Sonic Echo (SE) Data Interpretation

Olson Instruments, Inc.

Instruction Manual
For Sonic Echo
Data Interpretation

NOTICES

Errors and Omissions

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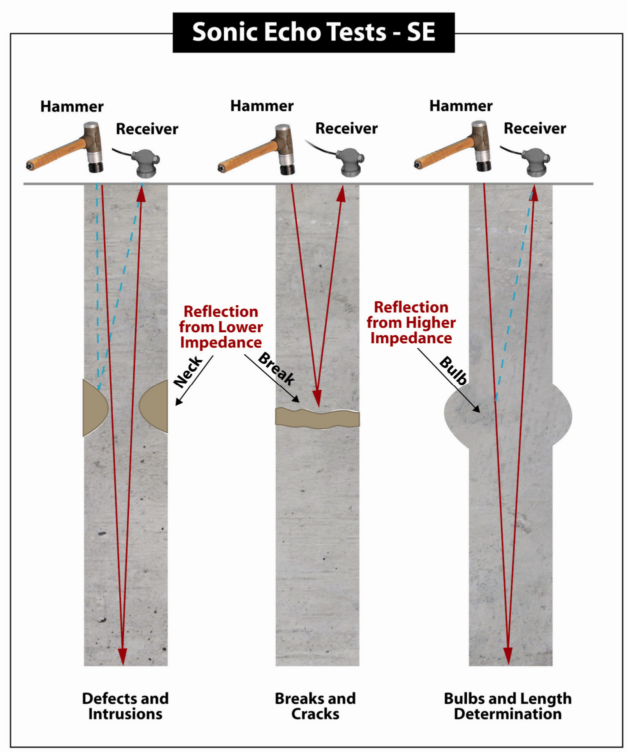
TEST METHODOLOGY

The Olson Instruments Sonic Echo (SE) system is commonly used for quality assurance, condition evaluation, and forensic testing of piles and deep foundations. Common applications of the SE system are determining the length of foundations and/or locating defects within foundations. The basic requirement for any foundation to be testable by this system is that an area of approximately 3 inches (7.6 cm) by 5 inches (12.7 cm) access be available on the foundation top, and that the surface to be tested is relatively smooth and flat. Alternatively, testing can be done by mounting the receiver to a block on the side of the pile, but the data quality will be lower. When used for quality assurance, forensic testing, and condition evaluation of deep foundations, the SE is a powerful tool for verifying foundation integrity, locating defects and determining length of a foundation.

The SE method is a low strain integrity test conducted from the top (or upper side) of the shaft as shown in the figure below. Test equipment includes a 3 pound (1.36 kg) hammer (instrumented or mechanical), receiver (accelerometer and/or geophone) mounted on the top (or upper side) of the shaft, and a data acquisition platform. The test involves hitting the foundation top with the hammer to generate wave energy that travels to the bottom of the foundation. The wave reflects off irregularities (cracks, necks, bulbs, soil intrusions, voids, etc.) and/or the bottom of the foundation and travels back along the foundation to the top. The receiver measures the vibration response of the foundation to each impact. The data collection platform acquires, processes and displays the receiver outputs. Foundation length and integrity of concrete are evaluated by identifying and analyzing the arrival times, direction, and amplitude of reflections measured by the receivers in time. The echo depth (D) is calculated by multiplying the reflection time (t) by the compression wave velocity (V) and dividing this quantity by 2 to account for the fact that the wave has gone down and reflected back, i.e., D = V*t/2 .



Analysis of the length determination and the integrity evaluation of a foundation with the SE method is based on the identification and evaluation of reflections. Test results are analyzed in the time domain for the SE test.

