This document has been converted from the original publication:

*Thigpen, Ben B., Dalby, A. E. and Landrum, Ralph, 1975, Report on Subcommittee on Polarity Standards *: Geophysics, 40, no. 04, 694-699. (* Discussion in GEO-41-02-0324-0324; Reply in GEO-41-02-0324-0324)*

SPECIAL REPORT OF THE SUBCOMMITTEE ON POLARITY STANDARDS[1]

BEN B. THIGPEN[2], A. E. DALBY[3], AND RALPH LANDRUM[4]

This is a report of the SEG Subcommittee on Polarity Standards in exploration seismic recording, A Polarity Standard is recommended for analog and digital representations of seismic impulse signals. A four-bit polarity code is proposed to define: (1) the polarity convention for impulse-source systems; and (2) the relative polarity between a swept-frequency pilot signal and the recorded seismic data for vibratory-source systems. Polarity conventions are to be demonstrated by field tests and confirmed by computer analysis.

INTRODUGTION

The Subcommittee on Polarity Standards was appointed by the Chairman of the Technical Standards Committee of the Society of Exploration Geophysicists as directed by a motion approved during the meeting of the Committee, at the 42nd Annual Meeting of the SEG in Anaheim. The problem of polarity that was given initially to the Subcommittee was limited to seismic systems using swept-frequency vibrator signals but the scope of the assignment was broadened at the 43rd Annual Meeting in Mexico City to include seismic systems using impulsive signals.

Establishing impulse-signal polarity is a straightforward matter that is easily demonstrated from simple field tests. Much more complex, however, is the problem of swept-frequency signal polarity. The Subcommittee submits that sweep-signal polarity can be established by defining the phase angle between the pilot signal and the output of a velocity detector mounted on top of the vibrator baseplate. This velocity detector output is polarized to match the output of a geophone placed on the ground and connected to a spread cable.

The pilot signal is defined to mean that reference signal, usually recorded on an auxiliary channel of a digital tape, with which the recorded seismic reflection signal will be cross-correlated to produce correlograms for later processing.

Manuscript received by the editor January 23, 1975.

[2] Member, Subcommittee on Polarity Standards, Western Geophysical Co., Houston, Tex., 77001

[3] Chairman, Subcommittee on Polarity Standards, Geophysical Consultant, Houston, Tex., 77001.

[4] Member, Subcommittee on Polarity Standards, Western Geophysical Co., Houston, Tex., 77001

RECOMMENDED IMPULSE-SIGNAL POLARITY

The recommended standard for impulse-signal polarity shall be defined as follows: A signal voltage going initially in the negative direction shall be produced by

(1) Upward motion of the ease of a seismic motion sensor, and

(2) Pressure increase detected by a pressure-sensitive hydrophone.

This negative-going initial signal voltage applied to the input of a recording system shall produce a

(1) Negative-going output of the recording system,

(2) Negative number on a digital tape, and

(3) Wavelet minimum or trough (downward kick) on a seismogram.

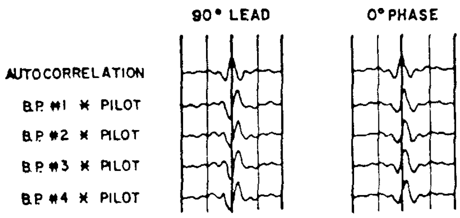

Fig. 1. Correlation pulses illustrating the recommended polarity (left) and an alternate polarity (right). The "autocorrelation" is the autocorrelation of the pilot signal; the other four traces show the crosscorrelation of the baseplate detector and the pilot.

The playback-system polarity is conveniently established by playing back to the camera a prerecorded tape having identical, negative-going pulses on each channel, After playback of the prerecorded tape, one or more geophones on the line spread may be tapped to establish the polarity from geophone to tape recorder and camera.

