ABEM
Instruction Manual

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ABEM TERRALOC MARK 3 SYSTEM

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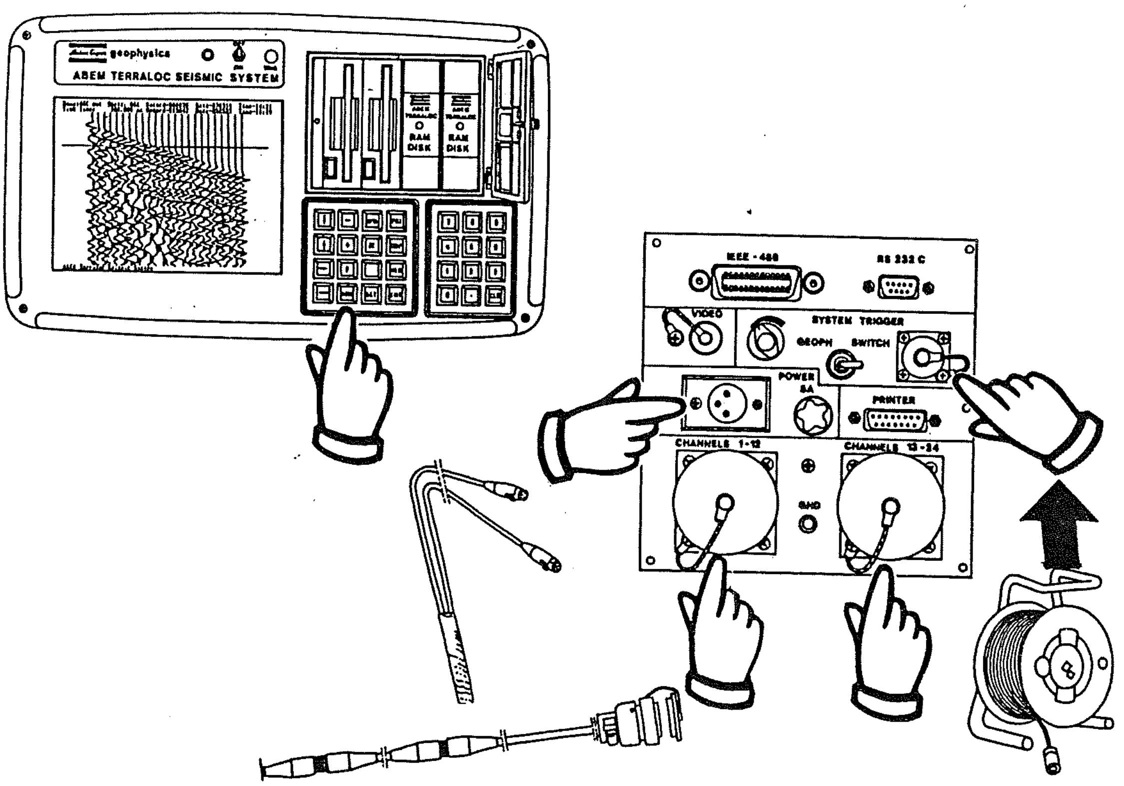
This Operation's Manual covers operation, maintenance and, where appropriate, reduction of data. A careful study of this manual is recommended before starting to work with the equipment.
There is also a Short-form Instructions Manual and a Service Manual available from ABEM.

OPERATION'S MANUAL



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1.1 INTRODUCTION

This Instruction Manual covers operation, maintenance and, where appropriate, reduction of data. A careful study of this manual is recommended before starting to work with the equipment.

ABEM instruments are carefully checked at all stages of production and are thoroughly tested before leaving our factory. They should provide many years of satisfactory service if handled and maintained according to the instructions given in this manual.

ABEM will be pleased to receive occasional reports from you concering your use of and experience with the equipment. We also welcome your comments on the contents and usefulness of this manual. When writning please be sure to include the instrument types and serial numbers.

In view of our policy of progressive development, we reserve the right to alter specifications without prior notice.

1.1.1 UNPACKING AND INSPECTION

Take great care when unpacking the instrument. Check the contents of the box or crate against the packing list that is included. Inspect the instrument and accessories for loose connections and inspect the instrument case for any damage that may have occured because of rough handling during shipment.

1.1.2 SHIPPING DAMAGE CLAIMS

File any claim for shipping damage with the carrier immediately after discovery of the damage and before the equipment is put into use. Forward a full report to ABEM, making certain to include the ABEM delivery number, instrument type(s) and serial number(s).

All packing materials should be carefully preserved for future re-shipment, should this be necessary.

1.1.3 WARRANTY

ABEM warrants each instrument manufactured by them to be free from defects in material and workmanship. ABEM's liability under this warranty is limited in accordance with the terms of Clause 9 of General Conditions for the Supply of Plant and Machinery for export prepared under the auspices of the United Nations Economic Commission for Europe, Geneva, March 1953.

It covers the servicing and adjusting of any defective parts (except tubes, transistors, fuses and batteries. The Warranty is effective for twelve (12) months after date of Bill of Lading or other delivery document issued to the original purchaser, provided that the instrument is returned carriage paid to ABEM, and is shown to ABEM's satisfaction to be defective. If the fault has been caused by misuse or abnormal conditions, repairs will be invoiced at cost.

The warranty does <u>not</u> cover any secondary costs that may have been incurred due to steps taken <u>in</u> response to a faulty measurement or any other way.

Should a fault occur that is not correctible on site, please send full details to ABEM. It is essential that instrument type and serial number are included and, if possible, the original ABEM delivery number. On receipt of this information, disposition instructions will be sent by return. Freight to ABEM must be pre-paid. For damage or repairs outside the terms of the Warranty, ABEM will submit an estimate before putting the work in hand.

Be sure to fill in the warranty registration card (included with the equipment) correctly and return it to ABEM promptly. This will help us process any claims that may be made under the warranty.

1.1.4 REPACKING AND SHIPPING

ABEM packing is selected for the instruments concerned and should be used whenever shipping becomes necessary. If original packing materials are unavailable, pack the instrument in a wooden box that is large enough to allow some 80 mm of shock absorbing material to be placed all around the instrument. This includes top, bottom and all sides. Never use shredded fibres, paper or wood wool, as these materials tend to pack down and permit the instrument to move inside its packing box.

Do not return instruments to ABEM until shipping instructions have been received from ABEM.

1.2 THE TERRALOC Mark 3 MODEL

With the Mark 3 Model of the Terraloc ABEM introduces a wide range of new features in the system. These include hardware changes as well as software changes. Below are lists of some of these improvements.

1.2.1 HARDWARE CHANGES

The hardware differences between the Mk II and Mark 3 models are numerous even though the external look is almost the same:

- Diskdrives instead of tape recorder
- RAM disks
- Analog filters
- Calibrated gain
- External power supply
- Lower power drain
- Office printer support
- Lower weight

1.2.2 SOFTWARE IMPROVEMENTS

The Mark 3 model includes the following software improvements:

- Extensive disk support software
- Digital AGC processing
- Office printer support
- New print modes
- Baudrates up to 19.200 baud
- Automatic gain set function
- Signal voltage readout
- Signal low/high warning during acquisition
- Amplifier offset check at power-up
- Preprogrammed trace assignments for 12 and 24 channel setups
- Possibility to clear selected traces
- Simplified clear procedure

1.3 GET ACQUAINTED TO YOUR TERRALOC

1.3.1 THE MANUALS

You have now at your hands one of the most powerful engineering seismographs there is. This is probably why you bought it in the first place. However, like any other sophisticated system it will need to be operated by someone and the performance of the combination will depend on both parties.

If you take the time to study this manual and the short form instructions and make a few initial experiments with the system you will be rewarded by finding that your gained experience lets you do things with the system that you did not expect from the outset. Since the operator's manual is such an important document we have put a lot of effort into making it complete yet easy to use.

It is divided into a number of sections and subsections. These sections cover different topics as indicated by their titles. All titles are listed in the index pages and this is where you should locate the information you need. Now is a good time to read through all titles!

As you have found by now there are sections covering practical things (like this very section) as well as a more theoretical section (2) covering seismic principles. One section (3) is a detailed run-through of all functions and menus that is found in the system. This is your reference whenever Terraloc operation capabilities are discussed.

Another section (4) deals with the communications functions and software support.

In section 5 external accessories are described and you are told of the proper use of these. Among these are the power supply and printer.

The next section give reference specifications (6)

Delivered with this manual are also a service manual and a short form operations guide. The service manual contains a technical description of the TERRALOC system, circuit diagrams and disassembly instructions.

The short form guide is meant to guide a first-time user so that he uses the system right from the beginning.

1.3.2 THE INSTRUMENT

The TERRALOC seismograph contains in one unit a set of seismic amplifiers to condition the weak signals picked up by the geophones. There is also a computer to control the operation of the instrument and a CRT (Cathode Ray Tube) display for the presentation of data and menues. Data are stored in digital form on PC compatible 3.5" disks. The whole system is controlled via a weather proofed keyboard and powered from standard 12 V batteries.

To start your acquaintance with the TERRALOC you should begin by looking at the instrument. There are a lot of connectors on the right hand side of the case. Here is where you connect the seismic line cables, trig cable, printer, power supply etc. You do not yet have to connect anything there except power - this introduction is run without any peripherals connected.

On the front panel near the TERRALOC nameplate you will find the On/Off switch. Switch it on.

The red indicator light should begin to shine but nothing else will happen for a while. (This is not strictly true, because inside the TERRALOC a host of activities are taking place. The computer is checking the system out part-by-part to make sure everything is in order.)

After about 10-15 seconds you will be greeted with the appearance of a screenful of text: the first menu.

This is menu 0, the power-up menu. The contents of this is described later but you may notice that here is where you set your TERRALOC clock for correct time if you move between time zones and you will also see the amount of time the system has been used.

Operate the MENU key a few times. You will see that there are a number of different looking menus displayed one after the other and that the power-up menu is not redisplayed. By the way, how many different menus are displayed? The correct answer is four. These four are chained together in a circle and it is by entering information into these that you control the TERRALOC to make it perform the tasks wished for. Now we will turn to the subject of control principles.

1.4 BASIC TERRALOC CONTROL

In the previous section you found that there are at least four menus accessible via the "MENU" key.

These menus are the heart of the TERRALOC control system. By setting up these menus the characteristics of measurement and interpretation are controlled.

These four menus deal with:

Menu 1: Recording parameters set-up. You set record time, delay, noise gate etc. here.

Menu 2: Amplifier control. Here you set the individual gains of the channel amplifiers and the noise gate and analog filters are controlled as well.

Menu 3: Processing of the received data is controlled here. You can select display size and type. You can digitally filter the data and pick arrival times and more..

Menu 4: The disk data storage system is controlled from this menu. All disk functions except the actual command to record data are started here. Recording is done via a special key on the keyboard.

There are three basic ways in which the TERRALOC is controlled from these menus.

1 A function is directly ordered to start. That is done by operating the "ENT" key whilst the screen cursor is positioned at the correct position in the menu. An example is the command to display the disk directory on the top line in menu 4.

2 Some data are entered that will be used by a function when it is later activated. An example of this is the digital filter function where you enter the filter frequency code. The filter function is not started until the traces are put on the display by the use of the "TRACES" key but then the entered code will be used.

3 Data needed by a function are entered immediately before the function itself is started. The memory functions on menus 1 and 2 are examples of this as well as the "Get record No." function on menu 4. In these cases the data are followed by operation of the "ENT" key.

To operate a function, or enter data into TERRALOC the cursor must first be positioned at the right place in the menu. This is done by the use of the "arrow" keys which control the movement of the cursor between different data items. Note here that the cursor is moved from item to item on the menu with the help of the arrow keys. No cursor move is possible within one item covering several characters except by actually writing new data.

The menu key and its use is already tested so just to make things complete: Use the "MENU" key to move from menu to menu.

1.5 MAKING A MEASUREMENT

Here you will be shown how to make a "measurement" of noise. It will give you insight in how to set your TERRALOC up for operation and it will need no more equipment than the instrument itself and the power supply.

- Switch on and wait for menu 0 to appear. Note the number of available channels in your system and get on to menu 1. (Remember how? Easy - operate the menu key once!)

- Using the arrow keys, move the cursor to the "Record time" parameter. Note how the entire data field of a parameter lights up when it is selected by the cursor and returns to normal when the cursor has passed.

- Try enter a few numbers here and notice the effect. How many and which different numbers can be used?
  Eight is correct, 0 through 7. As you see now you can easily set the record time as you wish by entering a code number from 0 to 7 and the system will respond by displaying the selected time. This is the total time during which recording of data will take place later on. One thousand signal samples will be evenly spread out over this time giving a sample internal equal to the record time divided by 1000. Set record time to 200 ms.

- Set "Record mode" to "Autostack" by entering a 0 in this field.

- Make sure that the "Channel No." and "Trace No." values in the table in the lower part of menu 1 correspond. Change the channel numbers if neccessary by moving the cursor to the retrieve function: type 3 followed by F.

- Go on to menu 2. By repeatedly operating the + key in the "All channels" field you can set all channels to a gain of 20. Do so!

- Go on to menu 3 and set the display mode for "Average" (1) and the trace type for "wiggle trace" (0). This will later cause the trace display to show the data in wiggle trace format. The traces will also be displayed in the averaged mode.

- Now is the time to make an initial measurement. Since nothing is connected the measurement will only show the instrument noise with maximum gain on all channels. Operate the "ARM" key and observe that the display shows something that resembles menu 2. Actually it is the background text from menu 2 that is redisplayed here along with the noise bars. These are the only thing active on the screen in this mode. On them you can see the noise level and how it changes.

- To make a measurement all you have to do is press the "Trig" button next to the "On/Off" switch on the front panel. Do so once!

- Now the noise bars are replaced by a set of traces going from top to bottom of the screen. A message at the bottom will tell you that the system is ready for a new shot. Another message may also appear telling you that the gains were incorrectly set. See more about this in section 1.6.1.1 below.

- Trig once more and see what happens! - The traces on the screen are replaced with a new set that look a little different. What you see now is the average of the two measurements made so far. The average is done for each sample separately so there are 1000 averaged points on each trace now displayed on the screen.

- Make several measurements by pressing the "Trig" button and then go back to menu 1.
  How do you get back? Try a few keys on the keyboard and you will discover that there is only one that actually has any effect at all. This is the "SET" key and this is the one you will have to press to get out of the measurement (or ARM) mode.
  Operation of the "SET" key brings you to menu 1.

1.6 THINGS TO REMEMBER WHEN USING YOUR TERRALOC

There are a few not so obvious things that you should know in order to get the most value out of your seismograph. A few of these are listed here.

1.6.1 GAIN SETTINGS

Always use the highest gain that will not clip the waveform of interest. You will always be able to adjust the playback scaling for your seismograms after recording.

The correct setting can be found by a few test shots at the start of a survey and modified during the measurements based on results obtained. It is important that high gains are used to utilize the analog to digital converters best. A reduction of the gain is equivalent to stripping one bit off the data for each gain step so the signals will be more coarsely measured if low gains are used.
Note that it is the signal of interest, e.g. the refracted first arrival, that needs to be observed when doing these adjustments. If the gains are set correctly in most cases the arrivals will be easily seen but the airblast arriving later will be clipped. This is of no consequence for the refraction measurement.

1.6.1.1 AUTOMATIC GAIN SETTING

If you are in doubt about which gain to use, set all gains to 10 and make a test shot. If the gain on any channel was too low or too high a warning message will be displayed on the screen. If this is the case, go to menu 2 and activate the "Auto gain set" function with the "ENT" key.

The TERRALOC computer will now adjust all gains to an optimum value. This value will produce traces ranging in maximum size from 30-60 % of full scale. In order to look at the complete record you may now have to change the "Display mode" on menu 3 to "Normal" (2) and the "Trace size" to a value between 10 and 20 %. You can also change the "Trace type" to "Variable area".

Before these new gains can be used you have to clear the stack memory. Press the "CLR" key followed by the "ENT" key to erase the data. Then make another test shot and observe the difference.

1.6.2 RECORD TIME

The TERRALOC has been designed with a broad range of applications in mind and as a consequence it exhibits a very wide range of possible record times. These are selectable on menu 1 from 24 ms to 5 s. It is important to set the record length at a value that is compatible with the measurement at hand. During the recording time the TERRALOC will sample the signal from the geophone 1000 times and store these values in memory. It is the contents of this memory that is displayed on the screen and printed on the printer as traces. The time resolution that can be achieved from such a record is dependent upon the record time and is between 24 microseconds and 5 milliseconds.

If you are working with rock mechanics and are using a signal source that produces signals in the kiloherz range then you will need to use the shortest recording times (24-48-100 ms) in order to catch the signal.

In ordinary refraction work record times ranging from 100 to 500 ms are usually satisfactory. If great precision in the arrival time determination is needed then the shortest time that will fit arrivals on all traces should be used. This means that the delay from the first arrival on the nearest geophone to the arrival at the farthest one should be less than the recording time.
When you are shooting refraction with very large distances between geophones you will be forced to increase the record length accordingly. This will however also mean that the available accuracy in arrival time determination is lower.
For shearwave measurements the longer times are also often used because of the low shear wave velocities and therefore longer travel times encountered.

1.6.3 WORK IN NOISY AREAS

When you have a noise problem for example within cities with ongoing traffic you can utilize the averaging effect of stacking several impacts. This will result in an improvement in signal-to-noise ratio proportional to the square root of the number of shots stacked. You will find that the noise will actually not be reduced by the stacking process but instead the signal will grow much faster. When you are using the stacking principle you can also utilize the NOISE GATE function of the TERRALOC to reject signals submerged in excessive amounts of noise.

You can also use the analog low cut filter selectable on menu 2 to reduce the noise contents of the record if the noise is at low frequencies.

It is as important when stacking as always that you use a high enough amplifier gain. (See 1.6.1) The high gain will of course also amplify the noise signals but the signal-to-noise ratio is improved by stacking and the true signal will be more clearly defined. The display size can be separately set and is not important for the measurement itself. What is important is to measure the signal at a high resolution because then processing, like digital filters, can later extract more information from the recordings.

1.7 MISCELLANEOUS USEFUL INFORMATION

In this section the answers to a number of questions have been assembled. These questions cover a broad range of TERRALOC use and are gathered here to make them easy to find. Some of the answers refer to special sections of the manual where more detailed information can be found.

1.7.1 DETERMINATION OF THE TRUE SIGNAL VOLTAGE

In order to evaluate vibration measurements and also to interpret reflection factors you often need to know the actual signal voltage at a certain point in a trace.

In the TERRALOC Mark 3 model this measurement is quite easily done in the following way:

1 Load the record in question into the TERRALOC main memory from disk.

2 Go to menu 3 and select the "Inspect and adjust" function.

3 You will now see a screen somewhat like in Fig. 1.7.1-1.

4 Move the trace select cursor with the right/left arrow keys to select the interesting trace.

5 Move the timeline to the point of interest with the +/- keys (perhaps also the UP/DOWN arrow key after using ENTER to time-enlarge the traces).

6 With the point identified by the timeline you push the "." key and the input voltage is displayed on the bottom line.

Note that this value takes into account both the number of stacks made and the gain used.

1.7.1.1 EXAMPLE ON HOW TO CALCULATE VIBRATION VELOCITY

Using the voltage measure functions described above (1.7.1) it is possible to calculate the vibration velocity from the measured data. Here is a simple example showing the procedure.

Geophone sensitivity:	$S = 290$ mVs/cm
Geophone resistance:	$R_G = 375$ ohms
TERRALOC input resistance:	$R_T = 600$ ohms
Voltage read from screen:	$V = -3.54$ mV

The voltage generated by the geophone is reduced by the input impedance of the TERRALOC amplifier working as a voltage divider in conjunction with the geophone resistance. The correction needed is easily determined using Ohm's law.
So the actual velocity is found using this formula:

$$\text{Velocity} = \frac{R_G + R_T}{R_T} * \frac{V}{S}$$ or in this case:

$$\text{Velocity} = \frac{375 + 600}{600} * \frac{3.54}{290} = 0.0198 \text{ cm/s}$$

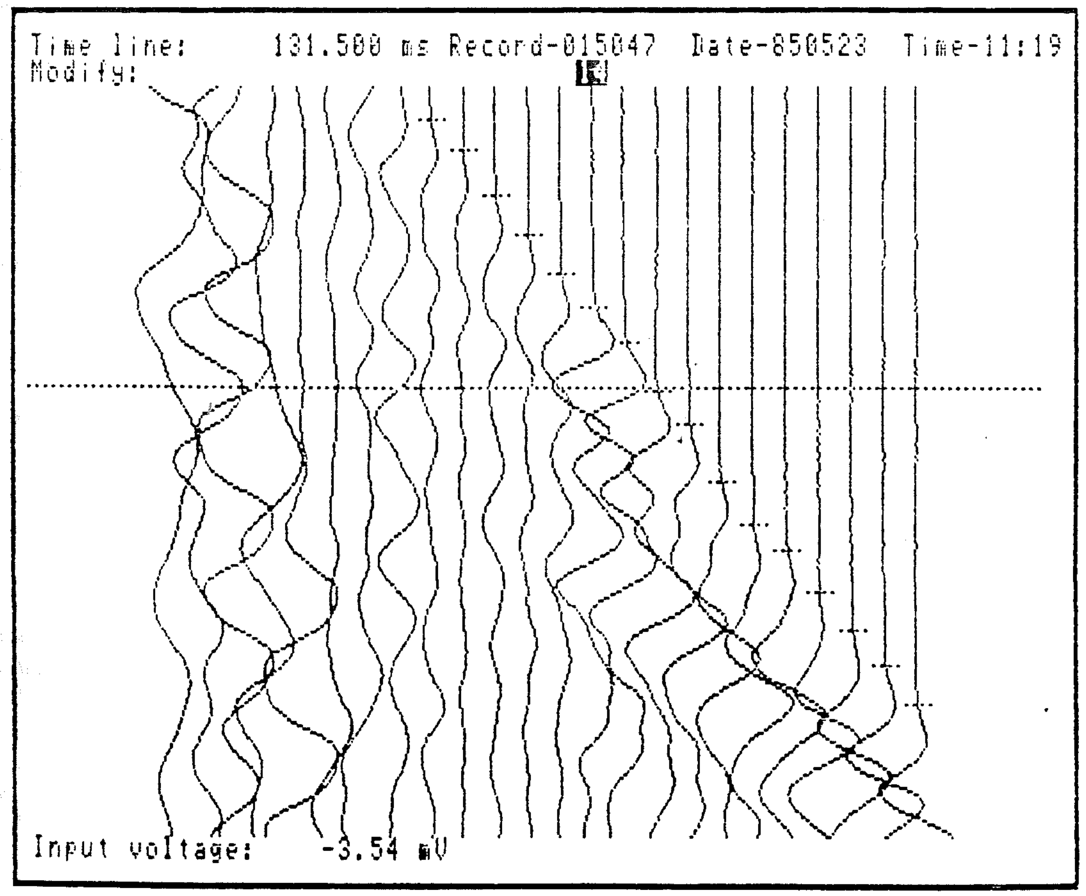

Fig. 1.7.1-1 Amplitude measurement on the screen using the "." function

1.7.2 HOW TO AVOID WIND NOISE AND GET BETTER SIGNALS

It is often a problem to do seismic measurements in windy weather. This is especially true if at the same time one has to use a small signal source such as a sledge hammer. In these cases there will be a great deal of high frequency noise signals coming from the geophones if they are placed in the ordinary way on the ground. The signal to noise ratio can deteriorate to such an extent that a very high number of stackings is required to get the neccessary quality.

To aviod this you can simply bury your geophones. This is done by digging a small hole to a depth of about 20 cm (depends on conditions) and then planting the phone on the bottom. Replace the soil firmly on top of the phone.

When this is done you will find that the wind noise is much reduced on your records and in most cases you will also have a much better coupling to the ground. This results in a higher received signal from your hammer.

1.7.3 FINDING A SUITABLE DIGITAL FILTER FREQUENCY

When you want to use the digital filter to get rid of some unwanted disturbance from your record you will have to find the proper cut-off frequency. To do this you can use the timing facilities of the TRACE display to determine the frequency of the signal to remove. You simply move the time line to one peak of the disturbance. Then operate the 0 key to zero the timeline time display on top of the screen. By moving the time line to the next peak of the disturbing signal you can directly read off the period time and by inverting this you get the frequency.

If you want to filter out a low frequency noise signal (as is mostly the case) then you engage the low cut filter on menu 3. Set it at a frequency about 2-4 times higher than the calculated frequency and operate the TRACE key. If the suppression is not good enough you can go back to menu 3 and increase the filter frequency even more. The limit here is the frequency of the signal of interest, if the filter is set higher than this then you will not enhance the record.

If you want to filter out high frequency noise (like wind hiss) you will use the high cut filter. Set it at a frequency about 2-4 times below the calculated noise frequency and proceed as above.

1.7.4 HOW TO USE THE ANALOG FILTERS

The analog low cut filter can be selected on menu 2 and has a cut-off frequency ranging from 50 to 400 Hz. It is intended to be used for removal of the high amplitude low frequency noise that is often present when you work near roads and high vegetation. Ground roll can also be suppressed by the use of this filter.
The filter is immediately put into operation when the select code in menu 2 is changed from 0. As can be seen by the noise display on this menu the noise is reduced when you switch in the filter. This means that you can use a higher gain setting over all in this mode.

It is strongly recommended that you set as high gains as possible so the analog-to-digital converter is used efficiently. One way to be able to do this is by using the analog filter to reduce high level noise.
You should select a frequency that lies below the fundamental frequency of your signal source so that you do not filter out the information.

1.7.5 USING A TRIGGER GEOPHONE

The TERRALOC can be triggered in a number of different ways as is described in section 5.6. One way that is mostly very convenient is by the use of a trigger geophone near the shot point. However, there are a few things that have to be clarified in this matter:

Crossfeed

When you use a standard geophone as source of trig signal the normal way is to plant it into the ground near the shot point. This will give a good coupling to the ground and when the shot is fired (hammer used etc) a very high voltage will be produced by the geophone. In some cases the phone will reach its end stops thus giving a signal that is very rich in high frequencies also. If the TERRALOC is set at high gains then there is a risk of crossfeed from the trig signal into the channel amplifiers. This is visible as high frequency noise in the beginning of the channels that use the highest gains.

If you encounter such a problem it is usually not sufficient to reduce the sensitivity by the use of the trig volume control. The best way is to reduce the trig voltage itself. One way of doing this is by reducing the ground coupling of the trig geophone. Simply balancing the phone on its spike leaning on the trig cable reel will usually do the trick. Another way is to modify a geophone to give lower output voltages and then always use this as the trigger phone. The modification consists of connecting a 100 ohm and a 4.7 ohm resistor in series across the phone terminals. Then connect the output leads across the 4.7 ohm resistor.

Trig delays and sensitivity to false triggings.

When a geophone is used as the source of the trig signal a time delay will always be present between the shot instant and the trig time. It is caused by two components:

- The propagation delay from the shot to the phone.
- The rise time of the phone output signal to the trig level.

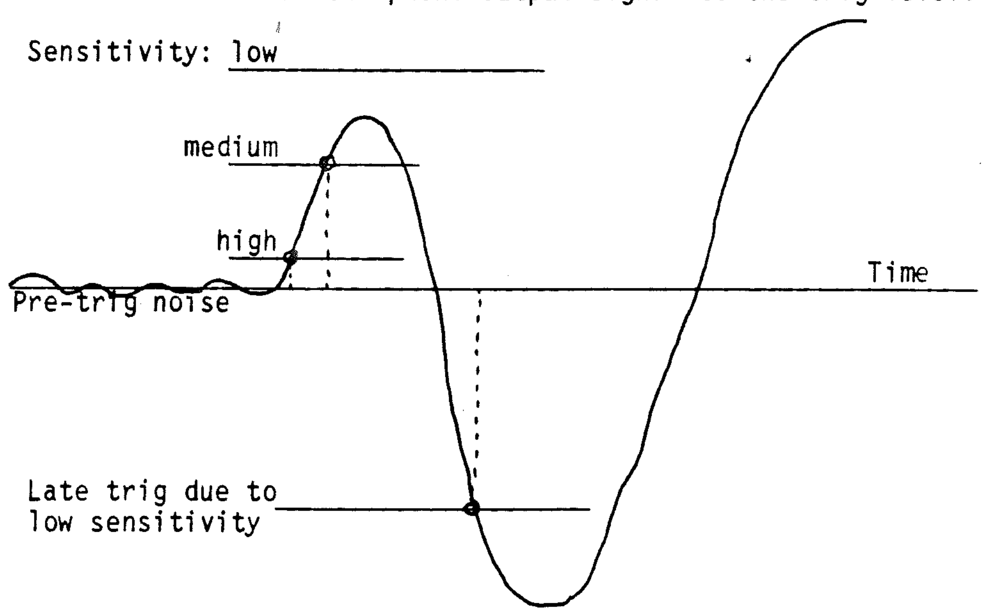

Fig. 1.7.5-1 Trig signal from a geophone and the trig point.

To reduce the propagation delay the only way is to move the phone closer to the shot. This can not always be done due to physical limitations in which case you will have to accept the delay.

The rise time effect is another matter because it is influenced by a number of conflicting requirements. If the trig sensitivity is increased the result is of course an earlier trig point (see Fig. 1.7.5-1) but increasing the sensitivity also means that the risk of trigging the system by a noise signal increases.
If the sensitivity is set too low noise trigging will not occur but instead a considerable and poorly defined delay is introduced. This can seriously degrade the performance of the stacking system of the TERRALOC since any signal frequency with a period time comparable to or less than this trig uncertainty will be attenuated.

So in conclusion you will have to find a suitable compromise between high sensitivity to false triggings and large timing errors.

1.7.6 SIGNAL SOURCE COMPARISON

In seismic work the selection of a suitable signal source is often a tricky task. The table below contains a characterization of the different available sources and their applicability. We do not claim that it is a complete nor entirely correct list but it can serve as an initial help to the user.

Source	Character
Sledge hammer	Low energy output, medium frequency. Usable at short range, with stacking up to 150 m. Cheap but needs strong assistants. It is important to use very high gain settings when stacking. See 1.7.8.
Dynamite	High to very high energy output, medium to high frequency. Usable only where a permit can be obtained (this is a problem in some areas). Very good for large scale refraction work.
Weight drops	Low to medium energy output, medium to high frequency. (High frequencies if small weights are used). In bad desert areas very large weights can be used if no dynamite permit is possible. Then use 250-1000 kg from 2-4 m heights.
Ignition caps	Low energy, high frequency output. Subject to permit limitations but is good for shallow depth reflection work. A bit expensive.
Betsy Seisgun™	Medium energy output, low to medium frequency. Permit problem with ammunition, needs at least two shots at each position with water injection into shot hole between the two. Heavy and difficult to transport in rough terrain. Creates large airwave.

Source	Character
Dynasource™	A vacuum enhanced weight drop with medium energy output, medium frequency. It is used mainly on roads due to transportation problems. Long shot-to-shot cycle time, sensitive release mechanism.
Sparkers	Low energy, high frequency output. Used mainly in boreholes. Complicated and dangerous high voltage circuits used.
Shell exploders	Medium energy, medium frequency output devices used in shotholes of 0.7-1 m depth. Easy to operate lightweight source. In some places permits may be required for the shells (standard shotgun shells are used).

1.7.7 TRIGGERING BY RADIO

The following section describes a method that can be used to transmit the trig pulse over radio.

What is needed is a source of a trig pulse at the shot point and a set of walkie-talkie radios. As trig pulse sensor you can use either a trig geophone or a shot current pickup unit such as the one delivered with the TERRALOC. Connect the transmitter external microphone input to the source. This can be easily done using the trig cable reel and an adaptor connector for the transmitter.
Then connect the loudspeaker output on the receiver unit to the TERRALOC trig input connector between pins B and D (ground).
By testing you may adjust the receiver output level and the TERRALOC trig input sensitivity so that false triggings do not occur from radio channel noise. This is done by switching the transmitter to the transmit position and then arming the TERRALOC. Without entering any trig signal into the transmitter you adjust the levels so that the TERRALOC stops triggering. Then make a test shot and observe the result. Readjust if neccessary with the transmitter at a distance.

1.7.8 PROCEDURE FOR STACKING HAMMER IMPACTS

In most cases where a hammer is used as the signal source the noise levels are almost the same as the received signal levels at the far end of the spread. This makes it neccessary to stack several impacts to improve the signal-to-noise ratio.
In doing this it is very important that a high enough gain is used so that the small p-wave arrival is not lost. You should increase the gain to such an extent that the surrounding noise will cover approximately 30-50 % of the maximum deflection on a trace after the first blow. Then use the "Average" display mode and start stacking. After a while the noise will be reduced so that you can see the first arrival and judge for yourself when you may stop hammering.

If the gains are set too low you can easily miss the p-wave and only get the slower surface waves on your record. Don't despair if the record at first looks completely useless: you are recording as much as is present in the ground and the stacking process will help to bring the information out from the noise. If you cannot see anything after 30-40 blows then the use of a more powerful source is the only remedy.

1.7.9 READING TERRALOC DISKS ON A PC COMPUTER

The data recorded by the TERRALOC on the 3.5" disks are written in a format compatible with the MS-DOS operating system used on the IBM-PC and compatible computers.

The disks can be read by any such computer equipped with:

1 - A 3.5" disk drive

2 - MS-DOS version 3.2 or above

Some lap-top computers running MS-DOS 2.1 can also read the TERRALOC disks directly.

If you have an IBM-PC computer only equipped with 5.25" disk drives you can easily upgrade by purchasing (from an IBM vendor or a reputable computer store) an external 3.5" disk drive and PC-DOS 3.2. Installation is quite simple since the drive connects to a 37-pin connector already present on the back of your computer.

To use the data on the disks you will need software adapted to the file format used by TERRALOC. Information on this can be found in sections 3.8.11 and 3.8.12.

A few demonstration programs have been prepared to read the disk directly, these are described in section 4.3. They are also delivered in source form on the demo diskettes that come with the TERRALOC.

1.7.10 SAVE PRINTER PAPER

Sometimes the full length of the paper record produced by the TERRALOC is not needed. This is the case for example when you are making refraction measurements and all arrivals are together in the front part of the record. If the "SET" key is pushed during a printing operation the printer will immediately stop. In this way the operator can determine the length of the printout himself by watching the record during printing.

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2. SEISMIC MEASUREMENT THEORY

2.1 INTRODUCTION

The seismic methods of geophysical prospecting uses the fact that elastic waves travels with different velocity in different medias.

The principle of seismic investigations is to initiate an elastic wave (shock wave) at a point and determine at a number of other points the arrival time of the energy that has travelled in the different rock formations. By geometrical calculations it is possible to interpret the seismic velocity and thickness of the different layers.

In seismic prospecting we are in principle using two different methods.

1 The refraction method
2 The reflection method

In the refraction method the main interest is the arrival time of the first part of the seismic pulse, the refracted wave. In the reflection method the later arrivals, the reflected waves, are also used.

Both methods make it possible, if properly handled, to interpret data in an almost unique and unambiguous way.

A third method that has become more and more important in recent time is the cross-hole or direct wave method. This method always uses the arrival time of the direct wave. The measurements are carried out in boreholes or tunnels and the interpretation requires access to computers and suitable software (tomographic programs). These facts explains why the method so far has mostly been used by research institutes or similar organisations.

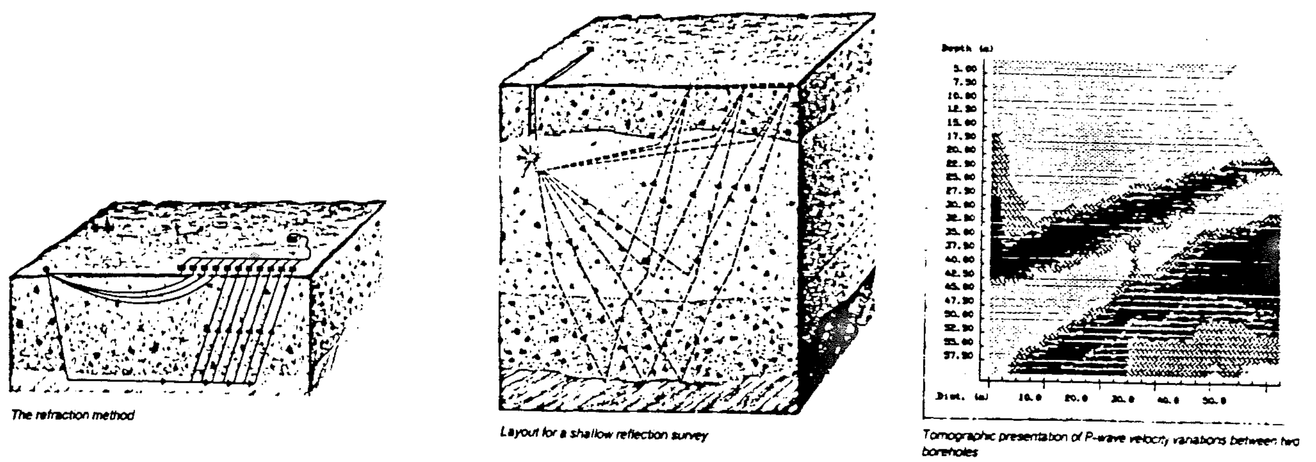


Fig 1 The refraction, reflection and cross-hole methods in sesmics.

2.2 SEISMIC SIGNAL SOURCES

The standard method of producing seismic waves is to explode a small dynamite charge in a short hole in the ground. Other signal sources such as falling weights, electrodynamic shakers etc have also been tested but the energy output from these sources is often too low for practical work. The tendency in recent years has nevertheless been to replace the dynamite with signal sources that are less destructive. The reasons are both economical and safety.

The seismic signal sources for shallow depths can be classified as follows:

1 Solid chemical explosives (Dynamite etc)
2 Electrical energy sources (Sparkers)
3 Gas exploders
4 Mechanical impulse sources (Hammers, falling weights)
5 "Shot guns" ("Terragun" fig 2, "Betsy")

All these sources produce a short sudden pulse and the decision of which to use depends only on the type of survey and of course as mentioned before economy and safety.

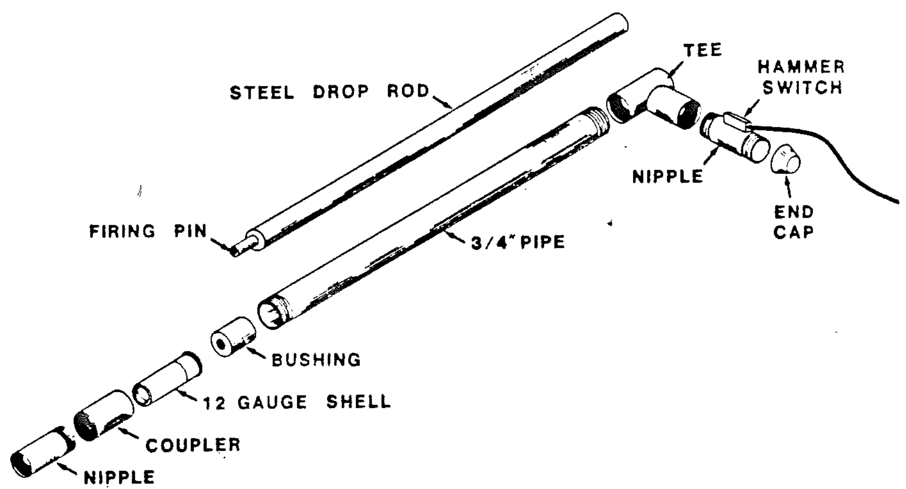


Fig 2 The "Terragun" seismic source.

2.3 SEISMIC WAVES AND THEIR PROPAGATION IN AN ELASTIC MEDIUM

2.3.1 ELASTIC CONSTANTS.

To be able to define the elastical properties in a medium a constant E called Young's Modulus is used.

When a moderate force is applied on a medium the strain is directly proportional to the stress producing it (Hooke's law). The relationship is written:

$$S = \varepsilon \cdot E$$

where S is the stress and ε the strain. E is the Young's Modulus of elastic moduli and is defined as a constant which specifies tne relation between the stress and the strain. The constant is only dependent on the material and expressed as force per unit area.

The stress is also defined as force per unit area

$S = F/A$ F = Force A = Area

while the strain (ε) describes the relation between the elongation or shortening Δl of a rod with the length l under the influence of a compressive or tensile force:

$$\varepsilon = \frac{\Delta l}{l}$$

If, on the other hand, a body is exposed to a uniform force acting on all sides its volume will decrease by an amount of ΔV. The Bulk modulus (k) is defined as the ratio between the force per unit area (F/A) and the differential change of volume ($\Delta V/V$):

$$k = \frac{F/A}{\frac{\Delta V}{V}}$$

This can be compared with Young's modulus:

$$E = \frac{F/A}{\frac{\Delta l}{l}}$$

If there is a shearing strain the deformation is as before proportional to stress. But this is only valid for moderate stress levels.

The shear modulus (n) is definied as:

$$n = \frac{F/A}{\emptyset} \quad \text{(see fig 3)}$$

n is in most materials about half the value of Young's modulus.

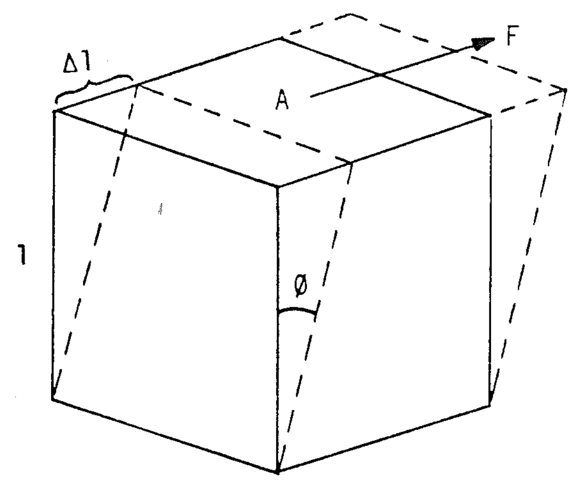


Fig 3 The shear modulus.

If we continue to use the rod as an example we can write the relation between the change in diameter to the original diameter ($\Delta d/d$) and the change of length to the original length ($\Delta l/l$)
The equation is written:

$$\sigma = \frac{\frac{\Delta d}{d}}{\frac{\Delta l}{l}}$$

σ is called Poisson's ratio.

Usually σ is about 0.25 for most rock types. The maximum value 0.5 is found in water. The minimum value 0.05 is found in very hard materials.

To describe a medium fully we need two more constants called Lamé's constants λ and μ . Expressed in E and σ they are:

$$\lambda = \frac{\sigma \cdot E}{(1+\sigma)(1-2\sigma)}$$

and

$$\mu = \frac{E}{2(1+\sigma)}$$

The Lamé's constant μ is the same as the shear modulus (n). When Poisson's ratio is 0.25, the constants λ and μ are equal and equal to 2E/5.

To sum up we have got some useful relations:

$$k = \lambda + 2/3\mu = \frac{E}{3(1-2\sigma)} \qquad \text{(Bulk modulus)}$$

$$n = \mu = \frac{E}{2(1+\sigma)} \qquad \text{(Shear modulus)}$$

$$E = \frac{\mu(3\lambda + 2\mu)}{\lambda + \mu} = \frac{9kn}{3k+n} \qquad \text{(Young's modulus)}$$

$$\sigma = \frac{\lambda}{2(\lambda+\mu)} = \frac{3k-2n}{6k+2n} = \frac{E}{2\mu} - 1 \qquad \text{(Poisson's ratio)}$$

$$\lambda = \frac{\sigma E}{(1+\sigma)(1-2\sigma)} = k - \frac{2n}{3} \qquad \text{(Lamé's constant)}$$

The two parameters that are of most interest for studies of elastic waves in rocks are the Bulk modulus, k, and the shear or rigidity-modulus n.

Some typical values for different rocks and a few substances are listed in the table below:

Substance	k Bulk modulus ($N/m^2 \times 10^{-10}$)	n Shear modulus ($N/m^2 \times 10^{-10}$)
Marbles, limestone	3.7 - 5.7	2.1 - 3.0
Granites	2.7 - 3.3	1.5 - 2.4
Diabase	7.3	3.7
Sandstone	1.25	0.61
Iron (wrought)	16.0	7.7
Iron (cast)	9.5	5.0
Glass	5.0	2.5
Water	0.21	0

2.3.2 SEISMIC WAVES

If an elastic medium in equlibrium is exposed to a sudden shock wave, for example a hammer impact, the stress in the medium will propagate as an elastic wave.

There are two types of elastic waves - bodywaves - that can travel <u>inside</u> a medium.

1 Longitudinal or P waves
2 Transverse or S waves

A third type of wave is called Rayleigh-wave, after the finder.

This type of wave differs from P- and S-waves since it is a surface wave, i.e. it will in principle travel only on the surface of a medium. The amplitude of the surface wave is decreasing exponentially with the distance from the surface.

Each of the above mentioned wavetypes cause a slight momentary displacement of earth material as it passes through (fig 4). The P-waves cause a back-and-forth (compressional) motion which is parallel to the direction in which the wave is travelling. S-waves cause a to-and-fro (shear) motion which i perpendicular to the direction in which the wave is travelling. Rayleigh surface waves cause an elliptic kind of motion, part of which is parallel to the surface of the earth along which the wave is travelling and part of which is perpendicular to the surface. The surface wave thus includes both a horizontal and a vertical of surface displacement component.

Fig 4 illustrates the motions associated with each of these wave types for a wave travelling horizontally.

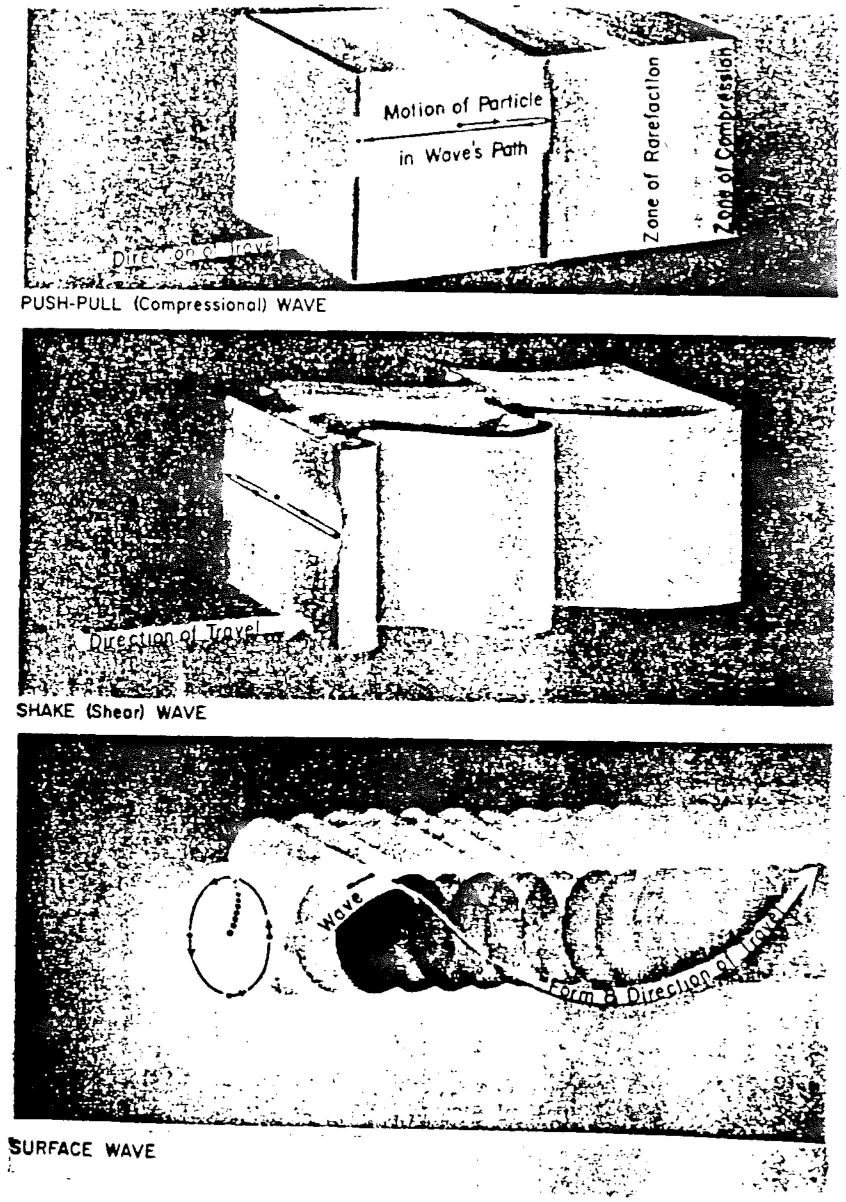


Fig 4 The motion of the P-, S- and Rayleigh-waves.

2.3.3 SEISMIC WAVE VELOCITIES

The seismic wave velocity in a medium depends of the density (ρ) and the elastic properties of the medium. The relationship could simply be written as:

$$V = \left(\frac{\text{elasticy}}{\text{density}}\right)^{1/2}$$

Looking at the P- and S-waves specifically the relations are:

$$Vp = \left(\frac{k + 4/3n}{\rho}\right)^{1/2}$$

and

$$Vs = \left(\frac{n}{\rho}\right)^{1/2}$$

As a simple rule of thumb we usually say that the P-wave velocity is related to the S-wave velocity as $1:1/(3)^{1/2}$ (or 1:0.58). For poorly consolidated rock types the value 1:0.45 is probably better. The Rayleigh-wave velocity is approximately 0.9 times the S-wave velocity.

The observed surface wave velocities are, however, somewhat lower than given in the equation above. This is because the Rayleigh wave travels along the surface where lower velocities are normally encountered and the surface waves tend to disperse (the wave velocity depends on the wave frequency). The low-frequency parts are followed by higher and higher frequency waves.

The frequency of body-waves (P-S waves) is normally between 15-200 Hz.The surface waves are usually of a frequency lower than 15 Hz.

The wave length (l) of the different wavetypes follows from the relationship between the velocity (v) and the frequency (f).

$$l = \frac{v}{f}$$

There are several methods to find the seismic velocity of a medium. In the laboratory the best way is to use a so called sonic to measure rock samples. In the field the velocity can be determined from ordinary registrations of arrival times and distances. In the table below you find some typical velocities found in practical studies.

Material	P-wave velocity (m/s)	S-wave velocity (m/s)
Air	330	------
Sand	300-800	100-500
Water	1450	------
Morain	1500-2700	900-1600
Limestone	3500-6500	1800-3800
Rocksalt	4000-5500	2000-3200
Granites	4600-6500	2500-4000
Diabases	5500-7000	3000-4500

From the table you can see that the velocity seems to increase with increasing density quite contrary to what was discussed in the beginning of this section. The reason for this is that the elastic properties of the materials will increase faster than the density. This makes the ratio elasticity/density increasing when the density increases.

2.4 REFRACTION AND REFLECTION OF ELASTIC WAVES

As other types of waves like light waves, seismic waves will be refracted and reflected at the boundary between media with different physical properties.

In the figure below it is shown how an incoming wave will be refracted and reflected at the boundary between medium 1 and medium 2.

When a seismic wave meets the boundary new waves will arise. These secondary waves will, as the primary wave, follow the law of Snell

$$\frac{\sin i}{V_{1p}} = \frac{\sin re_p}{V_{1p}} = \frac{\sin re_s}{V_{1s}} = \frac{\sin ra_p}{V_{2p}} = \frac{\sin ra_s}{V_{2s}}$$

Where V_{1p}, V_{2p} och V_{1s}, V_{2s} are the P- och S-wave velocities and i, re_p, re_s, ra_p, ra_s are the angle of approach for the primary wave, reflection- and refractionangle respectively for the arised P-wave and reflection- and refractionangle respectively for the arised S-wave.

The relations above are valid both if the primary wave is a P-wave or an S-wave. In seismic exploration we are mostly using P-waves since it is hard to create S-waves with enough energy to be used in prospecting work.

S-wave analysis is mostly used in studies of material conditions. By registration of both P- and S-wave velocities and by using the physical laws given in the previous section the E-modulus, k-modulus etc. can be calculated.

