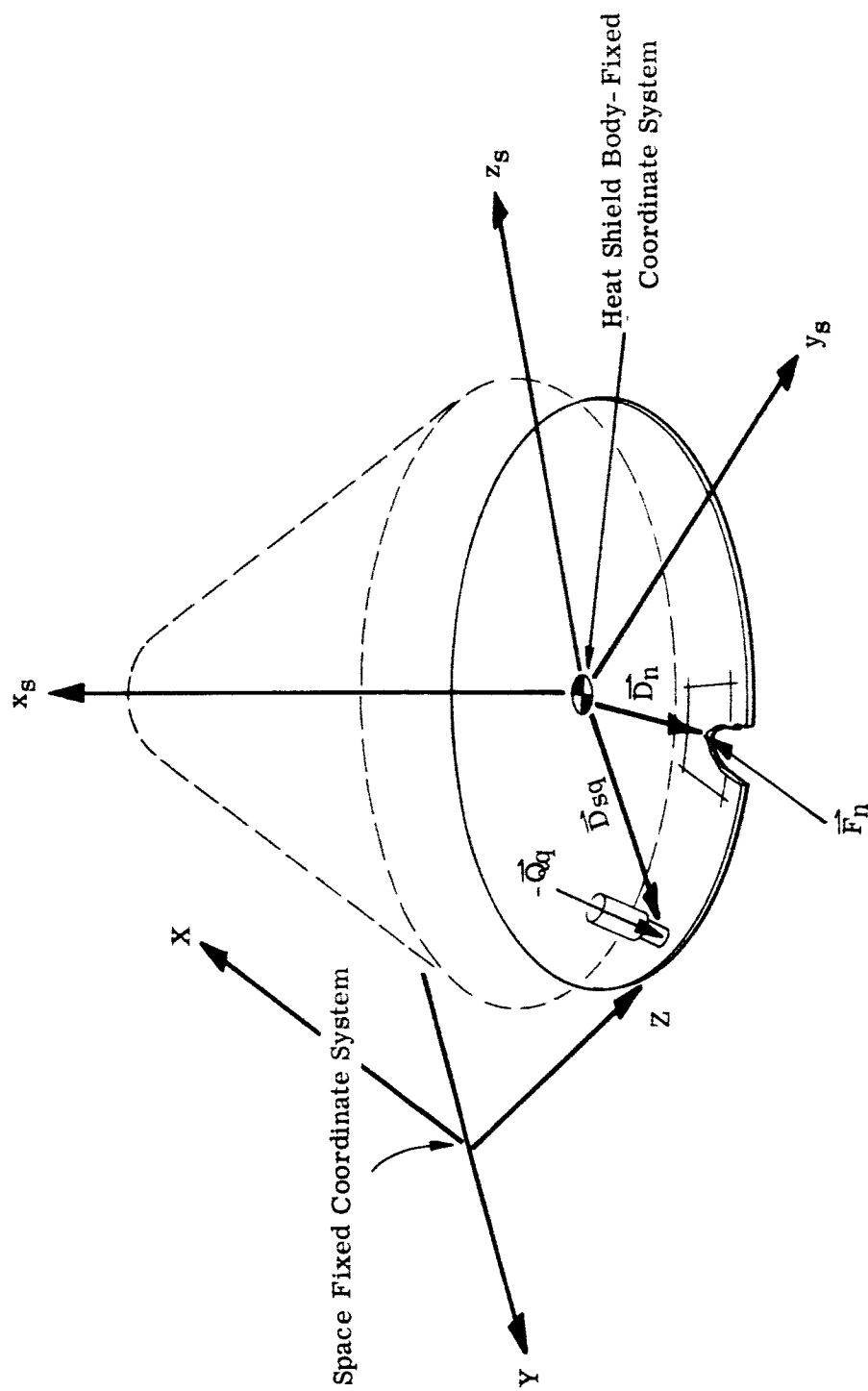


Figure 3-5. Nomenclature Associated with Moments Acting on Heat Shield System

The equations of angular motion are

$$M_{sx} = I_{xx}^s \omega_{sx} \quad (31)$$

$$M_{sy} = I_{yy}^s \omega_{sy} + \omega_{sz} \omega_{sx} (I_{xx}^s - I_{zz}^s) \quad (32)$$

$$M_{sz} = I_{zz}^s \omega_{sz} + \omega_{sx} \omega_{sy} (I_{yy}^s - I_{xx}^s) \quad (33)$$

Where

Axial symmetry about the X_s axis has been assumed.

3.4 SHOCK ABSORBER FORCES

This section presents the relationships used in determining the shock strut forces in the struts between the capsule and the astronauts couch and between the heat shield and capsule. Since the procedures for each set of shock struts are similar, only the development for the heat shield struts will be presented. The couch y direction struts, or bumpers, are treated as a separate case since they are rigidly attached at the couch end only and can therefore only take compressive loads.

3.4.1 Shock Strut Forces

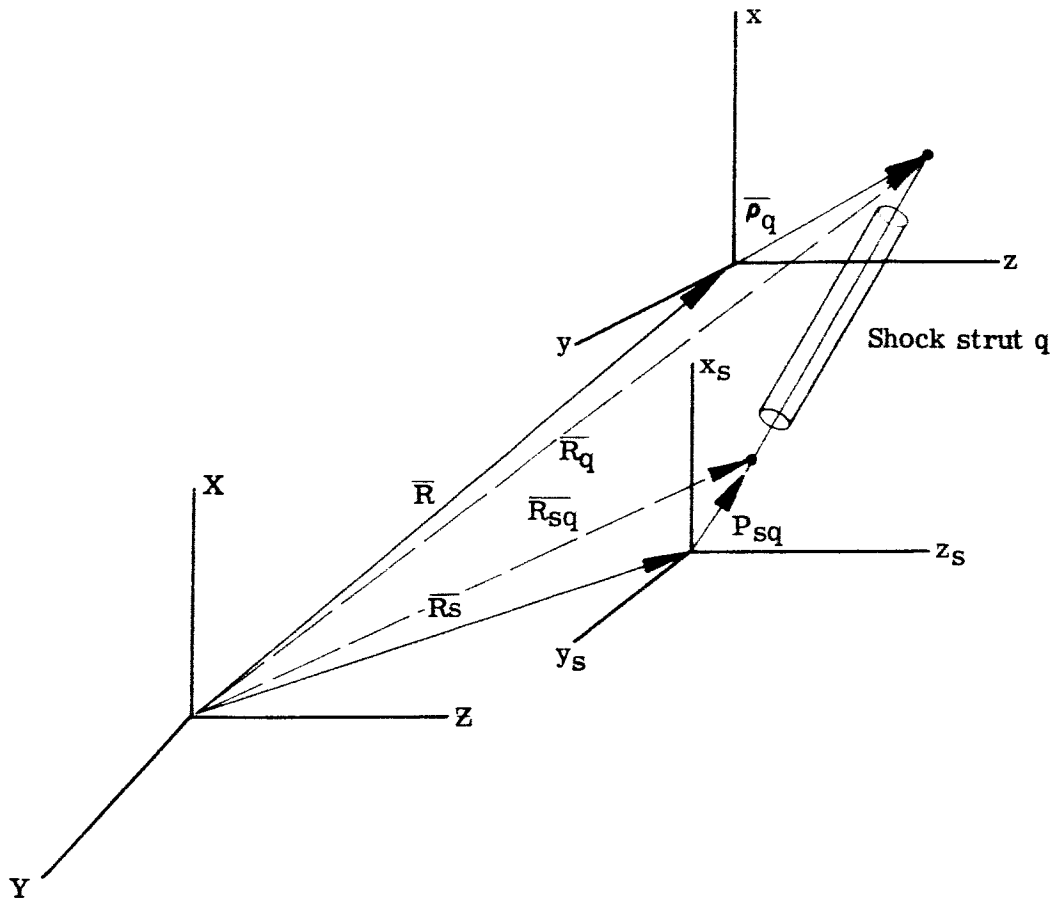
The heat shield is suspended from the capsule by a total of Q shock struts. The capsule coordinate system is denoted by x, y, z; the heat shield coordinate system by x_s, y_s, z_s . X, Y, Z is the space-fixed coordinate system.

The average absolute velocity over the time interval under consideration of the capsule hardpoint of shock strut q is,

$$\vec{v}_{qave} = \dot{\vec{R}}_{ave} + [d] [\vec{\omega}_{ave} \times \vec{\rho}_q] \quad (34)$$

and the average absolute velocity of the heat shield hardpoint is

$$\vec{v}_{sqave} = \dot{\vec{R}}_{save} + [d_s] [\vec{\omega}_{save} \times \vec{\rho}_{sq}] \quad (35)$$



where $\vec{R}_{ave}$, $\vec{\omega}_{ave}$, ω_{save} , and $\vec{R}_{save}$ are the "best average values" available from the integration subroutine.

If the location of shock strut q is given by (x_q, y_q, z_q) , (x_{sq}, y_{sq}, z_{sq}) , then

$$\vec{\rho}_q = x_q \mathbf{i} + y_q \mathbf{j} + z_q \mathbf{k}, \text{ and} \quad (36)$$

$$\vec{\rho}_{sq} = x_{sq} \mathbf{i} + y_{sq} \mathbf{j} + z_{sq} \mathbf{k} \quad (37)$$

in their respective coordinate systems.

The average compressive stroke velocity over the time interval is given by

$$\dot{S}_{sq_{ave}} = (\vec{V}_{sq_{ave}} - \vec{v}_{q_{ave}}) \cdot \vec{U}_{sq} \quad (38)$$

where $\vec{U}_{sq}$ is the unit vector in the direction of the shock strut from the heat shield hardpoint to the capsule hardpoint.

$$\vec{U}_{sq} = \frac{\vec{R}_q - \vec{R}_{sq}}{|\vec{R}_q - \vec{R}_{sq}|} \quad (39)$$

The strut stroke is given by

$$S_{sq} = \int_0^t \dot{S}_{sq} dt = S_{sq_{tn}} + \dot{S}_{sq_{ave}} \Delta t \quad (40)$$

The magnitude of the stroke force, Q_q , will be a function of the stroke position S_{sq} and (possibly) velocity $\dot{S}_{sq}$. Assuming that this force has been determined, the stroking force is then given by

$$\vec{Q}_q = Q_q \vec{U}_{sq} \quad (41)$$

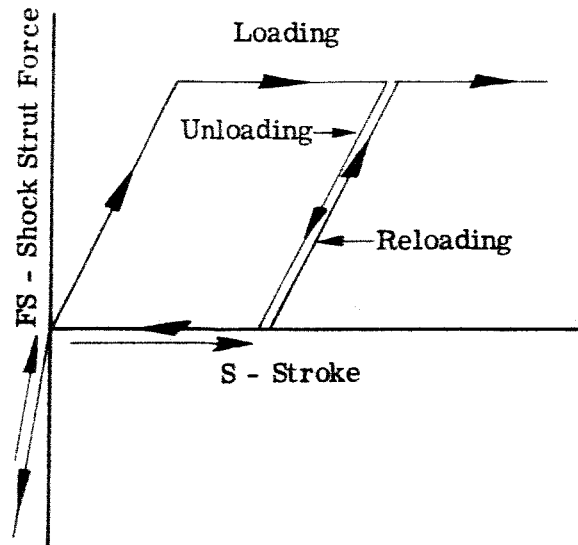
in the fixed coordinate system.

For moment calculations, the vector in the body fixed coordinate system will be employed.

$$\vec{Q}_q^b = [d^{-1}] \vec{Q}_q \quad (42)$$

The moments will then be given by $\vec{p} \times \vec{Q}$ where values of $\vec{p}$ for the capsule and heat shield are given by equations (36) and (37).

The magnitude of the stroke force is assumed to be a function of the stroke given by

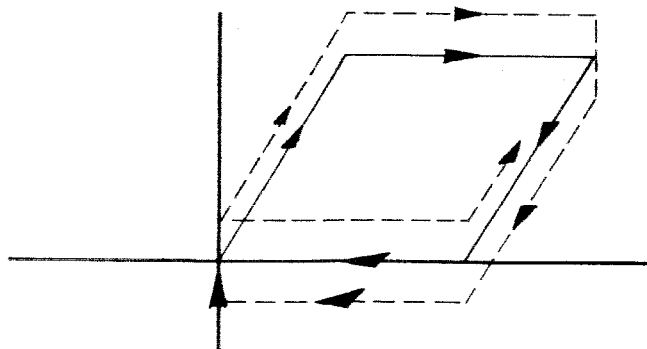


The slope of the loading or unloading portion of the curve is determined by the spring constant K of the honeycomb. It has been shown that the spring rate changes considerably when a portion of the honeycomb capsule has been crushed. This effect may be taken into account through an expression of the spring constant by the empirical equation

$$K = \frac{K_o}{1 + 6 P_c} \quad (43)$$

where K_o is the spring constant of the uncrushed honeycomb and P_c is the ratio of the crushed section of honeycomb to the original length.

A frictional force will be added to the force due to honeycomb compression. The stroke function thus becomes



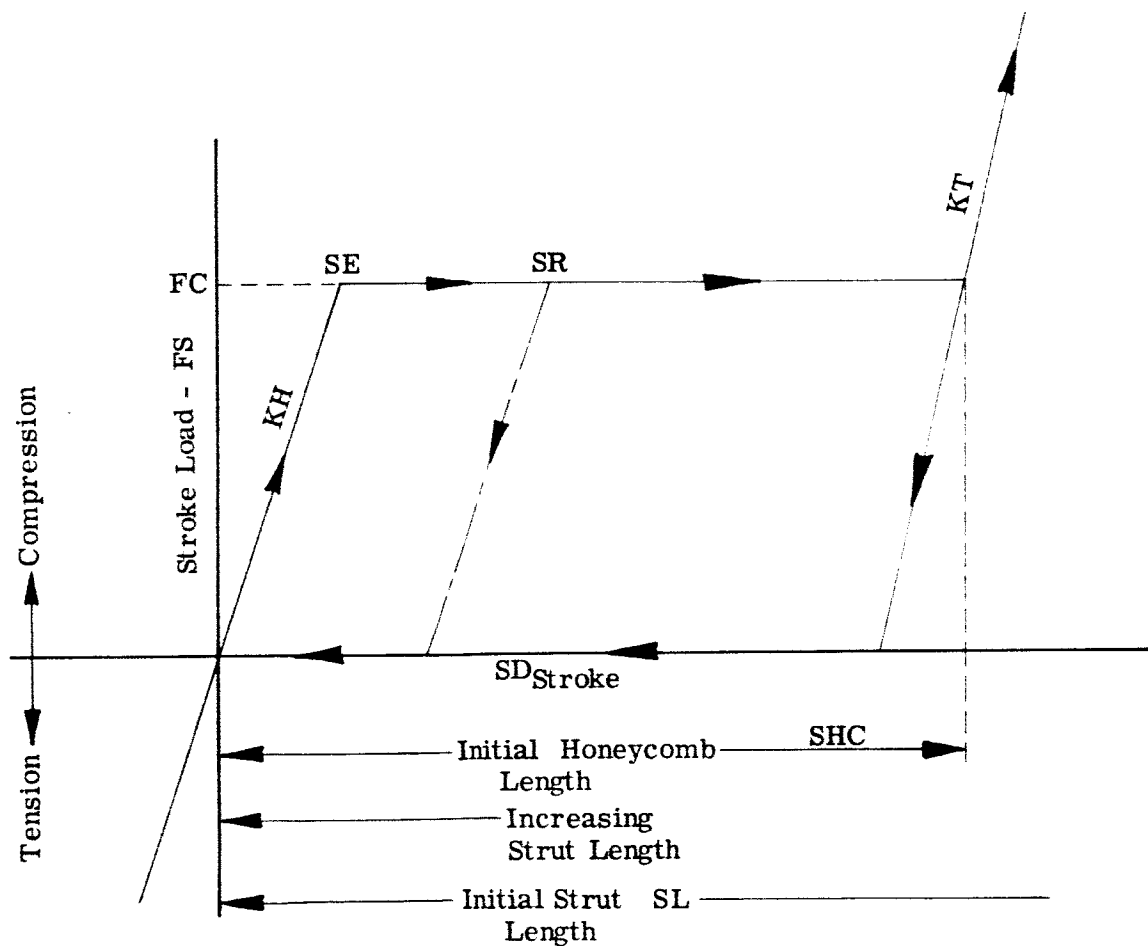
The friction force FF will be of the opposite sign as the stroke velocity, $\dot{S}$.

The magnitude of the shock strut force may therefore be expressed

$$P = FS - FF \frac{\dot{S}}{|\dot{S}|} \quad (44)$$

Stroking forces after complete crushing of honeycomb will be a function of the structural spring constants (elasticity).

The following strut stroke load versus strut length diagram will be used in developing the load-length relationships.



KH = honeycombe spring constant
 KT = stopped strut spring constant (structural elasticity)
 FC = plastic stroking force
 SL = initial strut length
 SD = crushed honeycomb
 S = stroke
 FF = friction force
 SE = stroke at change from elastic to plastic deformation
 SR = stroke at $\dot{S} = 0$
 SHC = initial honeycomb capsule length

For the elastic portion of honeycomb loading, the stroke load is given by

$$FS = KH' \cdot S' \quad (45)$$

where

$$KH' = \frac{KH}{1 + 6\left(\frac{SD}{SHC}\right)} \quad (46)$$

is the spring constant after a portion of honeycomb has undergone plastic deformation

and $S' = S - SD$ (47)

is the elastic compression of the remaining length of honeycomb.

During compression, FS will increase with S until the plastic stroking force FC is reached. P will then remain constant (FC) until either; 1) the stroke changes direction, or 2) the strut stop is reached due to completely crushing the honeycomb capsule.

In case 1), unloading will take place along a line determined by the new spring constant given by equation (46). Since SD has not yet been determined, a relationship between SD and SR must be used.

$$SD = SR - \frac{FC}{KH'} = SR - \frac{FC}{KH} \left(1 + 6 \frac{SD}{SHC} \right) \quad (48)$$

$$\text{then } SD \left(1 + \frac{6FC}{KH \cdot SHC} \right) = SR - \frac{FC}{KH} \quad (49)$$

$$\text{and } SD = \frac{SR - \frac{FC}{KH}}{\left(1 + \frac{6FC}{KH \cdot SHC} \right)}$$

Using this expression for SD in equation (2) yields

$$KH' = \frac{SHC \cdot KH + 6FC}{SHC + 6SR} \quad (50)$$

Strut force after strut "bottoming" due to full compression of the honeycomb is given by

$$FS = FC + KT (SL - SHC - S) \quad (51)$$

Similar relationships apply for strut force due to stroking in the tensile (strut elongated) portion of the strut, where tensile stroke values of initial honeycomb length (SHCT), stroke at $\dot{S} = 0$ (SRT), and portion of honeycomb crushed (SDT) are employed.

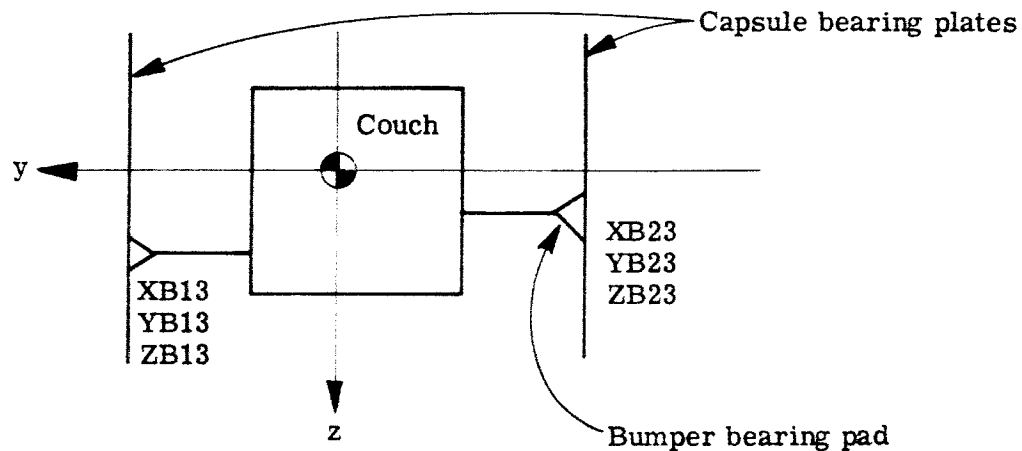
To make the stroke force subroutine as general as possible so that a variety of strut types can be handled, the honeycomb crush force is specified as a table of force versus stroke rather than a constant crush force. Also, provision is made to handle hydraulic or other velocity dependent stroking force components. Thus the complete shock strut stroking force is given by

$$P = FS - FF \frac{\dot{S}}{|\dot{S}|} - C_H \dot{S} |\dot{S}| \quad (52)$$

where C_H is some coefficient determined by the type of velocity dependent element employed. C_H could be made a function of S through a minor revision to the stroke force subroutine.

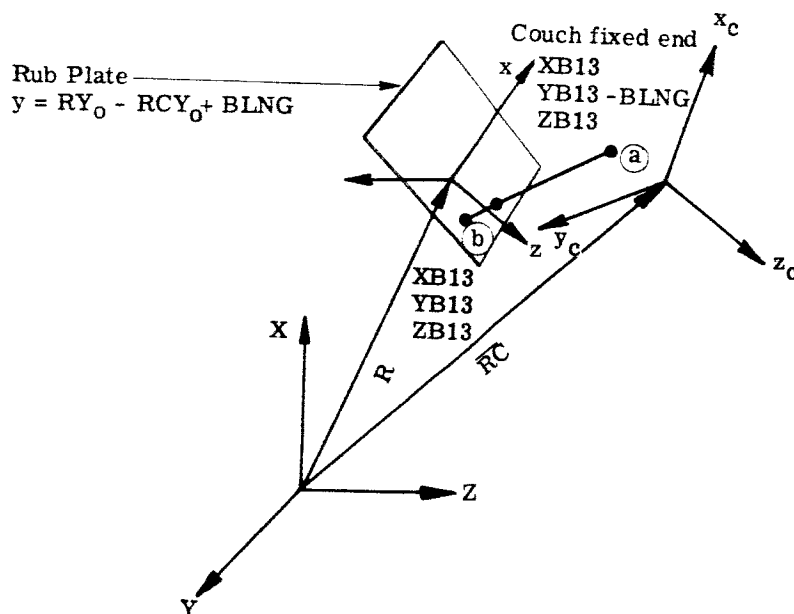
3.4.2 Bumper Forces (Couch Y-Y Struts)

The two couch y direction struts are assumed to be rigidly attached at the couch end, with the other end free to slide in the capsule X-Z plane on bearing plates attached to the capsule. This configuration may be depicted as



where (XB13, YB13, ZB13) are the coordinates of the bearing pad of bumper number one relative to the couch center of gravity at zero time.

It is assumed that stroking the bumpers results in a force normal to the capsule mounted rub plate. The rub plates are assumed to be planar, and parallel to the capsule X-Z plane.



Point (a) may be specified in the fixed coordinate system as

$$\begin{aligned} X_a &= RCX + d_{c11}(XB13) + d_{c12}(YB13-BLNG) + d_{c13}(ZB13) \\ Y_a &= RCY + d_{c21}(XB13) + d_{c22}(YB13-BLNG) + d_{c23}(ZB13) \\ Z_a &= RCZ + d_{c31}(XB13) + d_{c32}(YB13-BLNG) + d_{c33}(ZB13) \end{aligned} \quad (53)$$

Point (b) is similarly specified

$$\begin{aligned} X_b &= RCX + d_{c11}(XB13) + d_{c12}(YB13) + d_{c13}(ZB13) \\ Y_b &= RCY + d_{c21}(XB13) + d_{c22}(YB13) + d_{c23}(ZB13) \\ Z_b &= RCZ + d_{c31}(XB13) + d_{c32}(YB13) + d_{c33}(ZB13) \end{aligned} \quad (54)$$

where BLNG is the bumper length (allowable stroke).

The plane representing the rub plate is given in the capsule coordinate system as

$$y = RYO - RCYO + YB13 \quad (55)$$

The unit normal to the plane in terms of the fixed coordinate system is

$$N = d_{12} i + d_{22} j + d_{32} k \quad (56)$$

and the plane passes through the point

$$\begin{aligned} X_1 &= RX + d_{12}(RYO - RCYO + YB13) \\ Y_1 &= RY + d_{22}(RYO - RCYO + YB13) \\ Z_1 &= RZ + d_{32}(RYO - RCYO + YB13) \end{aligned} \quad (57)$$

The equation for the plane then becomes

$$d_{12}(x - X_1) + d_{22}(y - Y_1) + d_{32}(z - Z_1) = 0 \quad (58)$$

or

$$d_{12}x + d_{22}y + d_{32}z = d_{12}(RX + d_{12}YRP) + d_{22}(RY + d_{22}YRP) + d_{32}(RX + d_{32}YRP)$$

where $YRP = RYO - RCYO + YB13$.

A vector parallel to the line ab in the fixed coordinate system is given by

$$\vec{v} = (x_b - x_a) i + (y_b - y_a) j + (z_b - z_a) k \quad (59)$$

or
$$\vec{v} = d_{c12}(\text{BLNG}) i + d_{c22}(\text{BLNG}) j + d_{c32}(\text{BLNG}) k$$

The equation for a line through point b parallel to $\vec{v}$ is

$$\frac{x - x_b}{d_{c12}(\text{BLNG})} = \frac{y - y_b}{d_{c22}(\text{BLNG})} = \frac{z - z_b}{d_{c32}(\text{BLNG})} = \text{Constant} = C \quad (60)$$

or

$$\frac{x - x_b}{d_{c12}} = \frac{y - y_b}{d_{c22}} = \frac{z - z_b}{d_{c32}} = C_1 \quad (61)$$

Rewriting (9)

$$X = C_1 d_{c12} + X_b \quad (62)$$

$$Y = C_1 d_{c22} + Y_b$$

$$Z = C_1 d_{c32} + Z_b$$

Now substitute these values of x, y, z into equation (6) to obtain the point of intersection of the line and plate

$$C_1 = (-) \frac{d_{12}(RX + d_{12}YRP) + d_{22}(RY + d_{22}YRP) + d_{32}(RZ + d_{32}YRP) - d_{12}x_b - d_{22}y_b - d_{32}z_b}{d_{12}d_{c12} + d_{22}d_{c22} + d_{32}d_{c32}} \quad (63)$$

The point of intersection is determined from equations (10) and strut deflection is given by

$$\begin{aligned} \text{BST1} &= \left\{ (x_b - x)^2 + (y_b - y)^2 + (z_b - z)^2 \right\}^{1/2} \\ &= C_1 \left\{ d_{c12}^2 + d_{c22}^2 + d_{c32}^2 \right\}^{1/2} \end{aligned} \quad (64)$$

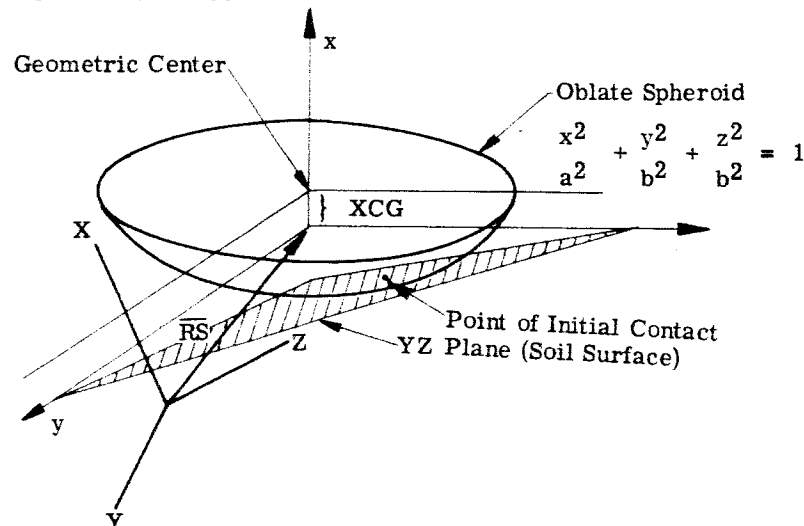
Similar equations define the stroke of bumper number 2 (BST2), for strut capsule end point XB23, YB23, ZB23 assuming the same initial strut length, BLNG.

3.5 GROUND CONTACT FORCES

This section presents the development of equations to determine the forces applied to the heat shield and/or capsule due to contact with a soil surface. The equations derived for the heat shield assume that its surface may be reasonably approximated by the equation for an oblate spheroid. A completely general surface configuration could be added by modifying the program to accept the (x, y, z) coordinates of N points on the heat shield surface. It is assumed that the capsule surface configuration may be approximated by a conic section combined with a cylindrical section at the capsule/heat shield interface. Any capsule surface configuration could be handled in a manner similar to that suggested above for the heat shield surface.

3.5.1 Heat Shield Ground Contact Forces

a. Point of Initial Contact



If the heat shield coordinate system has its origin at the c.g., which is some distance XCG from the geometric center of the oblate spheroid, the heat shield surface is defined by the function

$$f = \frac{(x-XCG)^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{b^2} - 1 = 0 \quad (65)$$

and the unit normal directed outward from this surface is given by

$$\frac{\nabla f}{|\nabla f|} = \frac{\frac{(x-XCG)}{a^2} i + \frac{y}{b^2} j + \frac{z}{b^2} k}{\left[\frac{(x-XCG)^2}{a^4} + \frac{y^2}{b^4} + \frac{z^2}{b^4} \right]^{1/2}} \quad (66)$$

A unit normal to the YZ plane is

$$\hat{r} = i \quad (67)$$

which in the heat shield coordinate system is

$$\hat{r}^S = ds_{11} i + ds_{12} j + ds_{13} k \quad (68)$$

At the point of initial contact, the unit vectors defined by equations (66) and (68) must be equal and of opposite sign. Therefore the i, j, and k components are equal and of opposite sign. This gives the equations

$$U + V + W = 1 \quad (69)$$

$$\frac{U}{a^2} = -ds_{11}^2 \left(\frac{U}{a^2} + \frac{V}{b^2} + \frac{W}{b^2} \right) \text{ or } \frac{(ds_{11}^2 - 1)}{a^2} U + \frac{ds_{11}^2}{b^2} V + \frac{ds_{11}^2}{b^2} W = 0 \quad (70)$$

$$\frac{V}{b^2} = -ds_{12}^2 \left(\frac{U}{a^2} + \frac{V}{b^2} + \frac{W}{b^2} \right) \text{ or } \frac{ds_{12}^2}{a^2} U + \frac{(ds_{12}^2 - 1)}{b^2} V + \frac{ds_{12}^2}{b^2} W = 0 \quad (71)$$

$$\frac{W}{b^2} = -ds_{13}^2 \left(\frac{U}{a^2} + \frac{V}{b^2} + \frac{W}{b^2} \right) \text{ or } \frac{ds_{13}^2}{a^2} U + \frac{ds_{13}^2}{b^2} V + \frac{(ds_{13}^2 - 1)}{b^2} W = 0 \quad (72)$$

where $U = \frac{(x - XCG)^2}{a^2}$, $V = \frac{y^2}{b^2}$, and $W = \frac{z^2}{b^2}$.

Equation(69) and any two of the three remaining equations may be solved using Cramers Rule, giving

$$X = \frac{ds_{11}^2 a^2}{\sqrt{b^2 - ds_{11}^2 (b^2 - a^2)}} + XCG \quad (73)$$

$$Y = \frac{-ds_{12}^2 b^2}{\sqrt{b^2 - ds_{11}^2 (b^2 - a^2)}} \quad (74)$$

$$Z = \frac{-ds_{13}^2 b^2}{\sqrt{b^2 - ds_{11}^2 (b^2 - a^2)}} \quad (75)$$

Which defines the point of initial contact. The height of the heat shield c.g. at contact is

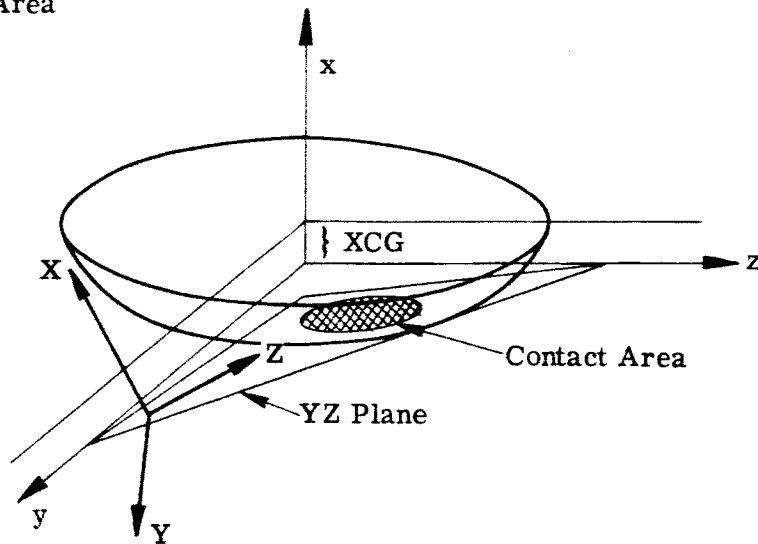
$$\rho_x = -(ds_{11} x + ds_{12} y + ds_{13} z) = \sqrt{b^2 - ds_{11}^2 (b^2 - a^2)} - ds_{11} XCG \quad (76)$$

Thus, contact has occurred if

$$RSX \leq \sqrt{b^2 - ds_{11}^2 (b^2 - a^2)} - ds_{11} XCG \quad (77)$$

Where RSX is the X component of the vector from the origin of the fixed coordinate system on the soil surface to the heat shield c.g.

b. Contact Area



The equation for the curve in the YZ plane which defines the area of contact may be found by a simultaneous solution of the equations for the heat shield surface and the YZ plane.

From the equation for the heat shield surface

$$x = -a \sqrt{1 - \frac{y^2}{b^2} - \frac{z^2}{b^2}} + XCG \quad (78)$$

The equation for the YZ plane in terms of the heat shield coordinate system gives

$$x = - \left(\frac{ds_{12}}{ds_{11}} y + \frac{ds_{13}}{ds_{11}} z + \frac{RSX}{ds_{11}} \right) \quad (79)$$

Setting (78) equal to (79) yields

$$-a \sqrt{1 - \frac{y^2}{b^2} - \frac{z^2}{b^2}} = - \left(\frac{ds_{12}}{ds_{11}} y + \frac{ds_{13}}{ds_{11}} z + \frac{RX}{ds_{11}} \right) \quad (80)$$

where $RX = \frac{RSX}{ds_{11}} + XCG$

Now, squaring equation (80) and combining terms gives

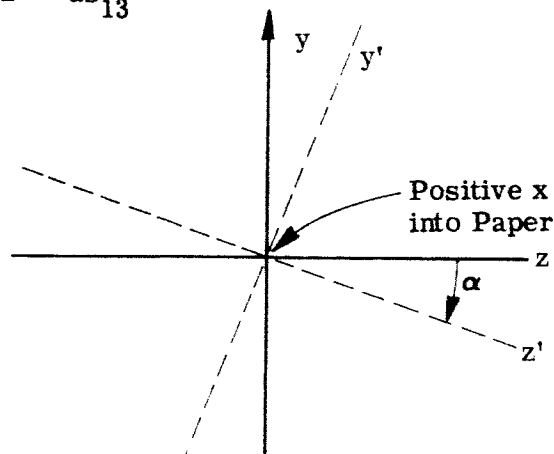
$$\begin{aligned} & \left(\frac{ds_{12}^2}{ds_{11}^2} - \frac{a^2}{b^2} \right) y^2 + \frac{2RSds_{12}}{ds_{11}} y + \frac{2ds_{12}ds_{13}}{ds_{11}^2} yz + \frac{2RXds_{13}}{ds_{11}} z \\ & + \left(\frac{ds_{13}^2}{ds_{11}^2} - \frac{a^2}{b^2} \right) z^2 + RX^2 - a^2 = 0 \end{aligned} \quad (81)$$

From the heat shield geometry it is seen that the contact area must be symmetrical about some plane

$$y = Kz \quad (82)$$

Since this plane of symmetry will pass through the low point on the shield surface, we obtain from equations (74) and (75)

$$\frac{y}{z} = \frac{ds_{12}}{ds_{13}} \quad (83)$$



If the coordinate system is now rotated until the z axis (now called z') lies in the plane of symmetry,

$$\tan \alpha = - \frac{d_{12}}{d_{13}}$$

where α is defined to be positive in the direction shown above. The relationship between the old and new coordinates are given by

$$y = y' \cos \alpha - z' \sin \alpha \quad (84)$$

$$z = y' \sin \alpha + z' \cos \alpha \quad (85)$$

Now,

$$\sin \alpha = \frac{-ds_{12}}{ds_{13}} \sqrt{\frac{ds_{13}^2}{ds_{12}^2 + ds_{13}^2}} \quad (86)$$

$$\cos \alpha = \sqrt{\frac{ds_{13}^2}{ds_{12}^2 + ds_{13}^2}} \quad (87)$$

and therefore,

$$y = \sqrt{\frac{ds_{13}^2}{ds_{12}^2 + ds_{13}^2}} \left(y' + \frac{ds_{12}}{ds_{13}} z' \right) \quad (88)$$

$$z = \sqrt{\frac{ds_{13}^2}{ds_{12}^2 + ds_{13}^2}} \left(z' - \frac{ds_{12}}{ds_{13}} y' \right) \quad (89)$$

Substituting these expressions for y and z into equation (81) and combining terms we obtain

$$y' = \frac{b}{a} \left\{ a^2 - \left[\left(\frac{ds_{12}^2}{ds_{11}^2} + \frac{ds_{13}^2}{ds_{11}^2} + \frac{a^2}{b^2} \right) z'^2 + \frac{2RX}{ds_{11}} \sqrt{ds_{12}^2 + ds_{13}^2} z' + RX^2 \right] \right\}^{1/2} \quad (90)$$

Integration of this equation for y' should yield the contact area. The limits of integration are found by setting $y' = 0$ which gives

$$\left(\frac{ds_{12}^2}{ds_{11}^2} + \frac{ds_{13}^2}{ds_{11}^2} + \frac{a^2}{b^2} \right) z'^2 + \frac{2RX}{ds_{11}} \sqrt{ds_{12}^2 + ds_{13}^2} z' + RX^2 - a^2 = 0 \quad (91)$$

Application of the quadratic formula then yields

$$z' = \frac{\frac{-RX}{ds_{11}} \sqrt{ds_{12}^2 + ds_{13}^2} \pm a \sqrt{\frac{ds_{12}^2}{ds_{11}^2} + \frac{ds_{13}^2}{ds_{11}^2} + \frac{a^2}{b^2} - \frac{RX^2}{b^2}}}{\left(\frac{ds_{12}^2}{ds_{11}^2} + \frac{ds_{13}^2}{ds_{11}^2} + \frac{a^2}{b^2} \right)} \quad (92)$$

Integration of equation (90) yields an integral of the form

$$\int (Az'^2 + Bz' + C)^{1/2} dz'$$

Which may be integrated to yield the result

$$\int (Az'^2 + Bz' + C)^{1/2} dz' = \frac{2Az' + B}{4A} \sqrt{Az'^2 + Bz' + C} + \frac{4AC - B^2}{8A} \left(\frac{1}{\sqrt{-A}} \sin^{-1} \frac{(-2Az' - B)}{\sqrt{B^2 - 4AC}} \right) \quad (93)$$

for $A < 0$. The first term in this result is seen to vanish for both the upper and lower limits of z' . Also, since these limits are

$$z' = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A}$$

the inverse sine term becomes $\sin^{-1}(1)$ for the upper limit of z' and $\sin^{-1}(-1)$ for the lower limit of z' . Thus the total contribution from this term is $(\pi/2) - (-\pi/2) = \pi$.

Substituting values for z' and the constants into what is left of equation (93) gives the area of contact

$$\text{AREA} = ab\pi \left[\frac{\left(\frac{ds_{12}^2}{ds_{11}^2} + \frac{ds_{13}^2}{ds_{11}^2} + \frac{a^2}{b^2} \right) - \frac{RX^2}{b^2}}{\left(\frac{ds_{12}^2}{ds_{11}^2} + \frac{ds_{13}^2}{ds_{11}^2} + \frac{a^2}{b^2} \right)^{3/2}} \right] \quad (94)$$

$$RX = \frac{RSX}{ds_{11}} + XCG \quad (95)$$

To obtain the proper sign for z' of equation (92), the equation may be rewritten

$$z' = \frac{-\frac{ds_{13}}{ds_{11}} RX \sqrt{1 + \frac{ds_{12}^2}{ds_{13}^2}} \pm a \sqrt{\left(\frac{ds_{12}^2}{ds_{11}^2} + \frac{ds_{13}^2}{ds_{11}^2} + \frac{a^2}{b^2} \right) - \frac{RX^2}{b^2}}}{\left(\frac{ds_{12}^2}{ds_{11}^2} + \frac{ds_{13}^2}{ds_{11}^2} + \frac{a^2}{b^2} \right)} \quad (96)$$

The area given by equation (94) is the contact area as projected in the heat shield yz plane. To obtain the area in the ground plane we use the relationship

$$(dA)_s = (dA)_{GP} ds_{11}$$

and rearrange equation (94) to obtain

$$(\text{AREA})_{\text{GP}} = ab \pi \left[\frac{ds_{12}^2 + ds_{13}^2 + ds_{11}^2 \left(\frac{a^2}{b^2} \right) - ds_{11}^2 \left(\frac{RX^2}{b^2} \right)}{\left(ds_{12}^2 + ds_{13}^2 + ds_{11}^2 \frac{a^2}{b^2} \right)^{3/2}} \right] \quad (97)$$

which is the area of contact in the ground plane.

c. Heat Shield Surface Subdivision

The area of a heat shield surface defined by the equation

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{b^2} = 1 \quad (98)$$

is given by

$$\text{AREA} = \int_0^a 2\pi y \sqrt{1 + \left(\frac{dy}{dx} \right)^2} dx \quad (99)$$

for $z = 0, y = b \sqrt{1 - x^2/a^2}$

$$\text{and } \frac{dy}{dx} = \frac{-b x/a^2}{\sqrt{1 - x^2/a^2}}, \quad \left(\frac{dy}{dx} \right)^2 = \frac{b^2 x^2/a^2}{1 - x^2/a^2}$$

$$\text{then } \text{AREA} = \frac{2\pi b}{a^2} \int_0^a \sqrt{a^4 + (b^2 - a^2) x^2} dx \quad (100)$$

from which is obtained

$$\text{AREA} = \pi b^2 + \frac{\pi b a^2}{\sqrt{b^2 - a^2}} \ln \left(\frac{\sqrt{b^2 - a^2} + b}{a} \right) \quad (101)$$

The distance from the center ($x = -a$) to an edge is approximated by

$$P = \frac{\pi(a+b)}{4} \left(1 + \frac{d^2}{4} + \frac{d^4}{64} + \frac{d^6}{256} \right) \quad (102)$$

where $d = \frac{(b-a)}{(b+a)}$

A first approximation of element size is obtained from

$$\Delta' = \sqrt{\text{AREA}/N} \quad (103)$$

where N is the desired total number of surface elements

Element area, A_{el} , is given by

$$A_{el} = (\Delta)^2 \quad (104)$$

The center of the heat shield will contain a circular element of area A_{el} , and will therefore have a radius of

$$r_o = \sqrt{\frac{A_{el}}{\pi}} = \Delta / \sqrt{\pi}$$

From this we obtain the equation

$$n \Delta + \Delta / \sqrt{\pi} = P$$

where n is the number of elements along the curve P . Thus,

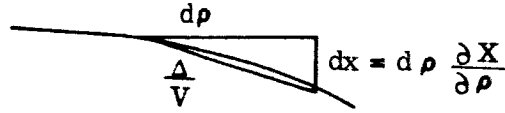
$$n' = (P/\Delta') - 1/\sqrt{\pi} \quad (105)$$

Now, let n be the next larger integer

$$n = \text{INT}(n' + 1) \quad (106)$$

and

$$\Delta = P/(n + 1/\sqrt{\pi}) \quad (107)$$



The radius ρ for a given ring will be found by proceeding along the surface in increments of ΔN , where V is chosen to yield sufficient accuracy, until a distance Δ is achieved, thus establishing ρ .

$$d\rho_v = \frac{\Delta}{V} \sqrt{\frac{b^2 - \rho_{v-1}^2}{b^2 + \left(\frac{a^2}{b^2} - 1\right) \rho_{v-1}^2}} \quad (108)$$

Thus,

$$\rho_{i+1} = \rho_i + \frac{\Delta}{V} \sqrt{\frac{b^2 - \rho_i^2}{b^2 + \left(\frac{a^2}{b^2} - 1\right) \rho_i^2}} + \frac{\Delta}{V} \sqrt{\frac{b^2 - \rho_{i+\frac{1}{v}}^2}{b^2 + \left(\frac{a^2}{b^2} - 1\right) \rho_{i+\frac{1}{v}}^2}} + \frac{\Delta}{V} \sqrt{\frac{b^2 - \rho_{i+\frac{v-1}{v}}^2}{b^2 + \left(\frac{a^2}{b^2} - 1\right) \rho_{i+\frac{v-1}{v}}^2}} \quad (109)$$

The number of elements in ring i is estimated by

$$Ni' = 2\pi\rho_i/\Delta \quad (110)$$

Then let Ni be the closest integer

$$Ni = \text{INT}(Ni' + 0.5) \quad (111)$$

The angle between elements in ring i is then

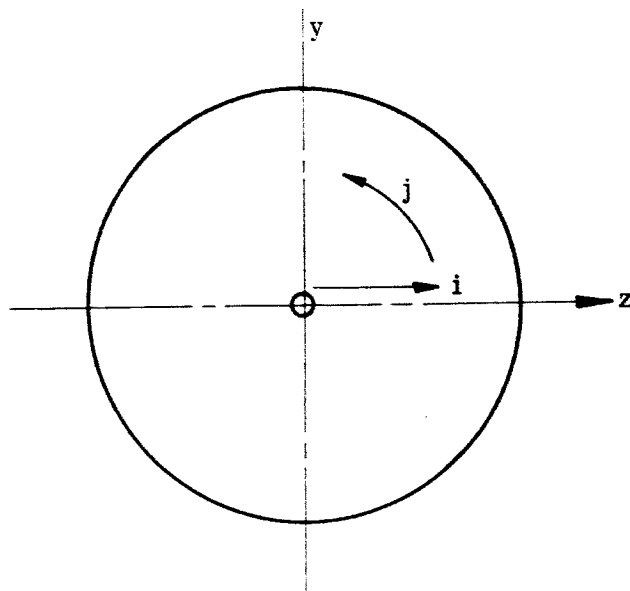
$$d\beta_i = 360/Ni \quad (112)$$

and y and z are defined by

$$y_{ij} = -\rho_i \sin \left[(j-1) d\beta_i \right] \quad (113)$$

$$z_{ij} = \rho_i \cos \left[(j-1) d\beta_i \right] \quad (114)$$

where j ranges from 1 to N_i with the element $j = 1$ located on the positive z axis



d. Forces Resulting from a Honeycomb Heat Shield Hull in Contact with a Rigid Surface

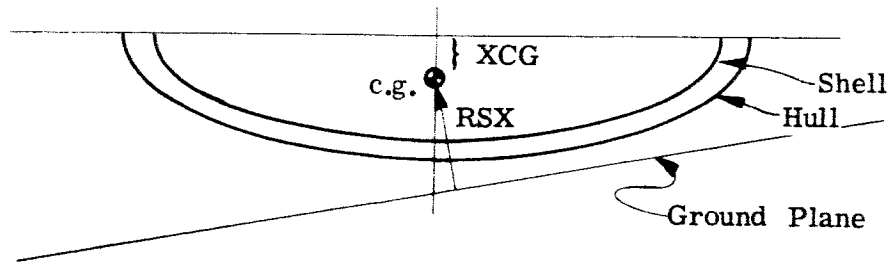
It will be assumed that the external surface of the heat shield (heat shield shell + honeycomb hull) is defined by an equation of the form

$$\frac{(x-XCG)^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{b^2} = 1 \quad (115)$$

For a hull thickness, t , the heat shield shell can then be defined by

$$\frac{(x-XCG)^2}{(a-t)^2} + \frac{y^2}{(b-t)^2} + \frac{z^2}{(b-t)^2} = 1 \quad (116)$$

where XCG is the distance from the heat shield geometric center to the c.g. (and origin of the coordinate system).

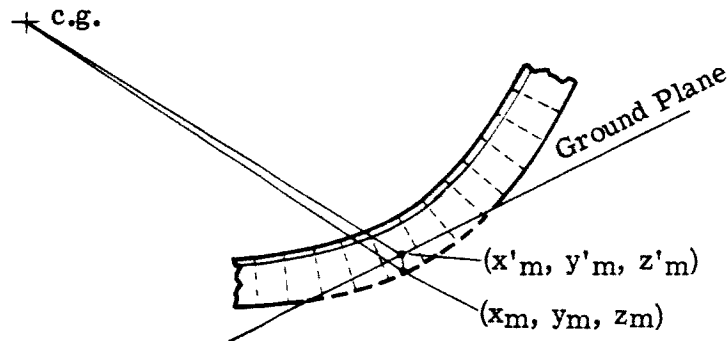


In the heat shield coordinate system, the equation of the ground plane ($X = 0$) becomes

$$ds_{11}x + ds_{12}y + ds_{13}z + RSX = 0 \quad (117)$$

where RSX is the distance from the ground plane to the heat shield c.g. (and origin) and the ds 's are the direction cosines relating the heat shield and ground (fixed) coordinate systems.

A section of the heat shield which is in contact with the soil surface is shown as



where the hull has been divided into elements of equal surface area. We will now consider an element m with the geometric center of the element surface area denoted by (x_m, y_m, z_m) . It is assumed that upon contact with the soil surface the honeycomb will be compressed (either elastically or plastically or both) in a direction normal to the hull surface at the point (x_m, y_m, z_m) . The magnitude of the resulting deflection will be called δ . An equation can now be written relating the vectors from the c.g. to (x_m, y_m, z_m) and to the

center of the area after compression (x'_m, y'_m, z'_m) with the deflection δ multiplied by the unit normal to the hull surface, $\vec{UN}_m$.

$$\vec{OM}' = \vec{OM} - \delta \vec{UN}_m \quad (118)$$

From equation (1) the unit normal is given by

$$\vec{UN}_m = \frac{\nabla f}{|\nabla f|} = \frac{\frac{(x_m - x_{cg})}{a^2} i + \frac{y_m}{b^2} j + \frac{z_m}{b^2} k}{\left[\frac{(x_m - x_{cg})^2}{a^4} + \frac{y_m^2}{b^4} + \frac{z_m^2}{b^4} \right]^{1/2}} \quad (119)$$

Equation (4) may now be written

$$\vec{OM}' = x_m i + y_m j + z_m k - \frac{\delta_m}{\left[\frac{(x_m - x_{cg})^2}{a^4} + \frac{y_m^2}{b^4} + \frac{z_m^2}{b^4} \right]^{1/2}} \left(\frac{(x_m - x_{cg})}{a^2} i + \frac{y_m}{b^2} j + \frac{z_m}{b^2} k \right) \quad (120)$$

Since the point defined by $\vec{OM}'$ lies in the ground plane, equations (117) and (120) may be employed to obtain the result

$$\frac{\delta_m}{\left[\frac{(x_m - x_{cg})^2}{a^4} + \frac{y_m^2}{b^4} + \frac{z_m^2}{b^4} \right]^{1/2}} \left(\frac{ds_{11}}{a^2} (x_m - x_{cg}) + \frac{ds_{12}}{b^2} y_m + \frac{ds_{13}}{b^2} z_m \right) = ds_{11} x_m + ds_{12} y_m + ds_{13} z_m + RSX \quad (121)$$

Now, solving for δ_m

$$\delta_m = A_m \frac{ds_{11} x_m + ds_{12} y_m + ds_{13} z_m + RSX}{b^2 ds_{11} (x_m - xc_g) + a^2 ds_{12} y_m + a^2 ds_{13} z_m} \quad (122)$$

$$\text{where } A_m = \sqrt{b^4 (x_m - xc_g)^2 + a^4 y_m^2 + a^4 z_m^2} \quad (123)$$

Equation (119) may be written

$$\frac{1}{UN_m} = \frac{1}{A_m} \left[b^2 (x_m - xc_g) i + a^2 y_m j + a^2 z_m k \right] \quad (124)$$

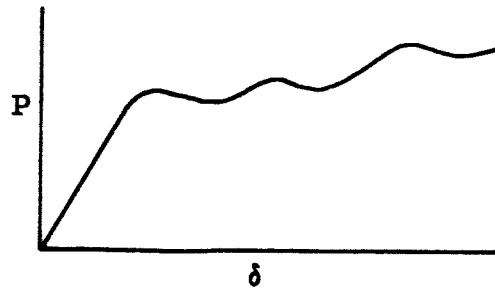
and the point (x'_m, y'_m, z'_m) is defined by

$$x'_m = x_m - \delta_m \frac{b^2}{A_m} (x_m - xc_g) = x_m \left(1 - \frac{\delta_m b^2}{A_m} \right) + \frac{\delta_m b^2}{A_m} (xc_g) \quad (125)$$

$$y'_m = y_m - \delta_m \frac{a^2}{A_m} y_m = y_m \left(1 - \frac{\delta_m a^2}{A_m} \right) \quad (126)$$

$$z'_m = z_m - \delta_m \frac{a^2}{A_m} z_m = z_m \left(1 - \frac{\delta_m a^2}{A_m} \right) \quad (127)$$

The magnitude of the soil force on a given element will be obtained as a function of δ for the element from a table of the form



where P is the pressure on the element. Thus the force is given by

$$F = P \cdot Ael \quad (128)$$

where Ael is the element area.

The total force will be assumed to be composed of a force normal to the soil surface

$$F_n = P \cdot Ael \quad (129)$$

and a friction force opposing the element velocity in the soil (YZ) plane.

$$F_f = \mu F_n \quad (130)$$

where μ is the coefficient of friction.

Denoting a particular element by the subscript ij ,

$$\overrightarrow{F}_{ij} = \overrightarrow{F}_{nij} + \overrightarrow{F}_{fij} \quad (131)$$

where $\overrightarrow{F}_{ij}$ is the total force on the element ij .

$$\overrightarrow{F}_{nij} = (P_{ij} Ael) i \quad (132)$$

$$\overrightarrow{F}_{fij} = \frac{-(\mu P_{ij} Ael)}{\left| \overrightarrow{V}_{ij(YZ)} \right|} \left[\overrightarrow{V}_{ijY} j + \overrightarrow{V}_{ijZ} k \right] \quad (133)$$

are the normal and friction forces in the fixed coordinate system, where $\overrightarrow{V}_{ij(YZ)}$ is the velocity of element ij in the YZ plane.

$$\begin{aligned}
\overrightarrow{V}_{ij} &= \overline{RSVEL} + [ds] \overrightarrow{\omega}_{ij} \times \begin{matrix} i \\ j \\ k \end{matrix} \\
&= \overline{RSVEL} + [ds] \begin{vmatrix} i & j & k \\ \omega_{SX} & \omega_{SY} & \omega_{SZ} \\ x_{ij} & y_{ij} & z_{ij} \end{vmatrix} \\
&= \overline{RSVEL} + [ds] \left[(z_{ij} \omega_{SY} - y_{ij} \omega_{SZ}) i \right. \\
&\quad \left. + (x_{ij} \omega_{SZ} - z_{ij} \omega_{SX}) j + (y_{ij} \omega_{SX} - x_{ij} \omega_{SY}) k \right]
\end{aligned} \tag{134}$$

and

$$\begin{aligned}
V_{ijx} &= RSXVEL + ds_{11} (z_{ij} \omega_{SY} - y_{ij} \omega_{SZ}) + ds_{12} (x_{ij} \omega_{SZ} - z_{ij} \omega_{SX}) \\
&\quad + ds_{13} (y_{ij} \omega_{SX} - x_{ij} \omega_{SY})
\end{aligned} \tag{135}$$

$$\begin{aligned}
V_{ijy} &= RSYVEL + ds_{21} (z_{ij} \omega_{SY} - y_{ij} \omega_{SZ}) + ds_{22} (x_{ij} \omega_{SZ} - z_{ij} \omega_{SX}) \\
&\quad + ds_{23} (y_{ij} \omega_{SX} - x_{ij} \omega_{SY})
\end{aligned} \tag{136}$$

$$\begin{aligned}
V_{ijz} &= RSZVEL + ds_{31} (z_{ij} \omega_{SY} - y_{ij} \omega_{SZ}) + ds_{32} (x_{ij} \omega_{SZ} - z_{ij} \omega_{SX}) \\
&\quad + ds_{33} (y_{ij} \omega_{SX} - x_{ij} \omega_{SY})
\end{aligned} \tag{137}$$

$$\left| \overrightarrow{V}_{ij(yz)} \right| = \sqrt{(V_{ijy})^2 + (V_{ijz})^2} \tag{138}$$

A more accurate calculation of element velocity may be obtained by replacing x_{ij} , y_{ij} , and z_{ij} by $(x', y', z')_{ij}$ from equations (125), (126), and (127).

The element forces may now be written

$$F_{ijx} = (P_{ij} \cdot Ael) \tag{139}$$

$$F_{ijy} = \frac{-\mu(P_{ij} \cdot Ael)}{\left| \overrightarrow{V}_{ij(yz)} \right|} V_{ijy} \tag{140}$$

$$F_{ijz} = \frac{-\mu(P_{ij} A_{el})}{|\bar{V}_{ij(yz)}|} V_{ijz} \quad (141)$$

The total soil force on the heat shield surface is then obtained from

$$FSGX = \sum F_{ijx} \quad (142)$$

$$FSGY = \sum F_{ijy} \quad (143)$$

$$FSGZ = \sum F_{ijz} \quad (144)$$

The moment on the heat shield due to the soil force on element ij is given by

$$\vec{T}_{ij} = \vec{r}_{ij} \times \vec{F}_{ij}^s \quad (145)$$

Where the forces must now be defined in the heat shield coordinate system

$$F_{ijx}^s = ds_{11} F_{ijx} + ds_{21} F_{ijy} + ds_{31} F_{ijz} \quad (146)$$

$$F_{ijy}^s = ds_{12} F_{ijx} + ds_{22} F_{ijy} + ds_{32} F_{ijz} \quad (147)$$

$$F_{ijz}^s = ds_{13} F_{ijx} + ds_{23} F_{ijy} + ds_{33} F_{ijz} \quad (148)$$

$$\vec{T}_{ij} = \begin{vmatrix} i & j & k \\ x_{ij} & y_{ij} & z_{ij} \\ F_{ijx}^s & F_{ijy}^s & F_{ijz}^s \end{vmatrix} \quad (149)$$

$$T_{ijx} = F_{ijz}^s (y_{ij}) - F_{ijy}^s (z_{ij}) \quad (150)$$

$$T_{ijy} = F_{ijx}^s (z_{ij}) - F_{ijz}^s (x_{ij}) \quad (151)$$

$$T_{ijz} = F_{ijy}^s (x_{ij}) - F_{ijx}^s (y_{ij}) \quad (152)$$

As in the velocity calculations of equations (135) and (138), replacing x , y , and z above by x' , y' , and z' from equations (125), (126), and (127) will result in greater accuracy.

The total moment on the heat shield due to soil forces is then found from

$$TSGX = \Sigma T_{ijx} \quad (153)$$

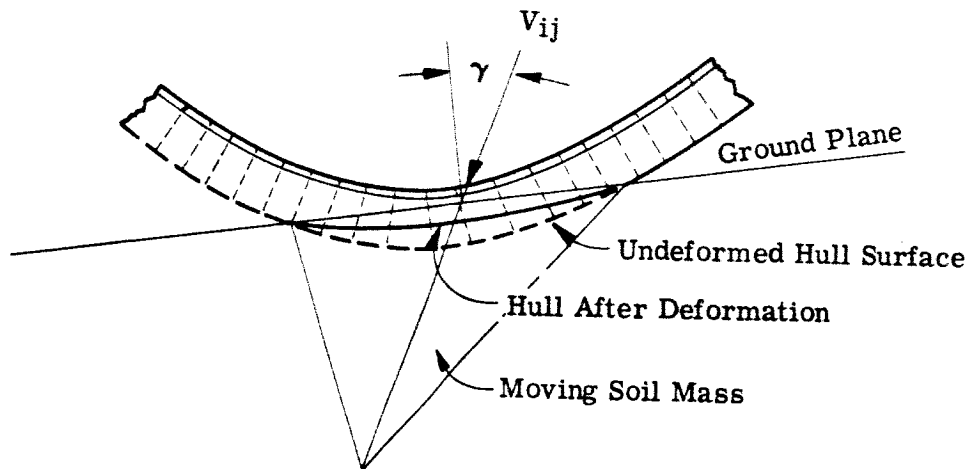
$$TSGY = \Sigma T_{ijy} \quad (154)$$

$$TSGZ = \Sigma T_{ijz} \quad (155)$$

e. Modifications to Heat Shield/Soil Contact Force Equations to Account For Real Soils

The inclusion of real soil dynamics into the equations previously derived for hard surface impact will basically involve a force balance between the hull and soil to determine hull deformation.

A section of the heat shield hull in contact with the soil surface may be pictured as shown below



The following procedure will be employed to determine the forces on the hull due to ground contact.

1. Determine area of contact. This could be achieved by determining the points of the hull in contact with the soil and summing. It is believed, however, that it will be advantageous to calculate contact area directly at this time, avoiding indexing over the hull surface until later in the calculations.

An expression for contact area is given by equation (97) as

$$\text{AREA} = ab\pi \left[\frac{ds_{12}^2 + ds_{13}^2 + ds_{11}^2 \left(\frac{a^2}{b^2} \right) - ds_{11}^2 \left(\frac{RX^2}{b^2} \right)}{\left(ds_{12}^2 + ds_{13}^2 + ds_{11}^2 \frac{a^2}{b^2} \right)^{3/2}} \right] \quad (156)$$

where $RX = \frac{RSX}{ds_{11}} + XCG$

2. Convert to equivalent circular area.

$$r = \sqrt{\text{AREA}/\pi} \quad (157)$$

3. Calculate velocity of center of contact area. From equations (88), (89), and (96) the center of the area of contact is obtained as

$$z'_c = \frac{-\frac{ds_{13}}{ds_{11}} RX \sqrt{1 + \frac{ds_{12}^2}{ds_{13}^2}} - SS(RX) \sqrt{ds_{13}^2 + ds_{12}^2}}{\left(\frac{ds_{12}^2}{ds_{11}^2} + \frac{ds_{13}^2}{ds_{11}^2} + \frac{a^2}{b^2} \right)} = \frac{-SS(RX) \sqrt{ds_{13}^2 + ds_{12}^2}}{\left(ds_{12}^2 + ds_{13}^2 + ds_{11}^2 \frac{a^2}{b^2} \right)} \quad (158)$$

$$y'_c = 0$$

$$y_c = \sqrt{\frac{d_{13}^2}{d_{12}^2 + d_{13}^2}} \left(\frac{ds_{12}}{ds_{13}} \right) z'_c = \sqrt{\frac{ds_{12}^2}{ds_{12}^2 + ds_{13}^2}} \left(\frac{S_{12}}{S_{13}} \right) z'_c \quad (159)$$

$$z_c = \frac{ds_{13}}{ds_{12}} y_c \quad (160)$$

$$x_c = -a \sqrt{1 - \frac{(y_c^2 + z_c^2)}{b^2}} + X_{CG} \quad (161)$$

The velocity is then given by

$$\overline{V}_c = \overline{RSVEL} + [ds] \overline{\omega}_s \times \overline{r}_c \quad (162)$$

$$\begin{aligned} \text{or } V_{cx} = & RSXVEL + ds_{11} [\omega_y z_c - \omega_z y_c] + ds_{12} [\omega_z x_c - \omega_x z_c] \\ & + ds_{13} [\omega_x y_c - \omega_y x_c] \end{aligned} \quad (163)$$

$$\begin{aligned} V_{cy} = & RSYVEL + ds_{21} [\omega_y z_c - \omega_z y_c] + ds_{22} [\omega_y x_c - \omega_x z_c] \\ & + ds_{23} [\omega_x y_c - \omega_y x_c] \end{aligned} \quad (164)$$

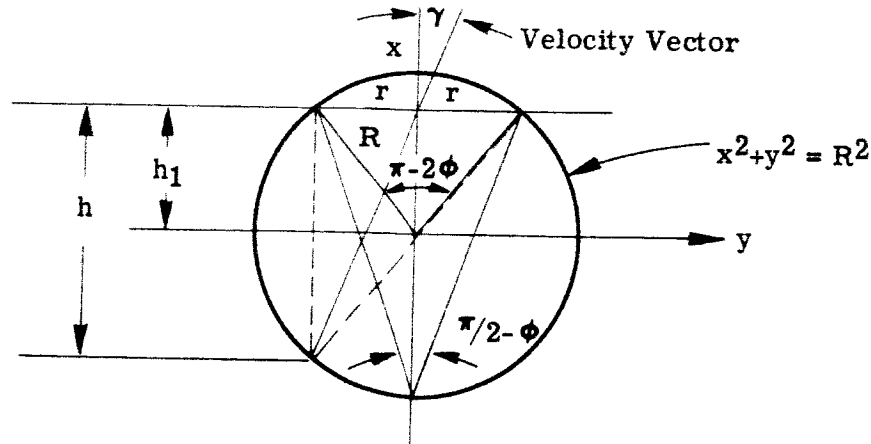
$$\begin{aligned} V_{cz} = & RSZVEL + ds_{31} [\omega_y z_c - \omega_z y_c] + ds_{32} [\omega_z x_c - \omega_x z_c] \\ & + ds_{33} [\omega_x y_c - \omega_y x_c] \end{aligned} \quad (165)$$

4. Determine mass and surface area of conical soil wedge.

The volume of the cone is $1/3 \times \text{base area} \times \text{height}$

$$\text{Base Area} = \pi r^2 \quad (166)$$

$$h_1 = \sqrt{R^2 - r^2} \quad (167)$$



$$r/R = \sin \left(\frac{\pi}{2} - \phi \right) = \cos \phi, \text{ or } R = r/\cos \phi \quad (168)$$

The velocity vector is given by the equation

$$x = \frac{1}{\sin \gamma} y + \sqrt{R^2 - r^2} \quad (169)$$

The height of the soil wedge is given by

$$h = h_1 - x_v \quad (170)$$

where x_v is the lower intersection of the velocity vector and the circle $x^2 + y^2 = R^2$

From the equation of the velocity vector,

$$y^2 = \sin^2 \gamma \left(R^2 - r^2 - 2x \sqrt{R^2 - r^2} + x^2 \right) \quad (171)$$

Combining the two equations for y^2

$$\left(1 + \sin^2 \gamma \right) x^2 - \left(2 \sin^2 \gamma \sqrt{R^2 - r^2} \right) x + R^2 \left(\sin^2 \gamma - 1 \right) - r^2 \sin^2 \gamma = 0 \quad (172)$$

Now, substituting $r = R \cos \phi$ and $1 - \cos^2 \phi = \sin^2 \phi$

$$\left(1 + \sin^2 \gamma \right) x^2 - \left(2 \sin^2 \gamma R \sin \phi \right) x + R^2 \left(\sin^2 \gamma - 1 \right) - R^2 \cos^2 \phi \sin^2 \gamma = 0 \quad (173)$$

Then

$$x = R \left[\frac{\sin^2 \gamma \sin \phi \pm \sqrt{2\sin^4 \gamma \sin^2 \phi + \cos^2 \phi \sin^2 \gamma - \sin^4 \gamma + 1}}{(1 + \sin^2 \gamma)} \right] \quad (174)$$

Choosing the negative value of the square root in the equation for x, the following expression for soil wedge height, h, is obtained.

$$h = \sqrt{R^2 - r^2} - R \left[\frac{\sin^2 \gamma \sin \phi - \sqrt{2\sin^4 \gamma \sin^2 \phi + \cos^2 \phi \sin^2 \gamma - \sin^4 \gamma + 1}}{(1 + \sin^2 \gamma)} \right] \quad (175)$$

The mass of the conical soil wedge is then given by

$$M_s = \pi r^2 h \rho_s / 3.0 \quad (176)$$

Surface area of the soil wedge for a right circular cone is given by

$$A_s = \pi r \times \text{slant height} \quad (177)$$

The surface area for the oblique cone resulting from impact at an angle γ will be approximated by using an "average" slant height in the above equation

$$SH1 = \sqrt{h^2 + (r + h \tan \gamma)^2} \quad (178)$$

$$SH2 = \sqrt{h^2 + (r - h \tan \gamma)^2} \quad (179)$$

$$\text{and } A_s = \pi r \left(\sqrt{h^2 + (r + h \tan \gamma)^2} + \sqrt{h^2 + (r - h \tan \gamma)^2} \right) / 2.0 \quad (180)$$

5. Compute the generalized spring rate for the soil and for each soil incremental area

$$K = \frac{\pi^2}{\pi + 1} \frac{Er}{(1 - \mu^2)} \quad (181)$$

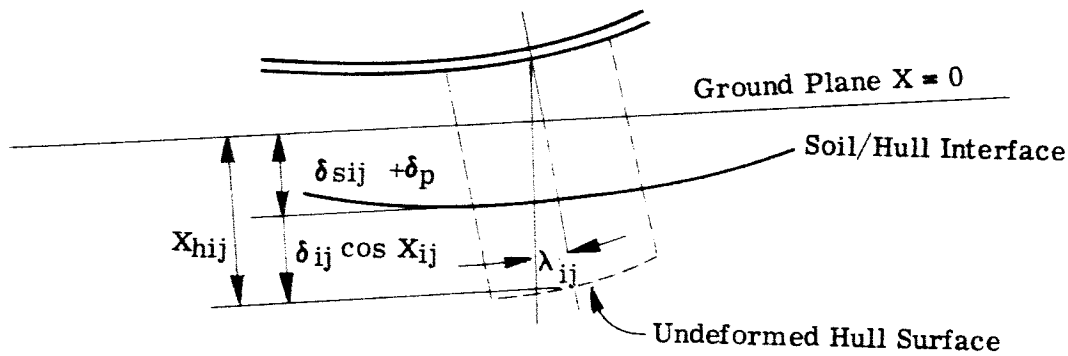
where E = elastic modulus of the soil
r = radius of loaded area
 μ = Poisson's ratio - (0.25 assumed)

The spring constant for each increment of area is

$$K_{el} = K \cdot \frac{A_{el}}{AREA}$$

where A_{el} is the element area and $AREA$ is the total contact area, πr^2

6. Determine hull deformation, δ_{ij}



where

λ_{ij} is the angle between the normal to the ground plane and the normal to the heat shield surface at point ij

δ_{ij} is the hull deformation normal to the hull surface

δ_{sij} = elastic deformation of the soil mass

δ_p = plastic deformation of the soil mass

X_{hij} = total deformation = $\delta_{ij} + \delta_{sm} + \delta_p$

$$\text{Then } \delta_{ij} = (X_{hij} - \delta_{sij} - \delta_p) / \cos \lambda_{ij} \quad (183)$$

where δ_p is based upon a projection from the previous time increment and δ_{sij} is found from compatibility of the hull load F_{ij} and the soil load F_{sij} where

$$F_{sij} = K_{el} (\delta_{sij}) = K_{el} (X_{hij} - \delta_p - \delta_{ij}) \quad (184)$$

and $F_{ijx} = f(\delta_{ij})$, such as (185)



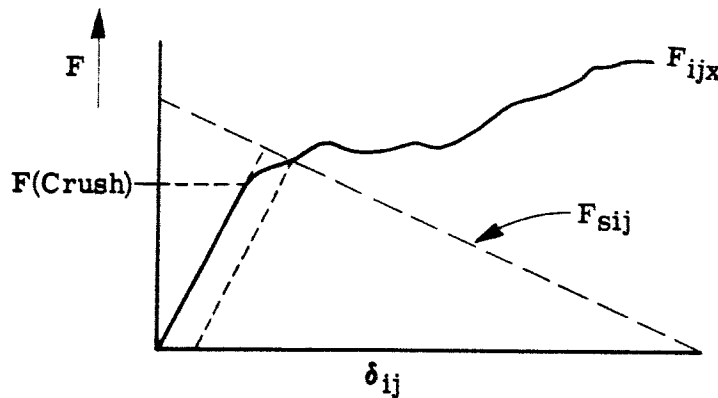
X_{hij} is equivalent to the hull deformation due to hard surface impact and is therefore given by equation (122) as

$$X_{hij} = A_{ij} \frac{ds_{11} x_{ij} + ds_{12} y_{ij} + ds_{13} z_{ij} + RSX}{b^2 ds_{11} (x_{ij} - XCG) + a^2 ds_{12} y_{ij} + a^2 ds_{13} z_{ij}} \quad (186)$$

where the constant A_{ij} is given by

$$A_{ij} = \sqrt{b^4 (x_m - XCG)^2 + a^4 y_{ij}^2 + a^4 z_{ij}^2} \quad (187)$$

Now a "trial and error" solution to obtain $F_{ijx} = F_{sij}$ will give the required value of δ_{ij} .



In the elastic portion of the honeycomb stroke load curve the force on the hull is given by

$$F_{ijx} = CHS (Ael) (\delta_{ij}) \quad (188)$$

where CHS is the honeycomb spring constant.

The force on the soil is given by

$$F_{sij} = Kel(X_{hij} - \delta_p) - Kel \delta_{ij} \quad (189)$$

Equating (188) and (189) and solving for δ_{ij} ,

$$\delta_{ij} = \frac{Kel (X_{hij} - \delta_p)}{CHS(Ael) + Kel} \quad (190)$$

We can find F_{ijx} from equation (1)

$$\begin{array}{c} \text{NO} \\ \boxed{\text{IS } F_{ijx} \leq F(\text{crush})?} \\ \text{YES} \end{array}$$

If yes, the stroke is in the elastic portion of the curve, and F_{ijx} has been defined.

If no, δ_{ij} must be increased until $F_{ijx} = F_{sij}$, where F_{ijx} is obtained by interpolation within the shield surface pressure versus deflection table.

7. Initialize new generalized soil mass velocity by setting its kinetic energy equal to the kinetic energy of the soil mass at the end of the previous time increment

$$\frac{1}{2} M_p \dot{\delta}_{pp}^2 = \frac{1}{2} M \dot{\delta}_p^2 \quad (191)$$

$$\text{or } \dot{\delta}_p = \dot{\delta}_{pp} \sqrt{\frac{M_p}{M}} \quad (192)$$

where $\dot{\delta}_p$ = new soil mass velocity
 $\dot{\delta}_{pp}$ = previous soil mass velocity
 M = new soil mass
 M_p = previous soil mass

8. Determine δ_p for next time increment from the differential equation defining the motion of the soil mass

$$M \ddot{\delta}_p = FSGX - A(\gamma) \cdot FS - B(\gamma) \frac{(A_s)(\rho_s)}{2} K\phi_c \dot{\delta}_p^2 \quad (193)$$

where $A(\gamma)$ and $B(\gamma)$ are functions of the angle of impact, γ ,
 FS is the static bearing strength of the soil, and
 $K\phi_c$ is a function of the angle of internal friction and the cohesive shear strength of the soil.

3.5.2 Forces Due to Capsule/Soil Contact

The equation for the conical portion of the capsule is (see sketch on next page for explanation of symbols)

$$\frac{y^2}{b^2} + \frac{z^2}{b^2} - \frac{(HC - HCG - x)^2}{(HC - HCYL)^2} = 0, \quad (HTOP - HCG) \geq x \geq (HCG - HCYL) \quad (194)$$

For the cylindrical portion of the capsule

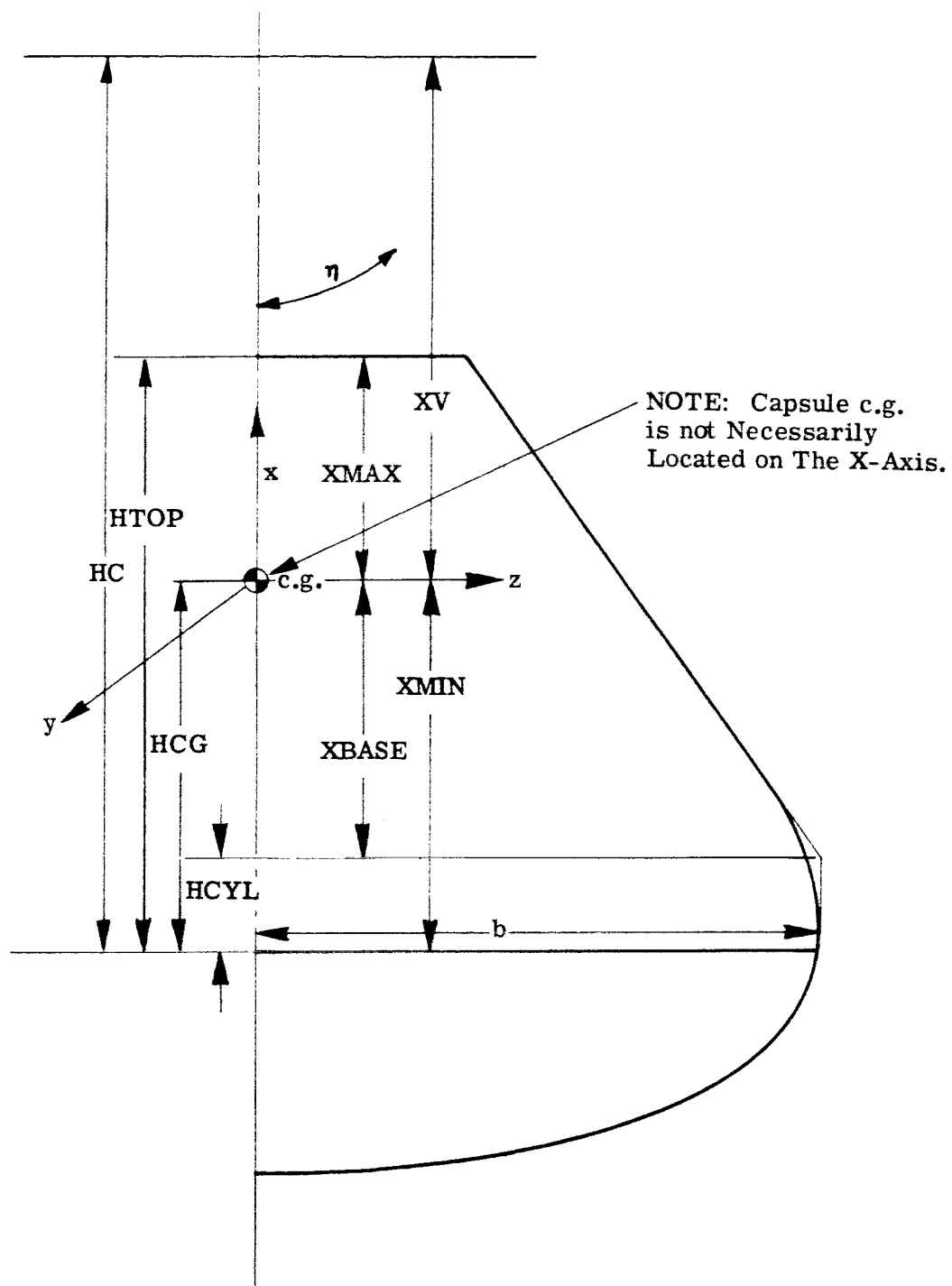
$$y^2 + z^2 = b^2, \quad (HCYL - HCG) \geq x \geq (-HCG) \quad (195)$$

It will be assumed that HC, HTOP, HCG, and η are specified. HCYL may be found from

$$HCYL = HC - b/\tan \eta \quad (196)$$

Then equation (1) may be written

$$\frac{y^2}{b^2} + \frac{z^2}{b^2} - \frac{(HC - HCG - x)^2}{b^2} (\tan \eta)^2 = 0, \quad (HTOP - HCG) \geq x \geq (HCG - HCYL) \quad (197)$$



Capsule Configuration Assumed

Now define constants as follows:

$$\begin{aligned}
 XV &= HC-HCG = \text{distance from origin (cg) to vertex} \\
 XMAX &= HTOP-HCG = \text{distance from c.g. to top of capsule} \\
 XBASE &= HCYL-HCG = \text{distance from c.g. to base of cone} \\
 XMIN &= -HCG = \text{distance from c.g. to base of capsule}
 \end{aligned}$$

Now the equations for the capsule surface are

$$y^2 + z^2 - (\tan \eta)^2 (XV - x)^2 = 0, XMAX \geq x \geq XBASE \quad (198)$$

$$y^2 + z^2 = b^2, XBASE \geq x \geq XMIN \quad (199)$$

assuming the capsule c.g. is located on the x axis.

