INTERNATIONAL STANDARD

ISO 13475-1

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Acoustics — Stationary audible warning devices used outdoors —

Part 1:
Field measurements for determination of sound emission quantities

Acoustique — Dispositifs d'alarme sonore fixes utilisés à l'extérieur

Partie 1: Mesurages sur le terrain des grandeurs d'émission acoustique

Reference number
ISO 13475-1:1999(E)

Contents

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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 3.

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.

International Standard ISO 13475-1 was prepared by ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

ISO 13475 consists of the following parts, under the general title *Acoustics — Stationary audible warning devices used outdoors*:

— *Part 1: Field measurements for determination of sound emission quantities*

— *Part 2: Test room measurements*

— *Part 3: Outdoor propagation of warning signals over built-up areas*

Annexes A and B form a normative part of this part of ISO 13475.

Introduction

ISO 13475-1 describes field measurements. The test methods are intended to produce field test values of the sound emission level of a siren as it is installed in an outdoor situation. These field test values may, together with the stated measurement uncertainties, be used to check the specifications of delivered sirens or to compare the performance of different sirens under the same conditions, emitting the same signals.

ISO 13475-2 describes precision measurements. This method is intended to produce a generally valid specification of sirens for type tests, acceptance tests, or for use in the design of outdoor warning systems, etc.

In part 1 of ISO 13475, two types of field measurements are discussed. They are:

a) **Flat-plate measurements:** this method uses a microphone placed on a flat plate which is located on the ground. During the measurement, the intended main sound radiation pattern of the warning devices is tilted toward the microphone and plate assembly.

b) **Horizontal measurements:** this method is performed with the microphone placed at the same elevation as the centre of the audible warning device (at a preferred height of 10 m).

Measurements made under optimal conditions in conformity with this part of ISO 13475 should result in standard uncertainties equal to or less than the values given in Table 1. The standard uncertainty for actual measurement conditions taking into account the cumulative effect of all causes of measurement uncertainty are treated in parts 1 and 2 of ISO 13475.

Table 1 — Uncertainty in determining immission-relevant C-weighted sound power levels for stationary audible warning devices

Reference	Measurement method	Expected expanded uncertainty
Part 1: Field measurements	Flat plate	2 dB
	Horizontal	4 dB
Part 2: Precision measurements	—	1 dB

Acoustics — Stationary audible warning devices used outdoors — Part 1: Field measurements for determination of sound emission quantities

1 Scope

This part of ISO 13475 specifies the test conditions by which the sound emission level of stationary audible warning devices can be obtained. The methods are applicable to sirens for use in public outdoor warning systems and sound signalling devices for use outdoors.

The purpose of this test code is to be able to produce reliable sound emission level measurements for stationary sirens used for warning outdoors.

This part of ISO 13475 does not cover spoken messages and contains no recommendations for specific warning signals.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 13475. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 13475 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

IEC 60651[1)], *Sound level meters.*

IEC 60804[1)], *Integrating-averaging sound level meters.*

IEC 60942, *Sound calibrators*.

IEC 61260, *Octave-band and fractional-octave-band filters.*

3 Terms and definitions

For the purposes of this part of ISO 13475, the following terms and definitions apply.

3.1
siren
audible warning device for use outdoors

1) These will be revised and combined as IEC 61672.

3.2
electronic siren
siren that produces tonal sounds by amplifying the output of an electronic signal generator and broadcasting the amplified signal from one or more electrodynamic loudspeakers

NOTE Such sirens may also be used for giving voice messages.

3.3
electromechanical siren
siren that produces tonal sounds by flow interruptions generated in a rotating wheel

NOTE Electromechanical sirens are mechanical sirens driven by an electric motor.

3.4
pneumatic siren
siren that produces sound by periodically interrupting or modulating a flow of compressed air

NOTE The air compressor may be integral with or separate from the flow interrupter.

3.5
horizontally omnidirectional siren
siren that radiates sound approximately uniformly (within a specified tolerance) in all horizontal directions from the siren at the specified frequency of the sound

3.6
directional siren
siren that radiates most of its sound in one or more specific directions

3.7
rotating or oscillating siren
directional siren that contains a mechanism which slowly rotates its beam of sound about a vertical axis

3.8
immission-relevant sound power level
$L_{W,\mathrm{imm}}$
sound power level from a monopole source that would give the same sound pressure level in the far field as the actual source

NOTE It is expressed in decibels (dB).

Table 2 — Symbols

Symbol	Definition	Unit
L_p	Sound pressure level, ref. 20 μPa	dB
$L_{p\mathrm{C}}$	C-Weighted sound pressure level, ref. 20 μPa	dB
$L_{p\mathrm{Cmax,F}}$	Maximum C-weighted sound pressure level, measured with time weighting F according to 4.5.3	dB
$L_{p\mathrm{Ceq},T}$	Equivalent C-weighted sound pressure level over a time period T	dB
$L_{W,\mathrm{imm}}$	Immission-relevant sound power level, ref. 1 pW	dB
$L_{W\mathrm{C,imm}}$	C-Weighted immission-relevant sound power level, ref. 1 pW	dB

4 Test conditions

4.1 Test site

The ground surface between the siren and the microphone shall be flat to within ±1,0 m.

The surface between the warning device and the microphone may be covered with grass and/or pavement. There shall be no sound-reflecting object (e.g. building walls or roofs) within the horizontal plane containing the base of the sound source that are closer than twice the measurement distance from the source.

