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16. Abstract

The depths of surface cracks in expansive clay deposits control the depths of the active zone in many cases. Rainfall and surface runoff can fill up these cracks and the water in the cracks can travel, impelled only by gravity, wherever the crack goes. If it goes beneath a pavement, the water will remain there, soaking into the soil on each side of the crack, and cause swelling. Thus, the depth of the surface cracks determines the depth to which a vertical moisture barrier should be placed in order to control moisture beneath a pavement. There is a need to be able to determine this depth of surface cracks by some means, and this report investigates a site investigation method which uses wave propagation.

The report presents a definition of the ideal characteristics of an appropriate site reconnaissance using wave propagation to detect the presence of cracks and estimate their depth within reasonable tolerances. A summary review of the wave types is included, considering their generation, propagation, and alteration at a crack, and the feasibility of detection and positive identification of the crack. This is complemented by the selection of several trial procedures for detecting surface cracks and estimating their depth. The results of field tests using several trenches excavated to different depths and naturally occurring shrinkage cracks are presented. The experimental set-ups that were used in these are illustrated. The field data are analyzed using a Fast Fourier algorithm to transform the recorded wave to the frequency domain. The depth of the crack is backfigured from the increase in travel time of the surface wave caused by the crack.

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DETECTION AND SIZING OF SURFACE CRACKS IN EXPANSIVE SOIL DEPOSITS

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September 1987

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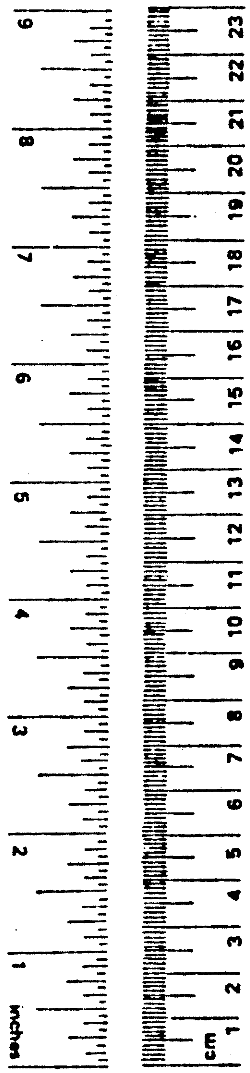
COLLEGE STATION, TEXAS

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

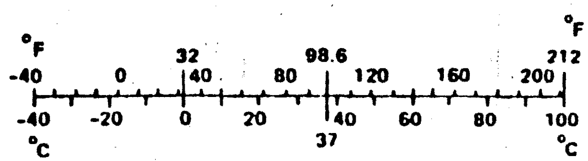
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



ABSTRACT

The depths of surface cracks in expansive clay deposits control the depth of the active zone in many cases. Rainfall and surface runoff can fill up these cracks and the water in the cracks can travel, impelled only by gravity, wherever the crack goes. If it goes beneath a pavement, the water will remain there, soaking into the soil on each side of the crack, and cause swelling. Thus, the depth of the surface cracks determines the depth to which a vertical moisture barrier should be placed in order to control moisture beneath a pavement. There is a need to be able to determine this depth of surface cracks by some means, and this report investigates a site investigation method which uses wave propagation.

This report presents a definition of the ideal characteristics of an appropriate site reconnaisance using wave propagation to detect the presence of cracks and estimate their depth within reasonable tolerances. A summary review of the wave types is included, considering their generation, propagation, and alteration at a crack, and the feasibility of detection and positive identification of the crack. This is complemented by the selection of several trial procedures for detecting surface cracks and estimating their depth. The results of field tests using several trenches excavated to different depths and naturally occurring shrinkage cracks are presented. The experimental set-ups that were used in these are illustrated. The field data are analyzed using a Fast Fourier algorithm to transform the recorded wave to the frequency domain. The depth of the crack is backfigured from the increase in travel time of the surface wave caused by the crack.

IMPLEMENTATION STATEMENT

The use of wave propagation to detect the depth of cracks in expansive soil is a site investigation method that will work only when the cracks are open during the dry weather. Thus, any survey of roadside conditions which are meant to determine the depth of a vertical moisture barrier must be made in the summer. Other methods must be used in the wet weather, when the cracks are closed. The wave propagation method appears to work well in the field tests that have been conducted and are reported here.

The method appears to be worthy of further development to the stage where a complete set of wave propagation recording, digitizing, and analyzing equipment is assembled for measuring crack depths. Perhaps the Falling Weight Deflectometer equipment, sensors, and circuits can be modified to perform the measurements and analyses that are presented in this report.

DISCLAIMER

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INTRODUCTION

This report describes field trials of and subsequent analyses of a method of measuring the depth of shrinkage cracks in expansive clay by using wave propagation techniques. The major reason for wanting to know the depth to which these cracks extend is because this is thought to be closely related to the depth to which a vertical moisture barrier should be carried in order to control moisture influx and efflux from beneath a pavement.

There are other ways that water can accumulate beneath a pavement, such as vertical and horizontal seams of sand or gravel, a high water table, a leaking storm sewer, or crack and joints in the pavement surface.

The method of detecting crack depth described here is intended as only one of several necessary site investigation techniques that are needed to establish the required depth of a vertical moisture barrier.

During periods of extended drought, an expansive soil mass will gradually lose excessive water to the atmosphere by evaporation. This will cause shrinkage of the soil mass. In turn, this will provoke the formation of vertical cracks that will propagate downwards as the soil gets drier. During wet periods, water will seep into the open cracks and from there will diffuse into the soil. This will cause the soil mass to expand both laterally, to close the cracks, and vertically, which will result in a swell of the ground surface.

The crack depth is a function of the mineralogical composition of the soil deposit and the climatological characteristics of the specific site. For Texas, typical values reported (1) in the vicinity of Austin are cracks of twenty feet in depth and openings of three inches at the ground surface. Nevertheless, these dimensions will change with the season.

When a light structure, such as a pavement, is founded on one of these deposits, there is an alteration of the moisture flow pattern. Since the pavement is essentially impermeable, the soil conditions at the center or at the edge are completely different. While the soils at the center will remain virtually unchanged through the year, the soils near the edge will lose or gain moisture depending on the climatic season. These will result in a shrink or swell under the edges of the pavement, while the center will remain unchanged. These differential movements are then responsible for the progressive deterioration of the structure.

For residential and light commercial construction, the differential movements are reduced to an acceptable level by increasing the stiffness of the foundation mat. However, this alternative is not economically viable in the case of pavements. For highway pavements, there is not any widely accepted solution to eliminate this progressive damage. One method that is being tried by the Texas Highway Department in Districts 1 and 15 is to install a vertical moisture barrier, as shown in Figure 1, in order to delay the water flow in or out of the foundation soils beneath the edges of the pavement.

It is apparent that the effectiveness of a vertical moisture barrier will be readily affected by the presence of shrinkage cracks. If the cracks are deeper than the barrier (case C_2 in Figure 1), they can render the barrier useless. Therefore, a procedure to design the depth of the barrier should consider the maximum depth of the shrinkage cracks in the area and the possible variations of the crack depth with the seasons.

These considerations suggest the need for a site exploration technique that is capable of detecting the depth of shrinkage cracks in expansive soil masses in the field. This report defines the scope of such an investigation, reviews existing non-destructive testing procedures, assesses their applicability to the detection of cracks, presents the results of field tests, and describes the analysis that was used to elaborate the results.

CHARACTERISTICS OF SITE INVESTIGATION

The ideal investigation should be a non-destructive test method that is inexpensive, accurate, simple to operate, and capable of making tests rapidly. The test would be used to cover long stretches of roadway and would be convenient for making several surveys during different times of the year, on some occasions.

From these characteristics, it appears that the use of some technique based on wave propagation may be the best approach. Of all possible procedures, only those that can make non-destructive measurements from the ground surface provide a cost effective investigation method. As a consequence, this report is concerned with methods in which the seismic source, from which waves propagate, and the receivers are placed on the ground surface. More sophisticated methods that can provide more reliable results can be devised, but the expense of such methods is much greater.

WAVES GENERATED ON THE SURFACE

A common surface seismic source is an oscillator or an impact hammer that interacts with the soil through a circular plate. This case has been analyzed theoretically (2) and it has been shown that three different wave types are generated, as shown in Figure 2. Both body waves, compression and shear waves, are generated and they propagate away from the point source with semi-spherical wave fronts. Rayleigh surface waves are the third type of wave generated, which propagate on cylindrical wave fronts.

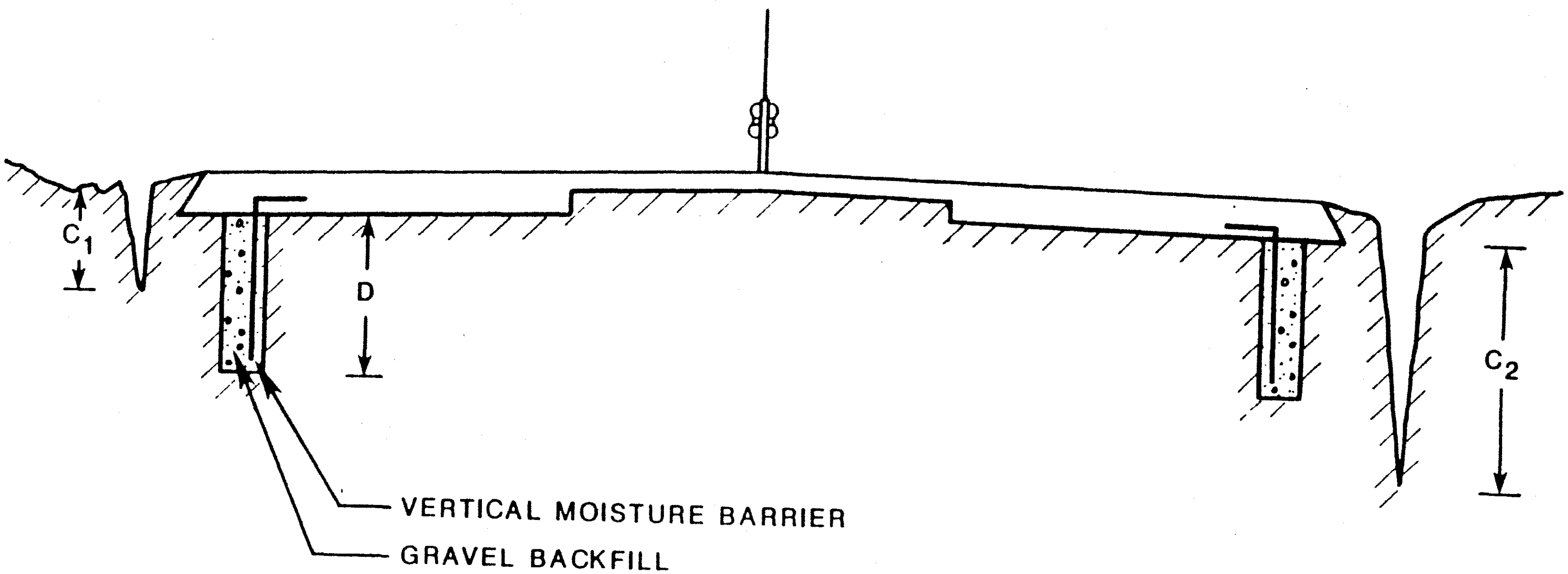


FIGURE 1. Sketch of a Highway Cross-section with a Vertical Moisture Barrier

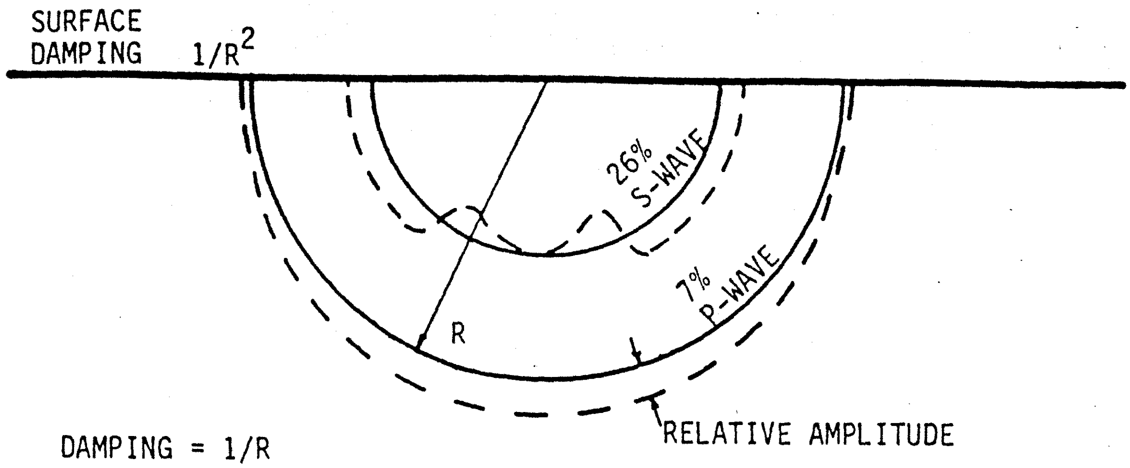


FIGURE 2a. Geometric Damping of Body Waves

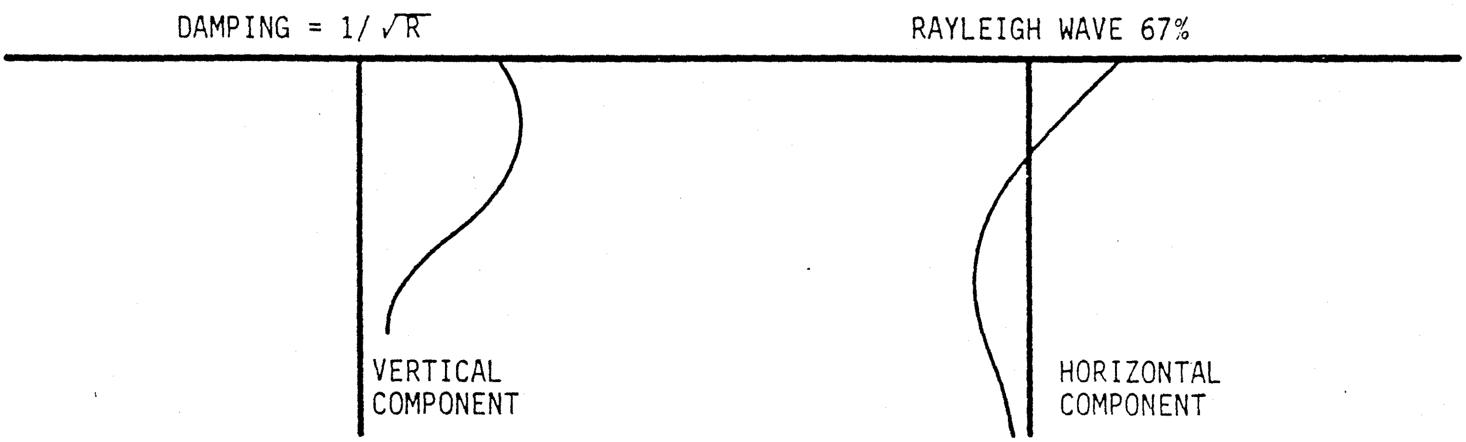


FIGURE 2b. Geometric Damping of Rayleigh Waves

It has been shown (3) that the total energy input at the source is unevenly split between all three waves. Only 7% of the total energy is transmitted away as a compression wave. The shear waves account for 26% of the total energy input. The remaining 67% is transmitted away from the source as Rayleigh surface waves. The body waves (3) not only account for less energy but their geometrical damping is also higher. For the body waves, damping is proportional to the inverse of the distance to the source, and on the ground surface their damping is proportional to the inverse of that distance squared; while for Rayleigh waves, the damping is proportional to the inverse of the square root of the distance.

Other types of surface sources are possible. The most frequently used correspond to multiple sources (2) which are arranged to minimize the amount of energy transmitted with the surface waves. These arrangements, however, are more complicated and expensive. Therefore, they do not satisfy the need of a simple and cheap elastic wave source.

Theoretically it might be possible to use any of the three wave types in a field survey. However, due to the peculiar characteristics of soils, not all are considered adequate. Since most of the energy is transmitted through a Rayleigh wave that is concentrated on the surface, and the cracks are also local features in this zone, it is felt that Rayleigh waves are the most likely candidates. In the following paragraphs, the opportunities offered by each of the three wave types are examined separately.

COMPRESSION WAVE SURVEY

The main advantage offered by compression waves is that identification of their arrival time at the receiver can be defined with acceptable certainty. Therefore, if travel time is measured, and it can be assumed that the ray path is straight and the wave velocity constant, a procedure to measure crack depth can be assembled readily. In broad outline, this would consist in striking the source located on one side of the crack and detecting the compression wave arrival at two independent receivers located on the opposite side of the crack, as shown in Figure 3. Two equations can be written expressing that the distance travelled by the wave is equal to its velocity times the travel time. These two equations have two unknowns: crack depth and wave velocity.

In terms of the dimensions shown in Figure 3, the two equations are:

$$\sqrt{D^2+D_1^{\,2}} + \sqrt{D^2+D_2^{\,2}} = v_c\ t_1 \qquad (1)$$

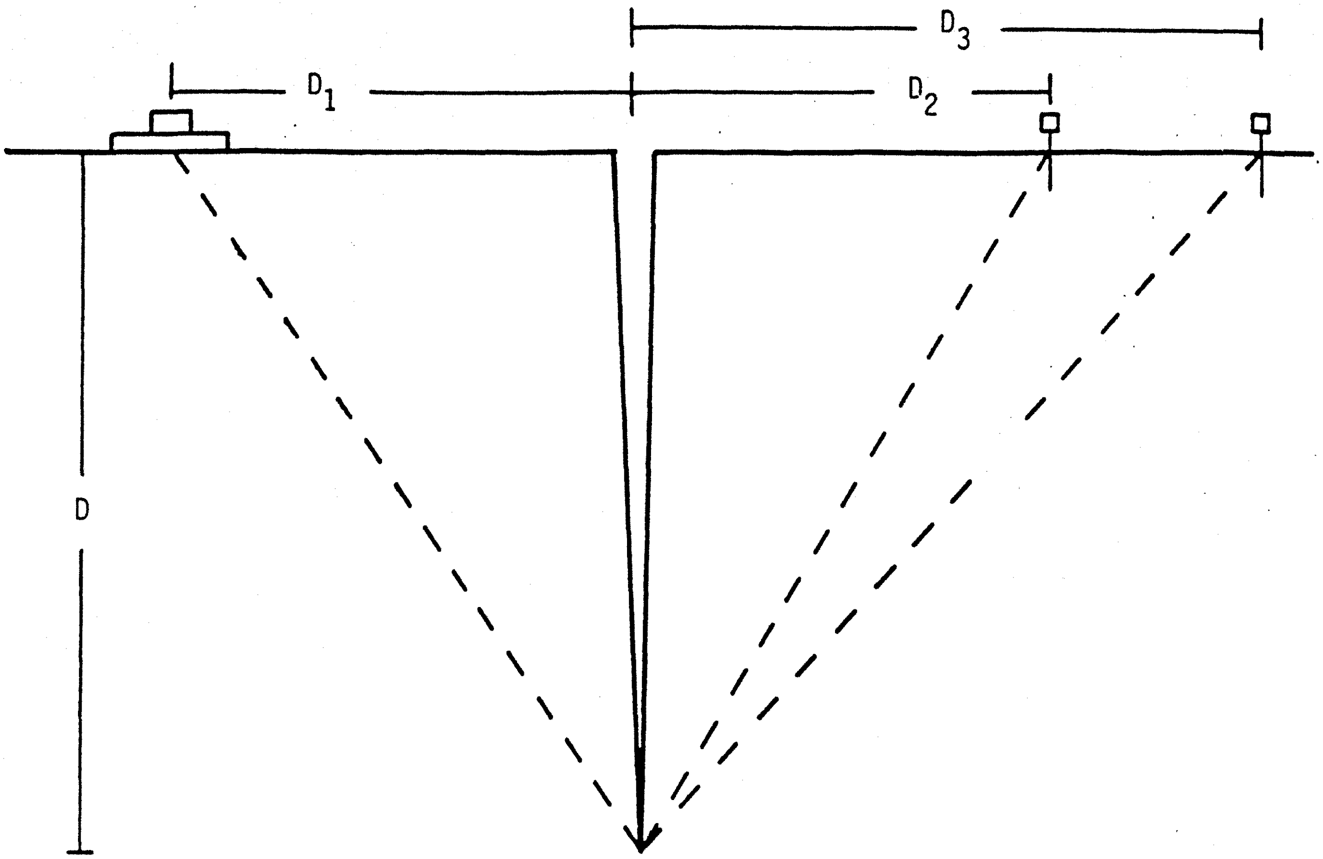


FIGURE 3. Compression Wave Paths Around a Crack

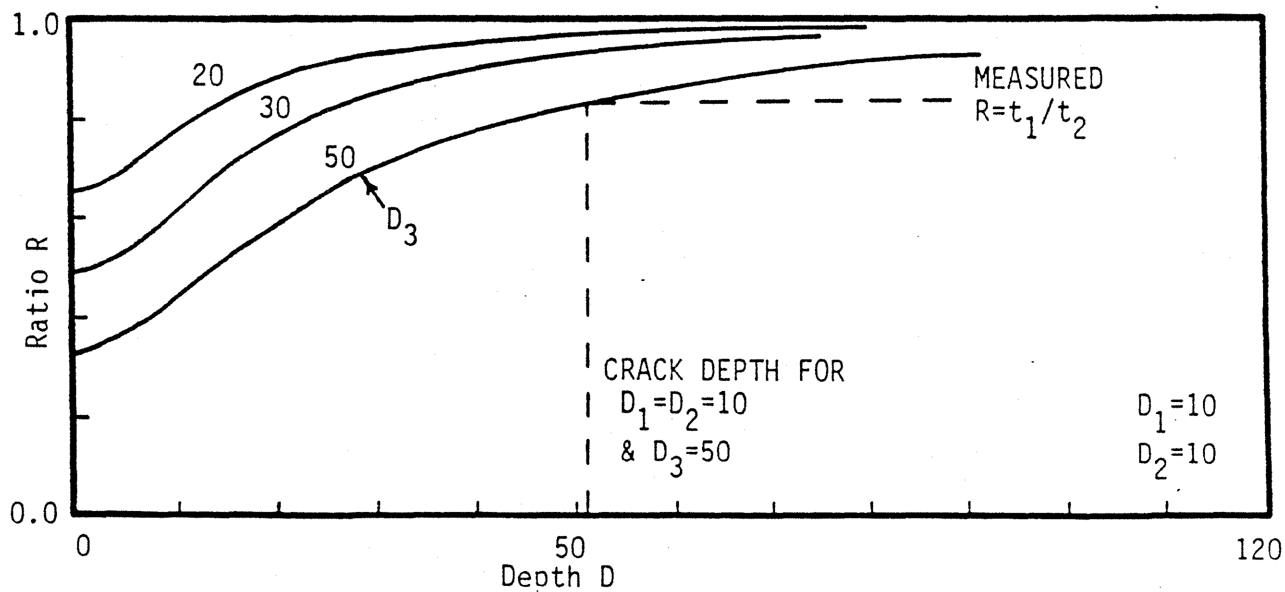


FIGURE 4. Solutions for the Depth of the Crack

$$\sqrt{D^2+D_1^{\,2}} + \sqrt{D^2+D_3^{\,2}} = v_c\, t_2 \qquad (2)$$

where

v_c = the compression wave velocity

t_1, t_2 = the travel time along the two paths

The compression wave velocity can be eliminated by dividing one equation by the other giving a nonlinear equation with the crack depth, D, as the only unknown.

$$\frac{t_1}{t_2} = \frac{\sqrt{D^2+D_1^{\,2}} + \sqrt{D^2+D_2^{\,2}}}{\sqrt{D^2+D_1^{\,2}} + \sqrt{D^2+D_3^{\,2}}} = R \qquad (3)$$

The equation can be solved by successive approximations and hypothetical results are illustrated in Figure 4.

This estimate of crack depth is as good as is the assumption of a straight ray path or constant wave velocity. It is a well documented phenomenon (4) that the ray path bends with the changing of the sub-soil elastic properties. Furthermore, since compression waves propagate in water, if the crack is partially filled, the ray path will not pass through the crack tip. Instead, it will cross the crack at the water level elevation in the crack.

The compression waves that can be generated by a simple source such as a drop weight, are extremely weak. The high geometrical damping and attenuation due to internal damping of the soil results in compression waves that can barely be differentiated from the background noise. Since precise identification of the travel time is essential, there is a need to enhance the compression wave. This is accomplished routinely by superimposing several consecutive identical seismic pulses, which requires a reproducible wave generating source. As successive pulses are superimposed, the compression wave is enhanced by summing up successive pulses, while the background noise, which is random in nature, cancels out.

The procedure just described requires a precise knowledge of the position of the crack and the relative position of the instruments. Since the location of cracks in vegetated areas can be cumbersome, there is a need for an expedient procedure to locate cracks in the field. Compression waves could also be used for that purpose, by using a normal exploratory compression wave survey.

This survey can be made with the source fixed at one location, and the receiver being moved successively to increasing distances from the source. The travel time to each position can be plotted vs. the distance to the source, as shown in Figure 5. If the points plot on a straight line, there is no crack between the last point and the source. However, a sudden jump away from the straight line will indicate the position of the crack. The plots shown in Figure 5 are for cracks that are 4.5 and 12.5 ft. deep, located 7.5 ft. from the source in a material with a compression wave speed of 1500 ft/sec.

This procedure has the limitation that the presence of a refracting layer at a shallow depth will limit the maximum length of survey line that is possible. For the conditions shown in Figure 5, in which a refracting layer causes a re-direction of the straight line to the new line A-B, it is impossible to use lines that are longer than 19.2 ft. from the source. The procedure could still be used by re-positioning the seismic source, each time a breakpoint in slope is found, on the last receiver position and begin the process again. Once a crack is located, the seismic source and the receivers should be placed in the position that is described above in order to measure the crack depth.

This procedure is straight forward, simple to use, and does not require sophisticated equipment. However, it is felt that it has several limitations and there are too many assumptions needed in order to interpret the results, all of which raise doubts about the reliability of the method.

SHEAR WAVE SURVEY

The identification of the arrival time of the shear wave pulse is impossible for normal conditions of soil deposits, mainly because they are not homogeneous. Any wave train moving through such a soil mass is diffracted and reflected at any interface of contrasting properties. According to Snell's Law, this will initiate a great number of parasitic body waves that eventually will reach the receiver. Since these inhomogeneities are very frequent in natural soil deposits, it is usually almost an impossible task to identify with certainty the arrival of any particular wave but the primary wave.

In practice, the use of shear waves for seismic exploration methods have been (5) uniformly disappointing. The main cause is because the identification of shear wave arrival can only be reasonably accomplished (5) when the position of the seismic equipment can be set up for that purpose alone. Essentially it requires: 1) a source rich in shear waves relative to any other wave generated, 2) positioning of the receiver where the source radiation pattern predicts maximum shear wave amplitude relative to the other waves, and 3) orientation of the receiver to take advantage of the directionality of the shear waves. All of these requirements rule out the shear waves for the type of surface exploration that is sought.

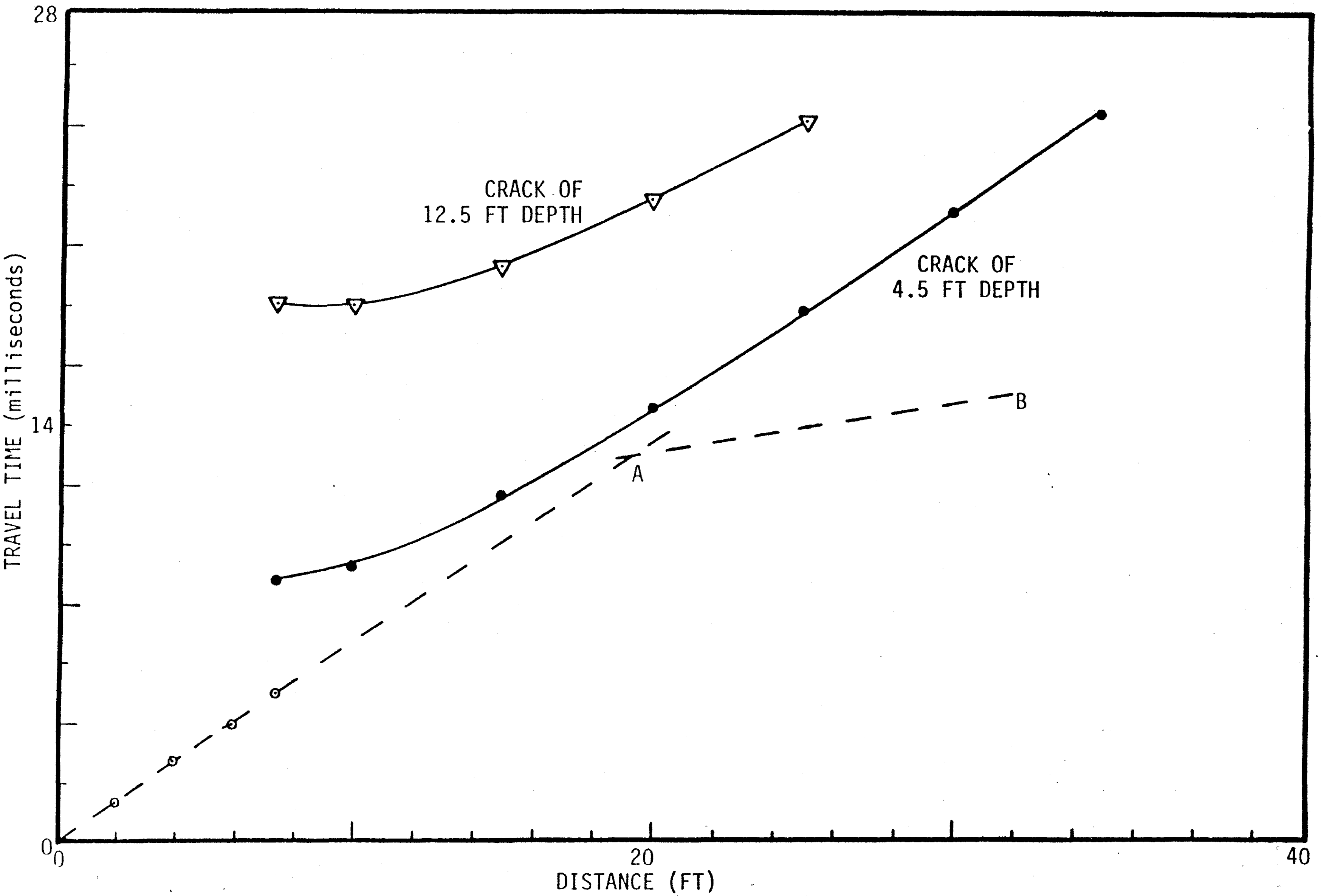


FIGURE 5. Plot of Travel Time vs. Distance to the Source

RAYLEIGH SURFACE WAVE SURVEY

The transmission of surface waves around surface cracks has no known analytical solution. However, a surface crack can be visualized as a succession of 90 and 270 degree surface corners, and these have received some theoretical consideration. Published results (8) obtained by numerical iteration techniques are available for a right angle corner of a material with a Poisson's ratio of 0.25. They indicate, as shown in Figure 6, that when the Rayleigh wave reaches the corner 13% of the incident energy is reflected in another surface wave, a second surface wave travels down the vertical face of the corner transmitting away about 41% of the energy, and the remaining 46% is converted into bulk modes that radiate into the solid.

If the incident pulse is split into its Fourier components, an amplitude ratio can be defined between the amplitude (perpendicular to the plane of propagation) of the surface wave transmitted, or reflected, and the amplitude of the same Fourier component in the incident wave. For the case under consideration, the transmitted wave will have an amplitude ratio of 0.64 and the reflected wave an amplitude ratio of 0.36.

If the Rayleigh wave strikes a 270 degree corner, as shown in Figure 7, the reflected surface wave is small with an amplitude ratio of only 0.09, as is the transmitted surface wave that moves up on the vertical face with an amplitude ratio of 0.28. The result of the wave reaching this corner is that most of the incident energy (91%) is converted to bulk modes that radiate into the body.

In both of the cases mentioned above, the vertical faces were assumed to be infinitely long. Nevertheless, these solutions will also be true when the wave length of the incident pulse is small compared to the length of the vertical face. In the particular case of a finite step change in elevation of the ground surface, it is found to be equivalent to 90 and 270 degree consecutive corners, provided that the step change is large compared to the Rayleigh wave length. It is also found that for step change that is small relative to the wave length, the amplitude ratio has a pronounced variation with the "scaled depth," which is the ratio of the step change to the Rayleigh wave length.

The theoretical solution (8) of amplitude ratio due to the finite step change, shown in Figure 8, shows two prominent features at "scaled depths" of 0.5 and 1.5. The first one corresponds to a minimum in the amplitude ratio and the second to the point where the amplitude ratio is no longer dependent on the incident wave length. Despite the fact that these results are for a step change, it seems reasonable to expect similar features on the corresponding curve for a finite surface crack. There is no theoretical treatment of this problem, but some experimental confirmation has been published.

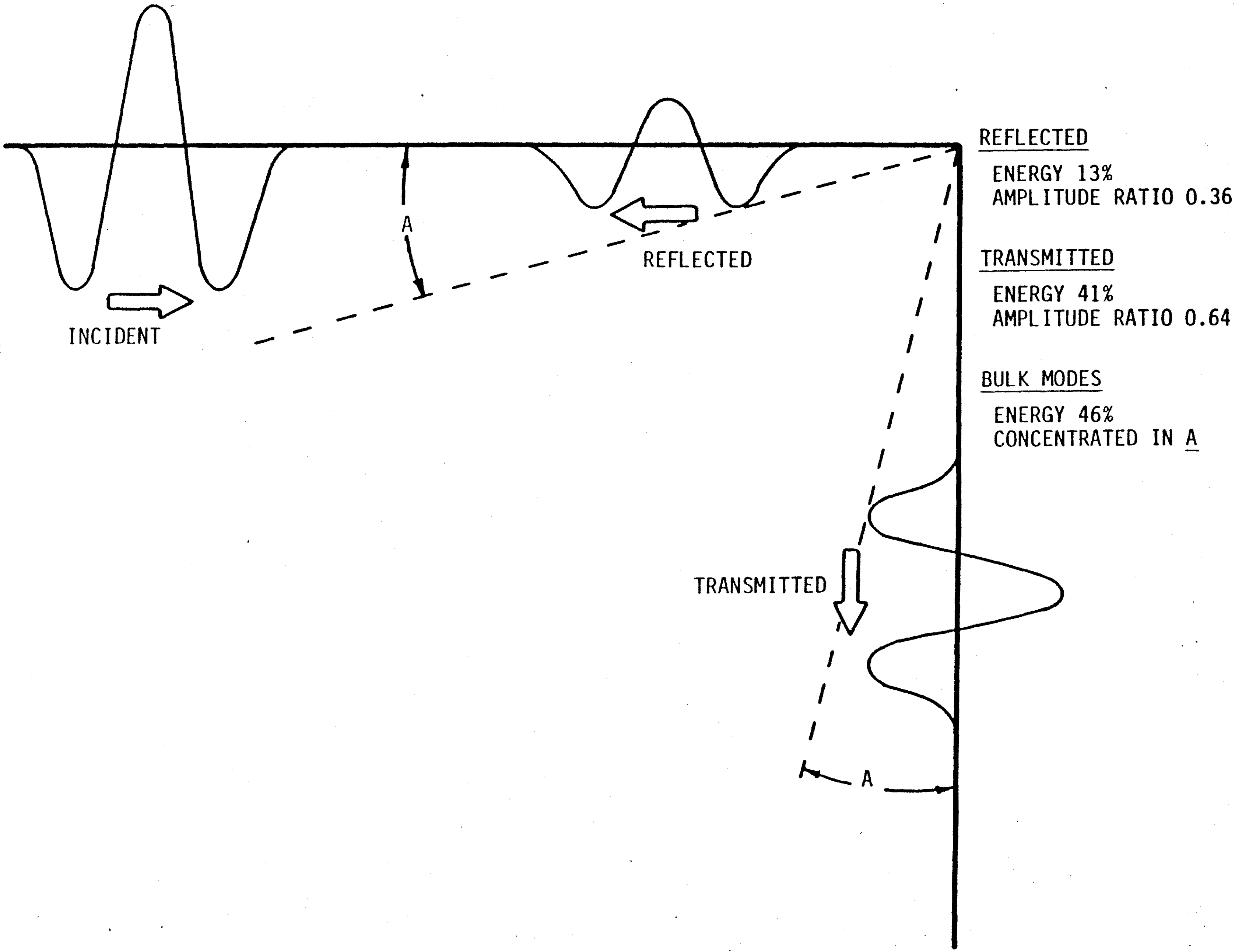


FIGURE 6. Behavior of a Rayleigh Wave Interfering With a 90° Corner

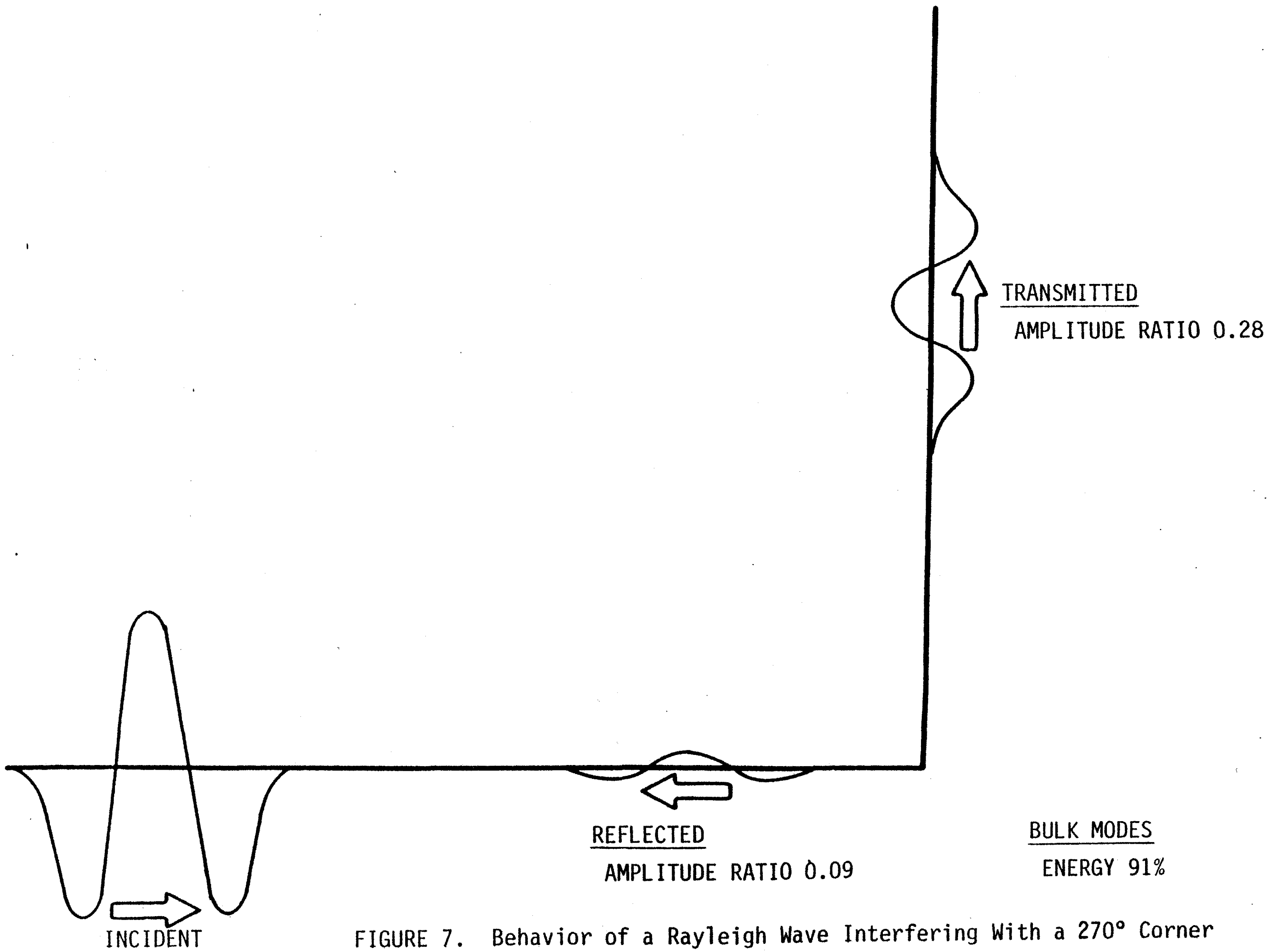


FIGURE 7. Behavior of a Rayleigh Wave Interfering With a 270° Corner

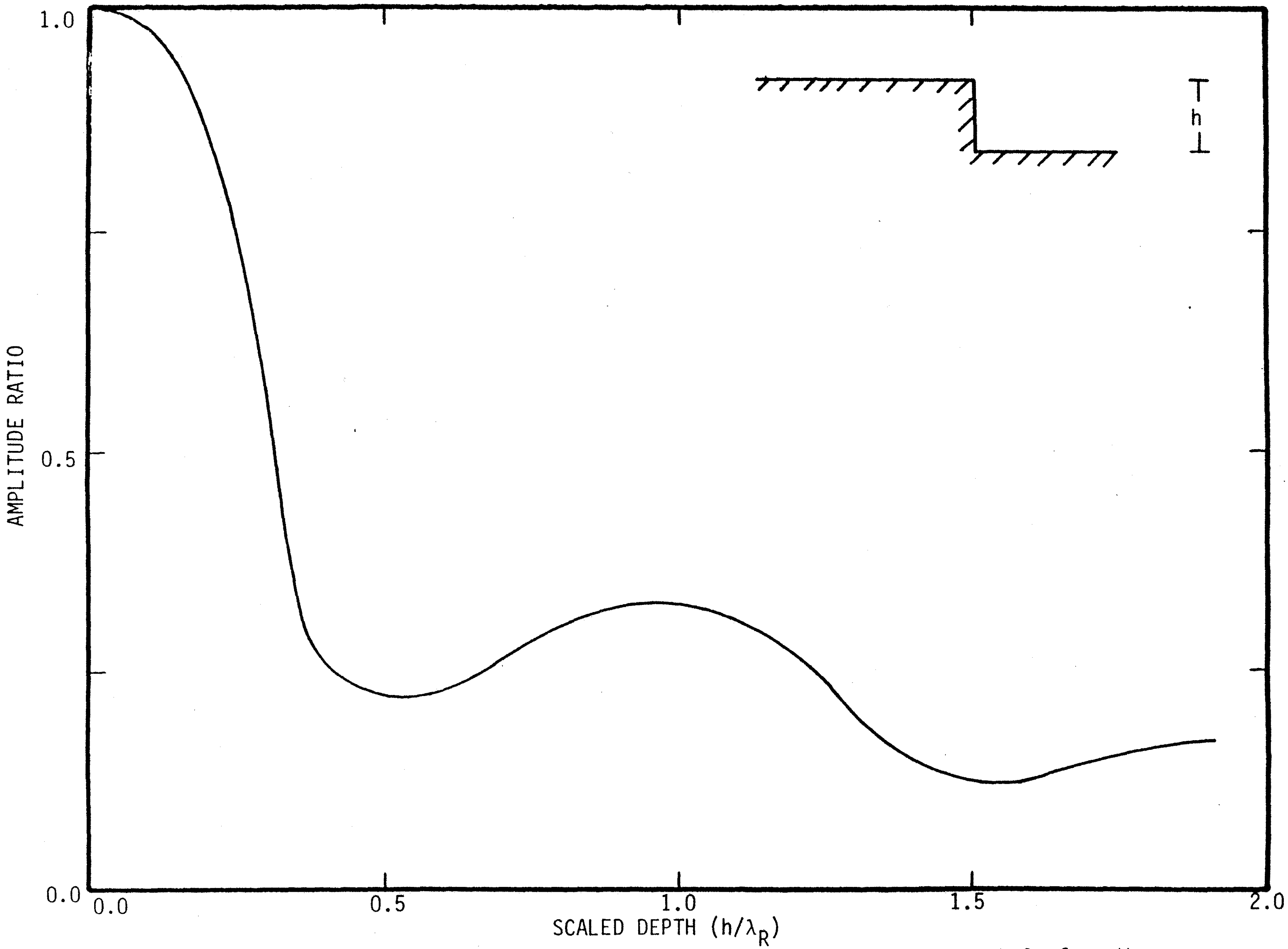


FIGURE 8. Theoretical Effect of a Finite Step Change on a Rayleigh Surface Wave

Viktorov (9) has used experimental determination of the amplitude ratio versus "scaled crack depth" for a variety of materials ranging from dural to steel. He found that this curve was reproducible with only slight modifications for the different materials as shown in Figure 9. Typically, he found the first minimum amplitude ratio at a "scaled depth" of 0.7 and the transmission coefficient ceases to depend on the wave length for "scaled depths" beyond 1.5.

Woods (3) has also published results that tend to confirm the position of the minimum in the amplitude ratio versus "scaled depth" curve. He considered the case of trenches in silty sand, and found that a "scaled depth" of 0.6 was needed to achieve an amplitude reduction factor of 0.25.

From this discussion of the behavior of Rayleigh waves incident on a surface it seems possible that some of the features of the amplitude ratio curve (Figures 8 and 9) might be used to identify the depth of the crack. In this manner, a possible procedure to test for the depth of the crack would be to determine the amplitude ratio of the incident wave over that of the wave after the crack.