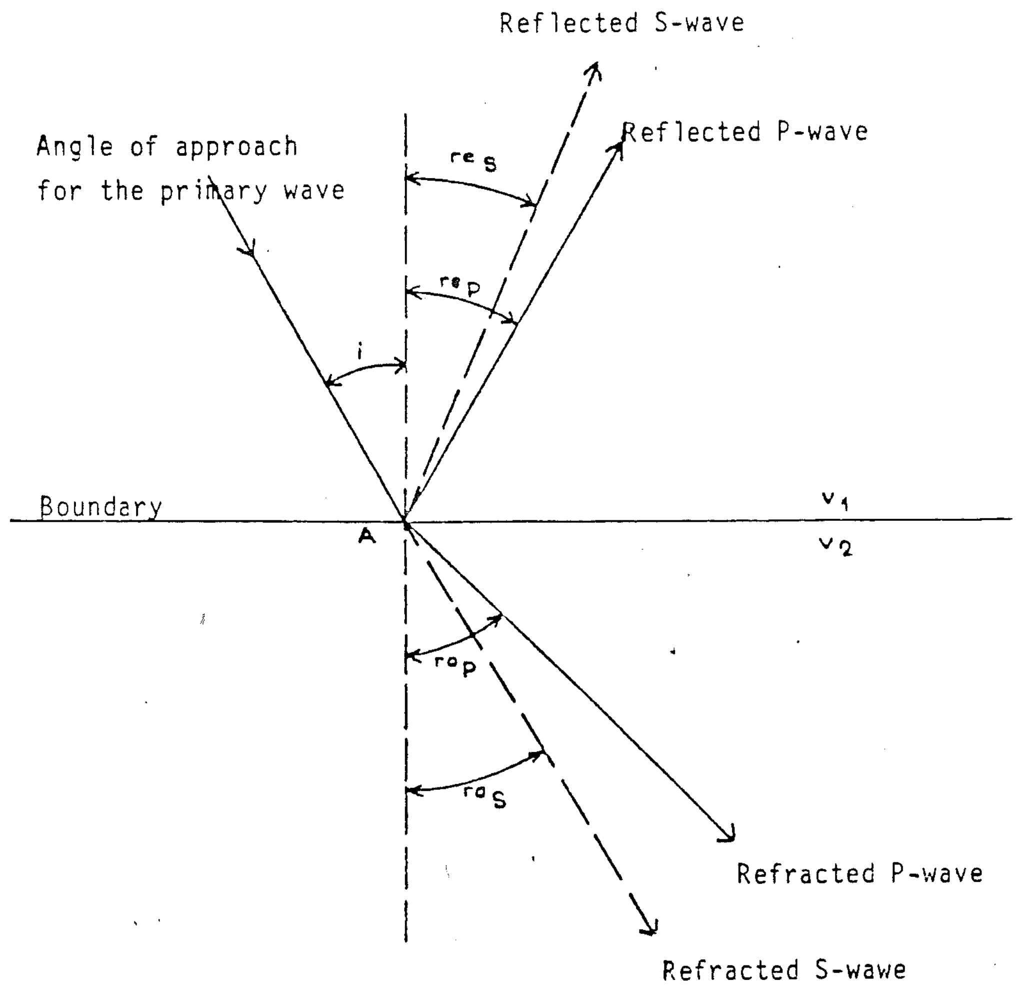


Fig 5 Reflection and refraction at a seismic boundary.

2.4.1 VOLUME WAVES IN STRATIFIED MEDIAS

By studying volume waves (P- and S-waves) that are reflected at and refracted along seismic boundarys close to the earth surface we get important information about the composition of the different geological layers.

We will start discussing the expression "wave front" and "wavepath". Suppose that an energy source (explosion) is acting at a point on the surface. In a homogenous and isotropic medium the energy will spread in the equally in all directions.

The wave-front will then look like an expanding half-sphere around the explosion point. By regularly "freezing" the position of the wave front an image showing the propagation of the seismic energy can be constructed like fig 6. In this figure the position of the wave-front each 10 ms is shown. The wavepath is the curve that perpendicularly cuts every wave-front.

Another type of wavefront should be mentioned - the diffracted wave-front - that is generated when a wavefront meets a boundary. This type of waveform is built up of a nearly plane parallel system (see fig. 6). The origin of this waveform is based on the principles of Huygen that states that each point on a wavefront acts as a source for an expanding spherical wavelet and that after a time lapse the envelope of all these wavelets defines the new wave-front. The raypaths are perpendicular to the wave-front in an isotropic medium (see fig. 6).

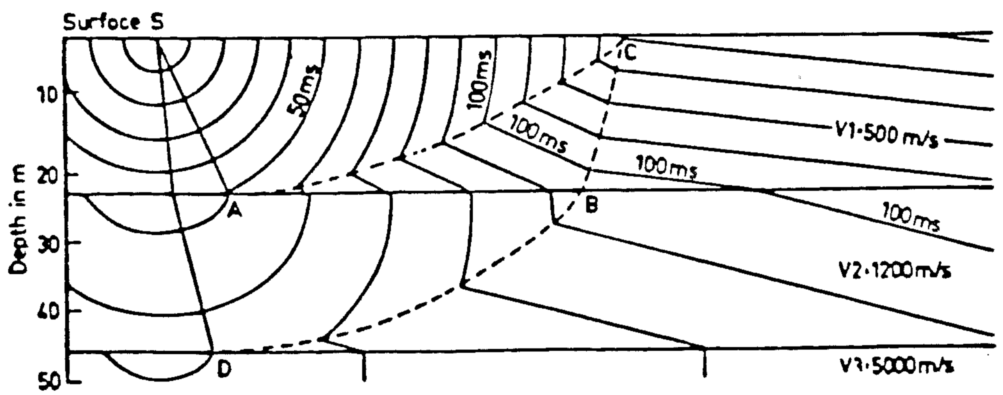


Fig. 6. Spherical and diffracted wavefronts with raypaths.

We are now going to look at a two-layer case i.e. a layer with a lower seismic velocity resting on an infinite substratum with a higher seismic velocity. In this case we can differ between the following wavetypes (fig. 7):

a) The direct wave that propagates from the source to the observation points without being reflected, diffracted or refracted (wavepath 1). The traveltime for this wave is found simply by this equation.

$$t_d = \frac{(x^2 + h_o^2)^{1/2}}{v_o}$$

t_d = the travel time of the direct wave

x = surface distance between the source and the observation point

h_o = depth of the source

v_o = P- or S-wave velocity

If the source is located at the surface $h_o = 0$ we will get

$$t_d = \frac{x}{v_o}$$

b) The reflected wave. This wavetype is reflected at the seismic interface at depth z from the surface. We distinguish between the following possibilities:

Close to the source the angle of incidence is less than the angle of total reflection. This means that one part of the total wave energy will continue downwards (diffracted wavepath 3), while the other part will be reflected back to the surface.

The amount of the reflected wave energy and its phase related to the incoming wave depends on the contrast between the physical parameters i.e. the acoustic impedance of the different media. The amplitude ratio between the reflected and incoming energy is:

$$\frac{A_r}{A_i} = \frac{v_1\rho_1 - v_2\rho_2}{v_1\rho_1 + v_2\rho_2}$$

where ρ_1 and ρ_2 are the densities of media 1 and 2

v_1 and v_2 are the velocities of media 1 and 2

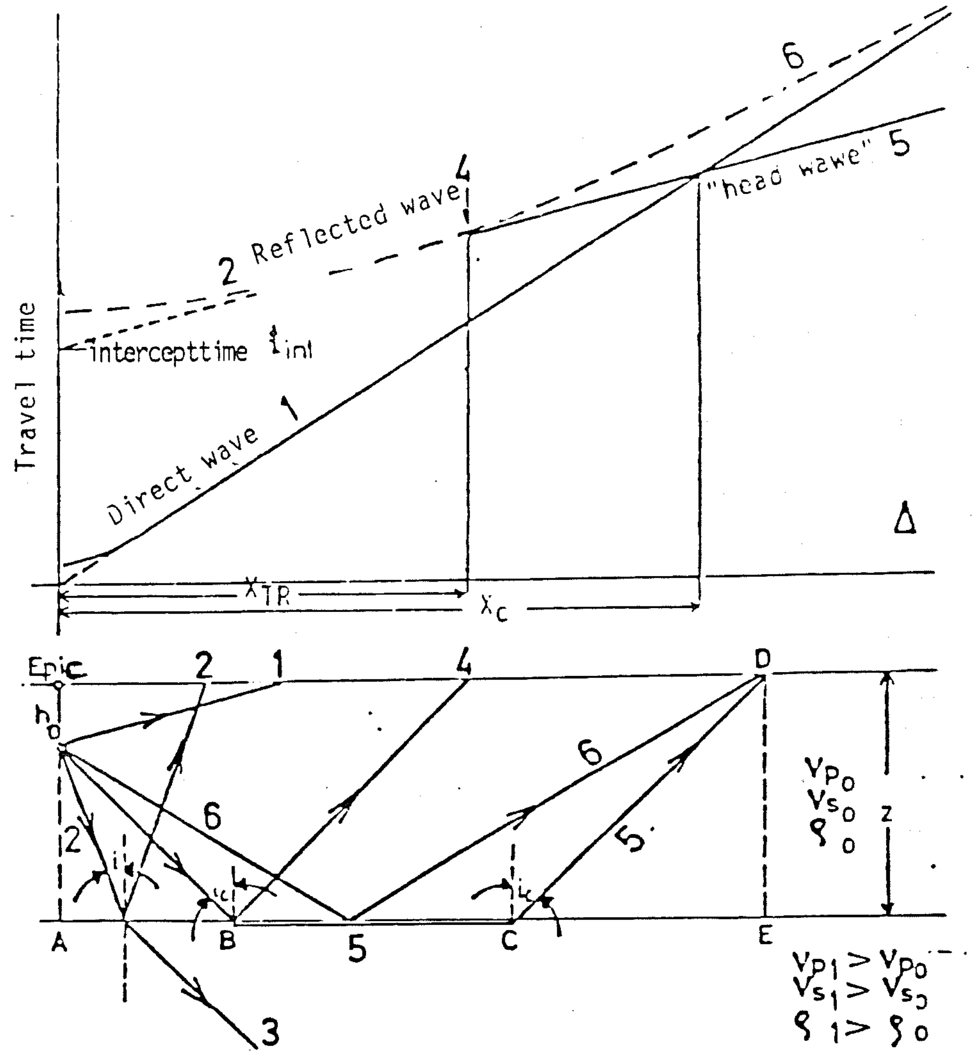


Fig 7 Seismic wavepaths and traveltimes in a two-layer case.

The traveltime for the reflected wave is

$$t_r = \frac{2z - h_o}{\cos i \; v_o}$$

z = depth to the seismic interface

h_o = depth of the source

i = angle of incident and reflection

v_o = seismic velocity of the upper layer.

If the source is at the surface ($h_o = 0$) we will get

$$t_r = \frac{2((\frac{x}{2})^2 + z^2)^{1/2}}{v_o}$$

If the angle of incidence is greater than the angle of total reflection then all of the wave energy will be reflected (wavepath 6 in fig. 7).

c) Of special interest is the wavepath that meets the boundary at point B in fig. 7 (critical angle i_c for total reflection). Here a diffracted wave will be generated that travels along the interface surface.

The wavetype that will travel along the surface of the second layer is called the Mintrop-wave or Head-wave. Mintrop was a German geophysicist first to observe this wavetype. In refraction seismic the Head-wave is the only wave type we need to consider to be able to calculate depths and velocities.

Looking at the case when a seismic wave meets the boundary at an angle of incidence equal to the critical angle we get according to Snell´s law:

$$\frac{\sin i_1}{\sin i_2} = \frac{v_o}{v_1}$$

$i_2 = 90^o \rightarrow \sin i_2 = 1$

$i_1 = i_c$

which gives

$$\sin i_c = \frac{v_o}{v_1} \qquad i_c = \arcsin \frac{v_o}{v_1}$$

The distance for which this condition will be fulfilled for the first time in the time-distance graph is called the cross-over distance.

The traveltime for the raypath H - B - C - D is

$$t_n = \frac{\overline{HB}}{v_o} + \frac{\overline{BC}}{v_1} + \frac{\overline{CD}}{v_o}$$

For the distances $\overline{HB}$, $\overline{BC}$ and $\overline{CD}$ we get

$$\overline{HB} : \frac{z - h_o}{\overline{HB}} = \cos i_c$$

$$\overline{BC} : \overline{BC} = x - (\overline{AB} + \overline{CE})$$

$$\frac{\overline{AB}}{z - h_o} = \tan i_c = \frac{\overline{CE}}{z}$$

$$\overline{BC} = x - (2z - h_o) \quad \tan i_c$$

$$\overline{CD} : \frac{z}{\overline{CD}} = \cos i_c$$

which gives

$$t_n = \frac{x}{v_1} + \frac{2z - {}_o h}{v_o \cos i_c} - \frac{(2z - h_o) \quad \tan i_c}{v_1}$$

using

$$\tan i_c = \frac{\sin i_c}{\cos i_c} , \; v_1 = \frac{v_o}{\sin i_c}$$

and we get for t_n

$$t_n = \frac{x}{v_1} + \frac{2z - h_o}{v_o \cos i_c} (1 - \sin^2 i_c)$$

or

$$t_n = \frac{x}{v_1} + \frac{(2z - h_o)(1 - (v_o/v_1)^2)^{1/2}}{v_o}$$

If the source is at the surface $h_o = 0$ we get

$$t_n = \frac{x}{v_1} + \frac{2z \; (1 - (v_o/v_1)^2)^{1/2}}{v_o}$$

This result shows that the arrival times (t_n) plotted against distance will form a straight line with a slope equal to $1/v_1$. The line will cross the t-axis at

$$t_{int} = \frac{2z \; (v_1^2 - v_o^2)^{1/2}}{v_o \quad v_1} = 2z \; (v_o^{-2} - v_1^{-2} \;)^{1/2}$$

This time is called the intercept time.

The depth z is given by this equation:

$$z = \frac{t_{int} \; v_o \; v_1}{2 \; (v_1^2 - v_o^2)^{1/2}}$$

The velocities v_0 och v_1 are found from the reciprocal slope of the traveltime curves. Using t_{int} the depth z can be calculated.

Another method to calculate the depth z is to use the distance x_c i.e. the distance from the shotpoint to the cross-over between the traveltime curves of the direct wave and the head wave. This distance is called the crossover distance x_c.

Using the $t_d = t_n$ we get

$$z = \frac{x_c}{2} \quad (\frac{v_1 - v_o}{v_1 + v_o})^{1/2}$$

The same concept can be used for reflected impulses. A traveltime diagram is constructed in the same way as before but using a quadratic scale in both the time- and distance axis. For calculation of the depth z it is only the mean velocity v_m that is of interest even if the velocity distribution is very complicated.

Looking at two reflections at the same boundary but registred at different distances, using the notations given in fig. 8 we will get:

Reflection 1 $$\left(\frac{v_m t_1}{2}\right)^2 = \left(\frac{x_1}{2}\right)^2 + z^2$$

Reflection 2 $$\left(\frac{v_m t_2}{2}\right)^2 = \left(\frac{x_2}{2}\right)^2 + z^2$$

$$v_m^2 = \frac{(x_1^2 - x_2^2)}{(t_1^2 - t_2^2)}$$

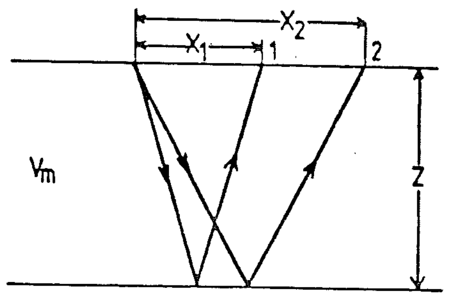


Fig 8 Reflection at a horizontal boundary.

From the reciprocal slope of the time distance curve we get the square of the mean velocity. The depth z can be calculated using the intercept time.

By setting x_1 or x_2 equal to 0 the equations above can be written

$$z = \frac{v_m t_{1\,int}}{2}$$

$$z = \frac{v_m t_{2\,int}}{2}$$

2.5 REFRACTION SEISMICS

Since seismic investigations yield a great variety of reliable data such as depth of various overburden layers, depth-to-bedrock, soil composition and solidity, rock quality, rippability, excavatability, water tables and rock structure, the results are utilized for a wide range of applications, some of which are listed below:

Underground	Tunnels and their entrances, machinery halls, gas and oil storage facilities, air raid shelters.
Foundations	Heavy industrial buildings, bridges, harbour quays and breakwaters, dams, piling, airfields.
Excavation	Harbour basins and entrances, pipelines, canals, roads, railways.
Resource searches	Gravel, sand and quarry sites.
Water prospecting	Groundwater table in the overburden, water- bearing sections of rock.
Ore prospecting	Mineralized weathered zones, buried channels with high mineral content.

A seismic survey is of unique value because it provides:

- Good economy. An immense amount of useful data is obtained at a very reasonable cost.
- A continuous picture of the underground geological conditions. This substantially reduces the risk of overlooking critical or promising areas.
- Terrain-independence. Rough terrain, urban sites and water-covered areas can all be surveyed with equal ease.

The following parameters are measured and computed. They are used for both interpretation and evaluation:

Apparent/average longitudinal velocity, V_p.	Apparent velocities - after being corrected - are used to determine thicknesses of layers, interfaces between discrete layers, water table and total depth-to-bedrock. Average velocities - obtained from reversed recording - are used to evaluate soil layer composition, rippability/excavatability and rock quality.

Apparent/average transverse velocity, V_s

Apparent/average transverse velocities are used - in conjunction with longitudinal velocities - to evaluate material composition and rock quality. Unlike longitudinal waves, the transverse waves are not affected by the water content of a material.

To evaluate the dynamic properties of soil and rock layers, the following parameters can be computed using longitudinal and transverse velocities and the material density:

- Young's modulus of elasticity
- Poisson's ratio
- Bulk modulus
- Shear modulus

To provide a more comprehensive picture of the composition and consolidation of a material, an interpretation can include analyses of amplitudes and frequencies.

The extensive use of the seismic refraction method for civil engineering in Sweden and later in many other countries under a wide range of climatic and topographic conditions including use across rivers and lakes has accelerated development and improvement of the necessary equipment.

Fieldworthiness, meaning

Simplicity of operation
Reliability and ease of maintenance
Rapid set-up for field work
Compactness for quick transport

has been and still remains very much in demand by field crews.

The type of field work to be carried out with seismic refraction equipment plays an important part in instrument design philosophy. A brief description of the present practice of refraction profiling and its applications is therefore warranted.

2.5.1 FIELD PROCEDURES

For civil engineering purposes and water prospecting, seismic measurements must yield accurate and detailed depths and velocities. Generally, continuous profiling with reversed recording and rather short distances between impact points and seismometers are employed.

There is no standard field work procedure. It has to be adapted to the project at hand, the desired information and the geological conditions.

Fig. 9 shows a typical field set-up. The seismograph recorder is placed at the end of layout 1, outside the profile. Two seismometer cables are used, one for seismometers 1-12 and another for seismometers 13-24. Connection cables are run to the recorder from seismometers 12 and 24.

For the first layout (1), records are made at points A, B, C, D, E and F to provide coverage (velocity lines) in both directions. For the second layout (2) the seismometers and their cables are moved to the positions shown by the broken lines. To provide a definite time relationship between the two layouts, seismometer 1 in the second layout is at the same location as seismometer 24 in the first one. The longer seismometer connection cable is now connected to seismometer 13. This procedure saves time since two layouts can be measured with the equipment at the same site. Records are repeated for the impact points B, C, D, E and F and offset record G is added. The recorded arrival times (velocity curves) are joined to each other by means of the overlapping seismometers at the junction of the layouts.

If the line (profile) is longer than these two layouts, the equipment is moved to enable two more layouts to be measured from the new instrument site.

Increasing the distance between the seismometers on the basis of the desired depth penetration is generally <u>not</u> recommended. If the seismometer separation is too great, details may be lost. This can lead to misinterpretation of the number of velocity layers and depths. The continuous profiling measuring technique, which utilizes repeated records to reach the desired depth combined with rather small distances between seismometers is preferable.

For shallow investigations, seismometer separations of 5 or 10 meters are generally used. However, it is a good idea to use uniform seismometer separations to facilitate the interpretation work. One or two overlapping seismometers can be used to connect the layouts. The distance between the impact points depends on the type of investigation (reconnaissance or detailed) and the depth of the refractor (bedrock). In shallow investigations the impact points are generally 25-50 metres apart. Note that the quality of the recorded arrival times is increased if the seismometers are firmly planted into the ground. Remove the upper layer of very loose ground, usually the top 10-20 centimeters.

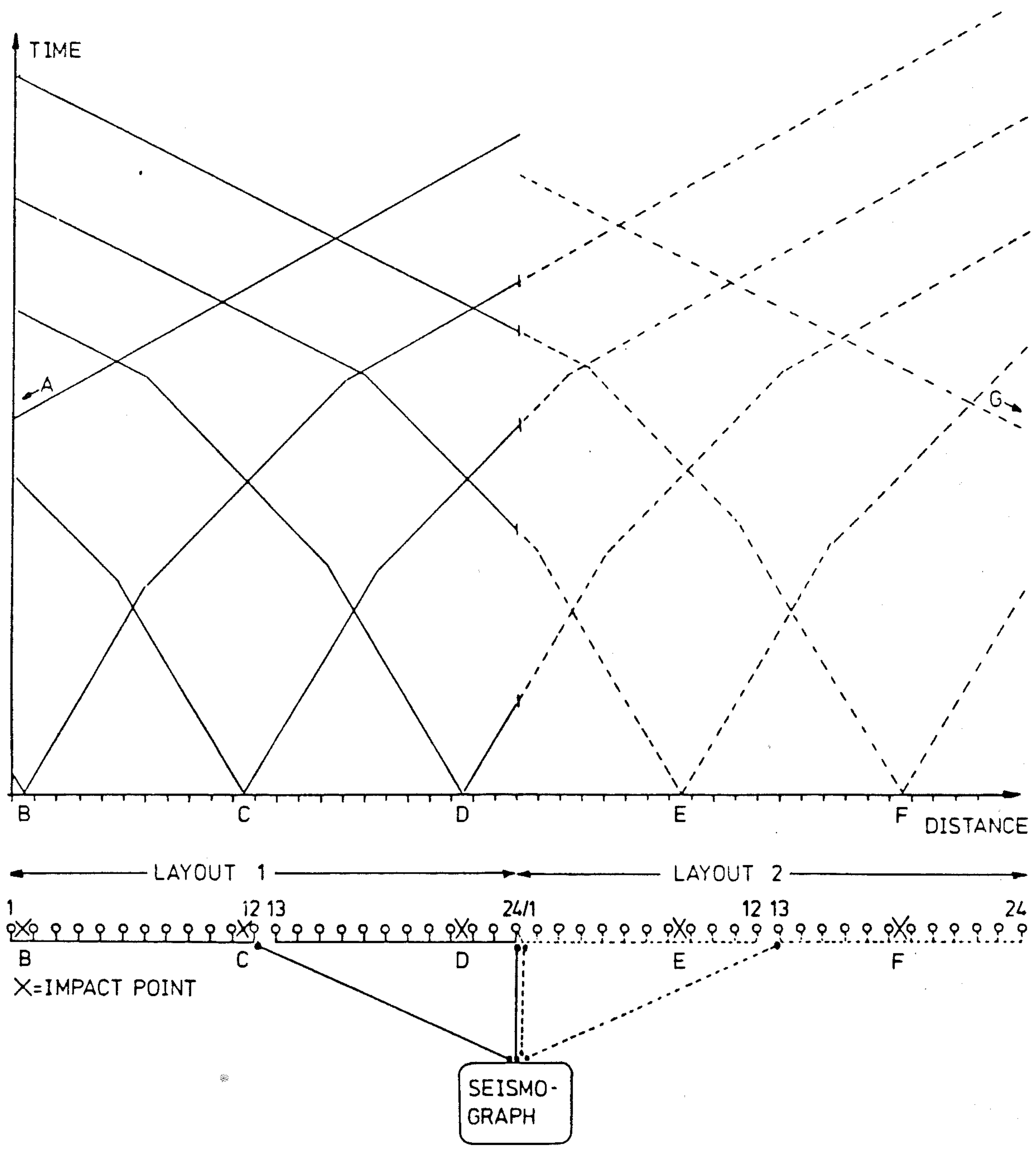


Fig 9 Continious profiling, field arrangement and time-distance graph.

2.5.2 INTERPRETATIONS OF SEISMIC REFRACTION MEASUREMENTS

The theory of refraction seismics is based on the Head-wave. This wave is generated when an incoming primary wave meets a boundary with an angle of incidence less than the critical angle

$$i_c = \text{arc sin} \left(\frac{V_0}{V_1} \right)$$ (see the wavepath in fig. 10)

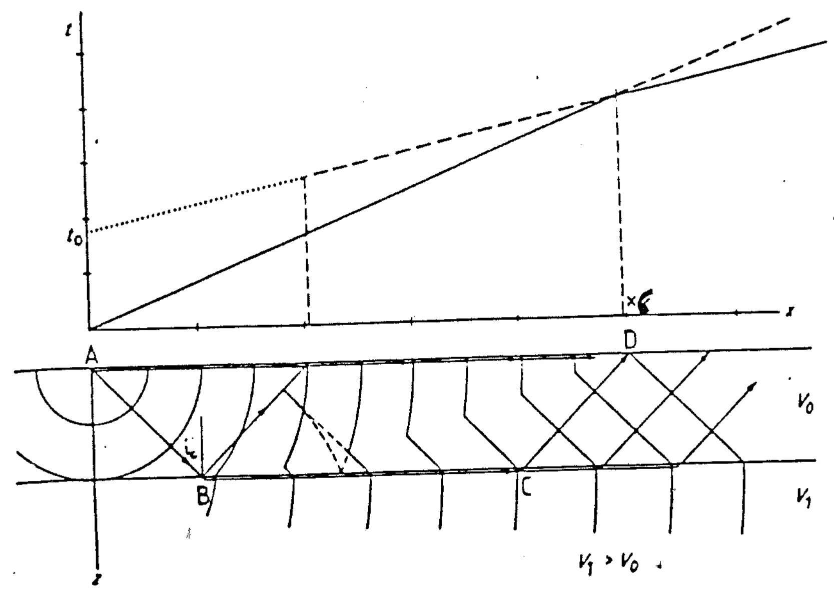


Fig. 10 Critical refraction at a boundary (wave path A-B-C-D).

In seismic work the parameter of interest is the time from an impact to the detection of the pulse at a certain distance. To interpret the data we only need to know the traveltimes for the first arrivals (headwave) and the distance to each registration point (geophone point). In the figure below (fig. 11) we can see such a registration called a seismogram.

ABEM Terraloc Seismic System Record-015047 Date-850523 Time-11:1
Shot pos.: 100 Layout start: 140 Layout end: 1060
Profile No.: 2301 Note: 123902 -4489 Operator: 470222
Record time: 500 ms Delay time: 0000 ms Analog filter: Off
Display mode: Normal. Low-cut: Off Hz High-cut: Off Hz Shots: 066

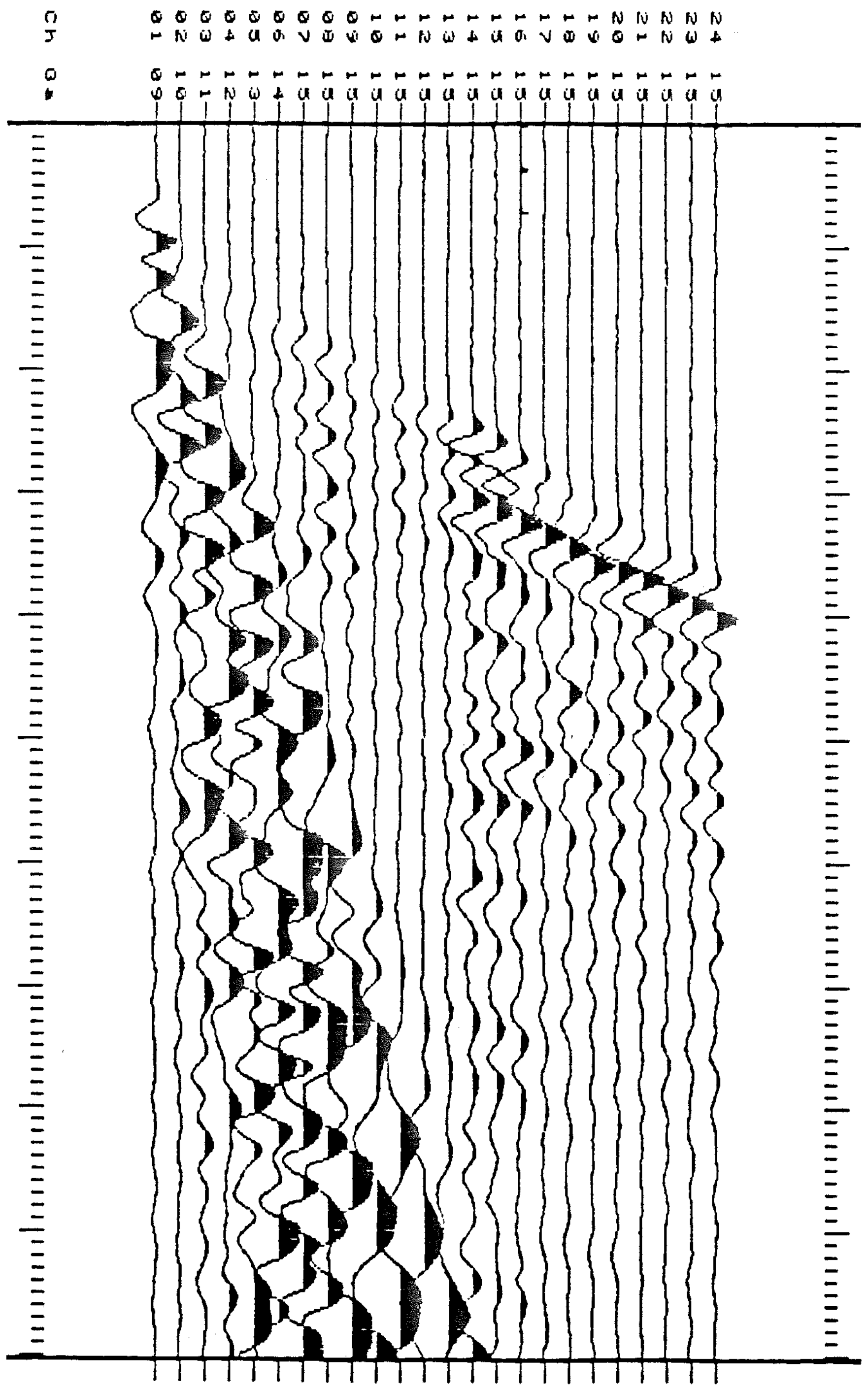


Fig 11 Example of a refraction seismogram.

THE TWO LAYER CASE - HORIZONTAL LAYERS

A horizontal plane layer with velocity v_0 resting on top of a layer with velocity v_1 can often be found when for example a layer of sand is covering the bedrock. Close to the shot point the direct wave will arrive first. At the distance x_c (cross-over distance) the direct wave and the head wave will be registerd at the same time. At distances greater than x_c the headwave will be the first wave to arrive.

Using the connection between the traveltimes for the direct wave and refracted wave we get the equation for the depth z (see last section for the derivation of the equations).

$$z = \frac{t_{int}\ v_0\ v_1}{2(v_1^2 - v_0^2)^{1/2}} \quad \text{or} \quad z = \frac{x_c}{2} \cdot \left(\frac{v_1 - v_0}{v_1 + v_0}\right)^{1/2}$$

where v_0, v_1 are the seismic velocities for the upper and lower layer respectively. These can be found from the time-distance graph by measuring the slope of the travel-time curves (slope = 1/V)

t_{int} is the intercept time that can be found by extrapolating the traveltime curve back to the shotpoint at the time distance graph

x_c is the cross-over distance i.e. the distance from the shotpoint to the point where the $1/v_0$ and $1/v_1$ curves intersects.

In another method of calculating the depth z we will introduce the terme "delay-time" (not to be mixed with delaytime in TERRALOC). The delay-time is defined as the "extra time" the wave needs to travel along the segment A B besides the time needed to travel along the horisontal projection of the hole segment in the media with higher velocity (see fig. 12).

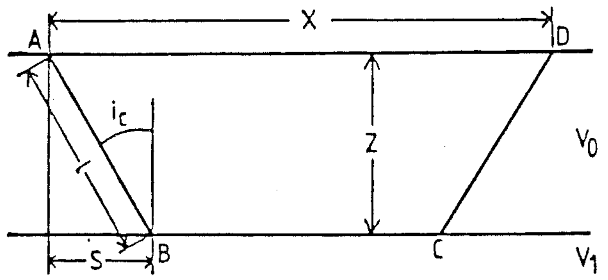


Fig. 12 Definition of Delay-time.

Writing this "extra time" do we get

$$D_{01} = \frac{l}{v_0} - \frac{s}{v_1} = \frac{z}{v_0 \cos i_c} - \frac{z \tan i_c}{v_1}$$

$$D_{01} = \frac{z}{v_0 \cos i_c} (1 - \sin^2 i_c) = \frac{z \cos i_c}{v_0}$$

Using

$$\cos i_c = \frac{(v_1^2 - v_0^2)^{1/2}}{v_1}$$

we will get

$$D_{01} = \frac{z(v_1^2 - v_0^2)^{1/2}}{v_0 v_1}$$

According to the definition above the time along the distance A B C D can be written as the time the wave needs to travel the distance x using the velocity v_1 plus the extra time for the segments A B and C D.

$$t_1 = \frac{x}{v_1} + 2 D_{01} = \frac{x}{v_1} + \frac{2 z \cos i_c}{v_0}$$

$$t_1 = \frac{x}{v_1} + \frac{2 z (v_1^2 - v_0^2)^{1/2}}{v_0 v_1}$$

Which is identical with the equation derived before.

THE TWO-LAYER-CASE, DIPPING-LAYER

The interpretation includes determination of both the depth and the dip of the boundary between the two layers.

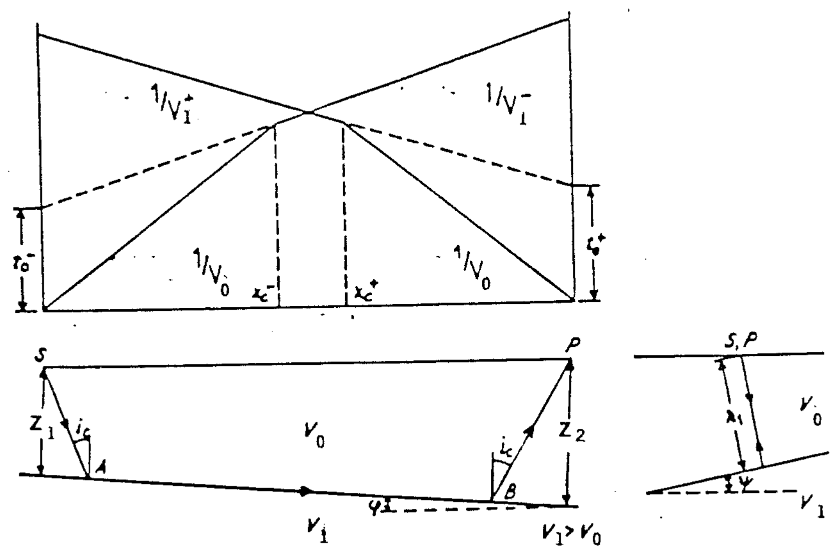


Fig. 13 Critical wavepath along a sloping boundary.

According to figure 13 the traveltimes between the shotpoints and the geophone point P are

$$t_{1d} = \frac{x \cos \varphi}{v_1} + \frac{(2 h_1 + x \sin \varphi) \cos i_c}{v_0} \quad \text{(down dip)}$$

Using $1/v_1 = \sin i_c/v_o$ we get

$$t_{1d} = \frac{2\,h_1 \cos i_c}{v_o} + \frac{x}{v_o}(\cos \quad \sin i_c + \sin\varphi \cos i_c)$$

$$= \frac{2\,h_1 \cos i_c}{v_o} + \frac{x}{v_o}\sin(i_c + \varphi)$$

The slope of the t_1 segment on the travel time curve is

$$\frac{1}{v_{1d}} = \frac{\sin(i_c + \varphi)}{v_o} = \frac{\sin(i_c + \varphi)}{v_1 \sin i_c}$$

This gives an apparent velocity that is lower than the true velocity v_1

$$v_{1d} = \frac{v_1 \sin i_c}{\sin(i_c + \varphi)}$$

If we move the shotpoint to the geophone point and vice versa the following equation is valied.

$$t_{1u} = \frac{x\cos\varphi}{v_1} + \frac{(2\,h_2 - x\sin\varphi)\cos i_c}{v_o} \quad \text{(up dip)}$$

$$t_{1u} = \frac{2\,h_2 \cos i_c}{v_o} + \frac{x}{v_o}(\cos\varphi \sin i_c - \sin\varphi \cos i_c)$$

$$= \frac{2\,h_2 \cos i_c}{v_o} + \frac{x}{v_o}\sin(i_c - \varphi)$$

The slope of the t_1 segment is

$$\frac{1}{v_{1u}} = \frac{\sin(i_c - \varphi)}{v_o} = \frac{\sin(i_c - \varphi)}{v_1 \sin i_c}$$

and the apparent velocity is

$$v_{1u} = \frac{v_1 \sin i_c}{\sin(i_c - \varphi)}$$

which is higher than the true velocity v_1.

Using the formulas above we will get the true velocity v_1, the dip angle and the critical angle i_c.

$$\frac{1}{v_{1u}} + \frac{1}{v_{1d}} = \frac{2\cos\varphi}{v_1}$$

$$v_1 = 2\cos\varphi \frac{v_{1u} \cdot v_{1d}}{v_{1u} + v_{1d}}$$

$$\varphi = \frac{1}{2}\left(\arcsin\frac{v_o}{v_{1d}} - \arcsin\frac{v_o}{v_{1u}}\right)$$

$$i_c = \frac{1}{2}\left(\arcsin\frac{v_o}{v_{1u}} + \arcsin\frac{v_o}{v_{1d}}\right)$$

For calculation of the depth z at every shotpoint it is necessary to know the true dipangle at the boundary (φ^*), i.e. you have to measure a profile perpendicular to the first one.

The depth is then calculated using either the cross-over distance or the intercept time t_{int}.

$$\frac{x_c}{v_o} = \frac{2\,h_1 \cos i_c}{v_o} + \frac{x_c}{v_o}(\sin i_c + \varphi)$$

$$h_1 = \frac{x_c}{2\cos i_c} \quad 1 - \sin(i_c + \varphi)$$

where h is the perpendicular distance to the boundary.

The depth becomes

$$z_1 = \frac{h_1}{\cos\varphi^*} = x_c \quad \frac{1 - \sin(i_c + \varphi)}{2\cos\varphi^* \quad \cos i_c}$$

"shooting up dip" we get

$$z_2 = x_c \quad \frac{1 - \sin(i_c - \varphi)}{2\cos\varphi^* \quad \cos i_c}$$

Using the intercept time t_{int} wher $x = 0$ instead we get for both "down dip" as for "dip shooting"

$$t_{int} = \frac{2\,h \cos i_c}{v_o} \quad \text{och} \quad h = \frac{t_{int}\, v_o}{2\cos i_c}$$

By the intercept times $t_{int(d)}$ and $t_{int(u)}$ we get the expressions for the depths z_1 and z_2

$$z_1 = \frac{t_{int(d)}\ v_o}{2\cos\varphi^*\ \cos i_c}$$

$$z_2 = \frac{t_{int(u)}\ v_o}{2\cos\varphi^*\ \cos i_c}$$

THE RECIPROCAL - OR THE ABC-METHOD

This method is usally used mapping shallow undulating boudarys covered by loose soils. The method makes it possible to determine the refractor velocity even if the time-distance graph shows an irregular pattern (not the whole segment as a straight line). The method is, however, not suitable for determination of the dipangle.

According to the definition the D-time is equal to the traveltime for the critical refracted wavepath between the refractor and the boundary minus the extra time needed for the wave to travel along its projection on the refractor using the refractor velocity.

In our case the D-time will be (see fig. 14).

$$D_{o1} = (BX/v_o - PX/v_1)$$

or

$$D_{o1} = \frac{z^*\cos i_c}{v_o}\ ;\quad z^* = \frac{D_{o1}\ v_o}{\cos i_c}$$

The D-time can now be calculated using the traveltimes between the shotpoints and the geophonepoints, and the time between the shotpoints. At geophone B the D-time is

$$D_{o1} = \frac{1}{2}(t_{AB} + t_{CB} - t_{AC})$$

or

$$D_{o1} = \frac{1}{2}(BX/v_o + BY/v_o - XY/v_1)$$

Supposing that the refractor is horisontal between X and Y we will get

$$D_{o1} = (BX/v_o - PX/v_1)$$

Which is the expression for the D-time.
To calculate the depth z* we have to know the velocity in the both layers. The velocity of the top layer is found from traveltime curve. To determine the true refractor velocity we are using the D-time.
By subtracting the D-time from the registred traveltime at each geophone point we are deleting the effect that the irregular surface and velocity distribution are causing.
The corrected traveltime from shotpoint A to geophone point B is then

$$t_{A'B} = t_{AB} - D_{o1}$$

where t_{AB} is the registred traveltime and D_{o1} is the D-time. The equation can be written

$$t_{A'B} = Aa/v_o + aP/v_1$$

that is equal to the traveltime from shotpoint A to the point P at the refractor from where the normal up to the geophone point B is drawn (see fig. 14).

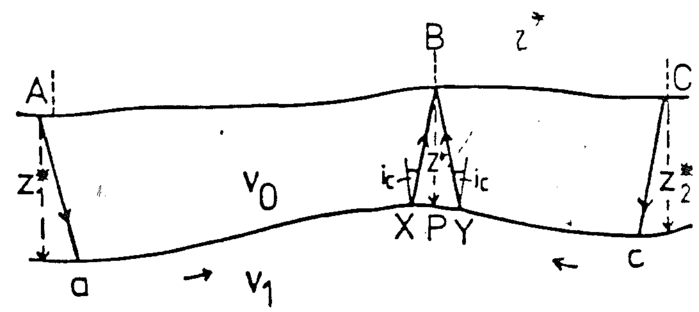


Fig 14 The A-B-C method

It is important to point out that the traveltimes and the D-times must come from the same refractor.

The corrected traveltimes at each geophone gives in this way the true velocity along the refractor. The slope of the curve should be the same even if the calculation is done using shotpoints A or C. The true velocity is determined from the slope of the curve or a curvesegment if there are more than one refractor velocity.

MULTILAYERS - PLANE PARALLEL-LAYERS

A quite common geological structor is the one where several horisontal layers with different and increasing velocity is placed on top of each other. In that case the 2-layer formula can be extended to yield an arbitrary number of layers.

For several horisontal layers of thickness z_0, z_1, z_2 etc and increasing velosities v_0, v_1, v_2 etc we get using the notations in the figure below and Snells law.

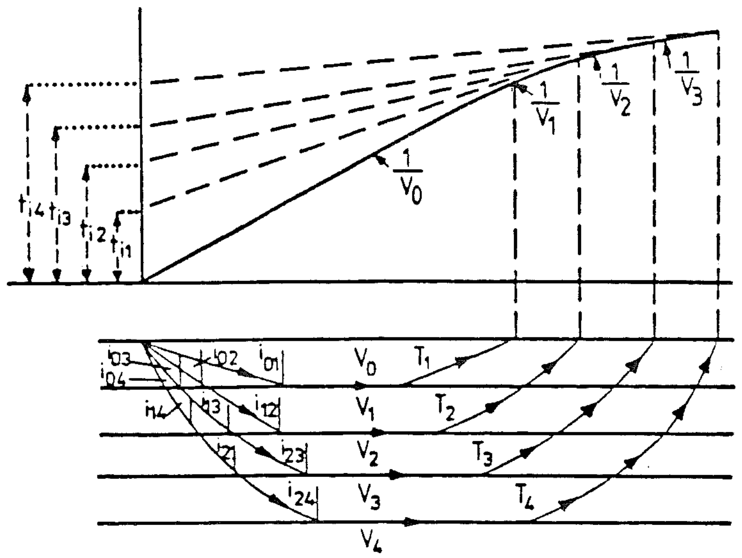


Fig 15 Time-distance graph and raypaths in a multi-layer model.

$$\sin i_{01} = \frac{v_0}{v_1}$$

$$\frac{\sin i_{02}}{\sin i_{12}} = \frac{v_0}{v_1} \quad \text{but} \quad \sin i_{12} = \frac{v_1}{v_2} \therefore \quad \sin i_{02} = \frac{v_0}{v_2}$$

$$\frac{\sin i_{03}}{\sin i_{13}} = \frac{v_0}{v_1} \qquad \frac{\sin i_{13}}{\sin i_{23}} = \frac{v_1}{v_2} \qquad \sin i_{23} = \frac{v_2}{v_3}$$

$$\therefore \quad \sin i_{03} = \frac{v_0}{v_3}$$

and generally

$$\sin i_{m\,n} = \frac{v_m}{v_n}$$

Using the D-times we get

$$t_0 = x/v_0$$

$$t_1 = x/v_1 + 2\,D_{01}$$

$$t_2 = x/v_2 + 2\,D_{02} + 2\,D_{12}$$

$$t_3 = x/v_3 + 2\,D_{03} + 2\,D_{13} + 2\,D_{23}$$

$$\vdots$$

$$t_n = x/v_n + 2\,D_{0n} + 2\,D_{1n} + 2\,D_{2n} + \ldots + 2\,D_{(n-1)\,n}$$

The D-times are

$$D_{01} = \frac{z_0 \cos i_{01}}{v_0}$$

$$\vdots$$

$$D_{mn} = \frac{z_m \cos i_{mn}}{v_m}$$

or

$$D_{01} = \frac{z_0\,(v_1^2 + v_0^2)^{1/2}}{v_0\,v_1}$$

$$\vdots$$

$$D_{mn} = \frac{z_m\,(v_n^2 - v_m^2)^{1/2}}{v_m\,v_n}$$

The general equation for the time is then

$$t_n = \frac{x}{v_n} + \frac{2\,z_0 \cos i_{0n}}{v_0} + \frac{2\,z_1 \cos i_{1n}}{v_1} +$$

$$+ \frac{2\,z_2 \cos i_{2n}}{v_2} + \ldots + \frac{2\,z_{n-1} \cos i_{(n-1)n}}{v_{n-1}}$$

or by using the D-time given above

$$t_n = \frac{x}{v_n} + \frac{2\, z_0\, (v_n^2 - v_0^2)^{1/2}}{v_0\, v_n} + \frac{2\, z_1\, (v_n^2 - v_1^2)^{1/2}}{v_1\, v_n} +$$

$$+ \frac{2\, z_2\, (v_n^2 - v_2^2)^{1/2}}{v_2\, v_n} + \ldots + \frac{2\, z_{n-1}\, (v_n^2 - v_{n-1}^2)^{1/2}}{v_{n-1}\, v_n}$$

If we extrapolate the different segments of the traveltime curve back to the time axis we get the intercept times t, t_i, t_{i2} etc (see fig 14). These times will be equal to the sum of the delay times by setting $x = 0$.

The thickness of the layers can be calculated in the same way as described in the 2-layer case.

Using the intercept times we get

$$z_0 = \frac{t_{i1}}{2} \frac{v_1\, v_0}{v_1^2 - v_0^2}$$

because

$$t_{i2} = 2\, D_{02} + 2\, D_{12} = \frac{2\, z_0\, (v_2^2 - v_0^2)^{1/2}}{v_0\, v_2} + \frac{2\, z_1\, (v_2^2 - v_1^2)^{1/2}}{v_1\, v_2}$$

we get for z_1

$$z_1 = (t_{i2} - \frac{2\, z_0\, (v_2^2 - v_0^2)^{1/2}}{v_0\, v_2}) \cdot \frac{v_1\, v_2}{2\, (v_2^2 - v_1^2)^{1/2}}$$

or generally

$$t_{in} = \frac{2\, z_0\, (v_n^2 - v_0^2)^{1/2}}{v_0\, v_n} + \frac{2\, z_1\, (v_n^2 - v_1^2)^{1/2}}{v_1\, v_n} + \ldots$$

$$+ \frac{2\, z_{n-1}\, (v_n^2 - v_{n-1}^2)^{1/2}}{v_{n-1}\, v_n}$$

and the layer thickness

$$z_{n-1} = \frac{v_{n-1}\, v_n}{2\, (v_n^2 - v_{n-1}^2)^{1/2}} (t_{in} - \frac{2\, z_0\, (v_n^2 - v_0^2)^{1/2}}{v_0\, v_n} -$$

$$- \frac{2\, z_1\, (v_n^2 - v_1^2)^{1/2}}{v_1\, v_n} - \ldots - \frac{2\, z_{n-2}\, (v_n^2 - v_{n-2}^2)^{1/2}}{v_{n-2}\, v_n})$$

2.5.3 INTERPRETATION IN PRACTICE

Ideal geological conditions are seldom encountered in nature. The travel time curves are generally affected by variations in ground elevation, layer thickness and velocity. Particularly the upper, dry and loose layers often heavily distort the recorded arrival times, sometimes to such a degree that reliable and accurate interpretations are impossible.

To solve these problems, ABEM introduced, in the 1950's, specific correction techniques to increase the accuracy of velocity and depth determinations. Unlike the near-surface correction methods described in the literature, the ABEM technique uses the measured arrival times directly for corrections.

The correction techniques are plotted in Figs. 16, and 17. However, they can just as well be programmed.

REFRACTOR VELOCITY DETERMINATION (MEAN-MINUS-T METHOD)

In Fig. 16, the time differences ΔT between the direct and the reversed recordings are computed for each seismometer and divided by two. The resulting times are then plotted at the associated seismometer positions relative to a horizontal reference line. This method involves systematic averaging of time increments between adjacent seismometer points. When the adjusted travel times are connected (dashed line), an acceptable evaluation of the refractor velocity distribution is possible. In this example there is a considerably lower velocity in the central part of the traverse, thus indicating the presence of a shear zone.

A detailed determination of refractor (bedrock) velocities considerably increases the usefulness of the refraction method since the lower velocities indicate weaker rock sections such as faults, jointed or weathered zones. These zones are often strongly waterbearing.

Before commencing the calculation of average refractor velocities, make sure that the arrival times to be used refer to the same refractor. Otherwise, serious errors will be introduced.

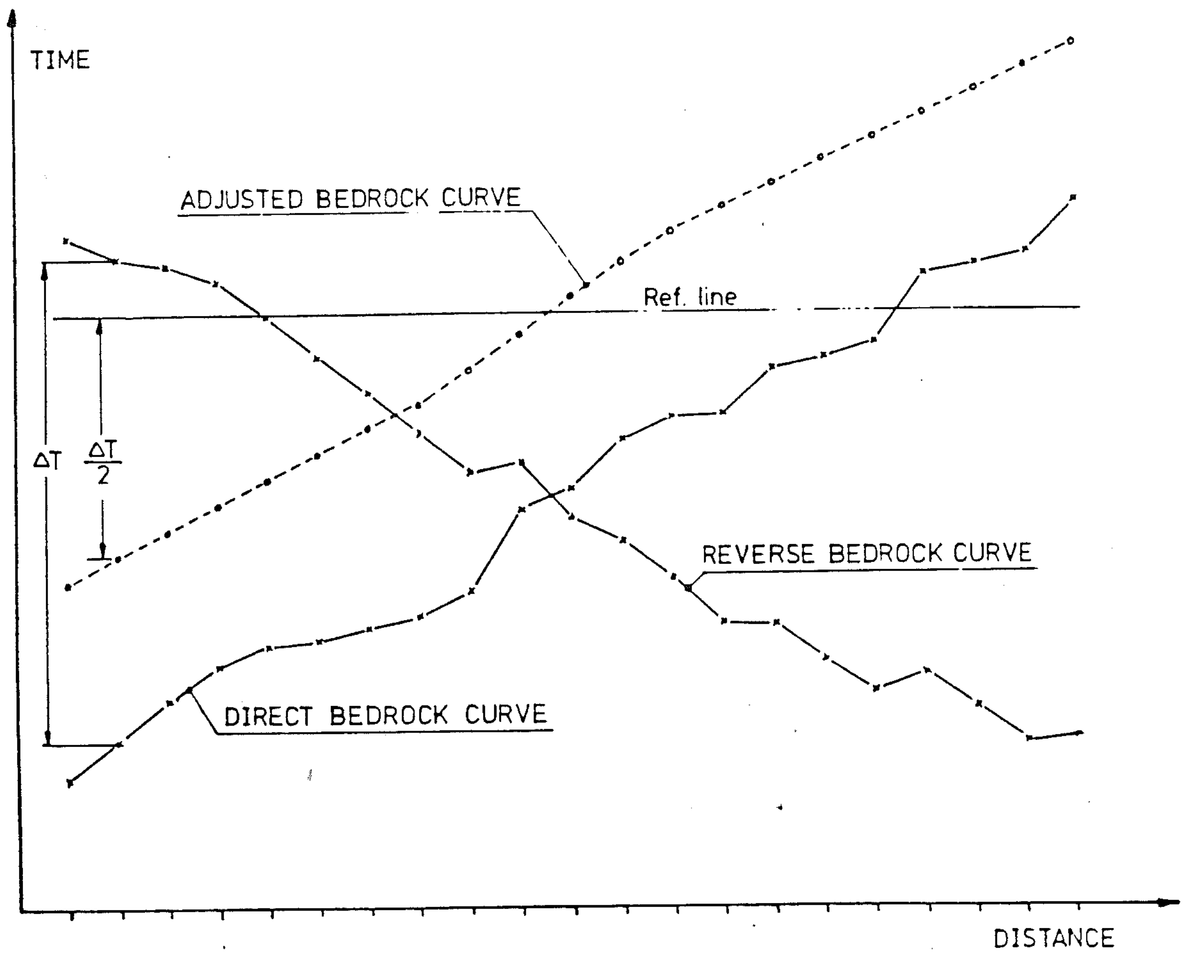


Fig. 16 Average refractor velocity determination

CORRECTIONS FOR DEPTH DETERMINATION

This correction technique is plotted in Fig. 17. It is assumed that the refractor (bedrock) velocity has been determined using the method described in the last section.

