FOURFIT—A COMPUTER CODE FOR DETERMINING EQUIVALENT NUCLEAR YIELD AND PEAK OVERPRESSURE BY A FOURIER SPECTRUM FIT METHOD

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25 May 1984

Technical Report

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A computer code is presented which performs least squares fitting of simulated airblast pressure Fourier amplitude spectra. The code iteratively determines the simulated nuclear yield and peak overpressure of a record by the FOURFIT method of analysis by comparing the data spectra to the spectra representing candidate fits.
SUMMARY

A computer code for determining the equivalent nuclear pressure and yield of airblast simulation records is presented. The code was written to automate a previously developed graphical fitting technique known as FOURFIT. FOURFIT determines a best fit nuclear waveform to airblast simulation data by comparing the Fourier amplitude spectra of the data with spectra for ideal nuclear waveforms. This report also presents results of the use of this code, also named FOURFIT, and a companion code, FOURPLT, which permits the results to be plotted. Fits to record traces from two separate simulation events are compared to previously published results which were determined using the graphical version of the technique.
PREFACE

The analysis presented herein was performed as part of work conducted during the period May 1983 to February 1984, on Contract DNA001-82-C-0098/P00002, Investigation of Scaling, Simulation and Associated Requirements for the STP 3 Combined Effects Program.
Conversion factors for U.S. customary to metric (SI) units of measurements.

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<td>torr (mm Hg, 0°C)</td>
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*The becquerel (Bq) is the SI unit of radioactivity; 1 Bq = 1 event/s.
**The Gray (Gy) is the SI unit of absorbed radiation.

A more complete listing of conversions may be found in "Metric Practice Guide E 380-74," American Society for Testing and Materials.
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SECTION 1
INTRODUCTION

The development and application of a Fourier domain technique for estimating the equivalent nuclear yield \( (W) \) and peak overpressure \( (P_{so}) \) of airblast simulation records are presented in References 1 and 2. The estimates are made graphically by comparing the Fourier amplitude spectra of the data records to the amplitude spectra of ideal nuclear airblast curves. Additionally, the methodology includes a means for identifying, through low pass filtering of the data, a "fidelity frequency" below which the data and the ideal curves are in good agreement.

The technique, called FOURFIT, has several advantages. These include:

- The Fourier amplitude representation of the data provides considerable insight into the frequency content of the data.
- The method provides consistent results for the values of \( W \) and \( P_{so} \) estimated for multiple records from the same event. Other methods give more scattered estimates (see Ref. 3).
- The technique is quick and easy to perform.
- FOURFIT can be performed graphically.

Despite the advantage of the physical insight provided to an analyst through graphical fitting, an alternative "automatic" fitting approach is desirable to enable quicker turn-around time for the results of large numbers of data records.
This report documents such a method. A computer program, FOURFIT, has been written which seeks to minimize the sum of the squares of the difference between the data Fourier amplitude and the amplitudes of candidate ideal nuclear fits. The amplitudes for the candidate fits are determined by an equation, parametric in $P_{SO}$ and $W$, which describes the spectra for the Speicher-Brode nuclear overpressure (Ref. 4). In addition, the program provides an estimate of the low pass fidelity frequency mentioned above.

Section 2 of this report reviews the background of the FOURFIT technique. Section 3 discusses the structure and use of the computer code and its algorithm for determining best fit equivalent yield and pressure. Section 4 presents some initial results determined by the code. Section 5 discusses some considerations into the effects of high pass and band pass filtering of airblast simulation data. Finally, Section 6 presents conclusions and recommendations.
SECTION 2
THE FOURFIT TECHNIQUE

2.1. REASONS FOR FOURFIT ANALYSIS

High explosive simulations of nuclear airblast often lead to inherent differences between the simulated environment and the ideal nuclear environment being modeled. For example, high frequency spikes in the early time portion of High Explosive Simulation Technique (HEST) simulated airblast records, as seen in Figure 1, are not normally present in actual nuclear overpressure pulses.

High frequency spikes in the HEST waveform and other simulation pressure history differences pose difficulties when fitting these records with an ideal nuclear pulse in the time domain. Time domain fitting methods and, indeed, the acceptance of HEST as a useful simulator, assume that the high frequencies of the HEST waveform do not drive the response of systems of interest. Yet time domain fitting is complicated by the fact that high frequencies and low frequencies are superimposed in that domain. This complication is especially difficult in the interpretation of HEST peak overpressure because the absolute peak overpressure is associated with a high frequency spike.

However, when viewed in the frequency domain, the relative importance of waveform differences is revealed. The Fourier transform unfolds the various frequency contributions to the pressure history and allows the analyst to fit those spectral portions of a record which dominate the power in the waveform. Use of the Fourier amplitude spectrum for fitting purposes thus provides for a more accurate ideal nuclear fit to the simulation data than do time domain techniques.
2.2. DEVELOPMENT OF THE FOURFIT TECHNIQUE

The nuclear airblast pressure waveform satisfies the conditions for existence of the Fourier integral transform. That is,

- It contains a finite number of minima and maxima.
- It contains a finite number of discontinuities.
- The function is aperiodic.

Therefore, a measured airblast waveform may be Fourier transformed using a fast Fourier transform (FFT) based upon the integral discrete Fourier transform (DFT) as represented by equation 1 below.

\[
H_c(n/N\Delta t) = T \sum_{k=0}^{N-1} h_c(k\Delta t)e^{-j2\pi kn/N}
\]

where
- \( T \) = duration of the signal
- \( \Delta t \) = timestep between data points
- \( k, n \) = integer values and represent the periodicity of the time and the frequency functions, respectively.

The DFT represents a limited duration signal, \( h \), as one period of an infinite periodic series summed over \( N \) samples of data and the subscript \( c \) above is used to denote an approximation caused by this truncation of the signal. The FFT computes a real portion and an imaginary portion of the Fourier transform, \( H \). These portions, in turn, may be used to compute Fourier amplitude and phase. Figure 2 shows the Fourier amplitude representation of the pressure history for the HEST record of Figure 1.

To determine the nuclear representation of the simulation data, the Fourier spectrum computed for that data must be compared to the spectra computed for ideal nuclear waveforms. The studies of References 1 and 2 and the example presented in this section were based upon the "New Brode"
description of the nuclear waveform (Ref. 5). However, a later study (Ref. 3) and the FOURFIT code discussed in following sections of this report are based upon the more recent Speicher-Brode formulations (Ref. 4). Figure 3 presents the "New Brode" pressure histories for several overpressures in scaled form. The scalars make the curves applicable for all yields.

2.2.1. Estimation of Peak Pressure and Yield

A parametric review of Fourier amplitude spectra and dimensional consideration of the DFT and the Brode equations revealed the proper scaling parameters for the airblast Fourier amplitude spectra. It was found that Fourier amplitude scales by the product of peak overpressure and the cube root of the yield (i.e., \( P_{so} \times W^{1/3} \)). Furthermore, Fourier frequency was found to scale by the cube root of the yield (i.e., \( W^{1/3} \)). Figure 4 illustrates a set of surface burst Brode Fourier amplitude spectra in scaled form.

The normalization of the ideal nuclear spectra provides the basis for the implementation of the FOURFIT technique. The analyst first notes that the slope of each Brode spectrum is inversely proportional to the value of peak overpressure. That is, \( P_{so} \) increases the spectra flatten as the amount of power carried within the higher frequencies increases relative to the power in the low frequency regime. With this in mind, the analyst makes an initial estimate of the data equivalent peak pressure by comparing the data spectrum to the Brode spectra. The ideal spectrum which best compares to the data defines the initial estimate of \( P_{so} \). The corresponding yield is determined as guided by the scaled amplitude plots. The steps discussed below and illustrated by Figure 5
utilize those scaled plots as an overlay to the data to find the final fit. The technique will be illustrated using the HEST spectrum shown in Figure 2.

In the first step, a comparison of the data spectrum to the Brode spectra indicates a peak pressure of about 3 megaPascals to be a reasonable estimate. Next, note that since amplitude scales by \((P_{so} \times \omega^{1/3})^{-1}\) and frequency scales by \(\omega^{1/3}\), the amplitude scalar is exactly \(P_{so}\) times the frequency scalar. With \(P_{so}\) already estimated, the problem is reduced to finding one unknown, namely, the yield. Graphically, this is performed by overlaying the spectral data onto the ideal spectra such that, at equal locations on the respective frequency axes

\[ i.e.\, F_B \times \omega^{1/3} = F_D \quad (2) \]

the amplitude axes are shifted by a ratio equal to the estimate for \(P_{so}\)

\[ i.e.\, P_{so} \times (A_B/(P_{so} \times \omega^{1/3})) = A_D \quad (3) \]

or, in the example, a vertical shift by a factor of about 3. The subscripts B and D refer to the Brode and the data, respectively. Since the plots are in the logarithmic domain any shift represents a constant multiplier.

Similarly, the scalar \(\omega^{1/3}\), as a constant multiplier, can be represented by a shift. This shift is defined such that, since \(\omega^{1/3}\) is the same multiplier on both axes, only a shift along a line of slope equal to 1:1 will maintain an equal axis shift. Furthermore, the shift occurs along a line of -1 slope since the actual scalars are \((\omega^{1/3})^{-1}\) for amplitude and \(\omega^{1/3}\) for frequency. With the shift thus defined, it simply is left to perform this shift until the data spectrum properly
interpolates the Brode spectra to a location representing the value for peak overpressure chosen for the fit (i.e., between the 2 MPa spectrum and the 5 MPa spectrum). The resulting pressure/yield pair is then computed by "unscaling" the overlay. That is, the comparisons of the respective frequency and amplitude axes for the data and for the normalized Brodes, as shown in the equations below, will result in estimates of the two variables \( P_{SO} \) and \( W \).

\[
\frac{F_f}{F_B \cdot W^{1/3}} = (W_f^{1/3})^{-1}
\]

and

\[
\frac{A_f}{[A_B/(P_{SO} \cdot W^{1/3})]} = P_{SO} \left( \frac{F_f}{F_B \cdot W^{1/3}} \right)^{-1}
\]

The subscript \( f \) refers to the fit to the data.

The results for the example are shown on Figure 5 and the yield is computed below.

\[
\frac{3300 \text{ Hz KT}^{1/3}}{200 \text{ Hz}} = W_f^{1/3}
\]

or

\[
W_f = (1.64 \text{ KT}^{1/3})^3 = 4.44 \text{ KT}
\]

Also, the calculation below confirms the amplitude scale using the peak pressure (2.78 MPa) and the yield (4.44 KT) defined for the fit.

\[
\frac{0.1 \text{ MPa-sec}}{0.0218 \text{ sec/KT}^{1/3}} = (2.78 \text{ MPa})(4.44 \text{ KT})^{1/3}
\]

A Brode overpressure history and associated impulse history and Fourier amplitude spectrum are then calculated for these values of peak
overpressure and yield. The three representations of this signal can now be compared to those of the data to refine the fit. A need for slight adjustment to the fit is expected considering the graphical nature of the technique.

The amplitude spectrum fit procedure is repeated to improve the frequency and time fits. The adjusted estimates for the example define the pressure to be 2.95 MPa and the yield to be 5.05 KT. Figures 6 to 8 show the pressure and impulse histories and the amplitude spectrum of the Brode defined by these final values compared to the respective representations of the record. This is an acceptable fit and thus will be carried to the next step of the process.

2.2.2. Estimation of Fidelity Frequency

It may be noted from Figure 4 that the low frequency regime of the nuclear airblast carries significantly more power than is carried by the high frequencies. Furthermore, most systems of interest in airblast simulations respond to low frequency input. This section describes a methodology which, through low pass filtering, quantitatively defines a frequency cutoff where systems sensitive to frequencies below that cutoff experience the loading as defined by the FOURFIT results in the preceding paragraphs. This frequency is identified as the fidelity frequency for the record since it defines a limit above which the fidelity of the simulation relative to the prototype degrades.

Identification of a fidelity frequency makes use of the fact that most of the power in the airblast signal exists in the low frequencies. This suggests that although low pass filtering of the signal may alter the exact shape of the waveform, it should have limited effect
on the total power delivered. This is illustrated in Figures 9 and 10 for a Brode pulse. In Figure 9 it is seen that as the cutoff frequency is lowered, the peak of the filtered pressure history decreases. However, this peak reduction is accompanied by a broadening of that peak. This suggests that the deliverance of power is only delayed, not diminished. This hypothesis is supported by noting that the total impulse of the filtered Brode (Fig. 10) is virtually unchanged.

The determination of fidelity frequency utilizes the relationships between peak attenuation and cutoff frequency. It was found that the filtered peaks of the data record show a similar trend versus the respective cutoff frequency. Fidelity frequency is identified by using this similarity and with an overlay technique similar to that used to determine $P_{SO}$ and $W$ using the Fourier amplitude spectra.

A plot of the data peak attenuation versus cutoff frequency is an overlay to the Brode peak attenuation curves (Fig. 11). Note that the filtered Brode peak is scaled by $P_{SO}$ and that the Brode cutoff frequency is scaled by $W^{1/3}$. As illustrated in Figure 11 for the record of the example, the data attenuation plot is shifted the proper amount on the vertical axis and on the horizontal axis as defined by $P_{SO}$ and by $W$, respectively. This allows that the data attenuation curve approaches and eventually merges into the attenuation curve for the equivalent value of $P_{SO}$. The merger of these curves defines the fidelity cutoff frequency (180 Hz for the example). Below this frequency the data record is similar to the equivalent Brode. Above this frequency, the data contains diversions from the Brode which, in effect, do not load systems sensitive only to frequencies below this cutoff. Figure 12 compares the filtered
data record to its filtered equivalent Brode for different cutoff frequencies. Note the excellent agreement between the data history and the Brode history at the 200 Hz (~180 Hz) cutoff.

Previous studies (Ref. 1, 2, 3) have shown that the FOURFIT technique provides consistent estimates of peak pressure and yield for multiple pressure records from the same event. In addition, the technique is graphical in nature and easy to perform. However, it is desirable that an alternative "automatic" fitting routine be available. The existence of a computer oriented fitting alternative would allow for more rapid analysis of airblast records and would be free of analyst bias. A computer program, FOURFIT, has been written to achieve this goal and is discussed in detail in the following section.
SECTION 3

PROGRAM FOURFIT

Despite the advantages of performing the graphical FOURFIT technique described earlier, a quick "automated" version of the method was desired to provide rapid analysis of the typical airblast simulation record. Program FOURFIT was written to achieve this goal. Appendix A provides a listing of this code.

Program FOURFIT finds the best fit nuclear waveform for airblast data based upon a search to minimize the sum of the squares of the differences between the data Fourier amplitude spectrum and trial ideal spectra. The Fourier transform of the data is performed by a call to the International Mathematics and Statistics Library (IMSL) routine FFTRC (Ref. 6). IMSL is maintained on the Defense Nuclear Agency (DNA) CDC Cyber 176 computer on which FOURFIT was written. The ideal nuclear Fourier amplitudes for trial fits are computed by an equation, parametric in $P_{SO}$ and $W$, which describes the amplitude spectra for a set of curves similar to those presented in Figure 4. The equation, however, describes the more recent Speicher-Brode fit to the nuclear overpressure waveform (Ref. 4) represented in scaled form in Figure 13. Scaled Speicher-Brode impulse histories and Fourier amplitude spectra are presented in Figures 14 and 15, respectively. A detailed description of the fitting program follows.

The program is run by reading an input deck (TAPE2) to define user options. Results are listed in output (TAPE6) and plotting information is written to TAPE48 to be plotted by FOURPLT, the accompanying plotting program.

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3.1. INPUT VARIABLES

The main purpose of the program FOURFIT is to perform fits to surface burst airblast simulation data. The program compares data Fourier amplitude spectra to estimates of the Fourier amplitude spectra of the ideal nuclear represented by the Speicher-Brode pressure-time equation. However, the code is also set up to perform FFT analysis of the data without finding a fit, or to perform a FFT on a specific Speicher-Brode defined by a pressure/yield pair requested by the analyst. FOURFIT also computes the impulse history for either of these latter cases. Finally, the code is set up to perform a low pass Butterworth filter of either data or a Speicher-Brode at up to seven cutoff frequencies, specified by the user, per run.

The options mentioned above are to be chosen by the analyst and read from an input deck, TAPE2, assembled by that analyst. The contents of TAPE2 are summarized below. The code reads all input lines, including those not used in analysis, in all runs.

