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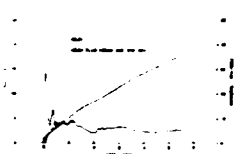

TECHNICAL REPORT SL-83-4

AN OBJECTIVE WAVEFORM COMPARISON TECHNIQUE

by

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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)

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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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LIST OF FIGURES

CONVERSION FACTORS, METRIC (SI) TO U. S. CUSTOMARY UNITS OF MEASUREMENT

Metric (SI) units of measurement used in this report can be converted to U. S. customary units as follows:

Multiply	By	To Obtain
centimetres	0.3937007	inches
centimetres per millisecond	0.3937007	inches per millisecond
metres	3.280839	feet
metres per millisecond	3.280839	feet per millisecond
newtons	0.2248089237	pounds (force)
megapascals	0.01	kilobars
megapascals	145.0377439	pounds (force) per square inch
grams per cubic centimetre	62.42797	pounds (mass) per cubic foot
kilograms	2.204622476	pounds (mass)

CHAPTER 1

INTRODUCTION

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 digitized 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):

$$P(t) = \sum_{n=-\infty}^{\infty} C_n \exp\ (inw_o t) \tag{2.1}$$

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

$$C_n = \frac{1}{T} \int_{-T/2}^{T/2} P(t) \exp\ (-inw_o t)\ dt \tag{2.2}$$

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

$$\frac{1}{T}\int_{-T/2}^{T/2} P^2(t)\,dt = \sum_{n=-\infty}^{\infty} \left|C_n\right|^2 \qquad (2.3)$$

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 ϕ). Such waveforms are correlated; Reference 3 defines this correlation as the temporal autocorrelation function $\chi(\phi)$, where

$$\chi(\phi) = \frac{1}{T}\int_{-T/2}^{T/2} P_1(t)P_2(t+\phi)\,dt \qquad (2.4)$$

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,

$$M_{cf}(t) = \frac{\left[\int_o^t R_2^2(\tau)\ d\tau\right]^{1/2}}{\left[\int_o^t R_1^2(\tau)\ d\tau\right]^{1/2}} \tag{2.5}$$

and

$$P_{cf}(t) = \frac{\left|\int_o^t R_1(\tau)R_2(\tau)\ d\tau\right|}{\left[\int_o^t R_1^2(\tau)\ d\tau\right]^{1/2}\left[\int_o^t R_2^2(\tau)\ d\tau\right]^{1/2}} \tag{2.6}$$

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.,

$$C_{ef}(t) = \left\{\left[M_{cf}(t) - 1\right]^2 + \left[P_{cf}(t) - 1\right]^2\right\}^{1/2} \tag{2.7}$$

Finally, the magnitude error, phase-and-frequency error, and combined error were defined by Geers as

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

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

$$E_{com}(t) = \text{SIGN}\left[E_{mag}(t)\right] \left\{\left[E_{mag}(t)\right]^2 + \left[E_{phs}(t)\right]^2\right\}^{1/2} \quad (2.10)$$

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 $E_{com}(t)$ in Equation 2.10 capitalizes on the orthogonality of $E_{mag}(t)$ and $E_{phs}(t)$, 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

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

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

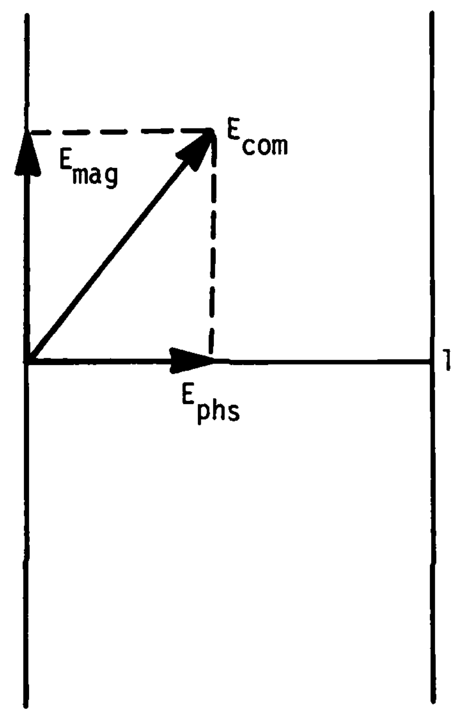


Figure 2.1 Orthogonality relationship for $E_{mag}(t)$, $E_{phs}(t)$ and their relation to $E_{com}(t)$.

$$MEAN\left[E_{mag}(t)\right] = \frac{\sum_{n=1}^{N}\left[E_{mag}(t)\right]_n}{N} \qquad (2.12)$$

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

and

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

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 $E_{mag}(t)$ and $E_{phs}(t)$. This is due to the vector magnitude aspect of $E_{com}(t)$; i.e., $\pm E_{mag}(t)$ or $\pm E_{phs}(t)$ produces the same $E_{com}(t)$.

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):

$$R_1(t) = \sin 2\pi t \tag{3.1}$$

and

$$R_2(t) = (1 + \varepsilon_m) \sin (2\pi t + \phi) \tag{3.2}$$

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 ε_m, and an error in phase equal to ϕ. Substitution of Equations 3.1 and 3.2 into Equations 2.8 and 2.9 leads to

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

and

$$E_{phs}(t) = 1 - \frac{\left|\cos \phi - \frac{\sin 2\pi t}{2\pi t} \cos (2\pi t + \phi)\right|}{\left[1 - \frac{\sin 2\pi t}{2\pi t} \cos (2\pi t + 2\phi)\right]^{1/2}\left[1 - \frac{\sin 2\pi t}{2\pi t} \cos 2\pi t\right]^{1/2}} \tag{3.4}$$

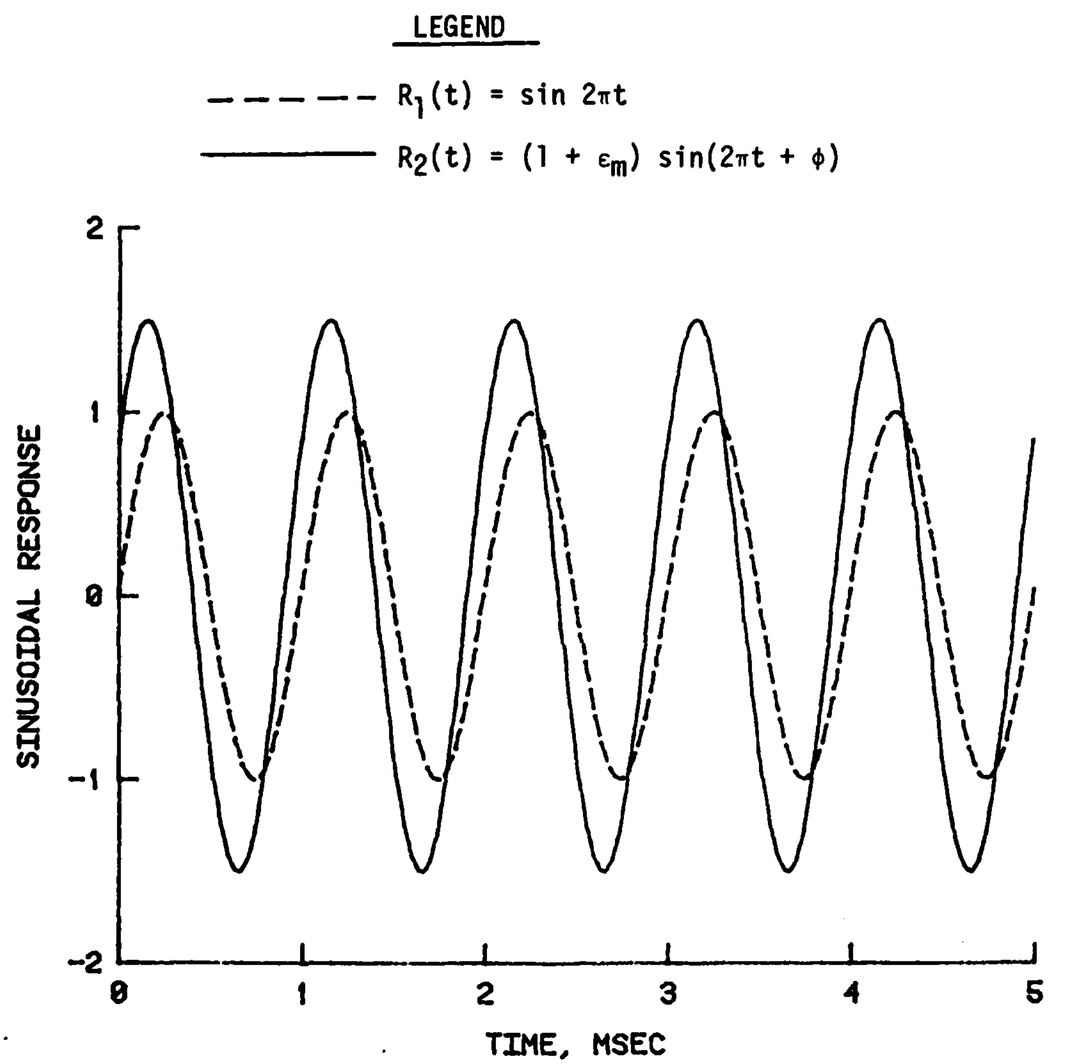


Figure 3.1 Example 1: Time histories of two undamped, identical frequency, sinusoidal responses; $\epsilon_m = 0.5$ and $\phi = 0.6$ radian.

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

$$E_{mag}(t) \approx \left|1 + \varepsilon_m\right| - 1 \tag{3.5}$$

and

$$E_{phs}(t) \approx 1 - \left|\cos \phi\right| \tag{3.6}$$

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

$$E_{mag}(t) = \varepsilon_m \tag{3.7}$$

and

$$E_{phs}(t) = 0 \tag{3.8}$$

Moreover, for $t > 2$, Equation 3.5 can be rewritten as

$$\left.\begin{aligned} E_{mag}(t) &= \varepsilon_m && \text{for } \varepsilon_m \geq -1 \\ E_{mag}(t) &= -(\varepsilon_m + 2) && \text{for } \varepsilon_m \leq -1 \end{aligned}\right\} \tag{3.9}$$

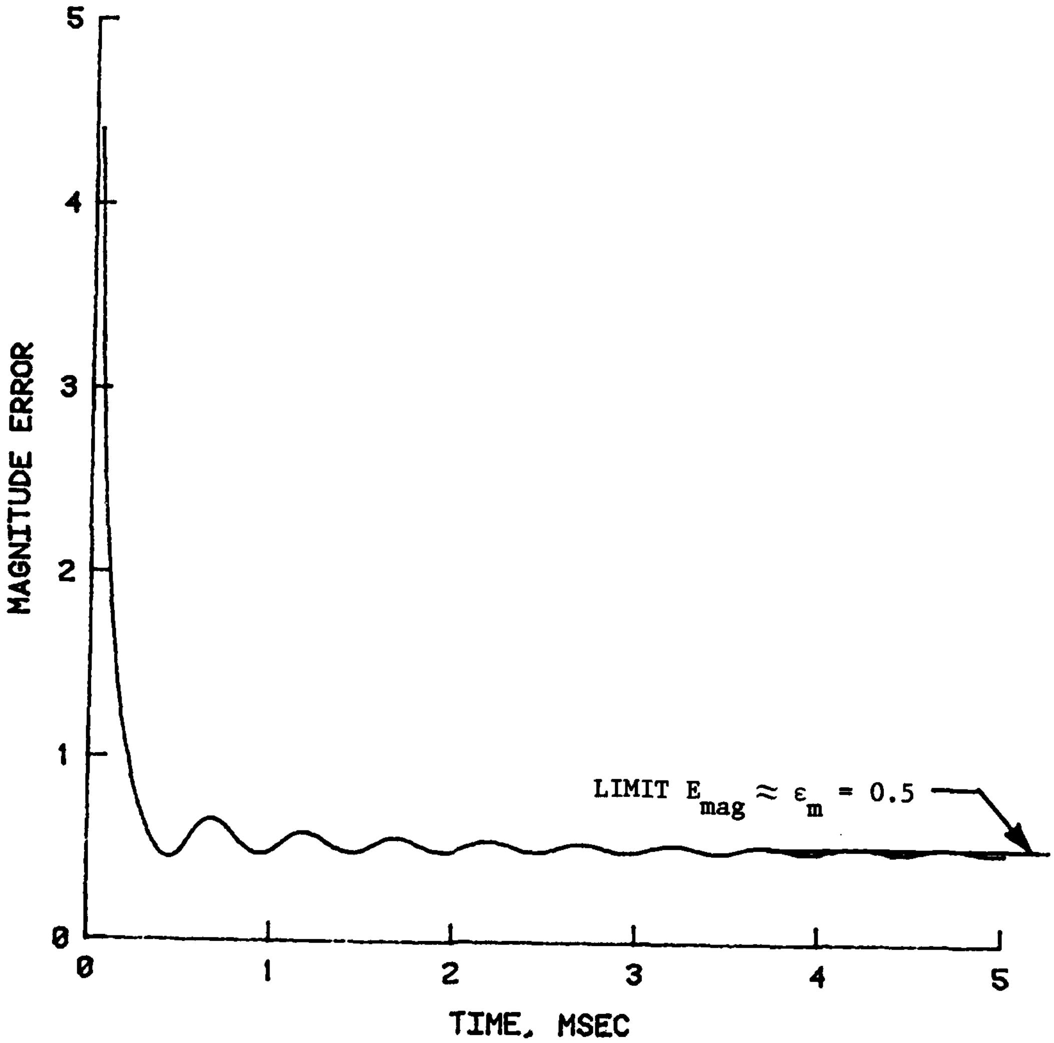


Figure 3.2 Time history of magnitude error for example 1.

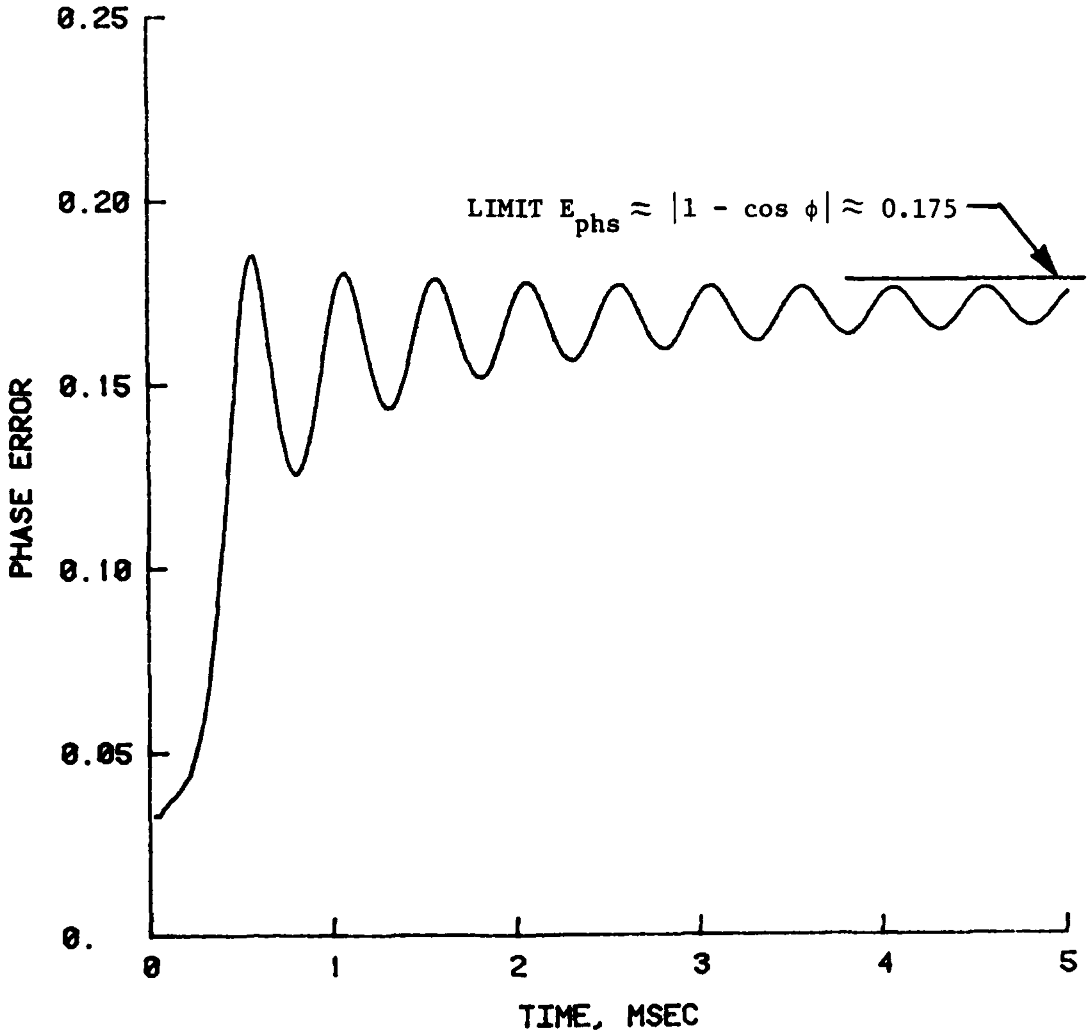


Figure 3.3 Time history of phase error for example 1.