Above impact point B, a correction line (dashed) with the inverse slope of the calculated refractor velocity is applied to the bedrock refractor curve A. Note that curve A must refer to arrival times from the refractor. Time differences between the recorded refractor curve A and the correction line are then used to adjust the measured travel times of the refractor velocity curve from impact point B, exemplified by Δ T in Fig. 17. A line with the inverse slope of the refractor velocity drawn back to B through the corrected travel times (dot-dash) gives the true intercept time T_{2i}, or the critical distance S when the velocity line from the upper layer is prolonged to intersect the corrected refractor line.

This method can also be used (at least to a certain degree) to adjust irregular overburden travel times making use of correction terms obtained from an underlying refractor.

Application of the ABEM correction technique has made it possible to reduce the differences between drilling depths and seismic depths to an average of $\pm 10\%$ at a depth of 10 metres. As depth increases, these differences are reduced to about 5-7% at a depth of 50 metres.

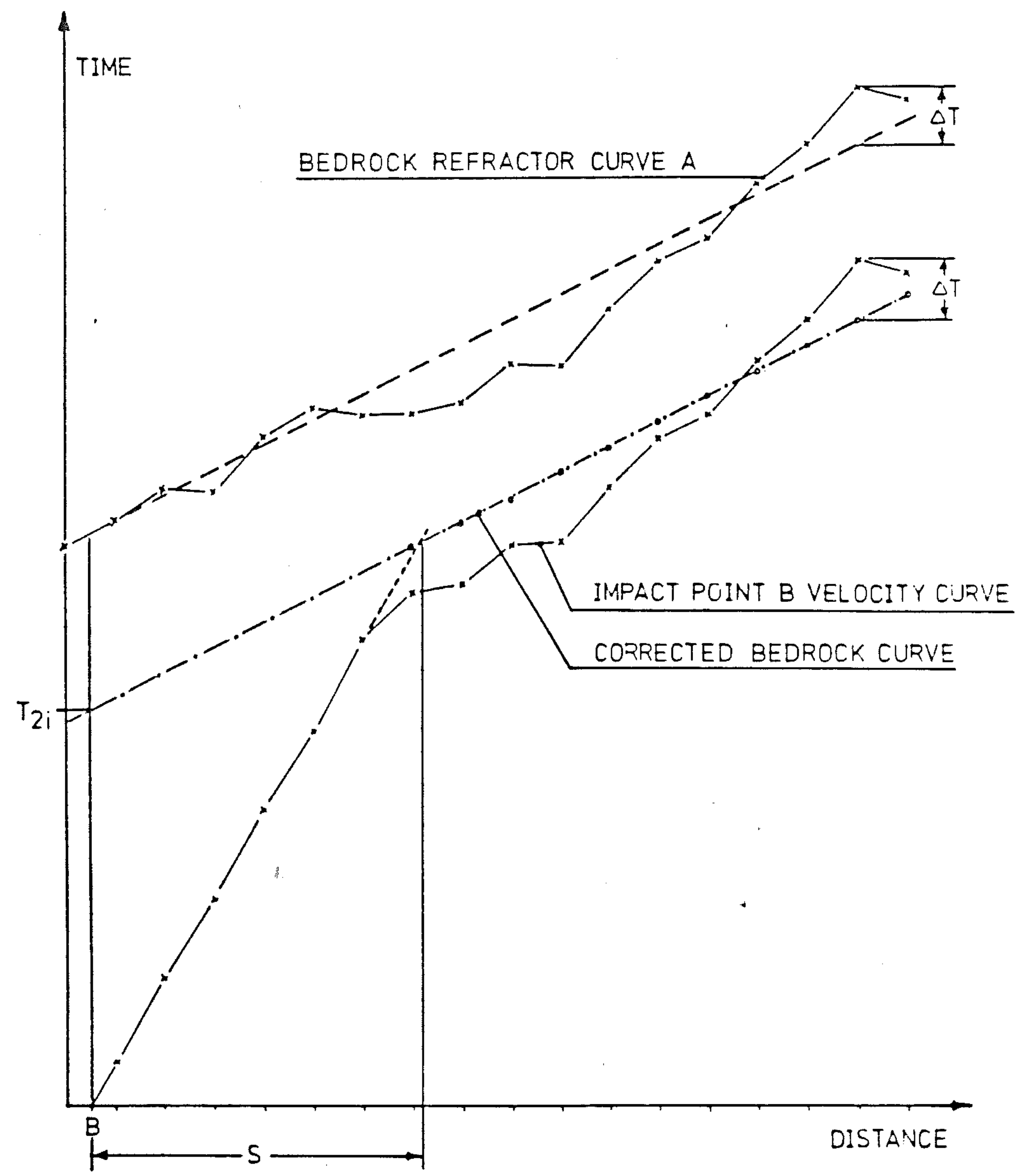


Fig 17 Corrections for depth calculations

2.5.4 LIMITATIONS AND PITFALLS

As stated in the introduction to this section, the basic formulae make certain assumptions. When actual conditions do not fulfil these assumptions, then seismic refraction results may be disappointing or even incorrect. These pitfalls must be taken into account and all results should be evaluated with them in mind.

INCOMPETENT OVERBURDEN MATERIAL

When the upper overburden layer is of loose, unconsolidated material, the seismic velocity in such a layer may be low, sometimes even lower than that of sound waves in air. If velocities of first arrivals have values near the velocity of sound waves in air, they should be treated with caution. This problem may often be overcome by using multiple and closer impact points.

If the loose material is water saturated, higher velocities of the order of 1500 m/s may be encountered. This may give the impression of a relatively compact earth layer, but it should be remembered that about 1500 m/s is the compressional wave velocity in water.

NO VELOCITY CONTRAST

It is not always certain that layers with different mechanical properties will show distinct velocity contrasts. Seismic velocities do not necessarily conform to geological strata, and correlation with drilling results should be carried out whenever possible.

HIDDEN LAYERS

A hidden layer is used to describe the conditions in a three layer case where the intermediate layer is thin and has a velocity V_2 much lower than that of the underlying layer V_3, fig 18. In such circumstances the wave refracted into the third layer travels at high velocity and may overtake the first arrivals from the second layer. Second arrivals, if not masked by "grass" attributable to first arrivals on the seismogram, may indicate by their line-up the presence of the hidden layer.

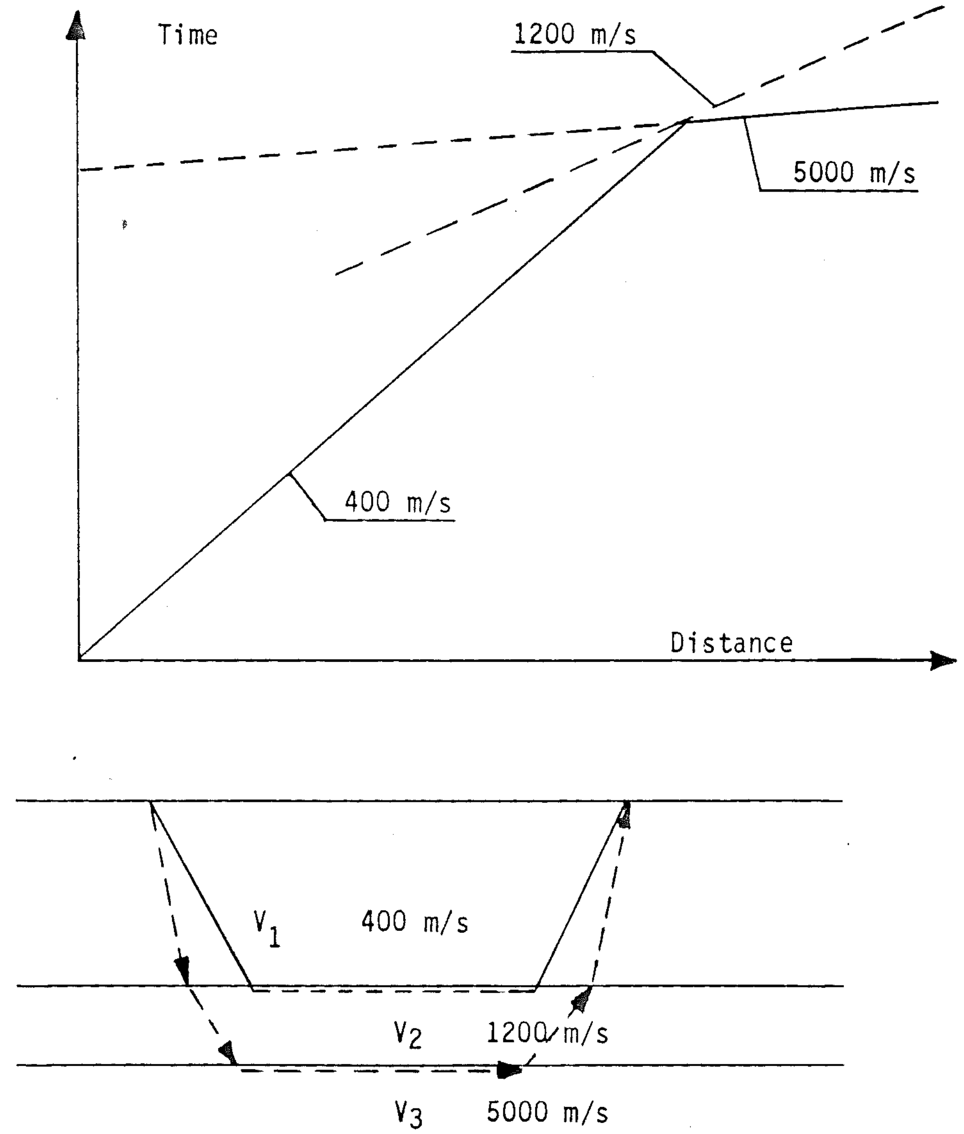


Fig 18 The hidden layer problem

The thin hidden layer does not show up easily or clearly on the seismogram. If it is ignored, serious errors will be caused in depth calculations to the third layer. Presence of a hidden layer may be suspected (a) if a second layer identified elsewhere along the profile thins out and finally disappears from the seismogram, (b) if drilling definitely shows the existence of a second layer or (c) if correlation of seismic results with geological or other geophysical data indicates that the first layer is thinner than the seismic interpretation.

The hidden layer problem can successfully been solved by the combination of refraction and shallow reflection surveys.

REVERCED VELOCITY RELATION, BLIND ZONE

If the increase in velocity with depth is inversed and a lower layer has a velocity less than that of the layer above it, then such a layer is undetectable by refraction methods. A blind zone refracts the entering wave towards the vertical and rays entering the zone never return from its upper surface. Presence of a blind zone will cause the calculated thickness of the layer above to be too great, and will give too great a depth to the layer underneath.

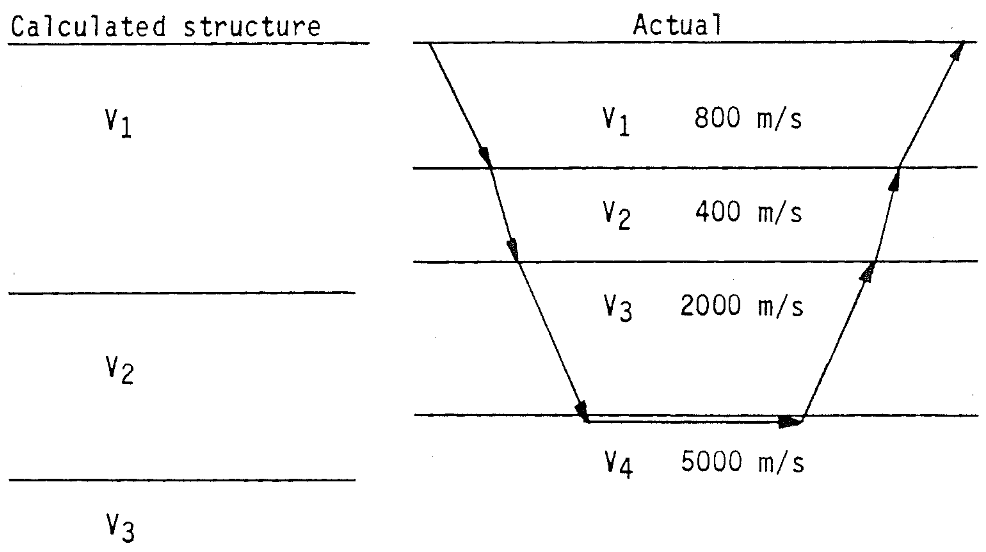


Fig 19 Reversed velocity relation, blind zone

2.6 SHALLOW REFLECTION METHODS

In recent years methods for the conduction of reflection seismic surveys have been developed for shallow depths (15-500 m) using engineering seismographs of the enhancement type. Two such methods are described below. These are the CDP (Common Depth Point) and the Common or Optium offset methods. The methods differ mainly in the amount of data that is recorded and processed and therefore also in the requirement of processing computers and programs. The field data aquired for a CDP survey will as a subset contain the Common Offset data thus enabling alternative processing at a later stage.

All reflection seismic methods produce so called time sections from the data collected in the field at an intermediate stage in the processing.
The time section consists of a large number of received signal traces related to successive geographical locations all displayed side by side on a plot diagram (see Fig. 20).

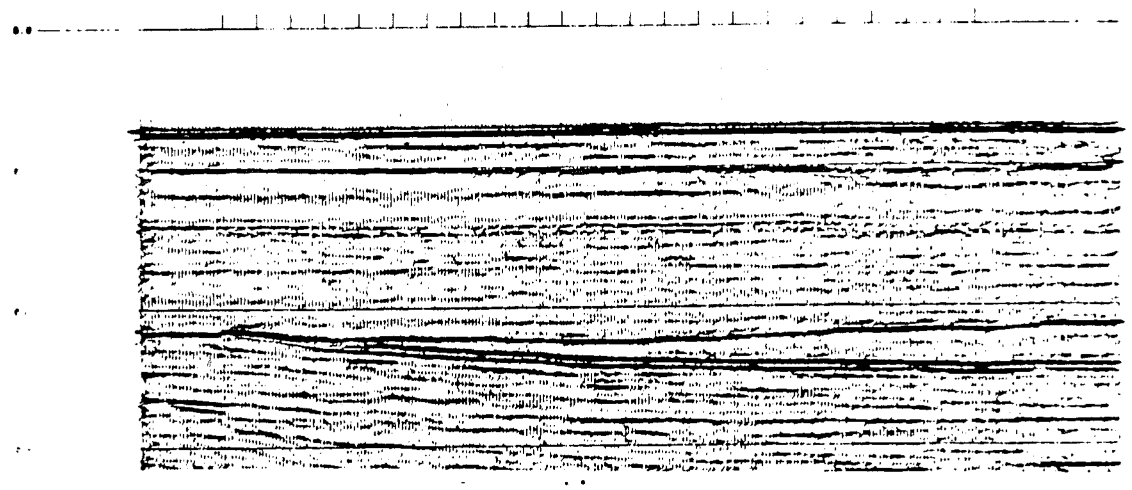


Fig 20 A seismic time section

By visual correlation of signal pulses that occur at nearly the same time from trace to trace one can see a subsurface structure of reflecting boundaries. To make this easier the section is always plotted using the variable area trace type.

The processing necessary to go from a time section to a depth section depends on the complications of the geological structures visible in the time section. If the section is very simple in structure the only necessary step may be the relabelling of the time axis into a nonlinear depth scale. However, in most cases (Especially the interesting ones!) this is not immediately possible. First one must "migrate" the section. By migration is meant the process whereby the reflections and diffractions visible in the section are moved to the correct positions in the same section. Due to the ray bending and slant reflections in curved or dipping structures and the diffractions caused by faults the signal received at one place may have originated at another place. It is the objective of the migration program to compute from where the signal came and move it there. Migration programs are somewhat complicated and can be obtained from several sources, for example universities and processing companies.

2.6.1 COMMON DEPTH POINT (CDP) MEASUREMENT

This technique, called CDP for short, is the method used by the hydrocarbon prospecting companies in their search for oil fields. There it is used in a larger scale than can be applied in shallow seismic work, but the main feature of the method is the same as will be described below.

To produce one CDP trace in the time section data from several traces in different shot records have to be combined. The selection is made such that reflection points (for a horizontal structure) in all traces lie on a vertical through the CDP point, see Fig. 21. As you can se all traces will get reflection data from the same point in the ground. (This is the reason for the name Common Depth Point.)

Thus, for one CDP trace select all those traces where the CDP point is located half way between the shot and the geophone.

For a given CDP point there will be only one trace in any shot record that is used. Thus several shot records have to be searched for appropriate traces. However, the shot record will supply data for as many CDP points as there are active traces in the record.

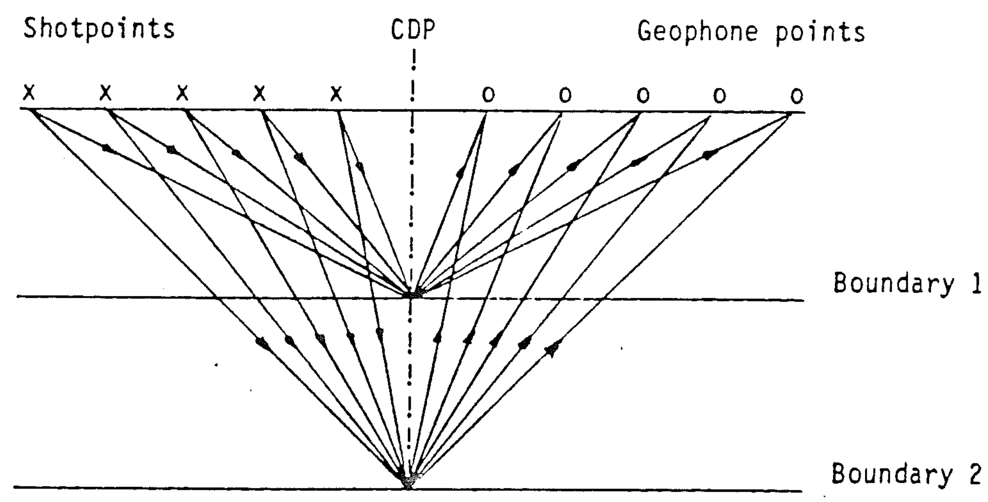
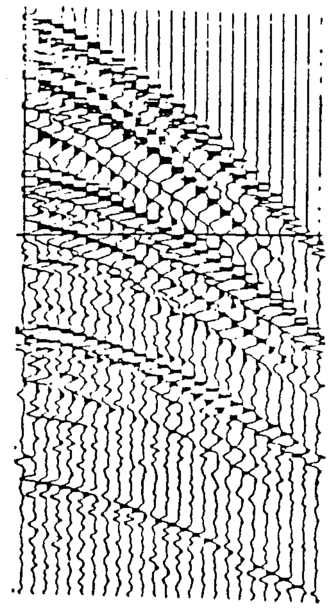


Fig 21 Raypaths for signals combined into CDP gather

The traces thus collected will display echoes from a boundary at different times depending on the distance from shot to geophone. If the traces are displayed side by side with shot-geophone distance as x-displacement the reflections will show up as hyperbolic structures, see Fig. 22.

In most cases the hyperbolic lineup will not be 100 % due to the fact that traces recorded by different shot-geophone combinations are differently affected by the time delays caused by the low velocity topsoil layer. This effect can be removed in processing if the values of the different delays can be calculated. The application of this Static Correction will time shift the traces and produce a set of traces which appear to have been measured without the presence of the top layer.
One method for the calculation of static correction values that is applicable to shallow reflection work will be described later.



The curvatures of the hyperbolae depend on the velocity of the rock and knowing that velocity one can compute how the data trace would have looked like if the geophone and the shot points coincide and are situated over the common depth point. This computation is the next step in the CDP processing and is done for all traces in the gather. It is called Normal Move Out correction or NMO for short. If the new traces are displayed the same way as before the reflections originating from one point will appear at the same time in all traces. The horizon will look horizontal! Now the final step is taken, namely to average all traces sample-by-sample. This is called stacking and will enhance the reflections but reduce all other disturbing signal features.

Fig 22 Record showing hyperbolic form of reflections

2.6.2 FIELD PROCEDURE FOR 6-FOLD CDP DATA COLLECTION

To acquire the data needed for CDP processing shots are fired at every geophone location along the profile. For each shot a record is made with the signals from 12 geophones located at constant distances from the shot. For the field procedure to be efficient one needs to have more than 12 geophones planted into the ground at any one time because for each new shot the geophone layout has to be advanced one geophone spacing. To avoid moving the entire geophone cable and reconnecting the phones between shots one ordinarily uses 24 geophones and a roll-a-long switch that reconnects the 24 input lines into

12 output lines with a displacement of one position for each click of the switch.

With the TERRALOC seismograph it is not neccessary to have a physical roll-a-long switch because it is built into the functions on menu 1 where you can reconnect the channel to trace connection at will. You must, however, use a 24-channel system to be able to do this even though you are recording with only 12 channels.

LAYOUT OF GEOPHONES AND SHOTS

The initial setup is (see Fig. 23) a 24 geophone layout with equal separation between geophones. This separation should be equal to twice the CDP interval on the final section. The seismograph is located at the forward end of the layout and two 12 channel geophone cables with extension cables are used (see Fig. 24). For the first shot geophones 1 through 12 are active (set on menu 1) all others having the "Stack on" parameter set to 0. The shot is fired at a distance of approximately 4 geophone separations from the first geophone. After recording this on the tape recorder the memory must be cleared and the shotpoint moved one geophone distance forward. At the same time geophone 1 is inactivated and 13 activated on menu 1. The next shot is fired one station forward and the process is repeated until 12 records have been made.

At this time the first 12 geophones have to be moved up front and the cables switched at the TERRALOC input so that channel 13 is now channel 1. Note that this may be done without moving the seismograph location at all, see Fig. 24. Then another 12 records can be obtained in the same way as before. After this geophones 13-24 are moved up front, the input cables switched at the TERRALOC and another set of 12 records obtained still without moving the seismograph at all. When 48 records are made the TERRALOC will have to be moved 48 separations forward and the initial layout reconnected there.

Station separation distance and the length of the extender cables will of course influence the coverage obtained. The above discussion holds for 4 m station intervals and using the standard cable set.

```
                          Station number
Record                      1 1 1 1 1 1 1 1 1 1 2 2 2 2 2 2 2 2 2 2 3 3 3 3
No.     0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3
-------------------------------------------------------------------------------
1       x       o o o o o o o o o o o o . . . . . . . . . . . .
2         x     . o o o o o o o o o o o o . . . . . . . . . . .
3           x   . . o o o o o o o o o o o o . . . . . . . . . .
4             x . . . o o o o o o o o o o o o . . . . . . . . .
5               x . . . o o o o o o o o o o o o . . . . . . . .
6               . x . . . o o o o o o o o o o o o . . . . . . .
7               . . x . . . o o o o o o o o o o o o . . . . . .
8               . . . x . . . o o o o o o o o o o o o . . . . .
9               . . . . x . . . o o o o o o o o o o o o . . . .
10              . . . . . x . . . o o o o o o o o o o o o . . .
11              . . . . . . x . . . o o o o o o o o o o o o . .
12              . . . . . . . x . . . o o o o o o o o o o o o .
- - - - - - - - -  move cable No. 1 forward - - - - - - - - - - -
13                                x       o o o o o o o o o o o o . . . . . . . .
14                                  x     . o o o o o o o o o o o o . . . . . . .
15        x = shotpoint               x   . . o o o o o o o o o o o o . . . . . .
16        o = geophone in use           x . . . o o o o o o o o o o o o . . . . .
17        . = unused geophone             x . . . o o o o o o o o o o o o . . . .
18      Offset = 4 station intervals      . x . . . o o o o o o o o o o o o . . .
19                                        . . x . . . o o o o o o o o o o o o . .
20                                        . . . x . . . o o o o o o o o o o o o .
21                                        . . . . x . . . o o o o o o o o o o o o
```

Fig 23 Layout of shots and geophones for CDP measurements

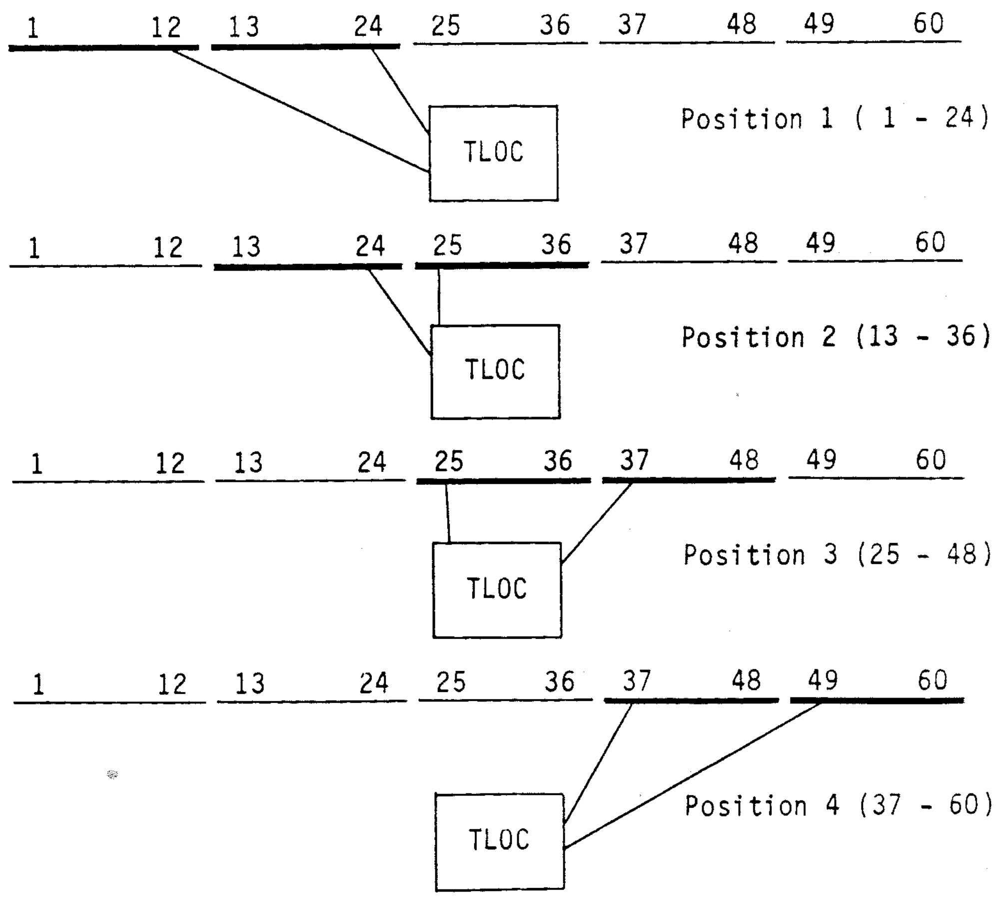


Fig 24 Connection diagram for CDP field work

Note that the first CDP point that will have data from 6 shots (6-fold) will be located midway between the first shotpoint and geophone location 11 in the first layout. This means that 8 records need to be taken during the build-up phase to reach full 6-fold coverage, and this coverage will then be retained until 8 shots before the end of the section (see Fig. 2.4).

ADJUSTMENT OF SIGNAL LEVEL

The setting of the amplifier gains require careful attention since the data processing that is to follow needs linear aquisition. Thus in no circumstance should an amplifier be saturated with a large amplitude signal! It is also necessary to receive the reflections at the highest possible amplitude for the depth penetration to be good. So in order to set the gains correctly you have to fire a few test shots before starting the actual data collection. From these shots you are able to deduce the appropriate gain settings that will just keep the highest amplitude events from saturating the system. During the survey you should keep a close look on the received waveforms using the normalize function and reduce the gain whenever you spot a saturated channel (flat topped waveforms).

By using a test shot and the autogain function in menu 2 of the TERRALOC an optimum amplifier adjustment is obtained automatically.

2.6.3 SIGNAL SOURCES FOR REFLECTION WORK

Seismic sources to be used with this method shall produce a fairly short signal signature (have good high frequencey content) and also have an energy output that is in accordance with the target structure depth. There is an assortment of different sources on the market and they all have their special use, none being universally adaptable to every case.

SOME GUIDELINES MAY BE GIVEN FOR DIFFERENT TARGET DEPTHS:

5-30 m For very shallow work the source must have a very definite high frequencey output and a short signature. Low energy content is important. Examples are ignition caps and small caliber blank shells fired below the surface. Small weight drops can also be used depending on the composition of the surface.

20-100 m For deeper work you need more energy while still keeping the high frequency content up. Examples are shotgun shell exploders, falling weights such as steel balls and small dynamite charges. If very high resolution is needed the only way is to stack several small charges to get the desired penetration and noise reduction. Increasing charge size will lower the frequency contents of the signal and thus diminish resolution.

50-500 m For even deeper penetration more stacking is needed even with somewhat bigger charges. Use 10 - 15 times. If it is possible to sacrifice some of the resolution the dynamite charge can of course be increased.

2.6.4 GEOPHONES FOR REFLECTION WORK

Since the object is to detect the structure in detail you will need to collect high frequency data so the use of high frequency geophones with a natural frequency of about 100 Hz is recommended. Note that the useful frequency range of any geophone is limited by internal resonances to about 10-15 times the natural frequency. Above this frequency the received signals will be distorted by the resonances. Thus, to record signals to 200 Hz you need a 20 Hz geophone and for 500 Hz a 50 Hz geophone. These phones will also reduce the low frequency ground roll interference.

In the absence of such phones an amplifier filter function of the low cut type may be used provided it is capable of removing the low frequency ground roll without saturating any preamplifiers before the filter. The frequency may be set at 50 to 400 Hz depending on conditions.

To reduce external influences such as air blasts and ground roll and to get good coupling to the ground we recommend that you use geophones mounted in marsh cases and planted securely in 0.5-1 meter deep holes.

The operational speed of data collection depends on a number of factors of which a selection is mentioned below. It is important to carefully plan a survey in advance and reduce the number of uncertainties the field party has to cope with to the barest minimum. When using the CDP technique the amount of data that has to be recorded is very large so efficient field procedures are of great importance.

Some hints:

1 Get an advance party to prepare geophone and shot holes at the geophone stations. They shall be drilled to about 0.5-1 meter when using shotgun shell exploders or ignition caps. This enables the phones to be rapidly placed in the correct positions when data are to be collected. If the surface is very soft the risk of cave-in may prohibit advance drilling.

2 Use 36 geophones and one spare geophone cable in addition to the two needed by the measurements.

3 Get people assigned to carry the extra phones and cable forward during the measuring intervals so that a lot of time is not lost waiting for the line to get ready.

4 Bring enough formatted diskettes out because there will be lots of records to store.

5 Be sure to have spare power. You are going to run nearly continuously so the batteries won't last a whole day!

6 Bring enough ammunition for your shotgun exploder or other explosive source. This can easily be underestimated whenever the need for stacking arises.

7 Remember to shoot for surface velocity at each layout position so you can estimate the statics. Shoot between geophones 1 and 2 with all 24 phones active. Save these records on a separate refraction disk.

2.6.5 STATIC CORRECTIONS

The static corrections are introduced to reflection data in order to eliminate the influence of the irregular and low velocity uppermost layer of the earth. This layer introduces time delays to the received signal that may vary considerably from station to station due to local depth variations. If this effect is not removed the stacking process may produce completely invalid results such as horizontal interfaces showing up with curvature or an interface present in the original data being supressed into invisibility by out-of-phase stacking.

There are a number of methods used in the petroleum industry to estimate the static corrections. Some of these make only coarse corrections based on data obtained at a few widely separated points along the profile. Others involve statistical evalutations applied on the data during final processing. In shallow seismic work high resolution is necessary and therefore high frequency signals are used to reduce the acoustic wavelength. This, however, means that the signal period is reduced and the sensitivity to incorrect phasing in the stacking process is increased. Static corrections must therefore be computed with high accuracy if the resolution aimed for is to be kept tnrough tne processing stages.

One example will show the necessary accuracy:

> If a 300 Hz pulse is used it will have a wavelength in a 2300 m/s material of 7.7 m and a period time of 3.3 ms. It will be able to detect structural features on the order of 2.5-3 m. If a static error of 1.65 ms is introduced between two stations the signals will cancel out completely instead of stacking to a higher amplitude. This amount of extra delay will be introduced by a top layer with a 600 m/s velocity if it varies in thickness by 1 m between the geophone stations used for stacking. Note here that the phones used for one CDP stack may be separated by as much as 50-100 m and that the shotpoints then also vary as much in distance. The total extra delay is the sum of the shot delay and the receiver delay so one can easily see that variations of this order is almost always present and force us to do careful statics computations.

The method described below uses the information present in the shot records to calculate static corrections. There are a few limitations and conditions to the method that need to be stated:

1 This method will remove the influence of a low velocity top layer from the data. The thickness of the second layer has to be such that critical refractions from this layer are observable over a distance at least equal to the offset from the shot to the first geophone receiving arrivals from this layer. In other words the distance between the beginning and ending breakpoint of the refractor shall be greater than the beginning breakpoint distance itself.

2 The receiver layout has to be such that the shot to first geophone offset is shorter than the spread itself. It is a good practice to use spread lengths of at least 3 times the initial offset. This makes it possible to select receiver pairs that can be used for statics evalutation.

3 No elevation correction is built into this method. It will correct to the surface. If the surface is uneven you will have to add elevation statics obtained from station elevations and refracter velocity to the final results.

4 The velocity of the top layer has to be evaluated using special shots much closer to the spread. This velocity is used as an input to the method and has to be calculated separately.

Description of the method:

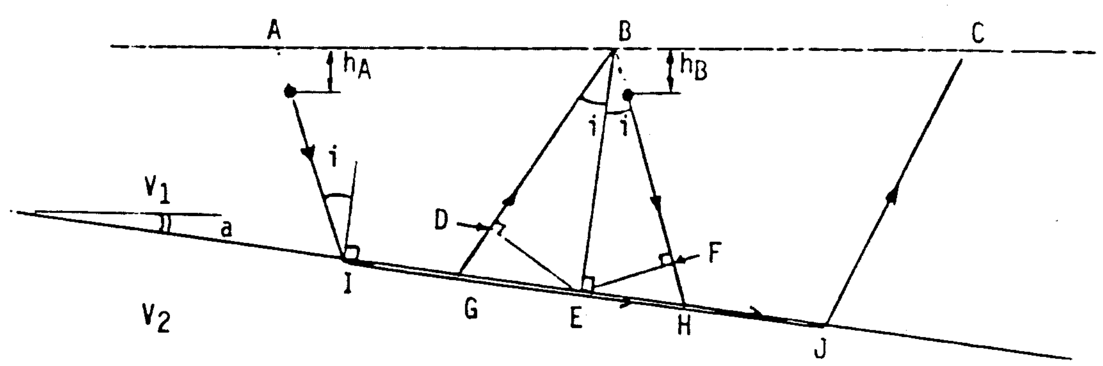


Fig 25 Ray diagram for one refractor

The traveltimes from the station points A, B, C down to the refractor surface is to be determined, fig 25. Knowing these times and the velocity V_1 the corrections needed to apply to the measured data in order to remove the top layer can be easily calculated.

The necessary data for calculation of the static corrections at station B are arrival times AIGB, AIJC and BHJC. Also needed are estimations of V_1 and V_2.

The following relations apply:

i = critical refraction angle, a = refractor dip angle

$$\sin i = \frac{V_1}{V_2} \qquad \text{(Snell's law of refraction)}$$

$$T_{AB} = T_{AD} + T_{DB} \quad \text{and} \quad T_{BC} = T_{BF} + T_{FC}$$

$$T_{AD} = T_{AE} \qquad \text{(the normal DE is a wavefront)}$$

$$T_{FC} = T_{EC}$$

$$T_{DB} = T_{BF} \qquad \text{(equal triangles BDE and BFE)}$$

This gives the following expression:

$$T_{AB} + T_{BC} - T_{AC} = T_{AE} + T_{DB} + T_{BF} + T_{EC} - T_{AE} - T_{EC} = 2 * T_{DB}$$

Shot delays have to be introduced as approximations:

$$d_A = \frac{h_A}{V_1 * \cos(i - a)} \quad \text{and} \quad d_B = \frac{h_B}{V_1 * \cos(i - a)}$$

The measured times are as follows:

$$t_{AB} = T_{AB} - d_A \; ; \; t_{AC} = T_{AC} - d_A \; \text{and} \; t_{BC} = T_{BC} - d_B$$

The above relations give the following formula for the delay DB:

$$T_{DB} = \frac{1}{2} * (t_{AB} + t_{BC} - t_{AC} + d_B)$$

Geometrical considerations give the relations:

$$DB = BE * \cos i \quad \text{and} \quad BE = BG * \cos i$$

$$DB = BG * \cos^2 i$$

Finally the two dêlay times along GB and EB can be determined:

$$T_{BG} = \frac{T_{DB}}{\cos^2 i} \quad \text{and} \quad T_{BE} = \frac{T_{DB}}{\cos i}$$

Since a reflected ray from A emerging at B will have passed the refractor surface somewhere between G and E we will use an estimation of this ray's delay through the top layer that is an average between the delays along BG and BE:

$$T_B' = \frac{T_{DB}}{(\cos^3 i)^{1/2}} \qquad \text{(Geometrical mean)}$$

The correction to apply to data received at B in order to move the refractor surface up to the physical surface at B is:

$$C_{Br} = T_B * (\frac{V_1}{V_2} - 1)$$

The total correction to apply will also contain the shotpoint delay T_A which is calculated as above but with a shotpoint to the left of point A. This correction also needs modification due to the shot depth h_A:

$$\text{Total correction } C_B = (\frac{V_1}{V_2} - 1) * (T_A + T_B) + d_A$$

Practical implementation of the method

To compute the static corrections one needs to know a few arrival times and the velocities of the layers. Also needed is the depth of each shot.

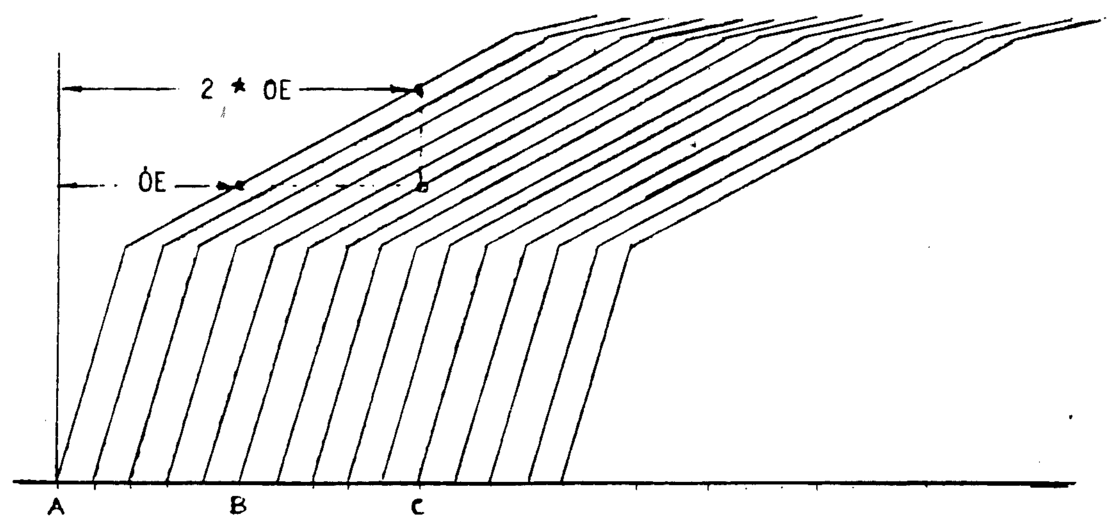


Fig 26 Traveltime curves for adjacent shots showing the recorded part (solid) and not recorded part (dashed)

In order to program automatic statics calculations the relevant first arrivals need to be evaluated and saved.

Selection of the arrivals to use is the first task to undertake. Here the 24 channel refraction shots are studied along the profile and the range of stations over which arrivals from the first refractor are visible is determined, fig 26. Then an offset OE is chosen such that for all records an arrival at this offset and at offset 2*OE will come from the refractor.

The arrival times at these two offsets are picked from each shot record and stored along with information on shot depths. The times are stored in an array T (3,X) where X = number of stations along the line.

Here T(1,N) is the arrival at OE and T(2,N) is the arrival at 2 * OE from a shot at N. T(3,N) is the delay from surface to shot (uphole time) at N.

$$T(3,N) = \frac{h(N)}{\cos(i-a)} * \frac{1}{V_1}$$

With $oe = \frac{OE}{\text{station separation}}$ the receiver delay is

$$T_{DB}(X) = \frac{1}{2} * (T(1,X\text{-}oe) + T(1,X) - T(2,X\text{-}oe) + T(3,X\text{-}oe)) = D(X)$$

The complete correction to apply to a trace shot at Y and recorded at Z is then:

$$C_{YZ} = \left(\frac{V_1}{V_2} - 1\right) * \frac{1}{2\ (\cos^3(i))^{1/2}} * \left(D(Y) - \frac{h(Y)}{\cos(i-a)} * \frac{1}{V_1} + D(Z) \right)$$

This value is calculated for each trace and the trace is time-shifted by that amount. <u>This must be done before stacking</u>.

Thus the necessary steps to include in a statics correction program:

1 Enter the offset OE and velocities V1, and V2 as determined by the interpreter.
2 Pick arrivals at OE and 2 * OE on each shot record. Can be done automatically or with the help of operator interaction.
3 Store these arrivals and the shot depth correction in array T(..., X).
4 Compute individual delays at each receiver and shot point, store in array D(X).
5 Compute static correction for each shot-receiver pair and modify the delay time of the traces accordingly.

This process if completed with elevation corrections will produce a set of traces ready for stacking after NMO-correction.

2.6.6 NMO CORRECTIONS

The Normal MoveOut (NMO) correction is applied to reflection traces prior to stacking in order to make reflections from the same point in the ground appear at the same time in all traces recorded with different shot offsets. The relations used are simply derived using geometry in Fig. 27. Note however that this is a first order simplification of the real case where V probably varies with depth and the rays therefore are curved.

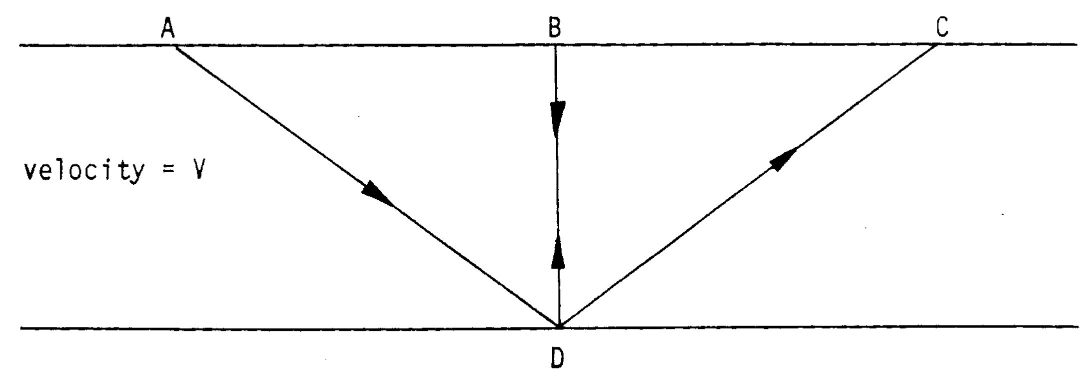


Fig 27 Ray path for wave reflected at the point D

$$ADC = 2 * (AB^2 + BD^2)^{1/2}$$

$$T_{ADC} = \frac{2}{V} * (AB^2 + BD^2)^{1/2} = T_R \quad \text{and} \quad T_{BDB} = \frac{2 * BD}{V} = T_N$$

The NMO correction works by a nonlinear transformation of the time scale of recorded traces. This gives them the time relations that would have been true if the data had been recorded by a geophone located at the shotpoint B. Every signal sample of the NMO corrected trace is moved from a location in the recorded trace that can be calculated based on the geometric properties above. The expression for the time in the recorded trace T_R that corresponds to a time T_N in the NMO corrected trace is:

$$T_R = \left(\left(\frac{2*AB}{V} \right)^2 + T_N^2 \right)^{1/2}$$

The velocity V of the layer is an unknown quantity that often varies with depth. It has to be approximated by some mean velocity.

V is in practice found by testing a few velocities doing an NMO correction of a CDP gather. The velocity that shifts the reflections most closely to a horizontal position is used for final correction before stacking. The velocity determination may include tests on CDP gathers from several positions along the section to find a velocity that can be used over the whole line.

2.7 COMMON OFFSET MEASUREMENT

This technique has the advantage over CDP that it does not need external data processing to produce the final reflection section. The functions available in the Terraloc are sufficient to collect the data, remove the static variations, equalize the signal levels and make a hardcopy printout.

On the other hand the data quality will depend much more on careful measurements in the field including selection of recording parameters and monitoring of data quality. This is due to the fact that no stacking of traces is done and consequently there will be no improvement in data quality from averaging. Therefore one must make sure from the outset that the reflections are visible and situated between the refracted wavelet and the ground roll noise. See Fig. 28

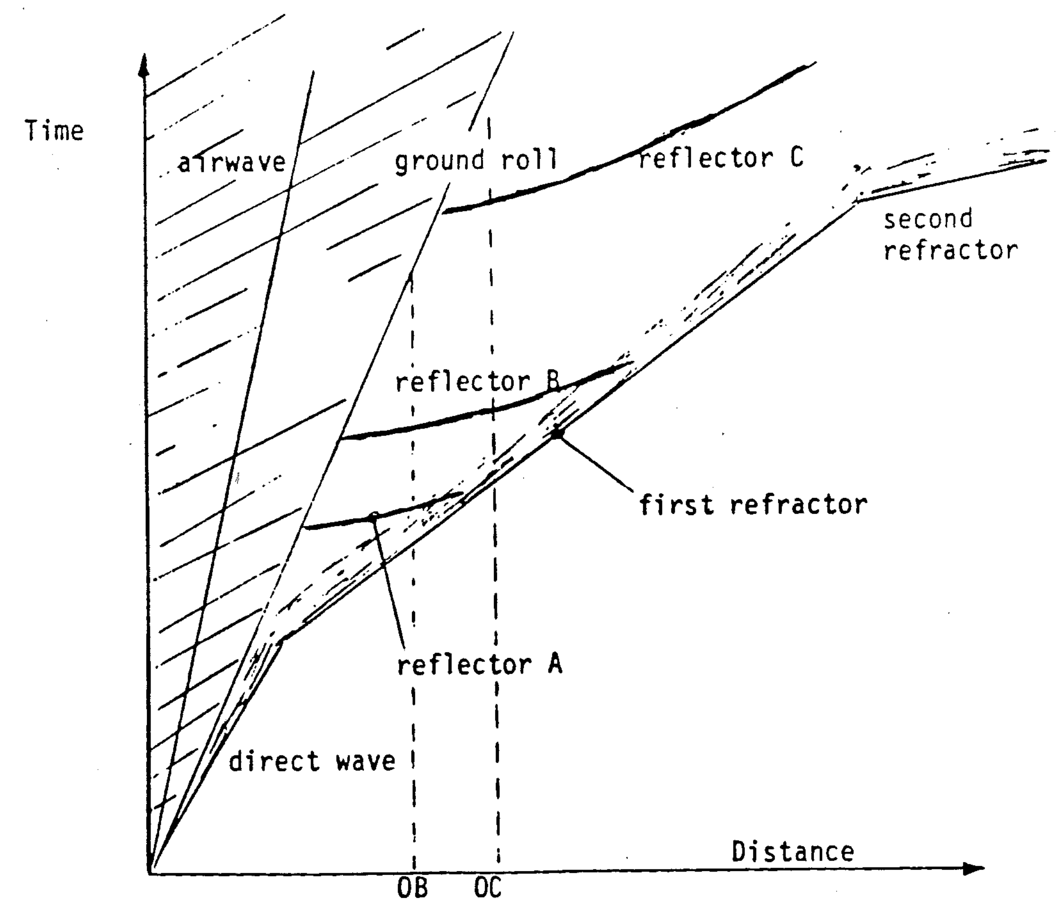


Fig 28 Time-distance graph showing position of a few events

If the target structure is reflector B then an offset OB may be selected. This offset will unfortunately submerge reflector C in the ground roll but is just about right to detect reflector A as well. When C is needed an offset OC must be selected that moves C out from the ground roll noise. As a side effect of this reflector A disappears completely into the refracted first arrival.

In short, using the common offset method one must select the shot offset carefully based on the target depth, refraction velocities and ground roll velocity and amplitude. It will not be possible to find a suitable compromise in all situations but when it can be done the survey will be quite straightforward and results can quickly be produced.

This method is particularly suited to shallow work in areas with high watertable level and sediments with depths from 15 to 200 m to bedrock.

2.7.1 LAYOUT AND RAY GEOMETRIES FOR THE COMMON OFFSET METHOD

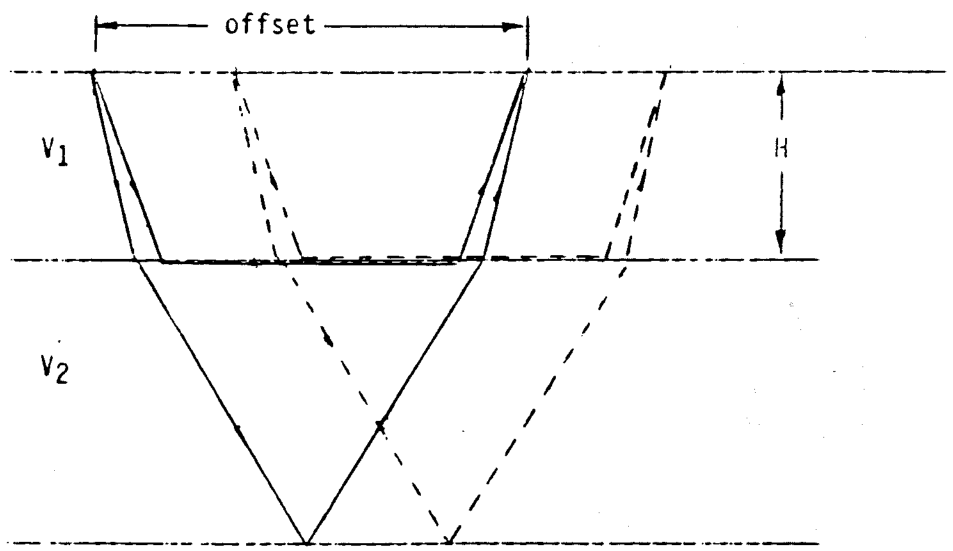


Fig 29 Raypaths for two common offset shots showing reflected and refracted waves

The basic geometry of the common offset method can be seen in Fig. 29 showing two shots. As can be seen the reflection point moves ahead by the same distance as the shotpoint does. Another observation is that the refracted and reflected rays travel through the top low velocity layer close to each other. This gives an opportunity to use refracted arrivals to compensate for wheathering layer variations (static correction). To do this the whole trace is time shifted so that the first arrival is moved to a time equal to the offset divided by the velocity of the lower layer (V_2). This can be done entirely within the Terraloc itself.