To perform this type of test, it would be necessary to have a Rayleigh wave source and to place two sensors, one on each side of the crack. Then decompose the real signals into its frequency components and then determine for each component the amplitude ratio. The depth of the crack (h in Figure 9) is not known, but each component will have a different wave length (λ_R). Therefore, it will be possible to plot a curve similar to Figure 9 of amplitude ratio versus frequency (or if we so desire $1/\lambda_R$). Then from this curve we could pick up the first minimum and assume that the minimum occurs for $h/\lambda_R = 0.6$. Another alternative could be to select the point where the amplitude ratio-frequency curve becomes flat and assume that at this point $h/\lambda_R = 1.5$. In summary, one possibility would be to try to relate the shape of the amplitude ratio curve with the depth of the crack.

A second possibility would be to use Rayleigh waves as they are commonly employed in non-destructive testing to determine the size of surface cracks in fabrication products. For this purpose, Rayleigh waves of the appropriate wavelength are excited. The crack forces (6) the surface wave to travel down and back up the crack sides, increasing the transit time relative to the time expected from the unique Rayleigh wave velocity of the material. From this time delay and the assumption that the crack is vertical, the depth of the crack can be calculated. For this type of survey, it is necessary to have a set up similar to that described above, but including an extra sensor. This extra sensor must be used to determine the travel time in the intact soil where no crack is present.

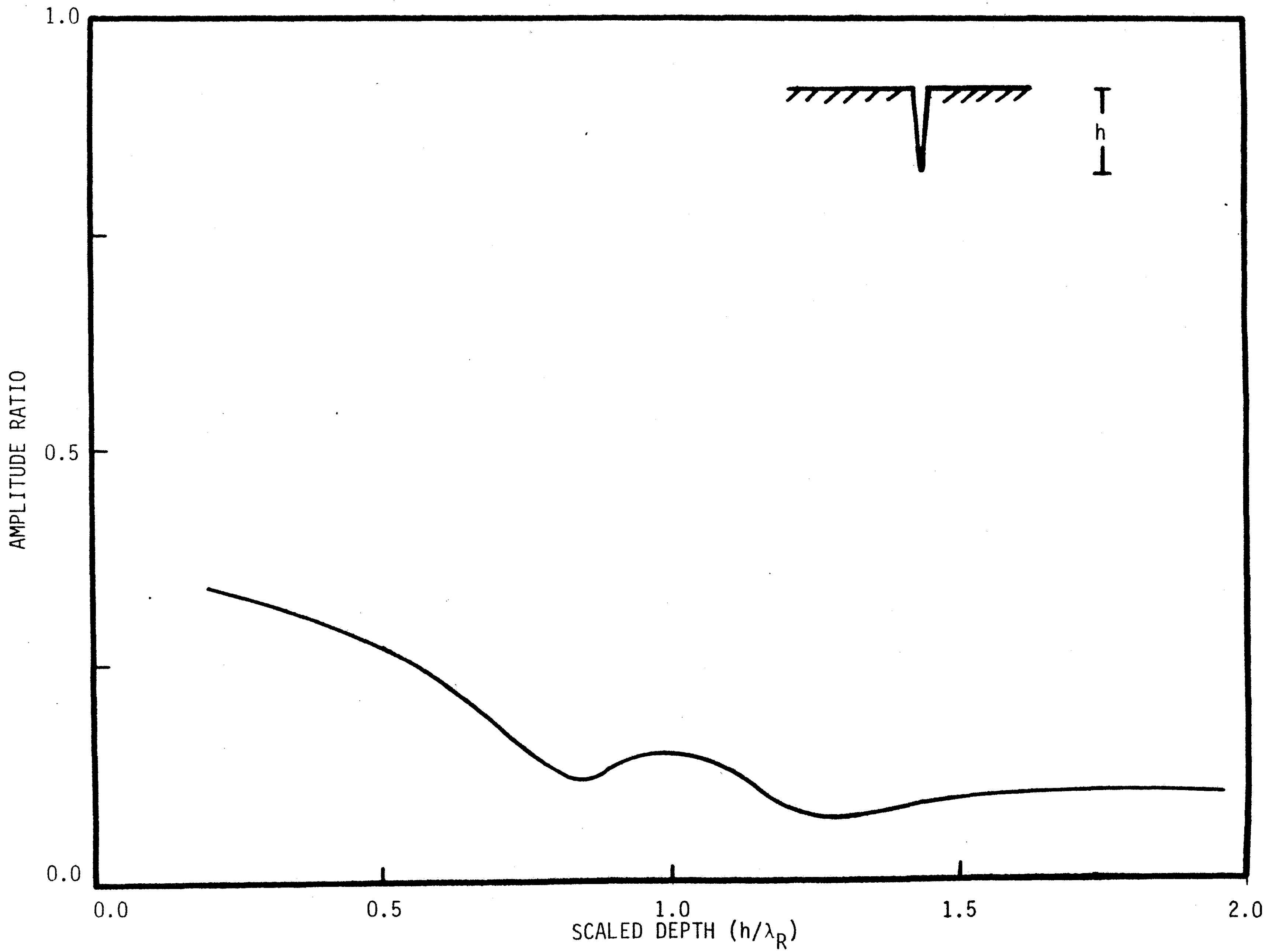


FIGURE 9. Experimental Determination of Amplitude Ratio Due to Crack

PROPOSED TESTING PROCEDURE

Field Trial Tests

Two types of field tests were performed to check the capabilities of the proposed test to measure the depth of shrinkage cracks. The first type of test consisted of exciting Rayleigh surface waves on one side of the pre-excavated trench and recording with accelerometers the surface wave that reached both sides of the trench. The second type of test was basically identical, but using a naturally occurring shrinkage crack instead of a trench and using geophones as the motion sensor. Both tests were performed at the Research Annex of Texas A&M University.

The tests of the first type were implemented first. The test preparation consisted of digging a 1 ft wide trench with a trenching machine to the desired depth and approximately 45 ft long. Then a linear arrangement of a wave source and 3 accelerometers were placed perpendicular to the trench at about the mid-point of the trench. The relative position of the source, the accelerometers, and the crack are shown in Figure 10.

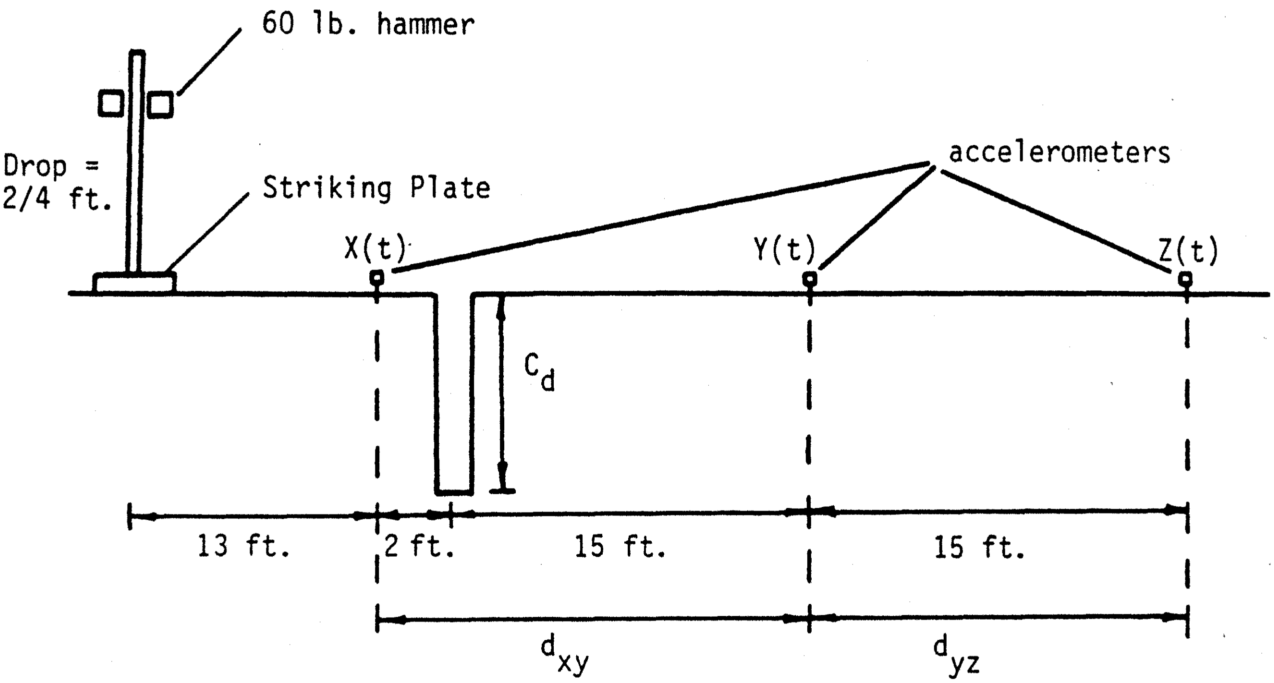
The accelerometers were tied to 6 in. long stakes that had been driven into the ground. The stakes were located inside 3 in. deep holes excavated on the ground surface. The assemblage in each hole was covered with a rigid board to protect the accelerometer from picking up noise from the wind and to prevent the output from being affected by temperature changes.

The test itself consists in dropping a 60 pound weight on the striking plate. Upon the impact of the weight, a trigger mechanism causes the analog recorder to start recording at the three stations labelled X, Y, and Z in Figure 10. For each trench depth and drop height, the test is repeated five times and all five recordings are stored in analog form.

The test was first performed before digging the trench and then the test was repeated for trench depths of 1.75 ft, 3.0 ft, and 4.0 ft. The drop height used in the tests was 4 ft. This drop was selected to obtain what seemed to be a noticeable signal/noise ratio in the farthest accelerometer labelled Z in Figure 10.

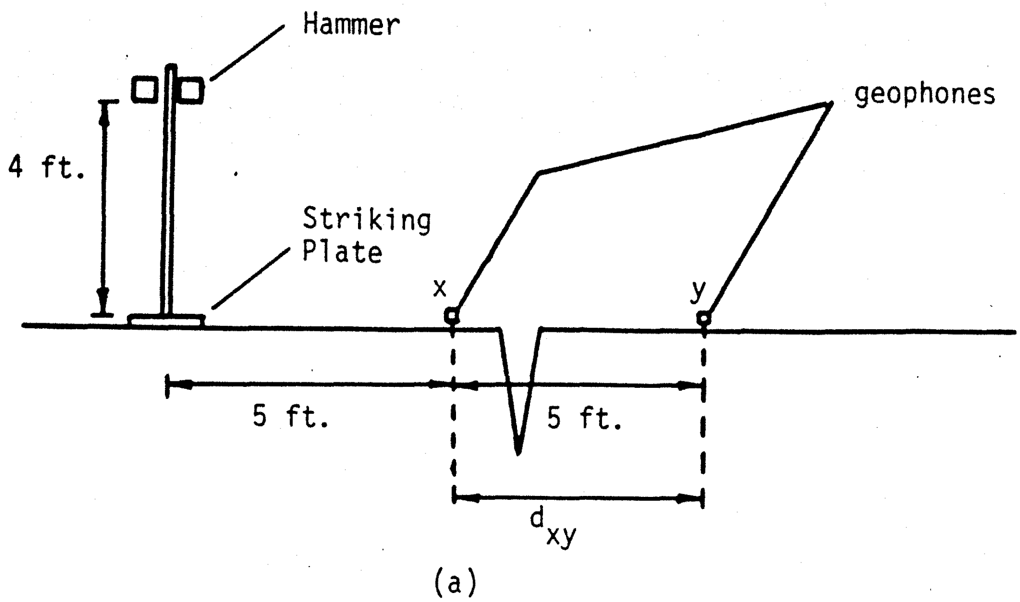
The test of the second type was performed using geophones that are more sensitive than the accelerometers. Also to alleviate the problem of weak signals at the farthest recording station, the geophones were placed at only 5 ft intervals.

The recording equipment used in these tests was a Nicolet oscilloscope that stored the recorded signal in digital form. This model can only record two channels simultaneously. This forced the need to perform each test in two steps. The first step consisted of recording in stations X and Y only as shown in Figure 11a. In the



d_{xy} = horizontal distance between stations X and Y
d_{yz} = horizontal distance between stations Y and Z
C_d = trench depth

FIGURE 10. Field Test Setup for the Type One Test



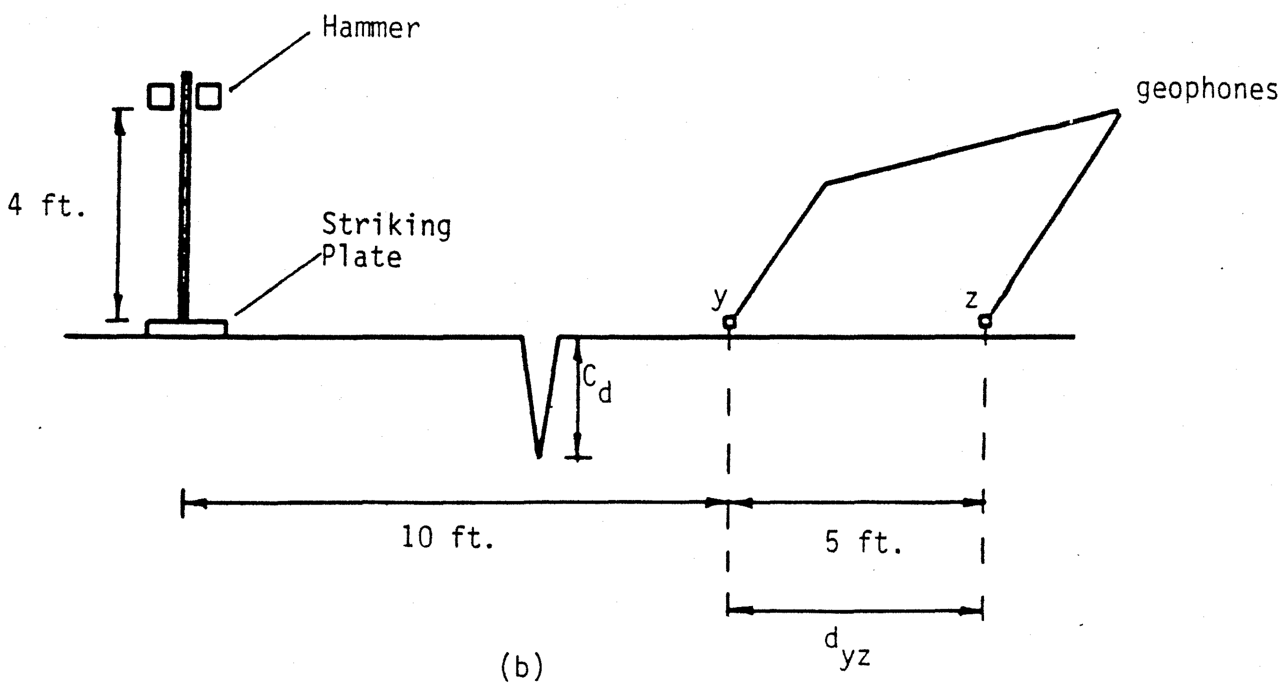


FIGURE 11. Field Test Setup for Test of the Second Type

second step, the geophone at the station x was re-positioned at the location of station Z and a new series of five blows was recorded for stations Y and Z shown in Figure 11b.

A more detailed description of the equipment and layout used in the field tests is presented in Appendix A.

Analysis of Field Data

The field data obtained in the first type of test was digitized at intervals of 1 millisecond. The field data obtained in the second type of test had been digitized at the time of recording the signal at intervals of 0.05 msec. The total interval extended over 0.256 seconds in the first type of test and over 0.1024 seconds in the second type of test. Typical waveforms registered by all three geophones are included in Figure 12.

For each trench depth or for each case of crack investigated, the test was repeated five times, and each time recorded at all three stations X, Y, and Z. These tests were repeated for identical drop heights of the hammer. After the signals were digitized, the five tests were averaged in an attempt to reduce the random noise. The waveforms shown in Figure 12 are the average of five determinations.

The rest of the analysis was then performed on the average signal. In broad terms, this consisted of processing the signal with a Fast Fourier algorithm to obtain the amplitude spectrum. This spectrum for the three stations was then used to obtain several other spectral measures. The most important one was the phase spectrum.

The phase spectrum is the phase angle lag that each frequency component exhibits between the two stations being analyzed. This phase angle allows a computation of the time that the particular frequency component has taken to travel between the two stations being considered. Since the distance between stations is known, the apparent velocity of each frequency component can be readily calculated. The difference in apparent velocity between stations X-Y and the velocity between stations Y-Z is used to calculate the crack depth.

A more complete description of all of the manipulation of the field data to determine the crack depth is presented in Appendix B. All of this analysis is performed automatically using a computer program named "CROSSP." The Fortran listing of "CROSSP" is included in Appendix C.

The only input necessary for the program "CROSSP" is the time series of the digitized output of the sensor in millivolts versus time recorded by each of the three stations. An example of this input is presented in Appendix J. This is the input data for the field test performed and this data can be used to check the program "CROSSP" in trial runs.

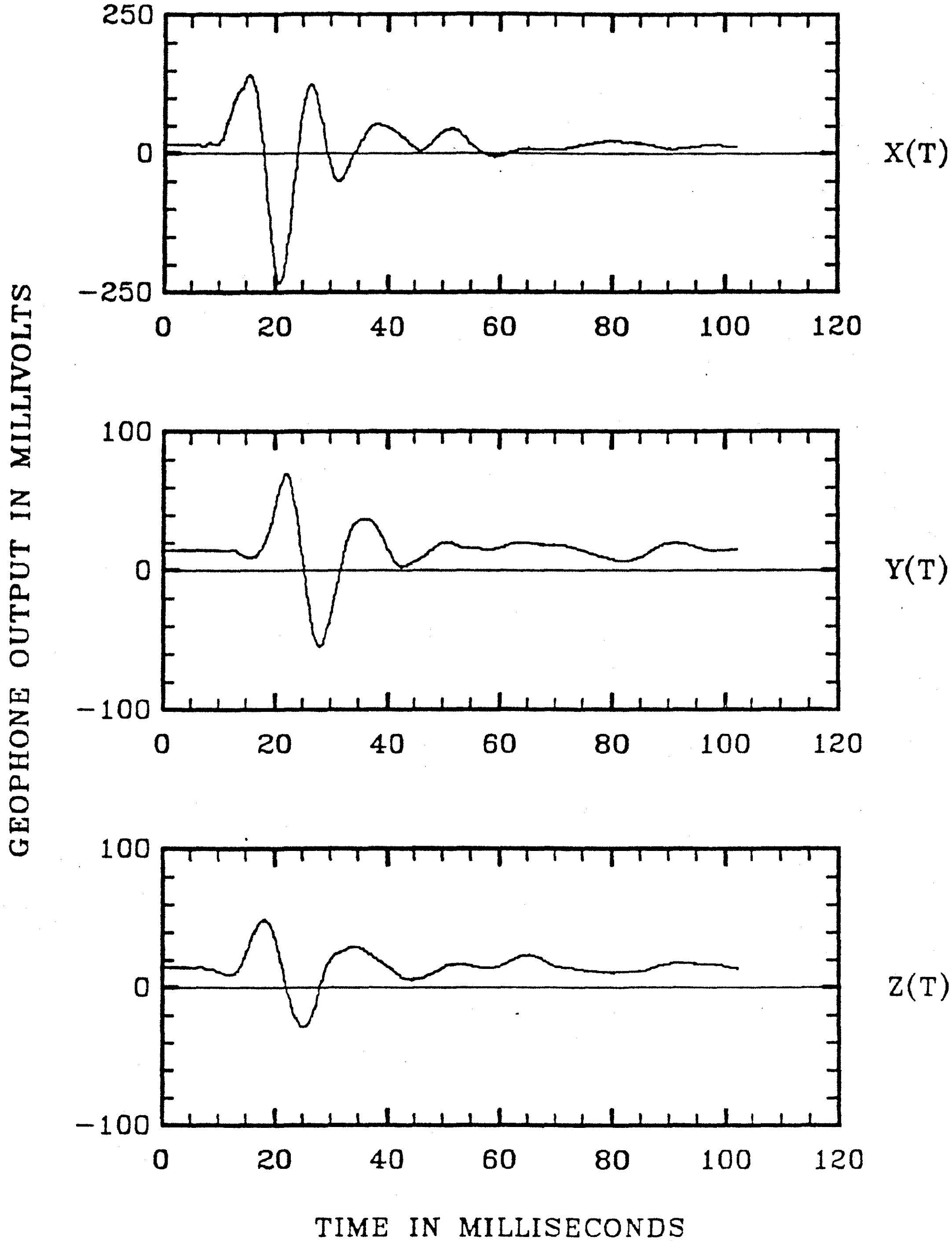


FIGURE 12. Typical Average Signals Picked up by the Geophones

In short, the test consists of recording the signal received at the three stations after striking the source plate. The signal recorded in each geophone is digitized. This digitized signal is the average of five tests, and this is used as the input for program "CROSSP" which after the run prints the calculated crack depth. This program also prints out all the intermediate results of different spectral measures.

DISCUSSION OF RESULTS

The first type of test was performed before the trench was excavated and then successively for progressively deeper trenches of 1.75 ft, 3.0 ft, and 4.0 ft depth. The complete set of spectral measures calculated in each case is presented in Appendices D through G, respectively.

The trench depths calculated from the wave measurements with the proposed procedure are presented in Table 1.

TABLE 1. Comparison of Actual & Measured Trench Depth for Type One Tests

Actual Depth ft	Calculated Depth ft
0.00	12.11
1.75	2.55
3.00	2.76
4.00	4.07

The spectral measures obtained in two Type Two Tests performed, are presented in Appendices H and I. The crack depths calculated with the proposed procedure are presented in Table 2, where they are compared with crack depths that were measured by inserting a measuring tape as far as possible into the crack.

TABLE 2. Comparison of Crack Depth Calculated and Measured on Naturally Occurring Shrinkage Cracks

Measured Depth ft	Calculated Depth ft
1.25	2.35
2.66	2.48

The calculated depths for the two types of test show a remarkable agreement when the depth of the crack is larger than about 2 ft. However, the results are clearly out-of-line for the smaller crack depths. The reason for this anomalous behavior is not clear.

There is apparent reason to explain the large crack depth indicated by the survey implemented before the trench was excavated. The most plausible explanation is that when unwinding the phase spectrum ϕ_{xy}, some extra inappropriate "cut" slipped in, causing an overestimation of the total phase lag. Equally probable could be that some "cut" that should have been included in the phase spectrum ϕ_{yz} was overlooked. The result in both cases is a larger difference in phase lag for the two intervals, which would be responsible for the difference in travel times, and consequently of the excessive crack depth calculated.

The overestimation indicated by comparing the results of the survey for the Type Two Tests in the case of a crack of 1.25 ft depth is probably due to some other reason. It is entirely possible that the measurement of 1.25 ft is the value that is in error. In fact, both shrinkage cracks surveyed were found in close proximity and they appeared to have similar crack widths on the ground surface. It seems reasonable to expect that both cracks would have had similar depths, which is precisely what the wave survey indicates.

CONCLUSIONS AND RECOMMENDATIONS

The results shown in the previous section illustrate a remarkable agreement between the trench or crack depth measured and those that were calculated from the survey of surface waves. This alternative consisted in using surface waves that are assumed to travel down and up the crack walls. The crack depth was calculated based on the increased travel time caused by the presence of the crack.

A second alternative mentioned earlier consisted in trying to correlate the shape of the amplitude ratio spectrum of two geophones one on each side of the crack with the depth of the trench or crack. The results obtained in this survey indicate that the shape of this curve is quite insensitive to the crack depth. Based on this observation, this alternative was discarded. The results of this study indicate that the alternative that measures the increased travel time offers the only possibilities.

Nevertheless, it is believed that the testing procedure used in these field tests must be modified to improve the accuracy of the results and to have a more efficient operation.

The initial aspect to improve the accuracy is to make sure that phase angle "cuts" do not slip by when unwinding the phase spectrum. To reduce this risk, the best solution is to increase the resolution of the phase spectrum; that is, to decrease the spacing between the discrete points that define this spectrum. This means increasing the total length of the period of measurement for a fixed sampling rate. Keeping in mind that the signal caused by the drop hammer dies off at about 100 milliseconds (see Figure 12), the increase of the time length of the period of measurement implies the need for a longer lasting surface wave source.

The best source to use in future trials would have to be determined by trial and error. However, to extend the signal duration, it seems that it would be necessary to switch to surface vibrators. Presumably, the best choice would be a vibrator that the frequency could be changed from say 20 Hz to 1kHz, and that total vibrating mass could also be altered.

Another consideration to include in the selection of the frequencies and masses of the vibrator is to require that the induced signal is rich in harmonics of small wavelength. This is because the test procedure assumes that the surface wave harmonic travels down and up the crack faces. But a surface wave will behave in this manner if the wavelength of the surface wave is small relative to the depth crack. At this time, it is not clear how small this ratio should be. The wavelengths excited in the trial field tests are listed in Table 3 along with the corresponding depths of the trench or crack.

TABLE 3. Wavelengths of Surface Waves Excited in the Field Tests

	Measured Depth (ft)	Calculated Depth (ft)	Wavelength Range (ft)
Trench	1.75	2.55	8.0/15.0
	3.00	2.76	7.0/10.0
	4.00	4.07	6.0/10.0
Crack	1.25	2.35	2.0/10.0
	2.48	2.42	1.3/ 4.0

The measurements shown in Table 3 indicate that the measurements appear to agree much closer when the wave lengths of the surface waves excited are of the size or smaller than the trench or the crack depth. The two cases that stand out are for a trench of 4.0 ft depth and the case of a crack of 2.48 ft depth.

These results are good evidence of the need to excite surface waves of short wavelengths. Furthermore, it is worth noticing that the smaller spacing used in the Type Two Tests have resulted in much smaller wavelengths of the harmonics that build up the surface wave signal. Therefore, in future trials, the spacing of the geophones should be kept at 5 ft or less to favor the presence of harmonics of short wave length.

In summary, the conclusion of this study is that the proposed procedure seems to work, but some improvements of the set up can probably improve dramatically the performance and the accuracy of the procedure. To improve the performance of the test, it is believed that it will be convenient to switch the seismic source to a surface vibrator, whose vibrating mass and frequency of vibration can be easily altered to sweep the range of frequencies desired. The selection of this vibrator should be based on some more field trials, where the wavelength of the induced surface wave harmonics should be carefully monitored. For a more efficient implementation, it would be convenient to have a recorder that could handle all the recording channels at once and with a somewhat larger storage capacity, so the tests could be implemented in a single step.

REFERENCES

1. Stevens, J. B., Brotcke, P. N., Bogard, D., and Matlock, H., "Observation of an Expansive Clay Under Controlled Conditions," Research Report 118-9F, Center for Highway Research, The University of Texas at Austin, 1976.

2. Miller, G. F. and Pursey, H., "On the Partition of Energy Between Elastic Waves in a Semi-infinite Solid," Proceedings, Royal Society, London Series A, Vol. 233, 1955, pp. 55-59.

3. Woods, R. D., "Screening of Surface Waves in Soils," Journal, Soil Mechanics and Foundation Division, ASCE, No. SM4, July 1968, pp. 951-979.

4. Soriano, A., Krizek, R. J., and Franklin, A. G., "Seismic Refraction Surveying in Soils With Variable Propagation Velocity," Soils and Foundations, Vol. 17, No. 2, June 1977.

5. Mooney, H. M., "Seismic Shear Waves in Engineering," Journal, Soil Mechanics and Foundation Division, ASCE, Vol. 100, No. GT8, August 1974, pp. 905-923.

6. Silk, M. G., "Sizing Crack-like Defects by Ultrasonic Means," Non-Destructive Testing International.

7. Maxwell, A. A. and Fry, Z. B., "A Procedure for Determining Elastic Moduli of In-situ Soils by Dynamic Techniques," International Symposium on Wave Propagation and Dynamic Properties of the Earth Materials, New Mexico, August 1967.

8. Farnell, G. W., "Types and Properties of Surface Waves," in Acoustic Surface Waves, Ed. A. A. Oliner, Springer-Verlag, New York, 1978.

9. Victorov, I. A., "The Effects of Surface Defects on the Propagation of Rayleigh Waves," Soviet Physics, Doklady 3, 1958, pp. 304-306.

10. Bremaecker, J. Cl. De, "Transmission and Reflection of Rayleigh Waves at Corners," Geophysics, Vol. XXIII, No. 2, April 1958, pp. 253-266.

11. Slobodnik, A. J., "Materials and Their Influence on Performance," in Acoustic Surface Waves, Ed. A. A. Oliner, Springer-Verlag, New York, 1978.

12. Ballard, R. F. and McLean, F. G., "Seismic Field Methods for In-situ Moduli," Proceedings, Conference on In-situ Measurements of Soil Properties, Geotechnical Engineering Division, ASCE, Raleigh, N.C., 1975.

13. Heisey, J. S., Stokoe II, K. H., and Meyer, A. H., "Moduli of Pavement Systems from Spectral Analysis of Surface Waves," Transportation Research Record 852.

APPENDIX A

Equipment and Layout Used in the Field Tests

The configuration of the total system in the Type One test is shown in Figure A1. A 60 lb. hammer with a switch trigger (Figures A2 and A3) is dropped from a 4 ft. height on the striking plate in order to generate strong enough surface waves to pass through the earth surface and trench. Before proceeding with the test, it is important to make sure the accelerometers are attached to the ground firmly in such a way that sensor motion is in tune with ground motion. This was accomplished by attaching the accelerometer to a small steel stake, 1/8 in. x 2 in. x 8 in., see Figure A5. The stake was hammered into the ground to accomplish this requirement. The accelerometers, manufactured by Sundstrand Data, are sensitive to temperature variations (on the order of 1.26 mg/^{o}C) and wind disturbances, the stakes were placed inside small holes and then covered, as indicated in Figure A1, to keep these disturbances small relative to the signal. The accelerometers full scale range is from $\pm$ 1 g to $\pm$ 20 g, while the real field measurement's range of sensor output is from $\pm$ 0.1 mg to 100 mg. This imposed the need to use an amplifier. This amplifier combined with a transmitter is shown in Figure A4. The preamplified signal, approximately 10 times larger, is transmitted to the base station through an antenna. The signal received then goes through a discriminator to separate four different signals (i.e., the trigger and 3 stations) and record them on a strip chart and magnetic tapes.

The analog data cannot be used in the computer program without being discretized. An A/D converter (analog to digital), model 6800 digitizer, made by Southwest Technical, was used in this processing stage and the digital output data was stored on a magnetic tape for further use. There are two points worthwhile noticing: (1) In the analog data after 256 msec of recording time, the background noise appears to dominate in such a way that it is appropriate to cut off the signal at this point; (2) The minimum sampling interval is limited by the A/D converter characters. In this equipment, the minimum sampling interval is 1.0 msec which means the device can read 1000 data points per sec. Finally, to complete the data gathering and processing cycle, all the digital information was sent through a "modem" (modulator demodulator) to the Texas A&M University computer center, where the computer analysis of the field data was completed.

In conducting Type Two tests, several changes were made in the set up in order to facilitate the gathering and processing of information. These modifications are illustrated in Figure A6. As it has been mentioned previously, some of the components in the set up remained the same. However, the sensors and the equipment used to record the data and later to process it are entirely different. For these tests, geophones manufactured by Mark Products, Inc., model L1-A were used (Figure A7). Again, in these tests it was important to accomplish coupling of the sensors with the ground and this was done in a similar manner as in tests of Type One.

Once the hammer has been dropped, the signals received from the geophone are recorded on the screen of the Nicolet oscilloscope

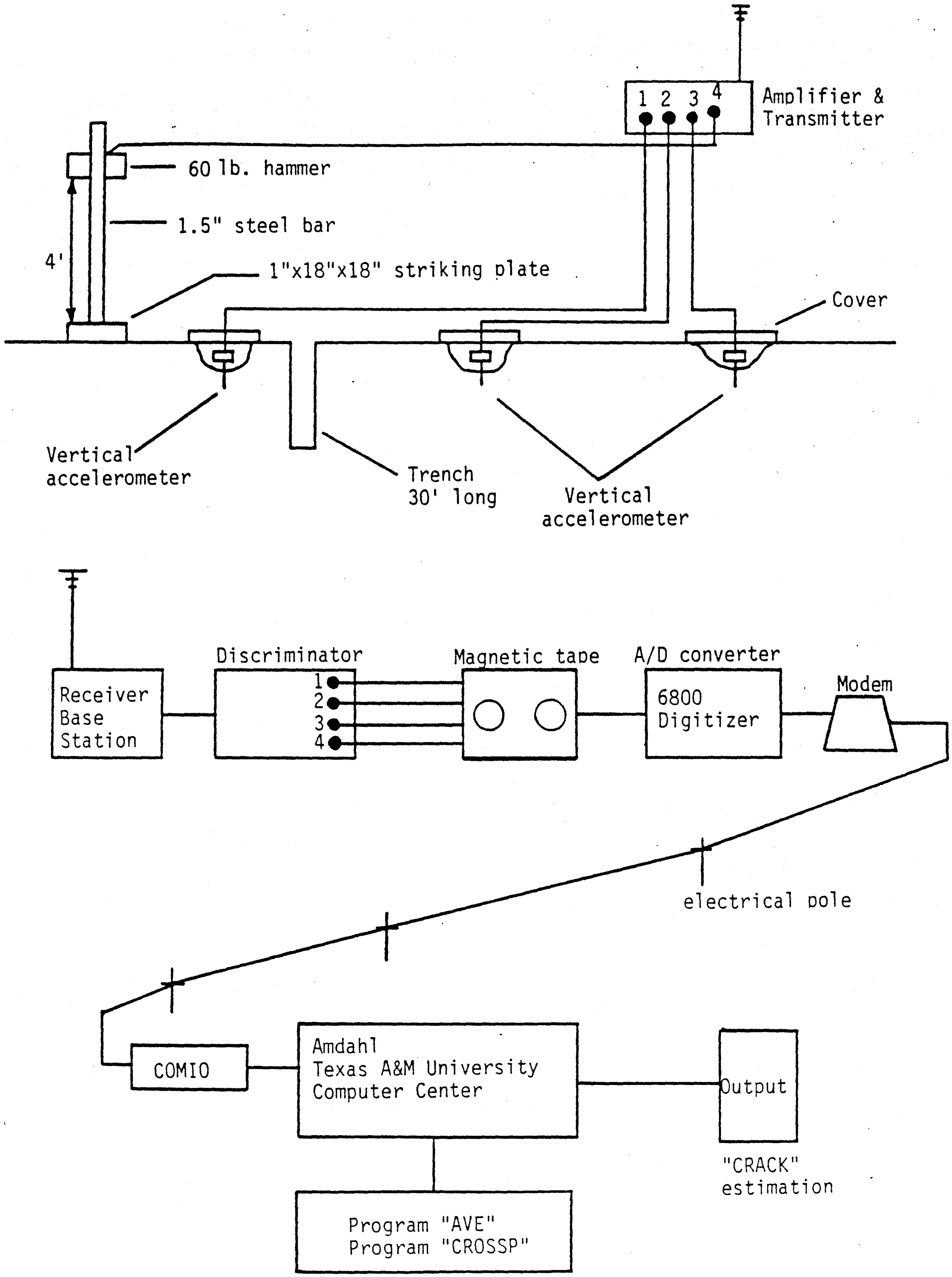


FIGURE A1. Complete Set up for Type One Tests

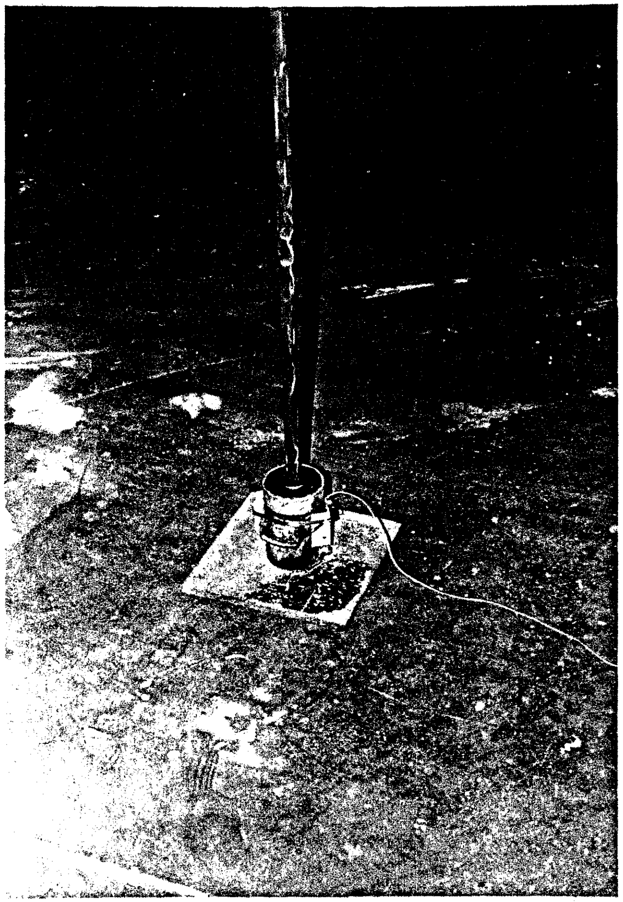


FIGURE A2. Striking Plate and Hammer

FIGURE A3. Hammer and Switch Trigger

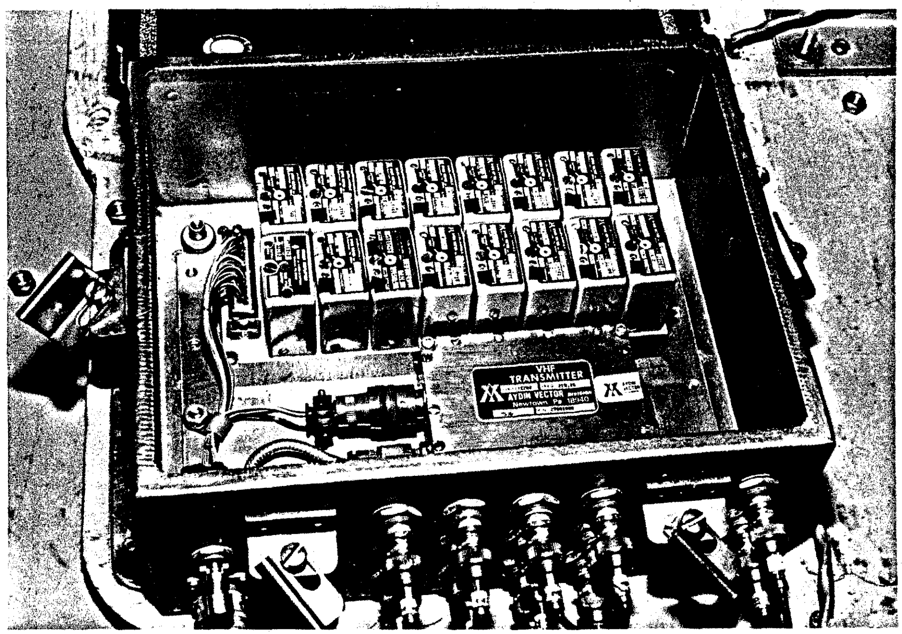


FIGURE A5. Preamplifier and transmitter

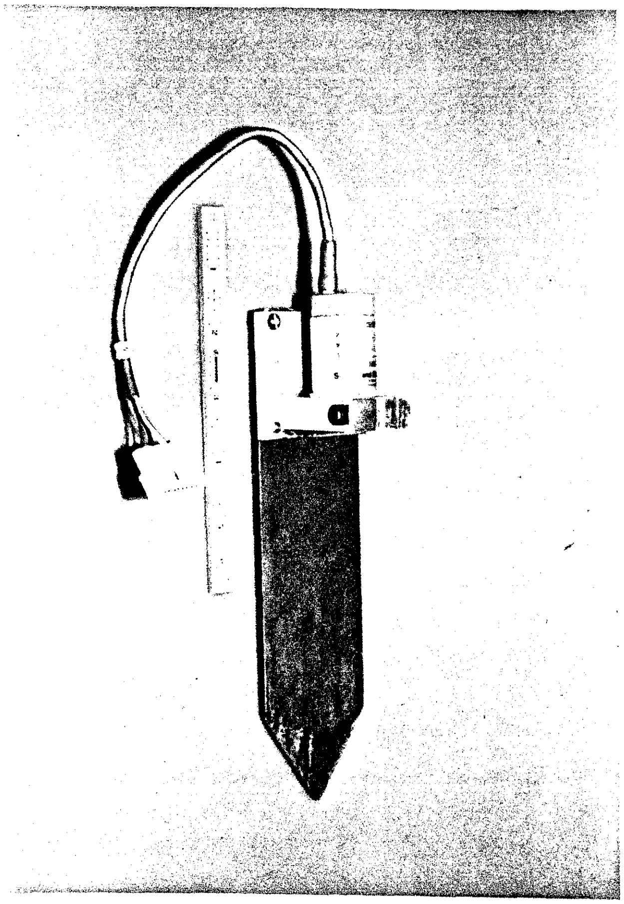


FIGURE A4. Accelerometer and Steel Plate

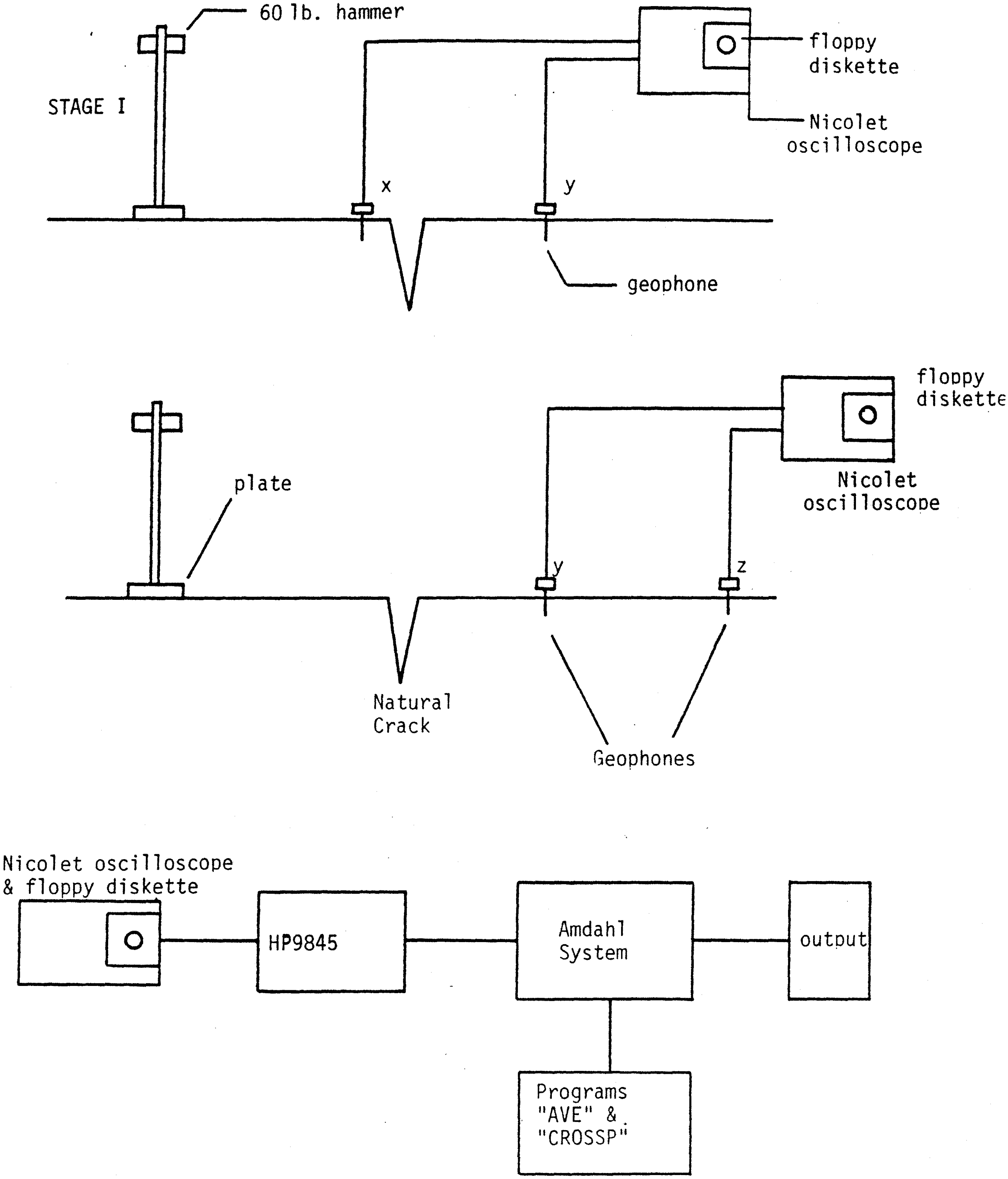


FIGURE A6. Complete Set up for Type Two Tests

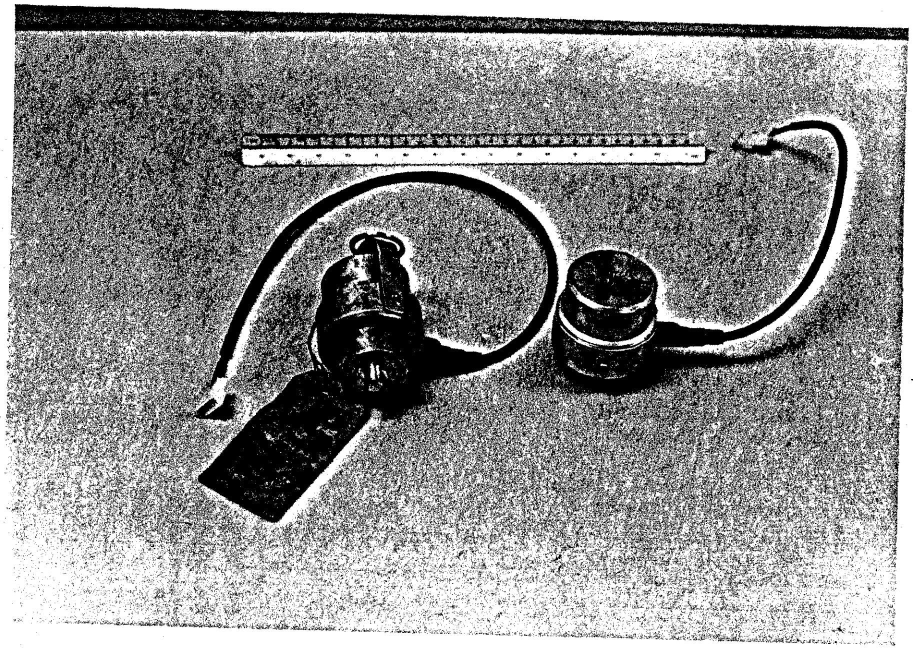


FIGURE A7. Geophones Used in Tests of Category Two, Produced by Mark Products Inc., Model L-1A

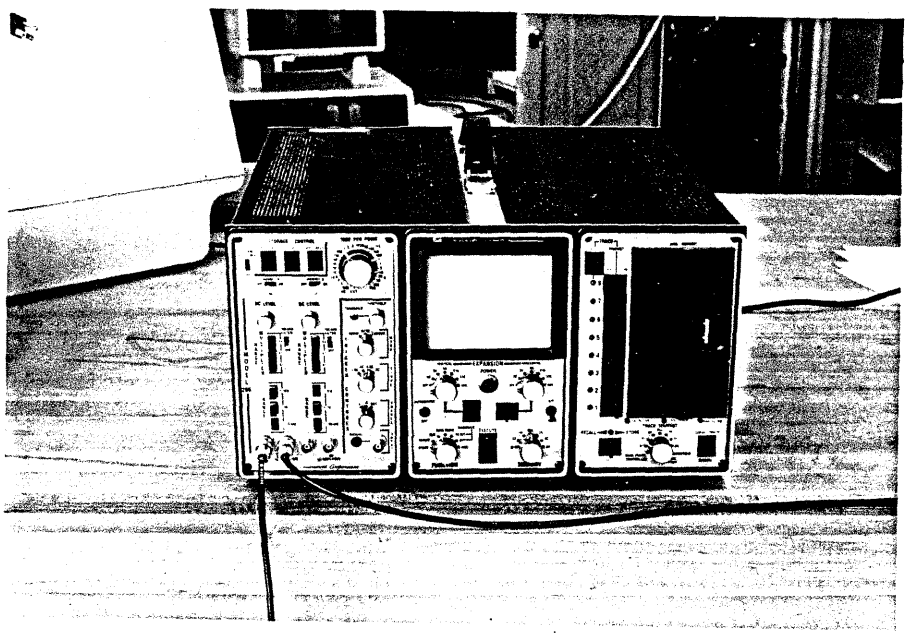


FIGURE A8. Oscilloscope From the Nicolet Instrument Corp., Model 206

(Figure A8). Once it has been determined by the operator whether the waveform is adequate, the signal is stored in a magnetic diskette.

