THE ESTABLISHMENT OF A DIGITAL SEISMIC ACQUISITION SYSTEM AND ITS SUBSEQUENT APPLICATION IN THE FIELD.

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This thesis is dedicated to my wife
Margaret, without whom it would not
have been typed and whose support and
encouragement was always rendered
in times of need.

ABSTRACT

The seismic method in exploration geophysics consists of creating a mechanical disturbance at or close to the surface of the earth, and observing its effects at a number of chosen locations along the surface. The purpose of seismic data acquisition is to record these effects in such a manner that their relation with the initial disturbance can be interpreted as a guide to the earth's subsurface structure (Nettleton,1940).

The validity of data interpretation depends upon the fidelity of recording. A better seismic interpretation can result from correctly collected data using instrumentation which faithfully records the seismic signal. Subsequent computer processing cannot reconstruct information which is not contained in the recorded field data. Hence, the quality of field data recording must be at an optimum level, otherwise the result will be an inferior interpretation (Donnell,1957)

A reflection seismic data acquisition system was assembled and put into operation. The basic instrument was a Texas Instruments DFS IV, obtained from marine vessel M/V Banksia, and commissioned for land application.

The system was tested and evaluated. The instrument analog filter phase distortion was studied in detail. The study indicated that phase distortion can be a major cause of seismic misties. Without a knowledge of the particular recording instrumentation filter transfer function, data processing

bureaux may not compensate for phase distortion effects adequately (Gray et al., 1968).

Once testing was completed satisfactorily, the operational system was applied to several practical field situations of commercial standard. A series of noise studies was performed to evaluate not only source generated noise, but also to study the effect of different types of energy sources on seismic data. In addition, two multi-fold seismic lines were recorded, both of which were considered superior to those previously produced by the industry, at each location (Jacia, pers. comm., 1984).

Finally, a single fold three-dimensional areal seismic survey was performed over the Woodada gas field. The results of this survey will be released after processing has been completed by Allied Geophysical Laboratories (University of Houston), and are not contained in this thesis.

Future areas for field application are discussed.

Recommendations are made for further research work in the area of phase distortion; the examination of different energy sources; a review of receiver properties and horizontally travelling seismic waves; a bore-hole seismic study and finally, a fourth-dimensional recording technique involving the performance of an offset VSP survey at the same time as an areal 3-D seismic survey.

Volume 1 describes the establishment of the acquisition system and its subsequent field application.

Volume 2 contains the Appendix of instrument tests and their analysis.

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Since little material has been published with regard to seismic data recording instrumentation, most references have been taken from books by M. Pienchot, 'Seismic Instrumentation', 1984 Geophysical Press Vol.2; B.J. Evans, 'Geophysics: Field Data Acquisition', W.A.I.T. publication 1983; Introduction to Geophysical Prospecting by M.B. Dobrin, 1981 McGraw-Hill Inc.; and manufacturers' technical manuals.

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CHAPTER 1

INTRODUCTION

1.1 Geophysical Surveying

Exploration geophysics involves the application of methods of physics to geological and related problem solving. In exploration work, measurements of the physical properties of geological structures enable the structures to be identified, and their dimensions and some of their physical properties to be determined. The most common geophysical techniques are broadly classified as seismic, gravity, magnetic, electrical, electromagnetic, thermal and radiometric (Nettleton, 1940).

The selection of any particular geohpysical method depends upon the particular property which contrasts the geological structure against the surrounding rocks. For example, the parameters used in seismic exploration are elasticity and density. The velocity of propagation of a seismic wave through a rock is a more easily measured characteristic parameter than geological elasticity. Boundaries between different geological beds or interfaces are frequently also boundaries of velocity and density. The term "acoustic impedance", which is the product of velocity and density, is the key parameter (Sheriff, 1980).

A seismic body wave travelling through one medium and arriving at a second medium separates so that there is partial reflection of the wave upward, and downward continuation of the balance. This refracted wave is remanent energy transmitted on as the body wave in the second medium. The same process occurs at each subsequent interface (Howell, et al., 1940).

1.2 The Seismic Method

Since most geophysical tools at the explorationist's disposal are used for physical property measurement at the surface, the seismic explorer must be content with utilising the upward reflected wave as a guide to an area's geology. For example, if knowledge of the geology in a particular region is desired, the seismic geophysicist would perform a seismic survey along a series of profiles so that, after data processing, an interpretation of reflected wave forms may be indicative of the geological structure beneath the profiles.

Due to progressive absorption with increasing travel path, the character of the returning wavelet becomes increasingly modified. Reflections from shallower horizons are stronger in amplitude and the frequency content matches more closely that of the source wavelet (Waters, 1980).

As a result of such body wave modification during both downward and upward energy transmission, the wavefront arriving for analysis at the earth's surface has undergone an amplitude and phase change which is directly related to the geology encountered at the various interfaces during transmission. With the knowledge therefore that certain geological configurations cause the attenuation and modification of the character of the wavefront, data observed at the surface may be processed so that an objective interpretation of the causitive geology may ensue.

Because reflections from deeper geological horizons will have experienced greater character modification, it is important that these be faithfully recorded. Furthermore, these signals will be much weaker due to wavefront spreading. Consequently, their detection in the presence of background noise is an important technical problem (McCoy, 1966).

1.3 Origin of the Project

Until the mid-1950's, seismic data was not submitted for processing because recordings taken in the field were not reproducible. Strip chart type records were a permanent representation of voltages generated in surface receiver geophone sensors. These voltages represented the seismic wavefront arrivals and the interpreter was required to develop a geological image from them (Dobrin, 1952).

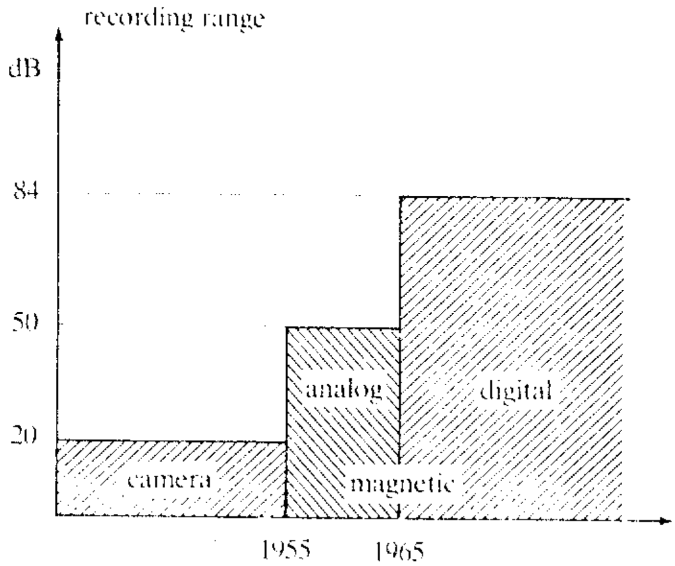
During the mid-1950's the introduction of analog magnetic recording allowed magnetic tape recorders to replay recorded data with enough accuracy to commence more sophisticated seismic data processing and subsequent interpretation.

Replacing the camera by a magnetic recorder increased the recording (or "dynamic") range from 10 times (or 20dB) to better than 300 times (or 50dB), see Figure 1.1. This big jump in technology allowed more accuracy of recording, but the important consequence of magnetic recording was reproducibility. Reproducible records when added or 'stacked' together, allowed the use of records with poor signal to noise ratio for the first time. Stacking enhances coherent signal while attenuating random noise. Analog computers were built to process the data, enhancing the accuracy of seismic interpretations (Pienchot, 1984).

In the mid-1960's, the introduction of the digital magnetic recorder improved recording dynamic range even further. This allows a signal range of 1:16,000 to be recorded. On the decibel scale, that is 84dB (Melton, 1968).

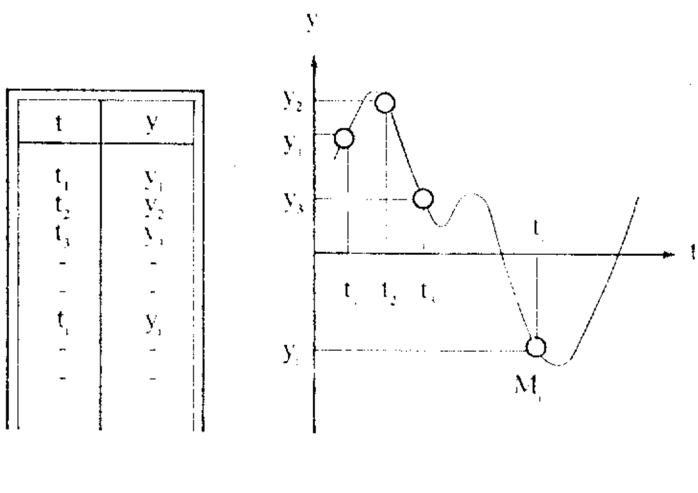
Thus, from the analog signal representing geophone voltages on paper, electronic technology progressed to sampling the same signal and storing its value in code on magnetic tape (Figure 1.2) in real time. Today, strip chart type camera records act only as a guide to data recording quality. All digital recording systems still have some form of camera. Even though its display is only a limited version of that which is recorded on magnetic tape, it provides a useful guide to recording quality in field operations.

Once the digital recording system has mobility, it can venture out to apply its technology in hithertofore unexplored regions. Dependent upon equipment sophistication, the use of digital field equipment thus allows the application of computers in



The recording dynamic range of different types of seismic recorders.

Figure 1.1



Analog and digital representations

Figure 1.2

the field and hence, on-site processing facilities. A new era of recording has occurred. The digital recording is followed by some degree of field processing, which reduces effort and cost of processing normally performed in the city bureaux (Nelson, 1983).

The financial cost of a digital seismic recording system is dependent upon the degree of sophistication. A typical digital 48 channel recording system costs at least A$500,000. This includes such essential peripheral devices as an oscilloscope and camera for data display. With marine application, a marine cable, reel, vessel, crew, and navigation system are additional, whereas with the land application, a land cable, geophones, interconnecting cables, vehicles and crew are required. Such equipment can add a minimum A$200,000 to the price in the case of a land system whereas the marine system would cost in excess of A$1,000,000. Thus, no seismic survey can be undertaken lightly. Careful planning and suitable recording equipment of satisfactory standard are needed. Without this, the enormous cost of exploration is totally wasted.

1.4 Aims of the Project

The establishment and incorporation of a mobile digital data recording instrument is a complex process involving the marrying of many components and peripheral devices into an operational system. A thorough understanding of the role and function of individual components is essential to enable them to be assembled into an efficient system. Furthermore, the physical installation requires a comprehensive appreciation of the way in which the equipment is to be used in the practical application.

A system of this complexity requires extensive testing and modification to bring it to the necessary state of preparedness to satisfy the rigorous demands of land field operations. Once established, such a system requires continual monitoring by means of a series of routine tests to ensure that the necessary recording standards are maintained.

The ultimate purpose of a recording system is to record field data in an efficient and effective manner. However, correct recording of data encompasses not only the recording instrumentation, but also the manner in which the equipment is employed. Consequently, the application of recording systems to seismic surveys requires extensive knowledge of the desired geological objectives. An understanding of the physics of acoustic wave transmission through the earth is also necessary to ensure optimum data gathering.

Inherent in the nature of digital recording is a thorough understanding of sampling systems for their correct application. Not only is data sampled in time, but it is also sampled spatially. Data values are recorded at fixed time intervals and detector elements are positioned at equal spatial intervals across the survey area (Pap, 1984).

An incorrectly sampled geological structure will be interpreted incorrectly, and thus an adequate knowledge of survey design is a pre-requisite (French, 1974).

The correct survey design, recording and subsequent collection of data is the foundation upon which data processing and interpretation is based. No amount of computer processing and interpretation can yield information not contained in the initial recorded data.

This research work involved the installation and establishment of a digital seismic data acquisition system for land operations. Following testing and performance evaluation, the system was used in field surveys.

1.5 Thesis Outline

This thesis is assembled in several parts. Volume 1 is the major portion of the work. Following this introductory chapter, Chapters 2 to 4 deal with the instrumentation and its associated evaluation. Chapter 5 is devoted to several field applications and proposed areas for future research. Computer analyses of recorded data are used throughout. Final conclusions are drawn in Chapter 6.

Because of the large amount of detail involved in the testing and operation of the equipment, a separate volume has been compiled. This contains the Appendices. Due to modifications of the equipment, manufacturers' technical manuals are inadequate alone, and very often are misleading to the degree that they require supplementation. Volume 2 is intended as the supplement, to serve as a guide towards the equipment and its performance in the present format. As such, Volume 2 may be used in stand-alone form by subsequent researchers and operators who require ready information on the equipment, its capability and operational acceptance levels.

CHAPTER 2

INSTRUMENTATION

2.1 Introduction

A seismic data acquisition system accepts all analog seismic signals presented at its input terminals, and it digitizes them ready for recording on magnetic tape.

Because seismic signals are reflected from different horizons at differing depths, the seismic wavefront arrivals at the surface are related to each other in real time. That is, shallower horizons will reflect wavefronts earlier than deeper horizons and thus, shallow events will be received at the surface earlier than deeper events. Consequently, reflections have a time relationship and are recorded in real time which must be accurately represented throughout the recording process. Thus, from seismic energy source detonation to received surface signal, all equipment instantaneous time functions must be in absolute synchronism.

A seismic system must also be capable of recording a wide range of signal amplitudes. For example, a single geophone tapped at its base can generate 10 volts peak-to-peak when viewed on an oscilloscope. A seismic wavefront reflected from a deeply buried boundary may cause a 5 microvolt output. Thus, the recording system must ideally have the ability to accurately digitize and record a range of voltage 10^6 times of minimum value i.e. 120dB of signal.

These seismic signals contain frequencies usually in the range 5 to 100Hz. Under some circumstances, they may have component frequencies as high as 300Hz. It is therefore necessary that the recording equipment responds with equal efficiency over this range. Furthermore, special attention must be paid to the fact that the final recording is in digital form. That is, the sample is represented by a sampled sequence.

Hence, the basic data acquisition system must have a circuit component (or 'module') which allows electrical impedance matching of receiver with recording system to maintain signal integrity; a component which will apply some form of initial step gain for minimal signal content; a component to allow analog filtering options; a component which performs the process of multiplexing the inputs into the correct sequence for analog to digital conversion; a component to perform this conversion and apply some form of gain to enable the conversion process to be performed; a component to re-format the data into a sequence for recording digitally on magnetic tape; a component which performs a range of logic functions such as those involved with the timing of electronic events.

If the system is to operate successfully in the field, some form of remote source firing is required such as radio. Finally, the whole system must be mobile, see Figure 2.1. The establishment and testing of a system which meets these requirements forms the first part of this thesis.

A basic 48 channel digital field system (DFS IV) was donated to

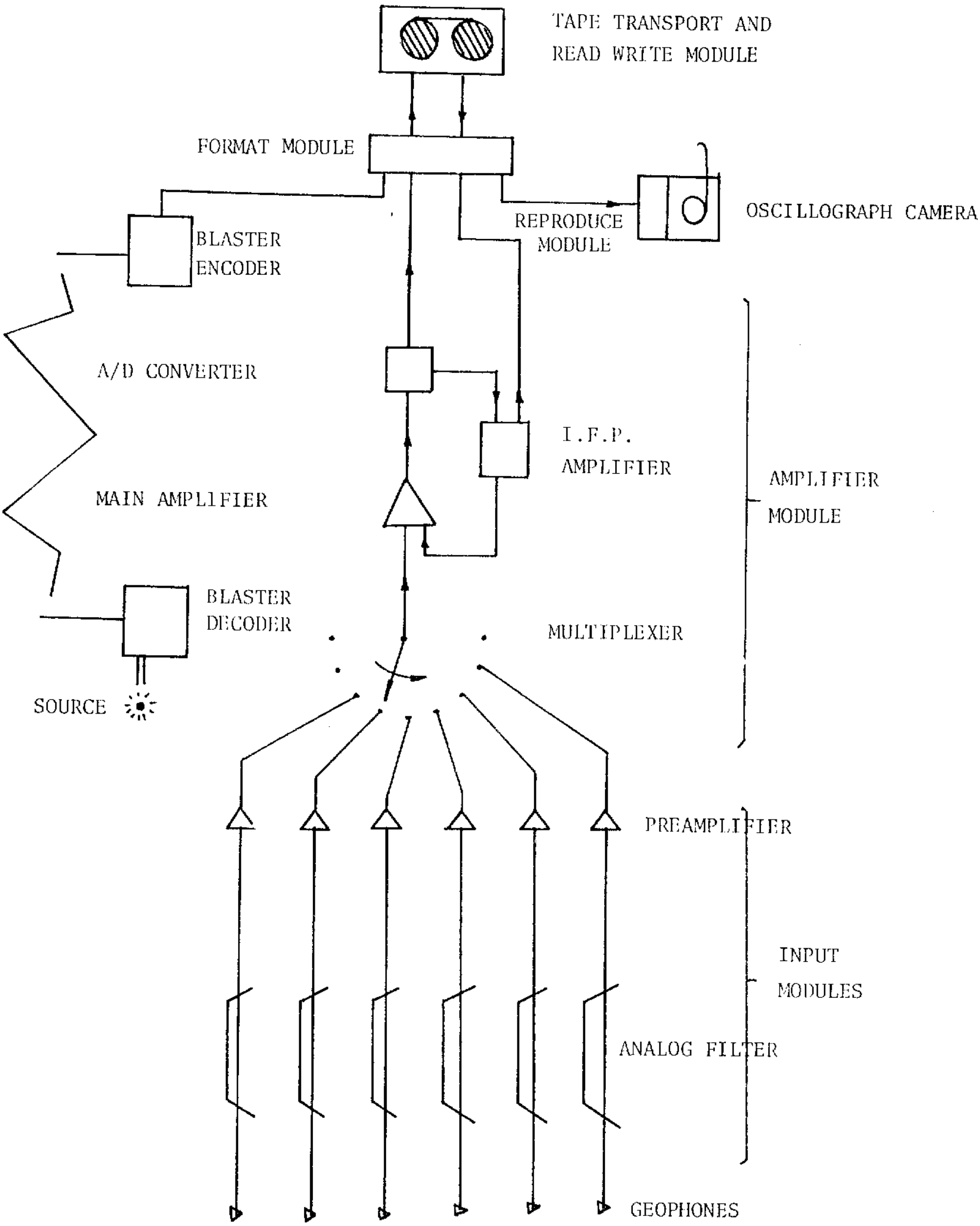


Figure 2.1 THE SEISMIC RECORDING INSTRUMENT SYSTEM

the WAIT Exploration Seismology Centre during June 1983. During July 1983, a 24 trace land seismic cable and 100 strings of geophones were loaned by the B.M.R. Neither seismic instruments nor cables were compatible. The recording instruments were in reasonable condition but a basic electronic fault existed. In order to fulfil this project's aims, it was necessary to modify and reconfigure all equipment so that a compatible system resulted, then to mount and test it in a mobile vehicle, and finally to mobilise to the field to perform seismic surveys.

2.2 Input Module

The system which was established has four identical input modules. The function of each Input Module is to:

a) accept 12 seismic data channels

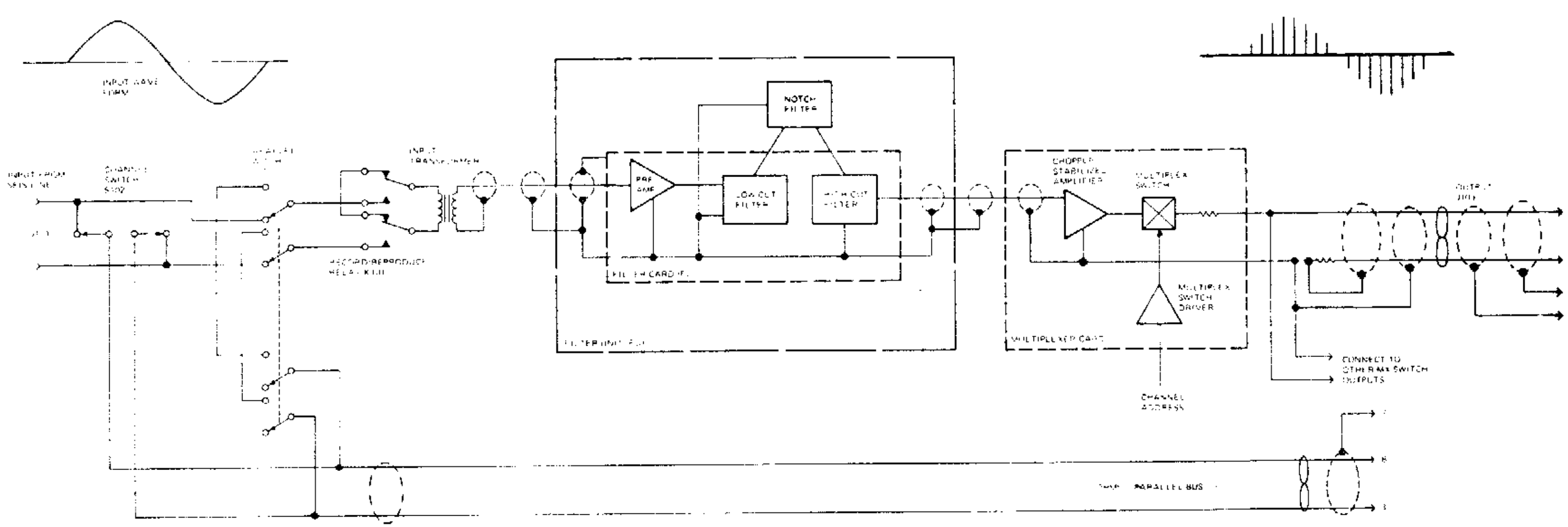
b) impedance match the transmission line (seismic cable)

c) apply optional analog preamplification gain and filtering

d) multiplex each channel ready for analog to digital conversion.

As a consequence, the input from each seismic line passes through an input transformer; a pre-amplifier; low cut, notch and high cut analog filter; a chopper stabilized amplifier; multiplex switch and outputs to the amplifier stage. These functions are all performed in the Input Module as shown on Figure 2.2.

In order to provide test capability for checking that all 12 seismic channels are functioning correctly, a PARALLEL Switch allows the switching of channels in parallel to a test circuit. This enables any desired signal from the Test Unit (Amplifier



INPUT MODULE SCHEMATIC

FIGURE 2.2

Module) to be injected into each channel if required. A further CHANNEL Switch allows independent channel selection, in order that individually selected channels may be addressed with the test signal.

Plate 2.1 shows the location of front panel controls, with the following indications:

1. Notch filter toggle switch placed in AUTO applied 50 or 60HZ cut-off filter, for use when power transmission line crossfeed to the seismic cable causes 50 or 60HZ to be impressed over the seismic signal. The system was supplied with 60HZ notch filter cards.
2. Notch filter indicator light.
3. FAULT light indicating when logic interlocking circuitry refuses to allow recording, due to a switch setting error on or in the Input Module.
4. 12 volt POWER switches - up is on.
5. Power on indicator lights.
6. DC VOLTAGE check switch for checking individual voltage levels.
7. CHANNEL Switch for switching test signals to individual channels.
8. PARALLEL Switch which switches all channels into parallel, ready to accept test signals.
9. LO-CUT filter switch with low cut filter options of 8, 12, 18 and 27Hz; SLOPE options of 17 or 36dB per octave. The OUT position puts the lo-cut filter out of circuit, thus eliminating any form of lo-cut filter. This switch

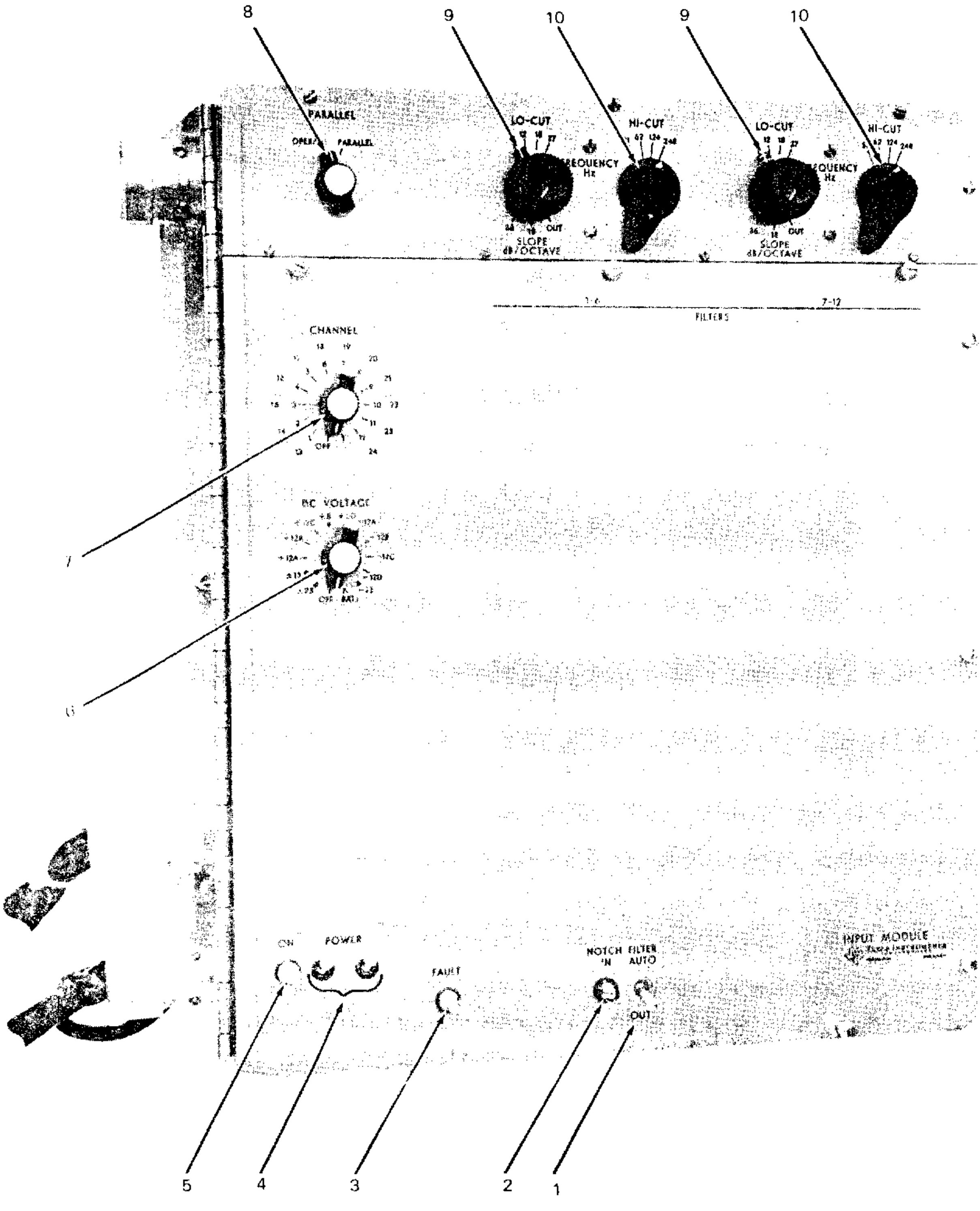


Plate 2.1 INPUT MODULE FRONT PANEL CONTROLS

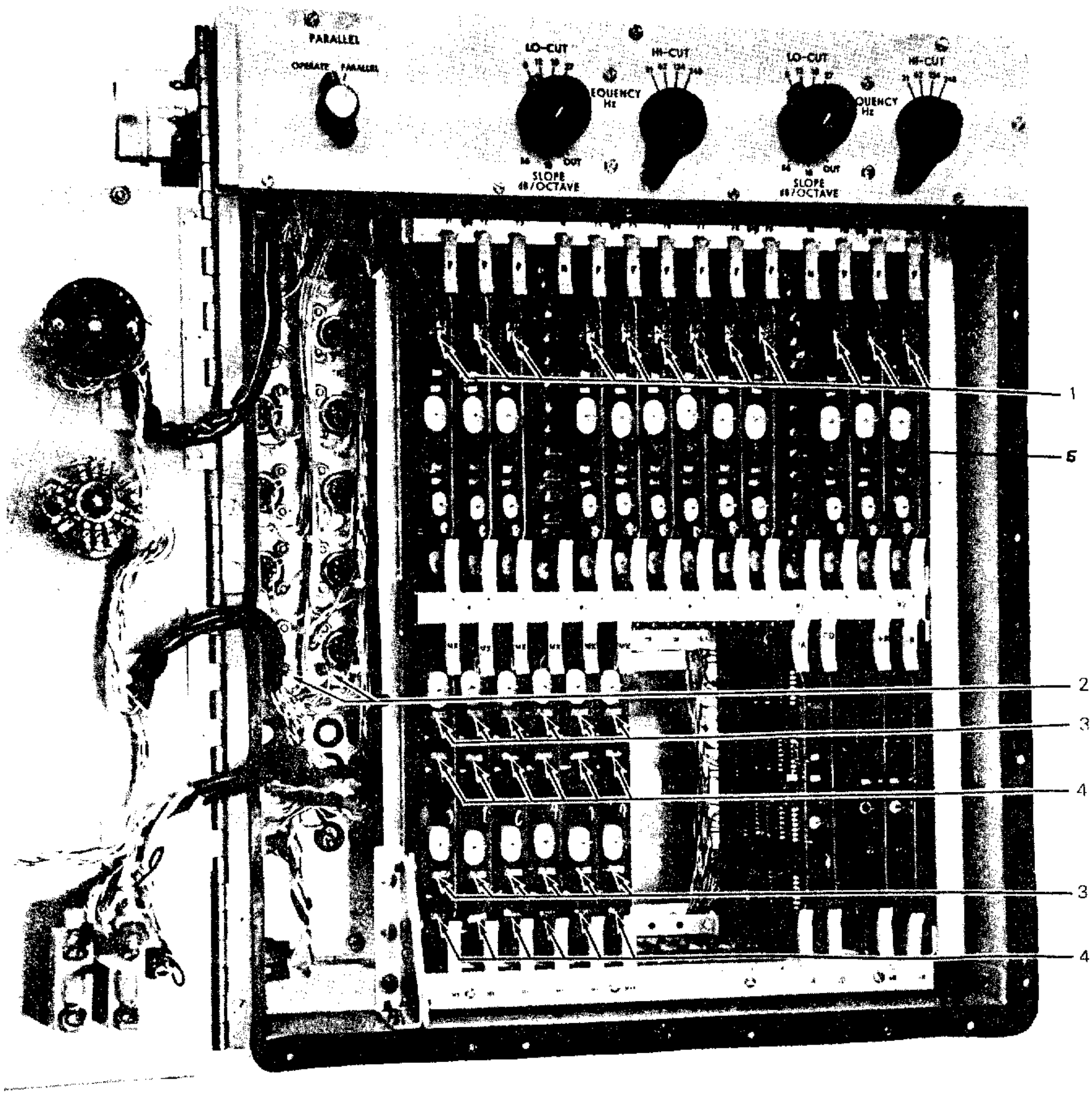


Plate 2.2 INPUT MODULE INTERNAL VIEW

operates on 6 channels.

The internal view is shown as Plate 2.2, with the following indications:

1. Gain constant switch with options of 12, 18, 24, 30 and 36dB steps, applied the selected pre-amplifier fixed gain level to each channel.
2. Input transformers and 500/2000 ohm logic connection posts.
3. Multiplexer zero set adjustment for each channel.
4. Gain calibration adjustment for each channel.
5. Hi-cut filter slope switch with options of 18 or 72dB per octave.

2.2.1 Input Impedance

A geophone group may be considered as a generator delivering its energy to a circuit made by the seismic line and input circuit of the recording instrument. In order to allow a maximum power transfer from the complex electrical geophone circuit to the Input Module circuitry it is necessary to introduce a matching transformer in circuit. The impedance of the transformers primary coils must match those of the geophones and cable, while the impedance of the secondary coil must match that of the Input Module.

Impedance is frequency dependent. This means that both the magnitude of the impedance and the phase shift produced by the transformer windings will vary with frequency. thus the primary connection windings of the input transformer windings will vary with frequency. Since the primary winding of 500 ohms or 2000 ohms may be selected by hard wire connection. For example, with the 500 ohm connection, the input impedance as a function of frequency is shown Figures 2.3 and 2.4 for a typical transformer of 783 Henries - a mean transformer value.

With a 500 ohm source resistance and 500 H inductance, signal will be 3dB down and have a 45 degree phase lead at 0.159Hz ($z = 2\pi fL$). With a 1000 H coil, this occurs at 0.0795Hz. At 5Hz, the loss and phase lead are small, and impedance z is 24.7 Kohms and, due to 0.0047 micro-Farad input capacitor across the secondary, the impedance increases rapidly to a peak in excess of 1 Mohm at 32Hz. At this frequency, the transformer is resonant and appears purely resistive, above which it is capacitive. With the 2000 ohm primary connection, impedance values are four times larger.

Attenuation of the input circuitry is called 'insertion loss' and, because the transformer is reactive, insertion losses and phase distortion in seismic signal may be expected, causing the seismic signal to be shifted in real time. Only at low seismic frequencies can the input transformer cause an appreciable time shift.

i.e. a one degree transformer phase change at 5Hz will give a time shift of $\frac{1 \times 1000}{360 \times 5} = 0.55$ milliseconds.

Since all pre-amplifiers have 500 ohm source, they will all have an identical shift and thus no shift between channels. With a 1000 ohm source, this increases to 0.61 milliseconds, and at 2000 ohms it becomes 1.86 milliseconds. This is undesirable since it is close to one sample period of 2 milliseconds. Thus, if the instruments are to record low frequency data with a minimum of insertion loss or phase distortion, seismic line inputs in excess of 1000 ohms are to be avoided.

At frequencies above 5Hz, the transformer impedance increases and the phase angle decreases, giving less insertion loss and smaller phase shift during matching. Figure 2.4 displays at 32Hz an input impedance of 985 Kohms, with a zero phase angle and thus 32Hz is the ideal centre frequency for minimum losses and minimum phase shift.

2.2.2 Input Transformer Distortion

Input transformer distortion must be considered. Due to the non-linear relationship between primary current and magnetic flux in a transformer, the output is not directly proportional to the transformer input. If the transformer inductance is increased, the distortion effect of the current is reduced as a result of distortion in the voltage waveform across the source resistance. This is the reason for having a large primary inductance in the input transformer. Input transformer distortion increases with frequency. This

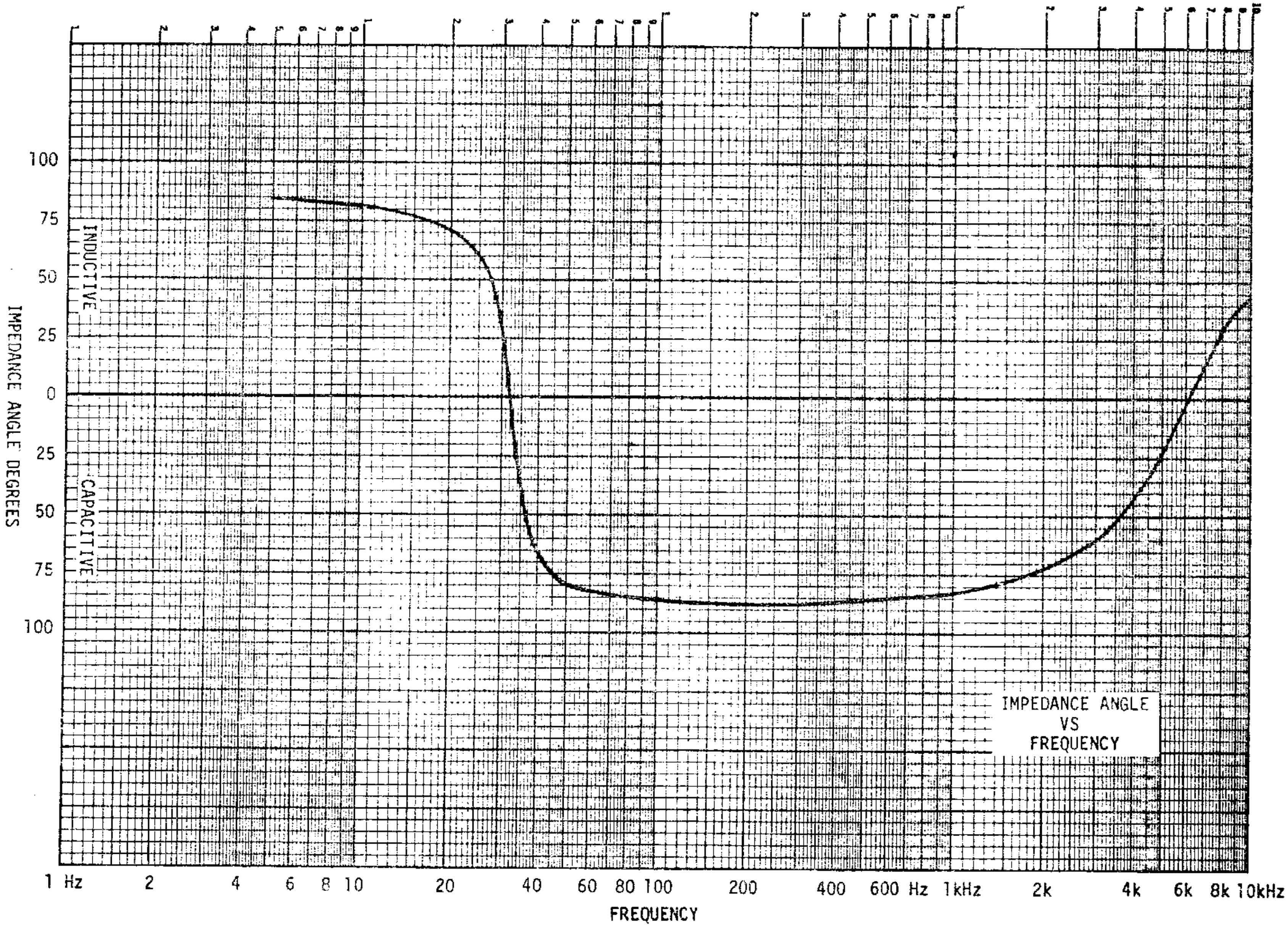


Figure 2.3 INPUT IMPEDANCE ANGLE

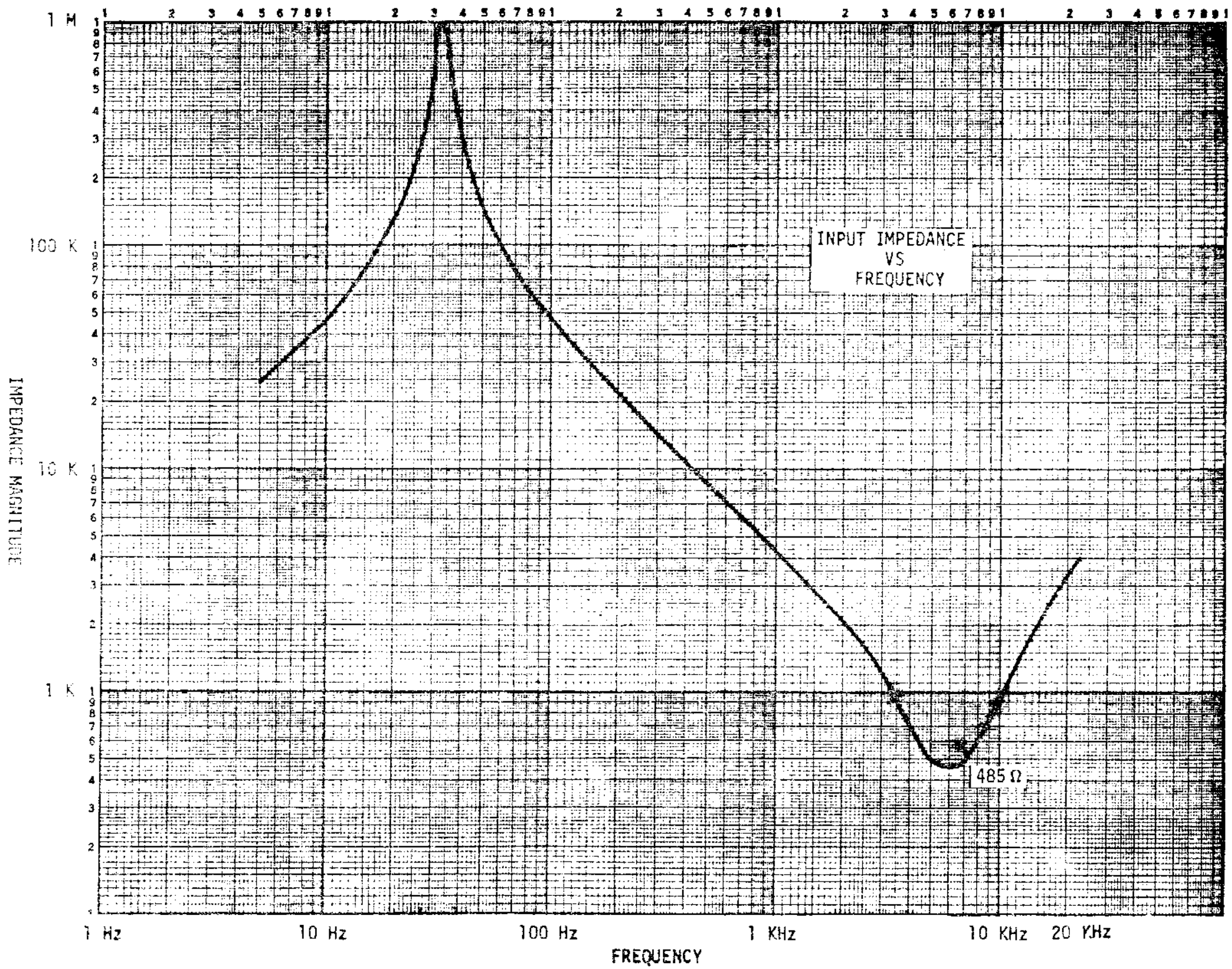


Figure 2.4 INPUT IMPEDANCE MAGNITUDE

however, only becomes substantial at frequencies in excess of 200Hz, well outside the seismic bandwidth of interest (see Figure 2.5).

2.2.3 Input Module Noise

In any system, an output voltage can be observed in the absence of an input signal. This is called "system noise". It represents an additional voltage level which, superimposed upon true signal, is erroneous. It is effectively the lower limit of what can be sensibly recorded. System noise has a Gaussian distribution with first and second order moments:-

$$m_i = \frac{1}{P} \sum_{i=1}^{P} n_i \qquad m_2 = \frac{1}{P} \sum_{i=1}^{P} n_i^{\,2}$$

n_i is the i^{th} sample of p samples taken as a representation of noise. If instrument noise could be represented by a Fourier series, the average noise m_1 would be d.c. component. This is called the "dc offset". The multiplexer zero adjustment is used to minimise the Input Module dc offset of the instrument noise.

2.2.4 The Pre-Amplifier (Gain Constant)

Ideally, the recording system must accommodate signal over a 120dB range and record it with a 60dB accuracy, since the 15 bit amplifier can theoretically only apply 90dB of gain. We are interested in recording signal which may require 100-120dB of gain. This can be done by the application of an initial fixed gain, such that all signal has an applied 30dB gain prior to the amplifier stage. This fixed gain is provided by a 'preamplifier' or 'gain constant' stage, which is ahead of the main amplifier. It has fixed steps of 12, 18, 24, 30 and 36dB. The options of choice are offered because of the range of energy sources which may be used. For example, some large charge dynamite recording requires a low preamplifier setting compared with the low intensity vibroseis signals which are applied over a time sweep.

Hence, the gain constant setting is chosen for the recording condition of the survey being conducted, such that the strongest input signal does not overscale the converter and that the weakest signal is recorded accurately.

2.2.5 Input Filtering

When recording seismic data, it is always necessary to apply some degree of filtering of signal prior to digitization. A low cut filter is frequently used to attenuate unwanted low frequency noise. A high cut filter is required to avoid the aliasing phenomenon.

For conversion of the analog seismic signal to a digital representation, the analog wave is sampled at a fixed time rate. Figure 2.6 indicates how a simple sine wave may be sampled, and how an incorrectly sampled sine wave could be later reconstituted as having lower frequency. The figure suggests there should be an upper limit on the

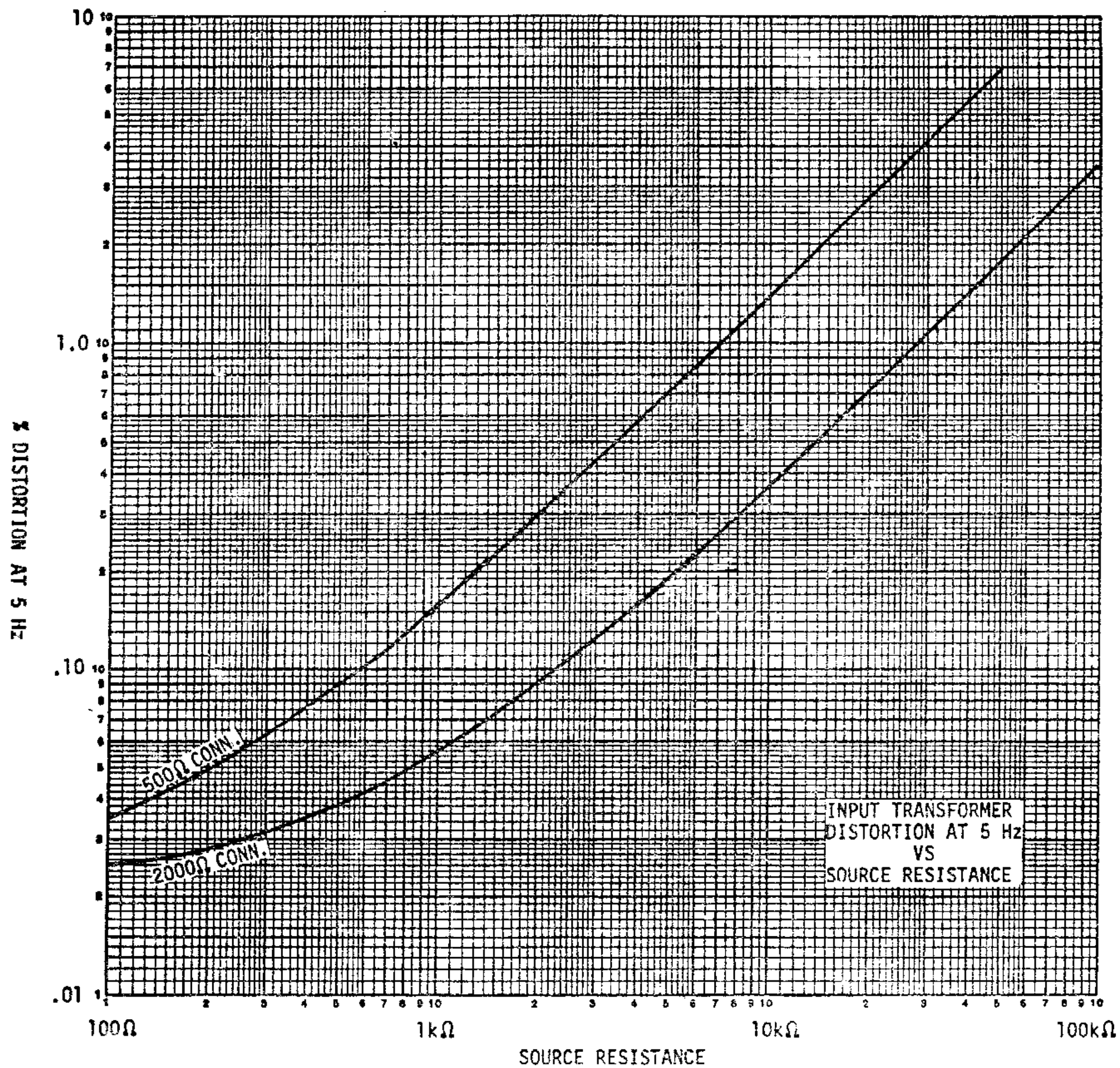


Figure 2.5 INPUT TRANSFORMER DISTORTION AT 5Hz

frequency allowed for accurate conversion - the limit being at the upper end of the frequency spectrum. Figure 2.7 illustrates how insufficient sampling of a waveform can produce a spurious low frequency wave after reconstitution.

Since the seismic recording equipment conventionally samples at 1, 2, 4 or 8 milliseconds, a desired maximum frequency is implied by the stated sample rates. From the waveforms illustrated, one sample per half cycle would be barely adequate. i.e. for a chosen sample rate of 4 milliseconds, the maximum frequency that can be adequately sampled is

$$f_N = \frac{1}{2T} = \frac{1}{2x4x10^{-3}} = \frac{1}{8x10^{-3}} = 125Hz$$

This is known as the "Nyquist frequency". If the original frequency is indeed reconstituted into another after sampling at too coarse a rate, it is "aliased". The new frequency is symmetrical to the original frequency around the Nyquist frequency, as if the frequency were folded over and hence the term "fold-over frequency". See Figure 2.8.

Hence, due to sampling alias criteria, the high cut filter must be set at a value dictated by the sample rate. Table 2.4 illustrates the Nyquist frequency for each of the sample rates available. Hence it is known as an anti alias filter.

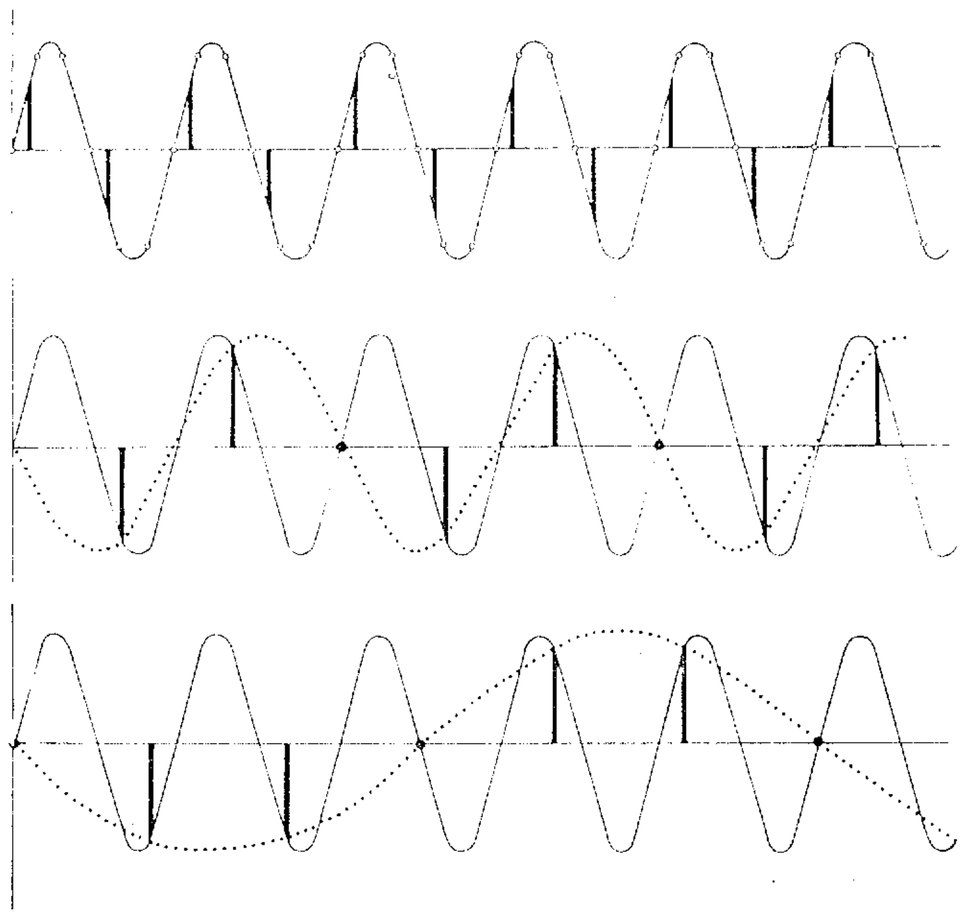
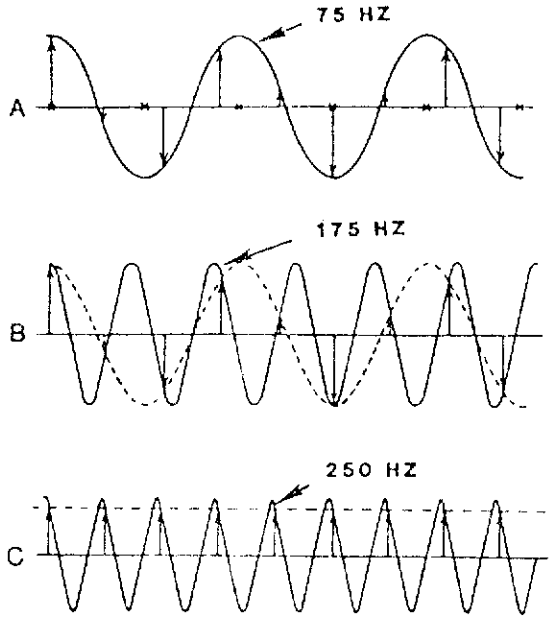


Figure 2.6 SAMPLING OF AN ANALOG WAVE



TIME	AMPLITUDE
.000	10
.004	- 3
.008	- 8
.012	8
.016	3
.000	10
.004	- 3
.008	- 8
.012	8
.016	3
.000	7
.004	7
.008	7
.012	7
.016	7

Analog to digital converter.

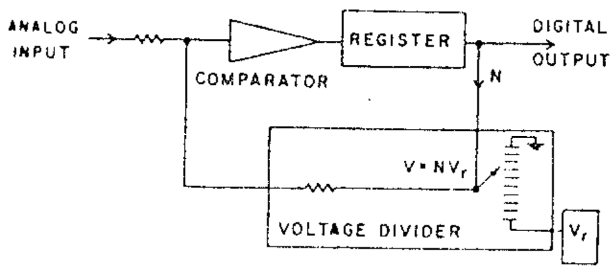


Figure 2.7 DIGITAL SAMPLING AND ALIASING

SAMPLE RATE VERSUS HIGH CUT-OFF FILTER

Table 2.1

Sample Rate (msec)	Nyquist Frequency (Hz)	Hi-cut anti-alias (Hz)
1	500	248
2	250	124
4	125	62
8	62	31

Table 2.1 also shows the hard-wired Hi-cut options available with the DFS IV.

2.2.5.1 Filter Amplitude Response

For most surveys, the upper seismic frequency is limited to 100Hz, and the anti-alias filter must operate at or above this maximum useful frequency. In order to avoid sampling before the Nyquist frequency is attained, the hi-cut is applied with a fixed tapering gradient with increasing frequency. This is called the hi-cut filter "slope" and applies attenuation in terms of dBs per octave. One octave is a frequency ratio of 2 to 1 and hence, a typical hi-cut filter of 124Hz with a slope of 72dB per octave would apply 72dB of attenuation at a frequency of 248Hz. This is just below the Nyquist frequency of 250Hz, and because the IFP amplifiers gain is limited to 78dB, it is considered that a slope of 72dB per octave would effectively

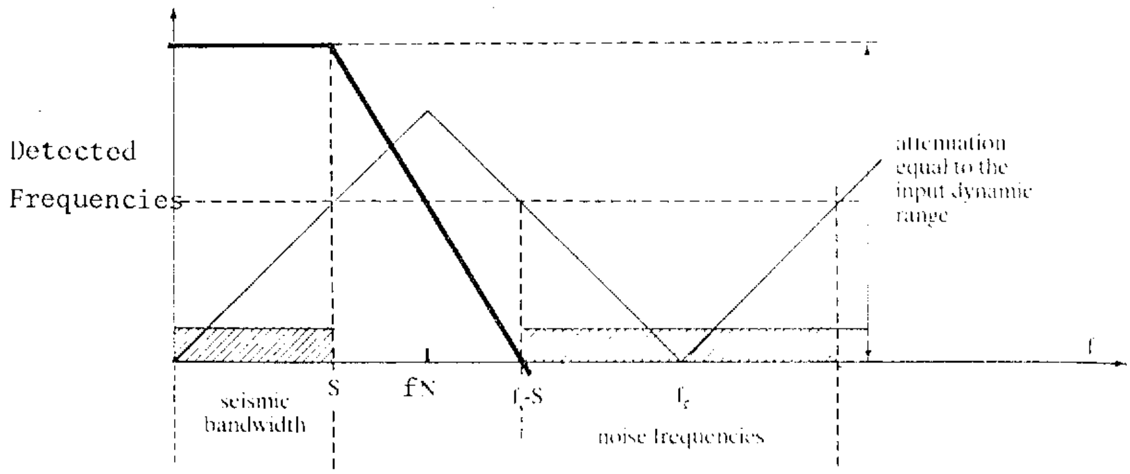


Figure 2.8 AMPLITUDE RESPONSE OF AN ALIASING FILTER

cut off all signal above 248Hz.

If it is assumed that higher frequency background noise above the frequency range of interest is not coherent but of a random nature, then the process of multi-fold data stacking or summing would attenuate background noise considerably. If this were so, it would allow the broadening of the anti-alias roll-off slope. Specifically, in the case where impulse energy sources such as explosive or air-gun are concerned, the high background noise is rarely coherent.

A filter with an 18dB per octave slope provides 27dB of attenuation at 1.5 octaves above cut-off. Due to high frequency absorption, frequencies in excess of 80Hz are rarely observed from the deeper reflection zones of interest. Consequently, if a greater degree of possible fold-over noise was tolerated in the shallower, higher amplitude zone of seismic recording, it could be possible to open out the hi-cut filter even though there is some 80dB of amplifier gain available. As a result of this practical approach to slope setting, an 18dB per octave slope option is included - the use being intended to provide higher signal frequency content at the deeper event zone, with the trade off being the acceptance of a high amplitude, higher frequency coherent noise in the vicinity. This is a reasonable assumption since such high level noises are rarely, if ever, present.

Figures 2.9 to 2.17 show the manufacturer's response for the four high-cut filter settings of 31, 62, 124 and 248Hz.

The following points are noted:

1. With OUT filters (eg. Figure 2.9), there is a 6dB per octave roll-off at 3Hz, below which frequency, signal is attenuated by up to 10dB. This attenuation reduces any low frequency input distortional effects of the input transformer and pre-amplifier, in the absence of a low-cut filter.
2. A 31Hz high cut filter rolls-off the flat response bandpass, having a 6dB signal attenuation at 31Hz, with a 72dB per octave slope.
3. Cut off frequencies are given at the 3dB down point for a slope of 18dB per octave, 6dB down for slopes of 36dB per octave and 72dB per octave.
4. Figures 2.9 and 2.12 indicate a far broader acceptance of high frequency content using the softer 18dB per octave slope than the 72dB equivalent, adding frequencies in the range 150-300Hz at 20dB down.

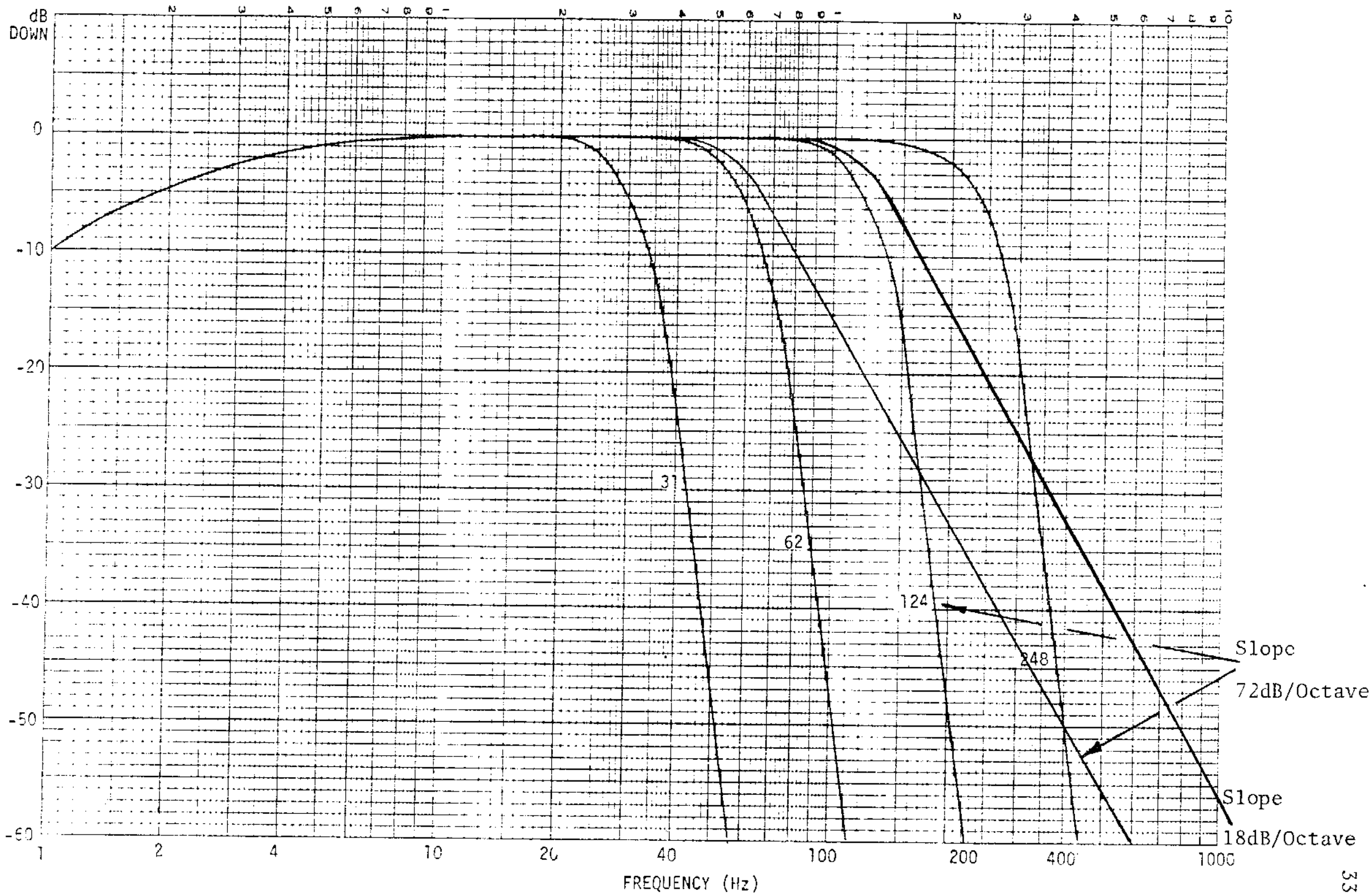


Figure 2.9 AMPLITUDE RESPONSE, LOW CUT OUT

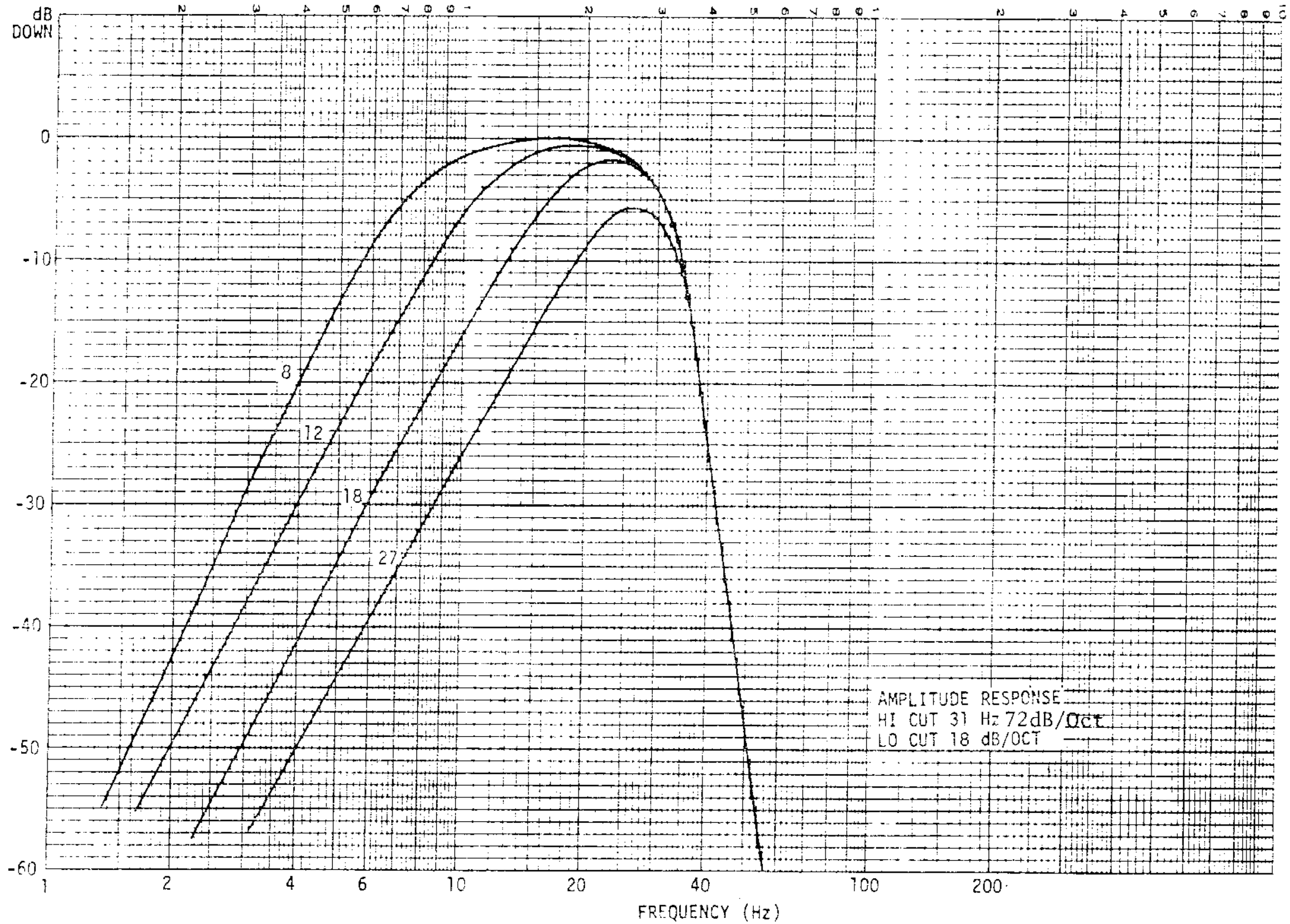


Figure 2.10 AMPLITUDE RESPONSE, 18dB/Oct, 31Hz

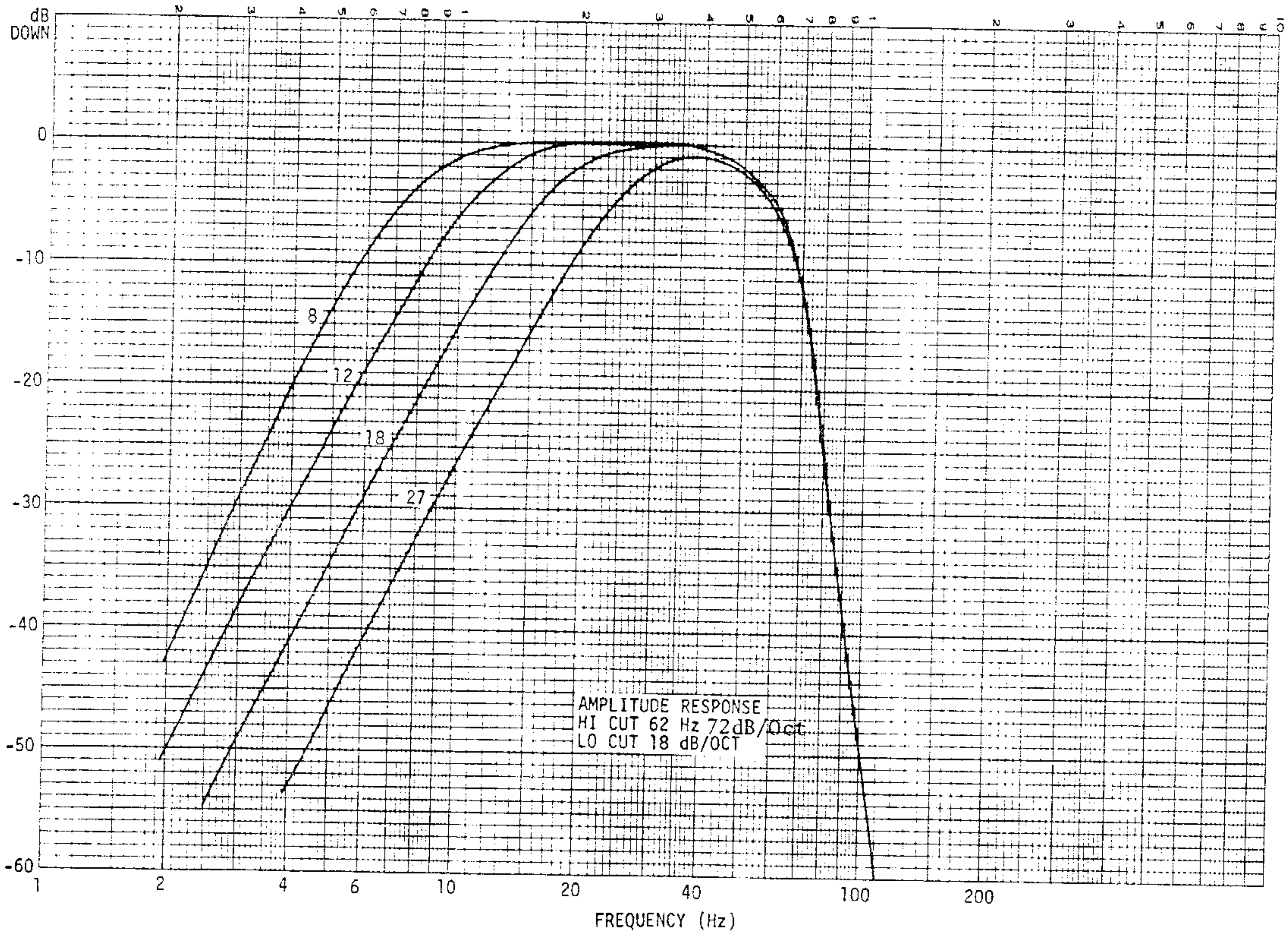


Figure 2.11 AMPLITUDE RESPONSE, 18dB/Oct, 62Hz

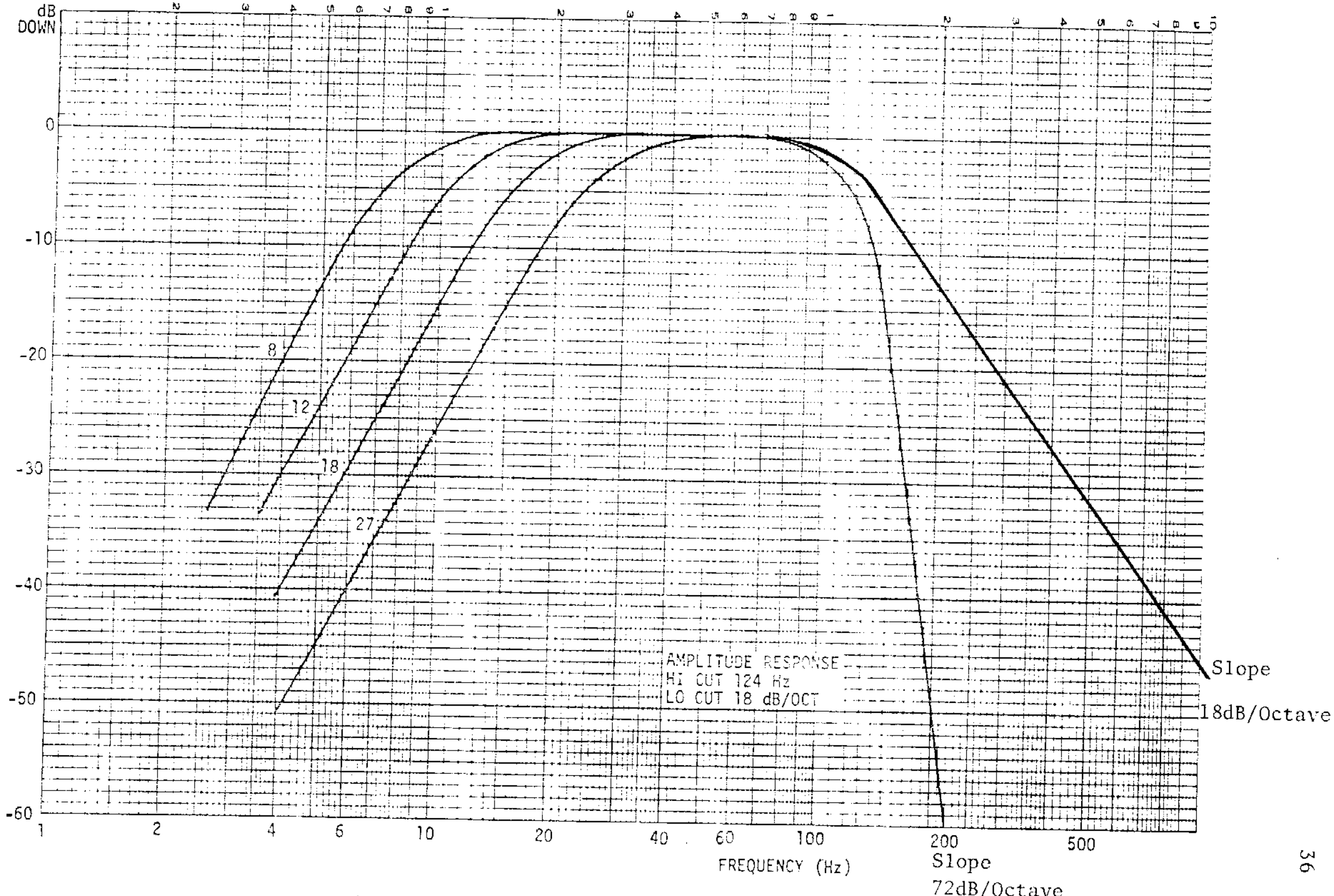


Figure 2.12 AMPLITUDE RESPONSE, 18dB/Oct, 124Hz

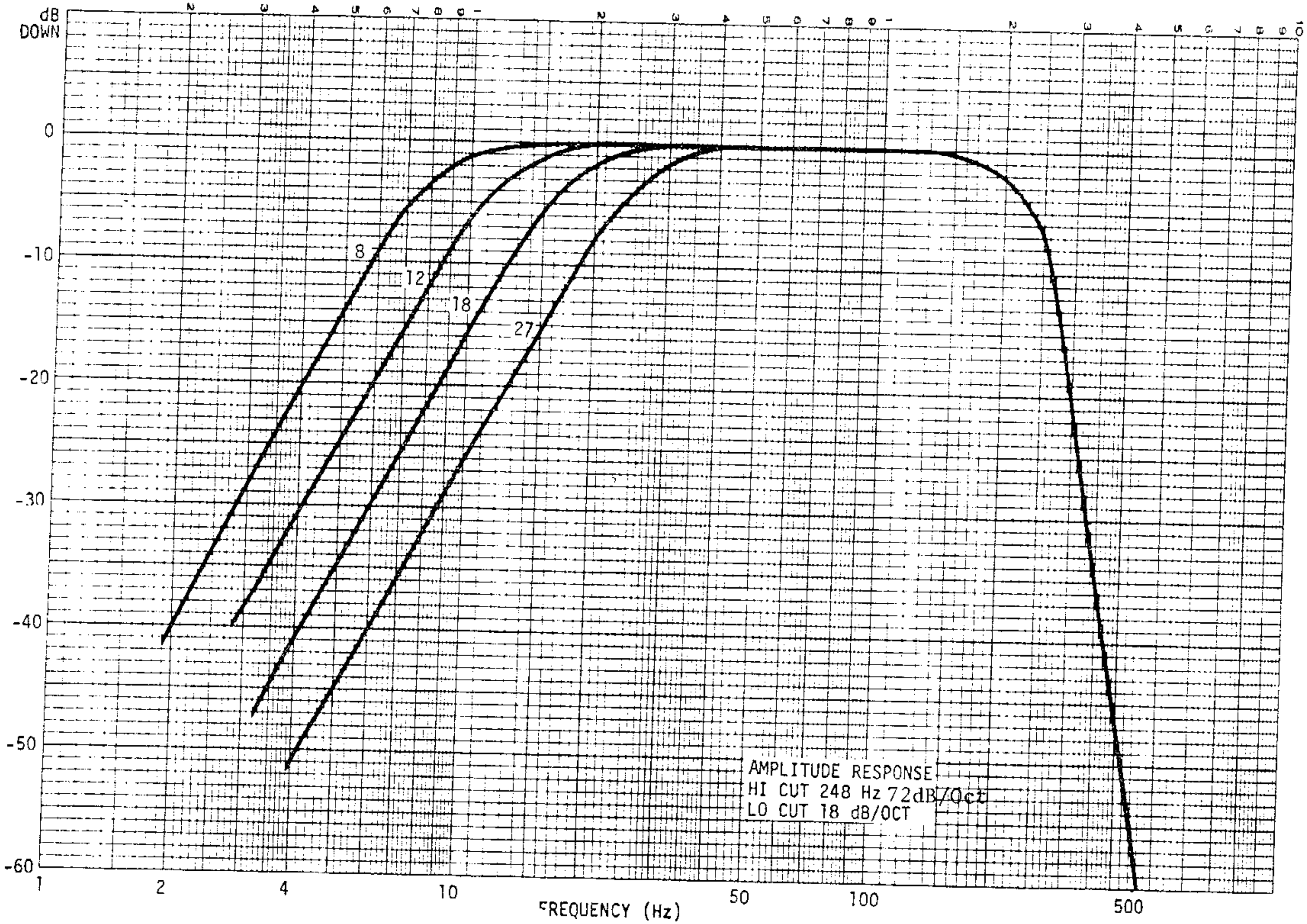


Figure 2.15 AMPLITUDE RESPONSE, 18dB/Oct, 248Hz

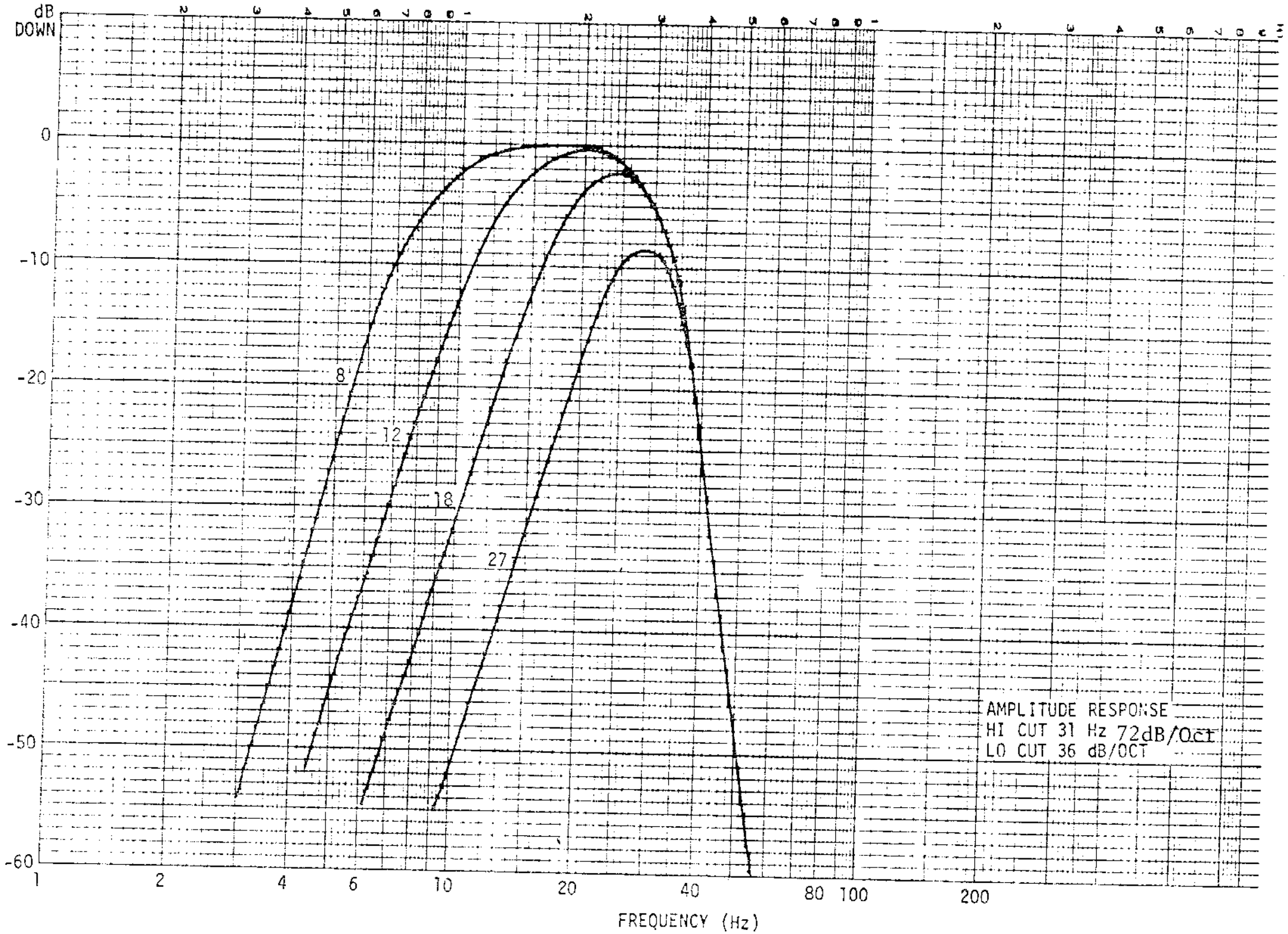


Figure 2.14 AMPLITUDE RESPONSE, 36dB/Oct, 31Hz

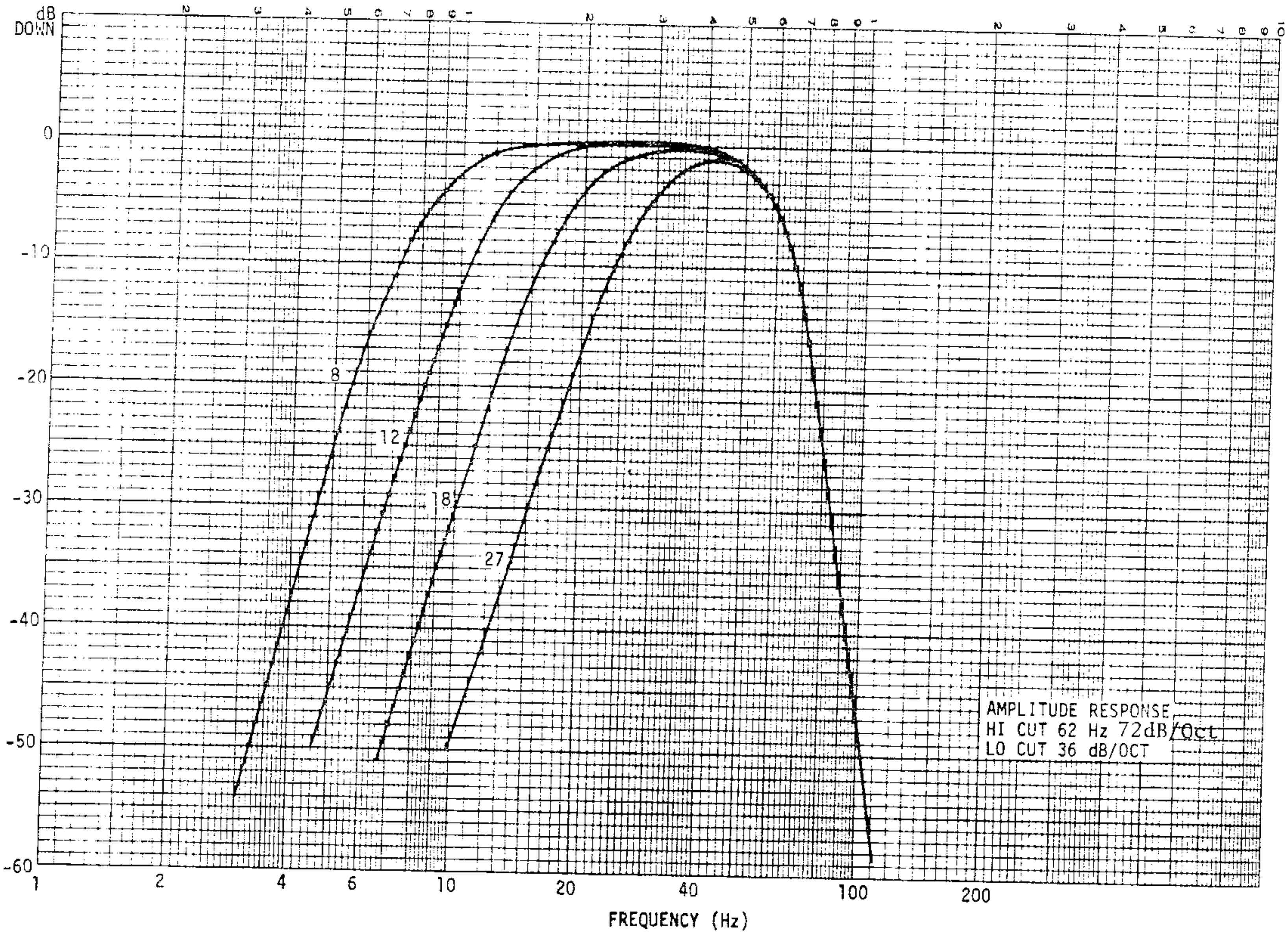


Figure 2.15 AMPLITUDE RESPONSE, 36dB/Oct, 62Hz

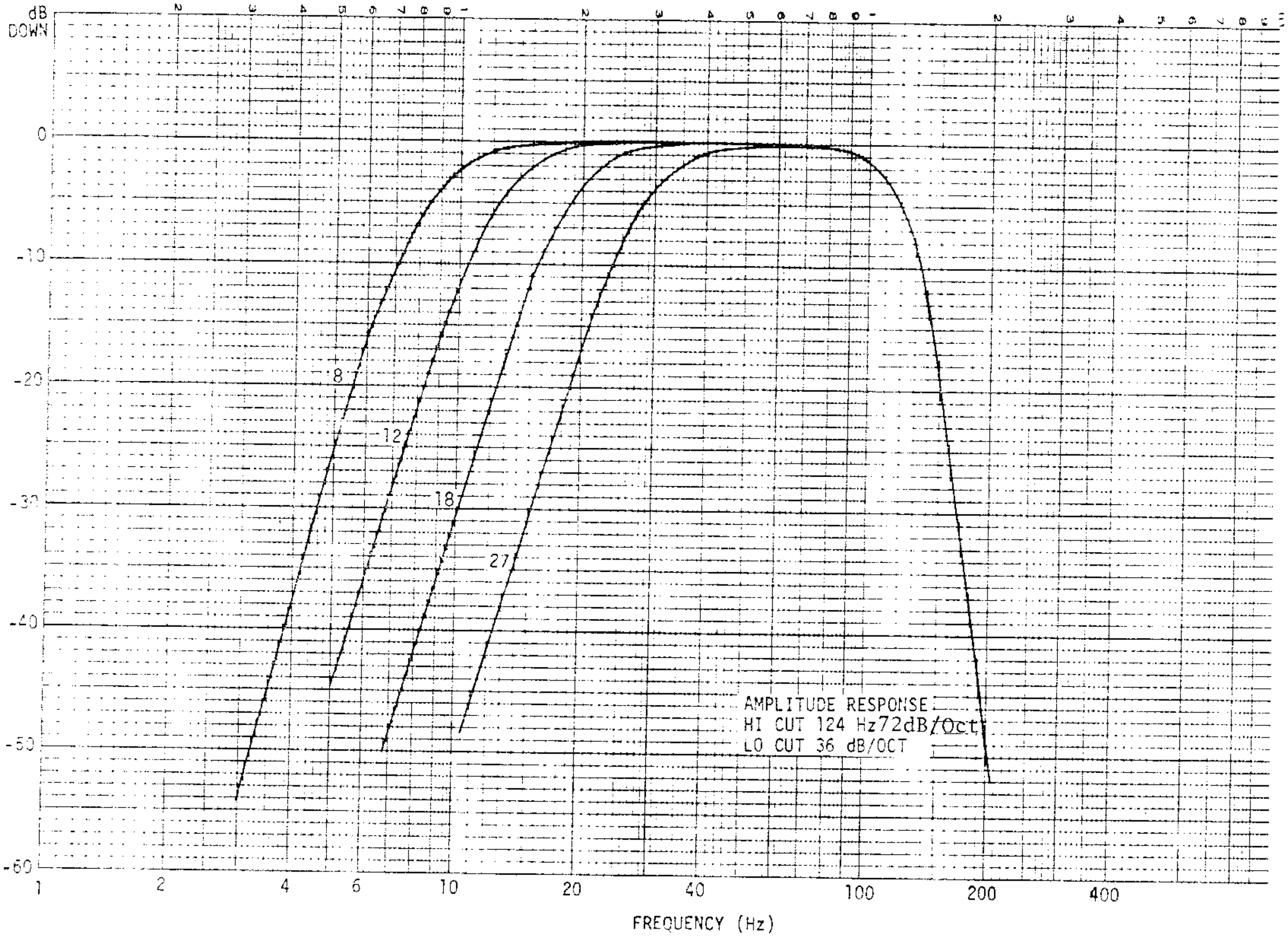


Figure 2.16 AMPLITUDE RESPONSE 36dB/Oct, 124Hz

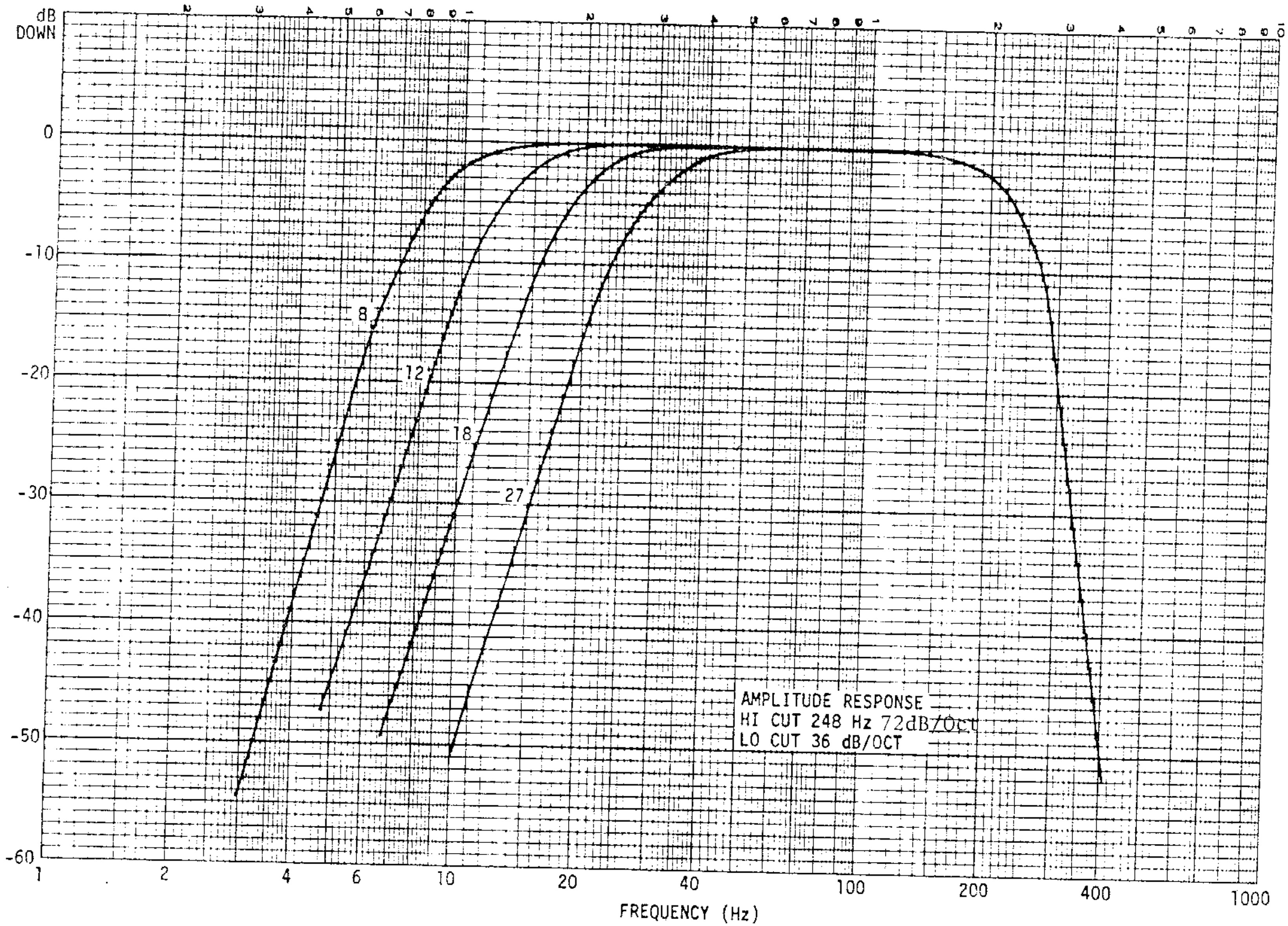


Figure 2.17 AMPLITUDE RESPONSE 36dB/Oct, 248Hz

2.2.5.2 Filter Phase Response

Figures 2.18 to 2.29 show different manufacturers' displays of the phase response of the Input Module filters. Since any filter comprises of a resistive, inductive and capacitive RLC circuit, some form of phase change may be expected due to the circuit's reactive components.

Figures 2.18 and 2.19 are manufacturer's published data showing that the DFS IV has an approximately linear phase relationship over a portion of the frequency range. The non-linear end effects coincide with the attenuation at each end of the pass band, and thus apply an overall non-linear response to the incoming seismic signal.

The important point here is that the signals that pass through such filters may not be minimum phase after filtering, because the filter modifies the incoming signal.

It is noted that the phase spectrum of minimum phase data is related to the amplitude spectrum by the relationship:

$$\emptyset(f) = -\frac{1}{\pi} \int_{-\infty}^{\infty} \frac{\ln |A(f)|}{(f-u)} du$$

$$= \ln |A(f)| * \frac{1}{\pi f}$$

In many processing sequences, a minimum phase spectrum is assumed. Thus correction to minimum phase may be necessary where signal has been rendered mixed phase by the filters. If this is not carried out, the performance of subequent processing may be impaired, due to basic assumptions not being obeyed.

2.2.6 Notch Filter

The notch filter is designed to be used whenever the seismic recording cable or system passes near or beneath overhead/underground public utility power lines. 50Hz or 60Hz notch cards are available, but in this instance the 60Hz response will be reviewed as the 60Hz option was supplied with the system. (See Figure 2.30)

Figure 2.31 shows the 60Hz notch filter amplitude response. Manufacturer Specifications require 6dB bandwidth signal attenuation between 56 and 64Hz, with an effective 40dB attenuation between 59.93 and 60.07Hz.

Figure 2.32 shows that at frequencies below 20Hz and above 200Hz there is minimal phase shift produced by this filter.

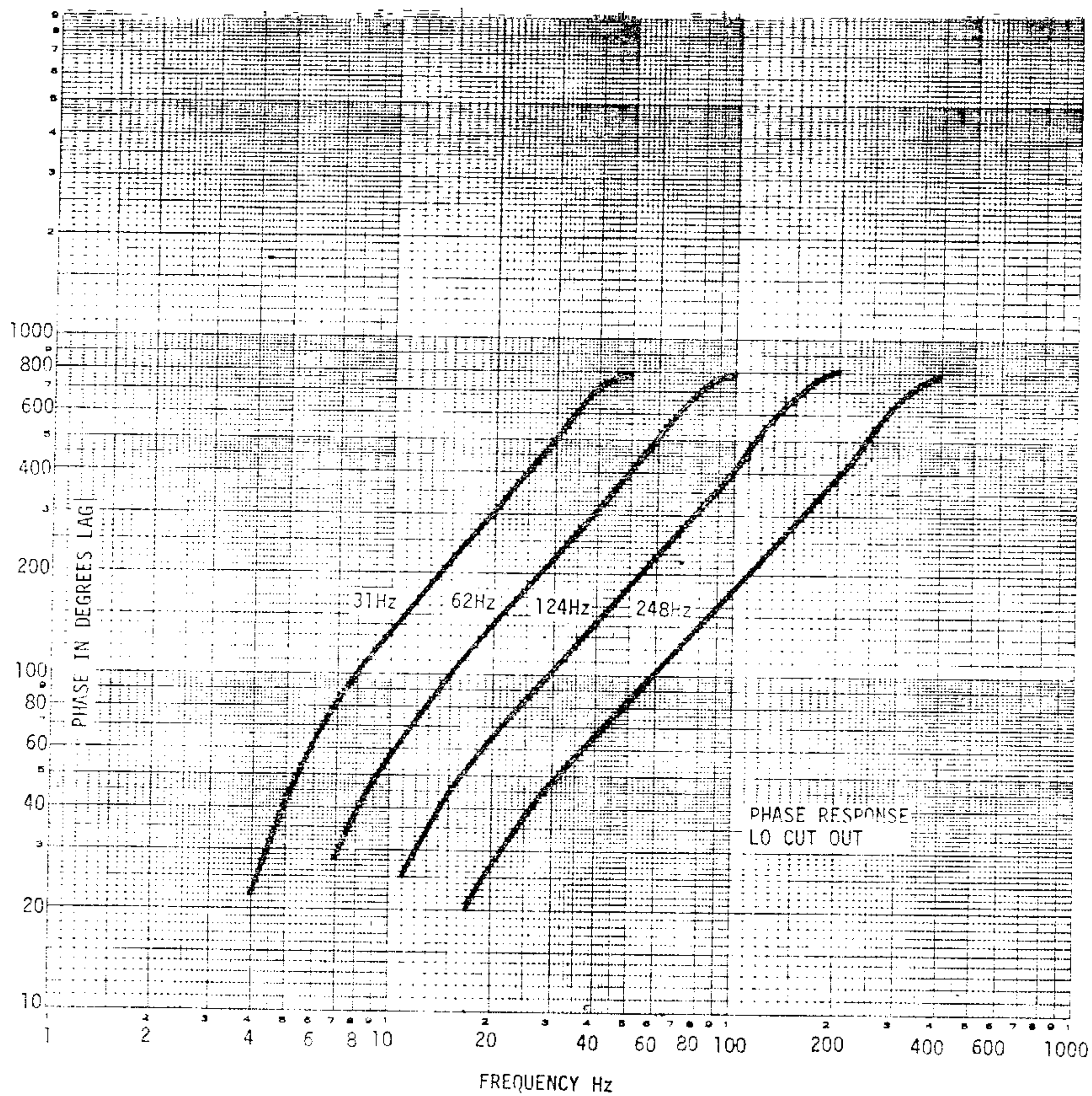


Figure 2.18 HI-CUT FILTER PHASE RESPONSE, LINEAR CHARACTERISTICS (PHASE LAG PLOTTED POSITIVE)

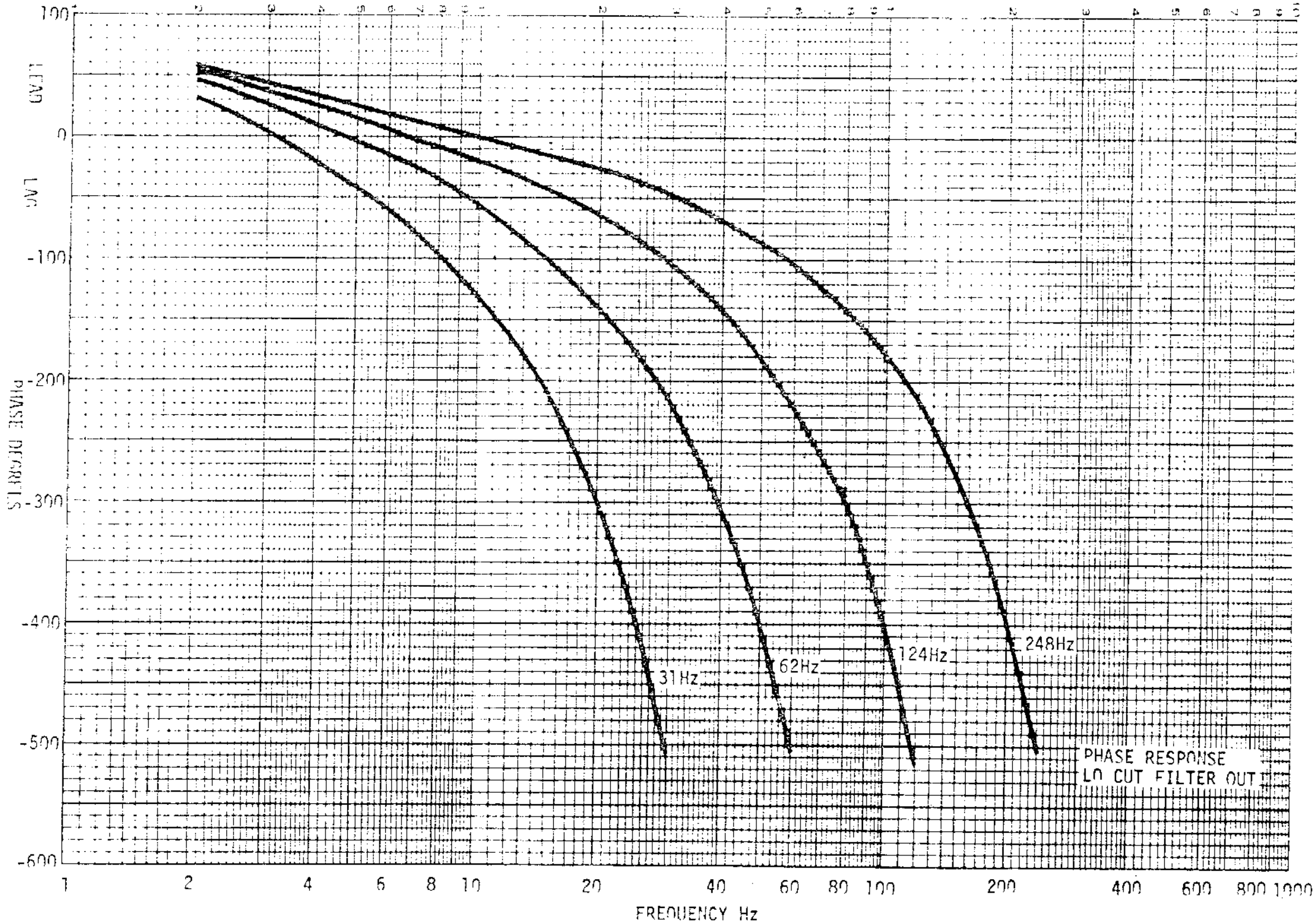


Figure 2.19 HI-CUT FILTER PHASE RESPONSE, DOWN TO 2HZ

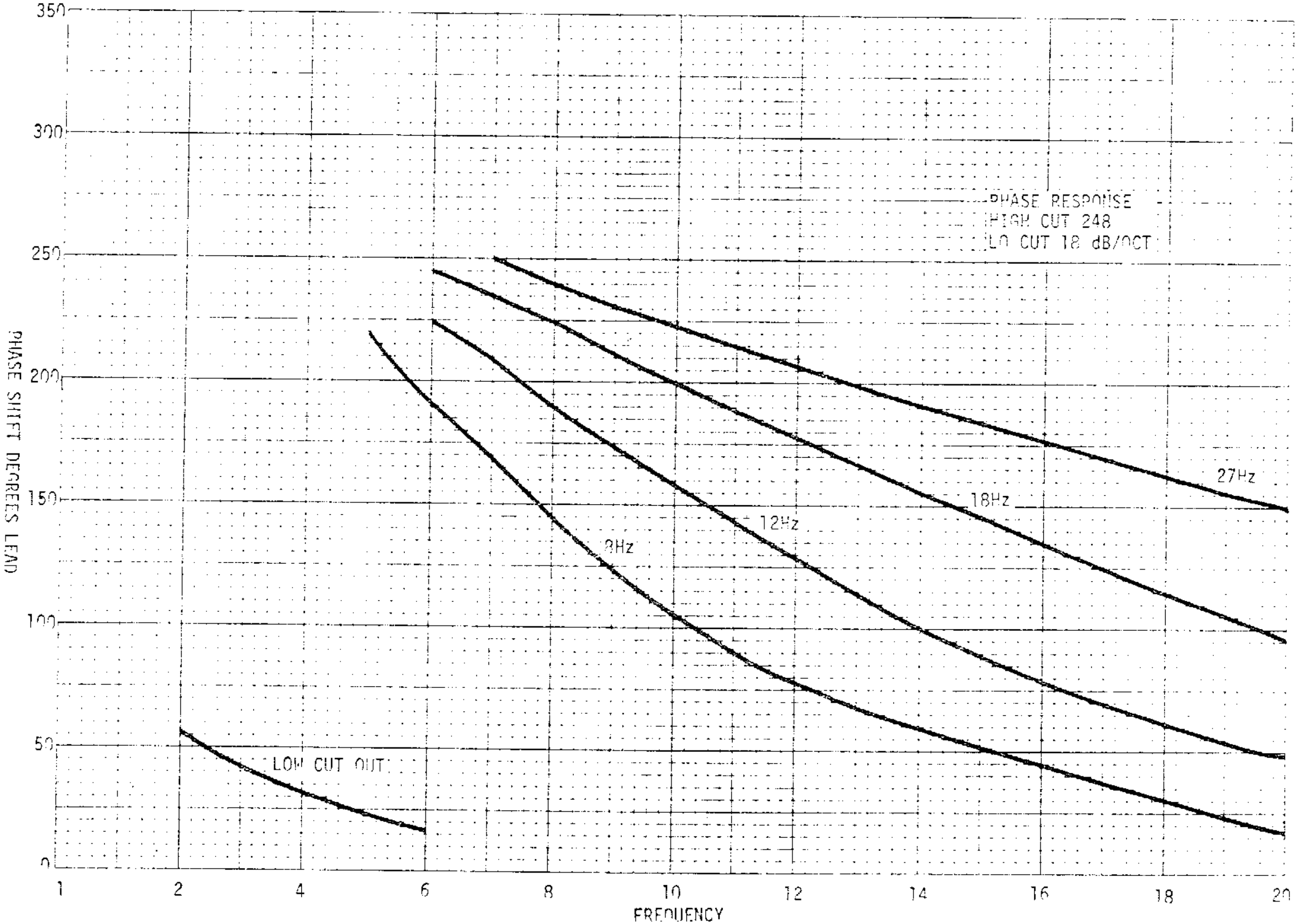


Figure 2.20 LOW CUT PHASE RESPONSE 18dB/OCT SLOPE

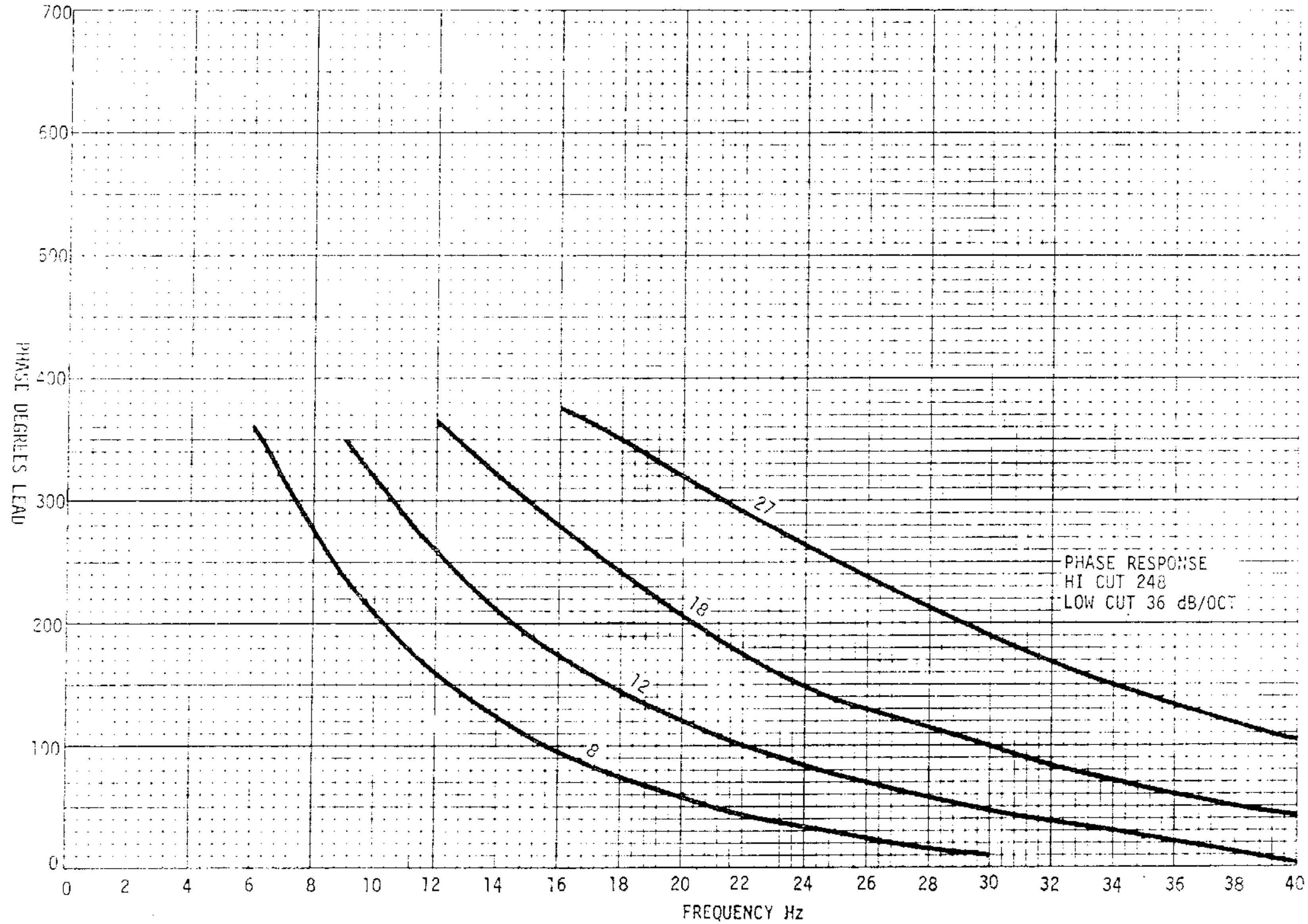


Figure 2.21 LOW CUT PHASE RESPONSE 36dB/OCT SLOPE

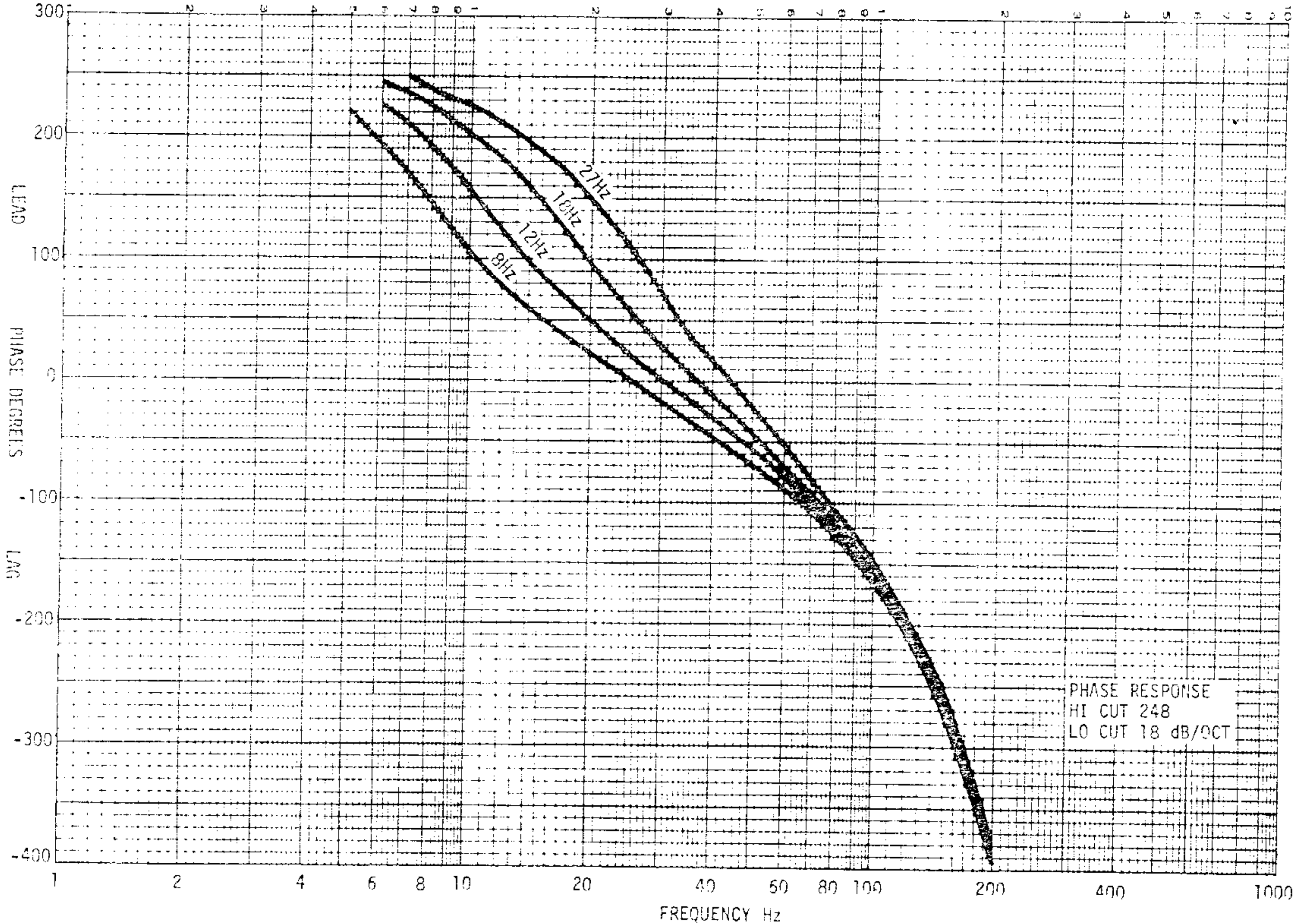


Figure 2.22 PHASE RESPONSE, 18dB/OCT, 248HZ

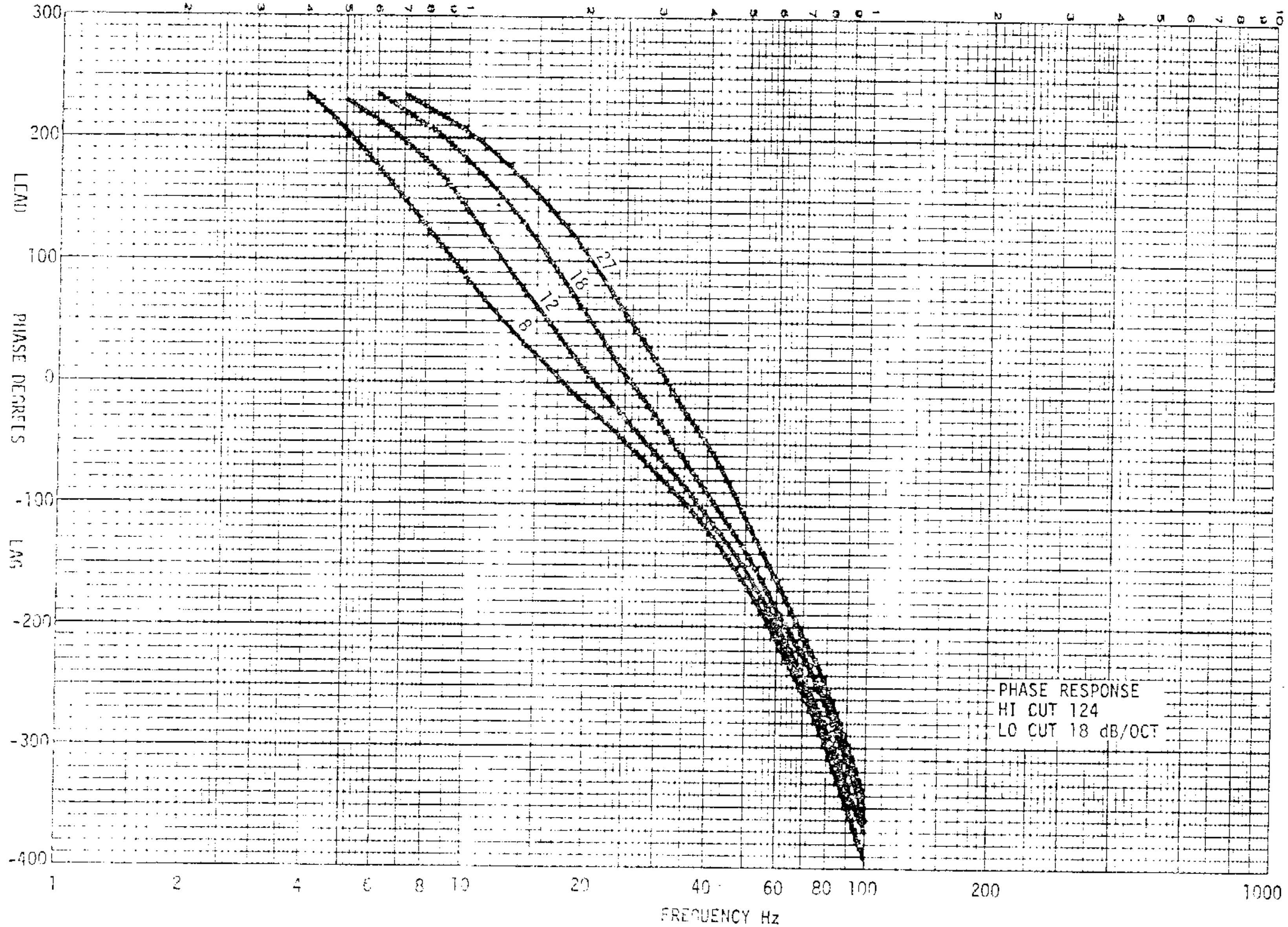


Figure 2.23 PHASE RESPONSE, 18dB/OCT, 124Hz

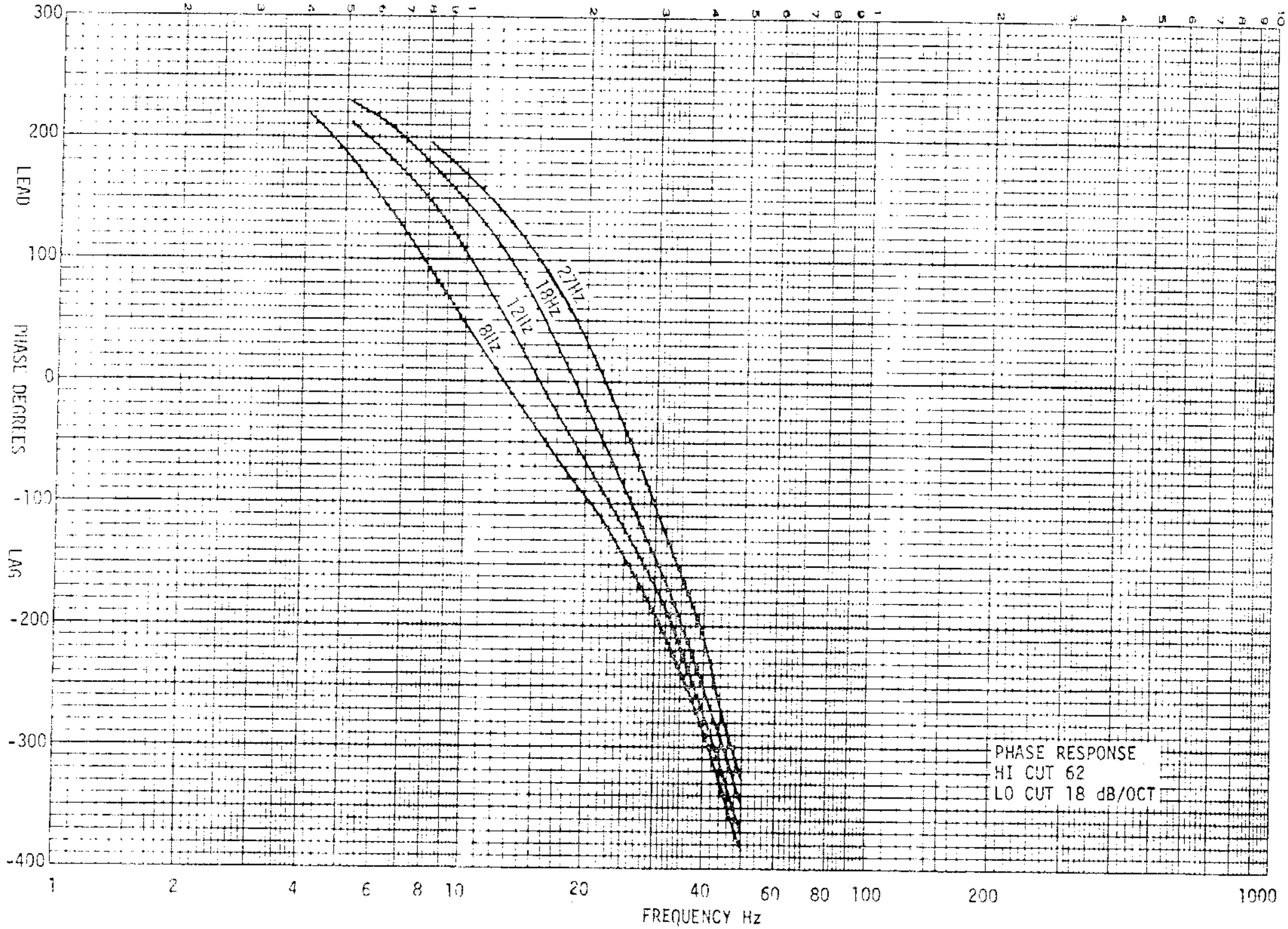


Figure 2.24 PHASE RESPONSE, 18dB/OCT, 62Hz

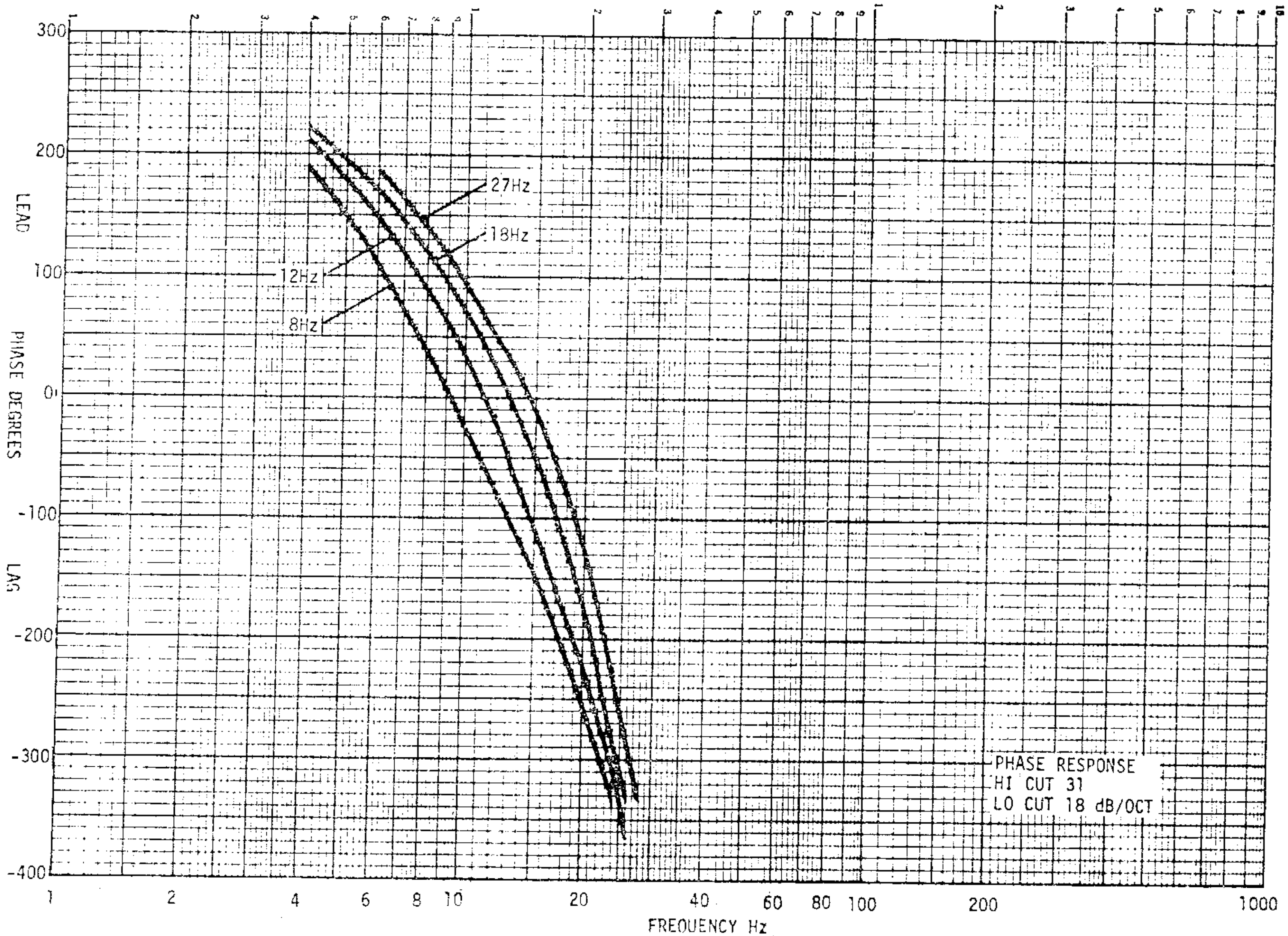


Figure 2.25 PHASE RESPONSE, 18dB/OCT, 31Hz

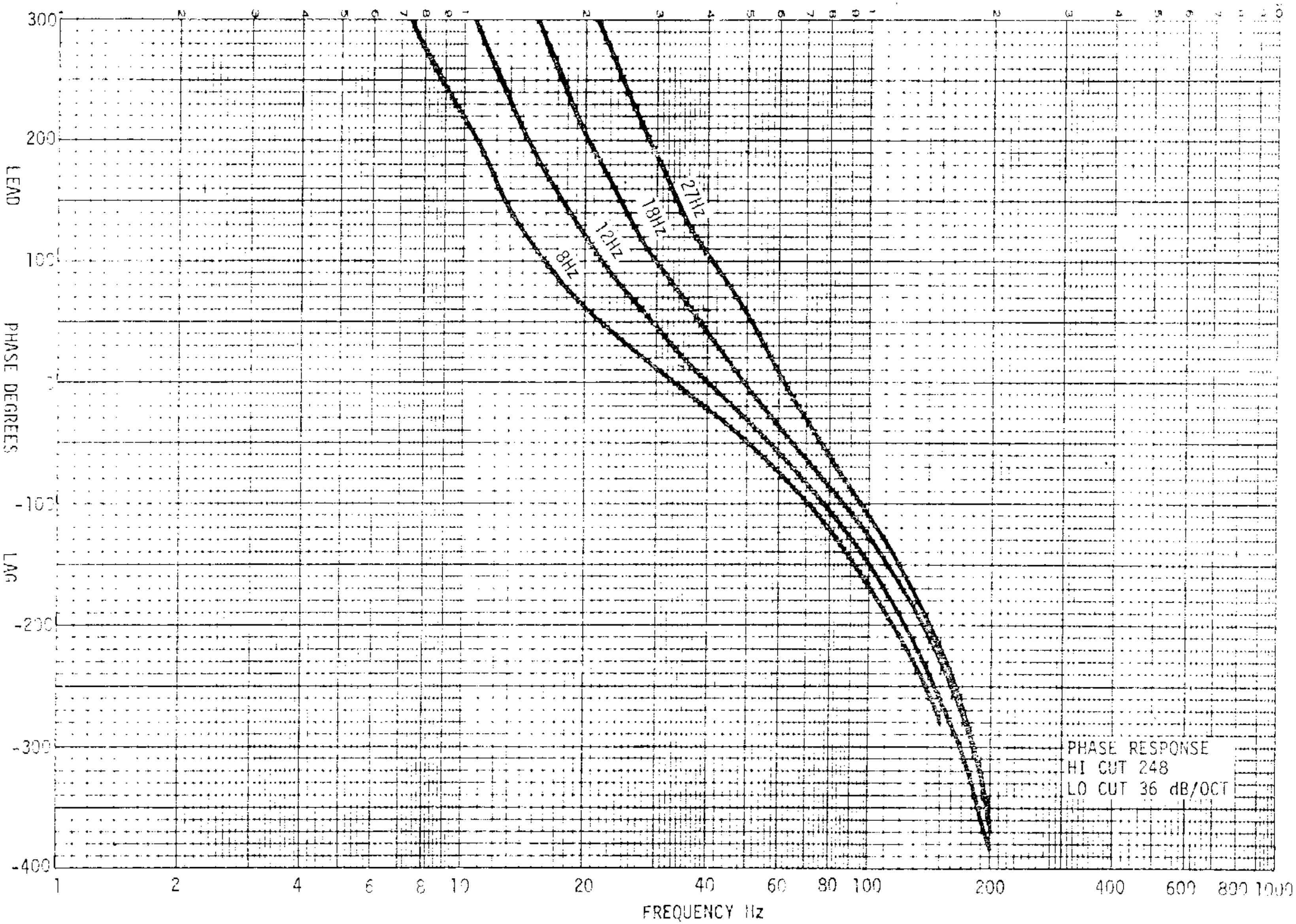


Figure 2.26 PHASE RESPONSE, 36dB/OCT, 248Hz

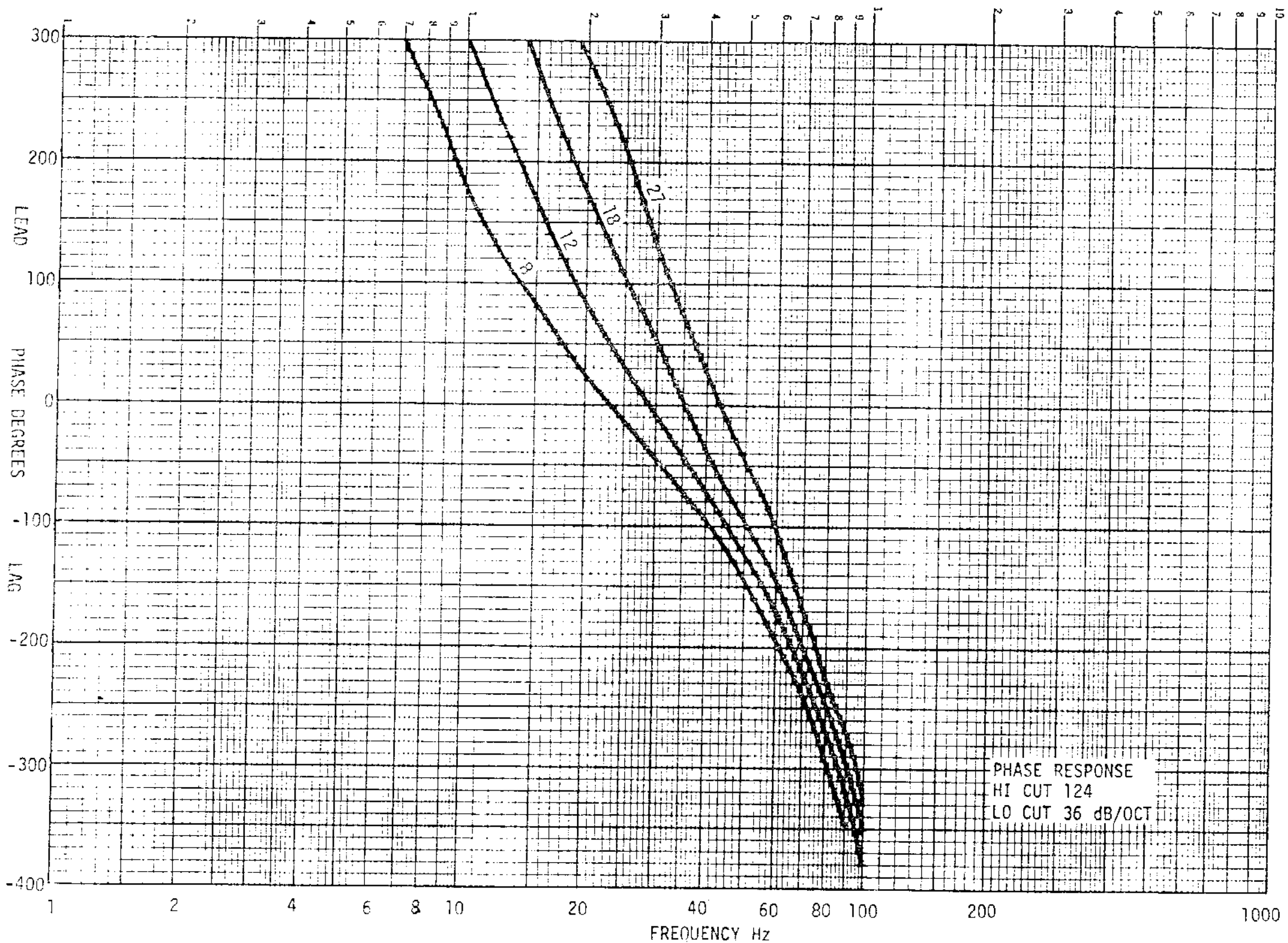


Figure 2.27 PHASE RESPONSE, 36dB/OCT, 124Hz

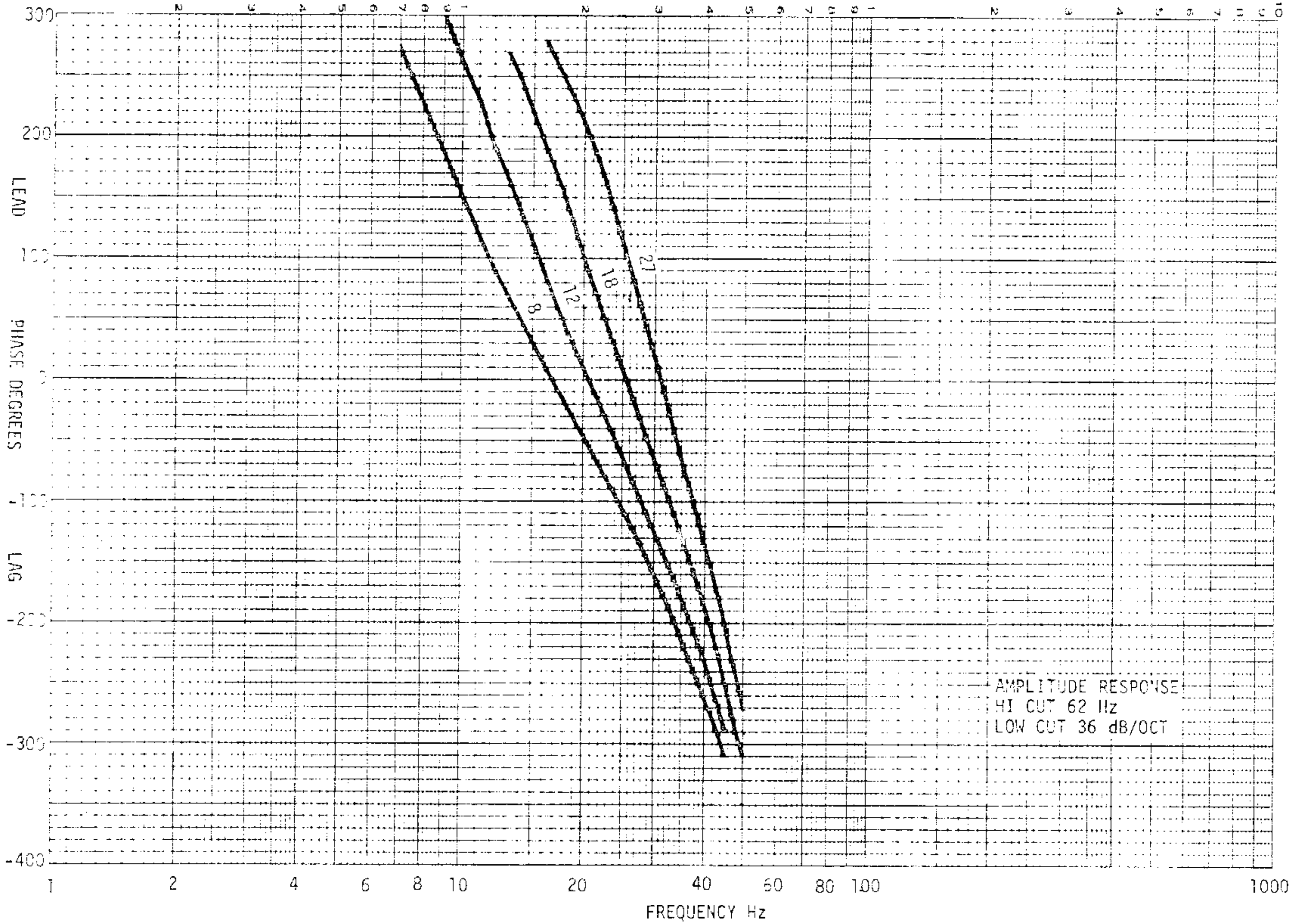


Figure 2.28 PHASE RESPONSE, 36dB/OCT, 62Hz

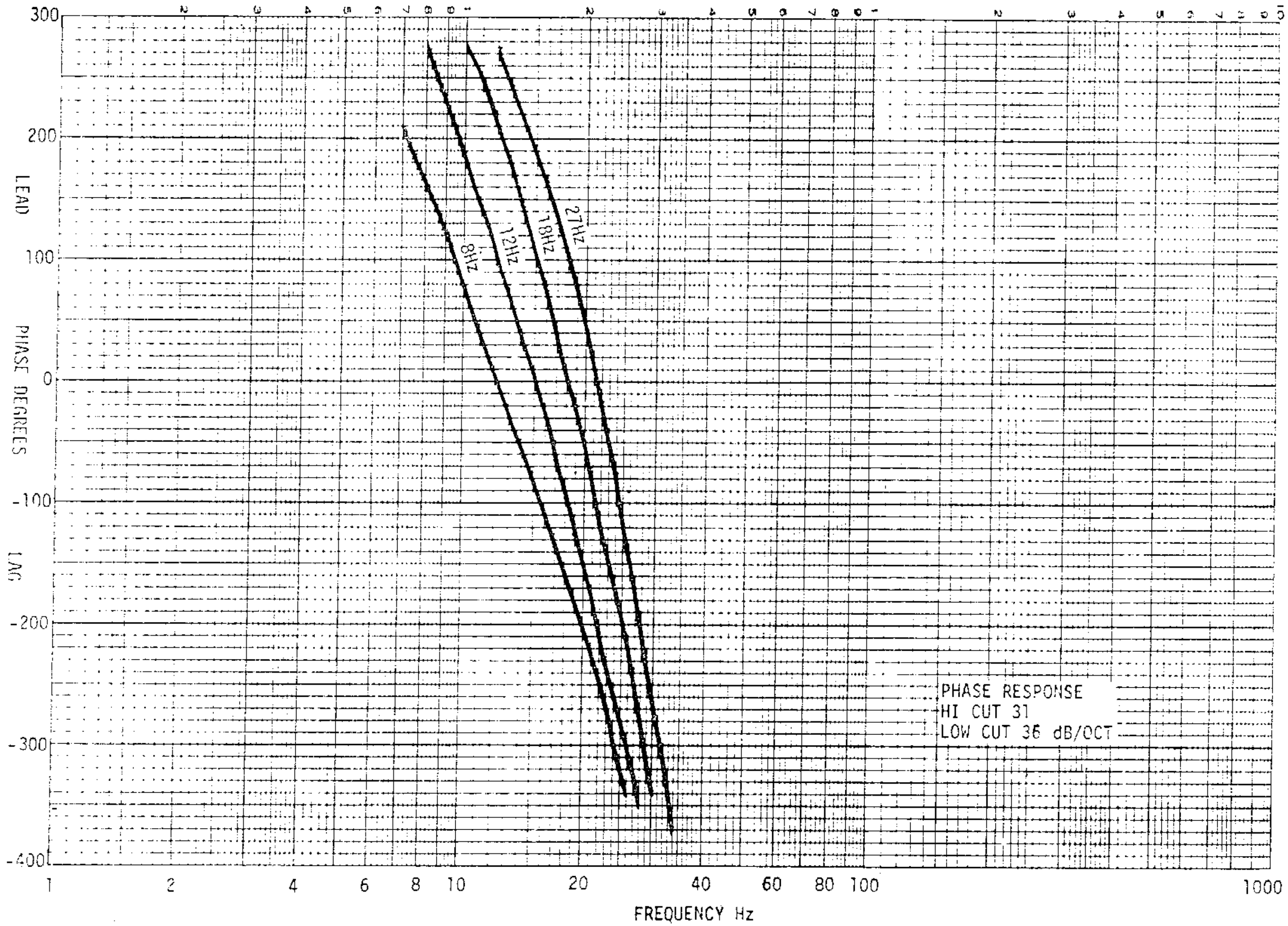


Figure 2.29 PHASE RESPONSE, 36dB/OCT, 31Hz

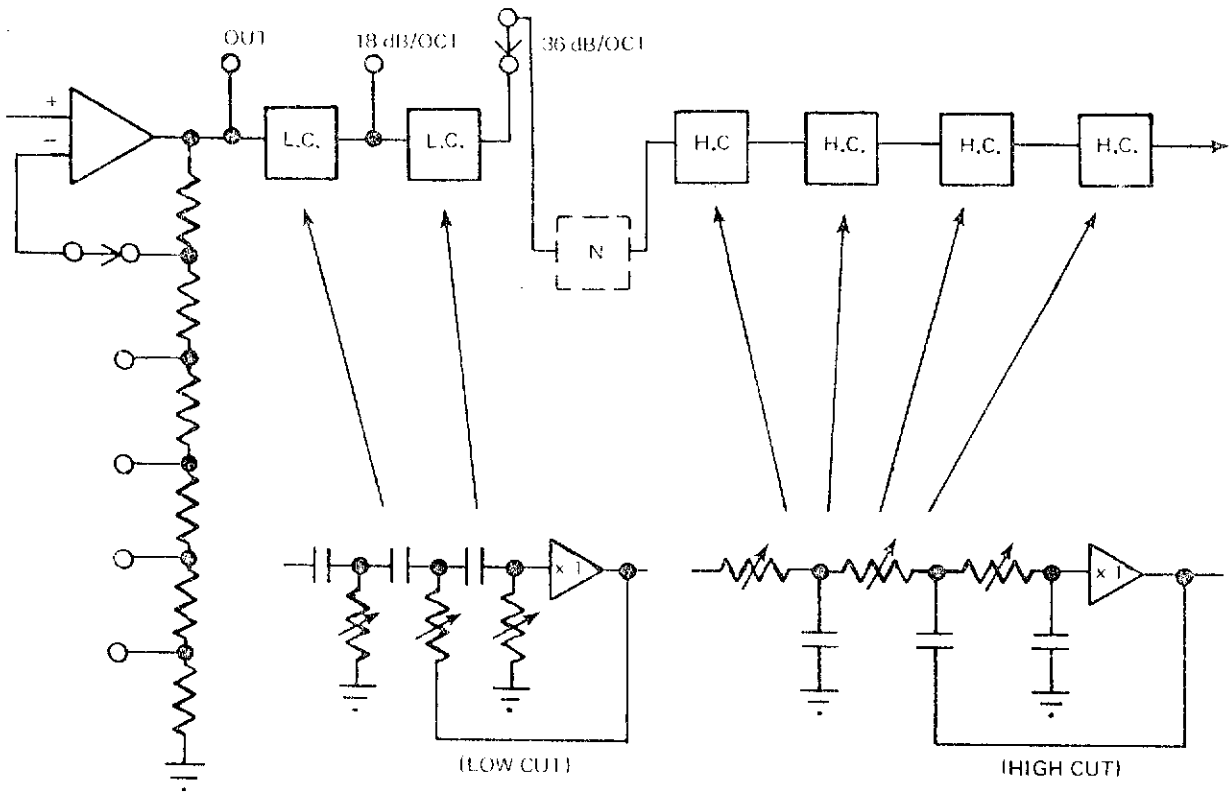
However, the phase lag increases dramatically between 20 and 60Hz in the typical seismic range, to become a leading phase (by some 20 degrees) up to 100Hz. It is assumed that some form of processing must cater for this extremely large phase change and when input signal has undergone previous phase change due to the low cut and anti-alias filters. It would not be incorrect to assume that the signal to be finally digitized may bear drastically reduced resemblence to the original input signal. Further work on the effects of notch filters is indeed merited in the future.

