TECHNICAL REPORT SL-83-4

AN OBJECTIVE WAVEFORM COMPARISON TECHNIQUE

by

George Y. Baladi and Donald E. Barnes

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<td>This report documents the development of objective waveform discrepancy measures for comparing arbitrary transient response histories. The objective waveform discrepancy measures consist of the magnitude correlation factor, the phase-and-frequency correlation factor, the magnitude error, the phase-and-frequency error, and the combined magnitude and phase-and-frequency errors. Their validity and behavior are checked and demonstrated for several simple sinusoidal responses. (Continued)</td>
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20. ABSTRACT (Continued).

The objective discrepancy measures are incorporated into a computer program, named WCT*, which processes digitized data tapes containing measured or calculated waveforms or both. The computer program is used to statistically analyze selected data from the DISC Test I event and objectively compare particle velocity measurements made in DISC Test II with expected value waveforms obtained from probabilistic prediction calculations.

Appendix A of this report presents a flow chart and user's guide for the computer program WCT.

It is recommended that the objective discrepancy measures be used whenever comparisons of two or more waveforms are made. It is also recommended that the technique be extended to objectively quantify differences in laboratory- and field-generated material property test results.

* Waveforms Comparison Technique.
PREFACE

The investigation reported herein was conducted by personnel of the Geomechanics Division (GD), Structures Laboratory (SL), U. S. Army Engineer Waterways Experiment Station (WES). It was sponsored by the Defense Nuclear Agency under Task Y99QAXSB, "Ground Shock Predictions," Work Unit 00020, "Waveform Comparison Techniques."

The study was conducted and this report prepared and written by Dr. G. Y. Baladi and Mr. D. E. Barnes (GD) during the period October 1981-October 1982 under the general direction of Mr. Bryant Mather, Chief, SL, and Dr. J. G. Jackson, Jr., Chief, GD.

COL Tilford C. Creel, CE, was Commander and Director of WES during the investigation and publication of this report. Mr. F. R. Brown was Technical Director.
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Metric (SI) units of measurement used in this report can be converted to U. S. customary units as follows:

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<tr>
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<td>pounds (force) per square inch</td>
</tr>
<tr>
<td>grams per cubic centimetre</td>
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</tr>
<tr>
<td>kilograms</td>
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1.1 BACKGROUND

It has been and still is customary to analyze explosion-generated ground shock waveforms (measured, computed, or both) subjectively. This is accomplished by comparing two or more waveforms and verbalizing their compatibility through the aid of statements such as "the peaks are within a factor of two" or "the overall agreement is pretty good." Each analyst, however, has his own opinion about what "pretty good" may mean, and their opinions quite often differ greatly. Consequently, subjective discrepancy measures have probably produced as much confusion and controversy as they have enlightenment on a host of ground shock issues.

It is time to minimize the confusion and controversy. Waveforms should be compared objectively, using discrepancy measures that are rooted in statistical theory. This report treats two such measures and recommends them for adoption by the ground shock calculation/measurement community.

Within the framework of the theory of probability there are two approaches that can be taken to develop objective waveform discrepancy measures. The first approach involves straightforward application of statistical concepts to obtain ensemble average (mean), mean square, standard deviation, etc., for a given instant of time. To use this approach, however, it is necessary to have information about the probability distribution of a ground shock parameter throughout the time history of its response or at least a large number of individual responses or measurements obtained at the same location. The second approach involves the use of temporal averages and
temporal mean squares in order to compare two response histories and make an
objective judgement on their agreement or disagreement throughout a given
period of time or "time window."

Using the second approach, T. L. Geers (Reference 1) developed two
objective discrepancy measures for comparing transient response histories;
these were the temporal root mean square and the correlation error history
measure. The objective discrepancy measures developed in this report closely
parallel Geers' development.

1.2 OBJECTIVE

The primary objective of this study was to develop and document objec­tive waveform discrepancy measures for comparing arbitrary transient response
histories. Secondary objectives were (a) to incorporate the newly-developed
waveform discrepancy measures into a computer program which can read digi­
tized measured or calculated waveforms and produce objective waveform compari­sons and perform probabilistic analyses on a given number of response time
histories, and (b) to demonstrate the potential utility of the computer
program using the results of recent field experiments and code calculations.

1.3 SCOPE

The theoretical development behind statistical objective discrepancy
measures is presented in Chapter 2. Chapter 3 demonstrates the application
of the objective discrepancy measures through the use of simple analytic
sinusoidal waveforms. To demonstrate the capabilities of the computer
program WCT (Waveforms Comparison Technique), statistical analyses of
measured data and examples of how calculated response histories can be
compared to measurements are given in Chapter 4. Chapter 5 summarizes the
report and presents recommendations.
Appendix A contains a flow chart and user's guide for the computer program WCT which reads digitized measured or calculated waveforms, produces objective waveform comparisons, and performs probabilistic analyses on a given number of response time histories.
CHAPTER 2

STATISTICAL METHOD FOR COMPARISON OF TRANSIENT RESPONSE HISTORIES

2.1 INTRODUCTION

In general, a waveform is characterized by its amplitude and its frequency. Thus, the comparison of two waveforms must be approached with these features in mind. In addition, phase shifts must be considered.

Historically, the shock and vibrations community has characterized individual waveforms by assigning them an average amplitude and by decomposing their frequency content to obtain a mean square spectral density function (References 2, 3, and 4). The average amplitude most commonly employed has been the root mean square value. Similar concepts and parameters are used in the following sections to develop objective waveform discrepancy measures.

2.2 BASIC EQUATIONS

2.2.1 Single Waveform

Let \( P(t) \) be a periodic function of period \( T \). Under very general conditions, \( P(t) \) may be represented by a superposition of sinusoids using the following exponential Fourier series (Reference 5):

\[
P(t) = \sum_{n=-\infty}^{\infty} c_n \exp (i\omega_0 t)
\]

where \( i = \sqrt{-1} \) is a complex number, \( \omega_0 = 2\pi/T \) is the fundamental angular frequency, and \( c_n \) is Fourier coefficients that can be evaluated directly from the relation

\[
c_n = \frac{1}{T} \int_{-T/2}^{T/2} P(t) \exp (-i\omega_0 t) \, dt
\]

(2.2)
Using Equation 2.1 and Parseval's theorem (Reference 5), it can be shown that

\[
\frac{1}{T} \int_{-T/2}^{T/2} P^2(t) \, dt = \sum_{n=-\infty}^{\infty} |C_n|^2
\]  

(2.3)

Note that the left-hand side of Equation 2.3, called the temporal mean square of \( P(t) \), equals the sum of the squares of the absolute values of the Fourier coefficients. Hence, the temporal mean square is indicative of the amplitude of \( P(t) \).

2.2.2 Two Waveforms

Let \( P_1(t) \) and \( P_2(t + \phi) \) be two identical waveforms except for a constant phase shift between them (equal to \( \phi \)). Such waveforms are correlated; Reference 3 defines this correlation as the temporal autocorrelation function \( \chi(\phi) \), where

\[
\chi(\phi) = \frac{1}{T} \int_{-T/2}^{T/2} P_1(t)P_2(t + \phi) \, dt
\]  

(2.4)

Note that when \( \phi = 0 \), \( P_1(t) = P_2(t) = P(t) \), and Equation 2.4 reduces to the temporal mean square of \( P(t) \).

Because \( \chi(\phi) \) is related to the mean square spectral density function (Reference 3) which determines the frequency decomposition of a given waveform, Equation 2.4 is indicative of the frequency content of waveforms as well as their phase shifts.

2.3 OBJECTIVE DISCREPANCY MEASURES

Based on Equations 2.3 and 2.4, T. L. Geers (Reference 6) suggested three objective discrepancy measures for comparing two (numerically or experimentally generated) waveforms.
Consider \( R_1(t) \) to be an errorless or true response function and \( R_2(t) \) to be a similar response history, but they differ somewhat in amplitude, frequency, and phasing. Geers defined two correlation factors to characterize the differences between \( R_1 \) and \( R_2 \) in terms of (a) magnitude (i.e., amplitude), and (b) phase and frequency; namely,

\[
M_{cf}(t) = \left[ \frac{\int_0^t R_2^2(\tau) \, d\tau}{\left( \int_0^t R_1^2(\tau) \, d\tau \right)^{1/2}} \right]^{1/2}
\]

(2.5)

and

\[
P_{cf}(t) = \left[ \frac{\int_0^t R_1(\tau)R_2(\tau) \, d\tau}{\left( \int_0^t R_1^2(\tau) \, d\tau \right)^{1/2} \left( \int_0^t R_2^2(\tau) \, d\tau \right)^{1/2}} \right]^{1/2}
\]

(2.6)

Here, \( M_{cf}(t) \) is the magnitude correlation factor, and \( P_{cf}(t) \) is the phase-and-frequency correlation factor. Note the distinct preservation of the above fundamental character of Equations 2.3 and 2.4 in the above expressions.

Geers also defined a combined correlation factor to enfold the magnitude correlation factor and the phase-and-frequency correlation factor into one expression, i.e.,

\[
C_{cf}(t) = \left\{ \left[ M_{cf}(t) - 1 \right]^2 + \left[ P_{cf}(t) - 1 \right]^2 \right\}^{1/2}
\]

(2.7)

Finally, the magnitude error, phase-and-frequency error, and combined error were defined by Geers as
Equations 2.8 through 2.10 represent powerful measures for quantifying temporal discrepancies between given waveforms; however, because they all involve time integrations, they are discrepancy measures throughout a given time window rather than time-discrete measures. This offers certain advantages because the quality of waveforms throughout their time histories is what is important in designing a structure to sustain such waveforms.

Note that the definition of $E_{\text{com}}(t)$ in Equation 2.10 capitalizes on the orthogonality of $E_{\text{mag}}(t)$ and $E_{\text{phs}}(t)$, as shown in Figure 2.1 and defined by Equations 2.8 and 2.9. Also, in keeping with Figure 2.1, it can be easily shown (using Equations 2.5 and 2.6) that

$$0 \leq E_{\text{phs}}(t) \leq 1$$ (2.11)

2.4 ENSEMBLE AVERAGING

Quite often, situations arise in which several waveforms need to be compared as a group; e.g., when redundant field records and/or multiple calculations are available. The above error concepts can readily be extended to cover these situations by "ensemble averaging."