The SE test method is sensitive to changes in the shaft impedance (shaft concrete area * velocity * mass density where mass density equals unit weight divided by gravity), which cause the reflections of the compression wave energy. Compression wave energy (hammer impact energy) reflects differently from increased shaft impedance than from decreased shaft impedance. This phenomenon allows the type of reflector to be identified as follows. Soil intrusions, honeycomb, breaks, cracks, cold joints, poor quality concrete and similar defects are identified as reflections that correspond to a decrease in the shaft impedance. Increases in the shaft cross-section or the competency of surrounding materials such as bedrock and stiffer soil strata are identified as reflections corresponding to increases in the shaft impedance. A decrease in impedance is indicated by a downward initial break of a reflection event in an SE record and frequency peaks positioned in a record such that a peak could be extrapolated to be near 0 Hz in the mobility plot. Conversely, an increase in shaft impedance is identified by an upward initial break for an SE reflector.

When length to diameter ratios exceed 20:1 to 30:1 for shafts in stiffer soils/bedrock, the attenuation of compression wave energy is high and bottom echoes are weak or unidentifiable in SE test results. If the shaft is embedded in a material which has similar impedance to that of the shaft, it may not be possible to see a reflection from the bottom of the shaft.

TEST PROCEDURE

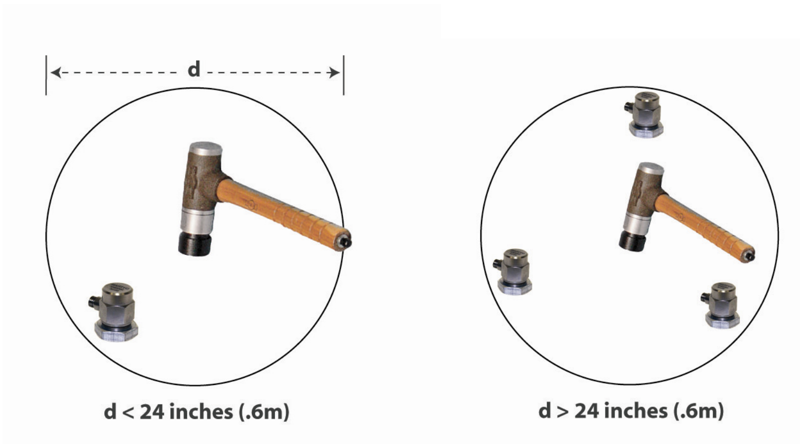
The contractor must provide a level testing surface on the top of the shaft. The test engineer must ensure that the shaft top is relatively smooth and clean. During the test, an accelerometer is attached to the shaft top with adhesive or grease. A rubber-tipped hammer is used to generate a low strain compressive impact wave.

If testing must be done from the upper side, a metal block must be affixed to the shaft side concrete with grease, epoxy, or an anchor bolt in such a way that it is firmly coupled to the concrete. The accelerometer is then mounted to the top of the block. Impacts can be made to the edge of the shaft top or the top of a grade beam/pile cap above the pile centerline.

For most piles, the accelerometer should be mounted as near to the edge of the pile as is practical. The location of the hammer impact should be as close as possible to the shaft center.

Plan View of Square Pile Shaft

For cast in-situ reinforced concrete shafts or bored piles, if the diameter of the shaft is less than 25 inches (0.6m), the accelerometer should be mounted as near to the edge of the pile as is practical. The location of the hammer impact should be at the shaft center. If the diameter of the shaft is greater than 24 inches (0.6m), the accelerometer should be mounted at three locations around the shaft perimeter while the impact should take place near the accelerometer mounting location. See diagrams below:



