
**Acoustics — Procedures for the
measurement of real-ear acoustical
characteristics of hearing aids**

*Acoustique — Méthodes pour le mesurage des caractéristiques
acoustiques des appareils de correction auditive sur l'oreille réelle*

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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.

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

International Standard ISO 12124 was prepared by Technical Committee ISO/TC 43, *Acoustics*.

Annex A of this International Standard is for information only.

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Introduction

The performance characteristics of hearing aids in actual use can differ significantly from those determined in accordance with standards such as IEC 60118-0 and IEC 60118-7, due to differing acoustical influence and coupling presented by individual ears. Measurement methods that take into account the acoustic coupling and the acoustical influence of the individual wearer on the performance of hearing aids are therefore important in the fitting of these devices. Such measurement methods have come to be known as "real-ear measurements" and are sometimes performed clinically in less than ideal acoustic environments. The accuracy and repeatability of measurements made under such conditions are complex functions of the sound field, the test environment, the nature of the test signal, the hearing aid under evaluation, the method of test signal control, the location of the sound source, the nature of the data acquisition, analysis and presentation, as well as the degree of subject movement permitted.

This International Standard details the terminology, test environment and test methods, and defines the necessary reference points to be used for the measurement of real-ear acoustical characteristics of hearing aids.

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Acoustics — Procedures for the measurement of real-ear acoustical characteristics of hearing aids

1 Scope

This International Standard specifies procedures and requirements for measuring the real-ear acoustical characteristics of hearing aids. Its purpose is to ensure that the same measurements made on a given hearing aid on a given human ear and a given hearing aid, following the procedures described and using equipment complying with the requirements of IEC 61669, give substantially the same results.

Measurements of real-ear acoustical characteristics of hearing aids which apply non-linear or analytical processing techniques are valid only for the test signals used and conditions employed. These measurements should be performed in accordance with the hearing aid manufacturer's recommendations as they may require specific test signals or test conditions outside the scope of this International Standard.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard 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.

ISO 8253-2, *Acoustics — Audiometric test methods — Part 2: Sound field audiometry with pure tone and narrow-band test signals*.

IEC 60942, *Electroacoustics — Sound calibrators*.

IEC 61669, *Electroacoustics — Equipment for the measurement of real-ear acoustical characteristics of hearing aids*.

3 Terms and definitions

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

3.1

test signal

acoustic signal at the field reference point

3.2

subject

person in whose ear canal the hearing aid performance is being characterized

3.3

subject test position

position with subject seated in a reproducible upright position with the head erect and the subject reference point located on the test axis at the working distance

3.4

subject reference point

point bisecting the line joining the centres of the openings of the ear canals of the subject (at the junction between concha and ear canal)

See Figure 1.

NOTE In cases of severe head shape abnormality or asymmetry, it may not be easy to determine the reference point of the subject. The subject reference point used should then be stated.

3.5

test axis

line joining the subject reference point to the sound source, passing along the axis of the sound source

See Figure 1.

3.6

working distance

distance from the subject reference point to the plane of the mounting ring or protective grille of the sound source, measured along the test axis

See Figure 1.

3.7

sound pressure level

SPL

20 times the logarithm to the base 10 of the ratio of a given root-mean-square sound pressure to the reference sound pressure

NOTE 1 Based on IEC 60050-801 (*International Electrotechnical Vocabulary*).

NOTE 2 Throughout this International Standard, all sound pressure levels refer to a reference level of 20 μ Pa.

3.8

band sound pressure level

sound pressure level measured for a defined band

3.9

test signal level

level of the test signal expressed as a sound pressure level

NOTE 1 It is expressed in decibels (dB).

NOTE 2 For broad-band signals, the frequency spectrum should be specified and stated.

3.10

equalization

process of controlling the test signal level as a function of frequency such that it does not vary from the desired level

3.11

reference microphone

microphone used to measure the test signal level in the measurement process and/or to control it in the equalization process

See Figure 2.

NOTE Alternatively it may be referred to as the controlling microphone.

3.12**sound inlet**

aperture through which sound enters a microphone and at which the microphone is calibrated

NOTE In the case of a probe microphone (see 3.15) which includes an extension tube, this will be the open end of the probe tube.