All structures within three times the measurement distance from both the source and the microphone shall be described.

NOTE All surfaces near the sound source will reflect sound and, depending on their material, location, and orientation may bias the results of the measurements. The intent of above specifications is to minimize the effects of all reflections except those from the ground surface. The accuracy of the field measurements depend on distance, reflecting objects, reflections off the ground, vertical directivity, near-field effects, and instrumentation. The contributions of uncertainty due to reflecting surface can be calculated according to the procedure in annex B.

4.2 Mounting of apparatus

The warning sound source to be tested shall be located at or above the manufacturer's recommended installation height above the ground; see Figures 1 and 5 and corresponding text.

The recommended height to the centre of the warning device (acoustic centre) according to this part of ISO 13475 is 10 m above the ground. The mounting should be carried out in accordance with this part of ISO 13475 or the manufacturer's recommendations.

When the flat-plate measurement method is used (see 4.5), a tilt is recommended for sirens that are directional in the vertical plane. The tilt shall be at such an angle that the normally vertical siren axis is perpendicular to the direction to the microphone. If not tilted, the measured values shall be corrected using the vertical directional characteristics (see annex B).

Power supply conditions shall be in accordance with annex A.

4.3 Instrumentation

4.3.1 Acoustical instruments

4.3.1.1 Equipment for determination of the sound pressure level

The sound level meter or the equivalent measuring system, including the windshield as recommended by the manufacturer, shall fulfil the requirements of a class 1 or class 2 sound level meter according to IEC 60651 and IEC 60804. The diameter of the microphone shall be less than or equal to 13 mm, when using the flat-plate method (see 4.5.2).

4.3.1.2 Equipment for the optional determination of octave and one-third-octave-band spectra

The filters shall meet the requirements of IEC 61260, class 1 or class 2; parallel filters are preferred.

The equivalent continuous sound pressure levels shall be determined simultaneously in octave or one-third-octave bands with centre frequencies from 50 Hz to 4 000 Hz.

4.3.1.3 Calibration of the measurement set-up

The calibration of the complete sound measuring system, including any recording, data logging, or r.m.s. computing systems, shall be checked immediately before and after the measurement session at one or more frequencies using a sound calibrator. The calibrator shall fulfil the requirements of IEC 60942, class 1 or class 2, and shall be used within its specified environmental conditions.

If a difference of 1,0 dB or more appears between subsequent calibration sessions, the instruments shall be checked and the measurements shall be rejected.

4.3.1.4 Calibration of the equipment and its traceability

All equipment for sound measurements shall be checked regularly and shall be calibrated with traceability to national standards. Calibration intervals for sound calibrators should be 12 months and for other equipment 24 months.

4.4 Microphone positions

Microphone positions are chosen in accordance with the measurement method.

Windshields shall be used during all measurements.

The reference distance between the siren centre and the microphone is 30 m. The maximum distance between the siren and the microphone shall not exceed 50 m.

For optimizing the measurement distance, uncertainties arising from near-field effects and ground effects shall be taken into consideration; see annex B.

4.5 Measurement methods

4.5.1 General

Two methods are described: the flat-plate method and the horizontal measurement method.

The flat-plate method requires the microphone to be placed on a flat plate on the ground. This method results in a 6 dB increase of the sound pressure level via the controlled reflection of the plate (relative to the free-field value). However, in order to measure sound pressure levels of directive sirens, the main sound radiation pattern of the siren shall be directed toward the flat plate.

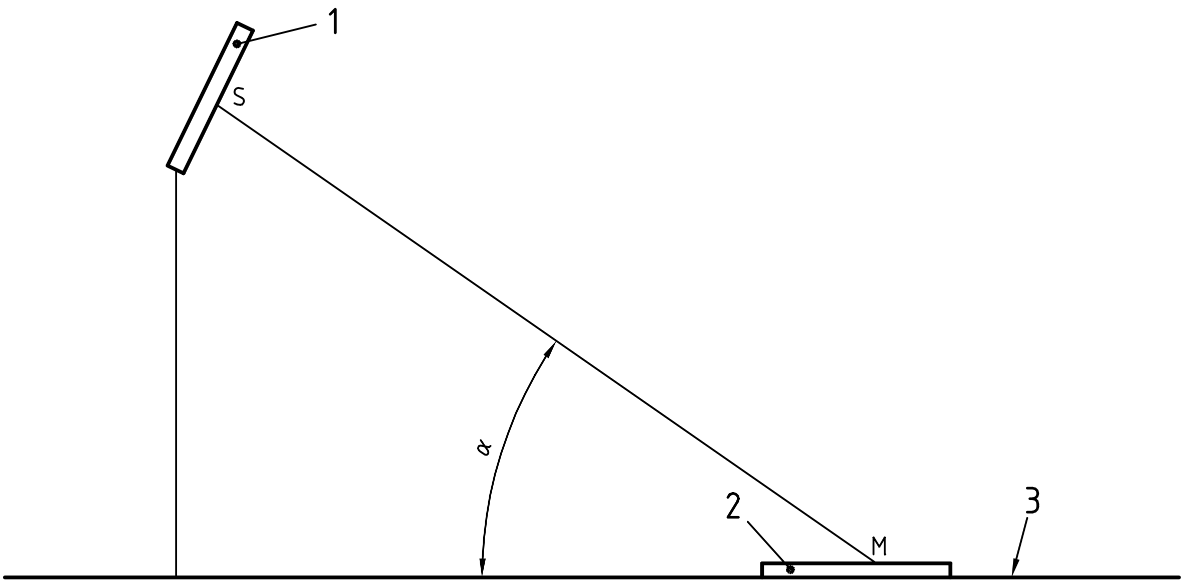
The horizontal measurement method specifies that the microphone be mounted at the same elevation as the warning device. This method results in a combined sound pressure measurement of both the direct sound path and the reflected sound path.

