

VMS-2000 Digital Seismograph System - Reference Manual

This equipment should be installed, maintained and operated by technically qualified personnel.
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March 2002 v1.02



Route 9 • P.O. Box 50

Spofford, New Hampshire 03462

(603) 363-4500 • FAX (603) 363-4249

www.vibration.com

IMPORTANT

1. The VMS-2000 is a high accuracy electronic measurement system. As such the VMS-2000 should be treated with care. When shipping, the unit should be packed in its original shipping carton with FRAGILE warning labels visible from every side.
2. The battery should be charged following use and should not be stored with discharged batteries. The VMS-2000 will not operate below a battery voltage of 5.6 volts as shown on the liquid crystal display (LCD) (select by pushing the ↓ key from the main menu). The VMS-2000 is equipped with a battery monitoring device. Once the battery voltage falls below 5.6 volts, the VMS-2000 will automatically shut itself down. Fully recharge the VMS-2000 as soon as possible should this occur.
The VMS-2000 should be used only with a voltage of 6.0 or above for best results.

Introduction

Thomas Instruments thanks you for purchasing the VMS-2000. We are committed to providing quality instruments and unsurpassed service to our customers.

The VMS-2000 has been designed from the ground up to provide complete 3-axis vibration and sound level recording capability so that every blast can be recorded and analyzed quickly, efficiently and effectively.

Simplicity of operation, versatility, accuracy and reliability are key attributes of the VMS-2000. The provided SeisWare software allows for easy configuration of the VMS-2000. Once in the field, an operator needs only to set up the unit, turn on the power and press the *MONITOR* key. Once triggered, the VMS-2000 records and stores the seismic activity, displaying on the LCD such information as the peak measurements. When convenient, the data is transferred to any PC compatible computer for analysis and printing through the SeisWare software. The analysis of the recorded vibration and sound returned by the SeisWare software, offer a high level of diagnostic capability. The VMS-2000 and SeisWare software were designed so that even non-technical personnel find it simple to operate.

DESCRIPTION OF SEISMIC AND ACOUSTIC WAVES

Surface Waves

One of the two different types of waveforms that are generated by the explosion are seismic, or surface waves (a.k.a. ground roll). Surface waves propagate outwardly from the blast site, but they force the ground to move in a direction which can be represented as the vector sum of three different components: radial, transverse, and vertical.

Radial Component

The radial component of the surface wave causes the ground to move along the direction of a straight line that connects the location where the explosion took place to the location where the geophone is set (see Figure 1 and Figure 2).

Transverse Component

The transverse component of the surface wave causes the ground to move in a direction along the earth's surface, but perpendicular to the straight line that connects the location where the explosion took place to the location where the geophone is set (see Figure 1 and Figure 2).

Vertical Component

The vertical component of the surface wave causes the ground to move in a direction perpendicular to the earth's surface; i.e. it causes the ground to vibrate in an up and down fashion (see Figure 1 and Figure 2).

