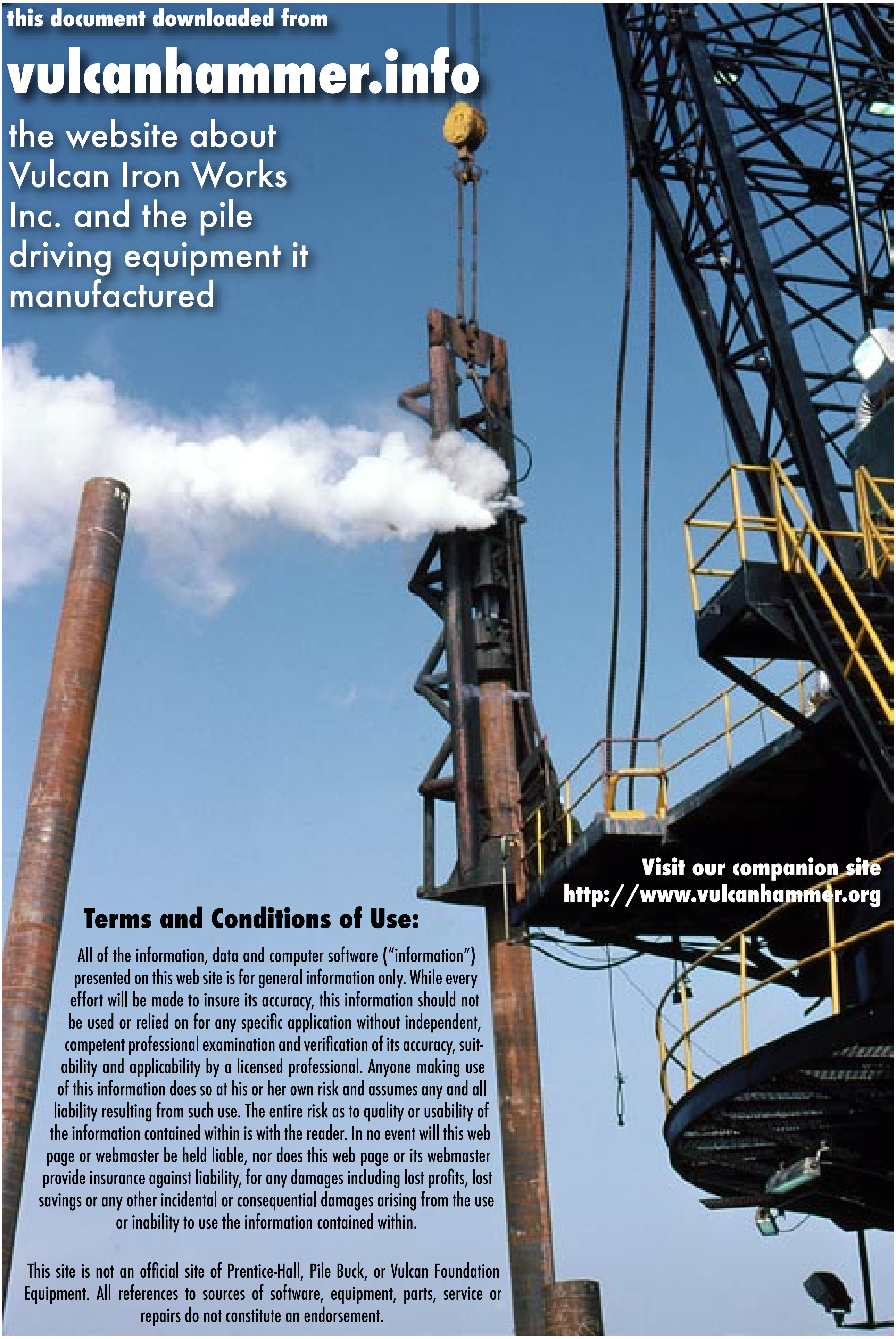
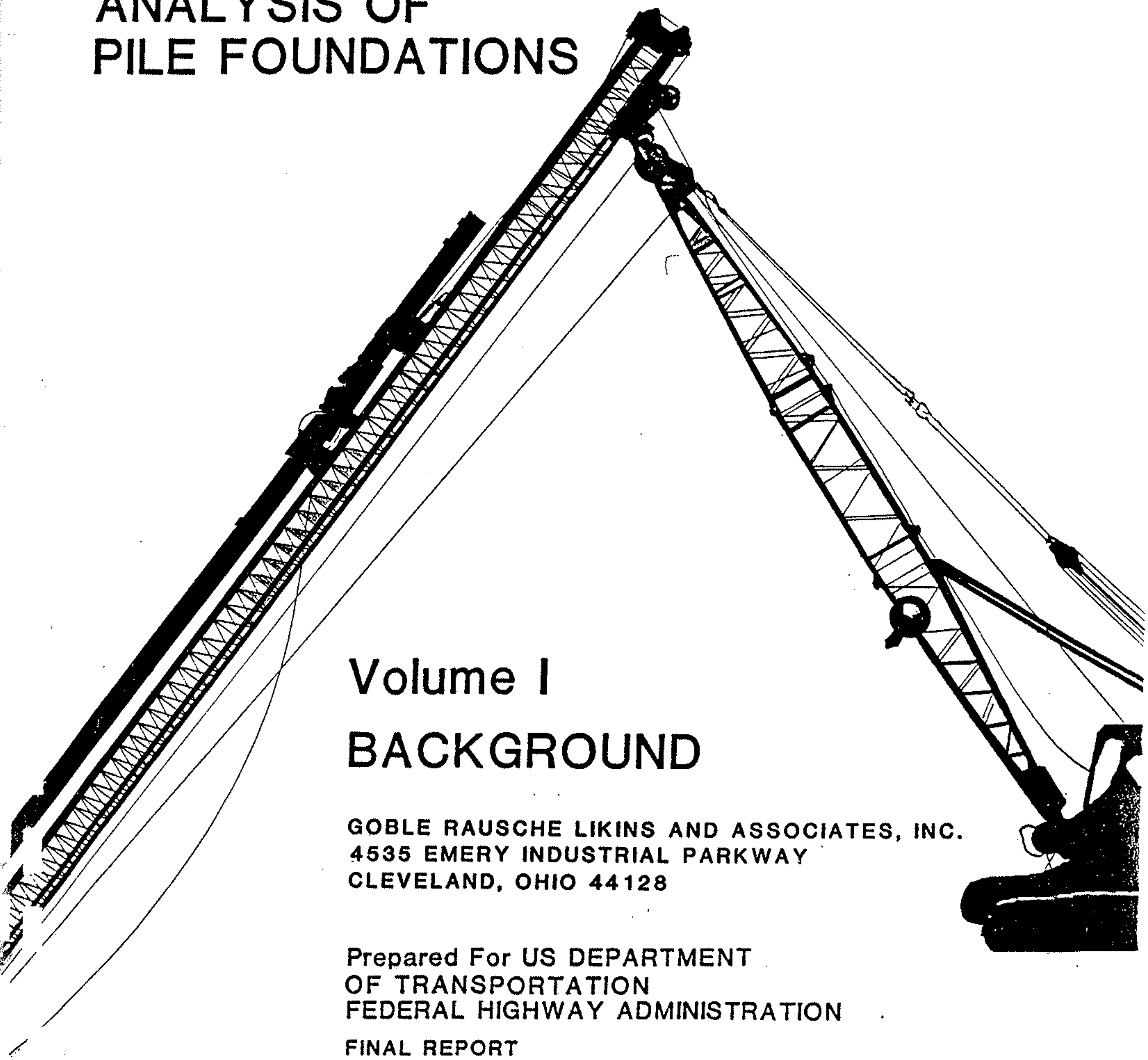


WEAP86

WAVE EQUATION ANALYSIS OF PILE FOUNDATIONS



Volume I

BACKGROUND

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Prepared For US DEPARTMENT
OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

FINAL REPORT
MAY 1986

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle	5. Report Date / 6. Performing Organization Code / 8. Performing Organization Report No.
WAVE EQUATION ANALYSIS OF PILE FOUNDATIONS WEAP86 PROGRAM Volume I. Background	5. Report Date: March 1986 6. Performing Organization Code: 8. Performing Organization Report No.:
7. Author(s) G.G. Goble and F. Rausche	
9. Performing Organization Name and Address Goble Rausche Likins and Associates, Inc. 4535 Emery Industrial Parkway Cleveland, OH 44128	10. Work Unit No. (TRAIS) 11. Contract or Grant No. DTFH61-84-C-00100
12. Sponsoring Agency Name and Address Office of Implementation Federal Highway Administration 6300 Georgetown Pike McLean, Virginia 22101-2296	13. Type of Report and Period Covered Final Report 14. Sponsoring Agency Code

15. Supplementary Notes

FHWA contract manager: Chien-Tan Chang (HDV-10)

16. Abstract

The WEAP Program, written and documented under a previous FHWA contract in 1976 and updated in 1981, was further developed. The documentation was completely rewritten for additional or revised information. The new program referred to as WEAP86, includes all of the WEAP features plus the following new models:

Separate models for liquid and atomized fuel injection of diesel hammers.
Residual stress analysis.
Realistic splice model.

An important addition was an updated and/or revised hammer data file with new efficiency values based on research performed under another contract for the FHWA. Furthermore, extensive tables covering helmets, cushions, and piles were compiled and included in the documentation. Another important facet of the WEAP86 work was the development of a program version for personal computers. The main effort consisted of providing for a user-friendly/menu-driven input program and a graphics output option.

This is the first volume among four. The others are

FHWA No.	Vol. No.	Title
	II	General Users Manual
	III	Program Installation Manual
	IV	Users Manual for PC Application

17. Key Words	18. Distribution Statement
Combustion, Computers, Design, Diesel, Dynamics, Foundations, Hammers, Impact, Pile driving, Residual stress, Soil mechanics, Wave equation.	No restrictions. This document is available to the public through the National Technical Information Service. Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	118	

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FOREWARD

Since the early 1950's, when E. A. L. Smith introduced the wave equation concept, this method of dynamic pile analysis has become more and more popular and its use widespread. Computer programs were prepared by many private individuals as well as by the Federal Highway Administration. The FHWA supported work in 1976 when both the TTI and the WEAP programs were published and in 1981 when the WEAP program was first updated.

In the meantime, the authors of WEAP have learned more about hammer and pile performance and, in order to avoid costly mistakes, the FHWA again sponsored a renewed effort towards keeping the WEAP program updated. The main reasons for concern were new insights and measurements obtained on hammers, and a better understanding of soil and pile stresses remaining in a pile after a hammer blow has been applied (residual stress).

New computer technology and the widely available personal computers (PC) also made it necessary to provide a new code. Thus, a program was developed that allows for interactive work with the PC while helping the user gain a better understanding of the mechanics of pile driving through graphic displays.

Because of all of these developments, it was decided that both report and program documentation be completely rewritten. Four volumes are herewith presented. The first one is a Background Report which introduces the reader to the wave equation concept and the particularities of WEAP86. However, it may be advantageous for the novice to read more basic material as referenced in the following chapters before beginning with the actual analysis. The second volume is the General Users Manual which is needed by both mainframe and PC users. The third volume describes the Program Installation and related files for both mainframe and PC (although PC users generally receive the program ready to use). Finally, Volume IV is an additional manual for PC users. It describes how to work with the interactive data input program.

The following individuals have greatly contributed towards the initial development of WEAP and current improvements in the WEAP86 program.

Mr. C. T. Chang, FHWA, Office of Implementation
Mr. Richard Cheney, FHWA, Construction and Maintenance Division
Mr. Suneel Vanikar, FHWA, Construction and Maintenance Division
Mr. Paul Bailey, New York Department of Transportation, Soil Mechanics Bureau

Gratefully acknowledged are the programming and documentation work of:

Ms. Amy R. Stroberg, Goble Rausche Likins and Associates, Inc.
Mr. Robert F. Miner, Goble Rausche Likins and Associates, Inc. Colorado

Mr. Phillipe Hery made an important contribution with research on the implications of residual stresses on pile driving at the University of Colorado. This research, as well as his programming and documenation efforts, became an important part of WEAP86.

The following individuals and firms have greatly contributed towards the development of WEAP86 by sponsoring measurements on their hammers and test stands and by releasing the data to the profession.

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Mr. C. H. Roth
Raymond Builders

Mr. G. Robert Compton
Mr. George Kurylko
MKT Geotechnical Systems

Mr. Don Warrington
Vulcan Iron Works

1. INTRODUCTION

Wave Equation Analysis of Pile Foundations, 1986 version, is a program which simulates a foundation pile under the action of an impact pile driving hammer. The program computes

- The blow count (number of hammer blows/unit length of permanent set) of a pile under one or more assumed ultimate resistance values and other dynamic soil resistance parameters, given a hammer and driving system (helmet, hammer cushion, pile cushion).
- The axial stresses in a pile corresponding to the computed blow count.
- The energy transferred to a pile.

Based on these results the following can be indirectly derived:

- The pile's bearing capacity at the time of driving or restriking, given its penetration resistance (blow count).
- The stresses during pile driving.
- The expected blow count if the actual static bearing capacity of the pile is known in advance (e.g., from a static soil analysis).

Of course, by varying the hammer type, driving system parameters and pile properties during a number of simulations, an optimal system can be selected.

Because of the production of ever more powerful and less costly computers, most engineering firms now posess some form of computer hardware system, often of the smaller PC variety. For this reason, WEAP86 has been written for both mainframe computers and the popular IBM-PC computers.

WEAP86 is a wave equation program after Smith (lumped mass analysis) and is based on the following WEAP versions:

- WEAP of 1976.
- WEAP of 1981.
- CUWEAP of 1983.

These three programs were documented in References 1, 2, and 3 respectively. The documentation of WEAP86 is being presented in four volumes. This

First volume contains background material. Volumes II and IV are Users Manuals for the mainframe and the PC version, respectively. Volume III contains installation details.

The contents of this first volume very closely follow the previous background reports. A few changes were made in an effort to simplify the mathematical representation of major portions of the code. Where necessary and appropriate the differences between WEAP86 and previous WEAP versions will be pointed out.

One major change is the addition of the section on case studies, which replaces the chapter on program performance included in previous WEAP documentation. The original program performance study was done in order to demonstrate the accuracy of the WEAP code. It now seems more important to show how the solution to a problem should be obtained.

This new Background report does not completely replace the older versions, but rather builds on them. In particular, certain basic features of wave equation programs will not be discussed. On the other hand, this volume will elaborate on those details which experience has shown to be the most difficult to comprehend.

Among other references useful to the engineer involved in the analysis of impact pile driving are:

- Smith of 1951 and 1960 (4,5), describing the beginning of the wave equation approach.
- Samson et al. of 1963 (6) and Forehand and Reese of 1964 (7) for their parameter studies.
- Lowery et al. of 1967 (8) and Coyle et al. of 1973 (9) as representative publications of the work performed at the Texas Transportation Institute (TTI).
- The program developed at TTI was also further developed and disseminated under FHWA sponsorship in 1976. (10)

It should be pointed out that the thorough checking of the original 1976 WEAP code would not have been possible without the work performed at Case Institute of Technology. (11) Additional development work conducted by the private practice of the authors, as well as studies done by others (12) supplied the necessary correlation data. In addition, recent findings of the FHWA sponsored study, "The Performance of Pile Driving Systems" (13) were used in the development of WEAP86.

WEAP86 also contains a so-called residual stress analysis which proves useful primarily in the analysis of long slender piles. This approach was originally proposed by Holloway (14) in 1978 and was further developed by Hery (15) in 1983. CUWEAP was a direct result of this latter effort, which had been sponsored by the Monotube Corporation. CUWEAP in turn was utilized in the development of WEAP86.

2. BASIC OPERATION AND USE OF THE WAVE EQUATION

The pile driving process readily provides information regarding the soil resistance: the greater the permanent set, s, of a pile under a hammer blow with energy E_k, the less the soil resistance, R_u, which opposes the pile penetration. This concept has been used for well over one hundred years in the so-called dynamic or energy formulas. (The most famous of these is the Engineering News Formula.) Note that E_k is the kinetic energy of the ram immediately preceeding impact and that R_u is the ultimate pile capacity, i.e. the maximum load that the pile can bear before it experiences large settlement due to soil failure.

The concept of the formula, therefore, is as follows:

$$E_s = R_u\, s \tag{2.1}$$

where E_s is the energy available to do work on the soil.

The energy value, E_s, is not simply obtained from E_k. In general, the following energy balance is applicable:

$$E_s = E_k - E_{pl} - E_{sl} \tag{2.2}$$

In this equation E_{pl} and E_{sl} are quantities of energy lost in the pile and soil, respectively. However, even E_k is not readily known. Generally, for modern hammers a "rated energy," E_r, is given by the manufacturer. Using the hammer efficiency, e_h, one computes

$$E_k = e_h E_r \tag{2.3}$$

The hammer efficiency, e_h, is typically a number between 0 and 1.

Modern hammers have an attachment at the bottom of the hammer called a helmet, and one or two cushions. These and other devices make up the components of the driving system. Energy is lost in the driving system and thus, another loss factor greater than zero and less than one, called e_d, has to be introduced into the energy balance (see Figure 2.1). Thus, the kinetic energy available at the top of the pile is

$$E_k = e_d e_h E_r \tag{2.4}$$

and the energy formula may be written as

$$e_d e_h E_r - E_{pl} - E_{sl} = R_u s \tag{2.5}$$

Assuming E_r to be known, an estimate of e_d, e_h, E_{pl} and E_{sl} would yield the permanent set, s, given R_u or vice versa. Computing s from R_u is done before a pile is driven. The blow count, B_c, is then merely the inverse of s and the engineer may require that the pile be driven to a minimum blow count to assure a minimum ultimate capacity, R_u. In this way the formula is used to establish a driving criterion.

On the other hand, during pile driving B_c may be observed and R_u computed. This process may be considered a dynamic pile test.

A third situation is also common. The engineer performs an accurate soil analysis and plots the ultimate soil capacity as a function of depth. Furthermore, he plots R_u vs. set or blow count, which is the so-called bearing graph. He then picks blow counts for certain R_u values, and matches them with corresponding depths from the first curve. In this way a blow count vs. depth curve is obtained. This process is called a driveability study, as it indicates the limits of an economical pile installation.

The modern wave equation approach differs from the energy formula only in the evaluation of e_d, E_{pl}, and E_{sl}. These losses are now computed by modeling the driving system, pile, and soil behavior. The hammer efficiency e_h is again only estimated.

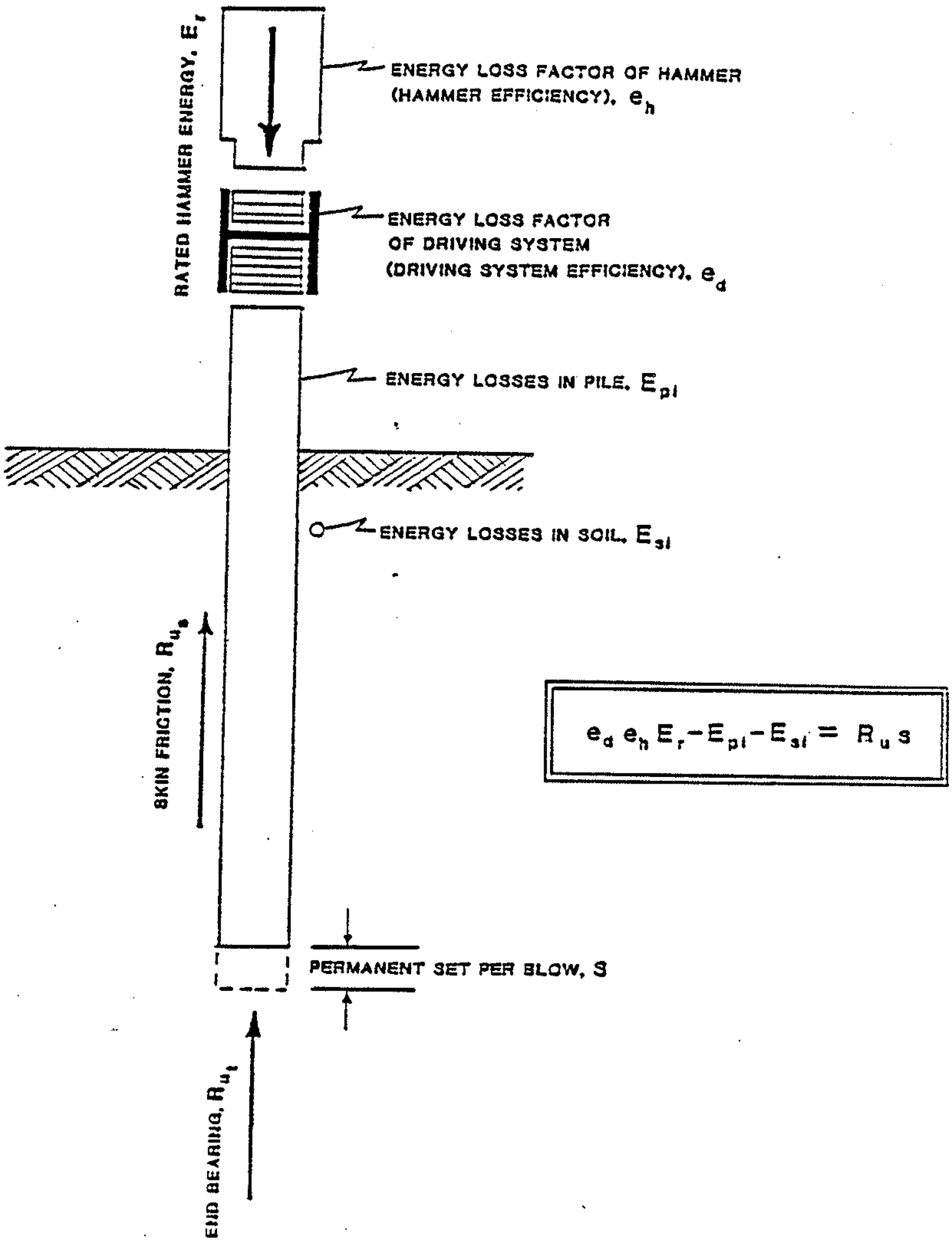


Figure 2.1. Greatly simplified WEAP86 equation.

For e_d the wave equation requires that stiffnesses and coefficients of restitution of the cushions and the weight of the helmet are known. For E_{pl} the elastic (elastic modulus, E) and mass properties (e.g., specific weight, w) of the pile are considered and the wave equation allows for the computation of the energy in the pile from both strain and motion. The soil losses are computed by considering both a soil stiffness and a soil damping factor.

Thus, in summary, the computational process in a wave equation is rather elaborate and involved in comparison to the simple equation derived earlier. The wave equation does not eliminate the need for assumptions and estimates. However, the total wave equation approach allows the engineer to obtain many of the necessary quantities relating to the pile and driving system from laboratory tests. Necessary quantities concerning the soil can be chosen using the recommendations found in the program documentation; these recommendations are based on simple soil classifications. For the hammer efficiency, e_h, an average value is usually recommended; however, depending on the state of the hammer maintenance, variations in actual performance should be expected.

Finally, a word about the term "wave equation." Actually, this term refers to a partial differential equation. However, it is totally unnecessary for the piling engineer to concern himself with this equation, and it would have been better to call the current approach the LM (lumped mass) or Smith program. It just so happens that the differential equation may be solved in an approximate manner by means of the LM model. The important contribution of Smith was not so much the solving of the wave equation, but rather the establishment of an approximating procedure which includes recommendations for the most relevant portions of the system consisting of hammer, driving system, pile and soil system.

The original Smith procedure did not provide sufficient detail for the following situations:

- Diesel hammers, which operate significantly different from the external combustion hammers (air/steam/hydraulic/cable) which were prevalent previously. Thus, additional models had to be developed based on manufacturers' specifications as well as measurement results. Both WEAP of 1976 and WEAP86 made contributions.

- Long and flexible skin friction piles. Actually, this is an irony since the wave equation approach deals particularly well with such piles. However, it was noticed that the wave equation overestimates the E_{pl} term and thus, the "Residual Stress Analysis" (RSA) had to be developed. The RSA considers that amount of E_{pl} and E_{sl} which is stored as strain energy at the end of a blow and is still available to do work during the next blow.

The following summary intends to clarify the problems that can be solved with the wave equation and how an engineer should approach a project utilizing WEAP86.

1. Preparations for a Wave Equation Analysis

- Obtain a soil profile, including approximate soil strength values such as standard penetration values, N.

- Establish a design (working) load, Q_d, and a safety factor (SF). The safety factor should reflect how well the loads are known, how variable the soil is, how sensitive the structure would be to settlements, how much engineering effort will be taken to determine the pile's exact bearing capacity once the pile has been driven, and other factors. In general, SF = 2 is acceptable if more than just a wave equation is done to ascertain pile bearing capacity.

- Compute the required ultimate pile capacity, $R_{ur} = Q_d$ SF.

- Decide on a pile type.

- From static formulas, establish at what depth the pile will most likely reach R_u, and calculate the percentage and distribution of the skin friction. If it is known how much the soil strength changes due to pile driving effects, determine the estimated amount of skin friction and end bearing for both the end of driving and the set up (restrike) situations. It may be possible to drive the pile only to R_{ur}/f_{su}, with f_{su} being a so-called setup factor, if the soil loses strength during driving and then regains it after driving. On the other hand, f_{su} may be less than one in the case of relaxation, wherein the soil appears to gain strength during driving but then loses this short term gain some time after driving. In this latter, rather dangerous case of relaxation, the pile has to be driven to a capacity in excess of R_{ur}.

- From the soil profile and the recommendations in the WEAP86 Manual (Vol. II or IV) determine the necessary dynamic soil resistance parameters such as damping and quake.

- Select a hammer and driving system based on local availability.

- Submit all this data for a wave equation analysis. Run the analysis using R_{ur} as well as other R_u values so that a curve can be plotted using R_u as a function of blow count.

- Plot R_u and also the maximum tensile and compressive stresses all as a function of blow count.

2. Interpretation of Wave Equation Results

- Check the pile stresses to see whether a safe pile installation is possible.

- If blow count is excessive (greater than 240 blows/ft or 800 blows/m), reanalyze with a more powerful hammer.

- If blow count is acceptable but compressive stresses are unacceptably high, reanalyze with either a decreased stroke (if hammer is adjustable) or an increased cushion thickness.

- If blow count is low but tension stresses are too high for concrete piles, either increase the cushion thickness or decrease the stroke or use a hammer with a heavier ram, and then reanalyze.

- If both blow count and compressive stresses are excessive, increase pile wall thickness, if applicable, and reanalyze.

3. Checking Wave Equation Results

- There are many potential error sources. It is the engineer's duty to assure that his simulation properly reflected the actual field conditions. The first check must be on the actual pile size, length, and material.

- Cushions and helmet must be checked in the field for size, material type and condition.

- The hammer type must be checked and during driving it must be ascertained that the hammer runs according to the manufacturers' specifications.

- In complicated cases, for high capacity piles or whenever unusual driving conditions occur, dynamic measurements should be taken. Under certain circumstances a static load test may also need to be performed.

- The engineer must keep in mind that the bearing capacity predictions obtained from correlation between wave equation analyses and actual pile driving blow counts will differ from static load test results.

In general, the finer grained the soil material, the larger these differences can become. Correlation of wave equation results with blow counts from restrike tests may reduce the potential for inaccurate results. However, less than a 10 percent difference cannot be expected, since even static load tests have errors inherent in their measurements and interpretations.

3. THE WEAP86 ANALYSIS MODEL

3.1 Introduction

After a short description of the construction and operation of commonly encountered impact hammers, this chapter describes how WEAP86 represents the significant features of hammers. The models of the driving system, pile and soil will also be described. Differences from earlier WEAP versions will be indicated.

3.2 Hammer Details

The following hammer types are distinguished:

- Diesel Hammers with Liquid Injection.
- Diesel Hammers with Atomized Injection.
- External Combustion Hammers (Air/Steam/Hydraulic/Cable)

In each category, closed end models have been produced. However, the differences between open end and closed end (double acting) hammers are of secondary importance for WEAP86.

3.2.1 Working Principle of Liquid Injection Diesel Hammers

Diesel hammers operate on a two stroke cycle. Figure 3.1 illustrates the working principle of a liquid injection open end diesel. The hammer is started by raising the ram with a lifting mechanism. At the upper end of its travel the lifting mechanism is tripped, the ram is released, and it descends under the action of gravity. When the ram bottom passes the exhaust ports, a certain volume of air, V_i, is trapped, compressed, and therefore heated (Figure 3.1a). Some time before impact, a certain amount of fuel is squirted into the cylinder under relatively low pressure.

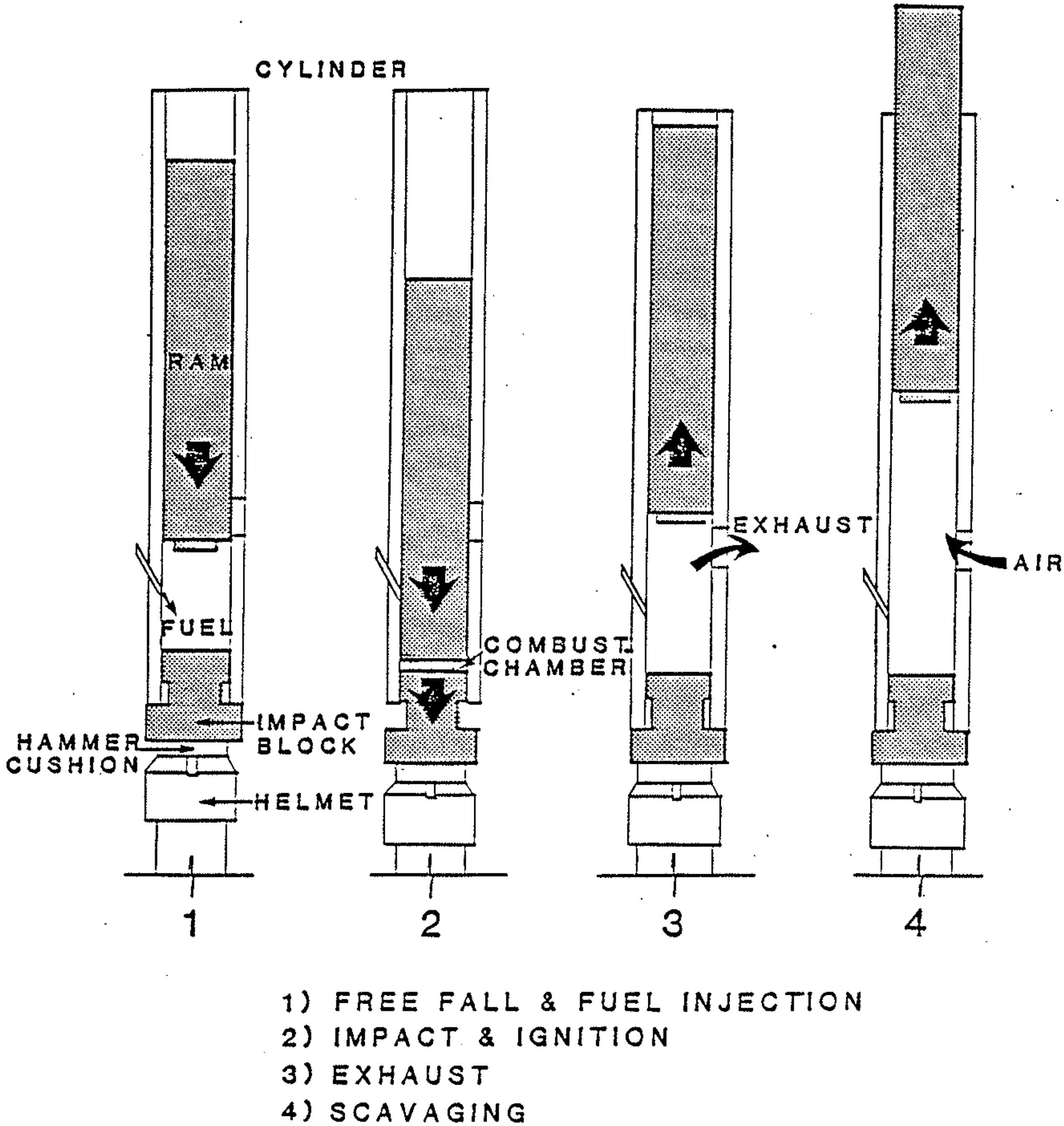


Figure 3.1. Working principle of a liquid injection open end diesel hammer.

When the ram collides with the impact block, the trapped air is compressed to a final volume, V_f, which is usually equivalent to the volume of the hammer's combustion chamber. The fuel is splattered by the impact into this combustion chamber, and combustion starts a short time later. This so-called combustion delay is due to the time that is required for the fuel to mix with the hot air and to ignite. More volatile fuels might have a shorter combustion delay than heavier ones. Combustion occurring before impact is called preignition and can be caused by the wrong fuel type or an overheated hammer. In hard driving, severe preignition is usually considered to be undesirable.

During impact, impact block, hammer cushion, and pile top are rapidly driven downward (Figure 3.1b) leaving the cylinder with no support. Thus, it starts to descend by gravity.

Pile rebound and combustion pressure push the ram upwards. When the exhaust ports are cleared, some of the combustion products are exhausted leaving in the cylinder a volume of burned gases at ambient pressure that is equal to V_i (Figure 3.1c). As the ram continues to travel upwards, fresh air, drawn in through the exhaust ports, mixes with the remaining burned gases (Figure 3.1d).

Depending on the reaction of the pile and the energy provided by combustion, the ram will rise to some height (stroke). It then descends again under the action of gravity to start a new cycle.

3.2.2 Working Principle of Atomized Injection Diesel Hammers

This hammer type is started in a manner identical to the L.I. (Liquid Injection) type. However, for the Atomized Injection (A.I.) hammer, the ram descends to within a small distance of the impact block and only then is fuel injected at high pressure. The high pressure injection mixes the fuel with the hot compressed air, and combustion starts nearly instantaneously. Injection then lasts until some time after impact, at which time the ram has traveled a certain distance from the impact block. Note that since distances govern the combustion, combustion start and stop volumes can be identified. Furthermore, the times from the start of injection to impact and then to the end of combustion depend on the speed of the ram. The higher the ram speed, the shorter the time periods between ignition, impact, and end of combustion.

3.2.3 Working Principle of External Combustion Hammers

Diesel hammers carry their own source of energy in a fuel tank attached directly to the hammer. All other hammers utilize an external engine or device to create mechanical energy. This energy is then transferred to the hammer either by means of hoses carrying steam, compressed air, or pressurized hydraulic fluid, or a hoist and rope.

For analysis purposes it is only important to realize that immediately prior to impact, the ram is descending at a certain speed. In some cases the action of the motive fluid may slow this descent, and have a self cushioning effect. This will occur if the fluid causes a lifting force on the ram <u>before</u> impact. However, this so-called preadmission is an abnormal condition, and occurs only in hammers with incorrect valve settings. In general, this situation cannot be detected by simple inspection methods and- -because of the large variety of hammer types- -cannot be modeled in detail.

The equivalent to the diesel hammer's cylinder is the so-called assembly of ECH (External Combustion Hammers). The assembly is simply the entire hammer, excluding the ram, and in many instances, this assembly is of significant weight. As the ram impacts against striker plate, hammer cushion, and pile, the assembly is momentarily unsupported and starts to fall due to gravity. When the assembly reaches the helmet again, a so-called assembly impact occurs which may create significant forces in the pile, particularly if the pile and helmet sharply rebound from the initial impact of the ram. Thus, if the assembly has a weight nearly equal that of the ram, the assembly should also be included in the hammer model. Figure 3.2 shows the working principle of a single acting air/steam hammer as an illustration.

3.2.4 Working Principle of Closed End or Double Acting Hammers

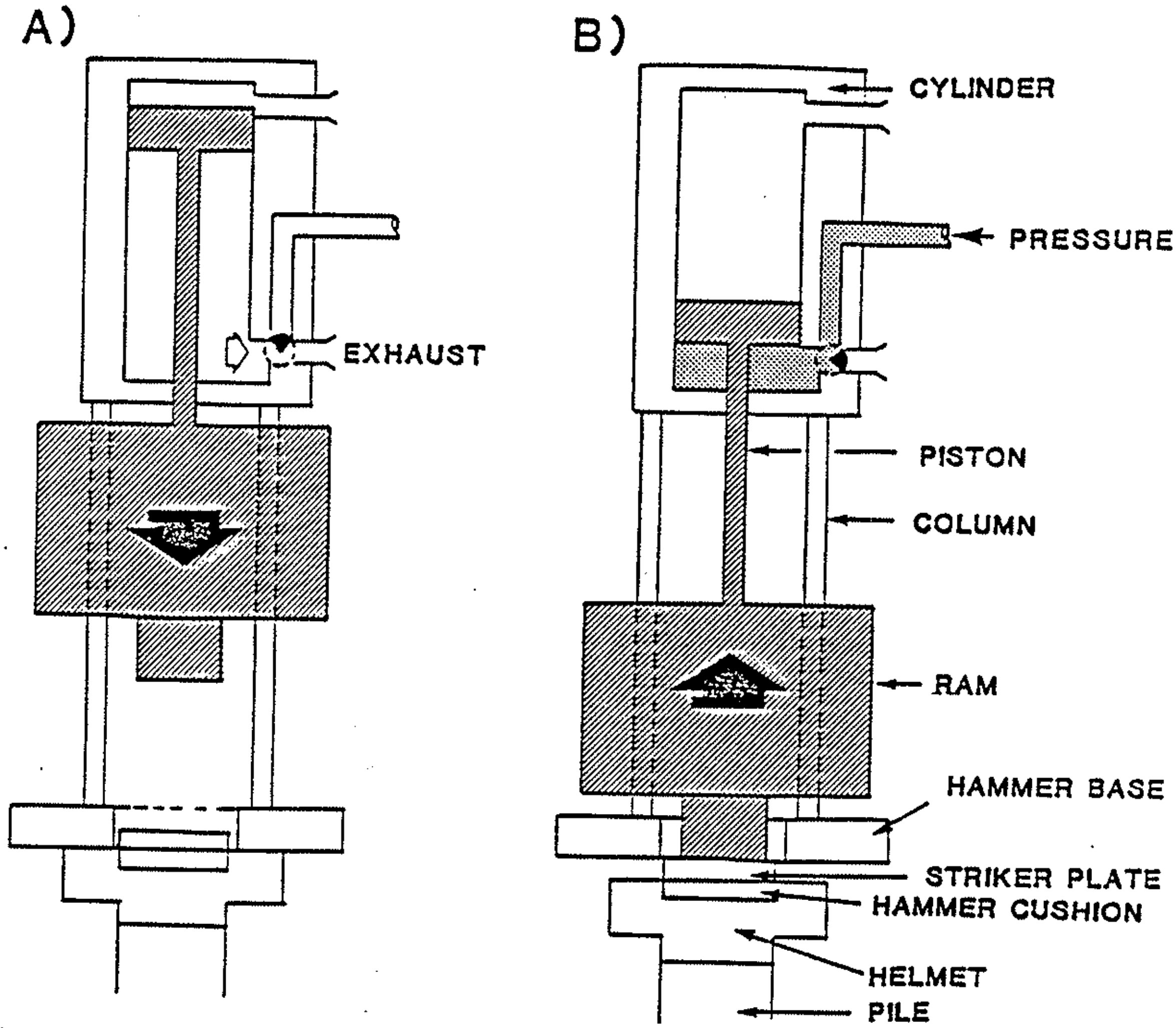
Closed end or double acting hammers operate at a higher blow rate than open or single acting units. The higher frequency of impacts is accomplished by the exertion of a downward force on the ram during its descent. For diesels, this force is created by an air cushion; for ECH this force is created by active pressure.

The analysis of this hammer type does not significantly distinguish itself from single acting units. Calculating "blows per minute" for diesels does however require a cumbersome analysis of the variation of pressure on the ram top. For air hammers, the impact velocity may be calculated under consideration of the active pressure, which stays constant during the downstroke.

3.2.4.1 Closed End Diesel Hammers

Closed end diesel hammers are very similar to open end diesels, except for the addition of a bounce chamber at the top of the cylinder. The bounce chamber has ports which, when open, allow the pressure inside the chamber to equalize with atmospheric pressure. As the ram moves toward the cylinder top, it passes these ports and closes them. Once these ports are closed, the pressure in the bounce chamber increases rapidly, stops the ram, and prevents a metal to metal impact between ram and cylinder top. This pressure can increase only until it is in balance with the weight and inertial force of the cylinder itself. If the ram still has an upwards velocity, uplift of the entire cylinder will result. In the field, this uplifting cannot be tolerated, as it can lead both to an unstable driving condition and to the destruction of the hammer. For this reason the fuel amount, and hence maximum combustion chamber pressure, has to be reduced such that there is only a very slight "lift off" or none at all.

Figure 3.3 shows two types of closed end diesel hammers, one with and the other without a compression tank attached to the bounce chamber. The difference between these two hammer types is subtle. The bounce chamber pressure in



A) Exhaust valve is opened and ram falls.
B) Inlet valve is opened and ram is lifted back up.

Figure 3.2. Working principle of a single acting air/steam hammer.

a hammer with a compression tank will increase at a lower rate than in the simpler unit. In closed end diesels which do have such a compression tank, the portion of the hammer between the tank ports and cylinder top is referred to as the safety chamber.

3.2.4.2 Double Acting, External Combustion Hammers

Various mechanical systems exist, among them the truly double acting air or steam hammers. Other systems are designed with differential or compound mechanisms (Ref. 13).

Because of these differences, the active pressure may or may not be allowed to expand during the downstroke. These hammers often run at rates of 120 blows/minute or more over relatively short strokes. Thus, proper valve timing is essential for good hammer performance. Since the downstroke of ECH's is not modeled, differences between single and double acting units need not be discussed in detail.

3.3 Hammer Models

3.3.1 Ram

The ram is the simplest and most important hammer component. Often a single mass element is sufficient for its model. For the slender rams often encountered in diesels and modern hydraulic units, more than one ram segment may be necessary for simulation. As a rule, ram segments should not be shorter than 2.5 ft (0.75 m) or unneccessary computational efforts will result.

With m being the number of ram segments, each segment, i, has a weight

$$W_{ri} = W_r/m, \; i = 1, \ldots, m \qquad (3.1)$$

where W_r is the total ram weight.

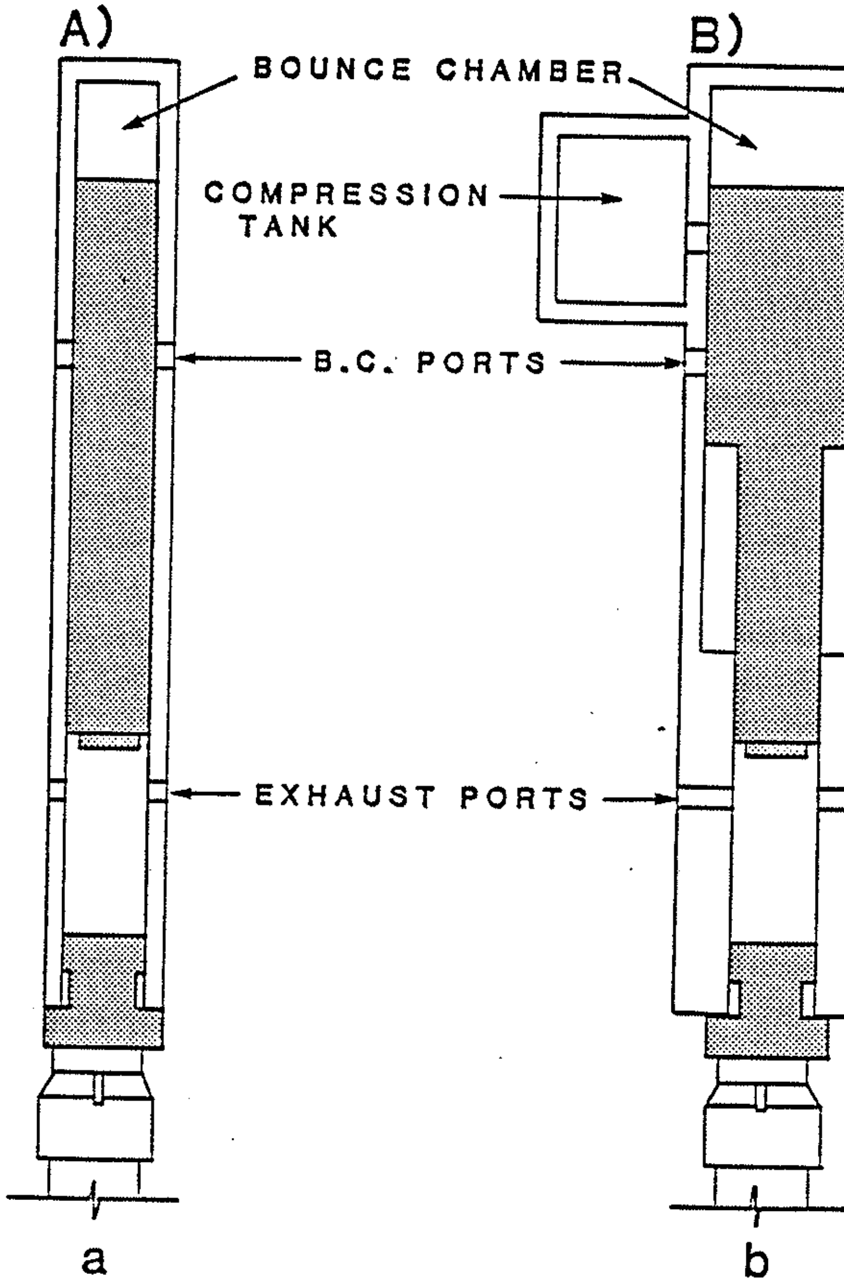


Figure 3.3. Closed end diesel hammers. (a) without, (b) with external compression tank.

A ram spring is attached under each segment mass. As with the segment weights, the stiffnesses of these springs are all assumed equal, which is of no consequence as far as accuracy is concerned, even for nonuniform rams.

Thus,

$$k_{ri} = m\, E_r\, A_r \;/\; L_r, \quad i = 1, \ldots, m \qquad (3.2)$$

E_r and A_r are the elastic modulus and average cross sectional area of the ram; L_r is the ram length.

As the ram impacts against the next lower segment, either helmet or impact block, it will contact the spring of that segment (below the ram, each spring is located above its corresponding mass). For that reason the m-th ram spring is combined with either the hammer cushion spring (ECH) or the impact block spring (Diesel).

The combined model of the bottom (m-th) ram spring and the spring below it must allow for separations and deformation caused by impact. For that reason a slack, d_{st}(distance which spring extends at zero tension force), a "round-out" deformation, d_{sc}, and a coefficient of restitution, c_s, are used to describe its behavior. A description of the characteristics of springs with slacks is given in Section 3.6. Standard values contained in the hammer data file are d_{st} = 99 inches (2.5 m) - really an unlimited slack-, d_{sc} = 0.12 inches (3 mm), and c_s = 0.9.

3.3.2 Assembly Model

The assembly is only considered for ECH's hammers. Its model consists of m_a assembly segments and springs. Their weights are calculated in a rather approximate manner since there is no need for great accuracy. The total assembly weight is approximately equal to the total hammer weight minus the ram weight. This information is readily available.

For hammers with columns, the total assembly stiffness may be approximated by the combined stiffness of the columns. An example is given in Volume II. The bottom assembly spring is nonlinear and a slack, round-out deformation, and coefficient of restitution are included in the model (see also Section 3.6).

3.3.3 Thermodynamic Models

3.3.3.1 Background and Available Data

The diesel hammer pressure data compiled in Appendix A forms the basis of the computational models developed for WEAP86. The support of the four manufacturers whose data is published in this report is gratefully acknowledged.

The data was collected starting in 1971. At that time, data processing and measurement methods were not as well developed as they are today. On the other hand, the tests became more and more ambitious, often subjecting transducers to rather high temperatures during long lasting heat tests. Thus, while earlier tests may not have included as many measurements as later ones, the later tests sometimes missed a few hammer setting readings when a transducer burned out. In addition, piezoelectric pressure transducers, used in all the tests, characteristically "leak-off" when a constant load is applied. Although this leak-off is slow, it is quite possible that at the end of the pressure records, the signals dropped a few percent below the actual values.

In all tests, pile top data was gathered together with pressure histories. This information allowed the computation of the transferred energy as an indirect indicator of hammer performance. It must be emphasized that these transferred energies do not establish a reference either for comparison of hammers or as a standard for a particular hammer. As an example, consider the ICE 1070 data which showed less than 20 kip-ft transferred energy. For a hammer rated at 70 kip-ft, this is an unusually low value. The same hammer (not the same unit) transferred more than 40 kip-ft of energy into a slender pipe in Savannah, Georgia, in May 1985. The reason for this different energy transfer is the rather high stiffness of the test stand, which reflected energy back to the hammer at a very early time during the impact.

Almost all test stands were built stiff to make them long lasting. An exception is the Bermingham test stand, which was heavily cushioned. In that case, the transferred energy values were even less representative of normal hammer performance, since they were measured underneath the cushion.

In this context it may be of interest to consider a closed end hammer on a stiff test stand (see ICE data). If the hammer's fuel pump were completely opened, then the hammer stroke would be high enough to cause uplifting or racking. Thus, a full stroke (maximum bounce chamber pressure) can be obtained with a reduced fuel setting and therefore a reduced combustion pressure.

Consider now the case of easy driving. No energy is transferred from the pile back to the hammer. In order to keep the hammer running, maximum fuel has to be supplied, and the combustion pressure is at a maximum while at the same time the bounce chamber pressure is low.

The above considerations may also be extended to open end diesels. They then lead to the following conclusion:

Hammer stroke (or bounce chamber pressure) and combustion pressure are not directly related. Stroke and combustion pressure measurements are related only under a given set of circumstances (driving system, pile, soil). This means that, in the case of the closed end hammers, in the field the maximum combustion pressure may exceed the maximum documented combustion pressure. Thus, the measurement results in the hammer data file cannot always be directly used, and must in some cases be corrected to become applicable in general pile driving analyses.

Such was the case for WEAP86. After the measurement results had been analyzed and the thermodynamic models had been set up, there were many trial wave equation runs. It was found that adjustments in the hammer data were sometimes necessary to bring all observations into agreement with the wave equation results.

3.3.3.2 Liquid Fuel Injection (Impact Atomization) Model

Liquid fuel injection is the most common design principle for diesel hammers. The process is as follows (see also Figures 3.4a and 3.4b):

- The ram descends and closes the exhaust ports.
- The air trapped inside the hammer cylinder between the ram and the impact block compresses and its temperature increases.
- Shortly after the ports are closed, fuel is injected into the chamber under low pressure, i.e., in liquid form. The liquid fuel collects on top of the impact block.
- The ram strikes the impact block, thereby causing the fuel to be atomized. Fuel atomization and combustion may occur spontaneously prior to impact in an overheated hammer; this is called preignition. Preignition, however, occurs only if the hammer is not performing within specifications.
- The atomized fuel starts to combust within a few milliseconds after impact. The time lag between impact and combustion is the combustion delay, t_d.
- The combustion process is finished within the combustion duration t_{cd}, i.e., within a few milliseconds after combustion started and the gases inside the chamber reached their maximum pressure.

  During combustion, the ram usually starts to separate from the impact block. The corresponding increase in chamber volume causes a reduction of the pressure inside the chamber.
- The ram reaches the ports, and chamber pressure drops to atmospheric pressure.

The foregoing stages of compression, combustion and expansion are all considered in the WEAP86 impact atomization model; the computational steps are detailed below. Computed pressures are expressed in terms of gage pressure (different from WEAP).

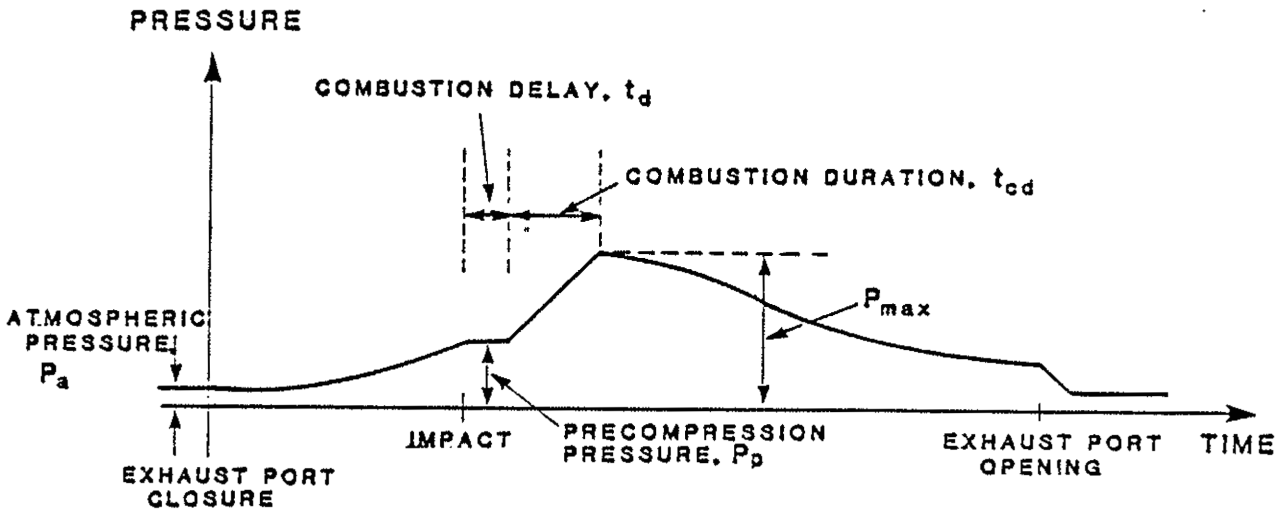


Figure 3.4a. Pressure vs. time relationship for liquid fuel injection model.

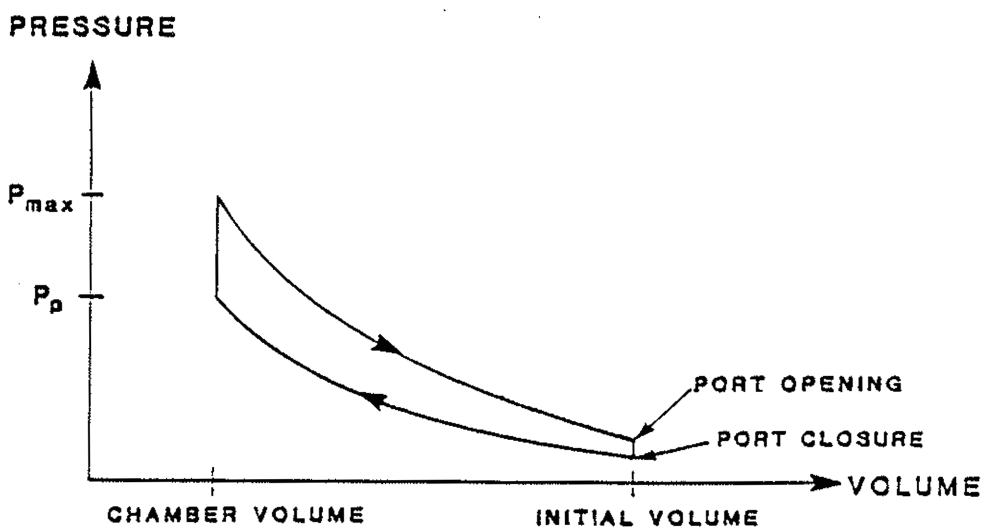


Figure 3.4b. Pressure vs. volume relationship for liquid fuel injection model.

Step a

At the beginning of compression, the chamber volume is equal to V_i, the initial volume. It can be computed from the combustion chamber volume, V_f, the cylinder area, A_c, and the compressive stroke, h_c.

$$V_i = V_f + A_c h_c \tag{3.3}$$

The position of the ram, u_r, is

$$u_r = -h_c \tag{3.4a}$$

(Note that the ram position at impact is considered to be zero.) The impact block position, u_{ib}, is zero at the time of port closure, thus

$$u_{ib} = 0.0 \tag{3.4b}$$

Step b

The ram has descended below the ports and the volume of the chamber is

$$V_c = V_f + A_c (u_{ib} - u_r) \tag{3.5}$$

The corresponding pressure, according to the Gas Law is

$$p_c = p_a ((V_i / V_c)^{c_p} - 1) \tag{3.6}$$

where p_a is the atmospheric pressure and c_p is the exponent for adiabatic compression.

Step c

No particular computation is necessary to reflect the injection process. However, thoughout the compression cycle, a check is made on the (negative) time until impact occurs.

$$t_i = (u_{ib} - u_r) / (v_{ib} - v_r) \tag{3.7}$$

where v_r and v_{ib} are the ram and impact block velocity, respectively. The time t_i is not exact since v_r changes under the effect of both gravity and gas pressure. However, since cases of preignition, i.e. where combustion starts before impact, contain great uncertainties, this prediction is sufficiently accurate.

For no preignition t_i does not affect the analysis. For preignition the combustion delay t_d, is negative. Once t_i is greater than t_d (e.g. t_d was -2 ms and t_i is now -1.95), t_c is set to $-t_i$. (Note that t_c is the time of start of combustion). The computations are then done as in the normal case.

Step d

At impact, time keeping is started for combustion control. The time of start of combustion is set to the time of impact whenever the combustion delay is zero or greater than zero.

Step e

Time has not exceeded the sum of time of combustion start, t_c, and the combustion delay, t_d. Chamber pressures are still computed as in Step b.

Step f

After the time has exceeded $t_c + t_d$, combustion starts. Until combustion is completed, two pressures are calculated. The first is the compression pressure, p_c, as in Step b with V_i and

p_a as the reference; the second is the expansion pressure

$$p_e = p_{max} (V_c / V_i)^{e_p} - p_a \tag{3.8}$$

i.e., with the maximum specified pressure, p_{max}, and the initial volume, V_i, as a reference. The exponent, e_p, is the expansion coefficient. To allow for the effects of cooling, e_p was made a function of time, increasing by up to 10 percent starting 10 ms after impact. This adjustment is of little consequence in all cases except those with low strokes.

With t_{cd} being the combustion duration and $t_d < t_c < t_d + t_{cd}$, the actual combustion pressure is

$$p_{ca} = p_c + (p_e - p_c)(t_c - t_d) / (t_{cd}) \tag{3.9}$$

which is merely a linear interpolation between p_c and p_e over time.

Step g

Expansion takes place and pressure is computed according to Equation 3.8.

Step h

The ports are reached, the pressure is set to zero.

Nine parameters are needed to compute the compression-combustion-expansion pressures. In summary, for liquid fuel injection these quantities are:

V_f .... the combustion chamber volume
A_c .... the inside cylinder area
h_c .... the compressive stroke
c_p .... the compression coefficient

c_e .... the expansion coefficient
p_{max} .. the maximum combustion pressure
t_d .... the combustion delay
t_{cd} ... the combustion duration
p_a .... the atmospheric pressure

Since c_p and c_e are not easily calculated from measurements, and since they may vary more for a given hammer (depending on its temperature) than among cold hammers of all types, c_p and c_e were set to be equal. The atmospheric pressure is known and only seven parameters need to be obtained from the hammer manufacturer. The first three geometric values are usually well known. The timing data t_d and t_{cd} vary only slightly for normally performing hammers.

Most importantly, the maximum pressure, p_{max}, should be determined by measurement. It can be iteratively computed if the stroke of the hammer is known for a particular situation (pile geometry and soil resistance). A recommended procedure to estimate p_{max} values is discussed in Appendix B.

3.3.3.3 The Atomized Fuel Injection Model

Atomized fuel injection is commonly used in diesel engines. The process requires that the fuel is injected into the chamber beginning and ending at exact piston positions. The injection pressure may be in the neighborhood of 1000 psi (7000 kPa) which produces a finely distributed fuel spray. As soon as the atomized fuel is mixed with hot air, it combusts. Compared to impact atomization, atomized fuel injection is used on only a small number of hammers, most notably in the U. S. on ICE (formerly Linkbelt) units.

The following phases need to be distinguished (see also Figure 3.5a and 3.5b).

- The ram descends and closes the exhaust ports.

- The air trapped between the ram and the impact block inside the hammer cylinder is compressed and its temperature increases.

- When the ram is at a certain, small distance from the impact block, atomized fuel is injected into the chamber. The ram distance from the impact block can be computed from the "initial combustion volume", V_{ci}. The fuel starts to burn and reaches a maximum pressure level at the time of impact (smallest volume).

- After impact, the ram rises and again at a certain distance from the impact block, combustion ends. The corresponding volume, V_{ce}, is the "end combustion volume". Until this point is reached, the pressure stays constant.

- The ram rises further allowing the gases to expand and pressures to decrease.

- The ram clears the exhaust ports and the pressure in the chamber returns to the atmospheric level.

Differences between the atomized and liquid fuel injection models only occur shortly before and after impact, i. e., in Steps (c) and (d). They are different from WEAP.

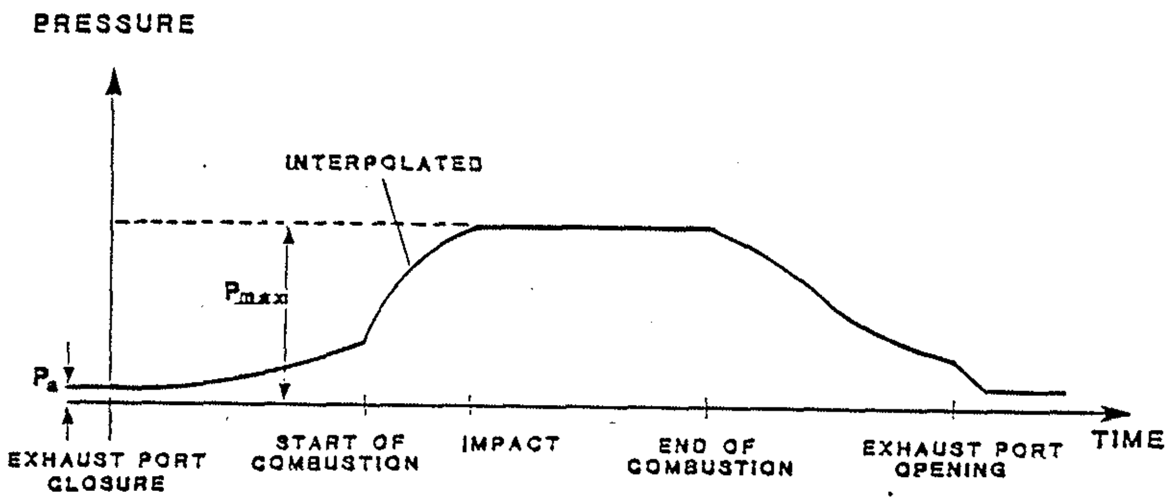


Figure 3.5a. Pressure vs. time relationship for atomized injection model.

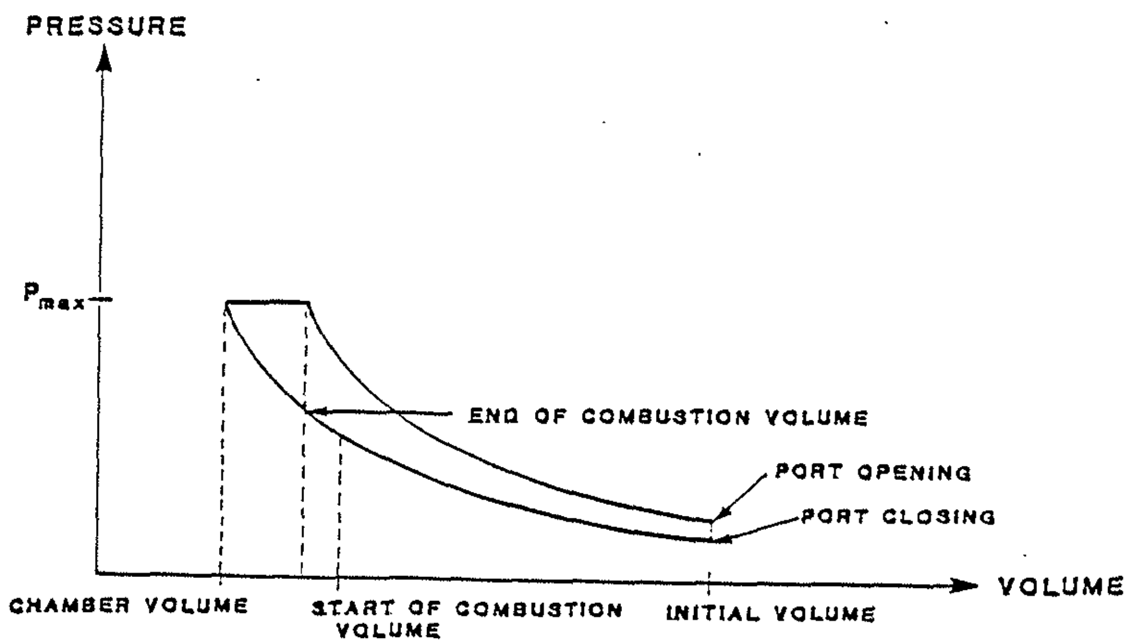


Figure 3.5b. Pressure vs. volume relationship for atomized injection model.

Step c

The gas pressure starts to increase from the precombustion pressure, p_{ci}, defined by the volume V_{ci} (volume at which combustion begins). It reaches the maximum combustion pressure, p_{max}, at impact (volume equal to V_f).

In WEAP86 this phase was modeled by a quadratic interpolation between p_{ci}, V_{ci} and p_{max}, V_f. Thus,

$$p_c = p_{max} - (p_{max} - p_{ci})[(V_c - V_f)/(V_{ci} - V_f)]^2 \qquad (3.10)$$

This equation assures that p_c approaches p_{max} as V_c approaches the chamber volume, V_f.

Step d

The pressure stays constant at p_{max} until the volume V_{ce} has been exceeded. At that point, both reference pressure and volume are set to p_{max} and V_{ce}, respectively.

In summary, once again nine quantities are needed to compute pressures for atomized fuel injection. All except the two timing quantities, t_{cd} and t_d, listed for liquid fuel injection are again needed. The two volumes, V_{ci} and V_{ce} take the place of t_{cd} and t_d.

3.3.4 Closed End Hammers (Double Acting)

As the ram descends, a closed end hammer not only falls under gravity but also experiences a downward pressure force. For a double (differential, compound) acting ECH, the wave equation program does not care how the ram has obtained its impact velocity and it is not necessary to deal with the active downward pressure. Instead of working with the actual stroke, it is therefore possible to calculate an equivalent stroke

$$h_e = E_r/W_r \quad (3.11)$$

where E_r is the hammer's rated energy and W_r is the weight of the ram.

The impact velocity is then

$$v_{ri} = (2g\ h_e\ e_h)^{1/2} \quad (3.12)$$

If a double acting hammer is run at a lower pressure than rated, the available energy due to pressure, E_{pa}, decreases. The rated energy portion due to pressure is the difference between rated and potential energy.

$$E_{pa} = E_r - h\ W_r \quad (3.13)$$

where h is the actual hammer stroke. This expression may be used to compute the "rated" pressure, p_r, under which the full impact velocity is obtained.

$$p_r = E_{pa}/(A_{eff}h) \quad (3.14)$$

A_{eff} is the effective piston area. Under a lower pressure, p_1, one obtains

$$E_{p1} = hp_1A_{eff} \quad (3.15)$$

If the rated pressure were known then one also could have computed a new hammer efficiency

$$e_h^1 = e_h\ (W_rh/E_r - 1)\ (p_1/p_r - 1) \quad (3.16)$$

and used it instead of e_h and with the reduced pressure. In fact, e_h^1 eliminates the need to differentiate between single and double acting hammers.

For double acting diesels, the need to compute (a) the hammer blow rate, (b) the precompression hammer-pile-soil behavior, and (c) the necessary fuel reductions to avoid uplift, requires that the force on the ram top be computed. Actually, the concept of equivalent strokes would also lead to acceptable results were it not for these three requirements. Thus, if bounce chamber information is not available, an equivalent open end diesel may be modeled and analyzed.

WEAP86 calculates gage pressure on the ram top based on a recommended expansion coefficient, c_{bp}. Thus, the bounce chamber pressure, p_b, may be calculated from:

$$p_b = p_a (V_{bi}/V_b)^{c_{bp}} - p_a \tag{3.17}$$

where V_{bi} is the initial volume in the bounce chamber.

$$V_{bi} = h_b\, A_{rt} + V_{ct} \tag{3.18}$$

with h_b being the "compressive stroke" of the bounce chamber, i.e., the distance from the bounce chamber ports to the top of the cylinder. A_{rt} is the cross sectional area of the ram top and V_{ct} is the compression tank volume.

Once the ram top penetrates the bounce chamber, by a distance u_b from the bounce chamber ports, the volume of the bounce chamber is

$$V_b = V_{bi} - u_b\, A_{rt} \tag{3.19}$$

The maximum stroke at which uplift is imminent is determined from the reaction (cylinder) weight of the hammer, W_c, yielding the uplift pressure

$$p_u = W_c/A_{rt} \tag{3.20}$$

and by back substitution of p_u into equations (3.17) and (3.18).

The ram velocity at the exhaust ports is important for starting the wave equation analysis. For WEAP86 (different from WEAP where it was computed in closed form) it is computed incrementally, by dividing the fall distance above the ports into 20 intervals. Gravity and bounce chamber pressure enter this calculation:

$$a_j = g(1+p_b A_{rt}/W_r) \tag{3.21}$$

(with a being the acceleration at time step j). This incremental approach was chosen in order to allow for the consideration of friction, variable expansion coefficients etc.

3.3.5 Hammer Energy Losses

Any wave equation analysis requires the calculation of an impact velocity, v_{ri}, which all ram segments possess before the ram contacts either striker plate or impact block. During the fall of an ECH ram the pile does not experience forces. Thus, the analysis only has to cover the time period at and after impact. For the diesel hammer, appreciable forces are exerted onto the pile before impact due to air compression in the cylinder. In general, therefore, prior to ram impact the pile already has a noticeable velocity and soil resistance is starting to be activated. Thus, it is necessary to start the analysis of diesels at the time of port closure.

For the ECH all energy losses in the hammer are easily deducted by introducing the hammer efficiency, e_h.

$$v_{ri} = (2g\ h\ e_h)^{1/2} \tag{3.22}$$

Note that for double acting ECH, h must be replaced by h_e in this equation.

For diesels, WEAP used the same concept except that the ram velocity, corrected for losses, was computed at the time of port closure. This concept yielded satisfactory results; however, it was not truly comparable to the ECH approach, particularly for low total strokes, relative to the compressive stroke. As an example, if a hammer has an 18-inch compressive stroke and its stroke above the exhaust ports is 60 inches, then correcting the velocity at the time of port closure would still leave 30 percent of the total stroke without consideration of losses. This inconsistency also leads to questionable results in the case of closed end hammers which have small total strokes and accelerate significantly during the compression cycle.

Ideally, the efficiency reduction of ram velocity would be calculated as energy losses occur. If, for example, friction were the major cause of a reduced impact velocity, then a reduction of the downward acceleration should be made. This concept was tested in WEAP86 by using a reduced gravity during the ram's downstroke and an increased gravity during the ram's upstroke.

As a result, the total cycle time (or the "blows per minute") increased proportionally as the efficiency decreased and the wave equation blow rate, b_m, did not agree with the wave equation stroke, h. Note that for open end diesels in English units $h = 4.01\ (60/b_m)^2 - 0.3$, with b_m in blows per minute and h in ft; this is called the Saximeter™ formula. The Saximeter™ formula has often been found to be accurate even when transferred energies are relatively low. It is not accurate whenever excessive friction reduces the ram velocity.

Another observation was made using a Hammer Performance Analyzer™ (HPA). This device measures ram velocity by means of radar technology. Often the HPA results indicated a very high impact velocity, near 95 percent of rated, yet the energy transmitted to the pile was only 50 percent of rated. Modeling of the driving system with low coefficients of restitution did not produce transferred energy values low enough for a good agreement with measurements, and it had to be concluded that a great deal of the losses modeled by e_h are not occurring before but during impact, for example, due to a nonaxial hammer-pile alignment.

As a result of the above considerations, it was decided not to reduce the ram velocity of diesel hammers until just before impact or ignition, i.e., when the compression analysis is finished, viz

$$v_{ri} = v_{rc} \, (e_h)^{1/2} \tag{3.23}$$

where v_{rc} is the velocity of the ram at the end of the compression analysis.

The point in time when this happens is within an inch of impact and practically the total ram stroke is therefore covered. The agreement of the Saximeter™ formula with WEAP86 is now maintained.

Efficiency values were derived in Reference 13. These efficiencies were

$$e_h = 0.67 \text{ for single acting ECH}$$
$$e_h = 0.50 \text{ for double acting ECH}$$

For the diesel hammers an efficiency of e = 0.72 had been derived with the old approach of correcting the ram velocity at the ports. Because the WEAP86 efficiency correction takes the total stroke into account, a higher efficiency value is used to produce an equivalent correction. Most of the data obtained in Reference 13 occurred during hard driving, where the ratio of total stroke to stroke above the ports was approximately 8/7. A WEAP86 efficiency of

$$e_h = 0.8$$

was therefore chosen for all diesel hammers. Of course, the reader must be aware that these recommendations represent an average hammer behavior and that significantly different efficiency values may be required to match measurements. It should also be reemphasized that e_h does not only cover losses that the ram experiences during its descent but - probably to a higher degree - losses occurring during impact and in the driving system.

3.4 Driving System Model

The driving system consists of striker plate, hammer cushion, helmet and, for concrete piles, pile cushion. This system is represented by two nonlinear springs (see Section 3.6) and a mass. The spring for the pile cushion is modeled in series with the first pile spring. For ECH the hammer cushion spring acts in series with the ram spring (see Figure 3.6).

If no hammer cushion is present, then WEAP86 splits the impact block spring and places one on top of the impact block and one on top of the helmet. Note that WEAP86 always requires that a helmet weight be input. For hammers which strike the pile directly, a top section of the pile should be "cut off" from the pile and used as a "helmet." However, even those hammers which do not require a helmet are usually fitted with a so-called anvil which is an integral part of the hammer and which therefore serves as a helmet. Note that the weight of devices like the striker plate, cushion, pile adaptors etc. should be included in the mass between hammer and pile top.

The driving system model also contains a dashpot in parallel with the hammer cushion spring. Its damping constant is computed from:

$$c_{dh} = 1/50 \; c_{dhi} \; (k_r m_a)^{1/2} \tag{3.24}$$

where c_{dhi} is a nondimensionalized input value, k_r is the hammer cushion stiffness and m_a is either the impact block (diesel) or helmet (ECH) mass. The default value of c_{dhi} is 2.

3.5 Pile Model

The pile model consists of springs, masses and dashpots (see Figure 3.7). The pile is divided into N segments whose lengths are given by

$$l_i = a_i \; L \tag{3.25}$$

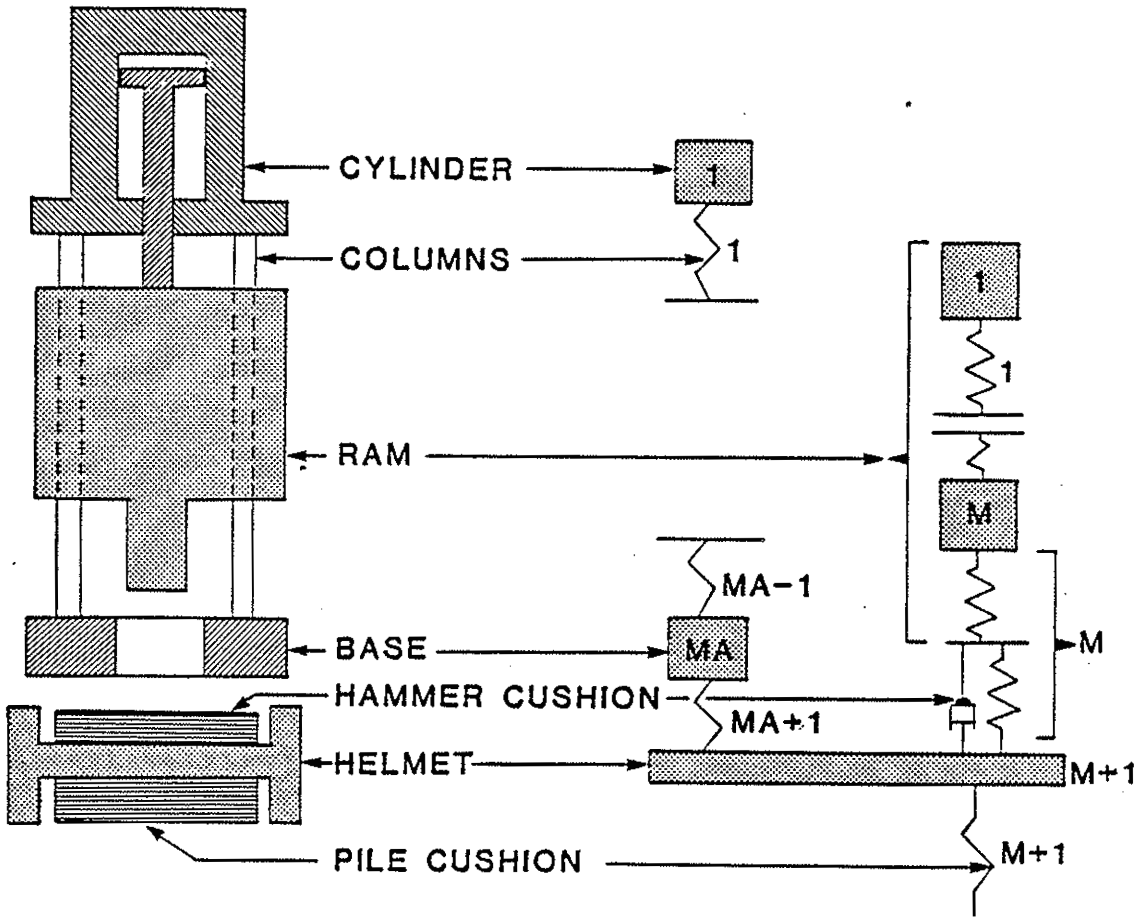


Figure 3.6. Hammer-driving system model for ECH hammers.

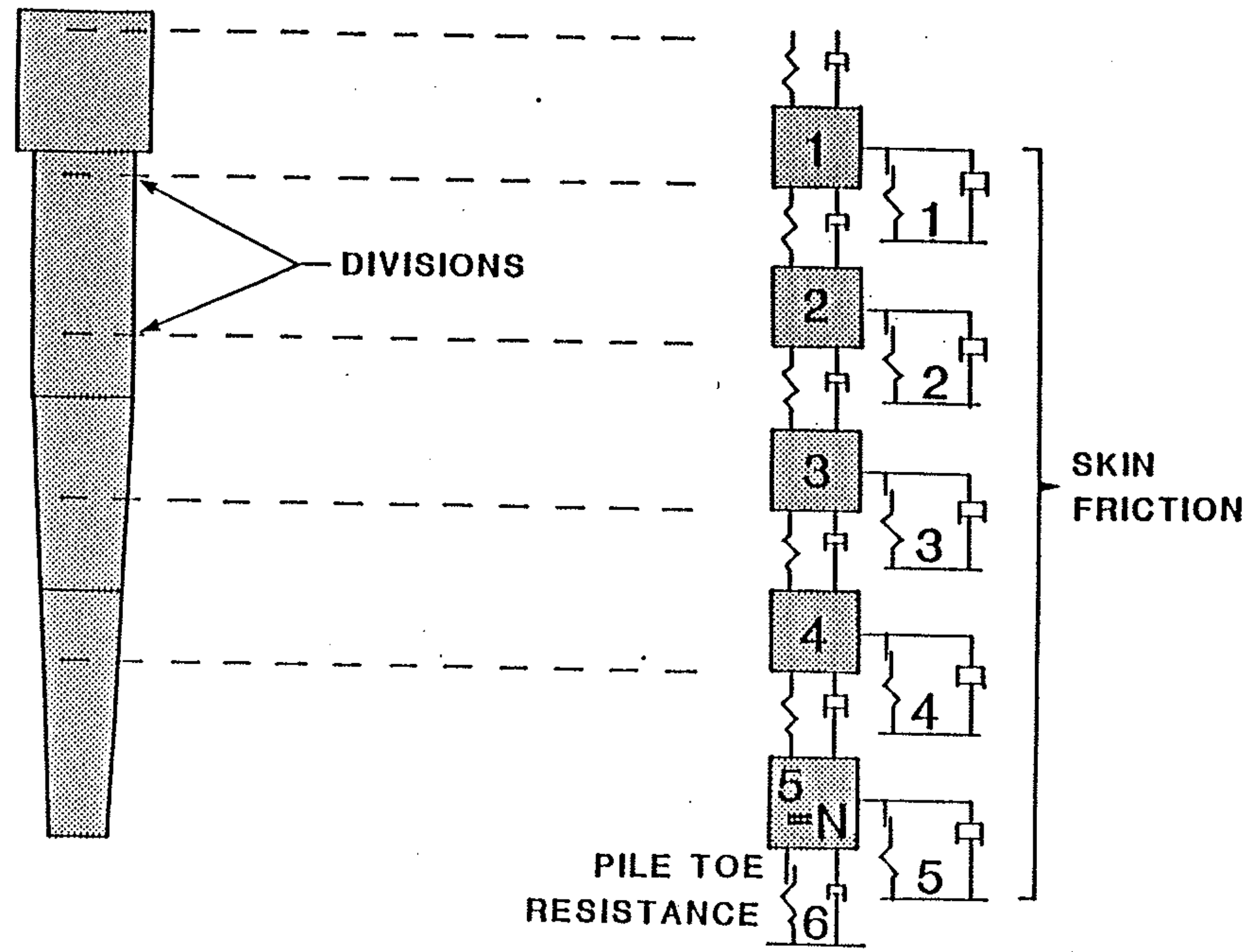


Figure 3.7. Pile and soil model, (a) real (b) model.

where L is the total pile length and a_i is a multiplier which is normalized such that:

$$\text{sum}(a_i) = 1.0, \; i = 1, 2, \ldots, N \tag{3.26}$$

The weight of segment i is

$$W_i = w_i \; A_i \; l_i \tag{3.27}$$

with w_i being the average specific weight and A_i the average cross sectional area of the pile element, both averaged over the distance l_i.

Similarly the segment stiffnesses are

$$k_{pi} = E_i \; A_i / l_i \tag{3.28}$$

where E_i is the average elastic modulus over the element length. Obviously, multimaterial piles can be treated in this fashion.

A third parameter, the pile damping value, can be specified for the pile. Since little is known about the correct structural damping model, and since this type of damping produces relatively small energy losses compared to soil damping, an elaborate model does not seem justified. Thus, viscous damping was assumed with parameters:

$$c_{dp} = 1/50 \; c_{dpi} \; EA/c \tag{3.29}$$

with c_{dpi} being a non-dimensionalized input quantity and EA/c being the impedance of the pile top; c_{dp} is assumed equal for all elements. This differs from the original WEAP program.

The computed damping constant, c_{dp}, is not directly related to pile length; it is, however, sensitive to the total number of pile segments. Thus, if for a particular pile two analyses are done, each with a different number of segments but with the same pile damping parameter, then the total damping loss will be different. This approach is not quite satisfactory and is only tolerated in light of the small effects of pile damping and the limited knowledge of material damping. Further efforts in this area are encouraged.

3.6 Splice Model

WEAP86 uses a splice model which has also been incorporated into the models for the cushions, impact block/helmet, and pile top. This model contains three parameters: a slack, d_{st}, a coefficient of restitution, c_s, and a round-out deformation or compressive slack, d_{sc}. The resulting force-deformation curve is shown in Figure 3.8.

During compression of the splice model, force increases parabolically with respect to deformation until the round out deformation, d_{sc}, is reached. The corresponding force at this point is F_{lim}. Beyond this point, force increases linearly, with the slope given by the spring stiffness, k. During the subsequent expansion, force decreases linearly with respect to deformation, but this time the slope is k/c_s^2. As soon as the force falls below F_{lim}, the curve once again becomes parabolic. However, now the deformation over which round out occurs is shorter. This is because F_{lim} stays constant, but the slope at the start of the parabolic curve is now steeper.

During tension in the splice model, the same rounding procedure is used; however, it starts only after the spring has been extended beyond the slack distance, d_{st}. Within this separation distance, the spring force is always zero.

For springs which cannot take any tension at all, d_{st} is set to a large value (e.g. 99 inches or 2.5 m). In this way, cushion, pile top, and splice forces can be calculated with the same algorithm. Because of the rounding feature, numerical stability of the analysis of spliced piling was assured. Note that the splice model is used in WEAP86 whenever $d_{st} > 0$. To model a linear spring, d_{st} must be set to a negative value.

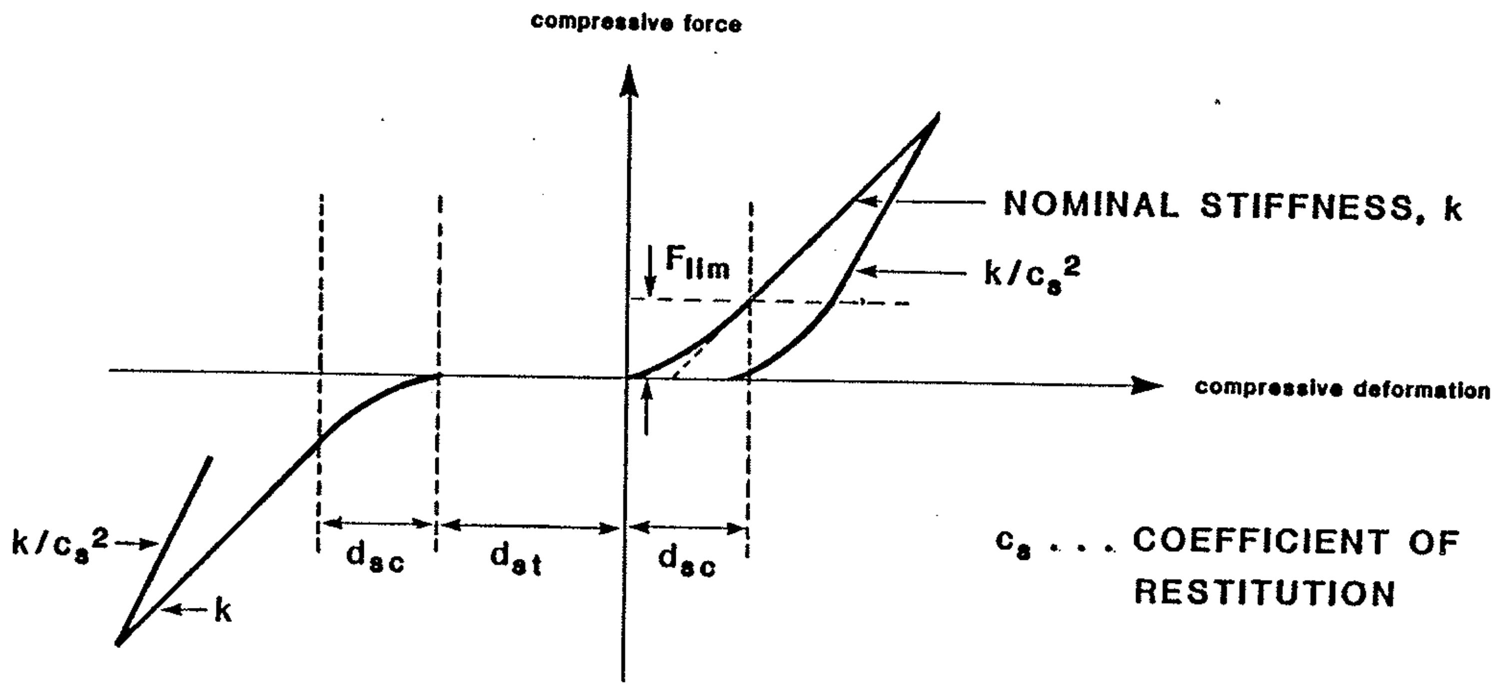


Figure 3.8. Force-deformation curve for slack model.

3.7 Soil Model

The soil model offers a few options beyond the original Smith approach. It basically consists of a spring and dashpot (Figure 3.7). The elastic spring yields at a pile segment displacement equal to q_i (quake). There is then no further increase in static resistance, R_{si}, with increased displacement, u_i. Thus,

$$R_{si} = (u_i / q_i) R_{ui} \text{ for } u_i \leq q_i \tag{3.30}$$

and

$$R_{si} = R_{ui} \text{ for } u_i > q_i. \tag{3.31}$$

where R_{ui} is the ultimate static resistance at segment i.

Unloading, i.e., when the pile segment has an upward velocity, follows at a spring rate that is equal to that used in the loading path. (Note that the ESOIL option of WEAP was removed in WEAP86.)

The damping model can be chosen according to Smith, viz

$$R_{di} = j_{si} R_{si} v_i \tag{3.32}$$

where R_{di} is a damping resistance force and j_{si}, v_i and R_{si} are the Smith damping factor, the pile segment velocity and the static resistance force, all at segment i, respectively. Smith's damping factor has units of time/length.

The second choice for soil damping is

$$R_{di} = j_{si} R_{ui} v_i \tag{3.33}$$

which means that R_{ui} replaces R_{si}. Thus, in this option the multiplier of v_i is constant and a truly viscous damping results. This is an advantage over the Smith approach. This approach is always recommended for RSA analyses.

The third choice is a nondimensionalized viscous damping for which

$$R_{di} = j_{ci}\ v_i\ (k_{pi} m_{pi})^{1/2} \tag{3.34}$$

Here j_{ci} is the Case (Institute of Technology) damping factor of unit dimension. Note that the bracketed expression on the right hand side of the above equation is equivalent to the impedance of pile segment i (Young's modulus, E, times cross sectional area, A, divided by wave speed, c). This approach is only recommended where experience with soil and pile type exist.

The distribution of damping is handled in the following way: The WEAP86 user decides on skin and toe damping factors. Then, for Smith's damping of both type 1 and type 2, a constant factor is used along the pile skin and another factor is used at the toe. This actually means that the corresponding viscous damping factor varies proportionally to the static resistance distribution along the skin. A similar system is used for the Case damping approach. Here the input also consists of skin and toe damping factors. After multiplication with the impedance (conversion to viscous damping), the skin damping factor is distributed among the pile segments in proportion to their static resistance values.

3.8 Numerical Procedure and Integration

Although ECH and diesel hammer analyses are performed in separate routines because of their distinctly different models, the numerical procedure for these hammers is very similar.

3.8.1 Time Increment

A lumped mass model is only stable if the time increments are chosen shorter than the corresponding wave travel time through a segment. The wave travel time through a segment, i, is

$$\Delta t_{cri} = (m_i / k_i)^{1/2} \tag{3.35}$$

which- -for uniform piles- -is equivalent to

$$\Delta t_{cri} = l_i / c_i \tag{3.36}$$

where l_i is the segment length and c_i the average wave speed in segment i. Note that

$$c_i = (E_i \; g/w_i)^{1/2} \tag{3.37}$$

In order to avoid instability, the computational time increment, Δt, is chosen as

$$\Delta t = \min(\Delta t_{cri})/p \tag{3.38}$$

where $\min(\Delta t_{cri})$ stands for the minimum critical time of all segments, i, and p is a number greater than 1. In WEAP86, p = 1.6.

3.8.2 Analysis Steps

3.8.2.1 Prediction of Pile Variables at Time j

The computation starts with a preintegration (see Figure 3.9) in order to predict velocities from v_{ij-1} and from accelerations, a_j. Displacements, u_{ij}, are predicted from v_{ij} and u_{ij-1}. The subscripts indicate the segment, i, and the time step, j. For example, the ram of an ECH is a simple mass, m, and has an initial velocity equal to the ram impact velocity, v_{ri}. Furthermore, at the beginning of the computations (j = 1) at the top segment (i = 1),

$$a_{11} = g \tag{3.39}$$

Thus the prediction produces

$$v_{12} = v_{ri} + a_{11} \; \Delta t \tag{3.40}$$

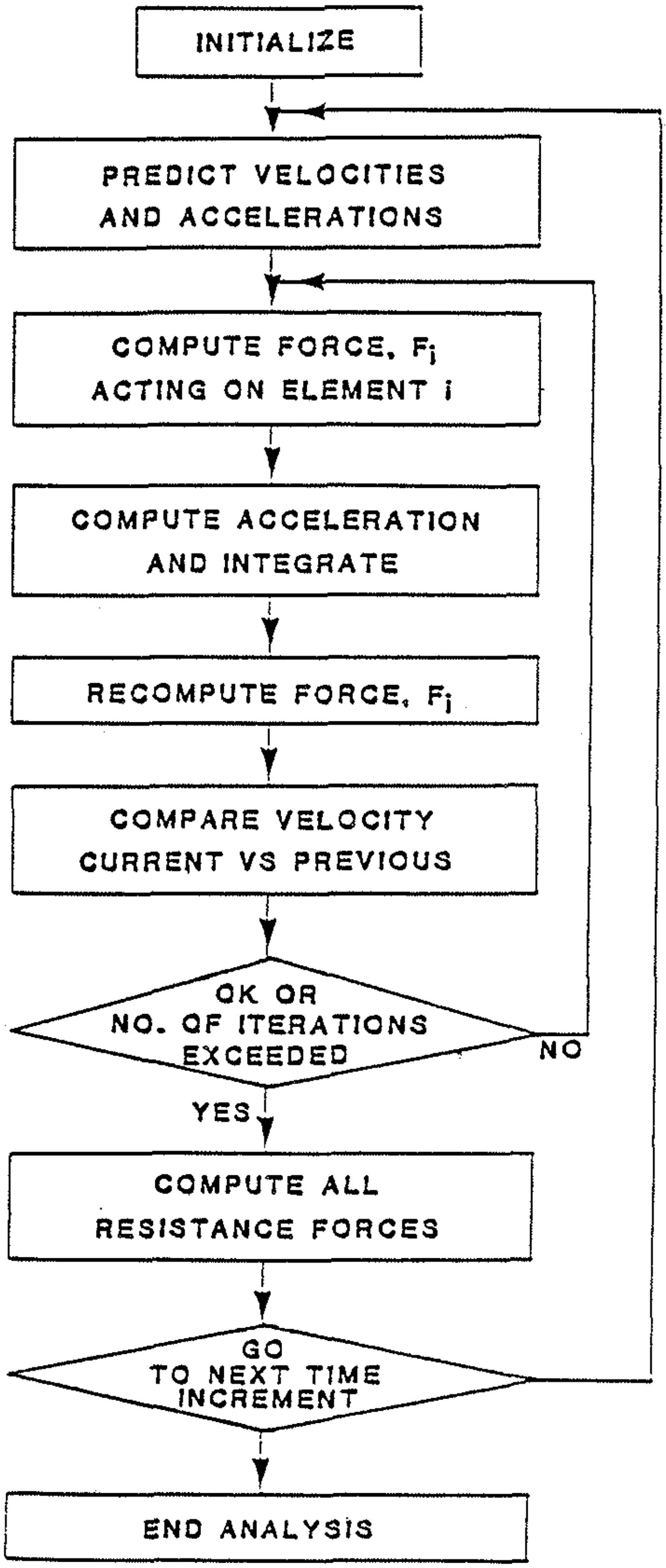


Figure 3.9. Block diagram of predictor-corrector analysis.

and $$u_{12} = u_{11} + v_{ri} \Delta t \tag{3.41}$$

Thus, in the prediction step a simple Euler integration is performed.

This prediction yields good estimates of $u_{i,j}$ for all segments i at time j. For each segment, i (see Figure 3-10), the following forces are now computed:

3.8.2.2 Forces at a Given Segment

The force at the top spring is

$$F^t_{sij} = k_i \ (u_{i-1} - u_i) \tag{3.42}$$

The stiffness k_i is that of any hammer, driving system, or pile segment, subject to modification if there is a positive slack d_{st} at spring i.

The force at the top dashpot is

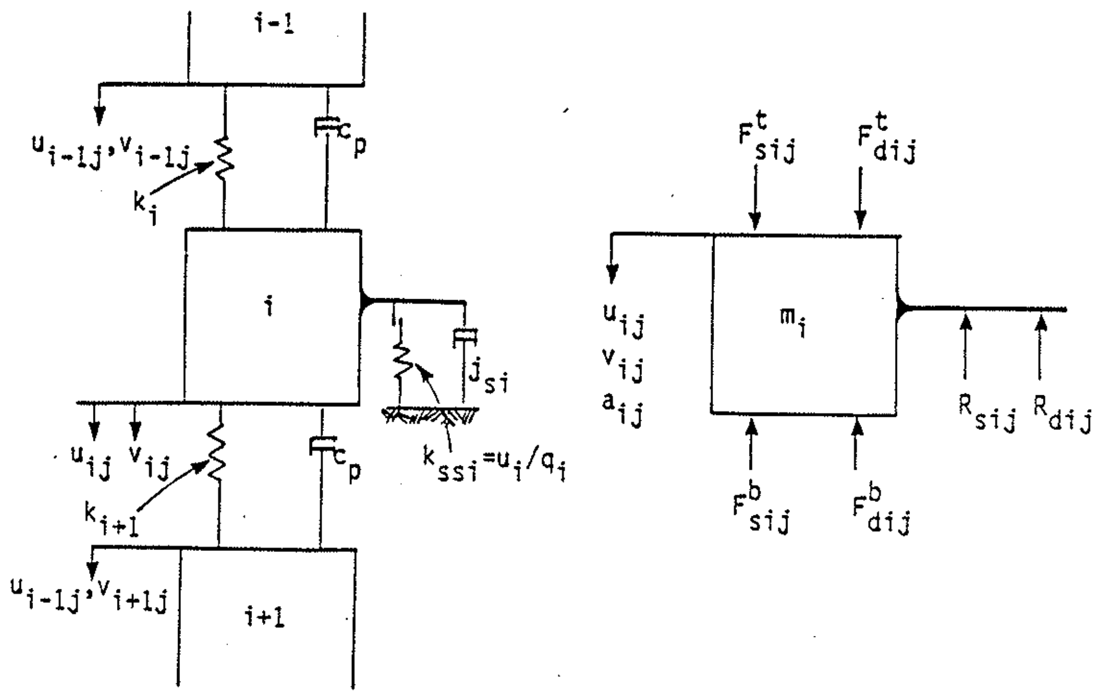
$$F^t_{dij} = c_p \ (v_{i-1} - v_i) \tag{3.43}$$

The force at the bottom spring is

$$F^b_{sij} = k_{i+1} \ (u_i - u_{i+1}) \tag{3.44}$$

The force at the bottom dashpot is

$$F^b_{dij} = c_p \ (v_i - v_{i+1}) \tag{3.45}$$



Superscripts	t . . . top side	b . . . bottom side
Subscripts	i . . . segment number	s . . . static
	j . . . time interval	d . . . dynamic
Main Symbols	u . . . segment displacement	q . . . quake
	v . . . velocity	k . . . spring stiffness
	a . . . acceleration	c_p . . pile damping constant
	F . . . forces in pile	j . . . soil damping constant
	R . . . resistance forces	m . . . mass

Figure 3.10. Computing forces acting on pile segment i.