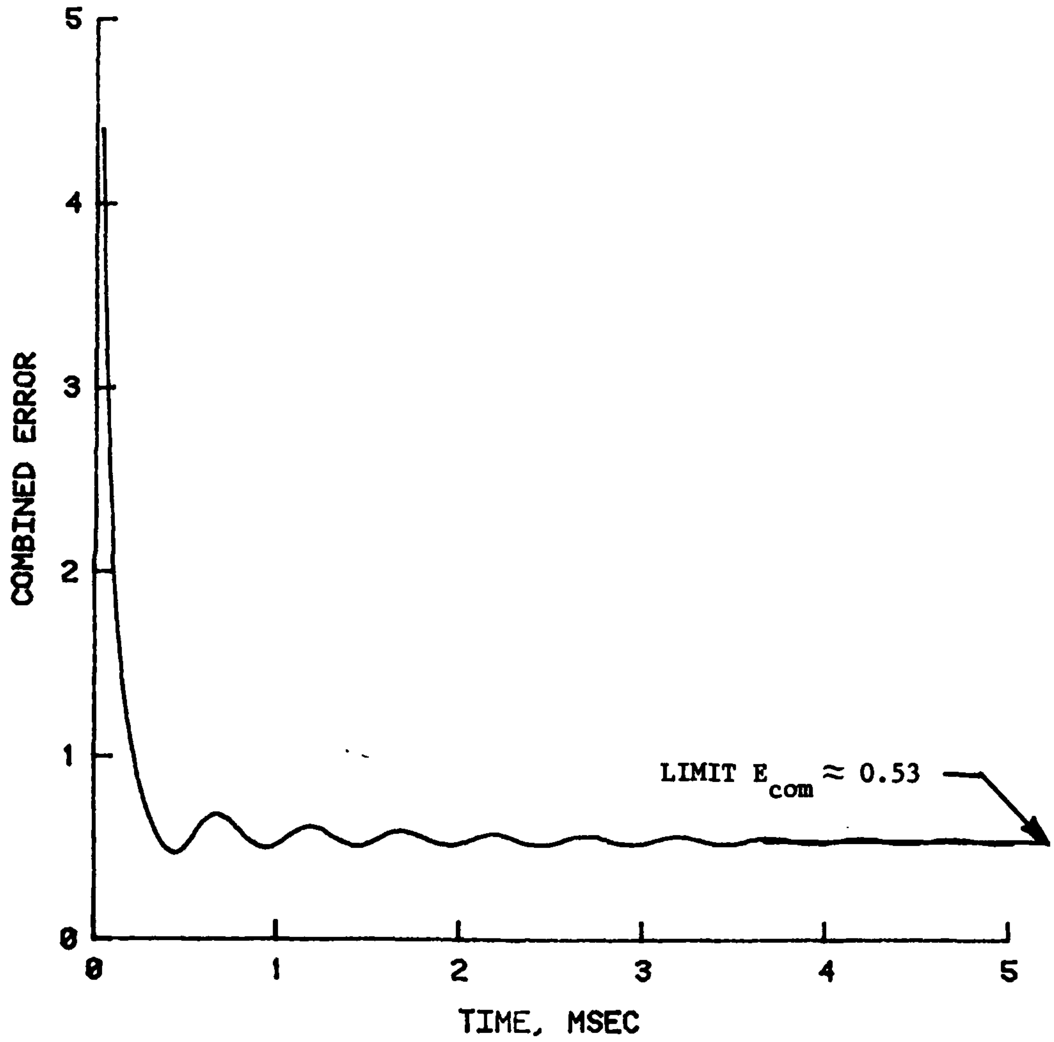


Figure 3.4 Time history of the combined error for example 1.

which leads to

$$-1 \leq E_{mag}(t) \leq \infty \tag{3.10}$$

Further, for $t > 2$, Equations 3.6 and 3.8 indicate that

$$0 \leq E_{phs}(t) \leq 1 \tag{3.11}$$

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

$$E_{phs}(t) \quad 1 - \frac{1 + \varepsilon_m}{\left|1 + \varepsilon_m\right|} \cos \phi \tag{3.12}$$

which would make the phase error dependent upon ε_m . This, in turn, could lead to unreliable results. For example, if $\phi = 0$ and $\varepsilon_m = -1 + \delta$, where δ is a small positive increment $<<1$, Equation 3.12 gives $E_{phs}(t) \approx 0$; yet for $\phi = 0$ and $\varepsilon_m = -1 - \delta$, $E_{phs}(t) \approx 2$. This suggests that in practical cases with $\left|R_2(t)\right| << \left|R_1(t)\right|$, $E_{phs}(t)$ 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)

$$R_1(t) = \sin 2\pi t \tag{3.13}$$

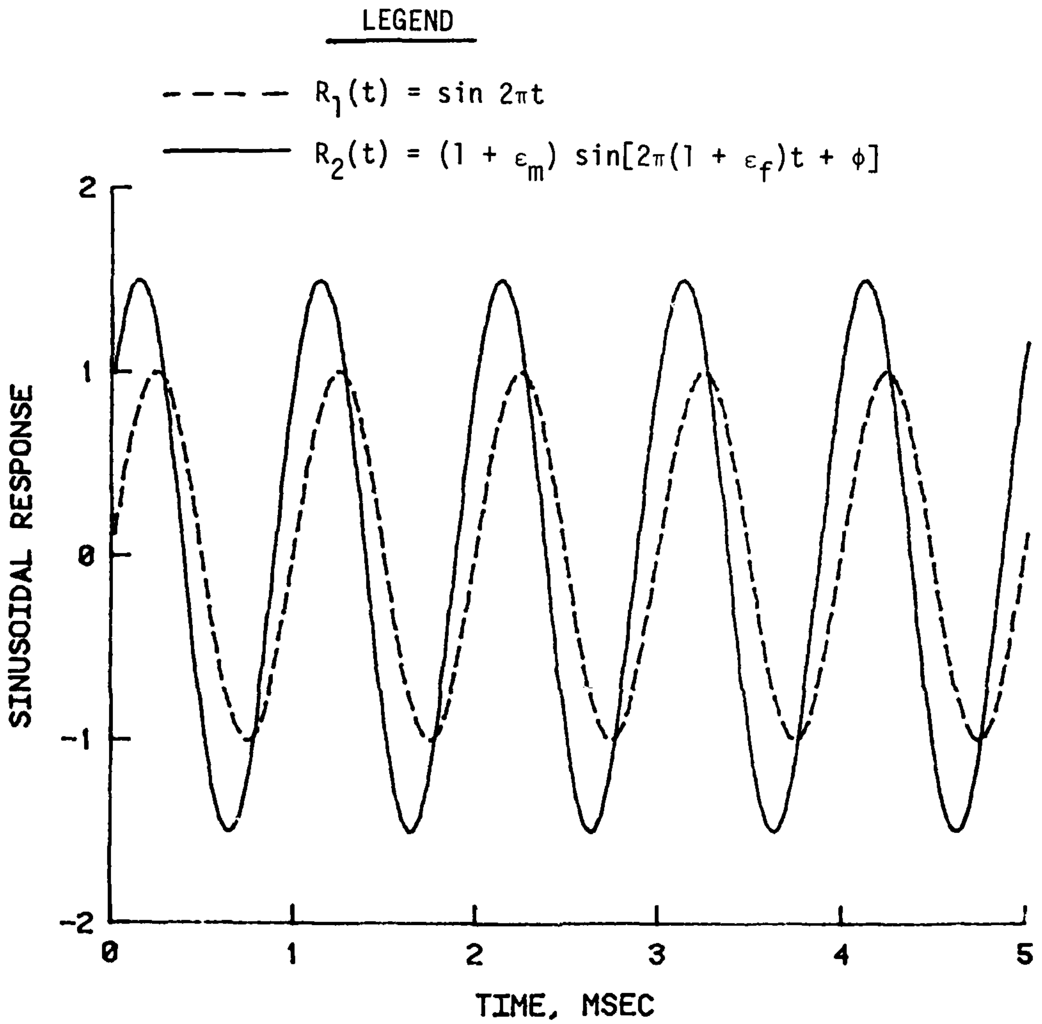


Figure 3.5 Example 2: Time histories of two undamped sinusoidal responses; $\varepsilon_m = 0.5$, $\phi = 0.6$ radian, and $\varepsilon_f = 0.005$.

$$R_2(t) = (1 + \varepsilon_m) \sin \left[2\pi(1 + \varepsilon_f)\ t + \phi\right] \tag{3.14}$$

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 ε_m, error in frequency equal to ε_f, and error in phase equal to ϕ. 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

$$E_{mag}(t) = \frac{\left\{1 - \dfrac{\sin\left[2\pi(1 + \varepsilon_f)t\right]}{2\ (1 + \varepsilon_f)t} \cos\left[2\pi(1 + \varepsilon_f)t + 2\phi\right]\right\}^{1/2}}{\left[1 - \dfrac{\sin 2\pi t}{2\pi t} \cos 2\pi t\right]^{1/2}} \left|1 + \varepsilon_m\right| - 1 \tag{3.15}$$

and

$$E_{phs}(t) = 1 - \frac{\left|\cos\phi\left[\dfrac{\sin 2\pi\varepsilon_f t}{2\pi\varepsilon_f t} - \dfrac{\sin 2\pi(2 + \varepsilon_f)t}{2\pi(2 + \varepsilon_f)t}\right] - \sin\phi\left[\dfrac{\sin^2\pi\ \varepsilon_f t}{\pi\varepsilon_f t} - \dfrac{\sin^2\pi\ (2 + \varepsilon_f)t}{\pi(2 + \varepsilon_f)t}\right]\right|}{\left[1 - \dfrac{\sin 2\pi t}{2\pi t} \cos 2\pi t\right]^{1/2}\left\{1 - \dfrac{\sin\left[2\pi(1 + \varepsilon_f)t\right]}{2\pi(1 + \varepsilon_f)t} \cos\left[2\pi(1 + \varepsilon_f)t + 2\phi\right]\right\}^{1/2}} \tag{3.16}$$

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 $\varepsilon_f \ll 1$, Equations 3.15 and 3.16 reduce to (see Figures 3.6 through 3.8)

$$E_{mag}(t) \approx \left|1 + \varepsilon_m\right| - 1 \tag{3.17}$$

and

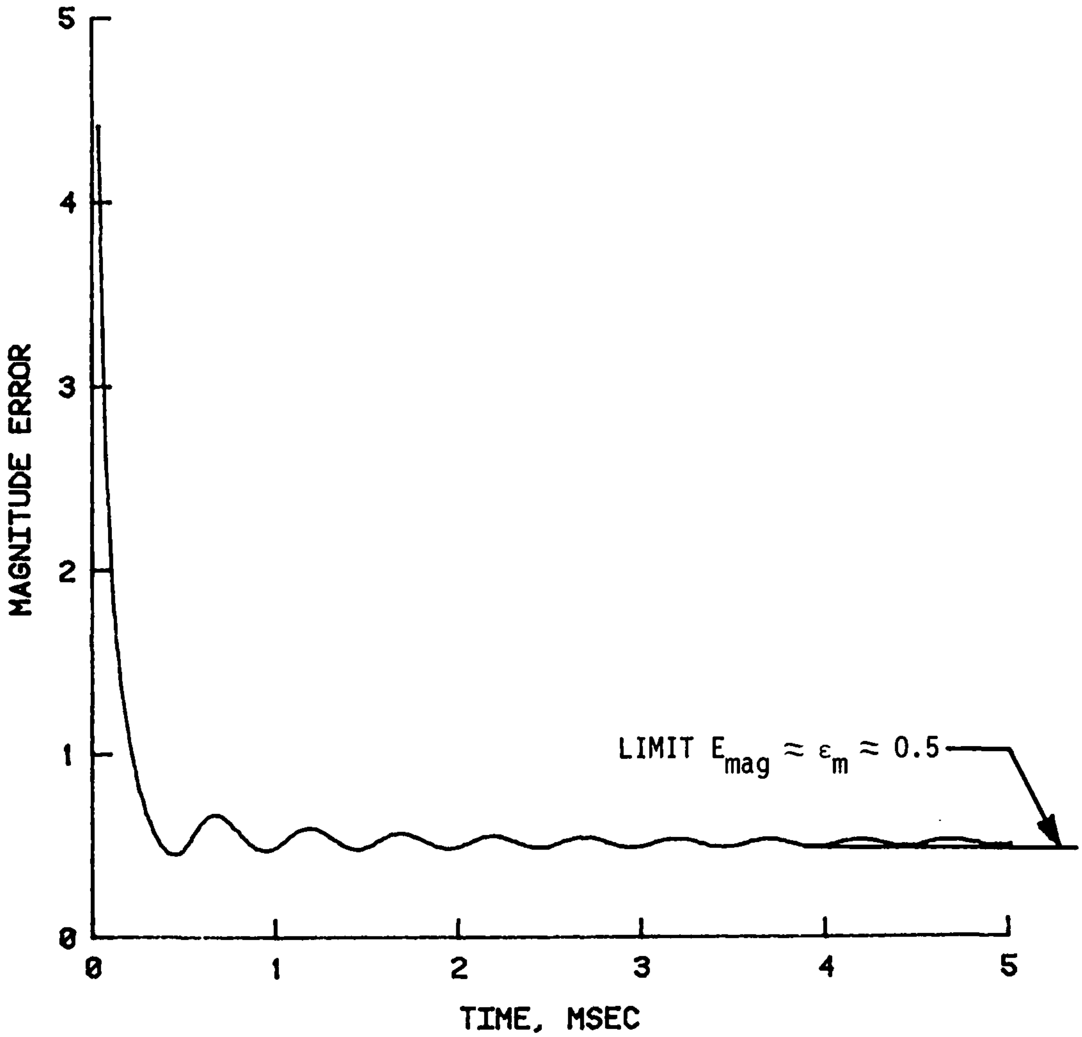


Figure 3.6 Time history of magnitude error for example 2.

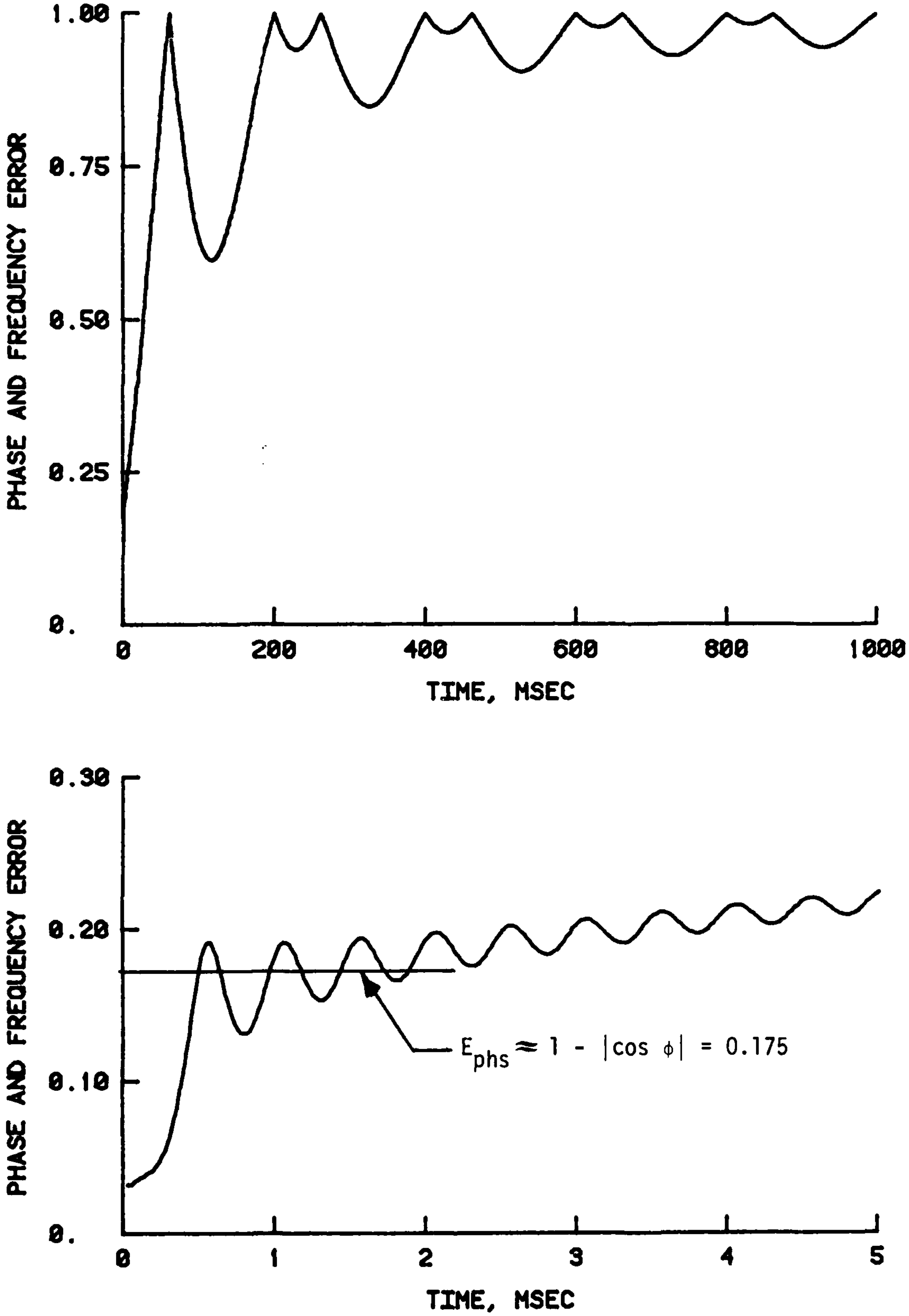
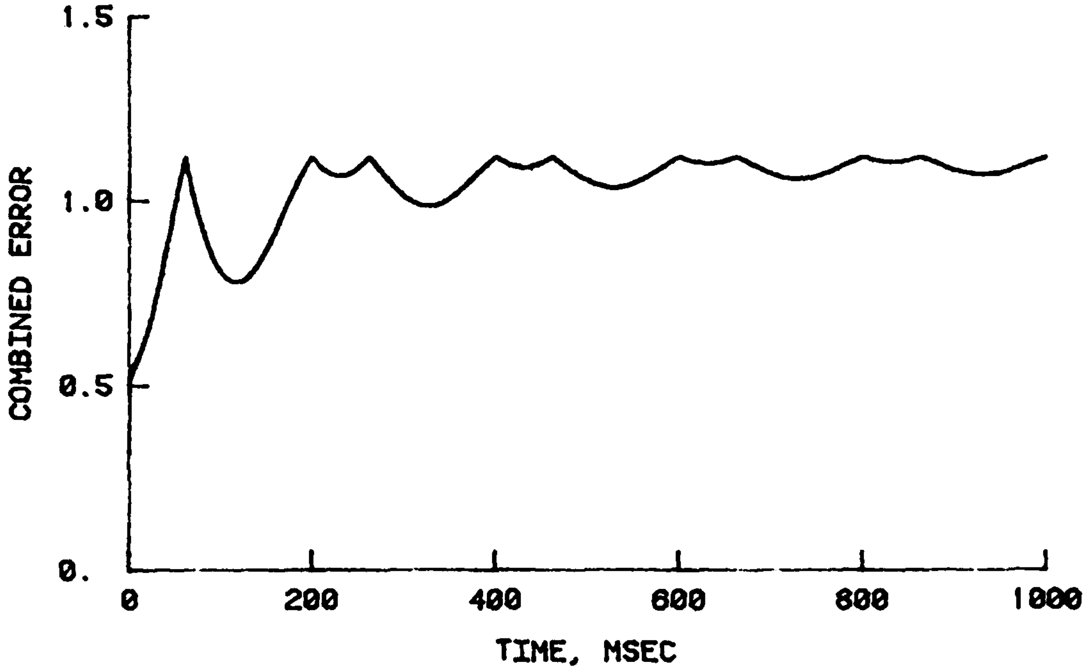


Figure 3.7 Time history of phase-and-frequency error for example 2.