For $N$ records in a set (either calculated or measured), average or mean error factors may be defined as

$$E_{\text{mag}}(t) = M_{\text{cf}}(t) - 1$$ (2.8)

$$E_{\text{phs}}(t) = 1 - P_{\text{cf}}(t)$$ (2.9)

$$E_{\text{com}}(t) = \text{SIGN}\left[E_{\text{mag}}(t)\right] \left\{\left[E_{\text{mag}}(t)\right]^2 + \left[E_{\text{phs}}(t)\right]^2\right\}^{1/2}$$ (2.10)
Figure 2.1 Orthogonality relationship for $E_{\text{mag}}(t)$, $E_{\text{phs}}(t)$ and their relation to $E_{\text{com}}(t)$.
MEAN \left[ E_{\text{mag}}(t) \right] = \frac{\sum_{n=1}^{N} E_{\text{mag}}(t)_n}{N} \tag{2.12}

MEAN \left[ E_{\text{phs}}(t) \right] = \frac{\sum_{n=1}^{N} E_{\text{phs}}(t)_n}{N} \tag{2.13}

and

MEAN \left[ E_{\text{com}}(t) \right] = \text{SIGN} \left( \text{MEAN} \left[ E_{\text{mag}}(t) \right] \right) \frac{\sum_{n=1}^{N} E_{\text{com}}(t)_n}{N} \tag{2.14}

A great advantage occurs in using Equation 2.14 (rather than straightforward statistical methods) to compute the mean combined error; i.e., one avoids the calculation of standard deviations (and other statistical measures) for $E_{\text{mag}}(t)$ and $E_{\text{phs}}(t)$. This is due to the vector magnitude aspect of $E_{\text{com}}(t)$; i.e., $\pm E_{\text{mag}}(t)$ or $\pm E_{\text{phs}}(t)$ produces the same $E_{\text{com}}(t)$.

In Chapter 3 we demonstrate the utility of Equations 2.8 through 2.10 and Equations 2.12 through 2.14 by applying them to analyses of simple sinusoidal waveforms.
CHAPTER 3
ANALYTIC EXPOSITION OF OBJECTIVE DISCREPANCY MEASURES

3.1 INTRODUCTION

In this chapter the statistical measures described in Chapter 2 (Equations 2.8 through 2.10) are examined analytically using three pairs of contrived sinusoidal waveforms. In Section 3.2, two undamped waveforms are used to demonstrate the objective description of phase and magnitude discrepancies; Section 3.3 extends this analysis to include a frequency discrepancy. Section 3.4 adds the further complication of slight damping.

3.2 EXAMPLE 1; UNDAMPED SINUSOIDAL RESPONSE; PHASE AND MAGNITUDE DIFFERENCES

Consider the following two sinusoidal responses (Figure 3.1):

\[ R_1(t) = \sin 2\pi t \] (3.1)

\[ R_2(t) = (1 + \varepsilon_m) \sin (2\pi t + \phi) \] (3.2)

where \( t \) is time in milliseconds. Assume that \( R_1(t) \) is an errorless base or true response while \( R_2(t) \) is a comparable response history with an error in magnitude equal to \( \varepsilon_m \), and an error in phase equal to \( \phi \). Substitution of Equations 3.1 and 3.2 into Equations 2.8 and 2.9 leads to

\[ E_{\text{mag}}(t) = \left[ 1 - \frac{\sin 2\pi t}{2\pi t} \cos (2\pi t + \phi) \right]^{1/2} \left[ 1 - \frac{\sin 2\pi t}{2\pi t} \cos 2\pi t \right]^{1/2} \left| 1 + \varepsilon_m \right| - 1 \] (3.3)

and

\[ E_{\text{phs}}(t) = 1 - \left[ 1 - \frac{\sin 2\pi t}{2\pi t} \cos (2\pi t + \phi) \right]^{1/2} \left[ 1 - \frac{\sin 2\pi t}{2\pi t} \cos 2\pi t \right]^{1/2} \] (3.4)
Figure 3.1 Example 1: Time histories of two undamped, identical frequency, sinusoidal responses; $\varepsilon_m = 0.5$ and $\phi = 0.6$ radian.
The combined error can be calculated directly using Equation 2.10 and the results of Equations 3.3 and 3.4.

Note that for large values of \( t \) (\( t > 2 \) in this problem), Equations 3.3 and 3.4 rapidly approach limits, i.e., they become

\[
E_{\text{mag}}(t) \approx \left| 1 + \varepsilon_m \right| - 1
\]

and

\[
E_{\text{phs}}(t) \approx 1 - \left| \cos \phi \right|
\]

respectively. Consequently, Equation 2.10 also approaches a limit. These limits are indicated on Figures 3.2 through 3.5 which illustrate the behavior of Equations 2.10, 3.3, and 3.4 for this example (in which \( \varepsilon_m = 0.5 \) and \( \phi = 0.6 \) radian). It is clear from these figures that within a very short time the objective discrepancy measures have essentially captured the correct values of the magnitude and phase errors and therefore improve their acquisition with time.

As a final note, if \( \phi = 0 \) and \( \varepsilon_m \geq -1 \), Equations 3.3 and 3.4 (as well as Equations 3.5 and 3.6) reduce to

\[
E_{\text{mag}}(t) = \varepsilon_m
\]

and

\[
E_{\text{phs}}(t) = 0
\]

Moreover, for \( t > 2 \), Equation 3.5 can be rewritten as

\[
E_{\text{mag}}(t) = \begin{cases} 
\varepsilon_m & \text{for } \varepsilon_m \geq -1 \\
-(\varepsilon_m + 2) & \text{for } \varepsilon_m \leq -1
\end{cases}
\]

\[\text{(3.9)}\]
Figure 3.2 Time history of magnitude error for example 1.
Figure 3.3 Time history of phase error for example 1.

LIMIT $E_{\text{phs}} \approx |1 - \cos \phi| \approx 0.175$
Figure 3.4 Time history of the combined error for example 1.
which leads to

\[-1 \leq E_{\text{mag}}(t) \leq \infty \quad (3.10)\]

Further, for \( t > 2 \), Equations 3.6 and 3.8 indicate that

\[0 \leq E_{\text{phs}}(t) \leq 1 \quad (3.11)\]

which is a conclusion that was previously stated in Equation 2.11.

And, finally, note that if the absolute value brackets were to be omitted from the numerator of the fraction in Equation 2.6, the present example problem would yield

\[E_{\text{phs}}(t) = \frac{1 + \varepsilon_m}{1 + |\varepsilon_m|} \cos \phi \quad (3.12)\]

which would make the phase error dependent upon \( \varepsilon_m \). This, in turn, could lead to unreliable results. For example, if \( \phi = 0 \) and \( \varepsilon_m = -1 + \delta \), where \( \delta \) is a small positive increment \(<1\), Equation 3.12 gives

\[E_{\text{phs}}(t) \approx 0; \text{ yet for } \phi = 0 \text{ and } \varepsilon_m = -1 - \delta, \quad E_{\text{phs}}(t) \approx 2. \text{ This suggests that in practical cases with } |R_2(t)| << |R_1(t)|, \quad E_{\text{phs}}(t) \text{ calculations (without the absolute value) might be unreliable.}\]

3.3 EXAMPLE 2; UNDAMPED SINUSOIDAL RESPONSE; PHASE, FREQUENCY AND MAGNITUDE DIFFERENCES

In this example, the following sinusoidal responses are considered (Figure 3.5)

\[R_1(t) = \sin 2\pi t \quad (3.13)\]
Figure 3.5 Example 2: Time histories of two undamped sinusoidal responses; $\varepsilon_m = 0.5$, $\phi = 0.6$ radian, and $\varepsilon_f = 0.005$. 

Legend

--- $R_1(t) = \sin 2\pi t$

--- $R_2(t) = (1 + \varepsilon_m) \sin[2\pi(1 + \varepsilon_f)t + \phi]$
Like the previous example, $R_1(t)$ is assumed to be an errorless base or true response while $R_2(t)$ is a comparable response history with error in magnitude equal to $\varepsilon_m$, error in frequency equal to $\varepsilon_f$, and error in phase equal to $\phi$. For this example, $\varepsilon_m = 0.5$, $\phi = 0.6$, and $\varepsilon_f = 0.005$.

Substitution of Equations 3.13 and 3.14 into Equations 2.8 and 2.9 leads to

$$E_{mag}(t) = \left\{ 1 - \frac{\sin[2\pi(1 + \varepsilon_f)t]}{2(1 + \varepsilon_f)t} \cos[2\pi(1 + \varepsilon_f)t + 2\phi] \right\}^{1/2}$$

and

$$E_{phas}(t) = 1 - \frac{\cos \phi \left[ \frac{\sin 2\pi \varepsilon_f t}{2\pi \varepsilon_f t} - \frac{\sin 2\pi(2 + \varepsilon_f)t}{2\pi(2 + \varepsilon_f)t} \right] - \sin \phi \left[ \frac{\sin^2 \pi \varepsilon_f t}{\pi \varepsilon_f t} - \frac{\sin^2 \pi(2 + \varepsilon_f)t}{\pi(2 + \varepsilon_f)t} \right]}{\left\{ 1 - \frac{\sin 2\pi t}{2\pi t} \cos 2\pi t \right\}^{1/2}}$$

and, as before, the combined error can be calculated using Equation 2.10 and the results of Equations 3.15 and 3.16. Figures 3.6 through 3.8 present the behavior of Equations 2.8 through 2.10 for this example (in which $\varepsilon_m = 0.5$, $\phi = 0.6$, and $\varepsilon_f = 0.005$).

For $t > 2$ and $\varepsilon_f << 1$, Equations 3.15 and 3.16 reduce to (see Figures 3.6 through 3.8)

$$E_{mag}(t) \approx \left| 1 + \varepsilon_m \right| - 1$$

and
Figure 3.6 Time history of magnitude error for example 2.

LIMIT $E_{mag} \approx \varepsilon_m \approx 0.5$
Figure 3.7 Time history of phase-and-frequency error for example 2.

$E_{\text{phs}} \approx 1 - |\cos \phi| = 0.175$
Figure 3.8 Time history of the combined error for example 2.
Note that Equation 3.17 is identical to the corresponding result for the previous example (Equation 3.5). Note too that if \(2 < t << (\pi e_f)^{-1}\), Equation 3.18 is essentially identical to its earlier counterpart (Equation 3.6); i.e., \(E_{phs}(t) \approx 1 - |\cos \phi|\); however, for \(t >> (e_f)^{-1}\) \(E_{phs} \approx 1\) (see Figure 3.7).

