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Hydrometry — Echo sounders for water depth measurements

Hydrométrie — Sondeurs à écho pour le mesurage de la profondeur de l'eau

Reference number
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Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 4366 was prepared by Technical Committee ISO/TC 113, *Hydrometry*, Subcommittee SC 5, *Instruments, equipment and data management*.

This second edition cancels and replaces the first edition (ISO 4366:1979), which has been technically revised.

Hydrometry — Echo sounders for water depth measurements

1 Scope

This International Standard provides information concerning the principles of operation, selection and performance criteria for echo sounders used in depth measurements for open-channel flow (and related) measurements. The use of standard terminology is promoted.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 772, *Hydrometric determinations — Vocabulary and symbols*

ISO 6420, *Liquid flow measurement in open channels — Position fixing equipment for hydrometric boats*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 772 and the following apply.

3.1
tracking window
vertical distance of limited size that follows and automatically centres itself on the depth indicated by the last received echo

NOTE If the next echo falls within the window, the signal is accepted as correct; if it does not, the signal is rejected. The purpose of a tracking window is to screen out erroneous readings caused by reflecting materials in the water (fish, debris, etc.).

4 Units of measure

The units of measurement used in this International Standard are SI units and decibels.

5 Principles of operation

5.1 General

The state-of-the-art of echo sounders is well advanced, and sounders have been put into widespread use for many different applications. Consequently, a variety of specialized echo sounders have evolved to best meet the specific requirements of the application. A digital echo sounder with an integrated analog chart generated by a thermal or inkjet print head is the most common echo sounder used for open-channel applications. Multiple-transducer systems are in common use by many professional surveyors and the use of single-transducer, multibeam-swath systems is expanding rapidly.

5.2 Theory of operation

The echo sounder is an electroacoustic instrument that determines the depth of water by measuring the time required for a burst of acoustic energy to travel from a transducer to the streambed and reflect back to the transducer (Figure 1). The travel time of the reflected wave can be converted to distance by use of the following equation:

$$d = \frac{vt}{2} + k + d_{\mathrm{r}} \qquad (1)$$

where

d is the distance from the reference water surface to the streambed;

v is the average velocity of sound in the water column;

t is the travel time of the acoustic energy from the transducer to the bottom and back to the transducer;

k is the system index constant;

d_{r} is the distance from the reference water surface to the transducer (draft).

NOTE All distance units are consistent.

The velocity of sound varies with the density and elastic properties of the water, which are primarily a function of the water temperature and suspended or dissolved constituents (i.e. salinity). Large variations in temperature and/or salinity with depth are not uncommon. For practical depth measurement with an echo sounder, the velocity of sound is usually determined by calibration (see 8.1), since measuring and correcting for the actual variation at each depth interval is difficult.

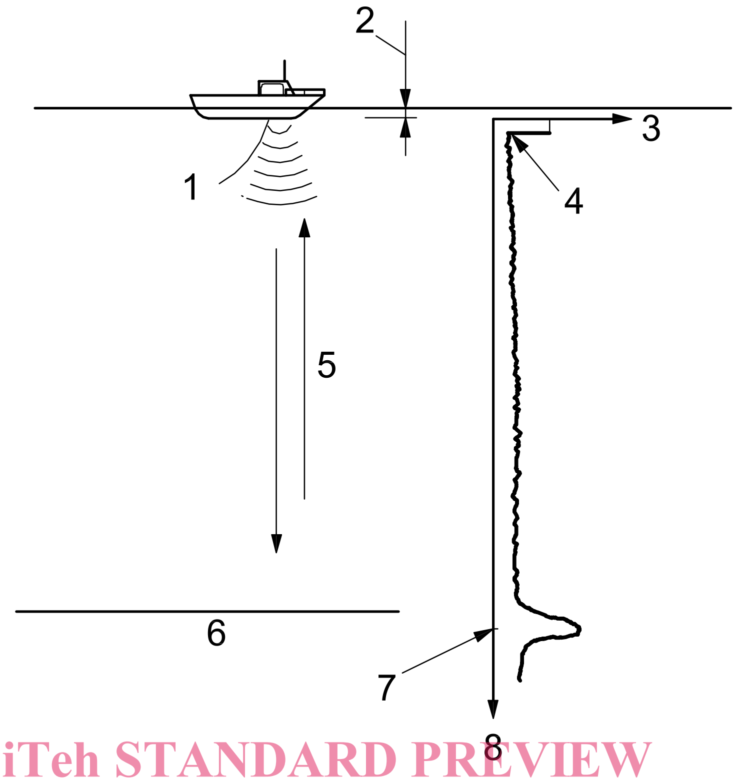
The travel time of the acoustic energy is recorded either electronically by a digital echo sounder or graphically by an analog chart echo sounder. The shape, or sharpness, of the reflected acoustic energy pulse plays a significant role in the accuracy of a depth measurement (Figure 1). The shape and magnitude of the reflected energy pulse is a function of the acoustic attenuation, background noise and acoustic reflectivity characteristics of the target.