4.5.2 Flat-plate method

The measurement set-up is sketched in Figures 1 to 4. The microphone shall be placed on the plate according to Figure 1. The flat plate and the microphone position shall be in accordance with Figure 4. The microphone shall be fixed to the plate according to Figures 2 or 3. The plate shall be painted white to avoid thermal effects.

The angle α between the line SM, see Figure 1, connecting the microphone and the siren and the horizontal plane shall not be less than 10°.

Since this measurement method doubles the sound pressures relative to free-field measurements because of reflections from the plate, 6 dB must be subtracted from the sound pressure level measured ($L_{p,\text{meas}}$) on the flat plate, according to 5.3.1.



Key

1 Siren

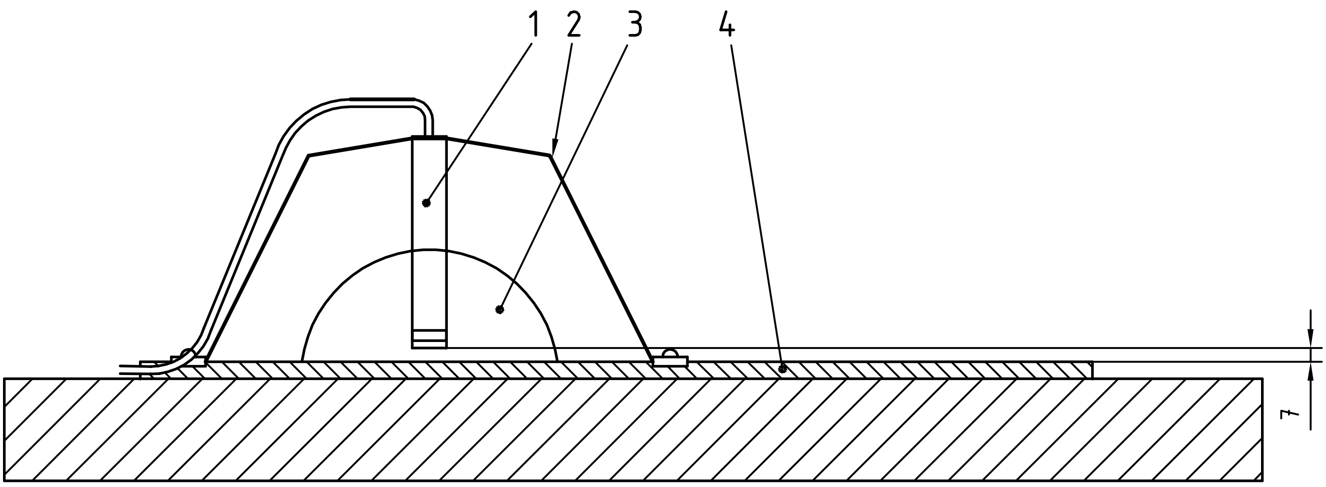
2 Microphone

3 Flat plate