After all the waveform recording is completed, the oscilloscope is hooked to a microcomputer, which in this case was a Hewlett Packard 9845 (Figure A9), that allows the transferring of data to the Texas A&M University AMDAHL system. Once the data are stored in a memory that has already been set upon the AMDAHL system, the programs AVE and CROSSP are used to obtain a final crack estimation output.

FIGURE A9. Hewlett Packard Microcomputer Model 9845, Used to Transfer Data to the Texas A&M University Computer Center

APPENDIX B

Summary Description of the Techniques Used in Developing the Computer Program "CROSSP"

Introduction

This appendix presents a summary of the most relevant concepts that are used in the analysis of the signals recorded at the three stations. It also includes a description of the computer program developed to analyze the data and a description of the most important features of the input/output for this program.

Auto-spectrum, Cross-spectrum, and Other Spectral Measures

The signal that is received by each accelerometer or geophone is made up of a combination of signals of many frequencies, each having their own amplitude. In analyzing this signal, the Fast Fourier Transform algorithm can break it down into its component frequencies. For a general waveform, the Fourier transform is a complex number with a real and an imaginary component.

$$c(x,k) = a(x,k) - i\ b(x,k)$$

where

$c(x,k)$ = the complex number for frequency number k at the station x

$a(x,k)$ = the real component for the frequency number k at the station x

$b(x,k)$ = the imaginery component for the frequency number k at the station x

This complex number can also be defined with the modulus and the phase angle. These two are given by the following relationships:

$$\text{Squared amplitude } (x,k) = a(x,k)^2 + b^2(x,k)$$

$$\text{Phase angle } (x,k) = \text{arc tan } [-\frac{b(x,k)}{a(x,k)}]$$

Another way of obtaining the squared amplitude is by multiplying the complex number, $c(x,k)$, by its conjugate, $c(x,k)$, as shown below.

$$\text{Squared amplitude } (x,k) = c(x,k) * \bar{c}(x,k)$$

$$= [a(x,k) - i\ b(x,k)] * [a(x,k) + i\ b(x,k)]$$

$$= a^2(x,k) + b^2(x,k)$$

The auto-spectrum, $S_{xx}(k)$, is derived from the collection of squared amplitudes, one for each frequency, k, by multiplying each by the time length of the sampling period (NNx t).

$$S_{xx}(k) = NN*\Delta t * c(x,k) * \bar{c}(x,k)$$

where

NN = the number of data points

Δt = the sampling rate

The cross-spectrum, $S_{xy}(k)$, is very closely related to the auto-spectrum. The only exception is that the conjugate of the complex number at station x, $\bar{c}(x,k)$, for each frequency, k, is multiplied by the corresponding complex number at station y, c(y,k) for the same frequency, and again this product is multiplied by the time length of the sampling period.

$$S_{xy}(k) = NN*\Delta t * c(x,k) * \bar{c}(y,k)$$

Because the real and imaginary components at stations x and y are not usually equal, the cross-spectrum has a real and imaginary component itself for each frequency. These components are $P_{xy}(k)$ and $Q_{xy}(k)$, as shown below.

$$S_{xy}(k) = P_{xy}(k) - i\, Q_{xy}(k)$$

Using all of these defined spectra, several other spectral quantities can be defined and calculated. For example, the cross-amplitude spectrum, $\alpha_{xy}(k)$ is given by:

$$\alpha_{xy}(k) = [P_{xy}{}^2(k) + Q_{xy}{}^2(k)]^{1/2}$$

The phase spectrum, $\phi_{xy}(k)$, which is essential to the calculation of crack depths, can also be defined as

$$\phi_{xy}(k) = \text{arc tan}\left[\frac{-Qxy(k)}{P_{xy}(k)}\right]$$

The coherence spectrum, $Co_{xy}(k)$, is the square of the cross-amplitude spectrum $S_{xy}(k)$ divided by the product of the auto-spectrum can be obtained from:

$$Co_{xy}(k) = \frac{\alpha^2{}_{xy}(k)}{S_{xx}(k) \quad S_{yy}(k)}$$

The coherence spectrum is used to determine the frequencies where noise begins to dominate. The signal can be used only in the frequency range in which the coherence is at or near 1.0.

The "amplitude ratio" spectrum, $R_{xy}(k)$ is actually the ratio of the squares of the amplitude ratios at stations x and y and it is a measure of the total energy that has been transmitted from one station to the next. It is given by:

$$R_{xy}(k) = \frac{S_{yy}(k)}{S_{xx}(k)}$$

All of these spectral measures are calculated by the computer program developed to analyze the field data.

Main Features of the Computer Program CROSSP

The flow chart of the program CROSSP is shown in Figure B1. The calculation of spectral measures shown in the flow chart were explained in the previous section with only one exception having to do with the "smoothing" of the data. The degree of smoothing that is desired is specified in the input by a designated "degree-of-freedom." If the degree-of-freedom is set to 1, as was the case with the present field test data, no smoothing is done. The provision for smoothing is made in case the signal that is to be analyzed is very jagged and erratic in which case the specified degree-of-freedom would be an odd number normally between 3 and 11.

The program CROSSP prints all the intermediate results such as the spectral measures. The program labels the stations as 1, 2, 3, and these correspond to:

station x(t) = station 1

station y(t) = station 2

station z(t) = station 3

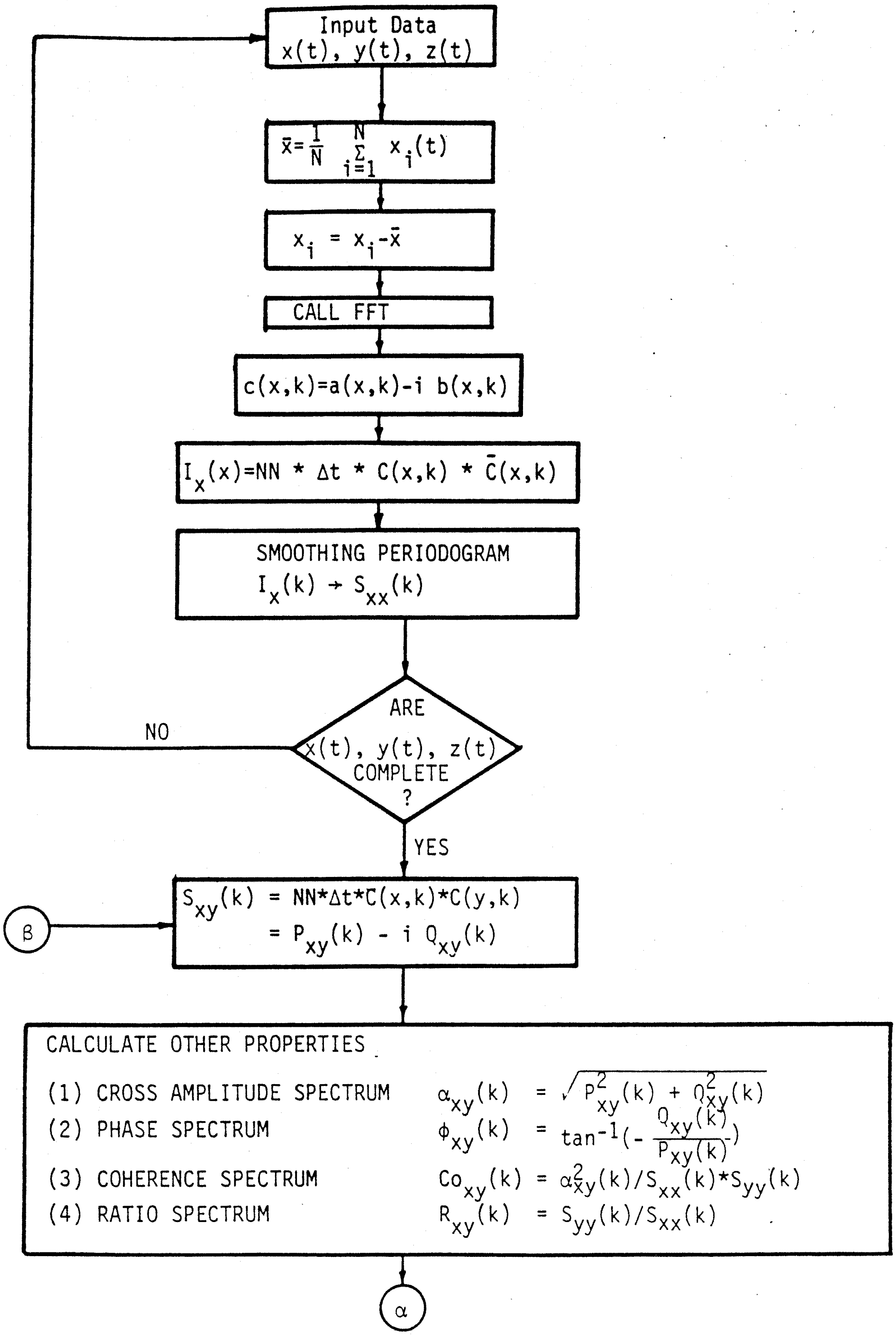


Figure B1. Flow Chart of Program CROSSP

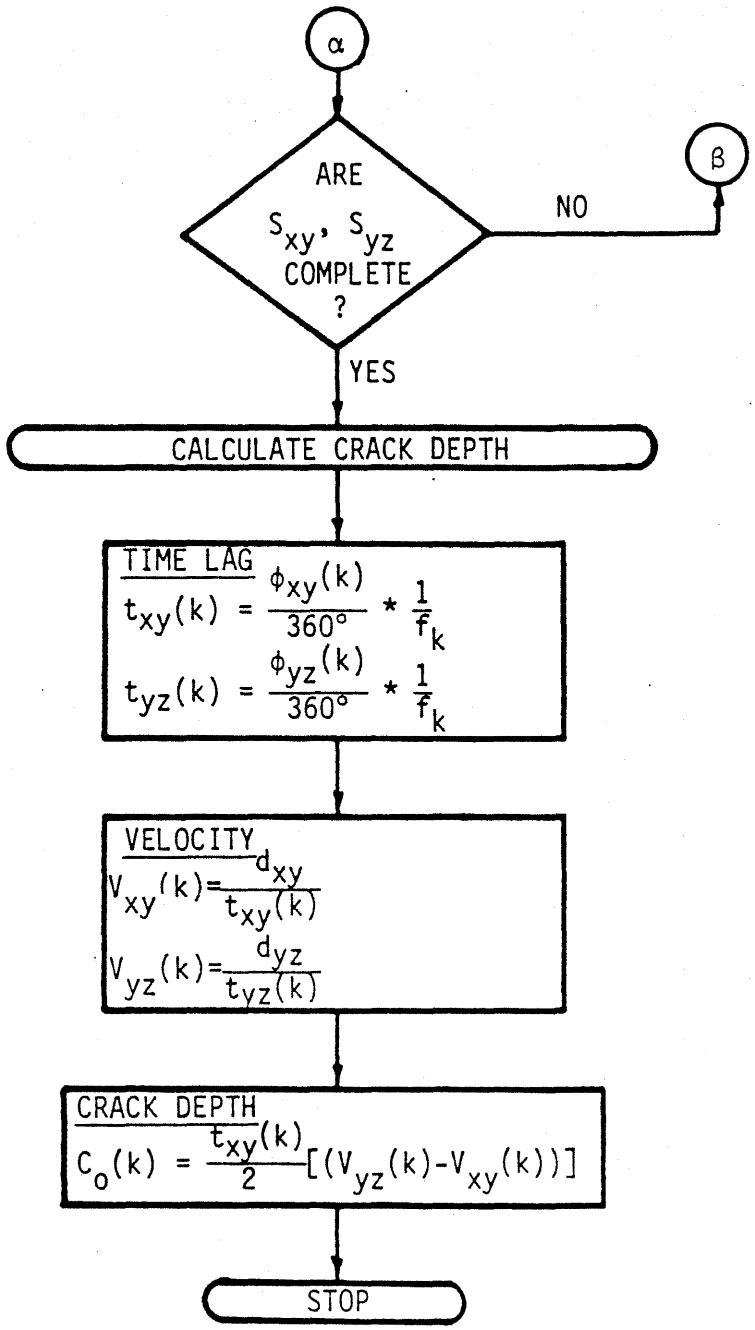


Figure B1. Flow Chart of Program CROSSP (Cont'd)

The program calculates the cross spectra for each combination of two of the three stations, that is, for the combinations:

$x(t)/y(t)$, $x(t)/z(t)$, $y(t)/z(t)$ or

1/2, 1/3, 2/3.

A sample of the output for the combination 1/2 is presented in Table B1. In this table, the meaning of the headings are as follows:

FREQUENCY: Frequency of the component in kHz

PERIOD: Time length of the period of the component in milliseconds

SPECTRUM-1: Auto spectrum of the signal recorded at station 1 [x(t)].

SPECTRUM-2: Auto spectrum of the signal recorded at station 2 [y(t)].

RATIO: Ratio of the amplitude of spectrum-2 over the amplitude of spectrum-1.

PHASE: Phase lag of the component as received in station 2 [y(t)] relative to the same component as received in station 1 [x(t)].

COHERENCY: Coherence spectrum between the signals recorded at stations 1 [x(t)] and 2 [y(t)].

CROSS AMPL: Cross amplitude spectrum between the signals recorded at stations 1 [x(t)] and 2 [y(t)].

GAIN SPEC: Gain spectrum between the components as recorded at station 2 [y(t)] over the same component as recorded at station 1 [x(t)].

The second part of the program consists of calculating the crack depth from the spectral measurements. These calculations are summarized in the continuation of Figure B1. This is accomplished using the Phase spectrum. In broad outlines, this consists of finding the travel time between stations x-y and y-z. The difference in travel time is assumed to be due to the surface wave travelling up and down the vertical faces of the crack.

The first step is to calculate the travel time from the phase spectrum. However, this spectrum has to be appropriately modified before the travel time can be calculated. The phase spectrum is calculated as the inverse function of a tangent (see Figure B1). In reality, the phase lag of the frequency components is a monotonically increasing function; but, when the total phase angle exceeds 360°,

TABLE B1. Cross-Spectra Table as Printed by the Program CROSSP

CROSS SPECTRUM PROPERTIES FOR STATION= 1 AND STATION= 2

FREQUENCY	PERIOD	SPECTRUM-1	SPECTRUM-2	RATIO	PHASE	COHERENCY	CROSS AMPL.	GAIN SPEC.
0.0000	0.0000	0.0027	0.0027	0.0000	0.0000	0.0000	0.0000	0.0000
0.0098	102.4000	2.2706	1.2271	0.5404	-1.7689	1.0000	1.6692	0.7351
0.0195	51.2000	11.2318	4.2777	0.3809	-0.1923	1.0000	6.9315	0.6171
0.0293	34.1333	18.3099	3.3146	0.1810	-33.1080	1.0000	7.7904	0.4255
0.0391	25.6000	13.1006	7.8596	0.5999	-39.6922	1.0000	10.1472	0.7746
0.0488	20.4800	18.2780	7.5624	0.4137	-57.9622	1.0000	11.7570	0.6432
0.0586	17.0667	20.8886	11.5455	0.5527	-48.4527	1.0000	15.5296	0.7434
0.0684	14.6286	26.6874	13.4032	0.5022	-31.6727	1.0000	18.9128	0.7087
0.0781	12.8000	36.0603	9.0589	0.2512	-59.0706	1.0000	18.0739	0.5012
0.0879	11.3778	31.5513	7.6183	0.2415	-86.5082	1.0000	15.5038	0.4914
0.0977	10.2400	23.9418	5.1631	0.2157	-107.8873	1.0000	11.1182	0.4644
0.1074	9.3091	19.0439	3.8139	0.2003	-135.1326	1.0000	8.5224	0.4475
0.1172	8.5333	13.8305	2.7860	0.2014	-178.8678	1.0000	6.2073	0.4488
0.1270	7.8769	8.4015	2.2888	0.2724	152.4977	1.0000	4.3851	0.5219
0.1367	7.3143	4.2265	1.5634	0.3699	134.0260	1.0000	2.5706	0.6082
0.1465	6.8267	2.8429	0.8531	0.3001	136.4668	1.0000	1.5573	0.5478
0.1563	6.4000	1.8869	0.2457	0.1302	133.5795	1.0000	0.6809	0.3609
0.1660	6.0235	1.2409	0.1234	0.0995	30.8936	1.0000	0.3913	0.3154
0.1758	5.6889	1.6833	0.3336	0.1982	29.3272	1.0000	0.7494	0.4452
0.1855	5.3895	1.7621	0.3542	0.2010	67.7965	1.0000	0.7900	0.4483
0.1953	5.1200	1.8360	0.2126	0.1158	90.7923	1.0000	0.6248	0.3403
0.2051	4.8762	1.3434	0.0622	0.0463	140.6332	1.0000	0.2890	0.2151
0.2148	4.6545	0.6652	0.1177	0.1770	-160.7647	1.0000	0.2799	0.4207
0.2246	4.4522	0.5512	0.2043	0.3707	-137.9363	1.0000	0.3356	0.6089
0.2344	4.2667	0.6036	0.2310	0.3828	-135.2995	1.0000	0.3734	0.6187
0.2441	4.0960	0.4929	0.1710	0.3470	-153.0414	1.0000	0.2904	0.5891
0.2539	3.9385	0.3197	0.1688	0.5280	-150.9451	1.0000	0.2323	0.7266
0.2637	3.7926	0.2857	0.0956	0.3345	-45.2801	1.0000	0.1652	0.5784
0.2734	3.6571	0.6213	0.0690	0.1111	41.3519	1.0000	0.2071	0.3333
0.2832	3.5310	0.5743	0.1054	0.1835	43.8390	1.0000	0.2460	0.4283
0.2930	3.4133	0.4399	0.1289	0.2930	40.1270	1.0000	0.2381	0.5413
0.3027	3.3032	0.3097	0.0944	0.3049	39.4602	1.0000	0.1710	0.5522
0.3125	3.2000	0.3191	0.0580	0.1818	3.8945	1.0000	0.1360	0.4263
0.3223	3.1030	0.2945	0.0944	0.3205	-48.3727	1.0000	0.1668	0.5662
0.3320	3.0118	0.2197	0.0896	0.4079	-74.9249	1.0000	0.1403	0.6387

the angle is always calculated to be an angle smaller than 360^{o}. Therefore, it is necessary to "unwind" the phase spectrum and attempt to construct the true time phase spectrum. The process of "unwinding" the spectrum is illustrated in Figure B2.

The Phase spectrum angles calculated by the computer and shown in Table 2 only include values between -180^{o} and $+180^{o}$. This is not the true lag, however. Everytime that there is a sharp drop in the graph of phase angle versus frequency, that means the <u>calculated</u> angle has switched from $+180^{o}$ to -180^{o}. The normal plot of phase angle versus frequency as produced by the computer analysis is shown in Figure B2. Each phase angle drop with increasing frequency in the graph is a candidate location for a "cut," meaning only that the calculated angle changes from $+180^{o}$ to -180^{o} and starts over. The actual accumulation of phase angle is also shown in Figure B2. This graph is achieved simply by adding each segment of the graph to the previous. To perform the unwinding of the phase spectrum with the computer, it is necessary to set some rules for determining when a "cut" has been encountered. The two rules that were used in this study are as follows:

1. The phase angle at M (see Figure B2) must be positive and the phase angle at N must be negative.

2. The difference (M-N) must be greater than [360-(M-N)].

If both of these conditions are satisfied, the computer program assumes that there is a "cut" between M and N. If the difference (M-N) is regarded as the "internal" range as illustrated in Figure B2, and the difference [360-(M-N)] the "external" range as illustrated in Figure B2, the second rule is seen as imposing the condition that the internal range is larger than the external range.

Once the phase angle graph has been put into the accumulative form, the data may be used to compute crack depth. The time lag corresponding to the phase angle lag $\phi_{xy}(k)$ is obtained from:

$$t_{xy}(k) = \frac{\phi_{xy}(k)}{360^{o}} \quad \frac{1}{f_k}$$

where

t_{xy} = the travel time for the k-th frequency from station x to station y,

f_k = the frequency of the k-th component, in Hertz

The apparent velocity of each component between these two stations ($v_{xy}(k)$) can be found from:

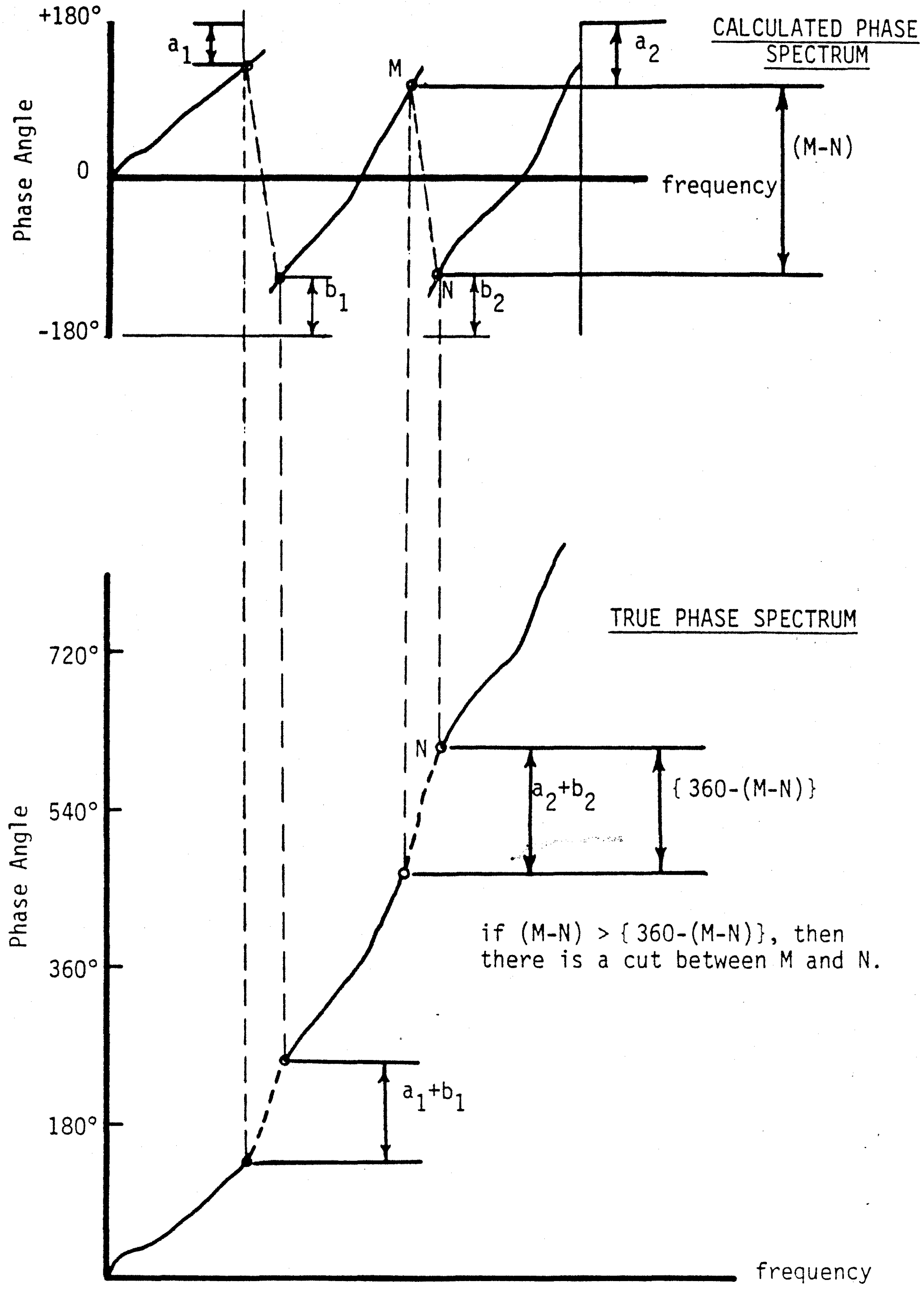


Figure B2. Calculated and True Phase Spectrum

$$v_{xy}(k) = \frac{d_{xy}}{t_{xy}(k)}$$

where

d_{xy} = the distance between the two stations X and Y

In a similar way, the apparent wave velocity between Stations Y and Z is

$$v_{yz}(k) = \frac{d_{yz}}{t_{yz}(k)}$$

where

d_{yz} = the distance between Stations Y and Z.

If there is a difference between the two computed apparent velocities, the program assumes that there is a crack between the two stations where the slower velocity was found. In the field test, a trench was dug (or the shrinkage crack was located) between Stations X and Y so that the apparent velocity $v_{xy}(k)$ was always smaller. The trench or crack depth was calculated for each frequency from the following relationship:

$$C_d(k) = \frac{t_{xy}}{2} [v_{yz}(k) - v_{xy}(k)]$$

The program calculates the crack depth C_d for each frequency component and determines the average and the standard deviations of all crack depths calculated. Then the program discards all the calculated crack depths that differ from the mean by more than half of a standard deviation. Then it recalculates the mean of the depths not rejected; this last mean is the value reported by the computer program CROSSP as the measured depth of the crack.

An example of the output of the computer program "CROSSP" is presented in Table B2. The headings included in this table have the following meanings:

FREQ (HZ) — Frequency in hertz of the corresponding component

PHASE XY — Phase spectrum "ϕ_{xy}"

PHASE YZ — Phase spectrum "ϕ_{yz}"

TIME XY — Travel time of the corresponding frequency component from x to y

TIME YZ — Travel time of the corresponding frequency component from y to z

VELOCITY XY — Velocity of travel of the corresponding frequency component from x to y

VELOCITY YZ — Velocity of travel of the corresponding frequency component from y to z

DEPTH CRACK — Calculated crack depth for the corresponding frequency component

WAVENGTH YZ — Wave length of the corresponding frequency component. This was calculated in the travel from y to z as the ratio of the velocity V_{yz} over the corresponding frequency "FREQ"

DEPTH — Wave length divided by two (WL/2) or divided by three (WL/3)

```
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
A                                           A
A       THE OUTPUT FOR CRACK ESTIMATION     A
A                                           A
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
```

TABLE B2. Output of the Crack Depth Estimation

FREQ (HZ)	PHASE XY	PHASE YZ	TIME XY	TIME YZ	VELOCITY XY	VELOCITY YZ	DEPTH CRACK	WAVENGTH YZ	DEPTH WL/2	DEPTH WL/3
9.766	-1.769	29.817	-0.001	0.008	-9937.098	589.538	-2.648	60.369	30.184	20.123
19.531	359.808	65.488	0.051	0.009	97.708	536.832	11.236	27.486	13.743	9.162
29.297	326.892	-14.025	0.031	-0.001	161.321	-3760.104	-60.771	-128.345	-64.172	-42.782
39.063	320.308	92.722	0.023	0.007	219.516	758.315	6.136	19.413	9.706	6.471
48.828	302.038	128.434	0.017	0.007	290.992	684.327	3.379	14.015	7.008	4.672
58.594	311.547	152.016	0.015	0.007	338.532	693.802	2.624	11.841	5.920	3.947
68.359	328.327	176.986	0.013	0.007	374.769	695.234	2.138	10.170	5.085	3.390
78.125	300.929	177.112	0.011	0.006	467.302	793.987	1.748	10.163	5.082	3.388
87.891	273.492	197.855	0.009	0.006	578.457	799.593	0.956	9.098	4.549	3.033
97.656	252.113	225.260	0.007	0.006	697.233	780.349	0.298	7.991	3.995	2.664
107.422	224.867	245.767	0.006	0.006	859.882	786.760	-0.213	7.324	3.662	2.441
117.188	181.132	298.990	0.004	0.007	1164.551	705.501	-0.985	6.020	3.010	2.007
126.953	512.498	293.418	0.011	0.006	445.886	778.805	1.867	6.135	3.067	2.045
136.719	494.026	463.595	0.010	0.009	498.140	530.838	0.164	3.883	1.941	1.294
146.484	496.467	525.216	0.009	0.010	531.097	502.026	-0.137	3.427	1.714	1.142
156.250	493.579	509.376	0.009	0.009	569.817	552.146	-0.078	3.534	1.767	1.178
166.016	390.894	664.903	0.007	0.011	764.474	449.431	-1.030	2.707	1.354	0.902
175.781	389.327	726.529	0.006	0.011	812.701	435.504	-1.160	2.478	1.239	0.826
185.547	427.796	733.263	0.006	0.011	780.709	455.477	-1.041	2.455	1.227	0.818
195.313	450.792	772.748	0.006	0.011	779.877	454.951	-1.042	2.329	1.165	0.776
205.078	500.633	731.881	0.007	0.010	737.348	504.373	-0.790	2.459	1.230	0.820
214.844	559.235	716.291	0.007	0.009	691.514	539.891	-0.548	2.513	1.256	0.838
224.609	582.063	733.800	0.007	0.009	694.593	550.964	-0.517	2.453	1.226	0.818
234.375	584.700	778.042	0.007	0.009	721.524	542.227	-0.621	2.314	1.157	0.771
244.141	566.958	848.246	0.006	0.010	775.107	518.073	-0.829	2.122	1.061	0.707
253.906	569.055	895.375	0.006	0.010	803.141	510.435	-0.911	2.010	1.005	0.670

AVERAGE CRACK DEPTH = 3.0544
STANDARD DEVIATION = 3.1786
UPPER BOUND VALUE = 4.6437
LOWER BOUND VALUE = 1.4651

THE FINAL DEPTH = 2.3510

APPENDIX C

FORTRAN LISTING OF THE PROGRAM CROSSP

```
//CROSSP JOB (B962,006C,S05,003,BC),'HUANG'
//*TAMU PRTY=3
//*FORMAT PR,DDNAME=,DEST=XEROX,
//*COPIES=1,JDE=JFMT1,FORMS=1101
//STEP EXEC WATFIV,REGION=640K
//FT01F001 DD DSN=USR.B962.BC.AVE16M1,DISP=SHR
//FT02F001 DD DSN=USR.B962.BC.AVE16M2,DISP=SHR
//FT03F001 DD DSN=USR.B962.BC.AVE16M3,DISP=SHR
//FT10F001 DD DSN=USR.B962.BC.SAS260UT,DISP=SHR
//FT11F001 DD DSN=USR.B962.BC.SAS270UT,DISP=SHR
//FT12F001 DD DSN=USR.B962.BC.SAS280UT,DISP=SHR
//SYSIN DD DATA
//$OPTIONS
        DIMENSION LL(2,3)
      DIMENSION HEADIN(20),DAT(1000),ADAT(1000),SPEC(1000)
      DIMENSION T(1000),PER(1000),QPER(1000),COSPEC(1000),QUSPEC(1000)
      DIMENSION SPECT(3,1000),X(3,1000),Y(3,1000),RATIO(1000),HEAD(3,1)
      DIMENSION CROSAM(1000),PHASE(1000),COHER(1000),GAIN(1000)
      COMMON FREQ(1000),RATIXY(1000),PHXY(1000),COHEXY(1000)
      COMMON RATIYZ(1000),PHYZ(1000),COHEYZ(1000)
      COMPLEX DFT(1000)
C
C     THE FOLLOWING INPUT DATA "HEADIN" COULD BE A TITLE OF EXPERIMENT
C
      READ(5,999) HEADIN
  999 FORMAT(20A4)
      WRITE(6,1000)HEADIN
C
C      THIS IS THE ONLY INPUT DATA FOR THIS PROGRAM
C
C      NN = THE NUMBER OF DATA POINTS FOR EACH DATA SET. IT IS
C           CALCULATED BY FORMULA,
C
C           NN = ( RECORD LENGTH )/( SAMPLING INTERVAL )
C
C       N = THE POWER OF 2 WHICH IS ASSOCIATED WITH NN BY THE
C           FORMULA,
C           2**N = NN
C
C    NDOF = THE DEGREE OF FREEDOM, EITHER 1 OR 3.
C
C     KEY = 0 OR 1, IF 0 THEN DO AUTO-SPECTRA ONLY,
C                   WHILE 1 DO CROSS-SPECTRA ALSO.
C
C      DT = THE SAMPLING INTERVAL, UNIT IN MSEC.
C
C     DXY = THE DISTANCE BETWEEN X AND Y.
C
C     DYZ = THE DISTANCE BETWEEN Y AAND Z.
C
C      THIS  READ FORMAT IS (4I5,3F5.2)
C
      READ(5,1001) NN,N,NFRQ,KEY,DT,DXY,DYZ
      WRITE(6,1004) NN,N,NFRQ,DT,KEY
      WRITE(6,1005) DXY,DYZ
 1001 FORMAT(4I5,3F5.2)
 1000 FORMAT(1H1,20A4)
 1004 FORMAT(//,15X,'NO. OF DATA FOR EACH SET = ',I5,/
     1           15X,'THE POWER OF 2           = ',I5,/
     2           15X,'DEGREE OF FREEDOM        = ',I5,/
```

```
     3            15X,'SAMPLING INTERVAL          = ',F5.2,'  MSEC',/
     4 15X,'KEY=0, DO AUTO-SPECTRA ONLY',/15X,'KEY=1, DO CROSS-SPECTRA
     5 ',/        15X,'IN THIS CASE KEY            = ',I5)
 1005  FORMAT(15X,'DISTANCE BETWEEN X & Y    = ',F5.2,'  FT',/
     1            15X,'DISTANCE BETWEEN Y & Z    = ',F5.2,'  FT',/)
C
C     READ IN THREE STATIONS'S DISCRITED DATA
C
      DO 50 K=1,3
      READ(K,1003) HEAD(K,1)
 1003 FORMAT(20A4)
      MM=NN+1
      READ(K,1002)(DAT(I-1),I=2,MM)
 1002 FORMAT(8X,F7.1)
      TOTAL =0.
      DO 10 I=1,NN
      TOTAL=TOTAL + DAT(I)
   10 CONTINUE
      WMEAN=TOTAL/NN
      DO 20 I=1,NN
      ADAT(I)=DAT(I)-WMEAN
   20 CONTINUE
      DO 30 I=1,NN
   30 DFT(I)=CMPLX(ADAT(I),0.)
      CALL FFTSUB(DFT,N,NN)
      NHAF=NN/2 + 1
      DO 40 I=1,NHAF
      PER(I)=(DFT(I)*CONJG(DFT(I)))*4.
   40 CONTINUE
      IF(NFRQ.NE.1) GO TO 100
      CALL NSMOTH(PER,SPEC,FREQ,T,DT,NN,NHAF,LAS)
      GO TO 110
  100 CALL SMOOTH(PER,SPEC,FREQ,T,NFRQ,DT,NN,NHAF,LAS)
  110 DO 42 L=1,LAS
      SPECT(K,L)=SQRT(SPEC(L))
   42 CONTINUE
C
C     DETERMINE TO DO AUTO-SPECTRA OR CROSS-SPECTRA
C
      IF(KEY.NE.0) GO TO 43
      WRITE(6,18)K
      WRITE(6,19)(FREQ(I),T(I),SPEC(I),I=1,LAS)
   18 FORMAT(1H ,//,19X,'WAVE SPECTRAL ESTIMATEFOR STATION=',I5,//,16X,
     $'FREQUENCY',10X,'PERIOD',10X,'SPECTRAL DENSITY',/)
   19 FORMAT(17X,F7.4,8X,F8.2,12X,F10.3)
      STOP
   43 DO 45 I=1,NN
      X(K,I)=REAL(DFT(I))
      Y(K,I)=AIMAG(DFT(I))
   45 CONTINUE
   50 CONTINUE
      DO 60 K=1,2
      J=K
   61 J=J+1
      DO 70 I=1,NN
      PER(I)=(X(K,I)*X(J,I) + Y(K,I)*Y(J,I))*4.
      QPER(I)=(X(K,I)*Y(J,I)- X(J,I)*Y(K,I))*4.
   70 CONTINUE
      IF(NFRQ.NE.1) GO TO 200
      CALL NSMOTH(PER,COSPEC,FREQ,T,DT,NN,NHAF,LAS)
      CALL NSMOTH(QPER,QUSPEC,FREQ,T,DT,NN,NHAF,LAS)
```

```
      MM=0
      CROSAM(1)=0.
      PHASE(1)=0.
      COHER(1)=0.
      GAIN(1) =0.
      RATIO(1)=0.
      GO TO 210
  200 CALL SMOOTH(PER,COSPEC,FREQ,T,NFRQ,DT,NN,NHAF,LAS)
      CALL SMOOTH(QPER,QUSPEC,FREQ,T,NFRQ,DT,NN,NHAF,LAS)
      MM=0
      CROSAM(1)=0.
      PHASE(1)=0.
      COHER(1)=0.
      GAIN(1) =0.
      RATIO(1)=0.
  210 DO 80 L=2,LAS
      CROSAM(L)=SQRT(SQRT(COSPEC(L)**2 + QUSPEC(L)**2))
   90   IF(CROSAM(L).LT.0.1) CROSAM(L)=0.
      PHASE(L) =ATAN2(-QUSPEC(L),COSPEC(L))*180./3.14159
      COHER(L) = SQRT(CROSAM(L)**2/(SPECT(K,L)*SPECT(J,L)))
      GAIN(L)  = CROSAM(L)/SPECT(K,L)
      RATIO(L)=SPECT(J,L)/SPECT(K,L)
C
C
C    DETERMINE THE NUMBER OF USEFUL FREQUENCY
C
C
      IF((COHER(L-1).NE.0).OR.(COHER(L).NE.0)) MM=0
      MM=MM+1
      IF(MM-4)80,82,82
   82 LL(K,J)=L-4
      GO TO 83
   80 CONTINUE
   83 WRITE(6,28) K,J
      LLL=LL(K,J)
      IF(K.EQ.1.AND.J.EQ.2) GO TO 150
      GO TO 160
  150 DO 151 I=1,LLL
      RATIXY(I) = RATIO(I)
      PHXY(I)   = PHASE(I)
      COHEXY(I) = COHER(I)
  151 CONTINUE
  160 IF(K.EQ.2.AND.J.EQ.3) GO TO 170
      GO TO 180
  170 DO 171 I=1,LLL
      RATIYZ(I) = RATIO(I)
      PHYZ(I)   = PHASE(I)
      COHEYZ(I) = COHER(I)
  171 CONTINUE
C
C     WRITE DOWN THE CROSS-SPECTRA INFORAMTION FOR PLOTTING
C
  180 WRITE(6,29)(FREQ(I),T(I),SPECT(K,I),SPECT(J,I),RATIO(I),
     1          PHASE(I),COHER(I),CROSAM(I),GAIN(I),I=1,LLL)
   28 FORMAT(1H1,//,25X,'CROSS SPECTRUM PROPERTIES FOR STATION=',I2,
     1        ' AND STATION=',I2,//5X,'FREQUENCY',5X,'PERIOD',3X,
     2        'SPECTRUM-1',2X,'SPECTRUM-2',4X,' RATIO',6X,
     3        'PHASE',4X,'COHERENCY',3X,'CROSS AMPL.',3X,
     4        'GAIN SPEC.'/)
   29 FORMAT(9F12.4)
C
```

```
C      WRITE DOWN THE CROSS-SPECTRA INFORMATION IN THE DATA FILES
C
        IF(K.EQ.1.AND.J.EQ.2) WRITE(10,39)(FREQ(I),T(I),SPECT(K,I),
     1 SPECT(J,I),RATIO(I),PHASE(I),COHER(I),CROSAM(I),GAIN(I),
     2 I=1,LLL)
        IF(K.EQ.1.AND.J.EQ.3) WRITE(11,39)(FREQ(I),T(I),SPECT(K,I),
     1 SPECT(J,I),RATIO(I),PHASE(I),COHER(I),CROSAM(I),GAIN(I),
     2 I=1,LLL)
        IF(K.EQ.2.AND.J.EQ.3) WRITE(12,39)(FREQ(I),T(I),SPECT(K,I),
     1 SPECT(J,I),RATIO(I),PHASE(I),COHER(I),CROSAM(I),GAIN(I),
     2 I=1,LLL)
   39 FORMAT(9F10.3)
      IF(J.LT.3) GO TO 61
   60 CONTINUE
      LAST = MINO(LL(1,2),LL(2,3))
      CALL CRACK(LAST,DXY,DYZ)
      STOP
      END
C
C
      SUBROUTINE SMOOTH(PER,SPEC,FREQ,T,NFRQ,DT,NN,NHAF,LAS)
      DIMENSION PER(1000),SPEC(1000),FREQ(1000),T(1000),SF(1000)
C
C     SMOOTH PERIODOGRAM - CALCULATE SPECTRUM
C
      M = (NFRQ-1)/2
      NHM = NHAF/M
      SF(1)=0.
      DO 54 J = 1,M
      SF(1) = SF(1)+PER(J)
   54 CONTINUE
      SPEC(1) = SF(1)/M
      K = 1
      L = NFRQ
      IF(NHM.EQ.NHAF) NHM=NHM-1
      DO 55 I = 2,NHM
      SF(I)=0.
      DO 56 J = K,L
      SF(I) = SF(I)+PER(J)
   56 CONTINUE
      SPEC(I) = SF(I)/NFRQ
      K = K+M
      L = L+M
   55 CONTINUE
      NLAS = NHAF-M+1
      LAS = NHM+1
      SF(LAS)=0.
      DO 57 I = NLAS,NHAF
      SF(LAS) = SF(LAS)+PER(I)
   57 CONTINUE
      SPEC(LAS) = SF(LAS)/M
C
C     CALCULATE FREQUENCIES AT WHICH SPEC(I) IS CALCULATED
C
      FREQ(1) = 0.
      T(1) = 0.
      DO 58 I = 2,NHM
      FREQ(I) =(I-1.)*M/(NN*DT)
      T(I) = 1./FREQ(I)
   58 CONTINUE
      FREQ(LAS) = 1./(2*DT)
```

```
      T(LAS) = 1./FREQ(LAS)
      RETURN
      END
C
C     SUBROUTINE TO CALCULATE DFT'S
C
      SUBROUTINE FFTSUB(DFT,N,NN)
      COMPLEX DFT(NN),U,W,T
C     DIVIDE ALL ELEMENTS BY NN
      DO 1 J = 1,NN
    1 DFT(J) = DFT(J)/NN
C     REORDER SEQUENCE ACCORDING TO FFT ALGORITHM
      NND2 = NN/2
      NNM1 = NN-1
      J=1
      DO 4 L = 1,NNM1
      IF(L.GE.J)GO TO 2
      T = DFT(J)
      DFT(J) = DFT(L)
      DFT(L) =  T
    2 K = NND2
    3 IF(K.GE.J)GO TO 4
      J = J-K
      K = K/2
      GO TO 3
    4 J = J+K
C     CALCULATE DFT'S
      PI = 3.14159265
      DO 6 M = 1,N
      U = (1.0,0.0)
      ME = 2**M
      K = ME/2
      W = CMPLX(COS(PI/K),-SIN(PI/K))
      DO 6 J = 1,K
      DO 5 L = J,NN,ME
      LPK = L+K
      T = DFT(LPK)*U
      DFT(LPK) = DFT(L)-T
    5 DFT(L) = DFT(L)+T
    6 U = U*W
      RETURN
      END
C
C      SUBROUTINE WHICH DOES NOT DO SMOOTHING PROCESS
C
      SUBROUTINE NSMOTH(PER,SPEC,FREQ,T,DT,NN,NHAF,LAS)
       DIMENSION PER(1000),SPEC(1000),FREQ(1000),T(1000)
      LAS=NHAF
      DO 10 I=1,LAS
   10 SPEC(I)=PER(I)
      LAS1=LAS-1
      FREQ(1)=0.
      T(1)=0.
      DO 20 I=2,LAS1
      FREQ(I)=(I-1)/(NN*DT)
      T(I)=1./FREQ(I)
   20 CONTINUE
      FREQ(LAS)=1./(2.*DT)
      T(LAS)=1./FREQ(LAS)
      RETURN
      END
```

```
C
C
C
      SUBROUTINE CRACK(LAS,DXY,DYZ)
      REAL LOB
      COMMON FREQ(1000),RATIXY(1000),PHXY(1000),COHEXY(1000)
      COMMON RATIYZ(1000),PHYZ(1000),COHEYZ(1000)
      DIMENSION DEPTH(256),A(100),B(100)
      DIMENSION N1(20),N2(20)
      WRITE(6,330)
      WRITE(6,331)
  330 FORMAT(1H1,'AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA',/
     *1X,'A',44X,'A'/1X,'A',8X,'THE OUTPUT FOR CRACK ESTIMATION',5X,'A'/
     * 1X,'A',44X,'A',/'AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA')
  331 FORMAT(  //,5X,'FREQ',7X,'PHASE',5X,'PHASE',4X,'TIME',6X,'TIME',
     1        8X,'VELOCITY',9X,'DEPTH',3X,'WAVENGTH',8X,'DEPTH',
     2        /5X,'(HZ)',7X,'XY',8X,'YZ',8X,'XY',8X,'YZ',8X,'XY',
     3        8X,'YZ',7X,'CRACK',6X,'YZ',6X,'WL/2',6X,'WL/3',/)
C
C     DETERMINE THE CUTTING PLACES
C
      L1=0
      L2=0
      IF((PHXY(2).LT.O.).AND.(COHEXY(2).NE.O.)) GO TO 501
      GO TO 500
  501 L1=L1 + 1
      N1(L1)=2
  500 IF((PHYZ(2).LT.O.).AND.(COHEYZ(2).NE.O.)) GO TO 511
      GO TO 510
  511 L2=L2 + 1
      N2(L2)=2
  510 DO 600 I=3,LAS
      IF(((PHXY(I-1).GT.O.).AND.(PHXY(I).LT.O.)).AND.((
     *      PHXY(I-1)-PHXY(I)).GE.180.)) GO TO 520
      GO TO 530
  520 L1=L1+1
      N1(L1)=I-1
  530 IF(((PHYZ(I-1).GT.O.).AND.(PHYZ(I).LT.O.)).AND.((PHYZ(I-1)
     *     -PHYZ(I)).GE.180.)) GO TO 540
      GO TO 600
  540 L2=L2+1
      N2(L2)=I-1
  600 CONTINUE
      L1=L1+1
      L2=L2+1
      N1(L1)=LAS
      N2(L2)=LAS
C
C      ACCUMULATE THE PHASE SPECTRA
C
      L1=1
      PHADXY=0.
      L2=1
      PHAYZ=0.
      RL1=1
      RL2=1
      DO 350 I=2,LAS
      IF(I.GT.N1(L1)) GO TO 319
      PHADXY=360.*(RL1-1.) + PHXY(I)
      GO TO 310
  319 L1=L1+1
```

```
          PHADXY=360.0*RL1 + PHXY(I)
          RL1=RL1 + 1
      310 CONTINUE
          IF(I.GT.N2(L2)) GO TO 329
          PHAYZ=360.*(RL2-1.) + PHYZ(I)
          GO TO 320
      329 L2=L2+1
          PHAYZ=360.0*RL2 + PHYZ(I)
          RL2=RL2 + 1
      320 CONTINUE
C
C         CALCULATE TIME LAGS AND WAVE VELOCITIES
C
          FREQ(I)=FREQ(I)*1000.
          TXY=PHADXY/360./FREQ(I)
          VXY=DXY/TXY
          WLXY=VXY/FREQ(I)
C
          TYZ=PHAYZ/360./FREQ(I)
          VYZ=DYZ/TYZ
          WLYZ=VYZ/FREQ(I)
C
          DEPTH(I)=(VYZ-VXY)/2.*TXY
          DL2 = WLYZ/2.
          DL3 = WLYZ/3.
          WRITE(6,340) FREQ(I),PHADXY,PHAYZ,TXY,TYZ,VXY,VYZ,DEPTH(I),
         1               WLYZ,DL2,DL3
      350 CONTINUE
      340 FORMAT(11F10.3)
C
C
C         CALCULATE THE CRACK DEPTH
C
C
          K=0
          TDEP=0.
          SDEP=0.
          DO 400 I=2,LAS
          IF((DEPTH(I).LT.0.).OR.(RATIXY(I).GE.1.).OR.(RATIYZ(I).GE.1.)
         *    .OR.(COHEXY(I).EQ.0.).OR.(COHEYZ(I).EQ.0.)) GO TO 400
          K=K+1
          A(K)=DEPTH(I)
          TDEP=TDEP + A(K)
          SDEP=SDEP + A(K)**2
      400 CONTINUE
          ADEP = TDEP/K
          SD = SQRT((SDEP - K*ADEP**2)/K)
          UPB  = ADEP + 0.5*SD
          LOB  = ADEP - 0.5*SD
          WRITE(6,410) ADEP,SD,UPB,LOB
      410 FORMAT(///,10X,'AVERAGE CRACK DEPTH = ',F10.4,/,
         *            10X,'STANDARD DEVIATION  = ',F10.4,/,
         *            10X,'UPPER BOUND VALUE   = ',F10.4,/,
         *            10X,'LOWER BOUND VALUE   = ',F10.4)
          N=0
          TA=0
          DO 420 I=1,K
          IF((A(I).GT.UPB).OR.(A(I).LT.LOB)) GO TO 420
          N=N+1
          B(N)=A(I)
          TA=TA+B(N)
```

```
  420 CONTINUE
      AA=TA/N
      WRITE(6,430)AA
  430 FORMAT(//,10X,'THE FINAL DEPTH     = ',F10.4)
      STOP
      END
//$DATA
 THIS PROGRAM DOES CROSS SPECTRUM USING FFT AND AVERAGE SMOOTHING TECQ.
  256     8     1      1 1.0 17.0 15.0
//
```

