Reflection Field Equipment

Seismic Sources

Seismic sources can be broadly divided into two categories: land energy sources and marine energy sources.

Land Energy sources: The choice of energy source is critical in land data acquisition because resolution and signal-to-noise ratio quality are limited by the source characteristics. A geophysicist should select a source based on the following five criteria:

- Penetration to the required depth: Knowing what the exploration objectives are, the geophysicist should select a source that has adequate energy to illuminate the target horizons. Past experience can help here.
- Bandwidth for the require resolution: If high resolution reflections are required to delineate subtle geological features such as a stratigraphic traps, the source must transmit a broad range of frequencies, both high and low. For very shallow targets, a detonator may possess adequate energy and frequency bandwidth. For deeper reflections, the longer travel path to a deep reflector requires the selection of a source that has enough energy at the higher frequencies to maintain a broad reflection bandwidth.
- Signal-to-noise- characteristics: Different areas have different noise problems. They may dictate the source selection.
- Environment: When working in populated areas, there are special safety requirements to which geophysicists must adhere.
- Availability and Cost: The time of arrival of a crew can be extremely important.

Land Energy Sources are of two types: Explosive sources and Non Explosive sources.

Explosive Sources: Explosive sources produce robust P-waves. The selection of explosives as the sources of choice depends primarily on near-surface conditions and the accessibility of other energy sources. If drilling is fast and efficient, single shot hole filled with explosives might be the most economical source option. The explosive source consists of a detonator and an explosive charge. In the seismic industry, the explosive charge is commonly referred to as 'powder' and the detonators are referred to as 'caps' or 'primers'.

Charge Size: The choice of charge size depends largely on the depth to the horizon of interest. The best charge size is that which achieved the maximum signal-to-noise ratio (S/N) at the target depth. Deeper targets usually require larger charge sizes. Generally, larger charge sizes cause more ground roll and air blast contamination of the record. Alternatively, smaller charge sizes mean higher frequency content, but less energy going into the ground. De convolution enhances the frequency content such that the bandwidth will be higher and have an improved S/N ratio compared to a record with a smaller charge size.

Charge Depth: The charge depth depends on the depth of the weathering layer and the level of noise interference one encounters when testing. Generally, the shallower the source, the stronger the air-blast and the ground-roll. On the other hand, it is usually not economical to go much beyond 50m depth. If the drilling is really tough and expensive, one may have to limit the shot hole depth to as little as 2m or a surface shot may be used instead.

Vibrators: Vertical vibrators produce and asymmetric radiation pattern of P-waves and S-waves. Horizontal vibratos produce weak P-waves and robust S-waves. If multiple dynamite patterns do not pump enough energy into the ground, vibrators may be preferred on technical grounds, regardless of relative cost. Vibrators are designed in two basic groups: Buggy-mounted and truck-mounted units.

Other sources: Although dynamite and Vibroseis are used in majority of surveys, other sources can be and are used in the field 3D surveys, such as:

- Airguns and mud guns (used in transition zone surveys)
- Shotgun (Betsy)
- Mini-Seis (Thumper)
- Land air gun
- Dinoseis
- Elastic wave generator (EWG)
- Mini-vibes

Seismic Receivers

Geophones: Conventional geophones are based on Faraday's law of electromagnetic induction. This law states that relative motion of a conductor through a magnetic field induces an electromagnetic force (EMF) which causes a current to flow through the conductor, if the conductor is an element of an electrical circuit. The two types of geophones widely used in geophysical surveys are

1. *moving coil geophone and 2. moving magnet geophone(**figure 6**)*

The essential ingredients to make a geophone are a permanent magnet, a conductor and a spring which positions either the conductor in the magnetic field space (in moving coil geophone) or the permanent magnet in the electric field space (as in moving magnet geophone). The conductor in reality is a length of copper wire wrapped into a cylindrical coil shape. It is often referred to as the coil or element.

The conductor's or the magnet's motion through the magnetic/electrical field, according to Faraday's law, causes an EMF to be induced that is proportional to the velocity of the earth's motion. Hence, such a geophone is called a velocity phone because its output is proportional to the velocity of the earth's motion.

The large amount of subsurface information carried by seismic signal would be fully available for interpretation only if the geophones follow ground movement faithfully with minimum distortion.

Electrical Characteristics:

- ***Sensitivity:*** Geophones are available with a wide range of sensitivities. For example, at one end of the sensitivity scale, a geophone can produce 0.1V output for a 2.5cm/sec velocity, while another geophone can produce as much as 0.4mV output for a tiny movement of 2.5 X 10 m/sec.
- ***Tolerances:*** Geophones have typical tolerances. That are as follows:
    - Natural frequency within ± 0.5Hz. of the manufacturer stated value
    - Natural frequency distortion with a maximum 20 tilt, ± 0.1Hz.
    - Sensitivity within ± 5% of the manufacturer stated value.