The result is a record that looks like what would have been measured if the shot and the geophone had been placed on a datum plane at a small distance above the V_1-V_2 interface. This distance is equal to $H*(V_1/V_2)^2$ which means that a considerable reduction of topological variation is obtained whenever V_1/V_2 is small. As an example consider the case where V_1 is 500 m/s and V_2 is 1600 m/s. This results in a ten times reduction of layer variations in the final section.

2.7.2 FIELD PROCEDURE FOR COMMON OFFSET MEASUREMENTS

For data collection according to this method only one geophone will actually record data for each shot. When the shotpoint is moved along the profile different phones are active so as to keep a constant distance between the shot and the active geophone.

For 24 channel recording a spread of 24 geophones is laid out with equal spacing. A few test shots are made with all geophones recording data. Based on these shots the offset to be used is determined so that the target reflector will fall within the reasonably quiet window after the refracted wave but before the ground roll arrives.

Using the "Channel on" parameter on menu 1 all geophones except the first are disconnected and the first shot is fired at a distance from geophone 1 equal to the selected offset. See Fig. 30. Then geophone 1 is disconnected on menu 1 and geophone 2 activated instead. The second shot is fired one geophone separation ahead from the first.

This sequence is repeated until 24 channels have been recorded into the Terraloc memory. During this you will be able to see a part of the section take form on the screen. The data are saved on tape when 24 shots have been made.

For a longer profile the memory is cleared and the spread is moved 24 stations forward where the process is repeated until the whole profile has been covered. The same shot-geophone offset distance must be used throughout.

```
                     Station number
Shot                        1 1 1 1 1 1 1 1 1 1 2 2 2 2 2 2 2 2 2 2 3 3 3 3
No.     0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3
        --------------------------------------------------------------------

 1      x       o . . . . . . . . . . . . . . . . . . . . . . .
 2        x     . o . . . . . . . . . . . . . . . . . . . . . .
 3          x   . . o . . . . . . . . . . . . . . . . . . . . .
 4            x . . . o . . . . . . . . . . . . . . . . . . . .
 5              x . . . o . . . . . . . . . . . . . . . . . . .
 6              . x . . . o . . . . . . . . . . . . . . . . . .
 7              . . x . . . o . . . . . . . . . . . . . . . . .
                                .
                               etc
                                .
15        x = shotpoint . . . . . . x . . . o . . . . . . . . .
16        o = geophone in use . . . . x . . . o . . . . . . . .
17        . = unused geophone . . . . . x . . . o . . . . . . .
18      offset = 4 station intervals. . . x . . . o . . . . . .
19              . . . . . . . . . . . . . . x . . . o . . . . .
20              . . . . . . . . . . . . . . . x . . . o . . . .
21              . . . . . . . . . . . . . . . . x . . . o . . .
22              . . . . . . . . . . . . . . . . . x . . . o . .
23              . . . . . . . . . . . . . . . . . . x . . . o .
24              . . . . . . . . . . . . . . . . . . . x . . . o
```

Fig 30 Layout of shots and geophones for common offset measurements. A disk record is made after 24 shots

It is of greatest importance in operating a common offset reflection survey to adjust the recording gains correctly. This is because there is no stacking so an error in one record can not be compensated for by data from another shot position. Gains should be adjusted so that the trace used is not saturated by high signal levels anywhere in the interesting section but there should be adequate signal levels for postprocessing within the TERRALOC to be possible. Postprocessing includes digital filtering and automatic time picking. These functions work better if signal levels are higher.

2.7.3 DATA PROCESSING FOR COMMON OFFSET SURVEYS

The records made are composites containing typically 24 traces with data from 24 different shots. Since they have been recorded with the same offset for each trace the records have the appearance of a reflection section. The processing that can be applied is removal of static variations due to the weathered overburden. This is quite simply done by identifying the refracted first arrivals and using this refractor as a datum plane to correct all traces to an equal time for this event. In doing this the variations caused by the layers above the refractor are reduced. Instead any level variations in the refractor itself will be transferred to the reflector horizons below so this effect has to be taken into account during interpretation. In most cases the refractor is the groundwater table and can be assumed to stay fairly uniform.

Practical data processing on the TERRALOC:

With the data collected in the form of 24 channel common offset records all processing needed to produce a printed section can be done within the Terraloc.

These processing steps include:

1 Static correction
2 Digital filtering
3 Amplitude equalization
4 Hard copy printing

They are performed as follows:

1 Static correction

- Set the display mode (menu 3) for Normalize with a Normal level of about 10 % and Normal window at 025.

- Engage the automatic arrival picking routine to pick the refracted first arrivals. Then use the "Inspect and adjust" routine to adjust the time marks where necessary. Note how the use of trace types variable area + and - as well as different settings of the Normal window will help in accurately picking these arrivals.

- From a separate record the refractor velocity should have been found. Using this and the offset distance the correct value for the time shift parameter can be found as:

$$\text{Time shift} = \frac{\text{Shot offset} * 1000}{\text{refractor velocity} * \text{record length}}$$

$$\text{Example:} \quad \frac{30 \text{ m} * 1000}{1600 \text{ m/s} * 0.2 \text{ sec}} = 94$$

2 Digital filtering

Set the digital filters for low cut at 100-300 Hz and use any high cut needed to reduce the noise.

3 Amplitude equalization

Set the Normal level parameter at about 15 % and change the Normal window so that the window will include the data up to the arrival of the air wave or the ground roll noise. Note that the window is defined with a starting point at the arrival time mark and a length expressed in sample points. If the recording was made with a 200 ms record length and the offset was 35 m then the air wave will arrive at 100 ms.

The refracted wave may have arrived at 25 ms which will give a usable span for equalization of 75 ms. In this case the window is set at 375. Set the "Normal limited" display mode. See Fig 31.

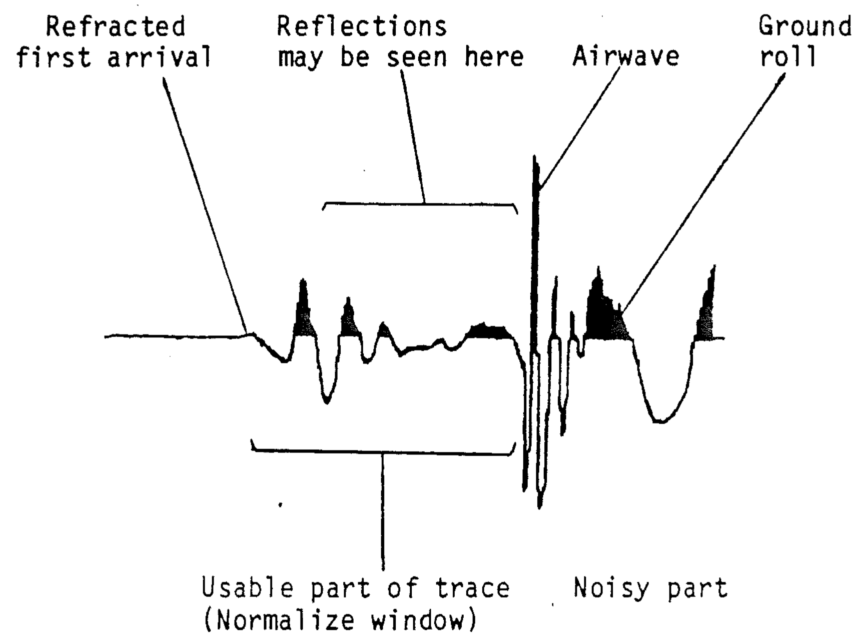


Fig 31 The different wave events within the trace

4 Hardcopy printing

Operate the PRINT key and the Terraloc will produce a record that

- has been time shifted to the correct datum time
- has been filtered to remove unwanted signals
- has been level equalized within the time of interest
- includes the field notes.

The printout will be ready within one minute if both high cut and low cut filters have been set.
Printouts from several 24 channel gathers can be taped together to form a complete section.

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3. OPERATING INSTRUCTIONS REFERENCE

3.1 GENERAL SYSTEM OVERVIEW

The TERRALOC seismic system is divided into two separate units:

- The field data collection unit with up to 24 seismic amplifiers, CRT display, keyboard and digital data storage system.
- The hardcopy printer that provides permanent records.

The field unit is a complete system. It will amplify, process and record data on floppy or RAM disk. It permits the field crew to process and record collected data, while ensuring maximum reliability and usability.

The printer is used to print the processed data along with survey parameters and instrument settings. It thus produces complete documentation of the survey. The output is on thermosensitive paper that can be stored in a normal office environment with no special precautions.

Data stored on disk can later be played back on the system and printed on a standard dot matrix office printer.
Disks can also be played back on a personal computer running the MS-DOS operating system.

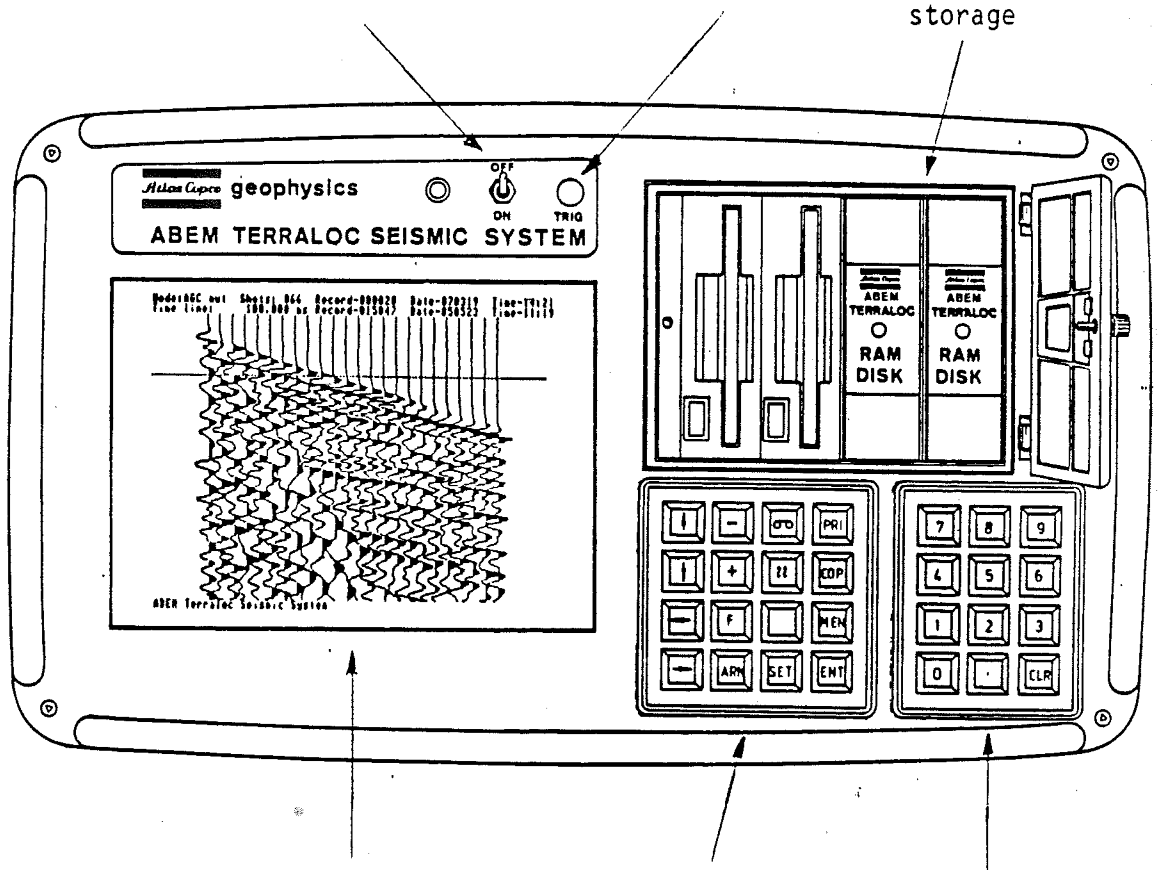


Fig. 3.1-1 TERRALOC seismograph front panel.

3.1.1 CONTROLS ON FRONT AND SIDE PANELS

The TERRALOC is controlled by the operator via a keyboard mounted on the front panel and a few control switches. Once the instrument power is turned on and the CRT display is warmed up (after about 10-20 s), all operator commands are entered via this keyboard. See Fig. 3.1-2.

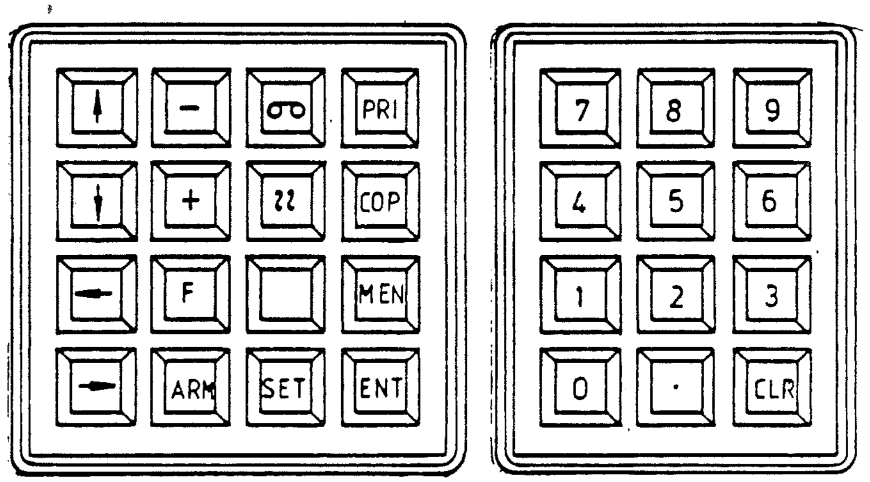


Fig. 3.1-2 TERRALOC keyboard

Key	Key function
(ARROWS)	Move the cursor.
+ -	Used to increase and decrease certain parameters, and to move the timeline on the trace display.
F	Used for special functions like transmission of the timeline time and editing of arrivals. It will generate the character F when used in other cases.
ARM	Puts the instrument in the armed state (ready and waiting for a shot).
O O (RECORD)	The Record key is used to record data on disk.
S S (TRACE)	The TRACE key is used to obtain the TRACE display.
(SPACE)	Can be used to provide spaces in data entries.
SET	Direct command to get to menu 1.
PRI (PRINT)	Used to print the entire signal stack contents.
COP (COPY)	Used to copy the content of the CRT screen to the printer.
MEN (MENU)	Used to step through menus 1-4 one at a time.
ENT (ENTER)	Used to execute commands.
0 1 2 3 4 5 6 7 8 9	Used to enter numerical information and to select modes.
.	Enters a decimal point, also used in the disk format and voltage readout command.
CLR (CLEAR)	Used to clear the memory, must be followed by the ENT key within one second to operate.

How the different keys are used will be explained in later sections of this manual.

Other controls:

- The POWER switch (Front panel)
- The manual SHOT TRIGGER pushbutton (Front panel)
- The GEOPHONE/SWITCH trigger source selector (Side panel)
- The Trigger sensitivity control (Side panel)

3.1.2 CONNECTORS ON THE SIDE PANEL

All external connections to the TERRALOC are made through connectors located in a recess on the side of the instrument case.

Connectors: SIGNAL CONNECTORS for the geophone spread cables. The two 12-channel connectors are connected according to industry standard with channel 1 on pins 1-2, channel 2 on pins 3-4 and so on.
Mating connector type: Cannon NK-27-21C-1/2"

TRIGGER SOURCE CONNECTOR for connection to a trigger geophone, shot instant contacts, a wire loop around the explosive charge or the trigger output of a mechanical energy source.
Mating connector type: Cannon KPT06-F8-4S.

PRINTER CONNECTOR that supplies data to the TERRALOC printer.
Mating connector type: Cannon DA-15P.

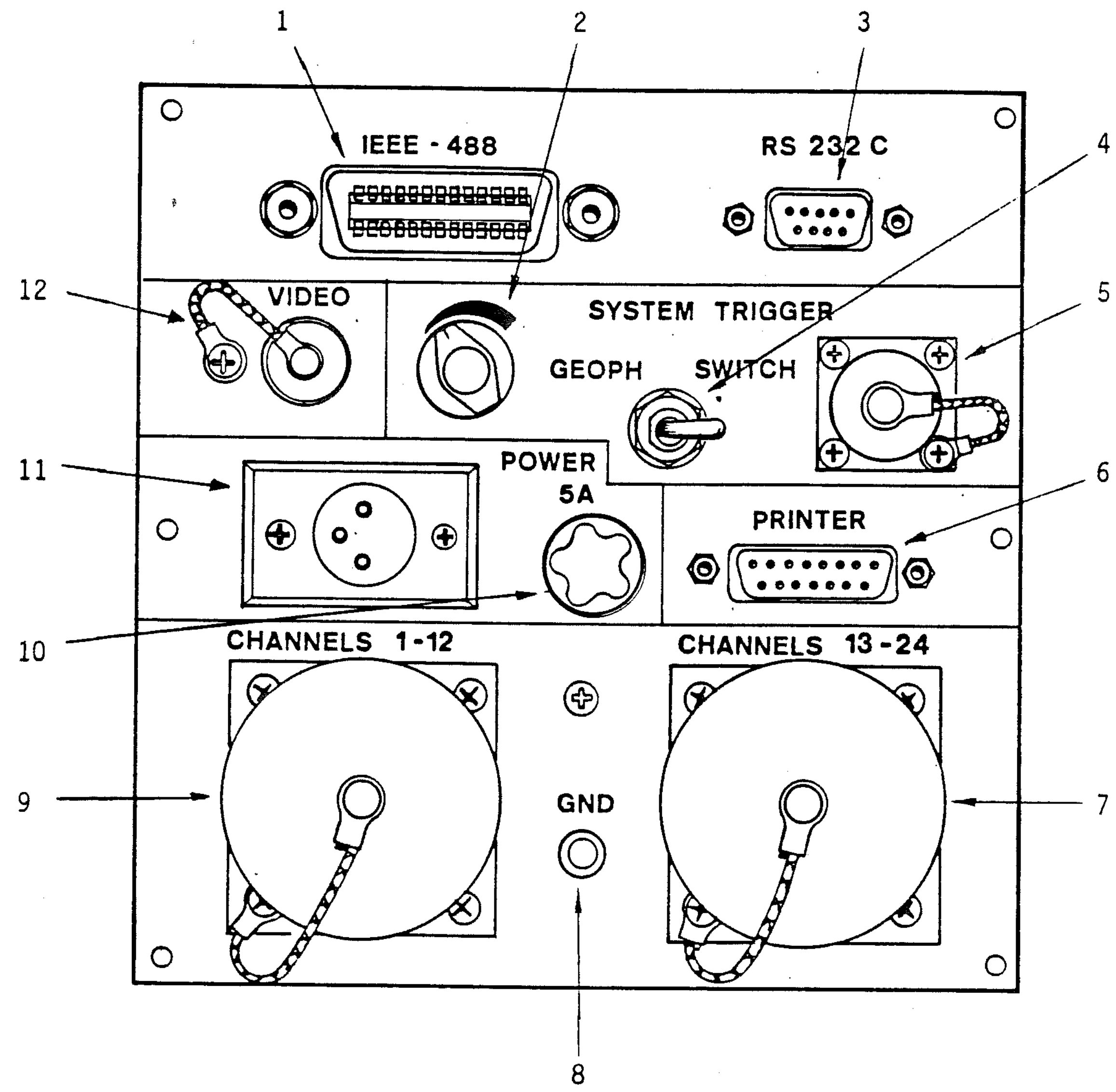
POWER CONNECTOR for an external 12 V battery power supply.
Mating connector type: Cannon XLR-3-11C

VIDEO CONNECTOR for a standard video monitor.
Mating connector type: 75 ohm BNC.

RS232C CONNECTOR for connection to a computer. Used for digital control and communication.
Mating connector type: Cannon DE-9P.

IEEE 488 BUS CONNECTOR for connection to a computer. Used for digital control and communication.
For this connection use any standard GPIB bus cable.

See service manual for connection details.



1 IEEE-488 Digital interface bus connector.
2 Trigger sensitivity control.
3 RS-232C Serial digital interface connector.
4 Trig mode switch, select geophone or contact trig.
5 Trig input connector.
6 Printer connector.
7 Geophone 13-24 input connector.
8 Earthing socket.
9 Geophone 1-12 input connector.
10 Main fuse.
11 Power input connector for +12 V battery.
12 External video connector.

Fig. 3.1-3 TERRALOC connector panel with all connectors

3.2 HOW TO OPERATE THE TERRALOC

After the outside inspection of the instrument in section 3.1 you are now ready to operate the TERRALOC. To do this you have to connect the proper cables as described below.

3.2.1 SETTING UP THE TERRALOC HARDWARE

If you are in your office or at home you can simply connect the TERRALOC to the power source (battery or mains power supply) using the orange power cable. If you are going to use the TERRALOC field printer as well you have to connect it separately to the power source using the other orange power cable. Then you must connect the printer and TERRALOC together using the printer cable.

If you are out in the field you must:

1. Connect the geophone cable(s) to the channel 1-12 and/or channel 13-24 connectors.
2. Connect the trig cable to the trig connector (the trig signal can be obtained from a trig geophone or electrical contacts or via radio).
3. Connect the battery using the orange power cable.
4. If you want to use the printer you must connect it to the TERRALOC and the battery.

When all is ready you can switch on the mains power supply if used and then operate the ON switch on the TERRALOC. After a short time (about 10 seconds) you will see the first screen containing a TERRALOC menu. See below!

3.2.2 THE TERRALOC MENU SYSTEM

The TERRALOC is controlled via user entries on menus shown on the CRT screen. To switch from one menu to another the MEN key is pressed. Menus 1-4 will appear one after the other in sequence.
All menus are shown on the following pages with a short description of the different functions and a reference into the manual where full information can be found.
We recommend that you use these pages as an index to the instrument functions. You should also study the manual carefully so that you can use your TERRALOC to its full capabilities.

There are four main menus and two supplementary menus in the TERRALOC system. The main menus (1-2-3-4) are reached one after the other by the use of the MEN key. Menu 1 can also be reached with the SET key.
The supplementary menus are reached via commands (see below).

Main menus:

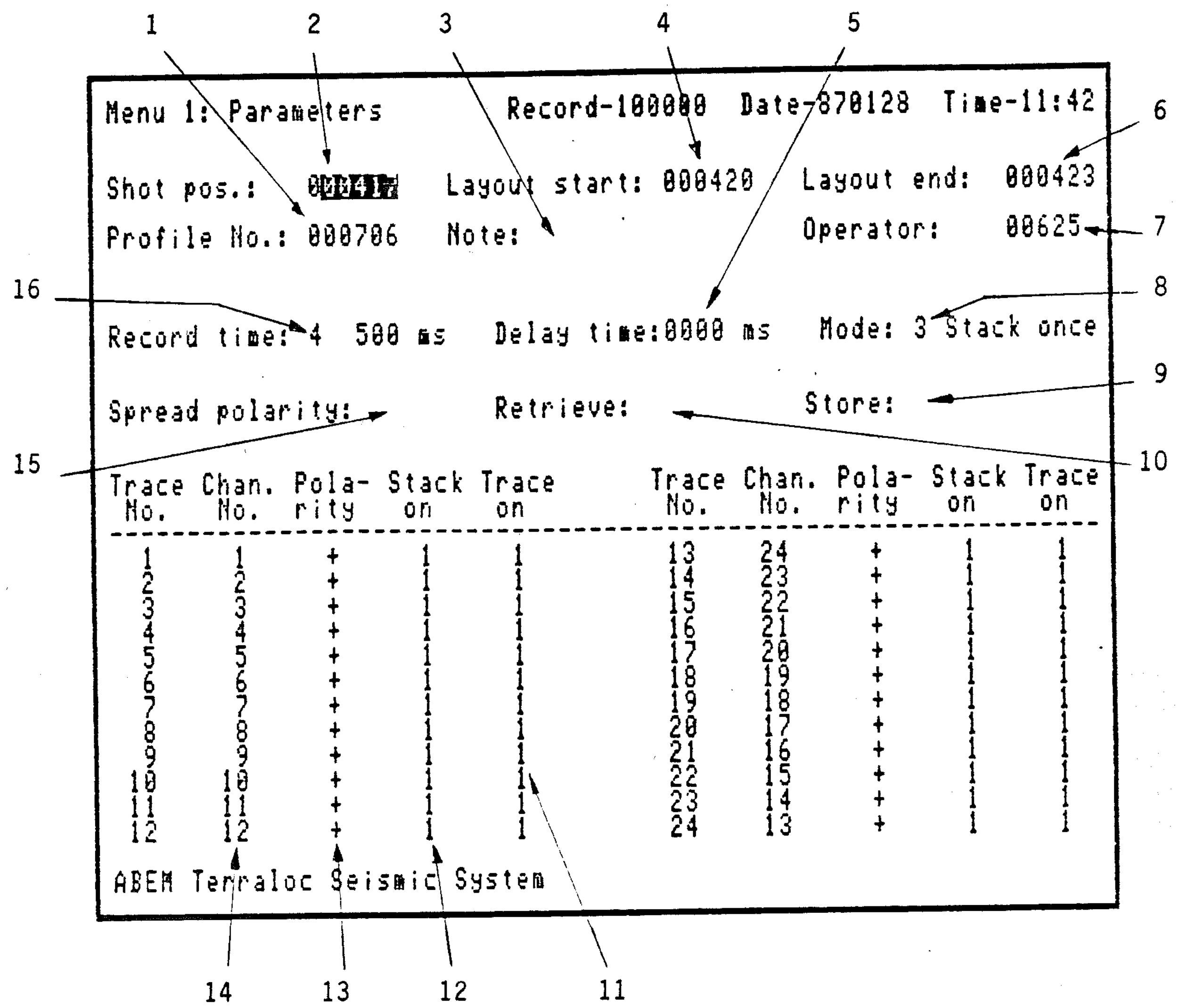
- Menu 1 — "Parameters" deals with the field notes and instrument setup.
- Menu 2 — "Channel gains" deals with amplifier gain setting and selection of analog filters.
- Menu 3 — "Processing" deals with selection of display and data processing.
- Menu 4 — "Recording" deals with data storage on floppy disk and RAM disk.

Supplementary menus:

- Menu 0 — "Power-up" is shown directly when the TERRALOC is switched on. It shows instrument status after error checking. It can also be reached from menu 5.
- Menu 5 — "System hardware" is used for hardware setup like selecting printer and digital interface and also for service purposes. It can be reached from menu 3.

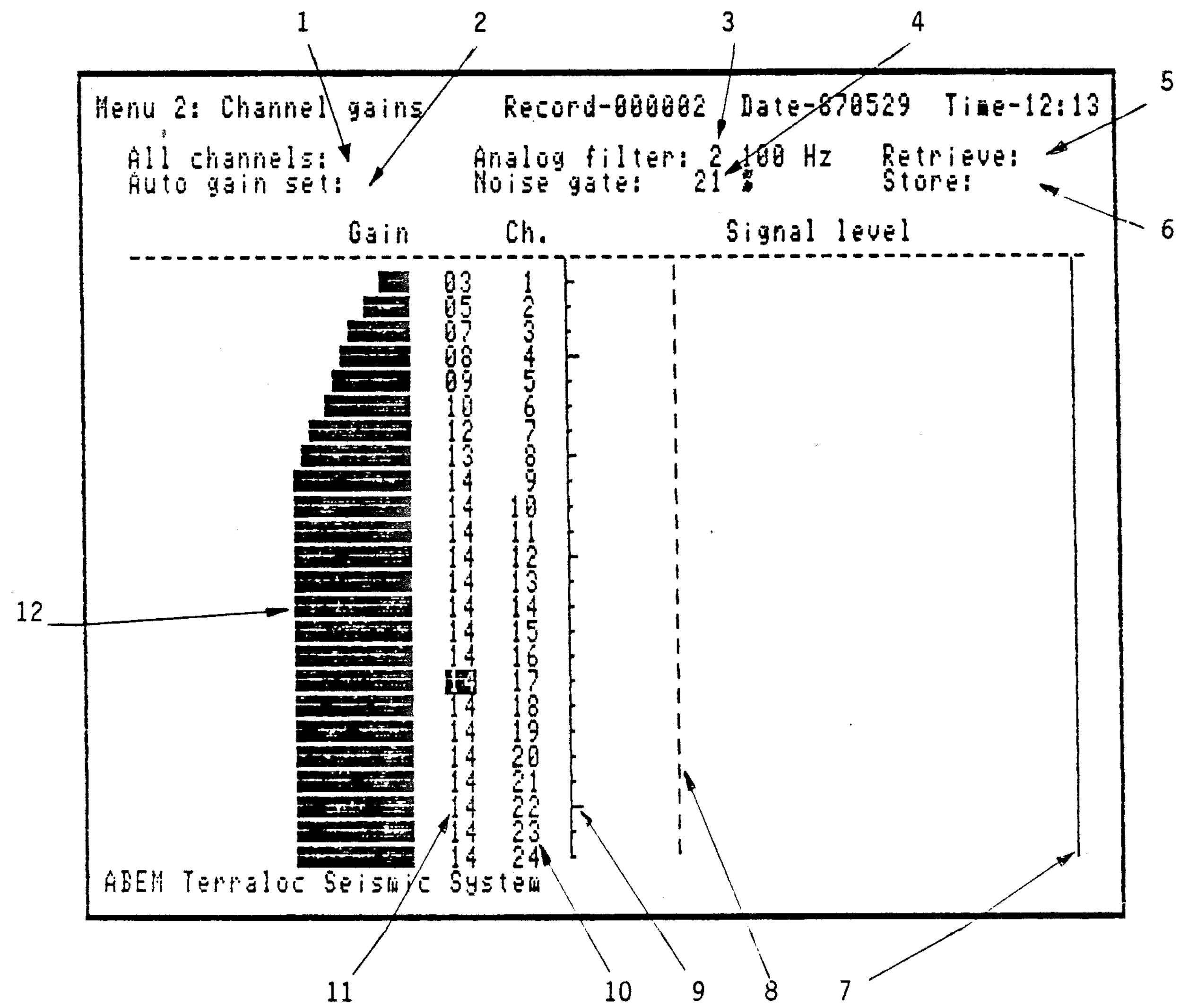
The four ARROW keys control the position of the entry cursor on the different menus. With these keys you can select a menu item (indicated by highlighting the item on the screen). The selected item can then be executed by the use of the ENT key if it is a command (such as Directory on the Recording menu). If the item is an instrument parameter you can change it by entering numeric information into the entry field.

Fig. 3.2.1-1 MAIN MENU 1 "Parameters"



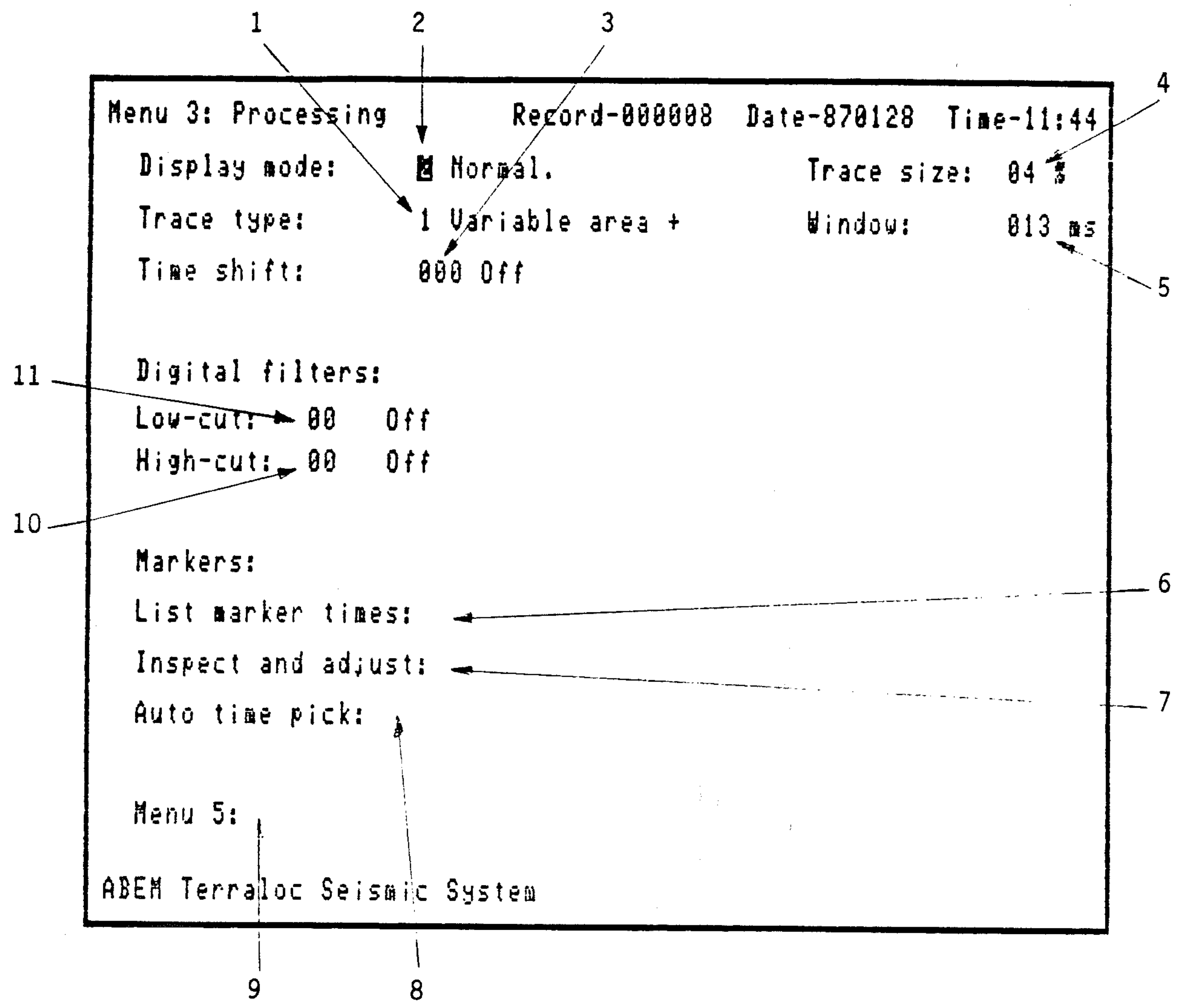
Item	Description	User entry	Reference
1	Field note: Profile Number	Any Number	(3.4.4)
2	Field note: Shot position	"	(3.4.4)
3	Field note: Note area	"	(3.4.4)
4	Field note: Layout start	"	(3.4.4)
5	Delay time in ms is entered here	0000-9999	(3.4.2)
6	Field note: Layout end	Any Number	(3.4.4)
7	Field note: Operator code No.	Any Number	(3.4.4)
8	Collection mode is selected here	0-3	(3.4.3)
9	Store assignments table in memory	0-9 + ENT	(3.4.7)
10	Retrieve assignments table from memory	0-9 + ENT or 0-4 + F	(3.4.8)
11	Trace on is selected here	0 or 1	(3.4.5.3)
12	Stack on is selected here	0 or 1	(3.4.5.2)
13	Trace polarity during stacking	+ or -	(3.4.5.1)
14	Select channel for the traces here	1-24	(3.4.5)
15	Change polarity for all traces here	+ or - or ENT	(3.4.6)
16	Set the recording length in ms here	0-7	(3.4.1)

Fig. 3.2.1-2 MAIN MENU 2 "Channel gains"



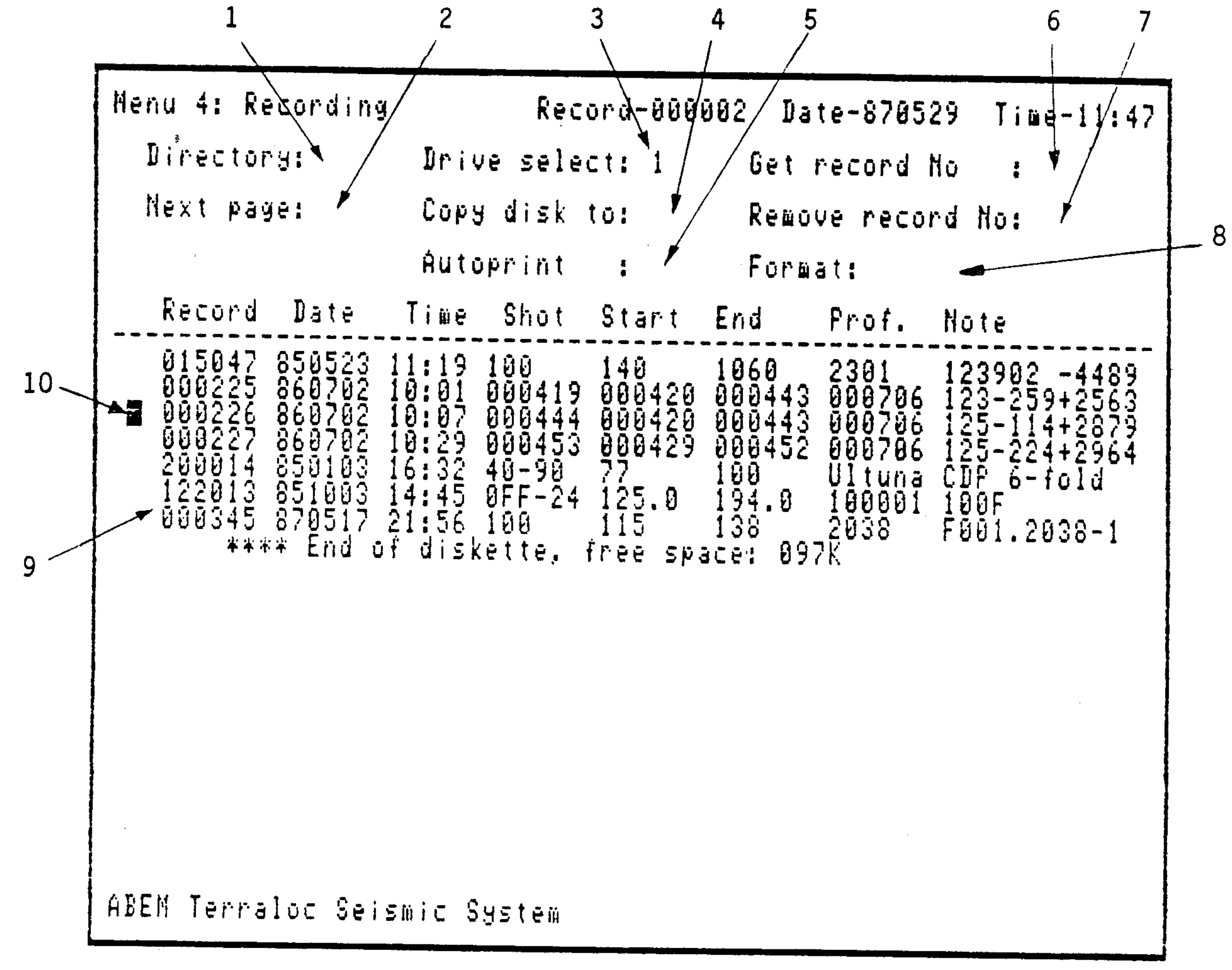
Item	Description	User entry	Reference
1	Increase/decrease gain of all channels	+ or -	(3.5.2)
2	Automatic gain adjustment after test shot	ENT	(3.5.7)
3	Set Analog filter frequency	0-8	(3.5.3)
4	Set Noise gate level in %	00-99 or + or -	(3.5.4)
5	Retrieve previously stored gain profile	0-9 + ENT	(3.5.5)
6	Store gain profile in memory	0-9 + ENT	(3.5.6)
7	100% signal level limit		
8	Noise gate level indicator		(3.5.4)
9	Noise monitor		(3.5.1)
10	Channel (amplifier) number indicator		
11	Individual channel gain adjust	+ or - or 00-20	(3.5.2)
12	Gain settings graphic display		

Fig. 3.2.1-3 MAIN MENU 3 "Processing"



Item	Description	User entry	Reference
1	Select trace type (Wiggle, Var. area..)	0-3	(3.6.2)
2	Select display mode (Average, Normal, AGC etc)	0-5	(3.6.1)
3	Select time shifting of traces	000-999	(3.6.3)
4	Set desired trace size (Normal, AGC)	01-99	(3.6.1-2)
5	Set desired window length (Normal, AGC)	000-999	(3.6.1-2)
6	List arrival time markers on screen	ENT	(3.6.5.1)
7	Inspect and adjust time markers on screen	ENT	(3.6.5.2)
8	Pick arrival times automatically	ENT	(3.6.5.4)
9	Go to hardware menu (Menu 5)	ENT	(3.6.6)
10	Set digital filter high cut frequency	00-99	(3.6.4)
11	Set digital filter low cut frequency	00-99	(3.6.4)

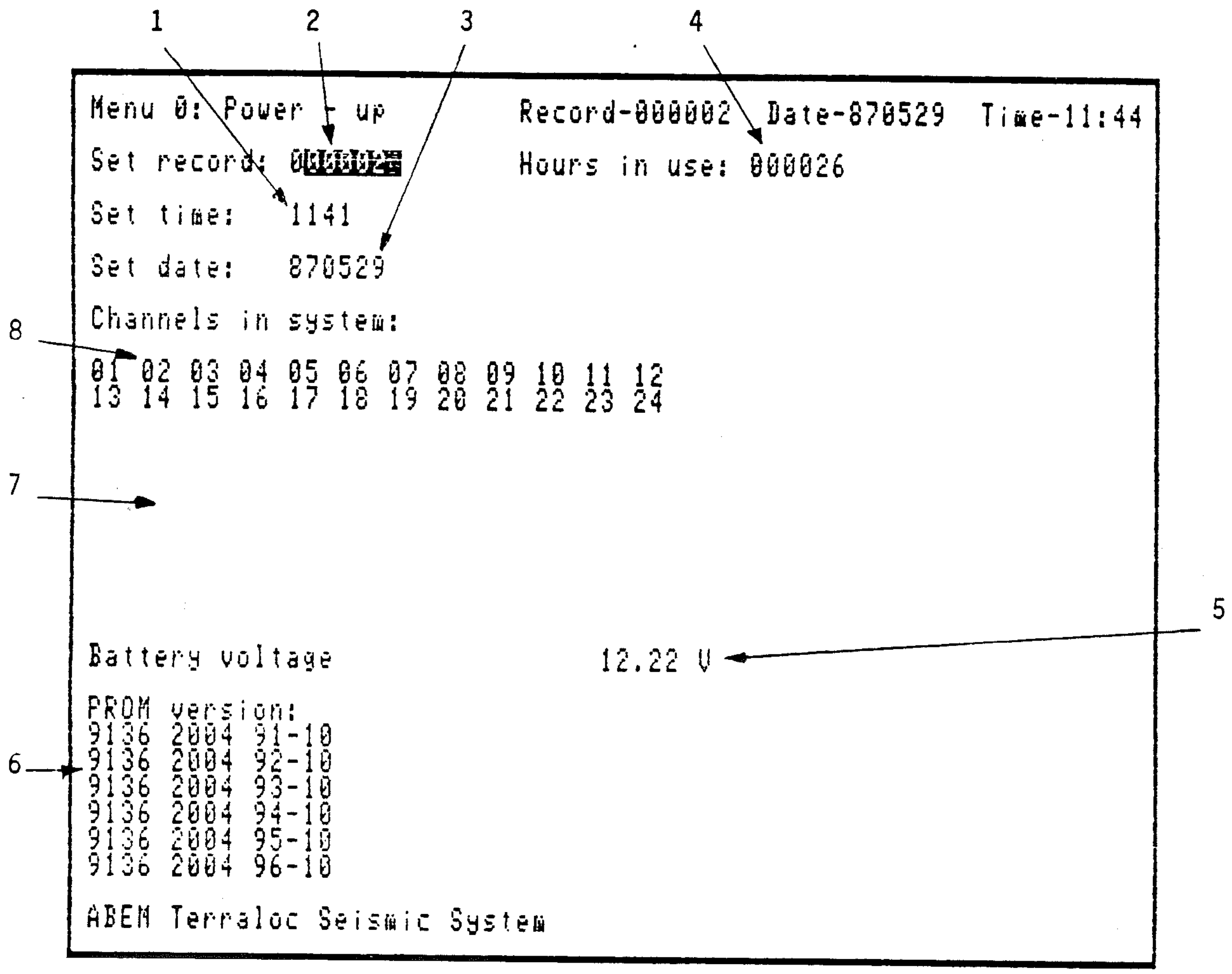
Fig. 3.2.1-4 MAIN MENU 4 "Recording"



Item	Description	User entry	Reference
1	Directory, list disk contents on screen	ENT	(3.8.1)
2	Display next page of a long directory	ENT	(3.8.1)
3	Select active drive	1-4	(3.8.2)
4	Copy disk contents to another disk	1-4 + ENT	(3.8.3)
5	Print all records on printer	ENT	(3.8.4)
6	Read a specified record	6 figures + ENT	(3.8.5)
7	Delete a Terraloc file from disk	6 figures + ENT	(3.8.6)
8	Format the active disk	. + ENT	(3.8.7)
9	Directory listing made in (1) above		
10	Read this file with the ENT key	ENT	(3.8.5)

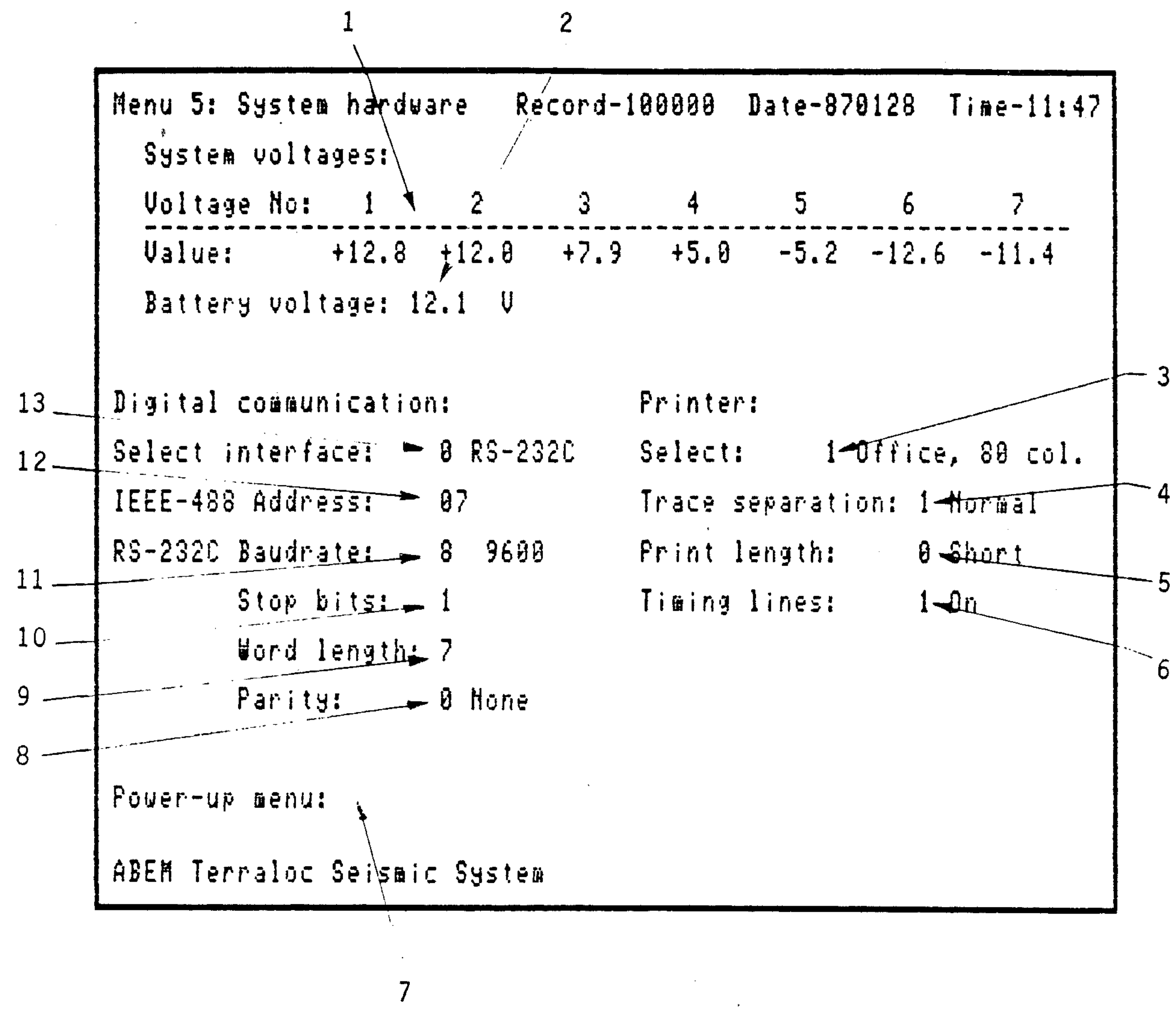
To read a record: position cursor in front of the record number item (10) and push ENT.

Fig. 3.2.1-5 SUPPLEMENTARY MENU 0 "Power-up"



Item	Description	User entry	Reference
1	Set the time of the internal clock	hhmm + ENT	(3.3.2)
2	Set the next record number to use	6 figures + ENT	(3.3.1)
3	Set the date of the internal clock	yymmdd + ENT	(3.3.2)
4	The TERRALOC time of usage		(3.3.3)
5	Battery voltage at power-up		
6	Software version identification		
7	Empty area reserved for self check error messages		
8	List of amplifiers installed in the system		

Fig. 3.2.1-6 SUPPLEMENTARY MENU 5 "System hardware"



Item	Description	User entry	Reference
1	System voltages: continuously measured		(3.7.1)
2	Battery voltage monitor		(3.7.1)
3	Select printer type	0-3	(3.7.3)
4	Select trace spacing on print and display	0-1	(3.7.4)
5	Select normal/short print length	0-1	(3.7.4)
6	Enable/disable timing lines on printout	0-1	(3.7.4)
7	Go to power-up self check menu (Menu 0)	ENT	(3.7.5)
8	Set serial interface parity	0-3	(3.7.2.6)
9	Set serial interface word length	7-8	(3.7.2.5)
10	Set serial interface stop bits	1-2	(3.7.2.4)
11	Set serial interface baudrate	0-9	(3.7.2.3)
12	Set address of IEEE-488 interface	00-30	(3.7.2.2)
13	Select serial or parallel interface	0-1	(3.7.2.1)

3.3 INSTRUMENT SELF CHECK. MENU 0

When the TERRALOC is switched on its computer starts immediately and runs through an extensive self-check procedure while the CRT is warming up. This will take about 10-20 seconds, whereupon the screen will display MENU 0 which presents the status of the TERRALOC: error messages, if any, the number of active installed channel amplifiers, the date and time of day, the number of the next record to be made, etc.

The battery voltage is measured about 10 seconds after switch-on and displayed in menu 0 so that it can be checked by the operator. The number of hours throughout which the TERRALOC has been used also appears.

3.3.1 RECORD NUMBER

In the top line of all menus the RECORD NUMBER appears as a 6-digit number. This is the identification number that will be given to the next measurement that is stored on disk.The record number is automatically incremented when an event is recorded on disk. It is used to identify recordings and printouts. The number is NOT incremented if data played back into the TERRALOC from a disk is recorded on another disk. It is only incremented once regardless of how many copies are made of the same event.

However, if the data changes between two recording operations, e.g. if another shot is added to the stack, the RECORD NUMBER will be incremented.

The RECORD NUMBER can be set at any convenient starting point in menu 0 (power-up).
The desired record number (six digits) is entered into the SET RECORD field after which ENT must be pressed. The new RECORD NUMBER is then transferred to the top line in the menus.

3.3.2 DATE AND TIME OF DAY

The DATE and TIME OF DAY are displayed in the top line of all menus. The time is kept by a quartz clock in the TERRALOC computer. It is recorded along with the signals on disk and serves as a second automatic means of identification.
The clock can be set by the operator if needed, e.g. when daylight savings time is introduced or when the instrument is moved between time zones. It is done on menu 0 following power-up. The operator moves the cursor to the SET TIME field and enters the desired time in "hhmm" format, after which ENT must be pressed. This will set the clock provided that a valid time was entered.
To set the date, the same procedure is used in the SET DATE field using a 6-digit format "yymmdd". When the ENT key is pressed, the new date will be entered if it is a valid date (the TERRALOC will not accept erroneous dates such as 840230 for example).