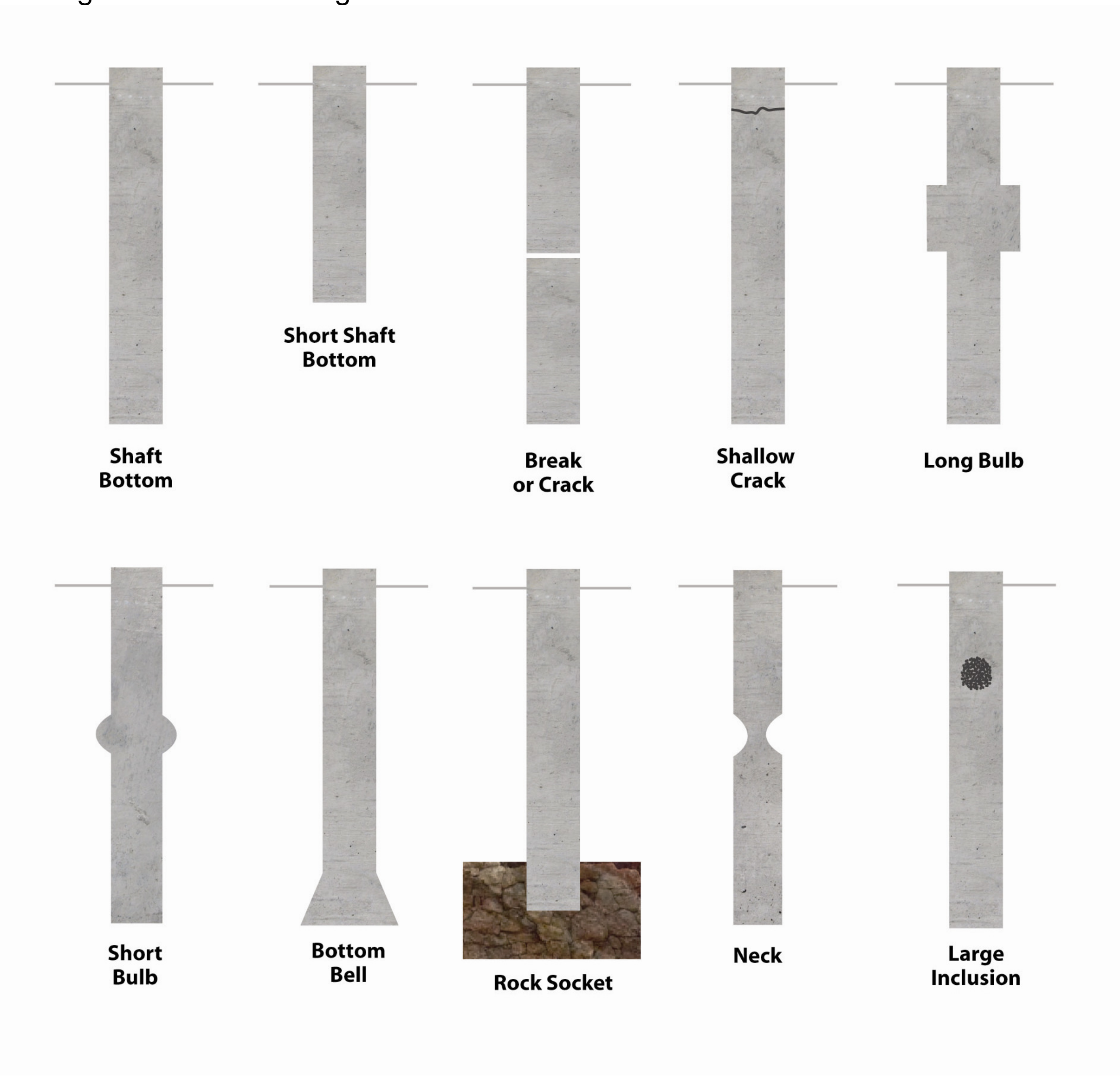
Plan View of Circular/Round Shaft Top

Several records should be collected and averaged; the test engineer is responsible for ascertaining that the records included in the average are consistent.

DATA ANALYSIS

A reflection may not be apparent if there are gradual changes or small local changes in the cross section of the shaft. Some conditions that do not lend themselves to clear results include small inclusions, gradual material changes, local loss of cover, debris at the bottom of the shaft, curved shafts, shafts with gradually decreasing diameters and shafts with gradually increasing diameters.