DEFINITION OF RELATIVE POLARITY BETWEEN SWEPT-FREQUENCY SIGNALS

The relative polarity, or phase relationship, between two swept-frequency signals, such as a pilot signal and the output of the baseplate detector, is defined as the difference in the zero-frequency intercepts of the apparent average lines through the phase-lag curves derived from said two signals. If the intercept difference is 0 degrees or n360 degrees (where n is an integer), the two signals are said to be in phase (have the same polarity); if the intercept difference is 180 degrees or (2n+1)*180 degrees, the two signals have opposite polarity. The so-determined relative polarity is quantitatively meaningful only on the linear part of tile phase-lag curve. If the frequency range under examination includes frequencies below about 15-18 Hz, there may be unaccountable differences between the phase lags and the waveforms due to non-linear low-frequency phase-response characteristics of the instrument filters, transducers, or baseplate. Note that the velocity detector resonance must be below the range of frequencies to be used in this test and the detector must be damped so that its output is essentially flat in the frequency range studied.

RECOMMENDED SWEPT-FREQUENCY POLARITY STANDARD

To conform to long-term traditional usage, the committee proposes that the recorded pilot signal shall lead the recorded output signal from the baseplate velocity detector, by 90 degrees + n360 degrees. The velocity detector system must have the same polarity as the geophones connected to a seismic cable as recommended above for the impulse-signal polarity. The vibrator is to be operated in the

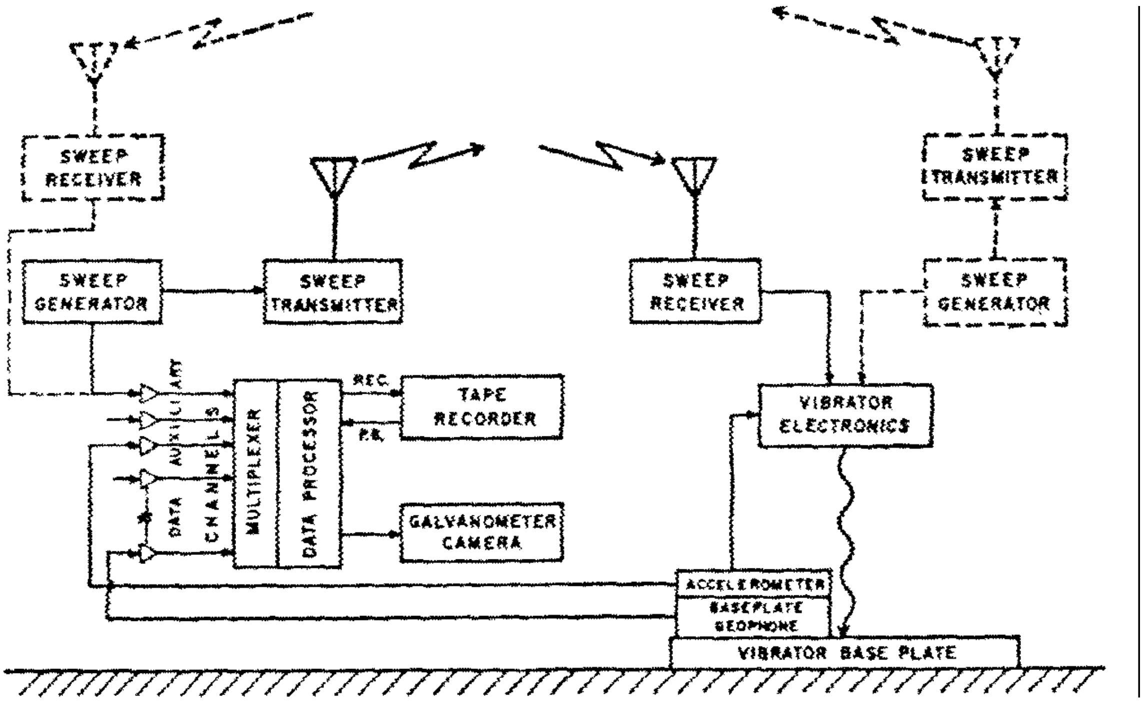

Fig. 2. Vibrator equipment configuration for polarity tests.

phase compensation mode. The set of traces at the left in Figure 1 illustrates a set of correlograms resulting from the proposed convention.