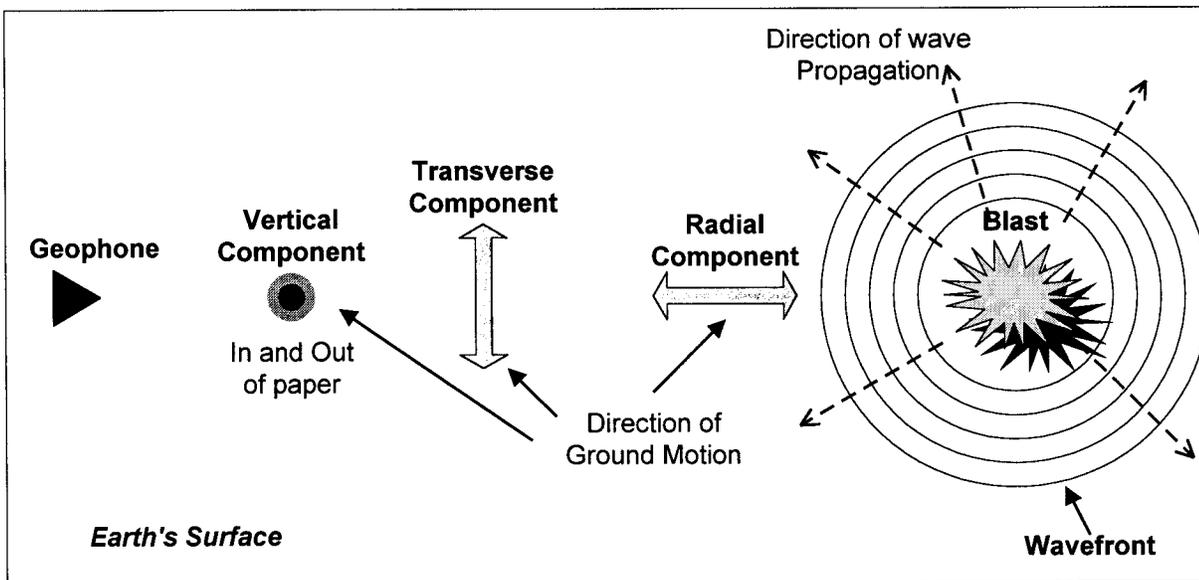


Figure 1 View of Earth's surface from above. Note the three different components of the surface wave, and the "Wavefront" that represents the blast, or shock wave

The vector sum of these three components is the total surface wave component which contains information about both the direction of ground motion and the amount of ground displacement (or magnitude). Mathematically speaking, the total surface wave component can be written as $\vec{s} = \vec{c}_r + \vec{c}_t + \vec{c}_v$, where \vec{c}_r is the radial component, \vec{c}_t is the transverse component, \vec{c}_v is the vertical component, and \vec{s} is the total surface wave component. Note that whether it is ground displacement, ground velocity, or ground acceleration that we are