The capsule surface will be divided into a total of M equal area elements. The total area of the capsule surface (neglecting the top of the capsule is found as follows:

$$\text{Area of cone} = \pi S (b_1 + b_2) \quad (200)$$

S = slant height

b_1 = radius of base

b_2 = radius of truncated surface

$$A_{\text{cone}} = \frac{\pi b (XV - XBASE)}{\cos \eta} - \frac{b (XV - XMAX)}{(XV - XBASE)} \cdot \frac{(XV - XMAX)}{\cos \eta} \quad (201)$$

$$A_{\text{cone}} = \frac{\pi b}{\cos \eta} \left((XV - XBASE) - \frac{(XV - XMAX)^2}{(XV - XBASE)} \right) \quad (202)$$

$$\text{Area of cylinder} = 2\pi b (XBASE - XMIN) \quad (203)$$

$$\text{Finally AREA} = \pi b \left\{ 2*(XBASE - XMIN) + \left((XV - XBASE) - \frac{(XV - XMAX)^2}{(XV - XBASE)} \right) / \cos \eta \right\} \quad (204)$$

The estimate of element area ($A_{el} = \Delta^2$) is given by

$$\Delta' = \text{AREA}/N \quad (205)$$

The element dimensions will then be altered slightly to obtain an integer number of elements along a line on the surface of the capsule defined by $y = 0, z = \text{positive}$.

This distance is given by

$$P = \frac{(XV - XBASE)}{\cos \eta} - \frac{(XV - XMAX)}{\cos \eta} + (XBASE - XMIN) \quad (206)$$

or

$$P = \frac{XMAX - XBASE}{\cos \eta} + (XBASE - XMIN) \quad (207)$$

The number of elements of size x located along this line is estimated by

$$n' = P/\Delta' \quad (208)$$

It is desired to make n the next larger integer, thus

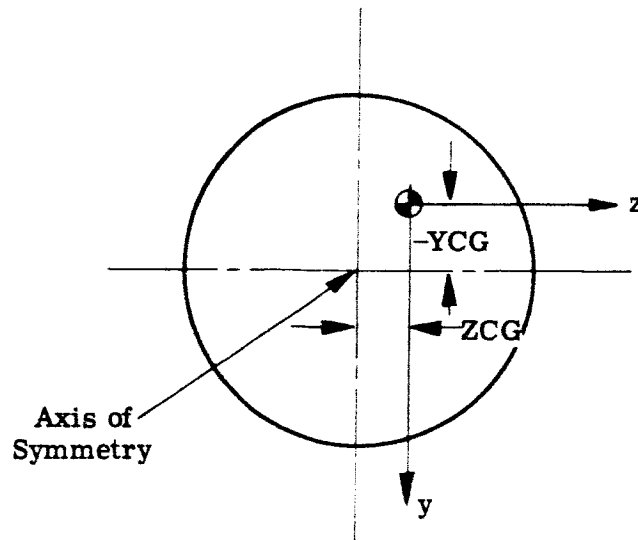
$$n = \text{INT}(n' + 1) \quad (209)$$

The x coordinate of each of the elements along the line defines a ring of elements around the capsule surface.

Before defining the elements in the various rings, we will correct equations (198) and (199) to account for a non-symmetrical location of the capsule c.g. Defining the y and z locations of the c.g. with respect to the line of symmetry by YCG and ZCG , equations (198) and (199) become

$$(y + YCG)^2 + (z + ZCG)^2 - (\tan \eta)^2 (XV - x)^2 = 0 \quad (210)$$

$$(y + YCG)^2 + (z + ZCG)^2 = b^2 \quad (211)$$



where the c.g. locations are measured from the axis of symmetry as shown at the right. This sketch represents looking at a section through the c.g. from above (positive x out of the paper).

The element size, Δ , may now be defined as

$$\Delta = P/n \quad (212)$$

The x coordinate of the first ring (starting at the capsule base) will be

$$x_1 = X_{MIN} + \Delta/2 \quad (213)$$

and rings will be spaced by Δ (as measured on the surface) until n rings are defined.

On the conic portion of the capsule

$$x_{i+1} - x_i = \Delta \cos \eta$$

or

$$x_{i+1} = x_i + \Delta \cos \eta \quad (214)$$

A test will be made along the cylindrical portion to determine the point of transition between cylinder and cone.

$$\begin{array}{ccc} \text{NO} & \boxed{\text{IS } x_i + \Delta > \text{XBASE?}} & \text{YES} \end{array}$$

$$\text{if no, } x_{i+1} = x_i + \Delta \quad (215)$$

$$\text{if yes, } x_{i+1} = \text{XBASE} - (x_i + \Delta - \text{XBASE}) \cos \eta$$

$$\text{or } x_{i+1} = \text{XBASE} + \text{XBASE} - [(x_i + \Delta)] \cos \eta \quad (216)$$

When $I = n$, all rings have been defined,

The radius of each ring is given by

$$\rho_i = (XV - x_i) \tan \eta, \text{XMAX} \geq x_i \geq \text{XBASE} \quad (217)$$

$$\rho_i = b, \text{XBASE} \leq x_i \leq \text{XMIN} \quad (218)$$

where ρ is measured from the axis of symmetry

Ring circumference is given by

$$C_i = 2 \pi \rho_i \quad (219)$$

and the number of elements in ring i is estimated by

$$N'_i = \frac{2 \pi \rho_i}{\Delta} \quad (220)$$

$$\text{and } N_i = \text{INT} (N'_i + 0.5) \quad (221)$$

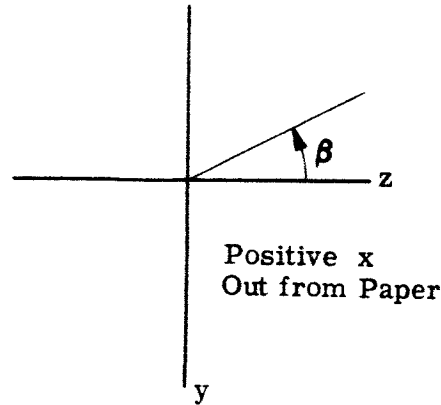
The angle between elements is given by

$$d\beta_i = 360/N_i \quad (222)$$

and the angular position of an element ij is

$$\beta_{ij} = (j - 1) (360/N_i), j = 1, 2, 3, \dots, N_i \quad (223)$$

Positive β will be measured in a counterclockwise direction from the positive z axis. Using this definition for β , the y and z coordinates of element ij are defined as follows:



$$y_{ij} = -\rho_i \sin \left[(j-1)(d\beta_i) \right] - YCG \quad (224)$$

$$z_{ij} = \rho_i \cos \left[(j-1)(d\beta_i) \right] - ZCG \quad (225)$$

In order to minimize the number of elements tested to determine the contact force and area, it is desirable to predict which capsule elements will be in contact.

The capsule cannot contact the soil unless the capsule geometric center is lower than the heat shield geometric center. This condition will occur only for $d_{11} = \cos \psi \cos \theta \leq 0$, assuming the longitudinal axes of the capsule and heat shield are colinear.

The angular location of the point of contact or the center of the area of contact may be found by differentiating the equation of the capsule surface with respect to the fixed x coordinate. Setting this result equal to zero will define the angular position of the minimum point on the surface, and thus the point of contact.

The equation for the capsule surface at the base ($x = XMIN$) may be expressed

$$f = (y + YCG)^2 + (z + ZCG)^2 - b^2 = 0 \quad (226)$$

The x dimension of a point x, y, and z on the capsule surface is given by

$$X = d_{11}x + d_{12}y + d_{13}z \quad (227)$$

Now the derivative may be written

$$\frac{\partial f}{\partial x} = \frac{\partial f}{\partial y} \frac{\partial y}{\partial x} + \frac{\partial f}{\partial z} \frac{\partial z}{\partial x} + \frac{\partial f}{\partial X} \frac{\partial X}{\partial x} = 0 \quad (228)$$

where $\frac{\partial f}{\partial x}$ is seen to be zero.

Then

$$\frac{2(y + YCG)}{d_{12}} + \frac{2(z + ZCG)}{d_{13}} = 0 \quad (229)$$

Squaring this result and substituting $(z + ZCG)^2$ in terms of y from equation (27) we obtain

$$\frac{(y + YCG)^2}{d_{12}^2} + \frac{(y + YCG)^2}{d_{13}^2} = \frac{b^2}{d_{13}^2}$$

or

$$(y + YCG)^2 (d_{12}^2 + d_{13}^2) = d_{12}^2 b^2 \quad (230)$$

and

$$y = \frac{-d_{12} b}{\sqrt{d_{12}^2 + d_{13}^2}} - YCG \quad (231)$$

The sign of the first term in equation (231) was determined from the angular relationships involved in the direction cosines and the fact that the minimum point on the curve was desired. In a similar manner we obtain

$$z = \frac{-d_{13} b}{\sqrt{d_{12}^2 + d_{13}^2}} - ZCG \quad (232)$$

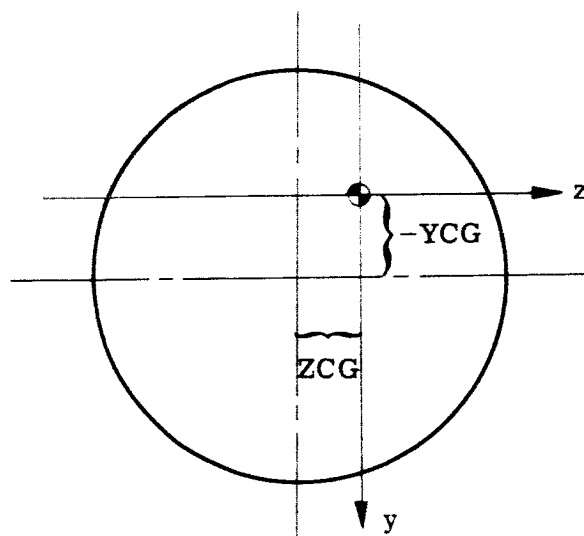
and

$$\frac{y}{z} = \frac{d_{12}b + YCG}{d_{13}b + ZCG} \sqrt{\frac{d_{12}^2 + d_{13}^2}{d_{12}^2 + d_{13}^2}} \quad (233)$$

The angular position of the point of contact is more conveniently expressed in relation to the axis of symmetry.

$$\text{Let } y' = y + YCG$$

$$z' = z + ZCG$$

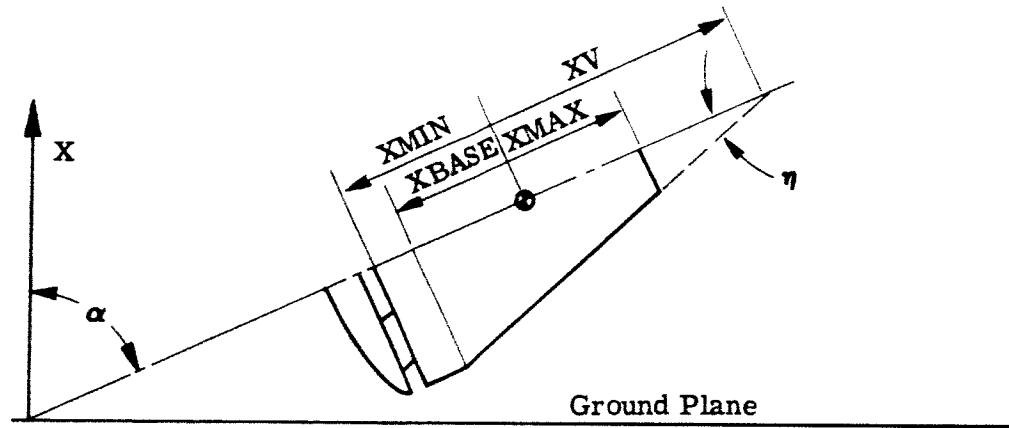


$$\text{Then } \frac{y'}{z'} = \frac{d_{12}}{d_{13}} \quad (234)$$

$$\text{and } \tan \beta = - \frac{d_{12}}{d_{13}} \quad (235)$$

$$\sin \beta = - \frac{d_{12}}{d_{13}} \sqrt{\frac{d_{13}^2}{d_{12}^2 + d_{13}^2}} \quad (236)$$

The x location of contact between the capsule and soil may be determined as follows



The angle α is the angle between the fixed X axis and the capsule x axis.

$$\cos \alpha = d_{11} = \cos \psi \cos \theta \quad (237)$$

It is seen that for a hard soil surface and small heat shield hull deformation, the capsule cannot contact the ground for $\alpha < \pi/2$ unless the heat shield shock struts undergo stroking. Capsule/soil contact for this condition will be considered later in the development.

For $\alpha = \pi/2$, contact will occur for all x between XMIN and XBASE.

For $\pi/2 < \alpha < \pi/2 + \eta$, contact will occur at $x = XBASE$.

For $\alpha = \frac{\pi}{2} + \eta$, contact will occur for all x between XBASE and XMAX.

For $\alpha > \frac{\pi}{2} + \eta$, contact will occur at $x = XMAX$.

These relationships will minimize the surface indexing procedure employed to determine contact force by allowing the procedure to start at the point of probable contact.

Contact is not possible for a point on the capsule surface if

$$RX + d_{11}x + d_{12}y + d_{13}z > 0 \quad (238)$$

where RX is the x coordinate of the vector from the origin of the space fixed coordinate system to the capsule c.g. For $\alpha \leq \pi/2$, the point of first contact is defined by equations (231) and (232). Using equation (238) and these y and z values ($x = XMIN$) we obtain.

$$RX + d_{11}(XMIN) - d_{12}(YCG) - d_{13}(ZCG) - b \sqrt{d_{12}^2 + d_{13}^2} \leq 0 \quad (239)$$

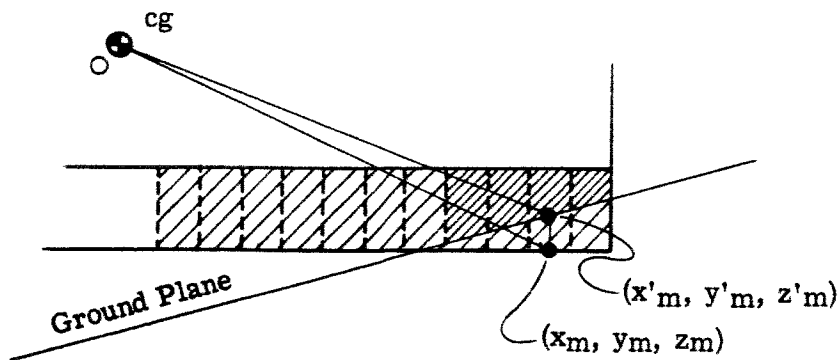
as a condition for capsule/soil contact for $\alpha \leq \pi/2$.

For $\alpha > \pi/2$, we obtain

$$RX + d_{11}(XMAX) + \left[b \frac{(XV - XMAX)}{(XV - XBASE)} \right] (d_{12} + d_{13}) - d_{12}YCG - d_{13}ZCG \leq 0 \quad (240)$$

as a condition for capsule/soil contact.

A section of the capsule in contact with the soil surface is shown as



where the center of element m has undergone a deformation δ due to contact with the soil surface. It is assumed that deformation is in the direction of the unit normal to the capsule surface, so that

$$\overline{OM'} = \overline{OM} - \delta_m \overline{UN}_m \quad (241)$$

From equations (210) and (211), the unit normal is given by

$$\overline{UN}_m = \frac{(\tan n)^2 (XV - x_m) i + (y_m + YCG) j + (z_m + ZCG) k}{\sqrt{(\tan n)^4 (XV - x_m)^2 + (y_m + YCG)^2 + (z_m + ZCG)^2}} \quad (242)$$

for $XMAX \geq x \geq XBASE$, and

$$\overline{UN}_m = \frac{(y + YCG) j + (z + ZCG) k}{\sqrt{(y + YCG)^2 + (z + ZCG)^2}} \quad (243)$$

for $XBASE \geq x \geq XMIN$.

Substituting equations (210) and (211) into equations (242) and (243) we obtain

$$\overline{UN}_m = (\sin \eta) i + \cos \eta \frac{(XV - XBASE)}{(XV - x_m)} \left\{ \frac{(y + YCG)}{b} j + \frac{(z + ZCG)}{b} k \right\} \quad (244)$$

for $XMAX \geq x_m \geq XBASE$, and

$$\overline{UN}_m = \frac{(y + YCG)}{b} j + \frac{(z + ZCG)}{b} k \quad (245)$$

for $XBASE \geq x_m \geq XMIN$

Equation (241) may now be written

$$OM' = (x_m i + y_m j + z_m k) - \delta_m \left\{ Ai + B \left[\frac{(y + YCG)}{b} j + \frac{(z + ZCG)}{b} k \right] \right\} \quad (246)$$

where for $XMAX \geq x_m > XBASE$, $A = \sin \eta$ and $B = \cos \eta \frac{(XV - XBASE)}{(XV - x_m)}$

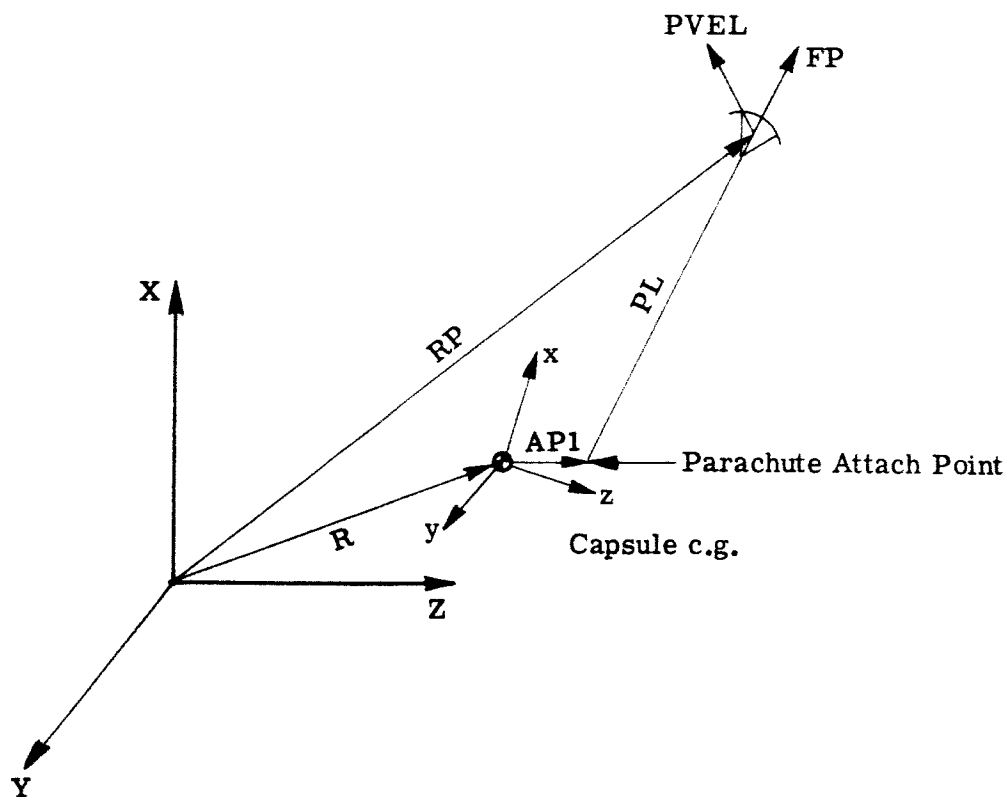
and for $XBASE \geq x_m \geq XMIN$, $A = 0$, $B = 1$.

Since the point defined by OM' lies in the ground plane, equation (238) may be used in conjunction with equation (246) to obtain

$$\delta_m = \frac{d_{11} x_m + d_{12} y_m + d_{13} z_m + RX}{d_{11} A + B \left[d_{12} \frac{(y_m + YCG)}{b} + d_{13} \frac{(z_m + ZCG)}{b} \right]} \quad (247)$$

Now that the element deformation, δ , has been determined, the computation of contact forces, moments, and areas follows the procedure used in the heat shield/soil subroutine.

3.6 PARACHUTE FORCE



Parameters which must be specified for the purpose of determining the force and moment due to a parachute are

1. Unstrained parachute line length; $PLGN \Phi F$
2. Parachute line spring rate; PK
3. Parachute force at zero time; FPX, FPY, FPZ
4. Parachute velocity; $PXVEL, PYVEL, PZVEL$
5. Parachute - capsule attach point; $APX1, APY1, APZ1$
6. Parachute cutoff height; $PHITE$

The parachute force will be removed for all time following $RX - PHITE < 0$. The vector from the capsule c.g. to the chute attach point is given in the fixed coordinate system as

$$\overline{AP} = [d] \overline{AP1} + \overline{R} \quad (248)$$

The initial magnitude of the parachute force is

$$FP = \left\{ (FPX)^2 + (FPY)^2 + (FPZ)^2 \right\}^{1/2} \quad (249)$$

and thus the initial line length is

$$PL = PLGN \Phi F + FP/PK \quad (250)$$

The unit vector in the direction of parachute force is given in the fixed coordinate system by

$$\overline{VP} = [d] \overline{FP}/FP \quad (251)$$

The initial position of the parachute is thus given in the fixed coordinate system by

$$\overline{RP} = \overline{AP} + PL \cdot \overline{VP} \quad (252)$$

Parachute position after time $= 0$ is determined by integrating the constant parachute velocity

$$RP_{(t+\Delta t)} = RP_t + PVEL \cdot \Delta t \quad (253)$$

and chute line length is found from

$$PL = |\overline{RP} - \overline{AP}| \quad (254)$$

thus giving magnitude of the parachute force

$$FOR = PK (PL - PLGN) F \quad (255)$$

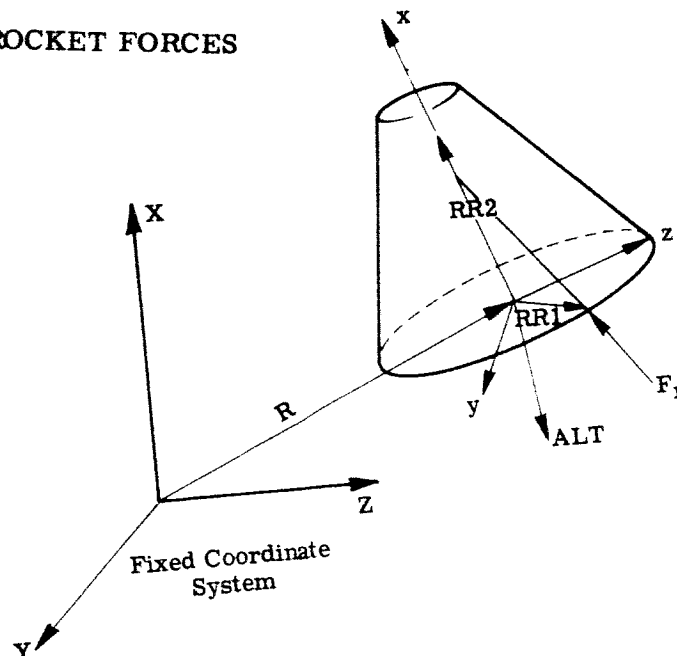
The force is given in the capsule coordinate system by

$$\overline{FPP1} = [d] \cdot \overline{VP} \cdot FOR \quad (256)$$

and the moment about the capsule c.g. is given by

$$\overline{TPP1} = \overline{AP} \times \overline{FPP1} \quad (257)$$

3.7 RETROROCKET FORCES



Provision is made for up to four retrorockets acting on the capsule. The parameters which must be specified for each retrorocket are,

1. the point of attachment to the capsule, $RR1$,
2. another point on the line of action of the retrorocket force, $RR2$, and
3. the retrorocket thrust as a function of time, F_r .

The retrorocket will be turned on either at a specified capsule c.g. height above the ground surface ($ALT_X + RX < 0$), or when the command module hits the ground surface ($FSGX > 0$).

Retrorocket force is given in the capsule coordinate system by

$$F_{rx} = F_r (RRX)/RRXYZ \quad (258)$$

$$F_{ry} = F_r (RRY)/RRXYZ \quad (259)$$

$$F_{rz} = F_r (RRZ)/RRXYZ \quad (260)$$

where

$$RRX = RRX2 - RRX1 \quad (261)$$

$$RRY = RRY2 - RRY1 \quad (262)$$

$$RRZ = RRZ2 - RRZ1 \quad (263)$$

$$RRXYZ = \sqrt{(RRX)^2 + (RRY)^2 + (RRZ)^2} \quad (264)$$

The retrorocket force is then given in the space fixed coordinate system by

$$\overline{FRR} = [d] \overline{F_r} \quad (265)$$

The moment about the capsule c.g. is given by

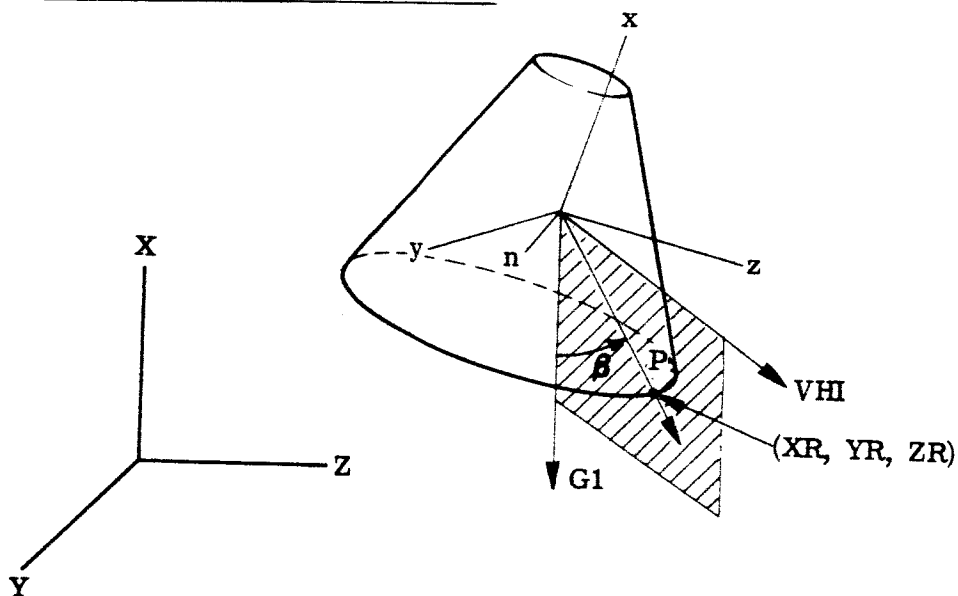
$$\overline{TRR} = \overline{RR1} \times \overline{F_r} \quad (266)$$

or $TRRX = F_r (RRY1 \times RRZ/RRXYZ - RRZ1 \times RRY/RRXYZ) \quad (267)$

$$TRRY = F_r (RRZ1 \times RRX/RRXYZ - RRX1 \times RRZ/RRXYZ) \quad (268)$$

$$TRRZ = F_r (RRX1 \times RRY/RRXYZ - RRY1 \times RRX/RRXYZ) \quad (269)$$

3.8 STABILITY ANGLE CALCULATION



The stability angle, β , is defined as the angle between the gravity vector through the capsule c.g. and a vector directed toward the nominal heat shield rim in the direction of motion of the capsule.

The unit gravity vector is defined in the fixed coordinate system by

$$\hat{G} = -\cos \delta \ i + \sin \delta \ k \quad (270)$$

where δ is the angle of ground slope. Transforming this vector into the capsule coordinate system yields

$$\begin{aligned} \hat{G}_1 = & (-d_{11} \cos \delta + d_{31} \sin \delta) i + (-d_{12} \cos \delta + d_{32} \sin \delta) j \\ & + (-d_{13} \cos \delta + d_{33} \sin \delta) k \end{aligned} \quad (271)$$

$$\text{or } \hat{G}_1 = AG i + BG j + CG k \quad (272)$$

The horizontal velocity vector is given in the fixed coordinate system by

$$\overline{VH} = RYVEL j + RZVEL k \quad (273)$$

which is given in the capsule coordinate system by

$$\begin{aligned}\overline{VH1} = & (d_{21}RYVEL + d_{31}RZVEL) i + (d_{22}RYVEL + d_{32}RZVEL) j \\ & + (d_{23}RYVEL + d_{33}RZVEL) k\end{aligned}\quad (274)$$

$$\text{or } \overline{VH1} = AV i + BV j + CV k \quad (275)$$

The plane defined by $\hat{G1}$, $\overline{VH1}$, and the capsule c.g. is given by

$$\overline{n} = \hat{G1} \times \overline{VH1} \quad \begin{vmatrix} i & j & k \\ AG & BG & CG \\ AV & BV & CV \end{vmatrix} \quad (276)$$

$$\overline{n} = (BG \cdot CV - CG \cdot BV) i + (CG \cdot AV - AG \cdot CV) j + (AG \cdot BV - BG \cdot AV) k \quad (277)$$

$$\text{or } \overline{n} = AN i + BN j + CN k \quad (278)$$

The vector from the c.g. to the heat shield rim at the point of intersection with the plane $\overline{n}$ is defined by

$$\overline{n} \cdot \overline{OP} = 0 \quad (279)$$

$$\text{where } \overline{OP} = XR i + y j + z k \quad (280)$$

$$XR = HSX1 + HSCG2 - XCG1 \quad (281)$$

$$\text{Then } AN \cdot XR - BN y + CN z = 0 \quad (282)$$

It is also required that y, z lie in the cylinder defined by the heat shield rim and the capsule x axis. Thus

$$(y - HSY1 + YCG1)^2 + (z - HSZ1 + ZCG1)^2 = HEATB^2 \quad (283)$$

$$\text{Let } YOFF = YCG1 - HSY1, ZOFF = ZCG1 - HSZ1$$

Then equation (283) becomes

$$(y + YOFF)^2 + (z + ZOFF)^2 = (HEATB)^2 \quad (284)$$

Solving equations (282) and (284) for z and equating gives

$$\frac{-AN \cdot XR - BN y}{CN} = \sqrt{(HEATB)^2 - (y + YOFF)^2} - ZOFF \quad (285)$$

$$\text{Let } D1 = \frac{AN \cdot XR}{CN} - ZOFF \quad \text{and } D2 = \frac{BN}{CN}$$

Then, substituting into (285) and squaring

$$(D1)^2 + 2D1 \cdot D2y + (D2)^2 y^2 = (HEATB)^2 - y^2 - 2y YOFF - (YOFF)^2 \quad (286)$$

which may be written

$$y^2 + \frac{(2D1 \cdot D2 + 2YOFF) y}{(D2)^2 + 1} + \frac{((D1)^2 + (YOFF)^2 - (HEATB)^2)}{(D2)^2 + 1} = 0 \quad (287)$$

$$\text{or } y^2 + 2By + C \quad \text{and} \quad YR = (-B \pm \sqrt{B^2 - C}) \quad (288)$$

$$\text{where } B = \frac{\left[\left(\frac{AN \cdot XR}{CN} - ZOFF \right) \left(\frac{BN}{CN} \right) + YOFF \right]}{\left(\frac{BN}{CN} \right)^2 + 1}$$

$$B = \frac{(AN \cdot BN \cdot XR - BN \cdot CN \cdot ZOFF + (CN)^2 YOFF)}{(BN)^2 + (CN)^2} \quad (289)$$

$$C = \frac{\left[\left(\frac{AN \cdot XR}{CN} - ZOFF \right)^2 + (YOFF)^2 - (HEATB)^2 \right]}{\left(\frac{BN}{CN} \right)^2 + 1}$$

$$C = \frac{(AN \cdot XR - CN \cdot ZOFF)^2 + (CN)^2 (YOFF)^2 - (CN)^2 (HEATB)^2}{(BN)^2 + (CN)^2} \quad (290)$$

Then z is given by

$$ZR = \pm \sqrt{HEATB^2 - (YR + YOFF)^2} - ZOFF \quad (291)$$

The vector $\overline{OP}$ is thus given by

$$\overline{OP} = XR i + YR j + ZR k \quad (292)$$

The angle β is defined by

$$\hat{G1} \cdot \overline{OP} = |G1| \cdot |OP| \cos \beta \quad (293)$$

$$\text{or } \cos \beta = \frac{AG \cdot XR + BG \cdot YR + CG \cdot ZR}{\sqrt{(AG^2 + BG^2 + CG^2)(XR^2 + YR^2 + ZR^2)}} \quad (294)$$

Since $\hat{G1}$ is a unit vector

$$\cos \beta = \frac{AG \cdot XR + BG \cdot YR + CG \cdot ZR}{\sqrt{(XR)^2 + (YR)^2 + (ZR)^2}} \quad (295)$$

The intersection of the plane $\vec{n}$ with the heat shield rim occurs at 2 points. The desired point will be calculated by taking the sign of RR and ZR consistent with the sign of the velocity vector. This is accomplished by the following equations

$$YR = -B + \sqrt{B^2 - C} \quad (BV/\text{abs}(BV)) \quad (296)$$

$$ZR = \frac{CV}{\text{abs}(CV)} \sqrt{(HEATB)^2 - (YR + YOFF)^2} - ZOFF \quad (297)$$

If there is no point of intersection the vehicle will be judged unstable in a sideways toppling mode. This will occur for

$$B^2 - C < 0 \quad (298)$$

The vehicle is also judged unstable if the gravity vector falls outside the heat shield rim in the direction of horizontal velocity. For this instability, the sign of $\overline{G1} \times \overline{OP}$ will be opposite that of $\overline{G1} \times \overline{VH1}$.

The sign of the x component of $\overline{G1} \times \overline{VH1}$ is

$$AN/abs(AN)$$

The sign of the x component of $\overline{G1} \times \overline{OP}$ is

$$(BG \cdot ZR - CG \cdot YR)/abs(BG \cdot ZR - CG \cdot YR)$$

Then if $AN \neq 0$, the sign of β is given by

$$\frac{AN \cdot abs(BG \cdot ZR - CG \cdot YR)}{abs(AN) \cdot (BG \cdot ZR - CG \cdot YR)}$$

If $AN = 0$ and $BN \neq 0$, the sign of β is given by

$$\frac{BN \cdot abs(CG \cdot XR - AG \cdot ZR)}{abs(BN) \cdot (CG \cdot XR - AG \cdot ZR)}$$

If $AN = 0$, $BN \neq 0$, and $CN \neq 0$, the sing of β is given by

$$\frac{CN \cdot abs(AG \cdot YR - BG \cdot XR)}{abs(CN) \cdot (AG \cdot YR - BG \cdot XR)}$$

3.9 ENERGY BALANCE CALCULATION

An energy balance calculation is made at the conclusion of each computer run for the purpose of providing a check on the accuracy obtained with the program. Ideally, the energy balance results indicate the accuracy of the integration procedure being used. In practice, however, other factors might have a marked effect on the degree of energy balance. For instance, an unsatisfactory energy balance obtained when using a time

interval of one millisecond or less with the fixed interval Runge-Kutta integration procedure can generally be attributed to either; 1) a shock strut bottoming out during the run, or 2) stroke-load data for some energy absorbing element not consistent with the assumptions made in writing the program.

The degree of energy balance is based upon the total energy absorbed during the run

$$E_{abs} = KE_0 + \Delta PE + E_{RR} - KE_F \quad (299)$$

where KE_0 is the initial kinetic energy, ΔPE is the change in potential energy during the run, E_{RR} is the work done by the retrorocket, and KE_F is the final kinetic energy.

The magnitude of these energy levels are determined by the following equations.

$$KE_0 = \frac{1}{2} (M \dot{R}_0^2 + M_c \dot{R}_{c0}^2 + M_s \dot{R}_{s0}^2 + I \bar{\omega}_0^2 + I_c \bar{\omega}_{c0}^2 + I_s \bar{\omega}_{s0}^2) \quad (300)$$

$$\Delta PE = g \left[(M_o (R_{xo} - R_x) + M_c (R_{cxo} - R_{cx}) + M_s (R_{sxo} - R_{sx})) \cos \delta + (M_o (R_{zo} - R_z) + M_c (R_{czo} - R_{cz}) + M_s (R_{szo} - R_{sz})) \sin \delta \right] \quad (301)$$

$$E_{RR} = \sum_{i=1, NRR} \int F_{RR} dR$$

where F_{RR} is retrorocket thrust and NRR is the number of retrorockets.

$$KE_F = \frac{1}{2} (M \dot{R}^2 + M_c \dot{R}_c^2 + M_s \dot{R}_s^2 + I \bar{\omega}^2 + I_c \bar{\omega}_c^2 + I_s \bar{\omega}_s^2)$$

The fraction of the total absorbed energy which was absorbed by each pertinent element in the system is then computed. The fraction absorbed by the heat shield struts is determined by

$$E_{sst} = \sum_{i=1, Q} \int (F_i + FF_i) ds / E_{abs} \quad (303)$$

where F_i is the honeycomb crush force and FF_i is the strut friction force. The integration is of course, performed throughout the computer run. For the couch struts, the following equation is used.

$$E_{cst} = \left\{ \sum_{i=1, P} \int (F_i + FF_i) ds + \int F_B ds \right\} / E_{abs} \quad (304)$$

where F_B is the bumper plastic stroking force. The fraction of energy absorbed by the capsule and heat shield surfaces are determined from

$$E_{cap} = \sum_{\substack{i=1, N \\ j=1, m}} \int F ds / E_{abs} \quad (305)$$

$$E_{hs} = \sum_{\substack{i=1, N_i \\ j=1, K-1}} \int F ds / E_{abs} \quad (306)$$

Where the i's and j's refer to element j of ring i on the capsule and heat shield surface. The energy absorbed by the soil, including the work done by friction on the heat shield and capsule surfaces is calculated from equations of the form

$$E_{soil} = \left\{ \int (F_s + F_d) ds + \int F_{yz} ds \right\} / E_{abs} \quad (307)$$

where $(F_s + F_d)$ is the total force opposing motion of the soil mass and F_{yz} is the force due to friction on the command module surface.

The fraction of the energy absorbed by all of the elements considered is then found from

$$E_{fract} = E_{sst} + E_{cst} + E_{cap} + E_{hs} + E_{soil} \quad (308)$$

Therefore, the degree of energy balance is determined by the variation of E_{fract} from unity.

SECTION IV

ANALYSIS OF SOIL INTERACTION

This section is concerned with the development of semi-empirical relationships between soil dynamic deformation and the resultant soil forces acting between the surface of the heat shield and/or capsule and the earth surface upon which the Apollo Command Module impacts.

The first portion of the section discusses the soils used in the experimental program and the control procedures used to assure uniform soil properties for all testing. Test equipment - both standard and specialized - is also described.

The second portion discusses the results of the testing, particularly the oblique impact tests which were the primary method of establishing empirical soil-force laws.

The last portion of this section covers the analysis of the test results and the formulation of the empirical relationships used in the computer program.

4.1 SOIL IDENTIFICATION TESTS

The purpose of performing the identification tests on the soils used in this program were:

- (a) To set control standard for each of the finished soil beds used for either model drop tests or oblique impact tests,
- (b) To determine the pertinent soil properties of the test beds for detailed analytical studies.

4.1.1 The Triaxial Test of Soil Samples

The triaxial soil test machine is used to measure the shear strength of the soil when loaded by a three-dimensional stress vector. The triaxial test equipment is shown in Figures 4-1 and 4-2.

A cylindrical soil specimen, enclosed in a rubber membrane, is subjected to constant radial stress generated by fluid pressure. The axial stress, generated by an external loading system is then gradually increased. Provisions are made to measure the pore water pressure in the soil during tests. Outlets are also provided to drain the pore-water from the soil during the tests; however triaxial tests conducted in this program were the undrained variety. A number of identical specimens must be tested at different constant radial stresses. The axial conditions at failure are analyzed by the Mohr circle method to determine the apparent cohesion and the angle of shear resistance. The triaxial test apparatus and test procedures are standardized (Reference 1).

4.1.2 Penetrometer

Penetrometers were used to measure the force required to force a specific penetrator a certain distance into the soil surface. For a given type of soil the penetrometer reading increases with increasing degree of compaction. Therefore, they are used as an index in the compaction control of the soil beds. A penetrometer (Model CL-700, Soiltest Inc.) with a cylindrical penetrator (1" diameter and $\frac{13}{16}$ " long) was used for compaction control of the silica sand test beds. A proving ring penetrometer with cone type penetrator ($1\frac{1}{8}$ " base diameter and 2" long) was used for compaction control of the clay test beds.

A one cubic foot volume box was used to correlate the penetrometer reading with the density of the sand. The box was filled with sand and compacted uniformly until a certain penetrometer reading was obtained; the box and its contents were then weighed and the density calculated. For correlating the penetrometer reading and density for clay, a split-tube core sampler (Model DR-120, Soiltest Inc.) was used to obtain samples from the finished clay bed which had been compacted to the desired penetrometer readings. Core samples were taken at different locations and depths of the finished clay bed.

These samples were weighed and the volume measured to obtain the wet clay density. The samples were then used in the triaxial tests, and finally they were dried in the oven to obtain the moisture content and the dry density of the clay.

4.1.3 Atterberg Liquid and Plastic Limits Indices

These standard tests (Reference 2) were performed on the clay to determine

- (a) The liquid limit (the boundary between the liquid and plastic state of the clay)
- (b) The plastic limit which is the boundary between the plastic and semi-solid state of the clay.

Results of these tests are given in the "Summary of Soil Properties".

4.1.4 Specific Gravity Tests

Standard ASTM D-854 specific gravity bottles were used to determine the specific gravity of the soil grain (Reference 3). Results of these tests are given in the "Summary of Soil Properties".

4.1.5 Proctor Compaction Tests

The standard Proctor Compaction Test equipment was used to determine the optimum water content of the clay for the soil bed (Reference 4). Results of these tests are given below in the discussion of soil bed preparation

4.1.6 Tests to Determine the Elastic Modulus of Soils

The 1/30 cubic foot Proctor compaction mold was used in conjunction with the triaxial soil test machine to determine the elastic modulus of the soils for the soil densities used in the test beds.

A measured weight of soil was compacted into the 1/30 cubic foot Proctor compaction mold to give the exact density desired. An aluminum piston with slight clearance with the inside diameter of the mold was placed on top of the compacted soil. The whole assembly was then placed on the triaxial test machine and an axial load was applied to the piston. The axial displacement of the piston was measured by a dial indicator. For the sand, an axial load of 200 pounds was used, and for the clay, 40 pounds of axial load was used. In both cases the unit pressure (16 psi for sand and 3.2 psi for clay) was not great enough to cause failure or re-formation of the soil confined within the mold. The axial load was applied and released repeatedly and the dial indicator readings observed. It was found that under such test conditions the soil behaved as perfect elastic material and there was no visible permanent set of the soil. The elastic modulus was then calculated from the stress and volume change of the soil at test conditions.

4.2 SOIL BED PREPARATION

This program required two separate soil beds. The larger soil bed was 18 feet long, 12 feet wide and 5 feet deep and was used for the Apollo model drop tests. The smaller soil bed was 5 feet in diameter and 2 feet deep and was used for the soil dynamic studies.

A gasoline engine powered compactor (Jay Temper, Model J-13, manufactured by Jay Corporation, Cincinnati 1, Ohio) was used to compact the sand to the desired density in the large soil bed. The sand was placed in the bed in ten-inch thick layers. Each layer was compacted before the next one was placed. This procedure was followed to insure that the sand density was uniform throughout the 5-foot depth. Penetrometer readings were taken at numerous points on the sand surface to judge the uniformity of the soil density. The desired penetrometer reading corresponded to 109 pounds per cubic foot density for the sand.

After each Apollo model drop, the sand in the disturbed and the surrounding area was thoroughly raked and recompactd by the compaction machine to obtain correct penetrometer readings.

The small soil bed was filled with sand in the same general manner as that used for the large soil bed. Sand was placed in the 5-foot diameter tank in four-inch layers and compacted before the next layer was placed. A small pneumatic compactor with an 8 1/4" x 8 1/4" square footpad was used to compact the sand to the desired penetrometer reading. The method of restoring the sand in the small soil bed after each impact test was the same as that used for the large soil bed. Aside from the large quantity of sand to be handled, there was little difficulty encountered with this cohesionless material throughout the program.

The cohesive material chosen for this program was a fine clay obtained from the Cedar Heights Clay Company. In dry form, this clay powder had zero cohesive shear strength and an angle of internal friction of approximately 43 degrees. When mixed with sufficient water, its angle of internal friction became zero and cohesive shear strength became quite high. At low moisture content the strength of the clay varied considerably with the amount of compaction, while at high moisture content the effect of compaction became less pronounced. Figures 4-3 and 4-4 show the above mentioned effect (Reference 5).

A Proctor compaction test was performed on the air-floated clay and the results are shown in Figure 4-5. It can be seen that at moisture content over 25 percent the density of this clay differs only about one pound per cubic foot between the standard and the modified Proctor compaction tests. The modified Proctor compaction test gives 4.5 times more energy to the same volume of clay than the standard Proctor compaction test. It can also be seen that the soil strength as measured by a cone-type penetrometer decreases rapidly with the increase of moisture content. During the course of preparing clay samples for the Proctor compaction tests, it was found that the effort of mixing the clay powder with water to form a uniform mixture varies inversely with the moisture content. At moisture contents below 15 percent, it was extremely difficult to get a uniform mixture. After careful consideration of the object of this study and the result of Proctor compaction tests, it was decided that clay to be used in this program should have 26 to 28 percent moisture content. The advantage of using high moisture content for the clay are as follows:

1. A uniform clay mixture will give consistent test results.
2. The strength of clay at high moisture content is less sensitive to the amount of compaction. This again helps to obtain consistent test results.
3. Lower soil strength requires smaller test equipment and also prolongs the duration of impact. The longer duration of impact reduces the difficulty in instrumentation and data analysis.

The clay used in this program was mixed with water by a mortar mixing machine and placed in the soil bed in a manner similar to that used on the sand. The clay surface was exposed to room atmosphere only during the brief time when the surface was prepared and during the time the tests were conducted. A wet cloth and a large plastic sheet were placed on top of the clay surface to prevent evaporation of the moisture between tests. It has been found that the moisture content of the clay did not change after months of storage in this manner. Penetrometer readings were taken regularly on the clay surface as a measure of quality control. The desired penetrometer reading corresponds to a wet density of 117 pounds per cubic foot. Core samples of the clay were taken frequently for the triaxial tests and moisture content check.

4.3 SUMMARY OF SOIL PROPERTIES

4.3.1 Silica Sand

1. Specific gravity of sand grains ---- 2.615
2. Density at the test condition ---- 109 lb./ft³
3. Internal angle of friction measured by triaxial test ---- 37° (Figure 4-6)
4. Cohesion ---- 0°
5. Elastic modulus (E) ---- 21,800 psi

6. Spring constant (K) under the 5.64" dia. footpad ---- 156,500 lbs./in.

7. Grain size distribution, see Figure 4-7.

4.3.2 Air-floated Clay

1. Specific gravity of clay grains ---- 2.584

2. Wet density at test condition ---- 117 lb./ft.³

3. Moisture content ---- 26.8%

4. Internal angle of friction ---- 0°

5. Cohesion as measured by Triaxial Test ---- 4.7 psi (See Figure 4-8).

6. Elastic Modulus (E) ---- 1900 psi

7. Spring constant (K) under the 5.64" dia. footpad ---- 13,650 lb./ft.

8. Liquid limit ---- 35.4%

9. Plastic limit ---- 22.7%

4.4 OBLIQUE IMPACT SOIL TESTER

The oblique impact soil tests shown in Figures 4-9 and 4-10 are designed to measure the dynamic soil reaction to an object impacting from 0° to 90° to the soil surface. This impact angle is maintained throughout the impact as well as during the penetration phase of the test. The equipment is so designed that the impacting object moves as a free body before making contact with the soil surface.

The oblique impact tester consists of three basic components:

1. The impact bar.
2. The bearing cage.
3. The supporting structure.

The impact bar is a 24-inch long square aluminum bar with a 2 1/2" diameter hole through its length. A footpad attachment piece is fastened to the lower end of the impact bar and it seals the 2 1/2" inch diameter hole at one end. The instrumented section of the footpad is fastened to this attachment piece at any desired angle.

The bearing cage contains eight pivoted flat bearing plates which completely restrain the motion of the square impact bar to only one degree of freedom. The bearing plates are Teflon coated in addition to being pivoted and lubricated with oil. The friction between the impact bar and the bearing plates is very low. A stationary cross-head, supported by four parallel steel rods, is attached to the top of the bearing cage. A threaded piston is fastened to the cross-head. This piston extends into the 2 1/2 inch diameter hole of the square impact bar which is locked to the bearing cage before the tests. Compressed gas is then introduced through the piston into the hollow impact bar. Upon release from the bearing cage, the impact bar is accelerated by the gas pressure until it leaves the stationary piston, and then it travels as a free body. The desired impact velocity can be achieved by varying the initial gas pressure and the length of the power stroke.

The supporting structure is a welded steel member which is attached to a vertical 'T' beam column. The bearing cage can be fastened to this supporting structure at any desired angle. Since the instrumented footpad can also be attached to the impact bar at any desired angle, infinite variations of impact direction and attitude can be accomplished with this instrument. The five-foot diameter soil bed was placed directly below the oblique impact tester.

4.5 INSTRUMENTATION OF THE OBLIQUE IMPACT SOIL TESTER

The instrumentation for the oblique impact soil tests consists of:

1. A sliding wire potentiometer mounted on the bearing cage to measure the impact bar travel.
2. A 500-g accelerometer mounted on the impact bar to measure the acceleration.
3. An instrumented section for the footpad to measure independently the vertical force, horizontal force and moment acting on the footpad. Figure 4-11 shows the instrumented section of the footpad. A "T" shaped steel strut is suspended vertically by a pair of steel sensor bars which are fitted with strain gages. A vertical cantilever bar with strain gages is fastened to the "T" strut. The cantilever bar restrains the lateral movement of the "T" strut. The interchangeable footpad is fastened to the lower end of the "T" strut. A vertical force acting at the center of the footpad will cause tensile stress in the two steel sensor bars. A horizontal force acting on the footpad will create a bending moment on the cantilever bar and a couple on the two vertical sensor bars. The upper portion of "T" strut has a square cross section. The flat surfaces of the "T" strut are lubricated and nested within a carefully machined slot in the housing. Therefore, any side load on the footpad will have very little effect on the stress level of the three sensor members. The frequency response of this instrument is 1170 cycles per second in the vertical direction and 200 cycles per second in the horizontal direction. The output signals from the test setup are recorded on an oscillograph which runs at a 115-inch per second paper speed.

4.6 TEST PROCEDURE

Two types of soils were used in the soil dynamic studies, the silica sand and the air-floated clay with 26.8 percent moisture content. Static and dynamic tests were performed on each of the two soils.

4.6.1 Static Tests

The stationary piston of the impact tester was extended into the hollow impact bar to give 5.5 inches of power stroke. The hollow impact bar was filled with oil and then lowered until the footpad almost touched the prepared soil surface while still in the locked position. The impact bar was then released and the footpad was allowed to touch gently and rest on the soil surface. Hydraulic oil under pressure was metered into the tester through the stationary piston so that the rate of travel of the impact bar was set at one inch per minute. While the footpad was penetrating the soil the oscillograph was allowed to run continuously (at a reduced speed) to record all the forces and displacement on the footpad. This procedure was repeated at angles $\gamma = 0, 10, 20, 30$ and 40 degrees (γ is the angle between the velocity vector of the impact bar with respect to the vertical) with the instrumented footpad always set such that the soleplate is parallel to the soil surface.

4.6.2 Dynamic Impact Tests

The stroke and air pressure was set to give the desired impact velocity regardless of the impact angle used. The hollow impact bar was first charged with compressed air and then isolated from the air source. The oscillograph recorder was then turned on until the paper speed reached 115 inches per second before the impact bar was released. Upon releasing from the bearing cage, the impact bar was accelerated by the air pressure until it left the stationary piston. It then moved as a free body until striking the soil surface. Dynamic impact tests were made with $\gamma = 0, 10, 20, 30$ and 40 degrees with the instrumented footpad soleplate parallel to the soil surface.

4.7 TEST RESULTS

Figures 4-12 and 4-13 show the result of the static penetration tests performed on silica sand and on the 26.8% moisture content clay. It can be seen that for sand there is a definite point at which the soil begins to fail. This point of shear failure can also be observed by the sudden upheaval of the sand surface immediately surrounding the cylindrical footpad. Further penetration into the sand from this point is accompanied by decreases of vertical load until another point is reached when the load again increases (at a lesser rate) with penetration. As the penetration progresses (accompanied by increasing load), successions of upheavals of the sand surface appear, each covering a larger area than the preceding ones. Figure 4-14 shows the wave pattern formed by the succession of upheavals of the sand surface during the static test at $\gamma = 40$ degrees.

For the static penetration test on the clay, there were no distinct points of sudden change as that which occurred with the sand. The vertical load increased evenly and gradually with the penetration. There was far less variation of load with angle of penetration on the clay than there was on the sand. At deep penetration, there was a gradual and general rise of clay surface around the footpad but there was no surface discontinuity.

Figures 4-15 to 4-19 inclusive show the vertical force versus time relationship for the impact tests on silica sand. " V_r " is the vertical force as measured by the rear sensor bar and " V_f " is that measured by the front sensor bar. The sum of the two forces is the net vertical force acting on the footpad. In the zero-degree impact (Figure 4-15) the force on the rear sensor bar is slightly higher and peaks a little earlier than that on the front sensor bar. This has been attributed to the reaction of the accelerating impact mass causing a slight bending of the vertical "I" beam column on which the whole test apparatus is mounted. The bending of the vertical "I" beam will cause the heel of the footpad to touch the soil surface first and thus create a moment resulting in a tensile force on the rear sensor bar and a compressive force on the front sensor bar as shown in Figure 4-15. When the impact angle is not zero, the horizontal force acting on the front of the footpad brings about a moment acting on the footpad. This is reacted by the two vertical sensor bars, the front bar having less tensile load than the rear bar.

At $\gamma = 40$ degrees (Figure 4-19) the tensile force on the front sensor bar becomes negative (i.e. compressive) after the initial peak. Figure 4-20 shows the net vertical forces on the footpad for different impact angles. The peak vertical forces decrease with the increase of the impact angle; however, the vertical force during the unloading period following the initial peak does not follow this same pattern. This has an effect on the empirical modeling of the dynamic reaction force as discussed in the later section of this report.

Figures 4-21 to 4-24 inclusive show the horizontal force acting on the front of the footpad for the various impact angles. Again, this data applies to the silica sand. It can be seen that the peak horizontal forces does not vary greatly with the impact angle but, as the impact angle increases, the area under the force vs. time curves increases. As the impulse becomes higher, the horizontal force near the end of the impact becomes negative, i.e. force acting on the rear of the footpad. This is due to the dynamics of the footpad mass and the horizontal sensor bar spring action which allows "spring-back" of the footpad in the last portion of the total impact period.

Figures 4-25 to 4-29 inclusive show the vertical penetration distance into the silica sand for different impact angles. It can be seen that in all cases the penetration distance into the sand is not great. The penetration distance is slightly higher when the impact angle is greater. This is due to the lower vertical force on the footpad at higher impact angles. From Figure 4-20 it can be seen that for dynamic impact, the peak load on the footpad occurs around 0.00075 seconds with its magnitude varying from 8700 pounds at zero degrees to 5200 pounds at 40 degrees. It is interesting to note that at 0.00075 seconds, the vertical penetration into the soil varies from 0.14 inch at zero degree to 0.08 inch at 40 degrees (Figures 4-25 to 4-29). From the static penetration test (Figure 4-12) the vertical load on the footpad at 0.14 to 0.08 inch penetration varies from 400 pounds at zero degree to 70 pounds at 40 degrees. Therefore, at zero degrees impact angle, the static load is only 4.6% of the total peak impact load, and at 40 degrees impact angle, the static load is only 1.3% of the total peak impact load. It is therefore safe to state that the contribution of static load (i.e. load due to penetration) to the total peak force on impact is almost insignificant for the initial kinetic energies investigated during the silica sand impact tests.

Figures 4-30 to 4-34 inclusive show the vertical force acting on the footpad for different impact angles on the clay with 26.8% moisture content.

Comparing these test results with the same tests on silica sand, it can be seen that clay reacts to dynamic impact differently than does the sand. First, the peak load for clay is much lower; less than half of that for sand. Second, the total duration of impact is much longer 1 - 1 more than double that for sand. Third, the difference between the forces on the front and rear sensor bars are much greater at oblique impact than that for the sand. After the initial peak load, the front sensor bar reading becomes negative (i.e. compressive force) at $\gamma = 10$ degrees. The compressive force on the front sensor bar increases with the impact angle. It indicates that the horizontal force on the footpad during penetration is high. Fourth, after the initial peak, the net vertical force on the footpad (i.e. the vertical force due to dynamic reaction of soil plus the vertical force due to static penetration) is almost independent of time for a considerable portion of the total impact time.

Figure 4-35 shows the vertical forces versus time plot at $\gamma = 0$ degree for a slightly wetter clay (27.6% moisture content compared with 26.8% moisture content for the other tests). Figure 4-36 shows the net vertical load versus time for different impact angles on clay.

Figures 4-37 to 4-40 inclusive show the horizontal force acting on the front of the footpad while impacting on clay at different angles. It can be noted that unlike that for the sand, the horizontal reaction force increases with the increase of the impact angle. This effect is discussed in detail in the analysis of the test result.

Figures 4-41 to 4-45 inclusive show the vertical penetration distance into the clay for different impact angles. It can be said in general that the vertical penetration decreases with the increase of impact angle and the depth of penetration into the clay is several times larger than that for the sand at the same impact angle and speed.

Another point of interest for the impact test on clay is the vertical spring-back of the footpad after all the kinetic energy of the impacting mass is absorbed. (See Figures

4-41 to 4-45 inclusive.) This spring-back is a significant percentage of the total maximum penetration. It shows that the clay can absorb a considerable amount of energy elastically. This is in agreement with the low spring rate measured for the clay.

Figure 4-46 shows the penetration versus time curve at $\gamma = 0^\circ$ for a slightly wetter clay (27.6% moisture content).

Figures 4-47 and 4-48 compare the results of impact test at $\gamma = 0$ degree on the two types of clay; one is slightly wetter than the other. It can be seen that the drier clay does give a higher peak load and allows less penetration although the long duration vertical loads are about the same for both clays.

Vertical impact tests were also performed at $\gamma = 0$ degree on clay with depth at $6\frac{1}{8}$, $12\frac{1}{8}$ and $17\frac{1}{2}$ inches (see Figures 4-49, 4-50 and 4-51). It was expected that the bottom effect would result in higher load on the footpad when tested in the $6\frac{1}{8}$ inch depth bed. The results of these tests did not show any significant difference. This could be due to the fact that the sum of soil wedge height and the penetration distance is less than 4.0 inches. This left over two inches of clay below the apex of the cone at all times. While this is a rather thin sublayer, it was (based on the test results) sufficient to allow the penetration resistance to approach very close to that of the idealized semi-infinite continued situation.

Figures 4-51 and 4-52 show the result of tests performed on clay bed with different "cure time" to demonstrate the thixotropic effect on the clay. The clay bed depth was $17\frac{1}{2}$ inches for both tests. One finished clay bed was allowed to age for 17 hours (covered to prevent evaporation) before the test, while the other was allowed only 15 minutes of aging. Thixotropic effects on clay should cause the one with longer cure time to become stronger and harder, and therefore to give a higher reaction force on impact. The result of the tests show that if the thixotropic effect were present in the clay bed, its effect was almost insignificant for this type of test.

Finally, a very interesting phenomenon was discovered during the course of the impact tests on the clay. It was found that after an impact test, if the clay surface was pierced so that air could reach the region beneath the footpad, on withdrawing the footpad, one would discover that a conical shaped clay wedge was attached to the bottom of the footpad. The geometrical shape of this clay wedge depends on the angle of impact. Figure 4-52-a shows the footpad after a 20-degree impact test on clay but before being withdrawn from the clay bed. Figure 4-52-b shows the shape of this clay wedge stuck beneath the footpad after it was carefully withdrawn from the clay bed. Measurement of a mold of the wedge obtained from the 20 degree impact test showed it to be reasonably close to the wedge shape assumed in the soil analysis.

4.8 ANALYSIS OF THE TEST RESULTS

The experimental result previously discussed may be summarized and presented in empirical form even though the basic mechanism on dynamic soil behavior is somewhat obscure.

A mathematical model for the soil and footpad interaction was made and presented in Reference 6. Figure 4-53 shows the mathematical model relating the impact apparatus and the soil beneath the moving footpad. The values of masses and spring constants were obtained from actual measurement. The shape and mass of the soil wedge were calculated from the assumption that the apex angle of the conical soil wedge is equal to $(\pi/2 - \phi_s)$ where ϕ_s is the internal angle of friction of the soil (Prandtl's analysis, Reference 7).

The object of the analysis was to establish the relationship between the soil reaction force and the motion of the soil wedge beneath the moving footpad. If the velocity is nearly zero, then the force acting on the soil wedge is the static resistance F_s which, for a given soil and penetration angle, is a function of displacement only. However, the soil reaction force also includes a dynamic effect. The magnitude of the dynamic force is highly significant for idealized earth soils in the sand and clay categories whichever the types of soils studied in this program. The difference between the measured

instantaneous vertical load on the soil wedge and the static load for the instantaneous penetration of the wedge is termed the dynamic resistance and is represented by F_D in Figure 4-53.

Figure 4-12 shows the static vertical resistance F_S versus the vertical penetration for various angles of penetration for the sand. The curves all show that initially the vertical load increases rapidly with vertical penetration. A peak point is reached after which the vertical load actually decreases with further penetration. The decreasing portion of this load-versus-penetration curve corresponds to the point when the first upheaval of sand occurs (See Figure 4-14). Since the sand around the footpad is highly compacted, the disturbance of the sand brought about by the first upheaval results in a reduction in the soil density and a large reduction of its angle of internal friction. Thus, the vertical resistance to penetration is lessened. Further penetrations causes compaction followed by secondary upheavals. These again result in inflection points in the load-versus-penetration curves, but the buildup of surcharge overshadows this effect so that the general slope of the load-versus-penetration curve is positive.

The experimental load versus vertical penetration data for the various angles at near zero penetration velocity can be fitted by an equation of the following form:

$$F_S(\gamma) = f(\gamma) F_S(\gamma = 0)$$

Figure 4-54 shows the function $F_S(\gamma = 0)$ taken from Figure 4-12.

Figure 4-55 shows the function $f(\gamma)$ obtained by proportioning the load at any angle γ with that obtained at $\gamma = 0$.

The static load versus penetration data for the clay is shown in Figure 4-13. The same empirical modeling was used for both the clay and sand.

$F_S(\gamma = 0)$ is shown in Figure 4-56. The function $f(\gamma)$ for the clay is shown in Figure 4-57. The cohesive effect of the clay results in far less of a drop-off in vertical resistance with velocity vector angle as can be seen by comparing Figures 4-55 and 4-57.

The dynamic resistance term requires considerably more analysis than the static resistance term for both the sand and the clay.

In the oblique impact test apparatus the displacement and velocity of the impact bar is known, and the forces acting on the impact bar by the footpad is measured by the two sensor bars between them. The reaction force exerted by the soil is then transmitted through another spring-mass system (i.e. soil spring and soil wedge) before reaching the footpad. In such a multi-degree-of-freedom system it is difficult to find the instantaneous velocity and force on the soil wedge in terms of the measured motion and forces of the large mass which is mechanically remote from the soil wedge. This is especially true when the event is of short duration and transitory and F_s and F_D are nonlinear.

Although it is theoretically possible to invert the nonlinear equations of motion of the idealized system and obtain the dynamic resistance as a function of x_2 , $\dot{x}_2$, $\ddot{x}_2$, etc., the practical implementation of this procedure presents many problems. A similar inversion was successfully carried out in Reference 8. However, this technique involved graphical differentiations and smoothing of the resulting derivatives using some degree of judgment based upon a physical understanding of what had to occur in the idealized system. The mechanical impact system was also somewhat more straightforward in that it contained only one mass rather than the two of the present impact tester (M_1 and M_1'), and the load instrumentation consisted of an accelerometer "potted" into that mass rather than the sensor bar used in the present system. In the present program an attempt was made to mechanize this inversion process using numerical differentiation to replace the graphical and least square fitting techniques to replace the smoothing operations carried out after each of the two required differentiations. The results of these attempts were not satisfactory for the type of data needed on the dynamic resistance force. The numerical differentiation was overly sensitive to slight anomalies in the recorded data, and the least square fitting technique - to be effective - required judgment as to the point spacing and point clustering in significant areas of the wedge displacement versus time function and the $(F_s + F_D) dx_2$ versus x_2 function. Due to these difficulties in the mechanization of the inversion technique, a second approach was taken which did not involve numerical differentiation directly.

In this second approach the quantity ($F_S + F_D$) was solved for in terms of x_1 , $\dot{x}_1$ and $\ddot{x}_1$ etc., with the assumption that x_1 and x_1' were identical. The term $\ddot{x}_1$ was determined from the sensor bar load versus time recording. The data ($\ddot{x}_1$ versus t) was fitted by a polynomial which was applicable over a given range of t . The wedge resistance was then given by

$$F_S + F_D = (M_1 + M_1' + M_2) \sum_{n=0}^N a_n t^n$$

$$+ \frac{M_2 (M_1 + M_1')}{K_S} \sum_{n=2}^N n (n-1) a_n t^{n-2}$$

In a similar manner x_2 , $\dot{x}_2$, etc. would be determined. This procedure was quite successful when applied to the data developed with the single mass impact tester, but was not successful when used with the data obtained on the present equipment. The general technique is felt to have merit but requires fine resolution of the data and elimination of the structural mode associated with relative motion between M_1' and M_1 . A direct reading of the acceleration of M_1 (and M_1') by way of an accelerometer potted into the impacting mass could then be used to obtain data from which the coefficients a_n , for specific time intervals, could be determined.

The third approach taken to establish a realistic mathematical model for the dynamic resistance of the soil from the impact data involved a physical interpretation of the test results. Figure 4-58 shows the general interpretation taken of a typical force versus time recording. The general characteristics of the curve appear quite similar to that obtained with the clay, but this is primarily due to the long duration of the slow penetration phase as explained below.

When the footpad mass impacts the soil, the first stage in the development of the ground reaction force is the compression of the material immediately below the footpad. This compaction causes a force which increases with time and the force, in turn, is propagated thru the uncompressed material as an elastic strain wave which increases with intensity and time. As it propagates outward, the change in the stress pattern

with distance causes an increase in the ratio of shear stresses to normal stress of a unit element. Eventually, the shear stress reaches the maximum allowable by the Coulomb failure criteria and slip planes are formed. By analogy with the static stress patterns this would occur very early in the impact period denoted by (1) in Figure 4-58. Once the slip planes are formed (the wedge) the further increase in the compressive forces acting on the surface causes an acceleration of the wedge into the soil. This continues until the wedge is moving at the velocity of the impacting mass. (Point 1 of Figure 4-58). Once this occurs, the wedge begins to decelerate since the applied force on the top surface of the wedges, due to compression, can no longer increase; but the resistance force on base of the wedge, which must equal the applied force at point 1, will increase for any further increases of wedge velocity. As the wedge decelerates along with the impact mass, the force acting on the impacting mass decreases, approaching the static wedge resistance obtained with near-zero penetration velocity. Since the wedge is, in one sense, a mass suspended by the generalized spring of its own structure and the overall elasticity of the soil continuum below it, some transient oscillation of the wedge motion can occur resulting in the wedge velocity oscillating slightly about that of the applied mass velocity. This can bring about an apparent resistive force less than the static resistive force such as is shown in the last portion of the time period denoted by (2) in Figure 4-58. The overall die-away of this transient oscillatory motion of the wedge is denoted by (3) in Figure 4-58. For cases where the velocity dependent portion of the dynamic resistance is high and the elastic modulus of the soil is high, the transient motion indicated in the time period (3) will not be observed.

The next phase of motion depends upon the amount of energy remaining in the impacting mass. In the case of the sand, the kinetic energy remaining is small and the system's motion is arrested with very little further penetration into the sand. In the case of the clay, the initial dynamic force is not sufficient to arrest the motion completely so that a long period of low velocity penetration of the wedge and impacting mass ensues (denoted by time period (4) in Figure 4-58). Finally, in time period (5) the system unloads elastically until the soil reaction drops to the level necessary to support the weight of the impacting mass.

The most significant time period for determination of the dynamic resistance is the unloading period denoted by (2) in Figure 4-58. This period corresponds to a decrease of the wedge velocity and a resultant decrease in the dynamic penetration resistance of the wedge. To obtain the functional relationship between the load and the wedge velocity it was assumed in the data analysis that the drop-off in wedge velocity in this period was identical to the drop-off in impact mass velocity from the beginning of the impact period. That is, the wedge velocity is equal to the impacting mass velocity but is shifted by a time period of (1) due to the necessity of first accelerating the wedge mass up to the impact velocity.

Figure 4-59 shows a comparison of the wedge velocity calculated by an inversion of the nonlinear equation of motion of the system and the wedge velocity obtained by the time shift method described above. Data for this comparison was obtained from Reference 10, page 2-74. It can be seen that the method provides a reasonable approximation of $\dot{x}_2$ versus time, particularly in the lower velocity region of the unloading phase. Knowing the displacement of the wedge, (essentially x_1 since the effective spring rate of the soil is quite high) the static penetration resistance also could be determined in the unloading phase. Subtracting this from the total ground reaction yields the portion due to the dynamic effects.

The dynamic resistance force was analyzed and found to be a function of the penetration velocity. A good empirical approximation, particularly in the lower velocity portion of the unloading phase, is that the force is proportional to the square of the penetration velocity. See Figures 4-60 to 4-64 for sand and Figures 4-65 to 4-70 for clay. The overall dynamic resistance was fitted by a semi-empirical equation of the following form:

$$F_D = 1/2 g(\gamma) K_{\phi c} (\gamma=0) \rho A V^2$$

where

F_D = dynamic reaction of soil - vertical direction

$g(\gamma)$ = dimensionless function - ratio of $K_{\phi c}$ at γ to $K_{\phi c}(\gamma=0)$

$K_{\phi c}$ = dimensionless resistance coefficient

ρ = mass density of soil (bulk)

A = conical surface area of soil wedge

V = instantaneous wedge velocity ($\dot{x}_2$ in Figure 4-53).

γ = velocity vector angle with respect to surface normal

The variation of $K_{\phi c}$ with γ is shown in Figure 4-71 for the sand and in Figure 4-72 for the clay. It can be seen that the dynamic resistance factor for the clay is considerably lower than that for the sand. The variation in $K_{\phi c}$ for the clay as a function of the velocity vector was within the normal scatter resulting from the data analyses and soil preparation techniques and was therefore not considered significant. A constant level of $K_{\phi c} = 4.6$ for all values of γ was used as the final empirical approximation. The factor $K_{\phi c}$ for the sand had significant variation with γ and in general increased with increasing γ . However, this is somewhat misleading in that with increasing γ a larger total velocity vector is required to obtain a fixed vertical velocity. If this is taken into account by multiplying the factor $K_{\phi c}$ by $\cos^2 \gamma$ the overall resistance shows a general decrease with increasing γ except for the region of $\gamma = 0$ to $\gamma \approx 20^\circ$. In this area there is a slight rise in $K_{\phi c} \cos^2 \gamma$. The degree of this rise is sensitive to the data resolution and approximation made in the analysis of the dynamic resistance.

The horizontal resistance measured in the oblique impact tests was quite low for the sand as previously shown. For the degree of penetration occurring on both the oblique impact tests and the model drop tests, surface friction effects predominated. They are dependent on the surfaces in contact; and, for the model, a friction coefficient of 0.10 provides an accurate representation of the horizontal resistance.

The horizontal resistance measured in the oblique impact tests of the clay was found to be a more complex function than that of the sand. It was not a surface friction phenomena but involved the internal shear of the clay itself. It was found that the horizontal resistance could be represented by an effective coefficient of friction times the vertical load. The effective coefficient of friction varied with the angle between the instantaneous velocity vector of the loading area and the surface normal. Figure 4-73a shows the effective μ versus the angle γ . Figure 4-73b shows the effective μ as a function of time. The data was taken directly from the horizontal and vertical load data previously presented. It can be seen that the ratio is essentially constant in the time interval from six milliseconds to 20 milliseconds for each of the impact angles. Data for the time interval of zero to six milliseconds is not shown because the horizontal load measuring device on the oblique impact tester can not respond to pulse shapes of the type indicated by the vertical load recordings. The natural frequency of the gage-footpad system in the horizontal direction is 200 cps.

Figure 4-73c shows the effective coefficient of friction as a function of penetration. It can be seen that the coefficient is essentially constant with penetration - a somewhat surprising result.

The soil model was implemented into the computer program in the following manner. The static vertical resistance acting on the wedge is placed into the program as a table look-up function. The same is true of the multiplier function $f(\gamma)$ and $g(\gamma)$. The parameters $K_{\phi C}$, ρ , ϕ , E , and μ are simply input data. The coefficient of friction is considered to be made up of two parts, μ and a γ dependent portion. At present, the γ dependent portion is limited to a linear variation of the total coefficient of friction with γ .

The contact area, wedge size, instantaneous wedge velocity, and soil generalized spring rate are calculation in the computer program. Details of the soil-hull interaction methods are explained in Section III of this report.

Reference
Number

- 1 T. W. Lamb, "Soil Testing for Engineers," 6th printing May 1960, Chapter 11 and 13
- 2 Same as above, Chapter 3.
- 3 Same as above, Chapter 2.
- 4 Same as above, Chapter 5.
- 5 Dept. of Scientific and Industrial Research, "Soil Mechanics for Road Engineers," Road Research Laboratory, London. H. M. Stationery Office, 1952. Page 156, Figure 9-2, page 161, Figure 9-7, Chapter 9.
- 6 Bendix Report No. MM-65-4 (Dept. 870), "Final Report - Lunar Landing Dynamics Specific Systems Engineering Studies", Page 2-69.
- 7 Road Research Laboratory D.S.I.R., "Soil Mechanics for Road Engineers," London H. M. Stationery Office, 1952; Chapter 22, page 453.
- 8 Bendix Report No. MM-65-4 (Dept. 870), "Final Report - Lunar Landing Dynamics Specific Systems Engineering Studies," pages 2-62 to 2-67, inclusive.
- 9 Bendix Report No. MM-65-4, listed above, page 2-77, Figure 2-62.
- 10 Bendix Report No. MM-65-4, listed above, page 2-74, Figure 2-62.