From this example we conclude that frequency error, as embodied in the term \(e_f\), has a negligible, if any, effect on \(E_{mag}(t)\), yet has a profound effect on \(E_{phs}(t)\). In order to put this into proper context, however, the effects of damping must be considered.

3.4 EXAMPLE 3; LIGHTLY DAMPED SINUSOIDAL RESPONSE; PHASE, FREQUENCY AND MAGNITUDE DIFFERENCES

In this example the effects of damping on the sinusoidal responses of the second example (i.e., Equations 3.13 and 3.14) are considered. We rewrite Equations 3.13 and 3.14 (with damping) as (Figure 3.9)

\[
R_1(t) = \sin (2\pi t) \exp (-\beta t)
\]

and

\[
R_2(t) = (1 + \varepsilon_m) \sin [2\pi(1 + \varepsilon_f)t + \phi] \exp \left[-(1 + \varepsilon_d)\beta t\right]
\]

where \(\varepsilon_m\), \(\phi\), and \(\varepsilon_f\) are as before, \(\beta\) is the damping factor (0.4 msec\(^{-1}\) in this example) and \(\varepsilon_d\) is the error in damping (assumed to be 0.1 for this example). The effects of the damping in Equations 3.19 and 3.20 can be clearly seen by comparing Figures 3.9 and 3.5.

Substitution of Equations 3.19 and 3.20 into Equations 2.8 and 2.9 leads to
Figure 3.9 Example 3: Time histories of two lightly damped sinusoidal responses; $\varepsilon_m = 0.5$, $\phi = 0.6$ radian, $\varepsilon_f = 0.005$, $\varepsilon_d = 0.1$, and $\beta = 0.4$ (msec)$^{-1}$. \\

**LEGEND**

- $R_1(t) = \sin(2\pi t) \exp(-\beta t)$
- $R_2(t) = (1+\varepsilon_m)\sin[2\pi(1+\varepsilon_f)t+\phi]\exp[-(1+\varepsilon_d)\beta t]$
\[ E_{\text{mag}}(t) = \frac{\sqrt{A}}{\sqrt{B}} - 1 \]  
(3.21)

and

\[ E_{\text{phs}}(t) = 1 - \frac{|C|}{\sqrt{A} \sqrt{B}} \]  
(3.22)

where

\[ A = \frac{(1 + \epsilon_m)^2}{4\epsilon(1 + \epsilon_d)} \left\{ 1 - \frac{a \sin 2\phi + a^2 \cos 2\phi}{1 + a^2} \right\} \left[ 1 - \frac{a \sin (2bt + 2\phi) + a^2 \cos (2bt + 2\phi)}{1 + a^2} \right] \exp (2abt) \]  
(3.23)

\[ B = \frac{1 - e^{-2\beta t}}{4\beta} \left[ \left( \frac{\beta}{2\pi} \right)^2 \sin^2 2\pi t + \frac{\beta^2}{2\pi} \sin 4\pi t + 1 \right] \]  
(3.24)

\[ C = \frac{(1 + \epsilon_m)^2}{2} \left\{ \right. \frac{- (2 + \epsilon_d) \beta \cos (2\pi \epsilon_d t + \phi) + 2\pi \epsilon_d \sin (2\pi \epsilon_d t + \phi)}{\left[ (2 + \epsilon_d) \beta \right]^2 + (2\pi \epsilon_d)^2} \]  

\[ + \frac{(2 + \epsilon_d) \beta \cos \left[ 2\pi (2 + \epsilon_d) t + \phi \right] - 2\pi (2 + \epsilon_d) \sin \left[ 2\pi (2 + \epsilon_d) t + \phi \right]}{\left[ (2 + \epsilon_d) \beta \right]^2 + (2\pi (2 + \epsilon_d))^2} \exp \left[ -(2 + \epsilon_d) \beta t \right] \]  
(3.25)

\[ \left. + \frac{(1 + \epsilon_m)^2}{2} \right\{ \frac{(2 + \epsilon_d) \beta \cos \phi - 2\pi \epsilon_d \sin \phi}{\left[ (2 + \epsilon_d) \beta \right]^2 + (2\pi \epsilon_d)^2} - \frac{(2 + \epsilon_d) \beta \cos \phi - 2\pi (2 + \epsilon_d) \sin \phi}{\left[ (2 + \epsilon_d) \beta \right]^2 + (2\pi (2 + \epsilon_d))^2} \} \]

\[ a = - \frac{(1 + \epsilon_d) \beta}{2\pi (1 + \epsilon_d)} \]  
(3.26)

and

\[ b = 2\pi (1 + \epsilon_d) \]
The combined error (Equation 2.10) becomes

\[
E_{\text{com}}(t) = \frac{\sqrt{A} - \sqrt{B}}{|\sqrt{A} - \sqrt{B}|} \left\{ \frac{A}{B} - 2 \sqrt{\frac{A}{B}} + \frac{C^2}{AB} - \frac{2|C|}{\sqrt{AB}} + 2 \right\}^{1/2} \tag{3.27}
\]

Figures 3.10 through 3.12 present the behaviors of Equations 3.21, 3.22, and 3.27.

For \( t \to \infty \), Equations 3.21 and 3.22 become

\[
E_{\text{mag}}(t) \bigg|_{t \to \infty} = \left| 1 + \varepsilon_m \right| \left\{ \frac{1 + \left( \frac{\beta}{2\pi} \right)^2}{1 + \varepsilon_d} \left[ 1 - a \sin 2\phi + a^2 \cos 2\phi \right] \right\}^{1/2} - 1 \tag{3.28}
\]

and

\[
E_{\text{phs}}(t) \bigg|_{t \to \infty} = 1 - \left| \frac{\frac{\beta}{2\pi}}{1 + \left( \frac{\beta}{2\pi} \right)^2 + \left( \frac{\varepsilon_f}{2} \right)^2} \left[ \left( 1 + \frac{\varepsilon_d}{2} \right)^2 + 2 \left( 1 + \frac{\varepsilon_f}{2} \right)^2 \right] - 1 \right| \left\{ 1 - a \sin 2\phi + a^2 \cos 2\phi \right\}^{1/2} \right\}^{1/2} \tag{3.29}
\]

Equations 3.21 and 3.22 or Equations 3.28 and 3.29 indicate that both the magnitude error and the phase-and-frequency error are dependent on the damping parameter \( \frac{\beta}{2\pi} \). However, the phase-and-frequency error is independent of \( \varepsilon_m \).

Note that if \( \varepsilon_m^2 \ll 1 \), \( \varepsilon_d^2 \ll 1 \), \( \varepsilon_f^2 \ll 1 \), \( \phi^2 \ll 1 \), \( \beta < 1 \), and \( (2\pi \varepsilon_f/\beta) < 1 \), Equations 3.28 and 3.29 become

\[
E_{\text{mag}}(t) \bigg|_{t \to \infty} \approx \varepsilon_m - \frac{1}{2} \varepsilon_d \tag{3.30}
\]

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Figure 3.10 Time history of magnitude error for example 3.
Figure 3.11 Time history of phase-and-frequency error for example 3.
Figure 3.12 Time history of combined error for example 3.
and

\[ E_{\text{phs}}(t) \bigg|_{t \to \infty} \approx 1 - \left| \frac{\cos \phi - \frac{\pi \varepsilon_f}{\beta} \sin \phi + \frac{\beta}{2\pi} \sin \phi}{\left[ 1 + \frac{\beta \sin 2\phi}{2\pi} \right]^{1/2}} \right| \]  

(3.31)

In this case, the magnitude error depends only on \( \varepsilon_m \) and \( \varepsilon_d \); and the phase-and-frequency error depends on \( \varepsilon_f \), \( \phi \), and the damping parameter \( \beta/2\pi \).

The previous three examples demonstrated the application of the objective discrepancy measures. The potential utility of the computer program WCT is demonstrated in the next chapter through statistical analyses of measured data and examples of how calculated response histories can be compared to measurements.
4.1 INTRODUCTION

The objective discrepancy measures established in Chapter 2 (Equations 2.5 through 2.13) were incorporated into a computer program named WCT. The listing of WCT, its flow chart, and its user's guide are included in Appendix A. The computer program WCT is capable of processing digitized data tapes containing either measured or calculated waveforms to produce (a) the mean value and standard deviation at each time-step of any set of transient response histories, and (b) time histories of the objective discrepancy measures established in Chapter 2 (Equations 2.5 through 2.13) for any pair of waveforms. To demonstrate this capability, WCT was used to analyze selected free-field data recorded on the DISC Test I and II events (References 7 and 8), which were High Explosive Simulation Technique (HEST) experiments performed in the desert alluvium of Ralston Valley, Nevada.

4.2 STATISTICAL ANALYSIS OF MEASURED DATA

Figure 4.1 presents nine cavity pressure measurements and their integrals recorded for DISC Test I. These cavity pressure measurements were input to the WCT code which integrated them and produced the mean integral and its standard deviation bounds, as shown in Figure 4.2. The mean integral was then differentiated to obtain the mean cavity pressure waveform (also shown in Figure 4.2). This mean cavity pressure-time history and its standard deviation bounds were subsequently used as airblast pressure drivers for one-dimensional ground shock calculations of the DISC Test II event, as reported in Reference 9.
Figure 4.1 Early-time cavity pressure measurements and integrals; DISC Test I event.
Figure 4.2 Early-time histories of mean cavity pressure and integral with standard deviation bounds for integrals; DISC Test I event.
Using the statistical variations of cavity pressure and soil compressibility from DISC Test I as input, a series of probabilistic 1D ground shock calculations was performed to predict particle velocity at the 3-meter depth for the DISC Test II event (Reference 9). The expected value obtained from these calculations and three records of measured velocities are plotted in Figure 4.3. Subjectively the comparison looks "pretty good." But in order to obtain a more objective judgment of the degree of agreement or disagreement among these velocities, the waveforms of Figure 4.3 were input to the computer program WCT, using the expected value from the probabilistic 1D calculations as a base (truth) record. The time histories of the magnitude errors, the phase-and-frequency errors, and the combined errors are shown in Figures 4.4 through 4.6, respectively. The errors associated with two of the measured waveforms (the dotted and the dash-dotted curves) are uniformly small and essentially identical. The errors are larger for the dashed curve, but only during the initial 2- to 3-msec toe (or precursor). The ensemble averages of the individual errors in Figures 4.4 through 4.6 are shown in Figures 4.7 through 4.9. These are simply the mean values of the errors computed using Equations 2.12, 2.13, and 2.14. Comparison of Figures 4.7 and 4.8 indicates that the dominant errors in this case are the magnitude errors.