Conditions that are more easily detected by the Sonic Echo method include the shaft bottom, a crack or joint, a large material change within the shaft, a large inclusion within the shaft, an increase in cross section, a decrease in cross section, and soil layer changes in the material surrounding the shaft. See diagrams below:

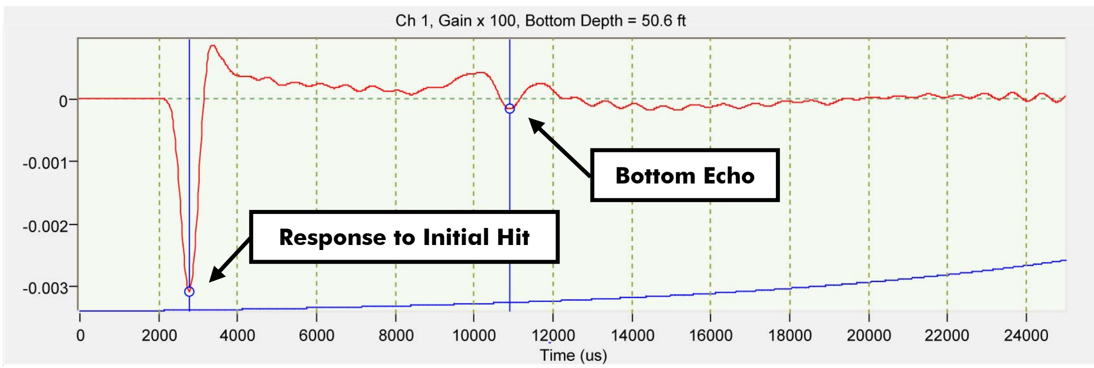


The Sonic Echo test does not provide any information about the static bearing capacity of the shaft and should not be used to determine the bearing capacity of a pile.

INTERPRETATION

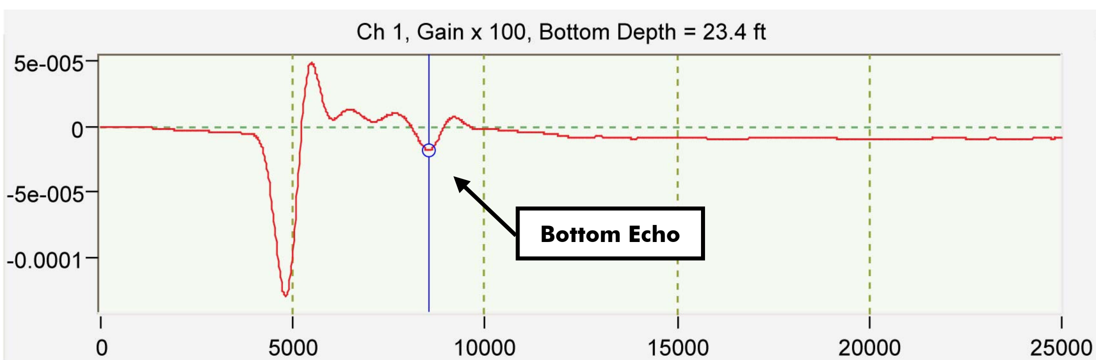
The recorded acceleration values are integrated to obtain velocity signals. The velocity values are then plotted against time. Generally, wave speeds should be estimated to be about 12,500 fps (4400 m/s) in sound concrete shafts, unless a direct measurement is made.