When the notch filter is not in use, it is replaced with a 'notch filter bypass' card, which is essentially a blank card and only provides a connection for signals from the output stage of the low cut filters to reach the high cuts filter input stages, as shown in Figure 2.30.

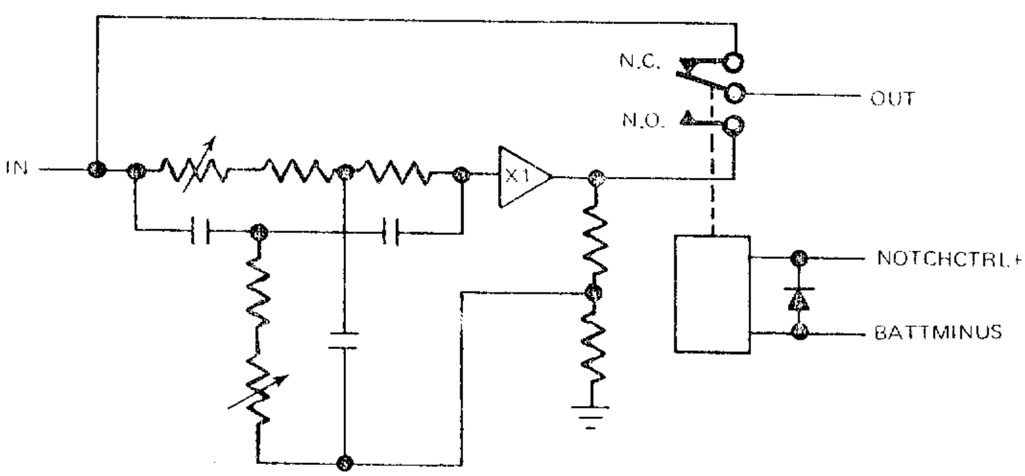
2.2.7 Analog Multiplexer

The multiplexer block diagram is shown in Figure 2.33.

The incoming seismic signal on each channel passes through a 'chopper stabilized amplifier'. This amplifier simply provides the seismic line with a fixed voltage reference level, so that the gain applied at the input to each multiplexer is identical for all channels. This gain level is established by adjustment of incoming test signals with the gain trim potentiometers.



Filter Block Diagram



Notch Filter

Figure 2.30

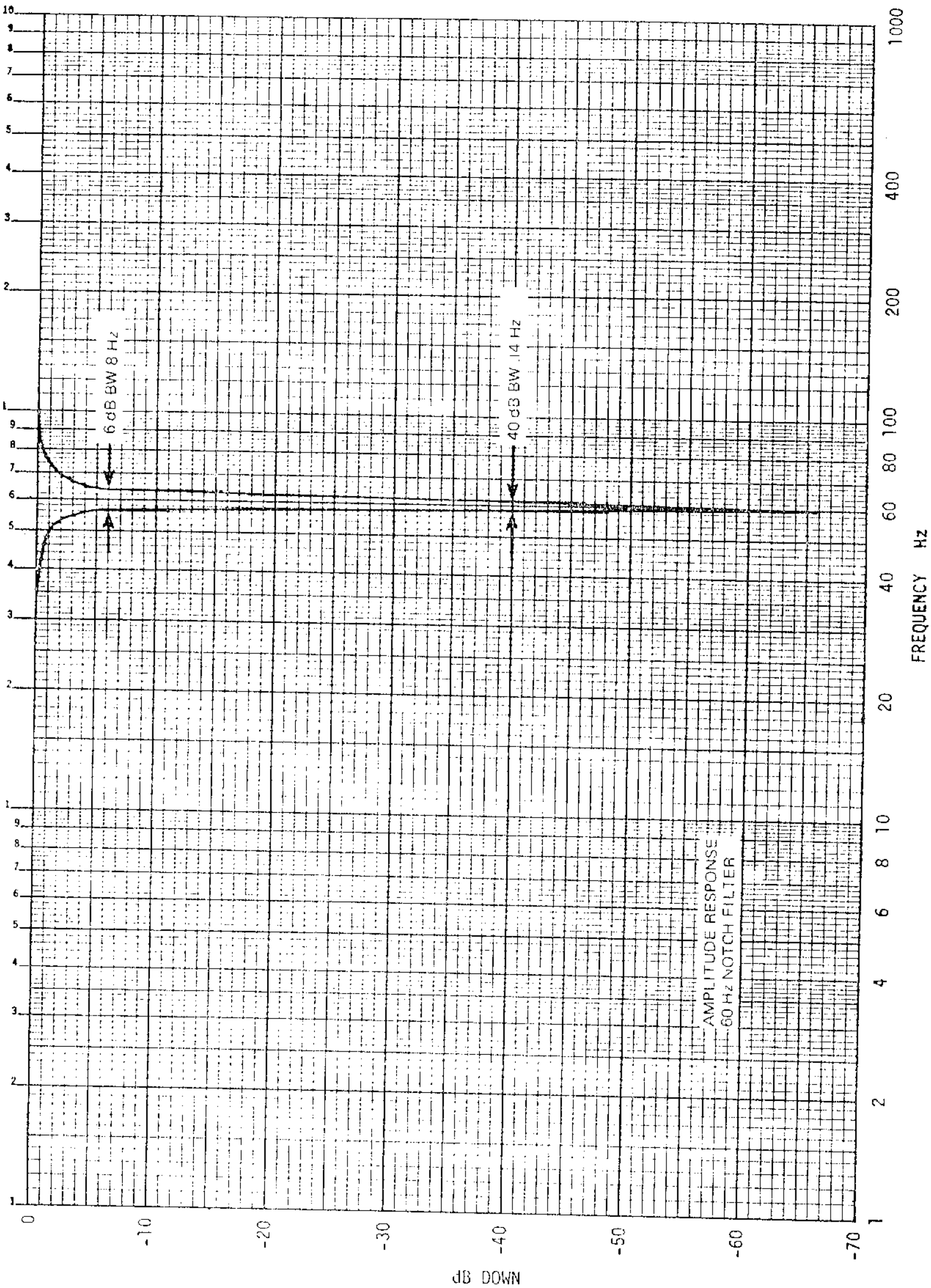


Figure 2.31 60Hz NOTCH FILTER, AMPLITUDE RESPONSE

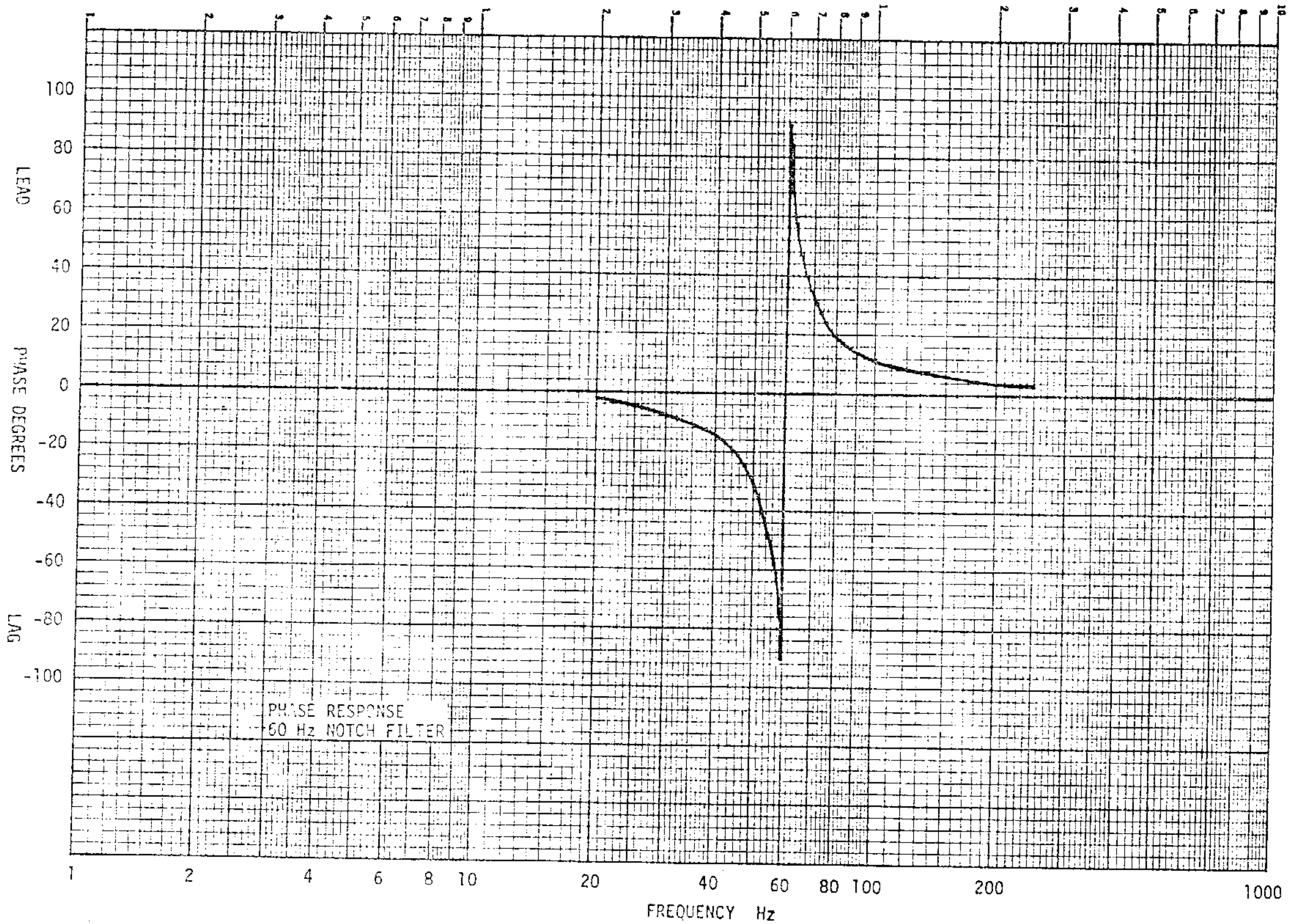


Figure 2.32 60Hz NOTCH FILTER, PHASE RESPONSE

Each multiplexer card multiplexes signals for two seismic channels. The chopper drive circuitry organises data by virtue of a 1 millisecond free running clock. The multiplexer passes the seismic signal on for sampling at a 1 millisecond rate. The chopper and multiplexer have a 3Hz and 500Hz frequency cut-off response.

2.3 Amplifier Module

The Amplifier Module contains the Module Multiplexer, the Amplifier System, the Analog-to-Digital Converter and the Test Unit.

2.3.1 Module Multiplexer

The Module Multiplexer (MM) position in the seismic channel circuit is shown in Figure 2.34. This work will confine the multiplexer's role to channels 1-48 alone.

The multiplexer operates as a selector switch connecting several parallel inputs and resorting them into a serial output. After the 48th input, the 1st input is readdressed and so on. The multiplexer consists of electrical switches at the inputs with a logic control to switch one on at a time. These gates are field effect transistors (FET's), the condition of which varies considerably under the effect of polarization. The output is a series of short segments of the input signals as shown on Figure 2.35 in which three channels are multiplexed.

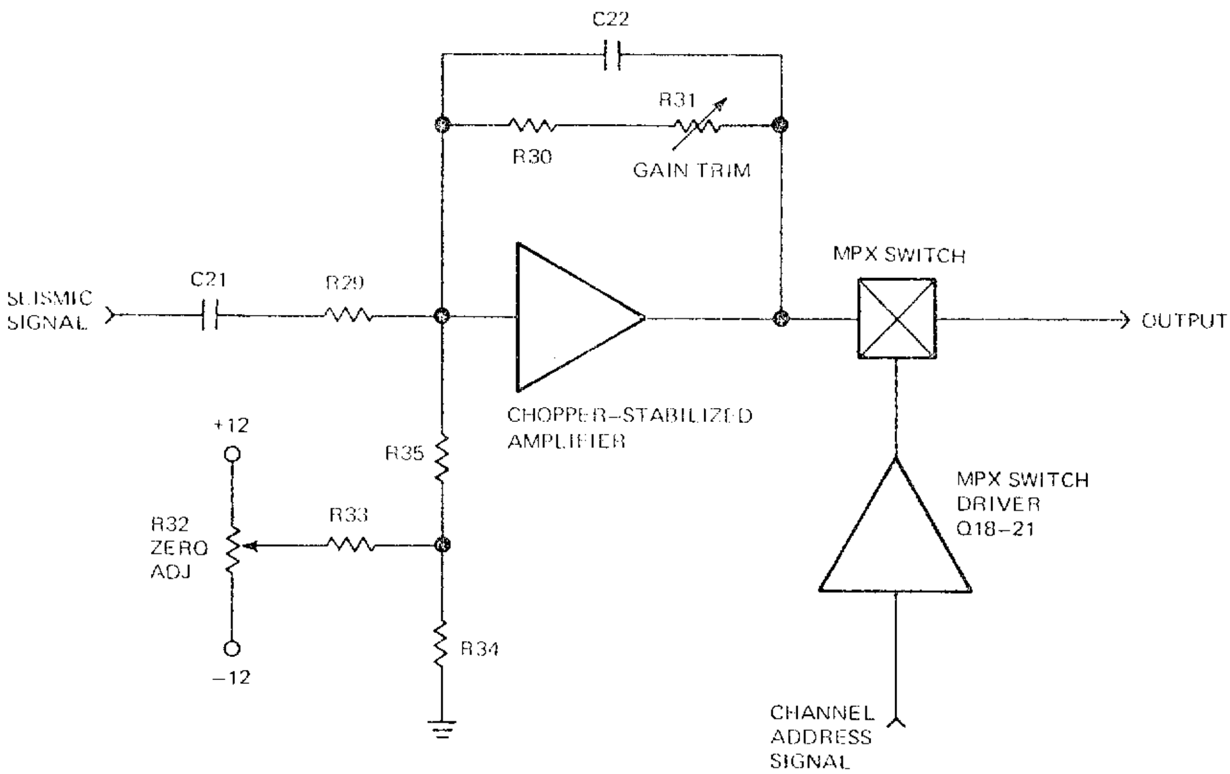


Figure 2.33 MULTIPLEXER BLOCK DIAGRAM

The time at which the voltage of one input channel is available at the output, is dependent upon how many channels are being multiplexed. This time is short of the full sample interval. This is the multiplexer cycle period which is often considered to be identical with the sample period. The difference is significant (and is compensated in data processing), and occurs in all switching elements.

2.3.2 Amplifier System

The Amplifier system time shares the floating point amplifier across up to 60 input channels, eight auxiliary data channels and an Expander Module (a module which allows the number of input channels to be doubled).

The Instantaneous Floating Point (I.F.P.) amplifier derives its name from the manner in which the output is expressed with a sign, a mantissa and a power of four as a characteristic. This floating point method of notation has the gain selected 'instantaneously' by the operation of the comparator circuit in the A to D converter. Hence "I.F.P."

With the I.F.P. amplifier, a gain level is determined for each voltage sample value. The output remains close to full scale for a maximum accuracy on all sample determinations and there is no delay for a gain incrementation operating up to full gain (84dB) in any single sample rate (e.g. for 2 millisecond operation, rate of gain variation is 42,000dB per second). This is a larger range than can

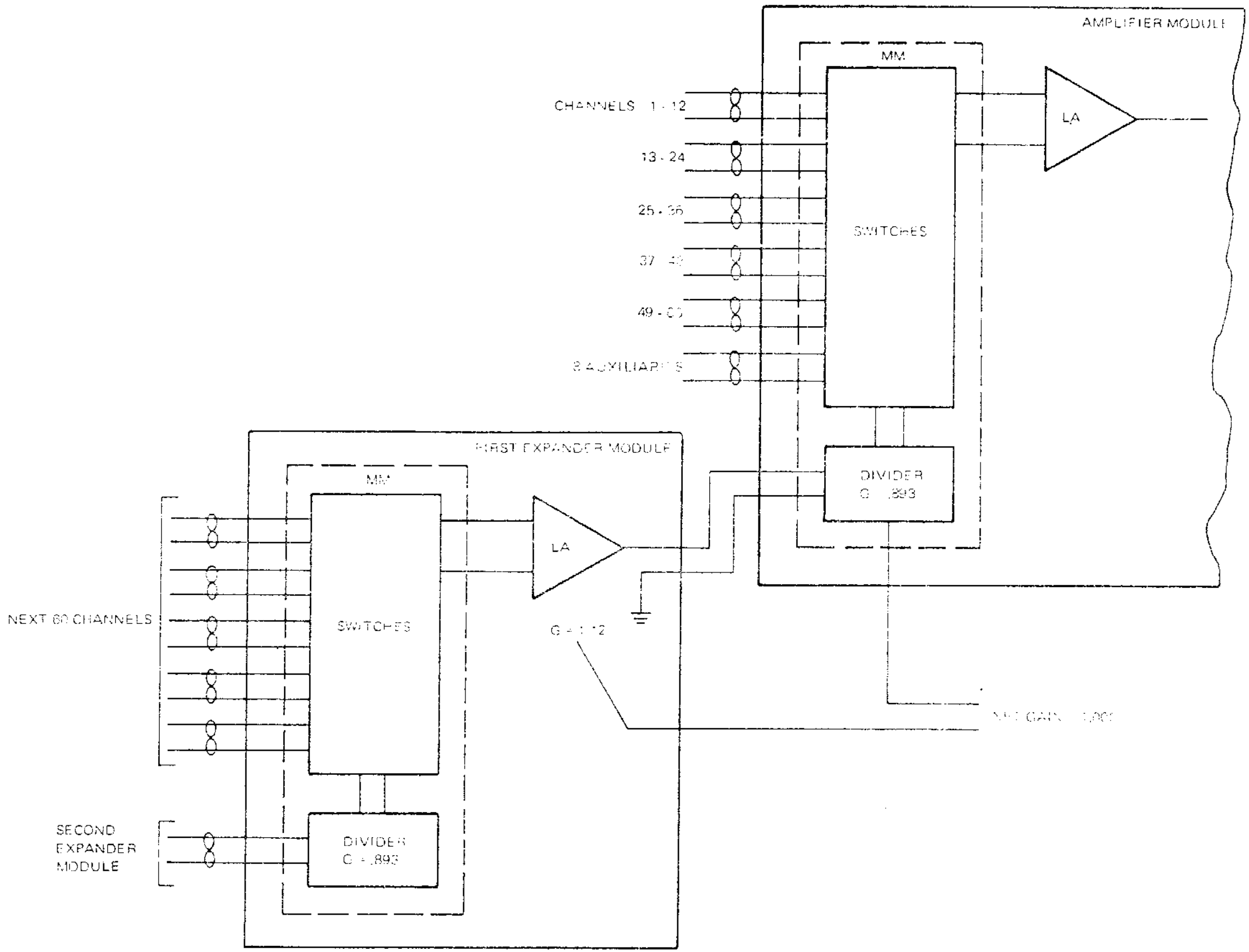


FIGURE 2.34 MODULE MULTIPLEXER

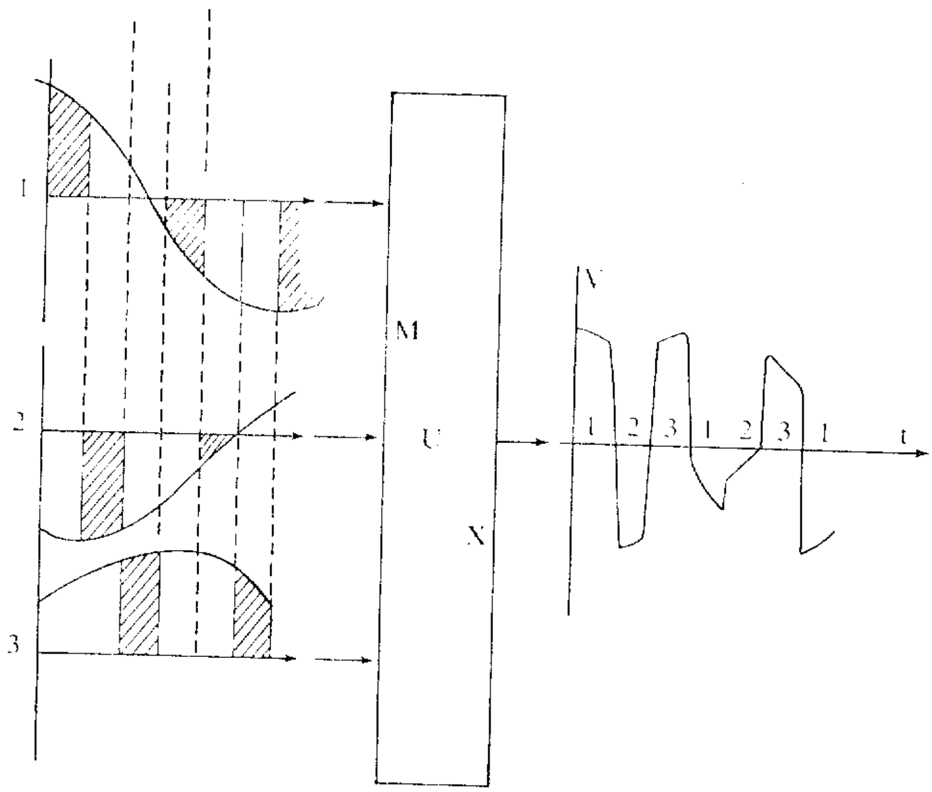


Figure 2.35 THE DATA BEFORE AND AFTER MULTIPLEXING

be expected from any seismic signal. With this capacity, there is no risk of data being recorded with a lack of sensitivity or accuracy.

At each zero crossing, the gain increases for each intermediate value, see Figure 2.36. Output data recorded with an IFP amplifier cannot be properly replayed without adequate decoding including gain recovery to bring the amplitude back to the recording range of the instrument upon which it is displayed. An oscillograph camera displaying IFP data gives a hashed output, and a straight number dump off magnetic tape would represent the output shown in Figure 2.36.

Instantaneous gain changing is assisted by three cascading stages of amplifier gain, with each stage in series. Gates connect the cascade to the amplifier's output, such that one gate is open at a time. If the gain is 'g' per stage, and the $(n+1)^{th}$ gate is open, the gain is g^n. If g is 2 or a power of 2, so is the gain.

The output level is compared to two thresholds. One is full scale voltage, the other is g times below. If the output is full scale, the $(n+1)^{th}$ gate is closed by logic and n^{th} gate opened. If the output is less than the lower reference, a higher order gate is opened. The proper selection of output gates is by scanning all levels. With N stages, the gain can range from 1 to g^N

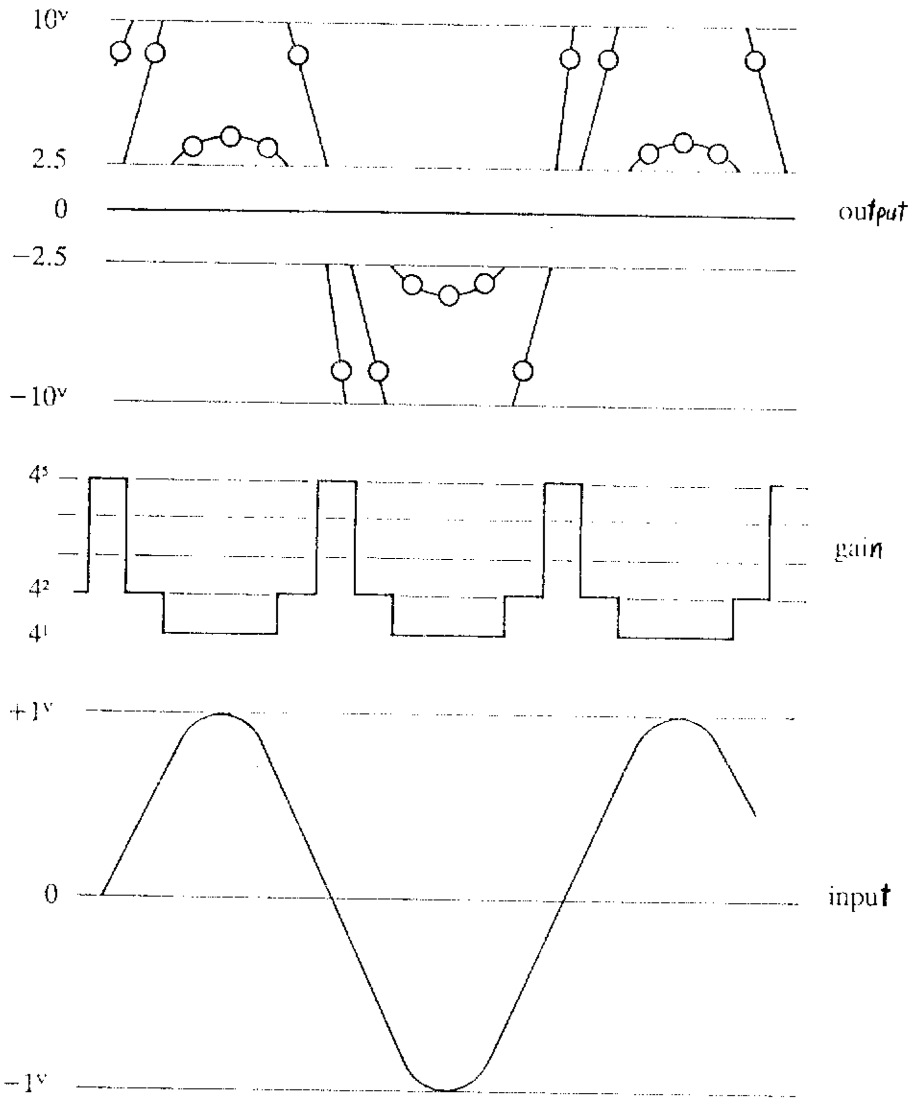


Figure 2.36 IFP AMPLIFIER OPERATION

in steps of g. Amplifiers with g=4 have a maximum gain of 84dB or 2^{14} (odd exponents of 2 are excluded with a base of 4). A 4 step gain is a "quarternary gain", increasing gain in 12dB steps.

The "slew rate" is a prediction of the next sample value, based upon the past signal value variation rate. Thus, the amplifier output enters the gain comparator which determines the slew rate and amplitude of the IFP amplifier, and decides whether to step up, down, or leave gain levels unchanged. It is an amount equivalent to a linear prediction i.e.

$$E = V + k \frac{dV}{dt}$$

where k = constant allowing for time between comparison and time taken for each sample (for DFS IV it is 10 microseconds).

$\frac{dV}{dt}$ = rate of change of original signal value.

V = last sample.

E = next predicted IFP sample.

A gain increase will occur if:

$$E \leq 0.73V \quad \text{and} \quad E + k \frac{dV}{dt} \leq 0.66V$$

A gain decrease will occur if:

$$E + k \frac{dV}{dt} \geq 3.14V \quad \text{or} \quad E \geq 3.36V$$

The check of $(E + k \frac{dV}{dt})$ keeps the signal within 19 to 84 per cent of full scale of the converter except at very small signals when maximum gain is attained. The check of E also prevents overloading an amplifier stage.

2.3.3 A/D Converter

Having determined the gain value with the gain comparator circuit, the remaining voltage level must be assessed for digitization. The Comparator circuit performs this task, the block diagram being shown in Figure 2.37. This card performs a further step towards the analog to digital conversion process, since the gain word is already obtained from the gain comparator circuit.

Because the remaining voltage level is to be assessed and compared for digitization, the voltage must be maintained for the short period of sampling time for digitization. To ensure this, a "sample and hold" circuit is placed before the digitizing circuitry. This is done by holding the voltage to be assessed on a 'hold' capacitor for a few microseconds, so that a correct conversion to a digital value can be made. For converting an analog magnitude to a digital 14 bit binary coded expression, conversion by successive approximations is performed.

Firstly, the voltage for assessment V is compared to a reference level $\frac{E}{2}$, see Figure 2.38. If V is bigger than $\frac{E}{2}$, a flip-flop switches a "1"into an output register. If V is smaller than $\frac{E}{2}$, a "0" is produced.

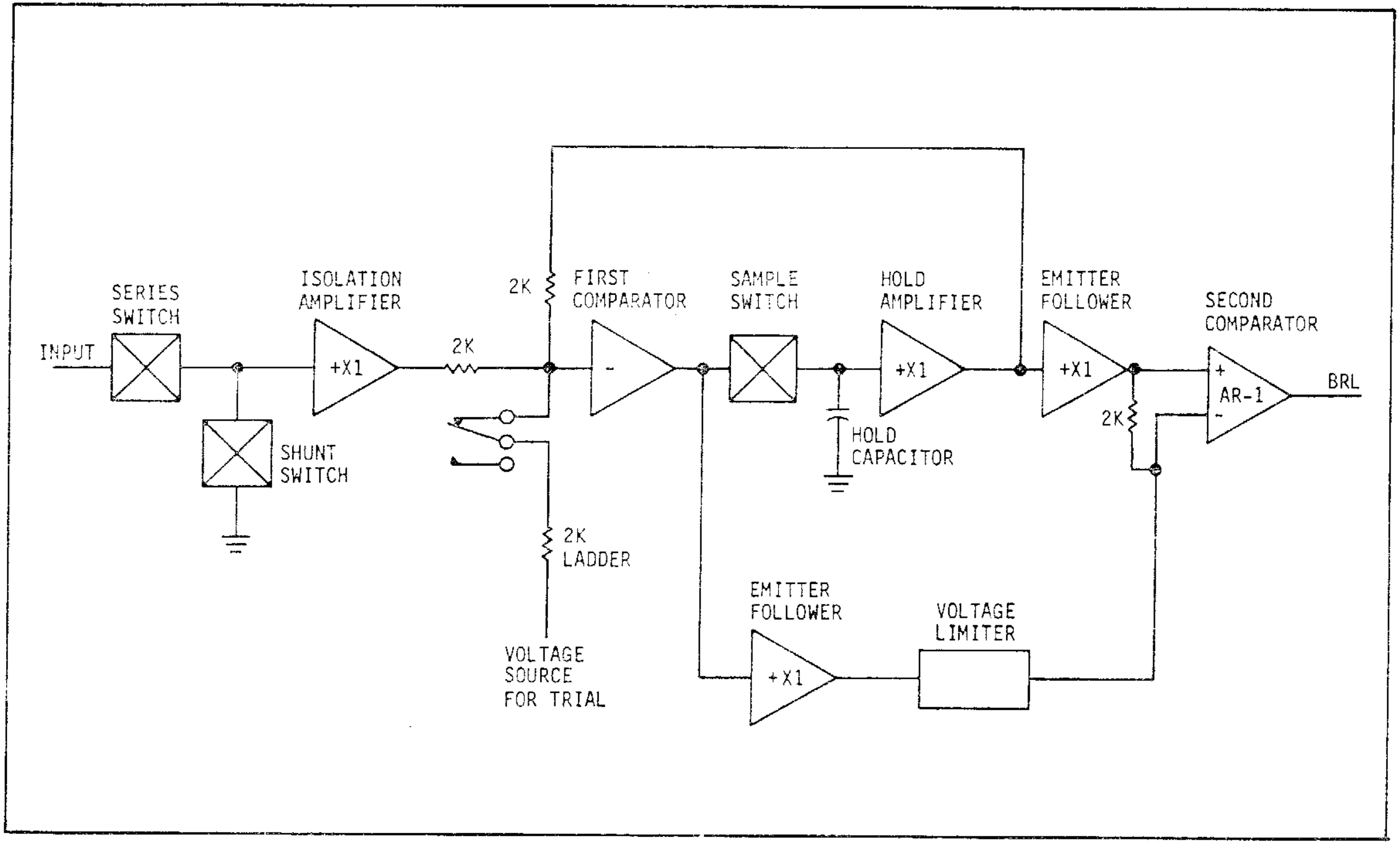


Figure 2.37 COMPARATOR BLOCK DIAGRAM

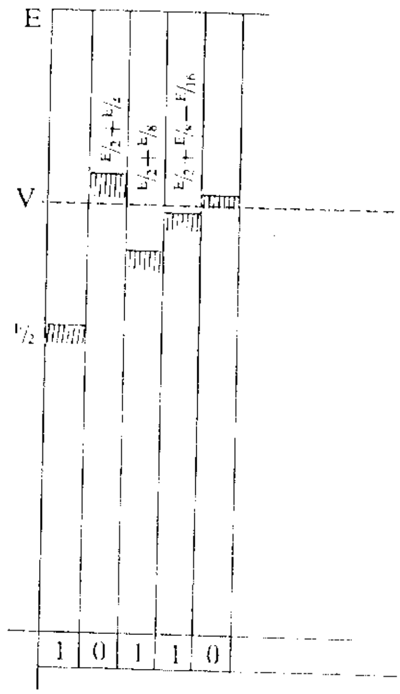


Figure 2.38 CONVERSION BY SUCCESSIVE APPROXIMATIONS

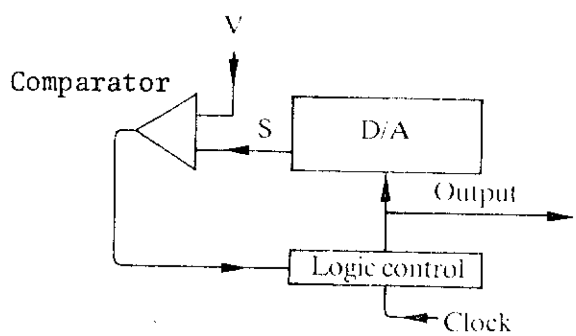


Figure 2.39 SIMPLIFIED A/D CONVERSION

At the second stage, $\frac{E}{4}$ is added to $\frac{E}{2}$ and the same routine performed to produce a "1" or "0" in the register. $\frac{E}{8}$ and $\frac{E}{16}$ and so on are compared, so that all bits representing a value from the most significant bit (MSB = E = 2048 millivolts) to the least significant bit (LSB = $\frac{E}{2^{14}}$ = 0.25 millivolts) have been tried. Each time a "1" or "0" is produced at each bit level, this constitutes the binary word representing a voltage value.

The reference voltage and its comparison voltages in reducing powers of two are generated on networks or "ladders". Any error in the reference value will make the conversion process non-linear and, hence, this is an extremely important circuit to maintain converter accuracy and linearity (see later tests).

The final analog to digital conversion process is made up of a D/A converter and a comparator. Two D/A converter cards accept ladder inputs so that, by closing the successive inputs, the output increases in binary stape (the first D/A card operates on 10 most significant bits, the second D/A card operates on the least significant 4 bits).

In Figure 2.39 input voltage V and output S of the converter (ladder network) are fed to a comparator. The ladder gates are controlled by a logic which reacts to the sign of the comparator's output. It controls the gates as explained until S is as close as possible to V. After all comparisons have been made, the state of the gates of the D/A converter is checked and transmitted as the digital code representing the analog signal magnitude.

2.3.4 Test Unit

The test unit front panel controls are shown on Plate 2.3 with the following indications:

1. 10 position ZERO switch which shorts inputs to converter, 3rd amplifier, 2nd amplifier, 1st amplifier and line amplifier to ground when checking noise levels. Switching to MX enables the CHANNEL switches on all Input Modules and shorts all inputs for multiplexer zero calibration.
2. Power supply circuit breakers.
3. Power supply indicator lamp.
4. Ground post.
5. 14 position DC VOLTAGE switch, used during checks of DC voltage levels.
6. Fault indicator lamp which is on when a fault (causing interruption to recording) exists.
7. Test signal level switch.
8. Test signal range switch which permits test signals from 0.5 microvolts to 512 millivolts to be output.
9. Output signal jacks, used for obtaining a test signal when the METER FUNCTION switch is in OUTPUT, OSC or PULSE.

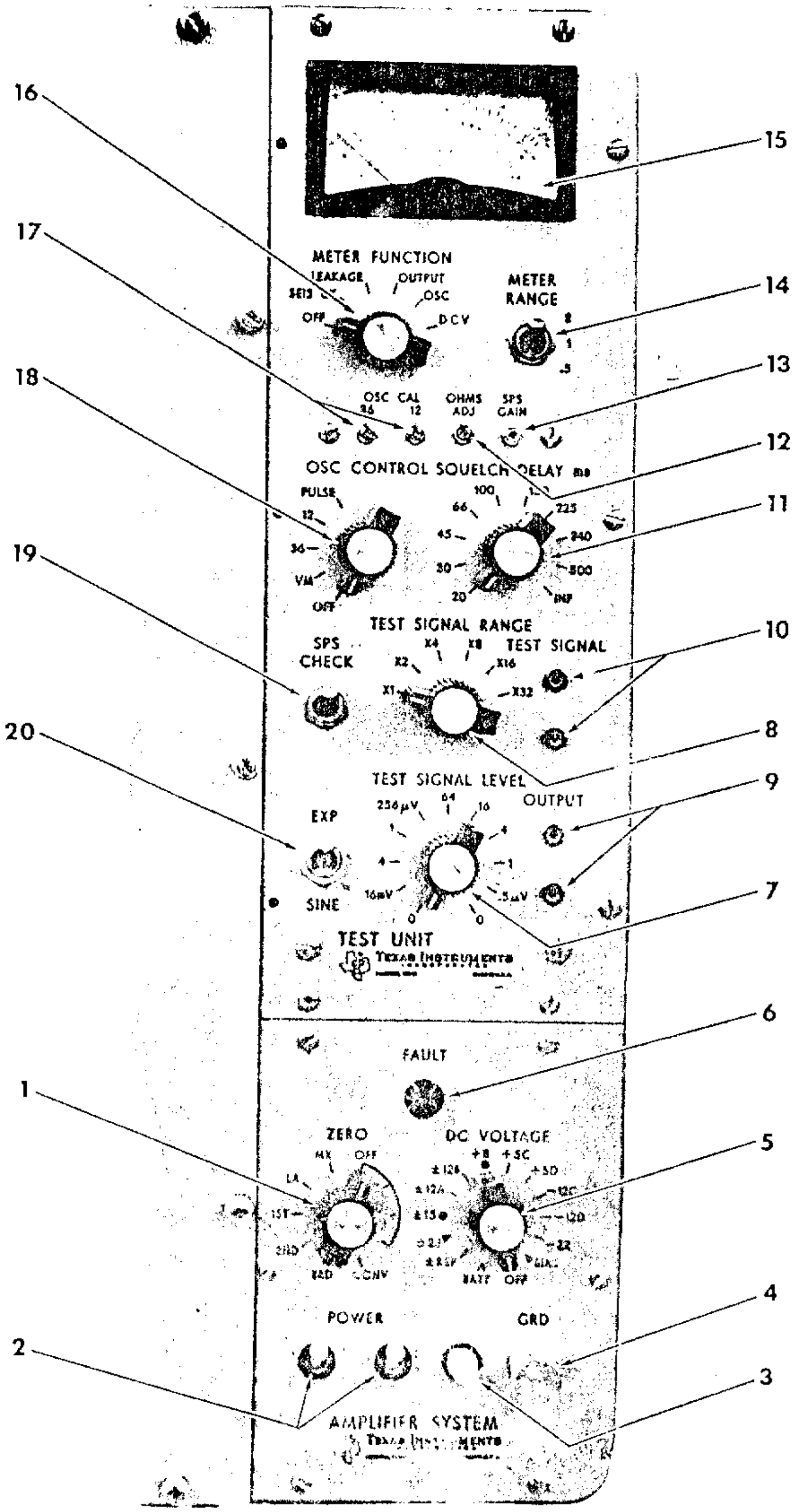


Plate 2.3 <u>TEST UNIT CONTROLS ON FRONT PANEL</u>

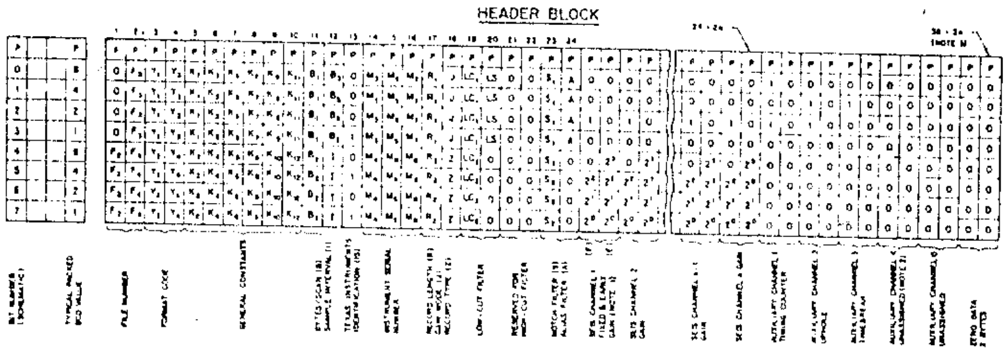
10. Test signal jacks, of 80 ohm impedance, can output a selected test signal.
11. Squelch delay, which is normally used when firing control utilizes a line in the seismic cable.
12. Ohms Adjustment is used to adjust the ohmmeter to infinity level during seismic continuity checks.
13. SPS gain is the gain potentiometer for the SPS amplifier.
14. Meter range switch changes the voltmeter scale factor.
15. This meter is a 200 microamp-meter with two ohmmeter scales and a 150% scale for voltage measurements.
16. 6 position meter function switch checks seismic line for continuity and leakage, outputs the Reproduce Mode signal, oscillator signal and reads DC voltages.
17. Oscillator calibration potentiometers.
18. 5 position oscillator control switch which energizes the voltmeter, 36 or 12Hz oscillators or pulse generator.
19. SPS check allows continuity and leakage checks of the shot point seismic cable line.
20. The exponential/sine toggle switch selects the required output waveshape for test signal purposes.

2.4 Format Module

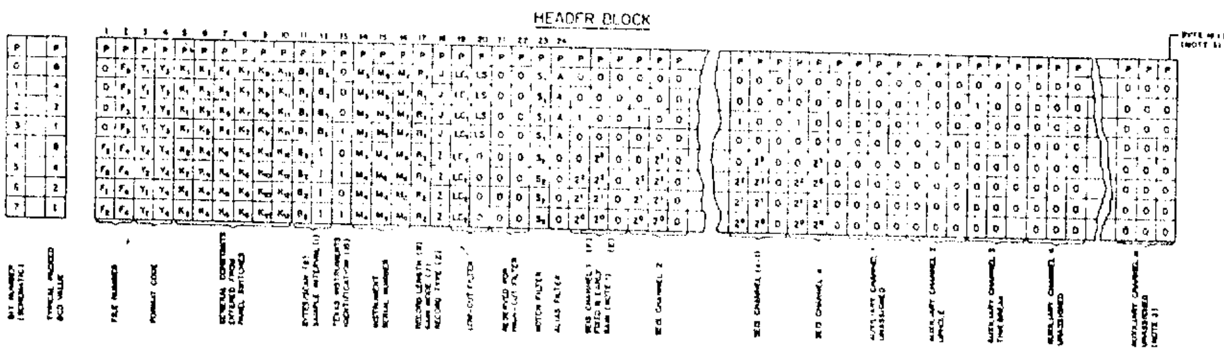
Whilst the earlier circuit elements are principally analog the format module is composed of digital logic or switching circuits. Timing control, logic instruction, control interlocking, record annotation, and translation of data into a code or 'format' to be written on magnetic tape, are performed by the Format Module. The module also provides inputs and outputs for peripheral devices such as oscillographs, external data encoders and field compositors, with the data acquisition system. The Format Module interfaces also with the Read/Write Module, recording data in 1600 bits per inch (BPI) phase encoded nine track mode.

It is capable of outputting data in the two basic 'Society of Exploration Geophysicists' standards. viz. SEG 'B' and SEG 'C'. Format 'B' is for 48 channel operation, 'C' for 60 channel, and additional Format 'D' for 96 channel. Due to the incapacity of the Amplifier system to handle 96 channels, only SEG 'B' and 'C' will be referred to herein (see Figure 2.40 to 2.43).

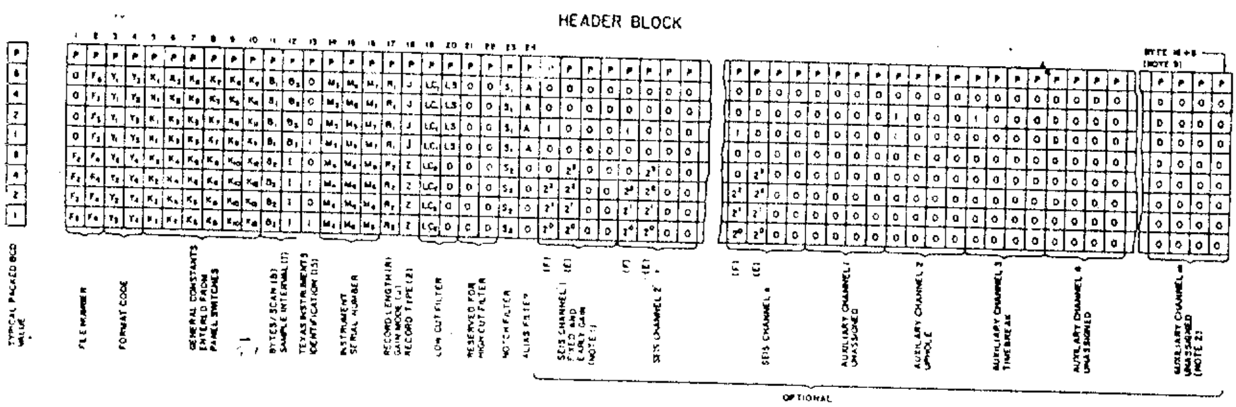
In the idle condition (when the system is not recording on magnetic tape), the Format Module performs all the essential features of logic control and display of system testing amplifier calibration, and dc offset adjustments. From a simplified view, it may be considered that whilst idle, the system still performs all the necessary basic functions, but that, when system recording commences, it merely dumps the data onto magnetic tape.



(a) FORMAT B HEADER

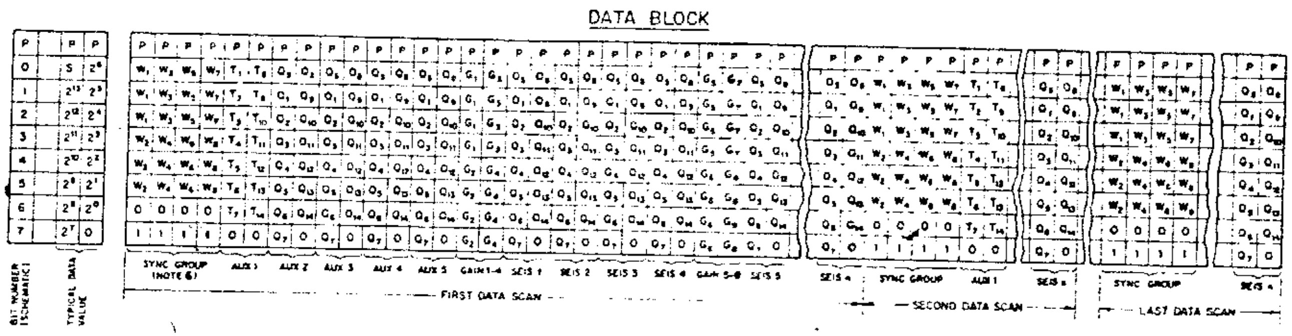


(b) FORMAT C HEADER

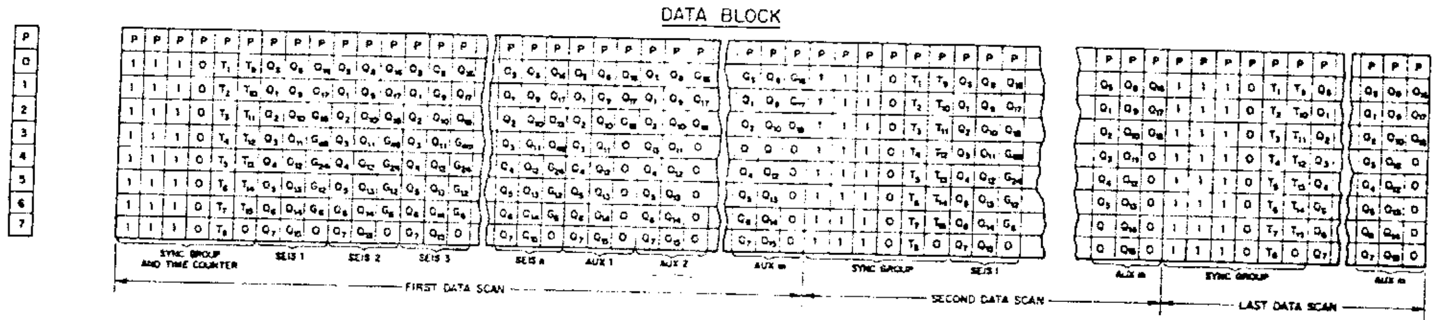


(c) FORMAT D HEADER

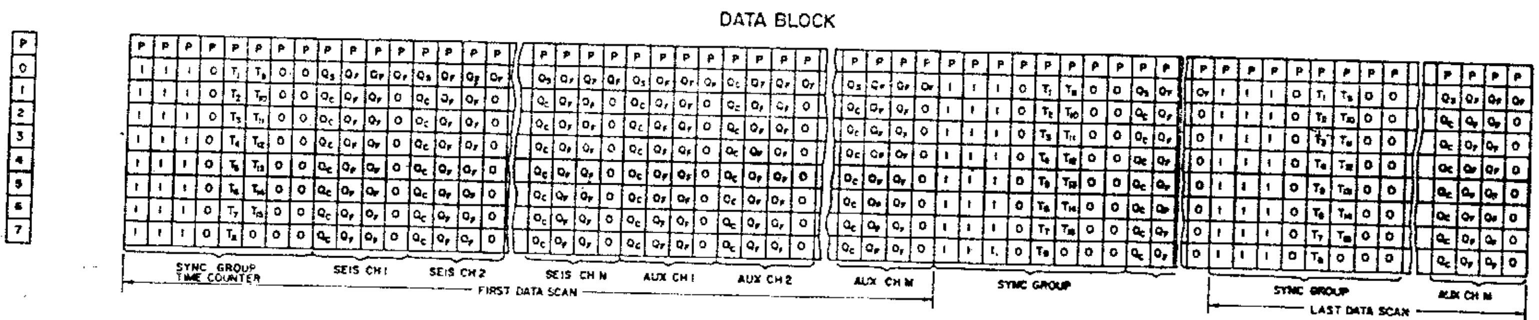
Figure 2.40 FORMATS B, C AND D HEADER BLOCKS



(a) FORMAT B DATA BLOCK

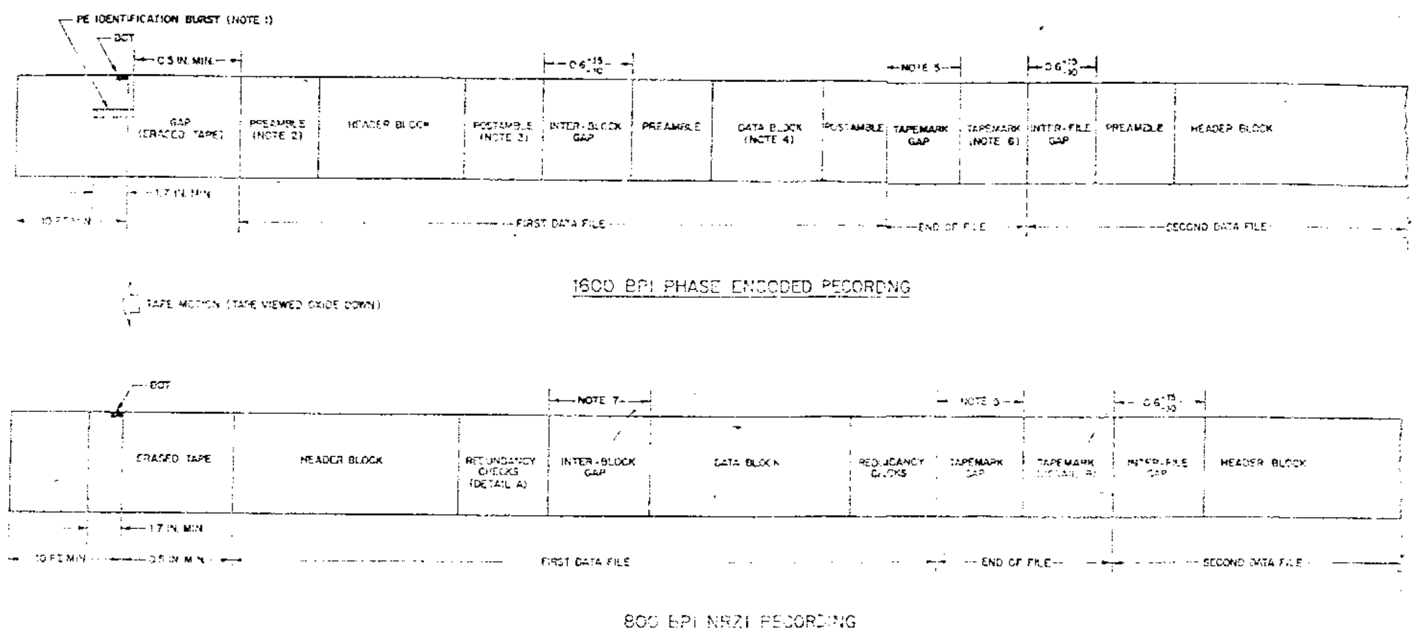


(b) FORMAT C DATA BLOCK



(c) FORMAT D DATA BLOCK

Figure 2.41 FORMATS B, C AND D DATA BLOCKS

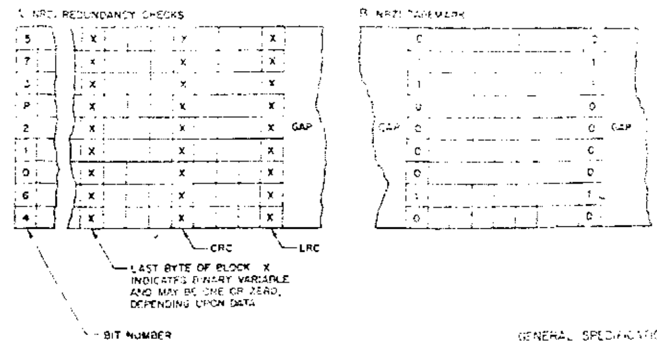


NOTES:

1. PE IDENTIFICATION BURST CONSISTS OF 3200 FLUX REVERSALS PER INCH IN TRACK P, ALL OTHER TRACKS DC ERASED
2. PREAMBLE CONSISTS OF FORTY CHARACTERS WITH 0-BITS IN ALL TRACKS FOLLOWED BY ONE CHARACTER WITH 1-BITS IN ALL TRACKS.
3. POSTAMBLE CONSISTS OF ONE CHARACTER WITH 1-BITS IN ALL TRACKS FOLLOWED BY FORTY CHARACTERS WITH 0-BITS IN ALL TRACKS.
4. SYNCHRONOUS DATA RECORDING (STANDARD): FOLLOWING PREAMBLE ZERO DATA IS WRITTEN UNTIL TIMEBREAK. FIRST START OF SCAN IS THEN WRITTEN. ZERO DATA SECTION ALWAYS CONTAINS AN EVEN NUMBER OF BYTES AND AN INTEGRAL NUMBER OF WORDS.

   ASYNCHRONOUS DATA RECORDING (OPTION): FIRST START OF SCAN IS WRITTEN IMMEDIATELY AFTER PREAMBLE. WHEN TIME BREAK OCCURS TIMING COUNTER IS RESET TO ZERO
5. TAPEMARK GAP
   STANDARD $0.6^{+.15}_{-.10}$
   OPTIONAL 3.75
6. PE TAPEMARK CONSISTS OF 80 FLUX REVERSALS AT 3200 FCI IN TRACKS P, 0, 2, 5, 6 AND 7. TRACKS 1, 3 AND 4 ARE DC-ERASED.
7. SYNCHRONOUS DATA RECORDING (STANDARD). INTERBLOCK GAP IS ERASED UNTIL TIMEBREAK. FIRST START OF SCAN IS THEN WRITTEN.

   ASYNCHRONOUS DATA RECORDING (OPTION). FIRST START OF SCAN IS WRITTEN AS SOON AS NOMINAL 0.6 IN. INTERBLOCK GAP HAS BEEN ERASED. TIMING COUNTER IS RESET TO ZERO AT TIMEBREAK
8. ORDER AND LOCATION OF TRACKS ON TAPE, DIRECTION OF MAGNETIZATION AND ALL OTHER APPLICABLE SPECIFICATIONS IN ACCORDANCE WITH IBM FILE S360-19, FORM A22-6862-4.



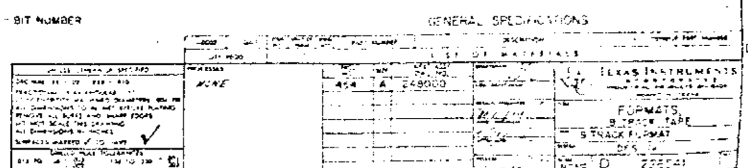


FIGURE 2.43

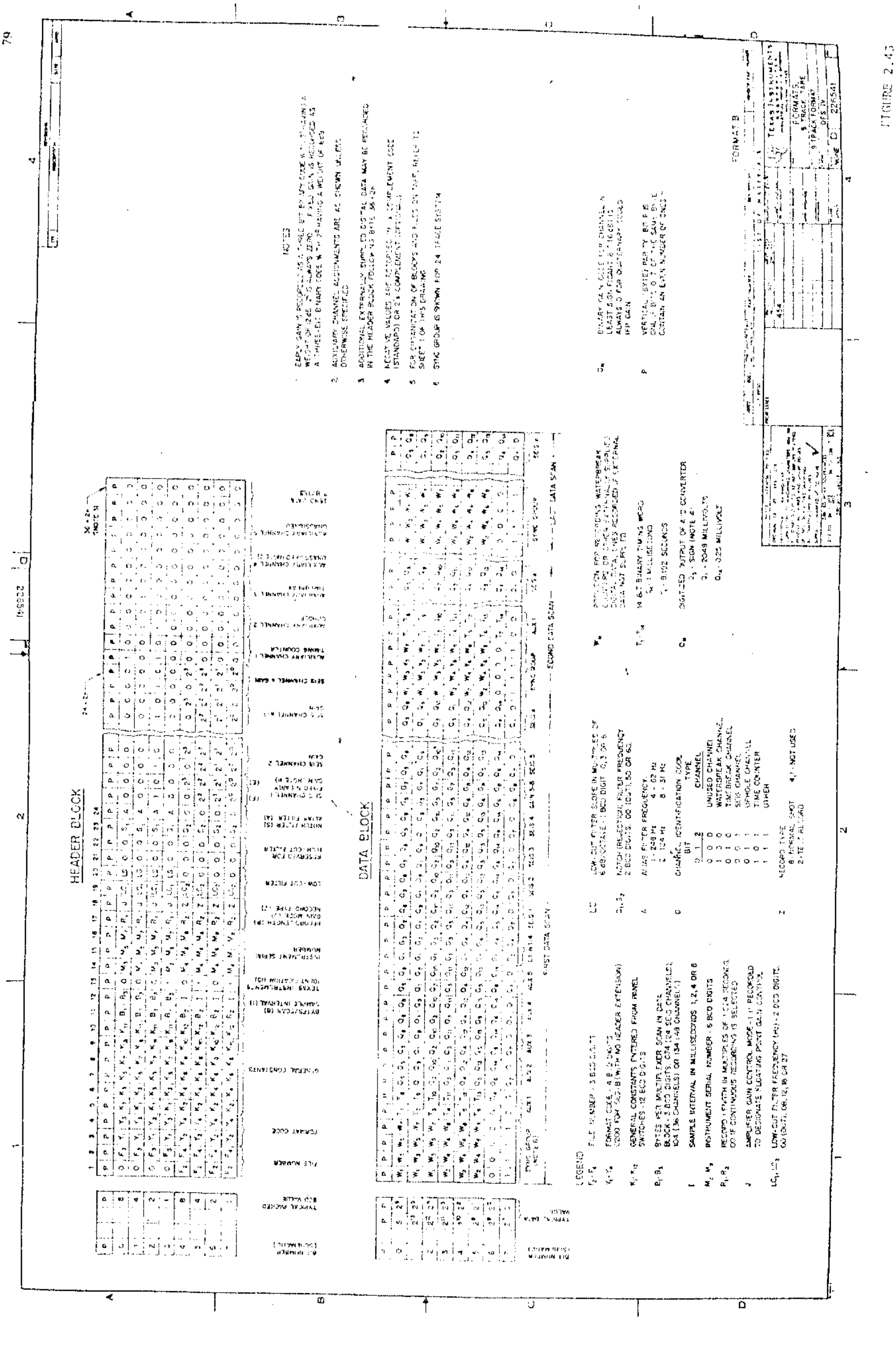


Plate 2.4 shows the front panel controls, with the following indications:

1. Power 'on' push-button.
2. Power 'off' push-button.
3. Power on indicator lamp.
4. Power circuit breakers.
5. DC VOLTAGE switch used for checking dc voltage levels in the Format Module.
6. MODE switch which in RECORD allows normal recording to commence dependent upon RECORD switch position; in SEARCH allows the magnetic tape to be searched for required files dependent upon SEARCH switch position; in REPRODUCE allows replay of desired file; and in TEST allows testing of the system dependent upon TEST switch position.
7. RECORD indicator lamp flashes when the system is READY to record, and remains on during recording of data.
8. REPRODUCE indicator lamp is on during playback of files.
9. START push-button depressed for starting recording or playback sequences.
10. STOP push-button depressed for terminating sequences.
11. OVERRIDE push-button held down for overriding logic errors which would otherwise interrupt recording.
12. FIRST FILE switch depressed for recording first file on magnetic tape.
13. TAPE MARK switch depressed for mark end of recorded data on tape.
14. EDIT switch depressed when overriding data already recorded on tape.
15. TRIP switch depressed for observation of pre-shot noise on oscilloscope (or oscillograph).

16. Five position RECORD switch selects DIRCH (direct channel) for recording a single channel input (applied at the A/D Converter) across all channels; CAL used during calibration file recording (length of record selected on internal panel); DATA used during Field recording at which time field time break is enabled; ONES used when recording a 'one' in bits 0 to 7 of all data block bytes; ALT (alternate) ones used to record 'ones' and 'zeros' alternately in bits 0 to 7.
17. Five position SEARCH switch selects LDPT when searching back to the beginning of tape (BOT) silver marker; BKSP (backspace) for searching back to the start of the previous file; REV (reverse) for searching in reverse for a particular file; FWD (forward) for searching forward for a particular file; EOD (end of data) for searching forward to end of data written on tape.
18. Three position TEST switch selects GAIN CAL when calibrating amplifier gain and test oscillator output; ZERO when adjusting amplifier and A/D converter offsets; TAPE BYPASS when test recording data without writing on tape.
19. GAIN MODE toggle switch selects MANUAL when recording in fixed gain, and IFP when recording in amplifier floating point mode.
20. MANUAL rotary switch selects a fixed gain level in 12 steps from 0 to 84dB.

21. BIT SLIDE rotary switch selects digital gain in 12dB steps from 0 to 72dB applied to playback signals.
22. Twelve 10-position push-button switches for setting constant information data to be written on the tape header (e.g. date, crew number, tape number).
23. FILE switches containing three 10-position push-button switches for selecting files to be located during search operations.
24. FILE COUNT push-button switches for advancing the file count or resetting the count to zero.
25. ERROR RESET switch resets (cancels) the overdrive count indicator lights (ODC) or parity error indicator lights (PEC).
26. Five position DISPLAY switch allows selection of LABEL for display of the first two header bytes; GAIN displays fixed gain for the particular word selected on the WORD switches; DATA displays sign, magnitude and gain bits for all channels; SEL displays sign, magnitude and gain bits for a particular channel selected on the WORD switch and PET which displays bytes containing parity errors.
27. WORD switches select desired header byte or channel required for DISPLAY switch setting.

The data display indicator lamp panel allows the display of gain, data bits, recording operation, overdrive, parity, fault condition, tape status, time break condition and synchronisation error status. This display is useful when monitoring normal recording, or during trouble shooting of the equipment.

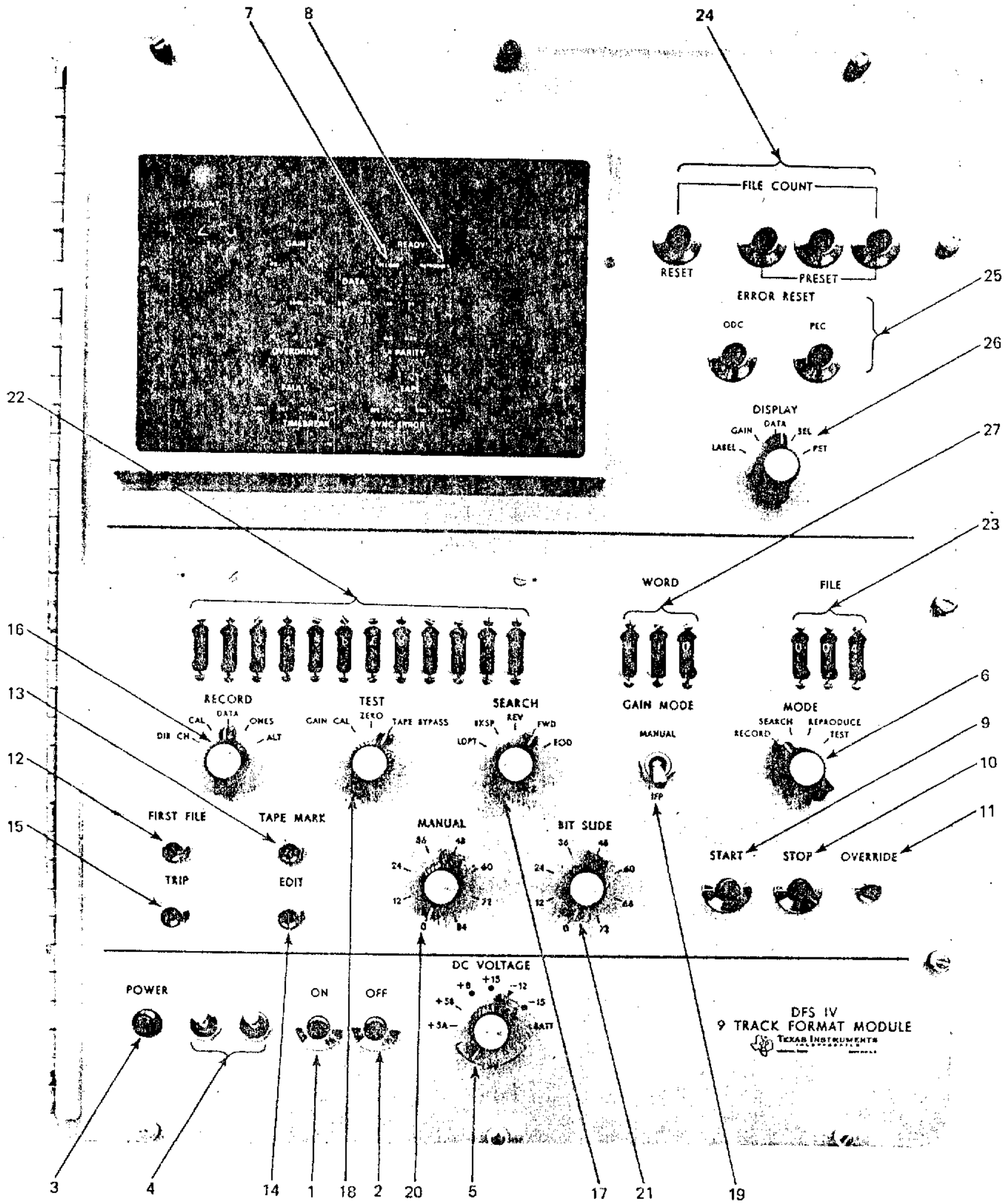


Plate 2.4 FORMAT MODULE FRONT PANEL CONTROLS (Courtesy Texas Instruments)

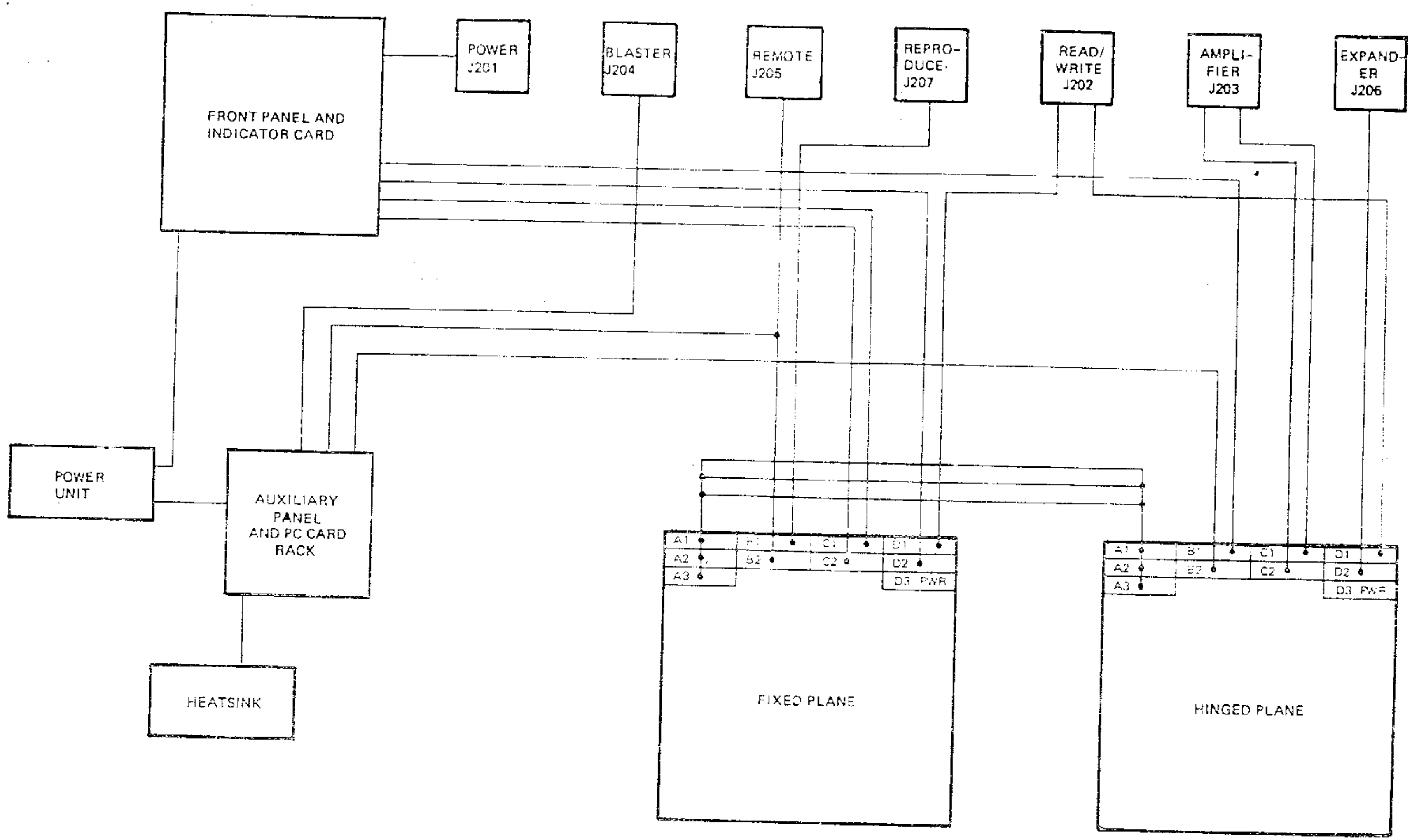
Internally, the Format Module consists of extremely complex circuitry which is the computation centre for the total recording system. General Format Module specifications are shown in the Appendix, with tape speed/sample interval on Table 2.2.

An auxiliary panel allows selection of record length in Data or Cal modes, field time break sensitivity, overdrive display, channel display, filter application, dc converter offset display, sample rate/tape speed and the application of power supplies.

Relay and power cards are included in the module, but the main functions are performed on two instrument chassis known as the hinged and fixed planes. These planes contain in excess of 500 integrated circuits - the final number being dependent upon the system configuration desired. The planes also contain "jolo" chips, which are jumper connectors allowing options of tape format, channel number, local and peripheral timing delays. Format module interconnections are shown on Figure 2.44, and the typical complexities of record data flow are shown on Figure 2.45.

2.4.1 <u>System Control</u>

The Format Module provides synchronization of the other system modules and peripheral equipment. It initiates and controls all events including the tape transport operation and the position of record on tape, see Figure 2.46.



Format Module Interconnections

FIGURE 2.44

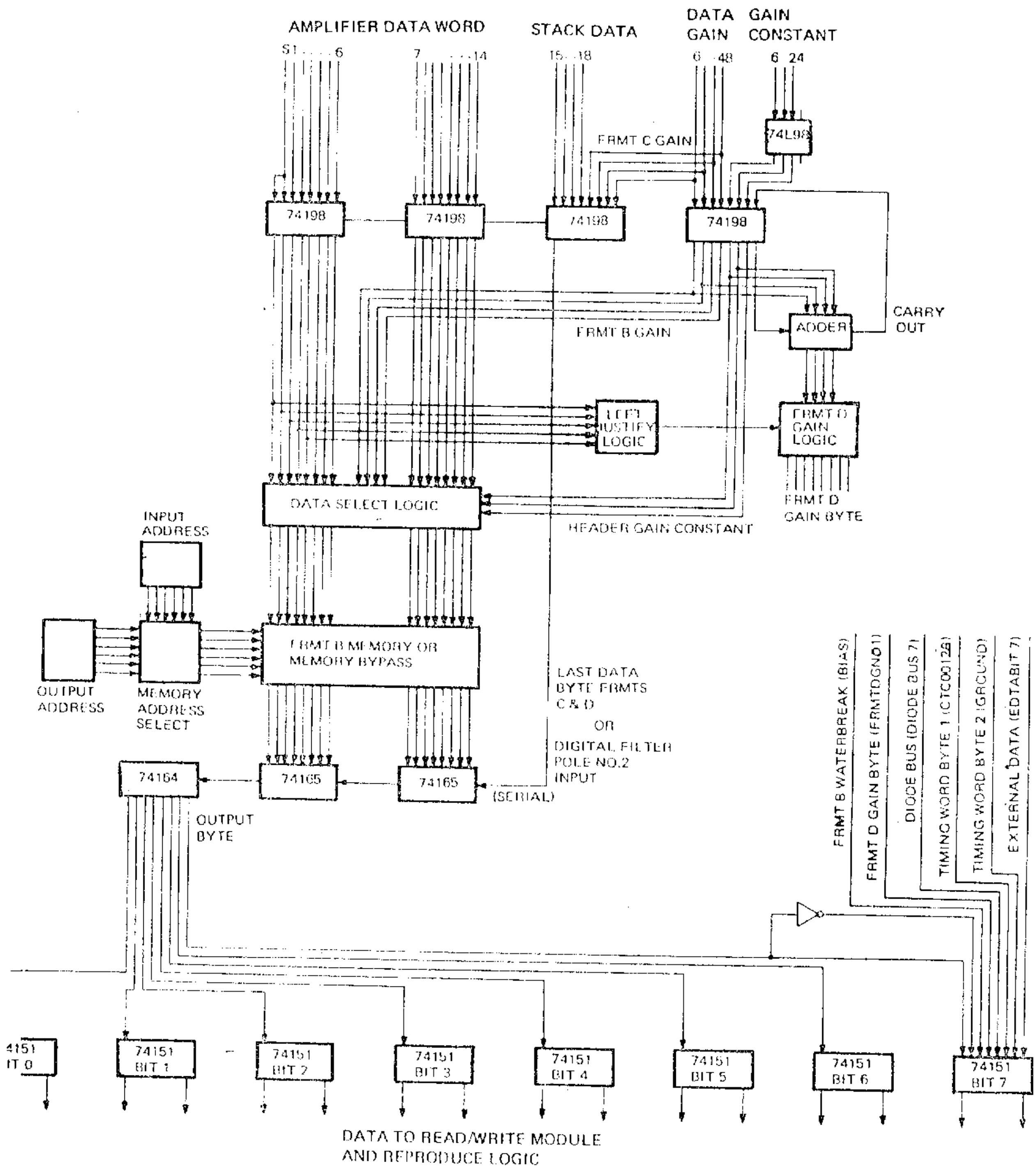


Figure 2.45 RECORD DATA FLOW

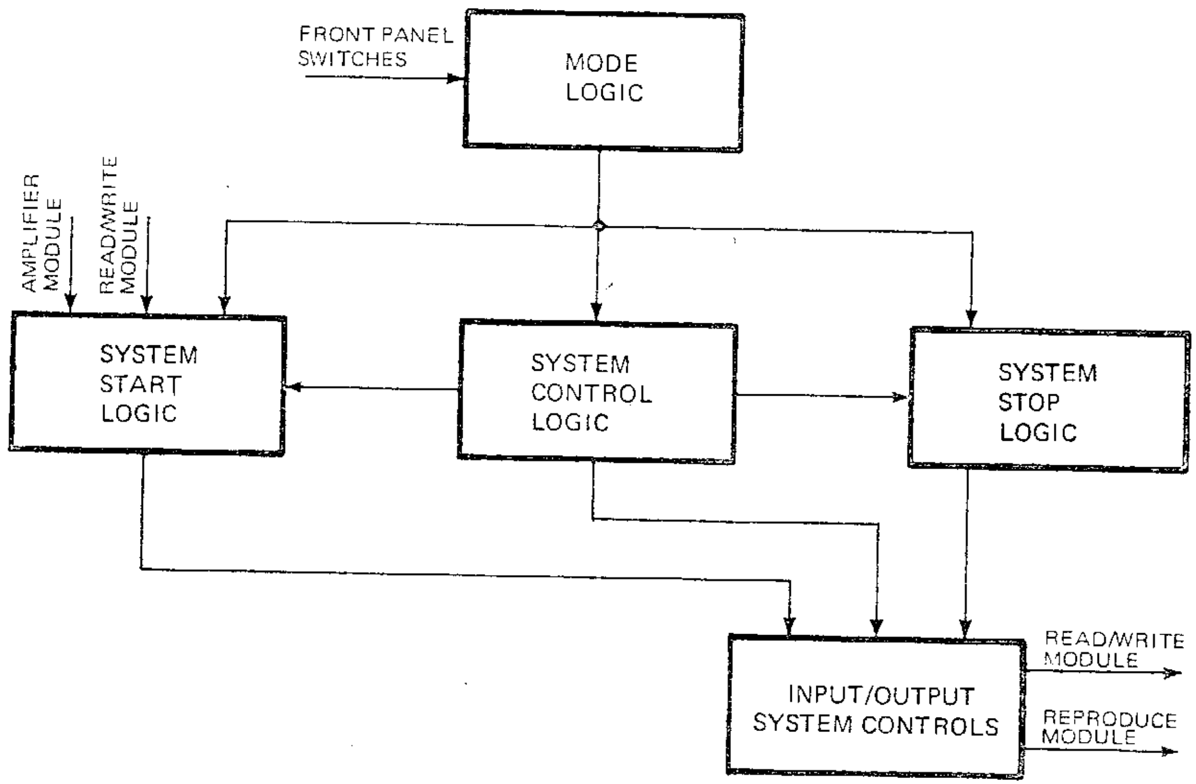


Figure 2.46 SYSTEM CONTROL BLOCK DIAGRAM

TABLE 2.2

TAPE SPEED AND SAMPLE INTERVAL REQUIREMENTS

Format	Channels	Tape Speeds (IPS) At Sample Intervals of			
		1 ms	2 ms	4 ms	8 ms
Format B 1600 BPI	24	46.25	23.12	11.56	
	36	-	32.5	16.25	
	48	-	41.88	20.94	10.47
Format C 1600 BPI	28	56.25	28.12	14.06	-
	58	-	56.25	28.12	14.06
	118	-	-	56.25	28.12
Format D 1600 BPI	30	80	40	20	-
	62	-	80	40	20
	126	-	-	80	40

*For Format B the number of channels indicated is the number of seismic channels: five auxiliary channels are also recorded, one of which is a timing counter. For Formats C and D, the number of channels is the total number of seismic and auxiliary channels. The DFS IV system is limited to a maximum of 8 analog auxiliary channels. Any words remaining in a tape data scan after all seismic and available analog auxiliary channels have been recorded will be zero-filled. The timing counter is recorded as part of the two-word start-of-scan group for Formats C and D and is not included in the channel count.

Format logic enables or inhibits system operations as a function of the data read from tape, Amplifier Module controls, and Format Module front panel controls.

The control logic is in two parts:

a) System control logic, most of which is located on the fixed plane.

b) Data sequence logic, most of which is located on the hinged plane.

Logic level commands are given abbreviated terminology, such that electronic trouble shooting may be simplified. Typically, prior to commencing recording, record and system start equations must be satisfied. The various logic command levels are shown on Figure 2.47, all of which must be set correctly to enable commencement of recording start. This is an example of one such logic command requirement which is given here as a typical illustration of the complexities of Format logic status at any instant in time.

2.4.2 System Timing

Basic system timing derives from a crystal-oscillator on the hinged plane of the format module. The oscillator signal is divided down in frequency to determine the Amplifier Module data rate and Read/Write Module byte rate. A timing counter operating in 1 millisecond increments is derived from the Amplifier data rate, and

```
Record Ready   = DTATAPE * · ILLEGALRATE * · MODESWREC ·
                 ALLIASERR * · (EDITPRTCTOP · EDIT +
                 TAPEMARK * · EOT + ITBFF · ITBOVRDOPT * +
                 FILTERMIX · FILTMOVRDOP *)* · (OVRRD +
                 (TAPELOW + GCSFAULT + CONTFAULT +
                 MANGN + RECLEN00 + RECDTA * +
                 BITSLIDE00 *)*) · TAPEOFF + BOT)*
```

DTATAPE	=	Over previously recorded data
ILLEGALRATE	=	Sample Rate Error
MODESWREC	=	Mode Switch in Record
ALLIASERR	=	Cutoff filter error
EDITPRTCTOP	=	Edit enabled option
EDIT	=	Edit switch
TAPEMARK	=	Tapemark switch
EOT	=	End of Tape
ITBFF	=	Internal Timebreak Flip-Flop
ITBOVRDOPT	=	Internal Timebreak Override Option
FILTERMIX	=	Input Modules Filters Different
FILTMOVRDOP	=	Filtermix Override Option
OVRRD	=	Override switch
TAPELOW	=	Tape Low Signal
GCSFAULT	=	Gain Constant Fault
CONTFAULT	=	Contact Fault
MANGN	=	Manual Gain Mode
RECLEN00	=	Manual Record Length
RECDTA	=	Record Data Switch Position
BITSLIDE00	=	Bit Slide Off
TAPEOFF	=	Transport Off
BOT	=	Beginning of Tape

Record Ready Equation

```
Reproduce Ready   = (TAPEOFF + BOT) * · (MANGN + OVRRD) ·
                    REPRODUCE
```

Reproduce Ready Equation

```
System Start = STARTLATCH·(STRTSW+FINAL STOP*)+STRTSW·
               (TSTTPBYPS+SRCHRDY+REPRDY+RECRDY)
```

STRTSW	=	START switch
TSTTPBYPS	=	Test-Tape Bypass Mode
SRCHRDY	=	Search Ready
REPRDY	=	Reproduce Ready
RECRDY	=	Record Ready

System Start Equation

Figure 2.47 "SYSTEM EQUATIONS"

is used for determining record length, control delays and timing word recorded on each data scan on tape. A tape word period is two bytes in SEG Format B, three bytes in Format C and four bytes in Format D. Byte time period is subdivided into 16 intervals called write timing counter periods.

In Format B, 24 channel timing records the following during a single scan:

a) 4 start-of-scan bytes

b) 2 timing word bytes

c) 8 auxiliary channel bytes

d) 48 channel bytes

e) $\frac{24}{2}$ = 12 gain word bytes

A total of 74 bytes are recorded during each scan, and the Amplifier module sends to the Format Module:

a) 4 start-of-scan words

b) 4 auxiliary channels

c) 24 data channels

Thus, 32 channels are addressed during each scan. Table 2.3 lists the number of bytes and amplifier words in each scan. Only one start-of-scan word is required during each scan by the Amplifier Module; however, additional start of scans are addressed to make the number of amplifier words addressed per scan to be a convenient ratio to number of bytes per scan, thereby simplifying timing division. Only Format B timing is referred to here, since the system is configured for that Format recording.

2.4.3 Controlling Sequences

The 1 KHz timing signal derived from the amplifier word rate drives a 15-bit binary counter. This Control Timing Counter (CTC) is one of the most important segments of the logic circuitry, since its output is used to measure realtime events (e.g. radio blast delay, camera start delay) and record length. Figure 2.48 is a block diagram of the CTC.

Tape speed changes as a function of sample rate. Some tape position delays are measured by counting bytes instead of milliseconds, and the CTC is used to measure these delays also.

Such timing of record, playback and reproduce data timing is critical. As an example, start of scan is initiated at timebreak, when the Format Module resets to send the first address of the scan to the Amplifier Module. Data transfer to the Read/Write Module must be delayed to allow data for the addressed channel to be valid at the input to the Format Module. First start of scan code transfers to the Read/Write Module early enough to put the first data channel information in the scan. Due to the Format Module memory storing 12 seismic channels of information before the first channel is read

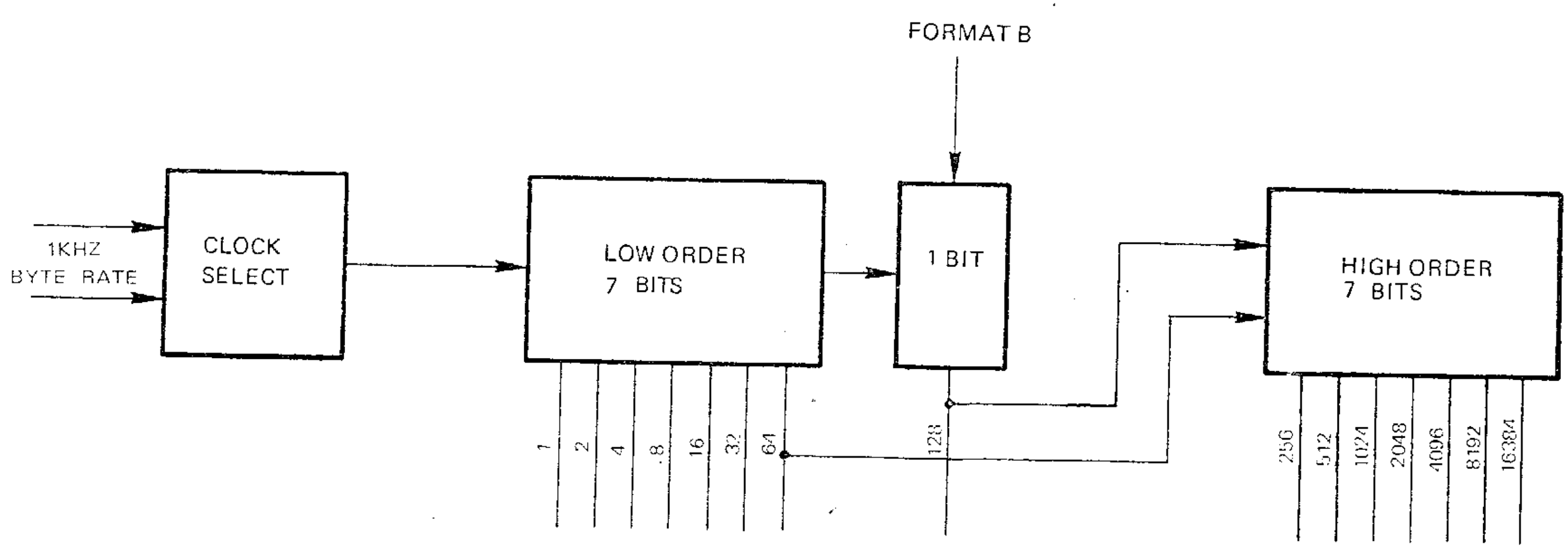


Figure 2.48 CONTROL TIMING COUNTER BLOCK DIAGRAM

from memory, the data transfer to Read/Write must be delayed by this time period also. Such is the complexity of timing for data transfer, that this work will not dwell upon the matter any further other than providing some indication of how important timing synchronization is, not only to sampling data, but also to encoding command and sequence timing.

Flow chart diagrams of record, reproduce and search sequences are shown in Figures 2.49 to 2.52. At power-up or after completion of any operation mode, the Format Module is considered to be in the Idle Mode. In idle, Amplifier Module data is read and processed through the Reproduce Module. If the START switch is depressed, First Start sequence is initiated. The tape transport rewinds until end-of-file code is detected. If any read clocks were set prior to end-of-file detection, the data protection circuitry assumes the tape is not positioned at End of Data and resets to the idle state. If no read clocks were read, sequence start control is set.

After pre-programmed delays (Radio Blast, Camera and Second Start) are executed, the tape transport is directed to wind tape at the correct speed for recording. When End of File of the last data record is detected, write power is applied. After writing the inter-record gap, the Header record is written followed by a second

TABLE 2.3

FORMAT B DATA CHANNELS AND BYTES PER SCAN

Format	Number of Channels					Number of Bytes				
	Start Of Scan	Auxiliary	Seismic	Total Per Scan	Start Of Scan	Timing Word	Auxiliary Date	Seismic Data	Seismic Gain	Total Per Scan
24 Channel B	4	4	24	32	4	2	8	48	12	74
36 Channel B	12	4	36	52	4	2	8	72	18	104
48 Channel	12	4	48	64	4	2	8	96	24	134

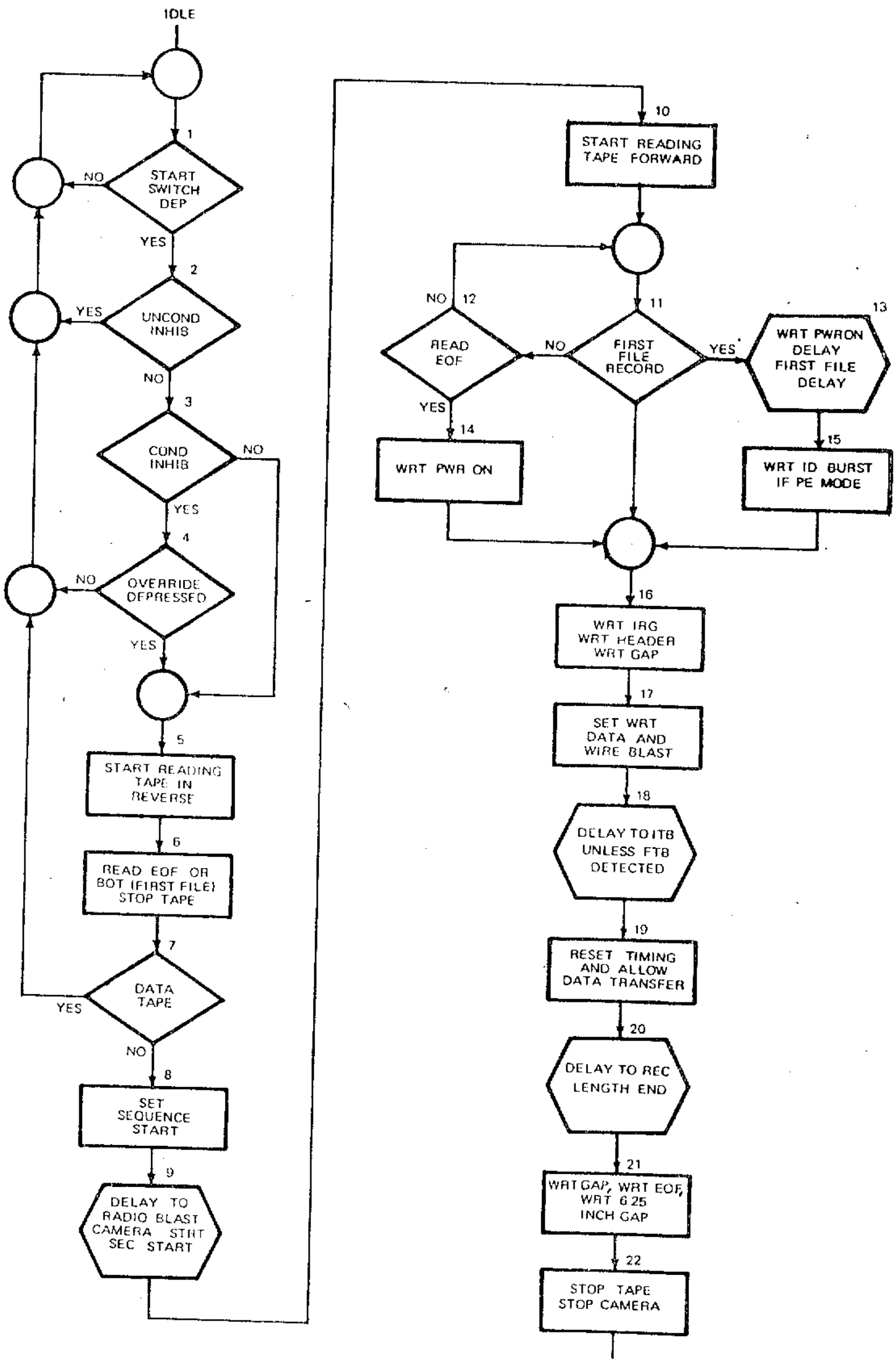


Figure 2.49 RECORD SEQUENCE

GAP. Write Data is set and Zero data is recorded until time break is received.

On time break reception, data transfer to the Read/Write Module commences and the CTC reset. When this indicates that the correct record length has elapsed, data transfer is stopped on completion of the scan. An inter-record gap is written and an end-of-file (EOF) recorded. After this, a 6.25 inch long EOF gap is erased before the tape is stopped.

In Reproduce Figure 2.50, when START commences, the Format Module initiates the reproduce procedure. Firstly, the tape transport rewinds. If the tape head is at end-of-data, the tape is rewound until two end-of-files have been read. Otherwise, first EOF stops the tape and sets sequence start. After camera start delay, tape is started forward. After EOF is read, header is read and data transfer starts at data start. When EOF is read, data transfer to the Reproduce Module is stopped and the data tape is reset if no data is read from the tape after EOF.

In Search Forward of End of Data Figure 2.51, after START, the tape moves in reverse until EOF is detected. After EOF is read, the tape moves forward until file match occurs in Search Forward, or until EOF latch remains set such that End of Data (EOD) is detected.

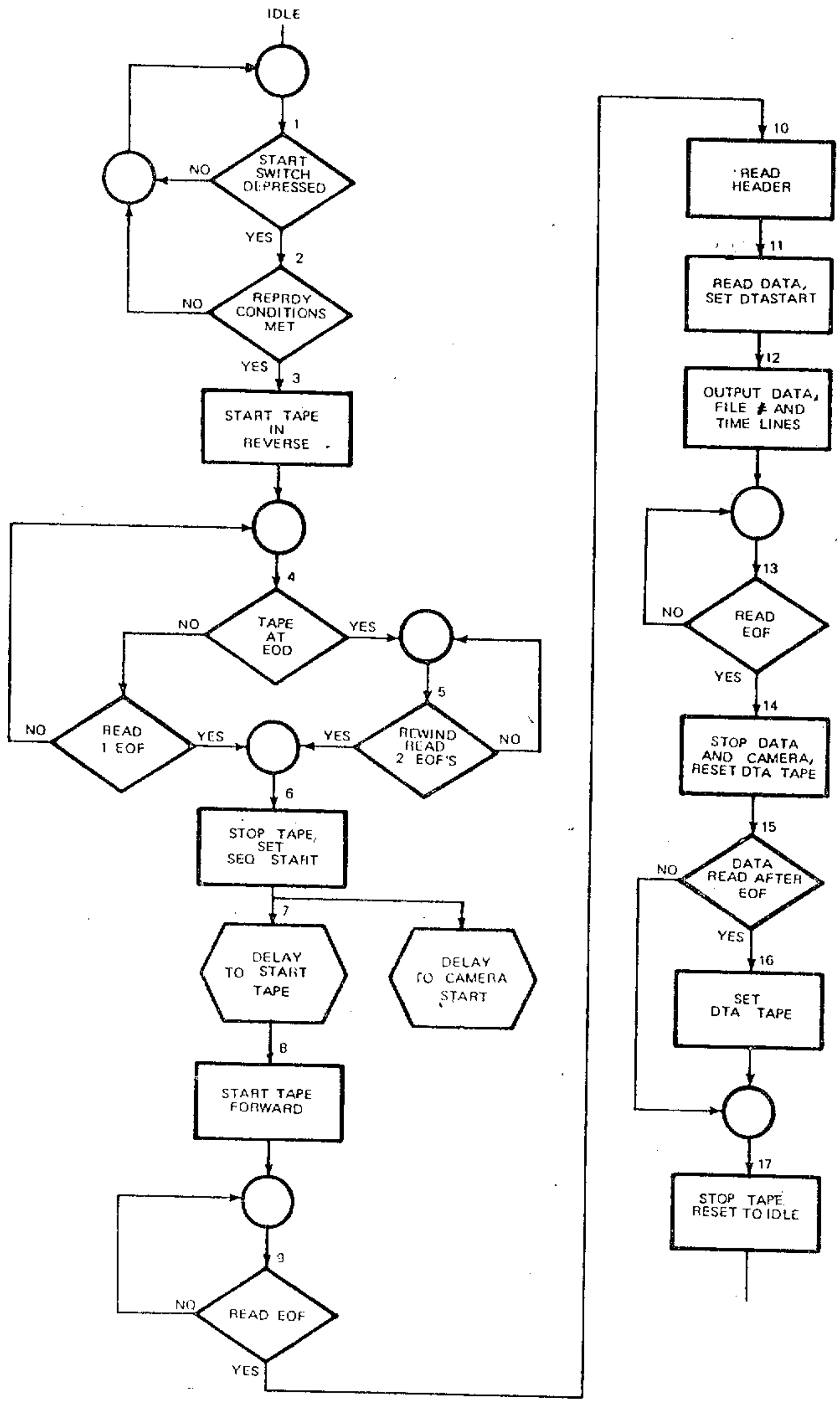


Figure 2.50 REPRODUCE SEQUENCE

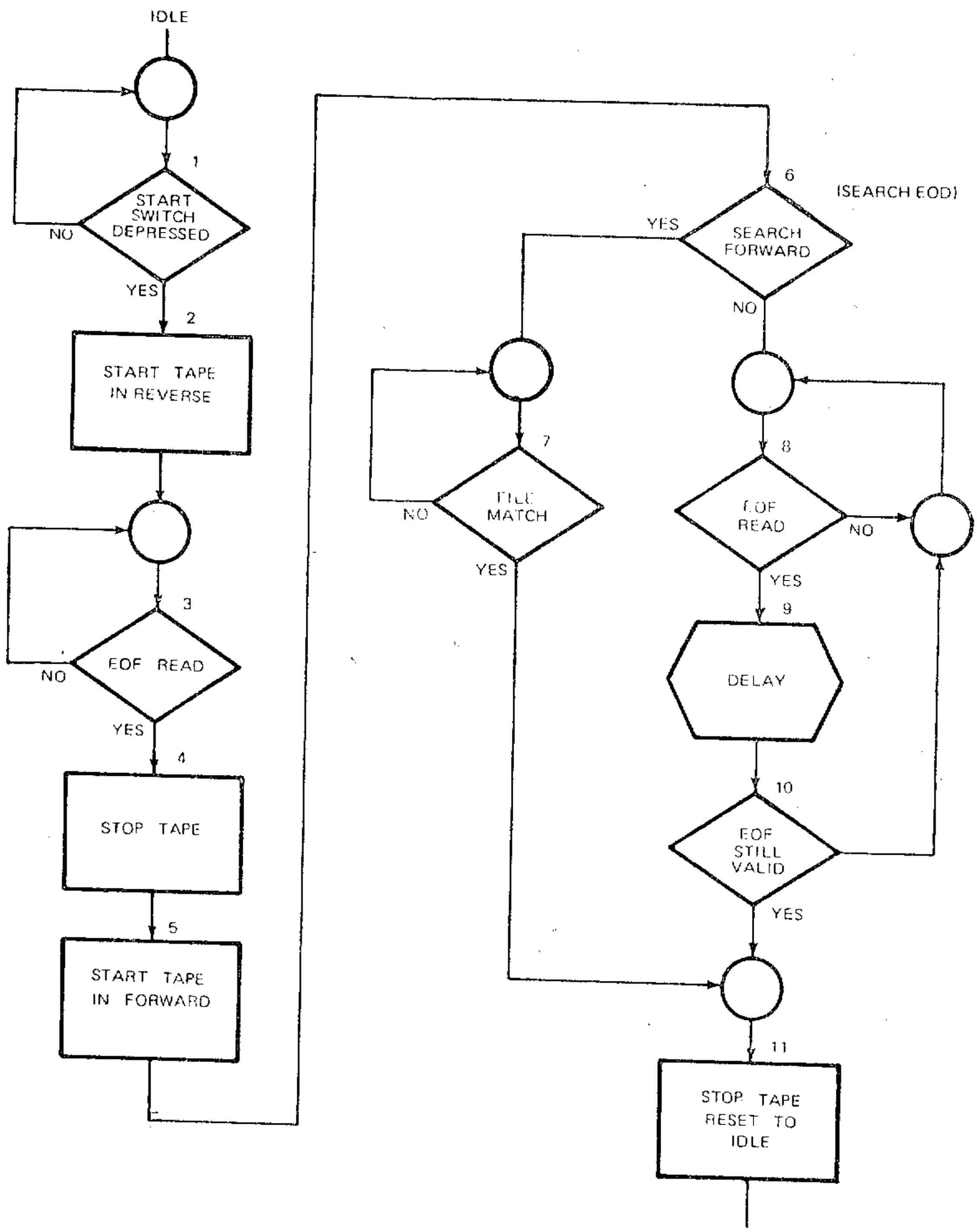


Figure 2.51 SEARCH FORWARD OR END OF DATA SEQUENCE

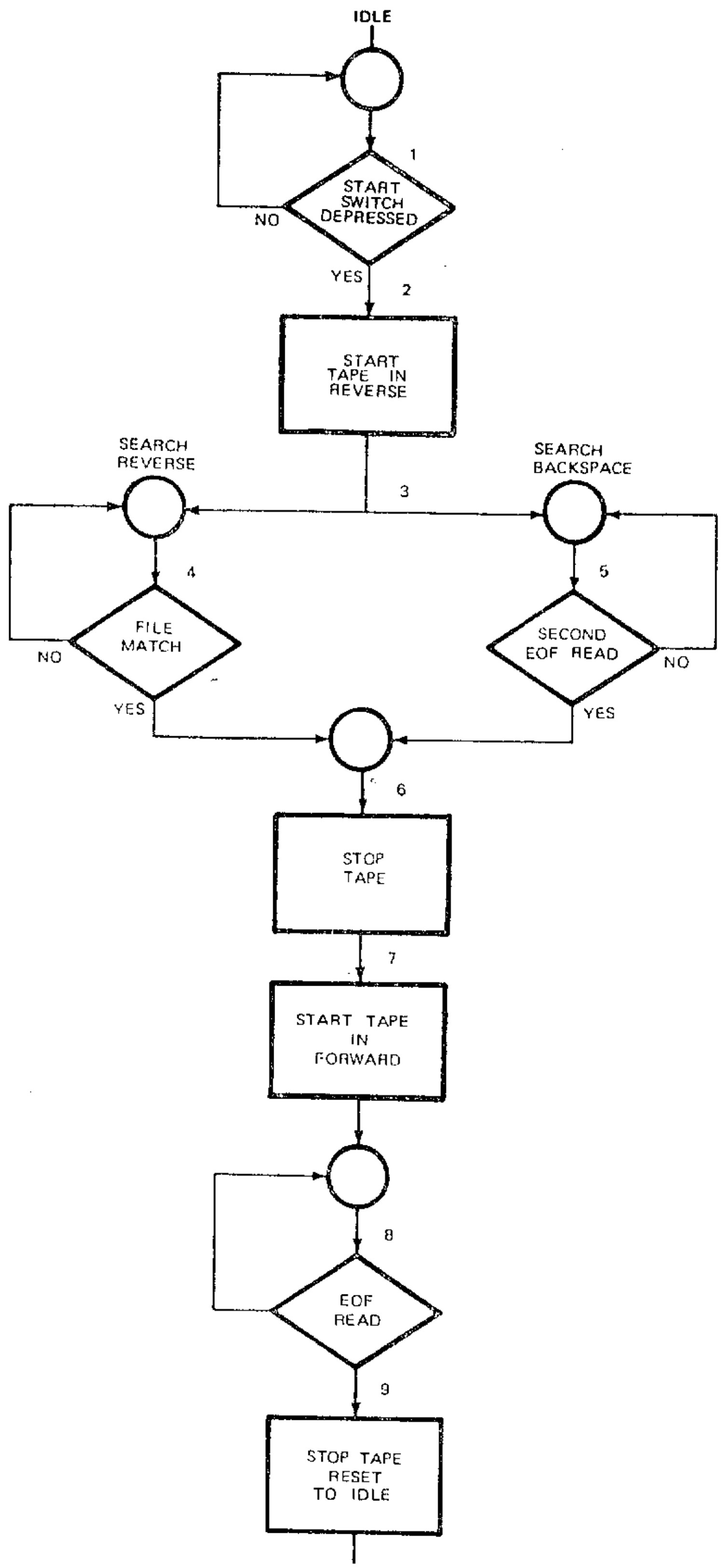


Figure 2.52 SEARCH REVERSE OR BACKSPACE SEQUENCE

In Search Reverse or Backspace Figure 2.52, the tape starts in reverse until a file match or two EOF's are read. Tape direction then reverses to search forward until EOF is read to put the tape over the record that was searched.

Record and playback timing, data display, power and mode control will not be discussed herein and, if a treatise is required, the manufacturer's manual on the 'Format Module' is the requisite material.

2.5 Reproduce Module

The purpose of this module is to convert digital input information into an analog signal suitable for hard copy display on an oscillograph or oscilloscope. Thus, the basic function is digital-to-analog conversion.

Figures 2.53 and 2.54 show the modules operation in simplified form. Time multiplexed data and gain information enters the Digital Gain Control block. Digital Channel address data enters the Address Decoding block where it is decoded and routed to the Gain Control and Demultiplex blocks. D/A conversion produces an analog signal, which is demultiplexed by sample and hold circuits, the output being passed through filters to remove sampling (multiplexing) frequency and other undesired frequency components. The output passes through an Interface circuit which removes any dc present and attenuates the signal to a level suitable for display on hard copy.

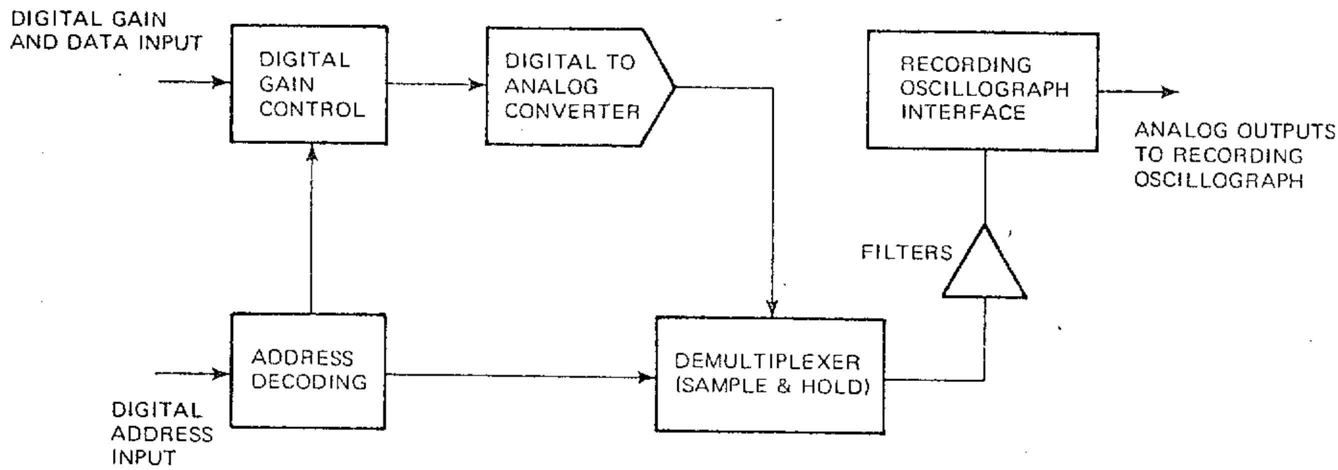


Figure 2.53 REPRODUCE MODULE SIMPLIFIED FUNCTIONAL BLOCK DIAGRAM

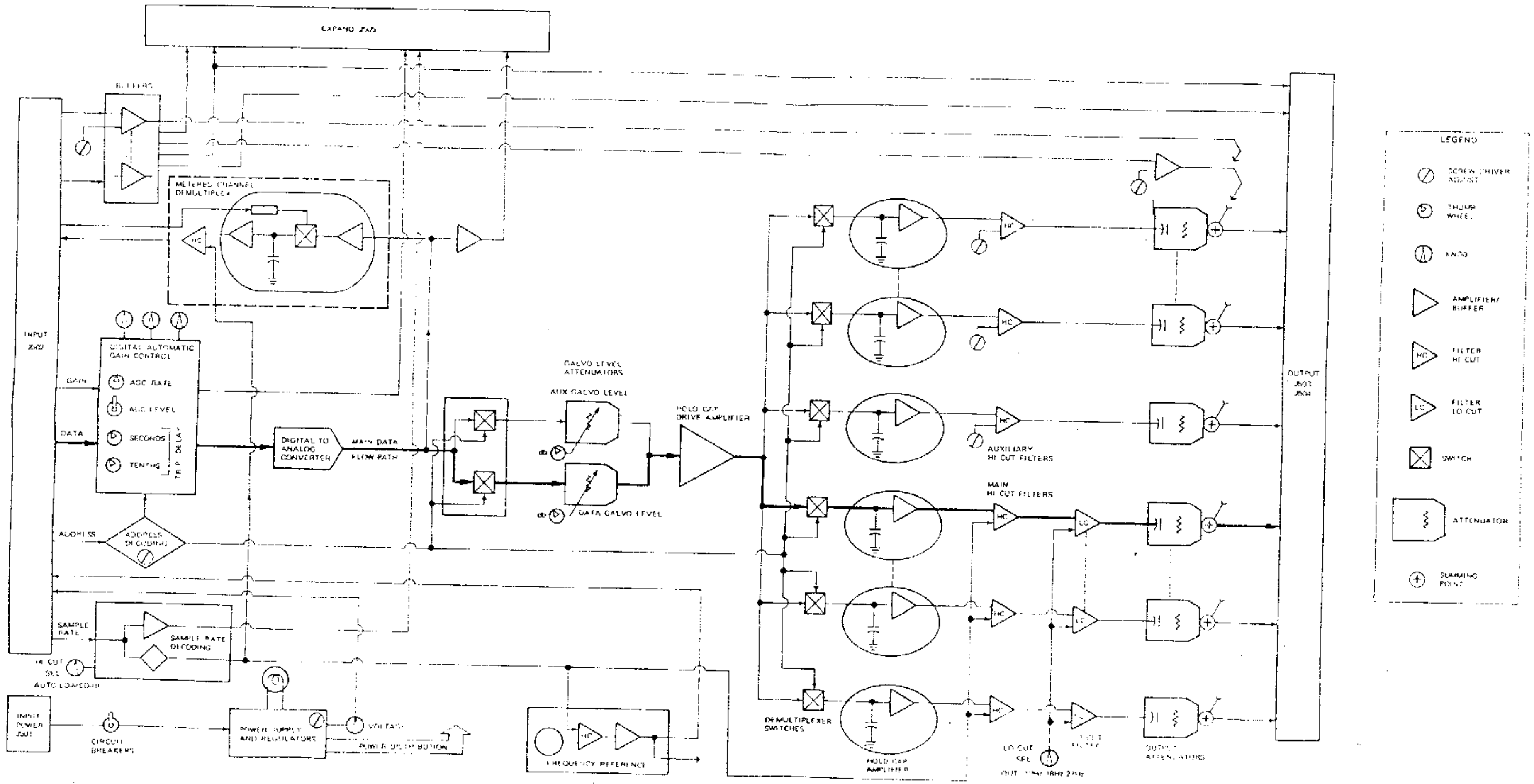


Figure 2.54 REPRODUCE MODULE BLOCK DIAGRAM

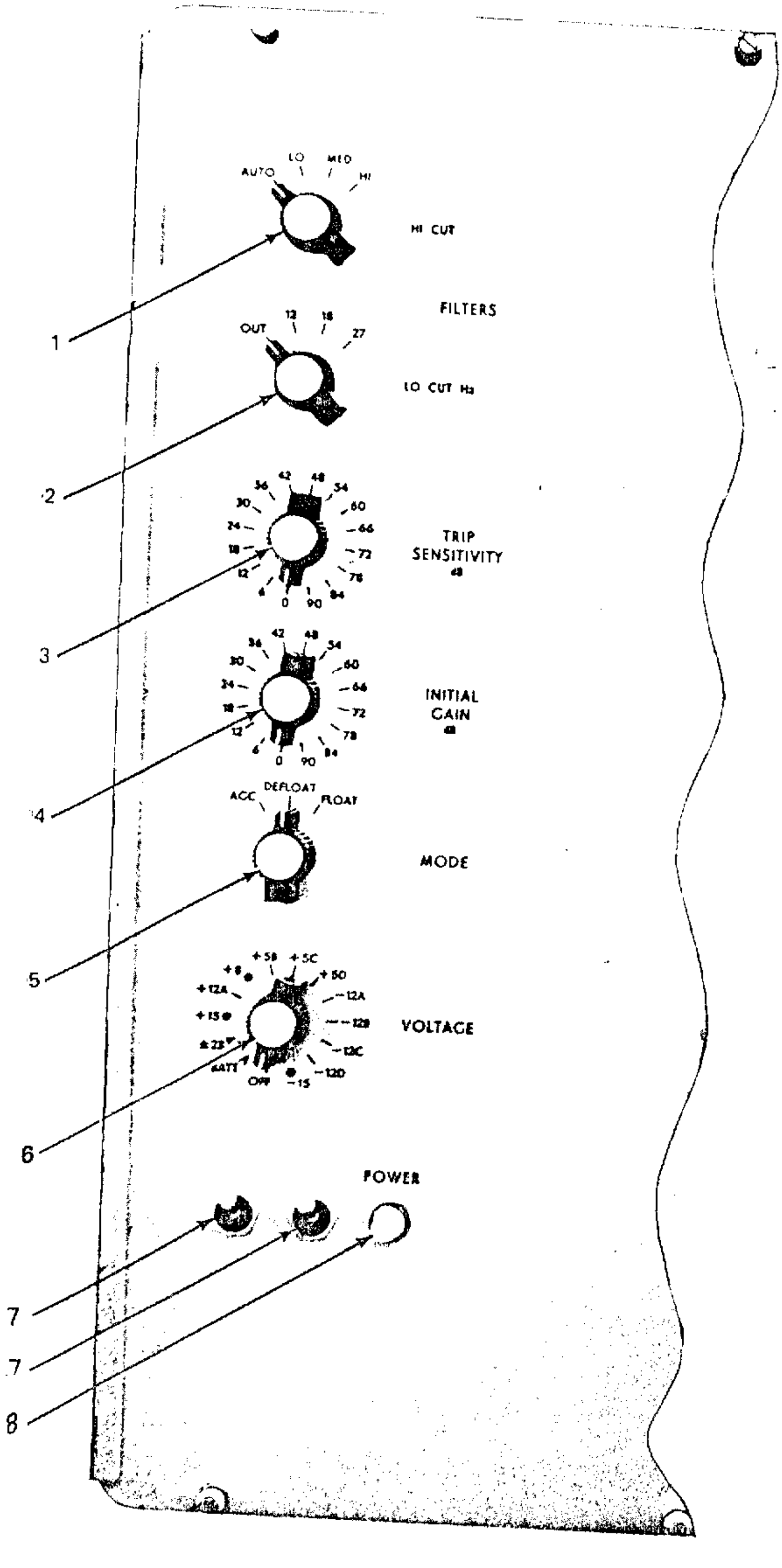


Plate 2.5 REPRODUCE MODULE FRONT PANEL CONTROLS

(Courtesy Texas Instruments)

Plate 2.5 shows the front panel controls, with the following indications:-

1. Hi-CUT filters may be used in Auto where the hi-cut filter is controlled by the sample rate; in Lo with a 45 Hz cut-off; MED with a 64Hz cut-off; HI with a 90Hz cut-off.
2. Lo-CUT filters have an OUT setting when Low-cut filters are bypassed; 12Hz, 18Hz, 27Hz cut-offs.
3. 16 position TRIP SENSITIVITY Switch which functions only in AGC mode of playback. This sets an initial reference level which allows start of digital AGC operations when the input signal rises above that point.
4. 16 position INITIAL GAIN Switch in AGC or PGC. In AGC, it fixes the AGC gain level until tirp occurs and gain control commences thereafter. With MODE Switch in DEFLOAT, the switch functions in fixed gain and in FLOAT it has no function.
5. The MODE Switch functions if digital recording gain control is used. In AGC, gain and data input are combined and the dynamic range is reduced to the narrow dynamic range of the osillograph. In DEFLOAT, combines gain and data input signals shifting the output by the INITIAL GAIN setting. In FLOAT, the gain control outputs only floating point data with no gain data.
6. 14 position DC VOLTAGE Switch used for dc voltage checks.
7. Power circuit breakers.
8. Power-on indicator lamp.

The Reproduce Module has the following specifications:-

a. 37 watt power at 12 Vdc for 48 channel operation.

b. Up to 60 channels and 8 auxiliarys may be accommodated.

c. 11 bits (10 data plus sign) are converted (i.e. dynamic range of 2^{10} = 60 dB).

Plate 2.6 shows the internal printed circuit board adjustment locations, and for further information on these, the manufacturers manual (page 3-7) should be consulted.

The four basic module inputs are:-

1. Address information.
2. Gain information.
3. Data information.
4. Clock signals.

Address information provides the channel location for Gain and Data information. A timing signal enables separation of multiplexed inputs, indicates when new Gain, Data and Address information at present at the input, and is used to transfer these into the module.

Gain and Data information represent signal amplitude. If a signal has a binary number S, gain and Data are binary numbers G and D, then:

$$S = D \times 2^G$$

The Reproduce Module outputs are multiple-parallel analog channels, representing the digital Gain and Data inputs. In AGC, the output is a relative level since signal decay

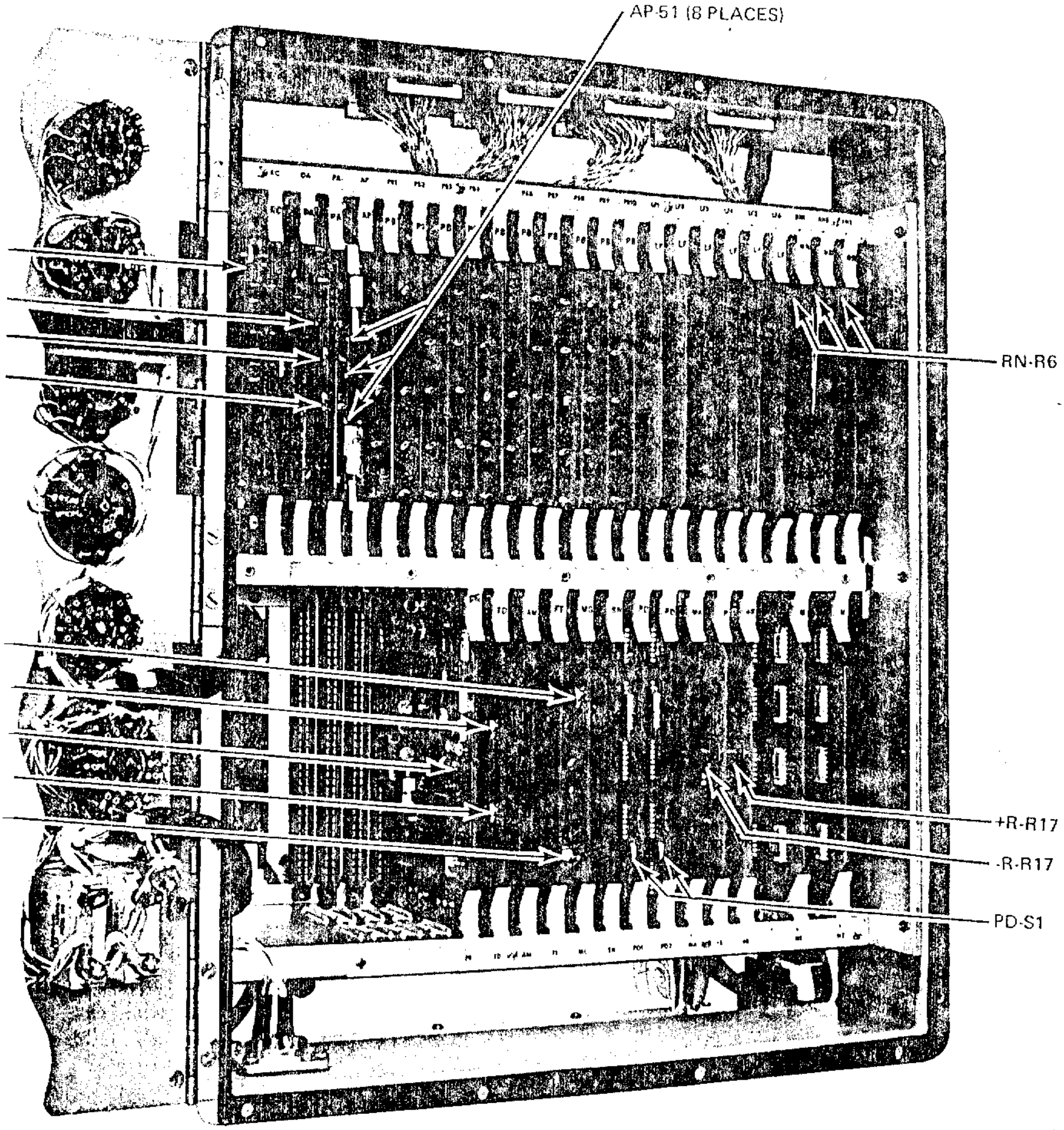


Plate 2.6 REPRODUCE MODULE CARD CONTROLS

(Courtesy Texas Instruments)

is compensated for by gain control. In DEFLOAT, Reproduce Module outputs are the original channel signal S, but with a reduced dynamic range of 60dB. In FLOAT, Data input is represented with no gain.

2.5.1 Gain Control - AGC

In a floating point system, deformatted data consists of a mantissa and the gain exponent. The mantissa alone cannot be used for a hard-paper representation and some form of gain recovery is necessary to bring all of the samples of the seismic signal back to the same scale, to the same gain, before assembling them in a continuous trace. This 'gain recovery' is accomplished through a series of shifts in a register where the 14 bit mantissa provides a maximum value of 14 bits of gain. After gain recovery, data values vary over 80dB or more for any seismic signal trace, which is excessive for the 60 bit camera display. Indeed, some cameras are limited to a 20 bit display only.

Automatic Gain Control (AGC) is applied to the sample sequences represented in digital form. The playback gain control requires an observation of data over a period of time, and thus again memory is associated with each channel. AGC action simply applied gain where the signal is weak, and reduces gain where the signal is strong, such that the eventual played back signal window to ensure it will be displayed in a form which is easily observed on a paper monitor record.

AGC compresses input data by multiplying the data in two parts (Figure 2.55):-

a) A number which equals 2 - (Shift Word + Gain)

b) A multiplicand between 1.0 and 2.0

The multiplicand generator monitors the output of the AGC: it then decides on the basis of previous scans whether or not the output is within specified limits. If the output is high, the multiplier is reduced by modifying the multiplicand and a shift word if necessary. If the output is low, the multiplier is increased so that there is a feedback loop which always keep the AGC output within a set window. All channels are addressed independently of each other.

During multiplication, the gain steps of IFP are removed placing each channel data in true amplitude form (Data 2 Gain), and it compresses the dynamic range for oscillograph use.

Data is stored in a shift register which applies the shifted data to a multiplier. If this output exceeds a limit, the Multiplicand decreases in value and vice versa when a lower limit is attained for at least a half cycle. Upper and lower limit set points are set at S2 on the MG card. The shift Number can be changed by changing the Shift Word i.e. if the Multiplicand reaches 2.0 (upper limit), 1.0 is subtracted from the Shift Number Adder, and the Multiplicand returns to 1.0.

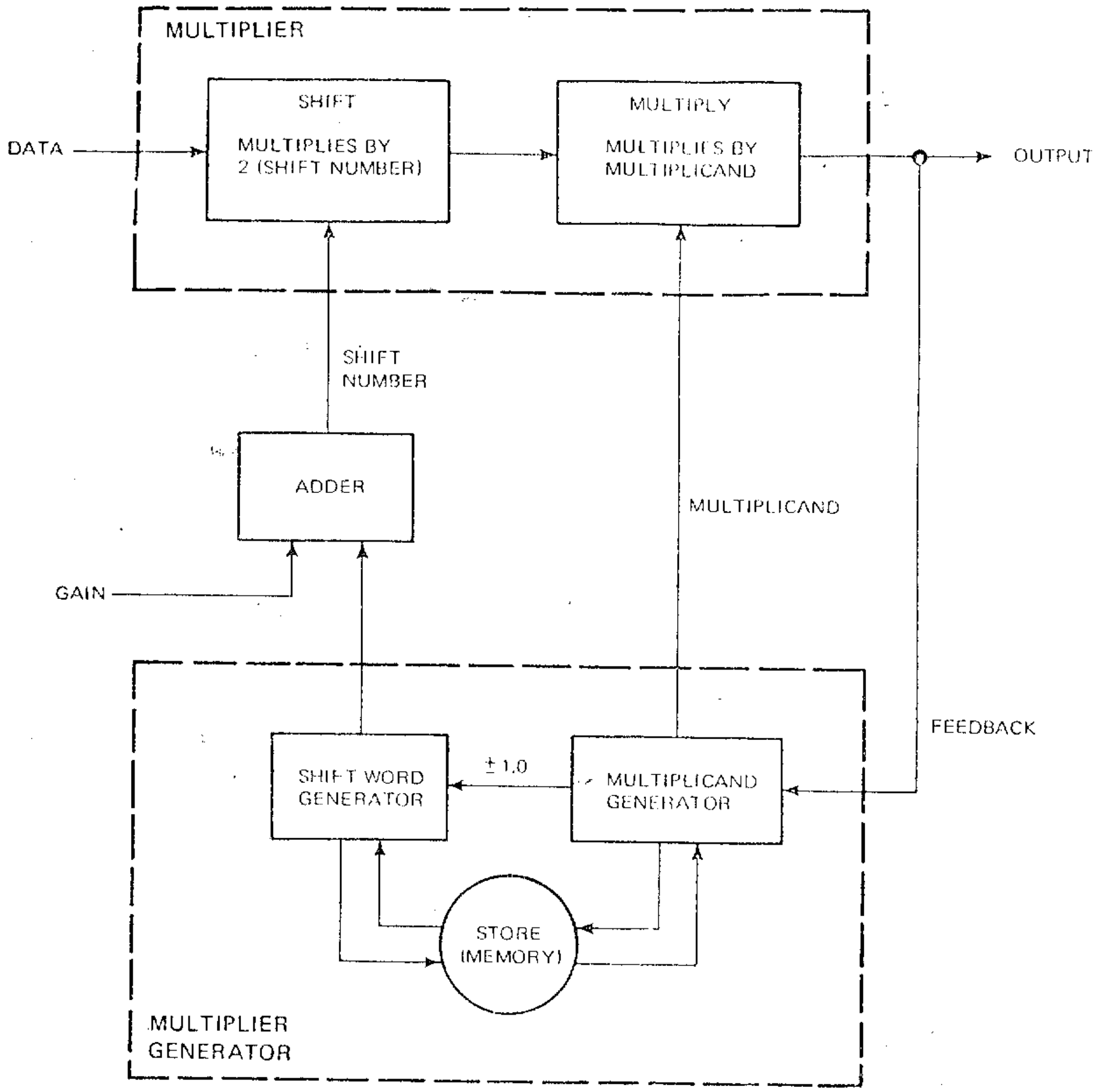


Figure 2.55 DIGITAL AGC/GAGC SIMPLIFIED BLOCK DIAGRAM

The Gain is applied to the Shift Number Adder card where it is added to the Shift Word which can be a positive or negative number.

Shift Number setting is dependent upon the Initial Gain setting. The range compression is inhibited until AGC is tripped. Trip occurs most often as a result of the seismic signal exceeding the set limit. The TRIP SENSITIVITY is the complement of the amplifier gain which, if greater than the TRIP SENSITIVITY, will not trip the AGC action. When the gain is less or equal to it, trip occurs and the Multiplicand and Shift Word change as a function of the AGC output.

Programmed Gain Control (PGC) is an alternative playback option which is different from AGC. The number which multiplies the combined data and gain is "programmed" and does not depend on signal levels. However it uses the same hardware (see Figure 2.56). After Trip, the product Multiplicand x 2 Shift Word is pre-programmed to increase gain at a selected dB/second rate until final gain is reached, at which point further increase of multiplicand and shift word is inhibited.

2.5.2 Digital to Analog Converter

The digital word representing the channel signal to be converted is fed into a buffer register. The register operates a series of switches, which connect reference voltages to a summing junction. Junction currents are

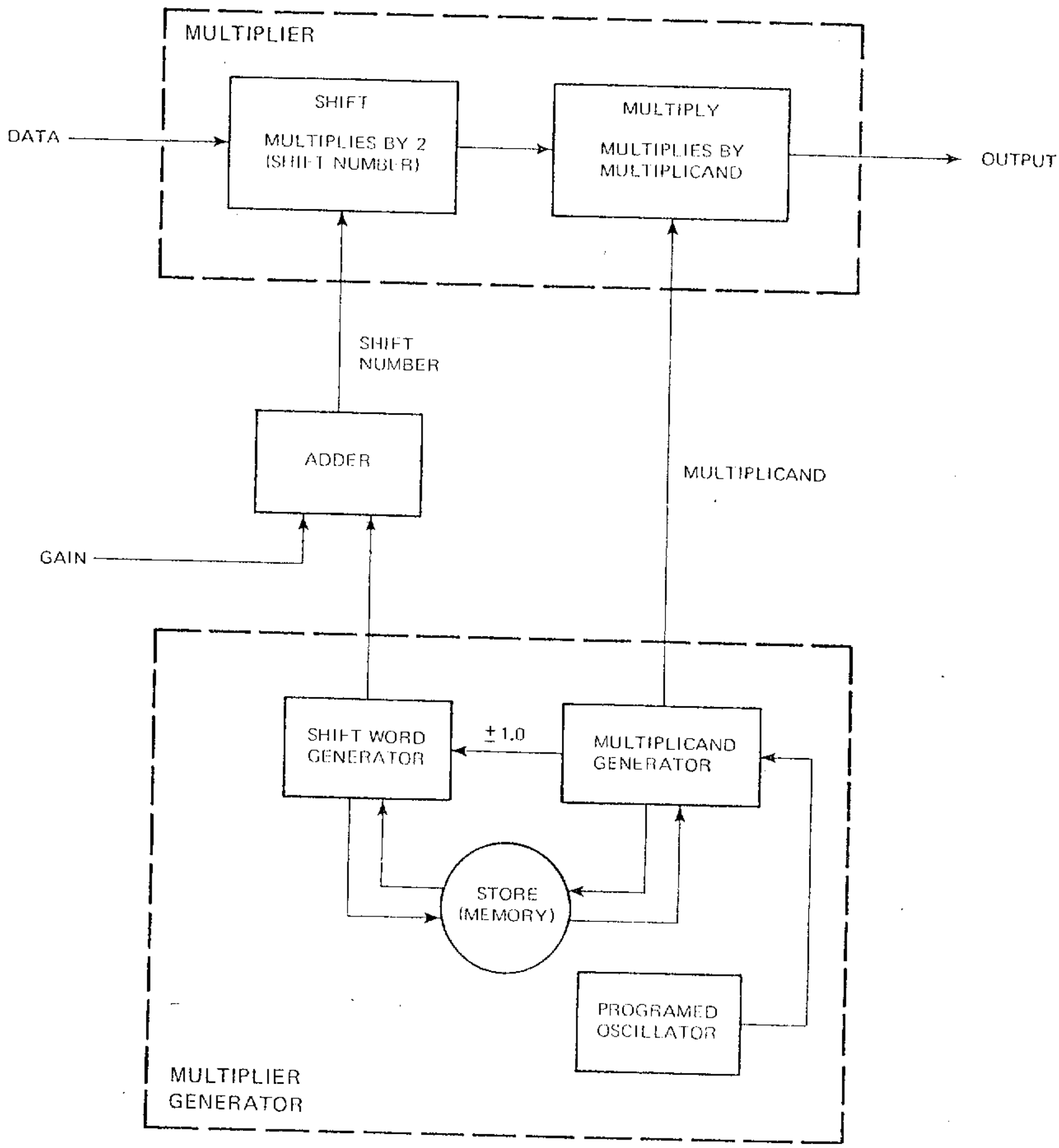


Figure 2.56 DIGITAL PGC SIMPLIFIED BLOCK DIAGRAM

added and converted to a proportional voltage by a summing amplifier. Thus 12 bit accuracy (12 most significant bits) is attained see Figure 2.57.

2.5.3 Galvanometer Level Attenuation

The auxiliary channels and the data channels are multiplexed after D/A Converter output. The attenuators are selectable series resistors which produce resistive divisions of the D/A output in 3dB steps. Zero on the attenuators gives the smallest analog signal output, 27dB the largest signal output.

2.5.4 Hold Capacitor Drive Amplifier

This amplifier buffers the digital-to-analog converter, and provides amplification to enable hold capacitors in the demultiplexer block to be charged in the time required.

2.5.5 Demultiplexer Switching

The output for location addressing from the Address Decoding circuit, closes the respective demultiplexer switch to store the channel information on Hold capacitors.

2.5.6 Hold Capacitor and Amplifier

The capacitor stores the multiplexer switch output voltage for a particular channel between sample periods, and applies a high input impedance buffer amplifier to minimise current drain.