Figures 4.10 through 4.13 compare the mean of the three DISC Test II measurements (dashed curve) with the calculated expected value (solid line). The magnitude error has a plus-and-minus oscillation during the rise portion and then settles on a numerical value of minus 0.1. For all practical purposes, the phase-and-frequency error is essentially zero; consequently, the combined error is dominated by the magnitude error.
Figure 4.3 Comparison of calculated and measured particle velocity-time histories for DISC Test II event; depth = 3.0 metres.
Figure 4.4 Time histories of magnitude errors between measured and calculated velocity waveforms; DISC Test II event, depth = 3.0 metres.

Figure 4.5 Time histories of phase-and-frequency errors between measured and calculated velocity waveforms; DISC Test II event, depth = 3.0 metres.
Figure 4.6 Time histories of combined error (magnitude, phase and frequency) for each measured velocity waveform relative to the calculated waveform; DISC Test II event, depth = 3.0 metres.

Figure 4.7 Time history of magnitude error between mean measured and calculated velocity waveforms; DISC Test II event, depth = 3.0 metres.
Figure 4.8 Time history of phase-and-frequency error between mean measured and calculated velocity waveforms; DISC Test II event, depth = 3.0 metres.

Figure 4.9 Time history of combined error (magnitude and phase-and-frequency) between mean measured and calculated velocity waveforms; DISC Test II event, depth = 3.0 metres.
Figure 4.10  Time histories of mean measured and mean calculated velocity waveforms; DISC Test II event, depth = 3.0 metres.

Figure 4.11  Time history of magnitude error between mean measured and mean calculated velocity waveforms; DISC Test II event, depth = 3.0 metres.
Figure 4.12  Time history of phase-and-frequency error between mean measured and mean calculated velocity waveforms; DISC Test II event, depth = 3.0 metres.

Figure 4.13  Time history of combined error (magnitude, phase-and-frequency) between mean measured and mean calculated velocity waveforms; DISC Test II event, depth = 3.0 metres.
5.1 SUMMARY

A set of objective discrepancy measures for the comparison of transient response histories has been established. It consists of the magnitude correlation factor, the phase-and-frequency correlation factor, the magnitude error, the phase-and-frequency error, and the combined magnitude and phase-and-frequency errors. Their validity and behavior were checked and demonstrated for several simple sinusoidal responses.

The objective discrepancy measures were incorporated into a computer program named WCT which processes digitized data tapes containing measured or calculated waveforms or both.

As a demonstration of capability, the computer program was used to statistically analyze selected data from the DISC Test I event and objectively compare particle velocity measurements made in DISC Test II with the expected value waveform obtained from probabilistic prediction calculations.

5.2 RECOMMENDATIONS

It is recommended that the objective discrepancy measures examined in this report be used whenever comparisons of two or more waveforms are made. It is also recommended that the technique be extended to objectively quantify differences in laboratory- and field-generated material property test results.
REFERENCES


5. R. V. Churchill; Fourier Series and Boundary Value Problems; 1941; McGraw-Hill Book Company, New York, NY.


7. A. E. Jackson, Jr., et al.; "Ralston Valley Soil Compressibility Study; Quick-Look Report for DISC Test I"; May 1981; U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, MS.

8. A. E. Jackson, Jr., and J. S. Zelasko; "Ralston Valley Soil Compressibility Study; Quick-Look Report for DISC Test II"; January 1982; U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, MS.

9. J. G. Jackson, Jr.; "Site Characterization for Probabilistic Ground Shock Predictions"; Miscellaneous Paper SL-82-8; July 1982; U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, MS.
APPENDIX A

USER'S GUIDE FOR COMPUTER PROGRAM WCT

A.1 INTRODUCTION

This user's guide for the computer program WCT describes typical input and output, contains a glossary of the variables, a flow chart, and a listing of the program, and presents sample tabulated output from two example runs. Program WCT has been coded in Honeywell Level 66 Fortran for the timesharing subsystem of the Honeywell DPS-1 digital computer currently operated at WES.

A.2 INPUT

The digitized waveforms for input to program WCT can be read directly from tapes or can be written to binary data files for subsequent access through the DPS-1 timesharing subsystem. Each input waveform consists of two records which are treated as one tape file by WCT. The first record contains the number of digitized data points, the digital time increment, and an identification (ID) label. For measured waveforms, this ID label consists of three 20-character alpha-numeric variables that contain all pertinent information about the gage and type of data; for calculated waveforms, the ID label consists of a title up to 60 characters in length. The record contains the digitized waveform as a single array of data points. All other input is in free-field format, and the program will call for the variables by name.

The first line of input variables contains the following information:

XFINAL-----Final time for calculations, msec.

DX---------Time increment, msec.

NTPLOT-----Type of calculations desired: For NTPLOT = 1, objective discrepancy measures (Equations 2.5 through 2.14 of Chapter 2) are computed;
for NT PLOT = 2, expected value and standard deviation are computed; and for NT PLOT = 3, expected value, standard deviation, and derivatives with respect to time for expected value and standard deviation are computed.

SEARV------Search value for normalizing the arrival times of the records (about 1/2 percent of peak value of the data). If SEARV is input as zero, the data will be read from the beginning of the record.

ISKIP------Print SKIP increment.

NIBASE------Number of integrations for base record.

NICOMP------Number of integrations for comparison records. (The base record is treated separately from the other records. This will allow a comparison of the base record to one, or more, measured or calculated waveforms.)

The second line of input contains the following variables which are required by the program for every record:

NSORCE----- = 0; no more waveforms to be read in.  
        = 1; measured waveforms.  
        = 2; calculated waveforms.

NFILE------File number. If NFILE = 0, the program will ask for the name of a data file containing the waveform(s).

The third line of input is the name of the data file, called "FILE," containing the waveform. Finally, the program asks for the value of ANS, which gives the user options to obtain plots or tables or both, as described below.
A.3 OUTPUT

WCT output consists of optional time history plots or tabulated data or both. In addition, the input records can be plotted either before or after preprocessing or both. A table of maximum and minimum values if produced for all computations.

The type of output depends on the value of NTPLLOT. For NTPLLOT = 1, the output consists of the magnitude error (Equation 2.8), the phase-and-frequency error (Equation 2.9), and the combined error (Equation 2.10). If there is more than one comparison record, the mean of each error (i.e., ensemble averages, Equations 2.12, 2.13, and 2.14) is also computed. For NTPLLOT = 2, the output consists of expected (or mean) values and standard deviation. If the arrival times of the records have been normalized, the expected waveforms can be plotted against the time associated with expected arrival time and the expected waveform plus or minus standard deviation can be plotted against the expected arrival time plus or minus the standard deviation, respectively. For NTPLLOT = 3, the output consists of data identical to NTPLLOT = 2, plus the derivatives with respect to time of (a) the expected value, (b) the expected value plus one standard deviation, and (c) the expected value minus one standard deviation.

A.4 GLOSSARY

A.4.1 Main Program

ANS Character variable through which the types of outputs are chosen.

CEF Combined error factor (Equation 2.7).

DE(I) Derivative with respect to time of E(I) at the Ith time step.
DEM(I) Derivative with respect to time of EM(I) at the Ith time step.

DEMAX Maximum value of DE(I).

DEMMIN Minimum value of DEM(I).

DEP(I) Derivative with respect to time of EP(I) at the Ith time step.

DEPMAX Maximum value of DEP(I).

DT(J) Time increment for the Jth record, msec.

DX Time increment for calculations, msec.

DXI \(1/\text{DX} \).

DX02 \(\text{DX}/2 \).

E(I) Expected value (mean of given set of records at the Ith time step.

ECMN(K) Minimum value of ECOM(I,K) at the Kth record.

ECMX(K) Maximum value of ECOM(I,K) at the Kth record.

ECOM(I,K) Combined error between the Kth record and the base one at the Ith time step (Equation 2.10).

ECOMAV(I) Mean combined error at the Ith time step (Equation 2.14).

EM(I) E(I) Minus one standard deviation at the Ith time step.