3.8.2.3 Newton's Second Law for Acceleration Calculation

Using the external resistance forces, R_{sij} and R_{dij}, calculated at the end of a previous time step, it is now possible to compute the acceleration of a given segment during the current time step.

$$a_{ij} = (F^t_{sij} + F^t_{dij} - F^b_{sij} - F^b_{dij} - R_{sij} - R_{dij}) / m_i \qquad (3.46)$$

3.8.2.4 Correction Integration

Now an integration is done under the assumption of a linearly increasing acceleration

$$v_{ij} = v_{ij-1} + (a_{ij}+a_{ij-1})\Delta t/2 \qquad (3.47)$$

and

$$u_{ij} = u_{ij-1} + v_{ij-1}\Delta t + (2a_{ij-1} + a_{ij})\Delta t^2/6 \qquad (3.48)$$

Since the displacements are now more accurately known, F^t_{sij} and F^b_{sij} are recalculated (Section 3.8.2.2). The changes of dashpot forces F^t_{dij} and F^b_{dij} are not recalculated.

3.8.2.5 Further Iterations

This process can now be repeated starting at Section 3.8.2.2, with the newly computed a_{ij}, v_{ij}, and u_{ij} values taking the place of the previous prediction. Whether or not this repeat calculation is done depends on:

- Whether the number of iteration steps specified by the user (usually zero) has been exceeded or
- Whether or not the velocities of the top and bottom pile elements have converged with their previous values.

3.8.2.6 Soil Resistance for End of Time j

If convergence has been achieved the resistance forces are calculated.

$$R_{sij} = R_{sij-1} + (R_{ui}/q_i)(u_{ij} - u_{ij-1}) \quad (3.49)$$

with

$$R_{sij} \leq R_{ui} \quad (3.50)$$

and

$$R_{sij} \geq - R_{ui} \text{ for skin segments and} \quad (3.51)$$

$$R_{sn+1j} \geq 0 \text{ for the end bearing} \quad (3.52)$$

Soil damping is computed according to equations 3.32, 3.33, or 3.34.

At this point the analysis for time increment j is finished and the next time increment is analyzed.

3.8.2.7 Splices and Interfaces

Of course, there are complications, e.g., at splices or impact interfaces. For example, if segment i has a slack $d_{st} > 0$ then it must also have a round-out, d_{sc}, and a coefficient of restitution, c_s. In this case, k_i must be reduced if $F^t_{sij} < F_{lim}$ and if the spring goes into unloading (effect of c_s). In addition, if $u_i - u_{i-1} < d_{st}$ (tension deformation less than tension slack), then $F^t_{sij} = 0$.

Furthermore, an air pressure force acts on top of the first ram segment of closed end diesels, and on all diesels, a compression-combustion-expansion force acts between segments m and m+1.

3.9 Stop Criteria

It is not possible to predict how much elapsed time an analysis must cover in order to assure that the permanent set can be accurately computed.

If the analysis runs longer than necessary, undue computational expenses occur. If it is stopped too early, the computed permanent set may be too low.

The stop criteria had to be made different for ECH and diesels because of the diesels' particular requirements, primarily the need to analyze long enough for an accurate stroke calculation.

For ECH the following stop criteria are used:

A1 The analysis is run until the user-specified elapsed time, t_{max}, has been covered. If t_{max} was specified as greater than 1/2 of a second (actually, 499 ms), it is ignored. However, in this case the analysis will be carried out over at least 4L/c for a complete stress check. In addition, the conditions of A2 must also be satisfied.

A2 If the user did not specify a time, the analysis will cover an elapsed time of at least 2L/c (twice pile length divided by wave speed) or 20 ms. The analysis is then stopped only when one or more of the following additional criteria are met:

A2.1 The pile toe displacement has exceeded 4 inches (100 mm). (Since this is rather easy driving not much can be learned from a longer analysis).

A2.2 The pile toe has rebounded to 80 percent of the maximum pile toe displacment. (Such a rebound is sufficient to assure that the pile will not penetrate any deeper).

A2.3 The pile toe has rebounded to 98 percent of the maximum pile toe displacement and no pile segment velocity is greater than 20 percent of the maximum pile top velocity.

For diesels, elapsed time is counted starting 2 ms before either impact or ignition, whichever occurs earlier. The analysis stops when either:

B1 the user-specified elapsed time, t_{max}, (subject to the conditions of A1) has been covered, or

B2 If the user did not specify a time, then the analysis will cover an elapsed time of 2L/c + 5ms, or 50 ms, whichever is longer. The analysis may be stopped earlier if at least 20 ms of elapsed time has been analyzed and one or more of the following occurs:

B2.1 the maximum pile segment velocity is less than 20 percent of the maximum pile top velocity

B2.2 the pile toe has rebounded to 80 percent of the maximum pile toe displacement and the ram has reached a distance of at least 10 percent of the compressive stroke from the impact block

B2.3 If the pile toe has rebounded to 98 percent of the maximum pile toe displacement and the ram has reached a distance of at least 20% of the compressive stroke from the impact block

3.10 Non Residual Blow Count Computation

The blow count calculation in WEAP was similar to other programs, in that the difference between the maximum toe displacement, u_{mt}, and the toe quake, q_t, was used as a prediction of the final net set of the pile. Suppose that a pile has a relatively large toe quake, say 0.4 inches, and normal skin quakes, say 0.1 inches. If the total toe resistance is small compared to the skin friction, then u_{mt} will not be significantly influenced by the toe quake. However, the large toe quake will significantly influence the computed blow count, for no physical reason.

In order to make the computed blow count less sensitive to toe quake changes, WEAP86 now uses an averaged quake.

$$q_{av} = \text{sum}[R_{ui}(q_i)]/R_{ut} \tag{3.53}$$

where R_{ui} and q_i are the individual ultimate resistance values and quakes, respectively, and R_{ut} is the total ultimate capacity. Sum means that a summation is to be made over all elements i = 1, N+1 (N is the number of pile segments). The N+1 st resistance is the end bearing. The predicted permanent pile set is then

$$s = u_{mt} - q_{av} \tag{3.54}$$

and the blow count is

$$B_{ct} = 1/s \tag{3.55}$$

It should be noted that for strongly variable quakes a residual stress analysis is the only accurate method for blow count computations.

3.11 Residual Stress Analyses (RSA)

3.11.1 Introduction

Primarily for reasons of computational economy, the Smith approach to wave equation analyses makes two important simplifications.

- In the beginning of the analyses it is assumed that the forces in the pile and the soil are zero. WEAP corrected this asssumption only to the extent that the helmet-hammer assembly and pile weight are balanced by the static soil resistance.
- At the end of the analysis, the pile starts to rebound. However, the full rebound is not analyzed, and the final permanent set is "predicted" from the difference between maximum toe displacement and toe quake. This approach assumes that the pile rebounds to a stressless state and is therefore consistent with Smith's simplifications.

There are many cases where this simplified approach is satisfactory. For example, if the soil exhibits little or no skin friction forces, the conventional assumptions are justified. Another example is a pile which is so rigid that its elastic compression is small compared to the soil quakes.

In general, however, a pile does not completely rebound after the hammer blow is finished. Often the toe quake is larger than the skin quake and therefore the toe tends to push the pile back up a relatively long distance.

As the skin elements of the pile move upward, their resistance first decreases to zero and then becomes negative until an equilibrium exists between the positive toe resistance and the negative skin friction. At this point the pile comes to rest and compressive forces are locked into pile and soil.

A large toe quake is not the only condition necessary for residual stresses to occur in pile and soil at the end of a blow. Consider a very flexible pile with a large amount of skin friction. During the first hammer blow, the pile's upper portion will move deeply downward due to the pile's high flexibility. The high skin friction will prevent a large toe motion. After the hammer ceases to load the pile head, the upper pile portion attempts to elastically spring back a large distance, the toe only a short one. Again, the friction forces will turn negative and the pile will stay compressed. The next blow will be able to drive the upper pile portion deeper since the pile now behaves stiffer (the pile is precompressed). At the end of the second blow the precompression in the pile may be a little larger and extend down a little deeper. Later blows will eventually drive all pile segments the same distance, and precompression will no longer increase at the end of each blow.

It is likely that the major portion of compressive soil resistance acts at the skin of the pile near its bottom. End bearing is not needed to cause residual effects.

It is also conceivable that in very long piles both tensile and compressive stresses remain after a blow is finished. Moreover, while in most piles the same compressive stress pattern will reoccur after a few startup blows, for very long piles two or three typical stress patterns may occur. Thus, for very long piles it may be difficult to decide whether or not convergence has occurred in an analysis.

3.11.2 How RSA Works

The analysis option built into WEAP86 was developed by P. Hery under the direction of Professor G.G. Goble at the University of Colorado at Boulder.

In his thesis, (15), Hery describes the background of the algorithm and references the work of Holloway. (14) In summary, the WEAP86 residual stress analysis (RSA) works as follows:

- After the normal dynamic analysis is finished for one R_{ut} value, and using these displacement and static resistance values together with the quakes, a static analysis is performed which predicts the displacements and forces at which pile and soil will be in static equilibrium (all velocities are zero).
- A second WEAP86 analysis is done with the displacements and forces from (1) as initial values. This analysis may be thought of as the simulation of a second blow.
- Again a static analysis is performed after the dynamic analysis is finished.
- The total pile compression is computed to check for differences between the first and second blow. If the two compression values are within 5 percent, then convergence is achieved. If the compression values have not converged, additional "blows" will be applied to the pile.
- As mentioned earlier, displacements and soil resistance values calculated at the end of one clow become the initial values used in the analysis of a subsequent blow. This subsequent blow, however, may also be ultimate capacity. Also, since a diesel analysis will automatically involve the use of stroke iterations anyway, use of the RSA option causes static values to be computed at the end of each diesel stroke iteration. As always, these values are then used as initial values in the analysis of the next blow.

WEAP86 contains the following modifications of the original CUWEAP RSA code:

- The convergence criterion was relaxed from 1 to 5 percent to avoid unnecessary computational efforts. Convergence is determined using pile compression, rather than pile displacement, as in CUWEAP.
- For the convergence criterion, compression is only calculated in that portion of the pile which encounters soil resistance. This makes the convergence criterion more sensitive in situations where long piles have a short embedment.

- The computed static displacement vector was normalized such that the pile top displacement is always zero at the beginning of an analysis. This is valid because pile segment displacements are relative values only. With a pile top displacement of zero at the beginning of the next blow, the hammer components will also show a zero net displacement.

- Instead of storing the pile segment displacements, computed at the time of maximum toe displacement, the displacements, occurring at the end of an analysis are stored. These displacements are then used as direct input to the static analysis. There is no reason why maximum displacements must be used. In fact, if the analysis has lasted a long time after the occurrence of the maximum toe displacement, better convergence can be achieved with the final displacaement values.

- The output was increased to include the final displacement pattern, normalized such that the top displacement equals the computed final pile set. Furthermore, the maximum stresses listed in the output include residual stresses.

3.11.3 Details of the RSA

The following contains excerpts from Reference (15).

3.11.3.1 Initial Conditions

The basic concept of RSA in WEAP86 is to find the displacements and static soil resistance values when the pile has completely come to rest or, in other words, when a static equilibrium of the system is achieved.

In his program, DUKFOR, Holloway stops the dynamic process when the "useful" work is done. By this, he means when the sum of all the dashpot forces is less than a prescribed minimum value (1 kip).

Another alternative, used in WEAP86, is to interrupt the dynamic analysis once it has been ascertained that the pile tip has started to rebound. This is usually the time at which the dynamic analysis is finished in non-RSA analyses and no more "useful" penetration work is being done.

At the end of the dynamic analysis, a set of final pile segment displacement and static resistance values are stored, namely

$$u_{fi}, \ i = 1, 2, \ldots, N \tag{3.56}$$

and

$$R_{sfi}, \ i = 1, 2, \ldots, N + 1 \tag{3.57}$$

The unknowns are the pile segment displacements, u_{si}, and static soil resistance values, R_{ssi}, for which static equilibrium exists.

3.11.3.2 Model for Computing Static Equilibrium in RSA

The representation used for the pile-soil model is the same as in the dynamic analysis, except that now the dashpots have been removed (Figures 3-11). The soil springs are still elastoplastic and keep their stiffnesses.

At the end of the dynamic phase, a soil spring may be in any one of the following situations:

- the spring did not go plastic and therefore loading and unloading will occur on the same path (Figure 3.12a).
- the spring did go plastic and the soil resistance is the ultimate resistance. The unloading will start from the point D and will follow a path parallel to the loading line (Figure 3.12b).
- the spring did go plastic but started to unload. Further unloading will occur on the same slope. If the ultimate soil resistance in tension is reached, the unloading will follow the plastic path (Figure 3.12c).
- the spring did go plastic in compression, then in tension. Thus, the unloading will occur along the plastic line (Figure 3.12d).

A priori, it is not known which springs will become plastic and if there will be loading or unloading of the soil springs, so the best formulation linking displacements and soil resistances is

$$R_{si} = R_{sfi} - (R_{ui}/q_i)(u_{fi} - u_i) \tag{3.58}$$

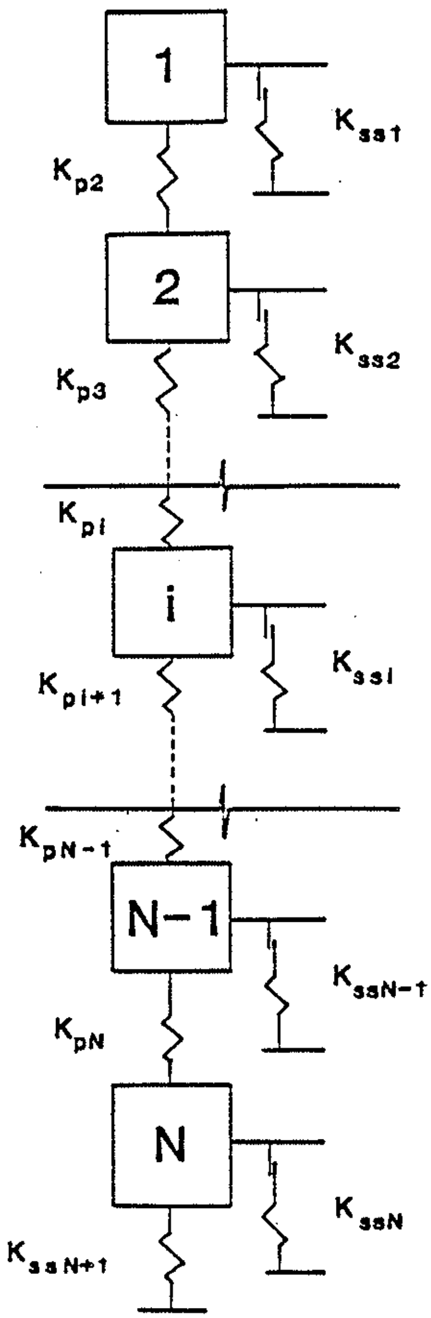


Figure 3.11. Static pile-soil model used in the RSA analysis.

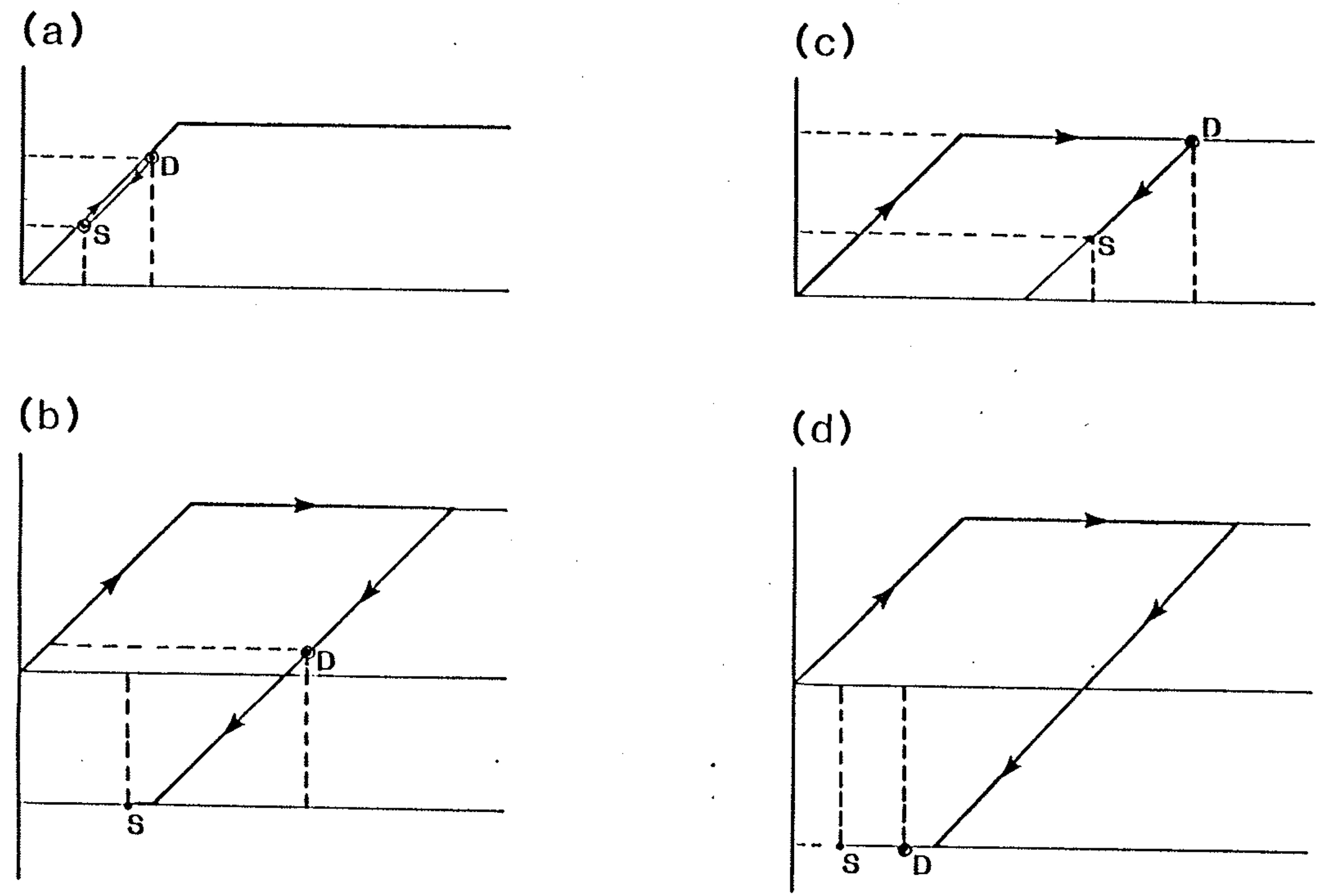


Figure 3.12. Resistance vs. displacement diagrams showing end of dynamic (D) and static (S) analyses.

with R_{si} being subjected to the same ultimate limits as discussed earlier.

The mathematical solution of the problem involves a set of linear equations subject to the conditions of elasto-plastic springs.

3.11.3.3 RSA Convergence

According to Holloway, the residual stress distribution generally remains unchanged after three blows. This means that final static displacements and static soil resistances will not change after three blows with the same R_{ut}. Since there is no change in pile stress, the permanent set due to a blow will be the same for all the pile elements. Using this concept, the convergence criterion was chosen as follows

$$abs\ [\ (du_o - du_n)\ /\ du_o\ ] < del \tag{3.59}$$

where du_o and du_n are the previous and current pile compression (the relative differences in pile displacement, between ground level and the pile toe, as calculated in the static analyses); del is a small number (0.05 in WEAP86). The simplified flowchart of the analysis (Figure 3.13) further illustrates this concept. Initial test runs showed that often only three blows are needed to achieve convergence.

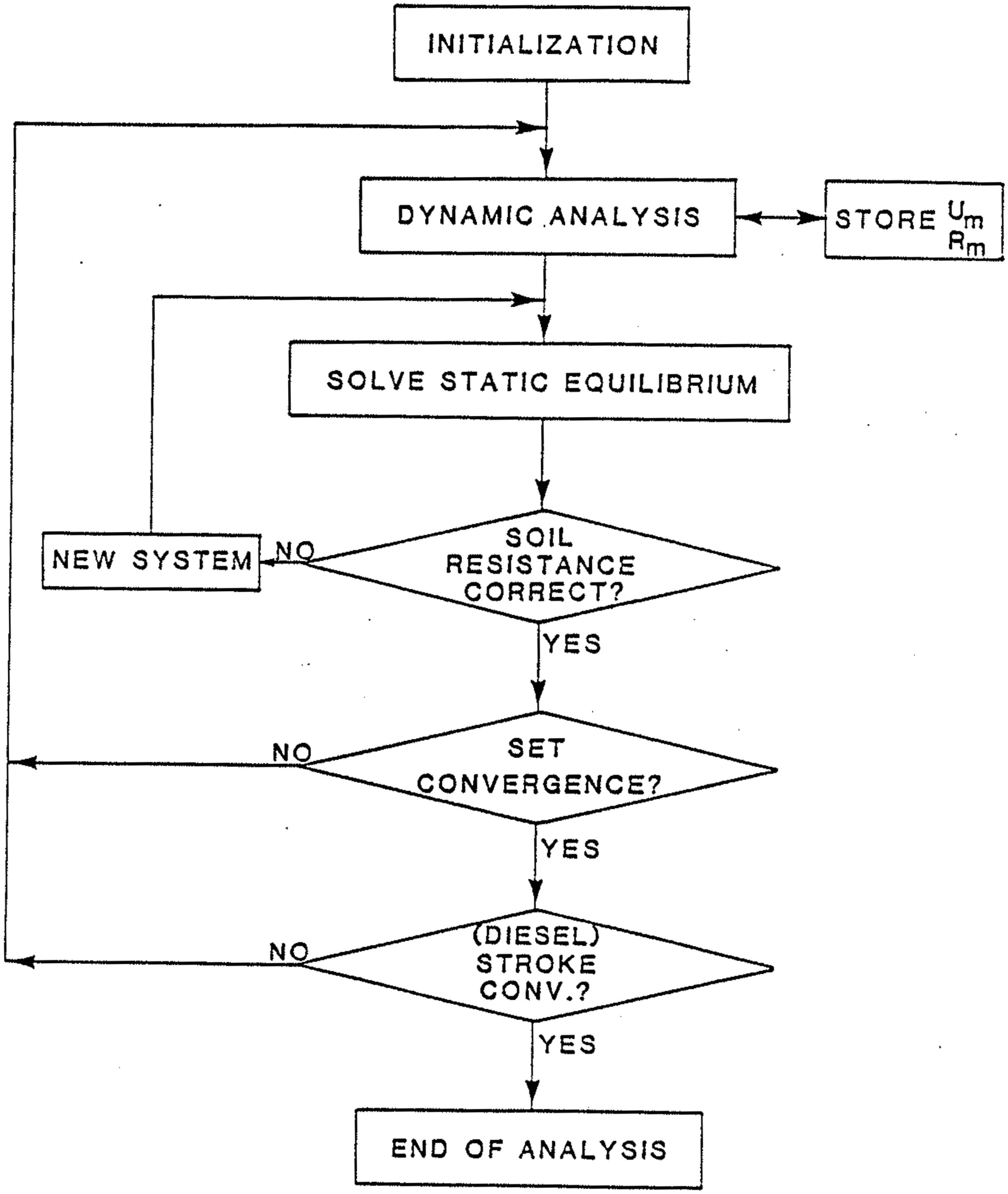


Figure 3.13. Simplified flowchart of the RSA analysis.

3.11.4 Discussion of the RSA Approach

There is no doubt that the RSA better approximates actual piling behavior. A drawback of using the approach is the fact that many correlation studies have been done without RSA. The magnitude of quake and/or soil damping values, obtained from such studies, may need adjustments when using RSA. The RSA will always produce lower blow counts and higher pile stresses.

Obviously, there is a large computational effort needed to accomplish the RSA iterations. CUWEAP and WEAP86 reduce the necessary amount of computation by utilizing the stroke iterations performed in the standard diesel analysis. Also, the final displacement value obtained at the end of one analysis is used as a starting value for the analysis of the next capacity value. In any event, however, it will be necessary to check whether an RSA is needed. This need has been proven for Monotube piles but not on regular pipe or concrete piles.

A final word of caution seems necessary. The effect of RSA becomes very clear when there are high soil resistances, i.e., when permanent sets are small. In those situations, the differences between the assumed elasto-plastic and the actual non-linear soil behavior are potentionally large. The RSA is a relatively sophisticated approach but it uses a rather crude soil model. Thus, RSA only reduces - but does not eliminate - the potential for errors.

3.12 Program Flow

- WEAP86 first reads the input data which specifies hammer, driving system, pile and soil. It then sets up a lumped mass model for hammer, driving system, and pile, and distributes the skin friction of the first ultimate capacity value. A description of the model is then printed.
- Next the analysis time increment is computed and then the actual wave equation is performed. This may involve several iterations for diesels and for the residual stress analysis.

- At the end of an analysis, extrema tables and variables vs. time are printed, depending on the user chosen output option and then the next ultimate capacity is analyzed, starting at step B.

- When all the ultimate capacity values have been analyzed, a summary table is printed; this is a numerical equivalent of a bearing graph, i.e., blow count and stresses are printed as a function of bearing capacity. In addition, stroke and transferred energy are printed. Wave equation results can then be checked by comparison with field measurements.

The logic for a diesel analysis is shown in Figure (3.14). Three basic stroke options may be chosen: (a) single blow analysis, (b) stroke convergence for a fixed maximum pressure value and (c) maximum pressure value convergence for a fixed stroke. Complications may arise when the stroke becomes excessively high. For closed end hammers, the hammer would uplift and a fuel reduction is necessary. For open end diesels the ram may actually blow out of the cylinder. Furthermore, a ram with an excessive stroke has a potential energy which is higher than rated. Thus, it is a good practice to reduce the maximum combustion pressure whenever the maximum (rated) stroke is exceeded, even for open end diesels. Introducing this concept into WEAP86 made the program logic very similar for closed end and open end hammers.

3.13 WEAP and WEAP86: Summary of Differences

The WEAP program was completely reedited and many "research type" features were removed which were never used in practice. Other changes were merely designed to provide better readability and transportability of the code. The program's translation to FORTRAN 77 is one such example. It is not expected that any problems will occur when loading this program on machines of different types. Most importantly, two new major models were built into WEAP86. First, the thermodynamic analysis for atomized fuel injection was added. Second, the residual stress analysis option of CUWEAP was introduced. These features were discussed in detail in the previous sections.

There has been a major change in philosophy which reflects a new approach

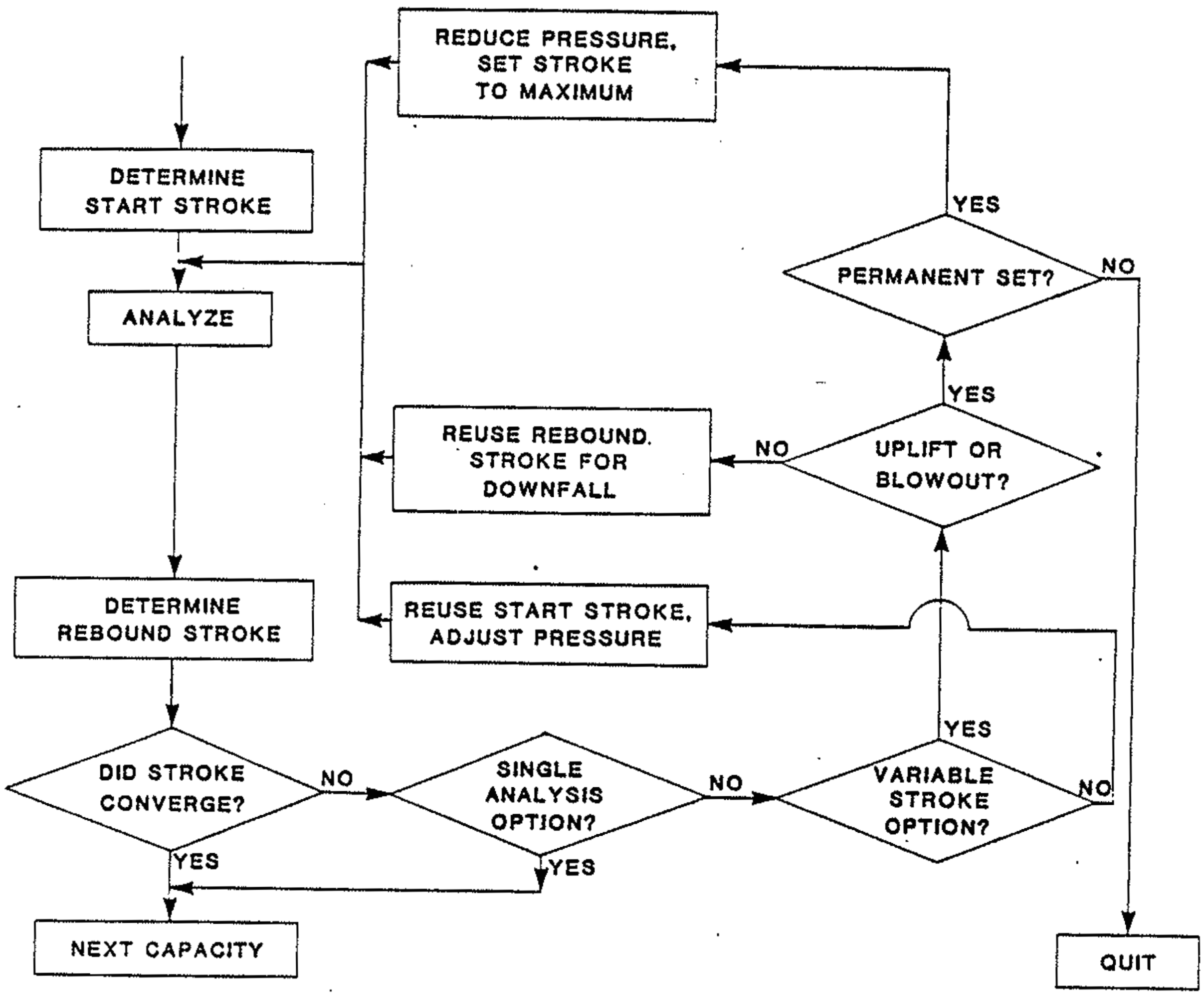


Figure 3.14. Flowchart for WEAP86 diesel analysis.

to the analysis of pile driving. In WEAP the hammer data was "hidden" on file and only obvious parameters like ram weight were printed out. In WEAP86, the selected hammer's complete data file may be printed during a computer run. Appropriate captions were added for ease of understanding. It is anticipated that this change will make the use of the program much easier and that the answers to many questions can be found there. The new approach became possible after the manufacturers agreed to release the data to the public. It is suggested that no data is entered in the public file which has not been released by the manufacturer.

Another important change was the rewriting of the hammer data file. All data has been checked by the manufacturer. Differences between various hammer models have been resolved (e.g. D 30, D 30-02, D 30-12, D 30-23, D 30-32). Realistic efficiencies were included based upon the study "The Performance of Pile Driving Systems," (Ref. 13). These efficiencies are:

- For all diesels $e = 0.8$
- For SA-ASH hammers $e = 0.67$
- For DA-ASH hammers $e = 0.5$

As far as efficiencies are concerned, there were no distinctions made between hammers of the same type but of different manufacture. The user is encouraged to use his own experience in choosing alternate efficiencies.

As with safety factors, the efficiency may be used to protect the user against unforeseen problems. Greater efficiencies should be tried for stress checks and lower efficiencies should be tried for blow count predictions.

The diesel hammer models now require the input of a minimum stroke. This minimum stroke is used as the starting stroke if the user did not provide another input. The minimum stroke is also an indication of the rated stroke at the lowest fuel setting.

The convergence criterion for diesel hammer stroke iterations has been tightened from 5 to 4 percent and from 2.5 to 2 percent for open and closed end diesels, respectively. In addition, the absolute difference between down-stroke and up-stroke is not to exceed 2.5 percent of the maximum stroke of a hammer.

The efficiency of diesel hammers is applied to the total stroke, not just to the stroke above the ports, as in WEAP. For closed end hammers, the equivalent stroke may be entered instead of the actual stroke (which is usually unknown). For open end diesels, a fuel reduction of 10% is applied if the hammer's stroke exceeds the maximum rated stroke during the analysis. A similar reduction is applied for closed end diesels if uplift is predicted.

Another improvement is that only raw hammer data needs to be entered. This raw data is obtained relatively easily from the manufacturer. No additional computational work needs to be done.

Similarly, cushion information may only need to include area, thickness, and elastic modulus of the material. WEAP86 computes the stiffness. On the other hand, the round-out deformations, also called compressive slacks, hidden in WEAP may now be input by the user. It was found from correlation studies, using WEAP86 output and field measurements, that soft plywood cushions may realistically be modeled using a large (say 0.04-ft) round-out deformation.

Improvements in the integration method allowed for a reduction of the default value controling the maximum number of iteration cycles per hammer blow. WEAP had a default value of three iterations; WEAP86 has a default value of no iterations.

WEAP limited the search for the maximum tension stress to the first 2L/c time period after impact. Thus, only the time up to the first wave return was included. Tension stresses occurring at a later time, as in the case of hard driving, were not recognized. WEAP86 now searches throughout the entire analysis.

In WEAP the pile weight was included in the computational procedure. This was acceptable for short land piles. However, for offshore piles significant pile displacements may be introduced by pile weight stresses. WEAP86 includes the pile weight only in the residual stress analysis. Note that for heavy piles, significant differences in blow counts must therefore be expected when comparing RSA with standard WEAP86 results. The R_{ut} value of the RSA includes the pile weight. This should be subtracted to yield the ultimate pile capacity. The R_{ut} value of standard analyses, however, includes only the load that is applied to the pile. In either case it is valid to add the helmet weight (and for ECH the assembly weight) to the final WEAP86 ultimate capacity result.

The slack/splice model is now identical to the cushion/pile top models. It added significantly to the numerical stability of WEAP86 when analyzing spliced piling.

4. INPUT INFORMATION

In WEAP86, it has been attempted to make the input proceedure as simple as possible. As in any other wave equation program, information about the hammer, driving system, pile, and soil is required. However, a hammer data file has been prepared which contains all the input information required for the most commonly encountered hammers. In addition, the remainder of the input information necessary to run a routine analysis doesn't require any hand calculation.

4.1 Hammer Data

For hammers whose data has not been entered into the file, a hammer data request form, with instructions, has been prepared. The information required depends upon the hammer type. A general data sheet for all hammer types is shown in Form 1. It is suggested that this sheet be sent directly to the manufacturer for information.

4.2 Driving System Data

The driving system consists of the hammer cushion, helmet (including striker plate, inserts, adaptors, etc.), and pile cushion (in the case of concrete piles). Form 2 details the necessary information.

4.3 Pile Data

Required pile data consists of total length, cross sectional area, elastic modulus and specific weight, all as a function of depth. This is the so-called pile profile. In most cases, these values are constant with depth and the data in Form 2 is adequate. For nonuniform piles, the values as a function of depth may be shown on an attached sheet.

4.4 Soil

Depending on the purpose of the analysis, complex soil analyses may be needed to describe the expected soil behavior. In most instances, however, e.g., when wave equation results are to be used in conjunction with an observed blow count, the soil data does not need to be highly detailed. For example, a soil profile including SPT values is satisfacatory for the preliminary static soil analysis and the assignment of, admittedly crude, damping and quake values.

It is common practice to allow the pile's depth of penetration and (relative) soil resistance distribution to remain constant throughout a series of anlayses, even though the pile's ultimate capacity is made to vary. In other words, it is usually unnecessary to recompute the skin friction distribution, end bearing, quake, and damping for each ultimate capacity. This simplification is probably the most confusing aspect of the wave equation approach. Of course, no blow count vs. depth information can be obtained using this method.

If a so-called driveablility study must be made, then it may be necessary to perform several WEAP86 runs; in each run the soil parameters may be altered so that they correspond to a specific depth of penetration. Again the required information should be entered in Form 2.

Form 1: Hammer Data Request Form

(1) General Information

1.1 Manufacturer ____________________ (abbreviate to at most 8 characters)

1.2 Model Name ____________________ (abbreviate to at most 8 characters)

1.3 Hammer Type ____________________ (1-Open End Diesel, 2-Closed End Diesel, 3-All Other)

(2) Ram

2.1 Ram Weight (kips), W_r = ____________________

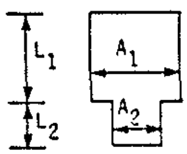
2.2 Ram Length (in), L_r = ____________________

2.3 Number of Ram Segments ____________________ (Approx. the ram length, in ft, /3)

2.4 Ram Diameter (in), D_r = ____________________

For nonuniform rams, ram diameter should yield the effective ram stiffness, k_r, over the length.

For example:



$k_1 = A_1E/L_1$ (E is the elastic modulus of steel)

$k_2 = A_2E/L_2$

By using Kirchoff's Law, solve for the effective ram stiffness

$$k_r = k_1\ k_2/(k_1 + k_2) = A_r\ E/L_r$$

Thus, $A_r = A_1\ A_2\ L_r/(A_1L_2 + A_2\ L_1)$

and $D_r = (4\ A_r\ /3.141)^{1/2}$

In general, D_r can be estimated with sufficient accuracy. Ignore piston rods or other light parts which do not directly participate in impact. You may just give the length and diameter of the rampoint. Length and diameter are used for calculating both ram stiffness and stress, but not ram weight. Ram stiffness is only important for hammers which do not use a hammer cushion.

Form 1, continued

(3) Strokes and Efficiencies

3.1 Maximum Stroke (ft), h ______

3.2 Minimum Stroke (ft), h_{min} ______

3.3 Hammer Efficiency, e_h ______

For single acting hammers, maximum stroke means the rated stroke; i.e. maximum stroke times ram weight should equal the hammer's rated energy. For double acting hammers, the definition of maximum stroke can vary. For closed end diesels, see the note following section (7). For double acting ECH, see the note following section (8).

Minimum stroke applies to diesels only. It should be the lowest (rated) stroke at which the hammer still runs. For step wise adjustable fuel pumps, this is the stroke corresponding to the lowest energy rating. Minimum stroke is used as a starting stroke for open end diesels.

Hammer efficiency values are usually $e_h = 0.8$ for all diesels, $e_h = 0.67$ for single acting external combustion hammers, $e_h = 0.5$ for double (differential, compound) acting external combustion hammers.

(4) Impact Block - for Diesels Only

4.1 Impact Block Weight (kips) W_{IB} ______

4.2 Impact Block Length (in), L_{IB} ______

4.3 Impact Block Diameter (in), D_{IB} ______

4.4 Impact Block Coefficient of Restitution, C_{IB} ______ (usually 0.9)

4.5 Impact Block Round Out Deformation (ft), d_{CIB} ______(usually 0.01)

(5) Combustion Details - for Diesels Only

5.1 Compressive Stroke (in), h_c ______

5.2 Combustion Chamber Area (in^2), A_c ______

5.3 Combustion Chamber Volume (in^3), V_f ______

5.4 Coefficient of Expansion, C_e ______(usually 1.35)

5.5 Liquid Injection Combustion Delay (sec), t_d ______

5.6 Liquid Injection Combustion Duration (sec), t_{cd} ______

5.7 Atomized Injection Combustion Start Volume (in^3), V_{ci} ______

5.8 Atomized Injection Combustion End Volume (in^3), V_{ce} ______

Note: t_d and t_{cd} are for liquid injection diesels only.
V_{ci} and V_{ce} are for atomized injection diesels only.

Form 1, continued

(6) Pressures - for Diesels Only

6.1 Atmospheric Pressure (psi), p_a ____________ (usually 14.7 psi)

6.2 Maximum Combustion Pressure at Highest Fuel Setting (psi), p_{max1} ____________

6.3 Maximum Combustion Pressure at 2nd Highest Fuel Setting (psi), p_{max2} ____________

6.4 Maximum Combustion Pressure at 3rd Highest Fuel Setting (psi), p_{max3} ____________

6.5 Maximum Combustion Pressure at 4th Highest Fuel Setting (psi), p_{max4} ____________

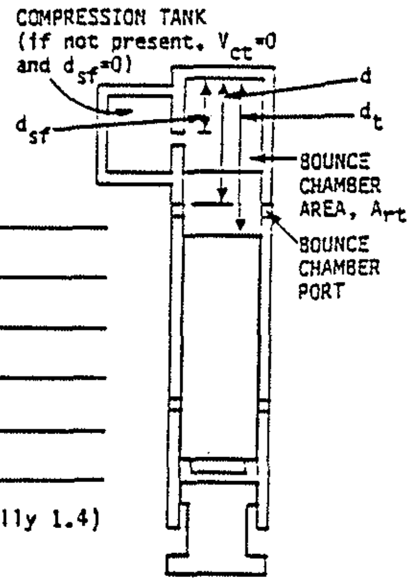
6.6 Maximum Combustion Pressure at Lowest Fuel Setting (psi), p_{max5} ____________

For hammers with continuously variable fuel pump settings, give only p_{max1}.

For hammers with less than 5 pump settings, leave bottom setting(s) blank.

For hammers which have a number of fuel settings, but only p_{max1} is known (or calculated using the method described in Appendix B), estimate pressures at lower settings by using 90% of the pressure at the next highest setting.

(7) Bounce Chamber - for Closed End Diesels Only



7.1 Bounce Chamber Ports to Cylinder Top (in), d_c ____________

7.2 Bounce Chamber Area or Area of Piston Top (in^2), A_{rt} ____________

7.3 Total Bounce Chamber Length (in), d ____________

7.4 Safety Distance (in), d_{sf} ____________

7.5 Compression Tank Volume (in^3), V_{ct} ____________

7.6 Reaction Weight (kips), R_{wt} ____________

7.7 Coefficient of Expansion in Bounce Chamber, c_{bp} ____ (usually 1.4)

For double acting diesels Reaction Weight, R_{wh}, should be such that rated energy corresponds to expansion energy in bounce chamber when uplift is imminent plus h W_c. This information is to be obtained from the manufacturer and must consider the value of the bounce chamber expansion coefficient.

Form 1, continued

(8) External Combustion Hammer Information

8.1 Rated Pressure (psi), p_r ____________

8.2 Effective Piston Area (in^2), A_{eff} ____________

8.3 Number of Assembly Elements, MA ____________

8.4 Weight of First Assembly Segment (kips), W_{a1} ____________

8.5 Stiffness of First Assembly Segment (kips/inch), k_{a1} ____________

8.6 Weight of Second Assembly Segment (kips), W_{a2} ____________

8.7 Stiffness of Second Assembly Segment (kips/inch), k_{a2} ____________

8.8 Weight of Third Assembly Segment (kips), Wa_3 ____________

8.9 Stiffness of Third Assembly Segment (kips/inch), ka_3 ____________

8.10 Coefficient of Restitution of Assembly, c_{ora} ____________(usually 0.85)

8.11 Round Out Deformation of Assembly (ft), d_{as} ____________(usually 0.01)

Note: Rated pressure and effective piston area are for double (differential, compound) acting ECH only, and are optional. If they are to be used, item 6.3 (maximum stroke) must be the hammer's actual maximum stroke. A double acting ECH hammer's energy may be calculated as either

$E_r = h\ W_r + h\ p_r A_{eff}/1000$, with h the actual maximum stroke, or

$Er = h\ W_r$, with h the "equivalent" maximum stroke.

Multiple assembly segments are not essential for running the program. A single segment may be adequate. For hammers with columns, use two segments (MA = 2). The first assembly weight would be the hammer's top portion (cylinder), the second one would be the bottom portion (hammer base). In this example, the k_{a1} and k_{a2} stiffnesses would both be entered as double the total stiffness of the hammer's columns.

(9) Miscellaneous

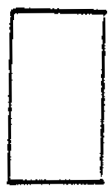
9.1 Coefficient of Confidence, C_{con} ____________

9.2 Date ____________

Coefficient of Confidence for diesels only - If set to 1, a statement is printed in WEAP86 output indicating that the hammer data was estimated - not measured.

Date should be effective date when data was obtained and/or coded.

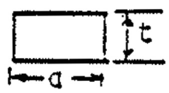
Form 2: Driving System, Pile and Soil Data



HAMMER

Manufacturer: ______________ Model: ____________

For uncommon or drop hammers, attach complete information including ram weight, fall height, efficiency, etc.



STRIKER PLATE

Weight, W_c (kips) = __________ Diameter, d (in) = ________
Thickness, t (in) = ________

HAMMER CUSHION

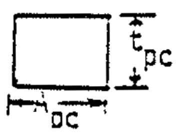
Material Name: ____________________

Cross Sect, $A_c(in^2)$ = ________ Thickness, t_{hc}(in) = ________

Modulus, E_c(ksi) = ___________ Coeff. of Restit, c_c = ______

HELMET
(including adaptors)

Weight, W_c (kips) = ____________

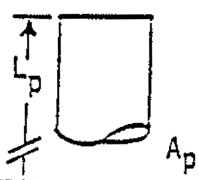


PILE CUSHION
For Concrete Piles

Material Name: ______________

Cross Sect, $A_{pc}(in^2)$ = _______ Thickness, t_{pc}(in) = _________

Modulus, E_{pc}(ksi) = _______ Coeff. of Restit, c_{pc} = ______

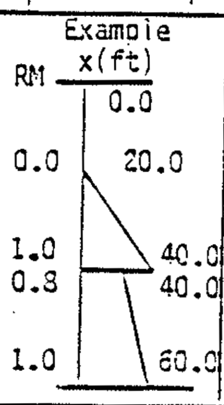


PILE
(if nonuniform attach sheet)

Material Description: ____________________

Length, L_p(ft) = _________ Cross Sect, $A_p(in^2)$ = ________

Modulus, E_p(ksi) = _______ Spec. Wt, $W_p(lbs/ft^3)$ = ________



SOIL

Attach a description or if known specify:

Skin Quake (in) = Skin Damping (s/ft) =

Toe Quake (in) = Toe Damping (s/ft) =

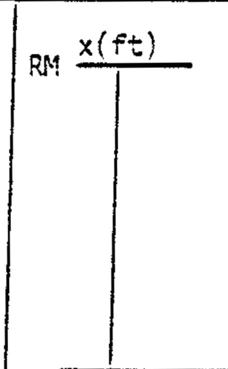
Max. Ult. Capacity, R_{ut}(kips) =

Skin Friction (%) =

Distribution of Skin Friction (sketch in graph at right, see example at left)

RM = Relative Magnitude

x = Depth Below Top in Feet



5. PROGRAM PERFORMANCE

5.1 Introduction

In the WEAP reports of 1976 and 1981, program performance was primarily judged by the comparison of measured with WEAP computed force and velocity curves. In order to produce the correlations, many trial runs were made. Hammer efficiencies, cushion stiffnesses and other quantities were then adjusted until a satisfactory match was achieved. The input parameters thus derived did not lend themselves for general conclusions since they pertained only to one particular data set.

There are two reasons why it seems inappropriate to repeat this matching exercise. First, WEAP86 is similar to WEAP (unless the RSA or AI models are used) and it is expected that force and velocity matches can be achieved that are identical with the WEAP results. Secondly, the WEAP program performance study did not show what correlations the user might expect when he <u>predicts</u> blow count and stresses. Thus, in order to provide new information, this chapter presents the following studies.

- Comparison of WEAP and WEAP86 results.
- Comparison of WEAP and CUWEAP results.
- Test Cases.

5.2 Comparison of WEAP and WEAP86 Results

As a basis of comparison the example runs in the WEAP manual (Volume II) were used. Table 5.1 shows blow count, compressive and tensile stress and transferred energies from the summary tables of both the 1981 and 1986 Users Manuals. The Example 9 - residual stress - result was compared with the equivalent example from the CUWEAP manual (Ref 3).

Greatest differences were found among transferred energies and blow counts. If the hammer efficiencies in WEAP86 were as high as those in WEAP

Table 5.1 COMPARISON OF WEAP AND WEAP86
1 kip = 4.45 kN; 1 ft = 3048 m; 1 ksi = kPa

Example Program	Capacity Kips	- - Stresses - - Tension ksi	Compression ksi	Enthru kip-ft	Blow Count BPF	Remarks
Ex 7.1, W[1]	60	0	17.8	9.8	14	Case Damping
Ex 1, 86[1]	60	0	13.6	10.1	11	Smith Damping
Ex 7.1,W	240	0	25.3	9.9	49	Case Damping
Ex 1, 86	240	1.9	24.5	9.2	66	Smith Damping
Ex 7.2, W	240	0	32.4	15.6	123	
Ex 2, 86	240	0	30.0	13.1	322	
Ex 7.3, W	20	1.08	2.60	15.6	3	
Ex 3a, 86	20	1.06	2.46	11.7	4	
Ex 7.3b, W	20	.44	2.02	12.3	4	
Ex 3b, 86	20	.54	1.90	10.0	4	
Ex 7.4, W	180	0	27.04	12.0	28	Case Damping
Ex 4, 86	150	.10	25.1	9.7	37	Smith Damping
Ex 7.5, W	150	0	2.47	6.3	49	
Ex 5, 86	150	0	2.39	4.2	144	
Ex 7.6a, W	400	0	4.53	11.8	95	
Ex 6a, 86	400	.62	3.43	9.3	165	
Ex 7.7a, W	300	0	31.2	29.0	16	
Ex 7a, 86	300	2.1	29.0	19.9	27	
Ex 7.8b, W	50	.93	2.23	13.8	5	
Ex 8b, 86	50	1.4	2.39	9.7	10	
Ex 3, CU[1]	240	0	35.8	15.6	53	Residual Stress Analysis
Ex 9, 86	240	0	33.9	12.0	83	
Ex 11a, CU	1000	3.3	31.0	81.7	50	Case Damping
Ex 10a, 86	1000	4.8	23.0	57.6	45	Smith Damping

[1]W ... WEAP(1981), 86 ... WEAP86, CU ... CUWEAP

then much lower differences in blow counts would have resulted. On the other hand, the WEAP86 transferred energy values agree very well with observations made during driving using dynamic measurements.

To be consistent with the recommendations made in the WEAP86 documentation, several cases were run with Smith rather than Case Damping. Of course, this change of damping factors also caused blow count differences.

The comparisons of Table 5.1 suggest that the WEAP86 user make a careful evaluation of his soil parameters, since artificially high hammer performance may formerly have been compensated for by either high soil damping or the expectance of an undefined amount of soil setup.

5.3 Comparison of CUWEAP and WEAP86 Results

Example No. 1 of Hery's thesis (15) was rerun using WEAP86 both with and without residual stress analysis. This example included a static load test result of 96 kips at 80 blows/ft for a pipe pile and more than 240 kips at an unknown blow count for a Monotube. Hammer, driving system, pile and soil details are listed in Table 5.2. (a) with CU,Ex1-1 identifying the pipe and CU,Ex1-2 the Monotube. Input Data for WEAP86 is given in Table 5.2(b).

The bearing graphs from the resulting four analyses are shown in Figure 5.1(a) and (b). Results were also compiled in Table 5.2 (c). Superimposed were the values taken from Figure 4-12 of Reference 15. Apparently the normal WEAP86 analyses produced somewhat higher blow counts than CUWEAP- -which is reasonable since WEAP86 was run with a hammer efficiency of 0.67 instead of 0.8. For the residual analysis, however, the differences were negligible.

5.4 Test Cases

5.4.1 Reanalysis of Example 1, CUWEAP

Hery (15) treated both pipe and Monotube identically as far as frictional

Table 5.2. Summary of test case data. (1 ft = .305m, 1 in = 25.4mm, 1 kip = 4.45 kN)
(a) Physical properties.

Case No:	Pile			Hammer				Pile Cushion	Soil	
	Type	Length ft	Area in^2	Name	Rating k-ft	Cushion	Weight kips	Thickness in	Skin	Toe
CU,EX1-1	Pipe	63.0	7.03	Vul No. 1	15	-----	.65	----	----	----
CU,EX1-2	Monotube	63.8 (30' Taper)	6.97 (Tip 4.4)	Vul No.1	15	----	.65	----	----	----
Pileco Yard	30"x1"	250.0	91.10	D46-23	107	23x2" Conb	4.00	----	Silty Clay	Silty Clay
ICE Yard	24"x5/8 and Concrete	48.0	45.90 (at top)	ICE1070	70	25x2" Nylon	3.69	----	Hard Clay	Rock
B-10	HP14x117	85.0	34.40	MKTDA55B	38	Urethane	1.40	----	Sl Sand Clay	Sl Clay Sand
M-11-4	16"x.312"	25.0	15.40	Vul 010	32.5	M/AC	2.00	----	Silty Clay	Dense Till
EP-250	12"x.25"	60.0	9.20	LB 520	27.7	Conbest	1.50	----	Sd Cl Clay	Silty Sand
2-24	Monotube Gage 3	55.0 (25' Taper)	9.65 (Tip 6.58)	Vul 010	32.5	M/AC?	2.00?	----	Sand & Gravel	Sand & Gravel
4-14	HP10x57	35.0	16.70	Ice640	40	M/AC	2.00?	----	Sand	Shale
C-6	Monotube Gage 5	40.0 (30' Taper)	8.18 (Tip 5.19)	LB440	18	5" M/AC	.84	----	Silty Sand	Silty Sand
WP6/C-7	16" PSC Hollow	32.0	236.00	DE70B	59.5	2" Neoprene	1.20	5.5" Plywood	Clay & Sand	Sand & Gravel
TP2/C-8	HP12x53	40.0	15.50	ICE640	40	2" Nylon	3.20	----	Silt	Weath'd Rock
C-10	16" PSC	90.0	256.00	MH35	65.6	2" Nylon	1.75	6"	Cl Sl Sand	Sand
C-11	11.9x.59	37.0	21.10	Vul 512	60	14x8" MAC	1.55	----	Clayey Silt	Basalt Rock
C-12	HP12x74	79.0	21.70	Conmaco 160	48.8	8" M/AC	2.50	----	Till	Till

Table 5.2. Summary of test case data. (b) Wave equation input. (continued.)

Case No.	Hammer Eff. %	Hammer Cushion Stiffness k/in	Pile Cushion Stiffness k/in	Quakes Skin in	Quakes Toe in	Damping* Skin s/ft	Damping* Toe s/ft	Soil Parameter: Skin Friction %	Soil Parameter: Distribution Type
Cu,Ex1-1	80	21000	-	.10	.10	(.30)	(.90)	50	N/A
	80			.10		(.30)	(.90)	50	N/A
	80			.10		(.30)	(.90)	50	60%T
	80			.10		(.30)	(.90)	50	
	67			.10		.20	.15	10	60%T
	67			.10		.20	.15	10	
Cu,Ex1-2	80	21000	-	.10	.10	(.30)	(.90)	50	N/A
	80			.10		(.30)	(.90)	50	N/A
	80			.10		(.30)	(.90)	50	60%T
	80			.10		(.30)	(.90)	50	
	80			.05	.05	.20	.15	90	60%T
	80					.20	.15	90	
Pileco Yard	80	58100	-	.10	.10	.20	.10	95	66%R
ICE Yard	80	52500	-	.10	.10	.10	.10	15	60%R
B-10	80	22400	-	.10	.10	.20	.15	70	100%T
M-11-4	67	6114	-	.10	.13	.20	.15	10	100%R
EP-250	80	8680	-	.10	.10	.20	.15	70	10%R
2-24	67	6114	-	.05	.05	.05	.15	90	40%T
4-14	80	22400	-	.10	.10	.05	.20	25	80%T
C-6	95	10080	-	.05	.05	.05	.15	90	60%R
WP6/C-7	80	19200	2146	.10	.13	.20	.15	25	80%R
TP2/C-8	80	42963	-	.10	.10	.20	.15	30	80%T
C-10	80	22400	2133	.10	.13	.05	.15	50	80%T
C-11	67	6737	-	.10	.10	.10	.10	160 kips Friction	60%R
C-12	67	11200	-	.10	.10	.20	.15	75 kips End Bearing	40%R

*Values in parantheses are dimensionless Case Damping Values.

Table 5.2. Summary of test case data. (c) Field observations and wave equation results. (continued.)

Case No.	Field Observations: Blow Count (b/ft)	Field Observations: Enthru (k-ft)	Field Observations: Pile Top Force (kips)	Field Observations: Load Test (kips)	Wave Equation Results: Enthru (k-ft)	Wave Equation Results: Max Pile Top Force (kips)	Wave Equation Results: Capacity at Blow Count (kips)	Remarks
Cu, Exl-1	80	N/A	N/A	96	N/A	N/A	112	CUWEAP - No RSA
					N/A	N/A	130	CUWEAP - RSA
					10.1	221	116	WEAP86 - No RSA
					10.0	249	130	WEAP86 - RSA
					8.4	226	160	WEAP86 - No RSA
					8.4	231	162	WEAP86 - RSA
Cu, Exl-2	N/A	N/A	N/A	240	N/A	N/A	152R	CUWEAP - No RSA
				N/F	N/A	N/A	180R	CUWEAP - RSA
					10.1	212	160R	WEAP86 - No RSA
					10.0	255	180R	WEAP86 - RSA
					10.0	225	210R	WEAP86 - No RSA
					9.8	26.3	240R	WEAP86 - RSA
Pileco Yard	R	42	2200	N/A	42	2300	2500R	see Figure 5.4(a)
ICE Yard	R	19	1020	N/A	24	1184	2000R	see Figure 5.4(b)
B-10	156	N/A	N/A	610	15	900	430	Ref. (12)
M-11-4	120	N/A	N/A	560	16	620	460	Ref. (12)
EP-250	14	N/A.	N/A	150	10	210	83	Ref. (12)
2-24	60	20	495	476	17	383	315	No RSA
					17	410	345	RSA
4-14	576	18	520	364	14	606	500R	Case of Ralaxation Re-strike Info
C-6	171	715	325	320	6.3	345	295	High Hammer Efficiency
WP6/C-7	292	11	621	950	15	690	800	End of Drive
	R	12	752	(BOR)	15	690	1000	Restrike Info.
TP2/C-8	348	17	500	500	18	570	505R	
C-10	75	19	900	700	22	697	605	
	168	13	600	(BOR)			815	Actually not Applicable (low energy)
C-11	240+	28	830	600	30	950	800R	Const Friction
C-12	48	22	500	640	28	570	400	Const End Bearing
	288	16/20	450		27	650	545	

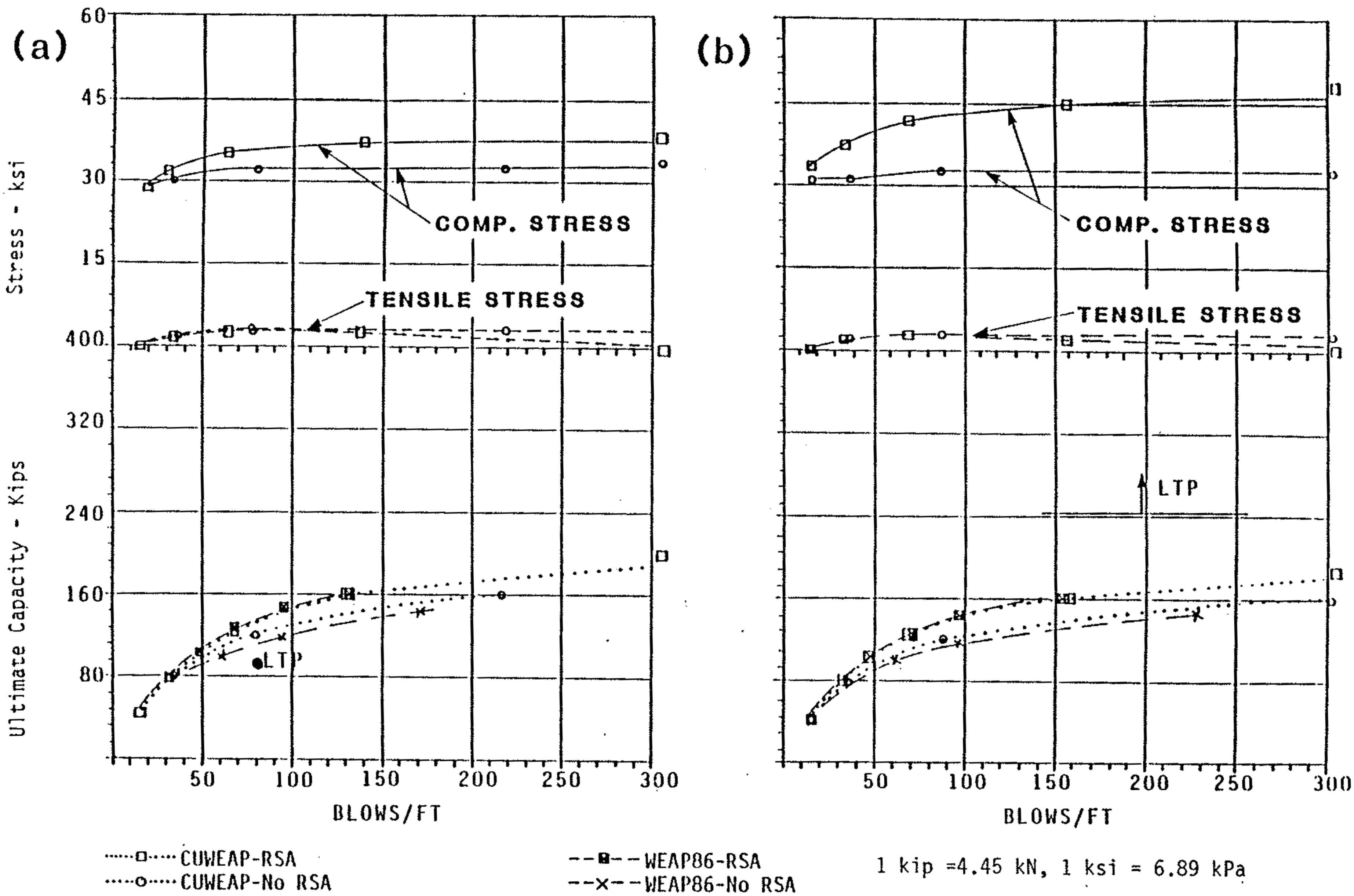


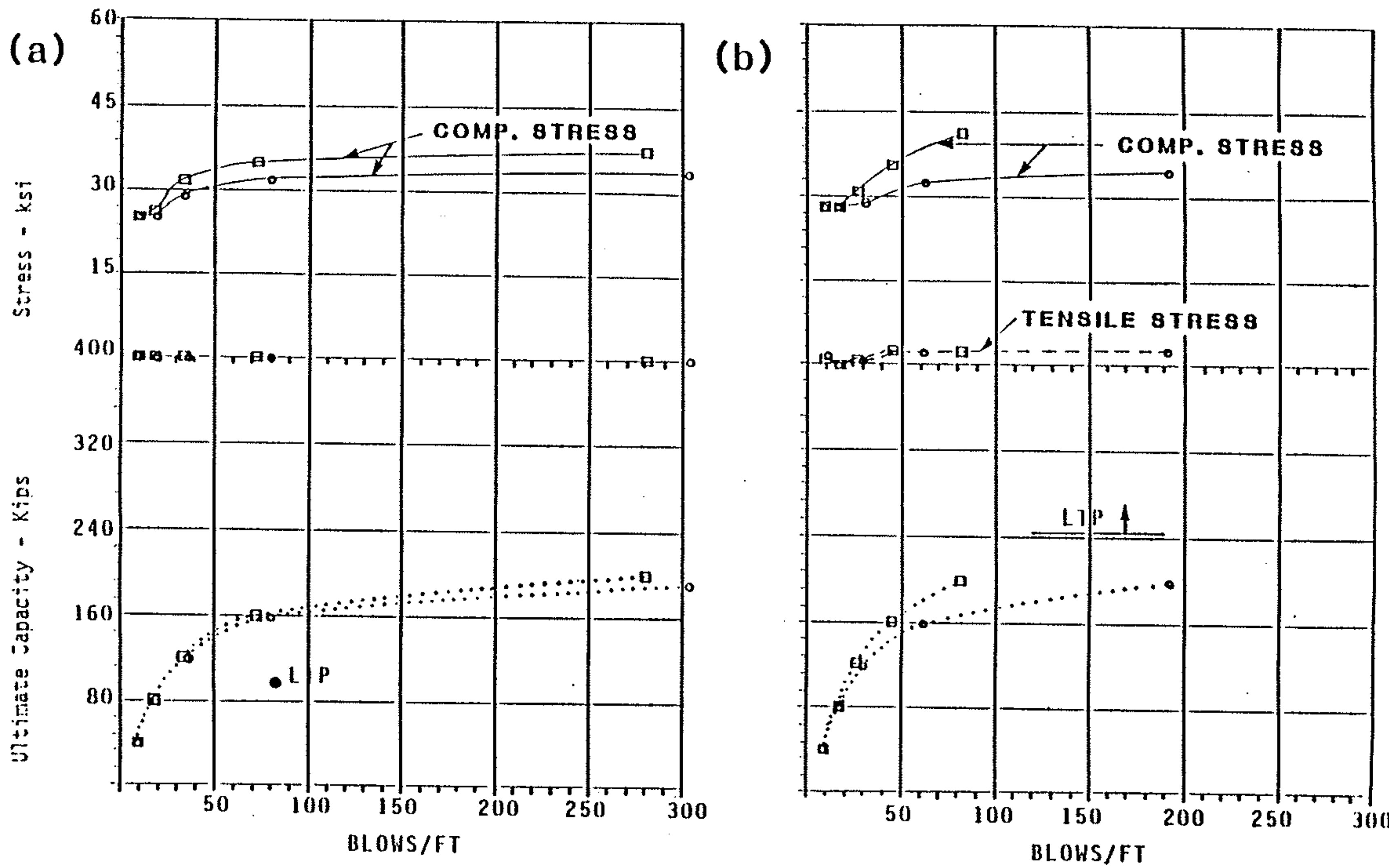
Figure 5.1. Comparison of CUWEAP and WEAP86 results. (a) pipe (b) monotube.

distribution, quakes and other soil parameters were concerned. For that reason it is not surprising that the results for the two pile types were nearly identical (their cross sectional areas were practically equal). On the other hand, it is known that the Monotube develops relatively high frictional resistance values because of its taper and its fluted cross section (see Appendix 4 of Reference 15). In fact, because of its small point diameter and the wedge like penetration behavior, a Monotube pile probably has relatively low end bearing, high skin friction resistance values, and small quakes. Thus it is recommended to analyze Monotubes with quakes of 0.5 inches (1.3 mm) and a large frictional resistance percentage. For the closed end pipe normal quakes (0.1-inch or 2.5 mm) are recommended.

Hery also used skin and toe damping values of 0.3 and 0.9 s/ft (1.0 and 3.0 s/m), respectively which do not correspond to the normally recommended values (see Table 5, Volume II) which range from 0.05 to 0.2 s/ft (0.17 to 0.66 s/m). Since no soil description was given, the highest standard skin and toe damping values of .20 and .15 s/ft (.66 and .50 s/m) were analyzed.

The input data for the modified wave equation analyses is shown in Table 5.2 (b), with results given in Table 5.2 (c). Figure 5.2 shows the resulting bearing graphs and demonstrates a definite improvement in correlation for the Monotube when compared with Figure 5.1.

As a demonstration of the magnitude of residual forces both in pile and soil, the results from the modified data analysis of Hery's Example 1 was used. Figure 5.3 and Table 5.3 show for both pipe and Monotube the forces which remained in soil and pile after several trial analyses or blows. A 200-kip ultimate capacity was analyzed. Since the pipe had significantly less frictional resistance, it stored much less energy than the Monotube, a fact that is apparent from the pipe's lower force levels. Note that the upper soil elements remained in a plastic state, however, with negative signs, i.e., with downward directed soil resistance forces. The graphs on the left indicate the triangular distribution of the frictional resistance.



□ RSA ○ No RSA 1 kip = 4.45 kN, 1 ksi = 6.89 kPa

Figure 5.2. Results for example 1 of reference 15 with modified input, run with WEAP86. (a) pipe (b) monotube.

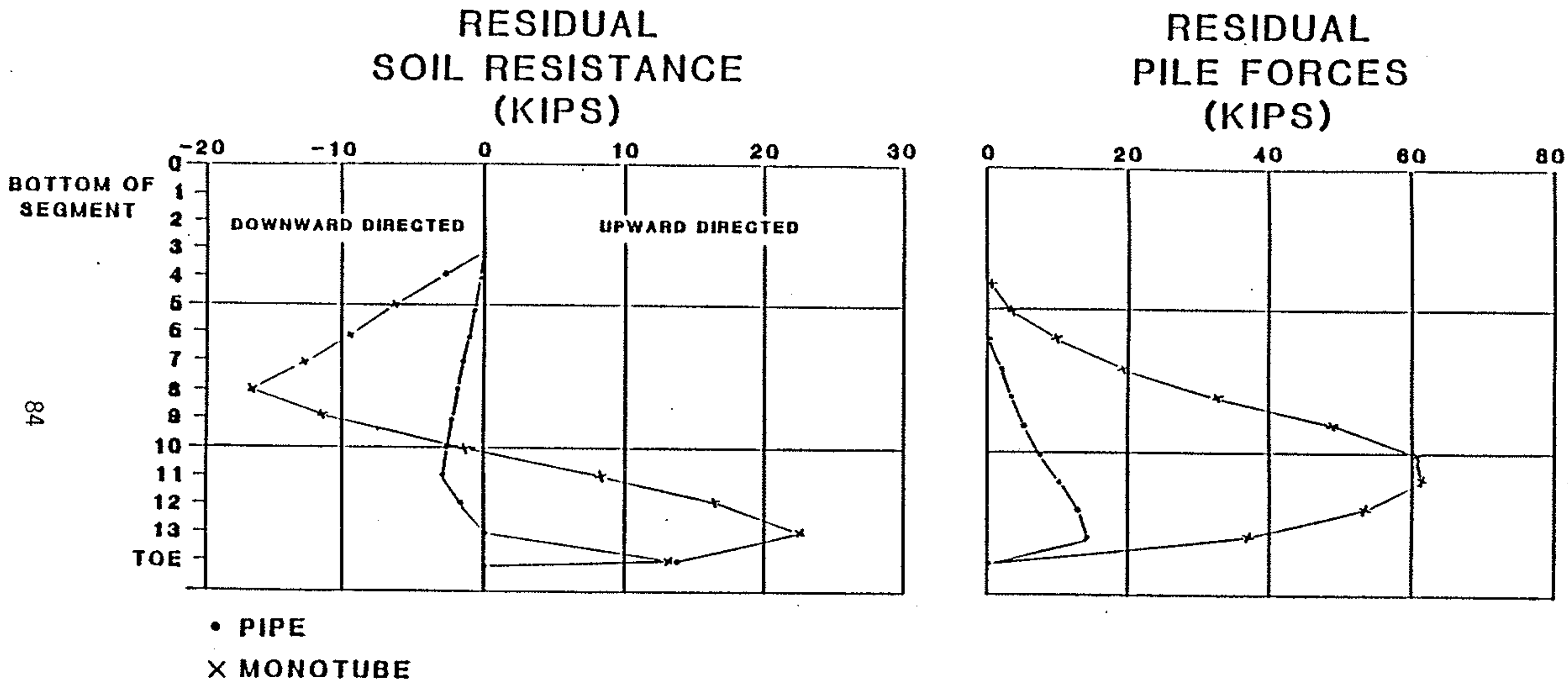


Figure 5.3. CU test case 1, residual forces at end of 200 kip analysis with modified input.

Table 5.3. Final residual stress table for example 1, reference 15 data with modified soil property input.

1 kip = 4.45 kN, 1 ksi = 6.89 kPa, 1 in = 25.4 mm.

WEAP OF 1986 CU Test Case 1.8 - Pipe, New Input, RSA
RULT = 200.0, RTOE = 124.1 KIPS

RESIDUAL VARIABLES AT END OF ANALYSIS

NO.	P-FORCE (KIPS)	P-STRESS (KSI)	S-RESIS (KIPS)	DISPL. (IN)
1	.00	.00	.00	.043
2	.00	.00	.00	.043
3	.00	.00	-.03	.043
4	.03	.00	-.33	.043
5	.36	.05	-.70	.043
6	1.07	.15	-1.07	.042
7	2.14	.30	-1.44	.042
8	3.58	.51	-1.81	.041
9	5.39	.77	-2.18	.039
10	7.57	1.08	-2.55	.037
11	10.13	1.44	-2.81	.034
12	12.94	1.84	-1.40	.031
13	14.33	2.04	.29	.027
TOE			14.05	

WEAP OF 1986 CU Case 1.6, Monot, New Input, RSA
RULT = 200.0, RTOE = 15.2 KIPS

RESIDUAL VARIABLES AT END OF ANALYSIS

NO.	P-FORCE (KIPS)	P-STRESS (KSI)	S-RESIS (KIPS)	DISPL. (IN)
1	.00	.00	.00	.147
2	.00	.00	.00	.147
3	.00	.00	-.27	.147
4	.27	.04	-3.00	.147
5	3.25	.47	-6.32	.146
6	9.59	1.38	-9.65	.143
7	19.24	2.82	-12.98	.138
8	32.22	4.80	-16.31	.129
9	48.53	7.72	-11.93	.113
10	60.46	10.32	-1.33	.093
11	61.79	11.38	8.46	.071
12	53.33	10.66	16.65	.050
13	36.68	7.00	22.83	.035
TOE			13.86	

5.4.2 Simulation of Hammer Tests

As a demonstration of the differences between the L.I. (Liquid Injection) and A.I. (Atomized Injection) models, analyses were made of the D 46-23 and ICE 1070 tests at the Pileco and ICE yards, respectively. Physical data is given in Table 5.1(a) and data inputs are summarized in Table 5.1(b). The results are shown in Figures 5.4(a) and (b) with plots of computed pile top forces, velocities and combustion pressures; measured pressures were superimposed on the computed ones. Selected numerical results are shown in Table 5.1(c). The corresponding field measurements are shown in Appendix A.

As discussed earlier, the L.I. yields a pressure curve which rises sharply at the time of impact; the A.I. produces a record which increases before impact and stays flat for a certain period of time. The agreement for the L.I. is very good. For A.I. the measured pressure at maximum stroke (26 psi bounce chamber pressure) was higher at impact and lower during expansion than the calculated curve. However, the average behavior was well represented. Also, the WEAP86 simulation reduced the maximum pressure during the analysis in order to avoid uplift; such a reduction was actually made during the field test, and was accomplished by reducing the fuel setting.

5.4.3 Correlation Analyses

In his paper, Blendy had analyzed nearly forty cases using WEAP and other programs (12). His conclusion was that WEAP gave good correlations with load test results evaluated according to Davisson's criterion (16). He used the programs in a standard manner with damping always 0.05 (0.17) and 0.15 (0.50) s/ft (s/m) for skin and toe, respectively. For cohesive soils, the skin damping value is usually recommended as 0.20 s/ft (0.66 s/m). Both the relatively low damping factors and the optimistic efficiency values of WEAP were compensated for by the use of blow counts from the end driving. Thus, the setup of piles occurring after driving was partially included in the prediction, even though the bias of Blendy's results was towards an underprediction.

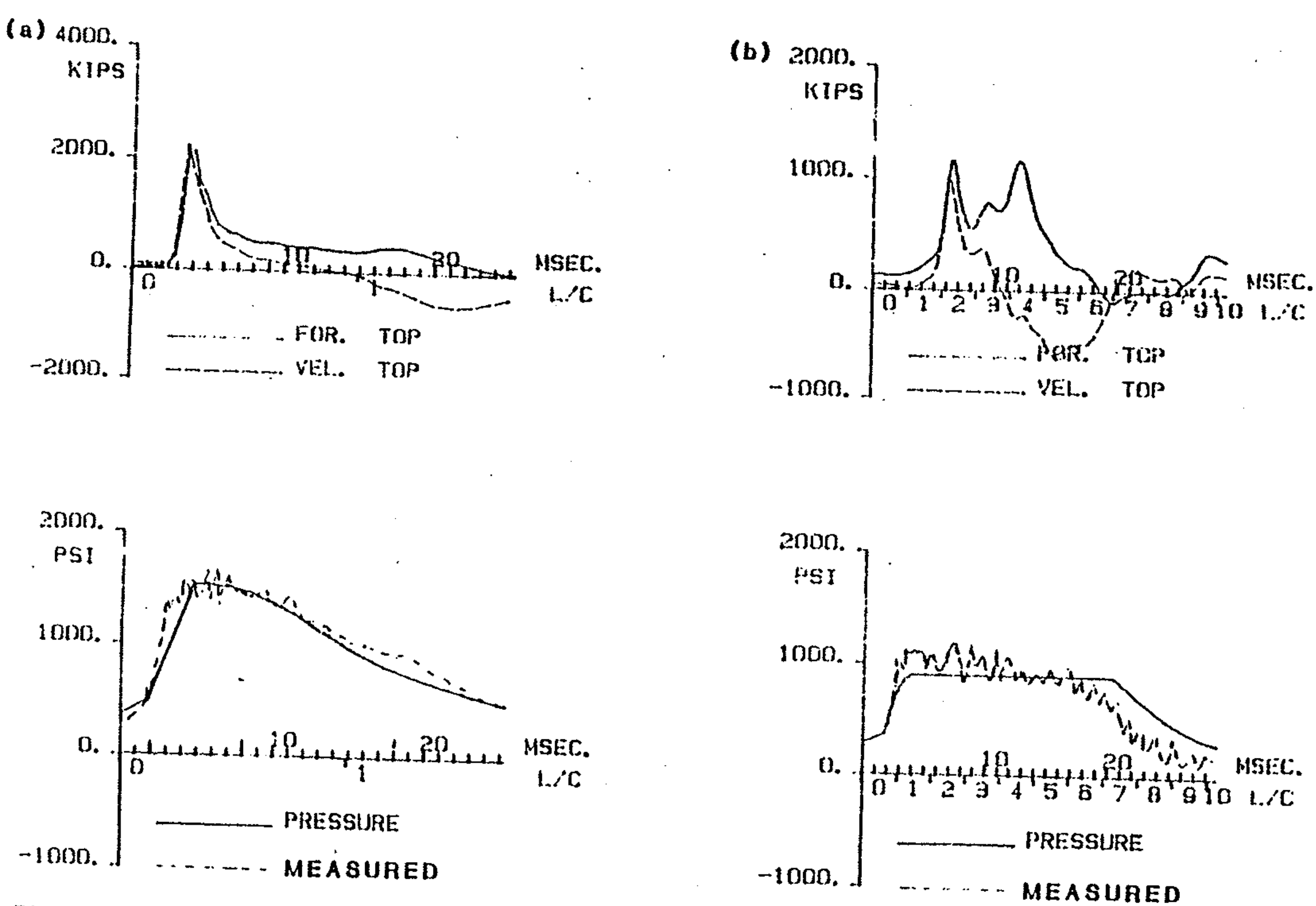


Figure 5.4. Simulated hammer test results; top: pile top force and velocity; bottom: computed and measured combustion pressures. (a) Delmag D 46-23 (b) ICE 1070.

As a demonstration of what might be the result if the WEAP86 recommendations of Volume II are followed, three cases of Blendy's paper were reanalyzed by WEAP86. They were labed B-10, M-11-4 and EP-250. Again, Tables 5.1(a), (b), and (c) list all pertinent information. Higher damping values and lower hammer efficiency produced reductions of predicted bearing capacity from Blendy's 580, 580, and 120 kips (2580, 2580, and 530 kN) to 430, 460, and 83 kips (1910, 2050, and 370 kN). The corresponding static test loads were 610, 560, and 150 kips (2710, 2490, and 670 kN). It is believed that setup indeed added considerable capacity, particularly since the frictional soils contained clay in all three cases.

The remaining cases were taken from the authors' consulting practice. They did not always include a complete knowledge of driving system components, but they did include measurement results such as maximum pile top force and transferred energy.

Case 2-24 was another Monotube analyzed by both normal and RSA analysis. The RSA improved both force and capacity prediction, although not very significantly. Some additional setup capacity gains are anticipated.

It is not always permissable to speculate on capacity gains due to setup. The next pile in the study, 4-14, was an H-Pile driven into shales. It was driven to virtual refusal (48 blows per inch, BPI, or 1900 blows/m, BPM), which indicates a 500-kip (2300 kN) capacity according to WEAP86. A restrike showed only 26 BPI (1000 BPM) at much lower energies and driving forces. During a maintained load test the pile only supported 364 kips (1650 kN). Such cases of relaxation are not uncommon when piles are driven into shale (see for example Reference 17).

Case C-6 was a Monotube analyzed by RSA. This case was unusual in that the observed transferred energy was nearly twice as high as commonly measured on LB440 hammers. This case was, therefore, analyzed with 95 instead of 80 percent hammer efficiency. The results then showed reasonably good agreement. In general, however, the standard efficiency should be used unless measurements would indicate that the given hammer performs better than average.

For WP6/C-7, both end of drive and restrike data was available. The load test indicated 950 kips (4300 kN). WEAP86 predicted 800 kips (3600 kN) at end-of-drive and 1000 kips (4500 kN) at beginning of restrike. Thus, a much better correlation was achieved by considering setup effects. Note that the restrike overprediction was primarily due to a lower than assumed hammer output (see transferred energies in Table 5.1(c).

Case TP2/C-8 is typical for situations where the static test was not carried to failure. A true comparison of predicted and computed capacities is then not possible.

The data for Case C-10 again includes restrike results. Note, however, the extremely low transferred energy measured during restrike, in contrast to the end of driving value. The end of drive results again underpredicted, and because of the poor hammer energy, the restrike results slightly overestimated the ultimate pile bearing capacity.

The last two cases again demonstrate a nonfailing static load test and the effect of setup as determined through restriking. These two cases were also used to demonstrate the two nonstandard friction options of WEAP86. Note that commonly, wave equation runs are made under the assumption that end bearing and skin friction are a fixed percentage of each R_{ut} value analyzed. WEAP86 also offers a fixed friction option (simulating a driving into rock) or a fixed end bearing (applicable where friction is unknown and end bearing is insignificant or rather well known).

5.5 Summary

The measured and predicted values of maximum pile top forces in Table 5.1 were converted to stress and correlated in Figure 5.5. Similar plots were made with ENTHRU (maximum transferred energy) and bearing capacity as shown in Figures 5.6 and 5.7 respectively. All correlations were relatively unbiased and their errors are near or within the 20 percent lines. Note that in many cases, end of driving, instead of restrike information, was used for capacity predictions.

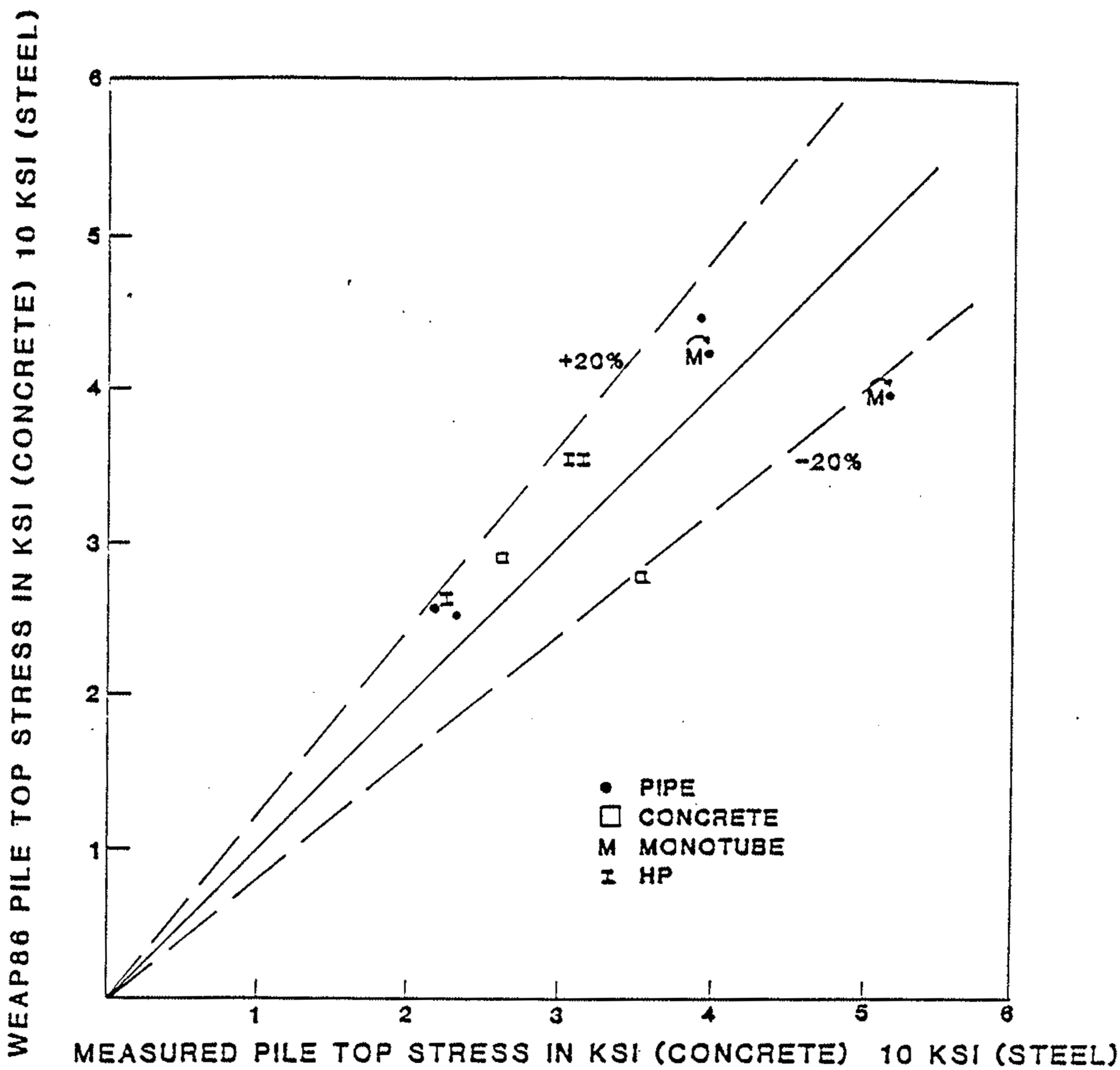


Figure 5.5. Correlation of pile top stress from WEAP86 and measurements (10 cases).

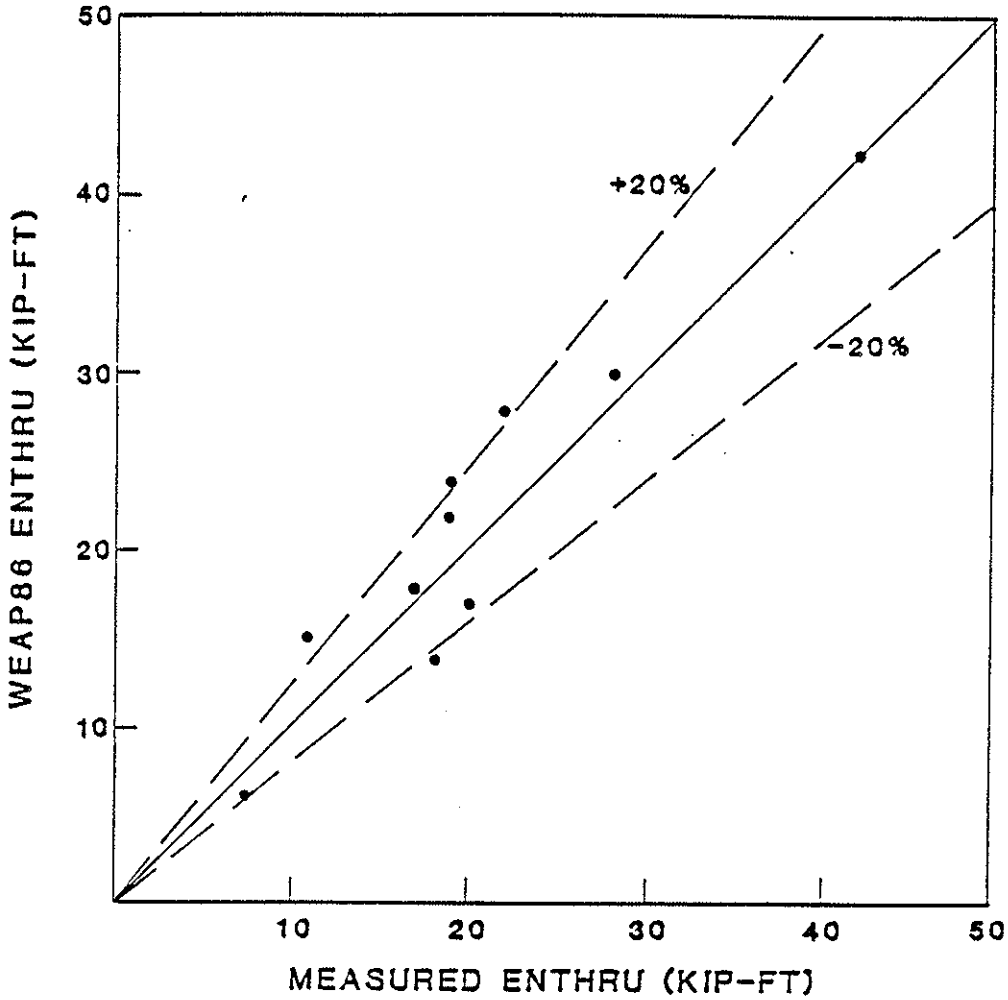


Figure 5.6. Correlation of ENTHRU from pile top measurements and WEAP86 (10 cases).

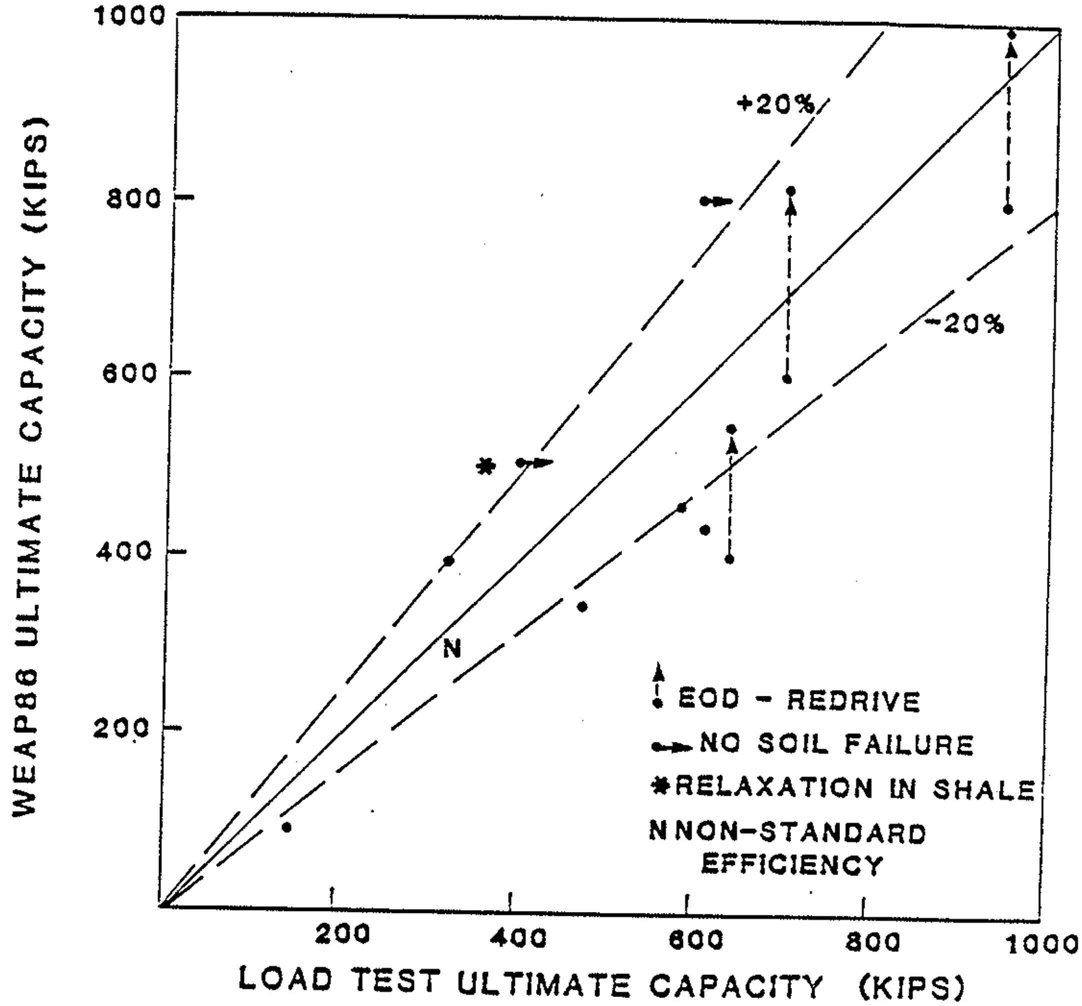


Figure 5.7. Correlation of load test and WEAP86 ultimate capacity (12 cases).

6. CONCLUSIONS AND RECOMMENDATIONS

WEAP86 has added a considerable amount of new models and computational procedures. This series of manuals attempts to reduce the amount of "guessing" of input data and increase the amount of "selecting". (At the same time it has been attempted to provide the engineer with as much latitude in modeling as possible, thus enabling him to simulate actual field conditions).

For the user who has been using WEAP and has performed correlation runs, the following should be remembered.

- The reduced hammer efficiency values in WEAP86 will tend to make his predicted capacties somewhat lower. It is believed that these lower capacities are more realistic when compared to "at time of driving" soil behavior.

- For Monotubes, the residual stress analysis (RSA) option is recommended. This will tend to make the predicted stresses and capacities higher. Underpredictions are, however, still anticipated, particularly when end-of-drive field blow counts are used instead of beginning of restrike blow counts.

Other general conclusions are:

- Good capacity correlations require restrike information.

- Average hammer performance parameters included in WEAP86 may overestimate or underestimate the actual hammer output, yielding either low or high predictions of stresses and bearing capacities.

- Properly applied, the predicted results should have an error less than 20 percent.

The current work is only another step towards more accurate analysis of pile driving. In particular, dynamic soil behavior is an area which requires further study; soil damping and soil setup factors are difficult to estimate, and uncertainties in these values can have great influence on the accuracy of bearing capacity predictions by the wave equation.

APPENDIX A: RESULTS FROM HAMMER PERFORMANCE TESTS

A.1 Introduction

The research and consulting practice of the authors provided opportunities for the collection of hammer and pile performance data. Of particular interest for the development of WEAP and WEAP86 were those data sets which included pressure measurements in the combustion chamber of diesel hammers.

For the development of WEAP86, a total of 55 data sets involving 21 different hammer models were investigated and catalogued. Examples of pressure vs. time curves, often together with pile top measurements, were compiled from measurement reports and then evaluated. The pressures were all recorded with piezoelectric transducers of 1 s time constant. Thus, some leak-off may have occured and reduced the recorded pressures. Also, the transducers sometimes suffered from extreme exposure to heat, and incomplete data sets may have resulted.

A.2 Evaluation Procedure

A summary of the results is given in Table A1. These values are, in general, averages over a number of blows. In general, both maximum pile top force and transferred energy were calculated from pile top strain and acceleration measurements and included in Table A1. From the pressure records, four characteristic values were extracted:

- Preignition pressure which is measured at the time of impact of liquid fuel injection (L.I.) hammers. The time of impact is easily identified if pile top records are available. There the forces and velocities show a sharp rise approximately 1/2 ms after the impact occurred in the hammer.

  For atomized fuel injection (A.I.) hammers, the preignition pressure was identified at the time when a sudden pressure

Table A1. Hammer performance measurement data.