APPENDIX D

TYPE ONE TEST

RESULTS OF A SURVEY PERFORMED BEFORE THE EXCAVATION OF THE TRENCH

```
THIS PROGRAM DOES CROSS SPECTRUM USING FFT AND AVERAGE SMOOTHING TECQ.

          NO. OF DATA FOR EACH SET =    256
          THE POWER OF 2           =      8
          DEGREE OF FREEDOM        =      1
          SAMPLING INTERVAL        =   1.00  MSEC
          KEY=0, DO AUTO-SPECTRA ONLY
          KEY=1, DO CROSS-SPECTRA
          IN THIS CASE KEY         =      1
          DISTANCE BETWEEN X & Y   =  17.00  FT
          DISTANCE BETWEEN Y & Z   =  15.00  FT
```

CROSS SPECTRUM PROPERTIES FOR STATION= 1 AND STATION= 2

FREQUENCY	PERIOD	SPECTRUM-1	SPECTRUM-2	RATIO	PHASE	COHERENCY	CROSS AMPL.	GAIN SPEC.
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0039	256.0000	0.3061	0.1603	0.5236	62.7098	1.0000	0.2215	0.7236
0.0078	128.0000	0.3912	0.0508	0.1297	-68.4120	1.0000	0.1409	0.3602
0.0117	85.3333	0.5420	0.1913	0.3529	99.8413	1.0000	0.3220	0.5941
0.0156	64.0000	0.7181	0.4105	0.5717	76.1471	1.0000	0.5429	0.7561
0.0195	51.2000	1.1346	0.4303	0.3792	-156.9013	1.0000	0.6987	0.6158
0.0234	42.6667	1.8052	1.0013	0.5546	-121.8710	1.0000	1.3444	0.7447
0.0273	36.5714	3.0902	1.0047	0.3251	-49.0745	1.0000	1.7620	0.5702
0.0313	32.0000	4.1296	1.0503	0.2543	40.0222	1.0000	2.0826	0.5043
0.0352	28.4444	4.4267	1.5856	0.3582	125.2496	1.0000	2.6493	0.5985
0.0391	25.6000	4.6208	2.2749	0.4923	-163.6991	1.0000	3.2422	0.7016
0.0430	23.2727	4.4619	2.1634	0.4849	-106.7333	1.0000	3.1069	0.6963
0.0469	21.3333	3.4241	1.5168	0.4430	-68.2311	1.0000	2.2790	0.6656
0.0508	19.6923	4.4294	0.8109	0.1831	-27.3362	1.0000	1.8952	0.4279
0.0547	18.2857	5.9811	0.4682	0.0783	79.9135	1.0000	1.6734	0.2798
0.0586	17.0667	7.5438	0.8923	0.1183	144.8762	1.0000	2.5945	0.3439
0.0625	16.0000	7.9441	1.0571	0.1331	-172.3125	1.0000	2.8978	0.3648
0.0664	15.0588	9.9188	0.9133	0.0921	-104.1912	1.0000	3.0098	0.3034
0.0703	14.2222	8.8661	0.3961	0.0447	-61.0177	1.0000	1.8740	0.2114
0.0742	13.4737	10.0362	0.3760	0.0375	112.3794	1.0000	1.9425	0.1936
0.0781	12.8000	6.3073	0.5836	0.0925	-120.0494	1.0000	1.9186	0.3042
0.0820	12.1905	6.8440	0.5828	0.0852	-83.8840	1.0000	1.9972	0.2918
0.0859	11.6364	5.4226	0.5233	0.0965	-47.0425	1.0000	1.6845	0.3106
0.0898	11.1304	3.6815	0.2091	0.0568	8.7808	1.0000	0.8774	0.2383
0.0938	10.6667	3.2888	0.0787	0.0239	47.8877	1.0000	0.5089	0.1547
0.0977	10.2400	1.3742	0.2257	0.1643	-55.8564	1.0000	0.5570	0.4053
0.1016	9.8462	2.6634	0.2693	0.1011	29.4834	1.0000	0.8469	0.3180
0.1055	9.4815	4.1713	0.3114	0.0747	76.6211	1.0000	1.1398	0.2732
0.1094	9.1429	6.2711	0.3930	0.0627	126.0686	1.0000	1.5699	0.2503
0.1133	8.8276	10.1805	0.4557	0.0448	161.0112	1.0000	2.1540	0.2116
0.1172	8.5333	11.1325	0.2205	0.0198	-82.3927	1.0000	1.5668	0.1407
0.1211	8.2581	10.9403	0.3279	0.0300	2.0136	1.0000	1.8940	0.1731
0.1250	8.0000	6.4176	0.3218	0.0501	-19.5289	1.0000	1.4371	0.2239
0.1289	7.7576	4.2259	0.4247	0.1005	69.7655	1.0000	1.3397	0.3170
0.1328	7.5294	2.7400	0.2020	0.0737	107.8784	1.0000	0.7440	0.2715
0.1367	7.3143	1.7263	0.1526	0.0884	89.0047	1.0000	0.5132	0.2973
0.1406	7.1111	1.1318	0.1248	0.1103	148.2300	1.0000	0.3758	0.3321
0.1445	6.9189	0.7690	0.0907	0.1179	171.7383	1.0000	0.2641	0.3434
0.1484	6.7368	1.0540	0.0499	0.0473	-135.7814	1.0000	0.2293	0.2175
0.1523	6.5641	0.0360	0.0419	1.1645	-116.3052	0.0000	0.0000	0.0000
0.1563	6.4000	0.3352	0.0283	0.0844	-179.4672	0.0000	0.0000	0.0000
0.1602	6.2439	0.3190	0.2252	0.7060	-120.4794	1.0000	0.2680	0.8402
0.1641	6.0952	0.6306	0.0585	0.0928	-34.7163	1.0000	0.1921	0.3046
0.1680	5.9535	0.6150	0.0147	0.0239	14.7994	0.0000	0.0000	0.0000
0.1719	5.8182	0.6124	0.0243	0.0397	-84.6723	1.0000	0.1221	0.1994
0.1758	5.6889	0.6038	0.0367	0.0607	-51.2138	1.0000	0.1488	0.2465
0.1797	5.5652	0.3327	0.0820	0.2464	-112.9981	1.0000	0.1652	0.4964
0.1836	5.4468	0.2235	0.0805	0.3602	-37.7093	1.0000	0.1341	0.6002
0.1875	5.3333	0.2360	0.0580	0.2456	-106.6632	1.0000	0.1170	0.4956
0.1914	5.2245	0.5802	0.0426	0.0734	41.3374	1.0000	0.1573	0.2710
0.1953	5.1200	0.3442	0.0422	0.1226	79.1880	1.0000	0.1205	0.3501
0.1992	5.0196	0.4469	0.0303	0.0679	66.7568	1.0000	0.1164	0.2605
0.2031	4.9231	0.4584	0.0402	0.0877	-171.8475	1.0000	0.1357	0.2961
0.2070	4.8302	0.2453	0.0212	0.0864	-120.8877	0.0000	0.0000	0.0000

0.2109	4.7407	0.4262	0.0666	0.1564	143.3375	1.0000	0.1685	0.3954
0.2148	4.6545	0.3688	0.0465	0.1261	102.8713	1.0000	0.1310	0.3551
0.2188	4.5714	0.2571	0.0322	0.1251	139.4067	0.0000	0.0000	0.0000
0.2227	4.4912	0.2941	0.0129	0.0439	91.7074	0.0000	0.0000	0.0000
0.2266	4.4138	0.1672	0.0210	0.1258	52.8010	0.0000	0.0000	0.0000
0.2305	4.3390	0.2366	0.0647	0.2736	17.9822	1.0000	0.1238	0.5231
0.2344	4.2667	0.1194	0.0414	0.3467	-75.7932	0.0000	0.0000	0.0000
0.2383	4.1967	0.1216	0.1268	1.0428	146.8086	1.0000	0.1242	1.0212
0.2422	4.1290	0.1943	0.1006	0.5175	101.3129	1.0000	0.1398	0.7194
0.2461	4.0635	0.1624	0.0763	0.4699	98.4696	1.0000	0.1113	0.6855
0.2500	4.0000	0.1110	0.0850	0.7659	113.1317	0.0000	0.0000	0.0000
0.2539	3.9385	0.6842	0.1045	0.1528	153.2178	1.0000	0.2674	0.3909
0.2578	3.8788	0.5886	0.0458	0.0778	81.9278	1.0000	0.1642	0.2789
0.2617	3.8209	0.3605	0.0306	0.0850	80.1284	1.0000	0.1051	0.2915
0.2656	3.7647	0.3348	0.0685	0.2045	120.7637	1.0000	0.1514	0.4522
0.2695	3.7101	0.1474	0.0080	0.0544	-54.3792	0.0000	0.0000	0.0000
0.2734	3.6571	0.1440	0.1135	0.7878	45.7591	1.0000	0.1278	0.8876
0.2773	3.6056	0.2291	0.0808	0.3525	-63.7412	1.0000	0.1360	0.5937
0.2813	3.5556	0.2008	0.0345	0.1716	-81.1849	0.0000	0.0000	0.0000
0.2852	3.5068	0.3678	0.0248	0.0674	-2.4584	0.0000	0.0000	0.0000
0.2891	3.4595	0.2085	0.0650	0.3119	-121.9746	1.0000	0.1164	0.5585
0.2930	3.4133	0.1686	0.0780	0.4626	76.3209	1.0000	0.1147	0.6801

CROSS SPECTRUM PROPERTIES FOR STATION= 1 AND STATION= 3

FREQUENCY	PERIOD	SPECTRUM-1	SPECTRUM-2	RATIO	PHASE	COHERENCY	CROSS AMPL.	GAIN SPEC.
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0039	256.0000	0.3061	0.0358	0.1169	14.4838	1.0000	0.1047	0.3420
0.0078	128.0000	0.3912	0.0894	0.2286	61.5520	1.0000	0.1871	0.4781
0.0117	85.3333	0.5420	0.0957	0.1765	-152.0792	1.0000	0.2277	0.4201
0.0156	64.0000	0.7181	0.3454	0.4810	86.4443	1.0000	0.4980	0.6935
0.0195	51.2000	1.1346	0.1587	0.1399	-47.0471	1.0000	0.4244	0.3740
0.0234	42.6667	1.8052	0.1010	0.0560	48.7316	1.0000	0.4270	0.2365
0.0273	36.5714	3.0902	0.5145	0.1665	-140.0408	1.0000	1.2609	0.4080
0.0313	32.0000	4.1296	0.8542	0.2069	-46.8488	1.0000	1.8782	0.4548
0.0352	28.4444	4.4267	0.6032	0.1363	37.8706	1.0000	1.6341	0.3691
0.0391	25.6000	4.6208	0.1230	0.0266	59.2778	1.0000	0.7540	0.1632
0.0430	23.2727	4.4619	0.0362	0.0081	90.6198	1.0000	0.4017	0.0900
0.0469	21.3333	3.4241	0.3463	0.1011	-134.0817	1.0000	1.0889	0.3180
0.0508	19.6923	4.4294	0.8187	0.1848	-90.7681	1.0000	1.9043	0.4299
0.0547	18.2857	5.9811	0.7792	0.1303	-60.4460	1.0000	2.1588	0.3609
0.0586	17.0667	7.5438	0.3218	0.0427	-65.1546	1.0000	1.5580	0.2065
0.0625	16.0000	7.9441	0.4880	0.0614	-103.7365	1.0000	1.9689	0.2478
0.0664	15.0588	9.9188	0.4674	0.0471	-45.4215	1.0000	2.1532	0.2171
0.0703	14.2222	8.8661	0.2209	0.0249	-53.3879	1.0000	1.3995	0.1578
0.0742	13.4737	10.0362	0.2091	0.0208	-91.8660	1.0000	1.4488	0.1444
0.0781	12.8000	6.3073	0.2842	0.0451	-86.5615	1.0000	1.3389	0.2123
0.0820	12.1905	6.8440	0.6511	0.0951	-53.0062	1.0000	2.1110	0.3084
0.0859	11.6364	5.4226	1.2042	0.2221	-9.7462	1.0000	2.5554	0.4713
0.0898	11.1304	3.6815	1.8572	0.5045	86.7995	1.0000	2.6148	0.7103
0.0938	10.6667	3.2888	1.0633	0.3233	-160.0474	1.0000	1.8700	0.5686
0.0977	10.2400	1.3742	0.4517	0.3287	-59.0664	1.0000	0.7879	0.5734
0.1016	9.8462	2.6634	0.0862	0.0323	28.0465	1.0000	0.4790	0.1799
0.1055	9.4815	4.1713	0.0638	0.0153	93.1972	1.0000	0.5157	0.1236
0.1094	9.1429	6.2711	0.0862	0.0137	-31.7109	1.0000	0.7351	0.1172
0.1133	8.8276	10.1805	0.0415	0.0041	-97.1315	1.0000	0.6502	0.0639
0.1172	8.5333	11.1325	0.1437	0.0129	-1.1878	1.0000	1.2649	0.1136
0.1211	8.2581	10.9403	0.0683	0.0062	-112.6167	1.0000	0.8642	0.0790
0.1250	8.0000	6.4176	0.0896	0.0140	-16.3613	1.0000	0.7583	0.1182
0.1289	7.7576	4.2259	0.0786	0.0186	-48.7947	1.0000	0.5764	0.1364
0.1328	7.5294	2.7400	0.0983	0.0359	-169.7932	1.0000	0.5191	0.1895
0.1367	7.3143	1.7263	0.0873	0.0506	-88.2474	1.0000	0.3882	0.2249
0.1406	7.1111	1.1318	0.0793	0.0700	-72.7222	1.0000	0.2995	0.2646
0.1445	6.9189	0.7690	0.0436	0.0567	-52.3770	1.0000	0.1831	0.2381
0.1484	6.7368	1.0540	0.0178	0.0169	-41.4170	1.0000	0.1372	0.1301
0.1523	6.5641	0.0360	0.0246	0.6841	-142.1968	0.0000	0.0000	0.0000
0.1563	6.4000	0.3352	0.0274	0.0818	-105.4033	0.0000	0.0000	0.0000
0.1602	6.2439	0.3190	0.0876	0.2746	-100.4757	1.0000	0.1671	0.5240
0.1641	6.0952	0.6306	0.0574	0.0911	-38.1831	1.0000	0.1903	0.3018
0.1680	5.9535	0.6150	0.0200	0.0325	52.5138	1.0000	0.1108	0.1802
0.1719	5.8182	0.6124	0.0240	0.0392	-149.1487	1.0000	0.1213	0.1980
0.1758	5.6889	0.6038	0.0265	0.0439	77.8097	1.0000	0.1266	0.2096
0.1797	5.5652	0.3327	0.0284	0.0853	78.0340	0.0000	0.0000	0.0000
0.1836	5.4468	0.2235	0.0315	0.1411	120.9602	0.0000	0.0000	0.0000
0.1875	5.3333	0.2360	0.1560	0.6610	149.4304	1.0000	0.1919	0.8130
0.1914	5.2245	0.5802	0.1734	0.2988	-146.5120	1.0000	0.3172	0.5466
0.1953	5.1200	0.3442	0.0589	0.1711	126.8192	1.0000	0.1424	0.4136
0.1992	5.0196	0.4469	0.0214	0.0478	-9.0221	0.0000	0.0000	0.0000
0.2031	4.9231	0.4584	0.0396	0.0865	70.2258	1.0000	0.1348	0.2940
0.2070	4.8302	0.2453	0.0595	0.2426	-35.0035	1.0000	0.1208	0.4925

0.2109	4.7407	0.4262	0.0381	0.0895	91.0079	1.0000	0.1275	0.2991
0.2148	4.6545	0.3688	0.0494	0.1339	106.1299	1.0000	0.1350	0.3660
0.2188	4.5714	0.2571	0.0618	0.2403	36.0587	1.0000	0.1260	0.4902
0.2227	4.4912	0.2941	0.0167	0.0569	-149.6304	0.0000	0.0000	0.0000
0.2266	4.4138	0.1672	0.1112	0.6647	-168.1301	1.0000	0.1363	0.8153
0.2305	4.3390	0.2366	0.1325	0.5600	-177.5202	1.0000	0.1771	0.7483
0.2344	4.2667	0.1194	0.0566	0.4742	128.0667	0.0000	0.0000	0.0000
0.2383	4.1967	0.1216	0.1356	1.1150	-158.3297	1.0000	0.1284	1.0559
0.2422	4.1290	0.1943	0.1102	0.5669	-97.5549	1.0000	0.1463	0.7529
0.2461	4.0635	0.1624	0.0321	0.1976	178.9232	0.0000	0.0000	0.0000
0.2500	4.0000	0.1110	0.2021	1.8215	142.4958	1.0000	0.1497	1.3496
0.2539	3.9385	0.6842	0.0520	0.0760	-157.0826	1.0000	0.1886	0.2756
0.2578	3.8788	0.5886	0.1349	0.2292	-40.3700	1.0000	0.2818	0.4788
0.2617	3.8209	0.3605	0.0924	0.2562	-110.2673	1.0000	0.1825	0.5061
0.2656	3.7647	0.3348	0.1021	0.3049	-171.5828	1.0000	0.1848	0.5521
0.2695	3.7101	0.1474	0.0820	0.5563	19.5659	1.0000	0.1099	0.7458
0.2734	3.6571	0.1440	0.0781	0.5419	90.5241	1.0000	0.1060	0.7362
0.2773	3.6056	0.2291	0.1088	0.4750	94.9295	1.0000	0.1579	0.6892
0.2813	3.5556	0.2008	0.0356	0.1771	-58.6056	0.0000	0.0000	0.0000
0.2852	3.5068	0.3678	0.0963	0.2617	-75.4458	1.0000	0.1882	0.5116
0.2891	3.4595	0.2085	0.1062	0.5093	85.0527	1.0000	0.1488	0.7136
0.2930	3.4133	0.1686	0.0713	0.4229	-103.7310	1.0000	0.1097	0.6503
0.2969	3.3684	0.2119	0.1616	0.7624	-170.7496	1.0000	0.1850	0.8732
0.3008	3.3247	0.2032	0.0168	0.0826	15.8185	0.0000	0.0000	0.0000
0.3047	3.2821	0.3608	0.0883	0.2446	-111.5189	1.0000	0.1785	0.4946

CROSS SPECTRUM PROPERTIES FOR STATION= 2 AND STATION= 3

FREQUENCY	PERIOD	SPECTRUM-1	SPECTRUM-2	RATIO	PHASE	COHERENCY	CROSS AMPL.	GAIN SPEC.
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0039	256.0000	0.1603	0.0358	0.2233	-48.2260	0.0000	0.0000	0.0000
0.0078	128.0000	0.0508	0.0894	1.7619	129.9639	0.0000	0.0000	0.0000
0.0117	85.3333	0.1913	0.0957	0.5002	108.0796	1.0000	0.1353	0.7072
0.0156	64.0000	0.4105	0.3454	0.8413	10.2972	1.0000	0.3765	0.9172
0.0195	51.2000	0.4303	0.1587	0.3689	109.8542	1.0000	0.2613	0.6074
0.0234	42.6667	1.0013	0.1010	0.1009	170.6027	1.0000	0.3180	0.3176
0.0273	36.5714	1.0047	0.5145	0.5121	-90.9664	1.0000	0.7189	0.7156
0.0313	32.0000	1.0503	0.8542	0.8133	-86.8709	1.0000	0.9472	0.9018
0.0352	28.4444	1.5856	0.6032	0.3804	-87.3789	1.0000	0.9780	0.6168
0.0391	25.6000	2.2749	0.1230	0.0541	-137.0232	1.0000	0.5290	0.2326
0.0430	23.2727	2.1634	0.0362	0.0167	-162.6469	1.0000	0.2797	0.1293
0.0469	21.3333	1.5168	0.3463	0.2283	-65.8506	1.0000	0.7248	0.4778
0.0508	19.6923	0.8109	0.8187	1.0096	-63.4319	1.0000	0.8148	1.0048
0.0547	18.2857	0.4682	0.7792	1.6642	-140.3595	1.0000	0.6040	1.2900
0.0586	17.0667	0.8923	0.3218	0.3606	149.9693	1.0000	0.5358	0.6005
0.0625	16.0000	1.0571	0.4880	0.4616	68.5760	1.0000	0.7182	0.6794
0.0664	15.0588	0.9133	0.4674	0.5118	58.7698	1.0000	0.6534	0.7154
0.0703	14.2222	0.3961	0.2209	0.5577	7.6298	1.0000	0.2958	0.7468
0.0742	13.4737	0.3760	0.2091	0.5562	155.7546	1.0000	0.2804	0.7458
0.0781	12.8000	0.5836	0.2842	0.4870	33.4879	1.0000	0.4073	0.6979
0.0820	12.1905	0.5828	0.6511	1.1172	30.8779	1.0000	0.6160	1.0570
0.0859	11.6364	0.5233	1.2042	2.3015	37.2963	1.0000	0.7938	1.5171
0.0898	11.1304	0.2091	1.8572	8.8815	78.0187	1.0000	0.6232	2.9802
0.0938	10.6667	0.0787	1.0633	13.5022	152.0650	1.0000	0.2894	3.6745
0.0977	10.2400	0.2257	0.4517	2.0012	-3.2100	1.0000	0.3193	1.4146
0.1016	9.8462	0.2693	0.0862	0.3199	-1.4369	1.0000	0.1523	0.5656
0.1055	9.4815	0.3114	0.0638	0.2047	16.5761	1.0000	0.1409	0.4525
0.1094	9.1429	0.3930	0.0862	0.2193	-157.7795	1.0000	0.1840	0.4682
0.1133	8.8276	0.4557	0.0415	0.0911	101.8575	1.0000	0.1376	0.3019
0.1172	8.5333	0.2205	0.1437	0.6517	81.2049	1.0000	0.1780	0.8073
0.1211	8.2581	0.3279	0.0683	0.2082	-114.6303	1.0000	0.1496	0.4563
0.1250	8.0000	0.3218	0.0896	0.2784	3.1676	1.0000	0.1698	0.5276
0.1289	7.7576	0.4247	0.0786	0.1851	-118.5600	1.0000	0.1827	0.4302
0.1328	7.5294	0.2020	0.0983	0.4868	82.3286	1.0000	0.1410	0.6977
0.1367	7.3143	0.1526	0.0873	0.5723	-177.2520	1.0000	0.1154	0.7565

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AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
A                                            A
A       THE OUTPUT FOR CRACK ESTIMATION      A
A                                            A
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
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5 10 16 20 30 36
7 31 35 36

FREQ (HZ)	PHASE XY	PHASE YZ	TIME XY	TIME YZ	VELOCITY XY	VELOCITY YZ	DEPTH CRACK	WAVENGTH YZ	DEPTH WL/2	DEPTH WL/3
3.906	62.710	-48.226	0.045	-0.034	381.220	-437.394	-18.252	-111.973	-55.986	-37.324
7.813	-68.412	129.964	-0.024	0.046	-698.891	324.609	-12.448	41.550	20.775	13.850
11.719	99.841	108.080	0.024	0.026	718.328	585.506	-1.572	49.963	24.982	16.654
15.625	76.147	10.297	0.014	0.002	1255.793	8193.996	46.962	524.416	262.208	174.805
19.531	203.099	109.854	0.029	0.016	588.538	960.079	5.366	49.156	24.578	16.385
23.438	238.129	170.603	0.028	0.020	602.352	741.855	1.969	31.652	15.826	10.551
27.344	310.925	269.033	0.032	0.027	538.212	548.840	0.168	20.072	10.036	6.691
31.250	400.022	273.129	0.036	0.024	478.099	617.840	2.484	19.771	9.885	6.590
35.156	485.250	272.621	0.038	0.022	443.393	696.365	4.850	19.808	9.904	6.603
39.063	556.301	222.977	0.040	0.016	429.736	946.006	10.212	24.218	12.109	8.073
42.969	613.267	197.353	0.040	0.013	428.800	1175.717	14.806	27.362	13.681	9.121
46.875	651.769	294.149	0.039	0.017	440.148	860.533	8.118	18.358	9.179	6.119
50.781	692.664	296.568	0.038	0.016	448.676	924.641	9.017	18.208	9.104	6.069
54.688	799.913	219.641	0.041	0.011	418.405	1344.527	18.814	24.586	12.293	8.195
58.594	864.876	509.969	0.041	0.024	414.619	620.442	4.220	10.589	5.294	3.530
62.500	907.688	428.576	0.040	0.019	421.401	787.492	7.384	12.600	6.300	4.200
66.406	975.809	418.770	0.041	0.018	416.481	856.303	8.976	12.895	6.447	4.298
70.313	1018.982	367.630	0.040	0.015	422.296	1032.800	12.288	14.689	7.344	4.896
74.219	1192.379	515.754	0.045	0.019	380.935	777.078	8.839	10.470	5.235	3.490
78.125	1319.950	393.488	0.047	0.014	362.229	1072.143	16.659	13.723	6.862	4.574
82.031	1356.116	390.878	0.046	0.013	370.198	1133.268	17.521	13.815	6.908	4.605
85.938	1392.958	397.296	0.045	0.013	377.569	1168.053	17.796	13.592	6.796	4.531
89.844	1448.781	438.019	0.045	0.014	379.522	1107.616	16.307	12.328	6.164	4.109
93.750	1487.888	512.065	0.044	0.015	385.614	988.644	13.292	10.546	5.273	3.515
97.656	1384.144	356.790	0.039	0.010	431.788	1478.024	20.596	15.135	7.567	5.045
101.563	1469.483	358.563	0.040	0.010	422.980	1529.543	22.237	15.060	7.530	5.020
105.469	1516.621	376.576	0.040	0.010	425.596	1512.396	21.706	14.340	7.170	4.780
109.375	1566.069	202.221	0.040	0.005	427.424	2920.699	49.583	26.704	13.352	8.901
113.281	1601.011	461.857	0.039	0.011	433.027	1324.476	17.498	11.692	5.846	3.897
117.188	1717.607	441.205	0.041	0.010	417.550	1434.283	20.697	12.239	6.120	4.080
121.094	1802.013	605.370	0.041	0.014	411.259	1080.177	13.825	8.920	4.460	2.973
125.000	1780.471	723.167	0.040	0.016	429.662	933.394	9.965	7.467	3.734	2.489
128.906	1869.765	601.440	0.040	0.013	421.928	1157.379	14.816	8.978	4.489	2.993
132.813	1907.878	802.328	0.040	0.017	426.030	893.883	9.334	6.730	3.365	2.243
136.719	1889.005	902.748	0.038	0.018	442.942	817.816	7.194	5.982	2.991	1.994

AVERAGE CRACK DEPTH = 13.6062
STANDARD DEVIATION = 11.8254
UPPER BOUND VALUE = 19.5189
LOWER BOUND VALUE = 7.6935

46.962	5.366	1.969	0.168	2.484	4.850	10.212	14.806
8.118	4.220	7.384	8.976	12.288	8.839	16.659	22.237
21.706	49.583	17.498	20.697	13.825	9.965	14.816	9.334
7.194							

THE FINAL DEPTH = 12.1115

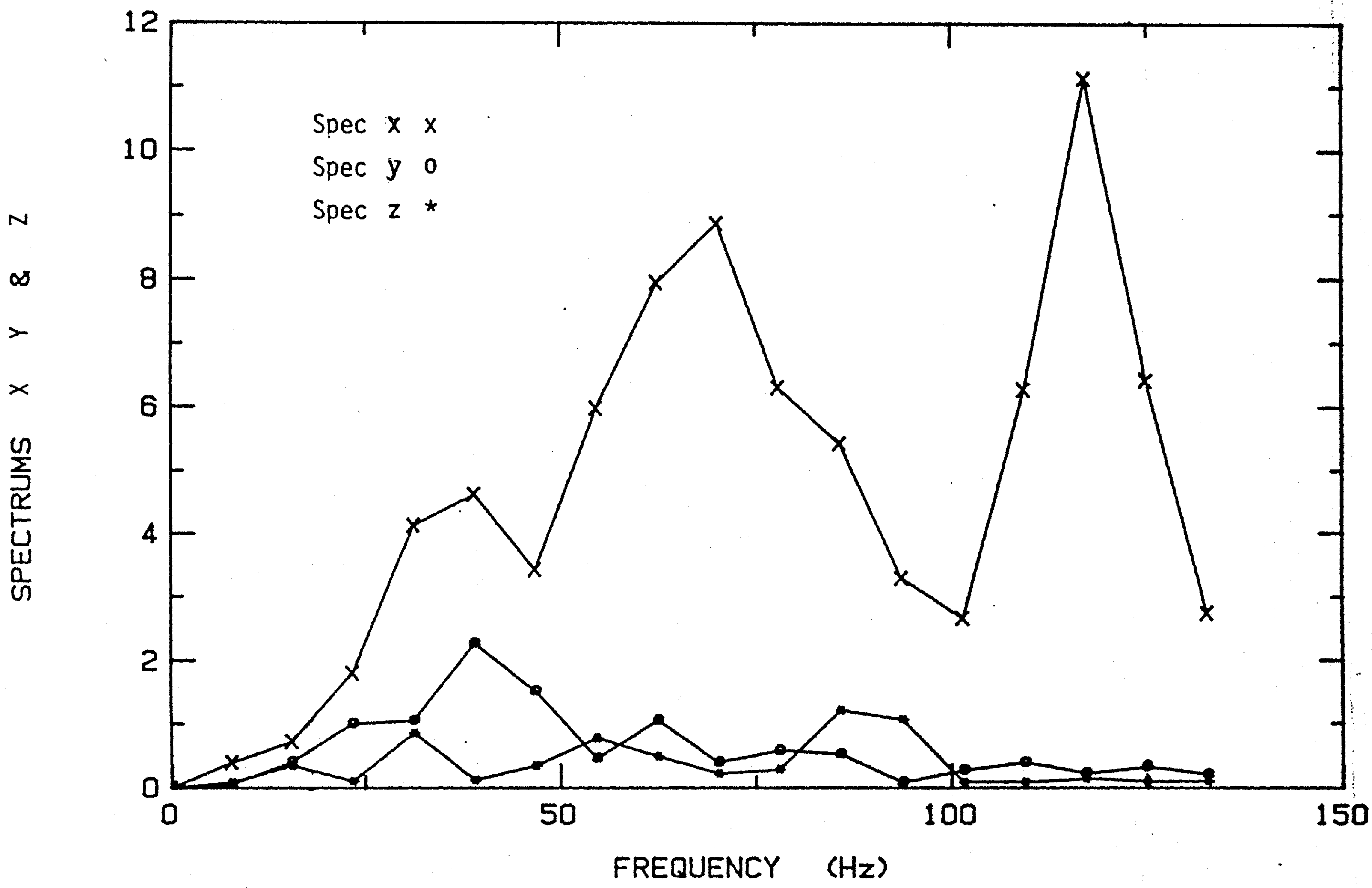

Figure D1. Auto Spectra of Type One Test - Before Excavation of the Trench

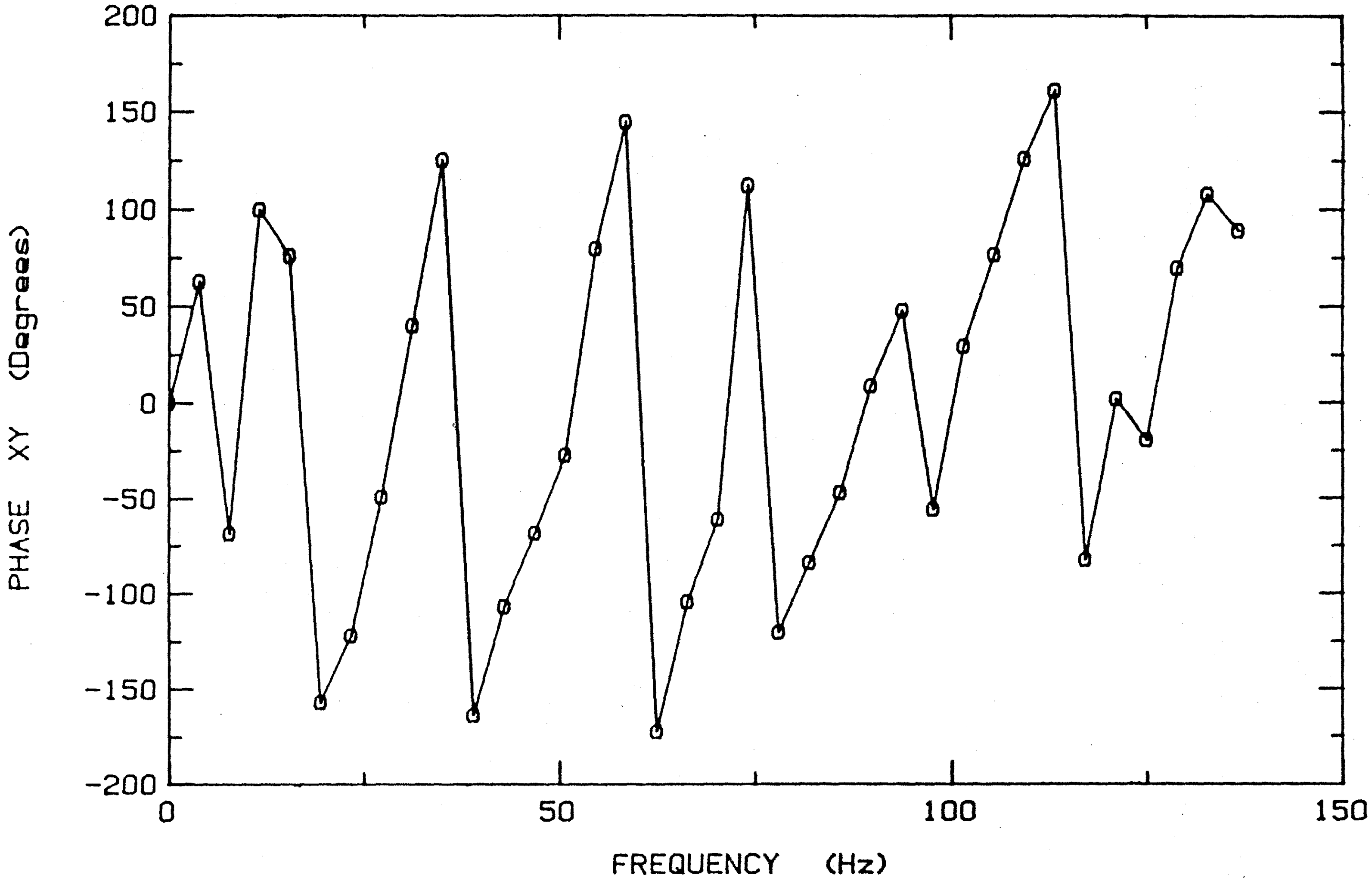

Figure D2. Phase Spectrum "ϕ_{xy}" of Type One Test - Before Excavation of the Trench

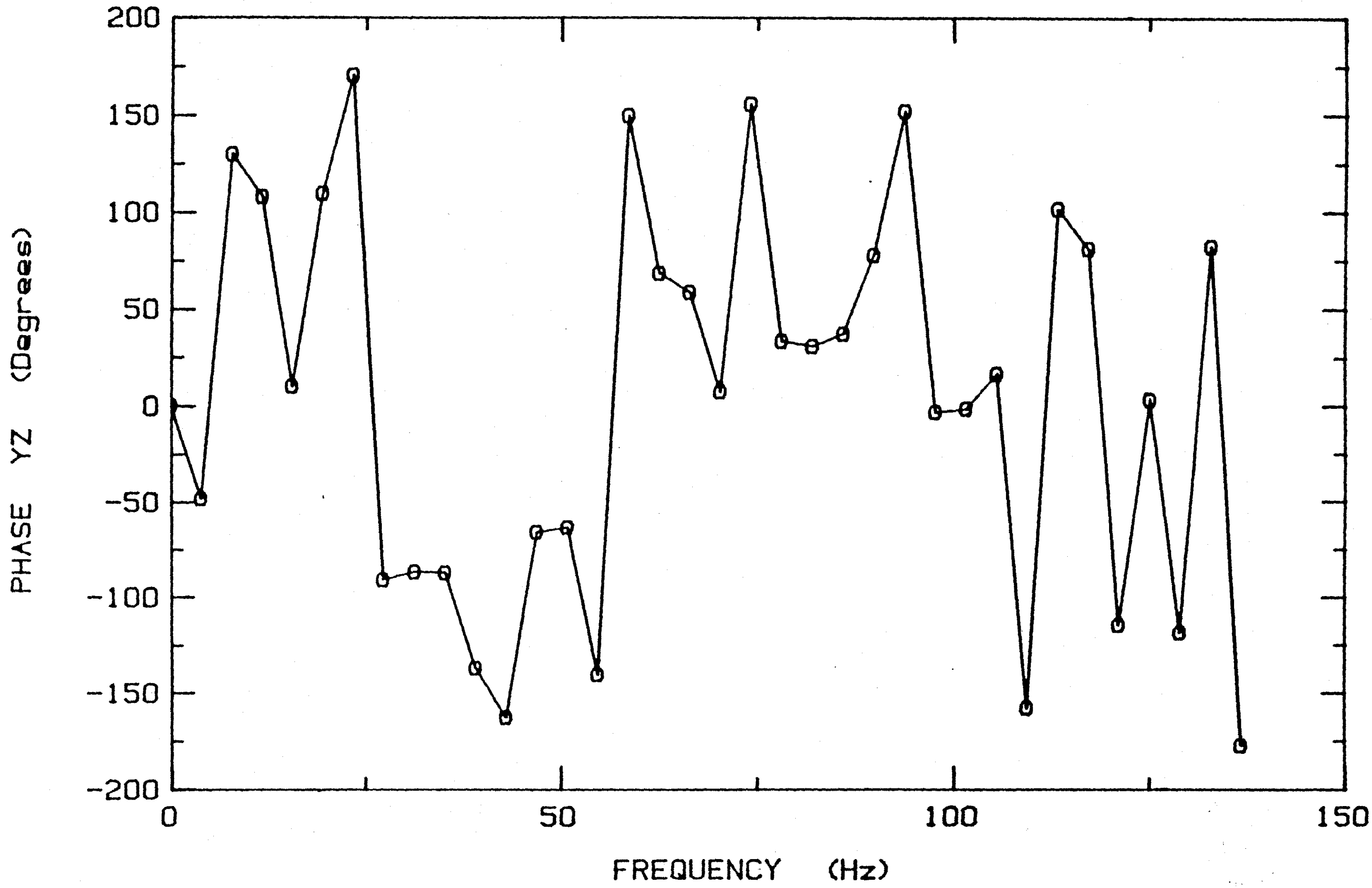

Figure D3. Phase Spectrum "ϕ_{yz}" of Type One Test - Before Excavation of the Trench

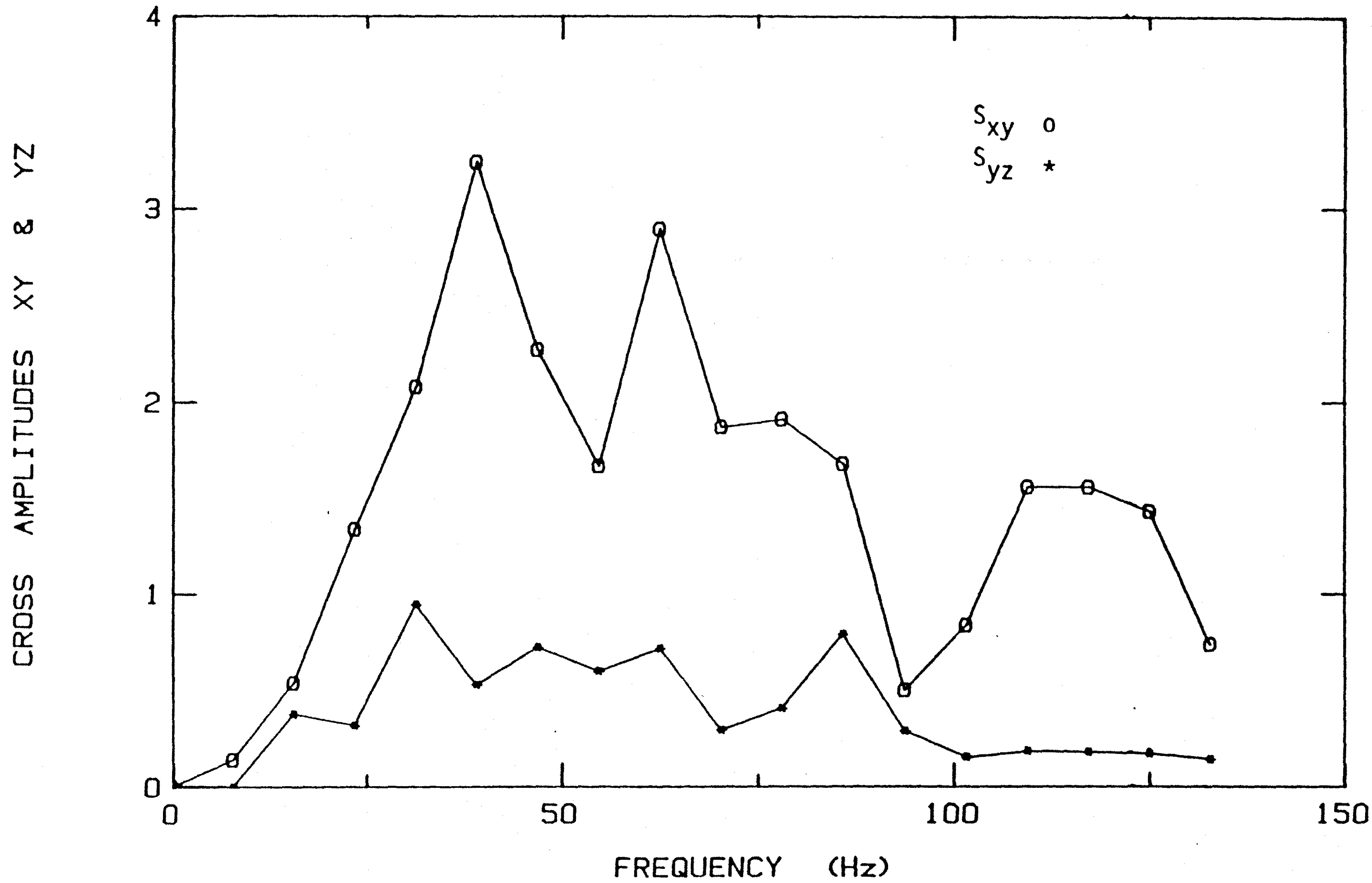

Figure D4. Cross Amplitude Spectra of Type One Test - Before Excavation of the Trench

APPENDIX E

TYPE ONE TEST

RESULTS FOR A TRENCH OF 1.75 FT DEEP

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THIS PROGRAM DOES CROSS SPECTRUM USING FFT AND AVERAGE SMOOTHING TECQ.