SM = 30 m

Figure 1 — Flat-plate measurement set-up

Dimensions in millimetres



Key

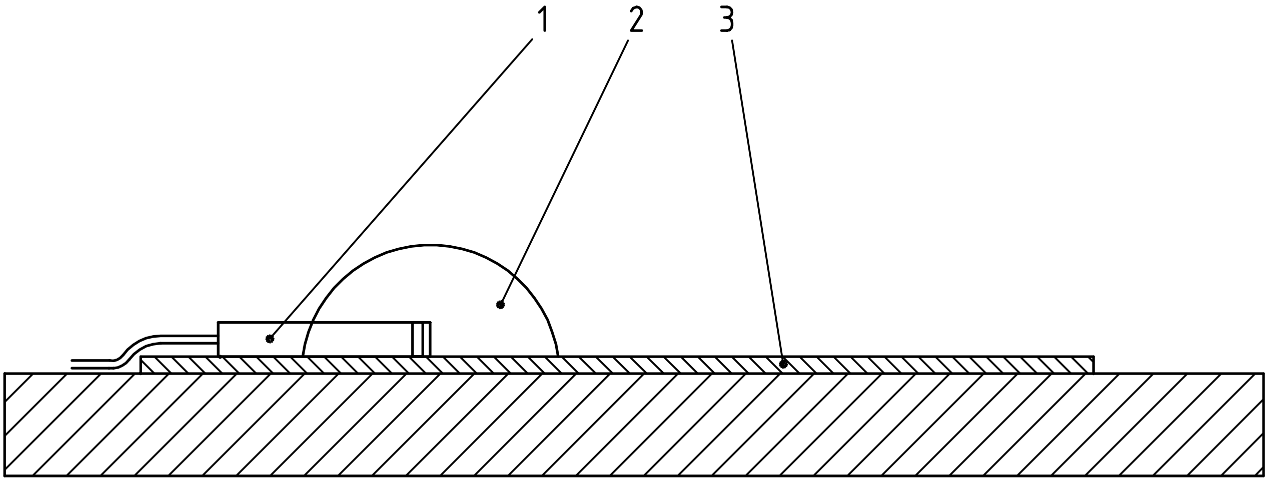
1 Microphone

2 Steel wire of 3 mm diameter, e.g. 3 pieces

3 Windshield

4 Metal plate, 2,5 mm thick

Figure 2 — Inverted microphone location — Side view



Key

1 Microphone

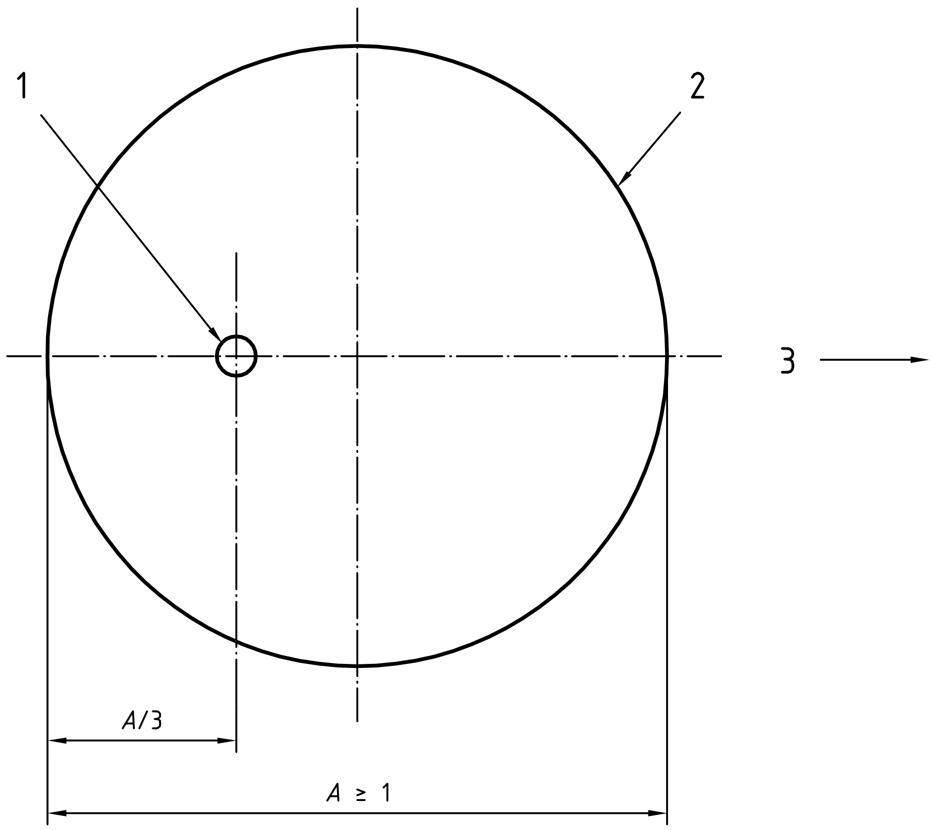
2 Windshield

3 Metal plate, 2,5 mm thick

NOTE Windshields are cut to purpose for this measurement.

Figure 3 — Microphone on its side

Dimensions in metres



Key

1 Microphone location

2 Metal plate, 2,5 mm thick

3 Warning device

NOTE Windshields are cut to purpose for this measurement.

Figure 4 — Position of microphone — Top view

4.5.3 Horizontal method

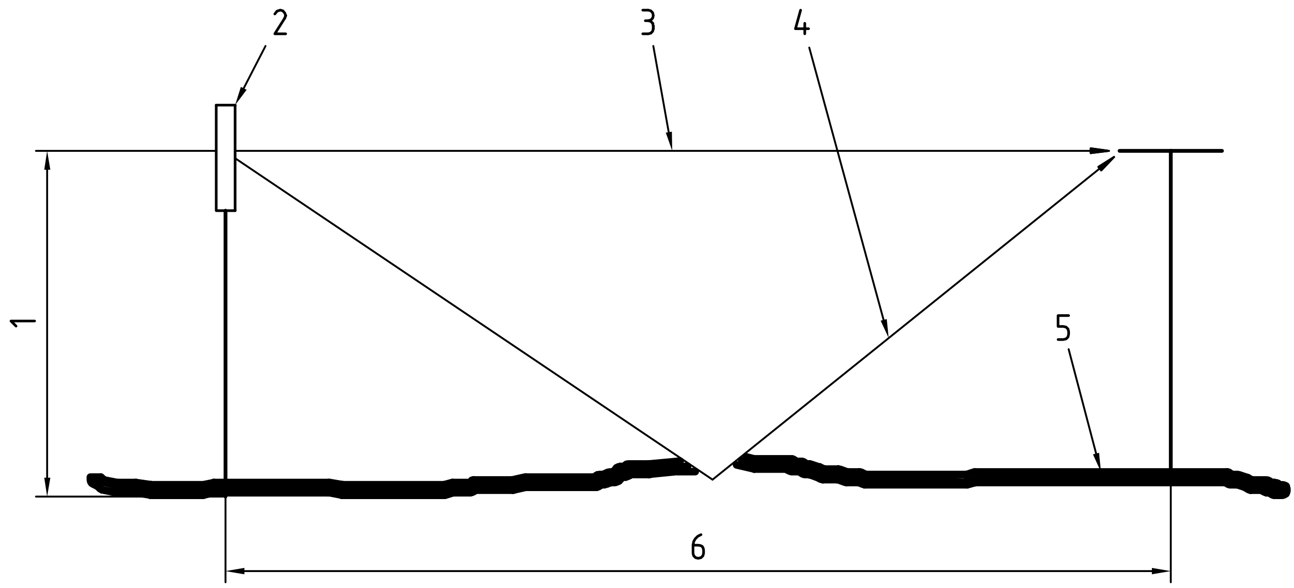
The measurement points for the horizontal measurement method are defined in Figures 5 and 6.