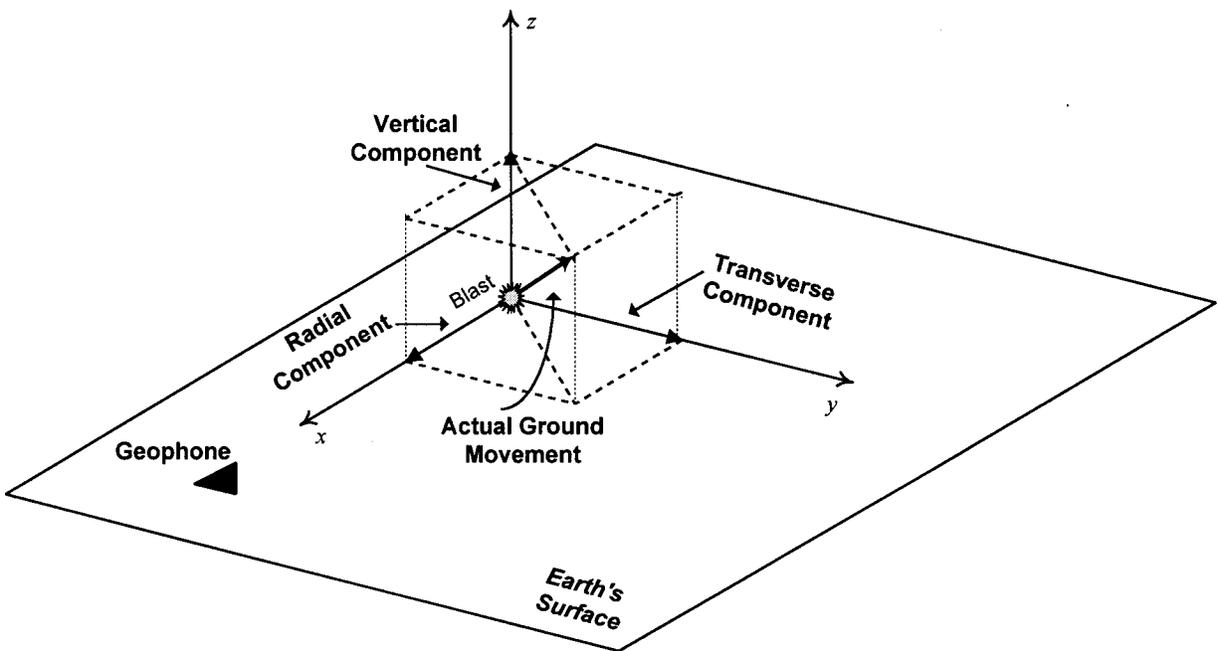


Figure 2 Pictorial representation of the vector sum of radial, transverse, and vertical components, resulting in the total component (“Actual Ground Movement”) of the surface wave

measuring, any of these three quantities may be represented by the radial, transverse, and vertical analyzing components shown in Figure 2 along the x , y , and z directions respectively. If the magnitudes of either the displacement, velocity, or acceleration components are known, then the magnitude of the total surface wave component will be given by $s = \sqrt{c_r^2 + c_t^2 + c_v^2}$, where the arrows on top of each of the three analyzing and total surface wave components have been omitted since c_r , c_t , c_v , and s now represent scalar (magnitude) quantities instead of vector quantities. For example, if the radial ground displacement is 2in, the transverse ground displacement is 1in, and the vertical ground displacement is 2in, then, the magnitude of the *actual ground displacement* (or the magnitude of the total surface wave component) will be $s = \sqrt{(2\text{in})^2 + (1\text{in})^2 + (2\text{in})^2} = 3\text{in}$. The same analogy holds if the three analyzing components were measured in in/sec (velocity), or in/sec² (acceleration) units.

Acoustic waves

Similar to surface waves, acoustic waves propagate in a spherical fashion outwardly from the blast site. The only difference is that they propagate through the air instead through the ground, and that their velocity is typically much lower than the velocity of the surface waves. Although acoustic waves could also be analyzed into three different components, however, this is not practical, and only their total magnitude is detected by the microphone attached to the seismograph and used for subsequent calculations.

BASIC SEISMOGRAPH OPERATION

This section describes the basic operation features of the seismograph that are necessary for properly recording explosions.

Powering up the seismograph

Once the seismograph is powered up, the LCD will first display the battery voltage level. If the battery voltage drops below 5.6V, the instrument will shut down itself until the battery is recharged to its proper level. Typically, the battery level should always exceed 6.0V. When the battery is at a proper operating level, the LCD will appear as follows:

```
BATTERY VOLTS: 6.467
BATTERY IS O.K.
/
PLEASE WAIT
```

Following the battery test, the seismograph will perform a geophone (or sensor) test, to ensure that the geophone is working properly. It is therefore *very important* that the external geophone is connected to the seismograph **before** the instrument is turned on. The following is an example of a properly working geophone:

```
- SENSOR TEST -
VERTICAL:      PASSED
TRANSVERSE:   PASSED
RADIAL:       PASSED
```

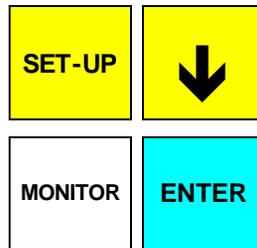
Next, the Model Number and Serial Number of the unit are displayed. This is the Main Display Screen.

```
THOMAS INSTRUMENTS
VMS2000      VER. 2.00
SERIAL#: V2KI281002
11-07-01    10:34:38
```

The VMS-2000 will remain at the message displayed above until the user presses the **SETUP**, **↓** or **MONITOR** key on the keypad.

SET-UP

The VMS-2000 incorporates a 4 line by 20 character LCD display and a 4 button keypad shown below:



To change parameter settings press the **SET-UP** key. The LCD will display the different available settings. Simply press the ↓ key to select the setting you wish to alter. Once your desired selection is pointed at by the > sign, press the **ENTER** key.

```
> TRIGGER SETTINGS
  RECORD SETTINGS
  EVENT RECALL
  END SETUP MODE
```

TRIGGER SETTINGS

The trigger settings allows the VMS-2000 to be altered in the field without the necessity of a computer. When selected; by pressing the **ENTER** key, the screen appears as follows:

```
> GEO TRIGGER LEVEL
  MIC TRIGGER LEVEL
  MANUAL TRIGGER
  END TRIGGER MODE
```

Press the ↓ key to select which setting to change, then press **ENTER**.