A large variety of modern geophones are available today to meet the specific requirement of the user. Close tolerance digital grade geophones have distortions as low as 0.03%, tolerance of 2-2.5% on frequency, sensitivity and damping, and very high geophone-to-geophone uniformity. To modern geophones has done away with the shunt resistance, resulting in very low distortion and high spurious response up to 250Hz. These geophones maintain their natural frequency specifications with high tilt angles.

The particular receiver type depends on the characteristics of the data to be recorded and the environment where the data acquired. In normal land operations, geophones have a resonant frequency of 10 or 14Hz., but in some parts of the world it is still normal practice to use 6 to 8Hz phones. However, geophones with resonant frequencies up to 40Hz are being manufactured.

Receivers are usually wired in groups of 1, 4, 6, 9, 12 or 24. While the trend is towards higher number of phones (9, 12, 24 on even 72 in the Middle East), however numbers (e.g., 6) are still used in certain areas, e.g., South America. In hilly, terrain, where the height difference between the ends of any receiver group exceeds 2m, geophones may be clustered in a small area. In steep terrain (over 5m. elevation difference) one can spread the phones out parallel to topographic contours to minimize inter-array statics smear. Three-component 3D recording requires three times the number channels of recording capacity since each component is recorded separately. This increased number of channels may make it difficult to create a patch that creates sufficient fold. Since shear-wave reflections contain a lower frequency bandwidth, phones with lower resonant/natural frequencies are used.

Hydrophones: The hydrophone is an electro acoustic transducer that converts a pressure pulse into an electrical signal by means of the piezoelectric effect. If mechanical stress is applied on tow opposite faces of a piezoelectric crystal, then electrical charges appear on some other pair of faces. If such a crystal is placed in an environment experiencing changes in pressure, it will produce a voltage proportional to that variations in pressure.

Dual Sensors: For ocean bottom cable (OBC) applications, combining the output of geophones and a hydrophone is now widely accepted technique for reducing the ghosting effect caused by the water/air interface. To overcome the disadvantage of using two separate sensors, both geophone and hydrophone are available in a single unit known as dual sensors or the 4-component (4C) receivers consist of a hydrophone, two horizontal geophones and a vertical geophone installed in a single water proof enclosure for recording P, SV and SH waves.

Seismic Instrumentation

Once a seismic signal is transmitted and received, it must be recorded. The different types signals are as follows:

- **Source Signal:** The pressure field created by the seismic source.
- **Reflectivity Signal:** The earth's reflection sequence convolved with the source wavelet.
- **Seismic Signal:** Everything received as a result of the source firing. The seismic signal includes the reflectivity signal as well as ground roll, refractions, diffractions, sidesweep, channel waves etc.
- **Received Signal:** The electrical output of the receiver group. This is the seismic signal plus all environmental noise.
- **Recorded Signal:** The data, that is the instrument filtered signal plus any addition instrument noise, which goes onto the tape.

The information contained in a signal can be characterized by three quantities:

Signal-to-noise ratio,

Bandwidth and

Duration

In seismic exploration, the recorded signal bandwidth is usually 0-250Hz. or lower. Often, data are processed in a narrower band, say 5-80Hz., even though they may be recorded in a broader band. The duration of recorded signals depends on the nature of the source and target depth.

A reflection is a physical event caused by a change in the acoustic impedance of the earth. It is recorded signal, that event is represented by a wavelet that has two components – the earth filter and the acquisition wavelet. The wavelet can be described in the time domain or alternately, in the frequency domain. The Fourier transform can be used to move form one representation to the other. If a wavelet has a short extent in a time and appears like a spike, it is likely to be composed of a broad band of frequencies, each separate frequency having its own phase value. The amplitude and phase of a wavelet contain all the spectral information of a wavelet. These spectra are called the frequency-domain representation of the wavelet, whereas the wavelet in time is considered to be in the time domain.

When seismic recording first began in a 1920s the recording systems consisted of heavy, metal cased geophones connected by wire cables to a recording truck. The signal was recorded on a rotating photographic drum. Drums were replaced by analog magnetic tape recorders during the late 1950s but these often failed to operate well. In the early 1960s they were replaced by digital tape recorders, each of which had an analog-to-digital converter at the input stage to the tape drive. The individual analog amplifiers also were unreliable, and by late 1960s, they were being replaced in recording devices by a single multiplexed analog amplifier.

In late 1970s, distributed systems were introduced that performed amplification, filtering, digitization and multiplexing at or near the receiver stations. By the mid 1980s distributed systems were in wide use throughout the industry.

Basic components: The basic components of the land recording systems are:

Roll-along switch: It allows the observer to record a selected subset of the geophones connected to the recording truck. It minimizes the need to move the recording truck.

