PILING ANALYSIS
WAVE EQUATION COMPUTER PROGRAM
UTILIZATION MANUAL

by

Thomas C. Edwards
Assistant Research Engineer

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Foreword

The information contained herein was developed on Research Project 2-5-62-33 entitled "Piling Behavior" which is a cooperative research project sponsored jointly by the Texas Highway Department and U. S. Department of Transportation, Federal Highway Administration, Bureau of Public Roads. The broad objective of this project is to fully develop the use of the computer solution of the wave equation so that it may be used to predict driving stresses in piling and be used to estimate the static load bearing capacity of a piling from driving resistance records and basic soils data. This report covers the specific objective of explaining the use of the wave equation computer program.

The opinions, findings, and conclusions expressed in this publication are those of the author and not necessarily those of the Bureau of Public Roads.

TABLE OF CONTENTS

LIST OF FIGURES

APPENDIX

LIST OF TABLES

APPENDIX

WAVE EQUATION COMPUTER PROGRAM UTILIZATION MANUAL

Introduction

This manual describes the utilization of the computer program for the application of the one-dimensional wave equation to the investigation of a pile during driving. The program is based upon a procedure developed by E. A. L. Smith.[1]

The program can be used to obtain the following information for one blow of the pile driver's ram for any specified soil resistance:

1. Stresses in the pile.
2. Displacement of the pile (penetration).
3. Static load capacity of the pile for a specified soil resistance and distribution. This capacity is the static resistance at the time of driving and does not reflect soil set-up due to consolidation.

The program is valuable in that system parameters heretofore ignored (in pile driving formulas) can be included and their effects investigated. It makes possible an engineering evaluation of driving equipment and pile type, rather than relying only upon experience and judgment.

General Pile System Simulation

Figure 1 shows a typical pile system and the idealization (discrete weight-spring idealization for use in the numerical solution of the wave equation) for this system. The idealization includes a simulation of the soil medium as well as the pile driver and pile. The pile hammer and pile are idealized as a system of discrete masses connected by massless springs. The springs represent the stiffness of the pile, cushion, and in some cases the pile driver's ram. The soil medium is assumed to be massless, i.e., the pile moves through the soil and does not move the adjacent soil mass, which is simulated by a spring and damper (dashpot) on each pile segment whose real counterpart is embedded in the medium. This system is completely general. Additions or deletions in the real system (for example, no pile cushion or addition of an anvil between the ram and capblock) can be handled.

In order to simulate a given system, the following information is essential:

1. Pile driver.
   - a) energy and efficiency of hammer,
   - b) weight and dimensions of ram,
   - c) weight and dimensions of anvil (if included),
   - d) dimensions and mechanical properties of capblocks,
   - e) weight and dimensions of pile cap helmet,
   - f) and dimensions and mechanical properties of cushion.
2. Dimensions, weight and mechanical properties of the pile.
3. Soil medium.
   - a) embedment of pile,
   - b) distribution of soil resistance over the embedded length of the pile expressed as a percentage of the total static soil resistance,
   - c) point soil resistance expressed as a percentage of the total static soil resistance,
   - d) ultimate elastic displacement for the soil on the side and point of pile.
   - e) and the damping constant for the soil on the side and point of the pile.

It should be recognized that the solution obtained with the program represents the results for one blow of the hammer at the specified soil embedment and soil resistance.

The techniques for idealization can be categorized in three groups:

1. the hammer,
2. the pile, and
3. the soil.

Idealization of Hammers

The program is formulated to handle drop hammers, single, double, and differential acting steam hammers and diesel hammers that operate on the head of the

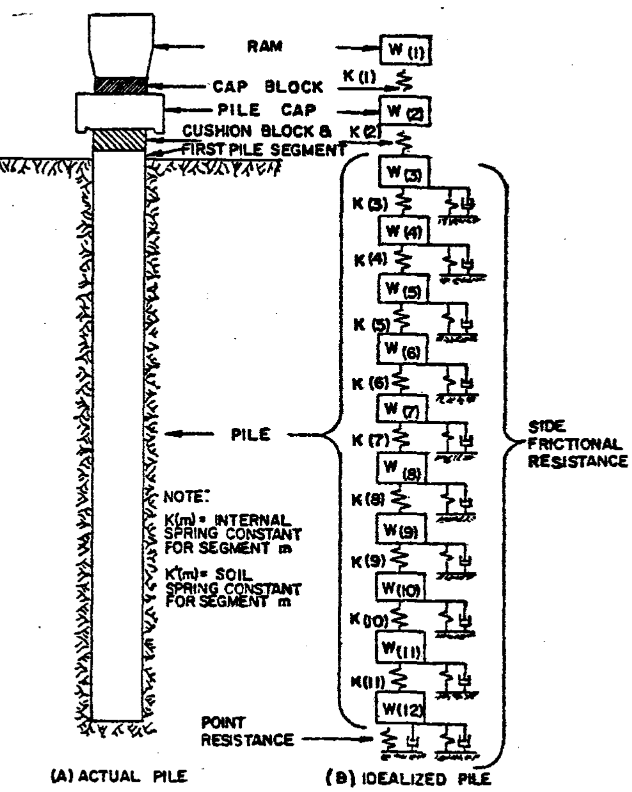
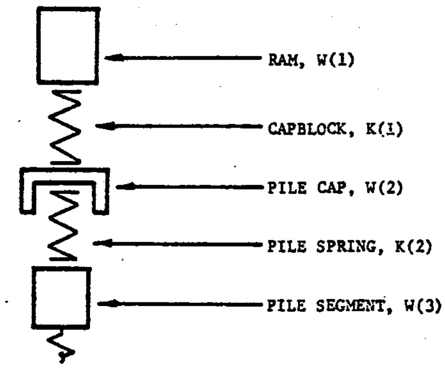


Figure 1. Idealization of a pile for purpose of analysis.



Calculations for idealization

W(1) = Weight of ram, (lb.)

$K(1) = \frac{A(1)\ E(1)}{L(1)}$, stiffness of the capblock, (lb./in.)

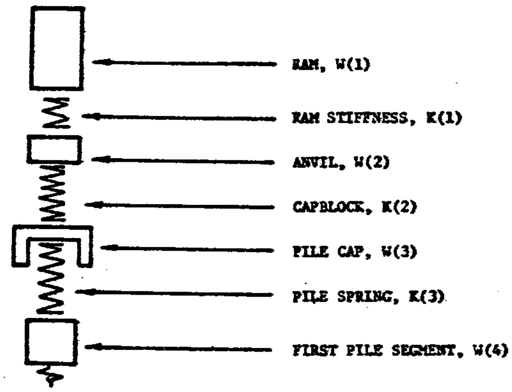
where A(1) = cross sectional area of the capblock, (in.^{2})

E(1) = modulus of elasticity of the capblock, (psi)

L(1) = thickness of the capblock, (in.)

Note: See reference 2 for capblock properties.

Figure 2. Case I—Ram, capblock, and pile cap.



Calculations for idealization

W(1) = Weight of ram, (lb.)

$K(1) = \frac{A(1)\ E(1)}{L(1)}$, the stiffness of the ram, (lb./in.)

where A(1) = ram cross sectional area, (in.)

E(1) = modulus of elasticity of ram material, (psi)

L(1) = length of ram, (in.)

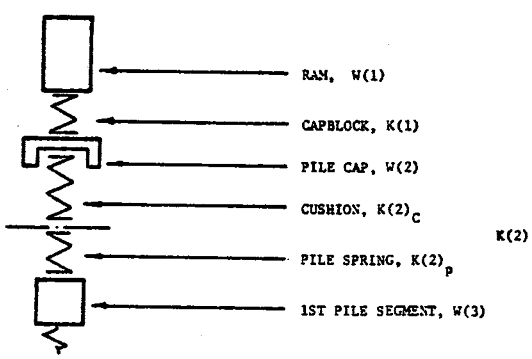
This calculation assumes that the pile cap and anvil are rigid.

Figure 4. Case III—Ram, anvil, capblock, and pile cap.

pile. The techniques presented in this section are general in scope and are presented for illustration. Appendix A gives the idealizations and pertinent information for the most common hammers.

Figures 2 through 4 describe the idealization for the following cases:

1. Case I—Ram, capblock, pile cap, and pile (Figure 1),



Calculations for idealization

W(1) = Weight of ram, (lb.)

K(1) = Stiffness of the capblock, (lb./in.)

$K(2)_c$ = Stiffness of cushion, (lb./in.)

$K(2)_p$ = Stiffness of pile spring, (lb./in.)

$K(2) = \frac{K(2)_c\ K(2)_p}{K(2)_c + K(2)_p}$, combined stiffness of $K(2)_c$ and $K(2)_p$ in series.

Note: See reference 2, for capblock and cushion properties.

Figure 3. Case II—Ram, capb... n.

2. Case II—Ram, capblock, pile cap, cushion and pile, (Figure 2), and

3. Case III—Ram, anvil, capblock, pile cap, and pile (Figure 3).

Methods of including coefficient of restitution in capblock and cushion springs. In the cases when K(1) is a capblock (Cases I and II), and K(2) is a cushion (Case II), it is desirable to include the energy loss due the coefficient of restitution of the particular material.

$$e = \sqrt{\frac{\text{Area BCD}}{\text{Area ABC}}} = \sqrt{\frac{\text{Energy output}}{\text{Energy input}}} \quad (1)$$

In Case II it is necessary to combine springs $K(2)_C$ and $K(2)_p$ to determine the equivalent spring K(2). In this instance it is also necessary to determine the coefficient of restitution of the combined springs. The stiffness of the spring in the restitution phase is the slope of the line DB in Figure 5.

$$K_{DB} = \frac{F_B}{\Delta_C - \Delta_D} \quad (2)$$

Since,

$$\text{Energy output} = \text{Area BCD} = F_B\ (\Delta_C - \Delta_D)/2$$

$$\text{Energy input} = \text{Area ABC} = F_B\ (\Delta_C)/2$$

$$e^2 = \frac{F_B\ (\Delta_C - \Delta_D)}{F_B\ (\Delta_C)} = \frac{\frac{F_B}{\Delta_C}}{\frac{F_B}{(\Delta_C - \Delta_D)}} = \frac{K_{AB}}{K_{DB}}$$

or
$$K_{DB} = \frac{K_{AB}}{e^2} \quad (3)$$

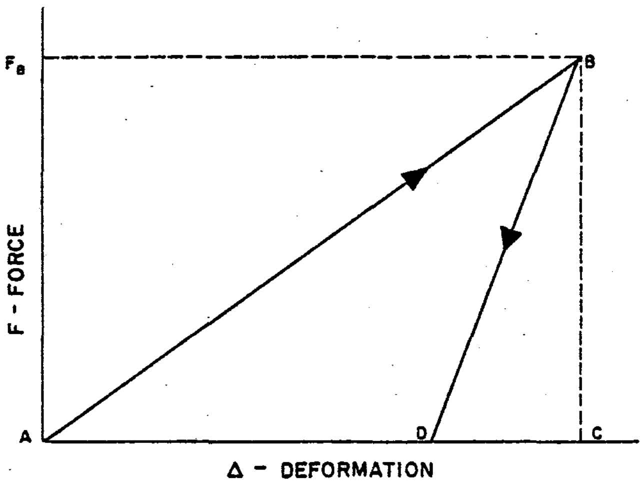


Figure 5. Definition of coefficient of restitution.

The combined restitution stiffness of $K(2)_C$ and $K(2)_p$ can be determined from,

$$\frac{1}{K(2)} = \frac{1}{K(2)_C} + \frac{1}{K(2)_p} \quad \text{(for restitution phase DB in Figure 5)}$$

from Eq. 3,
$$\frac{e(2)^2}{K(2)} = \frac{e(2)_C^2}{K(2)_C} + \frac{e(2)_p^2}{K(2)_p}$$

$$e(2)^2 = \frac{K(2)}{K(2)_C K(2)_p}\left[e(2)_C^2 K(2)_p + e(2)_p^2 K(2)_C\right]$$

since
$$K(2) = \frac{K(2)_C K(2)_p}{K(2)_C + K(2)_p}$$

$$e(2) = \sqrt{\frac{1}{K(2)_C + K(2)_p}\left[e(2)_C^2 K(2)_p + e(2)_p^2 K(2)_C\right]} \tag{4}$$

Ram kinetic energies. The kinetic energy of the ram for specific hammer types can be calculated as follows:

1. Drop hammers and single acting steam hammers;

$$E_H = W(1) \cdot h \cdot e_f \tag{5}$$

where

E_H = ram kinetic energy, (ft.-lb.)

$W(1)$ = ram weight, (lb.)

h = ram stroke, (ft.)

e_f = hammer mechanical efficiency (usually between 0.75 and 0.85 for most single acting hammers)

2. Differential and double-acting steam hammers;

$$E_H = h\left[1 + \frac{\text{p actual}}{\text{p rated}} \cdot \frac{W(h)}{W(1)}\right] W(1) \tag{6}$$

where

h = actual ram stroke, (ft.)

p actual = actual steam pressure, (psi)

p rated = manufacturers rated steam pressure, (psi)

$W(h)$ = hammer housing weight, (lb.)

$W(1)$ = ram weight, (lb.)

3. Diesel hammers;

$$E_H = W(1)\ (h_e - C) \cdot e_f \tag{7}$$

where

h_e = actual ram stroke for open-end hammers, and the effective stroke (includes effect of bounce chamber pressure) for closed-end hammers, (ft.)

C = distance from bottom-dead-center of ram to exhaust ports, (ft.)

Work done on the pile by the diesel explosive force is automatically accounted for by using an explosive pressure (see Sample Problem and Table A2).

In the hammer idealization, note that the parts composing the pile driver are physically separated, i.e., the ram is capable of transmitting compressive force to the anvil but not tension. The same is true of the interface between the anvil and pile cap, and the pile cap and the head of the pile. The program contains provisions for eliminating the capability of transmitting tensile forces between adjacent segments. The mechanics of this provision are more fully explained in the following section.

Idealization for Piles

The idealization of the pile is handled by breaking the continuum of the pile into discrete segments. Each segment is represented by its weight and spring representing the total segment stiffness. In Figure 6 the weight representing the segment is assumed to be concentrated at the end of the segment away from the impact. This places the spring on top of the weight whose stiffness it represents, i.e., $K(2)$ is associated with $W(3)$.

Piles should be broken into segments not to exceed approximately 10 feet in lengths, but into not less than five segments. The stiffness of each pile segment spring is calculated from

$$K(m-1) = \frac{A(m)\ E(m)}{L(m)} \tag{8}$$

where

$K(m-1)$ = spring stiffness for segment m, (lb.-in.)

$A(m)$ = cross sectional area of segment m, (in.^{2})

$E(m)$ = modulus of elasticity of the material of segment m, (psi)

$L(m)$ = length of segment m, (in.)

The weight of each pile segment is calculated by

$$W(m) = A(m)\ L(m)\ \alpha$$

where

α = unit weight of pile material, (lb/in.)

If the pile is tapered the average value of $A(m)$ should be used.

The program has provisions for handling cases where the physical construction of the pile prohibits the transmission of tensile stresses or is capable of transmitting tensile stresses only after a specified movement of a mechanical joint (joint slack or looseness). These conditions occur with certain types of pile splices. The program provides for this eventuality by entering the following:

1. If a joint (a joint is defined as the interface between two segments) can transmit tension the slack or looseness is entered as SLACK (m) = 0. (Refer to Figure 6.)

2. If a joint is completely loose, no tension can be transmitted and SLACK (m) should be made a very large number, i.e., SLACK (m) = 1000.0.

3. If a joint is capable of moving 1.25 in. before transmitting tension, SLACK (m) = 1.25, i.e., the physical value of the slack or looseness in a joint is entered in inches.

The SLACK (m) values are always associated with spring K(m). In Figure 6 if tension can be transmitted

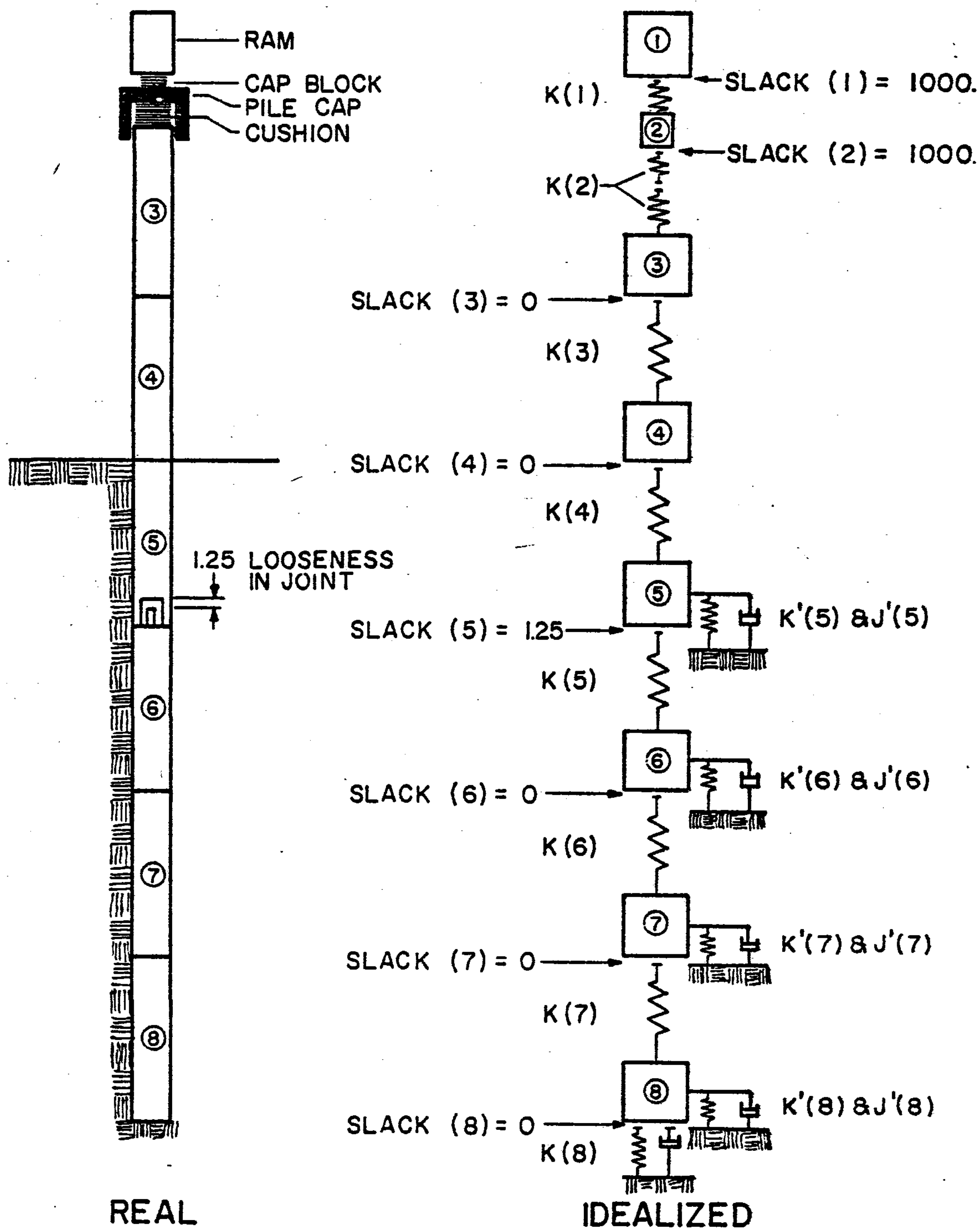


Figure 6. Pile idealization.

across the interface between segments 3 and 4 the slack value would be associated with spring K(3), i.e., SLACK (3) = 0.

The interfaces between the various parts composing the pile driver (ram, capblock, pile cap, etc.) which cannot transmit tension are also handled by setting the SLACK values equal to 1000.

Idealization for Soils

The true soil resistance to dynamic loading is not clearly understood. Simplifying assumptions are used in the program. Figure 7(a) shows the assumed static load deformation characteristic for the soil along the side of the pile or at the tip. For the soil on the side of the pile, path OABCDEFG represents the load-deformation that occurs as the pile moves in the soil. For the soil at the point only compressive loading can occur, since the point of the pile is free to rebound, and the load-deformation path is OABCO.

It can be seen that the characteristics of the spring representing the soil stiffness are defined by the quantities Q and RU. Q is the quake or maximum elastic deformation which occurs at the maximum elastic force RU. A load deformation diagram like that of Figure 7(a) can be established for each soil spring. The stiffness of a side soil spring is

$$K'(m) = \frac{RU(m)}{Q'(m)} \qquad (9)$$

where

RU(m) = side soil resistance on segment m, (lb.)

Q'(m) = side soil quake, (in.)

For the soil at the point

$$K(p) = \frac{RU(p)}{Q(p)} \qquad (10)$$

where

RU(p) = soil resistance at the point (lb.)

Q(p) = point soil quake, (in.)

The dynamic loading effects on the soil characteristics are included by assuming that the soil has a damper (dashpot) in parallel with the spring (see Figure 1). The resistance of the damper is assumed to be directly proportional to the velocity of the associated segment weight during the displacement. The total resistance of the spring and damper under dynamic load is expressed as[3]

$R(m) = [D(m) - D'(m)]\ K'(m)\ [1 + J'V(m)]$, in the elastic range

$R(m) = RU(m)\ [1 + J'V(m)]$, in the plastic range

where

R(m) = total resistance (static plus dynamics)

D(m) = displacement of W(m)

D'(m) = plastic displacement of soil

K'(m) = spring stiffness of side soil

J' = damping constant of side soil spring

V(m) = velocity of W(m)

This equation will produce a dynamic load-deformation behavior as shown by path OABCDEFG in Figure 7(b) for the side soil and the path OABC for the point soil. Note in Figure 7(b) that the dynamic and static parts of R(m) are easily separated. This point is important to the development that follows.

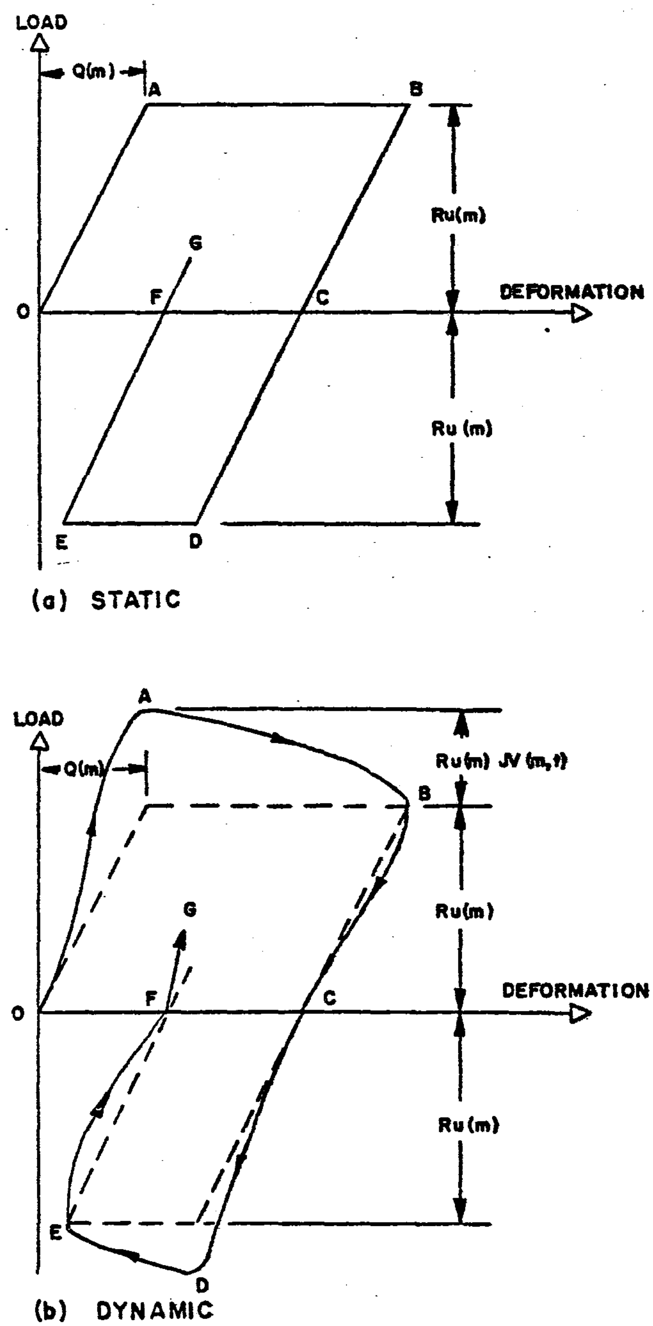


Figure 7. Soil load-deformation characteristics.