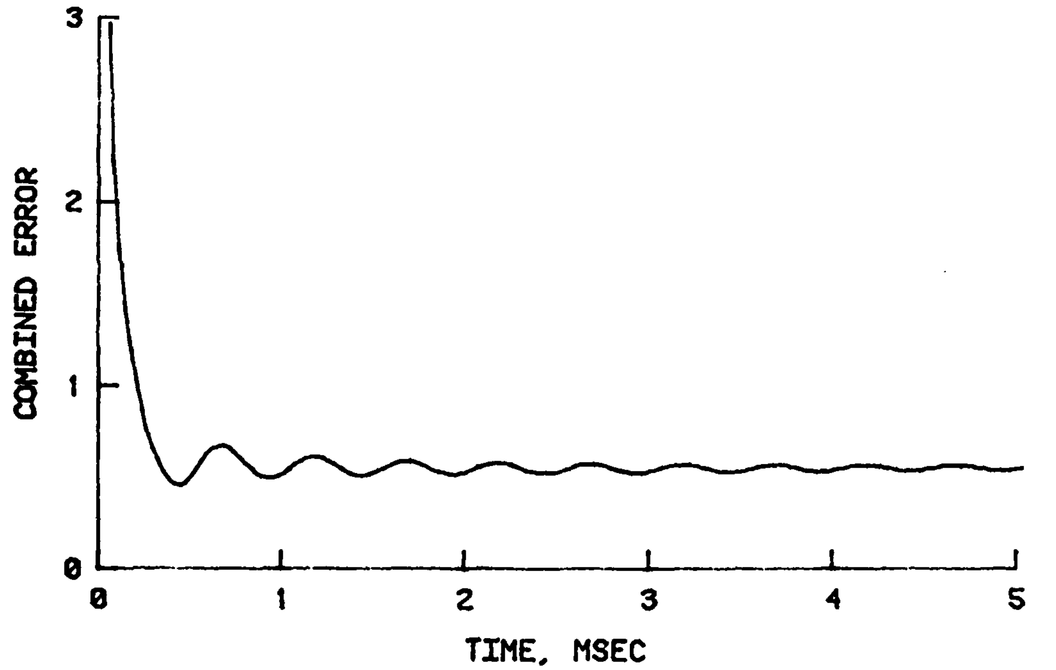


Figure 3.8 Time history of the combined error for example 2.

$$E_{phs}(t) \approx 1 - \left| \frac{\sin \pi\varepsilon_f t}{\pi\varepsilon_f t} \cos (\phi + \pi\varepsilon_f t) \right| \qquad (3.18)$$

Note that Equation 3.17 is identical to the corresponding result for the previous example (Equation 3.5). Note too that if $2 < t \ll (\pi\varepsilon_f)^{-1}$, Equation 3.18 is essentially identical to its earlier counterpart (Equation 3.6); i.e., $E_{phs}(t) \approx 1 - |\cos \phi|$; however, for $t \gg (\varepsilon_f)^{-1}$ $E_{phs} \approx 1$ (see Figure 3.7).

From this example we conclude that frequency error, as embodied in the term ε_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)

$$R_1(t) = \sin (2\pi t) \exp (-\beta t) \qquad (3.19)$$

and

$$R_2(t) = (1 + \varepsilon_m) \sin [2\pi(1 + \varepsilon_f)t + \phi] \exp [-(1 + \varepsilon_d)\beta t] \qquad (3.20)$$

where ε_m , ϕ , and ε_f are as before, β is the damping factor (0.4 $msec^{-1}$ in this example) and ε_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

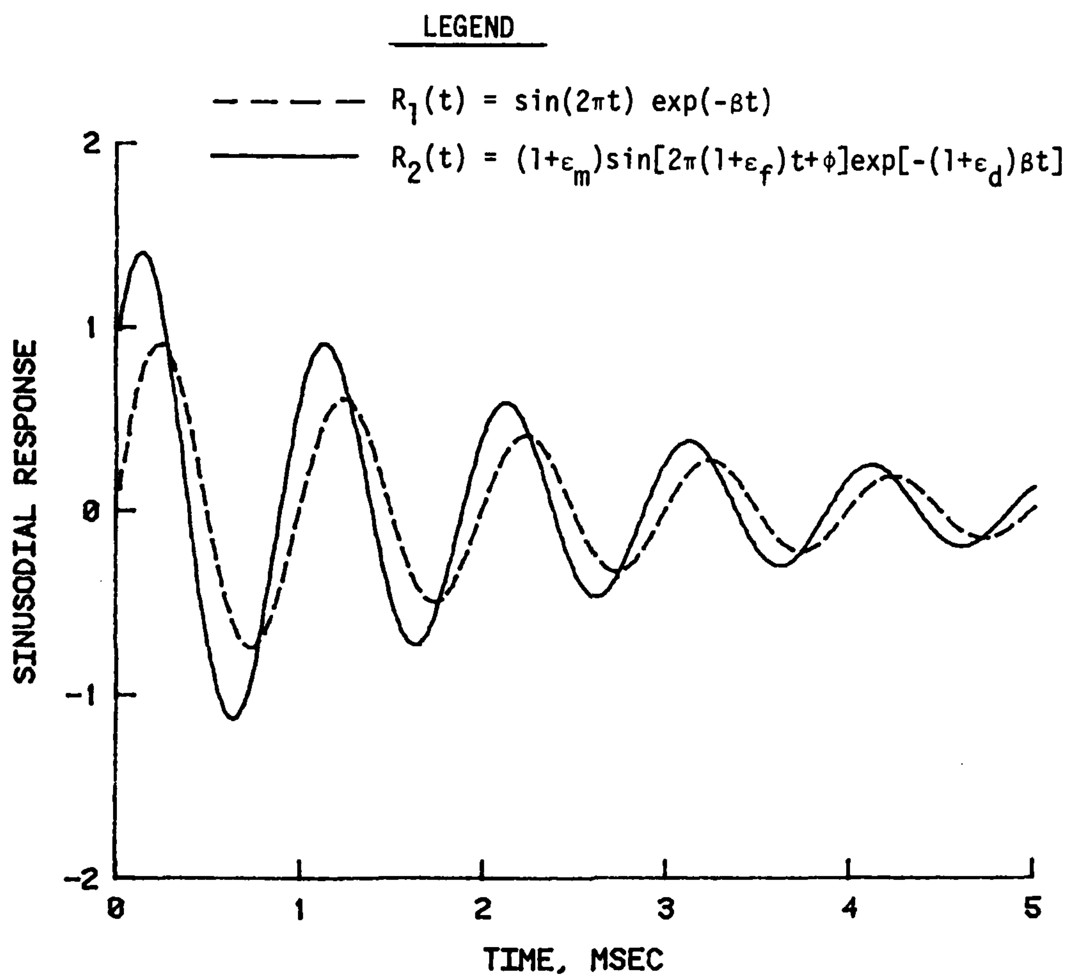


Figure 3.9 Example 3: Time histories of two lightly damped sinusoidal responses; $\varepsilon_m = 0.5$, $\phi = 0.6$ radian, $\varepsilon_f = 0.005$, $\varepsilon_d = 0.1$, and $\beta = 0.4$ (msec)$^{-1}$.

$$E_{mag}(t) = \frac{\sqrt{A}}{\sqrt{B}} - 1 \qquad (3.21)$$

and

$$E_{phs}(t) = 1 - \frac{|C|}{\sqrt{A}\ \sqrt{B}} \qquad (3.22)$$

where

$$A = \frac{(1 + \varepsilon_m)^2}{4\beta(1 + \varepsilon_d)} \left\{1 - \frac{a \sin 2\phi + a^2 \cos 2\phi}{1 + a^2} - \left[1 - \frac{a \sin (2bt + 2\phi) + a^2 \cos (2bt + 2\phi)}{1 + a^2}\right] \exp (2abt)\right\} \qquad (3.23)$$

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

$$\begin{aligned} C = \frac{(1 + \varepsilon_m)}{2} \Bigg\{ & \frac{-(2 + \varepsilon_d)\ \beta \cos (2\pi\varepsilon_f t + \phi) + 2\pi\varepsilon_f \sin (2\pi\varepsilon_f t + \phi)}{\left[(2 + \varepsilon_d)\beta\right]^2 + (2\pi\varepsilon_f)^2} \\ & + \frac{(2 + \varepsilon_d)\ \beta \cos \left[2\pi(2 + \varepsilon_f)t + \phi\right] - 2\pi(2 + \varepsilon_f) \sin \left[2\pi(2 + \varepsilon_f)t + \phi\right]}{\left[(2 + \varepsilon_d)\beta\right]^2 + \left[2\pi(2 + \varepsilon_f)\right]^2} \Bigg\} \exp\left[-(2 + \varepsilon_d)\beta t\right] \\ & + \frac{(1 + \varepsilon_m)}{2} \left\{ \frac{(2 + \varepsilon_d)\beta \cos \phi - 2\pi\varepsilon_f \sin \phi}{\left[(2 + \varepsilon_d)\beta\right]^2 + (2\pi\varepsilon_f)^2} - \frac{(2 + \varepsilon_d)\beta \cos \phi - 2\pi(2 + \varepsilon_f) \sin \phi}{\left[(2 + \varepsilon_d)\beta\right]^2 + \left[2\pi(2 + \varepsilon_f)\right]^2} \right\} \end{aligned} \qquad (3.25)$$

$$a = -\frac{(1 + \varepsilon_d)\beta}{2\pi(1 + \varepsilon_f)}$$

and

$$b = 2\pi(1 + \varepsilon_f) \qquad (3.26)$$

The combined error (Equation 2.10) becomes

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

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

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

and

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

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 $\beta/2\pi$. However, the phase-and-frequency error is independent of ε_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

$$E_{mag}(t)\Big|_{t\to\infty} \approx \varepsilon_m - \frac{1}{2}\varepsilon_d \tag{3.30}$$

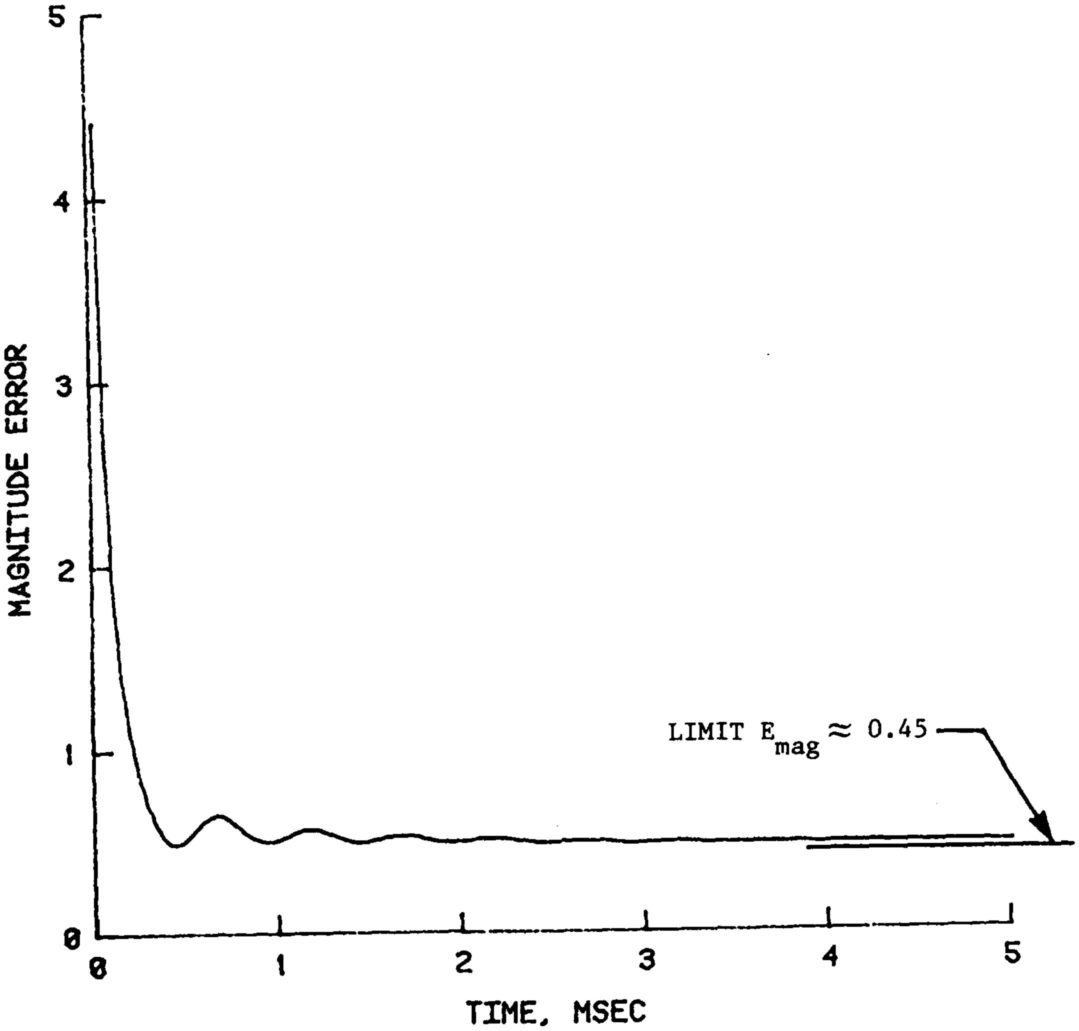


Figure 3.10 Time history of magnitude error for example 3.

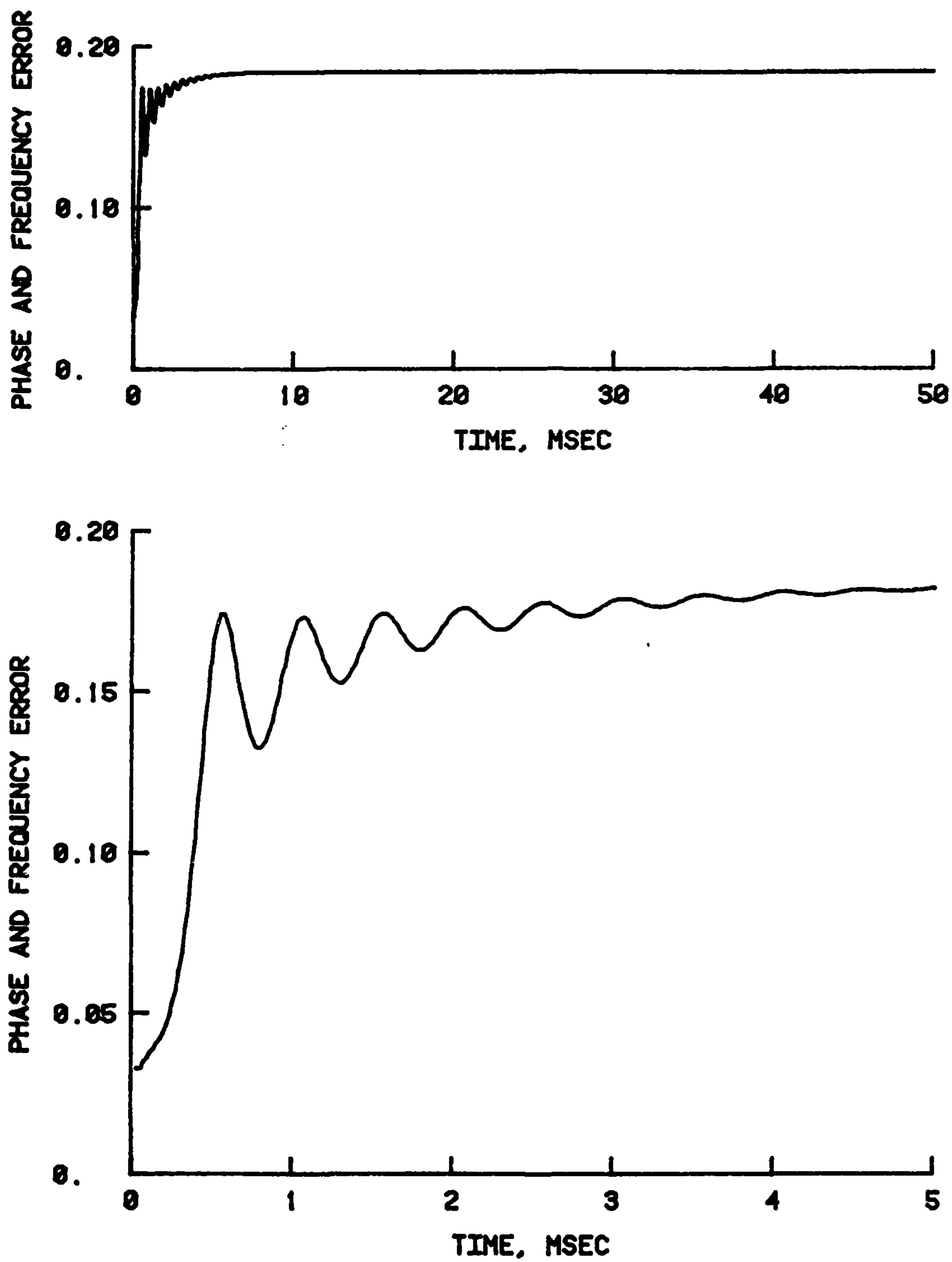


Figure 3.11 Time history of phase-and-frequency error for example 3.

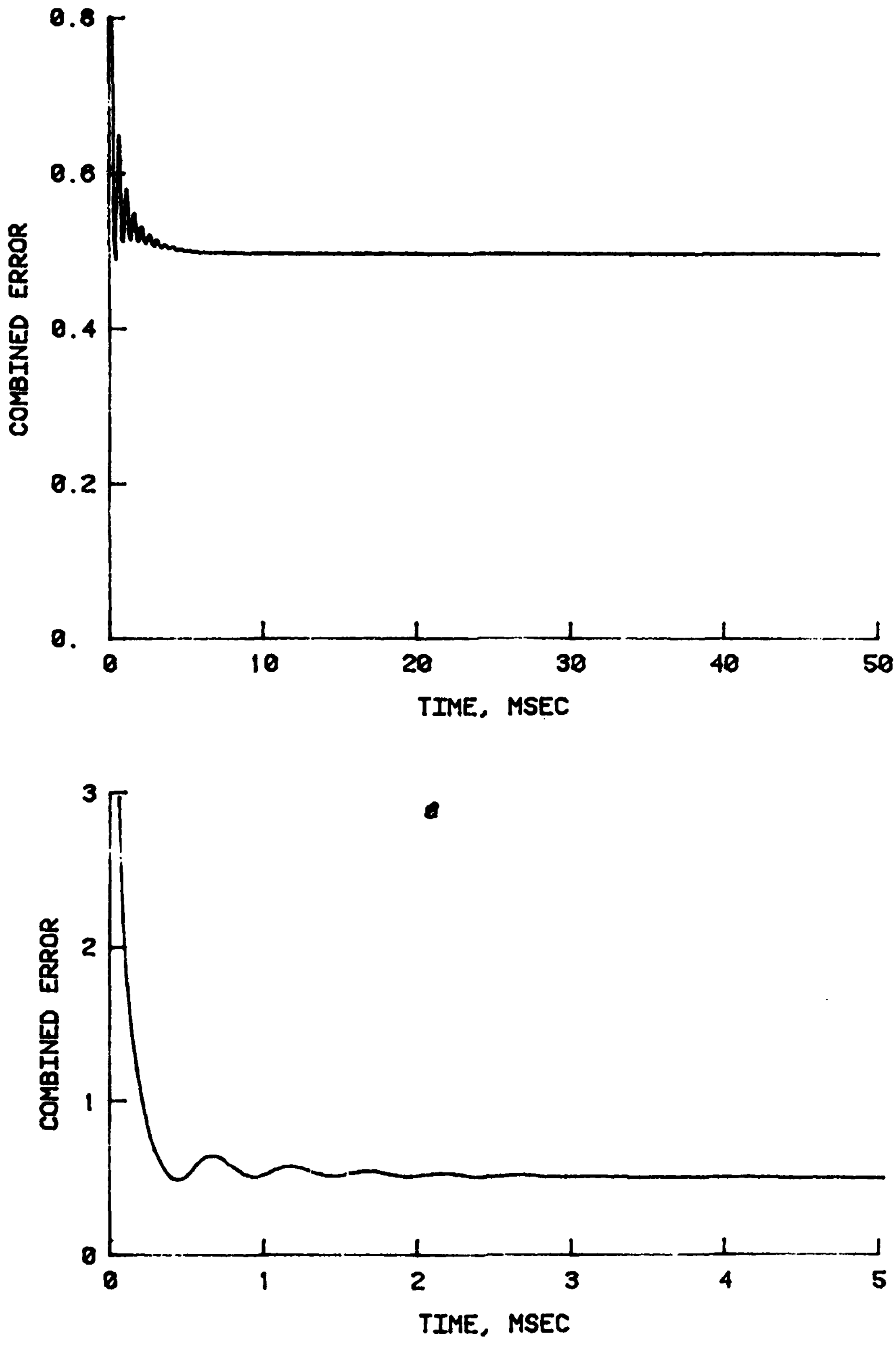


Figure 3.12 Time history of combined error for example 3.

and

$$E_{phs}(t)\Bigg|_{t\to\infty} \approx 1 - \left| \frac{\cos\phi - \frac{\pi\varepsilon_f}{\beta}\sin\phi + \frac{\beta}{2\pi}\sin\phi}{\left[1 + \frac{\beta\sin 2\phi}{2\pi}\right]^{1/2}} \right| \tag{3.31}$$

In this case, the magnitude error depends only on ε_m and ε_d ; and the phase-and-frequency error depends on ε_f , ϕ , 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.