One manufacturer provides a two-position switch on the sweep electronics to provide either a 90 degrees lead or 0 degrees phase shift. The set of traces at the right in Figure 1 are correlograms produced from the 0 degrees phase shift convention.

DETERMINATION OF THE PHASE RELATIONSHIP BETWEEN PILOT AND SEISMIC SIGNALS

The phase relationship between a pilot signal and baseplate motion can be determined from a computer analysis of a field test recording. Conduct of the test is briefly outlined here but is described in detail in the Appendix.

Figure 2 illustrates a typical vibrator equipment configuration suitable for a polarity test. For the relative polarity test, it is unimportant whether the pilot, signal originates at the recording truck (solid lines) or at the vibrator truck (dashed lines in figure). It is important, however, that the equipment be operated for the test in exactly the same manner as in routine surveying operations. If phase compensators are on during normal recording operations, they should be on during the test.

Before commencing the test, confirm that the polarities of all system components are internally consistent and conform to the standard for impulse polarity. Auxiliary channels used to record the pilot and baseplate detector signals must have the same polarity and filter response as the data channels.

The recommended test procedure is as follows:

(1) Attach a strong-motion velocity detector (of sufficiently low frequency) to the driver structure (baseplate) of each vibrator in use. Polarize the detectors so that when connected to the data channels, their responses to a tap on top are

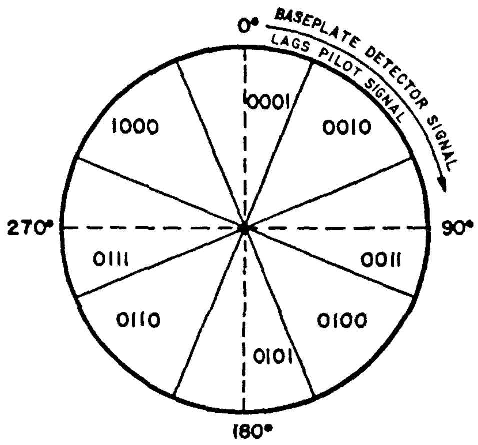

Fig. 3. Polarity code is determined by counting (in binary) the indicated 45 degree sectors of the phase circle clockwise from zero phase. The first 45 degree sector (0001) is centered at 0 degrees.

the same as the response to a tap on top of a normal (velocity) geophone properly connected to the reflection spread and a data channel. Connect the velocity detectors to a series of data channels.

(2) Select the pilot signal used in the area for normal profiling.

(3) Vibrate and record two or more files on magnetic tape. Play back the files to the camera,

Each record will have sets of traces showing the pilot sweep signal and the baseplate velocity detector signals. Note, however, that the velocity detector, not the accelerometer, is used in these tests for relative phase determination.

A preliminary, measure of the relative polarity between pilot and baseplate velocity detector signals can be made in the field by visual inspection of the monitor records or from a correlogram derived from the field correlator. It is preferable, however, that the relative polarity be determined by Fourier analysis in the data-processing center.