Use of the Program to Develop Dynamic-Static Soil Resistance Data

The engineer is most interested in the static load carrying capacity of the piles he drives. In the past he has had to rely on judgment based on empirical pile equations (Hiley, ENR, etc.) or static load tests. With the wave equation method of analysis of pile driving, a much more realistic engineering estimate can be made using data generated by the program. If it is assumed that the method of approximating the dynamic soil resistance is reasonably correct (this fact has yet to be proved), the static resistance of a pile, at the time of driving, can be determined from the dynamic driving behavior. This is accomplished in the following manner.

For any specified total static soil resistance and soil parameters, Q'(m), J'(m), Q(p), and J(p), the penetration of the pile under one blow of the hammer can be determined. The penetration per blow (or its reciprocal, blows/in.) is a measurable parameter which indicates the dynamic behavior of the pile. By specifying various total static soil resistances a data table of total static soil resistance, RU(TOTAL) and the corresponding penetrations under one blow of the hammer (expressed as blows/in.) can be developed for any constant set of pile and soil parameters. The graph of these values can be used as a field guide to estimate the total static soil resistance, at the time of driving, for any observed pile penetration (blows/in.). It should be recognized that any pile "set up" due to consolidation in cohesive soils is not included. The static values obtained should be viewed as a practical minimum of the static soil capacity that was achieved.

Explanation of Data Input Sheets

Data for the Pile Driving Analysis program is entered on two sheets. Page 1 contains data pertaining to the physical parameters of a particular pile. Page 2 is used to vary the soil, pile driver, or cushion characteristics for the pile described on page 1. Examples of the data sheets follow the explanation.

Page 1

Case No. = Any combination of up to six alphabetic or numerical characters used for identifying information. These characters will identify all problems associated with the pile data entered on sheets 1 and 2.

No. of Probs. = Total number of problems listed on page 2.

1/DELTA T = This space may be left blank in most cases as the program calculates the critical time interval from the parameters of the system. The value calculated is

$$1/\text{DELTA T} = 2(19.698\sqrt{K/W})$$

If, however, one desires to use a specific 1/DELTA T, it may be entered. The problem will then compare the entered value with the critical value calculated by the above formula and use the larger of the two. This is done so that the user cannot inadvertently enter a value too small and hence introduce instability into the numerical process.

P = Total number of weights including ram of hammer, follower and helmet, etc.

SLACK (1) = This indicates a specified looseness between W(1) and W(2) in inches. This is the amount of movement required before K(1) will take tension. If there is complete tensile freedom of K(1) then enter SLACK (1) = 1000. Leave blank if option 3 is "2".

SLACK (2), SLACK (3) = see notes on Slack (1).

Option 1 = This is an option for the manual entry of the cross sectional area of each segment.

(a) Enter "1" and all AREAS will automatically be set equal to 1.00. In this case, draw a horizontal line through all AREA rows on the middle portion of page 1. If "1" is used, do not enter areas in AREA rows.

(b) Enter "2" if the cross sectional area of each segment is to be entered manually in the AREA rows. In this case enter AREAS (1) to (P) inclusive.

Option 2 = This is an option for the manual entry of soil resistances.

(a) Enter "2" if the soil resistances (expressed as a percentage of the total soil resistance) are to be entered manually in the RU rows. The RU values are entered from (1) to (P + 1) inclusive. Note that (P + 1) is the point resistance and all others are side resistances. The total of all RU percentages entered must total 100%.

(b) Enter "1" if the soil resistances are not listed in the RU rows but are indicated under Option 12 on page 2.

Option 3 = This is an option for manual entry of the SLACK values.

(a) Enter "1" if SLACK values from SLACK (4) to SLACK (P − 1) are all 0.00 (indicating K(4) to K(P − 1) can take tension). In this case only SLACK (1) to SLACK (3) are entered in row 1. Draw a horizontal line through all SLACK rows in the lower portion of page 1. In this case do not enter any values in the Slack rows.

(b) Enter "2" if SLACK values are to be entered manually. In this case, SLACK (1) to SLACK (3) in row 1 may be left blank.

Option 4 = This is an option on the routine used to simulate the material behavior of springs K(1), K(2), and K(3).

(a) Enter "1" for use of Smith's routine 3 and 4.

(b) Enter "2" for use of Texas A&M's routine.[4] It is suggested that Option 4 = 2. Option 4 may be left blank in which case it is automatically set equal to 2.

IPRINT = This is an option on the amount of data printed out when the long form output is used (Option 15 = 2). If Option 15 = 2, IPRINT is the print interval expressed as the number of time intervals. As an example, if a print out is required every 10th time interval, 10 would be entered for IPRINT. If Option 15 is "1" or "3" leave IPRINT blank.

NSEG 1 = NSEG 1 is the mass number of the first pile segment. If NSEG 1 is left blank NSEG 1 = 2 will be used by the program.

The total weight of each segment, in pounds, is entered in the rows marked W(2), W(3), -----, W(24). The weights, W's, are entered from 2 to P inclusive. Note that W(1) is not entered as it will be included on page 2.

The spring stiffness of each segment, in lb./in., is entered in the rows marked K(1), K(2), -----, K(24). The stiffness, K's, are entered from 1 to P — 1 inclusive. Spring K(P) is the soil spring at the pile tip and is calculated by the program from the soil data entered on page 2.

If Option 1 = 2, the average area of each segment must be entered in the rows marked A(1), A(2), -----, A(24). The units of A should be consistent with the stress units desired in the output. The basic force unit of the output is the pound. The areas, A's, are entered from 1 to P inclusive. A(P — 1) and A(P) in most instances will be the same. Areas of segments of the hammer are usually entered as A(1) = 1.00, etc., since stress values obtained for these segments are not usually of concern. If Option 1 = 1 the area row should be marked through with a solid horizontal line indicating no data cards are to be included.

If Option 2 = 2, the side soil resistance on each segment, expressed as a percentage of the total soil resistance, is entered in the rows marked RU(1), RU(2), -----, RU(24). The soil resistances, RU's, are entered from 1 to P + 1 inclusive. The value of RU (P + 1) is the pile tip resistance. Mark out all rows when Option 2 = 1.

If Option 3 = 2 the physical slack or looseness, expressed in inches, is entered in each row marked SLACK (1), SLACK (2), -----, SLACK (24). SLACK'S are entered from 1 to P — 1 inclusive. If there is no slack, enter 0.0, if there is complete looseness, enter 1000.0. SLACK (P) is automatically set equal to 1000.0 since the point soil spring cannot take tension. If Option 3 = 1, mark out all rows.

Note that the forms have 24 spaces for W's, K's, A's, RU's and SLACK's. The program is capable of handling a pile with a maximum of 149 segments. Additional cards may be added to each parameter as needed.

Page 2

W(1) = The weight of the pile driver's ram in pounds.

NC = The number of the spring for which K(NC) is being varied, see discussion on page 8.

K(NC) = The spring constant of the spring being varied in pounds/inch. Only one spring can take on variable values per case.

EFF = The efficiency of the pile hammer.

ENERGY = The kinetic energy of the falling ram calculated by Equation 5, 6 or 7.

ERES (1) = The coefficient of restitution of spring K(1)

ERES (2) = The coefficient of restitution of spring K(2)

ERES (3) = The coefficient of restitution of spring K(3).

RU (TOTAL) = This space should be used only when Option 11 = 2. In this case RU(TOTAL) is the desired ultimate pile resistance in pounds. When Option 11 = 1 leave this entry blank.

% RU (TOTAL) AT POINT = The percentage of the total pile soil resistance, RU(TOTAL), under the point of the pile. This value is entered as a percentage.

MO = If Option 12 is "1" or "2" enter the number of the first pile segment acted upon by soil resistance. This space may be left blank if Option 12 = 3, i.e., RU's are read in on page 1.

Q POINT = Quake of the soil at the point. Normally "0.10" is used.

Q SIDE = Quake of the soil on the side of the pile. Normally "0.10" is used.

J POINT = Damping constant for the soil at the point.

J SIDE = Damping constant for the soil on the side of the pile.

FEXP = The diesel explosive force (in pounds) which acts on the ram and anvil of a diesel hammer. In the case where no explosive force exists, as with drop hammers or steam hammers, leave FEXP blank.

Option 11 = This option provides for single or multiple calculations.

(a) Enter "1" if multiple calculations for RU (TOTAL) VS. BLOW/IN., data are desired. The computer will assign suitable values of RU(TOTAL). Leave RU-(TOTAL) space on page 2 blank.

(b) Enter "2" if single calculation is to be made with RU(TOTAL) value entered on page 2.

Option 12 = This option is used for designation of the distribution of side friction on the pile.

(a) Enter "1" for a uniform distribution of side friction from segment MO to P.

(b) Enter "2" for a triangular distribution of side friction from segment MO to P.

(c) Enter "3" if Option 2 = 2, i.e., RU values are entered on page 1.

Option 13 = This option provides for computer plotted curves using the data generated for RU (TOTAL) VS. BLOW/IN. (Option 11 = 1).

(a) Enter "1" for computer plot of data. If no plot is desired, leave blank.

Option 14 = This is used to include or exclude gravity in the calculations.

(a) Enter "1" if the forces of gravity are to be included in the calculations.

(b) Enter "2" if the forces of gravity are to be excluded from the calculation. This alternate in effect excludes the weight of the pile from the calculations. It is used when the pile driver is in a horizontal position or for an extreme batter.

Option 15 = This option provides for versatility in the output format.

(a) Enter "1" for a normal data printout.

(b) Enter "2" for extra detail in printout. This alternate gives pertinent stresses, deformations, velocities, etc., at the print interval, specified as IPRINT on page 1.

(c) Enter "3" for short output. This alternate gives only a tabular summary of BLOWS/IN. VS. RU(TOTAL). Option 15 = 3 should be used only when Option 11 = 2.

SPECIAL NOTE Where anything listed for Problem 1 is to be repeated for Problem 2, 3, etc., draw an arrow down through the last problem to indicate repetition.

Comments on data input. On page 2 of the input forms, provisions are made for varying the stiffness of any spring, K(1) through K(P − 1), in the hammer or pile idealization. This is accomplished by entering the number of the spring to be changed in the NC column and then the stiffness of spring K(NC) in the K(NC) column. As soon as this problem is completed, the spring stiffnesses, K(NC) will be reset automatically to the value listed on page 1 of the input form.

The various output options, Option 15, are discussed in Appendix B in conjunction with example problems.

The program is capable of handling pile idealizations with a maximum of 149 segments. There is no limit on the number of problems that can be run for each case.

Sample Problems and Program Listing

A sample problem showing the use of the input forms and the output forms is presented in Appendix B.

The program listed is presented in Appendix C. It is coded in IBM FORTRAN IV. A flow diagram of the program logic is also presented. An attempt has been made to use variable names which correspond to the nomenclature presented by Smith.[5]

PILE DRIVING ANALYSIS TEXAS A&M UNIVERSITY						OPTIONS: AREAS, RU'S, SLACK	IPRINT USED WHEN OPTION15=2	NSEGI	BY:	DATE:	PAGE #1 OF 2
CASE NO.	NO. OF PROBS.	1/DELTA T	P	SLACK (1)	SLACK (2)	SLACK(3)	1 2 3 4				

LBS	W (1)	W (2)	W (3)	W (4)	W (5)	W (6)	W (7)	W (8)
	W (9)	W (10)	W (11)	W (12)	W (13)	W (14)	W (15)	W (16)
	W (17)	W (18)	W (19)	W (20)	W (21)	W (22)	W (23)	W (24)
LBS/IN	K (1)	K (2)	K (3)	K (4)	K (5)	K (6)	K (7)	K (8)
	K (9)	K (10)	K (11)	K (12)	K (13)	K (14)	K (15)	K (16)
	K (17)	K (18)	K (19)	K (20)	K (21)	K (22)	K (23)	K (24)
SQ IN	AREA (1)	AREA (2)	AREA (3)	AREA (4)	AREA (5)	AREA (6)	AREA (7)	AREA (8)
	AREA (9)	AREA (10)	AREA (11)	AREA (12)	AREA (13)	AREA (14)	AREA (15)	AREA (16)
	AREA (17)	AREA (18)	AREA (19)	AREA (20)	AREA (21)	AREA (22)	AREA (23)	AREA (24)
%	RU (1) %	RU (2) %	RU (3) %	RU (4) %	RU (5) %	RU (6) %	RU (7) %	RU (8) %
	RU (9) %	RU (10) %	RU (11) %	RU (12) %	RU (13) %	RU (14) %	RU (15) %	RU (16) %
	RU (17) %	RU (18) %	RU (19) %	RU (20) %	RU (21) %	RU (22) %	RU (23) %	RU (24) %
INCHES	SLACK (1)	SLACK (2)	SLACK (3)	SLACK (4)	SLACK (5)	SLACK (6)	SLACK (7)	SLACK (8)
	SLACK (9)	SLACK (10)	SLACK (11)	SLACK (12)	SLACK (13)	SLACK (14)	SLACK (15)	SLACK (16)
	SLACK (17)	SLACK (18)	SLACK (19)	SLACK (20)	SLACK (21)	SLACK (22)	SLACK (23)	SLACK (24)

NOTES: ONE OR MORE PROBLEMS MUST BE LISTED ON PAGE 2

W'S AND AREAS 1 TO P INCL.; K'S AND SLACK'S 1 TO P-1 INCL.; RU'S 1 TO P+1 INCL. (P+1 IS % RU UNDER POINT OF PILE.)

	PILE DRIVING ANALYSIS TEXAS A&M UNIVERSITY	BY :	DATE :	PAGE # 2 OF 2

PROB	W(I) POUNDS	NC	K(NC) POUNDS/INCH	EFF.	ENERGY	ERES (1)	ERES (2)	ERES (3)	RU (TOTAL) POUNDS	% AT POINT	MO	Q POINT	Q SIDE	J POINT	J SIDE	FEXP	OPTIONS 11 12 13 14 15
1																	
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	
10																	
11																	
12																	
13																	
14																	
15																	
16																	
17																	
18																	
19																	
20																	

NOTE : IF OPTION #11 = 1, RU (TOTAL) NOT REQUIRED

Options: 11 NO. OF CALCULATIONS; 12 RESISTANCE; 13 PLOT; 14 GRAVITY; 15 PRINT OUT

References

1. Smith, E. A. L., "Pile Driving Analysis by the Wave Equation," Journal of the Soil Mechanics and Foundations Division, *Proceedings of the American Society of Civil Engineers*, Proceedings Paper 2574, SM 4, August, 1960, pp. 35-61.
2. Hirsch, T. J. and T. C. Edwards, "Impact Load-Deformation Properties of Pile Cushioning Materials," Research Report 33-4, Project 2-5-62-33, Piling Behavior, Texas Transportation Institute, Texas A&M University, College Station, Texas, May, 1966, 12 pgs.
3. Smith, *op. cit.*, p. 47.
4. Samson, C. H., Hirsch, T. J. and L. L. Lowery, "Computer Study of Dynamic Behavior of Piling," Journal of the Structural Division, *Proceedings of the American Society of Civil Engineers*, Proceedings Paper 3608, ST 4, August, 1963, p. 419.
5. Smith, *op. cit.*, p. 44.

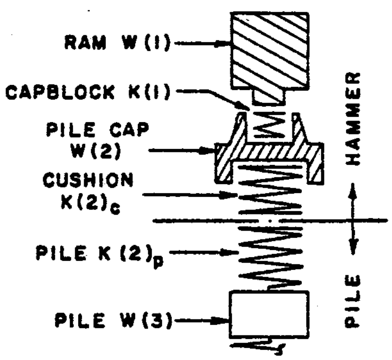
Appendix A

PILE DRIVING HAMMERS

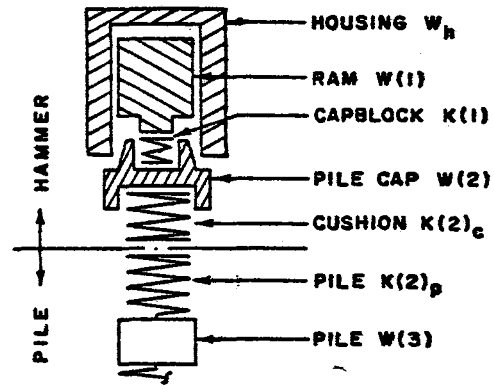
Table A1 and A2 list the information needed for the simulation of the most common type of pile driving hammers.

Equations (5) through (7), in the text, may be used to calculate the kinetic energy for a specific ram stroke. Capblock and cushion stiffness can be calculated using the equation in Figures 2 through 4 of the text. When it is necessary to calculate the coefficient of restitution of combined spring stiffnesses, Equation (4) of the text should be used.

The mechanical properties of selected cushion and capblock materials can be found in Reference 2 of the text.



DROP HAMMERS
SINGLE ACTING STEAM HAMMERS
(A)

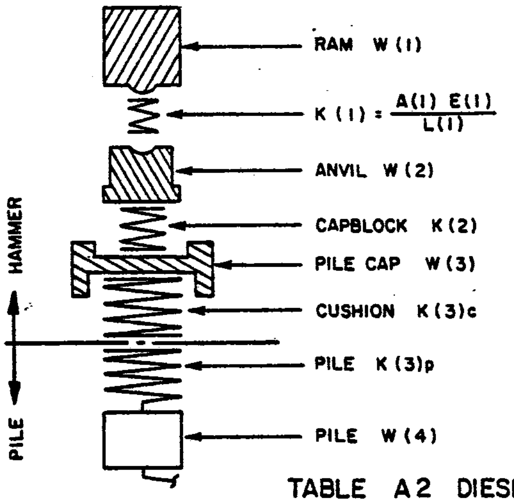


DOUBLE AND DIFFERENTIAL ACTING STEAM HAMMERS
(B)

TABLE A 1 DROP HAMMERS AND STEAM HAMMERS

HAMMER	TYPE	W (1) (LB.)	W (2)* (LB.)	W(h) (LB.)	K (1) (LB./IN.)	K (2)c (LB./IN.)	K (2)p (LB./IN.)	STROKE h, (FT.)	P rated (PSI)	EFF. e_f
MKT S3	A	3000	—	—	DEPENDS ON MATERIAL PROPERTIES & DIMENSIONS	DEPENDS ON MATERIAL PROPERTIES & DIMENSIONS	$K(2)_p = \frac{A(2)\,E(2)}{L(2)}$	3.00	—	0.80
MKT S5	A	5000	—	—				3.25	—	0.80
VULCAN 1	A	5000	1000	—				3.00	—	0.80
VULCAN 2	A	3000	1000	—				2.42	—	0.80
VULCAN 30C	B	3000	1000	4036				1.04	120	0.85
VULCAN 50C	B	5000	1000	6800				1.29	120	0.85
VULCAN 80C	B	8000	2000	9885				1.38	120	0.85
VULCAN 140C	B	14000	—	13984				1.29	140	0.85

* REPRESENTATIVE VALUES FOR PILE NORMALLY USED IN HIGHWAY CONSTRUCTION



NOTES FOR TABLE A2

* for actual stroke use field observations (may vary from 4.0 to 8.0 ft.)

** determine from bounce chamber pressure ($h_e = E/W(1)$ where E = Indicated Energy)

† average values

TABLE A2 DIESEL HAMMERS

TYPE HAMMER	W(1) (LB.)	W(2) (LB.)	W(3)† (LB.)	K(1) x10^6 (LB./IN.)	K(2) x10^6 (LB./IN.)	$K(3)_c$	$K(3)_p$	MAX h_e (FT.)	C (FT.)	E_n (FT.-LB.)	EXPLOSIVE FORCE (LB.)	e_f
MKT DE-20	2000	640	All sq. concrete — 1300 All wood — 690 All H-bearing — 1000 All pipe — 1000		14.2	VARIES	$K(3) = \frac{A(3)\,E(3)}{L(3)}$	8.00*	0.92	$E_n = W(1)(h_e - C)$ DEPENDS ON RAM STROKE h_e	46300	1.00
MKT DE-30	2800	775		38.7	63.8			8.00*	1.04		98000	1.00
MKT DE-40	4000	1350			101.0			8.00*	1.16		138000	1.00
DELMAG D 5	1100	330		18.5	13.6			8.00*	0.83		46300	1.00
DELMAG D 12	2750	816		31.5	18.6			8.00*	1.08		93700	1.00
DELMAG D 22	4850	1576		49.7	23.8			8.00*	1.08		158700	1.00
DELMAG D 44	9500	4081		106.2	56.5			8.00*	1.19		200000	1.00
LINK-BELT 180	1724	377		44.5	15.5			4.63**	0.64		81000	1.00
LINK-BELT 312	3857	1188		142.5	18.6			3.87**	0.50		98000	1.00
LINK-BELT 440	4000	705		138.0	18.6			4.55**	1.25		98000	1.00
LINK-BELT 520	5070	1179		108.5	18.6			5.20**	0.83		98000	1.00

Appendix B

SAMPLE PROBLEM

Consider the pile shown in Figure B-1.

Pile: 16 in. square prestressed concrete pile, 26 ft. in length. The modulus of the concrete is 7.82×10^6 psi and its unit weight is 154 lb./ft.^{3}. The pile is assumed to be embedded for its full length.

Pile hammer: Hypothetical diesel hammer with 4850 lb. ram with an input ram kinetic energy of 39,800 ft. lb. The explosive force produced by the diesel fuel is 158,700 lb. The stiffness of the ram is given as 42.25×10^6 lb./in. The anvil is assumed rigid and weighs 1150 lb. The capblock stiffness is 24.5×10^6 lb./in.

In order to illustrate the utilization of the input data sheets and explain the output data sheets four problems are considered.

Problem 1 and Problem 2 are concerned with the driving effects produced by two different cushions. The object of these two cases is to determine the dynamic-static resistance curves (RU(TOTAL) VS. BLOWS/IN.) for one blow of the hammer. In Problem 1, the cushion is assumed to have a cross sectional area equal to that of the pile, is 6¼ in. thick and has a modulus of elastacity of 1.0×10^6 psi. In Problem 2 the cushion area and properties are the same as in Problem 1 but the thickness is 3⅛ in. In Problems 1 and 2 the soil side friction is assumed to have a triangular distribution with 10% point resistance. The soil constants are:

(a) $Q = Q' = 0.10$ in.

(b) $J = 0.15$ sec./ft.

(c) $J' = 0.05$ sec./ft.

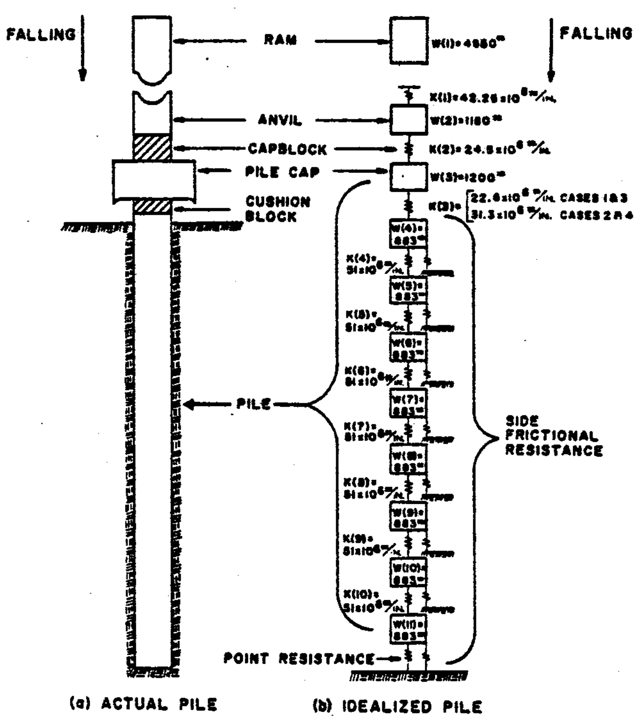


Figure B-1. Sample problem.