3.13**field reference point**

point at which the sound inlet of the reference microphone is located during equalization and/or measurement

See Figure 2.

3.14**tester**

person carrying out the test on the subject

3.15**probe microphone**

microphone adapted to determine the sound pressure level in the ear canal

NOTE The probe microphone may include an extension tube (see Figure 2).

3.16**test ear**

ear of the subject in which the sound inlet of the probe microphone is placed

3.17**axis of rotation**

straight line about which the subject can be rotated, passing through the subject reference point and lying in the vertical plane of symmetry

See Figure 1.

3.18**azimuth angle of sound incidence**

angle between the plane of symmetry of the subject and the plane defined by the axis of rotation and the test axis

See Figure 1.

NOTE When the subject faces the sound source, the azimuth angle of sound incidence is defined as 0° . When the test ear of the subject faces the sound source, the azimuth angle is defined as 90° . When the non-test ear faces the sound source, the angle is defined as -90° .

3.19**subject reference plane**

horizontal plane that contains the subject reference point

See Figure 1.

3.20**elevation angle of sound incidence**

angle between the subject reference plane and the test axis

See Figure 1.

NOTE When the top of the subject points towards the sound source, the elevation angle is defined as $+90^\circ$. When the test axis lies in the reference plane, the elevation angle is defined as 0° .

3.21

measurement point

point in the ear canal of the test ear at which the sound inlet of the probe microphone is placed

See Figure 2.

3.22

test signal type

identification of the test signal in terms of its frequency spectrum and/or temporal properties

3.23

concurrent equalization

equalization performed at the time of measurement, based on the monitoring of the test signal level

NOTE Alternatively it may be referred to as real-time equalization.

3.24

stored equalization

equalization performed at the time of measurement, based on data recorded during a prior measurement of the sound field

3.25

substitution method

method of measurement using stored equalization where the reference microphone is located at the subject reference point and the subject is absent during the recording of the sound field data

3.26

modified pressure method

method of measurement using stored or concurrent equalization with the field reference point near the surface of the head, close to the test ear but outside the acoustic influence of the pinna and the hearing aid

NOTE The exact location of the field reference point should be specified by its perpendicular distance from the surface of the head, and its distance (in millimetres) forward of and above or below the centre of the ear canal entrance.

3.27

differential comparison

measurement in which the test signal level is subtracted from the SPL at the measurement point

NOTE When using broad-band signals, band sound pressure levels should be used.

3.28

real-ear unaided response

REUR

SPL as a function of frequency at the measurement point for a specified test signal level with the ear canal unoccluded

3.29

real-ear unaided gain

REUG

difference, in decibels, between the SPL at the measurement point and the test signal level, as a function of frequency, with the ear canal unoccluded

NOTE When using broad-band signals, band sound pressure levels should be used.

3.30

real-ear occluded response

REOR

SPL as a function of frequency at the measurement point for a specified test signal level with the hearing aid in place and turned off

3.31**real-ear occluded gain****REOG**

difference, in decibels, between the SPL at the measurement point and the test signal level, as a function of frequency, with the hearing aid in place and turned off

NOTE When using broad-band signals, band sound pressure levels should be used.

3.32**real-ear aided response****REAR**

SPL as a function of frequency at the measurement point for a specified test signal level, with the hearing aid in place and turned on

3.33**real-ear aided gain****REAG**

difference, in decibels, between the SPL at the measurement point and the test signal level, as a function of frequency, with the hearing aid in place and turned on

NOTE When using broad-band signals, band sound pressure levels should be used.

3.34**real-ear insertion gain****REIG**

difference, in decibels, between the aided response and the unaided response ($REIG = REAR - REUR$), or between the aided gain and the unaided gain ($REIG = REAG - REUG$), expressed as a function of frequency

NOTE The REAR and REUR must be derived using the same test signal level.

3.35**curve**

real-ear acoustical characteristic (see 3.28 to 3.34) expressed and graphically displayed as a function of frequency

EXAMPLE Real-ear aided response curve.

