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Shipbuilding — Marine echo-sounding equipment

Construction navale — Appareils de sondage par écho

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Foreword

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Shipbuilding — Marine echo-sounding equipment

Section 1 : General

1.1 Scope

This International Standard specifies the performance and type testing of marine echo-sounding equipment required by Regulation 12 of Chapter V of the *International Convention for the Safety of Life at Sea, 1974* (SOLAS 1974) as amended.

It establishes, when used in conjunction with IEC 945, minimum performance requirements, test methods and required test results for marine echo-sounding equipment which measures the depth of water under a ship by transmitting pulsed acoustic energy and timing the return of the echo from the sea-bed.

Section 2 gives the performance requirements, based on IMO Resolution A.224(VII).

Section 3 consists of the test methods and the required test results.

1.2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 945 : 1988, *Marine navigational equipment — General requirements — Methods of testing and required test results.*

International Convention for the Safety of Life at Sea (SOLAS 1974) as amended, Chapter V, Regulation 12: Shipborne navigational equipment.

IMO Resolution A.224(VII), *Performance standards for echo-sounding equipment.*

IMO Resolution A.574(14), *Recommendation on general requirements for electronic navigational aids.*

1.3 Definitions

For the purposes of this International Standard, the following definitions apply.

1.3.1 source level, S: Maximum rms (root-mean-square) sound pressure level, expressed in decibels relative to 1 µPa, at a point on the principal axis of the transducer, as measured in the far field but referred to the distance of 1 m.

1.3.2 directivity index, D: Ratio, expressed in decibels, of the acoustic power density at a distant point on the principal axis of the transducer, when used as a transmitter, to that of an omnidirectional transducer, with the same total radiated acoustic power.

1.3.3 receiving bandwidth, B: 10 $\log_{10} (f_1 - f_2)$, expressed in decibels relative to 1 Hz, where f_1 and f_2 are the upper and lower frequencies respectively in hertz at which the response of the overall system, measured through water, is 3 dB below the maximum response of the system.

1.3.4 minimum detectable signal-to-noise ratio, E: Ratio, expressed in decibels, of the signal level to the background noise level in the bandwidth of the receiver required to give a minimum detectable signal on the display.

Section 2 : Requirements

All requirements (with the exception of numerical values and their units) that are extracted from the recommendations of IMO Resolution A.224(VII) are printed in italics.

2.1 General requirement

2.1.1 *The echo-sounding equipment shall provide reliable information on the depth of water under a ship to aid navigation.*

2.1.2 Any facility provided by the equipment which is additional to the minimum requirements of 2.1.1 shall be tested to ensure that its operation and, as far as is reasonably practicable, any malfunctioning, does not degrade the performance of the equipment.

2.2 Range of depths

Under normal propagation conditions, the equipment shall be capable of measuring any clearance under the transducer between 2 m *and* 400 m.

2.3 Range scales

2.3.1 *The equipment shall provide a minimum of two range scales, one of which, the deep range, shall cover the whole depth range, and the other, the shallow range, the first one-tenth of the range.*

2.3.1.1 Range scales in addition to those required in 2.3.1 may be provided.

2.3.1.2 Positive indication of the range in use shall be provided in all cases.

2.3.1.3 Where phased ranges, not starting from zero, are available, an indication shall be provided to show when such a range is in use.

2.3.2 *The scale of display shall not be smaller than* 2,5 mm *per metre depth on the shallow range scale and* 0,25 mm *per metre depth on the deep range scale.*

2.4 Method of presentation

2.4.1 *The primary presentation shall be a graphical display which provides the immediate depth and a visible record of soundings. Other forms of display may be added but these shall not affect the normal operation of the main display.*

2.4.2 *The record shall, on the deep range scale, show at least* 15 min *of soundings.*

2.4.3 Where paper is used for recording depth on the graphical display, *either by marks on the recording paper, or by other means, there shall be a clear indication when the paper remaining is less than approximately* 10 % *of the original roll length.*

2.5 Safety

In the case of equipment using a high voltage electro-sensitive recording medium and/or a moving writing mechanism, and where access to the record is possible while the echo-sounding equipment is operating, the equipment shall provide for operator safety.

