INVESTIGATION OF A TEXTURE LOGGING TECHNIQUE

By

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INVESTIGATION OF A TEXTURE

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CHAPTER I

INTRODUCTION

Electrical well logging was introduced to the oil industry over a quarter of a century ago. Since that time, many new and improved logging techniques have been developed and put into use.

"Well logging" denotes any operation, wherein some characteristic data of the formation penetrated by a drilling bit are recorded as a function of depth (1). This record is called a log. It has become general practice, when a hole has been drilled or is being drilled, to run logs to obtain records of the formations penetrated.

Information that is obtained from the interpretation of these logs concerns the identification of formations and their boundaries and the determination of rock properties such as porosity and connate water saturation. The information from all the logs in a given field is used to determine the thickness and lateral extension of potential reservoirs, to locate gas-oil and oil-water contacts, and to evaluate field porosity, and hydrocarbon saturation.

The logs are also used to select the intervals to be perforated for production and for computation of reserves.

The texture logging technique proposed in this work would be used to obtain information concerning the lithology of the subsurface formations and their boundaries. The technique presented here is based on the same principle as the hi-fi record player. The vibrations generated by moving a stylus across a rough surface can cause various vibration detectors to generate emfs of varying intensity. The texture and difference in textures of different materials will be reflected in the waveform and amplitudes detected by the vibration pickup.

CHAPTER II

REVIEW OF LOGGING TECHNIQUES

Many varieties of well logging techniques have been developed and are being used today. Electric logging is one of the most commonly employed techniques. Essentially, the electric log is a recording of formation resistivities or their reciprocals, the conductivities, at different lateral distances from the wellbore.

Some well logs commonly used include Neutron Logs, which are recordings of the secondary effects due to the bombardment of the formations with neutrons and Induction Logs which are obtained by measuring the conductivity of formations by means of induced alternating current.

More recently a new type logging device, the Sonic Log has been introduced. Sonic Logging provides a record of the sound velocity across formations.

Other logging techniques are the Gamma Ray Log and the Self Potential Log. Gamma Ray Logs are recordings of the measurement of natural radioactivity of the formations. The Self Potential Log is recordings of the net emf generated, in part, by the difference in salinity between the formation water and the water in the drilling fluid. These two logs are commonly used to identify formations and to determine the net pay thickness of oil-bearing sands.

Many factors can result in the Self Potential Logs being misleading.

Since the emf generated is dependent upon the mud resistivity, the selection of drilling mud is very important when using the Self Potential Log. Mud chemical make-up varies widely in oil-field practice. The composition is determined primarily by considerations of economy, mechanical drilling performance, and well completion, rather than by the quality of logs to be obtained for the well evaluation program. The following analysis by Pirson (2) indicates how mud composition will affect the Self Potential Log.

S. J. Pirson states:

For practical purposes, one may distinguish the following:

1. <u>Fresh water muds</u>.

   NaCl < 1 per cent

   Ca < 50 parts per million

   Types:

   (a) pH < 8.5 (phosphate treated)
   (b) 9 < pH < 10.5 (caustic-quebrancho)
   (c) 11.5 < pH < 13 (lime red mud, often with starch).

   Types (a) and (b) give normal Self Potential deflections. Type (c) containing starch, reduces the Self Potential considerably and the electrochemical Self Potential theory is of doubtful application when such muds are used.

2. <u>Salt-water muds</u>. Self Potential is considerably reduced. Nevertheless, the electrochemical theory applies to Self Potential interpretation.

3. <u>Calcium treated muds</u>. The Self Potential is reduced.

4. <u>Oil-base muds and inverted oil emulsion muds</u>. The filtrate of such muds is oil which is nonconductive to electricity. No meaningful Self Potential curve is generated when these muds are used.

Another factor which can result in a misleading Self Potential Log is the presence of shale streaks in a sand. These streaks suppress the emf response.

The Gamma Ray Log is a recording of the natural radiation occurring in various formations. Below is a graph showing the relative intensity of the Gamma Ray radiation of formation rocks.

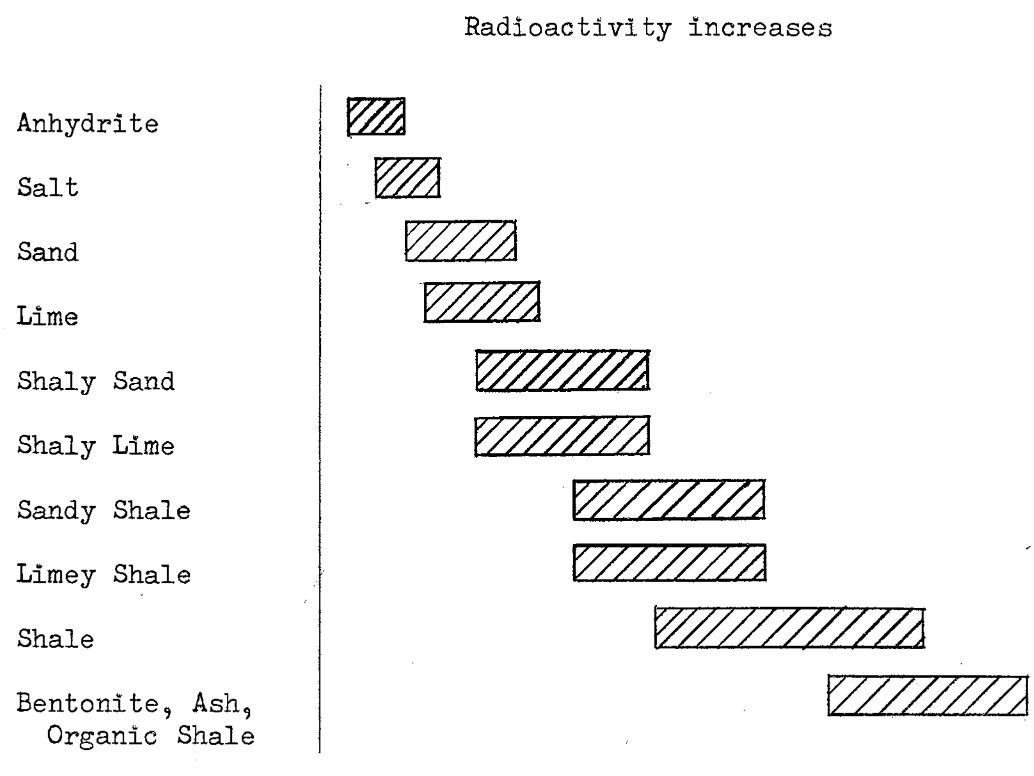

Figure 1. Relative Radioactivity Range of Rocks

These logs are commonly used to locate potential producing intervals in cased holes. They are also used when the drilling fluid in the hole will not yield a meaningful Self Potential Log. These logs, in general, are not as accurate as the Self Potential Log.

CHAPTER III

PATENTS GRANTED FOR DEVICES SIMILAR TO THE TEXTURE LOG

A patent search revealed the following logging techniques.

John E. Walstrom (3) patented an Acoustic Logging technique which uses a button shaped contact attached to a relatively rigid member. This member moves through a borehole while in contact with the formations intersected by the borehole. The rubbing of the button shaped contact against the formations produces mechanical vibrations whose intensity and frequency depend upon the physical properties of the respective formations encountered. As the contacts pass through formations of different texture and hardness, the vibrational energy is conducted to a microphone which gives an electrical output corresponding to the mechanical vibrations. The output from the microphone is then recorded at the surface.

Phillip S. Williams (4) devised a technique wherein a toothed wheel is rolled over formations comprising the wall of the borehole. The degree of sharpness of impact of the wheel upon the formation rock varies as the hardness of the rock. The impact energy is conducted to a microphone from which electrical energy corresponding to mechanical impact is recorded at the surface.

O. L. Goodwin's (5) technique employs a pointed stylus in contact with the formation. The stylus is mounted upon a leaf spring to which a strain gage is cemented. The resultant flexing of the spring as the stylus travels across the formations is translated into electrical current variations which are recorded at the surface.

Although these logging techniques are patented, no tool employing these techniques is being used today.

This report presents experimental data obtained using a somewhat different technique for converting mechanical vibrations to electrical impulses.

CHAPTER IV

STATEMENT OF PROBLEM

As stated in the preceding chapter, determination of formation thickness is usually based on data measured by either the Self Potential Log or the Gamma Ray Log. The Self Potential Log is usually preferred over the Gamma Ray Log. Since the Self Potential Log is only applicable when using certain drilling muds, it would be a great advantage to have a logging tool that could be used for accurate formation identity regardless of the type of drilling mud being used.

The problem considered in this study is to devise a unique texture logging technique, construct the testing apparatus, and test the apparatus by recording texture logs of a variety of materials usually encountered in drilling operations. The results of these tests demonstrate the feasibility of such a texture logging tool.

CHAPTER V

EXPERIMENTAL EQUIPMENT AND PROCEDURE

Logging Simulator: Figure 2 illustrates the apparatus used to simulate the proposed logging tool. The logging simulator consists of a cart with four wheels for support and a tandum set of wheels mounted upon a leaf spring that causes the cart to follow a straight track. On the back of the cart is mounted a tone arm to which is attached a crystal phonograph cartridge. The tone arm is designed for the proper tracking pressure upon the cartridge stylus.

Vibration Pickup: The phonograph cartridge is used as the vibration detector. The cartridge, or transducer, converts mechanical energy to electrical energy. The cartridge used in this study was an Astatic, model number L-40-A. The specifications for this cartridge are:

Type	- Crystal
Frequency Range	- 50 - 4500 cps
Output	- 1.4 volts
Tracking Pressure	- $2\frac{3}{4}$ oz.