CHAPTER 4

APPLICATIONS

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.

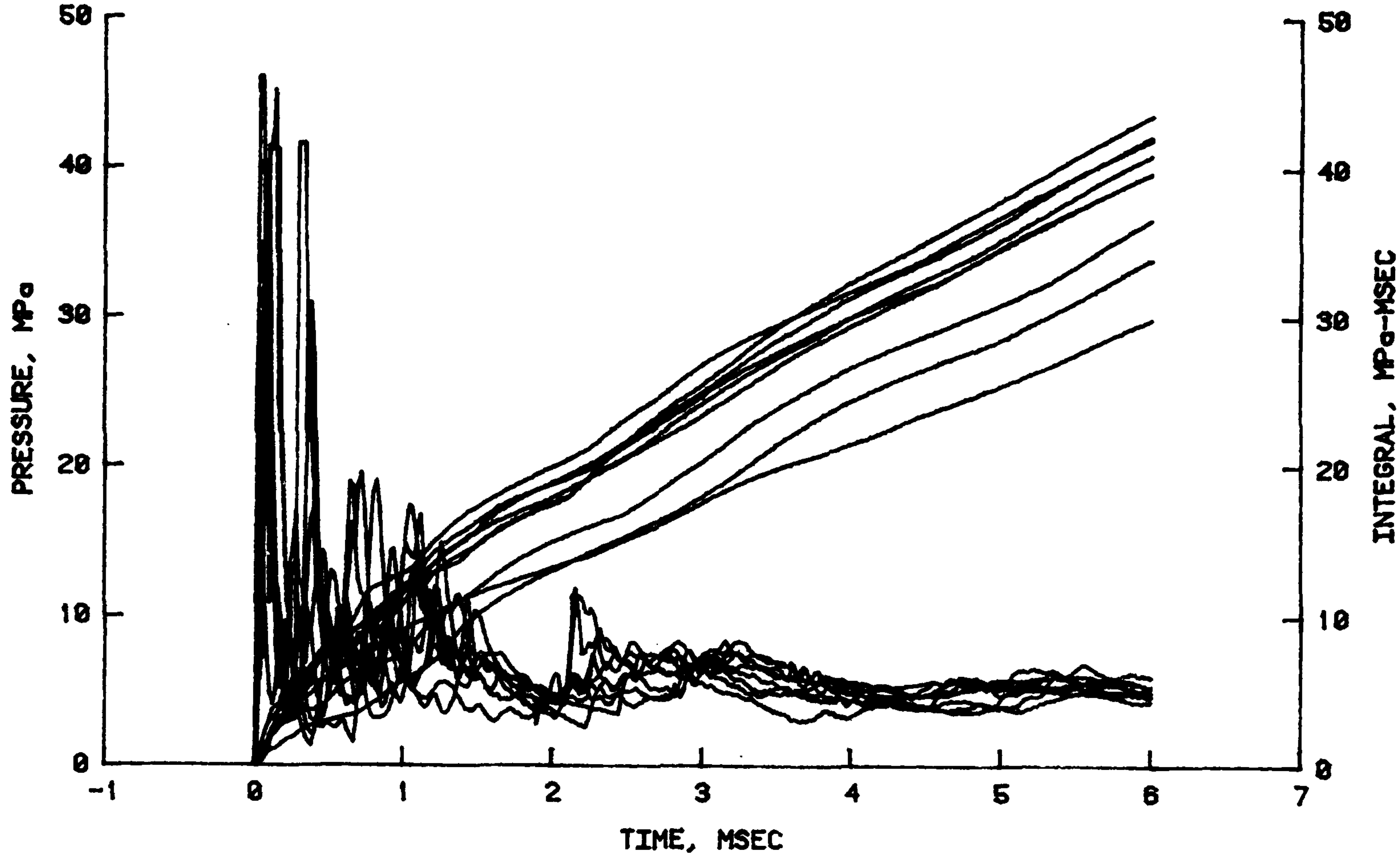


Figure 4.1 Early-time cavity pressure measurements and integrals; DISC Test I event.

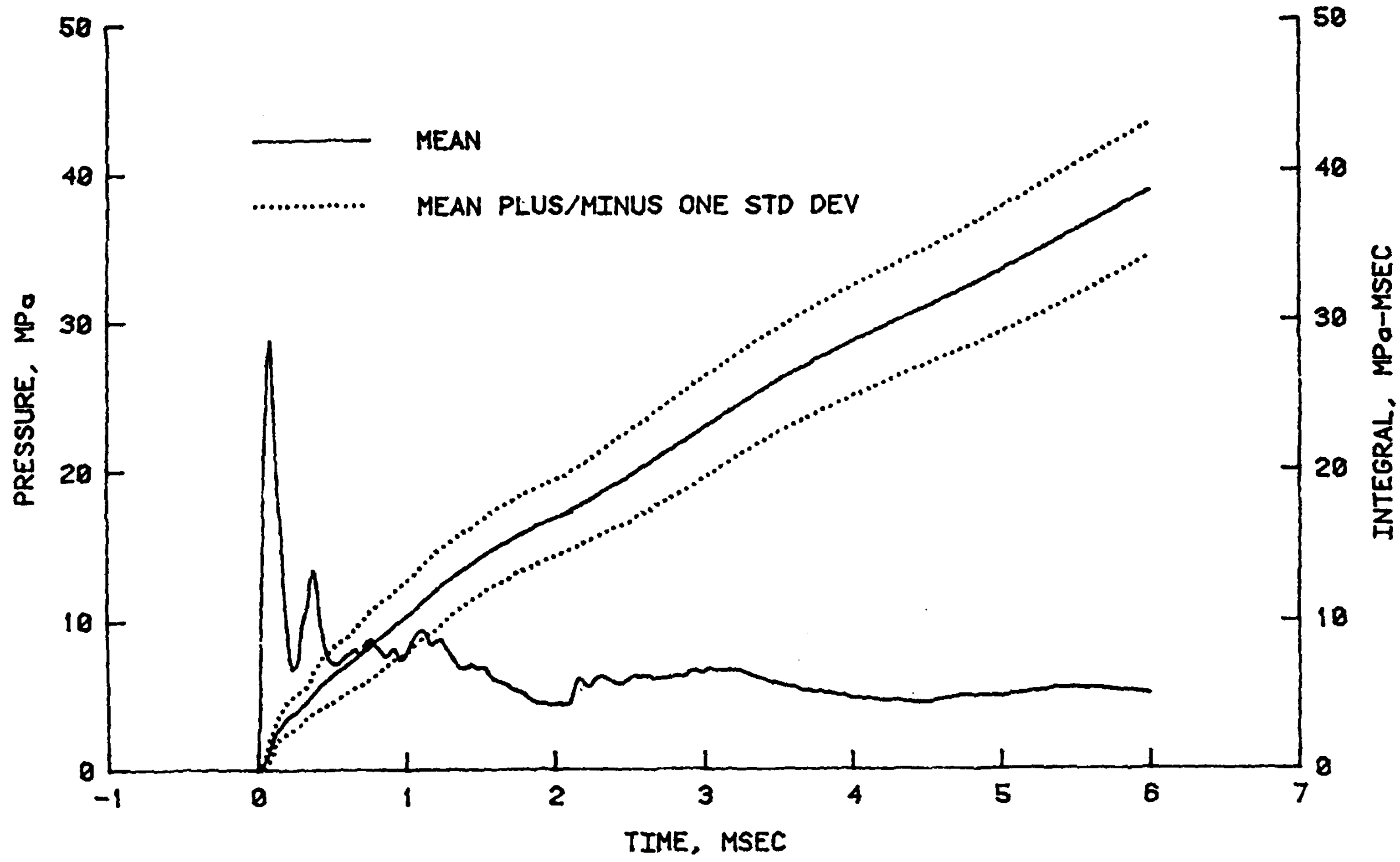


Figure 4.2 Early-time histories of mean cavity pressure and integral with standard deviation bounds for integrals; DISC Test I event.

4.3 COMPARISON OF MEASURED VERSUS CALCULATED RESPONSE HISTORIES

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.

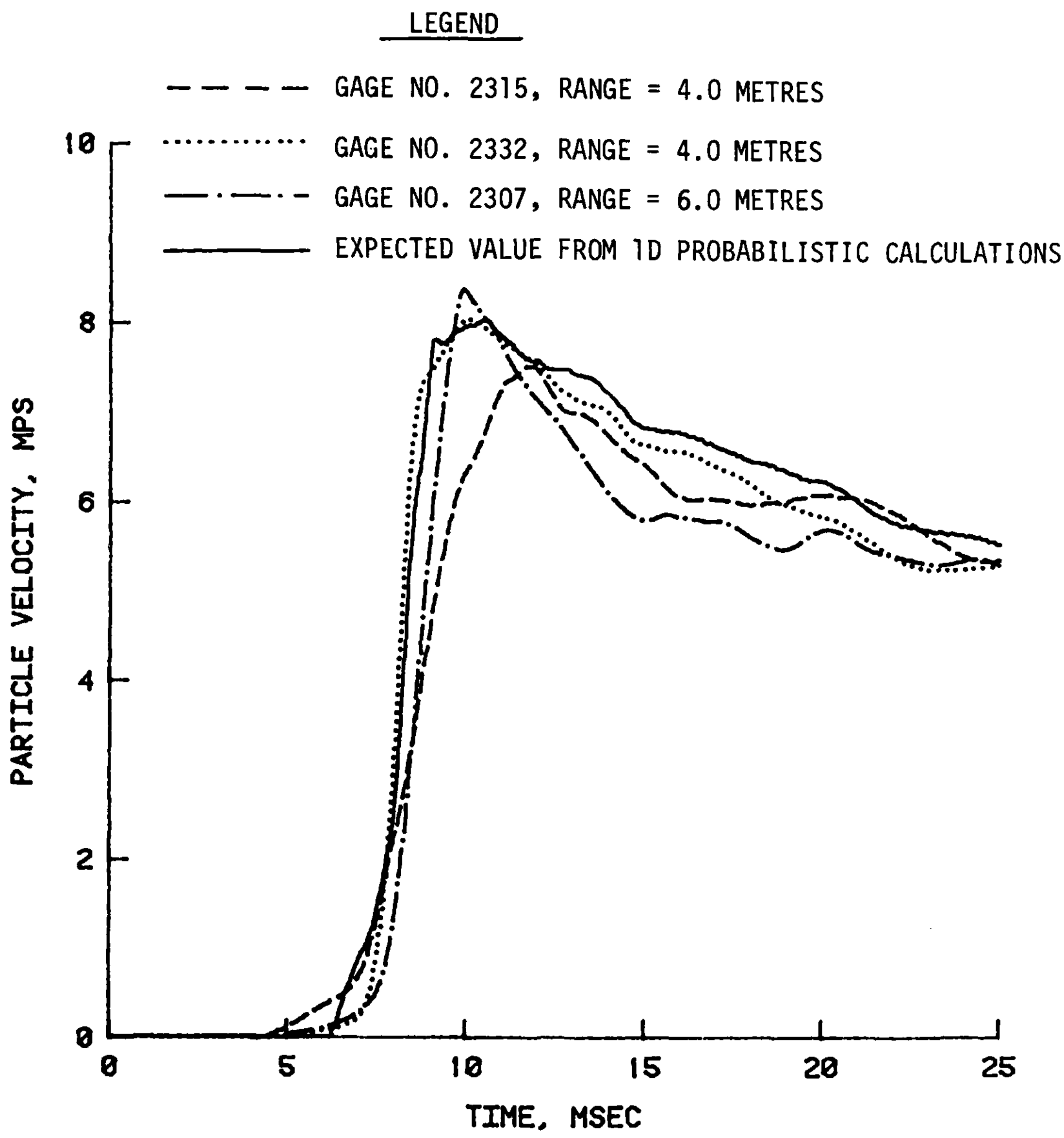


Figure 4.3 Comparison of calculated and measured pa‑ le velocity-time histories for DISC Test II event; depth = 3.0 metres.

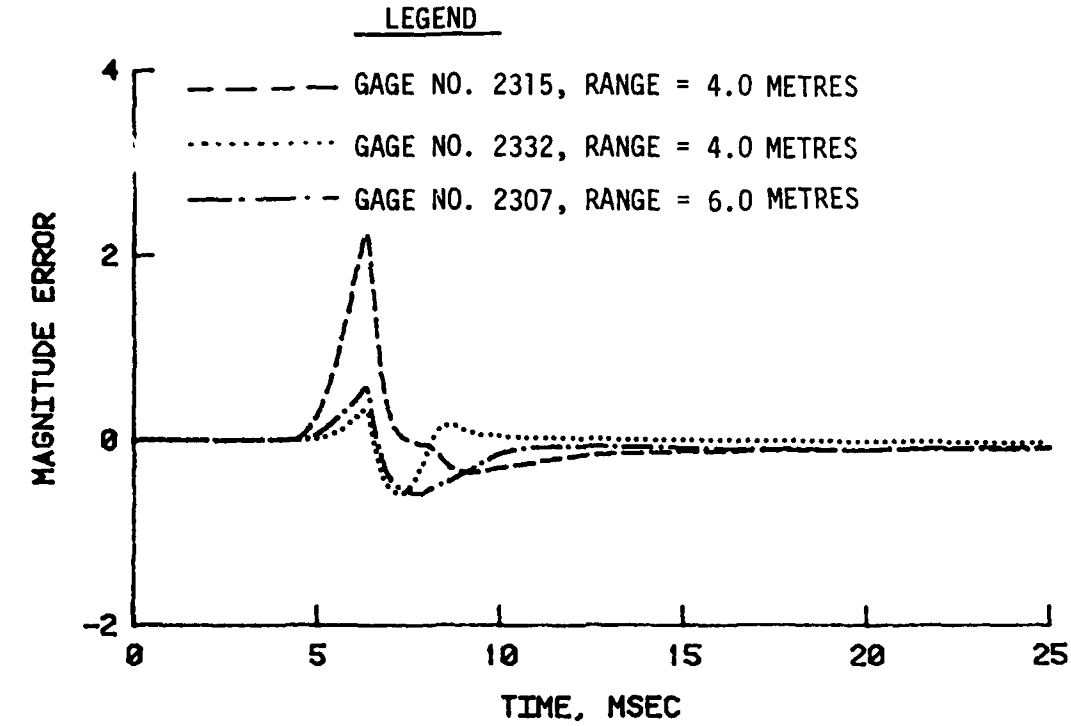


Figure 4.4 Time histories of magnitude errors between measured and calculated velocity waveforms; DISC Test II event, depth = 3.0 metres.

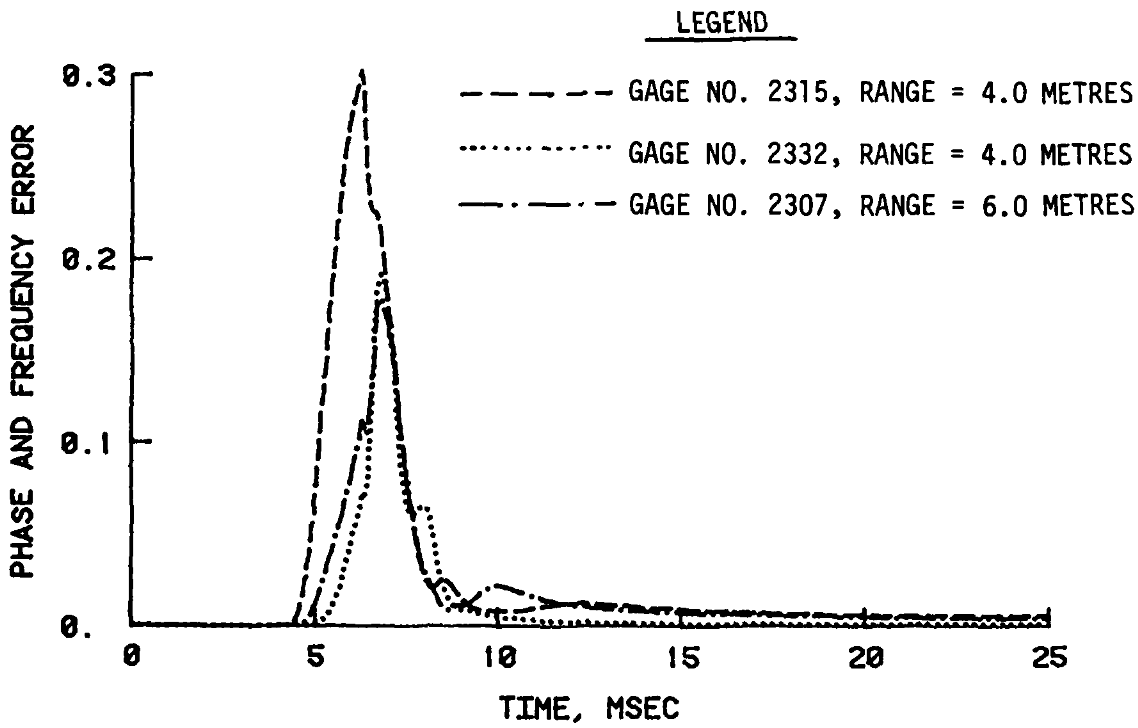


Figure 4.5 Time histories of phase-and-frequency errors between measured and calculated velocity waveforms; DISC Test II event, depth = 3.0 metres.