Hammer Model	Setting	Pressure Preigtn psi	Pressure Cmbtn psi	Time Delay ms	Igtn Drtn ms	Max Force kips	Max Energy k-ft	Stroke ft	Driving Time mins	Driving Cond.	Pile/Capblock Detail
Delmag D-12	Max	490	1150	2.0	2.0	330	NA	6	warm	R=110 k	H-Pile 15.5"^{2} x 40' Conbest 4.5" x 169"^{2}
Delmag D-15	Max	440	1130	1.3	1.7	630	10.3	NA	<10	easy	Pipe 18" x .5" x 30'
	Max	440	1000	0.0	2.4	620	10.8	NA	<30	300 bpf	Conbest/Alum 4.5"
Delmag D-16-32	1	500	1030	0.8	1.5	1050	6.7	6.1	<10	refusal	Pipe 30" dia x 325'
	2	400	1240	0.8	1.8	1350	10.9	8.1	<10	refusal	2" Conbest/1.5" Alum
	3					1480	14.0	9.6	<10	refusal	
	4	525	1450	0.6	1.4	1590	16.0	10.0	<10	refusal	
Delmag D-22-02	4	520	980	0.0	9.0	NA	NA	NA	NA	NA	NA
Delmag D-30	4	420	925	2.4	2.4	NA	NA		warm	R=270 k	H-Pile 12-53 x 76'
	6	405	975	2.1	2.0	NA	NA		warm	270 k	
	8	410	1035	2.1	2.3	NA	NA		warm	270 k	
	10	425	1195	1.5	2.5	NA	NA		cool	270 k	
Delmag D-30-02	1	390	500	0.0	5.0	235	10.7		10	32 bpf	Pipe 12.75" x 0.288"
	2	400	675	0.0	5.0	335	22.0		8	25 bpf	x 94'
	3	400	720	0.0	5.0	367	27.0		7	18 bpf	Capblock NA
	4	380	750	0.0	5.0	368	30.2		4	16 bpf	
	4	390	685	0.0	5.0	354	26.6	8±	12	14 bpf	
Delmag D-30-23	1	640	1220	0.5	2.8	1220	11.0	7.5	cold	refusal	Pipe 30" x 250'
	2	690	1370	0.5	1.9	1560	17.0	8.9	cold	refusal	Conbest/Alum
	3	690	1510	0.5	1.2	2000	23.0	9.9	cold	refusal	
	4	720	1890	0.5	1.4	2100	27.0	10.3	cold	refusal	

Table A1. Hammer performance measurement data. (continued.)

Hammer Model	Setting	Pressure Preigtn psi	Pressure Cmbtn psi	Time Delay ms	Igtn Drtn ms	Max Force kips	Max Energy k-ft	Stroke ft	Driving Time mins	Driving Cond.	Pile/Capblock Detail
Delmag D-36-23	1	560	1085	0.0	2.7	1600	17.0	7.6	warm	refusal	Pipe 30" x 250'
	2	640	1260	0.0	2.7	1750	21.0	8.8	warm	refusal	Conbest/Alum
	4	850	1425	0.0	2.8	1950	25.5	10.2	warm	refusal	
Delmag D-80-12	1	1145	1225	0.0	1.5	2220	37.0	7.2	9	refusal	Pipe 30: x 250'
	2	1255	1345	0.0	1.0	2500	50.0	8.3	8	refusal	27" sq x 1" Conbest
	3	1255	1385	0.0	1.0	2800	62.0	9.7	6	refusal	0.5" Alum, 4" Steel +
	4	1305	1480	0.0	1.5	2900	69.0	10.2	3	refusal	47" dia x 8" Steel
FEC-1500	Max	550	1220	0.6	1.9	620	9.8		<10	1900 bpf	Pipe 18" x 0.5" x 30'
	Max	850	1210	0.0	1.5	690	10.2		60	refusal	Conbest/Alum 4.5"
FEC-2800	10	415	1250	0.0	4.5	1150	NA	32.2	15	refusal	Pipe 18" x 0.5" x 30'
	10	475	1135	0.0	4.6	1210	9.8	29.8	50	refusal	Con/Alum 4.5" Steel 5"
FEC-3000 (1980)	8	560	1400	0.0	2.2	1130	32.6	9.1	13	refusal	Pipe 18" x 0.5" x 30'
	10	560	1480	1.1	5.6	960	36.1	9.4	17	refusal	Pipe 18" x 0.5" x 75'
	10	820	1310	0.0	4.5	995	26.5	9.6	40	refusal	Con/Alum 4.5" Steel 5"
FEC-3000 (1983)	Max	540	1500	0.9	2.0	960	14.0	6.8	cool	86 bpf	Pipe 20" x 0.8" x 200'
FEC-3400	Max	460	1240	1.3	2.0	880	14.0	6.8	cool	65	see FEC-3000 (1983)
	max	460	1160	1.1	2.0	925	16.0	6.8	warm	68	
Bermingham B200	max	960	1310	0.0	1.5	172	1.9	8.1	cool	refusal	Pipe 24" x 0.5" x 95'
	Max	930	1375	0.0	1.5	171	1.8	8.4	warm	refusal	Micarta 4" Alum 0.5" Timber 16"

Table A1. Hammer performance measurement data. (continued.)

Hammer Model	Setting	Pressure Preigtn psi	Pressure Cmbtn psi	Time Delay ms	Igtn Drtn ms	Max Force kips	Max Energy k-ft	Stroke ft	Driving Time mins	Driving Cond.	Pile/Capblock Detail
Bermingham B225	Max	610	1410	2.2	1.0	175	1.9	5.7	cool	refusal	as for Bermingham B200
	Max	1390	1440	0.0	1.0	161	1.8	9.7	warm	refusal	
Bermingham B400	Max	830	1340	0.5	1.5	367	7.0	9.2	cool	refusal	as for Bermingham B200
	Max	1100	1330	0.0	1.9	327	7.2	8.3	warm	refusal	
ICE 440	15 psi	270	870	-3.2	10.0	270	1.7	**	warm	refusal	Pipe 24" x 5/8" x 48'
	18 psi	290	910	-2.3	9.4	380	2.8	**	warm	refusal	Nylon 2" Alum 0.5"
	21 psi	300	950	-2.4	9.9	480	4.2	**	warm	refusal	x 22.5" square
ICE 1070	10 psi	250	714	-2.8	13.7	530	3.2	**	23	refusal	Pipe 24" x 5/8" x 48'
	16 psi	270	954	-2.2	14.4	730	8.0	**	21	refusal	Nylon 2" Axlum 0.5"
	20 psi	280	1038	-1.4	15.2	810	11.0	**	19	refusal	x 25" square
	26 psi	320	1134	-1.1	14.8	1020	19.0	**	16	refusal	
KOBE KC-45	MAX	445	790	1.1	1.5	677	14.8	9+	<5	EASU	PSC 24" OCT. x 95'

NA - not available

** See ICE conversion charts for actual and equivalent stroke from bounce chamber pressure.

increase was apparent. This type of preignition pressure was only present in the ICE 440 and ICE 1070 data.

- Combustion pressure, also often referred to as maximum pressure, p_{max}, was taken as an average over approximately 2 ms. Averaging was only necessary where the pressure records contained high frequency waves. These waves were always filtered to some degree by the recording apparatus.

- Time delay, also called combustion delay, is the time between impact and ignition. It is negative if ignition occurs before impact. Sometimes a clear time of ignition is not apparent and partial combustion may have taken place before impact; then the time delay was set to zero, although, strictly speaking, it should be some negative value. This early partial combustion often occurs in hot hammers and indicates some preignition.

- Ignition Duration is the time period between ignition and the occurrence of p_{max}. Because of the rounded behavior of the curves, straight line approximations were used to obtain an approximate result. Both time delay and ignition duration are relatively insensitive computational parameters.

A.3 Discussion of Results

A.3.1 D-12 DATA

The Delmag D-12 hammer was tested on May 14, 1975 in the yard of The Foundation Equipment Corporation, which was then located in Newcomerstown, Ohio. Nineteen different tests, including battered piling, modified fuel, modified hammer compression, etc. were run. The first test (No. 1) was without hammer modification on a 40 ft (12 m) HP 12x53 pile. Note that the D-12 hammer has a single setting fuel pump. The records showed a large combustion delay when cold (early in the record) and a shorter one when warm (late).

Since these tests were performed, modifications may have been made to this hammer; the current reported factory maximum pressure value (1400 psi or 7400 kPa) differs from the one measured in 1975 and listed in Table A1 (1050 psi or 9870 kPa). The factory data was checked and found to yield good results with hammers of current manufacture.

A.3.2 D-15 Data

Comparative performance tests were conducted on a Delmag D-15 and an FEC 1500 (see B.3.11). An 18x.5 inch (450x12 mm) pipe of 30-ft (10 m) length was driven to rock to provide an unyielding test stand. The hammers were cold during easy driving and hot during hard driving.

A.3.3 Delmag D-16-32 Test

Pileco of Houston, the US distributor of Delmag Hammers, sponsored these tests in its yard on July 24, 1984. The Pileco test stand consists of a 30x1 inch (750x25 mm) pipe of 250-ft (75 m) length, partially filled with concrete, and driven to refusal.

The D-16-23 is equipped with a 4-step fuel pump which allows for a calibrated fuel adjustment. During the test, measurements were conducted for all but the No. 3 fuel settings.

A.3.4 Delmag D-22-02 Test

This test was conducted on November 10, 1977, again in the yard of Pileco. Unfortunately, good quality pile force records did not result. However, pressure records from the chamber of the D-22-02 were useful. The D-22-02 used a medium-high pressure injection which produces a fuel spray between the liquid and the atomized state.

A.3.5 Delmag D-30

The test was conducted on the D-30 hammer on July 26, 1971. The location was the FEC yard (see A.3.1) and the pile driven and tested was an HP 12x53 of 76-ft (23 m) length. The D-30 had a 10-step fuel pump. Tests were conducted on settings 4, 6, 8, and 10 (No. 10 is highest setting).

A.3.6 Delmag D-30-02

This hammer was tested on an actual construction site in New Philadelphia, Ohio on September 13, 1976. The test pile was a 12-3/4x.288 inch (330x7 mm) closed end pipe of 94 ft length. Several tests were conducted, including some with different fuel types. The D-30-02 has a 4-step fuel pump and pressure records were taken for all four settings. For the maximum setting both early and late records were evaluated (Table A1).

It should be noted that similar to the D-22-02, the D-30-02 utilized medium-high pressure injection. It is believed that these hammer models have been modified since the time that the present test results were obtained because the -02 series models tended to preignite. Thus, it is possible that different pressure histories would be obtained today.

A.3.7 Delmag D-30-23

Three hammers of the Delmag 23 series were tested on December 9 and 10 on the Pileco test stand in Houston. Comparing early and late records, it became apparent that the combustion delay was lost as the hammer warmed up. The Table A1 results were all from early records.

A.3.8 Delmag D-36-23

For this hammer, records for HS1, 2, and 4 were evaluated. On setting 3, problems with the pressure transducer arose during the test. For further details, see A.3.7.

A.3.9 Delmag D-46-23

Chamber pressure and pile top velocity records from the Delmag D-46-23 are shown in Figure A1. For further details see A.3.7. This data was also used for a program example run (see Chapter 5).

A.3.10 Delmag D-80-12

Between February 14 and 16, 1984 a hammer performance test was again run at the Pileco test stand in Houston. The D-80-12 has four fuel pump settings, and for each one of these settings, pressure, pile top force and pile top velocity were recorded.

A.3.11 FEC 1500

At the same time at which the D-15 tests were performed (see A.3.2), records were also taken on the FEC 1500 model. This hammer was a prototype at the time of testing. The values given in Table A1 were taken as an average over a large number of records.

A.3.12 FEC 2800

The Foundation Equipment Corporation performed this test in Newcomerstown, Ohio on April 4, 1980. They drove an 18x1/2 inch (450x12 mm) pipe to rock. Again, measurements of pile top force, pile top acceleration and hammer pressure were taken at five fuel pump settings. Note that the FEC 2800 is identical to the FEC 3000 but with a 2800 instead of 3000 kg ram.

A.3.13 FEC 3000(1980)

At the time of the FEC 2800 tests, an FEC 3000 hammer was also tested under similar conditions.

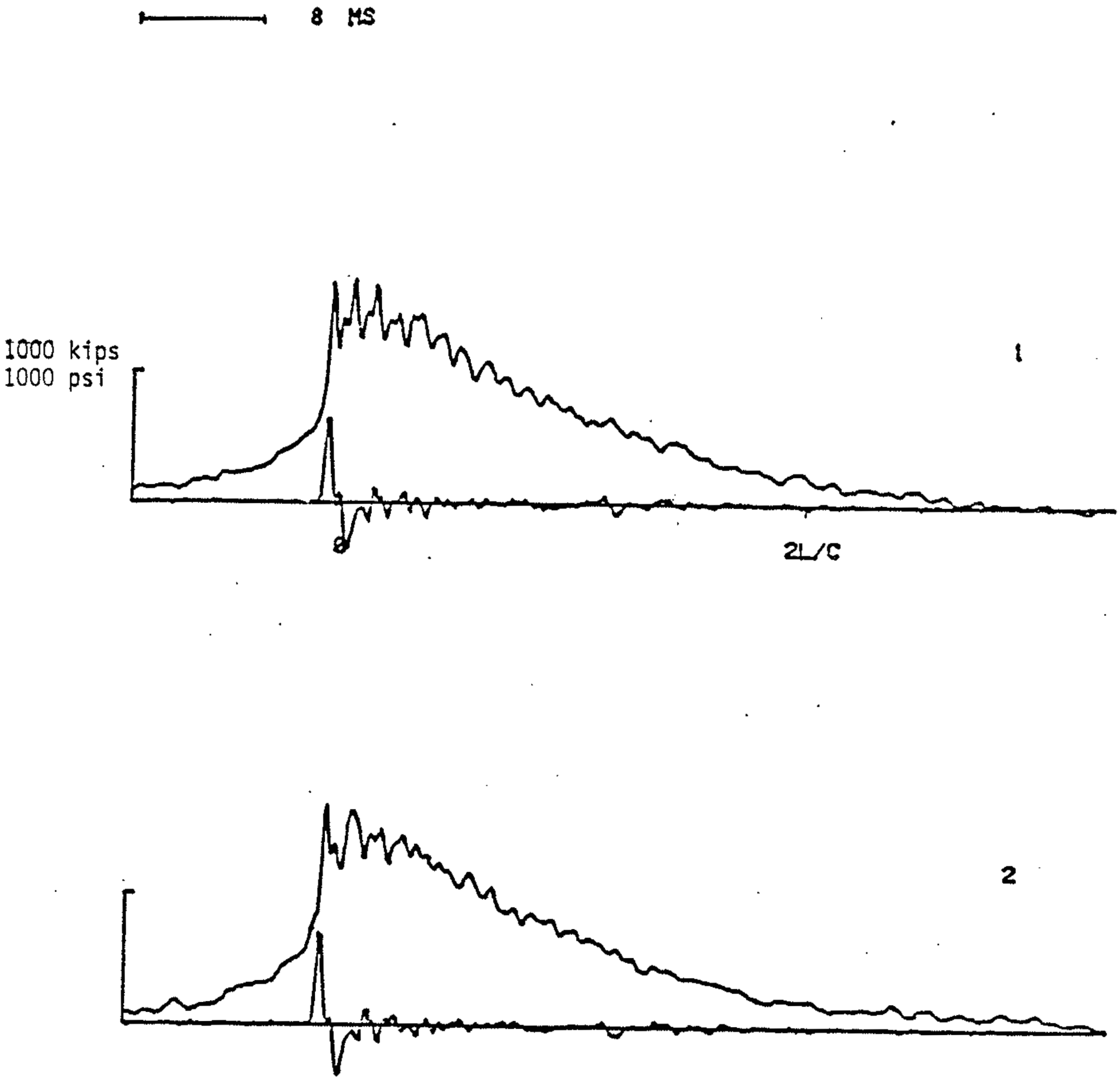


Figure A1. Pressure records together with pile top velocity, for timing reference, for the D46-23 hammer at setting 2.

A.3.14 FEC 3000(1983)

After the Foundation Equipment Corporation had moved to Dover, Ohio, it installed a test stand consisting of a 20x0.8 inch (500x20 mm) pipe of 200-ft (60 m) length. The pipe was driven to refusal and the performance of the FEC 3000 hammer was again investigated on April 4, 1983.

This was an excellent opportunity to test a similar hammer under somewhat different conditions. Note that the 200-ft (60 m) pile has a very long time of wave travel compared to the 75-ft (23 m) pipe tested in Newcomerstown. Thus, the pile rebound occured too late to be beneficial to a high ram rebound and strokes and transferred energies stayed relatively low.

A.3.15 FEC 3400

Together with the FEC 3000 test a new 3400 model was also tested in 1983. The record appearance was not very different from the one obtained for the FEC 3000(1983).

A.3.16 Berminghammer B 200

On October 10, 1983, a test was conducted on three types of Berminghammers in the yard of the Berminghammer Corporation in Hamilton, Ontario. Their test stand consisted sof a 24x0.5 inch (610x12 mm) pipe, protected by 16 inches (400 mm) of timber and a 4-inch (100 mm) Micarta/Aluminum assembly. The test stand pipe was at refusal. The forces and transferred energies in the pile are very low because of the 16-inch timber cushion which was sandwiched between heavy steel plates and rubber sheets.

A.3.17 Berminghammer B 225

The test was conducted as in A.3.16. Again two records are shown for a hot and a cold hammer. Again the transferred energies and pile top forces were very low because of the cushioning.

A.3.18 Berminghammer B400

Again reference is made to the test description in B.3.16.

A.3.19 ICE 440

On September 20, 1982, both the ICE 440 and 1070 hammers were tested in the ICE yard at Matthews, NC. The ICE test stand consisted of a 24x5/8 inch pipe filled with concrete to almost its top. This pipe had been driven to refusal. The records presented for the ICE hammers are particularly useful since these units have atomized fuel injection.

The ICE hammers have a continuously adjustable fuel pump and tests were conducted with reduced fuel amounts such that a predetermined bounce chamber pressure was achieved. Because of the refusal situation, full fuel could have caused the hammer to uplift. For this reason it cannot be expected that the hammer transferred energy to its fullest potential. A pressure record, corresponding to 21 psi bounce chamber pressure is shown in Figure A2; pile top force and velocity were included to allow for a determination of the time of impact.

A.3.20 ICE 1070

The general remarks of A.3.19 are applicable. Records for the 26 psi bounce chamber pressures are presented in Figure A3. They include pile top force and velocity for timing purposes. Because of the particular location of the access hole of the pressure transducer, the ram temporarily blocked this passage and caused an erratic reading of short duration. It is felt that the sudden high values are incorrect and that the actual combustion pressure behaves as smoothly as for the 440 hammer. An example WEAP86 run was also made and discussed in Chapter V.

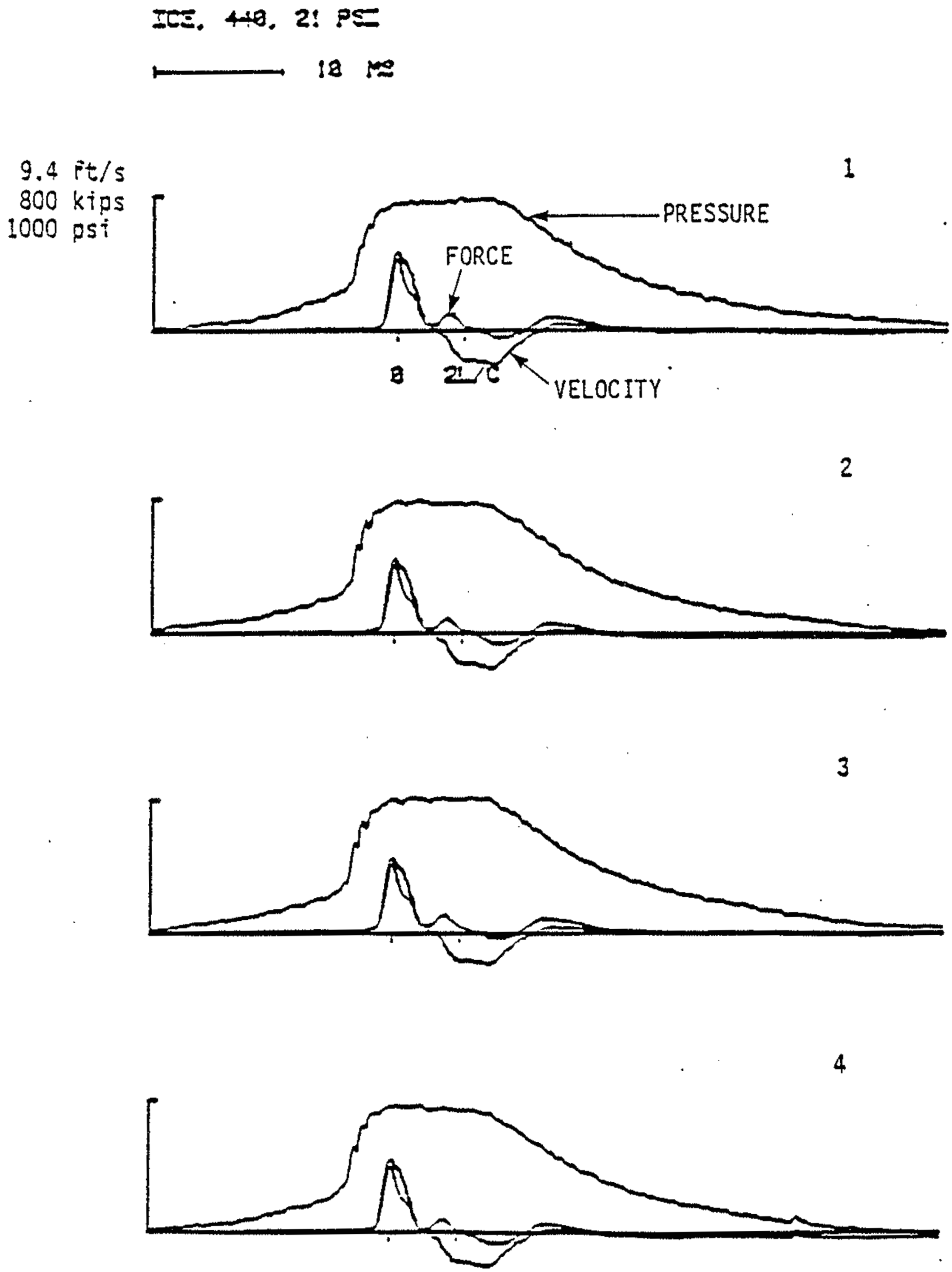


Figure A2. Pressure in hammer, force and velocity at top of pile stand measured on ICE 440 hammer.

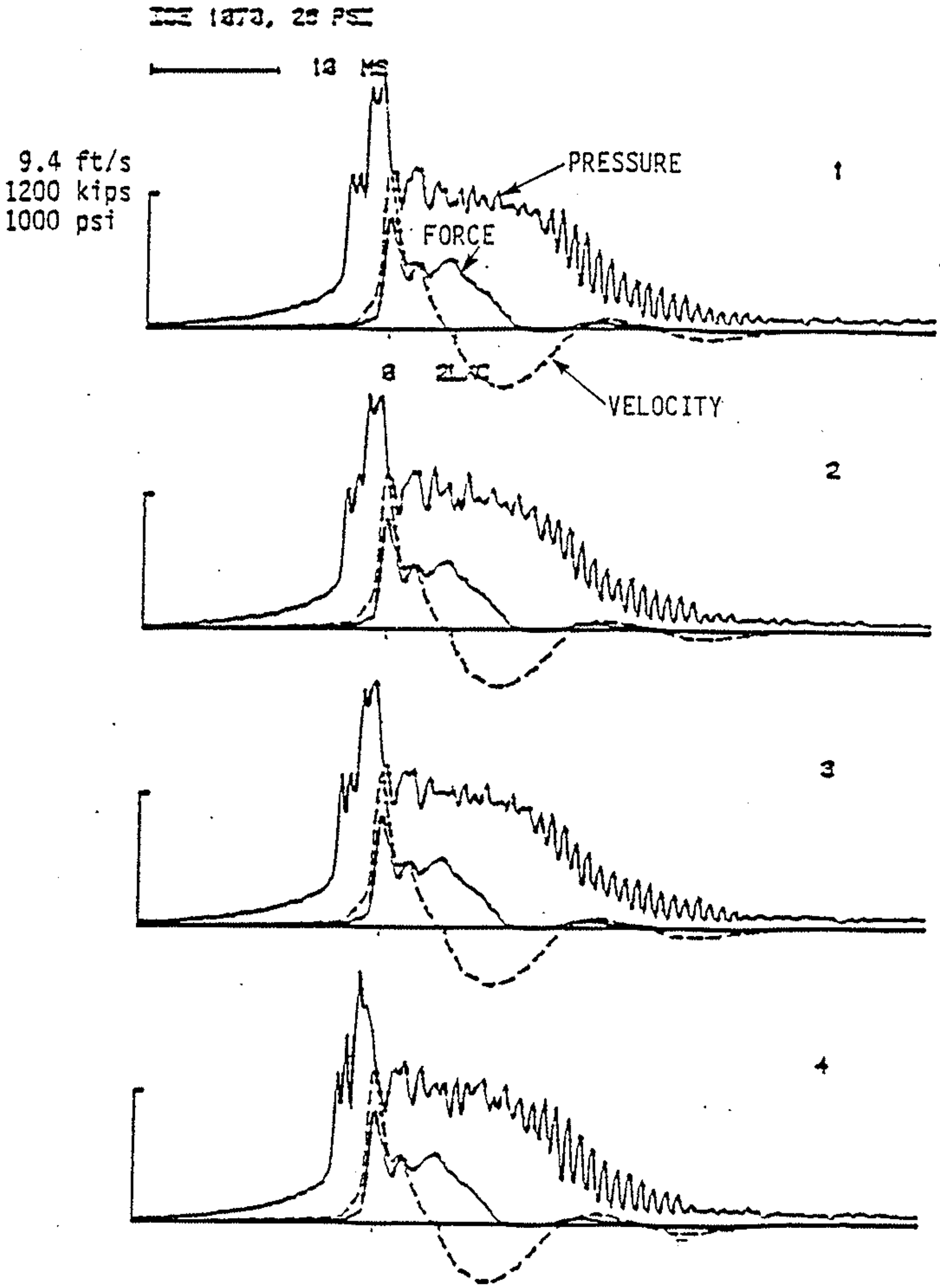


Figure A3. Pressure in hammer, force and velocity at top of pile stand measured on ICE 1070 hammer.

A.3.21 Kobelco KC45

This hammer also features atomized fuel injection. However, it is an open end hammer and its pressure record was very similar to that of impact atomization hammers before impact. After impact it shows the flat behavior of atomized fuel combustion. The records were taken on an actual construction site in Seattle, Washington on a 24-inch (610 mm) octagonal prestressed pile.

APPENDIX B: CALCULATION OF p_{max}

If no measurements are available and if the hammer manufacturer does not know p_{max}, then it is proposed to perform the following analysis for hammers with impact atomization.

(1) Assume t_d = 0.001 and t_{cd} = 0.002 s

(2) Assume $c_p = c_d = 1.35$

(3) Assume p_{max} = 1100 psi (7700 kPa)

Perform an analysis with a 50 foot (15m) long pile having a cross-sectional area matched to the hammer size. The soil resistance should be high enough to cause refusal. The constant hammer stroke option should be chosen with an input stroke equal to the rated stroke. The analysis will give, as a result, the maximum pressure value, p_{max}, corresponding to the rated hammer performance. However, for more conservative results it may be advisable to use only 90% of the rated stroke as an input to the trial analysis.

For atomized fuel injection hammers, a similar process may be used. However, V_{ci} and V_{ce} <u>must</u> be accurately known and cannot be assumed. The thermal coefficients, c_p and c_d, may again be set equal to 1.35. The resulting p_{max} may be as low as 900 psi (630 kPa).

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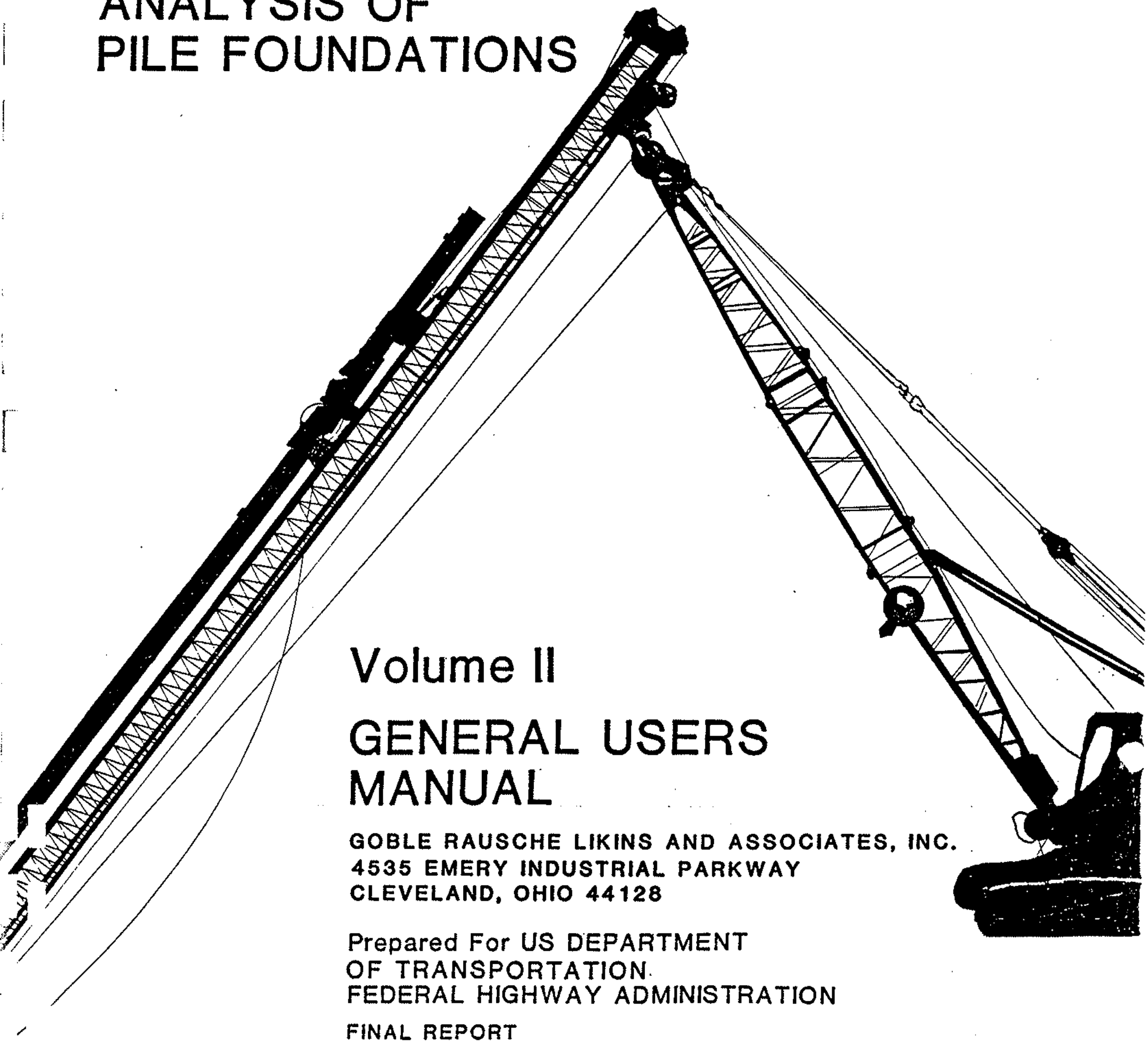
WEAP86

WAVE EQUATION ANALYSIS OF PILE FOUNDATIONS



Volume II

GENERAL USERS MANUAL

GOBLE RAUSCHE LIKINS AND ASSOCIATES, INC.
4535 EMERY INDUSTRIAL PARKWAY
CLEVELAND, OHIO 44128

Prepared For US DEPARTMENT OF TRANSPORTATION FEDERAL HIGHWAY ADMINISTRATION

FINAL REPORT
MAY 1986

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle	5. Report Date
WAVE EQUATION ANALYSIS OF PILE FOUNDATIONS WEAP86 PROGRAM Volume II. General Users Manual	March 1986
	6. Performing Organization Code
7. Author(s) G.G. Goble and F. Rausche	8. Performing Organization Report No.
9. Performing Organization Name and Address Goble Rausche Likins and Associates, Inc. 4535 Emery Industrial Parkway Cleveland, OH 44128	10. Work Unit No. (TRAIS) 11. Contract or Grant No. DTFH61-84-C-00100
12. Sponsoring Agency Name and Address Office of Implementation Federal Highway Administration 6300 Georgetown Pike McLean, Virginia 22101-2296	13. Type of Report and Period Covered Final Report 14. Sponsoring Agency Code

15. Supplementary Notes

FHWA contract manager: Chien-Tan Chang (HDV-10)

16. Abstract

The WEAP Program, written and documented under a previous FHWA contract in 1976 and updated in 1981, was further developed. The documentation was completely rewritten for additional or revised information. The new program referred to as WEAP86, includes all of the WEAP features plus the following new models:

Separate models for liquid and atomized fuel injection of diesel hammers.
Residual stress analysis.
Realistic splice model.

An important addition was an updated and/or revised hammer data file with new efficiency values based on research performed under another contract for the FHWA. Furthermore, extensive tables covering helmets, cushions, and piles were compiled and included in the documentation. Another important facet of the WEAP86 work was the development of a program version for personal computers. The main effort consisted of providing for a user-friendly/menu-driven input program and a graphics output option.

This is the second volume among four. The others are

FHWA No.	Vol. No.	Title
	I	Background
	III	Program Installation Manual
	IV	Users Manual for PC Application

17. Key Words	18. Distribution Statement
Combustion, Computers, Design, Diesel, Dynamics, Foundations, Hammers, Impact, Pile driving, Residual stress, Soil mechanics, Wave equation.	No restrictions. This document is available to the public through the National Technical Information Service. Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	174	

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VOLUME II

VOLUME II: GENERAL USERS MANUAL

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1. INTRODUCTION

This volume serves two purposes. First, the user of WEAP86 is familiarized with the preparation of input quantities, and second, a collection of data is presented in an effort to facilitate the input preparation by inexperienced users. The reader should be aware that this Manual cannot give a full discussion of the significance of this data which is described in Volume I and its references. However, as much as possible, Chapters 2 and 3 deal with important details and peculiarities of the WEAP86 program.

An essential portion of the current (WEAP86) effort was devoted to the updating of program input data. This data is based on (i) the earlier WEAP manuals, (ii) the data submittals of hammer and accessory manufacturers, and (iii) results based on the authors' field measurements and analyses. Acknowledgements were included in Volume I.

Table 1: Hammer Data File Contents
Table 2: Helmet and Hammer Cushion Data
Table 3: Cushion Properties
Table 4: Pile Data
Table 5: Soil Parameters

Since these tables are organized in the beginning of this manual, a quick reference will be possible.

The input preparation is further simplified by the following figures.

Figure 1: Preprogrammed Resistance Distributions.
Figure 2: Definition of "Cap" Terminology.
Figure 3: Example of Nonuniform Pile Profile Input.
Figure 4: Example of Nonstandard Resistance Distribution Input

This Manual also contains ten computational examples dealing with more or less unusual circumstances. The necessary steps in the analysis of a problem are shown and general recommendations are given.

Before starting to use WEAP86, the program must be installed in the user's machine. A special manual, Volume III, was written to facilitate that work. Installation and use of the program on a general main frame computer means:

- Compilation and loading of the WEAP86 program.
- Compilation and loading of the hammer data file maintenance program.
- Loading the hammer data file.
- Preparation of either the data input cards or writing of the data input file.
- Running WEAP86 using input data and hammer data file. WEAP86 will produce output in printed form.

WEAP86 is also available for IBM/PC compatible microcomputers . The data preparation using such machines is facilitated through the use of W86IN, a special input program which guides the user through the input. However, even for the PC user, Volume 2 is an indispensable tool as far as tables of input data and definition of variables is concerned. PC users have the further advantage of being optionally provided with graphics output.

The authors hope that the use of WEAP86 will help to provide for better foundation practice through increased knowledge. But remember the old saying "GIGO," i.e., "The output cannot be any better than the input."

A few changes in terminology were made after it was noticed that confusion over WEAP's terms occurred in various parts of the United States or in other countries. These changes are as follows:

OLD TERM	NEW TERM
capblock	hammer cushion
cushion	pile cushion
anvil	impact block

Table 1. Hammer data file listing.
1 kip = 4.45 kN   1 kip-ft =1.36 kJ
ID...Hammer File ID Number: Type OED Open End Diesel. CED Closed End Diesel. SECH Single Acting External Combustion. DECH Double Acting ECH

ID	MANUFGR	NAME	RAM WEIGHT	ENERGY	TYPE
1	DELMAG	D 5	1.10	8.23	OED
2	DELMAG	D 8-22	1.76	17.60	OED
3	DELMAG	D 12	2.75	23.59	OED
4	DELMAG	D 15	3.30	28.31	OED
5	DELMAG	D 16-32	3.52	39.25	OED
6	DELMAG	D 22	4.91	40.61	OED
7	DELMAG	D 22-02	4.85	48.50	OED
8	DELMAG	D 22-13	4.85	48.50	OED
9	DELMAG	D 22-23	4.85	51.26	OED
10	DELMAG	D 25-32	5.51	61.49	OED
11	DELMAG	D 30	6.60	59.60	OED
12	DELMAG	D 30-02	6.60	66.00	OED
13	DELMAG	D 30-13	6.60	66.00	OED
14	DELMAG	D 30-23	6.60	73.66	OED
15	DELMAG	D 30-32	6.60	73.66	OED
16	DELMAG	D 36	7.93	83.82	OED
17	DELMAG	D 36-02	7.93	83.82	OED
18	DELMAG	D 36-13	7.93	83.82	OED
19	DELMAG	D 36-23	7.93	88.50	OED
20	DELMAG	D 36-32	7.93	88.50	OED
21	DELMAG	D 44	9.50	90.44	OED
22	DELMAG	D 46	10.14	107.18	OED
23	DELMAG	D 46-02	10.14	107.18	OED
24	DELMAG	D 46-13	10.14	96.53	OED
25	DELMAG	D 46-23	10.14	107.18	OED
26	DELMAG	D 46-32	10.14	113.16	OED
27	DELMAG	D 55	11.86	124.53	OED
28	DELMAG	D 62-02	13.66	152.45	OED
29	DELMAG	D 62-12	13.66	152.45	OED
30	DELMAG	D 62-22	13.66	152.45	OED
31	DELMAG	D 80-12	17.62	186.24	OED
32	DELMAG	D 80-23	17.62	196.64	OED
33	DELMAG	D100-13	22.03	245.85	OED
35	DELMAG	D 350	66.08	738.11	OED
41	FEC	FEC 1200	2.75	22.50	OED
42	FEC	FEC 1500	3.30	27.09	OED
43	FEC	FEC 2500	5.50	50.00	OED
44	FEC	FEC 2800	6.16	55.99	OED
45	FEC	FEC 3000	6.60	63.03	OED
46	FEC	FEC 3400	7.48	73.00	OED
61	MITSUB.	M 14	2.97	25.25	OED
62	MITSUB.	MH 15	3.31	28.14	OED
63	MITSUB.	M 23	5.06	43.01	OED
64	MITSUB.	MH 25	5.51	46.84	OED
65	MITSUB.	M 33	7.26	61.71	OED
66	MITSUB.	MH 35	7.72	65.62	OED
67	MITSUB.	M 43	9.46	80.41	OED
68	MITSUB.	MH 45	10.05	85.43	OED
70	MITSUB.	MH 72B	15.90	135.15	OED
71	MITSUB.	MH 80B	17.60	149.60	OED
80	VULCAN	VULC 300	3.00	30.00	OED
81	VULCAN	VULC 330	3.31	33.10	OED
82	VULCAN	VULC 660	6.61	66.10	OED
83	VULCAN	VULC 800	8.00	80.00	OED
101	KOBE	K 13	2.87	25.43	OED
104	KOBE	K 25	5.51	51.52	OED
107	KOBE	K 35	7.72	72.18	OED
110	KOBE	K 45	9.92	92.75	OED
112	KOBE	KB 60	13.23	130.18	OED
113	KOBE	KB 80	17.64	173.58	OED
121	ICE	ICE 180	1.73	8.10	CED
122	ICE	ICE 422	4.00	23.10	CED
123	ICE	ICE 440	4.00	18.55	CED
124	ICE	ICE 520	5.07	30.39	CED
125	ICE	ICE 640	6.00	40.56	CED
126	ICE	ICE 660	7.57	51.60	CED
127	ICE	ICE 1070	10.00	72.60	CED
131	LINKBELT	LB 180	1.73	8.10	CED
132	LINKBELT	LB 312	3.86	14.95	CED
133	LINKBELT	LB 440	4.00	18.55	CED
134	LINKBELT	LB 520	5.07	27.66	CED
135	LINKBELT	LB 660	7.57	51.60	CED
144	MKT	DE 20	2.00	16.00	OED
148	MKT	DE 30	2.80	22.40	OED
149	MKT	DA35B SA	2.80	23.80	OED
150	MKT	DE 30B	2.80	23.80	OED
151	MKT	DA 35B	2.80	N/A	CED
152	MKT	DA 45	4.00	N/A	CED
153	MKT	DE 40	4.00	32.00	OED
159	MKT	DE 50B	5.00	42.50	OED
160	MKT	DA55B SA	5.00	40.00	OED
161	MKT	DA 55B	5.00	N/A	CED
162	MKT	DE 70B	7.00	59.50	OED
171	CONMACO	C 50	5.00	15.00	SECH
172	CONMACO	C 65	6.50	19.50	SECH
173	CONMACO	C 550	5.00	25.00	SECH
174	CONMACO	C 565	6.50	32.50	SECH
175	CONMACO	C 80	8.00	26.00	SECH
176	CONMACO	C 100	10.00	32.50	SECH
177	CONMACO	C 115	11.50	37.38	SECH
178	CONMACO	C 80E5	8.00	40.00	SECH
179	CONMACO	C 100E5	10.00	50.00	SECH
180	CONMACO	C 115E5	11.50	57.50	SECH
181	CONMACO	C 125E5	12.50	62.50	SECH
182	CONMACO	C 140	14.00	42.00	SECH
183	CONMACO	C 160	16.25	48.75	SECH
184	CONMACO	C 200	20.00	60.00	SECH
185	CONMACO	C 300	30.00	90.00	SECH
186	CONMACO	C 5200	20.00	100.00	SECH
187	CONMACO	C 5300	30.00	150.00	SECH
188	CONMACO	C 5450	45.00	225.00	SECH
189	CONMACO	C 5700	70.00	350.00	SECH
190	CONMACO	C 6850	85.00	510.00	SECH

Table 1. Hammer data file listing (continued)

ID	MANUFGR	NAME	RAM WEIGHT	ENERGY	TYPE
204	VULCAN	VUL 01	5.00	15.00	SECH
205	VULCAN	VUL 02	3.00	7.26	SECH
206	VULCAN	VUL 06	6.50	19.50	SECH
207	VULCAN	VUL 08	8.00	26.00	SECH
208	VULCAN	VUL 010	10.00	32.50	SECH
209	VULCAN	VUL 012	12.00	39.00	SECH
210	VULCAN	VUL 014	14.00	42.00	SECH
211	VULCAN	VUL 016	16.25	48.75	SECH
212	VULCAN	VUL 020	20.00	60.00	SECH
213	VULCAN	VUL 030	30.00	90.00	SECH
214	VULCAN	VUL 040	40.00	120.00	SECH
215	VULCAN	VUL 060	60.00	180.00	SECH
220	VULCAN	VUL 30C	3.00	7.26	DECH
221	VULCAN	VUL 50C	5.00	15.10	DECH
222	VULCAN	VUL 65C	6.50	19.20	DECH
223	VULCAN	VUL 65CA	6.50	19.58	DECH
224	VULCAN	VUL 80C	8.00	24.45	DECH
225	VULCAN	VUL 85C	8.52	26.00	DECH
226	VULCAN	VUL 100C	10.00	32.88	DECH
227	VULCAN	VUL 140C	14.00	36.00	DECH
228	VULCAN	VUL 200C	20.00	50.20	DECH
229	VULCAN	VUL 400C	40.00	113.49	DECH
230	VULCAN	VUL 600C	60.00	179.13	DECH
231	VULCAN	VUL 320	20.00	60.00	SECH
232	VULCAN	VUL 330	30.00	90.00	SECH
233	VULCAN	VUL 340	40.00	120.00	SECH
234	VULCAN	VUL 360	60.00	180.00	SECH
235	VULCAN	VUL 505	5.00	25.00	SECH
236	VULCAN	VUL 506	6.50	32.50	SECH
237	VULCAN	VUL 508	8.00	40.00	SECH
238	VULCAN	VUL 510	10.00	50.00	SECH
239	VULCAN	VUL 512	12.00	60.00	SECH
240	VULCAN	VUL 520	20.00	100.00	SECH
241	VULCAN	VUL 530	30.00	150.00	SECH
242	VULCAN	VUL 540	40.90	200.00	SECH
243	VULCAN	VUL 560	62.50	300.00	SECH
245	VULCAN	VUL 3100	100.00	300.00	SECH
246	VULCAN	VUL 5100	100.00	500.00	SECH
247	VULCAN	VUL 5150	150.00	750.00	SECH
248	VULCAN	VUL 6300	300.00	1800.00	SECH
251	RAYMOND	R 1	5.00	15.00	SECH
252	RAYMOND	R 1S	6.50	19.50	SECH
253	RAYMOND	R 65C	6.50	19.50	DECH
254	RAYMOND	R 65CH	6.50	19.50	DECH
255	RAYMOND	R 0	7.50	24.38	SECH
256	RAYMOND	R 80C	8.00	24.45	DECH
257	RAYMOND	R 80CH	8.00	24.45	DECH
258	RAYMOND	R 2/0	10.00	32.50	SECH
259	RAYMOND	R 3/0	12.50	40.63	SECH
260	RAYMOND	R 150C	15.00	48.75	DECH
261	RAYMOND	R 4/0	15.00	48.75	DECH
262	RAYMOND	R 5/0	17.50	56.88	SECH
263	RAAYMOND	R 30X	30.00	75.00	SECH
264	RAYMOND	R 8/0	25.00	81.25	SECH
265	RAYMOND	R 40X	40.00	100.00	SECH
266	RAYMOND	R 60X	60.00	150.00	SECH
271	MENCK	MH 68	7.72	49.18	SECH
272	MENCK	MH 96	11.02	69.43	SECH
273	MENCK	MH 145	16.53	104.80	SECH
274	MENCK	MH 195	22.05	141.12	SECH
275	MENCK	MHU 220	25.13	159.07	SECH
276	MENCK	MHU 400	50.71	289.55	SECH
277	MENCK	MHU 600	77.16	433.64	SECH
278	MENCK	MHU 1700	207.23	1228.87	SECH
279	MENCK	MHU 3000	363.76	2171.65	SECH
280	MENCK	MRBS 500	11.02	45.07	SECH
281	MENCK	MRBS 850	18.96	93.28	SECH
282	MENCK	MRBS1100	24.25	123.43	SECH
283	MENCK	MRBS1800	38.58	189.81	SECH
284	MENCK	MRBS3000	66.13	325.36	SECH
285	MENCK	MRBS3900	86.86	513.34	SECH
286	MENCK	MRBS4600	101.41	498.94	SECH
287	MENCK	MRBS5000	110.23	542.33	SECH
288	MENCK	MRBS8000	176.37	867.74	SECH
289	MENCK	MRBS8800	194.01	954.53	SECH
290	MENCK	MBS12500	275.58	1581.83	SECH
291	BRMNGHMR	B-200	2.00	18.00	OED
292	BRMNGHMR	B-225	3.00	29.00	OED
293	BRMNGHMR	B-300	3.75	34.00	OED
294	BRMNGHMR	B-400	5.00	45.00	OED
295	BRMNGHMR	B-500	6.90	62.10	OED
301	MKT	No. 5	.20	1.00	DECH
302	MKT	No. 6	.40	2.50	DECH
303	MKT	No. 7	.80	4.14	DECH
304	MKT	9B3	1.60	8.78	DECH
305	MKT	10B3	3.00	13.07	DECH
306	MKT	C5-Air	5.00	14.23	DECH
307	MKT	C5-Steam	5.00	16.21	DECH
308	MKT	S-5	5.00	16.25	SECH
309	MKT	11B3	5.00	19.11	DECH
310	MKT	C826 Stm	8.00	24.38	DECH
311	MKT	C826 Air	8.00	21.27	DECH
312	MKT	S-8	8.00	26.00	SECH
313	MKT	MS-350	7.72	30.80	SECH
314	MKT	S 10	10.00	32.50	SECH
315	MKT	S 14	14.00	37.52	SECH
316	MKT	MS 500	11.00	44.00	SECH
317	MKT	S 20	20.00	60.00	SECH

Table 2. Helmet and hammer cushion properties.

Cap weight in kips
Cushion Thickness in inches
COR = Coefficient of Restitution
Cushion Area in square inches
WEAP86 Input: E = Elastic Modulus in ksi

1 Kip = 4.45 kN; 1 inch = 25.4 mm; 1 ksi = 6.89 MPa

Table 2(a). Berminghammer

For all pile types:

Hammer Model	B-200	B-225	B-300	B-400	B-500
Cap Weight	1.10	1.39	1.39	2.14	2.14
Cushion Area	188.0	188.0	188.0	281.0	281.0

Note: For piles larger than 14", an adapter is hung below the normal cushion. Hammer cushions are aluminum/micarta with a thickness of 4.75 in and a WEAP86 Input of E = 350 ksi and COR = 0.8

Table 2(b). Delmag pile drivers

Cap weights for all hammer models:

	HP	Pipe*		Square				
		Small	Large	12"	14"	16"	18"	20"
Cap Wt.	2.15	2.02	3.53	2.41	2.28	2.46	3.39	3.57

For 16 and 24" concrete piles, it is possible to use square caps with weights 1.4 and 3.42 kips, respectively.

For piles up to 16", the hammer cushion has an area of 283.5 in^2 and a Conbest thickness of 2". For piles up to 24", the hammer cushion area is 415.5 in^2 and a Conbest thickness of either 2 or 3.5 inches.

All hammer cushions are Aluminum/Conbest combinations with WEAP86 Input E = 280 ksi, and COR = .8.

* Small: up to 16"; Large: up to 24".

Table 2(c): Foundation Equipment Corporation

For all hammer models:

Pile Size	12"	14"	16"	18"	20"	24"	36"
Cap Weight	1.10	1.26	1.68	1.90	2.60	2.50	7.00
Cushion Area	175.0	232.0	297.0	370.0	370.0	370.0	433.0

Note: Hammer cushions are aluminum/micarta with a thickness of 4.5 in and a WEAP86 Input of E = 410 ksi and COR = 0.8

Table 2(d). International Construction Equipment

Hammer Model	Cap Weights ICE 180			ICE 422			ICE 440		
Pile Type*	H	P	C	H	P	C	H	P	C
Pile Size									
10"	.50	.425	.50	2.09	2.05	1.96	2.23	2.19	2.10
12"	.50	.425	.50	2.09	2.05	1.96	2.23	2.19	2.10
14"	----	.425	----	2.09	2.05	2.01	2.23	2.19	2.15
16"	----	----	----	----	2.55	2.47	----	2.69	2.61
18"	----	----	----	----	2.55	2.62	----	2.69	2.76
20"	----	----	----	----	2.55	----	----	2.69	----
24"	----	----	----	----	----	----	----	----	----

Hammer Model	Cap Weights ICE 520			ICE 640			ICE 660		
Pile Type*	H	P	C	H	P	C	H	P	C
Pile Size									
10"	2.72	2.68	2.60	2.72	2.68	2.60	3.62	3.58	----
12"	2.72	2.68	2.60	2.72	2.68	2.60	3.62	3.58	3.50
14"	2.72	2.68	2.60	2.72	2.68	2.60	3.62	3.58	3.50
16"	----	3.18	3.10	----	3.18	3.10	----	4.08	4.00
18"	----	3.18	3.25	----	3.18	3.25	----	4.08	4.15
20"	----	3.18	3.46	----	3.18	3.46	----	4.08	4.35
24"	----	----	----	----	4.74	4.53	----	5.38	5.17

Hammer Model	Cap Weights ICE 1070		
Pile Type*	H	P	C
Pile Size			
10"	3.02	2.98	----
12"	3.02	2.98	2.90
14"	3.02	2.98	2.90
16"	----	3.48	3.40
18"	----	3.48	3.55
20"	----	3.48	3.75
24"	----	4.78	4.57

Note: * Pile Type: H = H-Pile, P = Steel Pile Pile, C = Concrete

For All Pile Types:

Hammer Model ICE	180	422 440 520 640	640* 660 1070
Cushion Matl	alum/mic	nylon	nylon
Cushion Area	48.7	398.0	491.0
Cushion Thick.	1.50	2.00	2.00
WEAP86 Input E=	350	175	175
COR=	.80	.92	.92

Note: * Only for 24" steel pile and concrete piles.

Table 2(e). Link belt

Hammer Model	Cap Weights LB 180			LB 312			LB 440		
Pile Type*	H	P	C	H	P	C	H	P	C
Pile Size									
10"	.50	.425	.50	2.15	1.80	----	1.332	1.47	1.25
12"	.50	.425	.50	2.15	1.80	2.00	1.32	1.32	1.25
14"	----	.425	----	2.15	1.80	1.80	1.26	1.26	1.35
16"	----	----	----	----	1.80	2.52	----	1.62	1.37
18"	----	----	----	----	1.80	2.30	----	2.54	1.36
20"	----	----	----	----	1.80	----	----	----	----
24"	----	----	----	----	----	----	----	----	----

Hammer Model	Cap Weights LB 520			LB 660		
Pile Type*	H	P	C	H	P	C
Pile Size						
10"	2.15	1.80	----	----	----	----
12"	2.15	1.80	2.00	3.07	3.07	----
14"	2.15	1.80	1.80	3.07	3.22	----
16"	----	1.80	2.52	----	3.22	3.08
18"	----	1.80	2.30	----	3.22	3.05
20"	----	1.80	2.75	----	3.78	3.80
24"	----	2.40	2.14	----	3.22	4.26

Note: * Pile Type: H = H-Pile, P = Steel Pile Pile, C = Concrete

For All Pile Types:

Hammer Model LB	180	312 440	520
Cushion Matl	aluminum/micarta		
Cushion Area	48.7	93.0	93.0
Cushion Thick.	1.5	2.5	3.0
WEAP86 Input E=	350	350	350
COR=	.80	.80	.80

Table 2(f). Menck hammers

Hammer Model	MRBS 850 MRBS 1100	1800	3000 3900	4600	5000	8000	8800	12500	500
Pile Size(in)	24-48	30-54	36-72	42-72	42-84	42-72	42-84	48-90	20"*
Cap Weight	11.46	22.50	34.80	59.60	66.10	93.40	97.00	154.30	1.14
Cushion Area	744.0	1350.0	2120.0	3040.0	3040.0	4770.0	4770.0	7920.0	329.0
Cushion Thick.	7.10	7.90	7.90	9.80	9.80	11.80	11.80	13.80	5.90
WEAP86 Input E=	3.5	3.4	3.4	3.4	12.0	3.4	12.0	3.4	3.4
COR=	.75	.75	.75	.75	.75	.75	.75	.75	.75

Note: * 20" Square Concrete
Hammer cushions are Bongossi.

Table 2(g). Mitsubishi hammers

Hammer Model	M14 MH15 MH23 MH25			M33 MH35			M43 MH45		
Pile Type*	H	P	C	H	P	C	H	P	C
Pile Size	Cap Weights								
10"	2.09	2.05	1.96	2.44	2.40	----	----	----	----
12"	2.09	2.05	1.96	2.44	2.40	2.32	3.37	----	3.26
14"	2.09	2.05	2.01	2.44	2.40	2.32	3.37	3.33	3.26
16"	----	2.55	2.47	----	2.90	2.82	----	3.83	3.75
18"	----	2.55	2.62	----	2.90	2.97	----	3.83	3.90
20"	----	2.55	----	----	2.90	3.17	----	3.83	4.11
24"	----	----	----	----	4.20	4.00	----	5.13	4.92

Note: * Pile Type: H = H-Pile, P = Steel Pipe Pile, C = Concrete
Hammer cushions for hammer models M14, MH15, M23, MH25, M33 and MH35 are nylon with a thickness of 2 inches and a WEAP86 Input of E = 175 ksi and COR = 0.92.

Hammer cushions for hammer models M43, MH45, MH72B, and MH80B are micarta with a thickness of 2 inches and a WEAP86 Input of E = 225 ksi and COR = 0.80.

Hammer models MH72B and MH80B with piles of sizes 36" and 48" have a cap weight of 10.1 kips and hammer cushion are of 707 in^2; with 24" pile, the cushion area is also 707 in^2 but the cap weight is 4.92 kips.

Table 2(h). Raymond hammers

For All Pile Types: Hammer cushion are aluminum/micarta with COR = 0.8

Hammer Models	1 15 65C 65CH	0 80C 80CH 2/0	3/0 4/0 5/0	3/0 4/0 5/0	30X 40X 150C	60X	8/0
Cushion Area	86.85	146.92	146.92	235.62	235.62	235.62	235.62
Cushion Thick.	18.	16.5	16.5	23.5	16	19.25	23.25
E, WEAP86 Input	394	394	394	330	383	341	343

Table 2(i). Vulcan hammers

Hammer Model	1 06 50C	65C 505 506		08 010 012 65CA 80C	85C 100C 508 510 512		014 016 140C		
Pile Type*	H	P	C	H	P	C	H	P	C
Pile Size	Cap Weights								
10"	.75	.725	----	1.45	1.38	----	----	----	----
12"	.75	.725	1.03	1.45	1.38	2.62	2.85	1.675	----
14"	.75	.84	1.08	1.45	1.38	2.40	2.85	1.675	----
16"	----	.92	.96	----	1.425	2.22	----	1.675	----
18"	----	1.025	----	----	1.55	2.10	----	1.825	3.975
20"	----	----	----	----	1.85	2.22	----	1.900	3.725
24"	----	----	----	----	1.85	2.55	----	2.200	3.225
30"	----	----	----	----	----	----	----	----	----
Cushion Area	99.40	99.40	99.40	148.49	148.49	148.49	233.71	233.71	233.71
Thickness	7.375	7.375	7.375	8.500	8.500	8.500	7.000	7.000	7.000

Hammer Model	020 030 200C			320 330 520 530		
Pile Type*	H	P	C	H	P	C
Pile Size	Cap Weights					
10"-18"	----	----	----	----	----	----
20"	----	----	5.40	----	----	5.40
24"	----	----	----	----	----	----
30"	----	----	5.175	----	4.00	7.00
Cushion Area	----	----	298.65	----	397.61	397.61
Thickness	----	----	7.00	----	5.00	5.00

Note: * Pile Type: H = H-Pile, P = Steel Pipe Pile, C = Concrete.

For Steel Pipe Piles:

Hammer Model	040 400C 340	060 360	3100	540	560 600C	5100	5150	5150	6300
Max. Pile Length	72'	72'	72'	72'	72'	96'	96'	97-120'	120'
Cap Weight	31.00	32.00	46.00	31.00	32.00	70.00	77.00	110.00	145.00
Cushion Area	500.7	583.2	1032.0	583.2	767.0	1336.4	1608.4	1608.4	3987.1
Cushion Thick.	9.5	6.5	7.5	7.5	7.5	7.5	9.5	9.5	10.5

Table 2(j). Conmaco hammers

Hammer Models	50 550 65 565			80 125E5 110 100E5 115 115E5 125E5			140 640		
Pile Type*	H	P	C	H	P	C	H	P	C
Cushion Type 0 Aluminum/Micarta									
Pile Size				Cap Weights					
10"	1.881	----	2.181	3.277 3.287	----	----	----	----	----
12"	1.881	----	2.176	3.277 3.287	----	3.830	----	----	----
14"	1.881	1.651 2.113	2.308	3.277 3.287	3.999	3.667	4.315 5.385	----	6.375
16"	----	1.651 2.113	2.136	---- 3.287	3.999	3.602	----	----	6.085
18"	----	----	1.993	----	3.999	3.717	----	----	5.580
20"	----	----	----	----	3.999	3.667	----	5.715	----
24"	----	----	----	----	3.999	4.537	----	5.715	7.085
36"	----	----	----	----	----	----	----	10.165 10.165	----
Cushion Type: Nylon or MMPAC									
Pile Size				Cap Weights					
10"	.722	----	1.072	1.375 1.385	----	----	----	----	----
12"	.722	----	1.067	1.375 1.385	----	1.928	----	----	----
14"	.722	.542 1.004	1.199	1.375 1.385	2.097	1.765	2.008 3.078	----	4.068
16"	----	.542 1.004	1.027	1.385	2.097	1.700	----	----	3.778
18"	----	----	.884	----	2.097	1.815	----	3.408	3.273
20"	----	----	----	----	2.097	1.765	----	3.048	----
24"	----	----	----	----	2.097	2.635	----	3.048	4.778
36"	----	----	----	----	----	----	----	7.858	----

Table 2(j). Conmaco hammers (continued).

Cushion Type	Al/Mic			Nylon or MMPAC		
Hammer Models	200 5200 300 5300			200 5200 300 5300		
Pile Type*	H	P	C	H	P	C
Pile Size			Cap Weights			
10"	----	----	----	----	----	----
12"	----	----	----	----	----	----
14"	7.678 10.924	----	----	4.254 7.500	----	----
16"	----	11.603	----	----	8.179	----
18"	----	11.603	10.068	----	8.179	6.644
20"	----	11.603 16.594	10.068	----	8.179 13.170	6.644
24"	----	11.603 16.594	9.884 12.615o	----	8.179 13.170	6.460 9.191o
30"	----	11.603 16.594 13.859 14.644	----	----	8.179 13.170 10.435 11.220	----
36"	----	11.603 16.594 13.859 14.644 14.276 37.342	11.694 16.374c 19.824c	----	---- 13.170 10.435 11.220 10.852 33.900	8.270
42"	----	11.603 16.594 13.859 14.644 14.276 37.342	----	----	8.179 13.170 10.435 11.220 10.852 33.900	----
48"	----	16.594 13.859 14.644 14.276 37.342	----	----	13.170 10.435 11.220 10.852 33.900	----
54"	----	16.594 14.644 14.276	19.824c 18.524c	----	13.170 11.220 10.852 33.900	----
60"	----	37.342	----	----	33.900	----
72"	----	37.342	----	----	33.900	----

Table 2(j). Conmaco hammers (continued).
Cushion Type: Duracushion

Hammer Models	5450			5700 6850		
Pile Type*	H	P	C	H	P	C
Pile Size	Cap Weights					
36"	----	36.655	----	----	57.213	----
42"	----	36.655	----	----	57.213	----
					51.701	
					37.301	
48"	----	36.655	----	----	57.213	----
					51.701	
					37.301	
54"	----	36.655	----	----	57.213	----
					51.701	
					37.301	
60"	----	36.655	----	----	57.213	----
					51.701	
					37.301	
72"	----	36.655	----	----	57.213	----
					51.701	
					37.301	
84"	----	36.655	----	----	57.213	----

Hammer Model Conmaco	50 550 65 565			80 110 115 80E5 100E5 115E5 125E5			140 160		
Cushion Type	1	2or4	3	1	2or4	3	1	2or4	3
Cushion Area	108.43	108.43	----	159.48	159.48	----	247.45	247.45	----
Cushion Thick.	18.50	6.25	---	18.50	8.00	----	18.00	6.00	----

Hammer Model Conmaco	200 5200 300 5300			5450			5700 6850		
Cushion Type	1	2or4	3	1	2or4	3	1	2or4	3
Cushion Area	415.48	415.48	---	----	----	816.83	----	----	1418.63
Cushion Thick	29.00	8.00	---	----	----	9.00	----	----	9.00

Pile Types: H = H-Pile; P = Steel Pipe Pile;
C = Concrete Pile (normally Square, o and c designate octagonal and cylinder concrete, piles respectively.)

Properties of Cushion Types - generally recommended values and Conmaco data = paranthesis.

	WEAP86 INPUT,E	COEFF. OF RESTITUTION
1 = Aluminum/micarta	350 (280)	.80
2 = Nylon MC-904	175 (170)	92 (.84)
3 = Duracush	35 (49)	82 (.69)
4 = MMPAC	366	.88

Cap weight in kips

Table 3. Summary of cushion material property.

The following data was in part provided by the New York Department of Transportion, their contribution is gratefully acknowledged. For WEAP86, however, Modulus of Elasticity values were divided by 2 in order to improve correlation between WEAP86 and dynamic measurements on piles.

HAMMER CUSHION MATERIAL	WEAP 86 Input for MODULUS OF ELASTICITY (KSI)	COEFFICIENT OF RESTITUTION
Asbestos	22.5	.50
Ascon	112.5	.70
Duracush	35	.82
Wire rope	(150)	.80
Force-ten	(150)	.80
Urethane	175	.72
Micarta	225	.80
Conbest	280	.80
Forbon	400	.85
Fosterlon	380	.85
Hamortex	125	.77
MC-904 (Blue Nylon)	175	.92
Aluminum/Micarta	350	.80
Plywood	30	.50
Oak (parallel)	750	.50
Oak (transverse)	60	.50

Table 4. Pile data: (a) steel h-pile pile properties.

(1 inch = 25.4 mm, 1 ksi = 6.89 MPa, 1 lb/ft^3 = 0.157 kN/m^3)

Section	HP14x117	HP14x102	HP14x89	HP12x74	HP12x53	HP10x57	HP10x42	HP 8x36
Area, in^2	34.4	30.0	26.1	21.8	15.5	16.8	12.4	10.6

*Elastic Modulus = 30000 ksi; Wavespeed = 16800 ft/s Specific Wt = 492 lb/ft3

Table 4. Pile data: (b) monotube pile properties areas of top/toe of tapered sections in in^2.

	Top			Toe		
Diam. (in)	12	14	16	18	8	8.5
Gage						
9	5.81	6.75	7.64	---	3.63	3.93
7	6.97	8.14	9.18	10.40	4.40	4.77
5	8.18	9.50	10.80	12.20	5.19	5.61
3	8.96	10.60	12.00	13.60	5.87	6.58

*Elastic Modulus = 30000 ksi; Wavespeed = 16800 ft/s Specific Wt = 492 lb/ft3

Areas of Straight Sections in in^2

	Gage	9	7	5	3
Type	Diam. (in)				
N12	12	5.85	7.02	8.19	9.65
N14	14	7.02	8.48	9.65	11.23
N16	16	7.90	9.36	11.12	12.88
N18	18	----	10.83	12.58	14.34

*Elastic Modulus = 30000 ksi; Wavespeed = 16800 ft/s Specific Wt = 492 lb/ft3

Table 4. Pile data: (c) timber piles.

Note: These are commonly encountered properties for timber piling but great variations must be expected.

Pile Top Diameter	Pile Top Area	Pile Tip Area tip diameter 8 in	Pile Tip Area tip diameter 9 in	Elastic Modulus	Specific Weight	Wave Speed
in	in2	in2	in2	ksi	lb/ft3	ft/sec
10	78.5	50.3	63.6	1,800	60	11,800
12	113.1	50.3	63.6	1,800	60	11,800
14	153.9	50.3	63.6	1,800	60	11,800
16	201.1	50.3	63.6	1,800	60	11,800

Table 4. Pile data: (d) concrete pile properties.

NOTE: Concrete properties may vary depending on quality.

Solid Square Concrete Size in	Solid Square Concrete Area in2	Solid Octagonal Concrete Size in	Solid Octagonal Concrete Area in2
10x10	100	10	83
12x12	144	12	119
14x14	196	14	162
16x16	256	16	212
18x18	324	18	268
20x20	400	20	331
22x22	484	22	401
24x24	576	24	477

Square w/Hollow Core Size in	Square w/Hollow Core Area in2	Octagonal w/Hollow Core Size in	Octagonal w/Hollow Core Area in^2	Corresponding Core Void Diameter in
20x20HC	305	20HC	236	11
22x22HC	351	22HC	268	13
24x24HC	399	24HC	300	15

*For Concrete piles (unless measurements indicate otherwise): Assume Elastic Modulus = 5000 ksi, Wavespeed = 12430 ft/s, Specific Wt = 150 lb/ft3.

Table 4. Pile data: (e) concrete cylinder pile properties
(Raymond piles)

Note: Concrete Properties may vary depending on quality.

Outside Diameter in	Wall Thickness in	Area in2		
36	4.5	4	4	5
36	5.0	487		
42	5.0	5	8	1
48	5.0	6	7	5
54	5.0	7	7	0
54	6.0	905		
60	5.5	942		
66	6.0	1131		
72	6.0	1244		
78	6.5	1460		
84	7.0	1693		
90	7.0	1825		

*Elastic Modulus = 6000 ksi; Wavespeed = 13620 ft/s Specific Wt = 150 lb/ft3

Table 4. Pile data: (f) areas of standard steel pipe piles.

The following areas are based on uniform steel piles.

Outside Diameter (inch)	Wall Thickness (inch)											
	.141	.164	.172	.219	.250	.375	.438	.500	.625	.750	1.00	1.25
8	3.48	4.04	4.23	5.35	----	----	----	----	----	----	----	----
8-5/8	3.76	4.36	4.57	5.78	6.58	9.72	11.3	12.8	----	----	----	----
10	4.37	5.07	5.31	6.73	7.66	----	----	----	----	----	----	----
10-3/4	4.70	5.45	5.72	7.25	8.25	----	14.2	16.1	----	----	----	----
12	5.25	6.10	6.39	8.11	9.23	----	----	----	----	----	----	----
12-3/4	5.59	6.48	6.80	8.62	9.82	14.6	16.9	19.2	----	----	----	----
14	6.14	7.13	7.47	9.48	10.8	16.1	18.7	21.2	----	----	----	----
16	7.02	8.16	8.55	10.9	12.4	18.4	21.4	24.3	----	----	----	----
18	7.91	----	9.63	12.2	13.9	20.8	24.2	27.5	----	----	----	----
20	8.80	----	10.7	13.6	15.5	23.1	26.9	30.6	----	----	----	----
24	----	----	12.9	16.4	18.7	27.8	32.4	36.9	----	----	----	----
30	----	----	----	----	23.4	34.9	40.7	46.3	57.7	68.9	----	----
36	----	----	----	----	28.1	42.0	48.9	55.8	69.5	83.1	110	136
40	----	----	----	----	----	46.7	54.4	62.0	77.3	92.5	123	152
42	----	----	----	----	----	49.0	57.2	65.2	81.2	97.2	129	160
48	----	----	----	----	----	56.1	65.4	74.6	93	111	148	184

Table 5. Recommended soil parameters.

Note: The following recommendations represent an average soil behavior and may require adjustment based on local experience.

Soil Type	Dimension	Damping Skin	Damping Toe
Non-Cohesive	s/ft	0.05	0.15
	s/m	0.16	0.50
Cohesive	s/ft	0.20	0.15
	s/m	0.65	0.50

	Dimension	Quakes Skin	Quakes Toe
For All Soil Types			
	in	0.10	d/120*
	mm	2.54	d/120*

*d is the effective toe diameter of displacement piles. For open cross sections the full pile width or diameter is only applicable if the soil forms a plug in the pile. For d<12(in) or 305(mm) a quake, q, less than 0.1(in or 25.4(mm) may result. However, q should not be chosen less than 0.05(in) or 12.7mm.

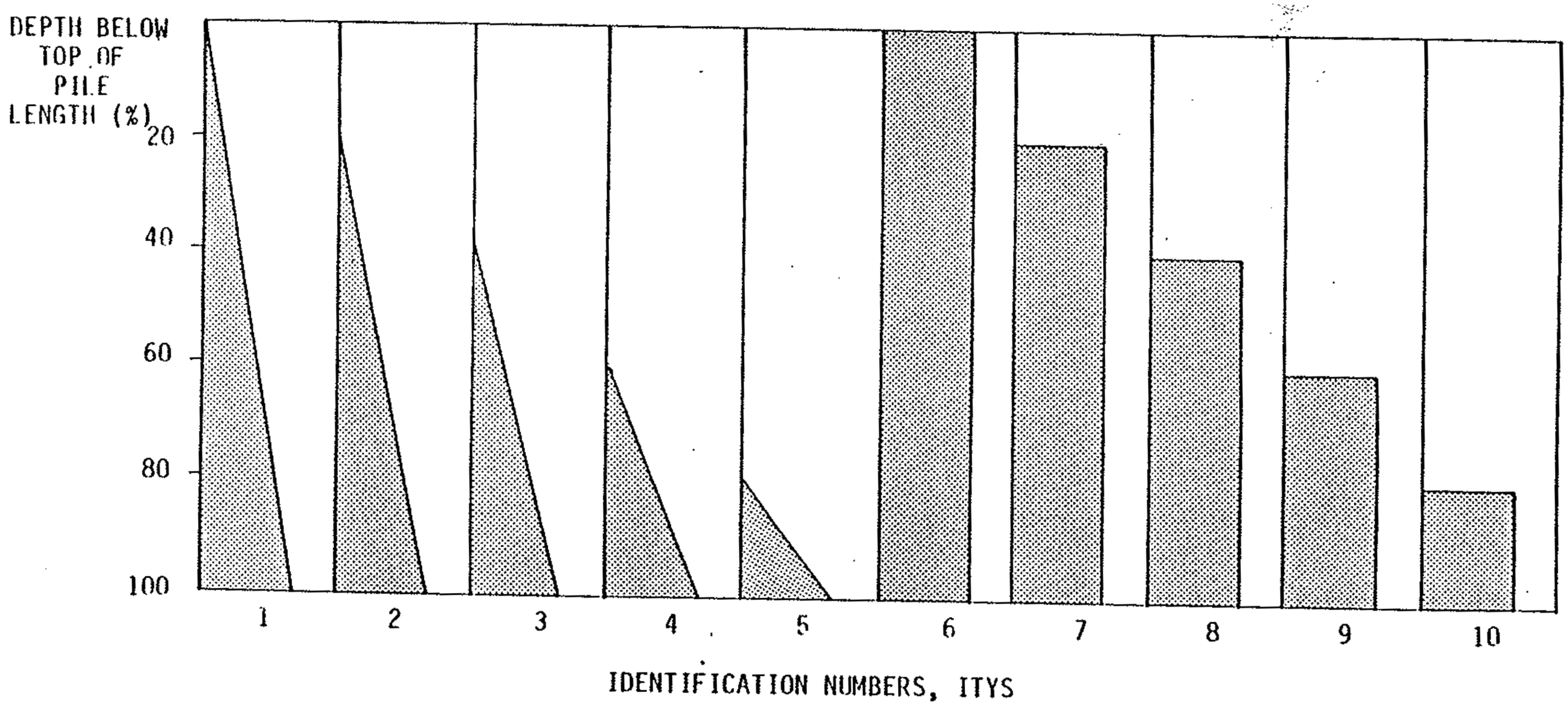
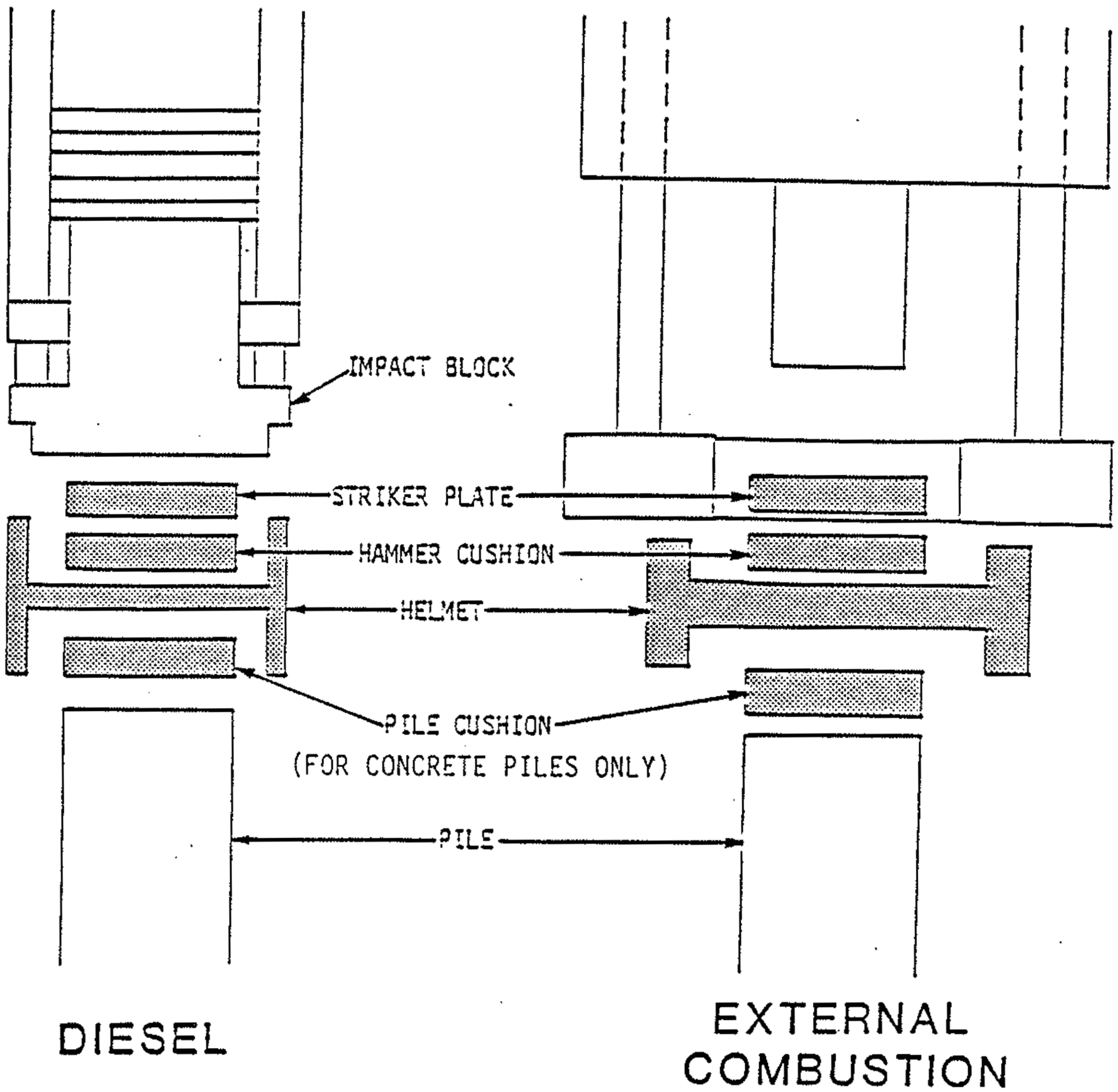


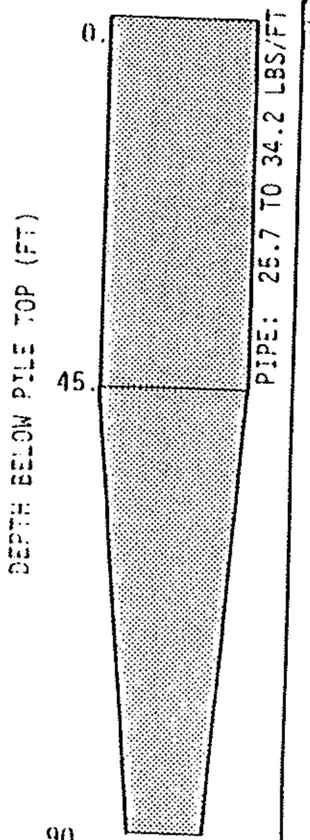
Figure 1. Preprogrammed resistance distributions.



NOTE: THE HELMET WEIGHT (CARD NO. 3.000) INCLUDES THE STRIKER PLATE, HAMMER CUSHION, HELMET AND PILE CUSHION FOR CONCRETE PILES.

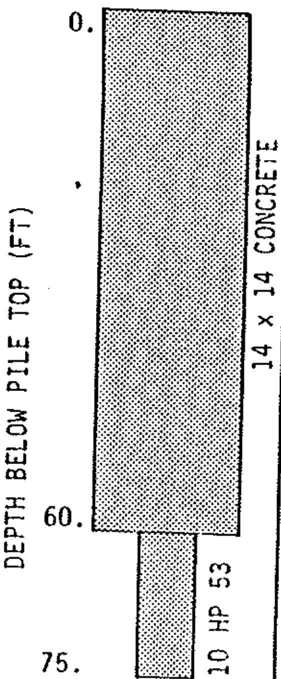
Figure 2. Definition of "cap" terminology.

(A)



	DATA			
	XTP/XP	AP	EP	WP
PILE TOP	90.0	10.0	30000.0	492.0
DEPTH NO.				
1	45.0	10.0		
2	90.0	7.51		

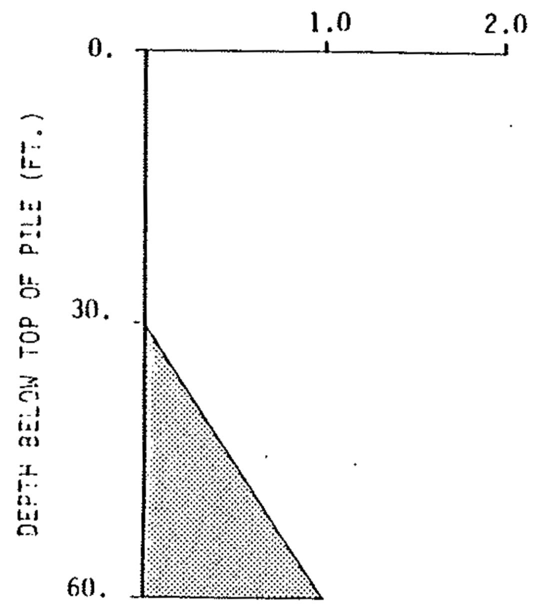
(B)



	DATA			
	XPT/XP	AP	EP	WP
PILE TOP	75.0	196.0	5000.0	150.0
DEPTH NO.				
1	60.0	196.0		
2	60.0	15.5	30000.0	492.0
3	75.0	15.5		

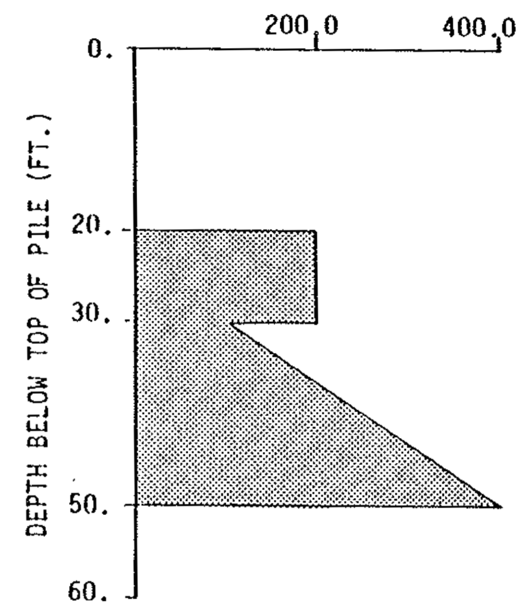
Figure 3. Example of nonuniform pile profile input.

(A)



DATA	
XP	DIS
30.0	0.0
60.0	1.0

(B)



DATA	
XP	DIS
20.0	0.0
20.0	200.0
30.0	200.0
30.0	100.0
50.0	400.0
50.0	0.0
60.0	0.0

Figure 4. Example of nonstandard resistance distribution input.

2. THE BASIC PROGRAM FLOW

This chapter provides background information on WEAP86 as an introduction to the detailed program description of the following chapters. A more complete presentation is given in Volume I.

2.1 Input

WEAP86 was programmed such that known parameters such as pile length, skin friction distribution, etc., can be input directly. Since hammer specification requires the input of a large amount of information, data has been prepared and stored on a file for most commonly encountered hammer types. Consequently, for most hammers, only an identifier number must be specified.

The program converts input data into standard wave equation parameters. Because of this automated data preparation, many quantities that appear in other programs are not found in WEAP86. The intention of the WEAP programmers was to make a standard computer run simple while also providing for unusual cases. For these reasons input data may be entered on either one of two forms: Short and Complete Input. The Short Input Form suffices for most standard analyses.

WEAP86 reads one data set for a complete analysis and then checks for the existence of more data. If more cards or lines are encountered, then a new initialization and data input is started. Thus, a few blank cards (lines) added at the end of a run may be interpreted as a new data set and cause an error message.

2.1.1 Input of Soil Damping

Soil damping is, in most cases, specified by a value for skin and toe and are usually referred to as "j" values. Since the soil damping force in Smith's approach is equal to the product of j, the segment velocity and the static soil resistance force, damping is automatically distributed like the static skin resistance. In fact, even though a damping parameter may have been specified, the toe damping force would be zero if skin friction were 100 percent of the total resistance.

WEAP86, also, allows the use of damping parameters which are independent of the static soil resistance. This type of damping is referred to as viscous or Case damping. The viscous damping force is calculated as the damping parameter times the segment velocity (the damping constant, therefore, has k/ft/s or kN/m/s.

In order to make the input comparable for the different damping options, skin and toe damping are also specified for viscous damping. The skin damping parameter for viscous damping is the sum of all segment-skin-damping values. This sum is apportioned by the program according to the skin friction distribution specified (and would be uniformly distributed for zero skin friction).

To further facilitate the input of the viscous damping parameters, nondimensionalized skin and toe damping constants are used (Case damping). Nondimensionalization is accomplished by division by the pile's impedance: EA/c = Young's Modulus times cross-sectional areas divided by the wave speed. This impedance has the dimensions of a viscous damping parameter. Thus, the input values for Case (or viscous) damping are truly dimensionless.

The steps taken by the program as far as damping is concerned are as follows:

- Smith
  1. Input - Set each segment's skin parameter to the input skin damping parameter. Set toe segment's damping parameter to the corresponding input constant.
  2. Analysis - Equate damping force at a segment to damping parameter times static resistance force (times the ultimate resistance for type 2 damping as described in Volume I) times velocity, all for the same segment.

- Viscous (Case)
  1. Input - Distribute input skin damping parameter to all segments according to their static skin friction (nondimensional). Multiply each damping parameter, both skin and toe, by the EA/c value of the corresponding segment yielding the viscous damping factor.
  2. Analysis - Calculate the damping force by multiplying the viscous damping parameter times the velocity.

In this context it should be mentioned that the equivalent viscous damping parameters of Smith's approach can become very large (especially at the toe). Since the corresponding viscous parameter is the product of Smith's constant and the static resistance, it can vary from analysis to analysis, with the static resistance force. For example: 80 percent toe resistance, j_{toe} = 0.15 ft (.50 s/m), RULT = 100, 200, 300, 400 kips (450, ... kN). In the first analysis the corresponding viscous damping constant is 2 x 50 x 0.8 x 0.15 = 12 kips/ft/s (179 kN/m/s). In the last analysis the constant is 48 kips/ft/s (716 kN/m/s), corresponding to a Case damping factor greater than 4 for a 12-inch steel pile with .178-inch wall, EA/c = 11.8 kips/ft/s (38.9 m/s).

WEAP86 reduces the analysis time increment when the damping constant at any one segment becomes large relative to the pile's impedance (EA/c). Thus, a large Smith damping value at an element which also has a high static resistance force may produce a long, and therefore costly, computer run.

Damping parameters affect the blow count result to a considerable degree. Therefore, it is advisable to use the rather well-documented Smith values whenever doubt exists as to the proper Case damping values.

2.1.2 Quake Input

In general, quakes are specified for skin and toe separately. The program user should be aware, however, that variable quake values must be used with care.

If a residual force analysis is not used, the analysis starts, for each strength level, with the assumption of zero initial soil spring forces. Some time after the hammer impact, the pile reaches a maximum penetration and starts to rebound. A zero soil force is obtained when the pile rebound equals the quake. Of course, if the various quakes have different magnitudes, a zero final spring force is not possible in all springs and a basic assumption of the analysis is violated.

In addition to the above problem, the blow count is computed as the reciprocal of the maximum tip displacement minus an average quake if a residual force analysis is not used. If substantial pile deformations result from residual forces then this measure of blow count can be substantially in error. When the user has questions regarding the importance of the above two considerations, a residual force analysis should be tried and its results compared with the regular analyses.

Usually a 0.1-inch quake is a reasonable value; this value has been used extensively with good correlation. For some soils it has been shown, with measurements, that the quake can be much larger. Also, for displacement piles with more than 12 inches width, the quake is usually larger than the commonly assumed 0.1 inches. Large quakes can substantially alter the results. Unfortunately, large quakes cannot be predicted in advance from a mere inspection of subsurface investigation data. Instead, it is computed by analysis of dynamic measurements taken during driving or restriking.

When piles are being driven into rock it may be necessary to reduce the quake to values less than 0.1 inch so an underprediction of capacity will not result. Also, for piles with small toe diameters (less than 12 inches), or for tapered piles, a reduced quake may be advisable.

2.1.3 Hammer Details

Hammer parameters are supplied in the hammer data file. This file may be updated at any time by the user. Descriptions of hammer parameters are given both in the <u>Background</u> report and in the <u>Manual</u>. This supplied data reflects the best <u>knowledge on</u> hammer performance <u>available</u> to the program authors. Actual field performance of a hammer will depend on a variety of operational factors such as its state of maintenance or the fuel or power supply. Hammer design parameters are also frequently modified. It is therefore imperative that the user insures agreement between predicted and actual hammer performance by field inspection. The following observations should be considered during field inspection (see also Volume I and its references).

(a) Diesel Hammers

For open end and closed end diesels, stroke and bounce chamber pressure, respectively, give a good indication of actual hammer performance. Also, blow rate (as printed by the program) may be used for construction control, and an automatic stroke indicator (Saximeter™) is a good tool for the purpose of measuring blow rate in the field. However, a hammer in a very poor state of maintenance may have friction losses of such magnitude that blow rate is not a sufficient indicator.

A diesel hammer will perform particularly poorly when it overheats during hard driving and then preignites. Preignition produces large strokes and low transferred energies and therefore high blow counts. This condition can be modeled by the program using a negative combustion delay for liquid fuel injection (see Section 3.4) on a reduced combustion start volume for atomized injection. However, preignition usually is an unexpected situation and cannot be detected in the field without electronic measurements.

A number of hammers, for example, the DELMAG and the FEC machines, have stepwise adjustable fuel pumps. The IFUEL (see section 3.2) values (between 1 and 5) usually cover the range between maximum and minimum fuel injection. Measurement results are, however, limited, and predictions using reduced fuel amounts must be backed up by field control, particularly where pile stress limitations are necessary. Another approach is to run constant stroke analyses and either require stroke limitations in the field or select the curve corresponding to the actual stroke for stress and bearing capacity predictions.

b) External Combustion Hammers (ECH)

These units are not as complicated as diesel hammers, but the correct choice of a proper efficiency (i.e., impact velocity) is not a simple task. For example, a thick cushion may produce a reduced stroke while a thin cushion may allow early air/steam injection and therefore, self-cushioning.

The WEAP86 hammer data file provides for average hammer efficiencies, they are smaller than would be expected for well maintained or new hammers.

2.1.4 Battered Pile Driving

No provision was made for the analysis of battered pile driving. As far as open end diesel hammers are concerned, only increased ram friction must be considered. For most other hammer types, the geometric stroke reduction must be accounted for. Conveniently, all of these losses are lumped into a reduced efficiency.

2.1.5 Driving System Parameters

Elements between the hammer and the pile top are part of the driving system and include (see also Figure 2):

- the hammer cushion, a light and flexible material.
- the helmet (containing the hammer cushion and often a striker plate) transferring the hammer forces to the pile top. The helmet is usually heavy and stiff.
- the pile cushion in the case of concrete piles.

The behavior of cushion materials is described by their elastic moduli and coefficients of restitution. The helmet is defined simply by its weight. Of course, striker plate or other accessory weights should be contained in the value given for the weight of the helmet. Note that in WEAP86, a helmet element must always exist between hammer and pile. If the hammer strikes the pile directly then a piece of pile should be used to substitute as a helmet in the wave equation model.

Unlike WEAP, the stiffnesses of the cushions and their coefficients of restitution are not linked in WEAP86. However, a nonlinear force deformation relation is still used to describe these "springs" (see Volume I). One of the reasons is a rounding of the force deformation relation (see Volume I). A correct input is one half of the secant modulus at the maximum working stress. Tables 2 and 3 contain these reduced moduli.

2.2 Analysis Cycle

2.2.1 Open End Diesel Hammers

Open end diesel hammers are usually started by assuming a minimal stroke (if the user did not specify another value). A dynamic analysis is then performed with the first ultimate capacity value, and the rebound stroke is determined. If the rebound stroke is different from the assumed value by more than four percent, then a new analysis is performed and a check is made on the convergence of the stroke. Up to four iterations are usually allowed except for cases where the stroke converges in an alternate mode. Six trials are then permitted. After the last stroke is analyzed, extreme values of forces, velocities, stresses, etc. are printed together with other optional output.

A new ultimate resistance, R_{ut}, is then analyzed starting with a new stroke. This new stroke is based on previous results assuming an increase in resistance. Of course, iterations are again performed.

This process is continued until all ultimate resistance values are analyzed or until no permanent set occurs. Then, a summary of all results is printed and the program is ready to analyze a completely new data set.

An exception to this "standard run" is the "constant stroke" analysis (IOSTR = -1). This option causes the change of combustion pressure until the return stroke equals the input stroke. The use of this option is recommended for hammers that have a variable fuel pump and/or for cases where reduced strokes are to be used. The program does not check on any fuel energy limits when the option is used. Thus, strokes may be accidently specified which are too large and cannot possibly be obtained in the field (e.g., when the soil resistance is low).

2.2.2 Closed End Diesel Hammers

This hammer is started like an open end diesel. Depending on the soil resistance, the stroke will, again, either be lower or higher and fuel reductions may be necessary to avoid uplift. Again, the program iterates until the proper stroke or fuel setting is found. Fuel setting or stroke is again used as a starting point for further r_{ut} values.

The "constant stroke analysis" can also be performed for closed end hammers. To facilitate the input of a certain energy level at which to perform the iterations, WEAP86 accepts the equivalent stroke as an input.

2.2.3 External Combustion Hammers

This hammer type is simply analyzed for the stroke and efficiency specified. In contrast to other programs, the motion and impact of the assembly are also modeled. This feature does not influence the overall program flow and no further discussion seems necessary.

2.3 Analysis Details (Diesel Hammers Only)

For a better understanding of the program output, a few details of the diesel hammer analysis should be known. The analysis is divided into three parts:

- Precompression (port closure to impact).
- Impact and/or combustion plus initial expansion.
- Ram rebound.

Whenever the Manual discusses "the analysis", it is usually referring to the time period at and after impact which starts approximately two milliseconds before either impact or ignition and lasts until it is ascertained that the permanent set of the pile is achieved (see also Volume I). Output values are stored for final printing and extrema are determined at time intervals which depend on the total expected analysis time (see the next section.)

2.4 Output

Several output options control the amount and type of printed results. Usually output is made for each R_{ut} analysis and summarized after the final ultimate resistance value. Variables such as forces as a function of time have to be stored temporarily since it is not known if the current analysis is for the correct stroke. To keep the program size reasonable, the storage area is restricted to at most two hundred time steps. To cover a sufficiently long time period, the stored values are usually not from consecutive time steps.

Short output options eliminate the listing of variables vs. time (IOUT = 0) and all output except for a final summary (IOUT = -100). It should be observed that short options do not provide the engineer with much insight into the actual wave propagation process and unusual behavior of hammer, pile, or soil may not be detected. Thus, short output should be an exception rather than the rule.

3. INPUT DESCRIPTION AND DATA FORMS

3.1 Definitions

Depending on the computer and its peripheral equipment, the WEAP86 input may be read from cards or from a sequentially formatted tape or disk file. The following description references cards, a traditional term, when lines or records may also be appropriate. Input forms included in Appendix A indicate the format in which the data must be submitted. Note that for each quantity a field of a certain length is provided.

The input format may be simplified by using the so-called free input format which allows the user to enter the individual quantities one behind the other and without regard to the field length. All numbers must be separated by commas; zeroes may be replaced by a space or two consecutive commas. This free input format is particularly useful for terminal input.

For microcomputers which allow the user to interact with computer (question and answer type input) a separate program was prepared. This interactive input program was called W86IN and is discussed in Volume IV.

The data may be prepared on either a SHORT INPUT or on a COMPLETE INPUT FORM. In most instances the shorter form is sufficient. The longer one is needed when hammer data, individual pile segment properties, pile splice properties, or individual soil segment properties are to be submitted. Such an effort is usually only required for a "research" type activity. Common construction type problems can be solved with file stored hammer data, the automatic pile segment generation, and with global skin/toe type soil parameters. In summary:

SHORT INPUT FORM: for all standard cases, including nonuniform piles and general skin friction distributions.

COMPLETE INPUT FORM: for conditional input (input that is required depending on the value of certain analysis options) such as pile segment stiffnesses, weights, lengths; hammer data input; individual segment soil quakes, damping and resistances; splice input; and choice of output segments.

The input quantities fall under one of the following categories.

1. Title.
2. Options and Selections.
3. Cap Information.
4. Cushion Information.
5. Pile Information.
6. Hammer Information.
7. Hammer Override Options.
8. Soil Information.
9. Ultimate Capacities.

The following terminology will be used:

Card No. as already mentioned, cards are individual lines of input values. each card has a number of the type x.yyy. the yyy portion is called the extension. A Card No. with the extension .000 MUST BE INPUT and only one card may be input.