EMAG(I,K) Magnitude error between the Kth record and the base one at the Ith time step (Equation 2.8).
EMAGAV(I)  Mean magnitude error at the Ith time step (Equation 2.12).
EMAX  Maximum value of E(I).
EMIN  Minimum value of E(I).
EMMIN  Minimum value of EM(I).
EMMN(K)  Minimum value of EMAG(I,K) at the Kth record.
EMMX(K)  Maximum value of EMAG(I,K) at the Kth record.
EP(I)  E(I) plus one standard deviation at the Ith time step.
EPHSAV(I)  Mean phase-and-frequency error at the Ith time step (Equation 2.13).
EPHS(I,K)  Phase-and-frequency error between the Kth record and the base one at the Ith time step (Equation 2.9).
EPHSAV(I)  Mean phase-and-frequency error at the Ith time step (Equation 2.13).
EPMAX  Maximum value of EP(I).
EPMN(K)  Minimum value of EPHS(I,K) at the Kth record.
EPMX(K)  Maximum value of EPHS(I,K) at the Kth record.
ES  Temporary variable for computing the expected value.
I1(I)  Integral of the base record squared at the Ith time step.
ICM1  Number of records to be compared with the base record.
ICNT  Total number of records to be processed.
ISKIP  Print SKIP increment.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAXC(K)</td>
<td>One plus maximum absolute value of the record at K.</td>
</tr>
<tr>
<td>MAXM</td>
<td>Maximum absolute of the base record.</td>
</tr>
<tr>
<td>MCF</td>
<td>Magnitude correlation factor (Equation 2.5).</td>
</tr>
<tr>
<td>NL</td>
<td>Parameter variable for setting the maximum number of comparison cases to be processed.</td>
</tr>
<tr>
<td>NC</td>
<td>Parameter variable for setting the maximum number of records to be processed.</td>
</tr>
<tr>
<td>NIBASE</td>
<td>Number of times for which the base record must be integrated.</td>
</tr>
<tr>
<td>NICOMP</td>
<td>Number of times for which the waveforms must be integrated.</td>
</tr>
<tr>
<td>NINT</td>
<td>Temporary counter for NIBASE and NICOMP.</td>
</tr>
<tr>
<td>NINVERS</td>
<td>(1/</td>
</tr>
<tr>
<td>NP</td>
<td>Parameter variable for setting the maximum number of time steps that can be processed.</td>
</tr>
<tr>
<td>NPOINT</td>
<td>Number of time steps to be used for given calculations.</td>
</tr>
<tr>
<td>NPIS(J)</td>
<td>Number of time steps in the Jth record.</td>
</tr>
<tr>
<td>NTPLOT</td>
<td>Variable determines the desired type of output.</td>
</tr>
<tr>
<td>PCF</td>
<td>Phase-and-frequency correlation factor (Equation 2.6).</td>
</tr>
<tr>
<td>PEF(K)</td>
<td>Peak error factor of the Kth record.</td>
</tr>
<tr>
<td>PLOT2</td>
<td>A subroutine for plotting on a Tektronix 4662 interactive digital plotter (Note: It is not the intent of this user's guide to explain the use of PLOT2).</td>
</tr>
<tr>
<td>Variable</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>RICNT</td>
<td>$1/\text{ICNT}$.</td>
</tr>
<tr>
<td>RNM1</td>
<td>$1/(\text{ICNT}-1)$.</td>
</tr>
<tr>
<td>SS</td>
<td>Variance.</td>
</tr>
<tr>
<td>ST</td>
<td>Standard deviation.</td>
</tr>
<tr>
<td>SUM1</td>
<td>Temporary variable for computing MCF.</td>
</tr>
<tr>
<td>SUM2</td>
<td>Temporary variable for computing PCF.</td>
</tr>
<tr>
<td>TAR(K)</td>
<td>Arrival time for the Kth record, msec.</td>
</tr>
<tr>
<td>TE(I)</td>
<td>Time associated with $E(I)$ at the Ith time step, msec.</td>
</tr>
<tr>
<td>TE1</td>
<td>Expected arrival time of the given set of records, msec.</td>
</tr>
<tr>
<td>TITLE(K)</td>
<td>Title with up to 60 characters for identifying the Kth record.</td>
</tr>
<tr>
<td>TM(I)</td>
<td>Time associated with $EM(I)$ at the Ith time step, msec.</td>
</tr>
<tr>
<td>TM1</td>
<td>$TE1-\text{ST}$.</td>
</tr>
<tr>
<td>TP(I)</td>
<td>Time associated with $EP(I)$ at the Ith time step, msec.</td>
</tr>
<tr>
<td>TP1</td>
<td>$TE1+\text{ST}$.</td>
</tr>
<tr>
<td>X(J,K)</td>
<td>Time associated with the Kth record at the Jth time step, msec.</td>
</tr>
<tr>
<td>XCUR</td>
<td>Temporary variable used for interpolation.</td>
</tr>
<tr>
<td>XFINAL</td>
<td>The length of the calculation, msec.</td>
</tr>
</tbody>
</table>
XX(I)  Time at the Ith time step, msec.

Y  An array for storing the input data.

YNEXT,YT  Temporary variables for integration.

YY  An array for storing the preprocessed data.

A.4.2 Subrouting READIN

ATTACH  System subroutine for opening a permanent file.

BCDASC  System subroutine for converting from BCD to ASCII.

C1,C2,C3  Identification for measured data; BCD labels (converted to ASCII for title).

DETACH  System subroutine for closing a permanent file.

DT(ICNT)  Time increment (in seconds, converted to milliseconds) for the ICNT record.

DX  Time increment, msec.

FILE  Variable name for input file.

ICNT  Record counter.

ISKIP  Print SKIP increment.

N1,NC,NP  (See main program).

NFILE  Tape file number in the input file.

NIBASE, NICOMP  (See main program).
<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPOINT</td>
<td>Number of points to be used for calculations. NPOINT will be reduced if any input record contains fewer than NPOINT data points (this would also reduce the value of XFINAL).</td>
</tr>
<tr>
<td>NPS</td>
<td>Maximum number of data points from an input record to be searched in order to obtain the arrival time.</td>
</tr>
<tr>
<td>NPT</td>
<td>Total number of data points to be read from an input record.</td>
</tr>
<tr>
<td>NPTX(ICNT)</td>
<td>(See main program.)</td>
</tr>
<tr>
<td>NSORCE</td>
<td>Origin of input data: NSORCE = 1 for measured data; NSORCE = 2 for calculated data.</td>
</tr>
<tr>
<td>NSTRT</td>
<td>The number of time steps at which the signal arrives.</td>
</tr>
<tr>
<td>NT PLOT</td>
<td>(See main program.)</td>
</tr>
<tr>
<td>SEARV</td>
<td>(See the input.)</td>
</tr>
<tr>
<td>TAR(ICNT)</td>
<td>Arrival time (in seconds, converted to milliseconds) for record number ICNT.</td>
</tr>
<tr>
<td>TDUM</td>
<td>Identification label. BCD label (converted to ASCII for title).</td>
</tr>
<tr>
<td>TITLE(ICNT)</td>
<td>(See main program.)</td>
</tr>
<tr>
<td>X,XFINAL,XX,Y,YY</td>
<td>(See main program.)</td>
</tr>
</tbody>
</table>
A.5 FLOW CHART

A.5.1 Main Program

START

CALL READIN

PRINT: WANT PLOT OF INPUT DATA?
READ ANS

ANS = YES

T

PLOT INPUT DATA

NINT = NIBASE

DO 30 J = 1, ICNT

NINT = 0

T

F

DO 20 L = 1, NINT

INTEGRATE Y(I, J)

20

30 NINT = NICOMP

a
DO 60 K = 1, ICNT

IF DT(K) < DX THEN

INTERPOLATE Y(I, K) INTO YY(I, K)

ELSE

TRANSFER Y(I, K) INTO YY(I, K)

END IF

CALCULATE XX(I)

PRINT: WANT PLOT OF PREPROCESSED DATA?
READ ANS

IF ANS = 'Y' THEN

PLOT THE PREPROCESSED DATA

END IF

a

b
CALCULATE EMAG(I, K); EPHS(I, K); ECOM(I, K)

ICNT = 2

PRINT: WANT TABULATED OUTPUT?
READ ANS

TABULATE THE MAXIMUM AND MINIMUM VALUES

ANS = 1HY

IF ANS = 1HY THEN F

NTPLOT > 1

400

T

A2

300

A1

200

F

A2

A1
TABULATE THE CALCULATED DATA

PRINT: WANT PLOTS?
READ ANS

ANS = 1HY

STOP

T

300

PLOT THE CALCULATED DATA

STOP

400

CALCULATE THE EXPECTED VALUE AND THE STANDARD DEVIATIONS

PRINT: WANT TABULATED OUTPUT?
READ ANS

d
TABULATE THE MAXIMUM AND MINIMUM VALUES

ANS = 1HY

TABULATE THE CALCULATED DATA

PRINT: WANT PLOTS?
READ ANS

ANS = 1HY

470

PLOT THE CALCULATED DATA

500

NTPLOT < 3

STOP

A14
CALCULATE THE DERIVATIVES WITH RESPECT TO TIME FOR THE EXPECTED VALUE AND THE STANDARD DEVIATIONS

PRINT: WANT TABULATED OUTPUT? READ ANS

TABULATE THE MAXIMUM AND MINIMUM VALUES

ANS = 1HY

TABULATE THE CALCULATED DATA

PRINT: WANT PLOTS? READ ANS

ANS = 1HY

STOP

PLOT THE CALCULATED DATA

STOP

END
A.5.2 Subroutine READIN

PRINT: READ XFINAL, DX, NTPLT, SEARV, ISKIP, NIBASE, NICOMP
READ XFINAL,...,NICOMP
CALCULATE NPOINT

NPOINT ≤ NP
T
F

CALCULATE NEW XFINAL
PRINT 300, NPOINT, NP, XFINAL

INCREMENT ICNT BY 1
PRINT: READ NSORCE, NFILE
READ NSORCE, NFILE

NSORCE = 0
T
F

NFILE < 1
T
F

200
B4
B5

700
READ MEASURED DATA FROM INPUT FILE

GO TO 10

READ CALCULATED DATA FROM INPUT FILE

GO TO 10

DECREMENT ICNT BY 1
COMPUTE TIME ARRAYS
CALCULATE NEW XFINAL, NPOINT
PRINT 310, NPOINT, XFINAL

RETURN

PRINT: READ INPUT FILE
READ FILE

OPEN INPUT DATA FILE

PRINT: READ NFILE
READ NFILE

NSORCE - 1 - 200
B4

0 + 100
B3

20
B2
A.6 EXAMPLES

OLD WCT
*FRN

12/08/82 21.070

READ XFINAL,DX,NTPLOT,SEARV,ISKIP,NIBASE,NICOMP
=7,02 1,5 50 0 0
NPOINT = 351
READ NSORCE,NFILE
=1 0
INPUT FILE ?
=ROSD222/OUTB1
READ NFILE
=1
READ NSORCE,NFILE
=1 2
READ NSORCE,NFILE
=1 5
READ NSORCE,NFILE
=1 3
READ NSORCE,NFILE
=0 0
WANT PLOT OF INPUT DATA?
=NO
WANT PLOT OF PREPROCESSED DATA?
=NO
WANT TABULATED OUTPUT ?
=YES

CASE      1      2      3
MAXC = 41.598 34.930 19.221
PEF = -0.097 -0.241 -0.583
EMMX = 105.420 88.186 51.388
EMMN = -0.460 -0.043 -0.321
EPMX = 0.987 0.995 0.991
EPMN = 0.0 0.0 0.0
ECHX = 105.423 88.191 51.398
ECHN = -0.777 -0.730 -0.704

BASE 3.5-0-0-AB 2-6 PRESSURE KPA  DISC TEST 1 0001
CASE 1 6-0-45-AB 2-7 PRESSURE KPA  DISC TEST 1 0002

 I  EMAG  EPHS  ECDM
 2  -0.460  0.626  -0.777
 50 105.243 0.898 105.247
100  0.148  0.777  0.791
150  0.093  0.647  0.654
200  0.097  0.588  0.596
250  0.069  0.537  0.542
300  0.073  0.497  0.503
350  0.059  0.470  0.474