3.36**free sound field**

sound field where the boundaries of the room exert a negligible effect on the sound waves

[ISO 8253-2]

3.37**quasi-free sound field**

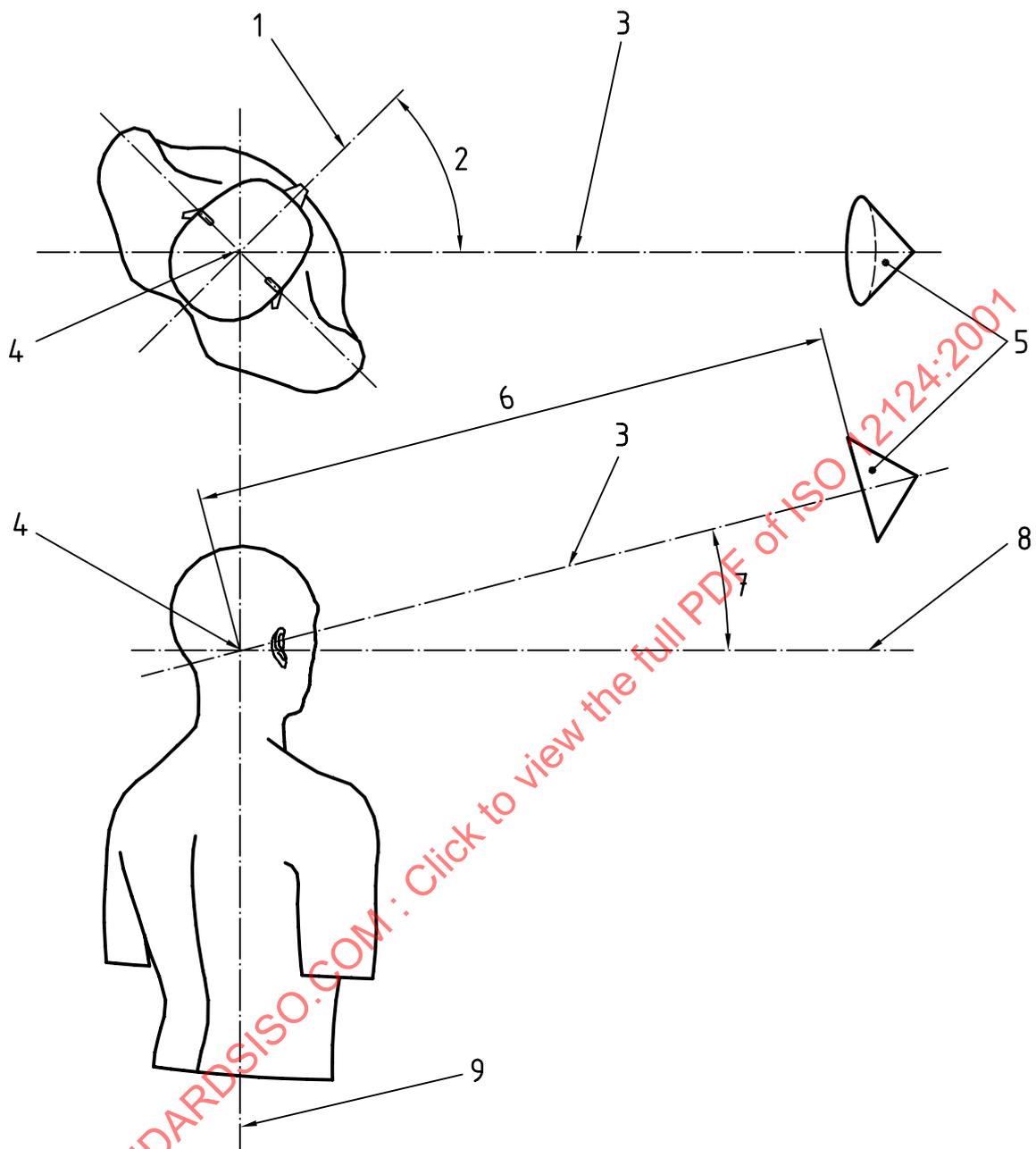
sound field where the boundaries of the room exert only a moderate effect on the sound waves

[ISO 8253-2]

3.38**diffuse sound field**

sound field which in a given region has statistically uniform energy density, for which the directions of propagation at any point are randomly distributed