For cards with a nonzero extension, i.e., .101, more than one card may be needed. The maximum number of cards that may be input is discussed in the input description. It usually depends on the number of pile segments. The maximum number of cards may be shown as follows:

2.101 - 2.113

In this example, up to 13 cards may be input.

Also note that Cards with a nonzero extension No. are conditional.

Some of the input Cards are conditional. Conditions for input are given on the input forms immediately preceeding the card number. If the condition is true, input must be made. If the condition is false, input must NOT be made, which means that the complete Card should be omitted.

Format Line Format. Each Card has its own line format given immediately following the CARD number in the input description. Examples:

40A1	-	40 Alphanumeric characters.
20I4	-	20 Integers with a field length of 4 each.
8R10.0	-	8 Real numbers with a field of 10 characters each.
2A8,3I4	-	2 Alphanumeric strings with a length of 8 each and then 3 Integers with a length of 4 each.

where

A - Alphanumeric characters consist of letters, numbers, symbols, or blank spaces.

R - Real values may include a decimal point. The commonly used F10.0 allows for integer input (whole numbers without a period) if the number is right-justified within its field of ten. Blank spaces are interpretated as zeroes. In the case of F10.0, a left justified 1 would be interpreted as 1000000000. However, a 1. anywhere in the field would be a 1.

I - Integers (whole numbers) which MUST NOT include a decimal point and should be right-justified in their respective field. Again, blanks are interpreted as zeroes. Thus, a 1 in the second space of an I4 format would be interpreted as 100.

Input Name — Variable name which appears on the Input Forms.

Internal Name — The symbolic variable name used in the FORTRAN program.

Default — A value assigned by the program if not user specified or if a zero was given.

Description — The translation of the meaning of a variable into normal terms.

[] — The WEAP86 program works with a maximum number of 98 segments; for piles longer than 500 ft (165 m), a special program with a large number of segments may be needed. Bracketed quantities in the input description refer to such a program.

Dimensions — are given both in English and SI units; however, WEAP86 will not work with SI dimensions.

R_{ut} — Total Ultimate Resistance (sum of all skin friction and end bearing resistance).

ECH — External Combustion Hammer, i.e., air/steam/hydraulic/drop hammer.

3.2 Overview Of Required and Conditional Input Cards

The following is a summary of the required and conditional input.

Card	UnCon*	Con**	Condition	Description
1.000	X			Title
2.000	X			Options
2.101		X	IPEL=2	Pile Segment Stiffnesses
2.201		X	IPEL=2	Pile Segment Weights
2.301		X	IPEL=1, 2	Relative Segment Lengths
3.000	X			Helmet and Hammer Cushion
4.000	X			Pile Cushion
5.000	X			Pile Top Information
5.101		X	NCROSS=1	Nonuniform Pile Information
6.101		X	IHAMR=0	Hammer Information
6.201		X	IHAMR=0	Hammer: Ram
6.301		X	IHAMR=0, ITYPH= 1, 2	Diesel: Impact block
6.401		X	IHAMR=0, ITYPH= 1, 2	Diesel: Stroke, Chamber
6.501		X	IHAMR=0, ITYPH= 1, 2	Diesel: Pressures
6.601		X	IHAMR=0, ITYPH= 2	CE Diesel Bounce Chamber
6.701		X	IHAMR=0, ITYPH= 3	ECH Hammer: Assembly
6.801		X	IHAMR=0, ITYPH= 3, MA=3	ECH Hammer: Assembly
7.000	X			Hammer Override Values
8.000	X			Soil Skin/Toe Information
8.101		X	ITYS = -2	Individual Quakes
8.201		X	ITYS = -1, -2	Individual Damping
8.301		X	ITYS = -2	Individual Resistance Values
8.401		X	ITYS = 0, -1	Resistance Distribution
8.501		X	ISPL = 1, 2, 3, ...	First Splice Input
8.502		X	ISPL = 2, 3, ...	Second Splice Input
8.503		X	ISPL = 3, ...	Third Splice Input
.....				
9.000	X			First 8 Ultimate Capacities
10.000	X			Last 2 Ultimate Capacities
10.101		X	IJJ=1	Output Pile Segment Numbers

* UnCon - Unconditional input--required.
** Con - Conditional input - input only required if condition is met.

3.3 Description of Input Variables

CARD 1.000 (FORMAT: 40A1)

Input Name	Internal Name		Description
TITLE	TITLE		PROBLEM TITLE
			Alphanumeric string identifying the current problem.

CARD 2.000 (FORMAT: 18I4)

Input Name	Internal Name		Description
IOUT	IOUT		OUTPUT LEVEL OPTION
		= -100	Mininum output with small model and final summary table only.
		= 0	Reduced output consisting of hammer and pile model, extreme values for each r_{ut} plus a summary. This is a very popular option as it provides for all necessary information without causing undue time or paper consumption. This option is recommended for beginners.
		= 1	In addition to the output of the 0 option, two forces in the hammer and as many as 13 in the pile are printed as a function of time for each r_{ut}.
		= 2	As for 1 but with velocities instead of forces.
		= 3	As for 1 but with stresses instead of forces.
		= 4	As for 1 but with accelerations instead of forces.
		= 5	As for 1 but with displacements instead of forces.
		= 6	As for 1 but with selected properties such as combustion pressure, sum of resistance forces, and force, velocity and displacement being printed at three different pile locations.

Input Name	Internal Name		Description
IOUT	IOUT		OUTPUT LEVEL OPTION - continued
		= -1...-6	Identical to the corresponding positive options but with debug output added such as forces, velocities, displacements, resistance forces, ... for all pile and hammer segments at 1 ms time intervals. for diesels and rsa, output will be produced for each trial analysis. This type of output is extremely time consuming and, for that reason, not recommended as a routine option.
IJJ	IJJ		OUTPUT SEGMENT SELECTION Explanation: Assume you want a printed table of forces as a function of time around a certain point along the pile. However, only 13 force values may be printed because of printer limitations. For more than 13 pile segments, some force values have to be omitted from the table. In general, an automatic selection of output segments with equidistant spacing is adequate. But an individual selection may be made later in the data input, if the IJJ is set to 1.
		= 0	Output segment numbers are automatically determined. Recommended option.
		= 1	Output segment numbers must be entered on Card No. 9.301 - Requires Complete Input Form.
IHAMR	IHAMR		HAMMER IDENTIFICATION NUMBER.
		= 0	Hammer information must be entered on Cards 6.101 to 6.801. Requires Complete Input Form.
		> 0	Hammer number corresponding to hammer data file location (Table 1). Hammer data will be read from the corresponding file location and used in the current analysis.

Input Name	Internal Name		Description
IOSTR	IOSTR		STROKE OPTION - for diesel hammers only Explanation: For any diesel hammer the stroke is a function of pile size and soil resistance. If the pressures developing during combustion are accurately known, then WEAP86 will compute a reasonably accurate stroke. Sometimes, however, the stroke is known with greater accuracy than the pressure. It is then desirable that WEAP86 computes the pressure for a given stroke. In either case it is necessary that the downstroke equal the upstroke of the hammer. This is the condition for stroke or pressure convergence. However, in the field, the downstroke may actually be different from the upstroke, e.g., when the soil resistance suddenly changes. In this case the analysis may be done without the convergence of stroke and/or pressure.
		= 0	Iteration on stroke with fixed maximum combustion pressure. The starting or first trial stroke and the combustion pressure may be program determined or user selected on Card 7.000.
		= 1	No iteration on either stroke or pressure. A single analysis with input or default stroke is made for each ultimate capacity value. Both stroke and/or pressure may be input or program selected.
		=-1	Iteration on combustion pressure with fixed stroke. The first trial pressure value may be from file or user's hammer data. The stroke may be program selected or user specified on Card 7.000

Input Name	Internal Name		Description
IFUEL	IFUEL		HAMMER SETTING - for diesel hammers only
			Explanation: A number of diesel hammers have several stepwise adjustable fuel pumps which allow for the injection of measured amounts of fuel into the combustion chamber. Depending on the hammer fuel setting, more or less combustion pressure, and therefore, more or less stroke will develop. For those hammers with more than one pump setting, the WEAP86 hammer data file contains more than one p_{max} value. The first pressure valve (P1) is always the highest. The second one is usually 10 percent lower. A choice of at most 5 values exists. The last one contained in the file, should correspond to the pump setting with the lowest energy output. For hammers with more than 5 settings, it should be assumed that the file contains values for pump settings in constant intervals.
		= 0	Analysis with the first (P1) and highest pressure value of the data file. Recommended for beginners.
		= 1	Identical to = 0.
		= 2 to 5	The analysis uses the 2nd through 5th pressure value of the data file (P2 through P5). Note that this is only meaningful for hammers with stepwise adjustable fuel pumps. If there is no equivalent pressure value contained in the file, then the next higher available value will automatically be used by WEAP86.

Input Name	Internal Name	Description
IPEL	IPEL	PILE SEGMENT OPTION

Explanation: WEAP86 usually generates pile segment stiffnesses and masses from the user supplied "pile profile". The pile profile details the variation of cross sectional area, A_p, elastic modulus, E_p, and specific weight, w_p, (mass) vs. depth. For uniform piles all segment stiffnesses and masses are usually equal. However, WEAP86 offers the option whereby the individual segments can be made of different length. This option may be useful when a pile has a very large and sudden change of cross section and when the user wants to make his segment boundaries match the points of cross sectional change, or if he wants to create a model which cannot be directly calculated from A_p, E_p and w_p.

= 0 Automatic determination of pile segment stiffnesses and weights. All segments will be of equal length. This is the recommended option under most circumstances.

= 1 Automatic determination of pile segment weights and stiffnesses but with relative segment lengths specified by the user (See Cards 2.301 ...). For this option "N", the number of segments, must be specified by the user (see below).

= 2 Segment stiffnesses (Cards 2.101, ...) and weights (Cards 2.201, ...) are specified along with relative segment lengths (Cards 2.301, ...) by the user. Again N (see below) must be given.

Input Name	Internal Name		Description
N	N		NUMBER OF PILE SEGMENTS (maximum 98)
			Explanation: The proper choice of the number of pile segments will always be a compromise between computational effort and accuracy. In general, 5-ft (1.65 m) segments give reasonably accurate results, however, for very hard driving systems (e.g., uncushioned) with sharply rising forces, the 5-ft (1.65 m) segment length may be too long to represent the quickly changing stress waves, and a decay of the waves may be observed in the results as they travel along piles of great length.
			In some instances the user may want to check try whether shorter segments (a greater N) would appreciably change his results. Note that shorter segments require shorter time increments. The computational time may therefore, increase by a factor of 4 if N is doubled. Moreover, the choice of very small segments may increase the computational effort to a point at which round-off errors have a major effect. It is, therefore, believed that segments should not be chosen shorter than 2 ft (.6 m).
			Note that the user MUST specify N if he or she intends to enter either pile segment lengths or properties with the IPEL > 0 option on Cards 2.101, ..., 2.201, ..., 2.301, ...
		= 0, 1	Automatic determination based on an element length of approximately 5 ft (1.65 m). This is the <u>recommended option.</u>
		> 1	Actual number of segments.

Input Name	Internal Name		Description
ISPL	ISPL		SLACK/SPLICE OPTION
			Explanation: Some piles are spliced with devices that allow for some slippage during extension. The amount of tensionless slippage is called a "slack". A crack in a regularly reinforced pile also has a slack. During compression of a splice, neighboring interfaces behave probably similar to the pile top, impact block and other interfaces in the driving system. A pile portion with slacks therefore should not be modeled with the linear springs of the regular pile model. Further details on slacks and splices are given in Volume I.
		= 0	No slacks/splices need to be modeled in pile.
		> 0	The number of slacks/splices to be modeled in pile. Since the slack/splice is modeled in a segment, splices occurring within a distance less than a segment length may need to be modeled as a single slack/splice. For each splice a card with splice/slack data must be given in 8.501, 8.502, ...
NCROSS	NCROSS		OPTION FOR nonuniform PILES
		= 0	Uniform pile. Pile top information given on Card 5.000 serves to describe properties of total pile.
		= 1	Nonuniform pile. The pile top information on Card 5.000 and additional pile information on Card 5.101, ... describes the nonuniform pile. Thus, the NCROSS=1 option requires the specification of the "pile profile".

Input Name	Internal Name		Description
IBEDAM	IBEDAM		PILE DAMPING
			Explanation: There is a difference between the static and dynamic behavior of most materials. For the pile material, WEAP86 models this different behavior by dashpots inserted between masses and in parallel with the springs. These dashpots transfer some of the dynamic load; they absorb more energy when the pile is suddenly loaded. The influence of pile damping is small in steel, but probably more significant in concrete and timber. Accurate data is not available. Where long piles are analyzed (longer than 330 ft or 100 m), comparison analyses with different IBEDAM values may be made to check on the influence of pile damping.
			Pile damping is computed as 0.02 x IBEDAM x EA/c, with EA/c being the pile impedance at pile midlength (the pile impedance is the product of cross sectional area, pile elastic modulus divided by the wave speed in the pile). It is the same value for all segments, even in nonuniform piles. Since there is one dashpot on top of each pile segment, the number of dashpots increases with the number of segments. On the other hand, the intersegmental damping force is a function of the relative velocity of two neighboring segments, which is smaller for a smaller segment length. Thus, in general, the analysis results will not be strongly affected by IBEDAM if the number of segments changes.
		< 0	Pile damping is set to zero.
		= 0	The default of IBEDAM=1 is used, this is the recommended input for steel piles.
		= 1	Like 0
		= 3	recommended value for concrete piles.
		= 5	recommended value for timber piles.
			Other values may be used, however, in general it is recommended to keep the IBEDAM value small, particularly for long piles (see Example 10).

Input Name	Internal Name		Description
IPERCS	IPERCS		PERCENTAGE OF SKIN FRICTION

Explanation: The percentage of skin friction is a major input for the representation of soil resistance. Standard wave equation practice calls for the assignment of a fixed percentage of the total R_{ut} to the skin friction and the remainder to end bearing. Thus if the R_{ut} values to be analyzed are 100, 200, 300 kips (kN) and if IPERCS is 20, then the corresponding skin friction values are 20, 40, and 60 kips (kN). WEAP86 offers two alternatives, (a) the constant friction and (b) the constant end bearing analysis. In (a) the skin friction would be 20, 20 and 20 kips, in (b) 20, 120 and 220 kips (kN).

Thus, where either (a) or (b) are used, the first R_{ut} determines the amount of either skin friction or end bearing to be used throughout all later analyses.

The reason for these two options is the need to analyze situations where the one type of resistance, say the friction in a clay, is well known and the other type, say the end bearing in sand, is only approximately known. Thus, the analyses with various R_{ut} values are performed with the well known resistance fixed and the other one variable.

0	It is not recommended to use a zero skin friction; the lowest value should be 1 percent.
1 .. 100	The actual and conventionally variable skin friction in percent of the R_{ut} for each analysis.
-1 ..-100	The negative value of the first skin friction percentage for a constant friction analysis. Thus, -20 will produce a skin friction of 20 percent of the first R_{ut} for all analyses.
101 .. 200	The skin friction percentage of the first R_{ut} analysis increased by 100. Thus a 120 will produce a skin friction of 20 percent of the first R_{ut}. For all later analyses the skin friction increases by the difference between a later and the first R_{ut}, leaving the end bearing constant.

Input Name	Internal Name		Description
ISMITH	ISMITH		SOIL DAMPING OPTION

Explanation: In most other wave equation programs, skin damping is computed according to Smith as $R_d = R_s (j_s) v$, where R_s is the static resistance at a certain time, j_s is the Smith damping factor and v is the pile velocity. WEAP-86 offers also the viscous Smith damping: $R_d = R_u (j_s) v$ with R_u being the ultimate static resistance. Since $R_u (j_s)$ is constant this approach yields viscous damping. The third approach is the Case damping where $R_d = j_c (EA/c) v$, with EA/c being the pile impedance. The first option is the most commonly used one, the second one leads to comparable results, for the third, experience is needed to find the proper damping factor.

The ISMITH option determines the interpretation of the soil damping factors specified by the user on Cards 8.000 or 8.201, ... However, since the distribution of individual Case Damping factors is difficult, it is not recommended to use Case damping when entering individual damping parameters (ITYS < 0).

= 0, 1 — Standard Smith damping. This is the recommended approach. Damping parameters of the Smith type have dimension s/ft (s/m).

= -1 — Case damping. Damping parameters are of the viscous type but nondimensionalized by division by EA/c.

= 2 — Smith damping paramaters, but instead of multiplying the damping parameter with the static resistance at a certain time, it is multiplied by the correponding ultimate capacity value.

Input Name	Internal Name		Description
ITYS	ITYS		SKIN FRICTION DISTRIBUTION
			Explanation: After the percentage of skin friction and, therefore, the total skin friction has been determined for a R_{ut} analysis, this skin friction must be distributed in a reasonably realistic manner along the embedded pile portion.
			Often a triangular or a rectangular distribution is sufficiently accurate. For this reason WEAP86 provides for 10 "canned" distributions which are schematically shown in Figure 1. Alternatively, the user may want to input a more complex distribution, by specifying the relative frictional intensity as a function of pile length.
		= 0	Input of detailed resistance distribution to be entered in Cards 8.401, ...
		= 1	Triangular distribution over 100 percent of pile.
		= 2	Triangular distribution over the lowest 80 percent of pile.
		= 3, 4, 5	Triangular distribution over the lowest 60, 40, 20 percent of pile, respectively.
		= 6	Rectangular distribution over 100 percent of pile
		= 7	Rectangular distribution over the lowest 80 percent of pile.
		= 8, 9,10	Rectangular distribution over the lowest 60, 40, 20 percent of pile, respectively.
		= -1	As in = 0 but also with the input of all damping parameters for the embedded pile segments, individually on Cards 8.201, ...
		= -2	No resistance distribution but the individual quake, damping and ultimate resistance values must be input on Cards 8.101, ..., 8.201, ... and 8.301, ...

Input Name	Internal Name		Description
IPHI	IPHI		ANALYSIS TIME INCREMENT
			Explanation: The analysis time increment cannot be arbitrarily long or instability will result, i.e., forces and velocities which will wildly fluctuate. If the time increment is too short then the computation takes too long. Thus, a reasonable compromise has to be made. WEAP86 computes the critical time increment, dt_c, based on the pile and soil resistance properties. It then computes the actual time increment by a number greater than one which is referred to as IPHI (percent). The result is the analysis time increment, $dt = dt_c/IPHI/100$. The default of IPHI is 160. An IPHI input less than 100 will not be accepted by WEAP86, values greater than 300 will result in unreasonably long analysis durations.
		= 0	Recommended for default of 160
		> 100	IPHI values in percent.
IRSAO	IRSAO		RESIDUAL STRESS OPTION
		= 0	A single analysis will be performed at each load level under the assumption that all of the soil springs have zero force at the initiation of impact. This option is not recommended for Monotube piles.
		= 1	A Residual stress analysis will be performed which involves several reanalyses of the same R_{ut} value and initial resistance forces and pile displacements are taken from the end of the previous analysis. Together with realistic soil resistance distributions, damping values and quakes, this analysis type is recommended for Monotube piles. For other pile types correlation analyses should be made before the RSA is chosen.

Input Name	Internal Name		Description
ITER	ITER		NO. OF ITERATIONS IN INTEGRATION ANALYSIS
		= 0, 1	One cycle of predictor corrector analysis is performed. This is the recommended option for optimal computation times.
		> 1	Additional predictor-corrector cycles are performed, depending on the convergence of pile top and bottom velocities.
IDAHA	IDAHA		HAMMER DAMPING
			Explanation: The hammer cushion dashpot acts in parallel with the hammer cushion spring. Its parameter is computed as c_{dh} = IDAHA (EA/c)/50 where EA/c is the impedance of the ram. The default value is IDAHA = 2.
		= 0	This is the recommended option.
		= 1	Somewhat smaller than default, usable.
		= 2	Identical to default
		< 0	A zero hammer damping is used, probably results in somewhat greater ram and pile vibrations not observed in measured records.
		> 2	Not recommended since an overdampened response would result.

Input Name	Internal Name		Description
IMAXT	IMAXT		ANALYSIS DURATION Explanation: The analysis duration may be a very important quantity. For example, in hard driving, with little skin friction, tension stresses may result some time after the pile has rebounded and the blow count is calculated. On the other hand, it may be unnecessary to analyze until it is certain that the stress maxima at all elements have been calculated with certainty. WEAP86 primarily analyzes until the blow count is computed with certainty and the rebound of the diesel ram is known. Extremely large or short analysis durations may cause problems in the diesel hammer stroke conversion or in the computation of the final set. The default is, therefore, the recommended input. However, for unusual pile types, such as very heavy or extremely long, piles may also be analyzed with other IMAXT values. The analysis time starts for ECH 2 ms before impact and for diesels 2 ms before either ignition or impact.
		= 0	Default - recommended
		1 ... 499	maximum analysis time in ms. The user is advised to chose values of at least 20. Note that 499 is an extremely long time (0.5 s).
		> 499	WEAP86 chooses 4L/c (4 times the time which the stress wave requires to travel along a pile of length L), but also satisfies all other requirements for a proper computation of blow count. The IMAXT > 499 option is recommended where all stress extrema must be determined (primarily of importance for concrete piles).

CARD 2.101 - 2.113 (Format: 8R10.0)

For: IPEL = 2 (See Card 2.000)

Input Name	Internal Name	Description
PILE ELEMENT STIFFNESSES	STP	PILE SEGMENT STIFFNESSES (k/in or kN/mm) are required for all pile elements when IPEL = 2. Since only 8 values are read per card, there may be up to 13 [38] cards (maximum 98 [298] segments). The first value must be given. If the (I)th value is the same as the (I-1)th value, the (I)th value may be left blank. (See N - Card 2.000).

CARD 2.201 - 2.213 (Format: 8R10.0)

For: IPEL = 2 (See Card 2.000)

Input Name	Internal Name	Description
PILE SEGMENT WEIGHTS	PM	PILE SEGMENT WEIGHTS (kips or kN) are required for all pile elements when IPEL = 2. Since only 8 values are read per card, there may be up to 13 [38] cards (max. 98 [298] segments). The first value must be given. If the (I)th value is the same as the (I-1)th value, the (I)th value may be left blank. (See N - Card 2.000).

CARD 2.301 - 2.313 (Format: 8R10.0)

For: IPEL > 0 (See Card 2.000)

Input Name	Internal Name	Description
PILE SEGMENT LENGTHS	ALPH	Relative PILE SEGMENT LENGTHS are required for all pile elements when IPEL > 0. Since only 8 values are read per card, there may be up to 13 [38] cards (max. 98 [298] segments). The first value must be given. If the (I)th value is the same as the (I-1)th value, the (I)th value may be left blank. (See N - Card 2.000). Note: ALPH must be given even though STP and PM may have also been entered.

CARD 3.000 (Format: 8R10.0)

Input Name	Internal Name	Description
HELMET AND HAMMER CUSHION INFORMATION		For an explanation of terms see Figure 2. For an extensive list of cap weights and cushion properties see Tables 2 and 3.
WEIGHT	CAPW	Weight of the helmet + hammer cushion + striker plate + all other components between ram (ECH) or impact block (Diesel) and pile top (kips or kN). Note that a CAPW MUST be given. The program cannot run without this value. If the ram strikes the pile directly, then an approximate solution may be obtained by modeling the pile 5 ft shorter and entering a CAPW and CAPST value which correspond to the properties of the pile top.
AREA	ACAP	Area of the hammer cushion (in^2 or cm^2); this value is used to compute the hammer cushion stiffness. If no CAPST is entered and TCAP is greater than 0, a default value is assigned as follows: ACAP = 113 in^2 (930 cm^2) for ECH or equal to the ram bottom area (diesels). Use of these defaults is not recommended.
ELASTIC MODULUS	ECAP	Elastic modulus of the hammer cushion (ksi or MPa). If neither ECAP nor CAPST values are entered, but TCAP is given, then the program assumes 400 ksi (2818 MPa). Not needed if CAPST is entered. Note that 1/2 of the secant modulus of the cushion material gives good stress correlations (see also Table 3.)
THICKNESS	TCAP	Thickness of the hammer cushion (in or mm). Not needed if CAPST is given.
C.O.R	CORCAP	Coefficient of restitution of the hammer cushion. Default is 1.0. A more appropriate value should be taken from Table 2. In general, if nothing else is known, a 0.8 value is recommended.
ROUND-OUT	DRCP	Round-out (or compressive slack; see also Figure 3.8 of Volume I) deformation of the hammer cushion (ft); a 0.01-ft (3 mm) default is used. The default is recommended, unless comparisons with measurements indicate different values.

Input Name	Internal Name	Description
STIFFNESS	CAPST	The hammer cushion stiffness in kips/in (kN/mm). Instead of ACAP, ECAP and TCAP, the resulting stiffness may be entered. If the CAPST is not given then it is computed from ECAP(ACAP)/TCAP. If neither TCAP nor CAPST are specified by the user then it is assumed that no hammer cushion is present. The corresponding spring stiffness is then the ram bottom stiffness. CAPST overrides the ACAP, ECAP and TCAP information. Therefore, the hammer cushion information printed by WEAP86 may show a hammer cushion stiffness which does not equal the corresponding value from ACAP, ECAP and TCAP.

CARD 4.000 (Format: 8R10.0)

PILE CUSHION INFORMATION		NOTE THAT THIS INPUT IS GENERALLY ONLY NECESSARY FOR CONCRETE PILES. IF NO CUSHION IS PRESENT BETWEEN HELMET AND PILE TOP, THIS CARD SHOULD BE LEFT BLANK.
AREA	ACUS	Area of the pile cushion (in^2 or cm^2). If left blank the program will substitute the pile top cross sectional area unless a CUST is entered.
ELASTIC MODULUS	ECUS	Elastic modulus of the pile cushion (ksi or MPa). If left blank and CUST = 0, then the program will substitute 50 ksi (352 MPa) which is reasonable for used plywood.
THICKNESS	TCUS	Thickness of the pile cushion (in or mm). If TCUS is not specified and CUST is also left at zero, then there is no pile cushion modeled.
C.O.R.	CORCUS	Coefficient of restitution of the pile cushion. In general a 0.5 is reasonable for any type of wood. Default is 1.0.
ROUND-OUT	DRCU	Round-out deformation (or compressive slack; see also Figure 3.8 of Volume I) of the pile cushion (ft or mm); default = 0.01 ft (3 mm). It is recommended that no input be made unless measurements require a value different from the default.

STIFFNESS	CUST	This is the pile cushion stiffness in kips/inch (kN/mm). It overrides the value computed from ACUS(ECUS)/TCUS. If ACUS, ECUS, TCUS and CUST have been specified and do not match each other, then the printout may show contradictory results without any further consequence in the analysis.

CARD 5.000 (Format: 8R10.0)

Input Name	Internal Name	Description
PILE AND PILE TOP INFORMATION		Note that the pile top information is all that is needed to create the pile model of uniform piles. Table 4 contains recommended pile material values for most common pile types.
LENGTH	XPT	Pile length (ft or m). This information MUST be given.
AREA	AP(1)	Pile top cross sectional area (in^2 or cm^2). This information MUST be given.
ELASTIC MODULUS	EP(1)	Pile top elastic modulus (ksi or MPa). This information MUST be given.
SPEC. WEIGHT	WP(1)	Pile top specific weight (lbs/ft^3 or kN/m^3). This information MUST be given.
C.O.R.	CORPTP	Coefficient of restitution of the pile top. A 0.85 for steel piles and 0.5 for timber piles is recommended. Default is 1.0 which is acceptable for concrete piles with pile cushions.
ROUND-OUT	DRPT	Round-out deformation (or compressive slack; see also Figure 3.8 of Volume I) of the pile top (ft or mm); default = 0.01 ft (3 mm) which is recommended unless a better value is known from measurements.

CARD 5.101 - 5.120 (Format: 8R10.0)

For: NCROSS> 0 (See Card 2.000)

Input Name	Internal Name	Description
NONUNIFORM PILE DESCRIPTION		The following cards are only needed if the pile is nonuniform and if the NCROSS=1 (see Card 2.000). Pile properties may be found in Table 4. For all four inputs, the program will substitute the previous corresponding value, if a zero (or blank) is entered. Thus, no Elastic Modulus or Specific Weight values need to be input if the pile is only of one material (values from Card 5.000 will be used). The program interpolates properties linearly between consecutive XP(I) values. Stepwise changes of cross section (or changes of material) have to be identified by two cards with identical XP(I) values, first giving the pile properties just above the change, and second, just below the section. Any combination of linear with straight sections and with any type of material is possible. The program recognizes the last set of input values by comparing XP(I) with XPT (See Card 5.000). It is, therefore, imperative that the last set of XP(I), AP(I)... specifications start with an XP(I) value that is greater than or equal to the pile length. An example input for two types of nonuniformity is given in Figure 3. Up to 19 cross sectional changes may be entered.
DEPTH	XP(I)	Depth (ft or m) below pile top at change of pile profile.
AREA	AP(I)	Cross sectional area (in^2 or cm^2) of pile at XP(I).
ELASTIC MODULUS	EP(I)	Elastic Modulus (ksi or MPa) of pile at XP(I).
SPECIFIC WEIGHT	WP(I)	Specific Weight (lbs/ft^3 or kN/m^3) of pile at XP(I).

THERE IS NO CARD NO. 6.000

CARD 6.101 (Format: 2A8,3I4)

For: IHAMR = 0 (See Card 2.000)

Input Name	Internal Name		Description
			The following is needed if the user does not find the desired hammer model in the hammer data file (see also Table 1). It is suggested that the hammer data request form of Volume III, Chapter 4 be used to collect the necessary data.
MANUFAC	NAMMAN		Hammer manufacturer name, i.e., DELMAG, VULCAN, etc. abbreviated, if necessary, to at most 8 characters.
NAME	NAMHAM		Hammer name or model, i.e., D-20, VUL 010, again at most 8 characters.
ITYPH	ITYPH		Hammer type:
		= 1	open end diesel
		= 2	closed end diesel
		= 3	external combustion hammer
M	M		Number of ram segments (usually = the segment length is chosen such that segments not shorter than 2.5-ft (0.75 m) result.

CARD 6.201 (Format: 8R10.0)

For: IHAMR = 0 (See Card 2.000)

Input Name	Internal Name	Description
RAM: WEIGHT	RAMW	Weight of the ram (kips or kN).
LENGTH	RAML	Length of the ram (ft or mm). This information is only used for the computation of a representative ram stiffness as explained in Chapter 4 of Volume I.
DIAMETER	RAMD	Average or effective diameter of the ram (in or mm); this value is used to compute the ram stiffness. Great accuracies are not required when computing the average RAMD of a nonuniform ram. See also Chapter 4 of Volume 1 for further instructions. Note, however, that it is also possible to enter the correct ram bottom diameter, RAMD, and an equivalent ram length for a correct ram stiffness.
STROKE: MAXIMUM	STRM	The RATED hammer stroke (ft or m). For open end diesels a higher stroke may physically be possible. However, for the sake of conservatism a higher than rated stroke should not be analyzed. For closed end diesels the actual (geometric) maximum stroke at which the hammer is rated. Note that the reaction weight and bounce chamber pressure are used to recompute the maximum stroke of closed end diesels. However, the user should secure accurate data such that a comparison of the computed with manufacturer supplied stroke value is possible. For single acting ECH the rated stroke. For double acting ECH the equivalent rated stroke, i.e., rated energy divided by ram weight.
MINIMUM	STRMN	Minimum stroke (ft or m). This value is used as a default stroke to start the analysis of diesels.

EFFICIENCY	EFFICY	Hammer efficiency (usually 0.5, 0.67, 0.8 for double acting, single acting ECH, and for diesels, respectively). This value must be entered. There is no default.

CARD 6.301 (Format: 8R10.0)

For: IHAMR = 0 and ITYPH = 1 or 2 (See Cards 2.000 and 6.101)

Input Name	Internal Name	Description
IMPACT BLOCK INFORMATION		FOR DIESELS ONLY
WEIGHT	ANVW	Weight of the impact block (kips or kN)
LENGTH	ANVL	Length of the impact block (in or mm); this information is only needed to compute the impact block stiffness.
DIAMETER	ANVD	Diameter of the impact block (in or mm); this information is needed for the calculation of impact block stiffness and does not need to be extremely accurate. In general, the smallest diameter governs.
C.O.R.	CORRA	Coefficient of restitution of the impact block; recommended is .90.
ROUND-OUT	DRRA	Round-out deformation (or compressive slack; see also Figure 3.8 of Volume I) of the impact block in ft (mm), usually 0.01 ft (3 mm).

CARD 6.401 (Format: 8R10.0)

For: IHAMR = 0 and ITYPH = 1 or 2 (See Card 2.000 and 6.101)

Input Name	Internal Name	Description
		COMBUSTION INFORMATION FOR DIESELS ONLY
DEPIB	DEPIB	Compressive stroke (in or mm) - distance between exhaust ports and top of impact block.
COMBUSTION CHAMBER:		
AREA	ACH	Area (in^2 or cm^2) of combustion chamber cross section.
VOLUME	VFIN	Final combustion chamber volume (in^3 or dm^3)
COMBUSTION TIMING:		FOR LIQUID FUEL INJECTION ONLY
DELAY	TDEL	Combustion delay (s); 0.001 s is a reasonable value.
DURATION	DTIGN	Combustion duration (s); 0.002 s is a reasonable value.
EXPANSION COEFFICIENT:		FOR ALL DIESEL HAMMERS
EXPAN COEFF	EXPP	Expansion coefficient - exponent used in Gas Law after combustion has taken place; usually 1.35.
COMBUSTION VOLUMES:		FOR ATOMIZED FUEL INJECTION ONLY
IGNITION	VSTI	The combustion chamber volume at which ignition starts (in^3 or dm^3).
FINAL COMB	VENDC	The volume after impact at which (in^3 or dm^3) where combustion ends (in^3 or dm^3).

CARD 6.501 (Format: 6R10.0,I5)

For: IHAMR = 0 and ITYPH = 1 or 2 (See Card 2.000 and 6.101)

Input Name	Internal Name	Description
PRESSURES		FOR DIESELS ONLY
ATMOSPH.	PATM	Atmospheric pressure (psi or kPa), usually 14.7 psi or 1.01 kPa.
SETTING 1	P1	Combustion pressure (psi or kPa) - Setting 1 - maximum combustion pressure. P1 corresponds to IFUEL = 1 (See Card 2.000)
SETTING 2	P2	Combustion pressure (psi or kPa) - Setting 2 - combustion pressure. P2 corresponds to IFUEL = 2 (See Card 2.000)
SETTING 3	P3	Equivalent to P2
SETTING 4	P4	See P2
SETTING 5	P5	See P2
CO CONF	IGUESS	Coefficient of confidence for diesels:
	= 0	Measurements of combustion pressures were made
	= 1	Assumed pressures

CARD 6.601 (Format: 8R10.0)

For: IHAMR = 0 and ITYPH = 2 (See Card 2.000 and 6.101)

Input Name	Internal Name	Description
		BOUNCE CHAMBER INFORMATION FOR CLOSED END DIESELS
DEPBB	DEPBB	Bounce chamber compressive stroke (in or mm) - distance between bounce chamber ports and cylinder top.
B C AREA	ART	Ram cross sectional area of bounce chamber or ram top (in^2 or cm^2).
DBBT	DBBT	Maximum internal ram travel distance (in or mm) - distance between impact block and cylinder top minus the ram length.
D SAFETY	DSF	Safety chamber distance (in or mm) - distance between compression tank ports and cylinder top.
C TANK VOLUME	VCT	Pressure tank volume (in^3 or dm^3).
REACTION WEIGHT	RWH	Reaction weight of diesel cylinder (kips or kN); this value is important for maximum stroke calculations of closed end diesels. Since uplift occurs at the time when bounce chamber pressure times bounce chamber area equal the reaction weight, the reaction weight practically governs the maximum hammer stroke or energy.
B C EXPONENT	EXPB	Exponent for bounce chamber expansion/compression Gas Law computations (usually 1.4).

CARD 6.701 (Format: 8R10.0)

For: IHAMR = 0 and ITYPH = 3 (See Card 2.000 and 6.101)

Input Name	Internal Name	Description
		FOR EXTERNAL COMBUSTION HAMMERS ONLY
EFF AREA	AEFBB	Effective piston area (in^2 or cm^2) for double acting ECH hammers.
RATED PRESSURE	PRT	Manufacturer's hammer pressure rating (psi or kPa) for double acting ECH hammers.
ASSEMBLY:		
C.O.R.	CORRAS	Coefficient of restitution for hammer assembly. Usually 0.8.
ROUND-OUT	DRRAS	Round-out deformation for assembly springs (ft or mm); default 0.01 ft (3 mm).
NO. OF ASSEMBLY ELEMENTS	MA	Number of assembly elements. Usually 2 and at most 3. May also be zero (if assembly weight is without consequence to pile stresses or blow count) or 1 if the assembly appears to be rather stiff.

CARD 6.801 (Format: 8R10.0)

For: IHAMR = 0, ITYPH = 3 and MA > 0 (See Cards 2.000, 6.101 and 6.701)

Input Name	Internal Name	Description
ASSEMBLY		GIVE MA STIFFNESSES AND MA WEIGHTS FOR ECH.
WEIGHT	AW(1)	Weight (kips or kN) of the first assembly segment (MA = 1, 2 or 3)
WEIGHT	AW(2)	Second assembly weight, see AW(1) (MA = 2 or 3)
WEIGHT	AW(3)	Third assembly weight, see AW(1) (MA=3)
STIFFNESS	STAI(1)	Stiffness (k/in or kN/mm) of the first assembly segment (MA = 1, 2 or 3)
STIFFNESS	STAI(2)	Second assembly stiffness, see STA(1) (MA = 2, 3)
STIFFNESS	STAI(3)	Third assembly stiffness, see STA(1) (MA = 3).

CARD 7.000 (Format: 8R10.0)

Input Name	Internal Name	Description
HAMMER		Overriding means that data obtained from file or CARDS 6.101 - 6.801 is altered. Only frequently changed values are included in this group of input information. Override values do not affect the contents of the hammer data file.
STROKE	STROOV	Overrides the minimum stroke for starting of diesels or the rated stroke for ECH. Stroke (ft or m) to be used as a starting value in the current analysis (diesels) or for the computation of impact velocity (ECH). Diesel analysis: If IOSTR = 1 or -1, only this stroke will be analyzed (See Card 2.000) For closed end diesels the override stroke is an equivalent stroke (this is different from WEAP). This stroke value is easily computed if a certain ram energy is to be analyzed. Then, stroke = energy/ram weight. For a given bounce chamber pressure, the manufacturer's chart, relating equivalent stroke or ram energy to bounce chamber pressure should be used. Note that WEAP86 computes bounce chamber pressures as they actually occur, i.e., without reductions due to hose length.
EFFICIENCY	EFFOV	Hammer efficiency.
PRESSURE	PROV	Pressure (psi or kPa) for either diesels to override the P1, ..., P5 values. For double acting ECH to override the rated pressure value. Ignored for single acting ECH.
REACTION WEIGHT	RWTOV	Reaction weight (kips or kN). Used only for closed end diesels.
TIME DELAY	TDELOV	Combustion Delay (s) for Liquid Injection Diesel hammers or Combustion Start Volume (in^3 or dm^3) for Atomized Injection Hammers.

CARD 8.000 (Format: 8R10.0)

Input Name	Internal Name	Description
SOIL PARAMETERS		Note that the following four parameters are usually thought to describe the dynamic soil behavior with sufficient accuracy. Table 5 lists commonly accepted values. For more detailed information, the individual damping and quake values may be entered on Cards 8.101, ... and 8.201,.... However, given the uncertainties of damping values and quakes, the skin/toe values suffice in most cases.
QUAKE-SKIN	QS(1)	Soil Quake on the skin (in or mm); often 0.1 in (2.5 mm)
QUAKE-TOE	QS(N1)	Soil Quake at the toe (in or mm); often 0.1 in (2.5 mm)
DAMPING-SKIN	SJ(1)	Soil Damping on the skin. Units depend on the ISMITH option of Card 2.000. ISMITH = -1 ... dimensionless (viscous - Case damping). ISMITH = 0, 1 s/ft or s/m (traditional Smith damping). ISMITH = 2 s/ft or s/m (viscous Smith damping).
DAMPING-TOE	SJ(N1)	Soil Damping at the toe; for units see SKIN DAMPING.

CARD 8.101 - 8.113 (Format: 8R10.0)

For: ITYS < -1 (See Card 2.000)

Input Name	Internal Name	Description
SOIL QUAKES	QS(I)	Soil quake (in or mm) for all segments plus pile toe (since there are N segments exactly N+1 quakes have to be entered; maximum 99 [299]). If the i-th value is entered as zero, then it is replaced with the previous value. The first value has to be given. On each card only 8 values can be entered. Thus it may be necessary to give as many as 13 [38] cards.

CARD 8.201 - 8.213 (Format: 8R10.0)

For: ITYS < 0 (See Card 2.000)

SOIL DAMPING PARAMETERS	SJ(I)	Soil Damping Parameters must be entered for all segments plus pile point, i.e., exactly N+1 values (maximum 99 [299]). Input represents the constant for each individual segment with dimensions as shown for SKIN DAMPING on Card 7.000.

Note that Case Damping must be properly distributed. For example: For N = 15, a 0.2 Case Skin Damping factor corresponds to 0.2/15 = 0.0133 for each element if a uniform damping distribution is desired.

Up to 13 [38] cards may be needed depending on the magnitude of N.

CARD 8.301 - 8.313 (Format: 8R10.0)

For: ITYS < -1 (See Card 2.000)

ULTIMATE STATIC SOIL RESISTANCE	SU(I)	Relative magnitudes of ULTIMATE STATIC SOIL RESISTANCE values for all elements plus pile toe (maximum 99 [299]).

Note that this input overrides IPERCS (See Card 2.000), i.e., the point resistance is determined using SU(N+1). The program normalizes the SU(I) values. Therefore, only relative magnitudes need to be given.

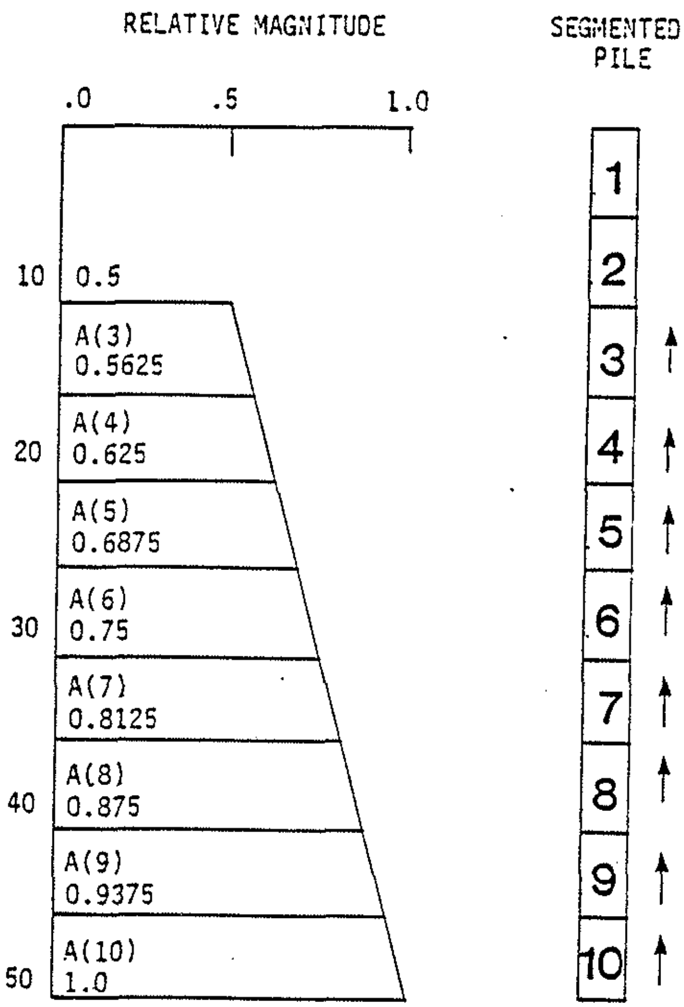
CARD 8.401 - 8.420 (Format: 8R10.0)

For: ITYS = -1 or 0 (See Card 2.000)

Input Name	Internal Name	Description
SKIN FRICTION DISTRIBUTION		For an example input see Figure 4. For a demonstration of the computational procedure in WEAP86 see Figure 5.
DEPTH	DIS(1,I)	Depth in feet at which corresponding skin friction distribution change occurs. Do not enter a zero depth. The program assumes that there is a zero resistance at the pile top.
DISTRIBUTION	DIS(2,I)	Relative, dimensionless skin friction distribution value at corresponding depth.

Note: Up to 20 cards may be given each containing one depth and corresponding distribution value.

Only the skin friction is affected by the distribtuion choice. The amount of skin friction is a certain percentage of the total ultimate resistance R_{ut} and was specified by IPERCS (See Card 2.000). As for the pile data on Cards 5.101 ..., it is imperative that the last depth value, DIS(1,I), be greater than or equal to the pile length (See XPT - Card 5.000)



SEGMENTED PILE	A(I)	FRACTION OF R_{ut}* ("1")	SU(I) (tons)
1			
2			
3	2.656	0.035	8.86
4	2.969	0.040	9.90
5	3.281	0.044	10.94
6	3.594	0.048	11.98
7	3.906	0.052	13.02
8	4.219	0.056	14.06
9	4.531	0.060	15.10
10	4.844	0.064	16.14
	30.000 (A_{tot})	0.40 (IPERCS)	100.00 (R_{skin})

$$\text{*FRACTION OF } R_{ut} = \frac{A(I)}{A_{tot}} \frac{(IPERCS)}{100} \qquad SU(I) = (\text{FRACTION OF } R_{ut}) \times (R_{ut})$$

EXAMPLE FOR THE COMPUTATION OF ELEMENT RESISTANCE FORCES:

IPERCS = 40 (%) R_{ut} = 250 (kips)
N = 10 Pile Length = 50 ft
Segments are of equal length (5)

Total Skin Resistance = 250 (40)/100 = 100 (kips)
Total Area under Resistance Curve = (0.5 + 1.0) 1/2 (50 - 10) = 30.0
Toe Resistance = SU(N1) = (100 - 40)(250)/100 = 150 (kips)

Figure 5. Computational proceedure in WEAP86.

CARD 8.501 (Format: I5,3F10.0)

For: ISPL > 0 (See Card 2.000)

Input Name	Internal Name	Description
		The following information is only required if there are any slacks or splices in the pile. Each card represents one slack/splice. The number of splice/slack specifying input cards must exactly match the ISPL number.
ELEMENT	J	Element number for corresponding SPLICE, CORP and/or DSCAP values. This number can be computed by the splice/slack depth divided by the segment length (XPT/N or 5-ft - 1.65 m, if N was not entered) plus 1, but not greater than N.
SLACK	SPLICE(J)	Tension slack at pile spring J in ft (mm). Note that the program recognizes the presence of a slack/splice by a positive SPLICE(I) value. Recommendations for mechanical concrete splices are 0.003 ft (1 mm), for can splices or all other splices which do not limit a pile extension: 99 ft or 1000 mm.
C.O.R.	CORP(J)	Coefficient of restitution of splice spring. Usually 0.8.
ROUND-OUT	DSACP(J)	For all springs with splices a round-out deformation must be given in ft (mm). This round-out deformation acts as a compressive slack. In general a 0.001 ft (3 mm) is acceptable.

CARD 9.100 - 9.200 (Format: 8R10.0)

Input Name	Internal Name	Description
ULTIMATE CAPACITIES	RESULT(I)	Up to 10 ultimate resistance or R_{ut} values (kips or kN) may be input. They must be given in increasing order. The first occurrence of a zero (or blank field) terminates the search for further R_{ut}T values. If the first R_{ut} is zero, then up to 10 ultimate capacity values will be computed by WEAP86. The analysis is stopped after the blow count of an R_{ut} has reached refusal. Thus, entering too many high values does not necessarily cause unnecessary computations. *** Note the difference between WEAP and WEAP86: WEAP capacities were in tons, WEAP86 capacities are in kips (kN). ***

CARD 9.301 (Format: 20I4)

For: IJJ = 1 (See Card 2.000)

Input Name	Internal Name	Description
PILE ELEMENT NUMBERS	INP(I)	Enter up to 13 element numbers at which output is to be made along with the two hammer variables which are always printed. The INP input also depends on the number of elements available (See N - Card 2.000). For IJJ=0, the element numbers are automatically computed. Example: If N = 40, a uniform spacing would be given using the following string of numbers (each number right-justified in a field of 4 starting in COLUMN 1). 1 4 7 10 13 16 20 24 30 33 36 40 which would include the pile top (1) and pile bottom (40). For N less than 13, all segments can be entered.

4. EXAMPLES OF UNCOMMON INPUT PROBLEMS

4.1 Specifying a Soil Plug

Suppose it is intended to analyze a steel pipe pile (A_s, E_s, W_s) which was driven open ended and wherein a soil plug formed during pile driving. A plug exists when the soil does not move relative to the pile. It may be assumed that the soil has a negligible stiffness compared to the pile. Thus, the pile area and modulus specified must yield the pile stiffness and therefore only the pile specific weight, WP, should reflect the combined pile and soil properties. This value can be calculated as follows:

$$WP = (W_{soil})(A_{plug})/A_s + W_s$$

where WP is the unit weight of steel plus soil combined, W_{soil} is the unit weight of the plug, and A_{plug} is the cross sectional area of the plug.

For a 24-in (610 mm) outside diameter pipe with 60-ft (18.3 m) length, 1-in (25 mm) wall thickness and 5-ft (1.5 m) plug, one would obtain

$$A_s = 23(1)3.1416 = 72.3 \text{ in}^2 \ (466 \text{ cm}^2)$$

$$W_s = 492 \text{ lb/ft}^3 \ (78.5 \text{ kN/m}^3)$$

$$E_s = 30{,}000 \text{ ksi} \ (210000 \text{ MPa})$$

assume

$$W_{soil} = 110 \text{ lb/ft}^3 \ (17.6 \text{ kN/m}^3)$$

$$A_{plug} = 22^2(3.1416)/4 = 380.1 \text{ in}^2 \ (2452 \text{ cm}^2)$$

and therefore

$$WP = 110(380.1)/72.3 + 492 = 1070 \text{ lb/ft}^3 \ (171.6 \text{ kN/m}^3)$$

The input would be:

Card No.	Lpile/XP	AP	EP	WP
5.000	60.	72.26	30000.	492.0
5.101	55.			
5.102	55.			1071.0
5.103	60.			

4.2 Specifying a Pile Point

Suppose input data is to be prepared for an HP 10x42 (AP = 42/3.42 = 12.28 in^2 or 79.2 cm^2) pile of 40-ft (12.2 m) length with a 75-lb (.34 kN) pile point or shoe that extends 3 in (75 mm) below the bottom of the H-pile. Since the effective cross sectional area of the pile point, A_{pt}, is not known it is sufficiently accurate to find

$$A_{pt} = (1728)(WT_{pt})/[(W_{pt})(T_{pt})]; \; (in^3/ft^3)(lb)/[(lb/ft^3)(in)$$

with WT_{pt} being the total weight, W_{pt} the unit weight and T_{pt} the maximum thickness of the pile point.

In the given example one obtains:

$$A_{pt} = 1728(75)/[492(3)] = 87.8 \text{ in}^2 \; (566 \text{ cm}^2)$$

The input would be:

Card No.	Lpile/XP	AP	EP	WP
5.000	40.25	12.28	30000.	492
5.101	40.0			
5.102	40.0	87.8		
5.103	40.25			

4.3 Specifying a Single Acting Air/Steam Hammer

This is the simplest hammer and, incidentally, a drop hammer would be specified in the same manner.

As an example, consider a hammer with 5.0 kips (22.7 kN) ram weight, efficiency 0.8, normal stroke 36 in (0.91 m). The assembly will be disregarded.

The ram consists of a a 24- by 24- by 30-in (609x609x762 mm) block with 12-in (305 mm) diameter ram point of 15-in (381 mm) length. Its stiffness can be computed from the two individual ram portions:

$$A_1 = 576 \text{ in}^2$$

$$A_2 = 12^2(3.1416)/4 = 113 \text{ in}^2$$

$$k_1 = 576(30000)/30 = 576000 \text{ k/in}$$

$$k_2 = (113)(30000)/[(4)(15)] = 226195 \text{ k/in}$$

$$k = k_1k_2/(k_1+k_2) = (576)(226)/(576+226) = 162000 \text{ k/in}$$

It may be desirable to use the the point area as an effective ram area for accurate stress computations in the hammer cushion. Then a length should be computed such that the stiffness computed by WEAP86 from ram area, length and elastic modulus equals k.

$$L_r = 30000(113)/162000 = 20.9 \text{ in } (.53 \text{ m})$$

The input for this hammer is as follows:

Card No.

6.101 NAME: 5 K RAM, MANUF: UNKNOWN, ITYPH: 3, M: 1
6.201 RAM WT: 5.0, LENGTH: 20.9, DIAM: 12., STROKE MAXIMUM: 3.0, EFFICIENCY: 0.67
6.701 EFF AREA: N/A, RTD PRESSURE: N/A, ASSEMBLY: N/A; Leave Card blank
6.801 Leave Card Blank

Should the assembly be considered the following must be determined: Weight of the assembly top, weight of hammer base and stiffness of total assembly. Suppose the assembly top weighs 3.0 kips (13.6) and the base 2.0 kips (9 kN) and that there are four columns of 4 1/2-in (114 mm) diameter ånd 90-in (2.286 m) length. Then the assembly stiffness is

$$k_a = 4(4.5^2)[3.1416/4](30000)/90 = 21200 \text{ k/in } (3790 \text{ kN/mm})$$

If two assembly segments are modeled, then the two assembly springs have twice the stiffness k_a. Thus the following data is to be given

6.701 COR: 0.8, ROUND OUT: 0.01, MA: 2
6.801 WEIGHT ELEMENT 1: 3.0, 2: 2.0
STIFFNESS ELEMENT 1: 42400, 2: 42400

4.4 Specifying an Open End Diesel Hammer

This example considers a diesel hammer with the following properties:

	Ram	Impact Block	
Weight:	2,750 (12.5)	810 (3.68)	lbs (kN)
Length:	95 (2413)	19 (483)	in (mm)
Diameter:	12.5 (318)	12.5 (318)	in (mm)

Chamber volume 120 (1.97)	in^3 (dm^3)
Compression ratio 12:1	
Combustion delay (liquid injection) 2	Ms
Combustion Duration is assumed to be 2	Ms
Max. combust. press., high setting 1150 (8100)	psi (kPa)
(Pressures for other settings not known, nor are measurements known to exist)	
Maximum stroke 8.5 (2.59)	ft (m)
Minimum stroke not known	
Expansion exponent not determined, assume 1.3	

2. The ram cross sectional area is $A_r = (12.5^2)\ (3.1416)/4 = 122.7\ in^2$ (792 cm^2).

3. The volume displaced by the ram is $V_d = 12(120) - 120 = 1320\ in^3$ (21.6 dm^3).

The distance between exhaust ports and impact block is therefore (assuming cylinder area equal ram cross section): $h_c = 1320/122.7 = 10.76$ in (2737 mm).

Choosing three ram elements the input is:

Card No.

6.101: NAME:HYPOTHET, MANUF: UNKNOWN, ITYPH: 1, M: 3
6.201: RAM WT: 2.75, RAM L: 95, RAM DIA: 12.5
STROKE MAX: 8.5, STROKE MIN: 0, EFFICIENCY 0.8
6.301 IB WT: .81, IB L: 19, IB DIA: 12.5, IB COR: 0.8, IB RND-OUT: .01
6.401 DEPIB: 10.76, COMB.CH. A: 122.7, COMB.CH. V: 120,
COMB. DELAY: .002, COMB. DURTN: .002, EXP. COEFF. 1.3
6.501 ATM. P: 14.7, P1: 1150, COEFF. OF CONF. 1.

A computer run demonstrating the use of this hammer data is discussed in Example 4 of Chapter 7.

4.5 Additional Specifications for a Double Acting ECH Hammer

If the hammer of Section 4.3 were double acting, the following additional specifications would be needed:

- The rated pressure.
- The effective piston area.

If these two values are not known then an equivalent rather than the actual stroke should be specified on Card No. 6.201 (MAXIMUM STROKE). However, the PRESSURE value on Card 7.000 then cannot be used for efficiency adjustment due to reduced power pressure.

4.6 Additional Specifications for Closed End Diesel Hammers

Suppose that the hammer of Section 4.4 had a closed cylinder top with the following known data:

> Ram top starts to compress bounce chamber air when the ram has moved 5 in (127 mm) up from the impact block. The ram is uniform and there is a distance of 4 1/4-ft (1295 mm) that the ram can move upwards from the time the bounce chamber compression begins before it hits the top. No compression tank and therefore, no safety chamber exists. The total hammer weight is 7.81 kips (34.8 kN) excluding helmet.

The necessary input data is (to be entered on Card 6.601):

Bounce Ch. Comp. Stroke, DEPBB: 4.25(12) = 51 in^2 (329 cm^2)
B C AREA = ram area: 122.72 in^2 (792 cm^2)
Total ram travel, DBBT: 51 + 5 = 56 in (1422 mm)
No pressure tank, therefore D SAFETY: 0
C TANK VOLUME: 0
REACTION WEIGHT = total hammer-ram-impact block weight =
7.81-2.75-.81 = 4.25 (18.9 kN)
BC EXPANSION COEFF: 1.4 (assumed).

Of course the maximum stroke would be smaller than in Section 4.4. It should be obtained from the manufacturer. This maximum stroke is related to the reaction weight and if the stroke value is inaccurate, not much damage will be done since WEAP86 figures the proper stroke under consideration of uplift using the reaction weight and bounce chamber information. The ITYPH input on CARD number 6.101 must be changed to 2.

4.7 Specifying Slack or Splice

Suppose that a 100-ft (30.5 m) pile had two different splices. First, 32 ft (10 m) above the pile bottom a connection was made which cannot transmit any tension at all (Can Splice). Sixty-five ft (20 m) above the toe a second, a so-called Mechanical Splice, is used for pile connection. The mechanical splice is a device with two matching surfaces on the pile ends to be connected; they can be fastened together through shear pins or other mechanical elements but usually allow for some slack. The slack in the splice is often assumed to be 1 mm, i.e., it allows a 1 mm or 0.003-ft extension before it transmits tension forces. Both splices are assumed to have a round-out deformation (compressive slack) of .01 ft (3 mm). For the can splice an unlimited extension at zero force has to be specified which may be represented by 99 ft (99 m.)

In order to properly assign SPLICE values, N should be specified, say N = 20 for 5-ft (1.5 m) segments. Then the sixth spring would correspond to the upper and the 13th spring to the lower splice.

The input would be specified on Card No. 8.501 and 8.502

Card No.	Element	SPLICE(J)	ROUND OUT	
8.501	6	0.003(1)	0.01(3)	ft (mm)
8.502	13	99.00(99.00)	0.01(3)	ft (mm)

5. PROGRAM MESSAGES

There are a number of messages that the program may either display on a terminal or print on the output. Depending on the nature of the message it may be only an information about the program progress or it may state the reason for an interruption of the program run.

The following categories are therefore distinguished:

1. Program Stop Messages.
2. Program Interrupt Information.
3. Warnings.
4. Terminal Messages.

5.1 Stop Messages

These messages occur usually before the final output (extrema, tables) of the RULT analysis during which the condition had been detected:

1. NEED N > 0 INPUT FOR EXTENDED PILE INPUT
   If IPEL is given greater than zero, N, the number of pile segments must specified by the user.

2. ERROR IN EXTENDED PILE SEGMENT INPUT: MASS OR STIFFNESS FOR AT LEAST FIRST SEGMENT NOT SPECIFIED
   Extended input requires at least the first segment specifications to be greater than zero.

3. NEED CAP WEIGHT GTR 0: SPLIT RAM, ANVIL, OR PILETOP
   The model must contain an element even if no helmet exists.

4. PILE PROPERTIES AT BOTTOM OF PILE NOT SPECIFIED
   During the specification of AP, EP and RP an XP value had been encountered that was less than earlier ones. This is interpreted as out of range or as a later input card. Thus, pile bottom specifications were not found.

5. ***DATA ERROR OR DATA END***
   Message was probably caused by improper data format. This in turn may have been caused by either missing or uncalled for cards.

6. ERROR IN READING HAMMER FILE, HAMMER ID = XXX
   The number of ram segments specified was less than one. Either the hammer data file or the user supplied data cards were in error, or the user has specified a hammer identifier corresponding to an empty file.

7. ERROR DURING HAMMER DATA READING
IHAMR was specified greater than the available number of hammers on file.

8. INCORRECT ASSEMBLY DATA, ASSEMBLY SEGMENT NO: XXX
The specified number of assembly segments and the actually specified stiffnesses and masses did not match. Check hammer data.

9. ERROR DURING OVERRIDE HAMMER DATA READING
Check line 7.000 of input data

10. TIME INCREMENT TOO SMALL: XXX MS
HAMMER MASSES....
PILE MASSES...
....
Critical time increments were not sufficiently large. Probably input error; a segment mass may have been zero or a stiffness very large.

11. *** STROKE DID NOT CONVERGE***
After four analyses the rebound stroke was still different from the input stroke. No new stroke is analyzed. Depending on the last rebound stroke, the user should decide whether an additional analysis would be necessary using the last stroke value as an input on Card No. 7.000.

12. *** NO PERMANENT SET, ANALYSIS IS DISCONTINUED***
The condition encountered was no permanent set (infinite blow count) and no increase in stroke in the case of diesel hammers. Therefore no additional RULT values were analyzed since they are assumed to be even larger and therefore would also lead to refusal.

13. RAM STILL MOVING DOWNWARD AT END OF BLOW, VR = XXX ()
End of blow is here defined as the end of the impact analysis. Reasons may be insufficient combustion pressure, extremely low soil resistance or incorrect hammer or pile data. It may also indicate that the hammer does not run under the given conditions. VR stands for ram velocity.

14. IMPROPER CONDITION MET IN UP ROUTINE
When calculating the rebound stroke an improper condition occurred which in most instances must be attributed to incorrect hammer data.

5.2 Interrupt Messages

The difference between interrupt and stop message is the continuation of the program run with a new RULT value while stops are absolute for a problem.

1. INSTABILITY?!, ANALYSIS INTERRUPTED AT TIME XXX, MAX. PILE VEL. XXX
   This message may occur when analyzing an ECH.
   The velocities of the pile segments became unreasonably high and the program run was therefore interrupted. Output and additional analysis attempts for further RULT values are made. However, the user should use the results with extreme caution. It may be necessary to resubmit the problem with a higher IPHI or with less static or damping resistance.

2. *** INSTABILITY?! TIME, MAX V PILE = XXX ***
   This message is the equivalent to 1., but for diesels.

3. *** UNSUCCESSFUL PRESSURE REDUCTION AGAINST UPLIFT, ANALYSIS IS DISCONTINUED***
   The uplift condition was not corrected after at least four pressure reductions. For this reason the analysis was interrupted. It may be necessary to reanalyze with an additional, smaller R_{ut}-value. Also, the analysis may be repeated starting with a substantially lower pressure value than previously analyzed on CARD 7.000.

4. *** UNSUCCESSFUL PRESSURE REDUCTION AGAINST RAM BLOW OUT, ANALYSIS IS DISCONTINUED***
   The uplift condition did not get corrected by at least four pressure reductions. For this reason the analysis was interrupted.

5. *** HAMMER DOES NOT RUN AT THIS RESISTANCE LEVEL***"
   For the given parameters no impact occurred or the ram did not get sufficiently close to the anvil for a reasonable analysis. The current analysis is therefore skipped and a higher RULT value is analyzed if RULT was specified ≤ 0 in Card No. 6.000. Otherwise the next set of data is read.

6. RAM TURNS AROUND TOO EARLY. POSSIBLY NOT ENOUGH RESISTANCE
   This condition occurred during the precompression phase of a diesel hammer. The program moves on to analyze the next higher R_{ut} value.

7. TIME LIMIT EXCEEDED IN STARTC. POSSIBLY NOT ENOUGH RESISTANCE
   This is another condition causing an interruption of the current R_{ut} analysis in the precompression phase of diesels. Again it may have been caused by a pile with insufficient resistance. STARTC is the name of the routine where the precompression phase is analyzed.

5.3 Warnings

Warnings are printed whenever a potentially dangerous situation or unusual result is recognized by WEAP86. Note that the printout of warnings usually occurs before the page on which the corresponding printout is made. Warnings do not affect the program performance.

1. *** NO RSA CONVERGENCE*** see 3.

2. NO RSA CONVERGENCE see 3.

3. *** NO CONVERGENCE OF RESIDUAL STRESS ANALYSIS***
   All three messages inform the user that the convergence crtieria of the residual stress analyses were not satisfied. Caution should by exercised when using the results. The analysis is not interrupted.

4. *** CAUTION RAM MIGHT BLOW OUT***
   For open end diesel hammers if the stroke exceeds the maximum (rated) stroke specified by the manufacturer. Note that at most the maximum stroke will be analyzed.

5.4 Terminal Messages

Depending on the hardware available to the user and the mode of program installation (ITW output unit, see Installation Manual), a number of messages may be displayed on the user's terminal during the program execution. These messages inform the user about the state of the analysis.

1. RULT = XXX, R TOE= XXX, TIME INCR.= XXX
   An analysis with a new R_{ut} (RULT) has been started. Depending on the IPERCS option, the toe resistance may be changed (the skin friction is of course the difference between total and end bearing capacity).

2. TIME () STROKE () DOWN VEL. AT PORTS ()
   In a diesel hammer analysis the ram has passed the ports. TIME is the time of ram fall from the top of the STROKE to the exhaust ports. The preimpact compression phase is now being analyzed.

3. EXHAUST!!! - UPSTROKE = XXX
The ram has passed the exhaust ports during its upward travel. It has allowed the gases to EXHAUST and an Upward STROKE has been computed.

4. FIN SET() XX, BLOW CT() XX, FIN, MAX ENTHRU XX, XX ()
The analysis of one R_{ut} vlue has been finished. The results, i.e., permanent pile penetration (FIN SET), Blow Count computed from the inverse of FIN SET and both the maximum and final energy transferred to the pile top (ENTHRU) has been computed. MAX ENTHRU and BLOW COUNT will reappear in the summary output.

5. BEGIN STATIC ANALYSIS (RESIDUAL STRESS)
After this message the final pile and soil stresses and displacements are calculated. Either another trial analysis is then performed or the residual analysis of one R_{ut} is then finished.

6. TIME () VELOCITY AT IMPACT
This message occurs for diesel hammers upon contact of ram with impact block. This is the only occasion to obtain an accurate output of ram impact velocity.

7. UPLIFT!!!
For a closed end diesel a stroke greater than maximum was computed. Thus, the fuel pressure was reduced and, in general, a new trial analysis was started.

6. OUTPUT DESCRIPTION

The output from WEAP86 falls in three categories. First, a printout is provided which allows the user to check whether his input data correctly reflects the problem to be analyzed. The user is urged to check this first part of the output carefully. Secondly, there are actual results from the analysis and finally, messages may be interspersed in the output depending on the conditions encountered.

The following description shows headings, or the wording of messages, and then gives an explanation. Depending on the output option chosen by the user, all or only part of these quantities may actually appear on the printout.

Note that, all pages after the echo print on page one are headed by a so-called Super Title which indicates the program used and a Subtitle which is the user chosen identification of the problem.

The user also should be aware that there are two different printout formats. The first is for an 80-column printer, the second for a 132-column printer. Columns in this context means the number of characters that can be printed on one line. Depending on the available hardware, the ICOL option may have to be set within the program or in the file specification file (see Volume III). The line width affects only the "Variables vs. Time Tables."

6.1 Input Check

Heading	Description
ECHO PRINT OF INPUT DATA	The following output is an image of the input file with the exception that the data read from the hammer data file is also included. On occasion, asterisks (*) may be printed. This would only indicate that the corresponding number entered is large and not necessarily that it has been misread. A data check, more careful than usually, of the following input and output is suggested.
HAMMER MODEL OF xxxx MADE BY xxx	A summary of the lumped mass hammer model itself and various parameters governing the hammer performance is given. The xxx indicate hammer name and manufacturer.
ELEMENT	This column identifies with numbers the ram segments and with captions the driving system components.

Heading	Description
ASSEMBLY	Identifies with numbers the individual assembly segments of ECH.
CAP/RAM	Identifies the helmet weight and the properties of the spring between ram and helmet for ECH. For ECH this spring is a combination of the lowest ram segment and the hammer cushion. For diesels this spring only represents the hammer cushion.
IMP. BLK	Printed are the weight and spring properties for the diesel hammer impact block. The spring is a combination of the lowest ram segment and the impact block.
WEIGHT	The weight of a segment.
STIFFNESS	The loading stiffness of a segment.
COEFF. OF RESTITUTION	The coefficient of restitution of a nonlinear spring.
D-NL.	The round-out deformation or compressive slack of a nonlinear spring.
CAP DAMPG	The damping parameter of the hammer cushion dashpot.
HAMMER OPTIONS	Individual options are identified by the following subheadings:
HAMMER NO.	The file number of the hammer. If 0 then a user specified hammer was analyzed.
FUEL SETTING	Only applicable to diesels. This is the IFUEL option.

Heading	Description
STROKE OPT.	Applicable to diesels only; equals IOSTR.
HAMMER TYPE	1 for open end diesels, 2 for closed end diesels and 3 for ECH.
DAMPNG-HAMR	The IDAHA option used to comput CAP DAMPG; this option is often the defaulted value.

Heading	Description
HAMMER PERFORMANCE DATA	Individual subheadings below this general heading identify the most important hammer performance specifiers obtained from either the hammer data file or from the user. For the debug option, practically all parameters are listed.
RAM WEIGHT	The total ram weight.
RAM LENGTH	The ram length used for ram stiffness calculations.
MAX STROKE	The maximum stroke: for ECH the rated stroke for open end diesels the stroke where "ram blow out" is indicated. For closed end diesels, this stroke corresponds to the theoretical uplift point. This stroke value is the file stroke which may be overridden by computed or user specified values.
STROKE	The actual stroke analyzed. For diesels this stroke is analyzed at least in the very first trial depending on the stroke option.
EFFICIENCY	The hammer efficiency, either from the hammer data file or from the override values.
RTD PRESS.	The rated pressure of double acting ECH.
MAX PRESS.	The maximum pressure (P1) for diesels.
ACT PRESS.	The pressure actually used for any type of hammer except single acting ECH where pressure is not used. For diesels this may only be a starting value depending on the stroke option.
EFF. AREA	The effective piston area for double acting ECH; the computation of a reduced energy is based on this area and the actual pressure for double acting ECH.
IMPACT VEL.	For ECH only, the velocity of the ram at time of impact. This is the most important value for ECH performance as it encompasses the effects of effiency, stroke and actual pressure.

Heading	Description
TIME DELAY	For diesels with liquid fuel injection, the combustion delay from file or override values.
IGN DURATION	For diesels with liquid fuel injection, the ignition duration.
V START INJ.	For diesels only. The volume at which atomized injection starts. If this value is zero than a hammer with liquid fuel injection is analyzed.
REACTN WEIGHT	For closed end diesel hammers the reaction weight that the cylinder and attachments provide against the bounce chamber pressure. WEAP86 reduces the combustion pressure when uplift occurs, i.e., when the bounce chamber pressure times ram top area exceeds the reaction weight.
MAX ENERGY	WEAP86 computes the energy which ram weight and bounce chamber pressures contain when uplift is imminent and prints it under this heading for closed end diesels.
MAX STR CPT	For closed end diesels MAX ENERGY divided by the ram weight yields a maximum equivalent stroke. This stroke is used by WEAP86 even though a different one may have been given in the hammer data file.
EQU. STROKE	The actual "equivalent" stroke analyzed by WEAP86 at least in the first trial analysis of a closed end diesel. This equivalent stroke may have been a user input (STROOV) and corresponds to STROKE (see above) which is the corresponding actual stroke.
C TANK VOL	The compression tank volume of closed end diesels.
Debug I B WEIGHT	Impact block weight (diesels).
Debug I B DIA	Impact block diameter (diesels).
Debug I B LENGTH	Impact block length (diesels).
Debug RAM DIAMTR	Ram diameter (diesels).

Heading		Description
Debug	COMP. STRKE	Compressive stroke (diesels).
Debug	CYL AREA	Cylinder Area of the diesel combustion chamber.
Debug	EXP COEFF	Expansion coefficient of diesel combustion.
Debug	CHAMBR VOL.	The combustion chamber or final volume of diesels.
Debug	V END COMB.	The combustion chamber volume after impact when atomized injection ends.
Debug	DIST B-PORTS	The distance between bounce chamber ports and top of ram of closed end diesels.
Debug	TOTAL DIST	The ram travel distance from contact with impact block to contact with cylinder top of closed end diesels.
Debug	SAFETY DIST	The distance between compression tank ports and top of cylinder.
Debug	B CH AREA	The cross sectional area of the top of the ram for closed end diesels.
Debug	B C EXP	The expansion coefficient of the air in the bounce chamber.
	HAMMER CUSHION	A summary of the raw hammer cushion data including the STIFFNESS which may have been directly entered or computed from AREA x E MODULUS / THICKNESS. If no HAMMER CUSHION data is printed, neither THICKNESS nor STIFFNESS were given as an input and no HAMMER CUSHION is included in the model.
	PILE CUSHION	As for HAMMER CUSHION.

Heading	Description
PILE PROFILE	A listing of the pile properties vs depth.
L BT	Length below top at which a change of pile cross sectional properties is indicated.
AREA	The cross sectional area of the pile at L BT.
E-MOD	The pile elastic modulus at L BT.
SP.W.	The pile specific weight at L BT.
WAVE SP	The wave speed at L BT, computed from E-MOD and SP.W.
EA/C	The pile impedance at L BT, computed from E-MOD, AREA, and Wave SP.
WAVE TRAVEL TIME - 2L/C	The time required for the stress wave to travel from pile top to bottom and to return to the top. Computed from the pile length and WAVE SP.
PILE AND SOIL MODEL FOR RULT = xxx	The following table is a summary of the pile and soil model parameters as they were setup for the first ultimate capacity (R_{ut}) to be analyzed. Note that only the SOIL-S column would change for later analyses. For the sake of brevity, repetitive lines showing only changes in L BT are omitted in the printout.
NO.	Indicates pile segment numbers; the soil model also the pile TOE.
WEIGHT	The weight of the pile segment.
STIFFN	The stiffness of the spring of a pile segment. This spring is located on top of the corresponding segment mass. If there is a pile cushion present, then its spring is combined with the first pile top spring. The combined stiffness is not shown.
D-NL	The round-out deformation of a spring. This value is only used in the computation of the pile top spring and if the corresponding SPLICE value is greater than zero.

Heading	Description
SPLICE	The slack of a splice; it is only used if it is greater than zero. The pile top is an exception as it has an unlimited extension with zero tension force and a printed SPLICE value of zero.
COR	The coefficient of restitution of a non-linear spring. This value only enters the calculations if SPLICE is greater than zero or for the pile top.
SOIL-S	The ultimate static soil resistance at the pile segments (skin) and at the toe.
SOIL-D	The soil damping parameters at the pile segments (skin) and at the toe. The dimension indicates the type of damping used. For Case damping the tabulated values are the distributed viscous factors.
QUAKE	The soil quake values at skin and toe.
L BT	The length below pile top for the bottom of the corresponding pile segment.
AREA	The cross sectional area of the pile of a segment. This may be an average value if the cross section changes somewhere along the segment. The AREA value is used for stress computations.
<u>PILE OPTIONS</u>	This is a summary of options which affect the pile model generation.
N/UNIFORM	The NCROSS or pile uniformity option.
AUTO S.G.	The IPEL option or pile segment generation option.
SPLICES	The ISPL or number of splices/slacks option.
DAMPNG-P	The pile damping option utilized in the computation of the D-P VALUE.
D-P VALUE	The dashpot parameter for the dashpots between the pile segments. This value is identical for all segments.

Heading	Description
SOIL OPTIONS	The options utilized in the generation of the soil model.
% SKIN FR	The percentage of skin friction; see also note.*
% END BG	The percentage of end bearing, i.e., 100 - % SKIN FR. See also note.*
DIS. NO.	The soil frictional distribution option, ITYS.
S DAMPING	The soil damping type either SMITH-1, i.e., the standard, SMITH-2, i.e., Smith damping with R_u rather than the variable R_s as a multiplier, or VISCOUS, i.e., damping constants which are independent of the static soil resistance.
	*Note: depending on the skin friction option IPERCS, the following may be printed:
CONSTANT SKIN FRICTION ANALYSES	If IPERCS was entered with a minus sign, then this message is printed as part of the SOIL OPTIONS and the % SKIN FR, % END BG printout pertains only to the first RULT.
CONSTANT END BEARING ANALYSIS	If IPERCS was entered greater 100, then this message is printed as part of the SOIL OPTIONS and the % SKIN FR, % END BG printout pertains only to the first RULT.
ANALYSIS/OUTPUT OPTIONS	The options affecting the analysis and the output are printed here.
ITERATNS	The maximum number of predictor/corrector iterations after the first one, allowed in the integration process (ITER).
DTCR/DT(%)	The ratio of critical to computational time increment (IPHI).
RES STRESS	The residual stress option IRSAO which is active if printed as 1.
IOUT	The output option.
AUTO SGMNT	The IJJ option for the generation of output segment numbers.

Headings	Description
OUTPT INCR	The number of time intervals between individual lines in the variable vs time output computed by the program.
MAX T(MS)	The maximum analysis time option IMAXT.

6.2 Result Printout

6.2.1 Variable vs Time Printout

This is part of the extensive output options. Two types of tables are printed. The first with only one type of quantity like forces (IOUT = 1,...,5), the second with a mixed table.

Heading	Description
RULT = xxx, RTOE = xxx	A heading identifying the current total and end bearing capacity.
HAMMER AND PILE FORCES H.. AND P.. VELOCITIES H... AND P... STRESSES H. AND P. ACCELERATIONS H. AND P. DISPLACEMENTS	If the output option was set to 1, ...,5 then for each ultimate capacity analyzed, several pages of tables will be printed. Depending on the value of the output option, IOUT, the headings on the left will occur. Furthermore, the following subheadings are printed for further clarification.
JP	The time counter which multiplied by the individual analysis time increment yields the analysis time.
TIME	The analysis time corresponding to JP.
RAM BT	The variable is computed for the bottom ram segment. If there is only one ram segment then either forces or stresses cannot be computed for the ram (there is no spring in the ram, the first spring is the hammer cushion or impact block). Stresses in the ram bottom are computed using the "ram diameter" given in the hammer strinput data. Note that this may be an averaged value.

Heading	Description
H CUSH	The variable is computed for the hammer cushion spring (forces, stresses) or for the helmet mass (motion variables). Stresses in the hammer cushion utilize the hammer cushion area. However, if the stiffness of this cushion was directly entered, and if the program therefore has no hammer cushion area for stress computations, then the defaults discussed in Chapter 3, hammer cushion input, are applicable.
P TOP	The variable is computed for the (nonlinear) pile top spring or the first pile mass.
PILE ELEMENTS	... refer to the pile model. The individual numbers reflect either the automatically generated or user specified pile segment numbers (IJJ option). However, for 80 column printers a truncation of this table usually occurs.

Mixed Variable Table — For output option 6.

Heading	Description
J	Identical to JP (see above).
TIME	See above.
F AS	Assembly bottom spring force for ECH.
P	Pressure in combustion chamber for diesels.
D RAM	Displacement of ram.
D HEL	Displacement of helmet.
FTOP	Force at the pile top.
VTOP	Velocity of the pile top segment.
DTOP	Displacement of the pile top segment.
FMID, VMID, DMID	Force, Velocity, Displacement at middle of pile.

Heading	Description
FTOE, VTOE, DTOE	Force, Velocity, Displacement at bottom of pile.
SUM ST	Sum of all simultaneously occurring static soil resistance forces.
SUM DP	Sum of all simultaneously occurring soil damping forces.
RT TOE	Sum of static and damping resistance force at pile toe, i.e., total toe resistance.

6.2.2 Extrema Tables

The following is always printed except for the case of the IOUT = -100 option. It is an important output for result checking, particularly for composite material piles where the maximum stress may occur, say in the steel, although the much lower concrete stress may be critical.

Heading	Description
RULT = xxx, RTOE = xxx, DEL T = xxx	Heading of the extrema table includes the analysis time increment which may change from R_{ut} to R_{ut}. The time increment is needed to convert the JMN, JMX, etc values to actual times.
NO.	The pile segment for which the extreme values are listed.
FMIN	The minimum segment force. Negative values indicate tension. The maximum is zero.
JMN	The time interval at which the minimum force occurred.
FMAX	The maximum compressive force.
JMX	The time interval at which the maximum force occurred.
STRMIN	The minimum stress; negative values indicate tension; maxima are zero.
JSN	The time interval at which the minimum stress occurred.

Heading	Description
STRMAX	The maximum compressive stress.
JSX	The time interval at which the maximum stress occurred.
VMAX	The maximum velocity.
JVX	The time interval at which the maximum velocity occurred.
DMAX	The maximum displacement. Note that in particular the maximum pile toe displacement is of interest since it is used for the calculation of the blow count.
JDX	The time interval at which the maximum displacement occurred.

6.2.3 Final Residual Pile/Soil Quantities

If a residual stress analysis was performed then additional output is made at the end of each individual R_{ut} analysis following the extrema table. This output indicates the final state of soil and pile stresses. There are the same values that are used as initial values for the next RSA analysis.

6.2.4 Debug Output: Variable vs. Time

For a negative output option, except IOUT = -100, WEAP86 generates output in analysis time, intervals of approximately 1 ms. This output includes all major variables. Since printout will be made for all trial analyses of diesels or RSA iterations, extremely long outputs must be expected. Dimensions are in kips (kN) and ft (m).

Heading	Description
PO	Reference combustion chamber pressure (diesels).
VO	Reference volume (diesels).
IIGN	Ignition flag (diesels).
IADIA	Adiabatic pressure computation flag (diesels).
TNOW	Current time start.

Heading	Description
TIGN	Time of ignition (diesels).
TCOM	Time of completed ignition (diesels).
IPR	Combustion chamber pressure converted to force (diesels).
FH	Hammer force, in ram and driving system.
VH	Ram and driving system velocities.
DH	Ram and driving system displacements.
FP	Pile forces.
VP	Pile velocities.
DP	Pile displacements.
RES	Static resistance values.

6.2.5 Summary Table

Under all options the final summary is printed. It contains the data necessary to plot a bearing graph.

Heading	Description
RULT	The total ultimate static bearing capacity, R_{ut}.
BL CT	The computed blow count.
STROKE (EQ.)	The real or equivalent stroke of ECH.
STROKE DOWN	The diesel downstroke analyzed. Note that it is the real stroke of closed end diesels.
STROKE UP	The return stroke resulting in the analysis of open end diesels.
BCP	The maximum bounce chamber pressure of closed end diesel hammers occurring during the upstroke of closed end diesels. This is the actual bounce chamber pressure. Gauge readings may be lower depending on the hose length.

Heading	Description
MINSTR I,J	The minimum stress (tension if negative) in the pile with an indication where (segment number I) and when (time interval J) it occurred.
MAXSTR I, J	The maximum compressive stress in the pile with segment, I, and time interval, J.
ENTHRU	The maximum transferred energy at the pile top.
BL RT	The blow rate (speed of hammer) of diesel hammers.
NO.	Pile segment number.
P-FORCE	The force remaining in the pile at the end of the residual stress analysis (RSA).
P-STRESS	The stress remaining in the pile at the end of the RSA.
S-RESIS	The soil resistance forces at the end of the RSA.
DISPL.	The final pile displacements. Note, that at the beginning of each RSA trial, the pile top displacement (segment No. 1) is subtracted from the final displacements of all segments. Thus, the permanent set of the pile is equal to the pile top displacement listed in this table. The starting displacement of any other segment was neither the value printed nor zero but, equal to the value printed minus the final pile top displacement.

7. WAVE EQUATION EXAMPLES

7.1 Open End Diesel Hammer - Generation of Bearing Graph

7.1.1 Situation

A 45 ton design-load pile is to be driven through a soft compressible layer into a dense, coarse sand with gravel. The contractor wants to use an HP 10x53 profile of 40-ft length and a Delmag D-12 hammer. He uses a standard 12-by 12-in helmet with 2-in of Conbest.

7.1.2 Problem

Determine the blow count/bearing capacity relation.

7.1.3 Approach

Since extensive static and dynamic testing will be performed at the site, a safety factor of 2 is sufficient. A safety factor of 3 may otherwise be appropriate. Using a safety factor of 2, the pile has to be driven to an ultimate capacity of 90 tons. A curve can be constructed for the desired range if capacities of 60, 120, 180 and 240 kips are analyzed.

7.1.4 Solution

The short input form is sufficient for solving this problem.

Card	ID		Data Explanation
1.000	TITLE		Insert a descriptive title of up to 40 characters.
2.000	ANALYSIS OPTIONS		
		IOUT/0	for only a printed summary, but a bearing graph plot. This option corresponds to IOUT=0 and can only be used when a plotter is available.
	IJJ	0	Default is satisfactory.
	IHAMR	3	For DELMAG D-12 (see Table 1).
	IOSTR	0	Leave it blank (stroke iteration allowed).
	IFUEL	0	Full combustion pressure.
	IPEL	0	Computer determines pile segment properties.
	N	8	For 40-ft pile and 5-ft segments (may also be automatically determined).
	ISPL	0	No splices or slacks.
	NCROSS	0	Uniform pile.
	IBEDAM	0	Steel.
	IPERCS	10	For 10 percent skin friction.
	ISMITH	0	Standard Smith damping.
	ITYS	1	For skin resistance distribution type 1 of Figure 1 (triangle over 100 percent of pile).

IPHI	0	Normal.
IRSAO	0	No residual force analysis.
ITER	0	Normal.
IDAHA	0	Normal.
IMAXT	0	Normal.

3.000 HELMET AND HAMMER CUSHION INFORMATION

HELMET WEIGHT	2.15	(kips) as per Table 2b.
AREA	283.5	(in^2) as per Table 2b.
EL. MODULUS	280.0	(ksi) as per table 2b..
THICKNESS	2.0	(in) as per Table 2b.
C.O.R.	0.8	As per Table 2b.
ROUND-OUT	0.0	For default value of 0.01 (ft).
STIFFNESS	0.0	Stiffness to be computed from EA/t.

4.000 PILE CUSHION INFORMATION

This is not a concrete pile; all data is zero

5.000 PILE TOP INFORMATION

TOTAL LENGTH	40.0	(ft).
AREA	15.5	(in^2) as per Table 4a.
EL. MODULUS	30000.0	(ksi)1 steel.
SP. WEIGHT	492.0	(lb/ft^3) steel.
C.O.R.	0.8	Coefficient of restitution, pile top.
ROUND OUT	0.01	This is equivalent to default.

5.101, ... Do not insert since NCROSS = 0.

7.000 HAMMER OVERRIDE VALUES

All data is zero for normal hammer performance.

8.000 SOIL PARAMETERS

QUAKE-SKIN	0.1	(in) as per Table 5 (standard).
QUAKE-TOE	0.1	(in) as per Table 5 (standard).
DAMPING-SKIN	0.05	(s/ft) for cohesionless soil as per Table 5.
DAMPING-TOE	0.15	(s/ft) for cohesionless soil as per Table 5.

8.401, ... Do not insert since ITYS=1.

9.100 ULTIMATE CAPACITIES

60.0, 120.0, 180.0, 240.0 (kips) as discussed before.

The input form is shown in Form 1. The output is shown in Form 2. The bearing graph data was also plotted as shown in Figure 6.

7.1.5 Discussion of Results

It can be concluded that a design load of 45 tons (180 kips with a safety factor = 2) requires a blow count of 42 blows/ft. The stroke should at this time be 5.3 ft. Then the maximum compressive stress would be 21.3 ksi.

WEAP86 - Short Input Form

1.000 TITLE (40 Characters)

EXAMPLE 1, 45 TON DESIGN, HP 10X53, D-12

ANALYSIS OPTIONS

	IOUT	IJJ	IHAMR	IOSTR	IFUEL	IPEL	N	ISPL	NCRSS	IDDAM	IPTCS	ISMIH	ITYS	IPIH	IRSAO	IIER	IDAHA	MAXT
2.000	10		3				8				10		1					

HELMET AND HAMMER CUSHION INFORMATION

	HELMET WEIGHT KIPS	HAMMER CUSHION AREA SQ IN	ELASTIC MODULUS KSI	THICKNESS IN	C.O.R.	ROUND OUT FEET	STIFFNESS* KIPS/IN
3.000	2.15	283.5	280.	2.	.8		

PILE CUSHION INFORMATION

	AREA SQ IN	ELASTIC MODULUS KSI	THICKNESS IN	C.O.R.	ROUND OUT FEET	STIFFNESS* KIPS/IN
4.000						

* OVERRIDES AREA (EL. MOD.) / THICKN.

PILE TOP INFORMATION

	TOTAL LENGTH FEET	AREA SQ IN	ELASTIC MODULUS KSI	SPECIFIC WEIGHT LBS/CU FT	C.O.R.	ROUND OUT
5.000	40.	15.5	30000.	492.	.8	.01

NCRSS > 0: NON-UNIFORM PILE PROFILE

	DEPTH FEET	AREA SQ IN	ELASTIC MODULUS KSI	SPECIFIC WEIGHT LBS/CU FT
5.101				
5.102				
5.103				
5.104				
⋮				
5.120				

Column scale: 10 20 30 40 50 60 70 80

FORM 1: INPUT, EXAMPLE 1

NOTE: THERE IS NO CARD NUMBER 6.000

HAMMER OVERRIDE VALUES

Card	STROKE FEET	EFFICIENCY	PRESSURE PSI	REACTION WEIGHT* KIPS	COMB DELAY+ SECONDS -or- IGNITION VOL++ CU IN
7.000					

* FOR DOUBLE ACTING HAMMERS ONLY

\+ FOR DIESELS WITH LIQUID FUEL INJECTION ONLY

++ FOR DIESELS WITH ATOMIZED FUEL INJECTION ONLY

SOIL PARAMETERS

Card	QUAKE-SKIN IN	QUAKE-TOE IN	DAMPING-SKIN SEC/FT**	DAMPING-TOE SEC/FT**
8.000	.1	.1	.05	.15

**ISMITH = -1: DIMENSIONLESS (CASE)
0:, 1: S/FT (STANDARD SMITH)
2: S/FT (VISCOUS SMITH)

ITYS = -1 or 0: SKIN FRICTION DISTRIBUTION

Card	DEPTH FEET	RELATIVE DISTRIBUTION
8.401		
8.402		
8.403		
8.404		
⋮		
8.420		

ULTIMATE CAPACITIES

KIPS (Give up to 10 capacities)

Card								
9.000	60.	120.	180.	240.				
10.000								

Columns: 10, 20, 30, 40, 50, 60, 70, 80

FORM 1, continued

```
WEAP86: WAVE EQUATION ANALYSIS OF PILE FOUNDATIONS
          1986, VERSION 1.001

    EXAMPLE 1, 45 TON DESIGN, HP 10X53, D-12

     HAMMER MODEL OF: D 12      MADE BY: DELMAG

ELEMENT     WEIGHT  STIFFNESS  COEFF. OF    D-NL.    CAP DAMPG
            (KIPS)   (K/IN)   RESTITUTION    FT      (K/FT/S)
        1     .917
        2     .917   91278.2     1.000      .0100
        3     .917   91278.2     1.000      .0100
IMP. BLK      .810   56654.1      .900      .0100
CAP/RAM      2.150   39690.0      .800      .0100        5.6

HAMMER OPTIONS:
 HAMMER NO. FUEL SETTG. STROKE OPT. HAMMER TYPE DAMPNG-HAMR
    3          1           0           1           2

HAMMER PERFORMANCE DATA
 RAM WEIGHT  RAM LENGTH   MAX STROKE     STROKE    EFFICIENCY
   (KIPS)       (IN)         (FT)         (FT)
     2.75      104.41        8.58         5.35        .800

MAX PRESS.    ACT PRESS.  TIME DELAY  IGN DURATN V START INJ.
  (PSI)         (PSI)         (S)         (S)        (IN3)
  1408.0        1408.0      .00200      .00200         .0

THE HAMMER DATA INCLUDES ESTIMATED (NON-MEASURED) QUANTITIES


 HAMMER CUSHION     AREA   E-MODULUS    THICKNESS   STIFFNESS
                   (IN2)     (KSI)         (IN)     (KIPS/IN)
                  283.50     280.0        2.000      39690.0


PILE PROFILE:
   LBT     AREA    E-MOD      SP.W.    WAVE SP      EA/C
  (FT)    (IN2)    (KSI)    (LB/FT3)    (FT/S)    (K/FT/S)

    .00    15.5    30000.    492.000   16806.8      27.7
  40.00    15.5    30000.    492.000   16806.8      27.7

         WAVE TRAVEL TIME - 2L/C - =    4.760 MS
```

```
                PILE AND SOIL MODEL FOR RULT =     60.0 KIPS

NO  WEIGHT   STIFFN  D-NL  SPLICE    COR  SOIL-S SOIL-D  QUAKE   L BT   AREA
    (KIPS)   (K/IN)  (FT)   (FT)         (KIPS) (S/FT)   (IN)   (FT) (IN**2)
 1    .265    7750.  .010    .000   .800     .1   .050   .100   5.00   15.5
 2    .265    7750.  .010 -1.000  1.000     .3   .050   .100  10.00   15.5
 3    .265    7750.  .010 -1.000  1.000     .5   .050   .100  15.00   15.5
 4    .265    7750.  .010 -1.000  1.000     .7   .050   .100  20.00   15.5
 5    .265    7750.  .010 -1.000  1.000     .8   .050   .100  25.00   15.5
 6    .265    7750.  .010 -1.000  1.000    1.0   .050   .100  30.00   15.5
 7    .265    7750.  .010 -1.000  1.000    1.2   .050   .100  35.00   15.5
 8    .265    7750.  .010 -1.000  1.000    1.4   .050   .100  40.00   15.5
TOE                                       54.0   .150   .100

    PILE OPTIONS:
    N/UNIFORM  AUTO S.G.  SPLICES  DAMPNG-P   D-P VALUE
                                               (K/FT/S)
       0          0          0         1         .553
    SOIL OPTIONS:
     % SKIN FR  % END BG   DIS. NO.  S DAMPING
        10         90         1       SMITH-1

   ANALYSIS/OUTPUT OPTIONS:
   ITERATNS  DTCR/DT(%)  RES STRESS   IOUT  AUTO SOMNT OUTPT INCR  MAX T(MS)
      0         160          0         10       0          2           0

             RULT =    60.0, RTOE =   54.0 KIPS, DEL T = .101 MS
NO.   FMIN,JMN    FMAX,JMX  STRMIN,JSN STRMAX,JSX   VMAX,JVX  DMAX,JDX
        (K)         (K)       (KSI)      (KSI)       (F/S)      (IN)
 1     .0,  0    198.2, 46    .00,  0   12.78, 46    7.4, 48 1.210,290
 2     .0,  0    196.5, 49    .00,  0   12.68, 49    7.5, 51 1.205,290
 3     .0,  0    196.0, 53    .00,  0   12.64, 53    7.6, 88 1.200,290
 4     .0,  0    196.7, 56    .00,  0   12.69, 56    8.0, 84 1.194,291
 5     .0,  0    198.9, 59    .00,  0   12.83, 59    8.1, 82 1.188,291
 6     .0,  0    201.4, 62    .00,  0   12.99, 62    7.9, 79 1.182,293
 7     .0,  0    196.0, 65    .00,  0   12.64, 65    8.2, 72 1.175,295
 8     .0,  0    169.3, 66    .00,  0   10.92, 66    9.5, 71 1.168,296

  STROKES ANALYZED AND LAST RETURN (FT):
    5.35  3.62  4.08  3.95  3.93

             RULT =   120.0, RTOE =  108.0 KIPS, DEL T = .101 MS
NO.   FMIN,JMN    FMAX,JMX  STRMIN,JSN STRMAX,JSX   VMAX,JVX  DMAX,JDX
        (K)         (K)       (KSI)      (KSI)       (F/S)      (IN)
 1     .0,  0    254.3, 45    .00,  0   16.41, 45    8.7, 46  .649,163
 2     .0,  0    252.8, 48    .00,  0   16.31, 48    8.9, 50  .636,164
 3     .0,  0    251.0, 51    .00,  0   16.19, 51    8.9, 53  .623,166
 4     .0,  0    251.9, 55    .00,  0   16.25, 55    8.8, 56  .610,168
 5   -.1,268     257.0, 58  -.01,268    16.58, 58    8.5, 59  .596,169
 6  -1.2,268     261.6, 61  -.08,268    16.88, 61    8.3, 62  .582,171
 7  -2.4,268     259.4, 64  -.15,268    16.73, 64    8.4, 65  .568,173
 8  -2.2,268     260.3, 67  -.15,268    16.79, 67    8.3, 70  .554,175

  STROKES ANALYZED AND LAST RETURN (FT):
    4.72  4.80
```

FORM 2: OUTPUT, EXAMPLE 1

RULT = 180.0, RTOE = 162.0 KIPS, DEL T = .101 MS

NO.	FMIN,JMN (K)	FMAX,JMX (K)	STRMIN,JSN (KSI)	STRMAX,JSX (KSI)	VMAX,JVX (F/S)	DMAX,JDX (IN)
1	.0, 0	286.1, 44	.00, 0	18.46, 44	9.8, 46	.537,122
2	-2.6,218	286.1, 47	-.17,218	18.45, 47	9.9, 49	.515,123
3	-5.5,218	284.6, 51	-.35,218	18.36, 51	10.0, 52	.492,126
4	-7.5,218	285.1, 54	-.48,218	18.40, 54	9.8, 55	.470,130
5	-8.1,218	288.6, 57	-.52,218	18.62, 57	9.5, 58	.449,133
6	-7.9,218	293.3, 60	-.51,218	18.92, 60	9.2, 62	.428,135
7	-7.1,218	294.0, 63	-.46,218	18.97, 63	9.0, 64	.407,138
8	-4.2,217	329.8, 69	-.27,217	21.27, 69	7.3, 65	.386,141

STROKES ANALYZED AND LAST RETURN (FT):
5.10 5.34 5.29

RULT = 240.0, RTOE = 216.0 KIPS, DEL T = .101 MS

NO.	FMIN,JMN (K)	FMAX,JMX (K)	STRMIN,JSN (KSI)	STRMAX,JSX (KSI)	VMAX,JVX (F/S)	DMAX,JDX (IN)
1	.0, 0	343.3, 95	.00, 0	22.15, 95	10.4, 45	.497,110
2	-13.8,200	320.9, 98	-.89,200	20.70, 98	10.4, 48	.464,110
3	-24.4,201	327.8,101	-1.58,201	21.15,101	10.3, 51	.432,115
4	-29.6,200	320.6,104	-1.91,200	20.69,104	10.1, 55	.401,116
5	-29.6,198	332.3, 81	-1.91,198	21.44, 81	9.8, 58	.369,119
6	-25.2,196	331.2, 78	-1.62,196	21.36, 78	9.4, 61	.338,122
7	-17.9,193	332.8, 74	-1.16,193	21.47, 74	8.9, 63	.307,125
8	-8.8,193	377.6, 69	-.57,193	24.36, 69	6.6, 64	.279,129

STROKES ANALYZED AND LAST RETURN (FT):
5.66 5.70

R ULT KIPS	BL CT BPF	STROKE (FT) DOWN	UP	MINSTR KSI	I,J	MAXSTR KSI	I,J	ENTHRU FT-KIP	BL RT BPM
60.0	11.2	4.0	3.9	.00	(1, 0)	12.99	(6, 62)	9.7	59.4
120.0	26.4	4.7	4.8	-.15	(7,268)	16.88	(6, 61)	8.8	54.0
180.0	42.0	5.3	5.3	-.52	(5,218)	21.27	(8, 69)	9.1	51.2
240.0	67.1	5.7	5.7	-1.91	(5,198)	24.36	(8, 69)	9.0	49.6

FORM 2, continued

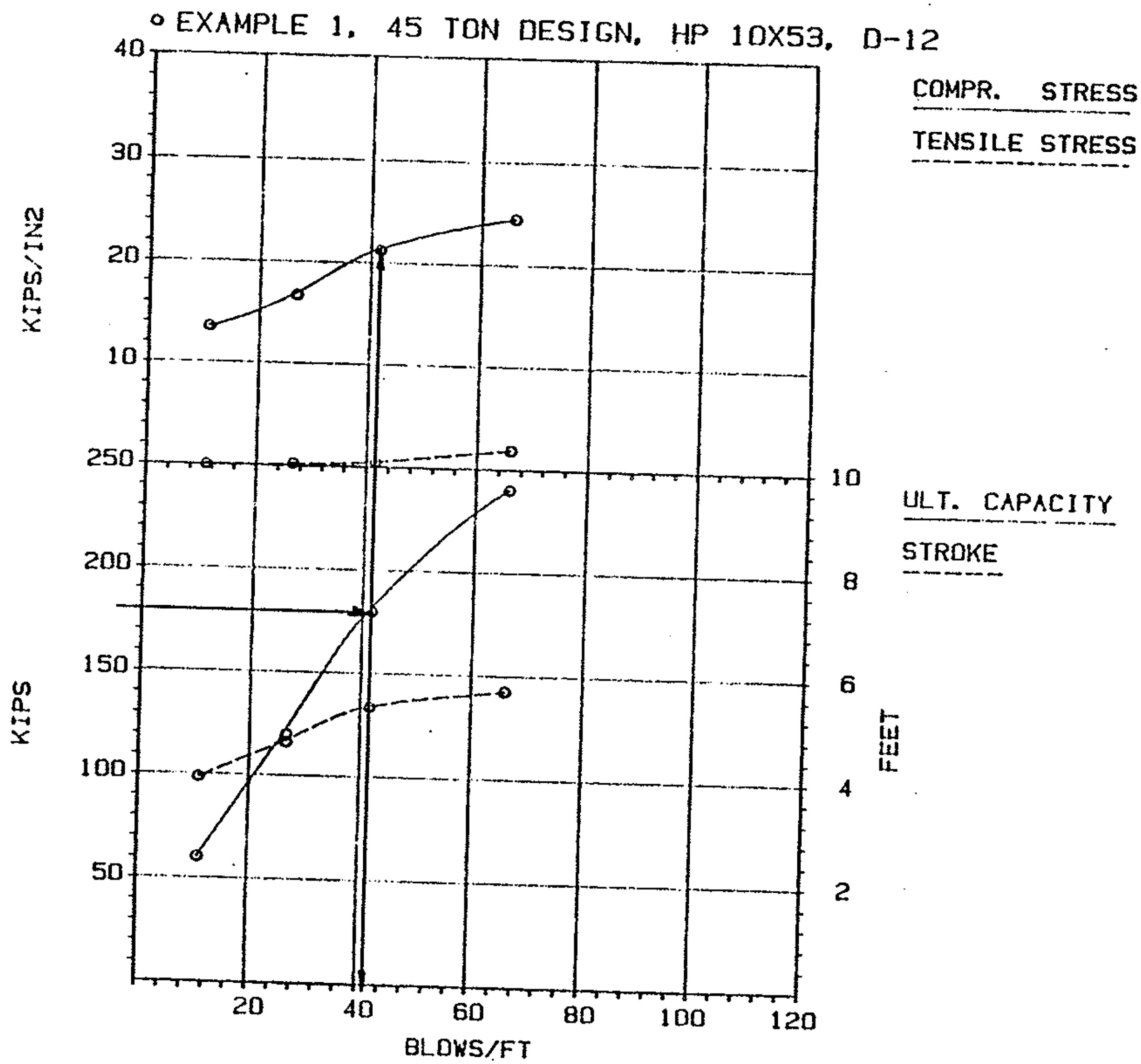


Figure 6. WEAP86 results, example 1.