Line 1: NEPTS, IUNITS, JUNITS (Format 315)

The value for NEPTS is the number of points to be read from the data tape. The other variables in this line account for data input units. For IUNITS greater than zero, the code assumes that the pressure values are read in pounds per square inch and converts the data to megaPascals, the internal units of the code. For IUNITS less than zero, the data is assumed to be read in the program units. Furthermore, the program works in units of seconds for time and Hertz for frequency. JUNITS less than zero indicates an input time step consistent with this fact. For JUNITS greater than zero, the program assumes input in milliseconds and performs
the proper conversion. The value of these variables do not affect the
calculation of a Speicher-Brode function.

Line 2: PSOI, WI (Format 2F5.2)

The meaning of these terms in line 2 differs depending on the
program option (explained in line 3) chosen. For analysis of a data trace
for its impulse and FFT or for filtering that data, without performing a
fit, PSOI and WI are not used. However, for the case of fitting the data
with a Speicher-Brode, these variables provide the "seeds" for defining
the candidate fits. PSOI is the seed for peak overpressure in MPa and WI
is the seed for nuclear yield in kilotons. A wide range about these seeds
(plus and minus a decade for each) is tested and so they need not be
exceptionally close to the final values. However, a good set of seeds may
nominally be considered to be the event design pressure and yield. For
cases in which only the Speicher-Brode will be analyzed, PSOI and WI are
the peak overpressure and yield values, respectively, of the ideal
waveform to be calculated.

Line 3: IOPT, IFILT (Format 2I5)

IOPT defines the program option to be run. IOPT equals 1 for
performing the FOURFIT automated fitting routine. To simply integrate and
FFT the data, IOPT equals 2. For IOPT equals 3, the code analyzes only
the Speicher-Brode specified by PSOI and WI in line 2. The value for
IFILT determines whether or not the pressure history is to be filtered.
No filtering is done for IOPT equal to 2 or 3 if the value of IFILT is
less than zero. A value of IFILT greater than zero for these same IOPT
values performs a low pass Butterworth filter on the pressure history at
the cutoff frequencies defined by FLO (line 4). For IFILT greater than
zero, neither impulse nor FFT calculations are performed. For IOPT equal to 1, IFILT may be any value.

Line 4: FLO(I), I=1,7 (Format 7F10.0)

FLO(I) are the low pass cutoff frequencies in Hertz used by the Butterworth filter. Up to seven filter levels, in any order, are allowed for options 2 and 3. For the number of filters, N, less than seven, FLO(N+1) must be set to 0. Although option 1 does not utilize the IFILT value (line 3), it nevertheless performs filtering in order to determine fidelity frequency. Therefore, IOPT = 1 requires that TAPE2 contain several filter levels to be defined on this line. Furthermore, the algorithm requires that these filters be in descending order (e.g., FLO(1) = 5000., FLO(2) = 2000., FLO(3) = 1000., etc.). The values for FLO in this series may be chosen by the analyst. However, bounding values of FLO(1) = 5000. and FLO(7) = 50. with a reasonable spread of values for FLO(I), I = 2,6 between these, have proven to be adequate. Additionally, each FLO(I) must be less than or equal to the Nyquist frequency for the digital filter to remain stable. (Note that if either FLO(1) or FLO(7), i.e., the limiting cases, is determined to be the fidelity frequency, the values should be altered accordingly and the program resubmitted.)

These four lines complete the input deck needed to submit a FOURFIT run. An example input deck is listed below. The program will subsequently compute a 6000 point FFT on data read in the units of psi and seconds (line 1). The initial estimated pressure and yield pair are 20. MPa and 2. KT, respectively (line 2). The third line indicates that a fit will be performed. The second value in this line represents the
filter switch and, since this run asks for a fit, it will not be used. The final line of input lists the seven low pass filter levels, in Hz, to be tested for locating the low pass fidelity frequency.

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3.2. PROGRAM STRUCTURE

3.2.1. Data Calculations

IOPT equal to 2 is the simplest option to perform and, hence, the option taking the most direct calculation route. This option simply requires a subroutine to read the data, a subroutine to integrate that data for impulse and a subroutine to calculate the Fourier transform of the record. For IFILT greater than 1 (filters to be executed) the impulse and FFT are not calculated. Instead, a filter subroutine is called and the record is low pass filtered at specified cutoff frequencies.

The program FOURFIT, as listed in Appendix A, calls the subroutine EBREAD to read the data pressure histories. EBREAD is set up to read a card image format (EBCDIC) tape of the data and its header. The format of EBREAD is the format of several tapes analyzed by the author which were provided by the U.S. Army Engineer Waterways Experiment Station (WES). The format that those tapes employed was pressure data written as five data values per card (5E16.8). The set of cards for a given trace is preceded by a header record containing shot and data information (i.e., shot title, gage title, time step, total number of points) in the format of 3(2A10), E15.8, I5. These tapes have been written in psi for pressure and the program converts the
values to MPa. The time step is written in seconds. Any tape of different format must be accompanied by a substitution for EBREAD to read that data. However, this new subroutine must retain the structure of EBREAD if the program is to perform properly. This includes proper units (pressure in MPa, time in seconds), proper ordering of calls to impulse, FFT and filtering subroutines and identical writes to TAPE48.

After the data has been read, IOPT equal to 2 causes EBREAD to take one of two paths, depending on the value of IFILT. If filtering is not to be done, the subroutine causes the impulse history and the Fourier amplitude spectrum to be calculated. Subroutine IMPULSE integrates the data by Simpson's approximation. Subroutine FFTRC computes the fast Fourier transform after the algorithm of Singleton (Ref. 7). On the other hand, if filter histories are desired, subroutine FILTER filters the data using the recursive equations derived for a two pole low pass Butterworth filter as found in, for example, Reference 8.

3.2.2. Speicher-Brode Calculations

IOPT equal to 3 causes calculation of a Speicher-Brode pressure history and either its impulse and FFT or its specified low pass filtered pressure histories. Structure of subroutine SPBRODE is similar to that of EBREAD except that the data reads are substituted for by the Speicher-Brode equations. Also, SPBRODE requires a target range to perform its calculations. Therefore, before entering into SPBRODE, the program utilizes subroutines RANGE and PPEAK to iterate on the distance from surface burst ground zero for the given PSOI and WI pair specified. Impulse and FFT or filter histories are calculated as described for IOPT equal to 2.
3.2.3. Fit to Data

A value of IOPT equal to 1 causes the code to find a best fit nuclear waveform for the data. That data is read, integrated and Fourier transformed. A least squares algorithm finds a best fit to the data Fourier amplitude spectrum based on an equation, parametric in peak pressure and yield, which describes the scaled Speicher-Brode Fourier amplitude spectra. The actual best fit Speicher-Brode waveform is calculated, integrated and Fourier transformed for comparison to the data in the form of plots. The data pressure history and the equivalent Speicher-Brode are low pass filtered at several levels of frequency cutoff. The peaks of these filtered histories are compared in the determination of fidelity frequency.

The best fit search is performed within the subroutine FIT. This subroutine is modeled after a similar subroutine discussed in Reference 9. The search begins with a set of five peak pressure values and five yield values. These values are equivalent to the product of the coefficients \(1,\ .4,\ 1.,\ 4.\) and \(10.\) times PSOI and WI. The final results for equivalent peak overpressure and yield are found within these values. (If the final result for either pressure or yield is either \(.1\) or \(10.\) times PSOI or WI, respectively, i.e., the limiting cases, the analyst is advised to alter the seeds accordingly and/or to check the quality of the data.)

Subroutine FIT takes a value of peak overpressure, PP, and pairs that value with each of the five yield values, W. The comparison between each candidate Speicher-Brode and the data occurs after, for each value of frequency for the data spectrum, a value of ideal nuclear Fourier amplitude is computed using the parametric equation below.
\[ A_1 = 0.1788PP^{-0.72}(F_s)^{-0.103} \]  \hspace{1cm} (8a)

\[ A_2 = 0.01474PP^{-0.15}\left(\frac{F_s}{F_{so}}\right)^{-1.75} \]  \hspace{1cm} (8b)

\[ A_3 = 0.0011PP(PP)^{-0.234}\left(\frac{F_s}{F_{so}}\right)^{-2.15} \]  \hspace{1cm} (8c)

\[ A_4 = 0.00132(F_s)^{-0.547} \]  \hspace{1cm} (8d)

\[ A_5 = 0.01034PP^{-0.113}(F_s)^{-1}\left(\frac{F_s}{F_{so}}\right)^{-1.5} \]  \hspace{1cm} (8e)

\[ A_6 = 0.000011PP^{-0.77}\left(\frac{F_s}{F_{so}}\right)^{-7.5} \]  \hspace{1cm} (8f)

\[ A_7 = 0.000066PP^{-3}\left(\frac{F_s}{F_{so}}\right)^{-1.5} \]  \hspace{1cm} (8g)

\[ ASCL = A_1 - A_2 + A_3 + A_4 + A_5 - A_6 + A_7 \]  \hspace{1cm} (8h)

\[ A_{SB} = ASCL \times PP \times W^{1/3} \]  \hspace{1cm} (8i)

where \( F_s \) = yield scaled frequency \((F \times W^{1/3})\)

\[ F_{so} = \text{yield scaled fundamental frequency} \ (F_o \times W^{1/3}) \]

\( F_o = 1/\text{positive phase duration} \)

ASCL = scaled Speicher-Brode Fourier amplitude

\[
A_{SB}/(P_{so} \times W^{1/3})
\]

\( A_{SB} \) = estimated Speicher-Brode Fourier amplitude

This equation represents a fit to the normalized surface burst Speicher-Brode Fourier amplitude spectra shown in Figure 15. (Use of this equation is facilitated when, for each candidate fit, successive calls to RANGE and PPEAK calculate the positive phase duration.)
For a given data frequency, equation 3 is used to calculate a Speicher-Brode amplitude for the trial peak pressure and yield pair. In order to assimilate the graphical methodology, which is carried out in log-log form, the common logarithm of the amplitude estimate is computed. The difference between this last value and the common logarithm of the data amplitude is computed and then is squared to accommodate algebraic sign. To further assimilate the graphical method, this difference is divided by the particular data frequency. This last step considers that the FFT is computed using a constant frequency step. Therefore, the point density increases by an order of magnitude with each decade increase in frequency. Division by the frequency compensates for the weighting that results.

The value just computed is added in a summation of squared differences for the PP/W pair for the present trial. This summation process is repeated starting at the data fundamental frequency and continuing to some high frequency (a value which is a function of the data record) which sufficiently includes the significant portion of the data. (This final frequency must be chosen so as to include the peak of the data, but must be limited to avoid extensive calculation within the high point density "record noise" frequency regime.) The results of this summation provide a value DELTAW for the present pressure/yield pair.

A DELTAW value is computed for each of the other candidate yields until, for the given PP(J), five DELTAW(I) values are available for comparison. The minimum of these five values is then located and the next iteration occurs with a new set of yields replacing the old set with the yield which gave the minimum DELTAW(I) being the central value. (For
example, for $W(I)$, $I = 1,5$, $\Delta W(2)$ may have been a minimum. For the next iteration, then, $W(2)$ becomes the new $W(3)$; $W(1)$ remains unchanged and the past $W(3)$ becomes the new $W(5)$. The new $W(2)$ and $W(4)$ values are intermediate to the new $W(1)$ and $W(3)$ and the new $W(3)$ and $W(5)$, respectively.) This procedure is repeated until, for the given $PP(J)$, the field of $W(I)$ is narrowed so that the extremes are within 1 percent of each other (i.e., $2 \times (W(5) - W(1))/(W(5) + W(1)) \leq .01$). When this tolerance is met, the minimum $\Delta W(I)$ of the final group is set to be $\Delta P(J)$ for the given value of $PP(J)$.

The iteration next proceeds to the second value for $PP(J)$ coupled with each of the original five values for yield. Eventually, four more $\Delta P(J)$ values are computed and the minimum of the five $\Delta P(J)$ values is determined. In this manner, the field of $PP(J)$, $J = 1,5$ is narrowed to five new values and the entire process continues until the spread of $PP(J)$ values are limited to within a tolerance as was specified for the $W(I)$ above. When this criterion is met, the best fit Speicher-Brode is considered to be found as the pressure/yield pair for which the final minimum $\Delta P(J)$ was found. (Recall, though, that if the final pressure or yield is either .1 times or 10. times the respective seed, the validity of the answer must be checked.)

Next, for this case where $IOPT = 1$, a Speicher-Brode pressure history is computed for the pressure/yield pair defined by FIT. This history is integrated and Fourier transformed so that final plots, provided by program FOURPLT, represent comparisons between the data and the best fit Speicher-Brode pressure history, impulse history and Fourier amplitude spectrum. Additionally, this ideal waveform is low pass
filtered. The peaks of the filtered pressure histories are determined and compared to the peaks, at their respective cutoff frequency, of the filtered data which have also been determined. Beginning with the highest frequency filter and proceeding in descending order, the level at which the filtered data peak is within 10 percent of the filtered Speicher-Brode peak is chosen as the low pass fidelity frequency. If a fidelity frequency is not found, a value of -999 is assigned to this variable. If this value appears in the output, further investigation is warranted.

The analysis discussed in the previous paragraphs creates a file, TAPE48, which contains information to be plotted. Program FOURPLT, discussed below, utilizes this file to produce plotted output of results for the three program options (IOPT). In addition, the results for IOPT equal 1, fitting of data, will be written to the output file for the analyst's record. An example of this output is shown in Figure 16. (For IOPT equal to 3, just Speicher-Brode calculations to be done, similar output is provided.) A flow chart of FOURFIT is presented in Appendix B. Appendix C provides a flow chart of subroutine FIT.

3.3. PROGRAM FOURPLT

Program FOURPLT is to be used in conjunction with program FOURFIT. FOURPLT exists to attach the TAPE48 made by FOURFIT, read that file, known as TAPE9 within FOURPLT, and plot the contents. The program uses the DISSPLA plotting capabilities maintained for the DNA CDC Cyber 176 computer. A separate plotting routine allows for analysis of greater sizes of data arrays and provides for quicker turn around by dividing the core requirement of the combined job. FOURPLT requires no input other than the TAPE48 file to run successfully. A listing of program FOURPLT is provided as Appendix D.
3.4. PROGRAMMING NOTES

Before continuing with presentation of the results from running FOURFIT and FOURPLT, a point should be noted which will assist the operator in successfully running the codes. The Speicher-Brode Fourier amplitude equations describe the total positive phase duration of the respective pressure histories. Therefore, the data to be analyzed should similarly be carried as nearly as possible through full positive phase.

Since the amount of data that can be analyzed is set within several arrays, these arrays must be large enough to contain all of the data. This includes pressure (PRESS) and time (TTIM) to be dimensioned at least as large as NEPTS; impulse (PIMP) and impulse times (TIMP) must be dimensioned at least (NEPTS/2)-1; amplitude (AMP) and frequency (FRQ) must be at least as large as (NEPTS/2)+1. In addition, the data FFT working arrays (IWKE, WKE) must be of sufficient size. (Reference 6 contains an algorithm for computing the necessary size of these two working arrays by factoring NEPTS.) The Speicher-Brode calculations use these identical arrays and the number of points assigned to these calculations is NBPTS equal to 2048. Each array must be at least large enough to accommodate this value.
SECTION 4
PROGRAM RESULTS

4.1. SAMPLE OUTPUT

Figures 17 to 28 illustrate the possible output from FOURFIT and FOURPLT for the various options. Figures 17 to 19 result from requesting IOPT = 2 with IFILT = -1. The program reads, integrates and Fourier transforms a data record, in this case record AB-5 from event 0.35 KBAR DISC HEST. In Figure 20, the same data record is read, IOPT = 2, but is low pass filtered, IFILT = 1, at a cutoff frequency, FLO, equal to 1000 Hz. In each case, the identifying header is presented at the top of the plot.

In Figures 21 to 23, the results of computing, integrating and Fourier transforming a Speicher-Brode pressure waveform (PSOI = 39.60 MPa, WI = 0.87 KT, IOPT = 3, IFILT = -1) are presented. Figure 24 presents this same waveform (IOPT = 3) low pass filtered (IFILT = 1) at 1000 Hz (FLO) frequency cutoff. Information to the right of the plot identifies the ideal waveform plotted. Each of the types of submittals discussed in this and the preceding paragraph require on the order of 0.5 CP seconds of execution time on the Cyber 176 computer.

Finally, Figures 25 to 27 show an example of the results of a run to fit the data record (IOPT = 1) presented in Figure 17. Both the data and the computed best fit Speicher-Brode are plotted for comparison of pressure histories, impulse histories and Fourier amplitude spectra. Figure 28 compares the data and its equivalent fit both low pass filtered at the low pass fidelity frequency identified by the fit. The job requiring a fit to this record required on the order of 80 CP seconds.
execution time on the Cyber 176 computer. (The required computer time will vary as the number of data points and, hence, frequency comparisons, varies.)