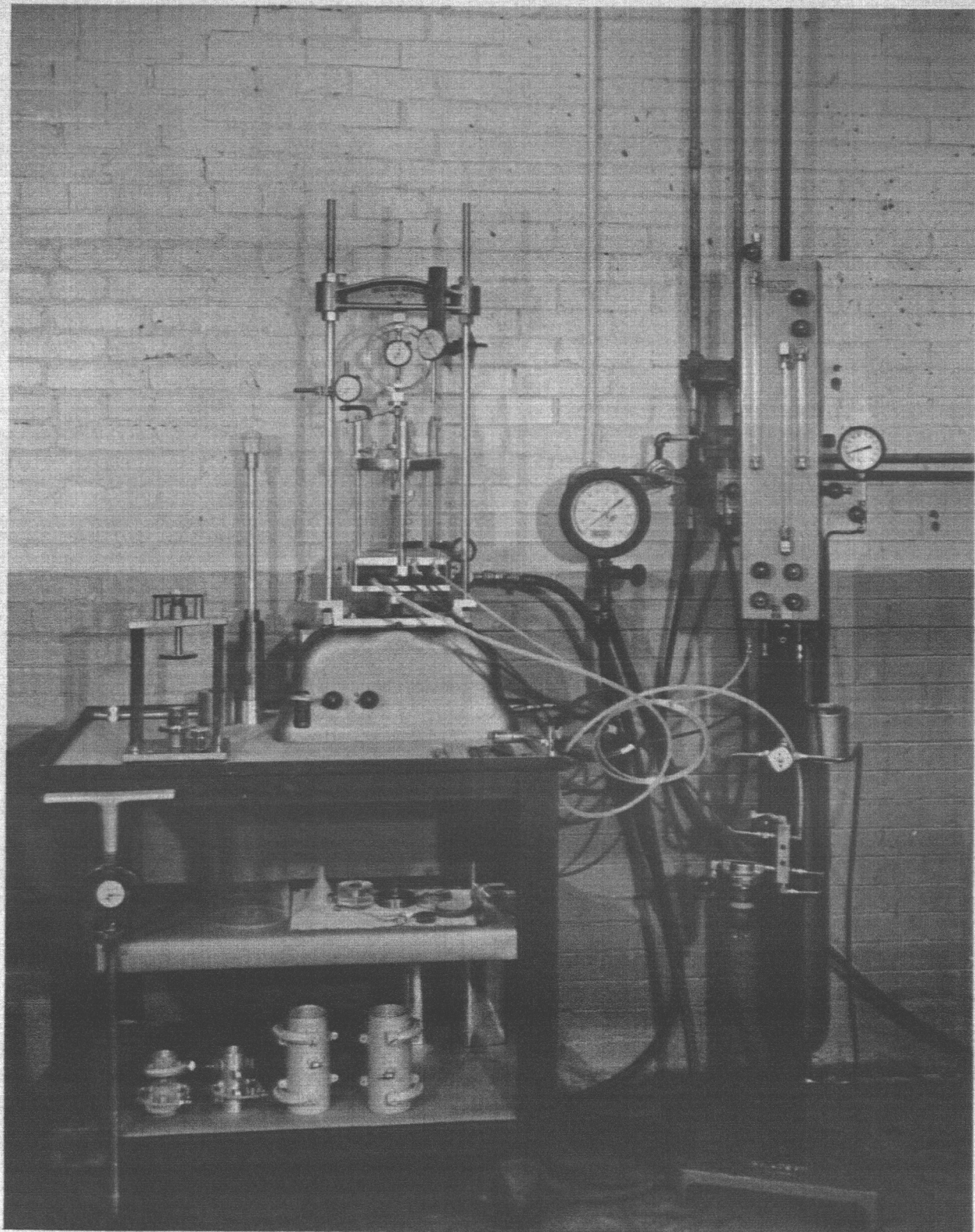


Figure 4-1. Triaxial Soil Test Equipment

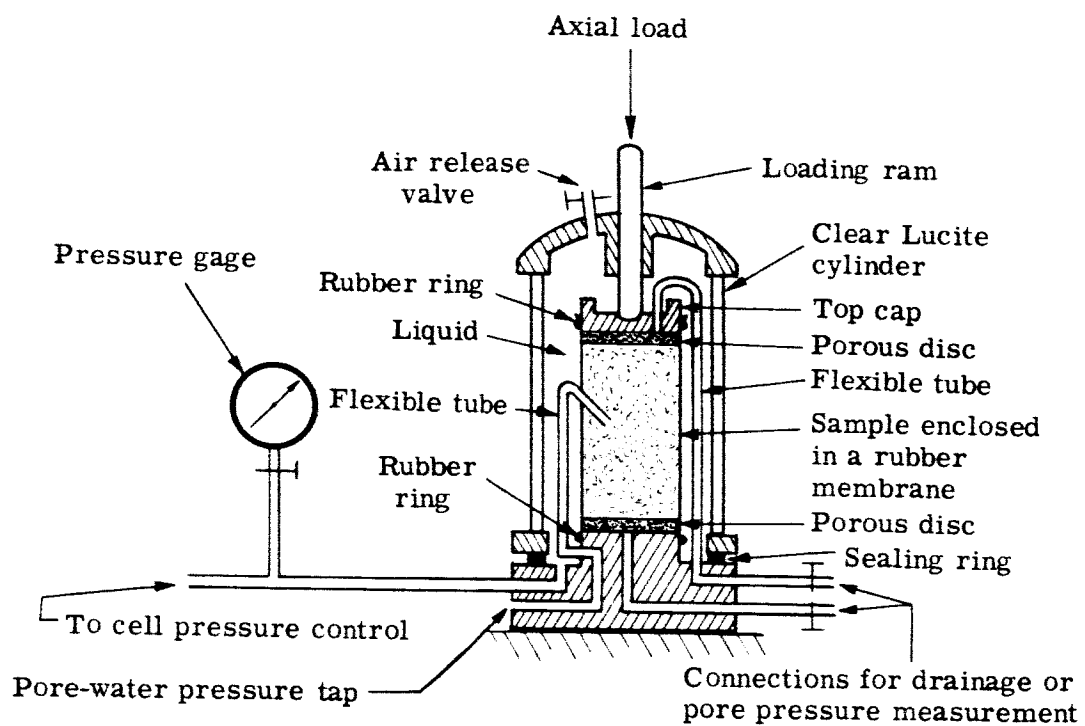
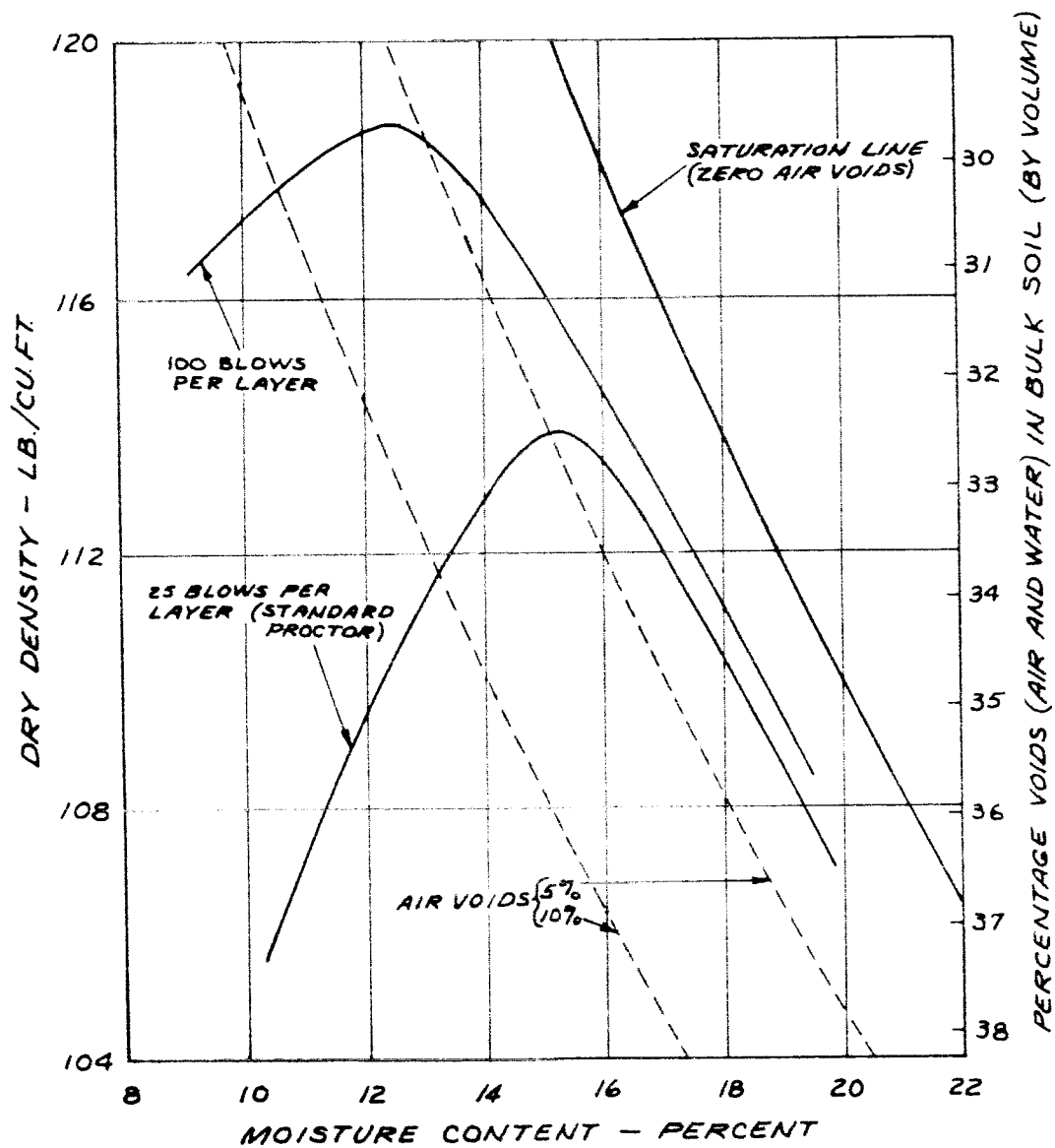
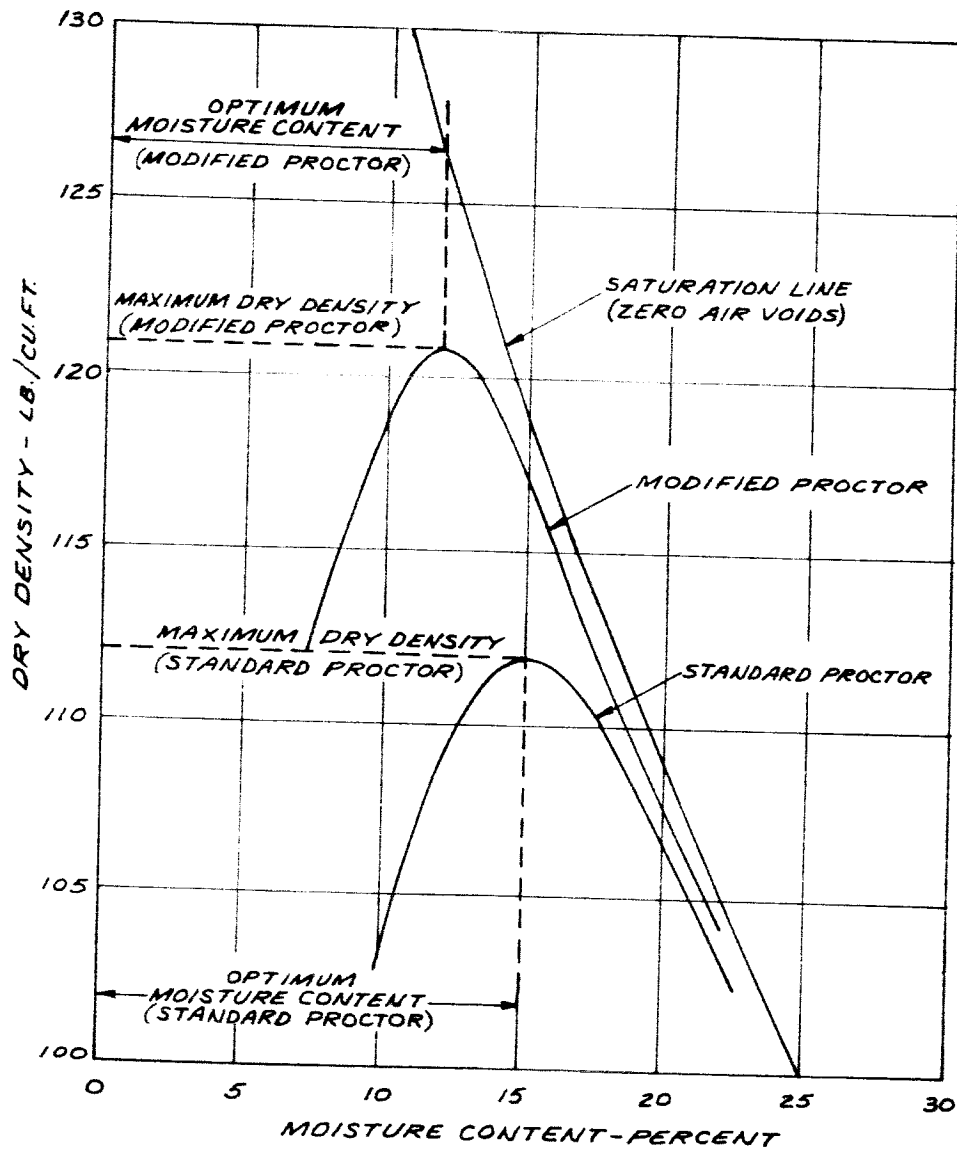


Figure 4-2. Schematic of Triaxial Test Cell



(SOIL MECHANICS FOR ROAD ENGINEERS, 1952, P. 156)

Figure 4-3. Density, Moisture, and Compaction Relationship



(SOIL MECHANICS FOR ROAD ENGINEERS, 1952, P.161)