7.2 Closed End Hammer - Driveability Study

7.2.1 Situation

A step tapered pipe pile (20.4 ft of 14-in O.D., .203-in wall, 23 ft of 11.5-in O.D., .219-in wall, the rest 10 in O.D., .219-in wall) of 79-ft length with an additional 11-in diameter toe plate of 1-in thickness is to be driven to a depth of 74 ft. The soil consists of silty clay and clayey silt with some sand. A 240-kip ultimate capacity is anticipated. However, it is also expected that driving is much easier due to loss of soil resistance during driving. Dynamic measurements were taken at a neighboring site during pile driving. These measurements were evaluated by dynamic analysis. From this experience Case damping values are known and may be used instead of the common Smith damping values.

7.2.2 Problem

The contractor, who must drive the pile to penetration, wants to use an LB-520 hammer. He is not sure, however, whether this hammer will do the job and he is worried about the driving stresses in this relatively thin-walled pile. He would also like to know if an interruption would affect the driveability. (The contractor supplied the following data: helmet weight 450-lb, stiffness 10,000 kips/in).

7.2.3 Solution

First, a sketch of the pile geometry is made on page 1 of the short input form. Similarly, a sketch is made of an assumed skin friction distribution (for both adhesion and friction) on page 2 of the short input form.

Card No.	ID	Data	Explanation
2.000	IOUT	1	It was decided to print forces as a function of time.
	N	16	To segments of nearly 5-ft length.
	IHAMR	134	From Table 1.
	NCROSS	1	Nonuniform pile.
	IPERCS	70	Percentage of skin friction.
	ISMITH	-1	For Case (viscous) damping.
3.000	HELMET WEIGHT	.45	As given.
	C.O.R.	.85	Assumed.
	STIFFNESS	10000.0	As given; area, el. modulus and thickness are now not needed; Round-Out is at default.
4.000	PILE CUSHION		Leave blank, steel pile without pile cushion. (C.O.R. and Round Out data may also be left blank).

5.000 PILE TOP INFORMATION

TOTAL LENGTH	79.08	The pile length includes the toe plate.
AREA	8.80	Computed from (14-.203)(3.1416)(.203).
EL. MODULUS	29000.	As per factory information.
SP. WEIGHT	492.	Standard steel specific weight.
C.O.R.	.85	Assumption for steel pile top.

5.101,.. NONUNIFORM PILE... There were three points of discontinuity which had to be described at depths of 20.4, 43.4 and 79.0 feet. Also, the cross sectional area of the end plate had to be given for the pile bottom. Thus, seven cards (lines) were necessary. See Form 3. Note that repetitive depth, area, modeling, or specific weight values actually need not be repeated.

7.00 HAMMER OVERRIDE VALUES No input was needed.

8.000 SOIL PARAMETERS Of interest on this card is primarily the damping input and because Case damping (ISMITH = -1) values from local experience were chosen as (2.0 and .8 for skin and toe, respectively.

Note: It is interesting to make a comparison of the Case damping values with the corresponding Smith parameters. The average pile impedance (EA/c) is about 14 kips/ft/s (using 8 $inch^2$ as an average steel area). Thus, the total skin viscous damping constant is 14 x 2 = 28 kips/ft/s. The static skin resistance at 240 kips ultimate is 0.7 x 240 = 168 kips because of the 70 percent IPERCS input on Card 2.000. Thus, the corresponding Smith damping parameter is 28/168 = .17 s/ft (somewhat less than the recommended 0.2 s/ft for cohesive, but much more than the 0.05 s/ft for noncohesive soils). The toe damping constant used here corresponds to about 0.17 s/ft.

6.401,.. SKIN FRICTION DISTRIBUTION A trapezoidal distribution was chosen assuming that the pile top was 5 ft above grade and that the skin friction would be twice as high at the bottom as it was at 10 ft below the pile top.

9.000 ULT. CAPACITIES The capacities to be investigated are 240 and 320 kips.

The two pages of input are shown in Form 3. The output is reproduced in Form 4.

7.2.4 Discussion of Results

The important results can be found in the summary, the last page of Form 4. It is found there that the blow count for R_{ut} = 240 kips is 265 blows per ft, more than 20 blows per inch. At segment 1, pile top, a stress of 31 ksi occurred which is high but tolerable for steel with a 36 ksi yield strength, if good hammer-pile alignment is maintained. For R_{ut} = 320 kips no permanent set resulted.

It must be concluded that even if driving is not interrupted and therefore, no soil setup occurs during the driving process, the blow count is too high to be economical. The danger of yielding in the pile, which will be greatest at the point of cross sectional change, is not great as long as the pile penetrates. The step tapered pile of this example is very flexible and therefore lends itself to an investigation by the residual stress method. Example 9 will demonstrate the advantages of this method.

A recommendation based on these results would be to increase the wall thickness rather than the hammer size. A pipe pile with greater wall thickness will, in general, drive easier than the more flexible one, even if hammer and hammer cushion are not changed.

WEAP86 - Short Input Form

1.000 TITLE (40 Characters)

EXAMPLE 2, DRIVABILITY STUDY, HB-520

ANALYSIS OPTIONS

	IOUT	IJJ	IHAMR	IOSIN	IFUEL	IPEL	N	ISPL	NCRSS	IDAM	IPRCS	ISMH	ITYS	IPHI	IISAO	IIER	IDAHA	IMAXT
2.000	1		134				16		1		70	1						

HELMET AND HAMMER CUSHION INFORMATION

	HELMET WEIGHT KIPS	HAMMER CUSHION AREA SQ IN	HAMMER CUSHION ELASTIC MODULUS KSI	HAMMER CUSHION THICKNESS IN	HAMMER CUSHION C.O.R.	HAMMER CUSHION ROUND OUT FEET	HAMMER CUSHION STIFFNESS* KIPS/IN
3.000	45				.85		10000.

PILE CUSHION INFORMATION

	AREA SQ IN	ELASTIC MODULUS KSI	THICKNESS IN	C.O.R.	ROUND OUT FEET	STIFFNESS* KIPS/IN
4.000				1.	.01	

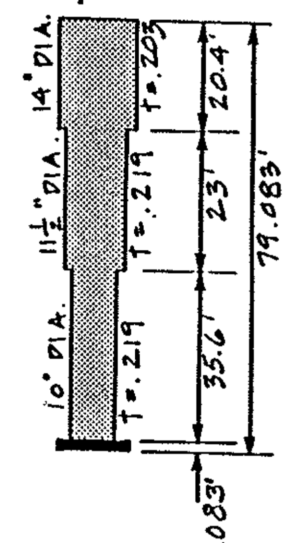
* OVERRIDES AREA (EL. MOD.) / THICKN.

PILE TOP INFORMATION

	TOTAL LENGTH FEET	AREA SQ IN	ELASTIC MODULUS KSI	SPECIFIC WEIGHT LBS/CU FT	C.O.R.	ROUND OUT
5.000	79.08	8.8	29000.	492.	.85	

NCRSS > 0: NON-UNIFORM PILE PROFILE

	DEPTH FEET	AREA SQ IN	ELASTIC MODULUS KSI	SPECIFIC WEIGHT LBS/CU FT
5.101	20.4	8.8	29000.	492.
5.102	20.4	7.76	29000.	492.
5.103	43.4	7.76	29000.	492.
5.104	43.4	6.73	29000.	492.
⋮	79.0	6.73	29000.	492.
⋮	79.0	95.00	29000.	492.
⋮	79.08	95.00	29000.	492.
5.120				



Column scale: 10 20 30 40 50 60 70 80

FORM 3: INPUT, EXAMPLE 2

NOTE: THERE IS NO CARD NUMBER 6.000

HAMMER OVERRIDE VALUES

Card	STROKE FEET	EFFICIENCY	PRESSURE PSI	REACTION WEIGHT* KIPS	COMB DELAY+ SECONDS -or- IGNITION VOL++ CU IN
7.000					

* FOR DOUBLE ACTING HAMMERS ONLY

\+ FOR DIESELS WITH LIQUID FUEL INJECTION ONLY

++ FOR DIESELS WITH ATOMIZED FUEL INJECTION ONLY

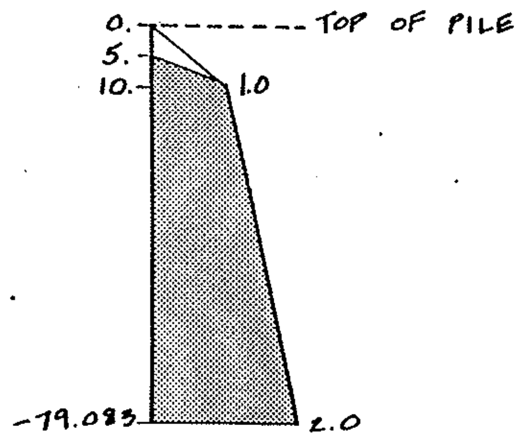
SOIL PARAMETERS

Card	QUAKE-SKIN IN	QUAKE-TOE IN	DAMPING-SKIN SEC/FT**	DAMPING-TOE SEC/FT**
8.000			2.	9

**ISMITH = -1: DIMENSIONLESS (CASE)
0:, 1: S/FT (STANDARD SMITH)
2: S/FT (VISCOUS SMITH)

IFYS = -1 or 0: SKIN FRICTION DISTRIBUTION

Card	DEPTH FEET	RELATIVE DISTRIBUTION
8.401	5.000	
8.402	10.000	1.
8.403	79.083	2.
8.404		
⋮		
8.420		



ULTIMATE CAPACITIES

Card	KIPS (Give up to 10 capacities)								
9.000	240.	320.							
10.000									

1 2 3 4 5 6 7 8 9 0 … 10 20 30 40 50 60 70 80

FORM 3, continued

WEAP86: WAVE EQUATION ANALYSIS OF PILE FOUNDATIONS
1986, VERSION 1.001

EXAMPLE 2, DRIVEABILITY STUDY, LB-520

HAMMER MODEL OF: LB 520 MADE BY: LINKBELT

ELEMENT	WEIGHT (KIPS)	STIFFNESS (K/IN)	COEFF. OF RESTITUTION	D-NL. FT	CAP DAMPG (K/FT/S)
1	1.690				
2	1.690	239284.6	1.000	.0100	
3	1.690	239284.6	1.000	.0100	
IMP. BLK	1.480	143547.5	.900	.0100	
CAP/RAM	.450	10000.0	.850	.0100	12.0

HAMMER OPTIONS:

HAMMER NO.	FUEL SETTG.	STROKE OPT.	HAMMER TYPE	DAMPNG-HAMR
134	1	0	2	2

HAMMER PERFORMANCE DATA

RAM WEIGHT (KIPS)	RAM LENGTH (IN)	MAX STROKE (FT)	STROKE (FT)	EFFICIENCY
5.07	80.50	3.80	2.66	.800

MAX PRESS. (PSI)	ACT PRESS. (PSI)	TIME DELAY (S)	IGN DURATN (S)	V START INJ. (IN3)
908.0	908.0	.00000	.00000	242.0

REACTN WGHT (KIPS)	MAX ENERGY (KIP-FT)	MAX STR CPT (FT)	EQU. STROKE (FT)	C TANK VOL (IN3)
6.30	27.56	3.79	3.31	8732.0

THE HAMMER DATA INCLUDES ESTIMATED (NON-MEASURED) QUANTITIES

HAMMER CUSHION	AREA (IN2)	E-MODULUS (KSI)	THICKNESS (IN)	STIFFNESS (KIPS/IN)
	.00	.0	.000	10000.0

PILE PROFILE:

LBT (FT)	AREA (IN2)	E-MOD (KSI)	SP.W. (LB/FT3)	WAVE SP (FT/S)	EA/C (K/FT/S)
.00	8.8	29000.	492.000	16524.3	15.4
20.40	8.8	29000.	492.000	16524.3	15.4
20.40	7.8	29000.	492.000	16524.3	13.6
43.40	7.8	29000.	492.000	16524.3	13.6
43.40	6.7	29000.	492.000	16524.3	11.8
79.00	6.7	29000.	492.000	16524.3	11.8
79.00	95.0	29000.	492.000	16524.3	166.7
79.08	95.0	29000.	492.000	16524.3	166.7

WAVE TRAVEL TIME - 2L/C - = 9.571 MS

PILE AND SOIL MODEL FOR RULT = 240.0 KIPS

NO	WEIGHT (KIPS)	STIFFN (K/IN)	D-NL (FT)	SPLICE (FT)	COR	SOIL-S (KIPS)	SOIL-D (KS/FT)	QUAKE (IN)	L BT (FT)	AREA (IN**2)
1	.149	4303.	.010	.000	.850	.0	.000	.100	4.94	8.8
2	.149	4303.	.010	-1.000	1.000	3.8	.695	.100	9.89	8.8
3	.149	4303.	.010	-1.000	1.000	8.1	1.487	.100	14.83	8.8
4	.149	4303.	.010	-1.000	1.000	8.7	1.591	.100	19.77	8.8
5	.133	3852.	.010	-1.000	1.000	9.2	1.518	.100	24.71	7.9
6	.131	3794.	.010	-1.000	1.000	9.8	1.584	.100	29.66	7.8
7	.131	3794.	.010	-1.000	1.000	10.3	1.675	.100	34.60	7.8
8	.131	3794.	.010	-1.000	1.000	10.9	1.766	.100	39.54	7.8
9	.127	3671.	.010	-1.000	1.000	11.5	1.799	.100	44.48	7.5
10	.114	3291.	.010	-1.000	1.000	12.0	1.689	.100	49.43	6.7
11	.114	3291.	.010	-1.000	1.000	12.6	1.767	.100	54.37	6.7
12	.114	3291.	.010	-1.000	1.000	13.1	1.846	.100	59.31	6.7
13	.114	3291.	.010	-1.000	1.000	13.7	1.925	.100	64.25	6.7
14	.114	3291.	.010	-1.000	1.000	14.2	2.004	.100	69.20	6.7
15	.114	3291.	.010	-1.000	1.000	14.8	2.082	.100	74.14	6.7
16	.138	3341.	.010	-1.000	1.000	15.4	2.397	.100	79.08	8.2
TOE						72.0	10.483	.100		

PILE OPTIONS:

N/UNIFORM	AUTO S.G.	SPLICES	DAMPNG-P	D-P VALUE (K/FT/S)
1	0	0	1	.272

SOIL OPTIONS:

% SKIN FR	% END BG	DIS. NO.	S DAMPING
70	30	0	VISCOUS

ANALYSIS/OUTPUT OPTIONS:

ITERATNS	DTCR/DT(%)	RES STRESS	IOUT	AUTO SGMNT	OUTPT INCR	MAX T(MS)
0	160	0	1	0	2	0

WEAP OF 1986 EXAMPLE 2, DRIVEABILITY STUDY, LB-520

RULT = 240.0, RTOE = 72.0 KIPS
HAMMER AND PILE FORCES(KIPS)

JP	TIME (MS)	HAMMER RAM BT	H CUSH	P TOP	PILE ELEMENTS 3	6	10	12	16
2	.2	45.3	44.5	43.3	37.3	20.8	8.5	5.3	2.0
4	.3	44.5	46.5	45.3	39.1	21.9	9.0	5.6	2.1
6	.5	44.4	48.5	47.4	41.0	23.1	9.5	5.9	2.3
8	.7	48.5	50.6	49.5	43.0	24.3	10.1	6.3	[illegible]
10	.8	51.8	52.7	51.7	45.0	25.6	10.7	[illegible]	
12	1.0	51.0	54.9	54.0	47.1	26.9	[illegible]		
14	1.2	50.3	57.1	56.2	49.3	[illegible]			
16	1.4	51.5	59.3	58.6	[illegible]				
18	1.5	54.5	61.6	[illegible]					
20	1.7	57.8							
22	1.9								
[illegible]									

FORM 4: OUTPUT, EXAMPLE 2

WEAP OF 1986 EXAMPLE 2, DRIVEABILITY STUDY, LB-520

RULT = 240.0, RTOE = 72.0 KIPS
HAMMER AND PILE FORCES(KIPS)

JP	TIME	HAMMER			PILE ELEMENTS				
									63.4
							[illegible]	91.6	63.2
						[illegible]	91.9	91.2	63.0
					[illegible]	61.8	91.4	90.9	62.8
				[illegible]	37.0	61.2	91.0	90.5	62.6
			[illegible].5	36.4	36.6	60.8	90.7	90.2	62.4
		[illegible].4	44.0	36.2	36.4	60.4	90.3	89.9	62.3
	[illegible].2	43.8	43.5	36.0	36.2	60.1	90.0	89.6	62.1
348	29.4	43.0	43.0	35.8	36.0	59.7	89.7	89.4	62.0
350	29.6	42.0	42.6	35.7	35.9	59.4	89.4	89.3	61.9
352	29.8	41.2	42.2	35.5	35.8	59.1	89.2	89.1	61.9
354	29.9	40.8	41.8	35.4	35.7	58.9	89.0	89.0	61.8
356	30.1	40.3	41.5	35.3	35.7	58.7	88.9	88.8	61.7
358	30.3	39.5	41.2	35.2	35.8	58.6	88.8	88.7	61.6
360	30.4	38.6	40.9	35.2	35.8	58.5	88.7	88.6	61.6
362	30.6	37.9	40.7	35.1	35.9	58.4	88.6	88.6	61.6
364	30.8	37.4	40.4	35.1	35.9	58.4	88.6	88.6	61.6
366	30.9	37.0	40.2	35.1	36.0	58.5	88.5	88.6	61.6

RULT = 240.0, RTOE = 72.0 KIPS, DEL T = .085 MS

NO.	FMIN,JMN (K)	FMAX,JMX (K)	STRMIN,JSN (KSI)	STRMAX,JSX (KSI)	VMAX,JVX (F/S)	DMAX,JDX (IN)
1	.0, 0	263.9,133	.00, 0	29.99,133	7.1,102	.859,185
2	.0, 0	269.0,137	.00, 0	30.56,137	6.8,105	.805,187
3	.0, 0	266.1,140	.00, 0	30.24,140	6.4,110	.751,190
4	.0, 0	255.4,146	.00, 0	29.03,146	6.1,112	.699,192
5	.0, 0	244.5,152	.00, 0	30.98,152	5.7,116	.642,195
6	.0, 0	233.3,158	.00, 0	30.07,158	5.3,119	.586,197
7	.0, 0	222.0,162	.00, 0	28.61,162	4.9,123	.532,200
8	.0, 0	210.4,169	.00, 0	27.12,169	4.5,128	.480,202
9	.0, 0	198.6,173	.00, 0	26.36,173	4.1,129	.429,204
10	.0, 0	186.7,181	.00, 0	27.74,181	3.6,136	.375,208
11	.0, 0	174.5,184	.00, 0	25.93,184	3.1,137	.324,213
12	.0, 0	161.9,191	.00, 0	24.06,191	2.7,145	.279,219
13	.0, 0	148.9,193	.00, 0	22.13,193	2.3,147	.238,224
14	.0, 0	135.0,193	.00, 0	20.05,193	1.9,155	.202,229
15	.0, 0	119.5,191	.00, 0	17.75,191	1.5,159	.171,234
16	.0, 0	102.4,189	.00, 0	12.55,189	1.2,163	.145,238

STROKES ANALYZED AND LAST RETURN (FT):
2.66 3.35 3.55 3.48

*** NO PERMANENT SET, ANALYSIS IS DISCONTINUED ***

WEAP OF 1986 EXAMPLE 2, DRIVEABILITY STUDY, LB-520

RULT = 320.0, RTOE = 96.0 KIPS
HAMMER AND PILE FORCES(KIPS)

JP	TIME (MS)	HAMMER RAM BT	H CUSH	P TOP	PILE ELEMENTS 3	6	10	12	16
312	26.4	61.8	58.4	45.9	46.8	82.6	113.7	108.4	65.3
314	26.5	60.4	57.2	45.0	45.8	81.0	112.7	107.7	65.0
316	26.7	59.0	56.2	44.2	44.9	79.6	111.8	107.1	64.6
318	26.9	58.0	55.1	43.5	44.0	78.3	110.9	106.5	64.2
320	27.1	57.4	54.1	42.9	43.2	77.3	110.1	105.9	63.9
322	27.2	56.5	53.2	42.3	42.5	76.4	109.5	105.3	63.5
324	27.4	55.2	52.4	41.7	41.8	75.5	108.9	104.8	63.2

RULT = 320.0, RTOE = 96.0 KIPS, DEL T = .085 MS

NO.	FMIN,JMN (K)	FMAX,JMX (K)	STRMIN,JSN (KSI)	STRMAX,JSX (KSI)	VMAX,JVX (F/S)	DMAX,JDX (IN)
1	.0, 0	283.1,143	.00, 0	32.17,143	7.2, 95	.845,185
2	.0, 0	288.7,146	.00, 0	32.81,146	6.8,100	.784,187
3	.0, 0	285.5,151	.00, 0	32.45,151	6.3,105	.724,189
4	.0, 0	273.7,154	.00, 0	31.10,154	5.9,106	.666,192
5	.0, 0	261.4,160	.00, 0	33.12,160	5.5,112	.603,194
6	.0, 0	248.4,164	.00, 0	32.01,164	5.0,117	.542,196
7	.0, 0	235.0,170	.00, 0	30.28,170	4.6,117	.483,198
8	.0, 0	220.9,173	.00, 0	28.46,173	4.1,124	.428,201
9	.0, 0	206.3,180	.00, 0	27.39,180	3.6,123	.373,203
10	.0, 0	191.7,185	.00, 0	28.48,185	3.1,131	.317,205
11	.0, 0	176.0,188	.00, 0	26.16,188	2.6,132	.264,206
12	.0, 0	160.0,194	.00, 0	23.78,194	2.1,141	.216,208
13	.0, 0	143.5,198	.00, 0	21.32,198	1.7,154	.173,210
14	.0, 0	126.3,202	.00, 0	18.77,202	1.3,149	.135,212
15	.0, 0	108.3,204	.00, 0	16.09,204	1.0,152	.103,214
16	.0, 0	89.2,207	.00, 0	10.93,207	.7,156	.076,216

STROKES ANALYZED AND LAST RETURN (FT):
3.79 3.78

R ULT KIPS	BL CT BPF	STRKE FT	BCP PSI	MINSTR KSI	I,J	MAXSTR KSI	I,J	ENTHRU FT-KIP	BL RT BPM
240.0	265.4	3.5	20.4	.00(	1, 0)	30.98(	5,152)	13.8	82.2
320.0	9999.0	3.8	24.7	.00(	1, 0)	33.12(	5,160)	14.5	81.1

FORM 4, continued

7.3 Tension Stress Check

7.3.1 Situation

Using a Vulcan 80C hammer, a 14- by 14-inch prestressed concrete pile is to be driven through very soft material. The pile length is 50 feet. The soil engineer has estimated that there will be only 10 tons of skin friction (no end bearing) in the early stages of driving (20-ft penetration) and that skin damping (Smith) is equal to 0.2 s/ft.

7.3.2 Problem

It is expected that tension stresses will develop in the pile during the early driving stages. These tension stresses should at no point exceed the 0.8 ksi prestress. (Actually, an additional 300 psi may be allowed considering the concrete's strength of rupture). How many sheets of 3/4 inch plywood should be put on the pile top to sufficienctly protect the pile? The helmet weight is 1.5 kips, the hammer cushion stiffness is 10000 kips/in with a coefficient of restitution of 0.8.

7.3.3 Solution

The following input was made solving first the case of a cushion consisting of 3 plywood sheets of 3/4-inch thickness each yielding a total cushion-thickness of 2.25 inches.

The short input form is sufficient for solving this problem.

Card	ID	Data	Explanation
2.000	ANALYSIS OPTIONS		
	IHAMR	65	From Table 2.
	IPERCS	100	For no toe resistance.
	ISMITH	0	For standard Smith damping.
	IBEDAM	3	For concrete.
3.000	HELMET AND H.C.		
	HELMET WEIGHT	1.5	As given by contractor.
	STIFFNESS	10,000.	As given.
	C.O.R.	.8	As given.
	ROUND-OUT		Standard (may be left blank).
4.000	CUSHION INFO.		
	AREA	196.	Like pile top.
	EL. MODULUS	30.	for relatively new material.
	THICKNESS	1.75	Assuming that the cushion is quickly compressed by 1/2 inch.
	C.O.R.	0.5	Standard for plywood.
	ROUND-OUT	.01	Standard.

5.000	PILE TOP INFORMATION		
	TOTAL LENGTH	50.0	ft
	AREA	196.0	in^2
	EL. MODULUS	5000.	ksi
	SP. WEIGHT	150.0	lb/ft^3
	C.O.R.	1.0	Presence of cushion allows for C.O.R.=1 for pile top.
6.401..	SKIN FR. DISTRIBTN		
	30.	0.	From 0 to 30 feet below the pile top, no skin friction. From 30 to 50 feet, uniform skin friction.
	30.	1.	
	50.	1.	
8.000	SOIL PARAMETERS		
	QUAKES	0.1	
	SKIN DAMPING	0.2	
	TOE DAMPING		Not specified since there is no toe resistance force.
9.000	ULTIMATE CAPACITIES		
		20.0	

The filled-in input is shown in Form 5. The corresponding output is reproduced in Form 6.

7.3.4 Discussion of Results

The output shows that the tension stress reaches .89 ksi (890 psi) at segment 5 (note that the output gives tension as a negative stress). Driving the pile with only 3 cushion sheets is, therefore, not advisable, particularly, since a low (though realistic) efficiency was analyzed (0.5 as per hammer data file).

7.3.5 Additional Computer Analysis

It is concluded that more cushion sheets should be used and a second computer run is made for six cushion sheets. Thus, the pile cushion thickness on Card No. 4.000 is merely doubled. The result summary is reproduced together with the results from the 3 sheet analysis on Form 6. Obviously, the maximum tension stress was reduced such (0.44 ksi) that tension cracks are less likely to occur.

It may be suggested that running the hammer at reduced pressures in the early phases of driving is another means of getting the pile safely into the ground. The program could have been used equally well to find that PRESSURE value on Card 7.000 (less than 120 psi) which would limit tension in easy driving.

WEAP86 - Short Input Form

1.000 TITLE (40 Characters): EXAMPLE 3, TENSION STRESS CHECK, 3-PLY

ANALYSIS OPTIONS

	IOUT	IJJ	IHAMR	IOSIR	IFUEL	IPEL	N	ISPL	NCRSS	IDDAM	IPICS	ISMIH	ITYS	IPIH	IISAO	IIER	IDAIA	MAXT
2.000			224							3	100							

HELMET AND HAMMER CUSHION INFORMATION

	HELMET WEIGHT KIPS	HAMMER CUSHION AREA SQ IN	HAMMER CUSHION ELASTIC MODULUS KSI	HAMMER CUSHION THICKNESS IN	HAMMER CUSHION C.O.R.	HAMMER CUSHION ROUND OUT FEET	HAMMER CUSHION STIFFNESS* KIPS/IN
3.000	1.5				.8	.01	10000.

PILE CUSHION INFORMATION

	AREA SQ IN	ELASTIC MODULUS KSI	THICKNESS IN	C.O.R.	ROUND OUT FEET	STIFFNESS* KIPS/IN
4.000	196.	30.	1.75	.5	.01	

* OVERRIDES AREA (EL. MOD.) / THICKN.

PILE TOP INFORMATION

	TOTAL LENGTH FEET	AREA SQ IN	ELASTIC MODULUS KSI	SPECIFIC WEIGHT LBS/CU FT	C.O.R.	ROUND OUT
5.000	50.	196.	5000.	150.	1.	.01

NCRSS > 0: NON-UNIFORM PILE PROFILE

	DEPTH FEET	AREA SQ IN	ELASTIC MODULUS KSI	SPECIFIC WEIGHT LBS/CU FT
5.101				
5.102				
5.103				
5.104				
⋮				
5.120				

10 20 30 40 50 60 70 80

FORM 5: INPUT, EXAMPLE 3

NOTE: THERE IS NO CARD NUMBER 6.000

HAMMER OVERRIDE VALUES

	STROKE FEET	EFFICIENCY	PRESSURE PSI	REACTION WEIGHT* KIPS	COMB DELAY⁺ SECONDS -or- IGNITION VOL⁺⁺ CU IN
7.000					

* FOR DOUBLE ACTING HAMMERS ONLY

\+ FOR DIESELS WITH LIQUID FUEL INJECTION ONLY

\++ FOR DIESELS WITH ATOMIZED FUEL INJECTION ONLY

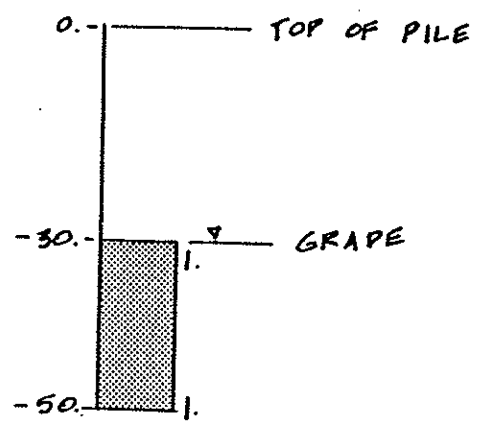
SOIL PARAMETERS

	QUAKE-SKIN IN	QUAKE-TOE IN	DAMPING-SKIN SEC/FT**	DAMPING-TOE SEC/FT**
8.000	.1	.1	.2	

** ISMITH = -1: DIMENSIONLESS (CASE)
0:, 1: S/FT (STANDARD SMITH)
2: S/FT (VISCOUS SMITH)

IHYS = -1 or 0: SKIN FRICTION DISTRIBUTION

	DEPTH FEET	RELATIVE DISTRIBUTION
8.401	30.	
8.402	30.	1.
8.403	50.	1.
8.404		
⋮		
8.420		



ULTIMATE CAPACITIES

	KIPS	(Give up to 10 capacities)
9.000	20.	
10.000		

1 2 3 4 5 6 7 8 9 0 ... 10 20 30 40 50 60 70 80

FORM 5, continued

WEAP86: WAVE EQUATION ANALYSIS OF PILE FOUNDATIONS
1986, VERSION 1.001

EXAMPLE 3, TENSION STRESS CHECK, 3-PLY

HAMMER MODEL OF: VUL 80C MADE BY: VULCAN

ELEMENT	WEIGHT (KIPS)	STIFFNESS (K/IN)	COEFF. OF RESTITUTION	O-NL. FT	CAP DAMPG (K/FT/S)
1	8.000				
CAP/RAM	1.500	9442.9	.800	.0100	6.7
CUSHION		3360.0	.500	.0100	

ASSEMBLY	WEIGHT (KIPS)	STIFFNESS (K/IN)	COEFF. OF RESTITUTION	O-NL. FT
1	4.940	47835.3		
2	4.940	47835.3	.800	.0100

HAMMER OPTIONS:

HAMMER NO.	FUEL SETTG.	STROKE OPT.	HAMMER TYPE	DAMPNG-HAMR
224	1	0	3	2

HAMMER PERFORMANCE DATA

RAM WEIGHT (KIPS)	RAM LENGTH (IN)	MAX STROKE (FT)	STROKE (FT)	EFFICIENCY
8.00	50.00	3.06	3.06	.500

RTD PRESS. (PSI)	ACT PRESS. (PSI)	EFF. AREA (IN2)	IMPACT VEL. (FT/S)
120.00	120.00	81.51	9.92

	AREA (IN2)	E-MODULUS (KSI)	THICKNESS (IN)	STIFFNESS (KIPS/IN)
HAMMER CUSHION	.00	.0	.000	10000.0
PILE CUSHION	196.00	30.0	1.750	3360.0

PILE PROFILE:

LBT (FT)	AREA (IN2)	E-MOD (KSI)	SP.W. (LB/FT3)	WAVE SP (FT/S)	EA/C (K/FT/S)
.00	196.0	5000.	150.000	12426.4	78.9
50.00	196.0	5000.	150.000	12426.4	78.9

WAVE TRAVEL TIME - 2L/C - = 8.047 MS

FORM 6: OUTPUT, EXAMPLE 3

WEAP OF 1986 EXAMPLE 3, TENSION STRESS CHECK, 3-PLY

PILE AND SOIL MODEL FOR RULT = 20.0 KIPS

NO	WEIGHT (KIPS)	STIFFN (K/IN)	D-NL (FT)	SPLICE (FT)	COR	SOIL-S (KIPS)	SOIL-D (S/FT)	QUAKE (IN)	L BT (FT)	AREA (IN**2)
1	.928	17967.	.010	.000	1.000	.0	.200	.100	4.55	196.0
2	.928	17967.	.010	-1.000	1.000	.0	.200	.100	9.09	196.0
4	.928	17967.	.010	-1.000	1.000	.0	.200	.100	18.18	196.0
7	.928	17967.	.010	-1.000	1.000	1.8	.200	.100	31.82	196.0
8	.928	17967.	.010	-1.000	1.000	4.5	.200	.100	36.36	196.0
11	.928	17967.	.010	-1.000	1.000	4.5	.200	.100	50.00	196.0
TOE						.0	.000	.100		

PILE OPTIONS:

N/UNIFORM	AUTO S.G.	SPLICES	DAMPNG-P	D-P VALUE (K/FT/S)
0	0	0	3	4.732

SOIL OPTIONS:

% SKIN FR	% END BG	DIS. NO.	S DAMPING
100	0	0	SMITH-1

ANALYSIS/OUTPUT OPTIONS:

ITERATNS	DTCR/DT(%)	RES STRESS	IOUT	AUTO SGMNT	OUTPT INCR	MAX T(MS)
0	160	0	0	0	1	0

RULT = 20.0, RTOE = .0 KIPS, DEL T = .228 MS

NO.	FMIN,JMN (K)	FMAX,JMX (K)	STRMIN,JSN (KSI)	STRMAX,JSX (KSI)	VMAX,JVX (F/S)	DMAX,JDX (IN)
1	.0, 0	418.1, 19	.00, 0	2.13, 19	8.2, 54	3.608,768
2	-84.6, 51	417.0, 20	-.43, 51	2.13, 20	7.6, 53	3.606,768
3	-132.1, 50	414.5, 21	-.67, 50	2.11, 21	6.9, 51	3.605,768
4	-167.3, 48	411.8, 23	-.85, 48	2.10, 23	7.2, 61	3.604,768
5	-175.4, 48	407.1, 25	-.89, 48	2.08, 25	7.2, 61	3.603,768
6	-144.0, 47	406.1, 26	-.73, 47	2.07, 26	8.0, 43	3.603,768
7	-75.1, 47	403.5, 28	-.38, 47	2.06, 28	8.5, 43	3.602,768
8	-96.8, 55	393.1, 29	-.49, 55	2.01, 29	8.4, 42	3.602,768
9	-116.6, 55	357.8, 30	-.59, 55	1.83, 30	7.9, 41	3.601,768
10	-109.4, 40	280.9, 31	-.56, 40	1.43, 31	8.7, 36	3.601,768
11	-72.5, 40	157.1, 31	-.37, 40	.80, 31	9.6, 36	3.601,768

WEAP OF 1986 EXAMPLE 3, TENSION STRESS CHECK, 3-PLY

R ULT KIPS	BL CT BPF	STROKE(EQ.) FT	MINSTR KSI	I,J	MAXSTR KSI	I,J	ENTHRU FT-KIP
20.0	3.4	3.06	-.89	(5, 48)	2.13	(1, 19)	11.6

WEAP OF 1986 EXAMPLE 3, TENSION STRESS CHECK, 6-PLY

R ULT KIPS	BL CT BPF	STROKE(EQ.) FT	MINSTR KSI	I,J	MAXSTR KSI	I,J	ENTHRU FT-KIP
20.0	5.1	3.06	-.44	(4, 50)	1.65	(2, 21)	7.6

FORM 6, continued

7.4 Hypothetical Hammer Input

7.4.1 Situation

A contractor has decided to build his own hammer. He supplied the data as used in Input Sample 4. A pile made of 12-3/4-inch O.D. pipe with 1/4-inch wall thickness has to be driven to 200-kips ultimate capacity (40-ton pile with a safety factor 2.5; this implies that the wave equation is backed up by dynamic measurements). The length of the pile is 60 ft including a 1-inch toe plate.

7.4.2 Problem

Determine whether this new hammer will drive the pile assuming that the ultimate resistance of 200 kips will be reached at a depth of 50 ft where the loose sand becomes dense.

7.4.3 Solution

Since the hammer being analyzed is not contained in the data file, the Complete Input Form must be used. A sketch is made of assumed skin friction distribution on Page 5 of that form.

Card	ID	Data	Explanation
2.000	ANALYSIS OPTIONS		
	IHAMR	0	Hammer data to be input.
	NCROSS	1	Nonuniform pile (toe plate).
	IPERCS	10	Loose sand on skin, dense sand at toe.
3.000	HELMET AND H.C.	.95	Assumed.
	STIFFNESS	10500.	Assumed.
	C.O.R.	0.8	Assumed.
5.000	PILE TOP INFO.		
	TOTAL LENGTH	60.	
	AREA	9.82	(12.75 - 0.25)3.1416(0.25)
	EL. MODULUS	30000.	
	SP. WEIGHT	492.	
5.101..	NONUNIF. PILE INFO.		The pile is uniform from top to end plate, so only three cards are required to specify the discontinuity and cross sectional area of the end plate $(12.75^2)3.1416/4=127.7$ in^2.
	59.92		
	59.92	127.7	
	60.0	127.7	
6.101 ..... 6.105	HAMMER		These five cards are required for open end diesels. The input data was discussed in Section 4.4 and is given in Form 7, and in the Appendix C.

7.000	HAMMER OVERRIDE VALUES	Nothing to be specified.
8.000	SOIL PARAMETERS	Standard with skin/toe damping of 0.05 and 0.15 s/ft.
8.401..	SKIN FR. DISTRI.	The skin resistance distribution was based on SPT values of 2, between grade and 20-feet depth, 4 between 30- and 40-feet depth and values increasing to 6 just above the dense sand. Note, that, these SPT readings could have been inserted directly in the percent Soil Res. column with no difference in the resulting resistance distribution.
9.000	ULT. CAPACITIES	Selected to produce a curve, for the desired value, interpolations can be made.

The input is listed in Form 7. The corresponding output is reproduced in Form 8.

7.4.4 Discussion of Results

The summary found on the last page of the ouput shows that for R_{ut} = 200 kips the blow count is 63 bl/ft or 5.2 bl/in. The stroke reached 8.1 ft at refusal with a speed of 41 bl/min and a transferred energy of 12 kip-ft. A reasonable hammer rating would be 2.75(8.0) = 22 kip-ft. Thus the transfer efficiency of the hammer would be expected to be as high as 55 percent at refusal blow counts.

The maximum stress was 30 ksi at 200 kips. It can be concluded that this hammer would be a reasonable choice for driving pile.

WEAP86 - Complete Input Form

TITLE (40 CHARACTERS)

1.000 EXAMPLE 4, DIESEL HAMMER INPUT

ANALYSIS OPTIONS

	IOUT	IJJ	IHAMR	IOSTR	IFUEL	IPEL	N	ISPL	NCRSS	IBDAM	IPRCS	ISMTH	ITYS	IPHI	IRSAO	ITER	IDAHA	IMAXT
2.000										1	10							

IPEL = 2: PILE SEGMENT STIFFNESSES

KIPS/IN (For all elements: 1 through N)

2.101
2.102
⋮
2.113

IPEL = 2: PILE SEGMENT WEIGHTS

KIPS (For all elements: 1 through N)

2.201
2.202
⋮
2.213

IPEL > 0: PILE SEGMENT LENGTHS

Relative Lengths (For all elements: 1 through N)

2.301
2.302
⋮
2.313

10 20 30 40 50 60 70 80

FORM 7: INPUT, EXAMPLE 4

WEAP86 - Complete Input Form

HELMET AND HAMMER CUSHION INFORMATION

Card	HELMET: WEIGHT KIPS	HAMMER CUSHION: AREA SQ IN	ELASTIC MODULUS KSI	THICKNESS IN	C.O.R.	ROUND OUT FEET	STIFFNESS* KIPS/IN
3.000	.95				.8	.01	10500.

PILE CUSHION INFORMATION

Card	AREA SQ IN	ELASTIC MODULUS KSI	THICKNESS IN	C.O.R.	ROUND OUT FEET	STIFFNESS* KIPS/IN
4.000						

* OVERRIDES AREA (EL. MOD.) / THICKN.

PILE TOP INFORMATION

Card	TOTAL LENGTH FEET	AREA SQ IN	ELASTIC MODULUS KSI	SPECIFIC WEIGHT LBS/CU FT	C.O.R.	ROUND OUT FEET
5.000	60.	9.82	30000.	492.	.8	.01

NCRSS > 0: NON-UNIFORM PILE PROFILE

Card	DEPTH FEET	AREA SQ IN	ELASTIC MODULUS KSI	SPECIFIC WEIGHT LBS/CU FT
5.101	59.92	9.82	30000.	492.
5.102	59.92	127.70	30000.	492.
5.103	60.00	127.70	30000.	492.
5.104				
⋮				
5.120				

IHAMR = 0: HAMMER INFORMATION

Card	HAMMFGR	NAME	ITYPH	M
6.101	HYPATHET	EX H	1	3

NOTE: THERE IS NO CARD NUMBER 6.000

IHAMR = 0: HAMMER INFORMATION

Card	RAM: WEIGHT KIPS	RAM: LENGTH IN	RAM: DIAMETER IN	STROKE: MAXIMUM FEET	STROKE: MINIMUM** FEET	EFFICIENCY
6.201	2.75	95.	12.5	8.5		.8

** FOR DIESEL HAMMERS ONLY

10 20 30 40 50 60 70 80

FORM 7, continued

IHAMR = 0 and ITYPH = 1 or 2: IMPACT BLOCK INFORMATION

	WEIGHT KIPS	LENGTH IN	DIAMETER IN	C.O.R.	ROUND OUT FEET
6.301	.81	19.	12.6	.8	.01

IHAMR = 0 and ITYPH = 1 or 2: DIESEL HAMMER INFORMATION

	DEPIB IN	COMBUSTION CHAMBER AREA SQ IN	COMBUSTION CHAMBER VOLUME CU IN	COMBUSTION DELAY SECONDS	COMBUSTION DURATION SECONDS	COMBUSTION EXP COEFF	A I VOLUME IGNITION CU IN	A I VOLUME FINAL COMB CU IN
6.401	10.76	122.7	120.	.002	.002	1.3		

IHAMR = 0 and ITYPH = 1 or 2: PRESSURES

	ATMOSPHERIC PSI	SETTING 1 PSI	SETTING 2 PSI	SETTING 3 PSI	SETTING 4 PSI	SETTING 5 PSI	COEFF OF CONF
6.501	14.7	1150.					1

IHAMR = 0 and ITYPH = 2: CED HAMMER INFORMATION

	DEPBB IN	B C AREA SQ IN	DBBT IN	D SAFETY FEET	C TANK VOLUME CU IN	REACTION WEIGHT KIPS	B C EXPANSION COEFFICIENT
6.601							

IHAMR = 0 and ITYPH = 3: A/S HAMMER INFORMATION

	PISTON EFF AREA SQ IN	PISTON RATED PRESSURE* PSI	ASSEMBLY C.O.R.	ASSEMBLY ROUND OUT FEET	ASSEMBLY NO OF ELEMENTS (MA)
6.701					

* FOR DOUBLE ACTING A/S HAMMERS ONLY

IHAMR = 0 and ITYPH = 3 and MA > 0: ASSEMBLY INFORMATION (Give input for MA assembly elements)

	WEIGHT ELEMENT 1 KIPS	WEIGHT ELEMENT 2 KIPS	WEIGHT ELEMENT 3 KIPS	STIFFNESS ELEMENT 1 KIPS/IN	STIFFNESS ELEMENT 2 KIPS/IN	STIFFNESS ELEMENT 3 KIPS/IN
6.801						

HAMMER OVERRIDE VALUES

	STROKE FEET	EFFICIENCY	PRESSURE PSI	REACTION WEIGHT** KIPS	COMB DELAY+ SECONDS -or- IGNITION VOL++ CU IN
7.000					

** FOR DOUBLE ACTING HAMMERS ONLY

+ FOR DIESELS WITH LIQUID FUEL INJECTION ONLY

++ FOR DIESELS WITH ATOMIZED FUEL INJECTION ONLY

1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0

10 20 30 40 50 60 70 80

FORM 7, continued

WEAP86 - Complete Input Form

SOIL PARAMETERS

	QUAKE-SKIN IN	QUAKE-TOE IN	DAMPING-SKIN SEC/FT*	DAMPING-TOE SEC/FT*
0.000	.1	.1	.05	.15

* ISMTH = -1: DIMENSIONLESS (CASE)
0:, 1: S/FT (STANDARD SMITH)
2: S/FT (VISCOUS SMITH)

IIYS < -1: SOIL QUAKES

IN (For all elements and pile tip: 1 through N+1)

0.101
0.102
⋮
0.113

IIYS < 0: SOIL DAMPING PARAMETERS

SEC/FT (For all elements and pile tip: 1 through N+1)

0.201
0.202
⋮
0.213

IIYS < -1: SOIL RESISTANCE DISTRIBUTION

Relative (For all elements and pile tip: 1 through N+1)

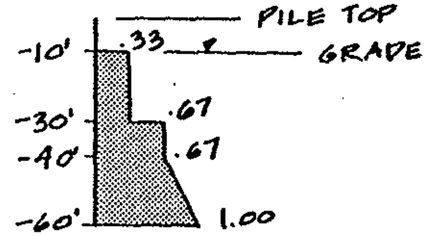
0.301
0.302
⋮
0.313

10 20 30 40 50 60 70 80

FORM 7, continued

ITYS = -1 or 0: SKIN FRICTION DISTRIBUTION

	DEPTH FEET	RELATIVE DISTRIBUTION
8.401	10.	
8.402	10.	.33
8.403	30.	.33
8.404	30.	.67
:	40.	.67
:	60.	1.00
:		
8.420		



ISPL > 0: SLACK INFORMATION

	ELEMENT	SLACK FEET	C.O.R.	ROUND OUT FEET
8.501				
8.502				
8.503				
8.504				
:				
:				
:				
8.599				

ULTIMATE CAPACITIES

KIPS (Give up to 10 capacities)

9.000	100.	150.	200.	250.	300.	350.	400.	
10.000								

IJJ = 1: PILE ELEMENT NUMBERS

Give up to 12 pile element numbers for output

10.101	

1 2 3 4 5 6 7 8 9 0 ... 10 20 30 40 50 60 70 80

FORM 7, continued

WEAP86: WAVE EQUATION ANALYSIS OF PILE FOUNDATIONS
1986, VERSION 1.001

EXAMPLE 4, DIESEL HAMMER INPUT

HAMMER MODEL OF: EX 4 MADE BY: HYPOTHET

ELEMENT	WEIGHT (KIPS)	STIFFNESS (K/IN)	COEFF. OF RESTITUTION	D-NL. FT	CAP DAMPG (K/FT/S)
1	.917				
2	.917	112384.3	1.000	.0100	
3	.917	112384.3	1.000	.0100	
IMP. BLK	.810	70240.2	.800	.0100	
CAP/RAM	.950	10500.0	.800	.0100	6.2

HAMMER OPTIONS:

HAMMER NO.	FUEL SETTG.	STROKE OPT.	HAMMER TYPE	DAMPNG-HAMR
0	1	0	1	2

HAMMER PERFORMANCE DATA

RAM WEIGHT (KIPS)	RAM LENGTH (IN)	MAX STROKE (FT)	STROKE (FT)	EFFICIENCY
2.75	95.00	8.50	2.69	.800

MAX PRESS. (PSI)	ACT PRESS. (PSI)	TIME DELAY (S)	IGN DURATN (S)	V START INJ. (IN3)
1150.0	1150.0	.00200	.00200	.0

THE HAMMER DATA INCLUDES ESTIMATED (NON-MEASURED) QUANTITIES

HAMMER CUSHION	AREA (IN2)	E-MODULUS (KSI)	THICKNESS (IN)	STIFFNESS (KIPS/IN)
	.00	.0	.000	10500.0

PILE PROFILE:

LBT (FT)	AREA (IN2)	E-MOD (KSI)	SP.W. (LB/FT3)	WAVE SP (FT/S)	EA/C (K/FT/S)
.00	9.8	30000.	492.000	16806.8	17.5
59.92	9.8	30000.	492.000	16806.8	17.5
59.92	127.7	30000.	492.000	16806.8	227.9
60.00	127.7	30000.	492.000	16806.8	227.9

WAVE TRAVEL TIME - 2L/C - = 7.140 MS

PILE AND SOIL MODEL FOR RULT = 100.0 KIPS

NO	WEIGHT (KIPS)	STIFFN (K/IN)	D-NL (FT)	SPLICE (FT)	COR	SOIL-S (KIPS)	SOIL-D (S/FT)	QUAKE (IN)	L BT (FT)	AREA (IN**2)
1	.168	4910.	.010	.000	.800	.0	.050	.100	5.00	9.8
2	.168	4910.	.010	-1.000	1.000	.0	.050	.100	10.00	9.8
3	.168	4910.	.010	-1.000	1.000	.6	.050	.100	15.00	9.8
7	.168	4910.	.010	-1.000	1.000	1.1	.050	.100	35.00	9.8
9	.168	4910.	.010	-1.000	1.000	1.2	.050	.100	45.00	9.8
10	.168	4910.	.010	-1.000	1.000	1.3	.050	.100	50.00	9.8
11	.168	4910.	.010	-1.000	1.000	1.5	.050	.100	55.00	9.8
12	.200	4984.	.010	-1.000	1.000	1.6	.050	.100	60.00	11.7
TOE						90.0	.150	.100		

PILE OPTIONS:

N/UNIFORM	AUTO S.G.	SPLICES	DAMPNG-P	D-P VALUE (K/FT/S)
1	0	0	1	.351

SOIL OPTIONS:

% SKIN FR	% END BG	DIS. NO.	S DAMPING
10	90	0	SMITH-1

ANALYSIS/OUTPUT OPTIONS:

ITERATNS	DTCR/DT(%)	RES STRESS	IOUT	AUTO SGMNT	OUTPT INCR	MAX T(MS)
0	160	0	0	0	2	0

RULT = 100.0, RTOE = 90.0 KIPS, DEL T = .091 MS

NO.	FMIN,JMN (K)	FMAX,JMX (K)	STRMIN,JSN (KSI)	STRMAX,JSX (KSI)	VMAX,JVX (F/S)	DMAX,JDX (IN)
1	.0, 0	199.2, 50	.00, 0	20.29, 50	11.4, 51	.846,195
2	.0, 0	202.7, 53	.00, 0	20.65, 53	11.2, 55	.830,198
3	.0, 0	205.4, 57	.00, 0	20.91, 57	11.0, 58	.813,200
4	.0, 0	207.4, 60	.00, 0	21.12, 60	10.8, 62	.795,202
5	.0, 0	208.4, 64	.00, 0	21.22, 64	10.6, 65	.777,204
6	.0, 0	209.2, 67	.00, 0	21.30, 67	10.5, 69	.759,207
7	.0, 0	209.4, 71	.00, 0	21.32, 71	10.3, 72	.741,211
8	.0, 0	209.5, 74	.00, 0	21.34, 74	10.2, 76	.724,213
9	.0, 0	209.6, 78	.00, 0	21.34, 78	10.0, 79	.706,214
10	.0, 0	210.5, 81	.00, 0	21.44, 81	9.7, 82	.687,217
11	.0, 0	210.5, 85	.00, 0	21.44, 85	9.4, 86	.669,219
12	.0, 0	222.4, 88	.00, 0	19.00, 88	8.8, 91	.651,221

STROKES ANALYZED AND LAST RETURN (FT):
2.69 5.58 4.94 5.05

FORM 8: OUTPUT, EXAMPLE 4

WEAP OF 1986 EXAMPLE 4, DIESEL HAMMER INPUT

RULT = 150.0, RTOE = 135.0 KIPS, DEL T = .091 MS

NO.	FMIN,JMN (K)	FMAX,JMX (K)	STRMIN,JSN (KSI)	STRMAX,JSX (KSI)	VMAX,JVX (F/S)	DMAX,JDX (IN)
1	.0, 0	235.6, 48	.00, 0	23.99, 48	13.4, 49	.769,153
2	.0, 0	235.7, 51	.00, 0	24.00, 51	13.3, 53	.734,157
3	.0, 0	237.5, 55	.00, 0	24.19, 55	13.1, 56	.702,161
4	.0, 0	238.1, 58	.00, 0	24.25, 58	12.9, 60	.671,164
5	.0, 0	239.8, 62	.00, 0	24.42, 62	12.6, 64	.638,167
6	.0, 0	240.0, 65	.00, 0	24.44, 65	12.4, 67	.606,171
7	.0, 0	241.7, 69	.00, 0	24.62, 69	12.1, 70	.575,174
8	.0, 0	246.1,105	.00, 0	25.06,105	11.9, 74	.544,178
9	.0, 0	240.8, 76	.00, 0	24.52, 76	11.6, 77	.513,181
10	.0, 0	240.3, 79	.00, 0	24.47, 79	11.3, 81	.483,185
11	.0, 0	243.2, 83	.00, 0	24.77, 83	10.6, 83	.455,188
12	-1.3, 1	284.4, 88	-.11, 1	24.29, 88	7.8, 85	.427,192

STROKES ANALYZED AND LAST RETURN (FT):
6.06 5.82 5.85

RULT = 200.0, RTOE = 180.0 KIPS, DEL T = .091 MS

NO.	FMIN,JMN (K)	FMAX,JMX (K)	STRMIN,JSN (KSI)	STRMAX,JSX (KSI)	VMAX,JVX (F/S)	DMAX,JDX (IN)
1	.0, 0	280.5,130	.00, 0	28.56,130	14.9, 49	.762,141
2	-10.8,277	264.1, 50	-1.10,277	26.90, 50	14.9, 52	.718,142
3	-18.3,277	263.6, 54	-1.86,277	26.84, 54	14.8, 56	.673,146
4	-22.7,277	265.7,119	-2.31,277	27.06,119	14.5, 59	.626,149
5	-26.7,275	263.8, 61	-2.71,275	26.86, 61	14.2, 63	.581,153
6	-28.5,274	264.8, 65	-2.91,274	26.97, 65	13.9, 66	.539,157
7	-29.3,270	281.2,107	-2.98,270	28.63,107	13.6, 70	.497,160
8	-28.5,268	297.4,105	-2.91,268	30.29,105	13.3, 73	.454,164
9	-24.3,266	282.0,103	-2.48,266	28.71,103	13.0, 77	.412,167
10	-19.7,262	268.1,111	-2.01,262	27.30,111	12.6, 80	.371,170
11	-15.7,260	269.0, 83	-1.60,260	27.40, 83	11.4, 82	.330,174
12	-9.2,260	336.1, 88	-.79,260	28.72, 88	7.6, 84	.291,179

STROKES ANALYZED AND LAST RETURN (FT):
6.26 6.59 6.56

WEAP OF 1986 EXAMPLE 4, DIESEL HAMMER INPUT

RULT = 250.0, RTOE = 225.0 KIPS, DEL T = .091 MS

NO.	FMIN,JMN (K)	FMAX,JMX (K)	STRMIN,JSN (KSI)	STRMAX,JSX (KSI)	VMAX,JVX (F/S)	DMAX,JDX (IN)
1	.0, 0	325.2,129	.00, 0	33.11,129	15.6, 48	.750,138
2	-10.9,261	300.5,127	-1.11,261	30.60,127	15.5, 52	.700,140
3	-19.5,259	293.7,121	-1.99,259	29.90,121	15.4, 55	.646,143
4	-26.0,258	297.4,119	-2.65,258	30.29,119	15.2, 59	.589,145
5	-32.6,261	300.3,143	-3.32,261	30.58,143	14.8, 62	.534,150
6	-36.5,261	290.5,145	-3.72,261	29.58,145	14.5, 66	.483,154
7	-35.9,259	310.4,107	-3.66,259	31.61,107	14.1, 69	.432,157
8	-33.5,266	329.9,104	-3.41,266	33.59,104	13.8, 73	.381,161
9	-30.9,263	316.8,103	-3.14,263	32.26,103	13.4, 76	.331,164
10	-28.6,259	288.2,110	-2.91,259	29.35,110	12.9, 79	.282,167
11	-23.2,259	286.9,113	-2.36,259	29.22,113	11.4, 82	.231,170
12	-13.4,260	363.6, 88	-1.14,260	31.06, 88	6.9, 83	.182,175

STROKES ANALYZED AND LAST RETURN (FT):
6.97 7.23

RULT = 300.0, RTOE = 270.0 KIPS, DEL T = .082 MS

NO.	FMIN,JMN (K)	FMAX,JMX (K)	STRMIN,JSN (KSI)	STRMAX,JSX (KSI)	VMAX,JVX (F/S)	DMAX,JDX (IN)
1	.0, 0	365.3,142	.00, 0	37.20,142	17.0, 53	.764,133
2	-15.0,274	338.2,140	-1.53,274	34.44,140	16.9, 57	.709,129
3	-24.4,277	325.5,134	-2.48,277	33.15,134	16.7, 61	.651,126
4	-32.7,280	328.8,130	-3.33,280	33.48,130	16.5, 65	.596,121
5	-36.4,280	331.9,157	-3.70,280	33.80,157	16.2, 68	.543,118
6	-37.5,276	323.2,159	-3.82,276	32.91,159	15.9, 72	.485,116
7	-38.7,274	339.9,117	-3.94,274	34.61,117	15.4, 76	.418,114
8	-35.9,292	360.4,114	-3.65,292	36.70,114	15.0, 80	.356,127
9	-35.7,289	351.6,113	-3.64,289	35.81,113	14.6, 84	.300,130
10	-35.6,287	310.2,107	-3.63,287	31.58,107	14.0, 87	.244,132
11	-31.3,286	306.8,123	-3.18,286	31.24,123	12.1, 90	.184, 99
12	-18.2,286	403.3, 96	-1.55,286	34.45, 96	6.7, 91	.126,190

STROKES ANALYZED AND LAST RETURN (FT):
7.16 7.69 7.77

FORM 8, continued

RULT = 350.0, RTOE = 315.0 KIPS, DEL T = .073 MS

NO.	FMIN,JMN (K)	FMAX,JMX (K)	STRMIN,JSN (KSI)	STRMAX,JSX (KSI)	VMAX,JVX (F/S)	DMAX,JDX (IN)
1	.0, 0	388.2,160	.00, 0	39.53,160	17.6, 59	.770,149
2	-16.7,307	360.9,158	-1.70,307	36.75,158	17.5, 64	.713,145
3	-25.0,307	344.3,151	-2.54,307	35.06,151	17.3, 69	.655,141
4	-32.8,315	346.8,147	-3.34,315	35.32,147	17.1, 73	.600,136
5	-38.2,313	346.4,178	-3.89,313	35.27,178	16.8, 77	.546,132
6	-42.1,309	340.0,179	-4.29,309	34.62,179	16.4, 82	.487,130
7	-41.9,308	356.9,132	-4.27,308	36.34,132	16.0, 86	.417,128
8	-34.5,322	378.7,129	-3.51,322	38.56,129	15.5, 90	.345,122
9	-36.6,327	371.6,127	-3.73,327	37.84,127	15.1, 95	.292,116
10	-38.0,325	327.1,121	-3.87,325	33.31,121	14.4, 99	.240,111
11	-33.6,323	320.0,139	-3.43,323	32.58,139	12.1,101	.179,111
12	-19.5,324	423.4,109	-1.66,324	36.17,109	6.2,102	.104,117

STROKES ANALYZED AND LAST RETURN (FT):
8.05 8.04

*** NO PERMANENT SET, ANALYSIS IS DISCONTINUED ***

RULT = 400.0, RTOE = 360.0 KIPS, DEL T = .065 MS

NO.	FMIN,JMN (K)	FMAX,JMX (K)	STRMIN,JSN (KSI)	STRMAX,JSX (KSI)	VMAX,JVX (F/S)	DMAX,JDX (IN)
1	.0, 0	399.6,179	.00, 0	40.69,179	17.9, 66	.769,166
2	-16.4,341	372.0,177	-1.68,341	37.88,177	17.8, 71	.711,162
3	-26.8,338	354.0,169	-2.73,338	36.05,169	17.6, 77	.653,157
4	-31.7,335	356.0,164	-3.23,335	36.25,164	17.3, 82	.598,151
5	-38.3,347	350.8,199	-3.90,347	35.72,199	17.0, 86	.543,147
6	-43.7,345	345.8,155	-4.45,345	35.21,155	16.7, 91	.483,145
7	-43.2,343	367.0,148	-4.40,343	37.37,148	16.2, 96	.413,142
8	-34.6,358	387.8,144	-3.53,358	39.49,144	15.7,101	.341,134
9	-36.6,364	380.2,142	-3.73,364	38.71,142	15.2,106	.288,129
10	-39.0,362	335.4,135	-3.97,362	34.15,135	14.4,110	.236,124
11	-34.1,361	326.8,132	-3.48,361	33.28,132	12.0,113	.173,124
12	-19.2,362	433.3,121	-1.64,362	37.02,121	5.8,114	.094,129

STROKES ANALYZED AND LAST RETURN (FT):
8.23 8.13

R ULT KIPS	BL CT BPF	STROKE (FT) DOWN	UP	MINSTR KSI	I,J	MAXSTR KSI	I,J	ENTHRU FT-KIP	BL RT BPM
100.0	21.8	4.9	5.1	.00	(1, 0)	21.44	(10, 81)	9.2	52.6
150.0	36.7	5.8	5.9	-.11	(12, 1)	25.06	(8,105)	9.7	48.7
200.0	62.7	6.6	6.6	-2.98	(7,270)	30.29	(8,105)	10.5	46.0
250.0	146.1	7.0	7.2	-3.72	(6,261)	33.59	(8,104)	10.7	44.3
300.0	463.4	7.7	7.8	-3.94	(7,274)	37.20	(1,142)	11.5	42.5
350.0	3337.9	8.0	8.0	-4.29	(6,309)	39.53	(1,160)	12.0	41.7
400.0	9999.0	8.2	8.1	-4.45	(6,345)	40.69	(1,179)	12.2	41.3

FORM 8, continued

7.5 Pile Segment and Damping Input

7.5.1 Situation

A timber pile (see also Figure 7 for details) has to be driven through a soil of stratified clay and sand to a dense gravel layer. The timber pile has a length of 36 feet 2 inches. Its cross sectional area varies from 128.7 at the top to 56.2 square inches at the bottom. For the timber an elastic modulus E = 2000 ksi and w = 51 lb/ft^3 was assumed. It will be driven by a Link Belt 440 hammer.

A soils investigation resulted in the following data: At a depth of 25 ft and 8 in the pile point will have penetrated into the gravel such that a total ultimate bearing of 150 kips (90 percent at the toe) is obtained. The Smith damping factors are 0.05 s/ft in the gravel (toe) and 0.20 s/ft in the clay.

7.5.2 Problem

The hammer should be run at a limited energy of 14.44 kip-ft to avoid pile damage. To what blow count must the pile be driven to insure the 75-ton (150 kip) ultimate bearing capacity and what would be the bounce chamber pressure (gauge) corresponding to this energy level?

7.5.3 Solution

The Complete Input Form must be used since the damping factors vary along the pile skin (although often a constant average value is used in such a situation with little loss of accuracy). For the purpose of demonstration only, the element masses and stiffnesses are also calculated and input in the Complete Form.

Form 9 lists the input parameters. Data important to the current demonstration are:

Card	ID	Data	Description
2.000	IHAMR	133	LB 440.
	IOSTR	-1	For constant stroke analysis.
	IPEL	2	For segment weight and stiffness input.
	N	12	3 ft length segments were chosen. N must be input for IPEL > 0.
	NCROSS	1	Nonuniform Pile.
	IBEDAM	5	Timber.
	IPERCS	10	10 percent skin friction assumed.
	ITYS	-2	For input of damping, quakes and static resistance values at individual segments. Note that this example could have been run with ITYS = -1 and a specification of the static soil resistance in Cards 8.401, ...

2.101	PILE SGMNT STIFFNESSES	See Figure 7 for a computational example. Note that an average area and a modulus of 2000 ksi was used. The symbol STP(6) stands for the sixth pile stiffness.
2.201	PILE SGMNT WEIGHTS	See Figure 7 for a computational example. Note that an average area and a specific weight of 51 lb/ft^3 was used. The symbol PM(6) stands for the sixth pile "mass".
2.301	PILE SEGMENT LENGTHS	See Figure 7. Instead of actual length values in ft, merely relative values could have been entered as well.
3.000	HELMET AND H.C. INFO.	
	HELMET WEIGHT .7	(kips) assumed.
	STIFFNESS 30000.	(kips/in) assumed.
	C.O.R. .8	Assumed.
5.000	PILE TOP INFO.	Must be given as though model would be automatically computed.
5.101..	NONUNIFORM PILE	The data from Figure 7 (DEPTH and A_p) must be given even though segment properties are automatically determined. The cross sectional area is needed by WEAP86 for stress computation. The repetition of E and w values was unnecessary.
7.000	HAMMER OVERRIDE VALUES	Hammer override data.
	STROKE	Since it is intended to run the hammer at a limited energy, a stroke must be input. For closed end diesels, this stroke is an equivalent value. The LB 440 has a ram weight of 4 kips. Thus, for a potential ram energy of 14.44 kip-ft the stroke should be set to 14.44/4 = 3.61 ft.
8.000	SOIL PARAMETERS	There is no need to enter any parameters on this line. In the example problem quakes and toe damping were, however, specified as 0.1 in and 0.05 s/ft, respectively.
8.101..	SOIL QUAKES 0.1	Was entered for each segment including the toe segment (No. 13). After the first quake, the repetition of input values was unnecessary.
8.201..	SOIL DAMPING 0.2.05	Are the values specified, depending on soil layers for the 12 skin plus the toe segment (No. 13). See also Figure 7.

8.301..ULT ST SOIL RES	Relative numbers representing a uniform total friction of 10 percent were modeled. The first 3 segments were specified with 0, the 4th with 0.5, the 5th and all remaining ones with 1 such that the sum of all values was 8.5. For soil segment No. 13 a 76.5 value was entered. The sum of all relative values was, therefore, 85 or 10 times the sum of all friction values. WEAP86 apportioned all relative numbers such that the total capacity equalled the 150-kip R_{ut} of Card 9.000 (see also PILE AND SOIL MODEL Out).
9.000 ULT CAPACITIES 150.	Only one value was specified. After a thorough check of the resulting analysis output, it is suggested to rerun the problem with more R_{ut} values for the generation of a complete bearing graph.

7.5.4 Discussion of Results

The relatively complicated input should be checked by comparing Figure 7 with the pile model table on the second page of the output (Form 10).. The summary output shows that a blow count of 127 blows per foot will drive the pile to a 150-kip ultimate capacity if the hammer runs at 15.4-psi bounce chamber pressure. The transferred energy in the pile is then 4.4 kip-ft and the hammer should run at a speed of 91 bl/min. Note that the hammer was kept at a relatively low energy setting. In fact, the program had to reduce the file specified combustion pressure of 1003 psi to 707 psi. At such an energy level the atomized fuel injection LB 440 does not impact and the blow count becomes extremely sensitive to small changes in hammer performance.

The summary lists B.C.P. as 15.4 psi which was the bounce chamber pressure on the last return stroke. The corresponding "actual" up-stroke was 2.67 ft which was within 2 percent of the 2.64-ft input stroke (corresponding to the equivalent stroke of 3.61 ft). It took 5 trial analyses for the stroke to converge.

The concentrated toe resistance was responsible for the high pile stresses of 2.41 ksi. Actually, this stress would be even higher if calculated from the toe cross sectional area of 56.2 in^2 rather than from the 70 in^2 value which the program determined under the IPEL = 2 option. Better results would have been obtained with automatically generated segment properties. The reader is encouraged to try this type of input and compare his results.

PILE DESCRIPTION DEPTH ft	Ap in^2	STIFFNESS kips/in	PILE MODEL WEIGHT kips	SEGMT NO.	DEPTH below top feet		SOIL PROFILE	DAMPING J sec/ft	STATIC % Soil Resist.
0.167	128.67	6592	.142	1	3.167			0.0	
7.0	112.65	6557	.126	2	6.167			0.0	
		6176	.118	3	9.167	10.5	GRADE	0.0	1.0
		5800	.111	4	12.17	13.0	SAND	0.05	
14.0 15.17	97.33 94.92	5445	.104	5	15.17			0.20	
18.17	88.87	5100	.098	6	18.17	18.2	CLAY	0.20	
21.0	83.13	4764	.091	7	21.17	21.2	SAND	0.05	
		4440	.085	8	24.17			0.20	
		4128	.079	9	27.17	27.2	CLAY	0.20	
28.0	70.04	3823	.073	10	30.17			0.05	
		3534	.068	11	33.17		SAND	0.05	
36.17	56.20	3257	.065	12	36.17	36.2		0.05	1.0
							TOE:	0.05	

EXAMPLE CALCULATION: $STP(6) = \dfrac{2000(94.92 + 88.87)}{2\ (3.0)\ 12} = 5100$ kips/inch

$$PM(6) = \frac{94.92 + 88.87}{2\ (144)\ 1000}\ 51\ (3.0) = .098 \text{ kips}$$

Figure 7. Details of example 5.

WEAP86 - Complete Input Form

TITLE (40 CHARACTERS)

1.000 EXAMPLE 5: PILE SEGMENT DRIVING INPUT

ANALYSIS OPTIONS

	IOUT	IIJ	IHAMR	IOSTR	IFUEL	IPEL	N	ISPL	NCRSS	IBDAM	IPRCS	ISMTH	ITYS	IPHI	IRSAO	ITER	IDAHA	IMAXT
2.000			133	1		2	12		1	5	10		2					

IPEL = 2: PILE SEGMENT STIFFNESSES

KIPS/IN (For all elements: 1 through N)

2.101	6592.	6557.	6176.	5800.	5445.	5100.	4764.	4440.
2.102	4128.	3823.	3534.	3257.				
...								
2.113								

IPEL = 2: PILE SEGMENT WEIGHTS

KIPS (For all elements: 1 through N)

2.201	.142	.126	.118	.111	.104	.098	.091	.085
2.202	.079	.073	.066	.065				
...								
2.213								

IPEL > 0: PILE SEGMENT LENGTHS

Relative Lengths (For all elements: 1 through N)

2.301	3.167	3.	3.	3.	3.	3.	3.	3.
2.302	3.000	3.	3.	3.				
...								
2.313								

1 2 3 4 5 6 7 8 9 0 ... 10 20 30 40 50 60 70 80

FORM 9: INPUT, EXAMPLE 5

WEAP86 - Complete Input Form

HELMET AND HAMMER CUSHION INFORMATION

Card	HELMET: WEIGHT KIPS	HAMMER CUSHION: AREA SQ IN	ELASTIC MODULUS KSI	THICKNESS IN	C.O.R.	ROUND OUT FEET	STIFFNESS* KIPS/IN
3.000	.7				.8	.01	30000.

* OVERRIDES AREA (EL. MOD.) / THICKN.

PILE CUSHION INFORMATION

Card	AREA SQ IN	ELASTIC MODULUS KSI	THICKNESS IN	C.O.R.	ROUND OUT FEET	STIFFNESS* KIPS/IN
4.000						

PILE TOP INFORMATION

Card	TOTAL LENGTH FEET	AREA SQ IN	ELASTIC MODULUS KSI	SPECIFIC WEIGHT LBS/CU FT	C.O.R.	ROUND OUT FEET
5.000	36.17	128.67	2000.	51.	.5	.01

NCRSS > 0: NON-UNIFORM PILE PROFILE

Card	DEPTH FEET	AREA SQ IN	ELASTIC MODULUS KSI	SPECIFIC WEIGHT LBS/CU FT
5.101	.17	128.67	2000.	51.
5.102	7.00	112.65	2000.	51.
5.103	14.00	97.13	2000.	51.
5.104	21.00	83.13	2000.	51.
⋮	28.00	70.04	2000.	51.
	36.17	56.20	2000.	51.
5.120				

NOTE: THERE IS NO CARD NUMBER 6.000

IHAMR = 0: HAMMER INFORMATION

Card	MANUFGR	NAME	IHYPH	M
6.101				

IHAMR = 0: HAMMER INFORMATION

Card	RAM: WEIGHT KIPS	RAM: LENGTH IN	RAM: DIAMETER IN	STROKE: MAXIMUM FEET	STROKE: MINIMUM** FEET	EFFICIENCY
6.201						

** FOR DIESEL HAMMERS ONLY

1 2 3 4 5 6 7 8 9 0 ... 10 20 30 40 50 60 70 80

FORM 9, continued

HAMR = 0 and ITYPH = 1 or 2: IMPACT BLOCK INFORMATION

Card	WEIGHT KIPS	LENGTH IN	DIAMETER IN	C.O.R.	ROUND OUT FEET
6.301					

HAMR = 0 and ITYPH = 1 or 2: DIESEL HAMMER INFORMATION

Card	DEPIB IN	COMBUSTION CHAMBER: AREA SQ IN	COMBUSTION CHAMBER: VOLUME CU IN	COMBUSTION: DELAY SECONDS	COMBUSTION: DURATION SECONDS	EXP COEFF	A 1 VOLUME: IGNITION CU IN	A 1 VOLUME: FINAL COMB CU IN
6.401								

HAMR = 0 and ITYPH = 1 or 2: PRESSURES

Card	ATMOSPHERIC PSI	SETTING 1 PSI	SETTING 2 PSI	SETTING 3 PSI	SETTING 4 PSI	SETTING 5 PSI	COEFF OF CONF
6.501							

HAMR = 0 and ITYPH = 2: CED HAMMER INFORMATION

Card	DEPBB IN	B C AREA SQ IN	DBBT IN	D SAFETY FEET	C TANK VOLUME CU IN	REACTION WEIGHT KIPS	B C EXPANSION COEFFICIENT
6.601							

HAMR = 0 and ITYPH = 3: A/S HAMMER INFORMATION

Card	PISTON: EFF AREA SQ IN	PISTON: RATED PRESSURE* PSI	ASSEMBLY: C.O.R.	ASSEMBLY: ROUND OUT FEET	ASSEMBLY: NO OF ELEMENTS (MA)
6.701					

* FOR DOUBLE ACTING A/S HAMMERS ONLY

HAMR = 0 and ITYPH = 3 and MA > 0: ASSEMBLY INFORMATION (Give input for MA assembly elements)

Card	WEIGHT: ELEMENT 1 KIPS	WEIGHT: ELEMENT 2 KIPS	WEIGHT: ELEMENT 3 KIPS	STIFFNESS: ELEMENT 1 KIPS/IN	STIFFNESS: ELEMENT 2 KIPS/IN	STIFFNESS: ELEMENT 3 KIPS/IN
6.801						

HAMMER OVERRIDE VALUES

Card	STROKE FEET	EFFICIENCY	PRESSURE PSI	REACTION WEIGHT** KIPS	COMB DELAY+ SECONDS -or- IGNITION VOL++ CU IN
7.000	3.6				

** FOR DOUBLE ACTING HAMMERS ONLY

\+ FOR DIESELS WITH LIQUID FUEL INJECTION ONLY

\+\+ FOR DIESELS WITH ATOMIZED FUEL INJECTION ONLY

Columns: 10 20 30 40 50 60 70 80

FORM 9, continued

SOIL PARAMETERS

	QUAKE-SKIN (IN)	QUAKE-TOE (IN)	DAMPING-SKIN SEC/FT *	DAMPING-TOE SEC/FT *
8.000	.1	.1		.05

* ISMITH = -1: DIMENSIONLESS (CASE)
0:, 1: S/FT (STANDARD SMITH)
2: S/FT (VISCOUS SMITH)

IIYS < -1: SOIL QUAKES

IN (For all elements and pile tip: 1 through N+1)

	1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80
8.101	.1	.1	.1	.1	.1	.1	.1	.1
8.102	.1	.1	.1	.1	.1			
⋮								
8.113								

IIYS < 0: SOIL DAMPING PARAMETERS

SEC/FT (For all elements and pile tip: 1 through N+1)

	1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80
8.201				.05	2.0	.2	.05	.2
8.202	.2	.05	.05	.05	.05			
⋮								
8.213								

IIYS < -1: SOIL RESISTANCE DISTRIBUTION

Relative (For all elements and pile tip: 1 through N+1)

	1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80
8.301				.5	1.0	1.0	1.0	1.0
8.302	1.	1.	1.	1.0	76.5			
⋮								
8.313								

10 20 30 40 50 60 70 80

FORM 9, continued

ITYS = -1 or 0: SKIN FRICTION DISTRIBUTION

	DEPTH FEET	RELATIVE DISTRIBUTION
8.401		
8.402		
8.403		
8.404		
⋮		
8.420		

ISPL > 0: SLACK INFORMATION

	ELEMENT	SLACK FEET	C.O.R.	ROUND OUT FEET
8.501				
8.502				
8.503				
8.504				
⋮				
8.599				

ULTIMATE CAPACITIES

KIPS (Give up to 10 capacities)

9.000	150.
10.000	

IJJ = 1: PILE ELEMENT NUMBERS

Give up to 13 pile element numbers for output

10.101	

1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0

10 20 30 40 50 60 70 80

FORM 9, continued

WEAP86: WAVE EQUATION ANALYSIS OF PILE FOUNDATIONS
1986, VERSION 1.001

EXAMPLE 5: PILE SEGMENT + DAMPING INPUT

HAMMER MODEL OF: LB 440 MADE BY: LINKBELT

ELEMENT	WEIGHT (KIPS)	STIFFNESS (K/IN)	COEFF. OF RESTITUTION	D-NL. FT	CAP DAMPG (K/FT/S)
1	1.333				
2	1.333	130434.4	1.000	.0100	
3	1.333	130434.4	1.000	.0100	
IMP. BLK	.700	75752.9	.900	.0100	
CAP/RAM	.700	30000.0	.800	.0100	7.8

HAMMER OPTIONS:

HAMMER NO.	FUEL SETTG.	STROKE OPT.	HAMMER TYPE	DAMPNG-HAMR
133	1	-1	2	2

HAMMER PERFORMANCE DATA

RAM WEIGHT (KIPS)	RAM LENGTH (IN)	MAX STROKE (FT)	STROKE (FT)	EFFICIENCY
4.00	89.90	3.12	2.64	.800

MAX PRESS. (PSI)	ACT PRESS. (PSI)	TIME DELAY (S)	IGN DURATN (S)	V START INJ. (IN3)
1003.0	1003.0	.00000	.00000	161.0

REACTN WGHT (KIPS)	MAX ENERGY (KIP-FT)	MAX STR CPT (FT)	EQU. STROKE (FT)	C TANK VOL (IN3)
5.21	18.25	3.08	3.61	9185.0

THE HAMMER DATA INCLUDES ESTIMATED (NON-MEASURED) QUANTITIES

HAMMER CUSHION	AREA (IN2)	E-MODULUS (KSI)	THICKNESS (IN)	STIFFNESS (KIPS/IN)
	.00	.0	.000	30000.0

PILE PROFILE:

LBT (FT)	AREA (IN2)	E-MOD (KSI)	SP.W. (LB/FT3)	WAVE SP (FT/S)	EA/C (K/FT/S)
.00	128.7	2000.	51.000	13478.3	19.1
.00	128.7	2000.	51.000	13478.3	19.1
.17	128.7	2000.	51.000	13478.3	19.1
7.00	112.7	2000.	51.000	13478.3	16.7
14.00	97.3	2000.	51.000	13478.3	14.4
21.00	83.1	2000.	51.000	13478.3	12.3
28.00	70.0	2000.	51.000	13478.3	10.4
36.17	56.2	2000.	51.000	13478.3	8.3

WAVE TRAVEL TIME - 2L/C - = 5.367 MS

WEAP OF 1986 EXAMPLE 5: PILE SEGMENT + DAMPING INPUT

PILE AND SOIL MODEL FOR RULT = 150.0 KIPS

NO	WEIGHT (KIPS)	STIFFN (K/IN)	D-NL (FT)	SPLICE (FT)	COR	SOIL-S (KIPS)	SOIL-D (S/FT)	QUAKE (IN)	L BT (FT)	AREA (IN**2)
1	.142	6592.	.010	.000	.500	.0	.000	.100	3.17	128.7
2	.126	6557.	.010	-1.000	1.000	.0	.000	.100	6.17	128.7
3	.118	6176.	.010	-1.000	1.000	.0	.000	.100	9.17	128.7
4	.111	5800.	.010	-1.000	1.000	.9	.050	.100	12.17	112.7
5	.104	5445.	.010	-1.000	1.000	1.8	.200	.100	15.17	112.7
6	.098	5100.	.010	-1.000	1.000	1.8	.200	.100	18.17	97.3
7	.091	4764.	.010	-1.000	1.000	1.8	.050	.100	21.17	97.3
8	.085	4440.	.010	-1.000	1.000	1.8	.200	.100	24.17	83.1
9	.079	4128.	.010	-1.000	1.000	1.8	.200	.100	27.17	83.1
10	.073	3823.	.010	-1.000	1.000	1.8	.050	.100	30.17	83.1
11	.068	3534.	.010	-1.000	1.000	1.8	.050	.100	33.17	70.0
12	.065	3257.	.010	-1.000	1.000	1.8	.050	.100	36.17	70.0
TOE						135.0	.050	.100		

PILE OPTIONS:

N/UNIFORM	AUTO S.G.	SPLICES	DAMPNG-P	D-P VALUE (K/FT/S)
1	2	0	5	1.365

SOIL OPTIONS:

% SKIN FR	% END BG	DIS. NO.	S DAMPING
10	90	-2	SMITH-1

ANALYSIS/OUTPUT OPTIONS:

ITERATNS	DTCR/DT(%)	RES STRESS	IOUT	AUTO SGMNT	OUTPT INCR	MAX T(MS)
0	160	0	0	0	3	0

RULT = 150.0, RTOE = 135.0 KIPS, DEL T = .074 MS

NO.	FMIN,JMN (K)	FMAX,JMX (K)	STRMIN,JSN (KSI)	STRMAX,JSX (KSI)	VMAX,JVX (F/S)	DMAX,JDX (IN)
1	.0, 0	186.9,111	.00, 0	1.45,111	8.4,113	.534,205
2	.0, 0	183.3,115	.00, 0	1.42,115	8.4,116	.512,207
3	.0, 0	180.9,118	.00, 0	1.41,118	8.4,119	.489,210
4	.0, 0	179.0,121	.00, 0	1.59,121	8.4,122	.464,212
5	.0, 0	176.5,124	.00, 0	1.57,124	8.3,126	.437,214
6	.0, 0	170.7,127	.00, 0	1.75,127	8.2,129	.408,217
7	.0, 0	164.7,131	.00, 0	1.69,131	8.2,132	.378,220
8	.0, 0	161.4,134	.00, 0	1.94,134	8.1,135	.346,223
9	.0, 0	156.0,137	.00, 0	1.88,137	8.0,138	.312,226
10	.0, 0	151.3,141	.00, 0	1.82,141	7.7,141	.275,229
11	.0, 0	154.1,146	.00, 0	2.20,146	6.9,143	.236,233
12	.0, 0	169.0,149	.00, 0	2.41,149	5.0,144	.195,235

RETURN STROKES AND STROKE ANALYZED (FT):
3.08 2.93 2.50 2.70 2.67 2.64

MAX. COMBUSTION PRESSURE AT END: 707.2 PSI
*** UPLIFT OCCURRED, PRESSURE WAS REDUCED TO 707.2 PSI***

R ULT KIPS	BL CT BPF	STRKE FT	BCP PSI	MINSTR KSI	I,J	MAXSTR KSI	I,J	ENTHRU FT-KIP	BL RT BPM
150.0	126.8	2.6	15.4	.00(	1, 0)	2.41(	12,149)	4.4	90.8

FORM 10: OUTPUT, EXAMPLE 5

7.6 Comparison of Damping Parameters

7.6.1 General Remarks

The choice of damping parameters may have a rather substantial effect on the wave equation results. In addition, the two different definitions of damping, Smith and Case (viscous), may add confusion. The following illustrative example was therefore included as a demonstration of the effects of different damping values.

The situation assumed is as follows: A 12-by 12-inch prestressed concrete pile (E = 5000 ksi, L = 60 ft.) is driven by a Kobe K-25 hammer into clay. Two stages of the driving operation are investigated. First, easy driving, with the possibility of tension damage, and second, the hard driving situation, when the blow count for bearing is to be found.

7.6.2 Data Input

(a) Easy Driving, CASE Damping

An oak pile top cushion is chosen (E = 50 ksi across the grain, A = 144 in^2, t = 4 in). The soil resistance is uniformly distributed over the bottom 12 feet (20 percent, thus ITYS = 10) of the pile. The skin resistance is assumed to be 50 kips and no tip resistance is anticipated. The viscous skin and toe damping factors were taken as .5 and .3.

Other input data consisted of a helmet weight of .95 kips, a hammer cushion stiffness of 10500 kips/in, a pile cushion coefficient of restitution of 0.6 for the pile cushion, a pile cross sectional area of 144 in^2 and a pile specfic weight of 153 lb/ft^3. Quakes were set to 0.10 in and several ultimate capacity values were analyzed always with zero toe resistance (IPERCS = 100). Form 11 shows the complete input for this case.

(b) Easy Driving, Smith Damping

The only variation from Case (a) was the choice of Smith damping (ISMITH = 0) 0.20 and 0.01 s/ft. These values were chosen for agreement with earlier WEAP manuals, however, the toe damping value is not essential, since that is no static end resistance for skin and toe, respectively. The input forms for this and the next two cases were not reproduced in this manual.

(c) Hard Driving, CASE Damping

It is assumed that the skin friction is relatively well known to be 100 kips and a constant friction analysis is performed. Thus, various ultimate capacities are analyzed starting with 100 kips (IPERCS = -100). Viscous damping factors were again .5 and .3 for skin and toe, respectively.

(d) Hard Driving, Smith Damping

The situation is as in (c) except for ISMITH = 1, J_s = 0.20 and J_t = 0.01 s/ft.

7.6.3 Results

Stress and ultimate resistance vs. blow count graphs were constructed for all four cases analyzed (Figure 8). The summary tables of the four cases are shown together in Form 12.

The results were directly influenced by resistance distribution at high resistance values and damping type. There was an indirect effect in that the hammer stroke was slightly higher for the rather concentrated resistance in the easy driving cases. Naturally, the pile stresses were also larger when the stroke was higher and the resistance more concentrated.

Figure 8 shows for Smith, (Case 2) easier driving at low capacities and higher blow counts in harder driving than the corresponding viscous approach (Case 1). Of course, the reason was that the effective parameter of the Smith definition increased with R_{ut}. Case 4, however, shows always an easy driving condition relative to the viscous curve because of the rather low damping with most resistance acting at the toe (toe damping was only 0.01 s/ft).

WEAP86 - Short Input Form

1.000 TITLE (40 Characters)

EXAMPLE 6 G-1 EASY CASE DAMPING

ANALYSIS OPTIONS

	IOUT	IJJ	IHAMR	IOSTR	IFUEL	IPEL	N	ISPL	NCRSS	IDAM	IPTCS	ISMTH	ITYS	IPTH	IISAO	IIER	IDATA	MAXT
2.000	0		104				12				100	-1	10					

HELMET AND HAMMER CUSHION INFORMATION

	HELMET WEIGHT KIPS	HAMMER CUSHION AREA SQ IN	HAMMER CUSHION ELASTIC MODULUS KSI	HAMMER CUSHION THICKNESS IN	HAMMER CUSHION C.O.R.	HAMMER CUSHION ROUND OUT FEET	HAMMER CUSHION STIFFNESS* KIPS/IN
3.000	.95				.85	.01	10500.

PILE CUSHION INFORMATION

	AREA SQ IN	ELASTIC MODULUS KSI	THICKNESS IN	C.O.R.	ROUND OUT FEET	STIFFNESS* KIPS/IN
4.000	144.	50.	4.0	.6	.01	

* OVERRIDES AREA (EL. MOD.) / THICKN.

PILE TOP INFORMATION

	TOTAL LENGTH FEET	AREA SQ IN	ELASTIC MODULUS KSI	SPECIFIC WEIGHT LBS/CU FT	C.O.R.	ROUND OUT
5.000	60.	144.	5000.	153.	.85	.01

NCRSS > 0: NON-UNIFORM PILE PROFILE

	DEPTH FEET	AREA SQ IN	ELASTIC MODULUS KSI	SPECIFIC WEIGHT LBS/CU FT
5.101				
5.102				
5.103				
5.104				
⋮				
5.120				

Column scale: 10, 20, 30, 40, 50, 60, 70, 80

FORM 11: INPUT, EXAMPLE 6

NOTE: THERE IS NO CARD NUMBER 6.000

HAMMER OVERRIDE VALUES

	STROKE FEET	EFFICIENCY	PRESSURE PSI	REACTION WEIGHT* KIPS	COMB DELAY+ SECONDS -or- IGNITION VOL++ CU IN
7.000					

* FOR DOUBLE ACTING HAMMERS ONLY

\+ FOR DIESELS WITH LIQUID FUEL INJECTION ONLY

++ FOR DIESELS WITH ATOMIZED FUEL INJECTION ONLY

SOIL PARAMETERS

	QUAKE-SKIN IN	QUAKE-TOE IN	DAMPING-SKIN SEC/FT**	DAMPING-TOE SEC/FT**
8.000			.15	.3

**ISMITH = -1: DIMENSIONLESS (CASE)
0:, 1: S/FT (STANDARD SMITH)
2: S/FT (VISCOUS SMITH)

IIYS = -1 or 0: SKIN FRICTION DISTRIBUTION

	DEPTH FEET	RELATIVE DISTRIBUTION
8.401		
8.402		
8.403		
8.404		
⋮		
8.420		

ULTIMATE CAPACITIES

KIPS (Give up to 10 capacities)

9.000	50.	100.	200.	400.	500.	600.		
10.000								

Columns: 10, 20, 30, 40, 50, 60, 70, 80

FORM 11, continued

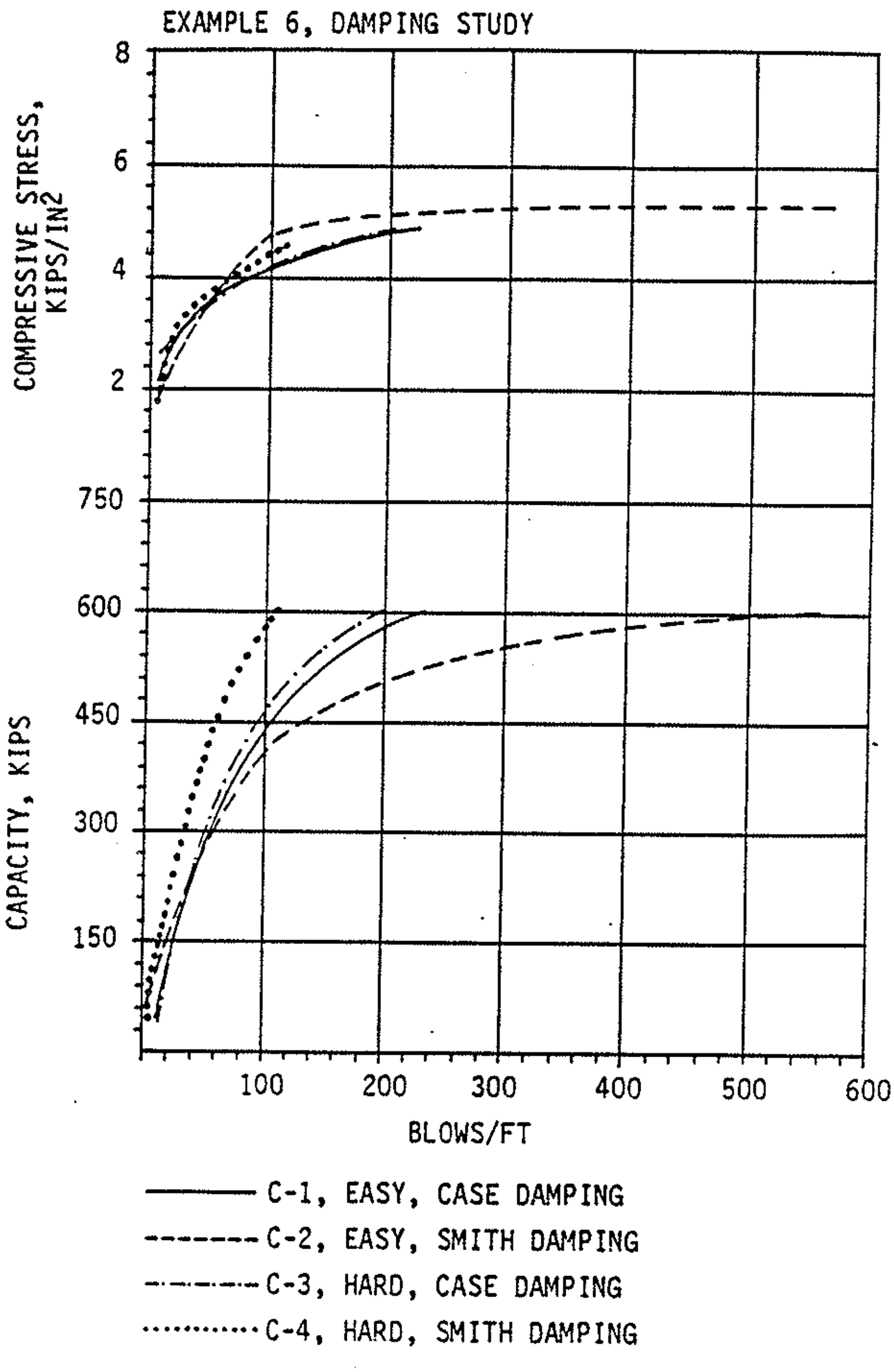


Figure 8. Blow count and stress results from example 6, C-1 to C-4.

