# Sound Quality Head and Torso Simulator Type 4100 & 4100 D

# Sound Quality Head and Torso Simulator Type 4100, 4100 D

Revision September 2001

# Contents

# Chapter 1

# Introduction

# 1.1 Introduction

Sound Quality Head and Torso Simulators Types 4100 and 4100 D are manikins for sound quality testing. Type 4100 includes Falcon Range® Preamplifiers Type 2669 L with charge injection calibration facility, while Type 4100 D includes DeltaTron® Preamplifiers Type 2671. Both types use high sensitivity, low noise, ½″ Falcon Microphones. Throughout this manual, we refer to both types as Type 4100 or "the simulator", except where the difference is specifically indicated.

Two microphones, positioned at the entrances to the manikin's ear canals, simulate the human ear separation and ensure a signal that includes the interference patterns caused by the head and upper body. This gives an extremely accurate three-dimensional, binaural recording.

Two moulded-silicone pinna simulators sit around the microphones to provide directivity patterns similar to the human ear.

The simulator has a sound-dampening fabric cover which slips easily over the manikin's neck. This assists in changing the reflections and diffraction from the body and shoulders to obtain the correct directivity.

The position of the head can be adjusted by turning the neck ring so that the head looks straight forward or slightly down at an angle of 17°.

# 1.2 Sound Quality

The sound quality of the noise from a product, as perceived by a person, is an increasingly important factor when assessing the total quality of the product. Objective measuring methods have shown themselves to be inadequate at identifying the differences which can be experienced by listening.

This applies to all forms of transport as well as household and office machinery products: all are increasingly subject to the optimization of their sound quality. Sub-suppliers of products and components to these industries are often required to include an acceptable sound quality as a part of the product specifications.

# 1.3 Subjective Listening Tests

The final evaluation of the sound quality of a product is normally made using a selected group of people – a jury in a listening test.

To have the jury listen to the sound in reality, for example each jury member driving a car and then reporting on the sound quality, is both time consuming and costly. To overcome this, the simulator can be used to make a high-quality binaural recording of the product's noise on a DAT recorder. This can then be simultaneously presented to all members of the jury off-site.

However, to avoid bias errors in this process, it is important that the acoustic properties of the recording and playback are as accurate as possible. Type 4100 therefore has a frequency response to sounds coming from all directions which closely approximates the direction-dependent human response, and inter-aural time differences very close to those of the average person.

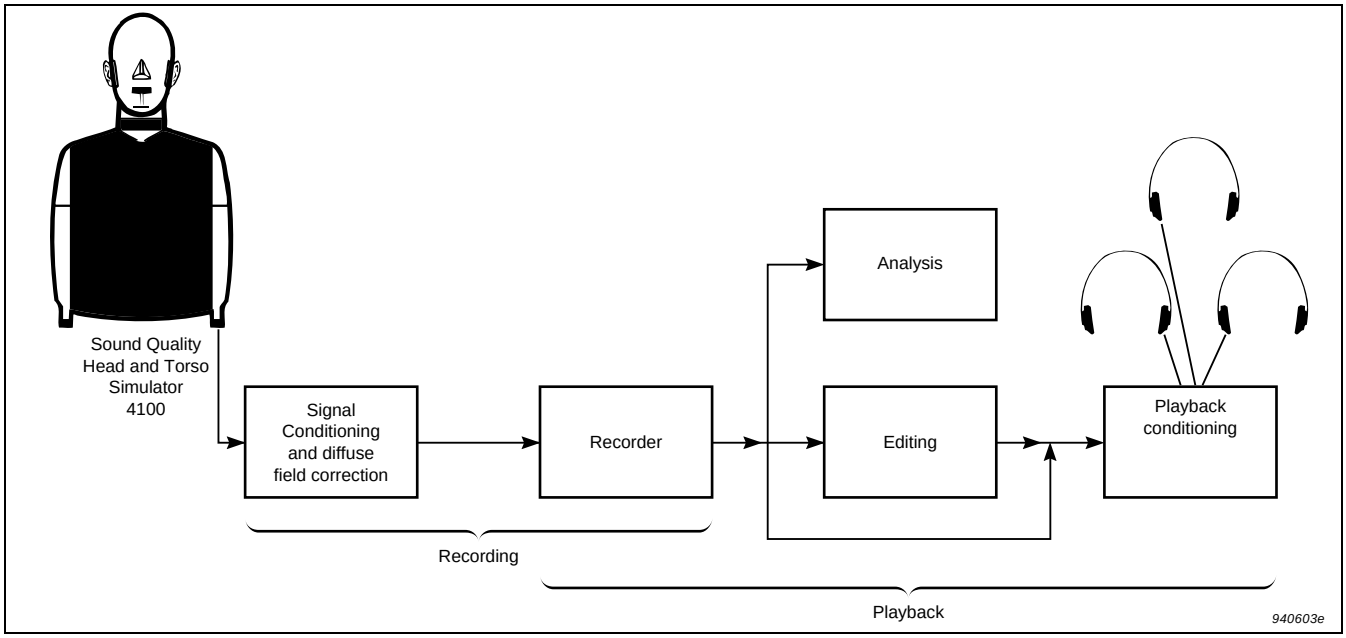
Sound quality is normally used interactively, for example in the product design phase, for time and frequency filtering of the played back signals. This allows the localization of signal components that are important for the subjective experience, or the simulation of proposed modifications to a test object. These manipulations, together with ordinary editing of recordings for playback, are often carried out from a special work station: a PC or a work station built up using a digital signal processor for signal analysis along with its own storage medium.