Problem 3 and 4 illustrate the use of program to investigate the penetration of a pile to 200 tons of static soil resistance produced by one blow of the hammer. In Problem 3 the soil resistance is distributed uniformly along the side with 10% at the point. The cushion is the same as in Case 1. In Problem 4 the soil has a triangular distribution along the side with 10% soil resistance (same as Problem 2). The cushion is the same as in Problem 2. Problem 4 will also illustrate the use of the output option (OPTION 15).

The following calculations illustrate the computations for the hammer and pile idealization.

(a) Pile: The pile is broken into eight equal length segments of 39 in. The spring stiffness for each segment is,

$$K(3)_p = \frac{A(3)_p E(3)_p}{L(3)_p}$$

where

$A(3)_p = 254$ in.^{2}

$E(3)_p = 7.32 \times 10^6$ psi

$L(3)_p = 39$ in.

therefore

$$K(3)_p = \frac{(254)\ (7.32 \times 10^6)}{39} = 51.0 \times 10^6 \text{ lb./in.}$$

(b) Cushion: Spring K(3) in Figure B1 (b) represents the combined stiffness of the cushion and first pile segment.

In Problem 1 and 3

$$K(3)_C = \frac{A(3)_C\ E(3)_C}{L(3)_C}$$

where

$A(3)_C = 254$ in.^{2}

$E(3)_C = 1.00 \times 10^6$ psi

$L(3)_C = 6.25$ in.

then

$$K(3)_C = \frac{(254)\ (1 \times 10^6)}{6.25} = 40.5 \times 10^6 \text{ lb./in.}$$

The combined stiffness of $K(3)_C$ and $K(3)_p$ is

$$K(3) = \frac{K(3)_C \times K(3)_p}{K(3)_C + K(3)_p} = \frac{(40.5)\ (51.0)\ (10^6)}{(40.5 + 51.0)\ (10^6)}$$

$$K(3) = 22.6 \times 10^6 \text{ lb./in.}$$

The coefficient of restitution for the combined springs is assumed to be 0.50.

For Problem 2 and 4 similar calculation yields

$$K(3) = 31.3 \times 10^6 \text{ lb./in.}$$

The output data sheets are completed as follows:

Page 1 (Same for all 4 problems)

No. of Problems = 4, there are 4 problems to be solved on page 2.

1/DELTA T = 0.0, since the program will calculate the correct value.

P = 11, there are 11 weights (3 for the hammer and 8 for the pile).

SLACK'S = all set equal to 1000 since there is complete looseness between the ram, anvil, capblock, pile cap, cushion, and pile head.

OPTION 1 = 2, all areas are entered manually in AREA rows.

OPTION 2 = 1, since OPTION 12 is used to describe the soil distribution.

OPTION 3 = 1, all pile segments are connected, hence SLACK (4) to SLACK (10) = 0.0.

OPTION 4 = left blank since it is desired to use the A&M routine.

IPRINT = 10, in Problem 4, OPTION 15 = 2, it is desired to print output every 10 iterations.

NSEG1 = 4, the first pile segment, see Figure B1 (b).

W'S = enter the weight of each element in lb. Note that W(1) is blank since it will be entered on page 2.

K'S = enter all spring stiffnesses for the pile system considered to be basic, i.e., the program will automatically reset the stiffnesses to these values after each problem on page 2.

A'S = enter all cross sectional areas of pile segments only.

Page 2—Problem 1

W(1) = 4850 lb., the ram weight.

NC = 3, the cushion spring number, see Figure B1 (b).

K(NC) = K(3) = 22,500,000, the stiffness of the combined springs.

EFF = 1.00, diesel hammers are considered to be 100% efficient.

ENERGY = 39,800, the input energy for this particular hammer blow.

ERES(1) = 0.60, coefficient of restitution of steel on steel impact.

ERES(2) = 0.80, coefficient of restitution of capblock material.

ERES(3) = 0.50, coefficient of restitution of combined cushion and first pile spring.

RU(TOTAL) = leave blank, since OPTION 11 = 1, i.e., the program will generate suitable values for curve generation.

% AT POINT = 10%.

MO = 4, the first pile segment with side soil resistance.

QPOINT = 0.10, Q.

QSIDE = 0.10, Q'.

JPOINT = 0.15, J.

JSIDE = 0.05, J'.

FEXP = 158,700, lb. the diesel explosive force.

OPTION 11 = 1, for program generated RU(TOTAL) VS. BLOWS/IN. curve.

OPTION 12 = 2, for triangular side soil resistance distribution.

OPTION 13 = leave blank since computer plotted curve is not desired.

OPTION 14 = 1, to indicate gravity.

OPTION 15 = 1, for normal data output.

PILE DRIVING ANALYSIS
TEXAS A&M UNIVERSITY

BY: A. Aggie DATE: 8/21/67 PAGE #1 OF 2

CASE NO.	NO. OF PROBS.	1/DELTA T	P	SLACK (1)	SLACK (2)	SLACK (3)	OPTIONS 1 (AREAS)	2 (RU'S)	3 (SLACK)	4	IPRINT USED WHEN OPTION15=2	NSEG1
HPS 10	4	0.0	11	1000.	1000.	1000.	2	1	1		10	4

LBS.	W (1)	W (2)	W (3)	W (4)	W (5)	W (6)	W (7)	W (8)
		1150	1200	883	883	883	883	883
	W (9)	W (10)	W (11)	W (12)	W (13)	W (14)	W (15)	W (16)
	883	883	883					
	W (17)	W (18)	W (19)	W (20)	W (21)	W (22)	W (23)	W (24)
LBS/IN.	K (1)	K (2)	K (3)	K (4)	K (5)	K (6)	K (7)	K (8)
	4220000	24500000	22600000	51000000	51000000	51000000	51000000	51000000
	K (9)	K (10)	K (11)	K (12)	K (13)	K (14)	K (15)	K (16)
	51000000	51000000						
	K (17)	K (18)	K (19)	K (20)	K (21)	K (22)	K (23)	K (24)
SQ. IN.	AREA (1)	AREA (2)	AREA (3)	AREA (4)	AREA (5)	AREA (6)	AREA (7)	AREA (8)
	10	10	254	254	254	254	254	254
	AREA (9)	AREA (10)	AREA (11)	AREA (12)	AREA (13)	AREA (14)	AREA (15)	AREA (16)
	254	254	254					
	AREA (17)	AREA (18)	AREA (19)	AREA (20)	AREA (21)	AREA (22)	AREA (23)	AREA (24)
%	RU (1) %	RU (2) %	RU (3) %	RU (4) %	RU (5) %	RU (6) %	RU (7) %	RU (8) %
	RU (9) %	RU (10) %	RU (11) %	RU (12) %	RU (13) %	RU (14) %	RU (15) %	RU (16) %
	RU (17) %	RU (18) %	RU (19) %	RU (20) %	RU (21) %	RU (22) %	RU (23) %	RU (24) %
INCHES	SLACK (1)	SLACK (2)	SLACK (3)	SLACK (4)	SLACK (5)	SLACK (6)	SLACK (7)	SLACK (8)
	SLACK (9)	SLACK (10)	SLACK (11)	SLACK (12)	SLACK (13)	SLACK (14)	SLACK (15)	SLACK (16)
	SLACK (17)	SLACK (18)	SLACK (19)	SLACK (20)	SLACK (21)	SLACK (22)	SLACK (23)	SLACK (24)

NOTES: ONE OR MORE PROBLEMS MUST BE LISTED ON PAGE 2

W's AND AREAS 1 TO P INCL.; K's AND SLACK's 1 TO P-1 INCL.; RU's 1 TO P+1 INCL. (P+1 IS % RU UNDER POINT OF PILE.)

Page 2, Problem 2

Only the value of K(3) is changed.

NC = 3.

K(NC) = K(3) = 31,300,000.

Page 2, Problem 3

The value of K(3) and the OPTIONS are changed.

NC = 3.

K(NC) = K(3) = 22,500,000.

RU(TOTAL) = 400,000, lb. for a 200 ton total static soil resistance.

OPTION 11 = 2, for single calculation using RU (TOTAL) = 400,000.

OPTION 12 = 1, for uniform side soil resistance distribution.

Page 2, Problem 4

In this problem the cushion and the options are changed.

NC = 3.

K(NC) = K(3) = 31,300,000.

OPTION 12 = 2, for triangular side soil resistance distribution.

OPTION 15 = 2, for output at interval expressed by IPRINT on page 1.

The output for the four sample problems are shown in Figures B2 through B6. Figure B2 is the output for one point on the RU(TOTAL) VS. BLOWS/INCH curve generated for Problem 1. The block of data on the upper part of the figure is a printout of the input data. The RU(TOTAL) value of 1,040,962.1 is the total static soil resistance for which this problem was run. This value was generated by the program and is only one point of 10 used to develop the data for the total RU(TOTAL) VS. BLOWS/INCH curve shown in Figure B3. The second block of data shows the maximum compressive and tensile stresses and the maximum displacement of each segment. The column labeled TIME N is the time interval at which the maximum compressive stress (MAX C STRESS) occurred, i.e., the maximum compressive stress of 7432 psi occurred in segment 3 at time interval 11 (11/9443.9 sec.). Similar data is printed for each point on the RU(TOTAL) VS. BLOWS/INCH shown in Figure B3.

Figure B4 shows the summary of the data for the RU(TOTAL) VS. BLOWS/INCH for Problems 1 and 2. Data of this type can be used to construct curves like that shown in Figure B3. These curves can be used to compare the effects of cushion stiffness (the cushion stiffness, $K(3)_C$, in Problem 2 was twice that in Problem 1). Note the stiffer cushion (Problem 2) produces the most efficient driving since for a specified resistance the penetration per blow is larger (BLOWS/IN. is smaller).

Figure B5 is a typical output when RU(TOTAL) is specified. The maximum penetration of the point of the pile under one blow of the hammer is 0.473011 in., listed

PILE DRIVING ANALYSIS
TEXAS A&M UNIVERSITY

BY: A. Aggie — DATE: 8/31/67 — PAGE #2 OF 2

PROB	W(I) POUNDS	NC	K(NC) POUNDS/INCH	EFF.	ENERGY	ERES (1)	ERES (2)	ERES (3)	RU (TOTAL) POUNDS	% AT POINT	MO	Q POINT	Q SIDE	J POINT	J SIDE	FEXP	OPTIONS 11	12	13	14	15
1	4850	3	22500000	100	39800	060	080	050		10	4	010	010	015	005	15870	1	2		1	1
2	〃	〃	31300000	〃	〃	〃	〃	〃		〃	〃	〃	〃	〃	〃	〃	1	2		1	1
3	〃	〃	22500000	〃	〃	〃	〃	〃	400000	〃	〃	〃	〃	〃	〃	〃	2	1		1	1
4	〃	〃	31300000	〃	〃	〃	〃	〃	400000	〃	〃	〃	〃	〃	〃	〃	2	2		1	2
5																					
6																					
7																					
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NOTE: IF OPTION #11 = 1, RU (TOTAL) NOT REQUIRED

NO. OF CALCULATIONS / RESISTANCE / PLOT / GRAVITY / PRINT OUT

TEXAS A & M UNIVERSITY PILE DRIVING ANALYSIS CASE NO.HSP 10 PROBLEM NO. 1 OF 4

1/DELTA T	P	OPTIONS 1	2	3	4	11	12	13	14	15	EXP. FORCE
9443.9	11	2	1	1	2	1	2	0	1	1	158700.

ENERGY	HAMMER EFFIENCY	RU(TOTAL)	PERCENT UNDER POINT	MO	Q(POINT)	Q(SIDE)	J(POINT)	J(SIDE)	N2
39800.00	1.00	1040962.1	10.0	4	0.10	0.10	0.15	0.05	125

M	W(M)	K(M)	AREA(M)	RU(M)	SLACK(M)	ERES(M)	VSTART(M)	KPRIME(M)
1	4850.000	0.4220000E 08	1.000	0.0	1000.000	0.60	22.99	0.0
2	1150.000	0.2450000E 08	1.000	0.0	1000.000	0.80	0.0	0.0
3	1200.000	0.2250000E 08	254.000	0.0	1000.000	0.50	0.0	0.0
4	983.000	0.5100000E 08	254.000	14638.531	0.0	1.00	0.0	0.1463853E 06
5	883.000	0.5100000E 08	254.000	43915.594	0.0	1.00	0.0	0.4391561E 06
6	883.000	0.5100000E 08	254.000	73192.625	0.0	1.00	0.0	0.7319265E 06
7	883.000	0.5100000E 08	254.000	102469.687	0.0	1.00	0.0	0.1024697E 07
8	883.000	0.5100000E 08	254.000	131746.750	0.0	1.00	0.0	0.1317467E 07
9	883.000	0.5100000E 08	254.000	161023.812	0.0	1.00	0.0	0.1610238E 07
10	883.000	0.5100000E 08	254.000	190300.875	0.0	1.00	0.0	0.1903009E 07
11	883.000	0.1040962E 07	254.000	219577.937	1000.000	1.00	0.0	0.2195780E 07
12	-0.0	-0.0	-0.0	104096.125	-0.0	-0.0	-0.0	0.0

SEGMENT	AREA	TIME N	MAX C STRESS	TIME N	MAX T STRESS	DMAX(M)	D(M)	V(M)
1	1.000	4	2883699.	0	-0.0	0.487338	0.486179	-0.50
2	1.000	7	2245092.	0	-0.0	0.430214	0.430214	4.07
3	254.000	11	7432.	42	-0.0	0.359616	0.359616	-1.17
4	254.000	13	7324.	0	-0.0	0.238627	0.223646	-3.80
5	254.000	15	7107.	0	-0.0	0.231331	0.211913	-1.14
6	254.000	17	6883.	0	-0.0	0.215890	0.204061	0.57
7	254.000	19	6633.	34	1.	0.203751	0.198904	-2.68
8	254.000	21	6344.	34	172.	0.190195	0.188150	-2.55
9	254.000	23	5834.	29	1973.	0.182027	0.174308	0.39
10	254.000	35	4195.	30	2491.	0.172878	0.168807	-0.03
11	254.000	27	1320.	0	-0.0	0.167608	0.166761	-1.43

PERMANENT SET OF PILE = 0.06760806 INCHES NUMBER OF BLOWS PER INCH = 14.79113579 TOTAL INTERVALS = 49

Figure B-2. Normal output (option 15 = 1) for prob. 1.

under DMAX(M), and the permanent set is 0.473011 (the ground quake Q) or 0.373911 in. Note that the input data is listed as well as the maximum stresses and the displacement of each segment.

Figure B6 is a sampling of the output when data is desired at some specified interval (OPTION 15 = 2, IPRINT = 1). The input information is listed in the first block of data. The next two blocks show the stresses at time interval N = 0 and N = 1. The data is defined as follows:

- D(M) = displacement of each mass point, (in.),
- C(M) = the compression in each spring, (in.),
- STRESS(M) = stress in each segment, (psi),
- F(M) = force in each spring, (lb.),
- R(M) = force in each soil spring, (lb.),
- W(M) = weight of each segment, (lb.),
- V(M) = velocity of each segment, (fps),
- DPRIME(M) = elastic displacement of soil, (in.),
- KPRIME(M) = soil spring stiffness, (lb./in.),
- FMAXC(M) = maximum compressive force in segment, (lb.), and
- FMAXT(M) = maximum tensile force in segment, (lb.).

Time interval N = 0 is for the pile under the influence of gravity alone. The particular output listed in Figure B6 shows that the point of the pile of Problem 4 would penetrate 0.002353 in. under gravity alone.

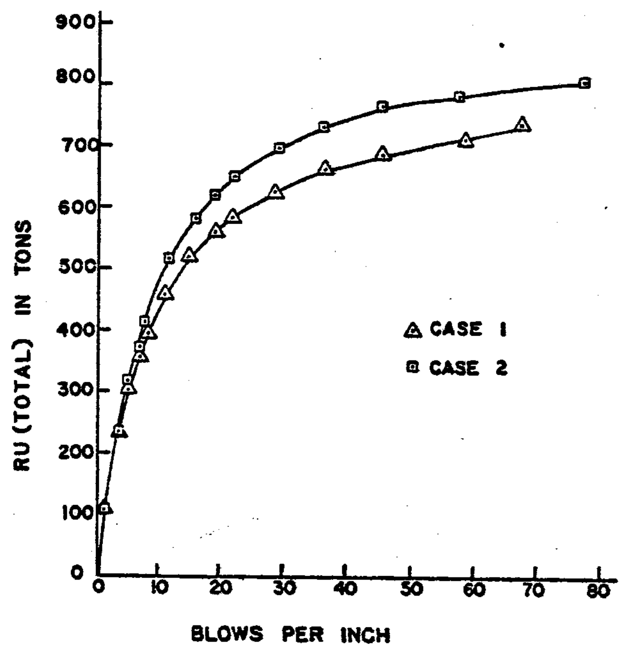

Figure B-3. Effect of varying cushion stiffness.

PILE DRIVING ANALYSIS   CASE NUMBER HSP 10   PROBLEM NUMBER

QPOINT = 0.10   JPOINT = 0.15

BLOWS PER IN.	RUTOTAL		POINT FORCE	MAX C STRESS	SEG	MAX T STRESS	SEG
1.0733	213593.-	107.T	92981.	7321.	4	4411.	10
3.3072	462346.-	231.T	185557.	7322.	4	3706.	10
4.9401	601539.-	301.T	232773.	7322.	4	3358.	10
6.6525	708095.-	354.T	266561.	7323.	4	3112.	10
8.1351	785875.-	393.T	285066.	7323.	4	2955.	10
10.7809	917031.-	459.T	312727.	7324.	4	2708.	10
14.7911	1040962.-	520.T	335193.	7324.	4	2491.	10
18.8100	1118220.-	559.T	350215.	7324.	4	2362.	10
21.5075	1166279.-	583.T	359397.	7324.	4	2285.	10
28.2780	1255360.-	628.T	375508.	7325.	4	2148.	10
36.2405	1321145.-	661.T	386685.	7325.	4	2051.	10
44.9512	1371145.-	686.T	394790.	7325.	4	1981.	10
58.1772	1421145.-	711.T	402573.	7325.	4	1908.	10
67.8860	1471145.-	736.T	410044.	7325.	4	1836.	10

PILE DRIVING ANALYSIS   CASE NUMBER HSP 10   PROBLEM NUMBER 2

QPOINT = 0.10   JPOINT = 0.15

BLOWS PER IN.	RUTOTAL		POINT FORCE	MAX C STRESS	SEG	MAX T STRESS	SEG
1.0377	213593.-	107.T	96645.	7664.	4	4171.	10
3.1615	470888.-	235.T	196306.	7663.	4	3412.	10
4.8150	622323.-	311.T	247556.	7662.	4	3083.	10
6.5367	736804.-	368.T	283048.	7662.	4	2857.	10
7.5466	819918.-	410.T	307190.	7661.	4	2703.	10
11.4121	1025674.-	513.T	361561.	7661.	4	2352.	10
15.8643	1158745.-	579.T	392988.	7660.	4	2145.	10
18.7758	1233466.-	617.T	409456.	7660.	4	2035.	10
22.0974	1297626.-	649.T	420576.	7659.	4	1950.	10
29.3317	1394207.-	697.T	430297.	7659.	4	1840.	10
36.8446	1460959.-	730.T	436023.	7659.	4	1766.	10
45.1832	1510959.-	755.T	439816.	7659.	4	1713.	10
57.8852	1560959.-	780.T	443210.	7658.	4	1663.	10
77.6870	1610959.-	805.T	446224.	7658.	4	1613.	10

Figure B-4. Summary output for RU(total) vs blows/in. (option 11 = 1) for prob. 1 and 2.

TEXAS A • M UNIVERSITY   PILE DRIVING ANALYSIS   CASE NO.HSP 10   PROBLEM NO. 3 OF 4

1/DELTA T	P	OPTIONS 1	2	3	4	11	12	13	14	15	EXP. FORCE
9443.9	11	2	1	1	2	2	1	0	1	1	158700.