Figure 5 shows the microphone at a distance d from the warning device at the same elevation (sphere B in Figure 6). Figure 6 shows two additional microphone positions (spheres A and C) at 5 % of the measurement distance d above and below that point.

The maximum level $L_{p,\text{Cmax,F},d}$ shall be determined according to the following procedure.

Move the microphone within each of the three spheres A, B and C with radius of 2 % of d. Determine and record the highest sound pressure level $L_{p,\text{Cmax,F},d}$. At that same point record the $L_{p,\text{Ceq},T,d}$ value. Of the resulting three pairs of data, the lowest pair of data shall be discarded and the average of the remaining two pairs arithmetically averaged, according to 5.3.2.

NOTE The results of the horizontal method tends to be 0 dB to 3 dB higher than those of the flat-plate method and the methods specified in ISO 13475-2. To reduce these systematic differences, refer to annex B.



Key

1 Elevation

2 Warning device

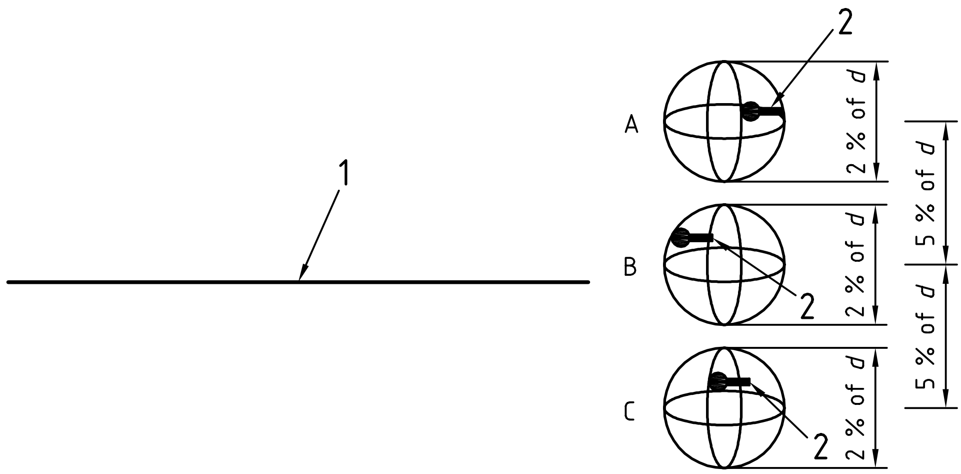
3 Direct wave

4 Reflected wave

5 Ground surface

6 Recommended distance 30 m

Figure 5 — Horizontal measurement method — General set-up



Key

1 Warning device centreline

2 Microphone position

Figure 6 — Horizontal measurement method — Microphone locations A, B and C inside spheres for measurement of $L_{p,\mathrm{max}}$ and $L_{p,\mathrm{eq}}$

4.6 Ambient conditions

The wind speed should preferably be less than 5 m/s at 10 m height or 3,5 m/s at 2 m height.

The temperature, humidity, barometric pressure, the wind speed and wind direction shall be recorded. It is recommended that the tests be performed under temperatures representative of the intended use of the siren.

Any noise events unrelated to the sound emission from the warning device under test shall not be taken into account.

Background noise shall be more than 10 dB (preferably 15 dB) lower than the signal level, with the applied frequency weighting. The background noise shall be measured over a period similar to the signal measurement duration.

4.7 Test procedure

Warm-up and heating shall be to a specified temperature according to the manufacturer's specifications, which shall be reported.

During the measurement, any limitations in the number of successive signals without pause and/or cool down time after signalling shall be observed. If any limitations exist, they shall be stated in the test report.

5 Acoustic characteristics

5.1 Test signals

The tests shall be performed with signals appropriate for the end use of the warning system. These signals may differ from the signals provided by the built-in signal source.

If the signal and/or the output of the siren can be influenced by external controls, the settings of these shall be chosen such that the test is representative of the end use of the warning system. These settings shall be recorded carefully.

It is important to note that the properties of the signals used in the test will have a significant influence on the results of the test and should therefore be chosen so that they are representative of the intended use.

Some sirens may be supplied with signals from an external signal source. If this is done (e.g. for measuring frequency characteristics or testing the sirens with signals not included in the system), the test signals shall be described carefully.

5.2 Duration of measurement

The duration of the measurement of the sound emission quantities of the siren shall be representative of the character of the test signal and shall be at least 10 s. If the signal emitted by the siren is periodical with a period longer than 10 s, the measurement duration shall be at least as long as the signal period.

5.3 Determination of sound emission quantities

5.3.1 Flat-plate method

5.3.1.1 Readings to be taken

During the time period required according to 5.2, the following quantities shall be recorded:

— $L_{p\text{Ceq},T,d,\text{meas}}$: the equivalent continuous C-weighted sound pressure level during a period T at distance d on the surface of the flat plate;

— $L_{p\text{Cmax,F},d,\text{meas}}$: the maximum C-weighted sound pressure level, determined with time weighting F at distance d on the surface of the flat plate.