## 1.4 Systems for Sound Quality Testing

Sound quality is an application in which an entire chain of apparatus comprises the finished system. The better integrated each link in the chain is, the greater its reliability.

Depending on your application, a greater or lesser number of components is required in order to obtain the results you are after. Fig. 1.1 illustrates the basic building blocks of a sound quality system. All of these building blocks must be accurate and reliable as the system is no better than the poorest of its components.

*Fig. 1.1 The basic building blocks of a sound quality system*



## Recording

Any recording portion of a sound quality system consists of:

- Microphone/transducer
- Preamplifier
- DAT recorder

In the case of Type 4100, the microphone and preamplifier are built into the head and torso casing.

The simulator is placed in the test environment (automobile, aeroplane, machine shop) in a position which simulates the position of a person in that situation, and the sounds around it are recorded using a DAT recorder. When a sufficient interval has elapsed to give an appropriate spectrum of the sound quality in the given environment, the recorder is switched off, and the data is ready for playback and analysis.

## Playback Systems

Playback systems are used to listen to and analyse the original sound recorded via the DAT recorder. A minimum configuration consists of the following elements:

- Equalizer
- Integrated amplifier
- Headphones

The equalizer compensates for errors in the diffuse-field response of the headphones, which may not be ideal. When using Type 4100 (D), the sound is usually recorded with a flat diffuse-field correction with respect to the entrance to the ear canal. If this is the case, the headphones should also be corrected to present a flat diffuse-field response at the entrance to the ear canal. Open or semi-open headphones are recommended.

## Analysis

Quite often, the first evaluation of the sound quality of a product, as perceived by the jury, is not satisfactory. Therefore, the recorded signals from the simulator can be modified using a PC with a sound quality software program which has a wide range of time/frequency domain editing and display techniques. The modified signals can then be compared with the original, by the jury, in a listening test. If the modified signal is preferred, information on the changes in the sound can be used by the product designer to obtain – by physical changes – improved sound quality.

Analysis is often performed on sound quality data in order to obtain specialized, non-subjective kinds of information about the sound. This kind of information can be used to measure certain parameters with respect to the sound, which have a well-understood meaning for the specific industry, or it could be used to develop objective tests which simulate subjective testing.

One set of objective parameters or metrics are those based on a Zwicker Loudness calculation:

- Loudness
- Sharpness
- Roughness
- Fluctuation strength

## 1.5 How to Use this Manual

This manual will help you set up and use the Sound Quality Head and Torso Simulator Type 4100, as well as provide you with information about using it in connection with larger sound quality systems.

**Chapter 2** lists the equipment which comes with the simulator, and tells you how to install and remove the pinna simulator, adjust the head angle, change preamplifier cables, etc.