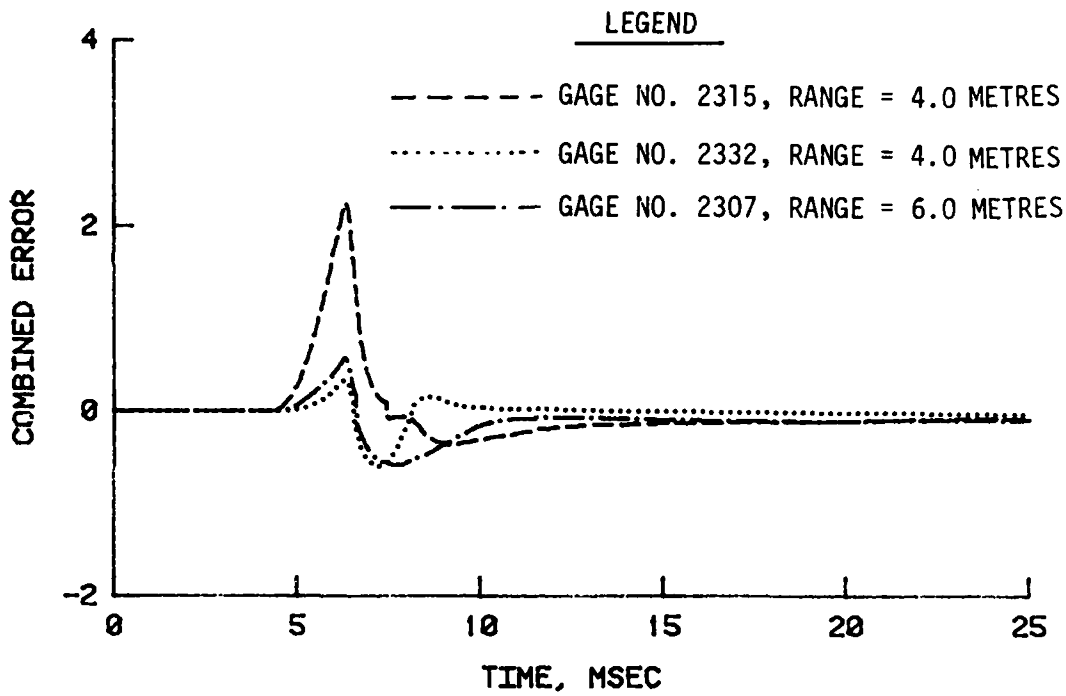


Figure 4.6 Time histories of combined error (magnitude, phase and frequency) for each measured velocity waveform relative to the calculated waveform; DISC Test II event, depth = 3.0 metres.

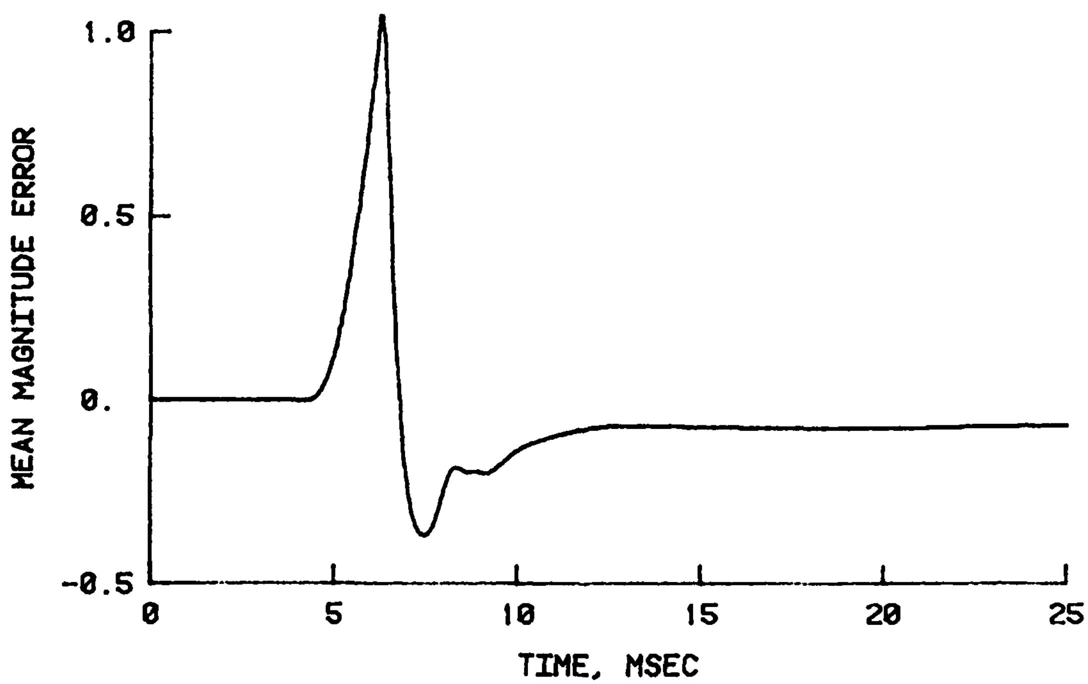


Figure 4.7 Time history of magnitude error between mean measured and calculated velocity waveforms; DISC Test II event, depth = 3.0 metres.

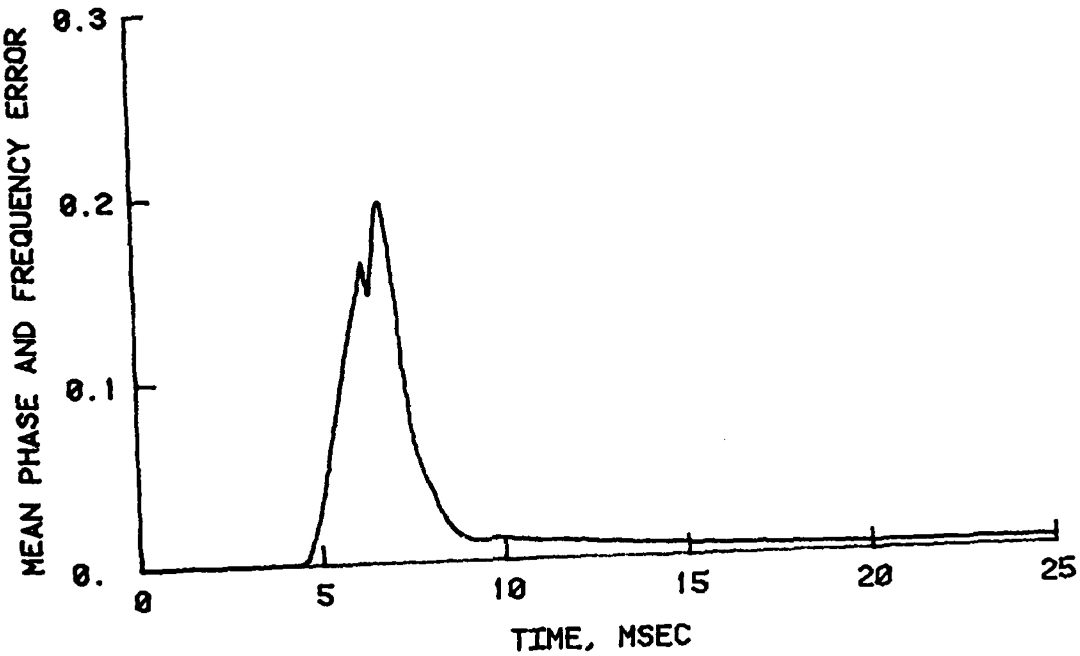


Figure 4.8 Time history of phase-and-frequency error between mean measured and calculated velocity waveforms; DISC Test II event, depth = 3.0 metres.

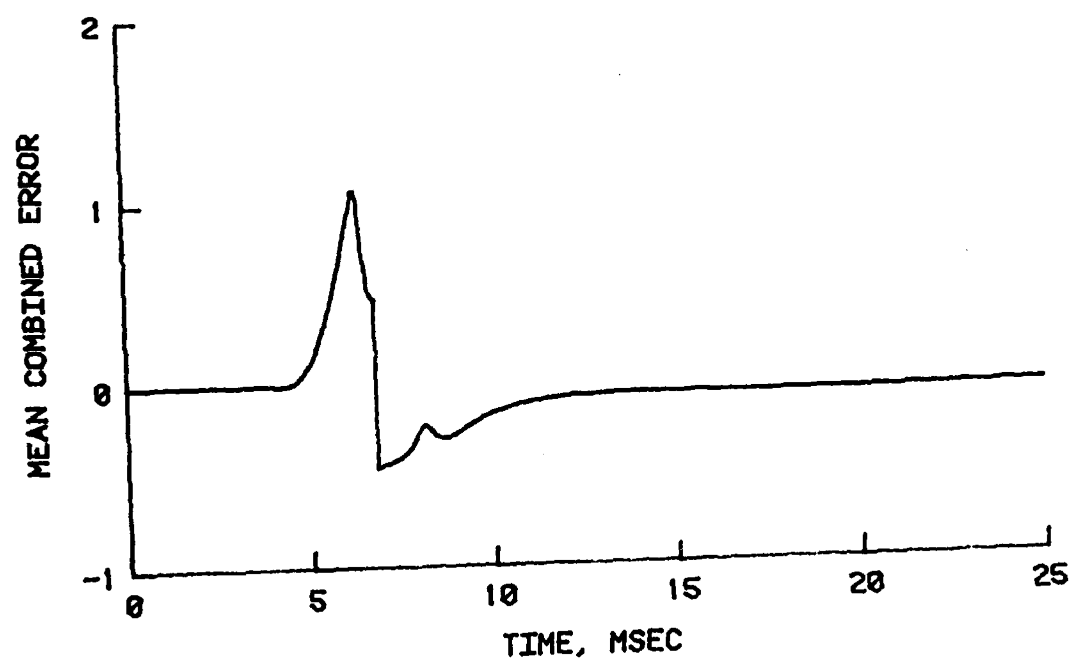


Figure 4.9 Time history of combined error (magnitude and phase-and-frequency) between mean measured and calculated velocity waveforms; DISC Test II event, depth = 3.0 metres.

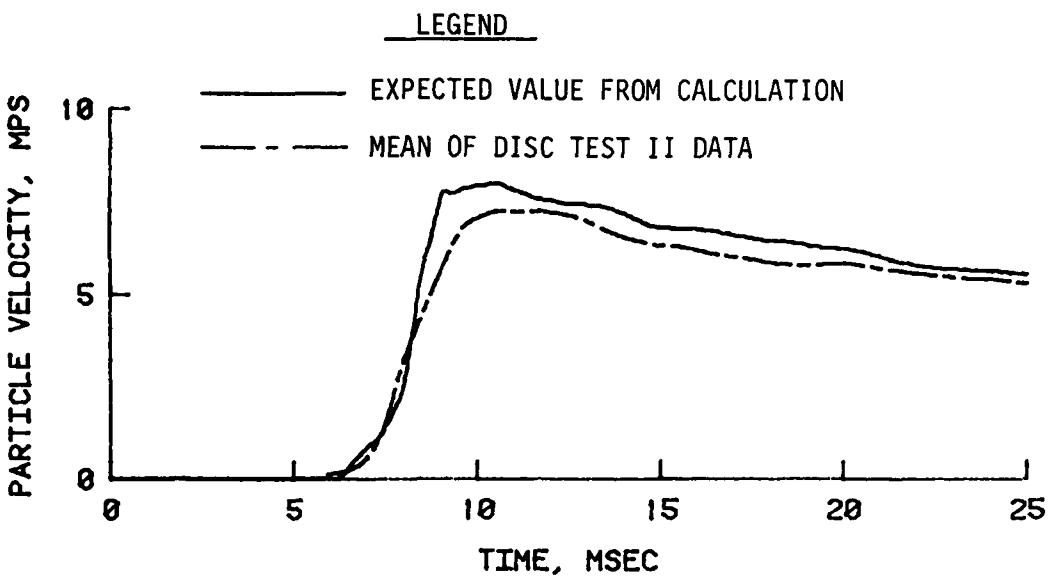


Figure 4.10 Time histories of mean measured and mean calculated velocity waveforms; DISC Test II event, depth = 3.0 metres.

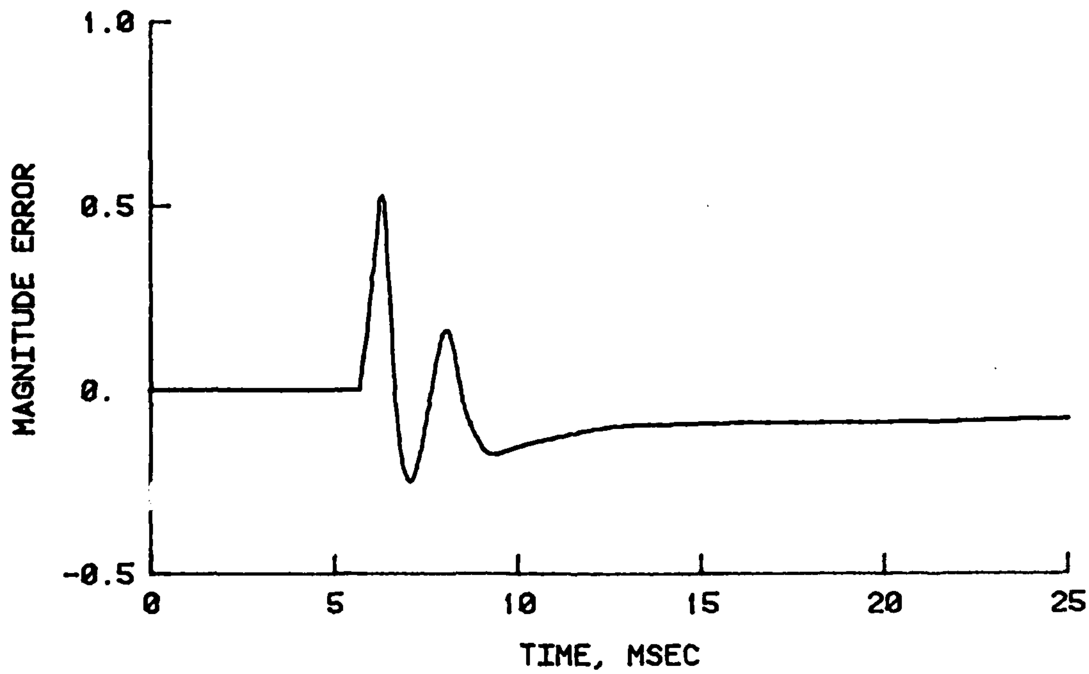


Figure 4.11 Time history of magnitude error between mean measured and mean calculated velocity waveforms; DISC Test II event, depth = 3.0 metres.

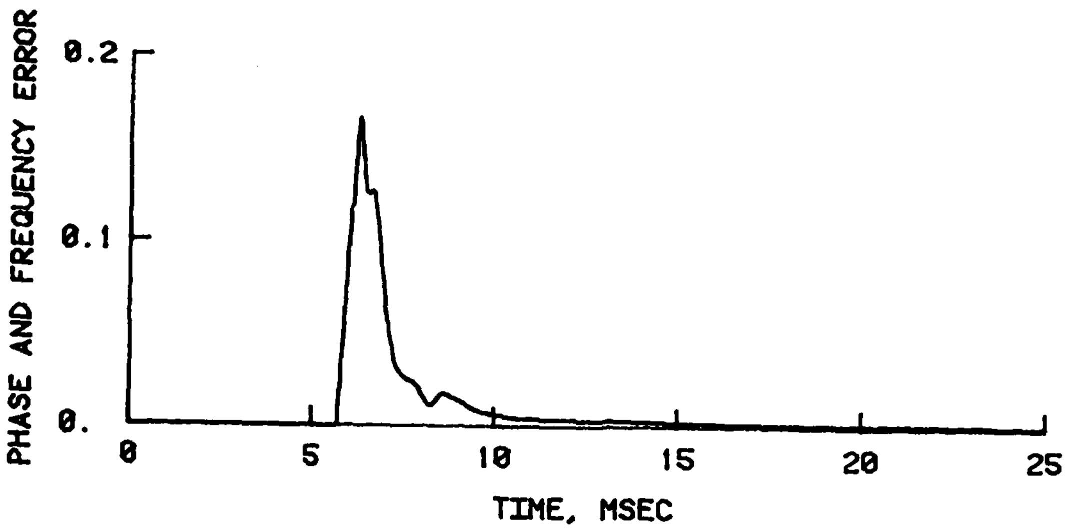


Figure 4.12 Time history of phase-and-frequency error between mean measured and mean calculated velocity waveforms; DISC Test II event, depth = 3.0 metres.

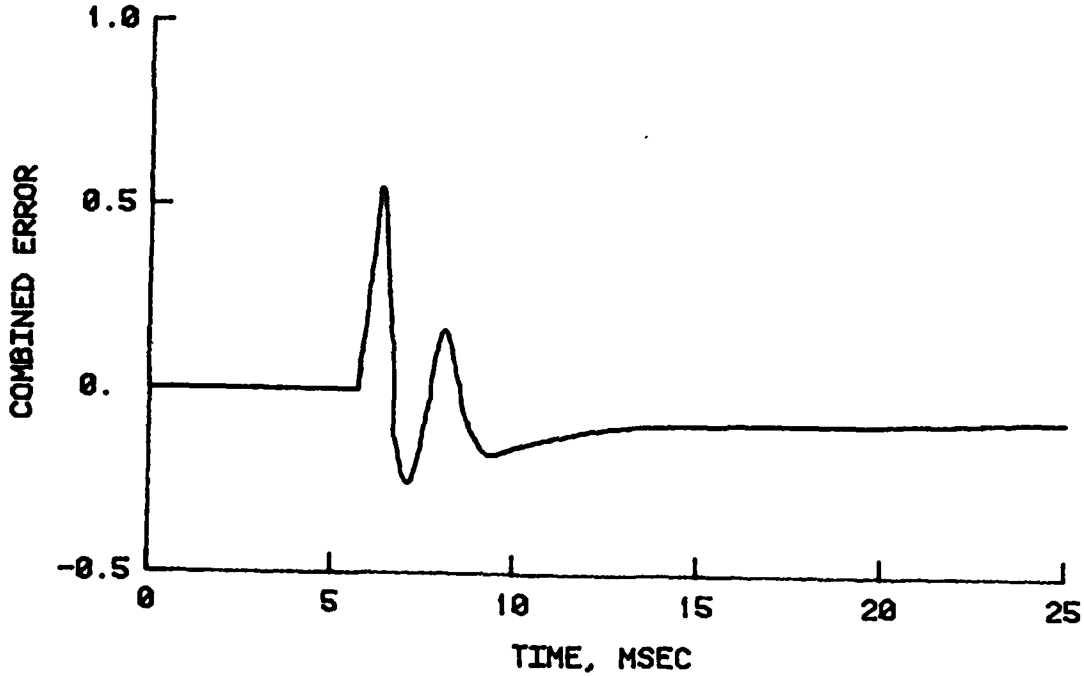


Figure 4.13 Time history of combined error (magnitude, phase-and-frequency) between mean measured and mean calculated velocity waveforms; DISC Test II event, depth = 3.0 metres.

CHAPTER 5

SUMMARY AND RECOMMENDATIONS

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

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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 NTPLOT = 2, expected value and standard deviation are computed; and for NTPLOT = 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 NTPLOT. For NTPLOT = 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 NTPLOT = 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 NTPLOT = 3, the output consists of data identical to NTPLOT = 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/DX.
DX02	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.
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.

MAXC(K)	One plus maximum absolute value of the record at K.
MAXM	Maximum absolute of the base record.
MCF	Magnitude correlation factor (Equation 2.5).
N1	Parameter variable for setting the maximum number of comparison cases to be processed.
NC	Parameter variable for setting the maximum number of records to be processed.
NIBASE	Number of times for which the base record must be integrated.
NICOMP	Number of times for which the waveforms must be integrated.
NINT	Temporary counter for NIBASE and NICOMP.
NINVERS	1/ICM1.
NP	Parameter variable for setting the maximum number of time steps that can be processed.
NPOINT	Number of time steps to be used for given calculations.
NPIS(J)	Number of time steps in the Jth record.
NTPLOT	Variable determines the desired type of output.
PCF	Phase-and-frequency correlation factor (Equation 2.6).
PEF(K)	Peak error factor of the Kth record.
PLOT2	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).