2.6 Pulse repetition rate

The pulse repetition rate shall not be slower than 12 pulses per minute.

2.7 Measurement accuracy

2.7.1 *Based on a sound speed in water of* 1 500 m/s, *the allowable tolerance on the indicated depth shall be either*

± 1 m *on the shallow range scale, and*

± 5 m *on the deep range scale;*

or

± 5 % *of the indicated depth,*

whichever is the greater.

NOTE — These tolerances take no account of ship roll and pitch.

2.7.2 Where a set zero control is provided, this shall be for use in calibration and installation and shall not be made available as an operator control.

2.7.3 Where depth measurement relative to the sea surface is provided, in addition to measurement of the depth of water under the ship, there shall be positive indication of the mode of operation in use.

2.8 Roll and pitch

The performance of the equipment shall be such that it will meet the requirements of this International Standard when the ship is rolling ± 10° *and/or pitching* ± 5°.

Section 3 : Test methods and required test results

3.1 General underwater test conditions

The equipment transducer in its housing, complete with acoustic window if provided, shall be attached underwater to a clamp calibrated in degrees to enable the transducer to be rotated to any required angle about the major axis of the face of its element (i.e. about the longer axis, which will run parallel to the ship fore-and-aft line) and about the minor axis (the athwartships axis) where the element is rectangular or elliptical, or about any facial axis where the element is circular.

A calibrated hydrophone, which can be replaced by a calibrated projector (or, alternatively, a single instrument capable of being used in either role as required) shall be mounted under the water at a suitable known distance, d, from the transducer and directed towards it. Initially, the transducer shall be directed towards the calibrated hydrophone.

NOTE — IEC 500 : 1974, *IEC standard hydrophone,* IEC 565 : 1977, *Calibration of hydrophones*, and IEC 565A : 1980, the first supplement to IEC 565 : 1977 give details on such equipment.

In order to minimize near-field effects, distance d, in metres, shall not be less than

$$1{,}25\ a^2 f/c$$

where

a is the largest active dimension of the transducer element, in metres, appropriate to the mode of use i.e. transmission or reception (usually the same figure for either);

f is the highest operation frequency of the echo-sounding equipment in hertz;

c is the sound speed in water, equal to 1 500 m/s (see 2.7.1).

Precautions shall be taken to minimize the effects of reverberation in the water. These precautions shall include the use of gated pulse measurement techniques. These techniques will be essential in the case of some echo-sounding equipment receivers that operate in a non-linear mode.

3.2 Range of depths

3.2.1 Minimum depth indication

3.2.1.1 Test method

The transducer in its housing, complete with acoustic window if provided, shall be normally connected and immersed in water with its axis of maximum response directed towards (i.e. normal to) an echoing boundary surface such as the bottom or side of the tank holding the water. It shall be possible to adjust and to measure the physical distance between the transducer and the boundary surface from zero to not less than 2 m.

The test shall be conducted such that no other object or discontinuity shall be capable of affecting the result significantly.

The equipment shall be set to the shallow scale with the longest pulse length available on that scale and the physical distance between the transducer and the boundary surface shall be adjusted until the echo from this surface is just indicated separately and distinctly on the display. This physical distance shall be measured and noted as the minimum depth indication.

3.2.1.2 Result required

The minimum depth indication shall not be greater than 2 m.

3.2.2 Maximum required measurable depth

3.2.2.1 Figure of merit

The equipment shall be tested by the assessment, under laboratory conditions, of the system figure of merit for a water depth of 400 m.