**Chapter 3** gives information about how to calibrate the simulator.

**Chapter 4** contains service information.

**Chapter 5** contains the simulators' specifications.

# Chapter 2

# Getting Started

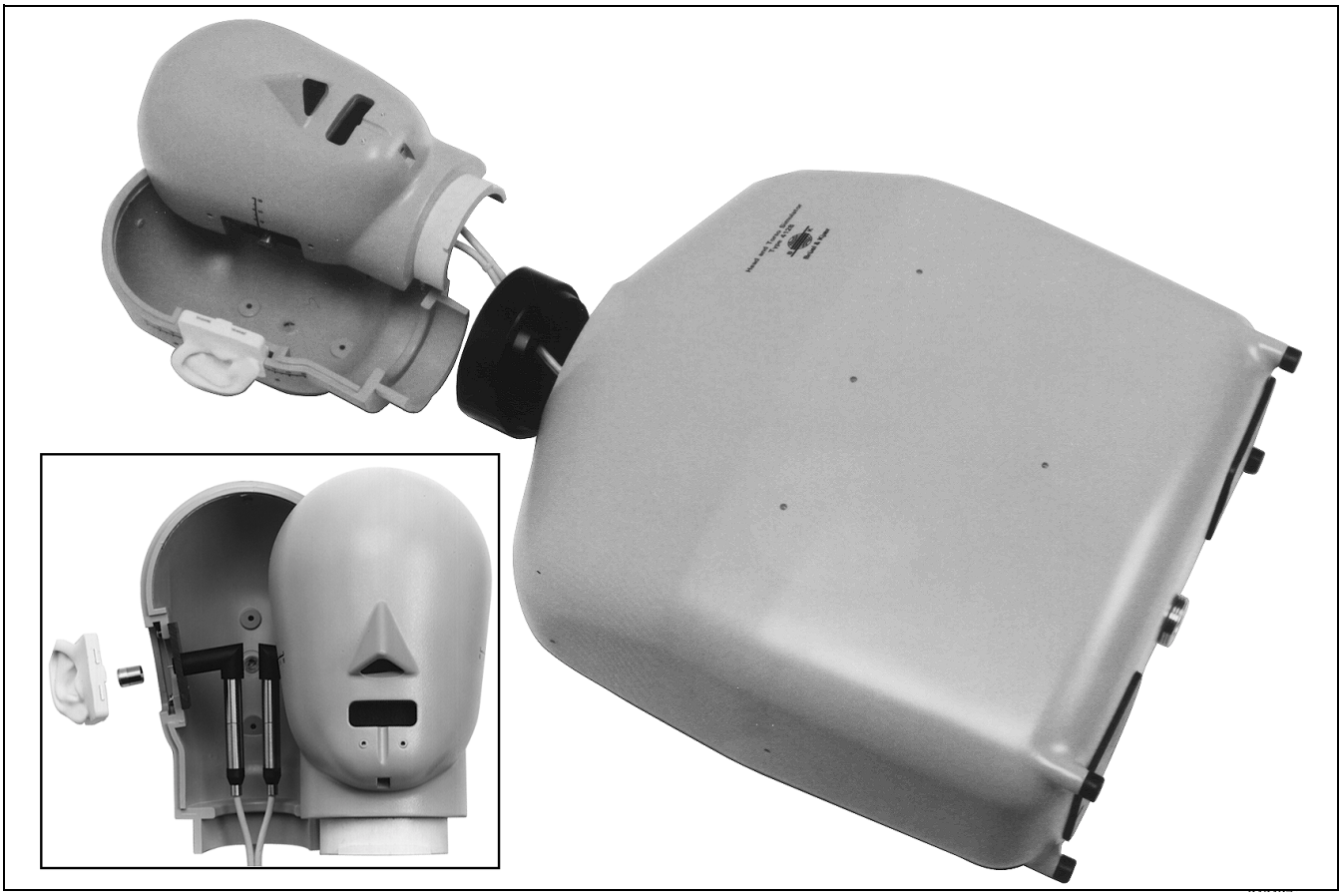
# 2.1 Inventory

## 2.1.1 Main Components

Your Sound Quality Head and Torso Simulator comes fully assembled and has its own calibration chart. It consists of eight main components as shown in Fig. 2.1:

- Head (consisting of two halves)
- Neck ring
- Torso
- Microphone/preamplifier assemblies
- Connection cables
- Silicone pinnae
- Absorptive cover for the torso (Fig. 2.3)

*Fig. 2.1 The main components of the Sound Quality Head and Torso Simulator*



### 2.1.2 Accessories

A number of accessories are provided with the simulator:

- Calibration adaptor
- Support leg
- Handle
- Tripod mounting adaptor

The use and mounting of these accessories is described in the sections and chapters which follow.