3.3.3 HOURS IN USE

This is the indicator for TERRALOC usage. It will display the number of hours that the unit has been working and can be used in a maintenance plan to indicate when service is needed.

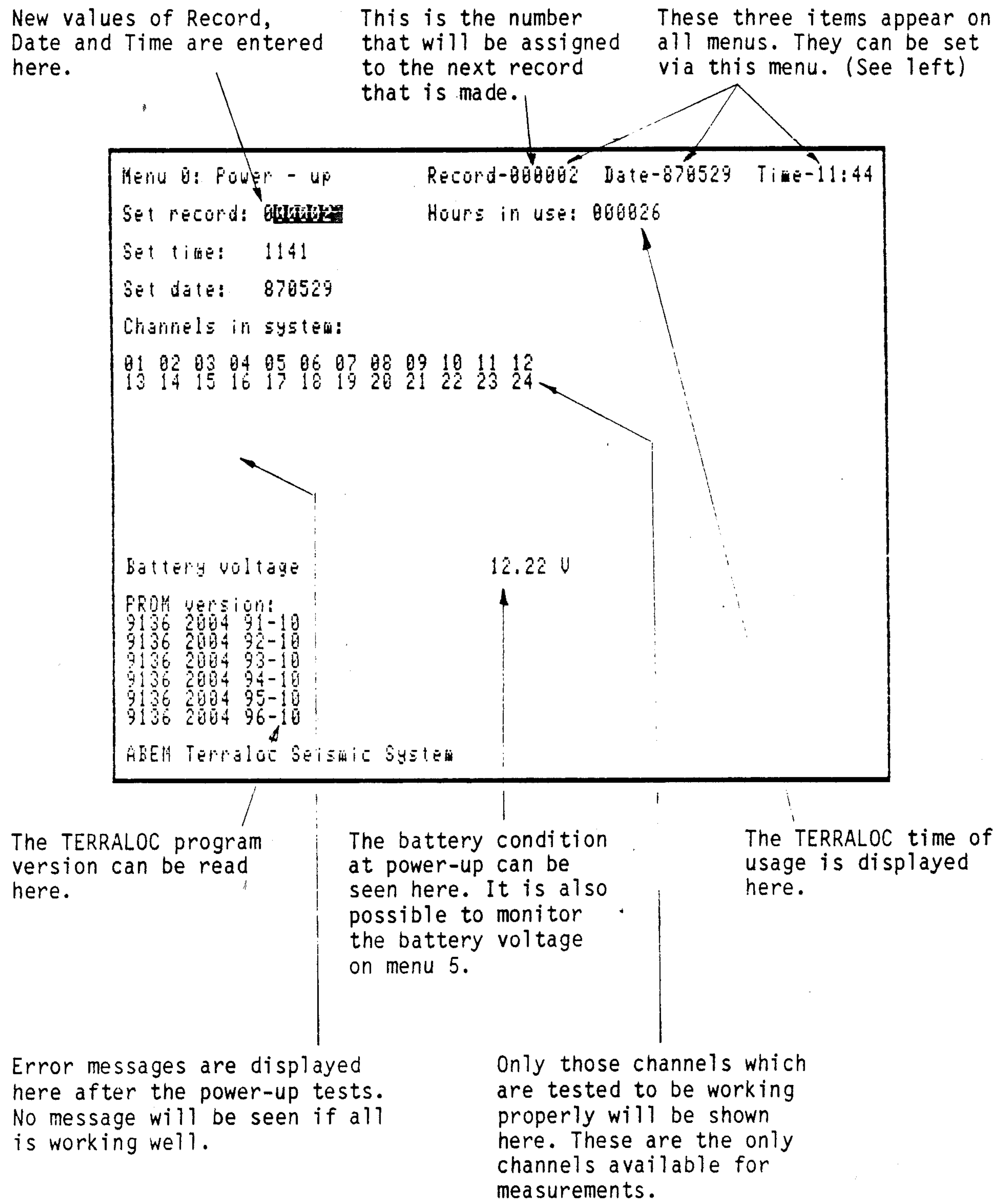


Fig. 3.3-1 Menu 0 which appears after power-up.

3.4 SETTING UP INSTRUMENT PARAMETERS. MENU 1

When the TERRALOC has completed the self-check procedure following initial power-up, you can reach menus 1-4 in succession by pressing the MEN key.

Menu 1 is used to enter instrument parameters, and it is reached by pressing MEN once.

The menu is displayed on the CRT screen as shown in Fig. 3.4-1. The parameter to be entered or changed is indicated by an inverse video parameter field (rectangle). The next character to be input is indicated by the cursor which flashes twice per second.

You can write in this field using the numeric keys on the keyboard. This process wraps around, i.e. if a key is pressed after the last number in the field is entered, the first number is changed and so forth.

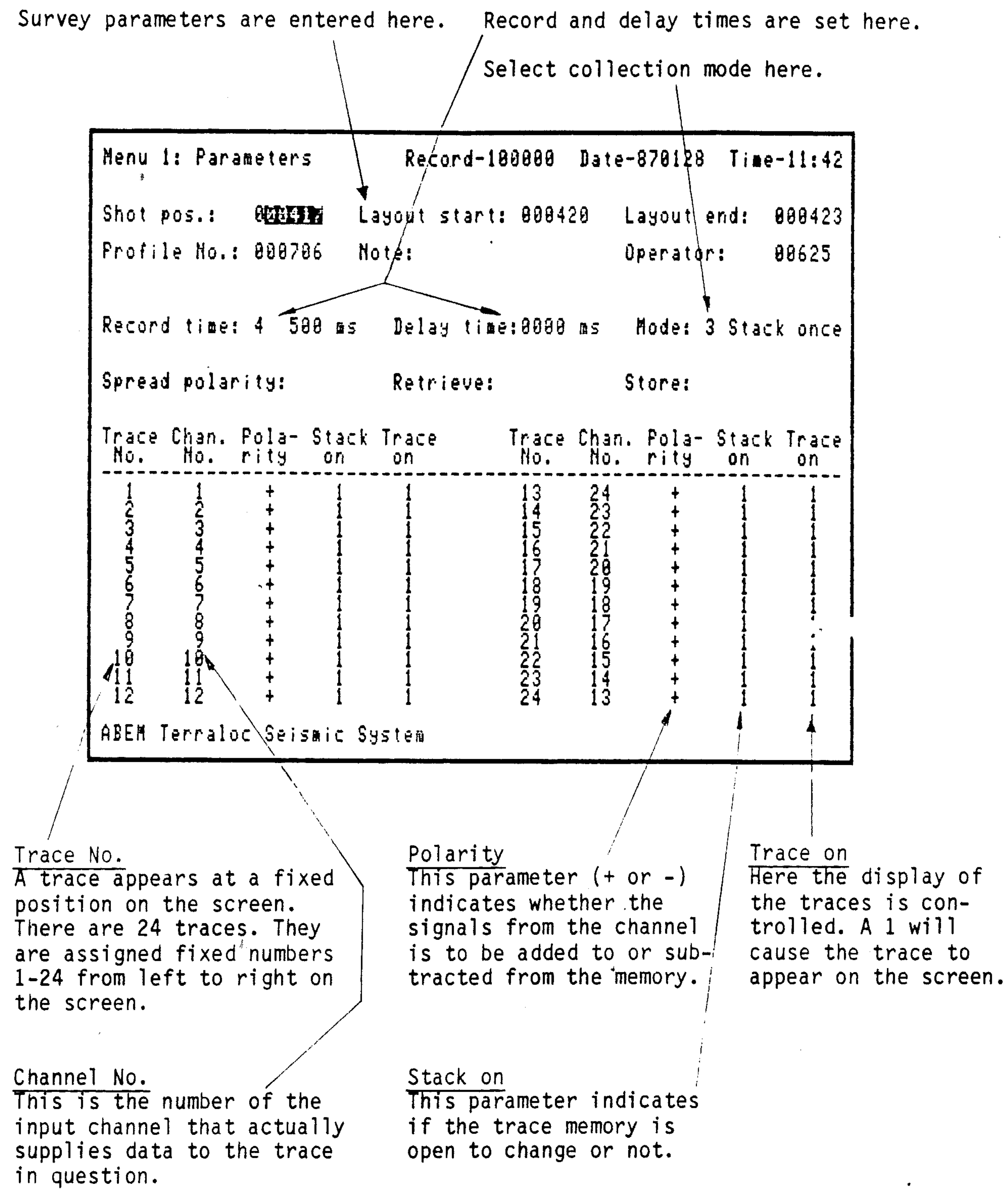
3.4.1 RECORD TIME

This is the time during which the instrument will sample the geophone waveform 1000 times and store the samples in digital memory on the amplifier boards. You select the desired record time by entering a code number 0-7. The selected time will appear to the right of the code number:
24, 48, 100, 200, 500, 1000, 2000 and 5000 ms, respectively.

If an entry is made that does not equal one of the above the computer will substitute the longest standard time (5000 ms) and output an error message and a short beep.

3.4.2 DELAY TIME

This is the period of time that will elapse after a shot trigger pulse is received before the waveform sampling process starts. The delay time ranges from 0 to 9999 ms and is crystal-controlled for precision.



A channel supplies the signal arriving from a geophone. Each channel is permanently connected to one amplifier. Numbers ranging from 1 to the number of channels included in your TERRALOC can be entered for this parameter.
This parameter gives you the option of assigning the signal received from any channel to any desired trace. Note that this signal can be assigned to more than one trace if so desired. This feature is very valuable in certain special situations. Note that there is one signal stack memory for each trace.

Fig. 3.4-1 MENU 1

3.4.3 COLLECTION MODE SELECTION

The operator can select one of four collection modes of operation by entering a code number (0-3) in the "Mode" field. The codes correspond to:

0 - Autostack
1 - Preview
2 - Fast stack
3 - Stack once

0: In the AUTOSTACK mode the received signals are automatically added to the signal stack at once. The stack contents are then displayed on the CRT screen as an enhanced/averaged/normalized/agc:ed waveform as selected in MENU 3. The TERRALOC is then ready to receive a new shot.

1: In the PREVIEW mode the received signals from a shot are NOT entered into the signal stack but are first displayed on the CRT screen. The signals are displayed in true received size. The operator can manually enter these signals with the ENT key. This enables him to select only good signals for entry into the stack.
If a new shot is received before the ENT key is pressed, the previous shot is lost.

2: The FAST STACK mode is the same as AUTOSTACK, but with no display of waveforms on the screen during data collection. Instead the noise monitor display stays on the screen at all times. In this mode, the rate at which the TERRALOC can accept new data is higher because the time needed to update the display with new waveforms is saved. This is useful when you are working with a hammer as the signal source or when you want to monitor the ambient noise during the whole recording sequence.
When the NOISE GATE function is in operation, all noisy signals will be immediately discarded rather than displayed for operator acceptance.

3: The STACK ONCE mode works exactly like AUTOSTACK with the exception that the TERRALOC will only accept one addition of signals into the trace stack memory each time the system is armed. This function is used whenever multiple trig pulses may be expected from a noisy trig source. Only the first pulse will start a measurement and any bounce and reverberation will have no trigger effect.

3.4.4 SURVEY PARAMETERS

There are six survey parameters at the top of menu 1:

- Shot position, layout start, layout end, profile number, operator and a note area.

All parameters (except "Note") are six characters in length and the operator can enter any combination of characters. The note area is 12 characters long to make room for information such as contract number etc. These parameters are not acted upon by the TERRALOC computer but are stored with the waveforms on disk and printed when a hardcopy is made. They thus serve as a means of bookkeeping for the field crew during surveys, thereby reducing the need for separate notes.

Positions can be specified as desired: in metres, in feet in lat/long or the like.

3.4.5 TRACE ASSIGNMENTS

In the bottom part of MENU 1 there is a table of trace-oriented parameters. One of these is the channel number. This parameter permits the operator to direct the channel input data to a selected trace or selected traces in the signal stack. Traces are numbered 1 to 24 from left to right on the CRT screen. This is useful for borehole surveys if a full 12 or 24 channel spread of geophones cannot be used. Here, the operator lowers a set of up to three geophones into the hole and measurements are taken one station at a time. Between each station, the assignments for those geophone amplifiers are changed. Finally, an ordinary recording can be displayed with all stations on the same output, just as if a full spread had been used.

3.4.5.1 POLARITY

The next parameter is the polarity of the channel-to-trace connection. Here, the operator can decide to invert (-) or leave uninverted (+) the data used for the specified trace. Note that if the same channel is assigned to several traces, different polarities can be used for the different traces.

This feature permits simultaneous S and P wave recordings to be made.

3.4.5.2 STACK ON

Another parameter in the table is STACK ON. With this, the operator can lock the stack memory of selected traces. If a 0 is entered, the trace memory will be protected from any change. No data will be added to that trace stack. If a 1 is entered the trace memory is open for entry of new data. This feature can be used together with the assignment function described in section 3.4.5 to make a borehole log using only three geophones lowered into the hole from station to station.
Note that the clear function only operates on traces with the memory set to "on". This makes it possible to selectively erase a trace with bad data.

3.4.5.3 TRACE ON

With this parameter, the operator can decide whether or not a trace is to be displayed on the CRT screen in the TRACES display. The trace is displayed if a 1 is entered. A 0 will inhibit display of that trace.

The data in the trace memory is not affected by this parameter. Only the display function is affected. This feature thus permits careful examination of selected traces even if many traces cross each other in the area of interest. One merely deselects all irrelevant traces by entering a 0 in the appropiate location in the TRACE ON column.
Note that the maximum number of traces that can be on simultaneously is equal to the number of installed amplifiers.

3.4.6 SPREAD POLARITY

To the left above the assignment table on MENU 1, you will find the SPREAD POLARITY field. This controls the polarity of data to be added to the traces. If a + is entered here all channel-to-trace connections will have + polarity. They will thus be additive. Likewise, if a - is entered, all connections will have - polarity. They will thus be subtractive.

If, however, the ENT key is pressed, all polarities will invert. This is useful when you are doing an S-wave survey and one or a few geophones are incorrectly connected.

3.4.7 STORE ASSIGNMENTS

All parameters entered into the table can be stored in battery-backed CMOS memory. You merely select a 1-digit code number for the present set of assignments, enter that code in the STORE field and then press ENT. The complete set is now stored under that code.

Ten different sets of assignments can be entered and retrieved as described below.

3.4.8 RETRIEVE ASSIGNMENTS

The desired set of user programmed assignments can be retrieved simply by entering the code number into the RETRIEVE field in MENU 1 and then pressing ENT.
There are also five predefined assignment sets that can be retrieved. They are two 12 channel setups (forward and reverse), two 24 channel setups (forward and reverse) and a cleared assignments table ready for user entries.
These predefined sets are retrieved by entering a code number 0-4 followed by depression of the F key. (F for fixed assignment).:

0 - clear assignments table
1, 2 - 12 channel sets
3, 4 - 24 channel sets.

3.5 GAIN SETTING AND NOISE MONITORING. MENU 2

If you want to change the amplifier GAIN settings or monitor the ground noise levels you press the MEN key until MENU 2 is displayed. In this menu you can also set the analog filter frequency and the noise gate level.

3.5.1 SIGNAL MONITORING

On the right side of MENU 2 there is a signal level monitor section where the instantaneous signal levels in all channels are displayed as horizontal lines. The length of each line is proportional to the voltage level at the amplifier output. If the NOISE GATE is active, its level is shown as a vertical dashed line.

3.5.2 GAIN SETTING

In the center of MENU 2 there is a table showing the amplifier gain settings. Gain codes range from 00 to 20 with a 6 dB gain difference per step. The gain settings are also displayed graphically to the left to enhance readability.
There are five ways to set the amplifier gains:

1. By selecting an individual amplifier (shown by an inverse video rectangle) and thereafter simply entering the desired gain setting. The gain of that amplifier is then immediately set at that value.

2. By entering a + or - into the gain code field of an individual amplifier. This will increase or decrease the gain of that amplifier one step.

3. By entering a + or - into the ALL CHANNELS field. This will increase or decrease the gain of all amplifiers simultaneously one step at a time.

4. By using the RETRIEVE function to recall a preset gain profile. See section 3.5.4.

5. By using the automatic gain set function. After making a test shot go to menu 2 and press the ENT key in the "Auto gain set" field. The amplifier gains will be automatically adjusted to an optimum value. See section 3.5.7.

3.5.3 ANALOG LOW-CUT FILTER

The analog low-cut filter supplied on the Mark 3 amplifier board can be set to 8 different cut-off frequencies. To engage the filter a code ranging from 1 to 8 is entered. This also selects the cut-off frequency. The cut-off frequency is 1 to 8 times 50 Hz (50 to 400 Hz) depending on the code number. The selected frequency will be displayed to the right of the code number.
If a 0 is entered the analog filter will be completely disconnected.

All channels are affected alike by this command. Incoming data will be filtered and any signals that are removed cannot later be restored.

The filter is used to remove low frequency ground roll so that a higher gain can be selected without saturating the system. In this way the P-wave can be recorded at greater distances than otherwise.

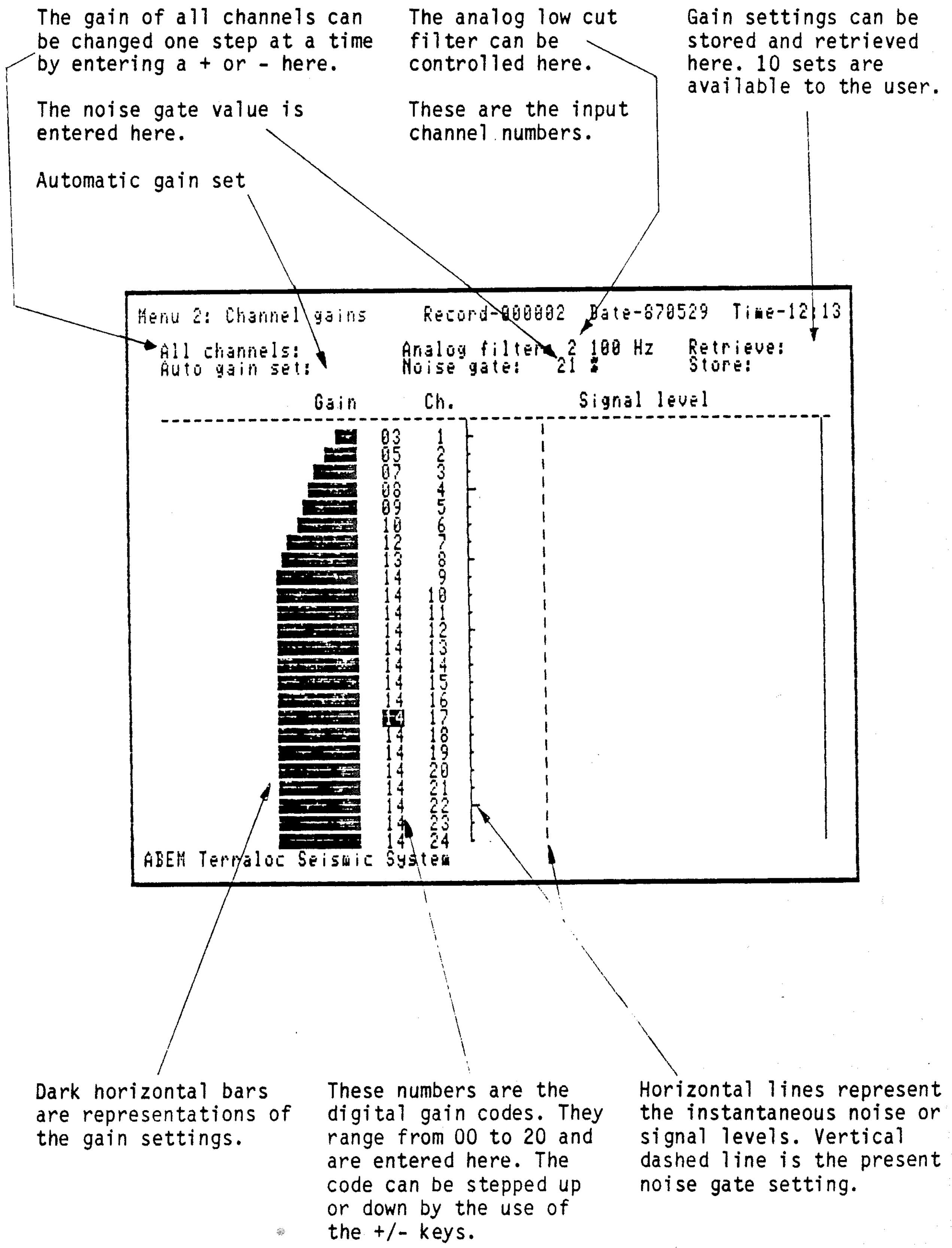


Fig. 3.5-1 MENU 2

3.5.4 NOISE GATE LEVEL

This is the level set for the noise gate function and it is specified as a percentage of full scale of the A/D converter, i.e. of full channel deflection on the CRT screen. The allowed level range is 00 to 99 %.

The noise gate operates as follows:

During the time immediately preceding the arrival of the trigger pulse, the signal on each channel is continuously monitored. Should a noise signal peak that is higher than the preset noise gate level be detected, the TERRALOC is automatically put into the PREVIEW mode for one second. (See section 3.4.3). Data collected from a shot during this period is added to the signal stack only when you press the ENT key. The stack is thus protected from entry of bad signals in noisy areas.

If the noise gate level is set at 00% no monitoring of noise levels will take place.
The set noise gate value is displayed as a vertical dashed line on the noise monitor section of the display. To change the level simply key the desired value or use the + and - keys to increase or decrease the level.

3.5.5 RETRIEVING THE GAIN SETTINGS

This function enables the operator to recall gain settings made in advance and stored in the internal battery-backed CMOS memory. It is possible to recall 10 sets of gains by a simple operation. On MENU 2 you simply position the cursor on the RETRIEVE field using the move keys. Then enter the number of the selected set and press the ENT key. This will recall from memory the gains previously stored for this number.

3.5.6 STORING GAIN SETTINGS

This function enables the operator to store the current set of gain settings in the CMOS memory.

The cursor is first positioned on the STORE field by means of the move keys. A code number is keyed in followed by ENT. The gains of all amplifiers are stored using this code number in the CMOS memory. If a set of gains with the same code number already exists, it will be erased and replaced with the new one.

3.5.7 AUTO GAIN SET

With this function you can set all amplifier gains at an optimum value at once. The procedure is as follows:

- Make a test shot with the gains set slightly lower than you expect for the final measurement.
- Go to menu 2 and position the cursor in the "Auto gain set" field. Press the ENT key once.
- Now all gains will be adjusted so that the next shot will use the A/D converter's dynamic range in an optimum way.

If the test shot has produced signals with amplitudes above the A/D range the auto gain set will reduce the gain on those amplifiers by a factor of 1/8. This adjustment is not exact and therefore a message will be displayed telling you that the Terraloc computer could not adjust correctly. After another test shot and auto gain set you should be O.K.

3.6 DIGITAL PROCESSING SELECTION. MENU 3

In MENU 3 you can select from a number of digital processing functions to be applied to the recorded waveforms. All processing is done non-destructively, which means that after processing the original data are still present in memory. The processing is done from the stack memory to the display buffer memory. You can thus test different processing settings on the same data.

3.6.1 DISPLAY MODE SELECTION

Six modes for the display of waveforms are available. The trace size is controlled by the different modes and the effect can be seen in Fig. 3.6-1. The modes are selected by the entry of a code number in the DISPLAY MODE field. The modes are:

0 ENHANCE	This will display the stacked sum of the signal values.
1 AVERAGE	This will display the average of the stacked sum of the signal values. The memory values are divided by the number of shots before tney are displayed.
2 NORMALIZE	Here the display shows normalized trace amplitudes. The maximum amplitude of each trace will be adjusted to the same value for all traces. This value is entered as the "Trace size" parameter by the user.
3 NORMALIZE Limit	In this mode the traces will be limited to stay within the normal level. Any part of the trace extending outside this level will be clipped. Normalization will take place as in mode 2 before limiting is done, so this function will only affect traces when the Window is in use. The limiting mode is useful to eliminate trace to trace interference when looking for first arrivals.
4 AGC	This will display the stack after performing a digital automatic gain control operation. This process changes the display gain along the trace so as to keep the short term mean amplitude constant. Large signals are reduced and small signals are amplified. The window used for calculating the mean is set with the Window parameter. The level is set with the Trace size parameter.
5 AGC muted	The same as AGC except that if first arrivals have been picked, the traces will be muted (zeroed) up to the arrival time. Thus noise will <u>not</u> be amplified on the display ahead of the first arrivals.

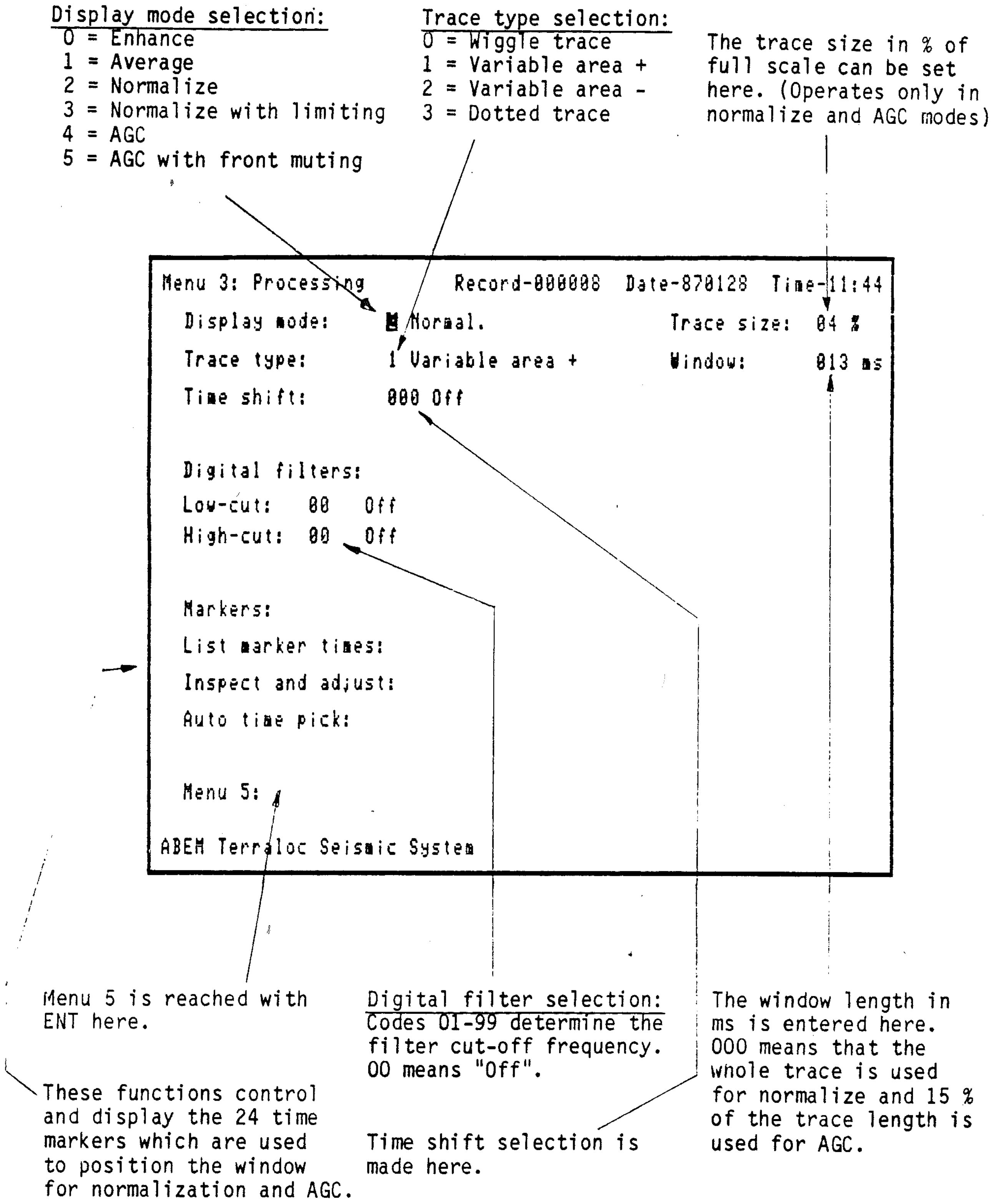


Fig. 3.6-1 MENU 3

3.6.1.1 DESCRIPTION OF THE NORMALIZE FUNCTIONS

Both normalize modes use the "Trace size" parameter by which the user sets the maximum amplitude of any trace. This size is expressed in % of full deflection just like the Noise Gate level in Menu 2.

Also used in some cases is the "Window" parameter. It makes it possible to normalize only a reduced part (a window) of the trace. For example the first arrival pulses of each trace can be automatically adjusted to exactly the same amplitude. Then the determination of a correct arrival time is easy.

The window length is expressed in milliseconds. 000 length means that the function is switched off.

To operate the window function the user has to set the window length with the "Window" parameter and the position of the window with the individual time markers (see 3.6.5 below). When these markers are set they define the front end of the window.

The normalize functions work in the following way:

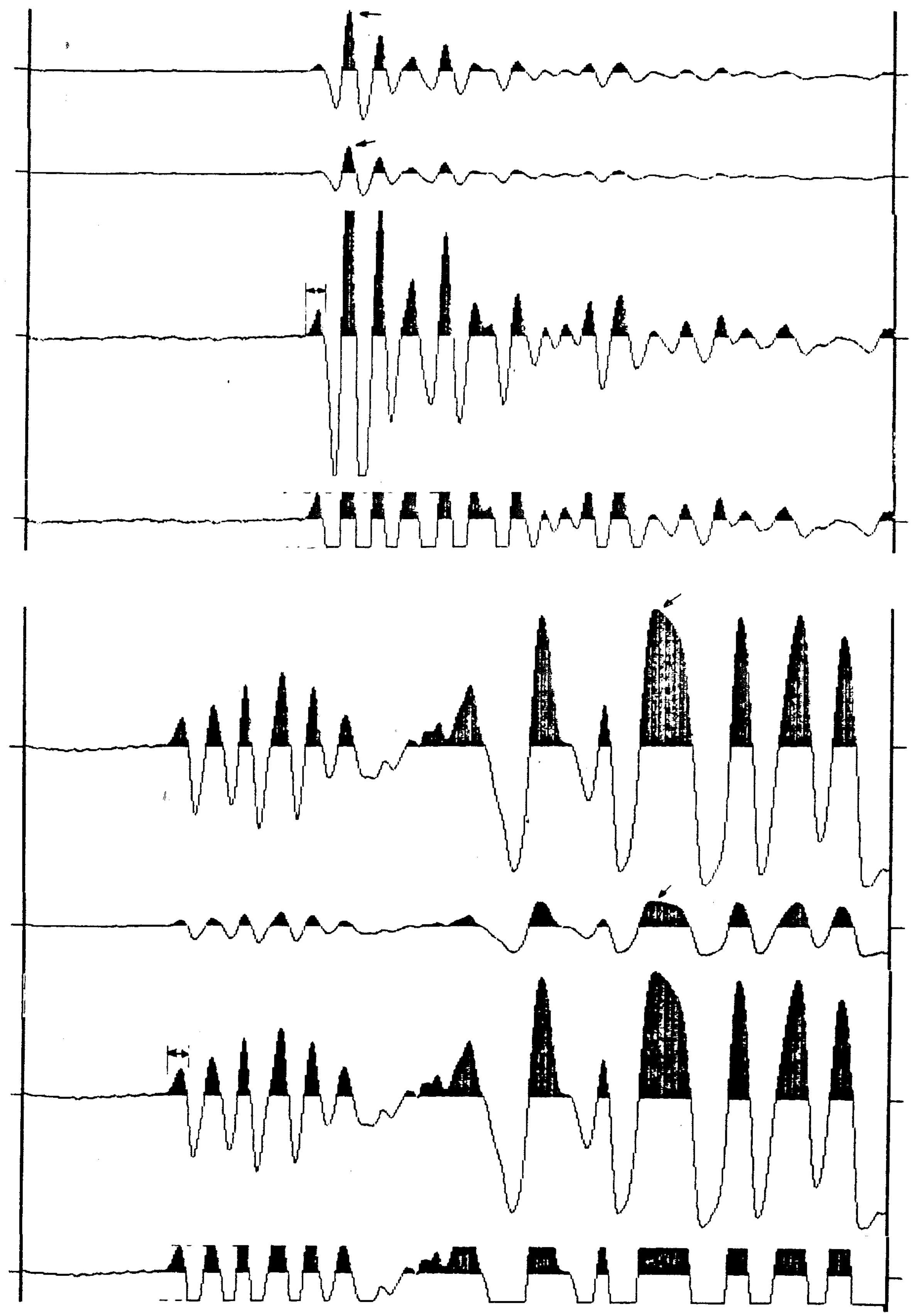
- First the trace stack memory is searched over the predefined range for the largest amplitude. The range is either the whole trace or a shorter window.
- Then this maximum is compared to the selected trace size in order to determine a suitable scaling factor that equalizes the maximum to the desired size.
- This scaling factor is then applied to the whole trace including the parts outside any selected window.
- Finally, if the "Normal. limited" mode is selected the result is limited so that any amplitude above the normal level is clipped back to that level. The limiting effect will never be seen inside a window since no signal is greater than the normal level there.

In Fig. 3.6.1-1 you can see an example showing the effect of the different normalization modes. There are four groups of two traces each. These trace pairs are the same throughout but displayed in different ways.

First they are shown in average mode (top), this indicates the signal size as received from the geophones. As you can see the two traces have different characteristics. The top trace has an energy concentration in the first part whereas the second trace shows high amplitude, low frequency waves in the later part of the trace.

If you look for the highest amplitudes in each trace you will find them at the position indicated by the small arrows. The second pair of traces from the top shows what happens when these max amplitudes are used for normalization (Normalize). The amplitudes at the arrows are equalized in size by the application of an automatically calculated scaling factor. This scaling factor is also applied to the other parts of the traces which are amplified or reduced in size.

Fig. 3.6.1-1 The effect of different processing on two traces of seismic data. From top to bottom: Average, Normalize, Normalize with window and Normalize limited.

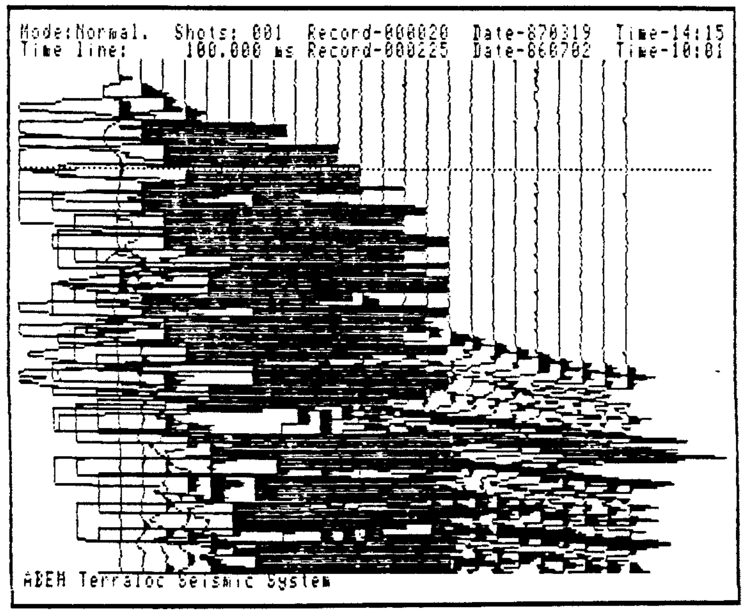


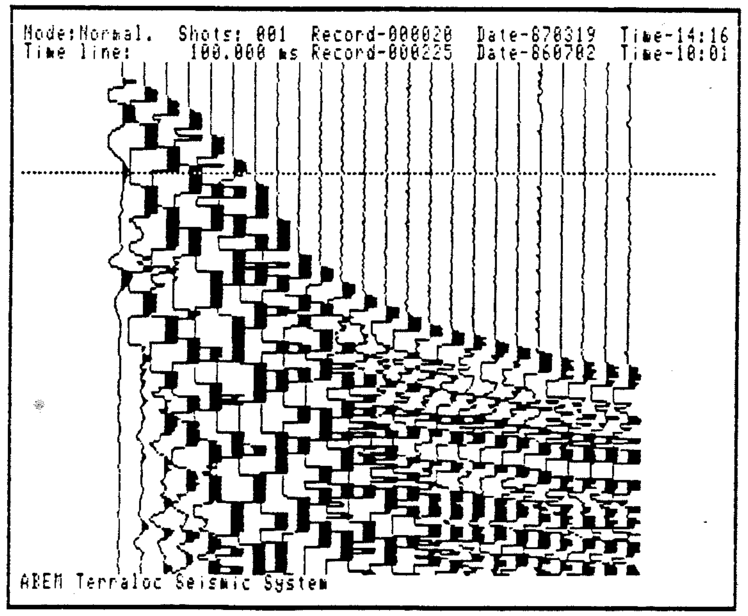
The third pair of traces have been treated differently using the window mode of "Normalize". The search for a maximum amplitude is only done over a short length of time (a window) around the first arrival pulse. This is accomplished by setting the window length to equal the length of the arrival pulse and positioning the arrival time markers at the start of the pulse. Therefore it is this pulse that is equalized in size. Note that the parts that follow the first pulse are enlarged and may possibly cover the adjacent traces.

To reduce this covering-effect the display mode "Normalize limit" is introduced. As shown on the bottom two traces this mode works as the previous one with one exception: all amplitudes extending above the user set trace size are clipped.

This effect can be seen on the two 24 channel records in fig 3.6.1-2. The first of these is normalized and the second is also limited.

Fig. 3.6.1-2 How the covering effect between traces can be removed by the use of the normalize limit function.





3.6.1.2 DESCRIPTION OF THE AGC FUNCTIONS

The AGC (Automatic Gain Control) modes in menu 3 (Display modes 4 and 5) work on the recorded data already present in memory as all other display modes.

The Terraloc digital AGC function will compensate for variations in signal strength along the trace. Whenever the signal size is large it will be reduced and whenever it is small it will be amplified. The net effect is that you can see, in the same trace display, both high amplitude first arrivals and late arriving tiny reflections.

The way this equalization of trace size is performed can be set by the operator. Using the "Trace size" you can set the level towards which the AGC process will adjust the trace amplitudes. You can also set the length of the window within which the size is equalized.

The AGC function operates like this:

- For each trace, a window is set up with a length determined by the entered value. If 000 is entered 15 % of the trace length is used instead. The window is first positioned at the beginning of the trace.
- Then the mean amplitude within the window is calculated and a scaling factor is found to bring the mean to the set trace size value. This scaling factor is used to adjust the data point in the center of the window.
- Then the window is moved one sample ahead and the same procedure is repeated once more. When the window has reached the end of the trace the next trace is processed and so on.

As you may understand this display mode involves quite a lot of calculations and that is why you have to wait a while longer for this display to appear on the screen.

Mode 5 (AGC, muted) is a variation on the AGC mode where the data up to the first arrivals time marks (set by the time pick routines or manually) are muted (reduced in size). This mode is used whenever you do not want to enhance noise signals that are present before the actual seismic signal arrives.

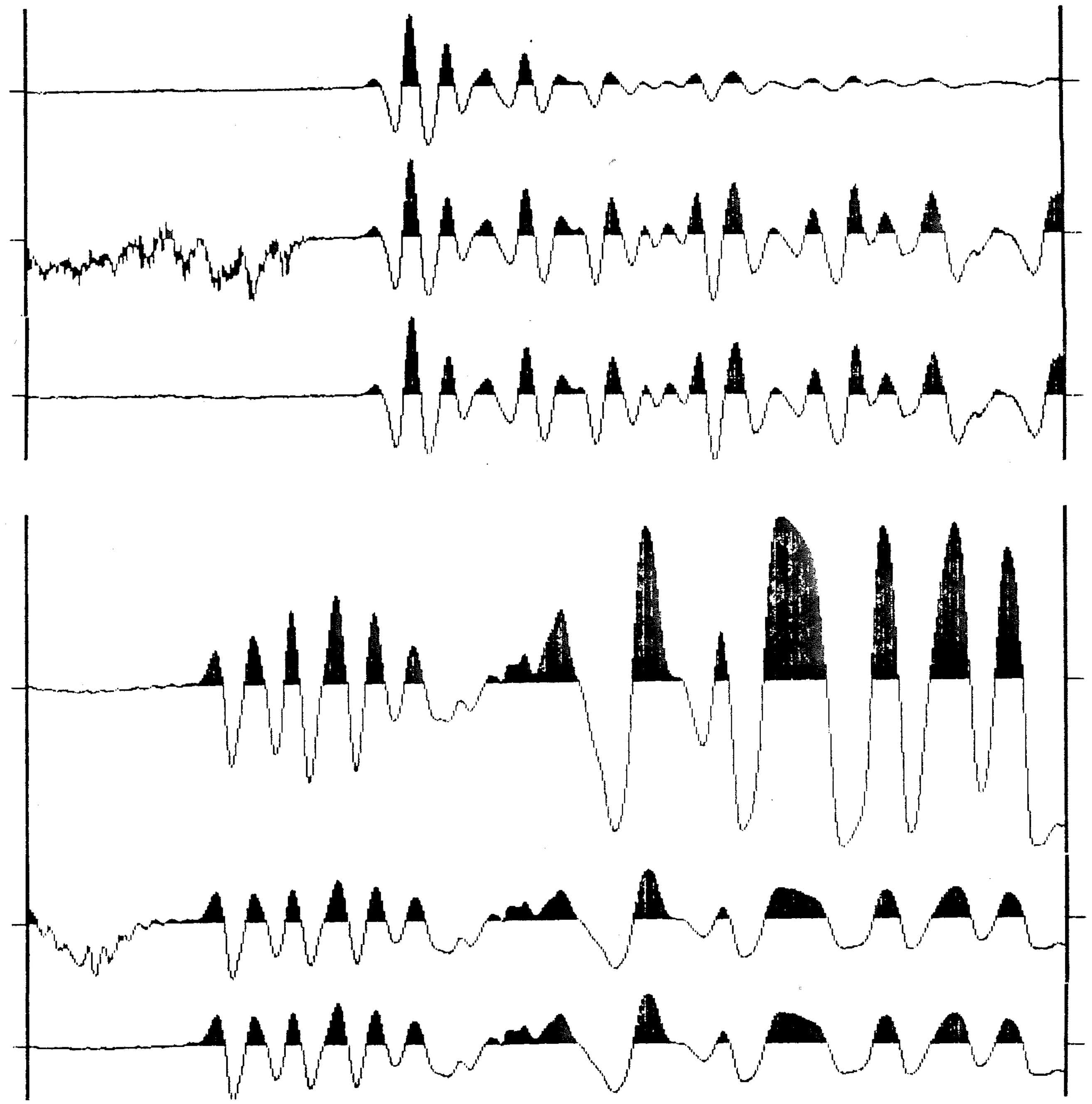
The effect of the two AGC modes are best visualized on real data, see Fig. 3.6.1-2. In this figure the same data that were used in Fig. 3.6.1-1 are now used again. The top two traces show unprocessed signals shown in the average mode.

In the middle trace pair the AGC function has been used (window 80 ms, size 20%). As you can see the signals are more uniform in size along the trace. In the top trace faint signals in the later portions have been amplified as has the noise preceding the first arrival.

In the lower trace the high amplitude signals in the later part has been reduced in size whereas the pre-arrival noise is amplified here as well.

The noise prior to the first arrival pulse can be removed from the printout and display by the use of the "AGC mute" display mode. This requires that first arrival markers have been set for these traces. All data prior to the marker positions will be reduced in size (muted) as shown in the lower part of Fig. 3.6.1-2.

Fig. 3.6.1-2 The AGC effect on two traces of seismic data. From top to bottom: Average, AGC and AGC muted.



3.6.2 TRACE TYPE SELECTION

With the trace type parameter the operator can select four types of trace display modes:

0 Wiggle trace
1 Variable area -
2 Variable area +
3 Dotted trace

3.6.2.1 WIGGLE TRACE

When wiggle trace is selected the waveforms will be displayed and printed as continuous traces. This is used for ordinary engineering refraction seismograms. The different traces can be followed across the screen even though they cross each other in several places.

3.6.2.2 VARIABLE AREA + or -

When variable area is selected the traces will be displayed and printed with the positive or negative parts of the waveforms filled in from the zero voltage line to the actual signal value. This is mainly used for reflection seismograms where time correlated reflection boundaries on neighbouring channels need to be visually enhanced. If traces cross each other in the filled in parts they will merge and cannot be separated on the display or printout. The natural display mode to select with variable area is normalize or AGC (see section 3.6.1.1).

Variable area can also aid the interpreter in finding where the p wave arrival is located. This is accomplished by visual correlation of neighbouring traces where arrivals may be seen more clearly.

3.6.2.3 DOTTED TRACE

When dotted trace is selected the traces will be displayed and printed as a series of sample points. This will give the effect of clearly showing the slowly varying signals up until the first break when they more or less disappear. The dotted trace is mainly used when there are a lot of crossing traces that hide the actual first breaks.

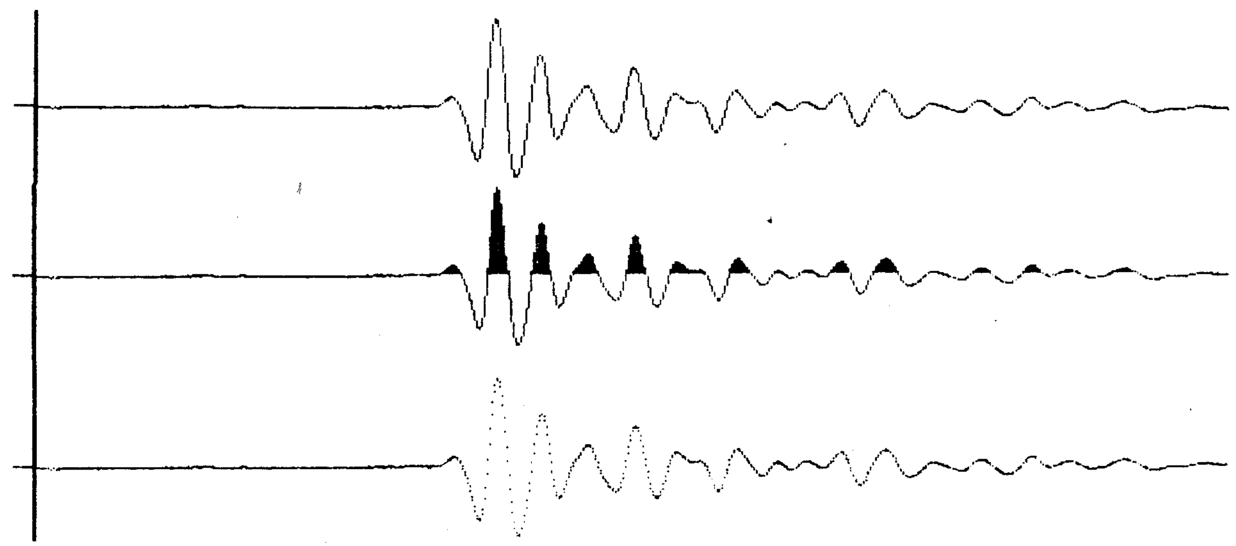


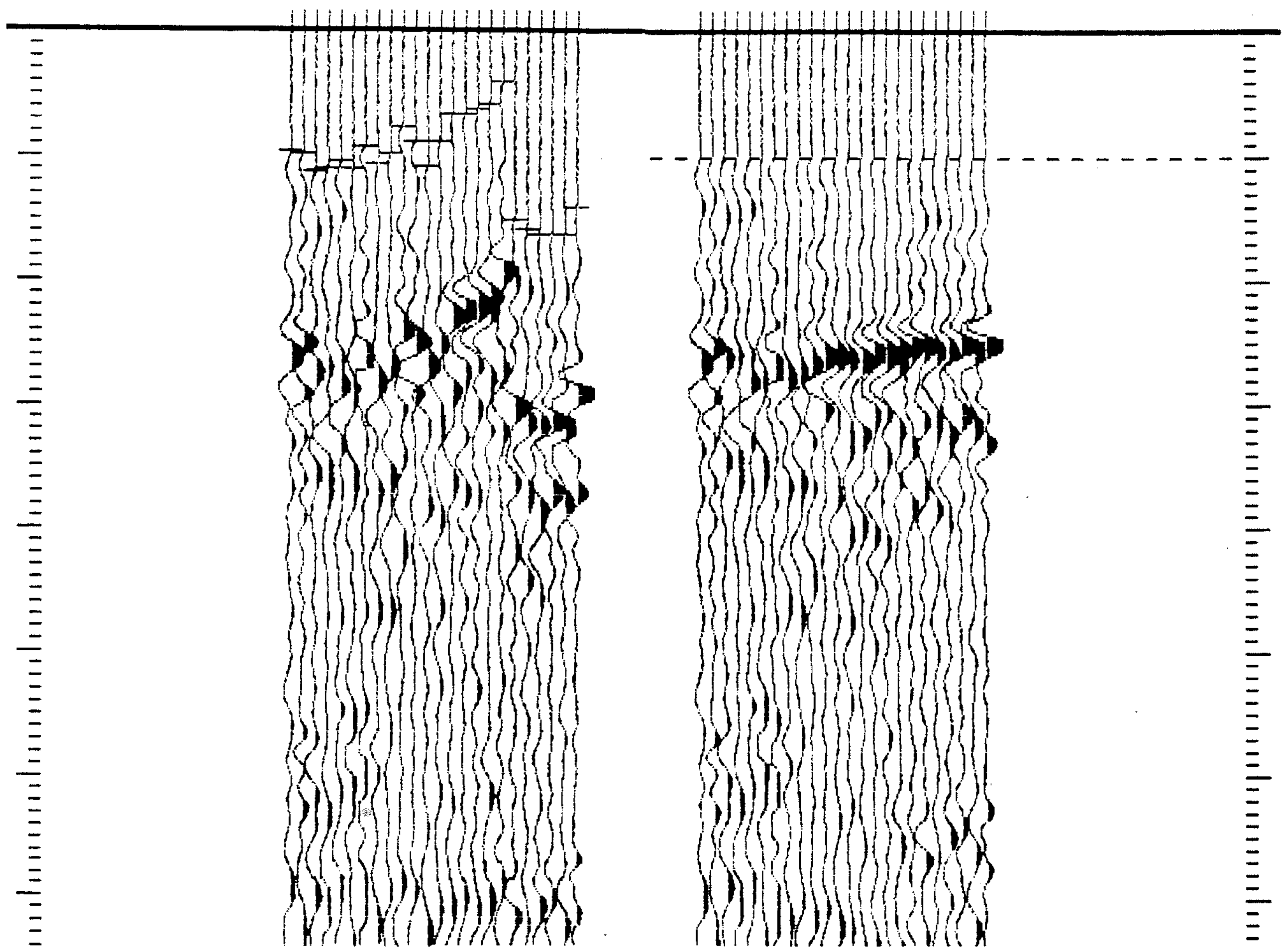
Fig. 3.6.2-1 The available trace types: wiggle, variable area and dotted trace.

3.6.3 TIME SHIFTING THE TRACES

In some cases there is a need for time shifting of the traces, for example in the application of static corrections to reflection records or when signal waveforms from different geophones are to be compared visually.
When this need arises the TERRALOC is ready to serve in the following way:

- Set time markers at the points in the traces that you want to have displayed at the same time position. (See 3.6.5)
- Enter the position to which these points shall be shifted in the "Time shift" field. The value shall be expressed as a sample number ranging from 001 to 999. If 000 is entered the time shift function is switched off.
- Press the TRACES key. The display will now show the traces time shifted so that all time marks are positioned at the selected sample number. This time is marked by a dashed line across the screen. See Fig. 3.6.3-1.

Fig. 3.6.3-1 Effect of time shifting common offset reflection data to remove static variations. Both displays show the same data with AGC processing and compressed trace display. To the left no time shift is used, to the right time shift has been applied to shift the refracted first arrivals to the same time.