GEO TRIGGER LEVEL

```
- GEO SETTING -
USE ARROW TO CHANGE
  0.05 in/s
PRESS ENTER TO END
```

(Note: Thomas Instruments recommends a setting of 0.05 in/s for general work)

MIC TRIGGER LEVEL

- MIC SETTING -
USE ARROW TO CHANGE
DISABLED
PRESS ENTER TO END

(Note: Thomas Instruments recommends disabling the MIC TRIGGER to prevent false triggers unless the operator has a specific reason to trigger on the air blast. Keep in mind that air blast data will always be recorded whether or not the microphone trigger is enabled.)

MANUAL TRIGGER

-MANUAL SETTINGS-
USE ARROW TO CHANGE
MANUAL KEY DISABLED
PRESS ENTER TO END

(Note: the VMS-2000 may be triggered manually by depressing the MONITOR button while in monitor mode. The user must be aware that the GEO and MIC triggers will be disabled automatically if the MANUAL key is enabled. This setting would be used for special applications. Normally the MANUAL key should be disabled.)

END TRIGGER MODE

Selecting this option will return the user to the main SETUP menu.

Optimal trigger

The main reason for preferring automatic geophone and microphone trigger levels (over manual) is to setup the seismograph such that it will record the seismic and acoustic waves generated by an explosion precisely at the time when the explosion takes place (allowing of course for the travel time delay that it takes for the seismic and acoustic waves to reach the seismograph location). Therefore, the automatic trigger levels should be set low enough to enable the seismograph to record all blasts, if possible.

Since one of the purposes of recording blast generated events is to monitor the amount of ground shaking and sound pressure so that they fall within acceptable limits, it is almost intuitive that if the trigger levels have been set to their minimum values and an explosion takes place which does not get recorded, then the effects of that explosion may be considered to be minimal. Therefore, by setting the trigger levels to their minimum values we should be able to record and monitor all significant explosions. However, the problem with setting the trigger levels too low may be that some completely *blast-unrelated* event may cause the seismograph to start recording. Explosion unrelated events may include an aircraft that went by overhead, heavy equipment moving nearby, a thunderstorm right over the seismograph area, and even people and cows(!) walking by near the seismograph shelter.

The point is that if the trigger levels have been set at some specific value (not necessarily the minimum value), and explosion unrelated events are being consistently recorded, then the trigger levels should be set at a higher level. A question arises however, how high should the trigger levels be set ? Unfortunately, there are no hard rules about setting up "optimal" trigger levels. An "optimal" trigger level would be one that would cause the seismograph to record all useful blast-related events, while at the same time preventing the instrument from recording blast-unrelated events. However, since some blast-unrelated events may also be powerful enough to set off the seismograph regardless of how carefully a trigger level is selected, it is concluded that it may be quite difficult to set an "optimal" trigger level anyway. Thus, it will be up to the user's discretion as to how high the trigger levels should be set. The best approach would be to run the seismograph for a variety of trigger levels and check the number of the actual explosions occurred against the number of events the seismograph recorded. If there is any significant difference between these two numbers (say the number of actual blasts occurred is much greater than the number of events recorded), then it is likely that the trigger levels have been set too high. If, at the other hand, the number of the total events recorded by the seismograph is much higher than the number of the actual explosions occurred, then it is likely that the trigger levels have been set too low (the seismograph is "picking up" too many blast-unrelated events). A little further investigation into this trial-and-error procedure should give the user a fairly good idea at which level the geophone and microphone triggers should be set in order to record the significant blast-related events, while at the same time reject most of the blast-unrelated events. These trigger levels will obviously have to be reset should the need to change the seismograph's location arises. The same holds true if either the nature of the blast is changed, or the instrument is needed to monitor a different explosion at a completely different location.