The basic element of the cartridge consists of a plate of crystalline material, Rochelle salt, to which the stylus is attached. The principle of operation in the piezoelectric effect. When a piezoelectric crystal is mechanically strained or twisted, it produces a voltage that is a function of the rate of strain. An important feature of a crystal cartridge

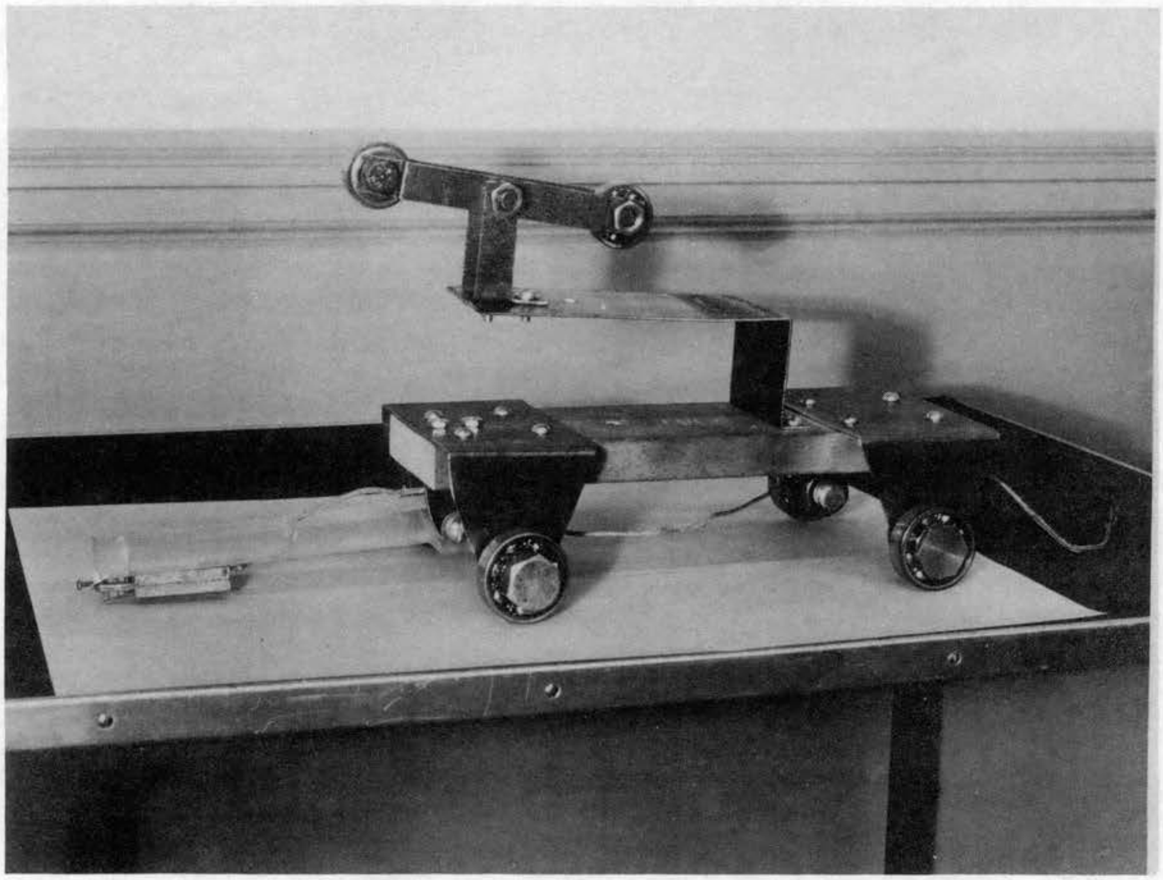

Figure 2. Logging Simulator

is that it produces a high voltage output and, therefore, requires no preamplification. The Astatic model L-40-A employs a chuck-type stylus holder so that the stylus (or needle) can be changed with ease. The crystal cartridge is shown in Figure 3.

Borehole Simulator: The enclosure used to simulate a borehole and to hold the core samples is shown in Figure 4. This borehole simulator consists of a trough on which the logging simulator rides and into which a removable core sample holder slides. Above the trough is a rigid top section with a groove cut down the middle. In this groove rides the tandum set of wheels that are mounted on the leaf spring of the logging simulator. The tandum wheels riding in this groove assures that the logging simulator tracks straight down the borehole simulator.

An electric motor mounted at one end of the borehole simulator drives an associated drum and cable that pulls the logging simulator the length of the borehole simulator. The motor used was a Telechron synchronous motor, type C-4-X requiring a 55 volt a.c. voltage source. It has an angular velocity of two revolutions per minute. A 1½ inch drum was attached to the shaft of the motor to provide a linear pulling speed for the logging simulator of .32 inches per second. This slow linear speed was necessary since the core samples were of relatively short lengths. Thus, to obtain a sufficient recording time as the logging simulator moved across each sample, a slow linear speed was required. A variac was used to reduce the available line voltage to the required 55 volts.

Design of the Stylus: The output signal from the crystal cartridge as a rough surface is scratched by the stylus depends to a great extent upon the stylus diameter. The stylii used in this research investigation