ENERGY	HAMMER EFFIENCY	RU(TOTAL)	PERCENT UNDER POINT	MO	Q(POINT)	Q(SIDE)	J(POINT)	J(SIDE)	N2
39800.00	1.00	400000.0	10.0	4	0.10	0.10	0.15	0.05	142

M	W(M)	K(M)	AREA(M)	RU(M)	SLACK(M)	ERES(M)	VSTART(M)	KPRIME(M)
1	4850.000	0.4220000E 08	1.000	0.0	1000.000	0.60	22.99	0.0
2	1150.000	0.2450000E 08	1.000	0.0	1000.000	0.80	0.0	0.0
3	1200.000	0.2250000E 08	254.000	0.0	1000.000	0.50	0.0	0.0
4	883.000	0.5100000E 08	254.000	45000.000	0.0	1.00	0.0	0.4500001E 06
5	883.000	0.5100000E 08	254.000	45000.000	0.0	1.00	0.0	0.4500001E 06
6	883.000	0.5100000E 08	254.000	45000.000	0.0	1.00	0.0	0.4500001E 06
7	883.000	0.5100000E 08	254.000	45000.000	0.0	1.00	0.0	0.4500001E 06
8	883.000	0.5100000E 08	254.000	45000.000	0.0	1.00	0.0	0.4500001E 06
9	883.000	0.5100000E 08	254.000	45000.000	0.0	1.00	0.0	0.4500001E 06
10	883.000	0.5100000E 08	254.000	45000.000	0.0	1.00	0.0	0.4500001E 06
11	883.000	0.3999999E 06	254.000	45000.000	1000.000	1.00	0.0	0.4500001E 06
12	-0.0	-0.0	-0.0	39999.984	-0.0	-0.0	-0.0	0.0

SEGMENT	AREA	TIME N	MAX C STRESS	TIME N	MAX T STRESS	DMAX(M)	D(M)	V(M)
1	1.000	4	2883701.	0	-0.0	0.502888	0.375493	-4.67
2	1.000	7	2245095.	93	-0.0	0.688212	0.688212	1.00
3	254.000	11	7445.	97	-0.0	0.608394	0.606307	1.22
4	254.000	13	7258.	41	2537.	0.497042	0.495229	-2.50
5	254.000	15	7017.	39	3001.	0.489747	0.489520	-0.17
6	254.000	17	6826.	38	2655.	0.484540	0.484376	1.46
7	254.000	19	6656.	35	2477.	0.481653	0.481653	0.52
8	254.000	21	6493.	34	3081.	0.479475	0.479301	-0.90
9	254.000	23	6133.	29	3078.	0.474198	0.473951	0.21
10	254.000	24	4278.	30	4194.	0.475263	0.470868	1.83
11	254.000	27	647.	0	-0.0	0.473911	0.473011	-1.43

PERMANENT SET OF PILE = 0.37391138 INCHES   NUMBER OF BLOWS PER INCH = 2.67442989   TOTAL INTERVALS = 98

Figure B-5. Normal output for single RU(total) (option 11 = 2) for prob. 3.

```
TEXAS A * M UNIVERSITY        PILE DRIVING ANALYSIS      CASE NO.HSP 10      PROBLEM NO.   4 OF  4
  1/DELTA T    P      OPTIONS     1    2    3    4            11   12   13   14   15            EXP. FORCE
    9443.9    11                  2    1    1    2             2    2    0    1    2             159700.
ENERGY     HAMMER EFFIENCY          RU(TOTAL)   PERCENT UNDER POINT    MO  Q(POINT)   Q(SIDE)  J(POINT)  J(SIDE)     N2
 39900.00        1.00               400000.0               10.0          4     0.10      0.10      0.15     0.05     140
```

M	W(M)	K(M)	AREA(M)	RU(M)	SLACK(M)	ERES(M)	VSTART(M)	KPRIME(M)
1	4850.000	0.4220000E 08	1.000	0.0	1000.000	0.60	22.99	0.0
2	1150.000	0.2450000E 08	1.000	0.0	1000.000	0.80	0.0	0.0
3	1200.000	0.3130000E 08	254.000	0.0	1000.000	0.50	0.0	0.0
4	883.000	0.5100000E 08	254.000	5625.000	0.0	1.00	0.0	0.5625002E 05
5	883.000	0.5100000E 08	254.000	16875.000	0.0	1.00	0.0	0.1687500E 06
6	883.000	0.5100000E 08	254.000	28125.000	0.0	1.00	0.0	0.2812501E 06
7	883.000	0.5100000E 08	254.000	39375.000	0.0	1.00	0.0	0.3937501E 06
8	883.000	0.5100000E 08	254.000	50625.000	0.0	1.00	0.0	0.5062501E 06
9	883.000	0.5100000E 08	254.000	61875.000	0.0	1.00	0.0	0.6187502E 06
10	883.000	0.5100000E 08	254.000	73125.000	0.0	1.00	0.0	0.7312502E 06
11	883.000	0.3999999E 06	254.000	84375.000	1000.000	1.00	0.0	0.8437502E 06
12	-0.0	-0.0	-0.0	39999.984	-0.0	-0.0	-0.0	0.0

TIME INTERVAL N = 0   NET PENETRATION = 0.0   N1 = 140   N2 =

SEGMENT M	D(M)	C(M)	STRESS(M)	F(M)	R(M)	W(M)	V(M)	DPRIME(M)	KPRIME(M)	FMAXC(M)	FMAXT(M)
1	0.002919	0.0	0.0	0.0	0.0	4850.00	22.988647	0.000566	0.0	0.0	0.0
2	0.002919	0.000047	1150.	1150.	0.0	1150.00	0.0	0.000566	0.0	0.0	0.0
3	0.002873	0.000075	9.	2350.	0.0	1200.00	0.0	0.000519	0.0	0.0	0.0
4	0.002797	0.000061	12.	3101.	132.	883.00	0.0	0.000444	56250.	0.0	0.0
5	0.002737	0.000070	14.	3586.	397.	883.00	0.0	0.000383	168750.	0.0	0.0
6	0.002666	0.000075	15.	3808.	662.	883.00	0.0	0.000313	281250.	0.0	0.0
7	0.002592	0.000074	15.	3764.	927.	883.00	0.0	0.000238	393750.	0.0	0.0
8	0.002518	0.000068	14.	3455.	1191.	883.00	0.0	0.000164	506250.	0.0	0.0
9	0.002450	0.000057	11.	2882.	1456.	883.00	0.0	0.000097	618750.	0.0	0.0
10	0.002394	0.000040	8.	2044.	1721.	883.00	0.0	0.000040	731250.	0.0	0.0
11	0.002353	0.0	4.	941.	1986.	883.00	0.0	0.0	843750.	0.0	0.0

TIME INTERVAL N = 1   NET PENETRATION = 0.0   N1 = 140   N2 =

SEGMENT M	D(M)	C(M)	STRESS(M)	F(M)	R(M)	W(M)	V(M)	DPRIME(M)	KPRIME(M)	FMAXC(M)	FMAXT(M)
1	0.032130	0.029211	1232689.	1232689.	0.0	4850.00	22.126266	0.000566	0.0	1232689.	0.0
2	0.002919	0.000047	1150.	1150.	0.0	1150.00	3.651348	0.000566	0.0	1150.	0.0
3	0.002873	0.000075	9.	2350.	0.0	1200.00	0.000000	0.000519	0.0	2350.	0.0
4	0.002797	0.000061	12.	3101.	132.	883.00	-0.000000	0.000444	56250.	3101.	0.0
5	0.002737	0.000070	14.	3586.	397.	883.00	-0.000000	0.000383	168750.	3586.	0.0
6	0.002666	0.000075	15.	3808.	662.	883.00	0.000000	0.000313	281250.	3808.	0.0
7	0.002592	0.000074	15.	3764.	927.	883.00	0.000000	0.000238	393750.	3764.	0.0
8	0.002518	0.000068	14.	3455.	1191.	883.00	0.000000	0.000164	506250.	3455.	0.0
9	0.002450	0.000057	11.	2882.	1456.	883.00	-0.000000	0.000097	618750.	2882.	0.0
10	0.002394	0.000040	8.	2044.	1721.	883.00	0.000000	0.000040	731250.	2044.	0.0
11	0.002353	0.0	4.	941.	1986.	883.00	-0.000000	0.0	843750.	941.	0.0

Figure B-6. Detailed output for single RU(total) (option 15 = 2) for prob. 4.

Appendix C

FORTRAN IV. PROGRAM STATEMENT

The listing that follows is known as an UNRAVI. listing. Each statement is numbered, for reference, consecutively from the first to the last statement. The variables and program statement numbers are indexed by their reference number. This listing facilitates finding each variable in the program and makes the logic much easier to follow.

```
               C       TEXAS A * M UNIVERSITY
               C       PILE DRIVING ANALYSIS BY THE WAVE EQUATION
               C       TEXAS A AND M PROGRAM REVISED 12/1/65 BY EAS
               C       PERMANENT SET,BLOWS PER INCH
               C       LCCSE,TIGHT,OR LIMITED MOTION AT JOINTS
               C       MAXIMUM STRESSES OR FORCES
               C       IOPT USED FOR OPTION.
               C       I,JT,JTM,LAMP,LAY,LT,LACK, ARE USED FOR CONTROL
               C       X AT END OF NAME = LAST PRECEDING VALUE EXCEPT IN MAX = MAXIMUM
               C       N ALWAYS MEANS NUMBER OF TIME INTERVAL.
               C       NCTATION FOLLOWS SMITHS ASCE PAPER CLOSELY. TO DECODE NOTE THAT
               C           NFMAXT = NO. OF TIME INTERVAL WHERE FORCE = MAXIMUM IN TENSION
ISN 0002        5000 REAL JPOINT,JSIDE,K,KPRIME,NPASS,NP1,KHOLD,CASE*8
ISN 0003        5001 INTEGER P,PPLUS1,PLESS1,PROB,PROBS
ISN 0004        5002 DIMENSION AREA(150),C(150),CX(150),CMAX(150),D(150),DX(150)
                    1 ,CMAX(150),DPRIME(150),ERES(150),F(150),FX(150),FMAXC(150),
                    2 FMAXT(150),K(150),KPRIME(150),LAM(150),NDMAX(150),
                    3 NFMAXC(150),NFMAXT(150),R(150),RU(150),SLACK(150),
                    4 LBLOWS(150),UFMAXC(150),URUTTL(150),V(150),
                    5  W(150),RULIST(150),RUHIL(30),RWENR(30),RWHICH(30),
                    6 XPLOT(50),YPLOT(50),STRESS(150),KHOLD(150),
                    7 FCMAX(50),NCMAX(50),FTMAX(50),NTMAX(50)
               C       24 CF EACH CF ABOVE SUFFICIENT FOR USUAL PROBLEMS
               C---- INPUT -- GENERAL
ISN 0005        5010 READ(5,5113) CASE,PROBS,TTDELT,P,SLACK(1),SLACK(2),SLACK(3),IOPT1,
                    1 ICPT2,IOPT3,IOPT4,IPRINT,NSEG1
ISN 0006             WRITE(6,5003)
ISN 0007        5003 FORMAT(1H1)
ISN 0008             IF(TTDELT.LE.0.) TTCELT=1.0
ISN 0010             IF(IOPT4.LE.0) IOPT4=2
ISN 0012             IF(IPRINT.LE.0) IPRINT=1
ISN 0014             IF(NSEG1.LE.0) NSEG1=2
ISN 0016             TCELTA=TTDELT
ISN 0017        5020 DELTAT =1./TDELTA
ISN 0018        5021 PPLUS1 = P+1
ISN 0019        5022 PLESS1 = P-1
ISN 0020        5030 READ  (5,5114)(W(M),M=1,P)
ISN 0021        5031 W(PPLUS1) = -0.0
               C-----CALCULATE PILE WEIGHT
ISN 0022             WPILE=0.
ISN 0023             DC 6 JT=NSEG1,P
ISN 0024           6 WPILE=WPILE+W(JT)
ISN 0025        5040 READ  (5,5115)(K(M),M=1,PLESS1)
               C       K(P) IS DETERMINED AT 5184
ISN 0026        5041 K(PPLUS1) = -0.0
ISN 0027        5083 DO 5084 M=1,P
ISN 0028             KHCLD(M)=K(M)
ISN 0029        5084 AREA(M) = 1.0
ISN 0030        5086 AREA(PPLUS1) = -0.0
ISN 0031        5087 IF(IOPT1-2)5090,5088,5088
ISN 0032        5088 READ  (5,5114)(AREA(M),M=1,P)
ISN 0033             IF(AREA(1).LE.0.) AREA(1)=1.0
ISN 0035             IF(AREA(P).LE.0.) AREA(P)=1.0
ISN 0037        5090 IF(IOPT2-2)5100,5092,5092
ISN 0038        5092 READ (5,5116)(RULIST(M),M=1,PPLUS1)
ISN 0039        5100 IF(IOPT3-2)5101,5104,5104
ISN 0040        5101 DO 5102 M=4,PLESS1
ISN 0041        5102 SLACK(M) = 0.0
ISN 0042        5103 GO TO 5105
ISN 0043        5104 READ (5,5114)(SLACK(M),M=1,PLESS1)
ISN 0044        5105 SLACK(P) = 1000.0
ISN 0045        5106 SLACK(PPLUS1) =  -0.0
ISN 0046        5110 DC 5111 M=4,P
ISN 0047        5111 ERES(M) = 1.0
ISN 0048        5112 ERES(PPLUS1) = -0.0
ISN 0049        5113 FORMAT(A6,I3,F10.4,I3,3F7.3,4I1,1XI3,I2)
ISN 0050        5114 FCRMAT(8F10.3)
ISN 0051        5115 FCRMAT(8F10.0)
ISN 0052        5116 FCRMAT(8F10.7)
ISN 0053        5117 FORMAT (I2,F8.2,I1,F9.0,F3.2,F6.0,3F3.2,F9.1,F4.1,I3,4F3.2,F9.0
                    1,5I1)
ISN 0054        5118 FCRMAT(1H0,5H CASE,A7,4X,5H PROB,A6,74H RU PERCENTAGES ON DATA SHE
                    1ET PAGE 1 SHOULD TOTAL 100.0 BUT ACTUALLY TOTAL,F15.7)
               C---- DO 5570 SOLVES PROBLEMS ONE AFTER ANOTHER
ISN 0055             NC=1
ISN 0056        5120 DC 5570  I=1,PROBS
ISN 0057             K(NC)=KHOLD(NC)
ISN 0058        5121 READ(5,5117) PROB,W(1),NC,K(NC),EFF,ENERGY,ERES(1),ERES(2),ERES(3)
                    1 ,RUSUM,PERCNT,MO,QPOINT,QSIDE,JPOINT,JSIDE,FEXP,IOPT11,
                    2 ICPT12,IOPT13,IOPT14,IOPT15
ISN 0059             IF(IOPT12.LE.0) IOPT12=3
ISN 0061             VSTART= SQRT(64.4*EFF*(ENERGY/W(1)))
ISN 0062             DO 9009 M=1,50
ISN 0063             FTMAX(M)=0.
ISN 0064        9009 FCMAX(M)=0.
ISN 0065             NKCNT=0
ISN 0066        5140 RUTTLX = 0.0
ISN 0067        5141 BLCWSX = 0.0
ISN 0068        5150 V(1) = VSTART
ISN 0069        5152 LT = 0
               C---- FIRST DETERMINE VALUE OF RUTOTL
ISN 0070        5154 IF(IOPT11-2)5151,5160,5151
```

```
                C       FOR CURVE PLOTTING
ISN 0071         5151 RUTOTL = W(1)* V(1)**2/12.0
ISN 0072         5153 GO TO 5170
                C       FOR SINGLE PROBLEM
ISN 0073         5160 RUTOTL=RUSUM
ISN 0074              GO TO 5170
                C       COMPUTER CYCLES FROM 707 NEAR END OF PROGRAM
ISN 0075          701 SLOPE = (RUTOTL-RUTTLX)/(BLOWS-BLOWSX)
ISN 0076              SLOPE=AMAX1(10000.,SLOPE)
ISN 0077              IF(BLOWS-7.0)5164,702,702
ISN 0078         5164 IF(IOPT4-2)5165,703,703
ISN 0079          702 IF(BLOWS-20.0)704,704,705
ISN 0080         5165 DB = 1.00
ISN 0081              GO TO 706
ISN 0082          703 DB = 1.25
ISN 0083              GO TO 706
ISN 0084          704 DB = 2.5
ISN 0085              GO TO 706
ISN 0086          705 DB = 5.0
ISN 0087              GO TO 706
ISN 0088          706 RUTTLX = RUTOTL
ISN 0089              RUTOTL = RUTTLX+(DB*SLOPE)
ISN 0090              BLOWSX = BLOWS
                C---- SECOND DETERMINE ALL VALUES OF RU(M)
ISN 0091         5170 DO 13 M=1,MO
ISN 0092           13 RU(M) = 0.0
ISN 0093         5171 RUPINT = (PERCNT/100.0)*RUTOTL
ISN 0094         5172 IF(IOPT12-2)143,146,5176
                C       FOR UNIFORM DISTRIBUTION
ISN 0095          143 DO 144 M=MO,P
ISN 0096          144 RU(M) = (RUTOTL-RUPINT)/FLOAT(P-MO+1)
ISN 0097         5173 RU(PPLUS1) = RUPINT
ISN 0098              GO TO 713
                C       FOR TRIANGULAR DISTRIBUTION
ISN 0099          146 DO 145 M=MO,P
ISN 0100          145 RU(M) = (2.0*(RUTOTL-RUPINT)*(FLOAT(M-MO)+0.5))/(FLOAT(P-MO+1))**2
ISN 0101         5175 RU(PPLUS1) = RUPINT
ISN 0102              GO TO 713
                C       FOR DISTRIBUTION PER RU LIST ON DATA SHEET
ISN 0103         5176 TOTAL = 0.0
ISN 0104              DO 5177 M=1,PPLUS1
ISN 0105         5177 TOTAL = TOTAL+RULIST(M)
ISN 0106         5178 IF((ABS(TOTAL-100.0))-2.0)5180,5180,5179
ISN 0107         5179 WRITE  (6,5118)CASE,PROB,TOTAL
ISN 0108              GO TO 5570
ISN 0109         5180 DO 5181 M=1,PPLUS1
ISN 0110         5181 RU(M) = (RULIST(M)/100.0)*RUTOTL
ISN 0111              GO TO 713
                C---- THIRD DETERMINE STARTING VALUES OF V(M)
ISN 0112          713 V(1)=VSTART
ISN 0113              DO 180 M=2,P
ISN 0114          180 V(M) = 0.0
ISN 0115         5183 V(PPLUS1) = -0.0
                C---- FOURTH DETERMINE VALUE FOR K(P)
ISN 0116         5184 K(P) = RU(PPLUS1)/QPOINT
                C       FIFTH CHANGE CYCLE COUNT
ISN 0117         5186 LT = LT + 1
                C----CHECK ON DELTAT
ISN 0118              CALL DELTCK(NPASS,TTDELT,P,W,K,TDELTA,DELTAT,N2)
                C----END DELTAT CHECK
                C---- ASSIGN OTHER VALUES REQUIRED (TEXAS A AND M REP1)
ISN 0119              DO 5218 M=1,P
ISN 0120           32 KPRIME(M) =RU(M)/QSIDE
ISN 0121              C(M) = 0.0
ISN 0122              F(M) = 0.0
ISN 0123              CMAX(M) = 0.0
ISN 0124              LAM(M)=1
ISN 0125              D(M) = 0.0
ISN 0126              NFMAXC(M) = 0
ISN 0127              NFMAXT(M) = 0
ISN 0128              DMAX(M) = 0.0
ISN 0129              NDMAX(M) = 0
ISN 0130              FMAXC(M) = 0.0
ISN 0131              FMAXT(M) = 0.0
ISN 0132              R(M) = 0.0
ISN 0133         5218 DPRIME(M) = 0.0
ISN 0134              KPRIME(PPLUS1)=0.
ISN 0135              DPRIMP = 0.0
ISN 0136              LAMP   = 1
                C---- SIXTH PRINT INPUT FOR ONE PROBLEM
ISN 0137         5190 WRITE  (6,5200)CASE,PROB,PROBS
ISN 0138         5191 WRITE  (6,5201)
ISN 0139         5192 WRITE(6,5202) TDELTA,P,IOPT1,IOPT2,IOPT3,IOPT4,       IOPT11,
                     1 IOPT12,IOPT13,IOPT14,IOPT15,FEXP
ISN 0140         5193 WRITE  (6,5203)
ISN 0141         5194 WRITE(6,5204) ENERGY,EFF,RUTOTL,PERCNT,MO,QPOINT,QSIDE,JPOINT,JSI
                     1DE,N2
ISN 0142         5195 WRITE  (6,5205)
ISN 0143         5196 WRITE (6,5206)(M,W(M),K(M),AREA(M),RU(M),SLACK(M),ERES(M),
                     1      V(M),KPRIME(M),M=1,PPLUS1)
ISN 0144         5200 FORMAT(///27H TEXAS A * M UNIVERSITY     ,3X,22H PILE DRIVING ANALY
                     1SIS,4X,9H CASE NO.,A7,3X,12H PROBLEM NO.,I4,3H OF,I4)
ISN 0145         5201 FORMAT(2X10H 1/DELTA T3X1HP4X62HOPTIONS     1     2     3     4
                     1        11    12    13    14    1510X10HEXP. FORCE)
ISN 0146         5202 FORMAT(F11.1,I5,11X4I5,10X5I5,F18.0)
ISN 0147         5203 FORMAT(113H ENERGY     HAMMER EFFIENCY         RU(TOTAL)    PERCENT UN
```

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                  1DER POINT   MO  O(POINT)  Q(SIDE)  J(POINT)  J(SIDE)     N2)
ISN 0148      5204 FORMAT(2F10.2,10XF12.1,F16.1,I11,F10.2,F9.2,F10.2,F9.2,I7)
ISN 0149      5206 FORMAT(I3, F14.3,E15.7,F10.3,2F14.3,F9.2,F11.2,E15.7)
ISN 0150      5205 FORMAT(3H  M,7X,5H W(M),7X,5H K(M),7X,8H AREA(M),6X,6H RU(M),7X,41
                  1H SLACK(M)  ERES(M)  VSTART(M)   KPRIME(M))
             C---- EFFECT OF GRAVITY BEFORE RAM STRIKES--TEXAS A AND M SMITHS GRAVITY
ISN 0151      5258 IF(IOPT14-2)5220,5221,5221
ISN 0152      5220 WTOTAL = 0.0
ISN 0153           RTOTAL = 0.0
ISN 0154           DO 5 JT=2,PPLUS1
ISN 0155           WTOTAL = WTOTAL + W(JT)
ISN 0156         5 RTOTAL = RTOTAL + RU(JT)
ISN 0157           DO 8 JT = 2,PLESS1
ISN 0158           R(JT) = (RU(JT)*WTOTAL)/RTOTAL
ISN 0159         8 F(JT) =  F(JT-1)+W(JT)-R(JT)
ISN 0160           IF(K(P))67,66,67
ISN 0161        66 IF(KPRIME(P))67,63,67
ISN 0162        67 D(P) = (F(PLESS1)+W(P))/(KPRIME(P)+K(P))
ISN 0163           IF(QSIDE-D(P))64,65,65
ISN 0164        64 R(P) = RU(P)
ISN 0165           F(P) = F(PLESS1) + W(P) - R(P)
ISN 0166           D(P) = F(P)/K(P)
ISN 0167           GO TO 63
ISN 0168        65 R(P) = D(P)*KPRIME(P)
ISN 0169           F(P) = D(P)* K(P)
ISN 0170        63 CONTINUE
ISN 0171           DO 111 JT = 1,PLESS1
ISN 0172           JTM = P-JT
ISN 0173           C(JTM) = F(JTM)/K(JTM)
ISN 0174           D(JTM) = D(JTM+1)+C(JTM)
ISN 0175           DPRIME(JTM) = D(JTM)-WTOTAL*QSIDE/RTOTAL
ISN 0176       111 CONTINUE
ISN 0177           DO 8000 M=1,P
ISN 0178      8000 STRESS(M)=F(M)/AREA(M)
ISN 0179      5221 N=0
ISN 0180           LAY = 1
ISN 0181      5230 IF(IOPT15-2)5240,5231,5240
ISN 0182      5231 WRITE(6,5234)N,DPRIPP,N2
ISN 0183      5232 WRITE  (6,5235)
ISN 0184      5233 WRITE(6,5236)(M,D(M),C(M),STRESS(M),F(M),R(M),W(M),V(M),DPRIME(M),
                  1KPRIME(M),FMAXC(M),FMAXT(M),M=1,P)
ISN 0185           NKCNT=0
ISN 0186      5234 FORMAT(//18H TIME INTERVAL N =I6,7X18HNET PENETRATION = F10.6,
                  17X5HN1 = I5,5X5HN2 = I5)
ISN 0187      5235 FORMAT(120H SEGMENT M       D(M)        C(M)  STRESS(M)       F(M)
                 1 R(M)        W(M)         V(M) DPRIME(M) KPRIME(N)  FMAXC(M)  FMAXT(M))
ISN 0188      5236 FORMAT(I8,F11.6,F10.6,F11.0,2F10.0,F10.2,2F10.6,3F10.0)
             C---- DYNAMIC COMPUTATION BASED ON SMITHS PAPER MODIFIED (TEXAS REPN)