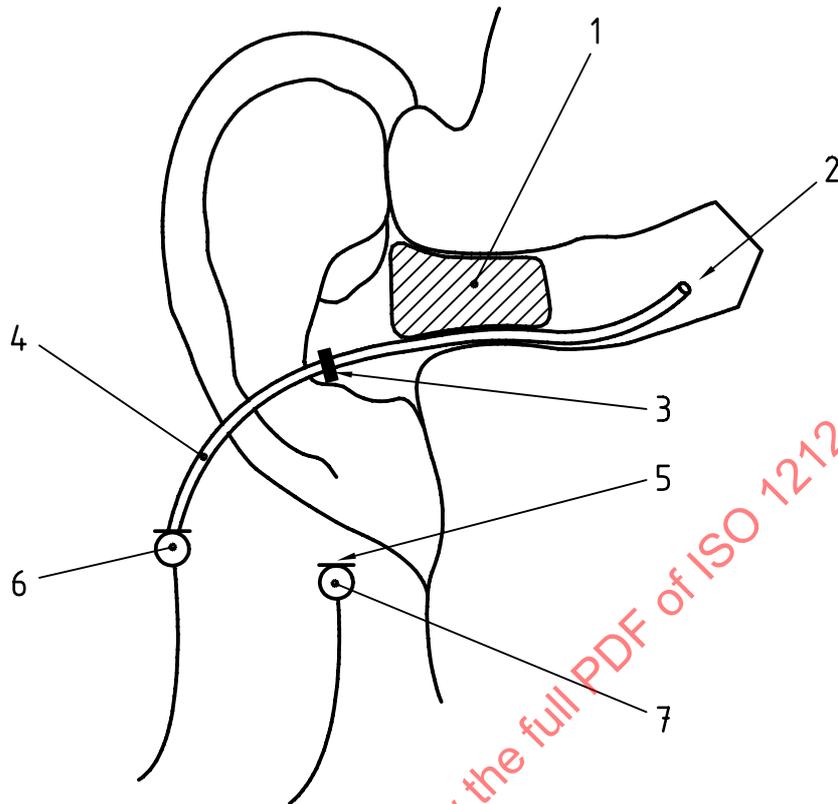
[ISO 8253-2]



Key

- 1 Plane of symmetry
- 2 Azimuth angle of sound incidence
- 3 Test axis
- 4 Subject reference point
- 5 Sound source
- 6 Working distance
- 7 Elevation angle of sound incidence
- 8 Subject reference plane
- 9 Axis of rotation

Figure 1 — Test arrangement

**Key**

- | | |
|---|---------------------------|
| 1 | Hearing aid or earmould |
| 2 | Measurement point |
| 3 | Marking or marking device |
| 4 | Probe extension tube |
| 5 | Field reference point |
| 6 | Probe microphone |
| 7 | Reference microphone |

Figure 2 — Measurement arrangement**4 Limitations**

Measurements of real-ear acoustical characteristics of hearing aids are influenced by the characteristics of the hearing aid, the test equipment, the test signal, the method of equalization, the test environment, the degree of subject movement permitted, the hearing aid subject interface and the physical characteristics of the subject.

NOTE Display and printing of results can be influenced by the method of analysis and presentation.

5 Conditions for test environment**5.1 Environmental conditions**

Environmental conditions in the test space at the time of the test shall be within the range specified by the equipment manufacturers.

5.2 Ambient background noise

Ambient background noise in the test space shall not alter the test results by more than 1 dB at any frequency. The level of noise permitted depends upon the measuring equipment being used, the level of the test signal and the hearing aid under test. The test signal shall be at least 10 dB above the noise floor in all frequency bands. For any test signal type, removal of the test signal should cause the level at the field reference point to drop by at least 10 dB.

Hearing aids with automatic gain control circuitry, or which apply other non-linear signal processing techniques, might respond to ambient background noise in a way which may not be apparent from the measured output. When testing such devices, the ambient background noise level shall be below the activation threshold of the automatic gain control circuitry or other signal processing technique at all frequencies, or at a level which will not influence the resulting measurement by more than 1 dB.