The figure of merit, L', expressed in decibels, is defined as

$$L' = S - 2r + D - B - E \qquad \text{. . . (1)}$$

and shall exceed L_0 as indicated by the following relationship:

$$L_0 = L + 2\alpha R + K + \mathrm{Ns} + x + y + z \qquad \text{. . . (2)}$$

where

S is the source level, in decibels relative to 1 µPa at 1 m;

r is the one-way loss figure due to roll and pitch, in decibels;

D is the receiving directivity index, in decibels;

B is the receiving bandwidth, in decibels relative to 1 Hz;

E is the minimum detectable signal-to-noise ratio, in decibels;

L is the spreading loss due to divergence, equal to 20 $\log_{10}$ (2 000 R);

R is the depth, in kilometres;

α is the sound absorption coefficient of sea water in decibels per kilometre (see annex A): combining R and α gives

$2\alpha R$, as the total water attenuation loss, in decibels;

K is the bottom reflection loss at normal incidence and is taken to be 25 dB;

Ns is the noise background level, in decibels relative to 1 µPa in a 1 Hz bandwidth, equal to 82,5 − (50/3) $\log_{10} f$;

x is the transmission loss in the case when the transducer is mounted inside the hull, in decibels;

y is a signal excess of 10 dB above the minimum detectable signal-to-noise ratio to provide a practical working level under all conditions;

z is a manufacturing tolerance of 3 dB.

3.2.2.2 Test methods

3.2.2.2.1 Source level, S

The transducer shall be immersed in water with its principal axis directed towards a calibrated hydrophone and lead (also immersed in the water) and situated at a known distance, d, in metres, in the far sound field from the transducer. The equipment shall be switched on.

The source level, S, is given by

$$S = (V + 120) - M + 20 \log_{10} d$$

where

M is the known response of the hydrophone and lead, in decibels relative to 1 µV/µPa;

V is the rms output voltage of the hydrophone and lead, in decibels relative to 1 V, measured during the pulse and averaged over its duration.

3.2.2.2.2 Roll and pitch, r

This test may be waived where suitable transducer beam direction stabilization is provided and can be demonstrated. Otherwise the one-way loss figure described below shall be determined to allow for the roll and pitch criteria specified in 2.8. The one-way loss figure, r, shall be the greatest reduction in response obtained when the source level measurement in 3.2.2.2.1 is repeated with the transducer element rotated by up to ± 10° about its roll axis and at the same time by up to ± 5° about its pitch axis.

3.2.2.2.3 Directivity index, D

This test may be carried out, at the discretion of the type test authority, with the transducer used in the transmitting mode as in 3.2.1 and 3.2.2.2.1, but whenever practicable, the receiving mode described as follows shall be used.

The transmitter shall be disabled, but the trigger shall be available for external use. With the transducer and a test projector directed towards each other, and the projector energized from a suitable pulsed signal source, the output voltage of the receiver of the echo-sounding equipment shall be monitored.

The pulse from the pulsed signal source shall be triggered by the echo-sounding equipment and delayed suitably to correspond with a definite depth within the scale. This pulse shall simulate the pulse normally transmitted by the equipment in regard to duration. The carrier frequency shall be adjusted to give maximum response on the echo-sounding equipment.

Using the method of maintaining constant receiver output voltage by varying the signal source voltage suitably, a pattern shall be plotted of transducer response against positive and negative angles of rotation of the transducer about each of its appropriate axes, in order to find the angular beam width, θ degrees between the two points giving a level 3 dB below maximum response.

The directivity index D shall be calculated as follows:

a) for circular transducers

$$D = 45{,}5 - 20 \log_{10} \theta$$

b) for rectangular or elliptical transducers

$$D = 45{,}5 - 10 \log_{10} (\theta_1) - 10 \log_{10} (\theta_2)$$

where θ_1 and θ_2 are the 3 dB beamwidths about the major and minor axes measured as specified above.

The type test authority shall take due note of the suitability of this method of calculating D from the measured beam patterns in the light of the patterns found. As a guide, the above method of calculating D is suitable provided that no narrow side lobe exceeds a level of 8 dB below the maximum of the main lobe. Extended side lobes, even at a much lower level, may render this method unsuitable.

3.2.2.2.4 Receiving bandwidth, B

The equipment shall be set up on the deep (400 m) range with the transducer in water and with its principal axis directed towards a calibrated projector fed by a cw signal source. The transmitter of the equipment shall be disabled, but not the transmitting trigger pulse where this is required to initiate the display trace.