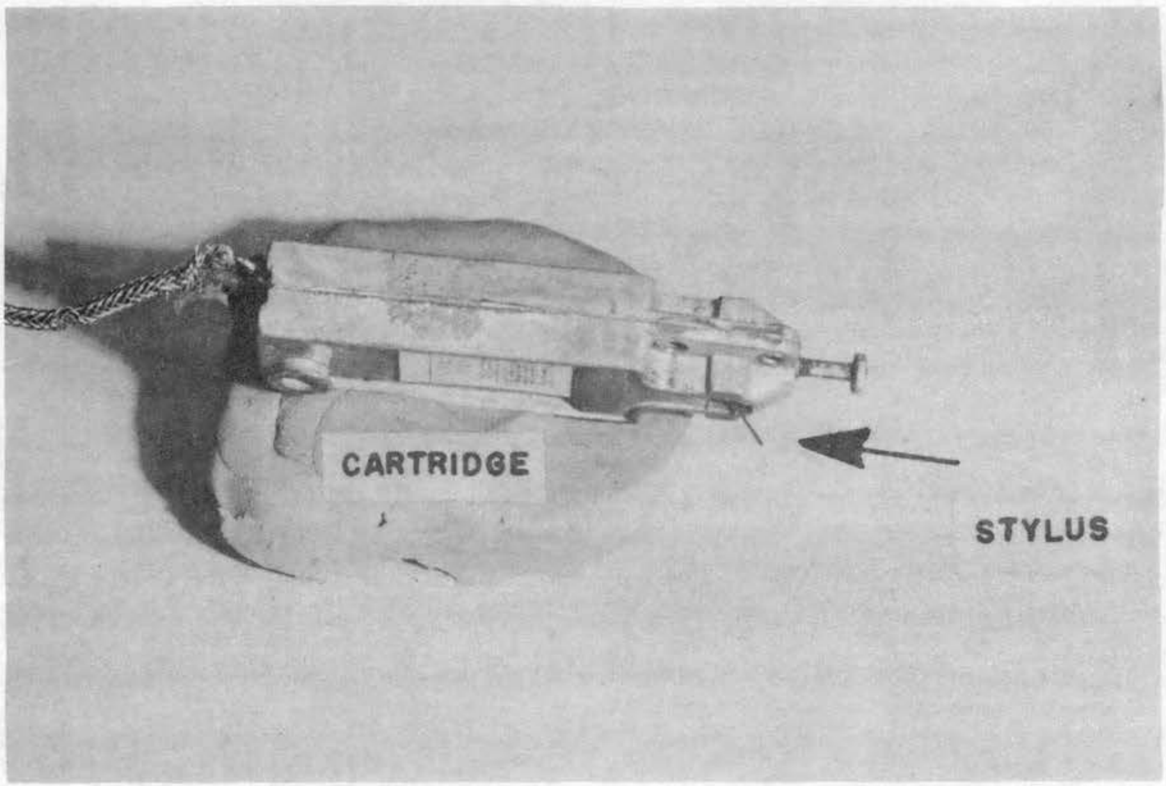

Figure 3. Crystal Cartridge

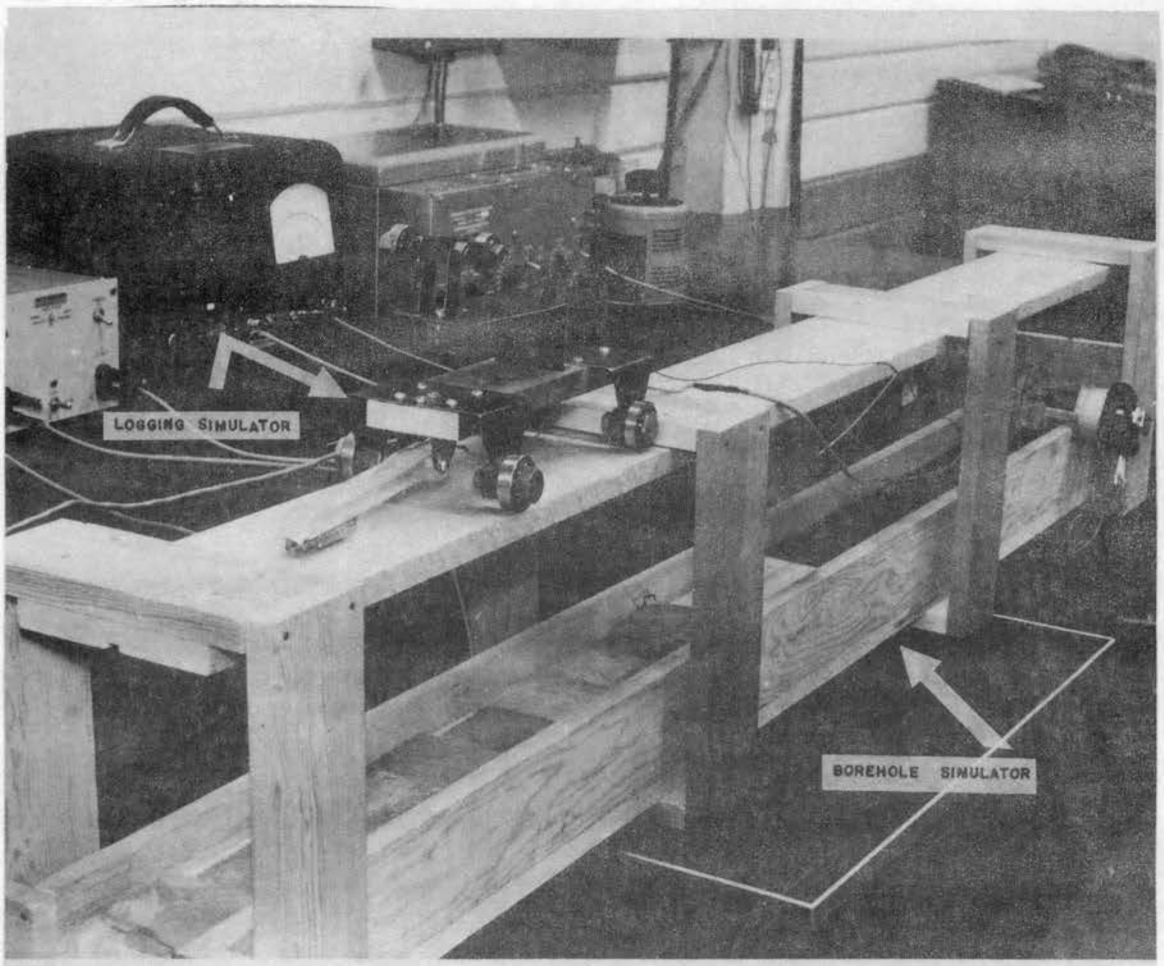

Figure 4. Borehole Simulator

were various sized "needles" made from piano wire. It was found that the larger diameter needles did not give good response because the needle diameter was too large with respect to the roughness of the material being tested. On the other hand, needles too small in diameter were not stiff enough to withstand the pressure applied as it was scratched across a rough surface. An optimum diameter between these extremes was found. A needle diameter of .016 inches was found to give best results and was used in all testing in this study.

Instrumentation: Preliminary tests showed that the output signal generated by the crystal cartridge as it scratched the rough surfaces was very random. A spectrum analyzer was used to determine the range of the major component waves that comprise the output signal. Figure 5 shows a typical plot of amplitude versus log frequency of the output signal generated by the crystal as the stylus scratched a typical core sample. This picture shows that the major components of vibration lie in the frequency range from 200 to 1000 cycles per second. A description of what the spectrum analyzer measures is found in Appendix A.

Figure 6 and Figure 7 show the instrumentation used in recording the output from the crystal cartridge. The output from the cartridge was first passed through a bandpass filter which allowed only the components in the range of 0-1000 cycles per second to be recorded. The output from the filter was then amplified by a voltage amplifier. The amplified signal was passed through a root-mean-square voltmeter. This voltmeter takes the root-mean-square of the input signal and converts it to a rectified output signal whose magnitude equals the root-mean-square value of the input signal. The output from the voltmeter was passed through an electrolytic capacitor and then to a recorder. The capacitor was used as