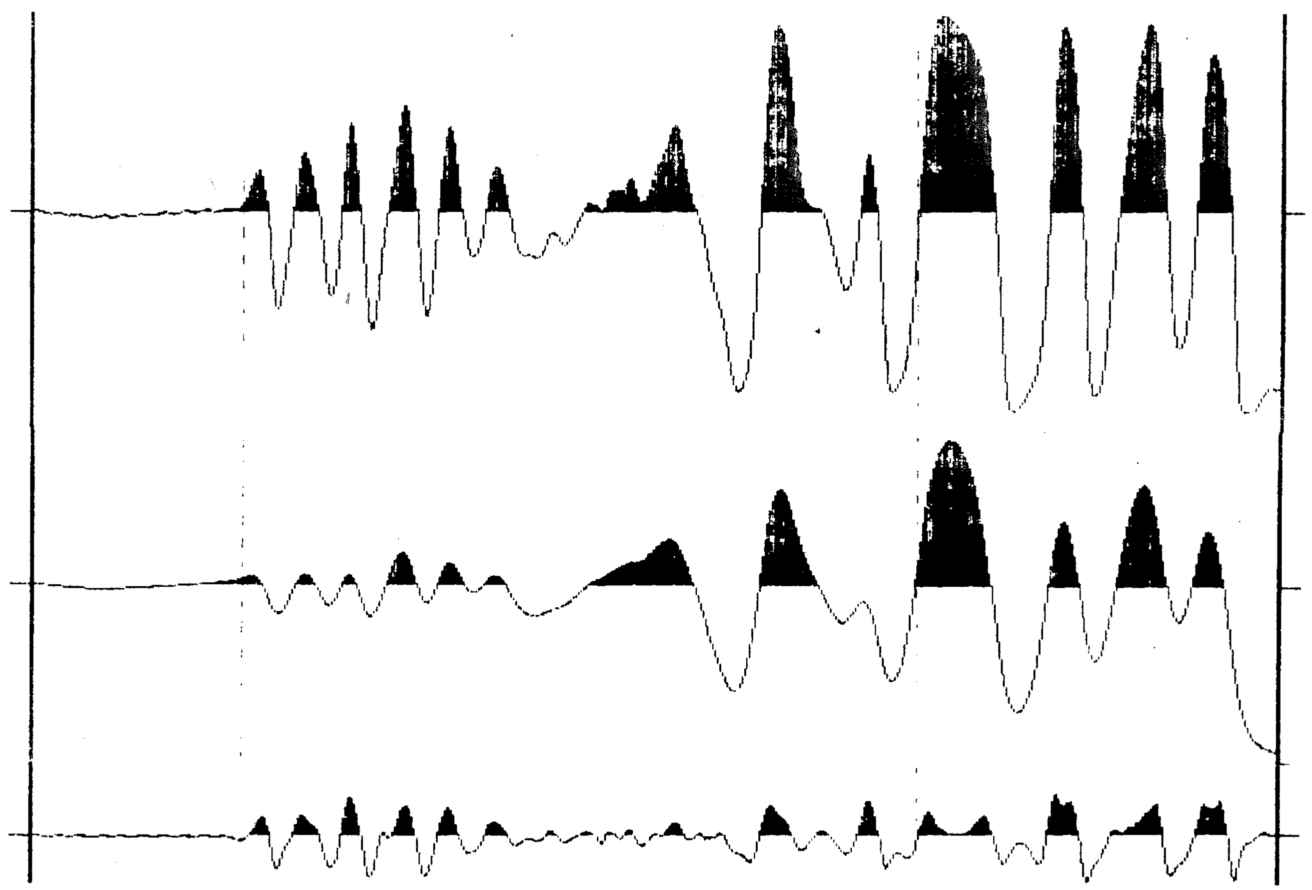
3.6.4 DIGITAL FILTER OPERATION

The TERRALOC seismic system enables the user to filter waveforms after they have been recorded. This is accomplished using the DIGITAL FILTER function which computes the response of a 2-pole recursive filter using the sampled signal values as input. It is thus possible to filter the recorded waveforms with different filter settings to arrive at the setting that gives the best results. The filter functions are devised in such a way that they minimize the introduction of phase and time delay errors. Arrival times can be picked from the filtered waveforms.

The digital filter will not change the data in the stack memory but will calculate signal values for display or printout only. Original measured signal data are always safe in memory. When the RECORD key is pressed only the original measured data are saved on disk but not the filtered signals. In this way you cannot accidentally lose information from your permanent records.

The filter process will affect the signal in a way that you never see in a real physical filter: when there is a transient signal such as the onset of a pulse after a period of total silence the filter will produce a pre arrival pulse of opposite polarity. This pulse is about 1/2 period of the real signal and of much lower size. It can however be confused for the real first arrival pulse of a refraction seismogram. See Fig. 3.6.4-1.

Fig 3.6.4-1 Effect of digital filtering of an arrival pulse and of a continuous wave. Top is unfiltered, middle is high cut filtered and bottom is low cut filtered data.



3.6.4.1 SELECTING FILTER FREQUENCIES

The filter frequencies are selected by entering code numbers in MENU 3. You can select 99 high-cut and 99 low-cut filter frequencies. The actual frequency of the filter depends on the sample rate used, and the TERRALOC computer calculates the resulting frequency which is then displayed adjacent to the entered code number.
The range of frequencies that can be selected is from 0.1 to 9.9 % of the sample rate set on menu 1. The filter frequency is selected by entering a number between 01 and 99 in the appropriate fields.
Entering 00 will disconnect the filter.
The sample rate depends on the record time and is equal to 1,000,000 divided by the record time in milliseconds. A record time of 200 ms means a sample rate of 5000 samples per second.

3.6.4.2 DISPLAYING FILTERED WAVEFORMS

To display the filtered version of the recorded waveforms you merely press the TRACES key after setting the desired filter frequencies. The screen will now display the normal non-filtered version of the traces. A message on the bottom line will tell you that filtering is being done. The TERRALOC computer calculates the filtered version. When ready a beep will sound and a new message telling that all is done will appear on the bottom line. To view the filtered traces you need only operate the ENT or TRACE key once and the unfiltered traces will be replaced with the filtered ones.

Once filtered the data remain in the display buffers so that you can move between the trace display and the different menues with no extra calculation delay. You can also print the filtered record instantly. If a parameter that affects the size of the traces is changed a new calculation will be done when the TRACES key is operated. This is accompanied by the beeps and messages mentioned above.

To calculate the filtered waveforms, the TERRALOC computer will require a certain amount of time. This is proportional to the number of displayed traces and also to the number of filters selected. A low-cut filter on 12 traces will take about 10 seconds of computing time.

3.6.5 TIME MARKERS

Time markers can be set one for each trace and are used in various ways as described above. Marker positions are controlled with the following commands activated by the ENT key.

3.6.5.1 LIST TIME MARKERS

When this function is activated all marker times will be listed on the screen. See Fig. 3.6.5-1.
This display will also contain the field notes from menu 1 as well as record number and time of measurement.
If copied to the printer this can be used as documentation of the arrival time picking.

```
Listing of markers:        Record-000227  Date-860702  Time-10:29

  Trace No    Marker time (ms)             Field notes

        01     238.5                       Record time:  500 ms
        02     237.0
        03     233.5                       Delay time:  0000 ms
        04     230.0
        05     226.5                       Shot pos.:    000430
        06     220.5
        07     214.0                       Layout start: 000406
        08     206.0
        09     199.0                       Layout end:   000429
        10     188.0
        11     177.5                       Profile No.:  000706
        12     166.0
        13     156.5                       Note:
        14     144.5
        15     134.5                       Operator:     00625
        16     123.5
        17     116.0
        18     107.5
        19      96.5
        20      75.5
        21      51.5
        22      40.0
        23      29.0
        24      16.5

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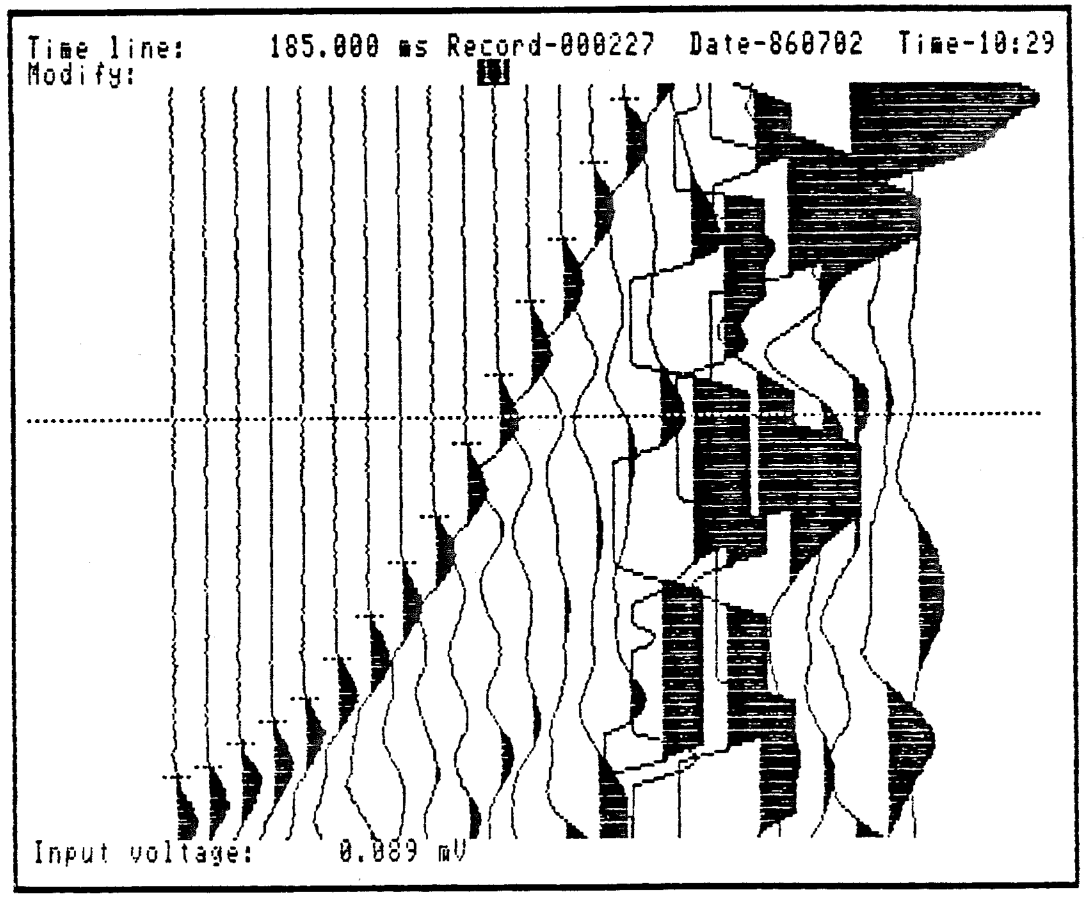
Fig. 3.6.5-1 Screen display of marker times and field notes.

3.6.5.2 INSPECT AND ADJUST TIME MARKERS

With this function time markers may be viewed as short dashed lines on the traces themselves to determine their locations.
A somewhat modified trace display will be seen on the screen, see Fig 3.6.5-2. On the second line from the top a trace identifier is seen in inverse video. It can be moved with the help of the RIGHT and LEFT arrows. The identifier will display the trace number selected for modification of the time marker position.
To change the position of a time marker you have to first select a trace with the arrow keys. Then the time line is positioned at the correct time with the + or - keys. When the "F" key is pressed the time mark for the selected trace will jump to the position of the time line. In this way the time marks may be set at the correct points for all traces.

Fig 3.6.5-2 Trace display in the "Inspect and adjust" mode.Time markers are visible as short dashed lines and trace selection is displayed above the traces. The measured signal voltage is displayed on the bottom line.



3.6.5.3 PRINT WITH TIME MARKERS

If a printout of the record is made while the time mark list is displayed or the inspect and adjust function is selected then the printed seismogram will also contain the time marks. In all other cases activation of the PRINT key will cause a normal record to be printed.

3.6.5.4 AUTOMATIC ARRIVAL TIME PICKING

This function on menu 3 will start a process that automatically positions the time marks on all traces at the first arrival pulse.

The process normally operates on unfiltered data in the stack memory, but can be forced to use filtered data. This is accomplished by starting the function with the "F" key instead of with ENT. Note however that the digital filter may produce a first arrival ghost pulse in front of the real pulse. This can cause the automatic arrival pick routine to pick early on this ghost. See section 3.6.4.

The picking algorithm is designed such that it will reject short noise bursts and also pulses that do not emerge above a noise floor determined in the first part of the seismogram. The automatic routine will pick accurately whenever the signal-to-noise ratio is good. In cases where a mispick occurs it can easily be adjusted by the "Inspect and adjust" function (3.6.5.2). This function is automatically called when the picking process is finished.

The noise rejection method used will discard short pulses as noise and pick on pulses with a predetermined minimum length. If the recorded arrivals are short in duration, for example because of a long recording time then they may be completely lost by the picking routine. In such a case the noise discrimination length can be adjusted in the following way:

- To make the routine more sensitive to short pulses it may be started by pressing any number between 1 and 4 instead of the ENT key. A lower number indicates shorter pulses.

- To make the routine less sensitive to short pulses you start by pressing a number in the range 6 to 9.

Pressing 5 starts the pick exactly as ENT would.

3.6.6 SIGNAL VOLTAGE MEASUREMENT

When the traces are displayed in the "Inspect and adjust" mode (3.6.5.2) it is possible to measure the actual signal input voltage of any point on a trace.
All you have to do is select the point of interest with the time line and the trace selector. If you then operate the "." key the signal voltage at the timeline position of the selected trace will be calculated and displayed on the bottom line, see fig 3.6.5-2.
In this calculation the present gain setting for the channel corresponding to the trace (taken from menus 1 and 2) and the number of stacks made is taken into consideration. The voltage on the input connector is calculated and displayed to a resolution of 1 microvolt and an accuracy of 3 %.
This function is valuable in vibration analysis as well as when reflection coefficients are evaluated.

3.6.7 INVOKING MENU 5

By positioning the cursor at "Menu 5:" and then operating the ENT key menu 5 will be displayed. In this menu you have access to a number of system hardware check routines which will be described in section 3.7.

3.7 SYSTEM HARDWARE CONTROL. MENU 5

This menu is reached via a command on menu 3, see section 3.6.6, and is not part of the normal menu sequence controlled by the MEN key.

Here the user is able to monitor the power supply voltages. The digital interface parameters are also set on this menu. This means that here is no need to open the instrument case just to change baud rate or IEEE address. See Fig. 3.7-1.
You can also select the type of printer to use with the Terraloc for printouts and select display and print parameters such as the width and length of printouts.

The different functions are described below.

```
Menu 5: System hardware   Record-100000  Date-870128  Time-11:47
  System voltages:
  Voltage No:   1      2      3      4      5      6      7
  ------------------------------------------------------------
  Value:      +12.8  +12.0  +7.9   +5.0   -5.2  -12.6  -11.4
  Battery voltage: 12.1  V

Digital communication:              Printer:
Select interface:      0 RS-232C    Select:          1 Office, 80 col.
IEEE-488 Address:      07           Trace separation: 1 Normal
RS-232C Baudrate:      8  9600      Print length:     0 Short
        Stop bits:     1            Timing lines:     1 On
        Word length:   7
        Parity:        0 None

Power-up menu:

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Fig. 3.7-1 Menu 5 with system voltages, printer and interface setup.

3.7.1 SYSTEM VOLTAGES

In menu 5 eight of the system voltages are displayed to ease trouble-shooting whenever some failure occurs. The voltages are numbered 1 through 7 on one line. The battery voltage appears on a separate line.
The different voltages are as follows

No.	Designation	Nominal	Tolerance (+/-)
1	CRT monitor supply voltage	+13.0 V	0.6 V
2	Pos. supply for the amplifiers	+12.0 V	1.2 V
3	A/D reference voltage	+ 8.5 V	0.2 V
4	Computer supply voltage	+ 5.1 V	0.2 V
5	Neg. supply for video & trigger	- 5.0 V	0.5 V
6	Neg. supply for the computer	-12.0 V	0.6 V
7	Neg. supply for the amplifiers	-12.0 V	1.2 V

The battery voltage, nominal value +12V, may vary considerably according to charge status. The TERRALOC will operate correctly if this voltage is between 10 and 20 Volts. Note that this value includes any ripple voltage present so it cannot be determined with a voltmeter, an oscilloscope is required.

Note also that the built-in voltage measurements are made with limited accuracy. On the positive voltages the voltage resolution is 0.1V but accuracy is only 2 % of the reading. For negative voltages the resolution is 0.2V with the same accuracy. Accurate values can only be obtained from direct measurements made on the test pins on the Power Supply board, see the service section.

3.7.2 DIGITAL COMMUNICATION SETUP

There are six items on menu 5 that will control the digital communications parameters. The TERRALOC can communicate with an external computer via one of two interfaces, the RS-232-C (serial) or the IEEE-488 (parallel). The last one may also be called HPIB, GPIB, the instrument bus or some other name. It is a byte parallel interface with a handshaking protocol defined in the standard.

3.7.2.1 SELECTION OF WHICH DIGITAL INTERFACE TO USE

By setting the "Select interface" parameter to 0 or 1 the user can select either the serial or parallel interface to be used for communications. The type selected will be displayed to the right of the data field at all times.

3.7.2.2 IEEE-488 ADDRESS

The parallel interface uses an address transmitted on the bus as a selection signal. Whenever a computer wishes to read data from or send data to the TERRALOC it has to "wake" the interface up by sending the right address as part of the handshaking procedure. The address is a number in the range 00 to 30 and can be set on menu 5 in the field labelled "IEEE-488 Address".

3.7.2.3 SERIAL INTERFACE BAUDRATE

The RS-232-C interface can operate at a number of different standard speeds. In the data field "Baudrate" in menu 5 this speed can be set by entering code numbers 0 to 9. The resulting baudrate is immediately displayed to the right of the code number field. The permissible range of baudrates is 75-19200.

When the highest speeds are used the handshake lines (DTR and CTS) of the interface must be used. If not, there is a risk of data loss during transmission.

3.7.2.4 SERIAL INTERFACE STOP BITS

The RS-232-C interface will transmit and receive data one character (byte) at a time. After a start bit the least significant bit of the data word will be output and then bit by bit ending with the most significant bit. Then a stop code of value = 0 is output for a duration set by the "Stop bits" parameter. This code separates characters in the transmitted data. The number of stop bits can be set at either 1 or 2.

3.7.2.5 SERIAL INTERFACE WORD LENGTH

The transmission code used by the Terraloc is ASCII which means that the most significant bit of each character is not defined by the standard. The transmission of this bit is thus optional and can be controlled by the parameter "Word length" in menu 5. Allowed lengths are 7 and 8 bits.

With the SEG-1 protocol you may double the speed of transmission by using the binary mode of data transfer (see 4.2.7). In this case the word length <u>must</u> be set to 8 bits.

3.7.2.6 SERIAL INTERFACE PARITY

Error checking can be performed in serial transmissions using a check bit called the parity bit. If used this bit will be set depending on the number of set bits in the transmitted character code. There are four possible versions of this check used by the TERRALOC and controlled via the "Parity" parameter in menu 5:

Code	Selected parity
0	No parity bit
1	Odd parity, the data will contain an odd number of ones
2	Even parity, the data will contain an even number of ones
3	Mark parity, the parity bit is always set to one

To the right of the code number the TERRALOC computer will always display the selection made.

3.7.3 PRINTER SELECTIONS

The TERRALOC Mark 3 model incorporates the possibility to use standard matrix printers in addition to the TERRALOC Field Printer.The matrix printers can of course only be used in office environments and near a mains power outlet. A matrix printer will also be much slower in producing a printout than the TERRALOC printer. It is nevertheless valuable to have this option for example if it is required that records are printed on ordinary paper or if the TERRALOC printer is out of order.

The printer selection is made on menu 5 (reached from menu 3):

Code	Printer type
0	TERRALOC field printer
1	80 column matrix printer, EPSON compatible with 960 dots high density graphics capability. Used with 8" paper.
2	132 column matrix printer, EPSON compatible with 480 dots graphics capability. Used with 12" paper.
3	80 column matrix printer, IBM compatible with 640 dots graphics capability. Used with 8" paper.

The difference between the printers lie in the way the graphics is printed. The header text of a printout is always printed using standard ASCII characters whereas the graphics is printed using a so called "escape sequence". Graphics is used for all COPY operations and for the traces part of a PRINT operation.
In the following section you will find a detailed description of the graphics commands and the hardware interface.
The following matrix printers have been checked to operate with good results:

Code	Printer manufacturer	Type
1,2	Commodore	MPS 1000
1,2	C.T.I Shinwa	CP 80
1,2,3	EPSON	FX 100
1,2,3	FAM International	FAX 180
1,2	OKI	Microline 192
1,2,3	WANG	PC-PM016

Many more printers are possible to use, please check the one you have available by copying the menu 5 screen with different settings of the select code. The copy function uses graphic printing so if a screen copy works then the printer is possible to use with this setting.

3.7.4 PRINTER AND DISPLAY FORMAT SELECTIONS

On menu 5 you can control the display and print format in the following ways:

- Trace separation on the screen and printer can be set to either normal or narrow.

  Normal separation uses the whole width of the screen and printer. Narrow separation uses half of the width.

- Print length can be selected between normal and short.

  A normal print will contain 1000 samples on a print length of approximately 350 mm (varies with the printer in use).
  A short print contains every other sample point (500) which makes the print length shorter.

- Timing lines on the printout can be turned on and off.

  When they are turned off there will only be a timing scale along the edges of the printout.
  When the timing lines are on 200 dotted timing lines will be printed across the record in the normal mode and 100 in the short mode.

To set the different formats you just enter a code number 0 or 1 in the appropriate control fields on menu 5. You will get immediate feedback on the screen of your present setting.

3.7.5 RETURN TO MENU 0

If for some reason you want to access menu 0 without switching off the power this is possible in menu 5 by keying ENT when the cursor is positioned at the "Power-up menu" data field. This function may be used to set the clock or change the record number without destroying the data within the TERRALOC stack memory.

3.8 DATA STORAGE CONTROL. MENU 4

This section describes the operation of the built-in disk drives used for storage of the measured data.

There are four drives in a TERRALOC, two of these are micro floppy disk drives using 3.5" micro diskettes and the remaining two are solid state RAM disks.
All of these drives can store 720 kilobytes (737280 bytes) per disk. This is sufficient to store 14 full 24 channel measurements each using 24 traces.

The disks are formatted according to MS-DOS standards so they can be read on ordinary PC computers equipped with 3.5" disk drives and the MS-DOS operating system (version 3.2 or higher is recommended).

Each record (file) on disk contains the following information:

Record number
Recording date and time
All user-entered parameters of MENU 1
The trace/channel assignments made in MENU 1
The amplifier gain settings
Analog filter setting
First arrival values (if picked)
Waveform data from the signal stack

When the disks are played back on the TERRALOC the instrument will be set to the same status on menus 1 and 2 as it were when the recording was made.

During disk operations the CRT screen will be shut off in order to protect the drive from electromagnetic noise generated by the deflection coils of the monitor. The video output signal will not be shut off in this way.

The following functions are available on menu 4:

* Directory — (Start with the ENT key)
  List the contents of the selected disk drive on the screen. If more than 21 files are present the listing will pause when one complete page is filled.

* Next page — (Start with the ENT key)
  Displays the next directory page on long directory lists. When the last page is displayed the next operation of "Next page" will display the first page.
  Can also be used to redisplay a directory list that has already been read off a disk but was cleared from the screen when traces were displayed.

* Drive select — (Enter number 1, 2, 3 or 4)
  With this function the active drive is selected among the four available drives. 1 and 2 are micro floppy disk drives, 3 and 4 are the TERRALOC RAM disk drives. All operations on menu 4 as well as the recording function use the selected drive.
  The drives are numbered 1-4 from left to right.

```
Menu 4: Recording           Record-000002  Date-870529  Time-11:47
  Directory:        Drive select: 1     Get record No    :
  Next page:        Copy disk to:       Remove record No:
                    Autoprint    :      Format:
   Record  Date   Time  Shot   Start  End    Prof.  Note
--------------------------------------------------------------------
   015047 850523 11:19 100    140    1060   2301   123902 -4489
   000225 860702 10:01 000419 000420 000443 000706 123-259+2563
 ■ 000226 860702 10:07 000444 000420 000443 000706 125-114+2879
   000227 860702 10:29 000453 000429 000452 000706 125-224+2964
   200014 850103 16:32 40-90  77     100    Ultuna CDP 6-fold
   122013 851003 14:45 0FF-24 125.0  194.0  100001 100F
   000345 870517 21:56 100    115    138    2038   F001.2038-1
       **** End of diskette, free space: 097K





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Fig. 3.8-1 MENU 4 Recording

* Copy disk to — (Start with the number of the receiving disk drive followed by ENT)
  Copies the contents of the selected disk to the disk drive given in the command. The receiving disk must be formatted to 713 kb capacity and empty. (See 3.8.7.)
  This function is often used to copy RAM disks to ordinary micro floppy disks.

* Auto print — (Start with the ENT key)
  Will automatically read all records from the selected disk into Terraloc memory one after the other. Each record is processed according to the setup on menu 3 and then printed on the hardcopy printer (Terraloc field printer or standard dot matrix printer).

* Get record No — (Start by entering the 6-digit record number and then press ENT)
  Will load the record into Terraloc memory. The previous memory contents will be lost as if using the clear function.

* Remove record No — (Start by entering the 6-digit record number and then press ENT)
  Will erase the record from the selected drive. Records that you don't need anymore can be removed to create space for new recordings on the disk.

* Format — (Start with the key sequence: . ENT)
  Formats the selected disk drive to 713 kbytes data capacity according to MS-DOS standards. All data present on the disk will be erased.

3.8.1 DIRECTORY

This command provides a list of all recordings stored on the selected disk.

DIRECTORY is started in menu 4 by positioning the cursor in the DIRECTORY field and then pressing the ENT key. A list of all TERRALOC records on the disk will be displayed on the screen with one record per line. Each line will contain the following information:

Record number
Date and time of recording
Shot position
Layout start
Layout end
Profile number
Note

If there are more records than can fit on one screen the listing will pause when the first screen is filled. To view the following records you have only to use the NEXT PAGE function by pressing ENT in that field. Then the next page full of records will appear. The last record is followed by a line telling you that there are no more records on the disk and also how much remaining data space there is. See Fig. 3.8-1.

3.8.2 SELECTING A DISK DRIVE

The TERRALOC has four disk drives, two 3.5" micro floppy drives and two RAM disk drives. Only one of these is active at any time, the active one is selected on menu 4. To select a drive you simply enter its number in the "Drive select" field. The drives are numbered from 1 to 4 from left to right.

3.8.3 COPYING DISKS

In menu 4 there is a diskcopy function primarily used for transfer of the contents of a RAM disk to an ordinary 3.5" micro floppy disk.
The function is also useful if you want to make an extra copy of a whole disk of data. It can actually copy any data on a 3.5" disk, not only TERRALOC files.

There must be two disks loaded into the Terraloc to make a diskcopy. Any combination of RAM disks and ordinary micro disks is allowed.

The source disk, which contains the data to be copied, must be in the selected drive. (See 3.8.2). We strongly recommend that you write protect your source disk to eliminate the possibility of erasing the data.

The target disk can be loaded in any of the remaining three drives and must be formatted to full capacity and empty. If it contains data or if the formatting function has discovered defects the disk cannot be used in the copy function.

When you have prepared the two disks you move the cursor to the "Copy disk to" field. Here you enter the drive number of the target disk. Then you press the ENT key.

The copy procedure will now start (you will see the screen go blank). It will last for about 2 minutes and then the screen will light up again. You can now remove your copy and write protect it with the small tab in one corner of the disk.

3.8.4 AUTOMATIC PRINTING FROM DISK

Complete printout of all records on a disk on the hardcopy printer can be carried out automatically by means of the AUTOPRINT function.

This is started by positioning the cursor in the AUTOPRINT field and pressing the ENT key. The TERRALOC computer will play back the first record into the instrument and then print that record on the printer with the proper heading etc. as explained in section 5.3.3. Then the following records will be treated in the same way until all records on the disk have been printed out.

3.8.5 PLAYING BACK DATA FROM DISK

The TERRALOC Mark 3 disks can be played back into memory restoring the seismograph settings and the stack memory contents from the field.

There are two ways to play back a record:

1 - Enter the record number into the field on menu 4 labeled "Get record No." and then press the ENT key. The disk in the selected drive will be searched for this record and if found it is read from disk to memory.

2 - Display the current disk directory by pressing the ENT key with the cursor located in the "Directory" field. This will produce a list of all records on the disk.
Now, move the cursor down to the line in the directory where the record is displayed. Then press the ENT key.
This record will now be read into the TERRALOC memory.

The read operation takes about 10 seconds for a 24 channel record and the screen will go blank during this time. When the reading operation is completed the screen lights up on showing the traces of the selected record.

NOTE: When a playback operation is made all previous settings of menus 1 and 2 and all signal data present in the TERRALOC will be lost since they are replaced with the data read from disk! Therefore make sure that the data in memory is already stored on disk before you play anything else back.

3.8.6 ERASING A RECORD FROM A DISK

In contrast to a tape based data storage system such as in TERRALOC Mk I and Mk II the disk storage system used in the Mark 3 model allows erasure of single records on a disk containing several other records.
This makes it possible to create space for new data on a disk that contains records that can be scrapped but also records that must be kept.

To erase a record you have to insert the disk with the record in the selected disk drive. Make sure that the disk is not write protected.
Then you move the cursor to the "Erase record No" field on menu 4. There you enter the 6-figure record number followed by the ENT key.

The record will now be searched for on the selected drive and removed if found.

Make a directory to check that it has disappeared and that the corresponding storage space is added to the free space of the disk.

3.8.7 FORMATTING A NEW DISK

TERRALOC recordings can only be made on formatted disks.
A new disk must therefore be formatted before it can be used.

To format a disk in the selected drive you just move the cursor to the "Format" field. Then you press the . key followed by ENT.
This will cause the TERRALOC computer to format the disk to MS-DOS standards with 713 kb capacity for data.
The disk will be completely erased with no trace of old data left on it.
Format will take about one minute to complete.
If defects on the disk are found during formatting, the disk areas with these defects are locked out and the remaining capacity is therefore lower. Still the disk can be used to store data but not in the "copy disk to" function (3.8.3).

3.8.8 RECORDING DATA ON DISK

When a recording of the stored data is to be made, you simply press the RECORD key. The TERRALOC computer will then start the recording process. This will last for up to 10 seconds, depending on the number of traces that are to be recorded. Only those traces which have received data will be recorded on disk.

If the data have already been recorded on the selected disk an error message will appear at the bottom line of the screen. Likewise if the remaining free space on the disk is too short to fit the data.

3.8.9 DISK TYPES TO USE

Only high quality 3.5" micro disks can be used with the TERRALOC to store data. The disks are of the double sided type with an unformatted capacity of 1 megabyte.

The following makes have been found to work well (at the time of writing). Since the development in this area is quite rapid many others may also work even though they are not listed here.

Manufacturer	Type
Dysan	807 822
3M	MIKRO-D
Verbatim	MD 355-01
MAXELL	MF1-DD
MEMOREX	3203-3460

Please note that a disk must be formatted before use. The format procedure is described in section 3.8.7.

Note also that floppy disk storage cannot be relied upon in extreme weather conditions such as low temperatures. In such cases the TERRALOC RAM disk should be used.

3.8.10 LOADING AND REMOVING A DISK

The four disk drives are located behind the sealed door in the upper right corner of the TERRALOC front panel. You have to open the door to be able to load and remove disks. This should only be done in fairly well conditioned surroundings since the drives and disks are rather delicate and cannot tolerate dust or water. A micro disk is inserted into the drive slot with the disk label facing right. Push the disk all the way in until it is latched in the drive.
To remove a micro disk you just push the eject button on the lower part of the drive. This will unlock the disk which is then pushed out of the drive.

The Terraloc RAM disk cartridges fit in the two slots to the right of the disk drives. The RAM disk is pushed in with the text label positioned such that it can be read normally.
If you have not already done so you first have to remove the cover plates from the RAM disk slots. It is easily done with a small screwdriver.

3.8.11 TERRALOC DISK FORMAT

The 3.5" micro floppy disks used by TERRALOC are formatted according to MS-DOS standard for such disks giving a total capacity of 720 kilobytes.
The disk space is divided into 80 tracks each containing 9 sectros on two sides. The sectors hold 512 bytes of data. Not all sectors are used for data; 14 sectors are reserved for the book-keeping on the disk itself. This leaves a total user accessible area for data storage of 713 kilobytes (730112 bytes).

The 14 non-data sectors are located on track zero and used as follows:

Side	Sector	Use
1	1	Reserved (BOOT sector on MS-DOS system disks)
1	2-4	FAT 1 (file allocation table, first copy)
1	5-7	FAT 2 (file allocation table, second copy)
1	8-9 and	Root directory, the directory where the index to
2	1-5	TERRALOC files is located. Max capacity 112 files.

3.8.12 TERRALOC FILE FORMAT

A data file written by TERRALOC on a disk has the following properties:

Directory location	Root directory.
Name	Rzzzzzz.ABM where zzzzzz is the six-figure record number.
Header section	4 sectors (2048 bytes) contain general info on instrument settings etc.
Data section	4 sectors (2048 bytes) per trace. The number of recorded traces can vary since only those traces which have recorded data will be written to disk.

Since the data section of a TERRALOC file varies in length with the number of used traces the disk capacity in terms of records can vary from 14 to 89 (24 channel versus single channel records).

The file header is written using ASCII characters and contains data according to the table in Fig. 3.8.12-1.

The data itself is an array of 1024 16 bit words per trace. Since the TERRALOC records 1000 samples per record the remaining 24 words are set to zero. The signal data are stored as a 16 bit 2:s complement integer word for each sample point. On disk the least significant byte of each word is stored first which makes the format compatible with the IBM-PC microprocessors 8088, 8086, 80286 etc.

Item No	Starting byte No	Description	Comment
1	1	Identification	"ABEM Terraloc"
2	16	Record No.	6 digits
3	24	Date	6 digits, format yymmdd
4	32	Time	5 characters, hh:mm
5	39	Shot position	6 characters
6	47	Layout start	6 characters
7	55	Layout end	6 characters
8	63	Profile No.	6 characters
9	71	Note	12 characters
10	85	Operator code	6 characters
11	93	Record time code	1 digit (0-7)
12	96	Delay time in ms	4 digits
13	102	Collection mode	1 digit code (0-3)
14	105	Noise gate value	2 digits
15	109	Filter code	1 digit (0-8)
16-29	112	Gain codes	24 values each 2 digits
30	208	Shots total	3 digits
31-54	213	Trace assignments	24 entries: channel No (01-24) polarity (+ or -) Stack on (1 or 0) Trace on (1 or 0)
55-78	381	Shots per trace	24 values each 3 digits
79-102	501	Arrival markers	24 values each 3 digits giving sample number of marker.
103	621	Active traces	2 digits (01-24) giving number of traces stored in file.
104	625	Reserved	Space up until 2048 bytes reserved for future use, filled with spaces.

Note: All items are followed by the <CR> <LF> end of line sequence.

Fig. 3.8.12-1 Record header block information

3.9 MAKING A MEASUREMENT

When the TERRALOC is set up as described in sections 3.2 and 3.3 it is ready to amplify and record seismic events. The instrument is put on standby (waiting for a trigger signal) by pressing the ARM key. This results in the display of submenu 2 (the signal monitor part of menu 2 with a "Ready for shot" message in the lower left-hand corner). The shot trigger circuits are now waiting for a trigger signal to occur. The TERRALOC will start the recording sequence when the trigger pulse is detected.

When the ARM key has been pressed no key entry is accepted by the system other than (ENT) in the preview mode and (SET) to get back to menu 1 (see below).

When the trig pulse is received it starts the delay timer which will run for the preset amount of time, as determined by the DELAY TIME parameter. At the same time the CRT screen will be shut off to reduce the internal electrical noise levels during recording.

After the delay time has elapsed, the sampling sequence is initiated during which 1000 samples of the seismic waveforms are taken, digitized and stored in the input buffer memory on each amplifier board. The interval between two samples is determined from the RECORD TIME parameter previously entered.

When all 1000 samples are stored in the input buffer the screen will light up again. The TERRALOC computer will either display the received waveforms on the CRT screen (in the PREVIEW mode) or add them to the signal stack and thereafter display the processed waveforms (in AUTOSTACK mode) or continue to display the signal levels (in FAST STACK mode).

Immediately after the received signals have been displayed on the screen, the TERRALOC is automatically enabled so that it can receive a new trigger signal. However, this is not done if the STACK ONCE mode is selected.

When the TERRALOC is in the PREVIEW mode, the operator is requested to approve the waveforms for entry into the signal stack. This is done by pressing the ENT key, whereupon the received signals are added to the stack and the new waveforms are displayed on the CRT.
If the operator does not press the ENT key before a new trigger is received, the displayed waveforms are lost and replaced with new data.

In the STACK ONCE mode of operation only one shot will be accepted for entry into the signal stack for each time the system is armed. This is useful when the trig source can be expected to produce a trigger waveform that will reverberate a long time causing multiple triggerings in the other modes.

Remote triggering of the TERRALOC is possible via the digital interface when the system is in the ARM mode. This is done by sending the ASCII character <BELL> to TERRALOC. The system will then self-trig and make one measurement. This function is mainly intended as a testing tool but can also be used in some monitoring applications. The remote trig time is not very accurate and can thus not be used for delay time determinations.

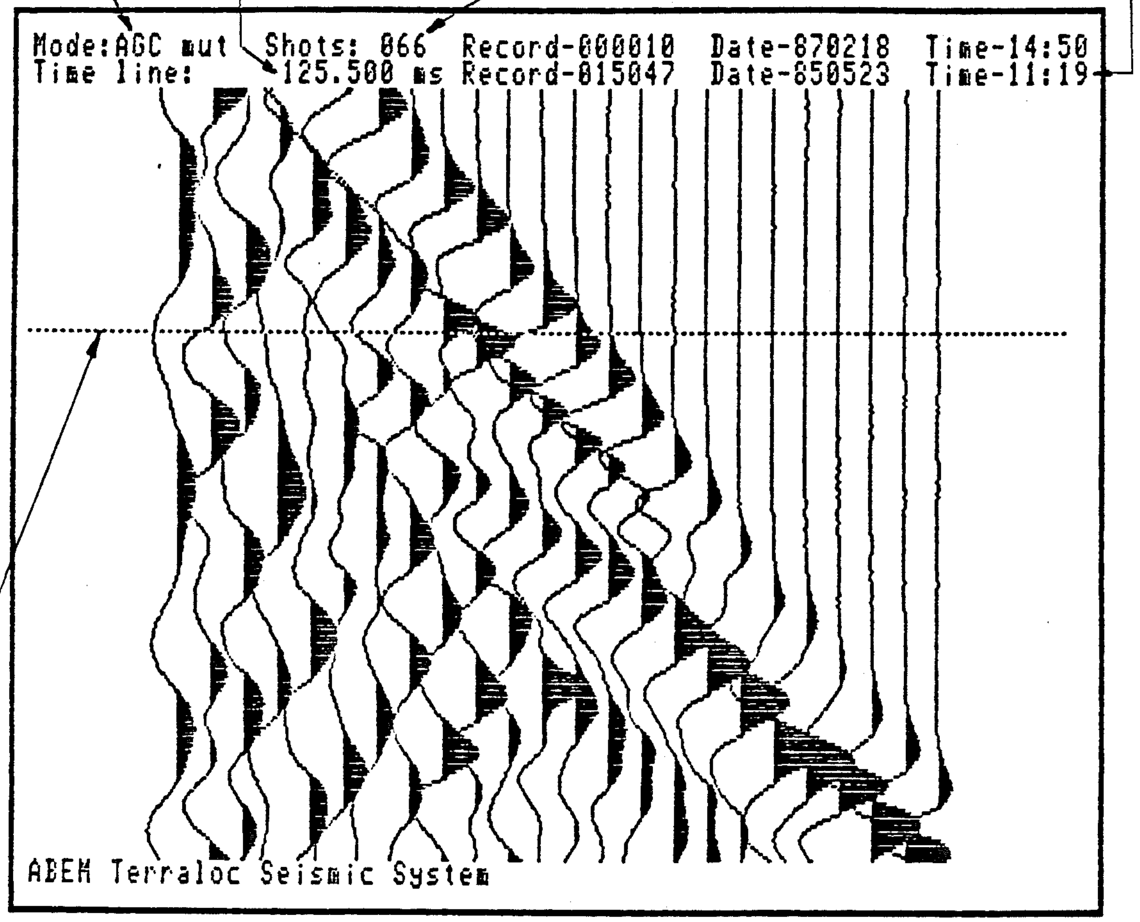
When all signals have been collected, you press the SET key to end the recording phase, and MENU 1 appears on the screen.

Display mode.

The position of the timeline expressed in milliseconds can be seen here.

Number of shots received.

Line 2 contains the record No. and time of recording for the record displayed on the screen.



The timeline can be moved up or down using the +/- keys. Its position can be read in milli-seconds at the top left part of the screen.

By pressing the ENT key the traces can be time enlarged by a factor of four. In the enlarged mode they can be scrolled up or down with the UP and DOWN keys. To bring back the entire record on the screen ENT is keyed once more.

Fig. 3.10-1 TRACES display. 24 traces and the timeline shown in the time expanded mode and with the variable area trace type.

3.10 DISPLAY OF MEASURED SIGNALS

You can watch the measured signals at any time by pressing the TRACES key. This will display the processed waveforms on the CRT screen as determined by the processing parameters set in MENU 3. The display will show the whole recorded time. A four times time enlargement is available if you press ENT.

3.10.1 TIME LINE, ARRIVAL TIME EVALUATION

When the display shows the recorded waveforms (as described above) you will be able to measure times by moving a time line with the aid of the + or - keys. The line will move up (-) or down (+) on the CRT screen as long as the key is kept pressed. + increases the delay after the trigger time.

The actual value of the time line position appears on the second line of the screen. This value is calculated by the TERRALOC computer taking into consideration the DELAY TIME and the RECORD TIME parameters. It is continuously updated as the time line is moved. It can be set at zero if you press the 0 key. This makes it easy to measure time differences with the help of the TERRALOC computer. The original total time from trigger is not lost but will be restored if the ENT key is pressed.

See also section 3.6.5 for more information on arrival time evaluations and positioning of timing markers on each trace.

3.10.1.1 TIME LINE TIME TRANSMISSION

The timeline time displayed on line 2 can be transmitted to a computer over the digital interface. To do so you just press the "F" key.

3.10.2 TIME EXPANSION DISPLAY

The display showing the waveforms for the whole recorded time period can be expanded by a factor of four to show finer detail. Pressing the ENT key changes the display to a time-expanded version on which all samples are shown, but only 1/4 of the total sampled time is displayed. This provides a magnification of 4. The displayed section will start about 50 samples before the time line position. See section 3.10.1
Pressing the ENT key once more will restore the original TRACES display which shows the entire record time period. The time line will remain in its set position within 4 samples when enlargement is switched on and off.

3.10.3 MOVING THE EXPANDED TIME WINDOW

When the display is expanded as explained in section 3.10.2, you can move the expanded window by using the UP or DOWN ARROW key. This will scroll the waveforms up or down on the CRT screen. As long as the ARROW key is pressed, the waveforms move at a constant speed. When the key is released they stop.

3.10.4 DATA DISPLAYED ON THE TOP TWO LINES

The record number of the displayed record appears on line 2, along with the date and time when it was made. The present date and time always appear on line 1 along with the next free record number (just as on all other menus).

3.11 ERASING THE SIGNAL STACK

The signal stack can be erased by the operator prior to a new measurement by pressing the CLEAR key. To prevent results from being accidentally destroyed, erasure will not take place unless the ENT key is pressed within 1 second after the CLEAR key. When the stack is erased, the number of received shots is also cleared.

When the TERRALOC is initially turned on, the stack will be automatically erased by the power-up check routines (self check).

Note that only those traces will be erased that have the "Stack on" parameter on Menu 1 set to 1 (on). If this parameter is 0 the trace data are protected from erasure and also updating from new measurements.

3.12 ERROR MESSAGES ON THE CRT DISPLAY

3.12.1 MESSAGES ON MENU 0 AT POWER UP

Immediately after power-up the TERRALOC computer executes a test program to determine the status of the seismograph electronics. The result of this test is displayed on menu 0. The following messages can appear:

Message	Cause of the message
Channels in system	Always displayed together with the number of all amplifier that were found to be present at power-up.
Offset error	High zero-offset on amplifier. The amplifier(s) with this type of fault is marked with a "*" on the "channels in system"-listing.
PROM error	The program memory checksum was not right when tested.
RAM error	The stack memory has some error
Parameters changed	Usually accompanied by beeps. A parameter stored in the CMOS memory was found to be out of range by the test program and consequently changed to an acceptable value. This error <u>may</u> indicate that the backup battery needs to be replaced.
Channel controller error 1	The trig reception circuits on the amplifier control unit did not work.
Channel controller error 2	The timing circuits on the same unit did not work properly.
I/O error 1	The multiply/divide unit (pos 170 on the main computer board) is faulty.
I/O error 2	The I/O chip 140 on the main computer board is faulty. This error will probably also cause a channel controller error 1 and/or 2.
I/O error 3	The interface circuit for keyboard and printer communication (pos 120 on the main computer board) is faulty.
I/O error 4	The interface circuit for the real time quarz clock and beeper (pos 130 on the main computer board) is faulty.
Power error 1	+13V for the CRT and disk drive is outside limits.
Power error 2	+12V for the amplifiers is outside limits.
Power error 3	A/D conversion reference voltage is outside limits.
Power error 4	+5V for the computer is outside limits.
Power error 5	-5V for video is outside limits.
Power error 6	-12V for the computer is outside limits.
Power error 7	-12V for the amplifiers is outside limits.
Other errors	Miscellaneous errors (nonspecified).

3.12.2 MESSAGES DURING OPERATION

A number of messages are given by the TERRALOC computer to the operator when certain operation errors are detected. These messages are printed on the bottom line of the CRT display and are accompanied by the sounding of a short beep to alert the operator of the message's presence. At certain times a message can be output without an error condition. All possible messages are given below with their meanings.

Message	Cause of the message
Ready for shot	System ready for trig pulse.
WARNING! Data in memory	When entering ARM-mode this messages indicates that the signal stack already contains data.
Press ENTER to save	Signals are received in preview mode. The operator is asked to accept the data for stacking.
Trig received	Trig pulse detected, data are being processed.
ENTER must follow CLEAR	Clear memory operator error.
Channel error	Requested amplifier not present (assignments in menu 1).
Out of range	Menu variable value error.
Too many shots	255 shots have been stacked and a new shot is made.
Invalid key	Illegal key pressed.
Scroll out of range	Traces scrolled max up or down.
Time out of range	Timeline at max or min position.
Too many traces	More traces requested to be displayed than there are amplifiers installed in system.
Printer fault	The printer did not respond.
Battery voltage too low	The battery has been almost completely discharged. The present operations can be concluded but if no action is taken the power supply will soon cease to operate properly.
Interface fault	Digital interface operation error.
No data in memory	Auto gain set function cannot operate since no test shot was made.
Data out of limits: Try another shot (after clear)	After Auto gain set on menu 2 this indicates overflow or poor data in signal stack. A new shot followed by 'Auto gain set' will improve the result.
Already done: Clear and make new shots	The Auto gain set function on menu 2 can only be activated once after a shot. This message indicates that a second attempt has been made.
(Low gain)	A warning displayed after a shot indicating very poor data on one or more traces.
(High gain)	A warning displayed after a shot indicating data overflow on one or more traces.

Message	Cause of the message
No data to record	A recording on disk was requested when the stack memory was erased.
Diskette unformatted	The diskette has not been formatted.
Check diskette	No diskette present or diskette not properly installed.
Not found	Requested record not found.
Write protected	The write protect tab on the diskette is switched for read operations only.
Diskette read error	The requested record or the directory on the diskette contains faulty data. The record or the whole contents of the diskette might be lost.
Diskette full	No more space for data on the diskette.
Record No. occupied	An attempt has been made to store data with the same record number that already exists on the diskette.
Continue on next page	The directory listing occupies more than one screen page. Position the cursor to the "Next page" field on menu 4 and press ENT.
Get new directory	The directory listing on the screen is not valid due to change of drive number.

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4. DIGITAL INTERFACE OPERATIONS AND SOFTWARE SUPPORT

This section of the manual deals with the data transfer between TERRALOC and a computer using the digital interface and the data disks.

4.1 DIGITAL INTERFACE HARDWARE

The digital interface unit contains circuits for both serial and parallel communication. The selection of circuit is made on menu 5. The two circuits are connected on the connector panel on the side of the TERRALOC. One of the connectors is for the IEEE-488 bus interface (also called GPIB) and the other is for RS-232C communication.

4.1.1 RS-232C SERIAL INTERFACE CIRCUIT

The RS-232C serial interface is used for connection to a computer in order to control or to communicate data to and from the TERRALOC.

It can be set for different baud rates, parity, stop bits etc. See 3.7.2. The settings depend on the computer or modem that is to be connected to the TERRALOC and should be determined from that instrument's operating manual. Sample connections are shown in Fig. 4.1-2 to 4.1-4.

To change the setting of the serial interface the corresponding item on menu 5 is altered and the TERRALOC computer immediately displays the new setting.

The RS-232C serial interface circuit operates with transmit and receive channels and four transmission control signals as described in the table in Fig. 4.1-1.
It uses a standard female D-type connector with 9 poles.

4.1.2 IEEE-488 PARALLEL INTERFACE CIRCUIT

The IEEE-488 or GPIB interface bus circuit operates according to the standard for these circuits. The operator need only set the proper talker/listener address before operation of the circuit. This is set using the keyboard on menu 5. The permissible range of addresses is 00 to 30.

Fig. 4.1-1 Description of the RS-232 C interface signals.

Pin	Item	Symbol	I/O	Function
2	Transmit Data	TxD	Out	Data signal: ON=0, OFF=1
3	Receive Data	RxD	In	Data signal: ON=0, OFF=1
4	Request To Send	RTS	Out	Modem control: ON: Send carrier OFF: Stop carrier
5	Clear To Send	CTS	In	Data transmission control: ON: Enabled OFF: Disabled
6	Data Set Ready	DSR	In	Modem status indicator: ON: Ready to operate OFF: Not ready
7	Signal ground	GND		Signal ground reference.
9	Data Terminal Ready	DTR	Out	TERRALOC receive control: ON: Ready to receive data OFF: Not ready to receive data

NOTES:

RTS: May be connected to CTS and DSR for continuous transmission

DSR: Disregarded by TERRALOC if switch DS on digital interface board is set to OFF.

DTR: This signal is used to indicate that TERRALOC is ready to receive data. The computer sending data to TERRALOC must check this signal before transmission of each byte when high data rates (>4800 baud) are used.

Voltages: ON: +5 to +10 V into 7 kohms
OFF: -5 to -10 V into 7 kohms

Fig 4.1-2 RS-232 C connection with no handshake, max 4800 baud.

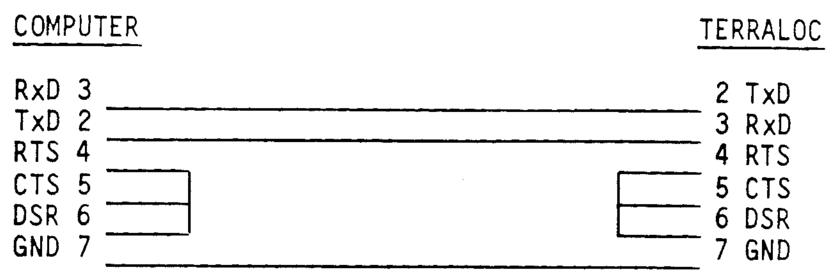

Fig 4.1-3 RS-232 C connection with an IBM PC computer (with handshake). Note different pinning on AT and XT models.

IBM COMPUTER PC/XT	AT	TERRALOC
RxD 3	2	2 TxD
TxD 2	3	3 RxD
DSR 6	6	5 CTS
DTR 20	4	6 DSR
GND 7	5	7 GND
CTS 5	8	9 DTR

The computer can be an IBM PC or compatible and it is set for correct communications parameters using the "MODE" command. See your DOS reference manual for details. See also 4.3.
Note that you have to use special communications software if you are going to use the handshake option. This software must be able to act on the DTR signal from Terraloc. The normal DOS usage of the COM ports does not include handshaking.
Note also that some portable computers use the AT connection pinning.

Fig 4.1-4 RS-232 C connection with an APPLE II computer (no handshake).

APPLE II Super Serial Card	TERRALOC	
RxD 2	2	TxD
TxD 3	3	RxD
	4	RTS
	5	CTS
GND 7	7	GND

Set the APPLE II+ Super Serial Card switches for the baud rate etc that you want to use (max 4800 baud). See your Super Serial Card User's Manual for details.

4.2 DIGITAL INTERFACE OPERATION

The digital interface operates over either of the two channels (IEEE-488 or RS-232C) as set on menu 5 (see 3.7.2).

There are two separate modes for digital communication using the digital interface:

1. Remote control, where the data sent to the TERRALOC over the interface are interpreted as if they came from the internal keyboard. In this mode the TERRALOC can be remotely controlled using any function accessible from the keyboard.

2. Advanced communication, where the connected computer can gain access to the data in the TERRALOC using a set of command codes.

4.2.1 REMOTE CONTROL

In this mode the external computer merely sends the control characters to the interface. They are then processed as if they were data from the built-in keyboard. To control the TERRALOC in this way the desired key sequence is determined from the normal keyboard operation and then this sequence is translated into a series of ASCII characters using the table in 4.2.2. This sequence is then sent over the interface into the TERRALOC thereby remotely controlling the seismograph functions.
Note that the MENU and SET codes are intercepted by the Terraloc software before the input buffer. This means that you should include a processing delay after sending data for setting up a menu before the MENU or SET codes are transmitted. Otherwise only partial or no data entry is performed on the menu.

4.2.2 TERRALOC KEYBOARD CONTROL CODES

When a key is pressed on the keyboard the TERRALOC computer receives the information as an ASCII character. The value of that character then determines what action is to be taken. Input to the TERRALOC may equally well come from the digital interface or the keyboard and the action will not depend on the source of the character. The codes used are given below:

KEY	ASCII	CTRL	Hex	Decimal	
ENTER	'		$60	96	
(LEFT)	BS	H	$08	8	
(RIGHT)	HT	I	$09	9	
(DOWN)	LF	J	$0A	10	
(UP)	VT	K	$0B	11	
SET	SO	N	$0E	14	
ARM	S1	O	$0F	15	
MENU	DC1	Q	$11	17	
TRACE	DC2	R	$12	18	
PRINT	DC3	S	$13	19	
COPY	DC4	T	$14	20	
RECORD	NAK	U	$15	21	
CLEAR	SYN	V	$16	22	
	BELL	G	$07	7	(Remote trigger code.)
	ESC		$1B	27	(Starts the digital interface operations.)

All other keys carry the standard ASCII codes.

4.2.2.1 REMOTE TRIGGERING

When the TERRALOC is armed and ready for shot it can be triggered via the digital interface. This is accomplished by transmitting the ASCII BELL character. When the TERRALOC computer receives this character an internal trigg pulse is produced which initiates a measurement. With this the TERRALOC can for example be used to monitor vibrations automatically by connecting a computer and using a suitable program.

4.2.3 ADVANCED COMMUNICATION

Using the advanced communications mode the control computer can reach data areas in the TERRALOC memory for read or write operations. This is used when interpretation programs need access to the actual signal values collected by the TERRALOC seismograph. Also data from the control computer can be written into TERRALOC memory for subsequent display on the CRT screen or recording on disk.

The advanced communication mode is entered when the control computer sends the ESC (see 4.2.2) character to the TERRALOC. After ESC is received the TERRALOC computer expects a character string containing a valid command to be sent over the digital interface and terminated with the carriage return character.

A summary of the commands used for these operations are listed in section 4.2.4.
The full syntax of the commands and data formats are listed in section 4.2.5.

4.2.3.1 TERRALOC MEMORY FUNCTIONS

Inside TERRALOC there are two memory banks accessible to the external computer:

1. The stack memory, containing 1000 16-bit values for each of 24 traces.
2. The display buffer memory, containing 1000 8-bit values for each displayed trace. This buffer will contain different data depending upon the selected display mode.

With the commands RST and WST the computer can read and write any trace stack in the TERRALOC memory.

With the commands RDB and WDB the computer can read and write the display buffers. The argument can have any value from 01 to 24 provided that the TERRALOC is equipped with 12 amplifier boards (24 channels). Otherwise the maximum value is twice the number of installed amplifier boards. This is due to the fact that the display buffers are physically located on these boards.
Note that the data contained in a display buffer are the data put there the last time traces were displayed on the screen. The display buffers are numbered in order of appearance from left to right on the CRT screen. The number is thus affected by the "Trace on" parameter in menu 1.

With the command RSE the instrument settings can be read by the computer. All settings including amplifier gains and survey parameters are read as one entity using the format shown in section 4.1.3.7.

The command RTM starts the transmission of arrival times as picked using the arrival time functions on menu 3. Also transmitted are a few field notes: Record No., Shot pos., Layout start and Layout end.

With the SEG-1 command a standardized (by the SEG) communications mode is initialized. Here a whole record is transmitted including header and trace data.

4.2.3.2 TERRALOC DISPLAY AND PRINT FUNCTIONS

To display the current contents of the display buffer memory on the TERRALOC screen the command DDB is used. This causes the data to be displayed as traces in the usual way.

To print the current contents of the display buffers on the TERRALOC printer the command PDB is issued. This causes the TERRALOC to print traces with no starting header using data from the display buffers.

4.2.4 SUMMARY OF AVAILABLE COMMANDS

Command	Function
DDB	Display the contents of the display buffers on the CRT as traces.
PDB	Print the contents of the display buffers on the TERRALOC printer.
RDB	Read the contents of the display buffer no. (NN). 1000 8-bit values will be sent to the computer.
RSE	Read the TERRALOC settings into the computer. Format as in section 4.2.6.
RST	Read the contents of the stack no. (NN). 1000 16-bit values preceeded by the associated shot counter value (0-255) will be sent to the computer.
RTM	Read the arrival times picked using the functions on menu 3.
SEG-1	Read header and trace data using the SEG-1 standard protocol as set by the Society of Exploration Geophysicists.
WDB	Write 1000 values to the display buffer no. (NN). Format as for read.
WST	Write 1000 values to the stack no. (NN). Format as for read.

4.2.5 FULL SYNTAX OF ADVANCED COMMANDS

This section contains the full syntax of the advanced commands that are available in the TERRALOC.

Abbreviations: Items enclosed in < > brackets shall be replaced with a string of characters as specified below.

<ETX>	=	the ASCII character "end of text", decimal 3
<ENQ>	=	the ASCII character "enquire", decimal 5
<CR>	=	the ASCII character "carriage return", decimal 13
<LF>	=	the ASCII character "linefeed" decimal 10
<GS>	=	the ASCII character "group separator", decimal 29
<ESC>	=	the ASCII character "escape", decimal 27
<US>	=	the ASCII character "unit separator", decimal 31
<trace>	=	the trace number, two ASCII characters: 01-24
<No. of shots>	=	the number of received shots, 3 characters: 000-255
<byte(NN)>	=	two's complement data byte number NN. Transmitted and received as a 2 character hex item: 00-FF.
<sample(NN)>	=	two's complement data word number NN. Transmitted and received as a 4 character hex item: 0000-FFFF.

<buffer No.> = the display buffer number, 2 characters: 01-24
<data field> = the characters entered into the different data fields in the TERRALOC menus. Each data field is a separate unit.
<Record No.> = the 6 digit TERRALOC record number.
<Shot pos> = the 6 characters entered into this field of menu 1.
<Layout start> = the 6 characters entered into this field of menu 1.
<Layout end> = the 6 characters entered into this field of menu 1.
<Record time> = as selected on menu 1 expressed in milliseconds.
<No. of used traces> = the number of traces that have received data.
<Time mark time> = the arrival time expressed in milliseconds.

Command syntax:

NOTE: If you are using the serial interface you should add a small delay in all commands between the transmission of the leading <ESC> character and the next character of the command. This delay should be at least 60 ms and ensures that the Terraloc digital communications program is properly started to take care of the command without losing characters.

DDB Display display buffers

Computer: <ESC> DDB <CR>

PDB Print display buffers

Computer: <ESC> PDB <CR>

RDB Read display buffer

Computer: <ESC> RDB, <buffer No.> <CR>
TERRALOC: <byte(1)> <byte(2)> .... <byte(1000)> <CR>

RSE Read settings

Computer: <ESC> RSE <CR>
TERRALOC: <data from menu 1> <CR> <data from menu 1> <CR> <data from menu 3> <CR> <data from menu 5> <CR> <data from the trace display> <CR> <LF>. See 4.2.6.

RST Read trace stack memory

Computer: <ESC> RST, <trace> <CR>
TERRALOC: <No. of shots> , <sample(1)> <sample(2)> .... <sample(999)> <sample(1000)> <CR>

RTM Read time markers

Computer: <ESC> RTM <CR>
TERRALOC: <Record No.> <CR> <Shot pos.> <CR> <Layout start> <CR> <Layout end> <CR> <Record time> <CR> <Number of used traces> <CR> <First used trace No.> , <First time mark time> <CR> <Next used trace No.> , <Next time mark time> <CR> .... <Last used trace No.> , <Last time mark time> <CR> <LF> / Total number of characters is 37+N*13
Only time marks for used traces are sent.

SEG-1 Read header and data using standard protocol SEG-1

Computer: <ESC> SEG-1 <CR>
TERRALOC: Data according to the standard, described in full in section 4.2.7.

WDB Write display buffer

Computer: <ESC> WDB, <buffer No.> , <byte(1)> <byte(2)> ...... <byte(999)> <byte(1000)> <CR>

WST Write trace stack memory

Computer: <ESC> WST, <trace> , <No. of shots> , <sample(1)> <sample(2)> .... <sample(1000)> <CR>

4.2.6 TRANSMISSION FORMAT FOR THE READ SETTINGS COMMAND (RSE)

The data fields transmitted by the TERRALOC after reception of the RSE command are the user entered data fields of menus 1 trough 3 and the 9 fields of the TRACES display. The data fields are separated with the ASCII character CR (Carriage Return decimal 13). The following table lists the data fields in the order they are transmitted.

	Item	Starting byte No.	Length	Contents	Range of values
MENU 1:	1	1	6	Shot position	--
	2	8	6	Layout start	--
	3	15	6	Layout end	--
	4	22	6	Profile No.	--
	5	29	12	Note	--
	6	42	6	Operator	--
	7	49	1	Record time code	0-7
	8	51	4	Delay time in ms	0000-9999
	9	56	1	Mode code	0-3
	10	58	1	Spread polarity field	always a space
	11	60	2	Retrieve field	always spaces
	12	63	2	Store field	always spaces
	13	66	2	Channel No. for trace 1	00-24
	14	69	1	Polarity for trace 1	+ or -
	15	71	1	Stack on for trace 1	0-1
	16	73	1	Trace on for trace 1	0-1
	17-20	75	..	Same as items 14-17 but for trace	2
	21-24	84	..	-"-	3
	.	..	..	.	.
	.	..	..		.
	105-108	273	..	-"-	24

Continue on next page

	Item	Starting byte No.	Length	Contents	Range of values
MENU 2:	109	282	1	All channels field	always a space
	110	284	1	Analog filter	0-8
	111	286	2	Retrieve field	always spaces
	112	289	1	Analog gain set	always a space
	113	291	2	Noise gate threshold %	00-99
	114	294	2	Store field	always spaces
	115-138	297	2 each	Gain codes for the amplif.	00-20 for installed amplifiers, spaces for amplifiers not in system.
MENU 3:	139	369	1	Display mode	0-5
	140	371	2	Trace size	00-99
	141	374	1	Trace type	0-3
	142	376	3	Window	000-999
	143	380	3	Time shift	000-999
	144	384	2	Low-cut filter code	00-99
	145	387	2	High-cut filter code	00-99
	146	390	1	List marker times	always space
	147	392	1	Inspect and adjust	always space
	148	394	1	Auto time pick	always space
	149	396	1	Menu 5 command	always space
MENU 5:	150	398	1	Select interface	0-1
	151	400	1	Select printer type	0-3
	152	402	2	IEEE-488 address	00-30
	153	405	1	Trace separation	0-1
	154	407	1	Baud rate	0-8
	155	409	1	Print length	0-1
	156	411	1	Stop bits	1-2
	157	413	1	Timing lines	0-1
	158	415	1	Word length	7-8
	159	417	1	Parity	0-3
	160	419	1	Power-up menu field	always space
TRACES:	161	421	6	Next Record No.	000000-999999
	162	428	6	Date	yymmdd
	163	435	5	Time	hh:mm
	164	441	9	Timeline time	see 4.1.4.7
	165	451	6	Present Record No.	000000-999999
	166	458	6	Date of measurement	yymmdd
	167	465	5	Time of measurement	hh:mm
	168	471	7	Display mode	--
	169	479	3	Number of shots	000-255
		483	2	Ending code	<CR> <LF>

4.2.7 SEG-1 COMMUNICATION STANDARD AND SYNTAX

The command SEG-1 is used to start a transmission of data from the TERRALOC in the SEG-1 standard format.
After reception of the start command the TERRALOC will transmit all the header data in one block according to the SEG-1 format and then wait for a continue command to send the first block of trace data.

The trace data blocks contain one full trace of samples (1000) each. After the transmission of each trace data block the TERRALOC waits for a continue command to send the next trace data until all traces in use have been transmitted.
It is not possible to give the continue command without first having transferred the header block. If other data are required the normal TERRALOC communications commands are recommended.

Since the TERRALOC seismograph can be configured as a 2 to 24 channel system and when configured use only a subset of those channels in any one measurement the identity of the channel number is somewhat complicated. In the TERRALOC each trace is associated with a memory of 1000 16 bit words in which the stacking function is performed. It is the content of this memory that is referred to below with the designation "traces". The TERRALOC input amplifiers can supply data to any desired trace memory as ordered by the user on menu 1.

The following definitions of terms apply to this SEG-1 transmission:

1. The trace data provided by the TERRALOC using the SEG-1 format are output in ascending order of used traces, i.e. traces that have received data.

2. The sequence is by the appearance from left to right on the TERRALOC screen.

3. Traces that have not received data are regarded as not present in the system.

4. The gain constants are provided by the amplifier that was connected to a specific trace at the time of recording on disk. Note that in the TERRALOC an amplifier (and thus a geophone) can provide signal to any of the traces by simple rearrangement of connection parameters.

Command syntax:

Computer:	<ESC> SEG-1 <CR>
TERRALOC:	SEG-1 header data (see following description).
Computer:	The continue command to start trace transmission: <ENQ> H Send trace data in hexadecimal format. <ENQ> B Send trace data in binary format.

Format of the SEG-1 header block.

After the start command is sent by the computer the TERRALOC transmits the header block listed below. The length of the block can vary depending on number of traces in use. At the end of the block an <ETX> character is transmitted, which makes it possible for the computer to detect the end of the transmission.

Item No.	SEG-1 name	TERRALOC Output	Range
1	File No.	Record No.	000000-999999
2	Job No.	Profile No.	Any 6 characters
3	Date & time	Shot time	yymmddhh:mm
4	Operator's note	Note	Any 12 characters
5	Mfgr's code	ABEM code	ABEM-1
6	No. of channels	No. of used traces	000-024
7	Samples/channel	Trace length	1000
8	Sample rate (ms)	Sample rate (ms)	0.024-5.000
9	Delay time (ms)	Delay time (ms)	0000-9999
10	HP filter	HP frequency (Hz)	001-999
11	LP filter	LP frequency (Hz)	1500
12	Notch filter	** Not available **	
13	Shot location X	Shot position	Any 6 characters
14	Shot location Y	** Not available **	
15	Shot location Z	** Not available **	
-------------<LF>------------- Sub-header separator			
16	Shot-Geoph. X	** Not available **	
17	Shot-Geoph. Y	** Not available **	
18	Shot-Geoph. Z	** Not available **	
19	Operator's note	** Not available **	
20	No. of stacks	Number of shots	001-255
21	Gain (dB or AGC)	Amplifier Gain	006-126
-------------<LF>------------- Sub-header separator			
22-27	Same as items 16-21 but for next channel.		
-------------<LF>------------- Sub-header separator			
..	Same as items 16-21 for all used traces		
-------------<LF>------------- Last sub-header separator			
-------------<ETX>------------ Final end of message			

NOTES: After each item a <CR> is transmitted.

The items described as '** Not available **' are marked by a single <CR> character.

<CR> = ASCII carriage return character (hex 0D)
<LF> = ASCII line feed character (hex 0A)
<ETX> = ASCII end-of-text character (hex 03)

Format of the TERRALOC SEG-1 trace data transmission.

Upon reception of a continue command after the header record has been transmitted the TERRALOC transmits one block of trace data in the following form:

<Trace No.>,<sample (1)><sample (2)>....<sample (1000)><CR>

The trace number is a two character ASCII coded number 01-24 corresponding to the numbering conventions used in the main header. The highest number used is equal to the number of channels as given there. When the last trace data block has been received no further continue commands should be given.

The samples are 16 bit integers in two's complement format and they are coded for transmission in two different ways depending on which continue command is given. These formats are described below.

Hexadecimal format

Computer: <ENQ> H

TERRALOC: Each sample is coded as a 4-character hex item 0000-FFFF. Total length of the block is 4004 bytes including the final <CR>-character.

Binary format

Computer: <ENQ> B

TERRALOC: Each sample is transmitted divided into 2 bytes with the msb transmitted first. Total length of the block is 2004 bytes including the final <CR>-character.

Notes: Because of the binary format, the code for <CR> can probably be found in the data and for this reason the final <CR> cannot be used as detection of the end of message. It can however be used as a check that the data transmission has been correctly completed.

When using this kind of data-transmission the word length of the RS-232C serial interface <u>must</u> be set to 8 bits.

After reception of a valid command (<ESQ>SEG-1<CR> or <ENQ>H or <ENQ>B) the TERRALOC will wait for about 500 ms before starting the transmission of data. This is to give the requesting computer time to switch transmission direction etc.

4.3 SOFTWARE FOR PERSONAL COMPUTERS

Sections 4.4 and 4.5 contain a few programs and procedures that demonstrate how to use a personal computer (IBM PC or compatible) with the TERRALOC seismograph. They are included as examples in order to acquaint you with the use of the digital interface commands and also to show you how to read Terraloc datafiles on disk. The programs are written using Quick-BASIC from Microsoft and TURBO-Pascal from Borland International.
This software is also supplied on the 5.25" software demo disk and the 3.5" demo disks that were delivered with the TERRALOC. On these disks there may be several programs that are not listed here. To get up to date information you should read the text file READ ME.TXT that is included on the disks.
Note that the software exists in two forms on the disks, source code and compiled executable code produced by the compilers. The compilers are not supplied. If you want to make changes in the software to adapt it to your own needs you have to get the compilers from your local computer shop.

The sample programs given here are meant to be a guide for making your own programs for use with the TERRALOC. They demonstrate how to get data into and out of the seismograph and how to read and write TERRALOC compatible data files on disk. They are not meant to be interpretation or processing programs.

4.4 QUICK-BASIC SOFTWARE

The Microsoft Quick-BASIC compiler for the IBM-PC/XT/AT and compatibles is very easy and efficient to use for Terraloc data processing. The compiler is readily available in computer shops everywhere. Please note that version 2.0 and above should be used.

The following sections give examples on how to use the available Terraloc commands. All examples are given in source code format and with a short description on how to use the software. The source and compiled executable code is also available on the Terraloc software demo disk in directory BASIC. You can also find it on the two 3.5" data disks that were delivered with the Terraloc.

A few important notes on the use of Quick-BASIC:

1 - Quick-BASIC supports communication at speeds up to 19200 baud. We recommend that you use this speed since the transfer times are much shorter then.

2 - When high speed transfers are made it is important that you use an RS-232 cable that is correctly connected. See figure 4.1-3.

3 - It is also important that you open the com file with the right handshaking options. See examples in the software lists. Please note that we have used 2 stop bits, this ensures safe data transfer at high speed.

4 - In order to use high speed transfers with Quick-BASIC the compiler must be invoked with a communications buffer length of 4100 or more. This is accomplished with the following command at the system prompt:

