International Standard 4366

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Echo sounders for water depth measurements

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Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

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Australia
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No member body expressed disapproval of the document.

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Echo sounders for water depth measurements

1 Scope and field of application

This International Standard provides information concerning the principle of operation, performance and selection criteria for echo sounders used in depth measurements for open channel flow (and related) measurements. The use of standard terminology is promoted. Information on the characteristics of sound in water is provided in annex.

2 Reference

ISO 772, *Liquid flow measurements in open channels — Vocabulary and symbols.*

3 Definitions

For the purpose of this International Standard, the definitions given in ISO 772 shall apply with the addition of the following :

tracking window : An opening of limited size which follows and automatically centres itself at the depth indicated by the last received echo. 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 measurement

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

5 General

The state-of-the-art in echo sounders is well advanced, and sounders have been put into widespread use for many different applications. Consequently, a variety of specialized sounders have evolved to best meet the specific requirements of the application.

6 Principle

The echo sounder is an electroacoustic instrument which indicates the depth of water (actually measuring the distance from the face of its transducer to the stream bed) by measuring the time differential between the transmission of a burst of acoustic energy and the reception of the echo from the stream bed or the bottom. Depth is determined from the equation

$$d = \frac{t}{2} c$$

where

d is the distance from the transducer to the stream bed;

t is the travel time of the acoustic energy;

c is the velocity of sound in water.

6.1 General

The echo sounder consists of two elements : the electronic assembly which usually includes the readout or recording device and the acoustic assembly or 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 return signal is received. The above equation is solved and the depth is displayed or recorded.

The transducer is an electroacoustic assembly which acts as a two-way energy conversion device. During transmission it converts pulses of electrical energy into pulses of sonic energy which travel through the water to the bottom. During reception, it receives the echos of sonic energy reflected from the bed and converts them into electrical energy to operate the electronic circuits.

6.2 Non-recording echo sounders

The most common type of non-recording echo sounder has a display in which a timing motor rotates a light behind a circular scale. When the light is directly behind the zero depth point, it is briefly illuminated; and, concurrently, the acoustic pulse is released. When the echo is received, the light is again briefly illuminated, indicating the depth.

6.3 Analogue recording echo sounders

The most common type of recording echo sounder is very similar in principle to the non-recording type. A timing motor drives a stylus at a constant speed across a carbon back chart paper. At the zero depth point, a burn mark is made on the carbon back chart paper and, concurrently, the acoustic pulse is released. When the echo is received, the stylus makes another burn mark on the paper. The distance the stylus has travelled on the chart paper represents the water depth.

6.4 Digital echo sounders

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 echo is received, the counter is stopped. The oscillator frequency is chosen so that the display of the counter gives the water depth directly.

Any material such as fish, debris, or air bubbles between the transducer and the stream bed could produce an erroneous reading since the first echo above a given trigger level stops the counter. To afford protection from such erroneous readings, a tracking window, which rejects all signals except those within a given tolerance of the preceding depth, is usually provided. The same difficulty is not experienced with the analogue recording sounder since the relatively weak signal returns from such materials produce only burn marks on the chart; and, in addition, produce a readable trace for the stream bed.

7 Selection of instrument

7.1 Effects of operating frequency

The frequencies commonly used for echo sounders lie in the range from 5 to more than 200 kHz. Those transmission losses associated with frequency generally restrict the ranges of the higher frequency sounders to 100 m or less. Sounders used in deeper ocean waters usually operate in the 20 kHz range. Depths encountered in open-channel flow measurements are almost always less than 100 m. Sounders operating at higher frequencies offer two advantages for open-channel work. In general, transducers designed for the higher frequencies have a much narrower beam width; and, therefore, better discriminate abrupt changes in the streambed. Higher frequency sound is reflected from the unconsolidated bed material instead of penetrating it, thus giving a sharper, more clearly defined trace. For flow-measuring work, the top of the unconsolidated material is the desired depth reading.

7.2 Effect of beam width

The beam width of a transducer is defined as the included angle between the half power points (see the figure). It is desirable that the beam width of an echo sounder transducer be narrow for two reasons :

a) only with a narrow beam width can abrupt changes or step inclinations in the stream bed be detected; a wide beam width would illuminate such a large area that the low points in the bed would be masked by the returning signals from the higher points which would arrive first;

b) since transmission losses are very high, concentrating the energy into a narrow beam permits operation over a greater range without expending excessive amounts of power.