## 2.2 Construction

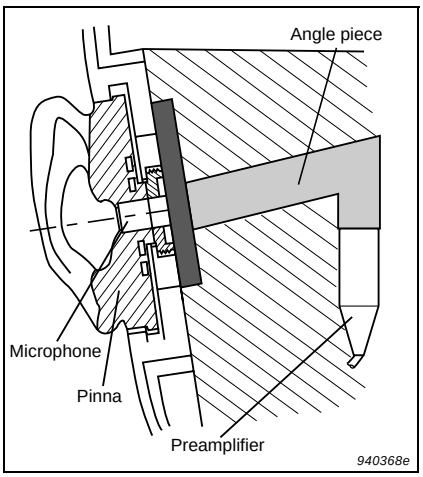
### 2.2.1 Ear Simulator

The ear simulator has a very simply construction:

- Type 4100 includes two Type 4190–L–002 microphone/preamplifier assemblies with built-in TEDS, each comprising a ½″ Falcon Range Microphone Type 4190 placed in the bottom of the concha, an angle piece and Falcon series Preamplifier Type 2669 L with charge injection calibration (CIC) facility and LEMO connector
- Type 4100 D includes two Type 4189–A–002 microphone/preamplifier assemblies with built-in TEDS, each comprising a ½″ Falcon Range Microphone Type 4189 placed in the bottom of the concha, an angle piece and a DeltaTron Preamplifier Type 2671 with BNC connector

An ear-shaped piece of silicone (the pinna), is fitted around the microphone.

*Fig. 2.2 Cross-section showing the construction of the ear simulator*

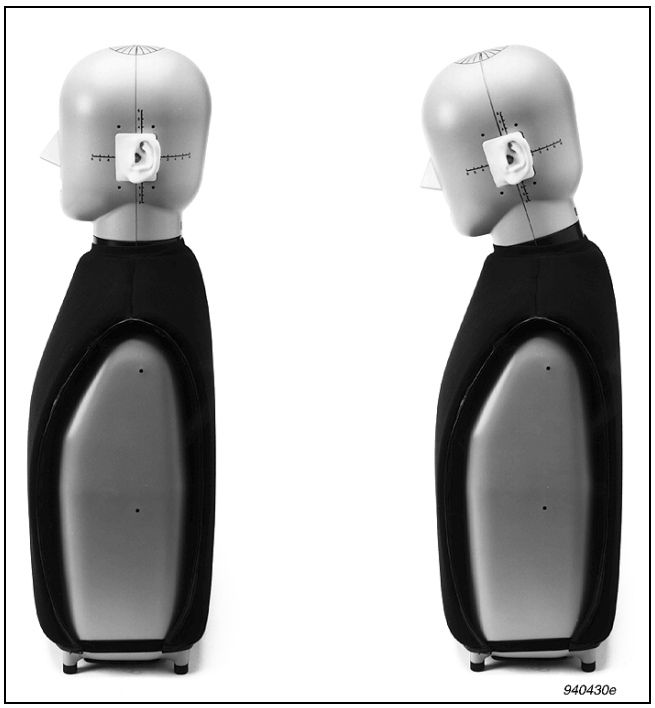


The microphones are mounted in the entrance to the ear canal. This means that, when played back through headphones, the sound presented at the ear canal of the listener is the same as the measured sound.

## 2.2.2 Head, Torso and Neck Ring

The head and torso are connected by a reversible neck ring. This allows two head positions: one with the head upright and the other with it tilted downwards at an angle of 17° from the horizontal. This approximates the head position of a person who is, for example, (i) a passenger in a car, (ii) a person sitting in a concert hall listening to music, or (iii) a person sitting at a desk, working. Fig.2.3 illustrates the two positions of the head.

*Fig.2.3 The position of the neck ring determines the angle of the head*




For calibration, only the pinnae have to be removed (see section 2.3.1). To replace a preamplifier cable, for example to use a longer one, you have to separate the head from the torso (see section 2.3.3). The microphones and preamplifiers should only be removed when the simulator is being serviced (see Chapter 4).

The simulator comes with an absorptive cover for the torso (see Fig.2.3). This adjusts reflections and diffraction from the upper part of the torso to optimize the directivity of the entire simulator.

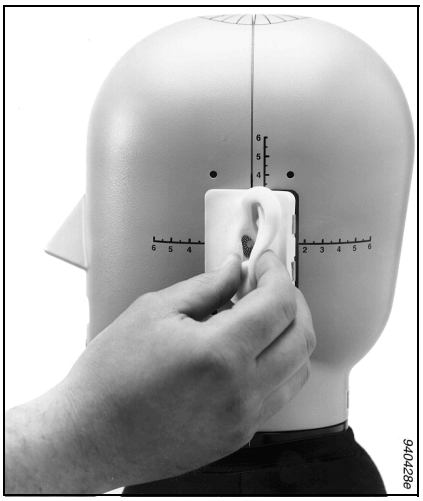
# 2.3 Assembly and Dismantling

## 2.3.1 Attaching and Removing the Silicone Pinna

The pinna simulator is attached to the head by four small lugs which fit into slots in the square opening on the side of the head.