4.2. RESULTS OF FITTING ROUTINE

Several records from the test 0.35 KBAR DISC HEST were fit using program FOURFIT. These records were chosen because they were data histories which were fairly representative of a nuclear pressure waveform. Furthermore, these records were previously analyzed using the graphical FOURFIT technique (Ref. 3) and thus provided a basis for comparison between the program results and accepted fits.

The fits calculated for several records from the DISC HEST are shown in Figures 29 to 49. (These results are in addition to those for record AB-5 shown earlier.) These figures represent the output from running FOURFIT and FOURPLT and includes both the data and the fit compared by pressure history, impulse history and Fourier amplitude spectrum for each record. Table 1 summarizes these fits and compares the results of the program ("automated") to fits found graphically ("graphical"). The authors feel that Figures 29 to 49 show favorable comparisons. (Though some of the latest automated results do not agree closely with previous graphical results--i.e., yield values for AB-4, for AB-9 and for AB-10--the plot comparisons for these records are very acceptable.)

The program was next applied in the analysis of a second event, 0.35 KBAR HEST. FOURFIT managed to determine acceptable fits to several of the records (e.g., the fit for record 51 shown in Figures 50 to 52). However, for other records of this event, the data record and its time domain fits diverge after several milliseconds. This divergence may be
Table 1. Comparison of FOURFIT results for 0.35 KBAR DISC HEST: graphical (ref. 3) versus automated.

<table>
<thead>
<tr>
<th>Gage</th>
<th>Yield (KT)</th>
<th>$P_{50}$ (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Graphical</td>
<td>Automated</td>
</tr>
<tr>
<td>AB-3</td>
<td>1.05</td>
<td>1.07</td>
</tr>
<tr>
<td>AB-4</td>
<td>0.52</td>
<td>1.15</td>
</tr>
<tr>
<td>AB-5</td>
<td>0.84</td>
<td>0.87</td>
</tr>
<tr>
<td>AB-7</td>
<td>0.80</td>
<td>0.97</td>
</tr>
<tr>
<td>AB-9</td>
<td>0.91</td>
<td>0.66</td>
</tr>
<tr>
<td>AB-10</td>
<td>0.66</td>
<td>0.99</td>
</tr>
<tr>
<td>AB-12</td>
<td>0.31</td>
<td>0.57</td>
</tr>
<tr>
<td>AB-13</td>
<td>0.80</td>
<td>0.73</td>
</tr>
<tr>
<td>AVE**</td>
<td>.74</td>
<td>.86</td>
</tr>
<tr>
<td>( \sigma )**</td>
<td>.23</td>
<td>.20</td>
</tr>
<tr>
<td>( \sigma /AVE )</td>
<td>.31</td>
<td>.23</td>
</tr>
</tbody>
</table>

*percent of graphical  
** |\( \Delta \% \) |
traced to trends in the pressure data which are atypical of the ideal nuclear pulse. These trends, as noted for one of the records, are discussed below.

Figure 53 presents the pressure history of record 417 from 0.35 KBAR HEST. Several variations between the ideal waveform and record 417 are readily noticeable. First, in contrast to the DISC HEST records, record 417 contains one relatively high magnitude (46 MPa), but very narrow spike suggesting a low amount of power carried in the peak of the record. This spike is followed by an extended vibratory component at about 11 MPa and another at about 7 MPa suggesting that a lower, but still fairly high frequency regime may be sustaining too much power. The remainder of the waveform shows, rather than a purely exponential decay, a decay that, at times, shows a nearly linear trend, upon which is superimposed a low frequency oscillatory component. This would foretell a rise in the amplitude spectrum in the low frequency end.

The Fourier amplitude spectrum for record 417 was computed and is presented in Figure 54. This figure fulfills the expectations resulting from review of the pressure history. The spectrum falls off rapidly between the fundamental frequency and about 150 Hz. At this point, the slope changes to a lesser decay of power toward the intermediate to high frequencies. As the Nyquist frequency is approached, the spectrum falls off more rapidly. These observations seem to correspond to the low frequency oscillation, the early time/low magnitude oscillations and the narrowness of the peak, respectively.

The factors listed above indicate that the recorded trace carries a low qualitative fidelity in comparison to the Speicher-Brode. These data
trends suggest that the fits to such records may show obvious variances in comparisons to those records. Figure 55 presents the Fourier amplitude fit determined by a FOURFIT run on record 417. It is seen that the data spectrum diverges from the fit at times, with the non-nuclear trends of the data becoming obvious. The pressure history comparison, Figure 56, also illustrates regions of divergence between the data and the nuclear waveform. The fit impulse history (Fig. 57) is seen to be a mismatch to the data beyond about 10 msec. The difficulties encountered in analysis of poor fidelity records, such as 417, indicates a need for more study into the approach for analysis of such records. For example, different frequency regimes of such data may be subject to varying weighting functions to perform the fit.

Comparisons between other records from 0.35 KBAR HEST and their respective fits are shown in Figures 58 through 72. These fits are summarized in Table 2.
Table 2. Comparison of FOURFIT results for 0.35 KBAR
HEST: graphical (ref. 3) versus automated.

<table>
<thead>
<tr>
<th>Yield (KT)</th>
<th>$P_{50}$ (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Graphical</td>
</tr>
<tr>
<td>411</td>
<td>1.01</td>
</tr>
<tr>
<td>418</td>
<td>.67</td>
</tr>
<tr>
<td>419</td>
<td>.50</td>
</tr>
<tr>
<td>51</td>
<td>.50</td>
</tr>
<tr>
<td>54</td>
<td>.74</td>
</tr>
<tr>
<td>55</td>
<td>.41</td>
</tr>
<tr>
<td><strong>AVE</strong></td>
<td>.65</td>
</tr>
<tr>
<td>σ</td>
<td>.20</td>
</tr>
<tr>
<td>σ/AVE</td>
<td>.31</td>
</tr>
</tbody>
</table>

*percent of graphical
** |△%|
SECTION 5
FILTER STUDY

The previous sections discuss the development of the FOURFIT technique and a computer code written for the purpose of performing that technique numerically. Consideration of fidelity through low pass filtering suggested that more information could be culled from data records through more extended analysis. Specifically, it was hypothesized that high pass filtering and possibly band pass filtering of the data and of the nuclear waveforms could prove insightful. For example, different frequency regimes of the simulated waveform may represent a different equivalent peak pressure and/or yield for systems with sensitivity in those frequency regimes.

An extended version of FOURFIT was written to include high pass and band pass filters. As in the low pass filter, these filter types were two pole recursive digital Butterworth filters. Extensive analysis into the effects of these filters on the Speicher-Brode waveform was undertaken. A band pass filtered ideal waveform of Figure 21 is shown in Figure 73. It can be seen that the band pass filter drastically alters the form of the signal. This most likely is due not only to a removal of low frequency power, but also to phase shifting.

Although low pass filtering left the final airblast impulse virtually unaffected, it is obvious from Figure 73 that the impulse and, hence, the power of the original signal are reduced. Several attempts were made to correlate this reduction in power to various factors. Comparisons using varying high pass cutoff and low pass cutoff combinations with various $P_{50}/W$ pairs failed to produce any promising
results. These comparisons included studies of the filtered peaks (both positive phase and negative phase peaks) and of impulse (both positive phase and total impulses).

High pass filter studies were more promising than those regarding the band pass filter. Figure 74 presents a high pass filtered waveform from Figure 21. Although the waveform is altered similar to the effect of the band pass filter, a correlation between the filtered trace and the filter was developed. Before discussing this effect, it must first be noted that recursive digital filters are a function of the data time step as well as of the cutoff frequency and the number of filter poles. It was found that the time step dependence is an important factor for a high pass filter of a waveform such as the nuclear airblast pulse (i.e., sudden rise to peak). With this in mind, several Speicher-Brode waveforms of various peak pressure and yield combinations were calculated with the same time step for each and were then filtered at various high pass cutoff levels. Figure 75 shows the effect of cutoff frequency on the scaled peak of the filtered ideal waveform. The curve applies for all yields and represents the high pass filter peak attenuation curve for data with a sampling rate of 100 kHz (the sampling rate of the 0.35 KBAR DISC HEST). The application of the attenuation curve to the data analysis is described below.

Given the time step of the data to be analyzed, a table of values for Speicher-Brode peak attenuation as a function of those cutoff frequencies listed in the input deck (TAPES) must be developed. This array of information is then added to the code. Then, in the process of running FOURFIT, the data must be high pass filtered and the filtered
record peaks stored. Next, the code determines a best fit Speicher-Brode and a fidelity frequency. For all systems with sensitivities below this value, the equivalent fit is a valid loading function. Systems sensitive to frequencies higher than the fidelity frequency will experience a different loading function. This different function is determined by reference to the high pass attenuation table for the ratio of filter peak to $P_{so}$ for the specific fidelity frequency just determined. Through this value, the high pass loading function is determined by the following relation:

$$\frac{(P_{HPD})_{FF}}{(Stored \ Ratio)_{FF}} = P_{soHP}$$

or

$$\frac{(P_{HPD})_{FF}}{(P_{HPB}/P_{so})_{FF}} = P_{soHP}$$

(9)

where $P_{HPD}$ = the peak of the high pass filtered data

$P_{HPB}$ = the peak of the high pass filtered Speicher-Brode

$P_{soHP}$ = the high pass equivalent Speicher-Brode for the data record.

The subscript FF refers to the respective values at the fidelity frequency.

No yield dependence was found in this study. Therefore, the high pass equivalent waveform is assigned a yield identical to that of the low pass equivalent waveform. Figure 76 presents a plot of record AB-5 from 0.35 KBAR DISC HEST with its FOURFIT comparison. The high pass equivalent peak overpressure is identified on the plot along with the information listed previously with FOURFIT plots. Figure 77 compares the data record high pass filtered at the fidelity frequency to the high pass equivalent Speicher-Brode filtered at the same cutoff frequency. These waveforms are seen to compare quite well.

The results of high pass equivalency have not been adequately tested. In addition, more investigation into yield dependence is
warranted. For example, Reference 10 discusses a method for removing the phase shift resulting from a filter. Application of this technique may prove useful. Therefore, though the work is promising, the FOURFIT code as presented in Appendix A does not include the capabilities discussed in this section.
SECTION 6
CONCLUSIONS AND RECOMMENDATIONS

Ambiguity and uncertainty in performing evaluations of airblast simulation records have suggested the need for a methodology to achieve consistent and meaningful analysis of such data. Previous studies (Refs. 1, 2, 3) have shown that the FOURFIT technique meets most requirements.

Until the present, FOURFIT has been used to graphically determine a best fit ideal nuclear waveform for a simulation record based upon comparison of the data Fourier amplitude spectrum to a set of normalized Fourier amplitude spectra derived from the formulations for the ideal nuclear airblast pressure history (i.e., "New Brode" or Speicher-Brode). In addition to providing consistent estimates for equivalent nuclear yield and peak overpressure for records from a single event, the frequency analysis provides considerable insight into the frequency content of the data relative to the ideal nuclear. Furthermore, the FOURFIT methodology allows for determination of a "fidelity" frequency. This frequency indicates a cutoff whereby systems with frequency sensitivity at or below that level experience a good simulated loading defined by the equivalent nuclear fit determined for the record. Above that frequency, the simulation breaks down.

The computer code FOURFIT, and its companion plotting routine FOURPLT, provide an automated method for fitting which allows for rapid analysis of records while eliminating analyst bias. In addition, the code allows for studies of individual records and of Speicher-Brode waveforms by allowing the analyst to specify a fast Fourier transform and integrated
impulse or low pass filtering of either type of waveform. These codes were written for use on the Defense Nuclear Agency CDC Cyber 176 computer.

The results of the application of these codes for analysis of two simulation events, 0.35 KBAR DISC HEST and 0.35 KBAR HEST indicates that the code is capable of determining nuclear fits for the records of the former of these events which compare favorably to those determined previously using the graphical methodology. It must be noted, however, that the 0.35 KBAR DISC HEST data base consisted of high fidelity, Speicher-Brode-like pulses. Data from the second event, 0.35 KBAR HEST, were not of such high fidelity. These records were analyzed graphically in the study of Reference 3 and at the time were found to be difficult to fit due to their poor fidelity marked by obvious diversions from the ideal nuclear wave shape. The FOURFIT code managed to fit several of the records rather well. However, in some cases the poor data waveforms caused the fit and the data to show poor agreement at late time. Closer examination of such records may enable better fits to be defined. However, it is not possible to automate a consistent method for fitting non-typical waveforms.

Finally, a study into the usefulness of high pass and band pass filtering yielded mixed conclusions. Although no important results were recovered from the band pass filter study, some limited insight was provided through high pass filtering. The extent of this effort was limited in the study of high pass filter effects and so was not totally conclusive. However, this study indicated that a high frequency equivalent nuclear waveform may be estimated through application of high pass filters.
Several recommendations may be made in view of the preceding comments. For example, when the available data from an event proves to be of low fidelity relative to the ideal nuclear waveform, a means for determining guidelines for pursuing the fitting of such data needs to be developed. Variable weighting schemes for the squared difference values may allow the analyst to better address the different power regimes in such signals. This analysis would be performed on a case by case basis.

Next, it is recommended that the FOURFIT code be applied to define record fidelity in addition to the low pass filter definition of fidelity frequency. It is suggested that the methodology may be expanded to enable quantification of fidelity and that, with increasing interest in the development of a high fidelity HEST, a set of fidelity guidelines may be established based upon a scheme of sum of differences between the data and its best fit Fourier amplitude spectrum. Various guidelines, as a function of frequency range, may help to determine the relative fidelity of various so-called Hi-Fi HEST candidates.

The fits to the normalized Speicher-Brode Fourier amplitude spectra have only been checked between peak pressure values of 1 MPa and 200 MPa. There is increased interest in higher overpressure regimes, on the order of 600 MPa and above. It is, therefore, recommended that the ability to fit simulated overpressure pulses in that range be demonstrated and/or developed. This would require a study of the Speicher-Brode Fourier amplitude equations to determine additional parametric validity up to, say, 1000 MPa.
It is recommended that the effects of high pass filtering on ideal and simulated nuclear overpressure histories be studied further. The high pass equivalency technique discussed in this report may perhaps be extended to evaluate the influence of high pass filters on estimates of equivalent yield for the high pass fit. This might be accomplished through use of the "zero phase shift" filter as discussed in Reference 10.

Finally, it is recommended that the computer program FOURFIT be used to determine equivalent nuclear yield and peak overpressure for all future simulation events.
LIST OF REFERENCES


4. Speicher, S.J. and Brode, H.L., Airblast Overpressure Analytic Expressions for Burst Height, Range and Time--Over an Ideal Surface, PSR Note 385, Pacific-Sierra Research Corp., Los Angeles, CA, November 1981, as modified for time of arrival at high overpressures by memo from S.J. Speicher, Pacific-Sierra Research Corp, 7 June 1982.


10. Carleton, H.D., Digital Filters for Routine Data Reduction, Miscellaneous Paper N-70-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, March 1970.
APPENDIX A

LISTING OF PROGRAM FOURFIT

PROGRAM FOURFIT(INPUT, OUTPUT, TAPE5, INPUT, TAPE6, OUTPUT, TAPE2, TAPE26, TAPE48)

**COMMON**

/FFT / FRQ(3001), AMP(3001), XFFT(3001)

/TERAT/ W(5), P(5), DELTAW(5), DELTAP(5), YLD(5)

/THIST / TIM(6000), PRESS(6000), TIMP(2999), PIMP(2999), PFILT(6000)

/IMP / IIMP, DT, DTB, TPEB, DTBN

/POINTS/ NEPTS, NEPTS, WI, NEF, NEF

/ESTIM / PSI(I), WI, PP, W15, PSDF, WP, FSO

/PEAK / DP, TA, PSO, ALPF

/SECONS/ RSKFT, Y5, E, XM

/FILT / IFILT, FLO(7), PFDM(7), PFM(7)

/PLOT / ITL(8), ILSL(6), IDE

/COUNT / ICOUNT, IOPT, IFILT

/UNITS / UNITS

/COINT / ICOUNT, IOPT, LFILT

/COMPLEX / XFFT

/TAPE2 CONTAINS INPUT PARAMETERS /

NEPTS = NO. OF POINTS TO BE READ FROM TAPE

JUNITS = 1 FOR TAPE INPUT PRESSURE IN PSI

JUNITS = 1 FOR TAPE INPUT PRESSURE IN MPa

JUNITS = 1 FOR TAPE INPUT TIME IN MILISECONDS

PSO1 = INITIAL PEAK OVERPRESSURE ESTIMATE IN MPa

WI = INITIAL NUCLEAR YIELD ESTIMATE IN KT

IOPT = 1: FITTING ROUTINE TO BE DONE

= 2: JUST FOURIER TRANSFORM THE DATA

= 3: JUST FOURIER TRANSFORM THE SPEICHER-BRODE

DEFINED BY PSO1, WI

IFILT = 1 FOR FILTER TO BE EXECUTED

=*1 FOR NO FILTER

FLO = LOW PASS CUTOFF FREQUENCY IN HZ (UP TO 7 ALLOWED)

(NOTE: FOR LESS THAN 7 FILTERS, FLO MUST BE SET TO 0. TO ESCAPE THE LOOP.)