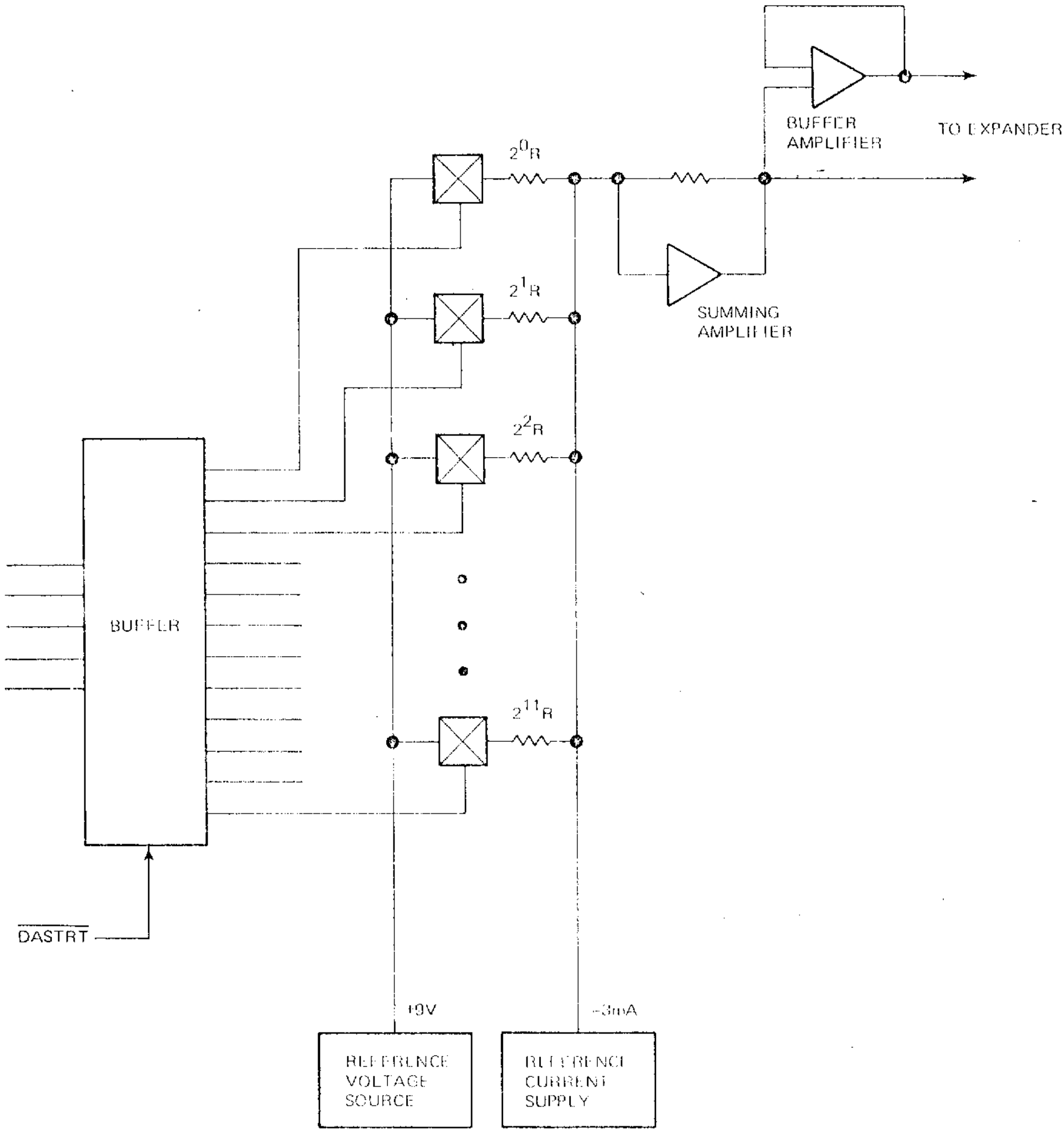


Figure 2.57 D/A CONVERTER SIMPLIFIED BLOCK DIAGRAM

2.5.7 Analog Filters

Hi-cut filters remove the sampling frequency from the output waveform and provide undesirable high frequency filtering. In AUTO, the hi-cut filters are selected by sample rate (eg. HI = 90Hz). Low Cut filters are selectable on the front panel and are by-passed in OUT. Low cut filters are an optional extra and thus, the absence of the filter cards requires low-cut filtering to be permanently by-passed. Since play-back filtering is only a cosmetic operation on traces displayed on paper, no technical information on the filters operation is available from the manufacturer.

They act as smoothing filters designed to give a suitable time constant so that the digital signals appear to be continuous (lo-cuts to control D.C. level).

2.6 Read/Write Module

This module contains all hardware necessary to read from and write onto ½ inch 9 track tape. It operates in 1600 bits per inch (BPI) phase-encoded (PE) mode, generating a PE-identification burst, parity check bit, preample, postamble and tape-mark during each recording.

In the WAIT system, two tape transports have been mounted side by side, the left hand transport and Read/Write Module are operational - the other is a spare system.

A switch on the module front panel allows dc voltage measurement in this module and the Tape Transport Module. Power is supplied from this module to the tape transport.

2.6.1 Record (Write) Functions

1) Receives 8-bit data bytes from the Format Module.
2) Generates a vertical parity bit.
3) Generates a PE I.D. burst.
4) Generates a tapemark.
5) Provides static skew compensation for 3.9 microseconds in 0.49 microsecond steps at 80 IPS tape speed. Static skew is 0.3 microseconds maximum after compensation.
6) Drives 1600 BPI PE data on a 9 track head.
7) Interfaces the tape controls with the Format Module.

2.6.2 Reproduce (Read) Functions

1) Delivers 8-bit data bytes to the Format Module.
2) Reads 9 tracks from tape.
3) Provides static skew compensation, 0.3 microseconds maximum after compensation.
4) Checks parity errors and delivers a parity error signal to the Format Module. It has in-built parity error correction circuitry.
5) Checks for sync errors and delivers a signal to the Format for each error.

The system advance clock (SAC) is 32 times the byte rate, such that at 40 ips 1600 bpi :-

Byte rate = tape speed x bpi

= 40 x 1600

= 64 KHz giving SAC = 2.048 MHz

The Byte rate = number of bytes per scan x sampling frequency.

2.6.3 Front Panel Controls

The 20 amp power circuit breakers are located either side of the 14 position rotary DC voltage switch, with power-on indicator lamps directly above the circuit breakers. When circuit breakers are in the power-off position, the Format Module indicator panel will display this condition. If the system interlocking logic refuses to allow RECORD mode function and this is indicated by the tape END lamp glowing, the interlocking logic must be reset. This is accomplished by shutting the system power-off (i.e. throw Read/Write power circuit breakers off and on and then depress the Format power-on pushbutton switch thereby powering-up again. System logic is then reset and the system will allow RECORD MODE to function correctly. This error in interlocking logic is peculiar to this system, and only occurs when the system has backed-up to start of tape silver marker.)

2.6.4 Internal Controls

Figure 2.58 shows the internal controls on the printed circuit boards. Numbers referred to are as follows:-

1-3 Write de-skew selector switches

4-6 Write head current balance (pulse pairing adjustment)

7 Toggle switch to enable display diodes on the card

8 Toggle switch enables error correction circuit in up-position

9 FWD read skew adjustment

10 REV read skew adjustment

11 -6 volt adjustment

12 +Reference voltage adjustment

13-15 Read Amplifier gain adjustment

2.6.5 Phase Encoded Recording

Before consideration is given to the operation of the Read/Write module, it should be understood that the module acts as the tape recording/formatting controller, and to some degree is not in isolation from the other tape transport operations. Thus, Read/Write data flow derives from the manner in which data is processed, and in this instance phase encoded operation is executed (as opposed to 'Non Return to Zero Inverted').

When writing bits on magnetic tape, positions of successive bits must be separated by lines at a constant interval called "cells" - spaces for writing a bit. However, these have no physical representation on tape and thus some forms of write clocking is required. Phase encoding provides a means to reconstruct the write clock, by means

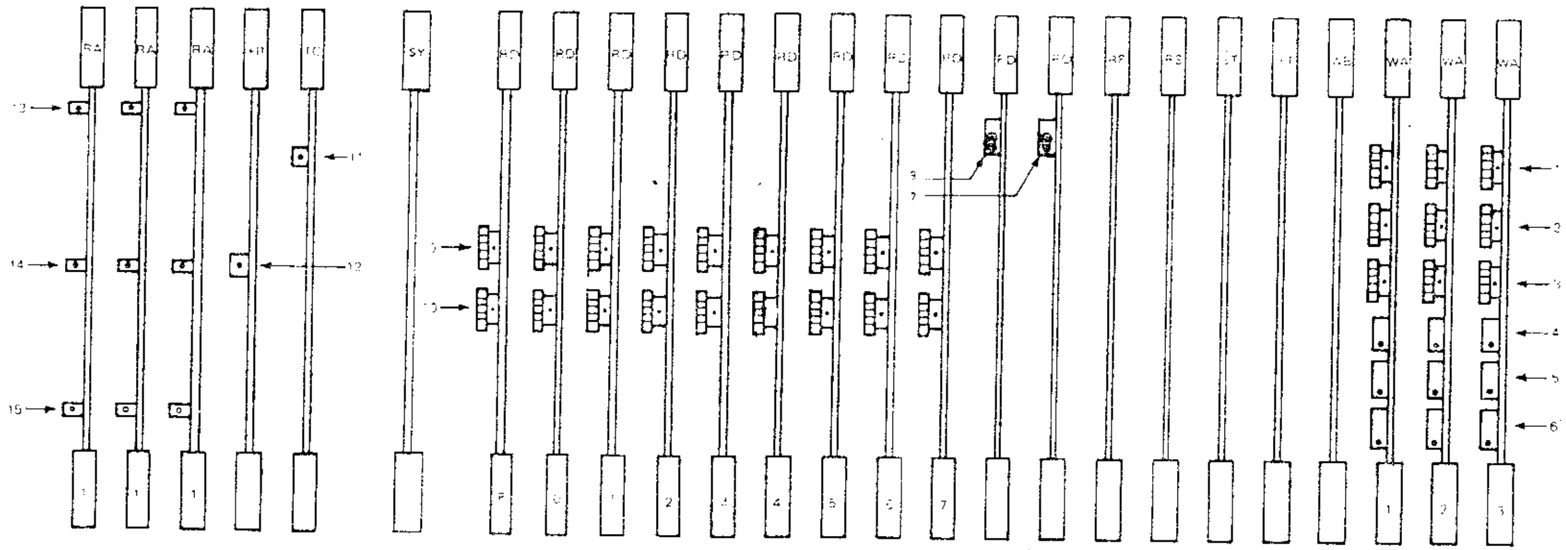


Figure 2.58 READ/WRITE INTERNAL CONTROLS

of a flux inversion in 'one direction' for a 1 bit and in the other for a 0. Another reversal is necessary when two similar bits follow each other, and if one track consists of two frequencies - one being twice the other when identical bits follow each other - the lower frequency is the write clock. Thus, reading a record is a matter of frequency detection over one octave, which is adequately narrow a bandwidth for automatic electronic adjustments. Writing two frequencies does not require saturation of tape oxide coating, thus reducing the demagnetization effect and allowing increased packing density.

Consider Figure 2.59. A change in flux in the direction of magnetically erased tape represents a 1, a change away represents a 0. If two 1's or two 0's are written, the flux changes between them to be in the correct direction to write the next bit. The bit clock writes the bit, the shift clock sets the flux to the correct direction to write the next bit.

The flux direction requires firstly a 1 written so the first bit clock causes a flux direction change with respect to that of the erased tape. The next bit is 1 so the shift clock changes flux direction. The next bit clock changes flux direction again and thus a 0 bit is allowed by the shift clock which does not change flux direction.

The next bit clock changes flux to write the 0. This process has encoded the flux changes to represent the data bits. Encoding is performed by the write Amplifier, such that "all ones" has 3200 flux changes per inch, or 1600 for 'alternate ones'.

In read, bits are packed close together and the recording head always reads more than one flux change. The voltage produced by the head is the sum of voltages produced by flux changes in contact with the head and on either side (before or after the head). The primary frequency produced during reading is a half the flux changes per inch times tape speed.

In Figure 2.59, the read signal peaks line up with flux changes passing under the head gaps. Doubling or halving flux changes causes peak shifting. Read decode allows a time margin for correcting of shifts, after which a filter or frequency compensation circuit produces a uniform amplitude.

Due to the filters lagging phase response, zero crossings occur after peaks of the original waveform. The read amplifier output is shown to be identical to the flux. The output has dynamic skew, 'pulse crowding' and tape speed variations. The read decode determines which flux change represents a data bit, and provides a time window during which flux changes are read as data bits.

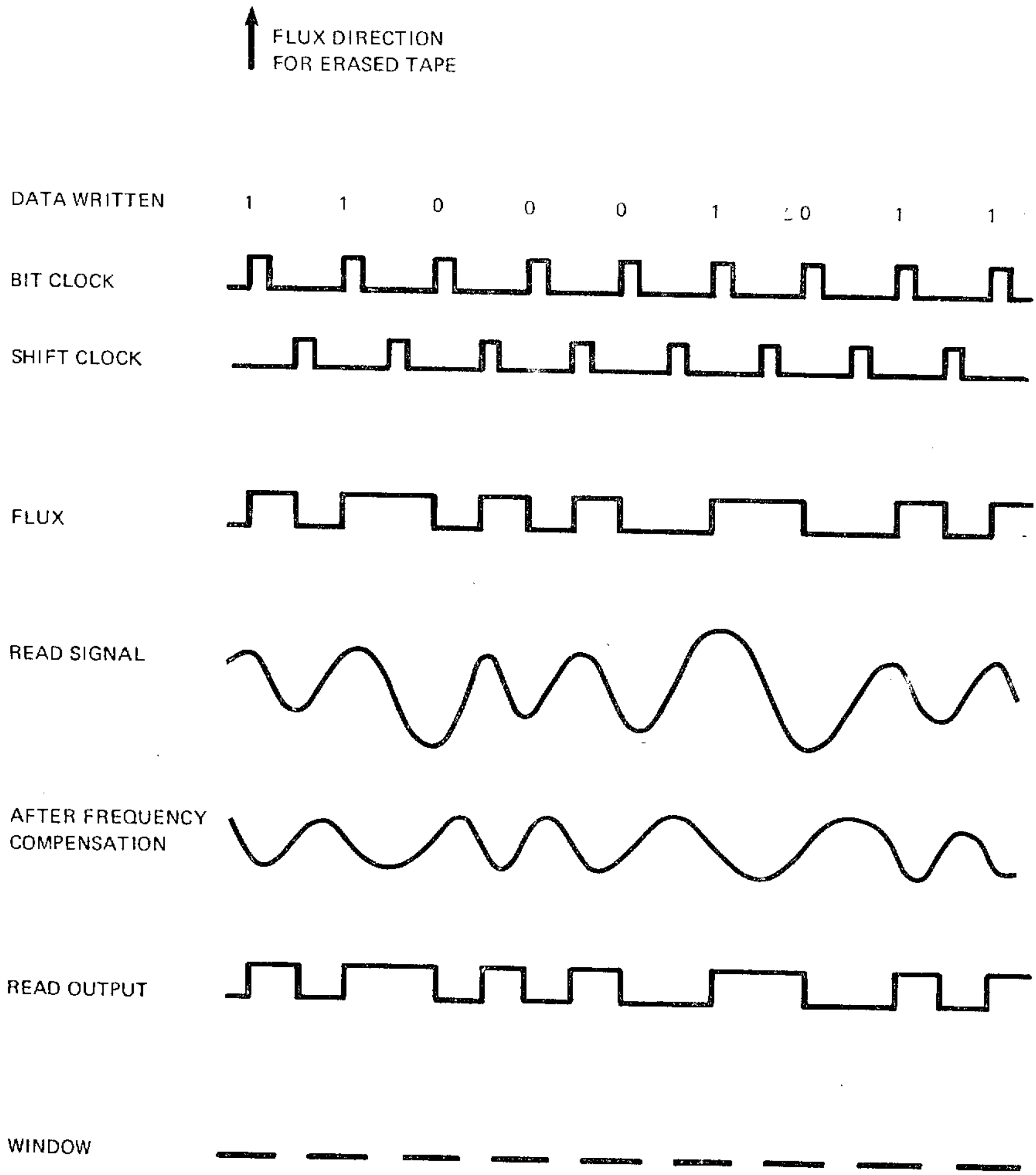


Figure 2.59 PE RECORDING

The read decode card (one per track or bit) are shown in Figure 2.61.

2.6.6 Write Data

Figure 2.60 displays the write data flow. Write data bits from the Format Module pass through the write buffer. This stores the data bits, generates the parity bit, selects data or control read clock (CRC) to be written on tape and makes all data bits a "1" or "0".

A tape mark is required to separate files on the tape, consisting of header record and data record. All records within a file are separated by 'gaps' of ½ inch minimum length. A gap separates last file record from the tape mark, which is also separated from the beginning of the next file. The PE tape mark has 3200 flux changes per inch (FCI) with at least 80 flux reversals in tracks of bits P, 0, 2, 5, 6 and 7. Bits 1, 3 and 4 are DC erased.

An ID burst has 1600 FCI in the parity track, indicating 1600 bpi operations. It starts at least 1.7 inches before the trailing end of BOT marker and continues past BOT. BOT is detected 9.5 inches past the tape head. The write amplifiers encode the bits for recording provide write skew correction and supply write current to the write headwindings. The Record Timing supplies record timing, write phases, write clocks and write

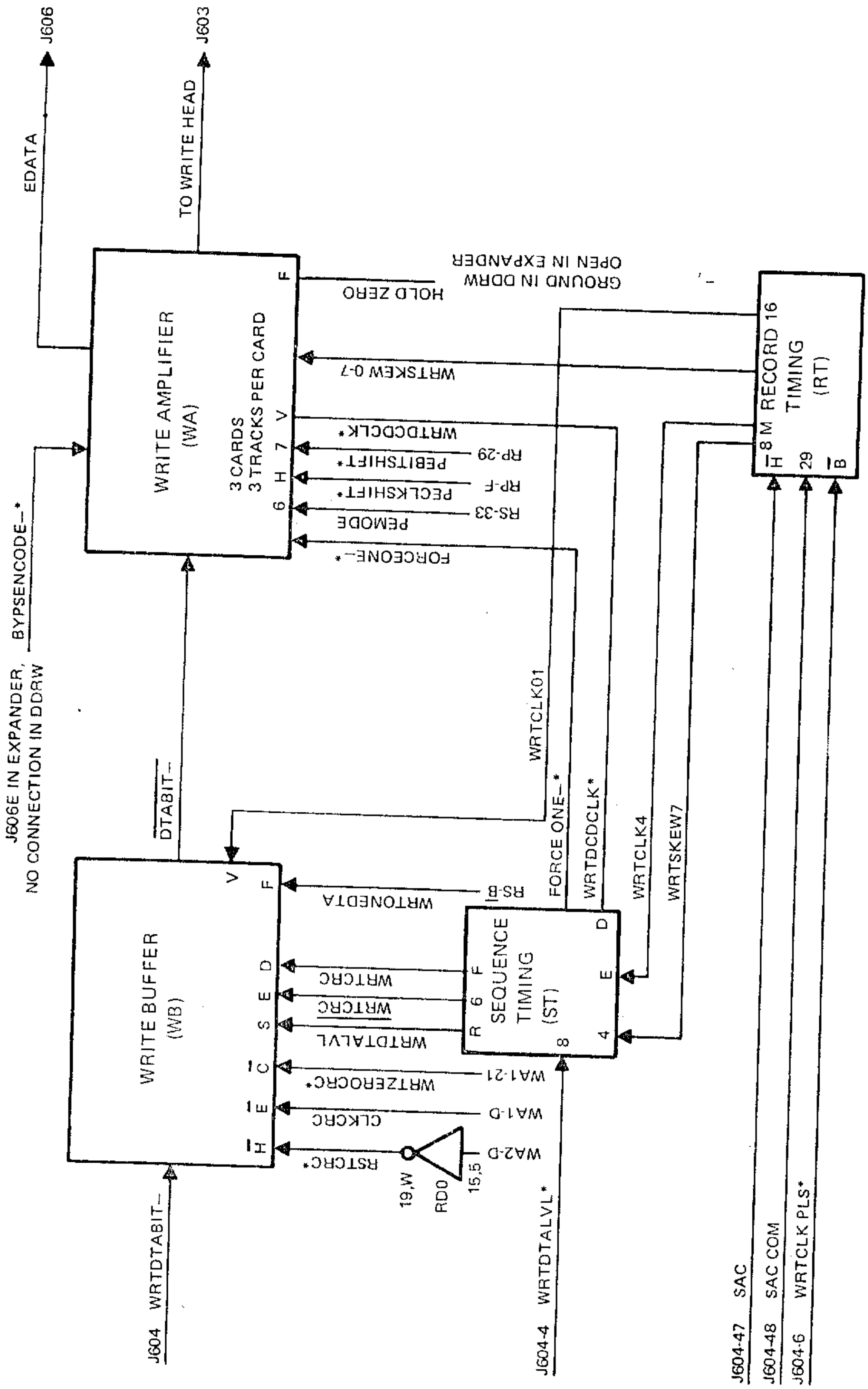


Figure 2.60 WRITE DATA FLOW

skew. Sequence Timing initiates the writing sequence, post ample and end of data.

2.6.7 Read Data

The read head windings connect directly to the read amplifiers, Figure 2.61. Read amplifier logic (from Transport Control card) selects amplifier gain in 2 to 1 steps. The read data output to the read decode is a reconstruction of flux changes in PE. Read data is deskewed by a shift register and the skew clock. All "0" bytes of the preamble determine which flux changes are data bits.

Each Read Decode Card has 3 outputs - data, new data level and amplifier level. Error Detect and Sync cards make parity checks and corrects the error if in a single track. Switch S1 can inhibit this correction.

Data enters the Read Output and is clocked through an output register to the Format Module. Read Phase card starts read timing, delivering 8 read phases. The Sync card provides time-alignment of all tracks on the all "1" byte of the preamble. The Record Timing card delivers a synchronized gap to the Format, and Record Sequence indicates parity errors. The transport control card enables writing.

2.7 Tape Transport Module

The Tape Transport and Read/Write modules are mounted in the

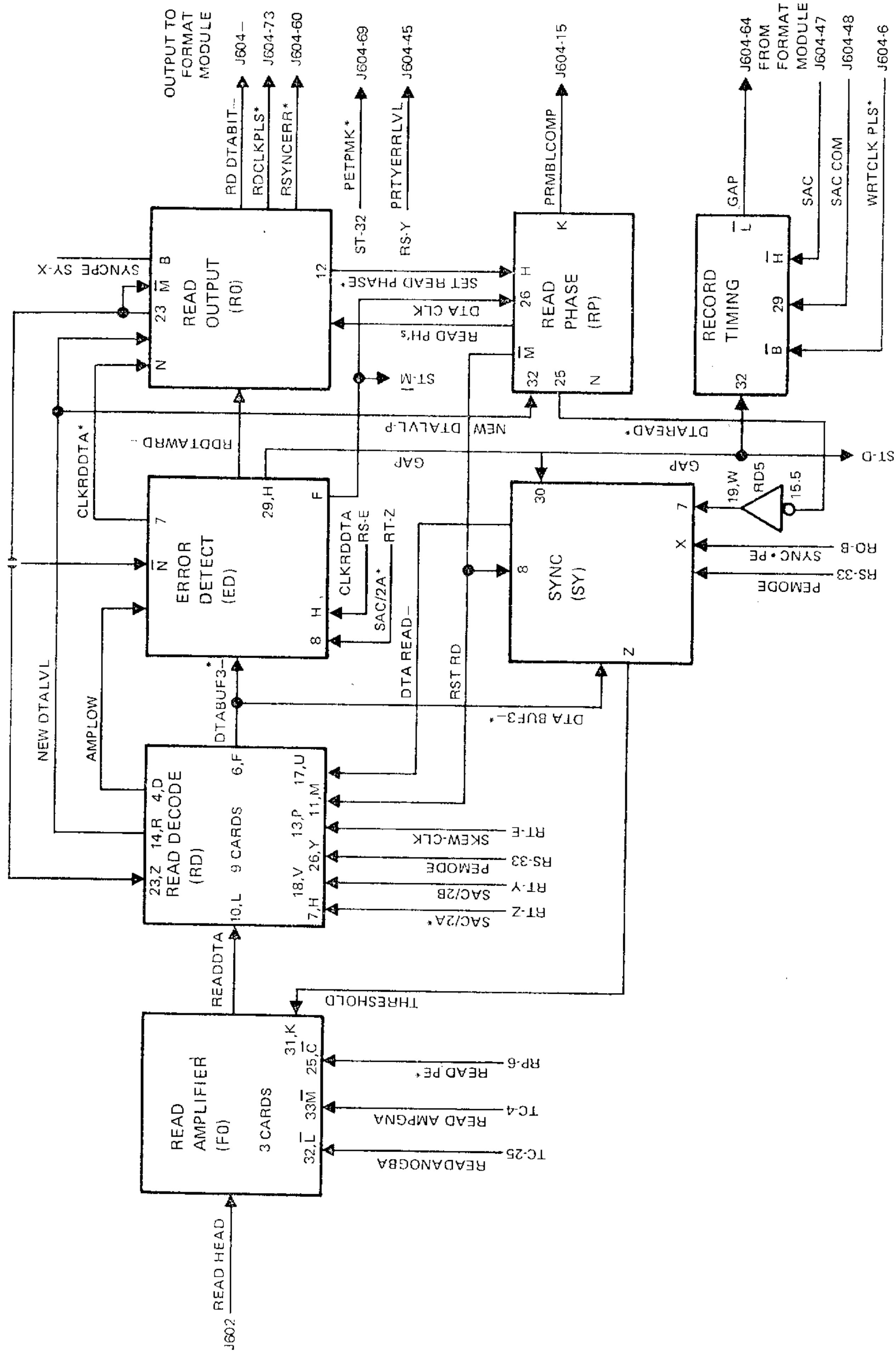


Figure 2.61 READ DATA FLOW

same cabinet, with power provided by the Read/Write module.

Plate 2.7 shows transport Model 510 and the transport is designed to move magnetic tape past a record/reproduce head at a controlled speed, the magnetic tape being in contact with the head at all times. 8 ounces of tape tension is applied, average velocity being maintained within 1%. Instantaneous speed variation is minimised so that recorded data may be reproduced without buffering.

Angular head misalignment or "skew" causes bits to be recorded incorrectly. The resulting time error limits packing density on tape, apart from difficulty in reproducing data off tape. To minimise skew, head guides ensure tape is supplied perpendicular to the head plate.

The capstan drive employs a velocity servo to maintain an accurate tape speed, which is driven by a dc shunt motor.

2.7.1 Capstan Drive

Fig. 2.62 shows the capstan block diagram. The input to the capstan motor power amplifier is derived by comparing a reference voltage with the output from a dc tachometer generator coupled to the capstan, the difference being a velocity error. This is amplified to drive the capstan motor. The capstan system gain allows a steady state error of less than 0.1%, and transient responses are compensated for. An RC filter is used on the tachometer generator to

Plate 2.7 TAPE TRANSPORT

attenuate ripple noise of the tachometer.

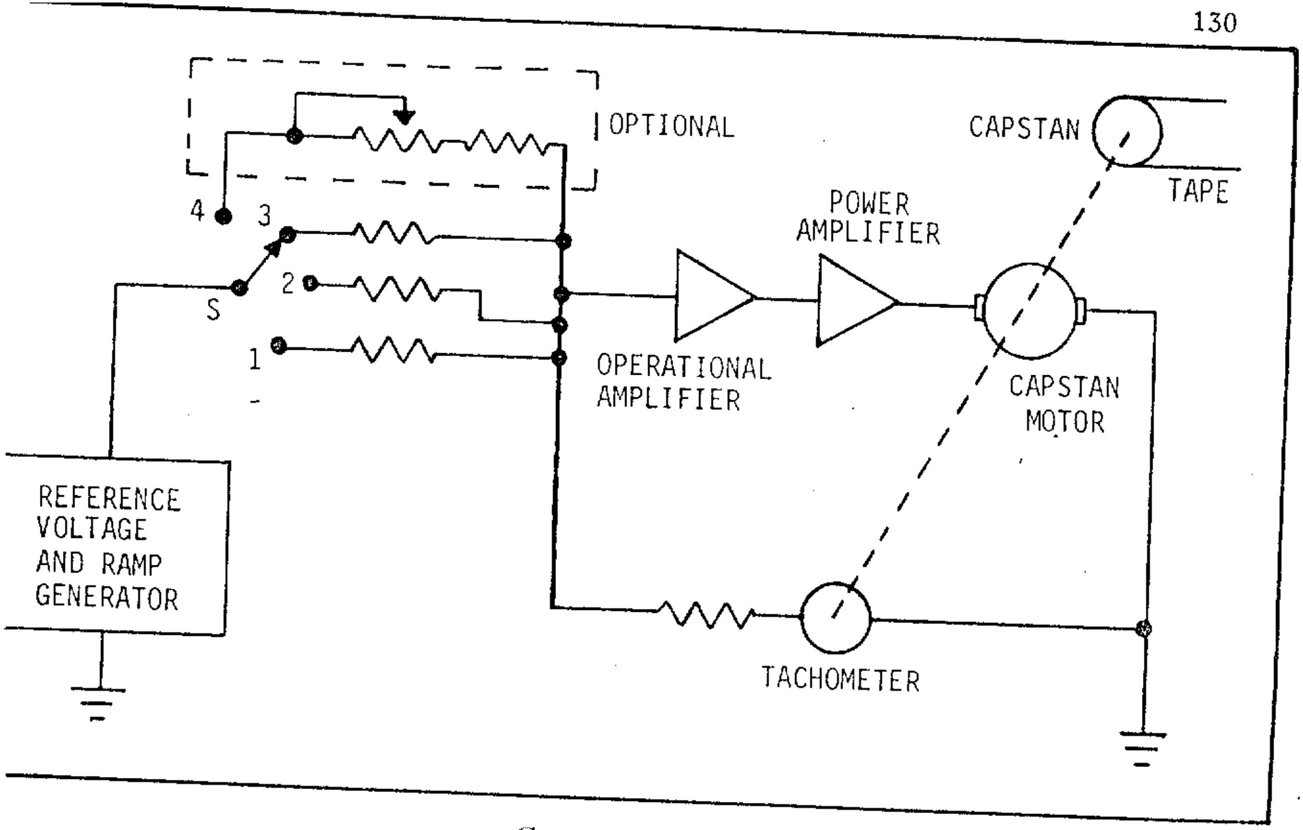
When a start command is given, a linear ramp voltage provides a smooth start. On stopping, a current source discharges a capacitor linearly for a smooth controlled stop.

The resistor from the reference voltage is selected for the desired tape speed. An open-loop operational amplifier gain is several thousand, and a closed-loop gain is set by the ratio of feedback to input resistors. The driver and power amplifier gain is 6.5 volts per volt giving an overall gain of 143 volts per volts. Preamplifier and drive amplifier are supplied with ±16 volts reference level, and voltage adjustment is allowed on power regulator cards rack mounted within the servo cabinet.

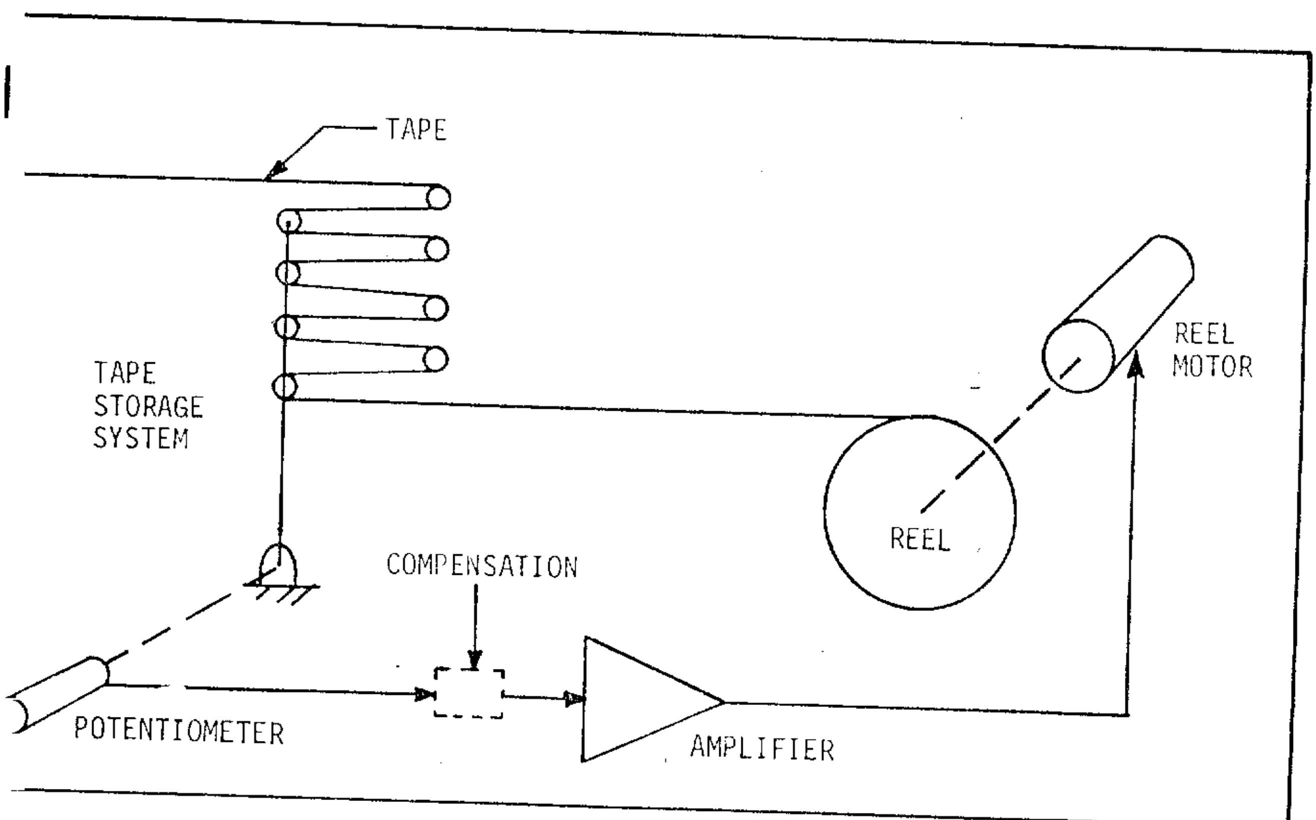
2.7.2 Reel Servomechanism

Two servo amplifiers control supply and take-up reels, which centre storage areas about mid-way for normal operations. The arms are spring loaded so that the reel motor develops enough torque to supply tape tension to move the arm to the correct position, See Figure 2.63.

Information on tape position for the reel servo is derived from a potentiometer connected to the Storage area. Potentiometer ends are supplied with ± 16 volts



Capstan Block Diagram FIGURE 2.62



Reel Servo Block Diagram

FIGURE 2.63

and the centre is connected to the servoamplifier that drives the reel motor, which turn in the direction to centre the arm. The servo amplifier consists of a preamplifier, driver and power amplifier. When power is applied, reel servos move to stand-by position, and the reel amplifier input gives sufficient reel motion torque to apply the correct tape tension.

When the capstan accelerates forward, tape offloads from supply to the take-up reel. The storage arm movement causes a voltage input to the reel motor amplifier, accelerating the motor in a direction to recentre the storage arm. The reel motor reaches speed to maintain equilibrium in the feedback circuitry. When the capstan stops, the two systems take-up or supply tape until the reel motor decelerates the highest inertia reel.

2.7.3 End-of-Reel

When 100ft of remaining tape is reached on the storage reel, a light source illuminates a photo cell thereby energizing an end-of-reel relay, which provides a Format indication lamp to glow.

2.7.4 Brake Control

Mechanical brakes are released when brake solenoids are energized or by use of the 'Brake Off' switch. This switch allows easy spooling of tape onto the reels prior to loading and power application. The circuit is self resetting when arms are released, and can be reset by throwing the power-off switch.

2.7.5 Magnetic Recording

Bits are recorded by the magnetic head over which the tape is driven. The head is an electromagnet, the direction of magnetic field being applied dependent upon the direction of coil current. As tape moves through the field, remnant induction of oxide granules occurs. This is 'writing' on tape. When the tape is then driven over the head, the remnant induction bits generate a magnetic flux through the electromagnetic core, and variations in magnetic flux direction induces a voltage in the coil. Flux reversals are read, and if there are no reversals, nothing is read.

The tape head is in fact two heads - a read head, a write head. After data is recorded on tape, it may be read and thus verified, by reading it immediately off tape. This is 'read-after-write' ability and is used to directly monitor what is recorded on tape, and ensures it can be readily reproduced.

For reading data, the read head is placed behind the write head, with a suitable gap (a few millimeters) between heads to prevent magnetic crossfeed. An additional 'head shield' prevents further crossfeed, and this hinges just over, but not touching, the recording head.

Some recording heads also have an 'erase head', which applies constant magnetization to the tape prior to arrival at the write head. Since bits are recorded by flux reversals, this has the effect of magnetizing the tape - performing the equivalent work of erasing the tape. However, such heads are in little demand now, since newly supplied tapes are generally guaranteed to be fully demagnetized.

CHAPTER 3

INSTALLATION, MODIFICATION AND RE-CONFIGURATION

3.1 Introduction

A DFS IV digital seismic recording system was donated to the W.A.I.T. Exploration Seismology Centre during July 1983. The system consisted of:

6 - 12 channel Input Modules, two of which were used for spare parts

1 - Amplifier Module

1 - Format Module

1 - Reproduce Module

2 - Read/Write Modules

2 - Tape Transport Modules.

Module Interconnecting cables were supplied and the system was considered to be in good working order. A set of four 12 channel input connection cables were also supplied, as well as a cable for connection to an SIE oscillograph camera. The system had seen previous service aboard Geophysical Service Inc. shallow water survey vessel M/V Banksia and deep water survey vessel M/V Eugene McDermott II.

The system was some 15 years old, and over the years had a number of electronic modifications performed on it. It was mounted in cabinets for bolting down to a ship's super-structure, in an airconditioned vibration free environment.

Because of its age, spares were difficult, if not impossible, to obtain.

After connecting up the basic system cabling, 12V dc power was applied and the system failed to power-up. In addition, the system had a basic logic fault which was not apparent without a number dump of the recording. During the following 12 months, a series of major and minor faults occured and were trouble-shot. These are explained herein.

Having accepted the donated system, the decision was made to make it mobile - sufficient to mobilize out to the field to record seismic data. However, seismic geophones, cables, shot firing system, oscillographic camera and oscilloscope were all minimum additional peripheral equipment necessary for such an event.

The WAIT Director donated $20,000 from his Discretionary Reserve towards the Seismology Centre work. This funding allowed mobile installation of the equipment and purchase of basic electronic equipment. Clearly, the funding could only be used sparingly, since seismic cables cost up to $200,000; geophone strings cost $1,200 each (minimum 48 required); shot firing system cost $2,000; camera cost $12,000 and oscilloscope $2,000 plus. The mobile installation was considered a priority for expenditure of funds.

Having decided that the system would become mobile, it was then necessary to make the following investigations:

a. Cost and effectiveness of available mobile vehicles

b. Ability to mobilize the equipment to the Australian outback under any extreme weather conditions

c. Availability of a cheap or donated seismic cable and geophones

d. Availability of basic recording peripherals necessary to perform data acquisition.

Equipment modifications were necessary from the outset. Because there was inadequate funding to purchase seismic cables, geophones and camera, it was necessary to approach the exploration industry and request the loan of equipment. Thus, the system configuration would change each time replacement seismic cables or camera were loaned.

The system was initially bench tested in a laboratory. A power fault was located in the system, and after being remedied, the system powered-up. It was then necessary to review mobilization requirements.

3.2 Mechanical Properties and Ergonomics

The recording system would be mounted in a vehicle which could be driven or towed to remote locations with relative ease. Ideally, a four wheel drive was required for operations in sandy terrain - a typical Australian operational environment.

Investigations were made towards the purchase of a four wheel drive truck of a type used for conventional seismic crews.

A new four wheel two tonne Ford or equivalent truck cost in excess of $20,000 and, hence, this option was excessively expensive. A second-hand truck was possible but the cost of mounting an enclosed cab on it was still prohibitive. Finally, it was felt that, if a steel chassis caravan ("trailer") were obtained at minimum cost, it could be possible to refurbish it with a new enclosed cab and then a vehicle could be purchased to tow it around. It was accepted that the caravan had limitations i.e. it could not venture to all grounds where a 4 wheel drive could. However, the caravan concept appeared feasible within the budgetry constraints. Furthermore, a steel framed caravan (as opposed to wood) would be desirable, since the vehicle must be rugged to endure the rigors of off-road work.

After visiting numerous caravan parks and yards, an acceptable single axle steel chassis caravan was located (this was a four-bed field van, the owner of which had plans to turn it into a hamburger stand). The basic chassis and frame were steel and in good order. The chassis had a one tonne axle. The caravan was purchased and towed to a fabrication yard. A short-wheel-base Toyota Landcruiser was purchased and would be the towing vehicle.

Prior to commencing refabrication, it was necessary to determine equipment weight and the ergonomics of operating the DFS IV. The system would be cabled together, to enable 48 channel operation as shown in Figure 3.1 The Expander Module option was not available. Provision had to be made

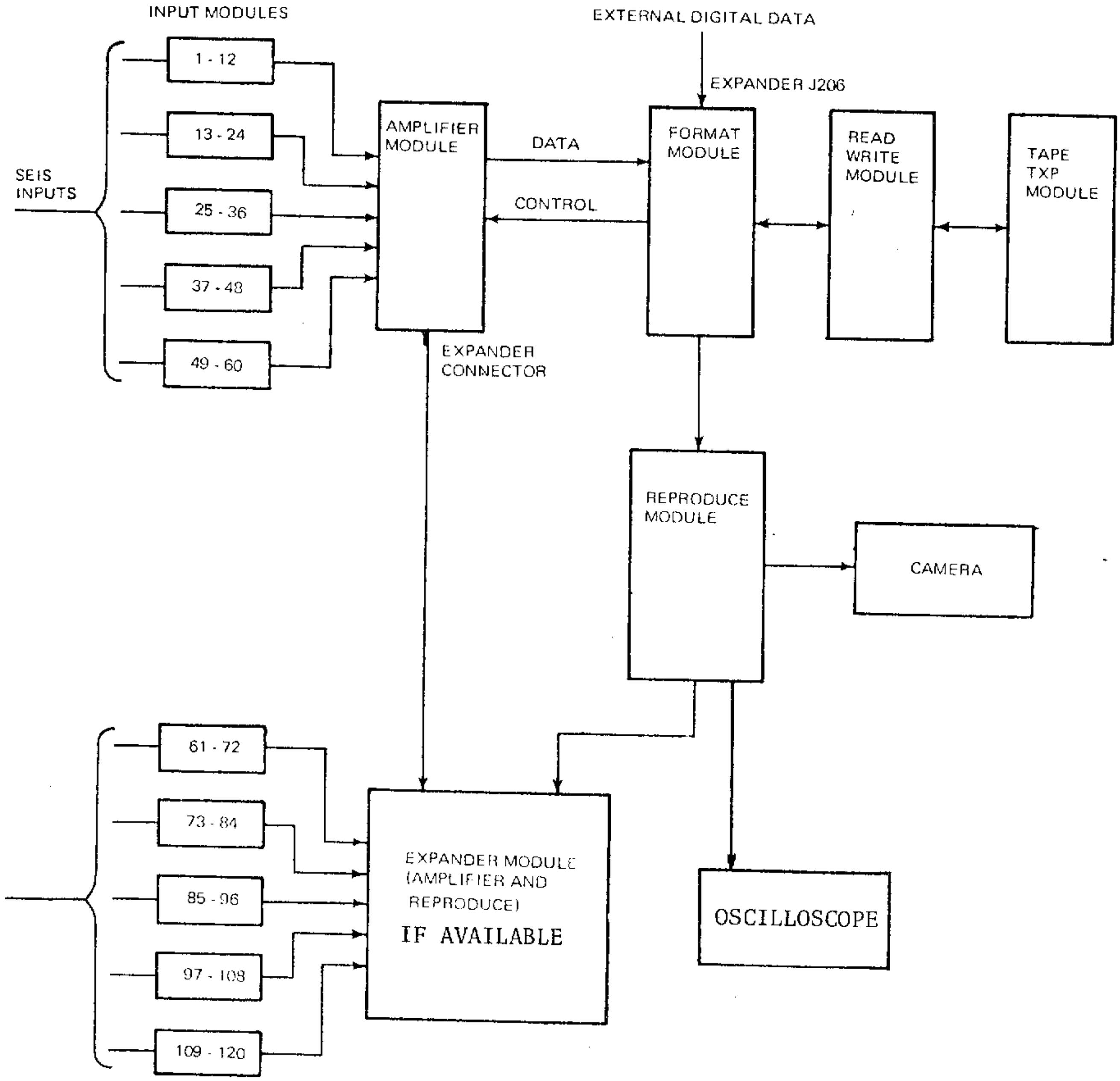


Figure 3.1 DFS IV SYSTEM BLOCK DIAGRAM

to allow for equipment weight distribution, for relative physical dimensions, and possible later additions in the event that the system was expanded. It was intended to mount four Input Modules, and Amplifier, a Format, a Reproduce, two Read/Write Modules and two Tape Transport Modules. Only one Read/Write and one Tape Transport would be used, with the others acting as spares. A brief consideration for mounting the two additional Input Modules was rejected on the basis of excessive loading.

In addition, dc power supplies were required; some form of airconditioning was a necessity; office desk top area was required as well as storage area for consumables.

To power the recording instruments and airconditioner, at least one generator was needed. The following equipment was purchased or donated:

Recording System	Weight (Kg)
4 - Input Modules @ 28 Kg each	112
3 - Cabinet Housing @ 50 Kg each	150
1 - Amplifier Module	30
1 - Format Module	25
1 - Reproduce Module	30
2 - Read/Write Modules @ 25 Kg each	50
2 - Tape Transport Modules @ 25 Kg each	50
2 - Transport Cabinet Housing @ 25 Kg each	50
1 - Camera	32

Power Supplies	Weight (Kg)
1 - Lambda 12V dc stabilized	60
1 - Unstabilized 12V dc	25
4 - 12V dc heavy duty truck batteries @ 45Kg	180
1 - 5KVA Honda generator	200
Airconditioning	
1 - Mitsubishi rotary 2HP airconditioner	56
1 - 5KVA Honda generator	200
Office Equipment	
4 - Tables with cupboard space @ 30Kg each	120
Ancillary Equipment	100
Total Weight	1470 Kg

Allowing for the fact that, on occasion, the seismic cables would be carried in the caravan, an initial endeavour in refabricating the caravan was to replace the existing axle with a two tonne axle. Eventually, a four tonne axle (which had not been available at the time of fabrication) replaced the two tonne version. Prior to equipment installation, the steel caravan chassis itself weighed some 500 Kg, and thus the decision to later upgrade to a 4 tonne axle.

The caravan was fitted with an aluminium skin on the exterior and a light brown board on the interior, with polystyrene sheeting between the two to provide insulation. A tropical roof was also fitted and the vehicle painted reflective white.

One generator supplied 240V ac power to the power supplies and wall sockets, whilst the other supplied air conditioning power. It was necessary to mount the power supply generator on the forward running board, with a specially constructed platform fabricated on the rear upon which the airconditioning generator was mounted. The intention was therefore to distribute the generator weight equally either side of the axle.

Three wheel hubs were specially manufactured since conventional 4 tonne truck tyre hubs did not have the five hub nut arrangement evident on the fitted 4 tonne axle.

The internal ergonomics were now considered, see Figure 3.2. Ideally, the operator should sit in the centre of his equipment, from which minimal effort would be required to operate the Format Module, wind magnetic tape reels, pull a camera record, monitor the oscilloscope, operate Reproduce Module playback gain levels, talk on the radio and write observer logs. In addition, the operator should be as far away from cultural disturbance (i.e. visitors wishing to look at the equipment) as possible, as this could upset the recording process. The caravan door, prior to refabrication, was at one end of the vehicle. Thus, the operating area would be at the other end, where the airconditioning equipment would also be mounted.

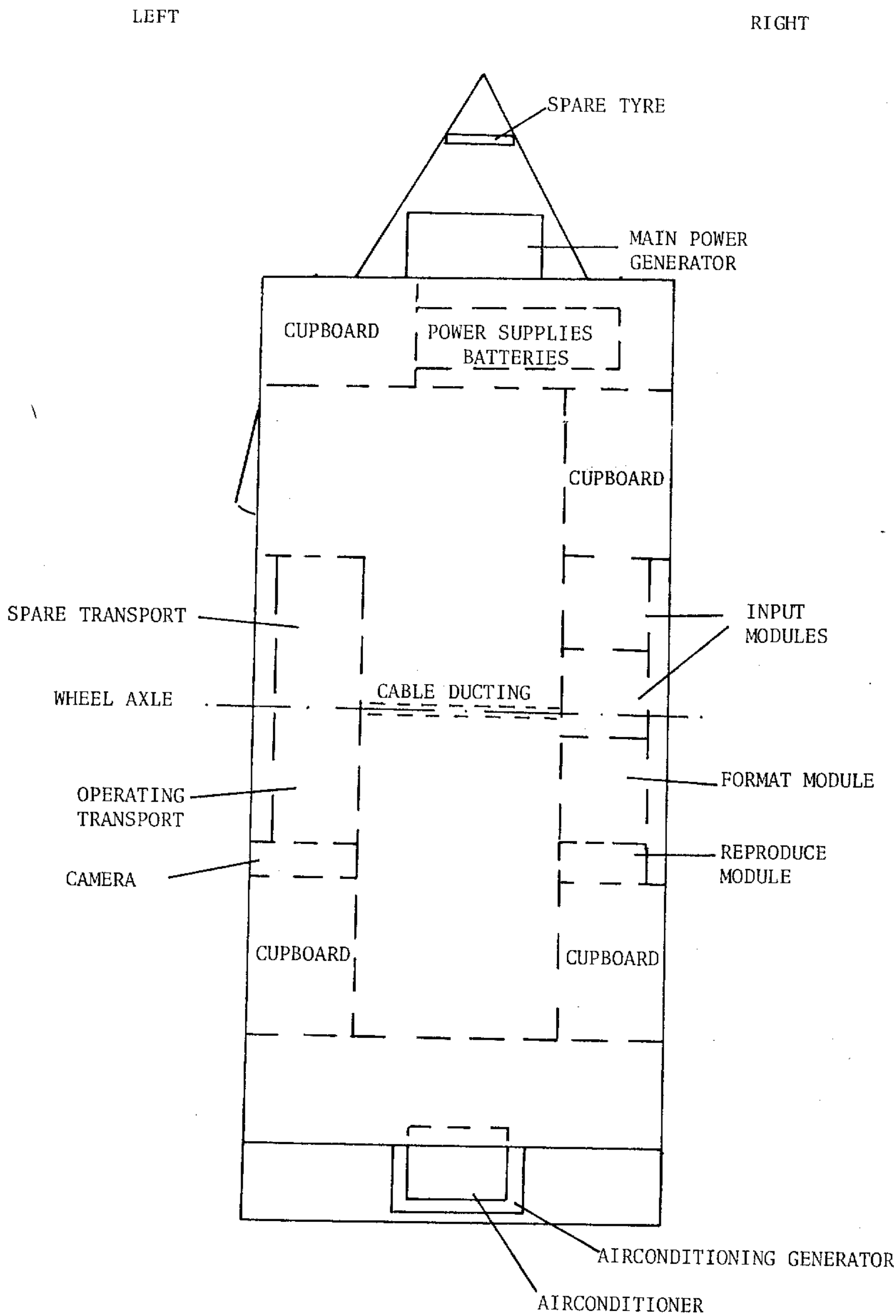


FIGURE 3.2 CARAVAN EQUIPMENT LAYOUT

Figure 3.2 was readily resolved, one important criterion being the length of Read/Write Module and Reproduce Module cabling to the Format Module. Since the Reproduce Module interface cable was only 2 metres long, this located the Reproduce Module adjacent to the Format Module. The camera and oscilloscope would therefore be positioned on the opposite side of the vehicle to counterbalance the Reproduce Module. It was preferable to mount the Input Modules together (for simplicity of operation) and their cable length to the Amplifier Module restricted remote operations. Thus, cable length deemed that Input Modules, Format/Amplifier Modules and Reproduce Modules must be adjacent.

Due to the Format to Read/Write cabling being some 5 metres in length, it was decided to mount the two Tape Transport Read/Write Modules on the opposite side of the caravan. Benches were positioned accordingly. Hence, the lateral weight loading was:

Left Side	Weight (Kg)
2 - Tape Transport Modules	50
2 - Read/Write Modules	50
2 - Transport cabinets	50
1 - Camera	32
1 - Camera Battery	45
2 - Cupboards	80
	307 Kg

Right Side	Weight (Kg)
4 - Input Modules	112
3 - Cabinet Housings	150
1 - Amplifier Module	30
1 - Reproduce Module	30
1 - Format Module	25
2 - Cupboards	80
	427 Kg

Thus, additional springing was necessary on the right side axle.

In terms of longitudinal weight distribution:

Forward Half	Weight (Kg)
2 - Input Modules	56
1 - Cabinet Housing	50
1 - Tape Transport	25
1 - Read/Write Module	25
1 - Cabinet	25
2 - Power Supplies	85
3 - Truck Batteries	135
2 - Cupboards	60
1 - 5KVA generator	200
	661 Kg

Rear Half	Weight (Kg)
2 - Input Modules	56
1 - Cabinet Housing	60
1 - Format Module	25

	Weight (Kg)
1 - Amplifier Module	30
1 - Cabinet Housing	50
1 - Reproduce Module	50
1 - Tape Transport	25
1 - Read/Write Module	25
1 - Cabinet	25
1 - Truck Battery (for camera supply)	45
2 - Cupboards	60
1 - Airconditioner	56
1 - 5KVA generator	200
	677 Kg

Thus, the rear half was some 16 Kg heavier than the front and, allowing for the fact that the airconditioning was raised on a framework just below roof height, this meant that relative loading either side of the axle was approximately balanced.

The addition of the spare wheel on the front towing board made the front half marginally heavier. This was proven on the completion of fabrication, when it was possible to pick up the front tow point of the vehicle with one hand (when the total vehicle weight, after an excursion to the government licensing weigh bridge, was just under 2 tonnes).

Referring to Figure 3.2, two Input Modules and one Amplifier/ Format Module were to be built on a frame on one side of the caravan, with the Tape Transports, Read/Write Modules and camera on the other side. A steel frame was constructed and bolted on each side. Because the wheel arches protruded above the floor level, the instrumentation had to be raised above the arches for the instruments to be bolted against the caravan walls. Hence, the frames were raised and platforms constructed to allow the instruments to bolt down on the platforms and back against the wall frames.

During travel, the instruments would directly receive vehicular vibration. Hence, vibration suppression was desirable. After an exhaustive search lasting 4 days, a set of forklift truck rubber mounts were located and purchased. The mounts (type M114/40) operated in the working range of 30-40 Kg. The mounts had to perform within their working range, otherwise vibrations would be transmitted. Allowing for cables and radio blaster box fitting, the right side had a weight of 360 Kg and the left side 180 Kg. With cabinets bolted together, this meant 12 mounts on the right side (i.e. one under each cabinet corner) and 6 on the left side.

A central floor channel was fitted to take power and logic cables connecting Format/Reproduce Modules to the Tape Transports and Read/Write Modules. 'Brake-away' vacuum brakes were fitted to both towing vehicle and caravan, normal brakes not being adequate for the 2 tonne static weight caravan.

3.3 Power Supplies

Manufacturers' manuals quote a power supply requirement of 11-14 volts DC from a battery source. A 12 voltsDC stabilized Lambda power supply was used to initially power the equipment. A current of some 40 to 50 amps DC was consumed with the tape transport in idle. Under recording conditions, the tape transport used a further 5 amps and, clearly, an800 watt power supply was inadequate for continuous use. The Lambda power-supply has a front panel thermal switch which frequently tripped-out under load greater than 40 amps.

Thus, four large truck batteries were purchased, with three of the batteries to power the recording instruments and the fourth to power peripheral devices (camera, radio, emergency lighting). In addition, a conventional industrial battery charger was purchased to top-up battery charge levels, and act in a utilitarian role when vehicle batteries required charging.

During field recording, the power generators generate extreme vibration which, transmitted into the ground, causes excessive coherent noise on geophone stations in the vicinity. Hence, during field recording, power generators must be shut down. During such times, it is necessary to operate the recording instruments on battery power supply alone. Thus, during operations, power supplies to the equipment must be selectable so that either the stabilized power supply could operate the equipment and maintain battery reserves, or the batteries alone could be used.

Figure 3.3 is the power supply schematic. The power generator was connected to the stabilized power supply via a wall switch. A "Lambda" switch, situated on a switchboard, allowed 12V DC power to the main power distribution board and extractor fan. The power distribution board feeds 12V DC to all module inputs. The unstabilized power supply could be placed across two tabs beneath the switchboard. By switching on the "Battery" switch, a single battery would be placed across the power distribution board and power supplies. The double knife switch allowed all three batteries to be connected in parallel, so that all three batteries may be either charged, or supply power to the distribution board. Thus, during recording operations, the generator may be shut down and power supplies turned off. With the "battery" switch on and the knife switch in, all batteries provided power to the recording instruments. Alternatively, the generator may be run and instruments powered independently from the stabilized power supply. The knife switch open circuitry to the batteries avoids leaving the batteries connected up and the inherent energy discharge through each other during times of minimum operations. The use of power diodes was investigated but found inferior to the common knife switch, since even an 80 amp rated power diode tended to generate an extreme amount of heat under normal operations. The use of the unstabilized power supply is for simply charging the batteries and not for supplying instrument power.

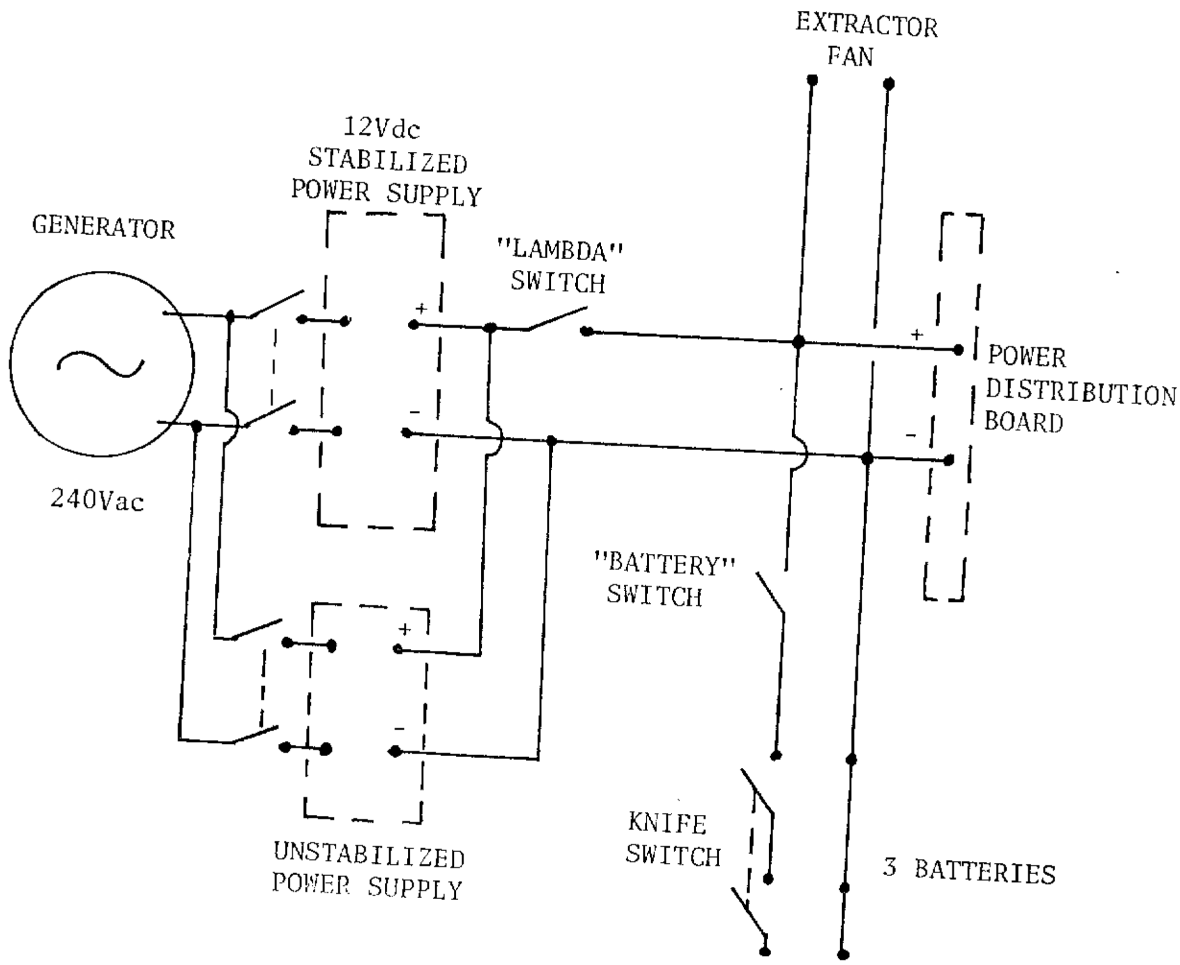


FIGURE 3.3 <u>POWER SUPPLY SCHEMATIC</u>

3.4 Radio Operations

In all forms of remote operations, good communication is essential to maintain the highest level of efficiency. With land seismic crew operations, the field crews have additional support crews operating from different location bases. That is, a line clearing crew consisting of bulldozers and graders plus meal/accomodation support may be necessary; a survey crew will go ahead and follow the line clearing crew ensuring that line positioning is correct at all times; a drilling crew may follow if explosive is the energy source to be used; the seismic crew then follows and finally the fence mending crew, if appropriate, may make good any damage incurred as a result of survey operations.

All crews often use radios of different frequencies, in order that they may converse with the other crews or amongst themselves. Single side band radios are used for long distance (greater than 10 Km.) communications, whereas VHF radios are used on shorter range work. Due to seismic party operations rarely exceeding 5 Km. from recording vehicle, it is normal for the recording crew to use VHF radios. In addition, where remote firing of source is required, VHF radio operations are the norm (the alternative is using the seismic cable as a conduit for source firing but, because circuit leakage and continuity can disrupt firing operations, this form of source initiation is not favoured).

Hence, it was necessary to purchase a VHF radio system and remote source firing blaster which would be compatible with the intended operations. After an exhaustive search, a blaster unit and three 'Willis' VHF radios were located. The radios each had a 157.57 MHz crystal, and a license to operate them was granted by the Department of Communications, with the call sign "VH 6CPH".

The radios were modified for operations with the Input/Output Inc. blaster unit Decoder and Encoder, details of which may be found in the manufacturer's schematic diagram for the Seismic Source Synchronizer. The Encoder output was connected to the Format Module "Blaster" input socket, after the appropriate plug was located and wired (see Figure 3.4).

The Encoder was positioned beneath the Reproduce Module, with the VHF radio sandwiched between the two. Initial power supply was via the 12 volt camera battery, but this was later changed by running cables to the main power distribution board for convenience.

The radio working frequency of 157.57 MHz required a tuned half-wavelength antenna of 0.95 metres (or 3 feet long). Three antennae of this length were purchased, the recording vehicle antenna being mounted on a raised extension pole, so that the additional height allowed greater line of sight communication ability over the horizon. The antenna was bolted to the rear airconditioner support framework, so that

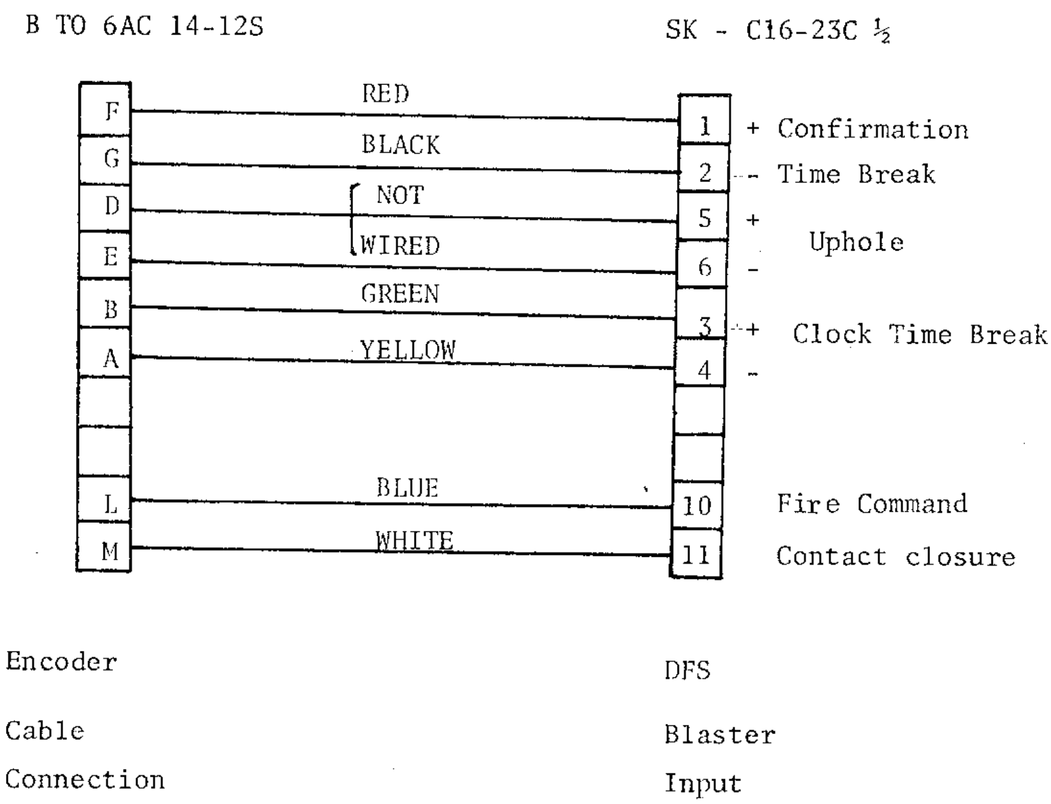


Figure 3.4 BLASTER TO FORMAT MODULE CONNECTIONS

signal polarization may be enhanced directionally along the plane of the vehicle. After mounting another whip antenna and radio in a vehicle, it was found that a range of 5 to 6 Kilometres could be attained - an adequate distance for conventional seismic operations.

For further information on antenna theory, the reader is advised to consult any standard radio theory text-book (e.g. H.F. Antennas by L.A. Moxon, G6XN).

3.5 Time Break Modifications

The recording instrument timing of events is critical and must be accurately synchronized, especially where remote source initiation is performed. Prior to start of data scan, all instrument constants are written in the header record. At the instant of data scan, channels 1 to 48 are sampled, digitized and their appropriate value and gain word recorded on magnetic tape. The instant of data scan with respect to source initiation is of extreme importance, since if this were not timed precisely, then data on successive recordings would not have an absolute time reference and, hence, would drift.

Start of scan command or 'time zero' is generated by the Format Module logic after receiving a time break pulse. The time break may be generated internally by depressing the "START" push-button, or externally by reception of a field time break from a radio receiver or firing line. The internal time break or 'ITB' is a hard wired logic which is used during test recording. The field time break or 'FTB' is generated as a result of remote firing or land-line firing.

3.5.1. Explosive Operations

Remote radio firing requires synchronization between firing shot blaster (or 'Decoder') and the recording unit (or 'Encoder'). Previously, the instruments had been wired to a marine air-gun array blaster. The blaster had been positioned adjacent to the recording instruments and, hence, a short length input cable from any air-gun solenoid control gave the desired FTB. However, with remote radio transmission firing, the reception and synchronization of signals was far more complex.

The basic equipment for seismic source firing was an Input/Output Inc. SSS-202 series Decoder and Encoder. The Encoder was mounted adjacent to the Format Module and connected to the radio system, the Decoder is operated remotely by the shot firer.

The firing sequency begins with verbal communication between recording instrument operator and shot firer. The shot firer "arms" the Decoder which charges a capacitor to 500 volts dc. The Decoder is armed when the H.V. lamp flashes continually. The shot firer verbally informs the instrument operator who arms the Encoder. The record "START" push-button switch is depressed which not only causes the tape transport to search reverse (see Chapter 2.4.3.) but initiates "FIRE" command to the Encoder. The Encoder starts transmitting a synchronization or 'sync' code beginning with the sequencing of 2280Hz and a gap frequency alternating at 50Hz. This sequence is followed by a "flag" tone, which signals the Decoder to identify the next 50Hz crossover as being sync zero. Logic gating in the Encoder determines sync zero at a preset time after "FIRE" has been initiated. The crossover is sync zero in the Decoder.

At sync zero, the Decoder clock is precisely synchronized with the Encoder clock. At a preset time later, the fire time is determined and correspondingly the Decoder counts a delay time from sync zero to be "FIRE" time. At this point, the Encoder counter outputs a clock time break and the Decoder counter triggers a silicon controlled rectifier that switches the charged capacitor across the cap terminals (which initiates the detonator). The capacitor is thus discharged a preset time after "FIRE" command and there is exact time coincidence with the clock time break outputted by the Encoder.

The real time occurence of shot initiation (confirmation time break) is transmitted back by radio as modulation of an FM subcarrier. Thus, the Decoder reverts from receiver to transmitter, repeating the time break every 200 msec six times over.

The Encoder has electronicallypreset delays to alternate from a transmitter to a receiver. Demodulation of the FM subcarrier is performed and the confirmation time break is output as a one volt spike to the Format Module Blaster Input. Clock time break and confirmation time break may be recorded with no time difference. Timing is programmable by jumper wires on the Encoder Timer Module, and on the Format Module hinged plane jolo circuits. Field time break detection is adjustable on the discriminator card and on the internal panel fire adjustment sensitivity potentiometer.

With reference to Format Module Manual Appendix C page C-2, the programmable jolo for setting ITB is in position A8 on the hinged plane, whereas the jolo for setting FTB is in position A9. Jolo A8 was found to have a link between pins 4 and 11 indicating an internal time break setting of 256 milliseconds for use with marine air-guns. Jolo A9 had links between pins 4 to 5, 6 to 8, and 11 to 3 giving a field time break delay of 256 msec (and secondstart delay 48 msec). i.e. The ITB and FTB coincided 256 msec after FIRE command in order to ensure the marine air-guns always fired on time.

Due to the inherent variation delays of radio operations, it was necessary to reduce the radio blast delay and/or expand the ITB delay. Hence, link 11 to 3 was replaced by link 10 to 3 (reducing radio blast delay to 128 msec) on A9, and link 11 to 4 replaced with 12 to 4 (increasing ITB to 512 msec). This adjustment was made after continual firing of radio equipment under test bench conditions. With 2 metres between radio antennae, the instruments fired remotely generating FTB without ITB interruption. However, an ITB generation 512 milliseconds after "FIRE" command is unreasonably long, since data is frequently of interest after 300 milliseconds. Hence, the ITB was reconnected (pins 10 to 5) to be 256 milliseconds. Manufacturer's manuals suggest an ITB delay of 128 milliseconds (Format Table 2-7, page 2-19) but this was considered too short for remote radio firing. With an FTB delay of 128 milliseconds, it was then necessary to establish delays in the shot firing equipment.

The Format manual (same page as above) also indicated that a 600 millisecond radio blaster delay is necessary to place the FTB in the middle of the time break window. This is to allow for the tape transport to start in reverse, read the end-of-file header of the previous record, and record the header record at start of recording. Consequently, a 600 millisecond delay to firing the source is necessary.

This is accomplished by programmable links on the Encoder 'Timing' Board and on the Decoder link card. A delay commences to allow time for Encoder and Decoder to synchronize - this is the sync zero delay time. A second delay in both Encoder and Decoder allows the Decoder charge to build up before firing the detonator, such that on firing a total 'FIRE' time of 600 milliseconds has elapsed in the Decoder. The Encoder must therefore have a programmed delay in order that it may transmit a time break at the same time of reception of FTB from the Decoder. This time break is the clock time and the true FTB is the 'confirmation time break'. Due to the vagaries of radio transmission, it is preferred to adjust the clock time break to coincide with the confirmation time break, in order that a definite FTB has been accurately received.

Thus, sync zero delay + Fire delay = Clock time break delay. Sinc zero and clock time break delays are programmable on the Encoder (recording vehicle), with FIRE delay programmable on the Decoder (shot firer). When programming sync zero, allowance is made for an additional 20 msec, which is automatically added by the Encoder circuitry. Programming is performed in BCD notation using links and, for a precise description, Please refer to the manufacturer's technical SSS 200 Installation and Maintenance manual (Section 4.4.2, page 7).

A typical delay calculation is shown:

For a sync zero of 200 msec, the delay setting operates in increments of 40 msec. With a 200 msec increment condition and, because the Encoder has a built in delay of 20 milliseconds, the actual link delay is 200-20 = 180 msec.

Since Sync Zero + Fire Delay = Clock Time Break (FTB = 600 msec), then Fire Delay = 600-200

= 400 milliseconds.

Thus, a 180 millisecond delay is executed with link pins FCO and FB3, and a clock time break of 600 milliseconds with link pins C1 and C2 on the Encoder.

A 400 millisecond FIRE delay is executed with link pin S3B2 on the Decoder.

Thus, a 600 millisecond delay is achieved allowing the DFS to perform necessary Search, Read and Write logic functions prior to reception of the FTB. The FTB and confirmation time breaks are recorded on auxiliary channels during normal data recording.

3.5.2. Vibrator Operations

The system was operated in conjunction with a Vibroseis source. Since the system does not contain a correlator, the function of this test was to observe the sweep frequency and compare it with the explosive impulse source. The system may be used to initiate a vibrator sweep via radio control or land-line. The following description is for use with a Geosource Controller type SHV-310/A.

The Decoder/Encoder delays remain the same as described earlier. However, the detonator leads are replaced by a high voltage relay coil. Upon energization, the normally open contacts short integrated circuit M22 pin 3 to earth ("manual start" - Mandrel Products drg. 57411-S). This pulses the NAND gate and initiates start of sweep. M22 is located on the Master Clock Assembly card (Geosource Electronic Systems Div. drg 57411).

3.6 Input Transformer

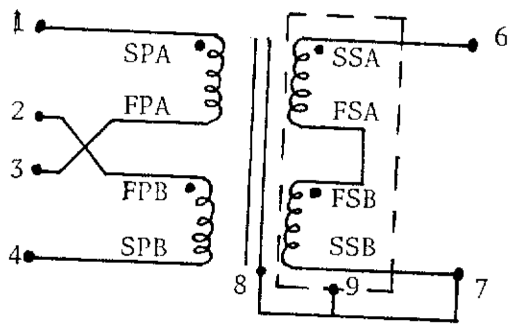
Chapter 2.2 discussed the reasons for the Input Transformer in terms of impedance matching. It explained when the marine application was reviewed, that marine hydrophones are transformer coupled in the seismic cable and, as a result, presented a high input impedance greater than 1000 ohm to the input transformer. As a result, the input transformer has a selectable input impedance so that the primary winding may have a value of 2000 ohms.

Alternatively, the relatively lower impedance values of land geophone strings (see Chapter 3.3) allow the use of a lower transformer primary impedance of 500 ohms. Hence, it is conventional to set the input windings at 2000 ohms for hydrophone use, and 500 ohms for geophone use.

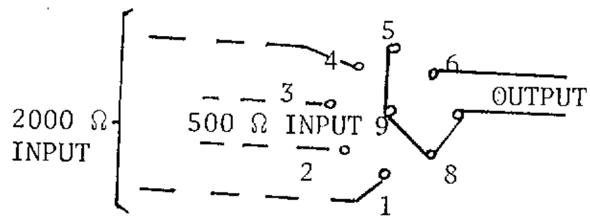
Input transformer circuit location is illustrated on Texas Instruments drawing 247802 (Input Module Manual), and Figure 3.5 clarifies the connection routine. As shown, connection of pins 1 to 2 and 3 to 4 puts the two primary windings in parallel to give 500 ohms line impedance, whereas the connection of 2 to 3 puts the primary windings in series to give a 2000 ohms line impedance. The line input signal is across terminals 1 and 4.

Consequently, all 48 input transformers had their windings changed from 2000 ohms (since they had previously been connected to a marine cable) to 500 ohms by removal of the link between 2 and 3, and the soldering of terminals 1 to 2 and 3 to 4.

CIRCUIT DIAGRAM



PIN ARRANGEMENT



SP = START PRIMARY

FP = FINISH PRIMARY

SS = START SECONDARY

FS = FINISH SECONDARY

LINE OHMS	CONNECTION	TURNS RATIO
500	1 to 2; 3 to 4	1: 2.50
2000	2 to 3	1: 1.25

Figure 3.5 INPUT TRANSFORMER CONNECTION DIAGRAM

(Extract from Texas Instruments Drg. 247802)

At the base of each Input Module transformer set, a pair of transformer posts are maintained to encode the desired logic for recording header constraints, informing that the transformer connection is either 2000 ohms or 500 ohms. A link was placed across each Input Module transformer set posts, to ensure that a 500 ohm input transformer would be encoded in the header record.

Since the input transformer's impedance was reduced from 2000 ohms to 500 ohms (an increase in turns ratio from 1.25 to 2.5), this gave an increase in signal amplitude of two times or 6dB. As a result, the incoming signal to the pre-amplifier stage would be 6dB higher in amplitude than with the higher impedance connection, requiring the pre-amplifier gain (or 'gain constant') to decrease by 6dB. Hence, after the transformer change was made, all gain constant switch settings were reduced by 6dB (30dB down to 24dB).

3.7 Seismic Cable Arrangements

Each Input Module accepts 12 seismic data channels via a 27 pin Cannon plug. For 12 signal wire pairs, pins 1 and 2 constitute trace 1, 3 and 4 are trace 2 and so on, until pins 23 and 24 are trace 12.

A 24 trace cable was loaned by the Bureau of Mineral Resources, details of which are shown in Figure 3.6. Geophone take-outs are staggered so that connecting a second cable to the left

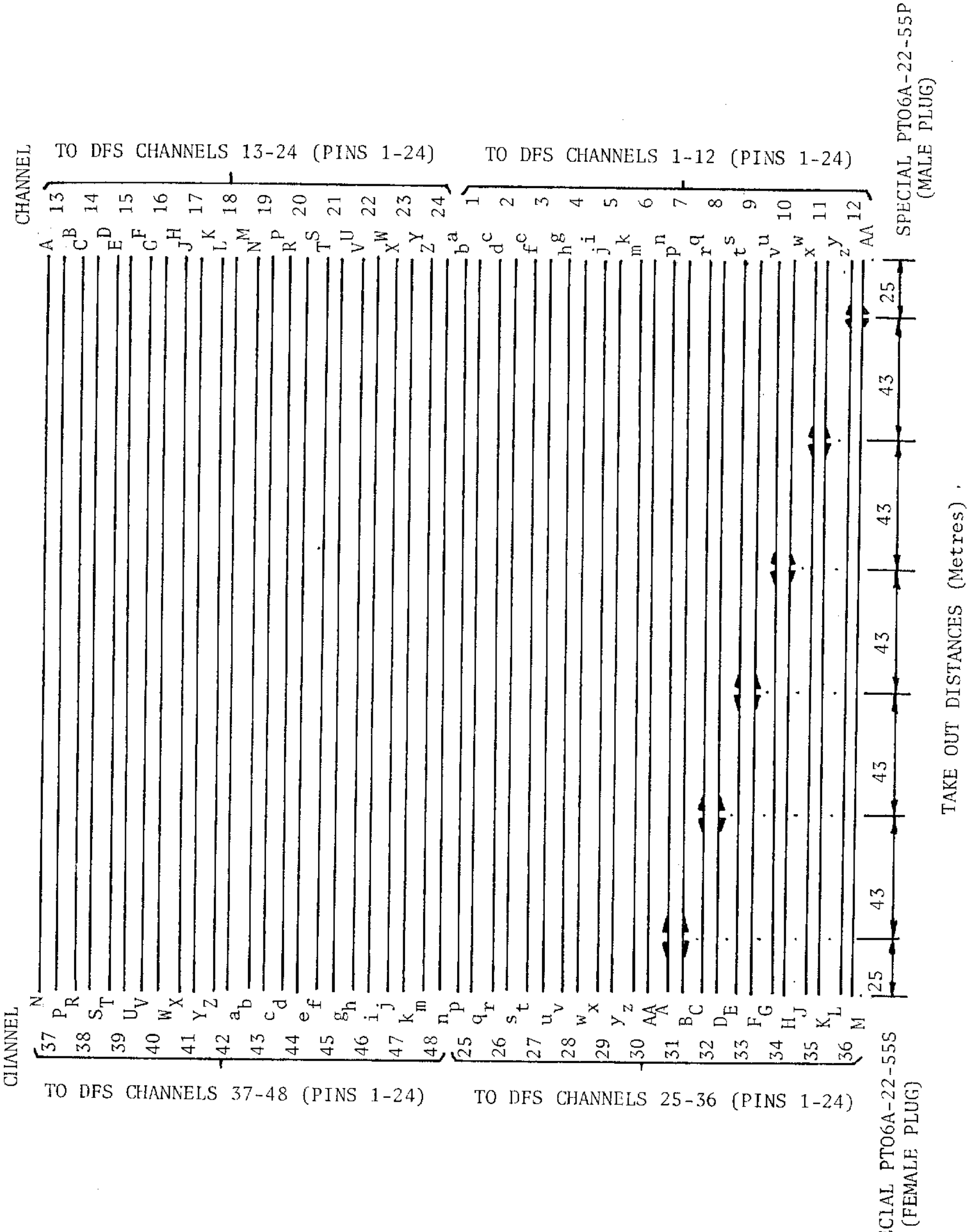


Figure 3.6 Cable Take-out Arrangement

(on the Figure) allows 6 more take-outs to be recorded on the right. To operate a 48 channel recording instrument with a 24 trace seismic cable, it is necessary to position the recording instrument centrally, allowing an input from 24 traces in one direction and 24 in the other - in "split-spread" recording configuration as shown in Figure 3.7. Hence, it was necessary to take the 12 channel input cable to two Input Modules and transform them into a single 24 trace cable.

After an exhaustive search, two 'Special' connectors were located and, with four standard common connectors, the appropriate interconnecting cables were manufactured.

During the normal multi-fold seismic recording routine, the recording instruments are connected at one point along the cable and, using a 'roll-along' switch, the instrument operator can switch-in any set of 48 traces he requires to monitor. When the production routine commences, the energy source is moved along the seismic line and, at each shotpoint, the roll-along switch selects the data traces to be recorded from the appropriate section of cable. After data from the first shot-point has been recorded, the observer rotates or moves the roll-along switch to the next set up, without having to move the instrument vehicle. In this manner, operations are speedier and more efficient for rolling-along the seismic line. The maximum amount the instruments can maintain in a single position is dependent upon the number of wire pairs in the seismic cable available for monitoring. The more pairs available, the more

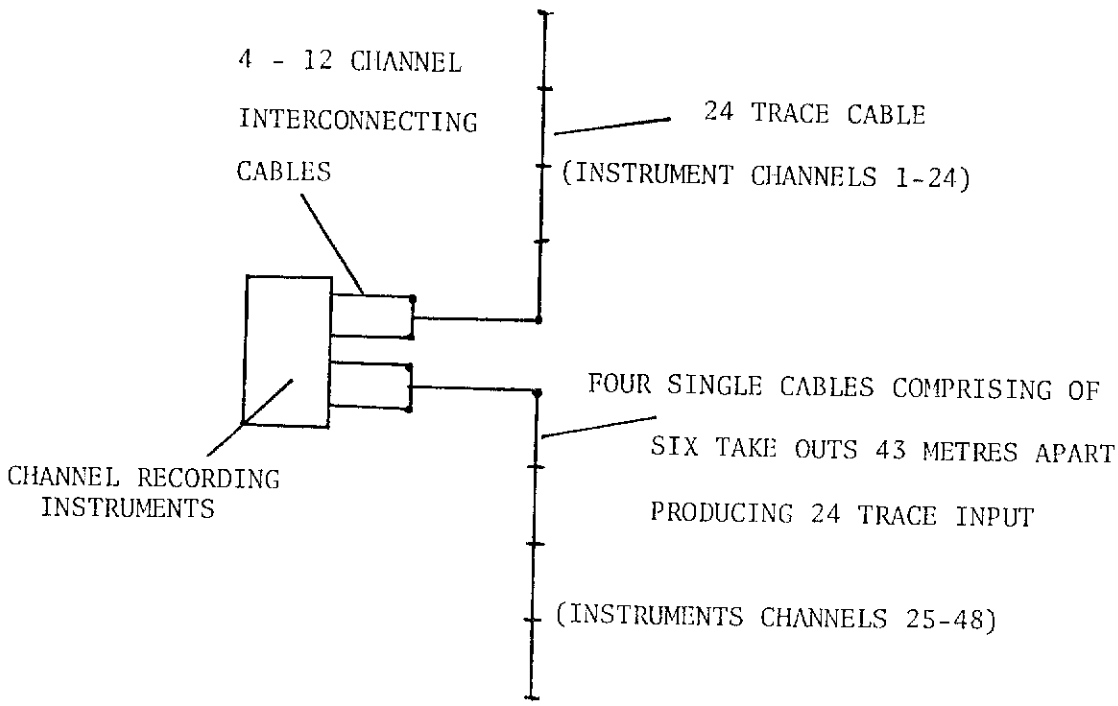


Figure 3.7 SPLIT-SPREAD RECORDING CONFIGURATION

recording which can be accomplished without moving the recording equipment.

The 24 trace cables were used in segments, each having six take-outs. Without a roll-along switch, the recording vehicle and cable was moved up after six shots (when each shot position coincided with a station take-out). This resulted in a variable offset in shooting. See Figure 3.8.

3.8 Oscillographic Camera Connections

As indicated in Chapter 1, a seismic oscillographic camera was initially loaned for the purpose of quality control of recording instrumentation.

The two conventional camera types which were later to be used, were the dry-write 24 trace ERC-10 and the wet-write 48 trace SDW-100. The ERC-10 was owned by WAIT but gave a poor display due mainly to the diminishing supply of good quality paper which had exceeded its expiry date. Consequently, it was preferable to wire the system for use with the loaned wet-write camera (although the product from this was poor as shown in the Appendix, it was far superior to the dry-write).

The re-wiring for any one particular camera, is a daunting task. If the 48 camera is to be used, 48 galvanometer data channels plus 4 or 6 auxiliary channels may be displayed. A rewire takes some two days to perform and, hence, the decision to perform the rewire is not taken lightly. The 24 trace camera

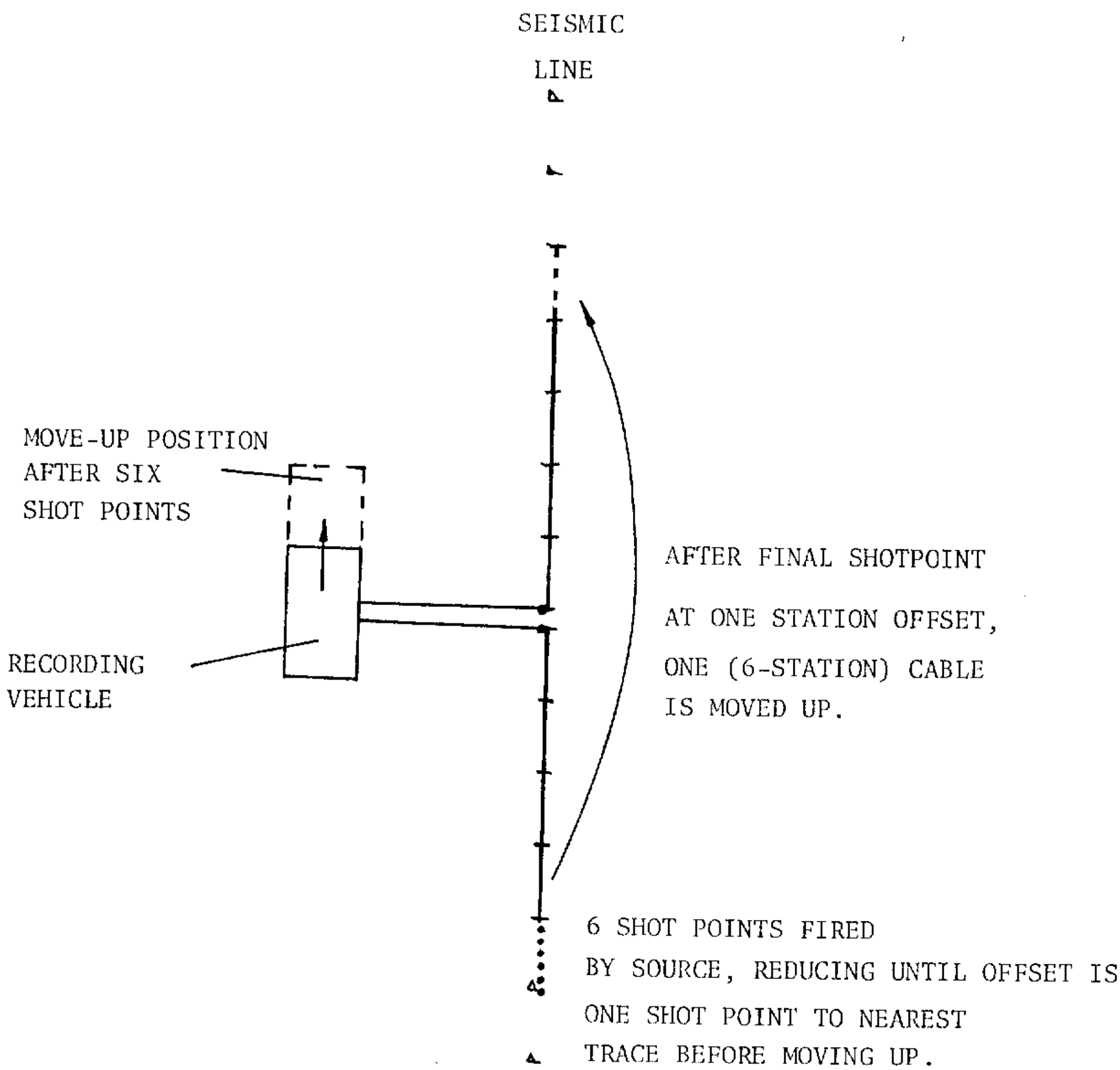


FIGURE 3.8 MULTI-FOLD RECORDING CONFIGURATION

takes no shorter time period since, to playback a 48 trace operation, it is necessary to plug in traces 1-24 first, run the playback, then unplug and replug in traces 25-48 to run these traces off the same recording.

Appendix V, Figure 5.1 shows reproduce galvanometer output connections; Appendix V, Table 5.1 shows the 48 pair inputs to 4-12 channel plugs. When other plugs are used, the 4-12 channel colour coding may be followed.

CHAPTER 4

INSTRUMENT TESTS

4.1 Instrument Calibration

Chapter 2 provided a technical appraisal of all equipment involved in the seismic data acquisition process. As indicated in that Chapter, if the recording equipment is to sample and store data in a precise manner, the equipment performance must be continually monitored.

To monitor equipment performance, and to ensure that it is operating under optimum conditions, a series of routine calibration and test procedures are adopted on a daily basis. If calibration checks are not performed, the data eventually recorded will not necessarily be truly representative of that presented at the input to the equipment. This is particularly the case where erroneous data levels during sampling can be amplified out of proportion. Thus, the main areas requiring calibration are those affected by the analog sampling and gain application processes. Other areas which have digital processes applied to them, such as logic commands and digital recording, tend not to drift but rather to fail completely. It is erroneous electronic DC-level drift which must be arrested from the outset.

The arrest of DC drift is performed by calibration routines, the major calibration adjustments being as follows:

4.1.1 Input Module

Gain calibration - The signal which passes through the analog filters has a fixed gain applied (gain constant) after filtering. The precise gain level is calibrated by injecting a signal of known value into the Input circuitry and the gain level is calibrated to the amount injected.

Zero offset calibration - The multiplexer DC offset must be reduced to zero, otherwise a DC noise level can result in multiplexed values being biased.

4.1.2 Amplifier Module

The three stages of amplification, as well as the input to the Line Amplifier, require DC offset adjustment on occasions. However, this is often not necessary since amplifiers tend to be fairly stable in operation and display minimal drift.

For these and other calibration procedures, the reader should consult the Input Module manual, and the Amplifier manual (Section 4.1, page 4-1). These calibration procedures are standard and use the Format Module display panel lights as indication of correct calibration. Less frequently performed calibration routines mainly involve the Read/Write/Transport modules. Minor adjustments to these units are performed when equipment fails and a component is replaced (refer to Amplifier manual).

4.2 Manufacturer's Approved Tests

A schedule of the manufacturer's approved instrument tests is provided in the Appendix. Note that Appendix 1 and II deal with tests performed on a daily basis whereas Appendix III indicates a more thorough set of tests - some of which require a computer print-out for evaluation.

Appendix 1 tests are performed daily, and are applied to the circuitry which may give early indications of circuit failures, and which allow a high potential for being repaired in the field.

Appendix III takes the test further and is performed monthly. Some contractors perform a further bi-monthly test which constitutes only a part of Appendix II. The important point is that Appendix III requires accurate equipment calibration before running, after which the magnetic tape is sent for analysis and evaluation at a computer processing centre. Hence, any errors not observed in daily tests will be located in the monthly tests.

4.3 Extraordinary Tests

4.3.1 Geophone/Hydrophone Testing

Apart from the series of approved manufacturer's tests, further tests may be performed on the recording equipment including seismic cables and geophone strings. If the seismic cable or geophones are not performing to specification the resultant data cannot be truly representative of the signal generated at the geophones (Pap, 1984).

Because the geophone is an electromechanical device, it applies some form of filtering of the received ground motion. Consequently, geophones ideally should be individually tested and compared against manufacturer's performance specifications. One method for testing a geophone is to place it on a 'shaker table'. After application of a fixed vibration of known frequency, the geophone's output voltage can be checked against specified values. Alternatively, the geophone being investigated may have its output connected across the vertical axis of an oscilloscope, and compared with a reference geophone which is also mounted on the shaker table, but has its output across the horizontal oscilloscope axis. When the shaker table is operating, the resultant outputs produce a straight line trace at 45 degrees across the oscilloscope screen. An open Lissajou's figure occurs if there is a phase difference between the reference phone and the phone under test. The 45 degree slope changes if there is an amplitude difference (see Figure 4.1).

An extraordinary test to check geophone performance is that of geophone polarity. A geophone's polarity is simply checked by connecting it across an oscilloscope galvanometer, such that the positive output is attached to the 'hi' line of the galvanometer. By running a record while lightly tapping its base vertically, a downbreak should occur and hence appear to break negatively. (SEG standard polarity definition.)

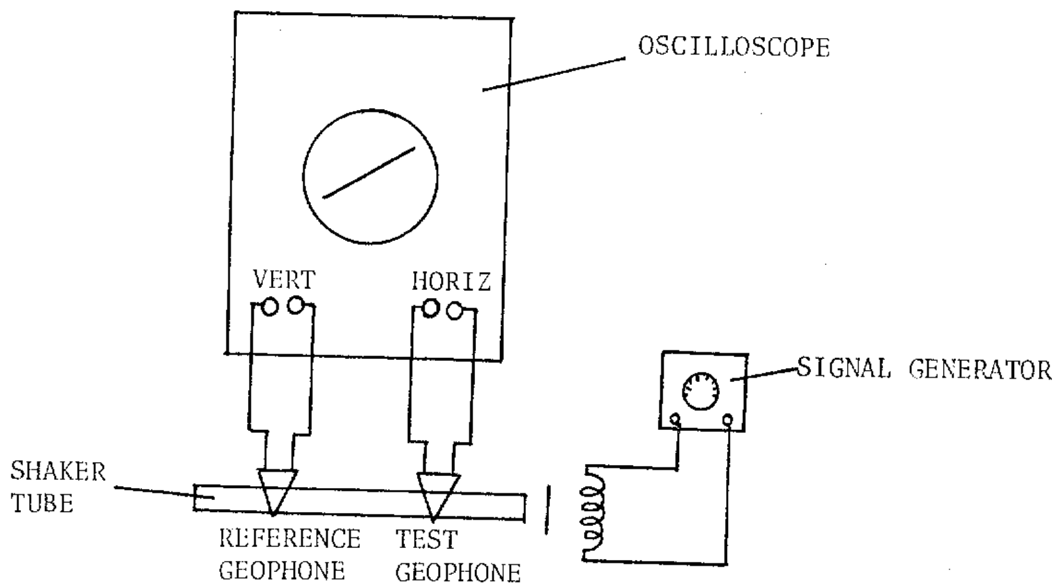


FIGURE 4.1 SHAKER TABLE GEOPHONE TESTER

Having determined the geophone's polarity, it may be inserted across any input pair at the converter input terminals. A tap will check the system polarity, and a negative break is indicated by a negative sign lamp flashing on the Format display panel (with zero fixed gain in order that the lamp does not toggle on noise).

A similar 'tap test' may be performed with the marine hydrophone to test its polarity and sensitivity. The hydrophone's performance is damped, being submerged within the cable body in a Naroma type cable fluid. Instead of lightly tapping it, the hydrophone requires a firmer tap with a mallet handle. Provided each hydrophone is given a similar blow, this is a simple but effective check that all hydrophones are of similar sensitivity and polarity.

A further check of equipment is known as the 'Impulse Response' test. This is performed with the analog filter as the 'pulse test', which is used to check that filters are performing to specifications. The pulse test or impulse response passes a 160 microsecond spike through all analog filters - the output being an indication of how the filter responds. However, the technique can also be applied to checking geophone and hydrophone response. In the geophone case, a square pulse is applied on one of the wires of a geophone. This causes the magnet in the geophone coil to physically move and the geophone's electrical output may be then analysed by analog oscilloscope trace or digital sampling equipment. Analysis of the waveform yields various properties of the geophone e.g. resonant frequency, sensitivity, phase characteristic and electrical properties such as resistance, inductance and capacitance.

In the case of the marine hydrophone, a square pulse is transmitted along the cable line to the hydrophone section. This executes the equivalent of a compressional action on the crystal hydrophones which respond with a transmitted signal back along the seismic cable. In like manner to the case of the geophones and hydrophones sensitivity, phase and damping resistance can be computed. However this method fails to produce the desired results often when transformer coupled hydrophone sections are used - the transformer damping resistors effectively damping both received and retransmitted signals. In addition, this method can only check groups of hydrophones rather than individual phones as in the case of the geophone application. It is thus often prefered to revert to the time honoured method of tapping the phones as the marine cable is streamed into the water.

4.3.2. Cable Testing

If the seismic cable is not in good condition, there is a high probability that it is in poor electrical condition also. For low voltage signal to pass a distance of one kilometre and be faithfully recorded, the conductors must have a high resistance across each other and to ground. The wire resistance between geophone and Input Module should be minimal. Hence, continuity of signal path and minimal leakage between conductors and ground is essential.

For this reason, the Amplifier Test Unit has an ohmmeter which enables the operator to check seismic signal path continuity and leakage conditions. If leakage occurs, it frequently displays itself as a high level 50Hz signal impressed on the seismic signal - irrespective of whether generators or other equipment is running. Hence, continuity and leakage checks are always of great importance in checking the seismic cable condition.

4.3.3. P and S-Wave Geophones

The instrument tests are described in the Appendix. One series of tests not discussed however was that performed as a comparison of P and S-wave geophones. Files 053 to 057 (Figures 4.2 to 4.5) were recorded with the geophones' outputs applied at the converter input terminals. A negative going break was observed (Figure 4.2 overpage) when the p-wave geophone was tapped vertically at its base. Figure 4.2 indicates the negative break also, while Figure 4.3 indicates a similar performance using a horizontally polarized S-wave geophone (tapped vertically from the top of its case). Figure 4.4 is the same geophone tapped at its base, and demonstrates an up-break, as it does in Figure 4.5 when it is tapped horizontally (in the direction of polarization).

These tests illustrate that it is of extreme importance, when working with the geophones of particular polarization, to which azimuth the horizontally polarized geophone is directed. Since the comparison of p and S wave is very much in vogue, this basic fact must not go unnoticed.

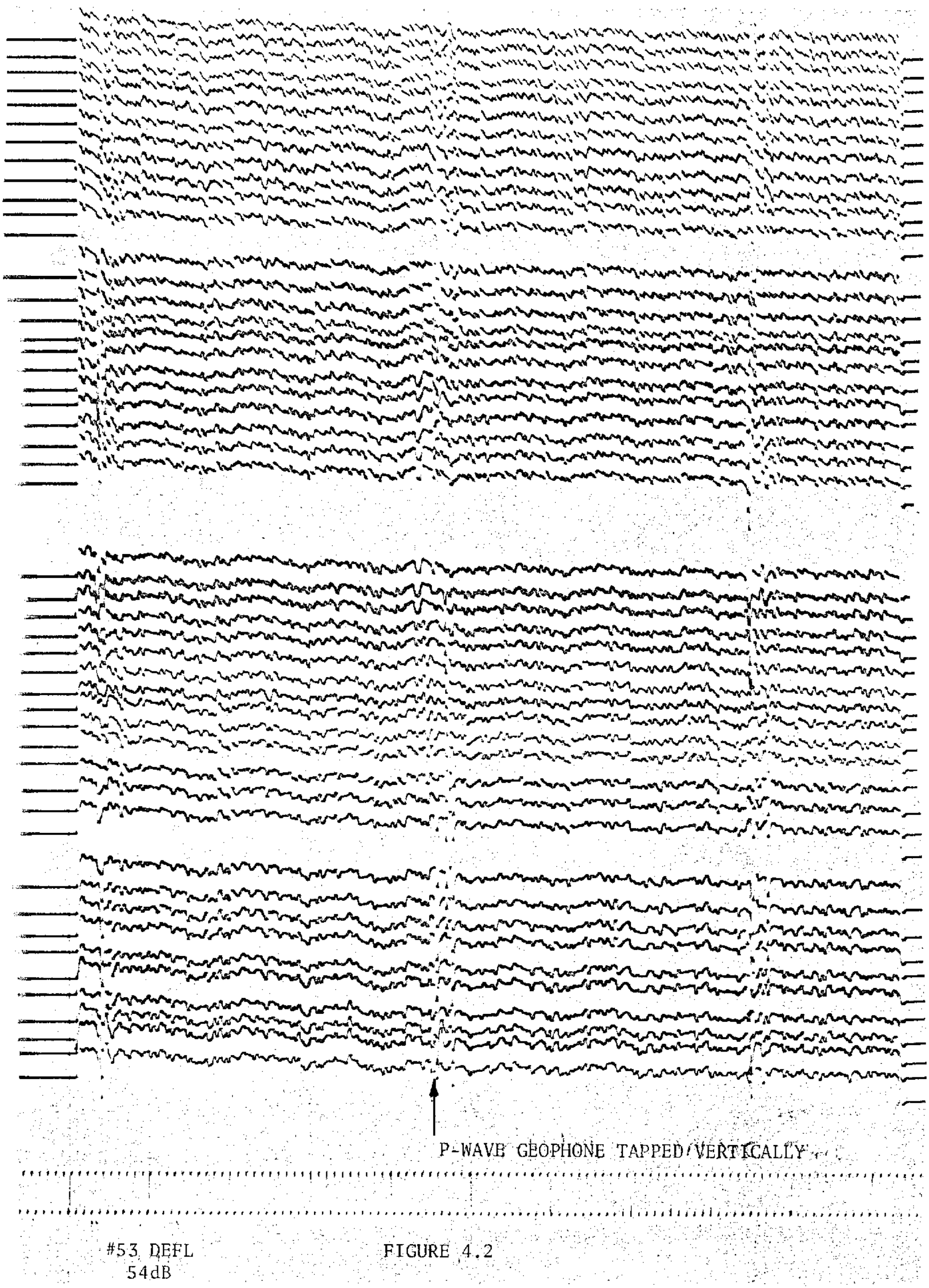
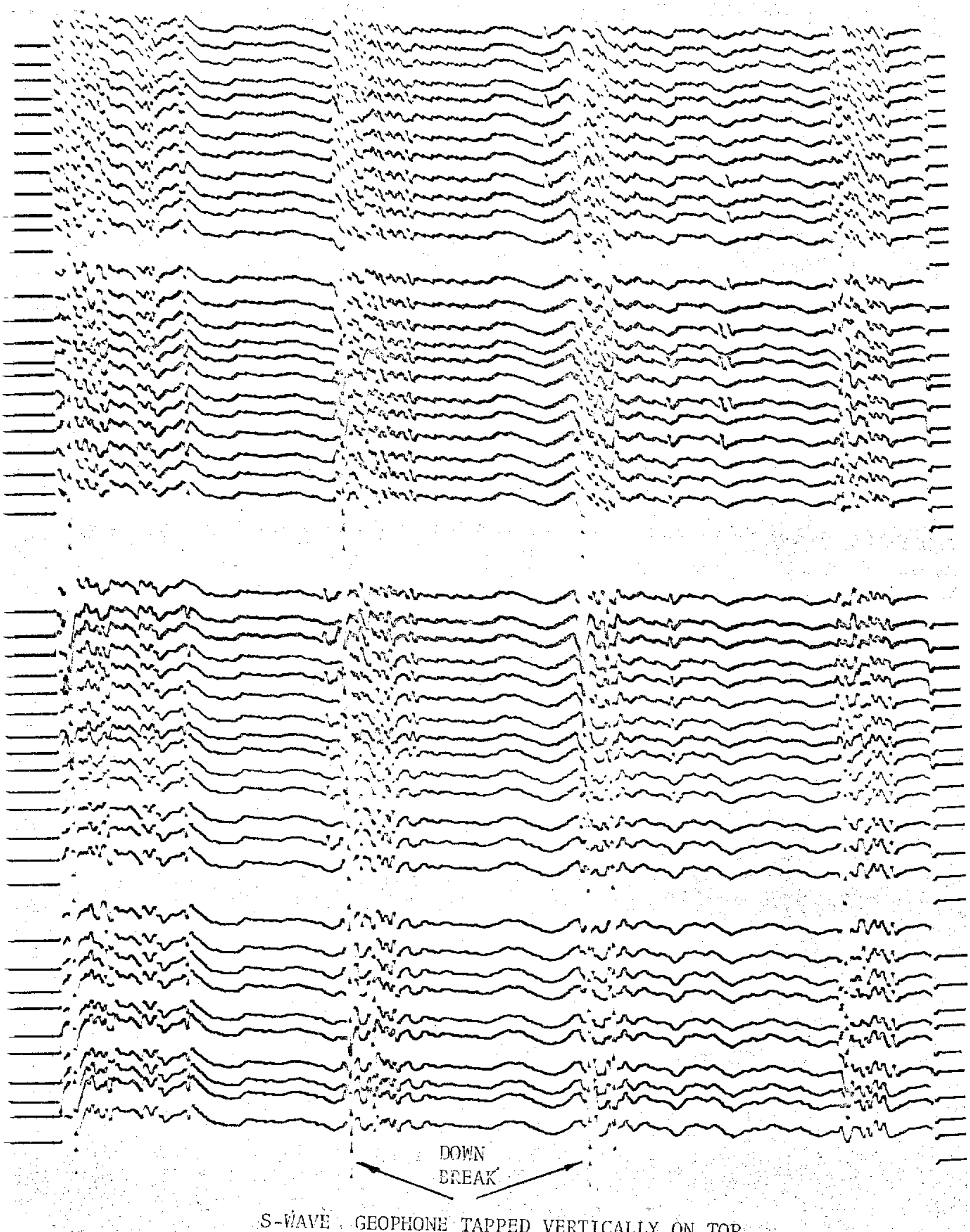


FIGURE 4.2



S-WAVE GEOPHONE TAPPED VERTICALLY ON TOP

#54 DEFL
48dB

FIGURE 4.3

0dB MANUAL GAIN

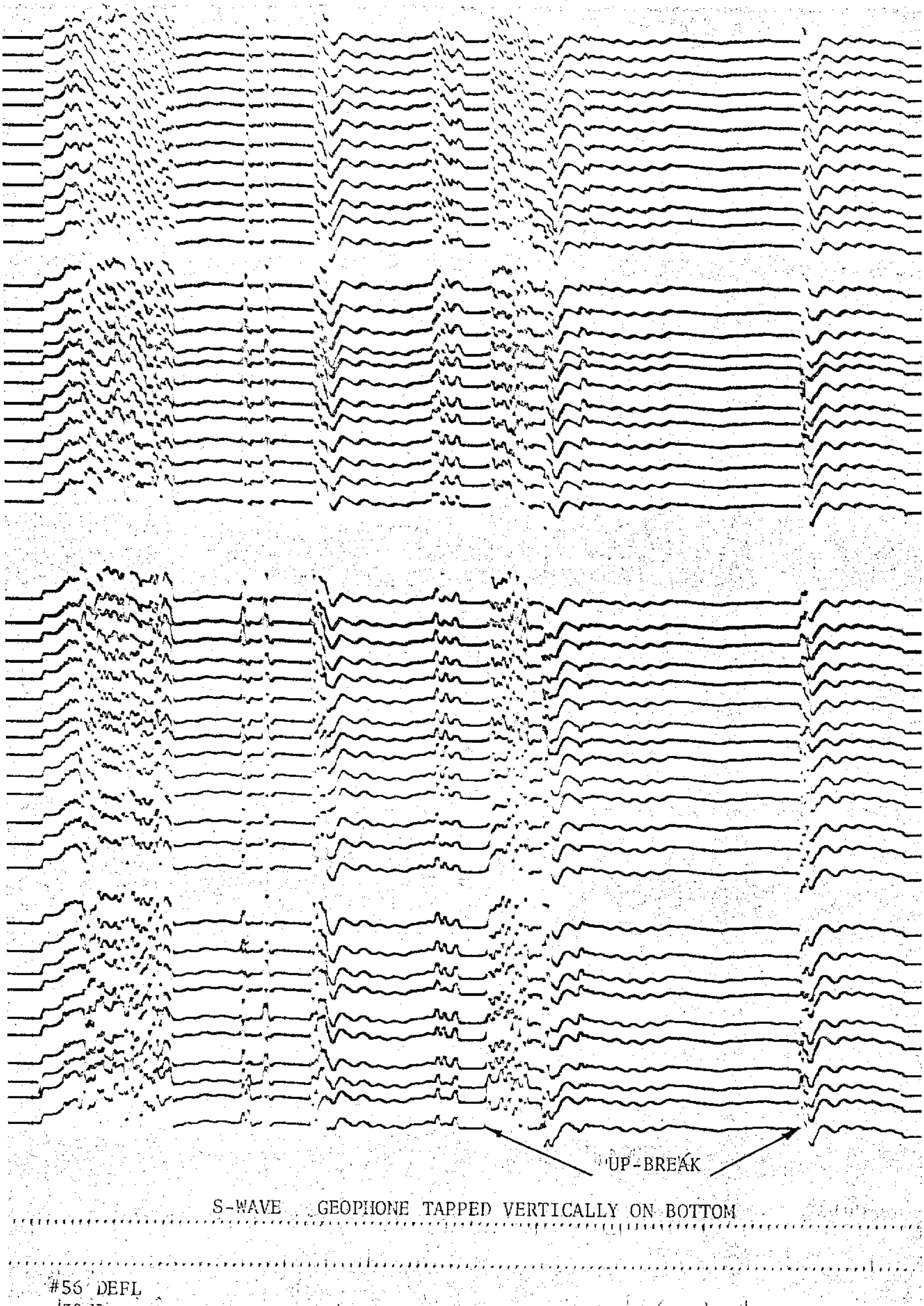
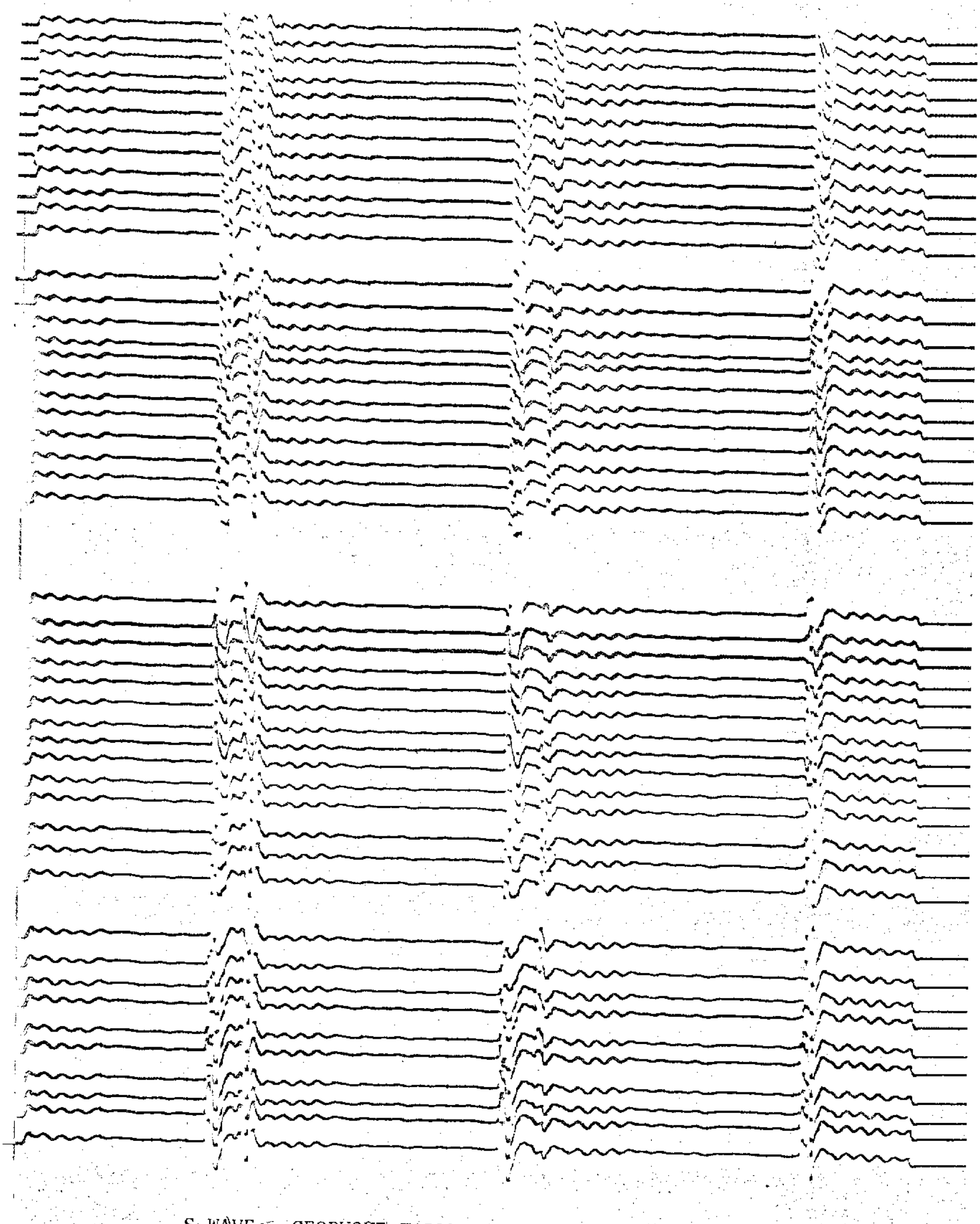

UP-BREAK
S-WAVE GEOPHONE TAPPED VERTICALLY ON BOTTOM
#56 DEFL
30dB

FIGURE 4.4



S-WAVE GEOPHONE TAPPED HORIZONTALLY

57 DEFL
-30dB

FIGURE 4.5

4.4 Test Analysis

The failure of any recording instrument to meet manufacturer's specifications may not only be technically avoided but is economically undesirable. If a crew's recording instruments fail their stringent tests, the crew shuts down costing the contractor up to $10,000 per land crew day, and as much as $40,000 per marine crew day. It is therefore cost beneficial, apart from other considerations, to have a rapid turn-around of the more stringent monthly tests.

For this reason, equipment manufacturers have produced software packages that rapidly assist the computer centre geophysicist to analyse and interpret computer number dumps or test print-outs. In the case of the DFS IV program, a standard test form was compiled by the manufacturer, as well as an analysis sheet. The Geophysical Service Inc. TIMAP computer uses processing package P905, and the guide to the use of the P905 interpretation is given as Appendix III Section 11 page 177. For this particular series of tests, the author felt it was preferable to accept typical bad traces, rather than spend hours calibrating the system to perfection (as is normally the case). As a result, the reader may appreciate what a good or bad trace looks like.

According to manufacturer's literature, the recording instruments are ready for operations within 2 to 3 minutes of powering-up. The series of tests analysed in the computer print-out Table 3.14 would pass the Dynamic Range Determination (DRD of 84dB), be within filter pulse amplitude and phase specifications, but would fail the converter offset, channel DC offset and amplitude tests. The reason for failing these tests, for the most part, is because the offset electronics had not settled, whilst the Test Unit signal generator had not stabilized.

A review of the instrument paper records will indicate in fact, that channel 35 was very noisy. However, it was not significantly noisy on the print-out since the test evaluation gives an average indication of noise levels and, clearly, the RMS noise of channel 35 still maintains instrument specification.

When the computer analyses noise levels, it always gives an RMS value less than that determined from field records. This is because the peak-to-peak value of a sine wave is just less than 3 times the RMS value, whereas the equivalent value of a noise waveform is more like 6 times the RMS value. The computer evaluates RMS noise with the following steps:

(i) reads each data sample and sums them

(ii) divides by a total number of samples to determine DC offset

(iii) subtracts the DC value from each sample

(iv) squares the difference

(v) sums squares and divides by the number of samples

(vi) square roots this (RMS voltage) and divides by total gain.

$$\text{RMS noise per channel} = \sqrt{\frac{\left(V_1 - \frac{\Sigma Vn}{n}\right)^2 + \left(V_2 - \frac{\Sigma Vn}{n}\right)^2 + \cdots}{n}} \quad (\div \text{ total gain})$$

(Espey, 1983)

where V_1 = First sample n = number of samples

4.5 Computer Displays

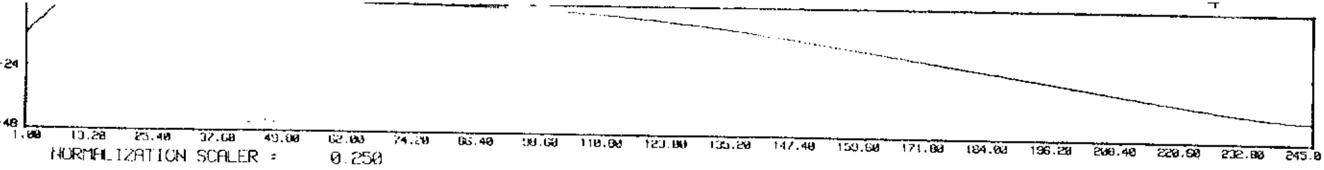
Apart from number dumps of test data, it is possible to produce computer derived graphic displays of instrument performance. One typical example is that of the filter pulse test. The amplitude and phase response to an input spike are found by Fourier Transformation. This impulse response characterizes the performance of the filter for any input.

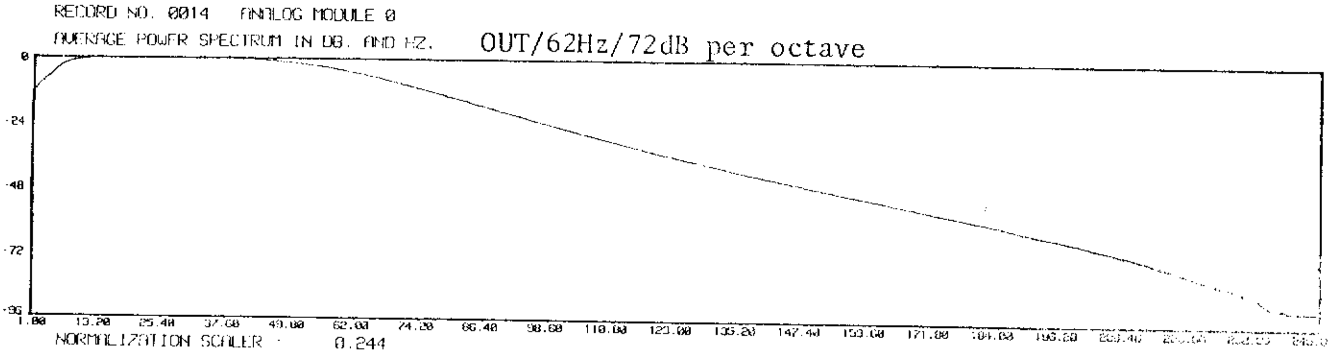
Displays shown herein after were processed by Geophysical Service Inc.

Figure 4.6 shows the power spectrum of various filters, with an upper slope of 72dB per octave. The expected 3Hz low cut off removing distortion effects of the input transformer is apparent. Since the frequency axis is not logarithmic, the presentation is different from that of Figure 2.9. Indeed, upon analysis, the following results are indicated at 48dB down when comparing Manufacturer's Figure 2.9 and computed amplitude response Figure 4.6:

Filter	Manufacturer's Cut-off (Hz)	Actual Value (Hz)
OUT/124/72	200	>245
OUT/62/72	100	160
OUT/31/72	50	77

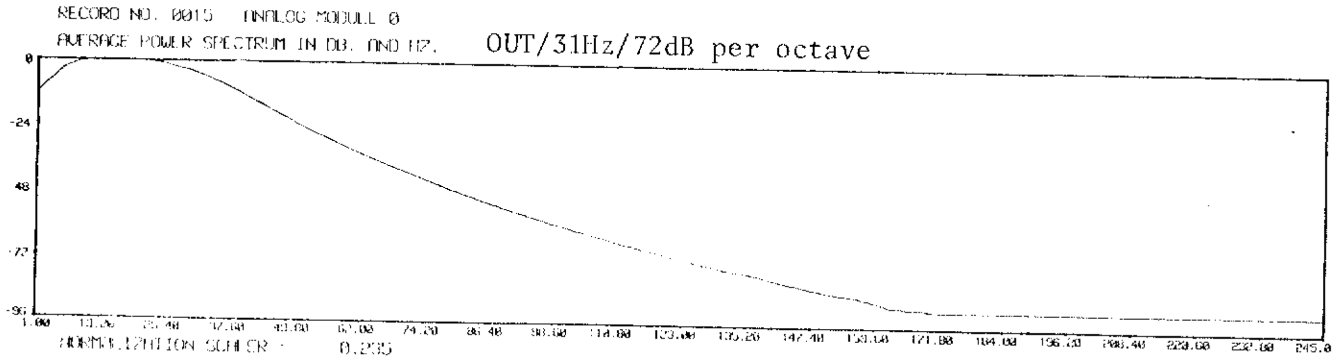
A comparison of high cut slope appears to have no effect, and suggests that the 72dB per octave option is not functioning effectively.



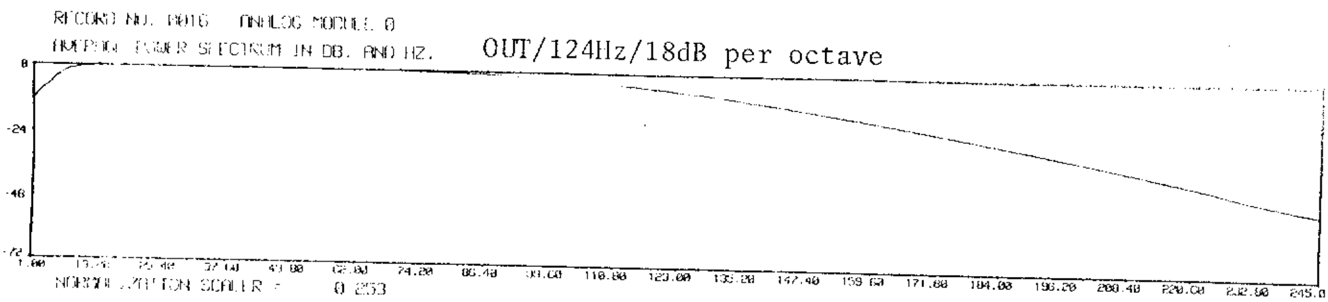


OUT/62Hz/72dB per octave

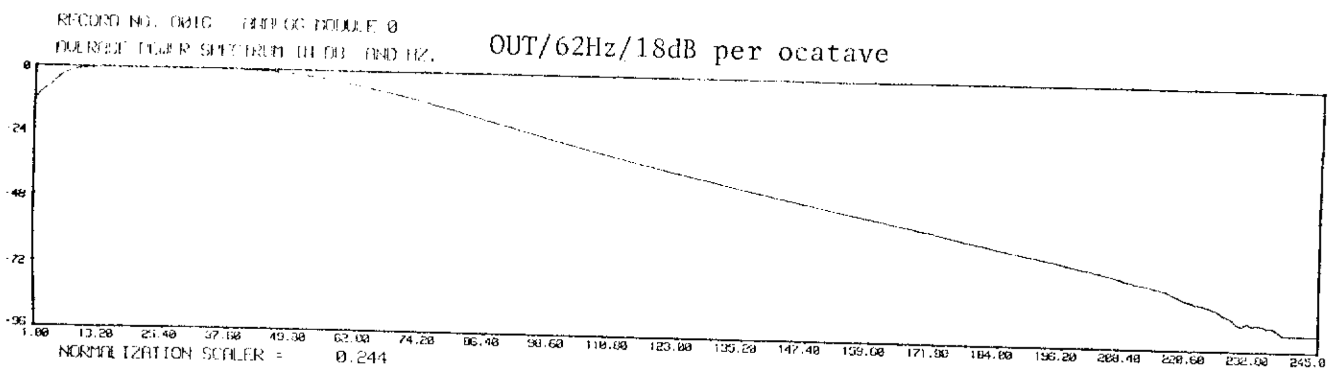
Figure 4.6 Power Spectrum of Various OUT Filters



OUT/31Hz/72dB per octave



OUT/124Hz/18dB per octave



OUT/62Hz/18dB per ocatave

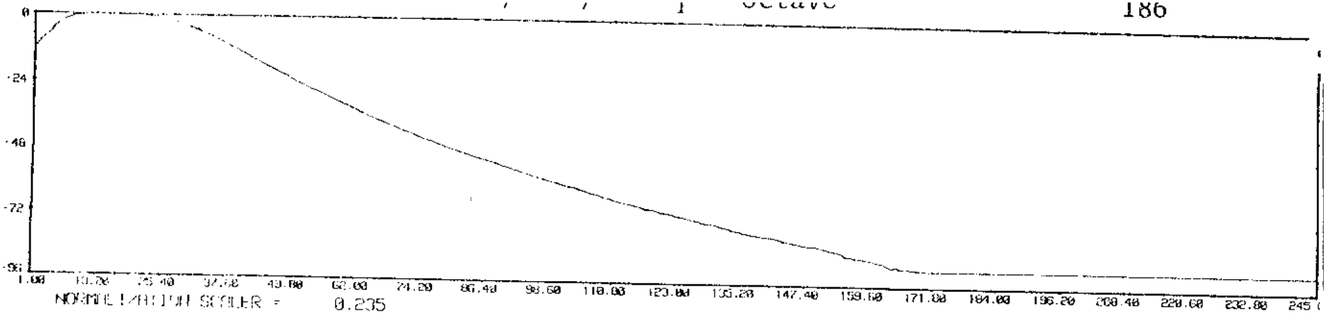
The value of actual slope appears to be closer to 30dB per octave than its 18 or 72dB per octave counterparts. It is also of interest to note the steep roll-off of the OUT/31Hz setting, the gradient of which reduces with increase in frequency.

The OUT/31Hz 18dB per octave slope is quite different from the other filter slopes at that setting. Indeed, all other settings are similar in gradient even when a low cut is employed, see Figure 4.7. On this figure, the low cut options of 8,12, 18 and 27 are effective passing through their respective 3dB down points at the desired values.

Finally, Figure 4.8 is a comparison of channels 1 with 43 at the same filter settings. It is noted that the 3Hz cut-off with channel 43 is more like 6Hz and, hence, it cannot be assumed that all channels have the same transfer function.

4.6 Fault Finding

After the system was initially connected up, it failed to power-up. The cause was found to be a faulty Reproduce Module power supply, the PNP power transistors of which had failed. Since the Reproduce Module power status is interlocked with the Format and Read/Write Modules, a failure in the Reproduce power supply disabled the powering-up logic circuitry. (If an Input Module had failed, this would not have been the case.) The power supply was replaced and the system powered-up.



RECORD NO. 0016 ANALOG MODULE 0
AVERAGE POWER SPECTRUM IN DB. AND HZ. 8/18/124/18

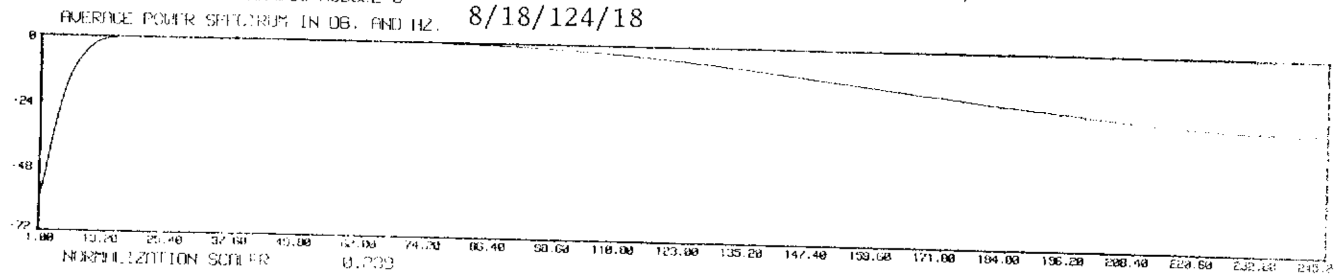
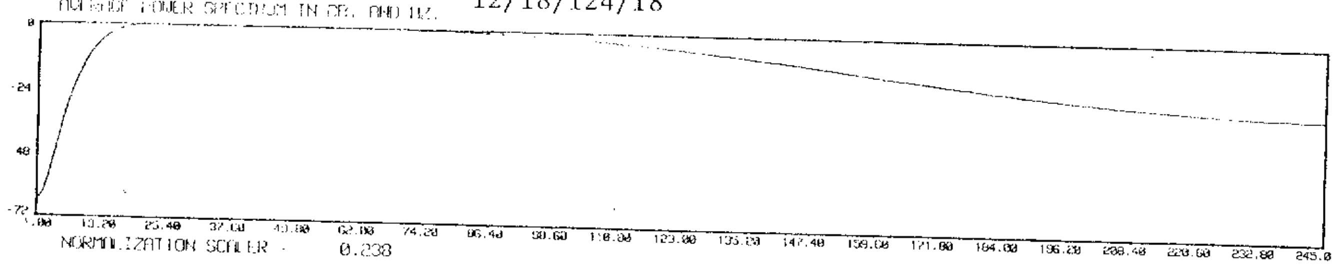
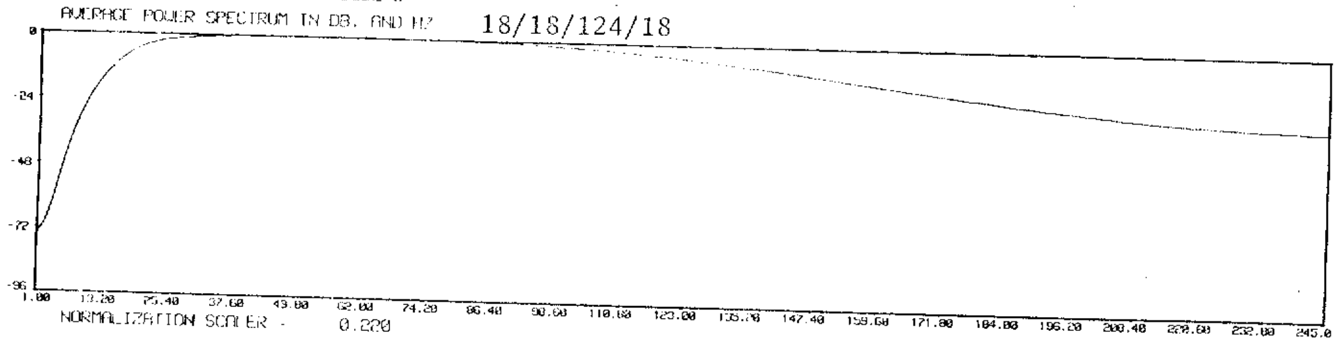


Figure 4.7 Power Spectrum of Various Low Cut Filters

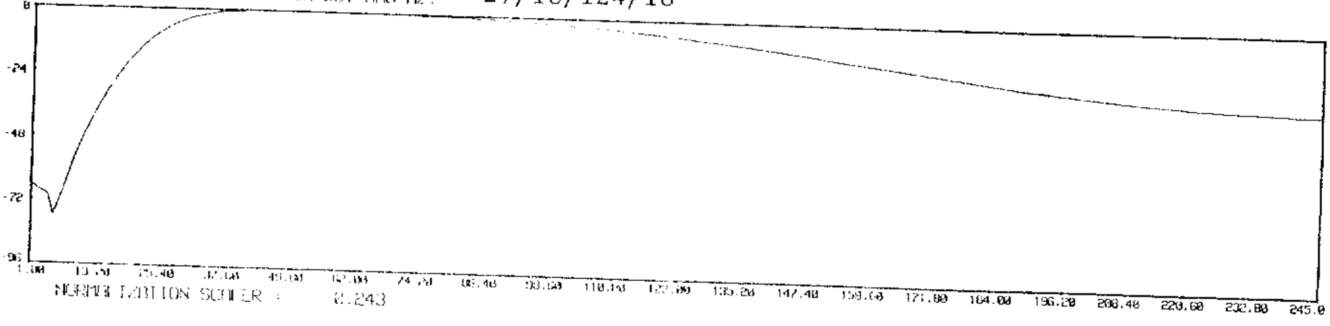
RECORD NO. 0016 ANALOG MODULE 0
AVERAGE POWER SPECTRUM IN DB. AND HZ. 12/18/124/18

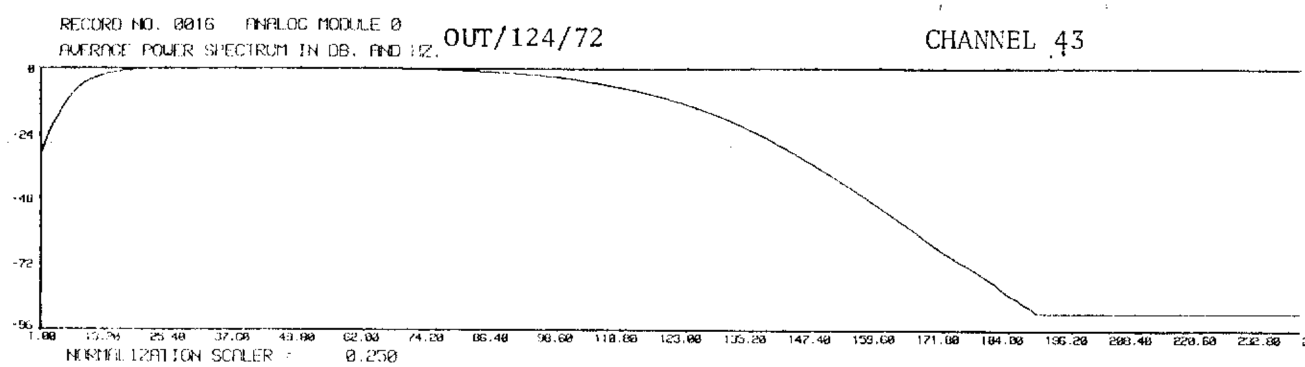


RECORD NO. 0016 ANALOG MODULE 0
AVERAGE POWER SPECTRUM IN DB. AND HZ 18/18/124/18



RECORD NO. 0016 ANALOG MODULE 0
AVERAGE POWER SPECTRUM IN DB. AND HZ. 27/18/124/18





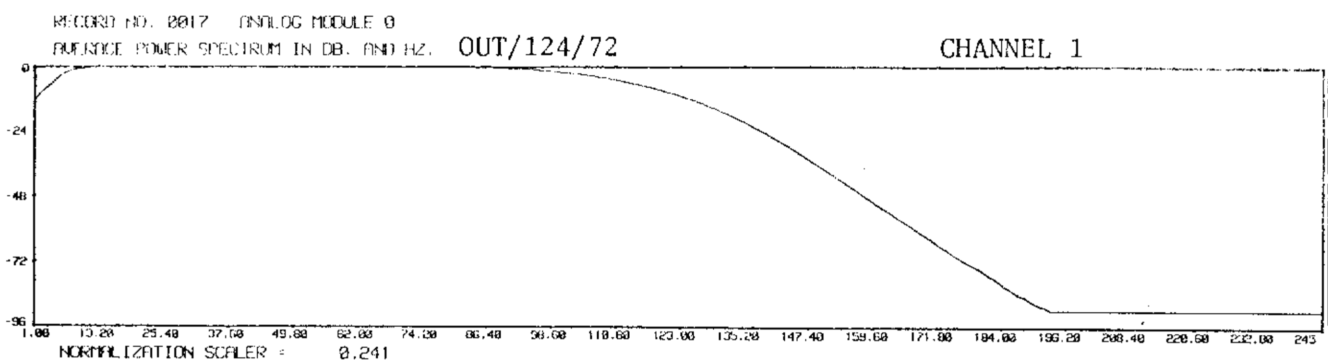


Figure 4.8 Power Spectrum Comparison of an OUT/124Hz Filter on Different Channels

A far more elusive fault was that of gain control. Under normal operations, the analog to digital converter provides a signal value in terms of mantissa and exponent. This is encoded on magnetic tape in the data block (see Figure 2.43). Four bit binary gain words for channels 1 to 4 are written on tape, ahead of the converter digitized 15 bit value for seismic channels 1 to 4. This is followed by the gain words for channels 5 to 8, their data values and so on.

From the outset, no gain control problems appeared to exist. All paper records appeared acceptable, except that occasionally at very weak signal input (when the Amplifier operated at full gain), the system noise would appear slightly spiky. A useful test to be performed is the exponential oscillator test. In that test, at an initial high signal level, paper records indicated no problem. Playback of the records, after the exponentially decaying signal had assumed a minimum value, appeared acceptable. However, this was a classic case where field monitors could not distinguish what was being digitized. In fact, the fault was random at first. The gain word logic in the Amplifier occasionally did not perform and hence, did not produce the gain word for encoding.