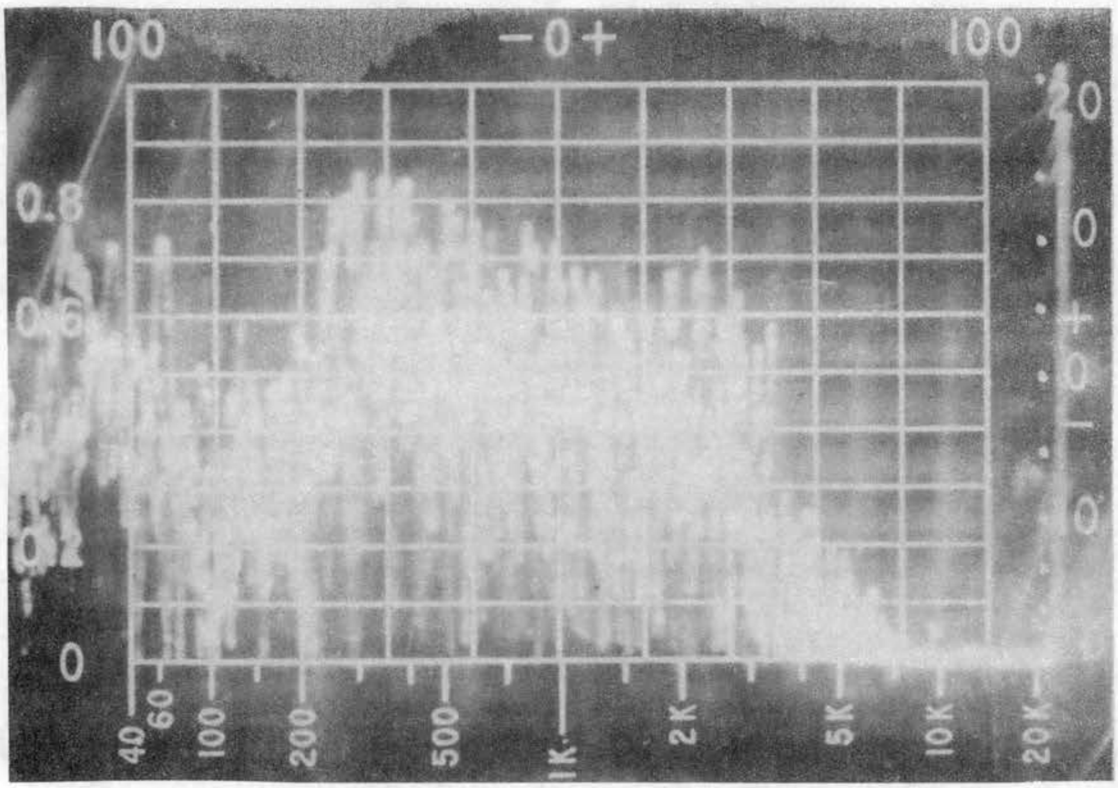

Figure 5. Spectrum Analysis

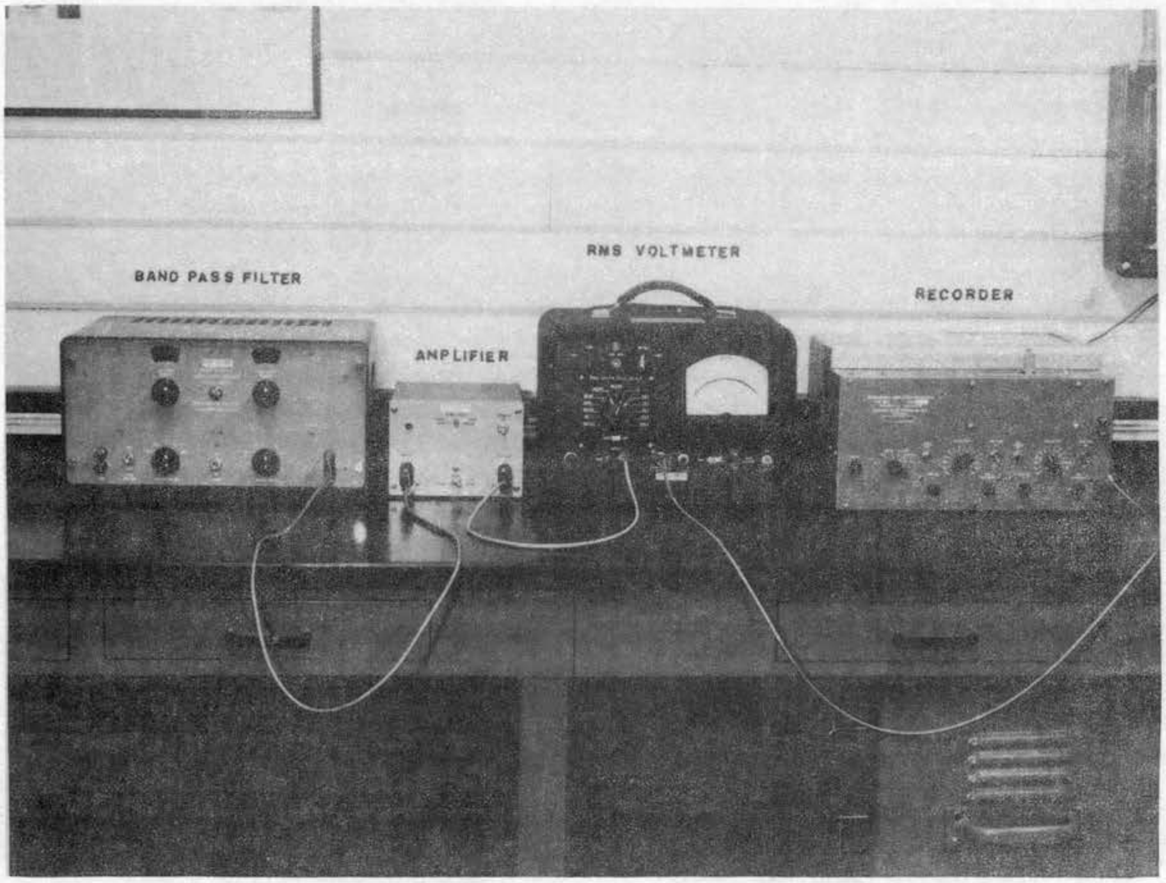

Figure 6. Instrumentation

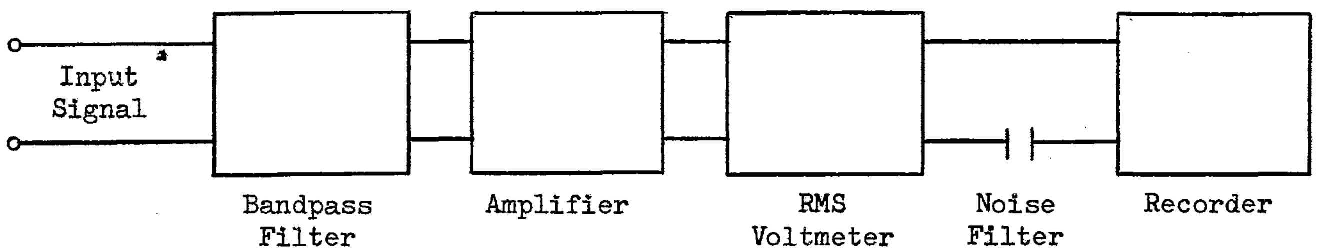

Figure 7. Circuit Diagram of Instrumentation

a noise filter. Co-axial cables were used between all instruments to eliminate as much extraneous noise as possible. The recorded signal was actually an amplitude versus time graph, but since the recorder speed and the logging simulator speed are both known, this record can be converted to an amplitude versus length graph. Thus, this graph presents a representative picture of the rectified wave form of the input signal.

Figure 8 shows the entire testing apparatus and instrumentation. Manufacturers' names and specifications of the instrumentation used in this study are found in Appendix B.

Test Specimens: Surfaces tested in this study included different grades of sandpaper and core samples. Figure 9 shows the three sandpaper samples used. These samples were 150 grit, 220 grit, and 320 grit waterproof silicon carbide paper. Preliminary tests were conducted using the sandpaper samples to determine if a difference in roughness could be detected by the technique presented in this thesis. The core samples used in this study are shown in Figure 10. The core samples, identifiable by the numbers in Figure 10, are:

Sample Number	Core Identity
1	Puente Sandstone of California
2	Vugular Limestone
3	Lansing K. C. Limestone
4	Cypress Sandstone
5	Siltstone and Shale
6	Siltstone

A geological description of each core sample is presented in Appendix C.