5.3 Acoustical properties

The physical size and absorption characteristics of the test space influence the accuracy of real-ear measurements. The extent of this influence depends upon the test signal used, the working distance, the method of sound field equalization, subject movement, and the type of hearing aid being tested.

In order to minimize errors due to reflected sound, the field reference point should be chosen such that the distance from both the field reference point and the sound source to the nearest reflective surface is at least twice the working distance.

5.4 Sound field characteristics

The environment in which measurements are made can vary considerably. See ISO 8253-2 for a description of three types of sound field that should provide a suitable test environment. The free sound field and the diffuse sound field are well defined. In practice, it is not always possible to meet these specifications and therefore a third sound field, the quasi-free sound field, may be used, but only if the effects can be defined and quantified. The type of sound field used shall be stated. The test space shall allow the test signal level to be controlled to within 3 dB of the desired test signal level.

6 Preparation of subject

6.1 Otoscopic examination

Using an otoscope, the ear canal should be inspected by a suitably qualified person for excess cerumen and any abnormalities giving contra-indication of fitness to undertake the test. Any abnormality that might influence the measurements should be recorded and considered before the test is initiated.

6.2 Position of subject

The subject should be comfortably seated upright at the subject test position. Unless otherwise specified by the equipment manufacturer, it is recommended that the subject be located at a minimum working distance of 0,5 m, and at an azimuth angle of sound incidence of 0° or 45° and an elevation angle of sound incidence of 0° (see Figure 1). The position of the subject shall be stated.

Alternatively, elevation angles of sound incidence between 0° and 45° may be used. If so, this should be stated.

6.3 Instructions to subject

Information on the test procedure shall be given unambiguously to the subject and should be fully understood. The subject shall be instructed to remain silent and avoid unnecessary movement during the measurements. The subject shall also be informed that he/she may interrupt the test at any time in the case of discomfort.

7 Measurement procedure

7.1 Equipment

All measurements of real-ear acoustical characteristics of hearing aids shall be made using test equipment in accordance with IEC 61669.

7.2 Calibration

Pretest calibration of the test equipment should be carried out directly, using a calibrator complying with IEC 60942, or indirectly following the manufacturer's instructions. Any setting-up procedures should also be performed in accordance with the manufacturer's instructions.

7.3 Equalization methods

7.3.1 Substitution method — Stored equalization

Following the equipment manufacturer's instructions, record the test signal at the subject reference point with the subject absent. The recording shall be updated whenever there is a change in the acoustic environment.

WARNING — This method requires a uniform sound field.

7.3.2 Modified pressure method — Stored equalization

Place the subject in the subject test position. Following the equipment manufacturer's instructions, determine the relevant equipment settings necessary to produce the desired test signal level then record the test signal. All objects that will be present during subsequent tests should be in position (including the tester). The recording shall be updated whenever there is a change in the subject's position, the field reference point or the acoustic environment.

7.3.3 Modified pressure method — Concurrent equalization

Equalization is not a separate process but occurs automatically during measurement by monitoring the test signal level.

This is the preferred method as other methods may produce unreliable results when measurements are made under non-ideal conditions. These other methods might only be suitable under laboratory conditions.

7.4 Test signal

7.4.1 Test signal characteristics

The test signal type may be narrow-band (pure tone, warble tone, narrow-band noise, etc.), or wide-band (broad-band noise, composite signal, speech weighted noise, etc.). The type of test signal used shall be recorded and specified according to the instructions of the equipment manufacturer.

7.4.2 Choice of test signal level

Special consideration shall be given to hearing aids with automatic gain control circuitry or which apply other signal processing techniques. For aided tests, this level shall be chosen with concern for subject safety and comfort.

When it is desired to test hearing aid performance in the linear operating region, the lowest possible test signal level should be used. Linearity should be verified by observing that over the frequency range 200 Hz to 6 000 Hz, or as

otherwise desired, a change in test signal level causes the same change at the measurement point. The frequency range used shall be stated.

NOTE The SPL presented to the hearing aid microphone can significantly exceed the test signal level because of the location of the hearing aid microphone and subject position.

7.5 Location of the subject

The subject shall be located at the subject test position (see 6.2) during all measurements except the initial sound field recording of the substitution method.