Pre-amplifier: This is a fixed gain amplifier that raises the incoming seismic signal above the background instrument noise level. The preamplifier has low noise, high input impedance and low distortion. Its input impedance is equal to or greater than the cable impedance to the farthest station so that no signal amplitude is lost because of mismatching of impedances. The amplifier must be completely linear throughout its operating range.

Multiplexer: This is an electronic switch that time shares data form multiple channels. It changes multiple parallel inputs to a serial output relay for amplification, digitization and recording. The multiplexer cycles through all of the inputs during each digital sampling interval.

Main Amplifier: This amplifier receives all analog signals input to it and passes then on to the A/D converter with an amount of gain determined by the gain controller.

A/D Converter: Analog signals are converted to digital signals with this device. It allows the analog stream of data to be recorded in digital form. The received incoming signal must be filtered to prevent aliasing prior to conversion to a digital form.

Gain Controller: The received signal includes, reflections, refractions, ground roll and environmental noise, all of which may have amplitudes varying in a range from microvolts to volts. A fixed form of amplification with only a relatively small number of data bits cannot handle that range without some dipping at the most significant bit end of the converter. Instead a variable or automatic gain control (AGC) level is determined for application by the main amplifier in the feedback loop with the A/D converter to reduce or amplify incoming signal to keep signal levels within the desired converter range. The controller sets the amount of gain while the amplifier applies it to the incoming signal. The AGC level set at each sample is recorded on tape as part of the gain word.

Formatter: The formatter arranges the data stream (in the form of voltage and gain levels) into a binary code for writing onto magnetic tape. In addition, instrument operational commands are distributed by the formatter to all the other components, making the formatter the "brain" of the recording operation.

Tape Drive: Data finally are recorded on tape in digital form, ready to be passed on to the processing center for further processing. Magnetic tape may be replaced by floppy disks, depending upon the system in use. In land using recording a non-distributed system, an analog seismic signal travels from the geophones along electrical conductors (the cable) to a roll-along switch in the recording truck (or "doghouse" or "dog box"), after which it is converted to a digital signal and recorded on tape or disk.

In contrast, in a distributed system, the seismic signal passes from the geophone string directly into an amplifier and/or A/D converter, after which it travels in digital form along a cable to the recording truck. Because digital transmission of multiplexed data uses many fewer cables than analog transmission, layout of the large receiver spreads often used for 3D acquisition became considerably simpler.

Today, majority of the acquisition systems provide 24-bit recording technology. A 24-bit technology system offers high fidelity because it records data over a large dynamic range. Peculiarities for each system need to be examined for the task at hand. In land operations, these recording units are usually truck or buggy mounted and can, therefore, travel easily to areas of data acquisition. Lower channel count systems with higher sampling rates, such as the DMT/SUMMIT and the 24-bit OYO DAS, can be used for small, near-surface 3D surveys. In the case of very low channel count systems (e.g. less than 120), it is normal practice for several recorders to be used together in a master-slave pattern to reach sufficient channel capacity even for small 3D surveys.

If a 3D survey crosses a variety of terrains (e.g., mountain, plain, transition zone), it is desirable to use one type of recorder to cover all the survey areas. Thus shots of different types in the mountains or in the swamp can be recorded by the same instrument. If more than one recorder is used, amplitude and phase matching will be required to compensate for the recorder differences. “Seam less” receiver coverage from a variety of sources enables application of surface-consistent processes as de convolution, statics, and amplitude correction.

Different Types of Seismic Recorders

Manufacturer	System	T/D/R	Boxes	Stations per Box	Line Units	Central System
Sercel	SN388	Distributed System	Station Unit (SU)	1-6	Crossing Station Unit (SU)	Central Control Unit (SU)
Sercel	408UL	Telemetry System/Distributed System/Remote Seismic Recording	Field Digitizer Unit (FPU)	1	Line Acquisition Unit Cross (LAUX)	Central Module (CMU)

Telemetry System

True telemetry system has no physical connection between the station recording unit and the control system in the recording truck. These systems should be used where access is limited due to rugged terrain, permit problems, or any other reason. Sercel Eagle system is an example of such systems. The SAR (Seismic Acquisition Remote unit) records the signal and sends it via radio frequencies to the CRS (Central Recording Station).

Some telemetry systems can receive data in real time. Other telemetry systems have a disadvantage over distributed system in that the radio transmission of the data from the boxes to the recording unit takes longer than real time. For some systems, data transmission time may be on the order of minutes per source point, which may slow down the shooting crew. Tree cover may also cause a problem for the signal transmission, and FM interference may be significant in populated areas. Mixed systems may be used to cross-rivers or roads at select locations.

Storage: The data obtained in the seismic field survey is stored on magnetic tapes or cartridges. While the conventional storage devices are the tape drives the latest equipment uses the cartridges with 10 GB memory capacity for storing the data. The data is stored in SEG D format. Previously it used to get recorded in SEG B format or SEG C formats.