Test Procedure: The first phase of tests were performed using an

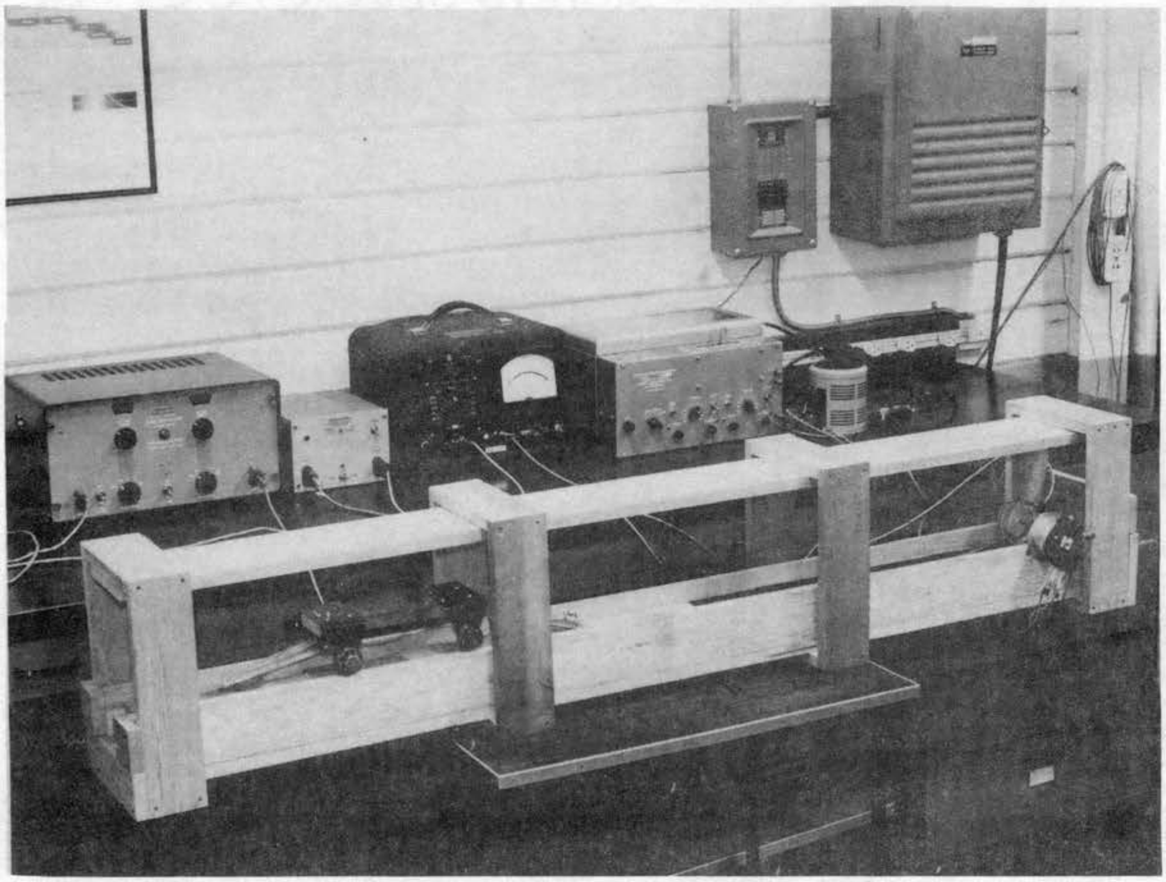

Figure 8. Complete Testing Apparatus

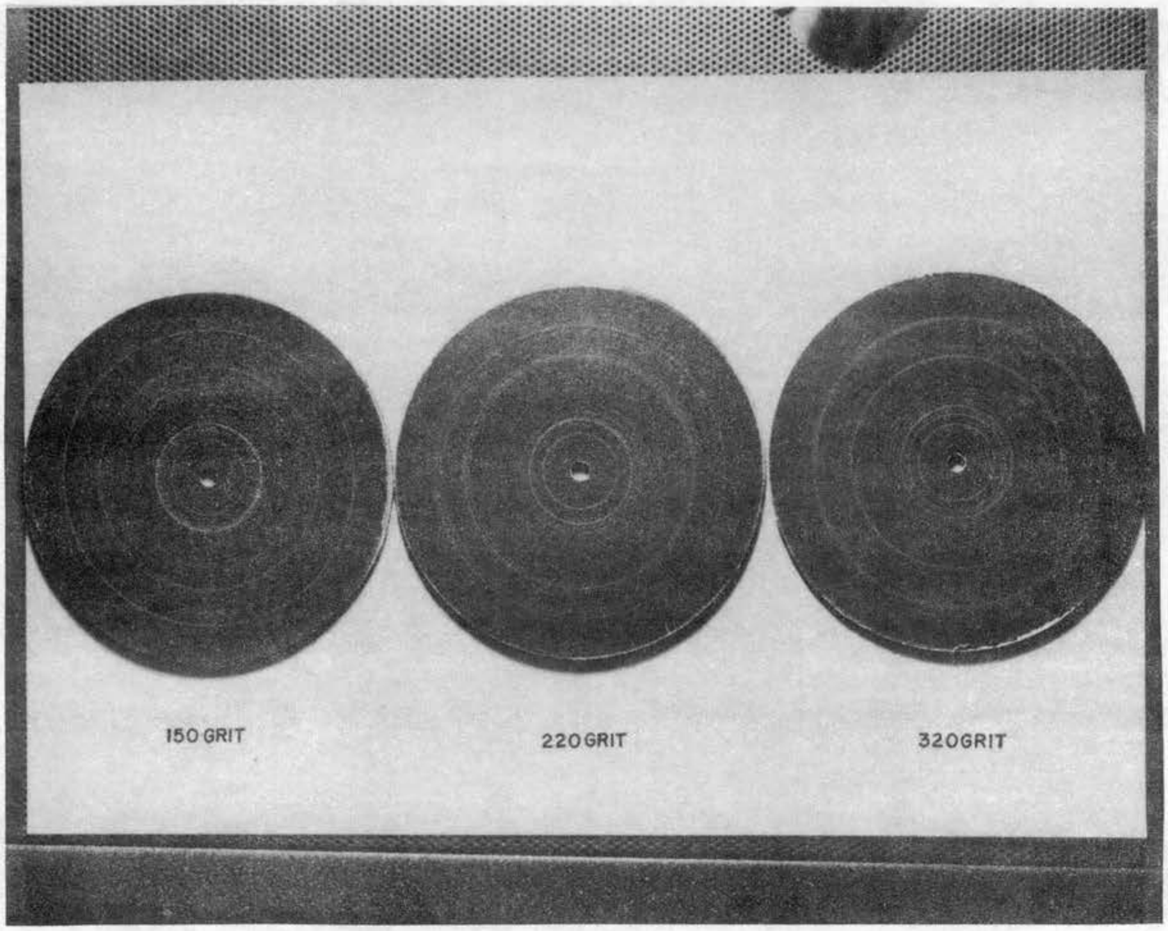

Figure 9. Sandpaper Samples

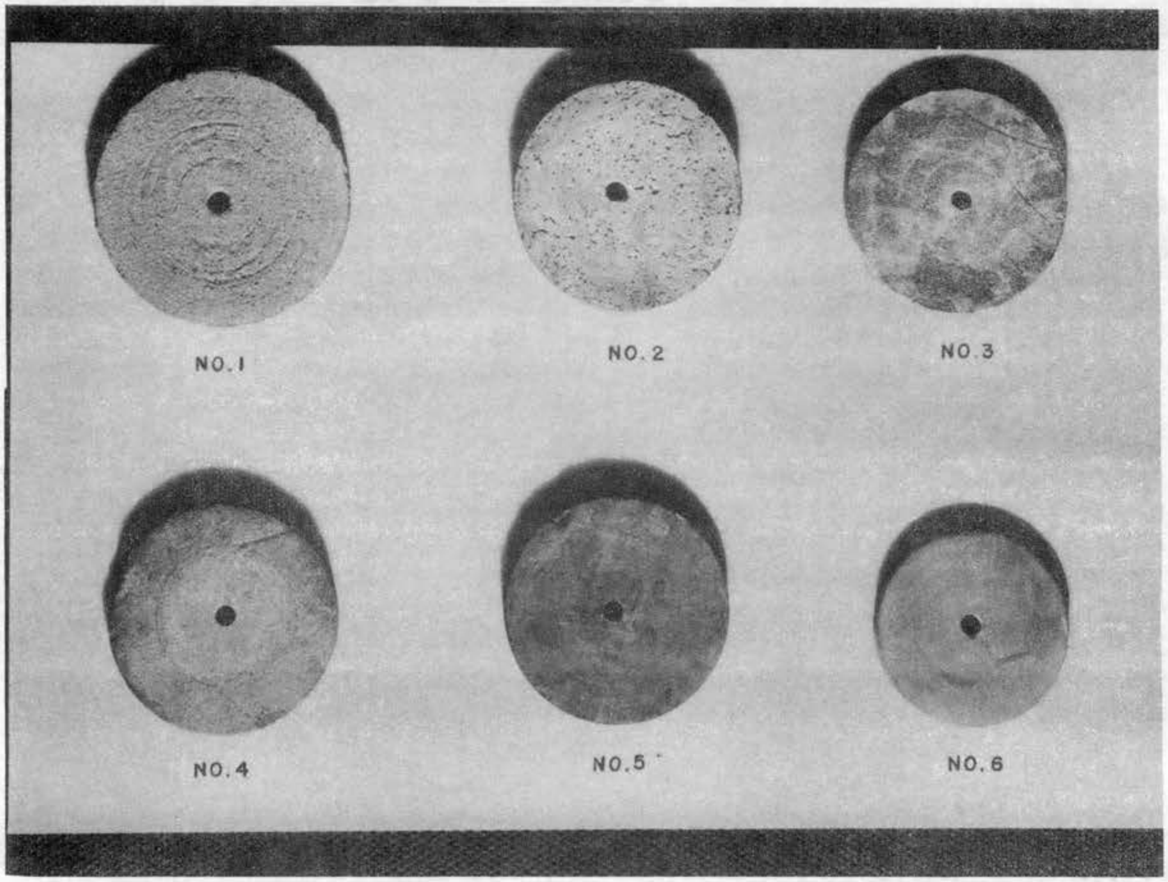

Figure 10. Core Samples

ordinary 78 rpm phonograph turntable, tonearm, and cartridge. The sandpaper and core sample disks were "played" on the turntable and the output signal from the cartridge was recorded using the instrumentation described earlier in this chapter. The turntable was used in order to record the characteristic signal of each sample over any desired time interval. By adjusting the point of contact radius of the needle, the equivalent linear speed could be varied.

The second phase of tests were performed using the combined logging and borehole simulator. Logs were obtained on both the sandpaper samples and the core samples.

Both amplitude versus time records, and amplitude versus frequency records were obtained in both phases of testing.

CHAPTER VI

EXPERIMENTAL RESULTS

Results from Phase One and Phase Two were obtained in the form of amplitude versus time records using the Offner recorder and scope pictures from the spectrum analyzer. The scope pictures showed a representation of the amplitude spectral density of the output from the crystal cartridge. The horizontal axis in the scope pictures represents a linear frequency range, 0-1000 cycles per second. The vertical axis represents amplitude measured in decibels.

The amplitude spectral density is defined as the amplitude divided by frequency bandwidth.

The graphs from the Offner recorder are plots of time on the horizontal axis and amplitude in volts on the vertical axis.

In Phase One, tests were conducted using the 78 rpm turntable in conjunction with the sandpaper and core sample disks. Figure 11 shows data from the Offner recorder giving an amplitude versus time graph for the various sandpaper disks. The results clearly show a decrease in amplitude for disks of decreasing roughness. Figure 12 shows scope pictures taken from the spectrum analyzer. These pictures show that the amplitude (or amplitude spectral density) decreases as the roughness of each sample decreases.