When the fault became a permanent feature, it was then possible to analyse test data number dumps. After recording a P905 IFPA oscillator test, the evaluation indicated a problem existed with the gain word setting (see Figure 4.9). Further octal number dumps of field records performed by the BMR in Canberra confirmed this (see Figure 4.10).

```
HEDUMP =0
IRFC   =12
NRFC   =1
DMPDAT =0
END

INPUT RECORD =  0012
   NO PARITY ERRORS DETECTED ON THIS HEADER RECORD
   NO PARITY ERRORS DETECTED ON THIS DATA RECORD
RECORD LENGTH =   8192 MSEC

++++++++++   1/2 INCH HEADER DECODE   ++++++++++

FILE NUMBER = 0012
FORMAT CODE = 0200
GENERAL CONSTANTS = 020584000000
BYTES PER SCAN =  134
SAMPLE RATE =  2
ID AND SERIAL NUMBER =  15000171
REC LEN * 1024 =  08
SYSTEM =  IFP
DATA RECORDED AS  TEST
LOW CUT FILTER SETTING IN HZ =  00
LOW CUT FILTER SLOPE IN DB/OCTAVE = 00
NOTCH FILTER SETTING IN HZ =  00
ALIAS FILTER SETTING IN HZ =  0128
CHAN  FIXED    EARLY
 01   30  DB  00  DB
FIXED/EARLY GAINS SAME THRU CHAN 04

IFPA OSCILLATOR TEST

FREQUENCY SAMPLE RATE IS   0.1221       FUNDAMENTAL FREQUENCY IS   35.8659

FOR TRACE   1, CHANNEL GAINS WERE TESTED IN  196 TIME GATES.
THE LAST GAIN TESTED WAS   0 DB.

FOR TRACE   4, CHANNEL GAINS WERE TESTED IN  196 TIME GATES.
THE LAST GAIN TESTED WAS   0 DB.

             TR =   1              TR =   4
   INDEX    TIME    GAIN          TIME    GAIN
     1         2     0               2     0
    10       380     0             380     0
    20       798     0             798     0
    30      1216     0            1216     0
    40      1634     0            1634     0
    50      2052     0            2052     0
    60      2470     0            2470     0
    70      2888     0            2888     0
    80      3308     0            3306     0
    90      3726     0            3726     0
   100      4144     0            4144     0
   110      4562     0            4562     0
   120      4980     0            4980     0
   130      5398     0            5398     0
   140      5816     0            5818     0
   150      6228     0            6228     0
   160      6646     0            6646     0
   170      7064     0            7064     0
   180      7484     0            7484     0
   190      7902     0            7902     0

*** THIS IFPA OSCILLATOR TEST IS NOT ACCEPTABLE.

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
```

Figure 4.9

IFPA Oscillator Test

```
10NOV84   TIME 11:28:08
TESTSW=10,
IRFC=13,
NRFC=3,
END1

FORMAT =52
NUMTRA =1
ITIM   =0
FTIM   =-1
AMOD   =2
ITRC   =1
NTRC   =4
REPORT =0
TESTSW =10
DECODE =1
HEDUMP =0
IRFC   =13
NRFC   =3
DMPDAT =0
END

INPUT RECORD =  0013
   NO PARITY ERRORS DETECTED ON THIS HEADER RECORD
   NO PARITY ERRORS DETECTED ON THIS DATA RECORD
RECORD LENGTH =   1024 MSEC

++++++++++   1/2 INCH HEADER DECODE   ++++++++++

FILE NUMBER = 0013
FORMAT CODE = 0200
GENERAL CONSTANTS = 020584000000
BYTES PER SCAN =  134
SAMPLE RATE =  2
ID AND SERIAL NUMBER =  15000171
REC LEN * 1024 =  01
SYSTEM =  IFP
DATA RECORDED AS  TEST
LOW CUT FILTER SETTING IN HZ =  00
LOW CUT FILTER SLOPE IN DB/OCTAVE = 00
NOTCH FILTER SETTING IN HZ =  00
ALIAS FILTER SETTING IN HZ =  0128
CHAN  FIXED    EARLY
 01   30  DB  36  DB
FIXED/EARLY GAINS SAME THRU CHAN 04

FILTER PULSE TEST
THE POWER USED FOR THE POWER RATIO TEST IS     0.2494

THE LIMITS USED ARE  MIN = 0.50   MAX = 2.00

NO TRACES FAILED THE POWER RATIO TEST.

THE CORNER FREQUENCIES OF THE AVERAGE POWER SPECTRUM ARE       2.9297    146.4844
TRACE
 NO.     [illegible]     PHASE IN [illegible]     PHASE IN MSEC [illegible]     DIFF IN
```

000000	000000	000000	000000	000000	000000	000000	000000
000000	000000	000000	000000	000000	177774	000000	000000
000000	000000	000000	000000	000000	000000	000000	000000
000000	000000	000000	000000	000000	177770	000000	000000
000000	000000	000000	000000	000000	000000	000000	177774
000000	177772	036475	036477	000024	177726	000036	177750
000034	000000	000000	000000	000000	177774	000000	000000
177772	000000	000000	000000	000000	000000	000000	177774
000000	000000	000000	000000	000002	000000	177774	000000

RECORD NUMBER 5

000000	000000	000000	000000	000000	000000	000000	000000
000000	177774	000000	000000	000000	000000	000000	177774
000000	000000	000000	000000	000000	177774	000000	000000
177766	177774	177774	000000	000000	000000 a	177774	000000
000000	000000	000000	000000	177774	036475 a	036477	000030
177732 c	000036 d	177746 e	000034 f	000000 g	000000 h	177774 j	000000
000000 l	000000 m	000000	000000	000000	000000	000000	177774
177774	177774	000000	000000	000000	000000	000000	000000
000000	000000	000000	000000	000000	000000	000000	000000
177774	000000	000000	177774	000000	000000	177774	000000
000000	177774	000000	000000	000000	000000	000000	000000
177772	000000	000000	177766	177774	177772	000000	177774
000000	000000	000000	000000	000000	000000	000000	177772
036475	036477	000034	177730	000036	177746	000034	000000
000000	000000	000000	177774	000000	000000	000004	177774
177772	000000	177774	000000	177774	000000	000000	000000

RECORD NUMBER 6

000000	000000	177770	000000	177772	000000	177774	000000
000000	177774	177774	177774	000002	000000	000000	177774
000000	000000	000000	000000	000000	177774	177774	000000
177774	177774	177774	177772	000000	000000	000000	177774
177772	000000	000000	000000	177774	000000	000000	000000
000000	000000	177774	036475	036477	000040	000044	000036
177750	000034	000000	000000	177774	000000	000000	000000
000000	000006	000000	000000	000000	000000	000000	000000
000000	000000	000000	000000	177774	177770	000000	000000
000000	000000	000000	000000	000000	000000	000000	001154
000000	000000	000000	000000	000000	000000	000000	000000
177774	000000	000000	000000	000000	000000	177774	000000
177774	000000	000000	177774	000000	000000	000000	177774
000000	000000	000000	000000	177774	000000	036475	036477
000044	000052	000040	177750	000032	000000	177774	000000
000000	000000	000000	000000	000006	000000	177774	000000

RECORD NUMBER 7

177774	000000	000000	000000	000000	000000	000000	000000
177764	000000	177774	177774	000000	000000	000000	000000
177774	000000	016522	000000	000000	000000	000000	000000
000000	000000	177774	000002	000000	000000	000000	000000
000000	177772	000000	000000	000006	000000	000002	000000
000000	000000	000000	000000	000000	000000	000000	000000
000000	036475	036477	000050	000050	000042	177750	000034
000000	000000	000000	000000	000000	000000	000000	000000
000000	000000	000000	000000	000000	000000	000000	000000
000000	000000	000000	177766	000000	000000	000000	000000
000000	000000	000000	000000	000000	055630	000000	177774
177774	177774	000000	000000	000000	000000	000412	000000
000000	000000	000000	000000	177774	000000	000000	000006
000000	000000	000000	000000	000000	000000	000000	000000
000000	000000	000000	177774	036475	036477	000054	000052

a - 2 SYNC WORDS
b - TIMING WORD AUX 1
c - AUX 2
d - AUX 3
e - AUX 4
f - AUX 5
g - GAIN WORD CH1-4
h - SAMPLE CH 1 DATA
j - SAMPLE CH 2 DATA
k - " CH 3 "
l - " CH 4 "
m - GAIN WORD CH 5-8

FORMAT
OCTAL DUMP

Figure 4.10

After a further series of tests, the Gain Comparator card was found to have failed. This card measures the slew rate and amplitude of the floating point amplifier, and decides whether to step up or down in gain level (see Chapter 2.3). After replacement, the system functioned correctly.

Apart from normal instrument failures such as those common to filter and multiplexer cards, a further complex fault occured while recording a three-dimensional research project. At the time of the failure, a six second recording was in progress. The magnetic tape failed to stop at the end of six seconds, although it did not appear to be recording data. When an attempt was made to Reproduce data, the tape searched to the load point and played back the first record on tape. It refused to search forward or move forward. The reproduced production record appeared normal but yet the system refused to reproduce further records. In 'Tape by-pass', the recording had incorrect synchronization. The fault had the hallmark of a timing error and, with some 300 integrated circuits having some timing function, the task to resolve the fault was not simple.

System timing derives from an 8.576MHz oscillator mounted on the hinged plane (see Chapter 2.4) in location B4. This clock is divided down to feed the appropriate timing requirements of individual circuits, clocking logic levels through during normal data processing sequences (see Chapter 2.4).

In order to troubleshoot the fault, it was necessary to isolate the areas where it was affected, and eventually work back to the source. The problem with logic fault finding is that many circuits have feed back loops and, hence, if a logic fault occurs in one segment of the circuit, the numerous feed back loops are also affected. The fault finder can literally go around in circles, which is the reason why field crews do not bother with fault finding, but return both hinged and fixed plane boards to the manufacturers for repair.

A further constraint imposed with the present system was that a number of integrated circuit chips were no longer manufactured and no stocks were available. The MOSTEK Read Address Memory (RAM) was typical, and only hope could be expressed that the four RAMs on the hinged plane had not failed.

The reproduce circuit performed correctly, but the data recording did not. Furthermore, the 'Search' mode failed to operate except for searching for the load point. This isolated the fault to the area in the region of the Master oscillator on the hinged plane, since reproduce functions were mainly on the fixed plane.

A typical diagram is shown as Figure 4.11, the Record Address Register Control. Inputs and outputs are timing clock dependent and checking of logic levels is performed with a logic probe. A fault locating micro-processor was used to check all components and 15 integrated circuits were found to have failed. All were associated with timing, and the most

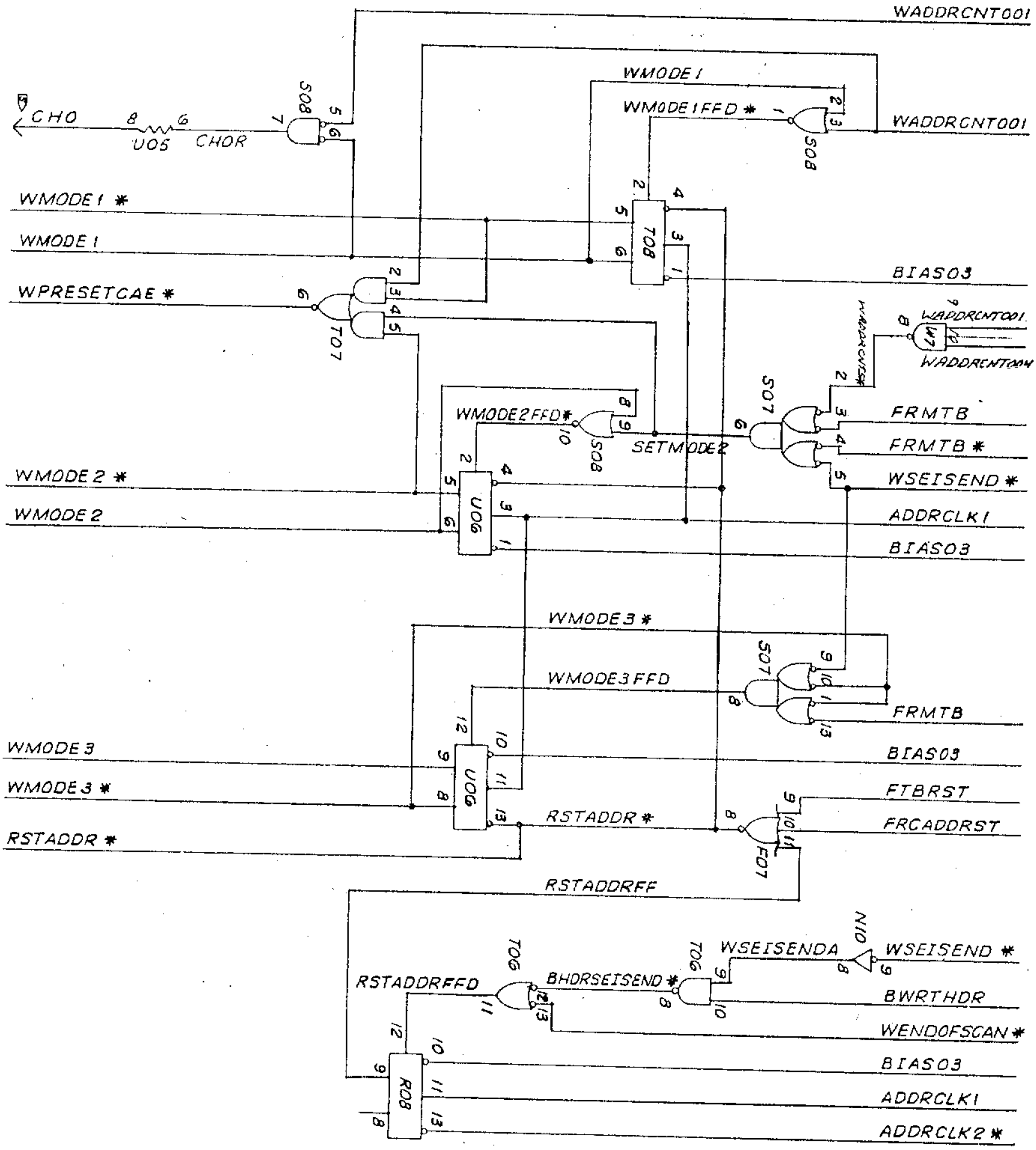


Figure 4.11 Record Address Register Control

(Courtesy Texas Instruments)

obvious component (DM8830 in position J5 hinged plane) had a burnt base.

During troubleshooting with the micro-processor, it was necessary to rewire special test boards to accept chips which did not conform to the pin-out arrangement required by the micro-processor. Some TTL integrated circuits were re-wired to give the appearance of a CMOS pin-out arrangement.

After troubleshooting this particular fault, a further fault was apparent. Basically, the system refused to read data when searching in reverse. After checking all search circuits and logic, the fault was found to be a faulty reverse skew adjustment thumb wheel switch which was not seated correctly. A minor touch of the switch with a finger was sufficient for contact to be made and there were no further failures.

CHAPTER 5

FIELD APPLICATION

5.1 Introduction

Modern recording instrumentation in the seismic industry has been adopted to digitize full-word 15 bit data of 48, 96 and 240 channels. The sign-bit recording technique was the fore-runner in digitizing 1000 channel data and, with the application of modern field computers, equivalent 1000 channel capacity will soon be available for the conventional full-word recording process(O'Brien, 1982)

The advantage to be gained by having the ability to digitize a greater number of channels, is that it provides more sampling points. This allows more channels to be recorded and, hence, a greater degree of horizontal resolution as a direct result of closer spatial sampling at the surface.

However, the operational and resultant data processing cost for 1000 channel activity often precludes the use of such high channel operations. The present WAIT owned 48 channel system can still be successfully used, even though it may not be commercially competitive with the higher channel systems.

The following list indicates areas in which the instruments have been used, or may be used at some future time:

(i) The walkaway noise analysis, which provides a quantitative study of the seismic noise as a result of the propagation of a surface generated wavefront (Dobrin, 1952)

(ii) Conventional multi-fold recording of land and marine seismic data. (Nettleton, 1940)

(iii) Conventional multi-fold three dimensional swath recording. (Cotton, 1981)

(iv) Unconventional single-fold three dimensional swath recording (McDonald, 1981)

(v) Deep Crustal recording to aid evaluation of the earth's crustal features (Fowler, 1975)

(vi) Bore-hole studies to evaluate down-hole seismic signal and noise as a result of a surface generated wavefront (Hardage, 1984)

This chapter discusses the field applications to which the recording instruments have been put. Areas in which a future application may be found are also suggested.

5.2 The Walk-away Noise Analysis

A major problem in seismic data recording is that of seismic noise. High amplitude surface or near-surface source generated noise often masks the low amplitude seismic signal which is desired to be recorded.

Coherent seismic noise is often generated as a result of the propagation of a wavefront within the unconsolidated weathering layer (in land terminology, this is referred to as "ground roll"). Random noise may also be generated as a result of diffraction of the seismic wavefront as it meets different geological interfaces during its travel path. Changes in propagation direction, waveform velocity, frequency and wavelength cause the signal which is received at the surface to be a complex series of wavetrains.

Useful signals which arrive at the surface may be compressional "p-waves", shear "s-waves" horizontally and vertically polarized. Shear waves and their components, have until recently been regarded along with ground roll, as coherent noise. Such noise is often troublesome since it not only masks the weaker coherent signal, but also utilizes much of the recording instrument dynamic range during recording. As a result, it is necessary to determine the individual characteristic of such coherent noise, in order that suppression techniques may be employed prior to the recording stage (Dobrin, 1952).

There are various methods which may be applied to the received signal, in order to attenuate unwanted ground roll. The methods commonly used for noise suppression are as follows:

(i) Arrays. If a string of receivers is distributed over the distance of one wavelength, and their collective response is summed electrically, then the receivers may be positioned so that the wave will be attenuated. A similar effect can be achieved with a distributed energy source. In addition, array simulation may be achieved by summing of separate shots of various receiver combinations in the data processing centre.

(ii) Field Filters. The application of low cut field filters can assist the attenuation of lower frequency noise trains. In addition, this may allow more recording instrument gain to be made available for recording weaker higher frequency seismic signals.

(iii) Controlled Energy Source. Only frequencies that are transmitted into the ground may also be received. Thus, the variable frequency source (e.g. Vibroseis, Minisosie) output may be adjusted sufficiently high that the lower ground roll frequencies are not generated.

However, prior to using any one of these noise suppression techniques, some assessment must be made of the unwanted noise, its wavelength and apparent frequency content. In order to make such an assessment, an evaluation of the seismic noise content is performed and is known as the 'noise spread test' or 'walk-away noise analysis'.

This test is a field technique which determines the wavelength and frequency of horizontally travelling noise, so that attenuation techniques may be selected and applied.

To perform such a test, the geophone spread is layed out so that there is a short station interval. Geophones are bunched together at each monitoring station, and recording instrument filters are adjusted to allow as wide a band-pass as possible for the particular sample rate in use.

As many geophone stations as possible should be positioned.

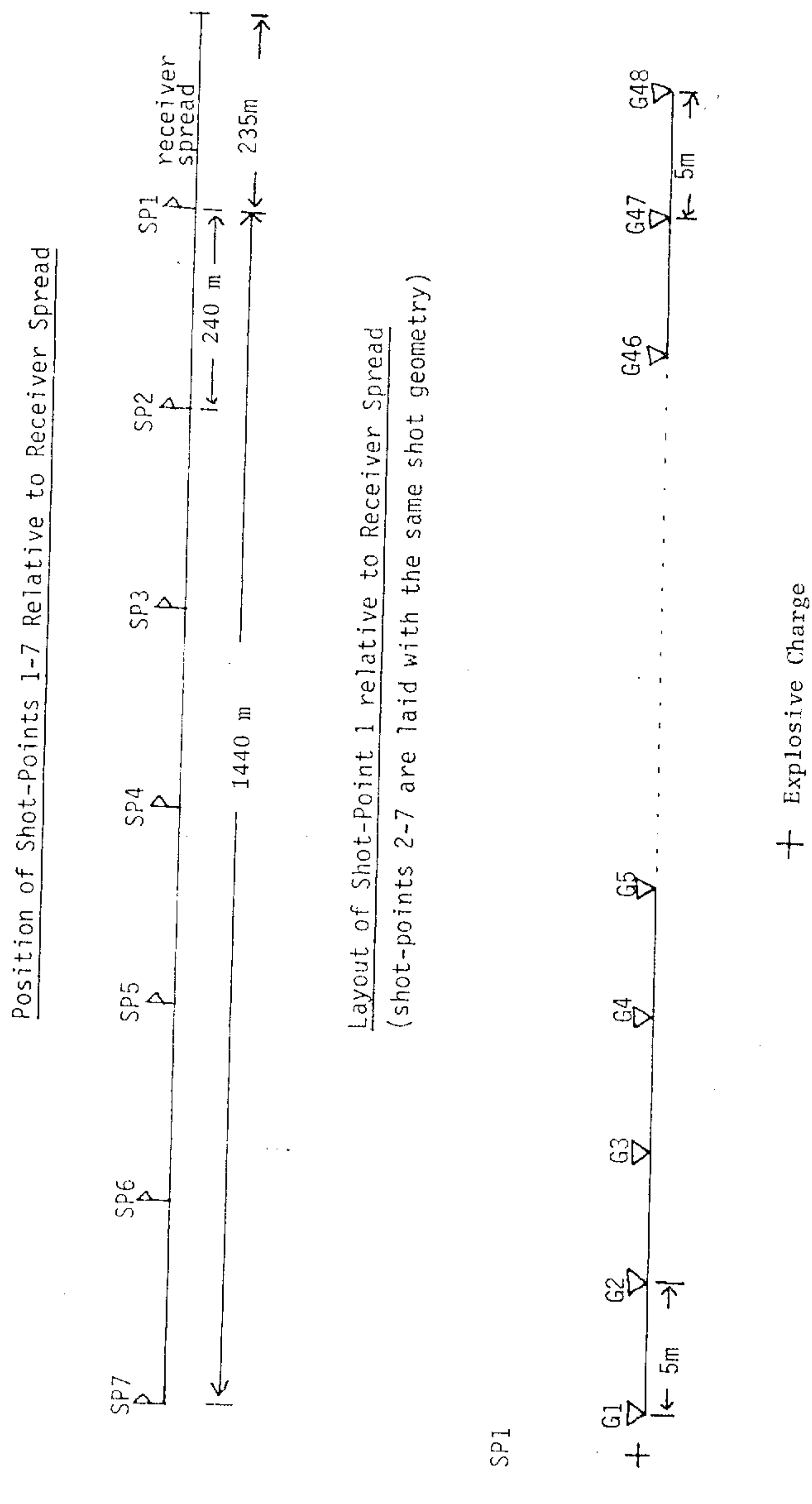
Ideally, the recorded noise test should be performed with at least 250 stations for an acceptable analysis to be executed. This is very easy if the system records 1000 channel data. However, for a 48 channel recording system, such a feat is not so simple. With 48 stations, theoretically, the first shot should be taken into the 48 station spread after which the spread is removed to a position where stations 49-96 would be. A second recording would then be performed by shooting again at the first shotpoint and the spread removed again and so on.

Such a noise spread is impractical to perform, requiring much effort in removing the spread after each recording. Alternatively, if the 48 stations are fixed and the energy source removed or 'walked-away', this would make the recording of a 250 station noise spread far easier with a 48 channel recording set-up.

The 'walk-away' noise spread test is illustrated by the following description of a noise spread conducted using the DFS IV recording instruments.

Figure 5.1 shows a walk-away noise spread ground layout. With 48 geophone stations positioned 5 metres apart, shotpoint 1 was fired with a 5 metre offset from source to nearest group station 48. Shotpoint 2 was taken 240 metres away, so that the two 48 trace records when positioned adjacent to each other, simulated a 96 trace record. The sequence was then repeated with walk-away shots every 240 metres, so that a

Figure 5.1 WALK-AWAY NOISE SPREAD LAYOUT



composite panel could be built up from five shot records, as shown on Figure 5.2.

The evaluated record was analysed to reveal wave trains resulting from refraction (2350 m/second); reflection (6000 m/sec); ground-roll (680 m/sec) and air-blast (370 m/sec). Different coherent noise trains being predominantly of 14-15 Hz content have wavelengths of 52 metres, 30.8 metres and 44 metres respectively.

Figure 5.3 shows that, in order to cancel a single waveform, the geophone separation distance can be determined once a knowledge of the waveform's wavelength is obtained. i.e. For a single string of geophones, the separation distance 'd' = $\frac{\lambda}{n}$, where 'λ' is the wavelength to be attenuated and 'n' is the number of geophones in the string (Dobrin, 1976).

However, for noise trains of differing wavelength as displayed on Figure 5.2 , the solution for cancellation would ideally be to position three sets of geophones, so that each set would cancel a selected noise train.

To cancel a number of noise trains of different wavelengths, a complex weighting pattern of geophones may be necessary as indicated by Dobrin (1976). So far the assumption has been that the noise being studied during the walk-away noise test, has emanated from directly beneath the geophone spread. If this is not so,

Figure 5.2 SEISMIC NOISE ANALYSIS

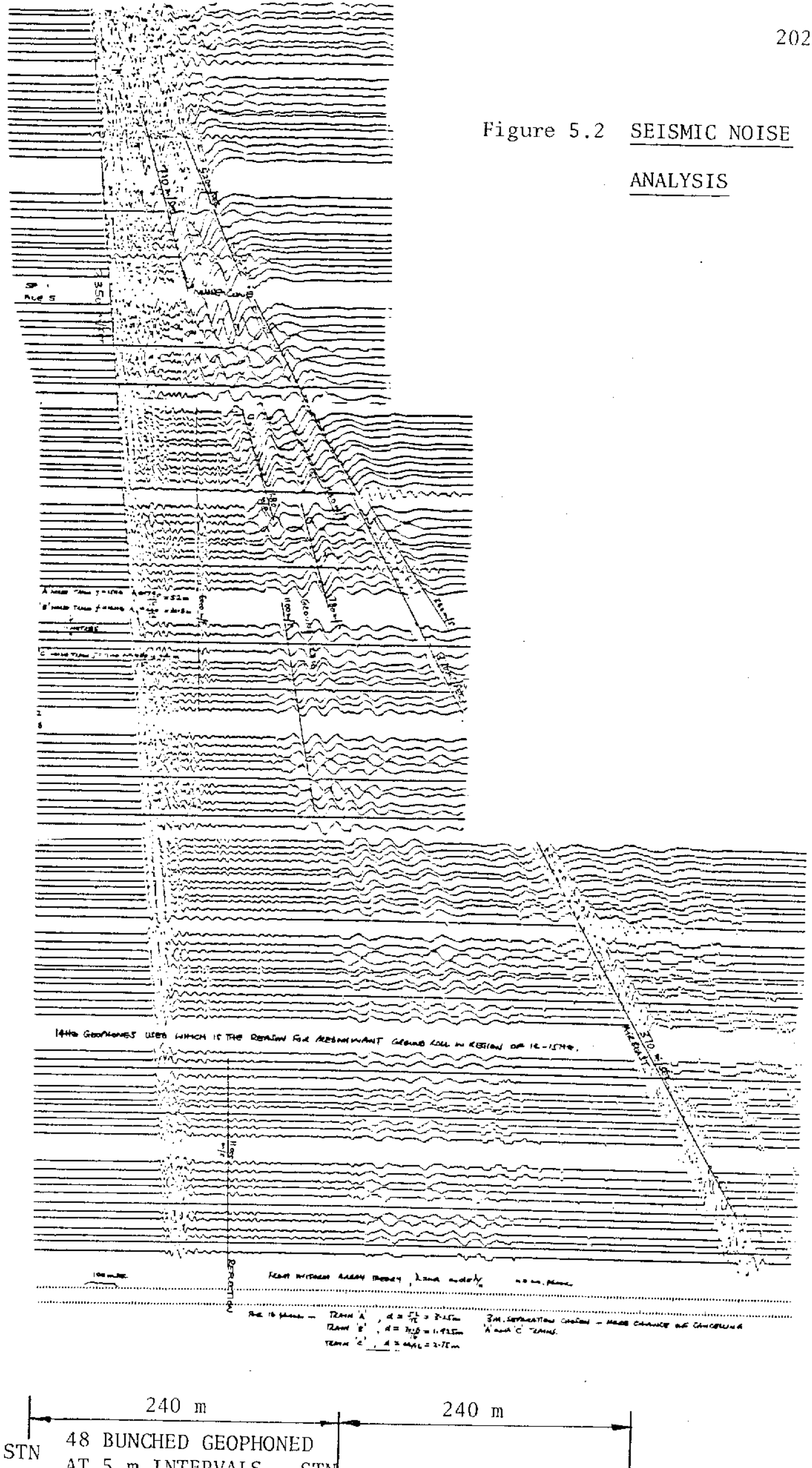


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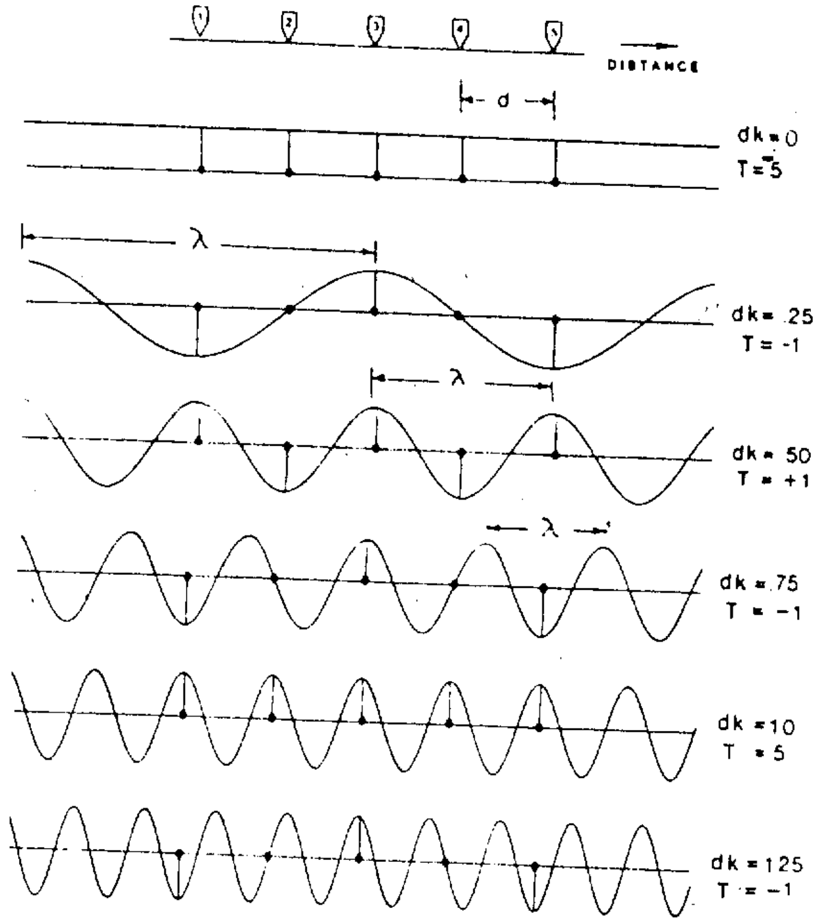
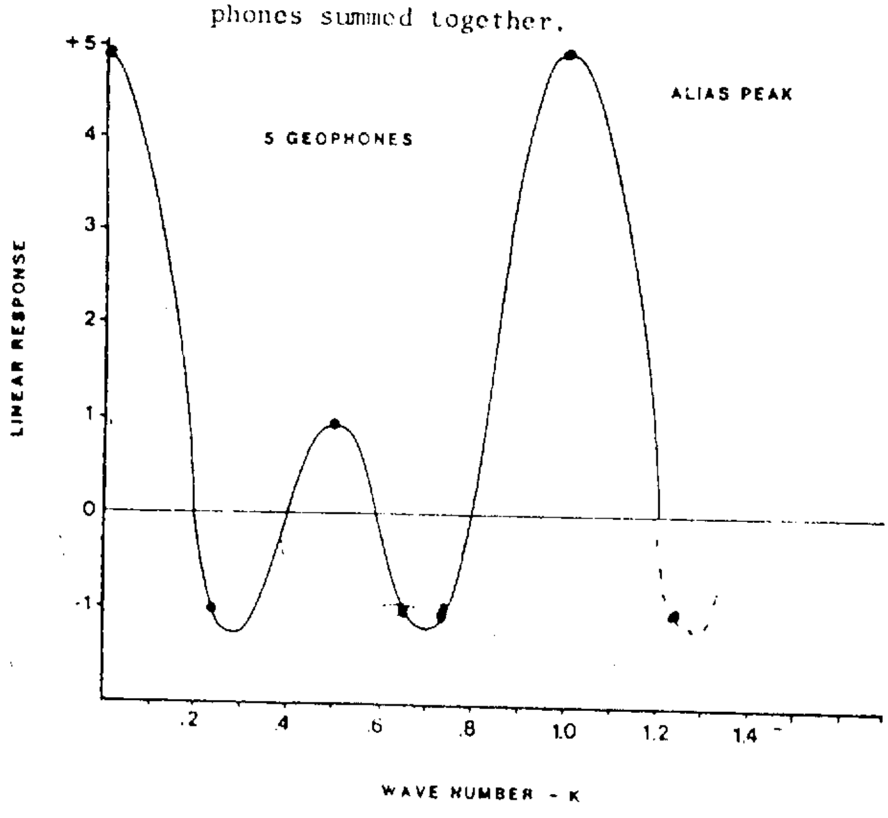
Figure 5.3 LINEAR GEOPHONE PATTERN RESPONSE



Cancellation of waves of different wavelengths using five geophones separated by a distance "d". Figures to the right show the product of phone spacing (d) with wave number (K), wave number being the reciprocal of wave length. T is the linear response of the 5 phones summed together.

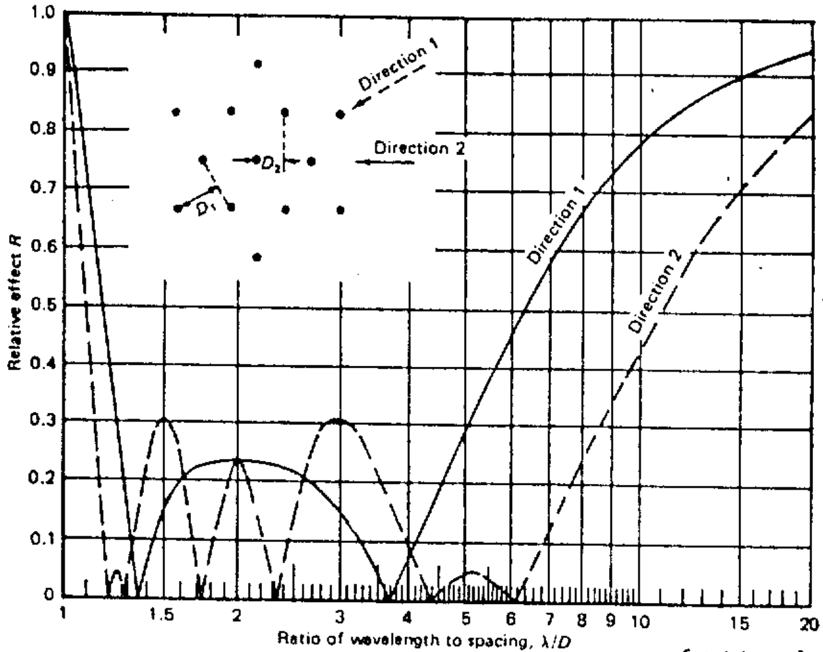


the solution is to design an areal geophone pattern to suppress the noise. Figure 5.4 indicates Dobrin's support for this method - however, in practical terms, such geophone patterns are time consuming to lay and pick-up and, hence, expensive.

Furthermore, due to changes in lithology and subsurface dipping beds, the ground-roll may rapidly alter within a very short surface distance, in both apparent frequency and wavelength. Hence, the pragmatist may prefer to simplify the geophone array and lay a pattern to cancel the most predominant ground-roll apparent on seismic data records.

Whenever noise attenuation techniques are adopted, they are performed on the basis that coherent noise has been recognised as distinct from useful signal. With such techniques, there is a very real danger of suppressing signal, if the segregation of signal from noise is not clearly apparent. Consequently, it is often preferred to perform noise attenuation by computer simulation methods, in order to retain all waveforms and perform numerical analysis to eliminate unwanted frequencies and wavelengths, at the computer processing stage. Such numerical analysis is discussed later in this chapter.

The walk-away noise spread test has been used by Dobrin (1952) to assess the intrinsic character of low velocity layer noise. Another application of the noise spread is the assessment of relative energy source signal strengths, typically performed by Bahia and Silva (1973).



(After Dobrin, 1952)

There are differences in cancellation for the two directions of approach of the wave to be attenuated.

Figure 5.4 AREAL GEOPHONE PATTERN RESPONSE

During 1984, the DFS IV recording instruments were successfully used on a number of occasions to conduct a variety of walk-away noise spread tests (see reports by Smith and McClerie, 1984).

In November 1984, the noise spread test was also performed by Evans and Uren, to assist in numerically analysing the performance of the shaped explosive charge as an energy source. During that test, a noise spread record similar to Figure 5.2 was obtained, and the recorded data processed to obtain a numerical display of relative frequency, signal strength, and hence signal-to-noise content of the recorded noise spread. Such an analysis is carried out by Fourier transformation into the frequency domain. The noise spread test was performed to compare relative energy levels of ammònium nitrate (AN60) explosive with an equivalent weight pentolite shaped charge. Typically, a single trace (1) was taken from each shot record and a Power Spectrum performed on it. This gave a quantitative analysis of the frequency content of that trace at a particular offset. By comparison of the different source power spectra at different offsets, a calibrated assessment of frequencies and corresponding amplitudes was obtained(Bracewell, 1965)

Figures 5.5 and 5.6 illustrate the frequency comparisons of ammonium nitrate explosive with a single pentolite shaped explosive charge. The figures indicate frequency and signal level of trace 1, for shotpoint 2 (240 metres offset). To analyse such figures, the 0dB gain line indicates that the 1 millivolt signal level is 23.09dB down from this peak value for Figure 5.5. Having determined the 1 millivolt signal level

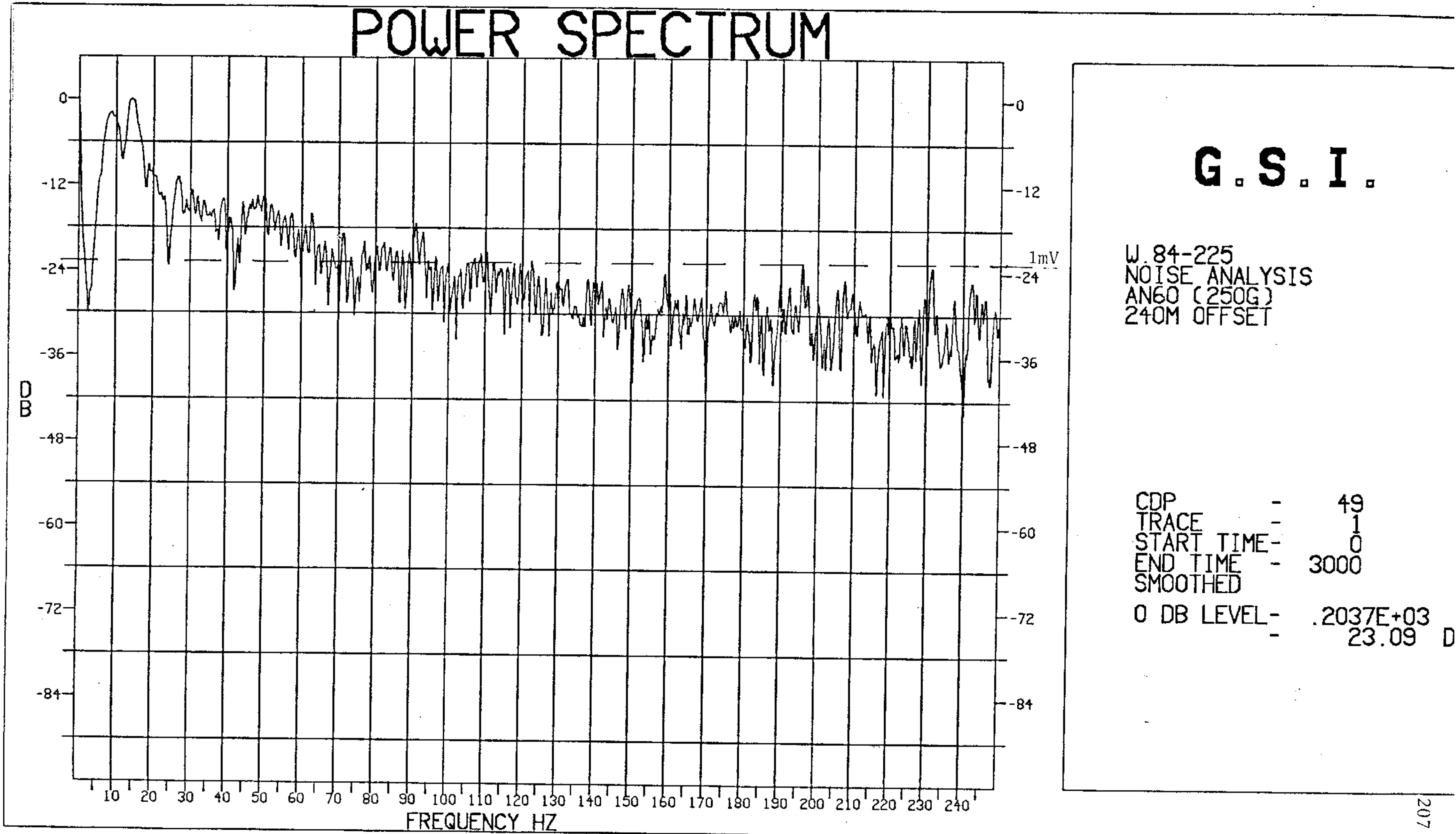


Figure 5.5 AMMONIUM NITRATE (AN60) POWER SPECTRUM

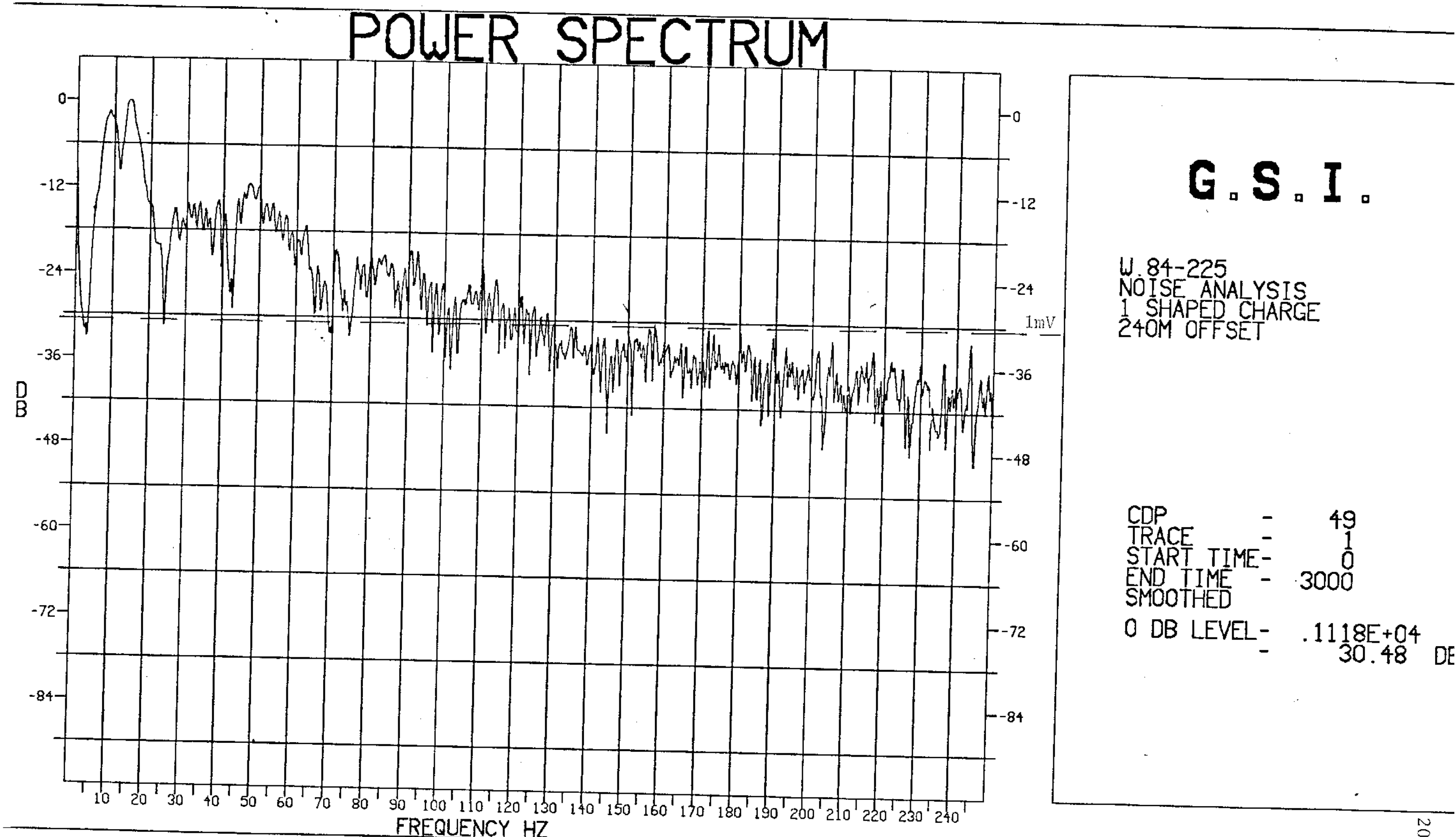


Figure 5.6 PENTOLITE SHAPED CHARGE POWER SPECTRUM

a peak ground roll value of 3,000 millivolts is determined at 14Hz for Figure 5.5, which compares with the 35,520 microvolts of ground roll generated at 14Hz for Figure 5.6. If signal is assumed to be 50Hz, relative signal to noise ratio of 1:13 is determined for the ammonium nitrate source, compared with the 1:12 ratio for the single pentolite shaped charge. Figures 5.7 and 5.8 illustrate the two dimensional frequency domain F-K diagrams for the AN60 and the pentolite shaped charge, respectively.

From the walk-away noise spread, it was evident that airblast had a low apparent velocity of 370 metres per second as was expected. Coherent noise trains had apparent velocities of 600-800 metres per second, while useful signal reflections arriving almost vertically had apparent velocities of 6000 metres per second.

Since velocity $V = \frac{F}{K}$, then the gradient of an F-K diagram may be used to determine apparent horizontal velocities. Because such velocities of reflected energy will be greater than that of refracted energy, it is reasonable to assume that no signal has an apparent velocity less than 1500 metres per second (velocity of sound through water). Ground roll velocities are generally half that of the corresponding p-wave velocities. Thus, on the basis of gradient on an F-K diagram, the various component wave trains may be segregated. Highest gradient components are determined to be signal, with lower gradient components determined as noise. In Figure 5.8, the apparent velocity for noise intersects the 100 K number

Figure 5.7 F-K DIAGRAM OF AMMONIUM NITRATE CHARGE

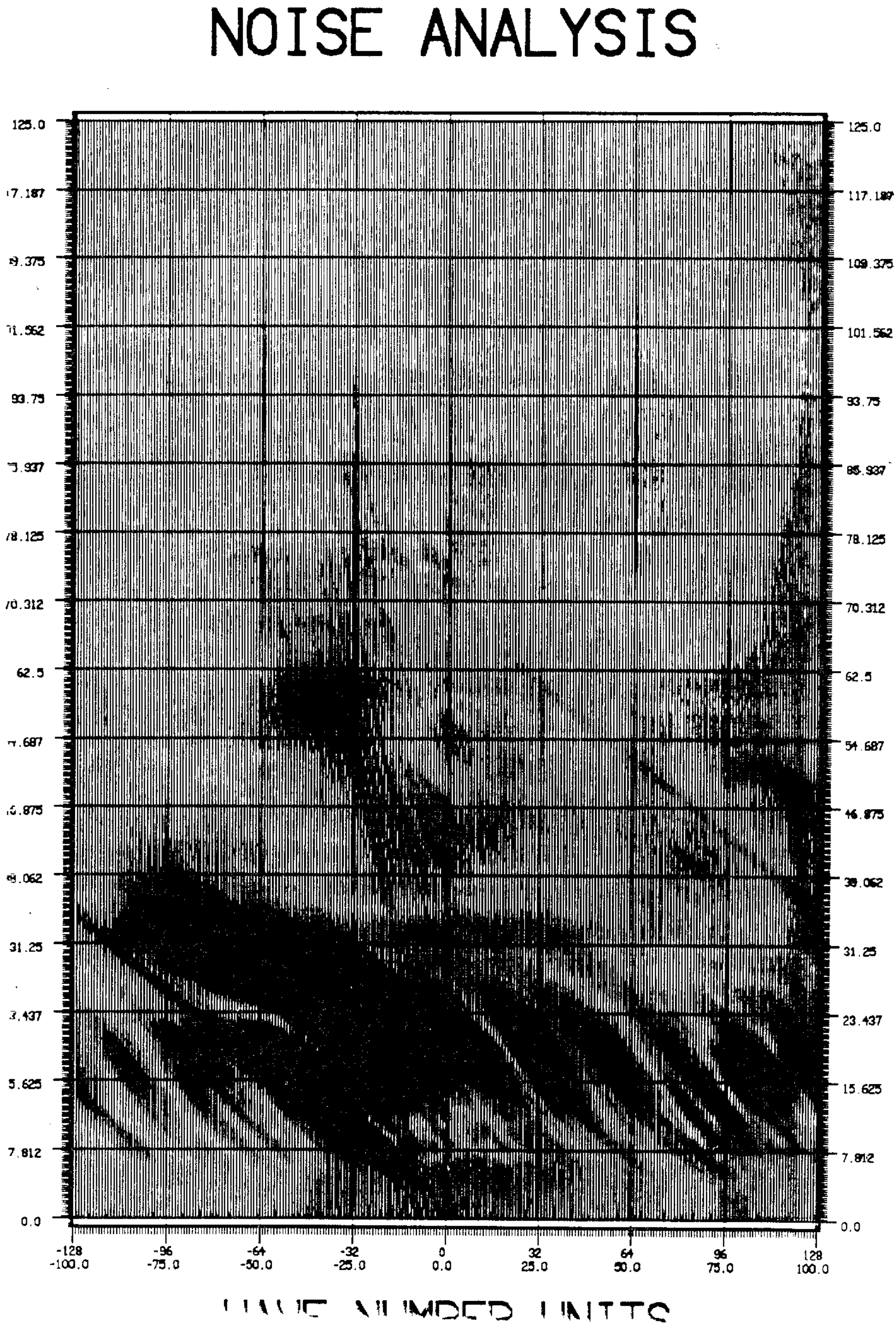
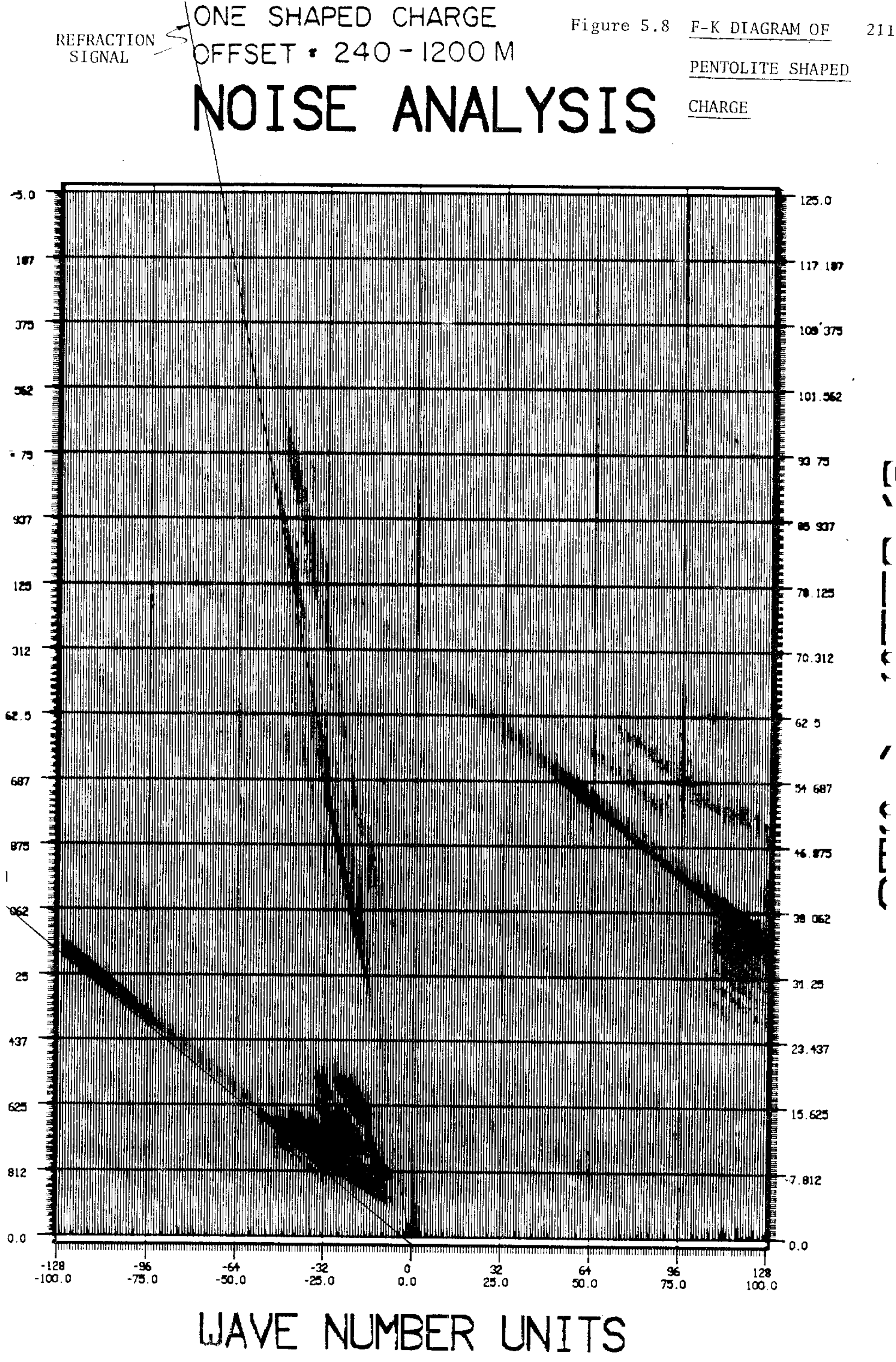


Figure 5.8 F-K DIAGRAM OF PENTOLITE SHAPED CHARGE



axis at 35Hz and, hence, the apparent velocity for noise is determined at 350 metres per second (similar to air-blast) and for refracted signal is extrapolated to 2300 metres per second.

Figure 5.8 indicates a strong low-frequency component in the range of 7 to 14Hz. Across this spectrum, the 14Hz Hall-Sears geophones used during the recording of the noise spread respond between 50 and 100% of full output voltage (0.05 to 0.1 volts per inch per second - see Figure 5.9). Consequently, there is little attenuation of low frequency ground roll as a result of geophone response.

If a higher resonant frequency geophone had been used (e.g. 30Hz), low frequency ground-roll may have been suppressed. This is another method for the attenuation of low-frequency noise, but this option reduces receiver bandwidth and hence, is not a favoured alternative.

In principle, the F-K diagram assists the identification of ground-roll, air blast, signal and noise trains. However, in practice, F-K analysis is rarely performed since data recording often allows minimal time to make individual judgements of field recordings. Consequently, field practice often confines itself to the less complex methods of noise elimination e.g. simple linear geophone patterns, high frequency source sweeps. Subsequent, more complex, array simulation techniques as discussed earlier, are increasingly adopted by field crews, and the advent of field computers allows further computer processing of data in the field.

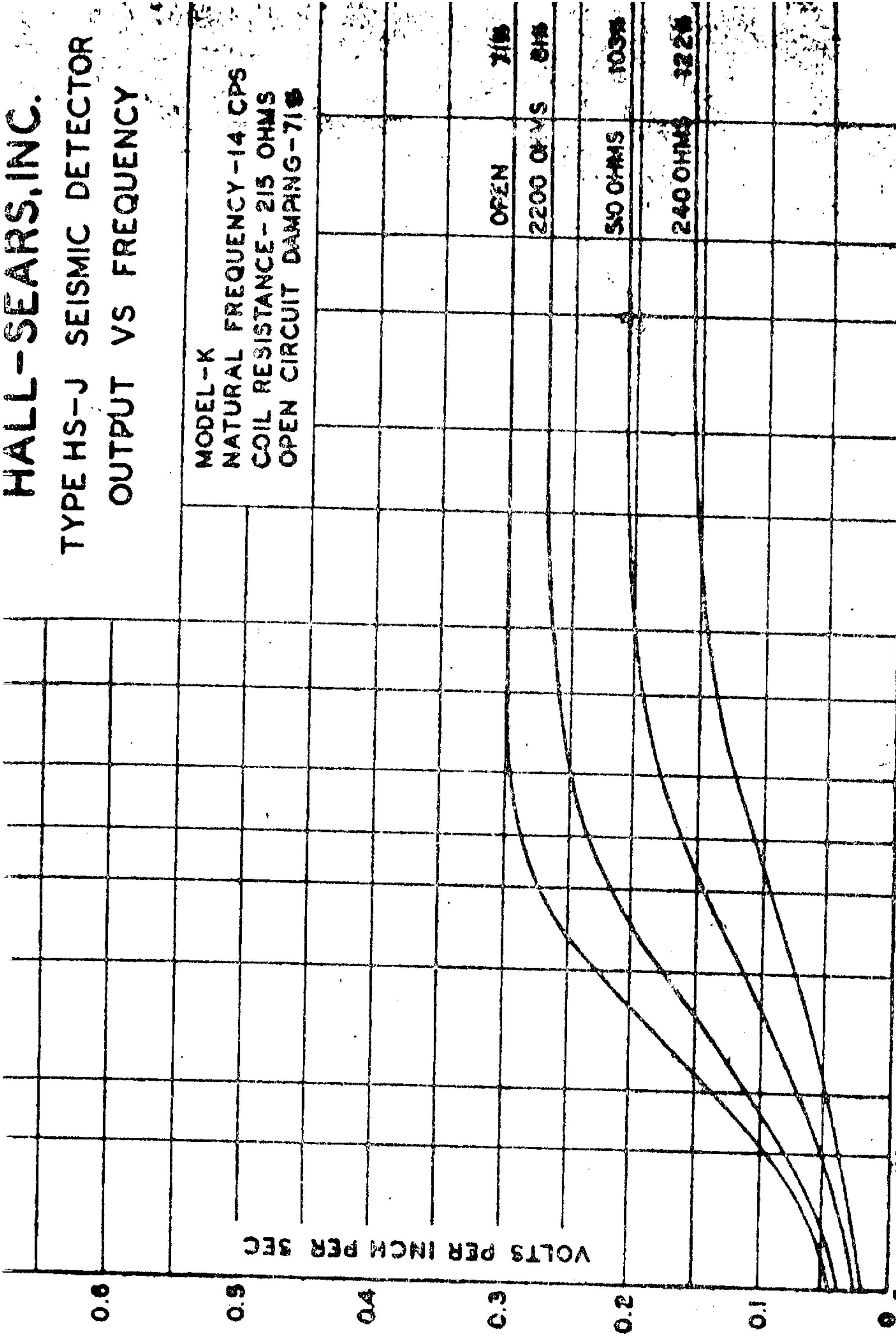


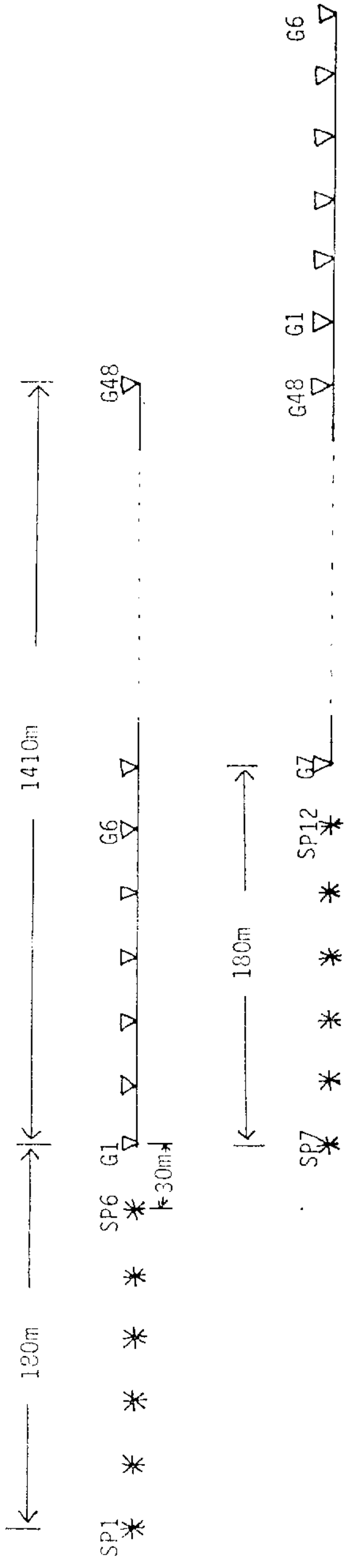
Figure 5.9 HALL-SEARS 14Hz GEOPHONE RESPONSE

5.3 Multifold Recording (with the present WAIT equipment configuration)

Chapter 3.7 discusses the seismic cabling arrangement and method of recording a multi-fold seismic line. Because, with the WAIT equipment, recording is constrained to the use of a 24 trace cable arrangement, with individual cables having 6 take-outs and no roll-along switch, it is necessary to connect up the recording equipment in split spread configuration. Channels 1-24 monitor one 24 station spread, and 25-48 monitor the other 24 station spread. Due to a lack of correlation equipment, impulse type recording (i.e. dynamite, air-gun, Betsy, thumper) is the preferred operational source (as opposed to the variable frequency source such as Vibroseis). However correlation in the processing centre is not precluded.

The shot firer is expected to commence source firing six shotpoints from the nearest live geophone station. Shots are fired moving towards the nearest live station until the shooter finishes his final shotpoint one station from the nearest live station, see Figure 5.10. At this point, the near 6 take-out cable is disconnected and moved to the far end of the full seismic cable. The shot firer's next shot is therefore 6 stations away from the next live station and so on. In this manner, a variable offset multiple fold coverage build up of 24 fold (in saw tooth manner) occurs, as shown on stacking diagram Figure 5.11. If the shot interval is increased to twice the station interval (i.e. a shot every second station), the coverage would be 12 fold. Thus, the variable offset geometry of recording requires

Figure 5.10 DIAGRAM ILLUSTRATING VARIABLE OFFSET SHOOTING



SP = Location of consecutive shots

G = Geophone groups

Shots are fired at 30m intervals. After every sixth shot the first six geophone groups are shifted to the end of the line.

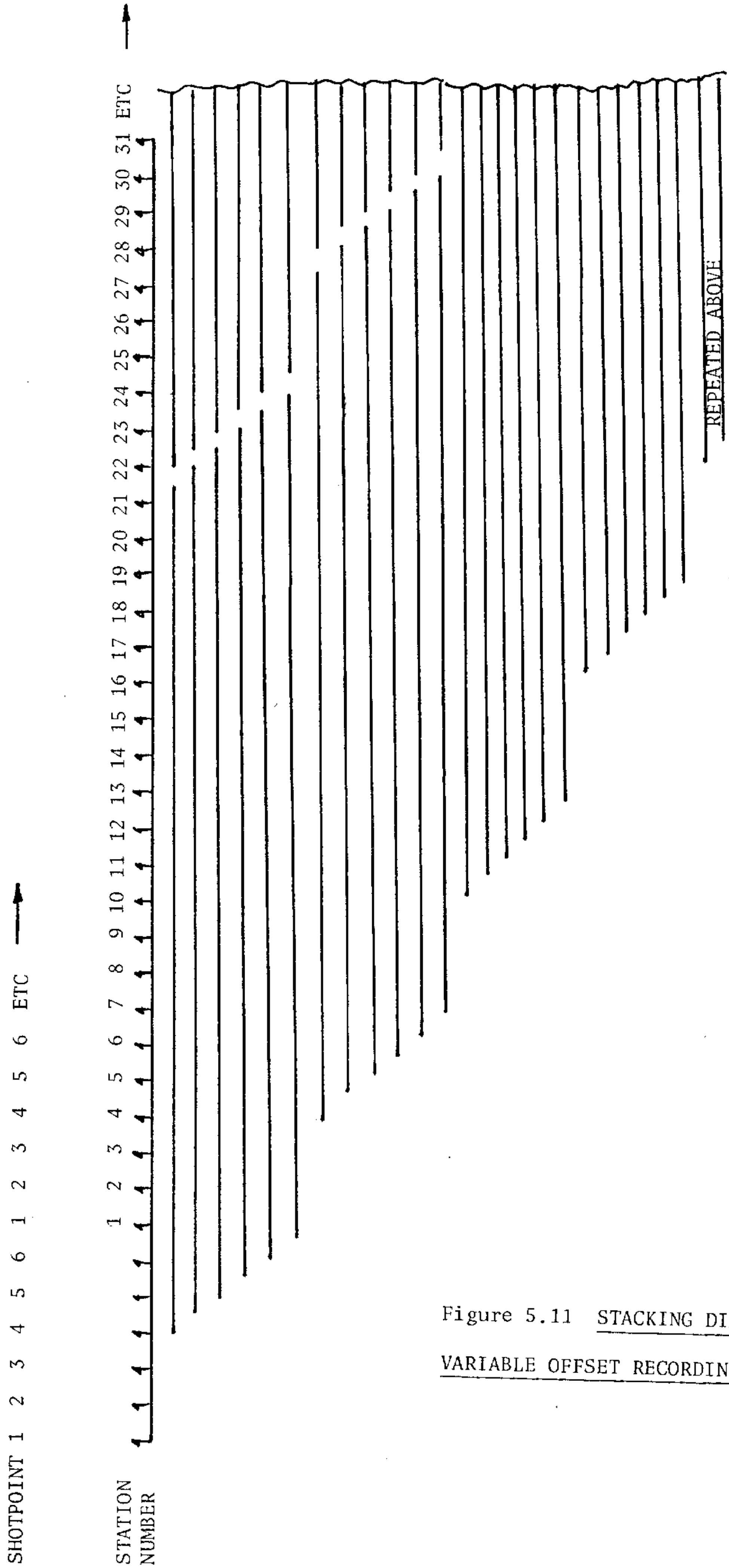


Figure 5.11 STACKING DIAGRAM FOR VARIABLE OFFSET RECORDING

extra care to be taken during data processing.

In order to correctly sample spatially, it is necessary not only to consider the degree of dip expected, but also velocities and maximum frequencies expected. Cotton (1981) determined that maximum spatial sampling distance is given by:

$$\Delta x = \frac{V}{4 f \sin\theta}$$

where Δx = subsurface interval

V = RMS velocity of objective horizon

f = maximum frequency expected

θ = maximum dip expected

For example, a typical RMS velocity of 3000 metres per second, maximum frequency of 100Hz, and maximum expected dip of 15 degrees will imply a maximum subsurface interval of 30 metres before aliasing occurs. Thus, in this example, to err on the safe side, it is preferred to use an interval no greater than 30 metres as a rule of thumb (i.e. station interval of 60 metres or less).

During September 1983, the DFS IV was mobilized to the Woodada gas field, Western Australia. (Gas was being produced from the Caryngìnia limestone by hydrochloric acidization.) Previous work performed over the northern section of the gas field had used large dynamite charges or vibroseis as the energy source. Verbal discussions with the permit operator's personnel had indicated that a dip of no more than 15 degrees was to be expected. From past seismic data, the RMS velocity of the objective horizon was 2500 metres per second with a maximum frequency between 80 and 100Hz.

After application of the spatial sampling formula above, subsurface interval was determined as 24 metres. To allow for unexpected dip, a station spacing of 25 metres was chosen. A 3.2 Km. 24 fold seismic line was recorded in the manner previously explained, using 500 gm explosive charges buried to 1 metre. The final stacked seismic section is shown as Figure 5.12, which, according to the permit operator's personnel, was superior in resolution to those previously produced along the same seismic profile. In addition, seven noise spreads were recorded and later analysed to assess the relative characteristics of different explosive charges (Uren and Evans, 1984).

During August and September 1984, a second visit was made to the southern margin of the Woodada gas field. An initial noise spread (Figure 5.2) indicated three noise trains as discussed earlier (Chapter 5.2). With a 16 geophone string, a uniform geophone separation of 1.92, 2.75 or 3.25 metres was required to attenuate the respective trains. A geophone separation of 3 metres was chosen since it not only was central to the three values, but was simple to physically pace. Since the RMS velocity for the objective horizon had been calculated at 3000 metres from previous seismic sections, a station interval of 30 metres was chosen.

A 3.4 Km. seismic line was recorded through well-heads Indoon

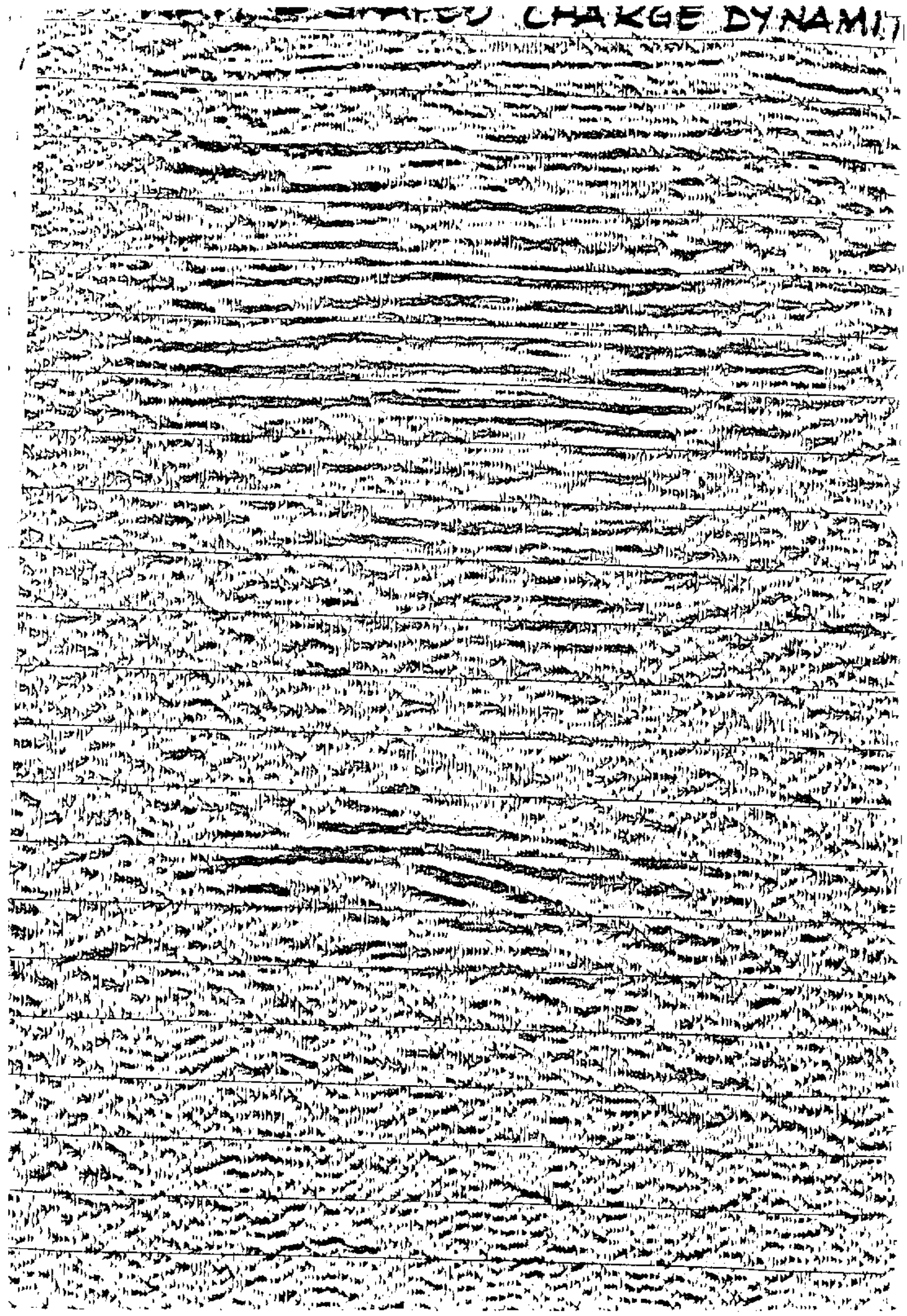


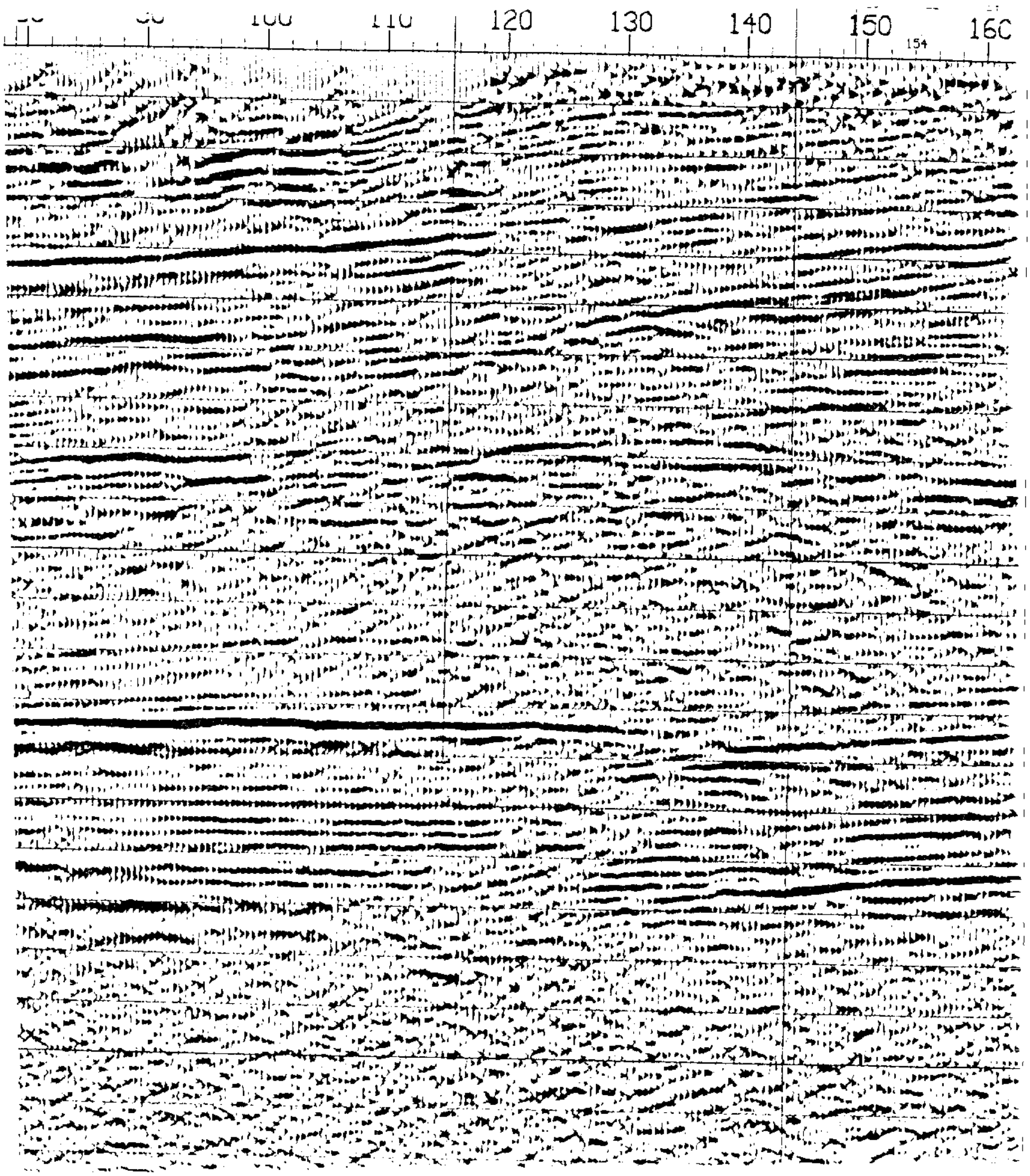
Figure 5.12 SEISMIC SECTION RECORDED 1983

No.1 (gas producer) and Woodada No.9 (dry hole). The final stacked seismic section is shown as Figure 5.13. The section delineates a reverse fault between the two wells (vertical lines) with Indoon No.1 to the left side of the fault. The section answered a number of geological questions posed by the permit operator's personnel, and was considered superior to that previously produced by the industry. The two seismic sections were superior in resolution (both horizontally and vertically) to those attained before. This was considered to be due to the close station interval adopted, and to the large bandwidth of small explosive charges. Improved data quality was also due possibly to a greater shallow event fold as a result of reduced offset distances.

With a 48 channel DFS IV, and only a 48 trace seismic cable configuration, the amount of field effort is dependent upon the operational methods adopted. The higher the number of recording channels, the closer the station spacing that is possible at reasonable cost. In addition, a larger number of stations enables a longer cable spread, which may assist to distinguish between primary and multiple reflections.

For deep reflection data, off-end recording is preferred, However, for shallow reflection/refraction recording, a shorter split-spread configuration may be adopted. Shooting refraction spreads from each end would also provide shallow dip information not readily obtainable from off-end shooting. With the present recording set up, the shooter would have to maintain a position mid-cable close to the recording equipment. While this is

Figure 5.13 SEISMIC SECTION RECORDED 1984



acceptable, the possibility of high level source generated noise cross-feeding onto the seismic cable is to be expected.

A shot every station would still provide coverage of 24 fold.

An alternative application of the instruments is their return to marine operations. If the instrument vehicle were loaded onto a marine vessel, there is no reason why a marine seismic cable could not be reconnected. The only modifications necessary for marine operations would be those associated with time break, transformer connections, gain constant, radio firing and system reconfiguration.

5.4 Three-Dimensional Recording

This chapter so far has discussed the conventional techniques of noise spreads, multi-fold recording and their analysis. Some alternative methods of recording reflection data have been proposed and experimental work on these has been carried out with the WAIT system.

With multi-fold recording, the concept is to obtain a number of traces which have precisely the same reflection point. After geometrical corrections have been applied, they are summed together. This enhances the quality of the recorded signal. As a result, an improved final 'stacked' section is obtained. Hence, a better geological interpretation may be performed on the results.

Signal arrivals received at the surface are not necessarily reflected from directly beneath the line of profile being recorded. They may be reflected from a tilted reflector to the side.

Because reflection points may occur at positions other than directly beneath the profile being surveyed, modern computer processing techniques have been devised to reposition data back to the point of reflection. Such programs are known as 'migration' processing. Migration processing often improves the seismic data quality since it is a form of stacking itself. However, since seismic signals are reflected three dimensionally, the migration procedure operates best on data which has been collected in the three dimensional recording manner.

The three dimensional recording technique requires identical reflection point traces to be summed together, just as with multi-fold recording. However, the technique requires the reflection points (or common mid-points) to be closely positioned, so that not only may single line profiles be constructed from the stacked data, but numerous crosslines may also be constructed at any desired azimuth (see Figure 5.14).

Assuming common mid-points (CMPs) can be gathered and summed, three-dimensional migration computer processing restores the signal content back to the three dimensional point of reflection from which it derived. As a result, a vastly improved geological interpretation is enabled.

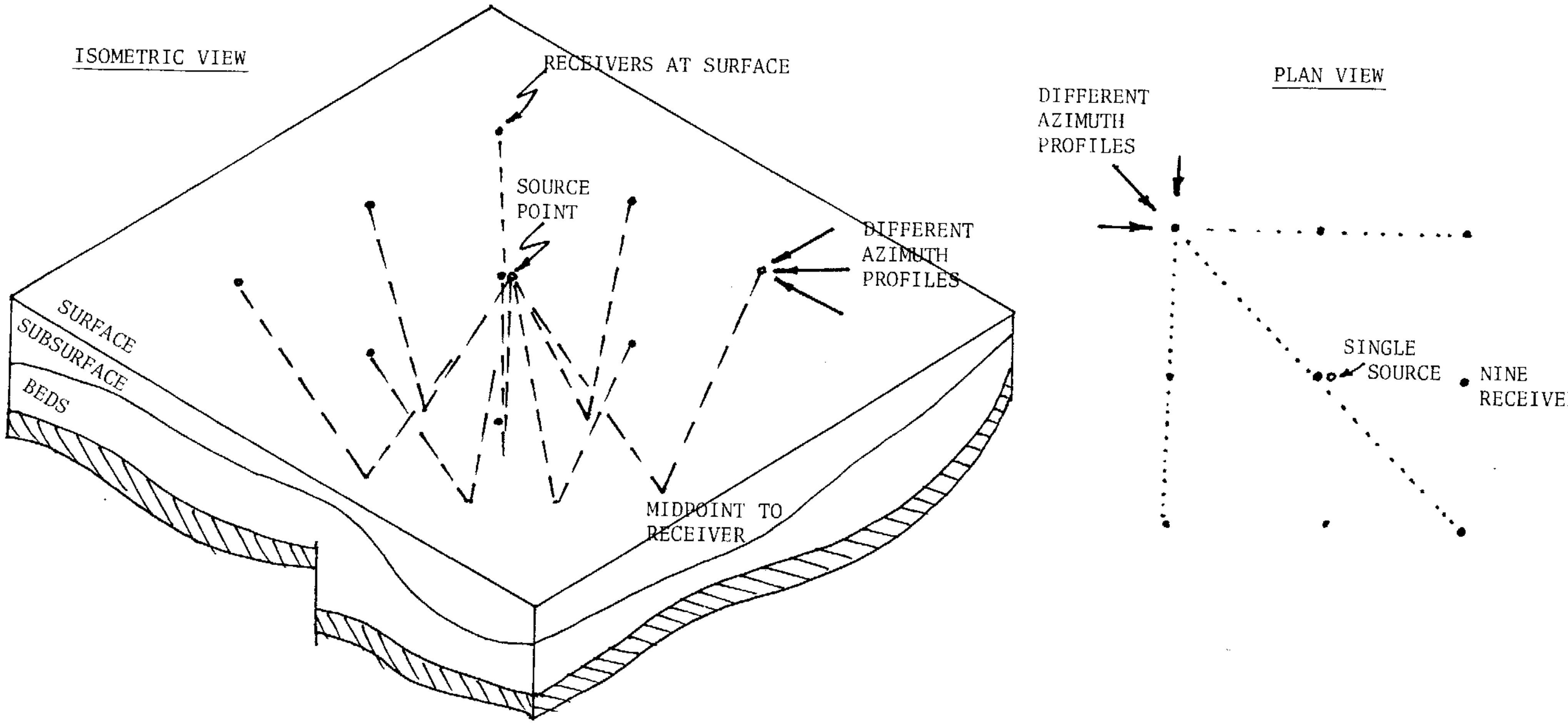


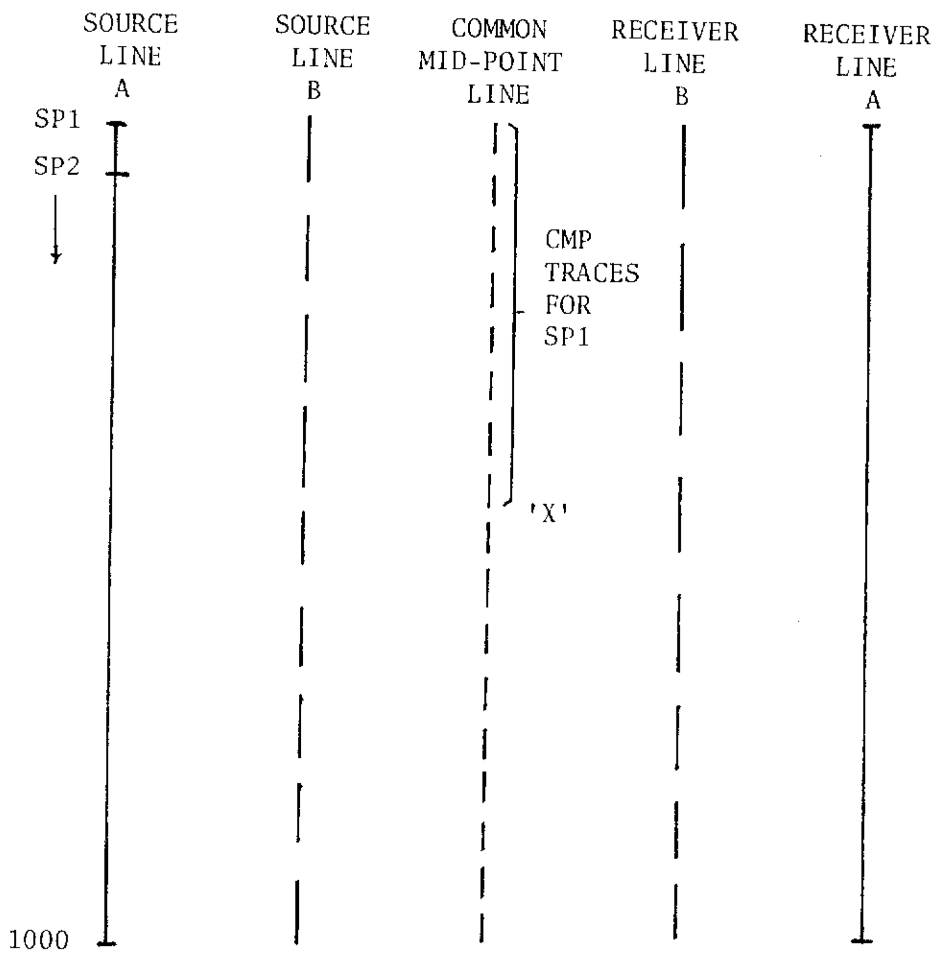
Figure 5.14 DIFFERENT AZIMUTH POSITIONS

(As a result of single source firing into nine receiver positions.)

Operationally on land, the field effort is not directed at rolling-along a single profile, but more a case of positioning the geophone receiver stations at static locations and allowing the energy source to move.

Figure 5.15 illustrates one method of the technique, where 'swath recording' can be employed. In this method, source line A may be fired into receiver line A with CMP line shown dotted. Then source line B may be fired into receiver line B, with the result that the same CMP portion of line is recorded, but using different source/receiver offsets and different travel paths. As with normal processing, multi-fold stacking is executed after initial processing adjustments have been made.

With the marine case, a two vessel operation would be required. However, to reduce costs, the three dimensional marine seismic survey technique is conducted in identical manner to conventional two dimensional marine data recording, in that multi-fold data is collected while towing a seismic cable along a straight line profile. The only subtle difference with marine three-dimensional data collection, is that line spacing can be very close, in order that the cross-line CMP spacing is close enough to prevent aliasing. Due to vagaries of marine currents, seastate etc, not all CMP traces fall identically in the desired location (particularly since the vessel is continually moving while recording the data). As a result, CMP traces are summed provided they fall within a limited area, known as a 'bin' of data. Thus, the term data



Source line A SP1 fires into Receiver line A. Common mid-point line (Half length of receiver line) shown.

SP2 initiated and next CMP line recorded.

CMP 'X' coverage builds with more shots until source line A completed.

Source line B now fires into Receiver line B, increasing coverage at 'X'.

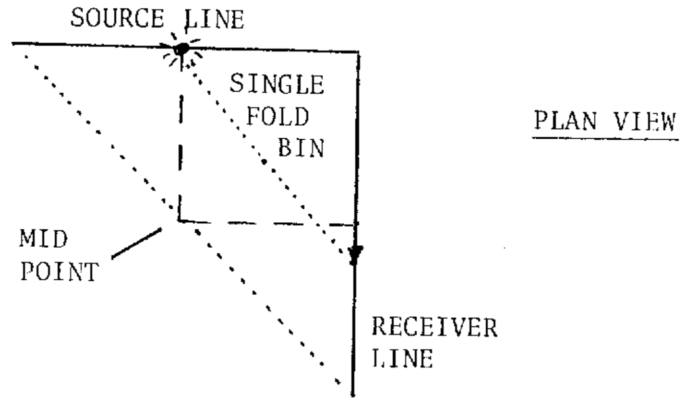
Figure 5.15 <u>SWATH RECORDING</u>

'binning' is frequently applied to the marine application.

With the land operation, the problem with three-dimensional swath recording is that it requires numerous fixed geophone receiver stations, and thus is ideally suited to higher channel systems. With a 48 channel system, such swath recording means that, to obtain the same number of CMP traces as 1000 channels provide, there must be 20 times more records taken per 1000 channel record. Hence, multi-fold swath recording is out of the question with a low number of recording channels. Recent advances in three-dimensional processing routines allow single fold data recording to be processed. In particular, work performed on three dimensional single fold migration routines point the way to reducing field effort to the degree that a 48 channel recording system is no longer inadequate.

Figure 5.16 illustrates how single fold data may be collected in mid-point bins, with the receiver line remaining static at 90 degrees to the source line. Gardner and McDonald (1979) recorded data in the single fold manner to explain the technique, and the processed seismic sections were encouraging.

During September 1984, the Field Research Laboratory (of Allied Geophysical Laboratories and WAIT) used the recording instruments to perform such a seismic survey over a known hydrocarbon accumulation. Figure 5.17 shows the single-fold spread layout and the relative area of coverage. While data processing of this project continues at Allied Geophysical



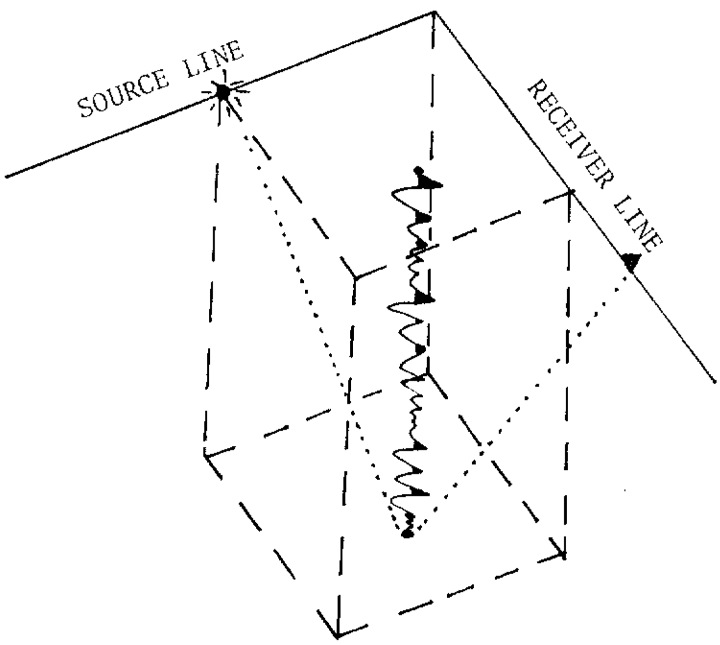


Figure 5.16 SINGLE-FOLD RECORDING

Figure 5.17 ACTUAL FIELD RECORDING LAYOUT

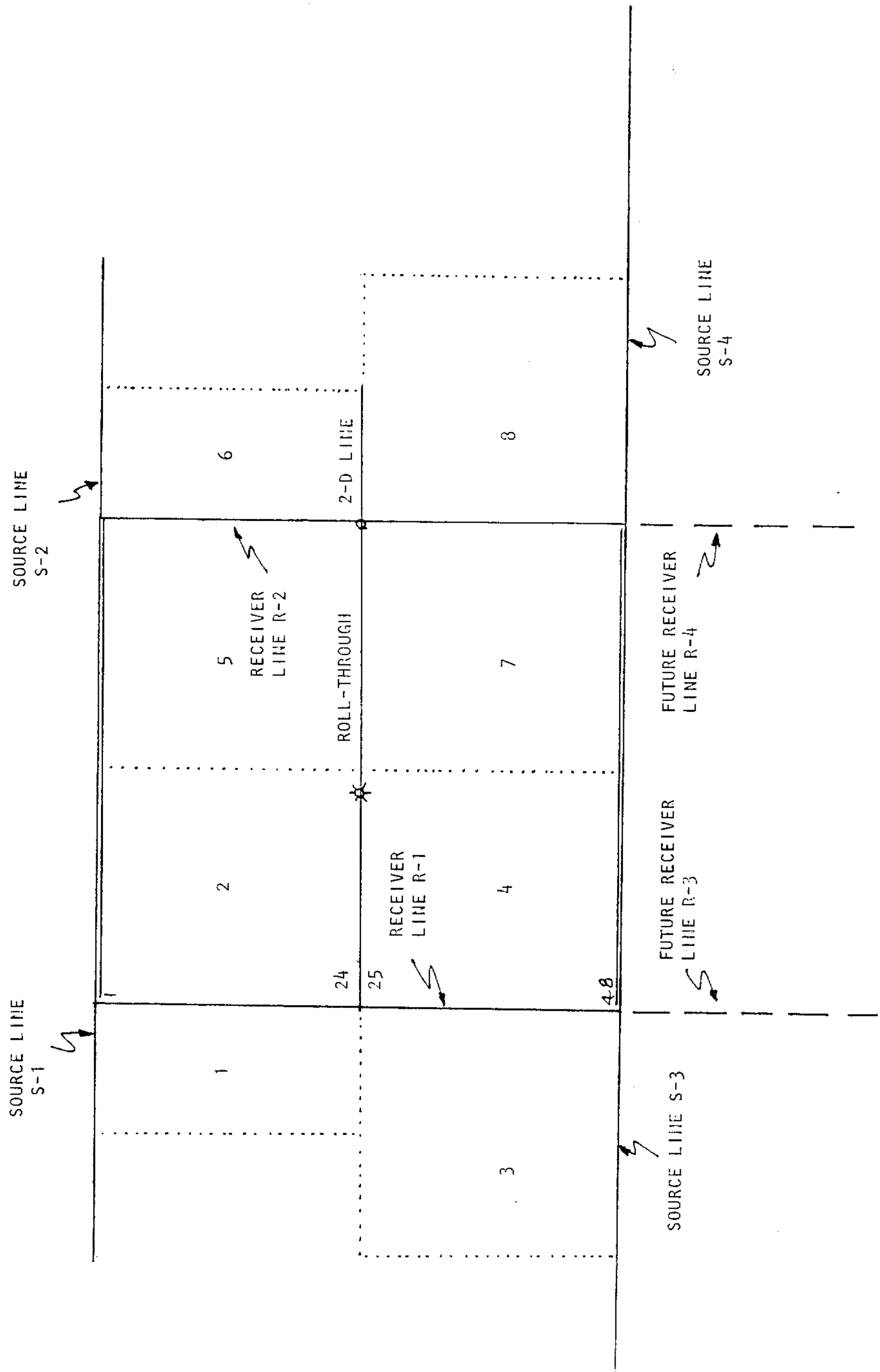
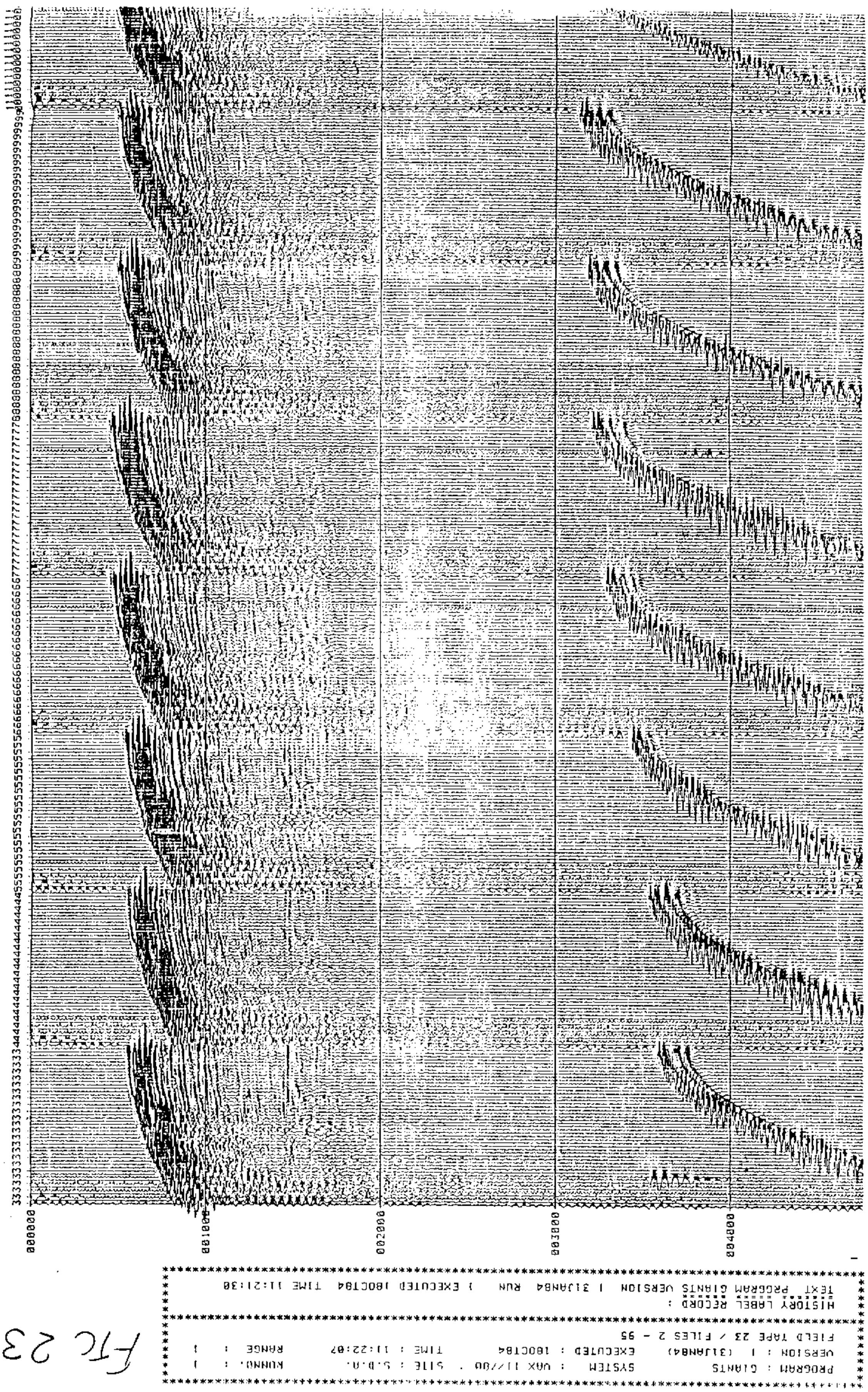


Figure 5.18 SWATH FIELD RECORDS



Laboratories, the area of coverage will be extended to the south during 1985.

Figure 5.18 is a typical series of records taken during this recent single-fold three-dimensional survey. The records display signal and noise effects. Clearly, the air-blast would require muting before advanced processing could be performed. However, the records do illustrate an area for further field application in the future.

5.5 Deep Crustal Recording (with the cable presently in use)

Cable take-outs are 43 metres apart. The application of adaptor connectors which allow every other take-out to be monitored, increases station interval to 86 metres. With cables configured in split spread manner, i.e. 6 cables (18 take-outs) per spread leg, it is then possible to extend the full spread to 36 take-outs i.e. a spread 3010 metres in length. This would provide some data for long range crustal recording, where widely spaced receivers are needed to get subsurface velocity information.

During September/October 1983, the recording system was used as part of a joint crustal research project with the Bureau of Mineral Resources (BMR). The recording equipment was mobilized to Corrigin (Western Australia). 48 stations were positioned 40 metres apart, whilst the BMR long range refraction equipment was positioned in a crossed formation with its centre also at Corrigin. Long offset (400 Km.) deep refraction shots were fired, and the DFS recording instruments were used to record crustal reflection and refraction data. In addition, off-end and split-spread dynamite charges were recorded for shallow velocity data. The long range shots were initiated by the BMR, and recording with the DFS IV commenced 15 seconds after a verbal radio communication was received, informing that the shot had been fired. This was done to avoid excessively long records with no data at the beginning. The local reflection shots were initiated by conventional radio firing means. Data is currently being processed by the Bureau of Mineral Resources, and the analysis of that data will not be presented in this thesis.

5.6 Borehole Recording

A potential application of the recording system is that of recording down hole seismic signals. Conventionally, seismic and well-logging contractors clamp a geophone to the bore wall, and on initiating a surface energy source, are able to observe the wavefront propagation downhole. In the knowledge that the majority of the wave arrivals have travelled one way, velocity determination and seismic multiple recognition techniques can assist horizon prediction. This technique allows computer processing of the recorded data, and is known as 'vertical seismic profiling' because the receiver is moved vertically in making a series of recordings.

With a single geophone in use, source generated noise called "tube waves" are observed in the annulus (Hardage, 1983) surrounding the bore-hole. To date, these have been difficult to isolate and, hence, attenuate. However, recent technological advances have indicated that multiple geophones will be used in future, using the time honoured noise cancellation theory used for conventional seismic recording. However, such multiple geophone strings require multi-channel recording and this is an area for future 48 channel recording instrument application.

A further multi-geophone downhole recording configuration is conceived, if three dimensional (triaxial) geophones are located down a bore. Since the recording system can accept 48 data channels, it follows that 16 triaxial geophone levels may be monitored in a bore, at any one time. Thus, in typical walk-away noise spread manner, a source may be initiated a number of times at the surface and, on each initiation, the 48 channel monitoring points would build up three equivalent walk-away tube-wave panels.

A further configuration called "Fourth Dimension Recording" would allow the recording of a surface areal seismic survey, and use the same source to record down-hole geophone responses. ("Fourth Dimension Recording" allows recording three dimensions in distance, and a seismic section in time.)

It is envisaged that the application of the DFS recording instrumentation to such future research projects, would be to the advantage of all those interested in geological interpretation and the advancement of science.

CHAPTER 6

6.1 CONCLUSIONS

The seismic reflection technique involves the acquisition, processing and interpretation of data. These are not separate aspects, but form an integrated continuum of considerable human effort and high financial cost.

It is fundamental that, unless the acquisition phase is properly planned and executed, processing cannot generate information that was not in the recorded data. Thus, the seismic interpretation is critically dependent on the data acquisition phase of a seismic survey.

The design, installation, mobilization and application of a seismic system is a particularly complex task. Not only must the system perform to the strictest specifications, but the design and application of the system to meet the geological constraints are also of extreme importance. In the course of this project, the equipment was tested and compared with the manufacturer's performance criteria. It was found that the recording filter performance was not as expected. The roll-off slope of the anti-alias filters had been modified to allow a 70dB per octave or 18dB per octave option. The modification did no more than reduce the slope to approximately 30dB per octave - irrespective of the option chosen.

Since manufacturers often distribute instrumentation performance literature to processing bureaux, it is quite likely that any inverse-filtering information supplied with this particular instrument would have been quite incorrect. Consequently, if this information had been used, final stacked seismic sections would not have been processed correctly. The point to be made therefore is that, rather than use manufacturers' idealised performance information, processing bureaux should use results obtained from the impulse response test, actually recorded on the seismic instruments in question.

The filter circuits produce large phase shifts. If a phase recovery operator is not used in data processing, the result will undoubtedly be a seismic section in which the character has been severely distorted. This is an explanation for the fact that wavelet character and phase relationships of differently recorded data over the same seismic lines (and down bore-holes) are frequently mismatched.

With regard to field applications, the results of recording various noise spreads and multi-fold seismic lines demonstrates the system is performing well. Indeed, the execution of a single-fold three-dimensional seismic survey over an established gas producing field, shows that the system can be applied to current field research.

6.2 RECOMMENDATIONS

Further work on the performance of the recording instruments is merited. A review of analog filter transfer functions would allow an assessment to be made of the effect of phase distortion on a final stacked seismic section. A seismic processing facility is needed to continue this work.

The instruments may be applied to further investigations of energy source levels, as well as a review of geophone properties. The recording system, when used with suitable receivers, could be utilized for recording p and s wave sections. This is important in reservoir studies.

Further work should be carried out on the effects at depth of horizontally travelling seismic waves. A repeat performance and quantative analysis of work executed by Dobrin (1952), would allow a revision of near-surface seismic wave motion theory.

A bore-hole seismic study could also be useful in determining down-hole noise, its origins and attenuation. Furthermore, the execution of an areal three-dimensional seismic survey and bore-hole study together may resolve many of the problems associated with tieing seismic sections to offset vertical seismic profiles. Such a programme would be termed "Fourth Dimensional Recording", since there are three dimensions in distance, with the seismic section in time.

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APPENDIX TO THESIS

THE ESTABLISHMENT OF A DIGITAL SEISMIC
ACQUISITION SYSTEM AND ITS SUBSEQUENT
APPLICATION IN THE FIELD.

by

B. J. Evans

This thesis appendix is presented as part of the requirements for the award of Master of Applied Science in Physics of the Western Australian Institute of Technology.

1984

VOLUME TWO - INSTRUMENT TESTS

ABSTRACT

The WAIT digital field system (DFS IV) 48 Channel recorder is installed in a mobile caravan for land based operations. In order to operate the system effectively, the operator must follow a step by step procedure to power-up the equipment and perform equipment tests, prior to recording field data.

The DFS IV recording system was originally donated to the Exploration Seismology Centre, and is supported by the following Texas Instruments technical manuals:-

1. Input Module.
2. Amplifier Module.
3. Format Module.
4. Reproduce Module.
5. Read/Write Module.
6. Tape Transport Module.
7. Systems Performance Manual.

This Appendix to the Masters thesis is designed to

a) provide guidance in powering up the equipment;
b) provide guidance in the performance of basic instrument daily test routines and how to analyse them;
c) display examples of the more comprehensive test routines, with limited analysis which may be performed in-situ (for the most part computer analysis is desired).

This Appendix attempts to walk the novice through a series of tests, until a completed test sheet (Section IV) has been completed.

A greater insight into instrumentation theory and performance is provided in the thesis' volume, and for more technical content the reader should refer directly to the manufacturers manual. The thesis provides additional and modification information relating to the instrumentation not contained in the technical manuals.

The author expresses his apologies for the quality of the paper monitor record reproductions. Unfortunately, the oscillographic camera lent for the production of records was not in the best of condition.

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I POWER-UP AND RECORDING ROUTINE

Prior to commencing any recording operation, the system must be powered up with all functional controls in their correct locations. The power-up routine must be adopted as follows:

1. Top battery knife switch thrown to close battery circuit. This shorts all live positive 12 volt battery terminals together, all negative terminals are already shorted. (Otherwise, if battery terminals are continuously shorted, the batteries would drain.)

2. Throw battery switch (causing 12 volt Format extractor fan to start rotating). This applies battery power to the instruments and radio. The radio should not be used without connecting an antenna.

3. Switch 240 volt Lambda power supply mains switch on, followed by Lambda power supply. Frequency of supply is tolerable between 48 and 52 Hz, voltage 230-250V. A dc output voltage from the Lambda is acceptable between 12 and 13.5 volts - preferably 13 volts under 'battery-only' load conditions.

4. Throw 'Lambda' switch which applies the Lambda output to the batteries. Since the instruments are not switched on yet, the Lambda is acting as a trickle charger supplying about 5 amps of current to the three batteries.

5. The DFS Format 'power-on' push-button switch may now be depressed. (1 on Front Panel Control Plate 1.1) Provided power circuit

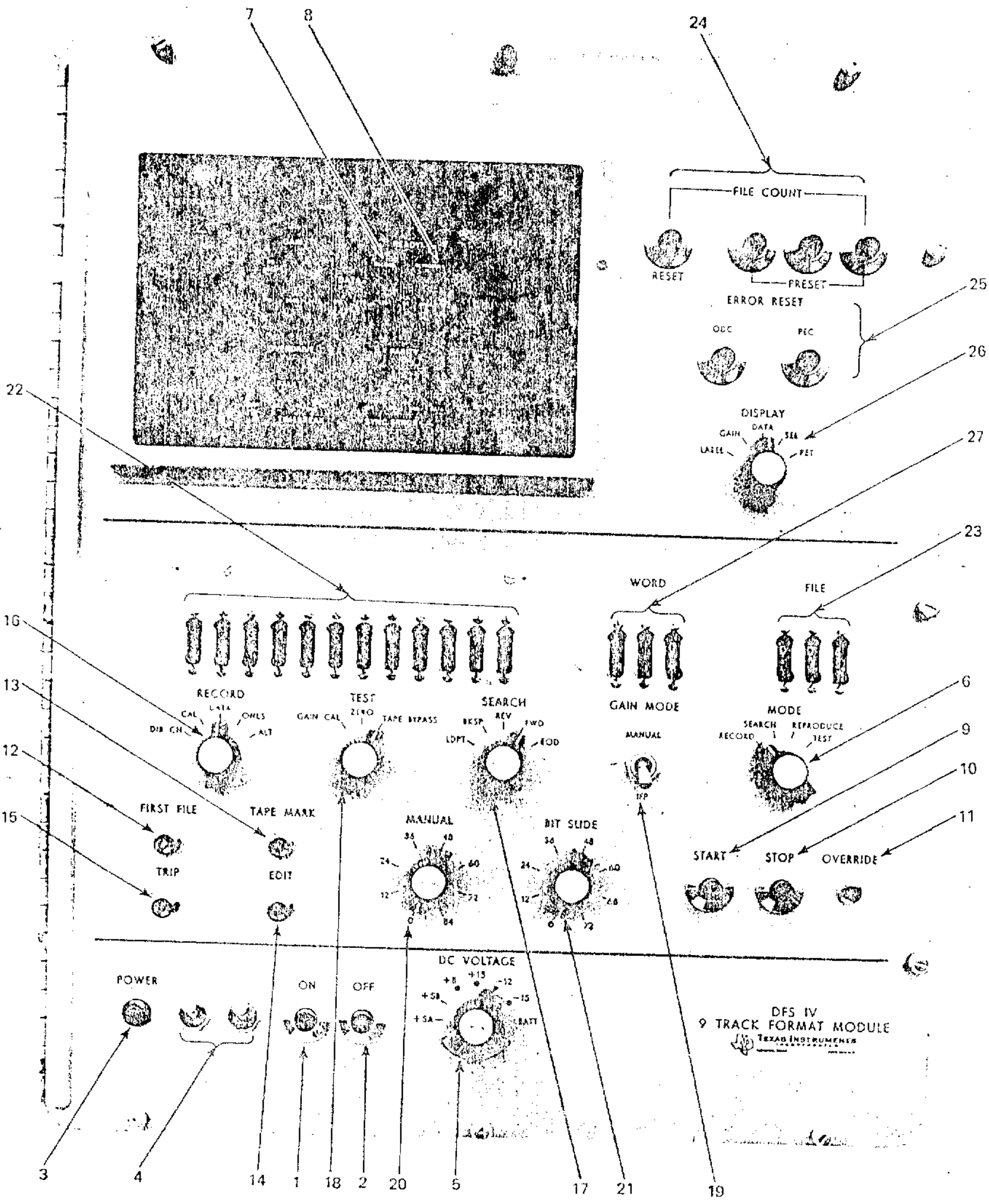


Plate 1.1 Front Panel Controls

breaker toggle switches (4) on the Format Module, Read-write Module and Reproduce Modules are up (i.e. 'ON'), the system will power-up.

6. If the tape transport arms are in the recording position (with magnetic tape mounted ready to record), but the Format Panel "TAPE" light indicates the transport is 'OFF', the transport power is off. This is switched on with the transport circuit breaker toggle switches on the Read/Write Module facia.

7. With the full system powered-up and batteries fully charged, the Lambda will indicate a current supply of 35 amps dc. With batteries fairly low, a supply of 60-65 amp dc is to be expected from the Lambda whereas, with very low batteries, a supply of up to 80 amps dc may be required. If this is the case, shut the instruments down by depressing the 'power-OFF' (2) pushbutton switch on the Format Module and connecting a battery charger immediately across the copper terminals beneath the 'battery/ Lambda' switches. Only under extreme circumstances should the instruments be run with an unstabilised power supply across the main 12 volt terminals. To expect a steady supply of 80 amps dc from the Lambda, or a flat stabilised response from a battery charger, is asking for trouble. An unstabilised charger may only be used for booster charging of the supply batteries.

8. Having powered-up the DFS, the instruments draw some 50 amps continuously. (They will run trouble-free for 3-4 hours on battery supply alone but don't allow the Lambda to recharge them alone without shutting down the instruments first.)

9. Assuming batteries and Lambda are in good shape (i.e. 35 amps from Lambda), switch on oscilloscope power. With the MODE switch (6 - Format Module) in 'RECORD' and the "READY" light (7) blinking, the system is ready to record data. The oscilloscope displays the output from the Reproduce Module - the signal prior to digitisation. If a straight line is traced out on the oscilloscope, either there is no signal being digitised or the oscilloscope is not in synchronisation with the system.

10. To observe a test signal on the oscilloscope, switch the Amplifier Module Test Meter Function switch to 'OUTPUT' and turn the signal level switch to 16mV and multiplication switch to x4 (i.e. 64mV output). An output frequency of 36 Hz may be chosen. Put each of the four Input Module "Operate/Parallel" switches to Parallel and observe the signal switched into each Module in turn.

11. If the 'OVERDRIVE' lights of the Format Display panel are glowing, this indicates the signal is in excess of the maximum allowable value the Analog to digital converter can handle. Ensure the Gain Mode switch (19) is in 'MANUAL' and that the gain level switch on the Format is at 0dB. No overdrives will now be observed and the amplifier circuitry is operating correctly.

12. With Record (7) light blinking, a recording may be made on magnetic tape by depressing the 'START' (9) switch. The tape will back-up (reading end of file header of previous record) and begin recording correctly, for the time set on the 'DATA' or 'CAL' push-button switches. To set the recording time, open the Format Module door and the switches are located on the left-hand side.

13. To make a recording without the magnetic tape (i.e. off-line), the Mode switch (6) may be placed in the 'TEST' position, and the 'TEST' switch (18) turned to 'TAPE BYPASS'. The electronics now puts the tape transport out of circuit and individual records may be made and observed on the oscilloscope.

14. To record data on-line, switch Input Module 'Operate/Parallel' switches back to 'OPERATE'. This puts the seismic line back in circuit and signal along the seismic line may be observed on the oscilloscope.

15. If no signal is observed on the oscilloscope, with the Gain Mode switch (19) in "MANUAL", there may be insufficient gain being applied to the incoming signal. Increase the gain level in 12dB steps (i.e. x4 per step). If no signal is observed by the 84dB switch position, but overdrive lights are glowing, this indicates signal is adequate to saturate the converter, and there is a display problem instead. Check the 'MODE' switch is in "RECORD", and that the Reproduce Module has the oscilloscope leads plugged-in. Ensure the Reproduce Module 'FLOAT/DEFLOAT/AGC' switch is in "FLOAT" position. Turn up the "INITIAL GAIN" Level switch if no signal appears - until one does. Some form of signal or noise will now be apparent on the oscilloscope.

16. So far the records have been recorded in Manual or 'fixed' gain mode i.e. a fixed gain has been applied to all incoming signal. This is useful in assessing individual channel/trace weaknesses. However, when seismic signals are recorded, the full system gain is required, which means recording in Instantaneous Floating

Point (I.F.P.) control. Full gain must be applied where signal reflections are weak. This operation is applied to all channels by the Amplifier Module and, in order to record a typical seismic record, the "GAIN MODE" circuit breaker switch (19) must be in "IFP".

17. To make a first record on magnetic tape, the tape must be mounted and tape wound through on to the empty take-up reel, sufficient until the silver start-of-tape marker has passed the recording head. With the tape transport arms released in the ready position, and Read/Write circuit breakers and transport switches on ('up'), depress the power-ON push button switch (1) on the Format Module.

18. With the system now powered-up, a tape 'END" warning light may indicate on the Format panel that end of tape is reached. In this case, the tape transport will not accept data until the warning light has been cleared. Shut the system down by depressing the "OFF" push-button (2) switch and back on depressing the "ON" switch (1) again.

19. System logic dictates that the first file on record is no less than two seconds. Hence, ensure the first file to be recorded is at least two seconds long. To record first file, depress 'FIRST FILE' push-button (12) and at the same time 'START'. The tape will back up to the silver tape mark, and roll forward recording the first record on tape for a time set by the "RECORD LENGTH' switches.

20. In 'RECORD' mode, the 'RECORD' switch may either be in the "DATA" or "CAL" switch positions - the record length being dependent upon the value set. However, in "TEST" mode, a test record in tape bypass will only be played for the value set on the "DATA" Record Length switch.

21. All successive records may be produced in like manner, and may be any value including one second in length. Maximum precise record length set is 39 seconds, or may be any longer length as desired, if the Record Length push-button "DATA" switch is set at 00 seconds. To stop such a record, the 'STOP' push-button (10) is depressed.

22. The logic encodes data on magnetic tape in SEG 'B' Format, (Figures 1.1 & 1.2), commencing with a Header block followed by the Data block (when data is being scanned and signal values recorded). Each side of these two blocks are 'Preamble' and 'Postamble' blocks. When the logic has been given the command to record, it reverses to the Data block 'Postamble', reads it, the tape mark and gap (end of file) and sets an inter-file gap 0.6 inches long prior to recording the next records 'Preamble' and Header block. The first code to be recorded in the Header is the file number. Logic circuitry and parity checking is so fast that all the observer may see is the tape back-up and roll forward with the appropriate file number displayed on both LED and goniometer indicators. However, having now recorded the second file with no difficulty, further files may be recorded in like manner.

23. Assuming a series of files are now recorded, they may be

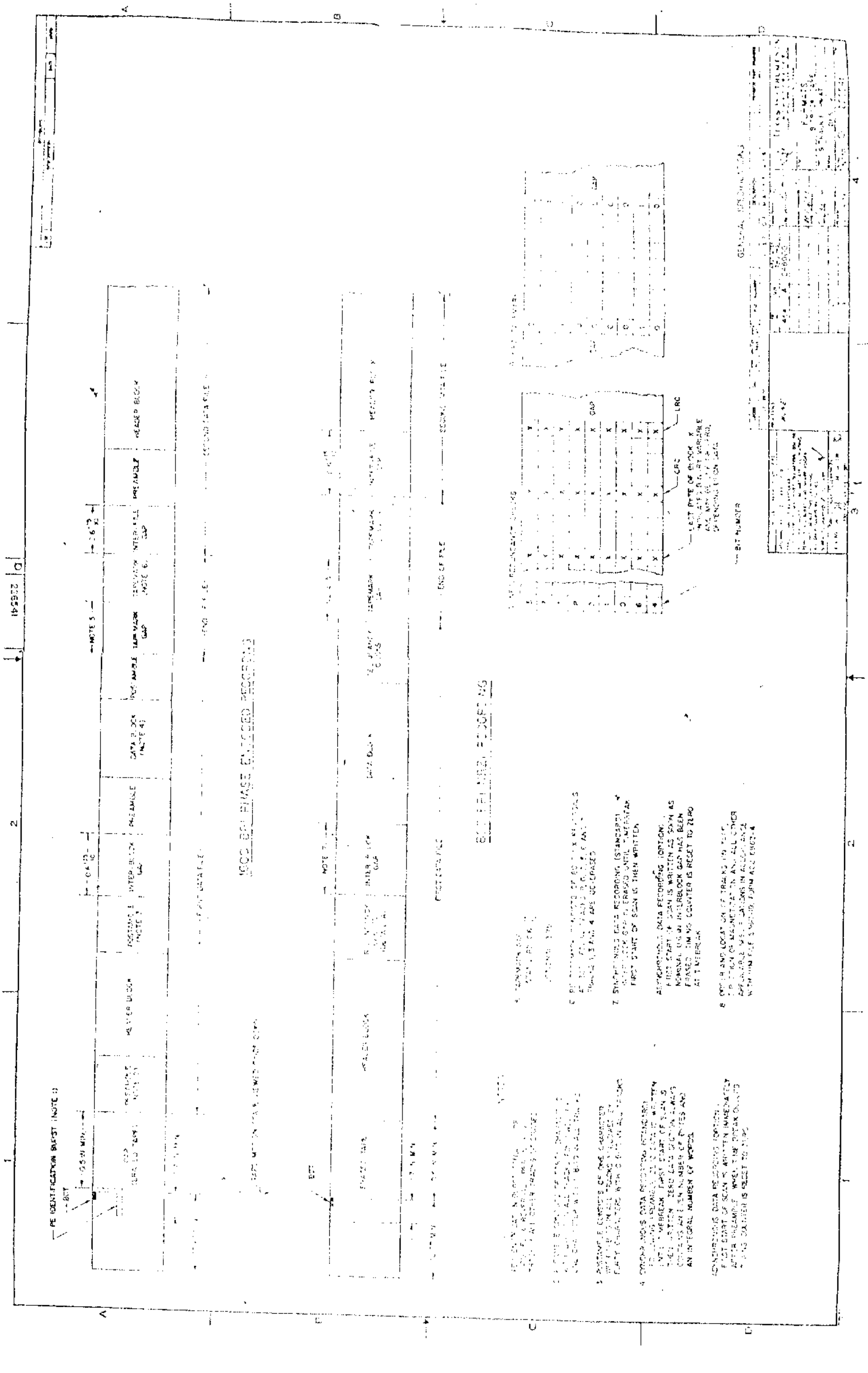
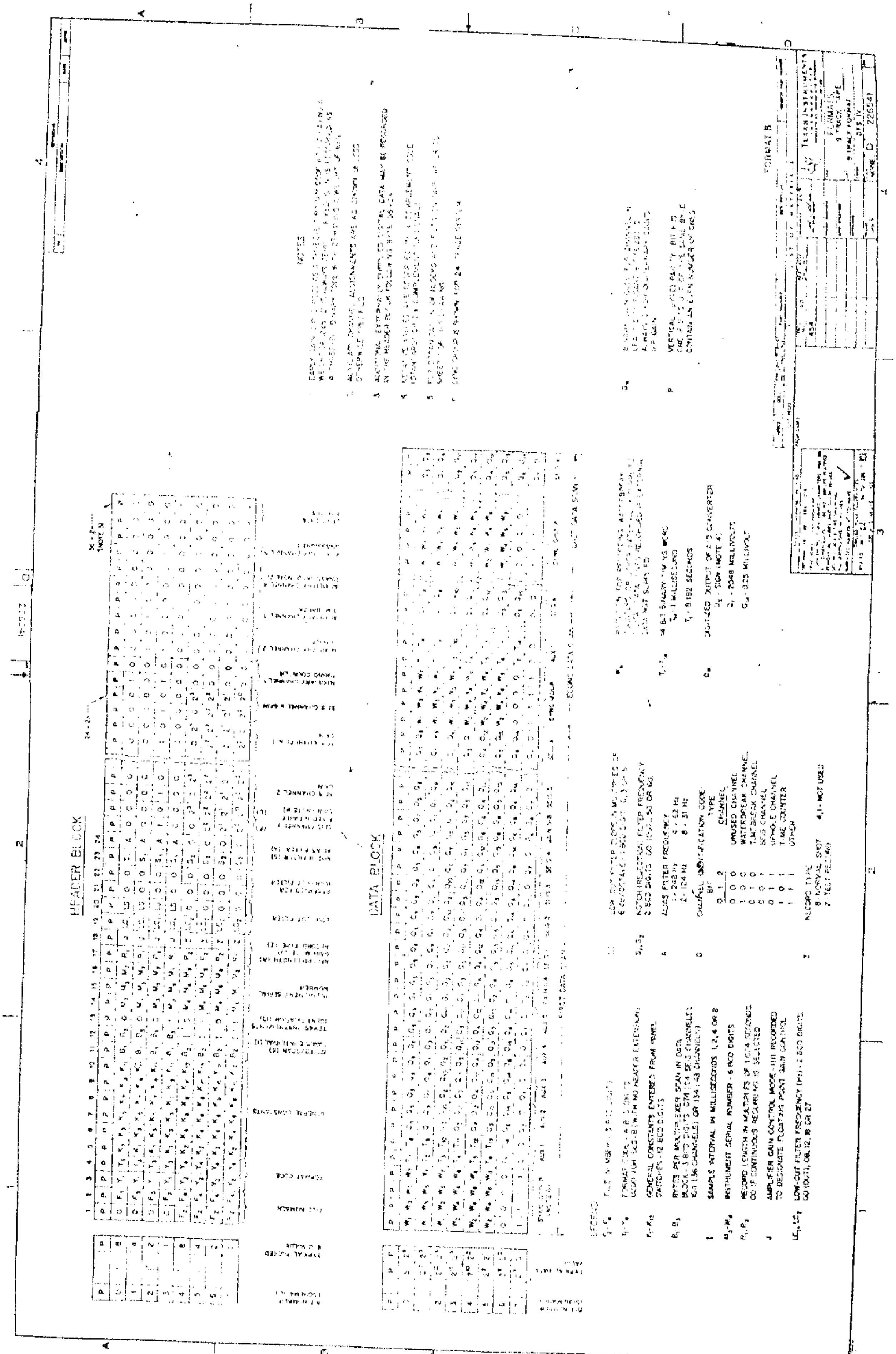

PE IDENTIFICATION BURST (NOTE 1)
HEADER BLOCK
PREAMBLE
DATA BLOCK
INTERBLOCK GAP
TAPE MARK
1600 BPI PHASE ENCODED RECORDING
800 BPI NRZI RECORDING
GENERAL SPECIFICATIONS

FIGURE 1.2



reproduced off magnetic tape for further inspection. To perform this act, place the Mode switch in the "REPRODUCE" position. Depress the "START" button and the file will be reproduced.

24. If a particular file is required to be reproduced, the tape must be searched to locate the requisite file. In this case, place the Mode switch (17) in either "REV" or "FWD" position. Apply the required file number to the "FILE" push-buttons and depress the "START" button (9). (Obviously, if the file number required to be reproduced is less than that displayed on the Record Count goniometers, it will be necessary to place the Search switch (17) into "REV".) The tape will firstly back-up, read the previous file number and continue forward or reverse dependent on Search option selected. On arrival at the required recording, the transport will halt at the start of the desired record.

25. Alternative modes of "SEARCH" are backspace "BKSP", loadpoint "LDPT" and end of data "EOD". If a file is to be reproduced, but the tape is situated at the end of that file, the back space option is used to search back to the start of that file. Load point is searched when the observer wishes to go back to the start-of-tape marker, whereas the end of data is selected when the observer wishes to position the tape head at the end of the last file, ready to record the next file.

26. Whenever recordings are made, a time break is necessary to determine the precise timing to commence scanning data prior to sampling (i.e. multiplexing). Two types of time break may be generated - Internal Time Break (ITB) or a Field Time Break (FTB).

The FTB only occurs when source firing is performed. In all other recording and test modes, an ITB is generated. The particular time break condition is indicated by the 'TIME BREAK' light illuminating.

27. In order to make a hard copy of what is recorded on magnetic tape, files may be reproduced from magnetic tape onto paper by the use of an oscillograph 'camera'. Two basic types of camera may be used - the 'dry-write' type (e.g. SDW-100 see Plate 1.2) or 'wet-write' type (e.g. ERC-10 see Plate 1.3). The dry-write camera simply focuses a light beam onto photographic paper. The light beam represents a single recording channel so that when the photographic paper is exposed to daylight, the trace exposed to the light beam previously will appear darker as the paper feeds out. The wet-write camera uses electrostatic paper such that after sensitizing by the use of a corona charge, the paper is exposed to the light beam. The paper is then automatically developed in a toner/freon solution prior to feeding out.

The dry-write camera often only allows 24 trace operation compared with the 48 trace capability of the electrostatic camera. A major difference between the two cameras is that the dry-write paper is very difficult to obtain since such cameras are no longer used by the industry, whereas the electrostatic camera paper is easily obtained since this camera is very much still state-of-the-art.

28. To operate the SDW-100, attach the 12 Vdc power terminals across a battery and switch on. A current of some 4 amps dc

shown on the meter (5) would be expected when the 'MANUAL RECORD' button (2) is depressed. Seismic traces may be viewed through the Galvanometer monitor screen (8) during recording. To load the paper magazine, hinge the housing forward and upwards and install as shown. Two 12-trace Cannon plugs will be inserted in the top of the unit, so that any two Input Module traces may be displayed at any one time.

29. To operate the ERC-10, attach the 12V dc power terminals across a battery and switch on. A current of 10-20 amps dc may be drawn and thus, a large battery is necessary for this camera. As with the dry-write version, seismic traces may be viewed on a monitor panel prior to a display proper. To load paper, the paper housing drawer is removed and loaded such that the sensitive side passes beneath the corona discharge correctly. Ensure that there is adequate freon and toner (ratio of 50:1) in the developer tank. Power is applied to the camera by depressing the 'POWER' push-button, and the xenon short-arc lamp start circuitry has a 500 volt dc supply applied across is when the 'GALVO LAMP' switch is depressed. Do not expose bare eyes to the lamp since this could prove fatal if the glass explodes. The 'NORMAL/STD BY' switch should be depressed - this starts the pump motor, which circulates developer fluid from the storage tank through the developer assembly. The "RECORD" switch may now be depressed, which causes the drive motor to start, and hence the paper to pass through the various mechanisms. The "PRESSURE" adjustment changes flow

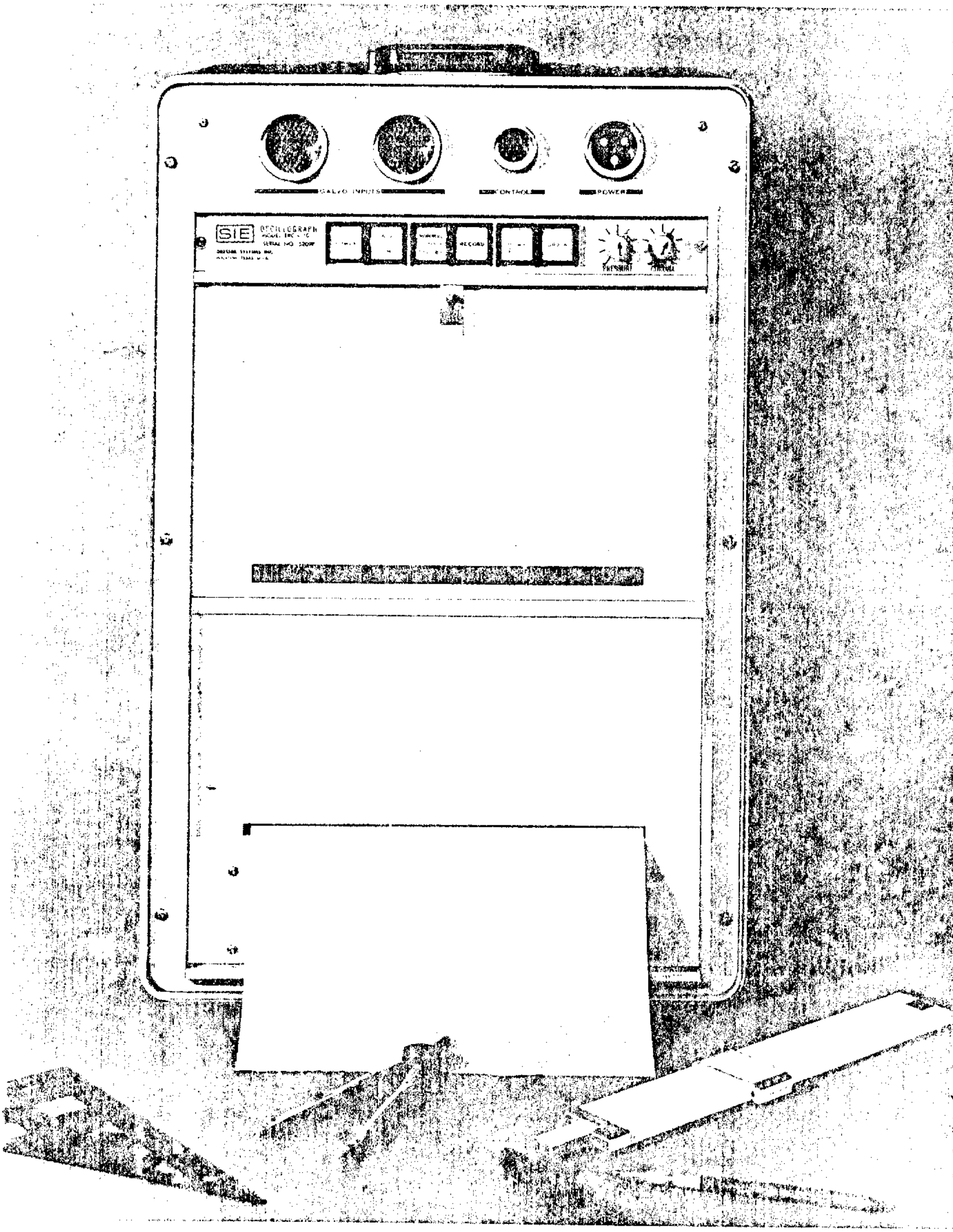


Plate 1.2 <u>ERC-10 CAMERA</u> (Courtesy S.I.E.)

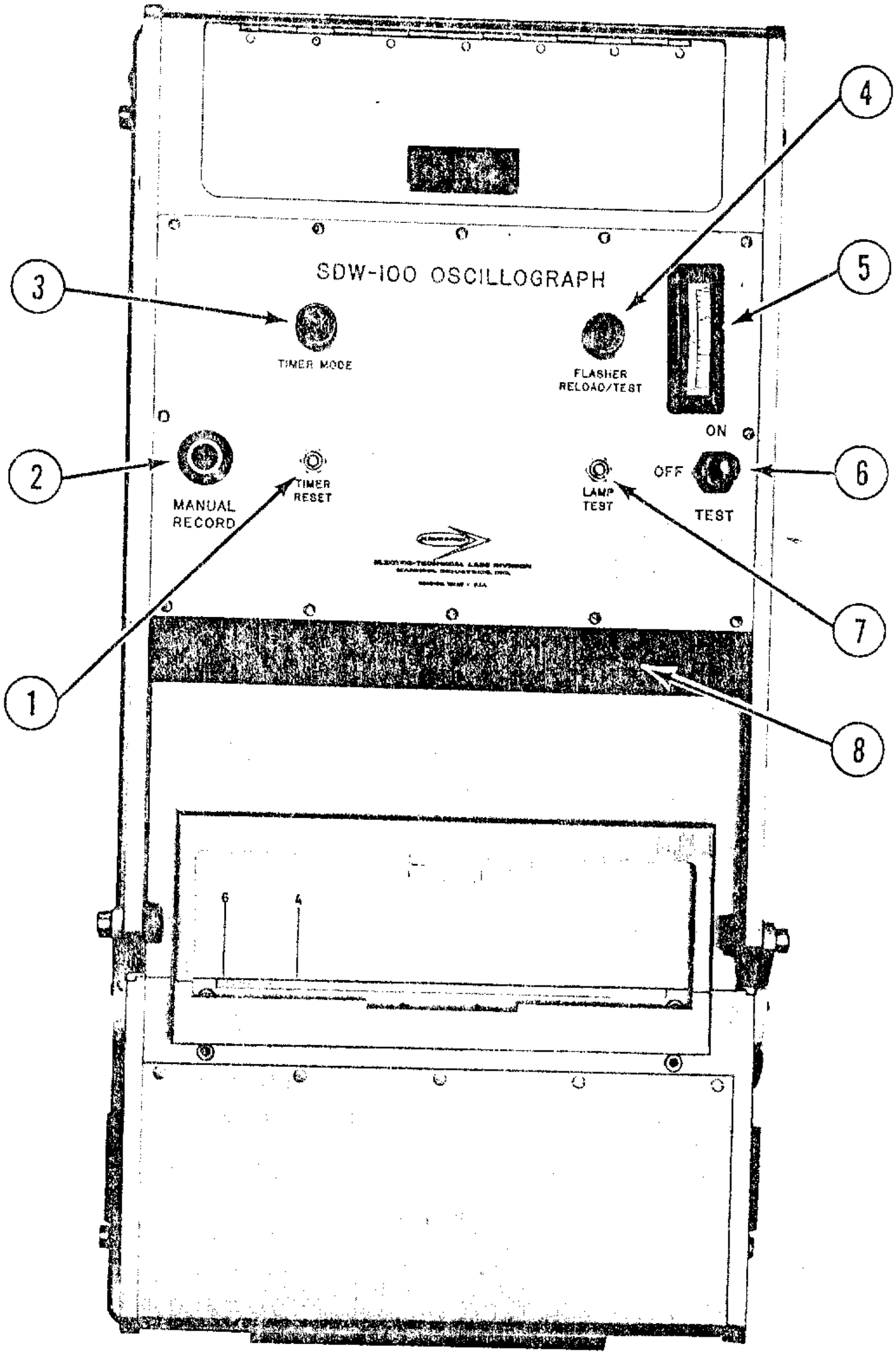


Plate 1.3

Plate 1.3 SDW-100 OSCILLOGRAPH CONTROLS AND DEVICES

(Courtesy ETL)

rate and pressure in the developing assembly, but very often has little real influence. The "CORONA" adjustment changes corona supply, which is often fixed.

Before removing the paper storage drawer, the developer assembly must be drained by depressing the "DRAIN" button. If this precaution is not taken, copious quantities of inky developing fluid may be liberated on removal of the drawer. Two 32-trace plugs are inserted in the top of the camera, allowing up to 64 traces to be displayed at any one time. If the trace contrast is poor, add more toner or check the power supply voltage. The electrostatic camera operates more effectively at 13 volts than 12 volts.

30. Paper records may now be reproduced off tape and the recording system operate correctly. For field recording, a radio-firing blaster unit is used. Provided the whip antenna is connected, and there is a decoder in use (to fire the explosive), the encoder may be used to supply an FTB to the DFS. During field operations, the operator depresses the "ARM' button to synchronize decoder and encoder, then presses the Format Module "START" button to initiate the recording sequence. In this case, an FTB is received to mark start of data scan, rather than ITB.

31. To power-down the system, the Format Module power "OFF" button is depressed, "battery" and "Lambda" switches switched to 'off', and the battery knife switch open circuited. The camera should be initially drained, switched to stand-by, galvo lamp switched off, followed by power off - in that order.

An incorrect power-down sequence may cause electronic faults on powering-up next time.

II TYPICAL DAILY INSTRUMENT TESTS

Most marine crews using these instruments record continuously 24 hours per day, whereas land crews will record for 8 hours per day. If an electronic problem exists which is not immediately apparent, it is clear that frequent checks should take place to avoid incorrectly recording data.

Consequently, on a daily basis, all crews operating DFS seismic instruments perform a series of daily instrument checks. More thorough checks are performed once monthly as indicated in the next Section of this Appendix.

On a daily basis, the following checks are performed:

(1) Dynamic Range Determination (DRD) test.

(2) Equivalent Input noise test.

(3) IFP Oscillator test.

(4) Filter Pulse test.

(1) Dynamic Range Determination test

a) Purpose

To check the dynamic ranging performance throughout the operating range of the system. Dynamic range is the amount of gain that may be applied or removed, to enable successful recording of a signal level to be converted from peak value to a minimum level at which signal is indistinguishable from noise.

The test gives a comprehensive picture of analog circuit performance and ADA conversion. It also checks:

Converter D.C. offset

Converter noise level

System noise level

Test signal level

Phase differences between channels (computer print out)

Defective circuits.

b) Dynamic Range Requirements

The A/D system records 14 data bits plus one sign bit. i.e. 2^{14} is 84 dB. Since digital noise uses about 6dB (least significant bit toggles), theoretical range available for recording is then 78dB - however, we will see on later crossfeed tests that a gain range greater than 80dB can be attained. If it is assumed that minimum instrument noise will toggle the least significant bit (0.25 μvolts), then at least 6dB will be used on noise. Thus, only a theoretical 78dB is available for dynamic recording. Table 2.1 overleaf is offered for consideration (courtesy Texas Instruments).

It is suggested therefore that the recording instruments have adequate dynamic range available. However, since the table is subjective, it is worthwhile noting that, if a particular marine prospect required a further 12dB greater range for signal to noise improvement, theoretically the instruments would fall short of requirements. It is worthwhile noting here therefore, that the instruments have limited dynamic range and may, in certain events, not record all signal presented to them.