Shaft Bottom

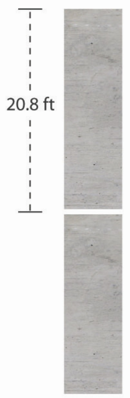


SE Record with Sound shaft, showing clear single bottom echo

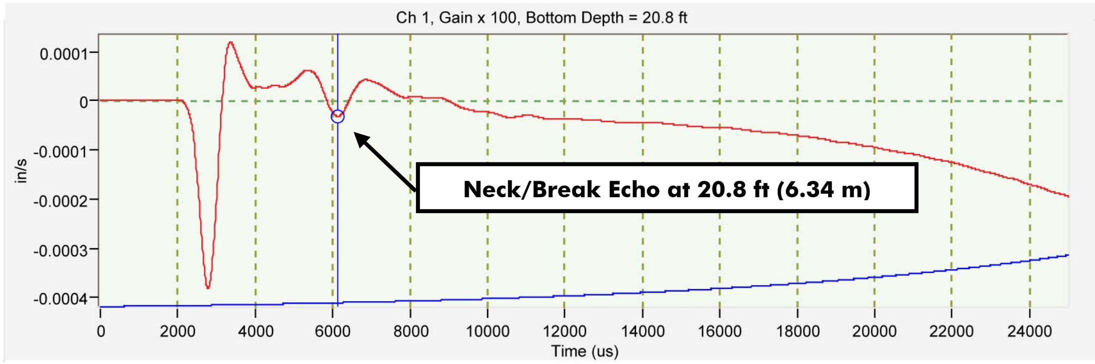
Short Shaft Bottom



Sound but short shaft

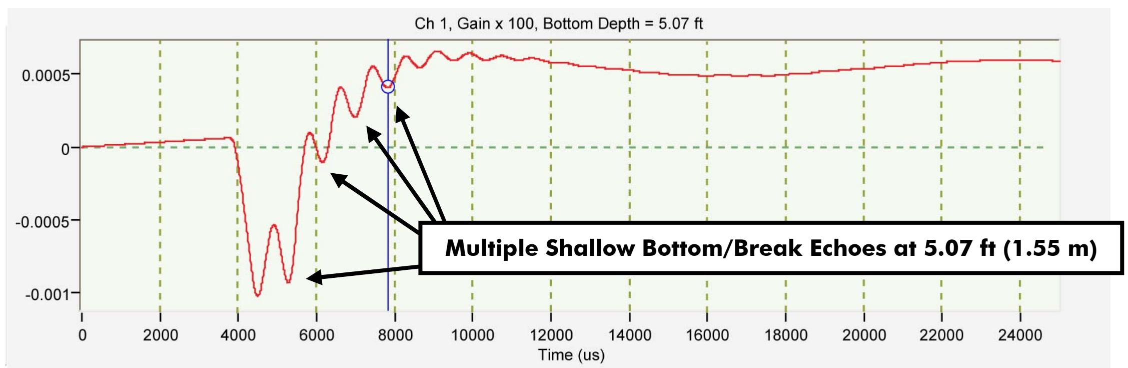


Break or Crack

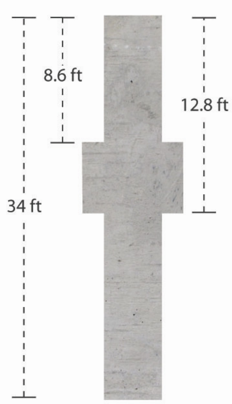


Shaft with neck/break at 20.8 ft (6.34 m). Note the actual shaft length is ~ 51 ft (15.5 m)

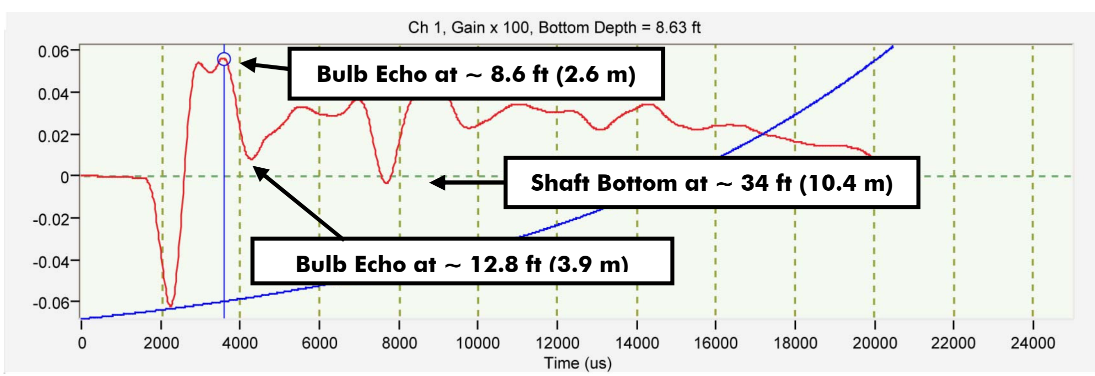
Shallow Crack



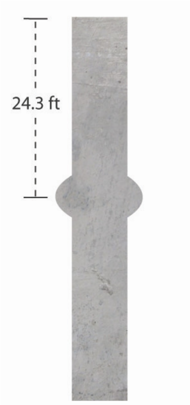
Multiple ringing echoes from a very short shaft or shallow break in a shaft