WEAP OF 1986 EXAMPLE 6, C-1, EASY, CASE DAMPING

R ULT KIPS	BL CT BPF	STROKE (FT) DOWN	UP	MINSTR KSI	I,J	MAXSTR KSI	I,J	ENTHRU FT-KIP	BL RT BPM
50.0	14.9	4.9	4.8	.00	(1, 0)	2.62	(10, 81)	15.2	53.2
100.0	20.8	5.1	5.1	.00	(1, 0)	2.87	(10, 81)	14.1	51.9
200.0	33.3	5.7	5.7	-.12	(10,292)	3.34	(10, 80)	13.7	49.2
400.0	75.0	6.5	6.6	-.61	(10,242)	3.93	(10, 80)	14.3	45.9
500.0	119.4	7.0	6.9	-.99	(10,237)	4.15	(10, 80)	15.1	44.7
600.0	212.0	7.2	7.1	-1.27	(10,230)	4.53	(10,100)	15.5	44.2

WEAP OF 1986 EXAMPLE 6, C-2, EASY, SMITH DAMPING

R ULT KIPS	BL CT BPF	STROKE (FT) DOWN	UP	MINSTR KSI	I,J	MAXSTR KSI	I,J	ENTHRU FT-KIP	BL RT BPM
50.0	5.4	3.8	3.9	-.05	(3,289)	1.95	(1, 75)	18.6	59.9
100.0	11.7	4.6	4.5	.00	(1, 0)	2.39	(8, 73)	16.4	54.7
200.0	29.3	5.6	5.6	-.36	(10,314)	3.36	(10, 81)	14.1	49.5
400.0	99.0	6.7	6.7	-.83	(10,232)	4.15	(10, 81)	14.7	45.4
500.0	198.1	7.2	7.1	-1.20	(10,226)	4.66	(10,100)	15.7	44.1
600.0	561.6	7.5	7.3	-1.45	(10,223)	4.99	(10, 99)	16.2	43.3

WEAP OF 1986 EXAMPLE 6, C-3, HARD, CASE DAMPING

R ULT KIPS	BL CT BPF	STROKE (FT) DOWN	UP	MINSTR KSI	I,J	MAXSTR KSI	I,J	ENTHRU FT-KIP	BL RT BPM
50.0	14.9	4.9	4.8	.00	(1, 0)	2.62	(10, 81)	15.2	53.2
100.0	20.8	5.1	5.1	.00	(1, 0)	2.86	(10, 81)	14.2	52.0
200.0	32.8	5.7	5.7	-.09	(10,292)	3.26	(10, 80)	13.9	49.3
400.0	73.2	6.6	6.6	-.50	(10,250)	3.79	(10, 99)	14.9	45.8
500.0	113.8	7.0	6.9	-.69	(9,232)	4.27	(10,100)	15.8	44.6
600.0	197.9	7.2	7.2	-.95	(10,220)	4.64	(11,102)	16.2	43.9

WEAP OF 1986 EXAMPLE 6, C-4, HARD, SMITH DAMPING

R ULT KIPS	BL CT BPF	STROKE (FT) DOWN	UP	MINSTR KSI	I,J	MAXSTR KSI	I,J	ENTHRU FT-KIP	BL RT BPM
50.0	5.4	3.8	3.9	-.05	(3,289)	1.95	(1, 75)	18.6	59.9
100.0	9.3	4.2	4.3	-.10	(4,411)	2.21	(6, 66)	16.6	56.4
200.0	20.2	5.1	5.1	-.44	(9,328)	3.03	(10, 79)	14.6	51.9
400.0	47.4	6.2	6.2	-.61	(9,254)	3.53	(10, 80)	15.1	47.1
500.0	71.0	6.8	6.7	-.69	(8,237)	3.69	(11,106)	15.8	45.2
600.0	109.6	7.1	7.0	-.65	(10,220)	4.29	(10,100)	16.4	44.3

FORM 12: OUTPUT, EXAMPLE 6

7.7 Reduced Diesel Fuel and Quake Variation

7.7.1 Situation

This example seeks to demonstrate the use of the IFUEL option for stress control and the effect of a change of quake on blow count. In the hypothetical situation, a 75-foot long steel pile with 16.8 in^2 cross sectional area is driven by a D-30 hammer through coarse grained soil (only 40-kips skin friction) to rock. The skin friction is uniformly distributed except for a triangular portion over the bottom seven feet. Case damping was chosen with .1 for both skin and toe.

7.7.2 Data Input

Four cases were run:

(a) Full fuel (IFUEL = 0) and 0.1 and 0.15 in skin and toe quakes, respectively.

(b) Reduced fuel to IFUEL = 3. Since the D-30 has a 10 step pump, (setting 10 equals maximum) this value corresponds approximately to the actual No. 6 setting.

(c) As in (a) but with quake values of 0.05 inches for both skin and toe.

(d) As in (b) but with the low quakes of (c).

Form 13 shows the input for the first case.

7.7.3 Results

All four summary tables were reproduced together in Form 14. They indicate pile stresses in excess of yield for high capacities and full fuel. The fuel reduction definitely decreases stroke and stresses. For small quakes, because of the high soil stiffness, the highest stresses now occur at the bottom (segment 15).

Lowering the quake has a significant effect on a high blow count (the reader is encouraged to try even higher capacities although stresses then become intolerable).

WEAP86 - Short Input Form

1.000 TITLE (40 Characters)

EXAMPLE 7A: FULL FUEL, HIGH QUAKES

ANALYSIS OPTIONS

2.000

IOUT	IJJ	IHAMR	IOSTR	IFUEL	IPEL	N	ISPL	NCRSS	IDDAM	IPRCS	ISMTH	ITYS	IPHI	IISAO	IIER	IDATA	IMAXT
1100		11				15				TA0	-1						

HELMET AND HAMMER CUSHION INFORMATION

3.000

HELMET WEIGHT KIPS	HAMMER CUSHION AREA SQ IN	HAMMER CUSHION ELASTIC MODULUS KSI	HAMMER CUSHION THICKNESS IN	HAMMER CUSHION C.O.R.	HAMMER CUSHION ROUND OUT FEET	HAMMER CUSHION STIFFNESS* KIPS/IN
.A5				.8	.01	10500.

PILE CUSHION INFORMATION

4.000

AREA SQ IN	ELASTIC MODULUS KSI	THICKNESS IN	C.O.R.	ROUND OUT FEET	STIFFNESS* KIPS/IN

* OVERRIDES AREA (EL. MOD.) / THICKN.

PILE TOP INFORMATION

5.000

TOTAL LENGTH FEET	AREA SQ IN	ELASTIC MODULUS KSI	SPECIFIC WEIGHT LBS/CU FT	C.O.R.	ROUND OUT
75.	16.8	30000.	492.	.85	.01

NCRSS > 0: NON-UNIFORM PILE PROFILE

	DEPTH FEET	AREA SQ IN	ELASTIC MODULUS KSI	SPECIFIC WEIGHT LBS/CU FT
5.101				
5.102				
5.103				
5.104				
⋮				
5.120				

Columns: 10 20 30 40 50 60 70 80

FORM 13: INPUT, EXAMPLE 7

NOTE: THERE IS NO CARD NUMBER 6.000

HAMMER OVERRIDE VALUES

Card	STROKE FEET	EFFICIENCY	PRESSURE PSI	REACTION WEIGHT* KIPS	COMB DELAY+ SECONDS -or- IGNITION VOL++ CU IN
7.000					

* FOR DOUBLE ACTING HAMMERS ONLY

\+ FOR DIESELS WITH LIQUID FUEL INJECTION ONLY

++ FOR DIESELS WITH ATOMIZED FUEL INJECTION ONLY

SOIL PARAMETERS

Card	QUAKE-SKIN IN	QUAKE-TOE IN	DAMPING-SKIN SEC/FT**	DAMPING-TOE SEC/FT**
8.000	.1	.15	.1	.1

**ISMITH = -1: DIMENSIONLESS (CASE)
0:
1: } S/FT (STANDARD SMITH)
2: S/FT (VISCOUS SMITH)

ITYS = -1 or 0: SKIN FRICTION DISTRIBUTION

Card	DEPTH FEET	RELATIVE DISTRIBUTION
8.401	13.	
8.402	13.	.063
8.403	68.	.063
8.404	75.	1.000
⋮		
8.420		

ULTIMATE CAPACITIES

KIPS (Give up to 10 capacities)

Card	1–10	11–20	21–30	31–40	41–50	51–60	61–70	71–80
9.000	100.	200.	300.	400.	500.			
10.000								

FORM 13, continued

WEAP OF 1986 EXAMPLE 7A: FULL FUEL, HIGH QUAKES

R ULT	BL CT	STROKE (FT)		MINSTR	I,J	MAXSTR	I,J	ENTHRU	BL RT
KIPS	BPF	DOWN	UP	KSI		KSI		FT-KIP	BPM
100.0	6.4	3.4	3.6	.00	(1, 0)	20.64	(1, 33)	23.3	62.2
200.0	12.1	4.5	4.5	-.77	(3,266)	26.87	(1, 32)	23.3	54.9
300.0	19.5	5.5	5.4	-1.91	(9,245)	30.20	(3, 36)	24.4	49.8
400.0	33.8	6.4	6.4	-3.07	(11,230)	32.88	(1, 31)	26.1	46.2
500.0	57.2	7.4	7.4	-2.48	(9,222)	35.25	(4, 38)	28.0	43.2

WEAP OF 1986 EXAMPLE 7B: REDUCED FUEL, HIGH QUAKES

R ULT	BL CT	STROKE (FT)		MINSTR	I,J	MAXSTR	I,J	ENTHRU	BL RT
KIPS	BPF	DOWN	UP	KSI		KSI		FT-KIP	BPM
100.0	8.4	3.1	3.0	-.03	(15,355)	18.74	(2, 36)	17.5	65.5
200.0	18.5	3.9	3.9	-1.33	(6,259)	24.30	(1, 32)	16.3	58.5
300.0	36.1	4.7	4.8	-2.19	(10,238)	28.13	(1, 31)	17.3	53.4
400.0	65.4	5.5	5.5	-1.79	(10,228)	30.57	(3, 36)	18.6	49.8
500.0	99.0	5.8	5.9	-1.47	(4,211)	31.68	(3, 36)	19.5	48.2

WEAP OF 1986 EXAMPLE 7C: FULL FUEL, LOW QUAKES

R ULT	BL CT	STROKE (FT)		MINSTR	I,J	MAXSTR	I,J	ENTHRU	BL RT
KIPS	BPF	DOWN	UP	KSI		KSI		FT-KIP	BPM
100.0	6.2	3.4	3.5	.00	(1, 0)	20.65	(3, 38)	23.6	62.4
200.0	12.2	4.4	4.4	-.87	(3,262)	26.86	(2, 34)	22.2	55.4
300.0	20.7	5.2	5.2	-1.60	(13,234)	30.89	(1, 31)	22.2	51.0
400.0	33.8	6.3	6.3	-2.52	(11,233)	33.98	(15, 64)	24.1	46.8
500.0	52.1	7.1	7.1	-1.55	(5,229)	40.00	(15, 68)	26.8	44.0

WEAP OF 1986 EXAMPLE 7D: REDUCED FUEL, LOW QUAKES

R ULT	BL CT	STROKE (FT)		MINSTR	I,J	MAXSTR	I,J	ENTHRU	BL RT
KIPS	BPF	DOWN	UP	KSI		KSI		FT-KIP	BPM
100.0	8.1	3.1	3.0	.00	(1, 0)	18.44	(1, 34)	17.6	65.6
200.0	18.1	3.8	3.8	-.98	(7,254)	23.34	(3, 37)	15.6	59.6
300.0	35.0	4.6	4.6	-1.68	(11,229)	28.00	(1, 31)	16.1	54.4
400.0	59.5	5.2	5.2	-1.12	(5,219)	31.82	(15, 64)	17.6	50.9
500.0	83.2	5.6	5.6	-.96	(5,217)	36.79	(15, 69)	18.0	49.5

FORM 14: OUTPUT, EXAMPLE 7

7.8 Effects of Splice/Slack on Pile Stress

7.8.1 Background

Concrete piles are, in general, sensitive to tension stress waves, in particular if the piles are long. In addition, long piles need to be spliced because of difficulties in handling. Many splices consist of two matching steel fittings that are held together by pins, bolts, bars, keys or other easily installable devices. Such connections are often referred to as mechanical splices. Another type is called a can splice and consists only of a steel sleeve that merely slides over the top of the lower concrete section. There is no tension transfer in a can splice. Thus, tension stresses must be relatively low in the neighborhood of the splice. A comparison between the effects of the two splice types will be demonstrated.

7.8.2 Input Data

Two cases are analyzed with a 160-foot pile (N = 32) spliced in the middle at N = 16. The hammer was a Vulcan 100C (IHAMR = 226) at a reduced pressure of 60 psi. Forty percent skin friction was assumed to act when the pile penetrated 120 feet. A situation with upper and lower high friction was modeled with a compressible layer between 52 and 130 feet below the pile top. Other details may be seen from Form 15 which represents the input data for the mechanical splice. The slack value for the mechanical splice was set to 0.0033 ft (equivalent to 1 min). The coefficient of restitution was 1.0 although a 0.8 is usually recommended. The round-out value was left at the usual 0.01 ft. For the can splice (see Appendix C for the example's echo print) the slack was set to 99 ft, in other words to an unlimited value.

7.8.3 Results

Form 16 shows the tables of extrema for a 50-kip ultimate resistance. The minimum stress values clearly show the effect of the can splice as a reduced tension in the upper section. This "filtering" effect becomes even more apparent if the extreme tension stress values are plotted along the pile.

WEAP86 - Complete Input Form

1.000 TITLE (40 CHARACTERS)

EXAMPLE 8: MECHANICAL SPLICES

ANALYSIS OPTIONS

	IOUT	IJJ	IHAMR	IOSTR	IFUEL	IPEL	N	ISPL	NCRSS	IBDAM	IPRCS	ISMTH	ITYS	IPHI	IRSAO	ITER	IDAHA	IMAXT
2.000	3		226				32	1			110							

IPEL = 2: PILE SEGMENT STIFFNESSES

KIPS/IN (For all elements: 1 through N)

2.101
2.102
⋮
2.113

IPEL = 2: PILE SEGMENT WEIGHTS

KIPS (For all elements: 1 through N)

2.201
2.202
⋮
2.213

IPEL > 0: PILE SEGMENT LENGTHS

Relative Lengths (For all elements: 1 through N)

2.301
2.302
⋮
2.313

1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0

10 20 30 40 50 60 70 80

FORM 15: INPUT, EXAMPLE 8

WEAP86 - Complete Input Form

HELMET AND HAMMER CUSHION INFORMATION

Card	HELMET: WEIGHT KIPS	HAMMER CUSHION: AREA SQ IN	ELASTIC MODULUS KSI	THICKNESS IN	C.O.R.	ROUND OUT FEET	STIFFNESS* KIPS/IN
3.000	2.				.8	.01	22500.

* OVERRIDES AREA (EL. MOD.) / THICKN.

PILE CUSHION INFORMATION

Card	AREA SQ IN	ELASTIC MODULUS KSI	THICKNESS IN	C.O.R.	ROUND OUT FEET	STIFFNESS* KIPS/IN
4.000				.5	.01	1200.

PILE TOP INFORMATION

Card	TOTAL LENGTH FEET	AREA SQ IN	ELASTIC MODULUS KSI	SPECIFIC WEIGHT LBS/CU FT	C.O.R.	ROUND OUT FEET
5.000	160.	144.	5000.	153.	1.	.010

NCRSS > 0: NON-UNIFORM PILE PROFILE

Card	DEPTH FEET	AREA SQ IN	ELASTIC MODULUS KSI	SPECIFIC WEIGHT LBS/CU FT
5.101				
5.102				
5.103				
5.104				
......				
5.120				

NHAMR = 0: HAMMER INFORMATION

Card	NAMMFGR	NAME	ITYPH	M
6.101				

NOTE: THERE IS NO CARD NUMBER 6.000

NHAMR = 0: HAMMER INFORMATION

Card	RAM: WEIGHT KIPS	RAM: LENGTH IN	RAM: DIAMETER IN	STROKE: MAXIMUM FEET	STROKE: MINIMUM** FEET	EFFICIENCY
6.201						

** FOR DIESEL HAMMERS ONLY

FORM 15, continued

IHAMR = 0 and ITYPH = 1 or 2: IMPACT BLOCK INFORMATION

Card	WEIGHT KIPS	LENGTH IN	DIAMETER IN	C.O.R.	ROUND OUT FEET
6.301					

IHAMR = 0 and ITYPH = 1 or 2: DIESEL HAMMER INFORMATION

Card	DEPIB IN	COMBUSTION CHAMBER AREA SQ IN	COMBUSTION CHAMBER VOLUME CU IN	COMBUSTION DELAY SECONDS	COMBUSTION DURATION SECONDS	COMBUSTION EXP COEFF	A I VOLUME IGNITION CU IN	A I VOLUME FINAL COMB CU IN
6.401								

IHAMR = 0 and ITYPH = 1 or 2: PRESSURES

Card	ATMOSPHERIC PSI	SETTING 1 PSI	SETTING 2 PSI	SETTING 3 PSI	SETTING 4 PSI	SETTING 5 PSI	COEFF OF CONF
6.501							

IHAMR = 0 and ITYPH = 2: CED HAMMER INFORMATION

Card	DEPBB IN	B C AREA SQ IN	DBBT IN	D SAFETY FEET	C TANK VOLUME CU IN	REACTION WEIGHT KIPS	B C EXPANSION COEFFICIENT
6.601							

IHAMR = 0 and ITYPH = 3: A/S HAMMER INFORMATION

Card	PISTON EFF AREA SQ IN	PISTON RATED PRESSURE* PSI	ASSEMBLY C.O.R.	ASSEMBLY ROUND OUT FEET	NO OF ELEMENTS (MA)
6.701					

* FOR DOUBLE ACTING A/S HAMMERS ONLY

IHAMR = 0 and ITYPH = 3 and MA > 0: ASSEMBLY INFORMATION (Give input for MA assembly elements)

Card	WEIGHT ELEMENT 1 KIPS	WEIGHT ELEMENT 2 KIPS	WEIGHT ELEMENT 3 KIPS	STIFFNESS ELEMENT 1 KIPS/IN	STIFFNESS ELEMENT 2 KIPS/IN	STIFFNESS ELEMENT 3 KIPS/IN
6.801						

HAMMER OVERRIDE VALUES

Card	STROKE FEET	EFFICIENCY	PRESSURE PSI	REACTION WEIGHT** KIPS	COMB DELAY+ SECONDS -or- IGNITION VOL++ CU IN
7.000			60.		

** FOR DOUBLE ACTING HAMMERS ONLY

\+ FOR DIESELS WITH LIQUID FUEL INJECTION ONLY

\+\+ FOR DIESELS WITH ATOMIZED FUEL INJECTION ONLY

Column scale: 10 20 30 40 50 60 70 80

FORM 15, continued

WEAP86 - Complete Input Form

SOIL PARAMETERS

	QUAKE-SKIN in	QUAKE-TOE in	DAMPING-SKIN SEC/FT *	DAMPING-TOE SEC/FT *
8.000				

* ISMITH = -1: DIMENSIONLESS (CASE)
0:, 1: S/FT (STANDARD SMITH)
2: S/FT (VISCOUS SMITH)

IIYS < -1: SOIL QUAKES

in (For all elements and pile tip: 1 through N+1)

8.101
8.102
⋮
8.113

IIYS < 0: SOIL DAMPING PARAMETERS

SEC/FT (For all elements and pile tip: 1 through N+1)

8.201
8.202
⋮
8.213

IIYS < -1: SOIL RESISTANCE DISTRIBUTION

Relative (For all elements and pile tip: 1 through N+1)

8.301
8.302
⋮
8.313

Columns: 10 20 30 40 50 60 70 80

FORM 15, continued

WEAP86 - Complete Input Form

ITYS = -1 or 0: SKIN FRICTION DISTRIBUTION

	DEPTH FEET	RELATIVE DISTRIBUTION
8.401	40.	
8.402	40.	40.
8.403	52.	45.
8.404	52.	12.
	130.	12.
	130.	18.
	150.	22.
8.420	160.	22.

ISPL > 0: SLACK INFORMATION

	ELEMENT	SLACK FEET	C.O.R.	ROUND OUT FEET
8.501	16	.0033	1.0	.01
8.502				
8.503				
8.504				
8.599				

ULTIMATE CAPACITIES

KIPS (Give up to 10 capacities)

9.000	50.
10.000	

IJJ = 1: PILE ELEMENT NUMBERS

Give up to 13 pile element numbers for output

10.101

FORM 15, continued

RULT = 50.0, RTOE = 30.0 KIPS, DEL T = .250 MS

NO.	FMIN,JMN (K)	FMAX,JMX (K)	STRMIN,JSN (KSI)	STRMAX,JSX (KSI)	VMAX,JVX (F/S)	DMAX,JDX (IN)
1	.0, 0	252.1, 21	.00, 0	1.75, 21	4.4,131	1.392,418
2	-57.2,127	251.4, 22	-.40,127	1.75, 22	4.2, 22	1.391,417
3	-90.3,126	250.5, 23	-.63,126	1.74, 23	4.3,136	1.389,417
4	-102.8,125	249.4, 25	-.71,125	1.73, 25	4.4,137	1.386,416
5	-112.1,123	248.1, 26	-.78,123	1.72, 26	4.3,137	1.383,415
6	-122.8,122	247.5, 28	-.85,122	1.72, 28	4.1, 29	1.380,411
7	-129.1,120	246.5, 30	-.90,120	1.71, 30	4.1, 30	1.380,408
8	-128.8,119	246.6, 31	-.89,119	1.71, 31	4.4, 48	1.379,407
9	-122.8,117	247.6, 33	-.85,117	1.72, 33	4.4, 48	1.377,407
10	-123.7,127	244.4, 34	-.86,127	1.70, 34	4.1, 48	1.375,431
11	-133.5,126	237.7, 36	-.93,126	1.65, 36	4.1, 37	1.375,436
12	-135.1,125	228.4, 37	-.94,125	1.59, 37	4.5, 40	1.377,438
13	-133.9,110	220.4, 55	-.93,110	1.53, 55	4.8, 40	1.379,439
14	-129.2,109	215.2, 56	-.90,109	1.49, 56	4.7, 40	1.379,438
15	-121.2,119	220.8, 44	-.84,119	1.53, 44	4.3, 41	1.379,438
16	-125.0,117	232.4, 45	-.87,117	1.61, 45	5.5,100	1.381,427
17	-120.1,116	232.6, 46	-.83,116	1.62, 46	5.2,101	1.379,427
18	-119.0,114	232.6, 48	-.83,114	1.62, 48	4.8,102	1.376,428
19	-120.0,112	232.3, 49	-.83,112	1.61, 49	4.6,105	1.372,429
20	-110.7,113	232.7, 51	-.77,113	1.62, 51	4.8,107	1.368,431
21	-84.6,114	232.6, 53	-.59,114	1.62, 53	4.9, 90	1.366,434
22	-78.9,252	232.2, 54	-.55,252	1.61, 54	5.1, 90	1.364,436
23	-81.1,251	232.6, 56	-.56,251	1.62, 56	5.1, 89	1.363,438
24	-89.5,248	232.6, 58	-.62,248	1.62, 58	5.0, 87	1.362,440
25	-91.5,248	232.0, 60	-.64,248	1.61, 60	5.4, 82	1.361,442
26	-79.1,249	232.5, 61	-.55,249	1.61, 61	6.0, 81	1.360,443
27	-68.1,137	232.4, 63	-.47,137	1.61, 63	6.3, 81	1.359,444
28	-64.4,135	229.6, 64	-.45,135	1.59, 64	6.4, 81	1.357,446
29	-61.6,133	220.8, 66	-.43,133	1.53, 66	6.1, 80	1.357,448
30	-70.0,131	198.8, 66	-.49,131	1.38, 66	6.0, 76	1.356,450
31	-60.3,132	158.1, 67	-.42,132	1.10, 67	6.5, 73	1.355,451
32	-22.7,132	97.4, 68	-.16,132	.68, 68	6.9, 73	1.354,451

WEAP OF 1986 EXAMPLE 8: MECHANICAL SPLICE

R ULT KIPS	BL CT BPF	STROKE(EQ.) FT	MINSTR KSI	I,J	MAXSTR KSI	I,J	ENTHRU FT-KIP
50.0	9.6	2.20	-.94	(12,125)	1.75	(1, 21)	8.3

FORM 16: OUTPUT, EXAMPLE 8A

WEAP86: WAVE EQUATION ANALYSIS OF PILE FOUNDATIONS
1986, VERSION 1.001

EXAMPLE 8: CAN SPLICE

HAMMER MODEL OF: VUL 100C MADE BY: VULCAN

ELEMENT	WEIGHT (KIPS)	STIFFNESS (K/IN)	COEFF. OF RESTITUTION	D-NL. FT	CAP DAMPG (K/FT/S)
1	10.000				
CAP/RAM	2.000	19752.5	.800	.0100	10.9
CUSHION		1200.0	.500	.0100	

ASSEMBLY	WEIGHT (KIPS)	STIFFNESS (K/IN)	COEFF. OF RESTITUTION	D-NL. FT
1	6.100	41777.1		
2	6.100	41777.1	.800	.0100

PILE PROFILE:

LBT (FT)	AREA (IN2)	E-MOD (KSI)	SP.W. (LB/FT3)	WAVE SP (FT/S)	EA/C (K/FT/S)
.00	144.0	5000.	153.000	12304.0	58.5
160.00	144.0	5000.	153.000	12304.0	58.5

WAVE TRAVEL TIME - 2L/C - = 26.008 MS

PILE AND SOIL MODEL FOR RULT = 50.0 KIPS

NO	WEIGHT (KIPS)	STIFFN (K/IN)	D-NL (FT)	SPLICE (FT)	COR	SOIL-S (KIPS)	SOIL-D (S/FT)	QUAKE (IN)	L BT (FT)	AREA (IN**2)
1	.765	12000.	.010	.000	1.000	.0	.100	.100	5.00	144.0
2	.765	12000.	.010	-1.000	1.000	.0	.100	.100	10.00	144.0
9	.765	12000.	.010	-1.000	1.000	3.5	.100	.100	45.00	144.0
10	.765	12000.	.010	-1.000	1.000	5.0	.100	.100	50.00	144.0
11	.765	12000.	.010	-1.000	1.000	2.5	.100	.100	55.00	144.0
12	.765	12000.	.010	-1.000	1.000	.1	.100	.100	60.00	144.0
16	.765	12000.	.010	99.000	1.000	.1	.100	.100	80.00	144.0
17	.765	12000.	.010	-1.000	1.000	.1	.100	.100	85.00	144.0
27	.765	12000.	.010	-1.000	1.000	.7	.100	.100	135.00	144.0
28	.765	12000.	.010	-1.000	1.000	.9	.100	.100	140.00	144.0
29	.765	12000.	.010	-1.000	1.000	1.1	.100	.100	145.00	144.0
30	.765	12000.	.010	-1.000	1.000	1.4	.100	.100	150.00	144.0
31	.765	12000.	.010	-1.000	1.000	1.5	.100	.100	155.00	144.0
32	.765	12000.	.010	-1.000	1.000	1.5	.100	.100	160.00	144.0
TOE						30.0	.100	.100		

PILE OPTIONS:

N/UNIFORM	AUTO S.G.	SPLICES	DAMPNG-P	D-P VALUE (K/FT/S)
0	0	1	1	1.170

SOIL OPTIONS:

% SKIN FR	% END BG	DIS. NO.	S DAMPING
40	60	0	SMITH-1

FORM 17: OUTPUT, EXAMPLE 8B

WEAP OF 1986 EXAMPLE 8: CAN SPLICE

RULT = 50.0, RTOE = 30.0 KIPS, DEL T = .250 MS

NO.	FMIN,JMN (K)	FMAX,JMX (K)	STRMIN,JSN (KSI)	STRMAX,JSX (KSI)	VMAX,JVX (F/S)	DMAX,JDX (IN)
1	.0, 0	252.1, 21	.00, 0	1.75, 21	4.2, 21	1.301,379
2	-12.9,296	251.4, 22	-.09,296	1.75, 22	4.2, 22	1.297,379
3	-21.9,296	250.5, 23	-.15,296	1.74, 23	4.2, 24	1.292,379
4	-25.6,296	249.4, 25	-.18,296	1.73, 25	4.1, 26	1.286,380
5	-24.9,115	248.1, 26	-.17,115	1.72, 26	4.1, 27	1.280,382
6	-23.3,117	247.5, 28	-.16,117	1.72, 28	4.1, 29	1.274,382
7	-21.6,117	246.5, 30	-.15,117	1.71, 30	4.1, 30	1.268,382
8	-17.3,118	246.6, 31	-.12,118	1.71, 31	4.4, 48	1.262,382
9	-18.3,305	247.6, 33	-.13,305	1.72, 33	4.4, 48	1.256,382
10	-24.8,305	244.4, 34	-.17,305	1.70, 34	4.1, 48	1.251,382
11	-28.4,305	237.7, 36	-.20,305	1.65, 36	4.1, 37	1.247,382
12	-26.4,304	228.4, 37	-.18,304	1.59, 37	4.5, 40	1.243,382
13	-28.9,281	220.4, 55	-.20,281	1.53, 55	4.8, 40	1.241,382
14	-25.0,281	215.2, 56	-.17,281	1.49, 56	4.7, 40	1.238,382
15	-14.6,282	220.8, 44	-.10,282	1.53, 44	4.3, 41	1.235,382
16	.0, 0	232.4, 45	.00, 0	1.61, 45	5.6,101	1.424,235
17	-47.8, 96	232.6, 46	-.33, 96	1.62, 46	5.3,101	1.423,235
18	-74.2, 96	232.6, 48	-.52, 96	1.62, 48	4.8,104	1.420,236
19	-83.5, 96	232.3, 49	-.58, 96	1.61, 49	5.0,108	1.418,236
20	-79.9, 95	232.7, 51	-.55, 95	1.62, 51	5.1,109	1.415,238
21	-66.2, 94	232.6, 53	-.46, 94	1.62, 53	5.1,109	1.411,239
22	-48.6, 93	232.2, 54	-.34, 93	1.61, 54	5.1, 90	1.408,239
23	-51.0,103	232.6, 56	-.35,103	1.62, 56	5.1, 89	1.405,237
24	-57.6,104	232.6, 58	-.40,104	1.62, 58	5.0, 87	1.401,236
25	-53.7,103	232.0, 60	-.37,103	1.61, 60	5.4, 82	1.397,236
26	-40.3,102	232.5, 61	-.28,102	1.61, 61	6.0, 81	1.395,253
27	-28.7,365	232.4, 63	-.20,365	1.61, 63	6.3, 81	1.395,253
28	-23.2,366	229.6, 64	-.16,366	1.59, 64	6.4, 81	1.394,254
29	-24.1, 95	220.8, 66	-.17, 95	1.53, 66	6.1, 80	1.393,254
30	-24.1, 95	198.8, 66	-.17, 95	1.38, 66	6.0, 76	1.390,254
31	-14.5,318	158.1, 67	-.10,318	1.10, 67	6.5, 73	1.388,255
32	-7.8,318	97.4, 68	-.05,318	.68, 68	6.9, 73	1.385,257

R ULT KIPS	BL CT BPF	STROKE(EQ.) FT	MINSTR KSI	I,J	MAXSTR KSI	I,J	ENTHRU FT-KIP
50.0	9.3	2.20	-.58	(19, 96)	1.75	(1, 21)	8.2

FORM 17, continued

7.9 Residual Force Analysis Example

In order to demonstrate the residual force analysis capability, Problem 2 was reanalyzed using the residual stress option. The only difference in the input data is on Card No. 2.000. The option IRSA is set to 1 invoking the residual stress analysis. The summary table together with the 320 kip extrema and residual force table is reprinted in Form 18.

7.9.1 Discussion of Results

A review of the results shows that the blow count for both RULT values is substantially reduced. At 240-kips ultimate capacity, the blow count is now 83 down from 265 blows per foot. At 320 kips the residual force analysis shows a blow count of 1467 blows per foot instead of absolute refusal.

The pile residual stresses are quite high at 14.5 ksi (see residual force/stress table following extremas), but the driving stresses only increased to 34 ksi (240 kips) and 35 ksi (320 kips ultimate).

An interesting observation may be made when inspecting the pile top forces vs time curves (Figure 9 shows the pile top force and velocity from both Examples 2 and 9. The velocity curve was scaled by multiplication with the pile top impedance, EA/C). In the normal analysis a very rounded behavior is apparent and, in fact, no actual impact happened since the pile, due to its elasticity, moved away from the hammer during the precompression phase. The residual stresses, on the other hand, made the pile stiff enough for impact, which is apparent from the slight steep force/velocity rise in the early record portion. The improvement in blow count therefore seems to be not only the result of a stiffer pile but also an improved hammer behavior. However, the ram reached the uplift condition of this closed end hammer and a fuel reduction had to be made. This explains why the transferred energies were lower in Example 9 than in Example 2.

7.9.2 Correlation

Measurements were taken when similar piles were redriven with the LB 520 hammer. Force records showed some evidence of ram impact, other records were smooth. The measured curves were superimposed on the computed ones in Figure 9. Note that a pile was load tested to 270 kips ultimate and that a blow count of 160 blows per foot resulted during restriking. The blow count during driving was 47 blows per ft. The transferred energy during restriking varied between 7 and 12 kip-ft.

In this case it is clear that a residual stress analysis is producing more realistic results than the standard wave equation approach. The pile type, being similar to the Monotube stored substantial energies between blows because of its flexibility.

WEAP OF 1986 EXAMPLE 9, DRIVEABILITY STUDY, LB-520

RULT = 240.0, RTOE = 72.0 KIPS, DEL T = .085 MS

NO.	FMIN,JMN (K)		FMAX,JMX (K)	STRMIN,JSN (KSI)		STRMAX,JSX (KSI)	VMAX,JVX (F/S)	DMAX,JDX (IN)
1	.0,	0	280.7,157	.00,	0	31.90,157	7.0, 99	.739,183
2	.0,	0	286.2,153	.00,	0	32.52,153	6.5,103	.677,187
3	.0,	0	285.4,155	.00,	0	32.44,155	6.0,107	.615,190
4	.0,	0	277.8,158	.00,	0	31.57,158	5.5,110	.556,194
5	.0,	0	268.7,158	.00,	0	34.05,158	5.0,114	.492,198
6	.0,	0	258.7,161	.00,	0	33.33,161	4.4,117	.430,202
7	.0,	0	247.7,163	.00,	0	31.92,163	3.8,122	.372,207
8	.0,	0	236.0,167	.00,	0	30.42,167	3.3,125	.316,212
9	.0,	0	223.5,169	.00,	0	29.66,169	2.8,128	.263,217
10	.0,	0	209.8,170	.00,	0	31.17,170	2.3,131	.207,222
11	.0,	0	195.3,172	.00,	0	29.02,172	1.9,138	.157,228
12	.0,	0	179.9,174	.00,	0	26.74,174	1.9,169	.111,234
13	.0,	0	163.8,178	.00,	0	24.34,178	1.8,174	.070,240
14	.0,	0	146.9,180	.00,	0	21.83,180	1.8,179	.035,246
15	.0,	0	129.2,183	.00,	0	19.20,183	1.8,185	.004,251
16	.0,	0	110.7,185	.00,	0	13.57,185	1.8,188	.000, 0

WEAP OF 1986 EXAMPLE 9, DRIVEABILITY STUDY, LB-520

RULT = 240.0, RTOE = 54.2 KIPS

RESIDUAL VARIABLES AT END OF ANALYSIS

NO.	P-FORCE (KIPS)	P-STRESS (KSI)	S-RESIS (KIPS)	DISPL. (IN)
1	.00	.00	.00	.145
2	.00	.00	-3.78	.145
3	3.78	.43	-8.09	.144
4	11.87	1.35	-8.65	.142
5	20.52	2.60	-9.21	.136
6	29.73	3.83	-9.77	.128
7	39.50	5.09	-10.33	.118
8	49.83	6.42	-10.89	.105
9	60.72	8.06	-8.53	.088
10	69.25	10.29	-4.83	.067
11	74.08	11.01	-1.52	.045
12	75.60	11.23	1.40	.022
13	74.20	11.03	3.95	-.001
14	70.25	10.44	6.17	-.022
15	64.08	9.52	8.12	-.042
16	55.95	6.86	9.84	-.058
TOE			46.11	

STROKES ANALYZED AND LAST RETURN (FT):
2.66 3.32 3.64 3.77 3.79 3.79 3.74
*** UPLIFT OCCURRED, PRESSURE WAS REDUCED TO 819.5 PSI***

WEAP OF 1986 EXAMPLE 9, DRIVEABILITY STUDY, LB-520

RULT = 320.0, RTOE = 96.0 KIPS, DEL T = .085 MS

NO.	FMIN,JMN (K)		FMAX,JMX (K)	STRMIN,JSN (KSI)		STRMAX,JSX (KSI)	VMAX,JVX (F/S)	DMAX,JDX (IN)
1	.0,	0	286.1,140	.00,	0	32.51,140	9.2, 92	.663,161
2	.0,	0	293.3,144	.00,	0	33.33,144	8.6, 96	.596,162
3	.0,	0	293.4,151	.00,	0	33.34,151	7.9,100	.529,164
4	.0,	0	287.3,153	.00,	0	32.65,153	7.3,103	.463,165
5	.0,	0	279.6,157	.00,	0	35.43,157	6.5,107	.391,166
6	.0,	0	270.7,160	.00,	0	34.88,160	5.7,110	.320,167
7	.0,	0	260.5,162	.00,	0	33.56,162	5.0,114	.251,169
8	.0,	0	249.1,161	.00,	0	32.11,161	4.4,117	.186,170
9	.0,	0	236.6,164	.00,	0	31.40,164	3.8,121	.122,171
10	.0,	0	222.8,166	.00,	0	33.10,166	3.2,124	.054,173
11	.0,	0	207.7,166	.00,	0	30.87,166	2.7,127	.000, 0
12	.0,	0	191.7,166	.00,	0	28.48,166	2.3,131	.000, 0
13	.0,	0	174.6,168	.00,	0	25.94,168	1.9,134	.000, 0
14	.0,	0	156.6,172	.00,	0	23.27,172	1.5,137	.000, 0
15	.0,	0	139.4,142	.00,	0	20.71,142	1.2,140	.000, 0
16	.0,	0	121.3,145	.00,	0	14.87,145	1.0,144	.000, 0

WEAP OF 1986 EXAMPLE 9, DRIVEABILITY STUDY, LB-520

RULT = 320.0, RTOE = 76.7 KIPS

RESIDUAL VARIABLES AT END OF ANALYSIS

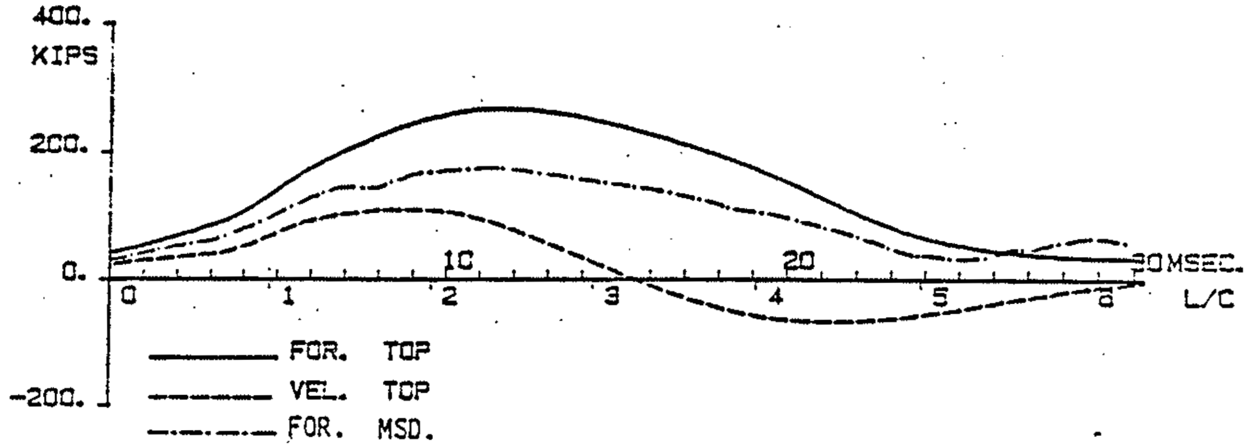
NO.	P-FORCE (KIPS)	P-STRESS (KSI)	S-RESIS (KIPS)	DISPL. (IN)
1	.00	.00	.00	.008
2	.00	.00	-5.04	.008
3	5.04	.57	-10.79	.007
4	15.82	1.80	-11.54	.003
5	27.36	3.47	-12.28	-.004
6	39.64	5.11	-13.03	-.014
7	52.67	6.79	-13.77	-.028
8	66.44	8.56	-14.52	-.046
9	80.96	10.75	-13.66	-.068
10	94.62	14.06	-8.13	-.096
11	102.76	15.27	-3.21	-.128
12	105.97	15.75	1.15	-.160
13	104.82	15.58	5.00	-.192
14	99.82	14.83	8.40	-.222
15	91.42	13.58	11.42	-.250
16	80.00	9.81	14.07	-.274
TOE			65.93	

STROKES ANALYZED AND LAST RETURN (FT):
3.79 3.79 3.79 3.72
*** UPLIFT OCCURRED, PRESSURE WAS REDUCED TO 739.6 PSI***

R ULT KIPS	BL CT BPF	STRKE FT	BCP PSI	MINSTR KSI	I,J	MAXSTR KSI	I,J	ENTHRU FT-KIP	BL RT BPM
240.0	82.6	3.8	24.1	.00(	1, 0)	34.05(	5,158)	11.9	81.2
320.0	1466.7	3.8	23.7	.00(	1, 0)	35.43(	5,157)	11.0	81.5

FORM 18: OUTPUT, EXAMPLE 9

WEAP OF 1986 - RESULTS
EXAMPLE 2. DRIVEABILITY STUDY, LB-520
26-FEB-86 WEAP CAPACITY 240. KIPS



WEAP OF 1986 - RESULTS
EXAMPLE 9. DRIVEABILITY STUDY, LB-520
26-FEB-86 WEAP CAPACITY 240. KIPS

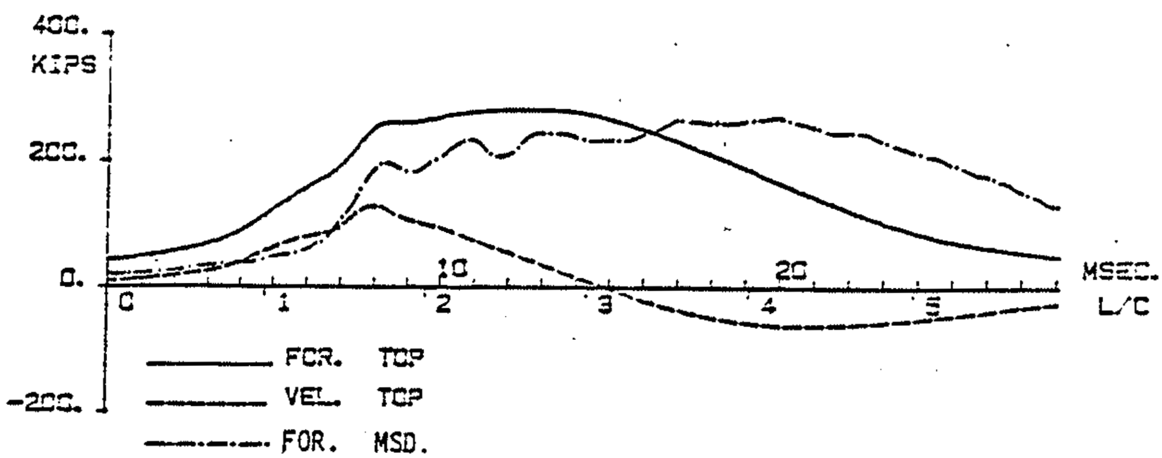


Figure 9. Pile top force and velocity from examples 2 and 9.

7.10 Pile Damping, Long Piles, Diesel Hammer Performance

7.10.1 Background

Dashpots connecting the pile segments usually have a damping parameter assigned that equal 2 percent of the pile segment's impedance (or the pile's impedance if the pile is uniform) at the middle of the pile. The impedance equals pile modulus, E, times pile cross sectional area, A, divided by pile wave speed, c. Using IBEDAM on Card No. 2.000, the dashpot value can be changed in increments of 2 percent; a zero value is input as a -1; a 2 percent value is input by either IBEDAM = 1 or 0.

The effect of pile damping is studied in the present example of a long steel pile; first for zero and second for 2 percent pile damping.

7.10.2 Input

A 300-ft long pile was modeled (30 inch diameter, 1 inch wall thickness). It was assumed to be driven by a Delmag D-62-22 hammer. Two ultimate capacity values of 1000 and 1500 kips (90 percent acting at the skin) with Smith viscous damping of 0.05 and 0.15 s/ft for skin and toe, respectively, were investigated. The input is further shown in Form 19. For the second case, IBEDAM was left blank on Card No. 2,000.

7.10.3 Results

The extrema tables of the 1000-kip analyses and the summary tables of both cases are shown in Form 20. Numerically, the two cases do differ, however, the results are rather close together. This is only true for blow counts less than 120 bl/ft. For greater blow counts the differences may be more pronounced.

Another observation is quite interesting. The static resistance had been distributed over 60 percent of the pile length, starting at the bottom. Thus, the upper 36 segments were without resistance. It is, therefore, expected that the wave (or say the maxima of forces and velocities) stays nearly constant as the wave progresses down the pile. For the 0 percent (2 percent) pile damping case, the maximum velocity is 11.5 (11.4) ft/s. The velocity value at segment 20 (sufficiently high above the friction elements for no major upwards stress wave effects interfering with the downward wave) is 11.5 (10.9) ft/s. This indicates wave reductions of 1 and 4 percent for the undampened and dampened pile, respectively. These results suggest that a long pile is better analyzed with zero or small pile damping.

Better numerical program performance can be achieved by using more pile and/or ram segments and by decreasing the time increment. This may be, respectively, accomplished by using a larger N, a larger M (hammer data file!) or a greater IPHI.

It is also important to realize that the hammer file data may contain combustion pressure values which do not accurately reproduce the field observed stroke. The 6.8-ft stroke is somewhat lower than expected for a D-60-22 hammer under normal circumstance. On the other hand, transferred energy values (ENTHRU) between 50 and 60 kip-ft are normally measured. Higher energy values are unusual. Thus, it can be concluded that the hammer model is realistic with the 1400 psi pressure. Because of these sometimes conflicting observations, all of the diesel hammer pressures in the data file were adjusted for reasonable energy transfer.

In summary, it is recommended to check

- The hammer performance, both actually delivered energy and stroke.
- To run the program with zero pile damping (IBEDAM=-1) for long piles (say longer than 150 ft or 45 m).

WEAP86 - Short Input Form

TITLE (40 Characters)

1.000 EXAMPLE 10: PILE DAMPING 5.0

ANALYSIS OPTIONS

	IOUT	IJJ	IHAMR	IOSTR	IFUEL	IPEL	N	ISPL	NCRSS	IDDAM	IPRCS	ISMTH	ITYS	IPIII	IISAO	IIER	IDAIA	IMAXT
2.000	1		30				60	0	0	1	90		4					

HELMET AND HAMMER CUSHION INFORMATION

	HELMET WEIGHT KIPS	HAMMER CUSHION AREA SQ IN	ELASTIC MODULUS KSI	THICKNESS IN	C.O.R.	ROUND OUT FEET	STIFFNESS* KIPS/IN
3.000	5.				.8	.01	30000.

PILE CUSHION INFORMATION

	AREA SQ IN	ELASTIC MODULUS KSI	THICKNESS IN	C.O.R.	ROUND OUT FEET	STIFFNESS* KIPS/IN
4.000				.5	.01	

* OVERRIDES AREA (EL. MOD.) / THICKN.

PILE TOP INFORMATION

	TOTAL LENGTH FEET	AREA SQ IN	ELASTIC MODULUS KSI	SPECIFIC WEIGHT LBS/CU FT	C.O.R.	ROUND OUT
5.000	300.	41.1	30000.	492.	.85	.01

NCRSS > 0: NON-UNIFORM PILE PROFILE

	DEPTH FEET	AREA SQ IN	ELASTIC MODULUS KSI	SPECIFIC WEIGHT LBS/CU FT
5.101				
5.102				
5.103				
5.104				
⋮				
5.120				

10 20 30 40 50 60 70 80

FORM 19: INPUT, EXAMPLE 10

NOTE: THERE IS NO CARD NUMBER 6.000

HAMMER OVERRIDE VALUES

Card	STROKE FEET	EFFICIENCY	PRESSURE PSI	REACTION WEIGHT* KIPS	COMB DELAY+ SECONDS -or- IGNITION VOL++ CU IN
7.000					

* FOR DOUBLE ACTING HAMMERS ONLY

\+ FOR DIESELS WITH LIQUID FUEL INJECTION ONLY

++ FOR DIESELS WITH ATOMIZED FUEL INJECTION ONLY

SOIL PARAMETERS

Card	QUAKE-SKIN IN	QUAKE-TOE IN	DAMPING-SKIN SEC/FT**	DAMPING-TOE SEC/FT**
8.000	/	/	.05	.15

**ISMITH = -1: DIMENSIONLESS (CASE)
0:, 1: S/FT (STANDARD SMITH)
2: S/FT (VISCOUS SMITH)

ITYS = -1 or 0: SKIN FRICTION DISTRIBUTION

Card	DEPTH FEET	RELATIVE DISTRIBUTION
8.401		
8.402		
8.403		
8.404		
⋮		
8.420		

ULTIMATE CAPACITIES

KIPS (Give up to 10 capacities)

Card								
9.000	1000.	1500.						
10.000								

Columns: 10 20 30 40 50 60 70 80

FORM 19, continued

WEAP OF 1986 EXAMPLE 10, PILE DAMPING = 0

RULT = 1000.0, RTOE = 100.0 KIPS, DEL T = .110 MS

NO.	FMIN,JMN (K)	FMAX,JMX (K)	STRMIN,JSN (KSI)	STRMAX,JSX (KSI)	VMAX,JVX (F/S)	DMAX,JDX (IN)
1	.0, 0	1931.2, 40	.00, 0	21.20, 40	11.5, 42	.881,260
2	-180.3,364	1935.3, 43	-1.98,364	21.24, 43	11.6, 45	.875,260
3	-286.0,364	1934.2, 46	-3.14,364	21.23, 46	11.6, 48	.869,259
4	-322.8,362	1931.1, 49	-3.54,362	21.20, 49	11.6, 51	.862,259
5	-323.0,360	1926.8, 52	-3.55,360	21.15, 52	11.6, 54	.855,258
6	-311.8,357	1921.7, 55	-3.42,357	21.09, 55	11.6, 57	.848,256
7	-295.8,355	1915.9, 58	-3.25,355	21.03, 58	11.6, 59	.840,255
8	-280.7,352	1909.2, 61	-3.08,352	20.96, 61	11.6, 62	.833,254
9	-276.7,349	1901.3, 64	-3.04,349	20.87, 64	11.6, 65	.825,253
10	-277.6,346	1892.0, 67	-3.05,346	20.77, 67	11.6, 68	.817,252
11	-268.8,344	1888.6, 69	-2.95,344	20.73, 69	11.6, 71	.808,253
12	-246.7,341	1885.7, 72	-2.71,341	20.70, 72	11.6, 74	.800,253
13	-220.1,339	1881.2, 75	-2.42,339	20.65, 75	11.5, 76	.791,255
14	-196.2,336	1875.3, 78	-2.15,336	20.58, 78	11.5, 79	.781,258
15	-175.4,333	1868.1, 81	-1.93,333	20.51, 81	11.5, 82	.773,262
16	-188.6,430	1859.7, 84	-2.07,430	20.41, 84	11.5, 85	.764,263
17	-197.6,432	1858.7, 86	-2.17,432	20.40, 86	11.5, 88	.755,263
18	-211.2,435	1857.0, 89	-2.32,435	20.38, 89	11.4, 91	.745,262
19	-215.2,438	1853.7, 92	-2.36,438	20.35, 92	11.4, 93	.735,261
20	-233.2,512	1848.6, 95	-2.56,512	20.29, 95	11.4, 96	.725,260
21	-237.6,512	1841.4, 98	-2.61,512	20.21, 98	11.4, 99	.714,258
22	-252.1,502	1839.0,100	-2.77,502	20.19,100	11.3,102	.703,256
23	-271.8,504	1837.1,103	-2.98,504	20.17,103	11.3,105	.692,254
24	-291.9,507	1833.2,106	-3.20,507	20.12,106	11.3,107	.680,253
25	-308.2,510	1828.4,109	-3.38,510	20.07,109	11.3,110	.668,251
26	-320.4,512	1823.7,112	-3.52,512	20.02,112	11.2,113	.658,310
27	-318.3,499	1826.7,114	-3.49,499	20.05,114	11.1,116	.651,308
28	-335.7,502	1832.0,117	-3.68,502	20.11,117	11.1,118	.643,305
29	-349.4,505	1835.4,120	-3.83,505	20.15,120	11.0,121	.635,303
30	-359.7,508	1832.9,123	-3.95,508	20.12,123	11.0,124	.626,300
31	-370.5,511	1825.1,125	-4.07,511	20.03,125	11.0,127	.617,298
32	-375.3,512	1817.8,128	-4.12,512	19.95,128	11.0,130	.607,295
33	-383.6,477	1811.7,131	-4.21,477	19.89,131	11.0,132	.596,292
34	-404.7,479	1814.0,134	-4.44,479	19.91,134	10.9,135	.585,290
35	-421.5,482	1823.9,137	-4.63,482	20.02,137	10.8,138	.574,287
36	-433.5,485	1837.6,139	-4.76,485	20.17,139	10.6,141	.562,285
37	-444.1,487	1853.6,142	-4.87,487	20.35,142	10.5,143	.550,282
38	-452.5,490	1863.9,145	-4.97,490	20.46,145	10.4,146	.537,279
39	-457.4,493	1868.4,148	-5.02,493	20.51,148	10.3,149	.524,277
40	-457.8,496	1868.4,151	-5.03,496	20.51,151	10.2,152	.511,274
41	-457.5,498	1870.9,153	-5.02,498	20.54,153	10.0,154	.498,272
42	-456.6,501	1869.3,156	-5.01,501	20.52,156	9.9,157	.484,269
43	-452.8,504	1862.5,159	-4.97,504	20.44,159	9.7,160	.470,267
44	-443.6,507	1848.3,162	-4.87,507	20.29,162	9.6,163	.456,264
45	-428.7,509	1828.7,164	-4.71,509	20.07,164	9.5,166	.443,261
46	-407.9,512	1797.1,167	-4.48,512	19.73,167	9.4,168	.429,259
47	-354.7,512	1750.0,170	-3.89,512	19.21,170	9.4,171	.416,256
48	-244.4,512	1695.5,173	-2.68,512	18.61,173	9.4,174	.403,254
49	-99.2,512	1649.5,176	-1.09,512	18.11,176	9.2,177	.391,265
50	-64.7,238	1624.3,178	-.71,238	17.83,178	8.9,179	.380,262
51	-104.2,236	1613.6,181	-1.14,236	17.71,181	8.6,182	.369,260

WEAP OF 1986 EXAMPLE 10, PILE DAMPING = 0

RULT = 1000.0, RTOE = 100.0 KIPS, DEL T = .110 MS

NO.	FMIN,JMN (K)	FMAX,JMX (K)	STRMIN,JSN (KSI)	STRMAX,JSX (KSI)	VMAX,JVX (F/S)	DMAX,JDX (IN)
52	-109.2,231	1598.5,184	-1.20,231	17.55,184	8.2,185	.359,257
53	-227.9,229	1568.6,187	-2.50,229	17.22,187	7.9,188	.351,254
54	-260.0,227	1528.1,190	-2.85,227	16.77,190	7.6,190	.344,251
55	-396.1,224	1487.0,192	-4.35,224	16.32,192	7.4,193	.337,249
56	-409.7,224	1431.6,195	-4.50,224	15.71,195	7.2,196	.330,247
57	-195.4,224	1341.0,197	-2.14,224	14.72,197	7.5,200	.324,243
58	-367.9,214	1178.3,198	-4.04,214	12.93,198	8.7,204	.321,241
59	-450.0,215	919.7,200	-4.94,215	10.10,200	10.2,206	.320,236
60	-244.8,216	573.0,201	-2.69,216	6.29,201	11.2,207	.322,235

STROKES ANALYZED AND LAST RETURN (FT):

5.81 6.62 6.63

WEAP OF 1986 EXAMPLE 10, PILE DAMPING = 0

R ULT KIPS	BL CT BPF	STROKE (FT) DOWN	UP	MINSTR KSI	I,J	MAXSTR KSI	I,J	ENTHRU FT-KIP	BL RT BPM
1000.0	54.0	6.6	6.6	-5.03	(40,496)	21.24	(2, 43)	49.1	45.3
1500.0	109.5	6.8	6.8	-6.67	(39,488)	21.51	(3, 47)	50.4	44.8

FORM 20: OUTPUT, EXAMPLE 10

WEAP OF 1986 EXAMPLE 10, PILE DAMPING = 2%

RULT = 1000.0, RTOE = 100.0 KIPS, DEL T = .110 MS

NO.	FMIN,JMN (K)	FMAX,JMX (K)	STRMIN,JSN (KSI)	STRMAX,JSX (KSI)	VMAX,JVX (F/S)	DMAX,JDX (IN)
1	.0, 0	1910.2, 40	.00, 0	20.97, 40	11.4, 42	.880,260
2	-141.3,363	1906.4, 43	-1.55,363	20.93, 43	11.4, 45	.874,260
3	-219.5,363	1899.9, 46	-2.41,363	20.85, 46	11.4, 48	.868,259
4	-245.5,362	1891.8, 49	-2.69,362	20.77, 49	11.4, 51	.861,258
5	-242.9,360	1883.3, 52	-2.67,360	20.67, 52	11.4, 54	.854,257
6	-231.5,357	1874.5, 55	-2.54,357	20.58, 55	11.3, 57	.847,256
7	-216.3,354	1865.4, 58	-2.37,354	20.48, 58	11.3, 59	.840,255
8	-202.8,352	1855.7, 61	-2.23,352	20.37, 61	11.3, 62	.832,255
9	-195.6,349	1845.2, 64	-2.15,349	20.25, 64	11.3, 65	.824,254
10	-190.7,346	1833.7, 67	-2.09,346	20.13, 67	11.2, 68	.816,254
11	-179.0,344	1823.5, 69	-1.97,344	20.02, 69	11.2, 71	.808,254
12	-161.0,341	1818.4, 72	-1.77,341	19.96, 72	11.2, 74	.799,255
13	-137.6,338	1812.0, 75	-1.51,338	19.89, 75	11.1, 76	.790,256
14	-143.5,508	1804.5, 78	-1.58,508	19.81, 78	11.1, 79	.781,259
15	-156.8,512	1795.9, 81	-1.72,512	19.71, 81	11.1, 82	.772,261
16	-170.5,512	1786.3, 84	-1.87,512	19.61, 84	11.0, 85	.763,262
17	-184.3,512	1780.8, 86	-2.02,512	19.55, 86	11.0, 88	.754,262
18	-197.9,512	1777.2, 89	-2.17,512	19.51, 89	10.9, 91	.744,261
19	-210.5,512	1772.1, 92	-2.31,512	19.45, 92	10.9, 93	.734,260
20	-221.5,512	1765.4, 95	-2.43,512	19.38, 95	10.9, 96	.724,258
21	-231.9,512	1757.1, 98	-2.55,512	19.29, 98	10.8, 99	.713,257
22	-243.9,512	1751.7,100	-2.68,512	19.23,100	10.8,102	.702,255
23	-260.2,508	1748.0,103	-2.86,508	19.19,103	10.7,105	.691,254
24	-277.1,510	1742.9,106	-3.04,510	19.13,106	10.7,107	.679,252
25	-292.2,512	1737.2,109	-3.21,512	19.07,109	10.7,110	.667,250
26	-304.4,512	1731.7,112	-3.34,512	19.01,112	10.6,113	.654,249
27	-311.5,512	1732.1,114	-3.42,512	19.01,114	10.5,116	.644,308
28	-314.2,512	1734.2,117	-3.45,512	19.04,117	10.5,118	.636,305
29	-315.9,512	1734.3,120	-3.47,512	19.04,120	10.4,121	.628,303
30	-319.0,512	1730.1,123	-3.50,512	18.99,123	10.4,124	.619,301
31	-320.3,512	1722.9,125	-3.52,512	18.91,125	10.4,127	.610,298
32	-311.8,512	1717.5,128	-3.42,512	18.85,128	10.4,130	.600,296
33	-325.1,478	1713.1,131	-3.57,478	18.80,131	10.3,132	.590,293
34	-342.0,481	1713.9,134	-3.75,481	18.81,134	10.3,135	.579,290
35	-357.3,483	1719.9,137	-3.92,483	18.88,137	10.1,138	.568,288
36	-371.0,486	1730.5,139	-4.07,486	19.00,139	10.0,141	.556,285
37	-382.1,489	1744.3,142	-4.19,489	19.15,142	9.9,143	.544,283
38	-391.2,491	1754.3,145	-4.29,491	19.26,145	9.8,146	.532,280
39	-397.2,494	1758.8,148	-4.36,494	19.31,148	9.6,149	.519,278
40	-399.9,497	1758.6,151	-4.39,497	19.30,151	9.5,152	.506,275
41	-400.5,500	1759.9,153	-4.40,500	19.32,153	9.3,154	.493,273
42	-398.4,503	1756.8,156	-4.37,503	19.28,156	9.2,157	.479,270
43	-393.8,505	1748.3,159	-4.32,505	19.19,159	9.0,160	.465,268
44	-384.4,508	1732.5,162	-4.22,508	19.02,162	8.9,163	.452,265
45	-369.6,511	1712.1,164	-4.06,511	18.79,164	8.8,165	.438,263
46	-346.8,512	1679.8,167	-3.81,512	18.44,167	8.8,168	.425,260
47	-289.7,512	1635.4,170	-3.18,512	17.95,170	8.7,171	.412,258
48	-204.8,512	1586.7,173	-2.25,512	17.42,173	8.6,174	.399,256
49	-104.0,512	1545.7,176	-1.14,512	16.97,176	8.5,176	.387,263
50	-23.6, 9	1520.4,178	-.26, 9	16.69,178	8.2,179	.376,261
51	-22.4, 11	1505.1,181	-.25, 11	16.52,181	7.9,182	.365,259

WEAP OF 1986 EXAMPLE 10, PILE DAMPING = 2%

RULT = 1000.0, RTOE = 100.0 KIPS, DEL T = .110 MS

NO.	FMIN,JMN (K)	FMAX,JMX (K)	STRMIN,JSN (KSI)	STRMAX,JSX (KSI)	VMAX,JVX (F/S)	DMAX,JDX (IN)
52	-50.4,232	1486.9,184	-.55,232	16.32,184	7.5,185	.355,255
53	-131.0,229	1458.2,187	-1.44,229	16.01,187	7.2,187	.347,253
54	-201.4,226	1420.2,190	-2.21,226	15.59,190	7.0,190	.340,250
55	-278.7,224	1378.0,192	-3.06,224	15.13,192	6.7,193	.333,248
56	-270.2,224	1317.8,195	-2.97,224	14.47,195	6.6,196	.326,246
57	-136.7,223	1220.1,197	-1.50,223	13.39,197	7.0,200	.321,243
58	-220.8,215	1060.7,198	-2.42,215	11.64,198	8.2,204	.317,240
59	-261.0,216	818.8,199	-2.87,216	8.99,199	9.3,206	.317,236
60	-114.2,216	509.9,201	-1.25,216	5.60,201	10.1,207	.317,236

STROKES ANALYZED AND LAST RETURN (FT):
5.81 6.62 6.63

WEAP OF 1986 EXAMPLE 10, PILE DAMPING = 2%

R ULT KIPS	BL CT BPF	STROKE (FT) DOWN	UP	MINSTR KSI	I,J	MAXSTR KSI	I,J	ENTHRU FT-KIP	BL RT BPM
1000.0	55.4	6.6	6.6	-4.40	(41,500)	20.97	(1, 40)	49.0	45.3
1500.0	129.4	6.3	6.3	-.61	(59,216)	19.76	(2, 44)	46.9	46.2

FORM 20, continued

APPENDIX A

WEAP86 INPUT FORMS

WEAP86 - Short Input Form

1.000 TITLE (40 Characters)

ANALYSIS OPTIONS

Line	IOUT	IJJ	IHAMR	IOSTR	IFUEL	IPEL	N	ISPL	NCRSS	IDDAM	IPRCS	ISMIH	ITYS	IPHI	KISAO	ITER	IDAHA	IMAXT
2.000																		

HELMET AND HAMMER CUSHION INFORMATION

Line	HELMET WEIGHT KIPS	HAMMER CUSHION AREA SQ IN	ELASTIC MODULUS KSI	THICKNESS IN	C.O.R.	ROUND OUT FEET	STIFFNESS* KIPS/IN
3.000							

PILE CUSHION INFORMATION

Line	AREA SQ IN	ELASTIC MODULUS KSI	THICKNESS IN	C.O.R.	ROUND OUT FEET	STIFFNESS* KIPS/IN
4.000						

* OVERRIDES AREA (EL. MOD.) / THICKN

PILE TOP INFORMATION

Line	TOTAL LENGTH FEET	AREA SQ IN	ELASTIC MODULUS KSI	SPECIFIC WEIGHT LBS/CU FT	C.O.R.	ROUND OUT
5.000						

NCRSS > 0: NON-UNIFORM PILE PROFILE

Line	DEPTH FEET	AREA SQ IN	ELASTIC MODULUS KSI	SPECIFIC WEIGHT LBS/CU FT
5.101				
5.102				
5.103				
5.104				
⋮				
5.120				

Columns: 10 20 30 40 50 60 70 80

NOTE: THERE IS NO CARD NUMBER 6.000

HAMMER OVERRIDE VALUES

	STROKE FEET	EFFICIENCY	PRESSURE PSI	REACTION WEIGHT* KIPS	COMB DELAY+ SECONDS -or- IGNITION VOL++ CU IN
7.000					

* FOR DOUBLE ACTING HAMMERS ONLY

\+ FOR DIESELS WITH LIQUID FUEL INJECTION ONLY

\++ FOR DIESELS WITH ATOMIZED FUEL INJECTION ONLY

SOIL PARAMETERS

	QUAKE-SKIN IN	QUAKE-TOE IN	DAMPING-SKIN SEC/FT**	DAMPING-TOE SEC/FT**
8.000				

**ISMTH = -1: DIMENSIONLESS (CASE)
0:, 1: S/FT (STANDARD SMITH)
2: S/FT (VISCOUS SMITH)

ITYS = -1 or 0: SKIN FRICTION DISTRIBUTION

	DEPTH FEET	RELATIVE DISTRIBUTION
8.401		
8.402		
8.403		
8.404		
⋮		
8.420		

ULTIMATE CAPACITIES

KIPS (Give up to 10 capacities)

9.000								
10.000								

1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0
10 20 30 40 50 60 70 80

WEAP86 - Complete Input Form

1.000 TITLE (40 CHARACTERS)

ANALYSIS OPTIONS

2.000 IOUT IJJ IIIAMB IOSTR IFUEL IPEL N ISPL NCRSS IBDAM IPRCS ISMTH ITYS IPHI IRSAO ITER IDAHA IMAXT

IPEL = 2: PILE SEGMENT STIFFNESSES

KIPS/IN (For all elements: 1 through N)

2.101
2.102
⋮
2.113

IPEL = 2: PILE SEGMENT WEIGHTS

KIPS (For all elements: 1 through N)

2.201
2.202
⋮
2.213

IPEL > 0: PILE SEGMENT LENGTHS

Relative Lengths (For all elements: 1 through N)

2.301
2.302
⋮
2.313

1234567890 1234567890 1234567890 1234567890 1234567890 1234567890 1234567890 1234567890

10 20 30 40 50 60 70 80

HELMET AND HAMMER CUSHION INFORMATION

Card	HELMET	HAMMER CUSHION					
	WEIGHT KIPS	AREA SQ IN	ELASTIC MODULUS KSI	THICKNESS IN	C.O.R.	ROUND OUT FEET	STIFFNESS* KIPS/IN
3.000							

PILE CUSHION INFORMATION

Card	AREA SQ IN	ELASTIC MODULUS KSI	THICKNESS IN	C.O.R.	ROUND OUT FEET	STIFFNESS* KIPS/IN
4.000						

* OVERRIDES AREA (EL. MOD.) / THICKN.

PILE TOP INFORMATION

Card	TOTAL LENGTH FEET	AREA SQ IN	ELASTIC MODULUS KSI	SPECIFIC WEIGHT LBS/CU FT	C.O.R.	ROUND OUT FEET
5.000						

NCRSS > 0: NON-UNIFORM PILE PROFILE

Card	DEPTH FEET	AREA SQ IN	ELASTIC MODULUS KSI	SPECIFIC WEIGHT LBS/CU FT
5.101				
5.102				
5.103				
5.104				
:				
5.120				

IHAMR = 0: HAMMER INFORMATION

Card	MANUFGR	NAME	ITYPH	M
6.101				

NOTE: THERE IS NO CARD NUMBER 3.000

IHAMR = 0: HAMMER INFORMATION

Card	RAM			STROKE		
	WEIGHT KIPS	LENGTH IN	DIAMETER IN	MAXIMUM FEET	MINIMUM** FEET	EFFICIENCY
6.201						

** FOR DIESEL HAMMERS ONLY

Columns: 10 20 30 40 50 60 70 80

IHAMR = 0 and ITYPH = 1 or 2: IMPACT BLOCK INFORMATION

	WEIGHT KIPS	LENGTH IN	DIAMETER IN	C.O.R.	ROUND OUT FEET
6.301					

IHAMR = 0 and ITYPH = 1 or 2: DIESEL HAMMER INFORMATION

		COMBUSTION CHAMBER		COMBUSTION			A 1 VOLUME	
	DEPIB IN	AREA SQ IN	VOLUME CU IN	DELAY SECONDS	DURATION SECONDS	EXP COEFF	IGNITION CU IN	FINAL COMB CU IN
6.401								

IHAMR = 0 and ITYPH = 1 or 2: PRESSURES

	ATMOSPHERIC PSI	SETTING 1 PSI	SETTING 2 PSI	SETTING 3 PSI	SETTING 4 PSI	SETTING 5 PSI	COEFF OF CONF
6.501							

IHAMR = 0 and ITYPH = 2: CED HAMMER INFORMATION

	DEPBB IN	B C AREA SQ IN	DBBT IN	D SAFETY FEET	C TANK VOLUME CU IN	REACTION WEIGHT KIPS	B C EXPANSION COEFFICIENT
6.601							

IHAMR = 0 and ITYPH = 3: A/S HAMMER INFORMATION

	PISTON		ASSEMBLY		
	EFF AREA SQ IN	RATED PRESSURE* PSI	C.O.R.	ROUND OUT FEET	NO OF ELEMENTS (MA)
6.701					

* FOR DOUBLE ACTING A/S HAMMERS ONLY

IHAMR = 0 and ITYPH = 3 and MA > 0: ASSEMBLY INFORMATION (Give input for MA assembly elements)

	WEIGHT			STIFFNESS		
	ELEMENT 1 KIPS	ELEMENT 2 KIPS	ELEMENT 3 KIPS	ELEMENT 1 KIPS/IN	ELEMENT 2 KIPS/IN	ELEMENT 3 KIPS/IN
6.801						

HAMMER OVERRIDE VALUES

	STROKE FEET	EFFICIENCY	PRESSURE PSI	REACTION WEIGHT** KIPS	COMB DELAY+ SECONDS -or- IGNITION VOL++ CU IN
7.000					

** FOR DOUBLE ACTING HAMMERS ONLY

+ FOR DIESELS WITH LIQUID FUEL INJECTION ONLY

++ FOR DIESELS WITH ATOMIZED FUEL INJECTION ONLY

1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0

10 20 30 40 50 60 70 80

SOIL PARAMETERS

	QUAKE-SKIN IN	QUAKE-TOE IN	DAMPING-SKIN SEC/FT*	DAMPING-TOE SEC/FT*
8.000				

*ISMTH = -1: DIMENSIONLESS (CASE)
0:
1: S/FT (STANDARD SMITH)
2: S/FT (VISCOUS SMITH)

ITYS < -1: SOIL QUAKES

IN (For all elements and pile tip: 1 through N+1)

8.101								
8.102								
⋮								
8.113								

ITYS < 0: SOIL DAMPING PARAMETERS

SEC/FT (For all elements and pile tip: 1 through N+1)

8.201								
8.202								
⋮								
8.213								

ITYS < -1: SOIL RESISTANCE DISTRIBUTION

Relative (For all elements and pile tip: 1 through N+1)

8.301								
8.302								
⋮								
8.313								

Columns: 1 2 3 4 5 6 7 8 9 0 … (10, 20, 30, 40, 50, 60, 70, 80)

ITYS = -1 or 0: SKIN FRICTION DISTRIBUTION

	DEPTH FEET	RELATIVE DISTRIBUTION
8.401		
8.402		
8.403		
8.404		
⋮		
8.420		

ISPL > 0: SLACK INFORMATION

	ELEMENT	SLACK FEET	C.O.R.	ROUND OUT FEET
8.501				
8.502				
8.503				
8.504				
⋮				
8.599				

ULTIMATE CAPACITIES

KIPS (Give up to 10 capacities)

9.000

10.000

IJJ = 1: PILE ELEMENT NUMBERS

Give up to 13 pile element numbers for output

10.101

1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0

10 20 30 40 50 60 70 80

APPENDIX B

SI CONVERSION FACTORS

To Convert	To	Multiply By
pounds (lbm)	kilograms (kg)	0.4536
pounds (lbf)	Newtons (N)	4.448
kips (1000 lbf)	kilo Newtons (kN)	4.448
inches (in)	meters (m)	0.0254
feet (ft)	meters (m)	0.3048
foot-pounds (ft-lbf)	joules (J)	1.356
pounds/foot (lbm/ft)	kilogram/meter (kg/m)	1.488
pounds/inch^2 (psi)	Pascal (p)	6894
kips/inch^2 (ksi)	Mega Pascal (MP)	6.894
kips/foot^2 (ksf)	kilo Pascal (kP)	47.88
pounds/foot^3 (pcf)	kilogram/meter^3 (kg/m^3)	16.02
seconds/foot (s/ft)	seconds/meter (s/m)	3.281

IMPORTANT CONSTANTS

Name	Symbol	English	SI
Earth gravitational acceleration	g	32.2 ft/s^2	9.81 m/s^2
Water specific weight	w_w	62.4 pcf	1000 kg/m^3
Steel specific weight	w_s	492 pcf	7880 kg/m^3
Steel elastic modulus	E_s	3000 ksi	207000 MP

APPENDIX C: ECHO PRINTS FOR EXAMPLES

ECHO PRINT OF INPUT DATA

(Boxed information from Hammer Data File)

```
 EXAMPLE 1. 45 TON DESIGN, HP 10X53, D-12
10   0   3   0   0   0   8   0   0   0  10   0   1   0   0   0   0   0
  2.150   283.500     280.0     2.000       .800       .000        .0
   .000        .0      .000      .000       .000        .0
 40.000    15.500 30000.000   492.000       .800       .010
DELMAG  0 12        1   3   0
  2.7500  104.4100   11.8100    8.5800    5.3500     .8000
   .8100   21.2700   11.8100     .9000     .0100
 11.0700  109.6000   97.0000     .0020     .0020    1.3500     .0000     .0000
  14.70    1408.00       .00       .00       .00       .00   1
   .0000     .0000     .0000     .0000     .0000
   .100      .100      .050      .150
      60.0      120.0      180.0      240.0         .0         .0         .0
        .0         .0         .0

 EXAMPLE 2. DRIVEABILITY STUDY, LB-520
 1   0 134   0   0   0  16   0   1   0  70  -1   0   0   0   0   0   0
   .450      .000        .0      .000       .850       .000   10000.0
   .000        .0      .000     1.000       .010        .0
 79.080     8.800 29000.000   492.000       .850       .000
 20.400     8.800 29000.000   492.000
 20.400     7.760 29000.000   492.000
 43.400     7.760 29000.000   492.000
 43.400     6.730 29000.000   492.000
 79.000     6.730 29000.000   492.000
 79.000    95.000 29000.000   492.000
 79.080    95.000 29000.000   492.000
LINKBELTLB 520      2   3   0
  5.0700   80.5000   16.7900    3.8000    2.6600     .8000
  1.4800   20.5000   17.9700     .9000     .0100
 10.0600  254.4700  165.0000     .0000     .0000    1.3500  242.0000  208.0000
  14.70     908.00       .00       .00       .00       .00   1
 48.5600  254.5000   50.0600    2.0000 8732.0000    6.3000    1.3100
   .0000     .0000     .0000     .0000     .0000
   .100      .100     2.000      .800
  5.000      .000
 10.000     1.000
 79.083     2.000
     240.0      320.0         .0         .0         .0         .0         .0
        .0         .0         .0

 EXAMPLE 3. TENSION STRESS CHECK, 3-PLY
 0   0 224   0   0   0  11   0   0   3 100   0   0   0   0   0   0   0
  1.500      .000        .0      .000       .800       .010   10000.0
196.000      30.0     1.750      .500       .010        .0
 50.000   196.000  5000.000   150.000      1.000       .010
VULCAN  VUL   80C   3   1   0
  8.0000   50.0000   19.2900    3.0600    1.3800     .5000
  81.510   120.000      .800      .010    2
   4.940     4.940      .000   47835.3   47835.3        .0
   .0000     .0000     .0000     .0000     .0000
   .100      .100      .200      .000
 30.000      .000
 30.000     1.000
 50.000     1.000
      20.0         .0         .0         .0         .0         .0         .0
        .0         .0         .0

 EXAMPLE 3. TENSION STRESS CHECK, 6-PLY
10   0 224   0   0   0  11   0   0   3 100   0   0   0   0   0   0   0
  1.500      .000        .0      .000       .800       .010   10000.0
196.000      30.0     3.500      .500       .010        .0
 50.000   196.000  5000.000   150.000      1.000       .010
VULCAN  VUL   80C   3   1   0
  8.0000   50.0000   19.2900    3.0600    1.3800     .5000
  81.510   120.000      .800      .010    2
   4.940     4.940      .000   47835.3   47835.3        .0
   .0000     .0000     .0000     .0000     .0000
   .100      .100      .200      .000
 30.000      .000
 30.000     1.000
 50.000     1.000
      20.0         .0         .0         .0         .0         .0         .0
        .0         .0         .0

 EXAMPLE 4. DIESEL HAMMER INPUT
 0   0   0   0   0   0   0   0   1   0  10   0   0   0   0   0   0   0
   .950      .000        .0      .000       .800       .010   10500.0
   .000        .0      .000      .000       .000        .0
 60.000     9.820 30000.000   492.000       .800       .010
 59.920     9.820 30000.000   492.000
 59.920   127.700 30000.000   492.000
 60.000   127.700 30000.000   492.000
HYPOTHET EX 4       1   3   0
  2.7500   95.0000   12.5000    8.5000     .0000     .8000
   .8100   19.0000   12.5000     .8000     .0100
 10.7600  122.7000  120.0000     .0020     .0020    1.3000     .0000     .0000
  14.70    1150.00       .00       .00       .00       .00   1
   .0000     .0000     .0000     .0000     .0000
   .100      .100      .050      .150
   .000      .000
 10.000      .000
 10.000      .330
 30.000      .330
 30.000      .670
 40.000      .670
 60.000     1.000
     100.0      150.0      200.0      250.0      300.0      350.0      400.0
        .0         .0         .0
```

ECHO PRINT OF INPUT DATA

```
 EXAMPLE 5: PILE SEGMENT + DAMPING INPUT
0   0 133  -1   0   2  12   0   1   5  10   0  -2   0   0   0   0   0
   6592.      6557.      6176.      5800.      5445.      5100.      4764.      4440.
   4128.      3823.      3534.      3257.
    .142       .126       .118       .111       .104       .098       .091       .085
    .079       .073       .068       .065
   3.167      3.000      3.000      3.000      3.000      3.000      3.000      3.000
   3.000      3.000      3.000      3.000
    .700       .000         .0       .000       .800       .010    30000.0
    .000         .0       .000       .500       .010         .0
  36.170    128.670   2000.000     51.000       .500       .010
    .000    128.670   2000.000     51.000
    .170    128.670   2000.000     51.000
   7.000    112.650   2000.000     51.000
  14.000     97.330   2000.000     51.000
  21.000     83.130   2000.000     51.000
  28.000     70.040   2000.000     51.000
  36.170     56.200   2000.000     51.000
LINKBELTLB 440     2   3   0
  4.0000    89.9000    13.1000     3.1200     1.4900      .8000
   .7000    18.0000    11.9500      .9000      .0100
 15.0000   113.0900   121.0000      .0000      .0000     1.3500   161.0000   139.0000
   14.70    1003.00        .00        .00        .00        .00     1
 41.3800   254.5000    42.3800     3.3800  9185.0000     5.2100     1.4000
  3.6100      .0000      .0000      .0000      .0000
    .100       .100       .000       .050
    .100       .100       .100       .100       .100       .100       .100       .100
    .100       .100       .100       .100       .100
    .000       .000       .000       .050       .200       .200       .050       .200
    .200       .050       .050       .050       .050
    .000       .000       .000       .500      1.000      1.000      1.000      1.000
   1.000      1.000      1.000      1.000     76.500
       150.0         .0         .0         .0         .0         .0         .0
          .0         .0         .0
```

```
 EXAMPLE 6, C-1, EASY, CASE DAMPING
0   0 104   0   0   0  12   0   0   0 100  -1  10   0   0   0   0   0
    .950       .000         .0       .000       .850       .010    10500.0
 144.000       50.0      4.000       .600       .010         .0
  60.000    144.000   5000.000    153.000       .850       .010
KOBE      K 25         1   3   0
  5.5100   114.2000    15.3500     9.3500     4.2600      .8000
  1.6000    26.9000    15.3500      .9000      .0100
 14.1000   185.2000   160.0000      .0020      .0020     1.2700      .0000      .0000
   14.70    1580.00    1422.00    1280.00    1152.00    1037.00     1
   .0000      .0000      .0000      .0000      .0000
    .100       .100       .500       .300
        50.0      100.0      200.0      400.0      500.0      600.0         .0
          .0         .0         .0
```

ECHO PRINT OF INPUT DATA

```
 EXAMPLE 6, C-2, EASY, SMITH DAMPING
0   0 104   0   0   0  12   0   0   0 100   0  10   0   0   0   0   0
    .950       .000         .0       .000       .850       .010    10500.0
 144.000       50.0      4.000       .600       .010         .0
  60.000    144.000   5000.000    153.000       .850       .010
KOBE      K 25         1   3   0
  5.5100   114.2000    15.3500     9.3500     4.2600      .8000
  1.6000    26.9000    15.3500      .9000      .0100
 14.1000   185.2000   160.0000      .0020      .0020     1.2700      .0000      .0000
   14.70    1580.00    1422.00    1280.00    1152.00    1037.00     1
   .0000      .0000      .0000      .0000      .0000
    .100       .100       .200       .010
        50.0      100.0      200.0      400.0      500.0      600.0         .0
          .0         .0         .0
```

```
 EXAMPLE 6, C-3, HARD, CASE DAMPING
0   0 104   0   0   0  12   0   0   0-100  -1  10   0   0   0   0   0
    .950       .000         .0       .000       .850       .010    10500.0
 144.000       50.0      4.000       .600       .010         .0
  60.000    144.000   5000.000    153.000       .850       .010
KOBE      K 25         1   3   0
  5.5100   114.2000    15.3500     9.3500     4.2600      .8000
  1.6000    26.9000    15.3500      .9000      .0100
 14.1000   185.2000   160.0000      .0020      .0020     1.2700      .0000      .0000
   14.70    1580.00    1422.00    1280.00    1152.00    1037.00     1
   .0000      .0000      .0000      .0000      .0000
    .100       .100       .500       .300
        50.0      100.0      200.0      400.0      500.0      600.0         .0
          .0         .0         .0
```

```
 EXAMPLE 6, C-4, HARD, SMITH DAMPING
0   0 104   0   0   0  12   0   0   0-100   0  10   0   0   0   0   0
    .950       .000         .0       .000       .850       .010    10500.0
 144.000       50.0      4.000       .600       .010         .0
  60.000    144.000   5000.000    153.000       .850       .010
KOBE      K 25         1   3   0
  5.5100   114.2000    15.3500     9.3500     4.2600      .8000
  1.6000    26.9000    15.3500      .9000      .0100
 14.1000   185.2000   160.0000      .0020      .0020     1.2700      .0000      .0000
   14.70    1580.00    1422.00    1280.00    1152.00    1037.00     1
   .0000      .0000      .0000      .0000      .0000
    .100       .100       .200       .010
        50.0      100.0      200.0      400.0      500.0      600.0         .0
          .0         .0         .0
```

ECHO PRINT OF INPUT DATA

EXAMPLE 7A: FULL FUEL, HIGH QUAKES

```
-100   0  11   0   0   0  15   0   0   0 -40  -1   0   0   0   0   0   0
       .950      .000        .0      .000      .800      .010   10500.0
       .000        .0      .000      .000      .000        .0
     75.000    16.800 30000.000   492.000      .850      .010
DELMAG  D 30          1   3   0
     6.6000  139.2700   15.3300    9.0300    4.0300     .8000
     1.6000   24.7000   15.3300     .9000     .0100
    15.0500  184.5800  239.9000     .0020     .0020    1.3500     .0000     .0000
      14.70   1360.00   1224.00   1102.00    991.00    892.00    0
      .0000     .0000     .0000     .0000     .0000
       .100      .150      .100      .100
       .000      .000
     13.000      .000
     13.000      .063
     68.000      .063
     75.000     1.000
        100.0     200.0     300.0     400.0     500.0        .0        .0
           .0        .0        .0
```

EXAMPLE 7B: REDUCED FUEL, HIGH QUAKES

```
-100   0  11   0   3   0  15   0   0   0 -40  -1   0   0   0   0   0   0
       .950      .000        .0      .000      .800      .010   10500.0
       .000        .0      .000      .000      .000        .0
     75.000    16.800 30000.000   492.000      .850      .010
DELMAG  D 30          1   3   0
     6.6000  139.2700   15.3300    9.0300    4.0300     .8000
     1.6000   24.7000   15.3300     .9000     .0100
    15.0500  184.5800  239.9000     .0020     .0020    1.3500     .0000     .0000
      14.70   1360.00   1224.00   1102.00    991.00    892.00    0
      .0000     .0000     .0000     .0000     .0000
       .100      .150      .100      .100
       .000      .000
     13.000      .000
     13.000      .063
     68.000      .063
     75.000     1.000
        100.0     200.0     300.0     400.0     500.0        .0        .0
           .0        .0        .0
```


ECHO PRINT OF INPUT DATA

EXAMPLE 7C: FULL FUEL, LOW QUAKES

```
-100   0  11   0   0   0  15   0   0   0 -40  -1   0   0   0   0   0   0
       .950      .000        .0      .000      .800      .010   10500.0
       .000        .0      .000      .000      .000        .0
     75.000    16.800 30000.000   492.000      .850      .010
DELMAG  D 30          1   3   0
     6.6000  139.2700   15.3300    9.0300    4.0300     .8000
     1.6000   24.7000   15.3300     .9000     .0100
    15.0500  184.5800  239.9000     .0020     .0020    1.3500     .0000     .0000
      14.70   1360.00   1224.00   1102.00    991.00    892.00    0
      .0000     .0000     .0000     .0000     .0000
       .050      .050      .100      .100
       .000      .000
     13.000      .000
     13.000      .063
     68.000      .063
     75.000     1.000
        100.0     200.0     300.0     400.0     500.0        .0        .0
           .0        .0        .0
```

EXAMPLE 7D: REDUCED FUEL, LOW QUAKES

```
-100   0  11   0   3   0  15   0   0   0 -40  -1   0   0   0   0   0   0
       .950      .000        .0      .000      .800      .010   10500.0
       .000        .0      .000      .000      .000        .0
     75.000    16.800 30000.000   492.000      .850      .010
DELMAG  D 30          1   3   0
     6.6000  139.2700   15.3300    9.0300    4.0300     .8000
     1.6000   24.7000   15.3300     .9000     .0100
    15.0500  184.5800  239.9000     .0020     .0020    1.3500     .0000     .0000
      14.70   1360.00   1224.00   1102.00    991.00    892.00    0
      .0000     .0000     .0000     .0000     .0000
       .050      .050      .100      .100
       .000      .000
     13.000      .000
     13.000      .063
     68.000      .063
     75.000     1.000
        100.0     200.0     300.0     400.0     500.0        .0        .0
           .0        .0        .0
```

ECHO PRINT OF INPUT DATA

```
 EXAMPLE 8: MECHANICAL SPLICE
 3   0 226   0   0   0  32   1   0   0  40   0   0   0   0   0   0   0
   2.000      .000        .0      .000      .800      .010   22500.0
    .000        .0      .000      .500      .010    1200.0
 160.000   144.000  5000.000   153.000     1.000      .010
VULCAN  VUL 100C    3   1   0
  10.0000   59.0000   20.4700    3.2900    3.2900     .5000
   99.400   140.000      .800      .010     2
    6.100     6.100      .000   41777.1   41777.1        .0
    .0000     .0000   60.0000     .0000     .0000
     .100      .100      .100      .100
     .000      .000
   40.000      .000
   40.000    40.000
   52.000    95.000
   52.000     2.000
  130.000     2.000
  130.000     8.000
  150.000    22.000
  160.000    22.000
       16     .0033    1.0000     .0100
         50.0        .0        .0        .0        .0        .0        .0
           .0        .0        .0
```

```
 EXAMPLE 8: CAN SPLICE
 3   0 226   0   0   0  32   1   0   0  40   0   0   0   0   0   0   0
   2.000      .000        .0      .000      .800      .010   22500.0
    .000        .0      .000      .500      .010    1200.0
 160.000   144.000  5000.000   153.000     1.000      .010
VULCAN  VUL 100C    3   1   0
  10.0000   59.0000   20.4700    3.2900    3.2900     .5000
   99.400   140.000      .800      .010     2
    6.100     6.100      .000   41777.1   41777.1        .0
    .0000     .0000   60.0000     .0000     .0000
     .100      .100      .100      .100
     .000      .000
   40.000      .000
   40.000    40.000
   52.000    95.000
   52.000     2.000
  130.000     2.000
  130.000     8.000
  150.000    22.000
  160.000    22.000
       16   99.0000    1.0000     .0100
         50.0        .0        .0        .0        .0        .0        .0
           .0        .0        .0
```

ECHO PRINT OF INPUT DATA

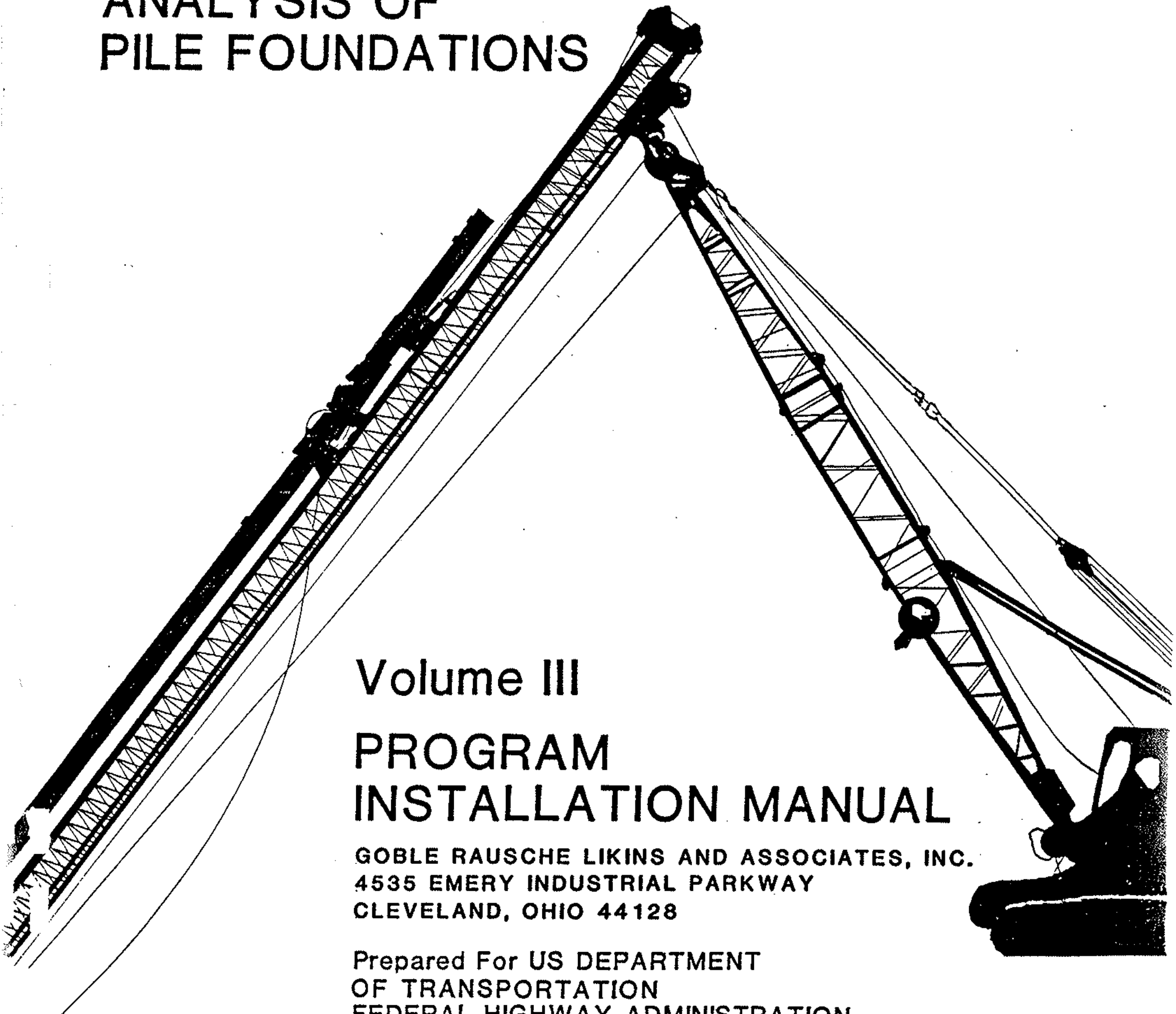
```
 EXAMPLE 9, DRIVEABILITY STUDY, LB-520
 1   0 134   0   0   0  16   0   1   0  70  -1   0   0   1   0   0   0
    .450      .000        .0      .000      .850      .000   10000.0
    .000        .0      .000     1.000      .010        .0
  79.080     8.800 29000.000   492.000      .850      .000
  20.400     8.800 29000.000   492.000
  20.400     7.760 29000.000   492.000
  43.400     7.760 29000.000   492.000
  43.400     6.730 29000.000   492.000
  79.000     6.730 29000.000   492.000
  79.000    95.000 29000.000   492.000
  79.080    95.000 29000.000   492.000
LINKBELTLB 520      2   3   0
   5.0700   80.5000   16.7900    3.8000    2.6600     .8000
   1.4800   20.5000   17.9700     .9000     .0100
  10.0600  254.4700  165.0000     .0000     .0000    1.3500  242.0000  208.0000
    14.70    908.00       .00       .00       .00       .00    1
  48.5600  254.5000   50.0600    2.0000 8732.0000    6.3000    1.3100
    .0000     .0000     .0000     .0000     .0000
     .100      .100     2.000      .800
    5.000      .000
   10.000     1.000
   79.083     2.000
       240.0     320.0        .0        .0        .0        .0        .0
          .0        .0        .0
```

```
 EXAMPLE 10, PILE DAMPING = 0
 1   0  30   0   0   0  60   0   0  -1  90   0   4   0   0   0   0   0
   5.000      .000        .0      .000      .800      .010   30000.0
    .000        .0      .000      .500      .010        .0
 300.000    91.100 30000.000   492.000      .850      .010
DELMAG  D 62-22     1   4   0
  13.6600  149.2000   21.6300   11.1600    5.8100     .8000
   2.8300   32.3600   21.6400     .9000     .0100
  22.7900  368.3000  677.0000     .0005     .0010    1.3500     .0000     .0000
    14.70   1260.00   1134.00   1021.00    919.00       .00    0
    .0000     .0000     .0000     .0000     .0000
     .100      .100      .050      .150
      1000.0    1500.0        .0        .0        .0        .0        .0
          .0        .0        .0
```

```
 EXAMPLE 10, PILE DAMPING = 2%
 1   0  30   0   0   0  60   0   0   0  90   0   4   0   0   0   0   0
   5.000      .000        .0      .000      .800      .010   30000.0
    .000        .0      .000      .500      .010        .0
 300.000    91.100 30000.000   492.000      .850      .010
DELMAG  D 62-22     1   4   0
  13.6600  149.2000   21.6300   11.1600    5.8100     .8000
   2.8300   32.3600   21.6400     .9000     .0100
  22.7900  368.3000  677.0000     .0005     .0010    1.3500     .0000     .0000
    14.70   1260.00   1134.00   1021.00    919.00       .00    0
    .0000     .0000     .0000     .0000     .0000
     .100      .100      .050      .150
      1000.0    1500.0        .0        .0        .0        .0        .0
          .0        .0        .0
```

WEAP86

WAVE EQUATION ANALYSIS OF PILE FOUNDATIONS



Volume III

PROGRAM INSTALLATION MANUAL

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Prepared For US DEPARTMENT
OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

FINAL REPORT
MAY 1986

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle	5. Report Date
WAVE EQUATION ANALYSIS OF PILE FOUNDATIONS WEAP86 PROGRAM Volume III. Program Installation Manual	March 1986
	6. Performing Organization Code
7. Author(s) G.G. Goble and F. Rausche	8. Performing Organization Report No.
9. Performing Organization Name and Address Goble Rausche Likins and Associates, Inc. 4535 Emery Industrial Parkway Cleveland, OH 44128	10. Work Unit No. (TRAIS)
	11. Contract or Grant No. DTFH61-84-C-00100
12. Sponsoring Agency Name and Address Office of Implementation Federal Highway Administration 6300 Georgetown Pike McLean, Virginia 22101-2296	13. Type of Report and Period Covered Final Report
	14. Sponsoring Agency Code

15. Supplementary Notes

FHWA contract manager: Chien-Tan Chang (HDV-10)

16. Abstract

The WEAP Program, written and documented under a previous FHWA contract in 1976 and updated in 1981, was further developed. The documentation was completely rewritten for additional or revised information. The new program referred to as WEAP86, includes all of the WEAP features plus the following new models:

Separate models for liquid and atomized fuel injection of diesel hammers.
Residual stress analysis.
Realistic splice model.