Table 2.1

DYNAMIC RANGE REQUIREMENTS TABLE

	Stratigraphic Trap	Marine	Noise Area with Reverberations	Severe Noise Area
Output S:N ratio for record interpretation	20	12	12	10
Deconvolution or dereverberation	30	40	32	6
Range required for multiples and ghosts	15	15	20	50
Dynamic Range required (dB)	65	67	64	66

c) Procedure

It is assumed that the system is fully operational and calibrated correctly.

(A) Set up the switches on the modules -

INPUT MODULES:

Operate - Parallel Switch	PARALLEL
Channel Select and DC Voltage Switch	OFF
Filter Switches: Lo-cut	OUT
Hi-cut	248Hz - 1msec sample
	124Hz - 2msec sample
	62Hz - 4msec sample

AMPLIFIER MODULE:

Range Switch)) Level Switch)	Selected Value - see Table 2.2
Meter Function Switch	OUTPUT
Oscillator Control	36Hz
Sine-exponential Switch	SINE
Zero Switch	OFF

FORMAT MODULE:

Mode Switch	RECORD
Record Switch	CAL
Record Length Switch	2 sec first file
	1 sec thereafter
Gain Mode Switch	MANUAL
Manual Gain Switch	0dB
Bit Slide Switch	See Table 2.3
Data Display Switch	DATA

REPRODUCE MODULE:

Hi-cut	AUTO
Lo-cut	OUT
Mode Switch	FLOAT

All DC voltage switches should be off, switches not listed have no effect on the test.

(B) Test Considerations

Several system variables that affect the settings should be considered before starting the test.

System Gain Constant is a fixed gain value which is applied to the incoming signal after the signal has passed through an input transformer and filters. For this system, a 24dB gain constant has been selected for use with the 500 ohm input transformer. The highest signal value which does not overload the converter is 64 mvolts.

The Floating Point Amplifier gain also affects the DRD test. With the FPA set in MANUAL at 0dB, 64 mvolt input signal to the converter can be digitised. However, a level of FPA gain above this would saturate the A/D converter and cause clipping of the signal - set the MANUAL gain to 12dB and check this (overdrive lights will indicate a clipped signal).

After taking a record at the highest signal prior to clipping (64 mV - 2.8 or 3dB down from peak converter signal level), the signal level is then reduced by 12dB for each succeeding record until signal has been reduced by 81dB. Finally, a record is made with no test signal, which is a measure of system noise. (see Table 2.2)

For all recordings, FPA gain is held at 0dB. Paper records may be made for the first three files (Reproduce Module galvo level 18 or 21dB) after which records appear dead - the signal reducing in 12dB steps. Records are then reproduced increasing the Bit Slide setting by 12dB (see Table 2.3 and 2.4), so that a constant level output is observed. This helps in assessing noisy data channels, and note that the noise record is played back with an increase in gain of 78dB.

For the purposes of observing test results - two sets of typical DRD test results are shown in Figures 2.1 to 2.10.

The first set is an actual recording on the instruments with DRD step 1 being a 64 mvolt input on all channels. Although a first step DRD recording of 128 mV with a 24dB gain constant setting is 2.8dB down and thus the advised first step, a 64 mV input signal (as applied to the 30dB gain constant setting) on Table 2.2 is only correct for a 2K ohm input transformer setting. Thus, with a 500 ohm transformer, the 30dB gain constant setting signal levels apply. (See Table 2.3)

With reference to recording Figs.2.1 to 2.9 the 64 mvolt signal is displayed. The camera display is clearly not the best and, hence, for the purposes of this instruction, the galvanometer level thereafter was reduced by 12dB. If successive records had been played out with the same galvanometer level, results may have proven inferior.

Referring to Figure 2.10, these are the ideal panels as displayed by Texas Instruments.

With step 1 then, a recording is made 3dB down from peak value acceptable to the converter (+2, 048 mV), which is 64 mV.

The next step is taken with a bit slide increase of 12dB to compensate for the 12dB signal level reduction. Because this is only a playback recording, it does not affect what is recorded on tape, but assists us make a subjective assessment of the channel performance.

Each succeeding step increases 12dB bit slide playback with signal decrease of 12dB, until zero signal is attained. Note that digital playback gain is accomplished with the bit slide, the use of digital gain being necessary because the D-A converter in the Reproduce Module does not have the capacity to examine all bits simultaneously.

Normally all levels down to step 5 (51dB) are noise free, step 6 (63dB) having minimal noise, step 7 (75dB) indicating noise present but the test signal is dominant. Step 8 (81dB) has considerable noise but the test signal is recognisable, and final step 9 (81dB) has no signal and is just noise.

A comparison of step 8 with 9 will indicate a signal to noise ratio of better than 1 to 1, i.e. at least 81dB gain on an analog basis. This is considered as a good set of tests, and step 9 constitutes converter generated noise.

From instrument steps 7, 8 and 9, channel 35 is apparently noisy. The test clearly indicates that channel 35 is defective and would probably absorb at least 12dB just digitizing noise alone. This channel would be considered unacceptable and would be repaired before tests progressed further. The T.I. tests indicate channels have a dynamic range of the order of 87dB.

The sample rate has considerable effect on the appearance of the last steps e.g. 1 msec sample rate has more noise because of a high cut filter of 248Hz and samples being taken twice as frequently as at 2 msec. The same statement is made with regard to a comparison of 2 versus 4 msec recording (62Hz hi-cut). If converter noise exceeds acceptable limits after computer evaluation and yet field records appear acceptable, this is because noise recorded by the camera has been subject to playback filtering and sluggish galvanometer response.

Also, the Reproduce Module has only 11 bit reproduction capacity, as opposited to the recorded 15 bits. Thus, it is wise to increase bit slide for least significant bits. The T.I. test sheet illustrates a set of typical DRD tests on the system. (See Table 2.10)

		GAIN CONSTANT											
		42db		36db		30db		24db		18db		12db	
Record	Signal Level	Range	True Level	Range	True Level	Range	True Level	Range	True Level	Range	True Level	Range	True Level
1	16mV	X1	16mV	X2	32mV	X4	64mV	X8	128mV	X16	256mV	X32	512mV
2	4mV	X1	4mV	X2	8mV	X4	16mV	X8	32mV	X16	64mV	X32	128mV
3	1mV	X1	1mV	X2	2mV	X4	4mV	X8	8mV	X16	16mV	X32	32mV
4	256uV	X1	256uV	X2	512uV	X4	1mV	X8	2mV	X16	4mV	X32	8mV
5	64uV	X1	64uV	X2	128uV	X4	256uV	X8	512uV	X16	1mV	X32	2mV
6	16uV	X1	16uV	X2	32uV	X4	64uV	X8	128uV	X16	256uV	X32	512uV
7	4uV	X1	4uV	X2	8uV	X4	16uV	X8	32uV	X16	64uV	X32	128uV
8	1uV	X2	2uV	X4	4uV	X8	8uV	X16	16uV	X32	32uV	X16*	64uV
9	0	X2	0	X4	0	X8	0	X16	0	X32	0	X16	0

*Use 4uV Signal Level

Table 2.2 DYNAMIC RANGE DETERMINATION TEST SETTINGS - 2 kohm Transformer

...UMBER	DATE	TIME	OBSERVER MAKING TEST
SERIAL NUMBER	PARTY NUMBER	PARTY MANAGER	PARTY CHIEF

...DATA	SYSTEM FORMAT	NUMBER OF TRACKS	PACKING DENSITY - BPI
☑ 2 MIL ☐ 4 MIL ☐ ____	☐ 9 TRACK ☑ SEG B ☐ SEG C	☐ 24 ☑ 48 ☐ OTHER	☐ 556 ☐ 712 ☐ 800 ☑ 1600 PE

DYNAMIC RANGE DETERMINATION TEST

MONITOR SECTION					PLAYBACK SECTION		
RANGE SWITCH	LEVEL SWITCH	VALUE OF TEST SIGNAL	DB DOWN	FILE OR RECORD NUMBER	Galvo Level	BIT SLIDE	DB UP
×4	16 mV	64 mV	−3	2 SEC REC 001	SAME AS RECORD	0 db	+3
	4 mV	16 mV	−15	1 SEC REC 002	R + 12	0 db	+15
	1 mV	4 mV	−27	003	R + 12	12 db	+27
	256 µV	1024 µV	−39	004	R + 12	24 db	+39
	64 µV	256 µV	−51	005	R + 12	36 db	+51
	16 µV	64 µV	−63	006	R + 12	48 db	+63
	4 µV	16 µV	−75	007	R + 12	60 db	+75
×8	1 µV	8 µV	−81	008	R + 12	66 db	+81
	0	CONVERTER NOISE		009	R + 12	66 db	+81

EQUIVALENT INPUT NOISE TEST

...n Signal - 1µV ...d Number	Monitor Gain ____ DB	Noise: File/Record Number

Gain

...AL ____ DB | NOISE ____ DB

IFPA OSCILLATOR TEST

...d Number	Record Length ____ SEC	Method Signal Changes ☑ Exponential ☐ Sine Stepped
...gnal Level	Record Gain Mode ☑ IFP ☐ Manual	Galvo Level Record ___ DB/REP ___ DB

...Mode ☐ Defloat ☐ Float | AGC Reproduce Settings: Trip Sens ____ DB Initial Gain ____ DB

...ion ☐ PGC ☐ GAGC | Trip ____ Secs LEVEL: ☐ High ☐ Low | AGC Speed ____ PGC Rate ____ DB/SEC

FILTER PULSE TEST

FILE NUMBER	HICUT FILTER-HZ	LOCUT FILTER-HZ	NOTCH IN-OUT-HZ

MODE GAIN	GALVO LEVEL
___ db MAN ☐ IFPA	____ dB

OTHER SYSTEM PARAMETERS FOR TESTS

...EM CONFIGURATION

...ONLY ☐ CFS SYSTEM

...NSTANT ___ DB	GALVO LEVEL I-24 ____ DB AUX ____ DB	NOTCH FILTERS ☐ IN ☐ OUT
...ER CONNECTION ☐ 2000 Ω	FILTERS LOW CUT ____ HIGH CUT ____	RECORD TYPE ☐ DATA ☑ CAL
...NITOR OUTPUT ☑ (NOT RAW)	GENERAL CONSTANTS	

ANALYSIS RESULTS:

...CURACY: ________ MILLISECONDS DIFFERENCE BETWEEN TIMING LINES AND PIPPER TRACE ON MONITOR RECORD.

...ARIATION: ________ MILLISECONDS PER SECOND MAXIMUM VARIATION BETWEEN TIMING LINES AND PIPPER TRACE ON PLAYBACK RECORD.

GAIN ACCURACY TEST

MODE ☐ CAL	GAIN CONSTANT ____ DB	RECORD LENGTH ____ SEC
FILE NUMBER	RECORD GAIN SETTING	TEST SIGNAL LEVEL SWITCH
(1)	84	1 µV
(2)	72	1 µV
(3)	72	4 µV
(4)	60	4 µV
(5)	60	16 µV
(6)	48	16 µV
(7)	48	64 µV
(8)	36	64 µV
(9)	36	256 µV
(10)	24	256 µV
(11)	24	1 mV
(12)	12	1 mV
(13)	12	4 mV
(14)	0	4 mV

HARMONIC DISTORTION TEST

FILE NUMBER	HICUT FILTER-HZ	LOCUT FILTER-HZ	NOTCH IN-OUT-HZ	RECORD LENGTH

CROSSFEED TEST

FILE NUMBER	RECORD GAIN SETTING	CHANNEL TERMINATION
	0 (MANUAL)	EVEN
	IFP	EVEN
	IFP	ODD
	0 (MANUAL)	ODD

REMARKS: LIST THE FOLLOWING. 1) ANY SCRATCH RECORDINGS 2) REPAIRS SINCE LAST TEST. 3) REMARKS AND OTHER TEST PROCEDURES OR RESULTS — SKEW CHECKS, CONVLIN, TB, ETC.

Table 2.3

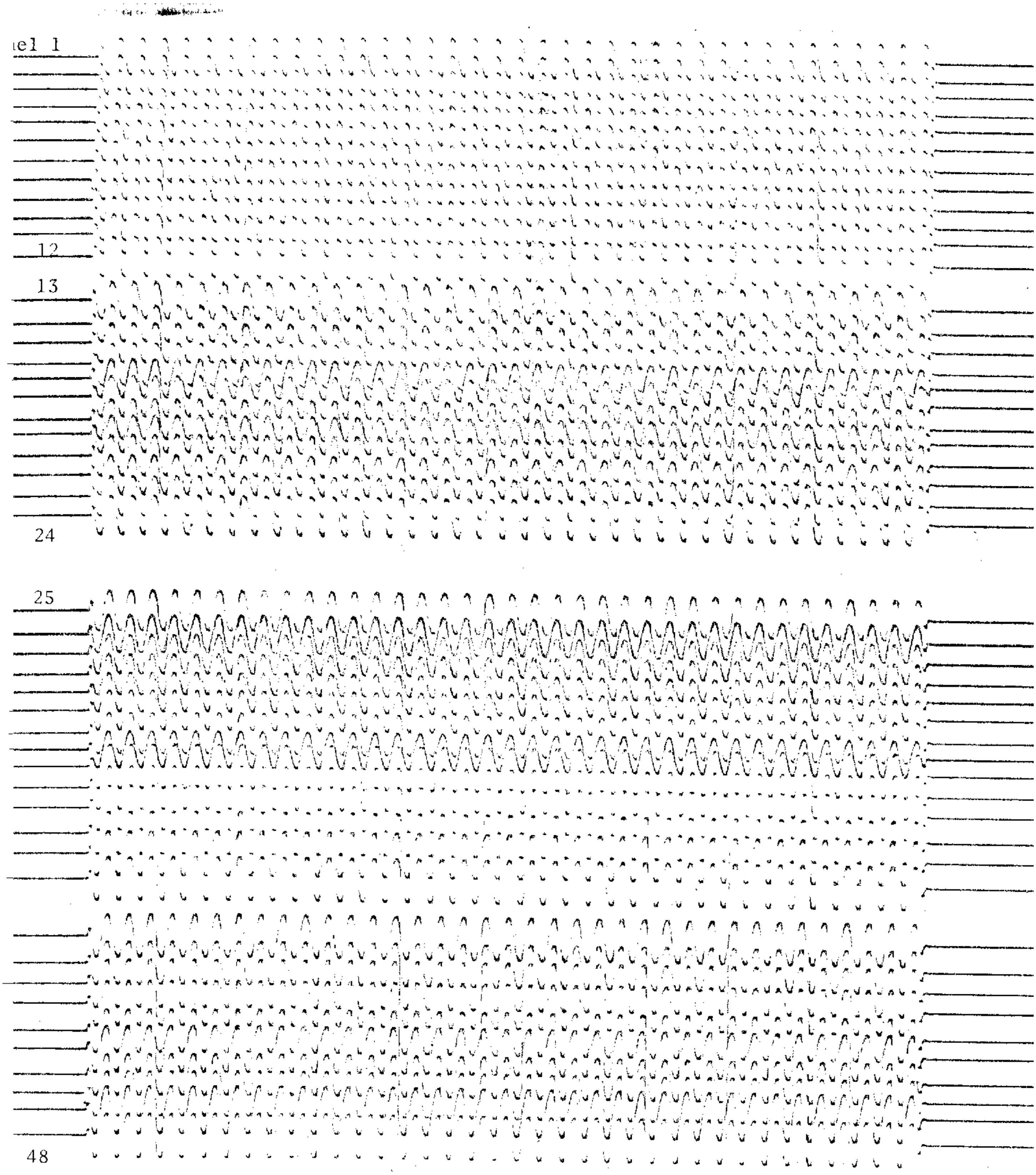
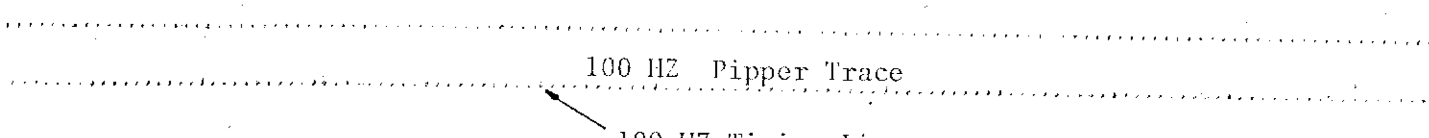


Figure 2.1



DRD Step 1

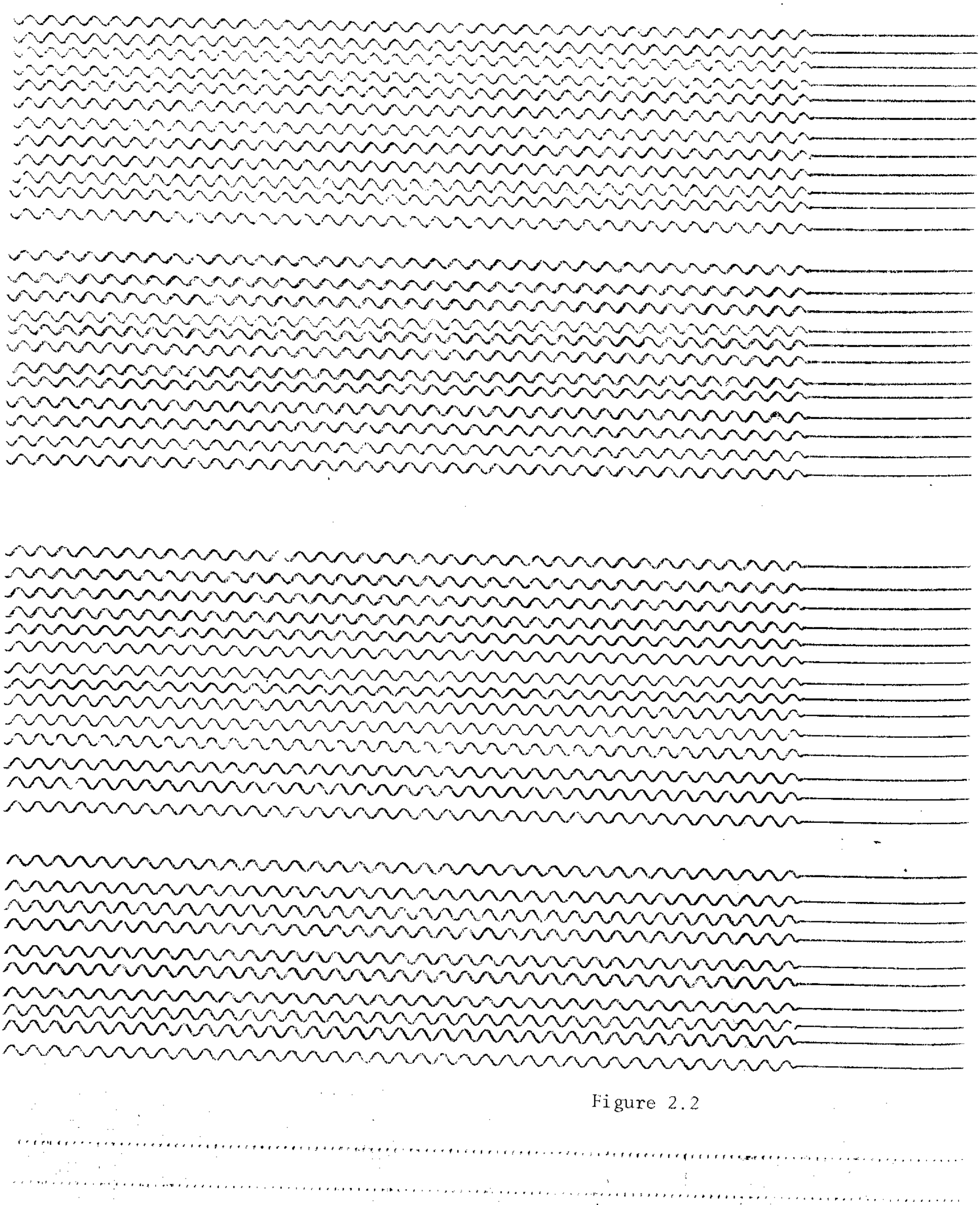


Figure 2.2

DRD Step 2

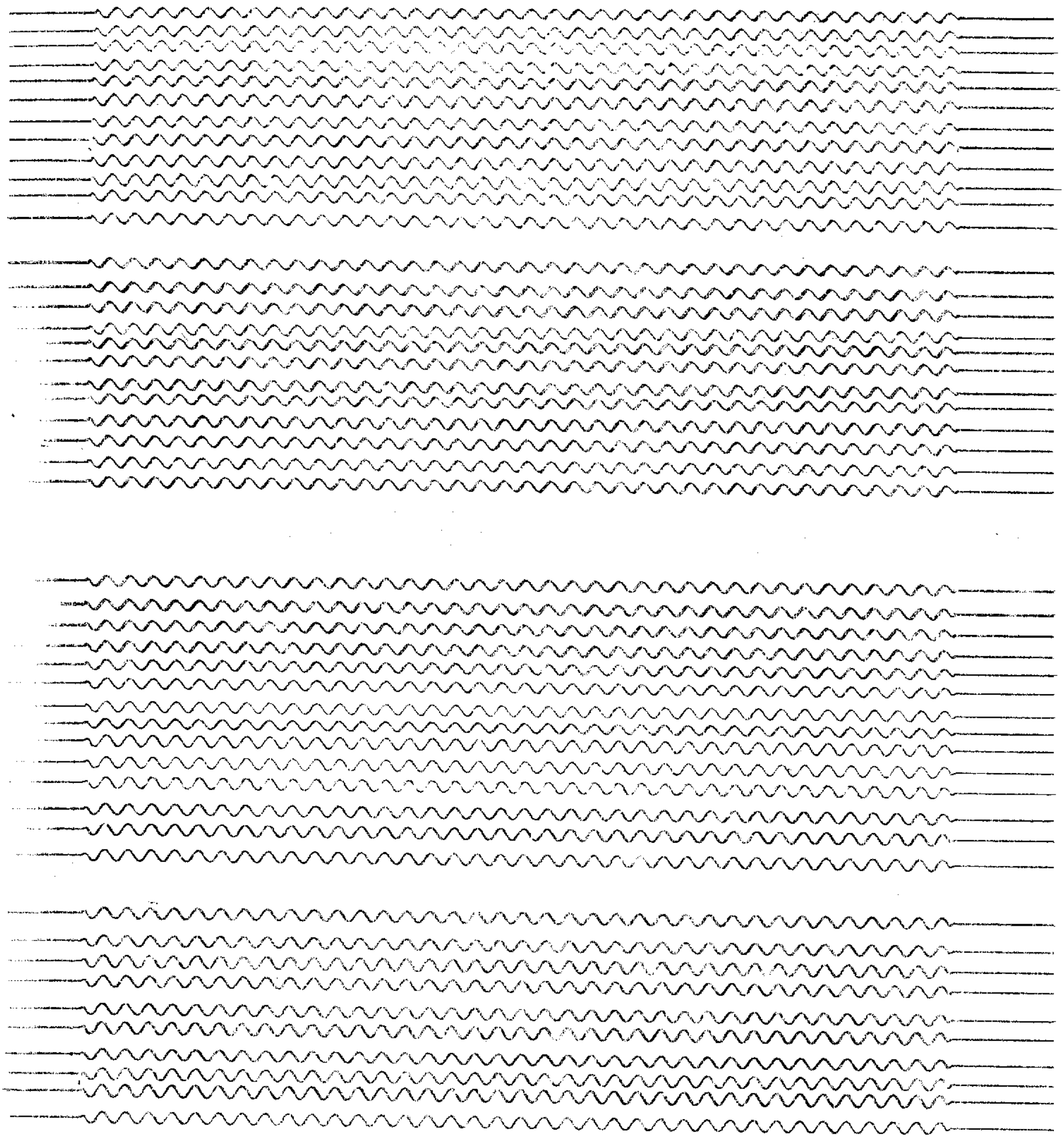


Figure 2.3

DRD Step 3

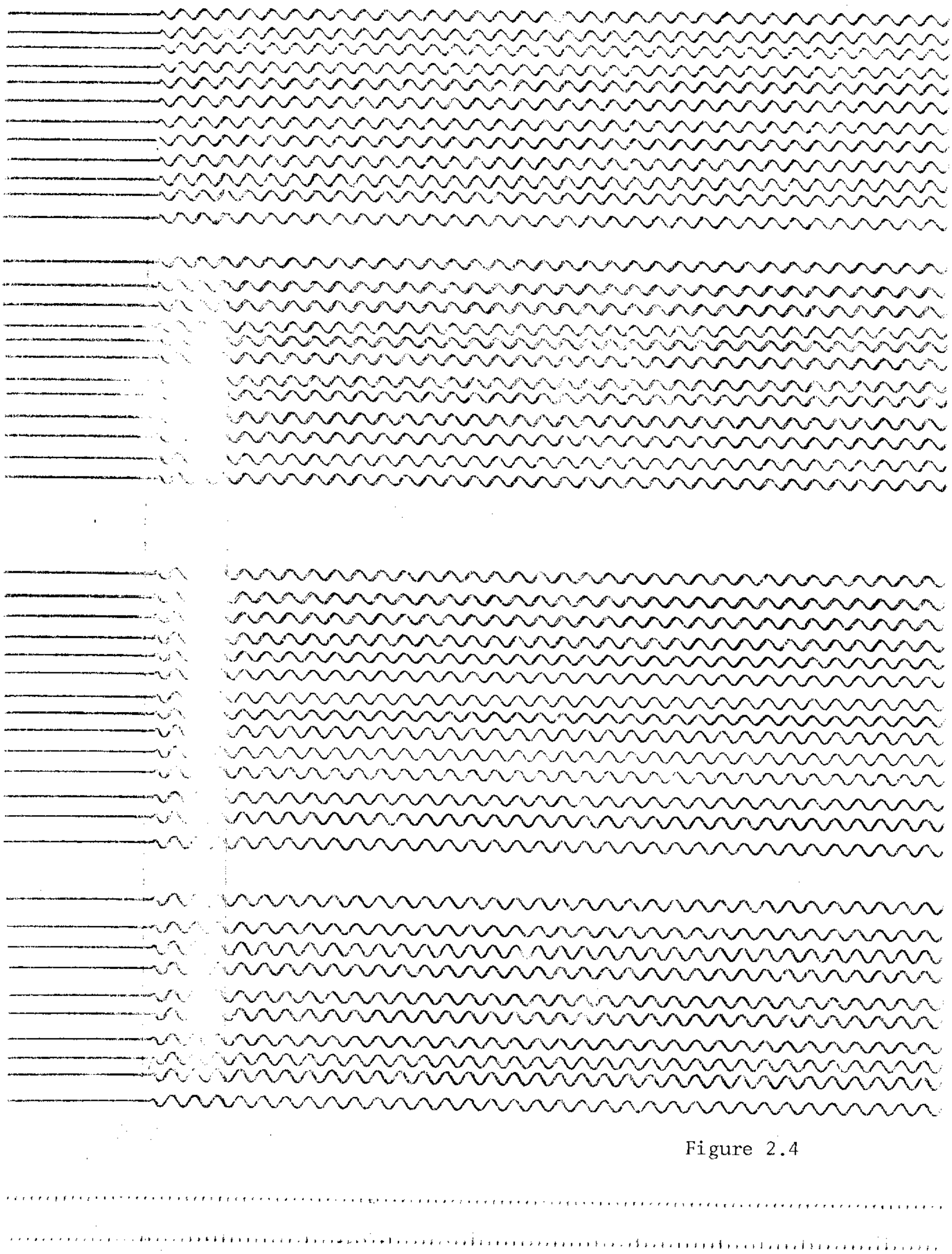


Figure 2.4

DRD Step 4

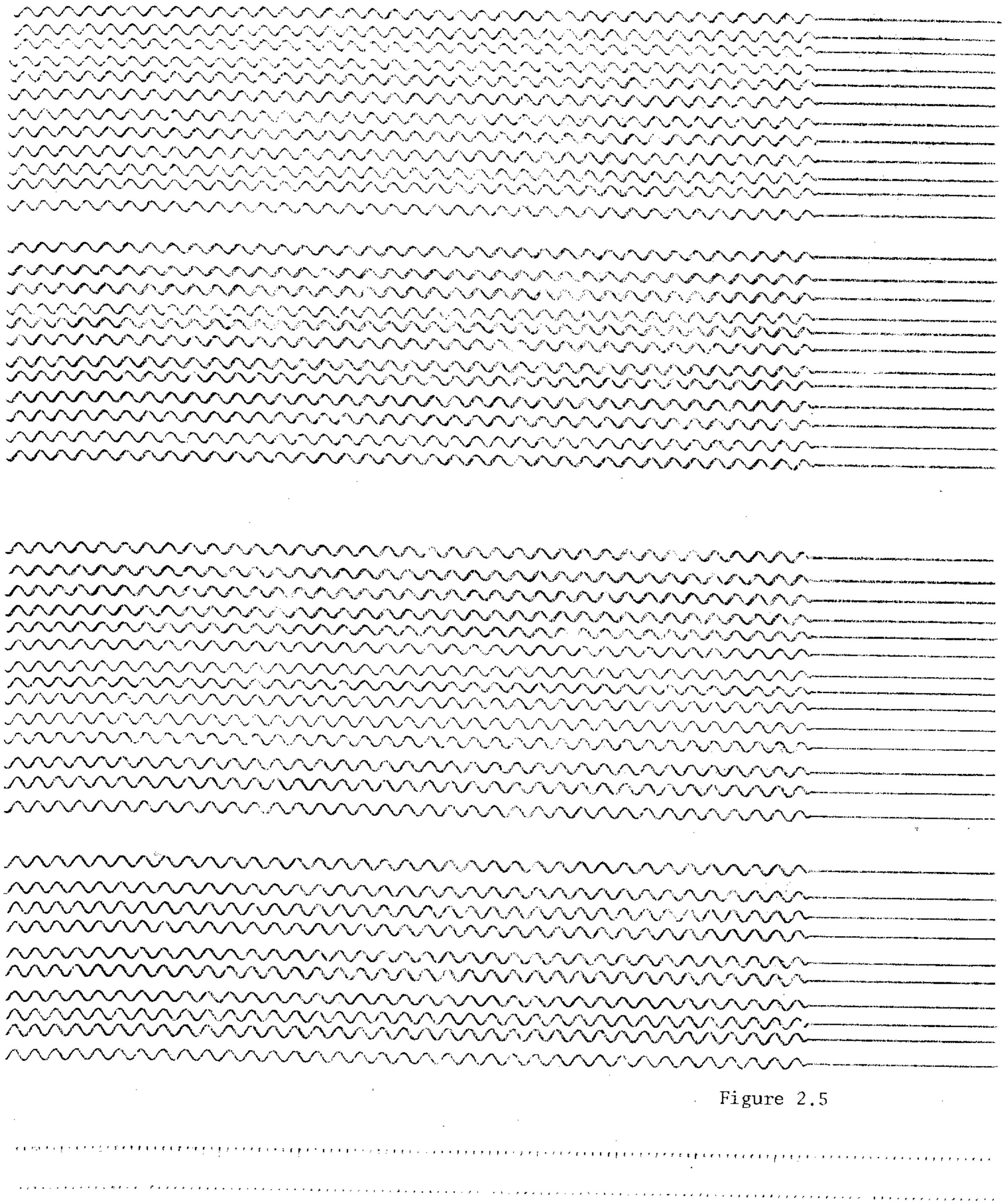


Figure 2.5

DRD Step 5

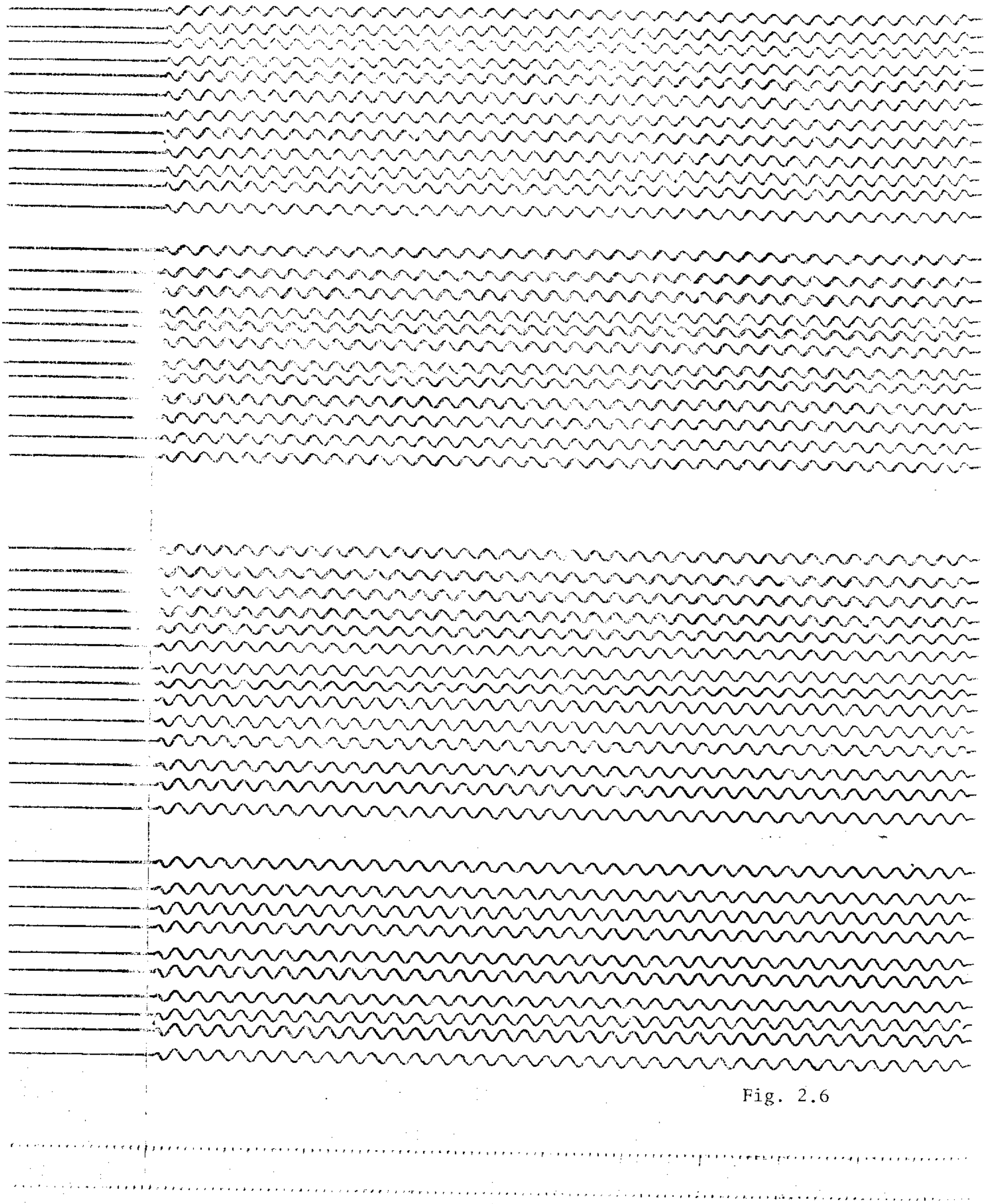


Fig. 2.6

DRD Step 6

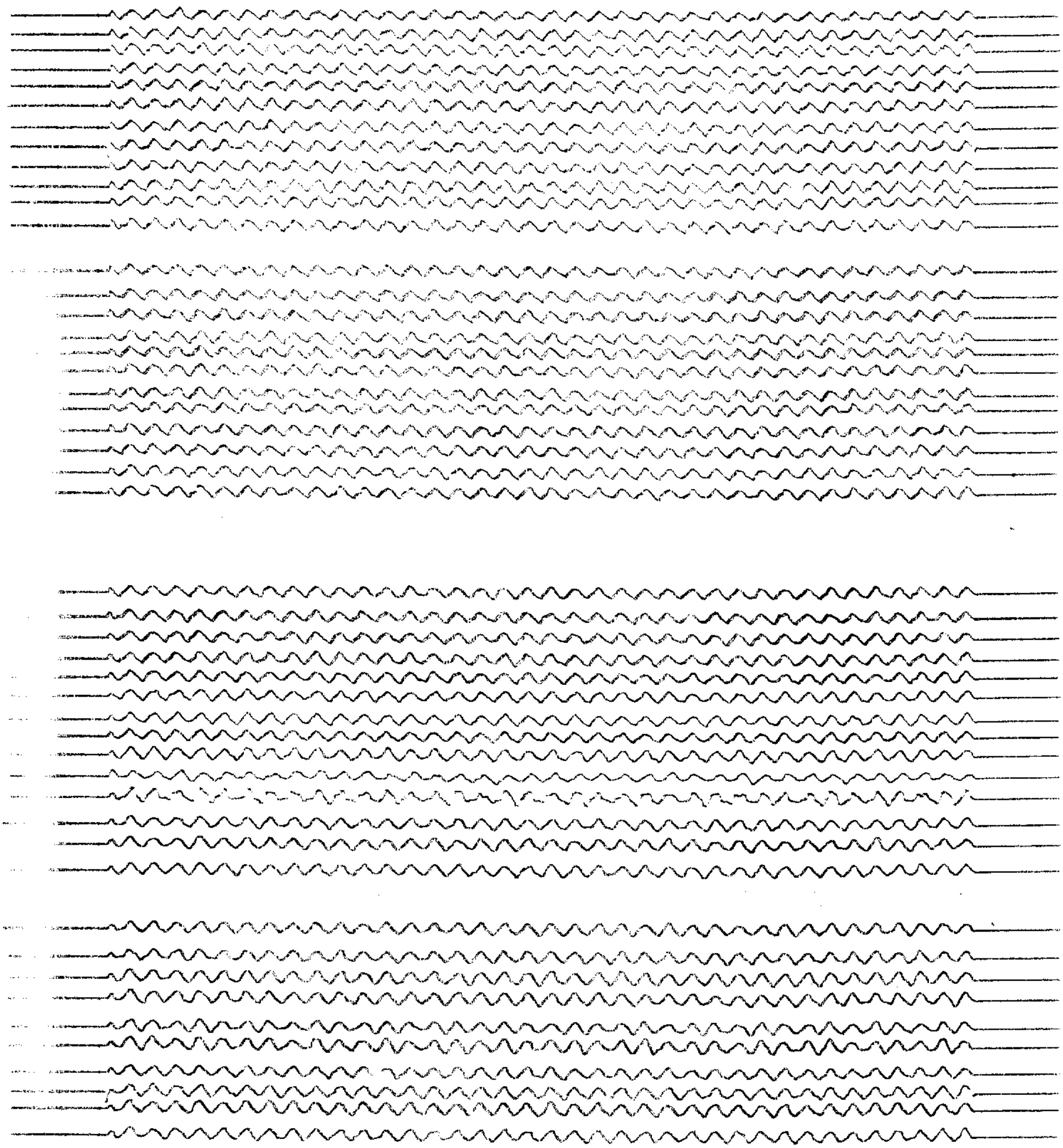
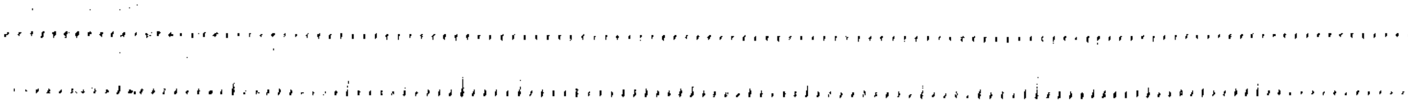


Figure 2.7



DRD Step 7

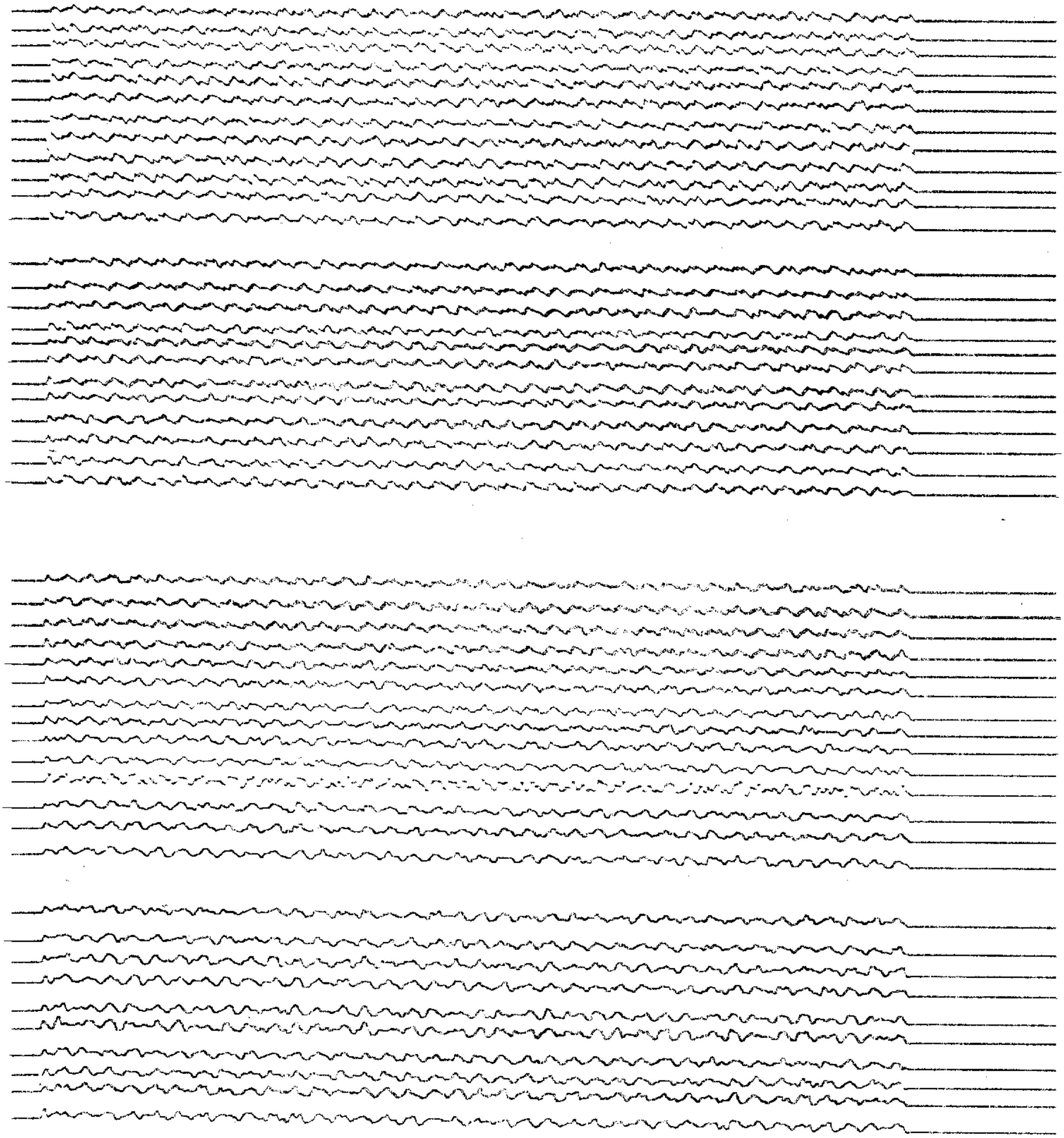
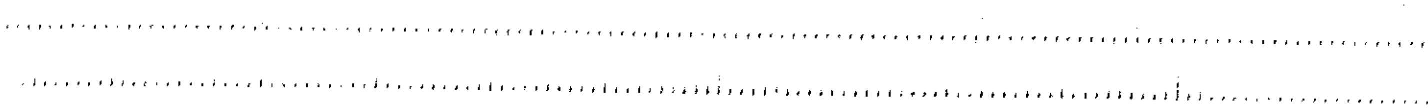


Figure 2.8



DRD Step 8

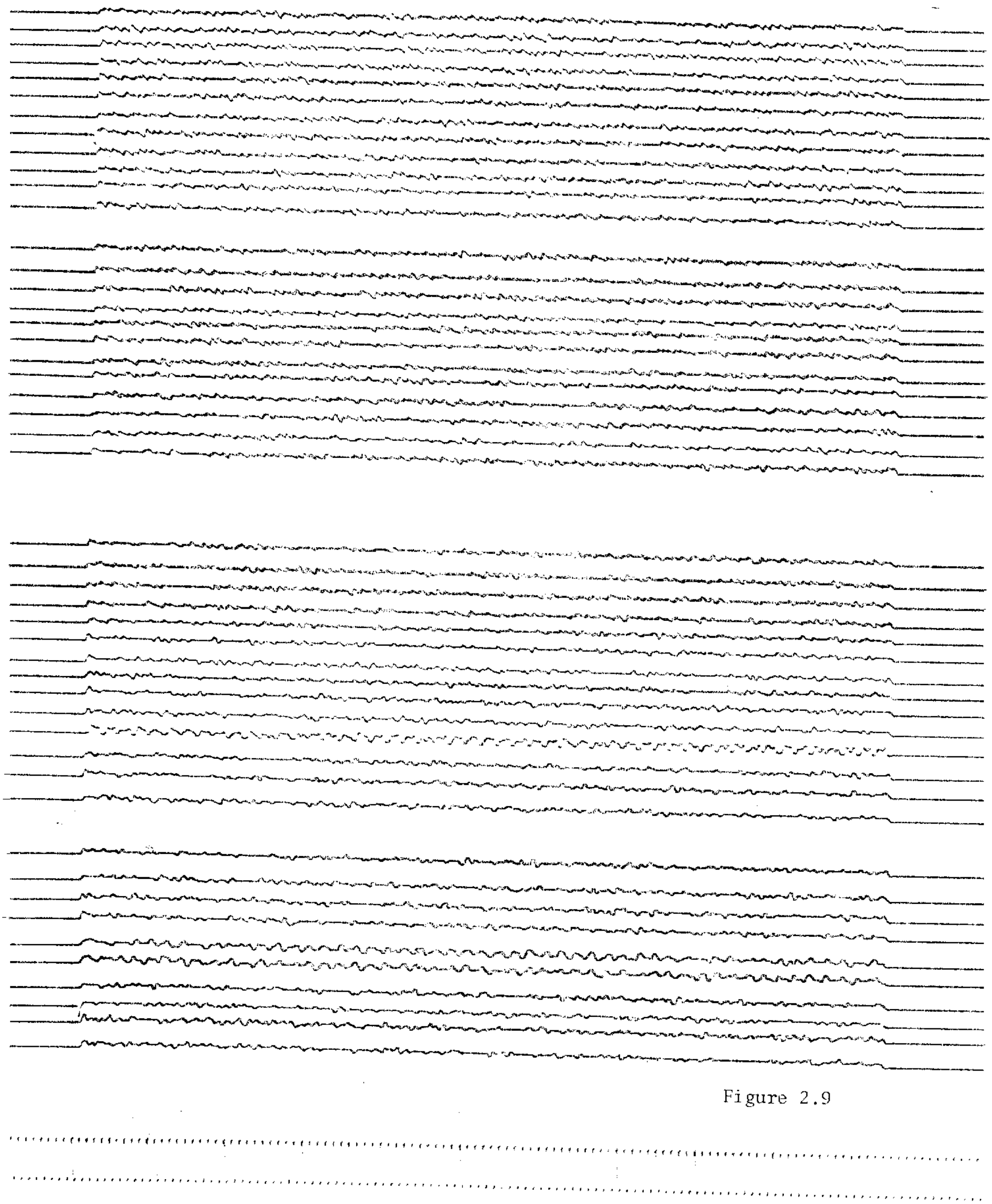
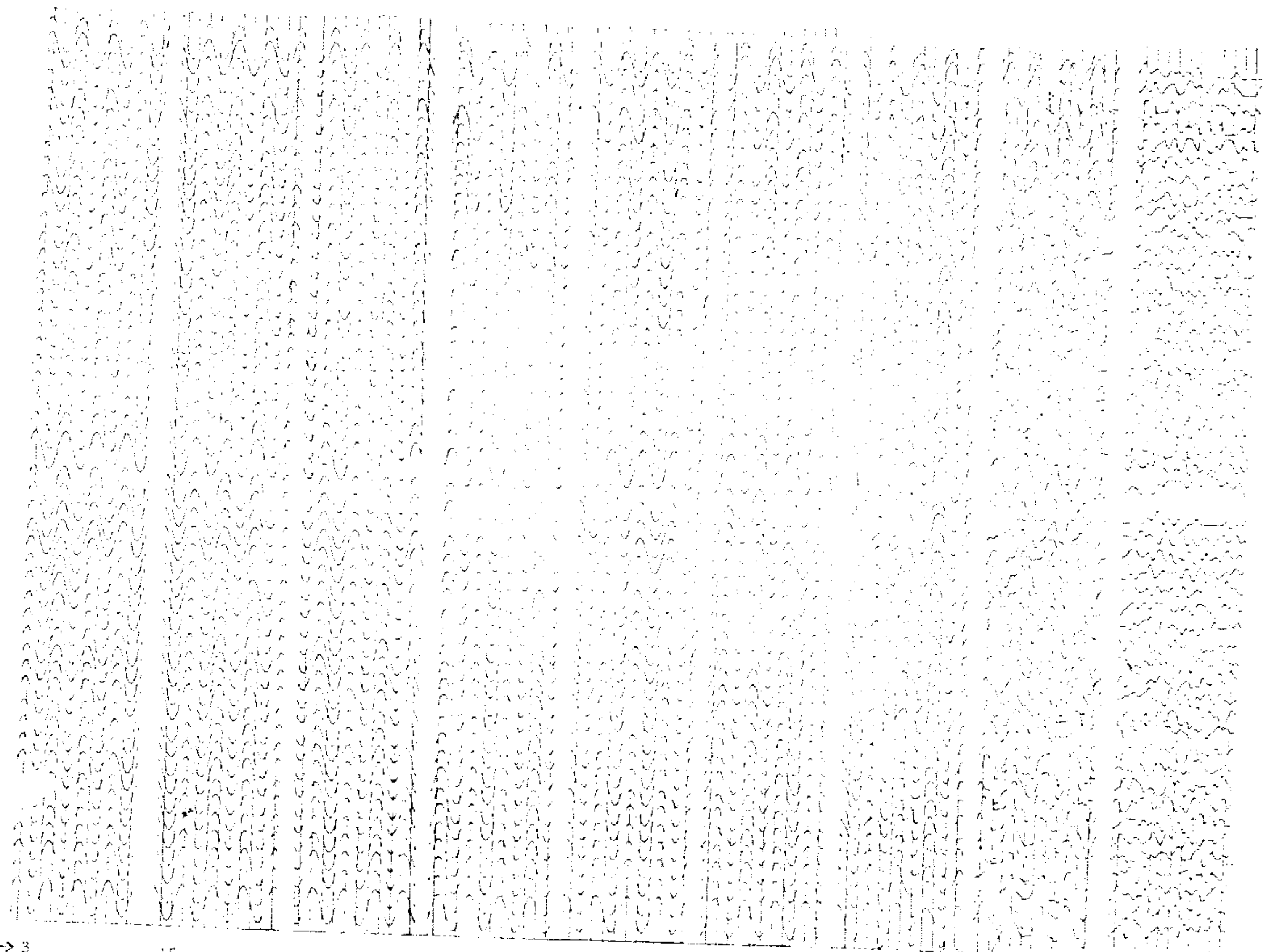


Figure 2.9

DRD Step 9

TYPICAL PLAYBACK SECTIONS FROM DFS IV DRD RECORDINGS



DB DOWN FROM MAXIMUM INPUT ⟶	3	15	27	39	51	63	75	81	Noise
INPUT TO AMPLIFIER SYSTEM - RMS ⟶	32,768 MV	8,192 MV	2,048 MV	512 μV	128 μV	32 μV	8 μV	4 μV	0
INPUT TO DIGITAL RECORDER and APPROX. ENCODED VALUE - PEAK ⟶	2,965.5 MV	741.5 MV	185.5 MV	46.5 MV	11.5 MV	3 MV	.75 MV	.36 MV	0

(2) Equivalent Input Noise Test

The previous DRD tests examined digitally generated noise in the DRD converter. However, a series of tests are now performed to check analog noise generated in the input, filter and amplifier stages - known at 'Input Noise'.

To perform this test, the instruments are operated at high gain, causing minute noise levels to become large enough to examine. The high gain is applied while recording so that in playback it cannot be construed as digitally generated, with low playback gain.

Specified limits of noise are shown on the tables 2.4 and 2.5 where, for a 500 ohm input transformer with a 24dB gain constant, a maximum acceptable limit of 0.31 microvolts RMS is required - a signal to noise ratio of 1:1.24.

To measure the noise level, a known signal level must first be used for comparison. Two recordings are made on tape - the first is a 1 microvolt signal with an 84dB MANUAL gain, the second removes the signal and signal input wires are terminated recording at 84dB again. (The termination may take the form of a plug containing 50 ohm resistors across each signal pair, or alternatively turn the Amplifier Test Meter Function switch to "Leakage" which shorts all inputs.)

The 1 microvolt signal acts as a reference.(Figure 2.11) It is played back at an amplitude shown on the record.

The noise record is reproduced 12dB up (Float-Initial Gain) or by galvo increase to give the display shown. (Figure 2.12)

Procedure

It is assumed that the system is calibrated and terminating plugs installed (or Meter Function Switch to "Leakage" if plugs unavailable).

(A) Set up the switches on modules:

INPUT MODULE:	Signal Test	Noise Test
Operate-Parallel Switch	PARALLEL	OPERATE
Channel Select - DC Voltage	OFF	
Filters: Lo-cut	OUT	
Hi-cut	As for DRD	
AMPLIFIER MODULE:		
Range Switch	x1	x1
Level Switch	1 microvolt	0
Meter Function Switch	OUTPUT	LEAKAGE
Oscillator Control	36Hz	
Sine-Exponential Switch	SINE	
Zero Switch	OFF	
DC Voltage Switch	OFF	
FORMAT MODULE:		
Mode Switch	RECORD	
Record Switch	CAL	
Record Length Switch	1 sec	
Gain Mode Switch	MANUAL	
Manual Gain Switch	84dB	
Bit Slide Switch	0	

REPRODUCE MODULE:	Signal Test	Noise Test
Hi-cut	AUTO	
Lo-cut	OUT	
Mode	FLOAT	

1. Make a record of a 1 microvolt test signal.
2. Turn Amplifier Meter Switch to Leakage (shorting inputs) or Off and Input Module Operate - Parallel Switch to Operate (if terminating plugs available).
3. Make a record of the input noise - played back 12dB up on signal by use of Initial Gain increase or galvo level (internal to Reproduce Module).

(B) Evaluation from Test Records

The system should not exceed 0.31 microvolts RMS. Examine the signal record - take one trace at a time and observe its amplitude. Compare this with the noise record which has had 12dB applied to it i.e. the peak-to-peak amplitude of the signal indicated between the arrows, when compared with a noise record 12dB up (i.e. 4 times) is effectively 1 microvolt ÷ 4 or 0.25 microvolts RMS. Thus, applying this level (with dividers or ruler) to the noise record traces suggests average noise of the system is of the order of less than 0.1 microvolt - good performance.

It may be noted again that trace 35 is excessively noisy. It further suggests that the noise is analog generated and, hence, all input signal paths (transformers, filters, multiplexers) should be checked to locate the cause of the noise. The channel would most definitely be unacceptable.

A second panel of T.I. tests indicate a system noise averaging about 0.2 microvolts. (Figure 2.13)

Input Transformer Connection	Gain Constant	Noise Level Specification µV RMS	Total System Gain	Playback Galvo Level Noise Section	Signal/ Noise Requirement
2000	36	.25	120	12db	1:1
	30	.25	114	12db	1:1
	24	.35	108	12db	1:1.4
	18	.62	102	6db	1:1.24
	12	1.2	96	Same	1:1.2
500	42	.1	126	18db	1: .8
	36	.11	120	18db	1: .9
	30	.17	114	18db	1:1.36
	24	.31	108	12db	1:1.24
	18	.6	102	6db	1:1.2

Table 2.4 EQUIVALENT INPUT NOISE TEST

NUMBER	DATE	TIME	OBSERVER MAKING TEST
SERIAL NUMBER	PARTY NUMBER	PARTY MANAGER	PARTY CHIEF

STATE: ☑ 2 MIL ☐ 4 MIL ☐ ______ | SYSTEM FORMAT: ☐ 9 TRACK ☑ SEG B ☐ SEG C | NUMBER OF TRACES: ☐ 24 ☑ 48 ☐ OTHER | PACKING DENSITY (BPI): ☐ 356 ☐ 712 ☐ 800 ☑ 1600 PE

DYNAMIC RANGE DETERMINATION TEST

MONITOR SECTION: RANGE SWITCH	LEVEL SWITCH	VALUE OF TEST SIGNAL	DB DOWN	FILE OR RECORD NUMBER	PLAYBACK SECTION: Galvo Level	BIT SLIDE	DB UP
			−3		SAME AS RECORD	0 db	+3
			−15		R + 12	0 db	+15
			−27		R + 12	12 db	+27
			−39		R + 12	24 db	+39
			−51		R + 12	36 db	+51
			−63		R + 12	48 db	+63
			−75		R + 12	60 db	+75
			−81		R + 12	66 db	+81
			NOISE		R + 12	66 db	+81

EQUIVALENT INPUT NOISE TEST

on Signal - 1μV Record Number	Monitor Gain	Noise: File/Record Number
010	84 DB	011

Gain
CAL ___0___ DB | NOISE ___12___ DB

IFPA OSCILLATOR TEST

Record Number | Record Length ____ SEC | Method Signal Changes: ☑ Exponential ☐ Sine Stepped

Signal Level | Record Gain Mode: ☑ IFP ☐ Manual | Galvo Level: Record ___ DB/REP ___ DB

Mode: ☐ Defloat ☐ Float | AGC Reproduce Settings: Trip Sens ____ DB Initial Gain ______ DB

Trip ______ Secs LEVEL: ☐ High ☐ Low

☐ PGC ☐ GAGC AGC Speed ______ PGC Rate ______ DB/SEC

FILTER PULSE TEST

FILE NUMBER	HICUT FILTER-HZ	LOCUT FILTER-HZ	NOTCH IN-OUT-HZ

MODE GAIN: ___ db MAN ☐ IFPA | GALVO LEVEL: ______ dB

OTHER SYSTEM PARAMETERS FOR TESTS

SYSTEM CONFIGURATION
ONLY ☐ CFS SYSTEM

CONSTANT ____ DB | GALVO LEVEL: 1-24 ____ DB | AUX ______ DB | NOTCH FILTERS: ☐ IN ☑ OUT

FR CONNECTION: ☑ 2000 Ω | FILTERS: LOW CUT | HIGH CUT | RECORD TYPE: ☐ DATA ☑ CAL

MONITOR OUTPUT ☑ (NOT RAW) | GENERAL CONSTANTS

ANALYSIS RESULTS:

ACCURACY: ______ MILLISECONDS DIFFERENCE BETWEEN TIMING LINES AND PIPPER TRACE ON MONITOR RECORD.

VARIATION: ______ MILLISECONDS PER SECOND MAXIMUM VARIATION BETWEEN TIMING LINES AND PIPPER TRACE ON PLAYBACK RECORD.

GAIN ACCURACY TEST

MODE: ☑ CAL | GAIN CONSTANT ______ DB | RECORD LENGTH ______

FILE NUMBER	RECORD GAIN SETTING	TEST SIGNAL LEVEL SWITCH
(1)	84	1 μ
(2)	72	1 μ
(3)	72	4 μ
(4)	60	4 μ
(5)	60	16 μ
(6)	48	16 μ
(7)	48	64 μ
(8)	36	64 μ
(9)	36	256 μ
(10)	24	256 μ
(11)	24	1 m
(12)	12	1 m
(13)	12	4 m
(14)	0	4 m

HARMONIC DISTORTION TEST

FILE NUMBER	HICUT FILTER-HZ	LOCUT FILTER-HZ	NOTCH IN-OUT-HZ	RECORD LENGTH

CROSSFEED TEST

FILE NUMBER	RECORD GAIN SETTING	CHANNEL TERMINATION
	O (MANUAL)	EVEN
	IFP	EVEN
	IFP	ODD
	O (MANUAL)	ODD

REMARKS: LIST THE FOLLOWING. 1) ANY SCRATCH RECORDINGS 2) REPAIRS SINCE LAST TEST. 3) REMARKS AND OTHER TEST PROCEDURES OR RESULTS – SKEW CHECKS, CONVLIN, TB, ETC.

Table 2.5

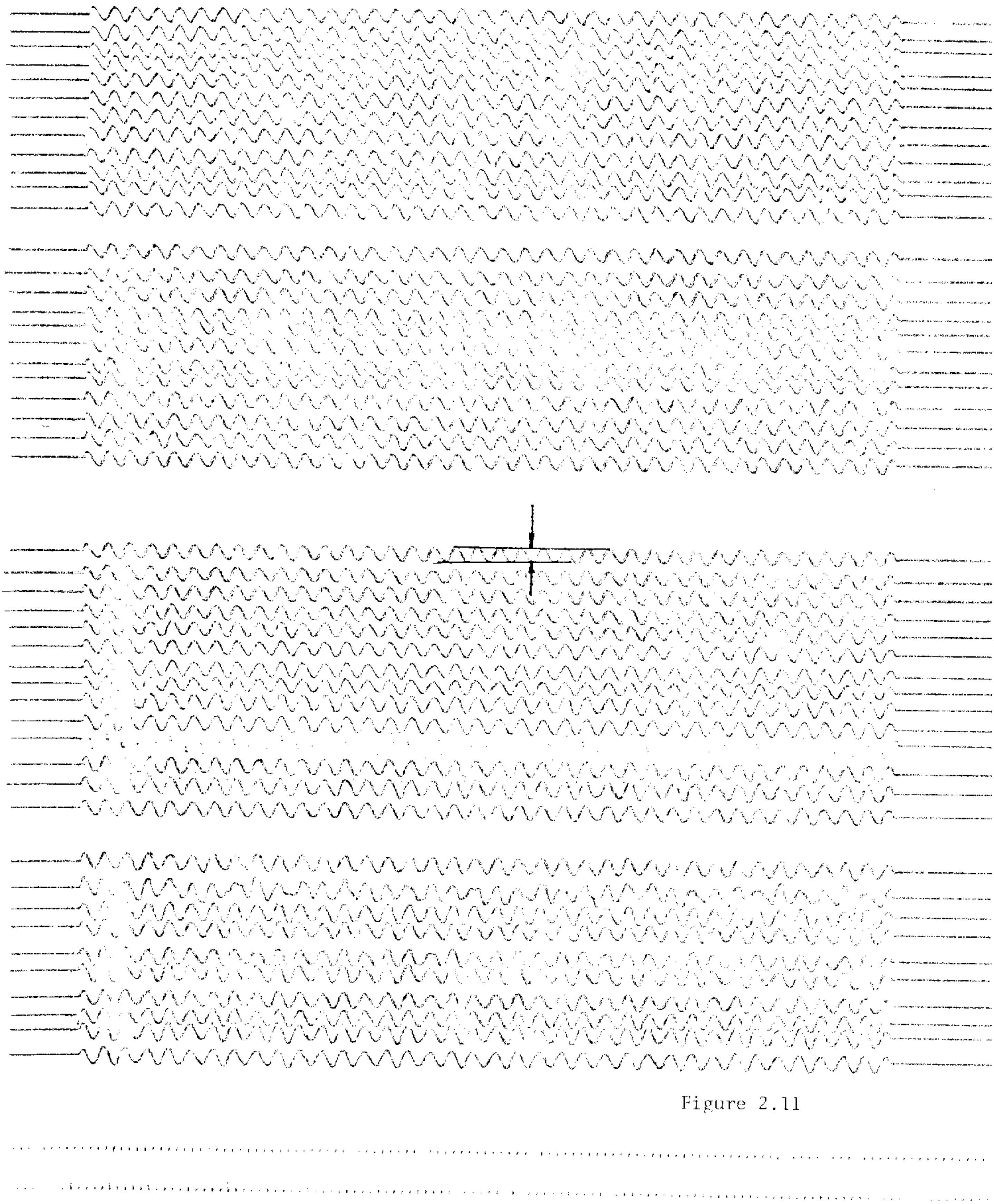


Figure 2.11

1 Microvolt Signal

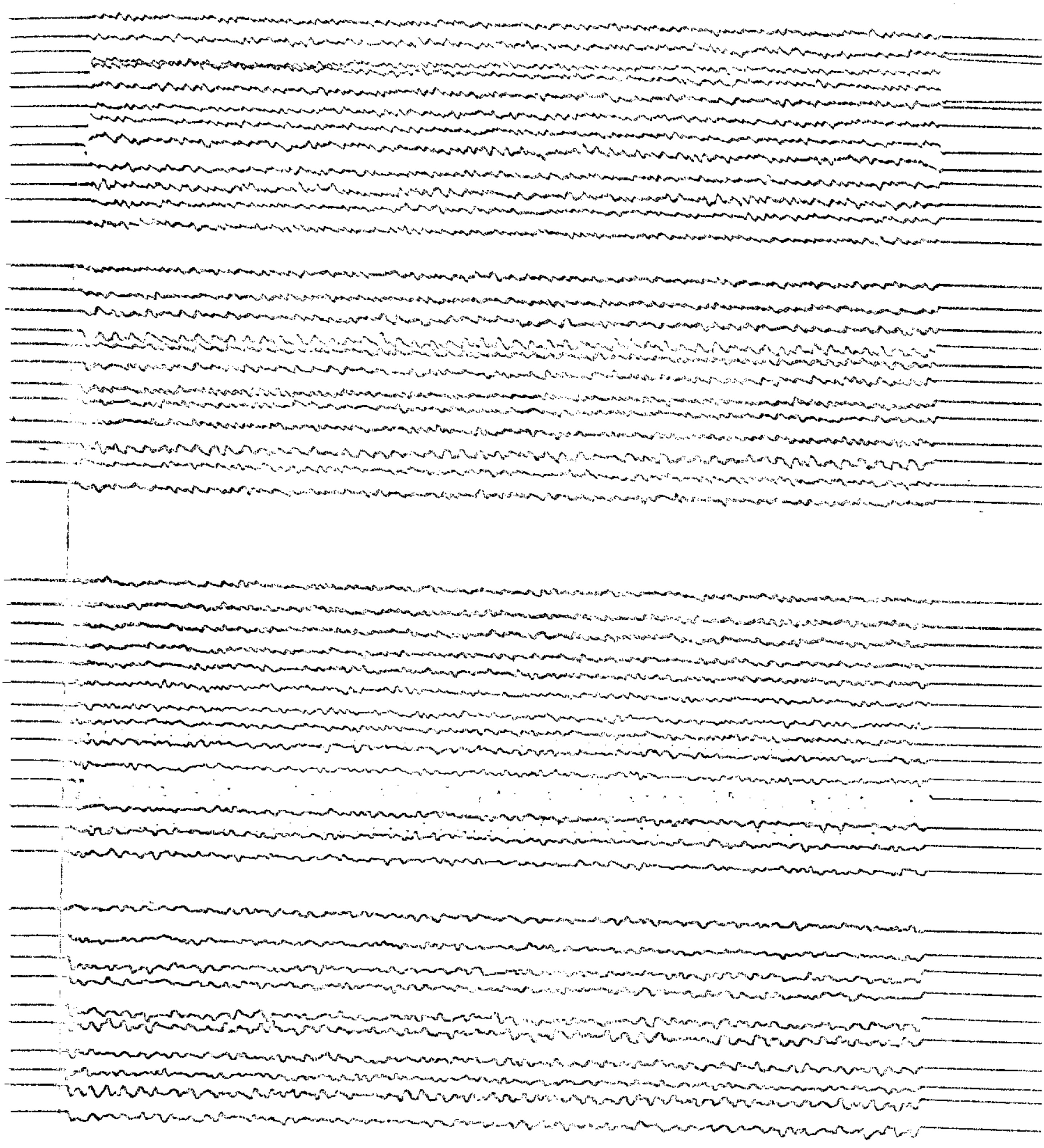


Figure 2.12

SYSTEM NOISE GAIN INCREASED 12dB

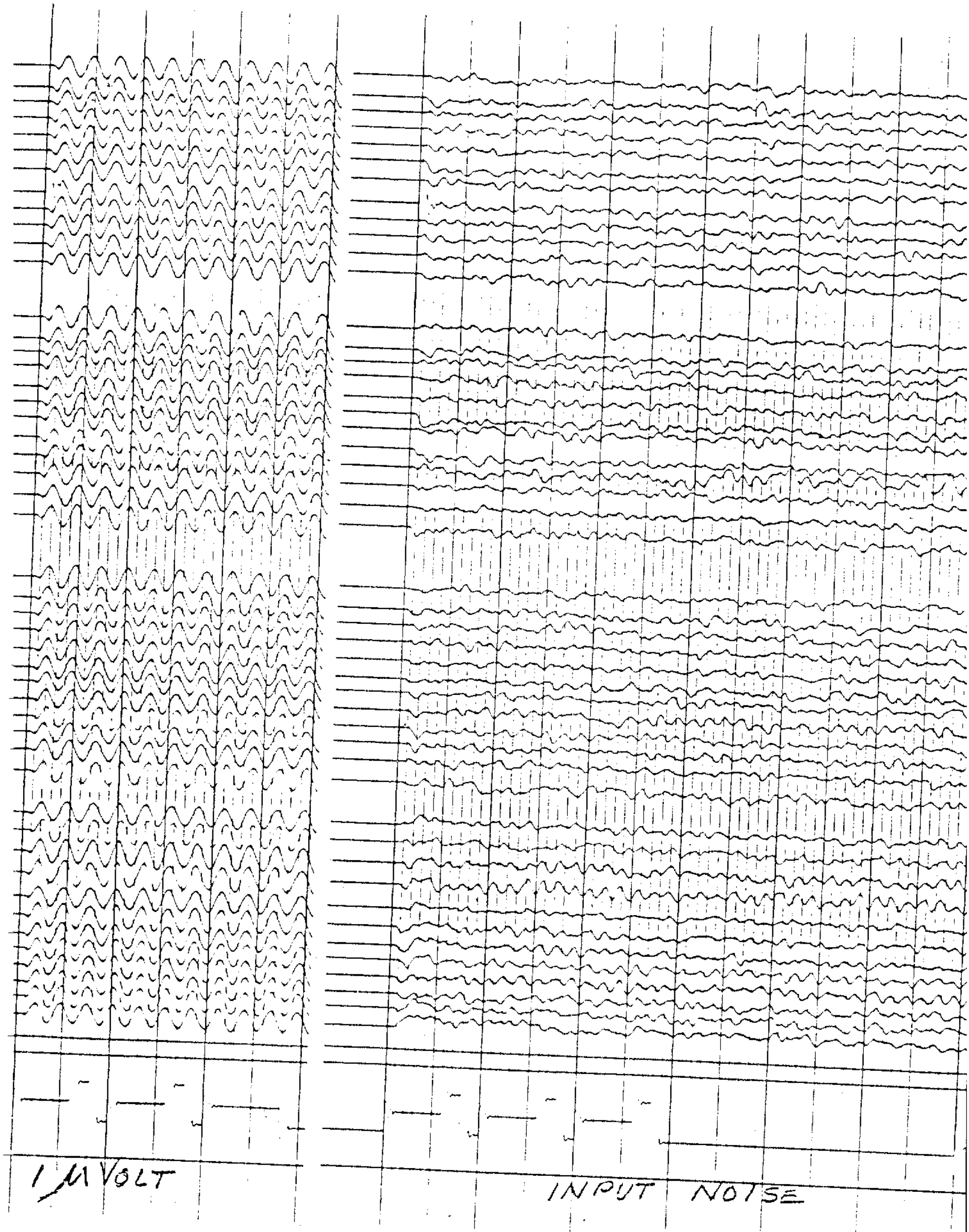


Figure 2.13

(3) The IFP Oscillator Test

This test checks recording system performance under IFP dynamic conditions. Amplifier gain changes can be checked, filter phase can be compared, automatic gain ranging can be observed and compared with true siganl variation, and system timing with speed variation may be checked.

A computer evaluation provides a method of checking gain words written on tape under dynamic conditions, whereas the monitor record will not provide an immediately visible error.

Description

The test consists of running a relatively long recording in IFP, while changing input signal level - thereby simulating real field recording conditions.

Gain changes occur in the floating point amplifier (FPA) dependent upon signal level, for each voltage sample received. It starts at a minimum gain and ranges up in 12dB (4 times) increments until the output signal is in a converter "window" of 16-71% of the converter range. Having reached a value in the window, the sample is digitized and a binary word generated containing 15 bits (14 data, 1 sign) and 3 gain bits attained by the FPA. This binary word comprising mantissa and exponent, is output to tape in its correct location in the data block on each scan. The FPA returns to a zero gain level again, to repeat the sequence on the next scan sample.

This test exercises the amplifier throughout its range, when an exponentially decaying oscillator signal is applied to each channel. The test is thus made commencing with a high (64mV) signal level, and decreasing signal to a zero level after some 8 seconds.

Paper records are made in the three Reproduce Module modes: FLOAT, DEFLOAT and AGC.

The FLOAT mode displays the FPA action as input signal decays. The FPA IFP action can be seen on the accompanying records.

The DEFLOAT mode produces a paper record displaying true signal amplitude form (here - decaying amplitude), having removed the gain word from the FLOAT option.

The AGC mode displays automatic gain control action, restoring weak signal to a value within the converter window thereby maintaining all signals at a visual level.

Test Procedure

A. Set up the switches on the modules.

INPUT MODULES:

Operate-Parallel Switch	PARALLEL
Channel Select and DC Voltage	OFF
Filter Switches: Lo-cut)) Hi-cut)	As Previously

AMPLIFIER MODULE:

Range Switch	x4
Level Switch	16mV
Meter Function Switch	OUTPUT
Oscillator Control	36Hz
Sine-Exponential Switch	EXP
Zero Switch	OFF
DC Voltage	OFF

FORMAT MODULE:

Mode Switch	RECORD
Record Switch	CAL
Record Length Switch	8 sec
Gain Mode	IFP
Bit Slide	0dB

REPRODUCE MODULE:

Hi-cut	AUTO
Lo-cut	OUT
Mode	FLOAT/DEFLOAT/AGC as required
Initial Gain	0dB
Galvo Level (internal)	As required for suitable trace amplitude

1. Make an 8 second record of the exponentially decaying input signal.
2. Make two playbacks (in Format REPRODUCE Mode). Select the DEFLOAT mode and run a camera record until traces go dead (after about 3-4 seconds).
3. Select AGC mode and run a record for the complete length

of 8 seconds. AGC playback speed and level can be controlled on Reproduce Module internal switches S1 on MG Card; S1 and SZ on TD (Trip Delay) Card.

Possible rates -

S1 MG Rate 8

S2 MG Level H1

Leave Trip at 0,0.

B. Test Evaluation

Examine the records for phase duplication. AGC recordings should have a constant level sinusoidal wave apparent throughout the record, as the exponentially decaying signal decreases to Zero. The DEFLOAT will show real amplitude signal decay, and the FLOAT will indicate where gain changes have occured.

Now timing accuracy may be addressed. The vertical timing lines are produced by the system clock. The 100Hz "ticker" or "pipper" trace at the bottom of the record is generated in the camera. This frequency standard is normally very stable and is used to check the system clock. The pipper trace is normally extremely stable, but it may be noticed that further down the records displayed, the 100Hz trace becomes occasionally erratic. This was due to the camera being very warm at the time of producing the record, and should thus be ignored where this occurs.

Timing lines are 10 milliseconds apart, and every 100 milliseconds the timing line is darkened to assist the observer counting them. It may be noted therefore that each pipper trace cycle is 10 msec and, hence, system timing may be compared with the camera generated pipper trace.

The relationship between timing line and pipper trace should hold within one millisecond in 10 seconds - or 1 in 10K.

Thus playback records may be used as a check of tape transport speed variation as well. During playback (i.e. DEFLOAT and AGC records), the deviation between timing lines and pipper is a measure of the combined record and playback transport speed variation. This is where "WOW" and "FLUTTER" can be assessed - i.e. WOW being the long term timing drift in transport speed. Speed variation should be less than 1% or 10 milliseconds per second theoretically. In practice, we try to ensure this timing is even tighter, at less than 1 millisecond per second or 1 in 1K.

Examining the FLOAT recording of 8 seconds length, Figure 2.14 displays the first 1.2 seconds of data. The FPA switches at 400 milliseconds and onwards as the exponential decaying amplitude reduces. All traces break within 2 milliseconds (i.e. sample rate used), with timing lines coinciding with the pipper trace trough. For the full FLOAT 8 second record, timing accuracy is better than 1 in 8000 and thus "better than 1 in 10K" (allowing for pipper trace movement). The 8 second record is in fact 8.192 seconds long since system timing is in binary format and, hence, a one second record is actually 1.024 seconds in length. See Figures 2.15 - 2.18.

Also, all traces should be ideally within ±5% in terms of amplitude. This is more a test of galvo deflection rather than channel performance, since the gain calibration test ensures all channels are recorded within 0.1 to 0.2% of each other.

Examining the DEFLOAT record, Figs.2.10 - 2.21, a gain change is known exist at 400 milliseconds (from FLOAT record). The peak to peak value at 400 milliseconds is approximately half that value extrapolated to the first timing line. Thus, a gain change has occured at 32mvolts being less than 17% of the converters value. Hence, the converter must have digitized the initial 64 mvolts signal at between 17 and 34% of the converter window. This example points to the difficulty in assessing FPA values, which is the reason for computer print out values of floating point levels being difficult to establish in absolute voltage terms. Unless the starting voltage value is known, the floating point value sampled thereafter is relative to a previous sample level, not a previous voltage level. From the DEFLOAT record, the signal decay can be seen to become close to zero at approximately 3 seconds.

Examining the AGC record, Figs. 2.22 - 2.25 AGC constant amplitude is attained at about 600 milliseconds, thereafter stabilised at that level until end of record. All traces are in phase, and noise becomes apparent on trace 35 at 6.0 seconds onwards. It is noted that the trace does not become recognisably noisy prior to 6 seconds - a typical field record length. Thus, this record indicates that this FPA test is inadequate to display noisy channels, and hence, the reason for performing the 'Input Noise' test described earlier.

A further point to be made is that this monitor record does not indicate gain word status. In fact, an instrument fault existed after 2 seconds, causing the FPA gain word to remain constant (in fixed gain mode) from that time onwards.

UMBER	DATE	TIME	OBSERVER MAKING TEST	
ERIAL NUMBER	PARTY NUMBER		PARTY MANAGER	PARTY CHIEF

RATE: ☑ 2 MIL ☐ 4 MIL ☐ ____ | SYSTEM FORMAT: ☐ 9 TRACK ☑ SEG B ☐ SEG C | NUMBER OF TRACES: ☐ 24 ☑ 48 ☐ OTHER | PACKING DENSITY-BPI: ☐ 556 ☐ 712 ☐ 800 ☑ 1600 PE

DYNAMIC RANGE DETERMINATION TEST

MONITOR SECTION: RANGE SWITCH	LEVEL SWITCH	VALUE OF TEST SIGNAL	DB DOWN	FILE OR RECORD NUMBER	PLAYBACK SECTION: Galvo Level	BIT SLIDE	DB UP
			−3		SAME AS RECORD	0 db	+3
			−15		R + 12	0 db	+15
			−27		R + 12	12 db	+27
			−39		R + 12	24 db	+39
			−51		R + 12	36 db	+51
			−63		R + 12	48 db	+63
			−75		R + 12	60 db	+75
			−81		R + 12	66 db	+81
			NOISE		R + 12	66 db	+81

EQUIVALENT INPUT NOISE TEST

n Signal - 1µV / rd Number	Monitor Gain ____ DB	Noise: File/Record Number

Gain

AL ____ DB NOISE ____ DB

IFPA OSCILLATOR TEST

rd Number: 012	Record Length: 8 SEC	Method Signal Changes: ☑ Exponential ☐ Sine Stepped
gnal Level: 64mV	Record Gain Mode: ☑ IFP ☐ Manual	Galvo Level: Record 18 DB/REP 18 DB

Mode: ☑ Defloat ☑ Float | AGC Reproduce Settings: Trip Sens ____ DB Initial Gain ____ DB

ion: ☐ PGC ☐ GAGC | Trip ____ Secs LEVEL: ☑ High ☐ Low | AGC Speed ____ PGC Rate ____ DB/SEC

FILTER PULSE TEST

LE BER	HICUT FILTER-HZ	LOCUT FILTER-HZ	NOTCH IN-OUT-HZ

MODE GAIN ____ db MAN ☐ IFPA | GALVO LEVEL ____ dB

OTHER SYSTEM PARAMETERS FOR TESTS

EM CONFIGURATION: ONLY ☐ CFS SYSTEM

NSTANT ____ DB | GALVO LEVEL 1-24 ____ DB | AUX ____ DB | NOTCH FILTERS ☐ IN ☑ OUT

ER CONNECTION ☐ 2000 Ω | FILTERS LOW CUT ____ HIGH CUT ____ | RECORD TYPE ☐ DATA ☑ CAL

ONITOR OUTPUT ☑ (NOT RAW) | GENERAL CONSTANTS

ANALYSIS RESULTS:

CURACY: < 1 IN 10 K MILLISECONDS DIFFERENCE BETWEEN TIMING LINES AND PIPPER TRACE ON MONITOR RECORD.

ARIATION: < 1 IN 1 K MILLISECONDS PER SECOND MAXIMUM VARIATION BETWEEN TIMING LINES AND PIPPER TRACE ON PLAYBACK RECORD.

GAIN ACCURACY TEST

MODE ☑ CAL | GAIN CONSTANT ____ DB | RECORD LENGTH ____ S

FILE NUMBER	RECORD GAIN SETTING	TEST SIGNAL LEVEL SWITCH
(1)	84	1 µ
(2)	72	1 µ
(3)	72	4 µ
(4)	60	4 µ
(5)	60	16 µ
(6)	48	16 µ
(7)	48	64 µ
(8)	36	64 µ
(9)	36	256 µ
(10)	24	256 µ
(11)	24	1 m
(12)	12	1 m
(13)	12	4 m
(14)	0	4 m

HARMONIC DISTORTION TEST

FILE NUMBER	HICUT FILTER-HZ	LOCUT FILTER-HZ	NOTCH IN-OUT-HZ	RECORD LENGTH

CROSSFEED TEST

FILE NUMBER	RECORD GAIN SETTING	CHANNEL TERMINATION
	O (MANUAL)	EVEN
	IFP	EVEN
	IFP	ODD
	O (MANUAL)	ODD

REMARKS: LIST THE FOLLOWING. 1) ANY SCRATCH RECORDINGS 2) REPAIRS SINCE LAST TEST. 3) REMARKS AND OTHER TEST PROCEDURES OR RESULTS — SKEW CHECKS, CONVLIN, TB, ETC.

Table 2.6

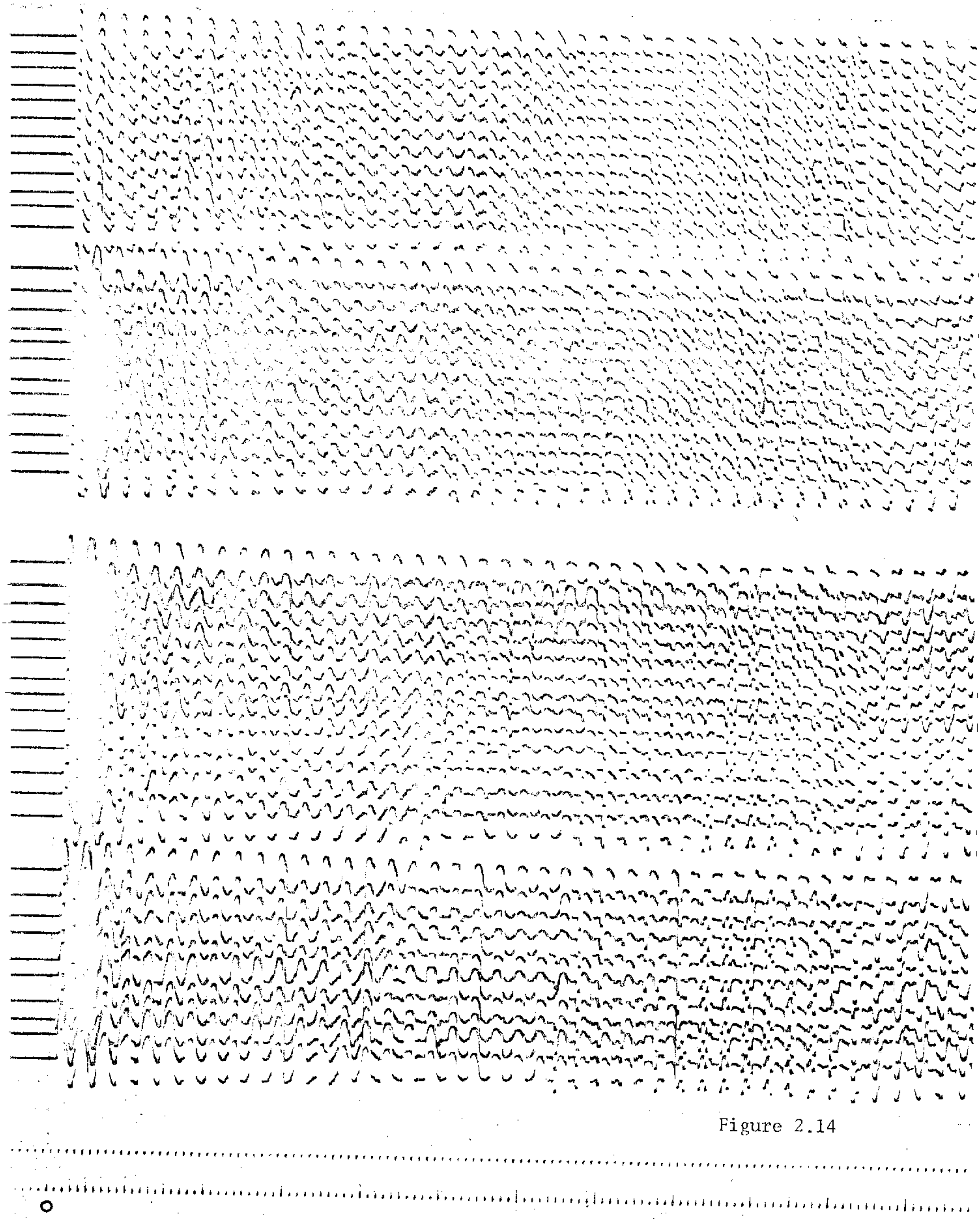
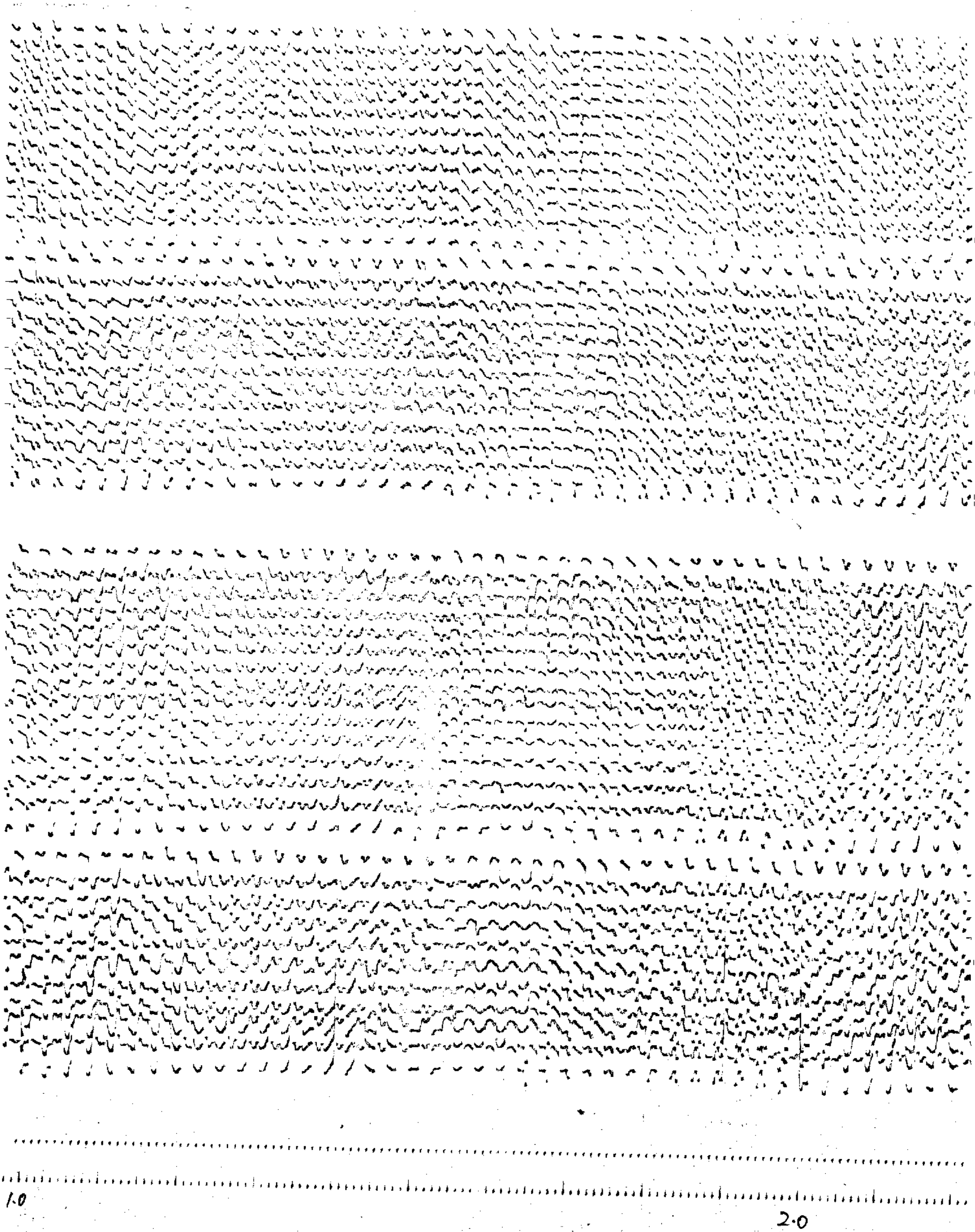


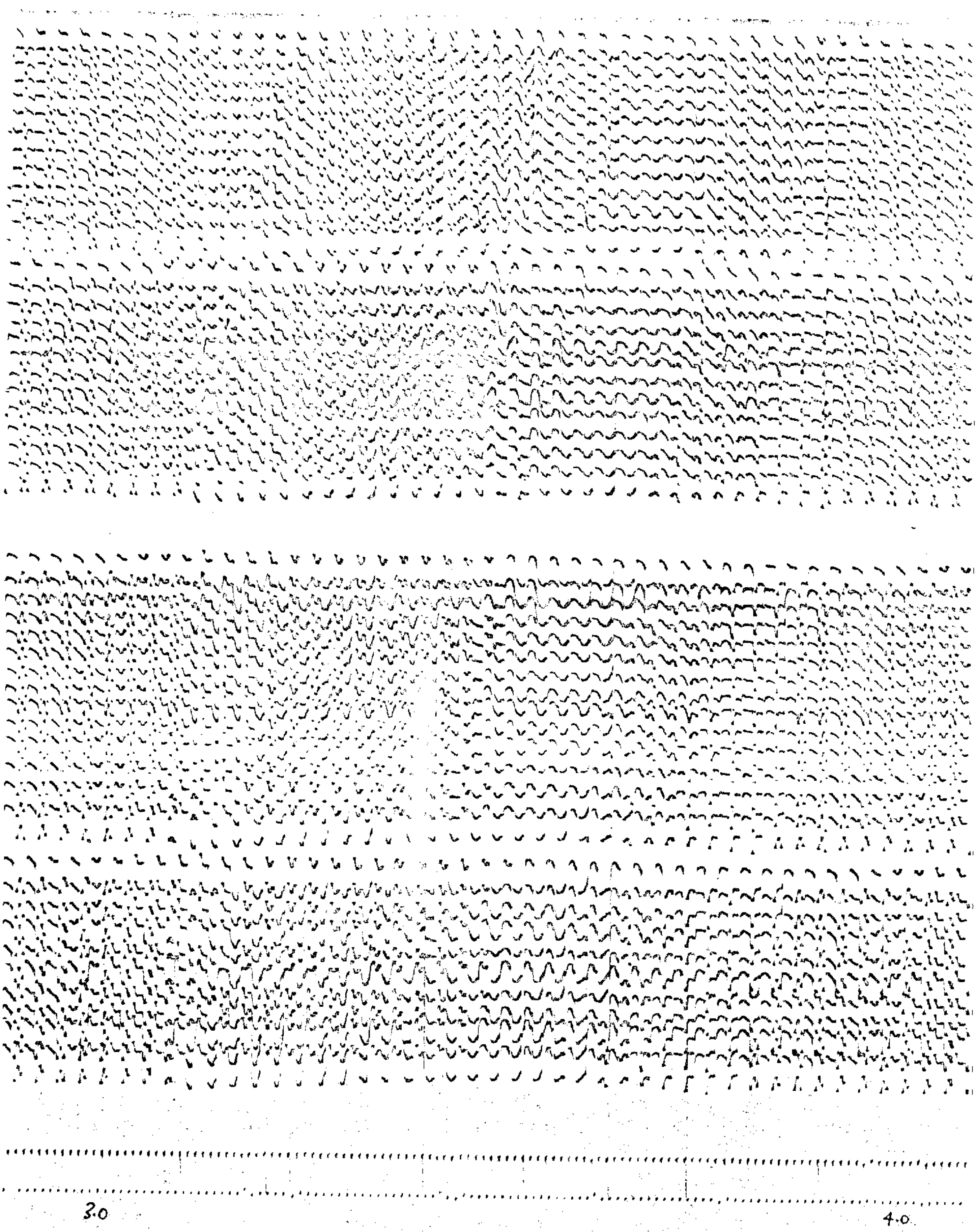
Figure 2.14

Exponential Decay Playback in FLOAT 0 - 1.0 seconds



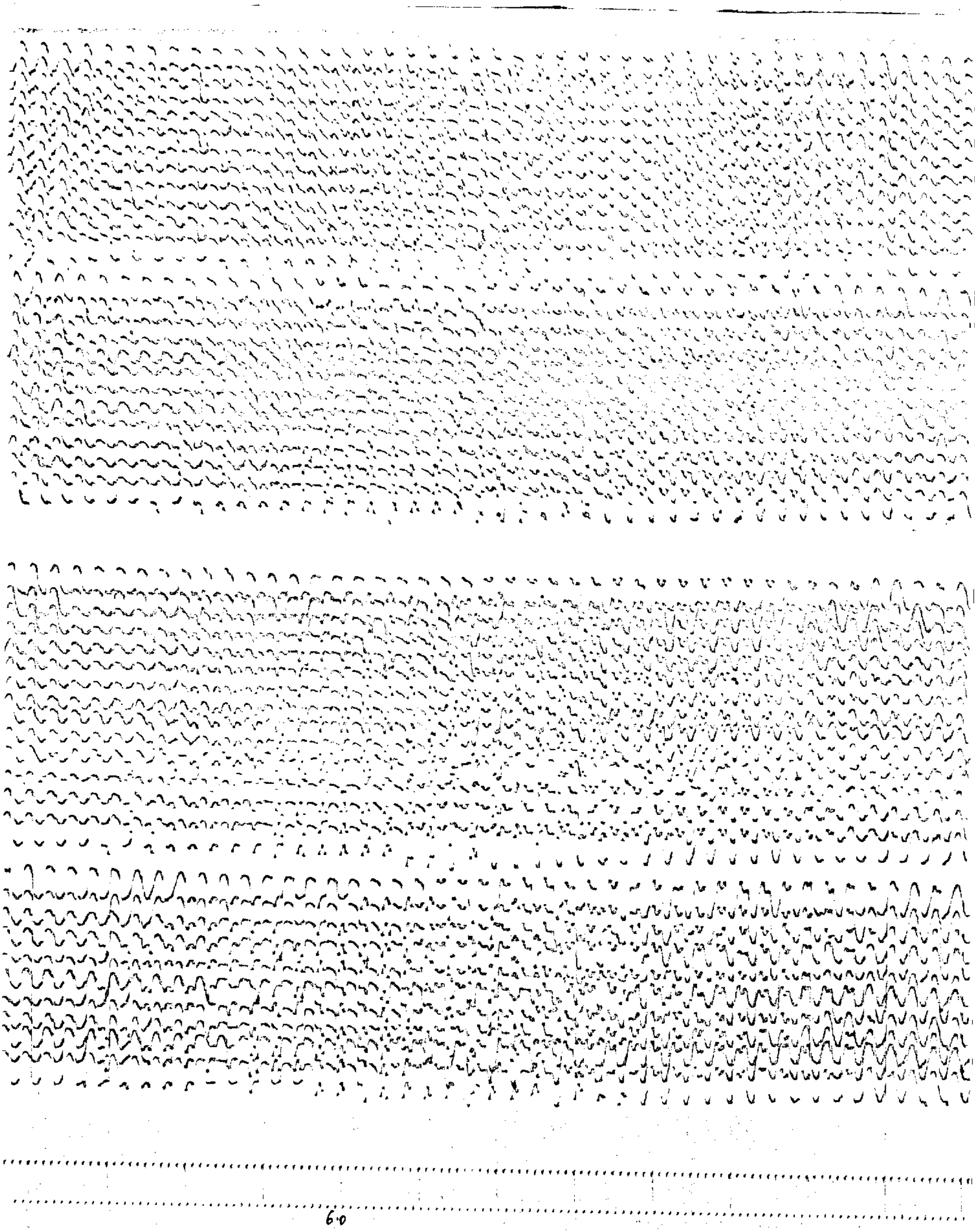
ponential Decay Playback in FLOAT 1 - 2.0 seconds

Figure 2.15

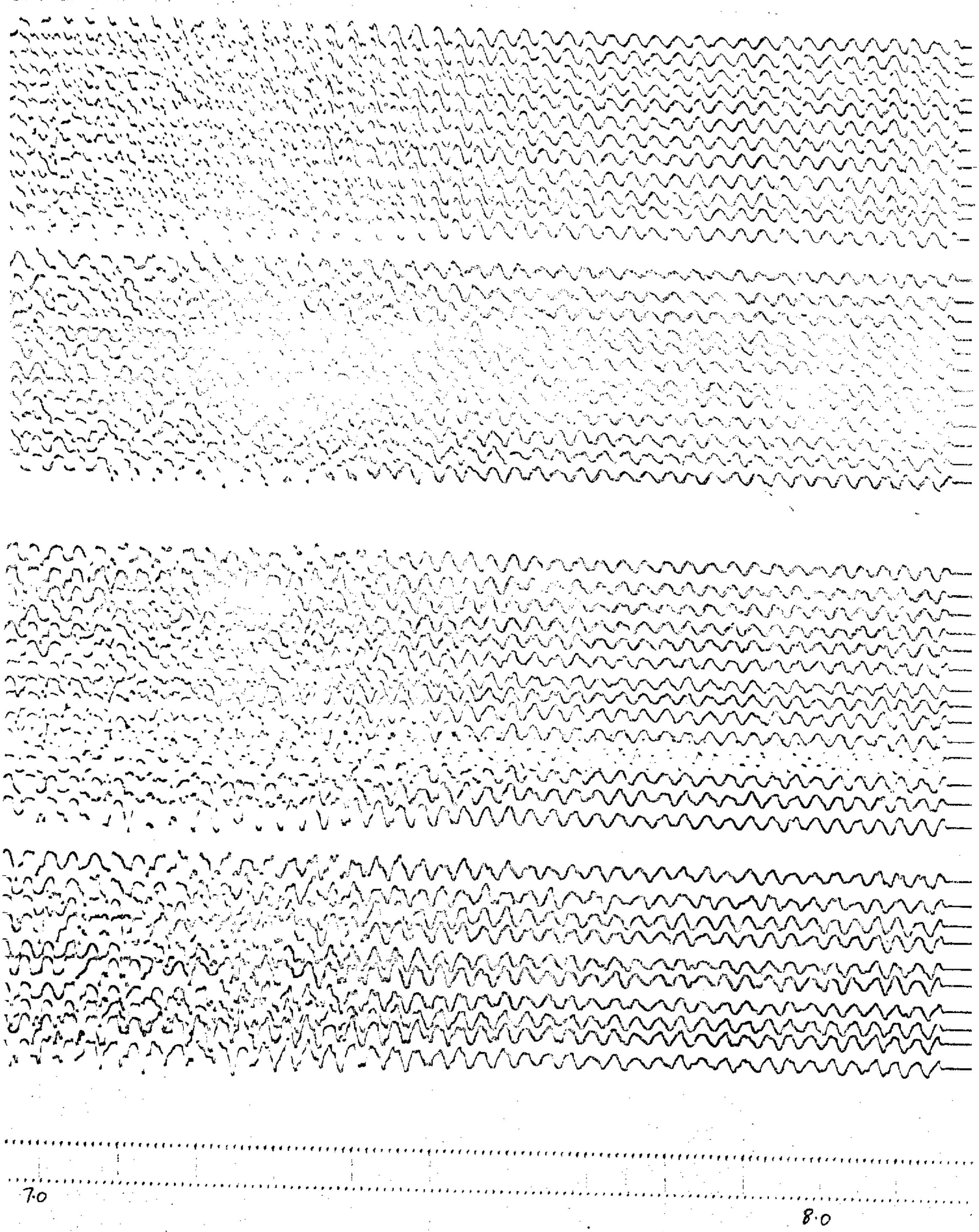


Ixpcnential Decay Playback in FLOAT 3.0 - 4.0 seconds

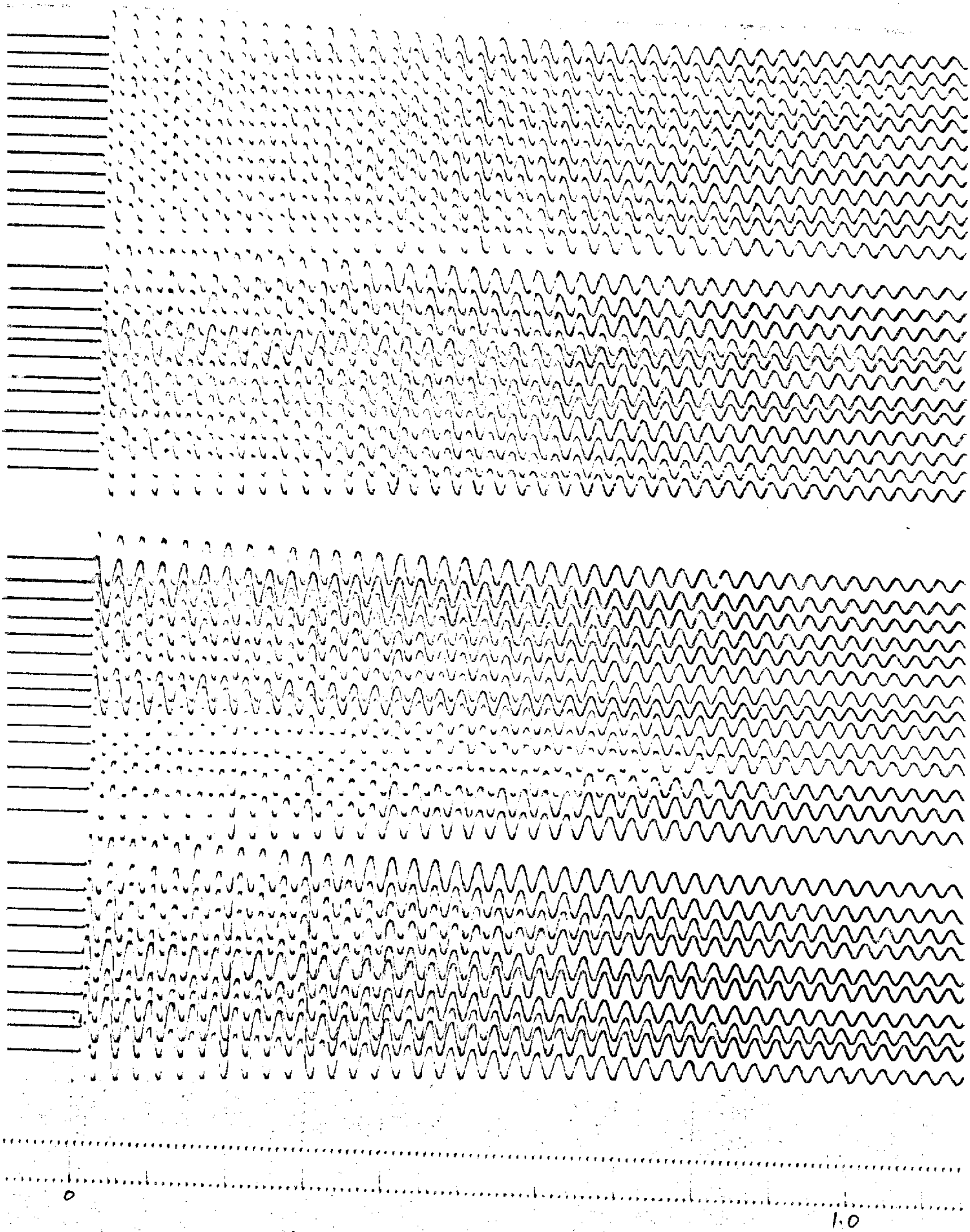
Figure 2.16



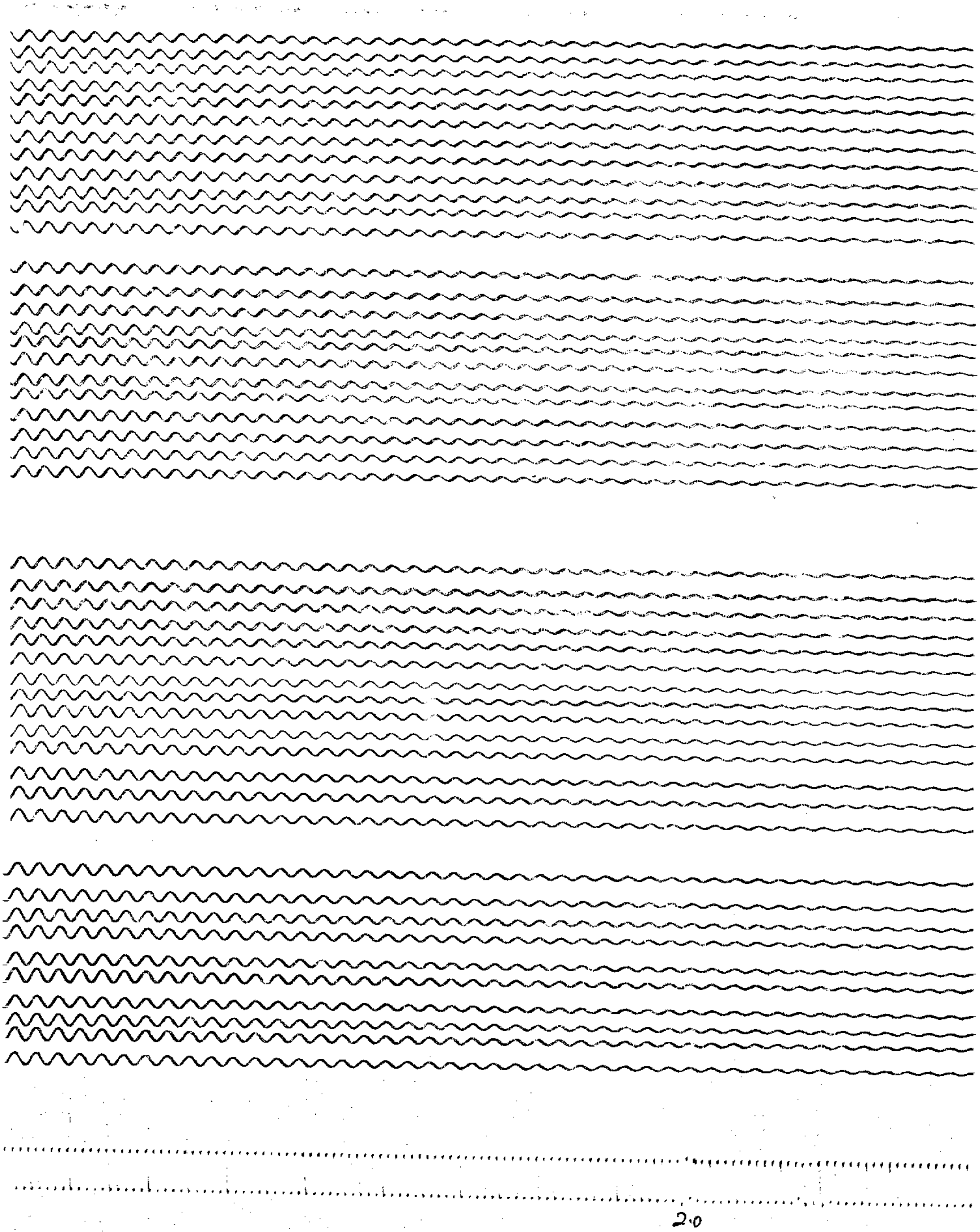
Exponential Decay Playback in FLOAT to 6.0 seconds   Figure 2.17



Exponential Decay Playback in FLOAT 7.0 - 8.0 seconds Figure 2.18

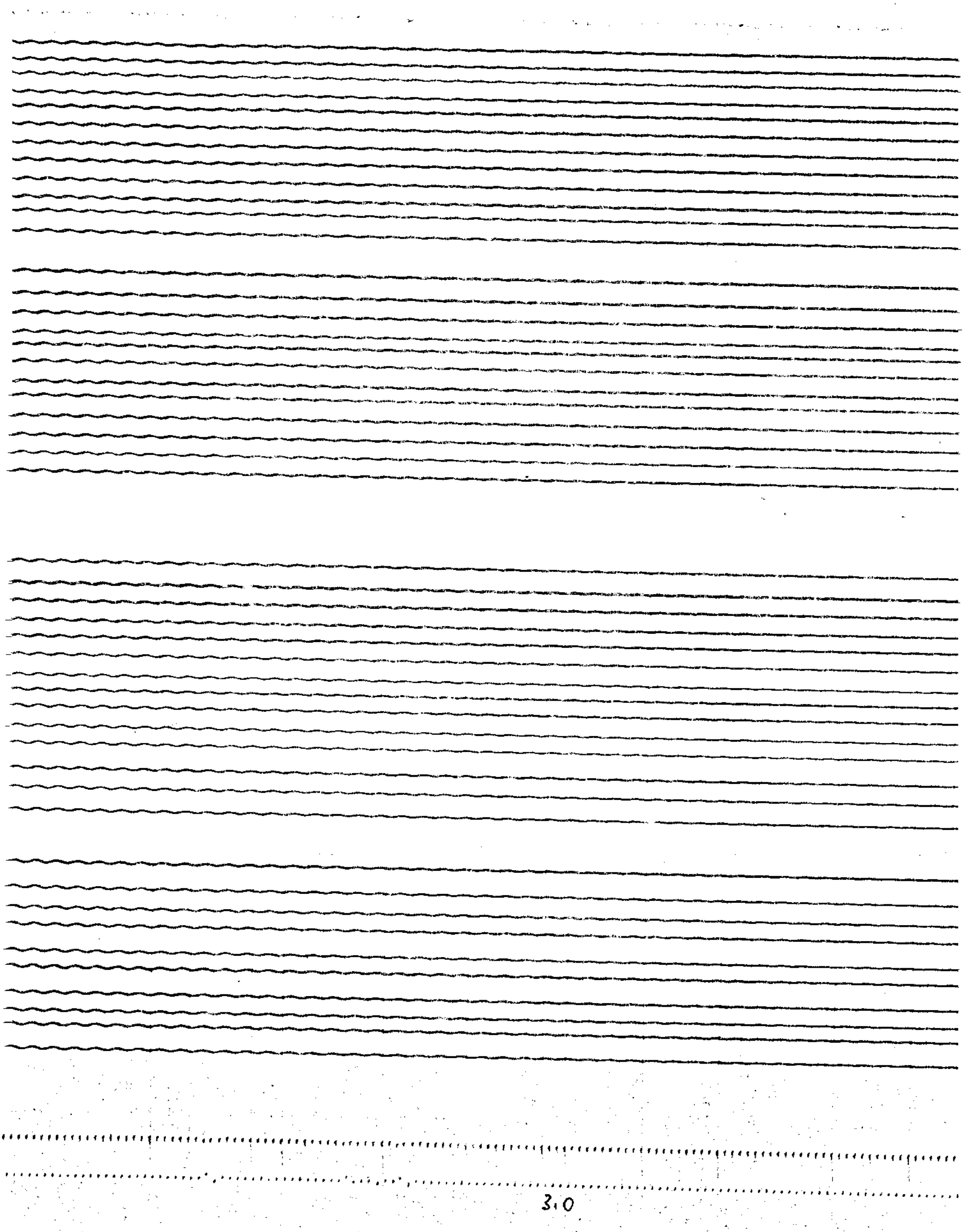


Exponential Decay Playback in DEFLOAT 0 - 1.0 seconds Figure 2.19



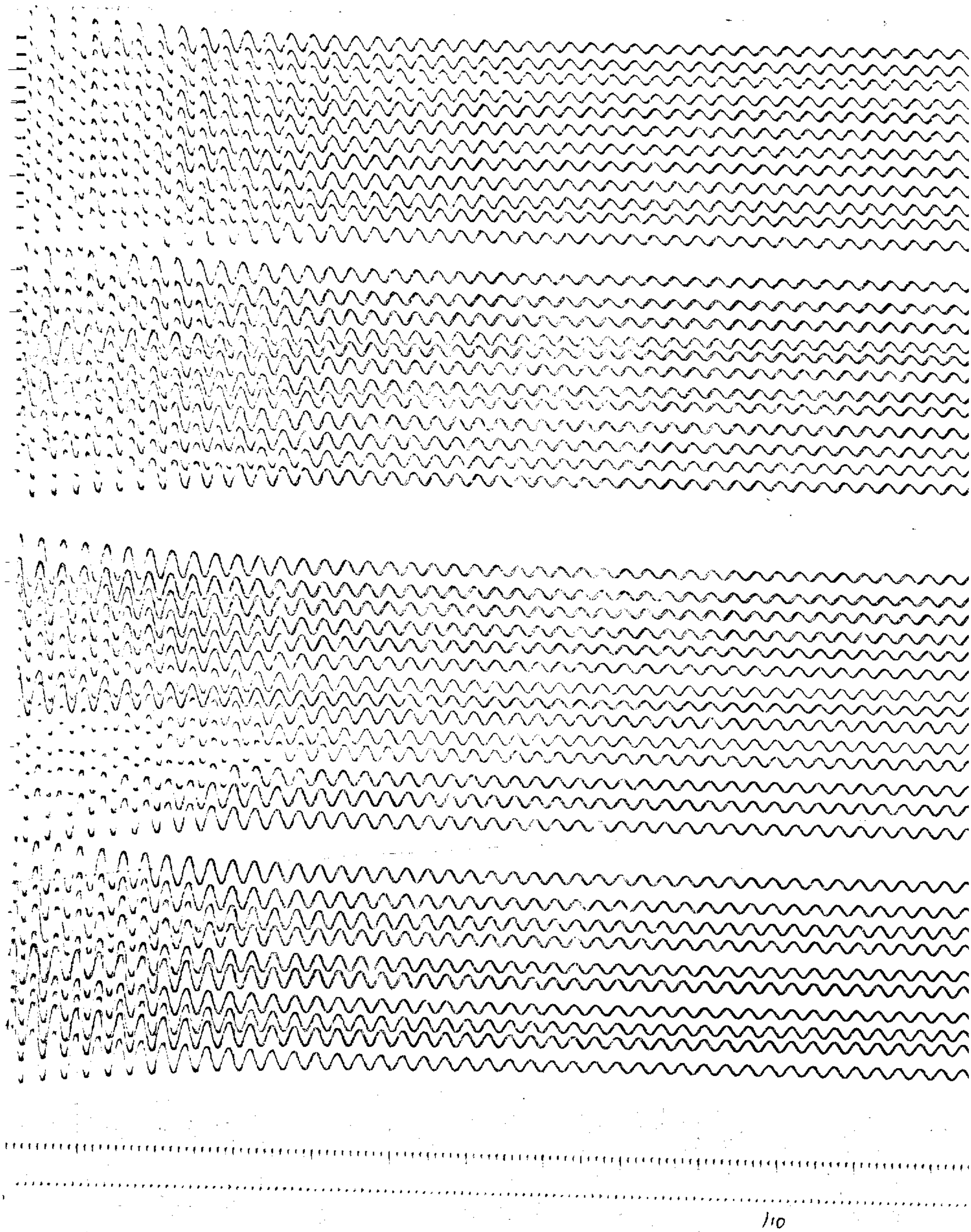
ɹential Decay Playback in DEFLOAT

Figure 2.20

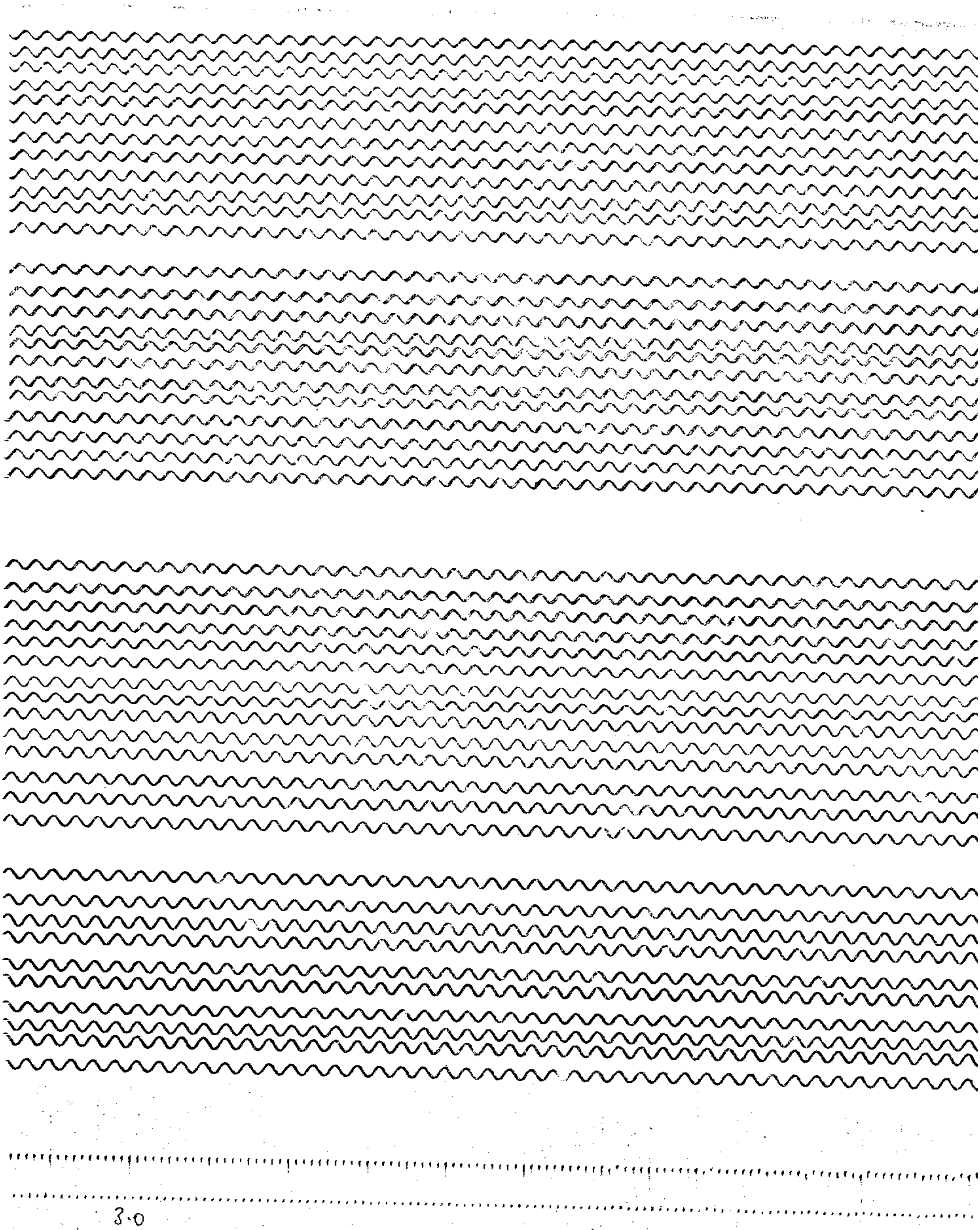


Exponential Decay Playback in DEFLOAT

Figure 2.21

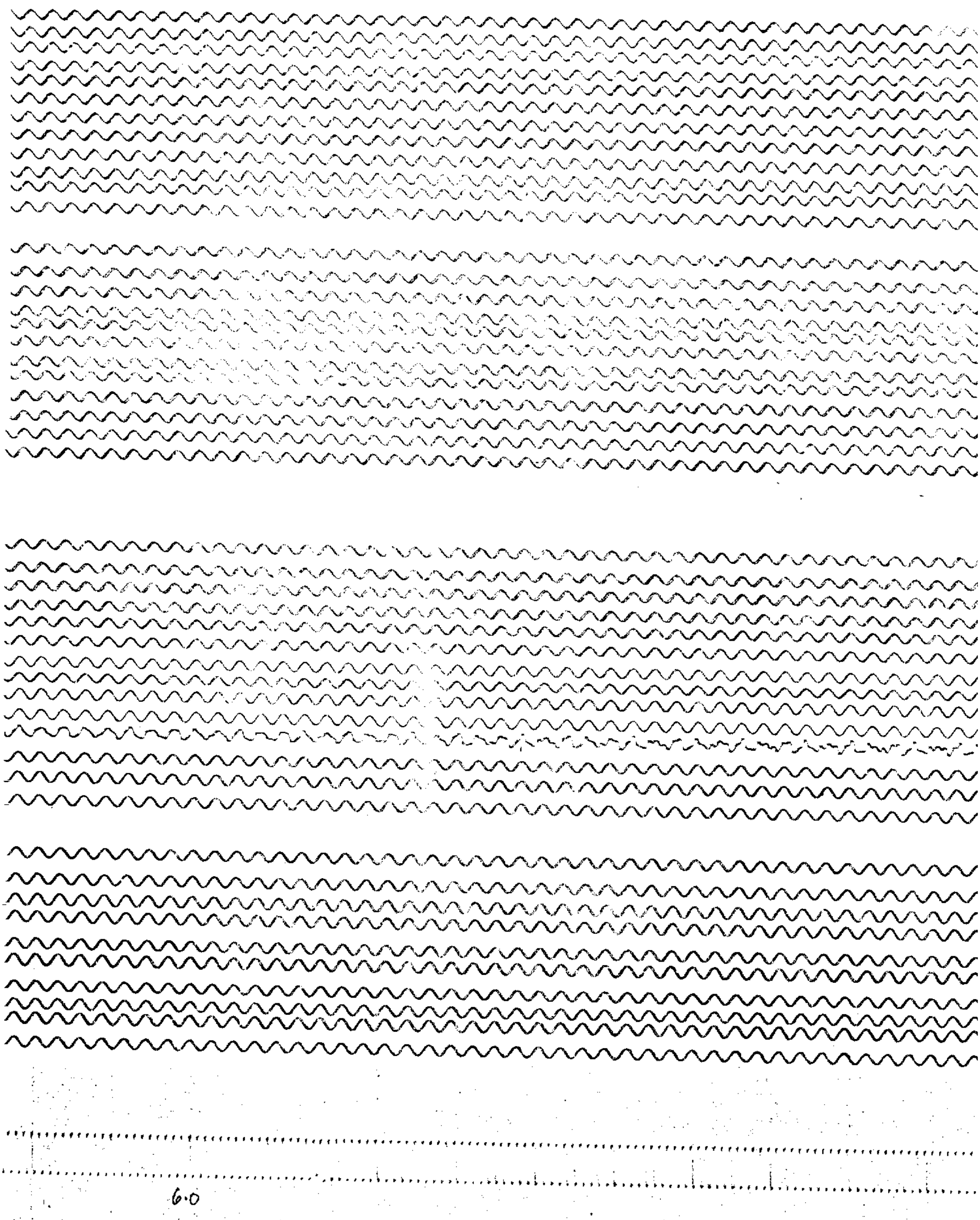


Exponential Decay Playback in AGC 0 - 1.0 seconds Figure 2.22



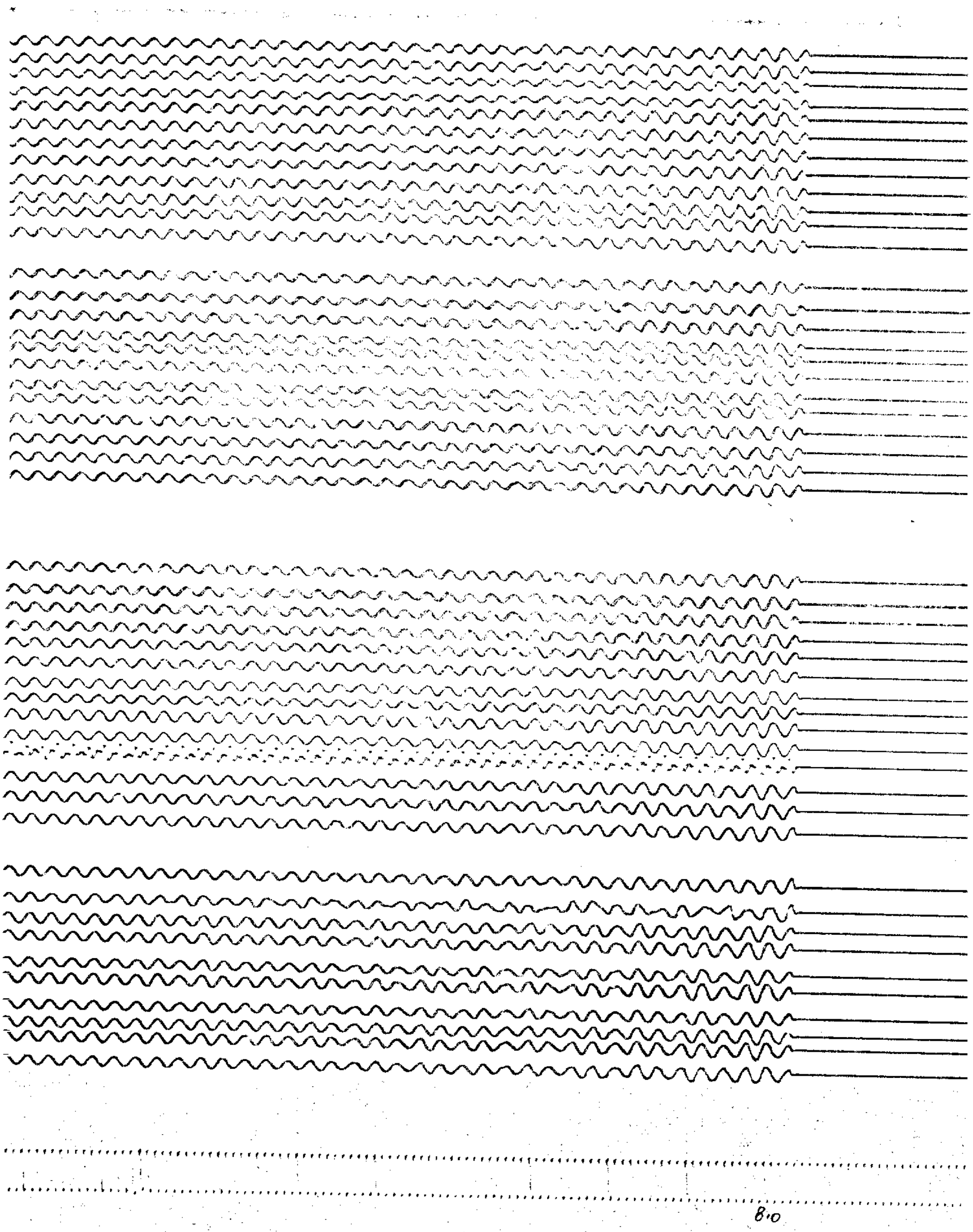
Exponential Decay Playback in AGC

Figure 2.23



Exponential Decay Playback in AGC at 6.0 seconds

Figure 2.24



Exponential Decay Playback in AGC to 8.0 seconds

Figure 2.25

(4) Filter Pulse Test

This test checks the response of the filters to an input spike 160 microseconds wide. Often referred to as checking the "Impulse Response" of the system, it can be used to check filter amplitude and phase response, trace duplication and provides a reliable means of monitoring tape-to-galvanometer polarity.

A computer evaluation can indicate filters which may perform incorrectly, and the resultant 'signature' (or filter response wiggle trace) may be used in processing seismic data by deconvolving the signature shape with data - in order to restore the recorded wave front back to its original shape.

Description

The test consists of making a series of one second records with different filter settings. An OUT filter may be used initially, the record of which (if processed to provide a power spectrum display) will show that the filter is passing all frequencies to the hi-cut value, thereafter suppressing signal to the requisite Nyquist value.

Under field conditions, production filters are employed. Since DFS IV filter switches are notorious for their ability to make poor contacts, a badly positioned filter switch can be immediately checked as a result of this recording.

Test Procedure

A. Set up the switches on the modules.

INPUT MODULES:

Operate-Parallel Switch	PARALLEL
Channel Select and DC Voltage	OFF
Filter Switches: Lo-cut	OUT
Hi-cut	124 Hz/18dB per octave slope

AMPLIFIER MODULE:

Range Switch	x4
Level Switch	16mV
Meter Function Switch	OSCILLATOR
Oscillator Control	PULSE
Sine-Exponential Switch	SINE
Zero Switch	OFF
DC Voltage	OFF

FORMAT MODULE:

Mode Switch	RECORD
Record Switch	CAL
Record Length Switch	1 sec
Gain Mode	MANUAL
Manual Gain	36dB
Bit Slide	0dB

REPRODUCE MODULE:

Hi-cut Switch	AUTO
Lo-cut Switch	OUT
Initial gain) Mode Switch)	Dependent upon camera record quality, AGC or FLOAT

1. For the purposes of the normal daily test, filters may be set at OUT/124 Hz with 18dB per octave slope. The slope determines the gradient of cut-off action performed by the hi-cut filter. A 72dB per octave slope would have a steeper gradient and hence cut out higher frequencies earlier than its 18dB counterpart.
2. A one second record is taken with the leading edge of the 160 microsecond spike commencing at time zero (first data scan). See Table 2.7.
3. A manual gain of 36dB was adopted here for a gain constant of 24dB. If the gain constant value were increased or decreased, the manual gain level may be decreased or increased as necessary.

The following record was taken Figure 2.26 and demonstrates the typical camera record. Figure 2.27 is the ideal display, which is superior due to differences in camera reproduction quality.

B. Evaluation

Examine each analog record for amplitude and phase duplication. All channels should agree within ±1 millisecond and within ±5% in amplitude. It is noted that the filters move positively on the leading edge of the pulse - if the pulse were to remain at a constant dc level, the galvo would then display each trace at a higher offset. Because the lagging edge of the pulse breaks down at a faster speed than the sample rate, the filter response to a spiking input, the negative downbreak being the underdamped filter response returning to zero.

Other filter values will be tested during the Monthly Test Procedure.

This test concludes the daily test routine schedule.

IMBER	DATE	TIME	OBSERVER MAKING TEST	
ERIAL NUMBER	PARTY NUMBER		PARTY MANAGER	PARTY CHIEF
ATE ☑ 2 MIL ☐ 4 MIL ☐ ___	SYSTEM FORMAT ☐ 9 TRACK ☑ SEG B ☐ SEG C		NUMBER OF TRACES ☐ 24 ☑ 48 ☐ OTHER	PACKING DENSITY-BPI ☐ 356 ☐ 712 ☐ 800 ☑ 1600 PE

DYNAMIC RANGE DETERMINATION TEST

MONITOR SECTION					PLAYBACK SECTION		
ANGE ITCH	LEVEL SWITCH	VALUE OF TEST SIGNAL	DB DOWN	FILE OR RECORD NUMBER	Galvo Level	BIT SLIDE	DB UP
			−3		SAME AS RECORD	0 db	+3
			−15		R + 12	0 db	+15
			−27		R + 12	12 db	+27
			−39		R + 12	24 db	+39
			−51		R + 12	36 db	+51
			−63		R + 12	48 db	+63
			−75		R + 12	60 db	+75
			−81		R + 12	66 db	+81
			NOISE		R + 12	66 db	+81

EQUIVALENT INPUT NOISE TEST

Signal - 1μV Number	Monitor Gain DB	Noise: File/Record Number

ain

L ______ DB | NOISE ______ DB

IFPA OSCILLATOR TEST

Number	Record Length SEC	Method Signal Changes ☑ Exponential ☐ Sine Stepped
nal Level	Record Gain Mode ☑ IFP ☐ Manual	Galvo Level Record ___ DB/REP ___ DB

Mode ☐ Defloat ☐ Float | AGC Reproduce Settings: Trip Sens ___ DB Initial Gain ___ DB

n ☐ PGC ☐ GAGC | Trip ___ Secs LEVEL: ☐ High ☐ Low | AGC Speed ___ PGC Rate ___ DB/SEC

FILTER PULSE TEST

E ER	HICUT FILTER-HZ	LOCUT FILTER-HZ	NOTCH IN-OUT-HZ
13	124/18	OUT	OUT

MODE GAIN ___ db MAN ☐ IFPA | GALVO LEVEL ___ dB

OTHER SYSTEM PARAMETERS FOR TESTS

M CONFIGURATION ONLY ☐ CFS SYSTEM

STANT ___ DB	GALVO LEVEL 1-24 ___ DB AUX ___ DB	NOTCH FILTERS ☐ IN ☑ OUT
R CONNECTION ☑ 2000 Ω	FILTERS LOW CUT ___ HIGH CUT ___	RECORD TYPE ☐ DATA ☑ CAL
NITOR OUTPUT ☑ (NOT RAW)	GENERAL CONSTANTS	

NALYSIS RESULTS:

URACY: ______ MILLISECONDS DIFFERENCE BETWEEN TIMING LINES AND PIPPER TRACE ON MONITOR RECORD.

RIATION: ______ MILLISECONDS PER SECOND MAXIMUM VARIATION BETWEEN TIMING LINES AND PIPPER TRACE ON PLAYBACK RECORD.

GAIN ACCURACY TEST

MODE ☑ CAL	GAIN CONSTANT ___ JB	RECORD LENGTH ___ S
FILE NUMBER	RECORD GAIN SETTING	TEST SIGNAL LEVEL SWITCH
(1)	84	1 μ V
(2)	72	1 μ V
(3)	72	4 μ V
(4)	60	4 μ V
(5)	60	16 μ V
(6)	48	16 μ V
(7)	48	64 μ V
(8)	36	64 μ V
(9)	36	256 μ V
(10)	24	256 μ V
(11)	24	1 m V
(12)	12	1 m V
(13)	12	4 m V
(14)	0	4 m V

HARMONIC DISTORTION TEST

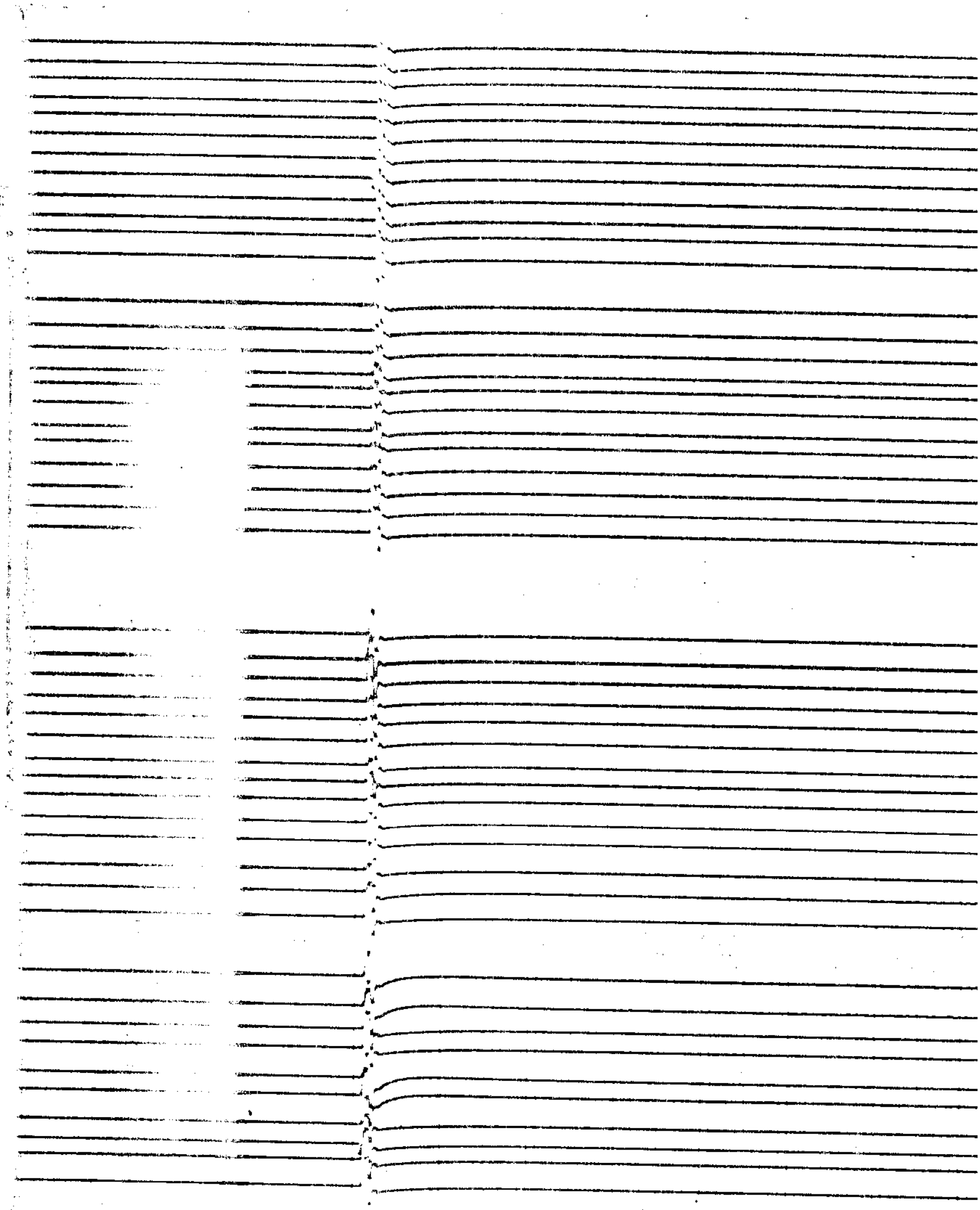
FILE NUMBER	HICUT FILTER-HZ	LOCUT FILTER-HZ	NOTCH IN-OUT-HZ	RECOR LENGT

CROSSFEED TEST

FILE NUMBER	RECORD GAIN SETTING	CHANNEL TERMINATION
	O (MANUAL)	EVEN
	IFP	EVEN
	IFP	ODD
	O (MANUAL)	ODD

REMARKS: LIST THE FOLLOWING. 1) ANY SCRATCH RECORDINGS. 2) REPAIRS SINCE LAST TEST. 3) REMARKS AND OTHER TEST PROCEDURES OR RESULTS – SKEW CHECKS, CONVLIN, TB, ETC.