CASE 2 2-0-300-AB 2-10 PRESSURE KPA  DISC TEST 1 0010

A19
<table>
<thead>
<tr>
<th>I</th>
<th>EMAG</th>
<th>EPHS</th>
<th>ECOM</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0.589</td>
<td>0.577</td>
<td>0.824</td>
</tr>
<tr>
<td>50</td>
<td>85.993</td>
<td>0.931</td>
<td>85.998</td>
</tr>
<tr>
<td>100</td>
<td>0.000</td>
<td>0.733</td>
<td>0.733</td>
</tr>
<tr>
<td>150</td>
<td>-0.012</td>
<td>0.583</td>
<td>-0.593</td>
</tr>
<tr>
<td>200</td>
<td>-0.007</td>
<td>0.530</td>
<td>-0.530</td>
</tr>
<tr>
<td>250</td>
<td>-0.033</td>
<td>0.486</td>
<td>-0.487</td>
</tr>
<tr>
<td>300</td>
<td>-0.031</td>
<td>0.450</td>
<td>-0.451</td>
</tr>
<tr>
<td>350</td>
<td>-0.043</td>
<td>0.425</td>
<td>-0.427</td>
</tr>
</tbody>
</table>

CASE 3 4-0-90-AB 2-8 PRESSURE KPA DISC TEST 1 0003

<table>
<thead>
<tr>
<th>I</th>
<th>EMAG</th>
<th>EPHS</th>
<th>ECOM</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>3.910</td>
<td>0.592</td>
<td>3.955</td>
</tr>
<tr>
<td>50</td>
<td>43.846</td>
<td>0.876</td>
<td>43.854</td>
</tr>
<tr>
<td>100</td>
<td>-0.293</td>
<td>0.503</td>
<td>-0.582</td>
</tr>
<tr>
<td>150</td>
<td>-0.307</td>
<td>0.411</td>
<td>-0.513</td>
</tr>
<tr>
<td>200</td>
<td>-0.238</td>
<td>0.366</td>
<td>-0.437</td>
</tr>
<tr>
<td>250</td>
<td>-0.248</td>
<td>0.330</td>
<td>-0.413</td>
</tr>
<tr>
<td>300</td>
<td>-0.223</td>
<td>0.302</td>
<td>-0.375</td>
</tr>
<tr>
<td>350</td>
<td>-0.219</td>
<td>0.279</td>
<td>-0.355</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>I</th>
<th>EMAGAV</th>
<th>EPHSAV</th>
<th>ECOMAV</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1.347</td>
<td>0.598</td>
<td>1.852</td>
</tr>
<tr>
<td>50</td>
<td>78.360</td>
<td>0.902</td>
<td>78.366</td>
</tr>
<tr>
<td>100</td>
<td>-0.048</td>
<td>0.671</td>
<td>-0.702</td>
</tr>
<tr>
<td>150</td>
<td>-0.075</td>
<td>0.547</td>
<td>-0.583</td>
</tr>
<tr>
<td>200</td>
<td>-0.049</td>
<td>0.494</td>
<td>-0.521</td>
</tr>
<tr>
<td>250</td>
<td>-0.071</td>
<td>0.451</td>
<td>-0.481</td>
</tr>
<tr>
<td>300</td>
<td>-0.060</td>
<td>0.416</td>
<td>-0.443</td>
</tr>
<tr>
<td>350</td>
<td>-0.068</td>
<td>0.391</td>
<td>-0.419</td>
</tr>
</tbody>
</table>

WANT PLOTS ?

=NO

PTU-SEC = 1.85

*
12/08/82  21.100

READ XFINAL, DX, NTPLOT, SEARV, ISKIP, NIBASE, NICOMP  
= 7, 02 3, 5 30 1 1
NPOINT = 351
READ NSORCE, NFILE  
= 1 0
INPUT FILE ?  
=ROSD222/OUTB201
READ NFILE  
= 1
READ NSORCE, NFILE  
= 1 2
READ NSORCE, NFILE  
= 1 5
READ NSORCE, NFILE  
= 1 3
READ NSORCE, NFILE  
= 0 0
WANT PLOT OF INPUT DATA?  
= NO
WANT PLOT OF PREPROCESSED DATA?  
= NO
WANT TABULATED OUTPUT ?  
= YES

<table>
<thead>
<tr>
<th>EMX</th>
<th>EMN</th>
<th>EPMX</th>
<th>EMMN</th>
</tr>
</thead>
<tbody>
<tr>
<td>41.336</td>
<td>0.000</td>
<td>44.986</td>
<td>-0.008</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TE1</th>
<th>TP1</th>
<th>TM1</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.960</td>
<td>1.646</td>
<td>0.274</td>
</tr>
</tbody>
</table>

CASE  | 1  | 2  | 3  | 4  |
TAR   | 0  | 1.600 | 1.000 | 1.240 |

<table>
<thead>
<tr>
<th>I</th>
<th>E</th>
<th>EP</th>
<th>EM</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>7.048</td>
<td>12.494</td>
<td>1.602</td>
</tr>
<tr>
<td>100</td>
<td>14.246</td>
<td>18.197</td>
<td>10.295</td>
</tr>
<tr>
<td>150</td>
<td>20.785</td>
<td>24.927</td>
<td>16.643</td>
</tr>
<tr>
<td>200</td>
<td>26.490</td>
<td>30.624</td>
<td>22.356</td>
</tr>
<tr>
<td>250</td>
<td>31.477</td>
<td>35.307</td>
<td>27.647</td>
</tr>
<tr>
<td>300</td>
<td>36.760</td>
<td>40.705</td>
<td>32.814</td>
</tr>
<tr>
<td>350</td>
<td>41.255</td>
<td>44.908</td>
<td>37.601</td>
</tr>
</tbody>
</table>

WANT PLOTS ?  
= NO
WANT TABULATED OUTPUT ?  
= YES

<table>
<thead>
<tr>
<th>DEMX</th>
<th>DEMN</th>
<th>DEPMX</th>
<th>DEMMN</th>
</tr>
</thead>
<tbody>
<tr>
<td>18.408</td>
<td>0.000</td>
<td>31.840</td>
<td>-0.880</td>
</tr>
<tr>
<td>I</td>
<td>DE</td>
<td>DEP</td>
<td>DEM</td>
</tr>
<tr>
<td>----</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>50</td>
<td>5.085</td>
<td>7.980</td>
<td>2.191</td>
</tr>
<tr>
<td>100</td>
<td>5.531</td>
<td>3.717</td>
<td>7.346</td>
</tr>
<tr>
<td>150</td>
<td>5.895</td>
<td>6.848</td>
<td>4.943</td>
</tr>
<tr>
<td>200</td>
<td>5.044</td>
<td>5.001</td>
<td>5.086</td>
</tr>
<tr>
<td>250</td>
<td>5.045</td>
<td>5.330</td>
<td>4.760</td>
</tr>
<tr>
<td>300</td>
<td>5.202</td>
<td>4.839</td>
<td>5.565</td>
</tr>
<tr>
<td>350</td>
<td>4.068</td>
<td>3.818</td>
<td>4.319</td>
</tr>
</tbody>
</table>