Take a firm hold of the ear-flap (Fig.2.4), and push (or pull) it forward towards the front of the ear. The two back lugs should come out. You can then pull the ear out of the two front slots.

*Fig.2.4 Removing the pinna ear simulator*




Once you have removed the pinna simulators from the head, you can calibrate the microphones (see Chapter 3).

## 2.3.2 Adjusting the Neck Ring

The black neck ring which sits between the head and the torso is used to change the angle at which the head rests on the torso. Change the angle as follows:

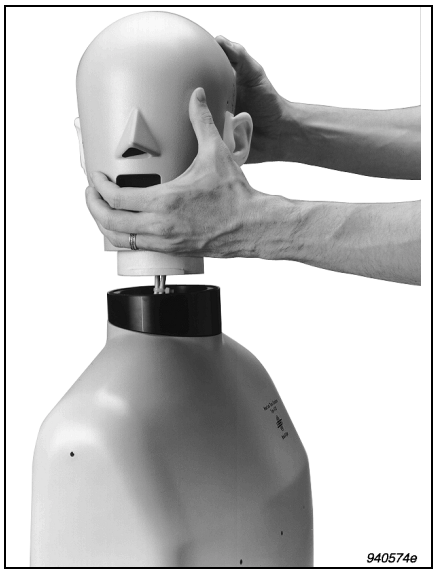
1. Remove the two square rubber inserts from the bottom of the torso by pulling them out. This loosens the preamplifier cables

2. Turn the head 90° to the side and lift off as shown in Fig.2.5

3. Rotate the neck ring 180° to its new position. With the thin side of the ring placed at the front of the torso, the head is lowered to a resting position. When the thicker side of the ring is at the front of the torso, the head is upright

4. Place the head back on the torso (90° from forward) and turn it so it once again is faces forwards (aligned with the mark on the neck ring, Fig.2.7)

*Fig. 2.5 Separating the head from the torso*




## 2.3.3 Changing Preamplifier Cables

Use the procedure given in section 2.3.2 to loosen the head and gain access to the preamplifier connectors.

## 2.3.4 Mounting and Mounting Holes

There are a number of threaded mounting holes on the simulator.

The holes on the sides of the torso are provided to allow you to attach the accompanying handle UA 1052 (see Fig. 2.6) or to fix the simulator in Positioning Frame UA 1324.

The holes at the top of the head and on the chest are for attaching optional equipment, for example clothing (hat) or other fixtures.