RECORD SETTINGS

Selecting this option will present the user with a menu that can be used to determine how the data collected will be stored in the VMS-2000 as shown below:

```
> RECORD TIME
  MEMORY STORAGE
  MONITOR DELAY
  END RECORD MODE
```

RECORD TIME

```
- RECORD TIME -
USE ARROW TO CHANGE
  1 sec [95]
PRESS ENTER TO END
```

(Note: Use this setting to determine the length of time AFTER triggering that the VMS-2000 will record data. There is a finite amount of memory in the instrument, consequently, lengthening the record time interval will decrease the number of events that can be stored and vice versa. In the example shown above, the instrument has enough available memory to store 95 separate 1 second events.)

MEMORY STORAGE

```
- STORAGE MODE -
USE ARROW TO CHANGE
STOP MONIT WHEN FULL
PRESS ENTER TO END
```

```
- STORAGE MODE -
USE ARROW TO CHANGE
RECORD OVER OLDEST
PRESS ENTER TO END
```

(Note: as shown, there are two modes of memory storage: STOP MONITORING WHEN FULL in which case the unit will record events until the internal memory is full. At that time no further events can be recorded until the data has been downloaded to the user's PC (personal computer) and the memory has been erased. In the second case, events will continue to be recorded over the oldest data in a "first in, first out" fashion indefinitely. This setting can only be changed on a unit with completely erased memory. Once data has been recorded, this setting cannot be changed until memory is once again erased or cleared.)

MONITOR DELAY

**- MONITOR DELAY -
USE ARROW TO CHANGE
DISABLED
PRESS ENTER TO END**

(Note: this setting may be disabled or set to provide a MONITOR DELAY of 1 to 120 minutes. A monitor delay would be the amount of time elapsing between the operator placing the unit in MONITOR mode and when the unit could be triggered to record an event. This monitor delay is used in special circumstances where the operator must set up the equipment some time prior to requiring event recording. Normally it is disabled.)

END RECORD MODE

Selecting this option will return the user to the main SETUP menu.

EVENT RECALL

This option will allow the user to scroll back through the recorded events in memory (from last to first) and displays the trigger date and time plus the PPV (peak vector sum) of each event stored in memory.

END SETUP MODE

Selecting this option will return the user to the main display of the VMS-2000.

VMS-2000 MONITOR MODE

MONITOR MODE

Depressing the **MONITOR** key on the keypad will place the VMS-2000 into **MONITOR** mode. While in the **MONITOR** mode, if an event occurs that exceeds the trigger level set during **SETUP**, the unit will record any seismic and air blast activity for the time duration also set during **SETUP**. The data collected will then be stored in memory and will be available for downloading into a personal computer at a convenient time, or viewed on the LCD display as described previously in **EVENT RECALL**.

When entering **MONITOR** mode, the VMS-2000 will display the trigger settings as in this example:

```
-TRIGGER SETUP DATA-  
GEO TRIG: 0.05 in/s  
MIC TRIG: DISABLED  
MANUAL:    DISABLED
```

The **MEMORY STORAGE** method will then be displayed as in this example:

```
-MEMORY FULL OPTION-  
MONITORING WILL STOP  
WHEN MEMORY IS FULL  
11-07-01    15:45:36
```

The next display will show the **EVENT STORAGE** statistics as follows:

```
-EVENT STORAGE DATA-  
EVENTS LEFT: 95  
STORED EVENTS: 0  
RECORD TIME: 1 sec
```

Line 2 above displays the total number of events capable of being stored in the unit's memory. This value will change depending on the length of **RECORD TIME** set, and the number of previously stored events. The longer the **RECORD TIME**, the fewer events that may be stored. This is because there is a fixed amount of memory in the VMS-2000 and that memory is allocated by time not the number of events.

Line 3 above displays the total number of events already stored in the unit's memory.