The system index constant (k) contains all electrical and/or mechanical delays inherent in the measuring system, including return signal threshold detection variations. The system index constant also contains any constant correction due to the change in the velocity of sound between the upper surface level and the average velocity used for the site. Therefore, the draft (d_{r}), set during calibration, is not necessarily the actual draft of the transducer that would be obtained by a physical measurement from the water surface to the transducer, but also includes corrections for the system index constant determined during on-site calibration.

5.3 System components

The echo sounder consists of two elements: the electronic assembly, which usually includes a display and/or recording device, and the acoustic assembly commonly called the transducer. The electronic circuitry generates high frequency electrical energy and provides regulated bursts of this energy to the transducer. When a burst of energy is released, time is measured until the reflected energy is received, then Equation (1) is solved and the depth is displayed or recorded.

The transducer is an electroacoustic assembly that acts as a two-way energy conversion device. During transmission, it converts pulses of electrical energy into pulses of acoustic energy that travel through the water to the bottom. During reception, it receives the reflected acoustic energy (echo) from the streambed and converts it into electrical energy for processing by the electronic circuits.



Key

1 depthsounder transducer
2 draft
3 signal
4 time acoustic pulse is transmitted
5 reduced energy
6 acoustically reflective bottom
7 time reflected pulse is received, $\left(\frac{2}{v}\right)$ (depth $- k - d_r$)
8 time

Figure 1 — Illustration of an acoustic depth measurement [2]

5.4 Non-recording echo sounders

The most common type of non-recording echo sounder has a liquid crystal display (LCD) that displays the depth numerically. Many of these echo sounders also display the return echo graphically and are commonly used as fish finders by fishermen. The numerical depth determination requires the same processing as a digital echo sounder (see 5.6). The non-recording echo sounders typically have wider beamwidth transducers and no calibration adjustments, resulting in a lower accuracy than survey-grade digital echo sounders. Some of the non-recording echo sounders digitally output the depth to an external device through a serial communications port.

5.5 Analog recording echo sounders

Traditionally, analog recording echo sounders have used an electric timing motor to rotate a stylus at a constant speed across heat-sensitive paper. When the stylus passes over the zero contact, it burns a mark on the paper and simultaneously triggers the release of acoustic energy. The stylus continues to move until reflected acoustic energy is received at the transducer generating an electrical current that is applied to the stylus to cause it to burn a mark on the chart again. The stylus continues to rotate until it reaches the zero contact and the cycle is repeated. As the stylus rotates, the chart is being moved by another motor and the resulting succession of marks made by the stylus creates a time-time graph. The stylus speed is adjusted through calibration to equal the speed at which the acoustic energy travels to the streambed and back, thus the distance between the zero mark and other marks on the chart are proportional to the distance between the transducer and the streambed. The speed at which the chart moves is arbitrary so that the chart transit does not necessarily indicate the distance the boat travelled.

Modern analog recorders, which are often combined with a digital display and output (see 5.6), use a fixed thermal or inkjet printing head in place of the rotating stylus. This helps reduce the potential synchronization error and allows electronic filters and processing algorithms to be applied to the data to compensate for the velocity of sound and allows electronic annotation of the chart. The mass, dimensions and power consumption of the fixed-head recorders are less than the rotating stylus design.