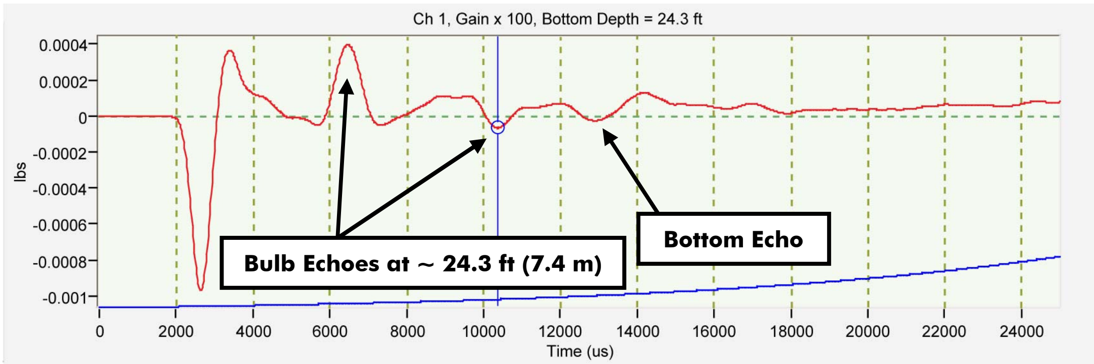
Long Bulb



Shaft with shallow enlargement from 8.63 to 12.8 ft (2.6 to 3.9 m), with bottom echo at 34.0 ft (10.4 m).