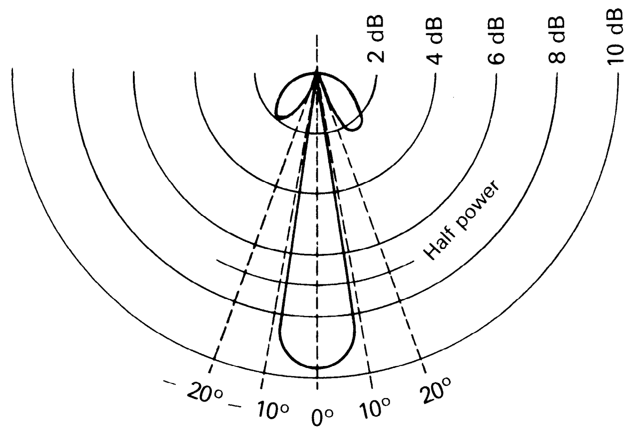

Figure — Beam width pattern

7.3 Type of data display

7.3.1 Non-recording echo sounders

The flashing light system on the non-recording sounder does not present a sharp and distinct display. Readability of such sounders is of the order of ± 0,35 m at best and can be poorer if reverberation is severe. The light is also difficult to read in strong sunlight.

Normally, no provision is made for correcting for changes in the velocity of sound and overall uncertainty can be quite high, ± 8 %. plus readability.

Because of the relatively low accuracy, this type of sounder is not satisfactory for most data collection purposes. Such sounders can sometimes be used to advantage for preliminary surveys.

7.3.2 Analogue recording echo sounders

The stylus burn marks of the recording sounder are relatively sharp; and if the scale of the chart paper is adequate, readability can be good. For shallow depth sounders, readability should be ± 0,15 m or better.

Provision for the correction of changes in the velocity of sound is made on the better quality recording sounders, and accuracy can be quite high, provided proper and frequent calibrations are made.

7.3.3 Digital echo sounders

On the digital sounder, readability should be ± 0,05 m or better, as the electronic circuitry is capable of detecting the leading edge of the acoustic pulse.

As on the recording sounders, provision is made for correcting for changes in the velocity of sound; and, with proper and frequent calibration, accuracy can be very high.

The tracking window described in 6.4 is a costly, but necessary item, as digital sounders without this feature are not reliable since false echoes occur frequently.

The display digits of most sounders are very difficult to read in strong sunlight, and some type of shielding is necessary. Displays that are readable in direct sunlight are becoming available.

7.4 Accuracy

The accuracy of readings from echo sounders depends on a number of factors. Among these factors are readability, calibrations to correct for the changes in velocity of sound, and the width of the acoustic beam. The latter item is of great significance in radically changing bed profiles. The operating frequency can also have a significant effect if the bed is made up of unconsolidated material.

For the above reasons, it is impossible to determine the accuracy of echo sounders for general situations. Under ideal situations, accuracy can approach the readability figures given in 7.3. As the accuracy required of an echo sounder may be better than 1 % of the depth measured, the factors described in the annex and clause 8 should be kept in mind by the user.

8 Instruments performance criteria

It is evident from the previous clauses that one type of echo sounder cannot meet world wide operational requirements. Therefore, no single specification can be written for such an instrument. Nonetheless what can be specified is the information which a prospective user should give to an instrument manufacturer and, in return the information which a manufacturer shall supply to the user, to enable the equipment to meet as nearly as practicable the user's requirements.

8.1 Information to be specified by the user

a) The range of depths to be measured.

b) The anticipated nature of the stream bed.

c) Where possible, the anticipated nature and the extent of suspended matter.

d) Other matter affecting the velocity of sound in water, such as anticipated pollution, salinity, etc.

e) The desired accuracy of depth determination.

f) Environmental conditions.

g) Power supply available.

h) Distance between transducer and recorder.

8.2 Information to be specified by the manufacturer

a) The frequency or frequencies at which the equipment operates.

b) Transducer beam width, which should as far as is practicable be not greater than 10°.

c) The smallest interval which may be read or recorded.

d) The minimum depth to which the echo sounder will respond.

e) The anticipated accuracy of depth determination having regard to the following :

1) installation of the equipment with full instructions adequately illustrated;

2) operational procedure;

3) maintenance routines;

4) special requirements for control of equipment environment.