Figure 4-4. Density, Moisture, and Compaction Relationship

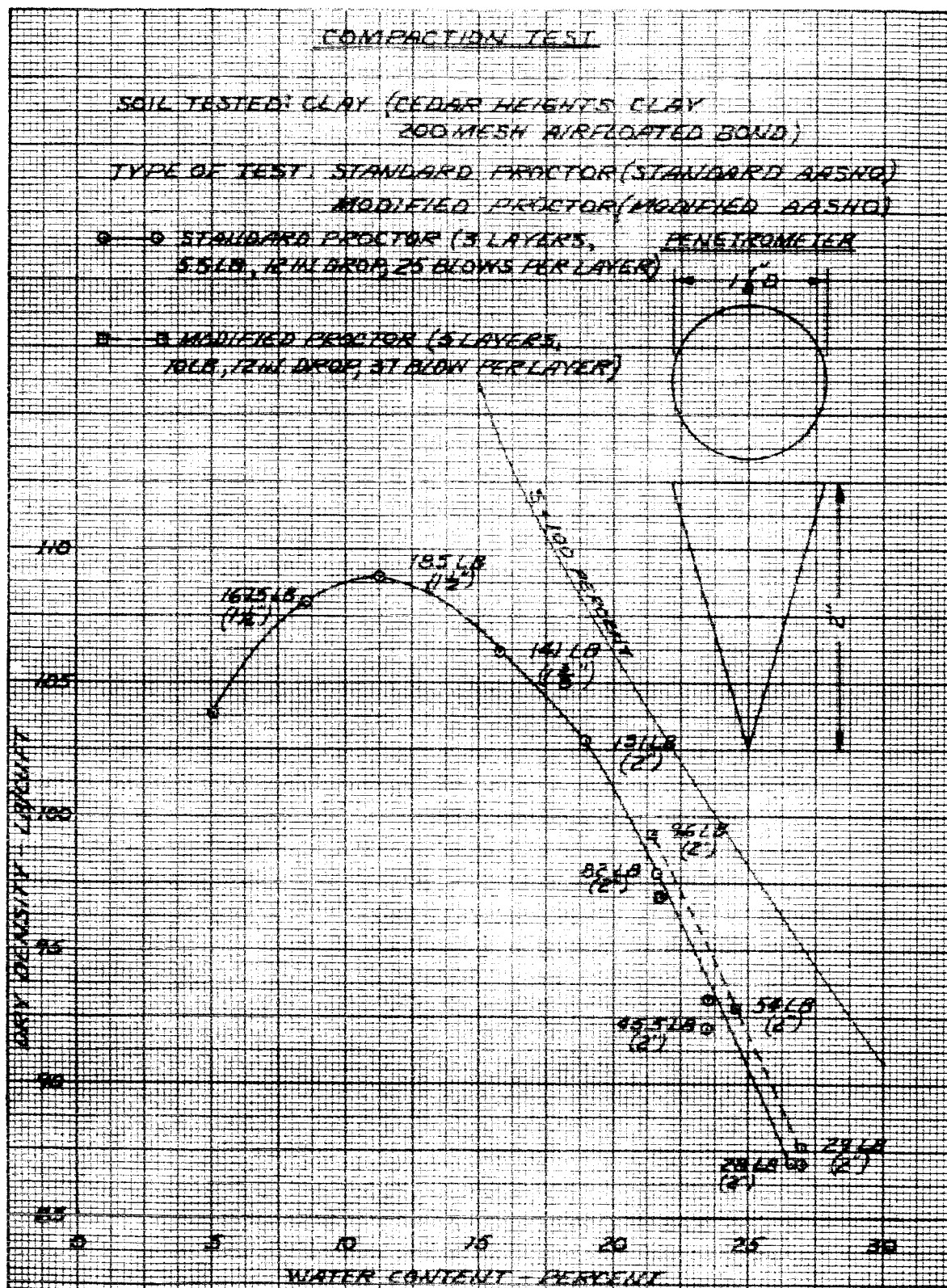


Figure 4-5. Compaction Test

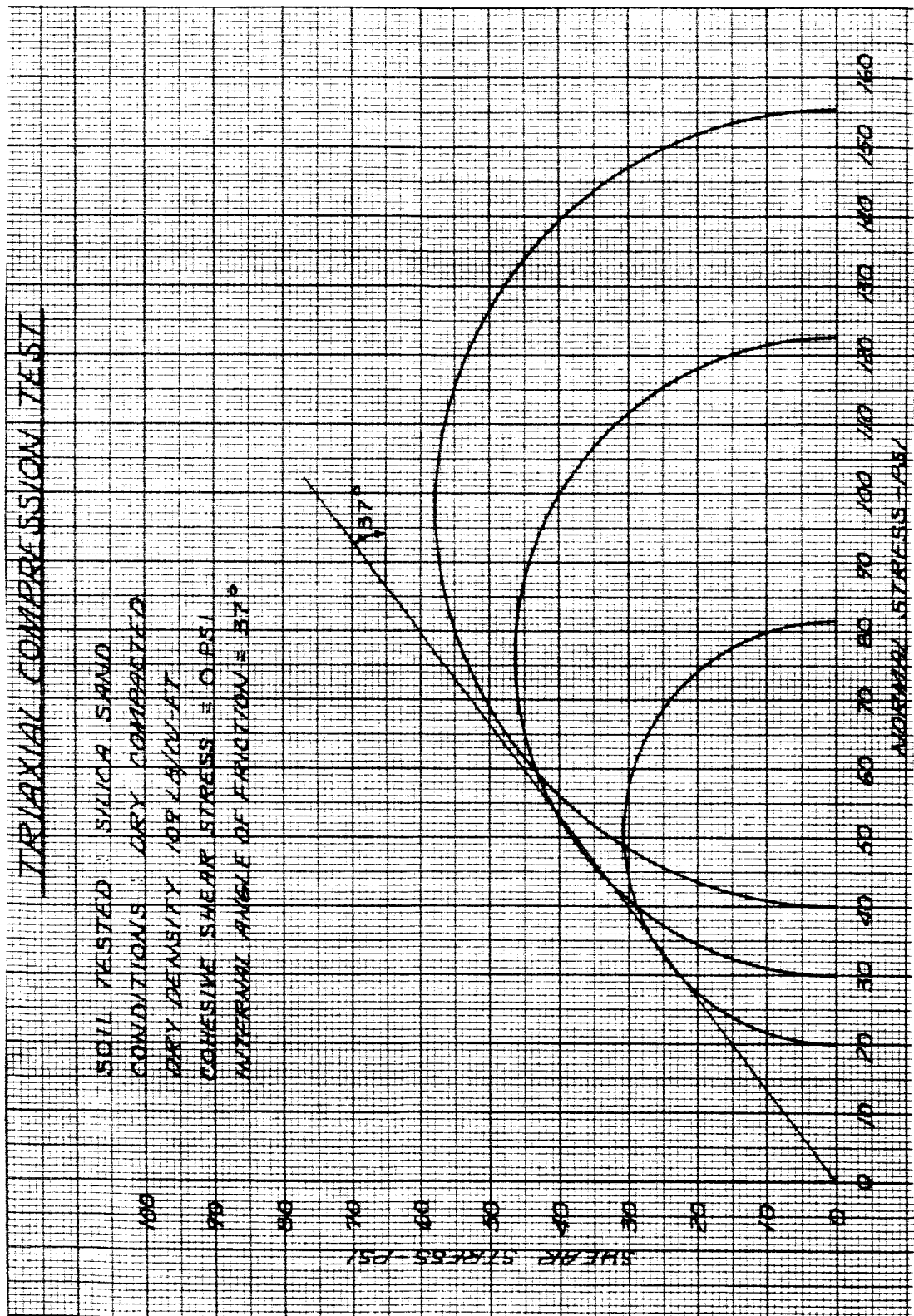


Figure 4-6. Triaxial Compression Test

GRAIN SIZE DISTRIBUTION

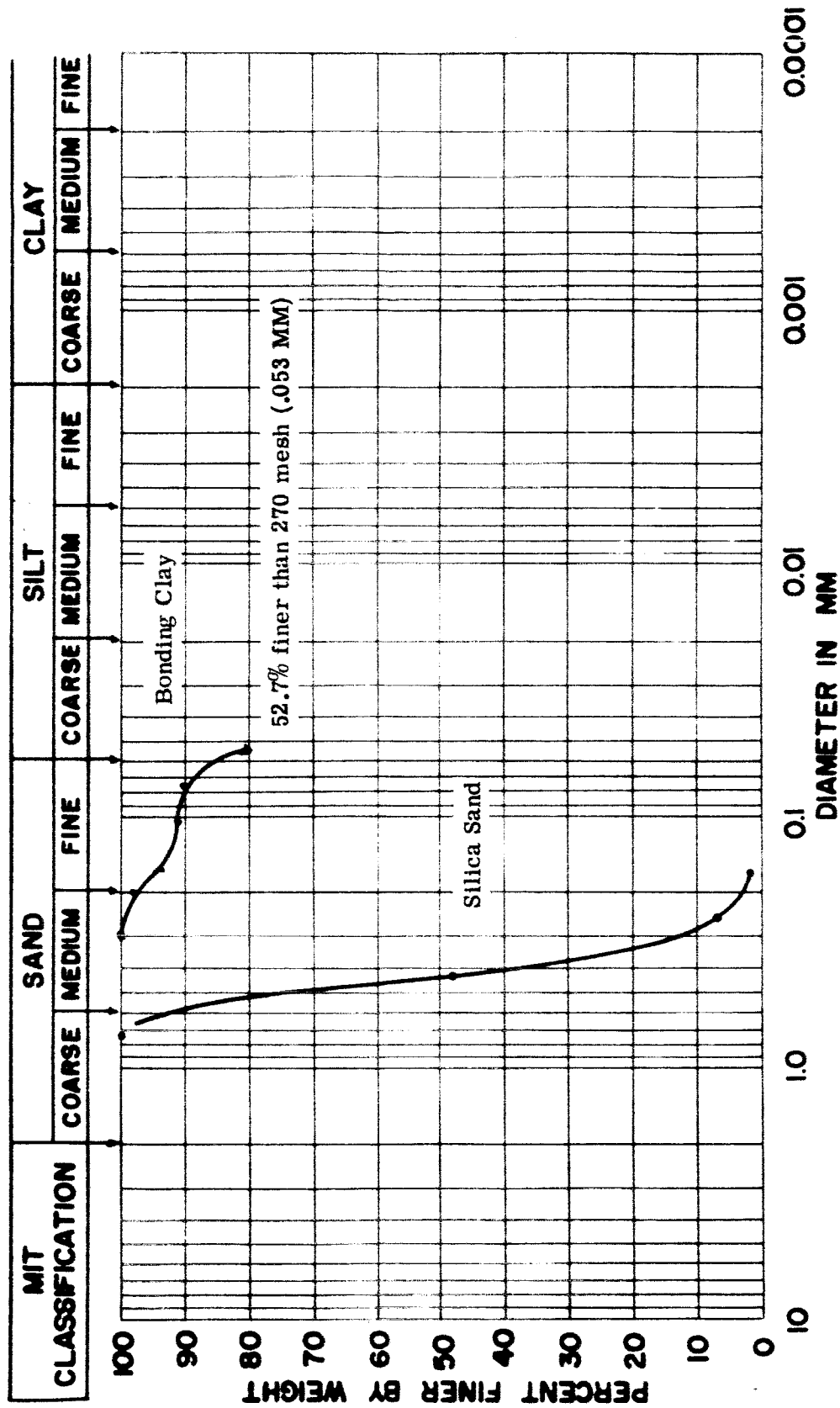


Figure 4-7. Grain Size Distribution

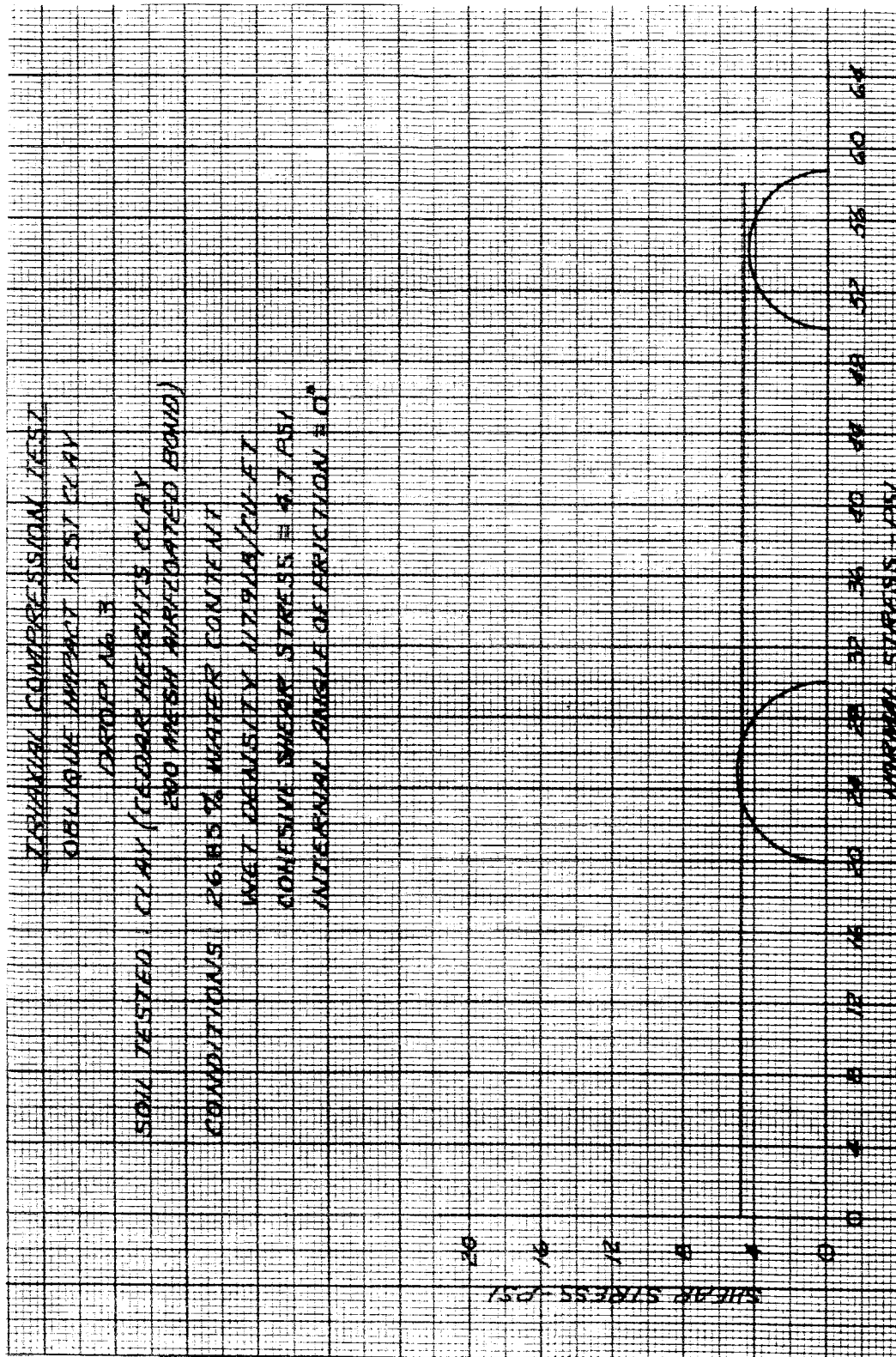


Figure 4-8. Triaxial Compression Test

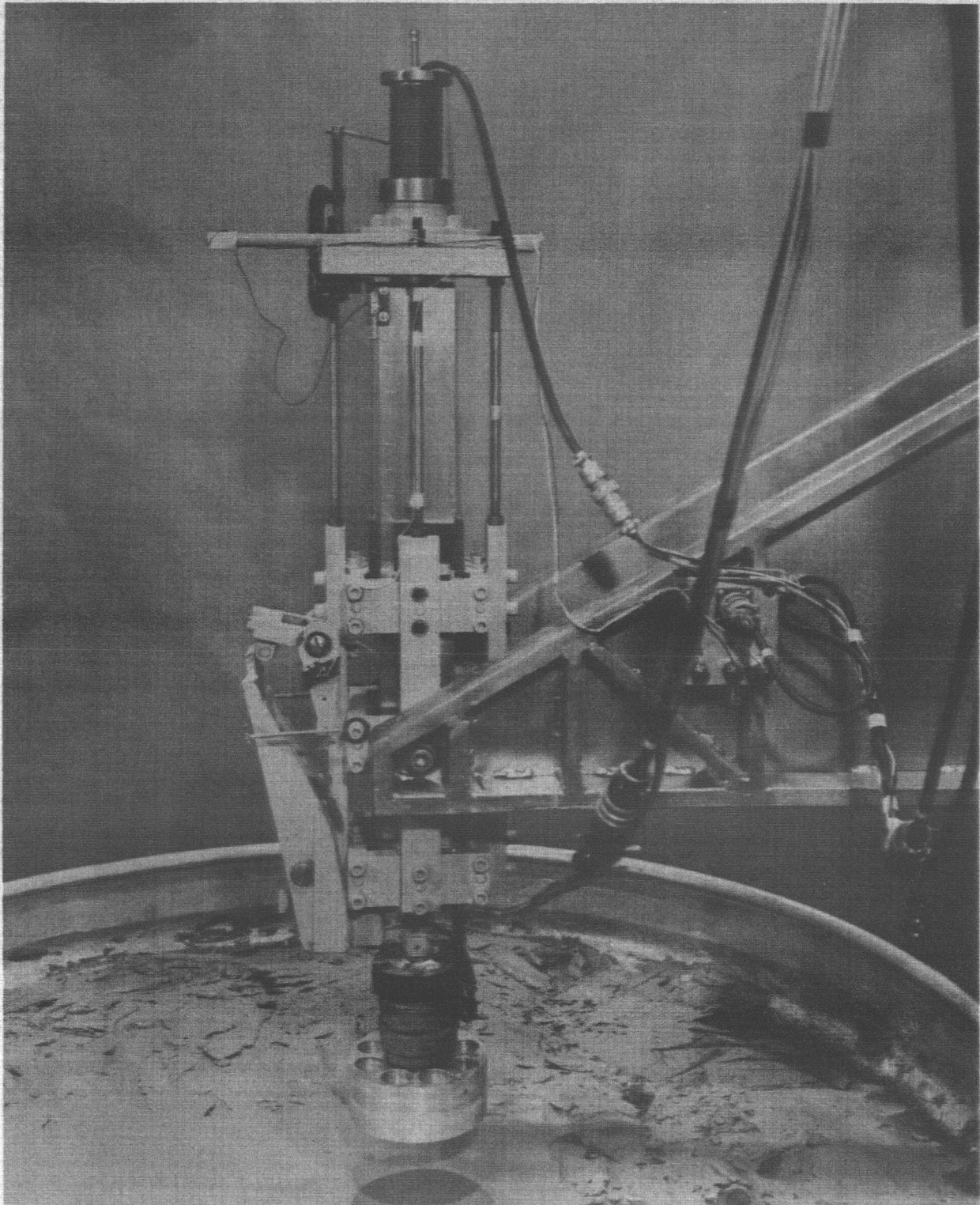


Figure 4-9. Oblique Impact Soil Tester

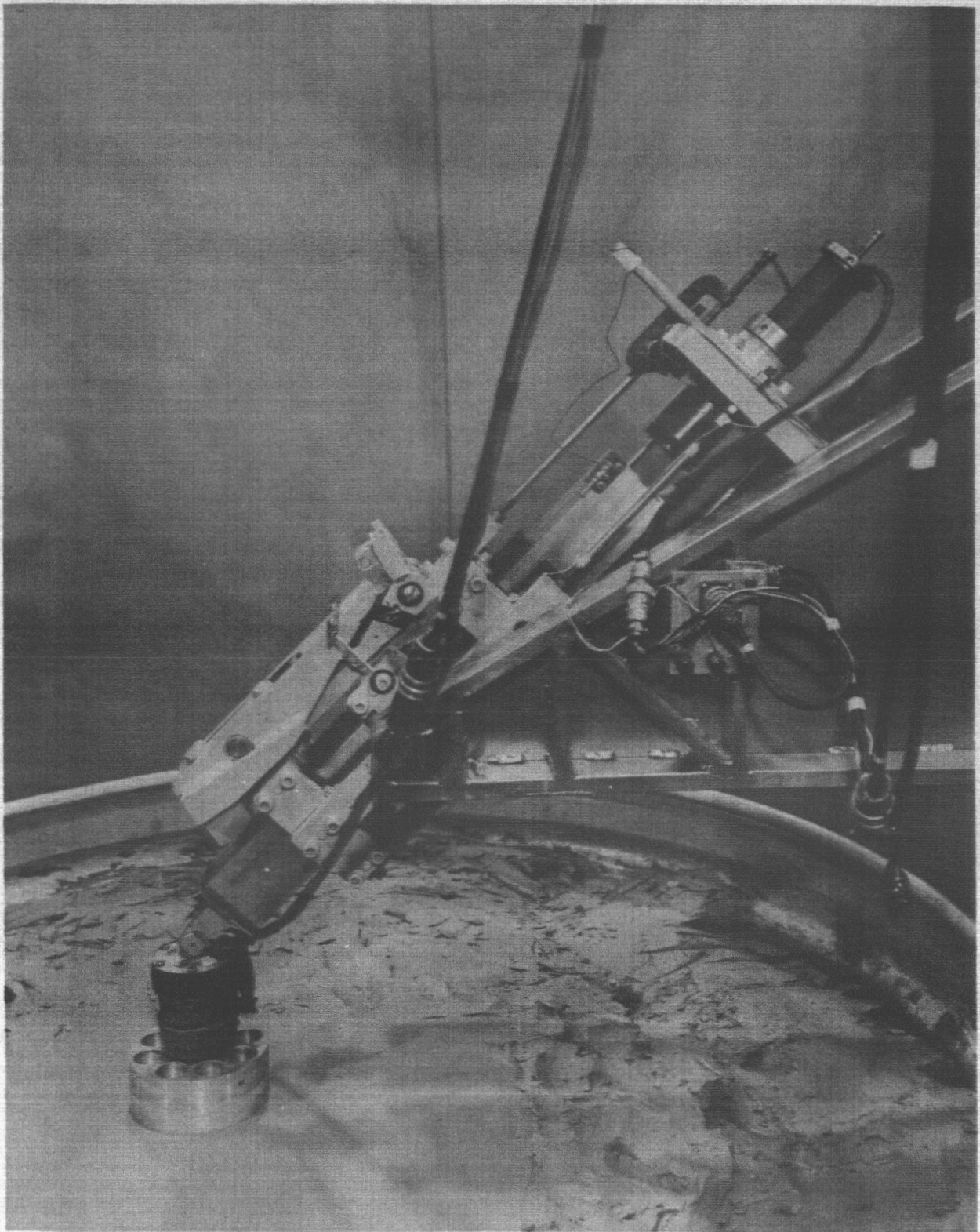


Figure 4-10. Oblique Impact Soil Tester

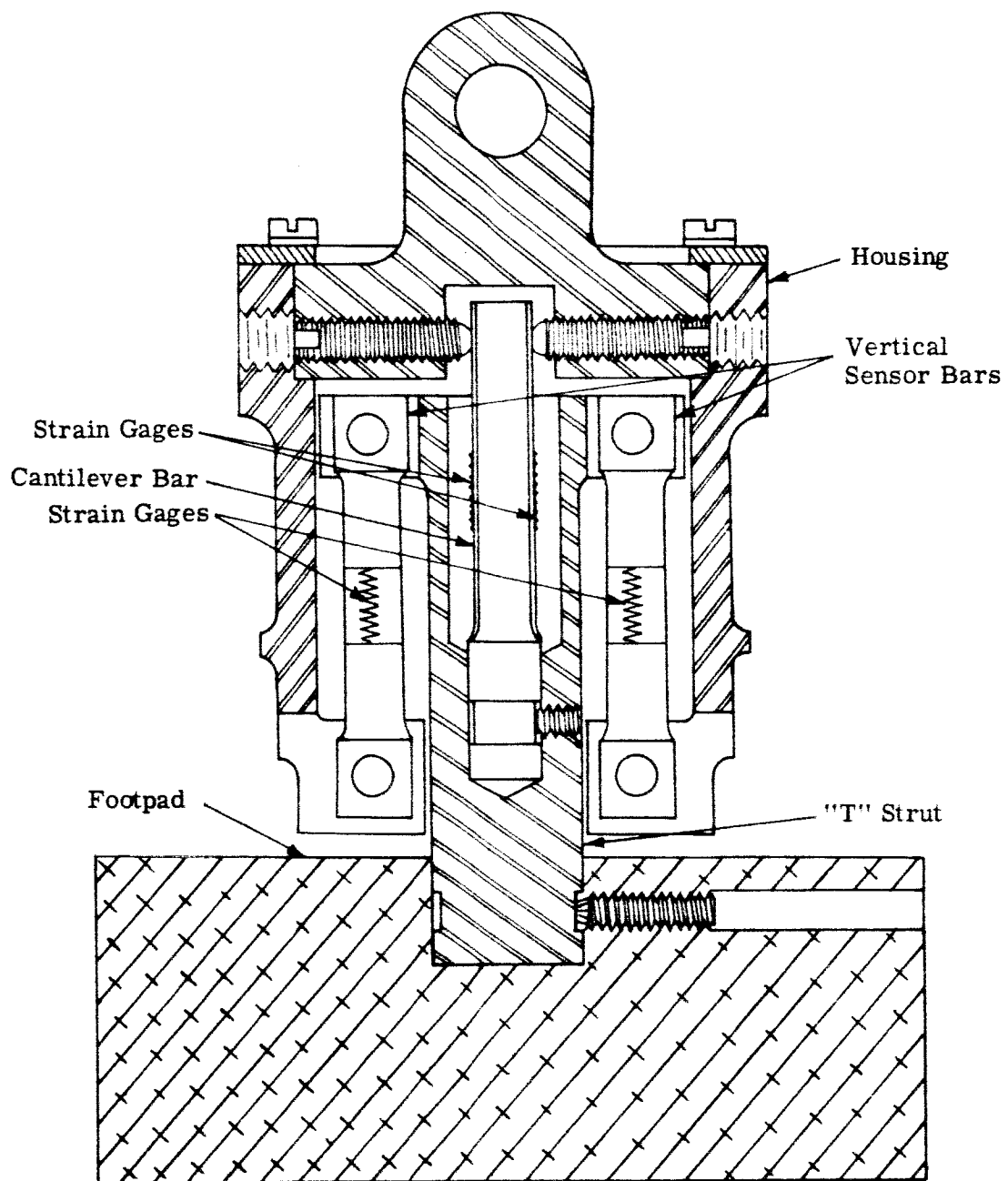


Figure 4-11. Instrumented Footpad Schematic

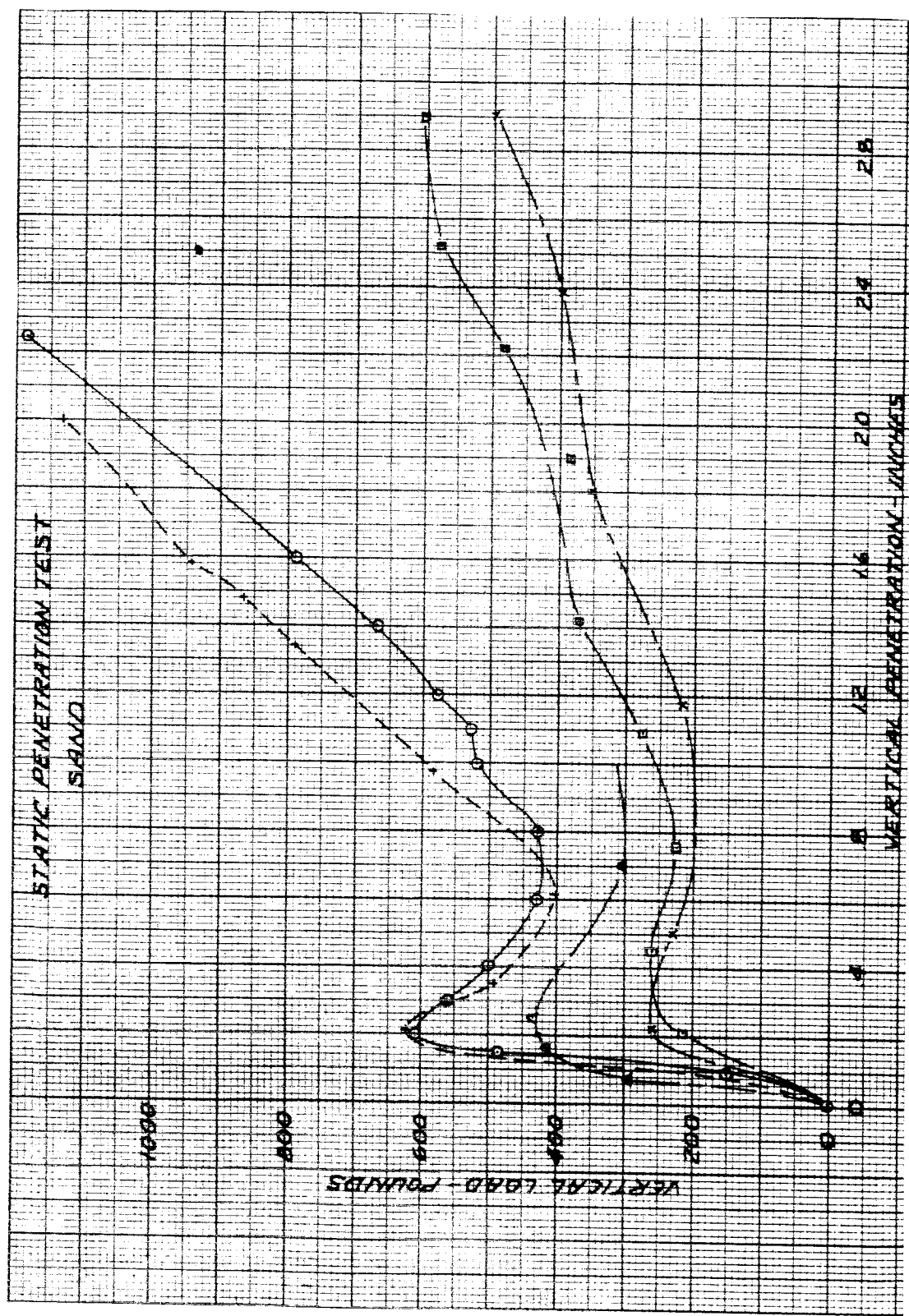


Figure 4-12. Static Penetration Test

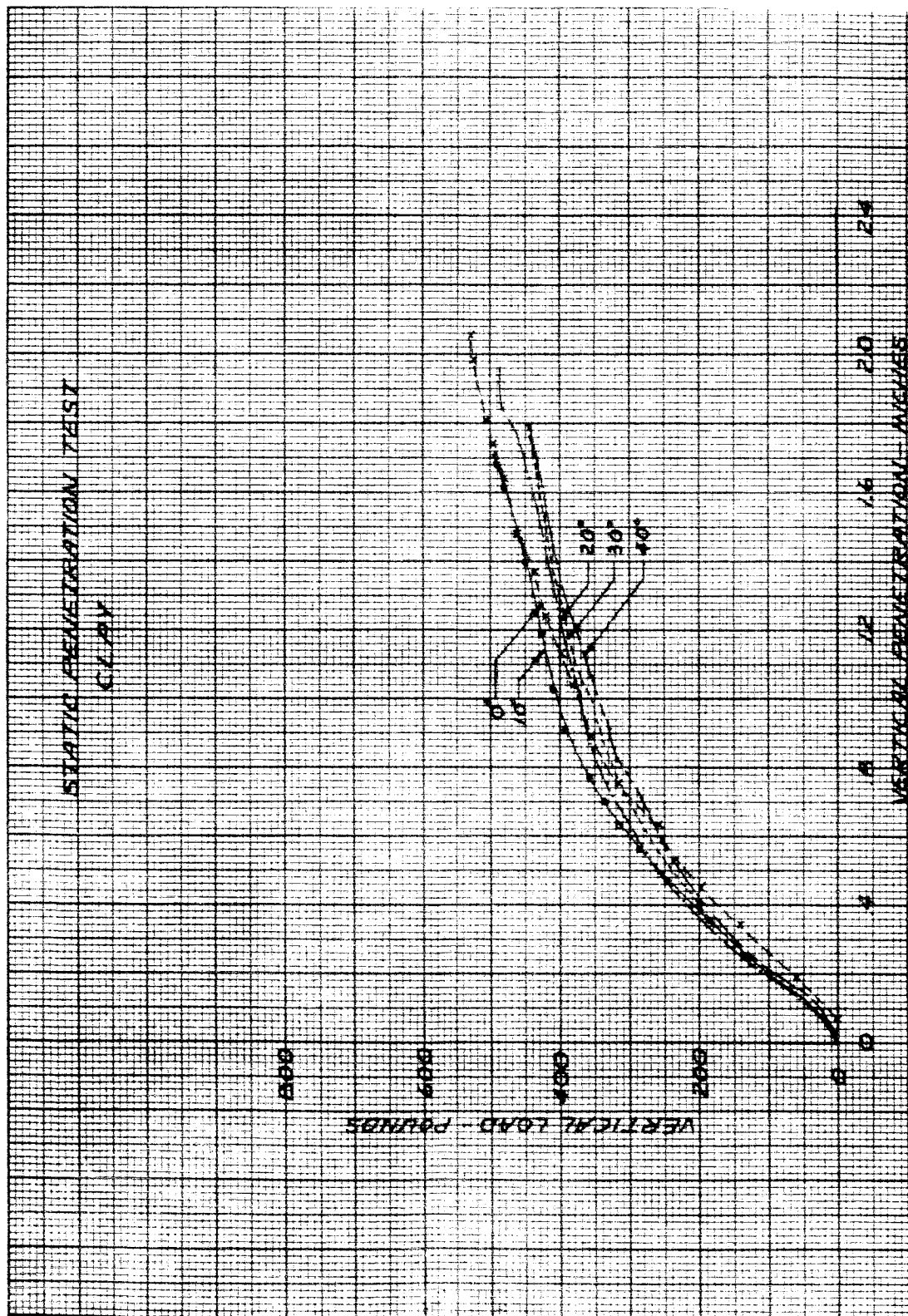


Figure 4-13. Static Penetration Test

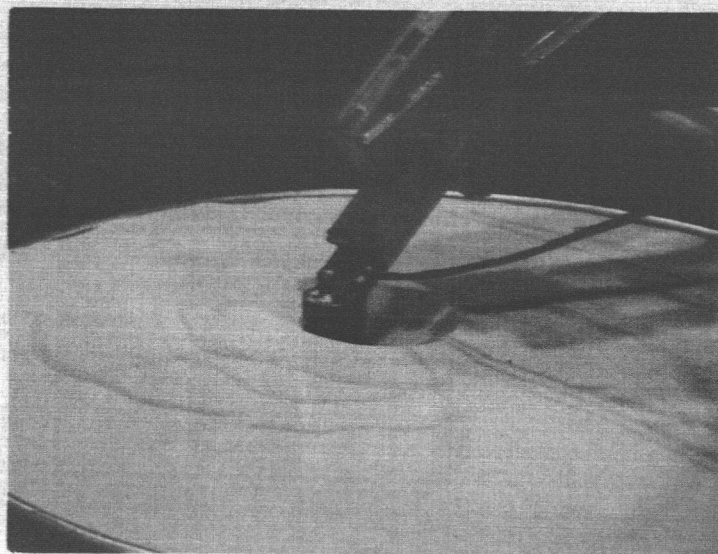


Figure 4-14. Wave Formation of Static Penetration

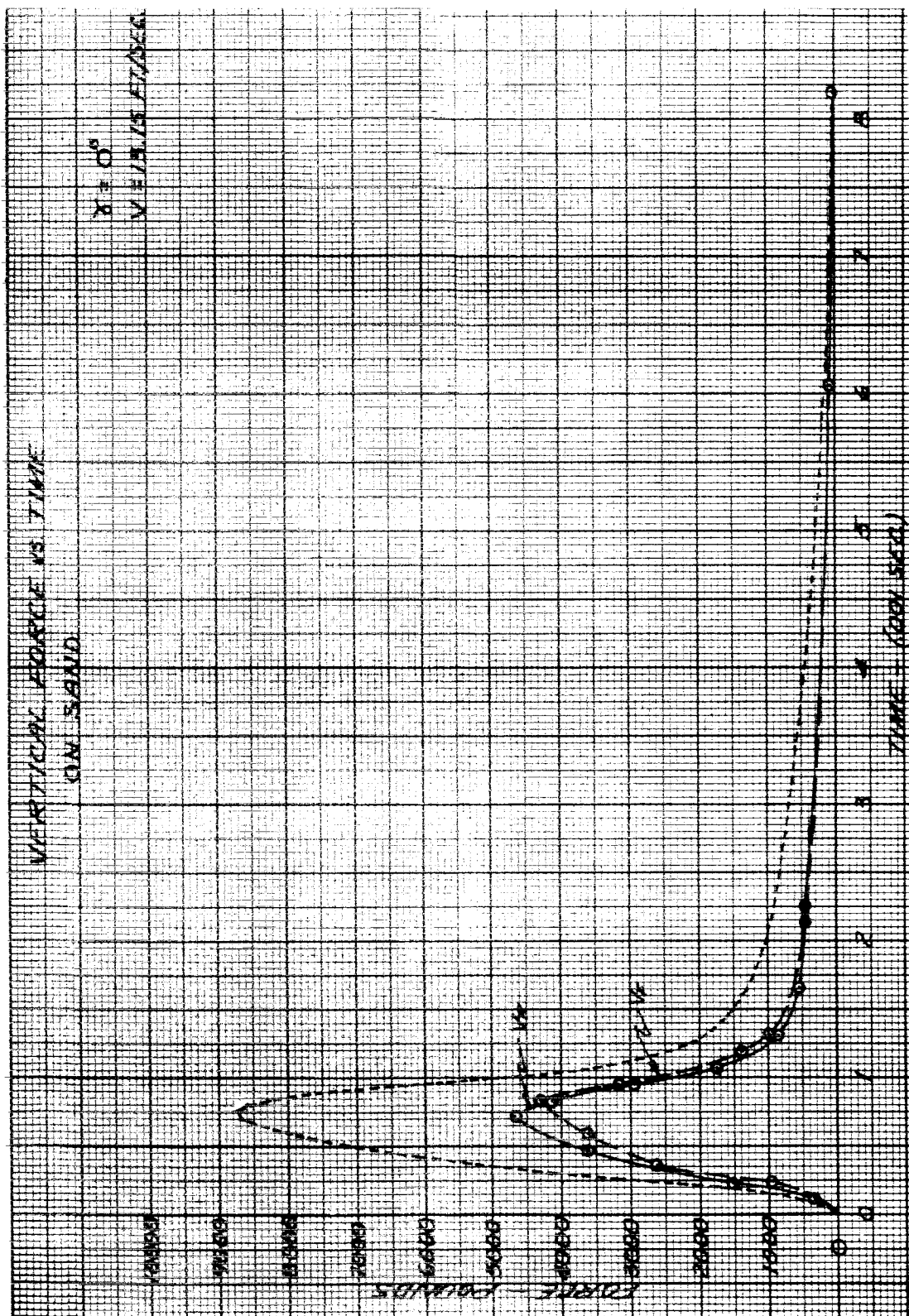


Figure 4-15. Vertical Force Versus Time

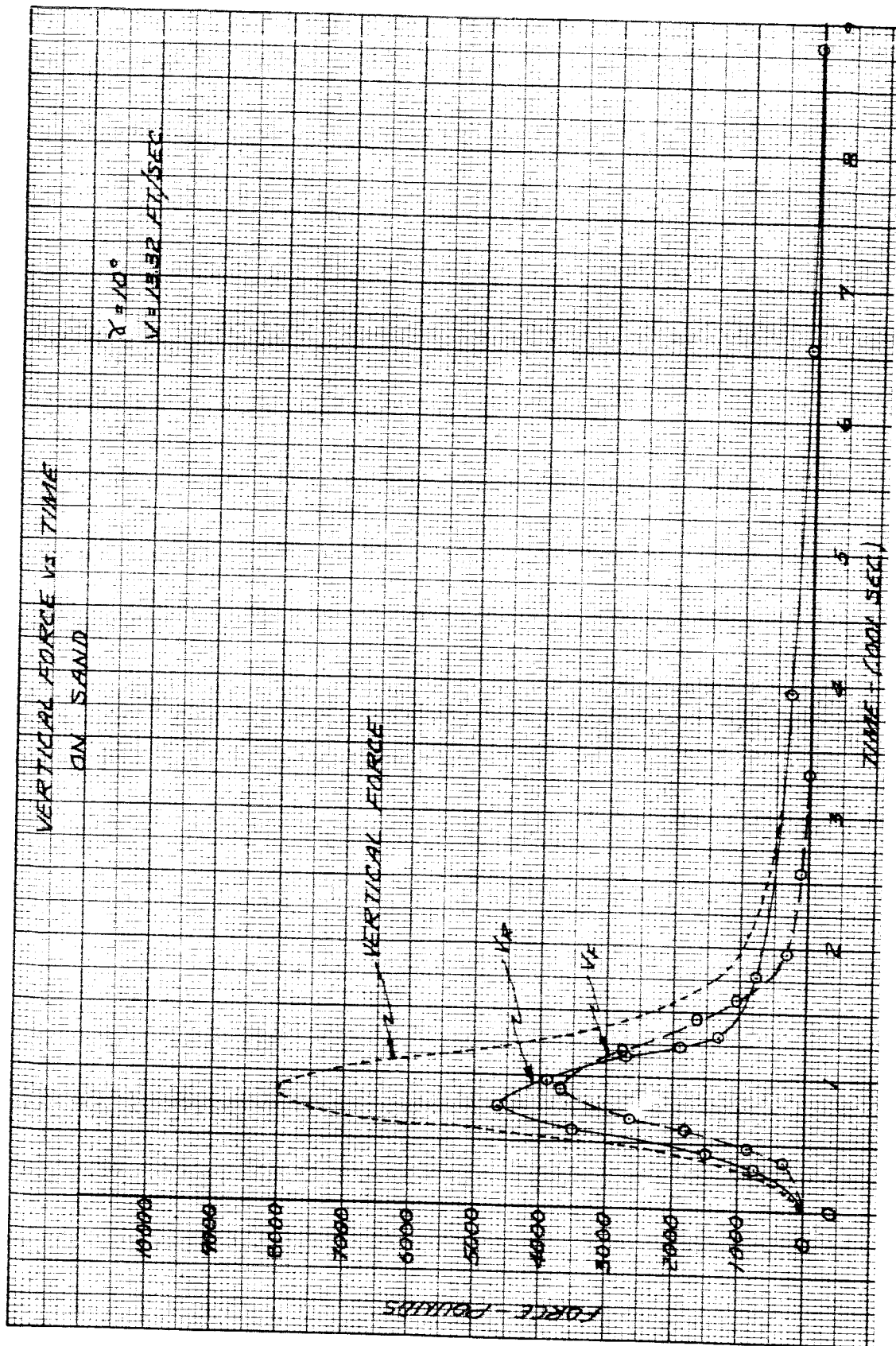


Figure 4-16. Vertical Force Versus Time

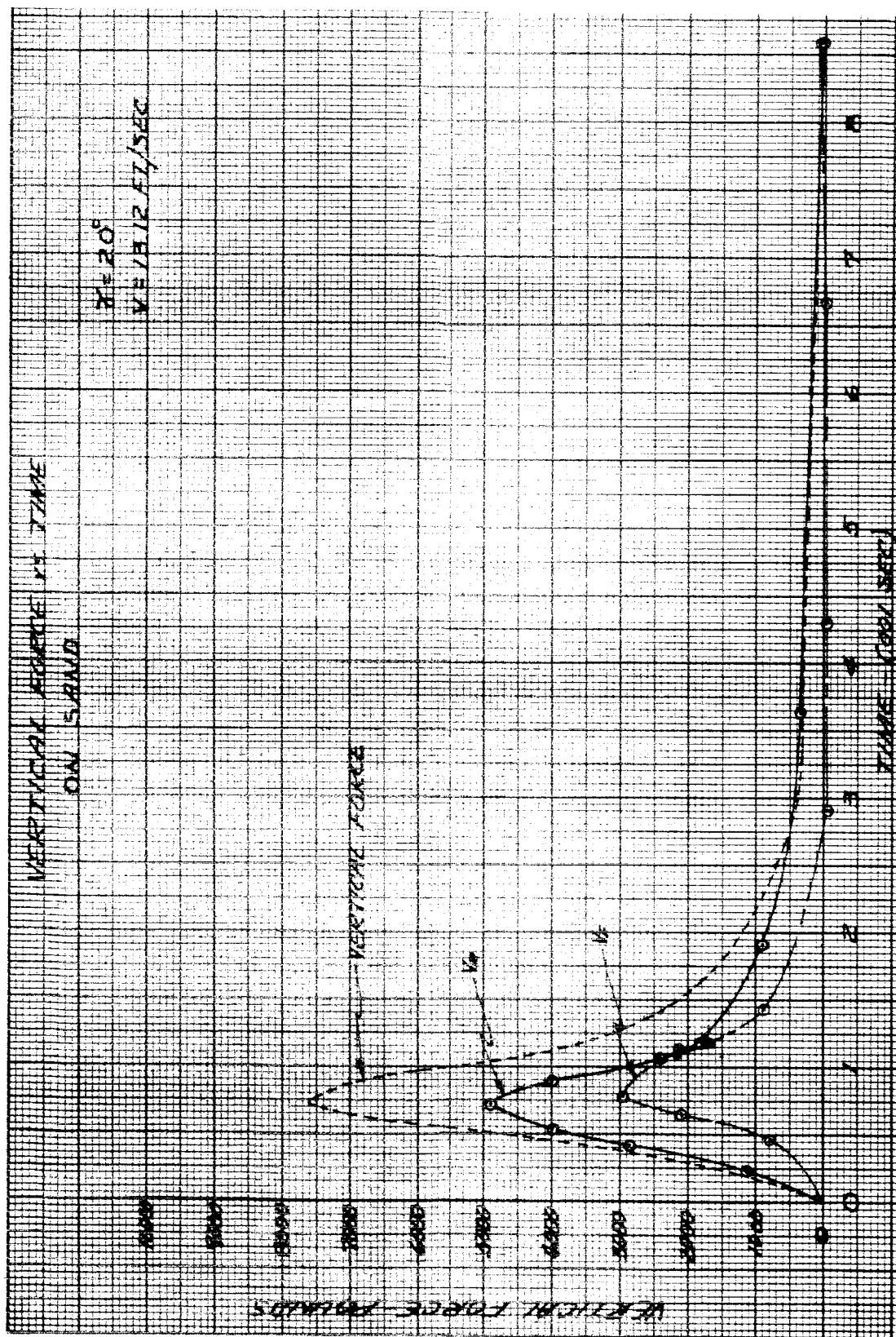


Figure 4-17. Vertical Force Versus Time on Sand

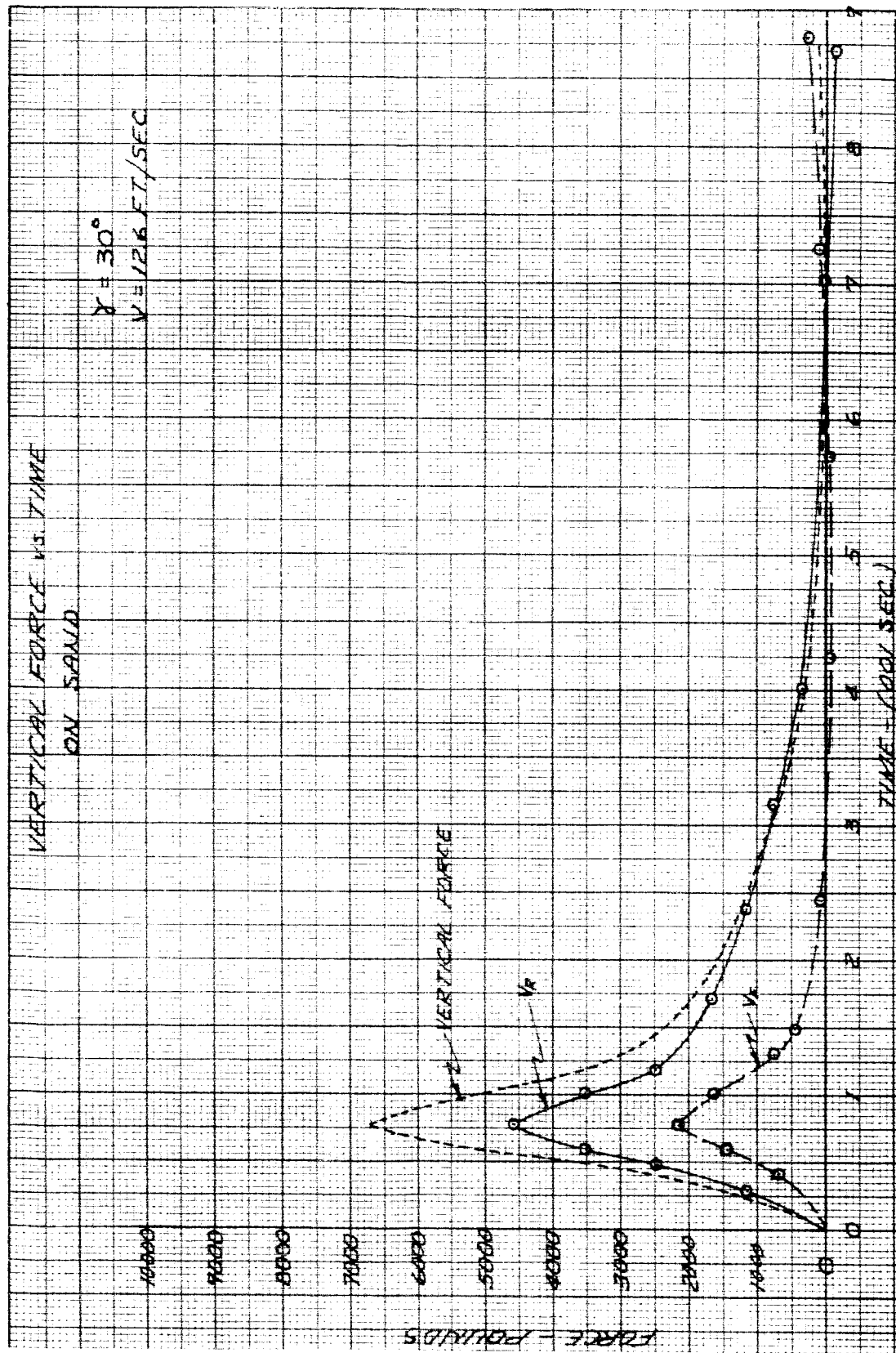


Figure 4-18. Vertical Force Versus Time on Sand

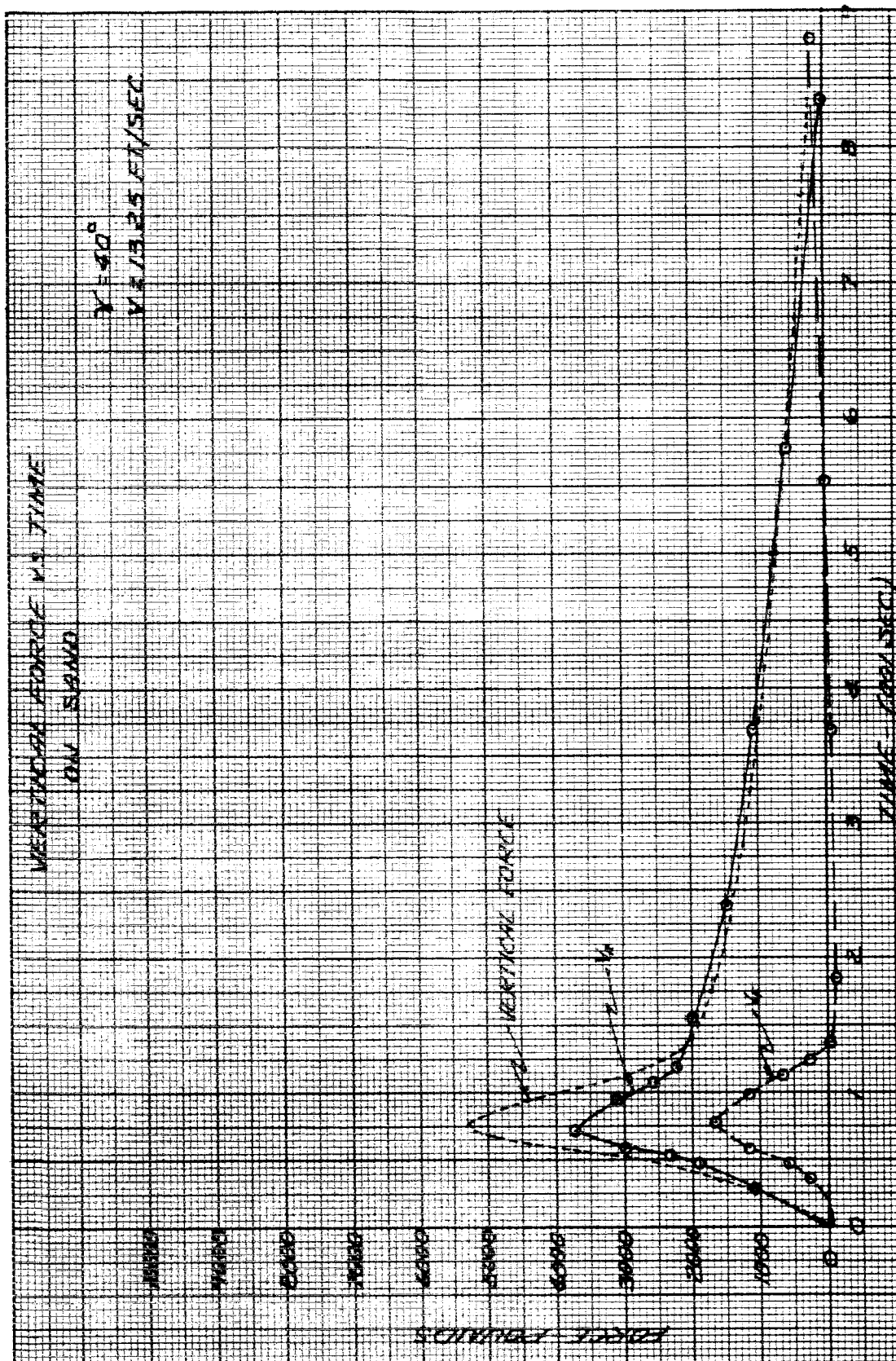


Figure 4-19. Vertical Force Versus Time on Sand

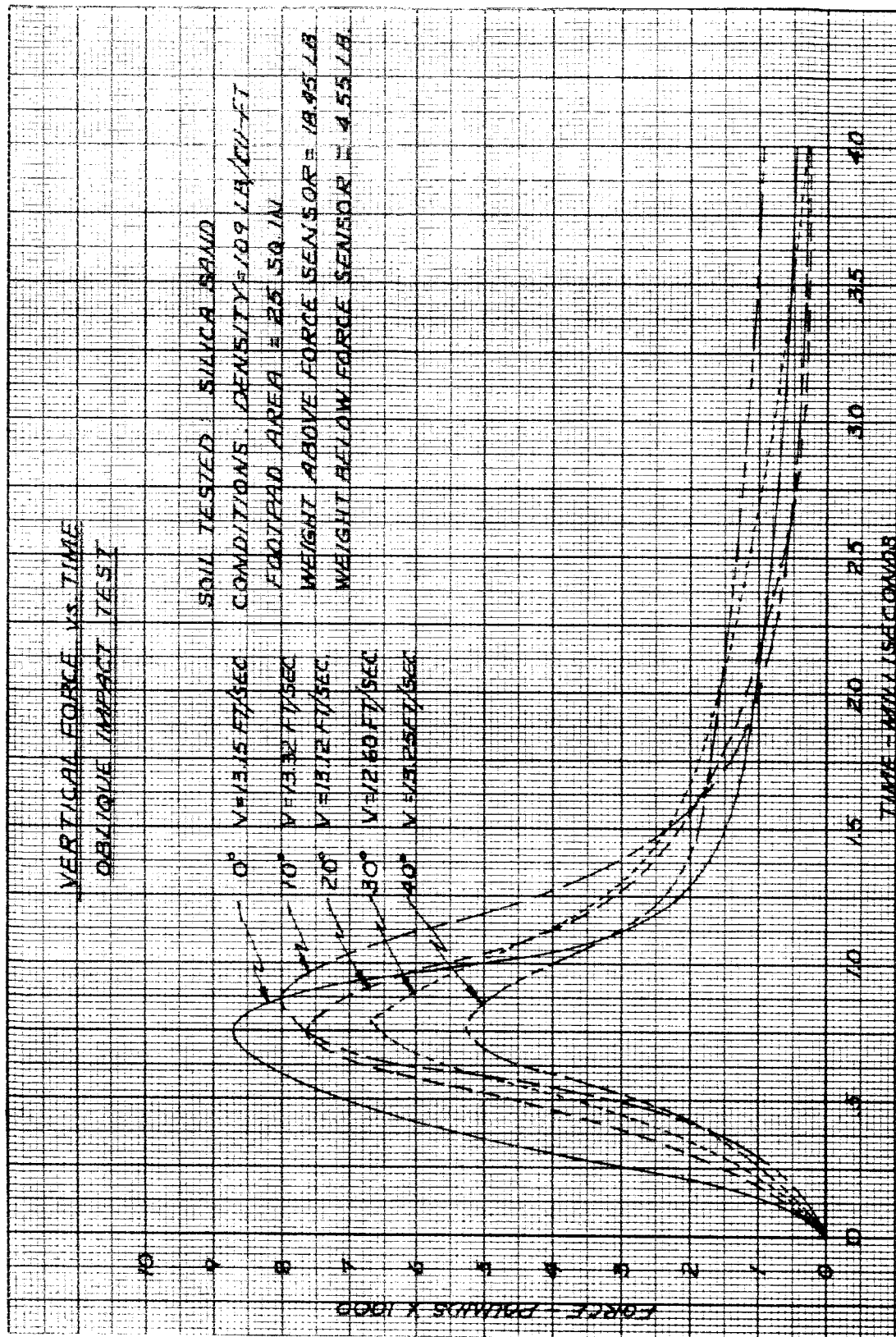


Figure 4-20. Vertical Force Versus Time Oblique Impact Test

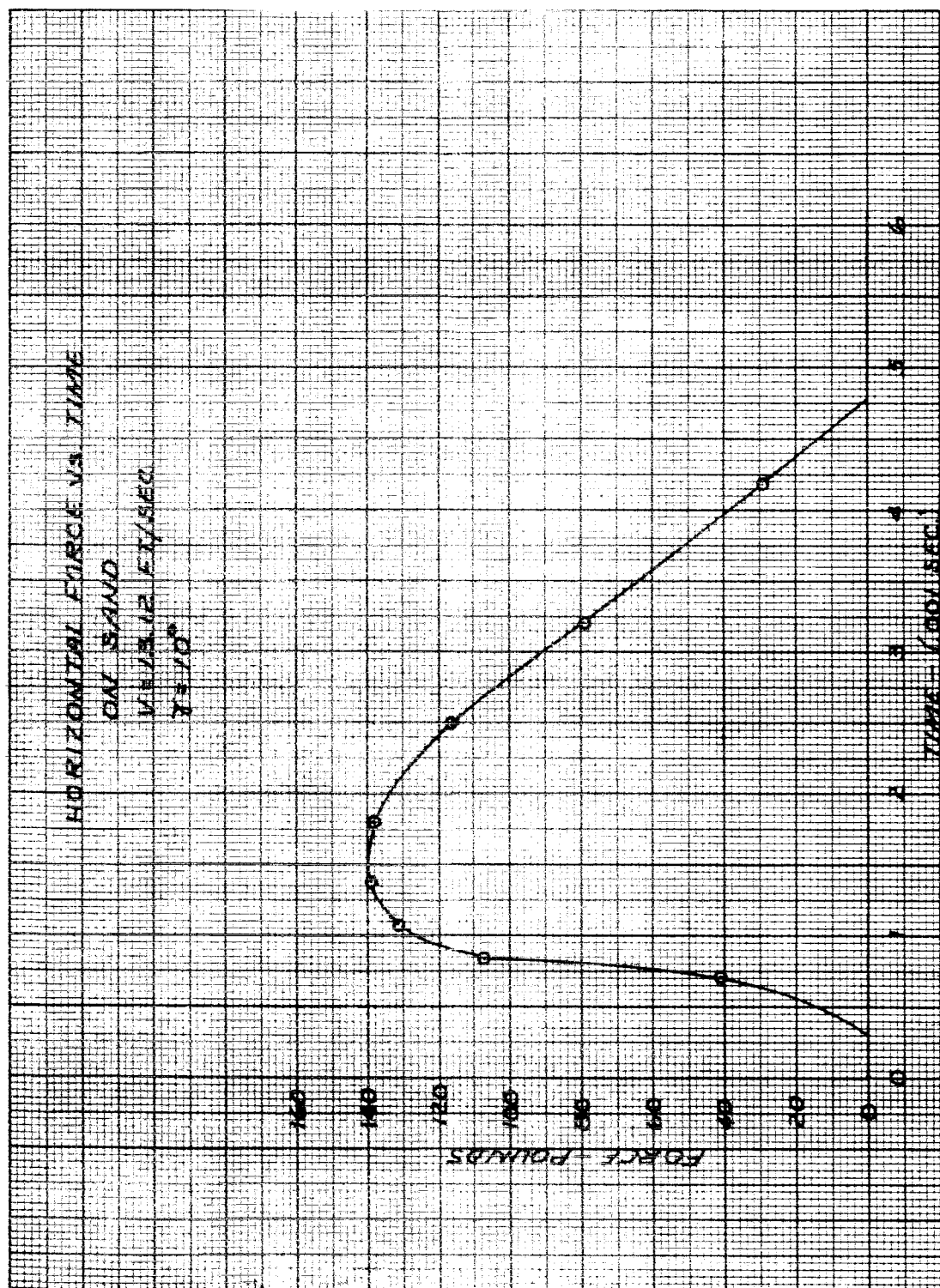


Figure 4-21. Horizontal Force Versus Time on Sand

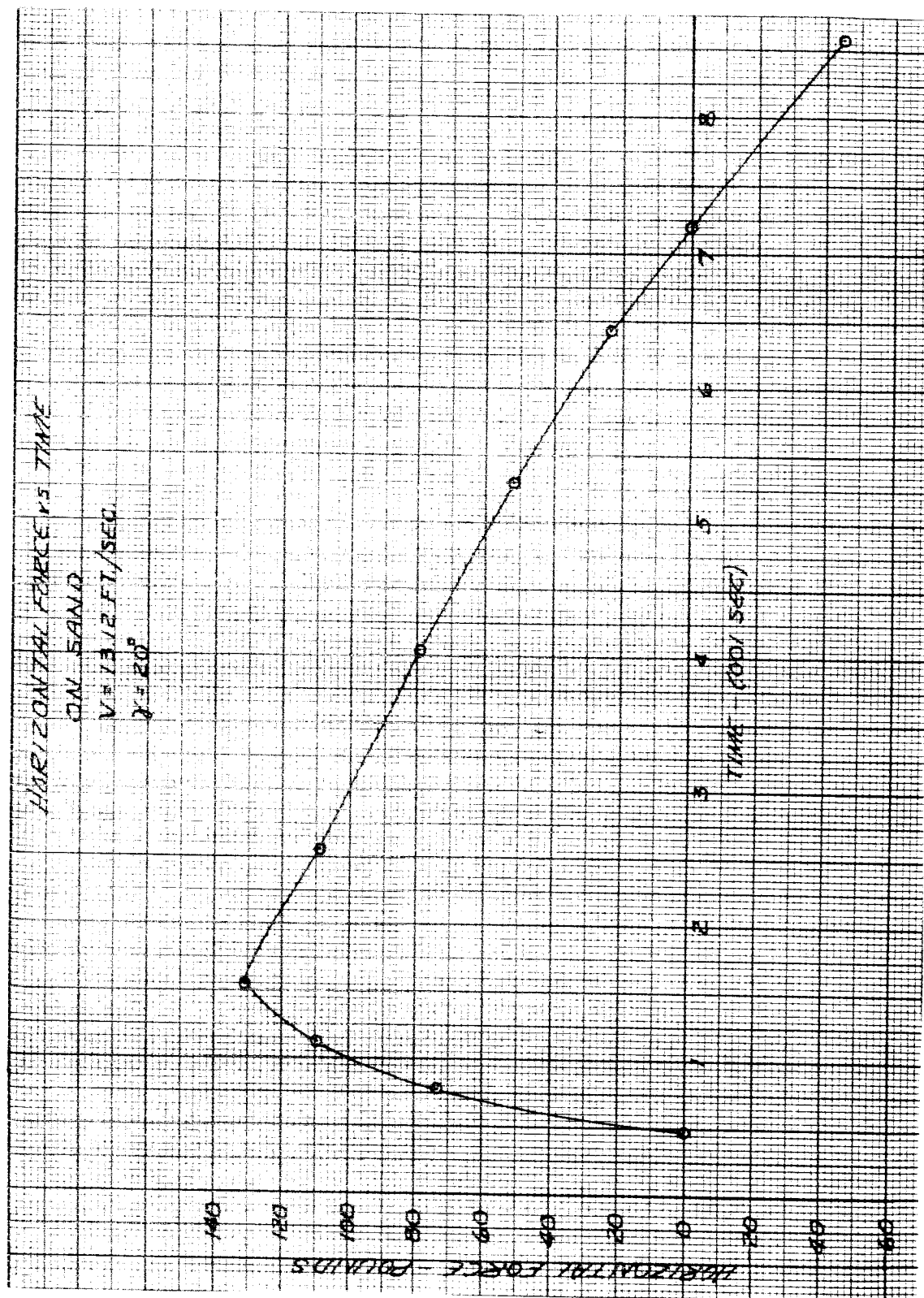


Figure 4-22. Horizontal Force Versus Time on Sand

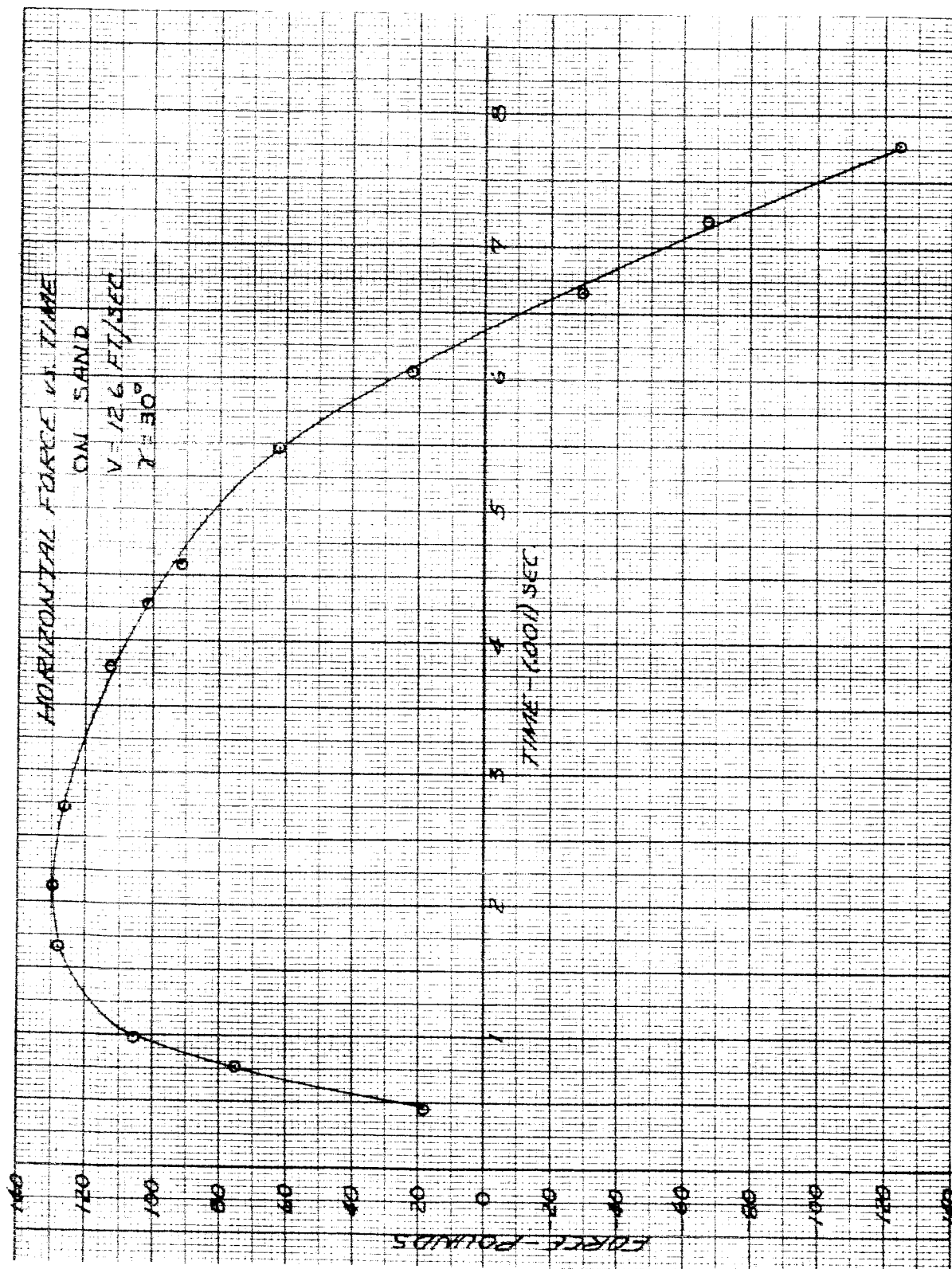


Figure 4-23. Horizontal Force Versus Time on Sand

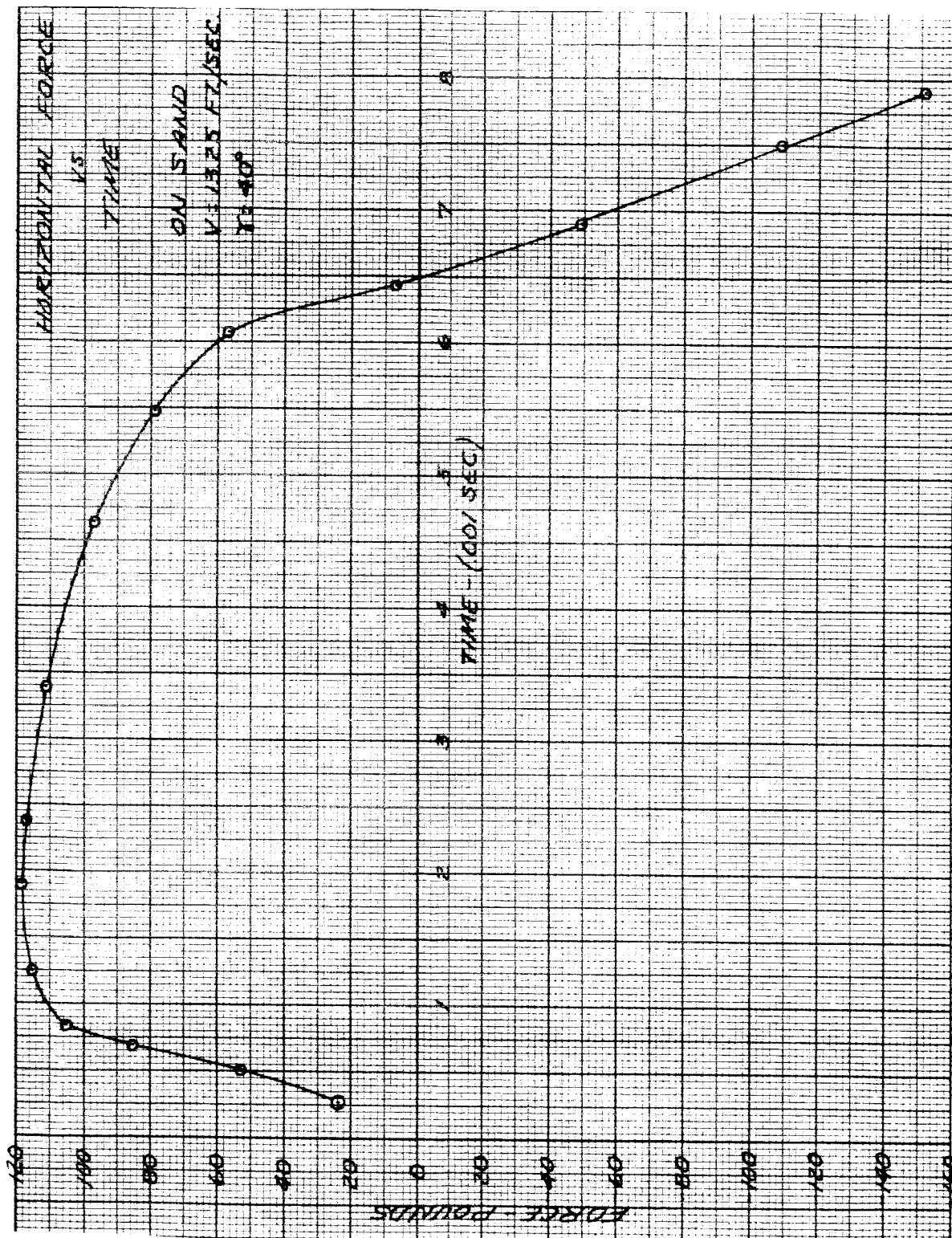


Figure 4-24. Horizontal Force Versus Time on Sand

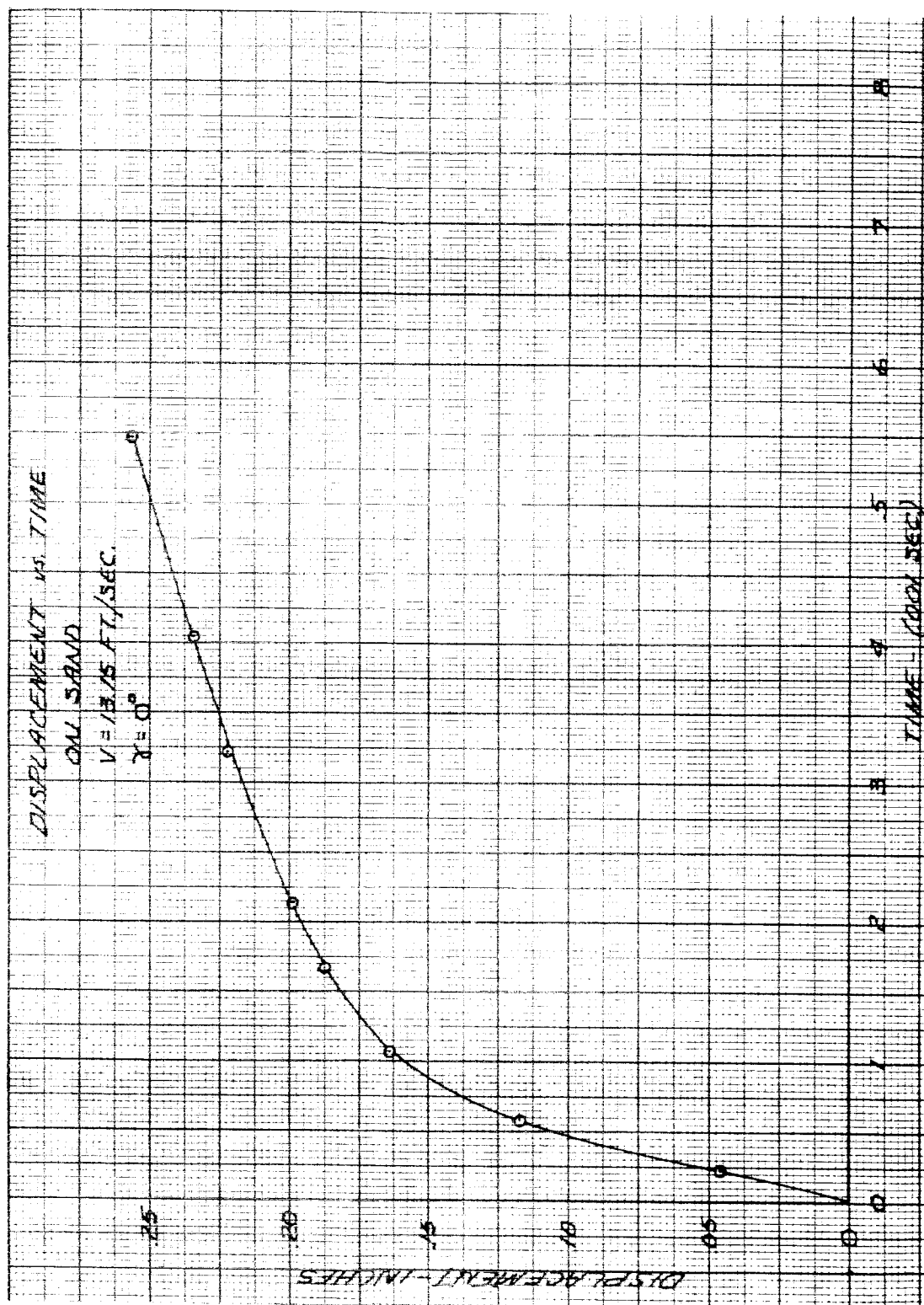


Figure 4-25. Displacement Versus Time on Sand

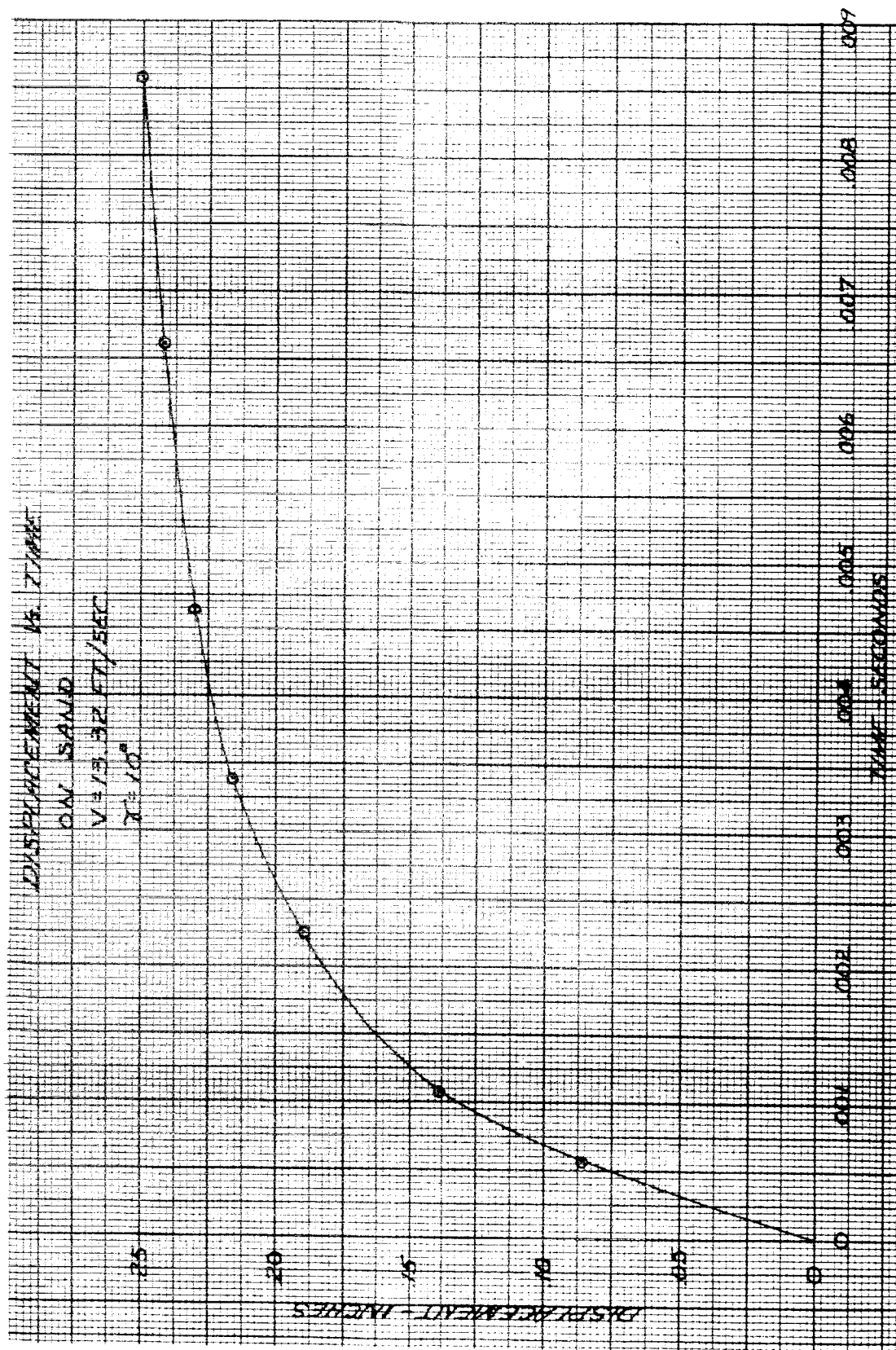


Figure 4-26. Displacement Versus Time on Sand

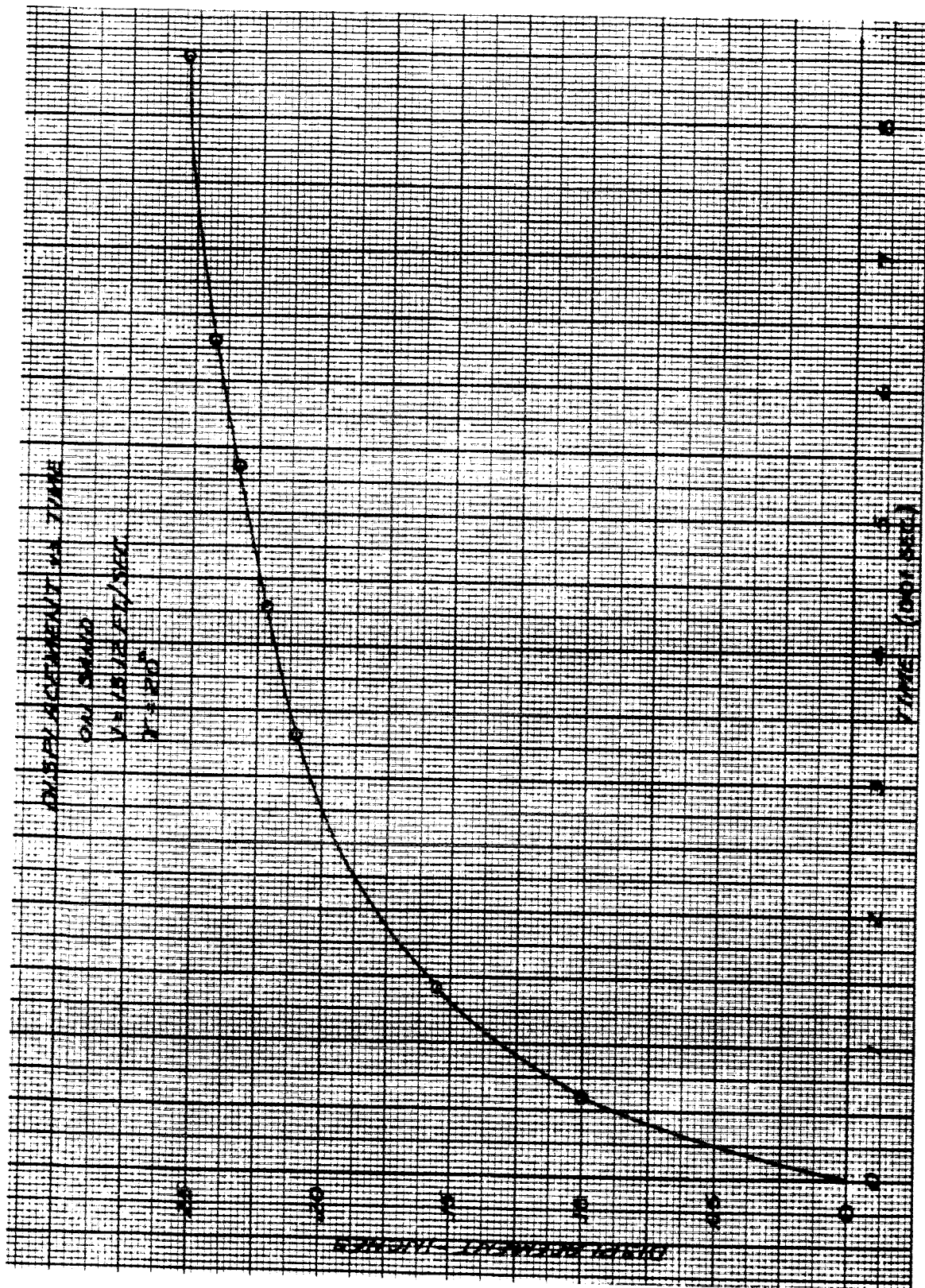


Figure 4-27. Displacement Versus Time on Sand

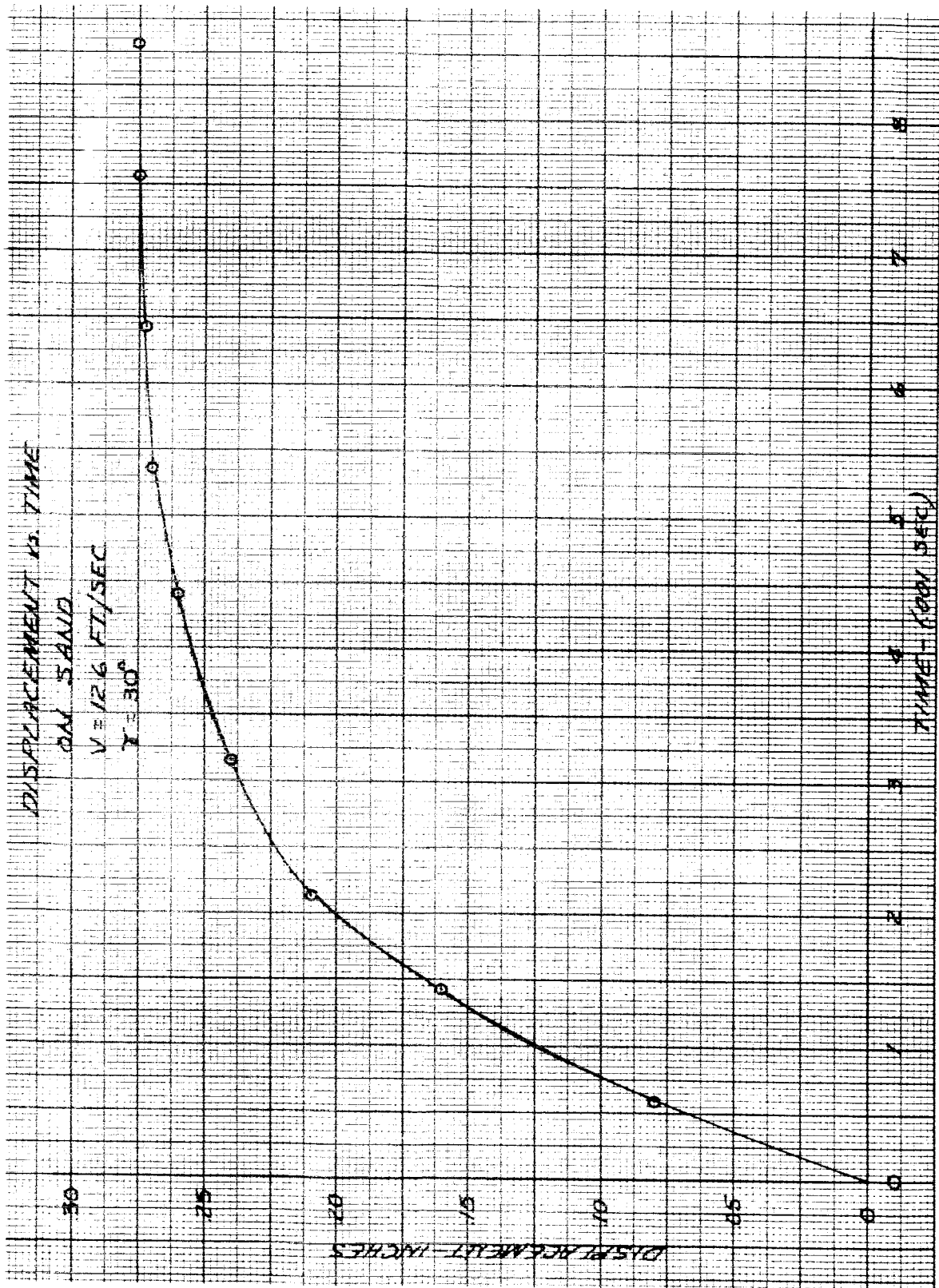


Figure 4-28. Displacement Versus Time on Sand

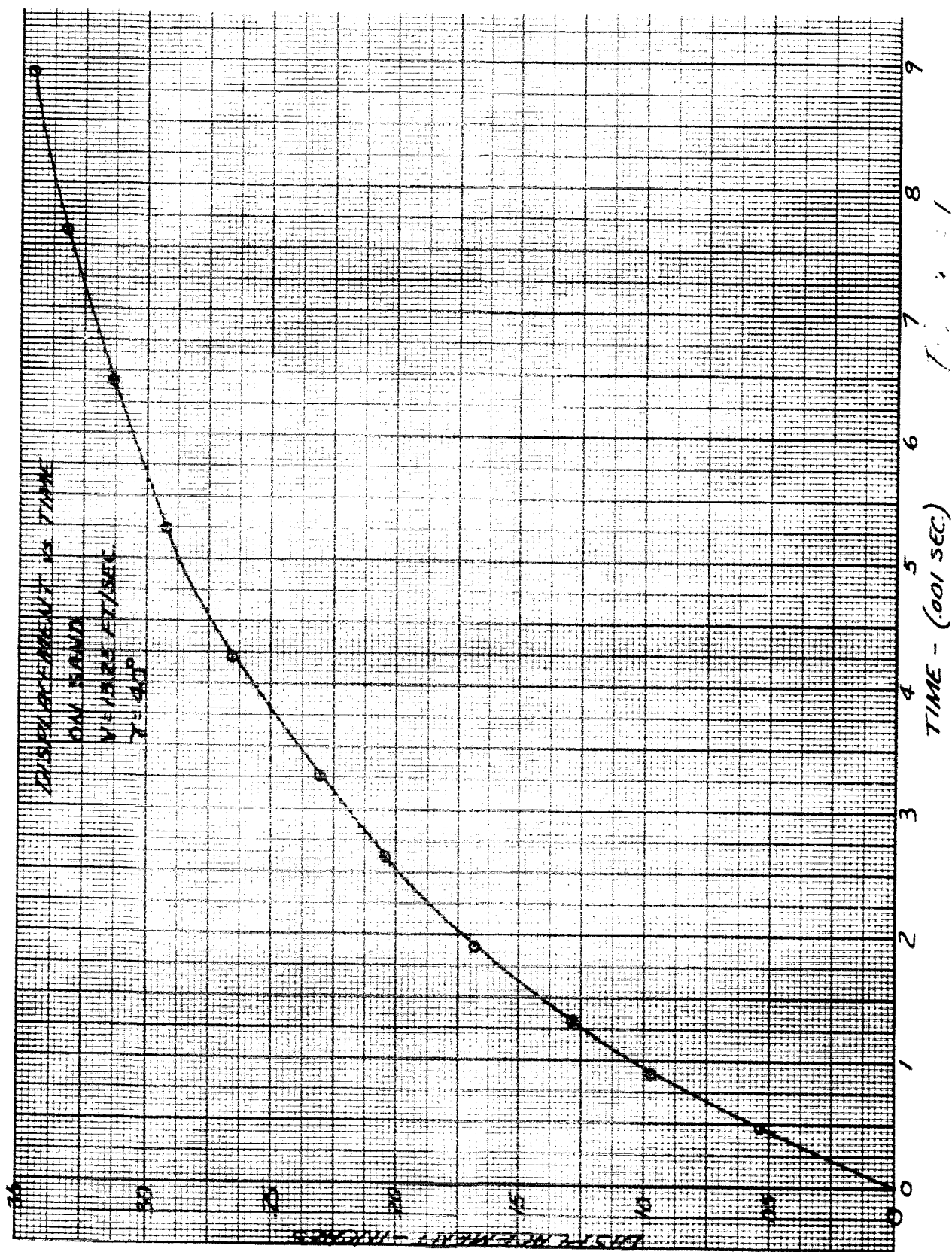
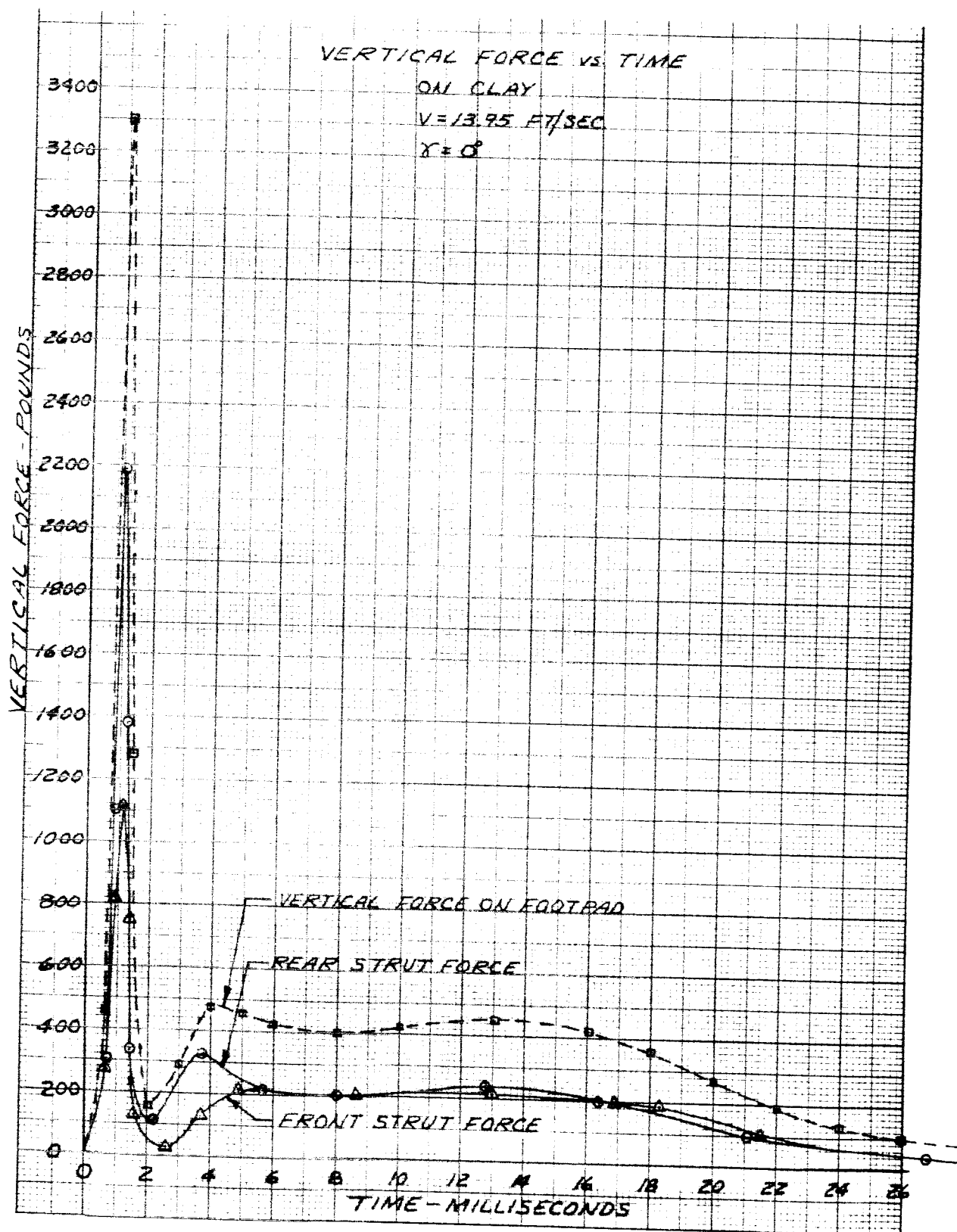


Figure 4-29. Displacement Versus Time on Sand



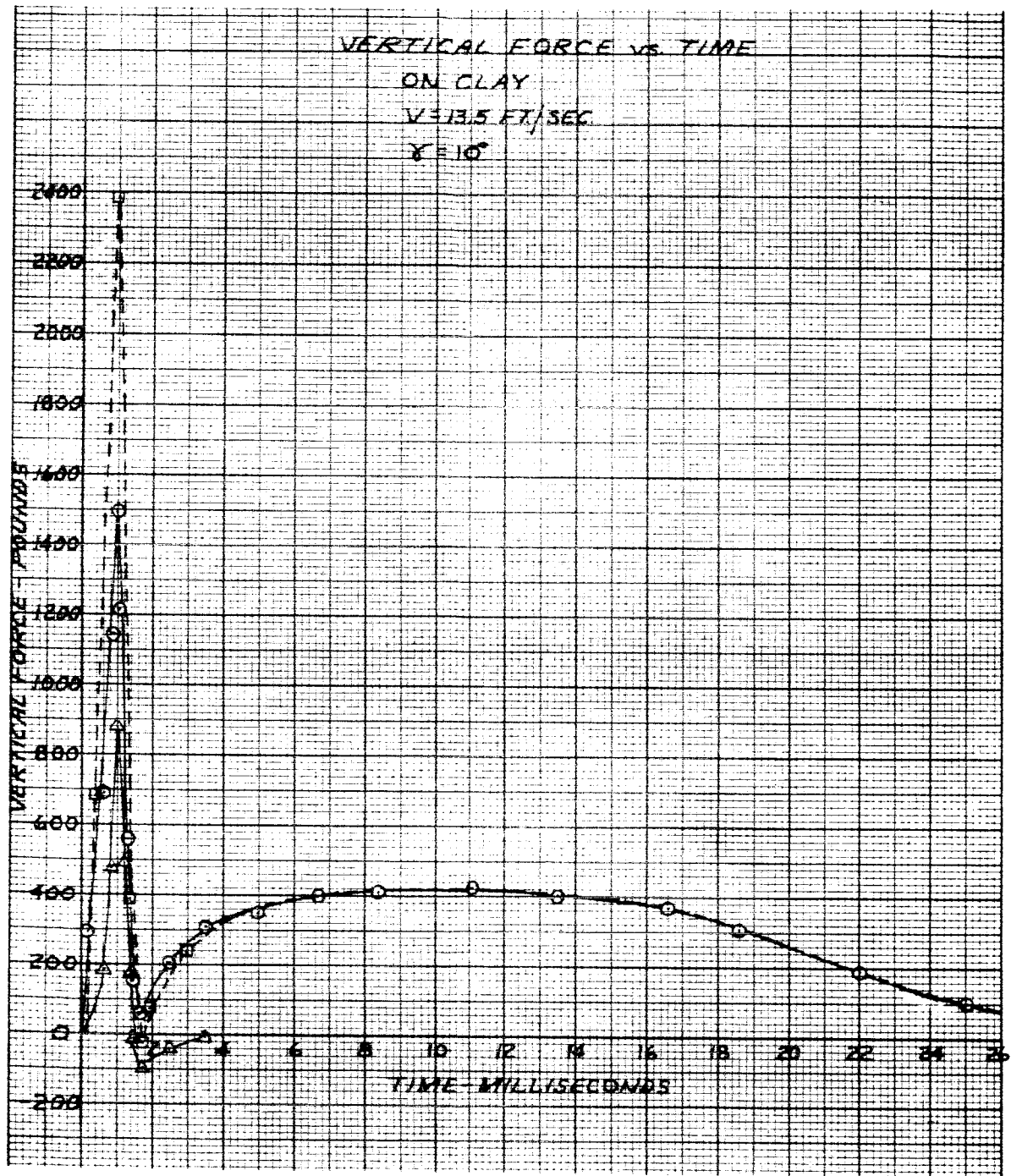


Figure 4-31. Vertical Force Versus Time on Clay

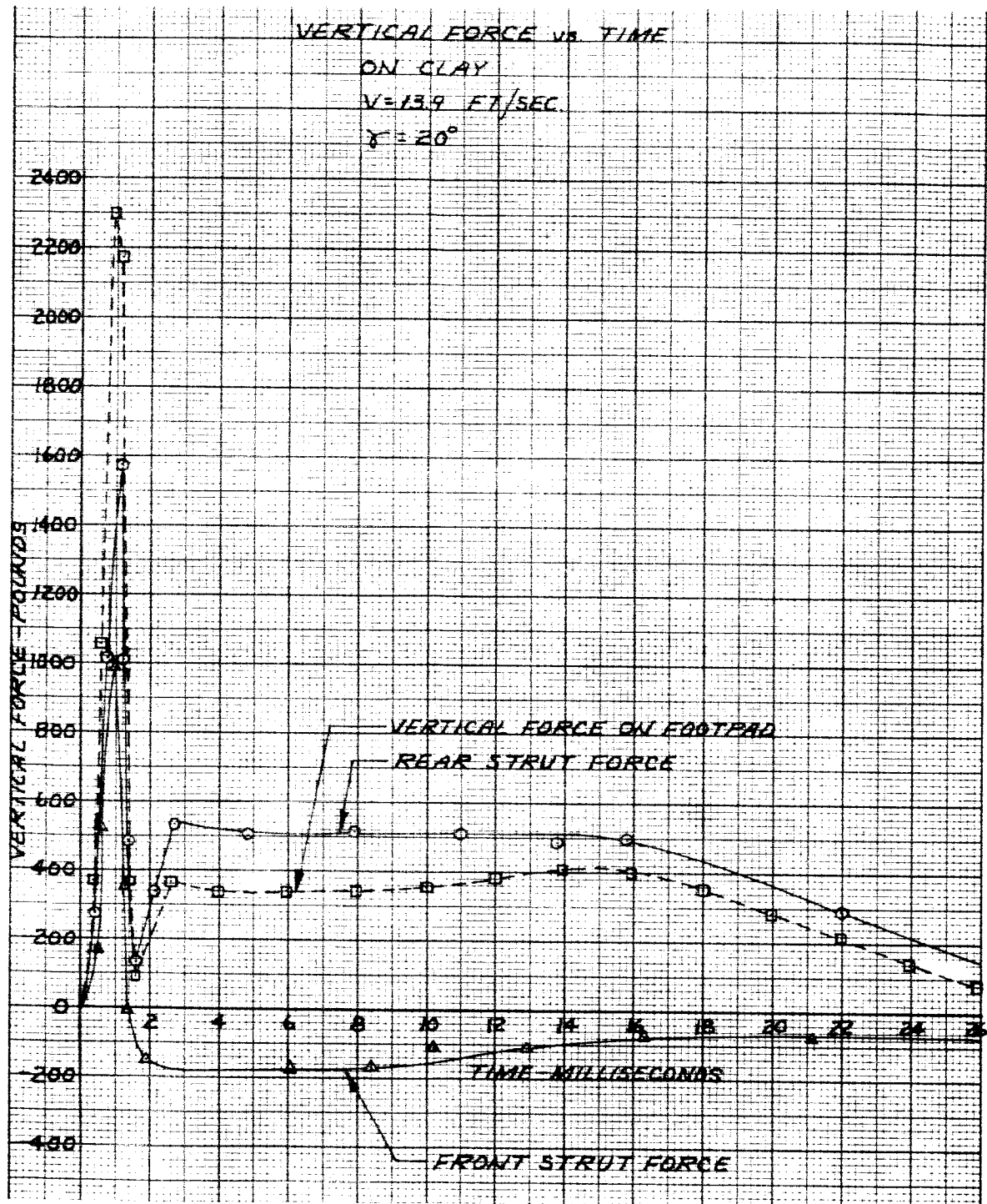


Figure 4-32. Vertical Force Versus Time on Clay

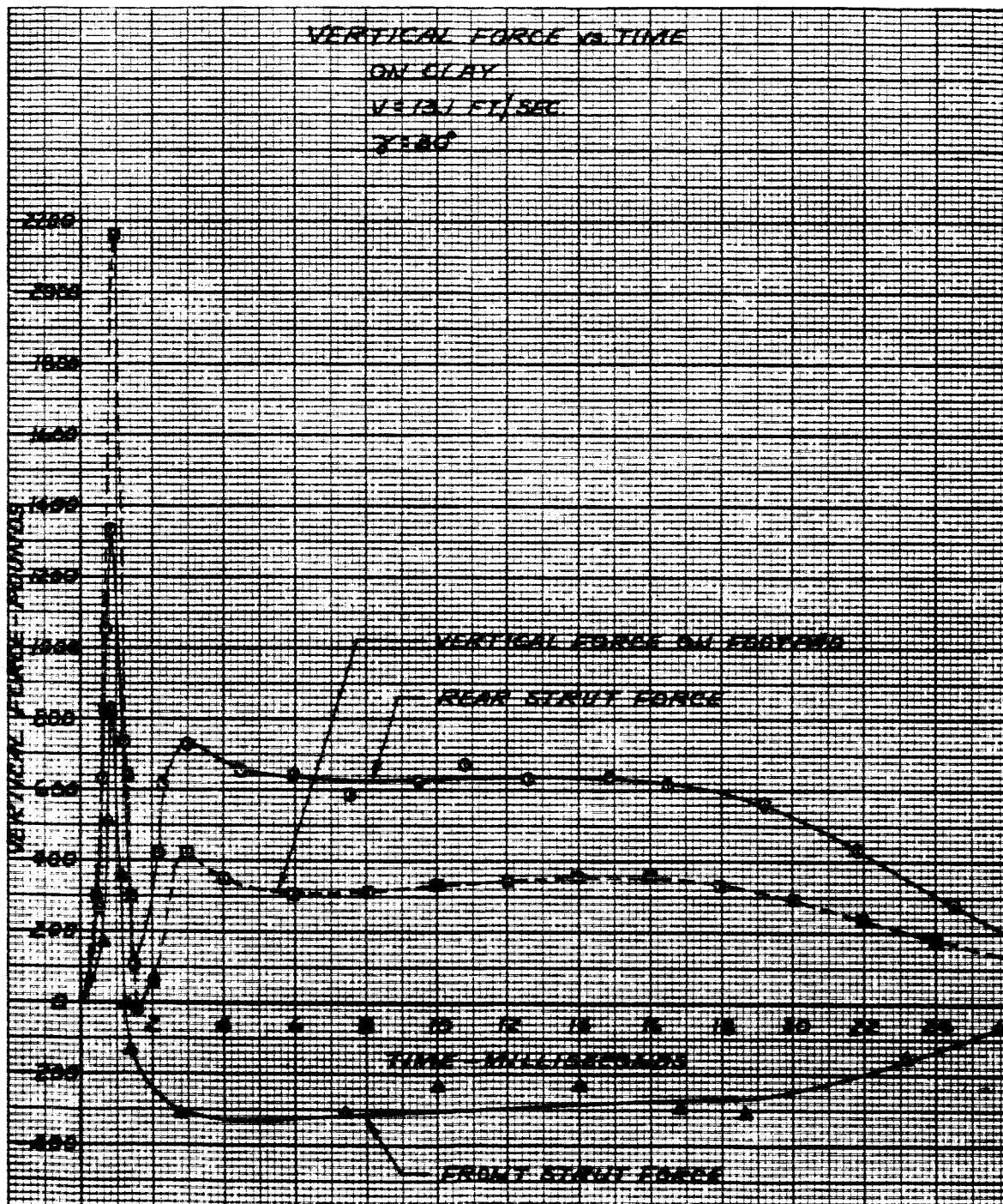


Figure 4-33. Vertical Force Versus Time on Clay

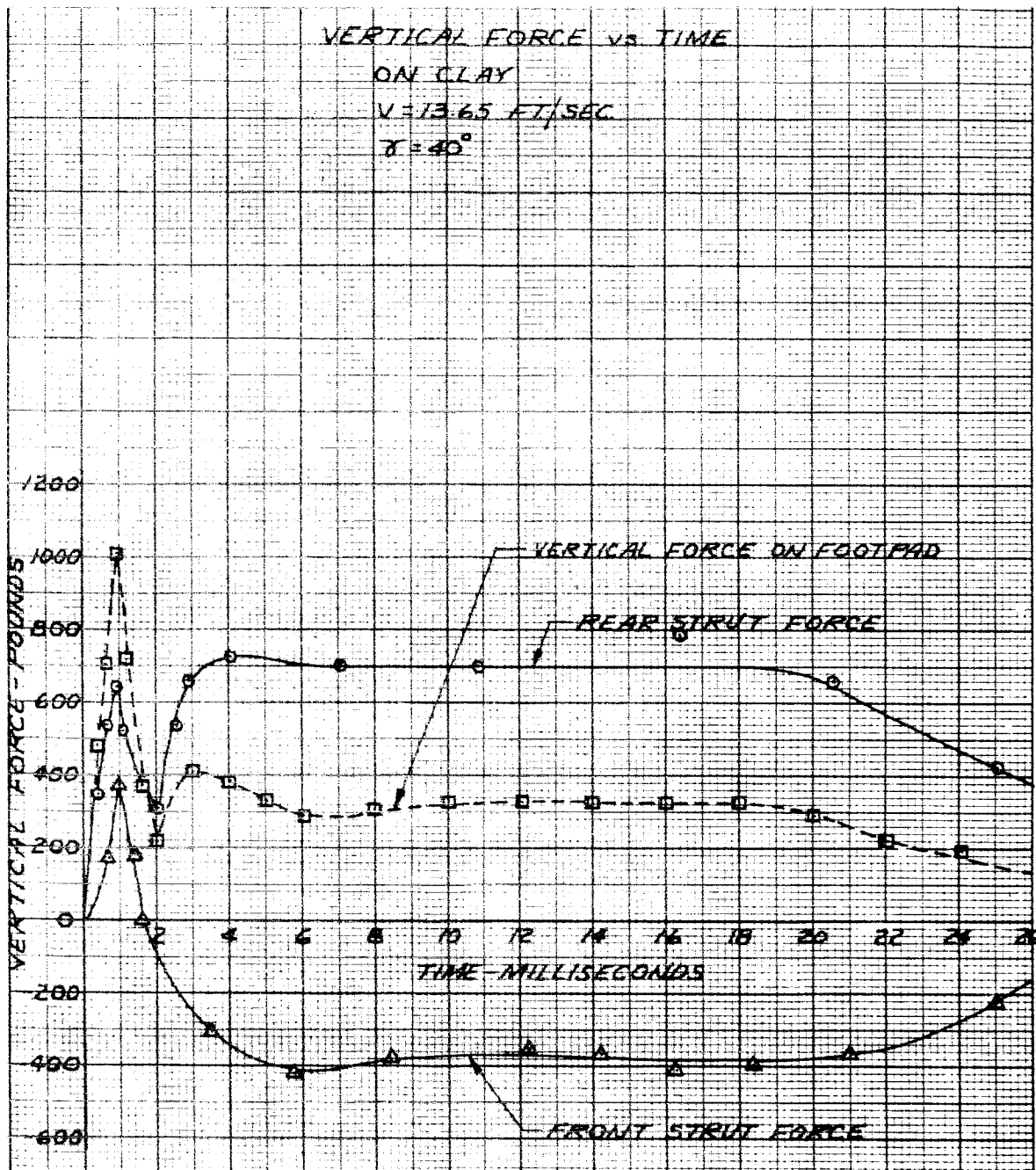


Figure 4-34. Vertical Force Versus Time on Clay

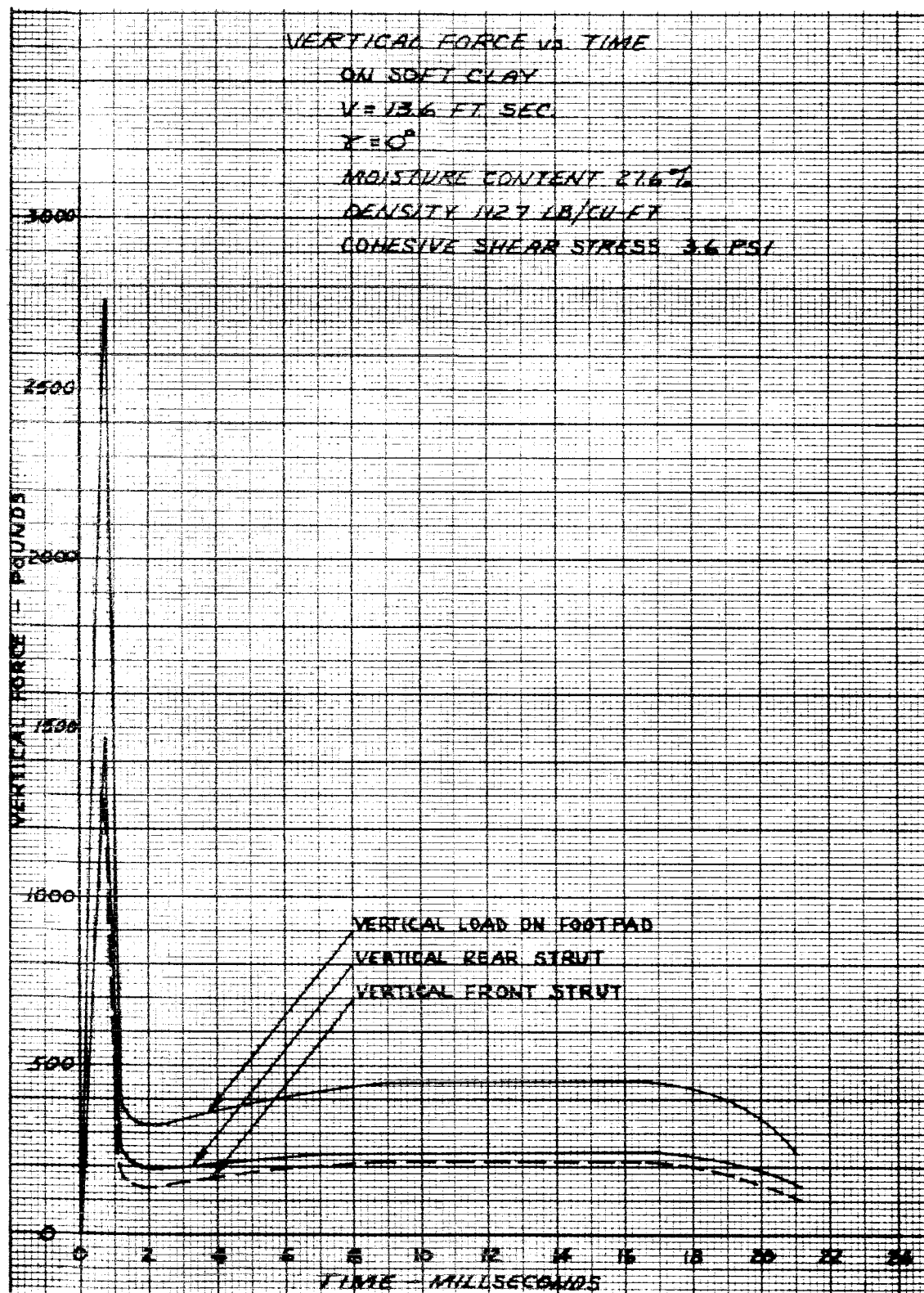


Figure 4-35. Vertical Force Versus Time on Soft Clay

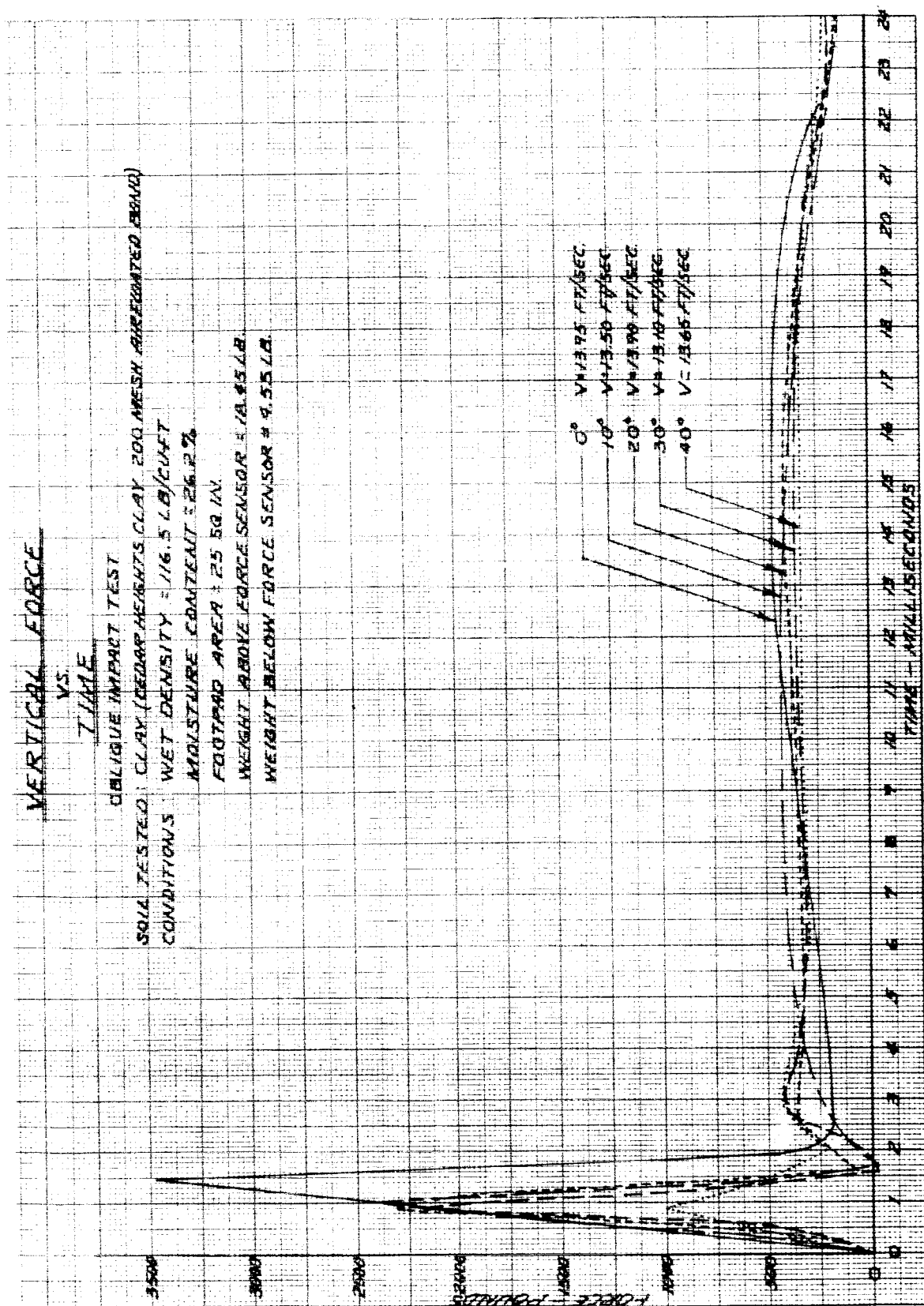


Figure 4-36. Vertical Force Versus Time

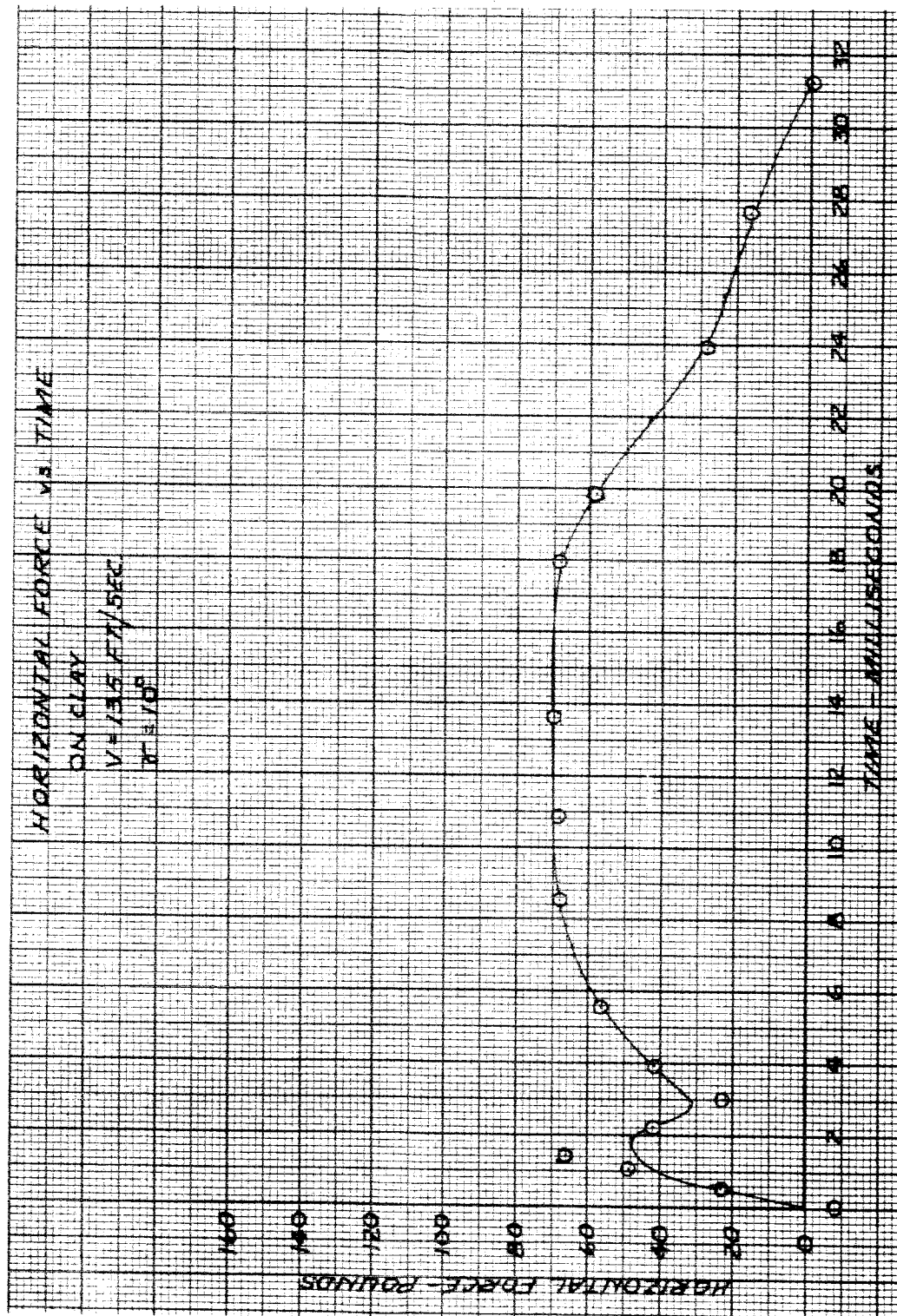


Figure 4-37. Horizontal Force Versus Time on Clay

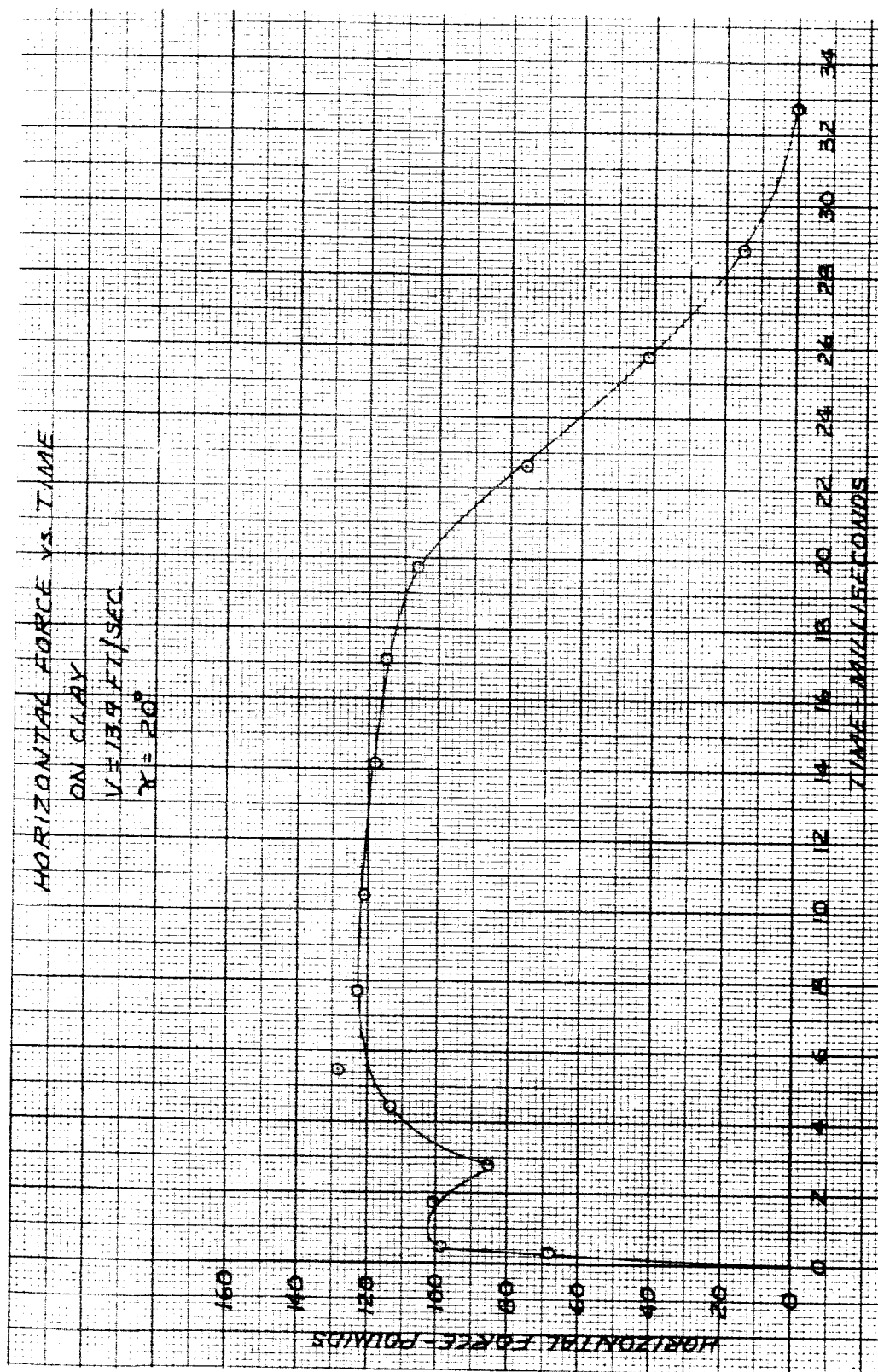


Figure 4-38. Horizontal Force Versus Time on Clay

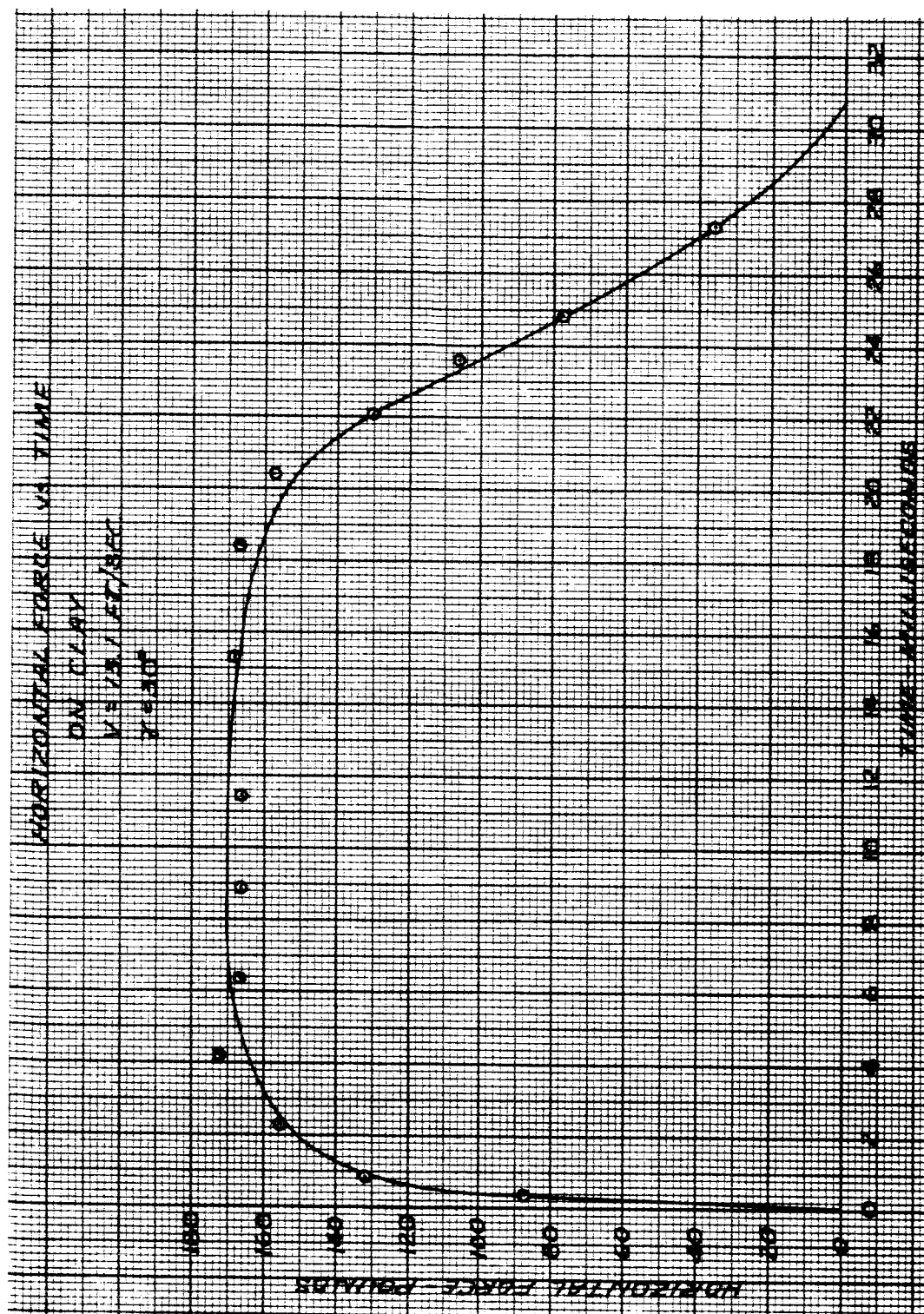


Figure 4-39. Horizontal Force Versus Time on Clay

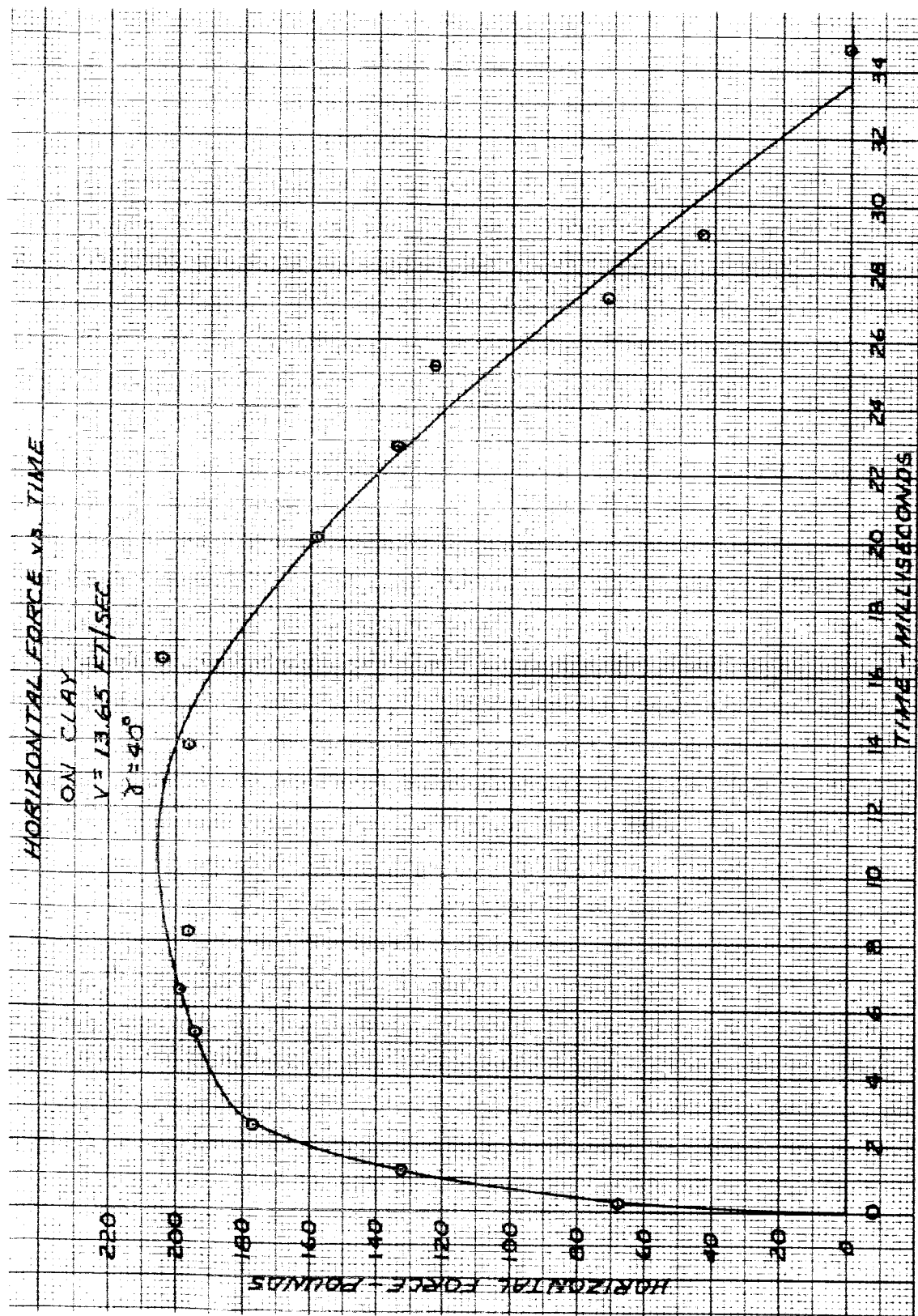
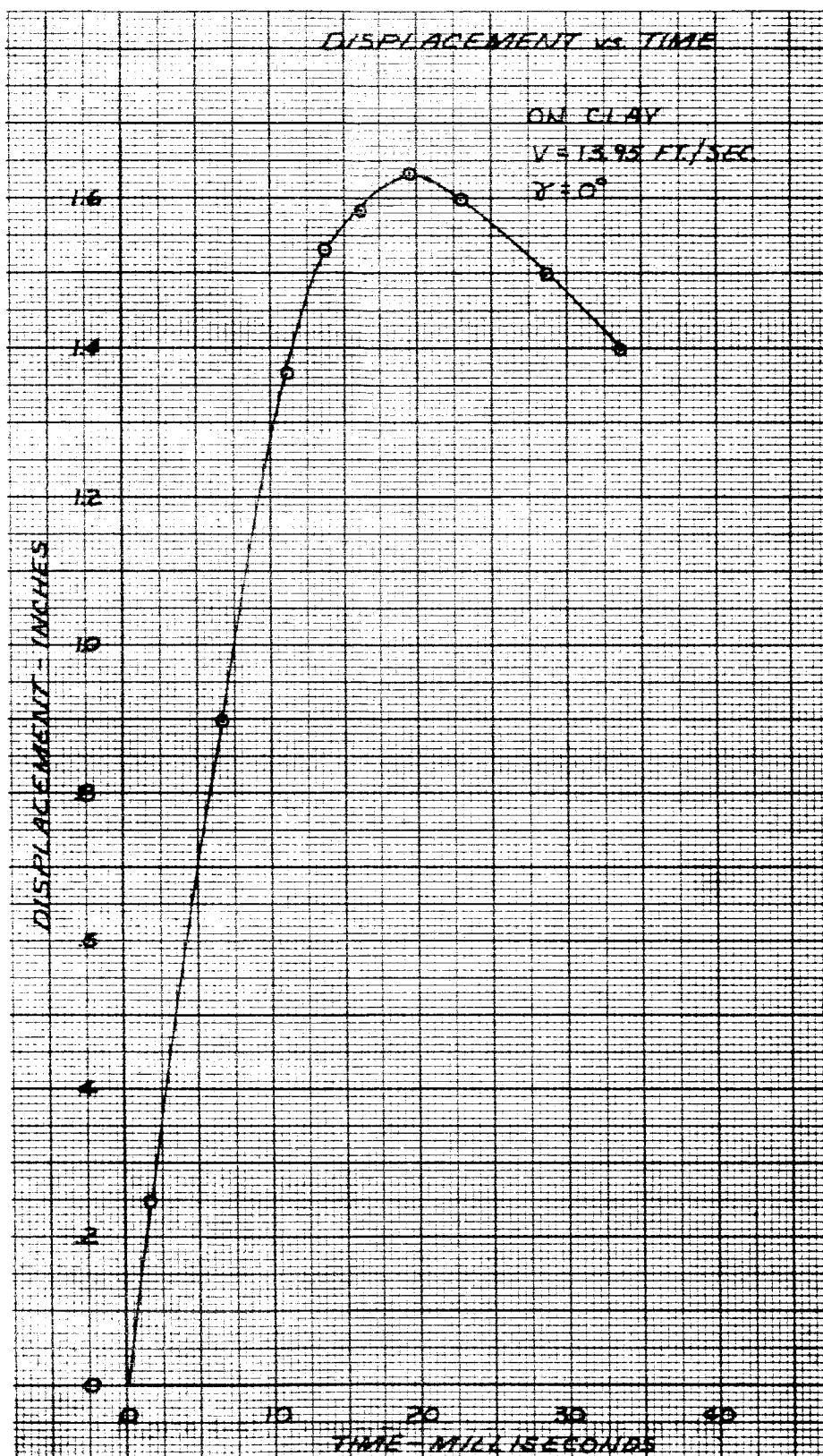
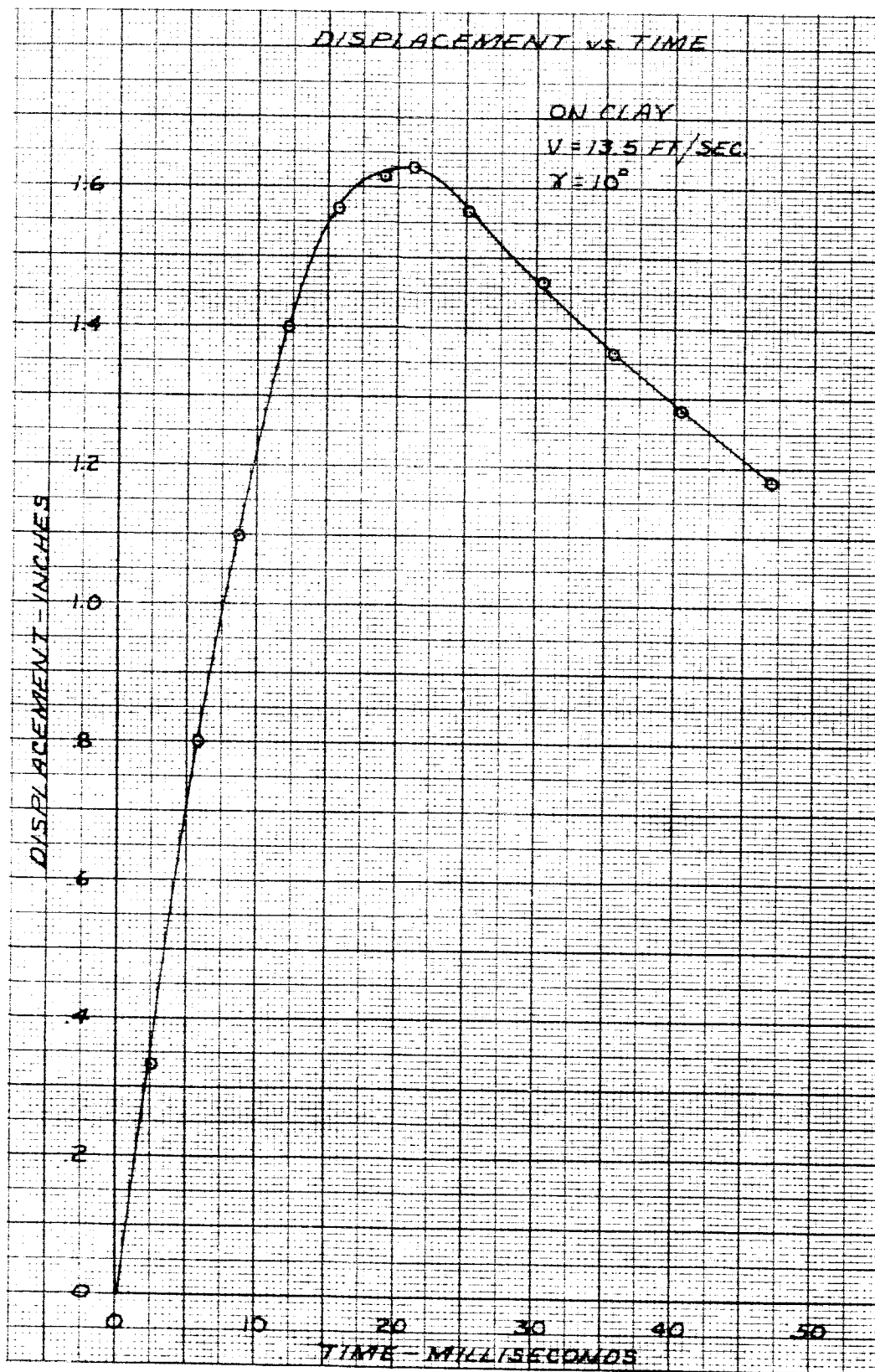