An important addition was an updated and/or revised hammer data file with new efficiency values based on research performed under another contract for the FHWA. Furthermore, extensive tables covering helmets, cushions, and piles were compiled and included in this documentation. Another important facet of the WEAP86 work was the development of a program version for personal computers. the main effort consisted of providing for a user-friendly/menu-driven input program and a graphics output option.
This is the third volume among four. The others are

FHWA No.	Vol. No.	Title
	I	Background
	II	General Users Manual
	IV	Users Manual for PC Application

17. Key Words	18. Distribution Statement
Combustion, Computers, Design, Diesel, Dynamics, Foundations, Hammers, Impact, Pile driving, Residual stress, Soil mechanics, Wave equation.	No restrictions. This document is available to the public through the National Technical Information Service. Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	48	

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1. INTRODUCTION

This volume describes how to install the WEAP86 programs on any type of general computer (mainframes), including Personal Computers (PC). It describes the files needed and, in particular, how to install the hammer data file.

Maintenance of the programs and data files may be required at regular intervals. Of course, updating of the programs is done by the usual editing-compiling-linking process. Maintenance of the hammer data file is accomplished with the use of a special Fortran program, HAMRMA for mainframes, and through the W86IN program for PC's.

In general, the WEAP86 package includes the following programs:

1. WEAP86 — The actual wave equation program which reads the input data from (a) either a short ASCII file or from data cards prepared for a particular problem, plus (b) the hammer data files.

2. HAMRMA — A program which provides for maintenance of the hammer data file (conversion from ASCII format, listing and loading of hammer data).

3. W86IN — A program that prepares the input file in an interactive mode. This program is optional since the input file may also be prepared on cards or using text/line editor. The program also provides for maintenance of the hammer data file. The w86in program was written with the intent of using it on a pc.

WEAP86 requires at least 320 kbytes of space in memory. The other programs require less. Also, for PCs, the program may be used to produce graphics output (monochrome monitor, ibm-pc enhanced graphics board) which then may be printed on an epson fx-100 printer. Different hardware will require reprogramming.

Note that the WEAP86 program is a "number cruncher." Thus, hardware/software switches should be chosen for maximum arithmetic effiency. In the following, an ASCII file means a formatted, sequentially written file.

In summary, to get started, the following items must be available:

(a) General Computer	Card or ASCII file data input WEAP86 Program source in FORTRAN F77 HAMRMA Program source in FORTRAN F77 ASCII Hammer Data File

or

(b) General Computer	File data input WEAP86 Program source in FORTRAN F77 HAMRMA Program source in FORTRAN F77 ASCII Hammer Data File	
or optionally	WEAP86 Program source in FORTRAN F77 W86IN Program source in FORTRAN F77 Hammer Data File (File HAMMER.DAT)	

or

(c) IBM-PC or Compatible	WEAP86.EXE:	Executable wave equation program
	W86IN.EXE:	Executable data input program
	FILES.DAT:	Data file with names and drive designators of all temporary and permanent disk files needed by WEAP86.EXE and W86IN.EXE.
	HAMMER.DAT:	Direct-access binary hammer data file.
	GRAPHIC.DEV:	Needed only for graphics display.
	PRINTER.DEV:	Needed only for graphics print.

2. WEAP86 PROGRAM INSTALLATION

This chapter deals with the installation of the WEAP86 program package which includes the data file and a data file maintenance program. It is assumed that the user is familiar with his machine and operating system.

2.1 Mainframe Application

2.1.1 The WEAP86 Program

This is the main wave equation program. A few changes usually have to be made in WEAP86 before it can be compiled and loaded onto a mainframe machine. The changes mainly pertain to the input/output device declarations. Due to the varied nature of machines, compilers and operating systems, only a few suggestions regarding the input and output units will be made.

For I/O, certain unit numbers have been assumed. The user may need to change the assignments including the open file statements to conform to his system's needs.

1. INPUT Unit: Set Variable IR (assumed to be unit number 5) in SUBROUTINE INIT in File MF1 as the input unit. The input file must be formatted and sequentially-accessed.

2. OUTPUT Unit: Set Variable IW (assumed to be unit number 6) in SUBROUTINE INIT in File MF1 as the output unit. The output unit may be either a line printer, console screen or a formatted, sequentially-accessed ASCII file.

3. HAMMER File: Set Variable IHF (assumed to be unit number 7) in SUBROUTINE HACCPT in File MF1 as the binary, direct-access Hammer data file which has a record length of 300 bytes each.

4. ICOL Option: Set Variable ICOL in SUBROUTINE INIT to
   0 for 80 column character/line printers or
   1 for 132 column character/line printers

See Chapter 3 for a complete description of the files.

2.1.2 The HAMRMA Program

The HAMRMA Program is the hammer maintenance program. It allows (a) for the conversions of the formatted, sequentially-accessed ASCII hammer data file, ASCIHM, to a direct-access binary file HAMRDAT; (b) loading of individual hammer records; and (c) listing of hammer data.

Again, a few changes may have to be made before using the program:

1. INPUT Unit: Set Variable INPT (assumed to be unit 5) in MAIN as the input file or console unit number.

2. OUTPUT Unit: Set Variable IOUT (assumed to be unit 6) in MAIN as the output file or console unit number.

3. ASCII Hammer File: Set Variable ISEQ (assumed to be unit 7) in SUBROUTINES TODIR and TOSEQT as the unit number of the formatted, sequentially-accessed ASCII hammer data file, ASCIHM.

4. Binary Hammer File: Set Variable IDIR (assumed to be unit 8) in SUBROUTINES TODIR, MDFDIR, LSTDIR and TOSEQT as the unit number of the direct-access binary hammer data file, HAMRDAT.

See Chapter 3 for a description of the files and Chapter 4 for a discussion of the HAMRMA Program.

2.2 PC Application

2.2.1 Hardware Requirements

The WEAP86-PC version has been designed to run on an IBM-PC (IBM-PC-AT) or compatible machine that contains:

- At least two 360K disk drives or one 360K disk drive and a hard drive.
- At least 320K RAM memory.
- A line printer for output.

Optional features include:

- An 8087 (80287) Math Co-processor. This will significantly speed up computation time if present but it is not necessary for program operation.
- An IBM Enhanced Graphics Board if graphics is desired.
- An EPSON FX-100 Graphics Printer for graphics screen to printer dumps. Of course, this unit will also serve as an ordinary printer for output.

2.2.2 Disk Contents

The WEAP86 Programs (executable versions only) and the data files are distributed on three diskettes. The disks' contents are as follows:

Disk 1:	W86IN.EXE	Interactive input program
	FILES.DAT	File specifier
	HEADNG.DAT	Headings and menu names for W86IN
Disk 2:	WEAP86.EXE	Wave equation analysis program
	FILES.DAT	File specifier
	GRAPHIC.DEV	IBM Enhanced Graphics Board configuration file
	PRINTER.DEV	Epson FX-100 Graphics Printer configuration file
Disk 3:	HAMMER.DAT	Hammer data file
	EXAMPL.???	Test Examples

For an explanation of the files, see Chapter 3, "Description of Files. It is important to understand that FILES.DAT is read by both the WEAP86 and W86IN programs and that it contains the file names and drive specifiers for a program execution.

2.2.3 Installation on Dual Drive Systems

Programs and data files are being supplied on IBM-PC compatible 360K disks. The disks do not contain operating systems.

In order to execute the programs, the user must first boot the system on a valid operating system disk before running the programs.

To run a program, make sure Drive A is the default drive (A> should be prompted). Then, simply insert the desired program disk (e.g., W86IN.EXE or WEAP86.EXE) in Drive A, the data file disk in Drive B and type the program name. Note FILES.DAT must reside on the default drive and FILES.DAT must be available to all the programs of the WEAP86 package. For two diskette drives, the FILES.DAT names may be used without change. For other systems it may be desirable to change drive numbers on FILES.DAT.

The user may create two system disks (see the DOS manual for the FORMAT/S command) containing only the minimum routines necessary for program operation (COMMAND.COM and PRINT.COM) and copy Disks 1 and 2 contents to the system disks, respectively.

2.2.4 Installation on a Hard Disk System

If the user works with a hard disk, then it is suggested to create a directory for the WEAP86 program package. Copy the contents of the three disks into the designated area. Edit the FILES.DAT file and edit the drive designators of the file names to the correct drive letter (e.g., C: or D:). This process is further explained in Chapter 3. When executing the programs, the default drive must be the designated area.

Again, remember FILES.DAT must reside on the default drive.

3. DESCRIPTION OF FILE

3.1 Mainframe Application

3.1.1 Input File

The input file may either consist of cards or it may be a formatted, sequential ASCII file which contains input data for the WEAP86 program. Refer to Volume II: General Users Manual for the contents of the input file.

For a list of the hammers on file and description of their contents see Volume II: The Users Manual , Table 1. If the user adds data to this file, a new listing should be created (See Chapter 7, HAMMER FILE MAINTENANCE).

3.1.2 Output File - Printed Results

The destination for printed output may either be set to the line printer, a terminal console or a data file.

3.1.3 Hammer Data File: HAMRDAT and ASCIHM

The hammer data file, HAMRDAT, is a direct-access binary file with record lengths of 300 bytes each for each hammer. ASCIHM is the formatted, sequentially-accessed ASCII hammer data file.

3.2 PC Application

3.2.1 File Name Declarations - FILES.DAT

FILES.DAT is a short formatted, sequentially-written, ASCII file which contains the ICOL option and the input/output filenames. Both WEAP86 and W86IN read this information.

The file contents are as follows:

Line 1: ICOL Option - if set to 0 (default), 80-column, or if set to 1, 132-column, output is made to the printer file. ICOL is read on a I4 format, i.e., the value must be in the fourth column on the first line of FILES.DAT.

Line 2: INPUT DATA FILE - name of the file which serves as both the current input for WEAP86 and the default filename for W86IN.

Line 3: OUTPUT FILE - name of the file where the "printed" results will be directed to, i.e., line printer, console, or filename.

Line 4: HAMMER DATA FILE - name of hammer data file to be used (usually HAMMER.DAT)

Line 5: BEARING GRAPH OUTPUT FILE - filename for storage of Summary table results.

Line 6: VARIABLES VS. TIME OUTPUT FILE - filename for storage of the variables, as chosen by IOUT, as a function of time.

IMPORTANT: The correct file names must occur on the proper line or data may be destroyed. For instance, if lines 3 and 4 were reversed, the actual hammer data could not be read from output device (such as the line printer) and the "printed" results would be sent to the hammer data file resulting in an operation error.

Example: The FILES.DAT contents may be as follows

```
   0        <----------- USE I4 FORMAT TO ENTER ICOL IN THIS PLACE
 B:W86.DAT             <-- NAME OF INPUT DATA FILE
 A:PRN                 <-- NAME OF OUTPUT FILE
 B:HAMMER.DAT          <-- NAME OF HAMMER DATA FILE
 B:FILE21.DAT          <-- NAME OF BEARING GRAPH OUTPUT FILE
 B:FILE22.DAT          <-- NAME OF VARIABLES VS. TIME OUTPUT FILE
```

This file would cause the following action:

1. 80-column printer output would be generated.
2. The input data would be read from W86.DAT located on Drive B.
3. The printer output would be made on a line printer.
4. The hammer data file would reside on Drive B.
5. Bearing graph data would be directed to Drive B.
6. Variables vs. Time would be directed to Drive B.

3.2.2 Input Data File

The input data file is a formatted, sequentially-accessed ASCII file which contains input data for the WEAP86 program. The file may be created with the use of an editor. Refer to Volume II for the contents of the input file.

The file may also be created using the W86IN program. The name of the input data file is defined by line 2 of FILES.DAT.

3.2.3 Output File: Printed Results

The output file or output destination is designated on line 3 of the FILES.DAT file. The output may be sent to either the line printer (A:PRN), the console screen (A:CON) or a formatted, sequential, ASCII file for storage.

Unless printer or console are used for outputs, the program assumes that the output file already exists in the current directory and therefore must be created prior to executing the WEAP86 program. The file can be created using an editor but need not contain any data.

3.2.4 Hammer Data File: HAMMER.DAT

The hammer data file, HAMMER.DAT, is a direct-access binary file with record lengths of 300 bytes each for each hammer. The hammer data filename must appear on line 4 of the FILES.DAT file. Again, the name in itself is not restricted to HAMMER.DAT but the file named on line 4 of the FILES.DAT file must contain the hammer data.

Hammer data may be added, listed or corrected using the W86IN program. For further information on the maintenance of the hammer data file, see Volume IV.

3.2.5 Bearing Graph Output File: FILE21.DAT

The bearing graph output file, FILE21.DAT, is a formatted, sequential ASCII file. It basically contains the title of the current analysis and a summary of the results (stresses, stroke, blow count and transferred energy for each R_{ut} analyzed).

The bearing graph output filename is not restricted to FILE21.DAT and may be renamed on line 5 of FILES.DAT.

The bearing graph output file is newly created for each analysis by WEAP86. Since WEAP86 allows for chaining of more than one problem (copying the input files of several problems together into one file) provision had to be made for preserving several output files. Thus, the following files will be created.

The results of the first problem will be written to FILE21.DAT.
The results of the second problem will be written to FIL121.DAT.
The results of the third problem will be written to FIL221.DAT.
: :
The results of the tenth problem will be written to FIL921.DAT.

If the WEAP86 program is started again, the process will be repeated starting with the name on line 5 of FILES.DAT. Thus, if the results are to be preserved, a new name should be given on line 5 of the FILES.DAT for subsequent runs. There cannot be more than 10 consecutive runs in PC applications.

3.2.6 Variables vs.Time Output: FILE22.DAT

The Variables vs. Time output file, FILE22.DAT, is a direct-access binary file with record lengths of 13000 bytes each. It contains digital representation of the curves selected by IOUT for the current analysis for each capacity analyzed. It is only written for IOUT>9.

The filename is not restricted to FILE22.DAT and may be changed on line 6 of the FILES.DAT file.

The "Variables vs. Time" output file is created as new for each analysis by WEAP86. If the input file has more than one problem to analyze (not to be confused with more than one capacity), then additional files are created.

The results of the first problem will be written to FILE22.DAT.
The results of the second problem will be written to FIL122.DAT.
The results of the third problem will be written to FIL222.DAT.
: :
The results of the tenth problem will be written to FIL922.DAT.

If the WEAP86 program is started again, the process will be repeated starting at FILE22.DAT, the name on line 6 of FILES.DAT. Note that the FILE22.DAT,... files are rather large and that a diskette is quickly filled.

3.2.7 Headings File: HEADNG.DAT

HEADNG.DAT is accessed by the W86IN program only.

The headings file, HEADNG.DAT, is a formatted, sequential, ASCII file which is accessed only by the W86IN input program. The file contains the variable names, 2-letter menu names and descriptions for the input requests in W86IN program. The file name cannot be changed by the user.

3.2.8 Graphics Files

GRAPHIC.DEV and PRINTER.DEV are the IBM Enhanced Graphics Board and the EPSON FX-100 configuration files, respectively. These files cannot be edited and must be availble to the WEAP86 program during execution if graphics is desired.

The graphics routines are set up for these devices only and additional reprogramming will be necessary if other hardware is to be used.

4. DESCRIPTION OF SUBROUTINES

This chapter gives a short description of the subroutines used in the WEAP86 programs.

For each subroutine, the following will be listed:

NAME: the subroutine name.

DESCRIPTION: a short description of the subroutine function.

CALL: subroutines called within the routine being described.

FILE: the file in which the subroutine source code resides.

At the end of each section, the subroutine calls will be graphically presented. This block diagram is a simplified representation of the overall program flow.

4.1 The WEAP86 Program

The WEAP86 subroutine description is divided into two sections:

- WEAP86 Analysis Subroutines which represents the routines needed to create the standard WEAP86 program.
- Graphics routines that may optionally be incorporated into the WEAP86 program. They can only be used on a PC with graphics capabilities.

4.1.1 WEAP86 Analysis Subroutines (*See Section 4.1.2 Graphics)

NAME	DESCRIPTION	CALLS	FILE
ADIA	Computes diesel hammer pressure in adiabatic compression or expansion	------	MF4
CAPCUS	Calculates hammer and pile cushion properties	------	MF2
CHECK	Checks options	------	MF2
CHTIME	Checks time increment and combines hammer/pile model	------	MF2
DATIN1	Data input routine	CHECK HACCPT	MF1

NAME	DESCRIPTION	CALLS	FILE
DIANAL	Diesel hammer main analysis routine	DIANHM DSTOUT EXTREM FILLA PILEAN SPLEEN SRESN STOREN	MF4AB
DIANHM	Diesel hammer analysis	FTR INTEGR PRSSRE STIFF	MF4AB
DIESL	Diesel main routine	DIANAL DISTAR DOWN NEWPRS NEWSTR REINIT RETRV STRCNV UP	MF3
DIMEN	Determine units of output quantities	------	MF6
DISTAR	Diesel start analysis (compression cycle)	DSTOUT FTR PRSSRE STIFF TEST	MF4A
DOWN	Diesel analysis of ram fall above ports	FTR	MF4B
DSTOUT	Diesel extensive output (negative option)	------	MF4AB
EXOUT	External combustion hammer extensive output (negative option)	------	MF3
EXTCOM	Main routine for external combustion hammers	EXOUT EXTHAM EXTREM FILLA PILEAN SPLEEN SRESN STOREN	MF3

NAME	DESCRIPTION	CALLS	FILE
EXTHAM	Analysis of external combustion hammers	INTEGR STIFF	MF3
EXTIT	Print title on extrema printout	------	MF6
EXTREM	Determine stress, force, velocity, displacement extrema	------	MF6
FILLA	Fill buffer with analysis results for later printing	GMAIN* GCURVE*	MF6
FTR	Calculates force on top of closed end diesel rams	------	MF4B
HACCPT	Sets up hammer model after reading hammer data file	CAPCUS HCARDR	MF2
HCARDR	Reads hammer data from cards	OVRRDE	MF2
INIT	Initializes, reads FILES.DAT, and sets up I/O unit numbers	------	MF1
INTEGR	Integrates acceleration, velocity	------	MF5
IPARAS	Prints buffer	------	MF6
JJNP	Assigns segment numbers for output	------	MF2
WEAP86	WEAP86 main program	CHTIME DATIN1 DIESL EXTCOM GHEAD* GRFOFF* PRTSC* INIT JJNP OUTSUM PIEL PRNTHM PRNTPL SETSOL STROUT SUMOUT	MF1
NEWPRS	Computes new pressure for next trial analysis (diesels)	------	MF4A
NEWSTR	Computes a new stroke in variable stroke analysis (diesels)	------	MF4A

NAME	DESCRIPTION	CALLS	FILE
OUT2	Prints variables vs. time	EXTIT IPARAS PRTIT	MF6
OUTSUM	Prints extrema	DIMEN OUT2 REINIT RSOUT1	MF6
OVRRDE	Accepts hammer override data	SACSEQ	MF2
PIEL	Sets up pile model	------	MF2
PILEAN	Performs pile wave analysis	INTEGR STIFF	MF5
PRNTHM	Prints hammer model	------	MF1
PRNTPL	Prints pile model	------	MF1
PRSSRE	Computes combustion pressure in chamber of diesel hammers	ADIA	MF4B
PRTIT	Prints title on top of page	------	MF6
REINIT	Reinitializes extrema arrays	------	MF6
RETRV	Retrieves diesel start up data	------	MF4A
RSOLVE	Residual stress analysis	SOLVE	MF5
RSOUT1	Residual stress output	------	MF5
SACSEQ	Computes actual from equivalent stroke of closed-end diesels	------	MF4B
SETSOL	Sets up soil model	------	MF2
SOLVE	Residual stress equation solver	------	MF6
SPLEEN	Residual stress main routine	RSOLVE	MF5
SRESN	Computes static soil resistance in wave analysis	------	MF5
STIFF	Computes force in spring with slack and roundout	------	MF5
STOREN	Stores displacements for residual stress	------	MF5
STRCNV	Checks convergence of diesel strokes	------	MF4A

NAME	DESCRIPTION	CALLS	FILE
SUMOUT	Summary output	------	MF6
TEST	Test ram condition in diesel startup routine	------	MF4AB
UP	Analyzes ram's upwards motion	------	MF4B

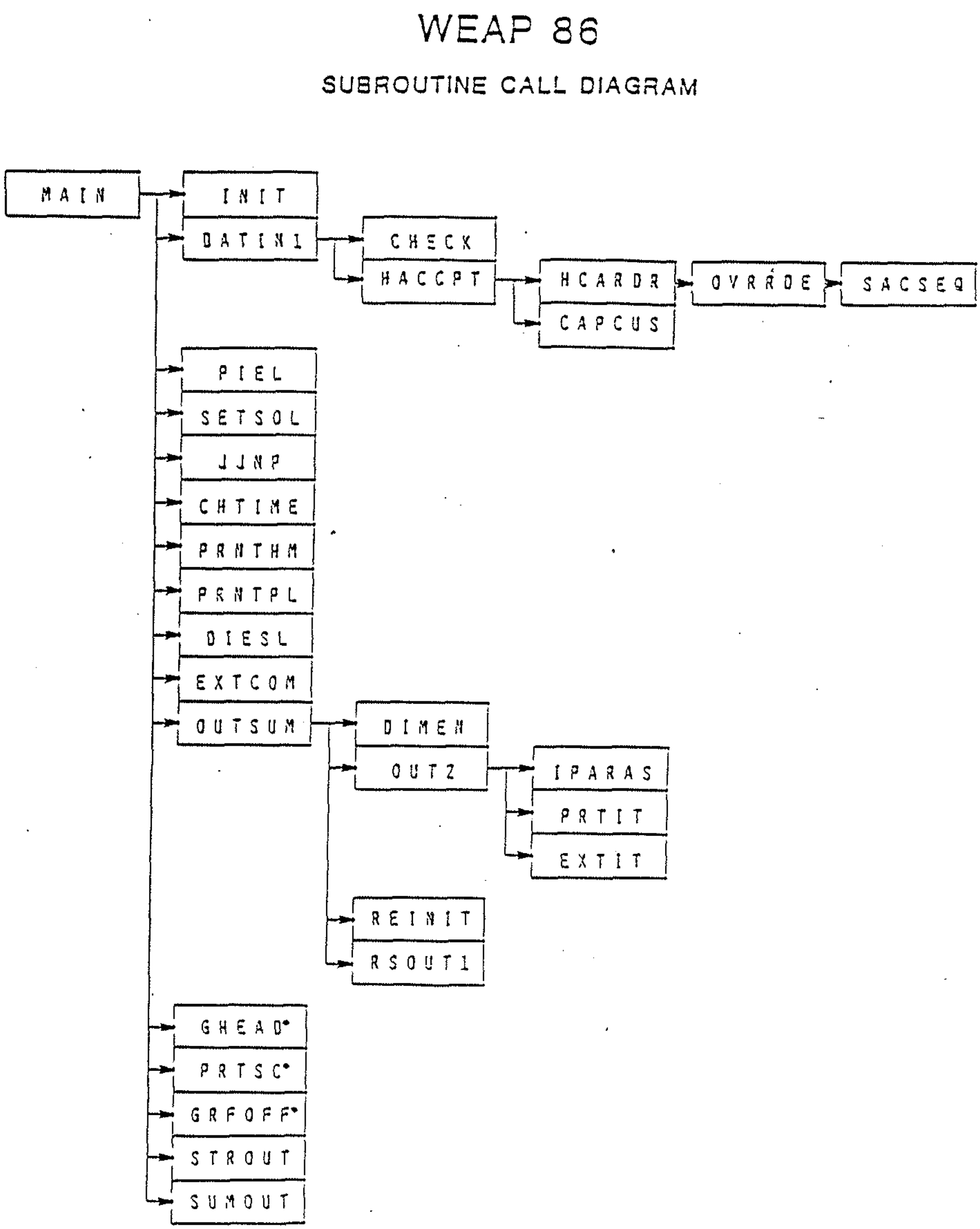


Figure 4.1a. WEAP86 subroutine call diagram.

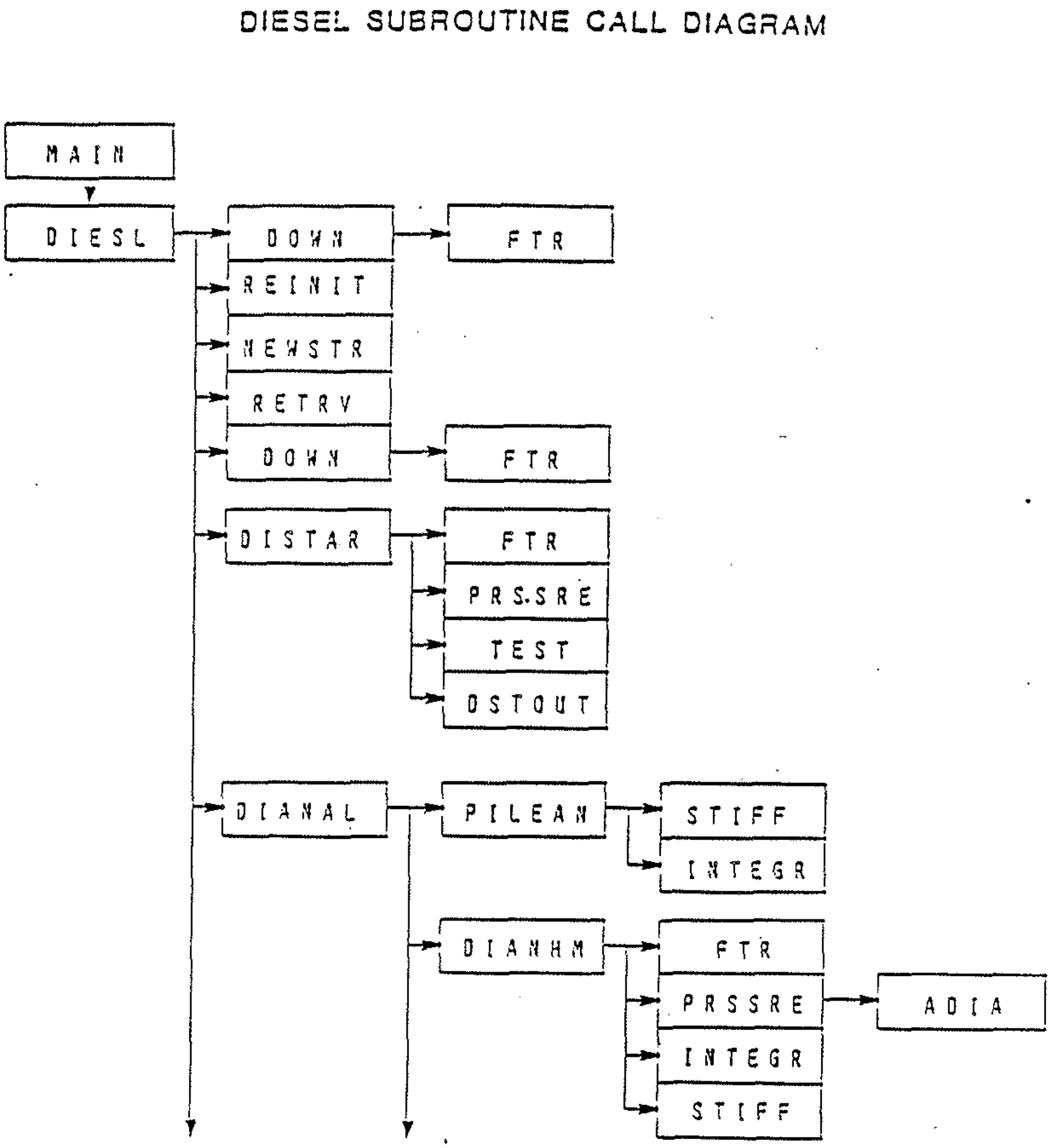


Figure 4.1b. Diesel subroutine call diagram.

DIESEL SUBROUTINE CALL DIAGRAM
(CONTINUED)

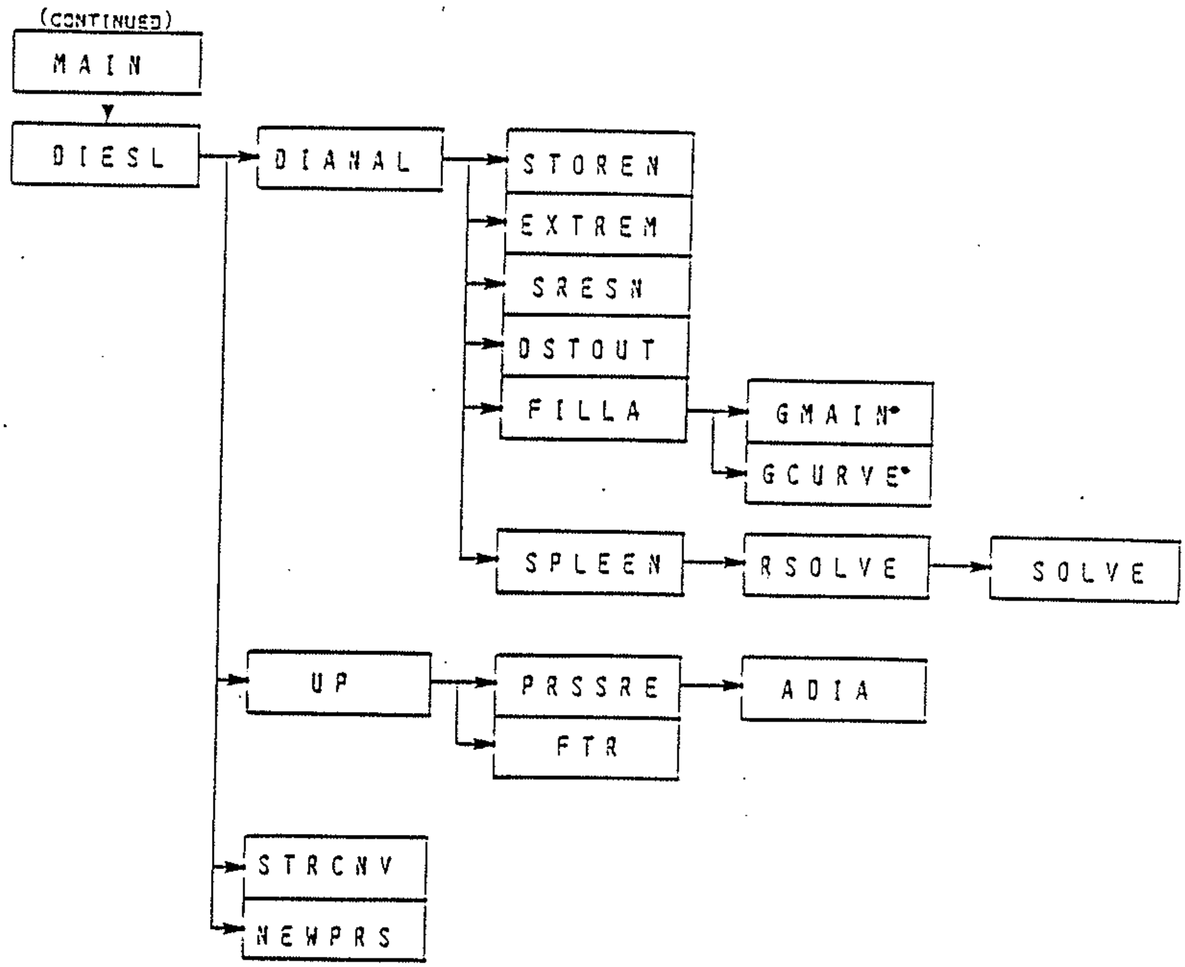


Figure 4.1b. Diesel subroutine call diagram (continued).

AIR/STEAM SUBROUTINE CALL DIAGRAM

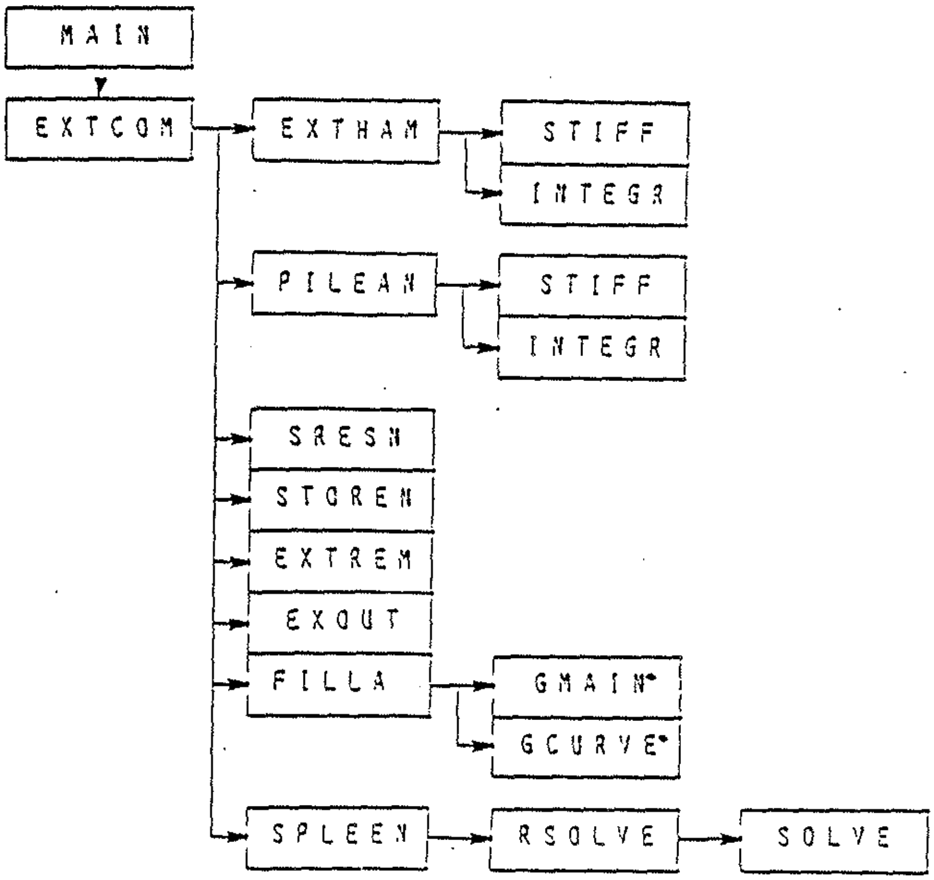


Figure 4.1c. Air/steam subroutine call diagram.

4.1.2 Graphics Subroutines

(Note: Plot refers to graphics on the terminal screen.)

NAME	DESCRIPTION	CALLS	FILE
CONV	Converts an integer to a character string	------	MF7
GCHAR	Plots character string	------	MF7
GCURVE	Controls plotting of data points for x-number of curves	CONV GCHAR GLINE GMOVE GPLOT OVRWRT	MF7
GHEAD	Plots title, curve, segment labeling, and base lines	CONV GCHAR GMOVE GPLOT GROTN	MF7
GLINE	Enables line styles--solid/dashed/dotted	------	MF7
GMAIN	Main control for graphics routines	GHEAD GRFON GSCALE	MF7
GMAGN	Sets character magnitude--height and width	------	MF7
GMOVE	Moves graphics cursor to new coordinates	LIMXY	MF7
GPLOT	Draws a line from previous coordinates to new coordinates	LIMXY	MF7
GRFOFF	Clears the terminal screen, disables graphics and restores screen to 80-column black and white mode (Monochrome)	------	MF7
GRFON	Enables graphics mode and sets up terminal characteristics	GRFOFF GMAGN	MF7
GROTN	Rotates the text (character) axis with respect to the X-axis	------	MF7
GSCALE	Computes scales and spacing for plotting of curves	------	MF7
LIMXY	Limits X and Y coordinates to extrema	------	MF7
OVRWRT	Enables/disables destructive overwriting	------	MF7

GRAPHICS SUBROUTINE CALL DIAGRAM

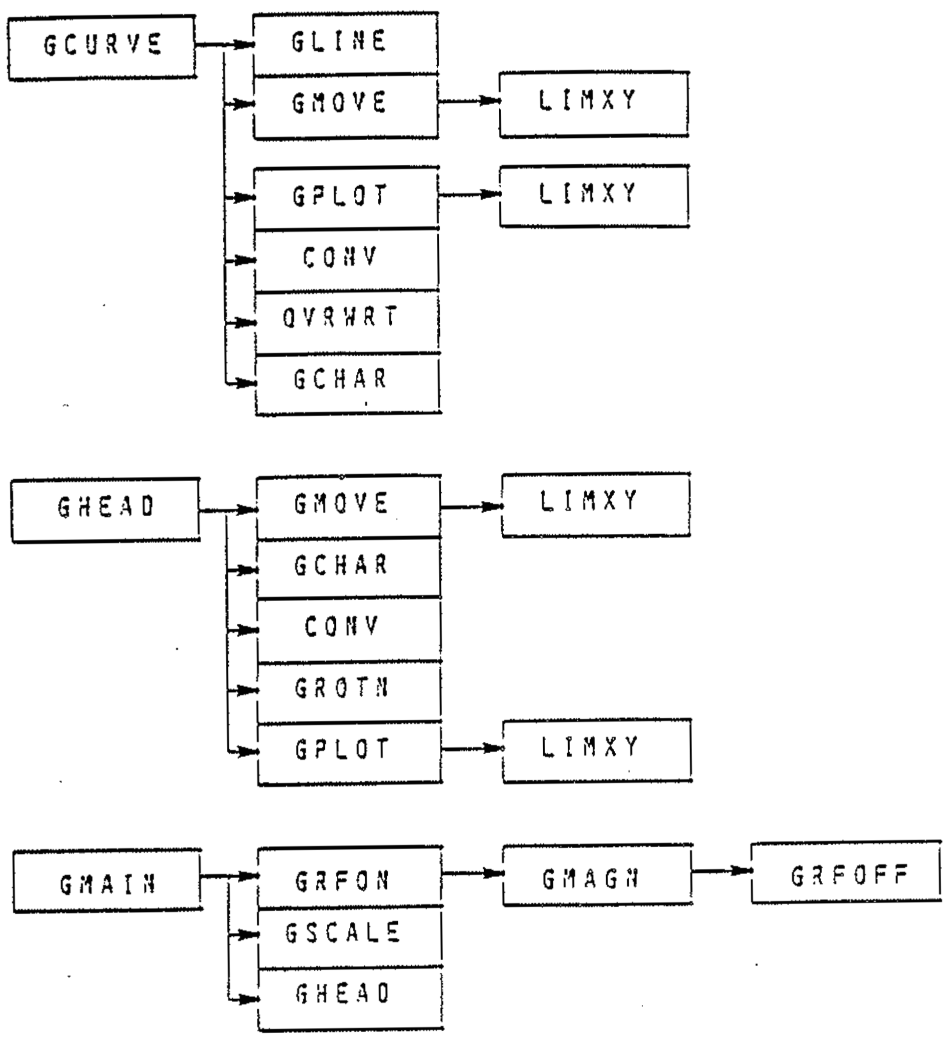


Figure 4.1d. Graphics subroutine call diagram.

4.2 The HAMRMA Program

NAME	DESCRIPTION	CALLS	FILE
HAMRMA	Main control	LSTDIR MDFDIR TODIR TOSEQT	HAMRMA
LSTDIR	Lists user-specified hammer data from HAMRDAT	------	HAMRMA
MDFDIR	Used for updating HAMRDAT hammer data file. Reads ASCII hammer data and writes hammer data to HAMRDAT file	------	HAMRMA
TODIR	Transfers ASCII hammer data to binary file (ASCIHM --> HAMRDAT)	ZERO	HAMRMA
TOSEQT	Transfers binary hammer data file to ASCII file (HAMRDAT --> ASCIHM)	------	HAMRMA
ZERO	Creates new HAMRDAT file	----	HAMRMA

HAMRMA SUBROUTINE CALL DIAGRAM

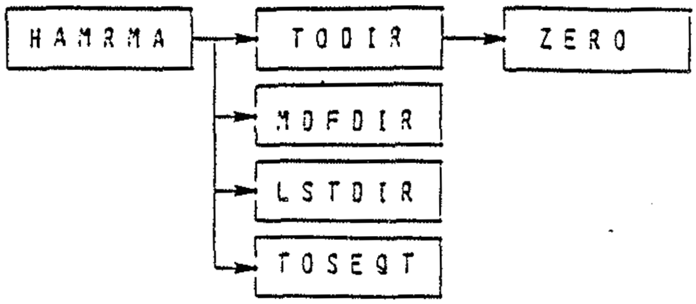


Figure 4.2. HAMRMA subroutine call diagram.

4.3 The W86IN Program

NAME	DESCRIPTION	CALLS	FILE
ARRIN	Input and correction of data arrays	------	WEAPIN
DATINF	Read input data file	------	DATIOF
DATINP	Interactive data input/modification	ARRIN DSPHAM HAMDAT HAMFIL HAMINP W2MENU	WEAPIN
DATOUF	Writes input data file	INQFIL	DATIOF
DSPDAT	Displays current input data	------	WEAPIN
DSPHAM	Displays current hammer data	______	DATIOF
HAMDAT	Main control for Hammer Maintenance routines	HAMFIL HMLIST	DATIOF
HAMFIL	Reads or writes hammer data to file	------	DATIOF
HAMINP	Allows for hammer data input/modifications	DSPHAM	DATIOF
HEADFL	Reads "HEADNG.DAT" for formats	------	WEAPIN
HMLIST	Lists selected hammer data records	------	DATIOF
IINIT	Reads "FILES.DAT" for filenames and initializes all input variables	------	WEAPIN
INQFIL	Inquires drives for existance of data files	------	DATIOF
W2MENU	Menu input routine	------	WEAPIN
W86IN	Main program for general control	DATINF DATINP DATOUF DSPDAT HAMINP	WEAPIN

W86IN SUBROUTINE CALL DIAGRAM

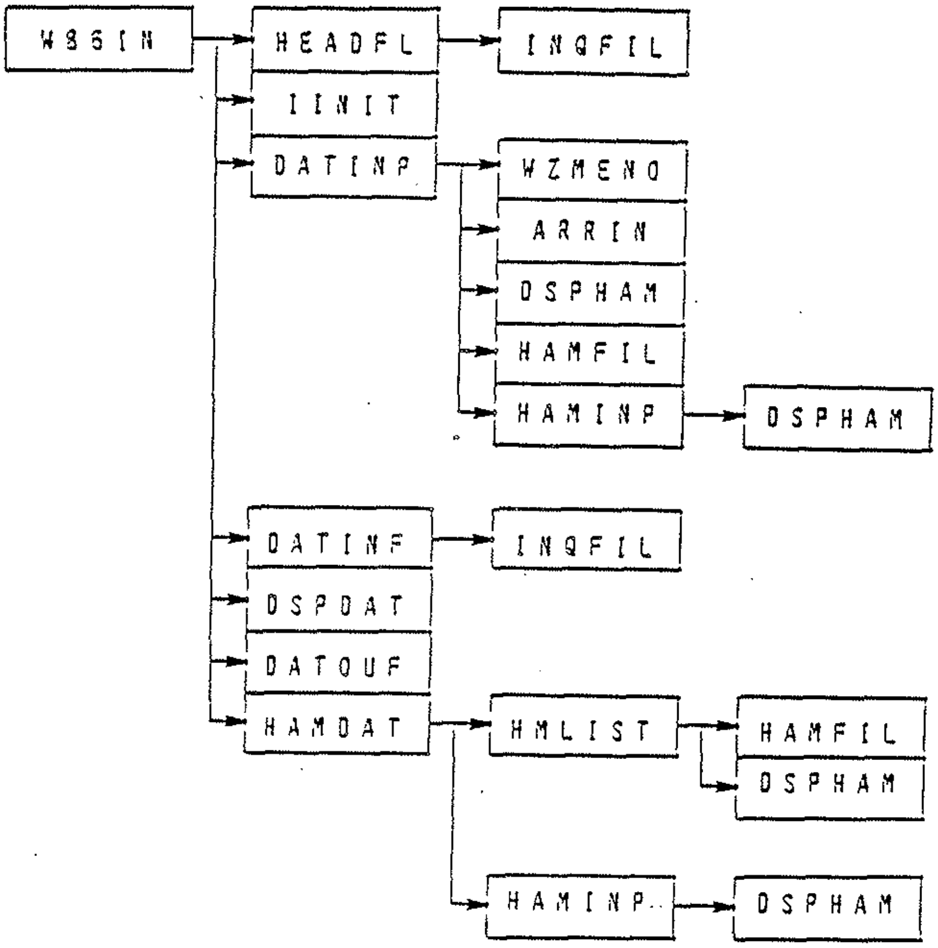


Figure 4.3. W86IN subroutine call diagram.

5. LIST OF COMMON VARIABLES

The following is a list of variables which reside in labeled COMMON. Each variable is described as follows:

NAME:	Internal variable name.
TYPE:	Variable type where: I - designates Integer type R - designates Real type C - designates Character type (x) - designates an Array of x length
DESCRIPTION:	Main purpose for variable.

5.1 The WEAP86 Program

The WEAP86 common variables have been divided into two sections:

- WEAP86 variables which represents the variables contained only in those routines needed for the standard WEAP86 program and
- Graphics variables contained in the routines that may be incorporated into the WEAP86 program which are to be used on a PC computer with graphics capabilities.

5.1.1 WEAP86 Analysis Common Variables

NAME	TYPE	DESCRIPTION
COMMON ASSMBL		
MA	I	Number of assembly segments
AW	R(3)	Weights of assembly segments
STAI	R(3)	Stiffnesses of assembly segments
CORAS	R	Coefficient of restitution of assembly
DRRAS	R	Round out of assembly
WASS	R	Total weight of the assembly

NAME	TYPE	DESCRIPTION
COMMON C		
VINH	R(10)	Unused
DINH	R(10)	Unused
AOH	R(10)	Hammer acceleration at end of the previous time increment
VOH	R(10)	Hammer velocity at end of the previous time increment
DOH	R(10)	Hammer displacement at end of the previous time increment
ANH	R(10)	Hammer acceleration at end of the current time increment
VNH	R(10)	Hammer velocity at end of the current time increment
DNH	R(10)	Hammer displacement at end of the current time increment
STH	R(10)	Hammer segment stiffnesses
HM	R(10)	Hammer segment masses
AM	R(10)	Assembly segment masses
STA	R(10)	Assembly segment stiffnesses
DROU	R(10)	Round out deformation of hammer springs
CORH	R(10)	Coefficient of restitution for hammer springs
AOP	R(99)	Pile acceleration at end of the previous time increment
ANP	R(99)	Pile acceleration at end of the current time increment
DOP	R(99)	Pile displacement at end of the previous time increment
DNP	R(99)	Pile displacement at end of the current time increment
VOP	R(99)	Pile velocity at end of the previous time increment
VNP	R(99)	Pile velocity at end of the current time increment
STP	R(99)	Pile segment stiffnesses
PM	R(99)	Pile segment masses
RSPD	R(99)	Sum of static and dynamic resistance
RES	R(99)	Static soil resistance for end of current time increment
RESD	R(99)	Static soil resistance for end of previous time increment
SJ	R(99)	Soil damping parameters for all pile segments plus the pile toe
SOK	R(99)	Static soil stiffnesses
QSR	R(99)	Soil quakes for all pile segments plus the pile toe
SU	R(99)	Ultimate static soil resistance values for all elments plus the pile toe
SPLICE	R(99)	Splice/slack values for pile segments
DSACP	R(99)	Roundout values for all pile segments
AREA	R(99)	Cross sectional area for all pile segments
CORP	R(99)	Coefficient of restitution for all pile segments
EX	R(600)	Extrema obtained during analysis
IEX	I(40)	Segment number of extrema
JEX	I(600)	Time counter values corresponding to EX array
OUT	R(3200)	Output array containing variables vs time
RESULT	R(100)	Summary Table Values
FOH	R(10)	Hammer forces at end of the previous time increment
FNH	R(10)	Hammer forces at end of the current time increment
FOA	R(10)	Assembly forces at the end of the previous time increment
FNA	R(10)	Assembly forces at the end of the current time time increment
FOP	R(99)	Pile forces at the end of the previous time increment

NAME	TYPE	DESCRIPTION
FNP	R(99)	Pile forces at the end of the current time increment
AOA	R(10)	Assembly accelerations at the end of the previous time increment
ANA	R(10)	Assembly accelerations at the end of the current time increment
VOA	R(10)	Assembly velocities at the end of the previous time increment
VNA	R(10)	Assembly velocities at the end of the current time increment
DOA	R(10)	Assembly displacements at the end of the previous time increment
DNA	R(10)	Assembly displacements at the end of the current time increment

COMMON CEDSTR

SEQU	R	Equivalent stroke
SACT	R	Actual stroke
CEDSMX	R	Maximum stroke for closed end diesel
CEDEMX	R	Maximum ending stroke for closed end diesel

COMMON CLOSED

DEPBB	R	Bounce chamber compressive stroke
ART	R	Bounce chamber top ram cross sectional area
DBBT	R	Maximum internal ram travel distance--distance between anvil and cylinder top minus the ram length.
DSF	R	Safety chamber distance--distance between compression tank ports and cylinder top.
VCT	R	Pressure tank volume
RWH	R	Reaction weight
EXPB	R	Exponent for bounce chamber expansion/compression
PRT	R	Manufacturer's hammer pressure rating for double acting external combustion hammers
AEFFB	R	Effective piston area as for PRT

COMMON CONSTS

G	R	Gravitational acceleration
CONVS	R	Conversion factor for inches to ft
PELE	R	Pile segment length
AREAF	R	Area factor
RKIPLB	R	Conversion factor for k to tons
NLIM	I	Maximum number of pile segments (98) [298]

NAME	TYPE	DESCRIPTION

COMMON COUNTER

KK	I	Counter for storage in OUT
KLIM	I	Limit counter
JMAX	I	Maximum number of output segments
JOUT	I	Output time increment
DTP	R	Time increment
TEMAX	R	Maximum analysis time
NT	I	Maximum number of time increments analyzed
IT	I	Iteration counter

COMMON CURSS

STRNOW	R	Input stroke
IPREA	I	Absolute pressure reduction counter

COMMON DIESEL

ANVW	R	Weight of the impact block
ANVL	R	Length of the impact block
ANVD	R	Diameter of the impact block
CORRA	R	Coefficient of restitution of the impact block spring
DRRA	R	Roundout of the impact block spring
DEPIB	R	Compressive stroke--distance between exhaust ports and anvil top.
ACH	R	Bounce chamber cross sectional area
VFIN	R	Final combustion chamber volume
TDEL	R	Combustion delay
DTIGN	R	Combustion duration
PATM	R	Atmospheric pressure
P1	R	Hammer pressure - Setting 1 (maximum pressure)
P2	R	Hammer pressure - Setting 2
P3	R	Hammer pressure - Setting 3
P4	R	Hammer pressure - Setting 4
P5	R	Hammer pressure - Setting 5
IGUESS	I	Certainty parameter
VSTI	R	Ignition volume (atomized fuel injection)
VENDC	R	Final combustion volume (atomized fuel injection)
EXPP	R	Expansion coefficient of combustion gases

COMMON DISTAT

VO	R	Chamber volume at the end of previous time increment
PO	R	Chamber pressure at the end of the previous time increment

NAME	TYPE	DESCRIPTION
VN	R	Chamber volume at the end of the current time increment at the end of the current time increment
DSTROK	R	Stroke difference between iterations
EPSTR	R	Stroke convergence criteria
ISTR	I	Trial analysis counter
STRAR	R(10)	Trial stroke results
IWT	I	Uplift indicator
PSI	R	Bounce chamber pressure
TDOWN	R	Time of fall to exhaust ports
TSTART	R	Time of compression cycle
TDIES	R	Time of diesel analysis
TUP	R	Time of expansion
VFR	R	Unused
IADIA	I	Adiabatic expansion/compression indicator
IIGN	I	Ignition flag
IBLOW	I	Exhaust flag
ISTART	I	Diesel start flag
STINH	R(4,12)	Storage of initial values from diesel start analysis
STINP	R(5,99)	As for STINH
IRA	I	Unused
TIGN	R	Time of ignition
TCOM	R	Time of combustion
TNOW	R	Current time
DELP	R	Unused
DCYL	R	Displacement of the diesel cylinder
VCYL	R	Velocity of the diesel cylinder
ACYL	R	Acceleration of the diesel cylinder
ISTST	I(5)	Startup flags

COMMON DRISYS

CAPW	R	Weight of the helmet
CAPST	R	Stiffness of the hammer cushion
CUST	R	Stiffness of the pile cushion
CORCAP	R	Coefficient of restitution of the hammer cushion
CORCUS	R	Coefficient of restitution of the pile cushion
CORPTP	R	Coefficient of restitution of the pile top
CHADA	R	Coefficient of hammer damping
DRCP	R	Round out of the hammer cushion
DRCU	R	Round out of the pile cushion
DRPT	R	Round out of the pile top
PTST	R	Pile top stiffness
ACAP	R	Area of the hammer cushion
ECAP	R	Elastic modulus of the hammer cushion
TCAP	R	Stiffness of the hammer cushion
ACUS	R	Area of the pile cushion
ECUS	R	Elastic modulus of the pile cushion
TCUS	R	Thickness of the pile cushion

NAME	TYPE	DESCRIPTION

COMMON FI2122

HAMFIL	C	Hammer data file name
OWNFIL	C	Not used
FILE21	C	File name for summary of results output (bearing graph)
FILE22	C	Filename for storage of selected curves data. Used in plotting

COMMON FILLQU

RSUM	R	Simultaneously occuring static resistance
DSUM	R	Simultaneously occuring dynamic resistance
RTOE	R	Toe resistance
TT	R	Time
J	R	Time counter
NO5	I	Pile midlength segment number
MAXJP	I	Maximum number of output time steps
PQ	R	Unused
EMAX	R	Maximum transferred energy
EFIN	R	Final transferred energy
BCT	R	Blow count
DFIN	R	Final displacement
QAV	R	Average quake
RULT	R	Ultimate capacity for current analysis
NULT	I	Total number of capacities to be analyzed
IULT	I	Analysis counter

COMMON FRCTIN

DIS	R(11,2,20)	Skin friction distribution. DIS(yy,1,XX) contains the depth and DIS(yy,2,XX) contains the corresponding soil resistance values for the yy distribution

COMMON GENHAM

ITYPH	I	Hammer type 1=Open-end Diesel, 2=Closed-end diesel, 3=Air/steam
IHAMR	I	Hammer ID--Storage location of hammer data on file.
IVAC	I	Unused
MH	I	Helmet segment number
M	I	Number of ram segments
RAMW	R	Weight of the ram
RAML	R	Length of the ram including point of application
RAMD	R	Diameter of the ram
STRM	R	Maximum stroke or stroke to be used in the analysis
STRMN	R	Minimum stroke
PRR	R	Rated pressure
EFFICY	R	Hammer efficiency

NAME	TYPE	DESCRIPTION
STROKE	R	Current stroke
STROKO	R	Stroke from previous iteration
VFALL	R	Ram velocity at time of port closure (diesel) or impact (air/steam)
VFALLM	R	Maximum ram velocity at ports for no uplift

COMMON GRAPHS

IGRAPH	I	Graphics option (enable/disable)

COMMON HAMNAM

NAMMAN	C(2)	Name of hammer manufacturer
NAMHAM	C(2)	Name or model or hammer

COMMON IOU

IHF	I	Hammer data file number
IW	I	Logical unit for file writing
IR	I	Logical unit for file reading
IRESF	I	Result file number
IVARF	I	File number for variable vs. time storage
ITR	I	Logical unit number for Terminal Input
ITW	I	Logical unit number for Terminal display

COMMON OPTION

IOUT	I	Output option. Controls amount and type of output
IJJ	I	Output segment number option
IOSTR	I	Stroke option for diesels
IFUEL	I	Fuel option corresponding to respective pressures
IPEL	I	Pile segment input option
N	I	Number of pile segments
ISPL	I	Number of splices/slacks
NCROSS	I	Uniform/Nonuniform (0/1) pile indicator.
IBEDAM	I	Pile internal damping in percent
IPERCS	I	Percent skin friction
ISMITH	I	Damping parameter type
ITYS	I	Skin friction distribution type
IPHI	I	Ratio of critical time increment to computational time increment
IRSAO	I	Residual stress analysis indicator
ITER	I	Maximum number of integrations iterations

NAME	TYPE	DESCRIPTION
IDAHA	I	Hammer damping in percent
ICOL	I	Width of output (80 or 132 columns)
INP	I(13)	Pile segment numbers for printed output
JDOUT	I	Number of time increments which are skipped between output values minus 1
JPMAX	I	Maximum time counter of values stored in OUT array
IOUTE	I	Extreme low output option flag
ITOE	I	Unused
IIOUT	I	Absolute value of output option

COMMON PILEPR

ALPH	R(99)	Relative segment lengths of pile segments
PROP	R	Proportionality factor F/V
T2LC	R	Time for wave to travel twice the pile length
WSPD	R	Pile wavespeed
PLEN	R	Length of the pile
CDP	R	Pile damping
XP	R(20)	Pile depths at which pile profile changes
AP	R(20)	Pile cross sectional area
EP	R(20)	Pile elastic modulus
WP	R(20)	Pile specific weight
XPT	R	Total pile length

COMMON QUKCOM

AMI	R(10)	Inverse of assembly masses
HMI	R(10)	Inverse of hammer masses
PMI	R(99)	Inverse of pile masses
STAU	R(10)	Unloading stiffnesses of assembly
STHU	R(10)	Unloading stiffnesses of hammer
STPU	R(10)	Unloading stiffnesses of pile
DT2	R	One-half time increment
DT6	R	One-sixth of square of time increment
PATMKF	R	Atmospheric pressure
ACHF	R	Chamber area
DEPIBF	R	Compressive stroke
DEPBBF	R	Compressive stroke of bounce chamber
ARTF	R	Area of top of ram
DBBTF	R	Ram travel
DSFF	R	Safety chamber distance
VCTF	R	Volume of compression tank
PRTKF	R	Rated pressure

NAME	TYPE	DESCRIPTION
AEFFPF	R	Effective area
PRRKF	R	Actual pressure
VFINF	R	Final volume
VSTIF	R	Ignition start volume
DSTIF	R	Ignition start distance
VENDCF	R	Ignition end volume
RAMWI	R	Inverse of ram weight
RAMI	R	Inverse of ram mass
CYLMI	R	Inverse of cylinder mass

COMMON RESOUT

RSMAX	R(10)	Maxima of residual stresses
IEXRS	I(10)	Segment number of residual stress maxima

COMMON RESSTR

BO	R(99)	Displacements from previous analysis
BS	R(99)	Displacements after static analysis
BST	R(99)	Difference between old and new displacements
CRITER	R	Convergence criteria
DPMAX	R(99)	Dynamic maximum displacements
ICARE	I	Residual stress continuation flag
IN	I	Residual analysis counter
IRESID	I	Residual analysis absolute counter
IRESTR	I	Not used
IRSA	I	Residual analysis option
ISTROK	I	Stroke convergence flag
NNN	I	Maximum number of trials
RESS	R(99)	Residual stresses in soil
RESSN	R(99)	Residual stresses in soil after static analysis
T	R(99)	Residual forces in pile
XERES	R	Pile compression differences

COMMON TIT

TITLE	C(10)	Title of current analysis
SUTI	C(40)	Supertitle

5.1.2 Graphics Routines

NAME	TYPE	DESCRIPTION
COMMON COORDS		
IYO	I(16)	Y-coordinate corresponding to zero for 16 curves
IXO	I(16)	Current X-coordinate for each curve
IYO	I(16)	Current Y-coordinate for each curve
COMMON GRFVAR		
IRES	I	Graphics resolution identifier
IMAG	I	Character magnitude
IROT	I	Text axis rotation factor
COL	R	Number of graphics columns
XMAX	R	Maximum number of pixels on X-axis
YMAX	R	Maximum number of pixels on Y-axis
XINC	R	Number of pixels per column
YINC	R	Number of pisels per row
IXX	I	Current X-coordinate
IYY	I	Current Y-coordinate
COMMON TIME		
OTIME	R	Previous analysis time in ms
COMMON TIT		
TITLE	C(10)	Title of current analysis
SUTI	C(40)	Proprietory header used for output
COMMON WEGRAF		
IGR	I	Output curve identifier
NCRVS	I	Number of curves to be plotted
YSCL	R	Y-axis scaling factor for force and when plotting pile segments
DSCL	R	Y-axis scaling factor for displacement curve
YSCL	R	Y-axis scaling factor for velocity curve
YSP	R	Y-axis spacing factor
XSP	R	X-axis spacing factor

5.2 The HAMRMA Program

NAME	TYPE	DESCRIPTION

COMMON IOU

ISEQ	I	Logical unit for ASCII hammer data file, ASCIHM
IDIR	I	Logical unit for binary hammer data file, HAMRDAT
IOUT	I	Logical unit for output (file or console)
INPT	I	Logical unit for input (file or console)
IRECMX	I	Maximum number of hammer records
IRECSZ	I	Record size for HAMRDAT

5.3 The W86IN Program

COMMON FILES

FILNAM	C	File name for input file

COMMON HAMMER

NAMMAN	C(2)	Name of hammer manufacturer
NAMMAN	C(2)	Name or model of hammer
MHAM	C(46)	Menu names corresponding to hammer input variables, HAM
HHAM	C(46)	Descriptions corresponding to hammer input variables, HAM
HMHD	C(2)	Labels for NAMMAN and NAMHAM
HAM	R(46)	Hammer input variables
		1- Hammer type
		2- Number of ram segments
		3- Ram weight
		4- Length of ram
		5- Diameter of ram
		6- Maximum stroke
		7- Minimum stroke
		8- Hammer efficiency
		9- Weight of the impact block
		10- Length of the impact block
		11- Diameter of the impact block
		12- Coefficient of restitution of te impact block
		13- Round out value of the impact block
		14- Compressive stroke
		15- Area of combustion chamber
		16- Volume of combustion chamber
		17- LI Combustion delay
		18- LI Combustion ignition duration
		19- Expansion coefficient
		20- AI volume at ignition
		21- AI Volume at final combustion

22- Atmospheric pressure
23- Hammer pressure at setting 1
24- Hammer pressure at setting 2
25- Hammer pressure at setting 3
26- Hammer pressure at setting 4
27- Hammer pressure at setting 5
28- Certainty confirmation
29- Distance B.C. port to top
30- Bounce chamber area
31- Maximum ram travel
32- Safety distance
33- Compression tank volume
34- Reaction weight
35- Bounce chamber combustion exponent
36- Effective area
37- Rated pressure
38- Assembly coefficient of restitution
39- Assembly round out value
40- Number of assembly segments
41- Weight of assembly segment no. 1
42- Weight of assembly segment no. 2
43- Weight of assembly segment no. 3
44- Stiffness of assembly segment no. 1
45- Stiffness of assembly segment no. 2
46- Stiffness of assembly segment no. 3

DATE	C(8)	Hammer entry date

COMMON IOU

IHF	I	Hammer data file number
IW	I	Logical unit for file writing
IR	I	Logical unit for file reading
IRESF	I	Not used
IVARF	I	Not used
ITR	I	Logical unit number for Terminal Input
ITW	I	Logical unit number for Terminal display
IPW	I	Logical unit for printer output

COMMON NAMES

(See COMMON W86IN for corresponding values)

MOPT	C(20)	Menu names for selected options
MCAP	C(8)	Menu names for CAP input
MCUS	C(6)	Menu names for CUS input
MPTP	C(6)	Menu names for PTP input
MHOV	C(8)	Menu names for HOV input
MDMP	C(4)	Menu names for DMP input
NOPT	C	Heading for selected options input

NAME	TYPE	DESCRIPTION
NCAP	C	Heading for CAP input section
NCUS	C	Heading for CUS input section
NPTP	C	Heading for PTP input section
NHOV	C	Heading for HOV input section
NDMP	C	Heading for DMP input section
HOPT	C(20)	Descriptions corresponding to selected option variables
HCAP	C(8)	Descriptions corresponding to CAP input
HCUS	C(6)	Descriptions corresponding to CUS input
HPTP	C(6)	Descriptions corresponding to PTP input
HDMP	C(4)	Descriptions corresponding to DMP input
NUP	C	Heading for nonuniform pile input
NSTP	C	Heading for STP input
NPM	C	Heading for PM input
NALPH	C	Heading for ALPH input
NQS	C	Heading for QS input
NSJ	C	Heading for SJ input
NSU	C	Heading for SU input
NDIS	C	Heading for DIS input
NSPLC	C	Heading for SPLC input
NCORP	C	Heading for CORP input
NDSACP	C	Heading for DSACP input
NRSLT	C	Heading for RSULT input
NINP	C	Heading for INP input
NHAMR	C	Heading for hammer input section
NPS	C	Heading for pile segment option (See IPEL)
DAEW	C(2)	Table heading and dimensions for non-uniform pile input (See XP, AP, EP, WP)
DRES	C(2)	Table heading and dimensions for skin friction distribution (See DIS)

COMMON W86IN

TITLE	C(10)	Problem title
SUTI	C(40)	Supertitle
IOUT	I	Output option. Controls amount and type of output.
IJJ	I	Option controlling determination of output segments numbers
IHAMR	I	Hammer ID number
IOSTR	I	Stroke option
IFUEL	I	Fuel option corresponding to respective pressures
IPEL	I	Pile segment option
N	I	Number of pile segments
ISPL	I	Number of slacks/splices
NCROSS	I	Uniform/Nonuniform (0/1) pile indicator
IBEDAM	I	Pile internal damping in percent of pile critical damping
IPERCS	I	Percent skin friction
ISMITH	I	Soil damping parameter type
ITYS	I	Type of skin friction distribution
IPHI	I	Ratio of critical time increment to computional time increment

NAME	TYPE	DESCRIPTION
IRSA	I	Residual stress analysis option
ITER	I	Maximum number of iterations
IDAHA	I	Hammer damping
IMAXT	I	Maximum analysis time
CAP	R(8)	Helmet/Hammer cushion information
		1- Weight of the helmet
		2- Area of the hammer cushion
		3- Elastic modulus of the hammer cushion
		4- Thickness of the hammer cusion
		5- Coefficient of restitution for hammer cushion
		6- Roundout valve for hammer cushion
		7- Stiffness of the hammer cushion
		8- Unused
CUS	R(6)	Pile cushion information
		1- Area of the pile cushion
		2- Elastic modulus of the pile cushion
		3- Thickness of the pile cushion
		4- Coefficient of restitution of pile cushion
		5- Roundout deformation of the pile cushion
		6- Stiffness of the pile cushion
PTP	R(6)	Pile top information
		1- Total pile length
		2- Area at the pile top
		3- Elastic modulus at the pile top
		4- Specific weight at the pile top
		5- Coefficient of restitution for pile top
		6- Round out value for the pile top
HOV	R(8)	Hammer override values
		(overrides corresponding data in COMMON HAMMER-HAM)
		1- Stroke option (see IOSTR)
		2- Hammer stroke
		3- Hammer efficiency
		4- Hammer pressure
		5- Hammer fuel setting (see IFUEL)
		6- Reaction weight
		7- AI Start ignition volume
		8- Hammer damping
DMP	R(4)	Soil parameters
		1- Quake of the skin
		2- Quake of the toe
		3- Damping of the skin
		4- Damping of the toe
XP	R(20)	Pile depths at which pile profile changes
AP	R(20)	Pile cross-sectional area
EP	R(20)	Pile elastic modulus
WP	R(20)	Pile specific weight
STP	R(99)	Pile segment stiffnesses
PM	R(99)	Pile segment weights
ALPH	R(99)	Pile segment lengths (relative)

NAME	TYPE	DESCRIPTION
QS	R(99)	Soil quakes for all pile segments plus the pile point
SJ	R(99)	Soil damping for all pile segments plus the pile point
SU	R(99)	Relative magnitudes of ultimate static soil resistance values for all pile segments plus the pile point
DIS	R(2,20)	Skin friction distribution. DIS (1,xx) contains the depth and DIS (2,xx) contains the corresponding soil resistance values
SPLICE	R(99)	Splice/slack for all pile segments
CORP	R(99)	Coefficient of restitution for all pile segments
DSACP	R(99)	Roundout deformation for all pile segments
RESULT	R(10)	Ultimate capacities for analysis
INP	R(13)	Pile segment numbers for printed output

6. GENERAL OPERATING INSTRUCTIONS FOR A WAVE EQUATION ANALYSIS

6.1 Mainframe Application

A. Prepare Program and Files

1. The WEAP86-MF program must be compiled into an executable program.
2. The hammer data file must be converted from ASCII form to a binary direct-access file (see Chapter 7, HAMMER FILE MAINTENANCE).
3. The input data file must be prepared (see Volume II, Chapter 3).

B. Execute the WEAP86 Program

1. The input file is read for the case to be analyzed.
2. The hammer data file is read for the required hammer.
3. The wave equation analysis is performed for as many ultimate capacity values as chosen by the user.
4. Output is made to the designated output unit.
5. The program is terminated.

C. Additional Problems

1. If more than one data set exists in the input datas file, then steps 1 through 4 in Section B are repeated until all problems have been analyzed. An unlimited number of problems may be solved in one run.

6.2 PC Application

A. Prepare Input File

1. Using either the W86IN program (see The Users Manual, Volume IV) or a text/line editor (see Volume II), create the input data file according to the required format.
2. Edit (if necessary) the FILES.DAT to correct the file names to be used in the WEAP86 run. If you have changed the FILES.DAT file, copy the new FILES.DAT to the WEAP86 disk, overwriting the old.

B. Execute the WEAP86 Program

1. FILES.DAT is read and other I/O files are assigned.
2. The input data file is read for the case to be analyzed.
3. The hammer data file is read for the required hammer.
4. The wave equation analysis is performed.
5. Output is made to the designated output unit.
6. The program is terminated.

C. Additional Problems

1. If the input file contains more than one problem, then steps 1 through 5 in Section B are repeated until all problems in the input file have been analyzed. Up to 10 cases may be "chained" together in the input file.

7. HAMMER DATA FILE AND MAINTENANCE

7.1 Mainframe Application

The hammer data file is distributed as a formatted, sequentially-accessed ASCII file called ASCIHM. To provide for quicker data access during program execution, the ASCII file, ASCIHM, is converted to a direct-access binary file called HAMRDAT.

The HAMRMA program provides for the maintenance of the hammer data file. It provides the following functions or tasks:

ITASK = 1: Transfer data from the formatted sequentially-accessed file ASCIHM to a newly created and initialized direct-access binary file, HAMRDAT.

ITASK = 2: Load new hammer data (ASCII format) to specified ID numbers in HAMRDAT (binary format).

ITASK = 3: List selected hammer data from HAMRDAT.

ITASK = 4: Transfer hammer data from HAMRDAT (binary format) to ASCIHM (ASCII form).

ITASK = 5: Program termination.

A task is invoked by providing a option card (or line) for each task to be performed. The option card reads as follows:

Columns		
1- 4	ITASK	See above.
5- 8	ISTART	For ITASK = 3 only; starting ID to be listed, otherwise ignored.
9-12	ISTOP	For ITASK = 3 only; ending ID to be listed, otherwise ignored.
13-15	LEVEL	For ITASK = 3 only; level of hammer data output, otherwise ignored. = 1 - ID number, hammer manufacturer and name. = 2 - As in 1 and also ram weight and stroke and entry date. = 3 - Complete data listing.
16-18	N	For ITASK = 2 only; number of data sets to be read from the input file and written into HAMRDAT, otherwise ignored.

All option line card inputs are read on I4 formats, i.e., the first integer should reside in columns 1 through 4, second 5 through 8, third 9 through 12 and so on. The integer values should also be right-justified in their respective field. Also note that the option line cards must start on the first input line and that more than one option line card may be input.

The individual tasks and their additional inputs are described below.

7.1.1 ITASK = 1 - Transferring ASCIHM (ASCII) to HAMRDAT (Binary)

To transfer or convert the formatted, sequentially-accessed, ASCII ASCIHM hammer data file to the direct-access, binary file HAMRDAT (which is used in WEAP86), the option line card would read

```
                              1   1
Column:              ...4...8...2...6...........

Option Card:            1
Option Card:            5
```

"1" performs the conversion (reading ASCIHM and writing to HAMRDAT) and "5" terminates the program properly.

7.1.2 ITASK = 2 - Loading New Hammers

The option line card for loading new hammers would contain a

```
                              1   1
Column:              ...4...8...2...6...........

Option Card:            2   0   0  nn
nn-Hammer Data       (insert hammer data here for nn sets)
Option Card:            5
```

where "2" invokes the loading subroutine and nn represents the number of hammers that are to be read and written to HAMRDAT. "5" terminates the program.

The hammer data is inserted as shown above. See Figure 7.1 for the correct format, refer to Volume II, Chapter 3 for a description of the quantities.

Hammer Data Loading Input Form

ID

MANUFACT	NAME	H TYPE	M

RAM WGHT KIPS	RAM LGTH FT	RAM DIAM IN

IB WGHT KIPS	IB LGTH IN	IB DIAM IN	COR IB	DR IB FT

DEPIB IN	CHMBR. A SQ IN	CHMBR. V CU IN	CMB DELAY SECONDS	CMB DRTN SECONDS

PATM PSI	P1 PSI	P2 PSI	P3 PSI	P4 PSI	P5 PSI

AI STRT V CU IN	AI END V CU IN	MAX STRK FT	MIN STRK FT	EFFICY

CO EXP	DEPBB IN	B C AREA SQ IN	DBBT IN	D SAFE IN	C TANK V CU IN	REACTN WT KIPS	CO EXP BC

E.C. RTD P PSI	EFF AREA CU IN	ASSM W 1 LBS/CU FT	ASSM W 2 LBS/CU FT	ASSM W 3 LBS/CU FT	ASSM ST 1 KIPS/IN	ASSM ST 2 KIPS/IN	ASSM ST 3 KIPS/IN

COR AS	DR AS FT

MA	CO CONF.	DATE

1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0

Figure 7.1. Hammer data loading form.

7.1.3 ITASK = 3 Listing Hammers Currently on File

For hammer data listing, the option line cards would read

```
                               1   1
Column:                 ...4...8...2...6...........

Option Card:               3  xx  yy  zz
Option Card:               5
```

where "3" invokes the listing subroutine, xx and yy are the inclusive starting and ending hammer ID numbers, respectively and zz is the output level (1 to 3). Option "5" terminates the program.

7.1.4 ITASK = 4 Transferring HAMRDAT (Binary) to ASCIHM (ASCII)

To transfer the contents of the binary hammer data file, HAMRDAT, to the ASCII file, ASCIHM, the option line cards would read

```
                               1   1
Column:                 ...4...8...2...6...........

Option Card:               4
Option Card:               5
```

NOTE: ACHIHM is created as a new file.

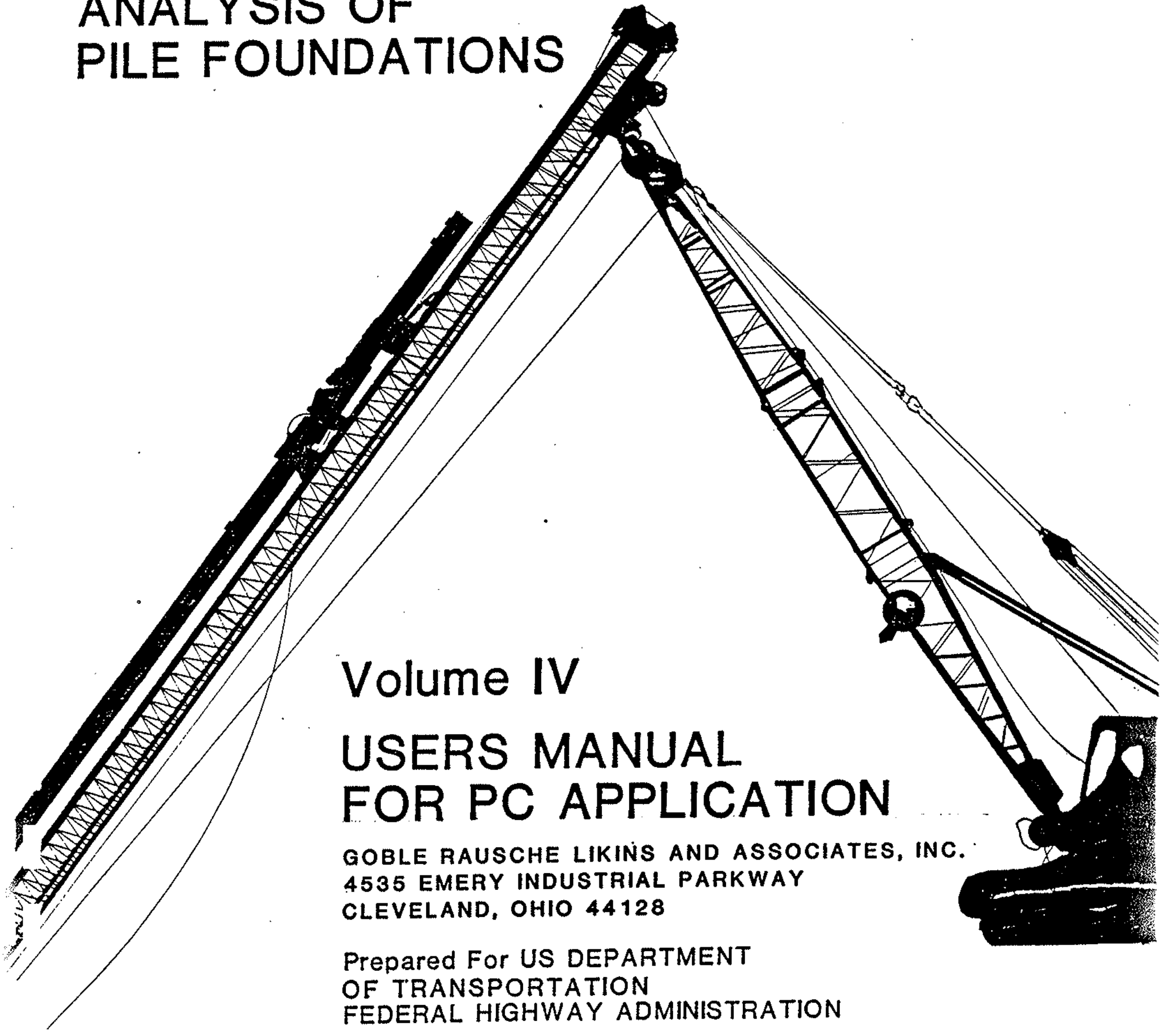
7.2 PC Application

The hammer data file (HAMMER.DAT) is distributed as a direct-access binary file with record lengths of 300 bytes each.

Listing, loading and the correction of the hammer data file can be made using the W86IN program - Main Branch Option 4 - Hammer Maintenance (see <u>PC Users Manual</u>, Volume IV).

WEAP86

WAVE EQUATION ANALYSIS OF PILE FOUNDATIONS



Volume IV

USERS MANUAL FOR PC APPLICATION

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Prepared For US DEPARTMENT
OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

FINAL REPORT
MAY 1986

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle	5. Report Date
WAVE EQUATION ANALYSIS OF PILE FOUNDATIONS WEAP86 PROGRAM Volume IV. Users Manual for PC Application	March 1986
	6. Performing Organization Code
7. Author(s) G.G. Goble and F. Rausche	8. Performing Organization Report No.
9. Performing Organization Name and Address Goble Rausche Likins and Associates, Inc. 4535 Emery Industrial Parkway Cleveland, OH 44128	10. Work Unit No. (TRAIS)
	11. Contract or Grant No. DTFH61-84-C-00100
12. Sponsoring Agency Name and Address Office of Implementation Federal Highway Administration 6300 Georgetown Pike McLean, Virginia 22101-2296	13. Type of Report and Period Covered Final Report
	14. Sponsoring Agency Code

15. Supplementary Notes

FHWA contract manager: Chien-Tan Chang (HDV-10)

16. Abstract

The WEAP Program, written and documented under a previous FHWA contract in 1976 and updated in 1981, was further developed. The documentation was completely rewritten for additional or revised information. The new program referred to as WEAP86, includes all of the WEAP features plus the following new models:

Separate models for liquid and atomized fuel injection of diesel hammers.
Residual stress analysis.
Realistic splice model.

An important addition was an updated and/or revised hammer data file with new efficiency values based on research performed under another contract for FHWA. Furthermore, extensive tables covering helmets, cushions, and piles were compiled and included in the documentation. Another important facet of the WEAP86 work was the development of a program version for personal computers. The main effort consisted of providing for a user-friendly/menu-driven input program and a graphics output option.

This is the fourth volume among four. The others are

FHWA No.	Vol. No.	Title
	I	Background
	II	General Users Manual
	III	Program Installation Manual

17. Key Words	18. Distribution Statement
Combustion, Computers, Design, Diesel, Dynamics, Foundations, Hammers, Impact, Pile driving, Residual stress, Soil mechanics, Wave equation.	No restrictions. This document is available to the public through the National Technical Information Service. Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	64	

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VOLUME IV: USERS MANUAL FOR PC APPLICATION

CHAPTER I

GENERAL DESCRIPTION OF PC APPLICATION

1.1 Introduction

This manual explains the use of the W86IN program which was written for a menu type terminal input of the data necessary for a WEAP86 program execution. This volume does not explain the relevance of the individual quantities, their defaults or their physical meaning. However, W86IN was written such that a cross reference to Volume II (in particular Chapter III) is very simple. Also, Volume I background should be read before proceeding with an analysis. This manual does not repeat the program installation recommendations which were discussed in Volume III. For quick reference, however, a brief summary follows for a complete new cycle of analysis.

A. Prepare Input Data

1. Obtain physical data as described in Volume I, Chapter IV.

2. Obtain hammer data. If desired hammer data is not referenced in Table 1, Vol II, contact manufacturer and obtain data as described in Vol I, Ch IV.

B. Create Input Data File

1. Using W86IN, prepare data input file WEAP.DAT. Any other file name maybe used as long as the same data input file name appears in FILES.DAT

2. Store data input file under a descriptive file name for future reuse before WEAP.DAT is overwritten by another problem set.

C. Run WEAP86

Note that step B can also be replaced by directly preparing WEAP.DAT using an editor and following the input instructions of Volume II, Chapter III.

For hammer data file maintenance, including the listing of available data sets, the W86IN program may also be used. Just follow the instructions and answer all questions step by step.

1.2 Details of PC Application

1.2.1 Hardware Requirements for WEAP86

The W86IN has been designed to run on an IBM-PC or compatible machine that contains

A. Two 360k disk drives or one 360k disk drive and one hard drive.

B. A printer for output.

In order to direct the computer to the proper drives, a file FILES.DAT has been provided which contains names and drive specifiers for all files called by WEAP86 and W86IN.

1.2.2 Disk Contents

The WEAP86 Programs (executable versions only) and the data files are distributed on three disketts. The disks' contents are as follows:

Disk 1:	W86IN.EXE	- Interactive input program
	FILES.DAT	- File specifier
	HEADNG.DAT	- Headings and menu names for W86IN
Disk 2:	WEAP86.EXE	- Wave equation analysis program
	FILES.DAT	- File specifier
Disk 3:	HAMMER.DAT	- Hammer data file
	EXA??.DAT	- Test examples

Before proceeding with program execution, the user is urged to make a backup set of disks.

For an explanation of the files, see VOLUME III, CHAPTER III - DESCRIPTION OF FILES. It is important to understand that FILES.DAT is read by both the WEAP86 and W86IN programs and basicallay lets the programs know on which drive the needed files reside.

The W86IN terminal input routine is executed with the use of Disk 1 and Disk 3 and one of the PC drive-combination described in Section 1.2.1.

1.2.3 Execution of W86IN on Dual Drive Systems

The W86IN program and data files are being supplied on IBM-PC compatible 360k disks. The disks do not contain operating systems.

In order to execute the programs, you must first boot your system on a valid operating system disk before running the program.

To run a program, make sure Drive A is the default drive (A> should be prompted). Then simply insert the desired program disk (e.g. W86IN.EXE or WEAP86.EXE) in Drive A, the data file disk in Drive B, and type the program name. Note FILES.DAT must reside on the default drive and FILES.DAT must be available to all the programs of the WEAP86 package. For two diskette drives, the FILES.DAT names can be used unedited.

1.2.4 Execution on a Hard Drive System Only

If the user works with a hard disk, then it is suggested to create a directory for the WEAP86 program package. Copy the contents of the three disks into the designated area. Edit the FILES.DAT file and edit the drive designators of the file names to the correct drive letter (in other words, to the drive where the files reside). This process is further explained in VOLUME III, CHAPTER III. When executing the program, the default drive must be the designated area.

Again, remember FILES.DAT must reside on the default drive.

1.3 File Name Declarations - FILES.DAT

FILES.DAT is a short formatted, sequential, ASCII file which contains the ICOL option and the input/output filenames which will be read automatically upon entering either WEAP86 or W86IN program.

The files contents are as follows:

Line 1: ICOL Option - if set to 0 (default), 80-column or if set to 1, 132-column output is made to the printer file. ICOL is read on a 14 format, i.e. the value must be in the fourth column on the first line of FILES.DAT.

Line 2: DATA INPUT FILE - name of the file which serves as both the current input for WEAP86 and the default filename for W86IN.

Line 3: OUTPUT FILE - name of the file where the "printed" results will be directed to, i.e. line printer, console, or filename.

Line 4: HAMMER DATA FILE - name of hammer data file to be used (HAMMER.DAT).

Line 5: BEARING GRAPH OUTPUT FILE - filename for storage of Summary Table results.

Line 6: VARIABLES VS TIME OUTPUT FILE - filename for storage of the variables (designated by IOUT) vs time (for every time increment during the analysis).

IMPORTANT: The correct file names must occur on the proper line or data may be destroyed. For instance, if Lines 3 and 4 were reversed, the actual hammer data could not be read from output device (such as the line printer) and the "printed" results would be sent to the hammer data file thus destroying its contents.

Example: The FILES.DAT contents are as follows:

```
   0         <--------- USE 14 FORMAT TO ENTER ICOL IN THIS PLACE
B:WEAP.DAT          <-- NAME OF DATA INPUT FILE
```

```
A:PRN            <-- NAME OF OUTPUT FILE
B:HAMMER.DAT     <-- NAME OF HAMMER DATA FILE
B:FILE21.DAT     <-- NAME OF BEARING GRAPH OUTPUT FILE
B.FILE22.DAT     <-- NAME OF VARIABLES VS TIME OUTPUT FILE
```

The above example causes the following action.

The input data would be read from WEAP.DAT located on Drive B, 80-column printer output would be generated and would go to a line printer (does not apply to W86IN). The hammer data file on Drive B would be used. The bearing graph output and the variables vs time data, both used in the WEAP86 executable program, not in W86IN, would be directed to FILE21.DAT and FILE22.DAT on Drive B, respectively.

Files PRN, FILE21.DAT and FILE22.DAT are not used with W86IN but only in the WEAP86 executable program. Refer to Volume III, Chapter III for an explanation of these files.

1.3.1 Input File

The input file called WEAP.DAT in the above example, is a formatted, sequentially-accessed ASCII file which contains input data for the WEAP86 program. The file may be created with the execution of the W86IN program or with the use of an editor. Refer to VOLUME II for the contents of the input file.

The name of the input file is designated by Line 2 of the FILES.DAT.

1.3.2 Hammer Data File - HAMMER.DAT

The hammer data file, HAMMER.DAT, is a direct-access binary file with record lengths of 300 bytes each for each hammer. The hammer data file to be used is designated on Line 4 of the FILES.DAT file. Again, the name in itself is not restricted to HAMMER.DAT but the file named on Line 4 of the FILES.DAT file must contain the hammer data.

Hammer data may be added, listed or corrected by means of the W86IN program. For further information on the maintenance of the hammer data file, see Section 3.4.

1.4 Summary

Further details are given in VOLUME III, however, a summary of the programs necessary and sufficient for wave equation analysis follows:

A. W86IN Routine

1. Creates new WEAP.DAT (or other name) for WEAP86.

2. Reads and modifies old WEAP.DAT (or other name) for WEAP86 execution.

3. Stores new or updated WEAP.DAT file.

4. Uses, updates and/or lists HAMMER.DAT.

B. WEAP86 Program

1. Reads Files.DAT and then reads WEAP.DAT or other input data filename as per FILES.DAT.

2. Reads HAMMER.DAT if so required by the IHAMR option.

3. Writes to a printer file (see FILES.DAT).

4. Writes to FILE21.DAT, FIL121.DAT, FILE221.DAT, ... if more than one data set was present in WEAP.DAT. FILE21.DAT contains the final summary, i.e. the bearing graph data.

5. Writes to FILE22.DAT (also FIL122.DAT,... if more than one data set). FILE22.DAT contains selected variables (depending on the IOUT option) as a function of time.

Regarding the chaining of problems: up to 10 problems may succeed each other. However, W86IN is not capable of writing more than one problem to a file. The user would need to use an editor for copying one file behind each other if he wants to execute more than one problem at one time.

CHAPTER 2

PROGRAM DESCRIPTION

2.1 Getting Started

First, make sure that W86IN.EXE and FILES.DAT are present on the default drive. All other files should be on the same (hard disk) or another drive (diskette). To load the program type W86IN and press RETURN. Upon entering the program the following message is displayed:

```
                      W 8 6 I N
                      =========

          WEAP86 Terminal Inout Routine - Version 1.0


BRANCHING:

  -2 ... Reinitialize
  -1 ... Terminate Program
   0 ... Begin Terminal Inout/Modifications
   1 ... Read Previously Stored Inout (Modifications/Analysis)
   2 ... Display Current Inout
   3 ... Store Current Inout
   4 ... Hammer Data FILE Maintenance
```

This is the main branching point in the program. From this menu, the user may undergo any option -2 through 4. Chapter 3 of this volume (IV) explains each option in detail and shows examples when applicable.

During the start up of W86IN, the FILES.DAT file is opened and read. Refer to Volume III, Chapter 3, for a detailed description of this file. In short, file FILES.DAT is a short, sequential file which contains the input-output file names referenced by W86IN and WEAP86. Default names are those file names read from FILES.DAT. The file names should also include the drive designation for the respective file.

2.2 Notes on Menu Input

Most of the Branch Options have been set up in a menu type format. An example of a menu format is displayed as follows:

```
Helmet/Hammer Cushion Information

WT=       .00 Weight of the Helmet                              (kips)      CAPW
AR=       .00 Area of the Hammer Cushion (H. C.)                (in2)       ACAP
EM=       .00 Elastic Modulus of the H. C.                      (ksi)       ECAP
TH=     .0000 Thickness of the H. C.                            (in)        TCAP
CR=     .8000 Coefficient of Restitution for H. C.                        CORCAP
RO=     .0100 Round Out Deformation of H. C. (0 --) 0.010)      (ft)        DRCP
ST=        0. Stiffness of the H. C. (Overrides: AR(EM)/TH)     (k/in)      STCP

Enter NAME=xxxxx.xx                        ** RETURN To End Inout **
```

The W86IN menu input name (WT, AR, EM, etc.), the WEAP86 internal variable names (CAPW, ACAP, ECAP, TCAP, etc.) and a short description of the variables are given.

To change an option, the user is required to enter the two-letter menu name (WT, AR, EM, etc.), an 'equal sign', then the numerical value and a RETURN. The required format is displayed by the

Enter NAME=xxxx.xx

where NAME represents the two-letter menu name, the '=' and the numerical value xxxx.xx. Example:

```
        WT=7.
or      WT=7
```

Both examples are considered identical. The two-letter menu name may be either lower- or uppercase letters and spaces are not allowed. If the input does not conform to the required format or is not a valid input, the following message is displayed

**** INVALID NAME OR FORMAT - TRY AGAIN! *****

and the input is ignored. Only those variables that are displayed may be modified.

Input for the menu continues until a double RETURN after an input or a single RETURN is given immediately following display. If changes were made on the current pass, the menu will be redisplayed with the updated values. If no changes were made, the program will branch to the next menu.

2.3 Nonuniform Pile Profile

If the pile in question is not uniform, then a pile profile must be specified. This is done by setting 'NC' = 1 in the menu shown below:

```
NN=      12. Number of Pile Segments   (N)                                 N
NC=       1. Uniform Pile Option       (0/1: Uniform/Non-Uniform)     NCROSS
PD=       5. Pile Damping              (0 --> Normal)                 IBEDAM
Enter NAME=xxxx.xx                     ** RETURN To End Input **
```

Once "NC" has been set to '1', the following message will be displayed:

```
Non-Uniform Pile Profile                                        NCROSS
  ** Start at First Cross-Sectional Change **
    Depth        Area      E-Mod   Sp. Wght
     (XP)        (AP)      (EP)     (WP)
      ft          in2       ksi    lbs/ft3
```

where

DEPTH (XP) is the pile depth below top where the pile section changes
AREA (AP) is the cross-sectional area in in^2 at Depth
EMOD (EP) is the elastic modulus in ksi at Depth
S.W. (WP) is the specific weight in lbs/ft^3 at Depth

The user should not input pile top profile because it had already been entered in the Pile Top Properties Menu.