WANT PLOTS ?
= NO
PTU-SEC = 1.26

*
A.7 PROGRAM LISTING

1000**RUN**;ROSD441/PILOTS,R
1010C     PROGRAM WCT
1020C
1030C     CALCULATIONS OF STATISTICAL MEASURES FOR
1040C     COMPARISON OF WAVEFORMS
1050C
1060     PARAMETER NC = 10, N1 = NC-1, NP = 200
1070     REAL II, MCF, MAXC, MAXM, NINVRS
1080     CHARACTER TITLE *60, ANS*1
1090     DIMENSION II(NP), EMAGAV(NP), EPHSAV(NP), ECOMAV(NP),
1100       & EMAG(NP,N1), EPHS(NP,N1), ECOM(NP,N1),
1110       & TE(NP), TP(NP), TM(NP), E(NP), EP(NP), EM(NP),
1120       & DE(NP), DEP(NP), DEM(NP)
1130     COMMON /INPUT/ XFINAL, DX, NTLOT, ISKIP, NIBASE, NICOMP,
1140       & ICNT, NPOINT, DT(NC), TAR(NC), NPTS(NC)
1150     COMMON /ARRA1/ X(NP,NC), Y(NP,NC), XX(NP,NC), YY(NP,NC),
1160       & MAXC(N1), PEF(N1), EMMX(N1), EMMN(N1), EPMX(N1),
1170       & EPHM(N1), ECMX(N1), ECMN(N1), TITLE(NC)
1180     EQUIVALENCE (EMAGAV(1),II(1),X(1,NC)), (EMAG(1,1),X(1,1)),
1190       & (EPHSAV(1),Y(1,NC)), (EPHS(1,1),Y(1,1)),
1200       & (ECOMAV(1),YY(1,NC)), (ECOM(1,1),YY(1,1)),
1210     EQUIVALENCE (TE(1),X(1,1)), (TP(1),X(1,2)), (TM(1),X(1,3)),
1220       & (E(1),Y(1,1)), (EP(1),Y(1,2)), (EM(1),Y(1,3)),
1230       & (DE(1),YY(1,1)), (DEP(1),YY(1,2)), (DEM(1),YY(1,3))
1240     CALL PTIHECPTI>
1250     CALL FPARAH(lrSO>)
1260C
1270     CALL READIN
1280C
1290     PRINT,'WANT PLOT OF INPUT DATA?'
1300     READ, ANS
1310     IF(ANS,NE.1HY) GO TO 10
1320     1 CONTINUE
1330     DO 5 K =1, ICNT
1340     CALL PLOT2<X(1,K),Y(1,K),NPTS(K))
1350     5 CONTINUE
1360     PRINT,'WANT REPLOT?'
1370     READ, ANS
1380     IF(ANS, EQ.1HY) GO TO 1
1390     10 CONTINUE
1400C
1410C     PERFORM INTEGRATIONS AS NEEDED ON DATA TO OBTAIN
1420C     DESIRED QUANTITIES FOR COMPARISON
1430C
1440     NINT = NIBASE
1450     DO 30 J =1, ICNT
1460     IF(NINT, EQ.0) GO TO 30
1470     DO 20 L =1, NINT
1480     DX02 = .5*DT(J)
1490     YNEXT = Y(1,J) + Y(2,J)
1500     Y(1,J) = 0.
Y(NPTS(J)+1,J) = 0.
DO 20 I = 2,NPTS(J)
YT = YNEXT
YNEXT = Y(I,J) + Y(I+1,J)
Y(I,J) = Y(I-1,J) + DX02 * YT
20 CONTINUE
NINT = NICOMP
INTERPOLATE VERTICAL ARRAYS FOR SAME DX IF REQUIRED
DO 60 K = 1,ICNT
IF(DT(K),LE,DX) GO TO 55
YY(1,K) = Y(1,K)
XCUR = DX
I = 1
DO 50 J = 2,NPTS(K)
40 IF(X(J,K),LT,XCUR) GO TO 50
I = I + 1
JM1 = J - 1
YY(I,K) = Y(JM1,K) + (Y(J,K) - Y(JM1,K))*(XCUR-X(JM1,K))
& (X(J,K)-X(JM1,K))
XCUR = I * DX
IF(I-NPOINT) 40,60,60
50 CONTINUE
GO TO 60
55 CONTINUE
IF INTERPOLATION NOT REQUIRED TRANSFER Y ARRAY INTO YY ARRAY
DO 58 I = 1,NPOINT
58 YY(I,K) = Y(I,K)
60 CONTINUE
SET UP HORIZONTAL ARRAY
DO 70 I = 1,NPOINT
70 CONTINUE
PRINT,'WANT PLOT OF PREPROCESSED DATA?'
READ,ANS
IF(ANS.NE.1HY) GO TO 90
80 CONTINUE
DO 85 K = 1,ICNT
CALL PLOT2(XX,YY(1,K),NPOINT)
85 CONTINUE
PRINT,'WANT REPLOT?'
READ,ANS
IF(ANS.EQ.1HY) GO TO 80
90 CONTINUE
IF(NTPLOT.GT.1) GO TO 400
FORM INTEGRALS FOR CORRELATIONS
DX02 = 0.5*DX
ICH1 = ICNT-1
II(1) = 0.
MAXM = ABS(YY(I,1))
DO 100 I = 2,NPOINT
MAXM = MAX(ABS(YY(I,1)),MAXM)
II(I) = II(I-1) + DX02 * (YY(I,1)**2+YY(I-1,1)**2)
100 CONTINUE
K = 2
KM1 = K - 1
MCF = 1.0
PCF = 1.0
EMMX(KM1) = 0.
EMMN(KM1) = 0.
EPSX(KM1) = 0.
EPMN(KM1) = 0.
MAXC(KM1) = ABS(YY(I,K))
PEF(KM1) = 0.
EMAG(I,KM1) = 0.
EPHS(I,KM1) = 0.
SUM1 = 0.
SUM2 = 0.
DO 130 I = 2,NPOINT
MAXC(KM1) = MAX(MAXC(KM1),ABS(YY(I,K)))
SUM1 = SUM1 + DX02 * (YY(I-1,K)**2+YY(I,K)**2)
SUM2 = SUM2 + DX02 * (YY(I-1,1)*YY(I-1,K)+YY(I,1)*YY(I,K))
MCF = SQRT(MAX(SUM1*0.001)/MAX(II(I),0.01))
PCF = MAX(ABS(SUM2),0.001) / MAX(SQRT(SUM1*II(I)),0.01)
EMAG(I,KM1) = (MCF-1.)
EPHS(I,KM1) = (1,-PCF)
EMMX(KM1) = MAX(EMMX(KM1),EMAG(I,KM1))
EPSX(KM1) = MAX(EPSX(KM1),EPHS(I,KM1))
EMMN(KM1) = MIN(EMMN(KM1),EMAG(I,KM1))
EPMN(KM1) = MIN(EPMN(KM1),EPHS(I,KM1))
130 CONTINUE
PEF(KM1) = MAXC(KM1)/MAX(MAXM,.001)-1.
K = K + 1
IF(K.LE.ICNT) GO TO 110
DO 140 K =1,ICH1
ECMX(K) = 0.
ECHN(K) = 0.
ECOM(I,K) = 0.
DO 140 I = 2,NPOINT
CEF = SQRT((EMAG(I,K))**2+(EPHS(I,K))**2)
ECOH(I,K) = SIGN(CEF,EMAG(I,K))
ECMX(K) = MAX(ECMX(K),ECOM(I,K))
ECHN(K) = MIN(ECHN(K),ECOM(I,K))
140 CONTINUE
IF(ICNT.EQ.2) GO TO 200
IF MORE THAN 1 COMPARISON COMPUTE THE AVERAGES
EMAGAV(1) = 0,
EPHSAV(1) = 0,
ECOHAV(1) = 0,
NINVRS = 1./ICM1
DO 160 I =2,NPOINT
EMAGAV(I) = 0,
EPHSAV(I) = 0,
ECOHAV(I) = 0,
DO 150 K =1,ICM1
EMAGAV(I) = EMAGAV(I) + EMAG(I,K)
EPHSAV(I) = EPHSAV(I) + EPHS(I,K)
ECOHAV(I) = ECOHAV(I) + ABS(ECOM(I,K))
150 CONTINUE
EMAGAV(I) = EMAGAV(I) * NINVRS
EPHSAV(I) = EPHSAV(I) * NINVRS
ECOHAV(I) = SIGN(NINVRS*ECOHAV(I),EMAGAV(I))
160 CONTINUE
200 CONTINUE
PRINT,"WANT TABULATED OUTPUT ?"
READ,ANS
K1 = 1
K2 = (ICM1/8) + 1
K3 = MIN(7,ICM1)
DO 205 I =1,K2
PRINT 665,(K,K=K1,K3)
PRINT 670,(MAXC(K),K=K1,K3)
PRINT 671,(PEF(K),K=K1,K3)
PRINT 672,(EMMX(K),K=K1,K3)
PRINT 673,(EMHN(K),K=K1,K3)
PRINT 674,(EPHM(K),K=K1,K3)
PRINT 675,(EPHN(K),K=K1,K3)
PRINT 676,(ECMX(K),K=K1,K3)
PRINT 677,(ECMN(K),K=K1,K3)
K1 = 8
K3 = ICM1
205 CONTINUE
IF(ANS.NE.1HY) GO TO 300
PRINT 650,TITLE(1)
DO 220 K=1,ICM1
PRINT 660,K,TITLE(K+1)
600 CONTINUE
PRINT 610,2,EMAG(2,K),EPHS(2,K),ECOM(2,K)
DO 210 I =ISKIP,NPOINT,ISKIP
PRINT 610,I,EMAG(I,K),EPHS(I,K),ECOM(I,K)
210 CONTINUE
IF(ICNT.EQ.2) GO TO 260
PRINT 620
PRINT 630,2,EMAGAV(2),EPHSAV(2),ECOHAV(2)
DO 230 I =ISKIP,NPOINT,ISKIP
3100 PRINT 630, I, EMAGAV(I), EPHSAV(I), ECOMAV(I)
3110 230 CONTINUE
3120 PRINT,
3130 260 CONTINUE
3140 PRINT,'WANT PLOTS ?'
3150 READ,ANS
3160 IF(ANS.NE.1HY) GO TO 999
3170 300 CONTINUE
3180 PRINT,'WANT PLOT OF XX-EMAG ?'
3190 READ,ANS
3200 IF(ANS.NE.1HY) GO TO 340
3210 DO 335 K =1, ICM1
3220 CALL PLOT2(XX, EMAG(I), NPOINT)
3230 335 CONTINUE
3240 340 PRINT,'WANT PLOT OF XX-EPHS ?'
3250 READ,ANS
3260 IF(ANS.NE.1HY) GO TO 350
3270 DO 345 K =1, ICM1
3280 CALL PLOT2(XX, EPHS(I), NPOINT)
3290 345 CONTINUE
3300 350 PRINT,'WANT PLOT OF XX-ECOM ?'
3310 READ,ANS
3320 IF(ANS.NE.1HY) GO TO 360
3330 DO 355 K =1, ICM1
3340 CALL PLOT2(XX, ECOM(I), NPOINT)
3350 355 CONTINUE
3360 360 IF(ICNT.EQ.2) GO TO 380
3370 PRINT,'WANT PLOT OF XX-EMAGAV ?'
3380 READ,ANS
3390 IF(ANS.EQ.1HY) CALL PLOT2(XX, EMAGAV, NPOINT)
3400 PRINT,'WANT PLOT OF XX-EPHSAV ?'
3410 READ,ANS
3420 IF(ANS.EQ.1HY) CALL PLOT2(XX, EPHSAV, NPOINT)
3430 PRINT,'WANT PLOT OF XX-ECOMAV ?'
3440 READ,ANS
3450 IF(ANS.EQ.1HY) CALL PLOT2(XX, ECOMAV, NPOINT)
3460 380 PRINT,'WANT REPLOT ?'
3470 READ,ANS
3480 IF(ANS.EQ.1HY) GO TO 300
3490 GO TO 999
3500C CALCULATE MEAN AND STANDARD DEVIATIONS
3510C
3520C
3530 400 CONTINUE
3540 ICNT = 1./ICNT
3550 RNH1 = 1./((ICNT-1)
3560 ES = 0.
3570 EMAX = 0.
3580 EMIN = 0.
3590 EPMAX = 0.
3600 EMMIN = 0.
3610 DO 410 K=1, ICNT
3620 ES = ES + TAR(K)
3630 CONTINUE
3640 TE1 = ES*RICNT
3650 SS = 0,
3660 DO 420 K=1,ICNT
3670 SS = SS + (TAR(K)-TE1)**2
3680 CONTINUE
3690 ST = SQRT(SS*RNK1)
3700 TP1 = TE1+ST
3710 TM1 = TE1-ST
3720 DO 450 I=1,NPOINT
3730 ES = 0,
3740 DO 430 K=1,ICNT
3750 ES = ES + YY(I,K)
3760 CONTINUE
3770 E(I) = ES*RICNT
3780 SS = 0,
3790 DO 440 K=1,ICNT
3800 SS = SS + (YY(I,K)-E(I))**2
3810 CONTINUE
3820 ST = SQRT(SS*RNK1)
3830 EP(I) = E(I)+ST
3840 EM(I) = E(I)-ST
3850 EMAX = MAX(E(I),EMAX)
3860 EMIN = MIN(E(I),EMIN)
3870 EPHAX = MAX(EP(I),EPHAX)
3880 EMHIN = MIN(EM(I),EMHIN)
3890 TE(I) = XX(I)+TE1
3900 TP(I) = XX(I)+TP1
3910 TH(I) = XX(I)+TM1
3920 CONTINUE
3930 PRINT,"WANT TABULATED OUTPUT?"
3940 READ,ANS
3950 PRINT 680,EMAX,EMIN,EPHAX,EMIN,TE1,TP1,TM1
3960 K1 = 1
3970 K2 = (ICNT/8) + 1
3980 K3 = MIN(7,ICNT)
3990 DO 455 I =1,K2
4000 PRINT 665, (K,K=K1,K3)
4010 PRINT 682, (TAR(K),K=K1,K3)
4020 K1 = 8
4030 K3 = ICNT
4040 CONTINUE
4050 PRINT,
4060 IF(ANS.NE.1HY) GO TO 470
4070 PRINT 690
4080 DO 460 I =ISkip,NPOINT,ISkip
4090 PRINT 630,I,E(I),EP(I),EM(I)
4100 CONTINUE
4110 PRINT,
4120 PRINT,
4130 PRINT,"WANT PLOTS?"
4140 READ,ANS
4150 IF(ANS.NE.1HY) GO TO 500