Figure 4-40. Horizontal Force Versus Time on Clay





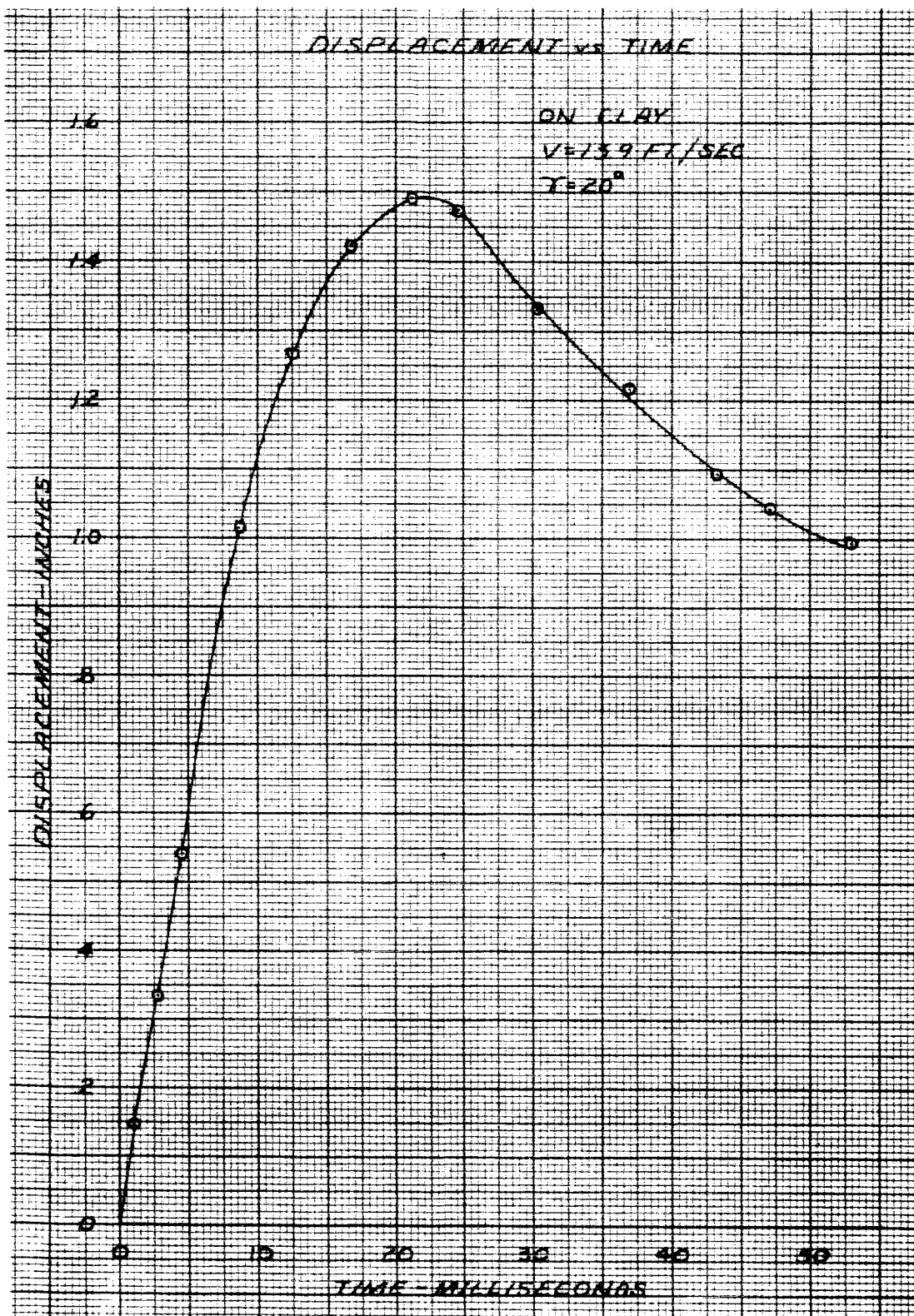
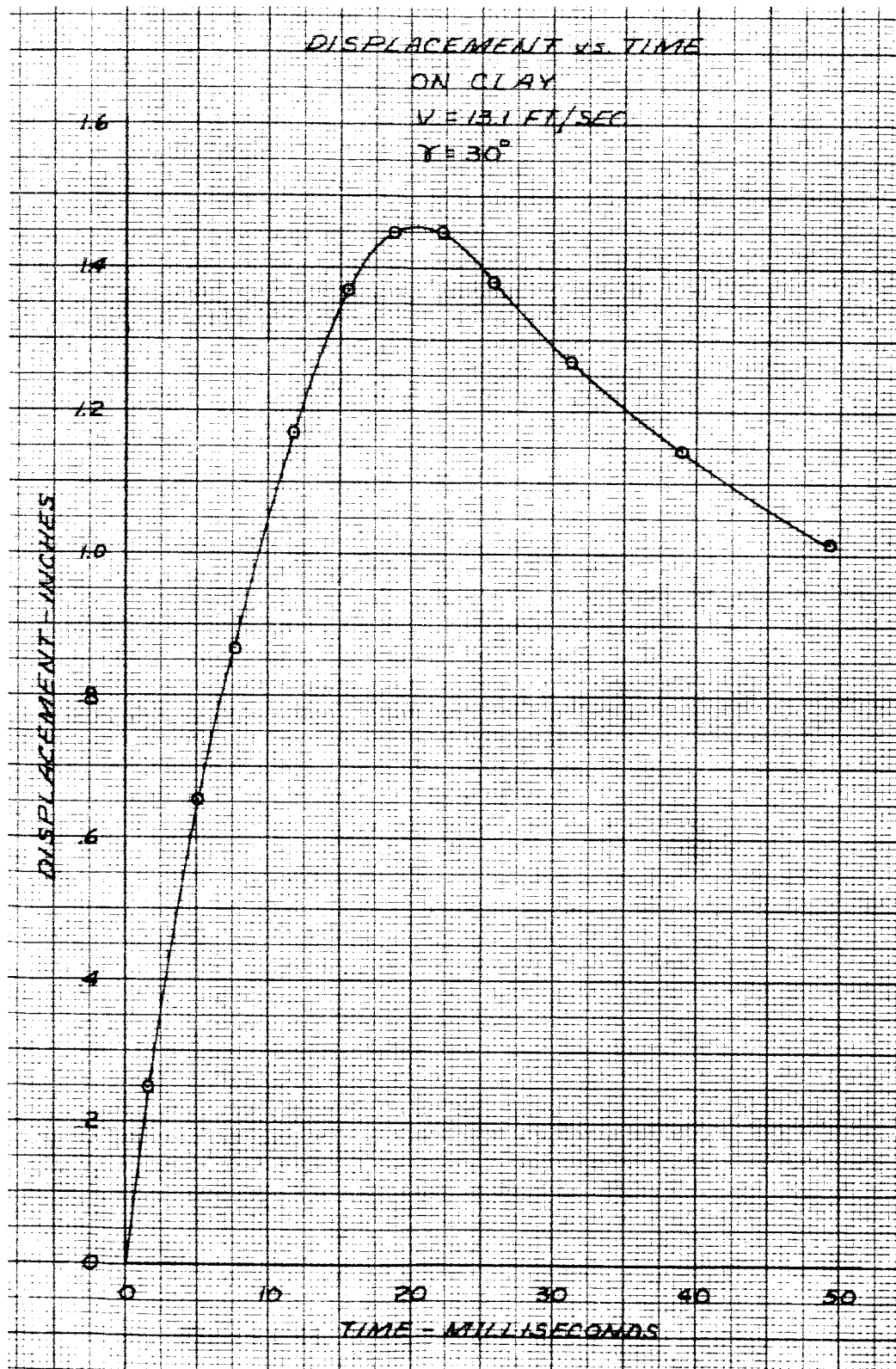


Figure 4-43. Displacement Versus Time on Clay



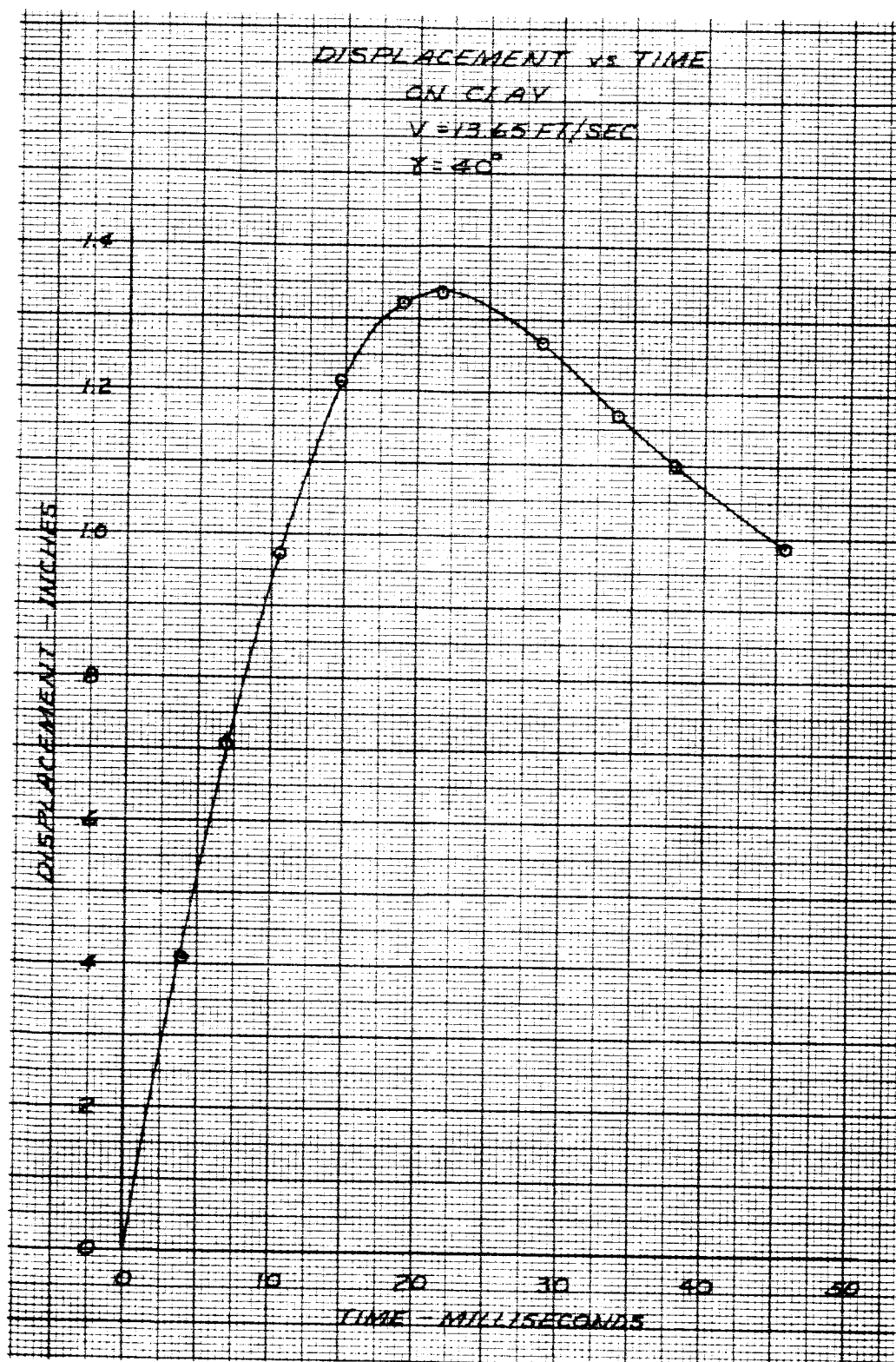


Figure 4-45. Displacement Versus Time on Clay

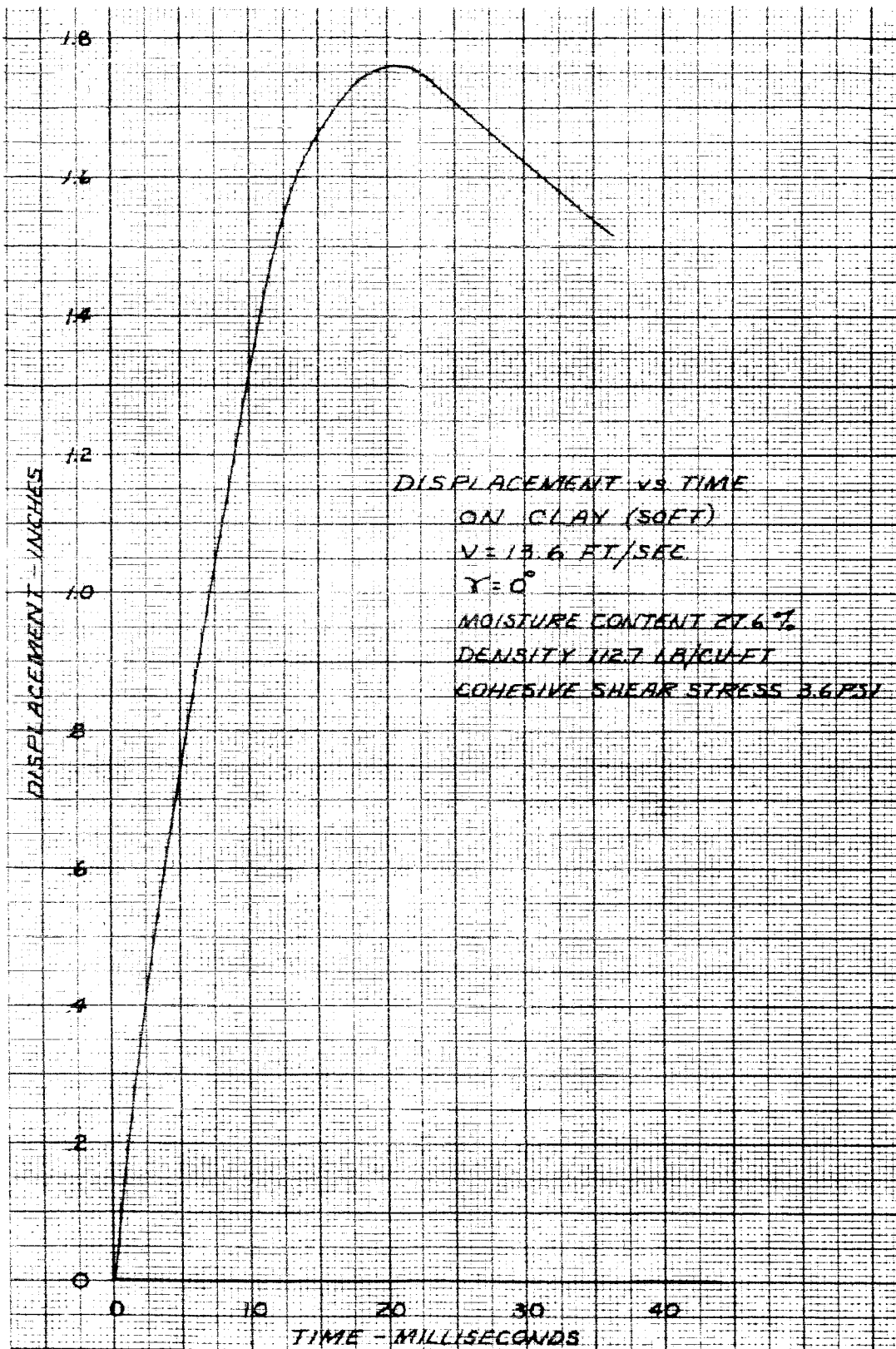


Figure 4-46. Displacement Versus Time on Clay (Soft)

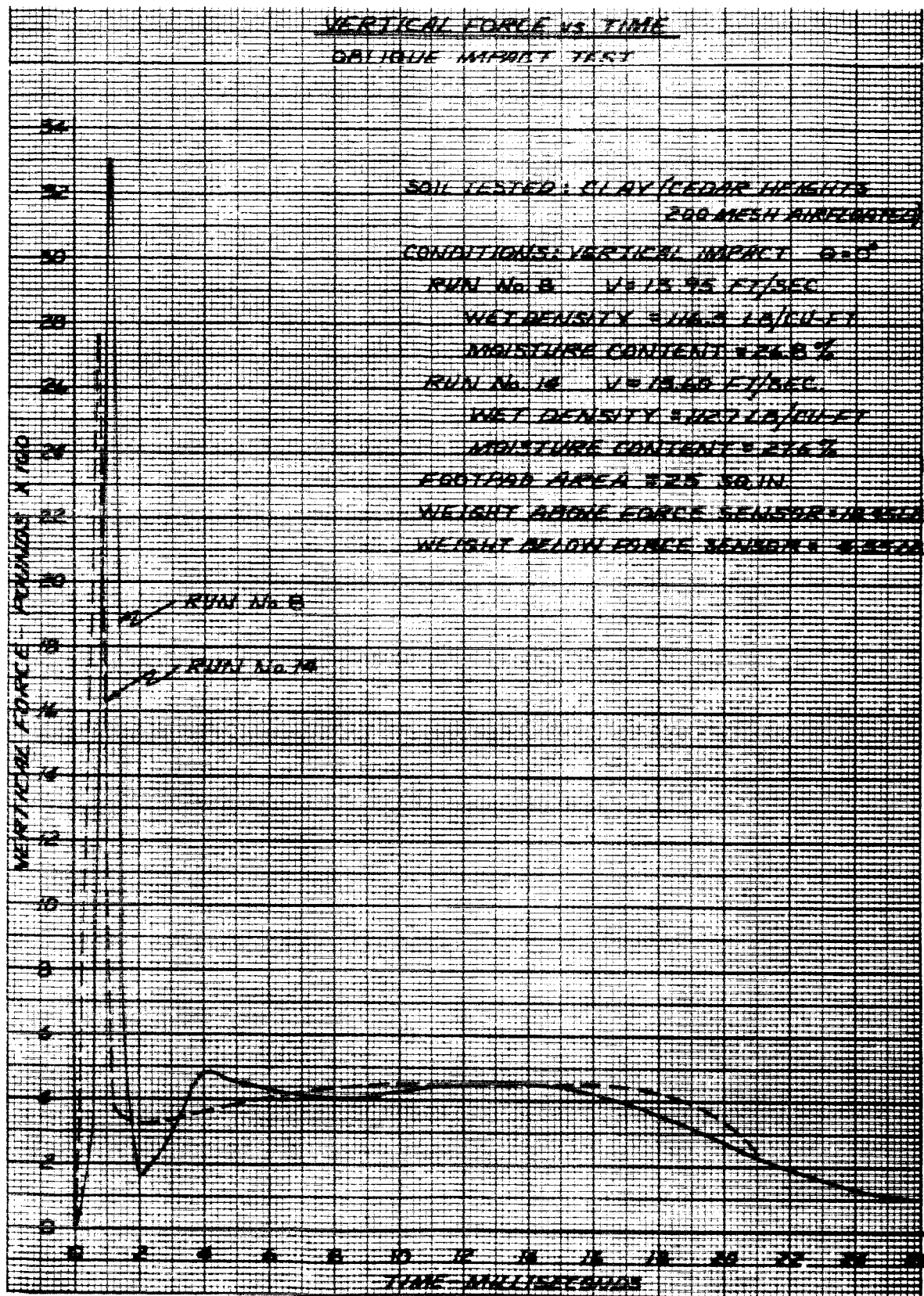


Figure 4-47. Vertical Force Versus Time

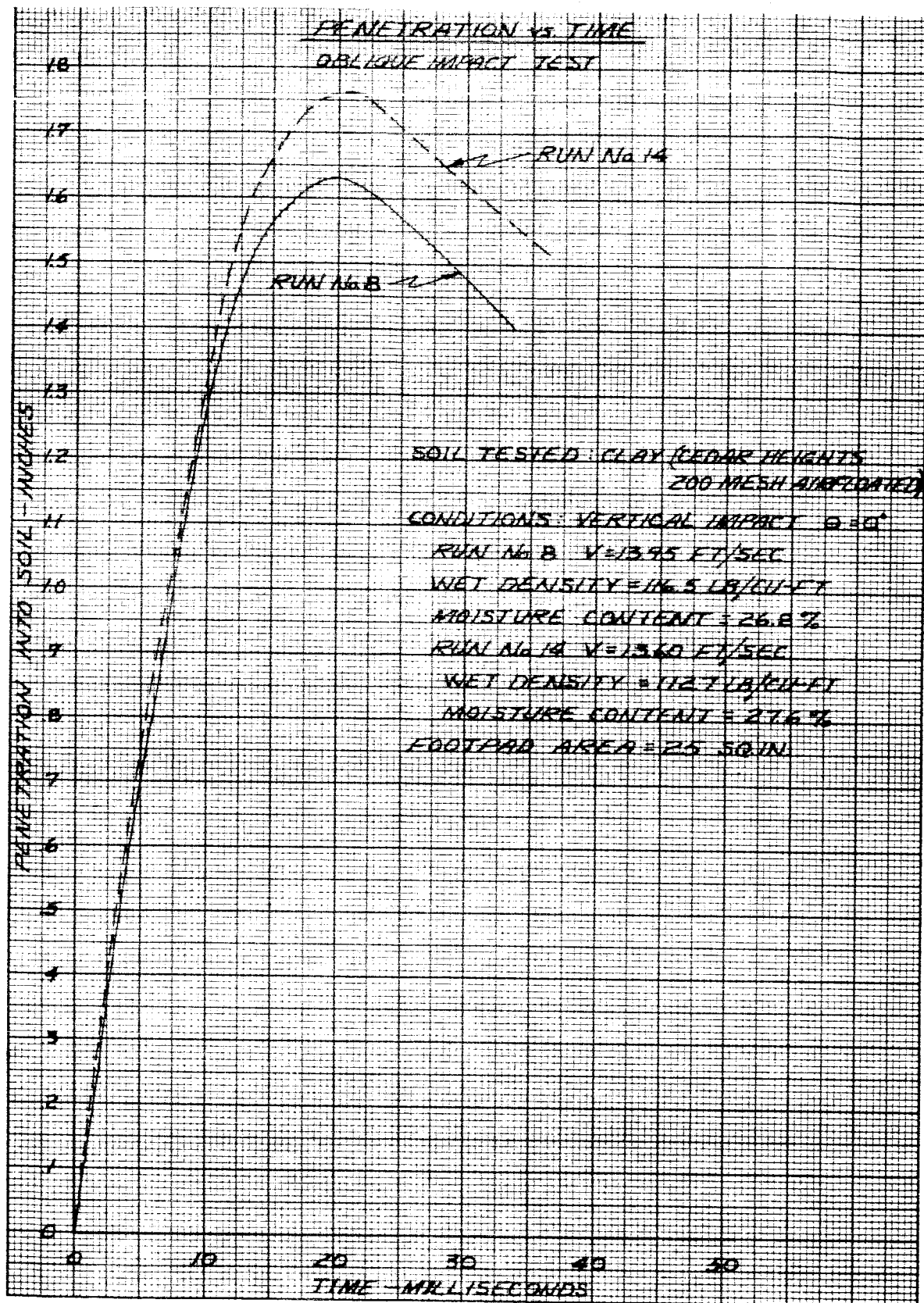


Figure 4-48. Penetration Versus Time

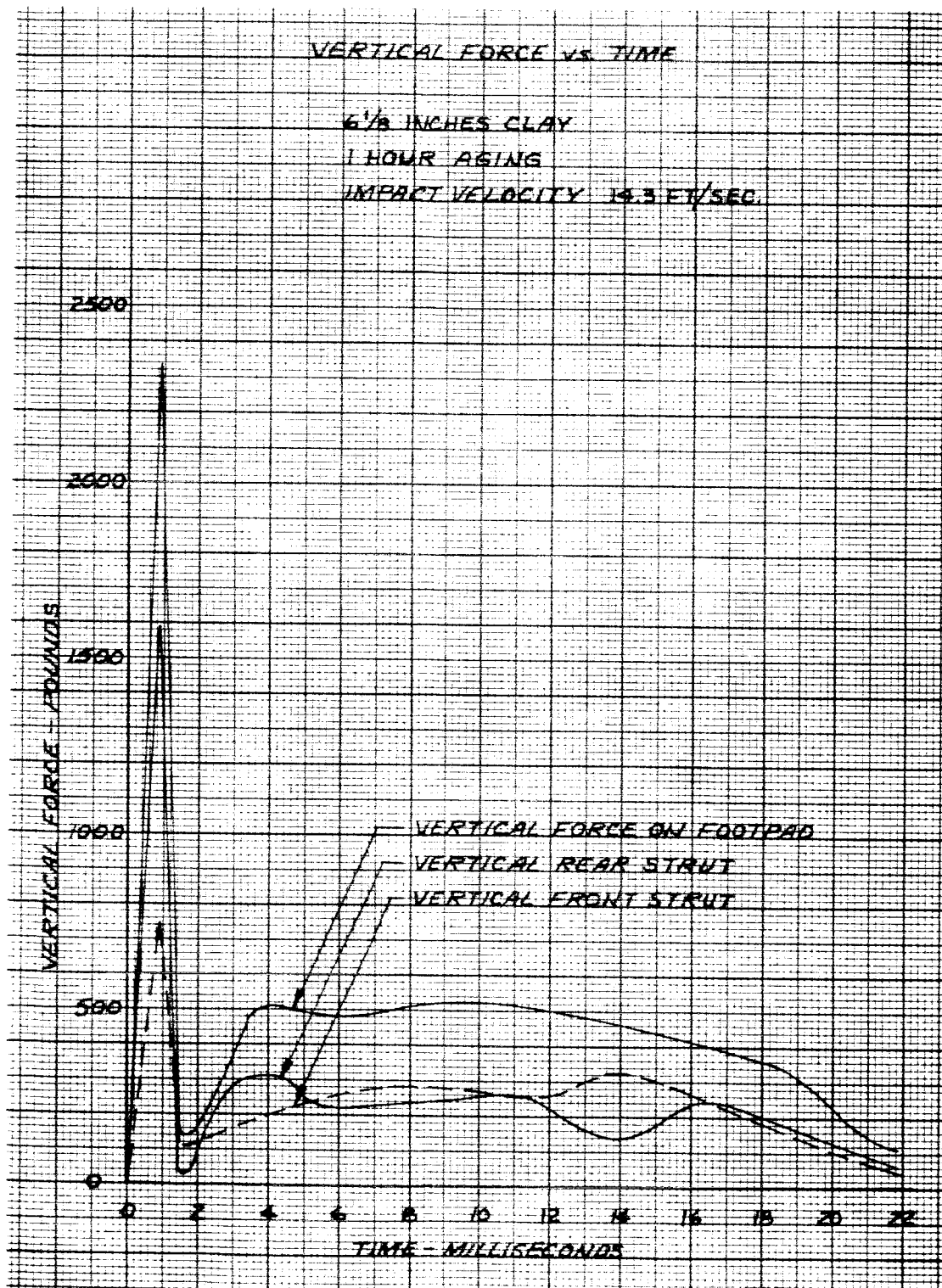


Figure 4-49. Vertical Force Versus Time

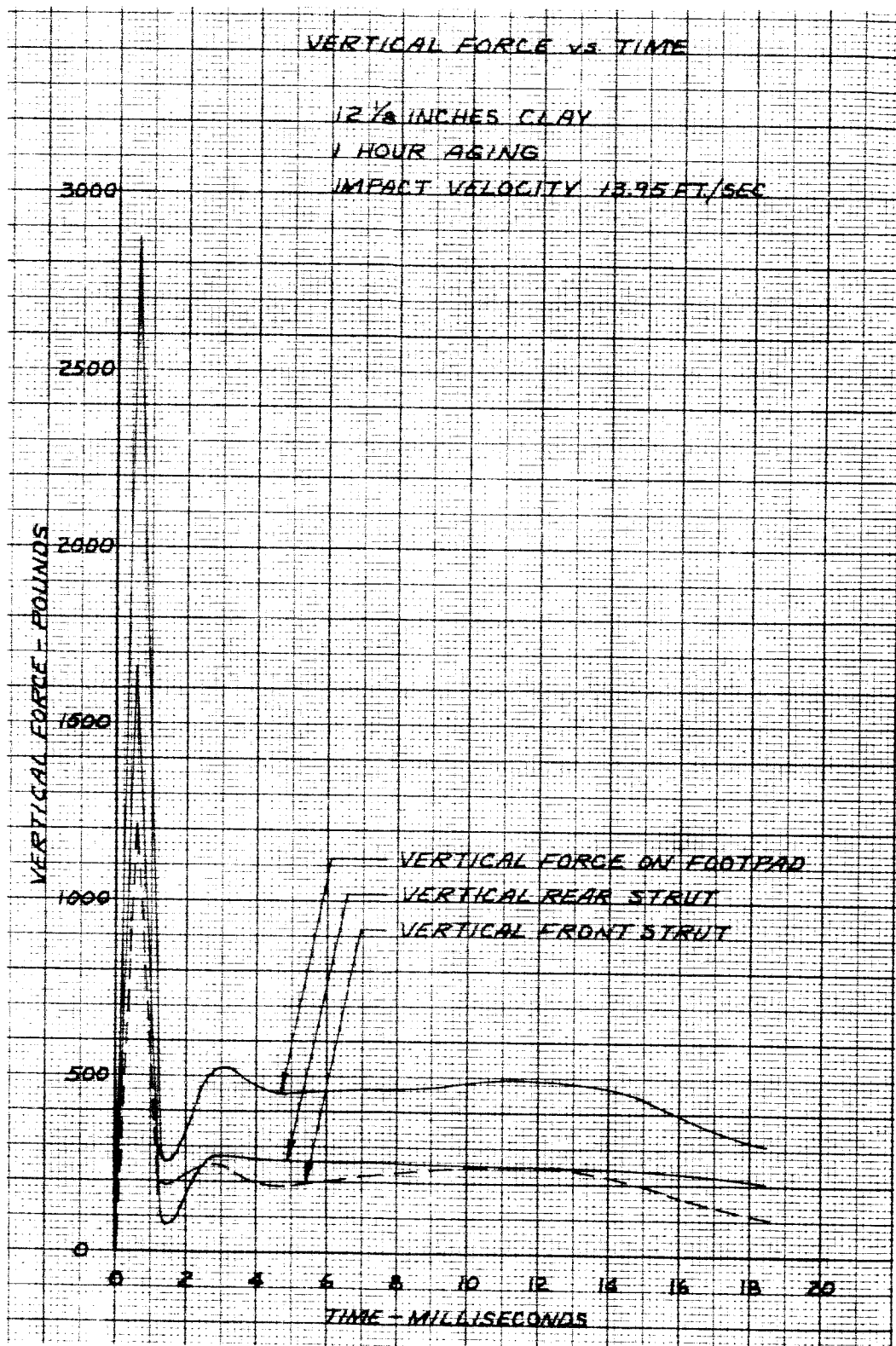


Figure 4-50. Vertical Force Versus Time

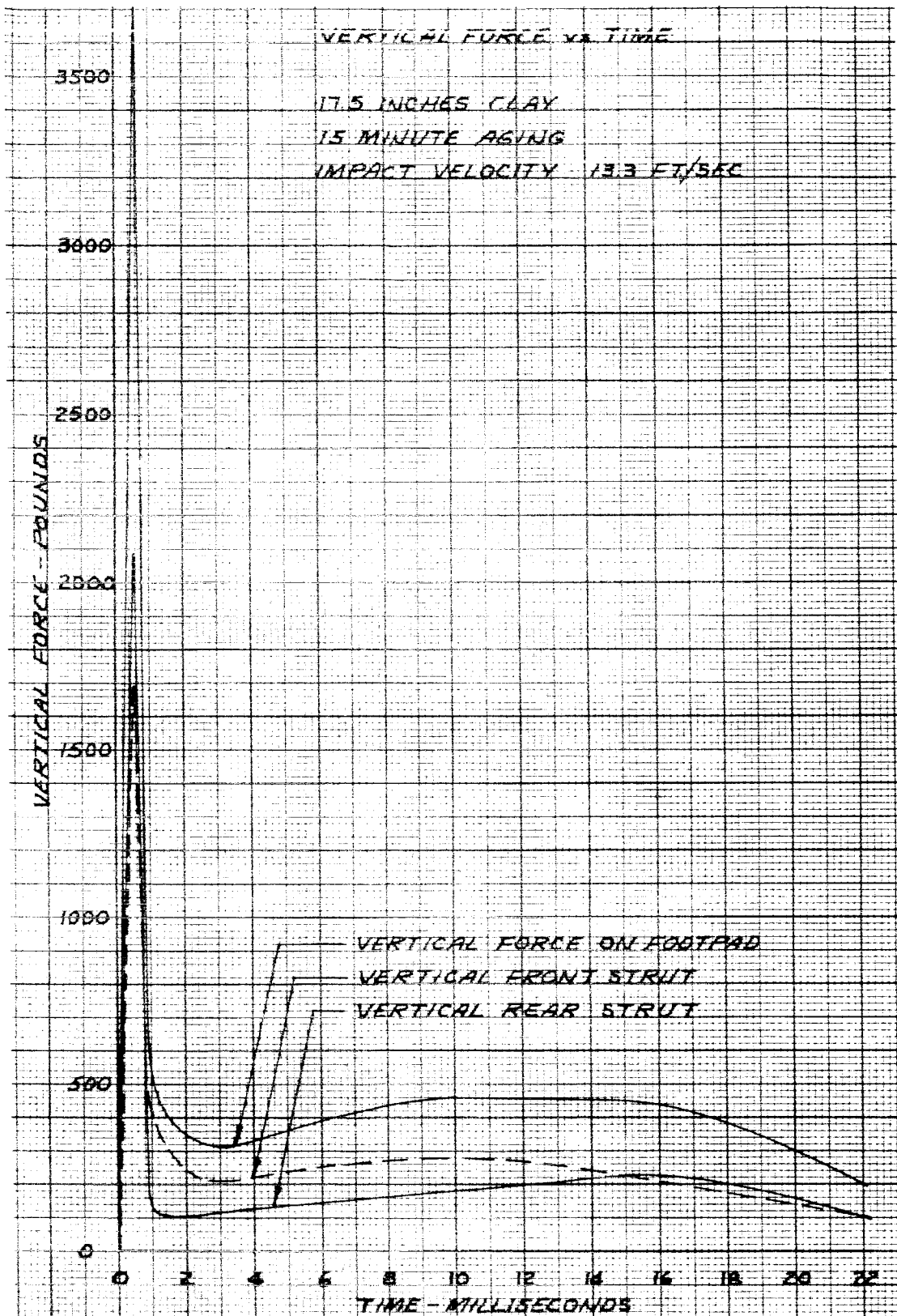


Figure 4-51. Vertical Force Versus Time

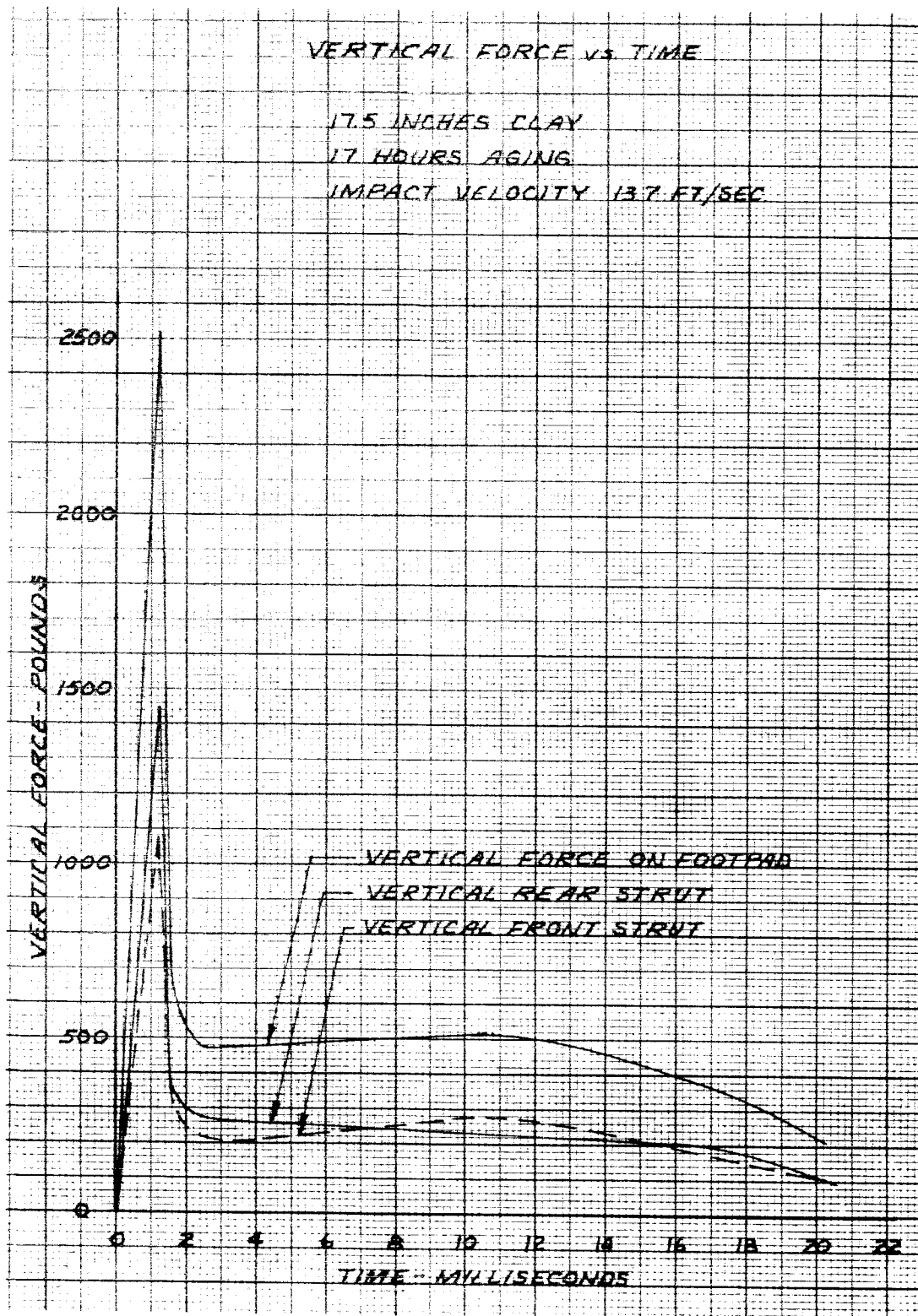


Figure 4-52. Vertical Force Versus Time



Figure 4-52A. Dynamic Impact on Clay

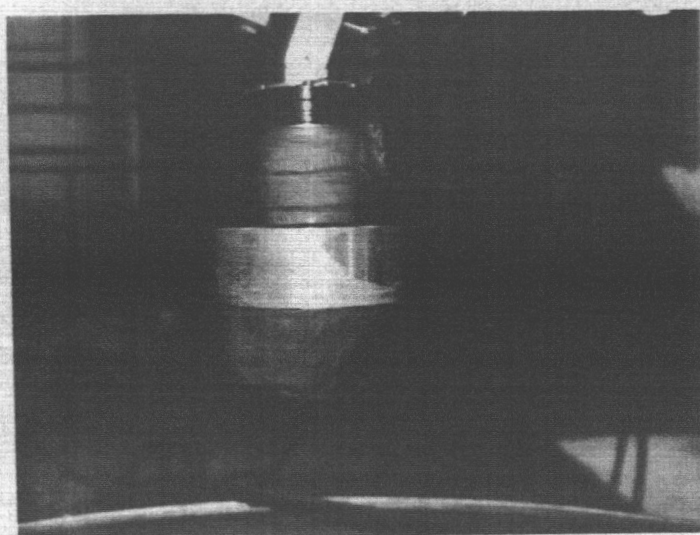


Figure 4-52B. Soil Wedge Beneath Footpad after Impact Test

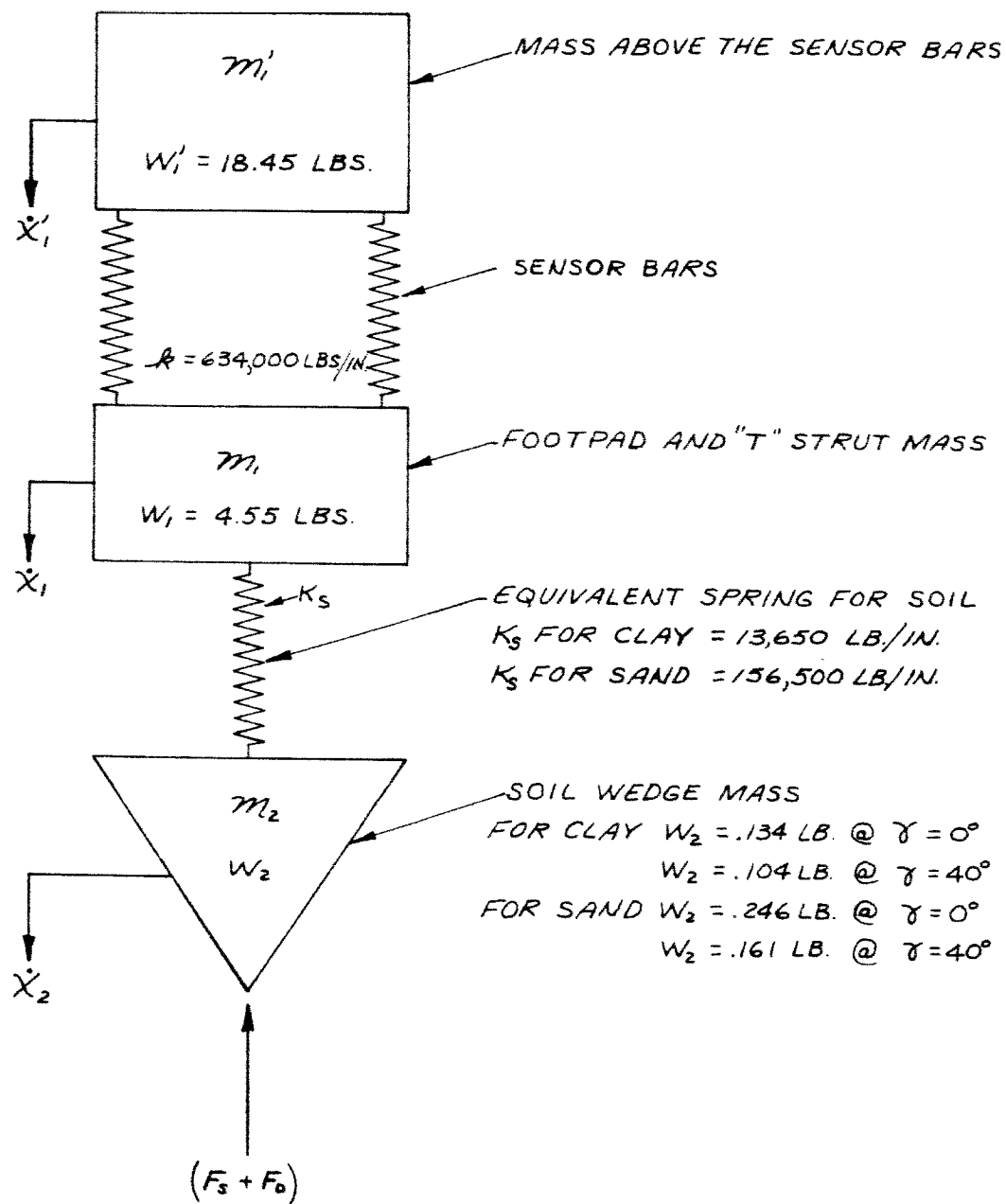


Figure 4-53. Mathematical Model of Footpad and Soil Relationship

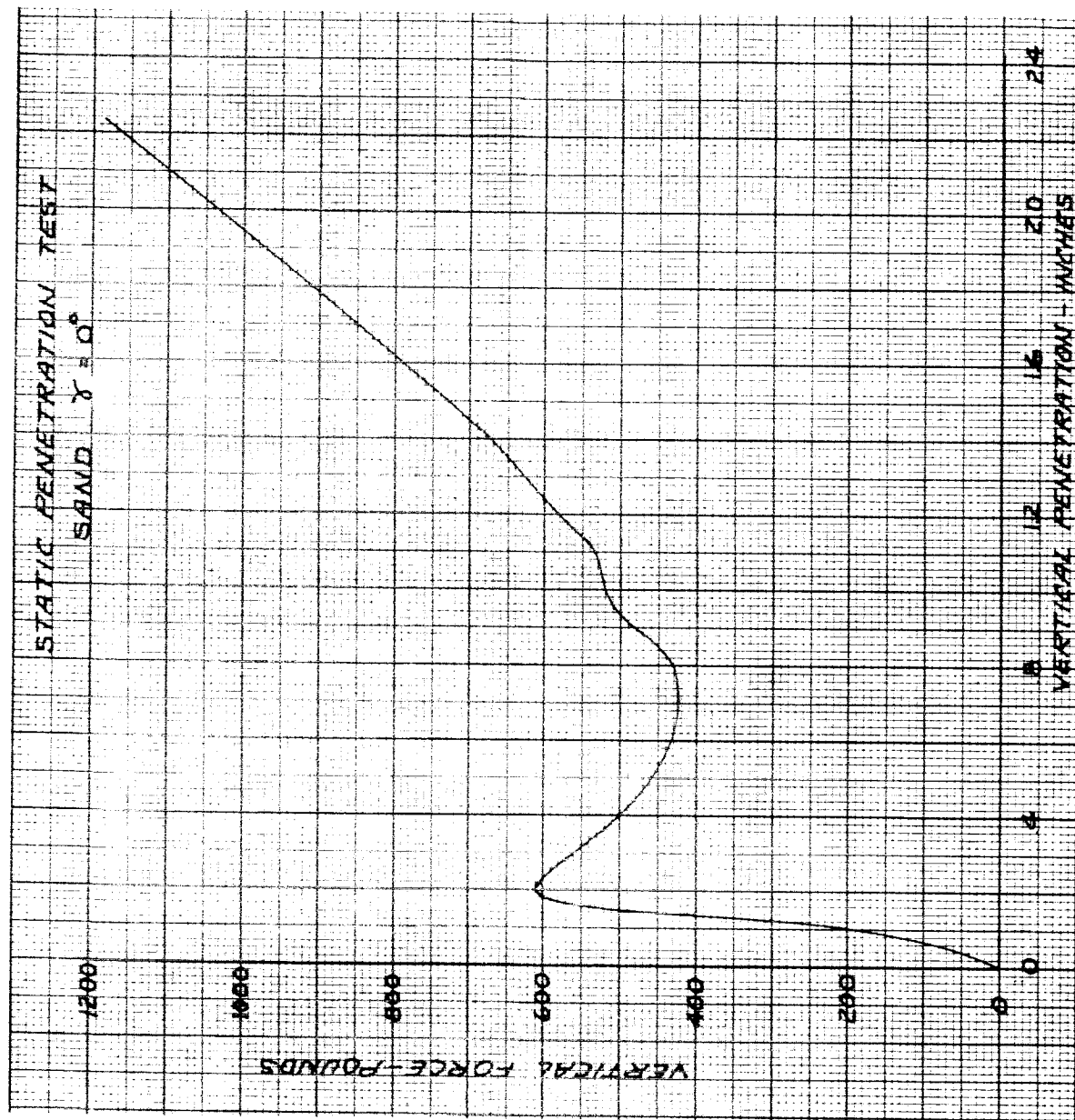


Figure 4-54. Static Penetration Test Sand

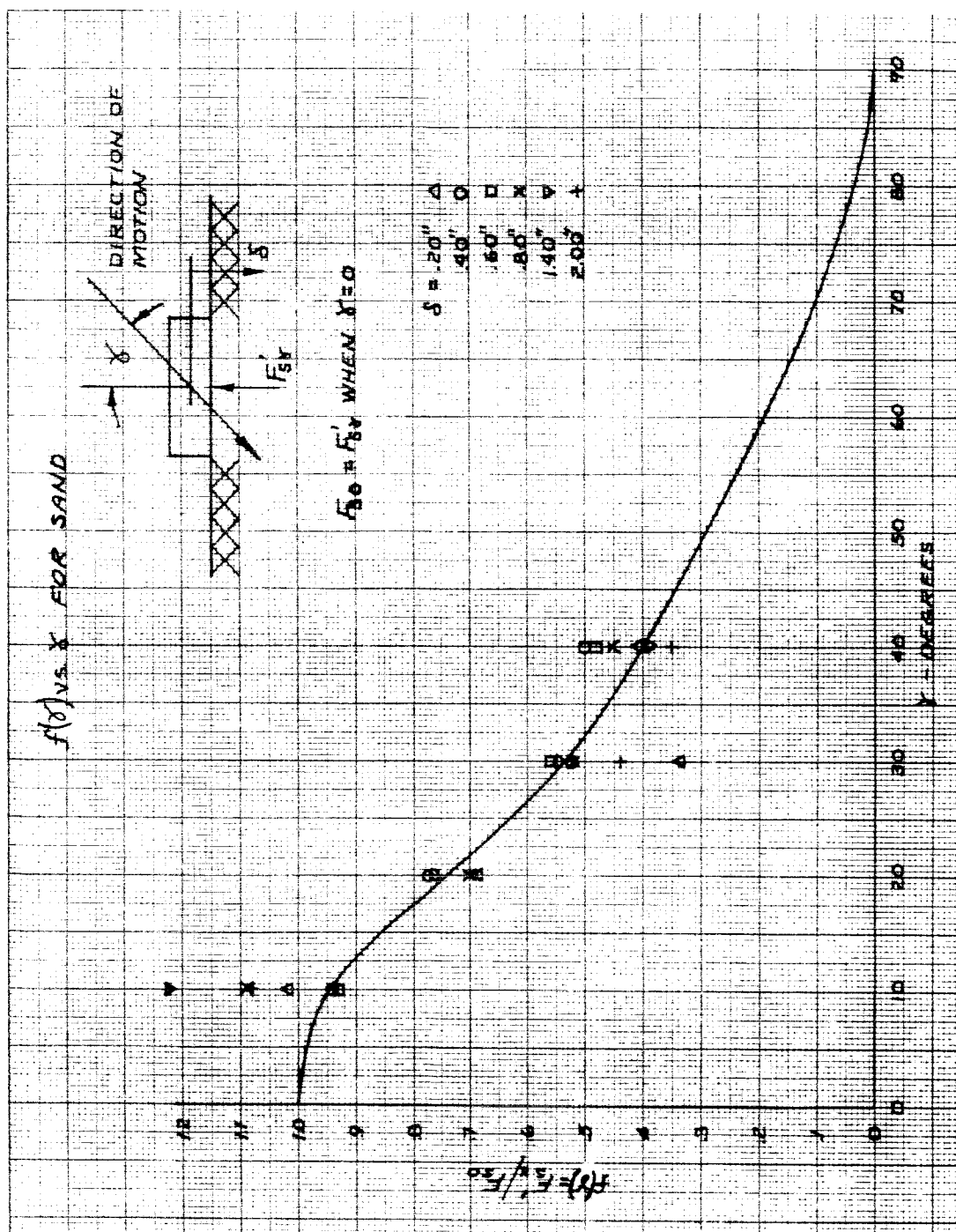


Figure 4-55. $f(\gamma)$ Versus γ For Sand

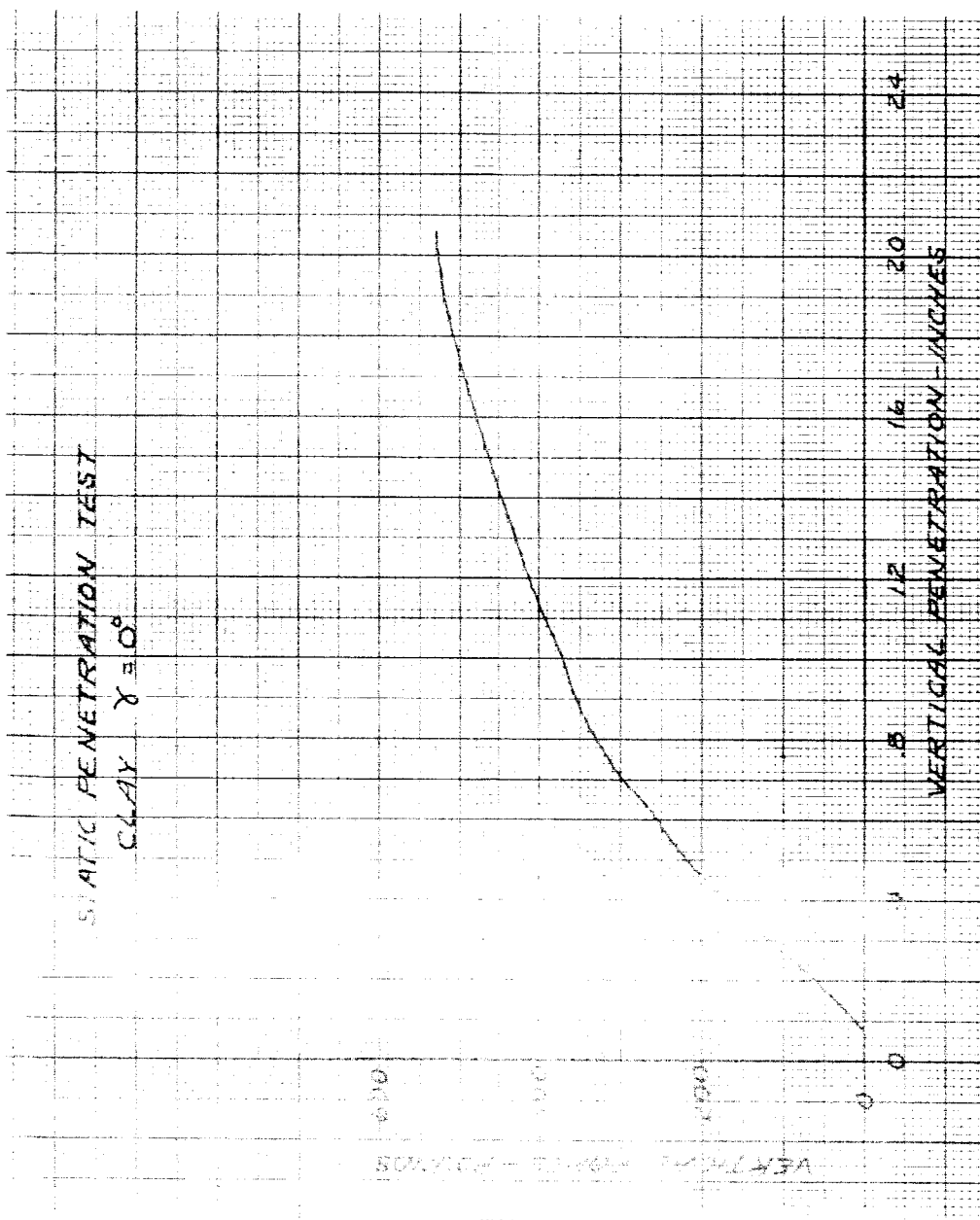


Figure 4-56. Static Penetration Test Clay

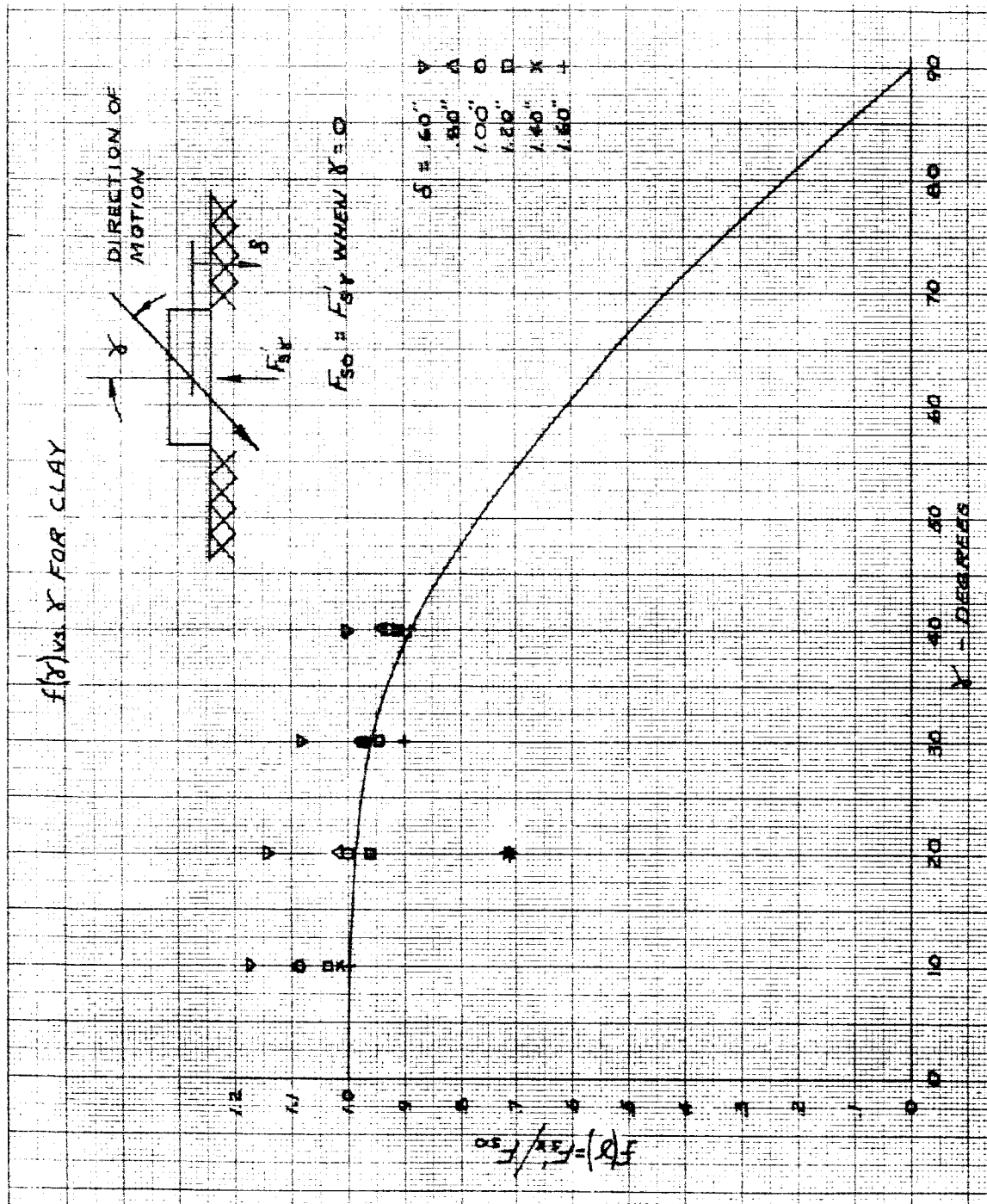
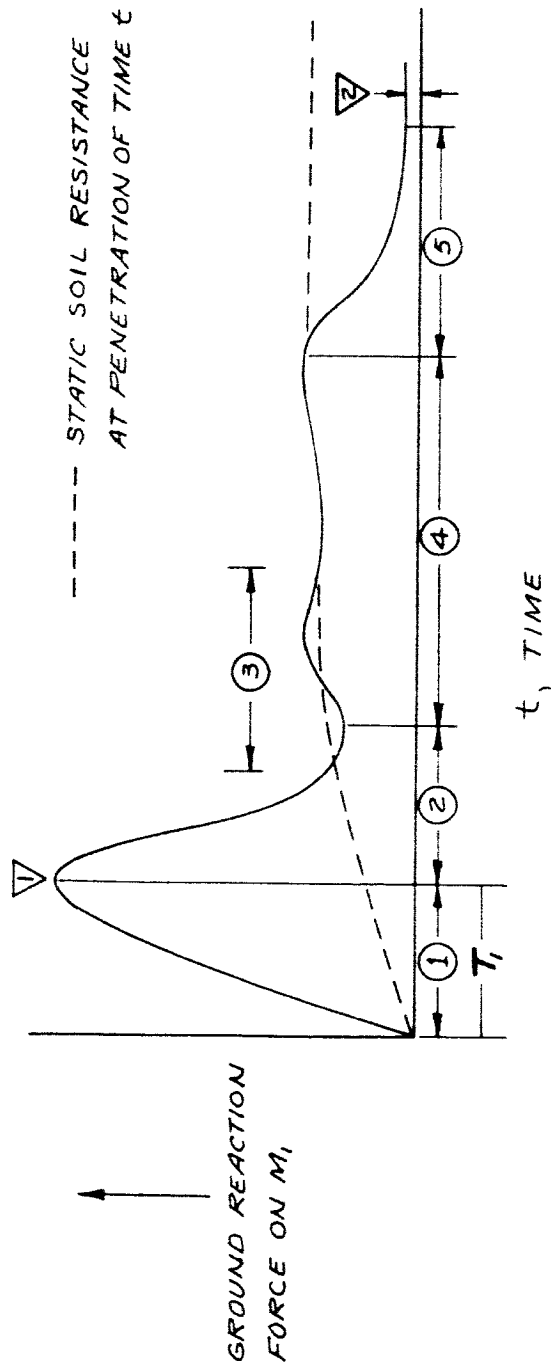
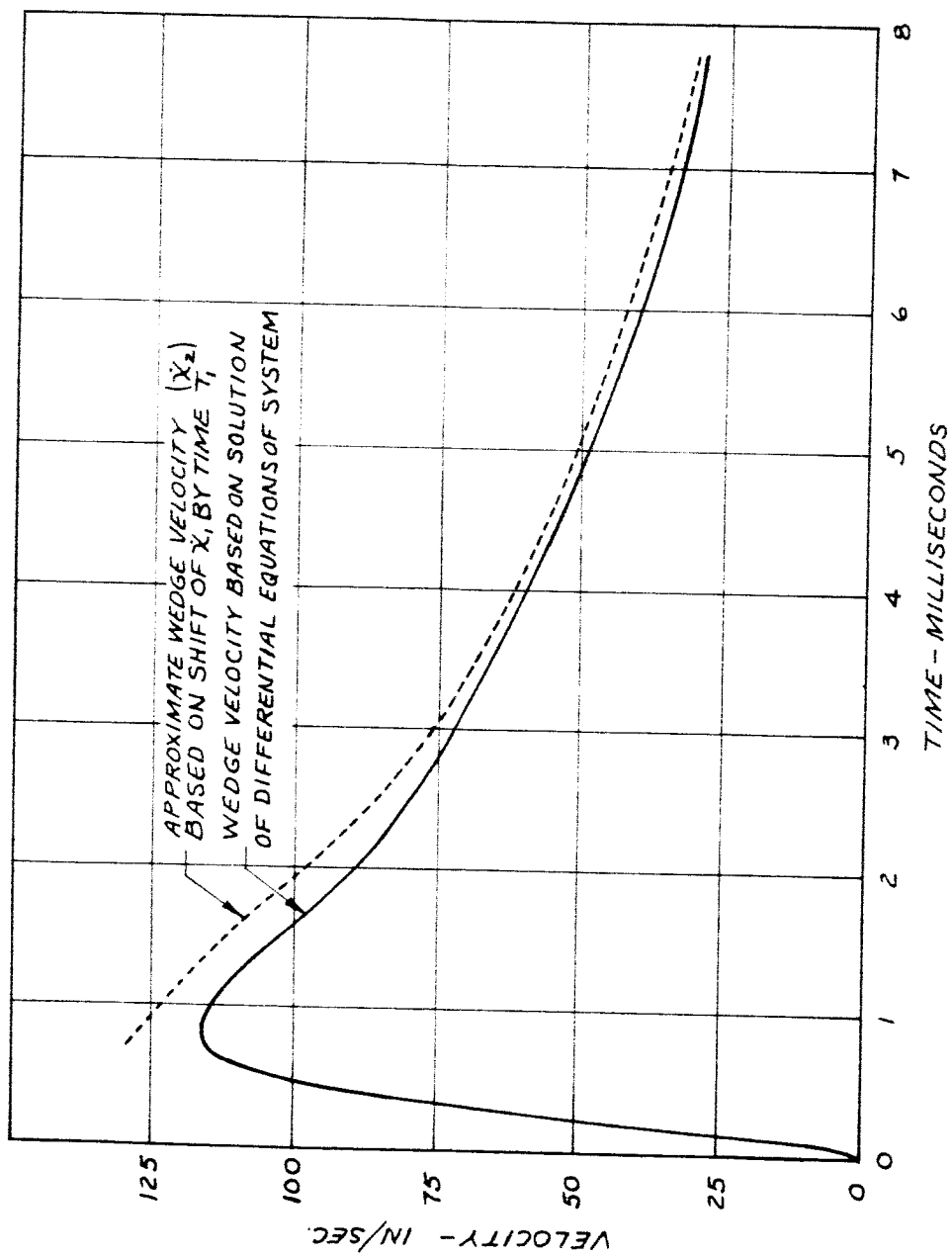


Figure 4-57. $f(\gamma)$ Versus γ For Clay



- ① K_s SPRING COMPRESSED AND SOIL WEDGE ACCELERATED
- ② SOIL WEDGE REACHES MAXIMUM PENETRATION VELOCITY
- ③ SOIL WEDGE DECELERATED BY F_s AND F_D
- ④ HIGHLY DAMPED TRANSIENT MOTION OF WEDGE - DEPENDENT ON $K_{\phi c}$ AND THE ELASTICITY ASSOCIATED WITH SOIL BELOW WEDGE
- ⑤ LOW VELOCITY WEDGE PENETRATION - F_D SMALL IN MAGNITUDE
- ⑥ UNLOADING PHASE
- ⑦ WEIGHT OF IMPACTING MASS