RICNT	1./ICNT.
RNM1	1/(ICNT-1).
SS	Variance.
ST	Standard deviation.
SUM1	Temporary variable for computing MCF.
SUM2	Temporary variable for computing PCF.
TAR(K)	Arrival time for the Kth record, msec.
TE(I)	Time associated with E(I) at the Ith time step, msec.
TE1	Expected arrival time of the given set of records, msec.
TITLE(K)	Title with up to 60 characters for identifying the Kth record.
TM(I)	Time associated with EM(I) at the Ith time step, msec.
TM1	TE1-ST.
TP(I)	Time associated with EP(I) at the Ith time step, msec.
TP1	TE1+ST.
X(J,K)	Time associated with the Kth record at the Jth time step, msec.
XCUR	Temporary variable used for interpolation.
XFINAL	The length of the calculation, msec.

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.

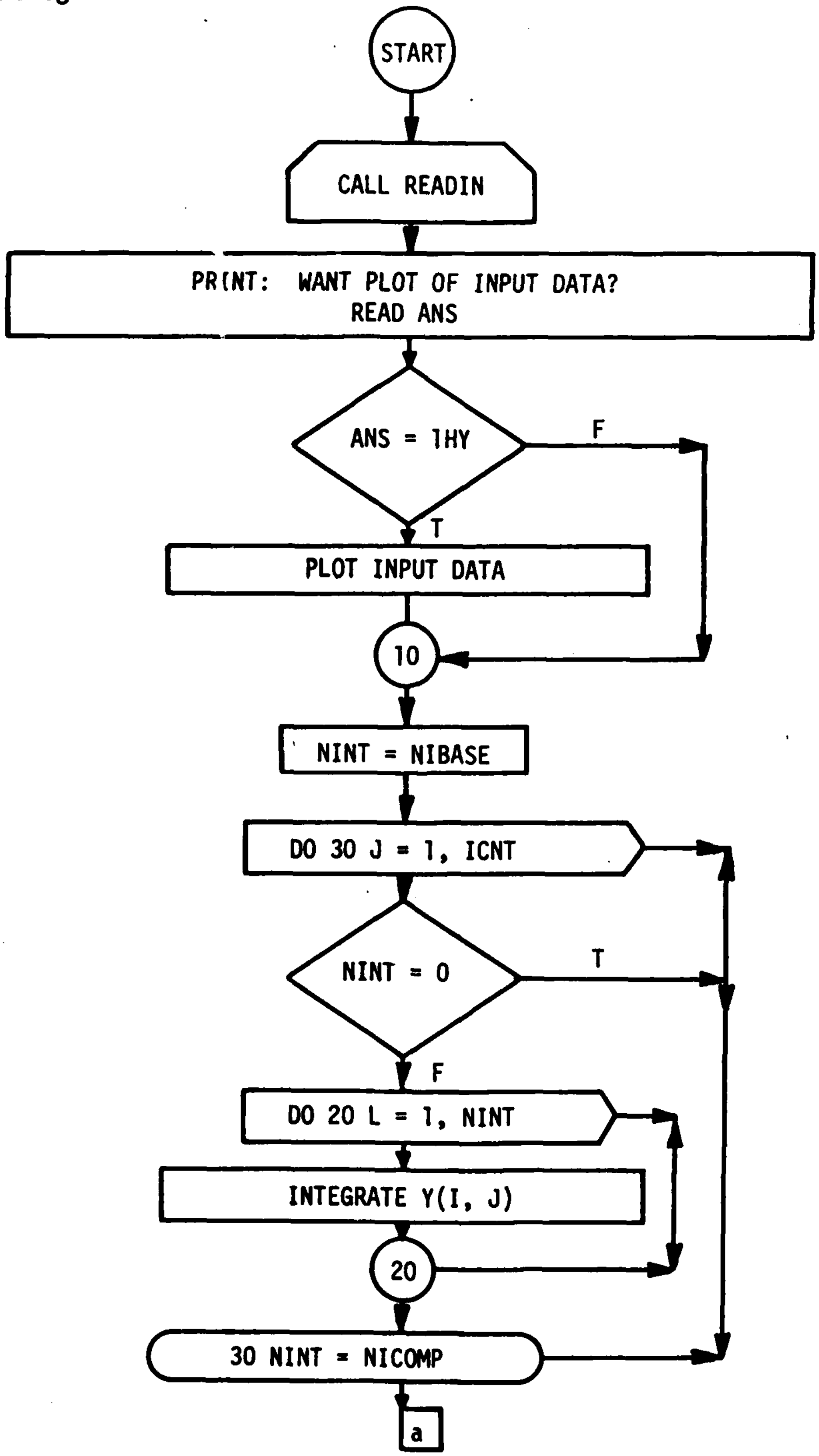
A.4.2 Subrouting READIN

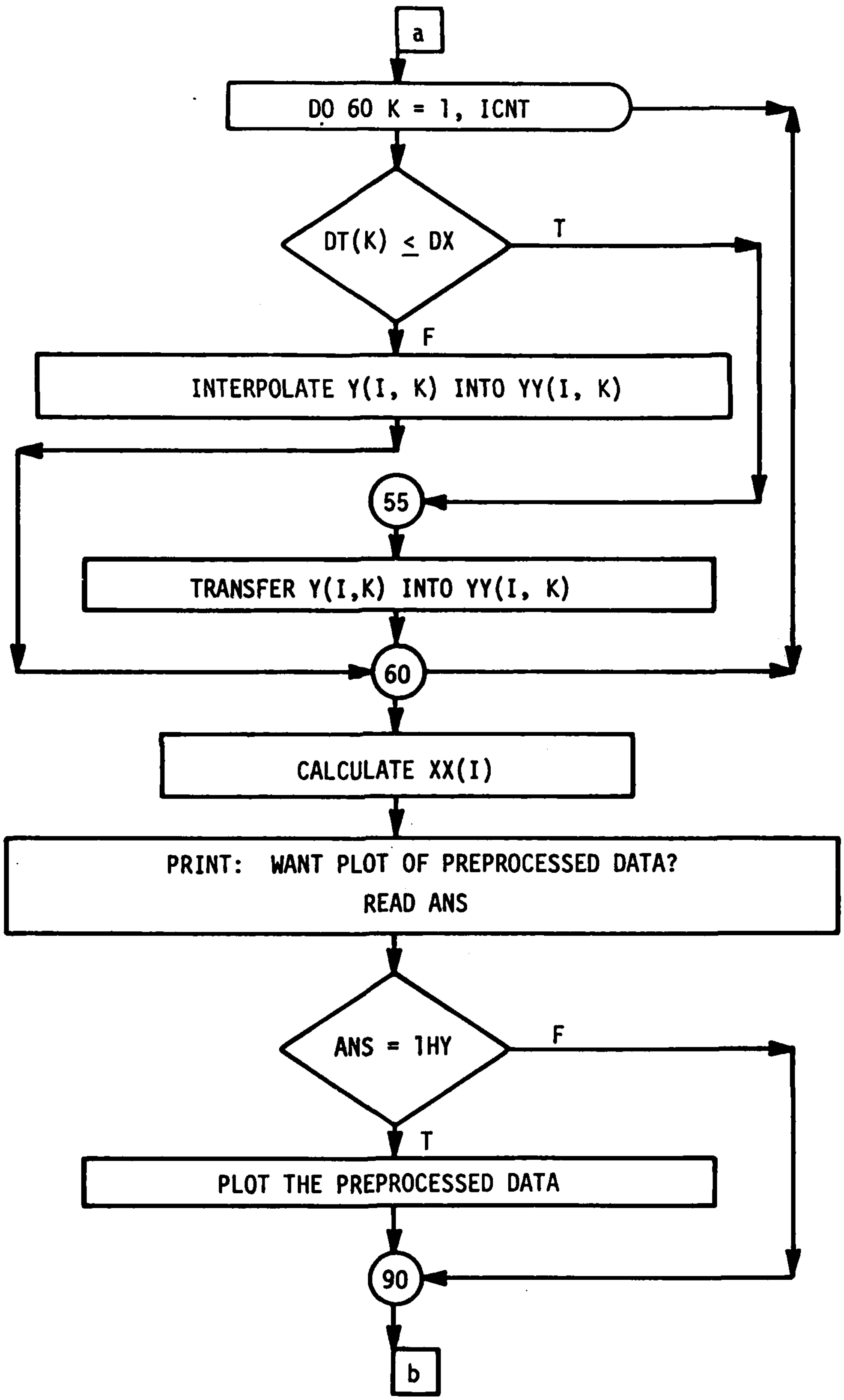
ATTACH	System subroutine for opening a permanent file.
BCDASC	System subroutine for converting from BCD to ASCII.
C1,C2,C3	Identification for measured data; BCD labels (converted to ASCII for title).
DETACH	System subroutine for closing a permanent file.
DT(ICNT)	Time increment (in seconds, converted 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).

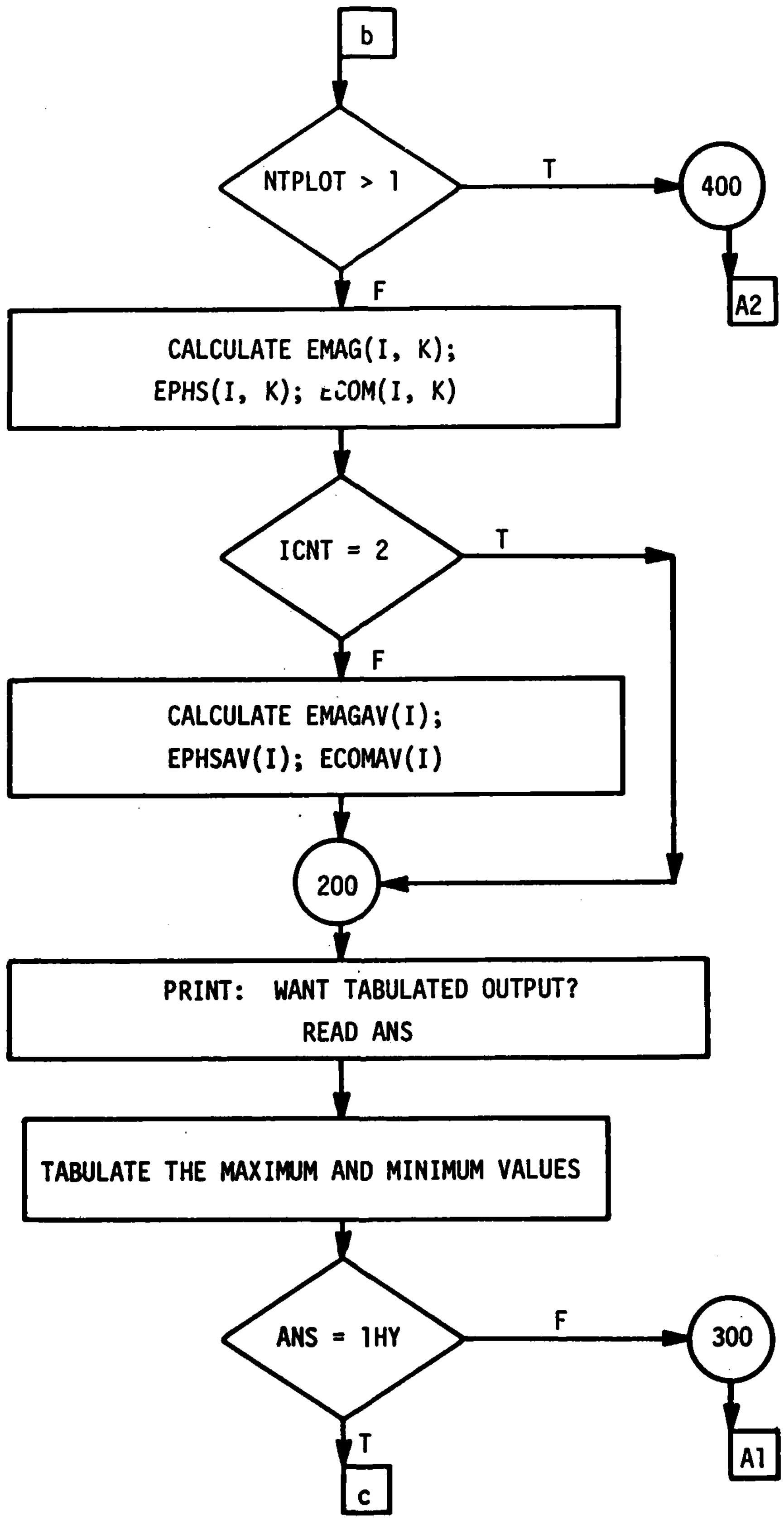
NPOINT	Number of points to be used for calculations. NPOINT will be reduced if any input record contains fewer than NPOINT data points (this would also reduce the value of XFINAL).
NPS	Maximum number of data points from an input record to be searched in order to obtain the arrival time.
NPT	Total number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