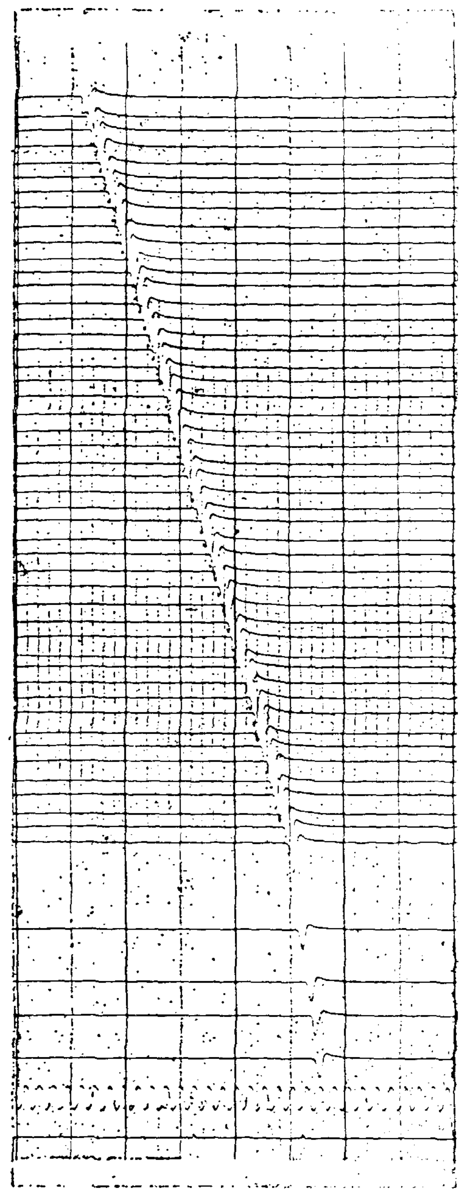

Fig. 4. Playback of scribed tape showing all channels in-phase and in proper sequence.

POLARITY IDENTIFICATION CODE

The Subcommittee proposes use of a four-bit polarity identification code. Entered in the least significant, half of byte 20 of the header block, the code number expresses either the impulse-signal polarity or the angular phase shift in 45-degree increments for a vibrator. Figure 3 illustrates the numbering system.

If the recording crew is using an

impulsive source, the polarity code defines the impulse signal polarity. The code is 0001 if the impulse signal polarity conforms to the Committee's recommendation; the code is 0101 otherwise.

For a vibrator crew, the polarity code will be selected (as in Figure 3) on the basis of the computer-determined phase shift between pilot and baseplate signals, not on the impulse polarity. Each code number has at least one bit on; an all-zero value indicates no polarity code has been inserted in byte 20. When the polarity is standard for a vibrator crew, that code number will be 0011.

ACKNOWLEDGMENTS

The Subcommittee thanks the many geophysicist-correspondents, who have made substantive contributions to this report,

APPENDIX

INTRODUCTION

This Appendix describes in detail methods for establishing the polarity of a recording system in accordance with the recommendations of the Subcommittee. In general, for impulsive or swept-frequency recording, the recording system is first polarized to conform to standards for impulsive seismic signals. If the crew is not equipped with a vibrator, no further testing is needed If the system is vibrator-equipped, the phase angle between the pilot sweep sigma] and the vibrator baseplate is next established.

TESTS TO ESTABLISH SYSTEM POLARITY

The following procedure is designed to set up the recording system and vibrator, if the crew is so equipped, according to the recommended polarity convention. In the procedure, it is assumed that pilot-signal channel and data-recording channels are electrically identical.

Step 1. Galvanometer polarity – Galvanometers on data and auxiliary channels must all deflect in the same direction when playing back tape-recorded numbers having the same polarity for both data and auxiliary channels.

The simplest way to test galvanometer deflection is to play back a computer-generated tape having prerecorded pulses (a "scribed" tape) that have the same polarity on all channels. Resulting galvanometer pulses must be similar and have the same polarity for all traces. The same tape can be used to check both polarity and trace sequence if the prerecorded pulses are properly sequenced in time. Figure 4 is a record played back from such a prerecorded tape.

An alternate method to test system polarization is to record known initially negative-going signals, such as from a pulser, on tape and to analyze the resulting read-after-write oscillogram. If the pulser output is paralleled to the data and auxiliary channel inputs, polarization of the entire system can be checked. Monitor the sign bit of the A/D converter with an oscilloscope. Connect the channels to turn on the sign bit to produce negative numbers on tape and a downward galvanometer trace-deflection for negative-going pulser signals.

Step 2. Geophone and baseplate-detector polarity – Plug the reflection spread into the recording system. With one finger, gently tap the top of a geophone in each group along the spread. Make monitor records of the group tapped. If the recommended polarity convention is followed, the first deflection will be up for a gentle finger-tap on top of the geophone. It is, of course, important that the gains be such that the first deflection is correctly identified and that the geophones be velocity detectors. Also, no metal or magnetic material should be used for the tap.

Replace the reflection-spread cable with a connector from a baseplate velocity detector. Set the detector upright on the ground; tap the top and record a monitor record. The seismometer must be placed on the ground (removed from the baseplate) or a gentle tap will not produce sufficient motion. The velocity detector trace must deflect in the same direction as it did for the geophone tap test, that is, first deflection up. Examples of tap tests that show correct polarity correspondence are shown in Figure 5. Note that for good similarity, the normal spread geophones and the baseplate velocity detector must both be velocity detectors of about the same resonant frequency and con-netted so as to have about the same damping.