The carrier frequency of the signal source shall be varied, and the level suitably adjusted and noted, and weighted by reference to the frequency calibration of the projector, in order to plot the frequency response of the equipment receiving system by the method of maintaining constant receiver output level. From the results, the upper and lower frequencies f_1 and f_2 respectively in hertz shall be found where the receiver response is 3 dB below maximum. Then

$$B = 10 \log_{10} (f_1 - f_2)$$

3.2.2.2.5 Minimum detectable signal-to-noise ratio, E

The transmitter shall be disabled while the trigger shall be available for external use. However, the test projector will not be required and the transducer need not be immersed in water.

A continuous random noise voltage of bandwidth equal to the bandwidth of the equipment receiving system and at a level well below saturation shall be added to a simulated echo pulse of variable amplitude which shall be triggered from the equipment delayed suitably to correspond with a definite depth within the shallow range scale. The combined signal shall be applied from a low-impedance source in series with the transducer. The level of the echo shall be adjusted to give a minimum detectable signal on the display of the equipment. E is then the ratio of the rms voltage of the echo pulse to the rms noise voltage.

3.2.2.3 Result required

The value of $L' = S - 2r + D - B - E$ shall be calculated and shall exceed the value of L_0 calculated for the appropriate operating frequency, a depth R of 400 m and the value of x declared by the manufacturer.

3.2.3 Receiver sensitivity

3.2.3.1 Test method

A simulated transmission pulse, giving a pressure level at the face of the transducer of the equipment of 10 dB less than the value of $(S - 2r - 2\alpha R - L - K - x)$ shall be applied through the water at the transmission frequency while the equipment is set to receive only. The effect at the display shall be observed and the pulse amplitude at the input terminals of the equipment shall be measured and recorded for use in the test of 3.2.4.2.

3.2.3.2 Result required

An indication shall appear on the display at the appropriate depth.

3.2.4 Performance checks

The following performance checks shall be carried out under normal conditions at room temperature. The results shall be recorded and retained for comparison with the results obtained from similar checks carried out when the equipment is being subjected to tests required by the relevant clauses in IEC 945.

3.2.4.1 Transmitter

3.2.4.1.1 Test method

The value of each of the following parameters shall be measured for the deep range scale:

a) transmission frequency;

b) transmission rms voltage during the pulse.

The output of the transmitter shall be fed, through the normal cable, to the transducer either in air or immersed in water, at the discretion of the type test authority in consultation with the manufacturer.

3.2.4.1.2 Result required

The transmitter frequency shall fall within the receiver pass band by a margin sufficient to accommodate the pulse spectrum defined by the reciprocal of the pulse duration.

During the tests in IEC 945, any decrease in the transmission rms voltage below that recorded in 3.2.4.1.1 under normal conditions shall not cause the figure of merit to fall below its required value.

3.2.4.2 Receiver

3.2.4.2.1 Test method

The transmitter (but not the internal trigger) shall be disabled. A simulated signal pulse of amplitude equal to that recorded at 3.2.3.1 delayed to correspond to a depth of approximately 400 m, shall be injected in series with the transducer. This test shall be repeated during each relevant test in IEC 945.

3.2.4.2.2 Result required

An indication shall appear on the display at the appropriate depth.

3.2.4.3 Transducer

3.2.4.3.1 Test method

The output of the transmitter shall be fed through the normal cable to the transducer. The transducer shall be either in air or immersed in water, as agreed by the type test authority and manufacturer. The arrangement agreed shall be used for all transducer performance checks. With the equipment operating, the transducer shall be directed at a suitable target. This test shall be repeated immediately after each relevant test in IEC 945.

3.2.4.3.2 Result required

An indication shall appear on the display related to the distance separating the transducer and the target.

3.3 Range scales

The range scale requirements laid down in 2.3 shall be verified by inspection and by measurement.

3.4 Method of presentation

The display requirements shall be verified by inspection during operation of the equipment.

3.5 Safety

The safety requirements shall be verified by inspection during operation of the equipment.

3.6 Pulse repetition rate

3.6.1 Test method

The transmitter pulse repetition rate shall be averaged over not less than 20 pulses on the deep range and not less than 100 pulses on the shallow range.