          NO. OF DATA FOR EACH SET =   256
          THE POWER OF 2           =     8
          DEGREE OF FREEDOM        =     3
          SAMPLING INTERVAL        =  1.00  MSEC
          KEY=0, DO AUTO-SPECTRA ONLY
          KEY=1, DO CROSS-SPECTRA
          IN THIS CASE KEY         =     1
          DISTANCE BETWEEN X & Y   = 17.00  FT
          DISTANCE BETWEEN Y & Z   = 15.00  FT
```

CROSS SPECTRUM PROPERTIES FOR STATION= 1 AND STATION= 2

FREQUENCY	PERIOD	SPECTRUM-1	SPECTRUM-2	RATIO	PHASE	COHERENCY	CROSS AMPL.	GAIN SPEC.
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0039	256.0000	0.1457	0.0254	0.1741	69.0693	0.0000	0.0000	0.0000
0.0078	128.0000	0.1680	0.0778	0.4631	95.5650	0.0000	0.0000	0.0000
0.0117	85.3333	0.2671	0.1702	0.6371	-141.1243	0.8209	0.1750	0.6553
0.0156	64.0000	0.7255	0.3443	0.4745	-177.9409	0.9584	0.4790	0.6602
0.0195	51.2000	1.4353	0.6862	0.4781	-138.0808	0.9600	0.9527	0.6638
0.0234	42.6667	2.4571	0.8055	0.3278	-98.4400	0.8331	1.1721	0.4770
0.0273	36.5714	3.6980	0.7669	0.2074	-69.3801	0.6510	1.0963	0.2965
0.0313	32.0000	4.4587	0.6427	0.1441	-130.0057	0.4081	0.6907	0.1549
0.0352	28.4444	4.6991	0.8885	0.1891	-152.3042	0.7314	1.4945	0.3180
0.0391	25.6000	4.4106	1.1153	0.2529	-121.7933	0.8125	1.8020	0.4086
0.0430	23.2727	4.3247	1.1584	0.2679	-76.7960	0.8325	1.8635	0.4309
0.0469	21.3333	4.8532	0.9179	0.1891	-27.7627	0.8478	1.7894	0.3687
0.0508	19.6923	6.0161	0.6211	0.1032	16.6362	0.7943	1.5354	0.2552
0.0547	18.2857	7.3226	0.3503	0.0478	74.3139	0.7969	1.2764	0.1743
0.0586	17.0667	8.3410	0.2311	0.0277	131.6775	0.7853	1.0902	0.1307
0.0625	16.0000	8.7376	0.1794	0.0205	162.3044	0.9083	1.1373	0.1302
0.0664	15.0588	8.4109	0.2082	0.0248	179.5010	0.9182	1.2151	0.1445
0.0703	14.2222	8.2963	0.2936	0.0354	176.7841	0.9495	1.4820	0.1786
0.0742	13.4737	7.7506	0.4231	0.0546	-150.4221	0.8878	1.6077	0.2074
0.0781	12.8000	7.6166	0.4989	0.0655	-112.2276	0.8482	1.6535	0.2171
0.0820	12.1905	6.6437	0.5074	0.0764	-76.1564	0.9455	1.7359	0.2613
0.0859	11.6364	5.7803	0.4334	0.0750	-52.9008	0.9798	1.5509	0.2683
0.0898	11.1304	4.2763	0.3190	0.0746	-32.6848	0.9868	1.1525	0.2695
0.0938	10.6667	2.9031	0.2169	0.0747	-12.7626	0.9401	0.7460	0.2570
0.0977	10.2400	2.6182	0.1510	0.0577	41.2551	0.8843	0.5561	0.2124
0.1016	9.8462	3.9288	0.1451	0.0369	77.5932	0.9782	0.7386	0.1880
0.1055	9.4815	6.3020	0.2068	0.0328	109.9341	0.9664	1.1032	0.1751
0.1094	9.1429	10.9338	0.2698	0.0247	148.1864	0.9221	1.5837	0.1448
0.1133	8.8276	12.8158	0.3151	0.0246	-172.2625	0.8142	1.6360	0.1277
0.1172	8.5333	12.5732	0.3493	0.0278	-134.1591	0.6292	1.3188	0.1049
0.1211	8.2581	9.1579	0.4069	0.0444	-44.1679	0.6879	1.3280	0.1450
0.1250	8.0000	5.7621	0.3921	0.0680	13.8432	0.9078	1.3645	0.2368
0.1289	7.7576	3.9677	0.3465	0.0873	46.1779	0.9141	1.0719	0.2701
0.1328	7.5294	2.6937	0.2215	0.0822	94.1501	0.9814	0.7581	0.2814
0.1367	7.3143	1.8130	0.1714	0.0945	115.7684	0.9754	0.5437	0.2999
0.1406	7.1111	1.1886	0.1249	0.1051	137.0926	0.9441	0.3638	0.3060
0.1445	6.9189	0.7026	0.0985	0.1402	170.9895	0.8884	0.2337	0.3326
0.1484	6.7368	0.5598	0.0659	0.1177	-133.2250	0.8200	0.1575	0.2814
0.1523	6.5641	0.4879	0.0499	0.1023	-98.0248	0.8771	0.1368	0.2805
0.1563	6.4000	0.5257	0.0375	0.0713	-130.8042	0.8786	0.1233	0.2345
0.1602	6.2439	0.5714	0.0288	0.0505	-152.9922	0.8971	0.1152	0.2016
0.1641	6.0952	0.6210	0.0451	0.0727	-172.1714	0.8989	0.1505	0.2423
0.1680	5.9535	0.6390	0.0448	0.0701	-172.3689	0.9003	0.1523	0.2384
0.1719	5.8182	0.5926	0.0621	0.1047	-165.6036	0.9598	0.1841	0.3106
0.1758	5.6889	0.4880	0.0585	0.1199	-135.1180	0.8690	0.1469	0.3009
0.1797	5.5652	0.4063	0.0673	0.1657	-101.8248	0.8459	0.1399	0.3443
0.1836	5.4468	0.3373	0.0535	0.1585	-54.9163	0.9388	0.1261	0.3738
0.1875	5.3333	0.3693	0.0588	0.1592	-4.1689	0.8847	0.1304	0.3530
0.1914	5.2245	0.3860	0.0516	0.1337	23.9938	0.9476	0.1337	0.3465
0.1953	5.1200	0.3945	0.0536	0.1359	41.5407	0.9576	0.1392	0.3530
0.1992	5.0196	0.3661	0.0435	0.1188	71.3329	0.9579	0.1208	0.3301
0.2031	4.9231	0.3573	0.0342	0.0958	89.5471	0.9174	0.1014	0.2839

CROSS SPECTRUM PROPERTIES FOR STATION= 2 AND STATION= 3

FREQUENCY	PERIOD	SPECTRUM-1	SPECTRUM-2	RATIO	PHASE	COHERENCY	CROSS AMPL.	GAIN SPEC.
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0039	256.0000	0.0254	0.0570	2.2460	36.8780	0.0000	0.0000	0.0000
0.0078	128.0000	0.0778	0.0744	0.9561	88.2819	0.0000	0.0000	0.0000
0.0117	85.3333	0.1702	0.1390	0.8171	74.8680	0.9861	0.1517	0.8914
0.0156	64.0000	0.3443	0.1583	0.4598	99.5146	0.8980	0.2096	0.6089
0.0195	51.2000	0.6862	0.1771	0.2581	117.9487	0.8723	0.3041	0.4431
0.0234	42.6667	0.8055	0.2162	0.2683	-153.8241	0.3800	0.1586	0.1968
0.0273	36.5714	0.7669	0.3980	0.5190	-87.5961	0.5437	0.3004	0.3917
0.0313	32.0000	0.6427	0.4452	0.6927	-99.9185	0.8223	0.4398	0.6844
0.0352	28.4444	0.8885	0.4132	0.4651	-137.9391	0.5918	0.3585	0.4036
0.0391	25.6000	1.1153	0.2476	0.2220	-150.1853	0.7821	0.4110	0.3685
0.0430	23.2727	1.1584	0.2707	0.2337	-115.4381	0.7413	0.4151	0.3583
0.0469	21.3333	0.9179	0.5044	0.5495	-103.6807	0.8170	0.5559	0.6056
0.0508	19.6923	0.6211	0.5566	0.8961	-105.8326	0.8867	0.5214	0.8394
0.0547	18.2857	0.3503	0.5490	1.5672	-130.4994	0.8544	0.3747	1.0696
0.0586	17.0667	0.2311	0.3923	1.6978	156.1593	0.7135	0.2148	0.9296
0.0625	16.0000	0.1794	0.3502	1.9514	103.1518	0.8783	0.2202	1.2270
0.0664	15.0588	0.2082	0.3223	1.5481	93.5524	0.8810	0.2282	1.0962
0.0703	14.2222	0.2936	0.2908	0.9903	106.0155	0.9339	0.2729	0.9293
0.0742	13.4737	0.4231	0.2987	0.7059	72.6537	0.9156	0.3255	0.7692
0.0781	12.8000	0.4989	0.4540	0.9099	40.6539	0.9332	0.4441	0.8902
0.0820	12.1905	0.5074	0.7977	1.5722	40.7350	0.9188	0.5845	1.1521
0.0859	11.6364	0.4334	1.3423	3.0972	69.5903	0.7996	0.6099	1.4072
0.0898	11.1304	0.3190	1.4340	4.4957	99.3340	0.7594	0.5136	1.6101
0.0938	10.6667	0.2169	1.2907	5.9503	140.8632	0.8196	0.4337	1.9992
0.0977	10.2400	0.1510	0.6822	4.5168	-139.0046	0.8671	0.2783	1.8428
0.1016	9.8462	0.1451	0.2466	1.6991	-68.2769	0.7629	0.1443	0.9945
0.1055	9.4815	0.2068	0.0605	0.2925	-16.8494	0.0000	0.0000	0.0000
0.1094	9.1429	0.2698	0.0887	0.3289	21.0534	0.9190	0.1422	0.5271
0.1133	8.8276	0.3151	0.0895	0.2842	16.6680	0.8775	0.1474	0.4678
0.1172	8.5333	0.3493	0.0945	0.2705	0.7543	0.8366	0.1520	0.4351
0.1211	8.2581	0.4069	0.0481	0.1182	-48.6214	0.9619	0.1346	0.3308
0.1250	8.0000	0.3921	0.0466	0.1189	-50.5740	0.9628	0.1302	0.3320
0.1289	7.7576	0.3465	0.0309	0.0893	-53.2987	0.9668	0.1001	0.2889

CROSS SPECTRUM PROPERTIES FOR STATION= 1 AND STATION= 3

FREQUENCY	PERIOD	SPECTRUM-1	SPECTRUM-2	RATIO	PHASE	COHERENCY	CROSS AMPL.	GAIN SPEC.
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0039	256.0000	0.1457	0.0570	0.3909	24.8999	0.0000	0.0000	0.0000
0.0078	128.0000	0.1680	0.0744	0.4428	33.7153	0.0000	0.0000	0.0000
0.0117	85.3333	0.2671	0.1390	0.5206	-63.2126	0.8425	0.1624	0.6079
0.0156	64.0000	0.7255	0.1583	0.2182	-64.3523	0.8654	0.2933	0.4042
0.0195	51.2000	1.4353	0.1771	0.1234	-23.6353	0.8179	0.4124	0.2873
0.0234	42.6667	2.4571	0.2162	0.0880	-106.0446	0.7826	0.5703	0.2321
0.0273	36.5714	3.6980	0.3980	0.1076	-59.7740	0.8727	1.0587	0.2863
0.0313	32.0000	4.4587	0.4452	0.0998	-34.2928	0.7719	1.0874	0.2439
0.0352	28.4444	4.6991	0.4132	0.0879	-15.2397	0.8513	1.1862	0.2524
0.0391	25.6000	4.4106	0.2476	0.0561	39.1829	0.7344	0.7674	0.1740
0.0430	23.2727	4.3247	0.2707	0.0626	-117.4199	0.7283	0.7880	0.1822
0.0469	21.3333	4.8532	0.5044	0.1039	-94.5467	0.9012	1.4100	0.2905
0.0508	19.6923	6.0161	0.5566	0.0925	-83.9365	0.9597	1.7560	0.2919
0.0547	18.2857	7.3226	0.5490	0.0750	-83.1040	0.9464	1.8977	0.2592
0.0586	17.0667	8.3410	0.3923	0.0470	-94.2793	0.9745	1.7629	0.2114
0.0625	16.0000	8.7376	0.3502	0.0401	-99.4188	0.9902	1.7320	0.1982
0.0664	15.0588	8.4109	0.3223	0.0383	-94.0286	0.9812	1.6157	0.1921
0.0703	14.2222	8.2963	0.2908	0.0351	-81.5032	0.9887	1.5356	0.1851
0.0742	13.4737	7.7506	0.2987	0.0385	-72.3764	0.9828	1.4953	0.1929
0.0781	12.8000	7.6166	0.4540	0.0596	-54.8792	0.9202	1.7111	0.2246
0.0820	12.1905	6.6437	0.7977	0.1201	-20.0266	0.8681	1.9984	0.3008
0.0859	11.6364	5.7803	1.3423	0.2322	28.0994	0.7189	2.0025	0.3464
0.0898	11.1304	4.2763	1.4340	0.3353	57.4955	0.6999	1.7332	0.4053
0.0938	10.6667	2.9031	1.2907	0.4446	99.8116	0.7414	1.4351	0.4943
0.0977	10.2400	2.6182	0.6822	0.2606	-130.1985	0.5754	0.7691	0.2937
0.1016	9.8462	3.9288	0.2466	0.0628	-3.4091	0.5948	0.5854	0.1490
0.1055	9.4815	6.3020	0.0605	0.0096	79.7169	0.7130	0.4402	0.0698
0.1094	9.1429	10.9338	0.0887	0.0081	-172.8222	0.9111	0.8975	0.0821
0.1133	8.8276	12.8158	0.0895	0.0070	-163.9827	0.9000	0.9640	0.0752
0.1172	8.5333	12.5732	0.0945	0.0075	-148.0625	0.8649	0.9427	0.0750
0.1211	8.2581	9.1579	0.0481	0.0053	-80.0073	0.8312	0.5518	0.0603
0.1250	8.0000	5.7621	0.0466	0.0081	-46.9464	0.9109	0.4721	0.0819
0.1289	7.7576	3.9677	0.0309	0.0078	-12.3205	0.8058	0.2823	0.0712
0.1328	7.5294	2.6937	0.0213	0.0079	69.2654	0.7179	0.1718	0.0638
0.1367	7.3143	1.8130	0.0264	0.0145	-64.9403	0.0000	0.0000	0.0000
0.1406	7.1111	1.1886	0.0319	0.0268	-70.9337	0.6575	0.1280	0.1077
0.1445	6.9189	0.7026	0.0327	0.0466	-12.4728	0.8389	0.1272	0.1810

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AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
A                                           A
A        THE OUTPUT FOR CRACK ESTIMATION    A
A                                           A
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
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3 19 29 34
6 25 34

FREQ (HZ)	PHASE XY	PHASE YZ	TIME XY	TIME YZ	VELOCITY XY	VELOCITY YZ	DEPTH CRACK	WAVENGTH YZ	DEPTH WL/2	DEPTH WL/3
3.906	69.069	36.878	0.049	0.026	346.120	571.988	5.547	146.429	73.214	48.810
7.813	95.565	88.282	0.034	0.031	500.314	477.873	-0.381	61.168	30.584	20.389
11.719	218.876	74.868	0.052	0.018	327.669	845.238	13.426	72.127	36.063	24.042
15.625	182.059	99.515	0.032	0.018	525.241	847.866	5.221	54.263	27.132	18.088
19.531	221.919	117.949	0.032	0.017	538.625	894.192	5.611	45.783	22.891	15.261
23.438	261.560	206.176	0.031	0.024	548.393	613.857	1.015	26.191	13.096	8.730
27.344	290.620	272.404	0.030	0.028	575.816	542.049	-0.498	19.824	9.912	6.608
31.250	229.994	260.081	0.020	0.023	831.542	648.835	-1.868	20.763	10.381	6.921
35.156	207.696	222.061	0.016	0.018	1035.920	854.918	-1.485	24.318	12.159	8.106
39.063	238.207	209.815	0.017	0.015	1003.593	1005.351	0.015	25.737	12.868	8.579
42.969	283.204	244.562	0.018	0.016	928.549	948.763	0.185	22.080	11.040	7.360
46.875	332.237	256.319	0.020	0.015	863.465	987.538	1.221	21.067	10.534	7.022
50.781	376.636	254.167	0.021	0.014	825.151	1078.890	2.614	21.246	10.623	7.082
54.688	434.314	229.501	0.022	0.012	770.613	1286.761	5.693	23.529	11.765	7.843
58.594	491.677	516.159	0.023	0.024	729.327	613.001	-1.356	10.462	5.231	3.487
62.500	522.304	463.152	0.023	0.021	732.332	728.703	-0.042	11.659	5.830	3.886
66.406	539.501	453.552	0.023	0.019	753.301	790.634	0.421	11.906	5.953	3.969
70.313	536.784	466.015	0.021	0.018	801.650	814.753	0.139	11.588	5.794	3.863
74.219	569.578	432.654	0.021	0.016	797.466	926.333	1.374	12.481	6.241	4.160
78.125	607.772	400.654	0.022	0.014	786.685	1052.967	2.877	13.478	6.739	4.493
82.031	643.844	400.735	0.022	0.014	779.741	1105.392	3.550	13.475	6.738	4.492
85.938	667.099	429.590	0.022	0.014	788.395	1080.245	3.147	12.570	6.285	4.190
89.844	687.315	459.334	0.021	0.014	799.988	1056.218	2.722	11.756	5.878	3.919
93.750	707.237	500.863	0.021	0.015	811.256	1010.756	2.090	10.781	5.391	3.594
97.656	761.255	580.995	0.022	0.017	785.094	907.656	1.327	9.294	4.647	3.098
101.563	797.593	651.723	0.022	0.018	779.298	841.520	0.679	8.286	4.143	2.762
105.469	829.934	703.150	0.022	0.019	777.735	809.971	0.352	7.680	3.840	2.560
109.375	868.186	741.053	0.022	0.019	771.004	797.008	0.287	7.287	3.643	2.429
113.281	907.737	736.668	0.022	0.018	763.747	830.386	0.742	7.330	3.665	2.443
117.188	945.841	720.754	0.022	0.017	758.254	877.987	1.342	7.492	3.746	2.497
121.094	1035.832	671.378	0.024	0.015	715.458	973.976	3.071	8.043	4.022	2.681
125.000	1093.843	669.426	0.024	0.015	699.369	1008.327	3.755	8.067	4.033	2.689
128.906	1126.178	666.701	0.024	0.014	700.517	1044.087	4.169	8.100	4.050	2.700

AVERAGE CRACK DEPTH = 2.7684
STANDARD DEVIATION = 3.1774
UPPER BOUND VALUE = 4.3571
LOWER BOUND VALUE = 1.1797

13.426 5.221 5.611 1.015 0.015 0.185 1.221 2.614
0.139 1.374 2.877 0.287 0.742 1.342 3.071 3.755
4.169

THE FINAL DEPTH = 2.5529

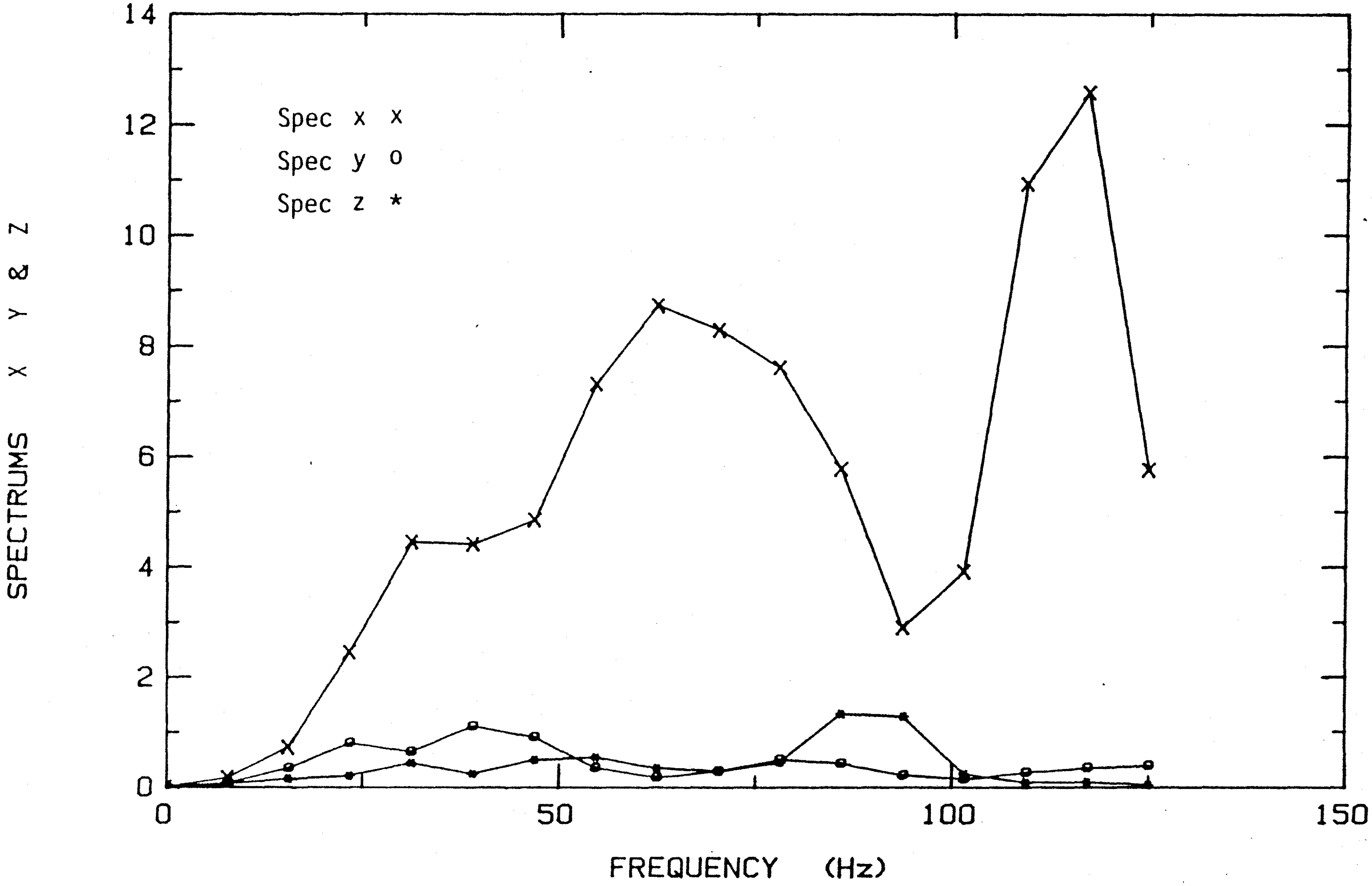

Figure E1. Auto Spectra of Type One Test - 1.75 ft. Trench Depth

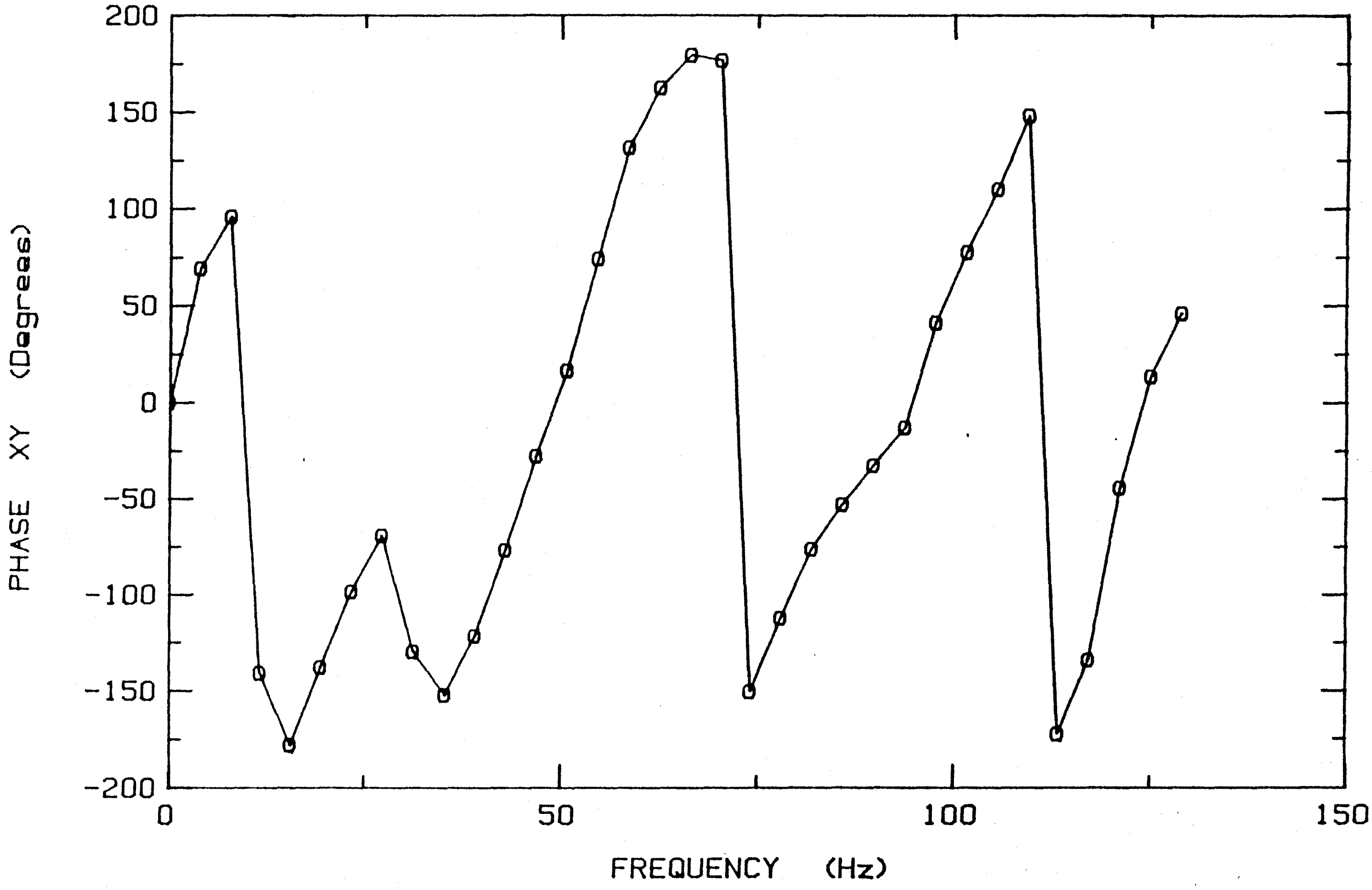

Figure E2. Phase Spectrum "ϕ_{xy}" of Type One Test - 1.75 ft. Trench Depth

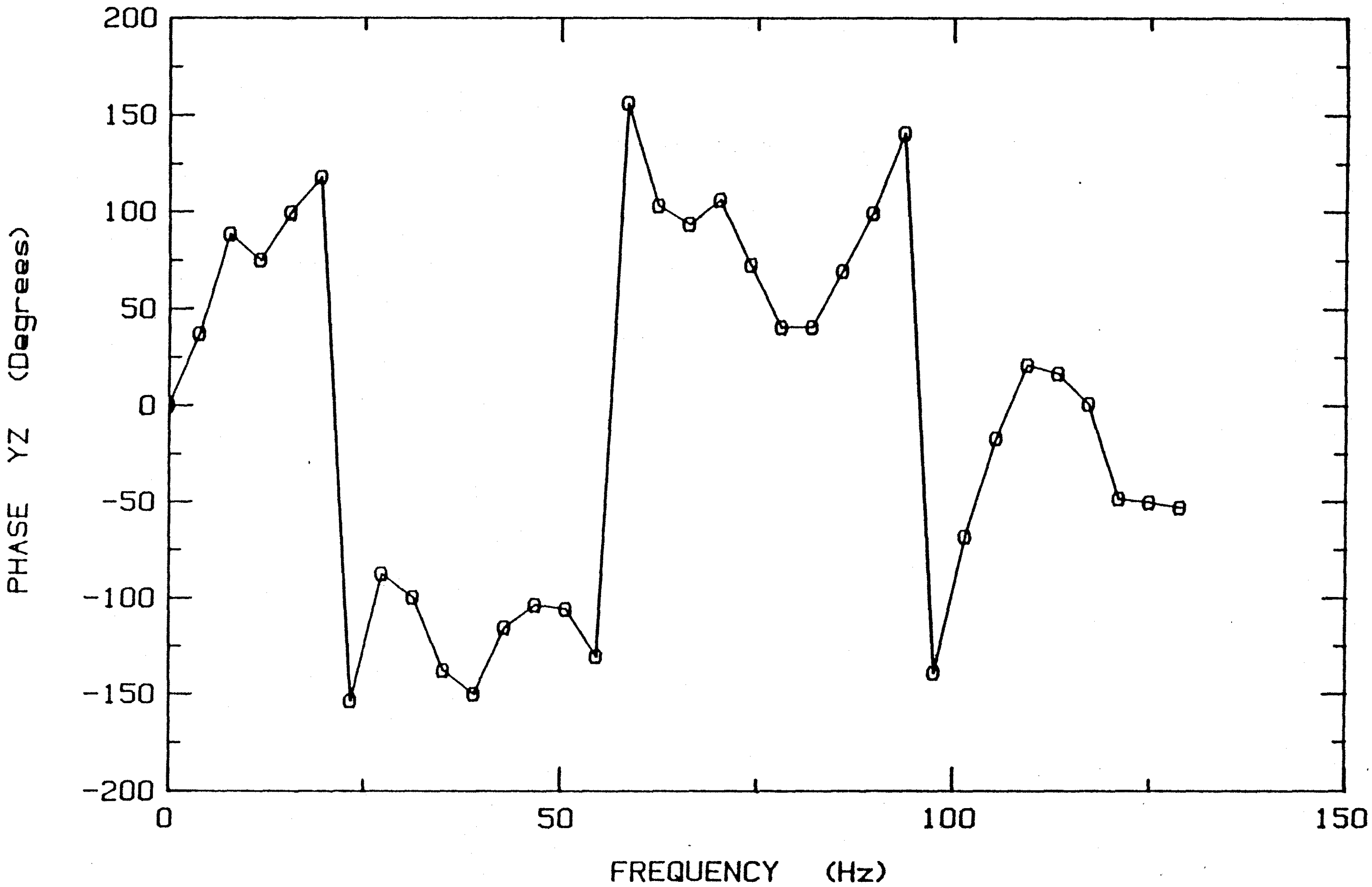

Figure E3. Phase Spectrum "ϕ_{yz}" of Type One Test - 1.75 ft. Trench Depth

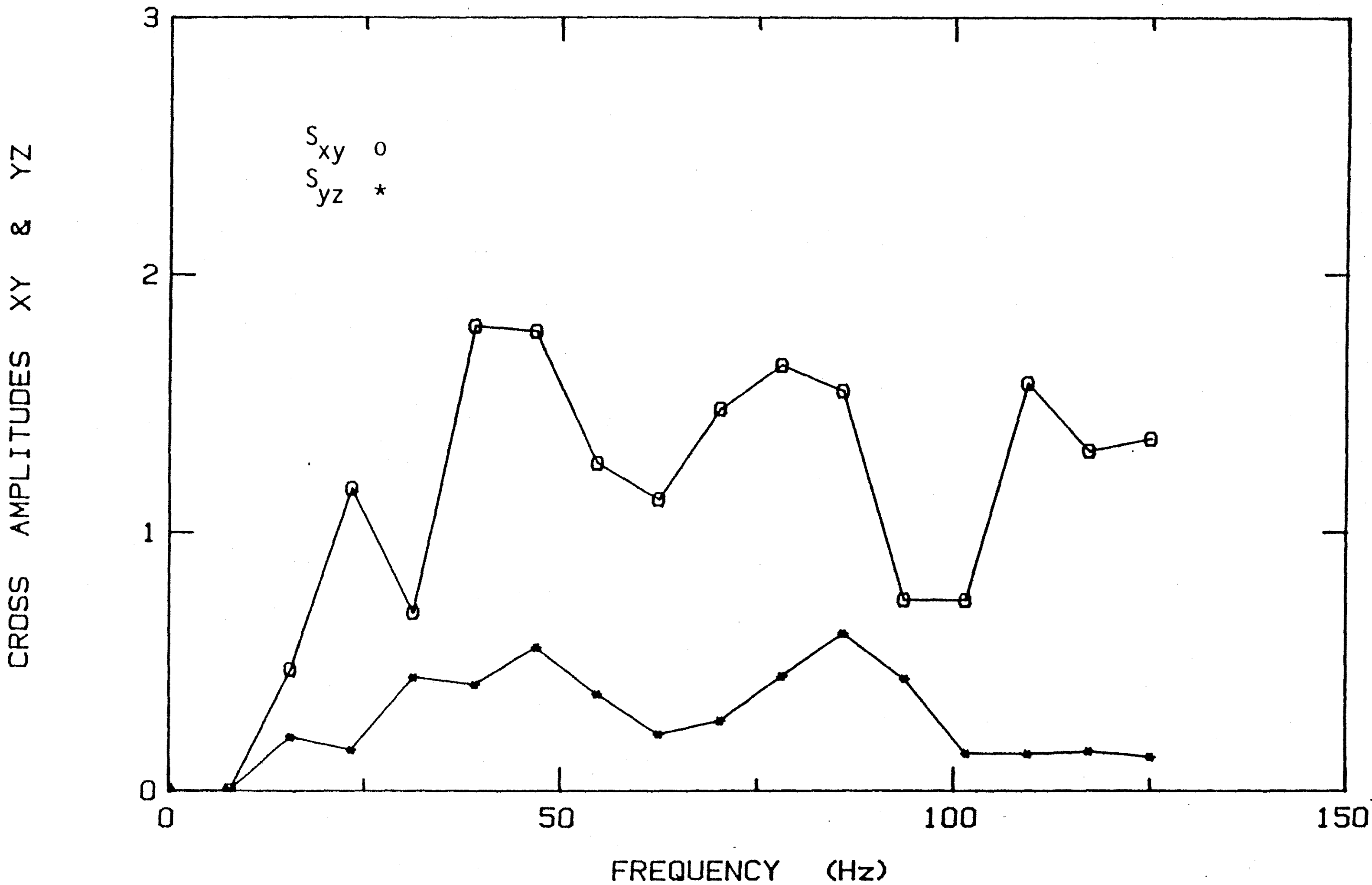

Figure E4. Cross Amplitude Spectra of Type One Test - 1.75 ft. Trench Depth

APPENDIX F

TYPE ONE TEST

RESULTS FOR A TRENCH OF 3.0 FT DEEP

THIS PROGRAM DOES CROSS SPECTRUM USING FFT AND AVERAGE SMOOTHING TECQ.