The distance d is the distance between the measuring microphone and the acoustical centre of the siren.

5.3.1.2 Processing of recorded data

Correct the recorded sound pressure levels according to equations (1) and (2) to compensate for the pressure doubling caused by reflection:

$$L_{p\text{Ceq},T,d} = L_{p,\text{Ceq},T,d,\text{meas}} - 6\ \text{dB} \quad (1)$$

$$L_{p\text{Cmax,F},d} = L_{p,\text{Cmax,F},d,\text{meas}} - 6\ \text{dB} \quad (2)$$

Convert the corrected sound pressure level values from the actual measurement distance d in metres to a reference distance of 30 m according to equations (3) and (4):

$$L_{p\text{Ceq},T,30\text{m}} = L_{p\text{Ceq},T,d} + 20\ \lg(d/30)\ \text{dB} \quad (3)$$

$$L_{p\text{Cmax,F},30\text{m}} = L_{p\text{Cmax,F},d} + 20\ \lg(d/30)\ \text{dB} \quad (4)$$

Calculate the immission-relevant equivalent sound power level $L_{W\text{eq,imm}}$ according to equation (5):

$$L_{W\text{Ceq,imm}} = L_{p\text{Ceq},T,30\text{m}} + 40\ \text{dB} \quad (5)$$

Calculate the immission-relevant maximum sound power level $L_{W\text{max,imm}}$ according to equation (6):

$$L_{W\text{Cmax,imm}} = L_{p\text{Cmax,F},30\text{m}} + 40\ \text{dB} \quad (6)$$

NOTE No information concerning the total radiated acoustic power can be drawn from the calculated immission-relevant sound power level.

5.3.2 Horizontal method

5.3.2.1 Readings to be taken

During the time period required according to 5.2, the following quantities shall be recorded:

— $L_{p\mathrm{Cmax,F},d,\mathrm{meas}}$: the C-weighted maximum sound pressure level, determined with time weighting F at distance d from the siren at three different microphone positions determined according to 4.5.3;

— $L_{p\mathrm{Ceq},T,d,\mathrm{meas}}$: the equivalent continuous C-weighted sound pressure level during a period T at a distance d from the siren at the same three microphone positions as used for the measurement of $L_{p\mathrm{Cmax,F},d,\mathrm{meas}}$.

The distance d is the distance between the measuring microphone and the acoustical centre of the siren.

5.3.2.2 Processing of recorded data

Of the recorded three pairs of values of $L_{p\mathrm{Cmax,F},d,\mathrm{meas}}$ and $L_{p\mathrm{Ceq},T,d,\mathrm{meas}}$ the pair with the lowest values shall be discarded. The remaining two pairs shall be averaged arithmetically resulting in the quantities:

$L_{p\mathrm{Cmax,F},d,\mathrm{av}}$ and $L_{p\mathrm{Ceq},T,d,\mathrm{av}}$

Convert the averaged sound pressure level values from the actual measurement distance d in metres to a reference distance of 30 m according to equations (7) and (8):

$$L_{p\mathrm{Ceq},T,\mathrm{30m,hor}} = L_{p\mathrm{Ceq},T,d,\mathrm{av}} + 20\ \lg(d/30)\ \mathrm{dB} \qquad (7)$$

$$L_{p\mathrm{Cmax,F,30m,hor}} = L_{p\mathrm{Cmax,F},d,\mathrm{av}} + 20\ \lg(d/30)\ \mathrm{dB} \qquad (8)$$

Calculate the immission-relevant equivalent sound power level $L_{W\mathrm{Ceq,imm,hor}}$ according to equation (9):

$$L_{W\mathrm{Ceq,imm,hor}} = L_{p\mathrm{Ceq},T,\mathrm{30m,hor}} + 40\ \mathrm{dB} \qquad (9)$$

Calculate the immission-relevant maximum sound power level $L_{W\mathrm{Cmax,imm,hor}}$ according to equation (10):

$$L_{W\mathrm{Cmax,imm,hor}} = L_{p\mathrm{Cmax,F,30m,hor}} + 40\ \mathrm{dB} \qquad (10)$$

NOTE No information concerning the total radiated acoustic power can be drawn from the calculated immission-relevant sound power level.

5.4 Measurement uncertainty

The measurement uncertainty of the sound emission quantities shall be determined according to annex B, taking into account the specific geometrical and environmental conditions of the test.

6 Information to be reported

The test report shall include the following information:

a) reference to this part of ISO 13475;

b) name and address of the organization (testing laboratory) performing the tests;

c) identification number of the test report;

d) name and address of the organization or person who ordered the test;

e) name and address of the manufacturer and supplier of the tested siren;

f) name and/or other identification marks of the tested siren;

g) list of documents identifying unambiguously the tested siren;

h) date of supply of the tested siren;

i) date(s) of the test;

j) test method;

k) identification and calibration dates of the test equipment and instruments used;

l) geometry, orientation and dimensions of the test site;

m) test conditions, viz: wind speed and direction, air temperature, barometric pressure and humidity;

n) description of the test signals with respect to frequency content and temporal distribution; settings of external controls, if any;

o) test results, viz.