Table 2.7



Filter Pulse Test OUT/124Hz Figure 2.26

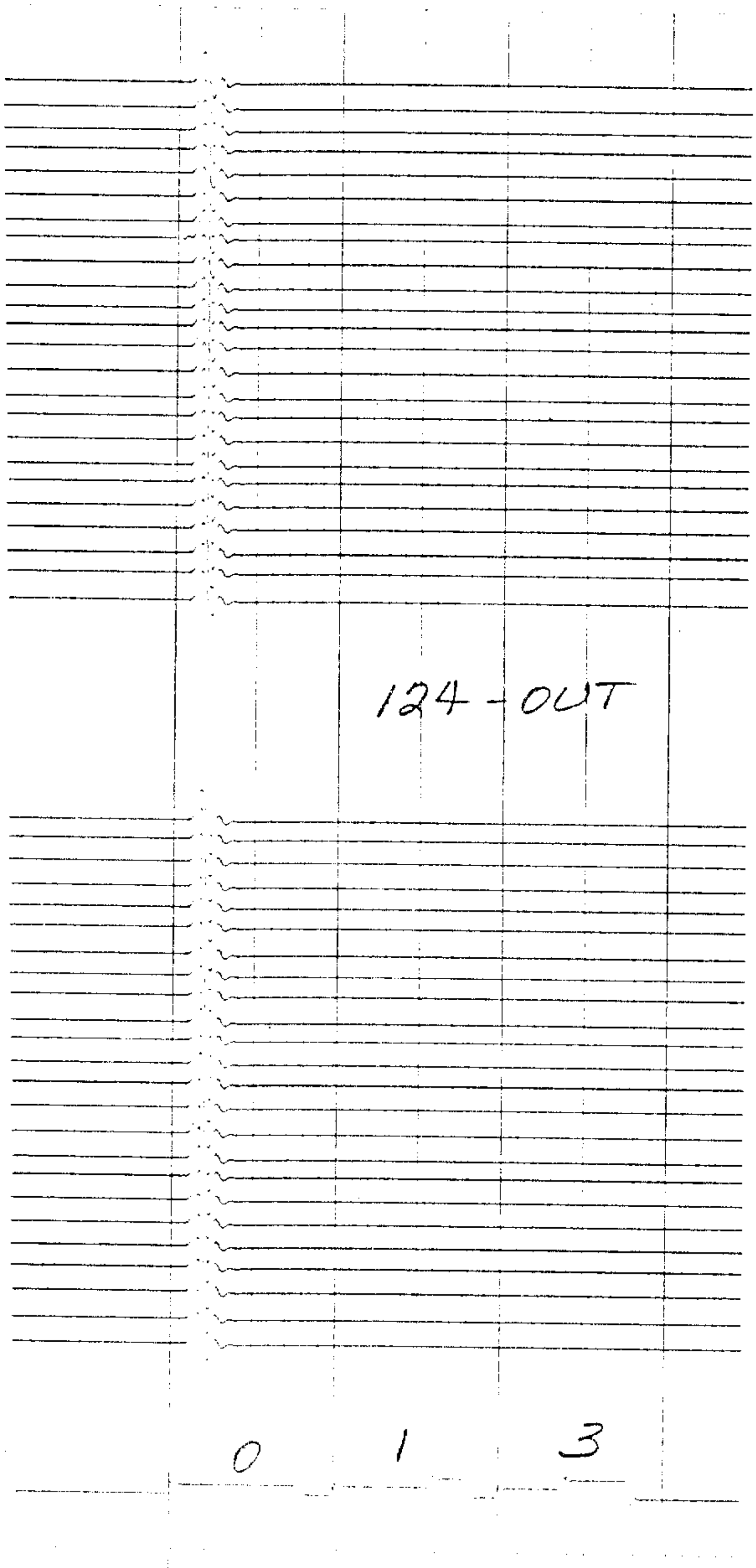


Figure 2.27

Filter Pulse Test

III TYPICAL MONTHLY TESTS

Once monthly, all seismic crews perform a series of tests which are in addition to daily tests described earlier. Monthly tests are therefore more rigorous than daily tests, particularly since they are always evaluated by computer, as opposed to the daily tests which are generally evaluated from paper camera records only.

In addition to the performance of the four sets of daily tests executed and assessed in the previous Section II, the following checks are performed.

(1) Further filter pulse tests
(2) Gain Accuracy test
(3) Harmonic Distortion test
(4) Crossfeed test
(5) Polarity test
(6) Converter Linearity test
(7) Skew check test
(8) Tap test
(9) "All ones" test.

(1) Filter Pulse Tests

As explained in the previous section, a suite of filter tests are performed and analysed during monthly tests. The intention of the additional tests is to observe the signature of each filter in turn - a defective channel may be indicative of problems to come. Hence, the monthly filter pulse test is often used as a guide for preventative maintenance.

Description

Instrument settings are as previously, recording a one second file. However, a series of further tests may be performed as follows:

Filter	Slope	Manual Gain (dB)
OUT/62	18	36
OUT/31	18	48

See Figures 3.1 and 3.2.

Analog Evaluation

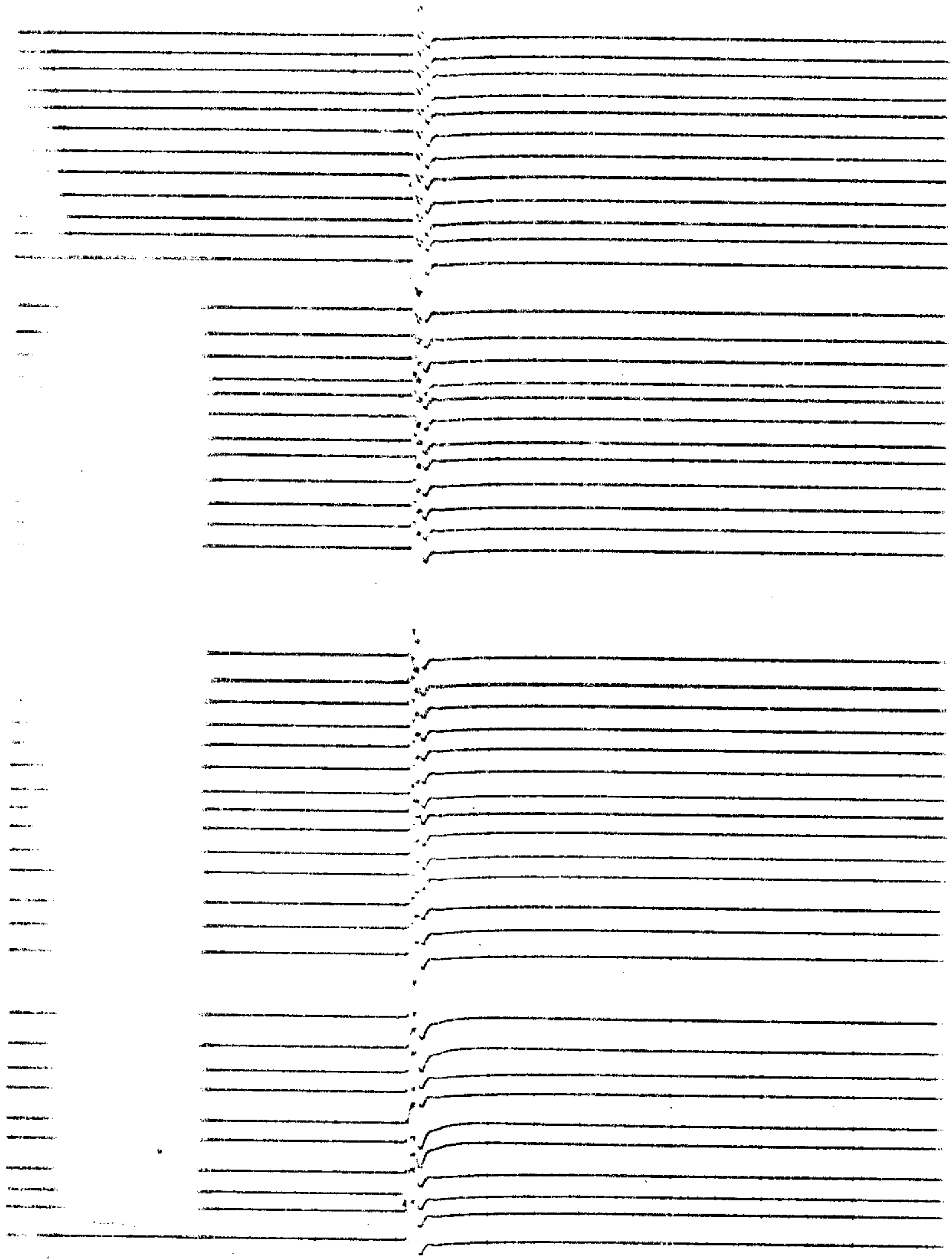
The two records shown are evaluated in terms of amplitude and phase, using the initial 'OUT' lo-cut filters (Figures 3.1 and 3.2).

The OUT/62Hz recording indicates all traces are in phase and have similar amplitude to the OUT/124Hz recorded previously. However, the 62Hz filter clearly has a slower impulse response time (longer time constant) and thus the filter's signature represents the passage of a lower frequency band width, as expected.

The OUT/31Hz filter's signature passes a further reduced band width of signal, and its response time allows ready inspection of the waveform signature. Amplitude is reduced, and it takes some 10 milliseconds longer to return to zero, than it does with the 62 and 124Hz counterparts. Clearly, a 31Hz filter would not be desired for seismic data acquisition because, apart from its suppression of frequencies above 31Hz, its impulse response to a wave front's arrival is too prolonged that any event arriving within 20 milliseconds of a first arrival break would not be recorded. Thus, the 31Hz filter option - which is the anti alias filter for 8 millisecond sampling - is never used for seismic data collection.

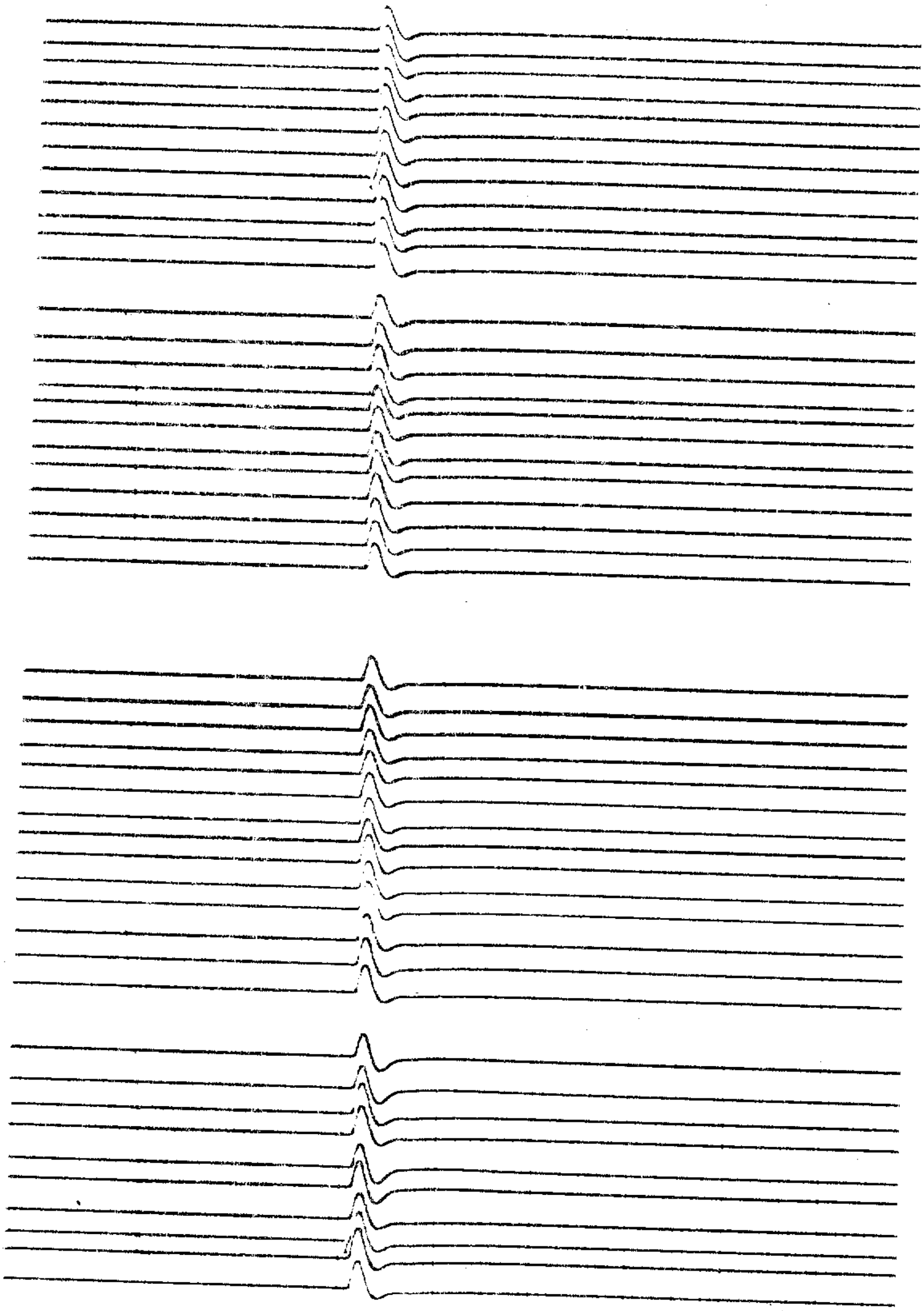
Figure 3.3 is the paper record displaying the various channels using different filter options. Inspecting the paper record, the longer time constant of the 62Hz filter compared with the 124Hz filter, is apparent as discussed previously. The longer 31Hz filter is then in evidence across channels 13 through 18, followed by a complete contrast in phase using a lo-cut of 8Hz and hi-cut of 124Hz across channels 19-24.

Comparison of the 8/124Hz option with the 12/124Hz option



Filter Pulse Test OUT /62 Hz

Figure 3.1



Filter Pulse Test OUT/31Hz

Figure 3.2

across channels 25-30 indicates the 12Hz lo-cut filter has a faster response than the 8Hz filter, as expected. However, it is not as fast as the 'OUT' lo-cut (i.e. no filter in circuit). Comparing phase relationships, the positive and negative peak time responses are very similar, but the 'OUT' lo-cut returns to zero 20 msec after the spike has passed (i.e. 10 samples later). The 8Hz lo-cut filter performs this task some 90 msec after and the 12Hz option makes it by 65 msec. Clearly, the use of a lo-cut filter introduces a phase error which should be appreciated in data-processing. However, this is rarely the case.

This comparison is extremely important because frequently a survey party will acquire data using one filter, only to return the following year to adopt the use of another. 'OUT', 8 and 12Hz filter options have been chosen here particularly because they are the filter options most commonly used. Since most seismic data lies in the 20-40Hz bandwith, the 18 and 27Hz options are very rarely exercised.

As a consequence of this phase shift and difference in lo-cut filter time constants, useful data may be masked and seismic misties due to differently filtered sections can result. Conversely, the lengthened delay time of the 8Hz filter may in fact be preferred, because it could aid or highlight a strong low frequency event for easier interpretation.

The 8Hz lo-cut option is commonly used on marine surveys to suppress marine cable noise, whereas the 12Hz filter is more useful with land operations in an effort to suppress low velocity layer ground-roll shot inspired noise. (It is not difficult to envisage difficulty in tying land data to marine data.)

The phase comparison between the 12Hz lo-cut filter channels and the 18Hz channels indicate further phase change, until finally the 27Hz option appears to have a very strong positive overshoot which is 180 degrees out of phase with the 'OUT' setting - hi-cut slope of 72dB per octave.

A comparison of the OUT/124/18db slope with the 72dB slope indicates an undesired greater amplitude negative notch with the higher slope and, since the current trend is to record data with lesser slope high cut filters, it may be presumed that data is enhanced partially because of the removal of the larger amplitude notching effect of the higher sloping filter.

Hi-cut filter slope phase comparison

The current trend to softening hi-cut filter slopes suggests a review of their phase relationships is of great interest. The fact that a filter change will introduce a phase change or signal distortion effect has not gone unnoticed, but the fact that a mere hi-cut slope change may, in itself, introduce significant phase change, is not often fully appreciated.

A comparison of Figures 3.3 and 3.4 illustrates the effect in analog format.

With the OUT/124Hz option, the 72dB per octave slope introduces a low frequency rippling tail not visible on the lower slope traces.

The OUT/31Hz 72dB per octave slope emphasizes this with a strong negatively going half-cycle.

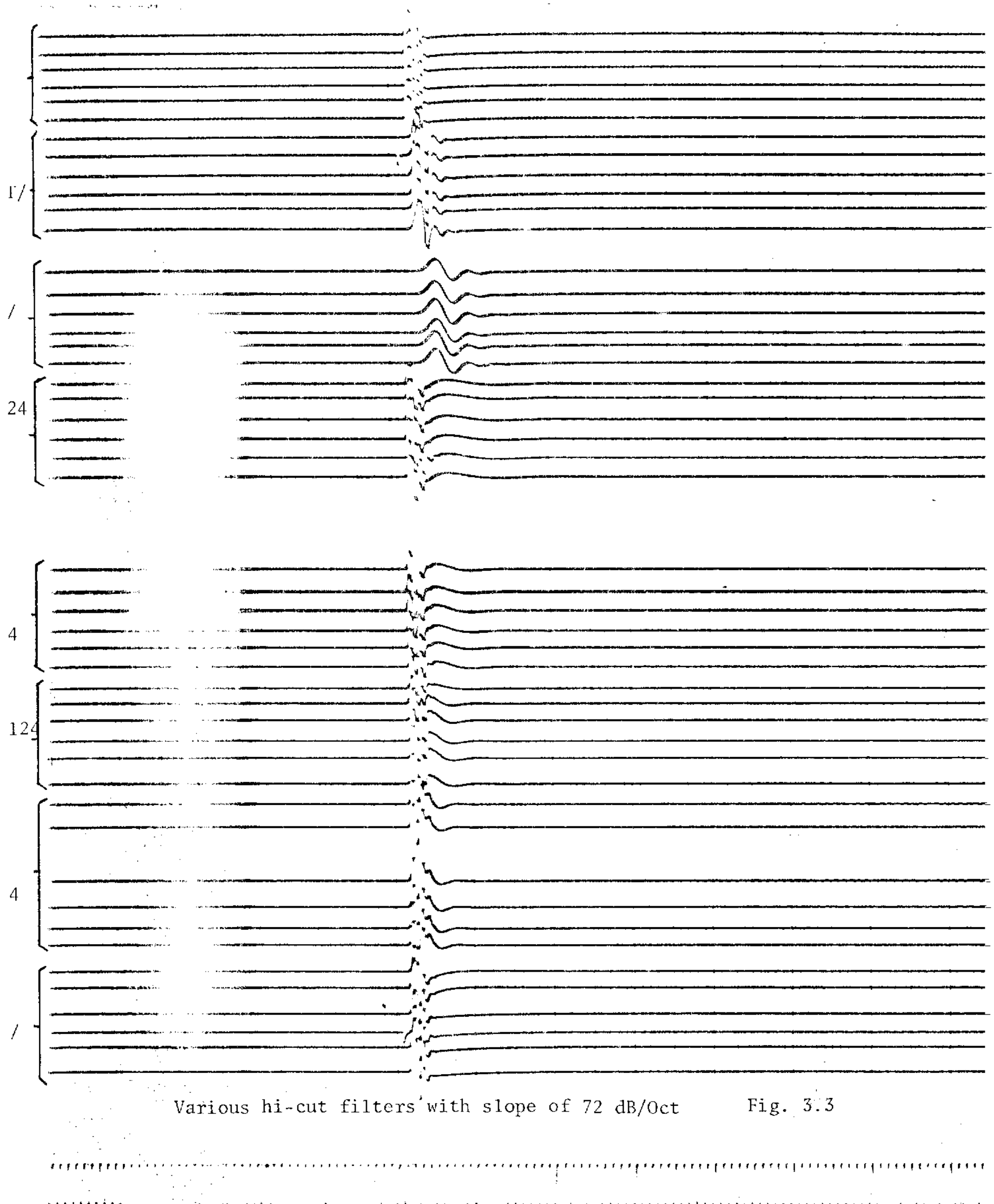
The 8/124Hz options indicate a notch on the waveform's tail, and this is repeated at 12/124Hz and 18/124Hz.

The 27/124Hz traces have the notch effectively squaring the overshooting tail and is an outstanding example of out of phase filter effects when compared with the OUT/124Hz traces.

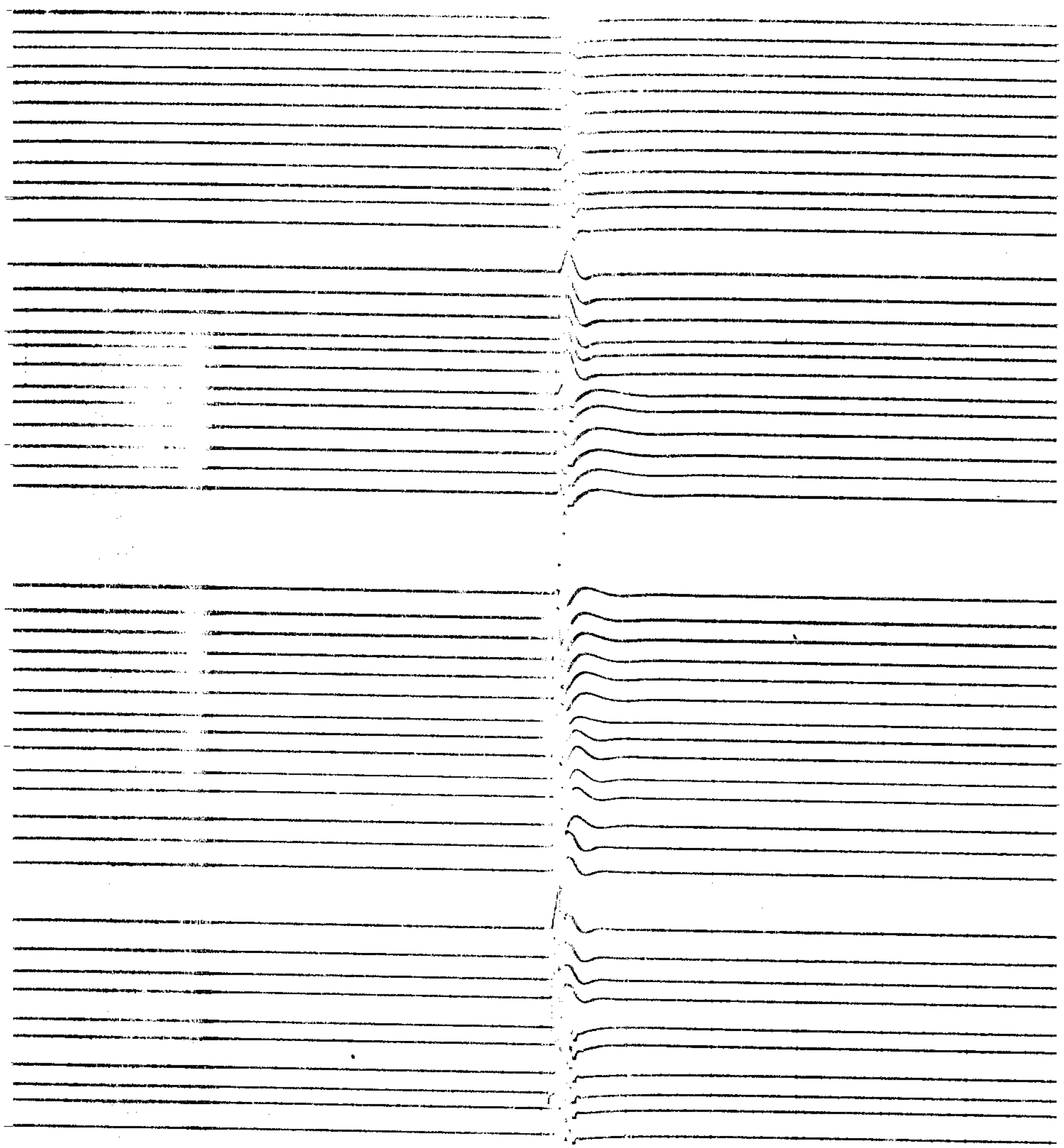
These comparisons indicate that a change of high cut filter slope alone can cause an extreme change in phase, which is not appreciated for the most part, and is rarely accounted for in data processing (by the use of predictive deconvolution techniques).

A further test was performed checking the effect using a 60Hz notch filter with normal recording OUT/124Hz filters. The notch filter is used as a common mode rejection filter which, essentially, removes 60Hz from the data. This filter is used where 60Hz power lines are encountered during surveying, but, since the power supply in Australia is 50Hz, this option has never been exercised (or is likely to be). However, assuming the 60Hz option performs on an equal basis with the 50Hz option, results of pulse tests may be analysed and assumed to apply equally.

The pulse test with the notch filter "in" is observed on Fig. 3.5 channels 13-36, and is compared with notch "out" channels 1-12. Clearly, the notch being "in" introduces a ringing tail for some 80 msec reminiscent of vibroseis side lobes. Considering that the filter would be used in and out (on an ad hoc basis) during conventional recording in populated areas, one would hope that an impulse response program would be deconvolved with the data to remove this ringing effect.

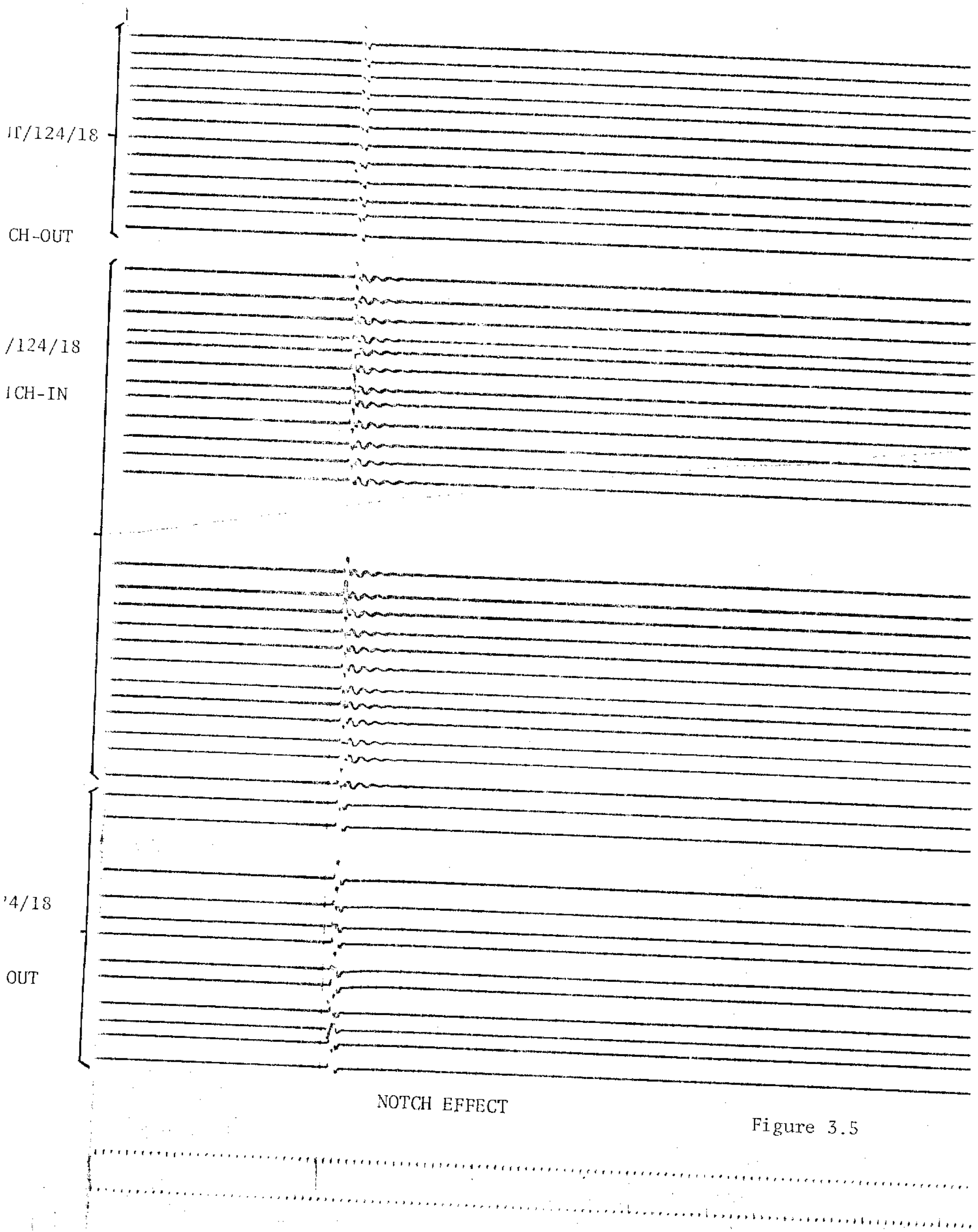


Various hi-cut filters with slope of 72 dB/Oct   Fig. 3.3



Hi-cut filters as Fig. 3.3 slope 18 dB/Oct

Figure 3.4



NOTCH EFFECT

Figure 3.5

IMBER	DATE	TIME	OBSERVER MAKING TEST	
RIAL NUMBER	PARTY NUMBER	PARTY MANAGER	PARTY CHIEF	
RATE ☑ 2 MIL ☐ 4 MIL ☐	SYSTEM FORMAT ☐ 9 TRACK ☑ SEG B ☐ SEG C	NUMBER OF TRACKS ☐ 24 ☑ 48 ☐ OTHER	PACKING DENSITY - BPI ☐ 556 ☐ 712 ☐ 800 ☑ 1600 PE	

DYNAMIC RANGE DETERMINATION TEST

MONITOR SECTION: RANGE SWITCH	LEVEL SWITCH	VALUE OF TEST SIGNAL	DB DOWN	FILE OR RECORD NUMBER	PLAYBACK SECTION: Galvo Level	BIT SLIDE	DB UP
			−3		SAME AS RECORD	0 db	+3
			−15		R + 12	0 db	+15
			−27		R + 12	12 db	+27
			−39		R + 12	24 db	+39
			−51		R + 12	36 db	+51
			−63		R + 12	48 db	+63
			−75		R + 12	60 db	+75
			−81		R + 12	66 db	+81
			NOISE		R + 12	66 db	+81

GAIN ACCURACY TEST

MODE ☑ CAL — GAIN CONSTANT ______ DB — RECORD LENGTH ______ S

FILE NUMBER	RECORD GAIN SETTING	TEST SIGNAL LEVEL SWITCH
(1)	84	1 μ V
(2)	72	1 μ V
(3)	72	4 μ V
(4)	60	4 μ V
(5)	60	16 μ V
(6)	48	16 μ V
(7)	48	64 μ V
(8)	36	64 μ V
(9)	36	256 μ V
(10)	24	256 μ V
(11)	24	1 m V
(12)	12	1 m V
(13)	12	4 m V
(14)	0	4 m V

EQUIVALENT INPUT NOISE TEST

Signal - 1μV / Number — Monitor Gain ______ DB — Noise: File/Record Number

Gain

______ DB | NOISE ______ DB

IFPA OSCILLATOR TEST

Record Number — Record Length ______ SEC — Method Signal Changes ☑ Exponential ☐ Sine Stepped

Signal Level — Record Gain Mode ☑ IFP ☐ Manual — Galvo Level Record ___ DB/REP ___ DB

Mode ☐ Defloat ☐ Float — AGC Reproduce Settings: Trip Sens ___ DB Initial Gain ___ DB

☐ PGC ☐ GAGC — Trip ______ Secs LEVEL: ☐ High ☐ Low — AGC Speed ______ PGC Rate ______ DB/SEC

HARMONIC DISTORTION TEST

FILE NUMBER	HICUT FILTER-HZ	LOCUT FILTER-HZ	NOTCH IN-OUT-HZ	RECORD LENGTH
045	FILTER	PULSE		

FILTER PULSE TEST

FILE NUMBER	HICUT FILTER-HZ	LOCUT FILTER-HZ	NOTCH IN-OUT-HZ
14	62/18	OUT	OUT
15	31/18	OUT	OUT
16	VARIOUS +	VARIOUS	
17	VARIOUS +	VARIOUS	

MODE GAIN ___ db MAN ☐ IFPA — GALVO LEVEL ______ dB

CROSSFEED TEST

FILE NUMBER	RECORD GAIN SETTING	CHANNEL TERMINATION
	O (MANUAL)	EVEN
	IFP	EVEN
	IFP	ODD
	O (MANUAL)	ODD

OTHER SYSTEM PARAMETERS FOR TESTS

M CONFIGURATION ONLY ☐ CFS SYSTEM

STANT ___ DB | GALVO LEVEL I-24 ______ DB | AUX ______ DB | NOTCH FILTERS ☐ IN ☑ OUT

R CONNECTION ☑ 2000 Ω | FILTERS LOW CUT | HIGH CUT | RECORD TYPE ☐ DATA ☑ CAL

NITOR ☑ OUTPUT (NOT RAW) | GENERAL CONSTANTS

NALYSIS RESULTS:

URACY: ______ MILLISECONDS DIFFERENCE BETWEEN TIMING LINES AND PIPPER TRACE ON MONITOR RECORD.

RIATION: ______ MILLISECONDS PER SECOND MAXIMUM VARIATION BETWEEN TIMING LINES AND PIPPER TRACE ON PLAYBACK RECORD.

REMARKS: LIST THE FOLLOWING. 1) ANY SCRATCH RECORDINGS 2) REPAIRS SINCE LAST TEST. 3) REMARKS AND OTHER TEST PROCEDURES OR RESULTS — SKEW CHECKS, CONVLIN, TB, ETC.

Table 3.1

(2) Gain Accuracy Test

The FPA changes gain in discrete steps - the amount of signal or gain being recorded for later signal recovery processing techniques. The accuracy of each step of change is of extreme importance, otherwise signal recovered is not representative of true signal levels.

Purpose

This test monitors the gain step accuracy of the instantaneous floating point amplifier (FPA), and the test also indicates test signal level switch accuracy. Since the test emphasizes gain and D.C. offset levels, the system must be correctly calibrated at designated settings.

Test Procedure

Set up the switches on the modules.

INPUT MODULES:

Operate-Parallel Switch	PARALLEL
Channel Select and DC Voltage	OFF
Filter Switches: Lo-cut	OUT
Hi-cut	124Hz production setting

AMPLIFIER MODULE:

Range Switch	x4
Level Switch	As shown on Table 3.2
Meter Function	OSCILLATOR
Oscillator Control	12Hz
Sine-Exp. Switch	SINE

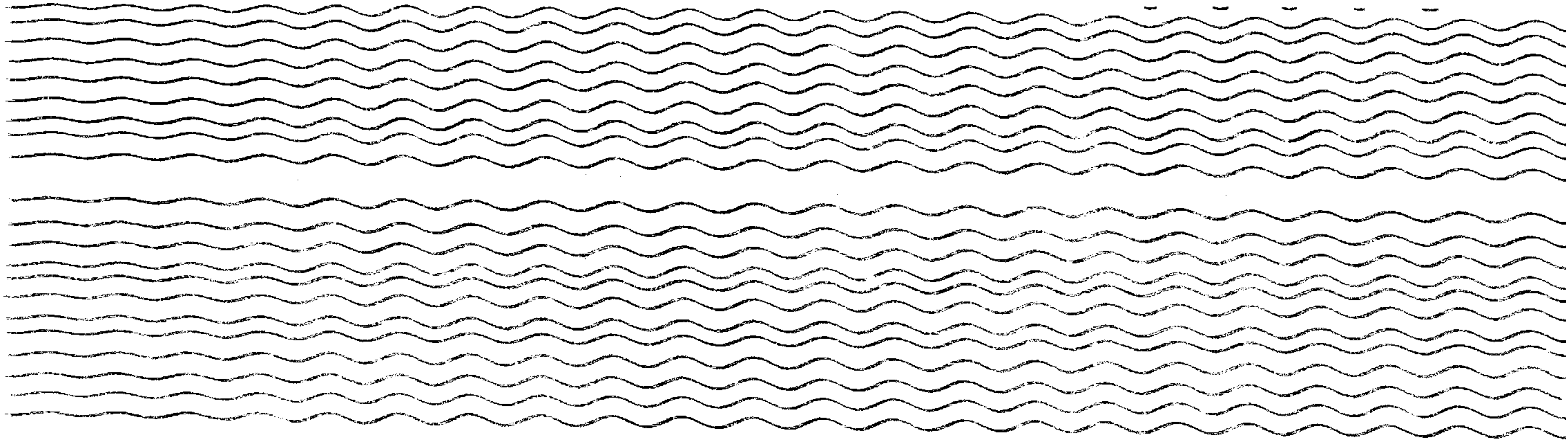
Zero Switch	OFF
DC Voltage	OFF
<u>FORMAT MODULE:</u>	
Mode Switch	RECORD
Record	CAL
Record Length Switch	3 sec
Gain Mode	MANUAL
Manual Gain	As shown on Table 3.2
Bit Slide	0dB
<u>REPRODUCE MODULE:</u>	
Leave as found	

1. Make a suite of 14 records at 12Hz and a further record at 36Hz. Figures 3.6 to 3.20.
2. Records are made in pairs using the same input signal for each pair but changing MANUAL gain one gain step for the second recording of each pair. Each step has a 12dB (4:1) signal or gain level change.

<u>Analog Evaluation</u>

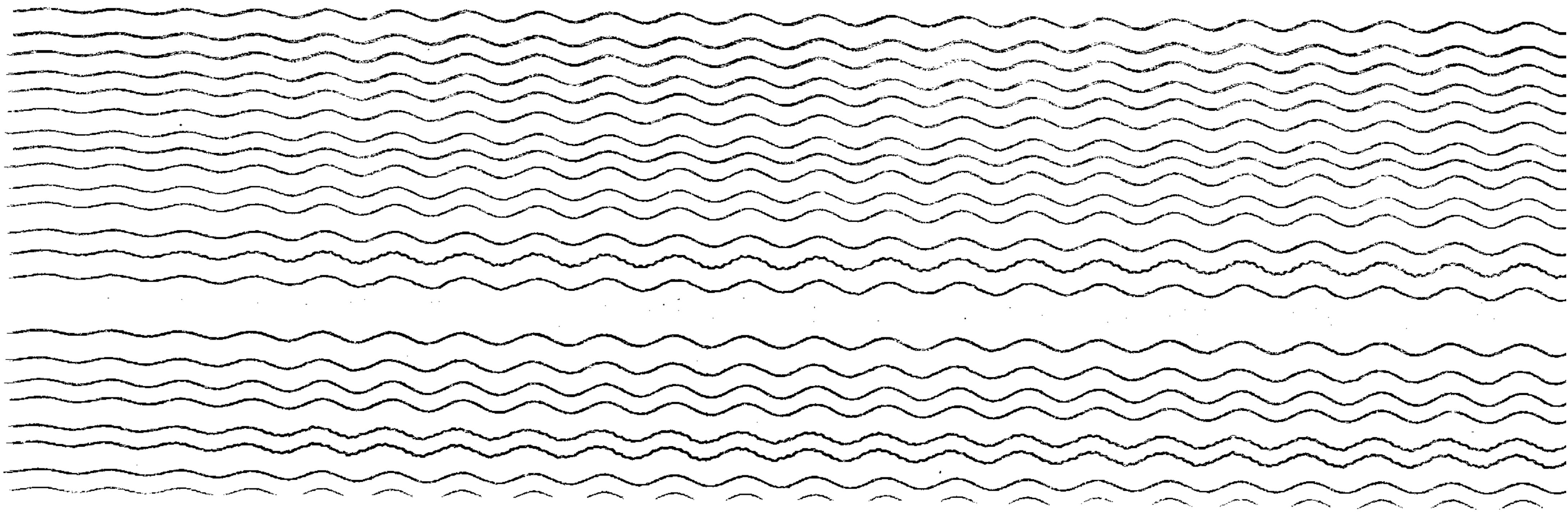
This test can best be evaluated by computer analysis, which must be performed with care.

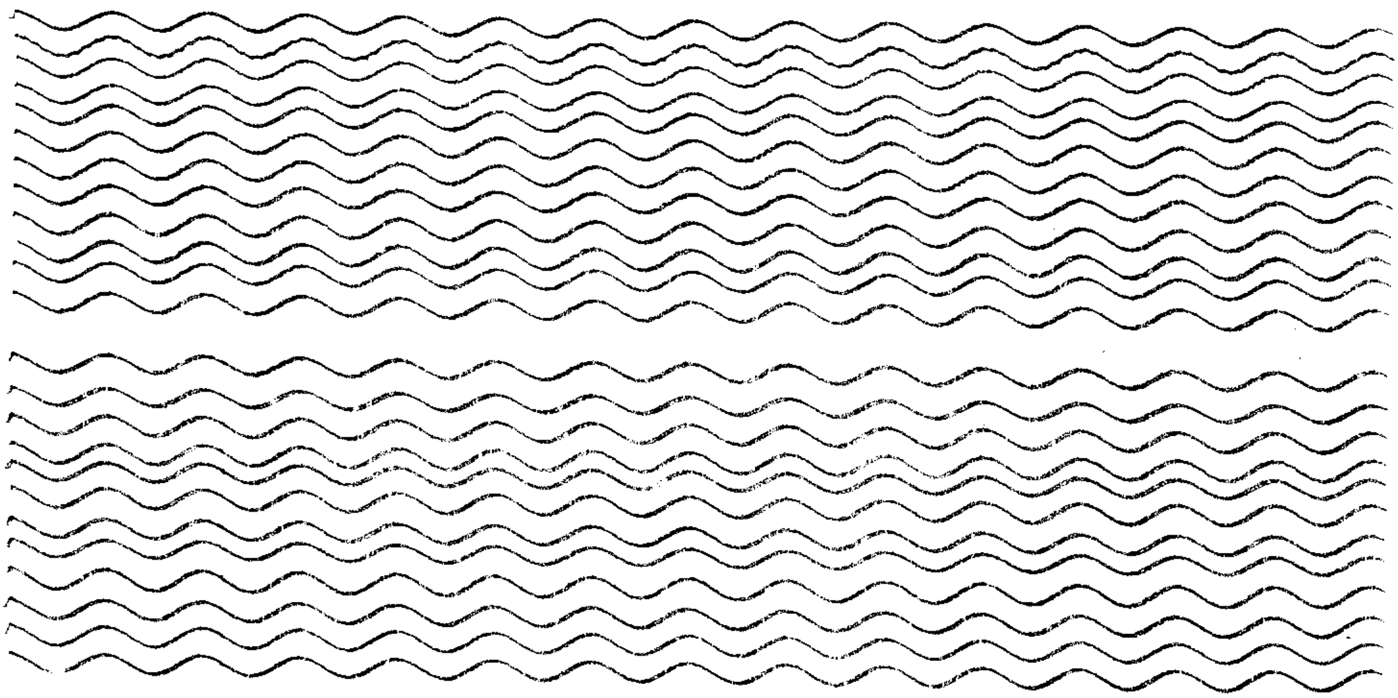
Gain step accuracy is determined from the ratio of the gain file pairs (18/19, 20/21 etc.). Test signal step accuracy is determined from ratios of the signal file pairs (19/20, 21/22 etc.). The ratio should be 4000 plus or minus manufacturers Acceptance Error.



Gain accuracy 4μV 84 dB

Figure 3.6





Gain Accuracy 4μV 72dB

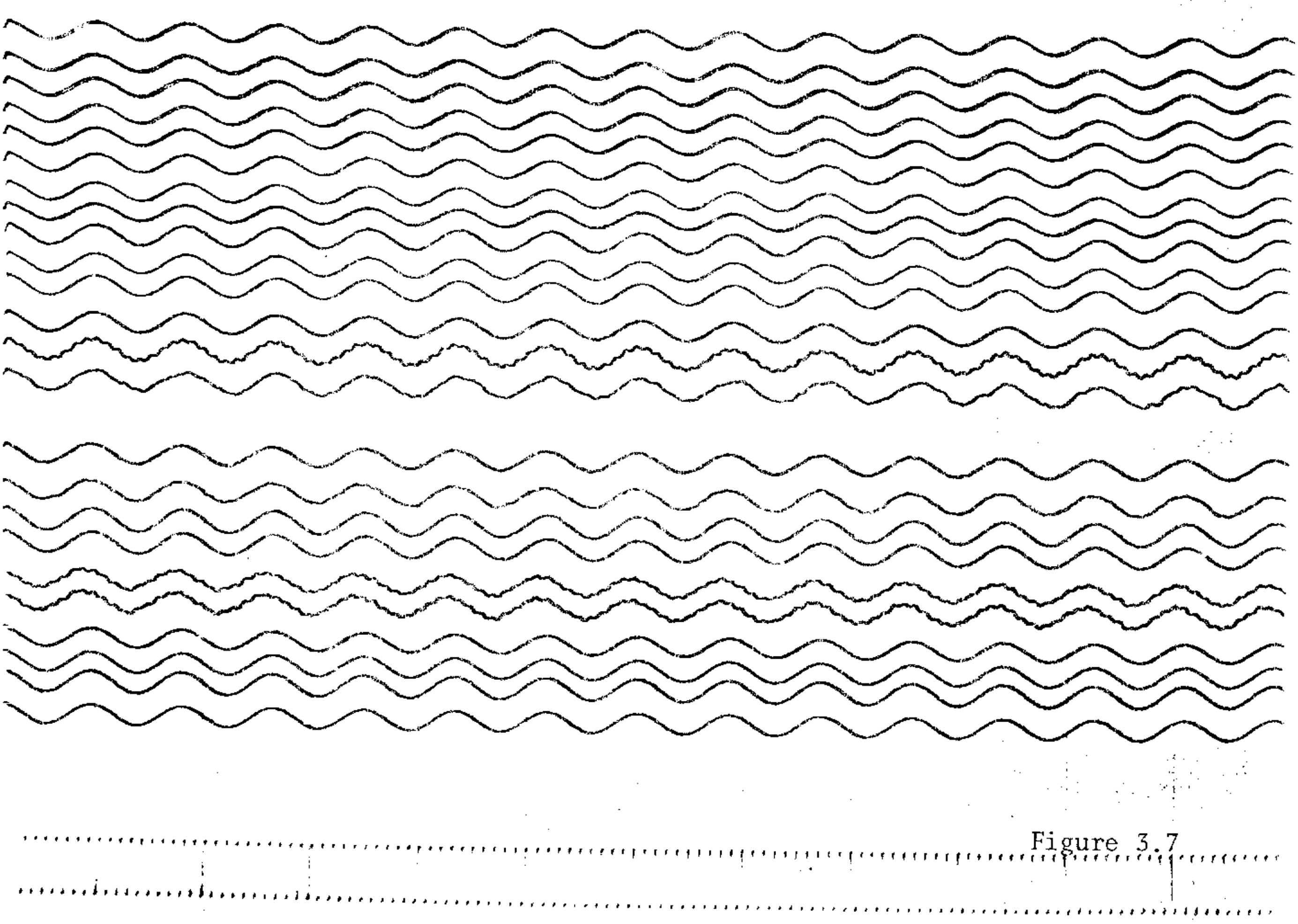
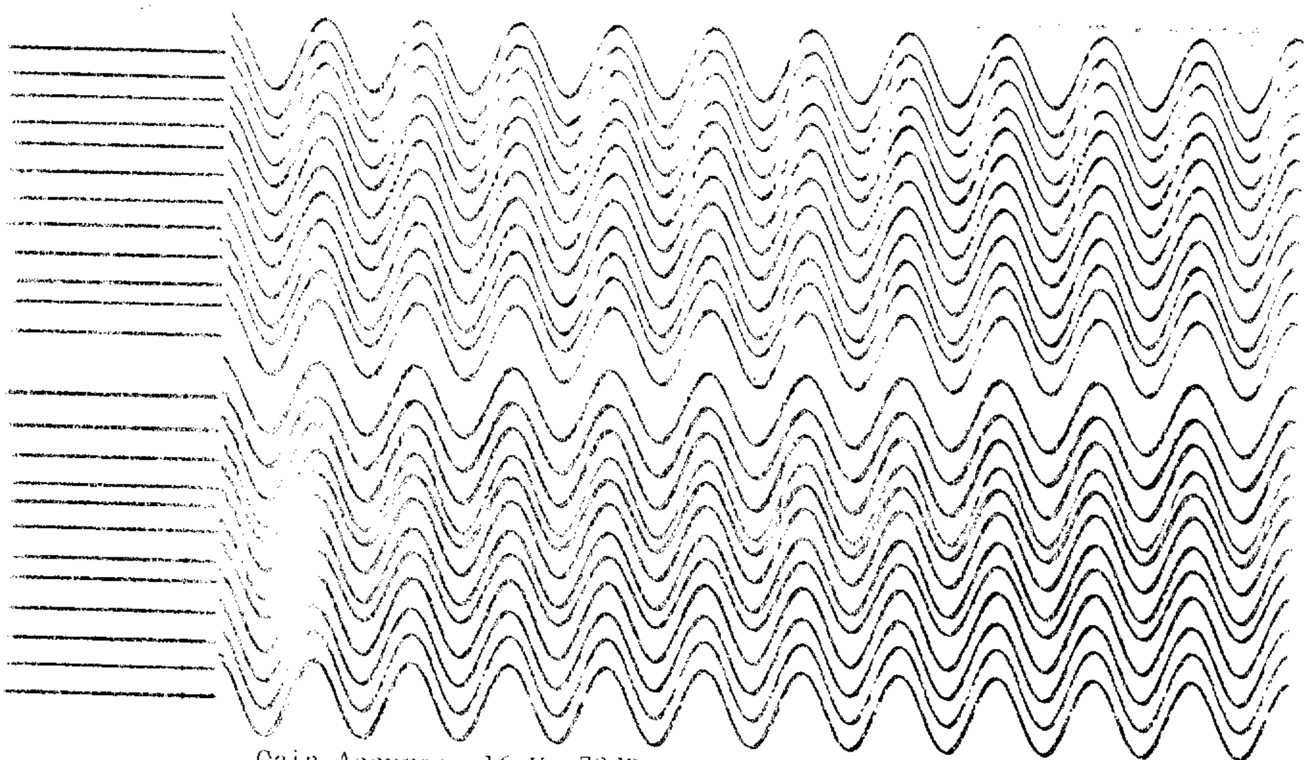


Figure 3.7



Gain Accuracy 16μV 72dB

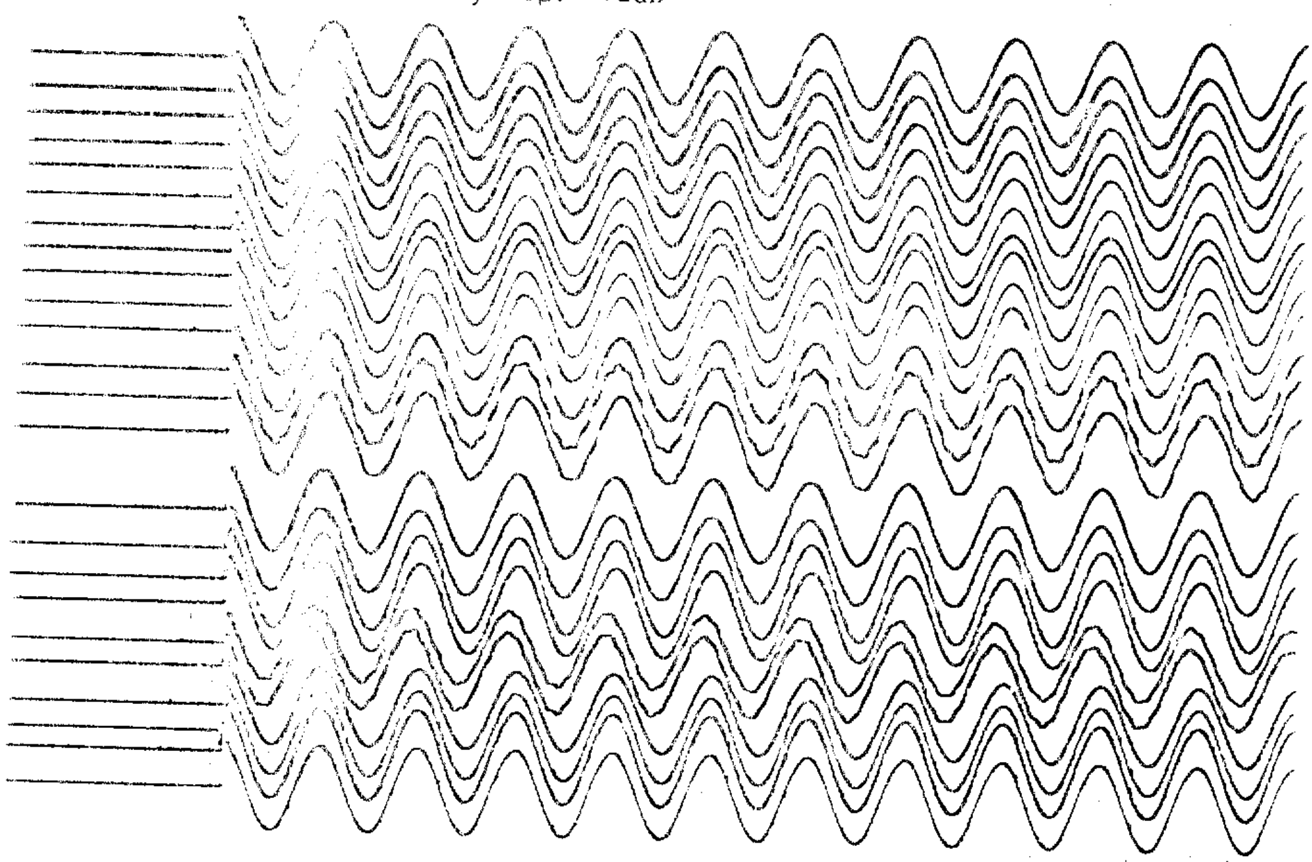
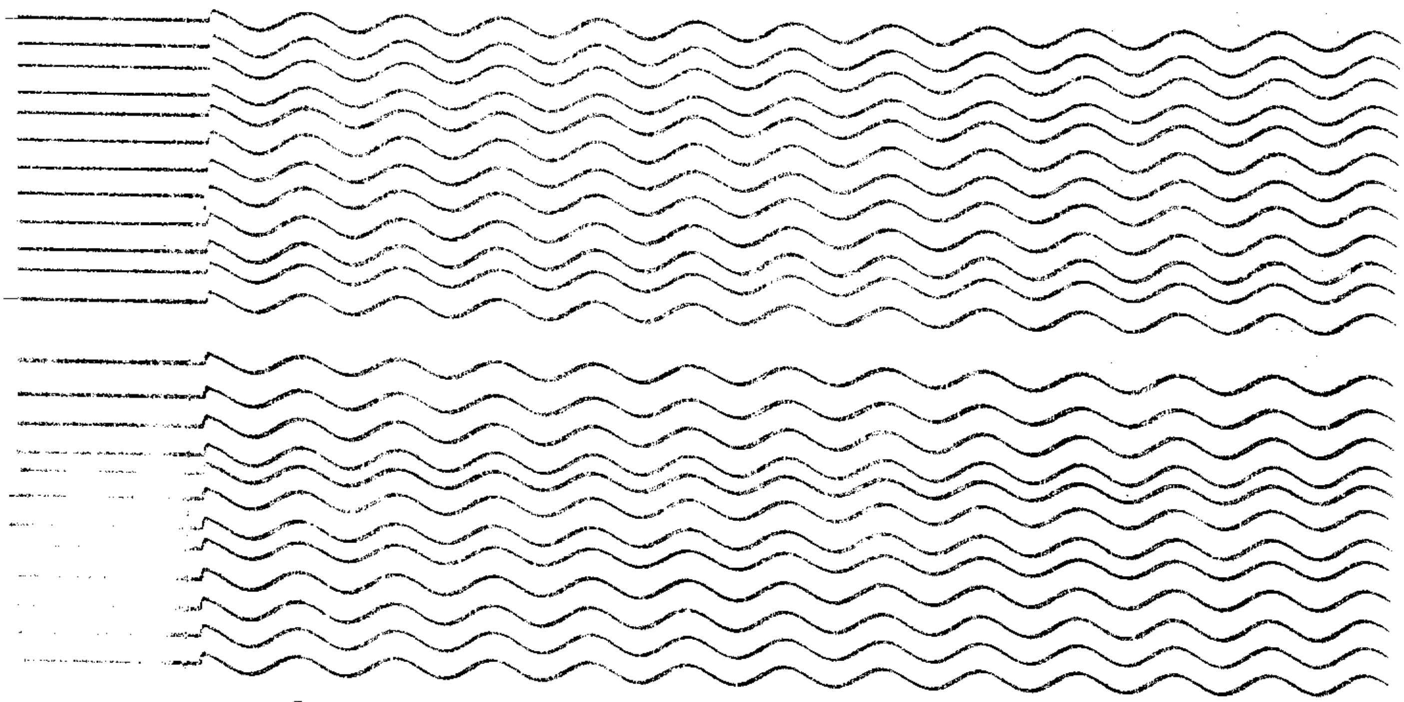


Figure 3.8



Gain Accuracy 16μV 60 dB

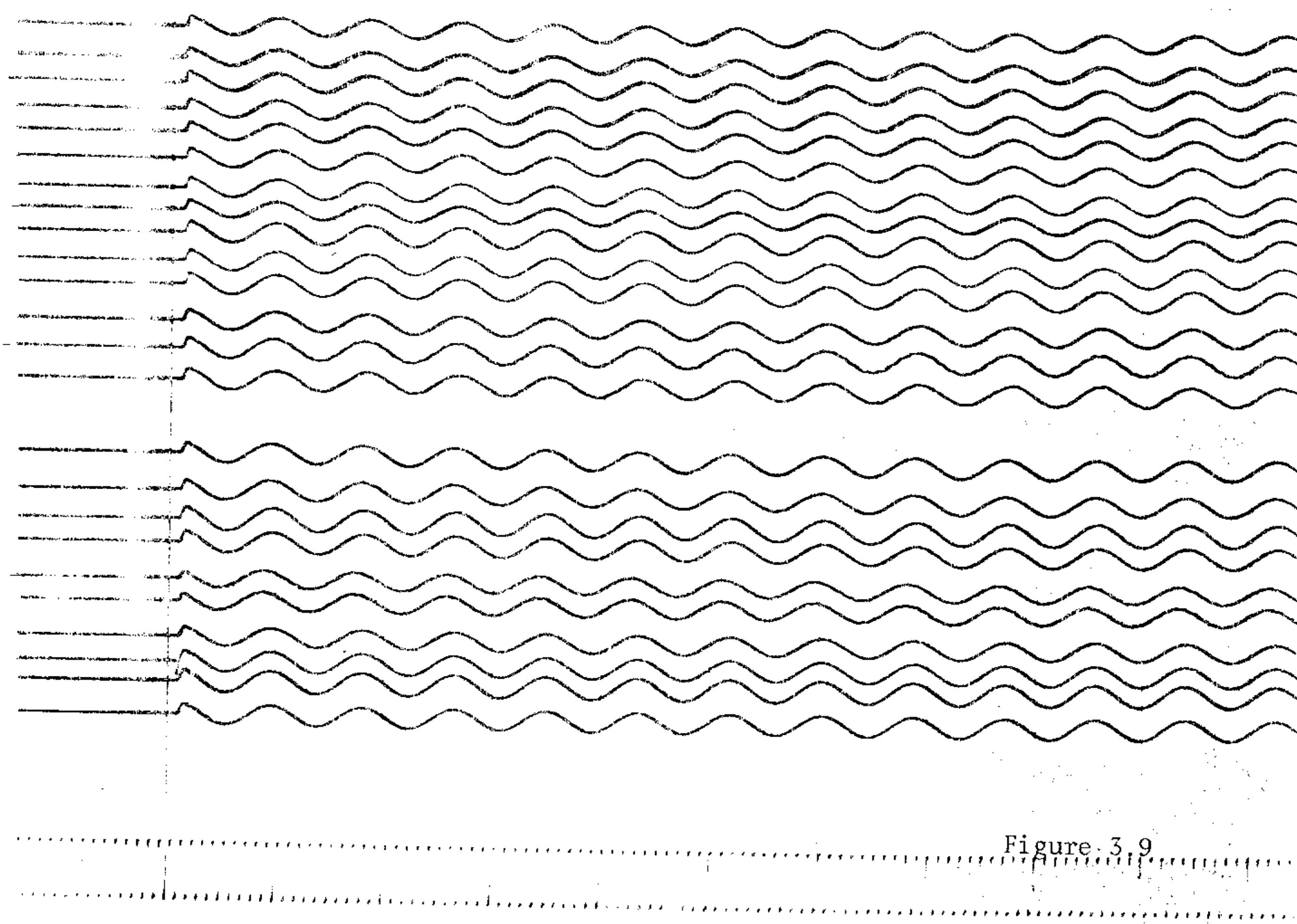
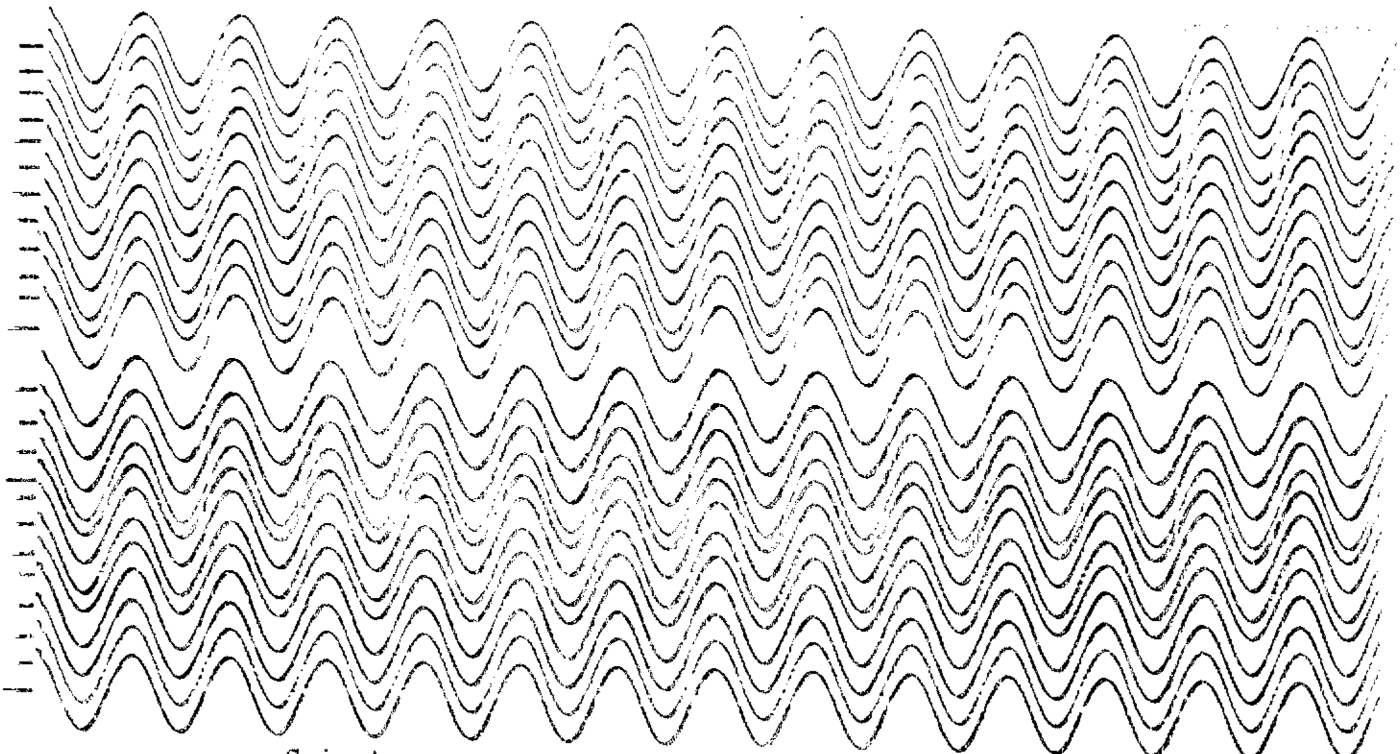


Figure 3.9



Gain Accuracy 64μV 60dB

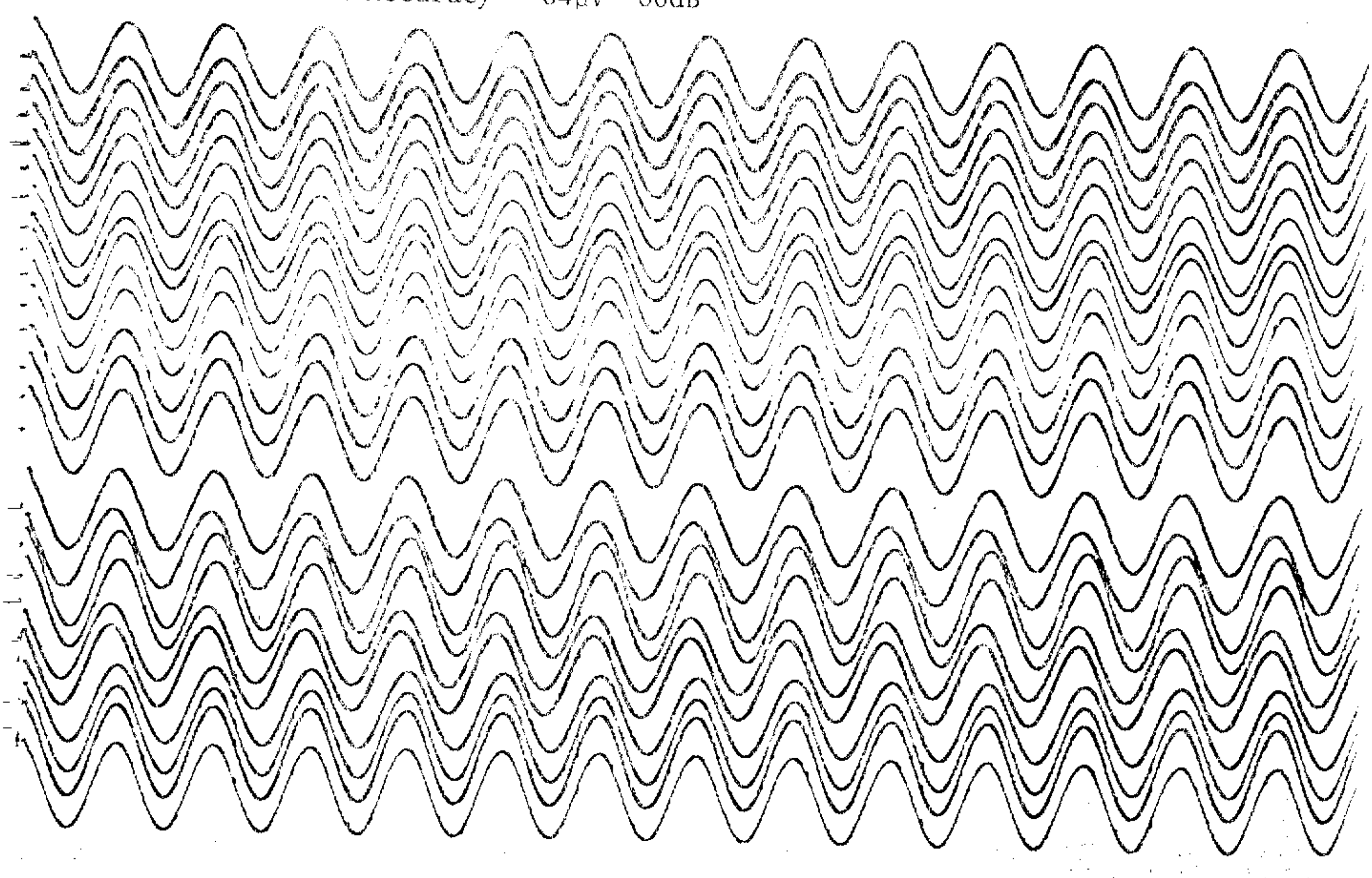
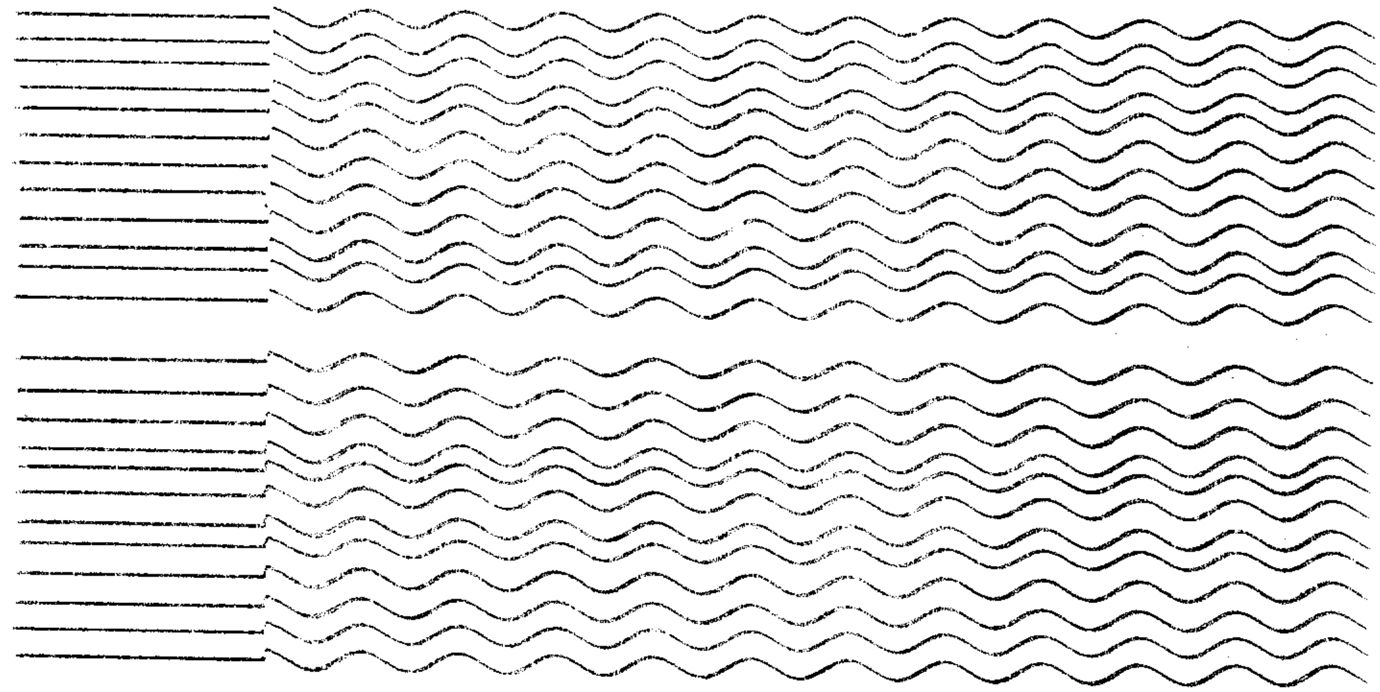


Figure 3.10



Gain Accuracy 64μV 48dB

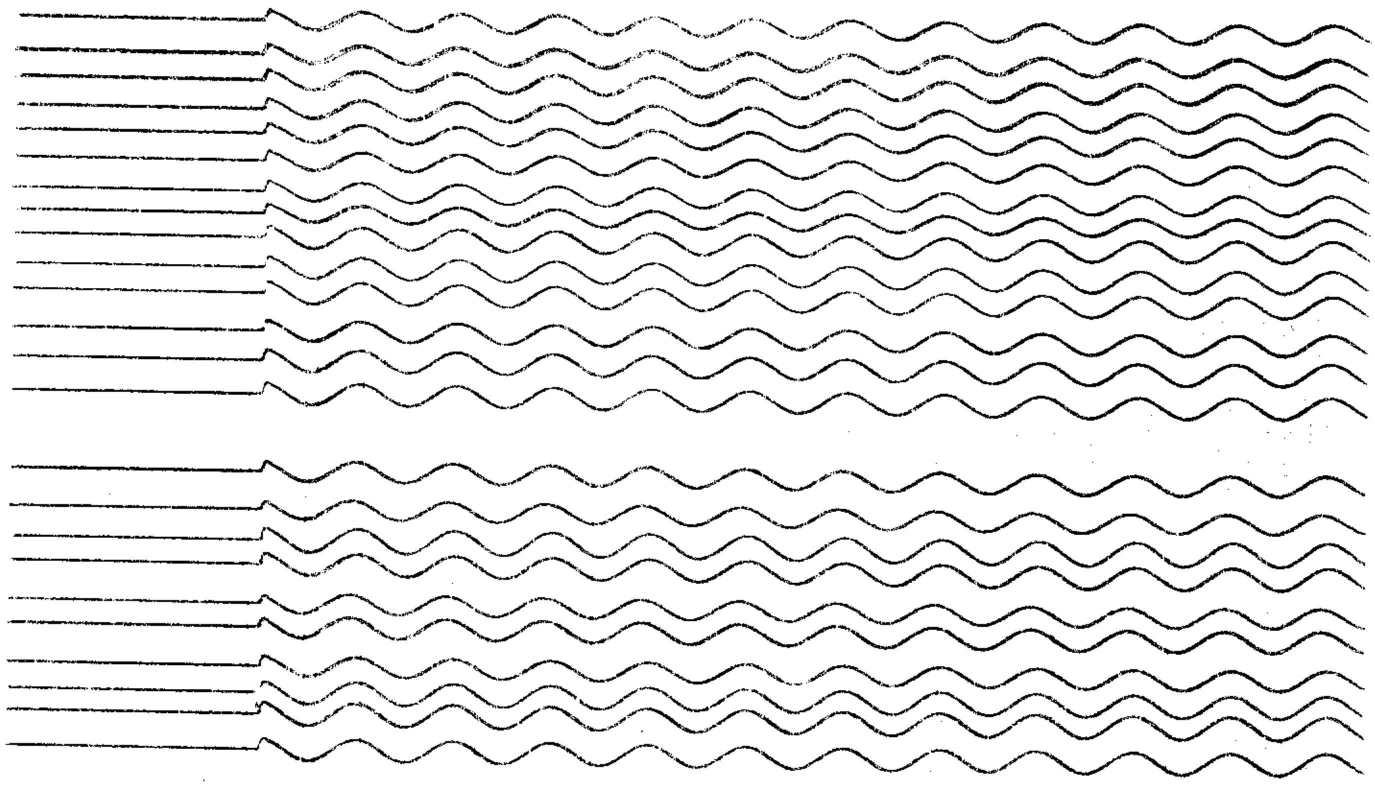
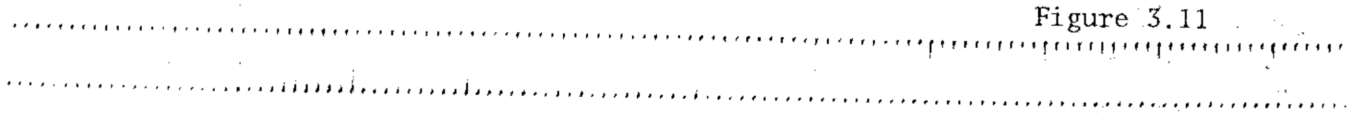
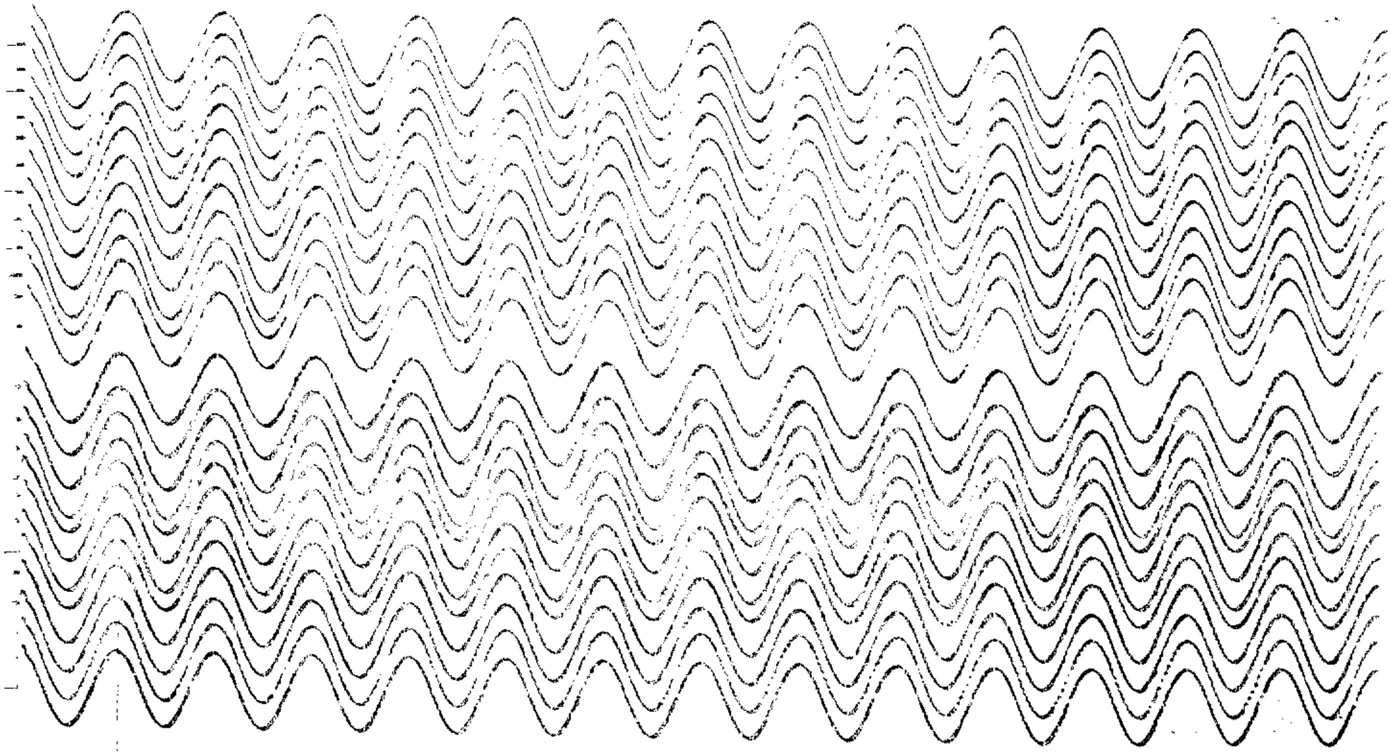


Figure 3.11





Gain Accuracy 256μV 48dB

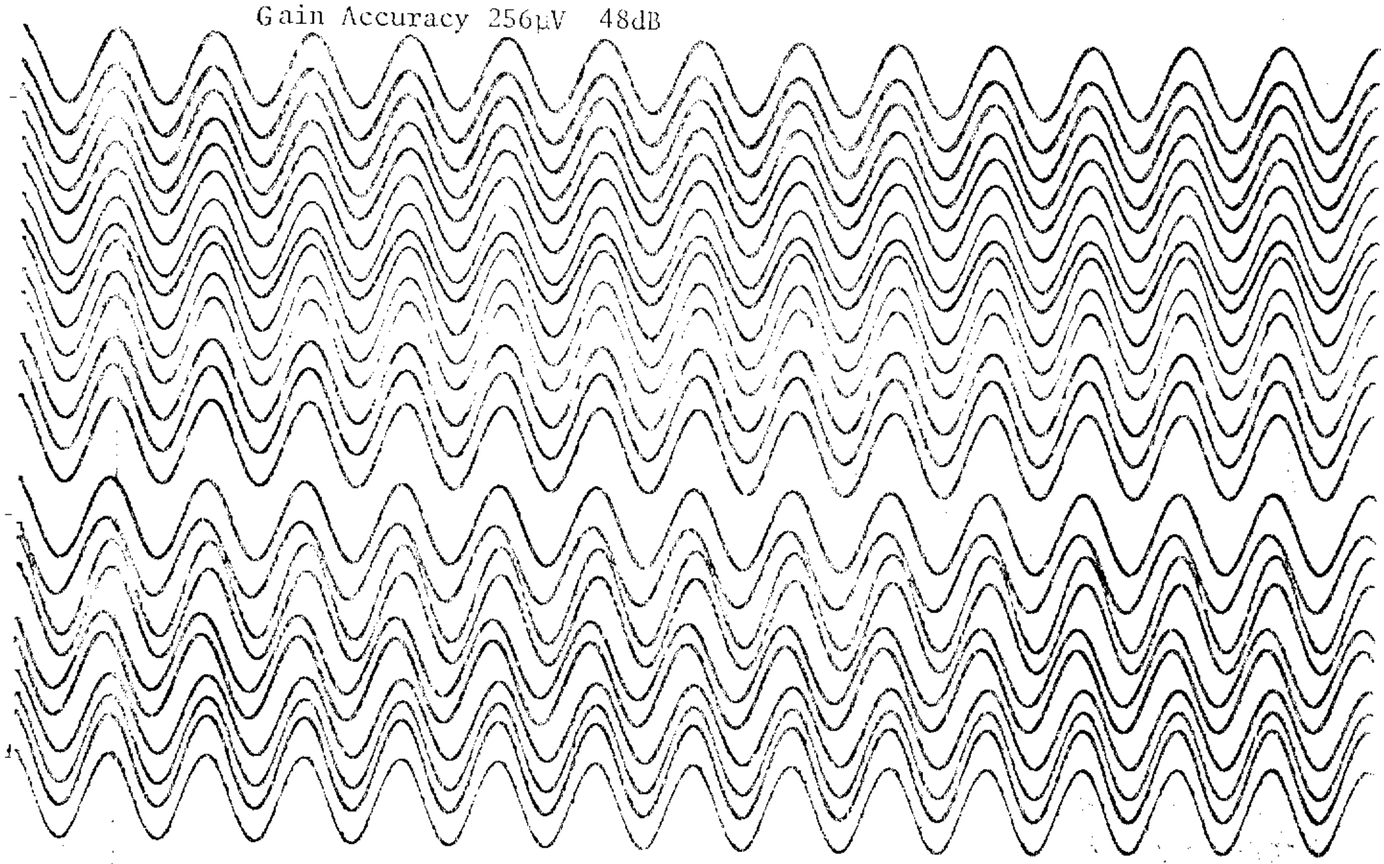
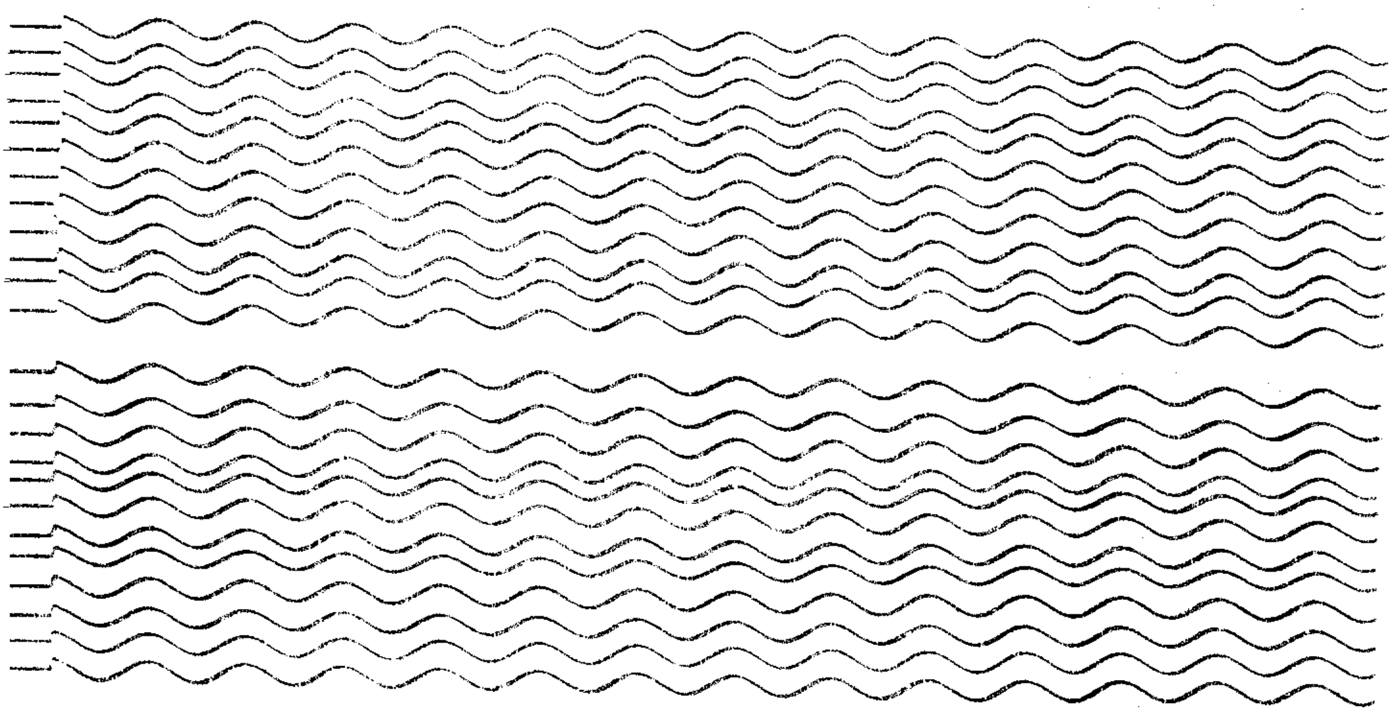


Figure 3.12



Gain Accuracy 256µV 36dB

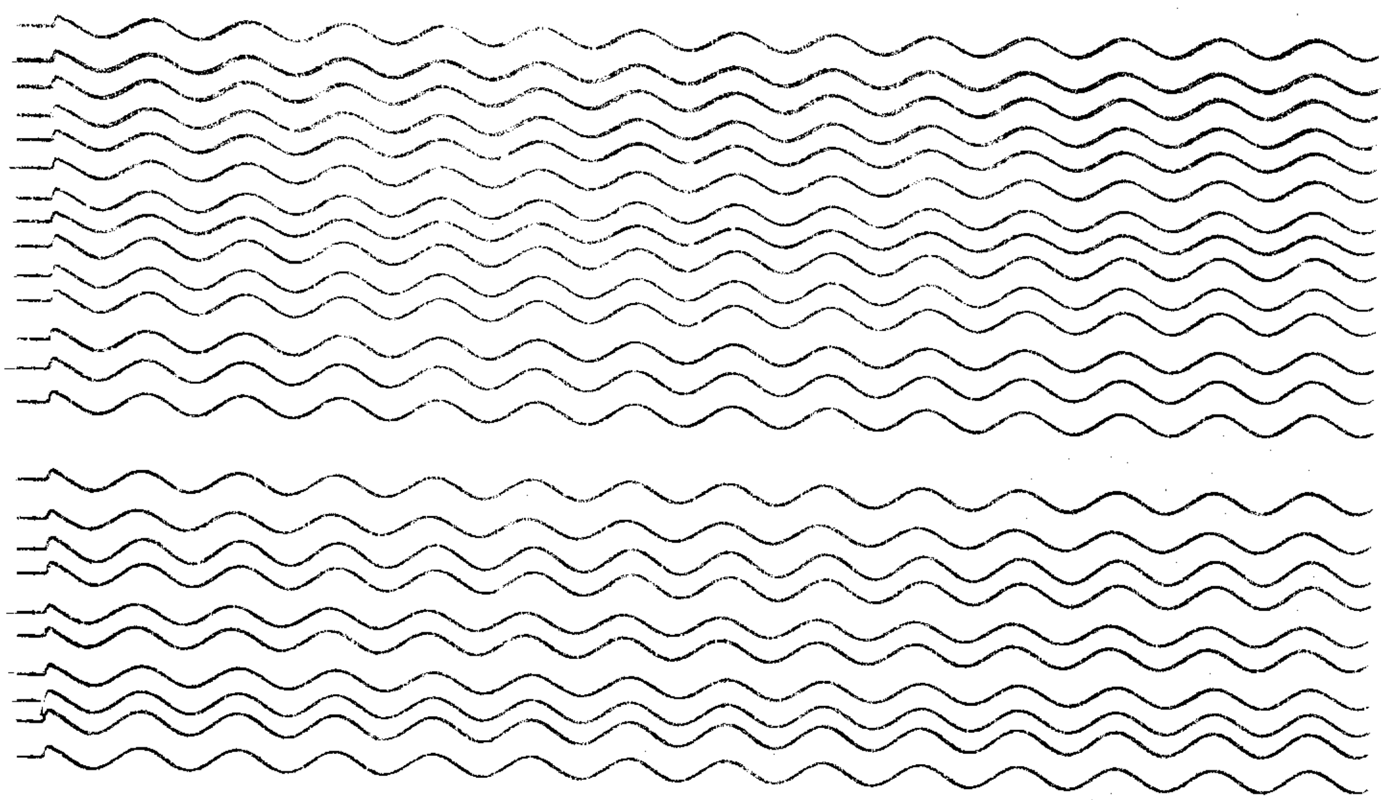
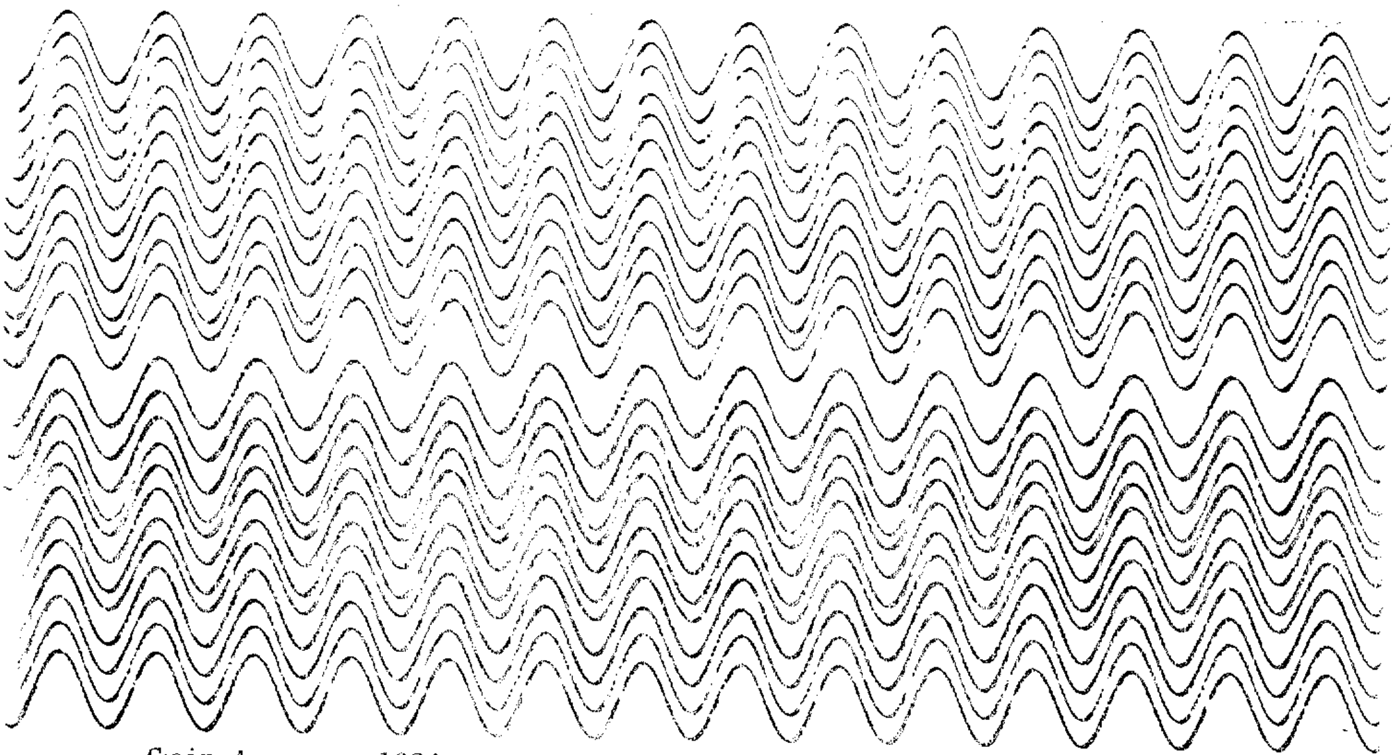


Figure 3.13



Gain Accuracy 1024 μV 36dB

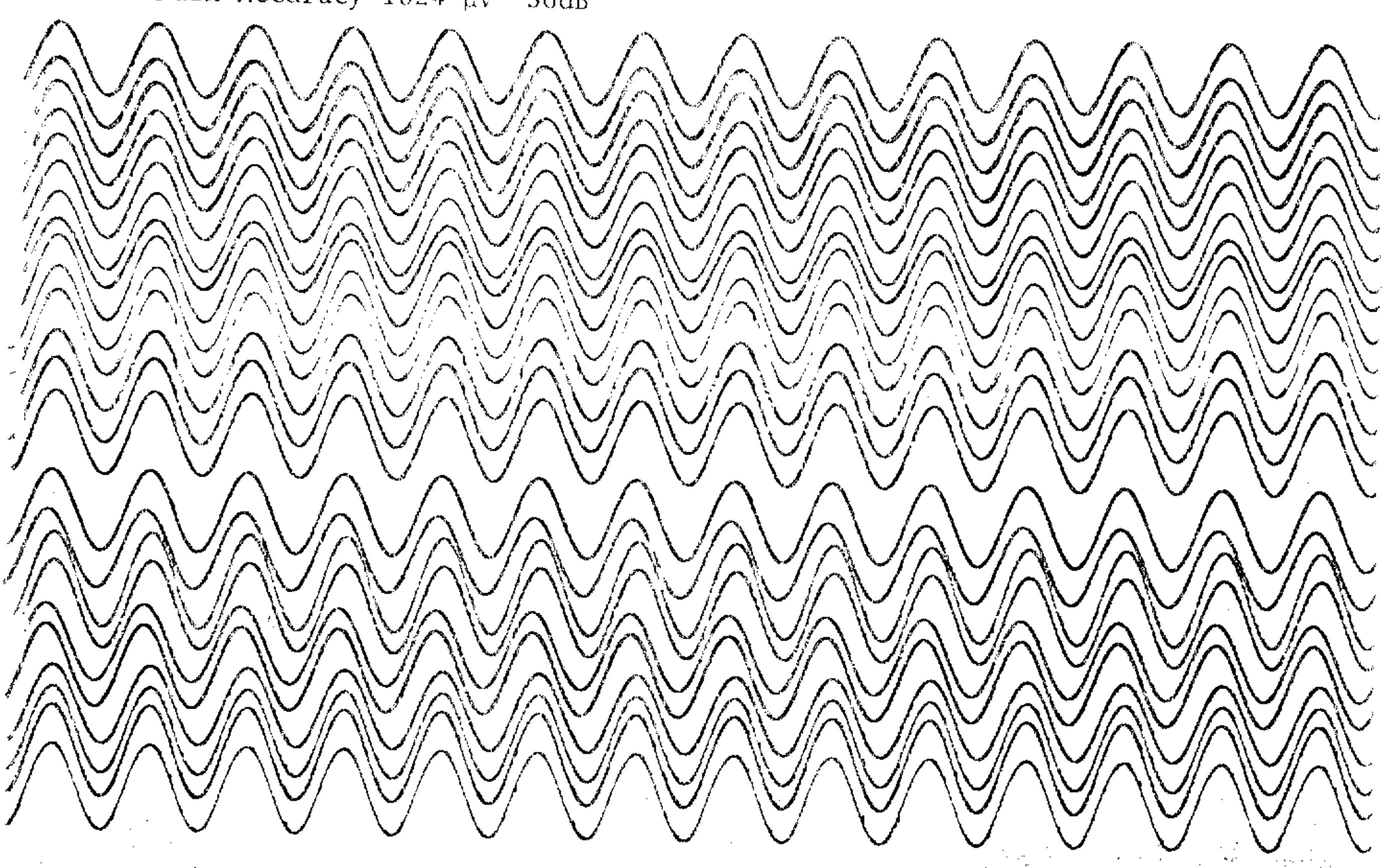
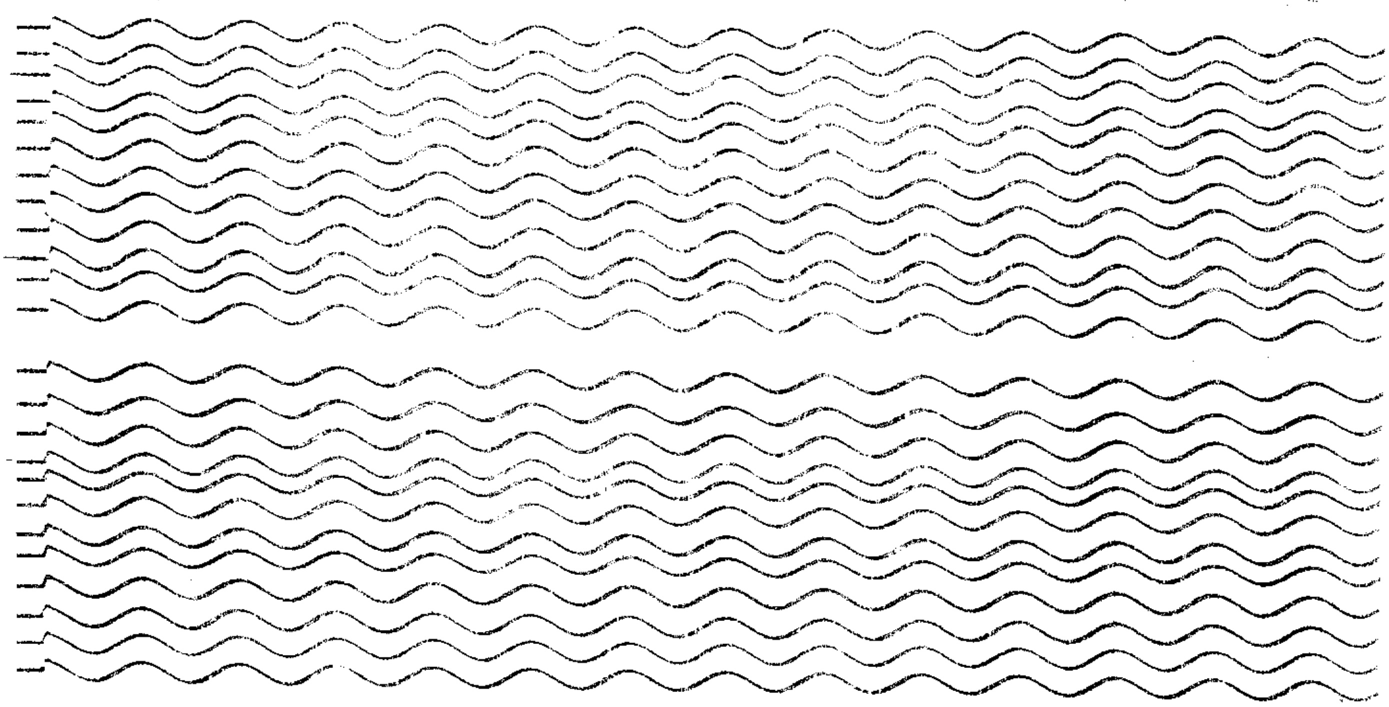


Figure 3.14



Gain Accuracy 1024µV 24dB

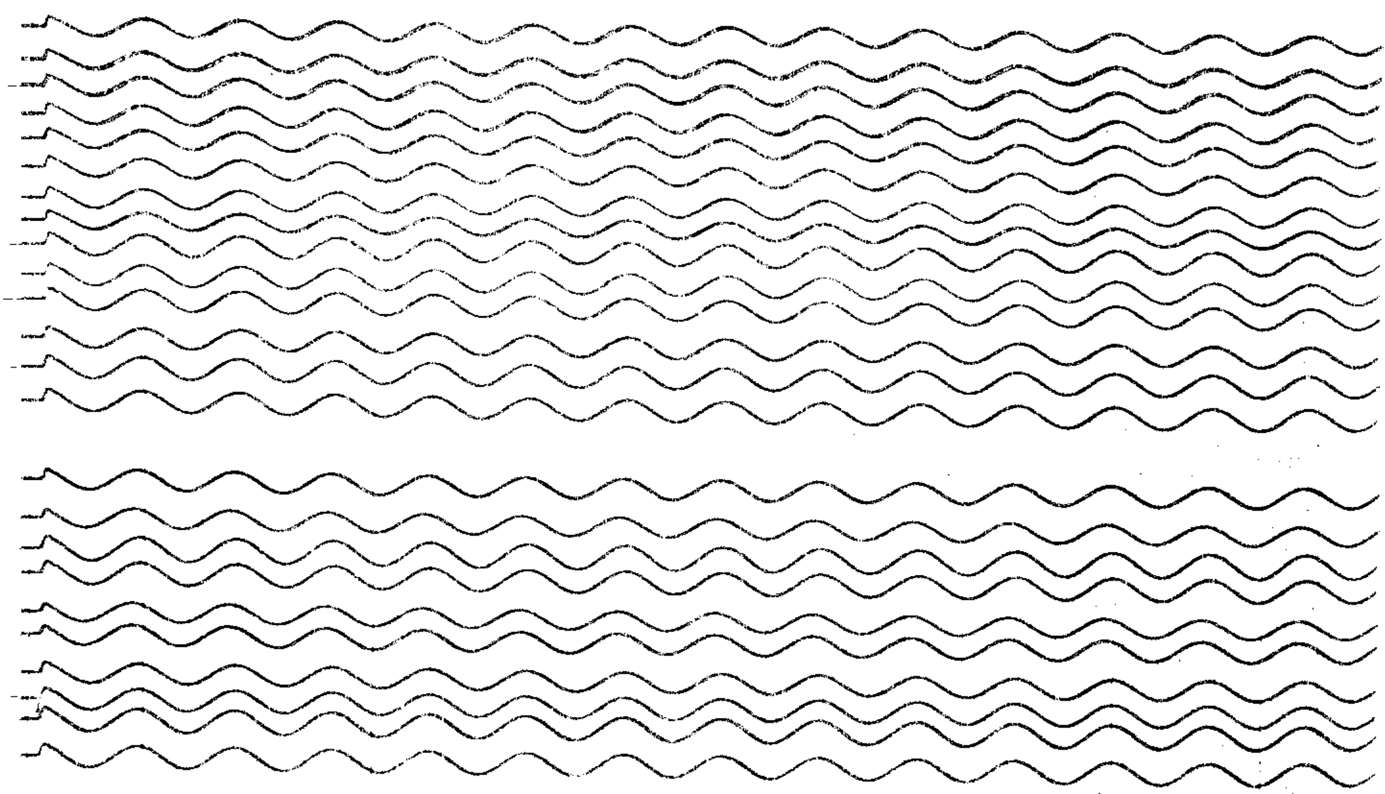
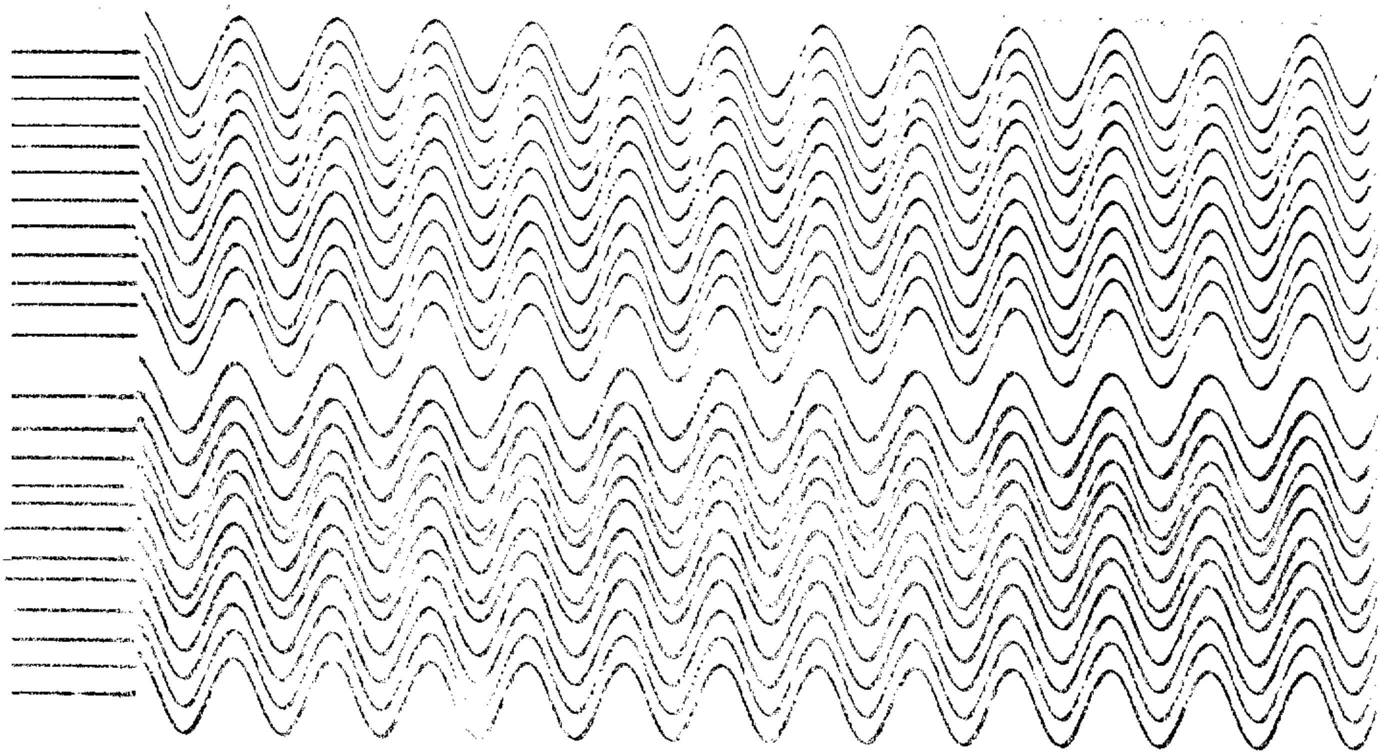


Figure 3.15



Gain Accuracy 4mV 12dB

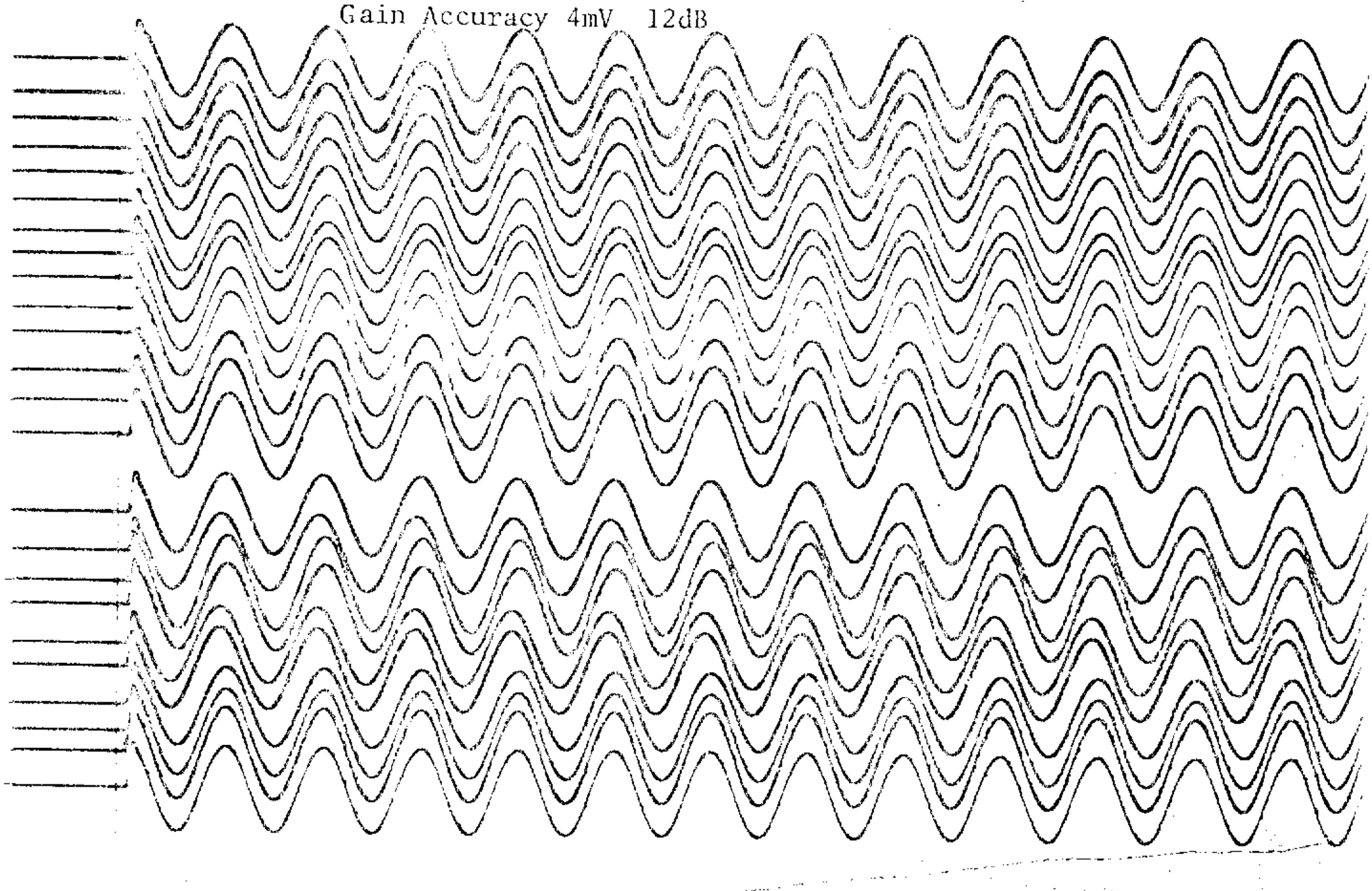
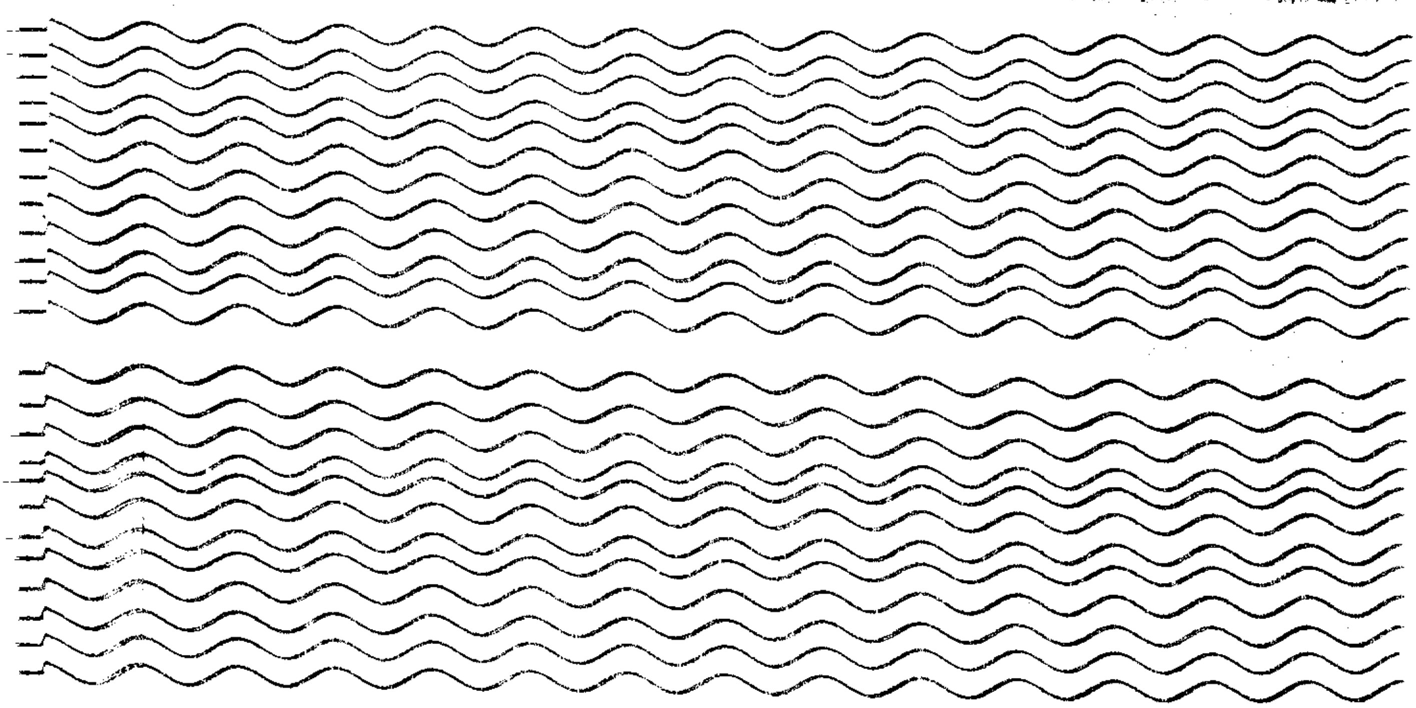


Figure 3.16



Gain Accuracy 4mV 12dB

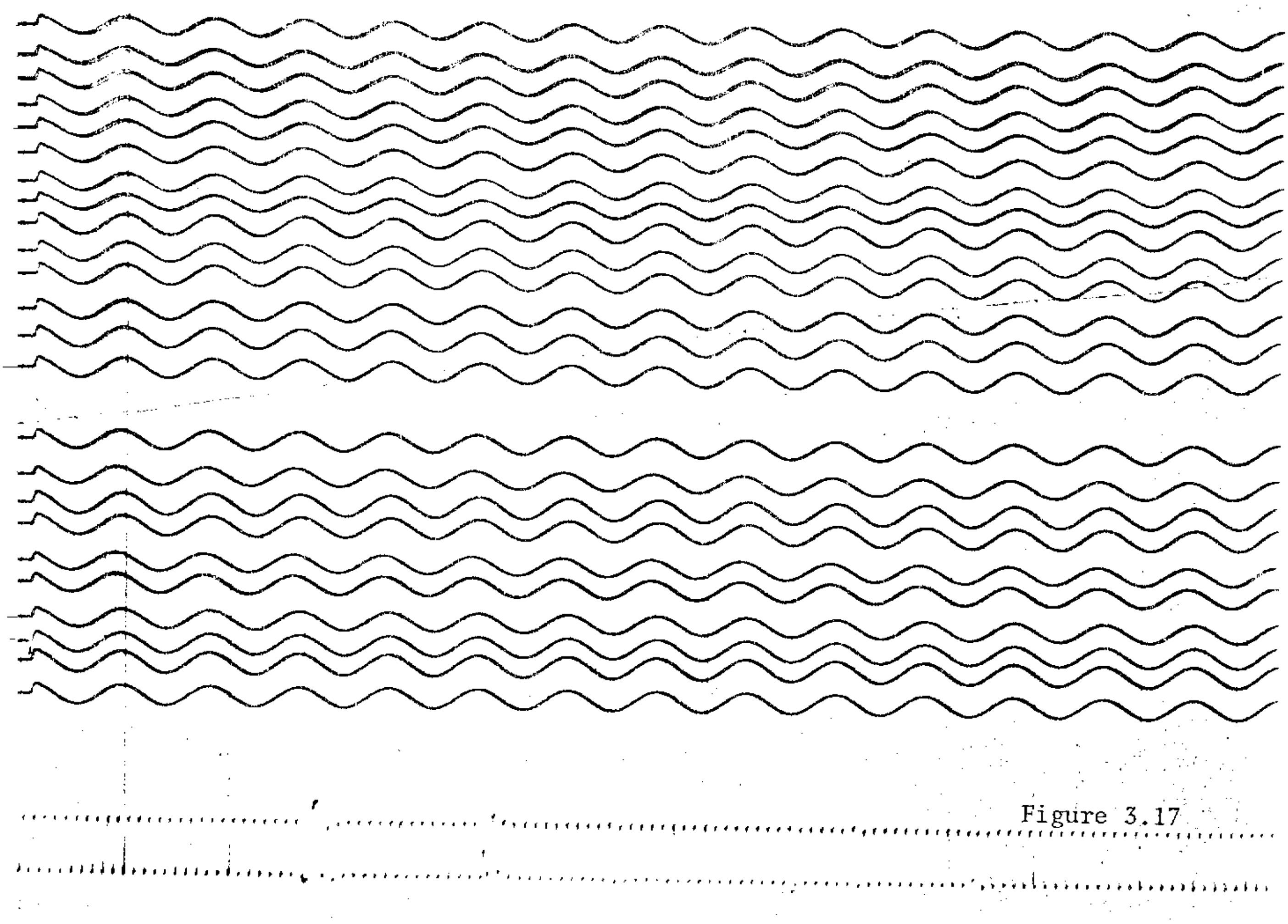
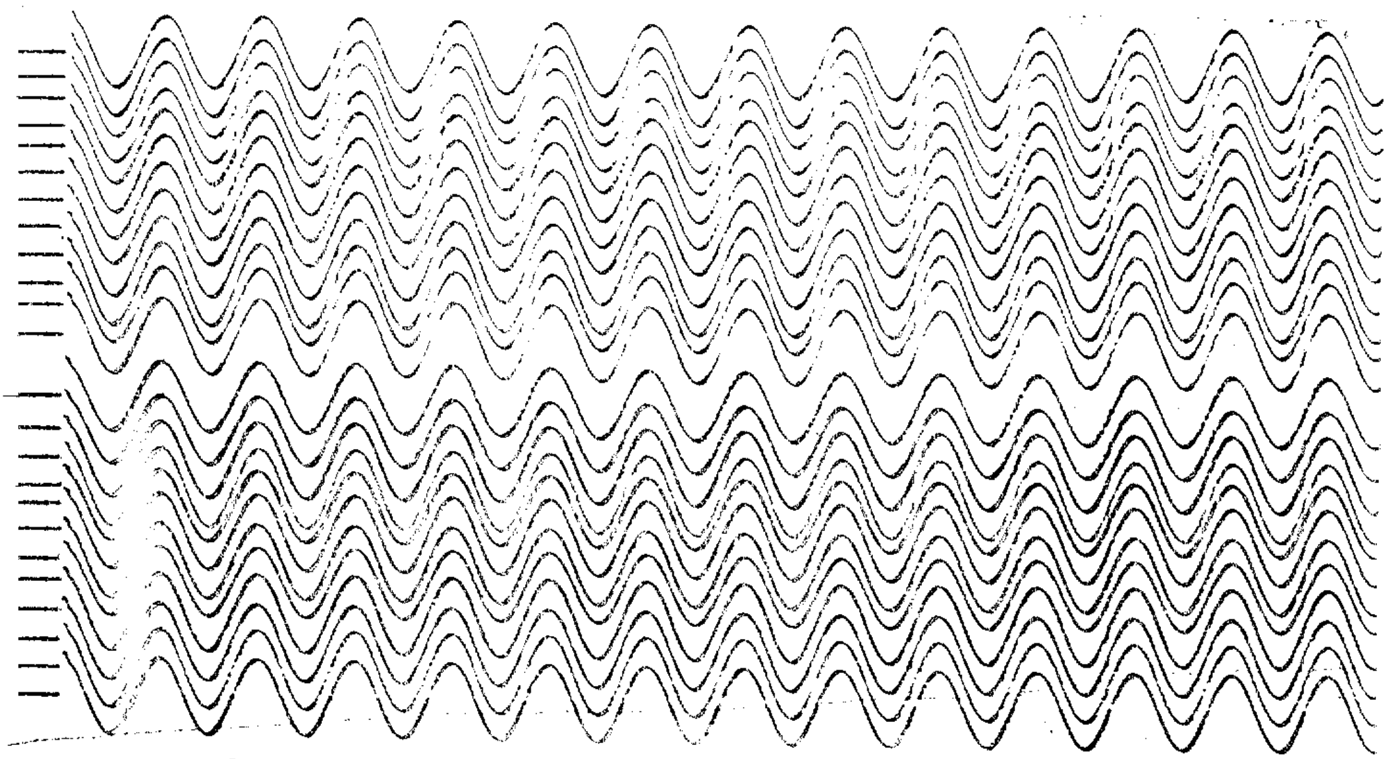


Figure 3.17



Gain Accuracy 16mV 12dB

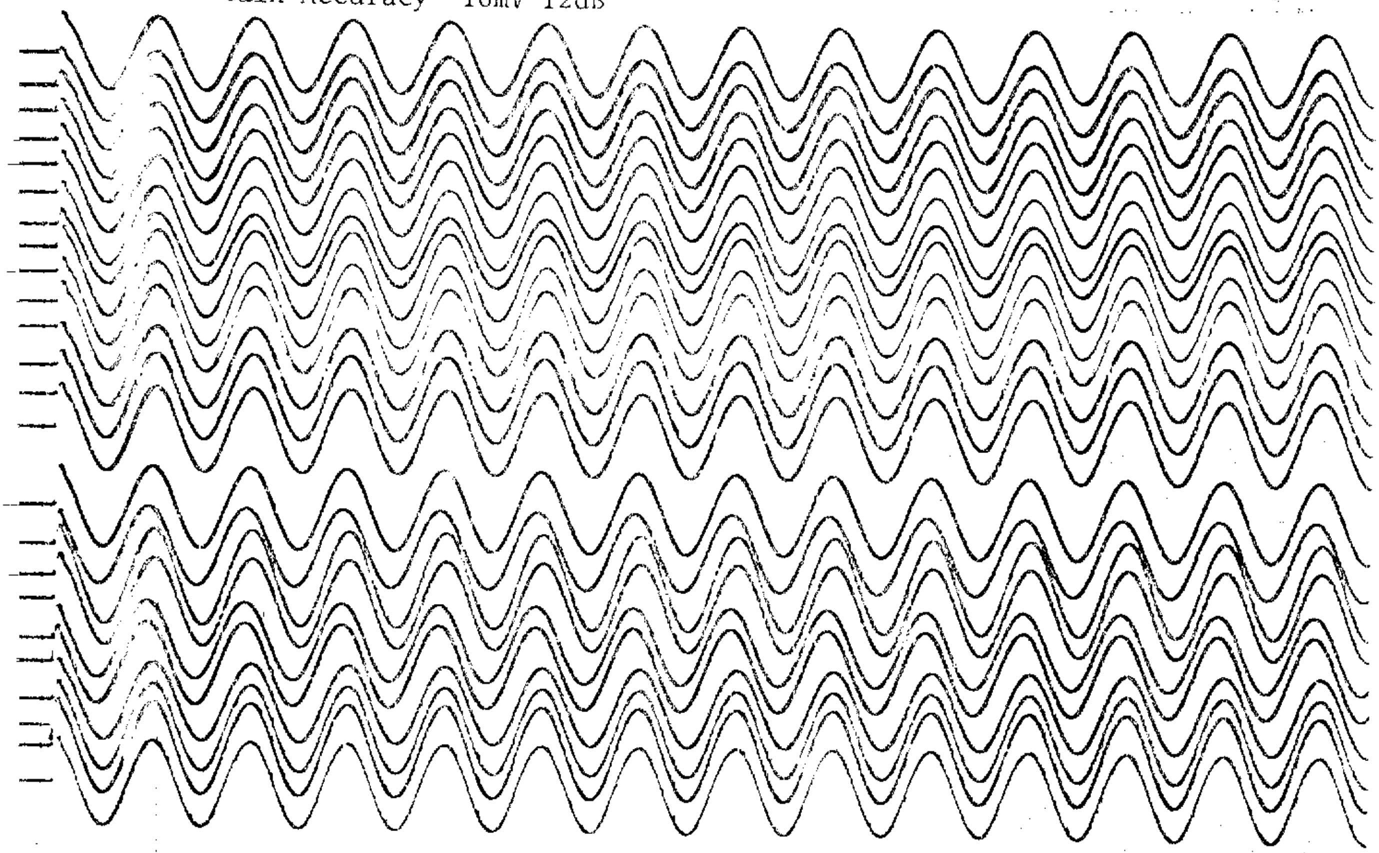
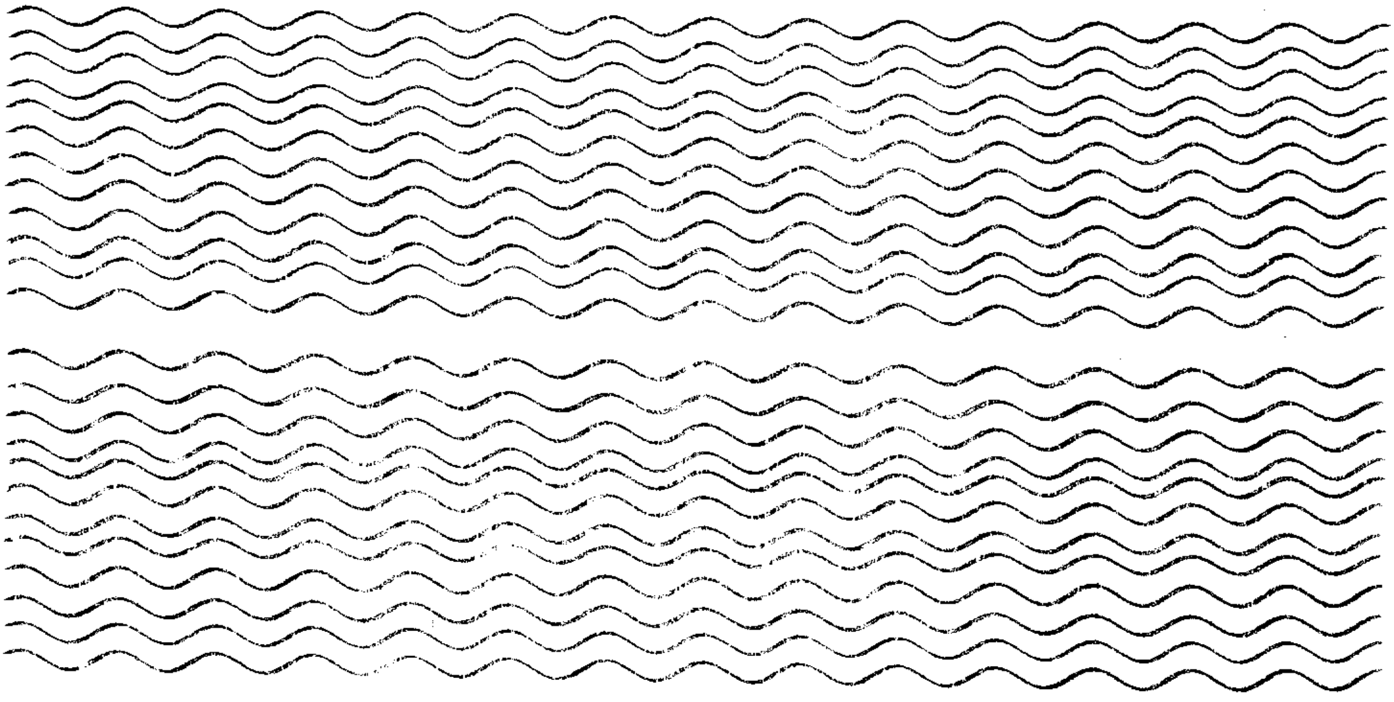


Figure 3.18



Gain Accuracy 16mV 0dB 12Hz

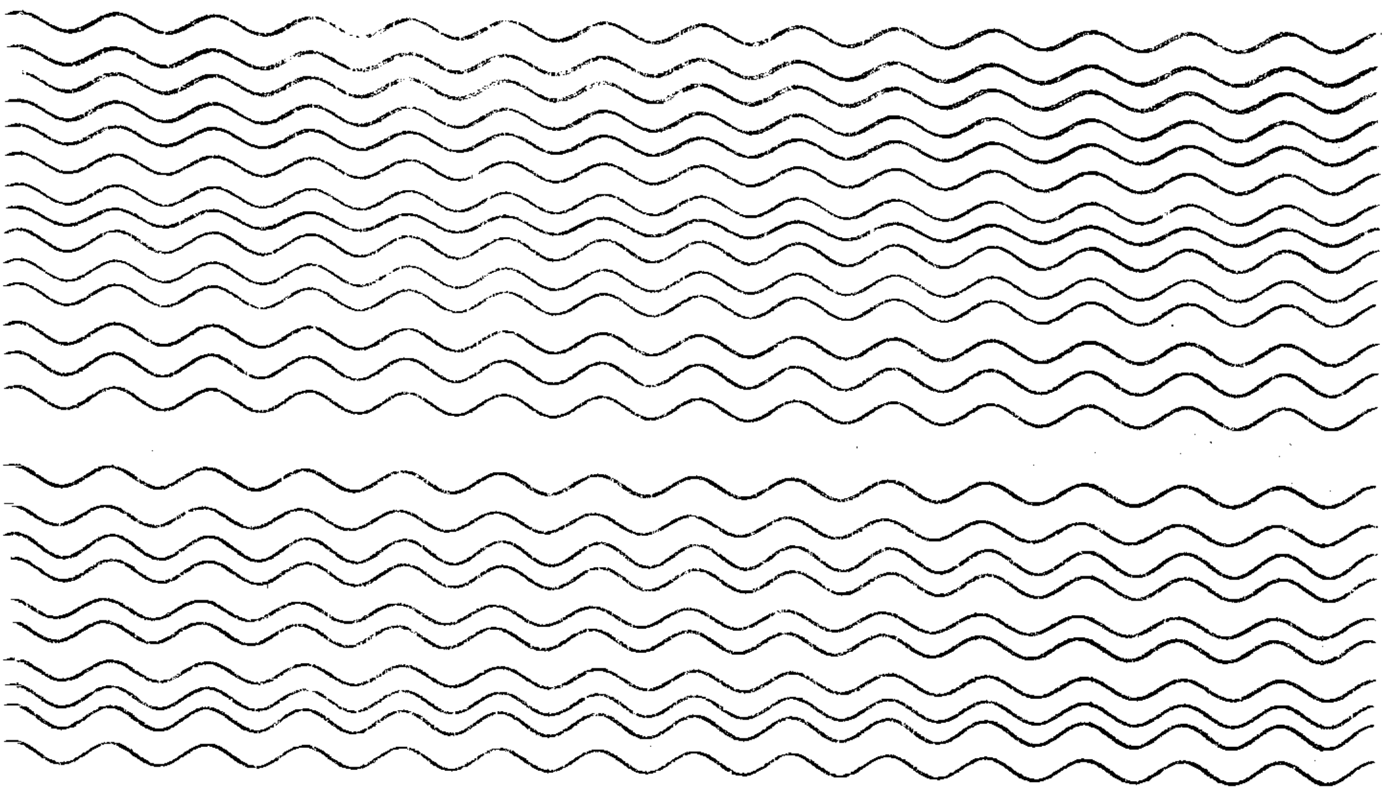
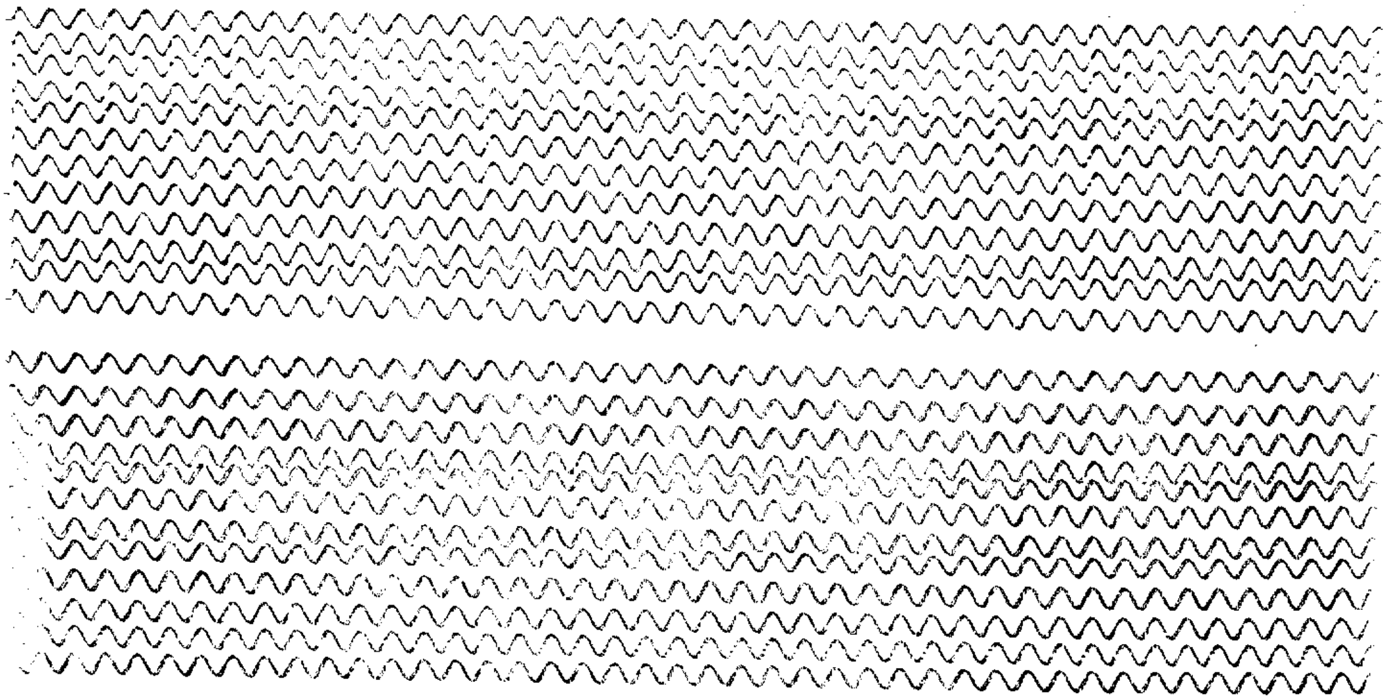


Figure 3.19



Gain Accuracy 16 mV 0dB 36Hz

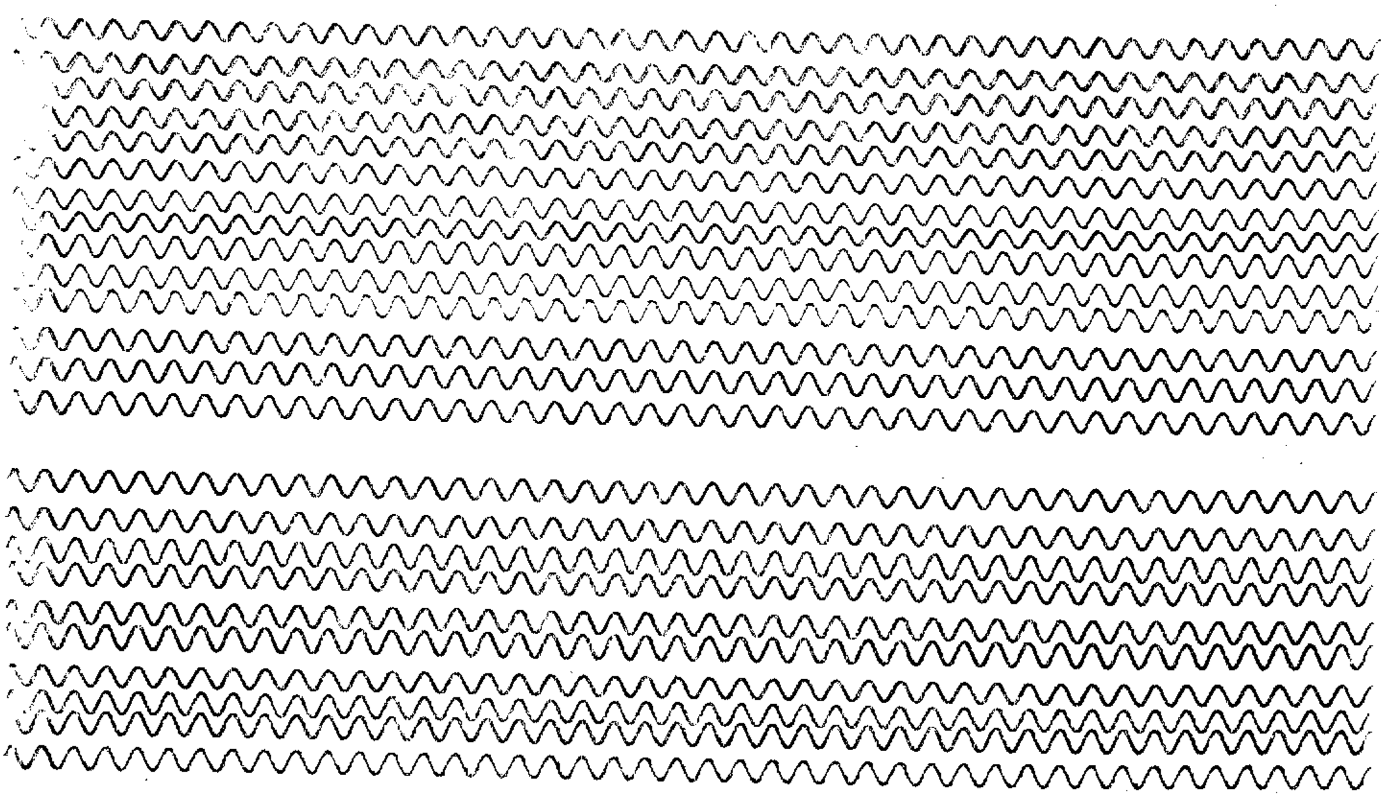


Figure 3.20

From the paper record Figure 3.6, record 18 shows a 4 microvolt signal at 84dB gain. The record shows an AGC playback commencing with minimal gain at the base and applying gain later in the record (top of figure).

Noisy traces channels 35, 36, 42 and 43 were poor Operate/Parallel switch contacts, and this shows significance on record number 19 (Figure 3.7), where signal level was a low 4 microvolts and gain was up at 72dB. As signal reduces, the noise reduces proportionally until it is difficult to observe by record 22 (Figure 3.10).

Last records 31 and 32 (Figures 3.19 and 3.20 show the difference between the 12Hz and 36Hz input signal.

MBER	DATE	TIME	OBSERVER MAKING TEST

RIAL NUMBER	PARTY NUMBER	PARTY MANAGER	PARTY CHIEF

ATE	SYSTEM FORMAT	NUMBER OF TRACES	PACKING DENSITY-BPI
☑ 2 MIL ☐ 4 MIL ☐ ____	☐ 9 TRACK ☑ SEG B ☐ SEG C	☐ 24 ☑ 48 ☐ OTHER	☐ 556 ☐ 712 ☐ 800 ☑ 1600 PE

DYNAMIC RANGE DETERMINATION TEST

MONITOR SECTION				FILE OR RECORD NUMBER	PLAYBACK SECTION		
NGE ITCH	LEVEL SWITCH	VALUE OF TEST SIGNAL	DB DOWN		Galvo Level	BIT SLIDE	DB UP
			−3		SAME AS RECORD	0 db	+3
			−15		R + 12	0 db	+15
			−27		R + 12	12 db	+27
			−39		R + 12	24 db	+39
			−51		R + 12	36 db	+51
			−63		R + 12	48 db	+63
			−75		R + 12	60 db	+75
			−81		R + 12	66 db	+81
			NOISE		R + 12	66 db	+81

EQUIVALENT INPUT NOISE TEST

Signal - 1µV Number	Monitor Gain DB	Noise: File/Record Number

ain

____ DB | NOISE ____ DB

IFPA OSCILLATOR TEST

Number	Record Length SEC	Method Signal Changes ☑ Exponential ☐ Sine Stepped
nal Level	Record Gain Mode ☑ IFP ☐ Manual	Galvo Level Record ___ DB/REP ___ DB

Mode ☐ Defloat ☑ Float

AGC Reproduce Settings: Trip Sens ____ DB Initial Gain ____ DB

Trip ____ Secs LEVEL: ☐ High ☐ Low

n ☐ PGC ☐ GAGC AGC Speed ____ PGC Rate ____ DB/SEC

FILTER PULSE TEST

ER	HICUT FILTER-HZ	LOCUT FILTER-HZ	NOTCH IN-OUT-HZ

ODE GAIN	GALVO LEVEL
db MAN ☐ IFPA	____ dB

GAIN ACCURACY TEST

MODE ☑ CAL | GAIN CONSTANT 24 DB | RECORD LENGTH 3 SE

	FILE NUMBER	RECORD GAIN SETTING	TEST SIGNAL LEVEL SWITCH	
(1)	018	84	×4	1 µV
(2)	019	72		1 µV
(3)	020	72		4 µV
(4)	021	60		4 µV
(5)	022	60		16 µV
(6)	023	48		16 µV
(7)	024	48		64 µV
(8)	025	36		64 µV
(9)	026	36		256 µV
(10)	027	24		256 µV
(11)	028	24		1 mV
(12)	029	12		1 mV
(13)	030	12		4 mV
(14)	031 – 12Hz 032 – 36Hz	0	×4	4 mV

HARMONIC DISTORTION TEST

FILE NUMBER	HICUT FILTER-HZ	LOCUT FILTER-HZ	NOTCH IN-OUT-HZ	RECOR LENGT

CROSSFEED TEST

FILE NUMBER	RECORD GAIN SETTING	CHANNEL TERMINATION
	O (MANUAL)	EVEN
	IFP	EVEN
	IFP	ODD
	O (MANUAL)	ODD

OTHER SYSTEM PARAMETERS FOR TESTS

CONFIGURATION ONLY ☐ CFS SYSTEM

STANT	GALVO LEVEL		NOTCH FILTERS
DB	I-24 DB	AUX ____ DB	☐ IN ☑ OUT

R CONNECTION	FILTERS		RECORD TYPE
☑ 2000 Ω -	LOW CUT	HIGH CUT	☐ DATA ☑ CAL

NITOR	GENERAL CONSTANTS
☑ OUTPUT (NOT RAW)	

NALYSIS RESULTS:

URACY: ________ MILLISECONDS DIFFERENCE BETWEEN TIMING LINES AND PIPPER TRACE ON MONITOR RECORD.