REWIND 2

READ(2, 111) NEPTS, JUNITS, JUNITS

READ(2, 112) PSI, WI

READ(2, 113) IOPT, IFILT

READ(2, 115) (FLO(I), I=1, 7)

111 FORMAT(3I5)

112 FORMAT(2F5.2)

113 FORMAT(2F5.1)

115 FORMAT(7F10.0)

WRITE(6, 1) PSI, WI

1 FORMAT(2X, PSI = *, F5.2, 5X, WI = *, F5.2)

WRITE(48, 113) IOPT, IFILT

ICOUNT = 0

NEPTS = 2048

1F1 IOPT EQ. 3) GO TO 7

CALL EBREAD

1F1 IOPT EQ. 2) GO TO 886

CALL FIT

7 ICOUNT = 1

CALL RANGE

CALL SPBRODE

886 END
SUBROUTINE EBRAD

*  THIS SUBROUTINE READS PRESSURE VALUES FROM AN
*  EBCDIC TAPE BASED UPON THE FORMAT PREVIOUSLY
*  USED BY WES.

COMMON /FFT/ FRQ(3001), AMP(3001), XFFT(3001)
COMMON /PGNITS/ NEPTS, NBPTS, NI, NEF, NEF
COMMON /THIST/ TTIM(6000), PRESS(6000), TIMP(2999), PIMP(2999).
COMMON /FILT/ IFILT, FLLO(7), PFDMX(7), PFDMX(7)
COMMON /IMP/ IMPDotted, DPEB, DPTN
COMMON /UNITS/ JUNITS, UNITS
COMMON /PLTOV/ ITL(B), ITL(1), ITL(1), ITL(1), ITL(1), ITL(1)
COMMON /COUNT/ ICOUNT, IOPT, LFFILT
COMPLEX XFFT
DIMENSION DUM(3), DA(5)

DELP IS THE DATA BASELINE SHIFT. BE
SURE THAT IT IS IN THE PROPER UNITS.
DELP = 0.0
REWIND26

READ TAPE HEADER INFORMATION

READ(26, 30) ITL(3), ITL(4),
             * DUM(1), DUM(2),
             * ITL(1), ITL(2),
             * DTD, NP
30 FORMAT(3(2A10), E15.8, 5)

ITL(5) = 10H PRESSURE
ITL(6) = 10H HISTORY
ITL(7) = 10H
ITL(8) = 10H
WRITE(49, 35) (ITL(L), L = 1, 8)
35 FORMAT(8A10)
DO 20 J = 1, NEPTS
     TTIM(I) = 0.
     PRESS(I) = 0.
20 CONTINUE
IF(EOF(26)) 900, 901

SET UP DATA UNITS CONVERSIONS.
MSEC TO SEC AND PSI TO MPA.
901 IF(JUNITs GE 1) DTD = DTD * 0.01
     PFCS = 0.006894757
     IF(JUNITs LT 0) PFCS = 1.
     IF = 1
     TIME = 0.
     NLINE = NEPTS/5
     FLINE = FLOAT(NEPTS)/5.
     IF(RLINE GT NLINE) NLINE = NLINE + 1

READ PRESSURE VALUES

DO 40 J = 1, NLINE
     READ(26, 50) (DA(JJ), JJ = 1, 5)
50 FORMAT(5E16.8)
     IF(EOF(26)) 900, 902
902 DO 60 K = 1, 5
     TTIM(IP) = TIME
     P = DAK
     PRESS(IP) = (P * PFCS) + DELP
     IF = IF + 1
     TIME = TIME + DTD
60 CONTINUE
40 CONTINUE

SPLINE THE END OF THE DATA TO ZERO IN
CASE OF A TRUNCATED RECORD
TLAST = TTIME(NEPTS),
CALL SPLINE(TLAST, NEPTS, TTIM, PRESS)

50
C IF IOPT = 1, FIND THE TIME TO DATA
C PEAK TO AID IN PHASING THE OVERLAYS.
C AID IN PHASING OVERLAYS
PMAX = 0.
DO 78 IK = 1, NEPTS
   PMAX = AMAXI(PMAX, PRESS(IK))
   IF(PMAX .EQ. PRESS(IK)) TRED = TIM(IK)
78 CONTINUE
C REMOVE BASELINE CORRECTION FOR POINTS
BEFORE THE ARRIVAL OF THE SHOCK
DO 77 M = 1, NEPTS
   IF(TIM(M) .GT. TRED) GO TO 990
   PRESS(M) = PRESS(M) + DELP
77 CONTINUE
C DO TO 990
900 WRITE(6, 70)
70 FORMAT(10, *, END OF FILE REACHED EARLY...)
990 CONTINUE
C CALL FOR FILTERS TO BE EXECUTED
CALL FMAX(PRESS, NEPTS, YPMN, YPMX)
CALL FMAX(TIM, NEPTS, XPMN, XPMX)
WRITE(48, 100) NEPTS, XPMN, XPMX, YPMN, YPMX
IF(IFILT .LT. 0) GO TO 700
C CALL FOR IMPULSE TO BE EXECUTED
CALL FLOOP(TIM, PRESS, DTD, NEPTS, PFILT)
RETURN
C IMPLUSE
CALL IMPULSE(JIMP, DTD, NEPTS, NJ)
IF(IOPT .NE. 2) GO TO 110
ITL(5) = 10H IMPULSE H
ITL(6) = 10H STORY
WRITE(48, 115) ITL(5), ITL(6)
CALL FMAX(TIM, NI, XIMN, XIMP)
CALL FMAX(PIMP, NI, YIMN, YIMP)
WRITE(48, 105) (TIMP(JH), JH = 1, NI)
WRITE(48, 105) (PIMP(JH), JH = 1, NI)
110 FORMAT(2A10)
C FIND THE FOURIER TRANSFORM AND CALCULATE AMPLITUDE.
C TDT = DTD + NEPTS
C FREQUENCY INCREMENT
DFE = 1./TDT
FOE = 0.
C FOURIER TRANSFORM
CALL FFTRC(PRESS, NEPTS, XFFT, WKE, WKE)
XRE = REAL(XFFT(1))/(2*NEPTS)
XIE = AIMAG(XFFT(1))/(2*NEPTS)
FOE = FGE + DFE
C AMPLITUDE SPECTRUM
FRO(1) = FOE
AMP(1) = SORT(2, *(XRE*XRE+XIE*XIE)*TDT)
NEF = NEPTS/2+1
DO 80 JK = 2, NEF
   FQE = FOE + DFE
   FRO(JK) = FQE
   XRE = REAL(XFFT(JK))/NEPTS
   XIE = AIMAG(XFFT(JK))/NEPTS
   AMP(JK) = SORT(XRE*XRE+XIE*XIE)*TDT
80 CONTINUE
C
IF(IDPT.NE.2) RETURN
ITL(5) = 10M FOURIER A
ITL(6) = 10M AMPLITUDE S
ITL(7) = 10M SPECTRUM
CALL FMAX(FRO.NEF.XFMN, XFMX)
CALL FMAX(AMP.NEF.YFMN, YFMX)
WRITE(48, 117) ITL(5), ITL(6), ITL(7)
117 FORMAT(3A10)
WRITE(48, 10) NEF.XFMN.XFMX
WRITE(49, 105) (FRO(LI).LI=1.NEF)
WRITE(48, 105) (AMP(JI).JI=1,NEF)
RETURN
END

SUBROUTINE FIT
C
C............................
C
C THIS SUBROUTINE ITERATES ON YIELD WITHIN ITERATIONS ON
C PEAK PRESSURE. ITS AIM IS TO REDUCE THE SUM OF THE SQUARES
C OF THE DIFFERENCE BETWEEN THE DATA AMPLITUDE AT F(I) AND
C THE ESTIMATED SPEICHER-BRODE AMPLITUDE AT F(I) DIVIDED
C BY F(I) BASED UPON A TOLERANCE ON PEAK PRESSURE AND YIELD.
C END RESULT IS A FINAL ESTIMATE OF PEAK OVERPRESSURE
C (PSOF) AND YIELD (WF). ALSO, AN ESTIMATE OF THE GOODNESS
C OF FIT (DELL) IS DETERMINED. PRESSURE IS IN MPA, YIELD IS
C IN KT.
C
C COMMON /POINTS/ NEPTS, NBPTS, NI, NEF, NEF
C COMMON /ESTIM/ PSOI, WI, PP, W13, PSOF, WF, FSQ
C COMMON /ITERAT/ W(5), P(5), DELTAW(5), DELTAP(5), YLD(5)
C COMMON /FIT/ FRQ(3001), AMP(3001), XFFT(3001)
C COMMON /PEAK/ DP, TA, PSO, ALPF
C DATA TOL/.01/
C
C P(1) = 1-PSOI
C P(2) = 4-PSOI
C P(3) = 1.0-PSOI
C P(4) = 4.0-PSOI
C P(5) = 10.0-PSOI
C JPRESS = 0
C
C LOOP ON PRESSURE TOLERANCE
C DO 100 JJ=1,50
C JPRESS = JPRESS+1
C JMIN = 2
C JMAX = 4
C IF(JPRESS.NE.1) GO TO 105
C JMIN = 1
C JMAX = 5
C
C LOOP ON PRESSURE
C 105 DO 200 II=JMIN.JMAX
C PP = P(II)
C JYLD = 0
C W(1) = 0.1*WI
C W(2) = 0.4*WI
C W(3) = 1.0*WI
C W(4) = 4.0*WI
C W(5) = 10.0*WI
C
C LOOP ON YIELD TOLERANCE
C DO 250 KK=1,50
C JYLD = JYLD+1
C IMIN = 2
C IMAX = 4
C IF(JYLD.NE.1) GO TO 255
C IMIN = 1
C IMAX = 5
C
C LOOP ON YIELD
C 255 DO 300 LL=IMIN.IMAX
C W13 = W(II)**.33333
C IF(ILL NE.1) GO TO 256
C CALL RANGE
C
**DETERMINATION OF RESIDUALS**

256\[ \text{DELTAW(\text{LL})} = 0 \]

230\[ \text{CONTINUE} \]

**RESET YIELDS**

250\[ \text{CONTINUE} \]

**RESET PRESSURES**

100\[ \text{CONTINUE} \]

**SUBROUTINE AMPALG(FSCL,BAMP)**

-- **COMMON /ESTIM/ PSO1,W1,PP, W13,PSDF,WF,FSO**

\[ A1 = 0.1788 \times PP^{(-0.72)} \times (FSCL^{(-1.02)}) \]
\[ A2 = 0.01474 \times PP^{(-0.15)} \times (FSCL/FSO)^{(-1.75)} \]
\[ A3 = 0.0011 \times PP^{(-0.234)} \times (FSCL/FSO)^{(-2.51)} \]
\[ A4 = 0.00001 \times PP^{(-0.975)} \times (FSCL/FSO)^{(-7.5)} \]
\[ A5 = 0.00001 \times PP^{(-0.975)} \times (FSCL/FSO)^{(-7.5)} \]
\[ \text{ASCL = A1-A2+A3-A4-A5-A6} \]

**END**
**SUBROUTINE RESETW**

***************

**THIS SUBROUTINE RESETS THE FIVE YIELD VALUES BASED UPON THIS ITERATION'S MINIMUM RESIDUAL.**

***************

COMMON /ITERAT/ W(5), P(5), DELTAW(5), DELTAP(5), YLD(5)

**C**

**FIND THE MINIMUM DELTA**

IF(DELTAW(5).LT.DEltaw(4)) GO TO 10
IF(DELTAW(4).LT.DEltaw(3)) GO TO 20
IF(DELTAW(3).LT.DEltaw(2)) GO TO 30
IF(DELTAW(2).LT.DEltaw(1)) GO TO 40

**REDEFINE YIELDS BASED UPON THE MINIMUM**

IF DELTAW(1) IS MIN.,
DYLD = (W(2)-W(1)) * 0.25
W(5) = W(2)
DELTAW(5) = DELTAW(2) 
GO TO 50

IF DELTAW(5) IS THE MINIMUM,
10  DYLD = (W(5)-W(4)) * 0.25
W(1) = W(4)
DELTAW(1) = DELTAW(4) 
GO TO 50

IF DELTAW(4) IS THE MINIMUM,
20  DYLD = (W(5)-W(3)) * 0.25
W(1) = W(3)
DELTAW(1) = DELTAW(3) 
GO TO 50

IF DELTAW(3) IS THE MINIMUM,
30  DYLD = (W(4)-W(2)) * 0.25
W(1) = W(2)
W(5) = W(4)
DELTAW(1) = DELTAW(2)
DELTAW(5) = DELTAW(4) 
GO TO 50

IF DELTAW(2) IS THE MINIMUM,
40  DYLD = (W(3)-W(1)) * 0.25
W(5) = W(3)
DELTAW(5) = DELTAW(3) 
GO TO 50

50  W(2) = W(1)+DYLD
W(3) = W(2)+DYLD
W(4) = W(3)+DYLD
RETURN

END

**SUBROUTINE RESEP**

***************

**THIS SUBROUTINE RESETS THE FIVE PRESSURE VALUES BASED UPON THIS ITERATION'S MINIMUM RESIDUAL.**

***************

COMMON /ITERAT/ W(5), P(5), DELTAW(5), DELTAP(5), YLD(5)

**C**

**FIND THE MINIMUM DELTAP**

IF(DELTAP(5).LT.DEltap(4)) GO TO 10
IF(DELTAP(4).LT.DEltap(3)) GO TO 20
IF(DELTAP(3).LT.DEltap(2)) GO TO 30
IF(DELTAP(2).LT.DEltap(1)) GO TO 40

**REDEFINE PRESSURES BASED UPON THE MINIMUM**

IF DELTAP(1) IS THE MINIMUM,
DPRESS = (P(2)-P(1)) * 0.25
P(5) = P(2)
W(5) = W(2)
DELTAP(5) = DELTAP(2) 
GO TO 50

RETURN
C IF DELTAP(5) IS THE MINIMUM.
10 DPRESS = (P(5)-P(4))*0.25
   P(1) = P(4)
   W(1) = W(4)
   DELTAP(1) = DELTAP(4)
   GO TO 50
C IF DELTAP(4) IS THE MINIMUM.
20 DPRESS = (P(5)-P(3))*0.25
   P(1) = P(3)
   W(1) = W(3)
   DELTAP(1) = DELTAP(3)
   GO TO 50
C IF DELTAP(3) IS THE MINIMUM.
30 DPRESS = (P(4)-P(2))*0.25
   P(5) = P(2)
   W(5) = W(2)
   DELTAP(5) = DELTAP(2)
   GO TO 50
C IF DELTAP(2) IS THE MINIMUM.
40 DPRESS = (P(3)-P(1))*0.25
   P(5) = P(3)
   W(5) = W(3)
   DELTAP(5) = DELTAP(3)
   GO TO 50
C
50 P(2) = P(1)+DPRESS
   P(3) = P(2)+DPRESS
   P(4) = P(3)+DPRESS
   RETURN
END
SUBROUTINE RANGE

C THIS SUBROUTINE IS AN ITERATION TO FIND THE RANGE
C OF THE ESTIMATED PEAK PRESSURE FOR THE ESTIMATED
C YIELD. THIS IS NECESSARY FOR COMPUTATION OF THE
C SPEICHER-BRODE PRESSURE HISTORY, TIME OF ARRIVAL
C AND POSITIVE PHASE DURATION.