$L_{p\mathrm{Ceq},T,d,\mathrm{meas}}$
$L_{p\mathrm{Cmax,F},d,\mathrm{meas}}$

and $L_{p\mathrm{Ceq},T,30\mathrm{m}}$ or $L_{p\mathrm{Ceq},T,30\mathrm{m,hor}}$
$L_{p\mathrm{Cmax,F,30m}}$ $L_{p\mathrm{Cmax,F,30m,hor}}$

and $L_{W\mathrm{Ceq,imm}}$ or $L_{W\mathrm{Ceq,imm,hor}}$
$L_{W\mathrm{Cmax,imm}}$ $L_{W\mathrm{Cmax,imm,hor}}$

p) expanded uncertainty of the test results (k = 2);

q) background noise, viz.:

$L_{p\mathrm{Ceq,back}}$ and $L_{p\mathrm{Cmax,back}}$

r) date and signature.

Reporting of the test conditions and measurement results may be carried out according to the data sheet in Table 3.

Table 3 — Field test measurement summary according to ISO 13475-1

Siren		**Model**	
Manufacturer		**Serial number**	
Description			
Test requested by:			
Test organization	Date	Time	
Personnel		Title	
Measurement location		Address	
Temperature, °C		Wind (m/s)	
Humidity, %			
Instrumentation	Manufacturer	Serial number	Calibration date
Calibrator			
Field calibration	Before test	After test	
Background noise			
Siren output			
Signal type			
L_{eq} **integration time**			
Measurement method	Flat plate	Horizontal	
	tilt:		
C-weighted sound pressure level, ref. 20 µPa, in dB			
$L_{p\text{Cmax,F}}$			
	@ measurement distance .... m	$L_{p\text{Ceq}}$	@ measurement distance .... m
$L_{p\text{Cmax,F}}$			
	@ 30 m	$L_{p\text{Ceq}}$	@ 30 m
Immission-relevant C-weighted sound power level, ref. 1 pW, in dB			
$L_{p\text{Cmax,F}}$			
		$L_{W\text{Ceq}}$	
Expanded measurement uncertainty (k = 2)			
Remarks on test procedure		Date of report	Signature

Description of signal
Description of test site

Annex A
(normative)

Supply conditions

During testing the device shall be powered from a source giving the nominal voltage, frequency, air pressure, etc. to within 5 % of the specifications given by the manufacturer. If a nominal range is specified, the average of that range shall be used during the testing.

If sound pressure level, sound power level, signal frequency, or signal timing depends significantly on the power supply, the variations of these parameters shall be measured within the specified supply range of the device.

If the siren being tested is operated outside the limits of the nominal supply range, corrections to the resulting output power shall be provided by the manufacturer.

According to this method the nominal power supply conditions shall normally be checked at the supply terminals of the siren. Other related methods may give guidelines on how to simulate the resistance between the supply source and siren.

Voltage, current, or pressure is used as validation parameter.

It may be relevant to test the power consumption of the device. This test is optional. Measure the mean of the total power consumption of the sound signalling device at nominal power supply conditions. When measuring L_{eq} values, the equivalent voltage measured over the same period should be used. Both the consumption when signals are activated, and when in any standby or power-down state, shall be measured.

Annex B
(normative)

Calculation of combined expanded uncertainty

B.1 Estimation of combined expanded uncertainty

The combined expanded uncertainty can be estimated by the following expression:

$$U = \sqrt{U_{\text{refl obj}}^2 + U_{\text{ground refl}}^2 + U_{\text{vert dir}}^2 + U_{\text{near field}}^2 + U_{\text{instr}}^2 + U_{\text{power}}^2}$$

where

$U_{\text{refl obj}}$ is the expanded uncertainty due to reflecting objects;

$U_{\text{ground refl}}$ is the expanded uncertainty due to reflection off the ground;

$U_{\text{vert dir}}$ is the expanded uncertainty due to the vertical directivity;

$U_{\text{near field}}$ is the expanded uncertainty due to near field effects;

U_{instr} is the expanded uncertainty due to instrumentation;

U_{power} is the expanded uncertainty due to variation in power supply conditions.

Estimations of the expanded uncertainties due to the mentioned uncertainty sources are treated in detail below and are assumed to approximate a 95 % confidence interval.

B.2 Reflecting objects

Uncertainties due to reflecting objects can be evaluated from Table B.1 giving the estimated expanded uncertainties, $U_{\text{ref obj}}$, as a function of the ratio of the reflected signal path to the direct signal path.

Table B.1 — Estimated expanded uncertainty

Ratio of reflected/direct path	2	3	4	6	8	10
$U_{\text{refl obj}}$, dB	3	2	1	< 1	< 1	≈ 0

B.3 Ground reflection effects

B.3.1 Ground reflection and near-field effects for the horizontal method

For the horizontal method, the uncertainty due to ground reflection and near-field effects are treated as one contribution, $U_{\text{ground refl}}$, to the combined uncertainty.

In Table B.2 the uncertainties are given for measurements at the reference distance and for the optimal measurement distance and a frequency interval of 200 Hz to 2 000 Hz. For the smaller sirens, measurement at the optimal measurement distance is recommended as it will decrease the uncertainties relative to the measurements at the reference distance.

Table B.2 — Optimal measurement distances for horizontal measurements and measurement uncertainties due to near-field effects and ground reflections.