Figure 4-58. General Interpretation of Force Versus Time Relationship



DATA TAKEN FROM REF. P. 2-74

Figure 4-59. Wedge Velocity Versus Time Relationship

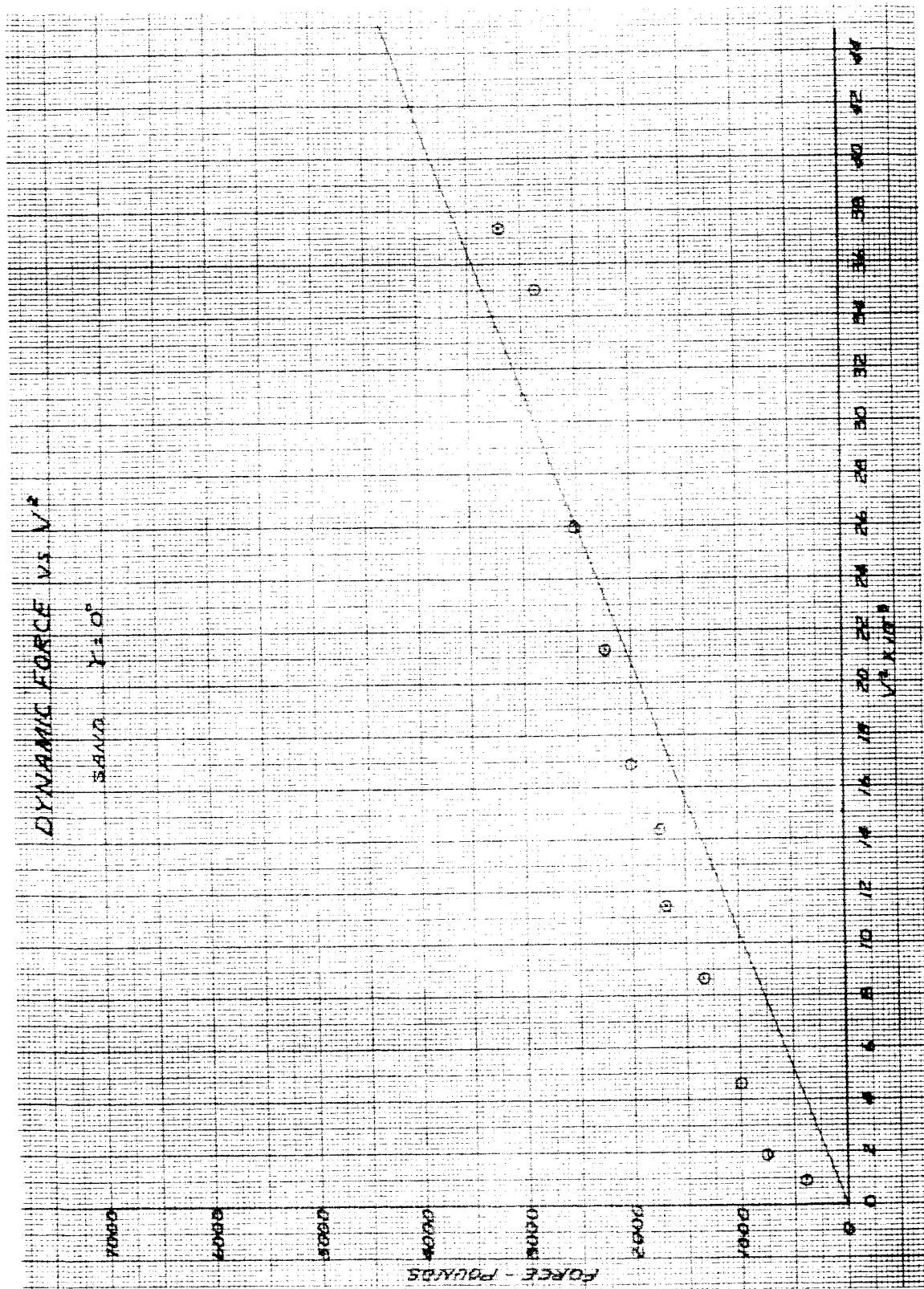


Figure 4-60. Dynamic Force Versus V^2 Sand

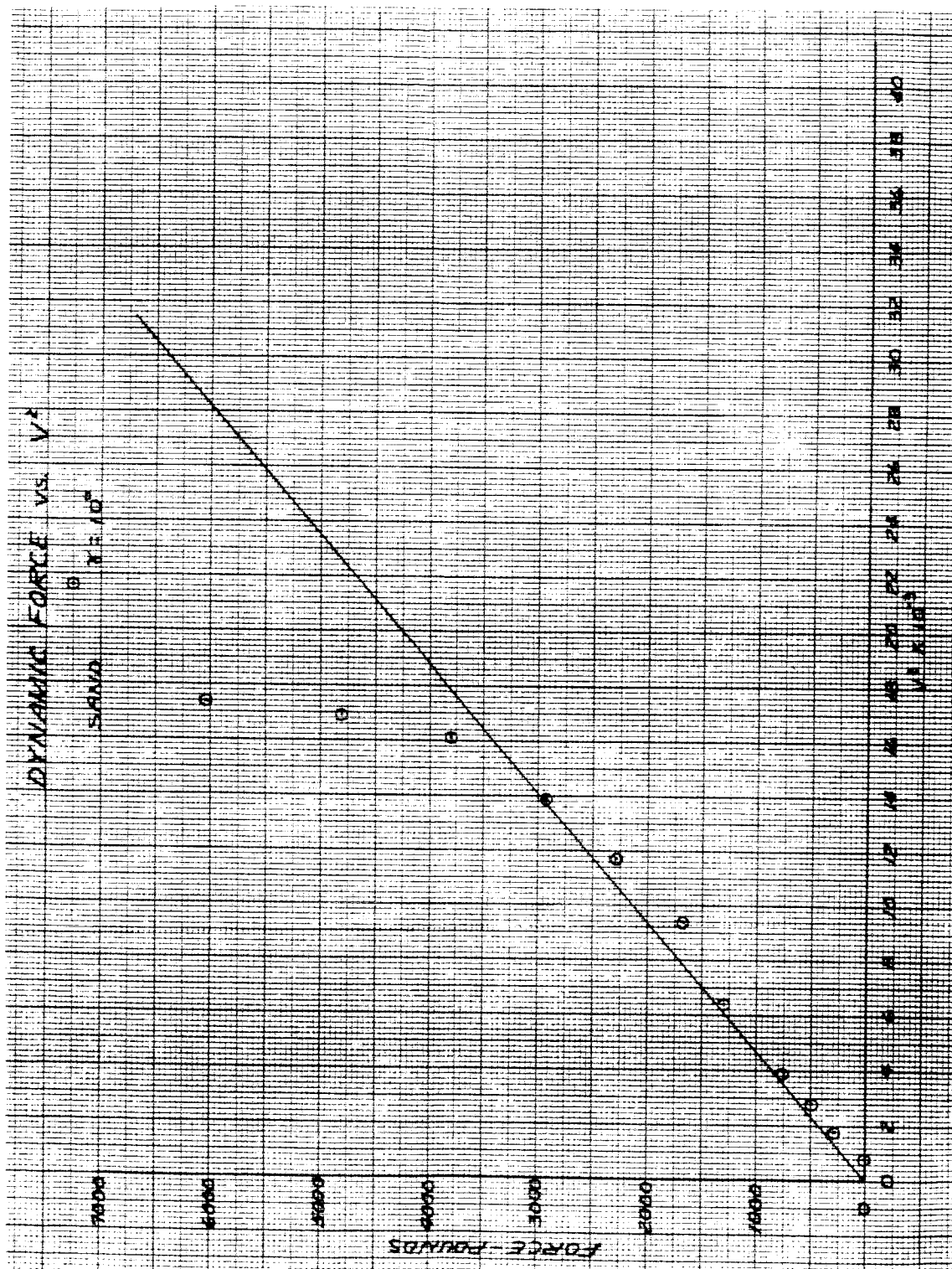


Figure 4-61. Dynamic Force Versus V^2 Sand

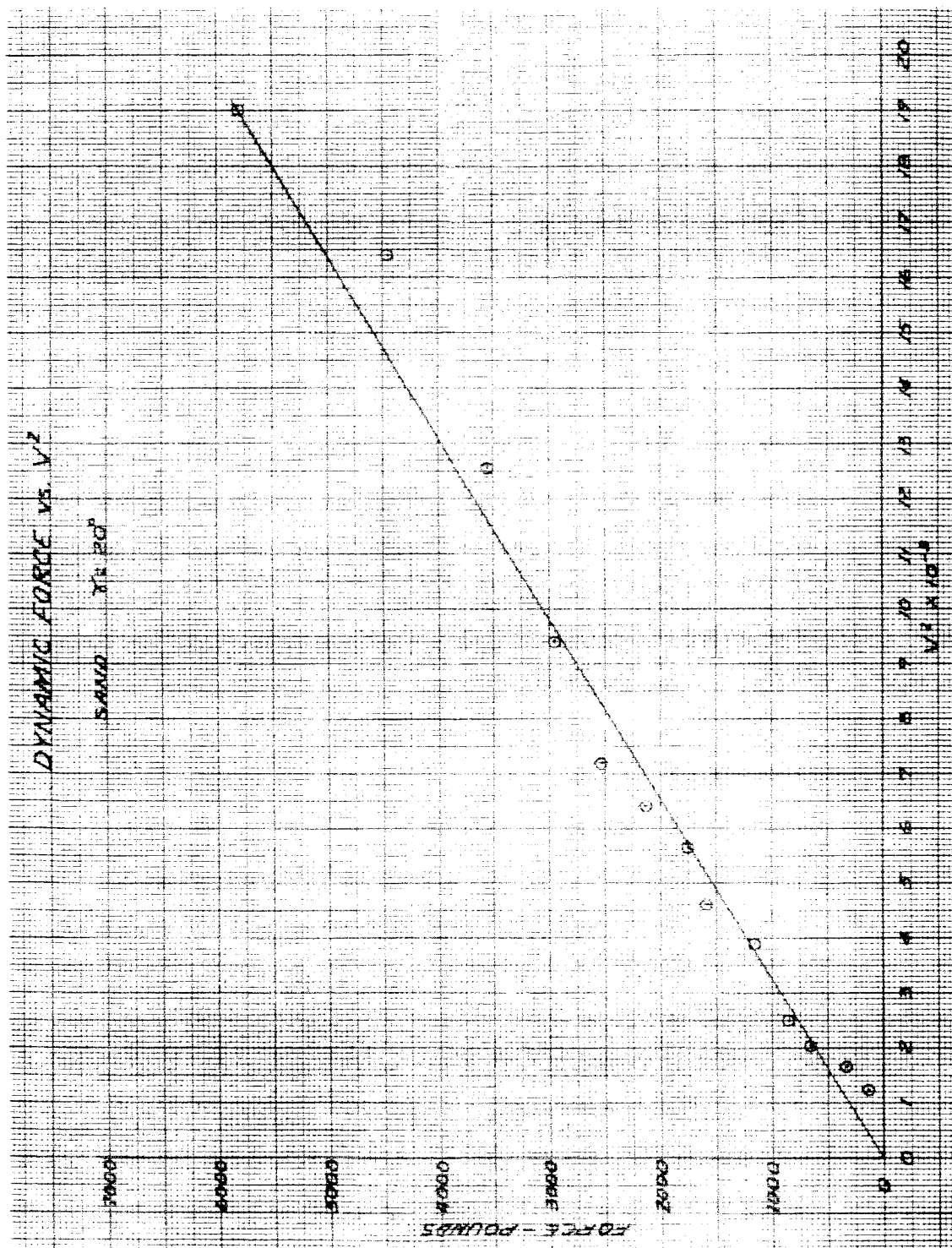


Figure 4-62. Dynamic Force Versus V^2 Sand

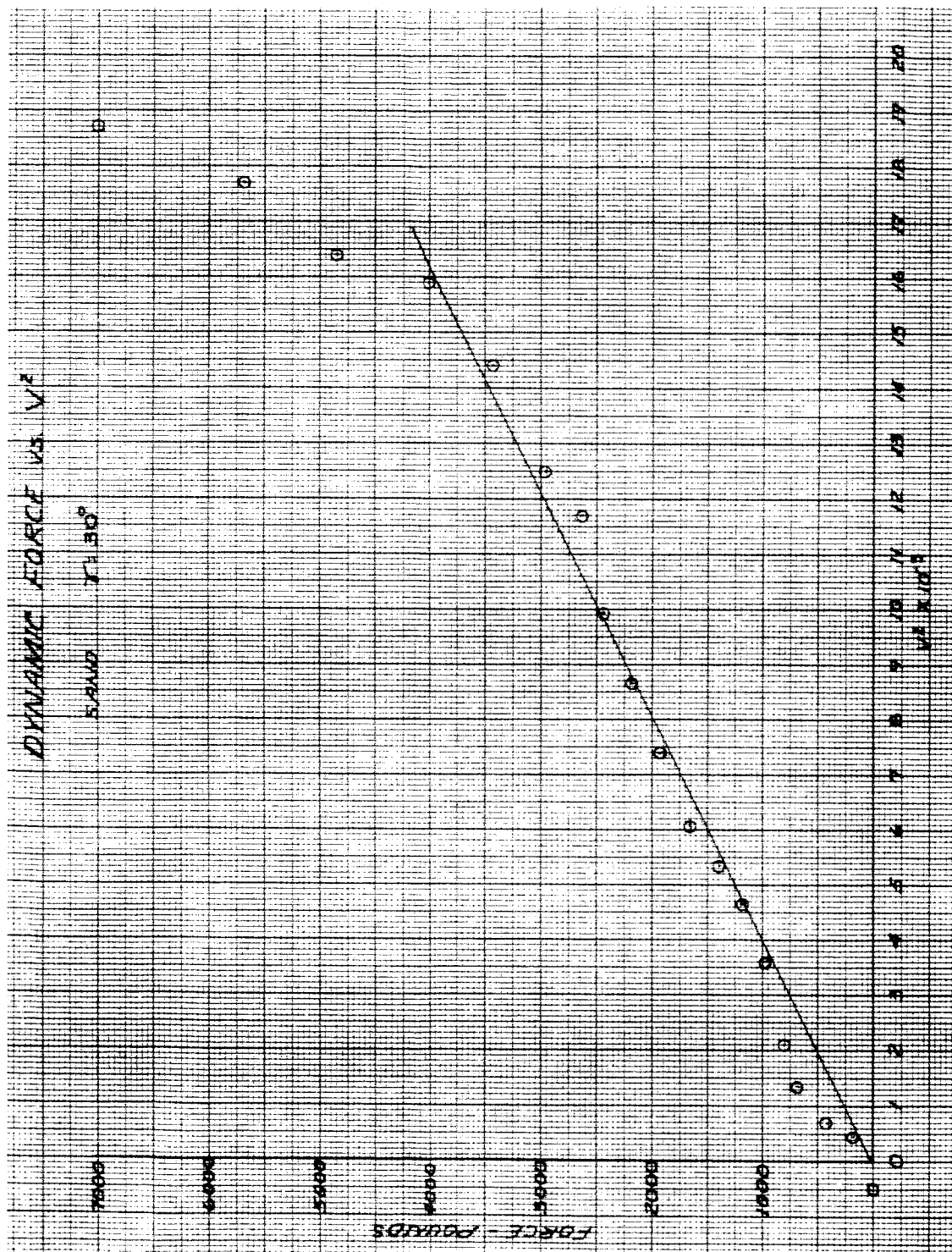


Figure 4-63. Dynamic Force Versus V^2 Sand

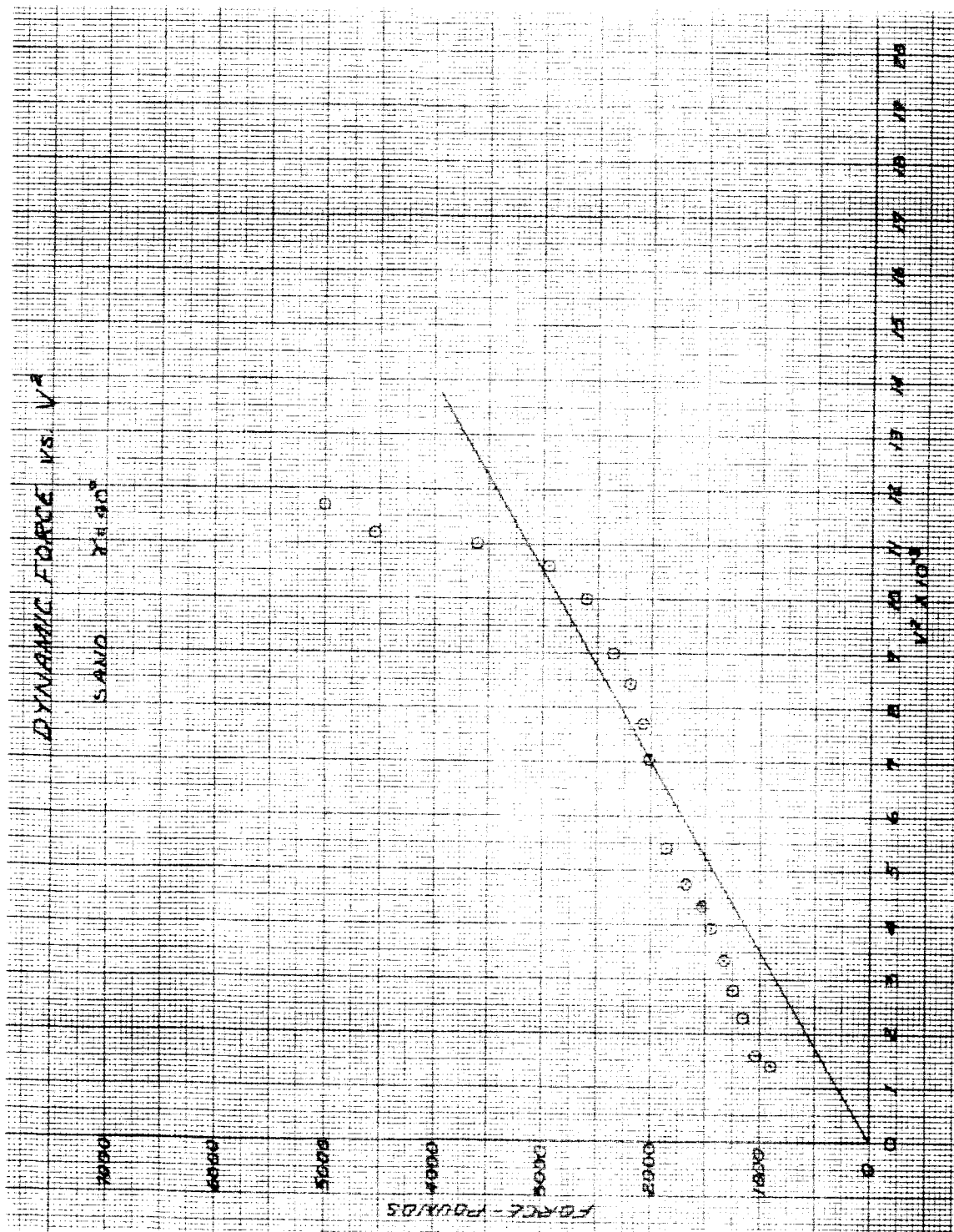


Figure 4-64. Dynamic Force Versus V^2 Sand

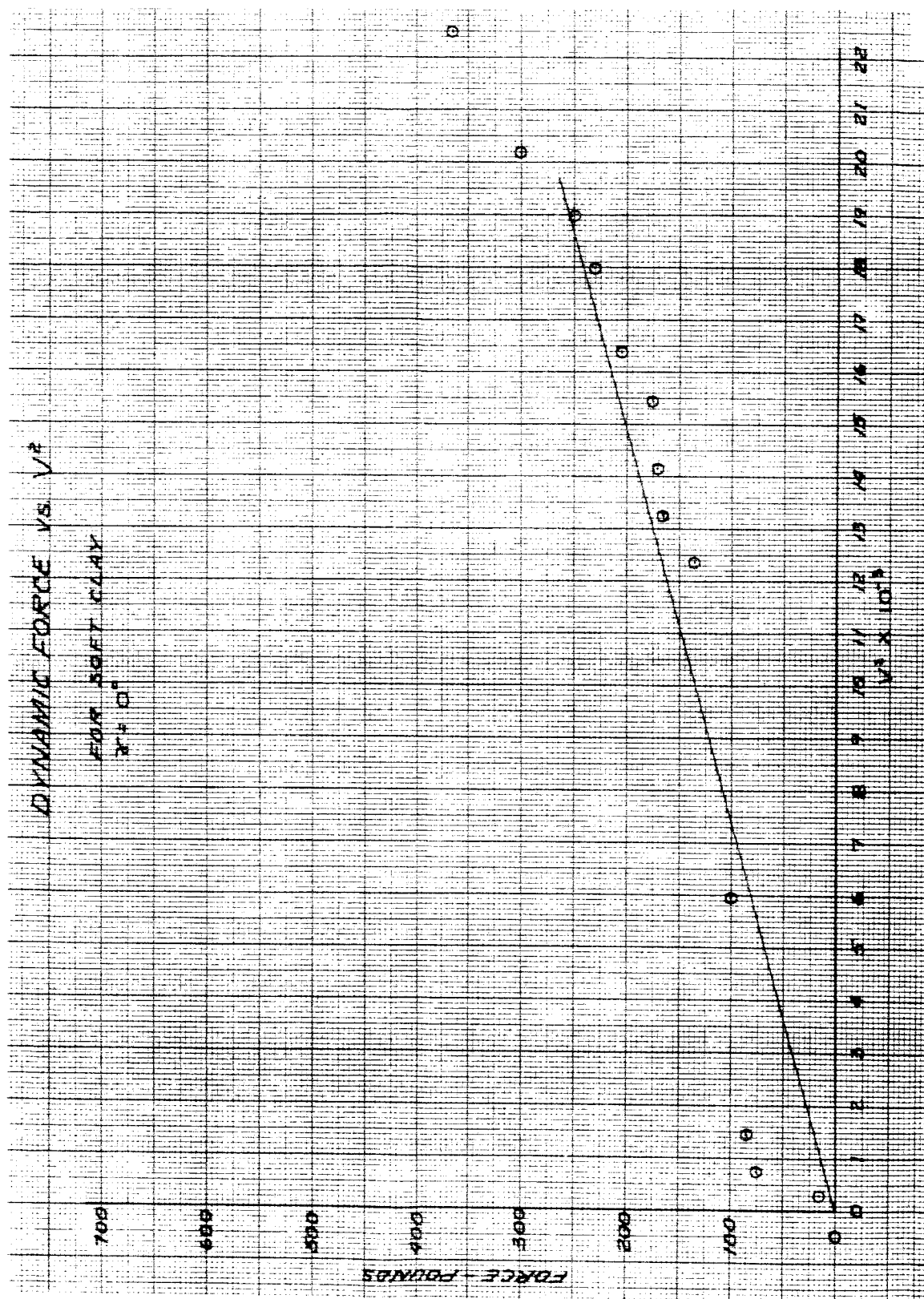


Figure 4-65. Dynamic Force Versus V^2 for Soft Clay

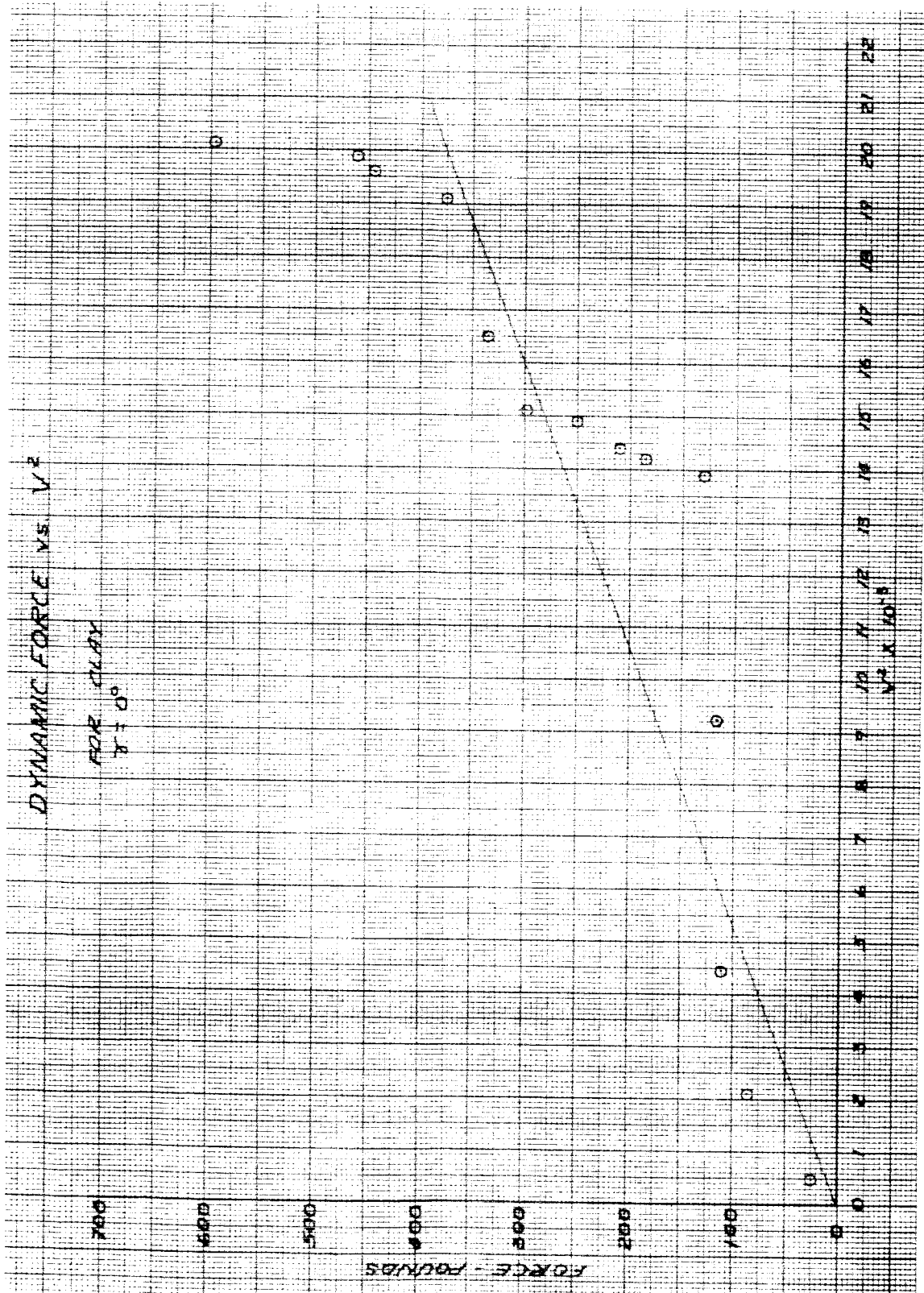


Figure 4-66. Dynamic Force Versus V^2 for Clay

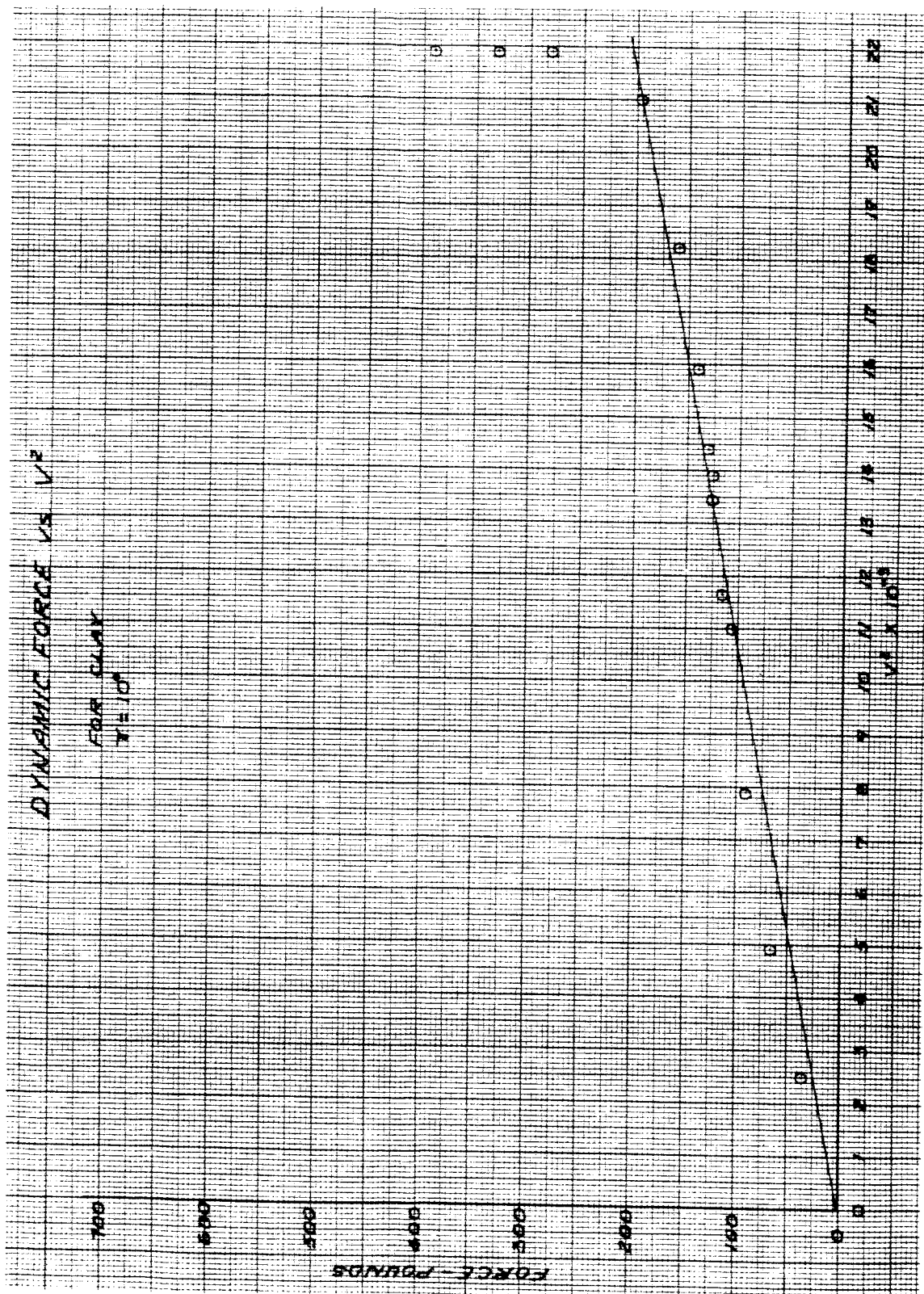


Figure 4-67. Dynamic Force Versus V^2 for Clay

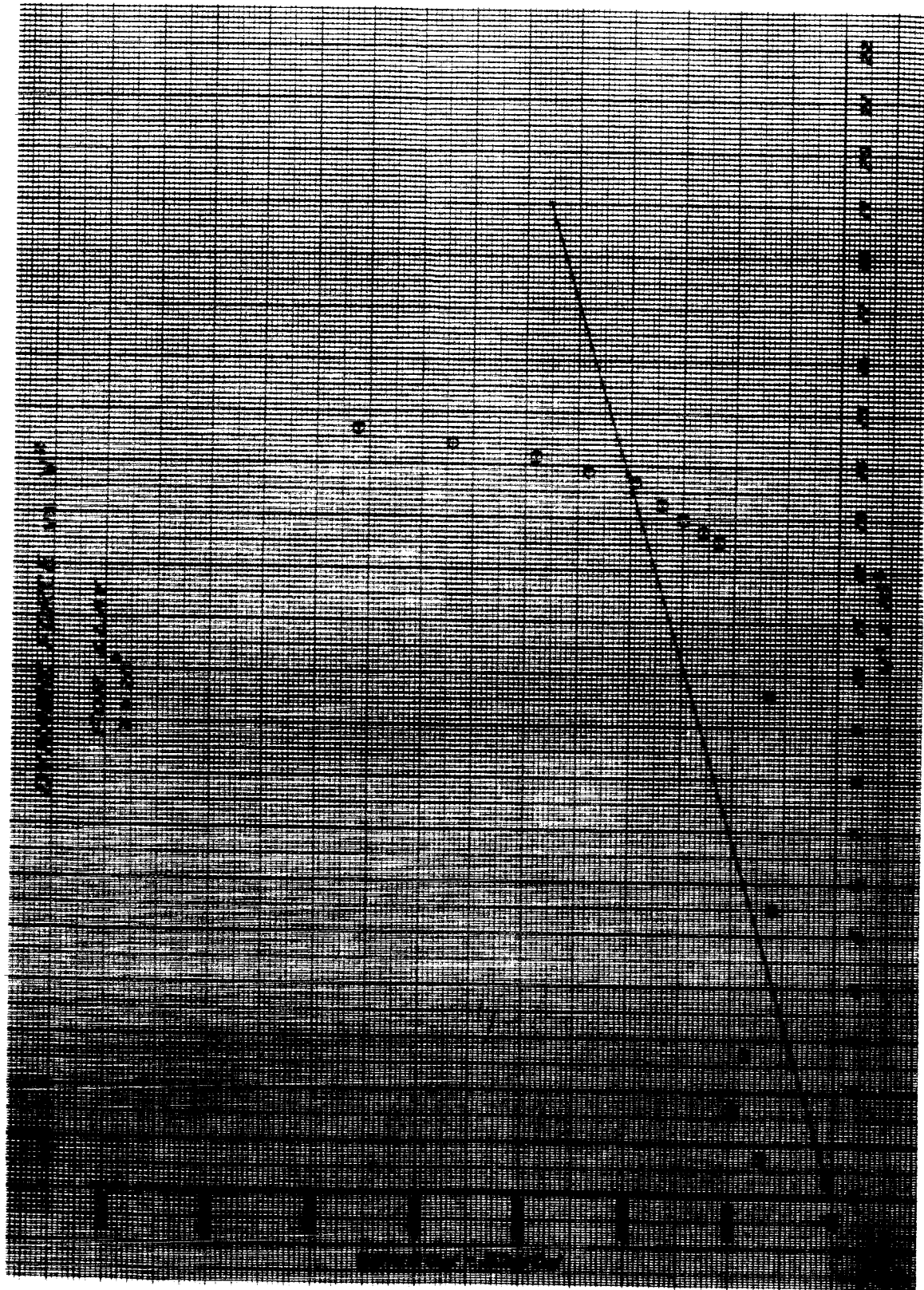


Figure 4-68. Dynamic Force Versus V^2 for Clay

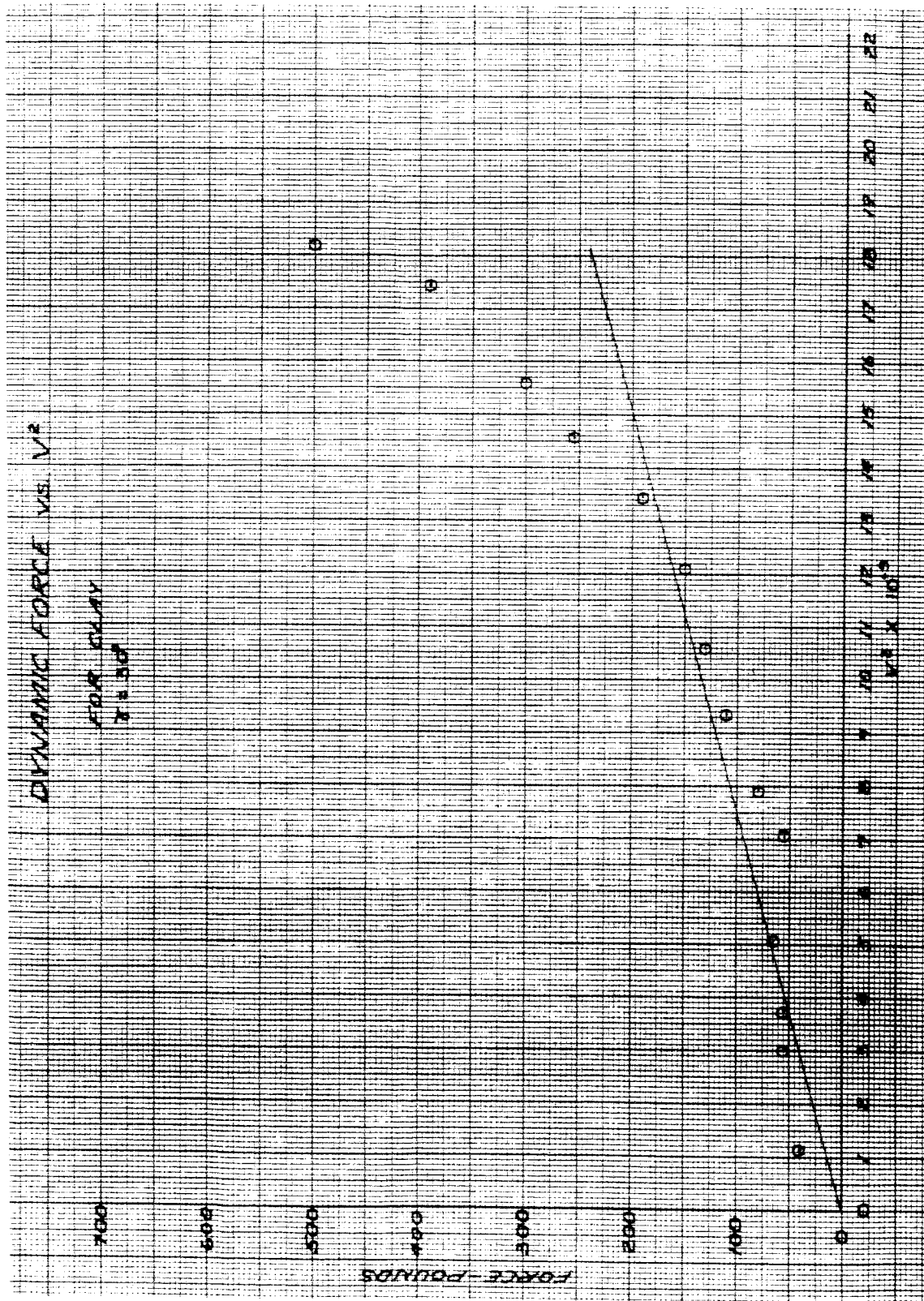


Figure 4-69. Dynamic Force Versus V^2 for Clay

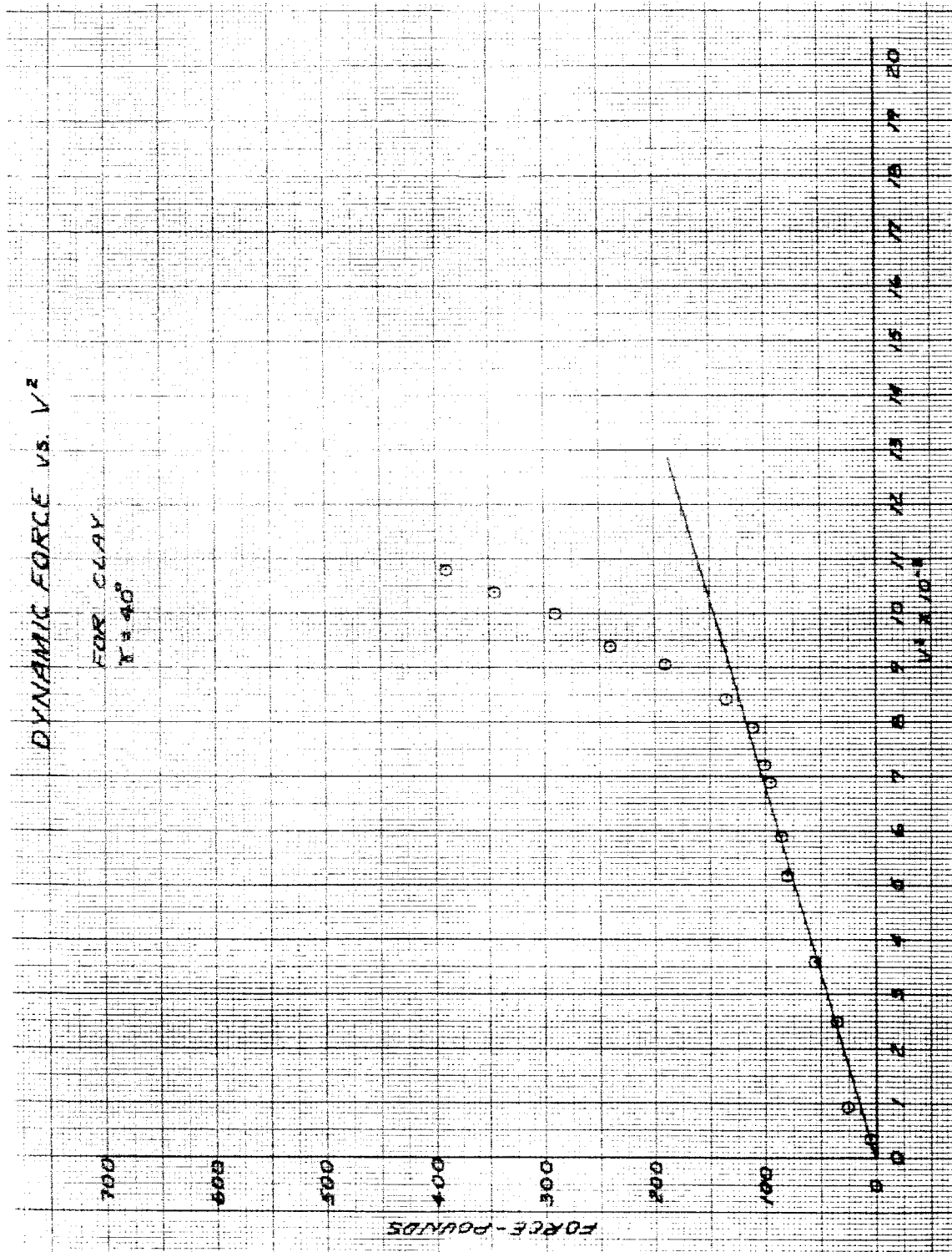


Figure 4-70. Dynamic Force Versus V^2 for Clay

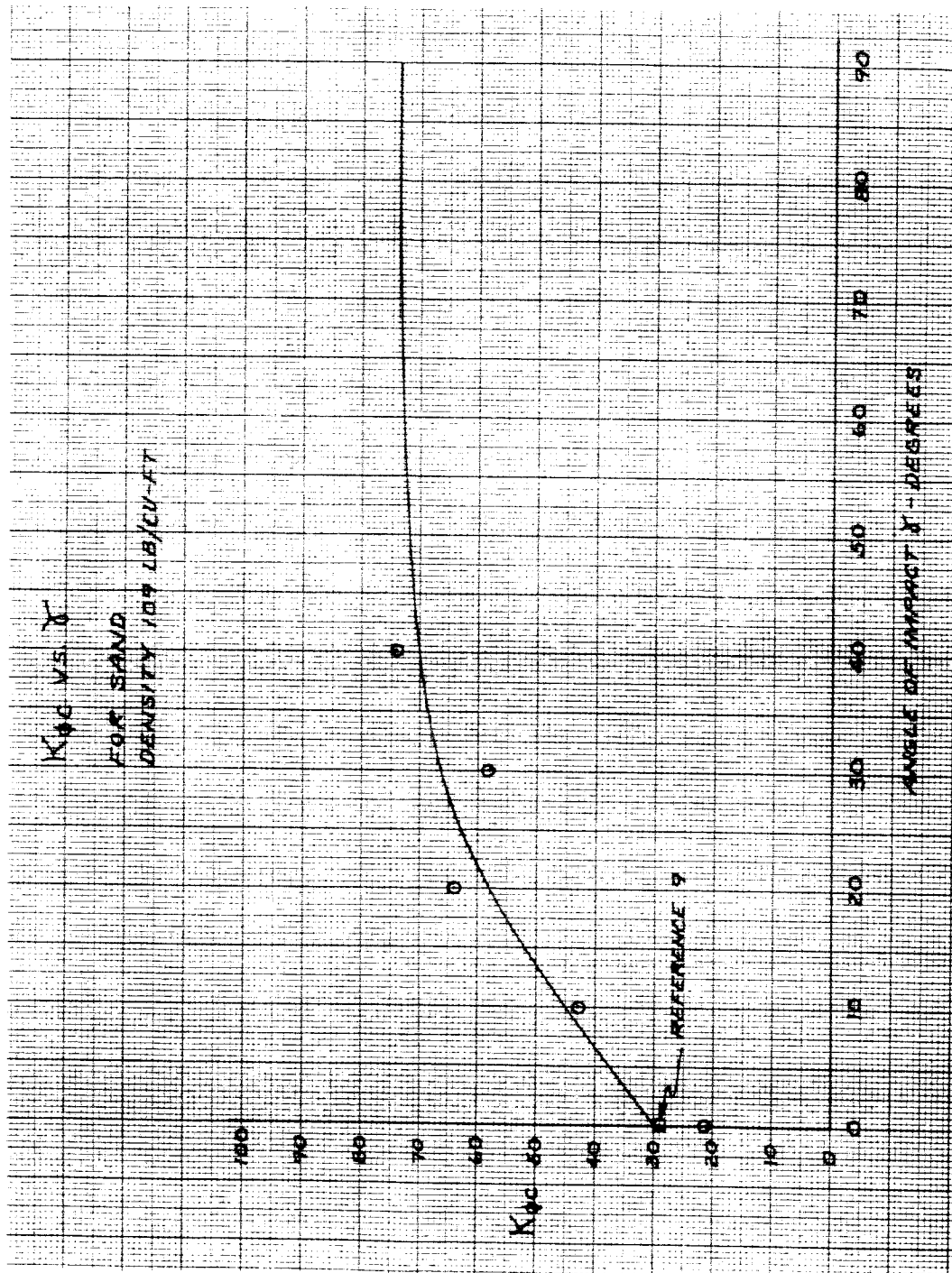


Figure 4-71. $K_{\phi c}$ Versus γ for Sand Density 109 lb/cu-ft.

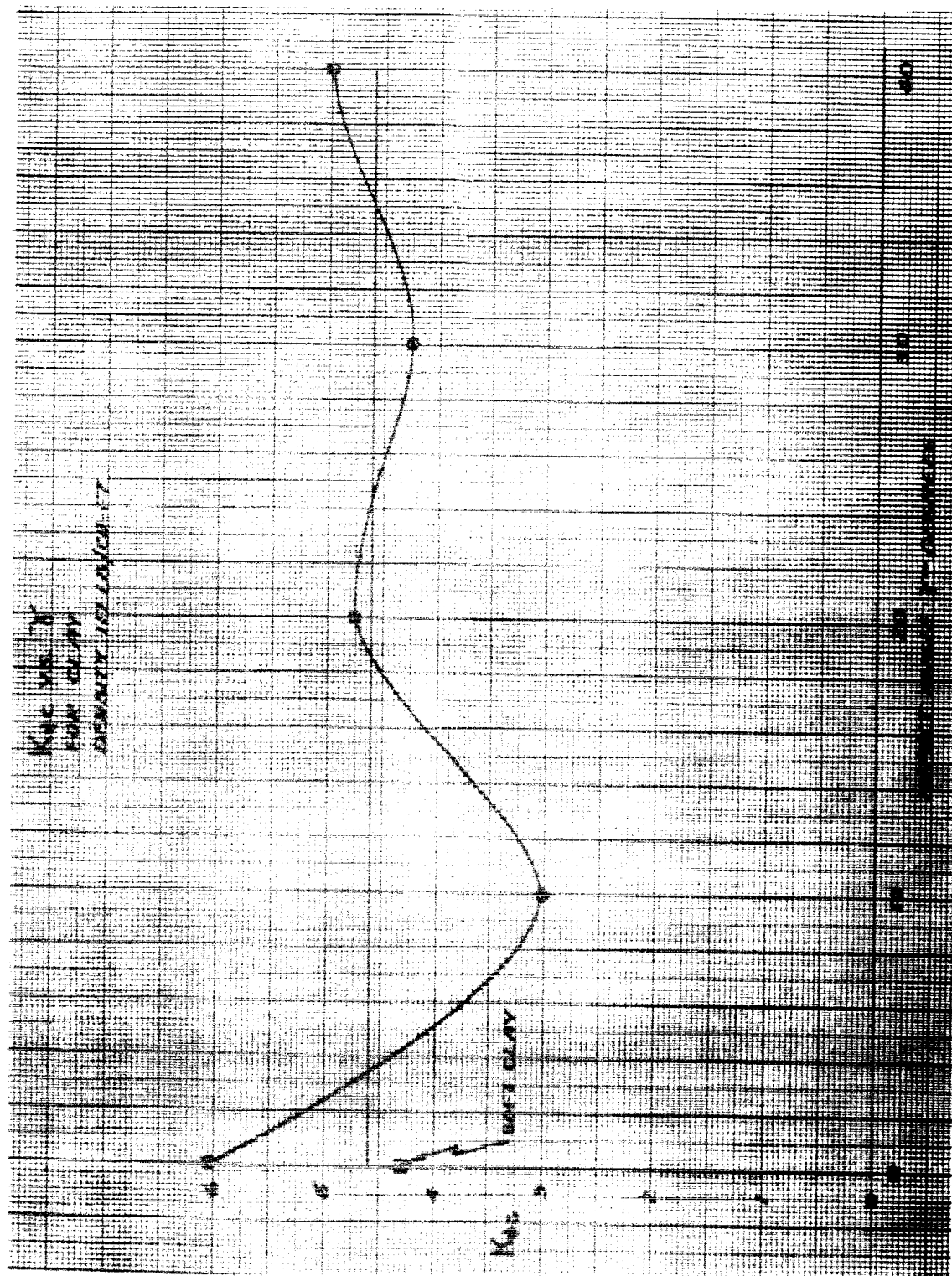


Figure 4-72. K_p Versus γ for Clay Density 117 lb/cu-ft.

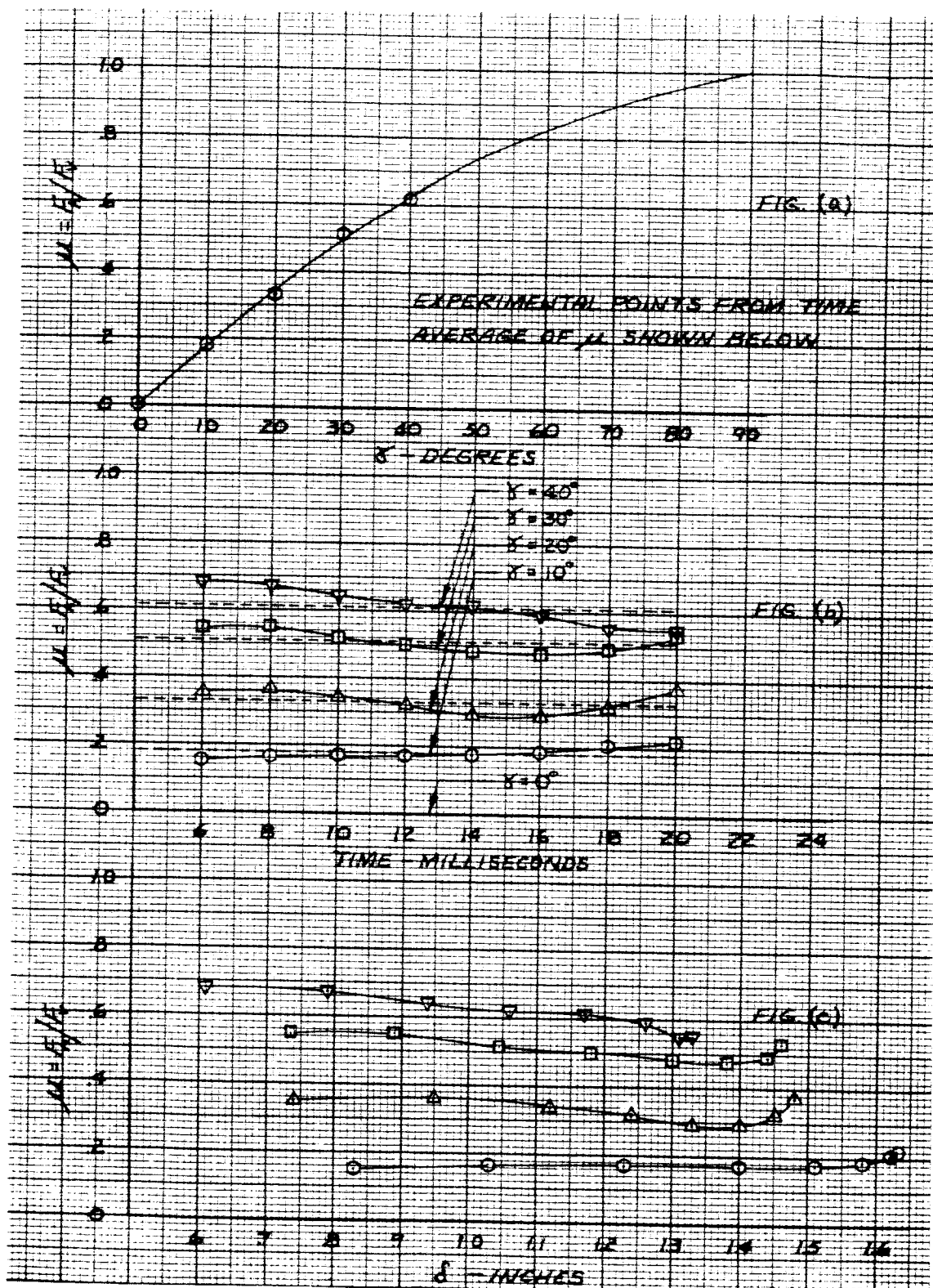


Figure 4-73. Relationship of μ to γ , Time, and δ

SECTION V

MODEL TEST PROGRAM AND COMPARISON OF EXPERIMENTAL AND ANALYTICAL RESULTS

In order to obtain varification of the accuracy of the computer program, from a practical standpoint, a drop test model was constructed and a test program undertaken. Output data of the drop test program was compared to the computer results for tests on three soil types, one of which was a rigid surface. The following section describes the model construction techniques, model characteristics, the drop test program, and a comparison of computed and experimental results for all of the model landings in the drop test program.

5.1 GENERAL DESCRIPTION

The model used in the drop test program is approximately one-fifth scale. It is composed of three masses separated by shock struts. The heat shield and outer body were fabricated from filament wound fiberglass and epoxy resin. The astronaut's couch was made of aluminum. The shock struts were all of the friction type composed of a Teflon sleeve surrounding an aluminum inner cylinder. The heat shield was connected to the outer body by eight shock struts. Each was inclined to the vertical axis of the model such that a projection of the strut on the horizontal plane lay on a chord of the base circle of the body. By this means, any translation or rotation of the heat shield relative to the body causes stroking of the shock struts.

The astronaut's couch was connected to the body by means of six shock struts. These were arranged in three pairs, each pair lying in one of the three principal planes of the coordinate system. Movement of the astronaut's couch, in any one principal plane, caused stroking of the shock struts in that principal plane only.

The outer surface of the model was covered with a foamed plastic material which crushed and absorbed energy upon impact with the landing surface.

Each shock strut was instrumented to measure stroke-load and stroke.

Twelve accelerometers were mounted on the model. Six were fastened to the outer body and six to the astronaut's couch. Three accelerometers were mounted at the c.g. of both the outer body and astronaut's couch. The other three were mounted in each of the principal planes of each mass. It was therefore possible to measure both translational accelerations and rotational accelerations of both the body and astronaut's couch. The translational accelerations were read directly from the c.g. accelerometers. The rotational accelerations in any principal plane could be determined by the difference in measured accelerations of the two accelerometers lying in that particular plane.

5.2 BODY AND HEAT SHIELD

The body and heat shield were machined from filament wound fiberglass reinforced epoxy resin material. Figures 5-1 through 5-5 show the steps in making the body and heat shield. Figure 5-1 is a picture of the mandrel mounted in the wrapping machine. The mandrel is made of salt blocks cemented together and machined to form the inside of the rough form. The grooves are to hold the material from which the shock strut mounting lugs will be machined. Figure 5-2 shows the form in the early stage of winding. Figure 5-3 shows the form in the latter stage of winding. Figure 5-4 shows the finished rough form after it has been cured in the oven. The rough form at this stage weighs 685 pounds with the salt mandrel and arbor upon which the form was wound.

The form was then parted at the major diameter by machining in a lathe and the salt was washed out with water. The two sections are shown in Figure 5-5. The bell-shaped half was machined to form the outer body of the model and the shallow half was machined to form the heat shield.

5.3 SHOCK STRUTS

Figure 5-6 shows a cross section of one of the shock struts. The inner cylinders are chrome plated aluminum tubes. The outer cylinders contain a preload capsule at one end. This capsule is composed of a steel tube (a) closed at one end, a Teflon sleeve (b) at the inner diameter, an aluminum packing ring (c), nine tetra seals (d) (square rubber packing rings), and an adjusting nut (e). The tetra seals are confined in the space between the steel tube and the Teflon sleeve. Tightening the adjusting nut applies pressure to the rubber which in turn transmits pressure to the Teflon sleeve thereby generating a normal force between the Teflon sleeve and the inner cylinder. Stroking of the inner cylinder produces energy absorbing heat.

Experience has shown that the stroking force produced by the Teflon - inner cylinder combination increases under impact loading. A load limiting device has been incorporated into the shock strut. This device utilizes a Belleville spring to decrease the amount of buildup normally associated with high stroking velocities. As the stroke load builds up, it further compresses the Belleville spring through which the load must pass. The Belleville spring is in series with the rubber tetra seal stack and any further compression of the Belleville spring results in a like expansion of the rubber stack. This expansion decreases the pressure in the rubber and thereby decreases the normal force between the Teflon sleeve and the inner cylinder.

5.4 CRUSHABLE SKIN

The foamed plastic skin which covers the model was made in the Bendix laboratory in two-piece wooden molds. The body mold requires about nine pounds of plastic. The heat shield mold requires about five pounds of plastic.

Some problem was encountered with excessive strength in the crushable skin which surrounds the model. The strength was such that only a small amount of the skin would crush under maximum energy drops. The manufacturer of the foaming plastic was unable to make any recommendations for reducing the strength of the foamed plastic other than the heating of one of the two constituents. This heating had little effect on the strength of the plastic and the crush strength remained between 25 and 30 psi. It was

decided to try adding impurities to the foam to weaken its bond strength. One apparent requirement for an impurity would be that it be very fine so that it could be uniformly dispersed throughout the foamed plastic. The foamed volume is about 20 times the initial liquid volume and a coarse material such as sand would probably be enclosed in the large volume with very little effect.

Two materials were tried: 200-mesh air floated clay and 200-mesh ultra fine powdered salt. The normal mix of plastic used for a model heat shield cover is 1200 gms of Poly-lite 8625 and 750 gms of 8605 Polylite. The 8605 is heated to 110°F before mixing. The maximum amount of clay which could be added to the 8625 was 600 gms, at which time the plastic became almost too thick to mix with the 8605 for foaming. A similar mold was made using 600 gms of 200-mesh salt. Both completed molds exhibited an appreciable decrease in strength over the pure foam.

The clay additive foam was more brittle than the salt additive foam but not entirely uniform. The salt additive foam was very uniform in cell size, even more so than the pure foam and was the final choice for model testing.

The foamed plastic skin was held to the body with a large washer and nut about the center tube of the model. The heat shield skin was glued to the heat shield.

Crush strength test results on the crushable skin used for drop test are shown in Figure 5-7. Six samples four inches on a side were crushed in an Instron machine. All exhibited the same crushing characteristics. The material has a very pronounced plastic failure point at 19 psi.

5.5 INSTRUMENTATION

A great deal of instrumentation was used on this model. Strobe photographs and high speed photography could not be used to determine the model, motion, such as had been used on previous model tests, because the astronaut's couch was not visible during the testing.

The outer cylinders were instrumented with strain gages to record load. These gages were wired into a bridge circuit so as to cancel bending stresses.

Figure 5-8 shows the details of the stroke measuring instrumentation. The variable resistance rod was made by winding number 28 Chromel "C" 4.251 ohms per foot resistance wire on number 5 - 40 tpi nylon rod. The wiping mechanism was made of three small diameter coil springs fastened to a brass plate to form a triangular opening. Insertion of the resistance wired rod into the wiper spread the small coil springs and maintained a tight contact. Approximately six feet of resistance wire was used in each stroke measuring mechanism.

Two types of accelerometers were used because those on the body are subjected to higher accelerations than those used on the couch. The accelerometers used are Consolidated Electrodynamics Co. #4-202-0001 DC strain gage types. The six used on the body have a range of plus or minus 100gs and those used on the couch have a range of plus or minus 50 gs.

Figure 5-9 shows the location and orientation of the accelerometers on the body and Figure 5-10 shows the location and orientation of the accelerometers on the couch.

The wiring of the instrumentation was done so as to facilitate easy servicing of the model during test.

The stroke load and stroke wires coming from the struts terminated in a miniature six pin quick disconnect fastened to the strut outer cylinder. It was necessary to remove each strut from the model after every drop so as to reset the strut length and check on the stroke load. The stroke wire leading from the strut inner cylinder was connected to the six pin connector through a single connector so that the inner cylinder could be removed in case it was necessary to work on the friction device.

The accelerometer leads terminated in four pin connectors and were interchangeable with the stroking load strain gage leads from the struts.

All of the model internal wiring terminated in an 80 pin master disconnect which was mounted inside the model center tube. This disconnect was required when the body foamed plastic skin was changed.

Figure 5-11 shows the model disassembled. Figures 5-12 through 5-14 show the model at various stages of assembly.

5.6 DROP TEST EQUIPMENT

The model was launched in the Bendix six degree of freedom drop test rig. The design of this rig is explained fully in Bendix Report MM-65-4. In brief, the model can be launched with a wide range of pitch, roll and yaw angles and of pitch, roll and yaw rates. The energy for imparting horizontal and vertical velocities and the desired pitch rates comes from gravity.

The model was dropped on three different "soils". The first was a rigid surface composed of a laminated fir plywood board 12 feet long by 8 feet wide by 4 inches thick underlaid with compacted silica sand. The second "soil" was silica sand. The third soil was wet clay using a ratio of 100 parts of 200 mesh air floated fire clay to 25 parts of water. The engineering properties of these soils have been previously described in Section IV.

Drops were made on the hard surface and the sand at both 0° and 10° slopes. Drops were made on the clay at 0° slope only.

The "soil" pit landing surface was 18 feet long by 12 feet wide by 5 feet deep. These dimensions were required to eliminate edge effects and make the soil an "infinite" volume as regards test results.

Removable sides formed a part of the landing soil pit to provide a 10° sloped surface. Figure 5-15 shows the empty pit with the 10° side extensions in place.

About 180,000 pounds of sand was required to fill the landing pit.

Considerable difficulty was encountered in mixing the air-floated clay in sufficient quantities to completely fill the 5 foot deep soil pit. It would require approximately 1750 - 100 pound bags of the clay to fill the pit when the 10° slope side frames are in place. Mixing experiments indicated that this was 7.5 to 10.0 man weeks of soil preparation.

Our analysis of the shell contact area indicated that at no time would it be greater than that of an 18-inch diameter circle when drop testing on the clay. Wedge depth should be no more than 9 inches. For this reason a 2-foot depth of clay should be fairly close to the "infinite continuum" case we were originally planning to obtain with a 5-foot depth of clay. "Bottom effect" tests conducted with the oblique impact soil tester also confirmed the validity of this approach (see Section IV).

Instrumentation data was recorded on three oscillographs. Each oscillograph received the information from ten sources. The total number of sources on the model were forty consisting of 14 strokes, 14 strut loads and 12 accelerometers. The use of 30 channels to record the information necessitated the elimination of ten sources of information on each drop. The strokes were always recorded but the accelerometers were interchanged with the strut stroke loads for various tests as will be explained later.

A new heat shield skin was used for each drop. A method of measuring crushing of the skin and/or penetration of the skin into the soil was used for each drop. Figure 5-16 shows the method used on the hard surface. Carbon paper was fastened to the hard surface with the inked side facing the model. When the model impacted the hard surface, the carbon paper made a record of the impact area on the surface of the heat shield as shown in Figure 5-17. When dropping on sand and clay, the outline of the soil sticking to the skin was traced and the impression of the heat shield skin in the soil was measured and recorded. This penetration was later used for correlation with the computer prediction. Figure 5-18 shows the outline of the sand adhering to the heat shield after a sand drop.

Figure 5-19 shows the model at the instant of impact on the clay (Drop No. 11). Figure 5-20 shows the impression of the model heat shield in the clay after this drop test.

5.7 COMPARISON OF EXPERIMENTAL AND ANALYTICAL RESULTS

As previously mentioned, computer runs for all of the 16 drops conducted on the hard surface, the sand, and the clay were made to establish the degree of correlation between predicted and experimental landing motions. In all cases the primary comparisons are between accelerations predicted by the computer runs and those measured by the twelve accelerometers mounted on the capsule and the astronaut's couch of the model. This represents a quite critical comparison technique in that model velocities, and translational and angular displacements can correlate to a close degree to those of an analytical solution, yet the time history of the model accelerations may be quite different from those of the analytical solution. This is due to "time-averaging" of the details of the acceleration history when looking at velocity or displacement histories.

This more critical correlation procedure was shown for two reasons. First, the detail acceleration histories of the astronauts and of various shock mounted components of the command module are of primary interest. Tumbling motions and vehicle stability, while of interest, are not primary and, in event, are guaranteed correlation by demonstration of correlation of translational and angular accelerations. Second, general three dimensional model accelerations could be conveniently measured by placement of accelerometers designed into the drop test model. The same acceleration locations and directions were used as computer output so that direct comparisons could be made between computed and experimental results.

The locations of the twelve accelerometers are shown in the assembly drawing of the model (Figure 5-21). The shock strut numbering system is also shown in this drawing.

It can be seen that the twelve accelerometers are sufficient to measure the three angular accelerations and three translational accelerations of both the astronaut's couch and the capsule proper.

The shock struts of the model did not give the idealized constant load level stroke load which was the original intention of the design. This is illustrated by the load versus stroke curves shown in Figure 5-22 and Figure 5-23 which apply to shock struts nos. one through eight on drop nos. 1AR and 7A. For this reason in the correlation studies,

the actual load versus stroke curves were used as input data to the computer program, where possible. This was not always possible because of the amount of instrumentation recorded on the individual drops.

The drop test schedule and the instrumentation for each of the drops is given in Figure 5-24. Pertinent acceleration comparisons between the drop test results and the computer results are given in Figures 5-25 to 5-59. Figure 5-27 which applies to drop No. 1-A shows the "long term" correlation achieved with the computer program. The remainder of the correlation studies are concerned with the first acceleration impulse. Subsequent impulse periods are of much lower magnitude.

The generally good correlation between the computed and the experimental results is felt to offer considerable validation to the basic computer program's ability to predict accurately the accelerations and three dimensional motions of the Apollo command module.

In addition to the acceleration correlation shown in Figures 5-25 through 5-29 the soil contact areas for the hard surface, clay, and sand model landings were compared to the maximum contact area predicted by the computer solution. These respective areas agreed to within 10 percent and again substantiated the validity of the computer solutions.

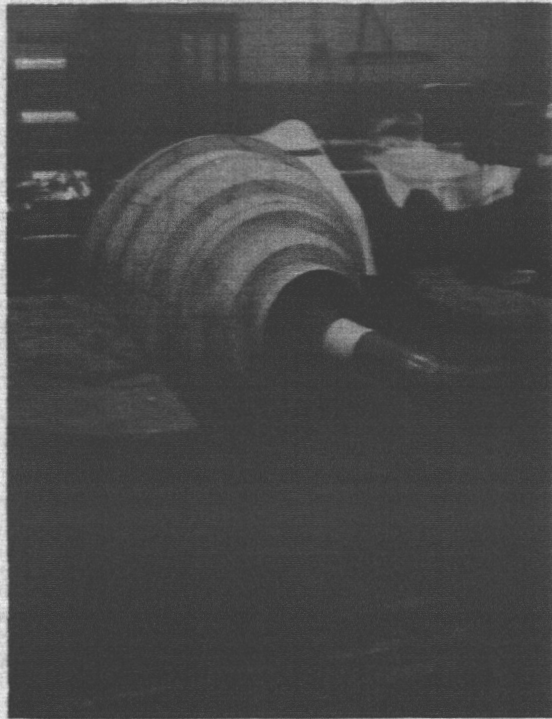


Figure 5-1. Salt Mandrel

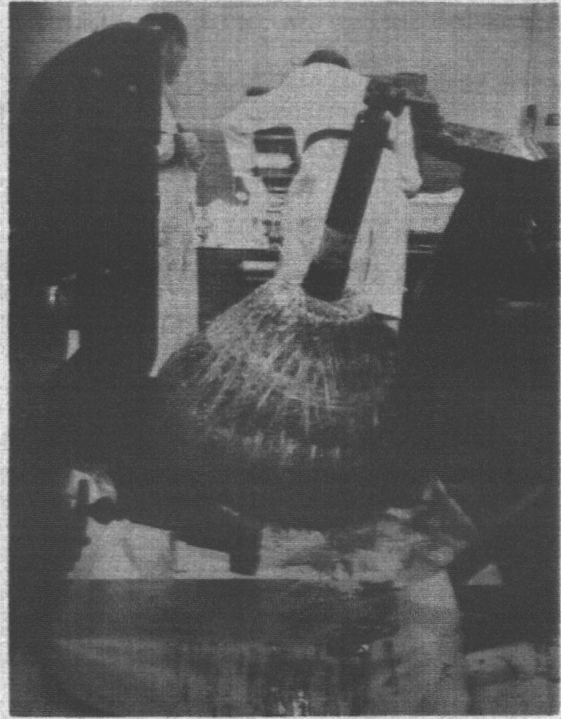


Figure 5-2. Early Stage of Winding



Figure 5-3. Final Stage of Winding



Figure 5-4. Wound Model Form

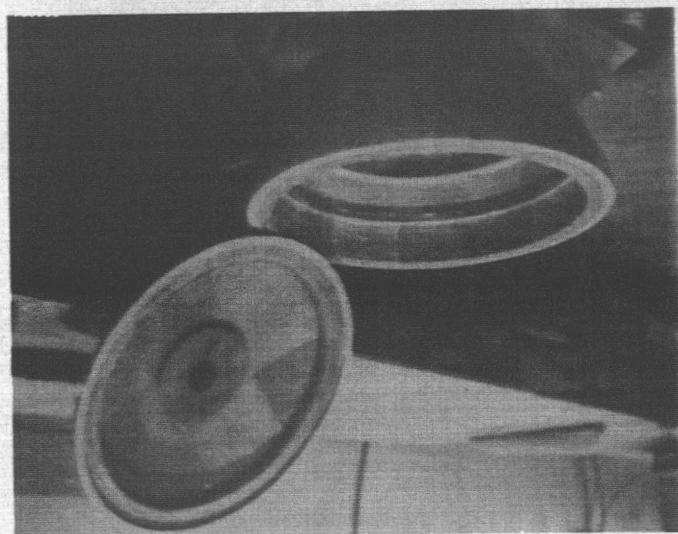


Figure 5-5. Rough Model Forms Ready for Machining

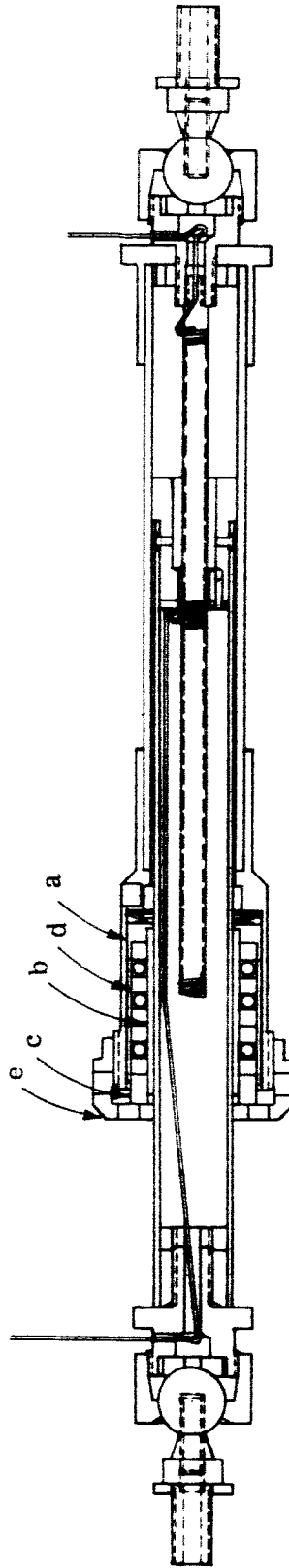


Figure 5-6. Apollo Shock Strut Showing Friction Device and Stroke Measuring Mechanism

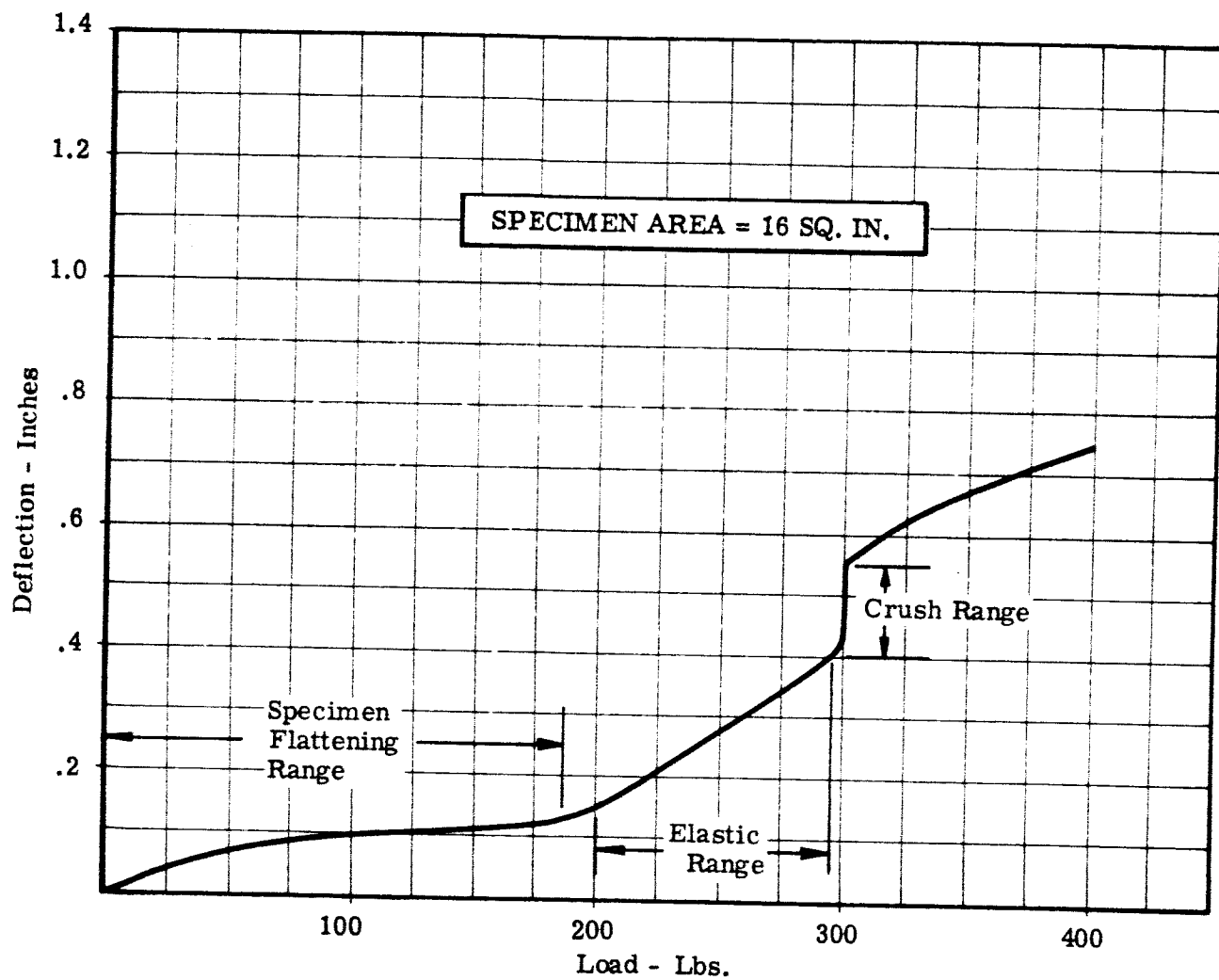
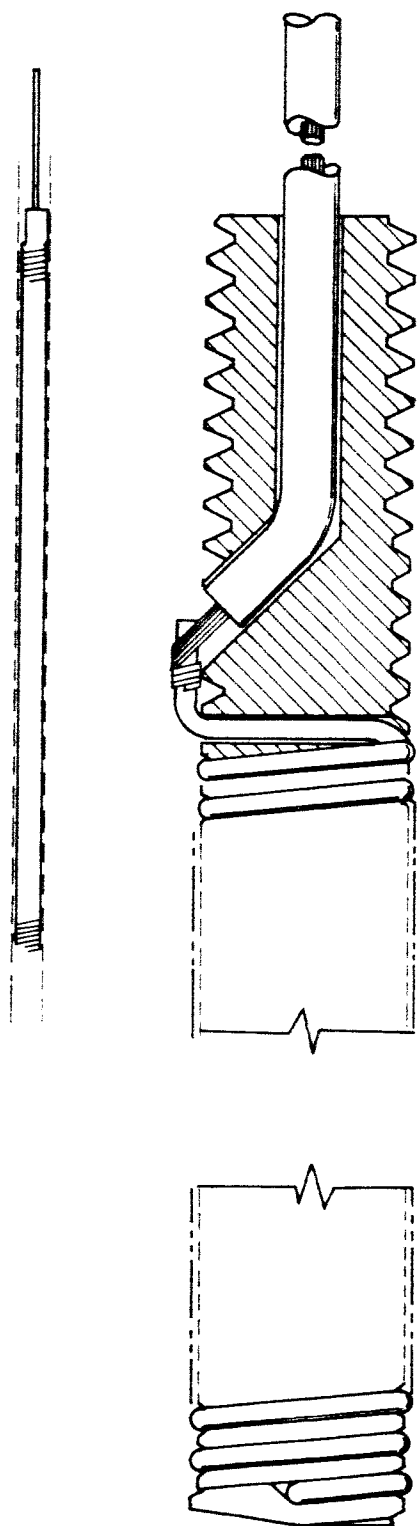