ISN 0189      5240 LACK = 1
ISN 0190      5241 DO 68 M=1,P
             C       68 IS BETWEEN 5439 AND 5440
ISN 0191           D(M) = D(M)+V(M)*12.0*DELTAT
ISN 0192           IF(DMAX(M)-D(M))20,21,21
ISN 0193        20 DMAX(M) = D(M)
ISN 0194           NDMAX(M) = N + 1
ISN 0195        21 CX(M) = C(M)
ISN 0196           IF(M-P)34,5400,34
ISN 0197        34 C(M) = D(M)-D(M+1)-V(M+1)*12.0*DELTAT
             C     STATEMENT 34 MUST USE A COMPUTED VALUE FOR THE ACTUAL D(M+1)
ISN 0198      5242 IF(C(M))5243,30,30
ISN 0199      5243 IF(ABS(C(M))-SLACK(M))5244,5244,5246
ISN 0200      5244 C(M) = 0.0
ISN 0201      5245 GO TO 30
ISN 0202      5246 C(M) = C(M)+SLACK(M)
             C     NOTE THAT ONLY A NEGATIVE VALUE OF C(M) RESULTS FROM 5246
ISN 0203        30 FX(M) = F(M)
             C     A TEXAS ROUTINE FOR B(M) IS OMITTED HERE
ISN 0204      5250 IF(IOPT4-2)5300,36,5300
             C---- 36 TO 35 IS A TEXAS ROUTINE REPLACING SMITH ROUTINE 3 OR 4
ISN 0205        36 IF(ABS(ERES(M)-1.0)-.00001)38,38,14
ISN 0206        38 F(M) = C(M)*K(M)
ISN 0207           GO TO 5400
ISN 0208        14 IF(C(M)-CX(M))12,35,15
ISN 0209        15 F(M) = FX(M)+((C(M)-CX(M))*K(M))
ISN 0210           GO TO 35
ISN 0211        12 F(M) = FX(M)+((C(M)-CX(M))*K(M)/ERES(M)**2)
ISN 0212        35 F(M) = AMAX1(0.0,F(M))
ISN 0213           GO TO 5400
             C     A TEXAS ROUTINE FOR GAMMA IS OMITTED HERE
             C---- SMITH ROUTINE 3 OR 4
ISN 0214      5300 IF(ERES(M)-1.00)5302,5301,5301
ISN 0215      5301 F(M) = C(M)*K(M)
ISN 0216           GO TO 5400
ISN 0217      5302 IF(C(M))5303,5303,5304
ISN 0218      5303 F(M) = 0.0
ISN 0219           GO TO 5400
ISN 0220      5304 IF(C(M)-CMAX(M))5306,5305,5305
ISN 0221      5305 CMAX(M) = C(M)
ISN 0222           F(M) = C(M)*K(M)
ISN 0223           GO TO 5400
ISN 0224      5306 F(M)=(K(M)/ERES(M)**2)*C(M)-(1./ERES(M)**2-1.)*K(M)*CMAX(M)
ISN 0225           F(M) = AMAX1(F(M),0.0)
ISN 0226           GO TO 5400
ISN 0227      5400 IF(M.GT.1) GO TO 48
ISN 0229           IF(FEXP.LE.0.) GO TO 48
ISN 0231           NP1=N+1
```

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ISN 0232          IF(NP1.GT.(0.0125/DELTAT)) GO TO 48
ISN 0234          IF(NP1-0.01/DELTAT)46,46,90
ISN 0235       46 IF(F(1)-FX(1))47,48,48
ISN 0236       47 F(1)=AMAX1(F(1),FEXP,0.)
ISN 0237          GO TO 48
ISN 0238       90 F(1)=AMAX1(0.0,FEXP*(1.0-(DELTAT*(NP1-0.01/DELTAT)/0.0025)))
ISN 0239       48 IF(KPRIME(M))50,55,50
ISN 0240       50 IF(DPRIME(M)-D(M)+QSIDE)51,52,52
ISN 0241       51 DPRIME(M) = D(M)-QSIDE
ISN 0242       52 CONTINUE
ISN 0243          IF(DPRIME(M)-D(M)-QSIDE)53,53,54
ISN 0244       54 DPRIME(M) = D(M)+CSIDE
ISN 0245       53 CONTINUE
ISN 0246     5410 LAP  =   LAM(M)
ISN 0247          GC TO(10,57),LAP
ISN 0248       10 IF(D(M)-DPRIME(M)-QSIDE)56,57,57
ISN 0249       56 R(M) = (D(M)-DPRIME(M))*KPRIME(M)*(1.0+JSIDE*V(M))
ISN 0250          GC TO 55
ISN 0251       57 R(M) = (D(M)-DPRIME(M)+JSIDE*QSIDE*V(M))*KPRIME(M)
ISN 0252          LAM(M)    = 2
ISN 0253       55 CONTINUE
ISN 0254       73 IF(M-P)71,74,71
ISN 0255       74 IF(DPRIMP-D(P)+QPOINT)75,76,76
ISN 0256       75 DPRIMP = D(P)-QPOINT
ISN 0257       76 CONTINUE
ISN 0258          LAMP = LAMP
ISN 0259          GC TO (77,78),LAMP
ISN 0260       77 IF(D(P)-DPRIMP-CPOINT)79,78,78
ISN 0261       79 F(P) = (D(P)-DPRIMP)*K(P)*(1.0+JPOINT*V(P))
ISN 0262          GC TO 171
ISN 0263       78 F(P) = (D(P)-DPRIMP+JPOINT*CPOINT*V(P))*K(P)
ISN 0264          LAMP    = 2
ISN 0265      171 F(P) = AMAX1(0.0,F(P))
ISN 0266       71 CONTINUE
            C     GRAVITY UPTION
ISN 0267     5420 IF(IOPT14-2)5421,5423,5423
ISN 0268     5421 IF(LACK-2)58,72,72
ISN 0269       58 V(1) = V(1)-(F(1)+R(1)-W(1))*32.17*DELTAT/W(1)
ISN 0270          LACK = 2
ISN 0271          GO TO 5429
ISN 0272       72 V(M) = V(M)+(F(M-1)-F(M)-R(M)+W(M))*32.17*DELTAT/W(M)
ISN 0273     5422 GO TO 5429
ISN 0274     5423 IF(LACK-2)5424,5427,5427
ISN 0275     5424 V(1) = V(1)-(F(1)+R(1))*32.17*DELTAT/W(1)
ISN 0276     5425 LACK = 2
ISN 0277          GO TO 5429
ISN 0278     5427 V(M) = V(M)+(F(M-1)-F(M)-R(M))*32.17*DELTAT/W(M)
ISN 0279     5429 CONTINUE
ISN 0280          IF(M.GT.1) GO TO 5430
ISN 0282          IF(F(1).LE.0..AND.V(1).LE.-0.1) V(1)=-VSTART
ISN 0284     5430 FMAXC(M) = AMAX1(FMAXC(M),F(M))
ISN 0285          FMAXT(M) = AMIN1(FMAXT(M),F(M))
ISN 0286     5439 IF(FMAXC(M)-F(M))166,167,166
ISN 0287      167 NFMAXC(M) = N+1
ISN 0288      166 IF(FMAXT(M)-F(M))68,69,68
ISN 0289       69 NFMAXT(M) = N+1
ISN 0290       68 STRESS(M)=F(M)/AREA(M)
ISN 0291          N=N+1
            C     THIS IS END OF DO 68 STARTING AT 5241
ISN 0292     5440 IF(IOPT15-2)5444,5441,5444
ISN 0293     5441 IF(N-1)7000,7001,7000
ISN 0294     7000 NKCNT=NKONT+1
ISN 0295          IF(NKONT-IPRINT)5444,7001,5444
ISN 0296     7001 WRITE  (6,5234)N,DPRIMP,N2
ISN 0297          WRITE  (6,5235)
ISN 0298          WRITE(6,5236)(M,D(M),C(M),STRESS(M),F(M),R(M),W(M),V(M),DPRIME(M),
                 1KPRIME(M),FMAXC(M),FMAXT(M),M=1,P)
ISN 0299     7003 NKCNT=0
ISN 0300     5444 GO TO (5443,192),LAY
ISN 0301     5443 IF((V(P)+0.1).GT.0.) GO TO 192
ISN 0303          WV=0.0
ISN 0304          DO 193 JA=NSEG1,P
ISN 0305      193 WV=WV+W(JA)*V(JA)
ISN 0306          IF(V(1).LT.0..AND.WV.LT.0..AND.DMAX(P).GT.D(P)) GO TO 190
ISN 0308          GO TO 192
ISN 0309      190 LAY=2
ISN 0310          GO TO (192,194,192),IOPT15
ISN 0311      194 WRITE(6,5234) N,DPRIMP,N2
ISN 0312          WRITE(6,5235)
ISN 0313          WRITE(6,5236)(M,D(M),C(M),STRESS(M),F(M),R(M),W(M),V(M),DPRIME(M),
                 1KPRIME(M),FMAXC(M),FMAXT(M),M=1,P)
ISN 0314      192 IF(V(2)/VSTART-3.1)61,60,60
ISN 0315       60 WRITE  (6, 105)
ISN 0316      105 FORMAT(74H  THE RATIO OF THE VELOCITY OF W(2) TO THE VELOCITY OF T
                 1HE RAM EXCEEDS 3.1)
ISN 0317          GO TO 5570
ISN 0318       61 IF(V(P)/VSTART-3.1)163,62,62
ISN 0319       62 WRITE  (6, 106)
ISN 0320          GC TO 5570
ISN 0321      106 FORMAT(74H  THE RATIO OF THE VELOCITY OF W(P) TO THE VELOCITY OF T
                 1HE RAM EXCEEDS 3.1)
            C --- CNC OF TEXAS REPN
ISN 0322      163 CONTINUE
ISN 0323          IF(LAY.EQ.2) GO TO 5447
ISN 0325          IF(N-N2)5240,5447,5447
            C---- 5240 CYCLES FOR NEXT TIME INTERVAL
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ISN 0326      5447 UG 5449 M=1,P
ISN 0327      5448 FMAXC(M) = FMAXC(M)/AREA(M)
ISN 0328      5449 FMAXT(M)=FMAXT(M)/(-AREA(M))
ISN 0329           GC TO(5442,5442,5553),IOPT15
ISN 0330      5442 WRITE  (6,2105)
ISN 0331      5550 WRITE(6,2106)(M,AREA(M),NFMAXC(M),FMAXC(M),NFMAXT(M),FMAXT(M),DMAX
                  1(M),D(M),V(M),M=1,P)
ISN 0332           BLCWS=0.0
ISN 0333      5553 IF(DPRIMP.GT.0.0) BLOWS=1.0/DPRIMP
ISN 0335      5551 UBLOWS(LT) = BLOWS
ISN 0336           URLTTL(LT) = RUTOTL
ISN 0337           UFMAXC(LT) = FMAXC(P)*AREA(P)
             C     INITIAL U ABOVE IDENTIFIES FIGURES USED IN SUMMARY
ISN 0338           GO TO(5552,5552, 150),IOPT15
ISN 0339      5552 WRITE (6,2107)DPRIMP,BLOWS,N
ISN 0340      2105 FORMAT(//103H SEGMENT      AREA    TIME N  MAX C STRESS       TIME N
                  1 MAX T STRESS       CMAX(M)         D(M)           V(M))
ISN 0341      2106 FORMAT(I3,F15.3,I8,F12.0,I14,F12.0,F16.6,F10.6,F13.2)
ISN 0342      2107 FORMAT(24H PERMANENT SET OF PILE =F15.8, 38H INCHES    NUMBER OF B
                  1LOWS PER INCH = F16.8,22H    TOTAL INTERVALS = I8)
ISN 0343       150 CONTINUE
ISN 0344      5558 UO 5563 M=NSEG1,P
ISN 0345           FTMAX(LT)=AMAX1(FTMAX(LT),FMAXT(M))
ISN 0346           FCMAX(LT)=AMAX1(FCMAX(LT),FMAXC(M))
ISN 0347           IF(FCMAX(LT)-FMAXC(M))5560,5561,5560
ISN 0348      5561 NCMAX(LT)=M
ISN 0349      5560 IF(FTMAX(LT)-FMAXT(M))5563,5562,5563
ISN 0350      5562 NTMAX(LT)=M
ISN 0351      5563 CONTINUE
ISN 0352      5555 IF(IOPT11-2)5556,5570,5570
ISN 0353      5556 IF (UPRIMP-0.001)59,707,707
ISN 0354       707 IF (BLOWS-60.0)701,701,59
ISN 0355        59 CONTINUE
ISN 0356           WRITE (6,803) CASE,PROB
ISN 0357           WRITE (6,804) QPOINT,JPOINT
ISN 0358           WRITE (6,805)
ISN 0359           DO 801 J=1,LT
ISN 0360           URUTON=URUTTL(J)/2000.
ISN 0361       801 WRITE(6,802) UBLOWS(J),URUTTL(J),URUTON,UFMAXC(J),FCMAX(J),NCMAX(J
                  2),FTMAX(J),NTMAX(J)
ISN 0362       802 FORMAT(4XF7.4,F10.0,1H-F5.0,1HTF13.0,F13.0,4XI2,F13.0,4XI2)
ISN 0363       803 FORMAT (1H0,10X,22H PILE DRIVING ANALYSIS,
                  1  10X,12H CASE NUMBER,3X,A6,10X,15H PROBLEM NUMBER,3X,I3)
ISN 0364       804 FORMAT(19X,9HQPOINT = F5.2,11X,9HJPOINT = F5.2)
ISN 0365       805 FORMAT(2X13HBLOWS PER IN.2X7HRUTOTAL7X11HPOINT FORCE2X12HMAX C STR
                  1ESS2X3HSEG2X12HMAX T STRESS2X3HSEG//)
             C-----PLCTTING ROUTINE
ISN 0366           IF(IOPT13-1)5570,5574,5574
ISN 0367      5574 CALL DRAW(WTCT[illegible],UBLCWS,LT,CASE,PROB)
             C-----END PLOTTING ROUTINE
ISN 0368      5570 WRITE(6,5572)
             C     DO 5570 STARTS AT 5120
ISN 0369      5572 FORMAT(1H1)
ISN 0370      5571 GO TO 5010
ISN 0371           END
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*****F O R T R A N   C R O S S   R E F E R E N C E   L I S T I N G*****

SYMBOL  INTERNAL STATEMENT NUMBERS
C       0004 0121 0173 0174 0184 0195 0197 0198 0199 0200 0202 0202 0206 0208 0209 0211 0215 0217 0220
        0221 0222 0224 0298 0313
D       0004 0125 0162 0163 0166 0168 0169 0174 0174 0175 0184 0191 0191 0192 0193 0197 0197 0240 0241
        0243 0244 0248 0249 0251 0255 0256 0260 0261 0263 0298 0306 0313 0331
F       0004 0122 0159 0157 0162 0165 0165 0166 0169 0173 0178 0184 0203 0206 0209 0211 0212 0212 0215
        0218 0222 0224 0225 0225 0235 0236 0236 0238 0261 0263 0265 0265 0269 0272 0272 0275 0278 0278
        0282 0284 0285 0286 0288 0290 0298 0313
I       0056
J       0359 0360 0361 0361 0361 0361 0361 0361 0361
K       0002 0004 0025 0026 0028 0057 0058 0116 0118 0143 0160 0162 0166 0169 0173 0206 0209 0211 0215
        0222 0224 0224 0261 0263
M       0020 0020 0020 0025 0025 0025 0027 0028 0028 0029 0032 0032 0032 0038 0038 0038 0040 0041 0043
        0043 0043 0046 0047 0062 0063 0064 0091 0092 0095 0096 0099 0100 0100 0104 0105 0109 0110 0110
        0113 0114 0119 0120 0120 0121 0122 0123 0124 0125 0126 0127 0128 0129 0130 0131 0132 0133 0143
        0143 0143 0143 0143 0143 0143 0143 0143 0143 0143 0177 0178 0178 0178 0184 0184 0184 0184 0184
        0184 0184 0184 0184 0184 0184 0184 0184 0184 0190 0191 0191 0191 0192 0192 0193 0193 0194 0195
        0195 0196 0197 0197 0197 0197 0198 0199 0199 0200 0202 0202 0202 0203 0203 0205 0206 0206 0206
        0208 0208 0209 0209 0209 0209 0209 0211 0211 0211 0211 0211 0211 0212 0212 0214 0215 0215 0215
        0217 0218 0220 0220 0221 0221 0222 0222 0222 0224 0224 0224 0224 0224 0224 0224 0225 0225 0227
        0239 0240 0240 0241 0241 0243 0243 0244 0244 0246 0248 0248 0249 0249 0249 0249 0249 0251 0251
        0251 0251 0251 0252 0254 0272 0272 0272 0272 0272 0272 0272 0278 0278 0278 0278 0278 0278 0280
        0284 0284 0284 0285 0285 0285 0286 0286 0287 0288 0288 0289 0290 0290 0290 0298 0298 0298 0298
        0298 0298 0298 0298 0298 0298 0298 0298 0298 0298 0313 0313 0313 0313 0313 0313 0313 0313 0313
        0313 0313 0313 0313 0313 0326 0327 0327 0327 0328 0328 0328 0331 0331 0331 0331 0331 0331 0331
        0331 0331 0331 0331 0344 0345 0346 0347 0348 0349 0350
N       0179 0182 0194 0231 0287 0289 0291 0291 0293 0296 0311 0325 0339
P       0003 0005 0018 0019 0020 0023 0027 0032 0035 0035 0044 0046 0095 0096 0099 0100 0113 0116 0118
        0119 0139 0160 0161 0162 0162 0162 0162 0163 0164 0164 0165 0165 0165 0166 0166 0166 0168 0168
        0168 0169 0169 0169 0172 0177 0184 0190 0196 0254 0255 0256 0260 0261 0261 0261 0261 0263 0263
        0263 0263 0265 0265 0298 0301 0304 0306 0306 0313 0318 0326 0331 0337 0337 0344
R       0004 0132 0158 0159 0164 0165 0168 0184 0249 0251 0269 0272 0275 0278 0298 0313
V       0004 0068 0071 0112 0114 0115 0143 0184 0191 0197 0249 0251 0261 0263 0269 0269 0272 0272 0275
        0275 0278 0278 0282 0282 0298 0301 0305 0306 0313 0314 0318 0331
W       0004 0020 0021 0024 0058 0061 0071 0118 0143 0135 0159 0162 0165 0184 0269 0269 0272 0272 0275
        0275 0298 0305 0313
CX      0004 0195 0208 0209 0211
DH      0080 0082 0084 0086 0089
DX      0004
FX      0004 0203 0209 0211 0235
JA      0304 0305 0305
JT      0023 0024 0154 0155 0156 0157 0158 0158 0159 0159 0159 0159 0171 0172
LT      0069 0117 0117 0335 0336 0337 0345 0345 0346 0346 0347 0348 0349 0350 0359 0367
MG      0058 0091 0095 0096 0099 0100 0100 0141
NC      0055 0057 0057 0058 0058
N2      0118 0141 0182 0296 0311 0325
RU      0004 0092 0096 0097 0100 0101 0110 0116 0120 0143 0156 0158 0164

*****F O R T R A N   C R O S S   R E F E R E N C E   L I S T I N G*****

SYMBOL  INTERNAL STATEMENT NUMBERS
WV      0303 0305 0305 0306
ABS     0106 0199 0205
EFF     0058 0061 0141
JTM     0172 0173 0173 0173 0174 0174 0174 0175 0175
LAM     0004 0124 0246 0252
LAP     0246 0247
LAY     0180 0300 0309 0323
NP1     0002 0231 0232 0234 0238
AREA    0004 0029 0030 0032 0033 0033 0035 0035 0143 0178 0290 0327 0328 0331 0337
CASE    0002 0005 0107 0137 0356 0367
CMAX    0004 0123 0220 0221 0224
DMAX    0004 0128 0192 0193 0306 0331
DRAW    0367
ERES    0004 0047 0048 0058 0058 0058 0143 0205 0211 0214 0224 0224
FCXP    0058 0139 0229 0236 0238
LACK    0189 0268 0270 0274 0276
LAMP    0136 0258 0258 0259 0264
PROB    0003 0058 0107 0137 0356 0367
SQRT    0061
AMAX1   0076 0212 0225 0236 0238 0265 0284 0345 0346
AMIN1   0285
BLOWS   0075 0077 0079 0090 0332 0333 0335 0339 0354
FCMAX   0004 0064 0346 0346 0347 0361
FLOAT   0096 0100 0100
FMAXC   0004 0130 0184 0284 0284 0286 0298 0313 0327 0327 0331 0337 0346 0347
FMAXT   0004 0131 0184 0285 0285 0288 0298 0313 0328 0328 0331 0345 0349
FTMAX   0004 0063 0345 0345 0349 0361
IOPT1   0005 0031 0139
IOPT2   0005 0037 0139
IOPT3   0005 0039 0139
IOPT4   0005 0010 0010 0079 0139 0204
JSIDE   0002 0058 0141 0249 0251
KHOLD   0002 0004 0028 0057
NCMAX   0004 0348 0361
NDMAX   0004 0129 0194
NKUNT   0065 0185 0294 0294 0295 0299
NPASS   0002 0118
NSEG1   0005 0014 0014 0023 0304 0344
NTMAX   0004 0350 0361
PROBS   0003 0005 0056 0137
QSIDE   0058 0120 0141 0163 0175 0240 0241 0243 0244 0248 0251
RUHIL   0004
RUSUM   0058 0073
RWENR   0004
SLACK   0004 0005 0005 0005 0041 0043 0044 0045 0143 0199 0202
SLOPE   0075 0076 0076 0089
```

```
*****F O R T R A N   C R O S S   R E F E R E N C E   L I S T I N G*****

SYMBOL  INTERNAL STATEMENT NUMBERS
TOTAL   0103  0105  0105  0106  0107
WPILE   0022  0024  0024
XPLOT   0004
YPLOT   0004
HLOWSX  0067  0075  0090
DELTAT  0017  0118  0191  0197  0232  0234  0238  0238  0269  0272  0275  0278
DELTCK  0118
UPRIME  0004  0133  0175  0184  0240  0241  0243  0244  0248  0249  0251  0298  0313
UPRIMP  0135  0182  0255  0256  0260  0261  0263  0296  0311  0333  0333  0339  0353
ENERGY  0058  0061  0141
IOPT11  0058  0070  0139  0352
IOPT12  0058  0059  0059  0094  0139
IOPT13  0058  0139  0366
IOPT14  0058  0139  0151  0267
IOPT15  0058  0139  0181  0292  0310  0329  0338
IPRINT  0005  0012  0012  0295
JPOINT  0002  0058  0141  0261  0263  0357
KPRIME  0002  0004  0120  0134  0143  0161  0162  0168  0184  0239  0249  0251  0298  0313
NFMAXC  0004  0126  0287  0331
NFMAXT  0004  0127  0289  0331
PERCNT  0058  0093  0141
PLESSI  0003  0019  0025  0040  0043  0157  0162  0165  0171
PPLUSI  0003  0018  0021  0026  0030  0038  0045  0048  0097  0101  0104  0109  0115  0116  0134  0143  0154
OPOINT  0058  0116  0141  0255  0256  0260  0263  0357
RTOTAL  0153  0156  0156  0158  0175
RULIST  0004  0038  0105  0110
RUPINT  0093  0096  0097  0100  0101
RUTOTL  0071  0073  0075  0088  0089  0093  0096  0100  0110  0141  0336
RUTTLX  0066  0075  0088  0084
RWHICH  0004
STRESS  0004  0178  0184  0293  0298  0313
TDELTA  0016  0017  0118  0139
TTDELT  0005  0008  0008  0016  0118
URLOWS  0004  0335  0361  0367
UFMAXC  0004  0337  0361
URUTON  0360  0361
URUTTL  0004  0336  0360  0361  0367
VSTART  0061  0068  0112  0282  0314  0318
WTOTAL  0152  0155  0155  0158  0175  0367
```

```
*****F O R T R A N   C R O S S   R E F E R E N C E   L I S T I N G*****

LABEL   DEFINED     REFERENCES
   5    0156        0154
   6    0024        0023
   8    0159        0157
  10    0248        0247
  12    0211        0208
  13    0092        0091
  14    0208        0205
  15    0209        0208
  20    0193        0192
  21    0195        0192  0192
  30    0203        0198  0198  0201
  32    0120
  34    0197        0196  0196
  35    0212        0208  0210
  36    0205        0204
  38    0206        0205  0205
  46    0235        0234  0234
  47    0236        0235
  48    0239        0227  0229  0232  0235  0235  0237
  50    0240        0239  0239
  51    0241        0240
  52    0242        0240  0240
  53    0245        0243  0243
  54    0244        0243
  55    0253        0239  0250
  56    0249        0248
  57    0251        0247  0248  0248
  58    0269        0268
  59    0355        0353  0354
  60    0315        0314  0314
  61    0318        0314
  62    0319        0318  0318
  63    0170        0161  0167
  64    0164        0163
  65    0168        0163  0163
  66    0161        0160
  67    0162        0160  0160  0161  0161
  68    0290        0190  0288  0288
  69    0289        0288
  71    0266        0254  0254
  72    0272        0268  0268
  73    0254
  74    0255        0254
  75    0256        0255
  76    0257        0255  0255
  77    0260        0259
```

*****F O R T R A N   C R O S S   R E F E R E N C E   L I S T I N G*****

LABEL	DEFINED	REFERENCES				
78	0263	0259	0260	0260		
79	0261	0260				
90	0238	0234				
105	0316	0315				
106	0321	0319				
111	0176	0171				
143	0095	0094				
144	0096	0095				
145	0100	0099				
146	0099	0094				
150	0343	0338				
163	0322	0318				
166	0288	0286	0286			
167	0287	0286				
171	0265	0262				
180	0114	0113				
190	0309	0306				
192	0314	0300	0301	0308	0310	0310
193	0305	0304				
194	0311	0310				
701	0075	0354	0354			
702	0079	0077	0077			
703	0082	0078	0078			
704	0084	0079	0079			
705	0086	0079				
706	0088	0081	0083	0085	0087	
707	0354	0353	0353			
713	0112	0098	0102	0111		
801	0361	0359				
802	0362	0361				
803	0363	0356				
804	0364	0357				
805	0365	0358				
2105	0340	0330				
2106	0341	0331				
2107	0342	0339				
5003	0007	0006				
5010	0005	0370				
5020	0017					
5021	0018					
5022	0019					
5030	0020					
5031	0021					
5040	0025					
5041	0026					
5083	0027					