3.6.2 Result required

The pulse repetition rate shall not be less than 12 pulses per minute.

3.7 Measurement accuracy

3.7.1 Depth scales

3.7.1.1 Test method

With the equipment set up normally, a signal pulse, whose delay from the trigger pulse of the equipment can be controlled to an accuracy of ± 100 µs or better, shall be fed into the receiver and be adjusted to represent echos at intervals of 1 m on the shallow range scale and 10 m on the deep range scale, by progressing in increments of 4/3 ms and 40/3 ms respectively. Suitable intervals of not less than 1 m (4/3 ms) shall be used on other scales.

The apparent depth of the leading edge of each pulse shall be read off the scale.

3.7.1.2 Result required

The difference between the simulated depth being fed into the receiver and the reading of the display shall not exceed

± 1 m on the shallow range scale, and

± 5 m on the deep range scale;

or

± 5 % of the indicated depth;

whichever is the greater.

3.7.2 Set zero control

The requirement of 2.7.2 shall be checked by inspection.

3.7.3 Depth measurement relative to sea surface

The requirements of 2.7.3 shall be checked by inspection.

Annex A
(normative)

Sound absorption coefficient

A.1 The value of the sound absorption coefficient, α, in decibels per kilometre, for sea water is given by the equation

$$\alpha = \frac{A_1 \times P_1 \times f_1 \times f^2}{f^2 + f_1^2} + \frac{A_2 \times P_2 \times f_2 \times f^2}{f^2 + f_2^2} + A_3 \times P_3 \times f^2$$

for frequency f in kilohertz, and where coefficients A_1, A_2, A_3, P_1, P_2, P_3, f_1 and f_2 are each functions of a sub-set of the parameters, water temperature, salinity, pH value and depth. The three expressions in the equation give, respectively, the contributions due to boric acid, magnesium sulfate and pure water. These are widely accepted as being the only three contributions to absorption which need be considered, as the only other contribution identified by researchers is insignificant by comparison.

A.2 Two articles entitled "Sound absorption based on ocean measurements", published in the *Journal of the Acoustical Society of America* [72(3) September 1982 and 72(6) December 1982], represent the most recent (November 1985) published work on the determination of expressions for the coefficients A_1, A_2, A_3, P_1, P_2, P_3, f_1 and f_2. They are quoted below and were used to calculate the values of α given in tables A.2 and A.3.

$$A_1 = \frac{8{,}86}{c} \times 10^{(0{,}78\,\text{pH} - 5)} \qquad (\text{dB}\cdot\text{km}^{-1}\cdot\text{kHz}^{-1})$$

$$A_2 = 21{,}44 \times \frac{s}{c} \times (1 + 0{,}025\ T) \qquad (\text{dB}\cdot\text{km}^{-1}\cdot\text{kHz}^{-1})$$

For $T \leqslant 20$ °C:

$$A_3 = 4{,}937 \times 10^{-4} - 2{,}59 \times 10^{-5} T + 9{,}11 \times 10^{-7} T^2 - 1{,}5 \times 10^{-8} T^3 \qquad (\text{dB}\cdot\text{km}^{-1}\cdot\text{kHz}^{-2})$$

For $T > 20$ °C:

$$A_3 = 3{,}964 \times 10^{-4} - 1{,}146 \times 10^{-5} T + 1{,}45 \times 10^{-7} T^2 - 6{,}5 \times 10^{-10} T^3 \qquad (\text{dB}\cdot\text{km}^{-1}\cdot\text{kHz}^{-2})$$

$$P_1 = 1$$

$$P_2 = 1 - 1{,}37 \times 10^{-4} D + 6{,}2 \times 10^{-9} D^2$$

$$P_3 = 1 - 3{,}83 \times 10^{-5} D + 4{,}9 \times 10^{-10} D^2$$

$$f_1 = 2{,}8 \times \left(\frac{s}{35}\right)^{0{,}5} \times 10^{(4 - 1\,245/\theta)} \qquad (\text{kHz})$$

$$f_2 = \frac{8{,}17 \times 10^{(8 - 1\,990/\theta)}}{1 + 0{,}001\,8 \times (s - 35)} \qquad (\text{kHz})$$

where

$c = 1\,412 + 3{,}21\,T + 1{,}19\,s + 0{,}016\,7\,D$, equal to the speed of sound in metres per second;

T is the temperature in degrees Celsius;

$\theta = 273 + T$, in kelvins;

s is the salinity in ‰ (per mil);

D is the depth in metres.