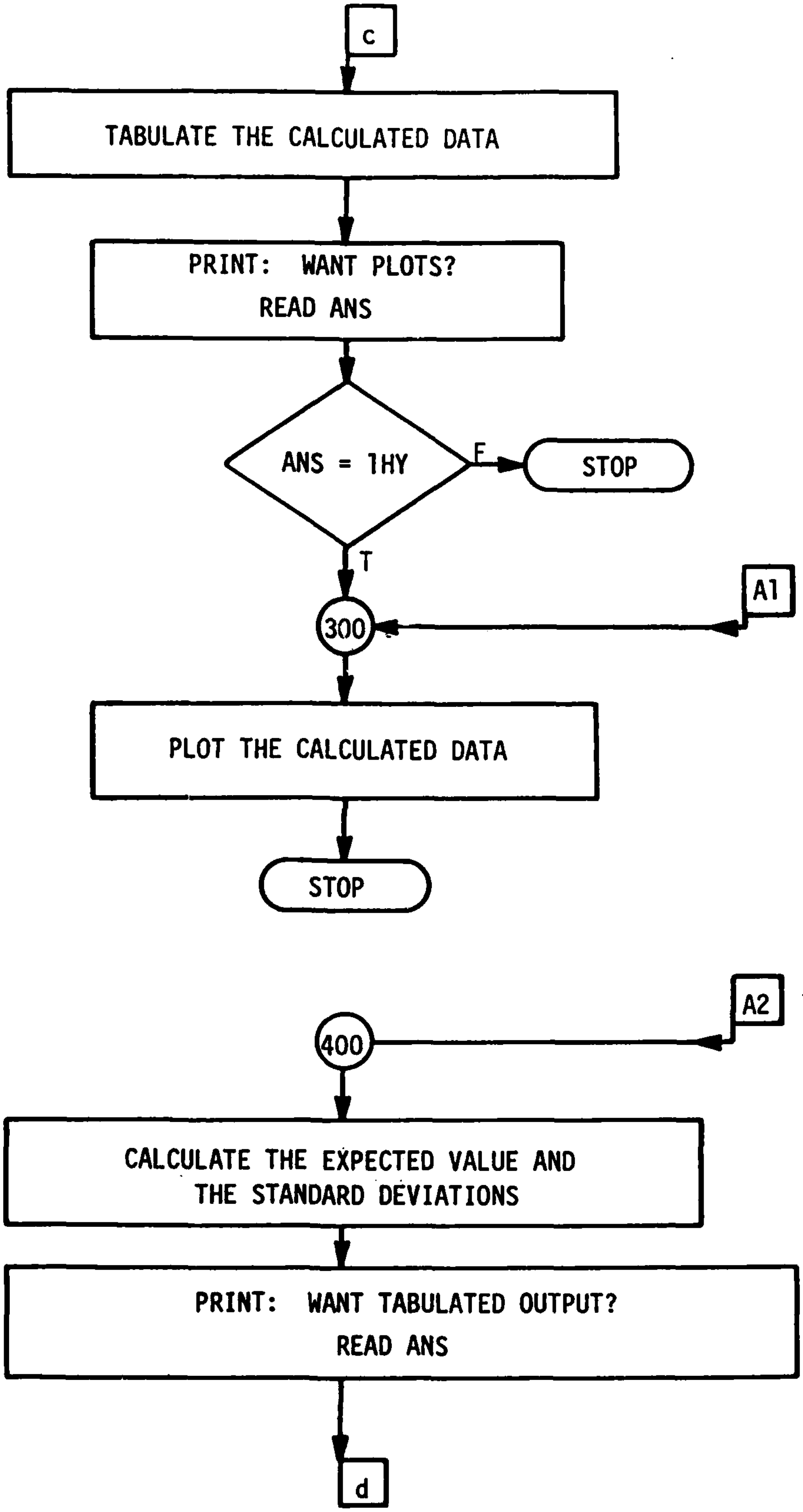
A.5 FLOW CHART

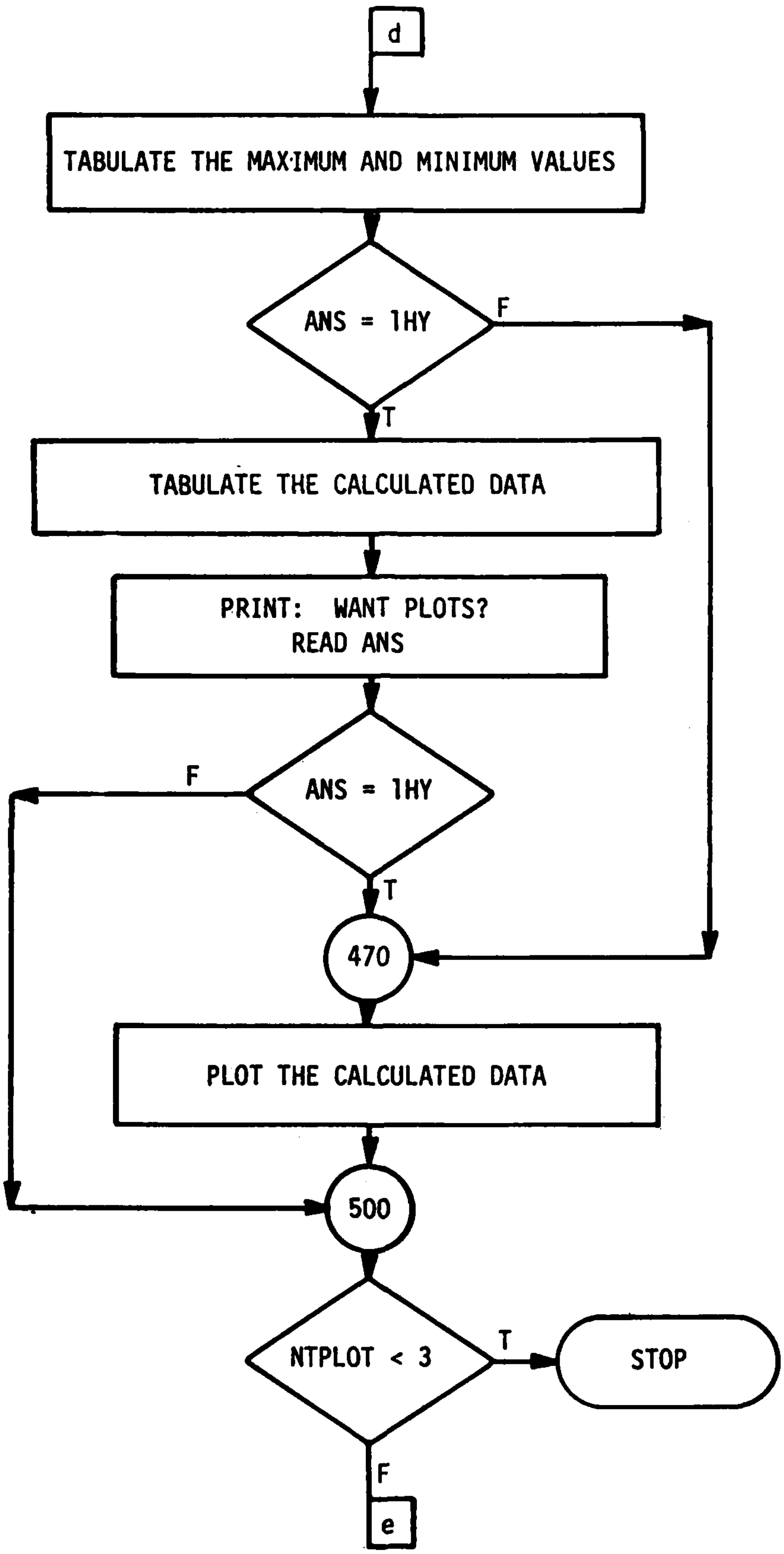
A.5.1 Main Program

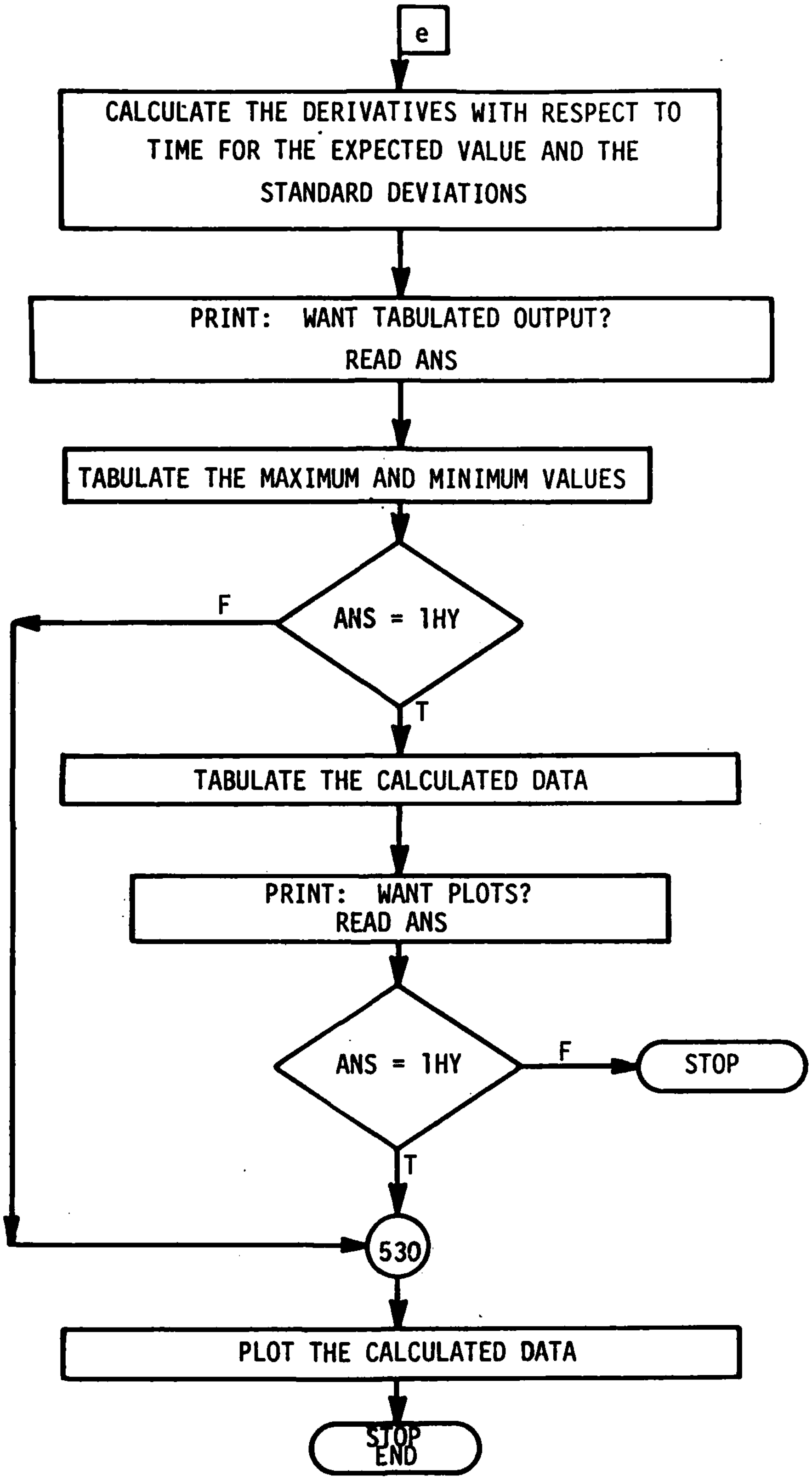



a
DO 60 K = 1, ICNT
DT(K) ≤ DX
T
F
INTERPOLATE Y(I, K) INTO YY(I, K)
55
TRANSFER Y(I,K) INTO YY(I, K)
60
CALCULATE XX(I)
PRINT: WANT PLOT OF PREPROCESSED DATA?
READ ANS
ANS = 1HY
F
T
PLOT THE PREPROCESSED DATA
90
b

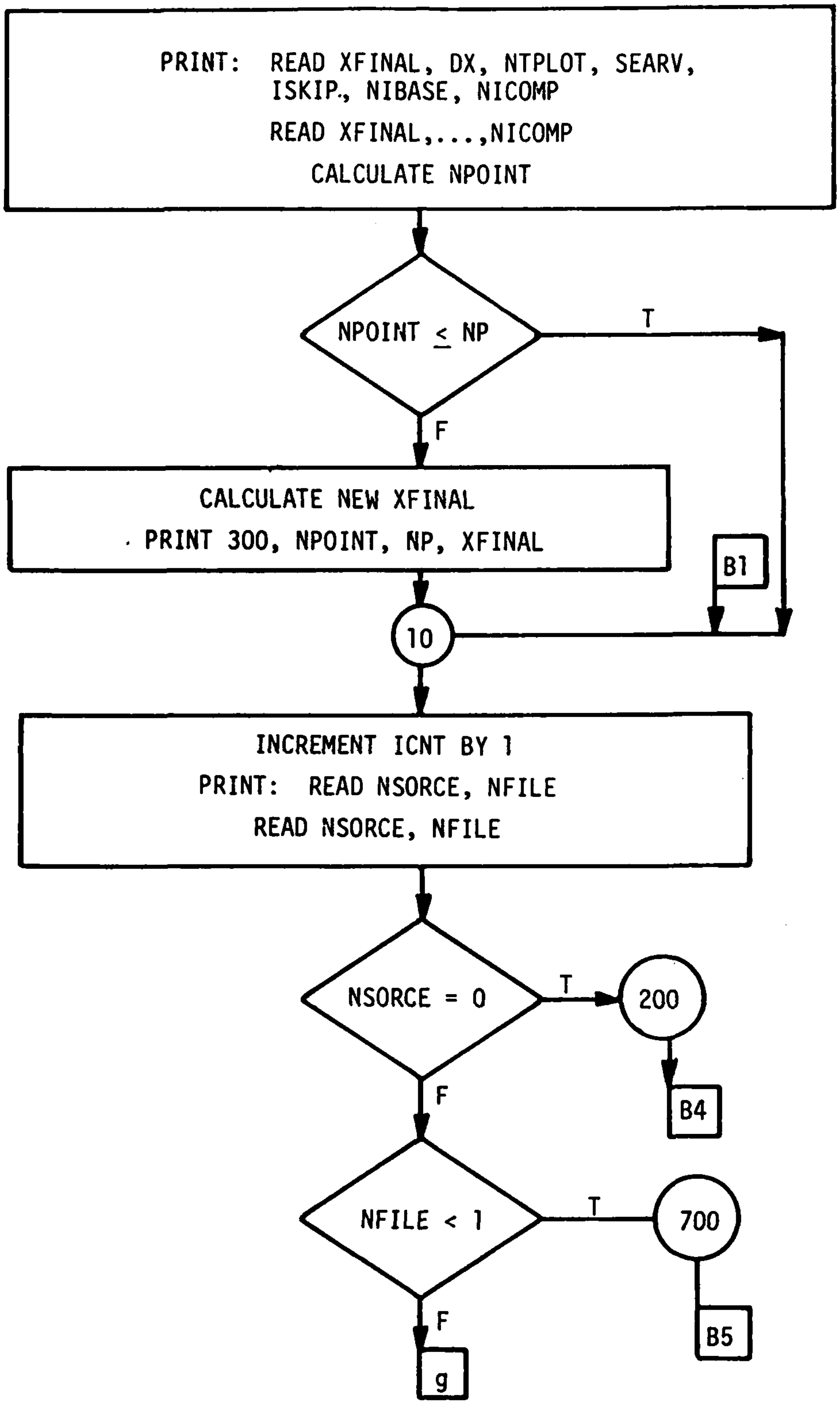

b
NTPLOT > 1
T
400
A2
F
CALCULATE EMAG(I, K);
EPHS(I, K); ECOM(I, K)
ICNT = 2
T
F
CALCULATE EMAGAV(I);
EPHSAV(I); ECOMAV(I)
200
PRINT: WANT TABULATED OUTPUT?
READ ANS
TABULATE THE MAXIMUM AND MINIMUM VALUES
ANS = 1HY
F
300
A1
T
c

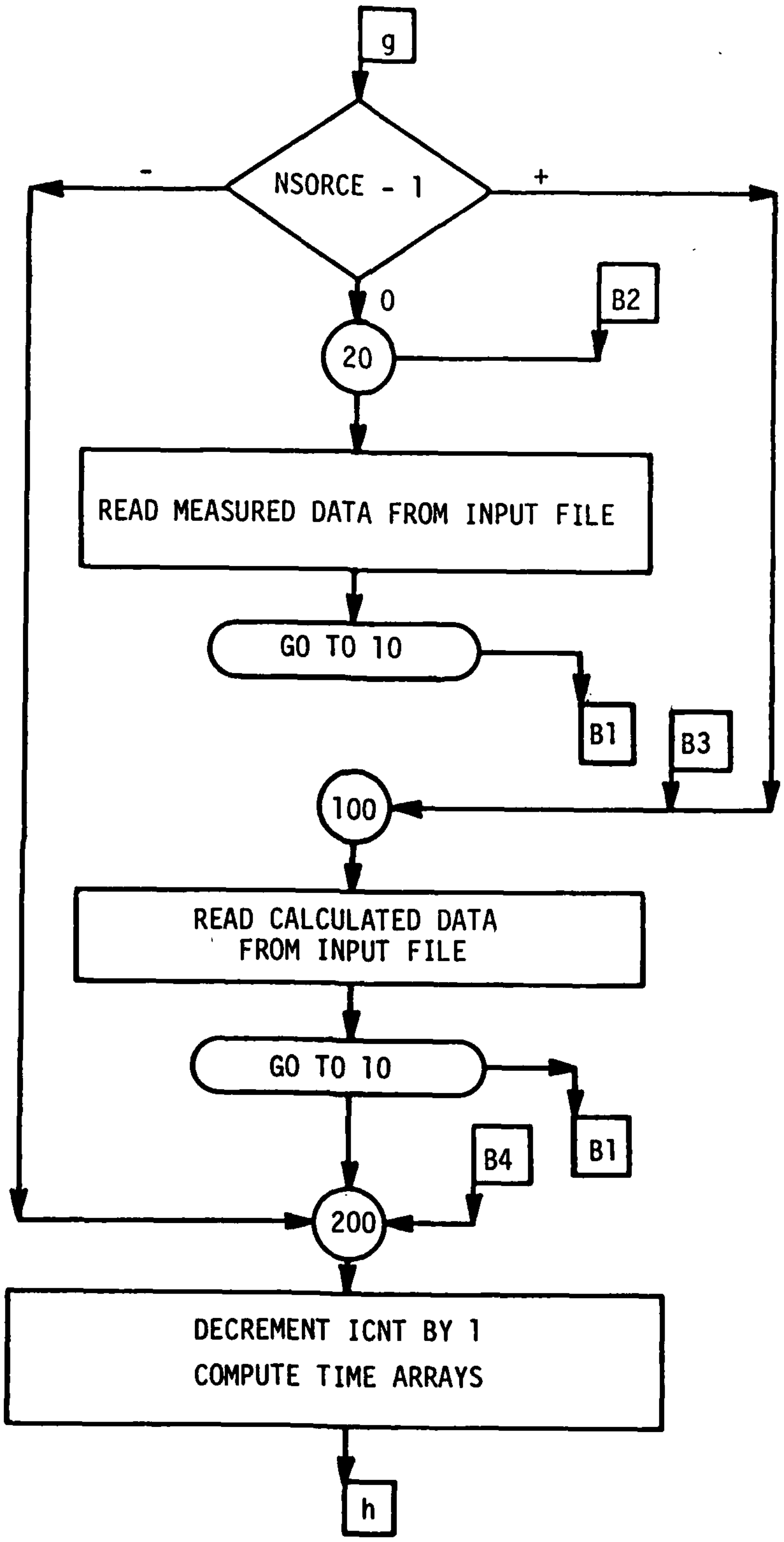

c
TABULATE THE CALCULATED DATA
PRINT: WANT PLOTS?
READ ANS
ANS = 1HY
F
STOP
T
A1
300
PLOT THE CALCULATED DATA
STOP
A2
400
CALCULATE THE EXPECTED VALUE AND
THE STANDARD DEVIATIONS
PRINT: WANT TABULATED OUTPUT?
READ ANS
d

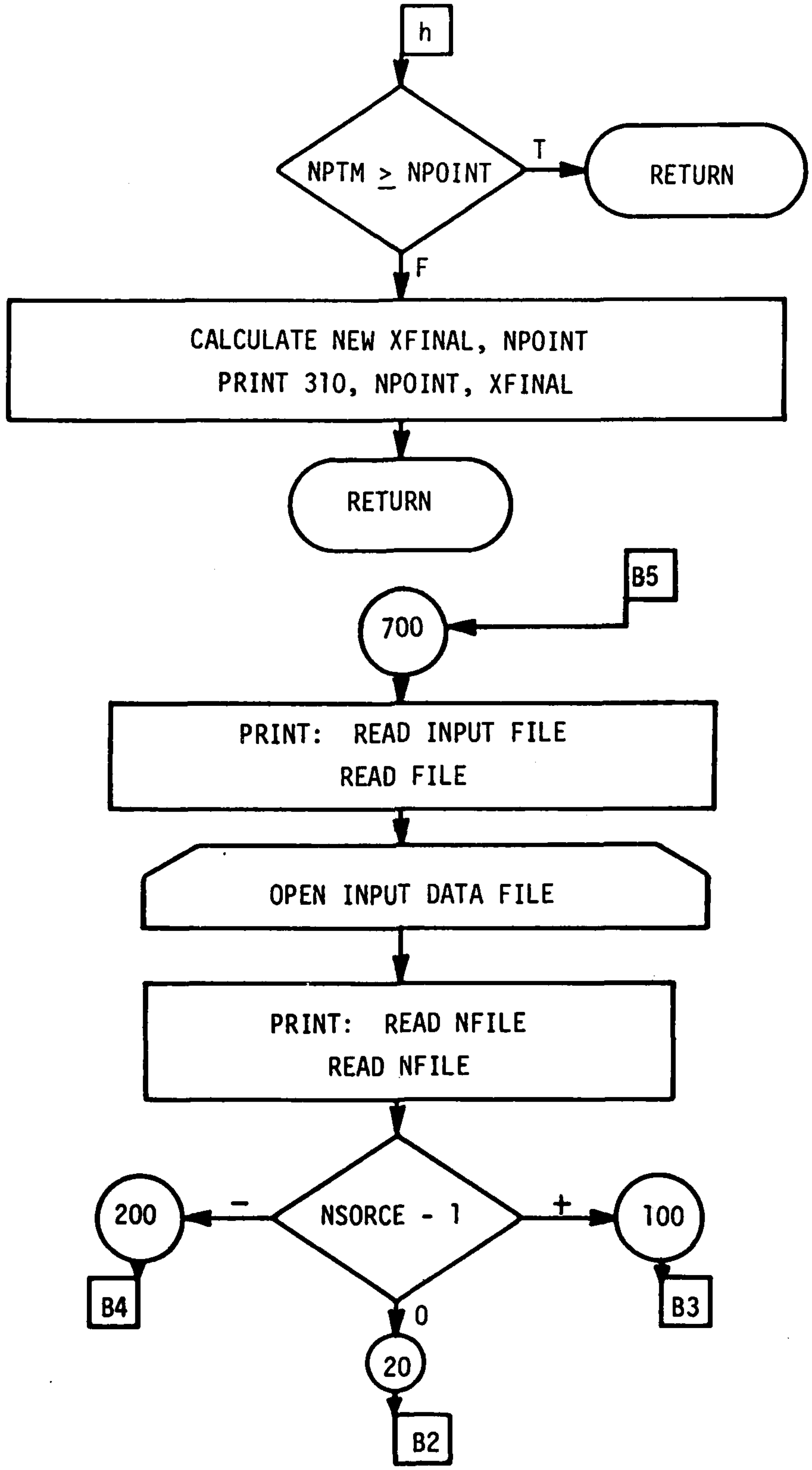

d
TABULATE THE MAXIMUM AND MINIMUM VALUES
ANS = 1HY
F
T
TABULATE THE CALCULATED DATA
PRINT: WANT PLOTS?
READ ANS
ANS = 1HY
F
T
470
PLOT THE CALCULATED DATA
500
NTPLOT < 3
T
STOP
F
e


e
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
F
ANS = 1HY
T
TABULATE THE CALCULATED DATA
PRINT: WANT PLOTS?
READ ANS
ANS = 1HY
F
STOP
T
530
PLOT THE CALCULATED DATA
STOP
END

A.5.2 Subroutine READIN




g
NSORCE - 1
-
+
0
B2
20
READ MEASURED DATA FROM INPUT FILE
GO TO 10
B1
B3
100
READ CALCULATED DATA FROM INPUT FILE
GO TO 10
B4
B1
200
DECREMENT ICNT BY 1
COMPUTE TIME ARRAYS
h



h
NPTM ≥ NPOINT
T
RETURN
F
CALCULATE NEW XFINAL, NPOINT
PRINT 310, NPOINT, XFINAL
RETURN
B5
700
PRINT: READ INPUT FILE
READ FILE
OPEN INPUT DATA FILE
PRINT: READ NFILE
READ NFILE
200
−
NSORCE - 1
+
100
B4
0
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
TEF =      -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.
ECMX =    105.423    88.191    51.398
ECMN =     -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      ECOM

   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
```

I	EMAG	EPHS	ECOM
2	0.589	0.577	0.824
50	85.993	0.931	85.998
100	0.000	0.733	0.733
150	-0.012	0.583	-0.583
200	-0.007	0.530	-0.530
250	-0.033	0.486	-0.487
300	-0.031	0.450	-0.451
350	-0.043	0.425	-0.427

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

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

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

WANT PLOTS ?
=NO
PTU-SEC = 1.85