*****F O R T R A N   C R O S S   R E F E R E N C E   L I S T I N G*****

LABEL	DEFINED	REFERENCES		
5084	0029	0027		
5086	0030			
5087	0031			
5088	0032	0031	0031	
5090	0037	0031		
5092	0038	0037	0037	
5100	0039	0037		
5101	0040	0039		
5102	0041	0040		
5103	0042			
5104	0043	0039	0039	
5105	0044	0042		
5106	0045			
5110	0046			
5111	0047	0046		
5112	0048			
5113	0049	0005		
5114	0050	0020	0032	0043
5115	0051	0025		
5116	0052	0038		
5117	0053	0058		
5118	0054	0107		
5120	0056			
5121	0058			
5140	0066			
5141	0067			
5150	0068			
5151	0071	0070	0070	
5152	0069			
5153	0072			
5154	0070			
5160	0073	0070		
5164	0078	0077		
5165	0080	0078		
5170	0091	0072	0074	
5171	0093			
5172	0094			
5173	0097			
5175	0101			
5176	0103	0094		
5177	0105	0104		
5178	0106			
5179	0107	0106		
5180	0109	0106	0106	
5181	0110	0109		
5183	0115			

*****FORTRAN CROSS REFERENCE LISTING*****

LABEL	DEFINED	REFERENCES						
5184	0116							
5186	0117							
5190	0137							
5191	0138							
5192	0139							
5193	0140							
5194	0141							
5195	0142							
5196	0143							
5200	0144	0137						
5201	0145	0138						
5202	0146	0139						
5203	0147	0140						
5204	0148	0141						
5205	0150	0142						
5206	0149	0143						
5218	0133	0119						
5220	0152	0151						
5221	0179	0151	0151					
5230	0181							
5231	0182	0181						
5232	0183							
5233	0184							
5234	0186	0182	0296	0311				
5235	0187	0183	0297	0312				
5236	0188	0184	0298	0313				
5240	0189	0181	0181	0325				
5241	0190							
5242	0198							
5243	0199	0198						
5244	0200	0199	0199					
5245	0201							
5246	0202	0199						
5250	0204							
5258	0151							
5300	0214	0204	0204					
5301	0215	0214	0214					
5302	0217	0214						
5303	0218	0217	0217					
5304	0220	0217						
5305	0221	0220	0220					
5306	0224	0220						
5400	0227	0196	0207	0213	0216	0219	0223	0226
5410	0246							
5420	0267							
5421	0268	0267						

*****FORTRAN CROSS REFERENCE LISTING*****

LABEL	DEFINED	REFERENCES						
5422	0273							
5423	0274	0267	0267					
5424	0275	0274						
5425	0276							
5427	0278	0274	0274					
5429	0279	0271	0273	0277				
5430	0284	0280						
5439	0286							
5440	0292							
5441	0293	0292						
5442	0330	0329	0329					
5443	0301	0300						
5444	0300	0292	0292	0295	0295			
5447	0326	0323	0325	0325				
5448	0327							
5449	0328	0326						
5550	0331							
5551	0335							
5552	0339	0338	0338					
5553	0333	0329						
5555	0352							
5556	0353	0352						
5558	0344							
5560	0349	0347	0347					
5561	0348	0347						
5562	0350	0349						
5563	0351	0344	0349	0349				
5570	0368	0056	0108	0317	0320	0352	0352	0366
5571	0370							
5572	0369	0368						
5574	0367	0366	0366					
7000	0294	0293	0293					
7001	0296	0293	0295					
7003	0299							
8000	0178	0177						
9009	0064	0062						

```
                                    OS/360   FORTRAN H

        COMPILER OPTIONS - NAME=  MAIN,OPT=00,LINECNT=50,SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,ID,XREF
  ISN 0002              SUBROUTINE DRAW(WTOTAL,URUTTL,UBLOWS,LT,CASE,PROB)
  ISN 0003              DIMENSION URUTTL(150),UBLOWS(150),YPLOT(51),XPLOT(51)
  ISN 0004         5574 YPLOT(1)=WTOTAL
  ISN 0005              XPLOT(1)=0.
  ISN 0006              LTP1=LT+1
  ISN 0007              DO 5573 IP=1,LT
  ISN 0008              YPLOT(IP+1)=URUTTL(IP)/2000.
  ISN 0009         5573 XPLOT(IP+1)=UBLOWS(IP)
  ISN 0010              YMAX=YPLOT(LTP1)
  ISN 0011              N2=N2
  ISN 0012              IF(YMAX.LE.400.) GO TO 3
  ISN 0014              IF(YMAX.LE.800.) GO TO 4
  ISN 0016              IF(YMAX.LE.1600.) GO TO 5
  ISN 0018              IF(YMAX.LE.3200.) GO TO 6
  ISN 0020            3 DY=50.
  ISN 0021              GO TO 10
  ISN 0022            4 DY=100.
  ISN 0023              GO TO 10
  ISN 0024            5 DY=200.
  ISN 0025              GO TO 10
  ISN 0026            6 DY=400.
  ISN 0027           10 DX=10.
  ISN 0028              PPROB=PROB
  ISN 0029              RETURN
  ISN 0030              END
```

```
                 *****F O R T R A N   C R O S S   R E F E R E N C E   L I S T I N G*****

SYMBOL   INTERNAL STATEMENT NUMBERS
DX       0027
DY       0020   0022   0024   0026
IP       0007   0008   0008   0009   0009
LT       0002   0006   0007
N2       0011   0011
CASE     0002
DRAW     0002
LTP1     0006   0010
PROB     0002   0028
YMAX     0010   0012   0014   0016   0018
PPROB    0028
XPLOT    0003   0005   0009
YPLOT    0003   0004   0008   0010
UBLOWS   0002   0003   0009
URUTTL   0002   0003   0008
WTOTAL   0002   0004
```

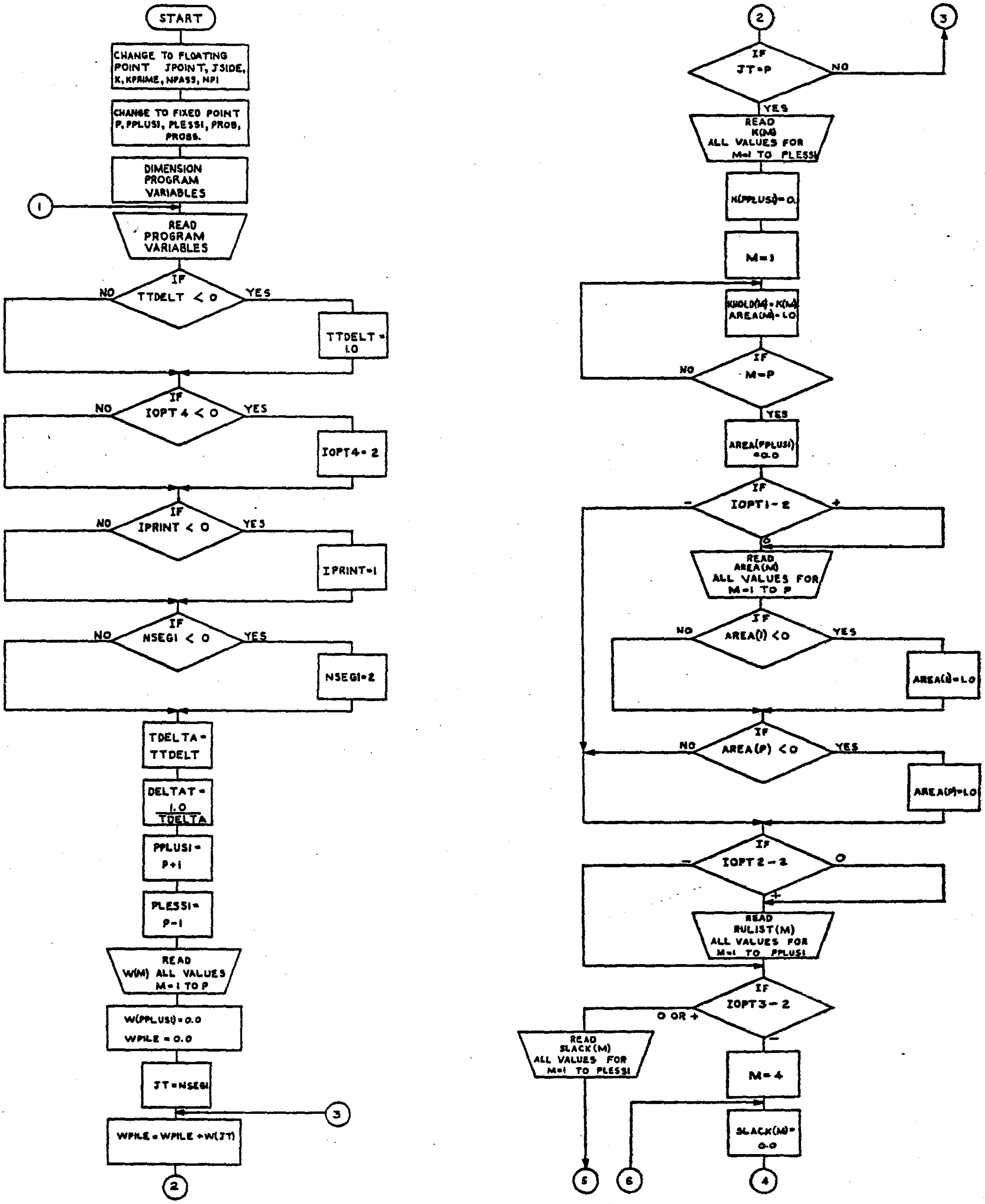
```
                 *****F O R T R A N   C R O S S   R E F E R E N C E   L I S T I N G*****

 LABEL    DEFINED    REFERENCES
   3       0020       0012
   4       0022       0014
   5       0024       0016
   6       0026       0018
  10       0027       0021   0023   0025
5573       0009       0007
5574       0004

****** END OF COMPILATION ******
```

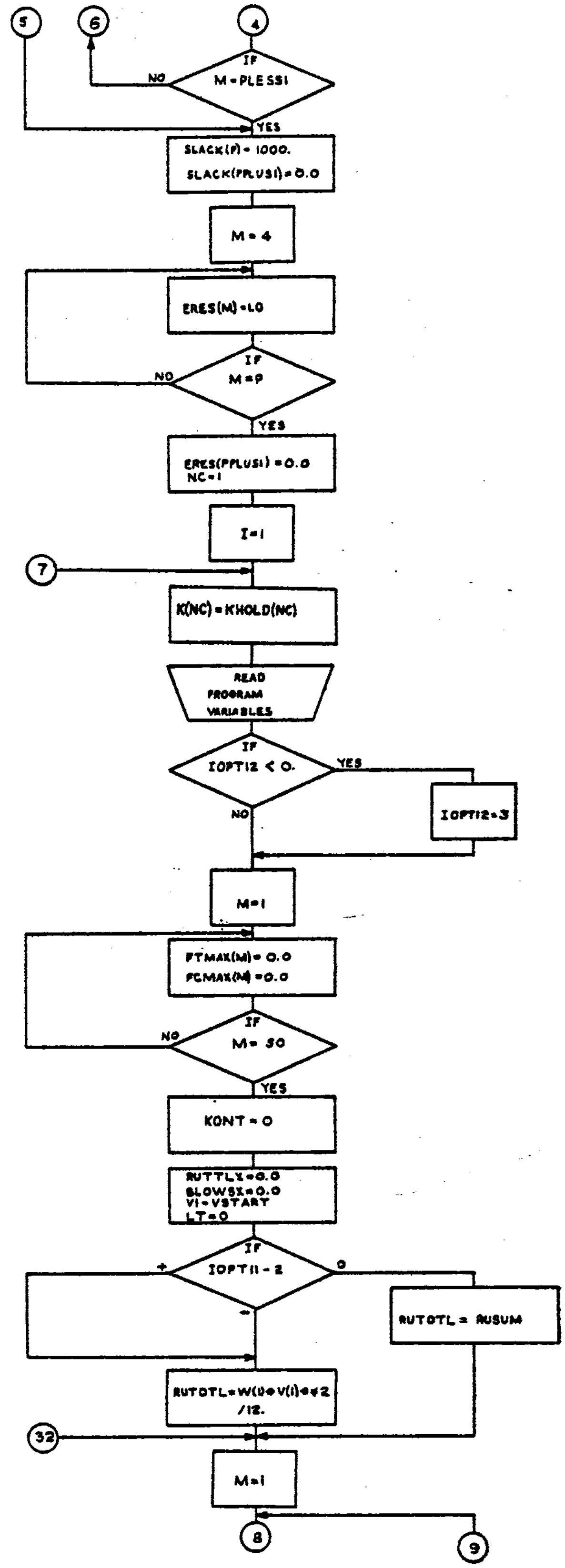
```
                                    OS/360   FORTRAN H

        COMPILER OPTIONS - NAME=  MAIN,OPT=00,LINECNT=50,SOURCE,EBCDIC,NOLIST,NODECK,LOAD,NOMAP,NOEDIT,ID,XREF
  ISN 0002              SUBROUTINE DELTCK(NPASS,TTDELT,P,W,K,TDELTA,DELTAT,N2)
  ISN 0003              REAL K,NPASS
  ISN 0004              INTEGER P,PLESS1
  ISN 0005              DIMENSION W(150),K(150),DELTI(300)
  ISN 0006              PLESS1=P-1
  ISN 0007              N=2*P-1
  ISN 0008              SUM=0.
  ISN 0009              TMIN=1.
  ISN 0010              TDELTA=TTDELT
  ISN 0011              DELTAT=1./TDELTA
  ISN 0012              DO 1 M=1,PLESS1
  ISN 0013              DELTI(M)=SQRT(W(M+1)/K(M))/19.648
  ISN 0014              NN=PLESS1+M
  ISN 0015            1 DELTI(NN)=SQRT(W(M)/K(M))/19.648
  ISN 0016              IF(K(P).GT.0.) GO TO 2
  ISN 0018              DELTI(N)=1.0
  ISN 0019              GO TO 3
  ISN 0020            2 DELTI(N)=SQRT(W(P)/K(P))/19.648
  ISN 0021            3 DO 4 M=1,N
  ISN 0022            4 TMIN=AMIN1(TMIN,DELTI(M))
  ISN 0023              IF(TMIN/2.-DELTAT)5,6,6
  ISN 0024.           5 DELTAT=TMIN/2.
  ISN 0025              TDELTA=1.0/DELTAT
  ISN 0026            6 DO 7 M=1,N
  ISN 0027            7 SUM=SUM+DELTI(M)
  ISN 0028              N2=4.0*SUM/(2.0*DELTAT)
  ISN 0029              RETURN
  ISN 0030              END
```

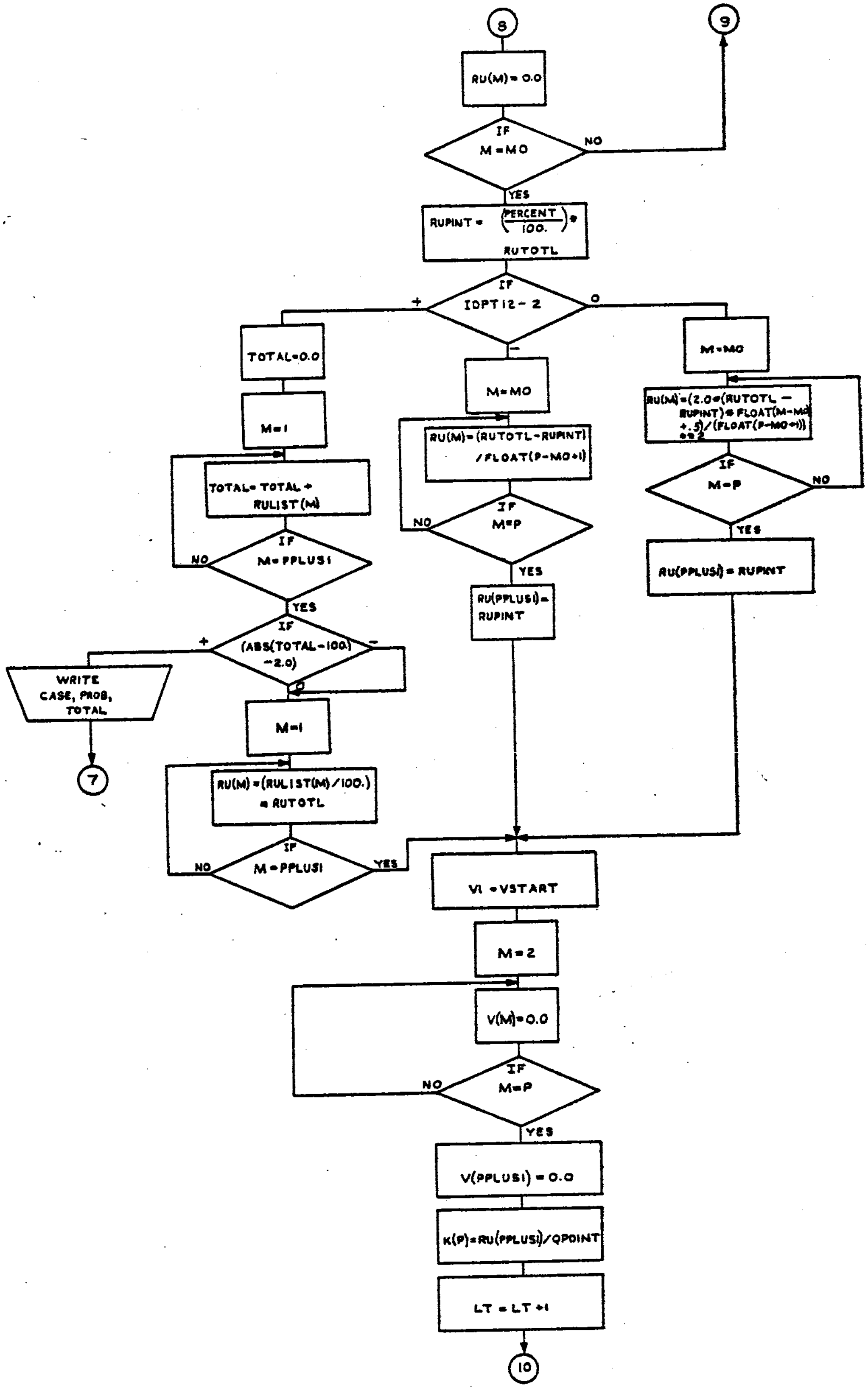
```
                                    *****FORTRAN   CROSS   REFERENCE   LISTING*****

SYMBOL   INTERNAL STATEMENT NUMBERS
K        0002   0003   0005   0013   0015   0016   0020
M        0012   0013   0013   0013   0014   0015   0015   0021   0022   0026   0027
N        0007   0019   0020   0021   0026
P        0002   0004   0006   0007   0016   0020   0020
W        0002   0005   0013   0015   0020
N1       0014   0015
N2       0002   0026
SUM      0008   0027   0027   0028
SQRT     0013   0015   0020
TMIN     0009   0022   0022   0023   0024
AMIN1    0022
DELT1    0005   0013   0015   0018   0020   0022   0027
NPASS    0002   0003
DELTAT   0002   0011   0023   0024   0025   0028
DELTCK   0007
PLESS1   0004   0006   0012   0014
TDELTA   0002   0010   0011   0025
TTDELT   0002   0010
```

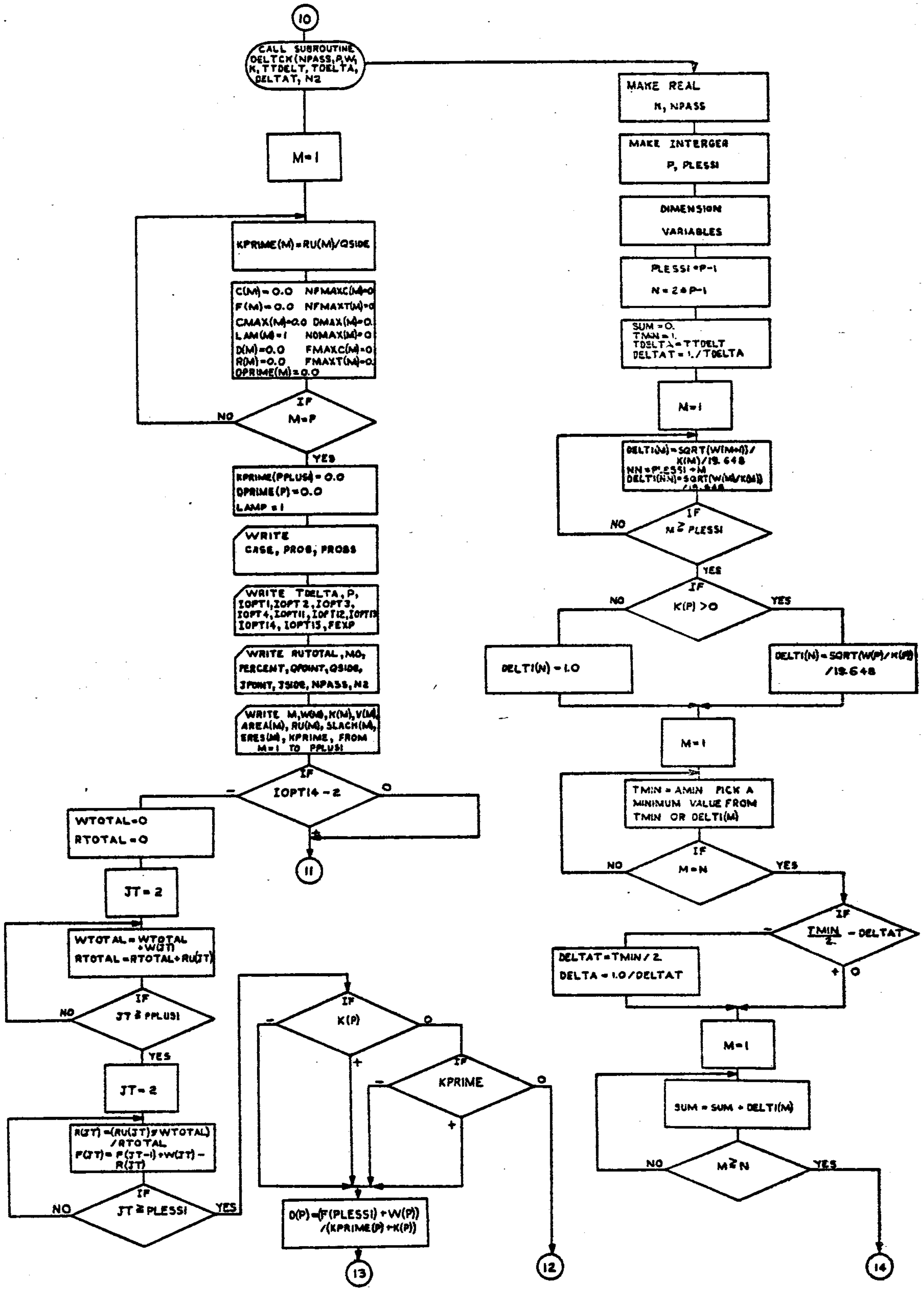
```
                                    *****FORTRAN   CROSS   REFERENCE   LISTING*****

 LABEL   DEFINED   REFERENCES
   1      0015      0012
   2      0020      0016
   3      0021      0019
   4      0022      0021
   5      0024      0023
   6      0026      0023   0023
   7      0027      0026

****** END OF COMPILATION ******
```