C COMMON /ESTIM/ PSO, WI, PP, W13, PSOF, WF, FS
COMMON /PEAK/ DP, TA, PSO, ALPF
COMMON /SBCONS/ RSKF, YS, S, XM
COMMON /COUNT/ ICOUNT, IP, LFIL
C C INITIAL RANGE SPREAD
IF (IOPT.NE.3) GO TO 78
   PP = PSO
   W13 = WI*0.33333
78 R1 = 0.01
   R2 = 0.1
   R3 = 1.0
   R4 = 10.
C C MOB EQUAL TO ZERO
   Y = 0.
   YS1 = 0.
   YS2 = 0.
   YS3 = 0.
   YS4 = 0.
   DO 100 I=1, 1000
      RS1 = R1/W13
      RS2 = R2/W13
      RS3 = R3/W13
      RS4 = R4/W13
C C CALCULATE PSO FOR EACH TRIAL SCALED RANGE
   CALL PPEAK(RS1, YS1, P1)
DPI i

CAL PPA, RS2, YS2, P2)
DP2 = DP
CALL PPA, RS3, YS3, P3)
DP3 = DP
CALL PPA, RS4, YS4, P4)
DP4 = DP

FIND BOUNCING RANGES
IF (PP GT P2 AND. PP LT P1) GO TO 110
IF (PP GT P3 AND. PP LT P2) GO TO 120
IF (PP GT P4 AND. PP LT P3) GO TO 130
WRITE (E, ' (140)
1110 FORMAT (2X, 'PRESSURE OUT OF RANGE')
STOP 11
110 BETWEEN R1 AND R2
R2 = (R2 - R1) / 3.
R4 = R2
R2 = R1 + DR
GO TO 99
120 BETWEEN R2 AND R3
R3 = (R3 - R2) / 3.
R1 = R2
R4 = R3
R2 = R1 + DR
GO TO 99
130 BETWEEN R3 AND R4
R3 = (R4 - R3) / 3.
R1 = R3
R4 = R2
R3 = R2 + DR
99 IF (R4 - R1) LE. .001) GO TO 101
100 CONTINUE
WRITE (6, 1100)
1100 FORMAT (2X, 'FAILED TO CONVERGE ON RANGE')
WRITE (6, 1200) 1
1200 FORMAT (2X, 'I = * .15)
WRITE (6, 1201) PP, R1, R4
STOP 12
101 RAKFT = (R1 + R2 + R3 + R4) * 0.25
RSKFT = RAKFT/W13
DP = (DP1 + DP2 + DP3 + DP4) * 0.25
F5O = 1.414 (DP 1000)
IF (IPCOUNT NE. 1) GO TO 103
TASEC = * TA 1000) * W13
DPCC = (DP 1000) * W13
ENSAM = RAKFT * 304E
PSO'F = PP
W13 = W13 * W13
103 CONTINUE
WRITE (6, 1102) PP, W13, R1, R2, R3, R4, F5O, W13, TASEC, DPCC
1102 FORMAT (2E 15.8)
1103 FORMAT (12E 15.8)
1104 FORMAT (12E 15.8)
C WRITE FINAL RESULTS TO OUTPUT FILE
WRITE (6, 1102) PP, W13, R1, R2, R3, R4, F5O, W13, TASEC, DPCC
1102 FORMAT (12E 15.8)
C WRITE (6, 1103) PP, W13, R1, R2, R3, R4, F5O, W13, TASEC, DPCC
1103 FORMAT (12E 15.8)
C WRITE (6, 1104) PP, W13, R1, R2, R3, R4, F5O, W13, TASEC, DPCC
1104 FORMAT (12E 15.8)
C RETURN
56
SUBROUTINE PPEAK(X,Y,PEAKP)
*****************************************************************************
THIS SUBROUTINE CALCULATES THE PEAK OVERPRESSURE (MPA),
TIME OF ARRIVAL (TA, MS/ KT**1/3), AND POSITIVE PHASE
DURATION (DP, MS/ KT**1/3) AFTER SPEICHER-BRODE, JUNE, 1982.
*****************************************************************************

COMMON /PEAK/, /DP.TA.PSD,ALPF/
COMMON /SCONS/, /RSKFT.YS.S.XM/

XLAST = 1.E-9
YLAST = 1.E-9
ZMXX = 100.
IF(X.LT.XLHAST) X = XLAST
IF(Y.LT.YLAST) Y = YLAST
R = SQRT(X*X+Y*Y)

Z = Y/X
Z2 = Z+Z
Z3 = Z2+Z
Z5 = Z2+Z3
Z17 = Z+17.
Z18 = Z+18.

IF(Z.GT.ZMAX) Z = ZMAX

XM = 170. Y/(1.+37.*Y**25)+.914*Y**2.5

SCALED TIME OF ARRIVAL

U1 = (.543-21.8+R+386.*R2+2383.*R3+R8)
U2 = .996+1.91*10^2+1.002*6+R4+4.43*E6*6+R6
U3 = (1.028+2.087+R2.69+R2+R8)
U1A = U1/(U2+U3)
TA = U1A
IF(X.LT.XM) GO TO 101

W1 = (1.086-34.605R+4863.*R2+2383.*R3+R8)
W2 = (3.0137E-13-1.2138E-9+R+4.128E-6+R4-1.116E5+R6
W3 = (1.639+2.029+R+692+R2+R8)
W1A = W1/(W2+K3)
TA = U1A*X/(X+TA+1.0)*X+W1A/(1.-XM/X)

SCALED POSITIVE PHASE DURATION

101 S = 1.-1.1E10*Y7/(1.+1.1E10*Y7)-(2.44*E-8*Y*Y/ 
* (1.+9.1E10*Y7)+(1.1.41*11*X**10.))
DP = ((1640700.+24629.+TA+416.15+TA+TA)/ 
* (1.0880.619.76+TA+TA+TA))
* *(4.+0.01204*(TA**1.5)/(1.+0.001559*TA**1.5)+ 
* (.0426+.5466*(TA**.25)/(1.+0.00367*TA**1.5)))+S)

AA = 1.22D-(3.908+22)/(1.+810.2+25)
BB = 2.321+1218/(1.+1.113+218)+6.195/(0.03831+217)/ 
* (1.+0.02415+217)+6.692/(1.+4.64+2+8.)
CC = 4.152^-1.15+218)/(1.+6.41+218)-1.1/(1.+2.77+2+2.5)
DD = -4.239+15+2.7+1.75/(1.+1.36+218+6.257+2/(1.+5.219+2)
EE = 1-(0.0462+2+218)/(1.+0.0386+218)
FF = 6.096D12.879+Z+9.25)/(1.+2.35+2+14.5)+17.15+22/
* (1.+7.16+23)
GG = 1.83+5.36+22*(1.+3.139+2+6.)
HH = -16.67+25+2.905/(1.+4.15+218)+1.389+Z/(1.+49.03+25)+ 
* (8.808+2+1.5)/(1.+154.5+2+3.5)+1.0014+R2/(1.+68+R+ 
* .0486*R+1.5-0.00002+R2))]*(1.+12.7+Y)

PEAK OVERPRESSURE
PD = 10.047/(R**AA)+BB/(R**CC)+DD+EE/(1.+FF*R**GG)+HH
PEAKP = PD*.00394757
RETURN
END

57
SUBROUTINE SPBRODE
******************************************************************************
THIS SUBROUTINE CALCULATES THE PRESSURE HISTORY FOR
THE FINAL PRESSURE-YIELD PAIR DETERMINED BY SUBROUTINE
FIT. IT USES THE SPEICHER-BRODE JUNE, 1982 ALGORITHM
******************************************************************************

COMMON /THIST/ TTIM(6000),PRESS(6000),TIMP(2999),PIMP(2999),
         PFFT(6000)
COMMON /FFT/ FRQ(3001),AMP(3001),XFFT(3001)
COMMON /ESTIM/ PSDT,W1,PP,W13,PSDF,WF,FSO
COMMON /PEAK/ DP,TA,PSO,ALPF
COMMON /FILT/ IFILT,FLD(7),PFDMX(7),PFBMX(7)
COMMON /SBCONS/ RSKFT,YS,S,XM
COMMON /POINTS/ NEPTS,NI,NEF,NEF
COMMON /IMP/ IMP,DTD,DTB,TPBDTBN
COMMON /COUNT/ ICOUNT,IOPT,LFILT
COMMON /PLDTV/ ITL(8),ISTL(8),IDB
COMPLEX *FFT
DIMENSION IWK(11)
DATA JCOUNT/0/

IF(IOPT.NE.3) GO TO 5
ITL(1) = 10H
ITL(2) = 10H
ITL(3) = 10H
ITL(4) = 10H
ITL(5) = 10H
ITL(6) = 10H
ITL(7) = 10H
ITL(8) = 10H
WRITE(4B,26) (ITL(IO),IO-1,8)
26 FORMAT(BA10)

CALCULATE SPEICHER-BRODE TIMESTEP BASED
UPON THE POSITIVE PHASE DURATION.
DTB = DP/NEPTS
GO TO 15
5
ISTL(1) = 10H
ISTL(2) = 10H
ISTL(3) = 10H
ISTL(4) = 10H
ISTL(5) = 10H
ISTL(6) = 10H
ISTL(7) = 10H
ISTL(8) = 10H
WRITE(4B,26) (ISTL(IO),IO-1,8)
CALL FMAX(PRESS,NEPTS,YPMN,YPMX)
CALL FMAX(TTIM,NEPTS,XPXM,XPXM)
WRITE(4B,210) (TTIM(IU),IU=1,NEPTS)
WRITE(4B,210) (PRESS(IP),IP=1,NEPTS)
200 FORMAT(15.4E15.8)
210 FORMAT(10E15.8)
ICOUNT = 0

FIND THE PEAKS OF THE LOW PASS
FILTERED DATA PRESSURE HISTORIES
DO 7 I=1,7
    CALL FILTER(DTD,NEPTS)
    CALL FMAX(IFILT,NEPTS,PFDMN,PFDMX(I))
7 CONTINUE
ICOUNT = 1

CALCULATE SPEICHER-BRODE TIME STEP BASED
UPON THE DATA TIME STEP FOR FILTERING
DTB = DTD/1000./W13

CALCULATE THE SPEICHER-BRODE TIME STEP BASED
UPON THE POSITIVE PHASE DURATION FOR OVERLAYS
35 IF(JCOUNT.EQ.1) DTB = DP/NEPTS
15 DO 25 KJ=1,NEPTS
    TTIM(KJ) = 0.
    PRESS(KJ) = 0.
25 CONTINUE

58
X = RSKFT
TF = TA*DP
PO = PSOF*145.038
F = (.01477*(TA**2.5))/(1.+.005836*TA)+7.402E-5*(TA**2.5)/
(1.+1.429*TA+4.75)-3.076*TA+7.076*TA/5*
TA+TA*TA/(1.+4.367E-5*TA+TA**2)
G = 10.+(77.58-64.99*(TA**2.5))/(1.+0.04386*SORT(TA))+S
H = 2.753+.05601*TA/(1.+.4736*9+TA**2.5)+(0.1769*TA/
(1.+3.207E-10*TA**4.25)-.03209*(TA**1.25)/(1.+9.914E-8*
TA**.4.75)-1.6)*S+
I = TA*(TA**2*TA/(1.+4.367E-5*TA**2))
J = G10.e(77.58-54.99*(TA-.1.25)/(1.+9.914E-8/
(1.+.04348*10.25)-.03209*(TA-.1.25)/
(1.+9.914E-8**2.3))**S+
C = CALCULATE PRESSURE HISTORY

DO 400 J = 1, NEPTS
   T = TA+(J-2)*DTB
C = SAVE UNSCALED TIMES

   TTIM(J) = T=W13/1000.
   PRESS(J) = 0.
   IF(T.LT.TA) GO TO 400
   IF(T.GT.TF) GO TO 410
   B = (F-(TA/T)**G*(1.-F)*(TA/T)**H)*(1.-T/T/DP)
   POFT = PO+E
   IF(Y.LT.XM. OR Y.GT.0.38) GO TO 390
   X = 3.039**/(1.-6.*Y)
   E = AES(1./XM)/(E-Y))
   IF(E.GT.50.) E = 50.
   D = 23-583000.*.27**/(26667.+1.E6+.Y)**.27*(1.5-583000.*Y**/
   A = (1.-1.*(1.-E**20.))/(1.+E**20.)
   DT = 474.2**Y**((-2))**1.25
   IF(DT.LT.1.E-9) DT = 1.E-9
   GA = (T-TA)/DT
   IF(GA.GT.400.) GA = 400.
   V = (1.-3.28E11*(Y**6.))/(1.+1.5E12*(Y**6.75))*(GA-GA/GA/
(6.13*GA-GA**11.)/(1.+8.23E4))**1.25
   C = ((1.04-240.9*(X**4.))/(1.+231.7*X**4.4))**((GA**7.)/
(1.-.923*GA**8.5***(1.+A)))*((1.-((T-T)/DP)**8.)**2.3E13**Y**9.)/(1.+2.3E13**Y**9)
   POFT = PO+(1.+A)*E+V+C
   390 PRESS(J) = POFT/145.
   400 CONTINUE
C = 410 JCOUNT = JCOUNT+1
C = UNSCALE THE SPEICHER-BRODE TIMESTEP

   DTNN = DTB=W13/1000.
   IF(JCOUNT.GT.1 OR IDPT.EQ.3) GO TO 900
C = FIND THE PEAKS OF THE LOW PASS FILTERED
C = SPEICHER-BRODE PRESSURE HISTORIES

   LFILT = 0
   DO 17 J = 1,7
      CALL FILTER(DTEN,NEPTS)
      CALL FMAX(PFILT,NEPTS,PFBM(J))
      17 CONTINUE
C = FIND THE LOW PASS FIDELITY FREQUENCY

   DO 27 K = 1,7
      PFMAX = FMAX(K)*0.90
      IF(PFMAX.LE.PFBM(K)) GO TO 47
   27 CONTINUE
   WRITE(6,37)
   37 FORMAT(2X,*** FAILED TO LOCATE LOW PASS FIDELITY ****)
      ALPF = -.999
      WRITE(48,57) ALPF
      GO TO 35
   47 ALPF = FLO(K)
      WRITE(48,57) ALPF
   57 FORMAT(F10.0)
      WRITE(6,67) ALPF
   67 FORMAT(2X,*** LOW PASS FIDELITY (HZ) = *,F10.0,***)
   IF(JCOUNT.EQ.1) GO TO 35
DETERMINE NUMBER OF SPEICHER BRODE PAIRS TO BE PLOTTED FOR OVERLAY

\[ 900 \text{TE} = \text{NEPTS-DTD} \]
\[ \text{NPPTS} = \text{FIX}(\text{TE} / \text{DTBN}) \]
\[ \text{IF} (\text{IOPT} . EQ. 3) \text{NPPTS} = \text{NBPTS} \]
\[ \text{WRITE}(48,450) \text{NPPTS} \]

450 FORMAT(15)
\[ \text{IF} (\text{IOPT} . EQ. 3) \text{GO TO 810} \]

AFFECT A TIME SHIFT IN SPEICHER-BRODE HISTORY TO ALLOW THE OVERLAY TO BE PROPERLY PHASED
\[ \text{TSHFT} = (\text{TA}-\text{W13}/1000) - \text{TPEB} \]
\[ \text{DO BOO} \text{JT} = 1, \text{NBPTS} \]
\[ \text{TTIM} (\text{JT}) = \text{TTIM} (\text{JT}) - \text{TSHFT} \]
800 CONTINUE

GO TO 130

810 CALL FMXX(TTIM,NPPTS,XPMN,XPMX)
CALL FMXX(PRESS,NPPTS,YPMN,YPMX)
\[ \text{WRITE}(48,840) \text{XPMN}, \text{XPMX}, \text{YPMN}, \text{YPMX} \]

840 FORMAT(4(15.6))
\[ \text{IF} (\text{IFILT} . LT. 0) \text{GO TO 130} \]

CALL FOR FILTERS TO BE EXECUTED
\[ \text{CALL FLDDP}(\text{TTIM}, \text{PRESS}, \text{DTBN}, \text{NBPTS}, \text{PFILT}) \]
RETURN

130 WRITE(48,420) (TTIM(I), I=1, NPPTS)
WRITE(48,420) (PRESS(I), I=1, NPPTS)
\[ \text{IF} (\text{IOPT} . LT. 3) \text{GO TO 850} \]

135 ITL(5) = 10H IMPULSE H
\[ \text{ITL}(6) = 10H HISTORY \]
\[ \text{WRITE}(48,215) \text{ITL}(5), \text{ITL}(6) \]

215 FORMAT(2A10)
CALL FMXX(TIMP,NI,XIMN,XIMX)
CALL FMXX(PIMP,NI,YIMN,YIMX)
\[ \text{WRITE}(48,200) \text{NI}, \text{XIMN}, \text{XIMX}, \text{YIMN}, \text{YIMX} \]

850 IPT = 2
CALL IMPULSE(IPT,DTBN,NPPTS,NI)
\[ \text{WRITE}(48,450) \text{NI} \]
\[ \text{IF} (\text{IOPT} . NE. 3) \text{GO TO 150} \]
\[ \text{ITL}(3) = 10H BRODE IMPU \]
\[ \text{ITL}(4) = 10H HISTOR \]
\[ \text{ITL}(5) = 10HY \]
\[ \text{WRITE}(48,225) \text{ITL}(3), \text{ITL}(4), \text{ITL}(5) \]