*

```
 FRN

        12/08/82    21.100

READ XFINAL,DX,NTPLOT,SEARV,ISKIP,NIBASE,NICOMP
=7 ,02 3 ,5 50 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

      EMX       EMN        EPMX      EMMN
     41.336     0.        44.986    -0.008

      TE1       TP1        TM1
      0.960     1.646      0.274

CASE          1          2          3          4
TAR =        0.        1.600      1.000      1.240

    I       E          EP         EM
   50      7.048     12.494      1.602
  100     14.246     18.197     10.295
  150     20.785     24.927     16.643
  200     26.490     30.624     22.356
  250     31.477     35.307     27.647
  300     36.760     40.705     32.814
  350     41.255     44.908     37.601

WANT PLOTS ?
=NO
WANT TABULATED OUTPUT ?
=YES

      DEMX      DEMN       DEPMX     DEMMN
     18.408     0.        31.840    -0.880
```

I	DE	DEP	DEM
50	5.085	7.980	2.191
100	5.531	3.717	7.346
150	5.895	6.848	4.943
200	5.044	5.001	5.086
250	5.045	5.330	4.760
300	5.202	4.839	5.565
350	4.068	3.818	4.319

```
WANT PLOTS ?
=NO
PTU-SEC =        1.26

*
```

A.7 PROGRAM LISTING

```
**RUNH*;ROSD441/PLOTS,R
C        PROGRAM WCT
C
C        CALCULATIONS OF STATISTICAL MEASURES FOR
C        COMPARISON OF WAVEFORMS
C
       PARAMETER NC = 10,N1 = NC-1,NP = 200
       REAL I1,MCF,MAXC,MAXM,NINVRS
       CHARACTER TITLE *60,ANS*1
       DIMENSION I1(NP),EMAGAV(NP),EPHSAV(NP),ECOMAV(NP),
     &           EMAG(NP,N1),EPHS(NP,N1),ECOM(NP,N1),
     &           TE(NP),TP(NP),TM(NP),E(NP),EP(NP),EM(NP),
     &           DE(NP),DEP(NP),DEM(NP)
       COMMON /INPUT/ XFINAL,DX,NTPLOT,ISKIP,NIBASE,NICOMP,
     &                ICNT,NPOINT,DT(NC),TAR(NC),NPTS(NC)
       COMMON /ARRA1/ X(NP,NC),Y(NP,NC),XX(NP),YY(NP,NC),
     &                MAXC(N1),PEF(N1),EMMX(N1),EMMN(N1),EPMX(N1),
     &                EPMN(N1),ECMX(N1),ECMN(N1),TITLE(NC)
       EQUIVALENCE (EMAGAV(1),I1(1),X(1,NC)),(EMAG(1,1),X(1,1)),
     &             (EPHSAV(1),Y(1,NC)),(EPHS(1,1),Y(1,1)),
     &             (ECOMAV(1),YY(1,NC)),(ECOM(1,1),YY(1,1))
       EQUIVALENCE (TE(1),X(1,1)),(TP(1),X(1,2)),(TM(1),X(1,3)),
     &             (E(1),Y(1,1)),(EP(1),Y(1,2)),(EM(1),Y(1,3)),
     &             (DE(1),YY(1,1)),(DEP(1),YY(1,2)),(DEM(1),YY(1,3))
       CALL PTIME(PTI)
       CALL FPARAM(1,80)
C
       CALL READIN
C
       PRINT,'WANT PLOT OF INPUT DATA?'
       READ,ANS
       IF(ANS.NE.1HY) GO TO 10
     1 CONTINUE
       DO 5 K =1,ICNT
       CALL PLOT2(X(1,K),Y(1,K),NPTS(K))
     5 CONTINUE
       PRINT,'WANT REPLOT ?'
       READ,ANS
       IF(ANS.EQ.1HY) GO TO 1
    10 CONTINUE
C
C        PERFORM INTEGRATIONS AS NEEDED ON DATA TO OBTAIN
C        DESIRED QUANITIES FOR COMPARISON
C
       NINT = NIBASE
       DO 30 J =1,ICNT
       IF(NINT.EQ.0) GO TO 30
       DO 20 L =1,NINT
       DXO2 = .5*DT(J)
       YNEXT = Y(1,J) + Y(2,J)
       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
   30 NINT = NICOMP
C
C      INTERPOLATE VERTICAL ARRAYS FOR SAME DX IF REQUIRED
C
      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
C
C      IF INTERPOLATION NOT REQUIRED TRANSFER Y ARRAY INTO YY ARRAY
C
      DO 58 I =1,NPOINT
   58 YY(I,K) = Y(I,K)
   60 CONTINUE
C
C      SET UP HORIZONTAL ARRAY
C
      DO 70 I =1,NPOINT
      XX(I) = DX * (I-1)
   70 CONTINUE
C
      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
C
C      FORM INTEGRALS FOR CORRELATIONS
```

```
C
      DXO2 = 0.5*DX
      ICM1 = ICNT-1
      I1(1) = 0.
      MAXM = ABS(YY(1,1))
      DO 100 I =2,NPOINT
      MAXM = MAX(ABS(YY(I,1)),MAXM)
      I1(I) = I1(I-1) + DXO2 * (YY(I,1)**2+YY(I-1,1)**2)
  100 CONTINUE
      K = 2
  110 KM1 = K - 1
      MCF = 1.0
      PCF = 1.0
      EMMX(KM1) = 0.
      EMMN(KM1) = 0.
      EPMX(KM1) = 0.
      EPMN(KM1) = 0.
      MAXC(KM1) = ABS(YY(1,K))
      PEF(KM1) = 0.
      EMAG(1,KM1) = 0.
      EPHS(1,KM1) = 0.
      SUM1 = 0.
      SUM2 = 0.
      DO 130 I =2,NPOINT
      MAXC(KM1) = MAX(MAXC(KM1),ABS(YY(I,K)))
      SUM1 = SUM1 + DXO2 * (YY(I-1,K)**2+YY(I,K)**2)
      SUM2 = SUM2 + DXO2 * (YY(I-1,1)*YY(I-1,K)+YY(I,1)*YY(I,K))
      MCF = SQRT(MAX(SUM1,.001)/MAX(I1(I),.001))
      PCF = MAX(ABS(SUM2),.001) / MAX(SQRT(SUM1*I1(I)),.001)
      EMAG(I,KM1) = (MCF-1.)
      EPHS(I,KM1) = (1.-PCF)
      EMMX(KM1) = MAX(EMMX(KM1),EMAG(I,KM1))
      EPMX(KM1) = MAX(EPMX(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,ICM1
      ECMX(K) = 0.
      ECMN(K) = 0.
      ECOM(1,K) = 0.
      DO 140 I =2,NPOINT
      CEF = SQRT((EMAG(I,K))**2+(EPHS(I,K))**2)
      ECOM(I,K) = SIGN(CEF,EMAG(I,K))
      ECMX(K) = MAX(ECMX(K),ECOM(I,K))
      ECMN(K) = MIN(ECMN(K),ECOM(I,K))
  140 CONTINUE
      IF(ICNT.EQ.2) GO TO 200
C
C      IF MORE THAN 1 COMPARISON COMPUTE THE AVERAGES
C
```

```
      EMAGAV(1) = 0.
      EPHSAV(1) = 0.
      ECOMAV(1) = 0.
      NINVRS = 1./ICM1
      DO 160 I =2,NPOINT
      EMAGAV(I) = 0.
      EPHSAV(I) = 0.
      ECOMAV(I) = 0.
      DO 150 K =1,ICM1
      EMAGAV(I) = EMAGAV(I) + EMAG(I,K)
      EPHSAV(I) = EPHSAV(I) + EPHS(I,K)
      ECOMAV(I) = ECOMAV(I) + ABS(ECOM(I,K))
  150 CONTINUE
      EMAGAV(I) = EMAGAV(I) * NINVRS
      EPHSAV(I) = EPHSAV(I) * NINVRS
      ECOMAV(I) = SIGN(NINVRS*ECOMAV(I),EMAGAV(I))
  160 CONTINUE
C
  200 CONTINUE
C     OUTPUT PHASE
C
      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,(EMMN(K),K=K1,K3)
      PRINT 674,(EPMX(K),K=K1,K3)
      PRINT 675,(EPMN(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)
      PRINT 600
      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
  220 PRINT,
      IF(ICNT.EQ.2) GO TO 260
      PRINT 620
      PRINT 630,2,EMAGAV(2),EPHSAV(2),ECOMAV(2)
      DO 230 I =ISKIP,NPOINT,ISKIP
```

```
      PRINT 630,I,EMAGAV(I),EPHSAV(I),ECOMAV(I)
  230 CONTINUE
      PRINT,
  260 CONTINUE
      PRINT,'WANT PLOTS ?'
      READ,ANS
      IF(ANS.NE.1HY) GO TO 999
  300 CONTINUE
      PRINT,'WANT PLOT OF XX-EMAG ?'
      READ,ANS
      IF(ANS.NE.1HY) GO TO 340
      DO 335 K =1,ICM1
      CALL PLOT2(XX,EMAG(1,K),NPOINT)
  335 CONTINUE
  340 PRINT,'WANT PLOT OF XX-EPHS ?'
      READ,ANS
      IF(ANS.NE.1HY) GO TO 350
      DO 345 K =1,ICM1
      CALL PLOT2(XX,EPHS(1,K),NPOINT)
  345 CONTINUE
  350 PRINT,'WANT PLOT OF XX-ECOM ?'
      READ,ANS
      IF(ANS.NE.1HY) GO TO 360
      DO 355 K =1,ICM1
      CALL PLOT2(XX,ECOM(1,K),NPOINT)
  355 CONTINUE
  360 IF(ICNT.EQ.2) GO TO 380
      PRINT,'WANT PLOT OF XX-EMAGAV ?'
      READ,ANS
      IF(ANS.EQ.1HY) CALL PLOT2(XX,EMAGAV,NPOINT)
      PRINT,'WANT PLOT OF XX-EPHSAV ?'
      READ,ANS
      IF(ANS.EQ.1HY) CALL PLOT2(XX,EPHSAV,NPOINT)
      PRINT,'WANT PLOT OF XX-ECOMAV ?'
      READ,ANS
      IF(ANS.EQ.1HY) CALL PLOT2(XX,ECOMAV,NPOINT)
  380 PRINT,'WANT REPLOT ?'
      READ,ANS
      IF(ANS.EQ.1HY) GO TO 300
      GO TO 999
C
C       CALCULATE MEAN AND STANDARD DEVIATIONS
C
  400 CONTINUE
      RICNT = 1./ICNT
      RNM1 = 1./(ICNT-1)
      ES = 0.
      EMAX = 0.
      EMIN = 0.
      EPMAX = 0.
      EMMIN = 0.
      DO 410 K=1,ICNT
      ES = ES + TAR(K)
```

```
410 CONTINUE
    TE1 = ES*RICNT
    SS = 0.
    DO 420 K=1,ICNT
    SS = SS + (TAR(K)-TE1)**2
420 CONTINUE
    ST = SQRT(SS*RNM1)
    TP1 = TE1+ST
    TM1 = TE1-ST
    DO 450 I=1,NPOINT
    ES = 0.
    DO 430 K=1,ICNT
    ES = ES + YY(I,K)
430 CONTINUE
    E(I) = ES*RICNT
    SS = 0.
    DO 440 K=1,ICNT
    SS = SS + (YY(I,K)-E(I))**2
440 CONTINUE
    ST = SQRT(SS*RNM1)
    EP(I) = E(I)+ST
    EM(I) = E(I)-ST
    EMAX = MAX(E(I),EMAX)
    EMIN = MIN(E(I),EMIN)
    EPMAX = MAX(EP(I),EPMAX)
    EMMIN = MIN(EM(I),EMMIN)
    TE(I) = XX(I)+TE1
    TP(I) = XX(I)+TP1
    TM(I) = XX(I)+TM1
450 CONTINUE
    PRINT,'WANT TABULATED OUTPUT ?'
    READ,ANS
    PRINT 680,EMAX,EMIN,EPMAX,EMMIN,TE1,TP1,TM1
    K1 = 1
    K2 = (ICNT/8) + 1
    K3 = MIN(7,ICNT)
    DO 455 I =1,K2
    PRINT 665,(K,K=K1,K3)
    PRINT 682,(TAR(K),K=K1,K3)
    K1 = 8
    K3 = ICNT
455 CONTINUE
    PRINT,
    IF(ANS.NE.1HY) GO TO 470
    PRINT 690
    DO 460 I =ISKIP,NPOINT,ISKIP
    PRINT 630,I,E(I),EP(I),EM(I)
460 CONTINUE
    PRINT,
    PRINT,
    PRINT,'WANT PLOTS ?'
    READ,ANS
    IF(ANS.NE.1HY) GO TO 500
```

```
  470 CONTINUE
      PRINT,'WANT PLOT OF TE-E ?'
      READ,ANS
      IF(ANS.EQ.1HY) CALL PLOT2(TE,E,NPOINT)
      PRINT,'WANT PLOT OF TP-EP ?'
      READ,ANS
      IF(ANS.EQ.1HY) CALL PLOT2(TP,EP,NPOINT)
      PRINT,'WANT PLOT OF TM-EM ?'
      READ,ANS
      IF(ANS.EQ.1HY) CALL PLOT2(TM,EM,NPOINT)
      PRINT,'WANT PLOT OF XX-E ?'
      READ,ANS
      IF(ANS.EQ.1HY) CALL PLOT2(XX,E,NPOINT)
      PRINT,'WANT PLOT OF XX-EP ?'
      READ,ANS
      IF(ANS.EQ.1HY) CALL PLOT2(XX,EP,NPOINT)
      PRINT,'WANT PLOT OF XX-EM ?'
      READ,ANS
      IF(ANS.EQ.1HY) CALL PLOT2(XX,EM,NPOINT)
      PRINT,'WANT REPLOT ?'
      READ,ANS
      IF(ANS.EQ.1HY) GO TO 470
  500 CONTINUE
      IF(NTPLOT.LT.3) GO TO 999
C
C       CALCULATE DERIVATIVE WITH RESPECT TO TIME
C       FOR MEAN AND STANDARD DEVIATIONS
C
      DEMAX = 0.
      DEMIN = 0.
      DEPMAX = 0.
      DEMMIN = 0.
      DXI = 1./DX
      DE(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)
  510 CONTINUE
      PRINT,'WANT TABULATED OUTPUT ?'
      READ,ANS
      PRINT 692,DEMAX,DEMIN,DEPMAX,DEMMIN
      PRINT,
      IF(ANS.NE.1HY) GO TO 530
      PRINT 694
      DO 520 I =ISKIP,NPOINT,ISKIP
      PRINT 630,I,DE(I),DEP(I),DEM(I)
```

```
 520  CONTINUE
      PRINT,
      PRINT,
      PRINT,'WANT PLOTS ?'
      READ,ANS
      IF(ANS.NE.1HY) GO TO 999
 530  CONTINUE
      PRINT,'WANT PLOT OF XX-DE ?'
      READ,ANS
      IF(ANS.EQ.1HY) CALL PLOT2(XX,DE,NPOINT)
      PRINT,'WANT PLOT OF XX-DEP ?'
      READ,ANS
      IF(ANS.EQ.1HY) CALL PLOT2(XX,DEP,NPOINT)
      PRINT,'WANT PLOT OF XX-DEM ?'
      READ,ANS
      IF(ANS.EQ.1HY) CALL PLOT2(XX,DEM,NPOINT)
      PRINT,'WANT REPLOT ?'
      READ,ANS
      IF(ANS.EQ.1HY) GO TO 530
 999  CONTINUE
      CALL PTIME(PTU)
      PRINT 640,(PTU-PTI)*3600.
      STOP
 600  FORMAT(4X,'I',5X,'EMAG',6X,'EPHS',6X,'ECOM'//)
 610  FORMAT(I6,3F10.3)
 620  FORMAT(5X,'I','    EMAGAV','    EPHSAV','    ECOMAV'//)
 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(' EPMX = ',7F10.3)
 675  FORMAT(' EPMN = ',7F10.3)
 676  FORMAT(' ECMX = ',7F10.3)
 677  FORMAT(' ECMN = ',7F10.3)
 680  FORMAT(/7X,'EMX',7X,'EMN',7X,'EPMX',6X,'EMMN'/2X,4F10.3//
     &        7X,'TE1',7X,'TP1',7X,'TM1'/2X,3F10.3)
 682  FORMAT(' TAR =  ',7F10.3)
 690  FORMAT(5X,'I',6X,'E',9X,'EP',8X,'EM')
 692  FORMAT(/7X,'DEMX',6X,'DEMN',6X,'DEPMX',5X,'DEMMN'/2X,4F10.3)
 694  FORMAT(5X,'I',6X,'DE',8X,'DEP',7X,'DEM')
      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(T12,1H;)/,ANS*1
      EQUIVALENCE (TITLE,TITL)
      COMMON /INPUT/ XFINAL,DX,NTPLOT,ISKIP,NIBASE,NICOMP,
```

```
     &                 ICNT,NPOINT,DT(NC),TAR(NC),NPTS(NC)
      COMMON /ARRA1/ X(NP,NC),Y(NP,NC),XX(NP),YY(NP,NC),
     &                 MAXC(N1),PEF(N1),EMMX(N1),EMMN(N1),EPMX(N1),
     &                 EPMN(N1),ECMX(N1),ECMN(N1),TITLE(NC)
      DATA NOE,NAFT/0400000000000,0403700000000/
      PRINT,'READ XFINAL,DX,NTPLOT,SEARV,ISKIP,NIBASE,NICOMP'
      READ,XFINAL,DX,NTPLOT,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,'NPOINT =',NPOINT
   10 ICNT = ICNT + 1
      PRINT,'READ NSORCE,NFILE'
      READ,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
      IF(XX(I)-SEARV) 50,60,60
   50 CONTINUE
   60 CONTINUE
      NSTRT = I-1
      TAR(ICNT) = DT(ICNT)*NSTRT
      NPT = MIN(NPTS(ICNT)-NSTRT,NPT)
      BACKSPACE 1
      READ(1) (SKIP,K=1,NSTRT-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
      NPTM = MIN(NPT,NPTM)
      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)
  140 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) 150,160,160
  150 CONTINUE
  160 CONTINUE
      NSTRT = I-1
      TAR(ICNT) = DT(ICNT)*NSTRT
      NPT = MIN(NPTS(ICNT)-NSTRT,NPT)
      BACKSPACE 2
      READ(2) (SKIP,K=1,NSTRT-1),(Y(I,ICNT),I=1,NPT)
      GO TO 180
  170 CONTINUE
      READ(2) (Y(I,ICNT),I=1,NPT)
      TAR(ICNT) = 0.
  180 CONTINUE
      NPTS(ICNT) = NPT
      NPTM = MIN(NPT,NPTM)
      CALL BCDASC(TDUM,TITLE(ICNT),60)
      GO TO 10
  200 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)
  500 CONTINUE
C
      IF(NPTM.GE.NPOINT) GO TO 600
      NPOINT = NPTM
      XFINAL = (NPOINT-1)*DX
      PRINT 310,NPOINT,XFINAL
  600 CONTINUE
      RETURN
  700 CONTINUE
      PRINT,'INPUT FILE ?'
      READ,FILE
      IF(FILE.EQ.1H ) GO TO 200
      CALL DETACH(NSORCE,,)
      ENCODE(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,O12)
      GO TO 700
   98 CONTINUE
      PRINT,'READ NFILE'
```

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

*

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