Figure 5-7. Crush Versus Load Test Curve for Apollo Crushable Skin



Wire Wound Resistance Rod for Stroke Measurement

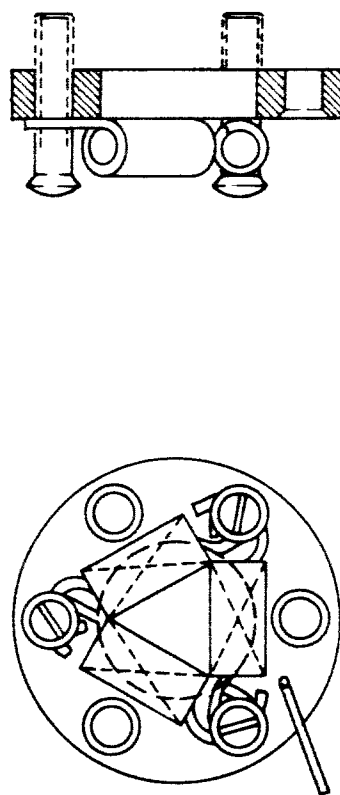


Figure 5-8. Wiper Assembly for Stroke Mechanism

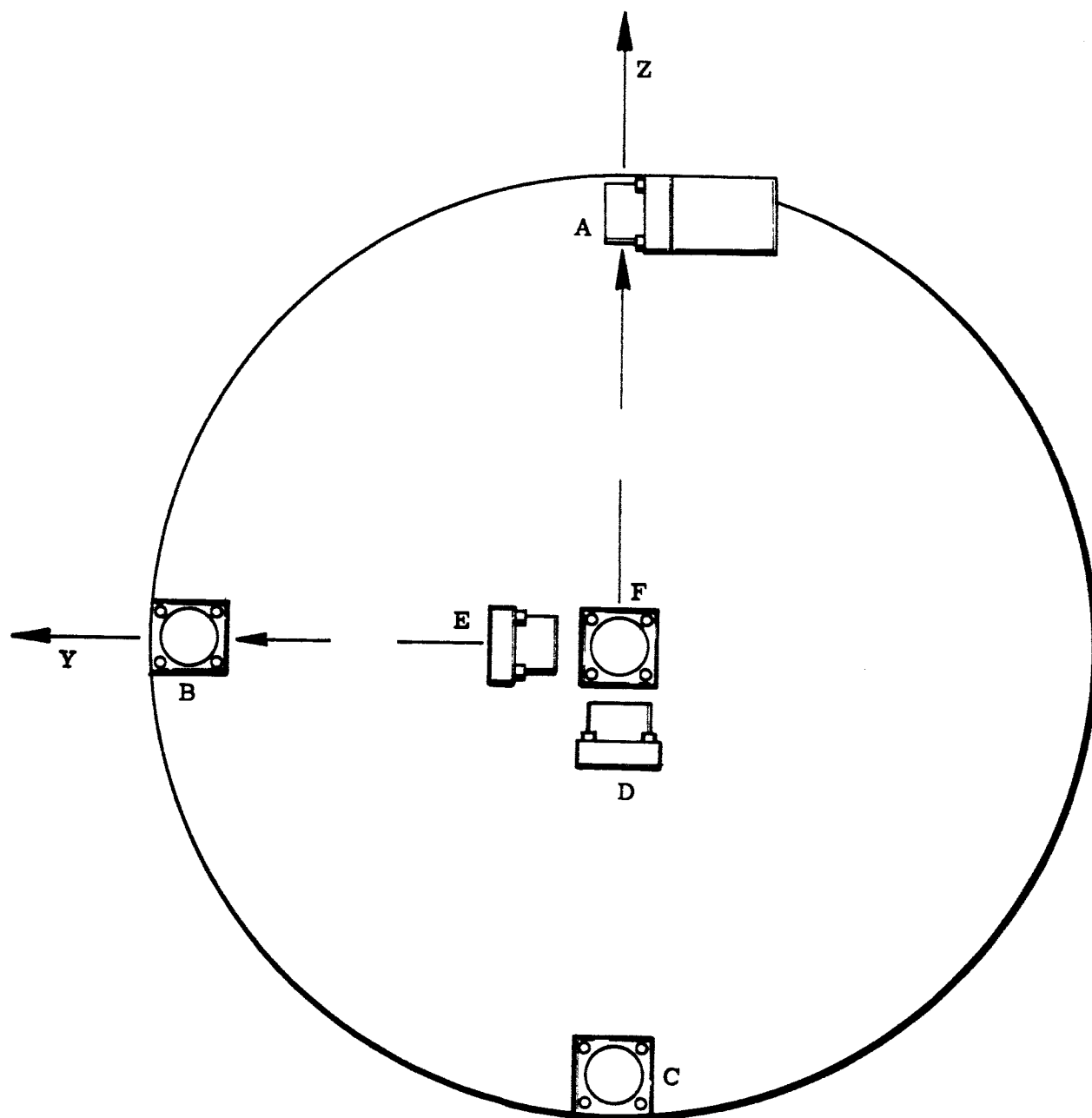


Figure 5-9 Accelerometer Locations on APOLLO Model Body

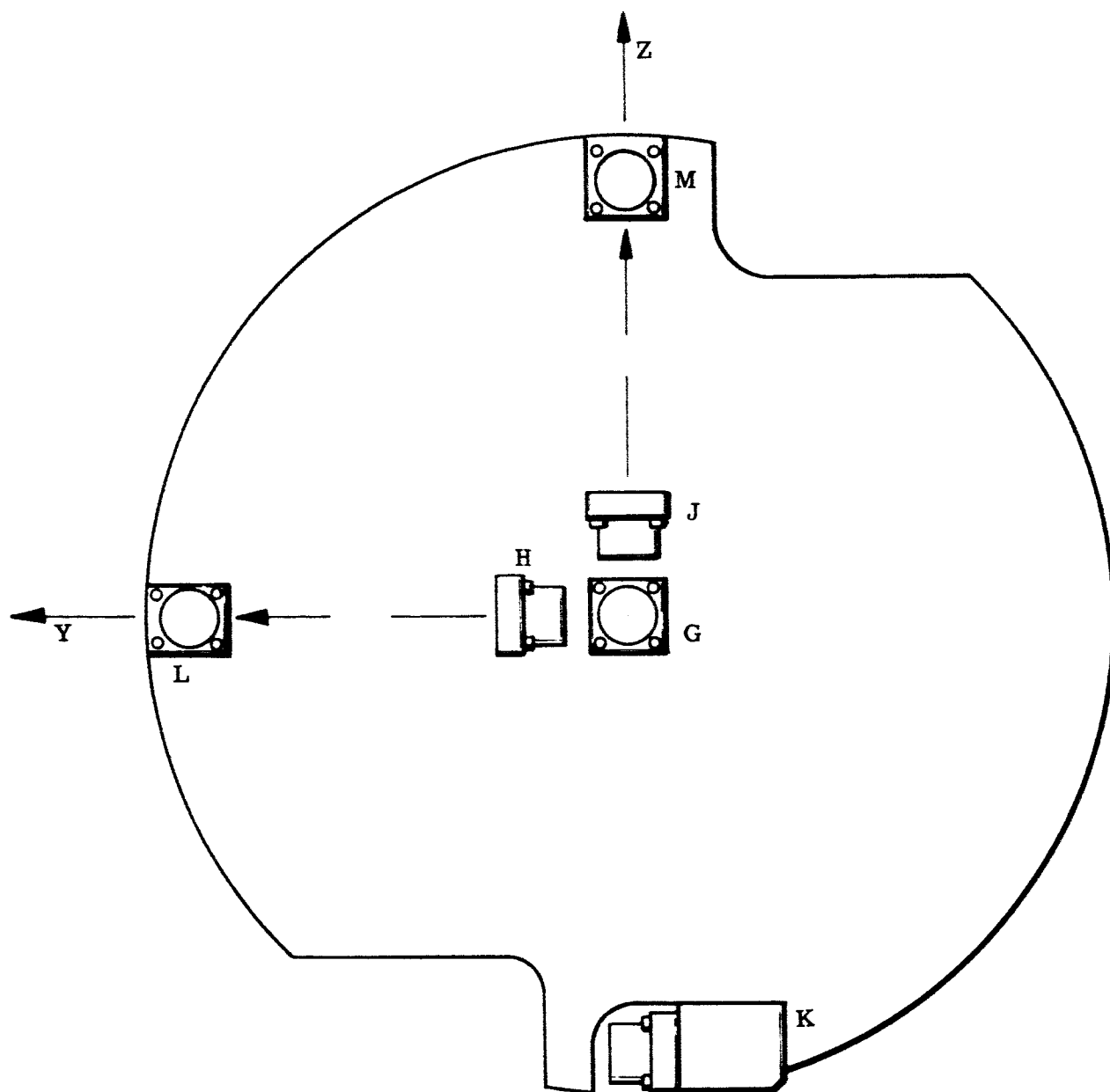


Figure 5-10. Accelerometer Locations on APOLLO Model Couch

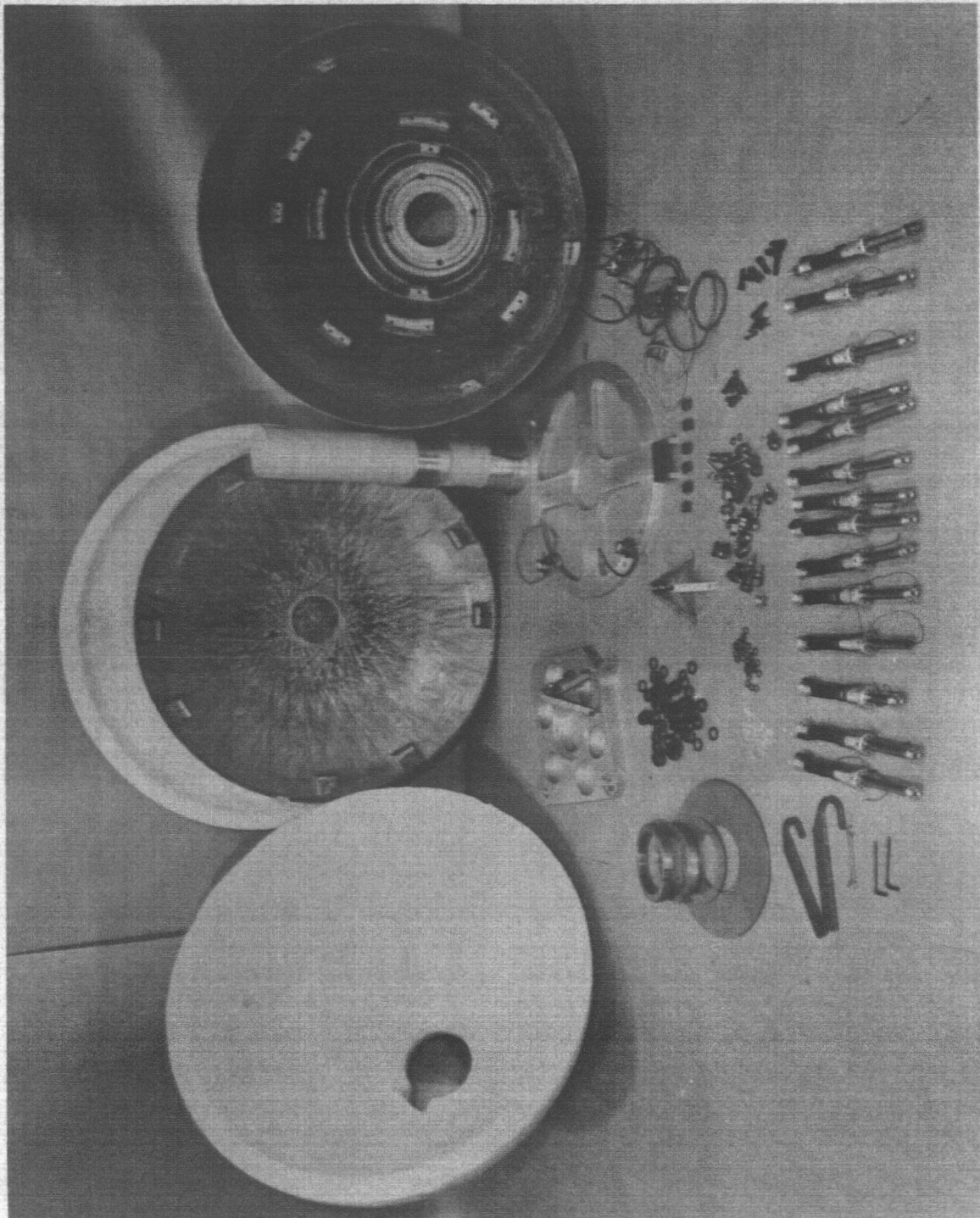


Figure 5-11. Disassembled Apollo Model

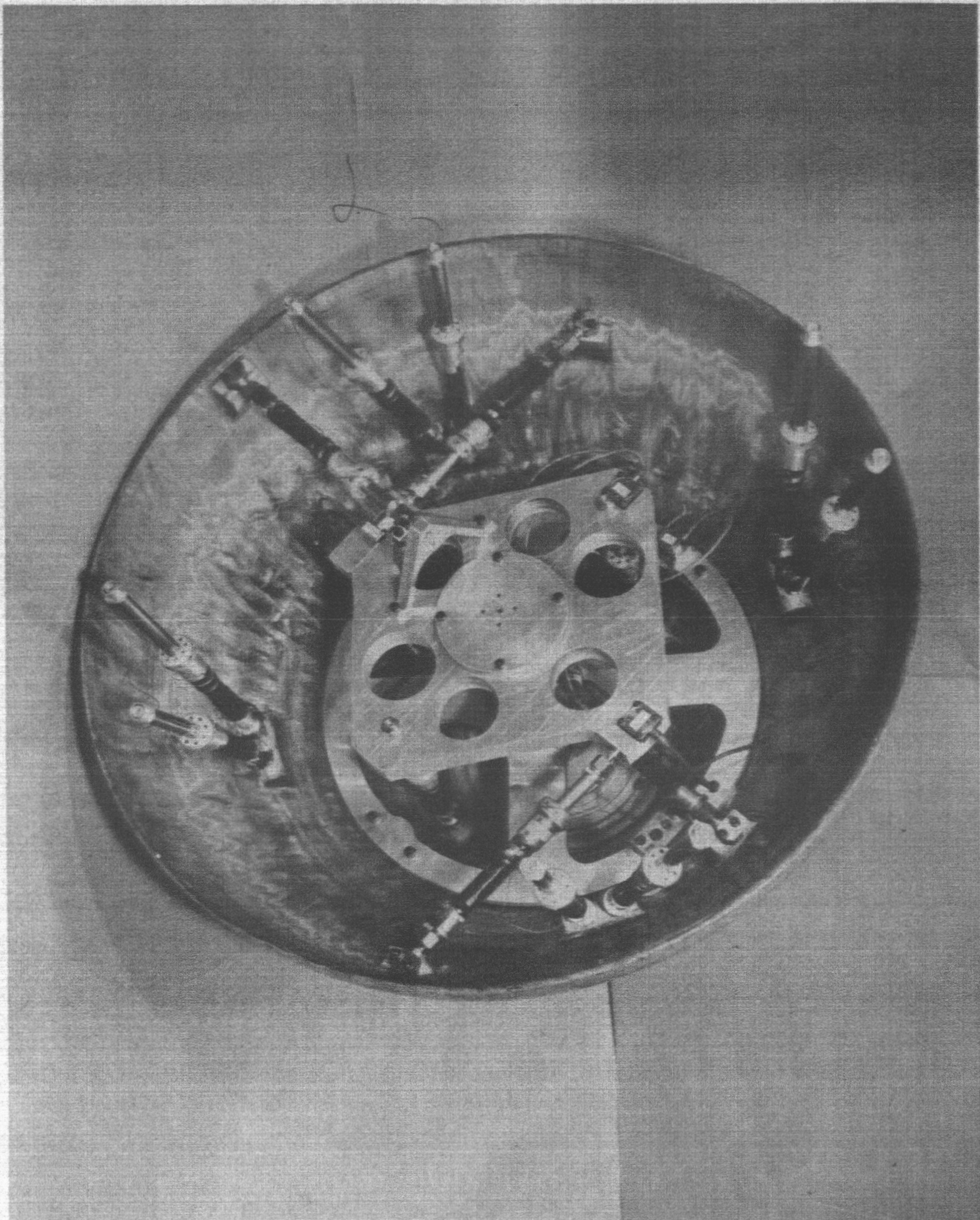


Figure 5-12. Apollo Model Showing Internal Parts

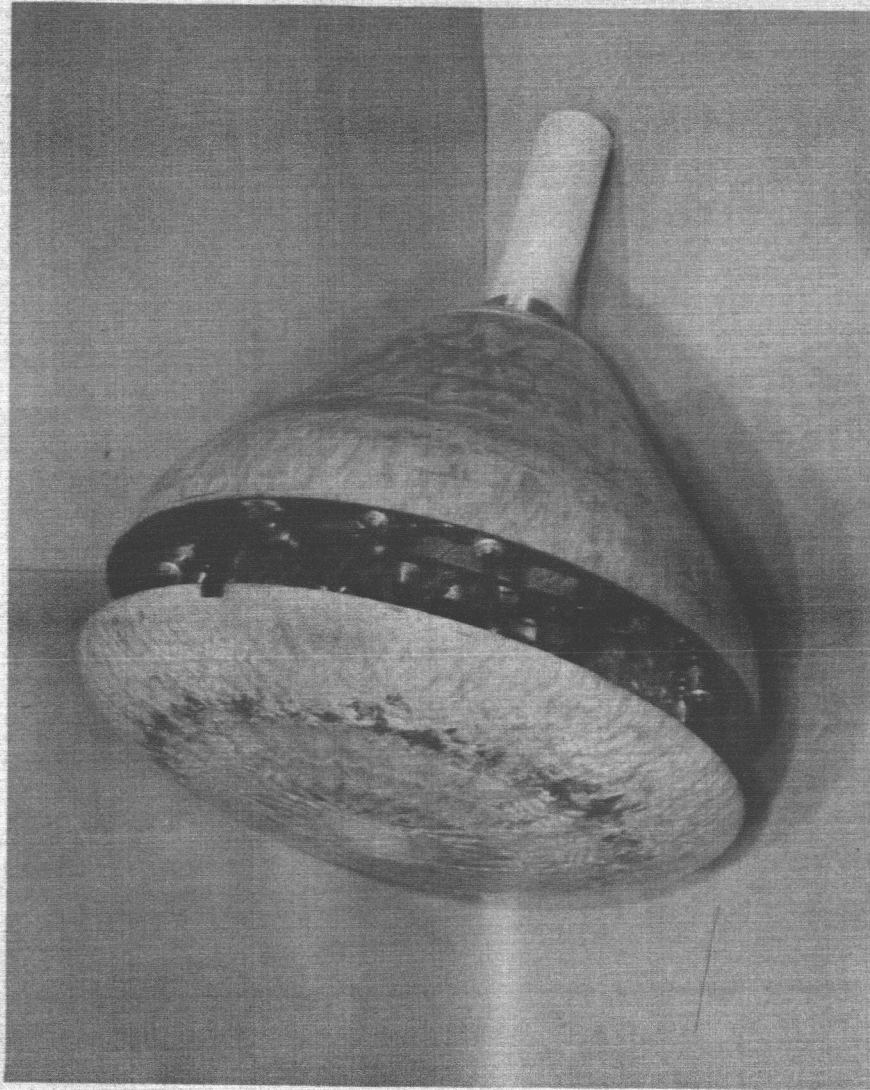


Figure 5-13. Assembled Apollo Model Without Crushable Skin

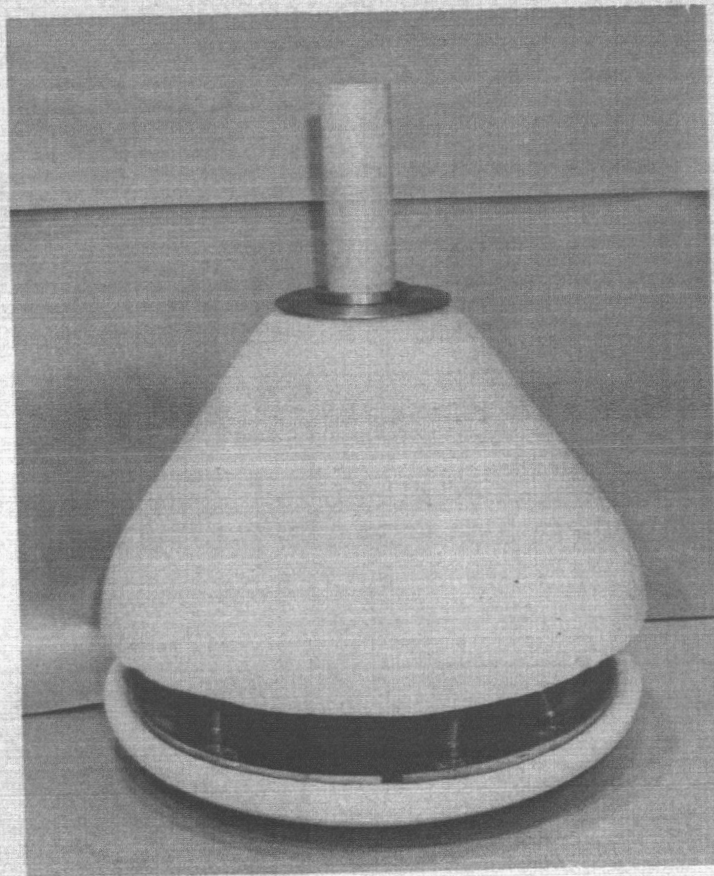


Figure 5-14. Apollo Model

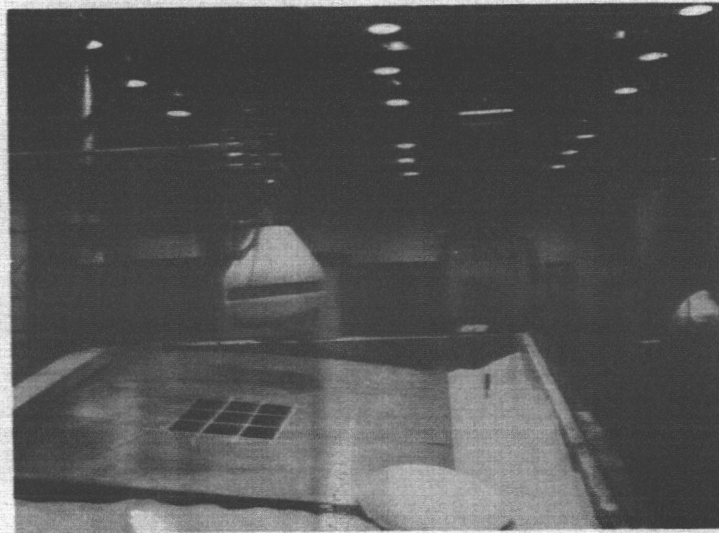


Figure 5-15. Drop Test Soil Pit for APOLLO Test Program

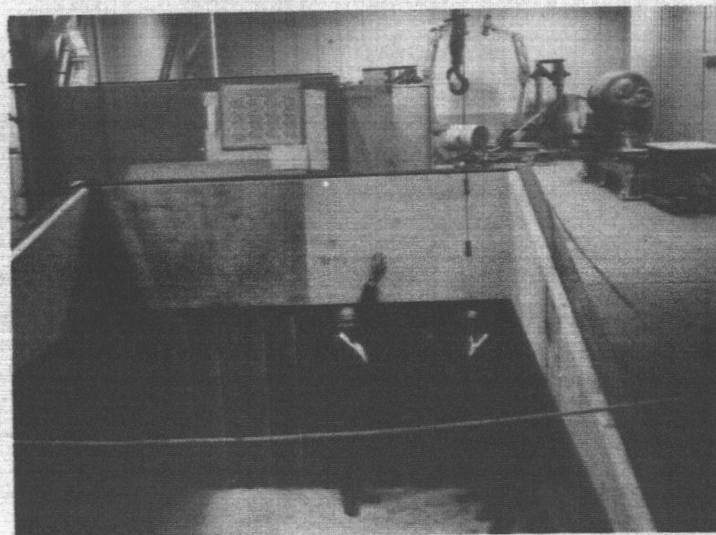


Figure 5-16. Method of Marking Contact Area on Hard Surface Drop

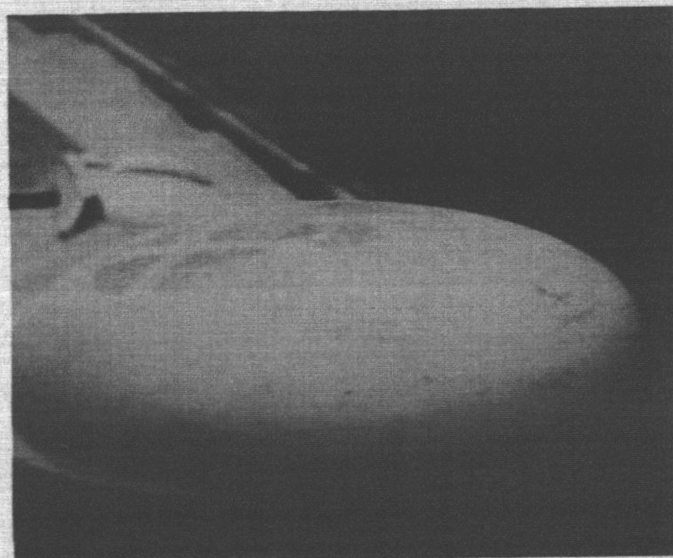


Figure 5-17. Marked Contact Area on Heat Shield for a Hard Surface Drop

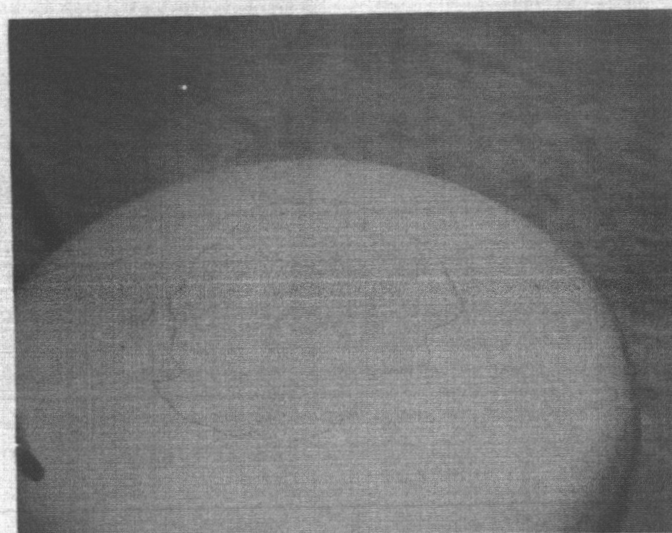


Figure 5-18. Outline of Contact Area on Heat Shield for a Soil Drop

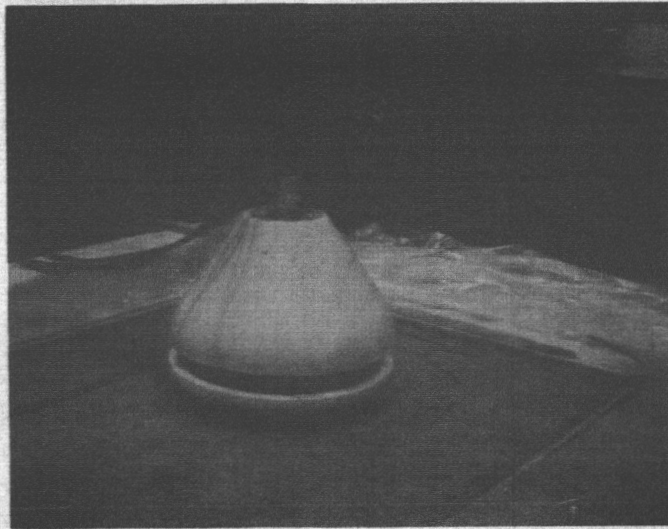


Figure 5-19. Model Impact Clay Soil

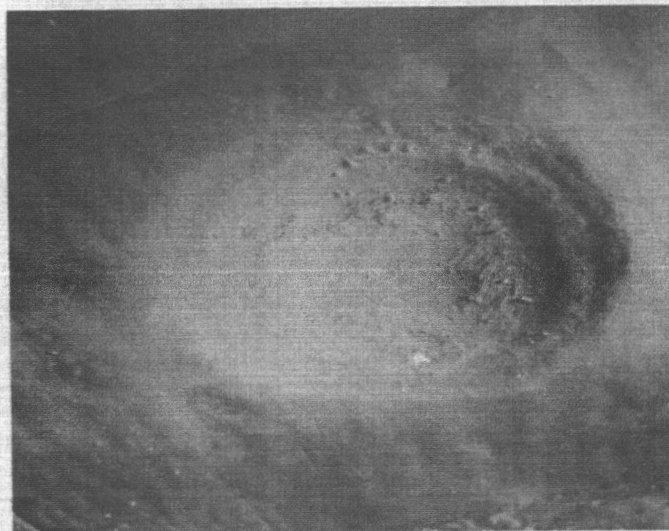


Figure 5-20. Imprint of Model Heat Shield in Clay After Drop

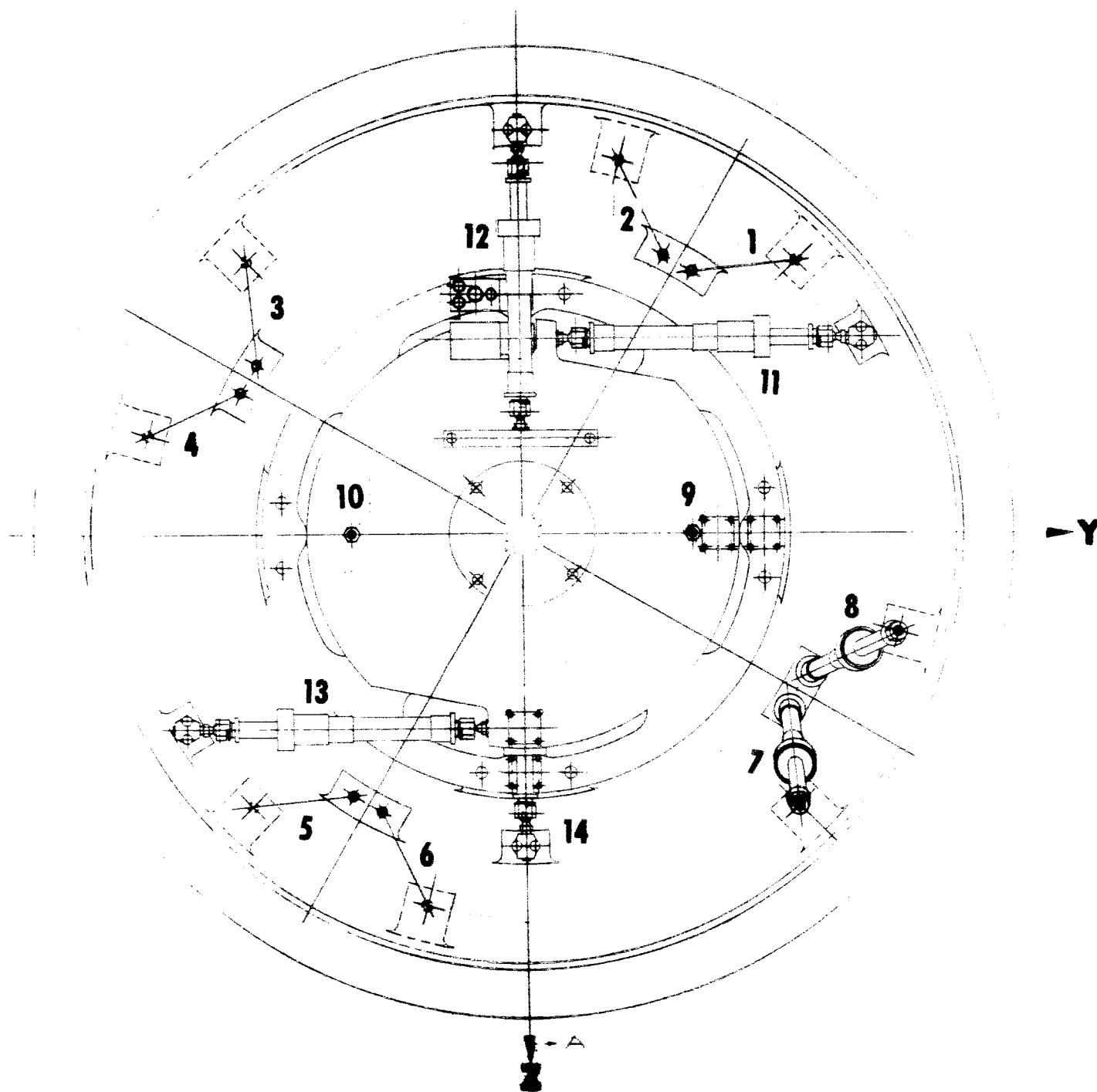


Figure 5-21. Assembly Drawing and Shock Strut Locations

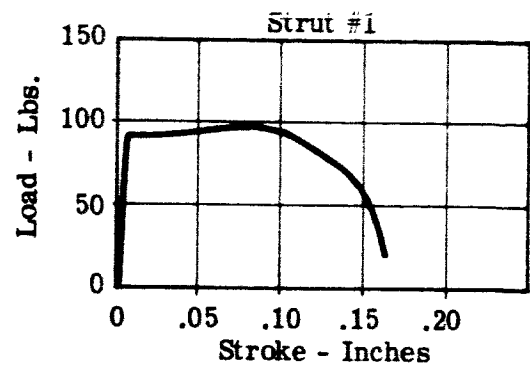
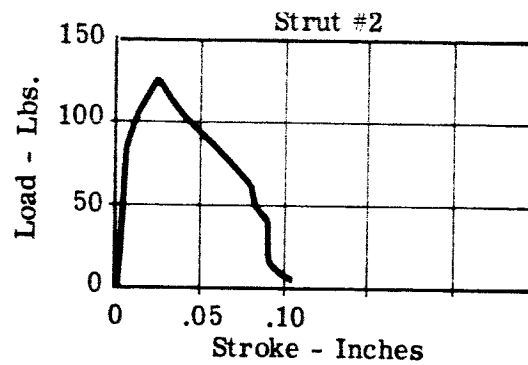
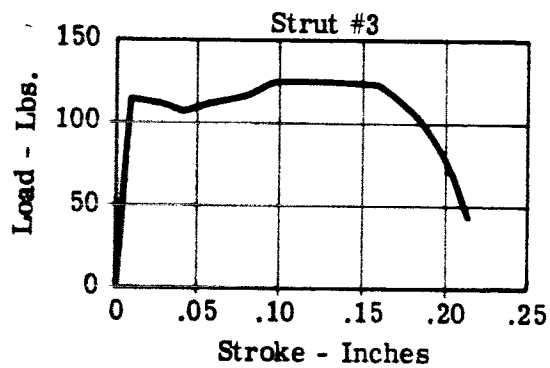
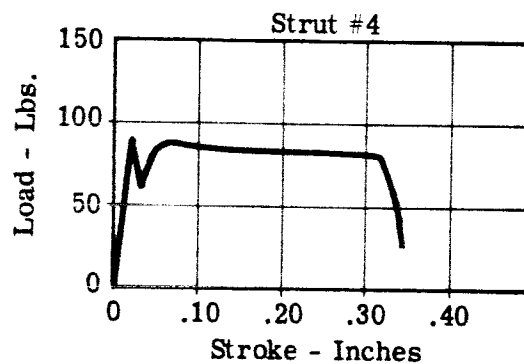
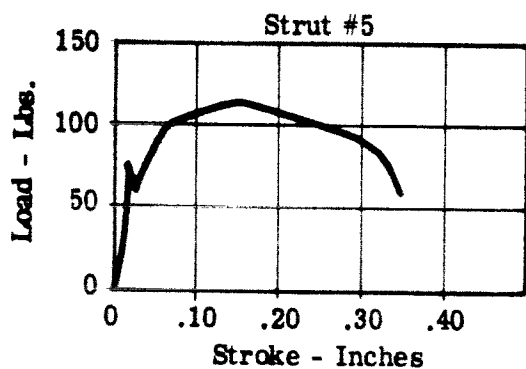
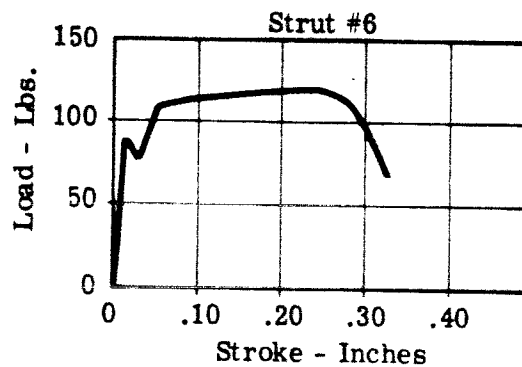
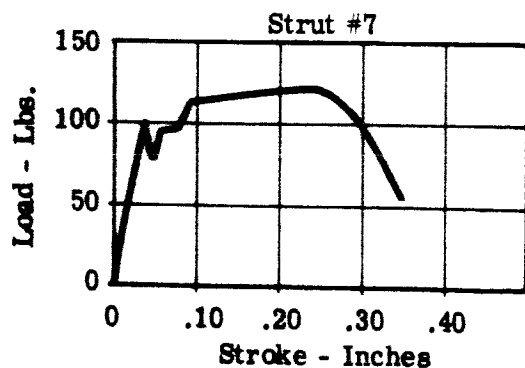
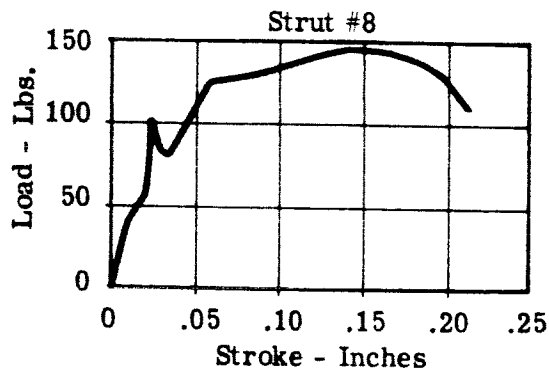


Figure 5-22. Drop 1AR

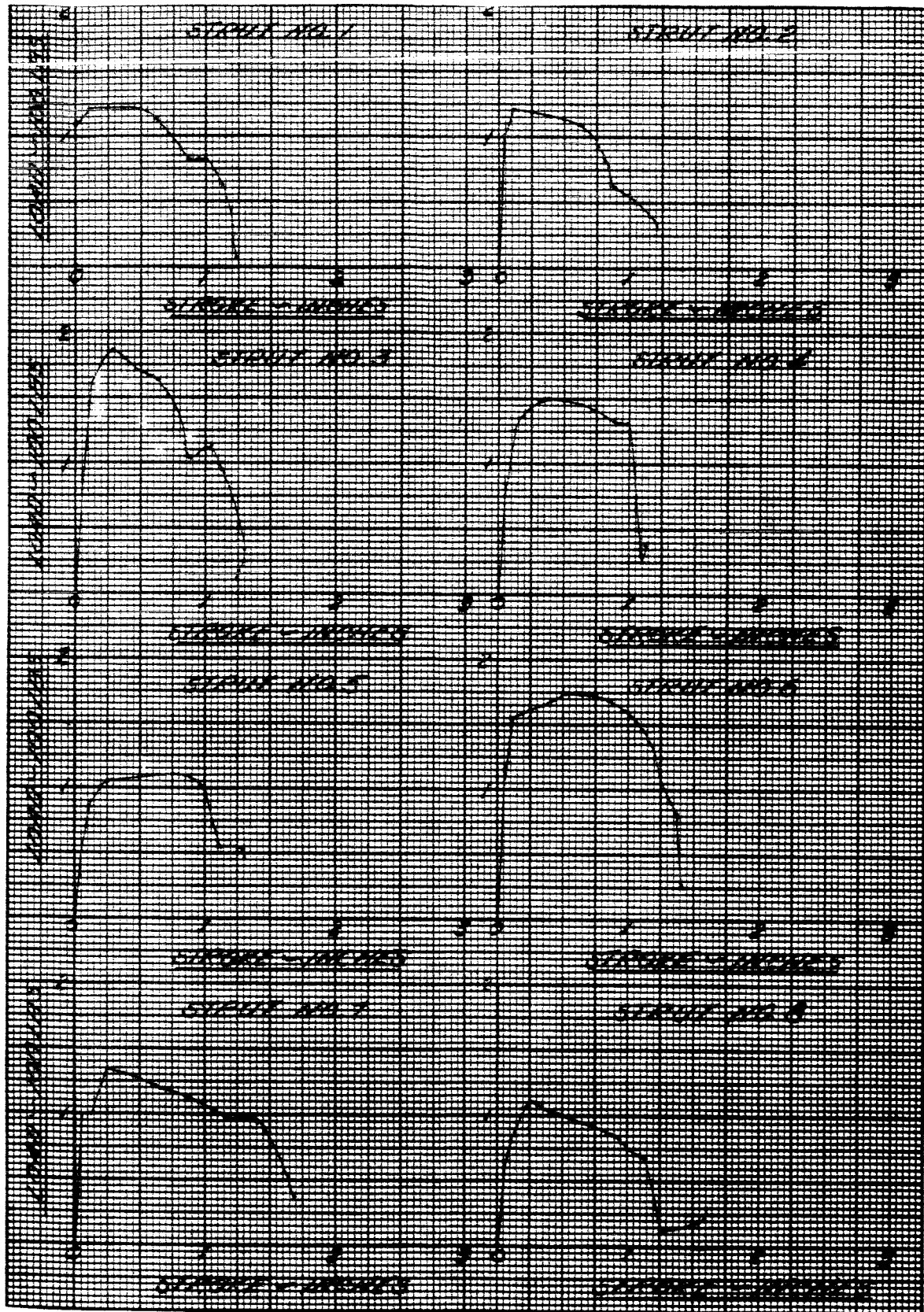


Figure 5-23. Drop 7-A

Drop No.	Strut Load	Instrumentation	
		Strut Stroke	Accelerometers
1	9, 10, 12, 14	1 thru 14	A thru M
1A	1 thru 14	1 thru 14	F, G
1A Repeat	1 thru 14	1 thru 14	F, G
2	9, 10, 12, 14	1 thru 14	A thru M
3	9, 10, 12, 14	1 thru 14	A thru M
4	2, 4, 9, 10	1 thru 14	A thru M
5	2, 4, 9, 10	1 thru 14	A thru M
6	2, 4, 9, 10	1 thru 14	A thru M
7	2, 4, 9, 10	1 thru 14	A thru M
7 Repeat	1 thru 14	1 thru 14	F, G
8	1 thru 14	1 thru 14	A thru M
9	2, 4, 9, 10	1 thru 14	A thru M
10	2, 4, 9, 10	1 thru 14	A thru M
11	1 thru 14	1 thru 14	F, G
11 Repeat	1 thru 14	1 thru 14	F, G
12	1 thru 12	1 thru 14	C, F, G, M

Figure 5-24. Instrumentation Used on Apollo Model Drop Tests

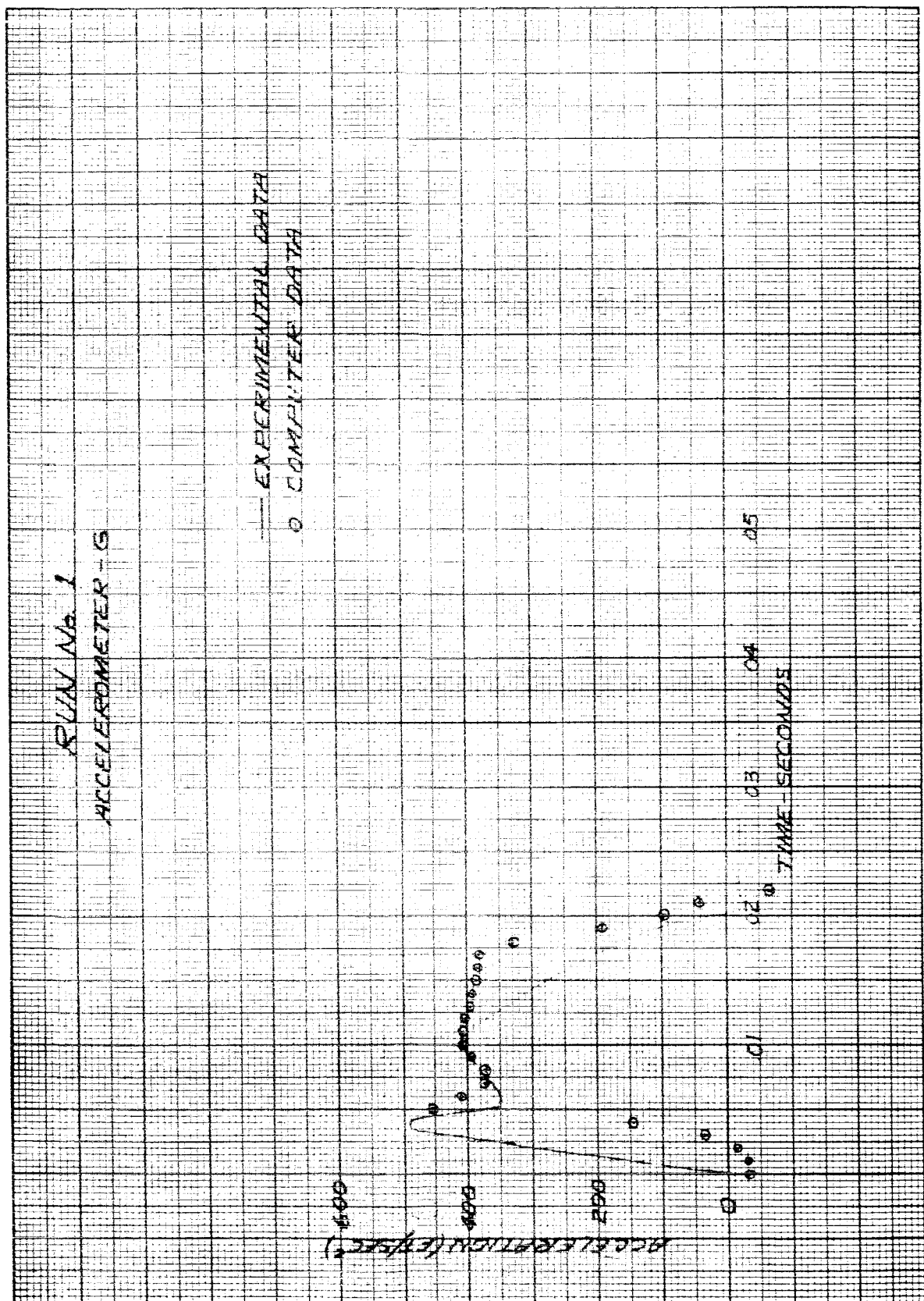


Figure 5-25. Run No. 1 Accelerometer - G

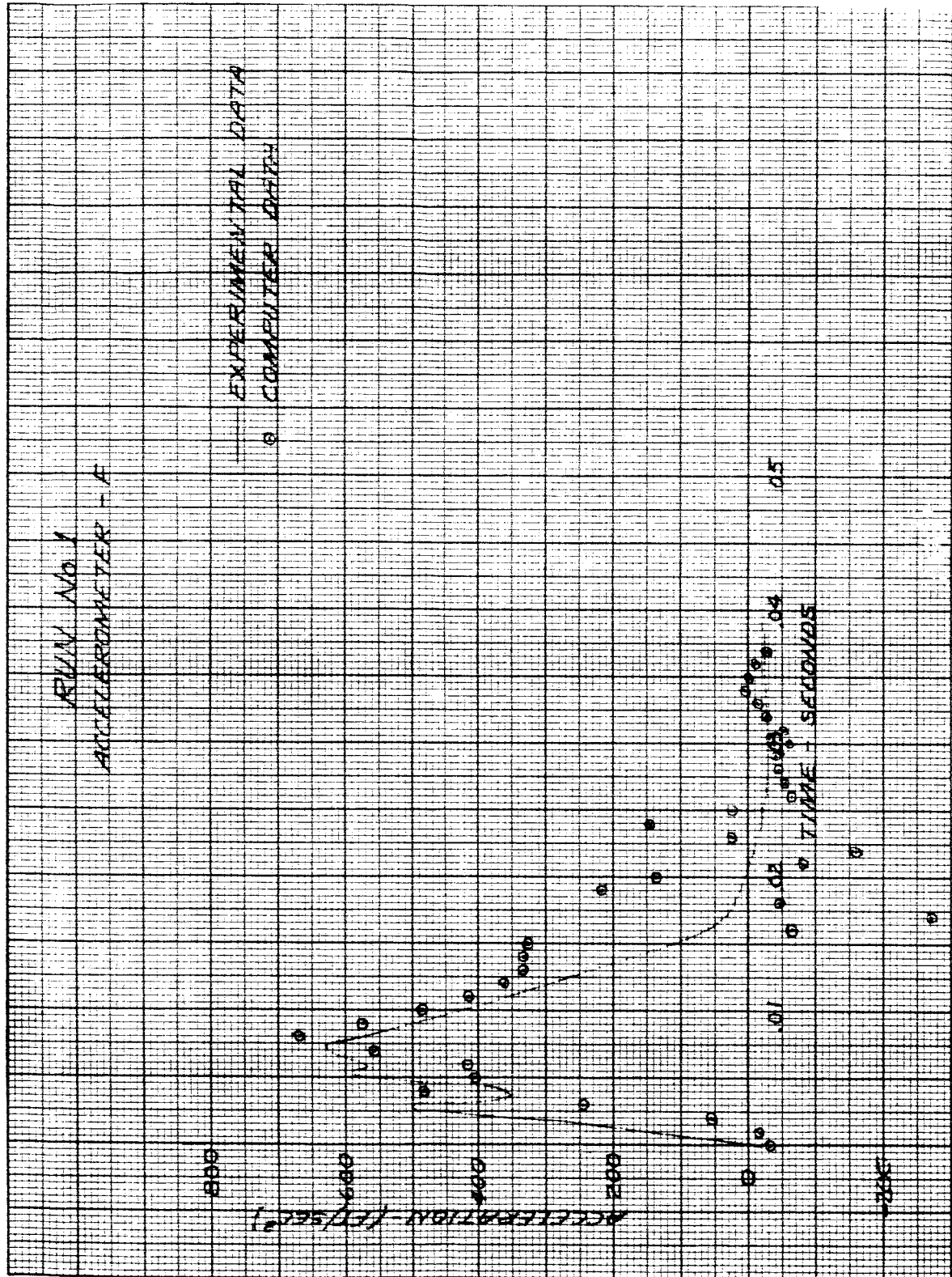


Figure 5-26. Run No. 1 Accelerometer - F

Figure 5-27. Comparison of Computer and Experimental Capsule Accelerations of APOLLO Command Module Test Model

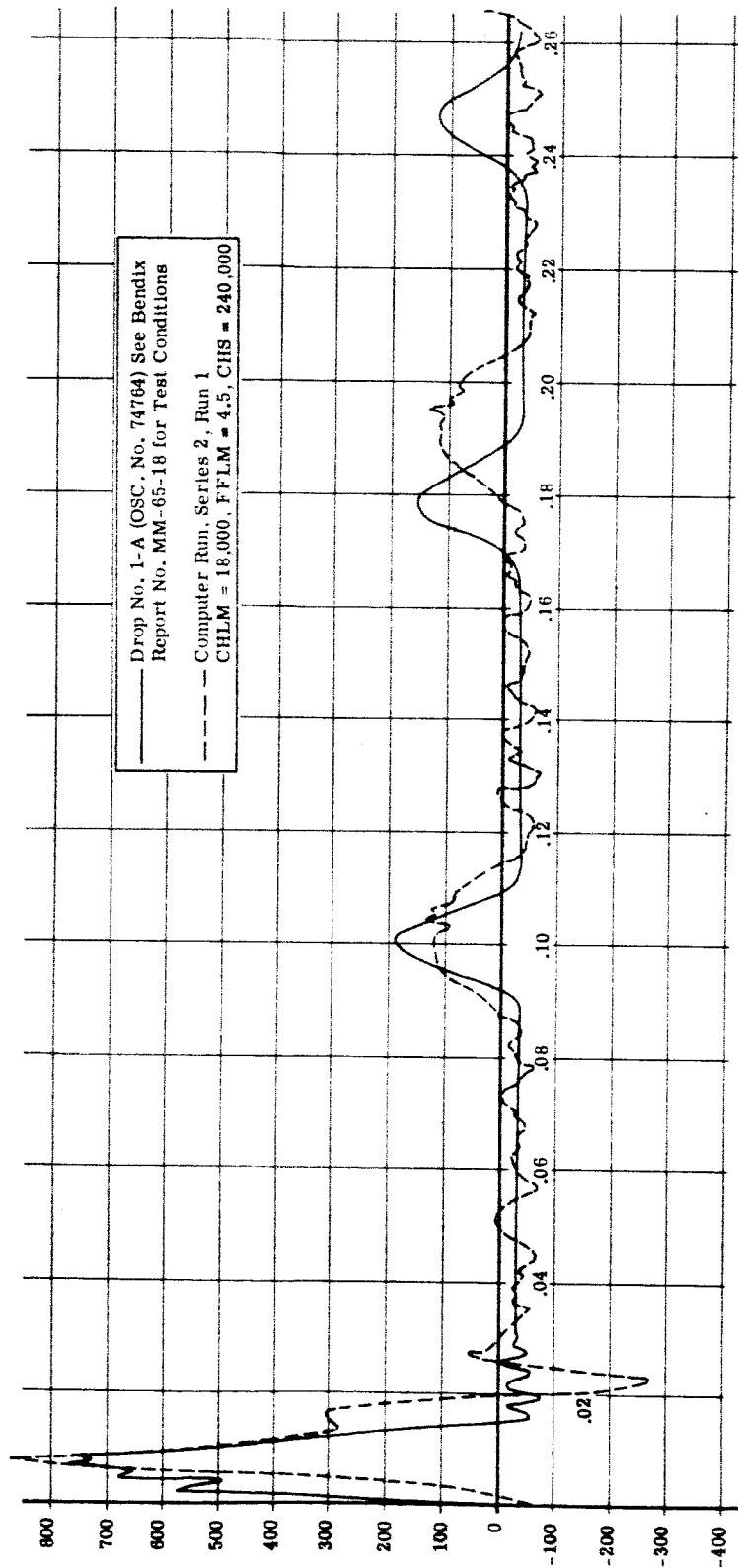


Figure 5-28. Comparison of Computer and Experimental Capsule Accelerations of APOLLO Command Module Test Model

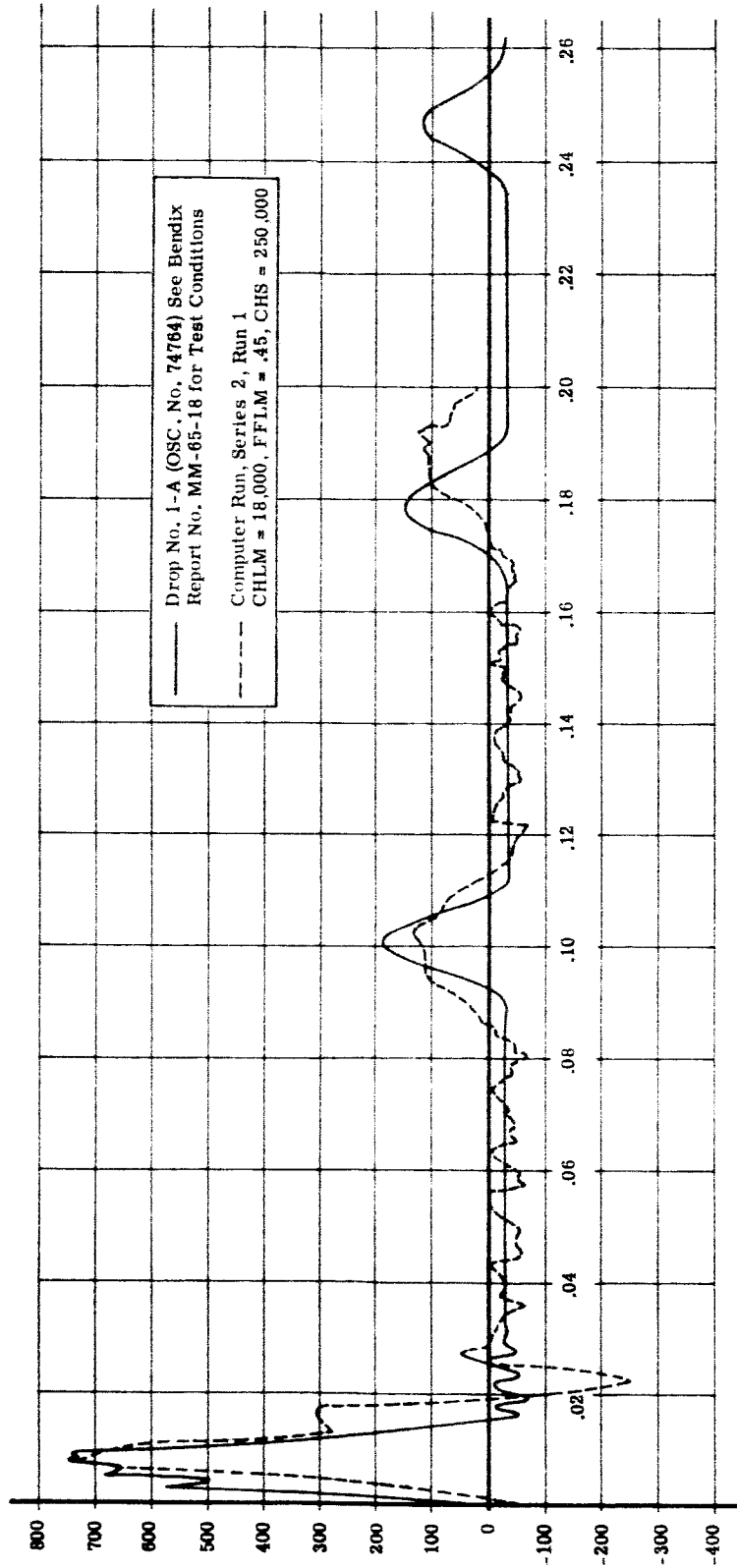


Figure 5-29. Comparison of Computer and Experimental Capsule Accelerations of APOLLO Command Module Test Model

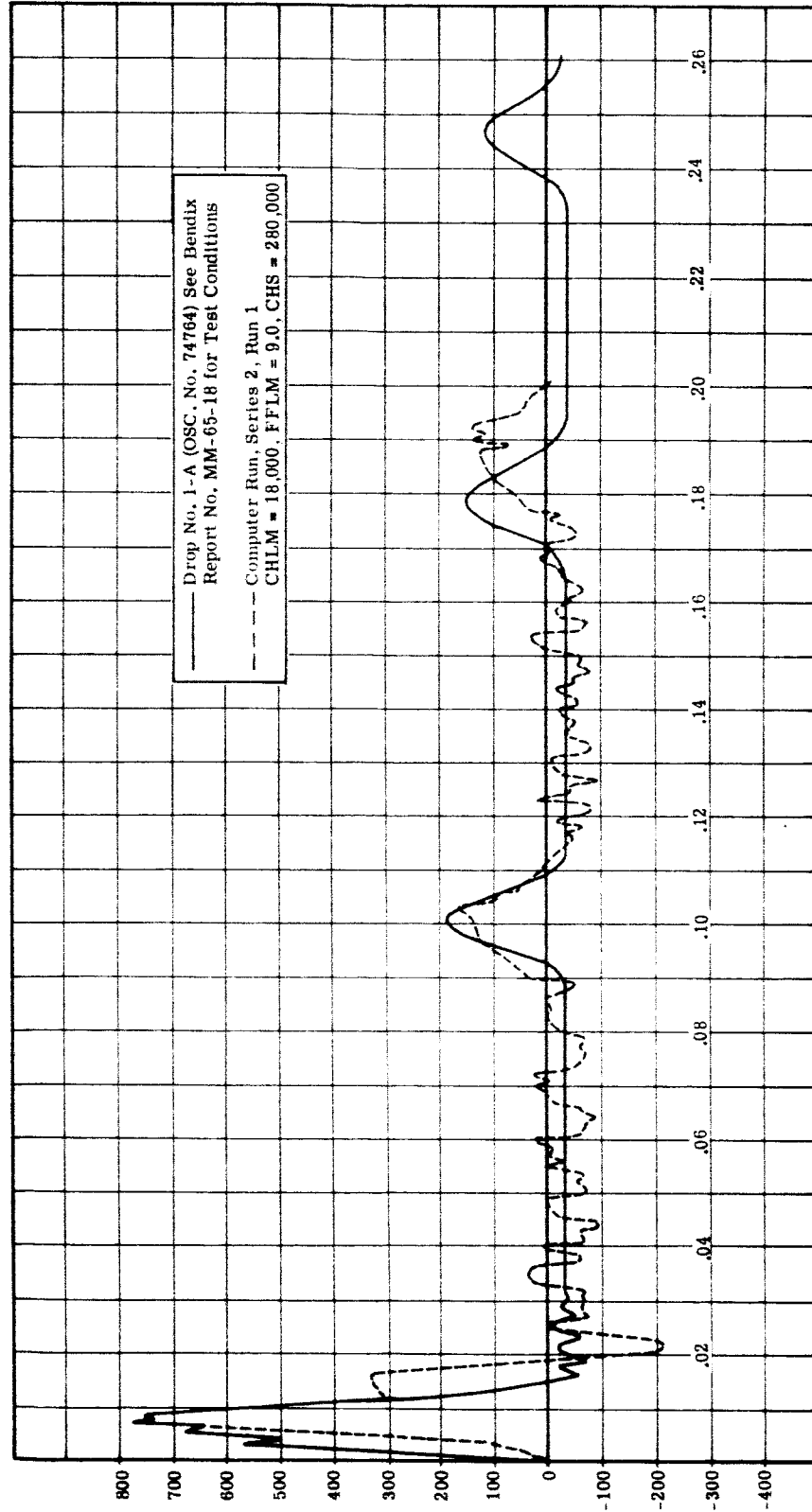


Figure 5-30. Comparison of Computer and Experimental Couch Accelerations of APOLLO Command Module Test Model

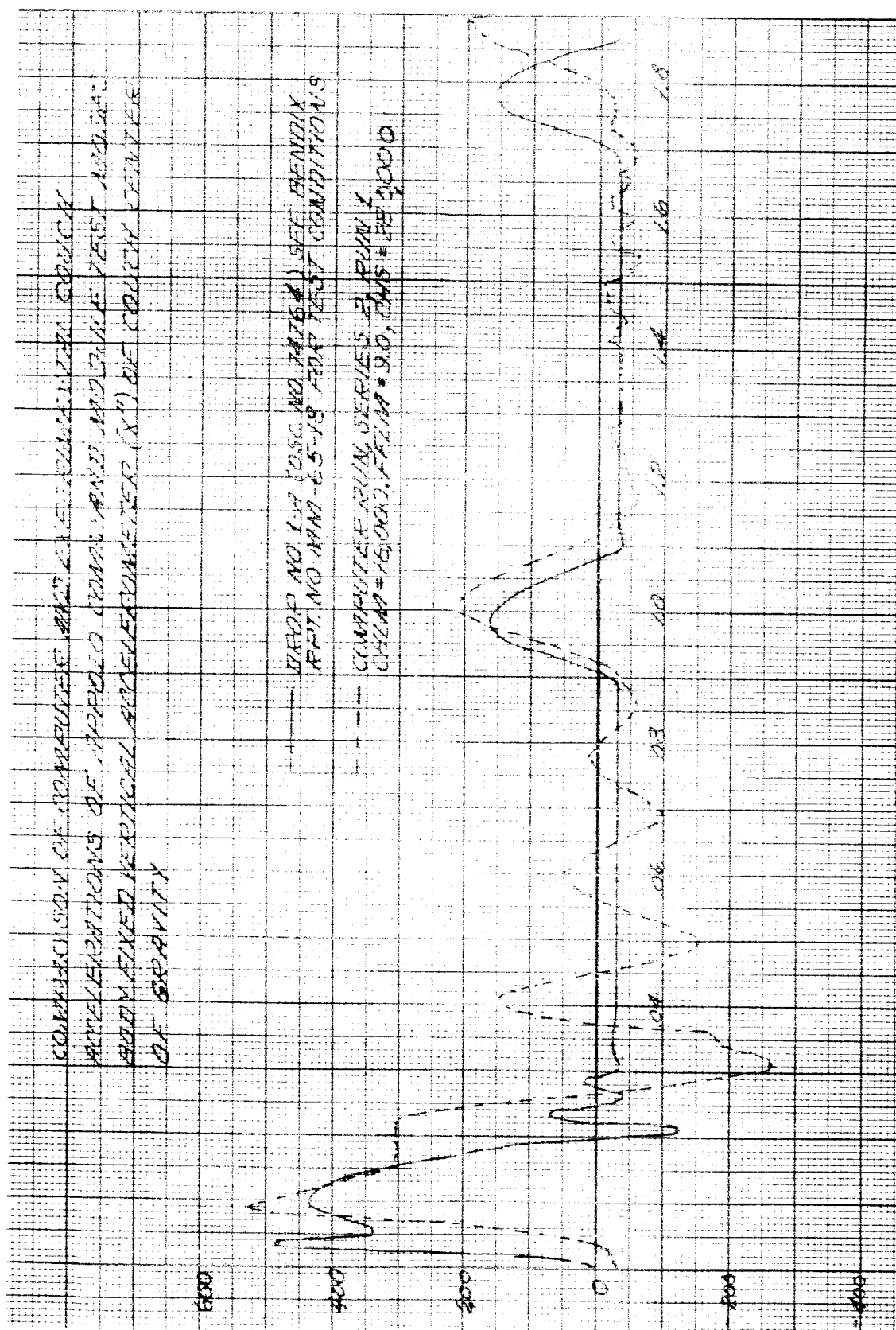


Figure 5-31. Comparison of Computer and Experimental Couch Acceleration of APOLLO Command Module Test Model Body Fixed Vertical Accelerometer (X") of Couch Center of Gravity