5.6 Digital echo sounders

5.6.1 General

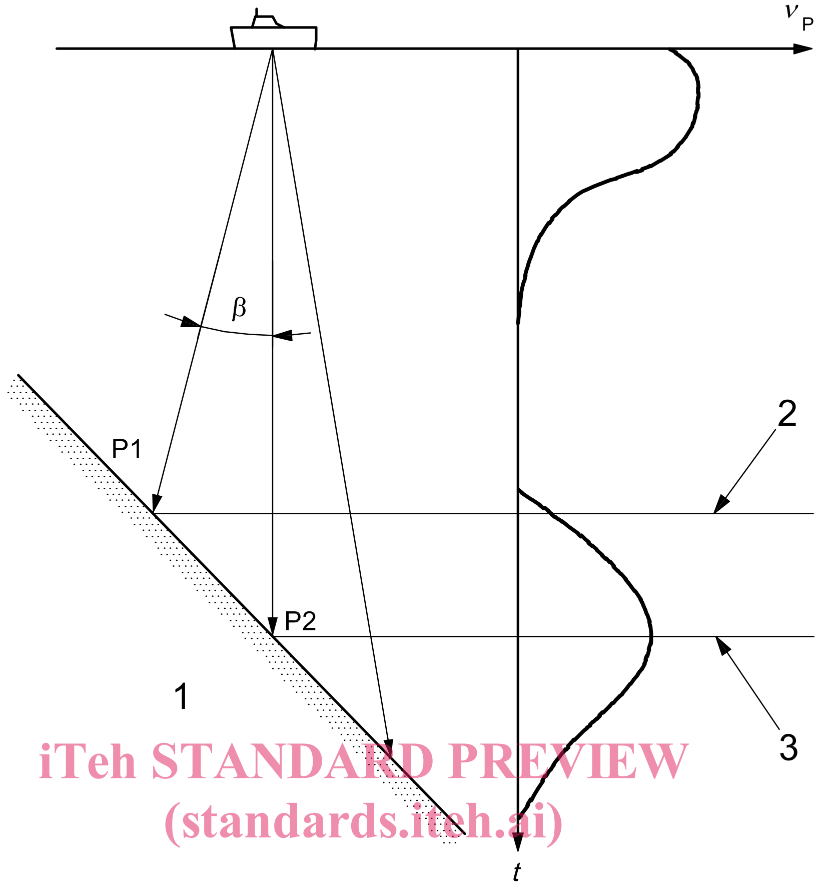
In the digital echo sounder, acoustic pulses are released at set intervals. When an acoustic pulse is released, a counter is started and counts the output of an oscillator. When the reflected acoustic energy is received, the oscillator counts are used to measure the elapsed time and the depth is computed using Equation (1). The accuracy of the depth measurement is highly dependent on the digitization techniques and filters that are used to determine what oscillator count represents the streambed.

Digital echo sounders are the most common echo sounders available. They range from non-recording LCD units to survey-grade echo sounders that usually combine an analog recorder with a numerical display and digital output.

5.6.2 Digitization techniques

Two digitization techniques are commonly used to screen erroneous data and improve the reliability of the acoustic data. The most common technique is threshold detection. Threshold detection measures the time from transmission of the acoustic signal until the energy of the reflected energy exceeds a predetermined threshold or strength. The remaining acoustic energy is not analysed. The threshold value may be adjusted by the user on advanced echo sounders, but it is often fixed and not user selectable. A more robust technique, employed on some survey-grade echo sounders, is peak value detection. Peak value detection analyses all of the reflected energy and computes the time from acoustic release to the peak of the reflected energy or strongest signal. Figure 2 illustrates the difference between the two techniques on a sloping bed. The peak value detection technique produces a measured depth more representative of the centre of the acoustic footprint of the transducer. The peak value technique can significantly reduce the effective beamwidth of the transducer, providing a more accurate representation of the streambed directly below the transducer.

Any material such as fish, debris or air bubbles between the transducer and the streambed can reflect acoustic energy. Peak value detection is less sensitive to these unwanted reflections than threshold detection; however, nearly all survey-grade echo sounders employ techniques to reduce or eliminate erroneous readings caused by reflectors in the water column. A tracking window that rejects all signals except those within a given tolerance of the preceding depth is commonly provided. These reflections from objects in the water column are recorded on the analog chart in addition to the bottom echo. The analog chart is very valuable for verifying the accuracy of the digitized depth. Despite the techniques employed in digital echo sounders, erroneous readings are still common, particularly around obstructions such as bridge piers and sea walls. Depth measurement in such areas without an analog presentation of the data is not recommended.



Key

1 sea bottom

2 threshold point, v_{P1}

3 peak point, v_{P2}

t time

β beamwidth

Figure 2 — Illustration comparing threshold and peak value detection techniques

5.6.3 Multiple-transducer systems

A variety of multiple-transducer channel sweep systems have been used since the mid-1970s. These systems are designed to provide a broad area of coverage, rather than a single line, for each pass of the vessel. Channel sweep systems are simply a series of standard transducers mounted on a vessel and/or on booms attached to the vessel. Sweep systems may use any number of transducers. The spacing between the transducers is determined by the nominal water depth, transducer beamwidth, and desired overlap of the transducers' acoustic footprints. The sweep width is determined by the type of vessel. The sweep width must be optimized with vessel manoeuvrability; wide sweeps are difficult to control. Both analog and digital data may be collected. When more than eight transducers are employed, digital terrain modelling display techniques are helpful for interpreting the large amount of data collected.

5.6.4 Single-transducer swath systems

Single-transducer swath survey technology was developed in the early 1960s for deep-water bathymetric mapping. Recently, this technology has been developed and marketed for shallow-water applications. These systems employ scanning or phased-array techniques to generate a series of measurements over a given arc (Figure 3).