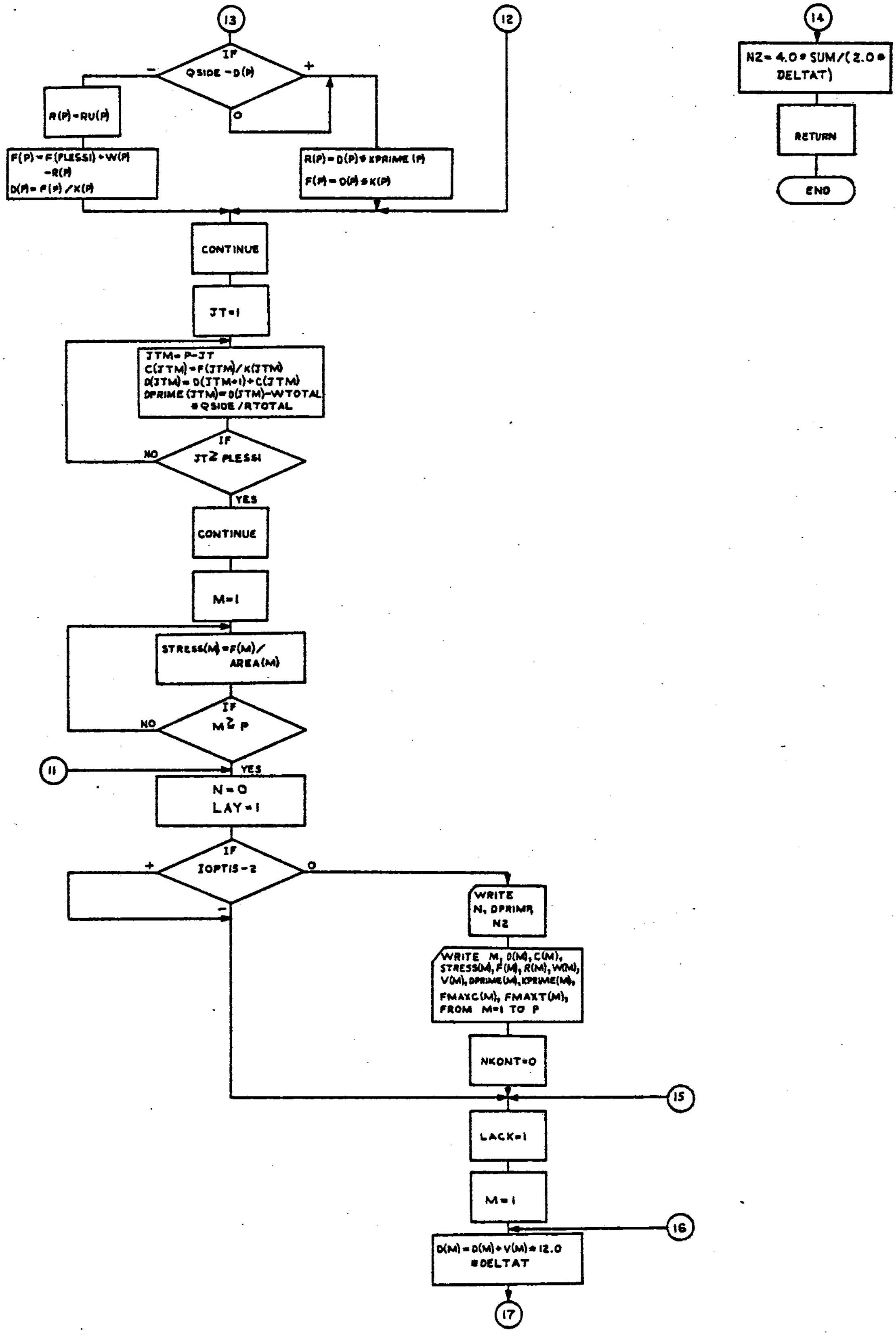
```
IEF285I   SYS68134.T145405.RP001.A49394.R0000444          DELETED
IEF285I   VOL SER NOS= 555555.
IEF285I   SYS68134.T145405.RP001.A49394.R0000445          DELETED
IEF285I   VOL SER NOS= STUBAU.
IEF285I   SYSOUT                                          SYSOUT
IEF285I   VOL SER NOS=        .
IEF285I   SYS68134.T145405.RP001.A49394.LOADSET           PASSED
IEF285I   VOL SER NOS= 666666.
IEF285I   SYS68134.T145405.RP001.A49394.LOADSET           DELETED
IEF285I   VOL SER NOS= 666666.
```

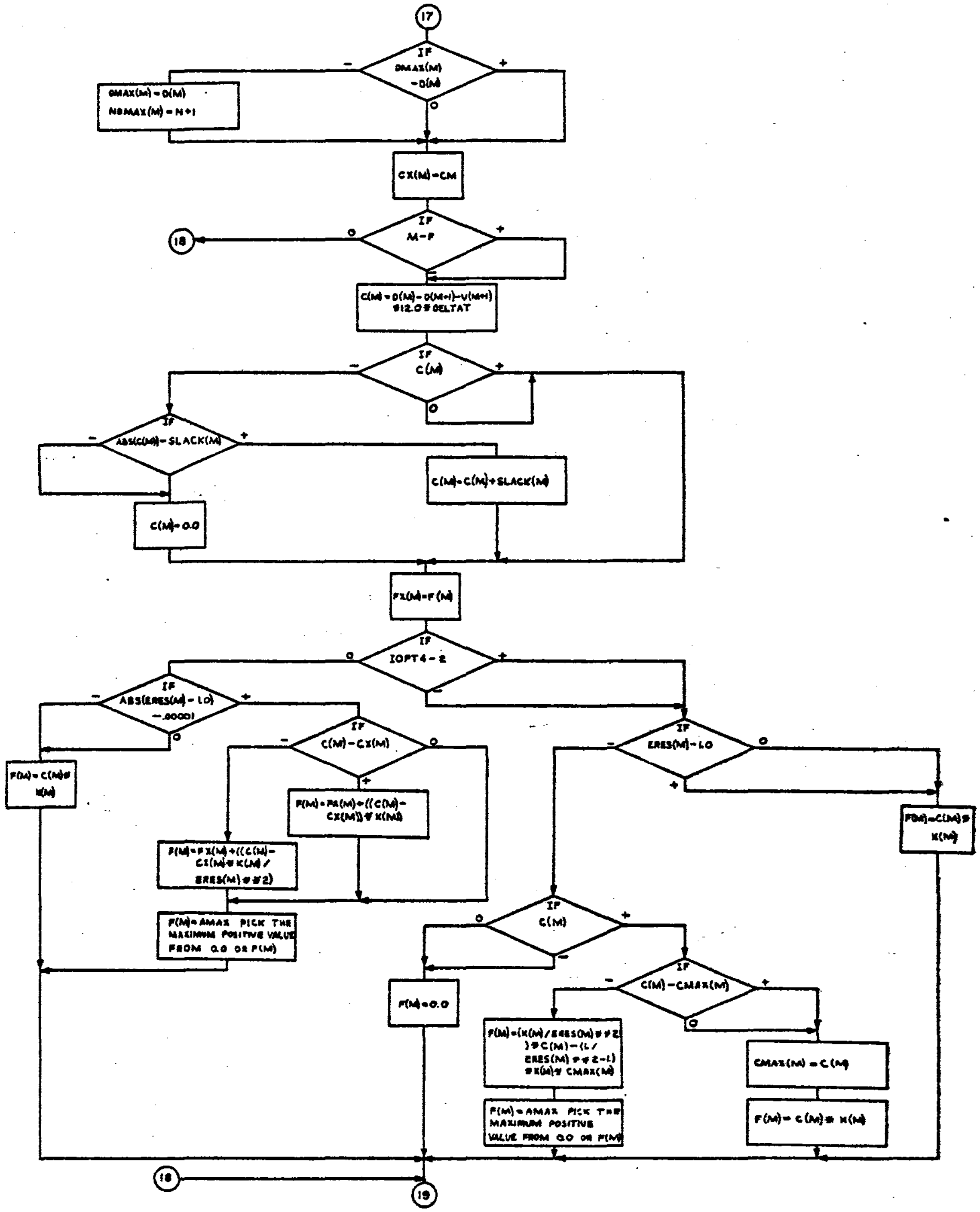

START
CHANGE TO FLOATING POINT JPOINT, JSIDE, K, KPRIME, NPASS, NPI
CHANGE TO FIXED POINT P, PPLUSI, PLESSI, PROB, PROBS.
DIMENSION PROGRAM VARIABLES
1
READ PROGRAM VARIABLES
IF TTDELT < 0
NO
YES
TTDELT = 1.0
IF IOPT 4 < 0
NO
YES
IOPT4 = 2
IF IPRINT < 0
NO
YES
IPRINT = 1
IF NSEGI < 0
NO
YES
NSEGI = 2
TDELTA = TTDELT
DELTAT = 1.0 / TDELTA
PPLUSI = P+1
PLESSI = P-1
READ W(M) ALL VALUES M=1 TO P
W(PPLUSI) = 0.0
WPILE = 0.0
JT = NSEGI
3
WPILE = WPILE + W(JT)
2
2
3
IF JT = P
NO
YES
READ K(M) ALL VALUES FOR M=1 TO PLESSI
K(PPLUSI) = 0.
M = 1
KHOLD(M) = K(M)
AREA(M) = 1.0
IF M = P
NO
YES
AREA(PPLUSI) = 0.0
IF IOPT1 - 2
-
+
0
READ AREA(M) ALL VALUES FOR M=1 TO P
IF AREA(1) < 0
NO
YES
AREA(1) = 1.0
IF AREA(P) < 0
NO
YES
AREA(P) = 1.0
IF IOPT 2 - 2
-
0
+
READ RULIST(M) ALL VALUES FOR M=1 TO PPLUSI
IF IOPT3 - 2
0 OR +
-
READ SLACK(M) ALL VALUES FOR M=1 TO PLESSI
M = 4
SLACK(M) = 0.0
5
6
4

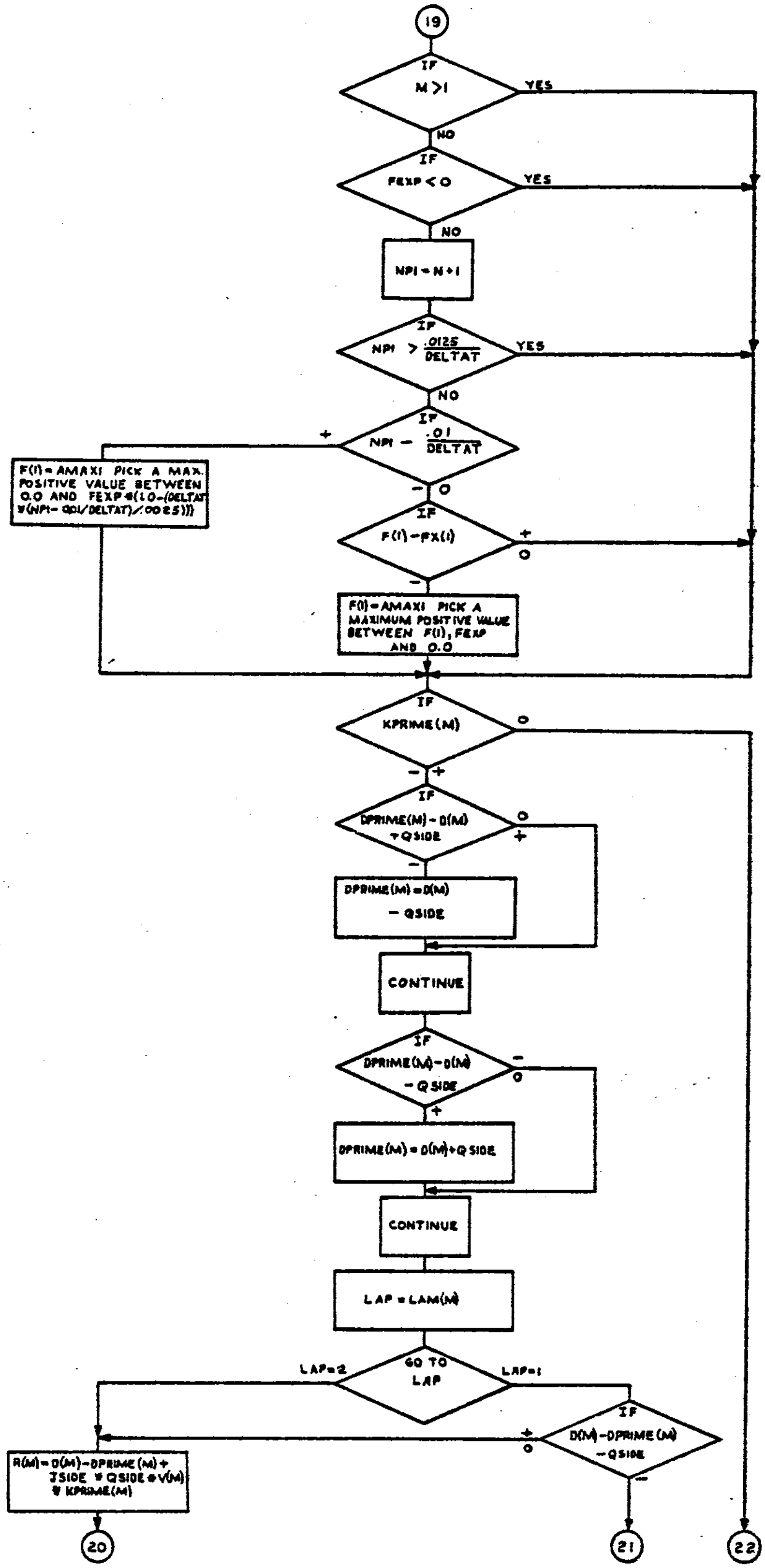

5
6
4
IF
M = PLESSI
NO
YES
SLACK(P) = 1000.
SLACK(PPLUS1) = 0.0
M = 4
ERES(M) = 1.0
IF
M = P
NO
YES
ERES(PPLUS1) = 0.0
NC = 1
I = 1
7
K(NC) = KHOLD(NC)
READ
PROGRAM
VARIABLES
IF
IOPT12 < 0.
YES
NO
IOPT12 = 3
M = 1
FTMAX(M) = 0.0
FCMAX(M) = 0.0
IF
M = 50
NO
YES
KONT = 0
RUTTLX = 0.0
SLOWSX = 0.0
VI = VSTART
LT = 0
IF
IOPT11 - 2
+
0
-
RUTOTL = RUSUM
RUTOTL = W(I)*V(I)**2
/12.
32
M = 1
8
9


8
9
RU(M) = 0.0
IF M = MO
NO
YES
RUPINT = (PERCENT / 100.) * RUTOTL
IF IDPT12 - 2
+
0
-
TOTAL=0.0
M=1
TOTAL= TOTAL + RULIST(M)
IF M = PPLUS1
NO
YES
IF (ABS(TOTAL-100.) -2.0)
WRITE CASE, PROB, TOTAL
7
M=1
RU(M) = (RULIST(M)/100.) * RUTOTL
IF M = PPLUS1
M=MO
RU(M)= (RUTOTL-RUPINT) /FLOAT(P-MO+1)
IF M=P
RU(PPLUS1)= RUPINT
M=MO
RU(M)=(2.0*(RUTOTL - RUPINT) * FLOAT(M-MO) +.5)/(FLOAT(P-MO+1)) **2
IF M=P
RU(PPLUS1) = RUPINT
V1 = VSTART
M = 2
V(M)=0.0
IF M=P
V(PPLUS1) = 0.0
K(P)=RU(PPLUS1)/QPOINT
LT = LT +1
10

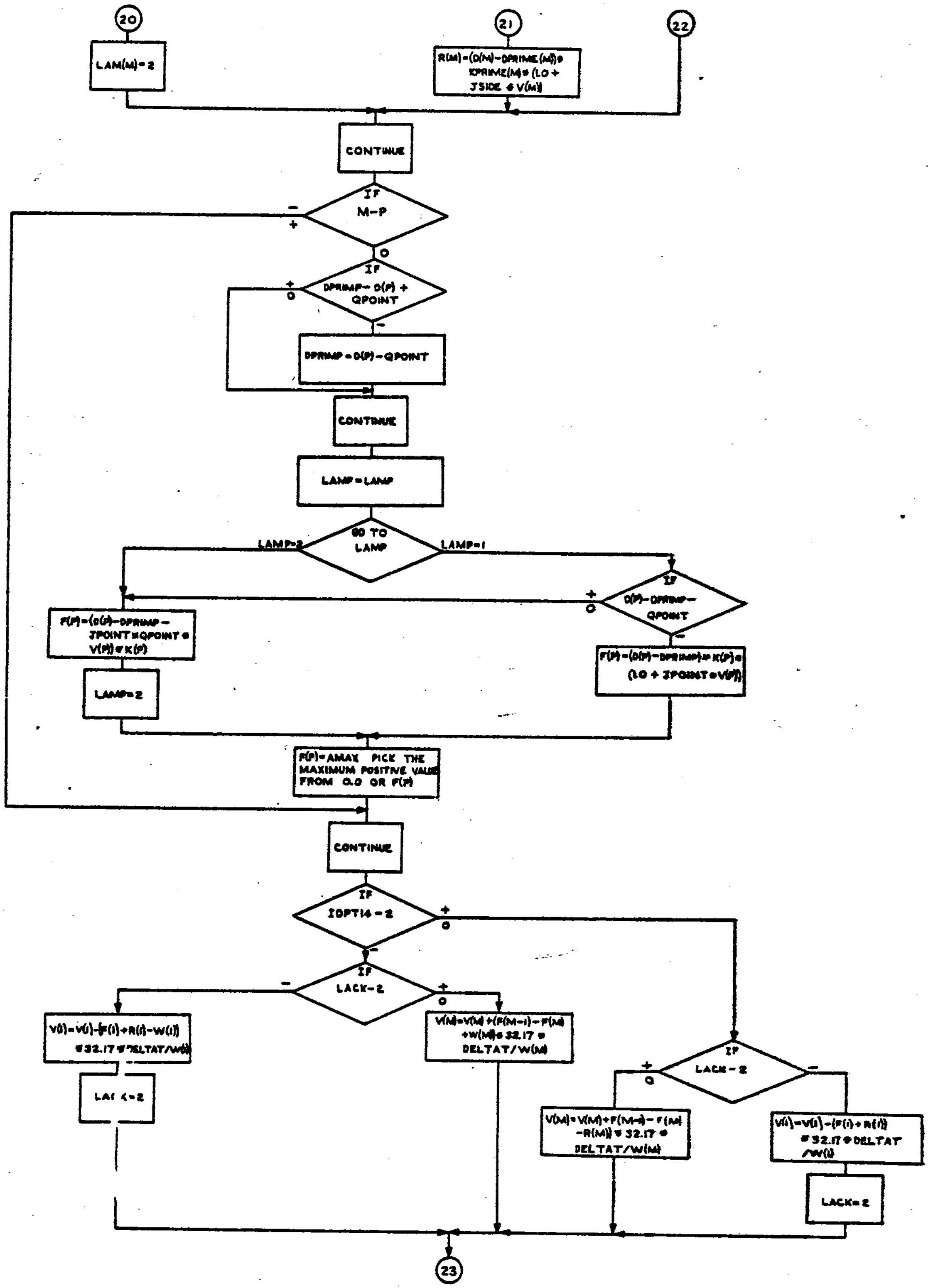

10
CALL SUBROUTINE DELTCK(NPASS,P,W,K,TTDELT,TDELTA,DELTAT,N2
M=1
KPRIME(M)=RU(M)/QSIDE
C(M)=0.0 NFMAXC(M)=0
F(M)=0.0 NFMAXT(M)=0
CMAX(M)=0.0 DMAX(M)=0.
LAM(M)=1 NOMAX(M)=0
D(M)=0.0 FMAXC(M)=0
R(M)=0.0 FMAXT(M)=0.
DPRIME(M)=0.0
IF M=P
NO
YES
KPRIME(PPLUSI)=0.0
DPRIME(P)=0.0
LAMP=1
WRITE CASE, PROB, PROBS
WRITE TDELTA, P, IOPT1, IOPT2, IOPT3, IOPT4, IOPT11, IOPT12, IOPT13, IOPT14, IOPT15, FEXP
WRITE RUTOTAL, MO, PERCENT, QPOINT, QSIDE, JPOINT, JSIDE, NPASS, N2
WRITE M, W(M), K(M), V(M), AREA(M), RU(M), SLACH(M), ERES(M), KPRIME, FROM M=1 TO PPLUSI
IF IOPT14-2
11
WTOTAL=0
RTOTAL=0
JT=2
WTOTAL=WTOTAL+W(JT)
RTOTAL=RTOTAL+RU(JT)
IF JT ≧ PPLUSI
JT=2
R(JT)=(RU(JT)*WTOTAL)/RTOTAL
F(JT)=F(JT-1)+W(JT)-R(JT)
IF JT ≧ PLESSI
IF K(P)
IF KPRIME
D(P)=(F(PLESSI)+W(P))/(KPRIME(P)+K(P))
13
12
MAKE REAL N, NPASS
MAKE INTERGER P, PLESSI
DIMENSION VARIABLES
PLESSI=P-1
N=2*P-1
SUM=0.
TMIN=1.
TDELTA=TTDELT
DELTAT=1./TDELTA
M=1
DELTI(M)=SQRT(W(M+1)/K(M)/19.648
NN=PLESSI+M
DELTI(NN)=SQRT(W(M)/K(M))/19.648
IF M ≧ PLESSI
IF K(P)>0
DELTI(N)=1.0
DELTI(N)=SQRT(W(P)/K(P))/19.648
M=1
TMIN=AMIN PICK A MINIMUM VALUE FROM TMIN OR DELTI(M)
IF M=N
IF TMIN/2 - DELTAT
DELTAT=TMIN/2.
DELTA=1.0/DELTAT
M=1
SUM=SUM+DELTI(M)
IF M ≧ N
14