The program interpolates properities lineraly between consecutive XP(I) values. Stepwise changes of cross-section (or changes of material) have to be identified by two input with identical DEPTH values, first giving the pile properities just above the change and second just below that section. Any combination of linear with straight section and with any type of material is possible. The program recognized the last set of input values by comparing DEPTH with the total length ofthe pile. It is therefore, imperative that the last set of 'DEPTH, AREA, EMOD, S.W.' specifications start with a DEPTH value greater than or equal to the total pile length.

The pile E-Mod (Elastic Modulus) and Sp. Wght (Specific Weight) do not have to be entered if they are the same as the values entered in the Pile Top Properties Menu or if they are the same as entered in the previous line.

After input is completed, the nonuniform pile model is redisplayed.

```
Non-Uniform Pile Profile                                      NCROSS
  I     Depth       Area       E-Mod     Sp. Wght
         (XP)       (AP)       (EP)       (WP)
          ft        in2        ksi       lbs/ft3

  X    XX.XX      XX.XX      XX.XX      XX.XX
  X    XX.XX      XX.XX      XX.XX      XX.XX
Corrections?
 0 ... Continue With Current Default
 1 ... Corrections to be Made
```

where xx.xx represent input data.

The user is now given the opportunity to modify any data that was input incorrectly by entering a '1' and a 'RETURN'. To modify selected lines of the pile model, the user must enter the line number 'I', and the corresponding corrected pile data.

Input continues until 'I' is equal to zero or just a 'RETURN' is entered. The model is then redisplayed with the modified values and the user again has the opportunity to make additional changes if necessary.

2.4 Pile Segment Option

Following the pile profile data input, the user is prompted to enter a pile segment option as shown below.

```
Enter:
 Pile Segment Option                                                    IPEL
  0 ... AUTOMATIC DETERMINATION of Parameters
  1 ... Input LENGTHS (Automatic Stiffnesses and Masses)
  2 ... Input LENGTHS, STIFFNESSES and MASSES
```

This menu allows the user to input pile segment characteristics as described above.

2.4.1 Pile Segment Option 0: AUTOMATIC DETERMINATION of Parameters

Enter option '0' if pile segment lengths, stiffnesses and masses are to be computed automatically (segments of equal length will be generated).

2.4.2 Pile Segment Option 1: Input LENGTHS (Automatic Stiffnesses and Masses)

Option '1' should be entered if the user chooses to input the segment lengths but not the pile segment stiffnesses and masses (determined automatically). The pile segment lengths are entered as shown below.

An input of '1' with a total pile length of 35 ft and dividing the pile into 7 segments, results in the following message to be displayed.

```
Pile Segment Lengths                                  (relative) ALPH ** N =    7 **

N:      1        2        3        4        5        6        7
D:    5.00    10.00    15.00    20.00    25.00    30.00    35.00
V:  1.0000   1.0000   1.0000   1.0000   1.0000   1.0000   1.0000

  0 ... Continue With Current Values
  1 ... Corrections To Be Made
```

where N: is the pile segment number
D: depth at which pile segment ends.
V: the actual length of pile segment N.

If the values are correct enter a '0' or simply give a 'RETURN' and the program will continue.

An input of '1' allows the user to change any pile segment length. The following message is displayed:

```
Enter N:START  N:STOP  VALUE          ** RETURN To End Input **
```

where N:START is the pile segment number starting value
N:STOP is the pile segment stopping value
VALUE is the corrected pile segment length

The following input sets segment number 1 equal to 4.0 ft, segments 2 thru 6 to 5.0 ft, and segment number 7 to 6.0 ft (sum of segment lengths must equal total pile length).

```
1.1.4.
2,6,5.
7.7,6.
```

Setting N:START equal to N:STOP allows the user to change one pile segment at a time. Input ends when N:START is equal to zero or just a 'RETURN' is given. After changes have been made, the pile segment lengths will be redisplayed as shown below.

```
Pile Segment Lengths                                  (relative) ALPH ** N =     7 **

N:      1         2         3         4         5         6         7
D:   5.00     10.00     15.00     20.00     25.00     30.00     35.00
V: 4.0000    5.0000    5.0000    5.0000    5.0000    5.0000    6.0000

  0 ... Continue With Current Values
  1 ... Corrections To Be Made
```

Notice that the D: values, which represent the depth at which the corresponding segment ends, did not change from the previous menu. The segment depths will be recomputed when all modifications of the segment lengths have been made and a final 'RETURN' is entered. When this occurs the following message will be displayed.

```
***** REFIGURING ACTUAL SEGMENT LENGTHS *****
```

After a few seconds the menu with the corrected depths will be displayed.

```
Pile Segment Lengths                                  (relative) ALPH ** N =     7 **

N:      1         2         3         4         5         6         7
D:   4.00      9.00     14.00     19.00     24.00     29.00     35.00
V: 4.0000    5.0000    5.0000    5.0000    5.0000    5.0000    6.0000

  0 ... Continue With Current Values
  1 ... Corrections To Be Made
```

Note that only pile segment length values can be input or modified (V: ...). The pile segment numbers and depths are computed within the program. At this point give a 'RETURN' to continue with the program.

2.4.3 Pile Segment Option 2: Input LENGTHS, STIFFNESSES, and MASSES

Branch Option 2 should be entered if it is necessary for the user to input the Pile Segment Length along with their corresponding segment stiffnesses and masses. The input format for the segment stiffnesses and masses is similar to that of the pile segment length input as described in Section 2.4.2. The only difference being that the segment depths will not be refigured since they were already refigured after the segment lengths input.

2.5 Skin Friction Distribution and Selected Parameters

The following menu appears after the skin friction percentage is entered (IPERCS):

```
Enter Type:
 Skin Friction Distribution                                  ITYS

 USER-SPECIFIED DISTRIBUTION and SELECTED PARAMETERS:
  -2 ... DAMPING, QUAKES and STATIC RESISTANCES
  -1 ... DSTRBN and DAMPING
   0 ... DSTRBN Only

 TRIANGULAR DISTRIBUTION Starting At:
   1 ... Pile Top
   2 ... 20% Below Pile Top
   3 ... 40% Below Pile Top
   4 ... 60% Below Pile Top
   5 ... 80% Below Pile Top

 UNIFORM DISTRIBUTION Starting At:
   6 ... Pile Top
   7 ... 20% Below Pile Top
   8 ... 40% Below Pile Top
   9 ... 60% Below Pile Top
  10 ... 80% Below Pile Top
```

This menu allows the user to choose either a skin friction distribution which is already programmed in the W86IN routine as described in Figure 1 of Volume II (options 1 thru 10) or the user may choose branch options -2 thru 0 for user specified parameters.

2.5.1 User Specified Parameters

2.5.1.1 Branch Option 0: DSTRBN Only

This branch option requires the user to enter a depth vs. soil resistance distribution in a manner described below. After entering option 0, the following message is displayed:

```
Enter:
      Depth     Resistance
    (DIS(1,X)) (DIS(2,X))
       ft        Relative
```

Here, the user would input the Depth, DIS(1,X), and the corresponding relative resistance, DIS(2,2) (see also Volume II, Chapter 3 Cards 8.401, ...). The depth is in feet and resistance is a relative dimensionless quantity. Up to 20 specification of Depth vs. Soil Resistance can be input. The last depth value input must be greater than or equal to the total pile length. If data is read from file, the program skips to the display of the skin friction distribution.

Only the skin friction distribution is effected by the branch option 0 - DSTRBN Only. The amount of skin friction is a certain percentage of the total ultimate resistance RULT and was specified by entering a value for IPERCS.

The input skin friction distribution is then displayed and the user has the opportunity to modify the data if he so chooses as described in the example below. The input skin friction distribution is displayed:

```
 Skin Friction Distribution                                        ITYS
   I      Depth     Resistance
        (DIS(1,X)) (DIS(2,X))
           ft        Relative
   1      .000       .0000
   2    40.000      1.0000
Corrections?
  0 ... Continue With Current Default
  1 ... Corrections to be Made
```

If no modification is needed, enter a '0' or a 'RETURN' and the program will continue.

To modify current skin friction model, enter a '1' and 'RETURN' and the following message will appear:

'I' refers to the line number in the previous display. Input will continue until I is equal to zero or just a 'RETURN' is given. The model is then redisplayed including modifications and the user is again given the opportunity to modify the skin friction distribution.

2.5.1.2 Branch Option '-1' DSTRBN and DAMPING

This option allows the user to input the skin friction distribution as described in Section 3.1.1 and also allows the user to input Soil Damping Parameters. The individual segment damping values are inputed in the same format as described in the Pile Segment Length input in Section 2.4.2. See also Volume II, Chapter 3, cards 8.201, ...

2.5.1.3 Branch Option '-2' DAMPING, QUAKES, and STATIC RESISTANCES

This option allows the user to input individual pile segment damping, quakes, and static resistance values. All three parameters are input in the same format as described in Section 2.4.2. The user is reminded that only the actual numerical values for damping, quakes, and static resistance are to be entered or modified (V: ...). The segment numbers (N: ...) and the segment depths (D: ...) are computed internally and displayed for reference purposes only. See also Volume II, Chapter 3, Cards 8.101, ...

In this option, the static resistances are input in the same format as damping and quake values (array format). Note that the ultimate static soil resistance values are to be input in relative magnitudes. The WEAP86 program will normalize the values. See Section 2.4.2 for mode of input and Volume II, Chapter 3, Cards 8.301, ... for further information.

Note that in this option, the damping, quake, and soil resistance array input contains an additional pile segment number (N: ...) equal to N+1. This additional segment number represents the toe.

2.6 Pile Segment: Slack/Splice

Slack/splice values, splice coefficient of restitution and roundout deformation values may be entered for the given pile segments.

The splice values are the tension deformation that a spring (N) can undergo without force. A splice value at 0.003 ft is recommended for mechanical splices. An input of 99 ft designates a splice which does not limit the pile extension at the N-location (e.g., the pile top allows such an unlimited extension). A value of '-1.0' denotes no splice and, therefore, no slack.

The splice/slack input is demonstrated in the following example by entering two splices.

```
Splice/Slack Segment Option                                ISPL
 0 ... Not Applicable - Ok to Continue
 1 ... Enable Option to Allow Input
```

```
[1]
```

"User's Response: Enable Option"

```
Enter:
  Segmnt     Slack     C.O.R.     Rnd Out
    No        ft                    ft
```

```
2,.002,.8,
4,.002,.8,
```

"User's Response: Input segment number and corresponding slacks and COR values."

```
Splice/Slack Segment Option                                ISPL
        I        Segmnt     Slack      C.O.R.     Rnd Out
                   No        ft                     ft
        1          2        .0020      .8000      .0100
        2          4        .0020      .8000      .0100
Corrections?
  0 ... Continue With Current Default
  1 ... Corrections to be Made
```

[1] "Data is displayed - check for accuracy - User's Response."

```
Correction Mode
Enter:  I     Segmnt     Slack     C.O.R.     Rnd Out
```

[2] "User's Response: Eliminate segment 4 - I = 2"

```
Splice/Slack Segment Option                                   ISPL
        I        Segmnt     Slack      C.O.R.     Rnd Out
                   No        ft                     ft
        1          2       .0020       .8000      .0100
Corrections?
  0 ... Continue With Current Default
  1 ... Corrections to be Made
```

"All input data is checked; give a RETURN to continue."

A check is made on the number of splice values given and is assigned to the ISPL variable.

CHAPTER 3

MAIN MENU
(BRANCHING)

This chapter is devoted to the description of each branch option listed in the main menu. A brief example and explanation will be given when possible with the exception of Branch Option '0': Begin Terminal Input, for which three detailed examples will be reviewed.

After starting W86IN, the following main menu is displayed on the terminal:

```
BRANCHING:

 -2 ... Reinitialize
 -1 ... Terminate Program
  0 ... Begin Terminal Inout/Modifications
  1 ... Read Previously Stored Input (Modifications/Analysis)
  2 ... Disolay Current Inout
  3 ... Store Current Inout
  4 ... Hammer Data FILE Maintenance
```

This menu may also appear at other times, however, when starting up W86IN, the user is most likely to choose either Branch Option '0' or '1' for terminal input and/or modifications or the user may choose Branch Option 4 for Hammer Data File Maintenance. The other branch options must not be employed before data has been entered. For this reason, the branch option will be explained starting with Branch Option '0' - Begin Terminal Input/Modifications.

3.1 Branch Option '0': Begin Terminal Input/Modification

Branch Option '0' is used for specifying new and complete data for a Wave Equation Analysis. Throughout the input procedure, the user is given an opportunity to modify any incorrect data input.

To better familiarize the user with the Begin Terminal Input Option, three detailed examples will be reviewed. The only purpose of the examples is to demonstrate the process of inputing necessary data to run the WEAP86 program. No WEAP86 results will be given or discussed. The results of the examples are given in Volume II, General Users Manual.

In the following three examples, all blocked data represents data that was entered by the user via the keyboard. All statements in quotes are comments which describe the data input. All other information is produced by the program.

The variables listed at the far right are the internal variables used in the WEAP86 program. They are also referenced in Volume II and thus make a cross-reference possible. Volume II contains a more complete explanation of variables than this input description. Further cross references to line numbers of input forms will also be given in the form of "Card x.xxx."

For general menu input the following should be noted:

> The first two identification letters must be capitalized. They must be followed by an equal sign (=). After each entry, a RETURN must be given. To end the input in a menu, a second RETURN is to be entered. A zero number may be given by a "blank," or just RETURN. Incorrect entries may be repeated after the RETURN is given. Before the RETURN, "backspace" will rub out an earlier entry.

All three examples were executed using a 360k disk drive on A and one hard drive, C.

3.1.1 Example 1 (same as example 1 in Volume II)

A 45-ton (design) pile is to be driven through a soft compressible layer into a dense, coarse sand with gravel. The contractor wants to use 10 HP 53 profiles and a D-12 hammer. He uses a standard 12-by 12-inch cap with 4 1/2 inches of Conbest. The pile has to be driven to an ultimate capacity of 180 kips. A curve can be constructed for the desired range if capacities of 60, 120, 180 and 240 kips are analyzed.

First start up program as specified in Chapter 2, Section 1: Getting Started. The following display should appear:

```
                         W 8 6 I N
                         =========

          WEAP86 Terminal Inout Routine - Version 1.0


BRANCHING:

 -2 ... Reinitialize
 -1 ... Terminate Program
  0 ... Begin Terminal Inout/Modifications
  1 ... Read Previously Stored Input (Modifications/Analysis)
  2 ... Disolay Current Inout
  3 ... Store Current Inout
  4 ... Hammer Data FILE Maintenance
```

[0]   "Input a 0 to begin terminal input."

```
Enter:  TITLE
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
```

```
EXAMPLE 1, 45 TON DESIGN, HP 10X53, 0-12
```

"Input a descriptive title and RETURN (Card 1.000)."

```
Analysis Options

IO=        0. Output Option                                          IOUT
RS=        0. Residual Stress Analysis     (0/1: Normal/RSA)         IRSAO
MT=        0. Maximum Analysis Time        (0 --> Normal)            IMAXT
IT=        0. Number Of Iterations         (0 --> Normal)            ITER
CT=        0. Critcl Time Increment Ratio  (0 --> 160)               IPHI
Enter NAME=xxxx.xx                   ** RETURN To End Input **
```

"Input Analysis Options (Card 2.000). Since all default values are correct, just RETURN."

```
Helmet/Hammer Cushion Information

WT=       .00 Weight of the Helmet                            (kips)    CAPW
AR=       .00 Area of the Hammer Cushion (H. C.)              (in2)     ACAP
EM=       .00 Elastic Modulus of the H. C.                    (ksi)     ECAP
TH=     .0000 Thickness of the H. C.                          (in)      TCAP
CR=     .8000 Coefficient of Restitution for H. C.                    CORCAP
RO=     .0100 Round Out Deformation of H. C. (0 --> 0.010)   (ft)      DRCP
ST=        0. Stiffness of the H. C. (Overrides: AR(EM)/TH)  (k/in)    STCP

Enter NAME=xxxx.xx                   ** RETURN To End Input **
```

```
WT=2.15
AR=283.5
EM=280.
TH=2.
```

"User's Response, Card 3.000."

"After all data is entered give an additional RETURN."

```
Helmet/Hammer Cushion Information

WT=      2.15 Weight of the Helmet                            (kips)    CAPW
AR=    283.50 Area of the Hammer Cushion (H. C.)              (in2)     ACAP
EM=    280.00 Elastic Modulus of the H. C.                    (ksi)     ECAP
TH=    2.0000 Thickness of the H. C.                          (in)      TCAP
CR=     .8000 Coefficient of Restitution for H. C.                    CORCAP
RO=     .0100 Round Out Deformation of H. C. (0 --> 0.010)   (ft)      DRCP
ST=        0. Stiffness of the H. C. (Overrides: AR(EM)/TH)  (k/in)    STCP
```

"All input data is checked and found to be correct; Enter RETURN to continue."

```
Pile Cushion Information

AR=        .00 Area of the Pile Cushion (P. C.)              (in2)         ACUS
EM=        .00 Elastic Modulus of the P. C.                  (ksi)         ECUS
TH=      .0000 Thickness of the P. C.                        (in)          TCUS
CR=      .5000 Coefficient of Restitution for P. C.                      CORCUS
RO=      .0100 Round Out Deformation of P. C. (0 -) 0.01)    (ft)          DRCU
ST=         0. Stiffness of the P. C.                        (k/in)        STCU

Enter NAME=xxxx.xx                       ** RETURN To End Input **
```

"Pile cushion (Card 4.000) is not being used, enter RETURN to continue."

```
Pile Top Properties

LG=       .000 Total Pile Length                             (ft)           XPT
AR=        .00 Area at the Pile Top (P. T.)                  (in2)          APT
EM=   30000.00 Elastic Modulus at the P. T.                  (ksi)          EPT
SW=     492.00 Specific Weight at the P. T.                  (lbs/ft3)      WPT
CR=      .8500 Coefficient of Restitution for P. T.                      CORPTP
RO=      .0100 Round Out Deformation of P. T.                (ft)         DRPTP

Enter NAME=xxxx.xx                       ** RETURN To End Input **
```

```
LG=40.
AR=15.5
CR=.8
```

"User's Response, Card 5.000."

```
Pile Top Properties

LG=     40.000 Total Pile Length                             (ft)           XPT
AR=      15.50 Area at the Pile Top (P. T.)                  (in2)          APT
EM=   30000.00 Elastic Modulus at the P. T.                  (ksi)          EPT
SW=     492.00 Specific Weight at the P. T.                  (lbs/ft3)      WPT
CR=      .8000 Coefficient of Restitution for P. T.                      CORPTP
RO=      .0100 Round Out Deformation of P. T.                (ft)         DRPTP

Enter NAME=xxxx.xx                       ** RETURN To End Input **
```

"All input data checked and found to be correct; enter RETURN to continue."

```
NN=         8. Number of Pile Segments   (N)                                  N
NC=         0. Uniform Pile Option       (0/1: Uniform/Non-Uniform)      NCROSS
PD=         0. Pile Damping              (0 --) Normal)                  IBEDAM
Enter NAME=xxxx.xx                       ** RETURN To End Input **
```

"All default values to these pile options (Card 1.000) are correct; enter RETURN to continue."

```
Enter:
 Pile Segment Option                                             IPEL
  0 ... AUTOMATIC DETERMINATION of Parameters
  1 ... Input LENGTHS (Automatic Stiffnesses and Masses)
  2 ... Input LENGTHS, STIFFNESSES and MASSES
```

| 0 |

"User's Response (see Section 2.4 and Card 1.000)."

```
Enter:
 Hammer ID Number          (0 - 300)                            IHAMR
```

| 3 |

"User's Response - Input Hammer ID No. - see Table 1, Vol II".

```
ID NO.:   3

DELMAG   D 12        1    3   0
     2.75     104.41     11.81      8.58      5.35      .8000
      .81      21.27     11.81     .9000     .0100
    11.07     109.60     97.00     .0020     .0020    1.3500        .0        .0
     14.7     1408.0        .0        .0        .0        .0    1
 Hammer ID Number          (0 - 300)                            IHAMR
  (Default:   3)
  0 ... Continue with Current Default
  1 ... Enter New Value
```

| 0 |

"User's Response - Correct Hammer Model, enter '0' or RETURN to continue."

```
Hammer File Override Values and Options

SO=        0.  Stroke Option                                              IOSTR
ST=      .000  Hammer Stroke                               (ft)           STROOV
EF=      .000  Hammer Efficiency                                          EFFOV
PR=        .0  Hammer Pressure                             (psi)          PROV
FS=        0.  Hammer Fuel Setting (0 = 1 = maximum)                      IFUEL
RW=     .0000  Reaction Weight                             (kips)         RWTOV
CD=     .0000  Comb Delay (LI) or Start Ignitn Volume (AI) (s or in3)     TDELOV
HD=     .0000  Hammer Damping               (0 --> Normal)                IDAHA

Enter NAME=xxxx.xx                       ** RETURN To End Input **
```

"All hammer data satisfactory (Note: IOSTR, IFUEL, IDAHA...Card 1.000, all others Card 7.000) Enter RETURN to continue."

```
Enter:
 Soil Damping Type        (0: Normal Smith Approach)        ISMITH
 -1 ... Use CASE Damping   - Viscous Type
  0 ... Use SMITH Damping  - Smith Type
  1 ... Use SMITH Damping  - Viscous Type
```

```
0
```

"User's Response, Card 1.000."

```
Soil Parameters

QS=     .1000 Quake of the Skin                                  (in)       QS(1)
QT=     .1000 Quake of the Toe                                   (in)       QS(N+1)
DS=     .1000 Damping of the Skin           (Smith: s/ft, Viscous: 1)       SJ(1)
DT=     .1000 Damping at the Toe            (Smith: s/ft, Viscous: 1)       SJ(N+1)
Enter NAME=xxxx.xx                          ** RETURN To End Input **
```

```
DS=.05
DT=.15
```

"User's Response, Card 8.000."

```
Soil Parameters

QS=     .1000 Quake of the Skin                                  (in)       QS(1)
QT=     .1000 Quake of the Toe                                   (in)       QS(N+1)
DS=     .0500 Damping of the Skin           (Smith: s/ft, Viscous: 1)       SJ(1)
DT=     .1500 Damping at the Toe            (Smith: s/ft, Viscous: 1)       SJ(N+1)
Enter NAME=xxxx.xx                          ** RETURN To End Input **


Enter:
 Skin Friction Percentage (%) (1 ( SF ( 101, Normal)       IPERCS
```

```
10
```

"User's response, Card 1.000".

```
Enter Type:
 Skin Friction Distribution                                ITYS

 USER-SPECIFIED DISTRIBUTION and SELECTED PARAMETERS:
  -2 ... DAMPING, QUAKES and STATIC RESISTANCES
  -1 ... DSTRBN and DAMPING
   0 ... DSTRBN Only
 TRIANGULAR DISTRIBUTION Starting At:
   1 ... Pile Top
   2 ... 20% Below Pile Top
   3 ... 40% Below Pile Top
   4 ... 60% Below Pile Top
   5 ... 80% Below Pile Top

 UNIFORM DISTRIBUTION Starting At:
   6 ... Pile Top
   7 ... 20% Below Pile Top
   8 ... 40% Below Pile Top
   9 ... 60% Below Pile Top
  10 ... 80% Below Pile Top
```

```
1
```

"User's Response - Refer to Figure 1, Chapter I, Vol II and Section 2.5, Chapter II, Vol. IV, for explanation."

```
Enter:
 Ultimate Capacities                          (kips)  RESULT
```

| 60,120,180,240 |

"User's Response."

```
Option for Output Segment Selection                      IJJ
 (Default:   0)
 0 ... Continue with Current Default
 1 ... Enter New Value
```

| 0 |

"User's Response, Card 1.000."

```
SELECT BRANCH:

  0 ... Return to Main Menu for Storage
Further Corrections:
  1 ... Title
  2 ... Analysis Options
  3 ... Helmet/Hammer Cushion Information
  4 ... Pile Cushion Information
  5 ... Pile Top Properties
  6 ... Pile Segment Information                              IPEL
  7 ... Hammer Information
  8 ... Hammer File Override Values and Options
  9 ... Soil Parameters
 10 ... Skin Friction Distribution                            ITYS
 11 ... Number of Splice/Slack Segments                       ISPL
 12 ... Ultimate Capacities                                 RESULT
 13 ... Option for Output Segment Selection                    IJJ
```

| 0 |

"User's Response - No corrections necessary; enter a 0 or give a RETURN to continue."

```
BRANCHING:

 -2 ... Reinitialize
 -1 ... Terminate Program
  0 ... Begin Terminal Input/Modifications
  1 ... Read Previously Stored Input (Modifications/Analysis)
  2 ... Display Current Input
  3 ... Store Current Input
  4 ... Hammer Data FILE Maintenance
```

| 3 |

"User's Response."

```
Give FILENAME For Data Storage (Default: A:WEAPBG.IN )
X:XXXXXX.XXX
```

"User's Response: Enter name of storage file or give a RETURN if default storage file is satisfactory."

```
            ECHO PRINT OF INPUT DATA BEING STORED ON FILE b:WEAPBG.IN

EXAMPLE 1, 45 TON DESIGN, HP 10X53, D-12
 10   0   3   0   0   0   8   0   0   0  10   0   1   0   0   0   0   0
     2.15     283.50    280.00    2.0000     .8000     .0100      0.
      .00
      .00        .00     .0000     .5000     .0100      0.
    40.00      15.50  30000.00    492.00     .8000     .0100
     .000       .000        .0     .0000     .0000
    .1000      .1000     .0500     .1500
    60.00     120.00    180.00    240.00       .00       .00       .00       .00
      .00        .00

DATA HAS BEEN STORED ON FILE:  b:WEAPBG.IN
```

"The above data summary may be printed using SHFT and PRTSC. SHFT is the upper case shift key. Give a RETURN to continue."

```
BRANCHING:

 -2 ... Reinitialize
 -1 ... Terminate Program
  0 ... Begin Terminal Input/Modifications
  1 ... Read Previously Stored Input (Modifications/Analysis)
  2 ... Display Current Input
  3 ... Store Current Input
  4 ... Hammer Data FILE Maintenance
```

| -1 |

"User's Response"

```
***** HAS CURRENT INPUT DATA BEEN STORED? *****
  0 ... (NO) - Return to BRANCH for Storage
  1 ... (YES)- OK to End Program
```

| 1 |

"User's Response"

```
Stop - Program terminated.


C>
```

3.1.2 Example 2: Hypothetical Hammer Input (Same as example 4 in Volume II)

A contractor has decided to build his own hammmer. A pile with 12 3/4-inch O.D. pipe with 1/4-inch wall thickness has to be driven to 180-kips ultimate capacity. The length of the pile is 60 ft including a 1-inch toe plate.

Since the hammer being analyzed is not contained in the Hammer Data File, the hammer information must be input using W86IN.

After loading W86IN. the following display should appear:

```
                         W 8 6 I N
                         =========

              WEAP86 Terminal Inout Routine - Version 1.0


BRANCHING:

 -2 ... Reinitialize
 -1 ... Terminate Program
  0 ... Begin Terminal Inout/Modifications
  1 ... Read Previously Stored Input (Modifications/Analysis)
  2 ... Disolay Current Inout
  3 ... Store Current Inout
  4 ... Hammer Data FILE Maintenance
```

| 0 |

"Input a 0 to begin terminal input."

```
Enter: TITLE
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
```

| EXAMPLE 4, DIESEL HAMMER INPUT |

"Input title (Card 1.000) and RETURN."

```
Analysis Ootions

IO=        0. Outout Ootion                                          IOUT
RS=        0. Residual Stress Analysis      (0/1: Normal/RSA)        IRSAO
MT=        0. Maximum Analysis Time         (0 --> Normal)           IMAXT
IT=        0. Number Of Iterations          (0 --> Normal)           ITER
CT=        0. Critcl Time Increment Ratio   (0 --> 160)              IPHI
Enter NAME=xxxx.xx                    ** RETURN To End Input **
```

"All default values are correct; (Card 2.000). Give a RETURN to continue."

```
Helmet/Hammer Cushion Information

WT=       .00 Weight of the Helmet                                  (kips)      CAPW
AR=       .00 Area of the Hammer Cushion (H. C.)                    (in2)       ACAP
EM=       .00 Elastic Modulus of the H. C.                          (ksi)       ECAP
TH=     .0000 Thickness of the H. C.                                (in)        TCAP
CR=     .8000 Coefficient of Restitution for H. C.                            CORCAP
RO=     .0100 Round Out Deformation of H. C. (0 --) 0.010)          (ft)        DRCP
ST=        0. Stiffness of the H. C. (Overrides: AR(EM)/TH)         (k/in)      STCP

Enter NAME=xxxx.xx                          ** RETURN To End Input **
```

```
WT=.95
ST=10500.
```

"User's response, Card 3.000."

```
Helmet/Hammer Cushion Information

WT=       .95 Weight of the Helmet                                  (kips)      CAPW
AR=       .00 Area of the Hammer Cushion (H. C.)                    (in2)       ACAP
EM=       .00 Elastic Modulus of the H. C.                          (ksi)       ECAP
TH=     .0000 Thickness of the H. C.                                (in)        TCAP
CR=     .8000 Coefficient of Restitution for H. C.                            CORCAP
RO=     .0100 Round Out Deformation of H. C. (0 --) 0.010)          (ft)        DRCP
ST=    10500. Stiffness of the H. C. (Overrides: AR(EM)/TH)         (k/in)      STCP

Enter NAME=xxxx.xx                          ** RETURN To End Input **
```

"All input data is checked; give a RETURN to continue."

```
Pile Cushion Information

AR=       .00 Area of the Pile Cushion (P. C.)                      (in2)       ACUS
EM=       .00 Elastic Modulus of the P. C.                          (ksi)       ECUS
TH=     .0000 Thickness of the P. C.                                (in)        TCUS
CR=     .5000 Coefficient of Restitution for P. C.                            CORCUS
RO=     .0100 Round Out Deformation of P. C. (0 -) 0.01)            (ft)        DRCU
ST=        0. Stiffness of the P. C.                                (k/in)      STCU

Enter NAME=xxxx.xx                          ** RETURN To End Input **
```

"Pile Cushion (Card 4.000) is not being used; give a RETURN to continue."

```
Pile Top Properties

LG=      .000 Total Pile Length                                     (ft)        XPT
AR=       .00 Area at the Pile Top (P. T.)                          (in2)       APT
EM=  30000.00 Elastic Modulus at the P. T.                          (ksi)       EPT
SW=    492.00 Specific Weight at the P. T.                          (lbs/ft3)   WPT
CR=     .8500 Coefficient of Restitution for P. T.                            CORPTP
RO=     .0100 Round Out Deformation of P. T.                        (ft)        DRPTP

Enter NAME=xxxx.xx                          ** RETURN To End Input **
```

```
LG=60.
AR=9.82
CR=.8
```

"User's Response, Card 5.000."

```
Pile Top Properties

LG=    60.000 Total Pile Length                          (ft)          XPT
AR=      9.82 Area at the Pile Top (P. T.)               (in2)         APT
EM=  30000.00 Elastic Modulus at the P. T.               (ksi)         EPT
SW=    492.00 Specific Weight at the P. T.               (lbs/ft3)     WPT
CR=     .8000 Coefficient of Restitution for P. T.                   CORPTP
RO=     .0100 Round Out Deformation of P. T.             (ft)         DRPTP

Enter NAME=xxxx.xx                      ** RETURN To End Input **
```

"All input data is checked; give a RE-TURN to continue."

```
NN=        12. Number of Pile Segments   (N)                                N
NC=         0. Uniform Pile Option       (0/1: Uniform/Non-Uniform)    NCROSS
PD=         0. Pile Damping              (0 --> Normal)                IBEDAM
Enter NAME=xxxx.xx                       ** RETURN To End Input **
```

```
NC=1
```

"User's response - Nonuniform pile (NCROSS on Card 1.000). Input to model the toe plate."

```
NN=        12. Number of Pile Segments   (N)                                N
NC=         1. Uniform Pile Option       (0/1: Uniform/Non-Uniform)    NCROSS
PD=         0. Pile Damping              (0 --> Normal)                IBEDAM
Enter NAME=xxxx.xx                       ** RETURN To End Input **
```

"All input data is checked; give a RETURN to continue."

```
Non-Uniform Pile Profile                                          NCROSS
  ** Start at First Cross-Sectional Change **
    Depth       Area      E-Mod   Sp. Wght
    (XP)        (AP)      (EP)     (WP)
     ft          in2       ksi    lbs/ft3
```

```
59.92,
59.92,127.7
60.,
```

"User's Input - Refer to Cards 5.101, ...and Section 2.3 for explanation."

```
Non-Uniform Pile Profile                                      NCROSS
   I     Depth        Area       E-Mod    Sp. Wght
         (XP)         (AP)       (EP)     (WP)
          ft          in2        ksi      lbs/ft3
   1       .00        9.82   30000.00     492.00
   2     59.92        9.82   30000.00     492.00
   3     59.92      127.70   30000.00     492.00
   4     60.00      127.70   30000.00     492.00
Corrections?
  0 ... Continue With Current Default
  1 ... Corrections to be Made
```

| 0 |

"User's Response: All input data is checked; enter a 0 or give a RETURN to continue."

```
Enter:
 Pile Segment Option                                          IPEL
  0 ... AUTOMATIC DETERMINATION of Parameters
  1 ... Input LENGTHS (Automatic Stiffnesses and Masses)
  2 ... Input LENGTHS, STIFFNESSES and MASSES
```

| 0 |

"User's Response: Refer to Card 1.000 and Section 2.4 for explanation."

```
Enter:
 Hammer ID Number            (0 - 300)                        IHAMR
```

| 0 |

"User's Response: Enter a 0 to input hammer data. The following data appears on Cards 6.101,... ."

```
Enter:                       ** A RETURN or 0 Input Retains Default **
Hammer Manufacturer                                          NAMMAN

XXXXXXXX
```

| HYPOTHET |

"User's Response: Enter hammer manufacturer name, Card 6.101."

```
Enter:                       ** A RETURN or 0 Input Retains Default **
Hammer Name                                                  NAMHAM

XXXXXXXX
```

| EX 4 |

"User's Response: Enter hammer name, Card 6.101."

```
Hammer Information

TP=        0. Hammer Type                                          ITYPH
RM=        0. Number of Ram Segments                                   M

Enter NAME=xxxx.xx                        ** RETURN To End Input **
```

```
TP=1
RM=3
```

"User's Response, Card 6.101."

```
Hammer Information

TP=        1. Hammer Type                                          ITYPH
RM=        3. Number of Ram Segments                                   M

Enter NAME=xxxx.xx                        ** RETURN To End Input **
```

"All input data is checked; give a RETURN to continue."

```
Hammer Information

WT=        .00 Ram Weight                         (kips)     RAMW
LG=        .00 Length of Ram                      (in)       RAML
DI=        .00 Diameter of Ram                    (in)       RAMD
SX=        .00 Maximum - Rated Stroke             (ft)       STRM
SN=        .00 Minimum Stroke (Diesels)           (ft)       STRMN
EF=       .000 Efficiency                                    EFFICY

Enter NAME=xxxx.xx                        ** RETURN To End Input **
```

```
WT=2.75
LG= 95.
DI=12.5
SX=8.5
EF=.8
```

"User's Response, Card 6.201."

```
Hammer Information

WT=       2.75 Ram Weight                         (kips)     RAMW
LG=      95.00 Length of Ram                      (in)       RAML
DI=      12.50 Diameter of Ram                    (in)       RAMD
SX=       8.50 Maximum - Rated Stroke             (ft)       STRM
SN=        .00 Minimum Stroke (Diesels)           (ft)       STRMN
EF=       .800 Efficiency                                    EFFICY

Enter NAME=xxxx.xx                        ** RETURN To End Input **
```

"All input data is checked; give a RETURN to continue."

```
Hammer Information

WT=        .00 Weight of the Impact Block                      (kips)     ANVW
LG=        .00 Length of the Impact Block                      (in)       ANVL
DI=        .00 Diameter of the Impact Block                    (in)       ANVD
CR=      .9000 Coefficient of Restitution of the Impact Block             CORRA
RO=      .0100 Round Out Value of the Impact Block             (ft)       DRRA

Enter NAME=xxxx.xx                          ** RETURN To End Input **
```

```
WT=.81
LG=19.
DI=12.5
CR=.9
```

"User's Response, Card 6.301."

```
Hammer Information

WT=        .81 Weight of the Impact Block                      (kips)     ANVW
LG=      19.00 Length of the Impact Block                      (in)       ANVL
DI=      12.50 Diameter of the Impact Block                    (in)       ANVD
CR=      .9000 Coefficient of Restitution of the Impact Block             CORRA
RO=      .0100 Round Out Value of the Impact Block             (ft)       DRRA

Enter NAME=xxxx.xx                          ** RETURN To End Input **
```

"All input data is checked; give a RETURN to continue."

```
Hammer Information

CS=        .00 Compressive Stroke                              (in2)      DEPIB
AR=        .00 Area of the Combustion Chamber                  (in2)        ACH
VL=        .00 Final Volume of the Combustion Chamber          (in3)       VFIN
CD=      .0000 Combustion Delay     (Liquid Injection)           (s)       TDEL
ID=      .0000 Ignition Duration    (Liquid Injection)           (s)      DTIGN
EX=     1.3500 Expansion Coefficient                                       EXPP
IV=         .0 Volume at Ignition (Atomized Injection)         (in3)       VSTI
FV=         .0 Volume at Final Combustion (Atmzd Injctn)       (in3)      VENDC

Enter NAME=xxxx.xx                          ** RETURN To End Input **
```

```
CS=10.76
AR=122.7
VL=120.
CD=.002
ID=.002
EX=1.3
```

"User's Response, Card 6.401."

```
Hammer Information

CS=      10.76 Compressive Stroke                              (in2)      DEPIB
AR=     122.70 Area of the Combustion Chamber                  (in2)        ACH
VL=     120.00 Final Volume of the Combustion Chamber          (in3)       VFIN
CD=      .0020 Combustion Delay     (Liquid Injection)           (s)       TDEL
ID=      .0020 Ignition Duration    (Liquid Injection)           (s)      DTIGN
EX=     1.3000 Expansion Coefficient                                       EXPP
IV=         .0 Volume at Ignition (Atomized Injection)         (in3)       VSTI
FV=         .0 Volume at Final Combustion (Atmzd Injctn)       (in3)      VENDC

Enter NAME=xxxx.xx                          ** RETURN To End Input **
```

"All input data is checked; give a RETURN to continue."

```
Hammer Information

AT=        14.7 Atmospheric Pressure (usually 14.7 psi)        (psi)      PATM
P1=          .0 Hammer Pressure Setting 1 = maximum            (psi)        P1
P2=          .0 Hammer Pressure Setting 2                      (psi)        P2
P3=          .0 Hammer Pressure Setting 3                      (psi)        P3
P4=          .0 Hammer Pressure Setting 4                      (psi)        P4
P5=          .0 Hammer Pressure Setting 5                      (psi)        P5
CC=         0.  Certainty Confirmation  (0/1 measured yes/no)           IGUESS

Enter NAME=xxxx.xx                      ** RETURN To End Input **
```

P1=1150.

"User's Response, Card 6.501."

```
Hammer Information

AT=        14.7 Atmospheric Pressure (usually 14.7 psi)        (psi)      PATM
P1=      1150.0 Hammer Pressure Setting 1 = maximum            (psi)        P1
P2=          .0 Hammer Pressure Setting 2                      (psi)        P2
P3=          .0 Hammer Pressure Setting 3                      (psi)        P3
P4=          .0 Hammer Pressure Setting 4                      (psi)        P4
P5=          .0 Hammer Pressure Setting 5                      (psi)        P5
CC=         0.  Certainty Confirmation  (0/1 measured yes/no)           IGUESS

Enter NAME=xxxx.xx                      ** RETURN To End Input **
```

"All input data is checked; give a RETURN to continue."

```
ID NO.:   0

HYPOTHET EX 4        1    3    0
     2.75      95.00     12.50       8.50        .00      .8000
      .81      19.00     12.50      .9000      .0100
    10.76     122.70    120.00      .0020      .0020     1.3000         .0          .0
     14.7     1150.0        .0         .0         .0         .0    0
HAMMER DATA
  0 ... Continue with Current Data
  1 ... Redisplay Data
  2 ... Corrections To Be Made
```

2

"The above is a summary of the Hammer Data and must be checked. User's Response - C.O.R. of Impact Block is incorrect: enter '2' and RETURN to continue".

```
Correction Mode      ** Give Return To End Correction Mode **
Line Numbers for Correction:
   1 ... Hammer Manufacturer                                          NAMMAN
   2 ... Hammer Name                                                  NAMHAM
   3 ... TP   RM
   4 ... WT   LG   DI   SX   SN   EF
   5 ... WT   LG   DI   CR   RO
   6 ... CS   AR   VL   CD   ID   EX   IV   FV
   7 ... AT   P1   P2   P3   P4   P5   CC
   8 ... PT   CA   RT   SD   CV   RW   EX
   9 ... EF   PR   CR   RO   NA
  10 ... W1   W2   W3   S1   S2   S3
  11 ... Hammer Entry Date
```

```
5
```

"User's Response - enter a '5' to Correct C.O.R. of Impact Block". Note that lines 1, 2, ... correspond to 6.101, 6.101, 6.101, 6.201, 6.301, ..., 6.801 of complete input form."

```
Hammer Information

WT=      .81 Weight of the Impact Block                    (kips)    ANVW
LG=    19.00 Length of the Impact Block                    (in)      ANVL
DI=    12.50 Diameter of the Impact Block                  (in)      ANVD
CR=    .9000 Coefficient of Restitution of the Impact Block          CORRA
RO=    .0100 Round Out Value of the Impact Block           (ft)      DRRA

Enter NAME=xxxx.xx                       ** RETURN To End Input **
```

```
CR=.8
```

"User's Response - Input correct C.O.R.; give a RETURN to continue."

```
WT=      .81 Weight of the Impact Block                    (kips)    ANVW
LG=    19.00 Length of the Impact Block                    (in)      ANVL
DI=    12.50 Diameter of the Impact Block                  (in)      ANVD
CR=    .8000 Coefficient of Restitution of the Impact Block          CORRA
RO=    .0100 Round Out Value of the Impact Block           (ft)      DRRA

Enter NAME=xxxx.xx                       ** RETURN To End Input **
```

"All input data is checked; give a RETURN to continue."

```
Correction Mode      ** Give Return To End Correction Mode **
Line Numbers for Correction:
   1 ... Hammer Manufacturer                                          NAMMAN
   2 ... Hammer Name                                                  NAMHAM
   3 ... TP   RM
   4 ... WT   LG   DI   SX   SN   EF
   5 ... WT   LG   DI   CR   RO
   6 ... CS   AR   VL   CD   ID   EX   IV   FV
   7 ... AT   P1   P2   P3   P4   P5   CC
   8 ... PT   CA   RT   SD   CV   RW   EX
   9 ... EF   PR   CR   RO   NA
  10 ... W1   W2   W3   S1   S2   S3
  11 ... Hammer Entry Date
```

"End Correction Mode; give a RETURN to continue."

```
ID NO.:   0

HYPOTHET EX 4        1    3    0
     2.75      95.00     12.50      8.50       .00      .8000
      .81      19.00     12.50     .8000     .0100
    10.76     122.70    120.00     .0020     .0020    1.3000         .0         .0
     14.7     1150.0        .0        .0        .0        .0   0
```

```
HAMMER DATA
  0 ... Continue with Current Data
  1 ... Redisplay Data
  2 ... Corrections To Be Made
```

0

"User's Response - All input data is checked; enter a 0 or give a RETURN to continue."

```
Store HAMMER DATA?           ** Current ID No.:   0 **
  0 ... Continue Without Storing Data on Hammer Data File
        (Hammer data will be written to input file.)
 >0 ... HAMMER DATA ID for Storage on Hammer Data File
```

0

"User's Response - Enter a '0' or give a RETURN to continue without storing hammer data. If hammer data is to be stored, enter an ID No. (be sure not to overwrite on another hammer ID No. However, the program will check file location for you)."

```
Hammer File Override Values and Options

SO=        0. Stroke Option                                                IOSTR
ST=      .000 Hammer Stroke                               (ft)            STROOV
EF=      .000 Hammer Efficiency                                           EFFOV
PR=        .0 Hammer Pressure                             (psi)            PROV
FS=        0. Hammer Fuel Setting (0 = 1 = maximum)                        IFUEL
RW=     .0000 Reaction Weight                             (kips)           RWTOV
CD=     .0000 Comb Delay (LI) or Start Ignitn Volume (AI) (s or in3)     TDELOV
HD=     .0000 Hammer Damping             (0 --> Normal)                    IDAHA

Enter NAME=xxxx.xx                      ** RETURN To End Input **
```

"No hammer override values; give a RETURN to continue".

```
Enter:
 Soil Damping Type         (0: Normal Smith Approach)        ISMITH
 -1 ... Use CASE Damping   - Viscous Type
  0 ... Use SMITH Damping  - Smith Type
  1 ... Use SMITH Damping  - Viscous Type
```

```
0
```

"User's Response, Card 1.000."

```
Soil Parameters

QS=     .1000 Quake of the Skin                                   (in)         QS(1)
QT=     .1000 Quake of the Toe                                    (in)       QS(N+1)
DS=     .1000 Damping of the Skin              (Smith: s/ft, Viscous: 1)       SJ(1)
DT=     .1000 Damping at the Toe               (Smith: s/ft, Viscous: 1)     SJ(N+1)
Enter NAME=xxxx.xx                            ** RETURN To End Input **
```

```
DS=.05
DT=.15
```

"User's Response; these are nondimensional Case Damping Factors, Card 8.000."

```
Soil Parameters

QS=     .1000 Quake of the Skin                                   (in)         QS(1)
QT=     .1000 Quake of the Toe                                    (in)       QS(N+1)
DS=     .3000 Damping of the Skin              (Smith: s/ft, Viscous: 1)       SJ(1)
DT=     .1500 Damping at the Toe               (Smith: s/ft, Viscous: 1)     SJ(N+1)
Enter NAME=xxxx.xx                            ** RETURN To End Input **
```

"All input data is checked; give a RETURN to continue."

```
Enter:
 Skin Friction Percentage (%) (1 < SF < 101, Normal)        IPERCS
```

```
10
```

"User's Response; Card 1.000."

```
Enter Type:
 Skin Friction Distribution                                  ITYS

 USER-SPECIFIED DISTRIBUTION and SELECTED PARAMETERS:
  -2 ... DAMPING, QUAKES and STATIC RESISTANCES
  -1 ... DSTRBN and DAMPING
   0 ... DSTRBN Only

 TRIANGULAR DISTRIBUTION Starting At:
   1 ... Pile Top
   2 ... 20% Below Pile Top
   3 ... 40% Below Pile Top
   4 ... 60% Below Pile Top
   5 ... 80% Below Pile Top

 UNIFORM DISTRIBUTION Starting At:
   6 ... Pile Top
   7 ... 20% Below Pile Top
   8 ... 40% Below Pile Top
   9 ... 60% Below Pile Top
  10 ... 80% Below Pile Top
```

0	"User's Response - Refer to Card 1.000 and Section 2.5 for explanation."

```
Enter:
      Depth      Resistance
  (DIS(1,X)) (DIS(2,X))
       ft         Relative
```

```
10.,0.
10.,.33
30.,.33
30.,.67
40.,.67
60.,1.
```

"User's Response - Refer to Card, 8.401, and Section 2.5 for explanation."

Skin Friction Distribution — ITYS

I	Depth (DIS(1,X)) ft	Resistance (DIS(2,X)) Relative
1	10.000	.0000
2	10.000	.3300
3	30.000	.3300
4	30.000	.6700
5	40.000	.6700
6	60.000	1.0000

```
Corrections?
  0 ... Continue With Current Default
  1 ... Corrections to be Made
```

0	"User's Response - Input data is checked; give a RETURN to continue."

```
Enter:
 Number of Splice/Slack Segments                              ISPL
```

"No Splice/Slack Segment; give a RETURN to continue."

```
Enter:
 Ultimate Capacities                              (kips)   RESULT
```

200	"User's Response."

```
Option for Output Segment Selection                           IJJ
 (Default:    0)
 0 ... Continue with Current Default
 1 ... Enter New Value
```

0	"User's Response, Card 1.000."

```
SELECT BRANCH:

   0 ... Return to Main Menu for Storage
Further Corrections:
   1 ... Title
   2 ... Analysis Options
   3 ... Helmet/Hammer Cushion Information
   4 ... Pile Cushion Information
   5 ... Pile Top Properties
   6 ... Pile Segment Information                                IPEL
   7 ... Hammer Information
   8 ... Hammer File Override Values and Options
   9 ... Soil Parameters
  10 ... Skin Friction Distribution                              ITYS
  11 ... Number of Splice/Slack Segments                         ISPL
  12 ... Ultimate Capacities                                   RESULT
  13 ... Option for Output Segment Selection                      IJJ
```

| 0 |

"User's Response - No corrections; enter a '0' or give a RETURN to continue."

```
BRANCHING:

  -2 ... Reinitialize
  -1 ... Terminate Program
   0 ... Begin Terminal Input/Modifications
   1 ... Read Previously Stored Input (Modifications/Analysis)
   2 ... Display Current Input
   3 ... Store Current Input
   4 ... Hammer Data FILE Maintenance
```

| 3 |

"User's Response."

```
Give FILENAME For Data Storage (Default: A:WEAPBG.IN )
X:XXXXXX.XXX
```

"User's Response - Enter name of storage file or give a RETURN if Default Storage File is satisfactory."

```
            ECHO PRINT OF INPUT DATA BEING STORED ON FILE b:WEAP8G.IN

EXAMPLE 4. DIESEL HAMMER INPUT
  0   0   0   0   0   0  12   0   1   0  10   0   0   0   0   0   0   0
       .95       .00       .00      .0000      .8000      .0100    10500.
       .00
       .00       .00     .0000      .5000      .0100        0.
     60.00      9.82  30000.00     492.00      .8000      .0100
       .00      9.82  30000.00     492.00
     59.92      9.82  30000.00     492.00
     59.92    127.70  30000.00     492.00
     60.00    127.70  30000.00     492.00
HYPOTHET EX 4        1   3   0
      2.75     95.00     12.50       8.50        .00        .80
       .81     19.00     12.50      .8000      .0100
     10.76    122.70    120.00      .0020      .0020     1.3000         .0         .0
      14.7    1150.0        .0         .0         .0         .0    0
      .000      .000        .0      .0000      .0000
     .1000     .1000     .0500      .1500
   10.0000     .0000
   10.0000     .3300
   30.0000     .3300
   30.0000     .6700
   40.0000     .6700
   60.0000    1.0000
    100.00    150.00    200.00     250.00     300.00     350.00     400.00        .00
       .00       .00
```

The above data display may be copied to the printer using the SHFT and PRTSC keys. SHFT is the upper-case shift key. Give a RETURN to continue.

```
BRANCHING:

 -2 ... Reinitialize
 -1 ... Terminate Program
  0 ... Begin Terminal Input/Modifications
  1 ... Read Previously Stored Input (Modifications/Analysis)
  2 ... Display Current Input
  3 ... Store Current Input
  4 ... Hammer Data FILE Maintenance
```

-1	"User's Response."

```
***** HAS CURRENT INPUT DATA BEEN STORED? *****
  0 ... (NO) - Return to BRANCH for Storage
  1 ... (YES)- OK to End Program
```

1	"User's Response."

```
Stop - Program terminated.

C>
```

3.1.3 Example 3: Pile Segment and Damping Input (same as example 5 in Volume II)

A timber pile has to be driven through a soil of stratified clay and sand to a dense gravel layer. The timber pile has a length of 36 ft 2 inches. Its cross-sectional area varies from 128.7 at the top to 56.2 square inches at the bottom. It has to be driven by a Link Belt 440 hammer. Refer to example 5 in Volume II for all the input data.

Startup program as described in Section 2.1. The following display should appear:

```
                              W 8 6 I N
                              =========

                WEAP86 Terminal Input Routine - Version 1.0


BRANCHING:

 -2 ... Reinitialize
 -1 ... Terminate Program
  0 ... Begin Terminal Input/Modifications
  1 ... Read Previously Stored Input (Modifications/Analysis)
  2 ... Display Current Input
  3 ... Store Current Input
  4 ... Hammer Data FILE Maintenance
```

| 0 |

"User's Response - Enter a '0' to begin terminal input."

```
Enter:  TITLE
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
```

| EXAMPLE 5: PILE SEGMENT + DAMPING INPUT |

"User's Response - Input title (Card, 1.001) and RETURN."

```
Analysis Options

IO=        0. Output Option                                          IOUT
RS=        0. Residual Stress Analysis     (0/1: Normal/RSA)         IRSAO
MT=        0. Maximum Analysis Time        (0 --> Normal)            IMAXT
IT=        0. Number Of Iterations         (0 --> Normal)            ITER
CT=        0. Critcl Time Increment Ratio  (0 --> 160)               IPHI
Enter NAME=xxxx.xx                   ** RETURN To End Input **
```

"All default values are checked (Card, 2.000); give a RETURN to continue."

Helmet/Hammer Cushion Information

```
WT=       .00 Weight of the Helmet                               (kips)      CAPW
AR=       .00 Area of the Hammer Cushion (H. C.)                 (in2)       ACAP
EM=       .00 Elastic Modulus of the H. C.                       (ksi)       ECAP
TH=     .0000 Thickness of the H. C.                             (in)        TCAP
CR=     .8000 Coefficient of Restitution for H. C.                         CORCAP
RO=     .0100 Round Out Deformation of H. C. (0 --> 0.010)       (ft)        DRCP
ST=        0. Stiffness of the H. C. (Overrides: AR(EM)/TH)      (k/in)      STCP

Enter NAME=xxxx.xx                        ** RETURN To End Input **
```

```
WT=.7
ST=30000.
```

"User's Response (Card 3.000)."

Helmet/Hammer Cushion Information

```
WT=       .70 Weight of the Helmet                               (kips)      CAPW
AR=       .00 Area of the Hammer Cushion (H. C.)                 (in2)       ACAP
EM=       .00 Elastic Modulus of the H. C.                       (ksi)       ECAP
TH=     .0000 Thickness of the H. C.                             (in)        TCAP
CR=     .8000 Coefficient of Restitution for H. C.                         CORCAP
RO=     .0100 Round Out Deformation of H. C. (0 --> 0.010)       (ft)        DRCP
ST=    30000. Stiffness of the H. C. (Overrides: AR(EM)/TH)      (k/in)      STCP

Enter NAME=xxxx.xx                        ** RETURN To End Input **
```

"All input data is.checked; give a RETURN to continue."

Pile Cushion Information

```
AR=       .00 Area of the Pile Cushion (P. C.)                   (in2)       ACUS
EM=       .00 Elastic Modulus of the P. C.                       (ksi)       ECUS
TH=     .0000 Thickness of the P. C.                             (in)        TCUS
CR=     .5000 Coefficient of Restitution for P. C.                         CORCUS
RO=     .0100 Round Out Deformation of P. C. (0 -> 0.01)         (ft)        DRCU
ST=        0. Stiffness of the P. C.                             (k/in)      STCU

Enter NAME=xxxx.xx                        ** RETURN To End Input **
```

"No pile cushion (Card 4.000); give a RETURN to continue."

Pile Top Properties

```
LG=      .000 Total Pile Length                                  (ft)         XPT
AR=       .00 Area at the Pile Top (P. T.)                       (in2)        APT
EM=  30000.00 Elastic Modulus at the P. T.                       (ksi)        EPT
SW=    492.00 Specific Weight at the P. T.                       (lbs/ft3)    WPT
CR=     .8500 Coefficient of Restitution for P. T.                         CORPTP
RO=     .0100 Round Out Deformation of P. T.                     (ft)       DRPTP

Enter NAME=xxxx.xx                        ** RETURN To End Input **
```

```
LG=36.17
AR=128.67
EM=2000.
SW=51.
CR=.5
```

"User's Response (Card 5.000)."

```
Pile Top Properties

LG=    36.170 Total Pile Length                          (ft)        XPT
AR=    128.67 Area at the Pile Top (P. T.)               (in2)       APT
EM=   2000.00 Elastic Modulus at the P. T.               (ksi)       EPT
SW=     51.00 Specific Weight at the P. T.               (lbs/ft3)   WPT
CR=     .5000 Coefficient of Restitution for P. T.                   CORPTP
RO=     .0100 Round Out Deformation of P. T.             (ft)        DRPTP

Enter NAME=xxxx.xx                  ** RETURN To End Input **
```

"All input data is checked; give a RETURN to continue."

```
NN=        7. Number of Pile Segments   (N)                              N
NC=        0. Uniform Pile Option       (0/1: Uniform/Non-Uniform)  NCROSS
PD=        0. Pile Damping              (0 --) Normal)              IBEDAM
Enter NAME=xxxx.xx                      ** RETURN To End Input **
```

```
NN=12
NC=1
PD=5
```

"User's Response (Card 1.000)."

```
NN=       12. Number of Pile Segments   (N)                              N
NC=        1. Uniform Pile Option       (0/1: Uniform/Non-Uniform)  NCROSS
PD=        5. Pile Damping              (0 --) Normal)              IBEDAM
Enter NAME=xxxx.xx                      ** RETURN To End Input **
```

"All input data is checked; give a RETURN to continue."

```
Non-Uniform Pile Profile                                  NCROSS
  ** Start at First Cross-Sectional Change **
    Depth      Area     E-Mod   Sp. Wght
    (XP)       (AP)     (EP)    (WP)
     ft        in2      ksi     lbs/ft3
```

```
.17,
7.,112.65,
14.,97.33
21.,83.13
28.,70.04
36.17,56.2
```

"User's Response (Card 5.101, ...)."

```
Non-Uniform Pile Profile                                  NCROSS
```

I	Depth (XP) ft	Area (AP) in2	E-Mod (EP) ksi	Sp. Wght (WP) lbs/ft3
1	.00	128.67	2000.00	51.00
2	.17	128.67	2000.00	51.00
3	7.00	112.65	2000.00	51.00
4	14.00	97.33	2000.00	51.00
5	21.00	83.13	2000.00	51.00
6	28.00	70.04	2000.00	51.00
7	36.17	56.20	2000.00	51.00

```
Corrections?
  0 ... Continue With Current Default
  1 ... Corrections to be Made
```

```
0
```

"User's Response - All input data checked; enter a '0' or give a RETURN to continue."

```
Enter:
 Pile Segment Option                                                  IPEL
  0 ... AUTOMATIC DETERMINATION of Parameters
  1 ... Inout LENGTHS (Automatic Stiffnesses and Masses)
  2 ... Inout LENGTHS, STIFFNESSES and MASSES
```

[2] "User's Response - (Card 1.000 and Section 2.4)."

```
Pile Segment Lengths                              (relative) ALPH ** N =   12 **

N:     1        2        3        4        5        6        7        8
D:  3.01     6.03     9.04    12.06    15.07    18.08    21.10    24.11
V: 1.0000   1.0000   1.0000   1.0000   1.0000   1.0000   1.0000   1.0000

N:     9       10       11       12
D:  27.13    30.14    33.16    36.17
V: 1.0000   1.0000   1.0000   1.0000

  0 ... Continue With Current Values
  1 ... Corrections To Be Made
```

[1] "User's Response: Refer to Chapter 2, Section 2.4, for explanation."

```
Enter N:START  N:STOP  VALUE          ** RETURN To End Inout **
```

```
1,1,3.167
2,12,3.
```

"User's Response (Card 2.301)." Note, line 1 of this input designates segment 1 only with length of 3.167 ft. Line 2 designates segments 2 through 12 all having length 3.0 ft."

```
Pile Segment Lengths                              (relative) ALPH ** N =   12 **

N:     1        2        3        4        5        6        7        8
D:  3.01     6.03     9.04    12.06    15.07    18.08    21.10    24.11
V: 3.1670   3.0000   3.0000   3.0000   3.0000   3.0000   3.0000   3.0000

N:     9       10       11       12
D:  27.13    30.14    33.16    36.17
V: 3.0000   3.0000   3.0000   3.0000

  0 ... Continue With Current Values
  1 ... Corrections To Be Made
```

[0] "User's Response - All input data is checked; give a RETURN to continue."

***** REFIGURING ACTUAL SEGMENT LENGTHS *****

"Program will pause for a few seconds; if segment lengths would not add up to total length, they would be refigured".

Pile Segment Lengths (relative) ALPH ** N = 12 **

N:	1	2	3	4	5	6	7	8
D:	3.17	6.17	9.17	12.17	15.17	18.17	21.17	24.17
V:	3.1670	3.0000	3.0000	3.0000	3.0000	3.0000	3.0000	3.0000
N:	9	10	11	12				
D:	27.17	30.17	33.17	36.17				
V:	3.0000	3.0000	3.0000	3.0000				

0 ... Continue With Current Values
1 ... Corrections To Be Made

0

"User's Response - All input data is checked; give a RETURN to continue."

Pile Segment Stiffnesses (k/in) STP ** N = 12 **

N:	1	2	3	4	5	6	7	8
D:	3.17	6.17	9.17	12.17	15.17	18.17	21.17	24.17
V:	0.	0.	0.	0.	0.	0.	0.	0.
N:	9	10	11	12				
D:	27.17	30.17	33.17	36.17				
V:	0.	0.	0.	0.				

0 ... Continue With Current Values
1 ... Corrections To Be Made

1

"User's Response - Input correct segment stiffnesses."

Enter N:START N:STOP VALUE ** RETURN To End Input **

```
1,1,6592.
2,2,6557.
3,3,6176.
4,4,5800.
5,5,5445.
6,6,5100.
7,7,4764.
8,8,4440.
9,9,4128.
10,10,3823.
11,11,3534.
12,12,3257.
```

"User's Response, Card 2.101. Note, this input again reads: from segment 1 to segment 1, stiffness 6592, from 2 to 2 ...."

Pile Segment Stiffnesses (k/in) STP ** N = 12 **

N:	1	2	3	4	5	6	7	8
D:	3.17	6.17	9.17	12.17	15.17	18.17	21.17	24.17
V:	6592.	6557.	6176.	5800.	5445.	5100.	4764.	4440.

N:	9	10	11	12
D:	27.17	30.17	33.17	36.17
V:	4128.	3823.	3534.	3257.

0 ... Continue With Current Values
1 ... Corrections To Be Made

0

"User's Response - All input data is checked; give a RETURN to continue."

Pile Segment Weights (kips) PM ** N = 12 **

N:	1	2	3	4	5	6	7	8
D:	3.17	6.17	9.17	12.17	15.17	18.17	21.17	24.17
V:	.000	.000	.000	.000	.000	.000	.000	.000

N:	9	10	11	12
D:	27.17	30.17	33.17	36.17
V:	.000	.000	.000	.000

0 ... Continue With Current Values
1 ... Corrections To Be Made

1

"User's Response - Input correct segment weights."

Enter N:START N:STOP VALUE ** RETURN To End Input **

```
1,1,.142
2,2,.126
3,3,.118
4,4,.111
5,5,.104
6,6,.098
7,7,.091
8,8,.085
9,9,.079
10,10,.073
11,11,.068
12,12,.065
```

"User's Response, Card 2.201, ..."

Pile Segment Weights (kips) PM ** N = 12 **

N:	1	2	3	4	5	6	7	8
D:	3.17	6.17	9.17	12.17	15.17	18.17	21.17	24.17
V:	.142	.126	.118	.111	.104	.098	.091	.085

N:	9	10	11	12
D:	27.17	30.17	33.17	36.17
V:	.079	.073	.068	.065

0 ... Continue With Current Values
1 ... Corrections To Be Made

```
Ø
```

"User's Response - All input data is checked; give a RETURN to continue."

```
Enter:
 Hammer ID Number            (Ø - 300)                          IHAMR
```

```
133
```

"User's Response, Card 1.000 see Vol II, Table 1."

```
ID NO.: 133

LINKBELT LB 440      2    3    Ø
     4.ØØ       89.9Ø       13.1Ø        3.12        1.49       .8ØØØ
      .7Ø       18.ØØ       11.95       .9ØØØ       .Ø1ØØ
    15.ØØ      113.Ø9      121.ØØ       .ØØØØ       .ØØØØ      1.35ØØ      161.Ø       139.Ø
     14.7     1ØØ3.Ø          .Ø          .Ø          .Ø          .Ø    1
    41.38      254.5Ø       42.38        3.38      9185.Ø      5.21Ø       1.4ØØ
 Hammer ID Number            (Ø - 3ØØ)                          IHAMR
  (Default: 133)
  Ø ... Continue with Current Default
  1 ... Enter New Value
```

```
Ø
```

"User's Response - All hammer data is correct give a Return to continue."

```
Hammer File Override Values and Options

SO=        Ø. Stroke Option                                                  IOSTR
ST=      .ØØØ Hammer Stroke                                  (ft)            STROOV
EF=      .ØØØ Hammer Efficiency                                              EFFOV
PR=        .Ø Hammer Pressure                                (psi)           PROV
FS=        Ø. Hammer Fuel Setting (Ø = 1 = maximum)                          IFUEL
RW=     .ØØØØ Reaction Weight                                (kips)          RWTOV
CD=     .ØØØØ Comb Delay (LI) or Start Ignitn Volume (AI)    (s or in3)      TDELOV
HD=     .ØØØØ Hammer Damping                 (Ø --> Normal)                  IDAHA

Enter NAME=xxxx.xx                    ** RETURN To End Input **
```

```
SO=-1
ST=3.61
```

"User's Response. Input override values."

```
Hammer File Override Values and Options

SO=       -1. Stroke Option                                                  IOSTR
ST=     3.61Ø Hammer Stroke                                  (ft)            STROOV
EF=      .ØØØ Hammer Efficiency                                              EFFOV
PR=        .Ø Hammer Pressure                                (psi)           PROV
FS=        Ø. Hammer Fuel Setting (Ø = 1 = maximum)                          IFUEL
RW=     .ØØØØ Reaction Weight                                (kips)          RWTOV
CD=     .ØØØØ Comb Delay (LI) or Start Ignitn Volume (AI)    (s or in3)      TDELOV
HD=     .ØØØØ Hammer Damping                 (Ø --> Normal)                  IDAHA

Enter NAME=xxxx.xx                    ** RETURN To End Input **
```

"All input data is checked; give a RETURN to continue."

```
Enter:
 Soil Damping Type        (0: Normal Smith Approach)        ISMITH
 -1 ... Use CASE Damping  - Viscous Type
  0 ... Use SMITH Damping - Smith Type
  1 ... Use SMITH Damping - Viscous Type
```

```
[ 0 ]
```

"User's Response, Card 1.000."

```
Soil Parameters

QS=     .1000 Quake of the Skin                          (in)        QS(1)
QT=     .1000 Quake of the Toe                           (in)      QS(N+1)
DS=     .1000 Damping of the Skin   (Smith: s/ft, Viscous: 1)        SJ(1)
DT=     .1000 Damping at the Toe    (Smith: s/ft, Viscous: 1)      SJ(N+1)
Enter NAME=xxxx.xx                 ** RETURN To End Input **
```

"Damping and Quakes will be user-specified by pile segment. The above data will be overriden; give a RETURN."

```
Enter:
 Skin Friction Percentage (%) (1 < SF < 101, Normal)       IPERCS
```

```
[ 10 ]
```

"User's Response, Card 1.000."

```
Enter Type:
 Skin Friction Distribution                                  ITYS

 USER-SPECIFIED DISTRIBUTION and SELECTED PARAMETERS:
  -2 ... DAMPING, QUAKES and STATIC RESISTANCES
  -1 ... DSTRBN and DAMPING
   0 ... DSTRBN Only

 TRIANGULAR DISTRIBUTION Starting At:
   1 ... Pile Top
   2 ... 20% Below Pile Top
   3 ... 40% Below Pile Top
   4 ... 60% Below Pile Top
   5 ... 80% Below Pile Top

 UNIFORM DISTRIBUTION Starting At:
   6 ... Pile Top
   7 ... 20% Below Pile Top
   8 ... 40% Below Pile Top
   9 ... 60% Below Pile Top
  10 ... 80% Below Pile Top
```

```
[ -2 ]
```

"User's Response - Card 1.000; also, refer to Section 2.5 for explanation."

Soil Quakes (in) QS ** N = 12 **
Plus Pile Toe

N:	1	2	3	4	5	6	7	8
D:	3.17	6.17	9.17	12.17	15.17	18.17	21.17	24.17
V:	.1000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

N:	9	10	11	12	13
D:	27.17	30.17	33.17	36.17	.00
V:	.0000	.0000	.0000	.0000	.1000

0 ... Continue With Current Values
1 ... Corrections To Be Made

[1] "User's Response - Input correct quakes per pile segment including pile toe."

Enter N:START N:STOP VALUE ** RETURN To End Input **

[2,12,.1] "User's Response - Refer to Card 8.101, ... and Section 2.5 for explanation. This input reads from segment 2 through 12 use a quake of 0.1."

Soil Quakes (in) QS ** N = 12 **
Plus Pile Toe

N:	1	2	3	4	5	6	7	8
D:	3.17	6.17	9.17	12.17	15.17	18.17	21.17	24.17
V:	.1000	.1000	.1000	.1000	.1000	.1000	.1000	.1000

N:	9	10	11	12	13
D:	27.17	30.17	33.17	36.17	.00
V:	.1000	.1000	.1000	.1000	.1000

0 ... Continue With Current Values
1 ... Corrections To Be Made

[0] "User's Response - All input data is checked; give a RETURN to continue."

Soil Damping Parameters (DampType Case:Non-Dim, Smith:s/ft) SJ ** N = 12 **
Plus Pile Toe

N:	1	2	3	4	5	6	7	8
D:	3.17	6.17	9.17	12.17	15.17	18.17	21.17	24.17
V:	.1000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

N:	9	10	11	12	13
D:	27.17	30.17	33.17	36.17	.00
V:	.0000	.0000	.0000	.0000	.1000

0 ... Continue With Current Values
1 ... Corrections To Be Made

[1] "User's Response - Input correct damping values per pile segment including pile toe."

```
Enter N:START  N:STOP  VALUE          ** RETURN To End Input **
```

```
1,1,0.
4,4,.05
5,6,.2
7,7,.05
8,9,.2
10,13,.05
```

"User's Response - Refer to Card 8.201, ... and Section 2.5 for explanation. This input reads 0 damping at segment 1, .05 at 4, .2 from 5 to 6, ..."

```
Soil Damping Parameters (DampType Case:Non-Dim, Smith:s/ft)   SJ ** N =   12 **
                                                                 Plus Pile Toe

N:      1        2        3        4        5        6        7        8
D:   3.17     6.17     9.17    12.17    15.17    18.17    21.17    24.17
V:  .0000    .0000    .0000    .0500    .2000    .2000    .0500    .2000

N:      9       10       11       12       13
D:  27.17    30.17    33.17    36.17      .00
V:  .2000    .0500    .0500    .0500    .0500

  0 ... Continue With Current Values
  1 ... Corrections To Be Made
```

```
0
```

"User's Response - All input is checked; give a RETURN to continue."

```
Ultimate Static Soil Resistance                    (relative)  SU ** N =   12 **
                                                                 Plus Pile Toe

N:      1        2        3        4        5        6        7        8
D:   3.17     6.17     9.17    12.17    15.17    18.17    21.17    24.17
V:    .00      .00      .00      .00      .00      .00      .00      .00

N:      9       10       11       12       13
D:  27.17    30.17    33.17    36.17      .00
V:    .00      .00      .00      .00      .00

  0 ... Continue With Current Values
  1 ... Corrections To Be Made
```

```
1
```

"User's Response - Input correct ultimate static soil resistances per pile segment including pile toe."

```
Enter N:START  N:STOP  VALUE          ** RETURN To End Input **
```

```
4,4,.5
5,12,1.
13,13,76.5
```

"User's Response - Refer to Cards 8.301, ... and Section 2.5 for explanation. This input means relative ultimate resistance 0.5 at segment 4, 1.0 for segments 5 to 12, and 76.5 at 13."

```
Ultimate Static Soil Resistance                    (relative)   SU ** N =   12 **
                                                                   Plus Pile Toe

N:      1        2        3        4        5        6        7        8
D:   3.17     6.17     9.17    12.17    15.17    18.17    21.17    24.17
V:    .00      .00      .00      .50     1.00     1.00     1.00     1.00

N:      9       10       11       12       13
D:  27.17    30.17    33.17    36.17      .00
V:   1.00     1.00     1.00     1.00    76.50

  0 ... Continue With Current Values
  1 ... Corrections To Be Made
```

[0] "User's Response - All input data is checked; enter a 0 or give a RETURN to continue."

```
Enter:
 Number of Splice/Slack Segments                              ISPL
```

[0] "User's Response, Card 1.000."

```
Enter:
 Ultimate Capacities                                  (kips)  RESULT
```

[150.] "User's Response, Card 9.100, 9.200."

```
Option for Output Segment Selection                           IJJ
 (Default:    0)
 0 ... Continue with Current Default
 1 ... Enter New Value
```

[0] "User's Response, Card 1.000."

```
SELECT BRANCH:

  0 ... Return to Main Menu for Storage
Further Corrections:
  1 ... Title
  2 ... Analysis Options
  3 ... Helmet/Hammer Cushion Information
  4 ... Pile Cushion Information
  5 ... Pile Top Properties
  6 ... Pile Segment Information                                    IPEL
  7 ... Hammer Information
  8 ... Hammer File Override Values and Options
  9 ... Soil Parameters
 10 ... Skin Friction Distribution                                  ITYS
 11 ... Number of Splice/Slack Segments                             ISPL
 12 ... Ultimate Capacities                                       RESULT
 13 ... Option for Output Segment Selection                          IJJ
```

[0] "User's Response for No Corrections; give a RETURN to continue."

```
BRANCHING:

 -2 ... Reinitialize
 -1 ... Terminate Program
  0 ... Begin Terminal Inout/Modifications
  1 ... Read Previously Storeo Inout (Modifications/Analysis)
  2 ... Disolay Current Inout
  3 ... Store Current Inout
```

[2]

"User's Response: Display all input data."

```
 Title:  EXAMPLE 5: PILE SEGMENT + DAMPING INPUT

Analysis Options
        IO         RS         MT         IT         CT
         0          0          0          0          0
Helmet/Hammer Cushion Information
        WT         AR         EM         TH         CR         RO         ST
       .70        .00        .00      .0000      .8000      .0100     30000.
Pile Cushion Information
        AR         EM         TH         CR         RO         ST
       .00        .00      .0000      .5000      .0100         0.
Pile Top Properties
        LG         AR         EM         SW         CR         RO
     36.17     128.67    2000.00      51.00      .5000      .0100
Number of Pile Segments  (N)                                    N     12
Uniform Pile Option      (0/1: Uniform/Non-Uniform)        NCROSS      1
Non-Uniform Pile Profile                                    NCROS
    Depth       Area      E-Mod   Sp. Wght
     (XP)       (AP)      (EP)      (WP)
      ft        in2        ksi    lbs/ft3
      .00     128.67    2000.00      51.00
      .17     128.67    2000.00      51.00
     7.00     112.65    2000.00      51.00
    14.00      97.33    2000.00      51.00
    21.00      83.13    2000.00      51.00
    28.00      70.04    2000.00      51.00
    36.17      56.20    2000.00      51.00
Pile Damoing               (0 --> Normal)                  IBEDAM      5
Pile Segment Ootion                                          IPEL      2
Pile Segment Stiffnesses                         (k/in)       STP
    6592.      6557.      6176.      5800.      5445.      5100.      4764.      4440.
    4128.      3823.      3534.      3257.
Pile Segment Weights                             (kios)        PM
     .142       .126       .118       .111       .104       .098       .091       .085
     .079       .073       .068       .065
Pile Segment Lengths                           (relative) ALPH
   3.1670     3.0000     3.0000     3.0000     3.0000     3.0000     3.0000     3.0000
   3.0000     3.0000     3.0000     3.0000
Hammer ID Number            (0 - 300)                       IHAMR    133
Hammer File Override Values and Ootions
        SO         ST         EF         PR         FS         RW         CD         HD
       -1.      3.610       .000         .0         0.        .00      .0000      .0000
Soil Damoing Tyoe          (0: Normal Smith Aooroach)      ISMITH      0
Skin Friction Percentage (%) (1 < SF < 101, Normal)        IPERCS     10
Soil Parameters
        QS         QT         DS         DT
     .1000      .1000      .0000      .0500
```

```
OPTION:  Skin Friction Distribution                                    ITYS    -2
Soil Quakes                                            (in)         QS
   .1000     .1000     .1000     .1000     .1000     .1000     .1000     .1000
   .1000     .1000     .1000     .1000     .1000
Soil Damping Parameters (DampType Case:Non-Dim. Smith:s/ft)         SJ
   .1000     .1000     .1000     .1000     .1000     .1000     .1000     .1000
   .1000     .1000     .1000     .1000     .1000
Ultimate Static Soil Resistance                        (relative)   SU
     .00       .00       .00       .50      1.00      1.00      1.00      1.00
    1.00      1.00      1.00      1.00     76.50
Ultimate Capacities                                    (kips)   RESULT
  150.00       .00       .00       .00       .00       .00       .00       .00
     .00       .00
Option for Output Segment Selection                                IJJ     0

BRANCHING:

 -2 ... Reinitialize
 -1 ... Terminate Program
  0 ... Begin Terminal Input/Modifications
  1 ... Read Previously Stored Input (Modifications/Analysis)
  2 ... Display Current Input
  3 ... Store Current Input
  4 ... Hammer Data FILE Maintenance
```

3

"User's Response; store input."

```
Give FILENAME For Data Storage (Default: A:WEAPBG.IN )
X:XXXXXX.XXX
```

"Default data storage file name is sufficient; give a RETURN to continue."

```
                  ECHO PRINT OF INPUT DATA BEING STORED ON FILE A:WEAPBG.IN

EXAMPLE 3(5), PILE SEGMENT+DAMPING INPUT
  0   0 133  -1   0   2  12   0   1   5  10   0  -2   0   0   0   0   0
   6592.     6557.     6176.     5800.     5445.     5100.     4764.     4440.
   4128.     3823.     3534.     3257.
    .142      .126      .118      .111      .104      .098      .091      .085
    .079      .073      .068      .065
  3.1670    3.0000    3.0000    3.0000    3.0000    3.0000    3.0000    3.0000
  3.0000    3.0000    3.0000    3.0000
     .70       .00       .00     .0000     .8000     .0100    30000.
     .00
     .00       .00     .0000     .5000     .0100       0.
   36.17    128.67   2000.00     51.00     .5000     .0100
     .00    128.67   2000.00     51.00
     .17    128.67   2000.00     51.00
    7.00    112.65   2000.00     51.00
   14.00     97.33   2000.00     51.00
   21.00     83.13   2000.00     51.00
   28.00     70.04   2000.00     51.00
   36.17     56.20   2000.00     51.00
   3.610      .000        .0     .0000     .0000
   .1000     .1000     .0000     .0500
   .1000     .1000     .1000     .1000     .1000     .1000     .1000     .1000
   .1000     .1000     .1000     .1000     .1000
   .0000     .0000     .0000     .0500     .2000     .2000     .0500     .2000
   .2000     .0500     .0500     .0500     .0500
     .00       .00       .00       .50      1.00      1.00      1.00      1.00
    1.00      1.00      1.00      1.00     76.50
  150.00       .00       .00       .00       .00       .00       .00       .00
     .00       .00

DATA HAS BEEN STORED ON FILE:  A:WEAPBG.IN
```

For a hard copy of the total input data depress SHFT and PRTSC. SHFT is upper-case shift key.

"User's Response; give a RETURN to continue."

```
BRANCHING:

  -2 ... Reinitialize
  -1 ... Terminate Program
   0 ... Begin Terminal Input/Modifications
   1 ... Read Previously Stored Input (Modifications/Analysis)
   2 ... Display Current Input
   3 ... Store Current Input
   4 ... Hammer Data FILE Maintenance
```

-1

"User's Response."

```
***** HAS CURRENT INPUT DATA BEEN STORED? *****
  0 ... (NO) - Return to BRANCH for Storage
  1 ... (YES)- OK to End Program
```

1

"User's Response."

```
Stop - Program terminated.


C>COPY A:WEAPBG.IN A:SAMPLE.DAT
        1 File(s) copied
```

"Copy data file to another name for later usage."

3.2 Main Menu Option 1: Read Previously Stored Input (Modification/Analysis

Option 1 is used to recall input data for modification. The modification procedure is similar to the terminal input procedure (option 0) as described in Section 3.1 and demonstrated in the three examples.

The modification process begins with the option to change the current title. From that point on, the program will list the current information in the same menu format that was used to input the data originally. The user may change any quantity as the program progresses from first to last input segment.

The modification routine saves the user the time and effort of reentering data which has been input previously.

CAUTION: There are some modifications which require changes in other parts of the input. The most severe effect is a change of pile length which was originally used for computation of the number of pile segments (N). A change in total length will make it necessary for the user to also check the following input quantities:

1. User-specified Skin Friction Distribution (ITYS)
2. Nonuniform Pile Profile
3. Pile Segment Option (IPEL = 1 or 2)
   a) Pile Segment Lengths, Stiffnesses and Masses
   b) Quakes, Damping and Resistance
   c) Splice/Slack
4. Option for Output Segment Selection (IJJ)

If the cross-sectional area, the Modulus of Elasticity or Specific Weight is changed, then the Nonuniform Pile Profile may also, need modification. Note that, automatically computed ultimate resistance values and pile damping (both based on pile impedance) may also be affected.

For first time users of W86IN, it is recommended to restart with the Terminal Input Routine (option 0) and reenter all data if pile length changes.

3.3 Main Menu Option 2: Display Current Input

This option will usually be undertaken after all data has been entered or modified and the user wants to check the data for accuracy or wants a hard copy of the input data.

To display the current input data, enter option 2 in the main menu as shown in the following example (input data for example 1 in Section 3.1.1):

```
BRANCHING:

  -2 ... Reinitialize
  -1 ... Terminate Program
   0 ... Begin Terminal Input/Modifications
   1 ... Read Previously Stored Input (modifications/Analysis)
   2 ... Display Current Input
   3 ... Store Current Input
   4 ... Hammer Data FILE Maintenance
```

2 "User's Response."

```
Title:  EXAMPLE 1, 45 TON DESIGN, 10HP 53, D-12

Analysis Options
       OO         RS          AT          IT          CT
       10          0           0           0           0
Helmet/Hammer Cushion Information
       WT         AR          EM          TH          CR          RO          ST
      .95        .00         .00       .0000       .8000       .0100      21000.
Pile Cushion Information
       AR         EM          TH          CR          RO          ST
      .00        .00       .0000      1.0000       .0100          0.
Pile Top Properties
       LG         AR          EM          SW          CR          RO
    40.00      15.50    30000.00      492.00       .8000       .0100
Number of Pile Elements (N)                                                8
Uniform Pile Option              (0/1: Uniform/Non-Uniform)                0
Pile Damping                     (0 --> Normal)                            0
Pile Segment Option.                                                       0
Hammer ID Number                 (0 - 300)                                 3
Hammer File Override Values and Options
       SO         ST          EF          PR          FS          RW          CD          HD
       0.       .000        .000          .0          0.         .00       .0000       .0000
Soil Damping Type                                                         -1
Skin Friction Percentage (%)                                              10
Soil Parameters
       QS         QT          DS          DT
    .1000      .1000       .3000       .1500
OPTION:  Skin Friction Distribution                                                  0
Skin Friction Distribution
     Depth      Resistance
      ft
    .0000       .0000
  40.0000      1.0000
Ultimate Capacities                                   (kips)
    60.00     120.00      180.00      240.00         .00         .00         .00         .00
      .00        .00
Option for Output Segment Selection                                        0
```

3.4 Main Menu Option 3: Store Current Input

This option whould be used after data has been input or modified (through options 0 or 1 in the main menu) and is to be stored for analysis by WEAP86. The input data is stored as shown in the following example:

```
BRANCHING:

 -2 ... Reinitialize
 -1 ... Terminate Program
  0 ... Begin Terminal Inout/Modifications
  1 ... Read Previously Stored Inout (Modifications/Analysis)
  2 ... Disolay Current Inout
  3 ... Store Current Inout
  4 ... Hammer Data FILE Maintenance
```

3

"User's Response."

```
Give FILENAME For Data Storage (Default: A:WEAPBG.IN )
X:XXXXXX.XXX
```

"Give a RETURN to assign the Default name or type in another file name modeling the given format."

```
          ECHO PRINT OF INPUT DATA BEING STORED ON FILE A:WEAPBG.IN

EXAMPLE 1, 45 TON DESIGN, 10HP 53, D-12
  0   0   3   0   0   0   8   0   0   0  10  -1   0   0   0   0   0   0
       .95        .00        .00      .0000       .8000       .0100    21000.
       .00
       .00        .00      .0000      .5000       .0100          0.
     40.00      15.50   30000.00     492.00       .8000       .0100
      .000       .000         .0      .0000       .0000
     .1000      .1000      .3000      .1500
     .0000      .0000
   40.0000     1.0000
     60.00     120.00     180.00     240.00         .00         .00         .00         .00
       .00        .00

DATA HAS BEEN STORED ON FILE:  A:WEAPBG.IN
```

Note that, the above ECHO of input data may be printed by depressing SHFT and PRTSC simultaneously. SHFT is the upper-case shift key.

NOTE: If the default file name is used (usually same name as in FILES.DAT) be sure to store the input data under another name for later use. If input data is stored under the default file name only, it is likely that it will be overwritten and, therefore, permanently lost upon the next execution of W86IN.

3.5 Main Menu Option 4: Hammer Data File Maintenance

The Hammer Data File Maintenance routine allows the user to display hammer data on file, input new hammer data to file, and modify old hammer data on file. All this is accomplished with a series of program prompts in the form of menus.

Upon entering the Hammer Data File Maintenance routine from the main menu, the following branch request is made:

```
Hammer Maintenance:

  -1 ... Return to Main Brancning
   0 ... Hammer Data File Listing
   1 ... Inout Hammer Data
   2 ... Correction to Existing Hammer Data
```

The above menu prompts the user to enter options -1 thru 2 in order to execute hammer maintenance tasks. The above menu along with it's four options is explained in the following sections using detailed examples.

3.5.1 Option -1: Return to Main Branching

This option allows the user to return to the main menu once all hammer maintenance has been accomplished.

3.5.2 Option 0: Hammer Data File Listing

This option allows the user to obtain a listing of hammers in various modes. Upon entering the hammer data file listing option, the following menu prompt will be displayed:

```
Enter Outout Ootion:
 -1 ... Return to Branch Point
  0 ... Hammer ID and Name Only (Default)
  1 ... Hammer ID, Name and All Quantities without Headings
  2 ... Hammer ID, Name and All Quantities with Headings
```

The hammer listing can be obtained by options 0 thru 2 and can be displayed in the following manner:

```
Enter Outout Destination
  0 ... Terminal Disolay - FAST
  1 ... Terminal Disolay - SLOW (Give RETURN after eacn Hammer Disolay)
  2 ... Printed Ouout - (Set TOP OF FORM oefore Continuing)
```

Otion 0: Hammer ID and Name Only

If Option 0 is entered, the following prompt is displayed:

```
Enter START ID, STOP ID
```

```
1,3
```

"User's Response - This will list hammer ID's 1 thru 3."

```
ID  MANUFGR   NAME      RAM WEIGHT    ENERGY  TYPE

 1  DELMAG    D  5           1.10       8.23   OED
 2  DELMAG    D 8-22         1.76      17.60   OED
 3  DELMAG    D 12           2.75      23.59   OED

Hammer Data File Listing Completed
 Enter a RETURN to continue
```

"Give a RETURN."

```
Enter Output Option:
 -1 ... Return to Branch Point
  0 ... Hammer ID and Name Only (Default)
  1 ... Hammer ID, Name and All Quantities without Headings
  2 ... Hammer ID, Name and All Quantities with Headings
```

Option 1: Hammer ID, Name and All Quantities Without Headings.

If Option 1 is entered, again the user is prompt for the start to stop ID numbers:

```
Enter START ID, STOP ID
```

```
1,2
```

"User's Response - Hammer listing from ID's 1 and 2."

```
ID NO:   1
DELMAG  D  5        1    3   0
     1.10      87.07      8.27
      .35      19.76      8.27        .90       .01
     8.78      53.43     34.90      .0020     .0020
    14.70    1380.00       .00        .00       .00       .00
      .00        .00      7.48       4.03       .80
     1.35        .00       .00        .00       .00       .00       .00       .00
      .00        .00       .00        .00       .00       .00       .00       .00
      .00        .00
  0    1 31May85
```

```
ID NO:  2
DELMAG  D 8-22     1    3   0
     1.76      94.10      9.84
      .37      23.15      9.84        .90        .01
    10.75      75.95     58.40      .0010      .0020
    14.70    1493.00   1344.00    1209.00    1088.00       .00
      .00        .00     10.00       5.33        .80
     1.35        .00       .00        .00        .00       .00       .00       .00
      .00        .00       .00        .00        .00       .00       .00       .00
      .00        .00
  0    1 31May85

Hammer Data File Listing Comoleted
 Enter a RETURN to continue
```

"Give a RETURN."

```
Enter Outout Ootion:
 -1 ... Return to Branch Point
  0 ... Hammer ID and Name Only (Default)
  1 ... Hammer ID, Name and All Quantities without Headings
  2 ... Hammer ID, Name and All Quantities with Headings
```

<u>Option 2</u>: Hammer ID, Name and All Quantities With Headings.

If Option 2 is entered, the user is once again prompt for start to stop ID numbers:

```
Enter START ID, STOP ID
```

```
1,1
```

"User's Response - Hammer listing for hammer ID No. 1 only."

```
       ID  MANUFACT       NAME   H TYPE          M       IVAC
        1  DELMAG       D  5          1          3          0
 RAM WGHT  RAM LGTH  RAM DIAM
     1.10     87.07      8.27
 IB  WGHT   IB LGTH   IB DIAM    COR IB      DR IB
      .35     19.76      8.27       .90        .01
    DEPIB CHMBR. A. CHMBR. V. CMB DELAY  CMB DRTN
     8.78     53.43     34.90     .0020      .0020
     PATM        P1        P2        P3         P4         P5
    14.70   1380.00       .00       .00        .00        .00
AI STRT V  AI END V  MAX STRK  MIN STRK     EFFICY
      .00       .00      7.48      4.03        .80
   CO EXP    DEPBB   B C AREA      DBBT     D SAFE   C TANK V  REACTN WT  CO EXP BC
     1.35       .00       .00       .00        .00        .00        .00        .00
E.C.RTD P  EFF AREA  ASSM W 1  ASSM W 2   ASSM W 3  ASSM ST 1  ASSM ST 2  ASSM ST 3
      .00       .00       .00       .00        .00        .00        .00        .00
   COR AS     DR AS
      .00       .00
       MA  CO CONF.      DATE
        0         1   31May85
```

```
Hammer Data File Listing Completed
 Enter a RETURN to continue
```

"Give a RETURN."

```
Enter Output Option:
 -1 ... Return to Branch Point
  0 ... Hammer ID and Name Only (Default)
  1 ... Hammer ID, Name and All Quantities without Headings
  2 ... Hammer ID, Name and All Quantities with Headings
```

-1

"User's Response."

```
Hammer Maintenance:

  -1 ... Return to Main Branching
   0 ... Hammer Data File Listing
   1 ... Input Hammer Data
   2 ... Correction to Existing Hammer Data
```

3.5.3 Option 1: Input Hammer Data

This option allows the user to input and store new hammer data. The input procedure is the same as described in example 2 (hypothetical hammer input) in section 3.1.2 in this chapter. Refer to this example and to Chapter 3, Volume II, Cards 6.101, 6.201, ... 6.801.

W86IN gives the user the option to store each new hammer data set under an ID number. For example, the following W86IN display shows the restoring procedure after modifications of hammer data (designated SAMPLE HAMMER and stored in ID 300). Notice that the W86IN program checks whether any hammer data exists in the designated storage ID number. In the example below, it is "ok" to overwrite the data stored on ED 300 since that was the hammer data which was modified.

```
Store HAMMER DATA?              ** Current ID No.: 300 **
  0 ... Continue Without Storing Data on Hammer Data File
 >0 ... HAMMER DATA ID for Storage
```

300

"User's Response."

```
SAMPLE    HAMMER   is currently stored on Hammer ID 300
 0 ... OK to Overwrite Data Currently on File
>0 ... New HAMMER ID
```

| 0 |

"User's Response."

** HAMMER DATA Stored on ID: 300 **

3.5.4 Option 2: Correction to Existing Hammer

This option allows the user to modify and restore hammer data. The user is once again referred to example 3.1.2 in this chapter for guidance. The modification procedure is similar to the hammer data input procedure.

The storing procedure is as described above in section 3.5.3.

3.6 Main Menu Option '-2': Reinitialize

This option will usually be utilized if another set of input data is to be entered or if for some reason the user wished to restart the W86IN program with zero on basic default values.

3.7 Main Menu Option '-1': Terminate Program

This option needs no explanation except that before terminating program, it reminds the user if input data has been stored. If input data has not been stored, it gives the user the opportunity to store before program is terminated. Refer to end of examples 1, 2, and 3 of Section 3.1 for description.

4.2 Data Files

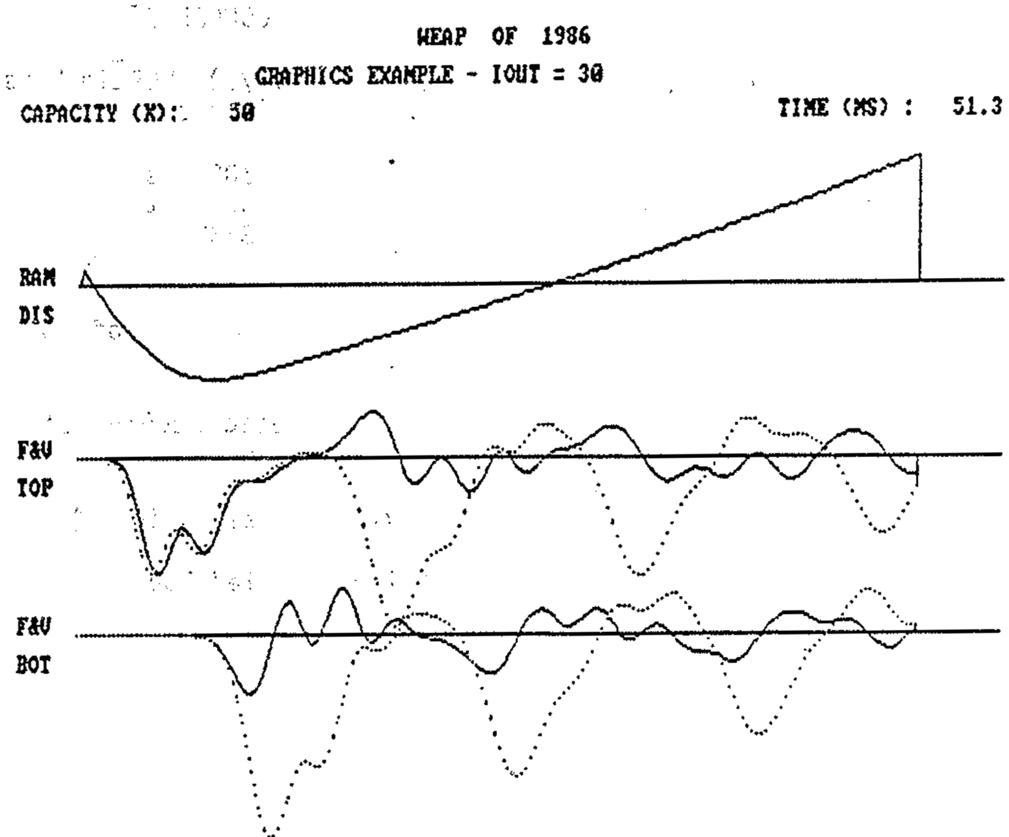
For graphics output the following files must reside on the default drive:

PRINTER.DEV - Epson printer configuration file.

GRAPHICS.DEV - Graphics board configuration file.

4.3 Output Examples With Graphics

The first graphics example includes the Ram Displacement curve along with the force and velocity curves at the pile top and bottom:



where:

IOUT = 30	is the OUTPUT LEVEL OPTION (IO).
CAPACITY (K): 50	is the capacity in kips being analyzed.

PILE SEGMENTS — Pile Segments at which graphic output was produced. Note that for long piles, all pile segments will not be shown (max of 11). Therefore, the pile segment numbers will not be consecutive.

All other information is defined as for the first example shown previously.

4.4 Scales

In the above two examples and all other graphics output, the following scales are used (per base line spacing). Note that graphics printing may take up to three minutes to complete.

		STEEL[1]	CONCRETE[2]
(a)	Force	(10ft/s)(PROP[+] in kips/ft/s)	(5 ft/s)(PROP[+] in kips/ft/s)
(b)	Velocity	10 ft/s	5 ft/s
(c)	Stress[3]		
(d)	Acceleration	500 g's	100 g's
(e)	Displacement	.1667 ft	.0833 ft
(f)	Ram Displacement	1.667 ft	.8333 ft

1 Steel defined by a pile material with an elastic modulus of 28000 ksi or greater

2 Concrete defined by a pile material with an elastic modulus of less than 28000 ksi

3 Instead of stresses, forces are displayed with scales as in (a)

[+]PROP (kips/ft/s) is the EA/c value in the "Pile Profile" Table.