```
NO. OF DATA FOR EACH SET =   256
THE POWER OF 2           =     8
DEGREE OF FREEDOM        =     3
SAMPLING INTERVAL        =  1.00  MSEC
KEY=0, DO AUTO-SPECTRA ONLY
KEY=1, DO CROSS-SPECTRA
IN THIS CASE KEY         =     1
DISTANCE BETWEEN X & Y   = 17.00  FT
DISTANCE BETWEEN Y & Z   = 15.00  FT
```

CROSS SPECTRUM PROPERTIES FOR STATION= 1 AND STATION= 2

FREQUENCY	PERIOD	SPECTRUM-1	SPECTRUM-2	RATIO	PHASE	COHERENCY	CROSS AMPL.	GAIN SPEC.
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0039	256.0000	0.2305	0.0486	0.2110	-22.7316	0.0000	0.0000	0.0000
0.0078	128.0000	0.3635	0.1226	0.3373	54.1009	0.8511	0.1797	0.4943
0.0117	85.3333	0.5204	0.1681	0.3230	-158.3232	0.4974	0.1471	0.2827
0.0156	64.0000	0.8538	0.4323	0.5063	-178.6053	0.8902	0.5409	0.6335
0.0195	51.2000	1.6015	0.7895	0.4930	-128.9181	0.9420	1.0592	0.6614
0.0234	42.6667	2.5507	0.8548	0.3351	-103.1141	0.8294	1.2246	0.4801
0.0273	36.5714	3.4795	0.7601	0.2185	-89.4545	0.7898	1.2845	0.3691
0.0313	32.0000	3.8964	0.3704	0.0951	-75.4579	0.7542	0.9061	0.2326
0.0352	28.4444	3.8553	0.5244	0.1360	-132.2850	0.7711	1.0963	0.2844
0.0391	25.6000	3.5419	0.7639	0.2157	-106.3625	0.8144	1.3396	0.3782
0.0430	23.2727	3.6221	0.8430	0.2328	-82.4495	0.8823	1.5418	0.4257
0.0469	21.3333	4.6414	0.6913	0.1490	-47.6270	0.8502	1.5230	0.3281
0.0508	19.6923	6.3813	0.4154	0.0651	-10.6556	0.7252	1.1809	0.1850
0.0547	18.2857	7.7661	0.2017	0.0260	40.7233	0.8110	1.0150	0.1307
0.0586	17.0667	8.5113	0.1594	0.0187	97.4925	0.9194	1.0707	0.1258
0.0625	16.0000	8.4274	0.1985	0.0236	122.9306	0.9418	1.2182	0.1446
0.0664	15.0588	8.3898	0.2889	0.0344	148.7236	0.9555	1.4876	0.1773
0.0703	14.2222	7.5857	0.3903	0.0515	177.7073	0.8653	1.4890	0.1963
0.0742	13.4737	7.0309	0.4744	0.0675	-138.0051	0.8457	1.5446	0.2197
0.0781	12.8000	5.8327	0.4878	0.0836	-96.7253	0.9261	1.5620	0.2678
0.0820	12.1905	5.2659	0.4267	0.0810	-71.8716	0.9681	1.4511	0.2756
0.0859	11.6364	3.8677	0.3173	0.0820	-50.0373	0.9847	1.0909	0.2820
0.0898	11.1304	2.8384	0.2153	0.0758	-26.3159	0.8609	0.6730	0.2371
0.0938	10.6667	3.3604	0.1865	0.0555	37.6135	0.8735	0.6915	0.2058
0.0977	10.2400	5.1175	0.1977	0.0386	56.5555	0.9917	0.9975	0.1949
0.1016	9.8462	8.0339	0.2778	0.0346	81.9996	0.9658	1.4429	0.1796
0.1055	9.4815	12.4979	0.3572	0.0286	107.7106	0.9651	2.0392	0.1632
0.1094	9.1429	13.2837	0.4037	0.0304	130.6502	0.9144	2.1177	0.1594
0.1133	8.8276	12.2567	0.4028	0.0329	145.7159	0.7324	1.6272	0.1328
0.1172	8.5333	7.6085	0.3836	0.0504	-117.4653	0.4429	0.7567	0.0995
0.1211	8.2581	4.9448	0.3381	0.0684	-11.1163	0.8774	1.1345	0.2294
0.1250	8.0000	3.3345	0.2748	0.0824	29.2097	0.9489	0.9083	0.2724
0.1289	7.7576	1.9465	0.1761	0.0905	68.5125	0.9733	0.5698	0.2927
0.1328	7.5294	1.2696	0.1061	0.0836	93.4349	0.9910	0.3637	0.2865
0.1367	7.3143	0.8527	0.0884	0.1037	108.9331	0.8991	0.2469	0.2895
0.1406	7.1111	0.6744	0.0753	0.1117	176.4396	0.5375	0.1212	0.1796
0.1445	6.9189	0.6603	0.0573	0.0867	-124.7497	0.7763	0.1510	0.2286
0.1484	6.7368	0.7115	0.0752	0.1057	-147.7174	0.7698	0.1781	0.2503
0.1523	6.5641	0.7176	0.0700	0.0975	-162.4244	0.8384	0.1879	0.2618
0.1563	6.4000	0.6768	0.0730	0.1078	-156.5029	0.9177	0.2040	0.3014
0.1602	6.2439	0.6099	0.0384	0.0629	-116.1701	0.9547	0.1460	0.2394
0.1641	6.0952	0.5083	0.0430	0.0845	-123.5185	0.8856	0.1309	0.2575
0.1680	5.9535	0.4520	0.0518	0.1146	-117.4660	0.8799	0.1346	0.2978
0.1719	5.8182	0.3758	0.0788	0.2096	-109.1721	0.9129	0.1571	0.4180
0.1758	5.6889	0.3087	0.0934	0.3026	-78.2043	0.9062	0.1539	0.4985
0.1797	5.5652	0.2405	0.0928	0.3861	-55.3309	0.8785	0.1313	0.5458
0.1836	5.4468	0.2287	0.0796	0.3481	20.0525	0.0000	0.0000	0.0000
0.1875	5.3333	0.2199	0.0546	0.2483	72.5936	0.9615	0.1053	0.4791
0.1914	5.2245	0.2358	0.0449	0.1905	83.3558	0.9843	0.1013	0.4296

CROSS SPECTRUM PROPERTIES FOR STATION= 1 AND STATION= 3

FREQUENCY	PERIOD	SPECTRUM-1	SPECTRUM-2	RATIO	PHASE	COHERENCY	CROSS AMPL.	GAIN SPEC.
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0039	256.0000	0.2305	0.0701	0.3040	-4.7698	0.9598	0.1220	0.5292
0.0078	128.0000	0.3635	0.0958	0.2635	28.5625	0.9105	0.1699	0.4674
0.0117	85.3333	0.5204	0.1714	0.3293	-18.7263	0.8908	0.2660	0.5112
0.0156	64.0000	0.8538	0.2361	0.2766	-56.5658	0.8857	0.3977	0.4658
0.0195	51.2000	1.6015	0.2504	0.1564	-7.9761	0.6184	0.3916	0.2445
0.0234	42.6667	2.5507	0.2965	0.1162	-94.0424	0.7468	0.6495	0.2546
0.0273	36.5714	3.4795	0.3272	0.0940	-56.1060	0.7897	0.8426	0.2422
0.0313	32.0000	3.8964	0.3618	0.0929	-38.9246	0.8079	0.9592	0.2462
0.0352	28.4444	3.8553	0.2874	0.0745	-4.5288	0.8568	0.9018	0.2339
0.0391	25.6000	3.5419	0.2871	0.0811	-31.6572	0.6075	0.6127	0.1730
0.0430	23.2727	3.6221	0.3862	0.1066	-99.9621	0.8844	1.0460	0.2888
0.0469	21.3333	4.6414	0.4995	0.1076	-94.9932	0.9918	1.5103	0.3254
0.0508	19.6923	6.3813	0.4990	0.0782	-102.2943	0.9439	1.6843	0.2639
0.0547	18.2857	7.7661	0.4470	0.0576	-107.3806	0.9636	1.7954	0.2312
0.0586	17.0667	8.5113	0.3744	0.0440	-113.8340	0.9993	1.7839	0.2096
0.0625	16.0000	8.4274	0.3603	0.0428	-114.2831	0.9986	1.7402	0.2065
0.0664	15.0588	8.3898	0.3171	0.0378	-103.9091	0.9738	1.5883	0.1893
0.0703	14.2222	7.5857	0.3030	0.0399	-91.1753	0.9534	1.4454	0.1905
0.0742	13.4737	7.0309	0.4091	0.0582	-66.4350	0.9441	1.6011	0.2277
0.0781	12.8000	5.8327	0.7222	0.1238	-37.5663	0.8928	1.8323	0.3141
0.0820	12.1905	5.2659	1.2463	0.2367	3.8100	0.7881	2.0190	0.3834
0.0859	11.6364	3.8677	1.5191	0.3928	28.1785	0.7197	1.7445	0.4510
0.0898	11.1304	2.8384	1.4191	0.4999	54.0440	0.7422	1.4895	0.5248
0.0938	10.6667	3.3604	0.9762	0.2905	126.7086	0.2625	0.4754	0.1415
0.0977	10.2400	5.1175	0.3005	0.0587	15.4268	0.5491	0.6810	0.1331
0.1016	9.8462	8.0339	0.0883	0.0110	112.9494	0.7205	0.6070	0.0756
0.1055	9.4815	12.4979	0.0664	0.0053	170.7371	0.9022	0.8222	0.0658
0.1094	9.1429	13.2837	0.0783	0.0059	-177.5863	0.9171	0.9354	0.0704
0.1133	8.8276	12.2567	0.0880	0.0072	-149.9293	0.7998	0.8307	0.0678
0.1172	8.5333	7.6085	0.1379	0.0181	-81.6180	0.5735	0.5875	0.0772
0.1211	8.2581	4.9448	0.1305	0.0264	-31.9992	0.8219	0.6603	0.1335
0.1250	8.0000	3.3345	0.1228	0.0368	-8.7167	0.7807	0.4996	0.1498
0.1289	7.7576	1.9465	0.0550	0.0283	130.5668	0.8852	0.2897	0.1488
0.1328	7.5294	1.2696	0.0429	0.0338	169.5921	0.6387	0.1491	0.1174
0.1367	7.3143	0.8527	0.0461	0.0541	-88.5262	0.6067	0.1204	0.1411
0.1406	7.1111	0.6744	0.0447	0.0663	44.9821	0.6140	0.1066	0.1581
0.1445	6.9189	0.6603	0.0457	0.0692	79.2517	0.9043	0.1571	0.2379
0.1484	6.7368	0.7115	0.0375	0.0527	130.8116	0.8620	0.1408	0.1978
0.1523	6.5641	0.7176	0.0355	0.0495	127.3044	0.0000	0.0000	0.0000
0.1563	6.4000	0.6768	0.0317	0.0469	92.1800	0.0000	0.0000	0.0000
0.1602	6.2439	0.6099	0.0248	0.0406	12.2148	0.8636	0.1062	0.1741

CROSS SPECTRUM PROPERTIES FOR STATION= 2 AND STATION= 3

FREQUENCY	PERIOD	SPECTRUM-1	SPECTRUM-2	RATIO	PHASE	COHERENCY	CROSS AMPL.	GAIN SPEC.
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0039	256.0000	0.0486	0.0701	1.4410	36.6797	0.0000	0.0000	0.0000
0.0078	128.0000	0.1226	0.0958	0.7812	3.6559	0.0000	0.0000	0.0000
0.0117	85.3333	0.1681	0.1714	1.0194	75.4759	0.8051	0.1367	0.8129
0.0156	64.0000	0.4323	0.2361	0.5462	95.7921	0.8982	0.2870	0.6638
0.0195	51.2000	0.7895	0.2504	0.3172	133.9309	0.7931	0.3526	0.4466
0.0234	42.6667	0.8548	0.2965	0.3469	149.6952	0.3563	0.1794	0.2099
0.0273	36.5714	0.7601	0.3272	0.4305	-89.9237	0.3885	0.1938	0.2549
0.0313	32.0000	0.3704	0.3618	0.9767	-43.1804	0.7488	0.2741	0.7401
0.0352	28.4444	0.5244	0.2874	0.5480	-121.4806	0.3634	0.1411	0.2691
0.0391	25.6000	0.7639	0.2871	0.3759	-44.6050	0.7250	0.3395	0.4445
0.0430	23.2727	0.8430	0.3862	0.4581	-45.0408	0.8548	0.4877	0.5785
0.0469	21.3333	0.6913	0.4995	0.7226	-47.7321	0.8858	0.5206	0.7530
0.0508	19.6923	0.4154	0.4990	1.2011	-69.5754	0.8654	0.3940	0.9485
0.0547	18.2857	0.2017	0.4470	2.2158	-122.4189	0.7791	0.2339	1.1597
0.0586	17.0667	0.1594	0.3744	2.3497	149.6660	0.9270	0.2264	1.4210
0.0625	16.0000	0.1985	0.3603	1.8149	122.9645	0.9287	0.2484	1.2511
0.0664	15.0588	0.2889	0.3171	1.0976	113.6556	0.9596	0.2904	1.0053
0.0703	14.2222	0.3903	0.3030	0.7763	90.7775	0.9392	0.3230	0.8275
0.0742	13.4737	0.4744	0.4091	0.8623	55.0178	0.9221	0.4062	0.8562
0.0781	12.8000	0.4878	0.7222	1.4805	42.8671	0.9261	0.5497	1.1268
0.0820	12.1905	0.4267	1.2463	2.9210	58.8202	0.8388	0.6117	1.4337
0.0859	11.6364	0.3173	1.5191	4.7877	90.2289	0.6844	0.4751	1.4976
0.0898	11.1304	0.2153	1.4191	6.5918	135.3119	0.6943	0.3838	1.7827
0.0938	10.6667	0.1865	0.9762	5.2341	-146.9791	0.7764	0.3313	1.7763
0.0977	10.2400	0.1977	0.3005	1.5197	-44.7288	0.6419	0.1565	0.7913
0.1016	9.8462	0.2778	0.0883	0.3180	33.6889	0.8125	0.1273	0.4582
0.1055	9.4815	0.3572	0.0664	0.1860	68.2694	0.9521	0.1467	0.4106
0.1094	9.1429	0.4037	0.0783	0.1940	36.0679	0.9164	0.1629	0.4036
0.1133	8.8276	0.4028	0.0880	0.2185	18.2940	0.8947	0.1684	0.4182
0.1172	8.5333	0.3836	0.1379	0.3595	-17.7202	0.9459	0.2176	0.5672
0.1211	8.2581	0.3381	0.1305	0.3861	-17.5955	0.8952	0.1881	0.5563
0.1250	8.0000	0.2748	0.1228	0.4469	-17.7024	0.8757	0.1609	0.5854

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AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
A                                           A
        THE OUTPUT FOR CRACK ESTIMATION     A
A                                           A
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
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3 19 30 33
7 24 33

FREQ (HZ)	PHASE XY	PHASE YZ	TIME XY	TIME YZ	VELOCITY XY	VELOCITY YZ	DEPTH CRACK	WAVENGTH YZ	DEPTH WL/2	DEPTH WL/3
3.906	-22.732	36.680	-0.016	0.026	-1051.673	575.081	-13.148	147.221	73.610	49.074
7.813	54.101	3.656	0.019	0.001	883.766	11539.610	102.487	1477.070	738.535	492.357
11.719	201.677	75.476	0.048	0.018	355.612	838.430	11.541	71.546	35.773	23.849
15.625	181.395	95.792	0.032	0.017	527.165	880.813	5.702	56.372	28.186	18.791
19.531	231.082	133.931	0.033	0.019	517.268	787.486	4.440	40.319	20.160	13.440
23.438	256.886	149.695	0.030	0.018	558.371	845.468	4.370	36.073	18.037	12.024
27.344	270.545	270.076	0.027	0.027	618.542	546.721	-0.987	19.994	9.997	6.665
31.250	284.542	316.820	0.025	0.028	672.133	532.637	-1.764	17.044	8.522	5.681
35.156	227.715	238.519	0.018	0.019	944.849	795.926	-1.340	22.640	11.320	7.547
39.063	253.637	315.395	0.018	0.022	942.536	668.805	-2.469	17.121	8.561	5.707
42.969	277.550	314.959	0.018	0.020	947.463	736.703	-1.891	17.145	8.573	5.715
46.875	312.373	312.268	0.019	0.019	918.374	810.602	-0.997	17.293	8.646	5.764
50.781	349.344	290.425	0.019	0.016	889.613	944.199	0.522	18.593	9.297	6.198
54.688	400.723	237.581	0.020	0.012	835.209	1242.997	4.150	22.729	11.365	7.576
58.594	457.492	509.666	0.022	0.024	783.824	620.811	-1.768	10.595	5.298	3.532
62.500	482.930	482.964	0.021	0.021	792.040	698.810	-1.001	11.181	5.590	3.727
66.406	508.724	473.656	0.021	0.020	798.875	757.077	-0.445	11.401	5.700	3.800
70.313	537.707	450.777	0.021	0.018	800.273	842.295	0.446	11.979	5.990	3.993
74.219	581.995	415.018	0.022	0.016	780.452	965.698	2.018	13.012	6.506	4.337
78.125	623.275	402.867	0.022	0.014	767.118	1047.182	3.103	13.404	6.702	4.468
82.031	648.128	418.820	0.022	0.014	774.586	1057.660	3.106	12.893	6.447	4.298
85.938	669.963	450.229	0.022	0.015	785.025	1030.726	2.660	11.994	5.997	3.998
89.844	693.684	495.312	0.021	0.015	792.643	979.497	2.004	10.902	5.451	3.634
93.750	757.614	573.021	0.022	0.017	757.312	883.476	1.416	9.424	4.712	3.141
97.656	776.555	675.271	0.022	0.019	769.625	780.937	0.125	7.997	3.998	2.666
101.563	802.000	753.689	0.022	0.021	775.016	727.671	-0.519	7.165	3.582	2.388
105.469	827.710	788.269	0.022	0.021	779.824	722.509	-0.625	6.850	3.425	2.283
109.375	850.650	756.068	0.022	0.019	786.898	781.180	-0.062	7.142	3.571	2.381
113.281	865.716	738.294	0.021	0.018	800.819	828.558	0.294	7.314	3.657	2.438
117.188	962.535	702.280	0.023	0.017	745.103	901.084	1.779	7.689	3.845	2.563
121.094	1068.884	702.405	0.025	0.016	693.334	930.954	2.913	7.688	3.844	2.563
125.000	1109.210	702.298	0.025	0.016	689.680	961.131	3.346	7.689	3.845	2.563

AVERAGE CRACK DEPTH = 2.8121
STANDARD DEVIATION = 1.7436
UPPER BOUND VALUE = 3.6839
LOWER BOUND VALUE = 1.9404

5.702 4.440 4.370 0.446 2.018 0.294 1.779 2.913
3.346

THE FINAL DEPTH = 2.7587

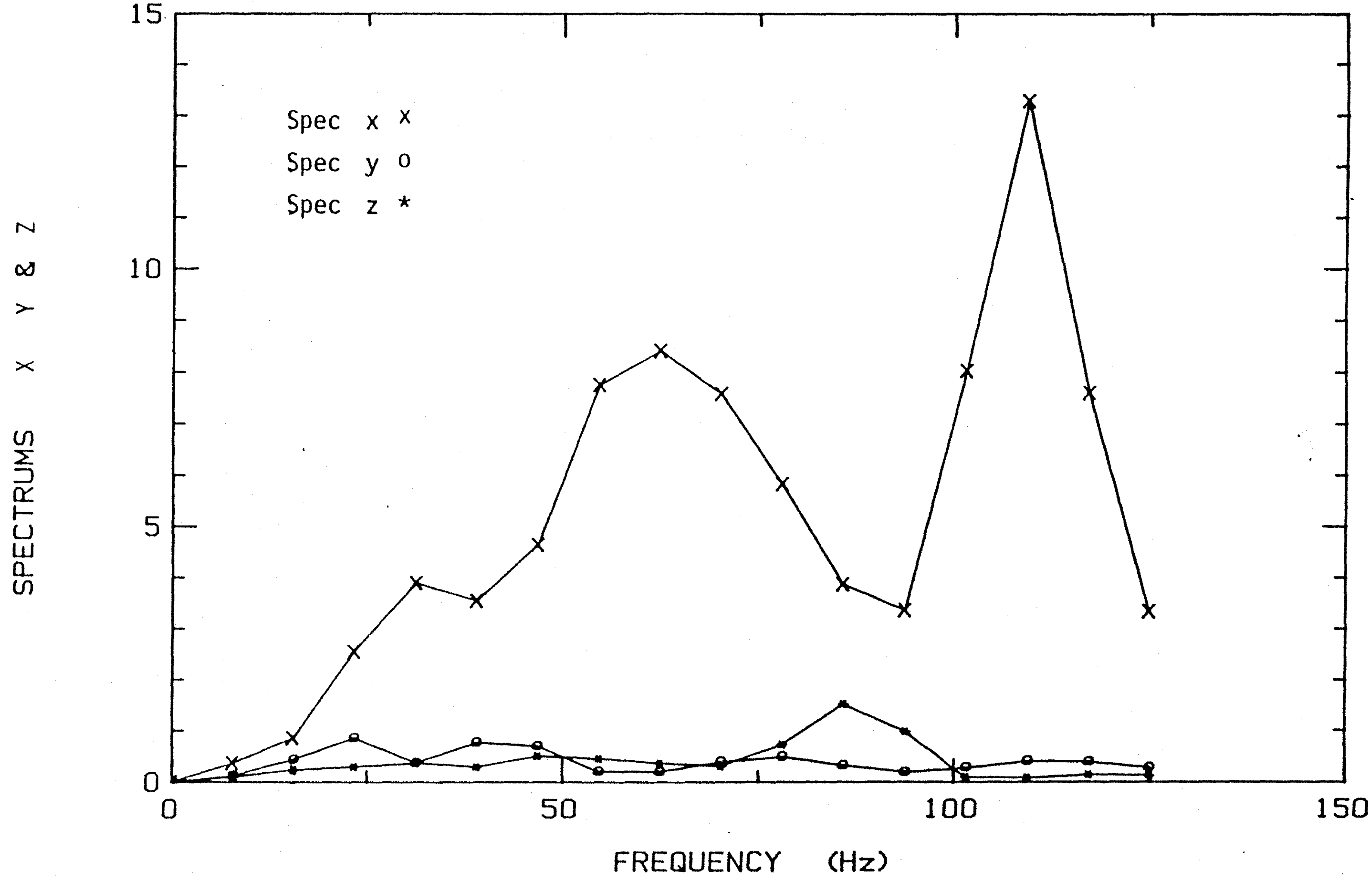

Figure F1. Auto Spectra of Type One Test - 3.0 ft. Trench Depth

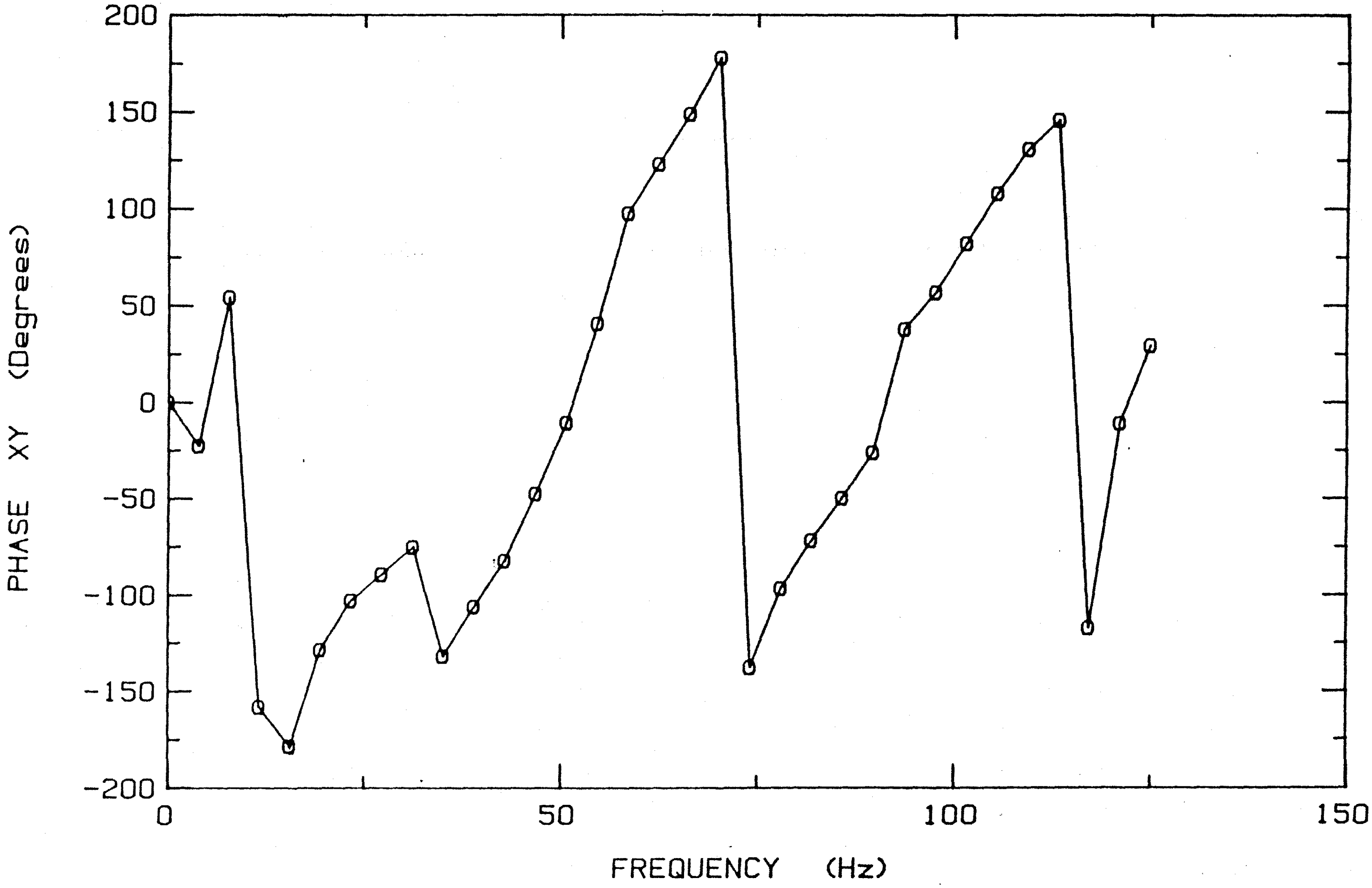

Figure F2. Phase Spectrum "ϕ_{xy}" of Type One Test - 3.0 ft. Trench Depth

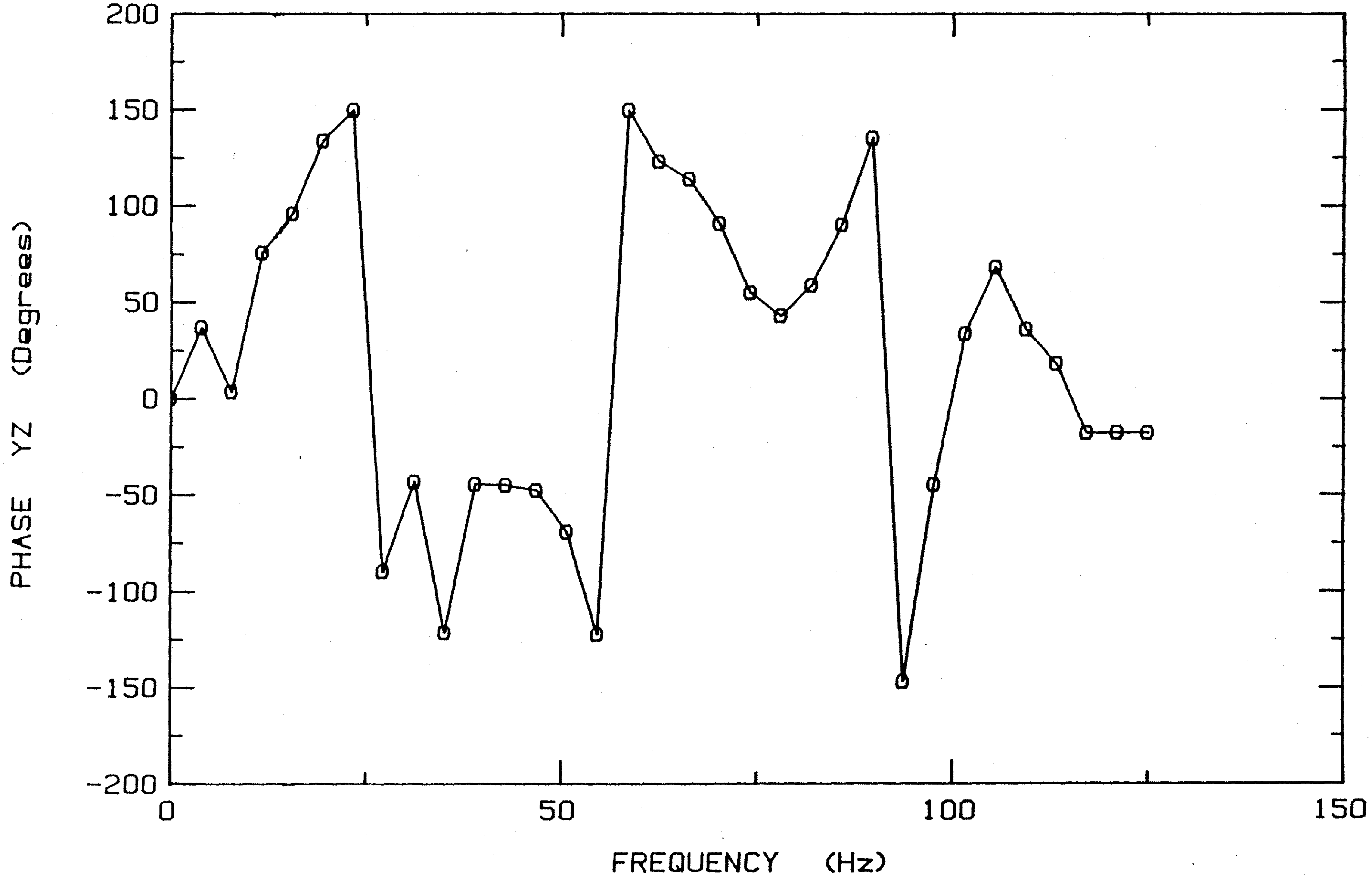

Figure F3. Phase Spectrum "ϕ_{yz}" of Type One Test - 3.0 ft. Trench Depth

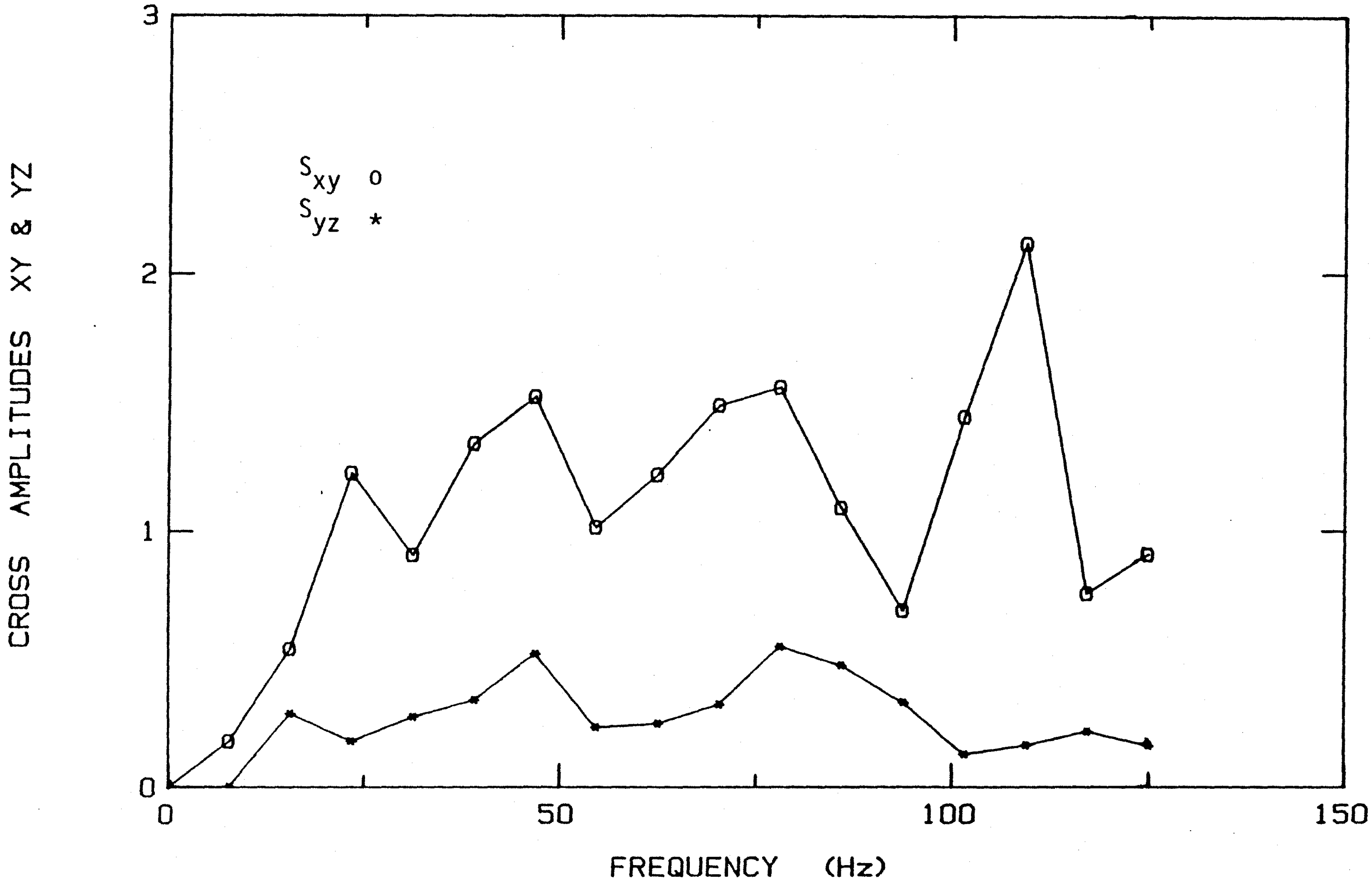

Figure F4. Cross Amplitude Spectra of Type One Test - 3.0 ft. Trench Depth

APPENDIX G

TYPE ONE TEST

RESULTS FOR A TRENCH OF 4.0 FT DEEP

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THIS P    RAM DOES CROSS SPECTRUM USING FFT AND AVERAGE SMOOTHING    Q.

          NO. OF DATA FOR EACH SET =   256
          THE POWER OF 2           =     8
          DEGREE OF FREEDOM        =     1
          SAMPLING INTERVAL        =  1.00  MSEC
          KEY=0, DO AUTO-SPECTRA ONLY
          KEY=1, DO CROSS-SPECTRA
          IN THIS CASE KEY         =     1
          DISTANCE BETWEEN X & Y   = 17.00  FT
          DISTANCE BETWEEN Y & Z   = 15.00  FT
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CROSS SPECTRUM PROPERTIES FOR STATION= 1 AND STATION= 2

FREQUENCY	PERIOD	SPECTRUM-1	SPECTRUM-2	RATIO	PHASE	COHERENCY	CROSS AMPL.	GAIN SPEC.
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0039	256.0000	0.2744	0.0405	0.1476	15.9162	1.0000	0.1054	0.3841
0.0078	128.0000	0.2302	0.0498	0.2163	-86.0971	1.0000	0.1071	0.4650
0 0117	85.3333	0.3633	0.1570	0.4322	153.9043	1.0000	0.2389	0.6574
0.0156	64.0000	1.0904	0.3041	0.2789	-173.7339	1.0000	0.5758	0.5281
0.0195	51.2000	1.6068	0.7462	0.4644	-170.4109	1.0000	1.0950	0.6815
0.0234	42.6667	2.6056	0.9936	0.3813	-116.6966	1.0000	1.6090	0.6175
0.0273	36.5714	2.9423	0.6042	0.2053	-65.1590	1.0000	1.3333	0.4531
0.0313	32.0000	2.7433	0.0977	0.0356	-14.9857	1.0000	0.5177	0.1887
0.0352	28.4444	3.2316	0.2309	0.0714	165.5900	1.0000	0.8638	0.2673
0.0391	25.6000	3.2363	0.6708	0.2073	-133.8894	1.0000	1.4734	0.4553
0.0430	23.2727	3.4255	0.7321	0.2137	-98.4398	1.0000	1.5836	0.4623
0.0469	21.3333	3.6120	0.5502	0.1523	-90.0790	1.0000	1.4098	0.3903
0.0508	19.6923	6.0327	0.3506	0.0581	-51.4013	1.0000	1.4542	0.2411
0.0547	18.2857	8.7255	0.2551	0.0292	4.8233	1.0000	1.4918	0.1710
0.0586	17.0667	10.0149	0.2041	0.0204	32.3853	1.0000	1.4298	0.1428
0.0625	16.0000	9.4809	0.3778	0.0398	72.0734	1.0000	1.8926	0.1996
0.0664	15.0588	8.2101	0.4484	0.0546	119.2810	1.0000	1.9186	0.2337
0.0703	14.2222	8.5158	0.4986	0.0586	167.1929	1.0000	2.0606	0.2420
0.0742	13.4737	5.8332	0.4996	0.0856	-125.6859	1.0000	1.7070	0.2926
0.0781	12.8000	5.8117	0.3720	0.0640	-98.6344	1.0000	1.4703	0.2530
0.0820	12.1905	4.6800	0.3737	0.0798	-76.6889	1.0000	1.3224	0.2826
0.0859	11.6364	2.8645	0.2710	0.0946	-40.0425	1.0000	0.8811	0.3076
0.0898	11.1304	2.2688	0.1396	0.0615	47.8029	1.0000	0.5628	0.2481
0.0938	10.6667	3.9165	0.0812	0.0207	5.3995	1.0000	0.5640	0.1440
0.0977	10.2400	6.9304	0.1935	0.0279	5.0011	1.0000	1.1582	0.1671
0.1016	9.8462	11.1748	0.3518	0.0315	11.7205	1.0000	1.9828	0.1774
0.1055	9.4815	9.1945	0.4249	0.0462	22.7202	1.0000	1.9766	0.2150
0.1094	9.1429	5.9123	0.3261	0.0552	72.1097	1.0000	1.3885	0.2348
0.1133	8.8276	3.8808	0.1254	0.0323	146.1130	1.0000	0.6976	0.1797
0.1172	8.5333	2.7096	0.0850	0.0314	-71.8039	1.0000	0.4798	0.1771
0.1211	8.2581	1.3715	0.2228	0.1624	75.1418	1.0000	0.5527	0.4030
0.1250	8.0000	0.6848	0.1162	0.1696	-23.9693	1.0000	0.2820	0.4119
0.1289	7.7576	0.1415	0.1151	0.8134	-39.4999	1.0000	0.1276	0.9019
0.1328	7.5294	0.1554	0.0827	0.5321	-175.1099	1.0000	0.1134	0.7294
0.1367	7.3143	0.3674	0.1318	0.3588	-112.6038	1.0000	0.2201	0.5990
0.1406	7.1111	0.6595	0.0822	0.1246	-103.3610	1.0000	0.2328	0.3530
0.1445	6.9189	0.5522	0.0238	0.0432	-66.4044	1.0000	0.1147	0.2078

CROSS SPECTRUM PROPERTIES FOR STATION= 1 AND STATION= 3

FREQUENCY	PERIOD	SPECTRUM-1	SPECTRUM-2	RATIO	PHASE	COHERENCY	CROSS AMPL.	GAIN SPEC.
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0039	256.0000	0.2744	0.0699	0.2546	12.3783	1.0000	0.1385	0.5046
0.0078	128.0000	0.2302	0.0911	0.3955	-14.1721	1.0000	0.1448	0.6289
0.0117	85.3333	0.3633	0.0838	0.2306	-86.1078	1.0000	0.1745	0.4802
0.0156	64.0000	1.0904	0.1578	0.1447	-77.0637	1.0000	0.4148	0.3804
0.0195	51.2000	1.6068	0.2389	0.1487	-50.6920	1.0000	0.6196	0.3856
0.0234	42.6667	2.6056	0.2048	0.0786	82.2549	1.0000	0.7305	0.2804
0.0273	36.5714	2.9423	0.2757	0.0937	-103.8247	1.0000	0.9006	0.3061
0.0313	32.0000	2.7433	0.3871	0.1411	-35.3910	1.0000	1.0305	0.3756
0.0352	28.4444	3.2316	0.1909	0.0591	15.1250	1.0000	0.7854	0.2430
0.0391	25.6000	3.2363	0.0857	0.0265	-140.7018	1.0000	0.5267	0.1627
0.0430	23.2727	3.4255	0.4374	0.1277	-93.9695	1.0000	1.2240	0.3573
0.0469	21.3333	3.6120	0.5166	0.1430	-98.7525	1.0000	1.3660	0.3782
0.0508	19.6923	6.0327	0.4264	0.0707	-102.1753	1.0000	1.6038	0.2659
0.0547	18.2857	8.7255	0.4075	0.0467	-113.9801	1.0000	1.8856	0.2161
0.0586	17.0667	10.0149	0.4342	0.0434	-115.1313	1.0000	2.0853	0.2082
0.0625	16.0000	9.4809	0.2053	0.0217	-146.1609	1.0000	1.3950	0.1471
0.0664	15.0588	8.2101	0.3424	0.0417	-113.3970	1.0000	1.6767	0.2042
0.0703	14.2222	8.5158	0.2386	0.0280	-85.8530	1.0000	1.4254	0.1674
0.0742	13.4737	5.8332	0.3891	0.0667	-82.2540	1.0000	1.5066	0.2583
0.0781	12.8000	5.8117	0.6199	0.1067	-65.2292	1.0000	1.8981	0.3266
0.0820	12.1905	4.6800	0.9279	0.1983	-20.4085	1.0000	2.0839	0.4453
0.0859	11.6364	2.8645	1.4114	0.4927	48.4135	1.0000	2.0107	0.7019
0.0898	11.1304	2.2688	1.4250	0.6281	-154.8250	1.0000	1.7981	0.7925
0.0938	10.6667	3.9165	0.3995	0.1020	-49.5491	1.0000	1.2509	0.3194
0.0977	10.2400	6.9304	0.0770	0.0111	-2.8379	1.0000	0.7307	0.1054
0.1016	9.8462	11.1748	0.0435	0.0039	-32.5207	1.0000	0.6976	0.0624
0.1055	9.4815	9.1945	0.1033	0.0112	60.2925	1.0000	0.9746	0.1060
0.1094	9.1429	5.9123	0.0939	0.0159	167.8085	1.0000	0.7453	0.1261
0.1133	8.8276	3.8808	0.0938	0.0242	163.6341	1.0000	0.6034	0.1555
0.1172	8.5333	2.7096	0.1100	0.0406	-96.9773	1.0000	0.5460	0.2015
0.1211	8.2581	1.3715	0.0774	0.0565	-145.7221	1.0000	0.3259	0.2376
0.1250	8.0000	0.6848	0.0257	0.0375	73.4344	1.0000	0.1326	0.1936
0.1289	7.7576	0.1415	0.0734	0.5187	71.3242	1.0000	0.1019	0.7202
0.1328	7.5294	0.1554	0.0413	0.2654	-29.5247	0.0000	0.0000	0.0000
0.1367	7.3143	0.3674	0.0276	0.0752	104.5626	1.0000	0.1007	0.2742
0.1406	7.1111	0.6595	0.0363	0.0550	88.4036	1.0000	0.1547	0.2345
0.1445	6.9189	0.5522	0.0461	0.0834	115.2921	1.0000	0.1595	0.2889
0.1484	6.7368	0.5697	0.0512	0.0899	143.7136	1.0000	0.1708	0.2998
0.1523	6.5641	0.4932	0.0259	0.0525	168.0254	1.0000	0.1130	0.2292
0.1563	6.4000	0.4135	0.0245	0.0592	145.7354	1.0000	0.1006	0.2434

CROSS SPECTRUM PROPERTIES FOR STATION= 2 AND STATION= 3

FREQUENCY	PERIOD	SPECTRUM-1	SPECTRUM-2	RATIO	PHASE	COHERENCY	CROSS AMPL.	GAIN SPEC.
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0039	256.0000	0.0405	0.0699	1.7256	-3.5379	0.0000	0.0000	0.0000
0.0078	128.0000	0.0498	0.0911	1.8289	71.9251	0.0000	0.0000	0.0000
0.0117	85.3333	0.1570	0.0838	0.5335	119.9879	1.0000	0.1147	0.7304
0.0156	64.0000	0.3041	0.1578	0.5188	96.6703	1.0000	0.2190	0.7203
0.0195	51.2000	0.7462	0.2389	0.3202	119.7189	1.0000	0.4222	0.5659
0.0234	42.6667	0.9936	0.2048	0.2061	-161.0485	1.0000	0.4511	0.4540
0.0273	36.5714	0.6042	0.2757	0.4563	-38.6656	1.0000	0.4081	0.6755
0.0313	32.0000	0.0977	0.3871	3.9627	-20.4053	1.0000	0.1945	1.9907
0.0352	28.4444	0.2309	0.1909	0.8267	-150.4650	1.0000	0.2099	0.9093
0.0391	25.6000	0.6708	0.0857	0.1278	-6.8123	1.0000	0.2398	0.3575
0.0430	23.2727	0.7321	0.4374	0.5974	4.4703	1.0000	0.5659	0.7729
0.0469	21.3333	0.5502	0.5166	0.9389	-8.6734	1.0000	0.5331	0.9690
0.0508	19.6923	0.3506	0.4264	1.2163	-50.7740	1.0000	0.3866	1.1029
0.0547	18.2857	0.2551	0.4075	1.5975	-118.8035	1.0000	0.3224	1.2639
0.0586	17.0667	0.2041	0.4342	2.1272	-147.5165	1.0000	0.2977	1.4585
0.0625	16.0000	0.3778	0.2053	0.5433	141.7658	1.0000	0.2785	0.7371
0.0664	15.0588	0.4484	0.3424	0.7638	127.3221	1.0000	0.3918	0.8739
0.0703	14.2222	0.4986	0.2386	0.4785	106.9542	1.0000	0.3449	0.6917
0.0742	13.4737	0.4996	0.3891	0.7790	43.4319	1.0000	0.4409	0.8826
0.0781	12.8000	0.3720	0.6199	1.6666	33.4052	1.0000	0.4802	1.2910
0.0820	12.1905	0.3737	0.9279	2.4834	56.2803	1.0000	0.5888	1.5759
0.0859	11.6364	0.2710	1.4114	5.2075	88.4560	1.0000	0.6185	2.2820
0.0898	11.1304	0.1396	1.4250	10.2060	157.3723	1.0000	0.4461	3.1947
0.0938	10.6667	0.0812	0.3995	4.9181	-54.9487	1.0000	0.1801	2.2177
0.0977	10.2400	0.1935	0.0770	0.3980	-7.8390	1.0000	0.1221	0.6309
0.1016	9.8462	0.3518	0.0435	0.1238	-44.2413	1.0000	0.1238	0.3518
0.1055	9.4815	0.4249	0.1033	0.2431	37.5723	1.0000	0.2095	0.4930
0.1094	9.1429	0.3261	0.0939	0.2881	95.6987	1.0000	0.1750	0.5368
0.1133	8.8276	0.1254	0.0938	0.7482	17.5211	1.0000	0.1085	0.8650
0.1172	8.5333	0.0850	0.1100	1.2949	-25.1735	0.0000	0.0000	0.0000
0.1211	8.2581	0.2228	0.0774	0.3477	139.1363	1.0000	0.1314	0.5896

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AAAAAAA AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
A                                           A
A        THE OUTPUT FOR CRACK ESTIMATION    A
A                                           A
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
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FREQ (HZ)	PHASE XY	PHASE YZ	TIME XY	TIME YZ	VELOCITY XY	VELOCITY YZ	DEPTH CRACK	WAVENGTH YZ	DEPTH WL/2	DEPTH WL/3
3.906	15.916	-3.538	0.011	-0.003	1502.006	-5962.141	-42.240	-1526.308	-763.154	-508.769
7.813	-86.097	71.925	-0.031	0.026	-555.332	586.548	-17.478	75.078	37.539	25.026
11.719	153.904	119.988	0.036	0.028	465.996	527.397	1.120	45.005	22.502	15.002
15.625	186.266	96.670	0.033	0.017	513.378	872.812	5.951	55.860	27.930	18.620
19.531	189.589	119.719	0.027	0.017	630.475	880.970	3.377	45.106	22.553	15.035
23.438	243.303	198.951	0.029	0.024	589.542	636.147	0.672	27.142	13.571	9.047
27.344	294.841	321.334	0.030	0.033	567.573	459.510	-1.618	16.805	8.402	5.602
31.250	345.014	339.594	0.031	0.030	554.325	496.916	-0.880	15.901	7.951	5.300
35.156	525.590	209.535	0.042	0.017	409.362	906.024	10.313	25.771	12.886	8.590
39.063	586.110	353.188	0.042	0.025	407.880	597.239	3.946	15.289	7.645	5.096
42.969	621.560	364.470	0.040	0.024	423.079	636.626	4.290	14.816	7.408	4.939
46.875	629.921	351.326	0:037	0.021	455.414	720.484	4.947	15.370	7.685	5.123
50.781	668.599	309.226	0.037	0.017	464.825	886.791	7.716	17.463	8.731	5.821
54.688	724.823	241.197	0.037	0.012	461.750	1224.365	14.038	22.388	11.194	7.463
58.594	752.385	212.483	0.036	0.010	476.609	1489.087	18.057	25.414	12.707	8.471
62.500	792.073	501.766	0.035	0.022	482.910	672.625	3.339	10.762	5.381	3.587
66.406	839.281	487.322	0.035	0.020	484.231	735.846	4.417	11.081	5.540	3.694
70.313	887.193	466.954	0.035	0.018	485.027	813.115	5.750	11.564	5.782	3.855
74.219	954.314	403.432	0.036	0.015	475.964	993.430	9.241	13.385	6.693	4.462
78.125	981.365	393.405	0.035	0.014	487.204	1072.368	10.209	13.726	6.863	4.575
82.031	1003.311	416.280	0.034	0.014	500.375	1064.112	9.576	12.972	6.486	4.324
85.938	1039.957	448.456	0.034	0.014	505.730	1034.801	8.892	12.041	6.021	4.014
89.844	1127.803	517.372	0.035	0.016	487.535	937.732	7.849	10.437	5.219	3.479
93.750	1085.399	665.051	0.032	0.020	528.607	761.219	3.740	8.120	4.060	2.707
97.656	1085.001	712.161	0.031	0.020	550.835	740.484	2.927	7.583	3.791	2.528
101.563	1091.720	675.759	0.030	0.018	569.342	811.588	3.617	7.991	3.996	2.664
105.469	1102.720	757.572	0.029	0.020	585.343	751.785	2.417	7.128	3.564	2.376
109.375	1152.110	815.699	0.029	0.021	581.000	724.073	2.093	6.620	3.310	2.207
113.281	1226.113	737.521	0.030	0.018	565.430	829.426	3.969	7.322	3.661	2.441
117.188	1368.196	694.826	0.032	0.016	524.185	910.749	6.268	7.772	3.886	2.591
121.094	1515.142	859.136	0.035	0.020	489.125	761.121	4.727	6.285	3.143	2.095

AVERAGE CRACK DEPTH = 4.2840
STANDARD DEVIATION = 2.3812
UPPER BOUND VALUE = 5.4746
LOWER BOUND VALUE = 3.0934

THE FINAL DEPTH = 4.0699

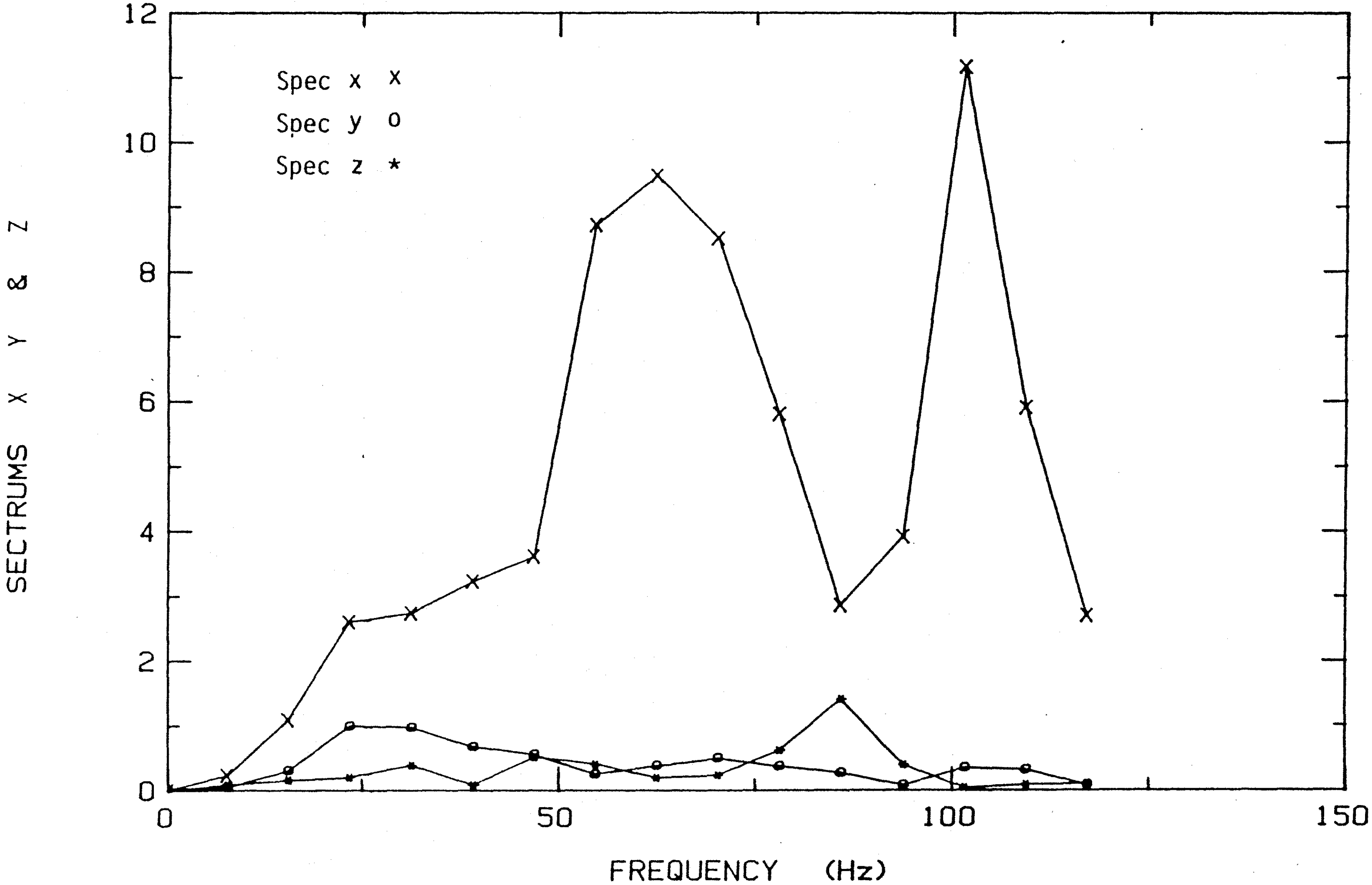

Figure G1. Auto Spectra of Type One Test - 4.0 ft. Trench Depth

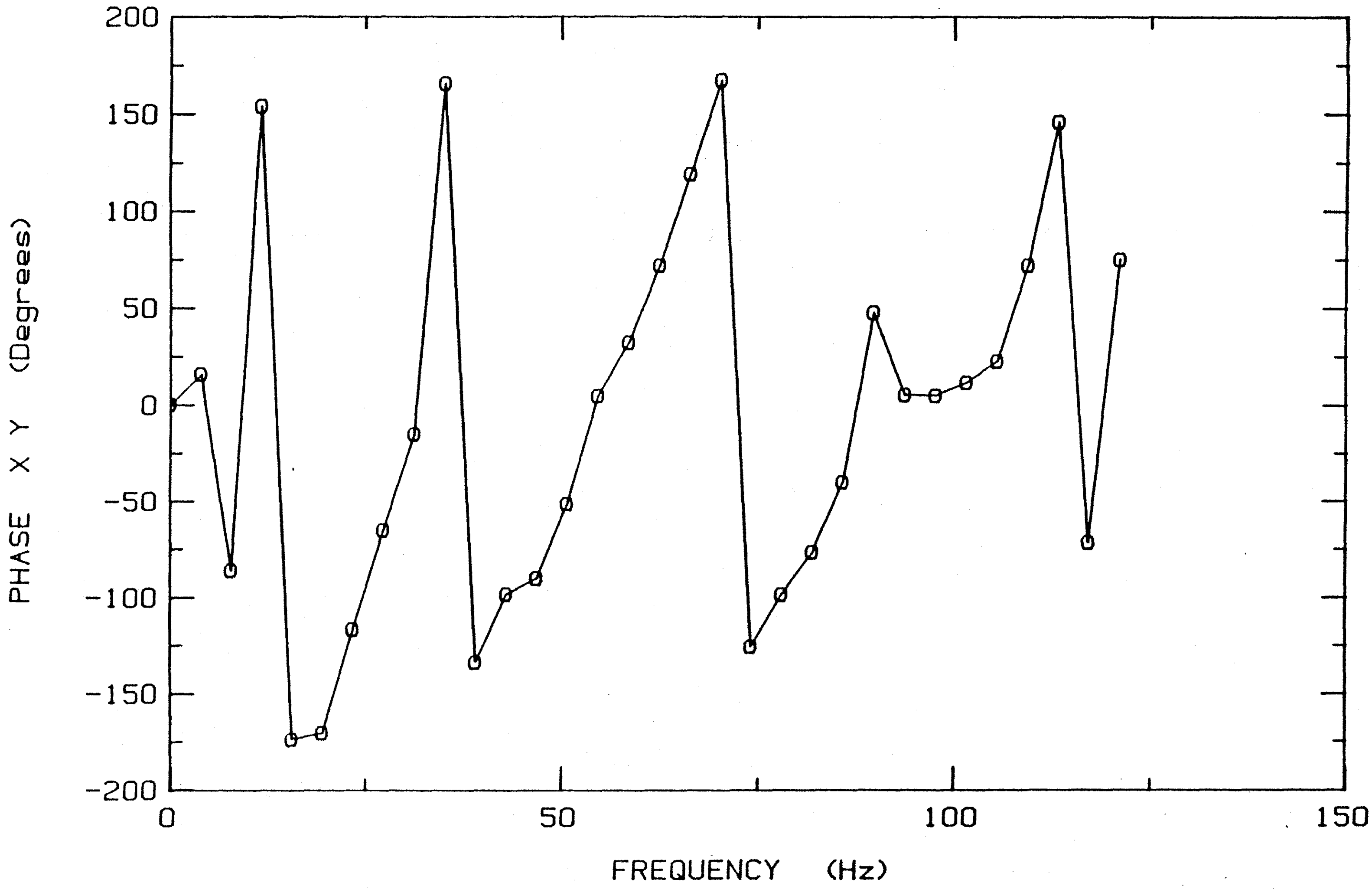

Figure G2. Phase Spectrum "ϕ_{xy}" of Type One Test - 4.0 ft. Trench Depth

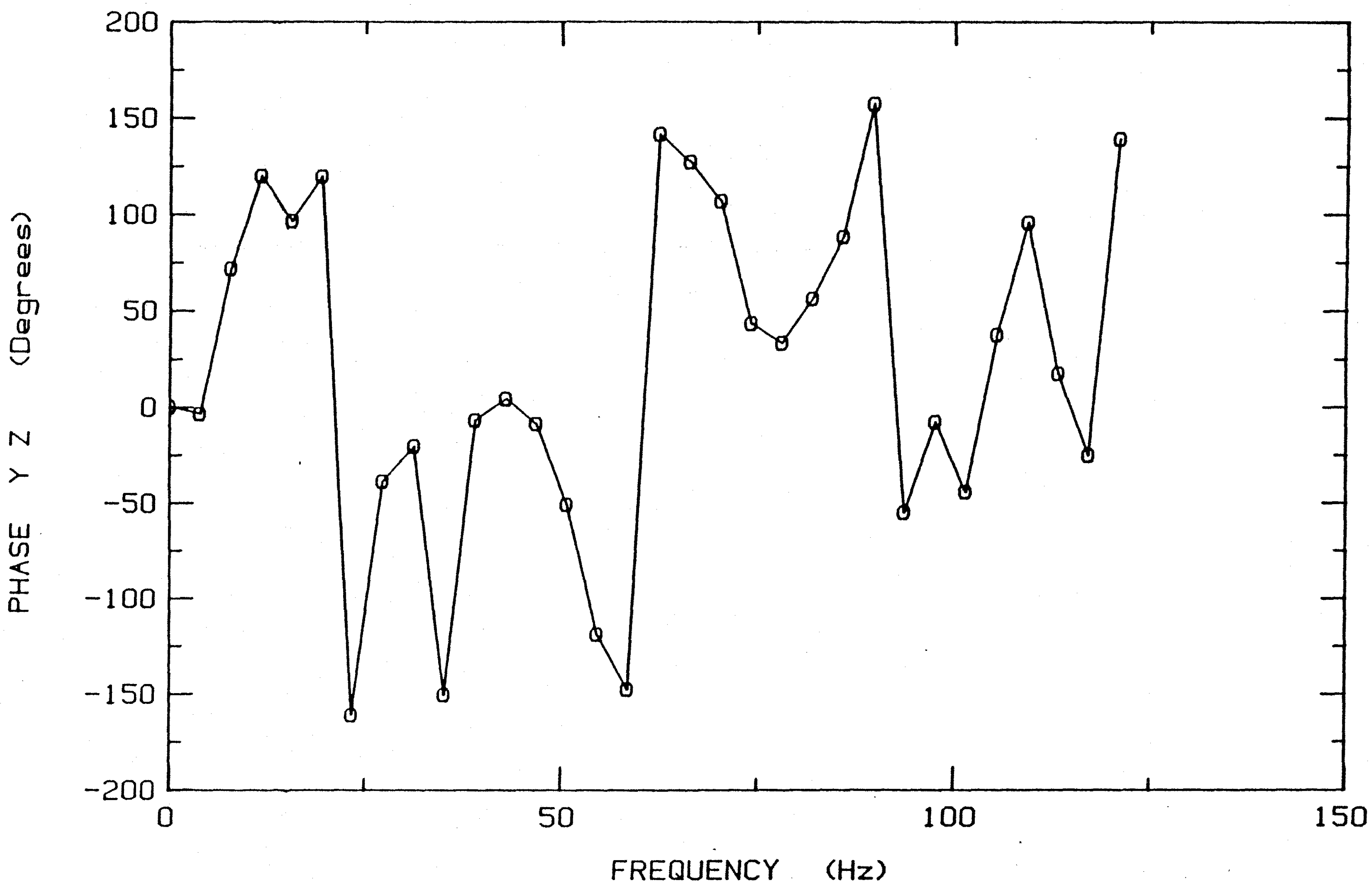

Figure G3. Phase Spectrum "ϕ_{yz}" of Type One Test - 4.0 ft. Trench Depth

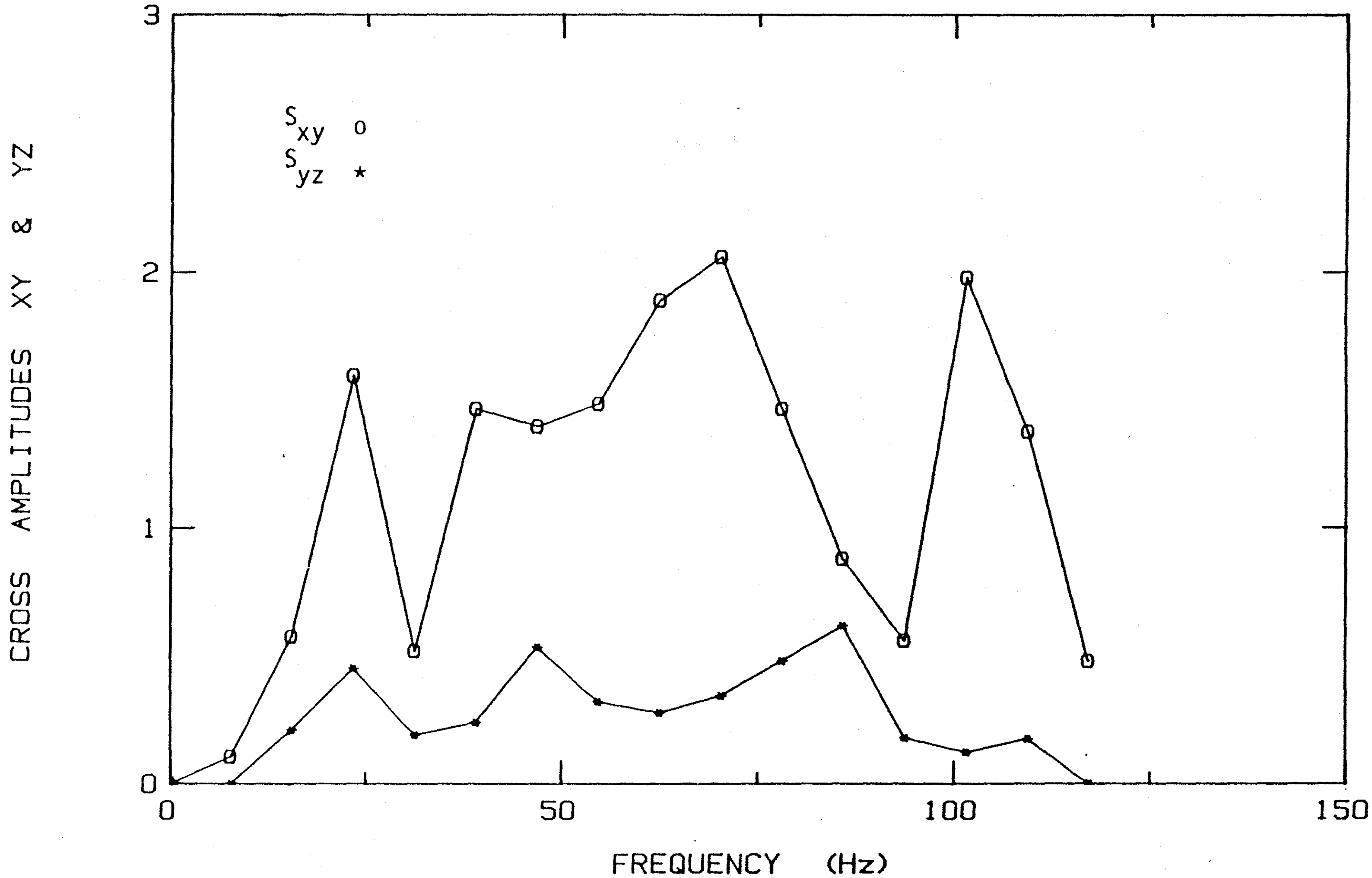

Figure G4. Cross Amplitude Spectra of Type One Test - 4.0 ft. Trench Depth

APPENDIX H

TYPE TWO TEST

RESULTS FOR A CRACK 1.25 FT DEEP

THIS [illegible]GRAM DOES CROSS SPECTRUM USING FFT AND AVERAGE SMOOTHIN[illegible] [illegible]ECQ.

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NO. OF DATA FOR EACH SET =  2048
THE POWER OF 2           =    11
DEGREE OF FREEDOM        =     1
SAMPLING INTERVAL        =  0.05  MSEC
KEY=0, DO AUTO-SPECTRA ONLY
KEY=1, DO CROSS-SPECTRA
IN THIS CASE KEY         =     1
DISTANCE BETWEEN X & Y   =  5.00  FT
DISTANCE BETWEEN Y & Z   =  5.00  FT
```