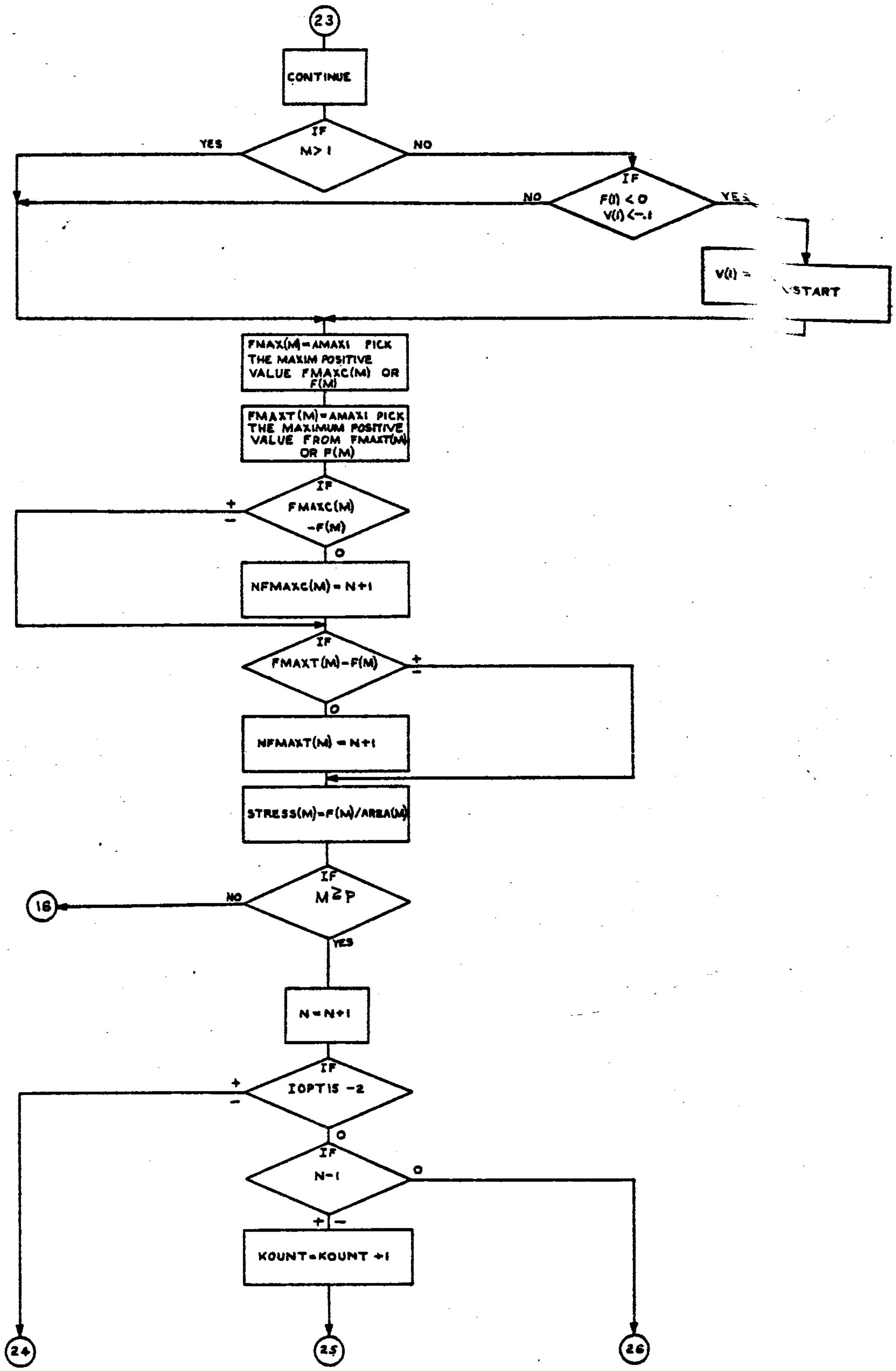

13
IF
QSIDE - D(P)
-
+
0
12
R(P)=RU(P)
F(P)=F(PLESS1)+W(P)
-R(P)
D(P)=F(P)/K(P)
R(P)=D(P)*KPRIME(P)
F(P)=D(P)*K(P)
CONTINUE
JT=1
JTM=P-JT
C(JTM)=F(JTM)/K(JTM)
D(JTM)=D(JTM+1)+C(JTM)
DPRIME(JTM)=D(JTM)-WTOTAL
*QSIDE/RTOTAL
IF
JT ≥ PLESS1
NO
YES
CONTINUE
M=1
STRESS(M)=F(M)/
AREA(M)
IF
M ≥ P
NO
YES
11
N=0
LAY=1
IF
IOPTIS-2
+
0
-
WRITE
N, DPRIME,
N2
WRITE M, D(M), C(M),
STRESS(M), F(M), R(M), W(M),
V(M), DPRIME(M), KPRIME(M),
FMAXC(M), FMAXT(M),
FROM M=1 TO P
NKONT=0
15
LACK=1
M=1
16
D(M)=D(M)+V(M)*12.0
*DELTAT
17
14
N2=4.0*SUM/(2.0*
DELTAT)
RETURN
END

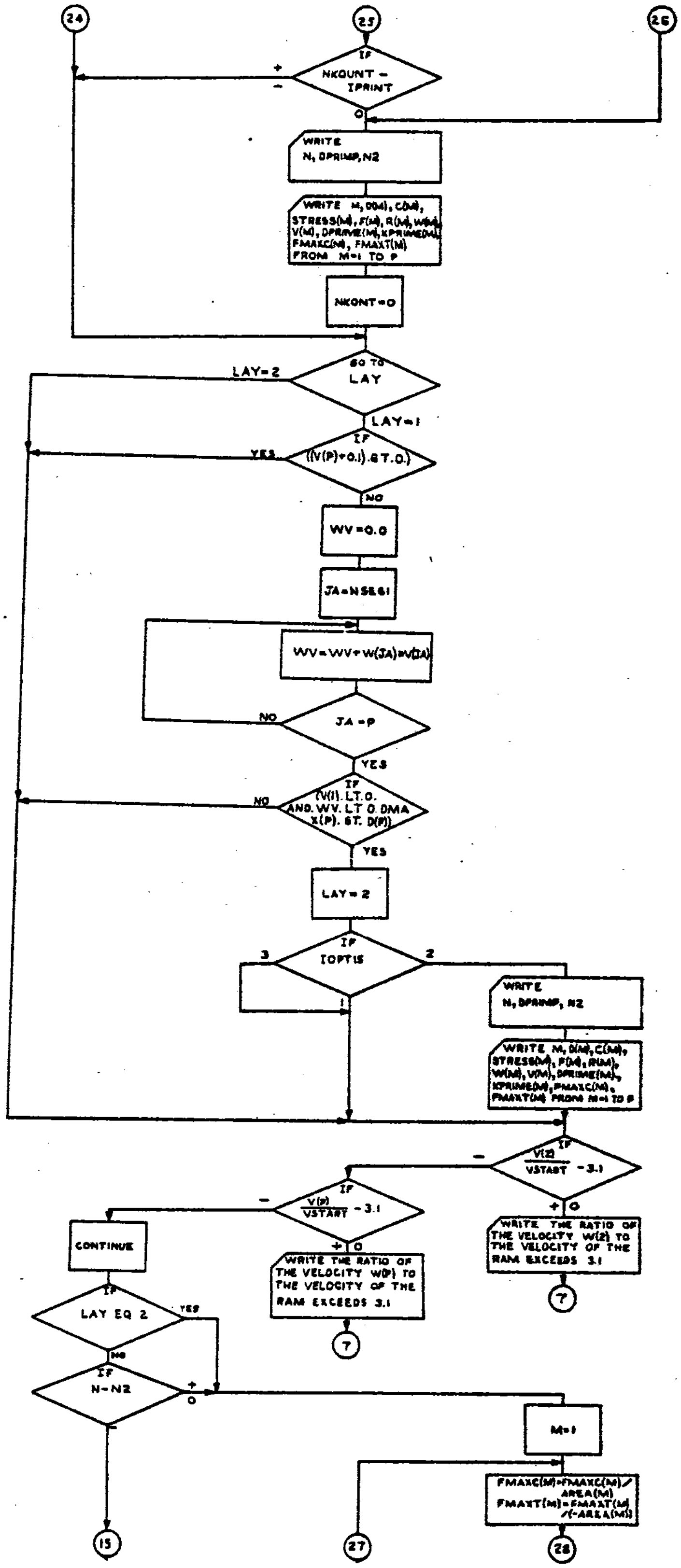

17
IF DMAX(M) -D(M)
DMAX(M) = D(M)
NDMAX(M) = N+1
CX(M) = CM
IF M-P
18
C(M) = D(M) - D(M+1) - V(M+1) *12.0 * DELTAT
IF C(M)
IF ABS(C(M)) - SLACK(M)
C(M) = C(M) + SLACK(M)
C(M) = 0.0
FX(M) = F(M)
IF IOPT4 - 2
IF ABS(ERES(M) - 1.0) -.00001
IF C(M) - CX(M)
F(M) = C(M) * K(M)
F(M) = FX(M) + ((C(M) - CX(M)) * K(M))
F(M) = FX(M) + ((C(M) - CX(M) * K(M) / ERES(M) ** 2)
F(M) = AMAX PICK THE MAXIMUM POSITIVE VALUE FROM 0.0 OR F(M)
IF ERES(M) - 1.0
F(M) = C(M) * K(M)
IF C(M)
F(M) = 0.0
IF C(M) - CMAX(M)
F(M) = (K(M) / ERES(M) ** 2) * C(M) - (1 / ERES(M) ** 2 - 1) * K(M) * CMAX(M)
CMAX(M) = C(M)
F(M) = AMAX PICK THE MAXIMUM POSITIVE VALUE FROM 0.0 OR F(M)
F(M) = C(M) * K(M)
18
19

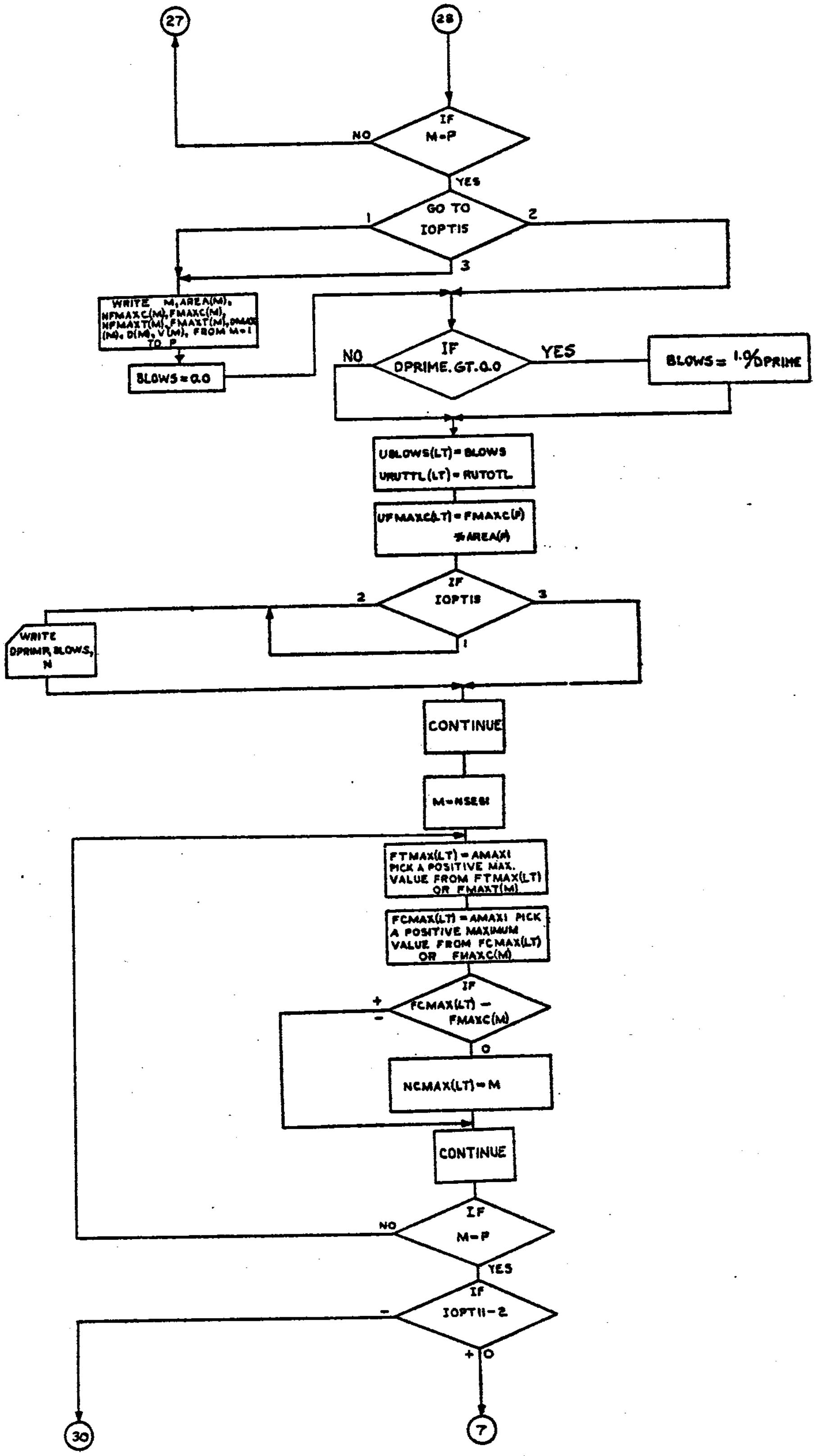


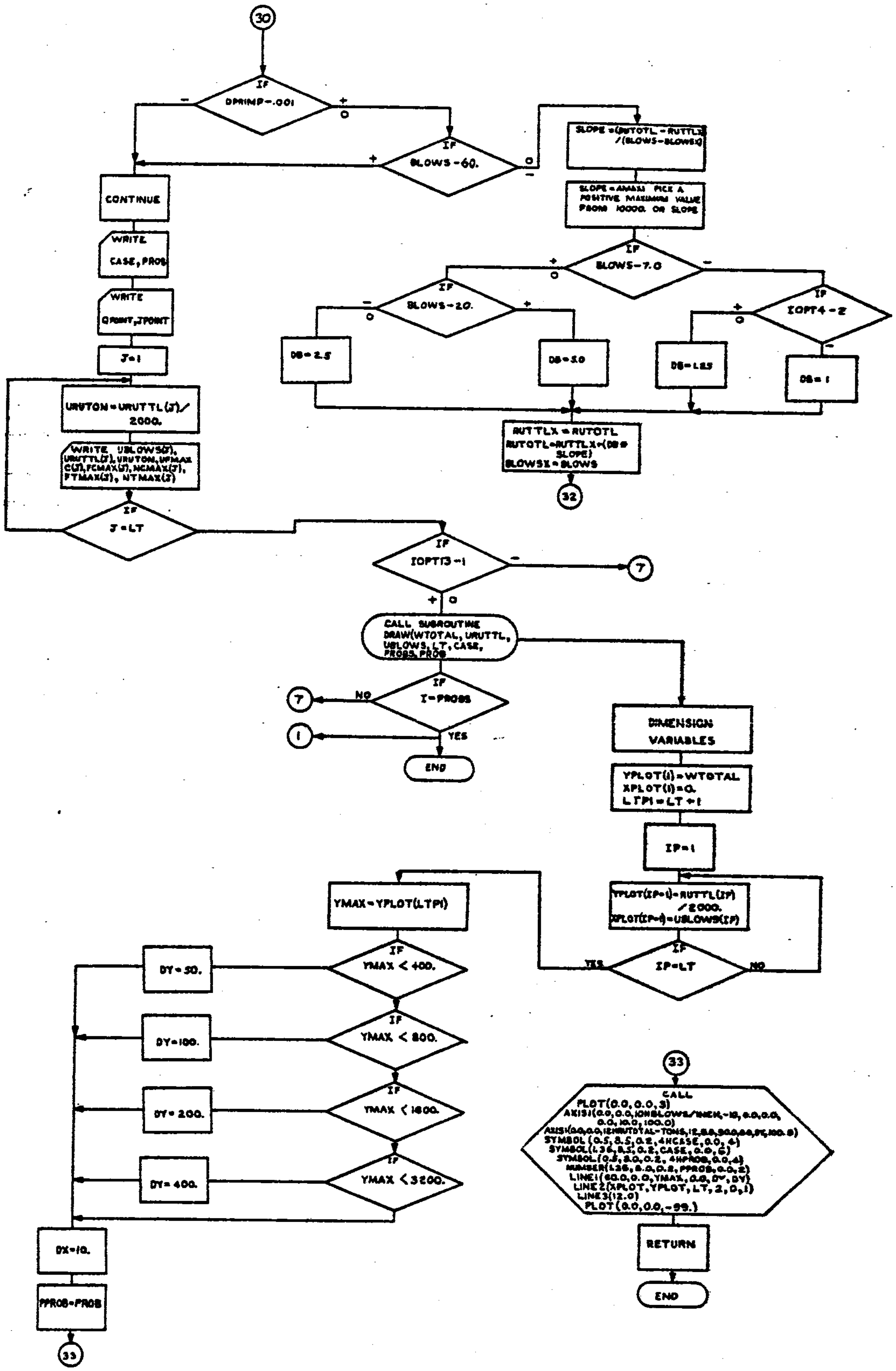
19
IF M > 1
YES
NO
IF FEXP < 0
YES
NO
NP1 = N+1
IF NP1 > .0125/DELTAT
YES
NO
IF NP1 − .01/DELTAT
+
− 0
F(I) = AMAX1 PICK A MAX. POSITIVE VALUE BETWEEN 0.0 AND FEXP*(1.0-(DELTAT*(NP1-.001/DELTAT)/.0025)))
IF F(I) − FX(I)
+ 0
−
F(I) = AMAX1 PICK A MAXIMUM POSITIVE VALUE BETWEEN F(I), FEXP AND 0.0
IF KPRIME(M)
0
− +
IF DPRIME(M) − D(M) + QSIDE
0 +
−
DPRIME(M) = D(M) − QSIDE
CONTINUE
IF DPRIME(M) − D(M) − Q SIDE
− 0
+
DPRIME(M) = D(M) + Q SIDE
CONTINUE
LAP = LAM(M)
GO TO LAP
LAP=2
LAP=1
IF D(M) − DPRIME(M) − QSIDE
+ 0
−
R(M) = D(M) − DPRIME(M) + JSIDE * QSIDE * V(M) * KPRIME(M)
20
21
22


20
LAM(M)=2
21
R(M)=(D(M)-DPRIME(M))*KPRIME(M)*(1.0+JSIDE*V(M))
22
CONTINUE
IF M-P
DPRIMP-D(P)+QPOINT
DPRIMP=D(P)-QPOINT
CONTINUE
LAMP=LAMP
GO TO LAMP
LAMP=2
LAMP=1
D(P)-DPRIMP-QPOINT
LAMP=2
F(P)=AMAX PICK THE MAXIMUM POSITIVE VALUE FROM 0.0 OR F(P)
CONTINUE
IOPT14-2
LACK-2
DELTAT/W(M)
LACK-2
LACK=2
23


23
CONTINUE
IF
M > 1
YES
NO
IF
F(I) < 0
V(I) < -.1
NO
YES
V(I) =
START
FMAX(M) = AMAX1 PICK THE MAXIM POSITIVE VALUE FMAXC(M) OR F(M)
FMAXT(M) = AMAX1 PICK THE MAXIMUM POSITIVE VALUE FROM FMAXT(M) OR F(M)
IF
FMAXC(M) -F(M)
+
-
0
NFMAXC(M) = N+1
IF
FMAXT(M)-F(M)
+
-
0
NFMAXT(M) = N+1
STRESS(M)=F(M)/AREA(M)
IF
M ≥ P
NO
16
YES
N = N+1
IF
IOPT IS -2
+
-
0
IF
N-1
0
+
-
KOUNT = KOUNT +1
24
25
26


24
25
26
IF NKOUNT − IPRINT
WRITE N, DPRIMP, N2
WRITE M, D(M), C(M), STRESS(M), F(M), R(M), W(M), V(M), DPRIME(M), KPRIME(M), FMAXC(M), FMAXT(M) FROM M=1 TO P
NKONT=0
GO TO LAY
LAY=2
LAY=1
IF ((V(P)+0.1).GT.0.)
YES
NO
WV=0.0
JA=NSEG1
WV=WV+W(JA)*V(JA)
JA=P
IF (V(1).LT.0. AND. WV.LT.0.DMAX(P).GT.D(P))
LAY=2
IF IOPTIS
WRITE N, DPRIMP, N2
WRITE M, D(M), C(M), STRESS(M), F(M), R(M), W(M), V(M), DPRIME(M), KPRIME(M), FMAXC(M), FMAXT(M) FROM M=1 TO P
IF V(2)/VSTART − 3.1
WRITE THE RATIO OF THE VELOCITY W(2) TO THE VELOCITY OF THE RAM EXCEEDS 3.1
IF V(P)/VSTART − 3.1
WRITE THE RATIO OF THE VELOCITY W(P) TO THE VELOCITY OF THE RAM EXCEEDS 3.1
CONTINUE
IF LAY EQ 2
IF N−N2
M=1
FMAXC(M)=FMAXC(M)/AREA(M)
FMAXT(M)=FMAXT(M)/(−AREA(M))
7
15
27
28


27
28
IF
M=P
NO
YES
GO TO
IOPTIS
1
2
3
WRITE M, AREA(M),
NFMAXC(M), FMAXC(M),
NFMAXT(M), FMAXT(M),
(M), D(M), V(M), FROM M=1
TO P
BLOWS = 0.0
IF
DPRIME. GT. 0.0
NO
YES
BLOWS = 1.0/DPRIME
UBLOWS(LT) = BLOWS
URUTTL(LT) = RUTOTL
UFMAXC(LT) = FMAXC(P)
/AREA(P)
IF
IOPTIS
2
3
1
WRITE
DPRIMR, BLOWS,
N
CONTINUE
M=NSEGI
FTMAX(LT) = AMAXI
PICK A POSITIVE MAX.
VALUE FROM FTMAX(LT)
OR FMAXT(M)
FCMAX(LT) = AMAXI PICK
A POSITIVE MAXIMUM
VALUE FROM FCMAX(LT)
OR FMAXC(M)
IF
FCMAX(LT) −
FMAXC(M)
+
−
0
NCMAX(LT) = M
CONTINUE
IF
M=P
NO
YES
IF
IOPTII−2
−
+
0
30
7



30
IF
DPRIMP-.001
IF
BLOWS-60.
CONTINUE
WRITE
CASE, PROB
WRITE
QPOINT, JPOINT
J=1
URUTON=URUTTL(J)/
2000.
IF
J-LT
SLOPE=(RUTOTL-RUTTLX)
/(BLOWS-BLOWSX)
IF
BLOWS-7.0
IF
BLOWS-20.
IF
IOPT4-2
DB=2.5
DB=5.0
DB=1.25
DB=1
RUTTLX=RUTOTL
BLOWSX=BLOWS
32
IF
IOPT13-1
7
CALL SUBROUTINE
DRAW(WTOTAL, URUTTL,
IF
I-PROBS
NO
YES
7
1
END
DIMENSION
VARIABLES
YPLOT(1)=WTOTAL
XPLOT(1)=0.
LTP1=LT+1
IP=1
/2000.
IF
IP-LT
YES
NO
YMAX=YPLOT(LTP1)
IF
YMAX < 400.
DY=50.
IF
YMAX < 800.
DY=100.
IF
YMAX < 1600.
DY=200.
IF
YMAX < 3200.
DY=400.
DX=10.
PPROB=PROB
33
33
CALL
PLOT(0.0,0.0,3)
PLOT(0.0,0.0,-99.)
RETURN
END

```fortran
      SUBROUTINE DELTCK(NPASS,TTDELT,P,W,K,TDELTA,DELTAT,N2)
      REAL K,NPASS
      INTEGER P,PLESS1
      DIMENSION W(150),K(150),DELT1(300)
      PLESS1=P-1
      N=2*P-1
      SUM=0.
      TMIN=1.
      TDELTA=TTDELT
      DELTAT=1./TDELTA
      DO 1 M=1,PLESS1
      DELT1(M)=SQRT(W(M+1)/K(M))/19.648
      NN=PLESS1+M
    1 DELT1(NN)=SQRT(W(M)/K(M))/19.648
      DELT1(N)=1.0
      IF(K(P).GT.0.) DELT1(N)=SQRT(W(P)/K(P))/19.648
    3 DO 4 M=1,N
    4 TMIN=AMIN1(TMIN,DELT1(M))
      IF(TMIN/2.-DELTAT)5,6,6
    5 DELTAT=TMIN/2.
      TDELTA=1.0/DELTAT
      IF(K(P).EQ.0.0) DELT1(N)=0.0
    6 DO 7 M=1,N
    7 SUM=SUM+DELT1(M)
      N2=4.0*SUM/(2.0*DELTAT)
      RETURN
      END
```

```
      SUBROUTINE DELTCK(NPASS,TTDELT,P,W,K,TDELTA,DELTAT,N2)
      REAL K,NPASS
      INTEGER P,PLESS1
      DIMENSION W(150),K(150),DELT1(300)
      PLESS1=P-1
      N=2*P-1
      SUM=0.
      TMIN=1.
      TDELTA=TTDELT
      DELTAT=1./TDELTA
      DO 1 M=1,PLESS1
      DELT1(M)=SQRT(W(M+1)/K(M))/19.648
      NN=PLESS1+M
    1 DELT1(NN)=SQRT(W(M)/K(M))/19.648
      DELT1(N)=1.0
      IF(K(P).GT.0.) DELT1(N)=SQRT(W(P)/K(P))/19.648
    3 DO 4 M=1,N
    4 TMIN=AMIN1(TMIN,DELT1(M))
      IF(TMIN/2.-DELTAT)5,6,6
    5 DELTAT=TMIN/2.
      TDELTA=1.0/DELTAT
      IF(K(P).EQ.0.0) DELT1(N)=0.0
    6 DO 7 M=1,N
    7 SUM=SUM+DELT1(M)
      N2=4.0*SUM/(2.0*DELTAT)
      RETURN
      END
```