Note: events stored in memory can be erased or cleared only with a computer running the SeisWare software.

Next, the seismograph will perform a sensor test on the external geophone to ensure proper operation (make sure that the external geophone is connected to the side of the seismograph). If the test is passed, the LCD will appear as follows:

```
- SENSOR TEST -  
VERTICAL:      PASSED  
TRANSVERSE:   PASSED  
RADIAL:        PASSED
```

If any of the sensor tests has failed, the complete event will not be recorded accurately. In this case, refer to the troubleshooting section of this document.

Once the sensor tests are passed, the seismograph will enter the automatic monitoring mode. In this case, the LCD display will appear as follows:

```
MONITORING IN  
  PROGRESS  
TO EXIT PRESS ENTER!  
MONITORING EVENT  1
```

The seismograph is now in recording mode. Whenever the selected trigger level is exceeded, the LCD display will flash,

```
MONITORING IN  
  PROGRESS  
TO EXIT PRESS ENTER!  
TRIGGERED EVENT  1
```

the event will be recorded,

```
MONITORING IN  
  PROGRESS  
TO EXIT PRESS ENTER!  
PROCESSING EVENT  1
```

and stored in memory.

After a trigger condition has occurred and the event has been completely recorded, the seismograph will automatically perform a sensor test and save it along with the event occurrence. Then it will return to monitoring mode so that it will be ready to record the next event should the selected trigger level is exceeded again. The LCD display will then show:

| | |
|-------------------------|--------------|
| RAD 1.02in/s | 39Hz |
| PVS 1.66in/s | |
| PSPL.000728psi | 108dB |
| MONITORING EVENT | 2 |

(Note: the data displayed above is a representative example of a possible event only)

This feature is very convenient for long-time monitoring. When the user is done recording, he/she may press the **ENTER** key to exit the automatic monitoring and recording mode and return back to the main menu.

Manual recording and monitoring

If the MANUAL TRIGGER option was selected from the trigger setup menu, then the seismograph is set to monitor and record events manually. In this case, the microphone and geophone trigger levels are disabled, and the only way an event will be recorded is to manually press a key to start recording. First, press the **MONITOR** key on the keypad to enter into the monitoring mode

To start recording, press the **MONITOR** key again. The seismograph will start recording for the amount of time specified in the RECORD TIME setup mode as discussed above.

When the specified length of time has passed, the seismograph's LCD display will return to the screen message shown above, and the number of events stored in memory will be incremented by one. To record a second event, press the MONITOR key and the same procedure will be repeated again. When the user is done recording, he/she may press the **ENTER** key to exit the manual monitoring and recording mode and return back to the main menu.

RECALLING EVENTS

After the seismograph has recorded a series of events, it may be desirable to recall some event(s) at a later time. The event recall feature of the seismograph will enable the user to do so. To recall an event and display the results on the LCD, choose **EVENT RECALL** from the main setup menu as shown below:

```
TRIGGER SETTINGS
RECORD SETTINGS
> EVENT RECALL
END SETUP MODE
```

After having selected the EVENT RECALL choice, press the **ENTER** key and the seismograph will go into the event recall mode. The LCD display will look as follows:

```
RAD 1.02 in/s 39Hz
PVS 1.66 in/s (1)
PSPL.000728psi 108dB
11-07-01 15:40:04
```

Pressing the **↓** key will enable the user to scroll from the last event recorded to the oldest event retained in memory. This can be particularly useful if the user needs to write down the data corresponding to some event.

An explanation of the information displayed on the LCD of the seismograph now follows: In the example above RAD indicates that the radial axis has recorded its highest peak ground velocity, and its value is 1.02 in/s. The frequency recorded at that value is 39 cycles per second, or 39Hz. (Note RAD = Radial, TRAN = Transverse, and VERT = Vertical)

Line 2 displays the PVS, or peak vector sum of the event as 1.66 in/s. The number in parentheses, (1), indicates that this event is the last stored in memory.