RIATION: ________ MILLISECONDS PER SECOND MAXIMUM VARIATION BETWEEN TIMING LINES AND PIPPER TRACE ON PLAYBACK RECORD.

REMARKS: LIST THE FOLLOWING. 1) ANY SCRATCH RECORDINGS. 2) REPAIRS SINCE LAST TEST. 3) REMARKS AND OTHER TEST PROCEDURES OR RESULTS – SKEW CHECKS, CONVLIN, TB, ETC.

Table 3.2

(3) Harmonic Distortion Test

Purpose

This test records system distortion data for computer analysis. One record per input signal frequency/filter value is made. Distortion in the system's performance can occur due to noisy filters, multiplexers, leakage, dc offsets, defective test oscillator and any other mechanical or electronic noise or pick-up.

Test Procedure

Set up the switches on the modules.

INPUT MODULES:

Operate-Parallel Switch	PARALLEL
Channel Select and DC Voltage	OFF
Filter Switches	As shown on Table 3.4

AMPLIFIER MODULE:

Range Switch	x4
Level Switch	16mV
Meter Function	OSCILLATOR
Oscillator Control	As shown on Table 3.4
Sine-Exp. Switch	SINE
Zero Switch	OFF
DC Voltage	OFF

FORMAT MODULE:

Mode Switch	RECORD
Record Switch	CAL

Record Length Switch	3 sec
Gain Mode	I.F.P.

Make the 12 records suggested on Tables 3.3, and 3.4 comparing the effect of frequency, lo-cut filters 'out' and 'in', different hi-cut filter values and notch filters out and in.

Computer analysis provides data on a channel by channel basis. Specified limits allow distortion to be less than 0.1%, and channel phase duplication data may also be available dependent upon computer program in use.

The accompanying figures are included to display how the records will appear on paper monitor.

MBER	DATE	TIME	OBSERVER MAKING TEST	
ERIAL NUMBER	PARTY NUMBER		PARTY MANAGER	PARTY CHIEF
ATE ☑2 MIL ☐4 MIL ☐	SYSTEM FORMAT ☐ 9 TRACK ☑SEG B ☐SEG C		NUMBER OF TRACES ☐ 24 ☑48 ☐OTHER	PACKING DENSITY-BPI ☐ 556 ☐ 712 ☐ 800 ☑ 1600 PE

DYNAMIC RANGE DETERMINATION TEST

MONITOR SECTION					PLAYBACK SECTION		
ANGE ITCH	LEVEL SWITCH	VALUE OF TEST SIGNAL	DB DOWN	FILE OR RECORD NUMBER	Galvo Level	BIT SLIDE	DB UP
			−3		SAME AS RECORD	0 db	+3
			−15		R + 12	0 db	+15
			−27		R + 12	12 db	+27
			−39		R + 12	24 db	+39
			−51		R + 12	36 db	+51
			−63		R + 12	48 db	+63
			−75		R + 12	60 db	+75
			−81		R + 12	66 db	+81
			NOISE		R + 12	66 db	+81

EQUIVALENT INPUT NOISE TEST

Signal - 1μV d Number	Monitor Gain DB	Noise: File/Record Number

ain

L ______ DB | NOISE ______ DB

IFPA OSCILLATOR TEST

d Number	Record Length SEC	Method Signal Changes ☑Exponential ☐ Sine Stepped
gnal Level	Record Gain Mode ☑ IFP ☐ Manual	Galvo Level Record ___DB/REP ___DB

Mode	AGC Reproduce Settings:
☐ Defloat ☐ Float	Trip Sens ___DB Initial Gain ___DB
☐ PGC ☐ GAGC	Trip ___ Secs LEVEL: ☐High ☐ Low AGC Speed ___ PGC Rate ___DB/SEC

FILTER PULSE TEST

E ER	HICUT FILTER-HZ	LOCUT FILTER-HZ	NOTCH IN-OUT-HZ

MODE GAIN	GALVO LEVEL
db MAN ☐ IFPA	___ dB

OTHER SYSTEM PARAMETERS FOR TESTS

M CONFIGURATION ONLY ☐ CFS SYSTEM

STANT __ DB	GALVO LEVEL I-24 __ DB AUX __ DB	NOTCH FILTERS ☐ IN ☑ OUT
R CONNECTION ☑2000 Ω -	FILTERS LOW CUT | HIGH CUT	RECORD TYPE ☐ DATA ☑CAL
NITOR OUTPUT ☑ (NOT RAW)	GENERAL CONSTANTS	

NALYSIS RESULTS:

URACY: __________ MILLISECONDS DIFFERENCE BETWEEN TIMING LINES AND PIPPER TRACE ON MONITOR RECORD.

RIATION: __________ MILLISECONDS PER SECOND MAXIMUM VARIATION BETWEEN TIMING LINES AND PIPPER TRACE ON PLAYBACK RECORD.

GAIN ACCURACY TEST

MODE ☑ CAL	GAIN CONSTANT ___ DB	RECORD LENGTH ___ S
FILE NUMBER	RECORD GAIN SETTING	TEST SIGNAL LEVEL SWITCH
(1)	84	1 μ V
(2)	72	1 μ V
(3)	72	4 μ V
(4)	60	4 μ V
(5)	60	16 μ V
(6)	48	16 μ V
(7)	48	64 μ V
(8)	36	64 μ V
(9)	36	256 μ V
(10)	24	256 μ V
(11)	24	1 m V
(12)	12	1 m V
(13)	12	4 m V
(14)	0	4 m V

HARMONIC DISTORTION TEST

FILE NUMBER	HICUT FILTER-HZ	LOCUT FILTER-HZ	NOTCH IN-OUT-HZ	RECORD LENGTH
33 - 44	SEE ATTACHMENT			

CROSSFEED TEST

FILE NUMBER	RECORD GAIN SETTING	CHANNEL TERMINATION
	O (MANUAL)	EVEN
	IFP	EVEN
	IFP	ODD
	O (MANUAL)	ODD

REMARKS: LIST THE FOLLOWING. 1) ANY SCRATCH RECORDINGS 2) REPAIRS SINCE LAST TEST. 3) REMARKS AND OTHER TEST PROCEDURES OR RESULTS — SKEW CHECKS, CONVLIN, TB, ETC.

Table 3.3

TABLE 3.4

HARMONIC DISTORTION TABLE

							FILTERS
033	HARMONIC	DISTORTION	I.F.P.	64mV	3 sec	12Hz	OUT/124/18
034	"	"	"	"	"	36Hz	OUT/124/18
035	"	"	"	"	"	36Hz	12/18/124/18
036	"	"	"	"	"	12Hz	12/18/124/18
037	"	"	"	"	"	12Hz	8/18/124/18
038	"	"	"	"	"	36Hz	8/18/124/18
039	"	"	"	"	"	12Hz	As Rec #016
040	"	"	"	"	"	36Hz	As Rec #016
041	"	"	"	"	"	12Hz	As Rec #017
042	"	"	"	"	"	36Hz	As Rec #016
043	"	"	"	"	"	12Hz	Ch 1 - 12 OUT 124/18 NOTCH OUT
							Ch 13 - 36 OUT 124/18 NOTCH IN
							Ch 47 - 48 OUT 124/18 NOTCH OUT
044	"	"	"	"	"	36Hz	As 043

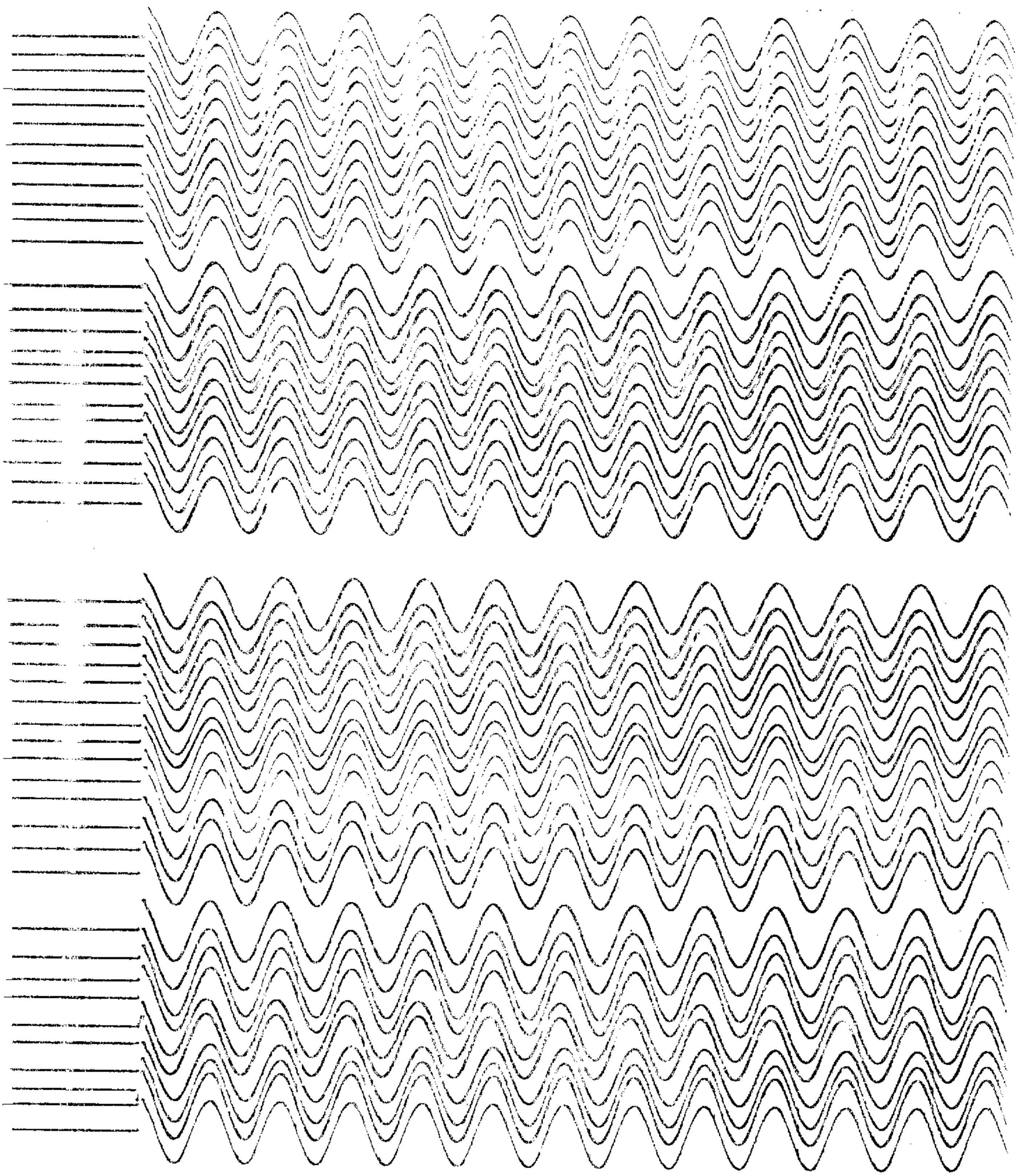


Figure 3.21

Harmonic Distortion 12Hz OUT/124/18Hz

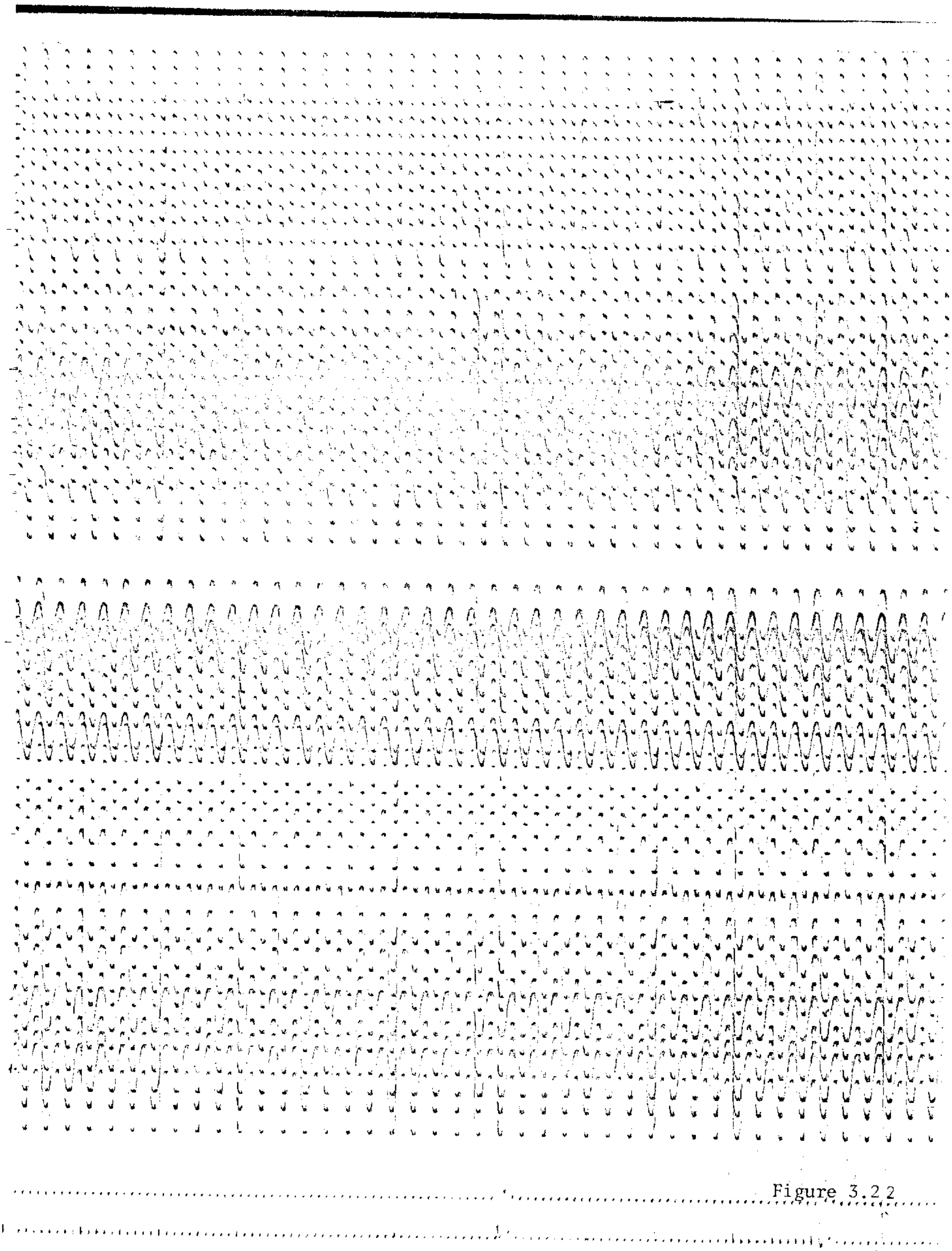


Figure 3.22

Harmonic Distortion 36Hz OUT/124/18 Hz

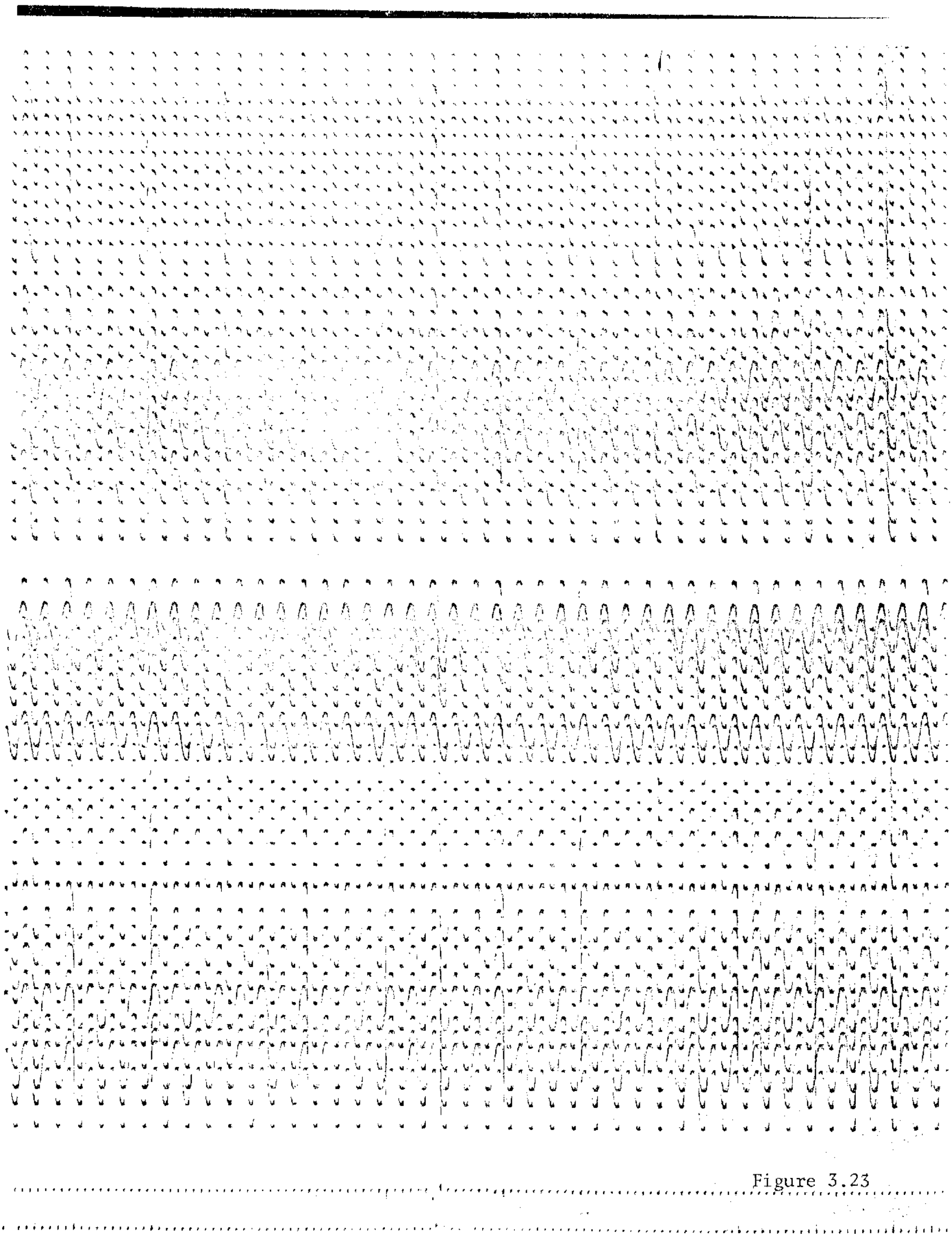


Figure 3.23

Harmonic Distortion 36Hz 12/18/124/18Hz

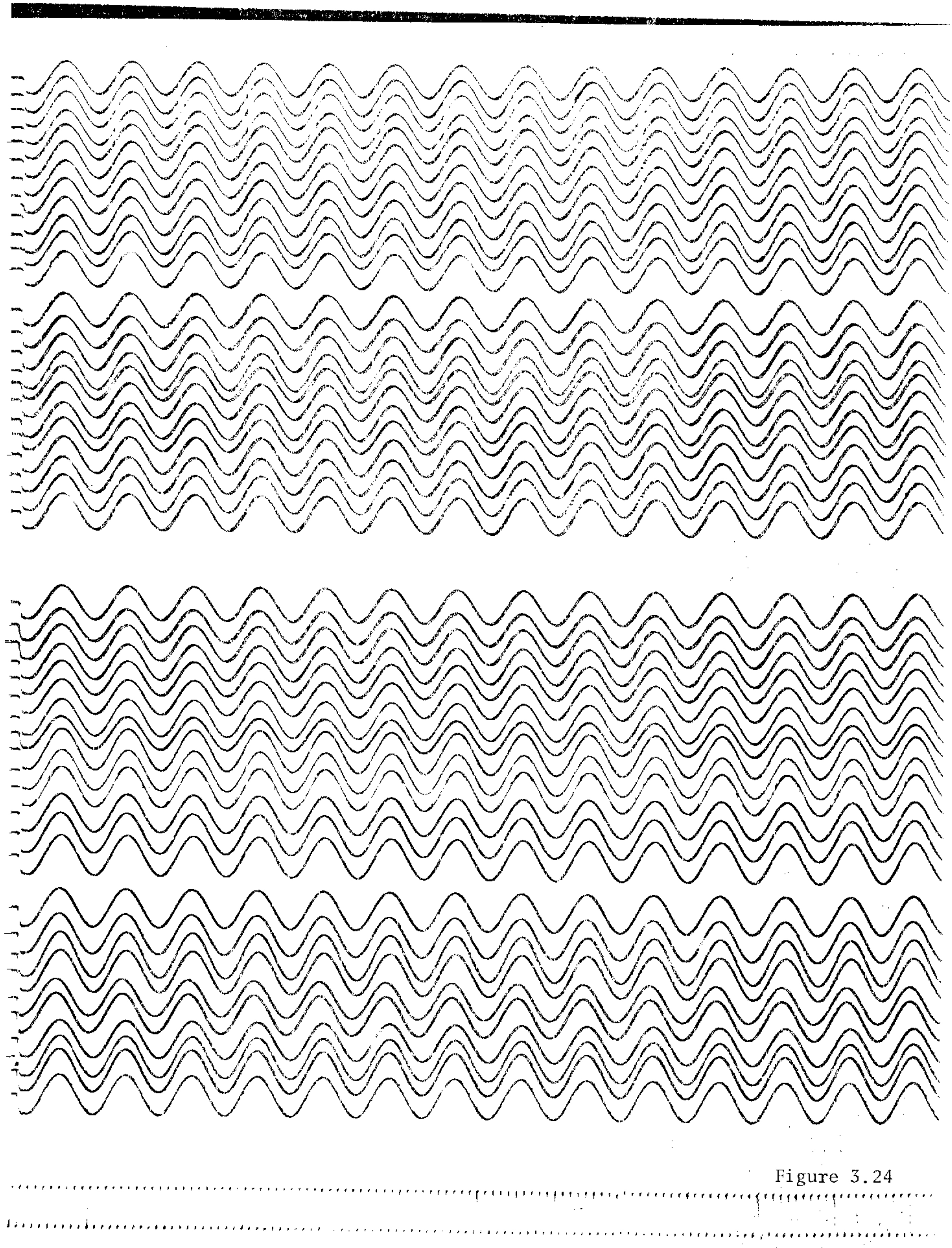


Figure 3.24

Harmonic Distortion 12Hz 12/18/124/18Hz

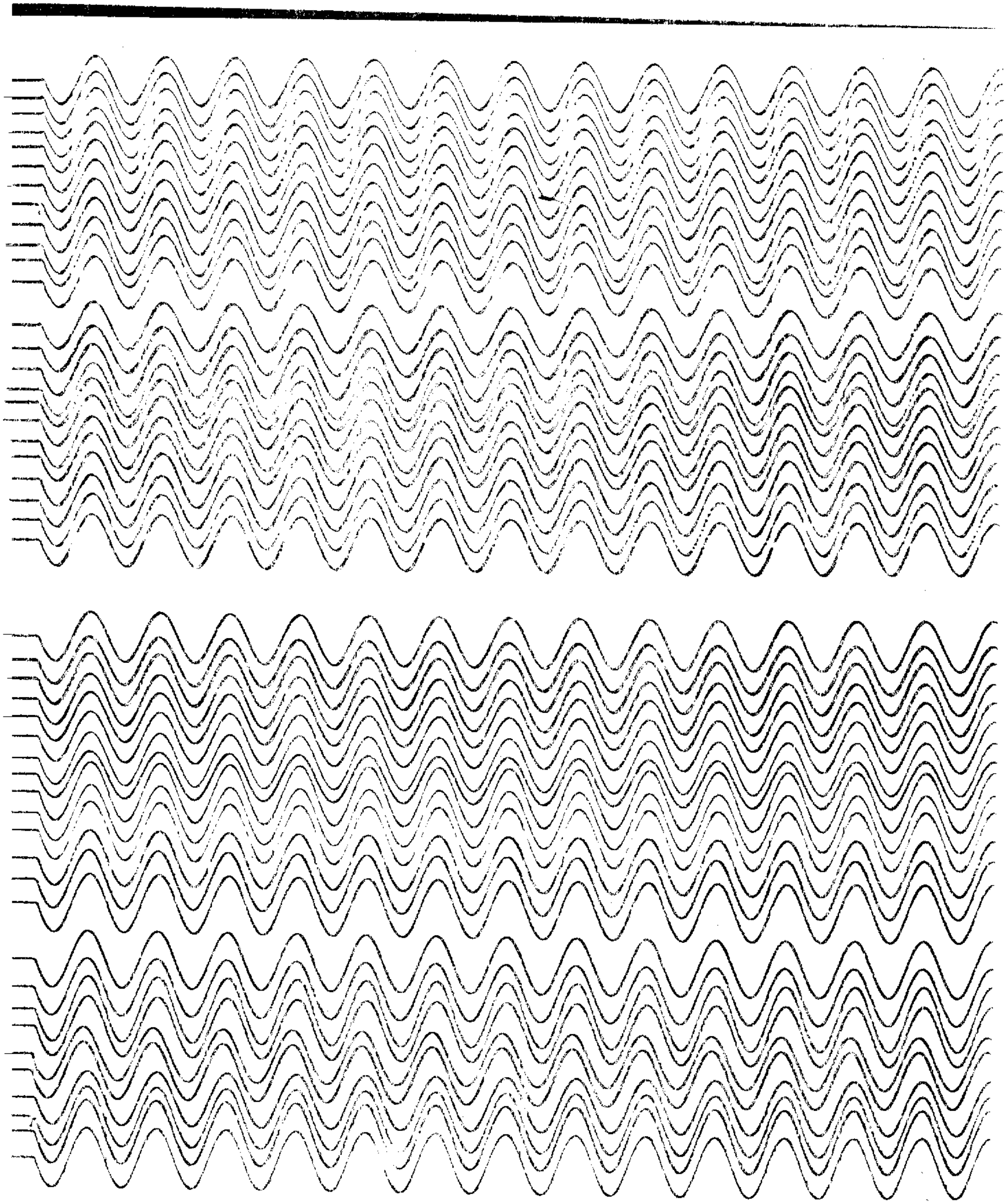


Figure 3.25

Harmonic Distortion 12Hz 8/18/124/18 Hz

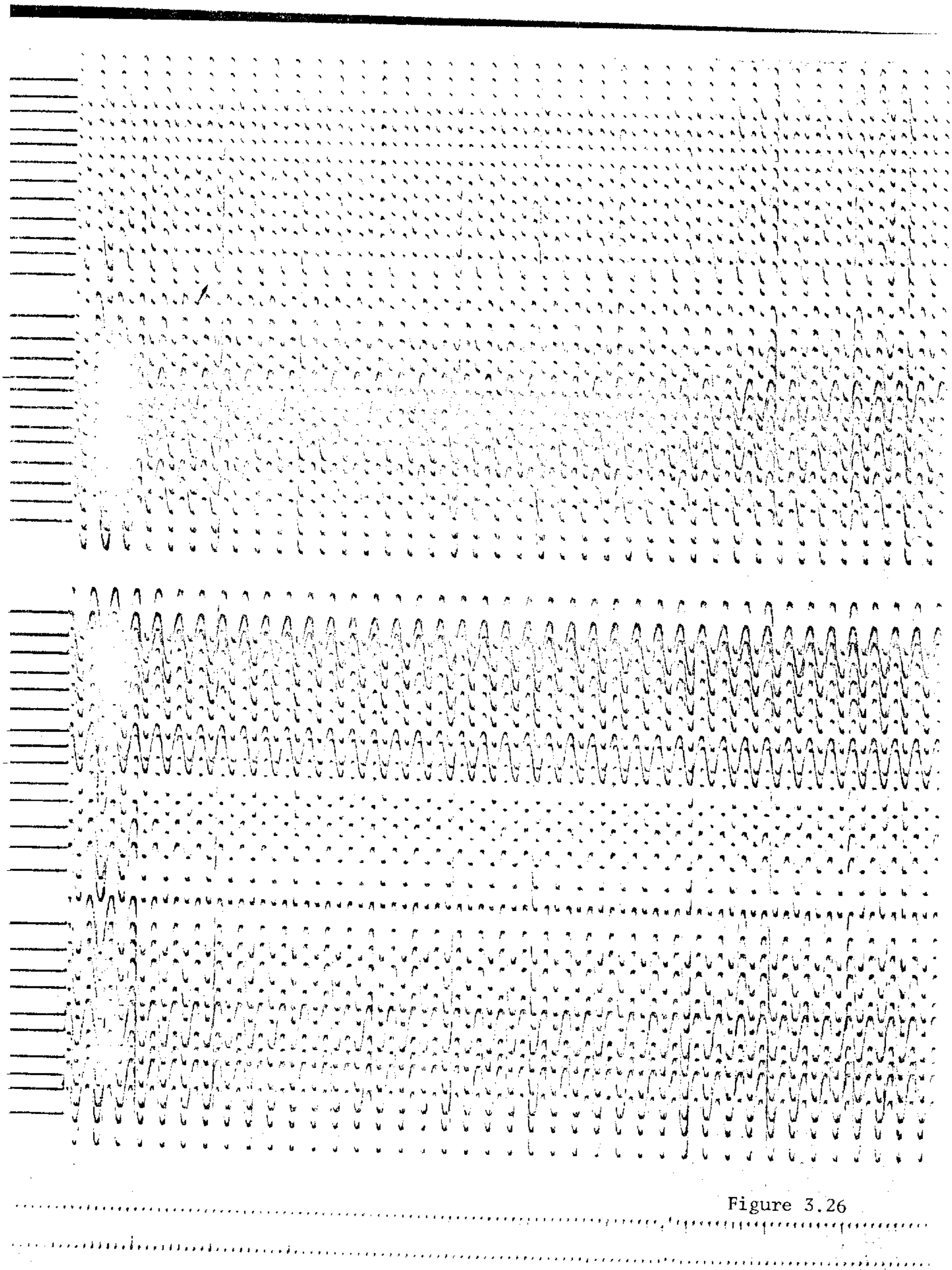


Figure 3.26

Harmonic Distortion 36Hz 8/18/124/18 Hz

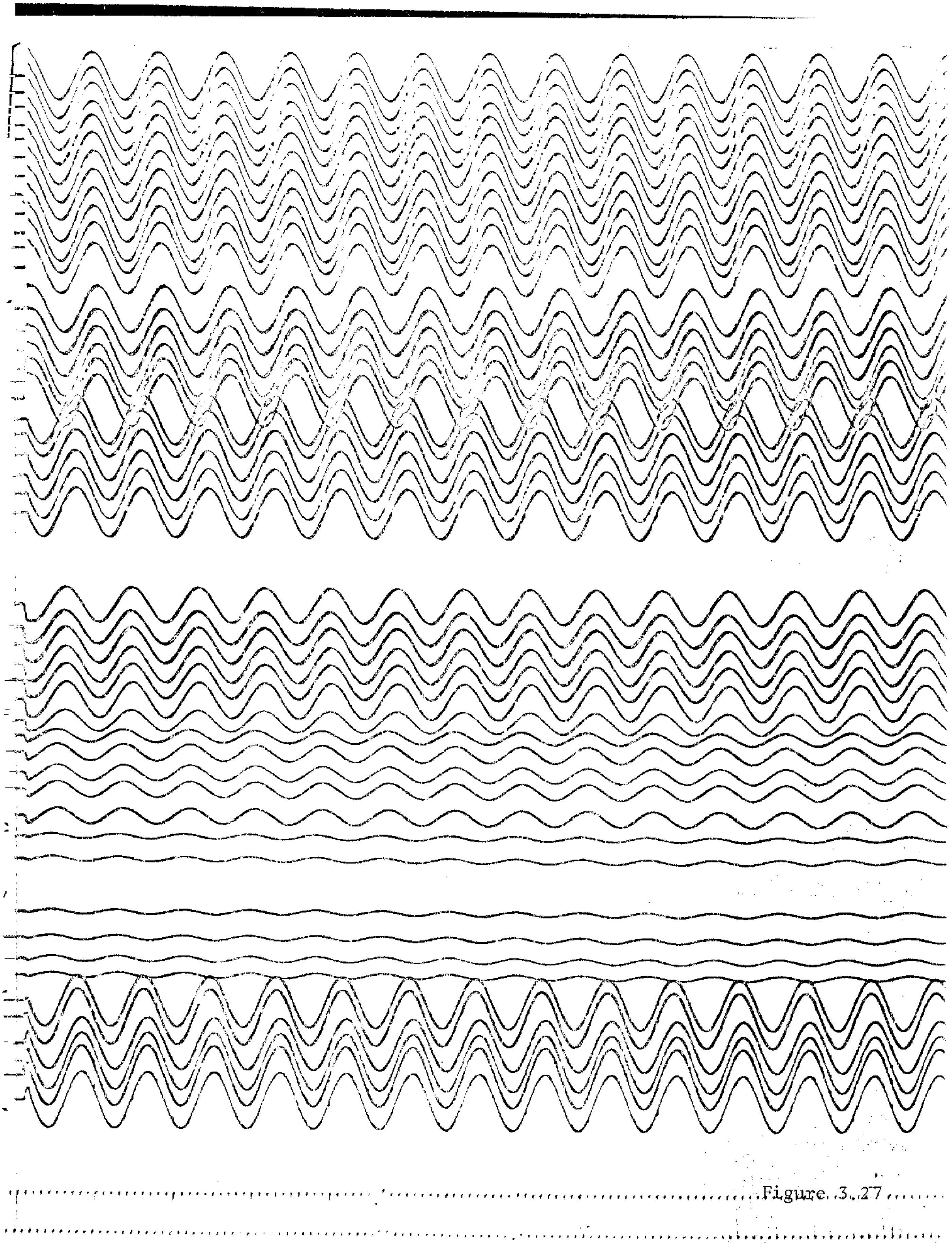


Figure 3.27

Harmonic Distortion 12Hz Filters as shown.

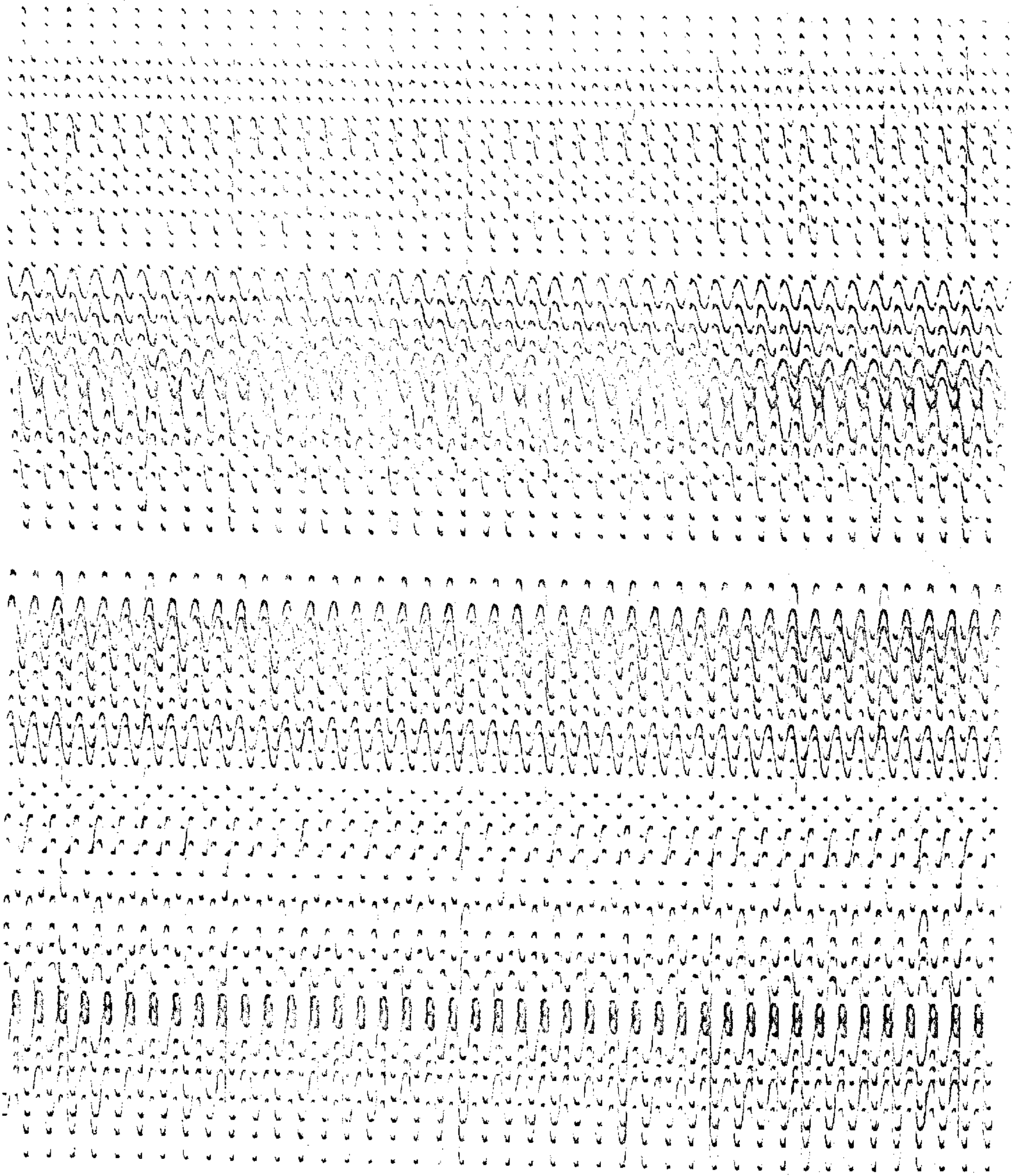


Figure 3.28

Harmonic Distortion 36Hz Filters as Fig. 3.27

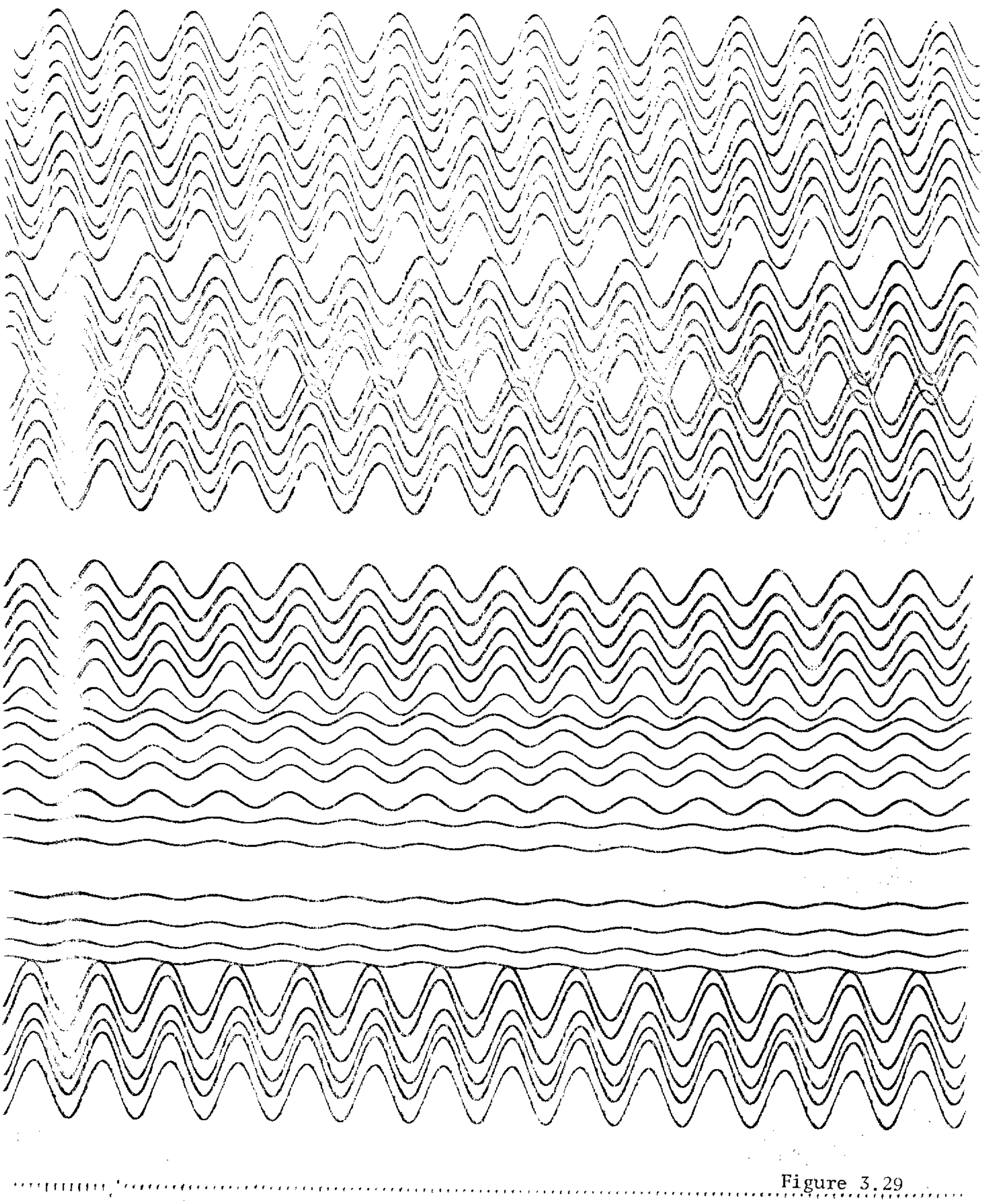


Figure 3.29

Harmonic Distortion 12Hz Filters as Fig. 3.27 but Slope 72dB/Oct

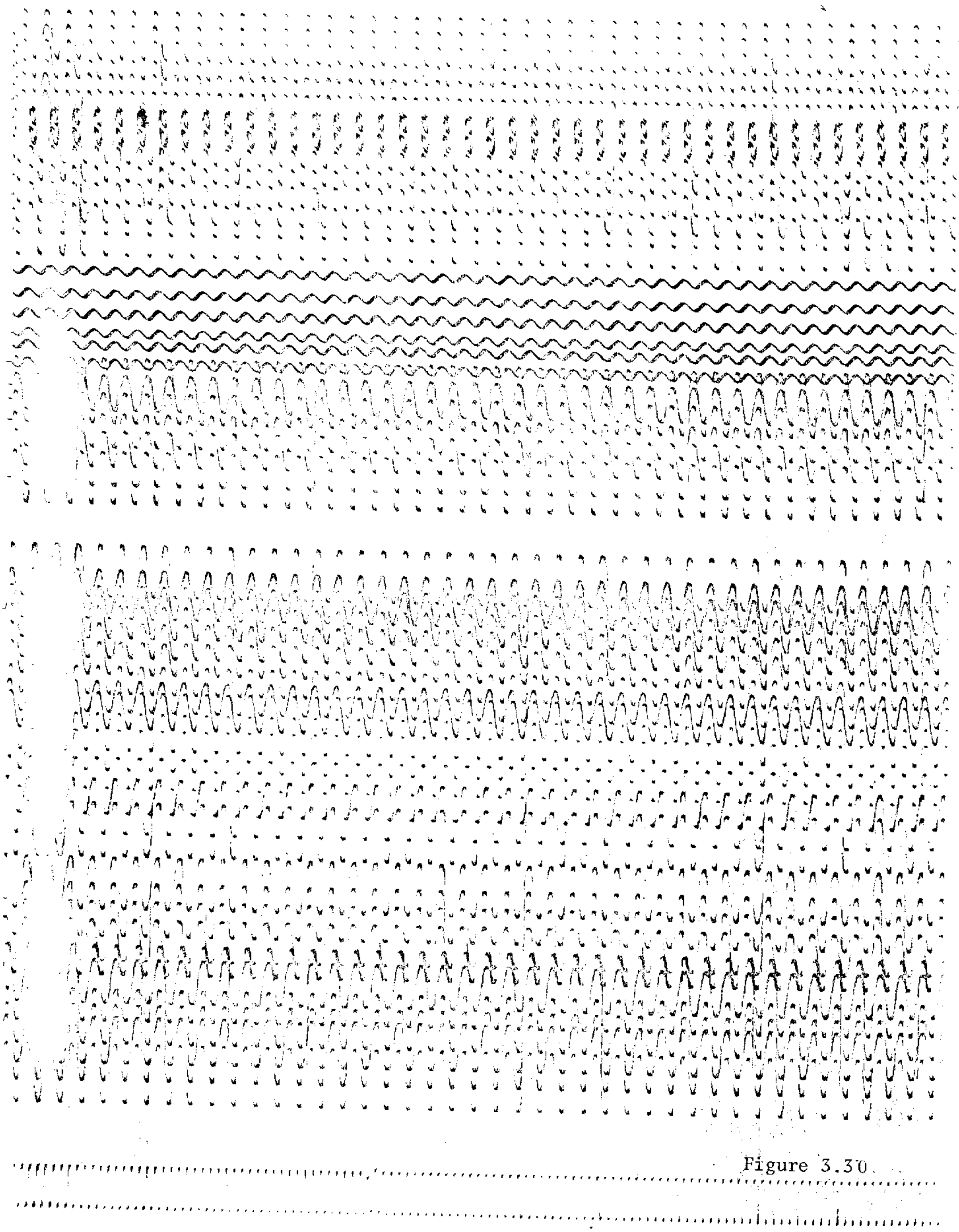


Figure 3.30

Harmonic Distortion 36Hz Filters as Fig. 3.27 but Slope 72dB/Oct

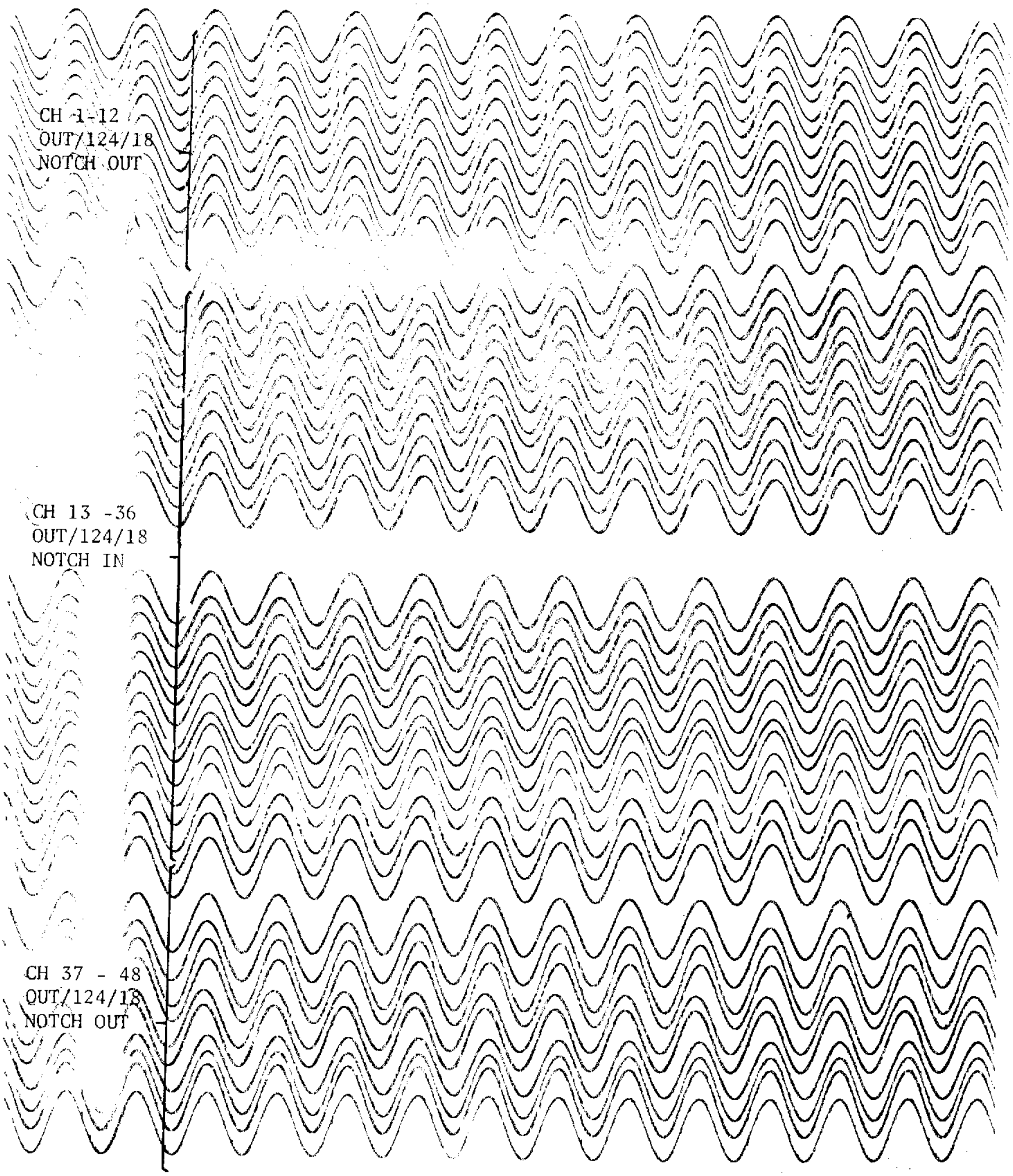


Figure 3.31

Harmonic Distortion
With Notch Filters 12Hz FILTERS AS SHOWN

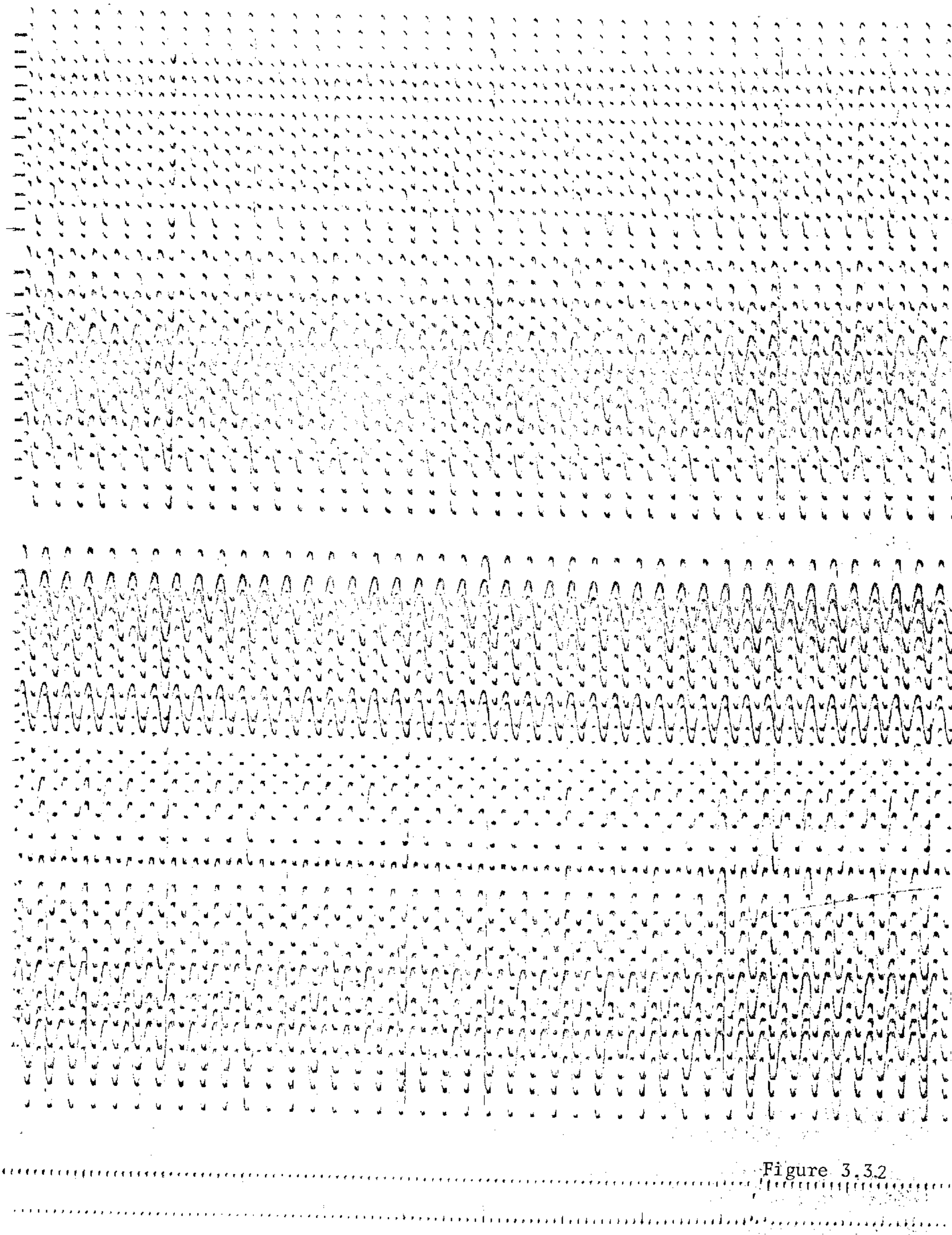


Figure 3.32

Harmonic Distortion 36Hz   Filters as Fig. 3.31

(4) Crossfeed Test

For all sophisticated high fidelity recording equipment, crossfeed (or "cross-talk") is of great importance. Crossfeed is the interference to data as a result of unintentional pick up by one channel of data or noise on another channel. If crossfeed occurs at low signal level, this can result in identical signal or noise being recorded on adjacent channels interfering with useful data, thereby rendering the data unusable.

Purpose

To establish channel to channel crossfeed level from input circuits to digital words on tape. By applying signal on alternate data channels, system crossfeed values may be determined by applying a measured value of gain to the channels not receiving signal, and observing their response.

The recording instruments should have a crossfeed isolation of no less than 60dB (for the most part, greater than 75dB). This means that at least 60dB of gain must be applied to channels not receiving signal, before signal from adjacent channels crossfeeds.

Procedure

Terminating plugs are inserted at the Input Modules connectors, which terminate every other channel with a terminating resistor, and provide a 'driving' signal to all alternate channels. (see Fig.3.33) Recordings are made in MANUAL and IFP gain modes, using first EVEN then ODD terminating connectors. Playbacks are made for field evaluation, and recordings are preferably computer analysed.

Set up the module switches as follows:

INPUT MODULES:	
Operate-Parallel Switch	OPERATE
Channel Select and DC Voltage	OFF
Filter Switches	OUT/124Hz
Notch Filter	OUT/IN as required
AMPLIFIER MODULE:	
Range Switch	x4
Level Switch	16mvolts
Meter Function	OUTPUT
Oscillator Control	36Hz
Sine-Exp. Switch	SINE
Zero Switch	OFF
DC Voltage Switch	OFF
FORMAT MODULE:	
Mode Switch	RECORD
Record Switch	CAL
Record Length Switch	1 sec
Gain Mode	Manual or IFP
Manual Gain	0dB
Bit Slide	0dB
REPRODUCE MODULE:	
Hi-cut	AUTO

Lo-cut	OUT
Initial Gain	0
Mode	FLOAT

1. Install crossfeed terminating plugs with channels 1-24 odds terminated, 25-48 evens terminated on Input Module connectors.
2. Connect terminating connector signal lead to TEST SIGNAL jacks on Amplifier Module front panel. Check polarity is correct (red positive).
3. The crossfeed test is a two part procedure:
   (a) The first measures total crossfeed (input circuits, filters, multiplexer, IFPA and A/D converter) and is made with high input signal/low MANUAL gain.
   (b) The second operates in floating point (and measures input circuits, filters and multiplexer).
4. Procedure (a)
   (i) Apply 64mvolt input signal in MANUAL gain. Set MANUAL GAIN to 0dB. (Table 3.4)
   (ii) Select galvanometer level to display active traces with measurable amplitude.
   (iii) Make a 1 second record producing a paper monitor record.

   Procedure (b)
   (i) Change gain to IFP. Make a 1 second record with paper recording.
5. Reproduce the record of Procedure (a) with Mode Switch in FLOAT, Bit Slide 0dB, Initial Gain 0dB. Replay with Bit Slide of 60 or 72dB,

6. Reproduce the record of Procedure (b) with Mode Switch In DEFLOAT, Bit Slide 0dB, initial Gain 0dB. Replay with Initial Gain of 60 or 72dB.

<u>Analog Evaluation</u>

The playback of step 5 Figure 3.34 with 0dB Bit Slide shows signal on all 'driven' channels and dead traces on all others. Measure the driven channel amplitude for reference.

The 60 or 72dB Bit Slide playback shows full amplitude on even channels across 1-24, and odd channels across 25-48. The undriven channels appear to be dead traces. Figure 3.35 is the 60dB Bit Slide playback which shows that the undriven channels of 1-24 are hardly affected by crossfeed at 60dB playback gain. However, undriven channels across 25-48 do demonstrate noise at a level approximately a quarter that of the signal amplitude. This suggests a crossfeed of 72dB would be appropriate.

The second playback of the same record Figure 3.36 shows the effect at 72dB crossfeed. Undriven channels across 1-24 are still relatively unscathed, yet those across 25-48 indicate a 72dB crossfeed assessment.

I.F.P. recording Figure 3.37 is now used as a reference for 60dB playback Figure 3.38 and Figure 3.39. As previously, values of 72dB can be applied to channels 25-48 and greater than 72dB can be applied to channels 1-24.

Also, it is noted that the crossfeed signal is 180 degrees out of phase with reference, which can be an important consideration under normal conditions when weak seismic signals cause the FPA to range to full value.

The remaining Figures are evaluated in like manner, and it is apparent that the lower order (1-24) channels have minimal crossfeed compared to the upper order (25-48). This is explained in that the logic samples channels 1 through to 48 per 2 millisecond period, then resets (which takes a few nanoseconds) before taking the next sample beginning with channel 1. Hence, channel 1 not only has immediately adjacent channel but the circuitry noise has a short time to stabilise. Further, the sample and hold capacitor between channels 24 and 25 has an adequate hold charge on it to commence sampling 25-48 with an increase in noise level. This also contributes to making 25-48 noisier than 1-24. However, it should be noted that channels 1-24 are impressively crossfeed-free here and are normally only just better than 80dB in crossfeed rather than the 90dB displayed here.

...BER	DATE	TIME	OBSERVER MAKING TEST
...RIAL NUMBER	PARTY NUMBER	PARTY MANAGER	PARTY CHIEF
...ATE ☑ 2 MIL ☐ 4 MIL ☐ ____	SYSTEM FORMAT ☐ 9 TRACK ☑ SEG B ☐ SEG C	NUMBER OF TRACKS ☐ 24 ☑ 48 ☐ OTHER	PACKING DENSITY - BPI ☐ 556 ☐ 712 ☐ 800 ☑ 1600 PE

DYNAMIC RANGE DETERMINATION TEST

MONITOR SECTION				FILE OR RECORD NUMBER	PLAYBACK SECTION		
...NGE ...ITCH	LEVEL SWITCH	VALUE OF TEST SIGNAL	DB DOWN		Galvo Level	BIT SLIDE	DB UP
			−3		SAME AS RECORD	0 db	+3
			−15		R + 12	0 db	+15
			−27		R + 12	12 db	+27
			−39		R + 12	24 db	+39
			−51		R + 12	36 db	+51
			−63		R + 12	48 db	+63
			−75		R + 12	60 db	+75
			−81		R + 12	66 db	+81
			NOISE		R + 12	66 db	+81

EQUIVALENT INPUT NOISE TEST

Signal - 1μV Number	Monitor Gain DB	Noise: File/Record Number

...ain ____ DB NOISE ____ DB

IFPA OSCILLATOR TEST

...Number	Record Length SEC	Method Signal Changes ☑ Exponential ☐ Sine Stepped
...nal Level	Record Gain Mode ☑ IFP ☐ Manual	Galvo Level Record ___ DB/REP ___ DB

...Mode ☐ Defloat ☑ Float — AGC Reproduce Settings: Trip Sens ___ DB Initial Gain ___ DB

Trip ___ Secs LEVEL: ☐ High ☐ Low

☐ PGC ☐ GAGC AGC Speed ___ PGC Rate ___ DB/SEC

FILTER PULSE TEST

...ER	HICUT FILTER-HZ	LOCUT FILTER-HZ	NOTCH IN-OUT-HZ

...ODE GAIN ...db MAN ☐ IFPA — GALVO LEVEL ____ dB

OTHER SYSTEM PARAMETERS FOR TESTS

... CONFIGURATION ...ONLY ☐ CFS SYSTEM

...STANT ... DB	GALVO LEVEL 1-24 ___ DB AUX ___ DB	NOTCH FILTERS ☐ IN ☑ OUT
...R CONNECTION ☐ 2000 Ω -	FILTERS LOW CUT ___ HIGH CUT ___	RECORD TYPE ☐ DATA ☑ CAL
...ITOR ☑ OUTPUT (NOT RAW)	GENERAL CONSTANTS	

...NALYSIS RESULTS:

...URACY: ____ MILLISECONDS DIFFERENCE BETWEEN TIMING LINES AND PIPPER TRACE ON MONITOR RECORD.

...RIATION: ____ MILLISECONDS PER SECOND MAXIMUM VARIATION BETWEEN TIMING LINES AND PIPPER TRACE ON PLAYBACK RECORD.

GAIN ACCURACY TEST

MODE ☑ CAL — GAIN CONSTANT ____ DB — RECORD LENGTH ____ SE...

FILE NUMBER	RECORD GAIN SETTING	TEST SIGNAL LEVEL SWITCH
(1)	84	1 μ V
(2)	72	1 μ V
(3)	72	4 μ V
(4)	60	4 μ V
(5)	60	16 μ V
(6)	48	16 μ V
(7)	48	64 μ V
(8)	36	64 μ V
(9)	36	256 μ V
(10)	24	256 μ V
(11)	24	1 m V
(12)	12	1 m V
(13)	12	4 m V
(14)	0	4 m V

HARMONIC DISTORTION TEST

FILE NUMBER	HICUT FILTER-HZ	LOCUT FILTER-HZ	NOTCH IN-OUT-HZ	RECOR... LENGT...

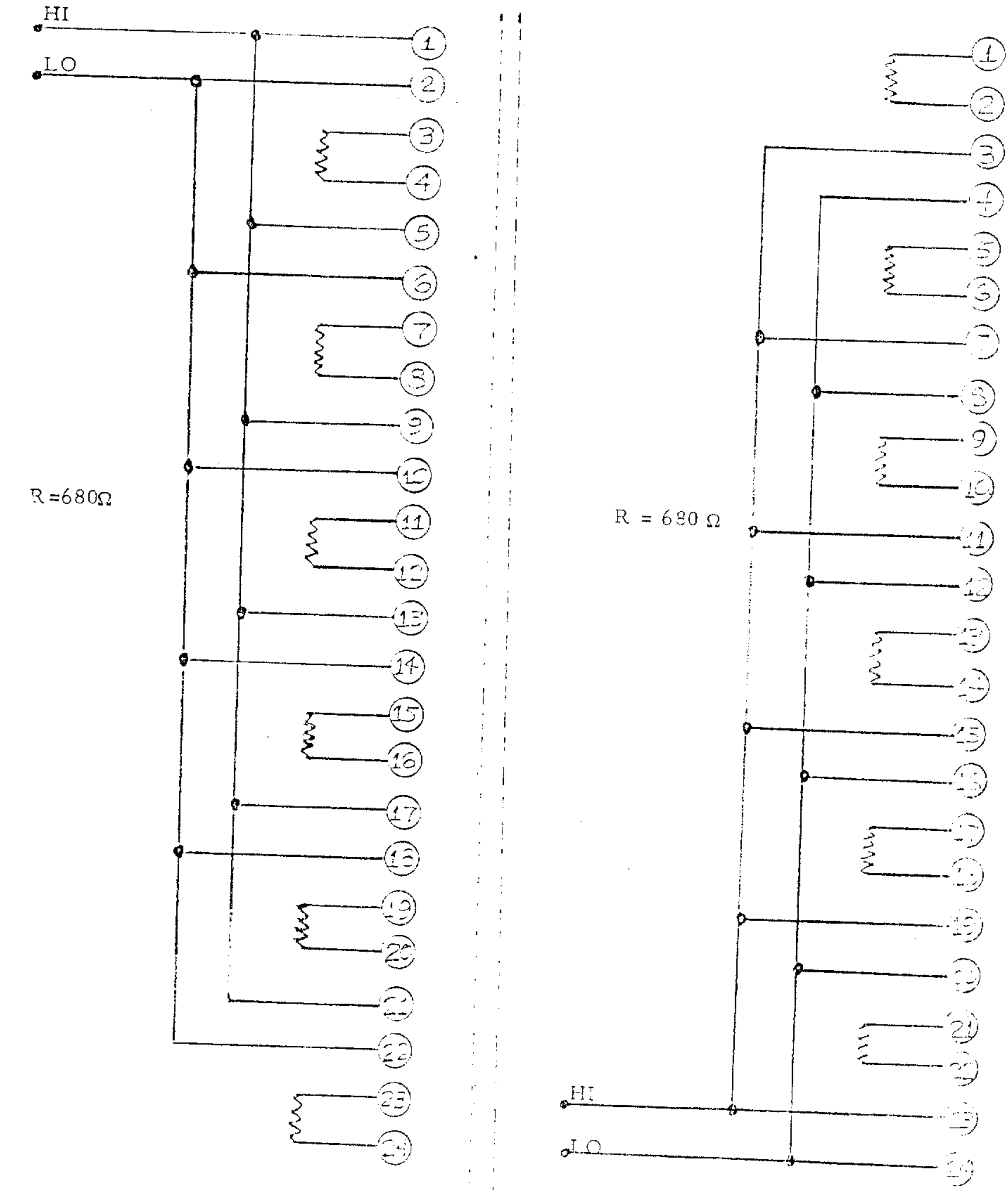
CROSSFEED TEST

FILE NUMBER	RECORD GAIN SETTING	CHANNEL TERMINATION
046	O (MANUAL)	1-24 odd 25-48 EVEN
047	IFP	1-24 odd 25-48 EVEN
048	IFP	1-24 EVEN 25-48 ODD
049	O (MANUAL)	1-24 EVEN 25-48 ODD
050	O - NOTCH IN 13-36 IFP - " " "	— " —

REMARKS: LIST THE FOLLOWING. 1) ANY SCRATCH RECORDINGS. 2) REPAIRS SINCE LAST TEST. 3) REMARKS AND OTHER TEST PROCEDURES OR RESULTS – SKEW CHECKS, CONVLIN, TB, ETC.

Table 3.5

CROSSFEED TEST CONNECTORS



EVEN
2 Required
NK-27-21-1/2

ODD
2 Required
NK-27-21-1/2

Fig. 3.3.3

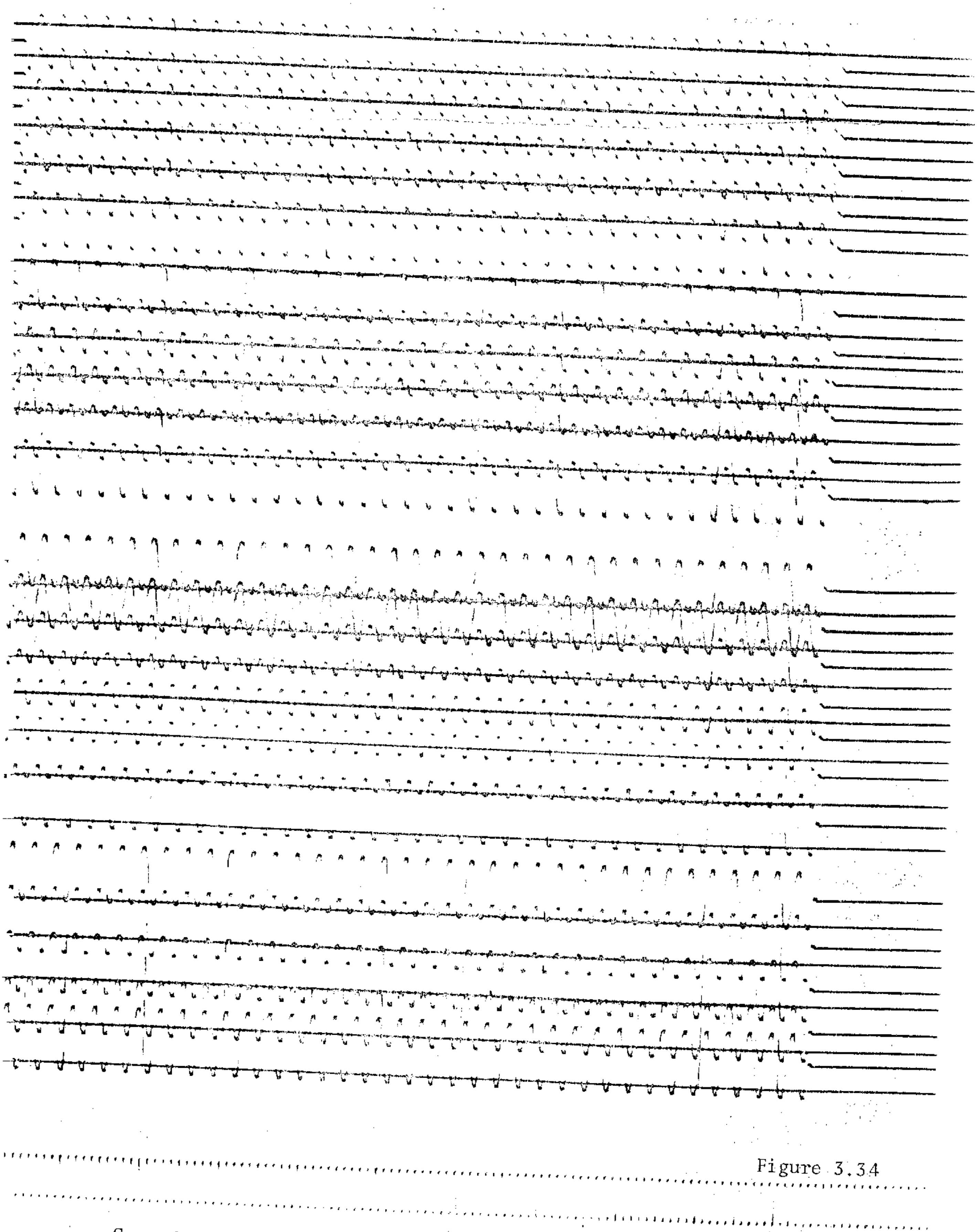


Figure 3.34

Crossfeed Test Manual Gain (Record 46)

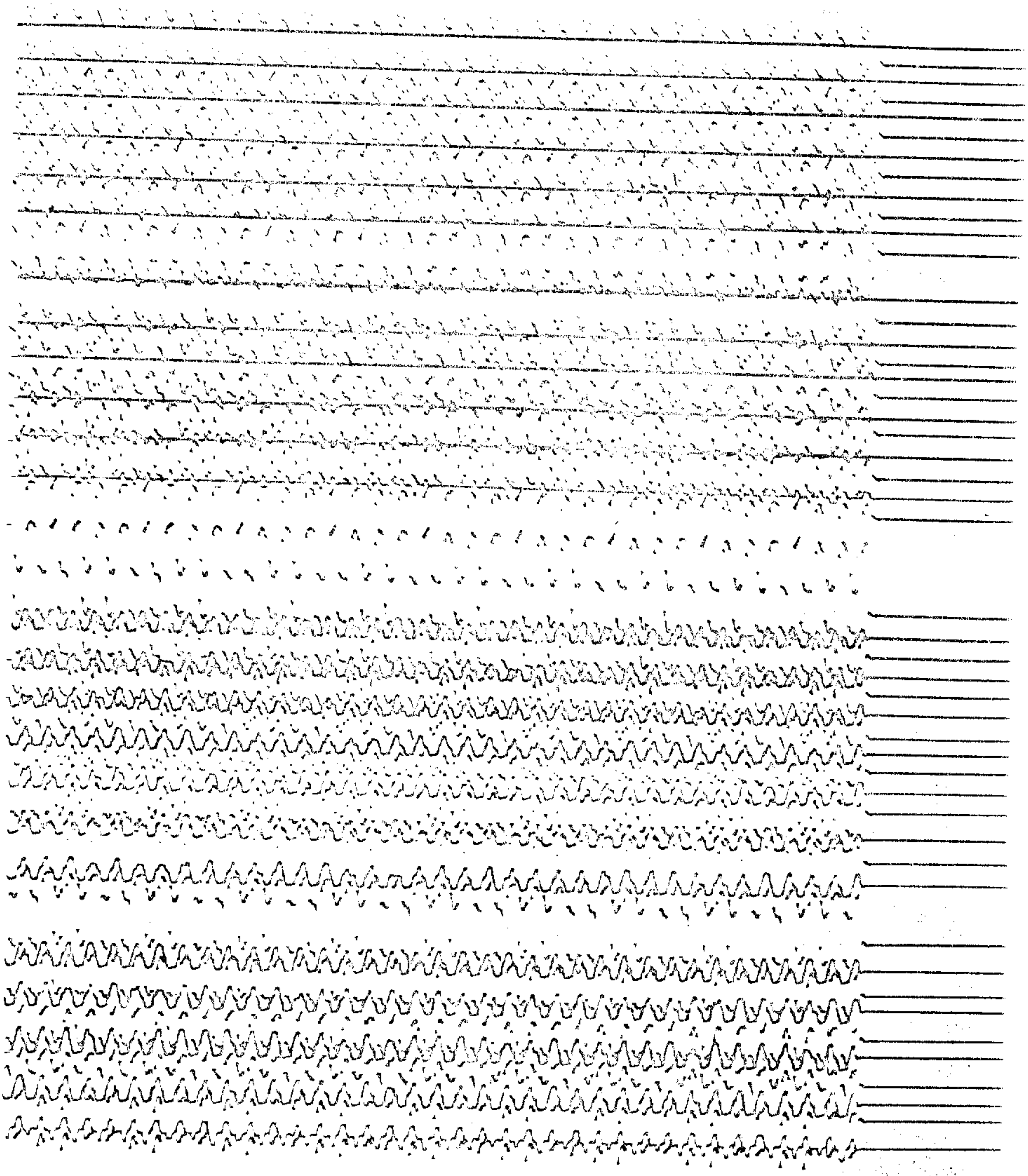


Figure 3.35

Crossfeed Playback 60dB up (Record 46)

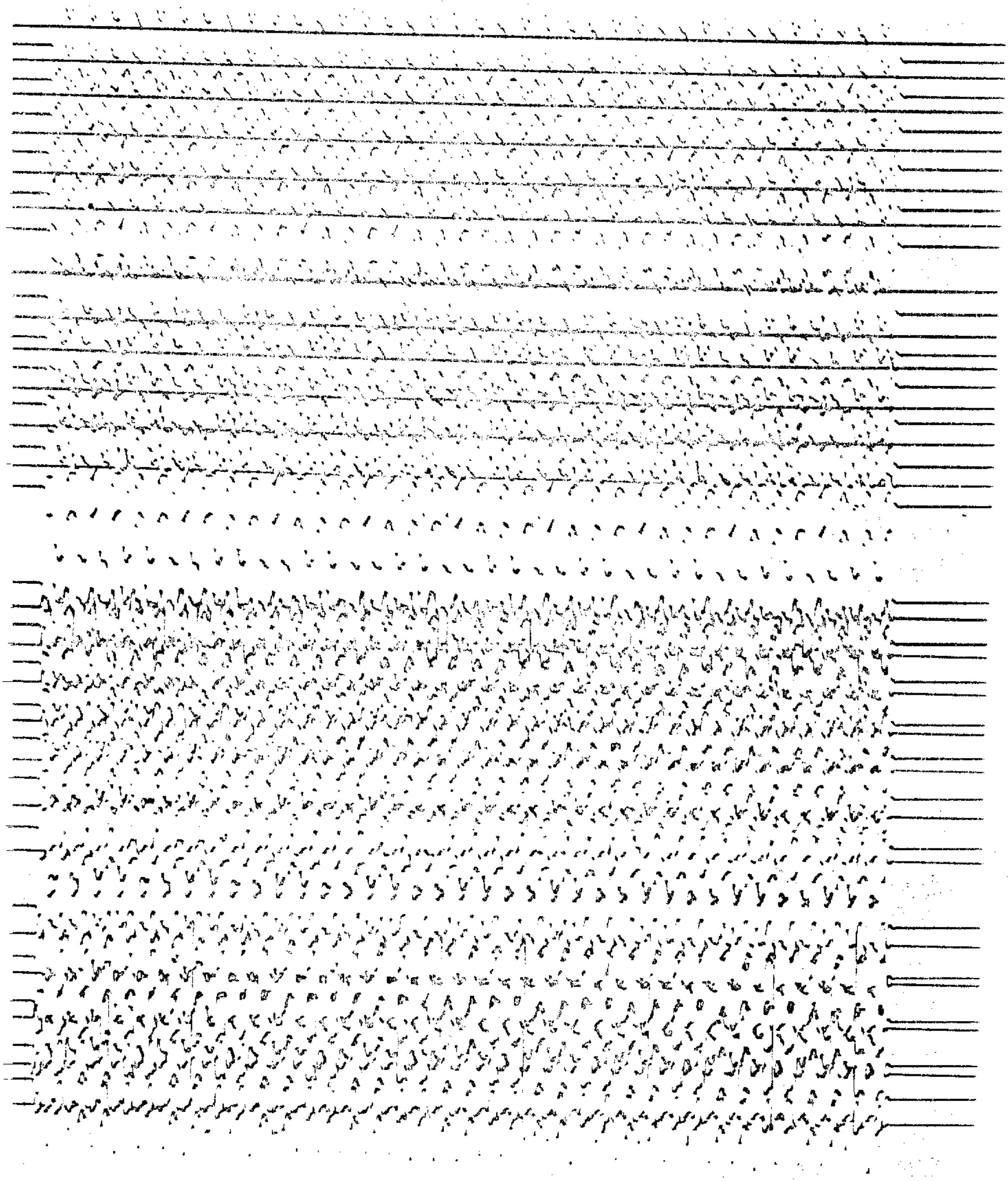


Figure 3.36

CROSSFEED PLAYBACK 72dB up (Record 46)

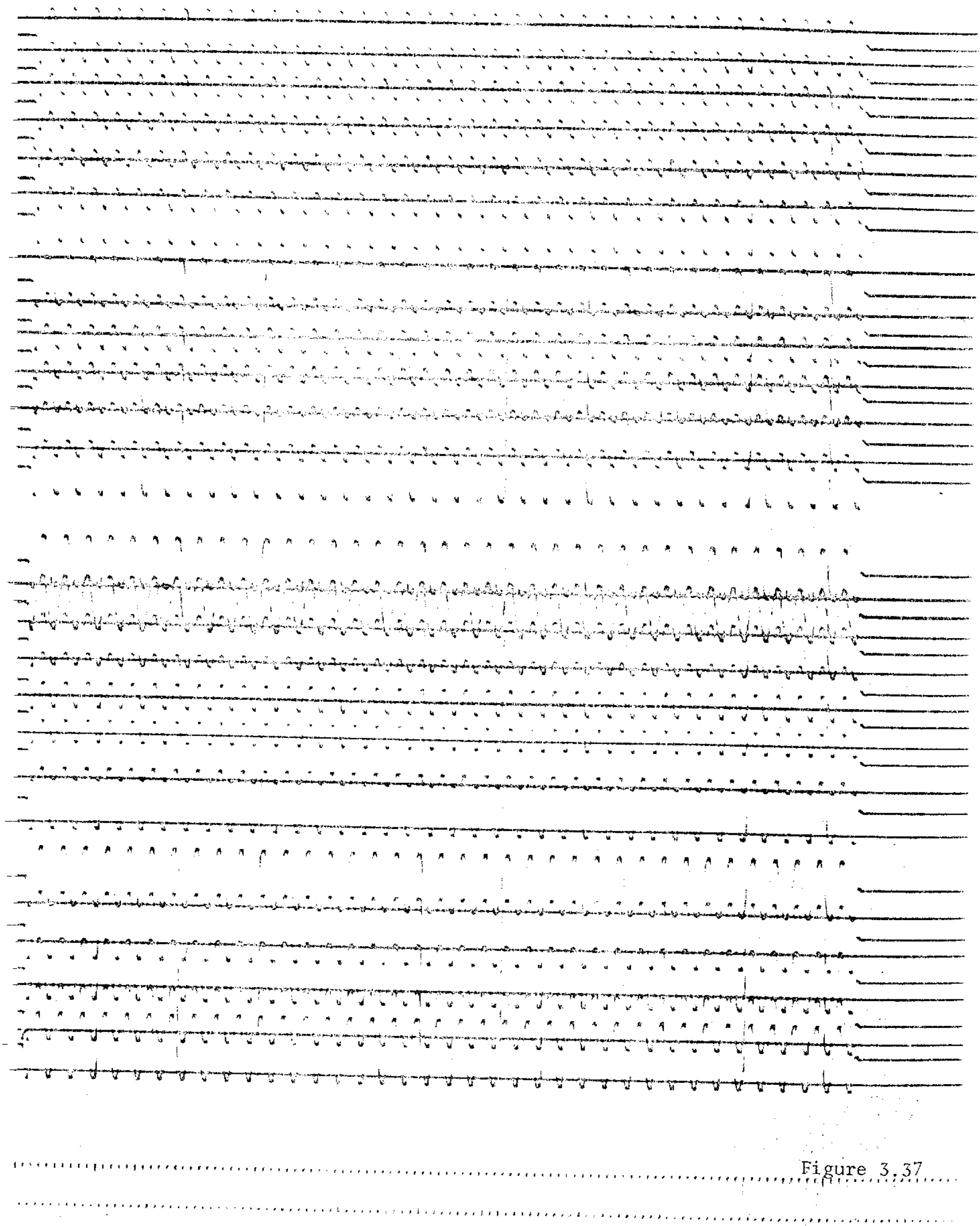


Figure 3.37

Crossfeed Test IFP Gain (Record 47)

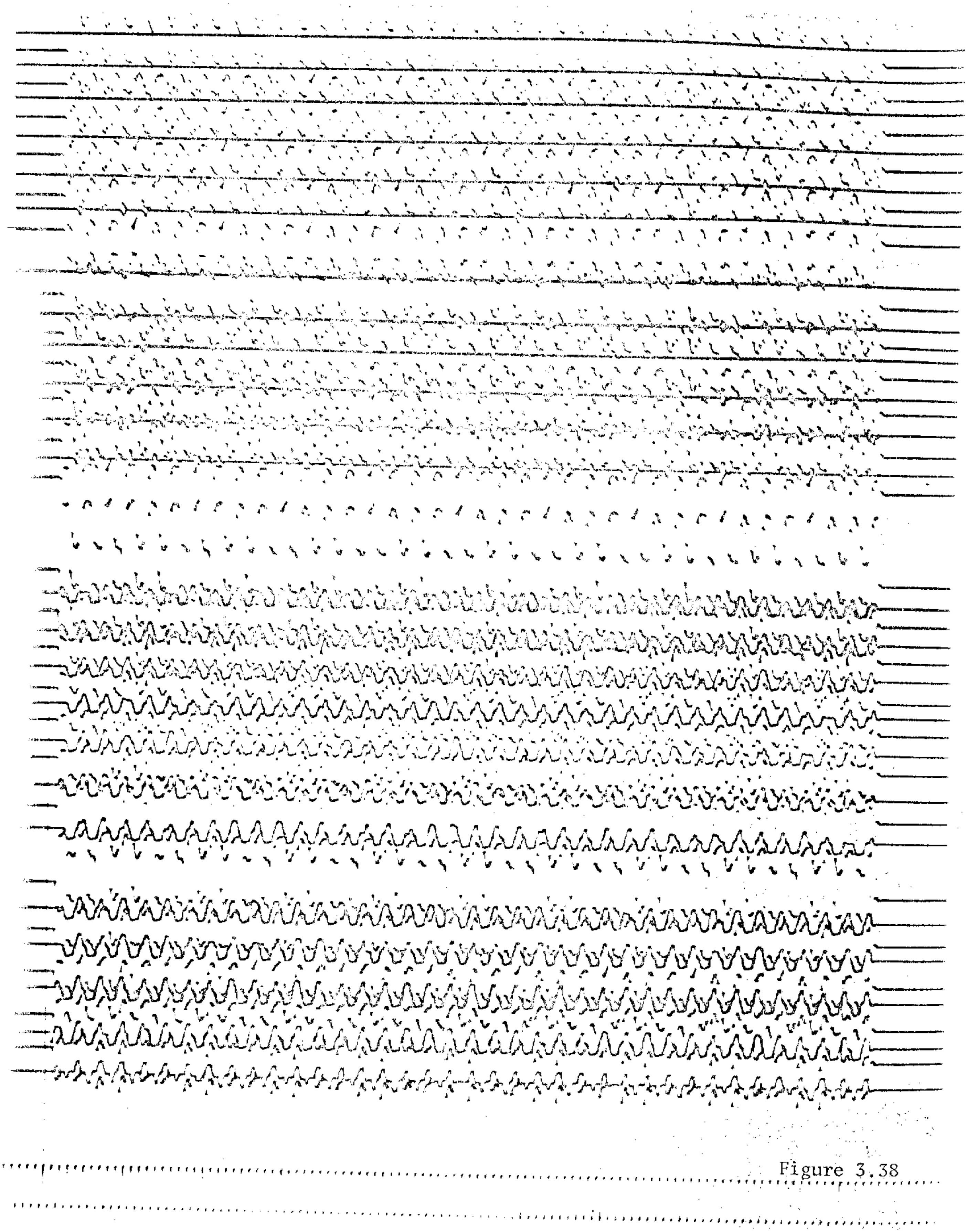


Figure 3.38

Crossfeed Playback 60dB up (Record 47)

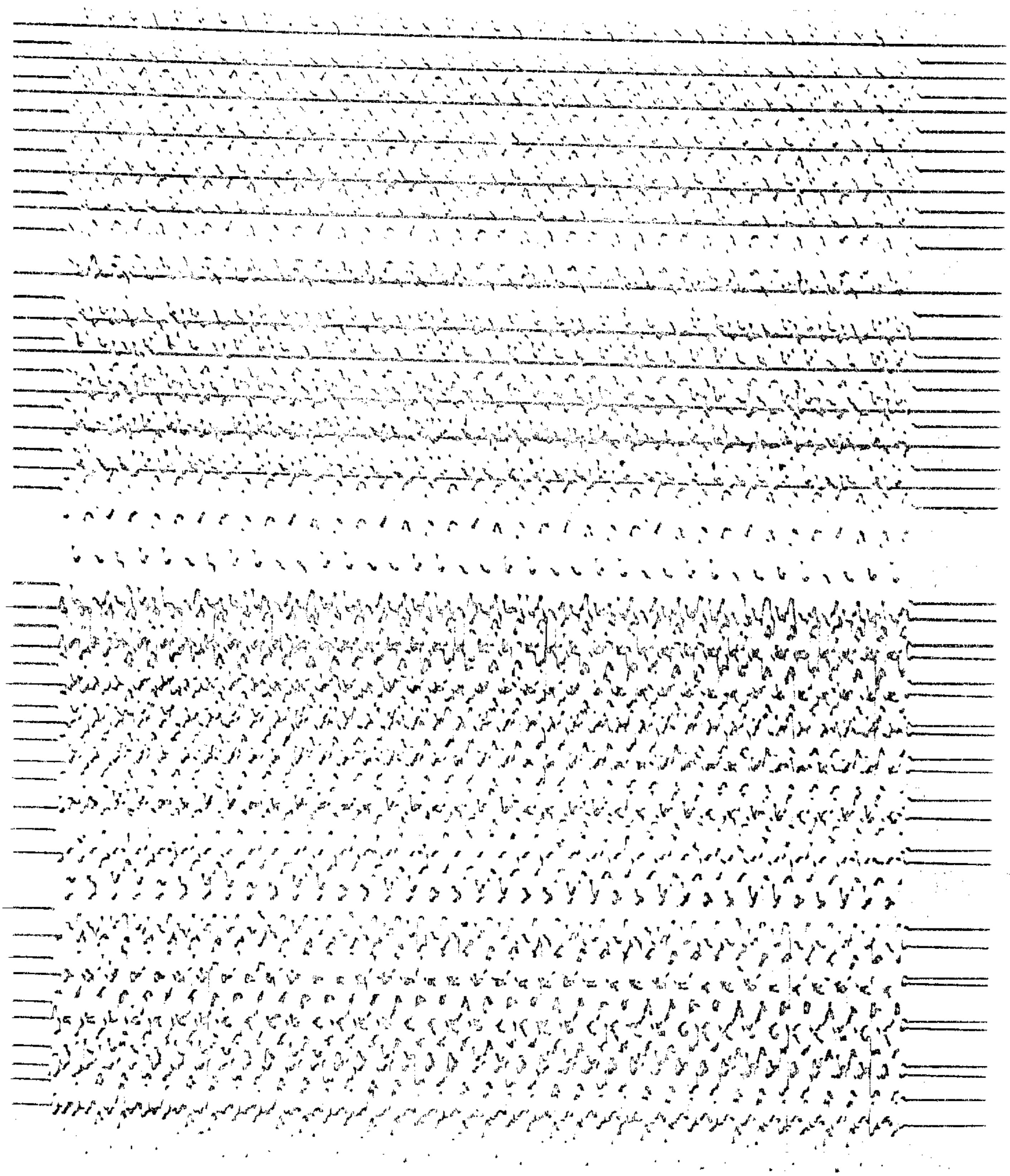


Figure 3.39

Crossfeed Playback 72dB up(Record 47)

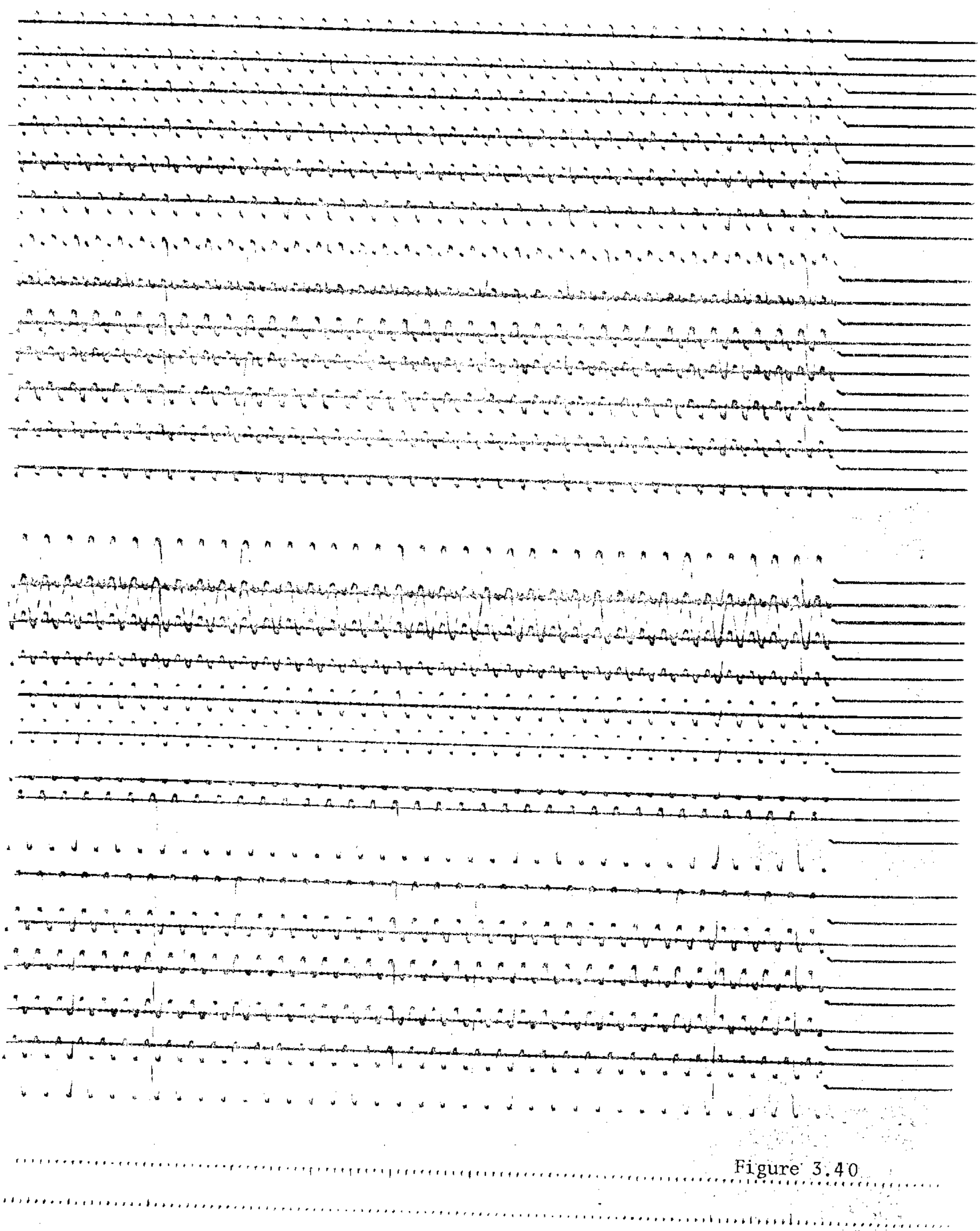


Figure 3.40

Crossfeed Test. Manual Gain (Record 48)

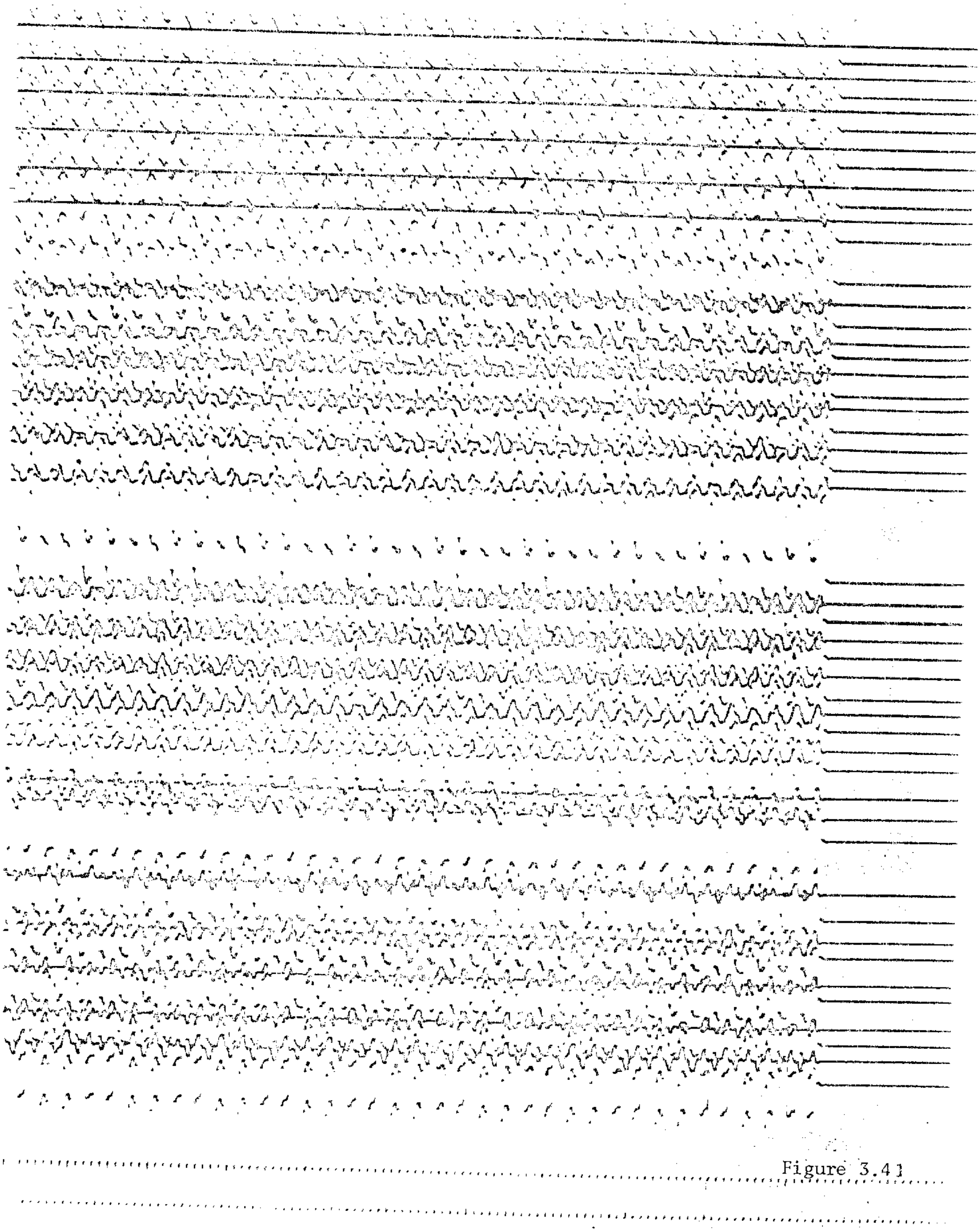


Figure 3.41

Crossfeed Playback 60dB up (Record 48)

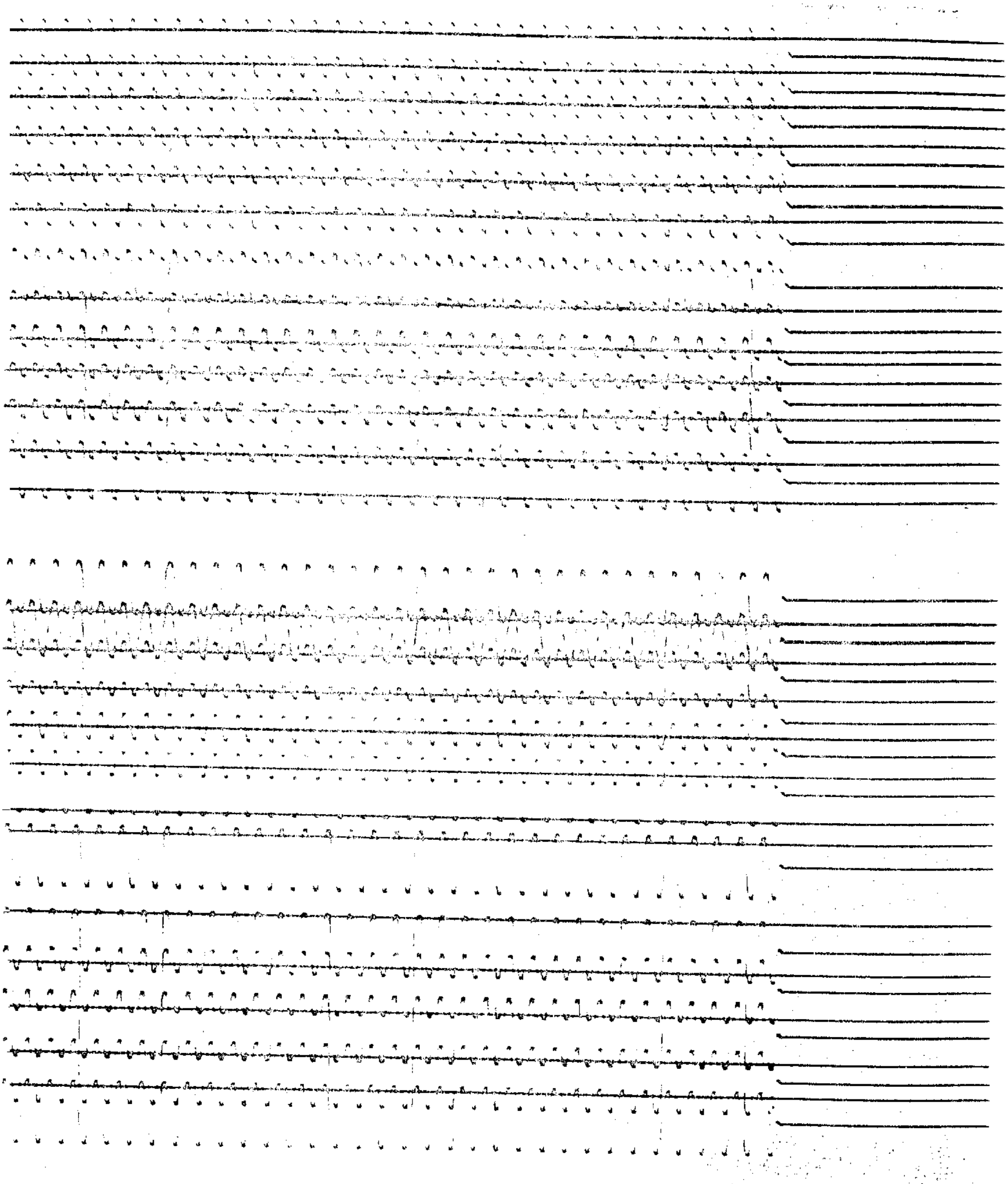


Figure 3.42

Crossfeed Test IFP Gain (Record 49)

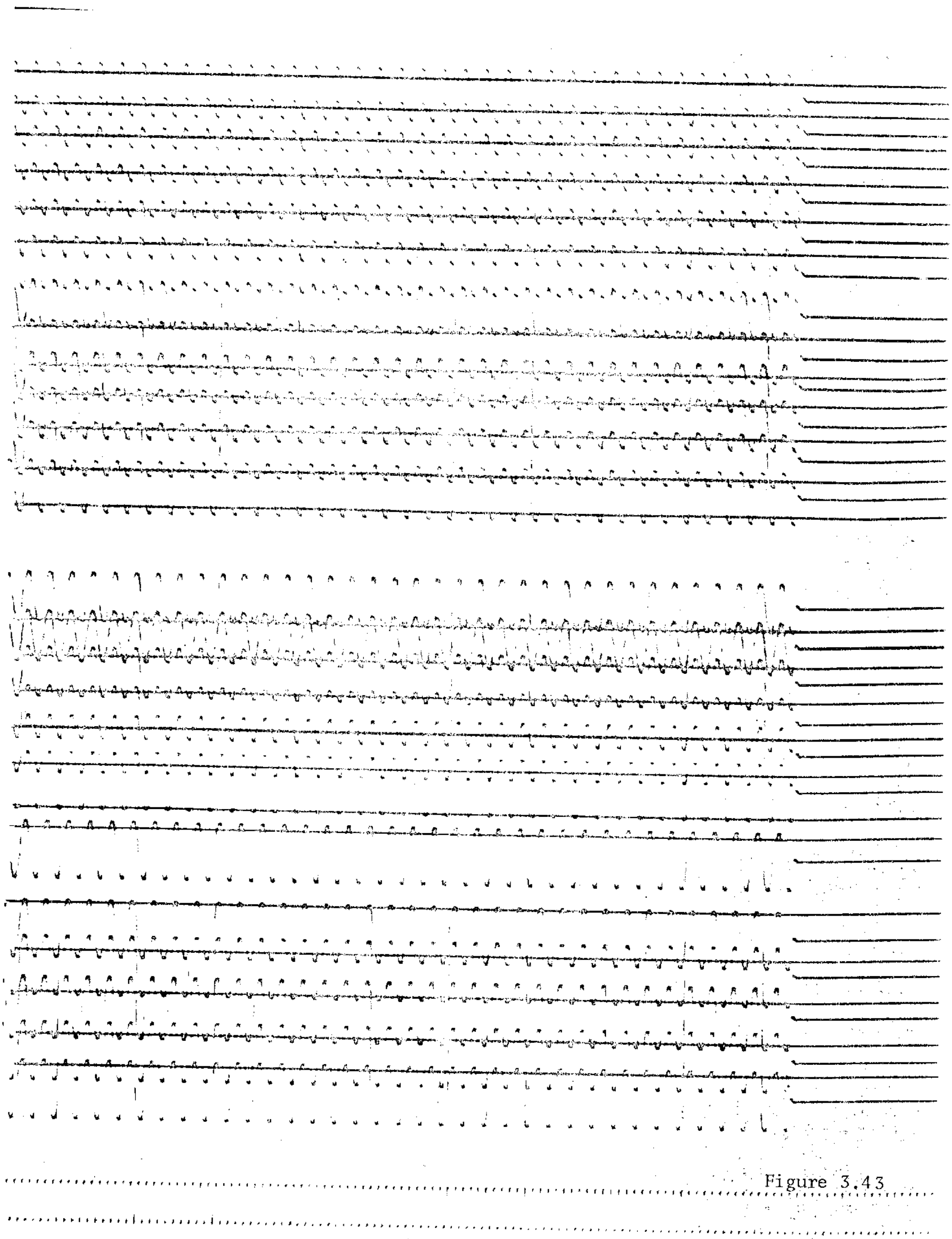


Figure 3.43

Crossfeed Test   IFP Gain   (Record 50)

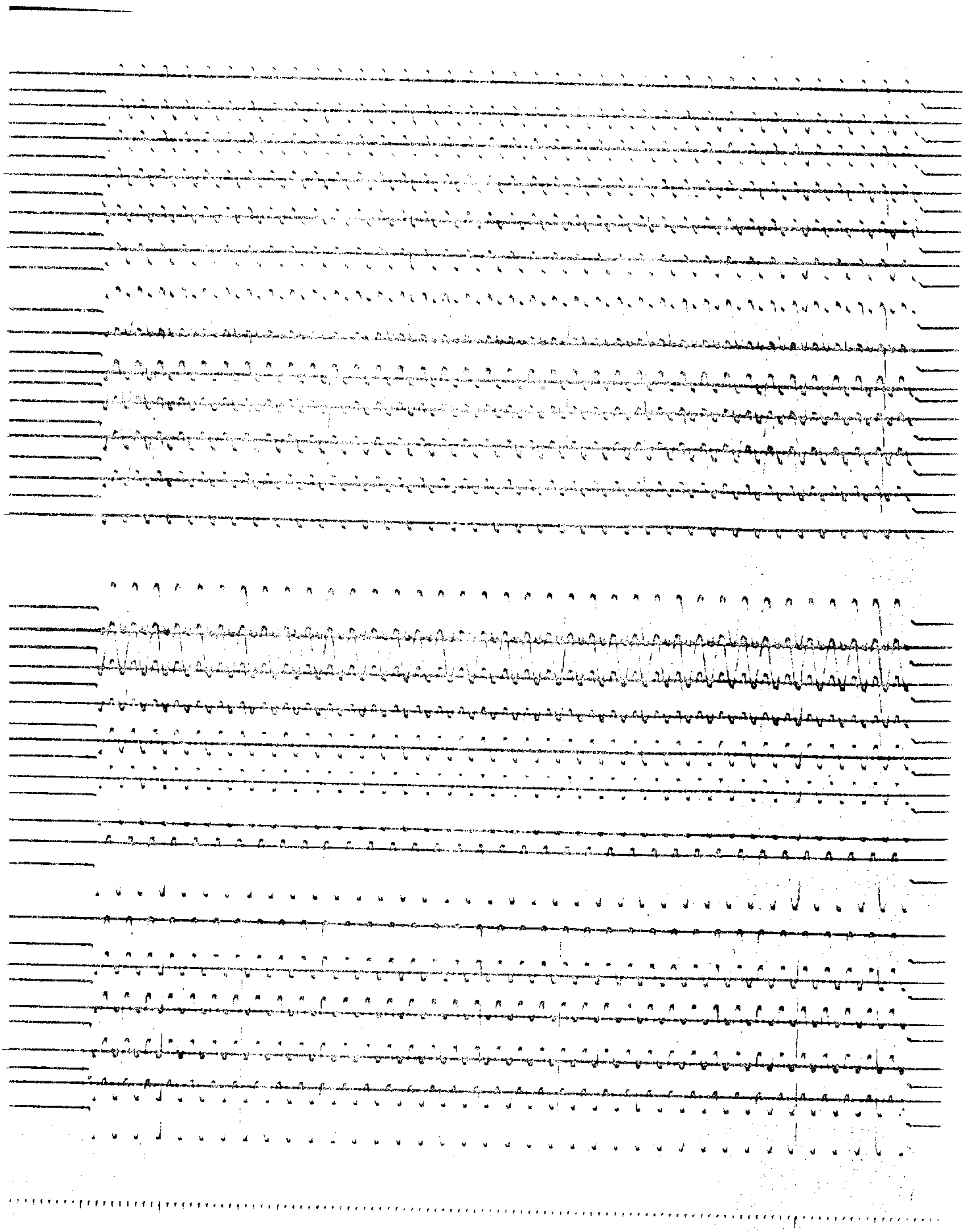
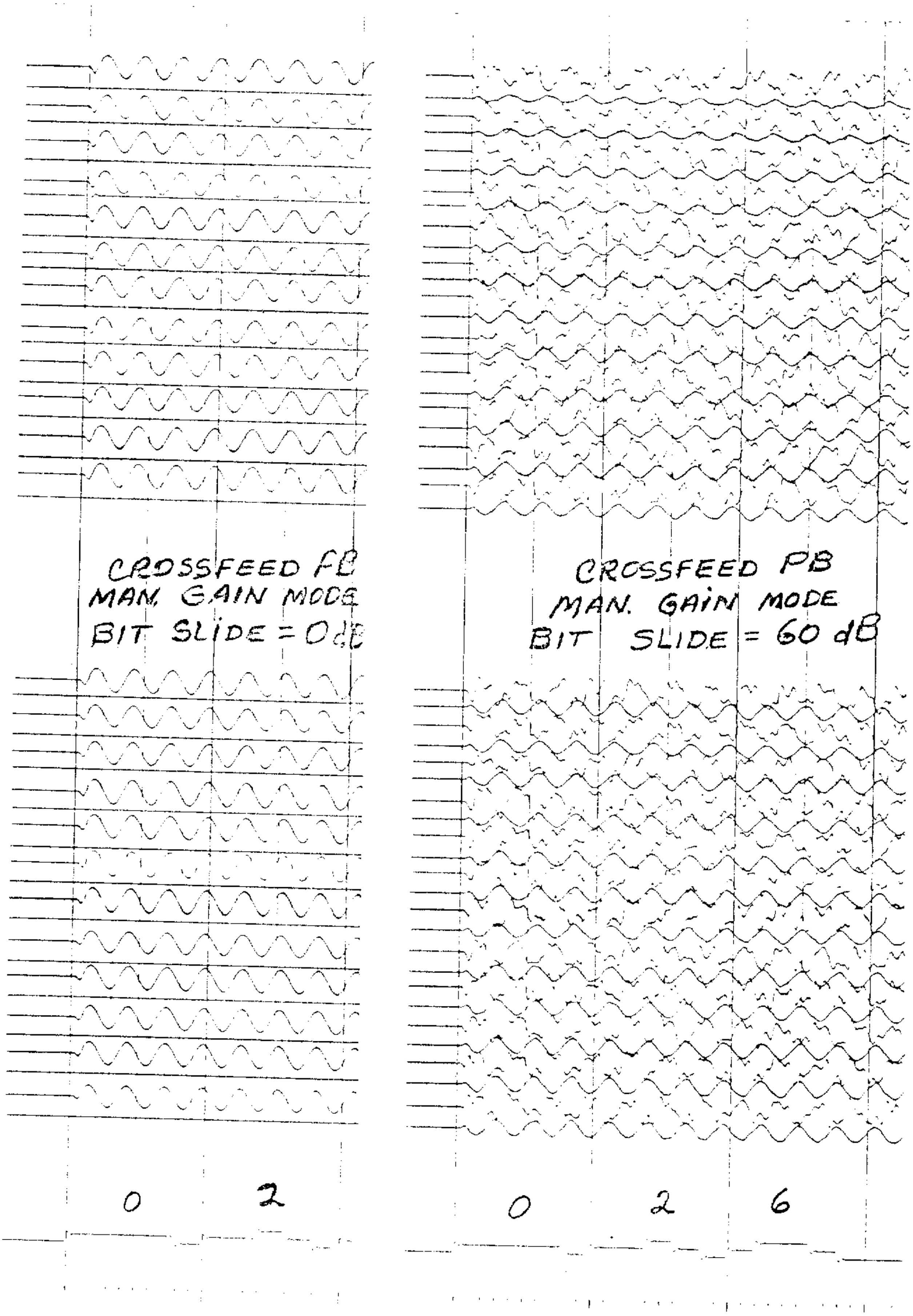


Figure 3.44

Crossfeed Test Manual Gain (Record 51)



Crossfeed Test Example   Figure 3.45

(5) Converter Linearity Test

This test provides an analysis of analog to digital conversion linearity and accuracy through the converter's range. Analysis is performed from computer number dump, and a feature of the test is that a precise binary-level DC voltage supply meter is used (e.g. "Fluke" meter).

Purpose

By inserting a series of precise Binary level DC voltages at the input to the analog to digital converter and recording the binary outputs, A/D converter accuracy and linearity can be determined. Thirty-one tests are recorded, and no paper records are run.

The accuracy of the DC voltage source must be better at 0.05%, or a voltage source and precision DC voltmeter to monitor source voltage must be used.

Note: Since no precise voltage source was available, this test was not run on the DFS IV and thus is not analysed. However, assuming such a source will be available at some time, the test routine will be described.

Set the system switches as follows:

Mode Switch	RECORD
Record Switch	DIR CHNL
Record Length Switch	2 SEC CAL
Gain Mode Switch	MANUAL

1. Make certain converter offset is zero (with no input, 0.25 light switches on and off).
2. On Amplifier Relay Card (RE), connect a twisted pair shielded wire across test points DIRCH and GRD. Connect a 500 to 1000 microFarad capacitor across at the test points. Float (unground) the voltage source output and ground the shield (if not, noise may be induced).
3. Set the supply to +4094 millivolts and make a 2 second record. Reverse DIRCH and GRD at the test points to give -4094 millivolts and take a second record.
4. Continue reducing the supply voltage on each step as shown in Table 3.6

Specification for A/D Converter is:

Accuracy	± 0.05%
Linearity	± 0.02% of full scale maximum departure from best straight line of input versus output.

Table 3.6

CONVERTER LINEARITY TEST

RECORDING	FILE NUMBER	CONVERTER INPUT-mV
1	________	+ 4094
2	________	- 4094
3	________	+ 2048
4	________	- 2048
5	________	+ 1024
6	________	- 1024
7	________	+ 512
8	________	- 512
9	________	+ 256
10	________	- 256
11	________	+ 128
12	________	- 128
13	________	+ 64
14	________	- 64
15	________	+ 32
16	________	- 32
17	________	+ 16
18	________	- 16
19	________	+ 8
20	________	- 8
21	________	+ 4
22	________	- 4
23	________	+ 2
24	________	- 2
25	________	+ 1
26	________	- 1
27	________	+ .5
28	________	- .5
29	________	+ .25
30	________	- .25
31	________	0

(6) Skew Check Test

One of the most important aspects of seismic recording is maintaining minimal tape skew during recording operations. Incorrect write skew (which is the writing of bits on magnetic tape at an angle other than directly across the magnetic tape) can generate tapes which cannot be read in a processing centre. Also, correct reading of the data after recording it, will confirm recording is correct and, if the read skew is incorrect, parity errors will occur.

Gradual changes in skew occur continuously during recording operations due to recording head and roller guide wear. Other types of tape transport such as those operating on the vacuum guide method do not have such roller guide associated problems. At worst, recording head wear can cause the loss of a track (resulting in head replacement) whereas rollers often require replacement.

The method used requires an "all ones" tape which is known to have "ones" in tracks correctly written in their respective location. This is often known as the 'IBM Master' skew tape. This is read and, using an oscilloscope, Read Amplifier voltage waveforms are checked and their positions logged. A new tape is then mounted and "all ones" recorded in each track - while writing "all ones" the Write Amplifier voltage waveforms are checked and adjusted.

Re-read the "all ones" from that tape and compare the waveforms with those from the 'Master' tape. If they are equally all in error, the 'write' voltages are adjusted again during writing once more until aligned with the 'Master' tape.

Re-read the "ones" just recorded after the write deskew procedure and adjust the Read Decode Switch (top) to line up with Bit 2 track 5 (reference). Repeat this in reverse with the Read Rev. Switch (bottom).

Procedure

1. Mount the 'Master' tape.
2. Set up a dual trace oscilloscope with internal trigger, synch on channel 1, horizontal sweep 2 microsec/division.
3. Connect oscilloscope probes to Read Amplifiers (Read/ Write Module RA Card) for two outer tracks. The bit/ track relationship for write deskew is as follows:

Bit	Track	Test Point	Adjustment
P	4	RA1 TP1	WA1 S1
0	7	RA1 TP2	WA1 S2
1	6	RA1 TP3	WA1 S3
2	5	RA2 TP1	WA2 S1
3	3	RA2 TP2	WA2 S2
4	9	RA2 TP3	WA2 S3
5	1	RA3 TP1	WA3 S1
6	8	RA3 TP2	WA3 S2
7	2	RA3 TP3	WA3 S3

4. Connect oscilloscope probes across outer tracks 1 and 9 at RA3 TP1 and RA2 TP3.

5. Put Mode Switch into SEARCH FWD and start the tape rolling. Adjust the oscilloscope traces so that only the peaks and troughs are displayed, and invert channel 2 for easier time judgement as shown in Figures 3.46 and 3.47.

6. Skewing may be measured in FWD direction and REV direction. Note readings on the form Table 3.8, indicating lag or lead. Ideally, the difference should not be greater than 2 microseconds.

7. Measure and note read skew going through each track by using centre track 5, RA2 TP1 as reference on channel 1, using it for triggering also. Channel 2 is used to compare peaks being noted on each check. No adjustments are made yet.

8. Remove the 'Master' tape and replace it with a 'scratch' tape. Connect channel 2 to TP4 on RD-P card (Read Decode-Parity) using internal trigger. Set Format Module to ONES and TEST. Record ONES on tape (note: all data lights off) and adjust the oscilloscope until three pulses appear.

   Switch time magnifier to x10, sweep vernier to x5.

   Adjust horizontal position until centre of each pulse is monitored, showing the superposition of two pulses.

   Potentiometer R2 on WA1 (Write Amplifier) card is adjusted so that both leading edges are superimposed (widths may vary). Repeat for all tracks as shown on the following table.

Bit/track relationship for pairing pulses:

Bit	Track	Test Point	Adjustment
P	4	RDP TP4	WA1 R2
0	7	RD0 TP4	WA1 R5
1	6	RD1 TP4	WA1 R8
2	5	RD2 TP4	WA2 R2
3	3	RD3 TP4	WA2 R5
4	9	RD4 TP4	WA2 R8
5	1	RD5 TP4	WA3 R2
6	8	RD6 TP4	WA3 R5
7	2	RD7 TP4	WA3 R8

9. The write deskew procedure is now commenced by writing "ones" and using channel 1 as oscilloscope reference, monitor each track with channel 2 adjusting the WRITE DESKEW switch as shown on the table for step 3 above. All adjustments now made cause the read skew pattern to be the same as the 'Master' tape.
   Each deskew switch position changes write skew 0.43 microseconds, and the higher the switch value causes a delay or induces a lag in writing the one.
   Tracks generally are set in the range of 2-5, with the centre track at position 3 or 4.
   When write- deskew is complete, note positions on the form's right column.
10. To read deskew, rewind the scratch tape and write ONES its entire length.
   Connect oscilloscope channel 1 to RD2 TP8 bottom test

point, channel 2 to RD-P TP8. Run the tape in SEARCH FWD and adjust RD-P S1 (top) so that channels 1 and 2 align.

Repeat for each track monitoring RD1 and RD3 through RD7 on channel 2.

11. SEARCH REV adjusting bottom read deskew switches S2 while monitoring RD-P through RD1 and RD3 through RD7, TP8. This completes REV deskew.

The deskew procedure is complete and all settings should be noted for future reference. Any replacement of Write Amplifiers should have deskew switch positions adjusted to agree with the replaced card, as should Read Decode Cards. One important point to remember is head wear per foot of tape travel has been shown to increase as tape velocity decreases. Also, tape speed is governed by the following table:

Format	No. of channels	Bytes/Scan	Tape Speed at sample rate		
			1ms	2ms	4ms
SEG-B	24	74	46.25	23.12	11.56
1600BPI	48	134	-	41.88	20.94
SEG-C	30	128	80.0	40.0	20.0
1600BPI	62	256	-	80.0	40.0
	126	512	-	-	80.0

Table 3.7

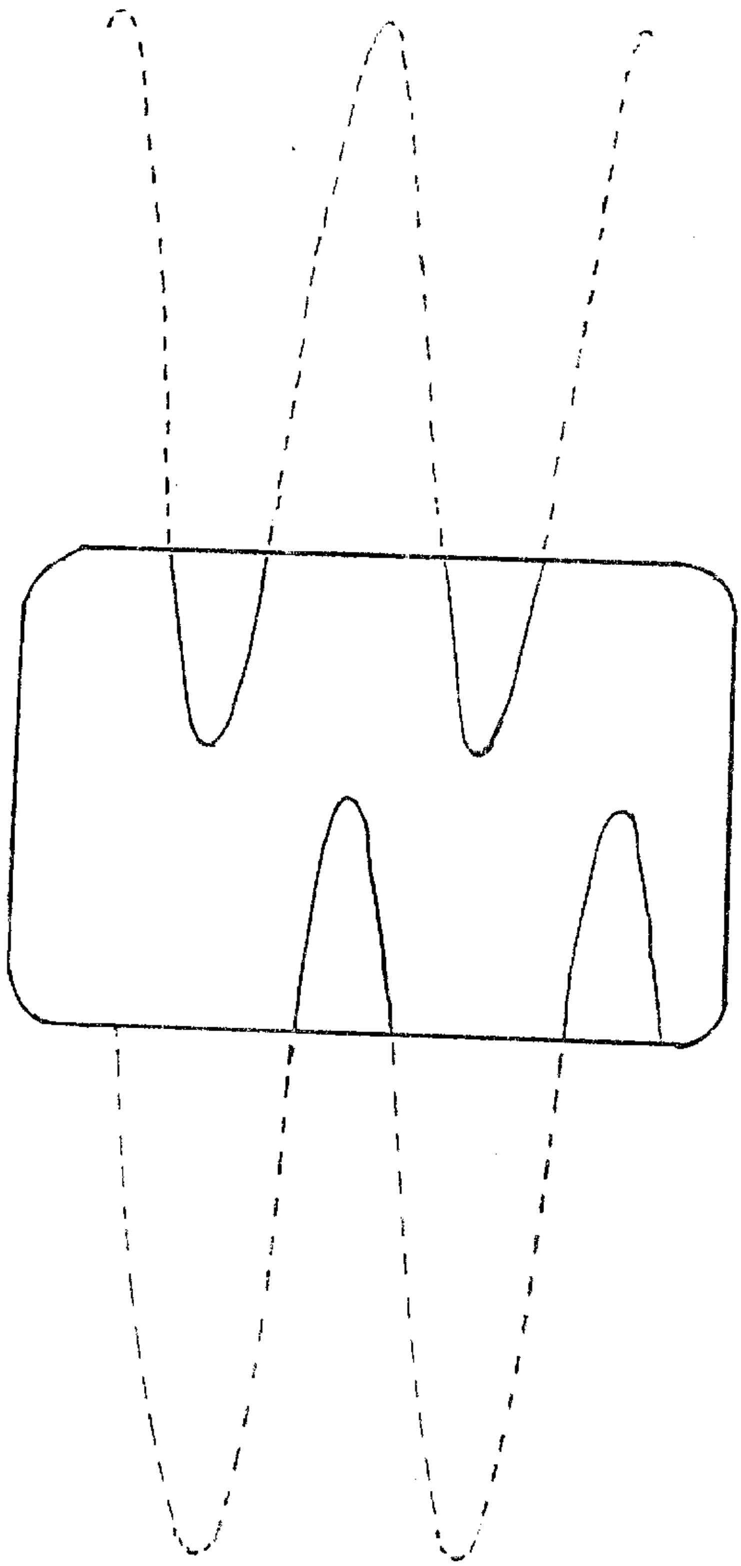


Figure 3.46 READ AMPLIFIER SCOPE DISPLAY

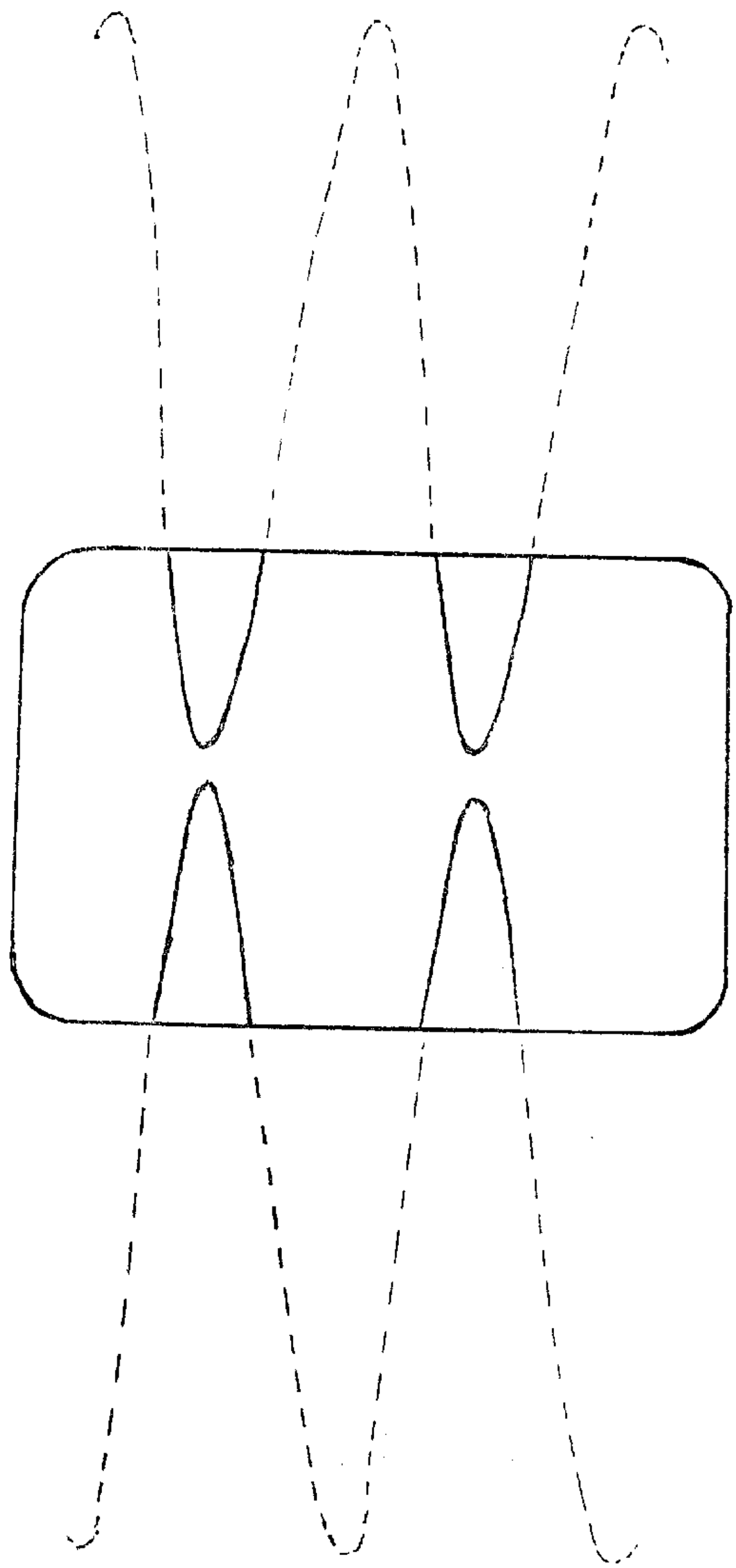


Figure 3.47 Read Amplifier Scope Display from Tape with Channel 2 Inverted

FORM FOR LOGGING DFS IV 9 TRACK READ SKEW DURING CALIBRATION PROCEDURES.

BIT	TRACK	TEST POINT LOCATION	READ SKEW LEAD FORWARD or LAG	READ SKEW LEAD REVERSE or LAG
P	4	RA1 TP1	____ µs ____	____ µs ____
0	7	RA1 TP2	____ µs ____	____ µs ____
1	6	RA1 TP3	____ µs ____	____ µs ____
2	5	RA2 TP1	Reference	Reference
3	3	RA2 TP2	____ µs ____	____ µs ____
4	9	RA2 TP3	____ µs ____	____ µs ____
5	1	RA3 TP1	____ µs ____	____ µs ____
6	8	RA3 TP2	____ µs ____	____ µs ____
7	2	RA3 TP3	____ µs ____	____ µs ____

FORM FOR RECORDING WRITE AND READ DESKEW SWITCH SETTINGS AFTER CALIBRATION

WRITE DESKEW SWITCH SETTING	READ DESKEW SWITCH SETTING forward	READ DESKEW SWITCH SETTING reverse
WA1 S1____	RDP S1____	RDP S2____
WA1 S2____	RD0 S1____	RD0 S2____
WA1 S3____	RD1 S1____	RD1 S2____
WA2 S1____	RD2 S1____	RD2 S2____
WA2 S2____	RD3 S1____	RD3 S2____
WA2 S3____	RD4 S1____	RD4 S2____
WA3 S1____	RD5 S1____	RD5 S2____
WA3 S2____	RD6 S1____	RD6 S2____
WA3 S3____	RD7 S1____	RD7 S2____

Transport Module____________ Byte Period____________microseconds Party____________

Read Write Module____________ TXP Speed____________IPS Date____________

NOTE: Use ONLY IBM Master Skew Tape 432640 for this procedure.

Signed________________________

(7) Polarity Test

Recording system polarity must always be identical, otherwise a seismic section produced by one seismic party may be reversed from that of the next, with the result that geological horizons will mis-tie (due to the recorded horizon being distinguished by a peak on one section and a trough on the other).

Hence, system polarity is of extreme importance. The Society of Exploration Geophysicists (S.E.G.) laid down a polarity convention as follows - a first break is the initial upward motion of the earth and such motion on an implanted upward geophone will generate a signal that will be digitized on tape as a negative data point value. This should be displayed on camera as a downbreak or negative deflection. i.e. an upward geophone motion is a downbreak on a paper record corresponding to a negative number on tape.

During conventional surveying, geophone strings, cables, recording instruments and camera should have their polarity checked whenever a change or equipment modification is made. To check camera polarity first, a PULSE TEST recording will indicate the break direction on each channel. From previous tests, it is observed that filter settings change the pulse phase and, hence, filter settings must be "OUT" for the sample rate in use (i.e. 2 msec - 124Hz hi-cut).

From II Section (4), the Filter Pulse Test response to the positive going input pulse of 160 microseconds, was to deflect all camera galvo channels upwards - a correct polarity.

However, it is not inconceivable that the recording instruments polarity has been reversed and, hence, that the camera traces have already been reversed prior to recording.

The solution is to obtain a 'polarity' tape, which is a tape generated in a processing centre having one continuous record on its full length. This record has a positive pulse applied to one channel at a time approximately every 10 milliseconds i.e. at 10 milliseconds after time zero, a 5 millisecond positive pulse appears at channel one; at 20 milliseconds another pulse appears at channel 2 and so on, until all channels have received a pulse by 480 milliseconds.

Such pulse scans across all channels reoccuring thereafter every second; it takes a few seconds to load the tape and playback the record to observe if read-after-write and galvo circuitry is correct.

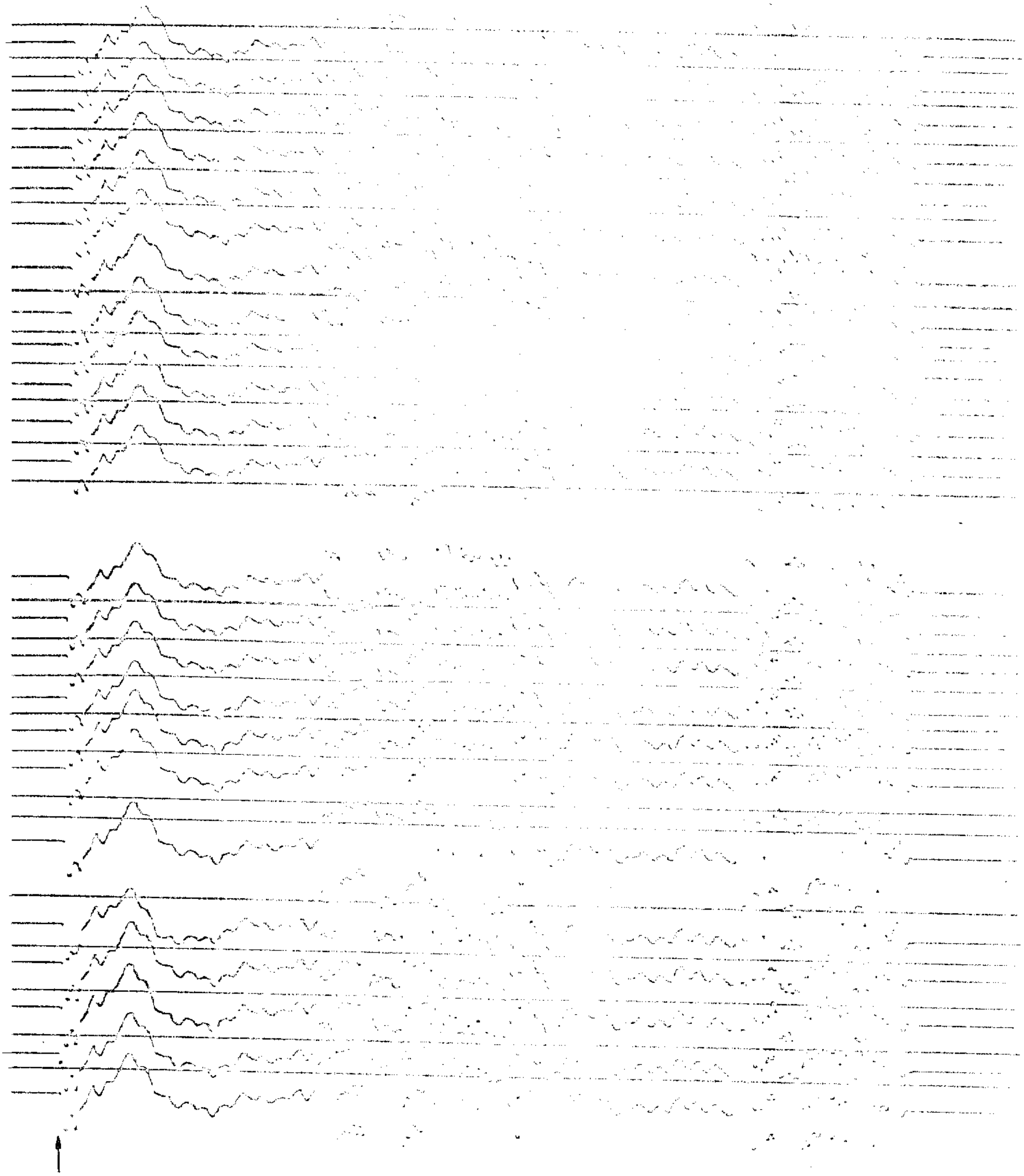
In the knowledge that the pulse test, read-after-write and camera circuitry is correct, a pulse or output from a geophone may be applied at the input connectors to the Input Modules. The odd/even input skew connectors may be used for this test, and a typical record showing a downbreak as a result of tapping a geophone is shown in Figure 3.4 8.

As an alternative if the polarity tape is not available, a geophone may be plugged in at the Direct Channel (DIRCH) input to the amplifier. By vertically tapping (lightly) the geophone base, a DIRCH record may be made and the camera record would display system polarity, and also an oscilloscope monitoring the amplifiers test points would indicate the polarity.

Recordings while tap testing geophones should be made in MANUAL not IFP gain mode, and from Figure 3.49 the first impression is that the break is up. The initial upward break is due to the geophones positive dc bias at the converters input terminals - and note the break is down at the end of recording. Such DIRCH recordings are not easy to distinguish because the slightest high frequency noise surrounding the geophone and its connectors, tends to mask the vertical tap. The upward break is clearly seen across all channels just prior to end of record.

With land data acquisition equipment, polarity reversals can occur at any point from the geophone output, along the cables, interconnecting cables and into the instruments. With marine, because crystal hydrophones are physically built into the plastic cable ("streamer") sections, the polarity can be determined by the application of a rapid pressure or blow to each cable section. This feat may be performed by lightly tapping each cable section before it enters the water and observing galvo deflections; by firing onboard airguns (if they are the source) and observing the galvo deflections or finally by laying the full cable out in the water and taking a normal recording.

Lightly tapping each cable section as it is streamed is the best initial indication because, if a fault exists, it can be rapidly resolved. Firing the energy source near the cable is often of little value, since vessel noise may mask the break (in similar manner to the DIRCH recording of a tapped geophone). A clean first break is always observed with the cable in the water - the only hazard to this practice is that if a fault exists it will take time to repair.



Polarity Test Tapped Phone at INPUT

Figure 3.48

Polarity Test - DIR CH RECORDING

Figure 3.49

(8) "All Ones" Test

The "all ones" test is essentially performed to check that tape transport skew is within specified limits (see "skew check"). It is always performed as the last test on magnetic tape, since very often the first quarter of tape is used on previous monthly tests, allowing the final three-quarters of test tape to be used to record "all ones".

In recording all ones, the DATA record length is put at '00' length and a 'one' will be placed at every data word value on magnetic tape. During recording and playback of this record, parity lights may be monitored to see if there is any form of read/write error. When run in reverse as well as forward, Read Amplifier cards may assist the skew assessment.

Evaluation at the processing centre can give further assessment of skew and tape speed over the head. Tape speed (40 ips at 2 msec 1600 bpi) has an allowable variation of ±1%, but computer centres have found no problems reading tapes as much as ±10% of the correct speed.

Note: When recording "all ones", the Format data indicator lights are off not on as expected. When recording "alternate ones" (i.e. a one in every alternate word), the bottom row of data lights will appear on. Hence, in "alternate ones", the 'off' lights are the ones being written on magnetic tape.