A.3 Consideration was given to the need for echo-sounding equipment, which is intended to meet the IMO requirement, to operate satisfactorily world-wide. Accordingly, for each frequency, values of α were calculated for several sea areas used by a significant number of merchant ships and in which water depths of at least 400 m exist. Specifically, these areas were:

a) Pacific ocean near Japan (South of Tokyo).

b) Pacific ocean near the North-West Coast of the USA.

c) Atlantic ocean near the East Coast of the USA.

d) Atlantic ocean South of Newfoundland.

e) Indian ocean South of India.

f) Western approaches to the English channel.

g) Gulf of Mexico.

h) Red Sea.

A.4 The data on the relevant parameters (water temperature, salinity and pH value) were obtained from the library of the Marine Information and Advisory Service (MIAS) of the Institute of Oceanographic Sciences. MIAS is the British Oceanographic Data Centre of the Intergovernmental Oceanographic Commission of UNESCO and obtains the data from participating nations which have made measurements of the parameters.

A.5 For areas where the values of any of the parameters were found to vary significantly throughout the year (this applied particularly to water temperature) more than one calculation of the value of α was made in order to allow for such seasonal changes. During initial investigations, it was found that variation of the value of pH had an insignificant effect on the value of α. It was therefore treated as a constant with a value of 8.

A.6 Investigation of the salinity of the sea world-wide indicated that area h) in A.3 is an isolated case. Here the salinity tends to be in excess of 40 ‰ while in coastal areas of the rest of the world, it is generally between 30 ‰ and 36,5 ‰. It was considered that this, coupled with the high water temperature in area h), placed a requirement more stringent than is strictly necessary on echo-sounding equipment operating at frequencies higher than 100 kHz. Accordingly, the values of α calculated for area h) were excluded from further consideration.

A.7 For the other seven areas listed in A.3, a total of 22 calculations was made at each of the 24 frequencies (10 kHz to 240 kHz in steps of 10 kHz). In these calculations account was taken of the variation of water temperature and salinity with depth.

A.8 Recognizing that the seven areas considered may well not have produced the maximum value of α which would otherwise result from a fully comprehensive world-wide study, the maximum value of α calculated for each operating frequency was used for calculation of the corresponding figure of merit.

A.9 Table A.1 gives the seven sets of data on temperature and salinity values, versus depth, which provided the values of α quoted in table A.2. The maximum value so calculated (for each operating frequency) is underlined in table A.2. These values are listed in table A.3. The other 15 sets of data used in the calculations produced, for all operating frequencies, values of α less than those listed in table A.3.

Table A.1

Depth	Column 1		Column 2		Column 3		Column 4		Column 5		Column 6		Column 7	
m	Temperature °C	Salinity ‰	Temperature °C	Salinity ‰	Temperature °C	Salinity ‰	Temperature °C	Salinity ‰	Temperature °C	Salinity ‰	Temperature °C	Salinity ‰	Temperature °C	Salinity ‰
0	− 1,4	32,86	5,7	35,5	14,2	35,9	20,1	35,9	25,64	36,4	29,9	36,35	30,57	36,74
10	− 1,37	32,87	5,95		13,8		19,4		25,62	36,41	29,67	36,32	30,27	36,68
15			6			35,75		35,75						
20	− 1,36	32,9							25,53	36,41	29,67	36,31	30,3	36,58
30	− 1,37	32,9	6			35,7		35,7	25,55	36,42	29,31	36,33	29,47	36,36
50	− 1,35	32,95	6,8		11,4	35,95		35,95	25,31	36,46	28,69	36,36	28,42	36,33
70							15,4							
75	− 1,47	33,09							25,03	36,51	27,94	36,46	27,28	36,44
80					10,6	36		36						
100	− 1,54	33,52	6,8		10,2	36		36	24,85	36,6	26,82	36,62	26,5	36,52
125	− 1,27	33,67							24,27	36,69	25,51	36,79	25,74	36,6
150	− 1,26	34,28	7,8						23,68	36,77	23,99	36,86	25,17	36,76
180						35,9		35,9						
200	1,38	34,63							21,91	36,81	21,21	36,78	22,56	36,8
250	3,5	34,56							20,08	36,7	19,62	36,69	20,47	36,63
300	3,69	34,43			9,9	35,9		35,9	18,45	36,53	18,74	36,57	17,99	36,46
320							12,5							
325			7,8											
400	3,69	34,43	8,6		9,4	35,7	11,9	35,7	16,58	36,26	16,58	36,26	15,27	36,01
600				35,45										