225 FORMAT(3A10)
CALL FMXX(TIMP,NI,XIMN,XIMX)
CALL FMXX(PIMP,NI,YIMN,YIMX)
\[ \text{WRITE}(48,840) \text{XIMN}, \text{XIMX}, \text{YIMN}, \text{YIMX} \]

150 WRITE(48,210) (TIMP(KJ), KJ=1, NI)
\[ \text{WRITE}(48,210) (PIMP(KL), KL=1, NI) \]
\[ \text{IF} (\text{IOPT} . LT. 1) \text{GO TO 175} \]

FIND THE FOURIER TRANSFORM AND CALCULATE AMPLITUDE.
\[ \text{ITL}(5) = 10H FOURIER A \]
\[ \text{ITL}(6) = 10H AMPLITUDE S \]
\[ \text{ITL}(7) = 10H SPECTRUM \]
\[ \text{WRITE}(48,225) \text{ITL}(5), \text{ITL}(6), \text{ITL}(7) \]
CALL FMXX(FFR,NEF,XFMN,XFNX)
CALL FMXX(AFP,NEF,YFMN,YFMY)
\[ \text{WRITE}(48,200) \text{NEF}, \text{XFNX}, \text{XFMY}, \text{YFMN}, \text{YFMY} \]
\[ \text{WRITE}(48,210) (\text{FFR}(IO), IO=1, \text{NEF}) \]
\[ \text{WRITE}(48,210) (\text{AFP}(IP), IP=1, \text{NEF}) \]

175 TOTT = DTBN-NBPTS
FREQUENCY INCREMENT
\[ \text{DF} = 1. / \text{TOTT} \]
\[ \text{FGB} = 0. \]
\[ \text{WRB} = 0. \]
\[ \text{NEF} = \text{NBPTS} / 2 + 1 \]
DO 349 LK=1,NBF
FRQ(LK) = 0.
AMP(LK) = C.
FFTR(LK) = 0.
CONTINUE
CALL FFTRC(PRESS,NEPTS, XFFT, WKB, WKB)
C AMPLITUDE SPECTRUM
DO 500 KK=1,NBF
FOB = FOE+DFB
FRQ(KK) = FOB
XRB = REAL(XFFT(KK))/NEPTS
XIB = AIMAG(XFFT(KK))/NEPTS
AMP(KK) = SQRT(XRB*XRB+XIB*XIB)*TOTT
500 CONTINUE
C WRITE(48,450) NBF
IF(IOPT.NE.3) GO TO 165
ITL(3) = 10*HBRD+FOUR
ITL(4) = 10*IER+AMP
ITL(5) = 10*HUM
WRITE(48,235) ITL(3),ITL(4),ITL(5),ITL(6)
235 FORMAT(4A10)
CALL FMAX(FRO,NBF, XFMT, YFMX)
CALL FMAX(AMP,NBF, YFMN, YFMX)
WRITE(48,840) XFMT, YFMX
165 WRITE(48,210) (FRQ(IU), IU=1,NBF)
WRITE(48,210) (AMP(IE), IE=1,NBF)
RETURN
END
SUBROUTINE FLOOP(TTIM,PRESS,DT,NP,PFILT)
C ...
C THIS SUBROUTINE PERFORMS THE LOOPING REQUIRED TO FILTER THE DATA OR THE RODD UP TO SEVEN TIMES. FOR LESS THAN SEVEN FILTER LEVELS, FLD MUST BE SET TO 0. IN THE INPUT DECK IN ORDER TO ESCAPE THE LOOP.
C
C COMMON /FILT/ IFILT,FLD(7),PFDMX(7),PFBMX(7)
DIMENSION TTIM(11),PRESS(1),PFILT(1)
C
DO 750 JF=1,7
IF(FLD(JF),EQ,0.) GO TO 555
IFLAG = 1
WRITE(48,95) IFLAG
95 FORMAT(15)
WRITE(48,96) FLD(JF)
96 FORMAT(F10.0)
DO 725 KF=1,NP
PFILT(KF) = 0.
725 CONTINUE
C CALL TO FILTER
CALL FILTER(DT,NP)
CALL FMAX(PFILT,NP, YFMN, YFMX)
WRITE(48,100) YFMN, YFMX
100 FORMAT(2E15.8)
WRITE(48,105) TTIM(LF), LF=1,NP
WRITE(48,105) (PFILT(MF), MF=1,NP)
105 FORMAT(10E15.8)
750 CONTINUE
555 IFLAG = -1
WRITE(48,95) IFLAG
RETURN
END
SUBROUTINE SPLINE(TLAST, NP, TTIM, PRESS)

C THIS SUBROUTINE SETS UP A COSINE SQUARED SPLINE
FUNCTION AND APPLIES IT TO THE FINAL 15% OF THE
PRESSURE HISTORY TO AVOID A FREQUENCY IMPULSE
IN TRUNCATED RECORDS.

DIMENSION TTIM(1), PRESS(1)

PIE = 3.1415927
K = IFIX(.85*NP)
N = NP-K+1
T1 = TTIM(K)

DO 10 J = 1, N
  TFACT = (TTIM(K)-T1)/(TLAST-T1)
  SFACT = COS(TFACT*PIE-.5)
  PRESS(K) = PRESS(K)*SFACT
  K = K+1
10 CONTINUE
RETURN
END

SUBROUTINE IMPULSE(IIMP, DT, NP, NI)

C THIS SUBROUTINE CALCULATES THE IMPULSE OF THE INPUT
PRESSURE DATA (IIMP = 1) OR OF THE CALCULATED SPEICHER-
BRODE (IIMP = 2) BY SIMPSON'S APPROXIMATION.

COMMON /THIST/ TTIM(6000), PRESS(6000), TIMP(2999), PIMP(2999),
* PFILT(6000)

NTMP = NP-3
NI = NTMP/2

DO 80 I = 1, NI
  TIMP(I) = 0.
  PIMP(I) = 0.
80 CONTINUE

DO 90 J = 3, NTMP/2
  SJ = SJ+1
  TIMP(J) = TTI(M(J))
  AREA = (PRESS(J-1)+4.*PRESS(J)+PRESS(J+1))*DT/3.
  SUMIMP = SUMIMP+AREA
  PIMP(J) = SUMIMP
90 CONTINUE

RETURN
END

SUBROUTINE FILTER(DT, NP)

C THIS SUBROUTINE FILTERS THE INPUT PRESSURE HISTORY
DATA OR SPEICHER-BRODE. IT USES THE DIFFERENCE
EQUATIONS DERIVED FOR A SECOND ORDER BUTTERWORTH
FILTER AS PRESENTED BY STEARNS. 1975

COMMON /THIST/ TTIM(6000), PRESS(6000), TIMP(2999), PIMP(2999),
* PFILT(6000)
COMMON /COUNT/ ICOUNT, IOPT, LFILT
COMMON /FILT/ IFILT, ILOD(7), PFDMX(7), PFBMX(7)
DATA LFILT/0/
PI = 3.1415927
S2 = SORT(2.)
LFILT = LFILT+1

62
LOW PASS FILTER COEFFICIENTS

AT = TAN(PI*FLO(LFILT)*DT)
AT2 = AT-AT
A1 = 1.0+S2+AT+AT2
A = AT2/A1
B1 = 2.0*(AT2-1.0)
B = B1/A1
C1 = 1.0+S2+AT+AT2
C = C1/A1
FAC = 1.0

CALCULATE THE FILTERED HISTORY

150 PFILT(1) = A*PRESS(1)
PFILT(2) = A*(PRESS(2)+2.0*FAC*PRESS(1))-B*PFILT(1)
DO 200 I=3,NP
PC = A*(PRESS(I)+2.0*FAC*PRESS(I-1)+PRESS(I-2))
PFILT(I) = PC-B*PFILT(I-1)-C*PFILT(I-2)
200 CONTINUE
RETURN
END

SUBROUTINE FMAX(ARY,NA,XMN,XMX)

** This subroutine finds the maximums and minimums of the various arrays to be plotted by FOURPLT **

DIMENSION ARY(NA)

XMN = ARY(1)
XMX = ARY(1)
IF(NA .EQ. 1) RETURN
DO 10 I=2,NA
IF(XMN.GT.ARY(I)) XMN = ARY(I)
IF(XMX.LT.ARY(I)) XMX = ARY(I)
10 CONTINUE
RETURN
END
APPENDIX B

FLOW CHART OF PROGRAM FOURFIT

Start

Read Input (TAPE5)

1OPT = ?

Read Data (TAPE26)

1OPT = ?

IFILT = ?

<0

Integrate Data

>0

Filter

End

PREVIOUS PAGE IS BLANK
Filtered Data Peaks

Compute Speicher-Brode $p(t)$

IOPT = ?

IFILT = ?

Filter Speicher-Brode

Filtered Speicher-Brode Peaks

End
Fidelity Frequency

Compare Filtered Peaks (Data vs Speicher-Brode)

Integrate Speicher-Brode

FFT Speicher-Brode

End
APPENDIX C

FLOW CHART OF SUBROUTINE FIT

Data
A(f)

P(J), J = 1,5

W(I), I = 1,5

Range:
R(P(J), W(I))

Speicher-Brode
A(f, P(J), W(I))

ΔA

Revise
P(J), J = 1,5

Revise
W(I), I = 1,5
APPENDIX D

LISTING OF PROGRAM FOURPLT

PROGRAM FOURPLT(INPUT, OUTPUT, TAPE5=INPUT, TAPE6=OUTPUT, TAPE9=OUTPUT)

C PROGRAM FOURPLT WAS WRITTEN TO PLOT THE RESULTS OF PROGRAM FOURFIT. IT READS INPUT ON ASSIGNED FILE TAPE5 AND PLOTS SPEICHER-BRODE OR DATA PRESSURE AND IMPULSE HISTORIES AND FOURIER AMPLITUDE SPECTRA OR PLOTS OVERLAYS IN THESE SAME DOMAINS OF A DATA TRACE AND ITS BEST FIT SPEICHER-BRODE AS DETERMINED BY FOURFIT.


C

COMMON /ESTIM/ PS01, WI, PP, W13, PSOF, WF, FSO
COMMON /PEAK/ DP, TA, PSO, ALPF
COMMON /THIST/ RSHFT, YS, S, XM
COMMON /FILTER/ ITYPE, FLO(?), FHI(?), PFDMX(?), PFBMX(?)
COMMON /COUNT/ ICOUNT, IOPT, LFILT
COMMON /PLT/ ITL(B), ISTALL, IDMX, IDMY
DIMENSION XARY(6000), YARY(6000)

CALL GPLOT(1HU, 7HARADDS, 7)
CALL BGPL(-1)
READ(9,100) IOPT, IFILT
100 FORMAT(215)
IF(IOPT.EQ.3) GO TO 200
READ(9,120) ITL(I), I=1,8
120 FORMAT(8A1)
IF(IOPT.EQ.2) GO TO 200
C
C OPTION 2 (DATA ONLY)
C
READ PRESSURE-TIME PAIRS OR FILTERED PRESSURE-TIME PAIRS
READ(9,130) NEPTS, XPMN, XPMX, YPMN, YPMX
130 FORMAT(15, 4E15.8)
DO 135 IT=1,7
135 IF(IIFILT.LT.0) GO TO 150
READ(9,155) ITL(I)
155 FORMAT(155)
IF(IFLAG.LT.0) GO TO 110
READ(9,172) YPMX, YPMX
172 FORMAT(14C1)
112 CONTINUE
CALL GOONE
STOP
112 CALL DDONE
STOP 11
C
C READ IMPULSE-TIME PAIRS FOR OPTION 2
144 READ(9,145) ITL(5), ITL(6)
READ(9,130) NEI, XIMN, XIMX, YIMN, YIMX
READ(9,140) (XARY(I), I=1, NEI)
READ(9,140) (YARY(I), I=1, NEI)
145 FORMAT(2A10)
CALL PLOTTER(XARY, YARY, NEI, XIMN, XIMX, YIMN, YIMX, 1, 1, 3)
CALL ENDP(-1)
C
C READ AMPLITUDE-FREQUENCY PAIRS FOR OPTION 2
READ(9,254) ITL(5), ITL(6), ITL(?)
READ(9,130) NEF, XFNM, XFMX, YFMN, YFMX
READ(9,140) (XARY(I), I=1, NEF)
READ(9,140) (YARY(I), I=1, NEF)
145 FORMAT(2A10)
CALL PLOTTER(XARY, YARY, NEF, XFNM, XFMX, YFMN, YFMX, 2, 4, 3)
CALL ENDP(-1)
CALL DDONE
STOP 777

71
OPTION 1 (OVERLAY) AND OPTION 3 (SPEICHER-BRODE)

200 READ(9,205) PSOF,WF
READ(9,207) DP.TA,RSKFT
205 FORMAT(2E15.8)
207 FORMAT(3E15.8)
IF(IOPT.NE.1) GO TO 765
READ(9,120) (ISTL(KK),KK=1,8)

READ PRESSURE-TIME PAIRS (DATA)
READ(9,130) NEPTS,XPMN,XPMX,YPMN,YPMX
READ(9,140) (XARY(IIT),IT=1,NEPTS)
READ(9,140) (YARY(IW),IW=1,NEPTS)
READ(9,766) ALPF
766 FORMAT(F10.0)
CALL PLOTTER(XARY,YARY,NEPTS,XPMN,XPMX,YPMN,YPMX,1,1,2,1,2)

READ PRESSURE-TIME PAIRS OR FILTERED
PRESSURE-TIME PAIRS (SPEICHER-BRODE)
765 IF(IOPT.EQ.3) READ(9,120) (ITL(IR),IR=1,8)
READ(9,160) NPPTS
160 FORMAT(15)
IF(IOPT.NE.3) GO TO 768
READ(9,170) XPMN,XPMX,YPMN,YPMX
170 FORMAT(4E15.8)
XPMX = XPMX/4.
NPPTS = NPPTS/4
768 DO 234 MPF=1,7
IF(IOPT.EQ.1 OR IFILT.LT.0) GO TO 171
READ(9,125) JFLAG
IF(JFLAG.LT.O) GO TO 236
READ(9,127) FLO(MF)
READ(9,172) YPMN,YPMX
172 READ(9,140) (XARY(LL),LL=1,NPPTS)
READ(9,140) (YARY(MN),MN=1,NPPTS)

PLOT SPEICHER-BRODE ONLY
IF(IOPT.EQ.3) CALL PLOTTER
* (XARY,YARY,NPPTS,XPMN,XPMX,YPMN,YPMX,1,1,2,1,2)

OVERLAY
IF(IOPT.EQ.1) CALL PLOTTER
* (XARY,YARY,NPPTS,XPMN,XPMX,YPMN,YPMX,-1,1,2,1,2)
CALL ENOPL(-1)
IF(IOPT.EQ.1 OR IFILT.LT.0) GO TO 264
234 CONTINUE
236 CALL GDONE
STOP22

IMPULSE
264 IF(IOPT.EQ.3) GO TO 280

READ IMPULSE-TIME PAIRS (DATA)
READ(9,145) ITL(5),ITL(6)
READ(9,130) NEI,XIMN,XIMX,YIMN,YIMX
READ(9,140) (XARY(NN),NN=1,NEI)
READ(9,140) (YARY(MN),MN=1,NEI)
CALL PLOTTER(XARY,YARY,NEI,XIMN,XIMX,YIMN,YIMX,1,1,3,1,3)

READ IMPULSE-TIME PAIRS (SPEICHER-BRODE)
280 READ(9,160) NIPTS
IF(IOPT.EQ.3) READ(9,254) ITL(3),ITL(4),ITL(5)
254 FORMAT(3A10)
IF(IOPT.EQ.3) READ(9,170) XIMN,XIMX,YIMN,YIMX
READ(9,140) (XARY(IJ),IJ=1,NIPTS)
READ(9,140) (YARY(IJ),IJ=1,NIPTS)

PLOT SPEICHER-BRODE ONLY
IF(IOPT.EQ.3) CALL PLOTTER
* (XARY,YARY,NIPTS,XIMN,XIMX,YIMN,YIMX,1,1,3,1,3)

OVERLAY
NIPTS=NIPTS-1
IF(IOPT.EQ.1) CALL PLOTTER
* (XARY,YARY,NIPTS,XIMN,XIMX,YIMN,YIMX,-1,1,3,1,3)
CALL ENOPL(-1)