8.3 Housing

The electronics and readout or recording unit should be housed in a splash-proof container for protection from spray and inclement weather conditions. The transducer(s) should be housed in a streamlined mounting so that air entrainment is held to a minimum.

8.4 Additional features

8.4.1 Non-recording instruments

A sensitivity control should be provided so that adjustments can be made to produce the most readable indication of depth under varying conditions.

8.4.2 Recording instruments

8.4.2.1 Chart readability

The recorder unit should have a sufficiently wide chart so that the desired readability can be achieved. The stylus should produce a clearly readable trace. Two or more selectable chart speeds should be provided so that the trace can be produced at a speed most suited for the application. It is desirable that the recorder indicate "zero" or the initial point of signal transmission.

8.4.2.2 Viewing window

A viewing window should be provided so that the record can be monitored with the case closed.

8.4.2.3 Depth range selector switch

It is frequently desirable to cover the entire depth range of the sounder in two or more steps in order to obtain better readability of the chart.

8.4.2.4 Event marker

A mark switch should be incorporated so that the operator can insert a reference mark on the record.

8.4.2.5 Sensitivity control

A sensitivity control should be provided so that changes in sensitivity can be made so as to produce the most readable trace as water conditions change or depth changes.

8.4.2.6 Tide or draft adjustment

The sounder should be equipped with a tide or draft adjustment control. Such adjustment is to provide a means of correcting for changes when the sounder is being used in tidal waters. It should also provide a means of correcting for the distance the transducer is placed below the water surface.

8.4.2.7 Velocity of sound adjustment

A control shall be provided for correcting for changes in the velocity of sound in water.

8.4.3 Digital instruments

8.4.3.1 Digital display

The digital display should be clear and distinct. A shroud should be provided so that the digits can be read even in strong sunlight.

8.4.3.2 Sensitivity control

A sensitivity control should be provided so that the signal can be adjusted for changes in water conditions and depth.

8.4.3.3 Velocity of sound adjustment

A control shall be provided to correct for changes in the velocity of sound in water.

8.4.3.4 Tracking window

A tracking window should be provided which rejects all signals except those within a given tolerance of the preceding depth.

9 Use of echo sounders

9.1 Calibration

Since the velocity of sound changes with changes in water density and elasticity, and these are changing with changes in temperature, pressure, suspended solids, dissolved solids, etc., and since indicated depth is directly proportional to the velocity of sound, the echo sounder must be calibrated on site in order to produce accurate measurements.

The standard calibration method is to adjust the sounder to read a known depth correctly. This, of course, is not a direct measurement of the velocity of sound but accomplishes the objective which is to calibrate the sounder to read correctly. This is usually accomplished by suspending on chains or cable a metal plate at a known distance below the transducer. The flat surface of the plate should be parallel with the face of the transducer.

When accurate soundings are to be made, the sounder should be calibrated at least daily and more frequently if there are suspected changes in the water density or elasticity.

9.2 Interpretation of data

Only the analogue recording sounder makes all data available so that any real analysis of the data can be made.

Reading of the depth from the chart is generally the primary objective. Since the duration of the burst of sonic energy is of a finite time, the stylus makes a broad mark at the "zero" or initial release point. The return signal is of even longer duration since it, besides having the initial time duration, is returning from all distances within the illuminated area of the bed. The depth reading is therefore obtained by reading the distance from the top (leading edge) of the "zero" mark to the top of the echo mark.

In addition to the depth information, the width and intensity of the echo mark provide some insight into the type of bed material. A wide trace indicates unconsolidated material while a narrow and intense trace indicates a firm bed.

Charts produced by sounders operating in the lower frequencies may, under some site conditions, indicate penetrations sufficiently to define both the depth and the underlying bedrock;

9.3 Precautions

Echo sounders should be used only with caution where the suspended sediment concentration is sufficiently high that one is not positive the return signal received is from the bed. The same is true where the amount of entrained air is high, such as down the chutes and spillways or immediately below hydroelectric plants. No specific figures can be given since satisfactory operation depends upon the operating frequency of the sounder, the make-up of the foreign material, and other factors.

10 Operational manual

A fully comprehensive operational manual, giving full instructions and, where necessary, illustrations, shall be supplied with each sounder. The manual should include any maintenance and trouble-shooting information deemed desirable. A list of recommended spare parts shall also be provided.