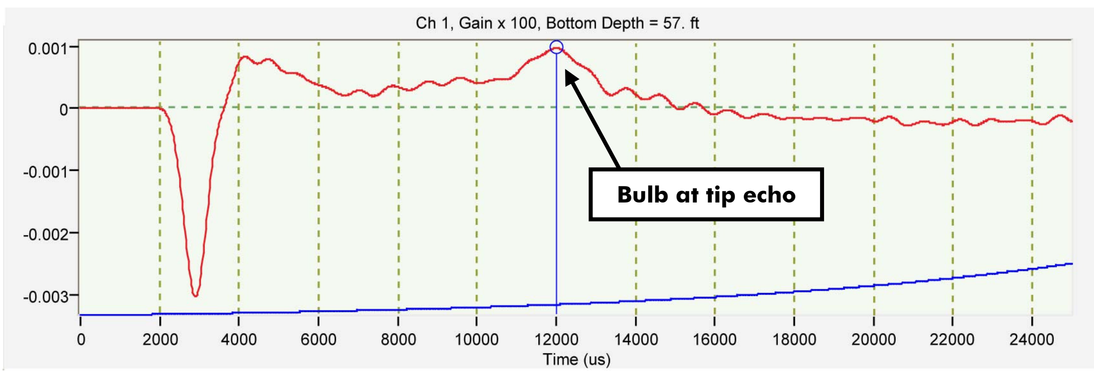


Short Bulb



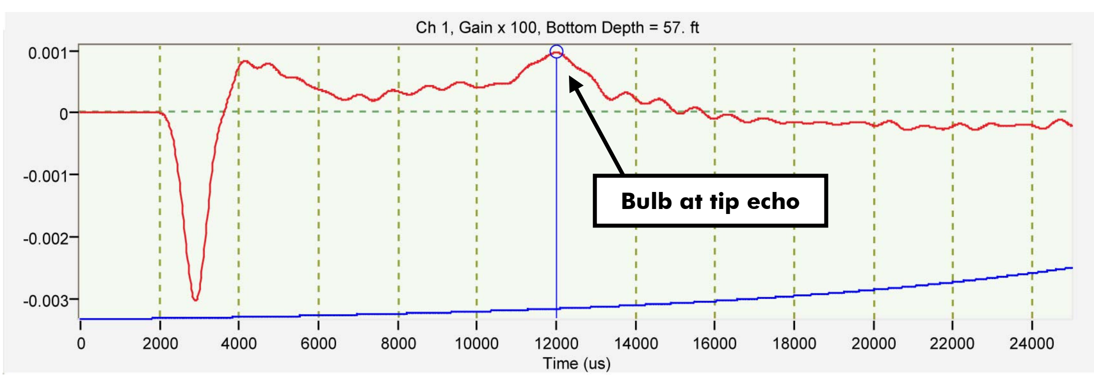
Shaft with wide, short shallow bulb at 24.3 ft (7.4 m), plus clear bottom echo at 64.1 ft (19.5 m)

Bottom Bell

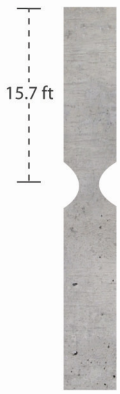


Shaft with bulb echo at the shaft bottom

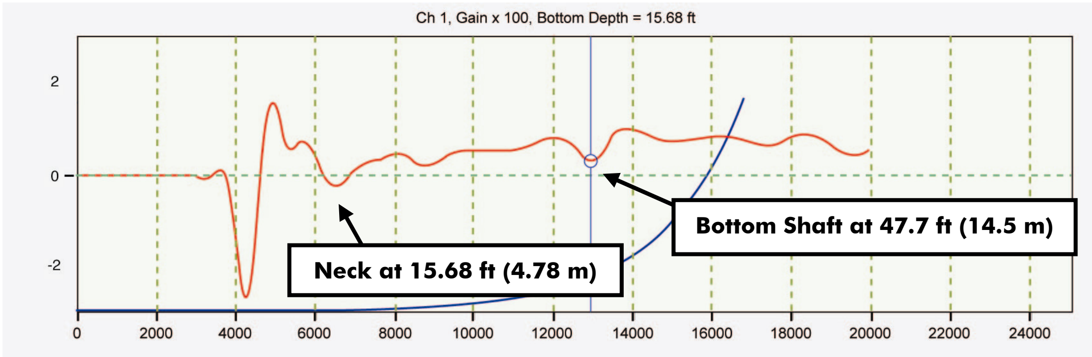
Rock Socket



Shaft with bulb echo at the shaft bottom

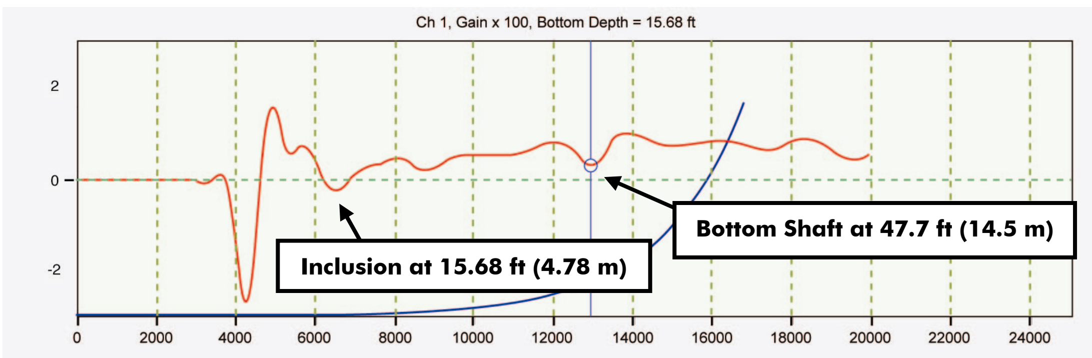


Neck



Shallow neck with bottom echo visible, shaft length at 47.7 ft (14.5 m) with a neck at 15.68 ft (4.78 m)

Large Inclusion



Large inclusion with bottom echo visible, shaft length at 47.7 ft (14.5 m) with an inclusion at 15.68 ft (4.78 m)