72
FOURIER AMPLITUDE
IF(IOPT.EQ.3) GO TO 340

READ AMPLITUDE-FREQUENCY PAIRS (DATA)
READ(9,254) ITL(5),ITL(6),ITL(7)
READ(9,130) NEF,XFMN,XFMX,YFMN,YFMX
READ(9,140) (XARY(KJ),KJ=1,NEF)
READ(9,140) (YARY(JK),JK=1,NEF)
CALL PLOTTER(XARY,YARY,NEF,XFMN,XFMX,YFMN,YFMX,2.5,4,3)

READ AMPLITUDE-FREQUENCY PAIRS (SPEICHER-BRODE)
340 READ(9,160) NEF
IF(IOPT.EQ.3) READ(9,256) ITL(3),ITL(4),ITL(5),ITL(6)
256 FORMAT(4A10) IF(IOPT.EQ.3)
READ(9,170) XFMN,XFMX,YFMN,YFMX
READ(9,140) (XARY(KL),KL=1,NEF)
READ(9,140) (YARY(LK),LK=1,NEF)

SPEICHER-BRODE ONLY
IF(IOPT.EQ.3) CALL PLOTTER
* (XARY,YARY,NEF,XFMN,XFMX,YFMN,YFMX,2.5,4,3)

OVERLAY
IF(IOPT.EQ.1) CALL PLOTTER
* (XARY,YARY,NEF,XFMN,XFMX,YFMN,YFMX,1.5,4,3)
CALL ENDPLT(-1)
CALL GDONE
END

SUBROUTINE PLOTTER(XARY,YARY,NEF,XFMN,XFMX,YFMN,YFMX,2.5,4,3)
* COMMON /ESTIM/ PSO1,WP,PSOF,WF,FSO
COMMON /PEAK/ DP,TA,PSO,ALPF
COMMON /FILT/ IFILT,ITYPE,FLO(7),FHI(7),PFDMX(7),PFEM(7)
COMMON /THIST/ RSKFT,YS,5,XM
COMMON /COUNT/ ICOUNT,IOPT,LFILT
COMMON /PLOTV/ ITL(8),ISTL(8),IDB
DIMENSION XARY(NP),YARY(NP),LABS(6,2),LEND(4,2),LABX(4),
* LABY(4)
DATA (LABS(J,1),J=1,2) /10H TIME /
DATA (LABS(J,2),J=1,2) /10H PRESSURE /
DATA (LABS(J,3),J=1,2) /10H IMPULSE /
DATA (LABS(J,4),J=1,2) /10H AMPLITUDE /
DATA (LABS(J,5),J=1,2) /10H FREQUENCY /
DATA (LABS(J,6),J=1,2) /10H RADIANS /

WRITE(6,2300) NP,XMN,XMX,YMN,YMX,KIND
2300 FORMAT(5X,ENTERED PLOTTER *,/.
* +NP,XMN,XMX,YMN,YMX,KIND = *,15,4(1X,F7.4),15)
CALL HEIGHT(0.1)
IF(KIND.LT.0) GD TO 200

DO 10 I=1,2
LABX(I) = LABS(LBLX,I)
LABY(I) = LABS(LBLY,I)
10 CONTINUE
LABX(3) = LEND(NITSX)
LABY(3) = LEND(NITSY)

IF(KIND.EQ.2) GD TO 100

**** IF KIND.EQ.1 THEN PLOT IS LINEAR-LINEAR ****

50 LINET = 0
LINES = 0
C  CALL SCLI(XMN,XMX,XORG,XSTP,XEND)
C  CALL SCLI(YMN,YMX,YORG,YSTP,YEND)
WRITE(6,2303) XORG,XSTP,YEND
CALL RLINEX(XORG,XSTP,YEND,LABX,LABY)
CALL DRAWC(XARY,YARY,NP,LINET,LINES)
GO TO 400
C
C  ***** IF KIND.EQ.2 THEN PLOT IS LOG-LOG *****
C
100 LINET = 0
LINES = 0
C
CALL SCL2(XMN,XMX,XCYC,KIND)
IF(KIND.EQ.1) GO TO 50
CALL SCL2(YMN,YMX,YCYC,KIND)
IF(KIND.EQ.1) GO TO 50
WRITE(6,2305) XCYC,YCYC
2305 FORMAT(2X.*LOG-LOG PLOT *)
CALL LOGLL(XORG,YORG,YCYC,LABY)
CALL DRAWC(XARY,YARY,NP,LINET,LINES)
GO TO 400
C
C  ***** IF KIND.LT.0 THEN PLOT AN OVERLAY *****
C
200 LINET = LINET+1
WRITE(6,2307)
2307 FORMAT(5X.*OVERLAY PLOT *)
CALL BLOFF(IDB)
CALL MESSAG(I5HLOW PASS FILTER.15.6.5.1.0)
CALL MESSAG(I5HFCUTOFF (HZ) = 15.6.5.1.0.75)
CALL REALNO(FLOMLILT1,1.8.2.0.75)
300 IF(IOPT.EQ.2) GO TO 900
CALL MESSAG(I5HTOA (SEC) = 15.6.5.4.5)
TAA = TA+0.001*(WF-0.3333333)
CALL REALNO(TAA,5.8.2.4.5)
IF(IDPT.NE.1) GO TO 900
WRITE(6,666) IOPT
666 FORMAT(2X,****IOPT**,15)
CALL MESSAG(I5HLOW PASS FID (HZ) = 20.6.5.4.25)
CALL REALNO(ALPF,0.8.2.4.25)
C
900 CONTINUE
RETURN
END
SUBROUTINE FMAX(ARY, NA, XMN, XMX)
    DIMENSION ARY(NA)

    WRITE(6, 2300)
2300 FORMAT(5X, SUBROUTINE FMAX(), 5X, XMN = ARY(1), XMX = ARY(1))
    IF(NA.EQ.1) RETURN
    DO 10 I = 2, NA
        IF(XMN.GT.ARY(I)) XMN = ARY(I)
        IF(XMX.LT.ARY(I)) XMX = ARY(I)
    10 CONTINUE

    RETURN
END

SUBROUTINE SCL1(XMN, XMX, ASTP, AORG, AMA)
    DIMENSION S(7)

    WRITE(6, 2300) XMN, XMX
2300 FORMAT(5X, SUBROUTINE SCLI(XMN, XMX, SCL), 5X, .2(FS.4, 2X))
    SMIN = 0.00006
    S(1) = 0.00012
    S(2) = 0.00018
    S(3) = 0.00024
    S(4) = 0.00030
    S(5) = 0.00036
    S(6) = 0.00060
    S(7) = 0.00120

    DIF = XMN - XMX
    IF(DIF.LT.S(1)) GO TO 90
    5 CONTINUE
    DO 10 I = 1, 7
        IF(DIF.LT.S(I)) GO TO 30
    10 D0 20 J = 1, 7
    20 Sb(I) - S(J) - 10.0
    IF(S(I).GT.1.0E15) STOP 111
    GO TO 5

    30 DMAX = S(IU)
    DSTP = DMAX/6.0

    DETERMINE OFFSET

    IF(XMN.LT.0.0) GO TO 60
    DORG = 0.0
    IF(XMN.LT.DSTP) GO TO 99
    OFFSET = DSTP
    35 OFFSET = OFFSET + DSTP
    IF(XMN.GT.OFFSET) GO TO 35
    DORG = OFFSET - DSTP
    DMAX = DMAX + DORG
    GO TO 99

    60 OFFSET = 0.0
    65 OFFSET = OFFSET - DSTP
    IF(XMN.LT.0.0) GO TO 65
    OFFSET = OFFSET
    DMAX = DMAX + DORG
    IF(XMN.LT.DSTP) GO TO 65
    IF(IU.LT.1) DMAX = S(IU-1)
    IF(IU.EQ.1) DMAX = S(1) - XCN
    DSTP = DMAX/6.0
    GO TO 60

    DIFFERENCE IS ZERO

    90 CONTINUE
    DORG = XMN - SMIN
    DMAX = XMN + SMIN
    DSTP = SMIN/3.0

    75
SUBROUTINE SCL2(XMN,XMX,AORG,ACYC,KIND)
C SCALE FOR LOG-LOG PLOTS
C
WRITE(6,2300) XMN,XMX
2300 FORMAT(5X,*LEAVING SCL2 *,3(F8.2X))
C RETURN
END

SUBROUTINE DRAWC(X,Y,NP,LINET,LINES)
DIMENSION X(NP),Y(NP)
C
WRITE(6,2300) NP,LINET,LINES
2300 FORMAT(5X,*ENTER DRAWC *,3(F8.2X))
C RETURN
END
SUBROUTINE RLINER(XORG,XSTP,XEND,YORG,YSTP,YEND,LABX,LABY)
COMMON /COUNT/ ICOUNT,IOPT,LFILT
COMMON /PLOTV/ ITL(8),ISTL(8),IDB
DIMENSION LABX(3),LABY(3)
C
WRITE(6,2500)
2500 FORMAT(1X,ENTERED RLINER..............)
CALL PAGE(10,5,0,5)
CALL PHYS(10,5,0,5)
CALL XNAME(LABX,30)
CALL YNAME(LABY,30)
CALL ARE(6,0,6,0)
IF(IOPT.EQ.1) CALL BLREC(4,4,5,5,1,6,0,5,1,0)
IF(IOPT.EQ.1) CALL BLKEY(IDB)
CALL MESSAG(80,0,0,6,5)
CALL GRAF(XORG,XSTP,XEND,YORG,YSTP,YEND)
CALL DOT
CALL GRID(1,1)
CALL RESET(3HDOT)
C
RETURN
END

SUBROUTINE LOGLLL(XOR,XY,VAR,YVAR,LABX,LABY)
COMMON /COUNT/ ICOUNT,IOPT,LFILT
COMMON /PLOTV/ ITL(8),ISTL(8),IDB
DIMENSION LABX(3),LABY(3)
C
WRITE(6,2300)
2300 FORMAT(1X,ENTERED LOGLLL..............)
CALL PAGE(10,5,0,5)
CALL PHYS(10,5,0,5)
CALL XNAME(LABX,30)
CALL YNAME(LABY,30)
CALL ARE(6,0,6,0)
IF(IOPT.EQ.1) CALL BLREC(4,4,5,5,1,6,0,5,1,0)
IF(IOPT.EQ.1) CALL BLKEY(IDB)
CALL MESSAG(80,0,0,6,5)
CYS = XCY
IF(YCY.LT.XCY) CYC = YCY
CALL LDGLDG(XOR,XY,VAR,YVAR,XYZ)
CALL DOT
CALL GRID(1,1)
CALL RESET(3HDOT)
C
RETURN
END
THIS PAGE IS INTENTIONALLY LEFT BLANK
Figure 1. Typical HEST pressure history.
Figure 2. Fourier amplitude spectrum for typical HEST record.
Figure 3. Normalized Brode pressure histories.
Figure 4. Normalized Brode Fourier amplitude spectra.
Figure 5. Overlay of first iteration fit to Fourier amplitude spectrum of the HEST record shown in Figure 1 with Brode spectra.
Figure 6. Pressure history for HEST record compared with final fit; $P_{so} = 2.95$ MPa, $W = 5.05$ KT.
Figure 7. Impulse history for HEST record compared with final fit; $P_{s0} = 2.95$ MPa, $W = 5.05$ KT.
Figure 8. Fourier amplitude spectrum for HEST record compared with final fit; $P_{so} = 2.95$ MPa, $W = 5.05$ KT.
Figure 9. Normalized low pass filtered Brode pressure histories; $P_{so} = 10$ MPa.
Figure 10. Normalized low pass filtered Brode impulse histories; $P_{so} = 10$ MPa.
Figure 11. Overlay of typical HEST record filtered peaks compared with normalized filtered Brode peaks.
Figure 12. FOURFIT pressure history compared with example HEST record.
Figure 13. Normalized Speicher-Brode pressure histories.
Figure 16. Example FOURFIT output for IOPT = 1: automated fit to 0.35 KBAR DISC HEST record AB-5 (Speicher-Brode parameters listed on file OUTPUT).
Figure 17
Example FOURFIT output for IOPT = 2, IFILT = -1:
0.35 KBAR DISC HEST record AB-5 pressure history.
Figure 18
Example FOURFIT output for IOPT = 2, IFILT = -1: 0.35 KBAR DISC HEST record AB-5 impulse history.
Figure 19
Example FOURFIT output for IOPT = 2, IFILT = -1:
0.35 KBAR DISC HEST record AB-5 Fourier amplitude spectrum.
Figure 20
Example FOURFIT output for
IOPT = 2, IFILT = 1,
FLO = 1000.: 0.35 KBAR DISC
HEST record AB-5 low pass
filtered pressure history.
CALCULATED SPEICHER-BRODE PRESSURE HISTORY

YIELD (KT) - 0.87
PSO (MPa) - 39.60
RANGE (KM) - 0.02475
POS. PHASE (SEC) - 0.14297
TOA (SEC) - 0.00153

Figure 21
Example FOURFIT output for
IOPT = 3, IFILT = -1: Speicher-Brode \((P_{SO} = 39.60\, \text{MPa}, W = 0.87\, \text{KT})\) pressure history.
Figure 22

Example FOURFIT output for
1OPT = 3, IFILT = -1:
Speicher-Brode ($P_{SO} =$
39.60 MPa, $W = 0.87$ KT)
impulse history.
CALCULATED SPEICHER-BRODE FOURIER AMPLITUDE SPECTRUM

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>YIELD (KT)</td>
<td>0.87</td>
</tr>
<tr>
<td>PSO (MPA)</td>
<td>39.60</td>
</tr>
<tr>
<td>RANGE (KM)</td>
<td>0.02475</td>
</tr>
<tr>
<td>POS. PHASE (SEC)</td>
<td>0.14297</td>
</tr>
<tr>
<td>TOA (SEC)</td>
<td>0.00153</td>
</tr>
</tbody>
</table>

Figure 23

Example FOURFIT output for
IOPT = 3, IFILT = -1: Speicher-Brode ($P_S = 39.60$ MPa,
$W = 0.87$ KT) Fourier amplitude spectrum.
CALCULATED SPEICHER-BRODE PRESSURE HISTORY

Figure 24

Example FOURFIT output for
IOPT = 3, IFILT = 1, FLO = 1000.: Speicher-Brode (P_{SO} = 39.60 MPa,
W = 0.87 KT) low pass filtered pressure history.

LOW PASS FILTER
FCUTOFF (HZ) = 1000.
0.35 Kbar disc HEST AB-5

WITH FOURFIT SPEICHER-BRODE

PRESSURE HISTORY

YIELD (KT) = 0.87
PSG (MPA) = 39.60
RANGE (KM) = 0.02477
POS. PHASE (SEC) = 0.14328
TOA (SEC) = 0.00154
LOW PASS FID (HZ) = 1000.

Figure 25

Example FOURFIT output for
ILOPT = 1: automated fit to
0.35 Kbar disc HEST record AB-5
pressure history comparison.
Example FOURFIT output for KBAR DISC HEST record AB-5 impulse history comparison.
Figure 27

Example FOURFIT output for
IOPT = 1: automated fit to
0.35 KBAR DISC HEST record AB-5
Fourier amplitude spectrum
comparison.
0.35 KBAR DISC HEST AB-5
WITH FOURFIT SPEICHER-BRODE

PRESSURE HISTORY

Filtered Peak (Fit)
Filtered Peak (Data)

DATA
FIT

YIELD (T) = 0.87
PSC (MPA) = 39.60
RANGE (KM) = 0.02477
POS. PHASE (SEC) = 0.14306
TOA (SEC) = 0.00154
LOW PASS FID (HZ) = 1000.

Figure 28
0.35 KBAR DISC HEST record AB-5
and FOURFIT automated fit:
fidelity frequency low pass
filter comparison.

LOW PASS FILTER
FCUTOFF (HZ) = 1000.
0.35 KBAR DISC HEST AB-3
WITH FOURFIT SPEICHER-BRODE

PRESSURE HISTORY

DATA
FIT

YIELD (KT) - 1.07
PSO (MPA) - 41.45
RANGE (KM) - 0.02608
POS. PHASE (SEC) - 0.15250
TOA (SEC) - 0.00158
LOW PASS FID (HZ) - 5000.

Figure 29
FOURFIT automated fit to 0.35 KBAR DISC HEST record AB-3: pressure history comparison.
0.35 KBAR DISC HEST AB-3
WITH FOURFIT SPEICHER-BRODE

IMPLE HISTORY

DATA
FIT

YIELD (KT) = 1.07
PSO (MPA) = 41.45
RANGE (KM) = 0.02608
POS. PHASE (SEC) = 0.15250
TOA (SEC) = 0.00158
LOW PASS FID (HZ) = 5000.