CROSS SPECTRUM PROPERTIES FOR STATION= 1 AND STATION= 2

FREQUENCY	PERIOD	SPECTRUM-1	SPECTRUM-2	RATIO	PHASE	COHERENCY	CROSS AMPL.	GAIN SPEC.
0.0000	0.0000	0.0027	0.0027	0.0000	0.0000	0.0000	0.0000	0.0000
0.0098	102.4000	2.2706	1.2271	0.5404	-1.7689	1.0000	1.6692	0.7351
0.0195	51.2000	11.2318	4.2777	0.3809	-0.1923	1.0000	6.9315	0.6171
0.0293	34.1333	18.3099	3.3146	0.1810	-33.1080	1.0000	7.7904	0.4255
0.0391	25.6000	13.1006	7.8596	0.5999	-39.6922	1.0000	10.1472	0.7746
0.0488	20.4800	18.2780	7.5624	0.4137	-57.9622	1.0000	11.7570	0.6432
0.0586	17.0667	20.8886	11.5455	0.5527	-48.4527	1.0000	15.5296	0.7434
0.0684	14.6286	26.6874	13.4032	0.5022	-31.6727	1.0000	18.9128	0.7087
0.0781	12.8000	36.0603	9.0589	0.2512	-59.0706	1.0000	18.0739	0.5012
0.0879	11.3778	31.5513	7.6183	0.2415	-86.5082	1.0000	15.5038	0.4914
0.0977	10.2400	23.9418	5.1631	0.2157	-107.8873	1.0000	11.1182	0.4644
0.1074	9.3091	19.0439	3.8139	0.2003	-135.1326	1.0000	8.5224	0.4475
0.1172	8.5333	13.8305	2.7860	0.2014	-178.8678	1.0000	6.2073	0.4488.
0.1270	7.8769	8.4015	2.2888	0.2724	152.4977	1.0000	4.3851	0.5219
0.1367	7.3143	4.2265	1.5634	0.3699	134.0260	1.0000	2.5706	0.6082
0.1465	6.8267	2.8429	0.8531	0.3001	136.4668	1.0000	1.5573	0.5478
0.1563	6.4000	1.8869	0.2457	0.1302	133.5795	1.0000	0.6809	0.3609
0.1660	6.0235	1.2409	0.1234	0.0995	30.8936	1.0000	0.3913	0.3154
0.1758	5.6889	1.6833	0.3336	0.1982	29.3272	1.0000	0.7494	0.4452
0.1855	5.3895	1.7621	0.3542	0.2010	67.7965	1.0000	0.7900	0.4483
0.1953	5.1200	1.8360	0.2126	0.1158	90.7923	1.0000	0.6248	0.3403
0.2051	4.8762	1.3434	0.0622	0.0463	140.6332	1.0000	0.2890	0.2151
0.2148	4.6545	0.6652	0.1177	0.1770	-160.7647	1.0000	0.2799	0.4207
0.2246	4.4522	0.5512	0.2043	0.3707	-137.9363	1.0000	0.3356	0.6089
0.2344	4.2667	0.6036	0.2310	0.3828	-135.2995	1.0000	0.3734	0.6187
0.2441	4.0960	0.4929	0.1710	0.3470	-153.0414	1.0000	0.2904	0.5891
0.2539	3.9385	0.3197	0.1688	0.5280	-150.9451	1.0000	0.2323	0.7266
0.2637	3.7926	0.2857	0.0956	0.3345	-45.2801	1.0000	0.1652	0.5784
0.2734	3.6571	0.6213	0.0690	0.1111	41.3519	1.0000	0.2071	0.3333
0.2832	3.5310	0.5743	0.1054	0.1835	43.8390	1.0000	0.2460	0.4283
0.2930	3.4133	0.4399	0.1289	0.2930	40.1270	1.0000	0.2381	0.5413
0.3027	3.3032	0.3097	0.0944	0.3049	39.4602	1.0000	0.1710	0.5522
0.3125	3.2000	0.3191	0.0580	0.1818	3.8945	1.0000	0.1360	0.4263
0.3223	3.1030	0.2945	0.0944	0.3205	-48.3727	1.0000	0.1668	0.5662
0.3320	3.0118	0.2197	0.0896	0.4079	-74.9249	1.0000	0.1403	0.6387

CROSS SPECTRUM PROPERTIES FOR STATION= 1 AND STATION= 3

FREQUENCY	PERIOD	SPECTRUM-1	SPECTRUM-2	RATIO	PHASE	COHERENCY	CROSS AMPL.	GAIN SPEC.
0.0000	0.0000	0.0027	0.0027	0.0000	0.0000	0.0000	0.0000	0.0000
0.0098	102.4000	2.2706	0.8706	0.3834	28.0479	1.0000	1.4060	0.6192
0.0195	51.2000	11.2318	2.3315	0.2076	65.2962	1.0000	5.1173	0.4556
0.0293	34.1333	18.3099	1.1353	0.0620	-47.1328	1.0000	4.5594	0.2490
0.0391	25.6000	13.1006	6.7258	0.5134	53.0299	1.0000	9.3868	0.7165
0.0488	20.4800	18.2780	6.9187	0.3785	70.4716	1.0000	11.2455	0.6152
0.0586	17.0667	20.8886	8.0835	0.3870	103.5632	1.0000	12.9943	0.6221
0.0684	14.6286	26.6874	6.7792	0.2540	145.3135	1.0000	13.4506	0.5040
0.0781	12.8000	36.0603	4.4444	0.1232	118.0418	1.0000	12.6597	0.3511
0.0879	11.3778	31.5513	4.6542	0.1475	111.3465	1.0000	12.1180	0.3841
0.0977	10.2400	23.9418	2.7961	0.1168	117.3727	1.0000	8.1819	0.3417
0.1074	9.3091	19.0439	1.9976	0.1049	110.6344	1.0000	6.1678	0.3239
0.1172	8.5333	13.8305	0.9892	0.0715	120.1221	1.0000	3.6988	0.2674
0.1270	7.8769	8.4015	0.5905	0.0703	85.9161	1.0000	2.2273	0.2651
0.1367	7.3143	4.2265	0.0569	0.0135	-122.3787	1.0000	0.4902	0.1160
0.1465	6.8267	2.8429	0.2266	0.0797	-58.3172	1.0000	0.8026	0.2823
0.1563	6.4000	1.8869	0.2677	0.1419	-77.0440	1.0000	0.7108	0.3767
0.1660	6.0235	1.2409	0.3256	0.2624	-24.2032	1.0000	0.6356	0.5122
0.1758	5.6889	1.6833	0.2995	0.1779	35.8560	1.0000	0.7100	0.4218
0.1855	5.3895	1.7621	0.2913	0.1653	81.0594	1.0000	0.7164	0.4066
0.1953	5.1200	1.8360	0.1745	0.0951	143.5398	1.0000	0.5660	0.3083
0.2051	4.8762	1.3434	0.1600	0.1191	152.5145	1.0000	0.4636	0.3451
0.2148	4.6545	0.6652	0.1935	0.2909	-164.4737	1.0000	0.3588	0.5394
0.2246	4.4522	0.5512	0.1556	0.2823	-124.1365	1.0000	0.2928	0.5313
0.2344	4.2667	0.6036	0.1154	0.1911	-77.2580	1.0000	0.2639	0.4372
0.2441	4.0960	0.4929	0.0963	0.1953	-24.7949	1.0000	0.2178	0.4420
0.2539	3.9385	0.3197	0.0793	0.2480	24.4306	1.0000	0.1592	0.4980
0.2637	3.7926	0.2857	0.0301	0.1055	134.5044	0.0000	0.0000	0.0000
0.2734	3.6571	0.6213	0.0145	0.0233	-90.3998	0.0000	0.0000	0.0000
0.2832	3.5310	0.5743	0.0262	0.0457	-91.6945	1.0000	0.1227	0.2137

CROSS SPECTRUM PROPERTIES FOR STATION= 2 AND STATION= 3

FREQUENCY	PERIOD	SPECTRUM-1	SPECTRUM-2	RATIO	PHASE	COHERENCY	CROSS AMPL.	GAIN SPEC.
0.0000	0.0000	0.0027	0.0027	0.0000	0.0000	0.0000	0.0000	0.0000
0.0098	102.4000	1.2271	0.8706	0.7095	29.8168	1.0000	1.0336	0.8423
0.0195	51.2000	4.2777	2.3315	0.5450	65.4884	1.0000	3.1581	0.7383
0.0293	34.1333	3.3146	1.1353	0.3425	-14.0247	1.0000	1.9399	0.5853
0.0391	25.6000	7.8596	6.7258	0.8558	92.7220	1.0000	7.2706	0.9251
0.0488	20.4800	7.5624	6.9187	0.9149	128.4337	1.0000	7.2334	0.9565
0.0586	17.0667	11.5455	8.0835	0.7001	152.0158	1.0000	9.6606	0.8367
0.0684	14.6286	13.4032	6.7792	0.5058	176.9862	1.0000	9.5322	0.7112
0.0781	12.8000	9.0589	4.4444	0.4906	177.1125	1.0000	6.3452	0.7004
0.0879	11.3778	7.6183	4.6542	0.6109	-162.1454	1.0000	5.9546	0.7816
0.0977	10.2400	5.1631	2.7961	0.5416	-134.7401	1.0000	3.7995	0.7359
0.1074	9.3091	3.8139	1.9976	0.5238	-114.2331	1.0000	2.7602	0.7237
0.1172	8.5333	2.7860	0.9892	0.3551	-61.0101	1.0000	1.6601	0.5959
0.1270	7.8769	2.2888	0.5905	0.2580	-66.5815	1.0000	1.1625	0.5079
0.1367	7.3143	1.5634	0.0569	0.0364	103.5953	1.0000	0.2981	0.1907
0.1465	6.8267	0.8531	0.2266	0.2656	165.2160	1.0000	0.4397	0.5154
0.1563	6.4000	0.2457	0.2677	1.0896	149.3766	1.0000	0.2565	1.0438
0.1660	6.0235	0.1234	0.3256	2.6380	-55.0969	1.0000	0.2004	1.6242
0.1758	5.6889	0.3336	0.2995	0.8977	6.5288	1.0000	0.3161	0.9475
0.1855	5.3895	0.3542	0.2913	0.8224	13.2629	1.0000	0.3212	0.9069
0.1953	5.1200	0.2126	0.1745	0.8209	52.7476	1.0000	0.1926	0.9060
0.2051	4.8762	0.0622	0.1600	2.5731	11.8814	0.0000	0.0000	0.0000
0.2148	4.6545	0.1177	0.1935	1.6437	-3.7089	1.0000	0.1510	1.2821
0.2246	4.4522	0.2043	0.1556	0.7615	13.7998	1.0000	0.1783	0.8726
0.2344	4.2667	0.2310	0.1154	0.4993	58.0416	1.0000	0.1632	0.7066
0.2441	4.0960	0.1710	0.0963	0.5629	128.2465	1.0000	0.1283	0.7503
0.2539	3.9385	0.1688	0.0793	0.4696	175.3757	1.0000	0.1157	0.6853

THE OUTPUT FOR CRACK ESTIMATION

FREQ (HZ)	PHASE XY	PHASE YZ	TIME XY	TIME YZ	VELOCITY XY	VELOCITY YZ	DEPTH CRACK	WAVENGTH YZ	DEPTH WL/2	DEPTH WL/3
9.766	-1.769	29.817	-0.001	0.008	-9937.098	589.538	-2.648	60.369	30.184	20.123
19.531	359.808	65.488	0.051	0.009	97.708	536.832	11.236	27.486	13.743	9.162
29.297	326.892	-14.025	0.031	-0.001	161.321	-3760.104	-60.771	-128.345	-64.172	-42.782
39.063	320.308	92.722	0.023	0.007	219.516	758.315	6.136	19.413	9.706	6.471
48.828	302.038	128.434	0.017	0.007	290.992	684.327	3.379	14.015	7.008	4.672
58.594	311.547	152.016	0.015	0.007	338.532	693.802	2.624	11.841	5.920	3.947
68.359	328.327	176.986	0.013	0.007	374.769	695.234	2.138	10.170	5.085	3.390
78.125	300.929	177.112	0.011	0.006	467.302	793.987	1.748	10.163	5.082	3.388
87.891	273.492	197.855	0.009	0.006	578.457	799.593	0.956	9.098	4.549	3.033
97.656	252.113	225.260	0.007	0.006	697.233	780.349	0.298	7.991	3.995	2.664
107.422	224.867	245.767	0.006	0.006	859.882	786.760	-0.213	7.324	3.662	2.441
117.188	181.132	298.990	0.004	0.007	1164.551	705.501	-0.985	6.020	3.010	2.007
126.953	512.498	293.418	0.011	0.006	445.886	778.805	1.867	6.135	3.067	2.045
136.719	494.026	463.595	0.010	0.009	498.140	530.838	0.164	3.883	1.941	1.294
146.484	496.467	525.216	0.009	0.010	531.097	502.026	-0.137	3.427	1.714	1.142
156.250	493.579	509.376	0.009	0.009	569.817	552.146	-0.078	3.534	1.767	1.178
166.016	390.894	664.903	0.007	0.011	764.474	449.431	-1.030	2.707	1.354	0.902
175.781	389.327	726.529	0.006	0.011	812.701	435.504	-1.160	2.478	1.239	0.826
185.547	427.796	733.263	0.006	0.011	780.709	455.477	-1.041	2.455	1.227	0.818
195.313	450.792	772.748	0.006	0.011	779.877	454.951	-1.042	2.329	1.165	0.776
205.078	500.633	731.881	0.007	0.010	737.348	504.373	-0.790	2.459	1.230	0.820
214.844	559.235	716.291	0.007	0.009	691.514	539.891	-0.548	2.513	1.256	0.838
224.609	582.063	733.800	0.007	0.009	694.593	550.964	-0.517	2.453	1.226	0.818
234.375	584.700	778.042	0.007	0.009	721.524	542.227	-0.621	2.314	1.157	0.771
244.141	566.958	848.246	0.006	0.010	775.107	518.073	-0.829	2.122	1.061	0.707
253.906	569.055	895.375	0.006	0.010	803.141	510.435	-0.911	2.010	1.005	0.670

AVERAGE CRACK DEPTH = 3.0544
STANDARD DEVIATION = 3.1786
UPPER BOUND VALUE = 4.6437
LOWER BOUND VALUE = 1.4651

THE FINAL DEPTH = 2.3510

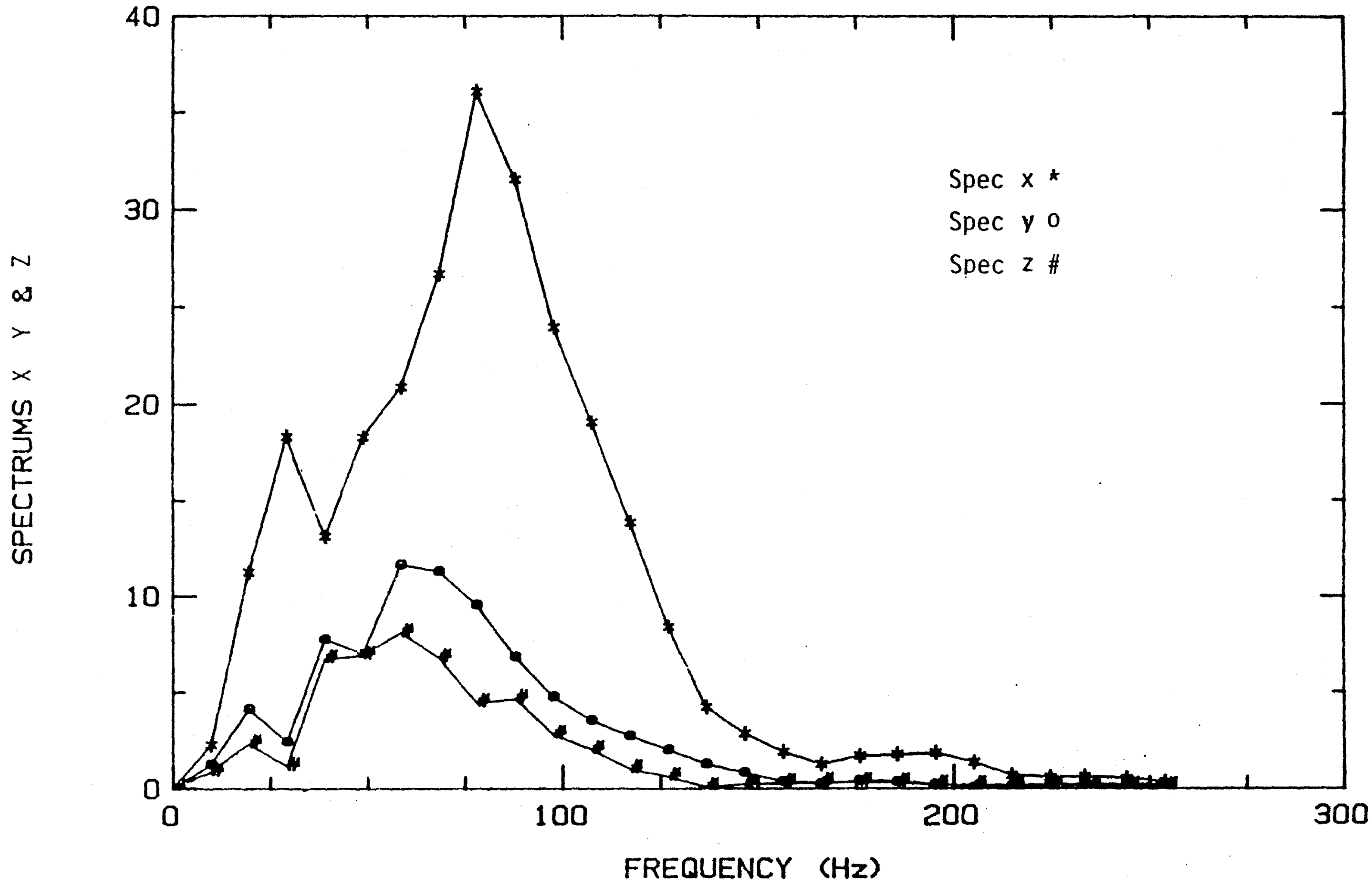

Figure H1. Auto Spectra of Type Two Test - 1.25 ft. Crack Depth

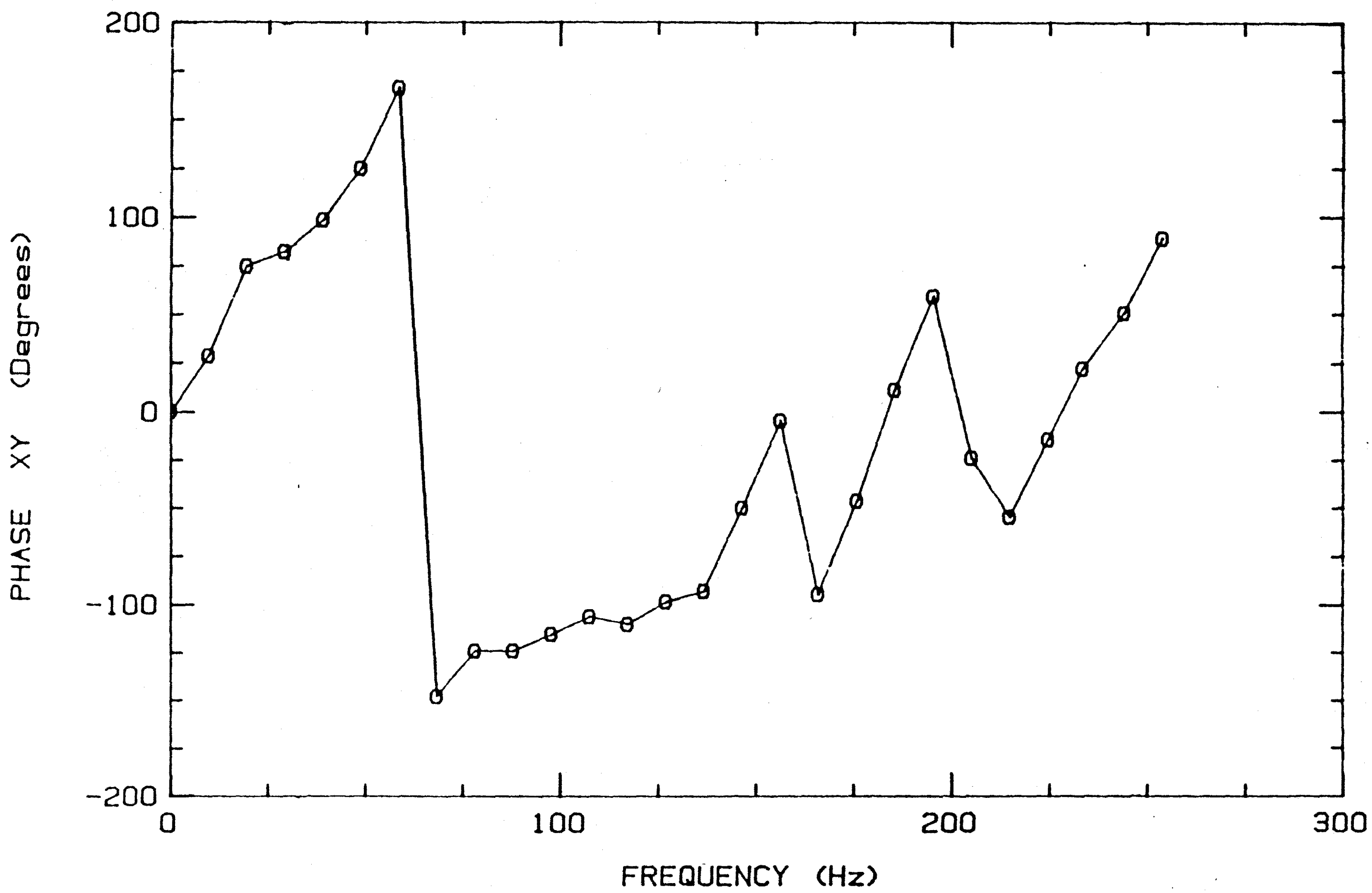

Figure H2. Phase Spectrum "ϕ_{xy}" of Type Two Test - 1.25 ft. Crack Depth

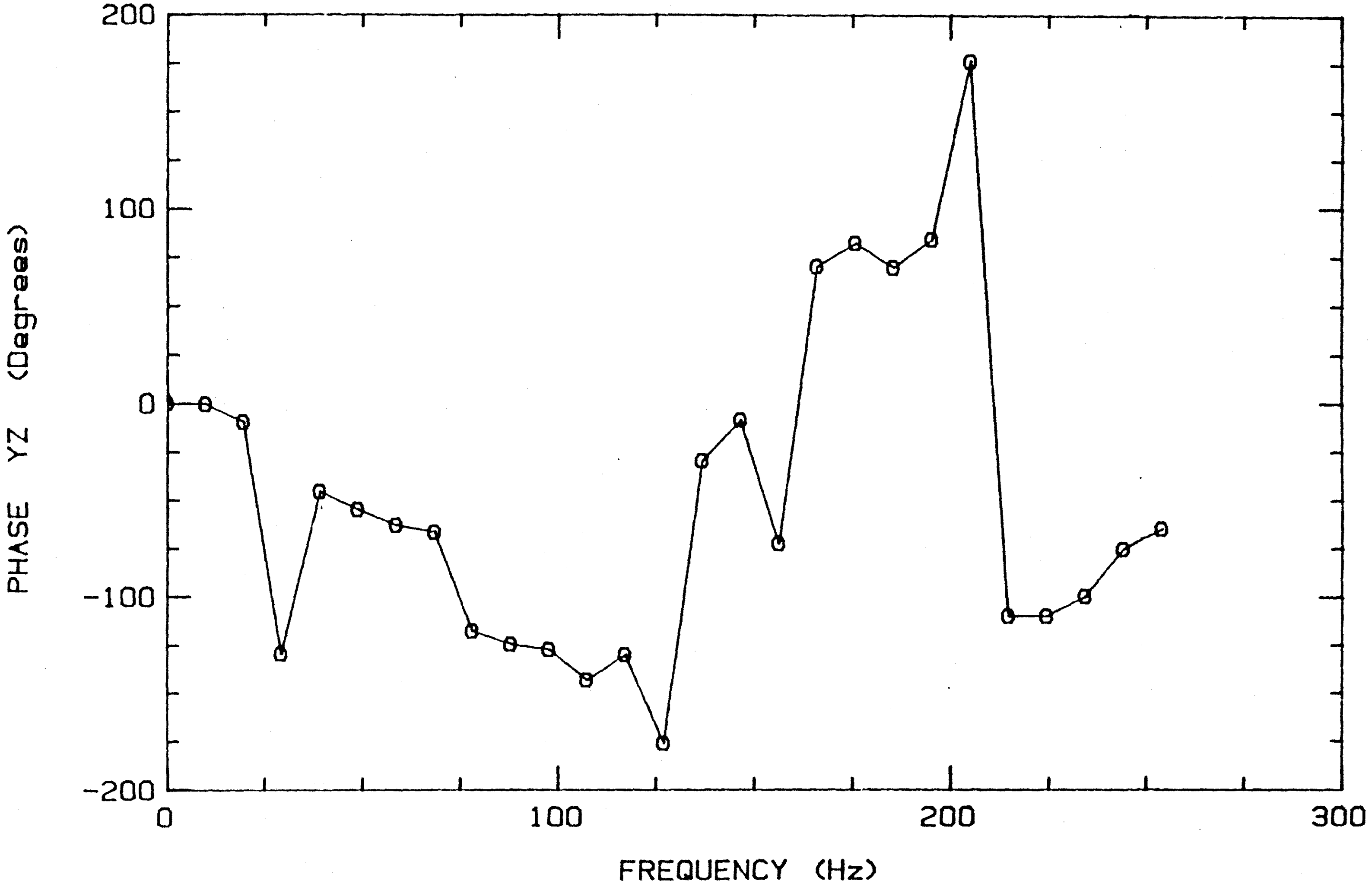

Figure H3. Phase Spectrum "ϕ_{yz}" of Type Two Test - 1.25 ft. Crack Depth

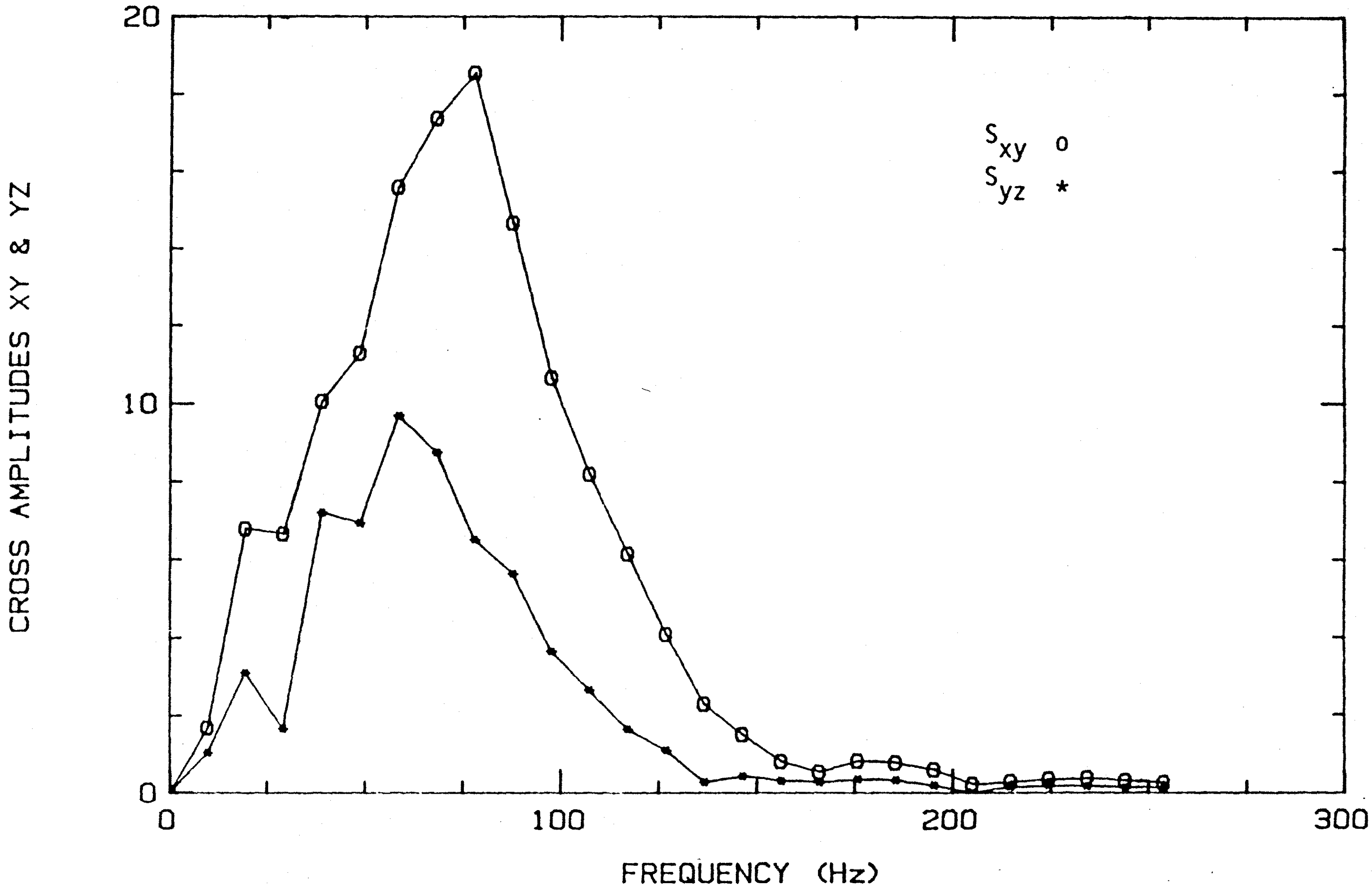

Figure H4. Cross Amplitude Spectra of Type Two Test - 1.25 ft. Crack Depth

APPENDIX I

TYPE TWO TEST

RESULTS FOR A CRACK 2.48 FT DEEP

THIS F RAM DOES CROSS SPECTRUM USING FFT AND AVERAGE SMOOTHINC Q.