Table A.2

Frequency kHz	Values of sound absorption coefficient calculated from data contained in table A.1 [1)] dB/km						
	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7
10	1,3	1,02	0,95	0,85	0,72	0,71	0,71
20	4,14	3,55	3,3	2,93	2,37	2,31	2,31
30	7,48	7,14	6,77	6,12	4,99	4,87	4,85
40	10,7	11,2	10,9	10,1	8,46	8,26	8,22
50	13,6	15,2	15,3	14,5	12,6	12,3	12,3
60	16,1	19	19,5	19,2	17,3	16,9	16,8
70	18,3	22,5	23,6	23,8	22,3	21,8	21,7
80	20,2	25,5	27,3	28,2	27,4	26,9	26,8
90	21,9	28,3	30,7	32,4	32,7	32,1	31,9
100	23,5	30,7	33,7	36,3	37,9	37,4	37,2
110	25,1	32,9	36,5	40	43	42,5	42,3
120	26,7	35	39,1	43,3	48	47,6	47,3
130	28,2	36,9	41,4	46,5	52,8	52,5	52,2
140	29,8	38,7	43,6	49,3	57,4	57,2	57
150	31,4	40,5	45,7	52,1	61,8	61,8	61,6
160	33,1	42,2	47,6	54,6	66	66,1	65,9
170	34,8	43,9	49,5	57	70	70,3	70,2
180	36,6	45,5	51,4	59,3	73,8	74,3	74,2
190	38,5	47,2	53,2	61,5	77,4	78,2	78,1
200	40,4	48,9	55	63,6	80,9	81,9	81,8
210	42,5	50,6	56,7	65,7	84,2	85,4	85,3
220	44,6	52,4	58,5	67,7	87,3	88,8	88,8
230	46,7	54,2	60,3	69,7	90,4	92	92,1
240	49	56	62,1	71,6	93,3	95,2	95,3

1) The values underlined are calculated maximum values (see clause A.9).

Table A.3

Operating frequency kHz	Sound absorption coefficient dB/km	Operating frequency kHz	Sound absorption coefficient dB/km
10	1,3	130	52,8
20	4,14	140	57,4
30	7,48	150	61,8
40	11,2	160	66,1
50	15,3	170	70,3
60	19,5	180	74,3
70	23,8	190	78,2
80	28,2	200	81,9
90	32,7	210	85,4
100	37,9	220	88,8
110	43	230	92,1
120	48	240	95,3

A.10 When used in conjunction with the expressions for L and Ns and the values given for R, K, y and z in 3.2.2.1, the values of α given in table A.3 produce the values for L_0, i.e. the figure of merit, given in table A.4.

Table A.4

Operating frequency kHz	Figure of merit dB	Operating frequency kHz	Figure of merit dB
10	162,93	130	185,57
20	160,19	140	188,71
30	159,92	150	191,73
40	160,82	160	194,7
50	162,48	170	197,63
60	164,52	180	200,41
70	166,85	190	203,14
80	169,4	200	205,73
90	172,15	210	208,18
100	175,55	220	210,56
110	178,94	230	212,88
120	182,31	240	215,13

A.11 The values in table A.4 are plotted in figure A.1. It is recommended that type test authorities use figure A.1 for determination of the required figure of merit for the echo-sounding equipment under test.