7.6 Location of the tester

The test signal level requirements shall be met with either the tester present or absent.

7.7 Choice of field reference point

This point may be recommended by the manufacturer or dictated by the physical construction of the equipment. Choose the field reference point to provide repeatable test signal levels that are within 3 dB of the desired value at the subject reference point.

The results of the measurements (REUR, REAR) depend upon the choice of field reference point. For devices operating linearly, REIG is independent of the field reference point. Care shall be taken to ensure that the presence of the hearing aid during the aided measurement does not alter the test signal.

7.8 Choice of measurement point

The measurement point shall be chosen such that a ± 2 mm change in its position shall produce a change of less than 2 dB in the measurement of interest over the frequency range 200 Hz to 6 000 Hz. For unoccluded measurements, this will generally require that the measurement point be within 6 mm of the tympanic membrane. Occluded measurements will, in general, additionally require that the measurement point be at least 5 mm beyond the sound outlet of the hearing aids (see annex A).

When locating the position of the sound inlet of the probe microphone at the measurement point, care should be taken to ensure the subject does not experience any discomfort.

WARNING — Take care to avoid blocking or compressing the probe microphone extension tube.

NOTE 1 Deeply inserted earmoulds and shells might not meet these requirements.

NOTE 2 Further information regarding the positioning of the probe microphone sound inlet can be found in annex A.

7.9 Location and coupling of the hearing aid

The hearing aid shall be placed on the subject and acoustically coupled to the ear canal in the manner of normal use. Care should be taken to avoid movement of the probe microphone sound inlet and the measurement point and to avoid blocking or compressing the probe extension tube. It is recommended that the hearing aid be fitted with a fresh battery.

7.10 Real-ear unaided response (REUR) curve

If this measurement is to be used in an REIG calculation, the field reference point, the test signal level and the measurement point shall be the same as that used in the REAR measurement.

For stored equalization methods, record the sound field with the reference microphone at the appropriate field reference point and the subject positioned as required (see 7.3.1 and 7.3.2).

Locate the subject in the subject test position.

Position the reference microphone at the appropriate field reference point as required.

Position the sound inlet of the probe microphone at the appropriate measurement point (see 7.8).

Select an appropriate test signal level and type within the capabilities of the equipment used (see 7.4.2).

Instruct the subject to remain silent and still.

Follow the equipment manufacturer's instructions to record an REUR curve.

7.11 Real-ear unaided gain (REUG) curve

If this measurement is to be used in an REIG calculation, the field reference point, the test signal level and the measurement point shall be the same as that used in the REAG measurement.

For stored equalization methods, record the sound field with the reference microphone at the appropriate field reference point and the subject positioned as required (see 7.3.1 and 7.3.2).

Locate the subject in the subject test position.

Position the reference microphone at the appropriate field reference point as required.

Position the sound inlet of the probe microphone at the appropriate measurement point (see 7.8).

Select an appropriate test signal level and type within the capabilities of the equipment used (see 7.4.2).

Instruct the subject to remain silent and still.

Follow the equipment manufacturer's instructions to record an REUG curve.

7.12 Real-ear occluded response (REOR) curve

For stored equalization methods, record the sound field with the reference microphone at the appropriate field reference point and the subject positioned as required (see 7.3.1 and 7.3.2).

Locate the subject in the subject test position.

Position the reference microphone at the appropriate field reference point as required.

Position the sound inlet of the probe microphone at the appropriate measurement point (see 7.8).

Insert the hearing aid or earmould, taking care not to change the location of the probe microphone sound inlet, collapse the probe tube, or create an acoustic leak around the hearing aid or earmould. The latter two problems can be avoided by providing a small bore through the hearing aid or earmould for probe tube insertion. This bore should be sealed after use. Inserting the probe tube through a vent used for acoustic modification may alter the effect of the vent and influence the measured results. Venting, if present, should be as normally used.

Ensure the hearing aid is switched off.

Select an appropriate test signal level within the capabilities of the equipment used (see 7.4.2).

Instruct the subject to remain silent and still.

Follow the equipment manufacturer's instructions to record an REOR curve.

7.13 Real-ear occluded gain (REOG) curve

For stored equalization methods, record the sound field with the reference microphone at the appropriate field reference point and the subject positioned as required (see 7.3.1 and 7.3.2).