In the second part of Phase One, tests were conducted using the core

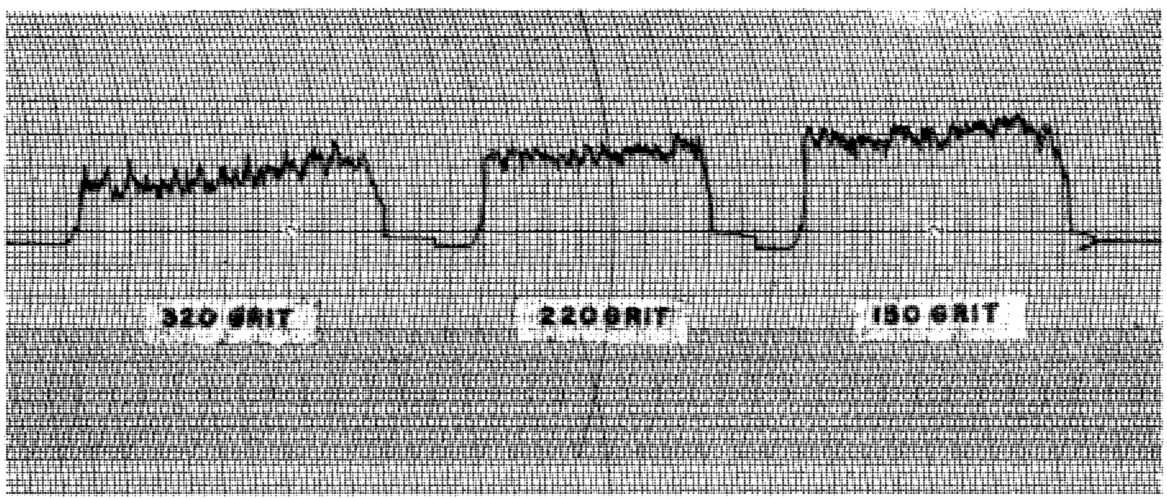

Figure 11. Amplitude Versus Time for Sandpaper Disks Using Turntable

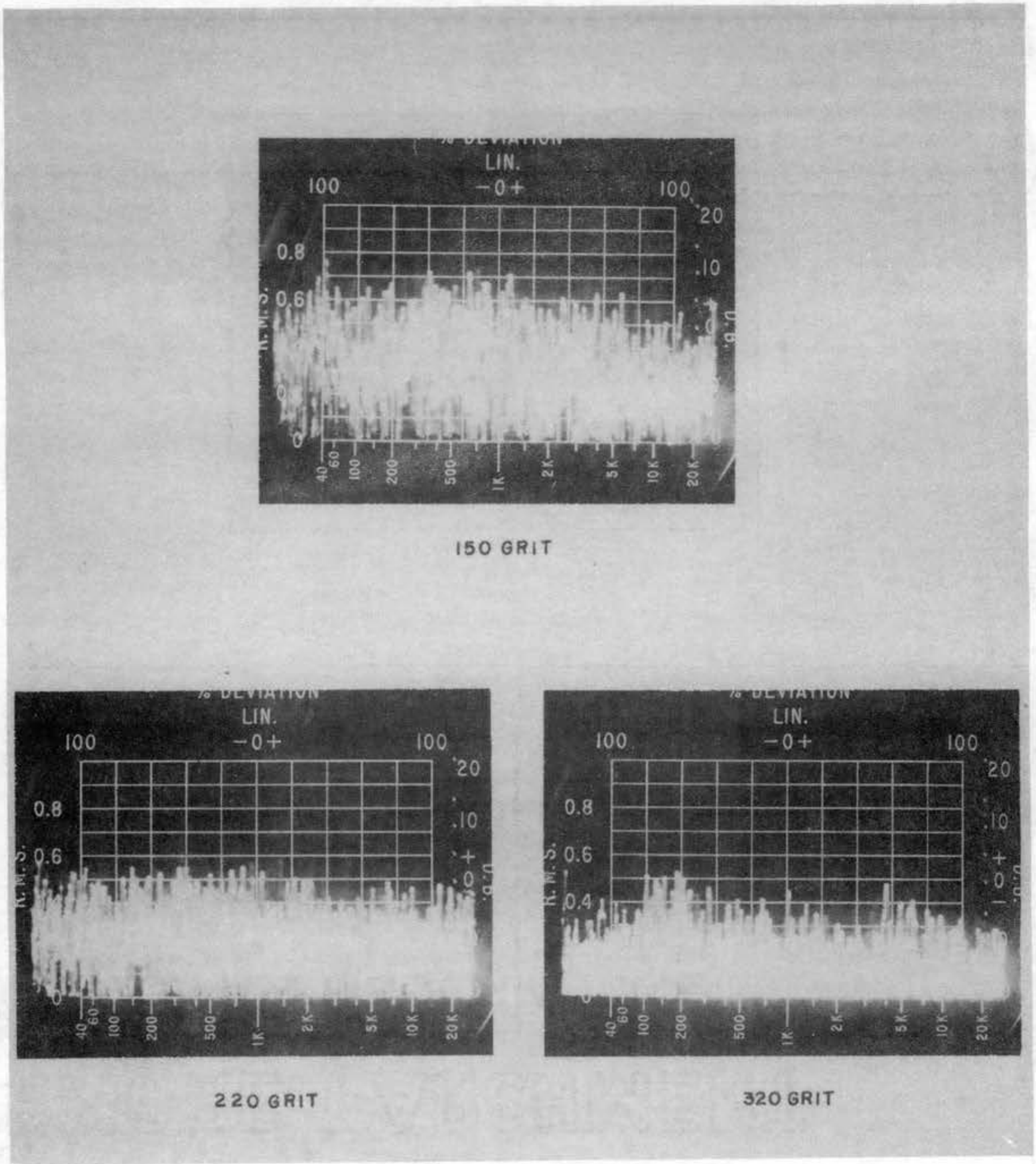

Figure 12. Amplitude Versus Frequency for Sandpaper Disks Using Turntable

samples. Figure 13 shows the amplitude versus time graph, and Figure 14 shows the scope pictures. Again, both figures show a definite decrease in amplitude results as core samples of decreasing roughness are tested.

The stylus was kept at a radius of one inch from the center of the turntable in all testing in Phase One. The equivalent linear speed was 8.2 inches per second. Instrument settings for the testing in Phase One were as follows:

Bandpass Filter:	Bandwidth 0-1000 cps low amplitude input mode
Amplifier:	Gain 20 db
Root-Mean-Square Voltmeter:	1 volt range rms output mode
Recorder:	Gain - 2 Sensitivity - 5 volts/cm Recording speed - 2.5 mm/sec.

Similar tests were conducted in Phase Two. As stated earlier in this report, a slow speed was necessary for pulling the logging simulator across the specimens in order to obtain a log of the short core samples. This speed was .32 inches per second. Instrument settings for tests conducted in this phase were the same as in Phase One.

Figure 15 shows the amplitude versus time graph recorded as the logging simulator traveled the length of the three sandpaper samples. Figure 16 shows corresponding pictures taken from the spectrum analyzer. As in Phase One, the amplitude decreases as the roughness decreases.

The final stage of testing in Phase Two was conducted using the same core samples used in Phase One. Figure 17 shows the amplitude versus time graph for each core sample. Figure 18 shows the corresponding pictures obtained from the spectrum analyzer. Again, it is clearly seen