NUMBER	DATE	TIME	OBSERVER MAKING TEST	
11T TEST TAPE 10	3RD AUG.		S. EVANS	
SERIAL NUMBER	PARTY NUMBER		PARTY MANAGER	PARTY CHIEF
	—		—	

DATE	SYSTEM FORMAT	NUMBER OF TRACES	PACKING DENSITY-BPI
IL ☑ 2 MIL ☐ 4 MIL ☐ ____	☐ 9 TRACK ☑ SEG B ☐ SEG C	☐ 24 ☑ 48 ☐ OTHER	☐ 556 ☐ 712 ☐ 800 ☑ 1600 PE

DYNAMIC RANGE DETERMINATION TEST (1 SEC LENGTH)

MONITOR SECTION				FILE OR	PLAYBACK SECTION		
RANGE SWITCH	LEVEL SWITCH	VALUE OF TEST SIGNAL	DB DOWN	RECORD NUMBER	Galvo Level	BIT SLIDE	DB UP
x4	16mV	64mV	−3	001 (2 SEC REC)	SAME AS RECORD	0 db	+3
	4mV	16mV	−16	002	R + 12	0 db	+15
	1mV	4mV	−27	003	R + 12	12 db	+27
	256µV	1024µV	−39	004	R + 12	24 db	+39
	64µV	256µV	−51	005	R + 12	36 db	+51
	16µV	64µV	−63	006	R + 12	48 db	+63
	4µV	16µV	−75	007	R + 12	60 db	+75
x8	1µV	8µV	−81	008	R + 12	66 db	+81
	0	CONVERT NOISE		009	R + 12	66 db	+81

EQUIVALENT INPUT NOISE TEST

...ion Signal - 1µV ...ord Number	Monitor Gain	Noise: File/Record Number
010	84 DB	011

...Gain

...NAL — DB | NOISE — DB

IFPA OSCILLATOR TEST

...rd Number	Record Length	Method Signal Changes
012	8 SEC	☑ Exponential ☐ Sine Stepped

Signal Level	Record Gain Mode	Galvo Level
64 mV	☑ IFP ☐ Manual	Record ___ DB/REP ___ DB

...Mode ☐ Defloat ☐ Float | AGC Reproduce Settings: Trip Sens ___ DB Initial Gain ___ DB

...ion ☐ PGC ☐ GAGC | Trip ___ Secs LEVEL: ☐ High ☐ Low | AGC Speed ___ PGC Rate ___ DB/SEC

FILTER PULSE TEST

...ILE ...MBER	HICUT FILTER-HZ	LOCUT FILTER-HZ	NOTCH IN-OUT-HZ
013	124/18	OUT	OUT
014	62/18	OUT	OUT
015	31/18	OUT	OUT
016	VARIOUS	– SEE ATTACHMENT	
017	"	"	"

...D MODE GAIN	GALVO LEVEL
... dB MAN ☐ IFPA	___ dB

GAIN ACCURACY TEST

MODE	GAIN CONSTANT	RECORD LENGT...
☑ CAL 12 HZ	24 DB	3

	FILE NUMBER	RECORD GAIN SETTING	TEST SIGNA... LEVEL SWIT...	
(1)	018	84	x4	1 µ...
(2)	019	72		1 µ...
(3)	020	72		4 µ...
(4)	021	60		4 µ...
(5)	022	60		16 µ...
(6)	023	48		16 µ...
(7)	024	48		64 µ...
(8)	025	36		64 µ...
(9)	026	36		256 µ...
(10)	027	24		256 µ...
(11)	028	24		1 m...
(12)	029	12		1 m...
(13)	030	12		4 m...
(14)	031 –12 HZ / 032 –36 HZ	0	x4	4 m...

HARMONIC DISTORTION TEST

FILE NUMBER	HICUT FILTER-HZ	LOCUT FILTER-HZ	NOTCH IN-OUT-HZ	RECO... LEN...
33 – 44	SEE ATTACHMENT			
045	FILTER	PULSE		

CROSSFEED TEST

FILE NUMBER	RECORD GAIN SETTING	CHANNEL TERMINATION
046	0 (MANUAL)	1-24 ODD 25-48 EVEN
047	IFP	1-24 ODD 25-48 EVEN
048	~~IFP~~ 0	1-24 EVEN 25-48 ODD
049	IFP ~~0 (MANUAL)~~	1-24 EVEN 25-48 ODD
050	0 – NOTCH IN 12-36	
051	IFP – " "	— " —

OTHER SYSTEM PARAMETERS FOR TESTS

...EM CONFIGURATION

...V ONLY ☐ CFS SYSTEM

...ONSTANT	GALVO LEVEL		NOTCH FILTERS
...+ DB	1-24 — DB	AUX — DB	☐ IN VARIABLE ☑ OUT

...MER CONNECTION	FILTERS		RECORD TYPE
☐ 2000Ω-	LOW CUT OUT	HIGH CUT	☐ DATA ☑ CAL

...NITOR	GENERAL CONSTANTS
☑ OUTPUT (NOT RAW)	

ANALYSIS RESULTS:

...CCURACY: ________ MILLISECONDS DIFFERENCE BETWEEN TIMING LINES AND PIPPER TRACE ON MONITOR RECORD.

VARIATION: ________ MILLISECONDS PER SECOND MAXIMUM VARIATION BETWEEN TIMING LINES AND PIPPER TRACE ON PLAYBACK RECORD.

63 – 066 4 RECORD FIELD TIME BREAK

67 – 8 SEC IFP OSCILLATOR TEST

REMARKS: LIST THE FOLLOWING. 1) ANY SCRATCH RECORDING 2) REPAIRS SINCE LAST TEST. 3) REMARKS AND OTHER TEST PROCEDURES OR RESULTS – SKEW CHECKS, CONVLIN, TB, ETC.

052 P-GEOPHONE DIRECT CH TAP (MAN) 1 SEC

053 " " (IFP) "

054 S-GEOPHONE " (MAN VERT) "

055 " " (MAN. HORIZ) "

056 " " (IFP. VERT) "

057 " " (IFP. HORIZ) "

058 AS 048 P-GEOPHONE TAP INPUT (MAN)

059 " " (IFP)

060 1 SEC "ALL ONES"

061 30 SEC " "

062 40 SEC " "

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Western Australia 6102
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Telex AA92983
Tel. 350-7539

OBSERVERS LOG

Prospect: INSTRUMENT TESTS	DFS IV	PAGE 1 of 4
Line: Dirn:	No. Traces 48	Sampling 2mS.
Observer: B.J. EVANS	Format SEG 'B'	9 Track
Date: 3RD AUG. 84	Offset	Stn. Para.
	~~Stn. Int.~~ GAIN CONST 24dB	

S.P.	R.N.	TIME	TAPE No.	SOURCE	Source Depth	COMMENTS
	001		10	ARD —		64mV. SIGNAL 2SEC RECORD
	002					16mV. 1SEC RECORD
	003					4mV. — —
	004					1024μV.
	005					256μV.
	006					64μV.
	007					16μV.
	008					8μV. (8. PARITY COUNT)
	009		CONVERTER NOISE			0
	010		INSTRUMENT		—	1μV SIGNAL 84dB MANUAL GAIN
	011		"		—	NOISE
	012		EXPONENTIAL OSCILLATOR.			64mV. I.F.P. 8SEC.
	013		FILTER PULSE		36dB MAN.	"OUT/124" 18dB/OCT SLOPE 1SEC.
	014		"	"	36dB	OUT/62
	015		"	"	48dB	OUT/31
	016		"	"	36dB	CH 1-6 OUT/124/18.
						7-12 OUT/62 /18
						13-18 OUT/31 /18
						19-24 8/18/124 /18
						25-30 12/18/124 /18
						31-36 18/18/124/18 CH31 LOW SIG. FILTER SW.
						37-42 27/18/124/18
						43-48 OUT/124/72 Slope
	017		AS 016 BUT WITH HI-CUT SLOPE 72dB/OCT			

OBSERVERS LOG	DFS IV	PAGE 2 of 4
Prospect:	No. Traces	Sampling
Line: Dirn:	Format	9 Track
Observer:	Offset	Stn. Para.
Date:	Sp. Int.	

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S.P.	R.N.	TIME	TAPE No.	SOURCE	Source Depth	COMMENTS
	018	GAIN ACCURACY TEST				4μV SIGNAL 84dB GAIN 3SEC RECORD
						12Hz " 24dB GAIN CONSTANT
						OP/PARALLEL SW. BAD CH 37-45
	019		"			4μV. 72dB 12Hz
	020		"			16μV 72dB
	021		"			16μV 60dB
	022		"			64μV 60dB
	023		"			64μV 48dB
	024		"			256μV 48dB
	025		"			256μV 36dB
	026		"			1024μV 36dB
	027		"			1024μV 24dB
	028		"			4mV 24dB
	029		"			4mV 12dB
	030		"			16mV 12dB
	031		"			16mV 0 12Hz
	032		"			16mV 0 36Hz
	033	HARMONIC DISTORTION				I.F.P. 64mV. 3SEC. 12Hz FILTERS OUT/124
	034		"			" " " 36Hz OUT/124
	035		"			" " " 36Hz 12/18/124/18
	036		"			" " " 12Hz — " —
	037		"			" " " 12Hz 8/18/124/18
	038		"			" " " 36Hz — " —
	039		"			" " " 12Hz AS REC #016
	040		"			" " " 36Hz — " —
	041		"			" " " 12Hz AS REC #017
	042		"			" " " 36Hz — " —

OBSERVERS LOG	DFS IV	PAGE 3 of 4
Prospect:	No. Traces	Sampling
Line: Dirn:	Format	9 Track
Observer:	Offset	Stn. Para.
Date:	Sp. Int.	

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S. P.	R.N.	TIME	TAPE No.	SOURCE	Source Depth	COMMENTS
	043	HARMONIC		DISTORTION		" " " 12Hz
						CH 1-12 OUT/124/18 NOTCH OUT
						CH 13-36 —"— NOTCH IN
						CH 37-48 —"— NOTCH OUT (BAD o/PARAMETER SET)
	044	———	"	———		AS 043 BUT 36Hz
	045	FILTER PULSE TEST				36dB manual. 1SEC REC.
						FILTERS AS 043
	046	CROSSFEED TEST			0dB	MAN GAIN. 1SEC REC. OUT/124/18
						64mV. 1-24 ODDS TERMINATED
						25-48 EVENS TERMINATED
	047	———	"	———		I.F.P. ——— " ———
	048	———	"	———	0dB	MAN GAIN 1SEC REC. OUT/124/18
						64mV. 1-24 EVENS TERMINATED
						25-48 ODDS TERMINATED
	049	———	"	———		I.F.P. ——— " ———
	050	———	"	———	0dB	MAN GAIN ——— " ———
						NOTCH-IN CH. 13-36
	051	———	"	———		I.F.P. ——— " ———
						NOTCH-IN CH. 13-36
	052	"DIRECT CHANNEL" RECORDING.				1SEC REC. 0dB MAN.
						P-PHONE TAPPED (-ve no. on tape).
	053	———	"	———		" " I.F.P.
	054	———	"	———		S-PHONE TAPPED 1SEC REC. 0dB MAN
	055	———	"	———		" " " " I.F.P.
	056	———	"	———		" " TAPPED VERTICALLY 0dB MAN
	057	———	"	———		" " TAPPED HORIZ. " "
	058	———	"	———		AS 048, GEOPH TAPPED 1SEC. MANUAL 0dB
	059	———	"	———		" " " " I.F.P.

OBSERVERS LOG | DFS IV | PAGE 4 of 4

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Prospect:	No. Traces	Sampling
Line: Dirn:	Format	9 Track
Observer:	Offset	Stn. Para.
Date:	Sp. Int.	

S. P.	R.N.	TIME	TAPE No.	SOURCE	Source Depth	COMMENTS
	060					1 SEC "ALL ONES"
	061					30 SEC "ALL ONES"
	062					110 SEC "ALL ONES"
	063					1 SEC. REC. F.T.B. RECORDED BY RADIO
	064					—— " ——
	065					—— " —— 2 SEC REC.
	066					—— " —— "
	067	EXPONENTIAL OSCILLATOR TEST 64mV. I.F.P. 8 SEC REC.				
		END OF TAPE — 2 TAPE MARKS				

NOTE: (PROGRAM P905)

1. STANDARD PRINT-OUT ANALYSIS REQUIRED FOR DRD, INST. NOISE, EXP. OSCILLATOR, FILTER PULSE, GAIN ACCURACY, HARMONIC DISTORTION AND CROSSFEED TESTS.
2. REQUIRE POWER AND PHASE SPECTRUM DISPLAY OF FILTER PULSE TESTS. REC. 13, 14, 15 — CH. 1 and 13. REC 45 — CH. 2, 14, 38. REC 16, 17. — CH. 2, 8, 14, 20, 26, 32, 38, 44.
3. REQUIRE TO KNOW GAIN WORD STATUS WITH REC# 012, AND IN PARTICULAR IF ANY GAIN WORD SETTING PROBLEMS AFTER 2 SEC DATA — ALSO FORMAT PRINT OUT.
4. FROM "DIRECT CHANNEL", REQUIRE POLARITY AND NUMBER DUMP. ALSO WIGGLE TRACE DISPLAY.
5. FROM "ALL ONES", DETERMINATION OF SKEW.
6. FROM F.T.B. TESTS, PRINT OUT OF WHEN F.T.B. IS BEING SET ON TAPE AND HOW LONG AFTER/BEFORE TIMING WORD ZERO.
7. TAPE SPEED ??
8. GAIN WORD STATUS WITH REC# 067, AND NUMBER DUMP

(10) MANUFACTURERS TEST EXAMPLES

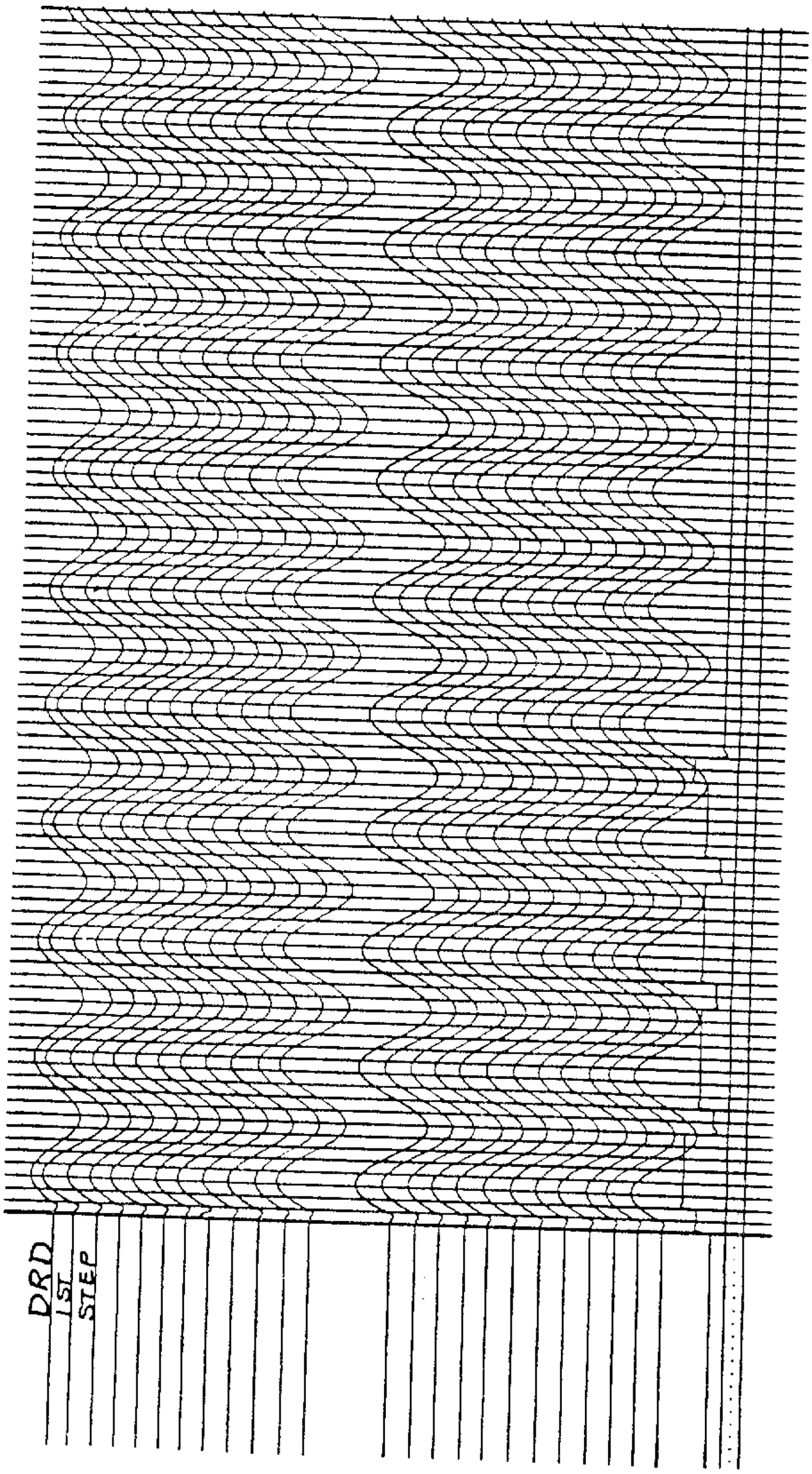

Figure 3.50 DRD EXAMPLE

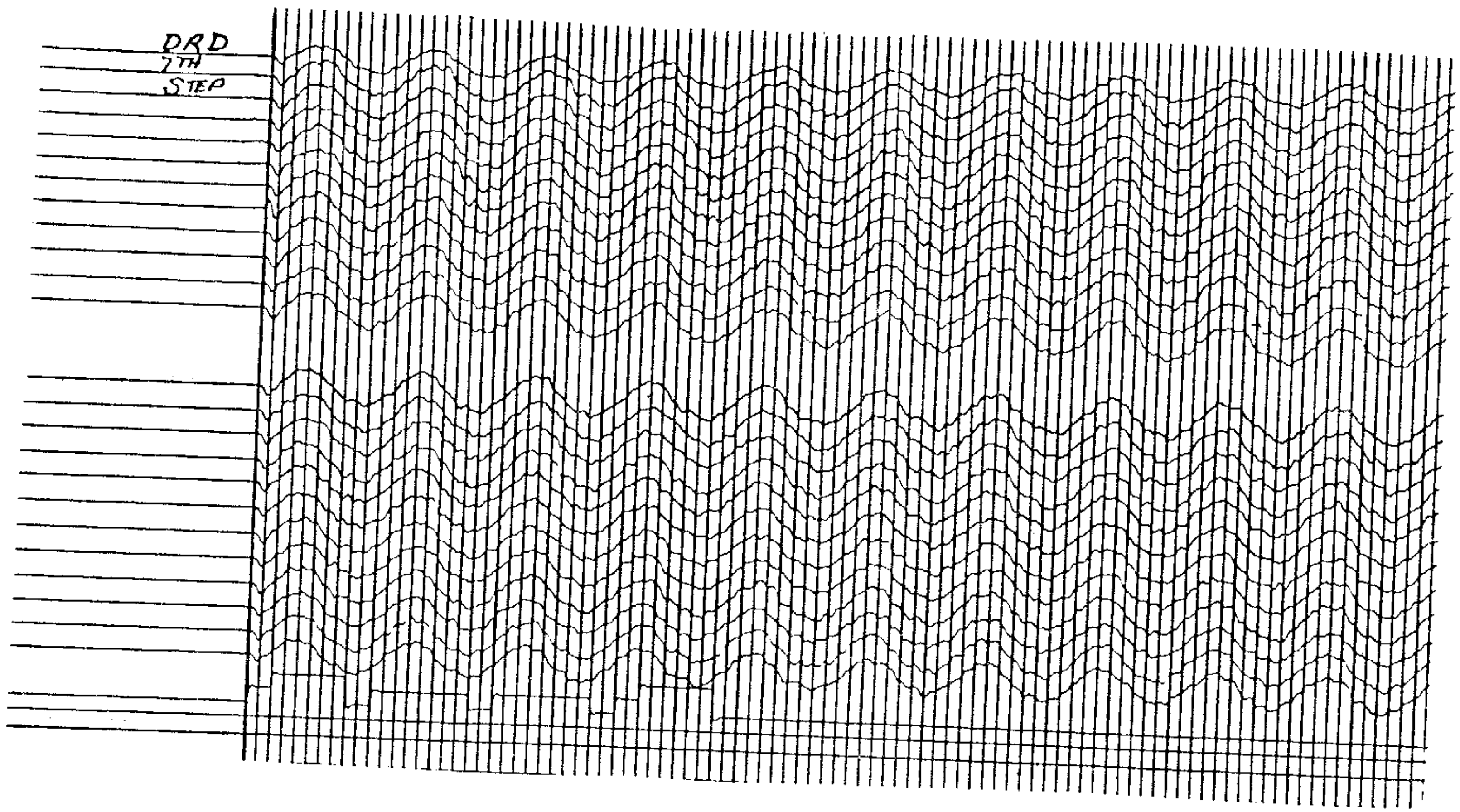

Figure 3.51 DRD EXAMPLE

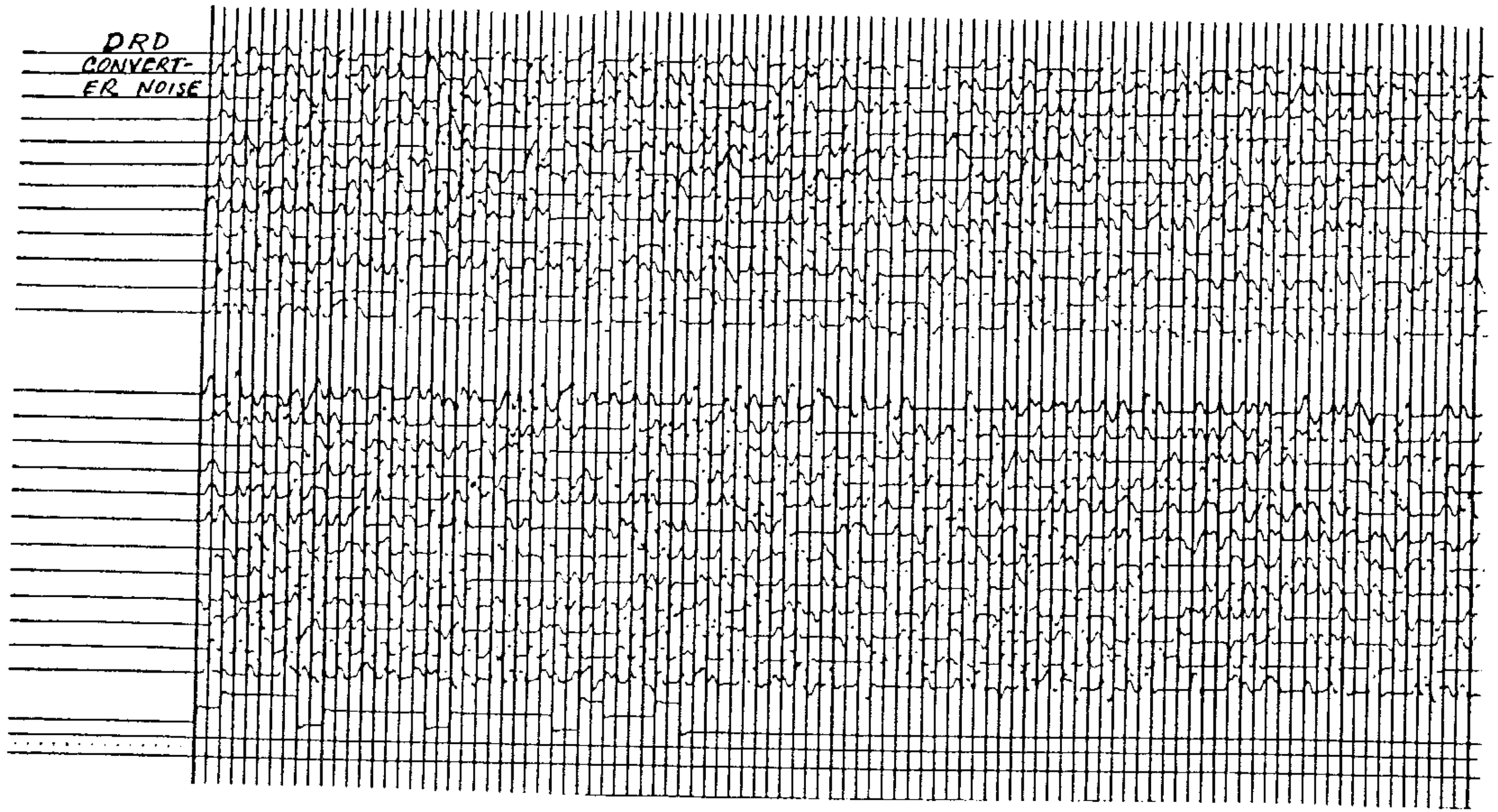

Figure 3.52 DRD EXAMPLE

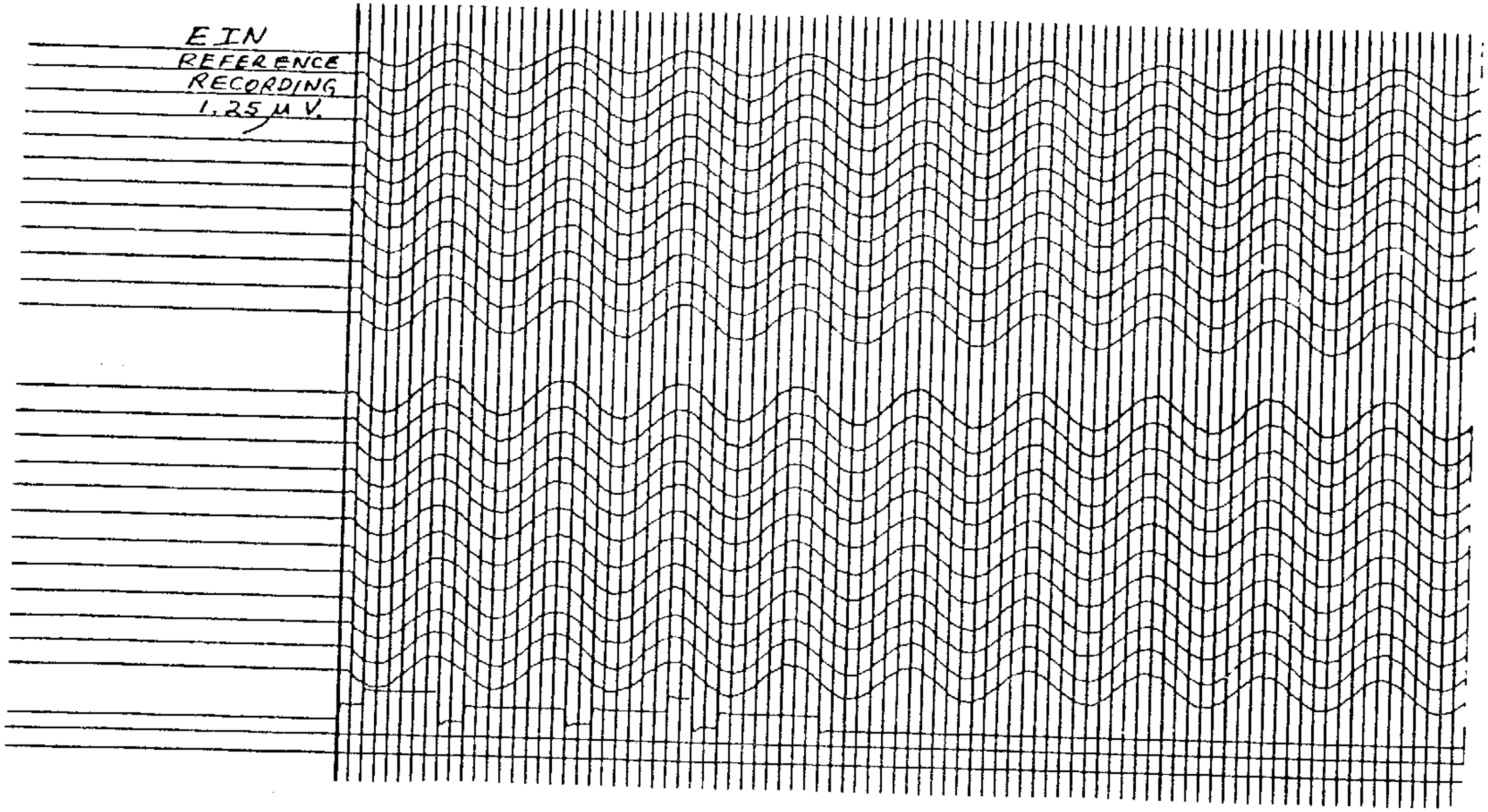

Figure 3.53 <u>REFERENCE SIGNAL EXAMPLE</u>

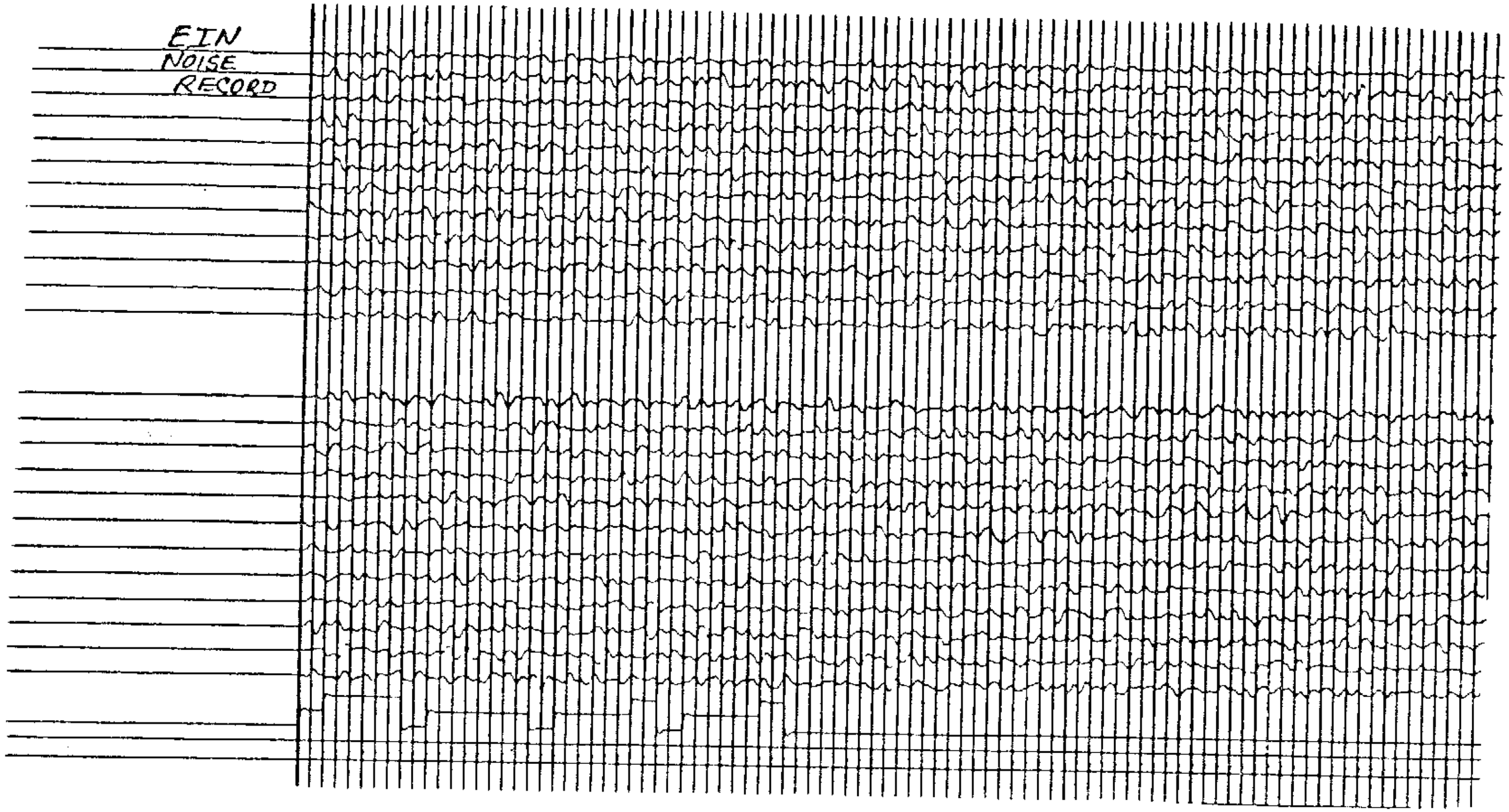

Figure 3.54 INSTRUMENT NOISE EXAMPLE

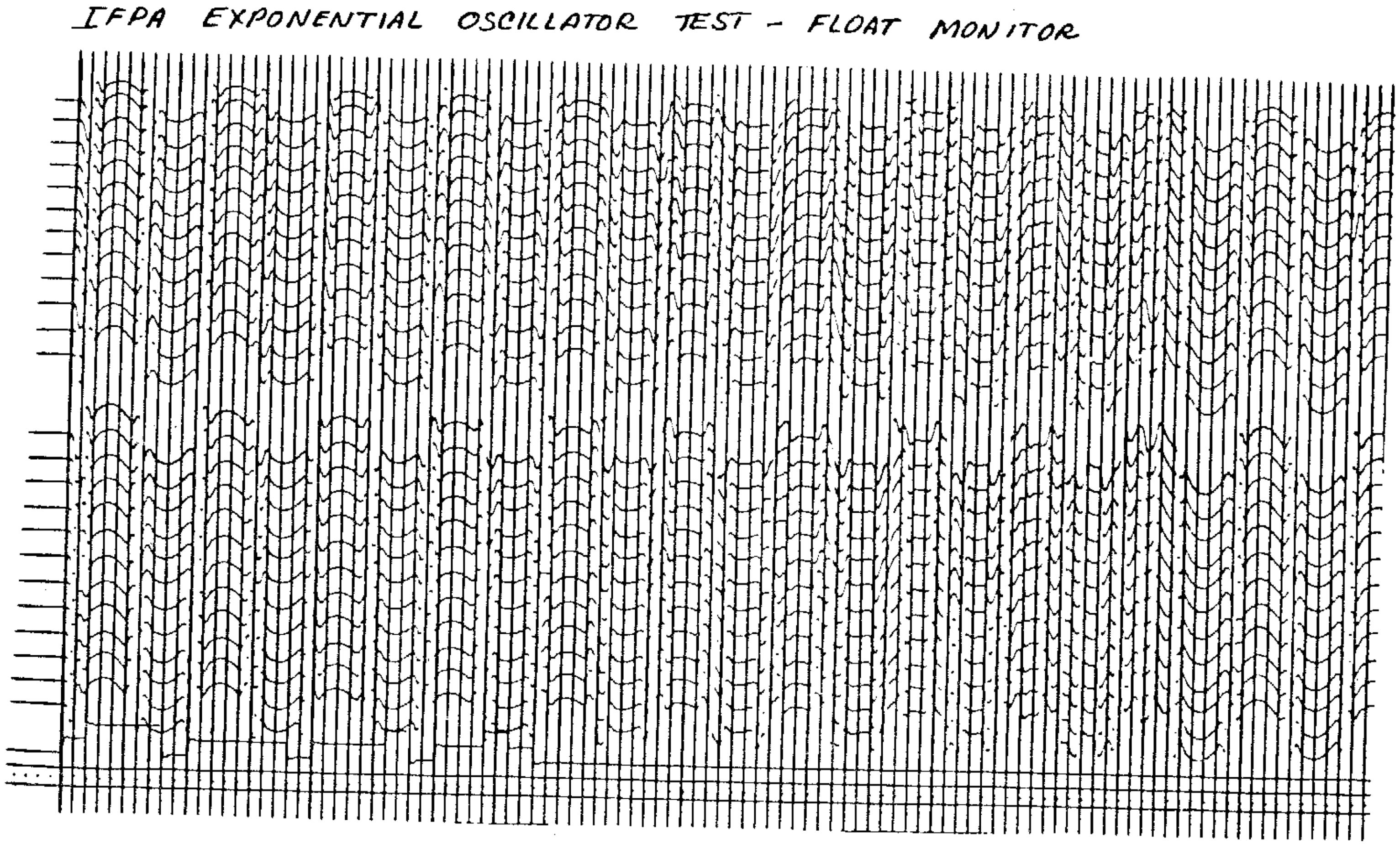

Figure 3.55 IFPA OSC EXAMPLE

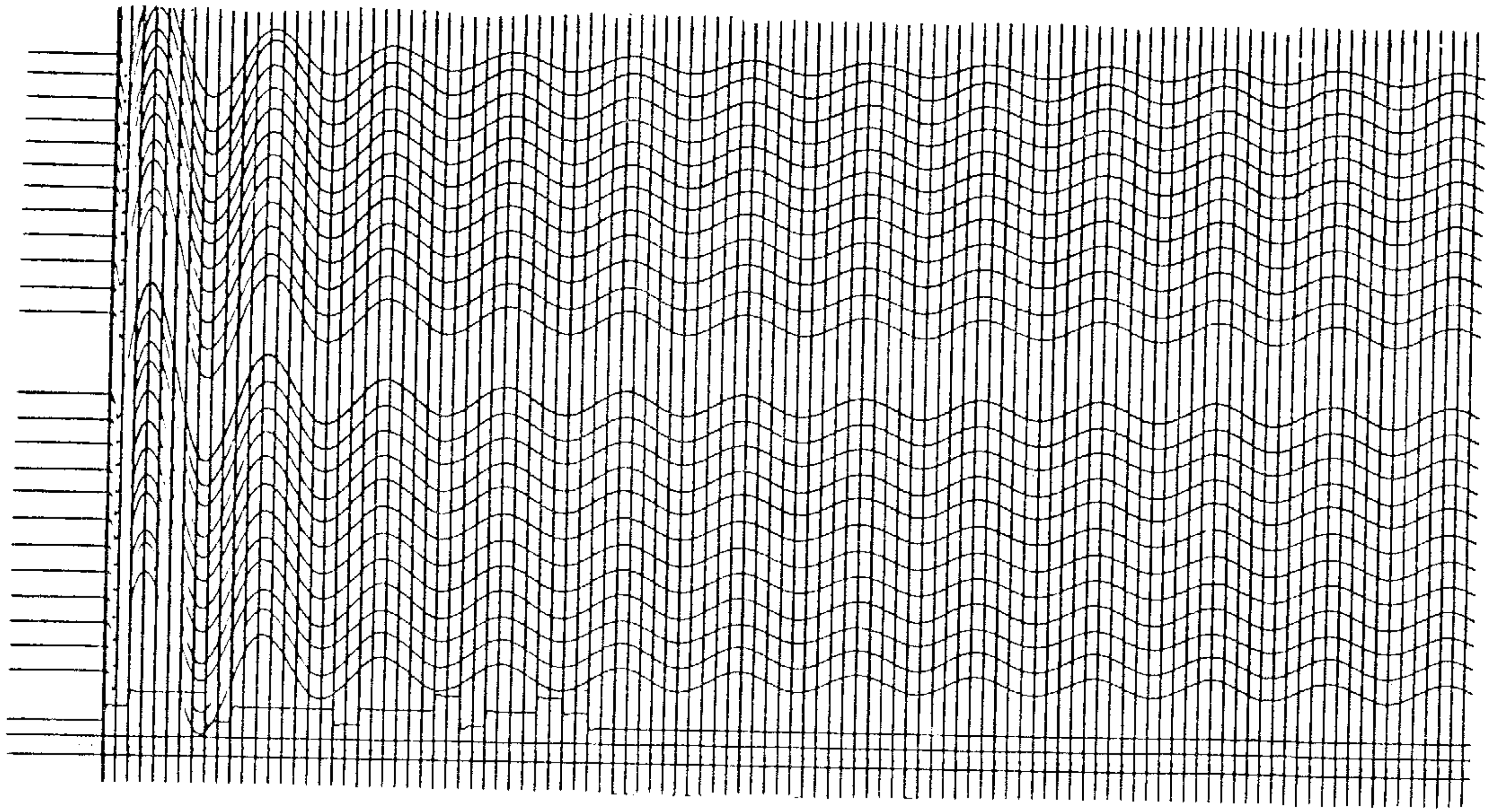

Figure 3.56 IFPA OSC EXAMPLE

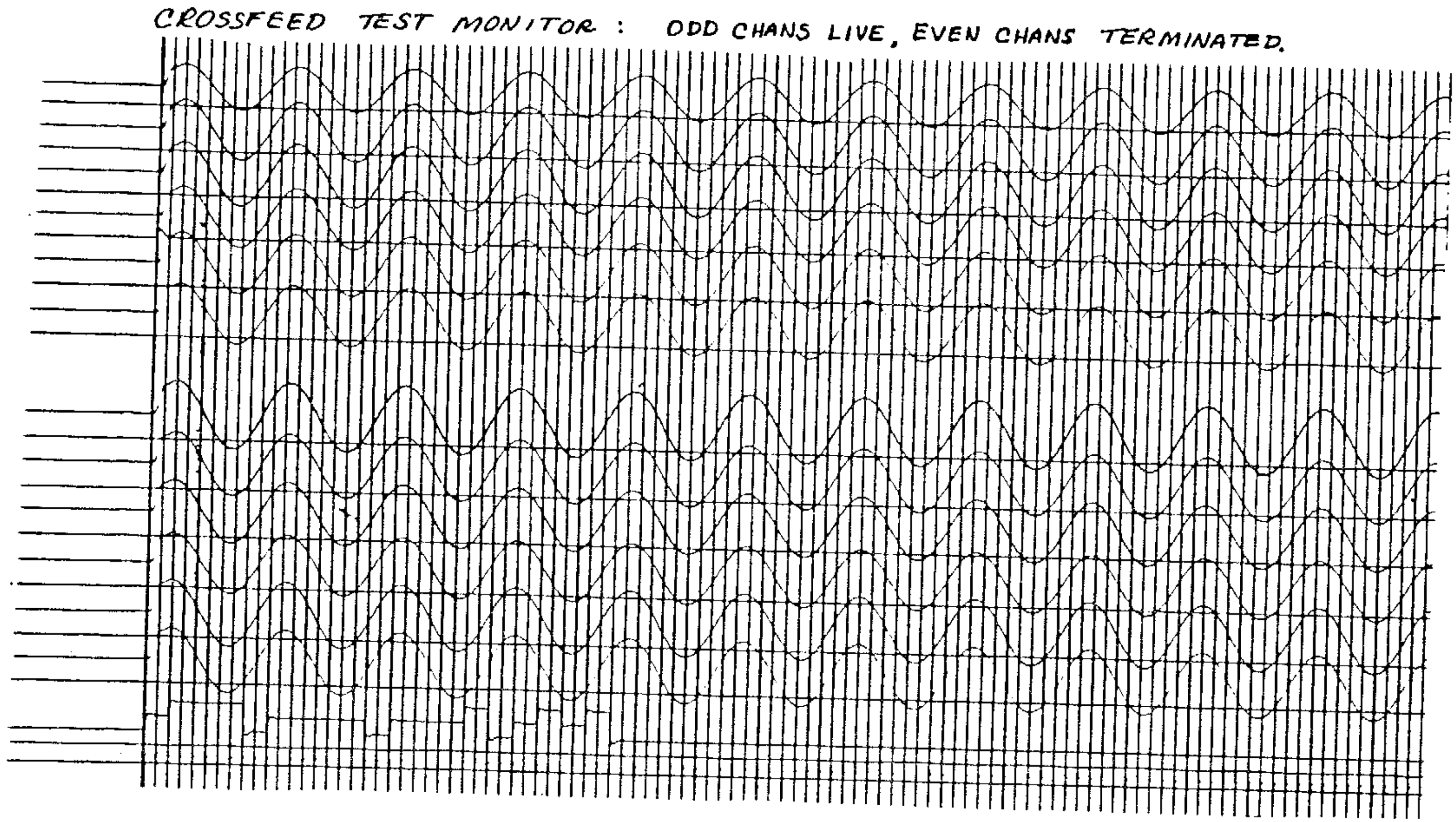

Figure 3.57 CROSSFEED EXAMPLE

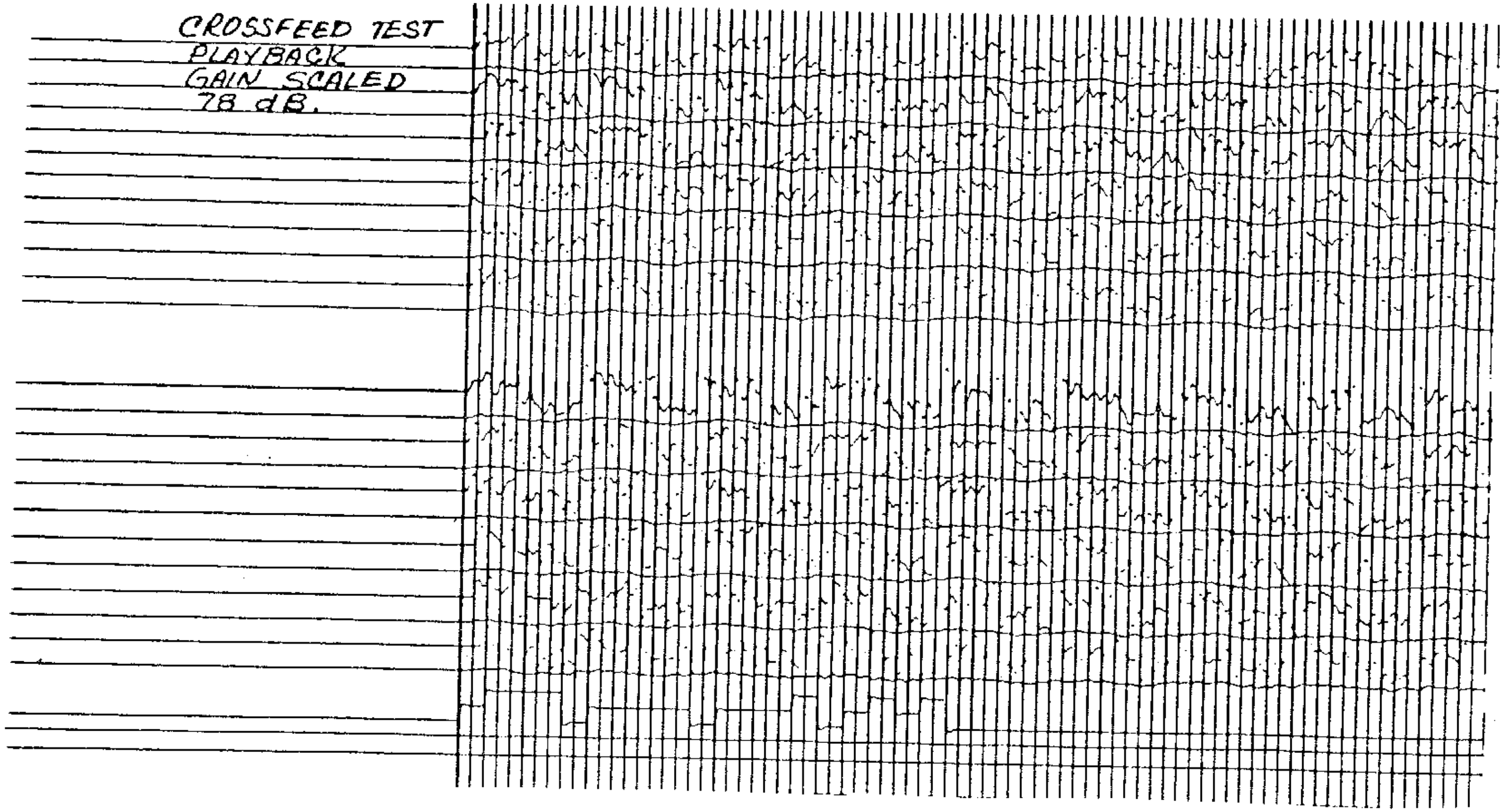

Figure 3.58 CROSSFEED EXAMPLE

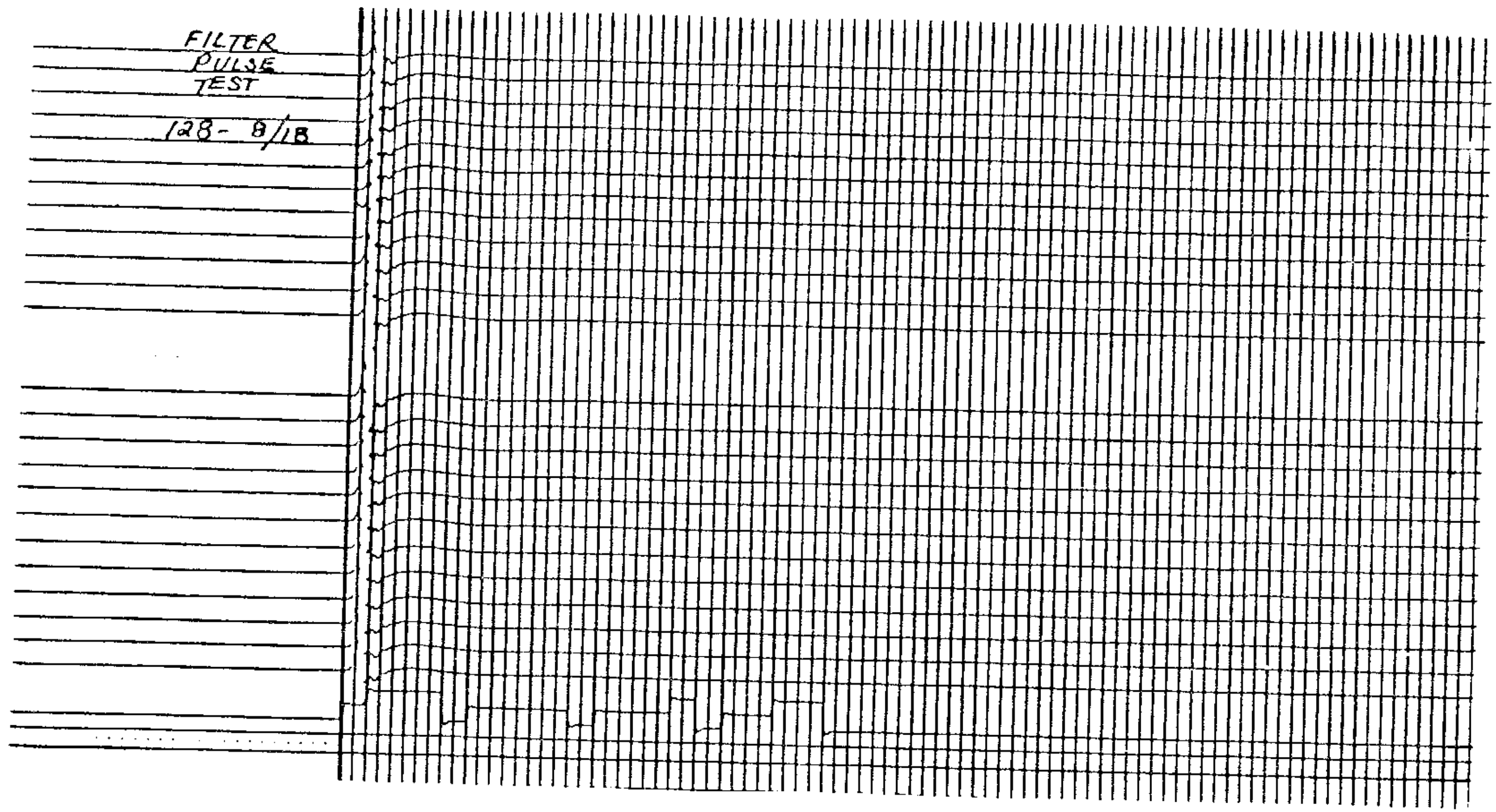

Figure 3.59 FILTER PULSE EXAMPLE

```
**** COMPUTED  IIIM =    0010    FIIM =    2044

    ++++++++++   1/2 INCH HEADER DECODE    ++++++++++

 ILE NUMBER = 0001
 ORMAT CODE = 0200
 GENERAL CONSTANTS = 020584000000
 BYTES PER SCAN =  134
 SAMPLE RATE =  2
 TO 21 SERIAL NUMBER =  15000171
 REC LL * 1024 =  02
 SYSTEM = TFP
 DATA RECORDED AS  TEST
 LOW CUT FILTER SETTING IN HZ =  00
 LOW CUT FILTER SLOPE IN DB/OCTAVE = 00
 NOTCH FILTER SETTING IN HZ =  00
 ALIAS FILTER SETTING IN HZ =  0128
 CHAN  FIXED   EARLY
  01   30  D0  00  08
 FIXED/EARLY GAINS SAME THRU CHA: 48
```

DYNAMIC RANGE TEST

ANALOG MODULE 1

CHAN	MAX VALUE AND	TIME	MIN VALUE AND	TIME	DC OFFSET	TRACE RMS	DB FROM FS
01	5987.0000**	2010	-5988.5000	0044	-16.5369	132.2759	2.7225
02	5994.0000**	2010	-5994.5000	0044	-16.5889	132.4237	2.7127
03	5990.5000**	1900	-5991.0000	0044	-16.5384	132.3594	2.7178
04	5992.0000**	1130	-5990.5000	0044	-16.3999	132.3823	2.7171
05	5991.0000**	1020	-5967.5000	1996	-16.2469	132.3576	2.7201
06	5992.5000**	0360	-5989.5000	1996	-16.2059	132.3945	2.7174
07	5996.0000**	0140	-5995.0000	1996	-16.1674	132.4758	2.7111
08	6000.5000**	0030	-6000.5000	1586	-16.0469	132.5789	2.7035
09	5995.5000**	0030	-5996.5000	1996	-16.0059	132.4791	2.7165
10	5984.5000**	0030	-5998.0000	1586	-16.5759	132.4735	2.7171
11	5994.0000**	0030	-5997.0000	1226	-1[illegible]	132.4434	2.7111
12	5998.5000**	0030	-6003.0000	1226	-15.7599	132.6004	2.7034
13	5995.0000**	0030	-6000.5000	1006	-15.6674	132.5487	2.7077
14	6001.0000**	1982	-6005.5000	0016	-15.4334	132.6761	2.6998
15	5993.5000**	1982	-5998.0000	0346	-15.4524	132.5003	2.7137
16	5998.0000**	1982	-6001.5000	0016	-15.3614	132.5778	2.7049
17	6001.0000**	1872	-6004.5000	0016	-15.2754	132.6402	2.7006
18	5998.5000**	1982	-5999.5000	0016	-15.1534	132.5655	2.7060
19	6001.0000**	1872	-6002.5000	0016	-15.1659	132.6232	2.7019
20	6003.5000**	1102	-6002.0000	0016	-14.9564	132.6599	2.7006
21	6003.0000**	1212	-6000.5000	0016	-14.9144	132.6538	2.7019
22	6000.5000**	0222	-5998.5000	1968	-14.7399	132.6049	2.7053
23	6007.0000**	0992	-6004.0000	1968	-14.8539	132.7476	2.6965
24	6002.0000**	0112	-6001.5000	1856	-14.5614	132.6428	2.7019
AVG	5996.660**		-5997.9140		-15.6837	132.5305	2.7084

ANALOG MODULE 2

CHAN	MAX VALUE AND	TIME	MIN VALUE AND	TIME	DC OFFSET	TRACE RMS	DB FROM FS
25	6000.5000**	0112	-6001.5000	1858	-14.5654	132.6210	2.7030
26	6008.0000**	0112	-6009.0000	1198	-14.3964	132.7955	2.6921
27	5998.0000**	0112	-6001.5000	1088	-14.2509	132.6091	2.7049
28	5998.0000**	0112	-6002.0000	1088	-14.1414	132.6347	2.7045
29	6000.0000**	0112	-6005.5000	0868	-14.0779	132.7099	2.7006
30	5987.5000**	1954	-5993.0000	1088	-13.9274	132.4193	2.7186
31	6000.0000**	1844	-6003.5000	0098	-13.8189	132.6660	2.7019
32	6000.5000**	1954	-6001.5000	0098	-13.6294	132.6348	2.7030
33	6003.5000**	1844	-6006.0000	0098	-13.7984	132.7296	2.6976
34	6006.5000**	1954	-6009.0000	0098	-13.7429	132.7861	2.6933
35	6001.5000**	1184	-6001.5000	0098	-13.4864	132.6677	2.7023
36	6006.0000**	1954	-6003.5000	0096	-13.4589	132.7407	2.6976
37	5949.5000**	1184	-5945.5000	1940	-13.0654	131.5085	2.7608
38	5945.0000**	0084	-5941.5000	1940	-13.0704	131.4151	2.7870
39	5952.0000**	0084	-5952.5000	1830	-12.7809	131.6020	2.7730
40	6009.5000**	0084	-6012.5000	1940	-12.7189	132.8982	2.6886
41	5987.0000**	0084	-5986.0000	1940	-12.9244	132.3450	2.7240
42	6012.5000**	0084	-6013.5000	1940	-12.8134	132.9230	2.6856
43	5966.0000**	2036	-5971.5000	0290	-12.1974	132.0003	2.7499
44	5928.0000**	2036	-5932.0000	0180	-11.9309	131.1258	2.8064
45	6000.5000**	0084	-6006.5000	1060	-12.4049	132.7532	2.6995
46	6004.5000**	2036	-6008.5000	0400	-12.2549	132.8022	2.6952
47	6004.5000**	2035	-6008.5000	0070	-12.1819	132.7939	2.6952
48	5999.0000**	2036	-6003.0000	0070	-12.1254	132.6751	2.7030
[illegible] AVG	5990.3320**		-5992.4570		-13.2401	132.4521	2.7170

```
 NOV80   TIME 11:27:12
 SISn=2,
 KL=09,
 CL=1,
 >

 ORMAT =52
 ALPA =1
     =0
     =-1
     =2
     =1
     =48
     =0
     =2
     =1
     =0
     =09
     =1
 AT  =0
```

Table 3.14 <u>COMPUTER PRINT-OUT</u>

<u>OF DRD TEST</u>

```
 UT RECORD =  0009
  PARITY ERRORS DETECTED IN THIS HEADER RECORD
  PARITY ERRORS DETECTED IN THIS DATA RECORD
 ORD LENGTH =   1024 MSEC

   ++++++++++   1/2 INCH HEADER DECODE    ++++++++++

 E NUMBER = 0009
 MAT CODE = 0200
 ERAL CONSTANTS = 020584000000
  S PER SCAN =  134
 LE RATE =  2
 AND SERIAL NUMBER =  15000171
 C LEN * 1024 =  01
 STEM =  TFP
 TA RECORDED AS  TEST
 W CUT FILTER SETTING IN HZ    00
```

```
[illegible]
NO PARITY ERRORS DETECTED ON THIS DATA RECORD
RECORD LENGTH =    1024 MSEC

 ++++++++++    1/2 INCH HEADER DECODE    ++++++++++

FILE NUMBER = 0009
FORMAT-CODE = 0200
GENERAL CONSTANTS = 020584000000
BYTES PER SCAN =  134
SAMPLE RATE =  2
[illegible] AND SERIAL NUMBER =  15000171
[illegible] * 1024 =  01
SYSTEM =  IFP
DATA [illegible]CORDED AS  TEST
LOW CUT FILTER SETTING IN HZ =  00
LOW CUT FILTER SLOPE IN DB/OCTAVE = 00
[illegible] FILTER SETTING IN HZ =  00
ALIAS FILTER SETTING IN HZ =  0128
CHAN  FIXED   EARLY
 01   30  DB  00  DB
FIXED/EARLY GAINS SAME THRU CHAN 48

CONVERTER NOISE ANALYSIS

ANALOG MODULE  1

LIMITS USED FOR THIS TEST ARE    MINIMUM DB =    78.0000    MAX DC OFFSET =    0.0000    MIN DC OFFSET =
```

CHAN	MAX VALUE	AND TIME	MIN VALUE	AND TIME	DC OFFSET	TRACE RMS	DB FROM FS
01	1.0000	0012	0.0000	0004	0.6769**	0.2552	84.2879
02	1.5000	0128	0.0000	0082	0.7079**	0.2602	80.7663
03	1.5000	0130	0.0000	0006	0.6859**	0.2634	80.7663
04	1.5000	0126	0.0000	0390	0.6949**	0.2616	80.7663
05	1.5000	0314	0.0000	0240	0.6989**	0.2586	80.7663
06	1.0000	0000	0.0000	0046	0.7229**	0.2505	84.2879
07	1.5000	0846	0.0000	0010	0.7219**	0.2601	80.7663
08	1.0000	0002	0.0000	0356	0.7219**	0.2543	84.2879
09	1.5000	0470	0.0000	0372	0.6759**	0.2510	80.7663
10	1.0000	0002	0.0000	0482	0.6989**	0.2487	84.2879
11	1.5000	0742	0.0000	0154	0.7039**	0.2614	80.7663
12	1.5000	0446	0.0000	0006	0.7299**	0.2551	80.7663
13	1.5000	0232	0.0000	0010	0.6609**	0.2715	80.7663
14	1.5000	0096	0.0000	0364	0.7219**	0.2582	80.7663
15	1.5000	0012	0.0000	0068	0.7069**	0.2590	80.7663
16	1.0000	0018	0.0000	0168	0.6799**	0.2580	84.2879
17	1.5000	0512	0.0000	0958	0.7209**	0.2522	80.7663
18	1.5000	0060	0.0000	0798	0.7299**	0.2628	80.7663
19	1.5000	0318	0.0000	0068	0.7249**	0.2604	80.7665
20	1.0000	0000	0.0000	0106	0.7099**	0.2547	84.2879
21	1.5000	0318	0.0000	0006	0.6779**	0.2555	80.7663
22	1.5000	0130	0.0000	0142	0.6989**	0.2566	80.7663
23	1.5000	0704	0.0000	0074	0.7079**	0.2621	80.7665
24	1.5000	0242	0.0000	0482	0.7249**	0.2604	80.7665
AVG	1.3750		0.0000		0.7050**	0.2580	81.6467

ANALOG MODULE 2

CHAN	MAX VALUE	AND TIME	MIN VALUE	AND TIME	DC OFFSET	TRACE RMS	DB FROM FS
25	1.5000	0174	0.0000	0368	0.6599**	0.2517	80.7663
26	1.0000	0000	0.0000	0030	0.7089**	0.2525	84.2879
27	1.0000	0000	0.0000	0396	0.7189**	0.2540	84.2879
28	1.5000	0374	0.0000	0730	0.7089**	0.2525	80.7663
29	1.5000	0540	0.0000	0160	0.7319**	0.2591	80.7663
30	1.0000	0002	0.0000	0052	0.7209**	0.2522	84.2879
31	1.5000	0496	0.0000	0366	0.7079**	0.2583	80.7663
32	1.5000	0328	0.0000	0822	0.7449**	0.2539	80.7663
33	1.5000	0120	0.0000	0034	0.6909**	0.2569	80.7663
34	1.0000	0000	0.0000	0190	0.6809**	0.2563	84.2879
35	1.0000	0014	0.0000	0454	0.6669**	0.2400	84.2879
36	1.0000	0004	0.0000	0114	0.7359**	0.2594	84.2879
37	1.0000	0000	0.0000	0182	0.6879**	0.2482	84.2879
38	1.5000	0018	0.0000	0232	0.6819**	0.2507	80.7663
39	1.0000	0002	0.0000	0250	0.7099**	0.2507	84.2879
40	1.5000	0140	0.0000	0018	0.7349**	0.2593	80.7663
41	1.5000	0008	0.0000	0044	0.7109**	0.2607	80.7663
42	1.5000	0054	0.0000	0356	0.6929**	0.2573	60.7663
43	1.5000	0526	0.0000	0006	0.6999**	0.2664	80.7663
44	1.5000	0414	0.0000	0154	0.7319**	0.2610	80.7663
45	1.5000	0170	0.0000	0120	0.7299**	0.2666	80.7663
46	1.5000	0430	0.0000	0224	0.6449**	0.2417	80.7663
47	1.5000	0052	0.0000	0026	0.6889**	0.2641	80.7663
48	1.5000	0096	0.0000	0204	0.7279**	0.2626	80.7663
AVG	1.3333		0.0000		0.7050**	0.2557	81.9401

```
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

NOV84  TIME 11:27:29
SISW=3,
IC=10,
 C=1,

FORMAT =52
 [illegible]RA =1
 [illegible]  =0
 [illegible]  =-1
 [illegible]  =2
 [illegible]  =1
 [illegible]  =48
 PORT =0
 SISW =3
 CODE =1
 COMP =0
 [illegible]  =10
 [illegible]  =1
 [illegible]T =0

OUT RECORD =  0010
NO PARITY ERRORS DETECTED ON THIS HEADER RECORD
NO PARITY ERRORS DETECTED ON THIS DATA RECORD
RECORD LENGTH =    1024 MSEC

*** COMPUTED  ITIM =    0010    FITM =    1000

 ++++++++++    1/2 INCH HEADER DECODE    ++++++++++

ILE NUMBER = 0010
ORMAT CODE = 0200
ENERAL CONSTANTS = 020584000000
YTES PER SCAN =  134
AMPLE RATE =  2
[illegible]
```

Table 3.15 COMPUTER PRINT OUT OF CONVERTER NOISE

```
... PER SCAN = 134
SAMPLE RATE = 2
... AND SERIAL NUMBER = 15000171
REC LEN * 1024 = 01
SYSTEM = TFP
DATA RECORDED AS TEST
.. CUT FILTER SETTING IN HZ = 00
.W CUT FILTER SLOPE IN DB/OCTAVE = 00
NOTCH FILTER SETTING IN HZ = 00
ALIAS FILTER SETTING IN HZ = 0128
CHAN FIXED EARLY
01 .. DB 84 DB
FIXED/EARLY GAINS SAME THRU CHAN 48

EQUIVALENT INPUT NOISE REFERENCE TEST RECORD.
RMS IS IN MICROVOLTS. DC OFFSET IS IN MILLIVOLTS.

ANALOG MODULE 1

LIMITS USED FOR THIS TEST ARE MINIMUM RMS = 1.2199 OR 4.9099 MAXIMUM RMS = 1.2799
```

CHAN	MAX VALUE AND	TIME	MIN VALUE AND	TIME	DC OFFSET	TRACE RMS
01	0.1121	0718	-0.0988	0648	97.0535	2.0302**
02	0.1431	0718	-0.1309	0952	-23.6264	2.1781**
03	0.1054	0856	-0.1057	0952	-1.4017	2.0638**
04	0.1094	0224	-0.1109	0870	-81.0265	2.0849**
05	0.1090	0554	-0.1036	0072	52.5860	2.0740**
06	0.1267	0140	-0.1034	0622	39.2469	2.0578**
07	0.1119	0772	-0.1077	0870	28.7125	2.0726**
08	0.1212	0332	-0.1099	0538	120.4564	2.0792**
09	0.1016	0552	-0.1164	0868	-77.2692	2.0615**
10	0.1138	0496	-0.1044	0898	6.7752	2.0705**
11	0.1048	0966	-0.1080	0758	-48.6214	2.0584**
12	0.1100	0334	-0.1091	0210	-16.5495	2.0773**
13	0.1244	0636	-0.1073	0540	175.9392	2.0950**
14	0.1122	0744	-0.1023	0868	61.4058	2.0793**
15	0.1243	0910	-0.1058	0016	185.8956	2.0419**
16	0.1050	0662	-0.1311	0670	-149.9696	2.1002**
17	0.1295	0526	-0.0903	0372	298.5556	2.0624**
18	0.1079	0800	-0.1098	0428	43.5406	2.0697**
19	0.1213	0470	-0.1050	0676	172.6699	2.0816**
20	0.1191	0690	-0.1091	0236	118.6932	2.0657**
21	0.1374	0772	-0.0919	0236	348.7045	2.1009**
22	0.1167	0828	-0.1069	0372	62.6740	2.0742**
23	0.1333	0248	-0.0908	0702	281.3359	2.0704**
24	0.1093	0910	-0.1109	0016	25.8329	2.0704**
MOD AVG	0.1170		-0.1072		71.9046	2.0775**

ANALOG MODULE 2

CHAN	MAX VALUE AND	TIME	MIN VALUE AND	TIME	DC OFFSET	TRACE RMS
25	0.1428	0304	-0.0870	0126	383.7124	2.0798**
26	0.1250	0222	-0.0890	0426	323.0322	2.0702**
27	0.1283	0662	-0.0949	0070	303.4938	2.0712**
28	0.1260	0772	-0.0974	0180	297.4594	2.0641**
29	0.1257	0772	-0.0846	0428	360.6467	2.0408**
30	0.1293	0524	-0.0885	0208	341.6831	2.0507**
31	0.1334	0662	-0.0833	0420	389.1274	2.0747**
32	0.1432	0194	-0.0800	0016	443.9646	2.0632**
33	0.1369	0194	-0.0892	0538	429.0119	2.0931**
34	0.1187	0094	-0.1092	0318	46.6601	2.0811**
35	0.1289	0552	-0.0858	0702	348.3398	2.0607**
36	0.1310	0414	-0.0846	0730	364.2204	2.0609**
37	0.1388	0112	-0.0958	0262	376.6716	2.0709**
38	0.1298	0660	-0.1100	0016	101.8398	2.0725**
39	0.1687	0986	-0.1271	0922	435.5483	2.1921**
40	0.1716	0664	-0.1674	0892	276.6091	2.3173**
41	0.1437	0664	-0.1567	0262	42.4422	2.1665**
42	0.1155	0058	-0.0973	0016	96.4797	2.0560**
43	0.1692	0990	-0.1691	0234	248.4678	2.2923**
44	0.1596	0990	-0.1482	0234	188.3693	2.2485**
45	0.1221	0796	-0.1022	0454	153.4726	2.0724**
46	0.1160	0112	-0.0962	0344	167.8625	2.0625**
47	0.1135	0112	-0.1056	0648	74.9210	2.0672**
48	0.1205	0552	-0.0992	0318	140.2540	2.0607**
MOD AVG	0.1349		-0.1060		258.2641	2.1037**

```
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

DNOV84 TIME 11:27:42
SISW=4,
REC=11,
ND

FORMAT =52
..IRA =1
TIM =0
TIM =-1
MOD =2
TRC =1
TRC =48
EPORT =0
ISISW =4
RCODE =1
LDUMP =0
TREC =11
NREC =1
.PDAT =0
END

INPUT RECORD = 0011
  NO PARITY ERRORS DETECTED ON THIS HEADER RECORD
  NO PARITY ERRORS DETECTED ON THIS DATA RECORD
RECORD LENGTH = 1024 MSEC

    ++++++++++  1/2 INCH HEADER DECODE  ++++++++++

FILE NUMBER = 0011
FORMAT CODE = 0200
GENERAL CONSTANTS = 020583000000
BYTES PER SCAN = 134
SAMPLE RATE = 2
ID AND SERIAL NUMBER = 15000171
REC LEN * 1024 = 01
SYSTEM = TFP
DATA RECORDED AS TEST
. CUT FILTER SETTING IN HZ = 00
.W CUT FILTER SLOPE IN DB/OCTAVE = 00
NOTCH FILTER SETTING IN HZ = 00
ALIAS FILTER SETTING IN HZ = 0128
CHAN FIXED EARLY
01 30 DB 84 DB
FIXED/EARLY GAINS SAME THRU CHAN 48
```

Table 3.16 COMPUTER PRINT OUT OF REFERENCE SIGNAL

```
...BER = 0011
FORMAT CODE = 0200
GENERAL CONSTANTS = 02058400P000
BYTES PER SCAN = 134
SAMPLE RATE = 2
ID AND SERIAL NUMBER = 15000171
REC LEN * 1024 = 01
SYSTEM = TFP
DATA RECORDED AS TEST
LOW CUT FILTER SETTING IN HZ = 00
LOW CUT FILTER SLOPE IN DB/OCTAVE = 00
NOTCH FILTER SETTING IN HZ = 00
ALIAS FILTER SETTING IN HZ = 0120
CHAN FIXED EARLY
 01  30 DB  84  0d
FIXED/EARLY GAINS SAME THRU CHAN 48

EQUIVALENT INPUT NOISE TEST RECORD.
RMS IS IN MICROVOLTS. DC OFFSET IS IN MILLIVOLTS.
```

ANALOG MODULE 1

LIMITS USED FOR THIS TEST ARE MAX DC OFFSET = +/- 25.0000 MAXIMUM NOISE = 0.6149

CHAN	MAX VALUE	AND TIME	MIN VALUE	AND TIME	DC OFFSET	TRACE RMS
01	0.0249	0372	-0.0124	0750	87.1509**	0.1938
02	0.0188	0576	-0.0179	0644	-5.1839	0.2062
03	0.0229	0526	-0.0190	0538	2.0979	0.2039
04	0.0152	0254	-0.0219	0332	-67.9639**	0.2139
05	0.0204	0404	-0.0193	0854	57.5139**	0.1967
06	0.0301	0014	-0.0216	0786	60.2659**	0.2243
07	0.0236	0288	-0.0178	0202	25.2009**	0.1992
08	0.0411	0780	-0.0135	0252	144.8949**	0.2391
09	0.0180	0668	-0.0238	0910	-68.0879**	0.2035
10	0.0253	0515	-0.0311	0062	19.2669	0.2542
11	0.0155	0302	-0.0192	0566	-49.0929**	0.1878
12	0.0234	0330	-0.0220	0494	-5.3309	0.2166
13	0.0489	0632	-0.0042	0784	265.1279**	0.2786
14	0.0302	0624	-0.0090	0508	146.9059**	0.2107
15	0.0428	0484	-0.0086	0190	270.4069**	0.2434
16	0.0214	0884	-0.0279	0774	-52.8359**	0.2623
17	0.0433	0586	0.0036	0972	388.5798**	0.2390
18	0.0289	0402	-0.0132	0756	142.7829**	0.2375
19	0.0383	0312	-0.0023	0128	266.2148**	0.2051
20	0.0372	0424	-0.0070	0026	206.0519**	0.2167
21	0.0475	0610	0.0098	0828	457.5539**	0.2123
22	0.0341	0026	-0.0158	0432	161.3699**	0.2370
23	0.0423	0966	0.0023	0962	370.7067**	0.2064
24	0.0311	0946	-0.0122	0888	138.6909**	0.2098
MOD AVG	0.0302		-0.0135		123.2619**	0.2207

ANALOG MODULE 2

CHAN	MAX VALUE	AND TIME	MIN VALUE	AND TIME	DC OFFSET	TRACE RMS
25	0.0489	0166	0.0079	0808	464.5087**	0.1975
26	0.0471	0276	0.0030	0630	433.4509**	0.2082
27	0.0453	0520	0.0048	0748	401.5397**	0.1952
28	0.0417	0890	0.0038	0524	379.2419**	0.2052
29	0.0466	0738	0.0012	0634	464.2939**	0.2029
30	0.0462	0692	0.0087	0346	451.5370**	0.2045
31	0.0557	0630	0.0074	0438	491.3790**	0.2010
32	0.0527	0460	0.0141	0116	543.4528**	0.2028
33	0.0500	0946	0.0147	0296	515.5949**	0.1874
34	0.0256	0228	-0.0107	0306	159.3939**	0.1965
35	0.0447	0402	0.0017	0134	441.9709**	0.2073
36	0.0476	0620	0.0035	0670	458.9297**	0.2136
37	0.0422	0302	-0.0018	0766	375.1838**	0.2167
38	0.0318	0358	-0.0202	0618	101.5549**	0.2445
39	0.0461	0940	0.0070	0606	411.6909**	0.2185
40	0.0420	0370	-0.0137	0404	260.1967**	0.2226
41	0.0250	1000	-0.0134	0158	70.7539**	0.1869
42	0.0320	1000	-0.0310	0038	95.2029**	0.2172
43	0.0341	0530	-0.0039	0236	211.5609**	0.2077
44	0.0353	0000	-0.0159	0434	194.9139**	0.2304
45	0.0306	0278	-0.0146	0346	169.3239**	0.2101
46	0.0450	0088	-0.0127	0268	198.2209**	0.2303
47	0.0255	0716	-0.0138	0364	72.9289**	0.1952
48	0.0271	0443	-0.0134	0660	124.8999**	0.2075
MOD AVG	0.0404		-0.0037		311.9079**	0.2087

- -

```
10NOV84  TIME 11:27:54
NIRC=4,
TESTSW=9,
TREC=12,
 ND

 FORMAT =52
 NUMTRA =1
 TIIM   =0
 TTIM   =-1
 MOD    =2
 TRC    =1
 NIRC   =4
 REPORT =0
 TESTSW =9
 ECODE  =1
 DUMP   =0
 TREC   =12
 TRSC   =1
 RDAT   =0
 END
```

Table 3.17 COMPUTER PRINT OUT OF INPUT NOISE

```
INPUT RECORD =  0012
  NO PARITY ERRORS DETECTED ON THIS HEADER RECORD
  NO PARITY ERRORS DETECTED ON THIS DATA RECORD
RECORD LENGTH =   8192 MSEC

    ++++++++++   1/2 INCH HEADER DECODE   ++++++++++

FILE NUMBER = 0012
FORMAT CODE = 0200
GENERAL CONSTANTS = 02058400000
BYTES PER SCAN = 134
SAMPLE RATE = 2
ID AND SERIAL NUMBER = 15000171
REC LEN * 1024 = 08
SYSTEM = TFP
DATA RECORDED AS TEST
LOW CUT FILTER SETTING IN HZ = 00
LOW CUT FILTER SLOPE IN DB/OCTAVE = 00
NOTCH FILTER SETTING IN HZ = 00
ALIAS FILTER SETTING IN HZ = 0120
```

DECODE =1
HEDUMP =0
IREC =12
NREC =1
DMPDAT =0
END

INPUT RECORD = 0012
NO PARITY ERRORS DETECTED ON THIS HEADER RECORD
NO PARITY ERRORS DETECTED ON THIS DATA RECORD
RECORD LENGTH = 8192 MSEC

++++++++++ 1/2 INCH HEADER DECODE ++++++++++

FILE NUMBER = 0012
FORMAT CODE = 0200
GENERAL CONSTANTS = 020584000000
BYTES PER SCAN = 134
SAMPLE RATE = 2
ID AND SERIAL NUMBER = 15000171
REC LEN * 1024 = 08
SYSTEM = IFP
DATA RECORDED AS TEST
LOW CUT FILTER SETTING IN HZ = 00
LOW CUT FILTER SLOPE IN DB/OCTAVE = 00
NOTCH FILTER SETTING IN HZ = 00
ALIAS FILTER SETTING IN HZ = 0128
CHAN FIXED EARLY
01 30 DB 00 DB
FIXED/EARLY GAINS SAME THRU CHAN 04

IFPA OSCILLATOR TEST

FREQUENCY SAMPLE RATE IS 0.1221 FUNDAMENTAL FREQUENCY IS 35.8659

FOR TRACE 1, CHANNEL GAINS WERE TESTED IN 196 TIME GATES.
THE LAST GAIN TESTED WAS 0 DB.

FOR TRACE 4, CHANNEL GAINS WERE TESTED IN 196 TIME GATES.
THE LAST GAIN TESTED WAS 0 DB.

	TR = 1		TR = 4	
INDEX	TIME	GAIN	TIME	GAIN
1	2	0	2	0
10	380	0	380	0
20	798	0	798	0
30	1216	0	1216	0
40	1634	0	1634	0
50	2052	0	2052	0
60	2470	0	2470	0
70	2888	0	2888	0
80	3308	0	3306	0
90	3726	0	3726	0
100	4144	0	4144	0
110	4562	0	4562	0
120	4980	0	4980	0
130	5398	0	5398	0
140	5816	0	5816	0
150	6228	0	6228	0
160	6646	0	6646	0
170	7064	0	7064	0
180	7484	0	7484	0
190	7902	0	7902	0

*** THIS IFPA OSCILLATOR TEST IS NOT ACCEPTABLE.

- -

10NOV84 TIME 11:28:05
TESTSW=10,
IREC=13,
NREC=3,
END1

FORMAT =52
NUMTRA =1
TTIM =0
FTIM =-1
AMOD =2
ITRC =1
NTRC =4
REPORT =0
TESTSW =10
DECODE =1
HEDUMP =0
IREC =13
NREC =3
DMPDAT =0
END

INPUT RECORD = 0013
NO PARITY ERRORS DETECTED ON THIS HEADER RECORD
NO PARITY ERRORS DETECTED ON THIS DATA RECORD
RECORD LENGTH = 1024 MSEC

++++++++++ 1/2 INCH HEADER DECODE ++++++++++

FILE NUMBER = 0013
FORMAT CODE = 0200
GENERAL CONSTANTS = 020584000000
BYTES PER SCAN = 134
SAMPLE RATE = 2
ID AND SERIAL NUMBER = 15000171
REC LEN * 1024 = 01
SYSTEM = IFP
DATA RECORDED AS TEST
LOW CUT FILTER SETTING IN HZ = 00
LOW CUT FILTER SLOPE IN DB/OCTAVE = 00
NOTCH FILTER SETTING IN HZ = 00
ALIAS FILTER SETTING IN HZ = 0128
CHAN FIXED EARLY
01 30 DB 36 DB
FIXED/EARLY GAINS SAME THRU CHAN 04

Table 3.18 COMPUTER PRINT OUT OF OSCILLATOR TEST

FILTER PULSE TEST
THE POWER USED FOR THE POWER RATIO TEST IS 0.2494

THE LIMITS USED ARE MIN = 0.50 MAX = 2.00

NO TRACES FAILED THE POWER RATIO TEST.

THE CORNER FREQUENCIES OF THE AVERAGE POWER SPECTRUM ARE 2.9297 146.4844
TRACE
NO. [illegible] PHASE IS [illegible] PHASE [illegible]

```
INPUT RECORD = 0013
  NO PARITY ERRORS DETECTED ON THIS HEADER RECORD
  NO PARITY ERRORS DETECTED ON THIS DATA RECORD
RECORD LENGTH =  1024 MSEC

    ++++++++++  1/2 INCH HEADER DECODE  ++++++++++

FILE NUMBER = 0013
FORMAT CODE = 0200
GENERAL CONSTANTS = 020584000000
BYTES PER SCAN =  134
SAMPLE RATE =  2
ID AND SERIAL NUMBER =  15000171
REC LEN * 1024 =  01
SYSTEM =  TFP
DATA RECORDED AS  TEST
LOW CUT FILTER SETTING IN HZ =  00
LOW CUT FILTER SLOPE IN DB/OCTAVE = 00
NOTCH FILTER SETTING IN HZ =  00
ALIAS FILTER SETTING IN HZ =  0128
CHAN  FIXED   EARLY
 01   30  DB  36  DB
FIXED/EARLY GAINS SAME THRU CHAN 04

FILTER PULSE TEST
THE POWER USED FOR THE POWER RATIO TEST IS    0.2494

THE LIMITS USED ARE  MIN = 0.50   MAX = 2.00

NO TRACES FAILED THE POWER RATIO TEST.

THE CORNER FREQUENCIES OF THE AVERAGE POWER SPECTRUM ARE     2.9297    146.4844
```

TRACE NO.	ERROR	PHASE IN RADIANS	PHASE IN MSEC MPLXR CORRECTED	DIFF IN PHASE IN MSEC	POWER RATIO
1	-0.0073	1.1378	5.9938	0.0	0.9956
2	0.0061	1.1425	5.9881	0.0057	0.9963
3	0.0013	1.1441	5.9652	0.0285	1.0022
4	-0.0001	1.1505	5.9686	0.0252	1.0062

```
ALL CHANNELS TESTED WERE WITHIN THE ALLOWABLE 0.07 ERROR LIMIT.

MAXIMUM PHASE DIFFERENCE IS  0.0285 MSEC.

THIS FILTER PULSE TEST IS ACCEPTABLE.

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

INPUT RECORD =  0014
  NO PARITY ERRORS DETECTED ON THIS HEADER RECORD
  NO PARITY ERRORS DETECTED ON THIS DATA RECORD
RECORD LENGTH =  1024 MSEC

    ++++++++++  1/2 INCH HEADER DECODE  ++++++++++

FILE NUMBER = 0014
FORMAT CODE = 0200
GENERAL CONSTANTS = 020584000000
BYTES PER SCAN =  134
SAMPLE RATE =  2
ID AND SERIAL NUMBER =  15000171
REC LEN * 1024 =  01
SYSTEM =  TFP
DATA RECORDED AS  TEST
LOW CUT FILTER SETTING IN HZ =  00
LOW CUT FILTER SLOPE IN DB/OCTAVE = 00
NOTCH FILTER SETTING IN HZ =  00
ALIAS FILTER SETTING IN HZ =  0064
CHAN  FIXED   EARLY
 01   30  DB  36  DB
FIXED/EARLY GAINS SAME THRU CHAN 04

FILTER PULSE TEST
THE POWER USED FOR THE POWER RATIO TEST IS    0.2410

THE LIMITS USED ARE  MIN = 0.50   MAX = 2.00

NO TRACES FAILED THE POWER RATIO TEST.

THE CORNER FREQUENCIES OF THE AVERAGE POWER SPECTRUM ARE     2.9297    75.1953    244.1406
```

TRACE NO.	ERROR	PHASE IN RADIANS	PHASE IN MSEC MPLXR CORRECTED	DIFF IN PHASE IN MSEC	POWER RATIO
1	0.0695	0.6258	3.2120	0.0	0.9970
2	0.0249	0.6356	3.2343	-0.0223	1.0018
3	-0.0602	0.6336	3.1921	0.0199	1.0009
4	-0.0342	0.6400	3.1957	0.0163	1.0004

```
ALL CHANNELS TESTED WERE WITHIN THE ALLOWABLE 0.07 ERROR LIMIT.

MAXIMUM PHASE DIFFERENCE IS -0.0223 MSEC.

THIS FILTER PULSE TEST IS ACCEPTABLE.

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

INPUT RECORD =  0015
  NO PARITY ERRORS DETECTED ON THIS HEADER RECORD.
  NO PARITY ERRORS DETECTED ON THIS DATA RECORD
RECORD LENGTH =  1024 MSEC

    ++++++++++  1/2 INCH HEADER DECODE  ++++++++++

FILE NUMBER = 0015
FORMAT CODE = 0200
GENERAL CONSTANTS = 020584000000
BYTES PER SCAN =  134
SAMPLE RATE =  2
ID AND SERIAL NUMBER =  15000171
REC LEN * 1024 =  01
SYSTEM =  TFP
DATA RECORDED AS  TEST
LOW CUT FILTER SETTING IN HZ =  00
LOW CUT FILTER SLOPE IN DB/OCTAVE = 00
NOTCH FILTER SETTING IN HZ =  00
ALIAS FILTER SETTING IN HZ =  0032
CHAN  FIXED   EARLY
 01   30  DB  48  DB
FIXED/EARLY GAINS SAME THRU CHAN 04

FILTER PULSE TEST
THE POWER USED FOR THE POWER RATIO TEST IS    0.1182

THE LIMITS USED ARE  MIN = 0.50   MAX = 2.00

NO TRACES FAILED THE POWER RATIO TEST
```

Table 3.19 COMPUTER PRINT OUT OF FILTER PULSE TEST

```
IN SEEN = 134
SAMPLE RATE = 2
ID AND SERIAL NUMBER = 15000171
REC LEN * 1024 = 01
SYSTEM = TFP
DATA RECORDED AS DATA
LOW CUT FILTER SETTING IN HZ = 00
LOW CUT FILTER SLOPE IN DB/OCTAVE = 18
NOTCH FILTER SETTING IN HZ = 00
ALIAS FILTER SETTING IN HZ = 0032
CHAN FIXED EARLY
 01 30 DB 36 DB
FIXED/EARLY GAINS SAME THRU CHAN 02

FILTER PULSE TEST
THE POWER USED FOR THE POWER RATIO TEST IS     0.2527

THE LIMITS USED ARE  MIN = 0.50   MAX = 2.00

NO TRACES FAILED THE POWER RATIO TEST.

THE CORNER FREQUENCIES OF THE AVERAGE POWER SPECTRUM ARE      2.9297   144.5312
TRACE                       PHASE IN     PHASE IN MSEC      DIFF IN
 NO.       ERROR            RADIANS      MPLXR CORRECTED    PHASE IN MSEC-   POWER RATIO
  1       -0.0081           1.1111          5.8089            0.0              0.9976
  2        0.0081           1.1179          5.8542           -0.0058           1.0024

ALL CHANNELS TESTED WERE WITHIN THE ALLOWABLE 0.07 ERROR LIMIT.

MAXIMUM PHASE DIFFERENCE IS -0.0059 MSEC.

THIS FILTER PULSE TEST IS ACCEPTABLE.

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

10NOV84  TIME 11:29:01
FIN
```

INSTRUMENT TEST RESULTS SUMMARY   GEOPHYSICAL SERVICE INC.

FORMAT=43,
SEG B 1600 BPI PE   48 TRACE DFS 5 2 MSEC SAMPLE RATE SERNO. 0171

TEST PARAMETER	GRADING MODULE 1	GRADING MODULE 2	RESULTS MODULE 1	RESULTS MODULE 2	SPECS/GUIDELINES
AMPLITUDE CALIBRATION	POOR**	POOR**	AVERAGE PEAK MV -5997.9141 **	-5992.4570 **	MAX/MIN STATED LIMITS.
A/D CONVERTER OFFSET	POOR**	POOR**	AVERAGE D.C. OFFSET MV 0.7050 **	0.7059 **	0.0 TO -0.5 MILLIVOLTS.
DYNAMIC RANGE OF DIGITAL RECORDER	GOOD	GOOD	AVERAGE DB FROM F.S. 81.6467	81.9462	> 78 DECIBELS.
LIN REFERENCE TEST SIGNAL	POOR**	POOR**	AVERAGE RMS MICROVOLTS 2.0775 **	2.1038 **	1.22 TO 1.28 MICROVOLTS OR 4.91 TO 5.14 MICROVOLTS.
EQUIVALENT INPUT NOISE	GOOD	GOOD	AVERAGE RMS MICROVOLTS 0.2208	0.2088	</= 0.615 MICROVOLTS.
CHANNEL D.C. OFFSET	POOR**	POOR**	AVERAGE D.C. OFFSET MV 123.2620 **	311.9060 **	</= 25 MILLIVOLTS.
IFPA CALIBRATION			GAIN RANGING		SATISFY GAIN RANGING ALGORITHM.
FILTER RESPONSE			IMPULSE RESPONSE		+/- 0.07 OF AVERAGE POWER, AND PLOT +/- 1 MILLISECONDS PHASE.
IFPA GAIN STEP ACCURACY			GAIN STEP ERROR		1.0 TO .05 %. REFER TO SPECIFICATION TABLE.
HARMONIC DISTORTION			% DISTORTION		</= .05 % HARMONIC DISTORTION </= 1 MILLISECOND PHASE DIFFERENCE.
CROSSFEED ISOLATION			CROSSFEED ISOL. - DB 0.0	0.0	>/= 72 DECIBELS.
CONVERTER ACCURACY			CONVERTER ERROR		REFER TO % ERROR GUIDELINE LISTING.
PARITY/SYNC ERRORS	GOOD		9 RECORDINGS READ 0 PAR.	0 SYNC	</= 10 PARITY ERRORS AND NO SYNC ERRORS.

GRADING AND REMARKS:	
HEADER ENCODING	MUST AGREE WITH TEST DATA SHEET AND SYSTEM SETTINGS.
TAPE/GALVO POLARITY	POSITIVE TAPE NUMBERS PRODUCE UPWARD TRACE DEFLECTION.
CAMERA PHOTOGRAPHY	ALL TRACES AND TIMING LINES CLEARLY VISIBLE.
SYSTEM TIMING	MAX ERROR </= 1 MSEC IN 10 SECONDS.
TXP SPEED VARIATION	MAX VARIATION < 10 MSEC PER SECOND.

RECORDED BY: ++++++++++++++++++++++++ COPIES: ++++++++++++++++++++++++
EVALUATED BY: ++++++++++++++++++++++++ ++++++++++++++++++++++++
DATE EVALUATED: ++++++++++++++++++++++ ++++++++++++++++++++++++

```
//DEL,**DATA
//MES=OP REWIND INPUT TAPE : WAIT-10
//PUP,P905,V=10
//IF,B.EQ.0,*+3
//XPC,PP2,U=4,F=P905,BL=50,V=10,FX=P905
//ASN,SYSTEM,JOBPRO
//ASN,FI06F001,PRT
//ASN,FI05F001,CRD
//DEF,OVLYFILE,FHD0,50,1280
//SET,P,0,7,10
//ASN,PRODLIB,P905
//XQT,PRODLIB,P905

10NOV84  TIME 11:30:43
FORMAT=43,
NUMTRA=1,
ITIM=0,
ITRC=7,
NTRC=2,
TESTSW=10,
IOPT=16,
)
```

Table 3.20 COMPUTER PRINT OUT OF TEST SUMMARY

```
FILE NUMBER = 0031
FORMAT CODE = 0200
GENERAL CONSTANTS = 020584000000
BYTES PER SCAN = 134
SAMPLE RATE = 2
ID AND SERIAL NUMBER = 15000171
REC LEN * 1024 = 03
SYSTEM = TFP
DATA RECORDED AS TEST
LOW CUT FILTER SETTING IN HZ = 00
LOW CUT FILTER SLOPE IN DB/OCTAVE = 00
NOTCH FILTER SETTING IN HZ = 00
ALIAS FILTER SETTING IN HZ = 0128
CHAN FIXED EARLY
01 30 DB 00 DB
FIXED/EARLY GAINS SAME THRU CHAN 02

INPUT RECORD = 0032
  NO PARITY ERRORS DETECTED ON THIS HEADER RECORD
  NO PARITY ERRORS DETECTED ON THIS DATA RECORD
RECORD LENGTH = 3072 MSEC

   ++++++++++  1/2 INCH HEADER DECODE   ++++++++++

FILE NUMBER = 0032
FORMAT CODE = 0200
GENERAL CONSTANTS = 020584000000
BYTES PER SCAN = 134
SAMPLE RATE = 2
ID AND SERIAL NUMBER = 15000171
REC LEN * 1024 = 03
SYSTEM = TFP
DATA RECORDED AS TEST
LOW CUT FILTER SETTING IN HZ = 00
LOW CUT FILTER SLOPE IN DB/OCTAVE = 00
NOTCH FILTER SETTING IN HZ = 00
ALIAS FILTER SETTING IN HZ = 0128
CHAN FIXED EARLY
01 30 DB 00 DB
FIXED/EARLY GAINS SAME THRU CHAN 02
```

GAIN ACCURACY TEST

CHAN	IR = 0019 RMS	GAIN STEP % ERROR	IR = 0020 RMS	TEST SIGNAL % ERROR	IR = 0021 RMS	GAIN STEP % ERROR	IR = 0022 RMS	TEST SIGNAL % ERROR	IR = 0023 RMS
01	0.0078	-74.9049**	0.0312	299.6616**	0.0312	-74.9741**	0.1250	299.9260**	0.1251
02	0.0079	-74.7741**	0.0315	300.1180**	0.0313	-74.9642**	0.1252	299.9294**	0.1252
	AVG ERR =	-74.8395**	AVG ERR =	299.8901**	AVG ERR =	-74.9692**	AVG ERR =	299.9277**	

CHAN	IR = 0023 RMS	GAIN STEP % ERROR	IR = 0024 RMS	TEST SIGNAL % ERROR	IR = 0025 RMS	GAIN STEP % ERROR	IR = 0026 RMS	TEST SIGNAL % ERROR	IR = 0027 RMS
01	0.1251	-74.9853**	0.5002	299.9101**	0.5003	-74.9922**	2.0007	299.9543**	2.0009
02	0.1252	-74.9805**	0.5007	299.8745**	0.5009	-74.9893**	2.0028	299.9184**	2.0032
	AVG ERR =	-74.9829**	AVG ERR =	299.8923**	AVG ERR =	-74.9907**	AVG ERR =	299.9362**	

CHAN	IR = 0027 RMS	GAIN STEP % ERROR	IR = 0028 RMS	TEST SIGNAL % ERROR	IR = 0029 RMS	GAIN STEP % ERROR	IR = 0030 RMS	TEST SIGNAL % ERROR	IR = 0031 RMS
01	2.0009	-74.9913**	8.0010	299.8889**	8.0033	-74.9894**	31.9998	299.9291**	32.0054
02	2.0032	-74.9887**	8.0096	299.8425**	8.0128	-74.9862**	32.0336	299.9042**	32.0413
	AVG ERR =	-74.9900**	AVG ERR =	299.8657**	AVG ERR =	-74.9878**	AVG ERR =	299.9167**	

CHAN	IR = 0031 RMS	GAIN STEP % ERROR	IR = 0032 RMS	TEST SIGNAL % ERROR	IR = RMS	GAIN STEP % ERROR	IR = RMS	TEST SIGNAL % ERROR	IR = RMS
01	32.0054	-2.3852**	32.7875						
02	32.0413	-2.1416**	32.7825						
	AVG ERR =	-2.2633**							

THIS GAIN ACCURACY TEST IS NOT ACCEPTABLE

TEST SIGNAL IS NOT ACCEPTABLE

10NOV84 TIME 11:48:50

Table 3.21 COMPUTER PRINT OUT OF GAIN ACCURACY TEST

P905 PROGRAM GUIDE

TEST	P905 LISTING	EVALUATION CRITERIA AND PROCEDURE
DYNAMIC RANGE (of digital recorder)	CONVERTER NOISE ANALYSIS (TEST SW=2)	1) Examine DB FROM FS column; all channels should be ≥ 78.26dB. Note the system average DB FROM FS at bottom of listing. 2) If some channels are below 78dB spec, list those channels below spec by number. If all channels meet 78dB spec or better, state "ALL CHANNELS≥ 78.26dB" unless all channels have higher values: then use the higher value in place of 78.26. 3) Make a RESULTS evaluation: GOOD - All channels ≥ 78.26dB, SYS. AVE. ≥ 79dB SAT - Most channels ≥ 78.26dB, SYS. AVE.= ≥ 79dB MARG - Channels ≥ 76.3dB, SYS. AVE = 76-78dB POOR - Channels ≤ 74.7dB, SYS. AVE.= < 76dB
CONVERTER OFFSET (of A/D converter)	CONVERTER NOISE ANALYSIS (TEST SW=2)	1) Examine DC OFFSET column. If all channels within specs, so state. If not, list channels out of specs. 2) Make RESULTS evaluation: GOOD - All channels within specs SAT - Most channels within specs, System Average within specs. MARG - Most or all channels and System Average slightly out of specs. POOR - Most or all channels and System Average well out of specs. 3) Spec Guidelines: DFS IV = 0 ±.75mV DFS V = 0 +-.5mV
AMPLITUDE CALIBRATION (of Analog or Input Modules)	DYNAMIC RANGE TEST-1st RECORD (or 2nd record if 1st record is unreadable)	1) Examine MAX and MIN values. All channels should be within limits stated on listing. 2) Examine TRACE RMS and DB FROM FS columns. All channels should be within limits stated in the INTERPRETATION AND SPECIFICATION SHEETS for DRD. 3) List all channels out of specs. If channels are uniformly calibrated and well within specs so state. 4) Make RESULTS evaluation: GOOD - All channels uniformly calibrated and approximately mid-point of upper and lower limits. SAT - All channels and System Average within specs, but crowding one limit, or moderate variation between channels.

TEST	P905 LISTING	EVALUATION CRITERIA AND PROCEDURE
		MARG - Wide variation between channels, some out of specs, System Average near limits or slightly out of specs. POOR - Most or all channels and System Average well out of specs.
INPUT NOISE TEST-SECTION 1:Evaluation of the signal reference recording	EQUIVALENT INPUT NOISE REFERENCE TEST RECORD (TEST SW=3) Part 1 of 2-part evaluation of the EIN test	1) Examine TRACE RMS values. All channels should be within limits stated on listing. If so, take no further action and proceed to part 2 evaluation of NOISE record. 2) If some channels, or system Average, are out of specs, so state. Then proceed to Part 2.
INPUT NOISE TEST-SECTION 2:Evaluation of NOISE recording.	EQUIVALENT INPUT NOISE TEST RECORD (TEST SW-4) Part 2 of 2-part evaluation of the EIN test.	1) Examine TRACE RMS values. All channels should be within limits stated on listing. 2) List all channels out of specs in TRACE RMS column. If all channels are in spec, so state. Do not enter any values from SIG/NOISE column in this evaluation. 3) Make RESULTS evaluation: GOOD - All channels within specs and System Average well below maximum spec. SAT - Most channels within specs, with remaining exceeding specs <10-15%; System Average <maximum spec. MARG - A number of channels slightly out of specs and System Average ≤max specs, or some channels exceeding max specs >50%. POOR - Worse than the above.
TRACE DC OFF-SET	EQUIVALENT INPUT NOISE TEST RECORD (TEST SW=4)	1) Examine DC OFFSET values. All channels should be within limits stated on listing. If so, so state; if not list channels out of specs and value. 2) Make RESULTS evaluation: GOOD - All channels within specs and System Average well within specs. SAT - Most channels within specs and remaining exceeding specs <2X, and System Average within specs. MARG - Some channels badly out of specs, or System Average out of specs. POOR - All channels near, at, or exceeding maximum specs, particularly if all channels are offset in same polarity.

TEST	P905 LISTING	EVALUATION CRITERIA AND PROCEDURE
AGC ACTION	IFPA EXPONENTIAL OSCILLATOR TEST- Use the paper test records.	1) Examine FLOAT monitor paper record. It should display, as accurately as galvo circuits can respond, the action of the Instantaneous Floating Point Amplifier (IFPA). Expect choppy hashed-up waveforms of nearly uniform amplitude from start to about 7 seconds, then smoothed, reduced amplitude to end of record. Keep this monitor paper record handy for evaluating system timing (INDEX NO. 15) and verifying polarity (INDEX NO. 18). 2) Examine DEFLOAT playback paper record. It should display input signal in true amplitude form. Signal would be clean; starting at high level, signal should decrease exponentially at approximately 12dB per second until traces go dead at 3-4 seconds. 3) Examine AGC playback. It should display the input signal starting at time zero, then decrease rapidly in amplitude (approximately .5 second) to the digital AGC level pre-selected. Once this level is reached, amplitude should remain constant to about 7 seconds, then may taper somewhat lower to the end of the record. Keep this AGC playback paper record handy for evaluating transport speed variation (INDEX NO. 16). 4) If paper records appear as described above, AGC action is normal. So state, and check RESULTS GOOD. If malfunctions or omissions are encountered, downgrade RESULTS evaluation accordingly
IFPA Calibration (provides IFPA GAIN COMPARATOR calibration data).	GAIN WORD LISTING from the IFPA EXPONENTIAL OSCILLATOR TEST RECORDING.	1) Examine GAIN WORD listing. This listing shows IFPA gain ranging action for listed channels during specified time gates in response to the exponentially - decaying test signal. 2) For any given trace, look at gain values in each time gate. These gain values are generated as the test signal makes sinusoidal positive and negative excursions and the instantaneous floating point amplifier "floats" this incoming signal. Gain values should change from positive to negative values uniformly and symmetrically, in step with the applied test signal. As each gate times increase, gain values should increase also since input test signal is decreasing with time. Gain values should range from ±00dB on peaks and troughs during gate 1 to ±84dB during gate 6.

TEST	P905 LISTING	EVALUATION CRITERIA AND PROCEDURE
		3) Evaluate each IFPA in the system. DFS IV and single-box DFS V systems have one IFPA. Any good channel can be used to evaluate IFPA gain ranging. DFS V multibox systems have an IFPA in each box; evaluate at least one good channel from each box. Typically this would be channels 48 and 49 for 96 channel systems, channels 60 and 61 for 120 channel systems. 4) Make RESULTS evaluation: consider each IFPA system: GOOD - IFPA performs as described above. SAT - IFPA ranges from ±00 to ±84dB, but is not completely symmetrical on peaks and troughs. Deviation does not exceed 12dB MARG - IFPA ranges from ±00 to ±84dB but is consistently non-symmetrical on peaks and troughs. Deviation does not exceed 24dB. POOR - IFPA fails to range at all; fails to generate gain words of all 7 gain values (particularly 84dB); generates gain values of all one sign (polarity); or otherwise indicates some malfunction. 5) Make suitable statement in COMMENTS, i.e. "BOTH IFPA GAIN COMPARATORS WELL CALIBRATED: or try to describe problem is present. NOTE: MALFUNCTIONS IN IFPA PERFORMANCE WARRANT IMMEDIATE NOTIFICATION TO INSTRUMENT PERSONNEL.
FILTER RESPONSE evaluation, both filter pulse and steady-state sine wave phase analysis	a) DYNAMIC RANGE TEST (TEST SW=1) USED TO PROCESS FILTER PULSE TEST and b) HARMONIC DISTORTION ANALYSIS (TEST SW=8) PHASE DATA, and c) PAPER RECORDS of PULSE TEST.	1) On FILTER PULSE recording, examine MAX and MIN values. Look for anomalous values for any given trace rather than absolute values, since variations of 10 to 20% will be noted from first to last trace. The variation should be a graduated change from trace to trace. Consider a trace anomalous that deviates greater than ±5% from nominal. 2) Examine TIME values at which MAX and MIN values occur. All channels should have peak and trough values falling in the same time block; however, due to multiplexing time skew, max/min values may ADVANCE to the preceding time block at some point down the channel listing. At the point of time block changeover two or three channels may "bobble" between time values. These occurrences are normal and are to be expected. DFS V multibox systems will display this effect on each Analog Module. Consider a channel out of phase whose TIME value disagrees with other column values except during time block changeover.

TEST	P905 LISTING	EVALUATION CRITERIA AND PROCEDURE
		3) Examine TRACE RMS values. Channel RMS values should normally fall within ±2% of System Average TRACE RMS. Example: System Average RMS = .0705mV; 2% of .0705 = .0014; all channels should fall between .7019 and .0691mV A channel out of limits here also usually has anamolous MAX/MIN values. Multibox DFS V systems should be evaluated on a module-by-module basis using an estimated average of channels in each module; the Systems Average RMS value is not valid for either module, since each module produces its own pulse and pulse amplitudes are not identical. 4) Proceed to HARMONIC DISTORTION P905 listings if HARMDIST tests were recorded and processed. Check the summary statement "MAXIMUM PHASE DIFFERENCE IS ____MS" on all recordings. Maximum phase difference should be less than ±1 MS. In practice, expected values are less than ±.25 MS with system LC filters OUT; less than ±.5 MS with LC filters IN. Header decoding tells which filters were used during HARM DIST and FILTER PULSE recordings. 5) Examine paper records of filter pulse test. All traces should duplicate closely in amplitude, phase, and character. Note carefully any trace judged out of limits using techniques outlined above. If the trace deficiency is evident on paper record, mark and send it (or a legible copy) to the IE. This is the IE's principal tool in identifying and correcting filter problems. 6) List all channels and filter settings out of limits. If all channels are within limits, so state. 7) Make RESULTS evaluation: GOOD - All channels within limits. SAT - Most channels within limits, and the ones outside limits only marginally failing. MARG - Serious defects on one or more channels. POOR - Serious defects on several channels or a number of marginal ones.
GAIN STEP ACCURACY of the Instantaneous Floating Point Amplifier.	GAIN ACCURACY TEST (TEST SW=6)	1) Fourteen consecutively numbered records are read and processed before any computed values are listed. Examine the 14-record FTQC and header encoding for error-free processing and correct recording parameters. 2) Examine data listings. There should be seven GAIN STEP % ERROR columns and six TEST SIGNAL % ERROR columns. The seven GAIN STEP % ERROR columns provide accuracy data of the IFPA gain steps. Test signal error is useful information but not the purpose of the test and does not affect grading of the GAIN ACCURACY category.

TEST	P905 LISTING	EVALUATION CRITERIA AND PROCEDURE
		3) Examine GAIN STEP % ERROR values for all channels at each step. All channels should fall within the TI acceptance error specs listed for the GAIN ACCURACY test procedure; flag any falling outside. If a multibox DFS V is being evaluated pay special attention to the groups of channels in each Analog Module. In other words, evaluate gain step accuracy of each IFPA in the system. 4) Examine AVE ERR figure at the bottom of each GAIN STEP % ERROR column. This is the key data wanted and represents (as closely as our measuring technique provides) IFPA gain step accuracy for the gain steps indicated. 5) Make RESULTS evaluation: GOOD - All channels within specs and system average within specs at each of the seven gain steps of each IFPA. SAT - Most channels within specs and system average within specs at each of the seven gain steps of each IFPA. MARG - Many channels out of specs, and system average out of specs less than or equal to 20% at any gain step. Example: 36-24dB step spec = .05%. 20% out of spec = .06%. Criteria applies to each IFPA in the system. POOR - Worse than above. This generally results from procedure errors in recording or processing the series of recordings. Error values near 75% or 300% indicates processing is out of step with recording (first two recording processed must be gain step changes, not test signal level changes). Error values outside specs a small amount indicates a faulty IFPA or procedural errors on part of IE; test should be re-run. 6) Make a statement under COMMENTS describing test results. This completes GAIN ACCURACY test evaluation. 7) Evaluate TEST SIGNAL % ERROR using same techniques in steps 1-6. The published specs are the same for test signal accuracy as gain accuracy. Experience indicates most DFS V systems meet specs at most steps, but DFS IV systems do not. 8) If the system being evaluated falls within specs or does not exceed specs by more than a factor of 2, take no further action. If any or all steps exceed this guideline, describe the problem either in INDEX NO. 19 or on an additional comment sheet and send to IE.

TEST	P905 LISTING	EVALUATION CRITERIA AND PROCEDURE
HARMONIC DISTORTION of the total recording system, and channel-to-channel phase duplication	HARMONIC DISTORTION ANALYSIS (TEST SW=8)	1) Examine % DISTORTION column for all channels and the print statement at end of channel listing. All channels should be within the stated allowable spec. If so, so state. If not, list channels out of specs and the filter settings used for the recording(s). 2) Check MAXIMUM PHASE DIFFERENCE print statement for phase duplication data on all harmonic distortion recordings. Maximum phase difference should be less than ±1 MS. In practice, expected values are less than ±.25 MS with System LC filters OUT; less than ±.5 MS with LC filters IN. Header decoding tells which filter combinations were used during each recording. These data are used in INDEX NO.8 FILTER RESPONSE analysis. 3) Make RESULTS evaluation: GOOD - All channels within the stated allowable distortion on all distortion recordings. SAT - All channels within distortion specs but crowding the upper limit, or, most channels well below allowable specs but an occasional channel slightly outside specs. MARG - Most or all channels at or slightly exceeding specs, or, one or more channels well beyond specs. POOR - Worse than the above.
CROSSFEED ISOLATION (between channels)	CROSSFEED TEST (TEST SW=5)	1) Examine print statements at end of channel listing for each CROSSFEED TEST recording. The first statement lists the worst case crossfeed isolation computation for the recording. This figure should be greater than the stated crossfeed isolation spec. If so, routine judges test ACCEPTABLE; if not, NOT ACCEPTABLE. All crossfeed test recordings should be ACCEPTABLE. If so, state "All Channels within Specs". If not, list all DEAD channels that do not meet crossfeed isolation specs. 2) Usually, four CROSSFEED TEST recordings are made in this gain mode sequence; MAN-IFPA-IFPA-MAN. Expect these results: DFS IV = $\geq$66dB MAN, $\geq$72dB IFPA. DFS V = $\geq$72dB MAN, $\geq$78dB IFPA. The higher the numbers, the better the results. 3) Make RESULTS evaluation: GOOD - All channels well within specs on all recordings. SAT - All channels within specs on all recordings, but crowding the lower limit, or, perhaps one channel slightly below specs. MARG - One or more channels well below specs, but most channels within specs. POOR - One or more channels far below specs, or other malfuntions.

TEST	P905 LISTING	EVALUATION CRITERIA AND PROCEDURE
		4) If the P905 listing indicates a problem, examine the paper records. If problem is evident of the high-gain playbacks (it normally is), mark and send it (or a legible copy) to IE. This is a primary tool in identifying and correcting crossfeed problems in the field.
HEADER RECORDS	ALL P905 HEADER DECODE LISTINGS for the various tests.	1) Examine HEADER DECODE listings. Check the parameters listed against TEST DATA SHEET information, tape format sheet, and other known system characteristics. 2) If all header information is correct, so state and check RESULTS GOOD. 3) If errors are detected, describe problem in COMMENTS and downgrade RESULTS evaluation according to seriousness of error. File numbers, sample rate and gain values are critical. Filter settings are important; other items of information are useful but not critical if in error. SPECIAL NOTE: many DFS V systems are now being outfitted with special HICUT/LOCUT filter modules which do not encode frequency correctly in the header. This is an unfortunate design limitation and not an error correctable by the IE. Do not downgrade HEADER RECORD test results if this is encountered. The most commonly encountered situation at the present time are systems equipped with 90Hz filter modules. 90Hz filters encode 64Hz in the DFS V header, and there is no way for anyone except the IE to know whether 90Hz or 64Hz filter modules are being used. Good bookkeeping and labelling is therefore important for all persons involved with field system data.
PARITY, BLOCK, or SYNC ERRORS (or header and data sections of recordings)	FTQC SECTION of ALL P905 PROCESSED RECORDINGS.	1) Examine the FTQC section print statements of each recording processed. Note the file numbers with parity errors. If the recording contains SYNC ERRORS the statement "XXXX SYNC ERRORS - RECORD NOT PROCESSED" will be printed, processing of the file aborted, and the next file attempted. 2) If errors are encountered, describe in COMMENTS, and make a RESULTS evaluation: SAT - No files lost due to sync errors; <10% of recordings with small parity counts not affecting test data. MARG - An occasional file with sync errors, or, >10% of files with parities. POOR - Extensive readability problems, or unable to read or process recordings.

TEST	P905 LISTING	EVALUATION CRITERIA AND PROCEDURE
SKEW	MONTHLY TEST TAPE (or any tape recorded by the field crew)	1) A skew check should be performed if the processing centre provides this service as a matter of course. If facilities are limited, however, use this guideline: if test tape is error-free, do not check. If parity or sync error count begins to mount, check.
SYSTEM TIMING	MONITOR PAPER RECORD OF IFPA OSCILLATOR TEST, or, any monitor paper record of any recording 8 seconds long.	1) Examine the 100Hz TICKER TRACE normally positioned near the bottom of the paper record. This signal is produced by an independent frequency module in the camera and should be visible as soon as paper starts, well ahead of the first timing line. 2) Examine timing lines starting at T_0. Timing lines are generated from the DFS digital clock which is the frequency timing standard of the digital recording system. 3) Note the precise phase relationship of the ticker signal to the timing lines at beginning of record. Using a magnifying glass can often enhance the accuracy of this evaluation. Scan this ticker/timing line phase all the way down the record making certain no radical shift occurs. Then, amount of drift, if any, between these two frequency standards. 4) Using 1 part in 10,000 as the criteria of this measurement (1 millisecond in 10 seconds, or 8 millisecond in our usual 8 second IFPA Oscillator test record), make RESULTS evaluation: GOOD - no measurable error (no drift in the phase relationship). Make statement "NO MEASURABLE ERROR" in COMMENTS. SAT - drift ≤ 1 millisecond in 8, 9, or 10 second record. MARG - drift $> 1, < 3$ milliseconds in 8, 9 or 10 second record. POOR - worse than the above. Describe the magnitude of the error in COMMENTS. NOTE: ERROR IN TIMING GREATER THAN 1 MILLISECOND WARRANTS IMMEDIATE NOTIFICATION TO INSTRUMENT PERSONNEL.
TRANSPORT SPEED VARIATION	PLAYBACK PAPER RECORD OF IFPA OSCILLATOR TEST, or, any recording 8 seconds long.	1) Examine phase relationship between ticker and timing lines as described in steps 1 and 3 of INDEX 15, SYSTEM TIMING. However, PLAYBACK paper record timing lines are generated from timing data recorded on tape. Any variation of tape transport speed during either RECORD or PLAYBACK mode will result in timing line drift with respect to the ticker.

TEST	P905 LISTING	EVALUATION CRITERIA AND PROCEDURE
		2) Maximum transport speed variation spec is ±1%. In practice, however TI transports perform far better than this; thus a transport operating near the maximum limit (±10 milliseconds per second) likely has a problem warranting attention (but not shutdown). 3) Make RESULTS evaluation, using these guidelines: GOOD - No measurable error, or, drift ≤ 1 millisecond/second, or, maximum of 10 milliseconds on long playback record. SAT - Drift $> 1, \leq 3$ milliseconds/second, or, maximum of 25 milliseconds on long playback record. MARG - Drift $> 3, \leq 10$ milliseconds/second, or, maximum of 100 milliseconds on long playback record. POOR - Worse than the above. This warrants notification of problem to IE.
PHOTOGRAPHY (quality and readability of camera paper records).	PAPER RECORDS of all tests.	1) Make RESULTS evaluation: GOOD - Good contrast; all traces in focus and clearly visible; timing lines in focus and totally visible on all parts of record, especially at start of record. Record number display and ticker trace clearly visible. SAT - All items above of acceptable of usable quality. MARG - Poor developing, fuzzy traces, high parallax error, fuzzy or erratic timing lines, paper speed variation. POOR - Display of such poor quality as to be unusable, or test evaluations using paper records unreliable.
POLARITY of digital recording system.	a) P905 FILTER PULSE TEST LISTING b) FILTER PULSE TEST PAPER RECORD c) P905 GAIN WORD LISTING FOR IFPA EXP. OSC. TEST RECORDING and d) IFPA EXPONENTIAL OSCILLATOR TEST use the defloat or AGC paper record.	1) Examine P905 listing and paper record of the filter pulse test. The initial break of the pulse should be UP on the paper record and P905 listing should list positive values for the peak of the upbreak. 2) Examine P905 GAIN WORD LISTING and paper record of the IFPA Exponential Oscillator test. Positive gain values should agree with positive (up) trace direction, negative gain values with negative (down) trace direction. 3) If the system is multibox DFS V, check both boxes for 1 and 2 above. 4) If any reversal is found, a problem exists.

TEST	P905 LISTING	EVALUATION CRITERIA AND PROCEDURE
CONVERTER LINEARITY (accuracy of A/D converter)	CONVERTER LINEARITY TEST (TEST SW=7)	See below

1) Examine CONVERTER LINEARITY test data sheet provided by the IE and the P905 CONVERTER LINEARITY TEST listing.
2) If system being evaluated is a DFS IV or a single box DFS V, one CONVLIN test listing will be produced. The first listing of multibox V systems contains data recorded in channels 1-24, or 1-48, or 1-60 (depending on system configuration).
3) AVERAGE VALUE on the P905 listing should agree with the CONVERTER INPUT mV value listed on the Converter Linearity test data sheet provided by the IE, within the accuracy specified for the system. The accuracy specification is ±.05% of full converter scale, which translates to ±4 mV for DFS V systems, ± 2 mV for DFS III and IV systems. Another specification stated for the A/D converter is linearity; the linearity spec is ±.02% of full scale. This spec dictates that the accuracy millivolt tolerance must be tightened somewhat as input voltages decrease.
4) Therefore, use these guidelines for evaluation:
DFS IV system:

STATED mV INPUT	AVERAGE VALUE LIMITS
+ 4095.75	stated input ± 2mV
- 4096.0	stated input ± 2mV
± 2048	stated input ± 2mV
± 1024	stated input ± 1mV
↓	
0	

5) Make RESULTS evaluation:
GOOD - AVERAGE VALUE agrees closely with input voltage stated on test data sheet on all recordings of the test, with all recordings within guidelines stated in 4 above.
SAT - AVERAGE VALUE agrees within limits stated in 4 above on all recordings; some may crowd limits however.
MARG - AVERAGE VALUE exceeds limits a small amount, more notably at high input levels.
POOR - AVERAGE VALUE exceeds limits by factor $\geq$ 50%.

TEST	P905 LISTING	EVALUATION CRITERIA AND PROCEDURE

6) This completes the basic evaluation procedure for this test. The following sections are provided to provide additional information about the test, the P905 listing, and the field system.

   a) If high input level recordings yield AVERAGE VALUES well outside limits on either positive or negative input voltages but are well within limits on lower input level recordings, this usually indicates REFERENCE VOLTAGE calibration error. This requires a careful converter recalibration using precision test instruments, followed with another converter linearity test to verify correct converter accuracy.

   b) If high input level recordings yield AVERAGE VALUES well within limits but fall outside limits on low order input voltages, this indicates converter offset calibration error. This requires only a minor converter zero procedure to correct.

   c) The effect of converter offset is to modify all recorded voltage values at all input levels by the same amount in the same direction. For example, assume the A/D converter zero calibration is off 2 millivolts in the positive direction. Assuming all other factors are correct, AVERAGE VALUE for all positive input levels will be 2 millivolts higher than the actual input; AVERAGE VALUE for all negative input levels will be 2 millivolts less than the actual input. Thus, an offset condition is readily apparent. In practice, a small amount of converter offset does not appreciably alter overall system performance or accuracy. Thus, while the converter linearity test results may seem rather dismal at very low levels, the cause and effect is not serious.

   d) The P905 listing provides other data for the user. The TRUE VALUE column provides a binary voltage number derived by selecting the binary value nearest the computed AVERAGE VALUE. This TRUE VALUE serves as a reference for computing % ERROR. The % ERROR column lists the difference percentage between TRUE VALUE and AVERAGE VALUE.

TEST	P905 LISTING	EVALUATION CRITERIA AND PROCEDURE
		TRUE VALUE represents the voltage level that should be used by the IE when making the test. AVERAGE VALUE is the numerical average of all sample points on all traces selected for processing. MAX VALUES and MIN VALUES list the sample point extremes on all traces selected for processing. These extremes provide a way to monitor noise present on the recordings.

IV (1) INPUT MODULE MANUFACTURERS SPECIFICATIONS

Item	Description
Frequency Response	Preamplifier: DC to 760 (min)/860(max)Hz depending on gain switch setting. Chopper-Stabilized Amplifier: 3 to 500 Hz
Equivalent Input Noise (8 to 248 Hz)	500-ohm connection: 0.10 μV rms, 500-ohm source 2000-ohm connection: 0.25 μV rms, 2000-ohm source
Manual Gain Change	Total change is 30 dB. The preamplifier has 5 binary gain levels selected by a 5-position gain switch (S1) on the filter card. This provides 24 dB of gain change. Changing input transformer primary configuration provides the remaining 6 dB gain change. Total voltage gain is always ten times an integral power of two. The gain switch settings must be the same in a module and this setting (the gain constant) is recorded in the header.
Gain Adjustment for Calibration	±9%
Gain Calibration Resolution	±0.1%
Maximum Input Signal (for the 5 gain switch settings)	
a. 500-ohm connection Gain Sw Setting:	
12	262.144 mV rms
18	131.072 mV rms
24	65.536 mV rms
30	32.768 mV rms
36	16.384 mV rms
b. 2000-ohm connection Gain Sw Setting:	
12	524.288 mV rms
18	262.144 mV rms
24	131.072 mV rms
30	65.536 mV rms
36	32.768 mV rms
Distortion	
a. 500-ohm connection	0.1% maximum 5 to 248 Hz, 500-ohm source
b. 2000-ohm connection	0.1% maximum 5 to 248 Hz, 2000-ohm source
Crossfeed Isolation	90 dB

(i) Cont. INPUT MODULE FILTER SPECIFICATIONS

Item	Description
Low-Cut	Frequencies: 8, 12, 18, and 27 Hz at 18 or 36 dB/octave slope. Cutoff frequencies are down 3 dB for 18 dB/Octave slope, and 6 dB for 36 dB/octave slope. The low-cut filter can be bypassed by setting the LO-CUT SLOPE switch to OUT. Phase Duplication: ±1 ms, 18 to 248 Hz ±2 ms, 5 to 17 Hz
High-Cut	Frequencies: 31, 62, 124, and 248 Hz: 6 dB down points. Slope: 72 dB/octave or 18dB/octave Phase Duplication: ±1 ms The steep slope of the high-cut filter provides the alias filter. High-cut filters cannot be bypassed. The filter is down 70 dB at one-half the sampling frequency. <u>Cutoff</u> — <u>70 dB Down At</u> 31 — 62.5 Hz 62 — 125 Hz 124 — 250 Hz 248 — 500 Hz
Notch	Notch Rejection: 54 dB When installed, notch filters are electrically connected between the low-cut and high-cut filters.

(1) Cont. INPUT MODULE MECHANICAL AND POWER SPECIFICATIONS

Item	Description
Power	40 watts from a 12-volt battery. Battery voltage may vary from 11 to 14 volts.
Humidity	100% without condensation.
Altitude, Maximum	12,000 feet
Temperature Range, Ambient Operating	
a. With Forced Air Ventilation Continuous Duty	0 to +55°C
b. Without Ventilation:	
Continuous Duty	0 to+40°C
Intermittent Duty:	
3 min. on, 3 min. off	0 to +50°C
3 min. on, 9 min. off	0 to +55°C
Storage Temperature Range	-55°C to +65°C
Shock, Non-operating	Non-repetitive, case lid on, 15 G maximum 1/2 sine wave with a duration of 11 milliseconds along any of the three perpendicular axes.
Vibration, Non-operating	2 G maximum over a frequency range of 10 to 500 Hz.
Dustproofing and Sandproofing	Effective with lids on.
Physical Size	20.5 in. x 17 in. x 10.63 in. deep. These are outside package dimensions and do not include external hardware such as handles, feet and vent plug.
Weight	61 lb

(2) AMPLIFIER MODULE MANUFACTURERS SPECIFICATIONS

Item	Description
Input	
Type input	Differential
Number of inputs	5 Input modules 1 Expander module 8 Auxiliary channels
Amplifier	
Common Mode Rejection	$\geq$ 80 dB @ 100 Hz $\geq$ 40 dB @ 100 kHz
Gain range	84 dB
Gain accuracy	$\pm$ .1%
Noise (350 kHz NBW)	10 μV rms referred to input at maximum gain, for all channels except auxiliaries
A/D Converter	
Number of Bits	15 including sign (full scale = $\pm$4.09575 volts, smallest signal = +0.25 mV)
Number System	Binary one's or two's complement
Noise	1 mV peak-to-peak, 290 μV rms including Floating-Point Amplifier at minimum gain
Accuracy	$\pm$0.05% of full scale
Linearity	$\pm$0.02% of full scale maximum departure from best straight line of input versus output.
Crossfeed Isolation	80 dB minimum including the Module Multiplexer and the Floating-Point Amplifier

(2) Cont. TEST UNIT MANUFACTURERS SPECIFICATIONS

Item	Description
Test Signal, Sine Wave	
Amplitude accuracy	±0.1% when calibrated
Accuracy of level steps	±0.01%
Distortion	0.02%
Frequency	12 or 36 Hz
Test Signal, Exponential	
Decay rate	12 dB per second
Distortion (CW)	0.02%
Frequency	12 or 36 Hz

NOTE

The Frequency Reference Card can be used in place of the Exponential Oscillator. It generates 60 or 50 Hz, selected by a toggle switch on the card. These frequencies may be used to adjust the notch filters in the Input Modules.

Item	Description
Test Signal, Pulse	Width 160 μs, coincident with ASTRTDATA (Timing word zero)
Shot Point Seis Amplifier	
Voltage Gain	40 dB maximum adjustable by a potentiometer, not calibrated
Squelch Times	20, 30, 45, 66, 100, 150, 225, 340 or 500 milliseconds. It can also operate without the squelch.
Meter, dc voltages	200 μA full scale. All dc voltages read 100% at the correct level. The scale is 0 to 150%. Coded tolerance marks on the meter scale give the allowed tolerance of each voltage. The voltage is at an acceptable level with the reading between the tolerance marks. The regulated voltages do not have tolerance marks.
Meter, ac voltages	Three meter scales are provided: 100% = 0.5, 1, or 2 volts RMS.
Ohmmeter	
Seis check	300-ohm center scale backup type
Leakage	30,000-ohm center scale forward type

(3) FORMAT MODULE SPECIFICATIONS

ITEM	DESCRIPTION
Tape Formats	Formats B or C or D
Tape Mode of Operation	1600 BPI PE, Formats B, C or D.
Number of Channels	Dependent upon Format: Format B - 24, 36, 48 Seismic Channels. Format C - Up to 118 Seismic and Auxiliary Channels Format D - Up to 126 Seismic and Auxiliary Channels
Timing Accuracy	1 Part in 20,000 (0.005%).
Temperature Range	
Operating Continuous Duty:	
With Forced Air Ventilation	0 to 55°C.
Without Ventilation	0 to +40°C.
Intermittent Duty:	
3 Minutes On and 3 Minutes Off	0 to +50°C.
3 Minutes On and 9 Minutes Off	0 to 55°C.
	-55° C to +65°C.
Humidity	Withstand 0 to 100% outside cabinet without condensation.
Altitude	Withstand 12,000 feet altitude equivalent pressure.
Shock, Non-operating	Non-repetitive, case lids on 15G maximum 1/2 sinewave with a duration of 11 msec along any axis.
Vibration, Non-operating	2G maximum over a frequency range of 10 to 500 Hz along any axis.
Dustproof	With lid on.
Waterproof	With lid on, immersion to 1 inch of head for 5 minutes.
Power Magnitude	Less than 115W at 12 volts.
Power Source	11 to 14 volts from a storage battery.
Physical Size	17,000 inches wide, 20.50 inches high, 10.62 inches deep. (These are external dimensions but do not include external hardware such as handles, feet, etc.)
Weight	50 pounds

(4) READ/WRITE MODULE MANUFACTURERS SPECIFICATIONS

Item	Description
Recording Medium	9 track, 1/2 inch wide magnetic tape (certified at 3200 FCI for 1600 BPI recording)
Type of Recording	PE
Bit Packing Density	1600 (PE)
Static Skew	0.3μs after compensation at 64 kHz byte rate.
Temperature Range Ambient, Operating:	
With forced-air ventilation, continuous duty	0 to +55^{o}C
Without ventilation, continuous duty	0 to +40^{o}C
Intermittent duty, 3 min.on and 3 min. off	0 to +50^{o}C
3 min.on and 9 min. off	0 to +55^{o}C
Storage Temperature	-55 to +65^{o}C
Humidity	100% without condensation
Altitude	12000 feet maximum
Shock (nonoperating)	Nonrepetitive, case lids on: 15G maximum, 1/2 sine wave with a duration of 11 ms along any axis
Vibration (nonoperating)	2G maximum over a frequency range of 10 to 500 Hz along any axis
Dustproof	With lid on
Waterproof	With lid on, immersion to 1 inch head for 5 minutes
Power	160W, includes tape transport T1 Model 508
Power Source	11 to 14 volts from a 12V battery
Physical Size	16.75 by 15.5 by 10.31-inch deep outside dimensions excluding external hardware such as handles, feet and vent plug

(4) Cont. READ/WRITE MODULE MANUFACTURER'S SPECIFICTIONS

Item	Description
Error Rates	
(1) Read Only (not read-after-write) 40 IPS or greater tape speed	< 1 parity error in 2 x 10^8 bits or 2.2 x 10^7 bytes
Recorded at 20 IPS Reproduce @ 20 IPS	< 1 parity error in 10^8 bits or 1.1 x 10^7 bytes
Read @ 40 IPS	< 1 parity error in 2 x 10^8 bits or 2.2 x 10^7 bytes
Recorded at 10 IPS Reproduce @ 10 IPS	< 1 parity-error burst in 10^8 bits or 1.1 x 10^7 bytes
Read FWD @ 40 IPS	< 1 parity error in 2 x 10^8 bits or 2.2 x 10^7 bytes
Read Rev @ 40 IPS	< 1 parity-error burst in 7 x 10^7 bits or 7.8 x 10^6 bytes
(2) Read-After-Write (Errors due to write-to-read crosstalk) 20 IPS or greater recording	< 1 parity error in 10^8 bits or 1.1 x 10^7 bytes
10 IPS Recording	< 1 parity-error burst in 5 x 10^7 bits or 5.5 x 10^6 bytes

NOTE

A burst of parity errors is defined as more than one parity error from a given point on the tape. In an extreme case, errors may cause a track to get out of sync resulting in parity errors at the byte rate for the remainder of that record (file).

(5) TAPE TRANSPORT MODULE MANUFACTURERS SPECIFICATIONS

Item	Description
Instantaneous speed variation	$\pm$ 2% from nominal
Long term speed variation	$\pm$ 1% from nominal
Start-stop time	0.150 sec $\pm$ 10%; the velocity profile of tape during start-stop is a ramp of 0.150 sec duration.
Start-stop distance	defined by D = 0.075V where V is the tape speed in ips.
Turn-around time	0.5 sec delay required after stop command before starting the transport in the opposite direction.
Operating temperature	-10°C to $+60^{\circ}$C ($+14^{\circ}$F to $+140^{\circ}$F)
Humidity	5% to 100% without condensation
Altitude	0 to 20,000 ft
Input power	10.5 to 16 vdc, less than 100 watts at 12 vdc
Mounting	Performance is independent of mounting position.
Electronics	Solid state
Remote controls reqd	
Transport power ON	Momentary N.O. SPST, 0.5-amp contact rating
Transport power OFF	Momentary N.C. SPST, 0.5-amp contact rating
Run forward ON	$\pm$8 to 12 volts, max source impedance of 50Ω
OFF	Less than $\pm$ 1 volt
Run reverse ON	$\pm$8 to 12 volts, max source impedance of 50Ω
OFF	Less than $\pm$ 1 volt
Speed select control	3-position, 2-pole, break-before-make, 10-mA. contact rating

(5) Cont. TAPE TRANSPORT MODULE MANUFACTURER'S SPECIFICATIONS

Item	Description
End-of-tape sense	Metallic leader (N.O. SPST, 0.5-amp contact rating)
End-of-reel sense (Optional)	N.O. SPST, 0.5-amp contact is provided to indicate when supply reel has 100 ft ± 20% remaining.
Photo tab detector (Optional on Model 510)	Two logic outputs indicate presence of reflective tab on the inside or outside of the tape: 0 volts true logic (tab present), +16 volts false logic. Outputs can absorb or supply 10 ma. Pulse width defined by the reciprocal of the tape speed in ips when a 1-inch tab is used.
Transport ready	SPDT relay 0.25-amp contact rating
Weight	50lbs

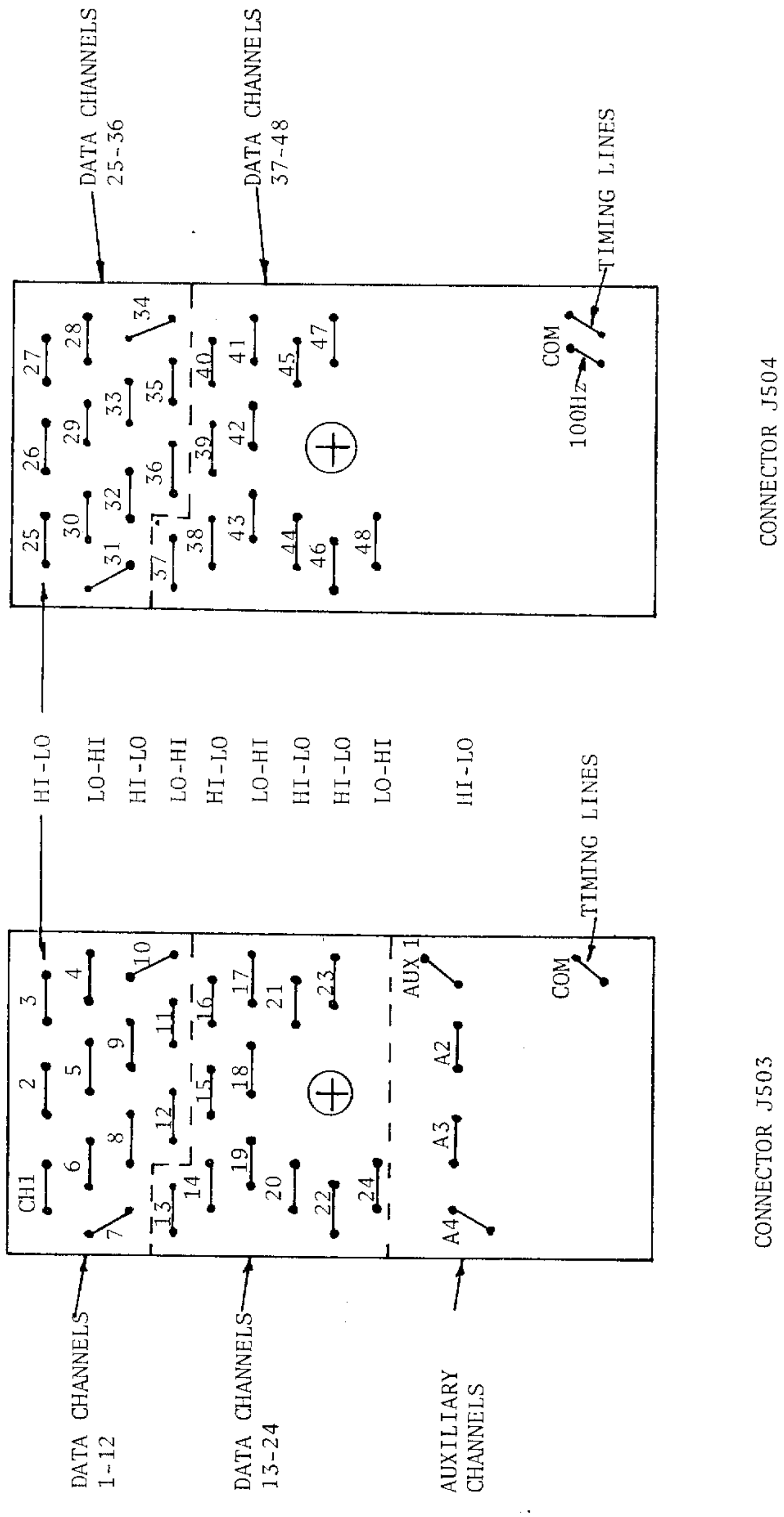

Figure 5.1 REPRODUCE MODULE GALVANOMETER OUTPUT CONNECTORS

Table 5.1 Cont. GALVANOMETER CONNECTIONS (PLUG J504)

GALVO CHANNEL	PLUG/ PIN	COLOUR	PINS FOR 12 PAIR CANNON	GALVO CHANNEL	PLUG/ PIN	COLOUR
25	J504/A	RED	A	37	J504/Y	RED
25	/B	BLK	B	37	/X	BLK
26	/C	YELLOW	C	38	/AE	YELLOW
26	/D	BLK	D	38	/AF	BLK
27	/E	ORANGE	E	39	/AH	ORANGE
27	/F	BLK	F	39	/AJ	BLK
28	/P	VIOLET	G	40	/AK	VIOLET
28	/N	BLK	H	40	/AL	BLK
29	/M	WHITE	J	41	/AU	WHITE
29	/L	BLK	K	41	/AT	BLK
30	/K	YELLOW	L	42	/AS	YELLOW
30	/J	BROWN	M	42	/AR	BROWN
31	/H	ORANGE	N	43	/AP	ORANGE
31	/R	BROWN	P	43	/AN	BROWN
32	/S	GREY	R	44	/AV	GREY
32	/T	BLK	S	44	/AW	BLK
33	/U	GREEN	T	45	/AX	GREEN
33	/V	BLK	U	45	/AY	BLK
34	/W	BROWN	V	46	/AZ	BROWN
34	/AD	BLK	W	46	/BA	BLK
35	/AC	BLUE	X	47	/BB	BLUE
35	/AB	BLK	Y	47	/BC	BLK
36	/AA	TAN	Z	48	/BD	BLK
36	/Z	BLK	a	48	/BE	TAN
				100Hz	/DA	NOT WIRED
				COM	/CU	" "