Height of sound opening	Optimal distance [a]		Reference distance, 30 m
	Measurement distance	Uncertainty	Uncertainty
m	m	dB	dB
0,5	2 to 3	< 1	4
1	4 to 6	1	2,5
2	10 to 15	1,5	2
3	18 to 25	2	2,5
4	30 to 35	3	3

[a] Both smaller and larger measurement distances will increase the uncertainty.

B.3.2 Ground reflection for flat-plate method

For the flat-plate method, $U_{\text{ground refl}} = 0$

B.4 Vertical directivity

If the flat-plate method is applied without tilting the warning device, a correction to the sound pressure can be applied according to the vertical directivity. This can be obtained by the method described in ISO 13475-2. Use the vertical characteristics when the tilt is not used. $U_{\text{vert dir}}$ is the uncertainty in determination of the vertical directivity.

B.5 Near-field effects, flat-plate method

Uncertainties due to near field effects in stacked array speaker units are calculated according ISO 13475-2. To achieve a expanded uncertainty $U_{\text{near field}} < 1$ dB, the following minimum measurement distances shall be observed:

$$(l^2 \times f)/(1{,}8 \times c) \leqslant d$$

where

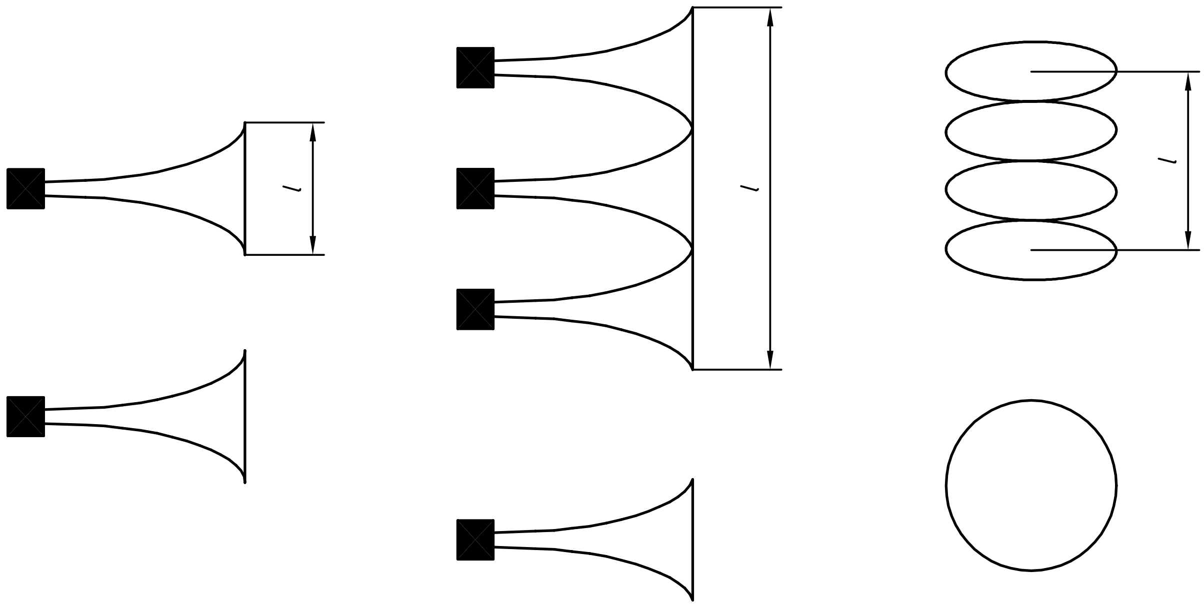
l is the height of the sound opening, in metres; see Figure B.1;

f is the frequency, in hertz;

c is the speed of sound, in metres per second;

d is the measurement distance, in metres.

Examples are given in Table B.3.



a) Single directional horn b) Stacked directional horn b) Stacked omnidirectional horn

Figure B.1 — Examples of the largest vertical dimension of the sound opening

Table B.3 — Minimum measurement distances for an expanded uncertainty $U_{\text{near field}}$ less than 1 dB

Dimensions in metres

l	*d*	
	f = 2 000 Hz	*f* = 200 Hz
0,5	0,8	0,08
1	3,3	0,03
1,5	7,4	0,74
2,0	13	1,3
2,5	20	2,0
3,0	29	2,9
3,5	40	4,0

B.6 Instrumentation

Typical estimation of the expanded uncertainty for the instrument chain is

U_{instr} = 0,7 dB for class 1 instrumentation;

U_{instr} = 2 dB for class 2 instrumentation.

B.7 Power conditions

Estimations of the expanded uncertainty due to variations in the power supply of the siren during the test are achieved by registration of systematic variations in power supply and acoustic output.

B.8 Typical field test measurement

An example of a typical field test measurement set-up is shown in Table B.4. The power is assumed to be constant giving no variation in output power.

Measurement set-up:

measurement distance, d	30 m
mounting height, h	20 m
height of sound opening	3 m
distance to reflecting object	50 m
highest frequency of interest	500 Hz

The expanded uncertainties determined according to this annex are shown in Table B.4.

Table B.4 — Example of field test measurement

Values in decibels

Parameter	Horizontal method	Flat-plate method
$U_{refl\ obj}$	2	1
$U_{ground\ refl}$	2	1
$U_{vert\ dir}$	0	0
$U_{near\ field}$	1	1
U_{instr} (class 1)	0,7	0,7
Combined U	3,1	1,7

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