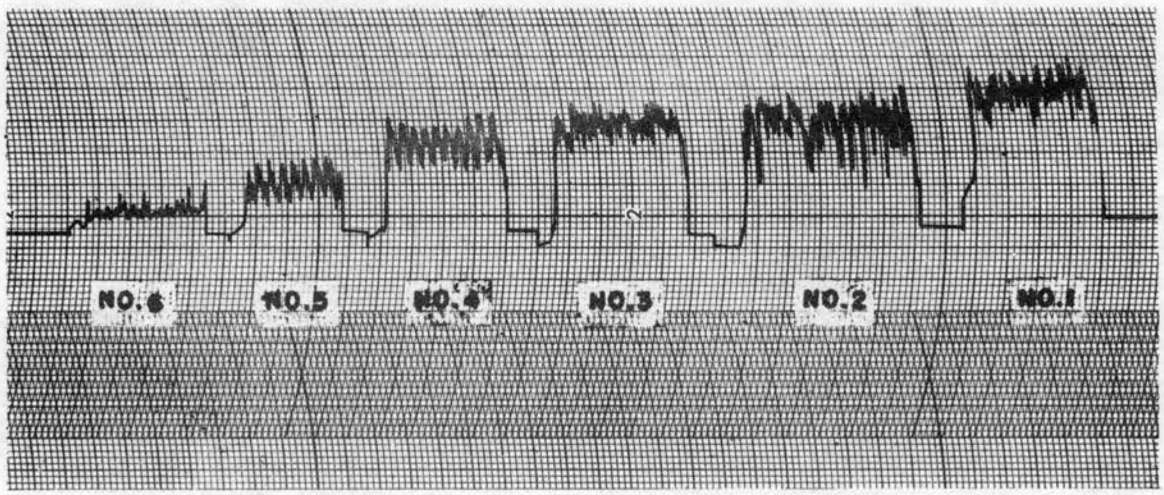

Figure 13. Amplitude Versus Time for Core Samples Using Turntable

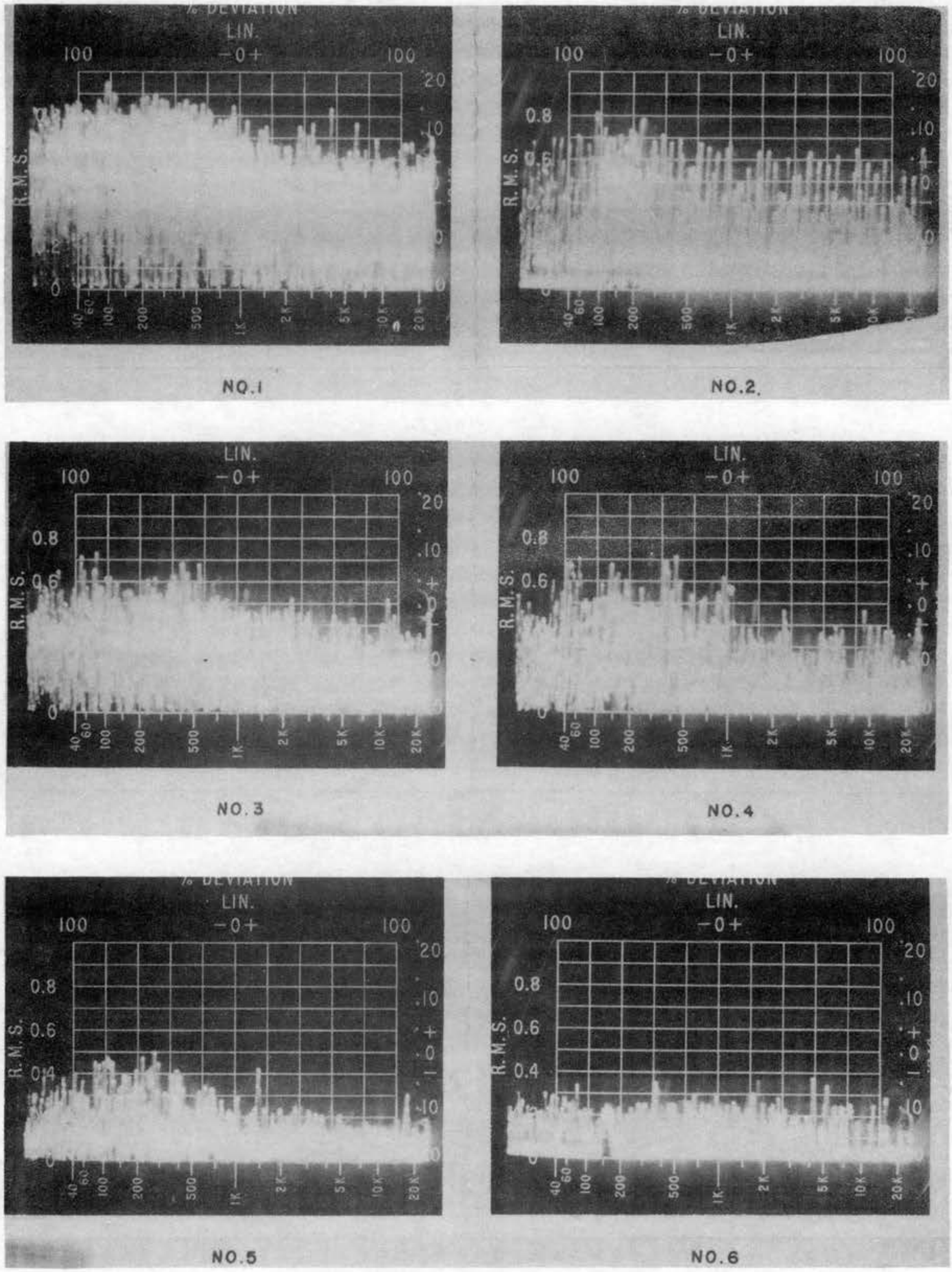

Figure 14. Amplitude Versus Frequency for Core Samples Using Turntable

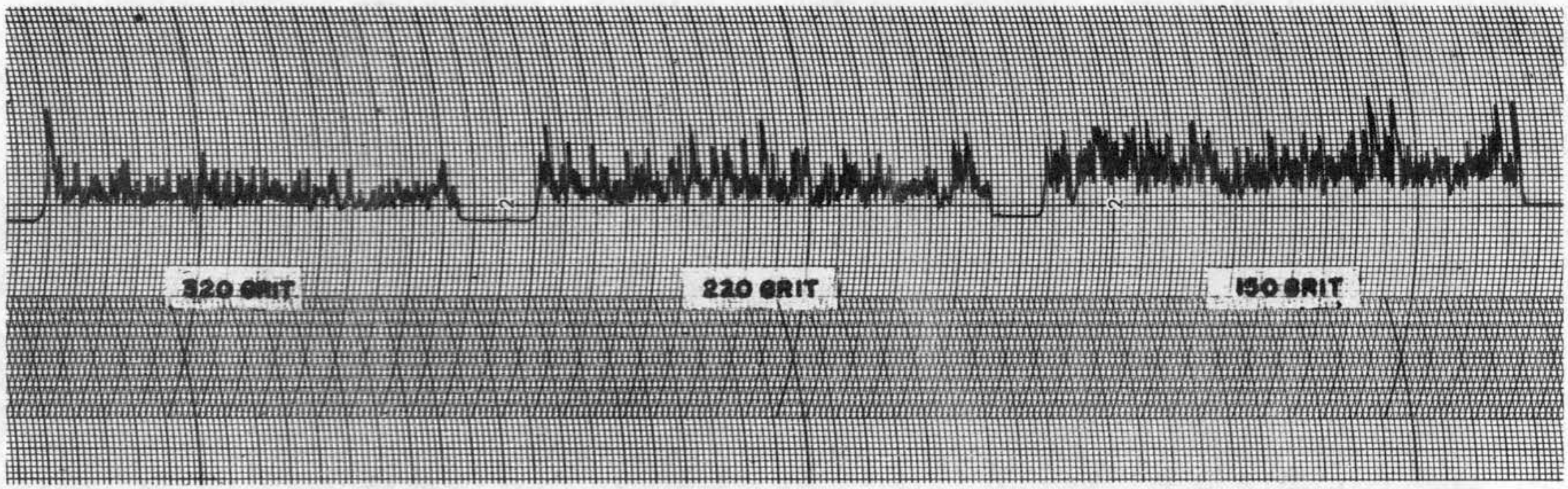

Figure 15. Amplitude Versus Time for Sandpaper Disks Using Logging and Borehole Simulator

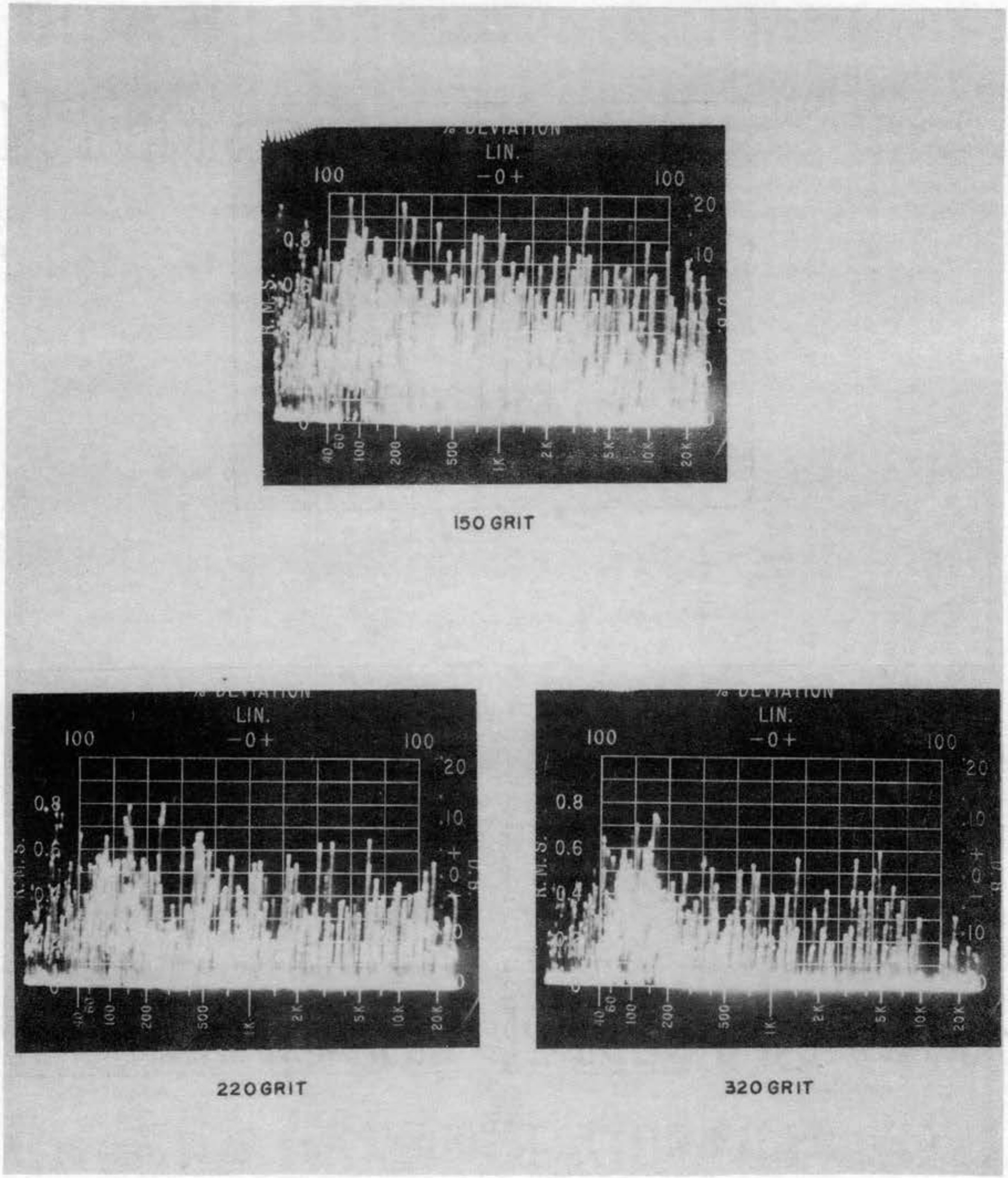

Figure 16. Amplitude Versus Frequency for Sandpaper Disks Using Logging and Borehole Simulator

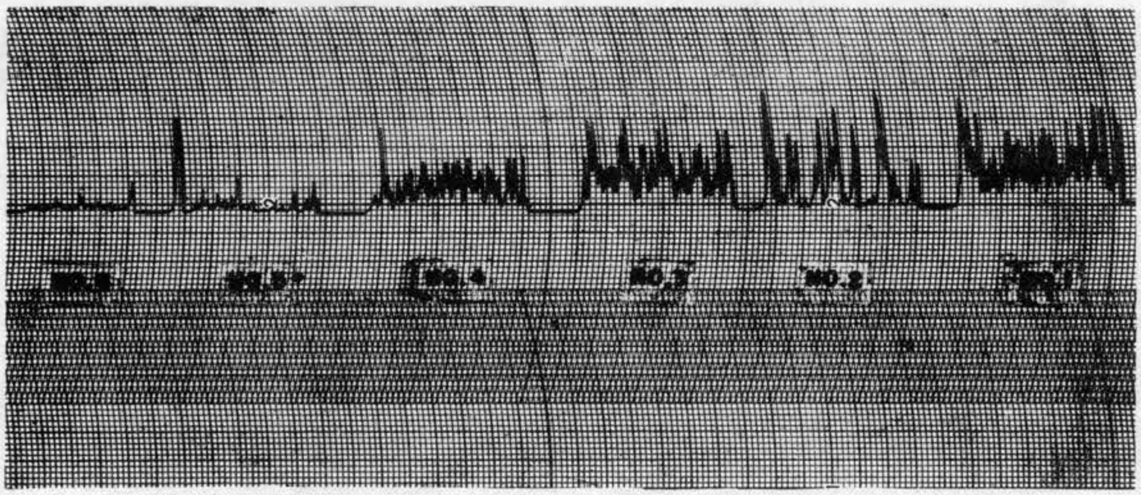

Figure 17. Amplitude Versus Time for Core Samples Using Logging and Borehole Simulator