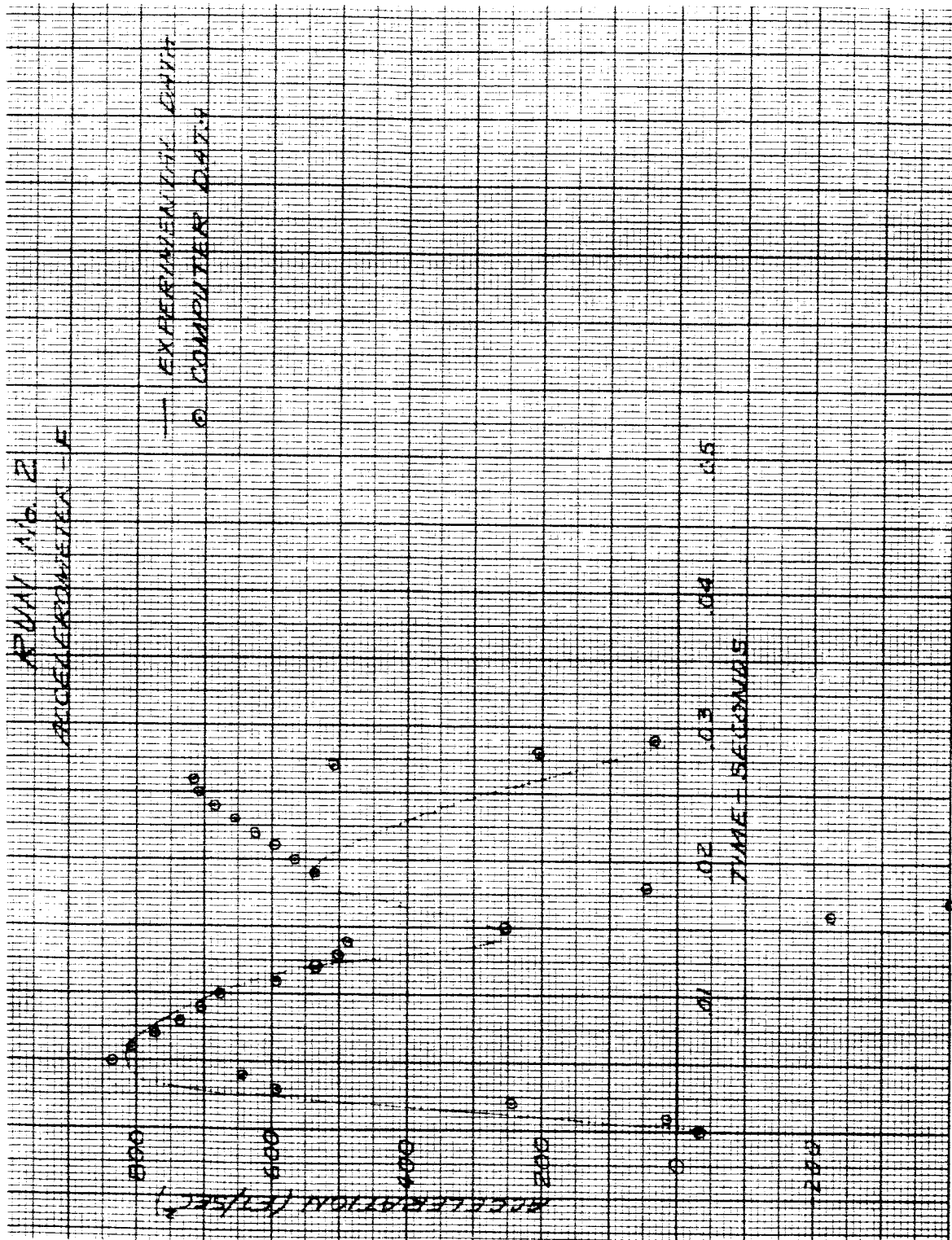


Figure 5-32. Run No. 2 Accelerometer - F

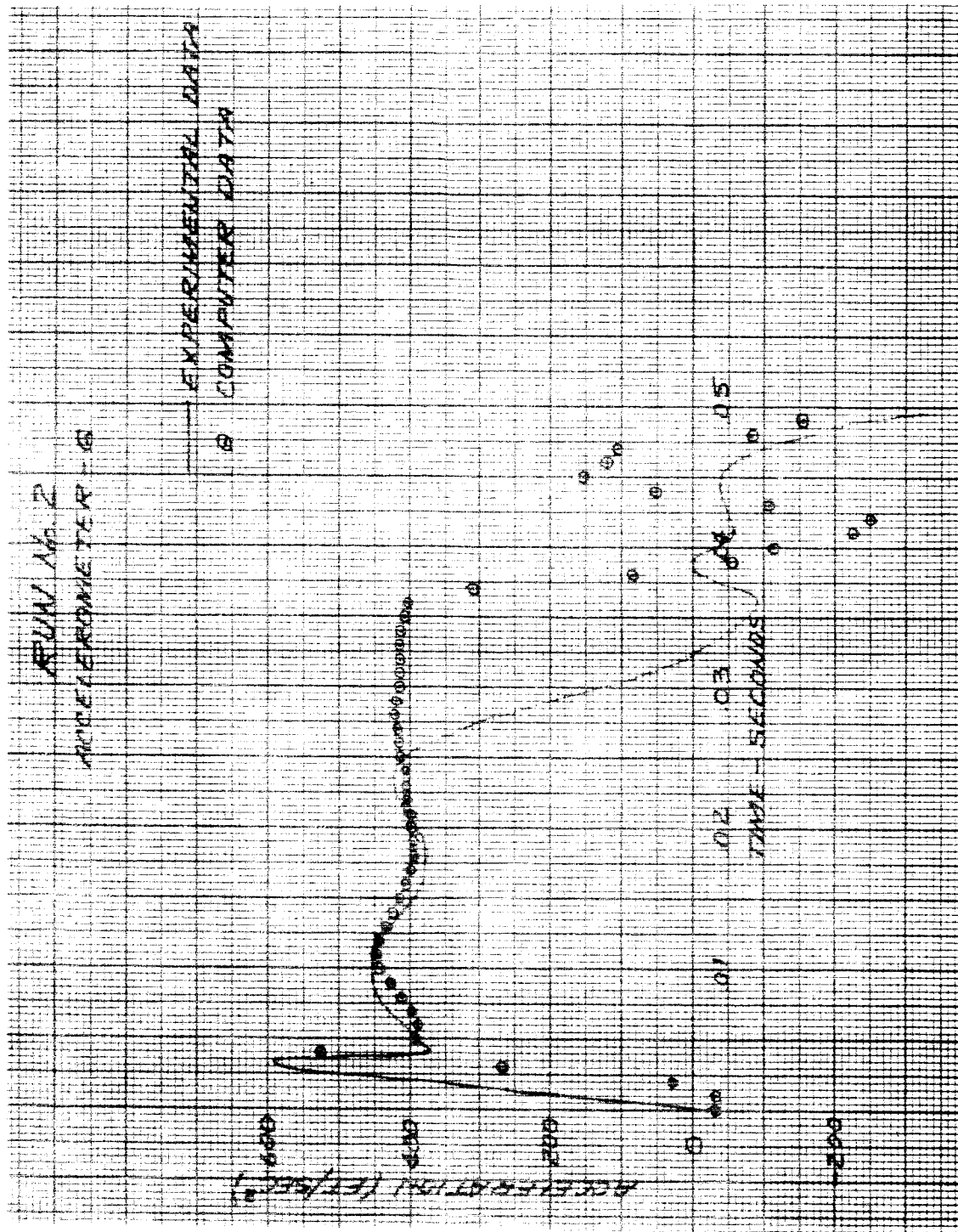


Figure 5-33. Run No. 2 Accelerometer - G

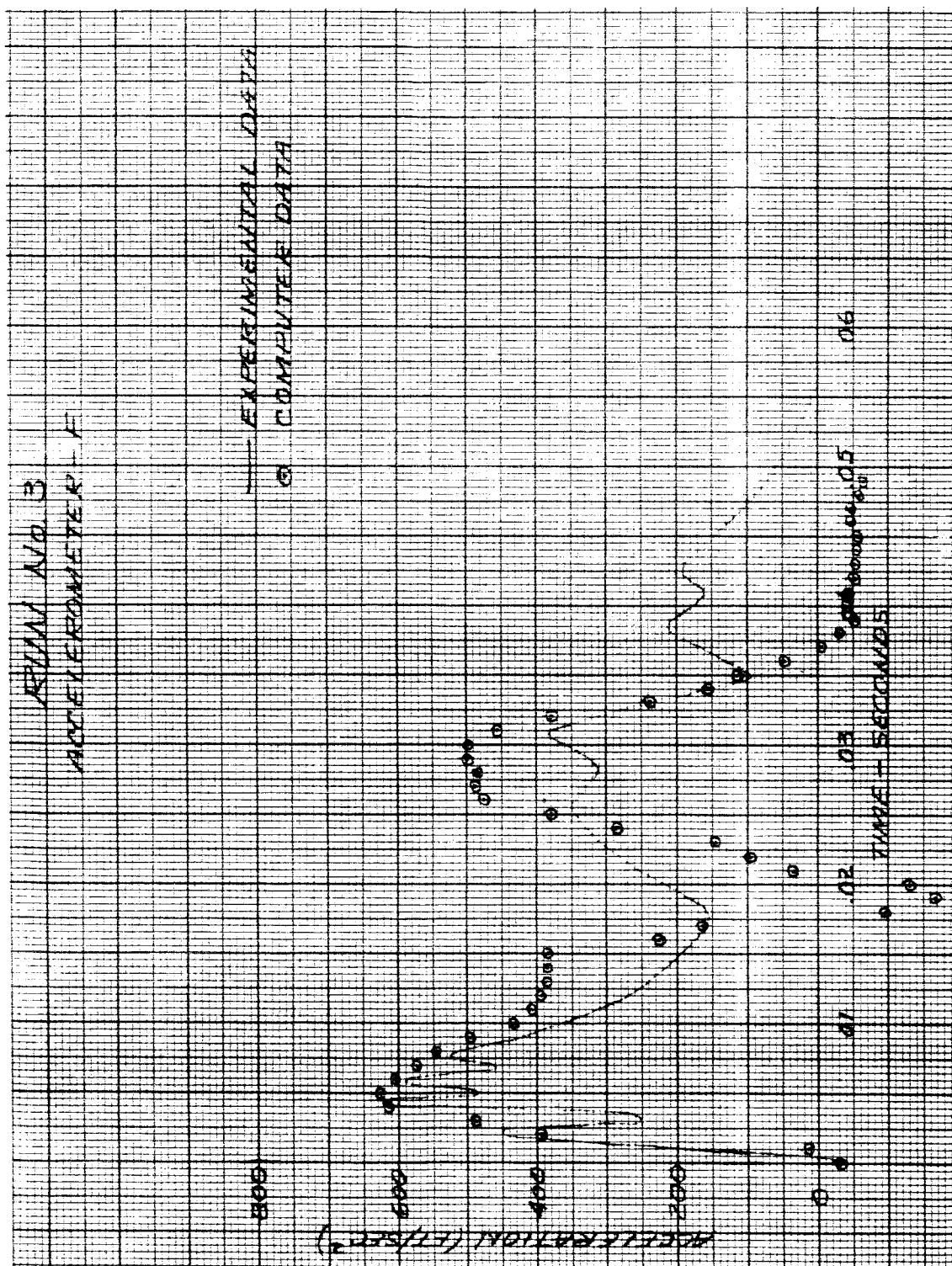


Figure 5-34. Run No. 3 Accelerometer - F

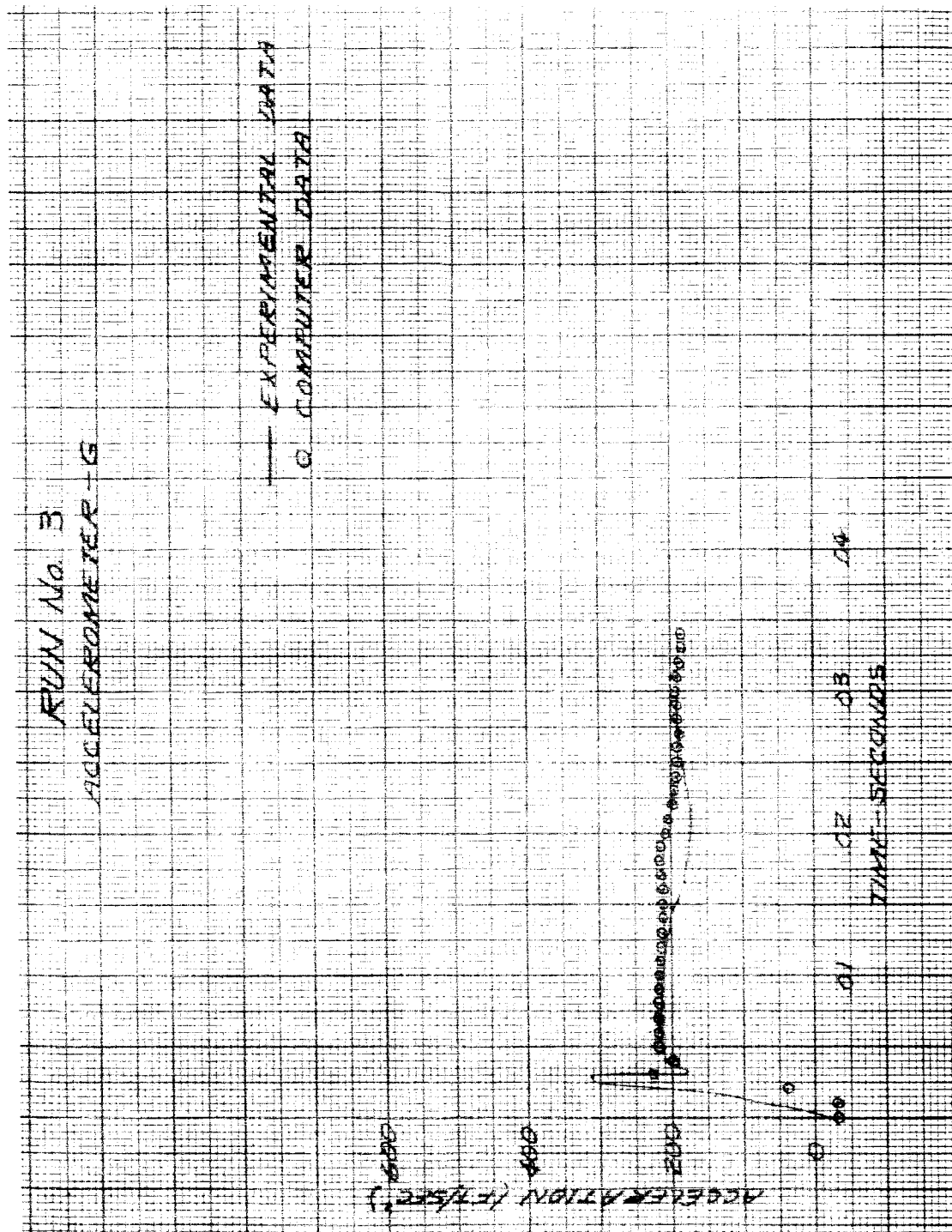


Figure 5-35. Run No. 3 Accelerometer - G

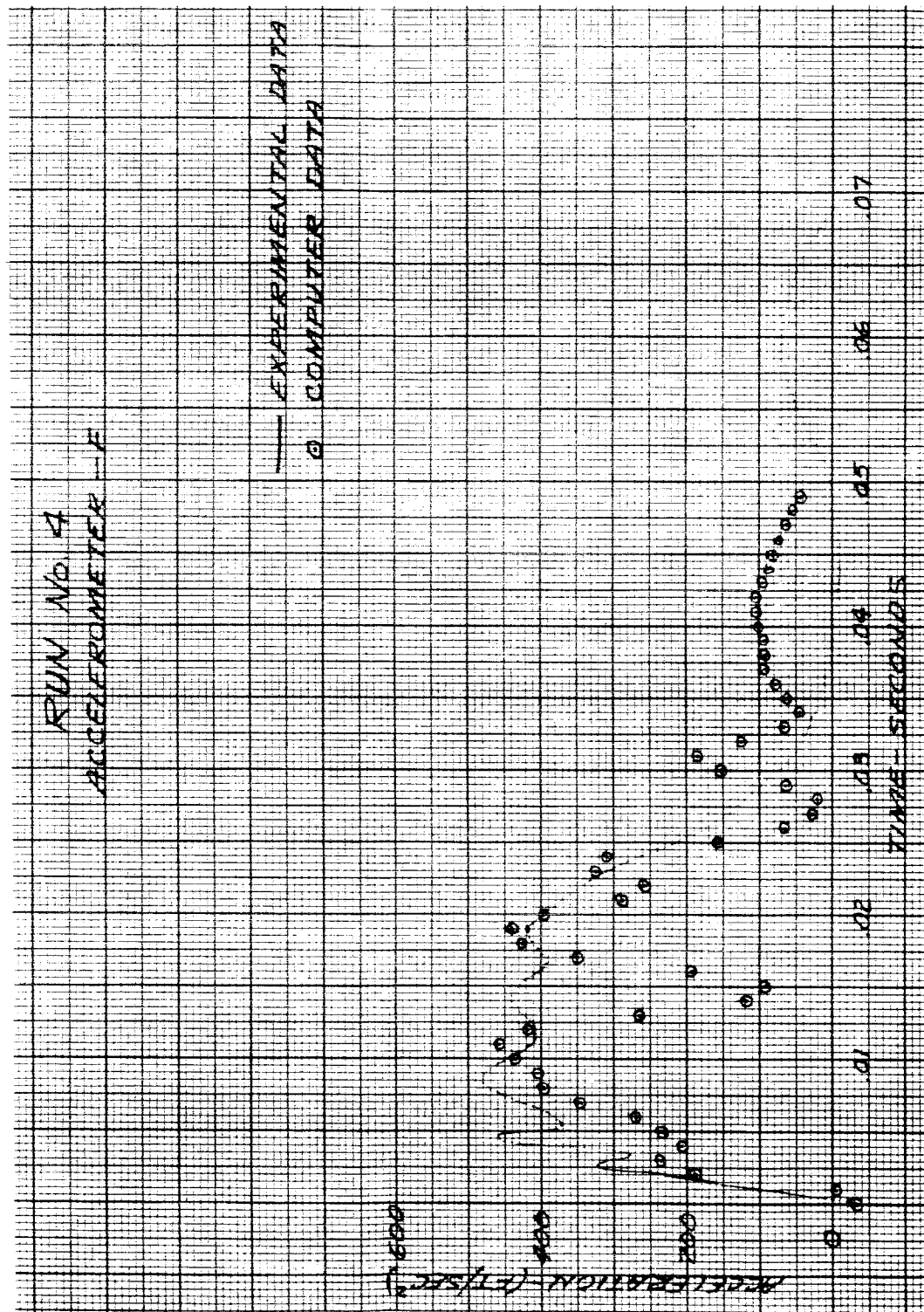


Figure 5-36. Run No. 4 Accelerometer - F

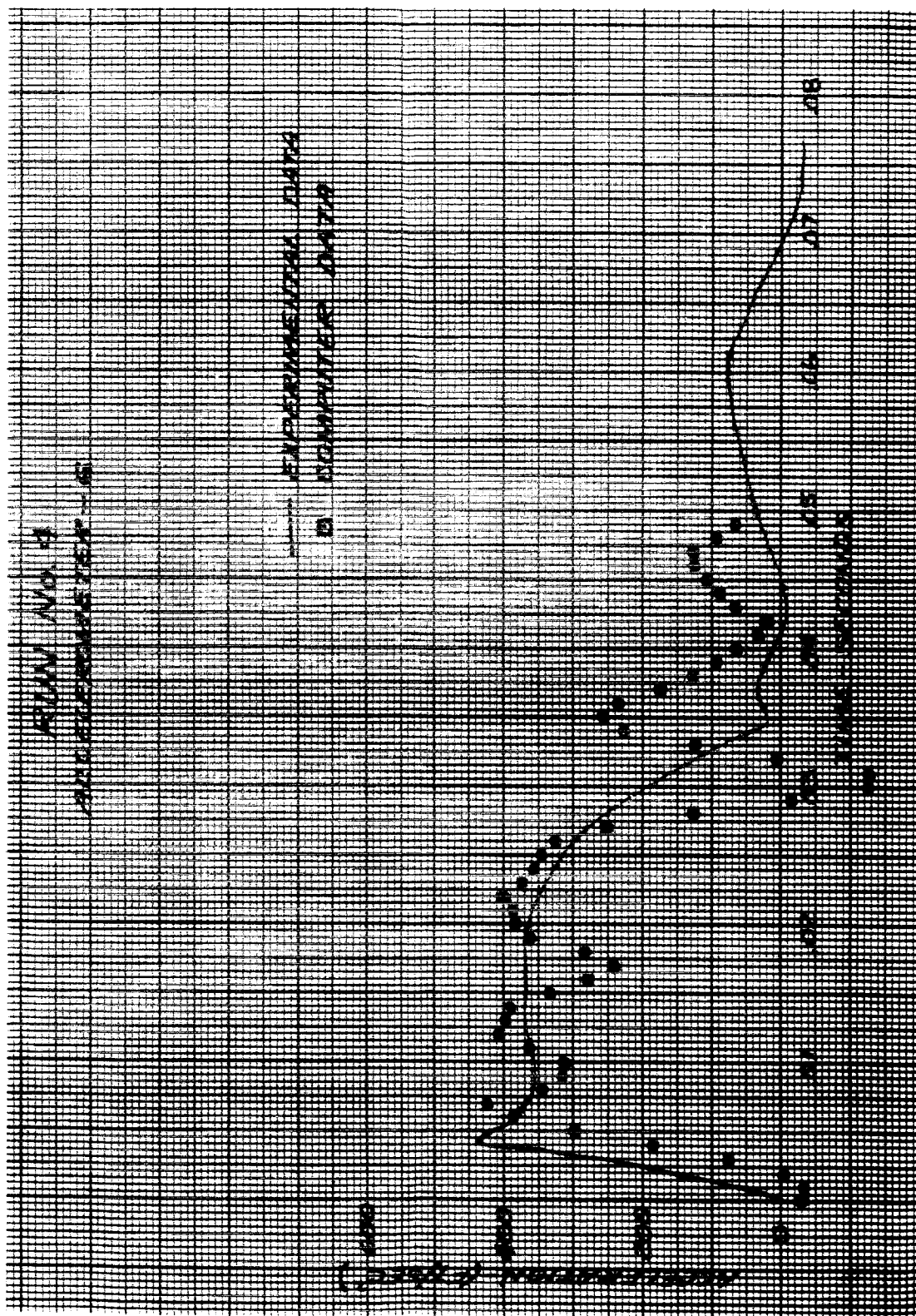


Figure 5-37. Run No. 4 Accelerometer - G

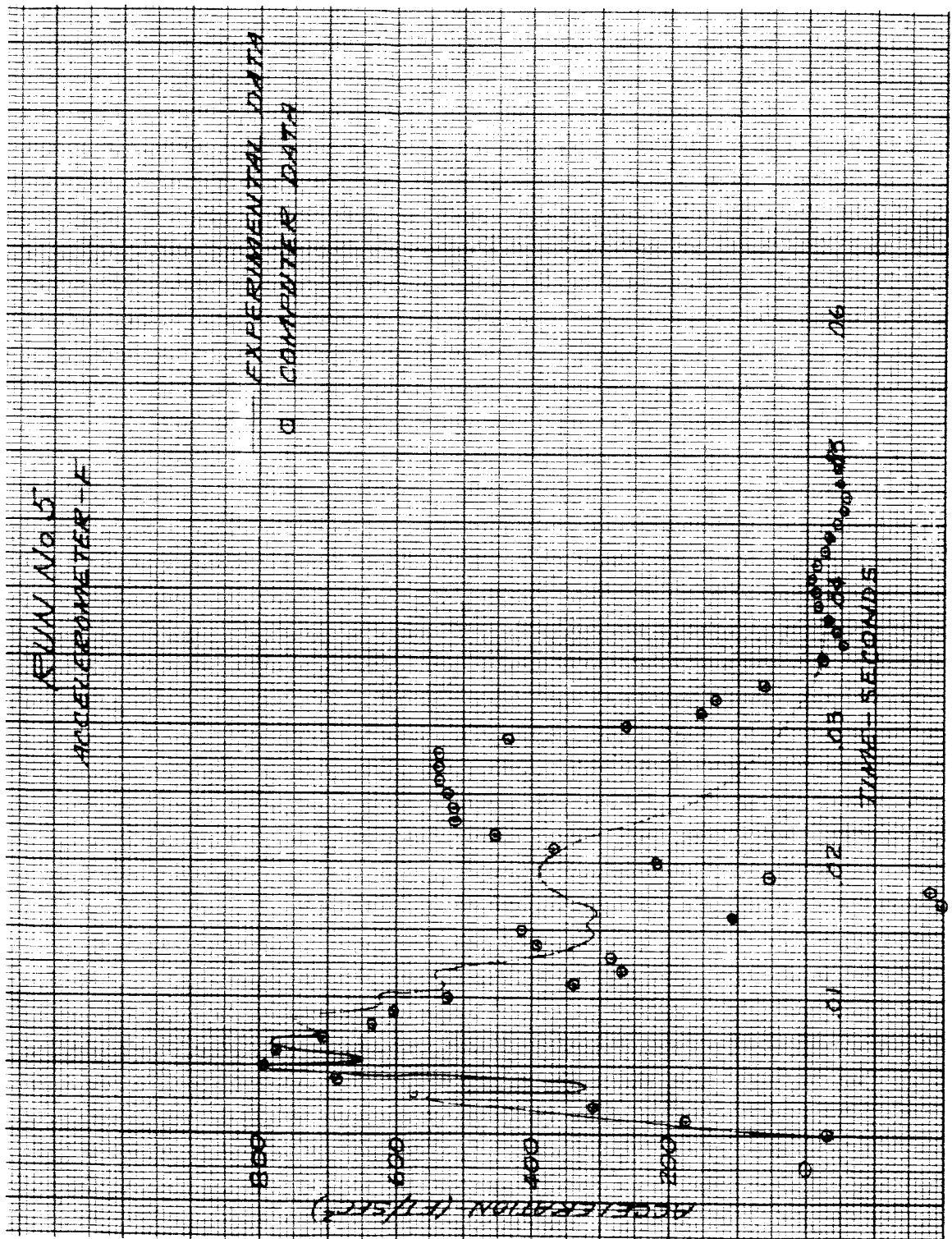


Figure 5-38. Run No. 5 Accelerometer - F

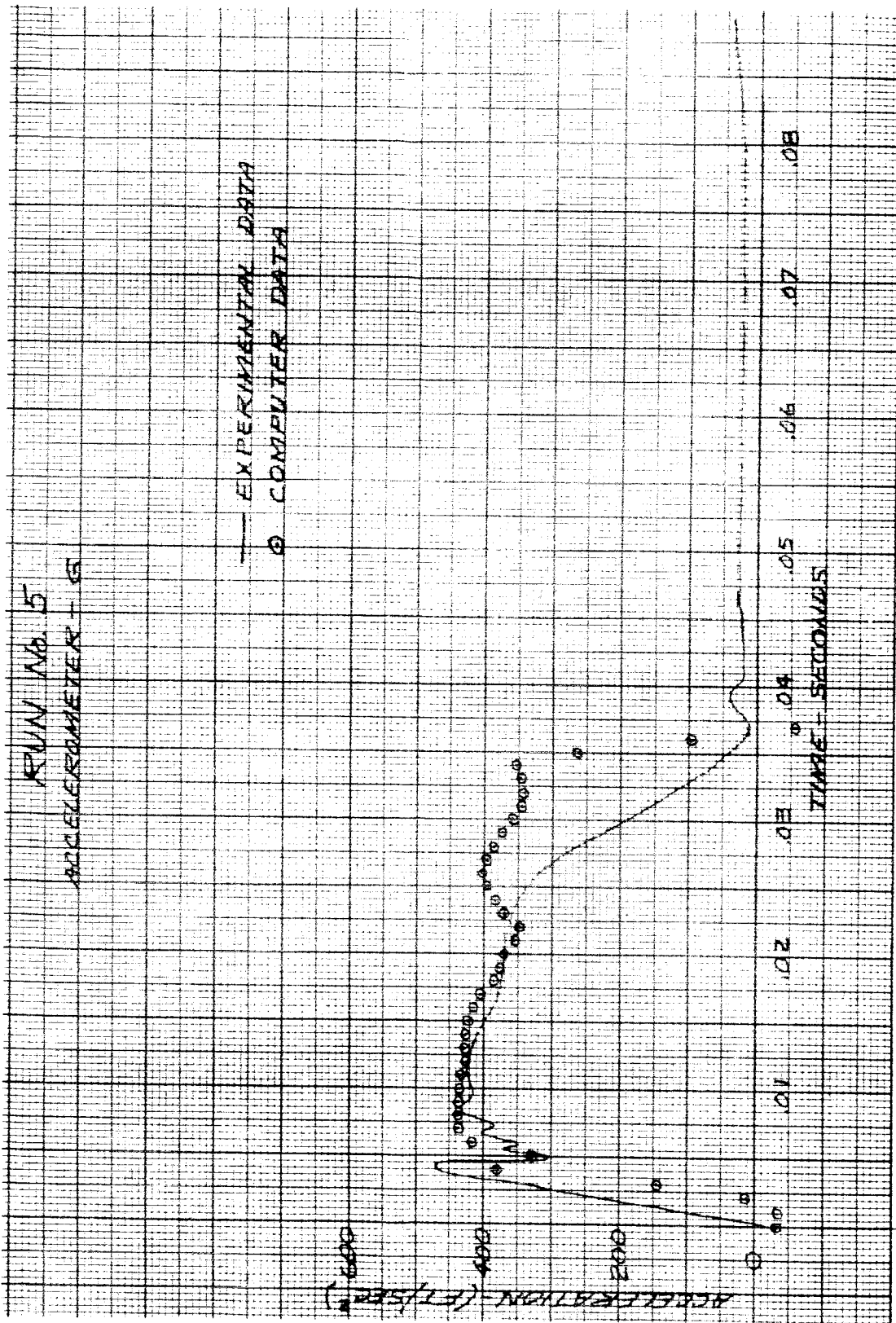


Figure 5-39. Run No. 5 Accelerometer - G

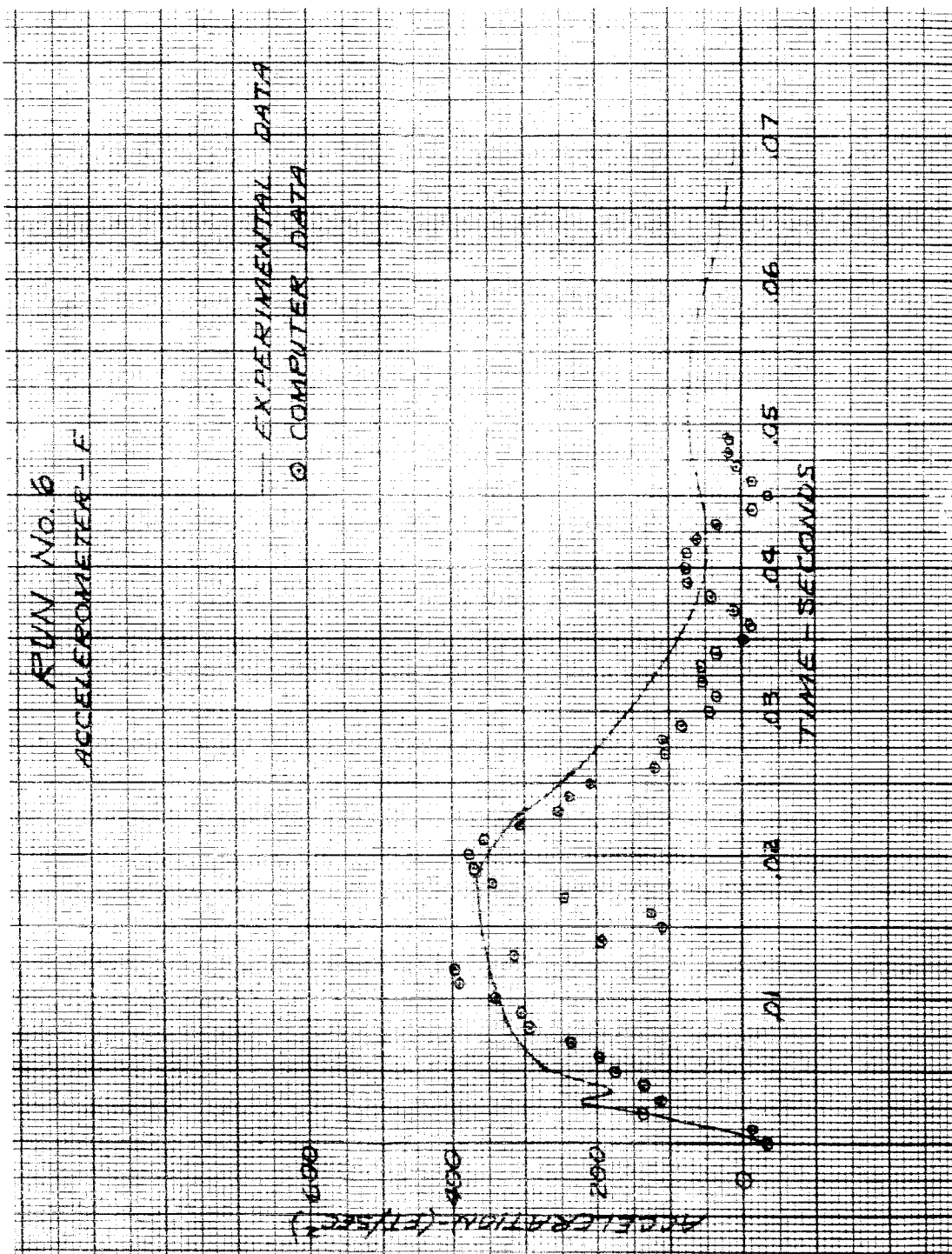


Figure 5-40. Run No. 6 Accelerometer - F

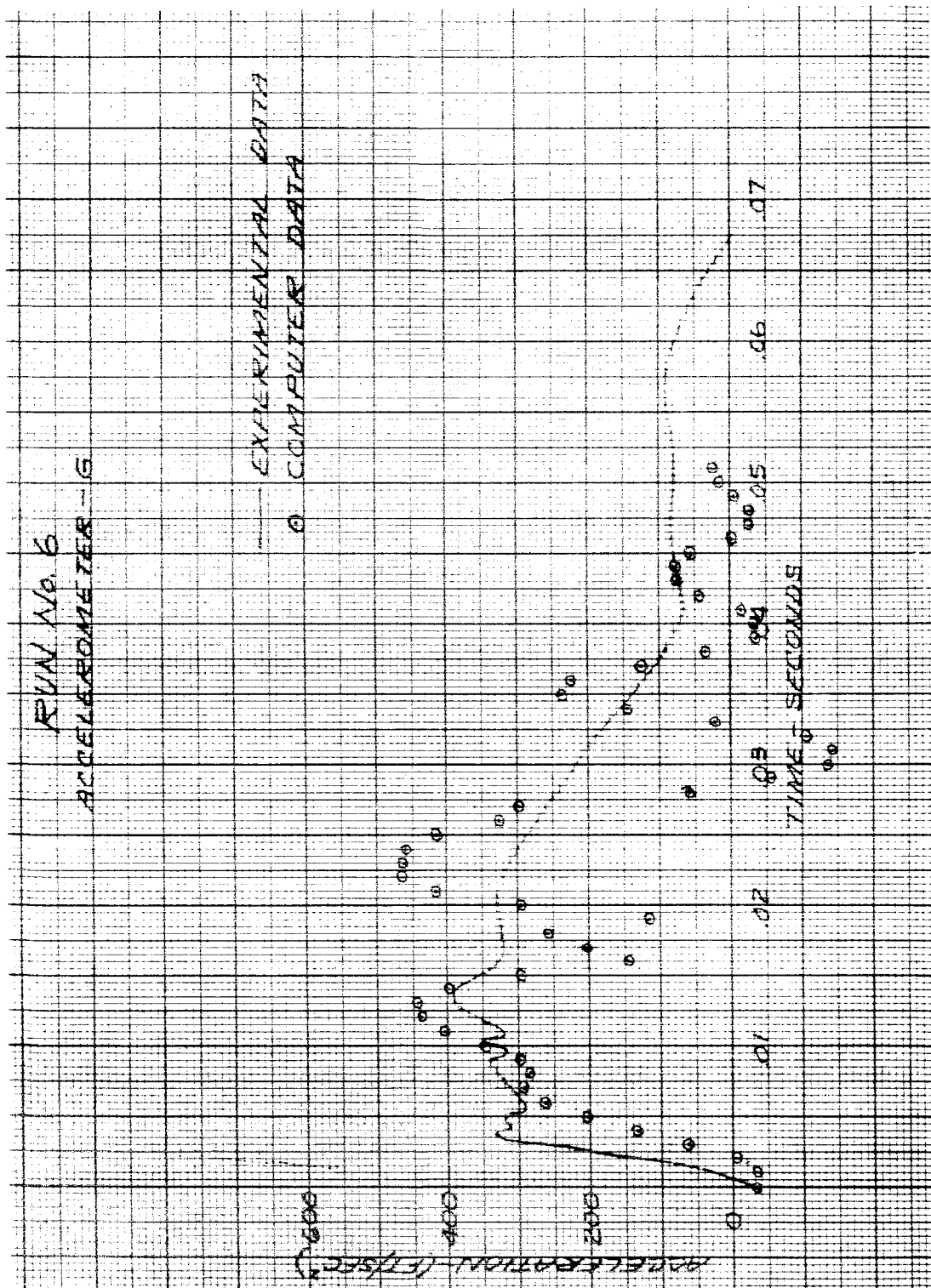


Figure 5-41. Run No. 6 Accelerometer - G

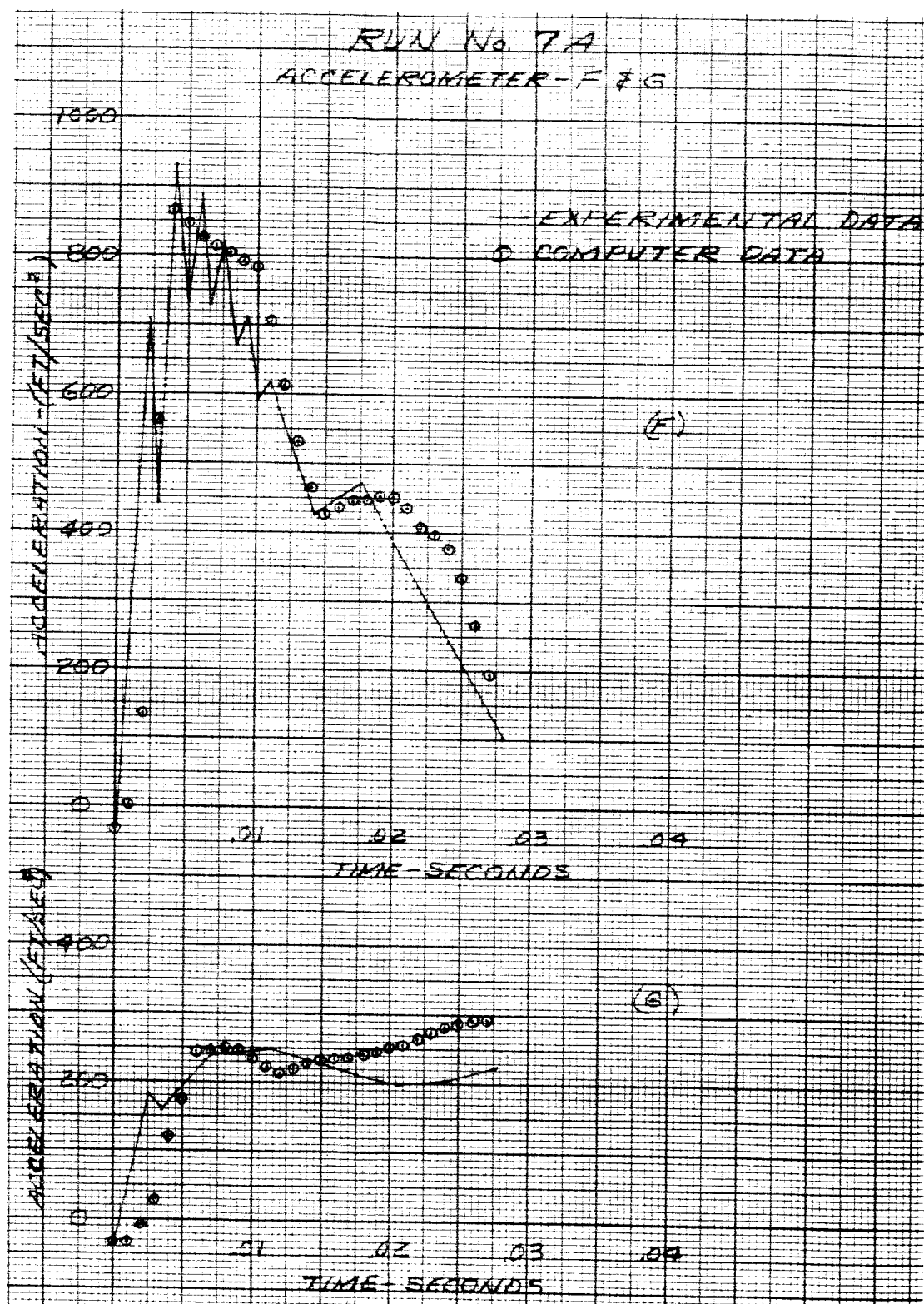


Figure 5-42. Run No. 7A Accelerometer - F & G

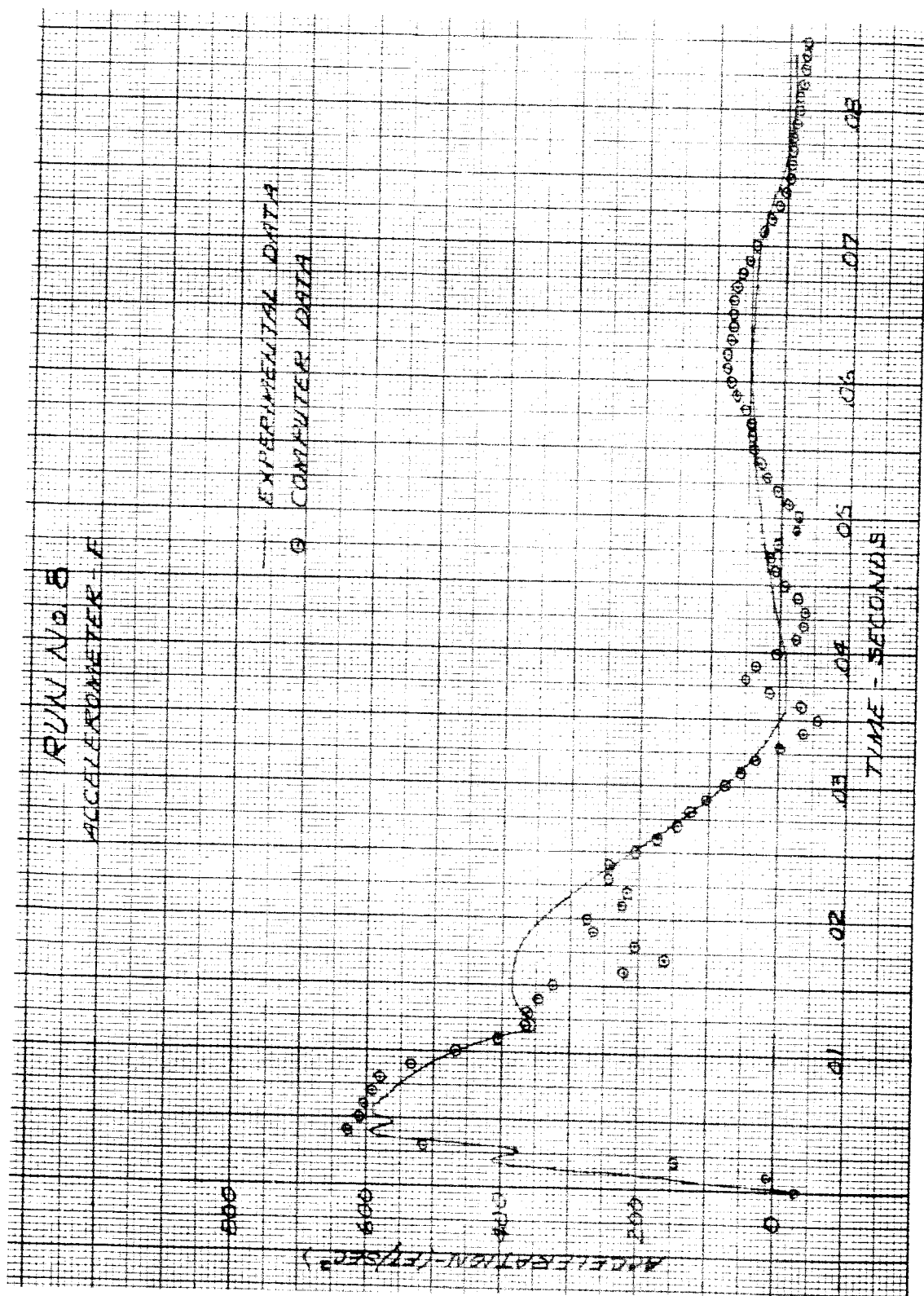


Figure 5-43. Run No. 8 Accelerometer - F

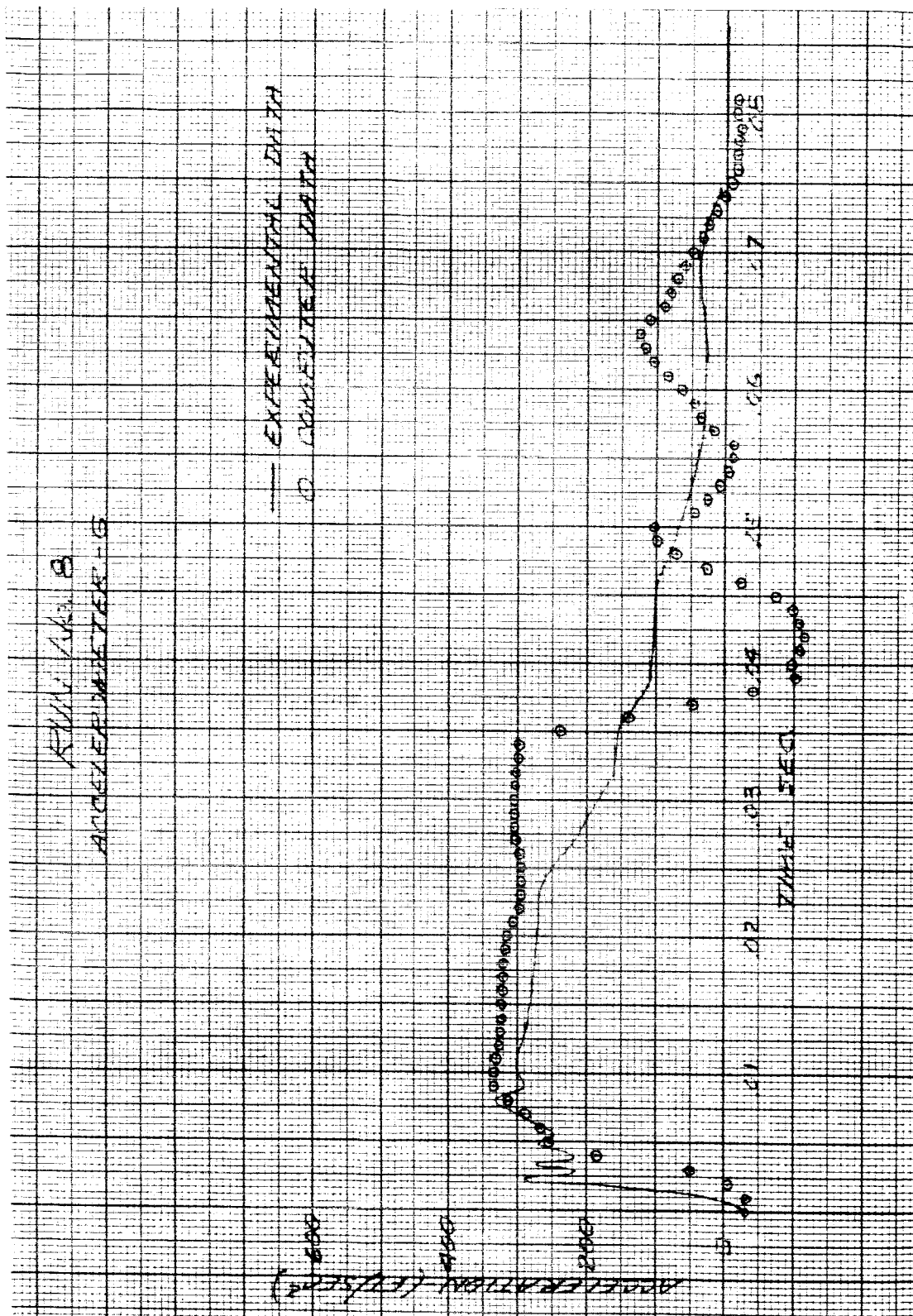


Figure 5-44. Run No. 8 Accelerometer - G

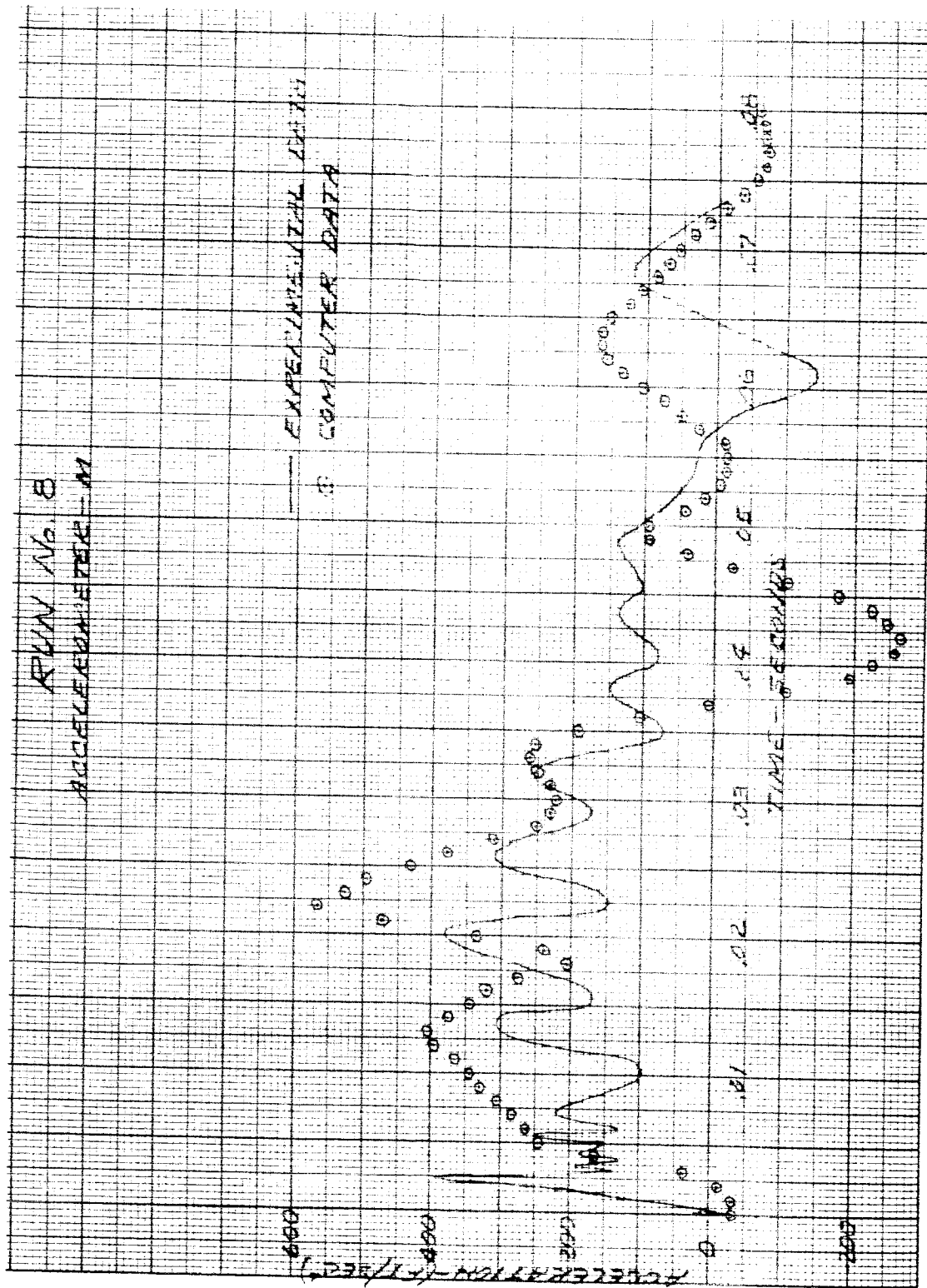


Figure 5-45. Run No. 8 Accelerometer - M

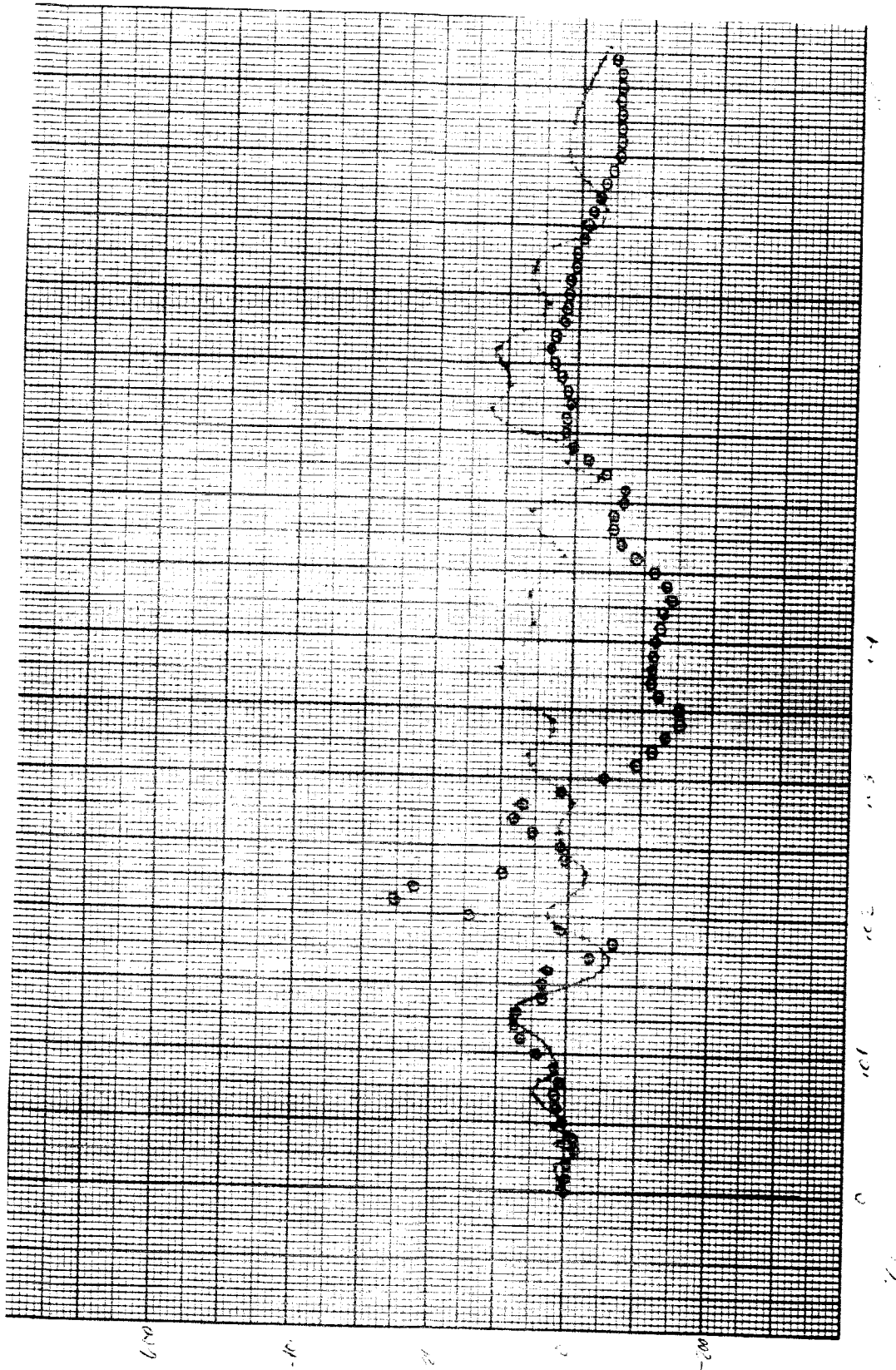


Figure 5-46. Run No. 8 Accelerometer - J

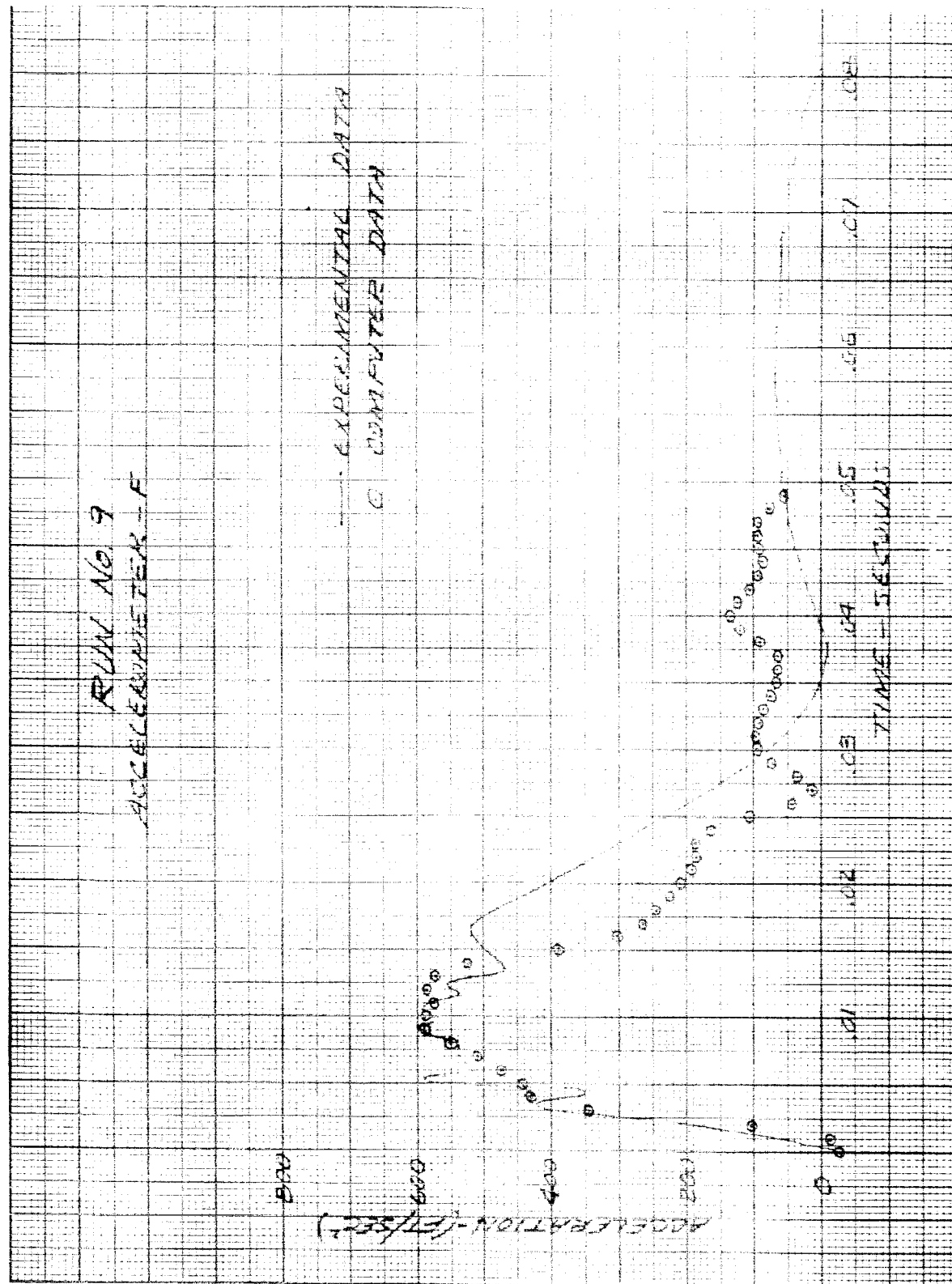


Figure 5-47. Run No. 9 Accelerometer - F

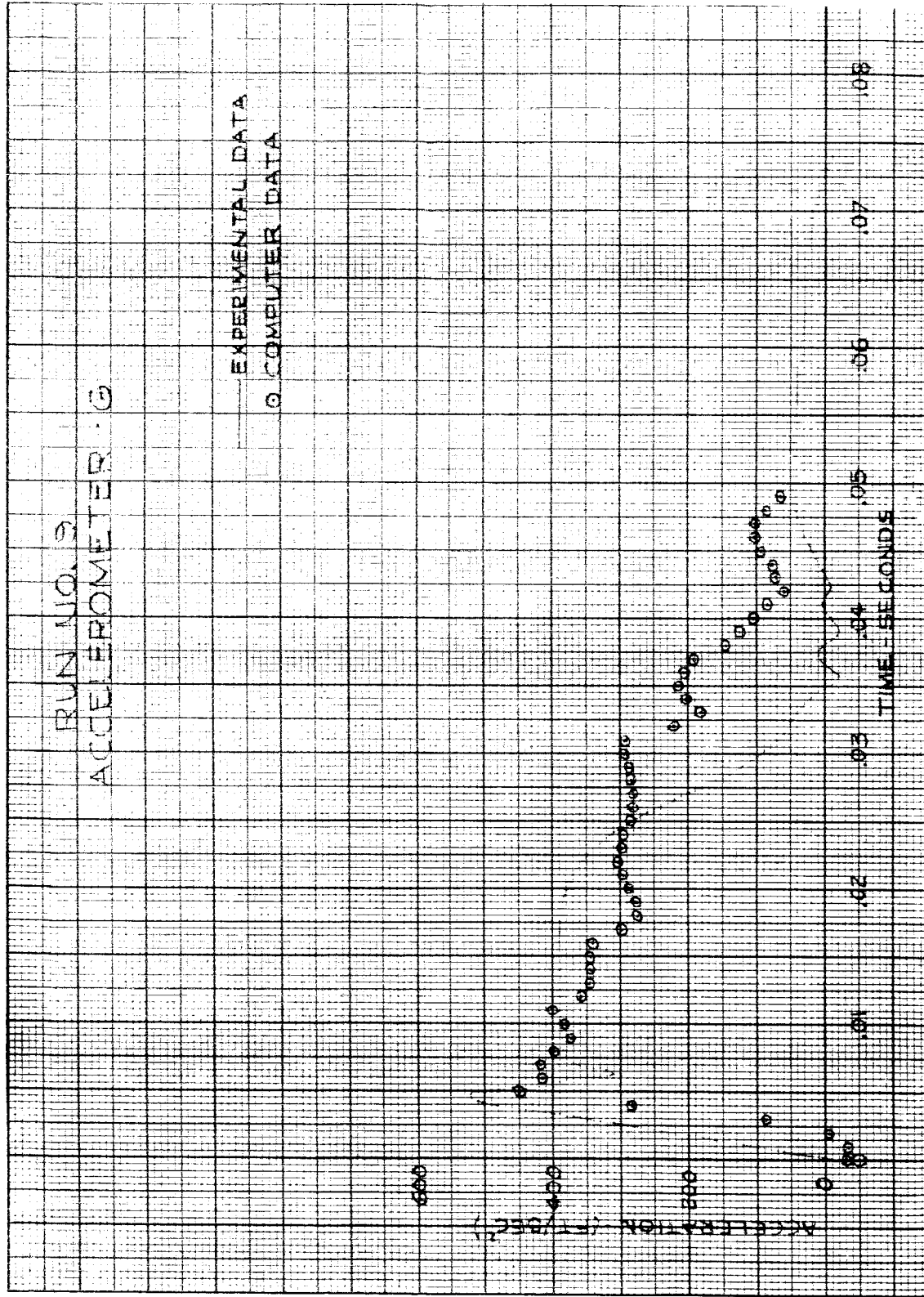


Figure 5-48. Run No. 9 Accelerometer - G

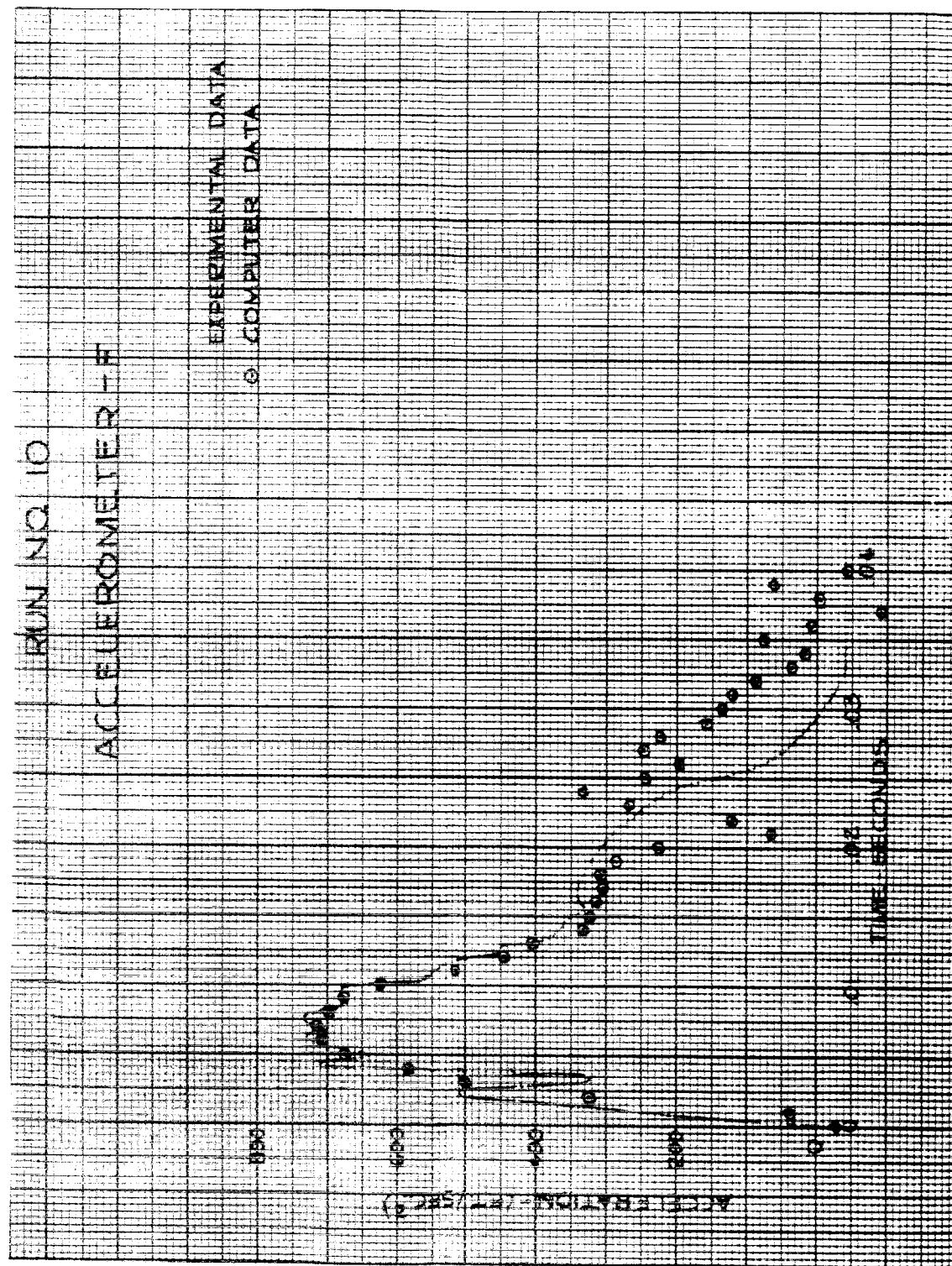


Figure 5-49. Run No. 10 Accelerometer - F

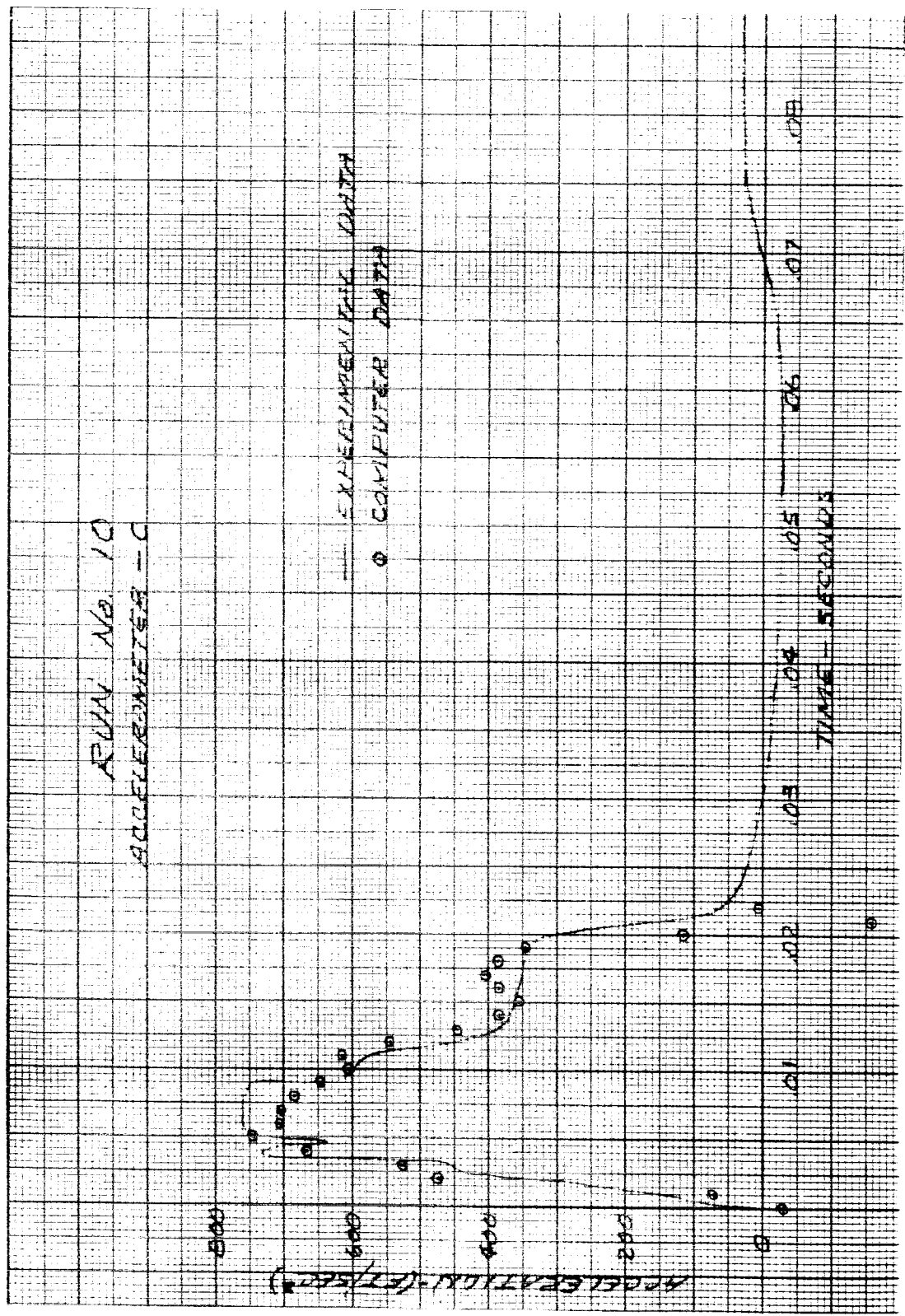


Figure 5-50. Run No. 10 Accelerometer - C

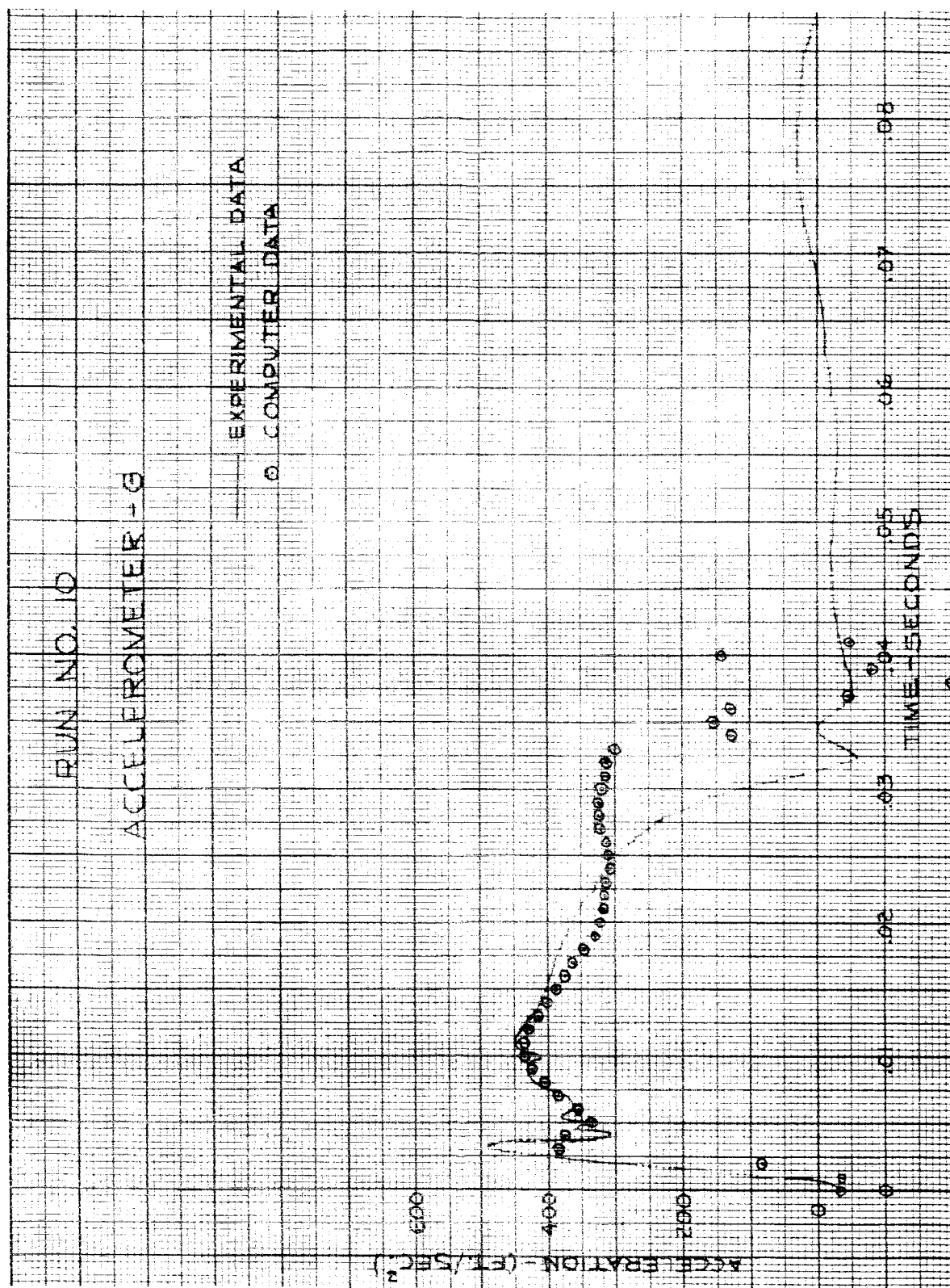


Figure 5-51. Run No. 10 Accelerometer - G

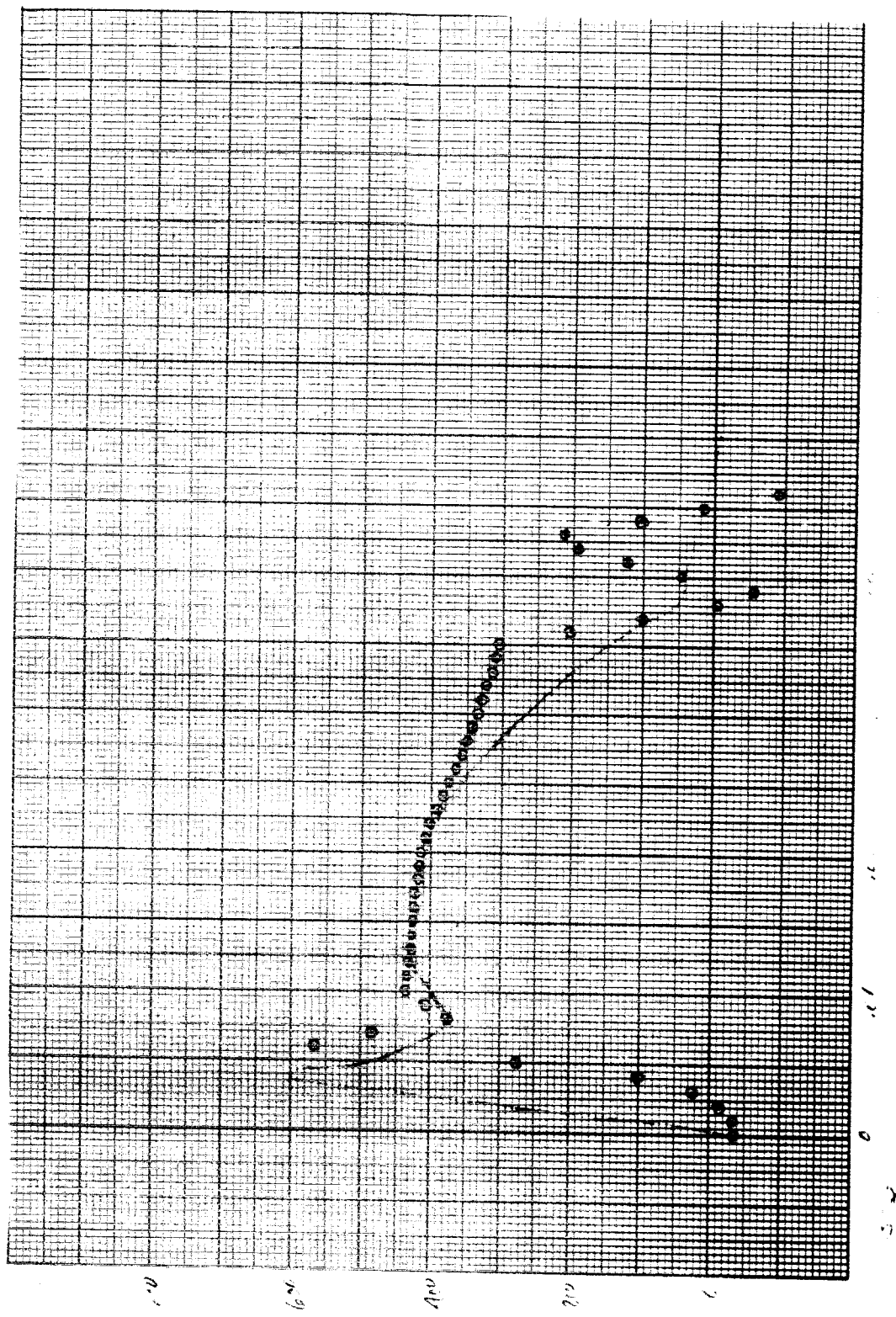


Figure 5-52. Run No. 11 Accelerometer - G

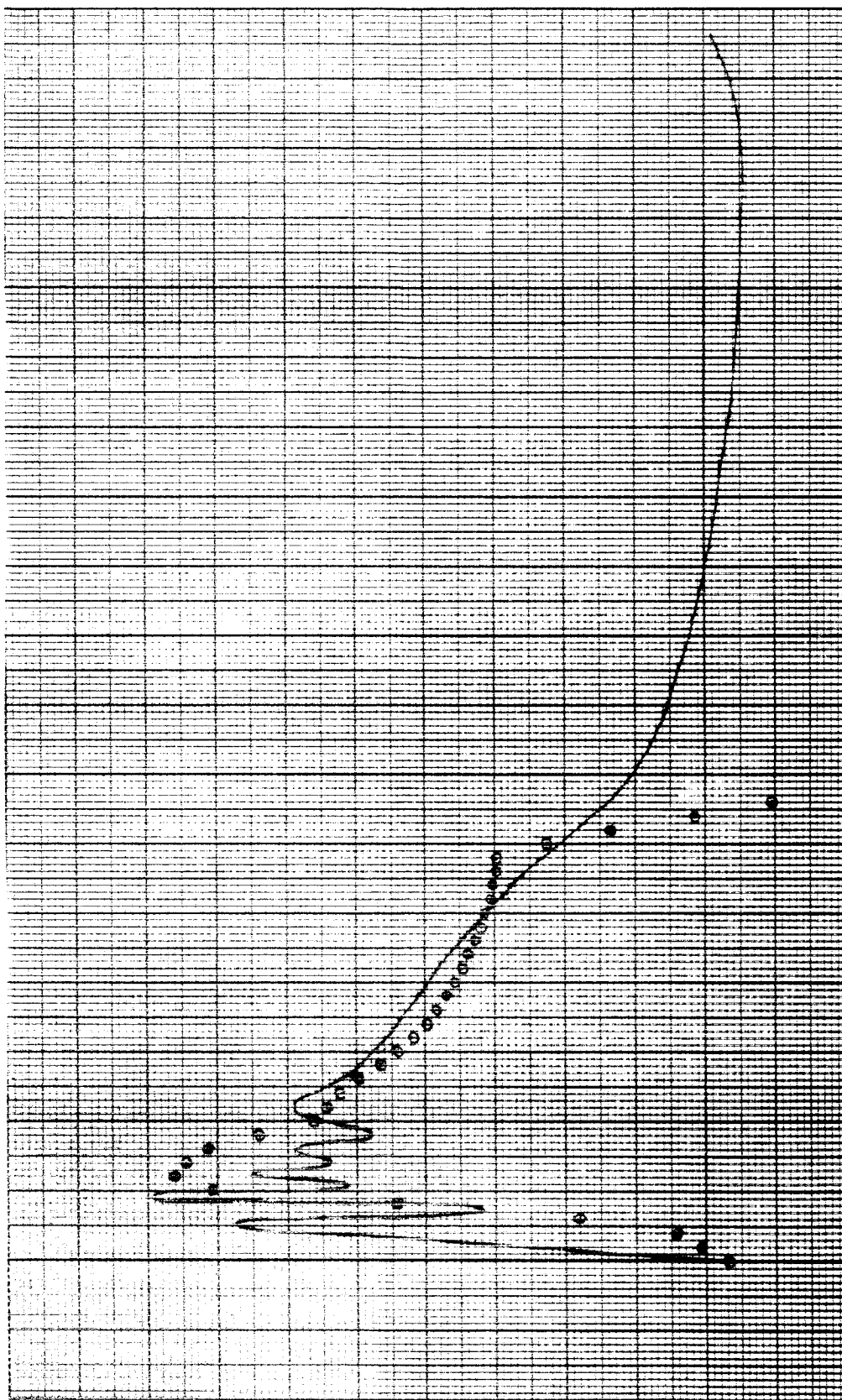
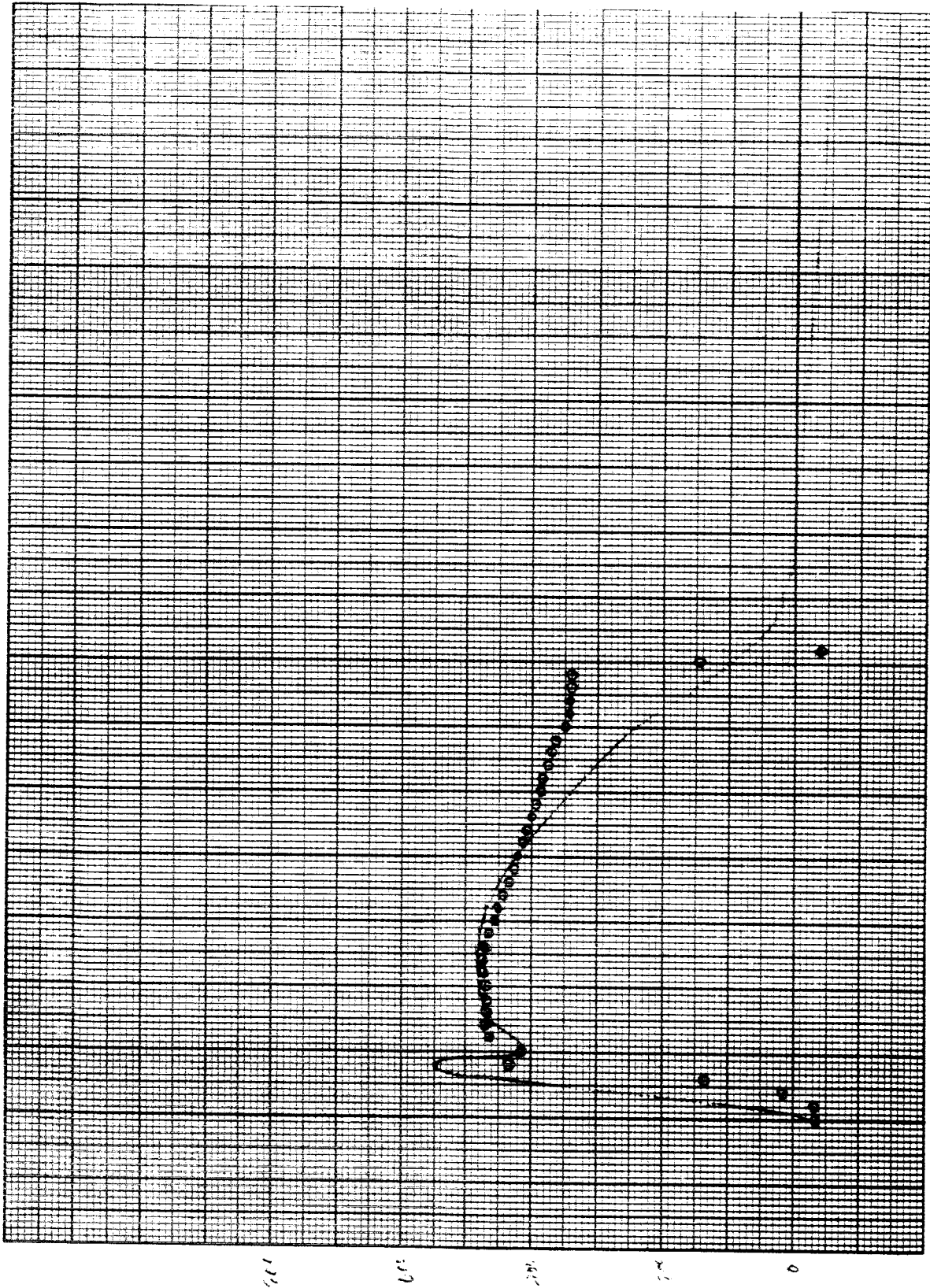


Figure 5-53. Run No. 11 Accelerometer - F



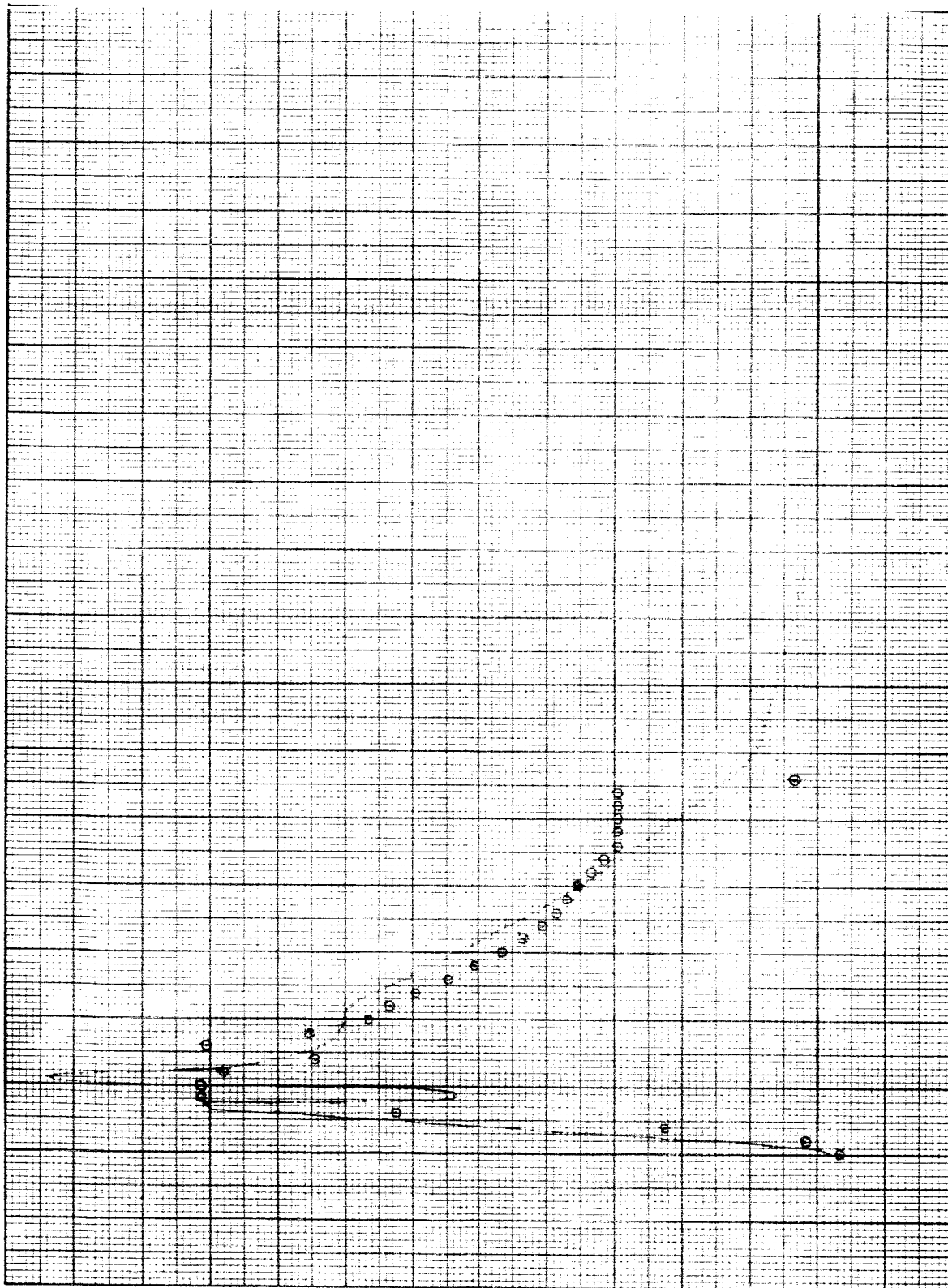


Figure 5-55. Run No. 11R Accelerometer - F

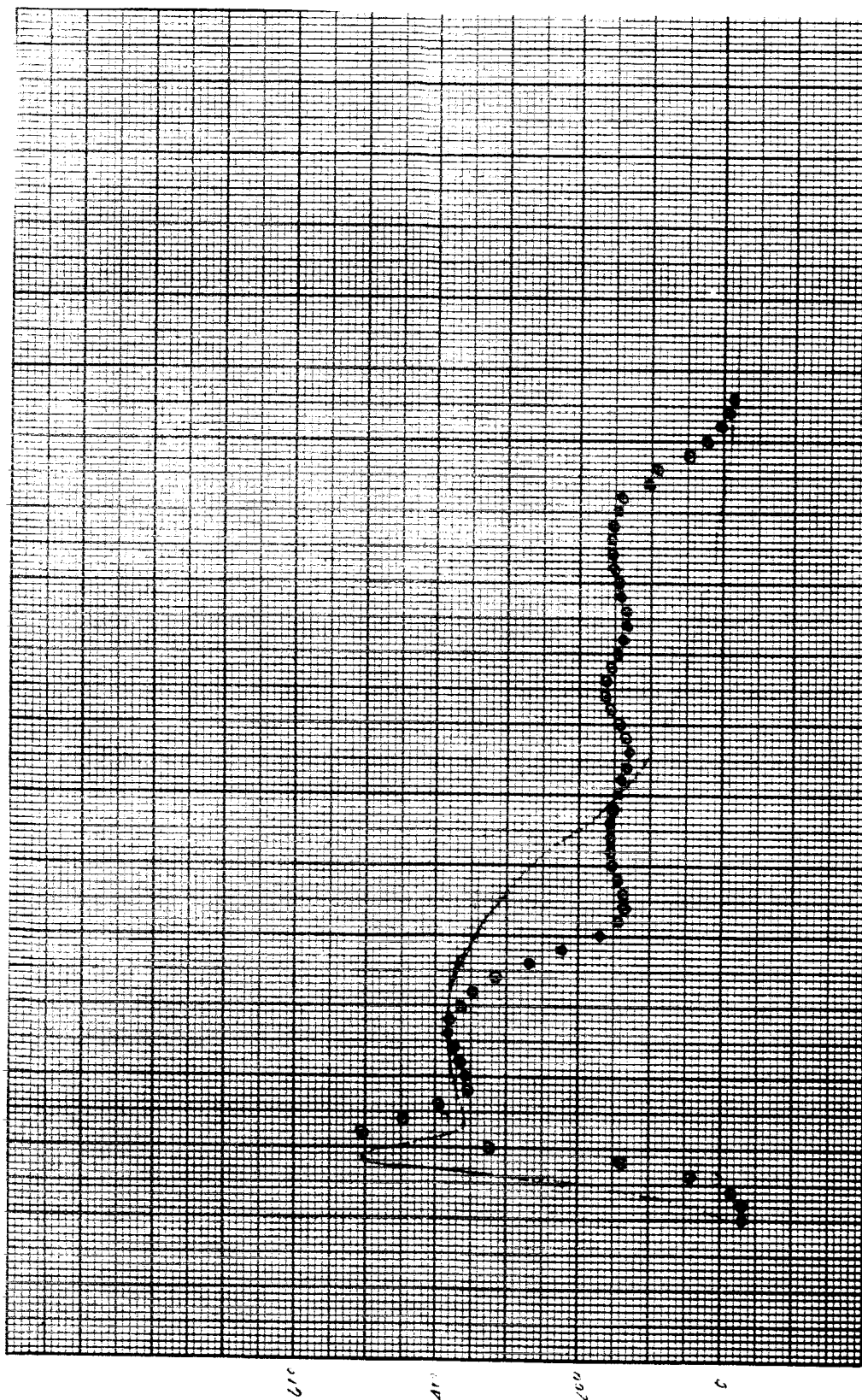


Figure 5-56. Run No. 12 Accelerometer - G

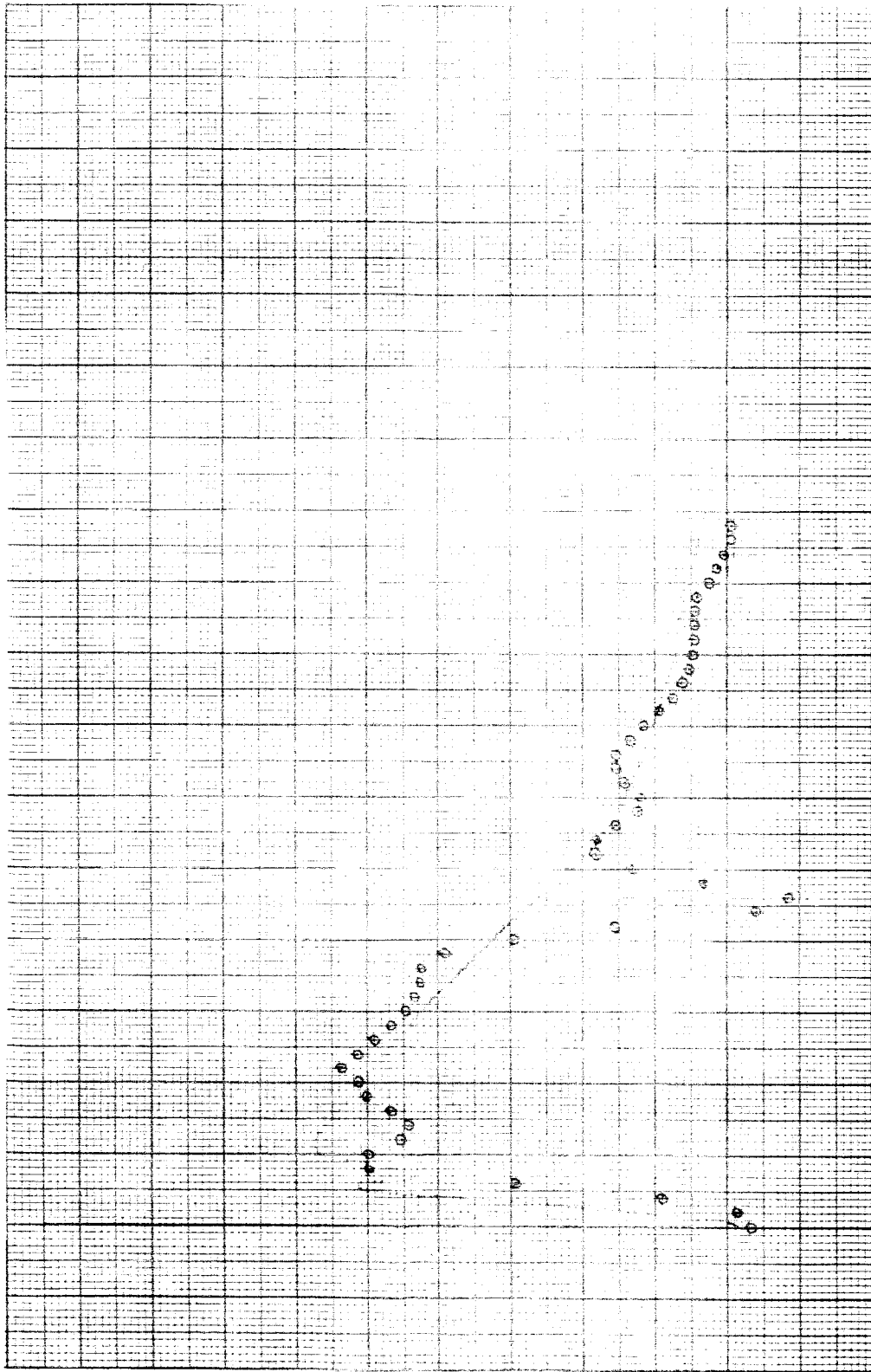


Figure 5-57. Run No. 12 Accelerometer - F

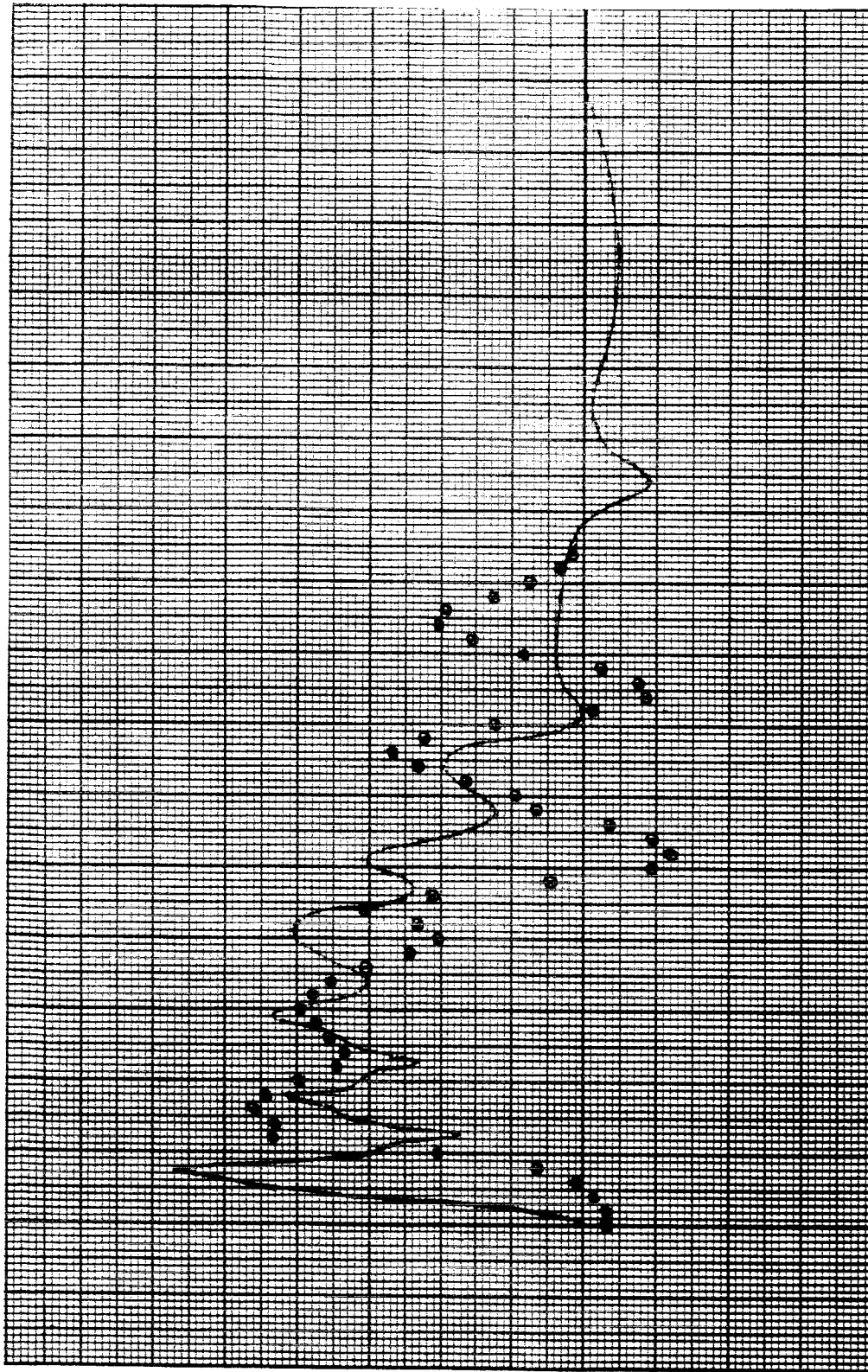


Figure 5-58. Run No. 12 Accelerometer - M

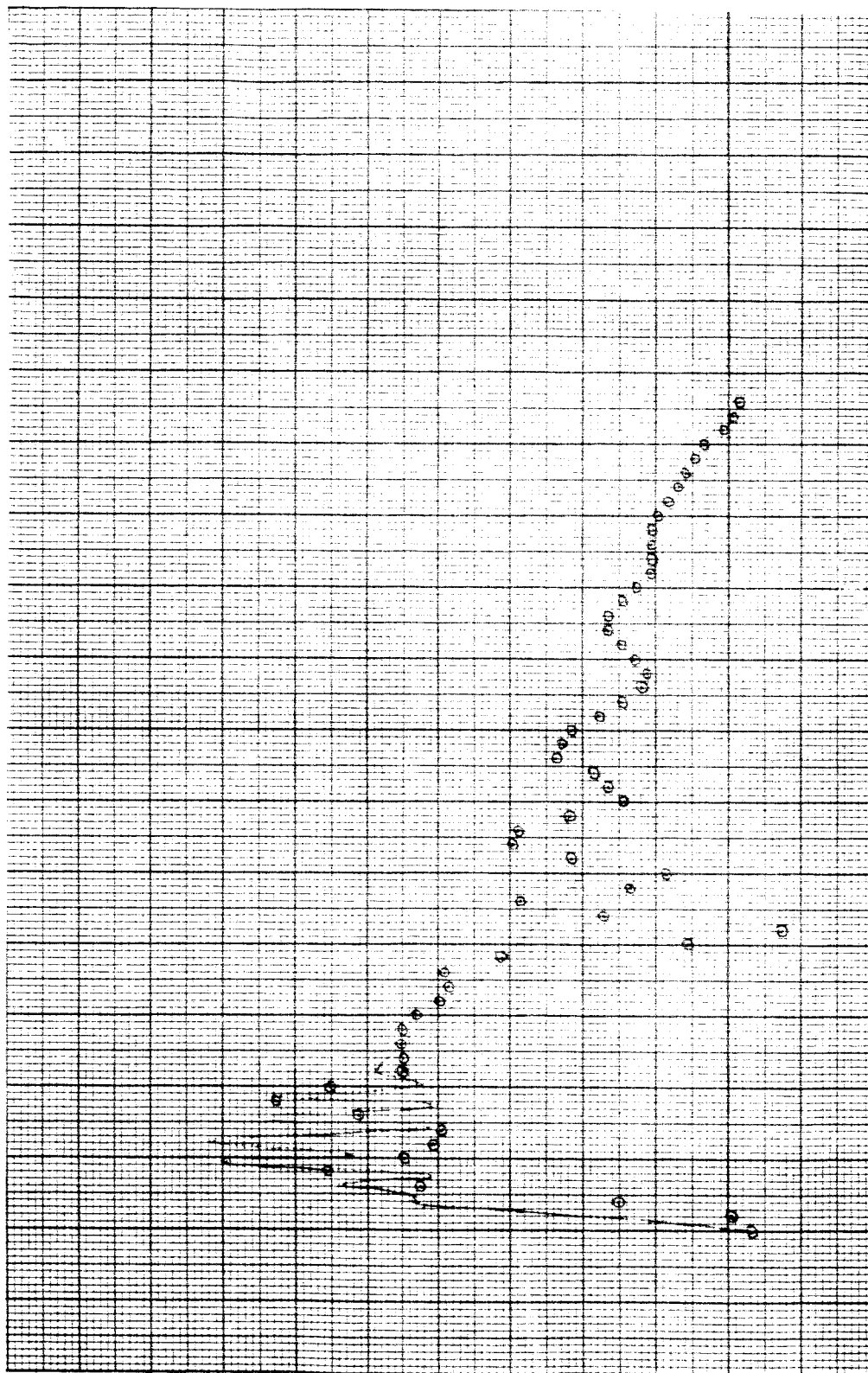


Figure 5-59. Run No. 12 Accelerometer - C