(Note: The number indicates events from last to first, (2) would be second last event and so on)

To view the next event, press the **↓** key. Line 3 displays the PSPL, or peak sound pressure level as .000728psi (pounds per square inch), and its equivalent of 108dB (decibels). Line 4 indicates the event occurred on January 16, 2001, and the trigger level was exceeded at 12:40:04 in the afternoon. If the trigger level was never exceeded, and the seismograph exited from **MONITOR** mode, a message such as the following will be stored in memory:

OPERATOR EXITED
FROM MONITORING (3)
WITHOUT A TRIGGER AT
11-07-01 16:38:13

Line 2 shows that event #3 (or lack of it thereof) is the third last event stored in memory. Line 4 indicates that the seismograph exited the MONITOR mode on November 7, 2001, at 4:38:13 pm. After having completed viewing all stored events press the **ENTER** key and the seismograph will return to the main setup menu.

VMS-2000 FIELD SETUP

SETTING UP THE SEISMOGRAPH

Once in the field, the seismograph first needs to be setup in order to record any events. A seismograph shelter should be used to house the seismograph and protect it from direct sunlight and/or adverse weather conditions. If a shelter is not available, then the following instructions can still apply. The shelter should be placed on a flat surface and in an *upright* position. Make sure that the shelter is at a location where it will not obstruct any other activities and that it is securely set on the ground. Since the seismograph does not include an internal geophone, make sure that the external geophone provided is connected to the side of the instrument to the port named "GEO". The geophone itself should be pressed into a level piece of ground right under the seismograph shelter with the arrow on top of it pointing towards the location where the blast is to take place. Placing the geophone inside the shelter as recommended will protect it from the elements too. Also make sure that the bubble on top of the geophone is centered properly. This, will ensure that the geophone is not tilted and is level with the ground surface. The three spikes on the bottom of the geophone should be pressed into the ground so that they are completely.

Next, the microphone should be screwed on top of the microphone stand and be securely placed inside the seismograph shelter as well. The microphone itself should "poke" through the small opening at the top of the shelter. This is the *preferred* and *recommended* method for setting up the microphone assembly since in this way the microphone is also protected against the weather elements. If for some reason the microphone assembly cannot be setup inside the seismograph shelter, then, the assembly should be pressed into the ground. If this method is used, make sure that the microphone is maintained approximately 3 feet off the ground. When the microphone has been securely placed, connect its cord to the "MIC" port which is located on the right side of the seismograph.

Keeping a log book

The data recorded by the seismograph contain important information about an event's time and date of recording, as well as about the event's duration. Although this information is useful, *it is, nonetheless, incomplete*. It is therefore suggested that the seismograph operator keep some additional information about each recorded event. The most important additional information is:

- a) Location of seismograph, geophone, and microphone;
- b) Location of blast site;
- c) Blast site to seismograph assembly distance;
- e) Weather conditions.

This information may be handwritten, or more preferably, tabulated on a spreadsheet computer application such as Microsoft Excel.

Once the seismograph's memory is full of events, the user will need to download them to a computer for permanent storage and data analysis purposes. Before the events can be downloaded, however, the user must make sure that the hardware connections between the seismograph and the computer are set properly. The SeisWare manual discusses these hardware issues.

Trouble Shooting Guide

Sensor Test Failed:

1. Make sure the VMS-2000 is level.
2. Make sure the geophone cable is plugged into the correct connector.
3. Make sure the bubble level on the geophone is centered and geophone is level.

No Display on LCD:

1. Battery voltage may be low. Recharge VMS-2000 back to it's proper operating voltage (6.0v or better) and turn the power switch on again.

Won't Enter Monitoring Mode:

1. Check to see if number of events stored is not at it's maximum value AND that the Event Storage Mode is not in STOP MONIT WHEN FULL. If this is the case the VMS-2000 is programmed to stop recording when memory is full.

Microphone Not Recording Correctly:

1. Make sure the mic cable is plugged into the proper connector.
2. If false triggering, the wind may be causing it to trigger. Try a higher trigger level or trigger on GEOPHONE only (recommended).