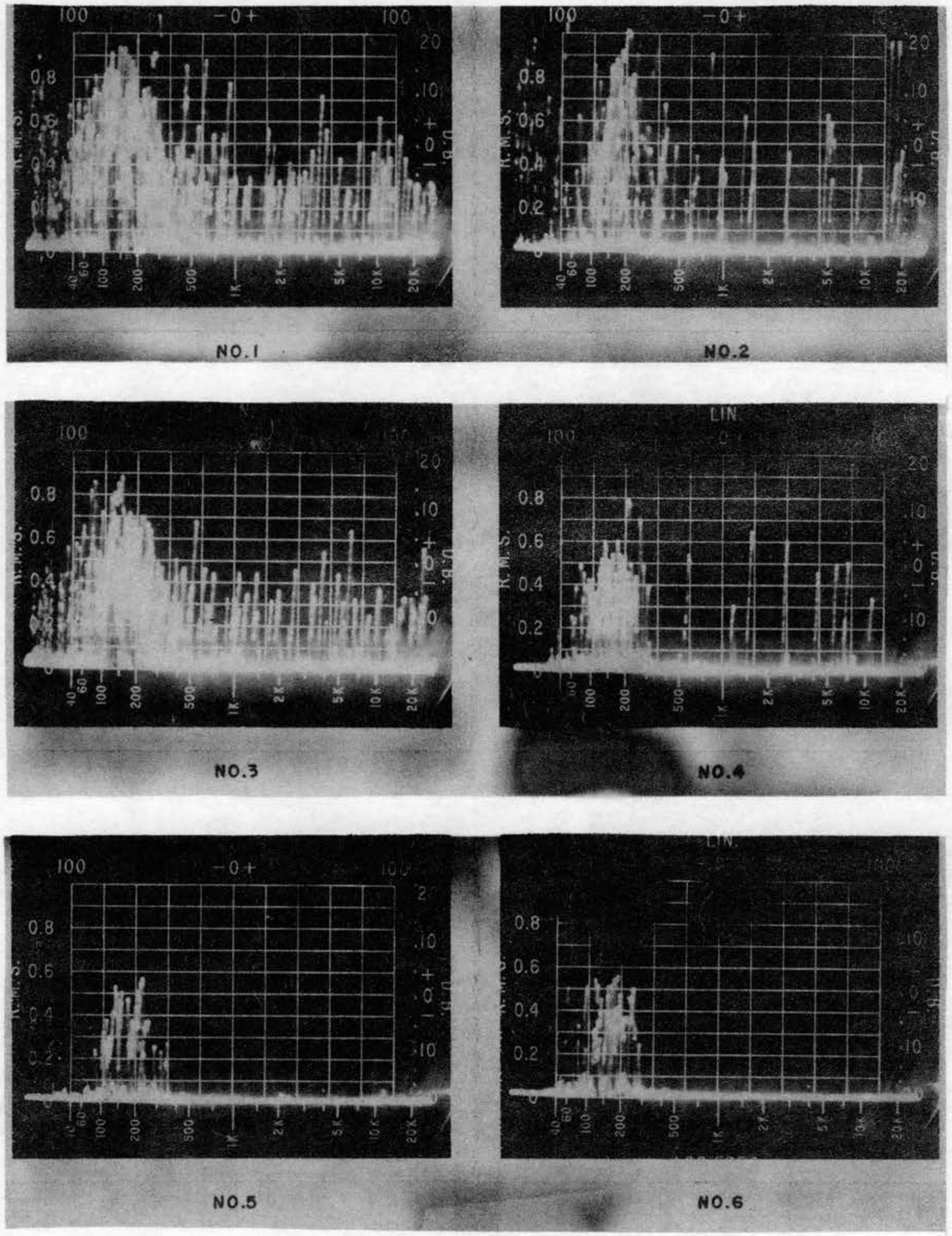

Figure 18. Amplitude Versus Frequency for Core Samples From Logging and Borehole Simulator

that the amplitude decreases as the roughness decreases. The larger spikes at the left end of the wave forms in Figure 17 are caused by the stylus striking the discontinuity between the core samples.

The shape of the wave form of Core Sample 2 in Figure 17 differs significantly from the wave forms of the other core samples. This sample is a vugular limestone which has a fairly smooth texture except for deep pits randomly spaced throughout the matrix rock. These pits are clearly indicated as sharp peaks as opposed to the low amplitude peaks that correspond to the otherwise smooth texture. This anomaly would be very useful in the interpretation of logs obtained using this technique.

It is noted that, although instrument settings were the same in both phases of testing, the amplitudes were higher in the results obtained from Phase One. This can be attributed to the difference in the linear speed of the stylus in the testing. The speed of the stylus in Phase One was much greater than in Phase Two. The greater speed produced extra inertia forces on the stylus, thereby making the output from the crystal cartridge greater.

CHAPTER VII

CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER STUDY

The results of this research study clearly show the feasibility of using a crystal cartridge as a vibration pickup to distinguish qualitatively the difference in the texture of formation rocks. It further establishes the feasibility of designing a logging tool, based on the concept proposed in this thesis, to differentiate between subsurface formations and, thereby, determine their boundaries.

It is recommended that further tests should be conducted using other cartridges, or similar emf generating devices, with better frequency response than the cartridge used in this study. It is suggested that a borehole simulator be constructed to simulate the adverse conditions that would be encountered in actual well logging. These conditions would vary from atmospheric conditions to the relatively high temperatures and pressures encountered in reservoirs. Also, the presence of mud cake on the wall of the wellbore and nonuniformity of the borehole diameter should be simulated. With this borehole simulator, texture logs could be obtained under realistic wellbore conditions. Thus, further research is needed in order to develop a texture logging tool employing the concepts proposed in this study. It is recommended that particular attention be devoted to stylus design. In particular, the optimum shape and material used for the stylus must be determined.

Further studies will be necessary in order to determine if quantitative data can be obtained from a texture log. Possibly, other logging tools could be used in conjunction with the texture logging tool for recording logs that could be interpreted quantitatively.

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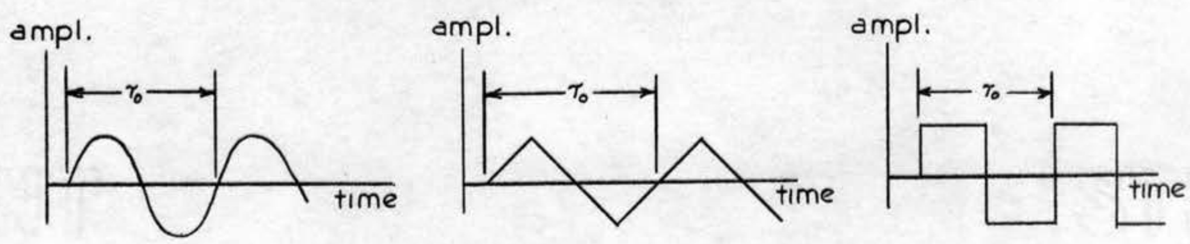
APPENDIX A

EXPLANATION OF SPECTRUM ANALYZER

The spectrum analyzer is a precision instrument for viewing signals from 40 cps to 20 kc on either a logarithmic frequency scale or a linear frequency scale. The spectral display appears on the screen of a long persistence cathode ray tube with the frequency of the applied signal being displayed on the horizontal axis while the amplitude of the signal is displayed on the vertical axis.

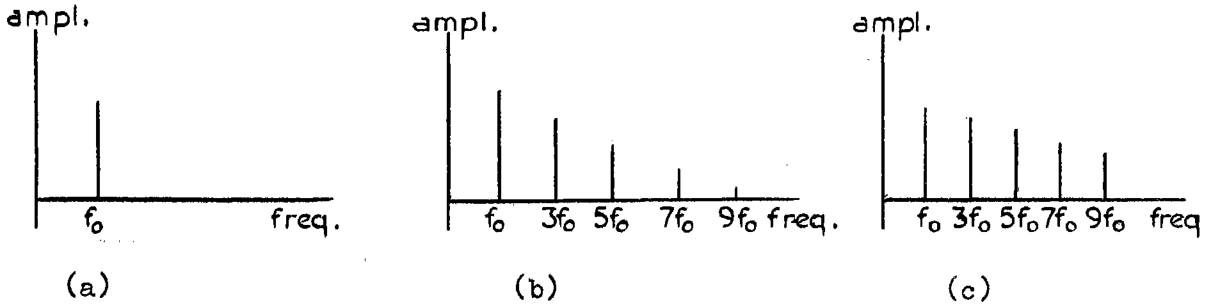
A complex wave form, having a large number of harmonics, can be directly analyzed by measuring the harmonic frequency components as they are displayed on the screen of the cathode ray tube. The figure below shows a typical frequency spectrum for different periodic signals.

The Composite Signal



(a) (b) (c)

Component Signals Detected by Analyzer



APPENDIX B

SPECIFICATIONS OF INSTRUMENTS USED

IN THE RESEARCH STUDY

1. Spectrum Analyzer:
   Model SS-20L
   Proboscope Co. Inc.
   Syosset, N. Y.

2. Dynograph Amplifier-Recorder:
   Type 542
   Offner Electronics Inc.
   Chicago, Ill.

3. True Root-Mean-Square Voltmeter:
   Model 320
   Ballantine Laboratories, Inc.
   Boonton, N. J.

5. Hewlet Packard Amplifier:
   Model 450-A

6. Bandpass Filter:
   Model 330M
   Krohn-Hite
   Cambridge, Mass.

APPENDIX C

GEOLOGICAL DESCRIPTION OF CORE SAMPLES

CORE IDENTITY	TITLE	QUALITATIVE DESCRIPTION
1.	Sandstone	Matrix of fine grained angular quartz and basalt with coarse grains of angular quartz scattered throughout-general appearance is grey-pores appear to be filled with silt.
2.	Limestone	Dense limestone containing small vugs (average diameter of 1/16 inch; 3/16 inch between vugs).
3.	Limestone	Many pores give the rock a sponge-like appearance. The pores are clearly distinguishable by the eye and are less than 1/64 inch in diameter.
4.	Sandstone	Fine grained-angular sandstone-very light brownish grey color-reactive to HCl-well cemented.
5.	Shale	Coherent, grey shale.
6.	Siltstone	Dense siltstone-light grey color-reactive to HCl.

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Master of Science

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Biographical:

Personal Data: Born January 20, 1941 in Duncan, Oklahoma, the son of Roy and Nola Barrett.

Education: Graduated from Wilson High School, Wilson, Oklahoma, in in 1959; received the Bachelor of Science degree from Oklahoma State University, with a major in Mechanical Engineering, in January, 1964; completed the requirements for the Master of Science degree in May, 1965.

Experience: Employed as a part-time research assistant in the School of Mechanical Engineering, Oklahoma State University, from June, 1963 to September, 1964.

Honorary Organizations: Pi Tau Sigma

Honors and Awards: Awarded the Pan American Fellowship in Mechanical Engineering, 1964-1965.