A28
CONTINUE
PRINT,"WANT PLOT OF TE-E ?"
READ,ANS
IF(ANS.EQ.1) CALL PLOT2(TE,E,NPOINT)
PRINT,"WANT PLOT OF TP-EP ?"
READ,ANS
IF(ANS.EQ.1) CALL PLOT2(TP,EP,NPOINT)
PRINT,"WANT PLOT OF TM-EM ?"
READ,ANS
IF(ANS.EQ.1) CALL PLOT2(TM,EM,NPOINT)
PRINT,"WANT PLOT OF XX-E ?"
READ,ANS
IF(ANS.EQ.1) CALL PLOT2(XX,E,NPOINT)
PRINT,"WANT PLOT OF XX-EP ?"
READ,ANS
IF(ANS.EQ.1) CALL PLOT2(XX,EP,NPOINT)
PRINT,"WANT PLOT OF XX-EM ?"
READ,ANS
IF(ANS.EQ.1) CALL PLOT2(XX,EM,NPOINT)
PRINT,"WANT REPOINT ?"
READ,ANS
IF(ANS.EQ.1) GO TO 470
CONTINUE
IF(NTPLOT.LT.3) GO TO 999
CALCULATE DERIVATIVE WITH RESPECT TO TIME FOR MEAN AND STANDARD DEVIATIONS
DEMAX = 0.
DEMIN = 0.
DEPMAX = 0.
DEMIN = 0.
DXI = 1./DX
E(1) = 0.
DEP(1) = 0.
DEM(1) = 0.
DO 510 I=2,NPOINT
DE(I) = (E(I)-E(I-1))*DXI
DEP(I) = (EP(I)-EP(I-1))*DXI
DEM(I) = (EM(I)-EM(I-1))*DXI
DEMAX = MAX(DE(I),DEMAX)
DEMIN = MIN(DE(I),DEMIN)
DEPMAX = MAX(DEP(I),DEPMAX)
DEMMIN = MIN(DEM(I),DEMMIN)
CONTINUE
PRINT,"WANT TABULATED OUTPUT ?"
READ,ANS
PRINT 692,DEMAX,DEMIN,DEPMAX,DEMMIN
PRINT,
IF(ANS.NE.1) GO TO 530
PRINT 694
DO 520 I =ISKIP,NPOINT,ISKIP
PRINT 630,I,DE(I),DEP(I),DEM(I)
CONTINUE
PRINT, "WANT PLOT OF XX-DE ?"
READ,ANS
IF(ANS.EQ.1) CALL PLOT2(XX,DE,NPOINT)
PRINT, "WANT PLOT OF XX-DEP ?"
READ,ANS
IF(ANS.EQ.1) CALL PLOT2(XX,DEP,NPOINT)
PRINT, "WANT PLOT OF XX-DEM ?"
READ,ANS
IF(ANS.EQ.1) CALL PLOT2(XX,DEM,NPOINT)
PRINT, "WANT REPLOT ?"
READ,ANS
IF(ANS.EQ.1) GO TO 530
999 CONTINUE
CALL PTIME(PTU)
PRINT 640,(PTU-PTI)*3600.
STOP
610 FORMAT(I6,3F10.3)
630 FORMAT(I6,3F10.3)
640 FORMAT(* PTU-SEC = *,F10.2)
650 FORMAT(/"BASE",5X,A60)
660 FORMAT(* CASE *,I3,1X,A60//)
665 FORMAT(/" CASE ",7I10)
670 FORMAT(* MAXC = *,7F10.3)
671 FORMAT(* PEF = *,7F10.3)
672 FORMAT(* EMMX = *,7F10.3)
673 FORMAT(* EMMN = *,7F10.3)
674 FORMAT(* EPHX = *,7F10.3)
675 FORMAT(* EPMN = *,7F10.3)
676 FORMAT(* ECNX = *,7F10.3)
677 FORMAT(* ECMN = *,7F10.3)
& 7X,"TE1",7X,"TP1",7X,"TH1"/2X,3F10.3)
682 FORMAT(* TAR = *,7F10.3)
END
SUBROUTINE READIN
PARAMETER NC = 10, N1 = NC-1, NP = 200
DIMENSION TDUM(20),C1(4),C2(4),C3(4)
 CHARACTER TITLE*60,TITL*20(3,NC)
 CHARACTER FILE*12,FMTF*9/9H(T12,1H1:)/,ANS*1
 EQUIVALENCE (TITLE,TITL)
 COMMON /INPUT/ XFINAL,DX,NTPLOT,ISKIP,NIBASE,NICOMP,
ICNT, NPOINT, DT(NC), TAR(NC), NPTS(NC).

COMMON /ARRA/ X(NP, NC), Y(NP, NC), XX(NP), YY(NP, NC), MAXC(N1), PEF(N1), EMHX(N1), EMHN(N1), EPMX(N1), EPMN(N1), ECMX(N1), ECMHN(N1), TITLE(NC)

DATA NOE, NAFT/04000000000000, 04037000000000/

PRINT 1, "READ XFINAL, DX, NTPLLOT, SEARV, ISKIP, NIBASE, NICOMP"

READ 1, XFINAL, DX, NTPLLOT, SEARV, ISKIP, NIBASE, NICOMP

ICNT = 0

NPTM = NP

NPOINT = XFINAL/DX + 1

IF(NPOINT.LE.NP) GO TO 5

XFINAL = (NP-1) * DX

PRINT 300, NPOINT, NP, XFINAL

NPOINT = NP

5 CONTINUE

PRINT 1, "NPOINT =", NPOINT

10 ICNT = ICNT + 1

PRINT 1, "READ NSORCE, NFILE"

READ 1, NSORCE, NFILE

IF(NSORCE.EQ.0) GO TO 200

IF(NFILE.LT.1) GO TO 700

IF(NSORCE-1) 200, 20, 100

20 REWIND 1

IF(NFILE.EQ.1) GO TO 40

DO 30 I = 1, 2*(NFILE-1)

30 READ(1, END=10)

40 READ 1, NPTS(ICNT), DT(ICNT), C1, C2, C3

NPT = MIN(NPTS(ICNT), NPOINT)

IF(SEARV.LE.0) GO TO 70

NPS = MIN(NPTS(ICNT), NP)

READ 1, (XX(I), I=1, NPS)

DO 50 I = 1, NPS

50 CONTINUE

NSTRT = I-1

TAR(ICNT) = DT(ICNT)*NSTRT

NPT = MIN(NPTS(ICNT)-NSTRT, NPT)

BACKSPACE 1

READ 1, (Y(I, ICNT), I=1, NPT)

GO TO 80

70 CONTINUE

READ 1, (Y(I, ICNT), I=1, NPT)

TAR(ICNT) = 0.

80 CONTINUE

NPTS(ICNT) = NPT

NPTH = MIN(NPT, NPTH)

CALL BCDASC(C1, TITL(1, ICNT), 20)

CALL BCDASC(C2, TITL(2, ICNT), 20)

CALL BCDASC(C3, TITL(3, ICNT), 20)

GO TO 10

100 REWIND 2

IF(NFILE.EQ.1) GO TO 140
DO 130 I = 1, 2*(NFILE-1)
130 READ(2, END=10)
DO 140 I = 1, NFILE
READ(2) NPTS(ICNT), DT(ICNT), TDUM
NPT = MIN(NPTS(ICNT), NPOINT)
IF(SEARV.LE.0.) GO TO 170
NPS = MIN(NPTS(ICNT), NP)
READ(2) (XX(I), I = 1, NPS)
DO 150 I = 1, NPS
IF(XX(I)-SEARV) 150, 160, 150
CONTINUE
NSTRT = I-1
TAR(ICNT) = DT(ICNT)*NSTRT
NPT = MIN(NPTS(ICNT) - NSTRT, NPT)
BACKSPACE 2
READ(2) (XX(I), I = 1, NPT)
DO 150 I = 1, NPT
CONTINUE
COUNT.
TAR(ICNT) = 0.
CONTINUE
NPTS(ICNT) = NPT
NPTM = MIN(NPT, NPTM)
CALL BCDASC(TDUM, TITLE(ICNT), 60)
GO TO 10
CONTINUE
ICNT = ICNT-1
DO 500 K = 1, ICNT
DT(K) = DT(K)*1000.
TAR(K) = TAR(K)*1000.
DO 500 I = 1, NPTS(K)+1
X(I, K) = DT(K) * (I-1)
CONTINUE
IF(NPTH.GE.NPOINT) GO TO 600
NPOINT = NPTM
XFINAL = (NPOINT-1)*DX
PRINT 310, NPOINT, XFINAL
CONTINUE
RETURN
CONTINUE
COUNT.
PRINT, 'INPUT FILE ?'
READ, FILE
IF(FILE.EQ.'1H') GO TO 200
CALL DETACH(NSORCE,)
ENCOD(FILE, FMTF)
CALL ATTACH(NSORCE, FILE, 1, 0, ISTAT)
IF(ISTAT.EQ.NOE, OR, ISTAT.EQ.NAFT) GO TO 98
PRINT, 'ISTAT = ', ISTAT, ' FILE ', FILE
PRINT 96, ISTAT
96 FORMAT(2X, 012)
GO TO 700
CONTINUE
PRINT, 'READ NFILE

A32
READ,NFILE
IF(NSORCE-1) 200,20,100
300 FORMAT(*XFIMAL TOO LARGE NPOINT = ',I10,' NP = ',I10/
& "NEW XFINAL = ',F10.2)
310 FORMAT(* NPOINT RESET TO ',I10,' XFINAL = ',F10.2)
END
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