```
C:> qb /c:4100
```


5 - Trace data transferred from Terraloc are always output with the most significant byte of a sample first. This means that before the data can be interpreted as integer arrays by Quick-BASIC the bytes of each sample have to be swapped since the storage order is reversed in the IBM-PC. See software listing for examples.

6 - Conversion from HEX to binary representation can be made with string manipulation and the CVI function. See examples in 4.4.1.8

7 - Note that Quick-BASIC only supports graphics on IBM-compatible display adapters of the CGA or EGA type. Hercules graphics is not supported.

4.4.1 DEMONSTRATION PROGRAM TERCOM

This program demonstrates how to use the different communication functions with an IBM-PC. When the program is executed it uses a number of subprograms which are listed separately. These subprograms handle one function each.

The TERCOM program lets you:

1 - Read one trace and display on the PC screen

2 - Read one display buffer and display on the PC screen

3 - Read header and trace data using the SEG-1 protocol

4 - Read arrival times and print on screen

5 - Control the Terraloc from the PC keyboard

6 - Write data to a trace stack

7 - Write data to a display buffer and display result

8 - EXIT from the program

The program displays the selections in a menu and depending on operatorinput different subprograms are called. Communications parameters are set by passing a string to the subprogram which is defined at the start of the main program:

```
ser$ = "COM 1:  19200, N, 8, 2, CS100"
```

Two subprograms used by the main TERCOM programs are:

```
SUB GETCHAN (no%) STATIC
'Get channel number from operator for trace transfers
L:
  PRINT "Select buffer/trace number to read/write: ";
  INPUT no% : IF no% < 1 OR no% >24 THEN GOTO L
END SUB

SUB FILLTRACE (trace%(1)) STATIC
'Fill array with sawtooth data
  FOR i% = 1 TO 1000
    trace%(i%) = i% MOD 200 - 100
  NEXT i%
END SUB
```

The main program listing can be found on the next page.

```
  DIM Trace%(1000), head$(20), shots%(24), gains%(24), times(2,24)
  RDB$ = "RDB": RST$ = "RST": WST$ = "WST": WDB$ = "WDB"
  ser$ = "COM1: 19200,N,8,2,CS100"    'COM parameters used by program
MAIN:
  ERASE trace%: a = FRE("")  'Clean up string space once per main loop
  CLS
  PRINT "Copyright 1987 Atlas Copco ABEM AB"
  PRINT "                    POBox 20086"
  PRINT "                    S-161 20 Bromma, Sweden"
  LOCATE 8,10: PRINT "Terraloc Mark 3 Communication Demonstration Software"
  LOCATE 10,1
  PRINT"This software uses 19200 baud, no parity, 8 data bits and 2 stop bits"
  PRINT"Make sure that Terraloc is set to the same parameters!"
  LOCATE 14,1
  PRINT "1 = Read trace data"
  PRINT "2 = Read display buffer data"
  PRINT "3 = SEG-1"
  PRINT "4 = RTM"
  PRINT "5 = REMOTE"
  PRINT "6 = Write trace data to Terraloc"
  PRINT "7 = Write display buffer data"
  PRINT "9 = EXIT"
  PRINT: INPUT "Select function: ", sel%
  IF sel% = 1 THEN      'Read trace data
    CALL GETCHAN (no%)
    CALL RDAT (ser$, RST$, no%, trace%())
    CALL PLOTTRACE (trace%())
  END IF
  IF sel% = 2 THEN      'Read display buffer data
    CALL GETCHAN (t%)
    CALL RDAT (ser$, RDB$, no%, trace%())
    CALL PLOTTRACE (trace%())
  END IF
  IF sel% = 3 THEN      'Read data using SEG-1 protocol
    CALL SEG1 (ser$, head$(), shots%(), gains%(), trace%())
    CALL PLOTTRACE (trace%())
  END IF
  IF sel% = 4 THEN      'Read time markers
    ERASE times
    CALL RTM(ser$, head$(), numtr, times())
  END IF
  IF sel% = 5 THEN      'Remote control from PC
    CALL REMOTE (ser$)
  END IF
  IF sel% = 6 THEN      'Write trace data to Terraloc
    CALL GETCHAN (no%)
    CALL FILLTRACE (trace%())
    CALL WDAT (ser$,WST$,no%,trace%())
  END IF
  IF sel% = 7 THEN      'Write display buffer data to Terraloc
    CALL GETCHAN (no%)
    CALL FILLTRACE (trace%())
    CALL WDAT (ser$,WDB$,no%,trace%())
    CALL DDB (ser$)
  END IF
  IF sel% = 9 THEN      'EXIT
    PRINT: PRINT: PRINT "End of DEMO run!"
    END
  END IF
  GOTO MAIN
END
```


4.4.1.1 READ TRACE DATA

The RDAT subprogram will read trace data over the serial interface and convert the hex format into an integer array. The data are read from the stack memory or display buffer depending on a call parameter. The calling parameters are:

- bdr$ - COM file specification string. See 4.4.1.
- cmd$ - RST (read stack) or RDB (read display buffer) declares which command to use.
- no% - An integer in the range 1-24 specifying which buffer to read.
- trace% ( ) - An integer array of at least 1000 values to receive the data from Terraloc.

The HEX to integer conversion is performed in subprograms HEX2 and HEX4. These are listed in section 4.4.1.8.

```
SUB RDAT (bdr$, cmd$, no%, trace%(1))  STATIC
'Reads trace data from Terraloc, either from stack or display buffer.
'Data are converted from hex to integer and returned in array trace%()
  IF (cmd$ <> "RDB") AND (cmd$ <> "RST") THEN EXIT SUB
  OPEN bdr$ AS #1
  no$ = STR$(no%)
  L = LEN(no$) - 1 : no$ = RIGHT$(no$,L)
  IF no% < 10 THEN no$ = "0" + no$
  cm$ = cmd$ + "," + no$ + CHR$(13)
  esc$ = CHR$(27)
  PRINT #1, esc$;       'by printing esc and the following part of the
  PRINT #1, cm$;        'command on different lines a small delay is created
  IF cmd$ = "RST" THEN INPUT #1, shots%
  INPUT #1, buf$
  CLOSE #1
  PRINT "reception OK, convert hex/integer"
  IF cmd$ = "RST" THEN
    CALL HEX4(buf$,trace%(),1000)
  ELSE
    CALL HEX2(buf$,trace%(),1000)
  END IF
END SUB
```

4.4.1.2 WRITE TRACE DATA

The WDAT subprogram writes the data in an integer array to a specified trace stack or display buffer over the serial interface. The calling parameters are:

- bdr$ - COM file specification string. See 4.4.1.
- cmd$ - WST (write stack) or WDB (write display buffer) declares which command to use.
- no% - An integer in the range 1-24 specifying whith buffer to write.
- trace% () - An integer array of 1000 values to be transmitted to Terraloc.

The conversion from integer to HEX prior to transmission is done within the subprogram itself.

```
SUB WDAT (bdr$,cmd$,no%,trace%(1)) STATIC
'Writes trace data to Terraloc, either to the stack or the display buffer.
'Data are converted from integer to hex prior to transmission
  OPEN bdr$ AS #1
  no$ = STR$(no%)
  L = LEN(no$) - 1 : no$ = RIGHT$(no$,L)
  IF no% < 10 THEN no$ = "0" + no$
  cm$ = cmd$ + "," + no$ + ","
  esc$ = CHR$(27)
  IF cmd$ = "WST" THEN cm$ = cm$ + "003,"        'Number of shots
  PRINT #1, esc$;
  PRINT #1, cm$;
  IF cmd$ = "WST" THEN
    FOR j% = 1 TO 1000
      a$ = HEX$(trace%(j%))
      IF LEN(a$)=3 THEN a$="0"+a$
      IF LEN(a$)=2 THEN a$="00"+a$
      IF LEN(a$)=1 THEN a$="000"+a$
      PRINT #1, a$;
    NEXT j%
  ELSE
    FOR j% = 1 TO 1000
      a$ = HEX$(trace%(j%) MOD 127)
      IF LEN(a$)=3 THEN a$="0"+a$
      IF LEN(a$)=2 THEN a$="00"+a$
      IF LEN(a$)=1 THEN a$="000"+a$
      PRINT #1, MID$(a$,3,2);
    NEXT j%
  END IF
  PRINT #1, CHR$(13);
  CLOSE #1
END SUB
```


4.4.1.3 SEG-1 COMMUNICATIONS

The SEG1 subprogram reads header and trace data from Terraloc over the serial interface. In this example only the first trace is read but the program is easily modified to read all traces into a bigger array as indicated by the commented program lines before and after the trace dump section. The calling parameters are:

- bdr$ - COM file specification string. See 4.4.1
- head$ (1) - A string array to receive the 15 header lines.
- sh% (1) - An integer array to receive the number of shots made in each of 24 channels.
- gn% (1) - An integer array to receive the gains used for each of 24 channels.
- t% (1) - An integer array to receive the actual trace data. This array spec can be changed to trace% (2) if a whole record is to be read with the loop mentioned above. Each trace needs space for 1000 values.

Conversion from binary, which is the transmission mode chosen here, to integer is done in subprogram BININT. It is described in section 4.4.1.8.

```
SUB SEG1 (bdr$, head$(1), sh%(1), gn%(1), t%(1)) STATIC
'Read Terraloc data using SEG-1 protocol
  OPEN bdr$ AS #1
  esc$ = CHR$(27)
  PRINT #1,esc$;
  PRINT #1, "SEG-1"; CHR$(13);
  b$ = INPUT$(86,#1)
  nochan% = VAL(MID$(b$,47,3))
  l% = 13 * nochan% + 1
  r$ = INPUT$(l%, #1)
  CLOSE #1
  posl% = 1
  FOR i% = 1 TO 15    'Parse header into substrings
    pos2% = INSTR(posl%, b$, CHR$(13))
    l% = pos2% - posl%
    head$(i%) = MID$(b$,posl%,l%)
    posl% = pos2% + 1
  NEXT i%
  FOR i% = 0 TO nochan%-1
    sh%(i%+1) = VAL(MID$(r$,i%*13+5,3))
    gn%(i%+1) = VAL(MID$(r$,i%*13+9,3))
  NEXT i%
  FOR i% = 1 TO 15
    PRINT i%; "  "; head$(i%)
  NEXT i%
'  Begin trace dump
  OPEN bdr$ AS #1
'  FOR i% = 1 TO nochan%
    PRINT #1, CHR$(5);
    PRINT #1, "B";
    r$ = INPUT$(2004,#1)
    trno% = VAL (LEFT$(r$,2))
    r$ = MID$(r$,4,2000)
    PRINT "Received trace no ";trno%; " Convert to integer"
    CALL BININT(r$,t%(),1000)
  'NEXT i%
  CLOSE #1
END SUB
```

4.4.1.4 READ ARRIVAL TIMES

The RTM subprogram reads the picked arrival times from Terraloc over the serial interface. The times and field notes are then printed on the PC screen. Calling parameters:

bdr$ - COM file specification string. See 4.4.1.

header$ (1) - string array to receive field notes.

num traces - the number of active traces received from Terraloc.

timemarks (2)- array of single precision values (DIM (2, 24)) to hold the trace number and the corresponding picked time in milliseconds.

In addition to reading the values into the specified variables the subprogram prints a table on the PC screen with the arrival times.

```
SUB RTM (bdr$, header$(1), numtraces, timemarks(2)) STATIC
'Read time markers over serial port and print on screen
 OPEN bdr$ AS #1
 esc$ = CHR$(27)
 cm$  = "RTM" + CHR$(13)
 PRINT #1, esc$;
 PRINT #1, cm$;
 a$ = INPUT$(36,#1)
 numtraces = VAL(RIGHT$(a$,3))
 l% = 13 * numtraces +1
 b$ = INPUT$(l%,#1)
 CLOSE #1
 FOR i% = 0 TO numtraces - 1
   timemarks(1,i%+1) = VAL(MID$(b$,i%*13+1,2))
   timemarks(2,i%+1) = VAL(MID$(b$,i%*13+4,9))
 NEXT i%
 FOR i% = 0 TO 3
   header$(i%+1) = MID$(a$,i%*7+1,6)
 NEXT i%
 header$(5) = MID$(a$,29,4)
 PRINT : PRINT
 PRINT "Record No:";header$(1)
 PRINT "Shot position: ";header$(2)
 PRINT "Layout start:  ";header$(3)
 PRINT "Layout end:    ";header$(4)
 PRINT "Record time:   ";header$(5)
 PRINT
 PRINT "Trace No" TAB(10) "Arrival" TAB(20) "Trace No" TAB(30) "Arrival"
 PRINT "--------------------------------------------"
 offs% = (numtraces + 1) \ 2
 FOR I% = 1 TO offs%
   PRINT timemarks(1,I%) TAB(10) timemarks(2,I%);
   IF i% * 2 > numtraces THEN
     PRINT
   ELSE
     PRINT TAB(20) timemarks(1,I%+offs%) TAB(30) timemarks(2,I%+offs%)
   END IF
 NEXT I%
 PRINT "Continue";
 INPUT ans$
END SUB
```


4.4.1.5 DISPLAY AND PRINT DISPLAY BUFFER

These two subprograms will cause Terraloc to display the contents of the display buffers on the Terraloc printer. There is only one calling parameter to supply:

bdr$ - COM file specification string. See 4.4.1.

```
SUB DDB (bdr$)  STATIC
'Send display display buffer command to Terraloc
  OPEN bdr$ AS #1
  PRINT #1, CHR$(27);
  PRINT #1, "DDB"; CHR$(13)
  CLOSE #1
END SUB

SUB PDB (bdr$)  STATIC
'Send print display buffer command to Terraloc
  OPEN bdr$ AS #1
  PRINT #1, CHR$(27);
  PRINT #1, "PDB"; CHR$(13)
  CLOSE #1
END SUB
```

4.4.1.6 REMOTE CONTROL

When this subprogram is run the Terraloc can be controlled from the PC keyboard over the serial interface. Numeric entries and text are entered using the standard keys and the specially coded Terraloc keys are entered via the function keys on the PC. The REMOTE program will display a function key description on the bottom lines. The only calling parameter is:

bdr$ - COM file specification string. See 4.4.1.

```
SUB REMOTE (bdr$) STATIC
'Remote control program for controlling the Terraloc from a PC
  CLS
  PRINT "Copyright Atlas Copco ABEM AB"
  PRINT "             POBox 20086"
  PRINT "             S-161 20 Bromma, Sweden"
  LOCATE 10,20: PRINT "Terraloc Mark 3 Demonstration Software"
  LOCATE 11,24: PRINT "Remote Control Functions"
  LOCATE 16,15: PRINT "Use the normal keyboard for entries."
  LOCATE 17,15: PRINT "Function keys are defined on the bottom rows."
  LOCATE 24,1
  PRINT" F1    F2    F3    F4    F5    F6    F7    F8    F9    F10";
  LOCATE 25,1
  PRINT" MEN   ENT   SET   ARM   TRACE PRN   COP   CLR   RECORD EXIT";
  KEY 1, CHR$(17)    'Menu
  KEY 2, CHR$(96)    'Enter
  KEY 3, CHR$(14)    'Set
  KEY 4, CHR$(15)    'Arm
  KEY 5, CHR$(18)    'Traces
  KEY 6, CHR$(19)    'Print
  KEY 7, CHR$(20)    'Copy
  KEY 8, CHR$(22)    'Clear
  KEY 9, CHR$(21)    'Record
  KEY 10, CHR$(1)    'Exit

  OPEN bdr$ AS #1
  LOCATE 22,6
  PRINT "Select   :";
LOOP:
  a$ = INKEY$
  IF LEN(a$) = 0 THEN GOTO LOOP
  IF a$ = CHR$(1) THEN GOTO FINISH
  IF LEN (a$) > 1 THEN
    k% = ASC(MID$(a$,2,1))
    IF k% = 72 THEN a$ = CHR$(11)       'UP
    IF k% = 75 THEN a$ = CHR$(8)        'LEFT
    IF k% = 77 THEN a$ = CHR$(9)        'RIGHT
    IF k% = 80 THEN a$ = CHR$(10)       'DOWN
  END IF
  IF ASC(a$) = 13 THEN a$ = CHR$(96)
  PRINT #1, a$;
  LOCATE 22,18
  PRINT ASC(a$)
  GOTO LOOP
FINISH:
  CLOSE #1
  CLS
  FOR i% = 1 TO 10
    KEY i%, ""
  NEXT i%
END SUB
```


4.4.1.7 PLOT TRACE

The PLOTTRACE subprogram will use the PC screen in graphics mode and plot the contents of an integer array with 1000 values. The scale is adjusted so that the graph covers half the CRT height. Positive parts of the trace is filled in with white. The calling parameter is:

Trace% (1) - an integer array containing 1000 values to plot on the screen.

```
SUB PLOTTRACE (trace%(1)) STATIC
'Plot trace data on screen after normalization
  max% = 0
  FOR i = 1 TO 1000
    IF max% < ABS(trace%(i)) THEN max% = ABS(trace%(i))
  NEXT i
  IF max% = 0 THEN max% = 2
  SCREEN 2
  WINDOW (0,-2*max%)-(1000,2*max%)
  FOR i=1 TO 1000 STEP 2
    IF trace%(i) =< 0 THEN
      PSET (i, trace%(i))
    ELSE
      LINE (i,0)-(i,trace%(i))
    END IF
  NEXT i
  PRINT"Press RETURN to leave graphics! ";
  INPUT ans$
  SCREEN 0
END SUB
```

4.4.1.8 CONVERSION ROUTINES

There are a few conversions that need be done when data are transferred to and from the Terraloc. On reception of trace data from the stack or display buffer the HEX format must be changed into an integer format for further processing by Quick-BASIC. This is done in two subprograms depending on whether a trace (four characters) or a display buffer (two characters) was received. The subprograms are appropriately called HEX(and HEX2. Both have the following calling parameters:

r$ - a string containing the input data

u% (1) - an integer array to receive the converted values

n% - an integer giving the number of values to convert

```
SUB HEX2 (r$, u%(1), n%) STATIC
'Convert 2 char HEX to INTEGER array
  j% = 1
  FOR i% = 1 TO n%
    u = 0
    FOR k% = 1 TO 2
      v$ = MID$(r$, j%, 1)
      v% = ASC(v$) - 48: IF v% > 9 THEN v% = v% - 7
      u = v% + 16 * u
      j% = j% + 1
    NEXT k%
    IF u > 127 THEN u = u - 256
    u% (i%) = u
  NEXT i%
END SUB

SUB HEX4 (r$, u%(1), n%) STATIC
'Convert 4 char HEX to INTEGER array
  j% = 1
  FOR i% = 1 TO n%
    u = 0
    FOR k% = 1 TO 4
      v$ = MID$(r$, j%, 1)
      v% = ASC(v$) - 48: IF v% > 9 THEN v% = v% - 7
      u = v% + 16 * u
      j% = j% + 1
    NEXT k%
    IF u > 32767 THEN u = u - 65536
    u% (i%) = u
  NEXT i%
END SUB
```

The SEG1 protocol can transmit the data as a binary string. This string has to be converted, first by swapping every byte pair due to storage differences in the Terraloc and the IBM-PC. Then Quick-BASIC has to interpret the bit pattern as integer values. Calling parameters are:

a$	-	string containing the binary input data
t% ( )	-	integer array to receive the data
n%	-	integer giving the number of values to convert

```
SUB BININT (a$, t%(1), n%)  STATIC
'Convert binary data string from Terraloc to integer array data
  FOR i% = 1 TO n%
    r$ = MID$(a$,(2*i%),1) + MID$(a$,(2*i%-1),1)
    t%(i%) = CVI(r$)
  NEXT i%
END SUB
```


4.4.2 DISK READ PROGRAM

The READMk3 program will read a Terraloc data file selected by the operator from a directory list. The traces will then be plotted on the screen.

The trace data are stored on disk in binary form, two bytes per sample. To convert this into Quick-BASIC INTEGER format the CVI function is used.

```
'READMK3.BAS  -  a Quick-BASIC program
'Initiate variables and arrays:
  DIM Assign$(24), Gains%(24), Shots%(24), Trace%(1023,24)
  DIM ARRTIM%(24), DIR$(25)
  I% = 0 : J% = 0    'Step variables for use in loops

'Get operator input:
  CLS
  PRINT "Copyright 1987 Atlas Copco ABEM AB"
  PRINT "                    POBox 20086"
  PRINT "                    S-161 20 Bromma, Sweden"
  LOCATE 7,20
  PRINT "Terraloc Mark 3 Demonstration Software"
  LOCATE 8,20
  PRINT "Datafile read demo"
PATHIN:
  LOCATE 12,1
  INPUT"Enter source drive and directory (A:\data  etc):", PATH$
'Display Terraloc datafiles in selected directory
  IF (LEN(path$) <> 0) AND (RIGHT$(path$,1) = "\") THEN
    path$ = LEFT$(path$,LEN(path$)-1)
  END IF
  com$ = "dir " + path$ + " > dirfile"
  SHELL com$
  OPEN "dirfile" FOR INPUT AS #2
  I% = 0
  WHILE (NOT EOF (2)) AND I% < 21   'Read dirfile, test for Terraloc files
    LINE INPUT #2, TMP$
    IF (LEFT$(TMP$,1) = "R") AND MID$(TMP$,10,3) = "ABM" THEN
      I% = I% + 1
      DIR$(I%) = LEFT$(TMP$,7) + ".ABM"
    END IF
  WEND
  CLOSE #2
  KILL "dirfile"
  MAXFILE% = I%
  IF MAXFILE% = 0 THEN
      CLS
      LOCATE 4,1
      PRINT "Directory ";path$;" contains no Terraloc files!"
      PRINT "Specify new path..."
      GOTO pathin
    ELSE
      FOR I% = 1 TO MAXFILE%
        PRINT I%;"  ";MID$(DIR$(I%),2,6)
      NEXT I%
```

```
LOOP:
      INPUT "Select record by entering the row number = ", F%
      IF F% < 1 OR F% > MAXFILE% THEN GOTO LOOP
  END IF
  IF LEN(path$) <> 0 THEN path$ = path$ + "\"
  FILE$ = PATH$ + DIR$(F%)
  PRINT "File selected is: "; file$

'Open selected file and read header data:
  OPEN FILE$ AS #1 LEN=2048
  GET #1, 1
  INPUT #1, IDENT$, RECNO, DAT$, TIM$, SHOTPOS$, LAYSTRT$, LAYEND$
  INPUT #1, PROFNO$, NOTE$, OPCODE$, RECTIME, DELAY, COLLMODE, NOISE, FILTER
'Interpret RECTIME code into record time in ms
  RESTORE 100
  FOR i% = 0 TO RECTIME
    READ j%
  NEXT i%
100 DATA 24, 48, 100, 200, 500, 1000, 2000, 5000 'Record times in ms
  RECTIME = j%
'Read amplifier gain codes
  FOR I% =1 TO 24
    INPUT #1, GAINS%(I%)
  NEXT I%
  INPUT #1 , SHOTS
'Read assignments for each trace. (Amp No, polarity, stack on, trace on)
  FOR I% = 1 TO 24
    INPUT #1, ASSIGN$(I%)
    NEXT I%
'Read number of shots for each trace
  FOR I% = 1 TO 24
    INPUT #1, SHOTS%(I%)
    NEXT I%
'Read arrival time picked for each trace, sample number 000-999
  FOR I% = 1 TO 24
    INPUT #1, ARRTIM%(I%)
    NEXT I%
'Read total number of traces in file
  INPUT #1, NUMTRACE
  PRINT "Record contains "; NUMTRACE; " traces. Reading trace No.:"

'Read the trace data into the trace array
  FOR I% = 1 TO NUMTRACE
    PRINT  I%;
    GET #1, I% + 1
    FOR j% = 1 TO 1000
      c$ = INPUT$(2,#1)
      trace%(j%,i%) = CVI(c$)    'Convert to integer
    NEXT j%
  NEXT I%
  PRINT
  CLOSE #1
```



```
'Normalize trace sizes
  PRINT "Normalizing size for trace No.: "
  FOR i% = 1 TO NUMTRACE
    PRINT i%;
    max% = 1
    FOR j% = 0 TO 999
      IF ABS(trace%(j%,i%)) > max% THEN max% = ABS(trace%(j%,i%))
    NEXT j%
    scale = 60.0 / max%
    FOR j% = 0 TO 999
      trace%(j%,i%) = scale * trace% (j%,i%)
    NEXT j%
  NEXT i%
  PRINT

'Print header data on screen
  print : print
  PRINT "Data read from disk were:"
  PRINT
  PRINT "Record No.: ";RECNO;" Date: ";DAT$; "  Time: "; TIM$
  PRINT "Shot pos.: ";SHOTPOS$;"  Layout start: ";LAYSTRT$;
  PRINT "  Layout end: ";LAYEND$
  PRINT "Profile No.: ";PROFNO$;"  Note: ";NOTE$;"  Operator: ";OPCODE$
  PRINT "Record time: ";RECTIME;"ms   Delay: ";DELAY; "ms"
  PRINT
  INPUT "Press RETURN to continue to graphics.....", Q$

'Graphic display of traces)
  SCREEN 2
  WINDOW (0, -500) - (999, 500)
  for j% = 1 to numtrace
    offs% = 455 - j%*35
    line (0,offs%)-(4, trace%(4,j%)+offs%)
    FOR I% = 4 TO 999 STEP 5
      LINE -(I%, TRACE%(I%,j%)+offs%)
    NEXT I%
  next j%
  INPUT "Press RETURN to quit..",Q$
  SCREEN 0
  PRINT "END of Terraloc disk read demo"
END
```

4.5 TURBO-PASCAL SOFTWARE

If you want to process data more in depth and handle data in files in a more convenient way you should probably look at the Pascal language. For the IBM PC and compatibles the Borland TURBO-Pascal is a defacto standard Pascal compiler. This compiler is available in most computer shops around the world. In this section we will describe a few programs and procedures that can be used to process Terraloc data. The software examples are available in source code on the demo disks delivered with the Terraloc.

The listings published in this manual are not complete programs, they need type definitions and a few support procedures in include files to work. These include files are also delivered on the demo disks.

There are a few important notes on the use of TURBO-Pascal:

1 - TURBO-Pascal cannot by itself support high speed serial communication over the COM ports. To enable operation at high speeds special communications software with TURBO-Pascal interface must be used. In our examples we have used a package called "TURBO Asynch Plus" from Blaise Computing Inc.

2 - TURBO-Pascal has only rudimentary graphics capabilities directed towards the IBM CGA and EGA adapters. A graphics package for example "TURBO-Graphix" from Borland has to be used if you want to do serious graphics work. This package supports the Hercules monochrome graphics standard as well as the normal IBM CGA and EGA standards.

3 - If you are writing big programs you will probably also need a support package called "TURBO Extender" from TURBO Power Inc. This package makes it possible to cross the 64 k limit for source code set by TURBO-Pascal and make really big programs.

If you are using the IBM PC or a compatible you will find that the highest baudrate available with the MODE command is 9600. However the PC is capable of using higher rates and on the demo disk you will find a small program called 192.com that will set the baudrate to 19200. To use this program you can add the following lines to your autoexec.bat file:

```
MODE COM1 9600,n,8,1
192 1
```

Line 1 sets 9600 baud, no parity, 8 data bits and 1 stop bit.
Line 2 changes the baudrate to 19200 baud.
Note that you have to use the 192 program after the mode command, otherwise the baudrate will be changed back to the low value.
If you want to use another COM port you just substitute the parameter in the 192 command to the proper value (192 2) for COM2 etc.

4.5.1 REMOTE CONTROL PROGRAM

In order to control the TERRALOC from a computer you can use the program "REMOTE". It will give you the same control as you have from the front panel keyboard but instead you use the computer keyboard. The program uses the serial port COM1 of the PC. Since Turbo Pascal does not support communications very well a software package from Blaise Computing Inc has been used to handle the com port. This software is installed in memory prior to the Turbo Pascal program and is used by the program via MS-DOS interrupt calls.

NOTE: It is absolutely required that the communications software is installed before you try to run this program. If not you will get an error message and exit from the program. The software is installed with the command "LCOM" and removed if not needed with the command "LCOM /R".
On the demo disk there is a batch file called com.bat that takes care of this when you want to run REMOTE.

The REMOTE program operates in two steps: first you are requested to accept or alter the communication parameters of the COM1 port. They are to be set equal to what has been set on the TERRALOC.
Then you are free to use the keyboard to control the TERRALOC. The cursor move keys (ARROWS) on the PC will operate just as the ARROW keys on the TERRALOC. The special keys (MEN, COP etc.) are copied on the PC function keys F1 to F10 as displayed on screen. ENT can also be transmitted if you press the RETURN key on your PC keyboard.

Since the listing of this program is quite long it is not printed here. If you want to examine the code you can print the source file REMOTE.PAS on the demo disk.

4.5.2 DISK READ AND PRINT PROGRAM

The "TLOC3.PAS" program will read data files created by TERRALOC and plot the traces on screen. It will also print them sideways on a matrix printer. The printer must be connected and switched on for the program to operate.

The source code uses two include files (READDIR.DOS and SIDEWAY.PAS). They contain the procedures used for locating the TERRALOC datafiles and printing traces sideways on the printer (see sections 4.5.2.1 and 4.5.2.2).

In the main source you will find the following procedures:

Getdatafile	-	Select the TERRALOC data file and read the header part
Unpackpicks	-	Convert timepicks from strings to integer format
Readtraces	-	Read the trace data into an array
PlotTimeMark	-	Plot the timemarks on the traces
Normalize	-	Normalize the size of a trace
AGC	-	Perform a digital AGC function on a trace
Plot traces	-	Plot all traces of a record on the screen after AGC processing with a variable area trace type. Include the time marks and print sideways on printer.

Tloc3 source (1)

```
{This is a TURBO Pascal program}
PROGRAM Tloc3; { Will read terraloc datafiles from disk and display on
                 the computer screen.
                 Originated 86 10 29 by Bo Berglund, ABEM Sweden
                 Last modification 87 03 20 BB }
CONST  maxEntries = 20;
(*$I readdir.dos *)
(*$I sideway.pas *)

TYPE
{  tracedat  = array [1..1024] of INTEGER;  defined in sideway.pas}
   charr     = array [1..8] of CHAR;
   header    = record
                 rec_id      : array [1..15] of CHAR;
                 rec_no      : charr;
                 date        : charr;
                 time        : array [1..7] of CHAR;
                 shot_pos    : charr;
                 lay_strt    : charr;
                 lay_end     : charr;
                 profile     : charr;
                 note        : array [1..14] of CHAR;
                 operator    : charr;
                 rec_time    : array [1..3] of CHAR;
                 delay       : array [1..6] of CHAR;
                 mode        : array [1..3] of CHAR;
                 noise_gate  : array [1..4] of CHAR;
                 filter      : array [1..3] of CHAR;
                 gains       : array [1..24,1..4] of CHAR;
                 shots       : array [1..5] of CHAR;
                 assign      : array [1..24,1..7] of CHAR;
                 shot_trace  : array [1..24,1..5] of CHAR;
                 timepick    : array [1..24,1..5] of CHAR;
                 num_trace   : array [1..4] of CHAR;
                 leftover    : array [1..1424] of BYTE
               end;

VAR
  rechead : header;
  trace   : array [1..24] of tracedat;
  cnt, trnum, numchan  : integer;
  ch, a   : char;
  fname, path   : string [25];
  seis    : file of header;
  seistr  : file;
  timespicked : array [1..24] of integer;
```


Tloc3 source (2)

```
PROCEDURE Getdatafile; { Get name of data file, open and read header }
  VAR
    dir : ListOfFiles;
    i, entries : INTEGER;
  BEGIN
    GotoXY (0,5);
    REPEAT
      Writeln,('Select Terraloc file to use for display:');
      Writeln;
      REPEAT
        Write ('Enter file path (disk:\dir\subdir\subdir etc) = ');
        Readln (path);
        i := Length(path);
        IF i > 0 THEN
          IF path[i] <> '\' THEN path := path + '\';
        {Find and select datafile }
          IF Length (path) > 0 THEN
             ReadDir (path + '*.abm', entries, dir)
          ELSE
             ReadDir ('*.abm', entries, dir);
        UNTIL entries <> 0;
      FOR i := 1 TO entries DO Writeln (i, ':  ',dir [i]);
      Writeln;
      REPEAT
        Write ('Enter file selection (row number)= ');
        Readln (i);
      UNTIL (i > 0) AND (i < entries + 1);
      fname := path + dir [i];
      Assign (seis, fname);
      Writeln ('Looking for file ', fname);
(*$I-*)
      Reset (seis);
    UNTIL IoResult = 0;
(*$I+*)
      Read (seis, rechead);
      Close (seis);
  END;

FUNCTION Numberofchannels : INTEGER; {Determine number of
                                      channels in seisrecord}
  VAR
    i,j,fel : integer;
  BEGIN
    Val(rechead.num_trace,j,fel);
    NumberofChannels := j;
    Writeln ('Record contains ',j,' traces');
  END;

FUNCTION NumShots : INTEGER; {Determine number of stacks made }
  VAR
    i, j : INTEGER;
  BEGIN
    Val (rechead.shots, i, j);
    NumShots := i
  END;

PROCEDURE UnpackPicks; {Will unpack string values into integer format
                        values stored in array timespicked}
  VAR
    i, err : INTEGER;
  BEGIN
    FOR i := 1 TO 24 DO
        Val(rechead.timepick[i],timespicked [i],err);
  END;
```

Tloc3 source (3)

```
PROCEDURE Read_traces (numch : integer); {Read all traces into array}
  VAR cnt, i : integer;
  BEGIN
    Assign (seistr, fname);
    Reset (seistr);   {Prepare for blockread }
    BlockRead (seistr,trace[1],16); {Dummy read to get past record header}
    FOR cnt := 1 TO numch DO BlockRead (seistr, trace [cnt],16);
    Close (seistr);
  END;

PROCEDURE PlotTimeMark(trace, x_pos, delta: integer); {Plot timemarks on traces}
  VAR x, y, z : integer;
  BEGIN
    x := x_pos - 7;
    y := timespicked [trace] div delta;
    draw (x, y, (x+14), y, 3);
  END;

PROCEDURE Normalize (VAR Trace : tracedat; level : BYTE);
  VAR  i, j, max   : INTEGER;
      konst       : REAL;
  BEGIN
    max := 0;
    FOR i := 1 TO 1024 DO IF Abs(Trace[i]) > max THEN max := Abs(Trace[i]);
    konst := level / max;
    FOR i := 1 TO 1024 DO Trace[i] := Trunc(konst * Trace[i]);
  END;

PROCEDURE Agc (VAR Tr:tracedat; level, window, mute : INTEGER);
  VAR a,i,j     : INTEGER;
      sum, mean, scale : REAL;
      t       : tracedat;
  BEGIN
    sum := 0;
    FOR i := 1 TO window DO sum := sum + Abs (Tr[i]);
    mean := sum / window;
    IF mean < 2 THEN scale := level / 2
                ELSE scale := level / mean;
    FOR i := 1 TO window DIV 2 DO t[i] := Trunc(scale * Tr[i]);
    FOR i := window+1 TO 1024 DO
      BEGIN
        sum := sum - Abs(Tr[i-window]) + Abs(Tr[i]);
        mean := sum / window;
        IF mean < 2 THEN
              t[i-(window DIV 2)] := Trunc(level/2.0*Tr[i-(window DIV 2)])
          ELSE t[i-(window DIV 2)] := Trunc(level/mean*Tr[i-(window DIV 2)]);
      END;
    IF mean < 2 THEN scale := level / 2
                ELSE scale := level / mean;
    FOR i:=1024-(window DIV 2) TO 1024 DO t[i] := Trunc (scale * Tr [i]);
    FOR i := 1 TO mute - (window DIV 2) DO t[i] := 0;
    i := 1;
    WHILE i < window DIV 2 DO
      BEGIN
        scale := i * 2.0 /window;
        a := mute - (window DIV 2) +i;
        IF a > 1024 THEN a := 1024;
        scale := scale * t[a];
        t[a] := Trunc(scale);
        i := i + 1;
      END;
     Tr := t;
    END;
```


Tloc3 source (4)

```
PROCEDURE Plot_traces (num : integer); { Plot num traces on screen }
  VAR offset, i, j, max, step, x1, x2, x, y, numsh : integer;
  BEGIN
    HiRes;
    HiResColor (white);
    FOR j := 1 TO num DO
      BEGIN
        Agc (trace[j],4,150,timespicked[j]);
{        Normalize (trace[j], 15);    switch between AGC and Normal here}
        offset := 25 * j;
        step := 4;
        max := 50;
        x2 := offset;
        y := 1;
        i := 1;
        WHILE (i < 1024) AND (y < 199) DO
          BEGIN
            numsh := NumShots;
            x1 :=  trace [j,i] {DIV numsh};
            IF x1 > max THEN
                x := offset + max
              ELSE
                IF x1 < - max THEN
                  x := offset - max
                ELSE
                  x := offset + x1;
            IF x1 > 0 THEN
               Draw (offset,y,x,y,1)
            ELSE
               {  Draw (x2,y,x,y,1);   }
              Plot (x, y, 1);
            y := y + 1;
            i := i + step;
            x2 := x;
          END; { WHILE i }
        PlotTimeMark (j, offset, step);
        Side ( trace [j] );
      END; { FOR j }
  END;


BEGIN
  InitPrint;          { prepare for printing of traces }
  REPEAT
    TextMode;
    ClrScr; GotoXY (1,10);
    Getdatafile;
    numchan := NumberofChannels;
    Read_traces (numchan);
    UnpackPicks;
    Plot_traces(numchan);
    Read (kbd, a);
  UNTIL a in ['q', 'Q'];
  ExitPrint;                  { dump print buffer and reset printer }
  TextMode;
  GotoXY (20,13);
  Writeln ('DEMO: Terraloc Plot ended.');
END.
```

4.5.2.1 READ DISK DIRECTORY PROCEDURE

The include file "READDIR.DOS" contains the procedure ReadDir which is used by TLOC3 to locate the datafiles in the given disk and directory.

The procedure is called with the following parameters:

SearchStr - a string which is an MS-DOS discriptor of the wanted file. In the TERRALOC case it may be the string "d: R*.ABM" if you are using an external 3.5" drive as drive d:.

n - an integer which is returned to the calling program with the number of file matches found.

dir - an array of matching filenames returned to the calling program.

A number of MS-DOS function calls are made to perform the directory search.