NO. OF DATA FOR EACH SET	=	2048	
THE POWER OF 2	=	11	
DEGREE OF FREEDOM	=	1	
SAMPLING INTERVAL	=	0.05	MSEC
KEY=0, DO AUTO-SPECTRA ONLY			
KEY=1, DO CROSS-SPECTRA			
IN THIS CASE KEY	=	1	
DISTANCE BETWEEN X & Y	=	5.00	FT
DISTANCE BETWEEN Y & Z	=	5.00	FT

CROSS SPECTRUM PROPERTIES FOR STATION= 1 AND STATION= 2

FREQUENCY	PERIOD	SPECTRUM-1	SPECTRUM-2	RATIO	PHASE	COHERENCY	CROSS AMPL.	GAIN SPEC.
0.0000	0.0000	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
0.0098	102.4000	5.2146	1.2441	0.2386	53.5746	1.0000	2.5470	0.4884
0.0195	51.2000	19.3386	6.1051	0.3157	39.4391	1.0000	10.8658	0.5619
0.0293	34.1333	19.2321	3.4221	0.1779	135.0421	1.0000	8.1126	0.4218
0.0391	25.6000	30.4096	6.8055	0.2238	39.7978	1.0000	14.3858	0.4731
0.0488	20.4800	24.4451	7.3781	0.3018	53.7266	1.0000	13.4297	0.5494
0.0586	17.0667	23.3812	5.4548	0.2333	118.9662	1.0000	11.2933	0.4830
0.0684	14.6286	16.0088	3.4384	0.2148	96.5645	1.0000	7.4192	0.4634
0.0781	12.8000	14.3302	1.9314	0.1348	116.0587	1.0000	5.2609	0.3671
0.0879	11.3778	11.3134	1.9150	0.1693	74.1304	1.0000	4.6546	0.4114
0.0977	10.2400	7.9370	0.6353	0.0800	109.0307	1.0000	2.2455	0.2829
0.1074	9.3091	6.1503	0.5694	0.0926	46.1924	1.0000	1.8713	0.3043
0.1172	8.5333	4.6465	1.2602	0.2712	37.2428	1.0000	2.4198	0.5208
0.1270	7.8769	4.3148	1.3875	0.3216	36.6383	1.0000	2.4468	0.5671
0.1367	7.3143	3.7649	1.3486	0.3582	44.6943	1.0000	2.2533	0.5985
0.1465	6.8267	3.6016	1.0305	0.2861	69.4861	1.0000	1.9266	0.5349
0.1563	6.4000	3.4543	0.4665	0.1350	123.9199	1.0000	1.2694	0.3675
0.1660	6.0235	3.5283	0.0419	0.0119	109.4934	1.0000	0.3843	0.1089
0.1758	5.6889	2.9097	0.2491	0.0856	-33.6809	1.0000	0.8514	0.2926
0.1855	5.3895	3.0381	0.4767	0.1569	4.7146	1.0000	1.2035	0.3961
0.1953	5.1200	3.2444	0.2052	0.0632	24.6468	1.0000	0.8159	0.2515
0.2051	4.8762	3.6115	0.3389	0.0938	-73.2740	1.0000	1.1063	0.3063
0.2148	4.6545	3.5823	0.5294	0.1478	-57.0170	1.0000	1.3771	0.3844
0.2246	4.4522	3.1063	0.5593	0.1800	-23.5701	1.0000	1.3181	0.4243
0.2344	4.2667	2.8924	0.4914	0.1699	15.7582	1.0000	1.1922	0.4122
0.2441	4.0960	2.7017	0.3289	0.1217	26.8865	1.0000	0.9426	0.3489
0.2539	3.9385	2.2316	0.1318	0.0591	15.8121	1.0000	0.5423	0.2430
0.2637	3.7926	1.6589	0.0382	0.0230	42.8847	1.0000	0.2517	0.1517
0.2734	3.6571	1.1908	0.1215	0.1020	108.1484	1.0000	0.3804	0.3194
0.2832	3.5310	0.8768	0.1498	0.1708	111.2280	1.0000	0.3624	0.4133
0.2930	3.4133	0.8003	0.0990	0.1237	117.4274	1.0000	0.2815	0.3517
0.3027	3.3032	0.5878	0.0336	0.0571	-157.5693	1.0000	0.1405	0.2390
0.3125	3.2000	0.3902	0.0395	0.1013	-148.4149	1.0000	0.1242	0.3183
0.3223	3.1030	0.2705	0.0692	0.2559	133.8639	1.0000	0.1368	0.5058
0.3320	3.0118	0.2828	0.0370	0.1307	44.7870	1.0000	0.1022	0.3615
0.3418	2.9257	0.2156	0.0344	0.1595	-86.0679	0.0000	0.0000	0.0000
0.3516	2.8444	0.1209	0.0831	0.6870	-130.2984	1.0000	0.1002	0.8288
0.3613	2.7676	0.1414	0.0872	0.6171	141.2354	1.0000	0.1110	0.7856
0.3711	2.6947	0.2098	0.0607	0.2895	89.7480	1.0000	0.1129	0.5380
0.3809	2.6256	0.2234	0.0232	0.1039	95.1799	0.0000	0.0000	0.0000
0.3906	2.5600	0.1598	0.0070	0.0437	179.6507	0.0000	0.0000	0.0000
0.4004	2.4976	0.1767	0.0259	0.1466	-73.8741	0.0000	0.0000	0.0000
0.4102	2.4381	0.1820	0.0622	0.3415	94.5253	1.0000	0.1064	0.5844
0.4199	2.3814	0.1238	0.0861	0.6954	51.7338	1.0000	0.1032	0.8339
0.4297	2.3273	0.1691	0.0836	0.4941	60.3614	1.0000	0.1189	0.7029

CROSS SPECTRUM PROPERTIES FOR STATION= 1 AND STATION= 3

FREQUENCY	PERIOD	SPECTRUM-1	SPECTRUM-2	RATIO	PHASE	COHERENCY	CROSS AMPL.	GAIN SPEC.
0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0098	102.4000	5.2146	0.6849	0.1313	22.3433	1.0000	1.8898	0.3624
0.0195	51.2000	19.3386	4.1135	0.2127	126.7522	1.0000	8.9190	0.4612
0.0293	34.1333	19.2321	1.8258	0.0949	-69.1456	1.0000	5.9256	0.3081
0.0391	25.6000	30.4096	4.3851	0.1442	139.2500	1.0000	11.5477	0.3797
0.0488	20.4800	24.4451	4.6862	0.1917	170.6993	1.0000	10.7031	0.4378
0.0586	17.0667	23.3812	4.6309	0.1981	-107.4994	1.0000	10.4056	0.4450
0.0684	14.6286	16.0088	3.3348	0.2083	-94.0017	1.0000	7.3065	0.4564
0.0781	12.8000	14.3302	1.6599	0.1158	-16.4154	1.0000	4.8771	0.3403
0.0879	11.3778	11.3134	0.9154	0.0809	-107.2572	1.0000	3.2182	0.2845
0.0977	10.2400	7.9370	1.6636	0.2096	-43.1501	1.0000	3.6338	0.4578
0.1074	9.3091	6.1503	1.4064	0.2287	-17.4843	1.0000	2.9411	0.4782
0.1172	8.5333	4.6465	0.4214	0.0907	43.6994	1.0000	1.3992	0.3011
0.1270	7.8769	4.3148	0.3490	0.0809	-37.9117	1.0000	1.2272	0.2844
0.1367	7.3143	3.7649	1.0924	0.2901	-6.8081	1.0000	2.0280	0.5386
0.1465	6.8267	3.6016	1.0857	0.3014	54.4352	1.0000	1.9774	0.5490
0.1563	6.4000	3.4543	0.7009	0.2029	127.7486	1.0000	1.5560	0.4505
0.1660	6.0235	3.5283	0.3902	0.1106	-171.2809	1.0000	1.1733	0.3326
0.1758	5.6889	2.9097	0.0503	0.0173	-14.1201	1.0000	0.3826	0.1315
0.1855	5.3895	3.0381	0.2439	0.0803	93.7276	1.0000	0.8609	0.2834
0.1953	5.1200	3.2444	0.2352	0.0725	-174.6959	1.0000	0.8736	0.2693
0.2051	4.8762	3.6115	0.2345	0.0649	-83.1847	1.0000	0.9203	0.2548
0.2148	4.6545	3.5823	0.0427	0.0119	-49.5703	1.0000	0.3913	0.1092
0.2246	4.4522	3.1063	0.0918	0.0296	154.4650	1.0000	0.5341	0.1719
0.2344	4.2667	2.8924	0.1192	0.0412	171.0454	1.0000	0.5872	0.2030
0.2441	4.0960	2.7017	0.1301	0.0482	-132.5914	1.0000	0.5929	0.2195
0.2539	3.9385	2.2316	0.2063	0.0924	-83.5760	1.0000	0.6785	0.3041
0.2637	3.7926	1.6589	0.1605	0.0967	-52.4790	1.0000	0.5159	0.3110
0.2734	3.6571	1.1908	0.0622	0.0522	1.0877	1.0000	0.2720	0.2285
0.2832	3.5310	0.8768	0.0832	0.0949	94.6713	1.0000	0.2701	0.3080
0.2930	3.4133	0.8003	0.0410	0.0512	131.6093	1.0000	0.1811	0.2262
0.3027	3.3032	0.5878	0.0239	0.0407	-98.4118	1.0000	0.1186	0.2018
0.3125	3.2000	0.3902	0.0380	0.0973	-94.2146	1.0000	0.1217	0.3119
0.3223	3.1030	0.2705	0.0364	0.1347	125.3358	0.0000	0.0000	0.0000
0.3320	3.0118	0.2828	0.0855	0.3023	59.4238	1.0000	0.1555	0.5499
0.3418	2.9257	0.2156	0.0487	0.2262	74.2994	1.0000	0.1025	0.4756
0.3516	2.8444	0.1209	0.0255	0.2106	158.8865	0.0000	0.0000	0.0000
0.3613	2.7676	0.1414	0.0315	0.2229	117.1451	0.0000	0.0000	0.0000
0.3711	2.6947	0.2098	0.0411	0.1960	24.5369	0.0000	0.0000	0.0000
0.3809	2.6256	0.2234	0.0448	0.2004	45.9495	1.0000	0.1000	0.4476

CROSS SPECTRUM PROPERTIES FOR STATION= 2 AND STATION= 3

FREQUENCY	PERIOD	SPECTRUM-1	SPECTRUM-2	RATIO	PHASE	COHERENCY	CROSS AMPL.	GAIN SPEC.
0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0098	102.4000	1.2441	0.6849	0.5505	-31.2312	1.0000	0.9231	0.7420
0.0195	51.2000	6.1051	4.1135	0.6738	87.3130	1.0000	5.0113	0.8208
0.0293	34.1333	3.4221	1.8258	0.5335	155.8124	1.0000	2.4996	0.7304
0.0391	25.6000	6.8055	4.3851	0.6443	99.4521	1.0000	5.4628	0.8027
0.0488	20.4800	7.3781	4.6862	0.6352	116.9727	1.0000	5.8801	0.7970
0.0586	17.0667	5.4548	4.6309	0.8490	133.5344	1.0000	5.0260	0.9214
0.0684	14.6286	3.4384	3.3348	0.9699	169.4339	1.0000	3.3862	0.9848
0.0781	12.8000	1.9314	1.6599	0.8594	-132.4741	1.0000	1.7905	0.9270
0.0879	11.3778	1.9150	0.9154	0.4780	178.6125	1.0000	1.3241	0.6914
0.0977	10.2400	0.6353	1.6636	2.6186	-152.1808	1.0000	1.0281	1.6182
0.1074	9.3091	0.5694	1.4064	2.4701	-63.6766	1.0000	0.8949	1.5717
0.1172	8.5333	1.2602	0.4214	0.3344	6.4566	1.0000	0.7287	0.5782
0.1270	7.8769	1.3875	0.3490	0.2515	-74.5500	1.0000	0.6959	0.5015
0.1367	7.3143	1.3486	1.0924	0.8100	-51.5023	1.0000	1.2137	0.9000
0.1465	6.8267	1.0305	1.0857	1.0535	-15.0510	1.0000	1.0578	1.0264
0.1563	6.4000	0.4665	0.7009	1.5025	3.8287	1.0000	0.5718	1.2258
0.1660	6.0235	0.0419	0.3902	9.3220	79.2259	1.0000	0.1278	3.0532
0.1758	5.6889	0.2491	0.0503	0.2019	19.5608	1.0000	0.1119	0.4494
0.1855	5.3895	0.4767	0.2439	0.5117	89.0130	1.0000	0.3410	0.7153
0.1953	5.1200	0.2052	0.2352	1.1466	160.6574	1.0000	0.2197	1.0708
0.2051	4.8762	0.3389	0.2345	0.6921	-9.9108	1.0000	0.2819	0.8319
0.2148	4.6545	0.5294	0.0427	0.0807	7.4467	1.0000	0.1504	0.2842
0.2246	4.4522	0.5593	0.0918	0.1642	178.0351	1.0000	0.2266	0.4052
0.2344	4.2667	0.4914	0.1192	0.2426	155.2872	1.0000	0.2420	0.4925
0.2441	4.0960	0.3289	0.1301	0.3956	-159.4780	1.0000	0.2069	0.6290
0.2539	3.9385	0.1318	0.2063	1.5655	-99.3881	1.0000	0.1649	1.2512
0.2637	3.7926	0.0382	0.1605	4.2012	-95.3636	0.0000	0.0000	0.0000
0.2734	3.6571	0.1215	0.0622	0.5115	-107.0608	0.0000	0.0000	0.0000
0.2832	3.5310	0.1498	0.0832	0.5554	-16.5567	1.0000	0.1116	0.7453

```
AAAAAAA    AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
A                                            A
A         THE OUTPUT FOR CRACK ESTIMATION    A
A                                            A
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
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FREQ (HZ)	PHASE XY	PHASE YZ	TIME XY	TIME YZ	VELOCITY XY	VELOCITY YZ	DEPTH CRACK	WAVENGTH YZ	DEPTH WL/2	DEPTH WL/3
9.766	53.575	-31.231	0.015	-0.009	328.105	-562.838	6.789	-57.635	-28.817	-19.212
19.531	39.439	447.313	0.006	0.064	891.406	78.594	2.280	4.024	2.012	1.341
29.297	135.042	515.812	0.013	0.049	390.503	102.236	1.845	3.490	1.745	1.163
39.063	39.798	459.452	0.003	0.033	1766.744	153.036	2.283	3.918	1.959	1.306
48.828	53.727	476.973	0.003	0.027	1635.887	184.268	2.218	3.774	1.887	1.258
58.594	118.966	493.534	0.006	0.023	886.544	213.701	1.897	3.647	1.824	1.216
68.359	96.565	529.434	0.004	0.022	1274.246	232.412	2.044	3.400	1.700	1.133
78.125	116.059	587.526	0.004	0.021	1211.672	239.351	2.006	3.064	1.532	1.021
87.891	74.130	898.612	0.002	0.028	2134.120	176.053	2.294	2.003	1.002	0.668
97.656	109.031	927.819	0.003	0.026	1612.218	189.456	2.206	1.940	0.970	0.647
107.422	46.192	1016.323	0.001	0.026	4185.961	190.254	2.386	1.771	0.886	0.590
117.188	37.243	1086.457	0.001	0.026	5663.848	194.152	2.414	1.657	0.828	0.552
126.953	36.638	1005.450	0.001	0.022	6237.070	227.277	2.409	1.790	0.895	0.597
136.719	44.694	1028.498	0.001	0.021	5506.160	239.275	2.391	1.750	0.875	0.583
146.484	69.486	1064.949	0.001	0.020	3794.598	247.591	2.337	1.690	0.845	0.563
156.250	123.920	1083.829	0.002	0.019	2269.611	259.497	2.214	1.661	0.830	0.554
166.016	109.493	1159.226	0.002	0.019	2729.189	257.782	2.264	1.553	0.776	0.518
175.781	-33.681	1099.561	-0.001	0.017	-9394.234	287.757	2.577	1.637	0.819	0.546
185.547	4.715	1169.013	0.000	0.018	70840.000	285.698	2.490	1.540	0.770	0.513
195.313	24.647	1240.657	0.000	0.018	14264.030	283.368	2.450	1.451	0.725	0.484
205.078	-73.274	1070.089	-0.001	0.014	-5037.813	344.962	2.671	1.682	0.841	0.561
214.844	-57.017	1087.447	-0.001	0.014	-6782.512	355.621	2.631	1.655	0.828	0.552
224.609	-23.570	1258.035	-0.000	0.016	-17153.000	321.372	2.547	1.431	0.715	0.477
234.375	15.758	1235.287	0.000	0.015	26771.770	341.520	2.468	1.457	0.729	0.486
244.141	26.887	1280.522	0.000	0.015	16344.750	343.183	2.448	1.406	0.703	0.469
253.906	15.812	1340.612	0.000	0.015	28903.930	340.912	2.471	1.343	0.671	0.448
263.672	42.885	1344.636	0.000	0.014	11067.100	352.965	2.420	1.339	0.669	0.446
273.438	108.148	1332.939	0.001	0.014	4551.035	369.250	2.297	1.350	0.675	0.450
283.203	111.228	1423.443	0.001	0.014	4583.066	358.122	2.305	1.265	0.632	0.422

AVERAGE CRACK DEPTH = 2.5504
STANDARD DEVIATION = 0.9981
UPPER BOUND VALUE = 3.0494
LOWER BOUND VALUE = 2.0513

THE FINAL DEPTH = 2.4284

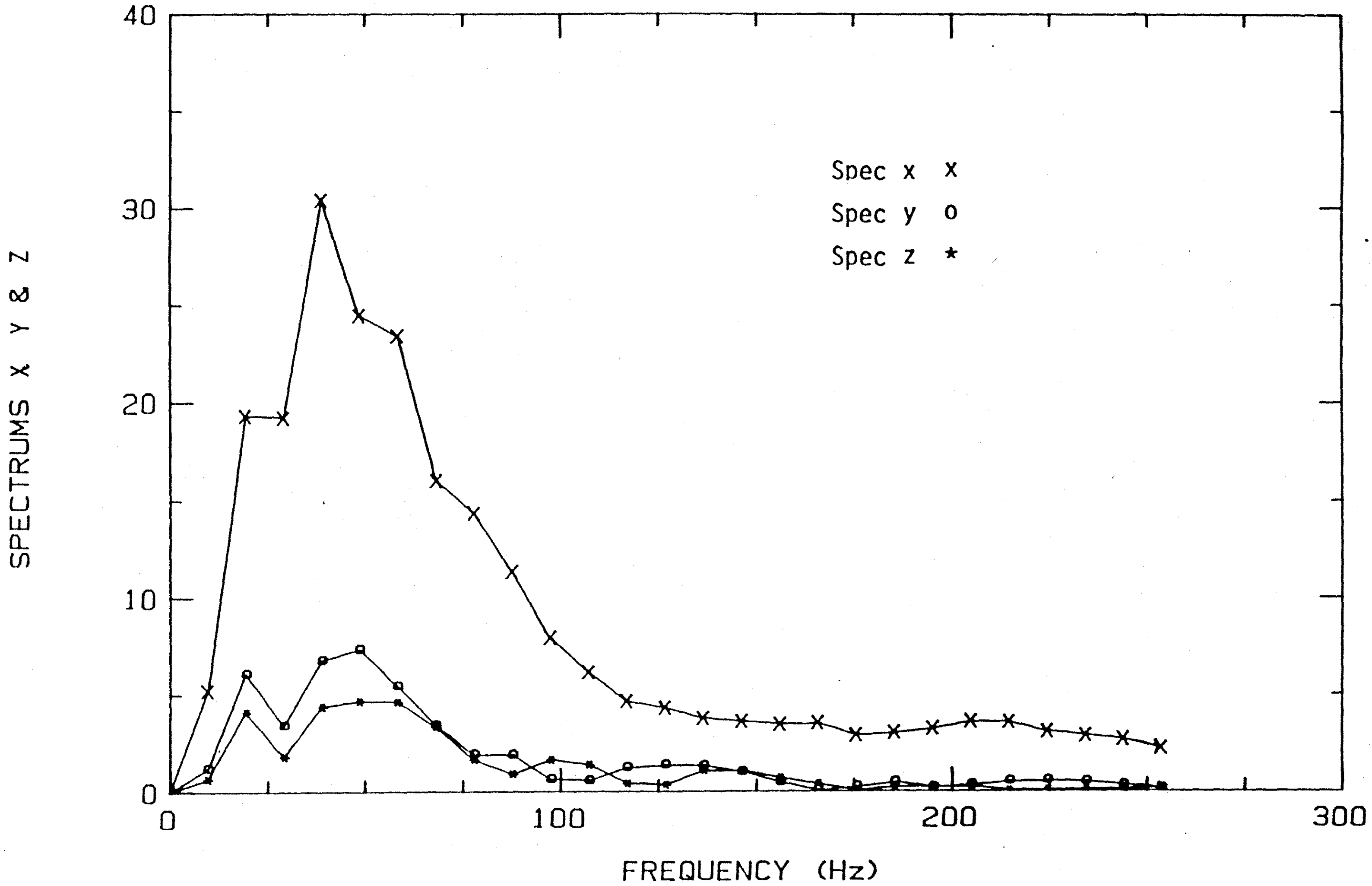

Figure I1. Auto Spectra of Type Two Test - 2.48 ft. Crack Depth

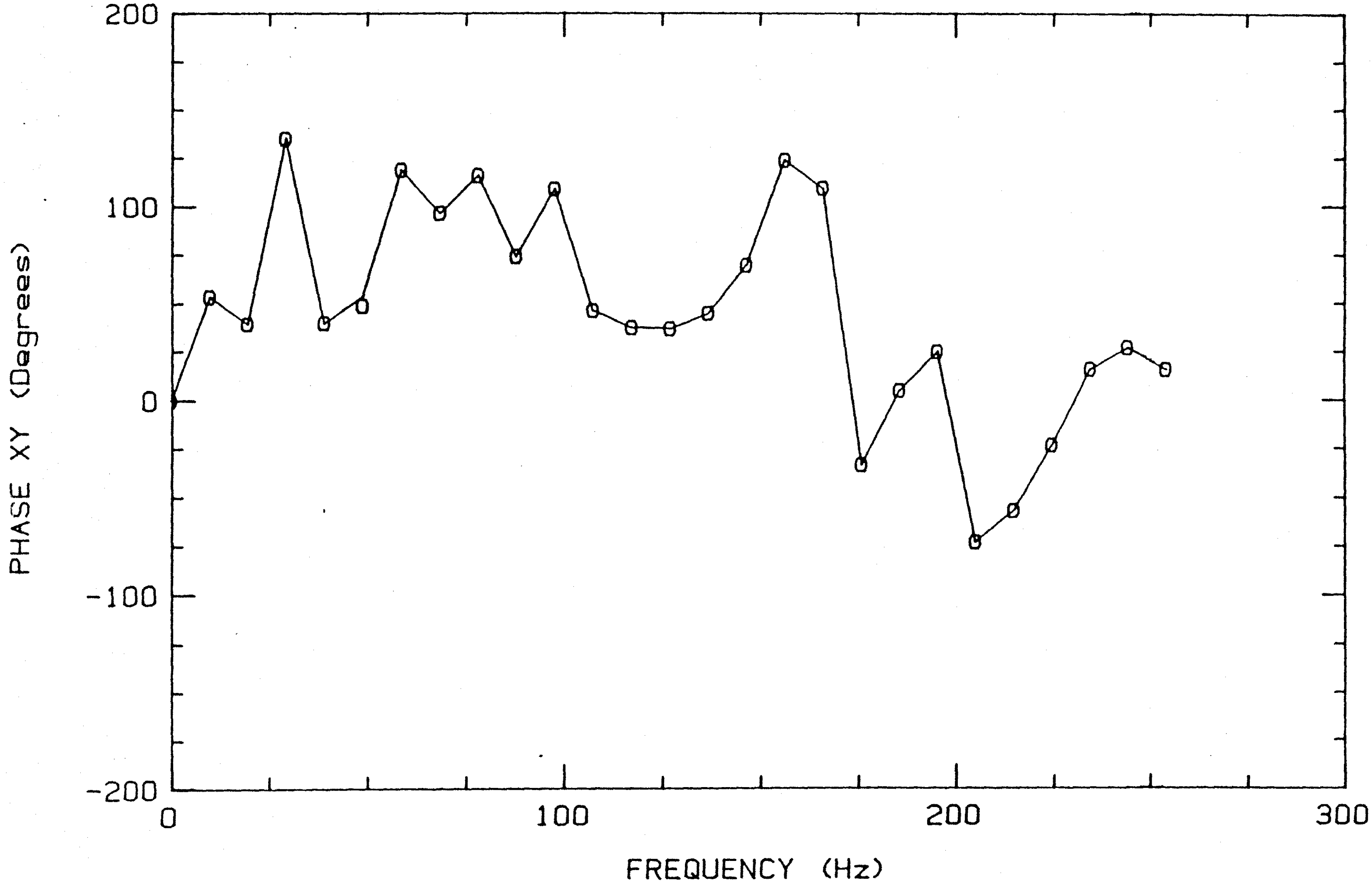

Figure I2. Phase Spectrum "ϕ_{xy}" of Type Two Test - 2.48 ft. Crack Depth

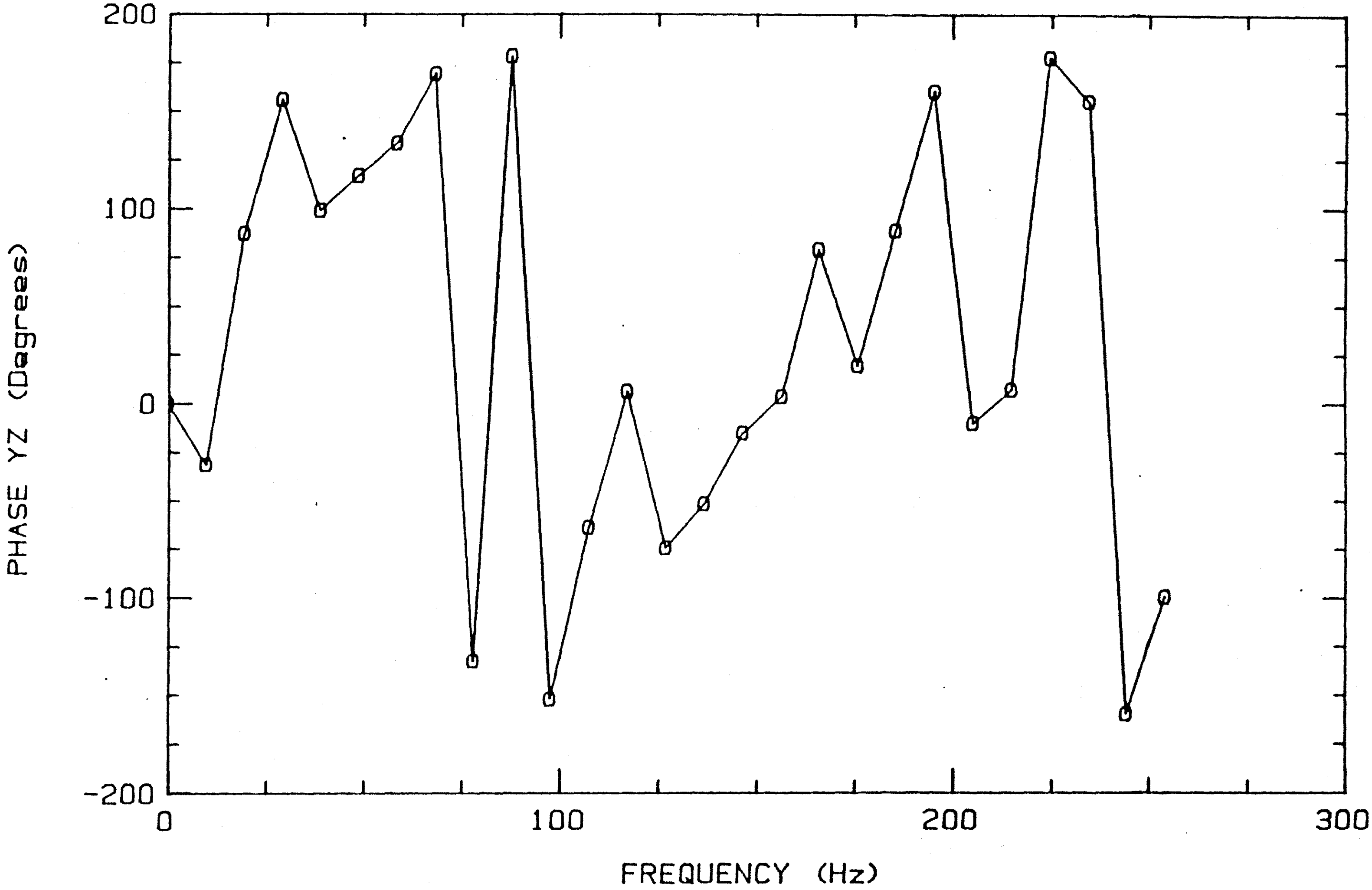

Figure I3. Phase Spectrum "ϕ_{yz}" of Type Two Test - 2.48 ft. Crack Depth

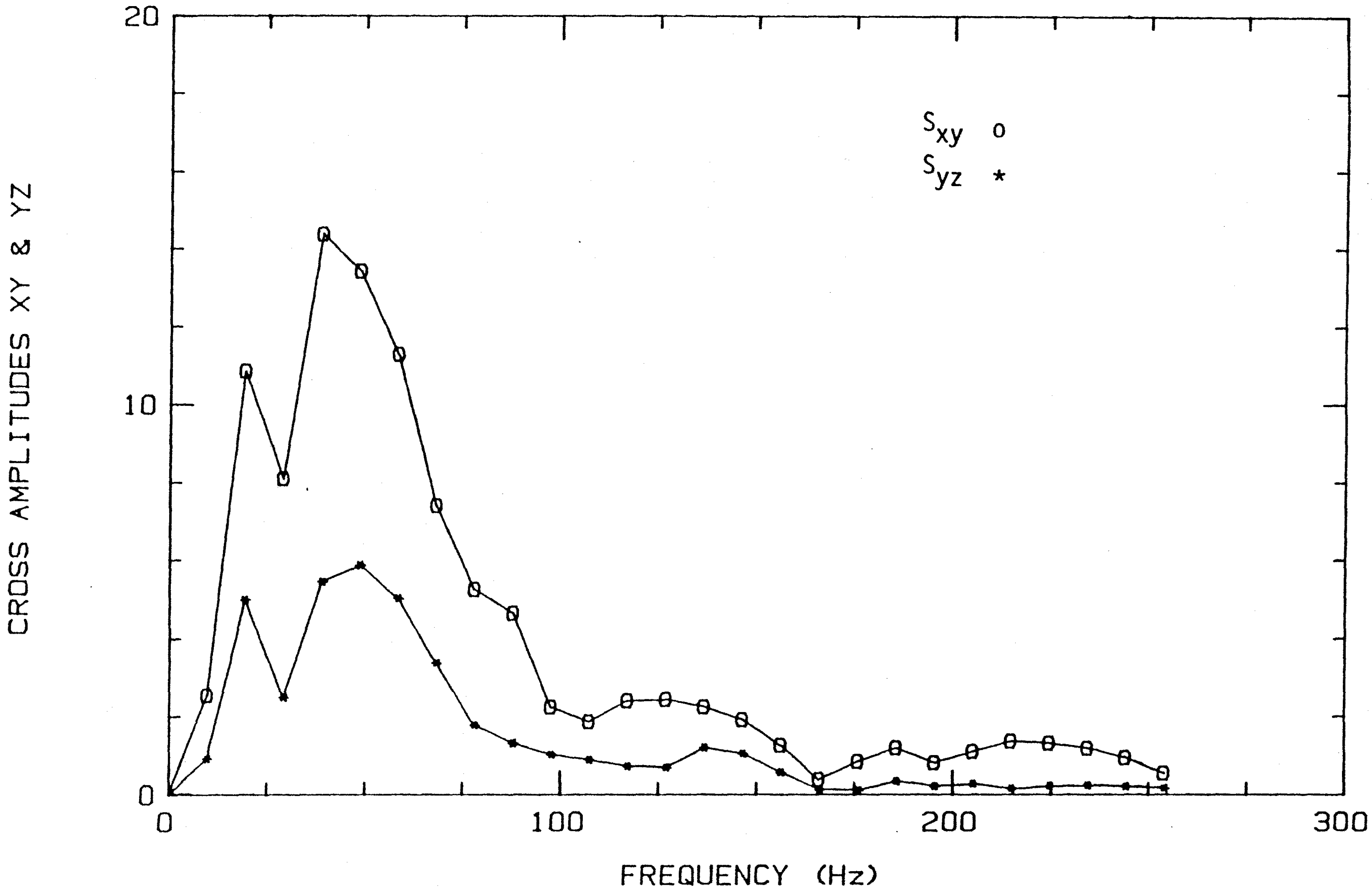

Figure I4. Cross Amplitude Spectra of Type Two Test - 2.48 ft. Crack Depth

APPENDIX J

TYPE TWO TEST

INPUT DATA FROM STATION X USED
TO CALCULATE A 2.48 FOOT CRACK DEPTH

		61.	0.5000000E-01	122.	0.2000000E 00	183.	0.3499999E 00
1.	0.1500000E 00	62.	0.1500000E 00	123.	0.2499999E 00	184.	0.3000000E 00
2.	0.2000000E 00	63.	0.9999996E-01	124.	0.1500000E 00	185.	0.2000000E 00
3.	0.3000000E 00	64.	0.1500000E 00	125.	0.2000000E 00	186.	0.3000000E 00
4.	0.2000000E 00	65.	0.2000000E 00	126.	0.2000000E 00	187.	0.3499999E 00
5.	0.1500000E 00	66.	0.1500000E 00	127.	0.3000000E 00	188.	0.3000000E 00
6.	0.2000000E 00	67.	0.9999996E-01	128.	0.1500000E 00	189.	0.1500000E 00
7.	0.1500000E 00	68.	0.5000000E-01	129.	0.1500000E 00	190.	0.3000000E 00
8.	0.1500000E 00	69.	0.9999996E-01	130.	0.1500000E 00	191.	0.2499999E 00
9.	0.1500000E 00	70.	0.1500000E 00	131.	0.1500000E 00	192.	0.2000000E 00
10.	0.2000000E 00	71.	0.9999996E-01	132.	0.3000000E 00	193.	0.2500000E 00
11.	0.2000000E 00	72.	0.2000000E 00	133.	0.9999996E-01	194.	0.3000000E 00
12.	0.2500000E 00	73.	0.2000000E 00	134.	0.2499999E 00	195.	0.2499999E 00
13.	0.2499999E 00	74.	0.1500000E 00	135.	0.3000000E 00	196.	0.2000000E 00
14.	0.9999996E-01	75.	0.1500000E 00	136.	0.2499999E 00	197.	0.3000000E 00
15.	0.9999996E-01	76.	0.9999996E-01	137.	0.2000000E 00	198.	0.2000000E 00
16.	0.2000000E 00	77.	0.1500000E 00	138.	0.2499999E 00	199.	0.2499999E 00
17.	0.9999996E-01	78.	0.2000000E 00	139.	0.2499999E 00	200.	0.3000000E 00
18.	0.1500000E 00	79.	0.2000000E 00	140.	0.2000000E 00	201.	0.3000000E 00
19.	0.9999996E-01	80.	0.2000000E 00	141.	0.2000000E 00	202.	0.1500000E 00
20.	0.9999996E-01	81.	0.2000000E 00	142.	0.2499999E 00	203.	0.2499999E 00
21.	0.1500000E 00	82.	0.5000000E-01	143.	0.2000000E 00	204.	0.2000000E 00
22.	0.2000000E 00	83.	0.2499999E 00	144.	0.3000000E 00	205.	0.2499999E 00
23.	0.2000000E 00	84.	0.2499999E 00	145.	0.2000000E 00	206.	0.3499999E 00
24.	0.9999996E-01	85.	0.2000000E 00	146.	0.1500000E 00	207.	0.2000000E 00
25.	0.2000000E 00	86.	0.1500000E 00	147.	0.2499999E 00	208.	0.3499999E 00
26.	0.9999996E-01	87.	0.2000000E 00	148.	0.1500000E 00	209.	0.2499999E 00
27.	0.2000000E 00	88.	0.1500000E 00	149.	0.2000000E 00	210.	0.9999996E-01
28.	0.1500000E 00	89.	0.2000000E 00	150.	0.2499999E 00	211.	0.2000000E 00
29.	0.2000000E 00	90.	0.1500000E 00	151.	0.2499999E 00	212.	0.1500000E 00
30.	0.9999996E-01	91.	0.1500000E 00	152.	0.2000000E 00	213.	0.4999998E-01
31.	0.1500000E 00	92.	0.9999996E-01	153.	0.2499999E 00	214.	0.4999998E-01
32.	0.9999996E-01	93.	0.1500000E 00	154.	0.2000000E 00	215.	0.5000000E-01
33.	0.1500000E 00	94.	0.2000000E 00	155.	0.2500000E 00	216.	-0.1490116E-07
34.	0.2000000E 00	95.	0.1500000E 00	156.	0.2499999E 00	217.	-0.1499997E 00
35.	0.1500000E 00	96.	0.1500000E 00	157.	0.2499999E 00	218.	-0.1499999E 00
36.	0.9999996E-01	97.	0.1500000E 00	158.	0.2499999E 00	219.	-0.2999997E 00
37.	0.9999996E-01	98.	0.2000000E 00	159.	0.2499999E 00	220.	-0.3999996E 00
38.	0.2000000E 00	99.	0.2000000E 00	160.	0.2499999E 00	221.	-0.5999997E 00
39.	0.2000000E 00	100.	0.1500000E 00	161.	0.3000000E 00	222.	-0.5999997E 00
40.	0.9999996E-01	101.	0.2000000E 00	162.	0.2000000E 00	223.	-0.7499995E 00
41.	0.9999996E-01	102.	0.2000000E 00	163.	0.1500000E 00	224.	-0.8999999E 00
42.	0.1500000E 00	103.	0.1500000E 00	164.	0.3499999E 00	225.	-0.1049999E 01
43.	0.2000000E 00	104.	0.2499999E 00	165.	0.2000000E 00	226.	-0.1150000E 01
44.	0.1500000E 00	105.	0.2000000E 00	166.	0.3000000E 00	227.	-0.1299999E 01
45.	0.9999996E-01	106.	0.9999996E-01	167.	0.3000000E 00	228.	-0.1400000E 01
46.	0.9999996E-01	107.	0.2000000E 00	168.	0.2000000E 00	229.	-0.1499999E 01
47.	0.2000000E 00	108.	0.2000000E 00	169.	0.3000000E 00	230.	-0.1650000E 01
48.	0.2000000E 00	109.	0.9999996E-01	170.	0.2000000E 00	231.	-0.1700000E 01
49.	0.5000000E-01	110.	0.2000000E 00	171.	0.3000000E 00	232.	-0.1900000E 01
50.	0.1500000E 00	111.	0.2000000E 00	172.	0.3999999E 00	233.	-0.2150000E 01
51.	0.2000000E 00	112.	0.1500000E 00	173.	0.3000000E 00	234.	-0.2200000E 01
52.	0.9999996E-01	113.	0.1500000E 00	174.	0.2000000E 00	235.	-0.2250000E 01
53.	0.2000000E 00	114.	0.1500000E 00	175.	0.2499999E 00	236.	-0.2299999E 01
54.	0.9999996E-01	115.	0.2000000E 00	176.	0.2499999E 00	237.	-0.2400000E 01
55.	0.2499999E 00	116.	0.2000000E 00	177.	0.2499999E 00	238.	-0.2450000E 01
56.	0.9999996E-01	117.	0.1500000E 00	178.	0.3000000E 00	239.	-0.2450000E 01
57.	0.9999996E-01	118.	0.2000000E 00	179.	0.3499999E 00	240.	-0.2300000E 01
58.	0.2000000E 00	119.	0.2499999E 00	180.	0.3000000E 00	241.	-0.2200000E 01
59.	0.1500000E 00	120.	0.2000000E 00	181.	0.2000000E 00	242.	-0.1950000E 01
60.	0.1500000E 00	121.	0.1500000E 00	182.	0.2499999E 00	243.	-0.1599999E 01

244.	-0.1300000E 01	305.	0.5770000E 02	366.	0.1204500E 03	427.	0.1115000E 02
245.	-0.8000000E 00	306.	0.5739999E 02	367.	0.1237000E 03	428.	0.6949997E 01
246.	-0.4000001E 00	307.	0.5700000E 02	368.	0.1269999E 03	429.	0.2849999E 01
247.	0.2999997E 00	308.	0.5664999E 02	369.	0.1300500E 03	430.	-0.1049999E 01
248.	0.9500000E 00	309.	0.5609999E 02	370.	0.1329999E 03	431.	-0.4899998E 01
249.	0.1549999E 01	310.	0.5550000E 02	371.	0.1359999E 03	432.	-0.8649998E 01
250.	0.2250000E 01	311.	0.5489999E 02	372.	0.1388499E 03	433.	-0.1210000E 02
251.	0.3000000E 01	312.	0.5420000E 02	373.	0.1417499E 03	434.	-0.1550000E 02
252.	0.3750000E 01	313.	0.5359999E 02	374.	0.1442500E 03	435.	-0.1884999E 02
253.	0.4549995E 01	314.	0.5300000E 02	375.	0.1466999E 03	436.	-0.2195000E 02
254.	0.5399994E 01	315.	0.5214999E 02	376.	0.1489000E 03	437.	-0.2489999E 02
255.	0.6149994E 01	316.	0.5155000E 02	377.	0.1511499E 03	438.	-0.2779999E 02
256.	0.6999996E 01	317.	0.5075000E 02	378.	0.1530499E 03	439.	-0.3045000E 02
257.	0.7749996E 01	318.	0.4995000E 02	379.	0.1549499E 03	440.	-0.3300000E 02
258.	0.8449997E 01	319.	0.4920000E 02	380.	0.1562999E 03	441.	-0.3539999E 02
259.	0.9299995E 01	320.	0.4845000E 02	381.	0.1576500E 03	442.	-0.3775000E 02
260.	0.1014999E 02	321.	0.4770000E 02	382.	0.1588499E 03	443.	-0.3979999E 02
261.	0.1089999E 02	322.	0.4695000E 02	383.	0.1597000E 03	444.	-0.4189999E 02
262.	0.1164999E 02	323.	0.4625000E 02	384.	0.1604499E 03	445.	-0.4389999E 02
263.	0.1255000E 02	324.	0.4564999E 02	385.	0.1607499E 03	446.	-0.4570000E 02
264.	0.1345000E 02	325.	0.4495000E 02	386.	0.1608999E 03	447.	-0.4745000E 02
265.	0.1450000E 02	326.	0.4454999E 02	387.	0.1607499E 03	448.	-0.4925000E 02
266.	0.1534999E 02	327.	0.4404999E 02	388.	0.1601499E 03	449.	-0.5084999E 02
267.	0.1634999E 02	328.	0.4359999E 02	389.	0.1595499E 03	450.	-0.5264999E 02
268.	0.1734999E 02	329.	0.4354999E 02	390.	0.1585499E 03	451.	-0.5430000E 02
269.	0.1845000E 02	330.	0.4345000E 02	391.	0.1574500E 03	452.	-0.5575000E 02
270.	0.1955000E 02	331.	0.4345000E 02	392.	0.1557499E 03	453.	-0.5730000E 02
271.	0.2064999E 02	332.	0.4345000E 02	393.	0.1541500E 03	454.	-0.5900000E 02
272.	0.2164999E 02	333.	0.4384999E 02	394.	0.1520500E 03	455.	-0.6075000E 02
273.	0.2299998E 02	334.	0.4430000E 02	395.	0.1497000E 03	456.	-0.6250000E 02
274.	0.2430000E 02	335.	0.4484999E 02	396.	0.1471500E 03	457.	-0.6419995E 02
275.	0.2559999E 02	336.	0.4539999E 02	397.	0.1443499E 03	458.	-0.6600000E 02
276.	0.2689999E 02	337.	0.4630000E 02	398.	0.1412499E 03	459.	-0.6789996E 02
277.	0.2839999E 02	338.	0.4725000E 02	399.	0.1380499E 03	460.	-0.6984998E 02
278.	0.2989999E 02	339.	0.4839999E 02	400.	0.1346499E 03	461.	-0.7169995E 02
279.	0.3145000E 02	340.	0.4964999E 02	401.	0.1309999E 03	462.	-0.7369995E 02
280.	0.3309999E 02	341.	0.5109999E 02	402.	0.1272499E 03	463.	-0.7579999E 02
281.	0.3475000E 02	342.	0.5270000E 02	403.	0.1232499E 03	464.	-0.7794995E 02
282.	0.3645000E 02	343.	0.5430000E 02	404.	0.1192000E 03	465.	-0.8014996E 02
283.	0.3800000E 02	344.	0.5629999E 02	405.	0.1149000E 03	466.	-0.8234998E 02
284.	0.3979999E 02	345.	0.5820000E 02	406.	0.1105499E 03	467.	-0.8450000E 02
285.	0.4139999E 02	346.	0.6039999E 02	407.	0.1060999E 03	468.	-0.8679999E 02
286.	0.4300000E 02	347.	0.6275000E 02	408.	0.1014999E 03	469.	-0.8919995E 02
287.	0.4459999E 02	348.	0.6504999E 02	409.	0.9679993E 02	470.	-0.9129993E 02
288.	0.4604999E 02	349.	0.6764996E 02	410.	0.9204999E 02	471.	-0.9364996E 02
289.	0.4754999E 02	350.	0.7029999E 02	411.	0.8725000E 02	472.	-0.9575000E 02
290.	0.4889999E 02	351.	0.7294995E 02	412.	0.8250000E 02	473.	-0.9799994E 02
291.	0.5029999E 02	352.	0.7575000E 02	413.	0.7764996E 02	474.	-0.1003499E 03
292.	0.5150000E 02	353.	0.7879999E 02	414.	0.7254999E 02	475.	-0.1025999E 03
293.	0.5259999E 02	354.	0.8179993E 02	415.	0.6775000E 02	476.	-0.1048499E 03
294.	0.5364999E 02	355.	0.8479993E 02	416.	0.6264999E 02	477.	-0.1070500E 03
295.	0.5454999E 02	356.	0.8804993E 02	417.	0.5795000E 02	478.	-0.1093000E 03
296.	0.5539999E 02	357.	0.9109998E 02	418.	0.5295000E 02	479.	-0.1114500E 03
297.	0.5620000E 02	358.	0.9429993E 02	419.	0.4809999E 02	480.	-0.1134999E 03
298.	0.5664999E 02	359.	0.9754993E 02	420.	0.4325000E 02	481.	-0.1154999E 03
299.	0.5709999E 02	360.	0.1008499E 03	421.	0.3839999E 02	482.	-0.1176500E 03
300.	0.5745000E 02	361.	0.1040499E 03	422.	0.3370000E 02	483.	-0.1196000E 03
301.	0.5775000E 02	362.	0.1074500E 03	423.	0.2900000E 02	484.	-0.1214000E 03
302.	0.5789999E 02	363.	0.1106499E 03	424.	0.2434999E 02	485.	-0.1233499E 03
303.	0.5795000E 02	364.	0.1139000E 03	425.	0.1989999E 02	486.	-0.1252000E 03
304.	0.5789999E 02	365.	0.1172500E 03	426.	0.1545000E 02	487.	-0.1269999E 03

488.	-0.1287000E 03	549.	-0.1272999E 03	610.	-0.6134999E 02	671.	0.1550000E 01
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