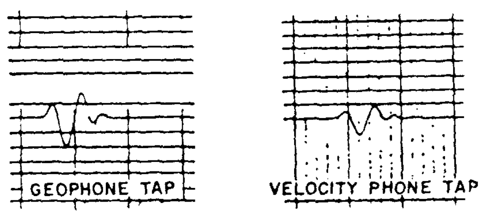

Fig. 5. Records from tap tests designed to confirm polarities of reflection-spread geophone (velocity detector) with respect to the baseplate geophone (velocity detector).

Step 3. Pilot signed polarity –The pilot signal is connected so that it leads the baseplate velocity signal by approximately 90 degrees throughout the sweep when the vibrator is phase-locked to a mid-range signal.

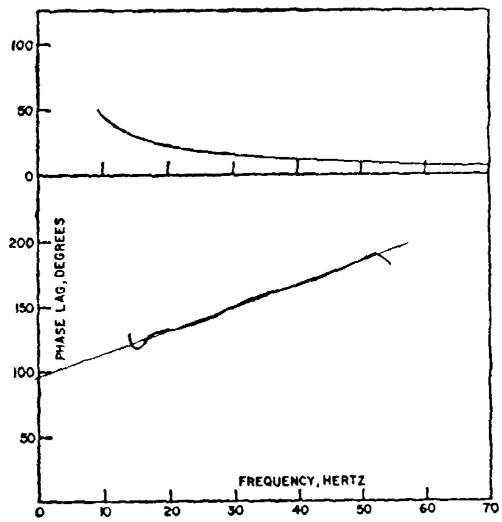

Fig. 6. (Top): Differential phase lag between velocity detector and cable geophone. (Bottom): Computer-determined phase lag between the compensated velocity detector and the pilot, signals.

For some vibrator control consoles, it may be necessary not only to invert the pilot, signal at the input terminals to the amplifier, but also to adjust a switch on the pilot signal generator from 0 degrees to 90 degrees to achieve the desired phase between baseplate velocity detector and pilot signal.

Setup the vibrator with phase compensator turned on and adjusted to lock to a 60- to 15 Hz sweep. Attach the baseplate velocity detector to the top cross member on the baseplate structure. The detector signals may need to be reduced in amplitude as much as 50 dB because of the strong baseplate motion.

Be sure that the baseplate detector circuit is correctly labeled as to type of motion measured: velocity, acceleration, or displacement. Often an accelerometer signal is integrated so that it becomes a velocity signal, but the signal terminals are incorrectly labeled "accelerometer".

Record several sweeps on tape, each with a read-after-write record.

Step 4. Analysis – On the camera records, visually compare the pilot-signal trace with the baseplate detector trace. The pilot signal should lead the baseplate velocity detector signal by 90 degrees. If the vibrator is operated with phase compensation, corresponding cycles of the wavetrain are easy to identify, particularly at the low-frequency end.

Step 5, Computer analysis – Computer determination of the phase lag between the pilot and baseplate detector signals is to be preferred over a determination by visual inspection of monitor records. In the computer processing, the differential phase lag between the baseplate detector and the cable geophones should be removed from the computed phase lag curve before plotting.

Figure 6, upper curve, is a typical differential phase lag curve for a particular velocity baseplate detector with respect to a specified geophone the operator must, of course, use a curve appropriate to his own instruments.

Figure 6, lower curve, is a computer-generated plot of phase lag versus frequency, compensated for the differential phase lag between the baseplate detector and the cable geophones. The intercept to be measured is that of the best fitting straight line to the phase lag curve over the frequency range of the sweep: the plot should be linear in both phase and frequency. Note that the phase lag curve becomes markedly nonlinear at the low-frequency end of the sweep. The illustrated intercept is about 96 degrees over the 15-50 Hz band of the sweep signal used. The polarity code will be 0011.