Figure 30
FOURFIT automated fit to
0.35 KBAR DISC HEST record
AB-3: impulse history
comparison.
FOURIERFIT automated fit to 0.35 KBAR DISC HEST record
AB-3: Fourier amplitude spectrum comparison.
0.35 KBAR DISC HEST AB 4
WITH FOURFIT SPEICHER-BROOC

PRESSURE HISTORY

YIELD (KT) = 1.16
PSG (MPA) = 37.32
RANGE (KM) = 0.02775
POS. PHASE (SEC) = 0.15789
TOF (SEC) = 0.00178
LOW PASS FID (HZ) = 500.

Figure 32
FOURFIT automated fit to 0.35 KBAR DISC HEST record
AB-4: pressure history comparison.
0.35 KBAR DISC HEST AB-4
WITH FOURFIT SPEICHER-GROOTE

DATA
FIT

YIELD (KT) - 1.16
PSO (MPA) - 37.32
RANGE (KM) - 0.02775
POS. PHASE (SEC) - 0.15789
TOA (SEC) - 0.00178
LOW PASS FID (HZ) - 500.

Figure 33
FOURFIT automated fit to 0.35 KBAR DISC HEST record AB-4
impulse history comparison.
FOURFIT automated fit to 0.35 KBAR DISC HEST record AB-4: Fourier amplitude spectrum comparison.
0.35 KBAR DISC HEST AB-7
WITH FOURFIT SPEICHER-BROSCE

PRESSURE HISTORY

<table>
<thead>
<tr>
<th>DATA</th>
<th>---</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIT</td>
<td>---</td>
</tr>
</tbody>
</table>

YIELD (kT) - 0.97
PSC (MPa) - 35.00
RANGE (KM) - 0.02676
POS. PHASE (SEC) - 0.14970
TOA (SEC) - 0.00178
LOW PASS FID (HZ) - 2000.

Figure 35
FOURFIT automated fit to 0.35 KBAR DISC HEST record AB-7: pressure history comparison.
0.35 KBAR DISC HEST AB-7
WITH FOURFIT SPEICHER-BRODE

IMPULSE HISTORY

DATA FIT

YIELD (KT) - 0.97
PSO (MPA) - 35.00
RANGE (KM) - 0.02676
POS. PHASE (SEC) - 0.14970
TOA (SEC) - 0.00178
LOW PASS FID (HZ) - 2000.

Figure 36

FOURFIT automated fit to 0.35 KBAR DISC HEST record AB-7: impulse history comparison.
0.35 KBAR DISC HEST AB-7
WITH FOURFIT SPEICHER-ERNOE

FOURIER AMPLITUDE SPECTRUM

DATA
FIT

YIELD (KT) - 0.97
PSO (MPA) - 35.00
RANGE (KM) - 0.02676
POS. PHASE (SEC) - 0.14970
TOA (SEC) - 0.00178
LOW PASS FID (HZ) - 2000.

Figure 37
FOURFIT automated fit to 0.35 KBAR DISC HEST record AB-7:
Fourier amplitude spectrum comparison.
Figure 38
FOURFIT automated fit to 0.35 KBAR DISC HEST record AB-9: pressure history comparison.
0.35 KBAR DISC HEST AB-9
WITH FOURFIT SPEICHER-GEODE

IMPULSE HISTORY

DATA
FIT

YIELD (KT) - 0.66
PSO (MPA) - 32.89
RANGE (KM) - 0.02408
POS. PHASE (SEC) - 0.1324
TOR (SEC) - 0.00166
LOW PASS FID (HZ) - 5000.

Figure 39
FOURFIT automated fit to 0.35 KBAR DISC HEST record
AB-9: impulse history comparison.
0.35 KBAR DISC HEST AB-9
WITH FOURFIT SPEICHER-ERODE

FOURIER AMPLITUDE SPECTRUM

YIELD (KT) - 0.66
PSO (MPA) - 32.89
RANGE (KM) - 0.02408
POS. PHASE (SEC) - 0.13241
TOA (SEC) - 0.00166
LOW PASS FID (HZ) - 5000.

Figure 40
FOURFIT automated fit to 0.35 KBAR DISC HEST record AB-9: Fourier amplitude spectrum comparison.
0.35 KBAR DISC HEST AB-10
WITH FOURFIT SPEICHER-BROOC

0.35 KBAR DISC HEST AB-10
WITH FOURFIT SPEICHER-BROOC

YIELD (KT) - 0.99
PSD (MPA) - 41.71
RANGE (KM) - 0.02542
POS. PHASE (SEC) - 0.14882
TOA (SEC) - 0.00153
LOW PASS FID (HZ) - 2000.

Figure 41
FOURFIT automated fit to 0.35
KBAR DISC HEST record AB-10:
presence history comparison.
Figure 42

FOURFIT automated fit to
0.35 KBAR DISC HEST record
AB-10: impulse history comparison.

YIELD (KT) = 0.99
PSC (MPa) = 41.71
RANGE (KM) = 0.02542
POS. PHASE (SEC) = 0.14882
TOA (SEC) = 0.00153
LOW PASS FID (HZ) = 2000.
Figure 43

FOURIER automated fit to 0.35 KBAR DISC HEST record
AB-10: Fourier amplitude spectrum comparison.

YIELD (KT) = 0.99
PSG (MPA) = 41.71
RANGE (KM) = 0.02542
POS. PHASE (SEC) = 0.14882
TOA (SEC) = 0.00153
LOW PASS FL (HZ) = 2000.
0.35 KBAR DISC HEST AB-12
WITH FOURFIT SPEICHER-BRODE

PRESSURE HISTORY

YIELD (KT) - 0.57
PSO (MPA) - 40.83
RANGE (KM) - 0.02132
POS. PHASE (SEC) - 0.12409
TOA (SEC) - 0.00130
LOW PASS FID (HZ) - 500.

Figure 44
FOURFIT automated fit to 0.35 KBAR DISC HEST record AB-12: pressure history comparison.
0.35 KBAR DISC HEST AB-12
WITH FOURFIT SPEICHER-BRODE

DATA
FIT

YIELD (KT) - 0.57
PSD (MPA) - 40.83
RANGE (KM) - 0.02132
POS. PHASE (SEC) - 0.12409
TOA (SEC) - 0.00130
LOW PASS FID (HZ) - 500.

Figure 45
FOURFIT automated fit to
0.35 KBAR DISC HEST record
AB-12: impulse history
comparison.
0.35 KBAR DISC HEST AB-12 
WITH FOURFIT SPEICHER-BRODE

FOURIER AMPLITUDE SPECTRUM

DATA 
FIT

YIELD (KT) - 0.57
PSO (MPA) - 40.83
RANGE (KM) - 0.02132
POS. PHASE (SEC) - 0.12409
TOR (SEC) - 0.00130
LOW PASS FID (HZ) - 500.

Figure 46
FOURFIT automated fit to 0.35 KBAR DISC HEST record AB-12: Fourier amplitude spectrum comparison.
0.35 KBAR DISC HEAT AB-13
WITH FOURFIT SPEICHER-BRODE

PRESSURE HISTORY

DATA
FIT

YIELD (KT) - 0.73
PSC (MPA) - 41.71
RANGE (KM) - 0.02294
POS. PHASE (SEC) - 0.13427
TOA (SEC) - 0.00138
LOW PASS FID (HZ) - 1000.

Figure 47
FOURFIT automated fit to 0.35 KBAR DISC HEAT record AB-13: pressure history comparison.
0.35 KBAR DISC HEST AB-13
WITH FOURFIT SPEICHER-BRODE

IMPULSE HISTORY

DATA
FIT

YIELD (Kt) - 0.73
PSO (MPA) - 41.71
RANGE (KM) - 0.02294
POS. PHASE (SEC) - 0.13427
TOA (SEC) - 0.00138
LOW PASS FID (HZ) - 1000.

Figure 48
FOURFIT automated fit to
0.35 KBAR DISC HEST record
AB-13: Impulse history
comparison.
FOURFIT automated fit to 0.35 KBAR DISC HEST record AB-13: Fourier amplitude spectrum comparison.
Figure 50
FOURFIT automated fit to
0.35 KBAR HEST record 51:
pressure history comparison.
Figure 51

FOURFIT automated fit to 0.35 KBAR HEST record 51: impulse history comparison.
Figure 52
FOURFIT automated fit to 0.35 KBAR HEST record 51: Fourier amplitude spectrum comparison.
Figure 53

0.35 KBAR HEST record 417: pressure history.
0.35 KBAR HEST record 417: Fourier amplitude spectrum.
FOURFIT automated fit to 0.35 Kbar HEST record 417. Fourier amplitude spectrum comparison.
0.35 KBAR HEST  417
WITH FOURFIT SPEICHER-BRODE

PRESSURE HISTORY

DATA
FIT

YIELD (KT) - 2.71
PSO (MPA) - 13.99
RANGE (KM) - 0.05132
POS. PHASE (SEC) - 0.21951
TOA (SEC) - 0.00571
LOW PASS FID (HZ) - 1000.

Figure 56
FOURFIT automated fit to 0.35 KBAR HEST record 417: pressure history comparison.
0.35 KBAR HEST 417
IMPULSE HISTORY
WITH FOURFIT SPEICHER-BRODE

YIELD (KT) - 2.71
PSD (MPA) - 13.99
RANGE (KM) - 0.05132
POS. PHASE (SEC) - 0.21951
TOA (SEC) - 0.00571
LOW PASS FID (HZ) - 1000.

Figure 57
FOURFIT automated fit to 0.35 KBAR HEST record 417: impulse history comparison.
0.35 KBAR HEST  411
WITH FOURFIT SPEICHER-BRODE

PRESSURE HISTORY

DATA

FIT

YIELD (KT) - 2.67
PSO (MPA) - 13.89
RANGE (KM) - 0.05125
POS. PHASE (SEC) - 0.21867
IOA (SEC) - 0.00572
LOW PASS FID (HZ) - 1000.

Figure 58

FOURFIT automated fit to 0.35 KBAR HEST record 411: pressure history comparison.
Figure 59
FOURFIT automated fit to 0.35 KBAR HEST record 411:
impulse history comparison.
0.35 KBAR HEST 411

FOURIER AMPLITUDE SPECTRUM
WITH FOURFIT SPEICHER-BRODE

YIELD (KT) - 2.67
PSO (MPA) - 13.89
RANGE (KM) - 0.05125
POS. PHASE (SEC) - 0.21867
TOA (SEC) - 0.00572
LOW PASS FID (HZ) - 1000.

Figure 60
FOURFIT automated fit to 0.35 KBAR HEST record 411: Fourier amplitude spectrum comparison.
0.35 KBAR HEST  418
WITH FOURFIT SPEICHER-BRODE

PRES sure HIST ORY

YIELD (KT) - 0.80
PSQ (MPA) - 15.28
RANGE (km) - 0.03315
POS. PHASE (SEC) - 0.14587
TOR (SEC) - 0.00351
LOW PASS FID (HZ) - 1000.

Figure 61
FOURFIT automated fit to 0.35 KBAR HEST record 418: pressure history comparison.
Figure 62
FOURFIT automated fit to 0.35 KBAR HEST record 418: impulse history comparison.
FOURFIT AMPLITUDE SPECTRUM
WITH FOURFIT SPEICHER-BRODE

0.35 KBAR HEST  418

DATA
FIT

YIELD (KT) = 0.80
PSO (MPA) = 15.28
RANGE (KM) = 0.03315
POS, PHASE (SEC) = 0.14587
TOR (SEC) = 0.00351
LOW PASS FID (HZ) = 1000.

Figure 63
FOURFIT automated fit to 0.35 KBAR HEST record 418: Fourier amplitude spectrum comparison.
0.35 KBAR HEST
WITH FOURFIT SPEICHER-BRODE

PRESSURE HISTORY

DATA
FIT

YIELD (KT) = 0.74
PSO (MPA) = 14.47
RANGE (KM) = 0.03293
POS. PHASE (SEC) = 0.14239
TOA (SEC) = 0.00360
LOW PASS FID (HZ) = 1000.

Figure 64
FOURFIT automated fit to 0.35 KBAR HEST record 419: pressure history comparison.
0.35 KBAR HEST 419
WITH FOURFIT SPEICHER-BRODE

Figure 65
FOURFIT automated fit to 0.35 KBAR HEST record 419: impulse history comparison.

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
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<tbody>
<tr>
<td>YIELD (KT)</td>
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<tr>
<td>PSO (MPA)</td>
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<tr>
<td>RANGE (KM)</td>
<td>0.03293</td>
</tr>
<tr>
<td>POS. PHASE (SEC)</td>
<td>0.14239</td>
</tr>
<tr>
<td>TOA (SEC)</td>
<td>0.00360</td>
</tr>
<tr>
<td>LOW PASS FID (HZ)</td>
<td>1000</td>
</tr>
</tbody>
</table>
Figure 66
FOURFIT automated fit to 0.35 KBAR HEST record 419: Fourier amplitude spectrum comparison.

YIELD (KT) - 0.74
PSO (MPA) - 14.47
RANGE (KM) - 0.03293
POS. PHASE (SEC) - 0.14239
TOA (SEC) - 0.00360
LOW PASS FID (HZ) - 1000.
0.35 KBAR HEST 54 PRESSURE HISTORY
WITH FOURFIT SPEICHER-BRODE

YIELD (KT) - 0.50
PSO (MPA) - 17.46
RANGE (KM) - 0.02714
POS. PHASE (SEC) - 0.12453
TOA (SEC) - 0.00268
LOW PASS FID (HZ) - 2000.

Figure 67
FOURFIT automated fit to 0.35 KBAR HEST record 54: pressure history comparison.
FOURFIT automated fit to 0.35 KBAR HEST record 54: impulse history comparison.
 FOURIER AMPLITUDE SPECTRUM
WITH FOURFIT SPEICHER-BRODE

YIELD (KT) - 0.50
PSQ (MPA) - 17.46
RANGE (KM) - 0.02714
POS. PHASE (SEC) - 0.12453
TOA (SEC) - 0.00268
LOW PASS FID (HZ) - 2000.

Figure 69
FOURFIT automated fit to 0.35 KBAR HEST record 54: Fourier amplitude spectrum comparison.
0.35 KBAR HEST  55
WITH FOURFIT SPEICHER-BRODE

IMPULSE HISTORY

DATA
FIT

YIELD (KT) = 1.23
PSO (MPA) = 16.61
RANGE (KM) = 0.03726
POS. PHASE (SEC) = 0.16835
TOA (SEC) = 0.00378
LOW PASS FID (Hz) = 2000.

Figure 71
FOURFIT automated fit to 0.35 KBAR HEST record 55: impulse history comparison.
FOURFIT automated fit to 0.35 KBAR HEST record 55: Fourier amplitude spectrum comparison.

YIELD (KT) - 1.23
PSD (MPA) - 16.61
RANGE (KM) - 0.03726
POS. PHASE (SEC) - 0.16835
TOA (SEC) - 0.00378
LOW PASS FID (HZ) - 2000.
CALCULATED EICHER-BRODE PRESSURE HISTORY

Figure 73
Band pass filtered (FLO = 200, FHI = 1000) Speicher-Brode
(W = 0.87 KT, Pso = 39.60 MPa) pressure history.
Figure 74

High pass filtered ($FHI = 1000$.)
Speicher-Brode ($W = 0.87$ KT,
$P_{so} = 39.60$ MPa) pressure
history.

YIELD (KT) - 0.87
PS0 (MPA) - 39.60
RANGE (KM) - 0.02475
POS. PHASE (SEC) - 0.14297
TOA (SEC) - 0.00153
Figure 75. Effect of high pass filter on peak Speicher-Brode overpressure.
0.35 KBAR DISC HEST AB-5
WITH FOURFIT SPEICHER-DOODE

PRESURE HISTORY

DATA
FIT

YIELD (KT) - 0.87
PSO (MPA) - 39.60
RANGE (KM) - 0.02475
POS. PHASE (SEC) - 0.14297
TIP (SEC) - 0.00153
FIDEL. FREQ. (HZ) - 1000.
HI PASS PSO (MPA) - 48.02

Figure 76
FOURFIT automated fit to 0.35 KBAR DISC HEST record AB-5 noting high pass equivalent peak overpressure.
0.35 KBAR DISC HEST AB-5
WITH FOURFIT SPEICHER-BRODE

PRESSURE HISTORY

DATA ---
FIT ---

YIELD (KT) - 0.87
PSO (MPA) - 48.02
RANGE (KM) - 0.02321
POS, PHASE (SEC) - 0.14081
TOA (SEC) - 0.00129

Figure 77
0.35 KBAR DISC HEST record
AB-5 and FOURFIT automated fit:
fidelity frequency high pass
filter comparison.

HIGH PASS FILTER
FCUTOFF (HZ) - 1000.
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