Locate the subject in the subject test position.

Position the reference microphone at the appropriate field reference point as required.

Position the sound inlet of the probe microphone at the appropriate measurement point (see 7.8).

Insert the hearing aid or earmould, taking care not to change the location of the probe microphone sound inlet, collapse the probe tube, or create an acoustic leak around the hearing aid or earmould. The latter two problems can be avoided by providing a small bore through the hearing aid or earmould for probe tube insertion. This bore should be sealed after use. Inserting the probe tube through a vent used for acoustic modification may alter the effect of the vent and influence the measured results. Venting, if present, should be as normally used.

Ensure the hearing aid is switched off.

Select an appropriate test signal level and type within the capabilities of the equipment used (see 7.4.2).

Instruct the subject to remain silent and still.

Follow the equipment manufacturer's instructions to record an REOG curve.

7.14 Real-ear aided response (REAR) curve

If this measurement is to be used in an REIG calculation, the field reference point, the test signal level and the measurement point shall be the same as that used in the REUR measurement.

For stored equalization methods, record the sound field with the reference microphone at the appropriate field reference point and the subject positioned as required (see 7.3.1 and 7.3.2).

Locate the subject in the subject test position.

Position the reference microphone at the appropriate field reference point as required.

Position the sound inlet of the probe microphone at the appropriate measurement point (see 7.8).

Insert the hearing aid or earmould, taking care not to change the location of the probe microphone sound inlet, collapse the probe tube, or create an acoustic leak around the hearing aid or earmould. The latter two problems can be avoided by providing a small bore through the hearing aid or earmould for probe tube insertion. This bore should be sealed after use. Inserting the probe tube through a vent used for acoustic modification may alter the effect of the vent and influence the measured results. Venting, if present, should be as normally used.

Turn the hearing aid on and adjust the user gain control to the desired setting.

Select an appropriate test signal level and type within the capabilities of the equipment used (see 7.4.2).

Instruct the subject to remain silent and still.

Follow the equipment manufacturer's instructions to record an REAR curve.

7.15 Real-ear aided gain (REAG) curve

If this measurement is to be used in an REIG calculation, the field reference point, the test signal and the measurement point shall be the same as that used in the REUG measurement.

For stored equalization methods, record the sound field with the reference microphone at the appropriate field reference point and the subject positioned as required (see 7.3.1 and 7.3.2).

Locate the subject in the subject test position.

Locate the reference microphone at the appropriate field reference point as required.

Position the sound inlet of the probe microphone at the appropriate measurement point (see 7.8).

Insert the hearing aid or earmould, taking care not to change the location of the probe microphone sound inlet, collapse the probe tube, or create an acoustic leak around the hearing aid or earmould. The latter two problems can be avoided by providing a small bore through the hearing aid or earmould for probe tube insertion. This bore should be sealed after use. Inserting the probe tube through a vent used for acoustic modification may alter the effect of the vent and influence the measured results. Venting, if present, should be as normally used.

Turn the hearing aid on and adjust the user gain control to the desired setting.

Select an appropriate test signal level and type within the capabilities of the equipment used (see 7.4.2).

Instruct the subject to remain silent and still.

Follow the equipment manufacturer's instructions to record an REAG curve.

7.16 Real-ear insertion gain (REIG) curve

Use one of the following procedures.

a) Procedure 1

- 1) Record the REUR curve following 7.10.
- 2) Record the REAR curve following 7.14.
- 3) Determine the REIG curve by subtracting the REUR from the REAR.

b) Procedure 2

- 1) Record the REUG curve following 7.11.
- 2) Record the REAG curve following 7.15.
- 3) Determine the REIG curve by subtracting the REUG from the REAG.

8 Data to be recorded

Record the following:

- a) details of the subject, test ear and tester, together with the date of test;
- b) details of the equipment used, including the manufacturer, model, serial number, software version and date of last full calibration;
- c) the real-ear acoustical characteristic measured;
- d) the test signal type and level, type of sound field, field reference point, measurement method and method of equalization used;
- e) the azimuth angle of sound incidence, elevation angle of sound incidence and the working distance;