Annex

Characteristics of sound in water

The utility of sound waves, not only in air but also in water, results from the fact that they are a form of energy having well defined characteristics. This energy may be controlled with great accuracy and may be transmitted from place to place. Because of these two properties, it may be used as a vehicle for carrying information.

Sound waves are generally classified into three regions : frequencies of less than 50 Hz are termed subsonic; the audible range between 50 and 15 000 Hz as sonic, and the range of frequencies greater than 15 000 Hz is termed ultrasonic.

A.1 Velocity of sound in water

One of the most important characteristics of sound as applied to echo sounders is the velocity of propagation in water. Sound velocity is dependent upon the density and elasticity of the medium and independent of frequency. The density is defined simply as the mass per unit volume. It is written as

$$\varrho = \frac{m}{V}$$

where

ϱ is the density;

m is the mass of a given volume;

V is the given volume.

The elasticity of water, as affecting the propagation of acoustic waves, is defined as the ratio of some given change in pressure to the accompanying fractional change in volume. Thus defined, it is known specifically as the volume elasticity or as the bulk modulus. It is written as

$$E = \frac{p_w - p_{wo}}{(V_o - V)/V_o}$$

where

E is the modulus of elasticity;

p_{wo} is the initial value of the total hydrostatic pressure of the water;

$p_w - p_{wo}$ is the change in total hydrostatic pressure;

V_o is the inital volume;

$V_o - V$ is the change in volume.

The propagation velocity c is expressed as

$$c = \sqrt{\frac{E}{\varrho}}$$

Since the velocity of sound is dependent upon the density and elasticity of the medium, it may be of interest to consider some of the factors that influence either. The density of water increases with increase in dissolved solids and with increase in pressure, or depth below the surface; and increases with temperature in such a manner that it passes through a maximum value at about 4 °C. The elasticity is affected to a much greater proportional degree by these three factors than is the density; consequently, when both vary due to some common cause, the velocity of sound increases or decreases as the elasticity increases or decreases.

The velocity of sound in fresh water varies from approximately 1 400 m/s to slightly above 1 500 m/s (approximately an 8 % variation) over the ambient water temperature range (− 4 °C to + 35 °C).

A.2 Transmission of sound in water

Of the acoustic energy transmitted, only a portion reaches the target. The remainder is lost in various directions. This loss in signal strength associated with transmission of sound energy through water is called propagation loss. It consists of spreading loss and attenuation loss.

A.2.1 Spreading loss

Spreading loss is the reduction in acoustic intensity due to the increase in area over which a given acoustic energy is distributed.

In the ideal situation, spreading occurs in accordance with the familiar inverse square law applicable, in general, to all forms of radiant energy. Spreading loss is independent of frequency.

A.2.2 Attenuation loss

Attenuation loss is the reduction in acoustic intensity due to the resistance of the medium to the transmission of acoustic energy. It is analogous to the loss suffered by electric energy transmitted over a wire line, where there is no spreading loss. Attenuation loss is due to the combined effects of scattering and absorption. Attenuation loss varies directly with the square of the frequency.

A.2.2.1 Scattering

Scattering is the modification of the direction in which acoustic energy is propagated, caused by reflections from the innumerable foreign bodies in the water. These bodies, which may include microscopic air bubbles and suspended particulate matter, as well as visible bubbles and suspended matter, present abrupt changes in specific acoustic impedence, causing the signal to be reflected and scattered.

A.2.2.2 Absorption

Absorption is the process by which acoustic energy is converted into heat by the friction between the water molecules as a sound wave in water is attended by repeated compressions and expansions of the medium.

A.3 Reverberation

Reverberation is the energy returned by reflectors other than that which it is desired to observe. Reverberation of sound in water is analogous to the familiar optical effect which impairs the utility of automobile headlights on a foggy night. The relation between echo and reverberation is in some respects similar to the signal-to-noise ratio and is often the factor which limits the performance of an echo-sounding system. Because of the large amount of reverberation associated with high suspended sediment concentrations in heavily silt laden streams or great amounts of entrained air bubbles frequently encountered below hydro-electric plants, the echo signal may be masked by reverberation signal. In such cases, echo sounders cannot be used to provide reliable data.

A.4 Reflection coefficient of the bed

The reflection coefficient, which is defined as the ratio of reflected to incident sound energy, depends on the material of the bed and the frequency of the sound.