```
{Turbo Pascal code}

{READDIR.DOS}
{This is an include file to read the MS-DOS file directory}

(* CONST maxEntries = 256;*) (* maxEntries must be set in calling program *)

TYPE FileName = STRING(.12.);
     ListOfFiles = ARRAY(.1..maxEntries.) OF FileName;
     FileNameString = STRING(.64.);

PROCEDURE ReadDir (searchStr: FileNameString;
                   VAR n:INTEGER; {number of files matching searchStr}
                   VAR dir: ListOfFiles); {output list of filenames}

CONST nul       = #0;
      attribute = $01; (* Fileattribute MS-DOS/PC-DOS *)

TYPE RegsInterpret = (oneByte,twoBytes);
VAR regs8086: RECORD CASE RegsInterpret OF
                 oneByte : (al,ah,bl,bh,cl,ch,dl,dh: BYTE);
                 twoBytes: (ax,bx,cx,dx,bp,si,di,ds,es,flags: INTEGER);
               END;

    dta: RECORD
             info1: ARRAY(.1..30.) OF BYTE;
             fn: ARRAY(.1..13.) OF CHAR;
             info2: ARRAY(.1..45.) OF BYTE
         END;

    oldDTA: RECORD
              segDTA,ofsDTA:INTEGER;
            END;

    done: BOOLEAN;
```


READDIR.DOS code (2)

```
PROCEDURE CheckDosVersion;
CONST getDosVer = $30; (* MS-DOS *)
      bel = #7;
BEGIN
   WITH regs8086 DO BEGIN
      ah:= getDosVer;
      MsDos(regs8086);
      IF al < 2 THEN BEGIN
         WriteLn(bel,'Incorrect MS-DOS version!');
         Halt;
      END;
   END (* WITH *);
END (* CheckDosVersion *);

PROCEDURE StoreDTA; (* Save old DTA-address *)
CONST getDTA = $2F;  (* MS-DOS*)
BEGIN
   WITH regs8086 DO BEGIN
      ah:= getDTA;
      MsDos(regs8086);
      oldDTA.segDTA:= es; oldDTA.ofsDTA:= bx;
   END (* WITH *);
END (* StoreDTA *);

PROCEDURE SetDTA(segDTA,ofsDTA:INTEGER); (* Set new DTA *)
CONST setDTA = $1A;
BEGIN
   WITH regs8086 DO BEGIN
      ah:= setDTA;
      ds:= segDTA; dx:= ofsDTA;
      MsDos(regs8086);
   END;
END (* SetDTA *);

PROCEDURE PrepareASCIIZString;

VAR zeroPos:INTEGER;
BEGIN
   zeroPos:= Length(searchStr);
   IF zeroPos < (SizeOf(FileNameString)-1) THEN zeroPos:=Succ(zeroPos);
   searchStr(.zeroPos.):= nul;
END (* PrepareASCIIZString *);


PROCEDURE GetFirstFile(VAR done:BOOLEAN);

CONST findFirst = $4E; (* MS-DOS *)
BEGIN
   WITH regs8086 DO BEGIN
      ah:= findFirst;
      cx:= attribute;
      ds:= Seg(searchStr);
      dx:= Ofs(searchStr)+1;
      MsDos(regs8086);
      done:= (al=0);
   END (* WITH *);
END (* FirstFileFound *);
```

READDIR.DOS code (3)

```
   PROCEDURE GetNextFile(VAR done:BOOLEAN);

   CONST findNext = $4F; (* MS-DOS *)
   BEGIN
      WITH regs8086 DO BEGIN
         ah:= findNext;
         MsDos(regs8086);
         done:= (al=0);
      END (* WITH *);
   END (* NextFileFound *);

   PROCEDURE ExtractFileName;
   VAR i: INTEGER;
       fname: STRING(.12.);
   BEGIN
      WITH dta DO BEGIN
         fname:='';
         i:= 1;
         WHILE fn(.i.) <> nul DO BEGIN
            fname(.i.):= fn(.i.);
            i:= Succ(i)
         END;
      END (* WITH *);
      fname(.0.):= Chr(i - 1);
      dir(.n.):= fname
   END (* ExtractFileName *);

BEGIN (* ReadDir *)
  WITH regs8086 DO BEGIN
     CheckDosVersion;           { ReadDir does not work on DOS 1.X }
     StoreDTA;                  { Save present DTA-address }
     SetDTA(Seg(dta),Ofs(dta));
     PrepareASCIIZString;
     n:= 0;
     GetFirstFile(done);
     WHILE done DO BEGIN
       n:= Succ(n);
       ExtractFileName;
       GetNextFile(done);
       IF n = maxEntries THEN done:= FALSE;
     END;
     SetDTA(oldDTA.segDTA,oldDTA.ofsDTA); { Restore previous DTA }
  END (* WITH *);
END (* ReadDir *);
```


4.5.2.2 PRINT TRACES SIDEWAYS PROCEDURES

The include file "SIDEWAY.PAS" contains the procedures neccessary for TLOC3 to print trace data sideways on a matrix printer. This function can be used to prepare a reflection section with a number of records plotted side-by-side on the printer.

The following procedures are included:

PrintLine	-	Prints one graphic line from the print buffer and updates the zero position in the buffer.
Side	-	Plots the ind array of values into the buffer and then prints one graphic line.
InitPrint	-	Initializes the printer in graphic mode for sideways printing. Resets printbuffer and plots graticule into buffer.
ExitPrint	-	Empties the print buffer contents to the printer. Prints final graticule and resets printer. Feeds paper to top-of-form.

```
{This is a TURBO Pascal program}

{SIDEWAY.PAS}
{ This is an include file for sideways printing of seismic traces
  Program written by Bo Berglund, Atlas Copco ABEM, SWEDEN
  Copyright 1987}

TYPE  tracedat  =  ARRAY [1..1024] OF INTEGER;

VAR   buf      :  ARRAY [0..8, 1..960] OF BYTE;   { Printer buffer, circular }
      zeroPos  :  INTEGER;                        { Pointer to buffer zero }
      grStrt   :  STRING[4];                      { Printer graphic command }

CONST pattern  :  ARRAY [0..7] OF BYTE = (128, 192, 224, 240, 248, 252, 254, 255);
      negpattern : ARRAY [-7..0] OF BYTE = (128, 64, 32, 16, 8, 4, 2, 1);
      fill     :  BYTE = 255;
      graphLine : INTEGER = 960;

PROCEDURE PrintLine;        {Prints one graphic line from print buffer, updates
                             buffer zero line pointer}
  VAR i, lnr : INTEGER;
      ch : CHAR;
  BEGIN
    lnr :=  zeroPos - 4;
    Write (lst, #27);   {Send graphic control command}
    IF graphLine > 480 THEN Write (lst,'L')
                       ELSE Write (lst,'K');
    Write (lst,Chr(graphLine MOD 256),Chr(graphLine DIV 256));
    FOR i := graphLine DOWNTO 1 DO
      BEGIN
        Write (lst, Chr(buf [lnr MOD 9, i]));
        buf [lnr MOD 9, i] := 0;
      END; { FOR i }
    Writeln (lst);
    zeroPos := zeroPos + 1;
  END; { procedure }
```

SIDEWAY.PAS code (2)

```
PROCEDURE Side (VAR Ind : tracedat);  {Plots Ind to buf at present position of
                                       zeroPos pointer then prints one line}
  VAR bytAdr, i  :  INTEGER;
      dots       :  BYTE;
  BEGIN
    FOR i := 1 TO graphLine DO
      BEGIN
        IF Ind[i] > 31 THEN  Ind[i] := 31
                      ELSE IF Ind[i] < -31 THEN Ind[i] := -31;
        IF Ind[i] < 0 THEN BEGIN
                      Ind[i] := Ind[i] - 7; {adjust for DIV operation}
                      dots := negpattern [Ind[i] MOD 8];
                      END
                    ELSE dots := pattern [Ind[i] MOD 8];
        bytAdr := Ind[i] DIV 8 + zeroPos;
        buf[bytAdr MOD 9, i] := buf[bytAdr MOD 9,i] OR dots;
        IF Ind[i] > 7 THEN
          BEGIN
            bytAdr := bytAdr -1;
            WHILE bytAdr >= zeroPos DO
              BEGIN
                buf[bytAdr MOD 9,i] := fill;
                bytAdr := bytAdr -1;
              END; {WHILE}
          END; {IF}
      END; {FOR i}
    PrintLine;
  END;  { procedure }

PROCEDURE InitPrint;   {Initializes graphic sideways printing}
  VAR i, j : INTEGER;
  BEGIN
    zeroPos := 13;      {Reset pointer}
    FOR i := 1 TO graphLine DO FOR j := 1 TO 8 DO buf [j,i] := 0;
    FOR i := 1 TO graphLine DO buf[0,i] := pattern [0];
    FOR i := 0 TO (graphLine DIV 10) DO  buf[0,10*i+1] := pattern [7];
    FOR i := 0 TO (graphLine DIV 100) DO  buf[1,100*i+1] := fill;
    Write (lst, #27, 'A', #8, #27, '2');   {Set linefeed to one char height}
    Writeln (lst);
  END;  { procedure }

PROCEDURE ExitPrint;   {Empty print buffer, print graticule, reset printer}
  VAR  Tr : tracedat;
       i  : INTEGER;
       ch : CHAR;
  BEGIN
    FOR i := 1 TO 4 DO PrintLine;
    FOR i := 1 TO graphLine DO buf[zeroPos MOD 9,i] := pattern[0];
    FOR i := 0 TO (graphLine DIV 10) DO buf[(zeroPos-1) MOD 9, 10*i+1] := fill;
    FOR i := 0 TO (graphLine DIV 100) DO buf[(zeroPos-2) MOD 9, 100*i+1] := fill;
    FOR i := 1 TO 5 DO PrintLine;
    Write (lst, #27,'A',#12, #27, '2');            {Normal line spacing}
    Write (lst, #12);                   {formfeed}
  END;  { procedure }
```


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PERIPHERALS AND ACCESSORIES FOR THE TERRALOC

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5. ACCESSORIES

The TERRALOC cannot by itself operate and make measurements. A few accessories are needed, and these are described in this chapter of the manual. The accessories covered range from system power supplies over the printer options to field accessories such as geophones, cables, trig circuits and energy sources.

5.1 POWER SUPPLY

The Terraloc and the field printer both operate on +12 V battery power. The battery has to be connected to both units with the supplied power cables (orange). See Fig. 5.1-1 for details.

The battery voltage must not be below 10 V at a current of 4 amperes or above 20 V. Within these limits the system will work properly, but the printer will print slightly faint records with low voltage batteries.

If you use a car battery as power source you should use the adaptor cable with two heavy duty crocodile clips, one red and the other black. The red clip is connected to the positive terminal and the black one to the negative terminal of the battery. Then the ordinary power cables are connected to the extension socket connectors on the adaptor cable.

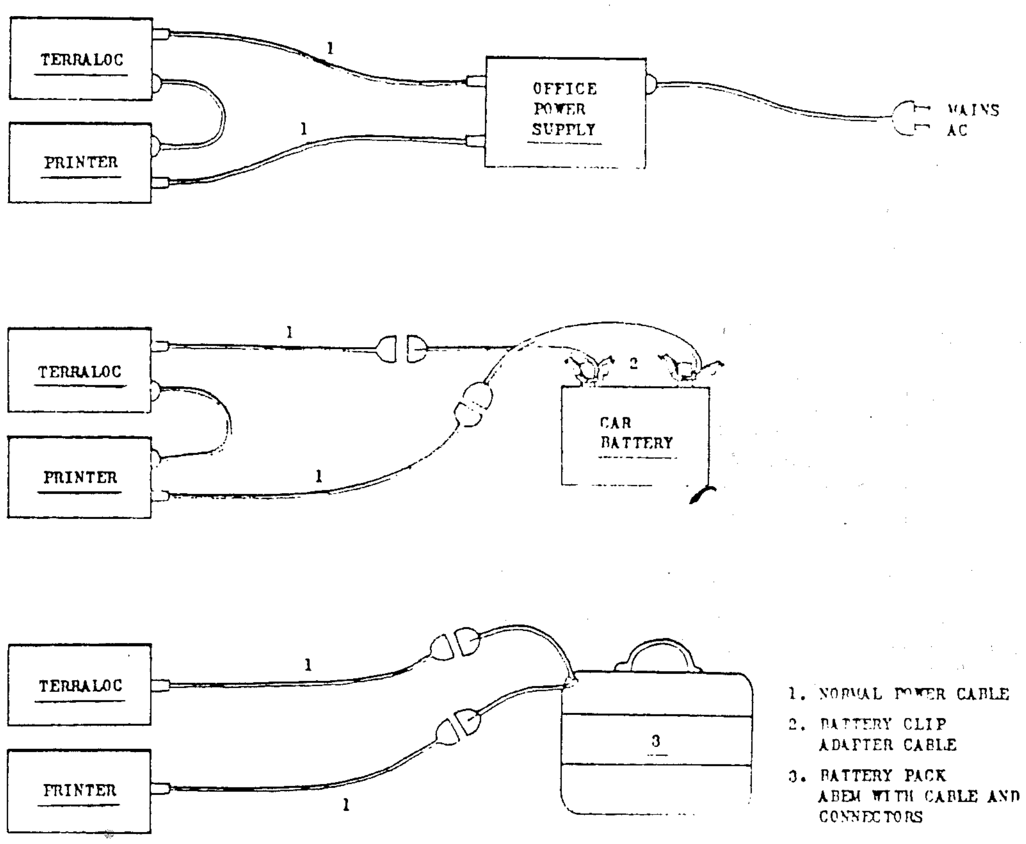


Fig. 5.1-1 Power connections

5.1.1 CHARGING BATTERIES

Depending on the type of batteries used charging methods vary considerably. If you purchased your batteries from ABEM with the Terraloc you will also have received a mains operated battery charger.

To charge your batteries you connect them to the charger using the ordinary power cable (orange) and then you plug the charger into the mains outlet (first you have to check the voltage switch on the battery charger to make sure that it matches the mains voltage in the area).

IMPORTANT NOTICE:

Whenever you are charging the batteries they must be disconnected from the Terraloc.

5.1.2 BATTERY VOLTAGE SUPERVISION

The Terraloc is constantly measuring the battery voltage during operation and will send a warning ("Battery low") if this voltage drops below 11 Volts. This will tell you to finish your work and replace the batteries with freshly charged ones.

The Terraloc will automatically switch off if the battery voltage drops below 8 V or increases above 21 V. This protection is built into the power supply electronics and is independent from the Terraloc computer circuitry. Once tripped the switch-off can only be removed by switching off the main power switch, replacing the low battery and then switching on again.

5.1.3 POWER CONNECTOR

The battery power is connected to the Terraloc via a 3-pole heavy duty Cannon XLR-connector.

The positive voltage is applied to pin 3 and negative to pin 1. If the voltage is reversed the Terraloc will not operate due to internal protection circuitry. No damage will be done so you have only to reverse battery polarity should this happen.

5.2 OFFICE POWER SUPPLY

In the office you do not have to operate the Terraloc from batteries. You can use the office power supply that was delivered with the Terraloc. In order to use the supply you must do the following:

1. - Check the mains power voltage and set the voltage selector on the office power supply accordingly. The voltage values allowed are
   110-120 V and 220-240 V AC (50 or 60 Hz)

2. - Connect Terraloc and printer using the ordinary orange power cables

3. - Switch on the office power supply and check that all indicator lamps are lit

4. - Switch on Terraloc and check that the indicator lamps on the power supply stay lit and that the indicator lamp on the Terraloc itself lights up.

Note: The office power supply can only by used indoors and should never be connected during measurements since it introduces hum noise into the sensitive amplifier inputs.

5.3 PRINTER OPERATION

The TERRALOC can make printed records of measurements and screen copies using either the TERRALOC Field Printer or an office printer. (See section 3.7.3)

5.3.1 CONNECTING THE FIELD PRINTER TO TERRALOC

The hardcopy printer used to print out the processed waveform data and survey parameters for filing purposes is a separate unit. It must be properly connected to the power source and the TERRALOC field unit and switched on to operate. The printer is then completely controlled by the TERRALOC computer and all printing commands are entered there.
The printer is connected to the TERRALOC seismograph by one multilead cable which carries the data to be printed. The printer is powered via a separate power cable to the same battery that supplies power to the TERRALOC itself. See fig 5.3-1.

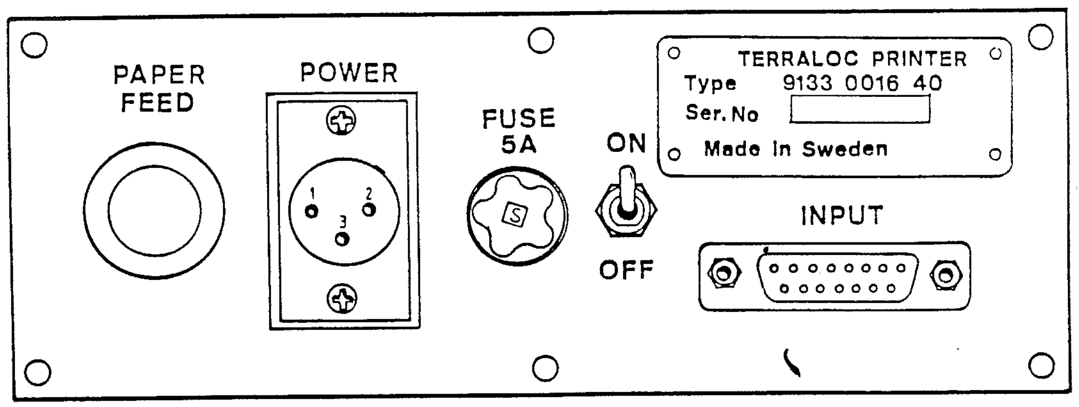


Fig. 5.3-1 Printer connector panel

5.3.2 OPERATING THE FIELD PRINTER

To operate the printer the main power ON/OFF switch located in the cable connector recess on the side of the printer case must be switched on. The printer will be switched on and off by TERRALOC as necessary when printouts are made. It is accomplished through the use of a switch-on circuit in the data cable.
There is one operator control on the printer: a paper feed control pushbutton located in a recess. To feed blank paper you merely push this button.

5.3.3 MAKING A HARDCOPY OF THE RECORDED WAVEFORMS

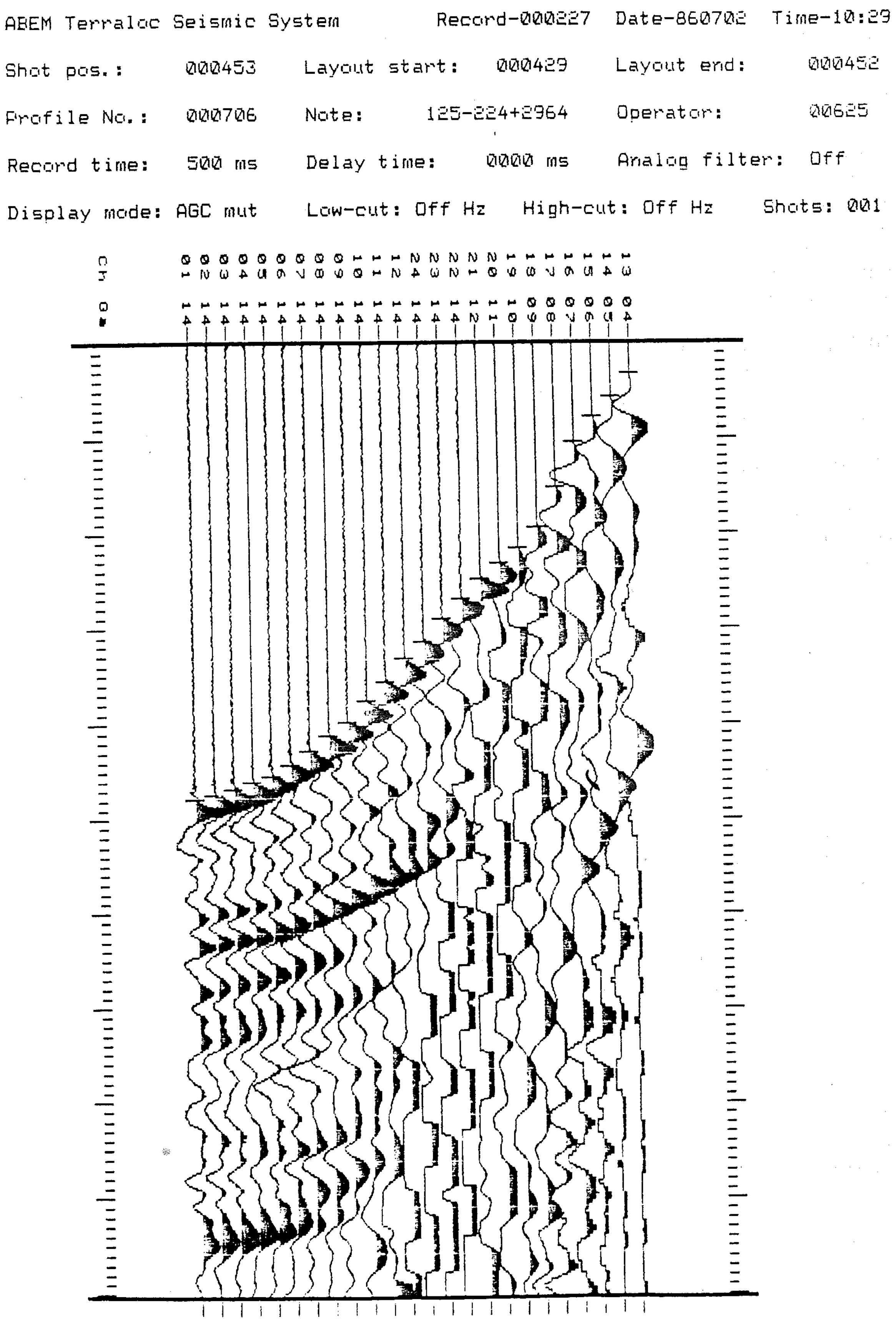
There are three printing modes possible with the TERRALOC/PRINTER combination:

- PRINTING OF THE ENTIRE SIGNAL STACK contents. This is started by pressing the PRINT key on the TERRALOC. The printout (see Fig. 5.3-1) will contain an information header with the instrument setup parameters, survey parameters, time and date etc. The waveform printout will be made according to the processing selected on Menu 3. The waveform part of the printout will also contain 200 evenly spaced timing lines, thus permitting accurate timing estimates to be made from the printout. (These may be switched off by the operator, see 3.7.4). The record thus obtained will then serve as complete documentation of the measurement.
  A printout that will also contain the picked arrival times as small markers on the traces can be made. The procedure to do so is described in section 3.6.5.3.

- COPYING THE CRT CONTENTS. This is started by pressing the COPY key on the TERRALOC. The content of the CRT screen will then be printed exactly as it is displayed. This function permits the operator to make hard copies of selected parts of the waveform and to document picked arrivals.

- AUTOMATIC PRINTING OF ALL RECORDINGS FROM DISK. This operation is started from menu 4 as described in section 3.8.4. The printouts will be made using the processing selected on Menu 3. The printing process will continue record after record until there are no more recordings on disk or the paper runs out.

Fig 5.3-1 A typical TERRALOC printout with automatically picked first arrivals displayed as short marks.



5.3.4 LOADING PAPER

The paper roll is fastened with a spring loaded retainer as shown in Fig. 5.3-2. To replace the roll, proceed as follows:

1. Switch off the PRINTER power.
2. Remove the old empty paper reel and move it to the takeup hub (A).
3. Cut about 2 turns of paper from the new roll to remove any residue from the sticker seal.
4. Place the new roll in place in the holder (B).
5. Operate the lever (C) on the printer to open the paper feed channel (D).
6. Insert the leading end of the paper into the paper feed slot (E).
7. Turn the paper feed knob (F) until the paper appears under the printhead (G).
8. Pull about 30 cm paper out of the printer.
9. Align the paper so that it is fed straight.
10. Release the printer lever (C) to close the paper channel.
11. Stick the paper end to the takeup reel using adhesive tape.
12. Switch on the PRINTER power.
13. Operate the paper feed pushbutton in the connector recess of the PRINTER to feed paper, and check to see that it is fed straight and taken up properly.

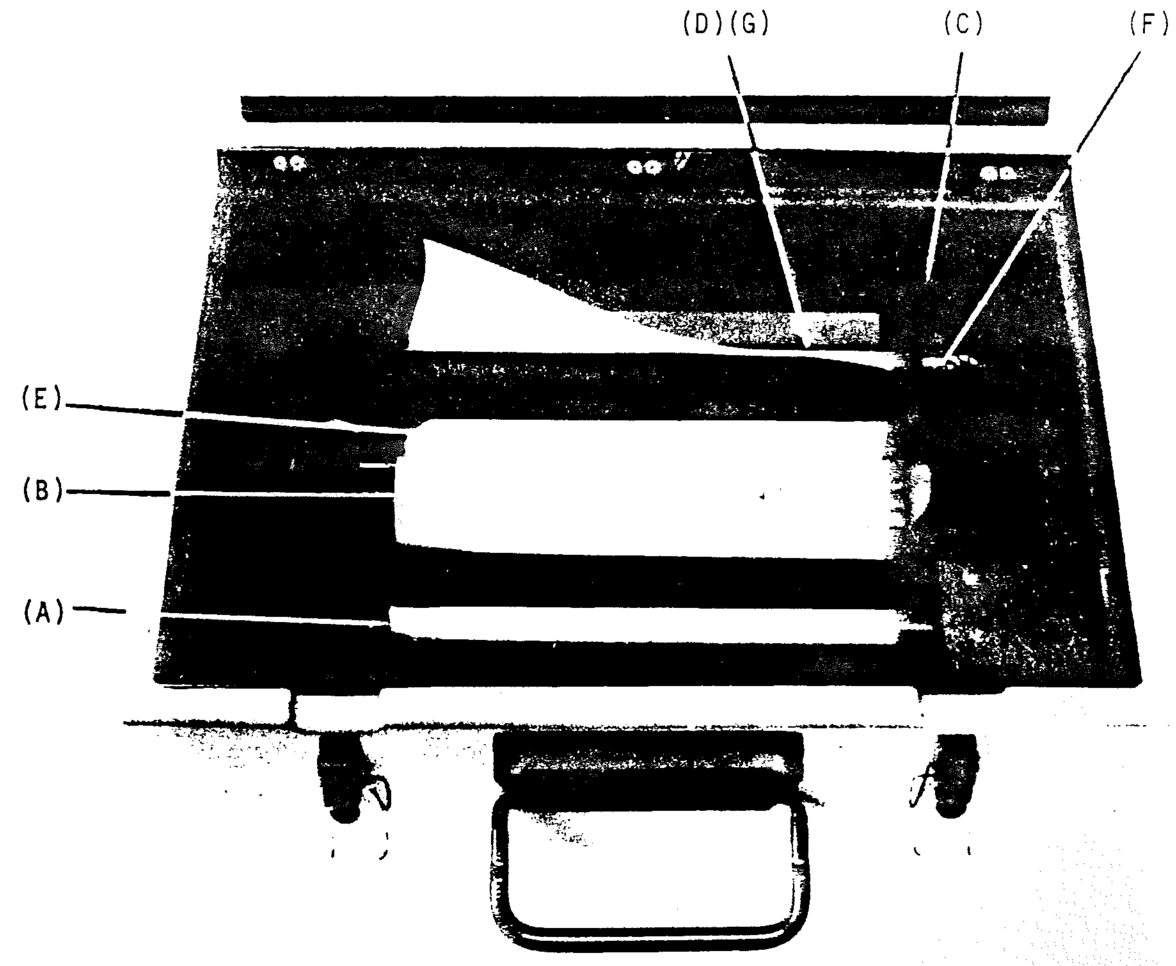


Fig. 5.3-2 Printer paper feed system

5.4 GEOPHONE SPREAD CABLES

The TERRALOC seismograph can use any geophone spread cables with a Cannon NK-27-21C connector connected according to Fig. 5.4-1.

ABEM supplies a cable set designed for efficient field work (described in section 2.3).

For 24-channel work it consists of two 12-channel spread cables with 12,5 m between the takeouts and a connector at each end and two 12-channel extension cables, one short (60 m) and one long (160 m).

Using this cable set it is possible to record two full 24-channel layouts without moving the TERRALOC.

The connectors on these cables are all provided with protective caps to keep dirt from clogging the connector pins and sockets. It is strongly recommended that these caps are fastened before every cable move to ensure reliable operation of the cables.

Pin No.	Channel	Pin No.	Channel
1	1	15	8
2		16	
3	2	17	9
4		18	
5	3	19	10
6		20	
7	4	21	11
8		22	
9	5	23	12
10		24	
11	6	25	not connected
12		26	
13	7	27	not connected
14			

Fig. 5.4-1 Connection table for spread cable set

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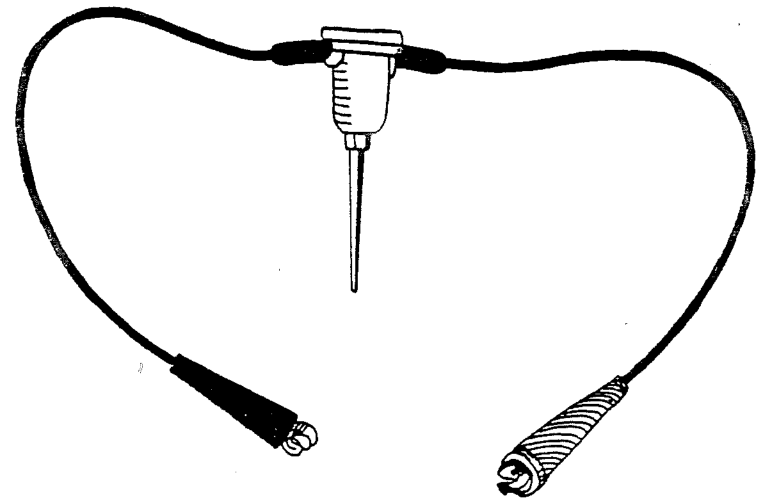
5.5 STANDARD GEOPHONES

The geophones supplied with the TERRALOC seismograph are vertical sensitive with a 10 Hz cut-off frequency. They are polarized with one narrow and one wide clip that matches the takeouts on the spread cables. This ensures proper connection polarity each time.

Geophone data:

Natural frequency:	10 Hz
Frequency tolerance:	.5 Hz within 25° tilt from vertical
Coil resistance:	375 ohms 5%
Sensitivity:	290 mVsec/cm
Damping:	84 % with 640 ohms load
Weight (moving mass):	11 g
Weight (total):	130 g
Temperature limits:	-40°C to +100°C



5.6 SYSTEM TRIGGER OPTIONS

To make a recording with the TERRALOC seismic system an initiating trigger signal is required. The trigger defines the impact instant and is the reference for all timing.

To facilitate for the TERRALOC operator the seismograph is provided with circuitry for several different types of trig sources: (See Fig. 5.3-1.)

- Trigger geophone
- Make or break switch
- Transistor detector
- Tone carrier for radio transmission.

The tone trig input is pin A and the geophone/switch input is pin B of the trig input connector. Ground is pin D.

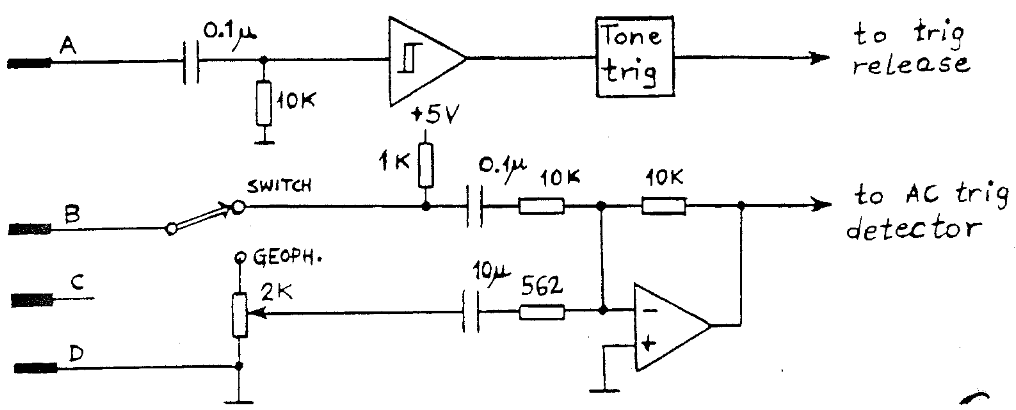


Fig. 5.6-1 Simplified diagram for the trig circuit.

5.6.1 TRIGGER GEOPHONE INPUT WITH SENSITIVITY CONTROL

A standard geophone planted close to the impact point provides a pulse when the impact wave starts propagating in the ground. To operate with a trig geophone the toggle switch next to the trigger connector has to be in the "Geoph." position. The input for this type of trig source is provided with a sensitivity control for adjustment of the trig level. The level is adjusted so that ground noise does not trigger the TERRALOC.

The trig cable reel has stainless steel posts for connection of a standard geophone as the trig source. Internal circuitry with full wave rectification ensures proper triggering from the front part of the pulse irrespective of how the trig geophone was connected.

5.6.2 MAKE OR BREAK SWITCH INPUT WITH INTERNAL BIAS

When the toggle switch next to the trigger input connector is in the "switch" position a +5V bias is supplied to the trigger cable over a 1K internal resistance.

The system will trigger if the leads of the trigger cable are shorted together (make switch). A break switch can also be used since the TERRALOC will also trigger on shorted leads opening.
When you use explosives one trigger method is to put a few turns of wire around the charge. The wire is cut by the explosion and triggers the seismograph.
You can also twist a pair of insulated wires together and insert the twisted part into the dynamite. The explosion will compress the wires and crush the insulation causing the leads to short together. This will trigger the TERRALOC.

5.6.3 SHOT CURRENT DETECTOR FOR EXPLOSIVES

If you want to trig the TERRALOC on the ignition current going out to the charge you can use the small current detector unit supplied with the TERRALOC accessories. See Fig. 5.3-2. To use this you merely feed one of the two shot leads through the small hole in the detector unit. The detector is either connected directly to the trig input or to the extension connector on the trig cable reel. Then the TERRALOC is put in the "Geophone" trig mode with the sensitivity control at about 50 %. When the charge is fired the ignition current will trig the TERRALOC at once. Note that you need to use seismic caps with no built-in delay to be able to use this method. If you use ordinary blasting caps the ignition delay will be included in your record. There are seismic caps of the safety type available from NITRO NOBEL. Their delay is only some 50 us if fired with the high power NITRO NOBEL blaster.
The current pickup trig method is very convenient since you only need to bring one cable to the shot hole.

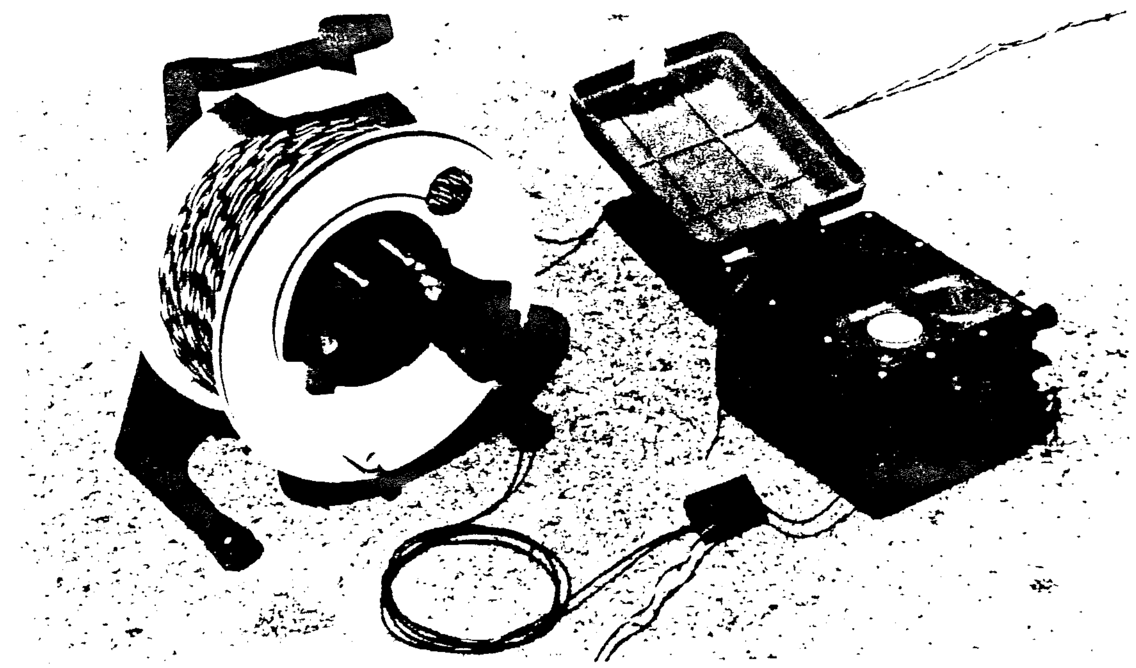


Fig. 5.6-2 Trig cable reel with steel posts and current pickup unit.

5.6.4 TONE DETECTOR INPUT

To enable transmission over radio of the trigger pulse a detector for tone interruption is built into the TERRALOC. The system will trigger when the 2kHz tone is interrupted. Trigger will occur within 600 us of the interruption time.

The tone must be present before the ARM key is pushed. Subsequent tone interruption will immediately cause a trigger of the TERRALOC.

5.6.5 FRONT PANEL TRIG SWITCH

When the front panel trig switch is pushed the TERRALOC will make a record exactly as if the trig signal had been received from some true trig source. This function can be used to test the system and also to monitor the ambient field noise character.

5.6.6 RADIO TRIGGERING

In case you need to trigger the Terraloc in places where you cannot use a trig cable you can use a simple two-way radio to transmit the trig pulse.
This is done in the following way:

1. - Connect the trig geophone or other trig source to the external microphone input of the radio.

2. - Connect the external loudspeaker output of the other radio to the trig input of the Terraloc.

3. - Set the Terraloc to the Geophone trig source position and adjust the sensitivity control to a low value (10-20 % of full scale).

4. - Try several combinations of transmitter microphone sensitivity adjustment and receiver volume control setting to find the one that gives the best reception of the trig pulse with no false triggerings from radio noise.

5. - When all is ready you should set the Terraloc to collection mode "Stack once" and arm the unit only just before the shot is to be fired. In this way you minimize the possibility of receiving false trig pulses and also false triggering on after-pulses.

Note that the success of this simple method depends largely on two factors, one - the quality of radio transmission in the area with the equipment at hand and two - the careful adjustment of the signal levels both on the radios and on the Terraloc trig input sensitivity control.

5.7 SEISMIC ENERGY SOURCES

When you are using the seismic method for measurements you need a source of seismic energy that can be controlled and that produces an energy pulse of the proper size and frequency content.
The energy character varies with the type of measurement to be made. For large scale refraction work the most often used source is explosives (dynamite). However, in many places you are not allowed to use explosives and then you need an alternative which can be a mechanical source. In these cases the energy output is much lower and you need to stack several impacts to get a record with acceptable signal to noise ratio.

In shear wave studies you need a directional source which rules out explosives altogether.
When doing shallow reflection measurements a very high frequency signal is needed and you must also use a low cut filter set at a high cut off frequency.

5.7.1 EXPLOSIVES

When explosive blasting is used as the signal source a detonating shotbox is needed. ABEM supplies as an accessory a high voltage capacitor discharge shotbox made by Nitro Nobel. For further information see the separate data sheet with instructions.

5.7.2 HAMMER WITH IMPACT PLATE

For hammer seismics any heavy hammer can be used with the trigger pulse picked up by a geophone planted near the impact plate.
The supplied impact plate is made of heavy duty syntetic rubber designed for good coupling of the impact energy to the ground and long service life.

If it is required to produce very high frequency signals with the hammer the impact plate has to be replaced with a steel plate. This plate should be about 25-30 mm thick and weigh about the same as the hammer to give the best energy transfer.

With such a plate the airwave noise will be much higher and the person swinging the hammer will need some form of protection for his ears in order not to damage his hearing.

5.7.3 SHEAR WAVES

To generate shear waves a number of methods have been used. One is to drive a pole into the ground and hammer it sideways in opposite directions.
Another method is to weigh down a thick plank on the ground with a car or other heavy vehicle and then strike the ends of the plank with a hammer. Whichever way you use you should be careful to arrange the hammer such that the blows in opposite directions are as nearly identical in energy as possible. This makes it possible to distinguish S-wave energy from P-wave energy in the Terraloc using its ability to subtract or add signals during stacking.

5.7.4 WEIGHT DROPS

One way of producing a sizeable amount of energy without using explosives is by the use of a weight drop. Several methods have been in use:

1. Tripod with an iron ball elevated to about 3 m height and dropped on the ground. The ball hits an impact plate of approximately the same weight as the ball. The plate is seated in the ground by a few drops before the measurement is taken.

2. A vehicle with hoisting crane lifts an oil barrel filled with concrete to a height of several meters. The barrel is dropped directly on the ground. Such a barrel will weigh several hundred kilos and produces a lot of energy on impact.

3. Several makes of vacuum assisted weight drops have been marketed. They consist of a vacuum tube which is positioned on top of an anvil on the ground. Inside the tube is an iron piston weighing from 20 to several hundred kilos. The piston is moved to the top end of the tube and the air is pumped out to produce a vacuum inside. Then the pisten is released. It accelerates due to both gravity and the atmospheric pressure onto the anvil. The impact produces the acoustic energy used for measurements.

5.8 TERRALOC RAM DISK

The RAM disk is used for data storage in climatic conditions where 3.5" micro floppy disks do not work properly. These conditions include hot and cold temperatures, excessive humidity, dust and so on.

The RAM disk is designed to hold the same amount of data as the floppy disks but the data are stored in battery protected CMOS memory. This means that no mechanical parts are involved in reading or writing a RAM disk and it is therefore much more reliable.

5.8.1 DATA PROTECTION DURING TRANSPORTATION

You can remove the RAM disk cartridges from the slot in the seismograph and store them separately.
When the RAM disks are removed the special RAM disk protection plug shall always be connected to the disk. This plug safeguards the connector from accidental application of voltages that can erase the data on the RAM disk.
If the protection plug is not used the data in the RAM disk may be damaged.

5.8.2 COPYING DATA TO 3.5" MICRODISKS

The data on a RAM disk can be easily copied onto a normal 3.5" micro floppy disk using the command "Copy disk to:" on menu 4. See section 3.8.3.
Note that the floppy disk that is to receive the data must be formatted and contain no data. It must also be completely free of defects. To check this you can make a directory of the disk. It shall show no record and the remaining free space shall be 713 k bytes.
To operate you select the RAM disk as the active drive and use the drive number where you have inserted your empty floppy disk as the destination number in the "Copy disk to:" command.

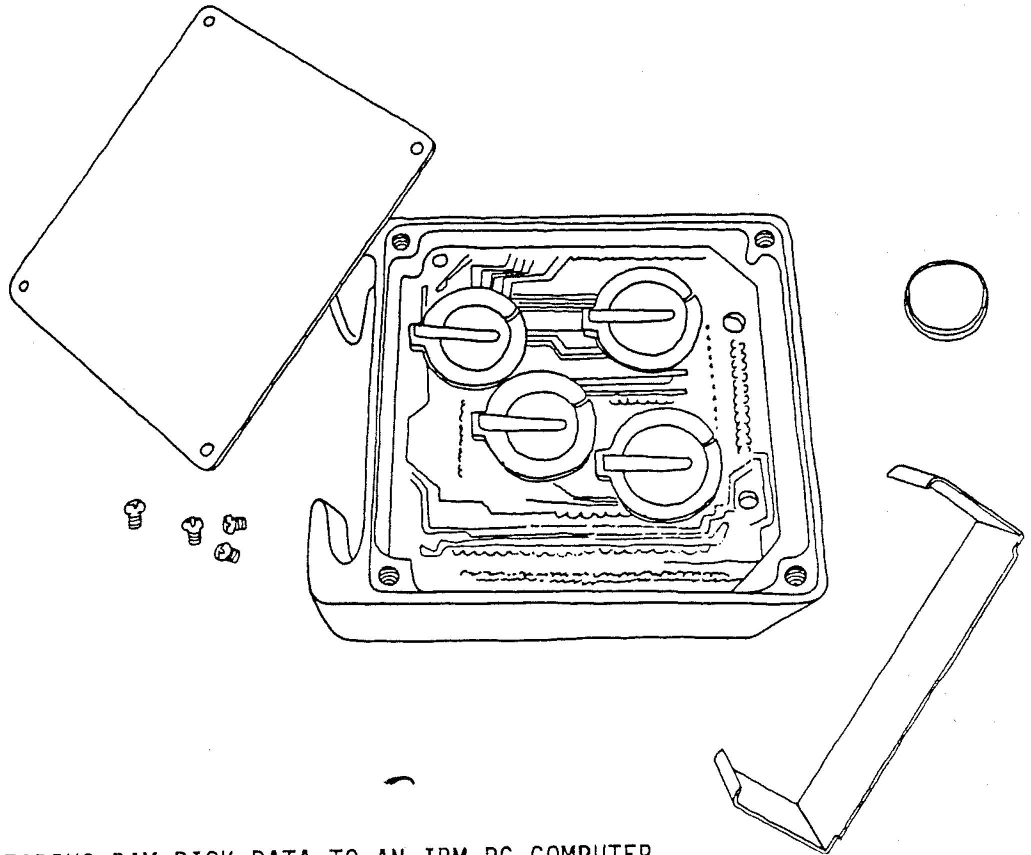
5.8.3 RAM DISK BATTERY CARE

The RAM disks are protected by 4 lithium batteries located inside the cartridge. They will supply power lasting for several years in normal conditions.
However, the power drain from the RAM circuits is temperature dependent, increasing at high temperatures.

If you expect hot conditions during a survey you will be better off if you replace the batteries before the job. The batteries are accessible if the four screws holding the cartridge side are removed.

The batteries are 3V lithium button cells with 3/4" diameter. When you change the batteries, make sure not to remove all batteries from the RAM cartridge at once. You should replace each in turn. In this way voltage is never removed from the RAM array and the data remain uncorrupted.

Fig. 5.8-1 RAM disk with batteries and protection plug



5.8.4 READING RAM-DISK DATA TO AN IBM-PC COMPUTER

The easiest way to interface the RAM disk to a PC computer is to use the "Disk copy to" command on menu 4 to transfer RAM disk data onto a 3.5" diskette (see 5.8.2). Then you can read the records directly on a PC equipped with a 3.5" disk drive. It is very simple to add the 3.5" drive to a PC, all you need is the external drive kit and DOS 3.2. Both can be obtained from any good computer shop.

However, the RAM disks can also be read directly by the PC using a RAM disk interface consisting of a plug-in board, cable and connector assembly. To read the disk over this interface special software is required. The interface and software can be obtained from ABEM.
In operation this software will copy the data files from the RAM disk to any ordinary disk drive you may have attached to your computer system. You can also copy data files from the PC disks to the TERRALOC RAM disk.

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