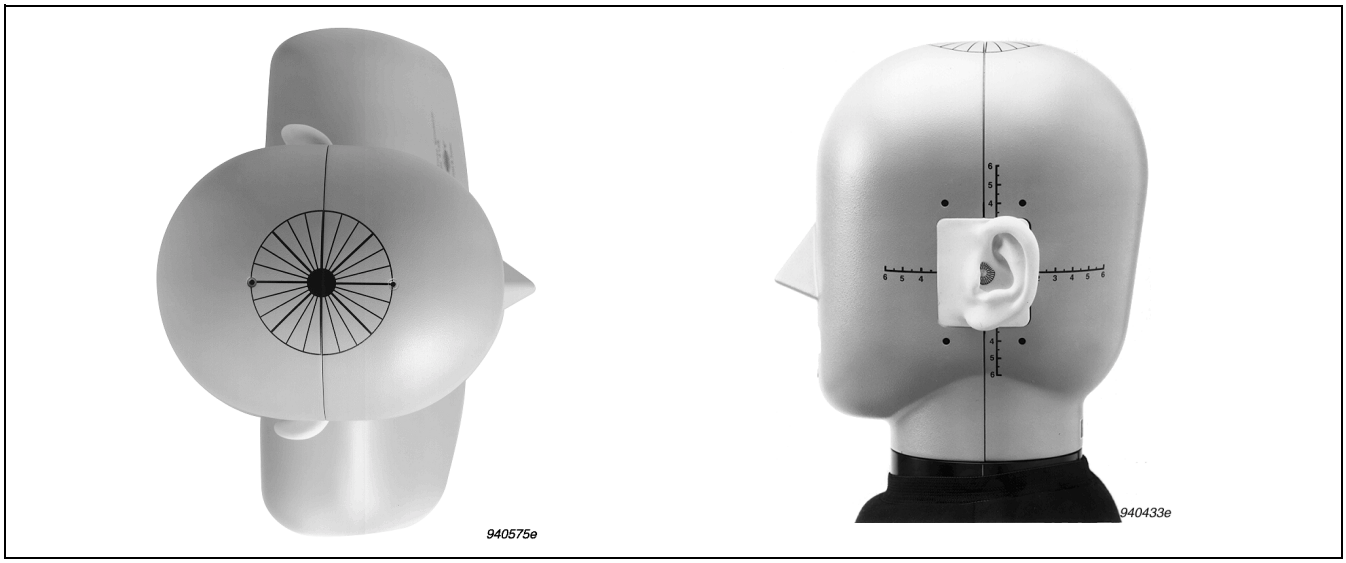
## 2.3.5 Scales and Mounting Guides

There are scaling and mounting guides on the top of the head, as well as around the ear cavities and on the side of the neck ring (see Fig. 2.7).

The scales at the top of the head are for determining the angle at which to locate the sound source for testing, while the mounting guides around the ear cavities are used to adjust the placement of headphones in a calibration procedure. The mark on the neck ring is to ensure that the head faces forwards.

*Fig. 2.6 The handle UA 1052 fitted to the torso. The bottom end-piece cover has not been fitted so that the screw and the end-piece can be seen*


*Fig. 2.7 Scaling and mounting guides (left), headphone and head mounting guides (right)*



# Chapter 3

# Calibration and Setup

# 3.1 Calibration

For reliable measurements using Type 4100, accurate calibration is extremely important. It serves both as a functional check of the microphone/preamplifier combination and as an individual calibration of the preamplifier voltage output for a specific acoustic input.

There are four (practical) methods:

- **Using Sound Level Calibrator Type 4231:** This calibrator requires Adaptor Extension DP 0887 (included as accessory). It provides a 1 kHz tone at a level of 94 or 114 dB re 20 µPa. At 94 dB, the accuracy is ±0.2 dB at reference conditions
- **Using Pistonphone Type 4228:** The pistonphone provides a 251.2 kHz tone at a level of 124 dB re 20 µPa. The accuracy is ±0.09 dB at reference conditions
- **Using Multifunction Acoustic Calibrator Type 4226:** Type 4226 provides test frequencies in octave intervals from 31.5 Hz to 16 kHz. You can choose from 3 calibration levels: 94, 104 or 114 dB re 20 µPa
- **Using Charge Injection Calibration (CIC):** Type 4100, with Falcon Range® Preamplifier Type 2669 L can be calibrated by charge injection. It requires a well-specified test level, which can be injected (supplied) directly from Sound Quality Conditioning Amplifier Type 2672, or via an input socket on, for example, Dual Microphone Supply Type 5935 L. The output signal from the microphone/preamplifier combination is then an accurate indicator of the functionality of the entire measurement chain

Types 4100 and 4100 D contain IEEE P1451.4-capable transducers with standardised Transducer Electronic Data Sheets (TEDS). This feature allows automatic front-end and analyzer setup, based on information stored in the transducer. This information includes, for example, sensitivity, serial number, manufacturer and calibration date.

To calibrate using a calibrator:

1. Remove the pinna simulator by sliding it towards the front of the head and then pulling the back of it outwards away from the head (described in greater detail in Chapter 2)

2. Fit the calibration device onto the microphone (if an adaptor is required, ensure that it has been fitted to the end of the calibration device). Ensure that the calibration device is pushed firmly over the end of the microphone as shown in Fig. 3.1 and Fig. 3.2

3. Switch the calibration device on

In all cases:

4. Record, store or note the signal level corresponding to the acoustic calibration level used. For example, if you record the output signal on a DAT recorder prior

*Fig. 3.1* *Calibration using Pistonphone Type 4228*

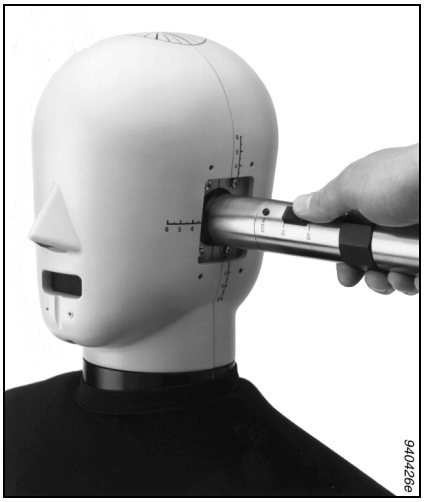
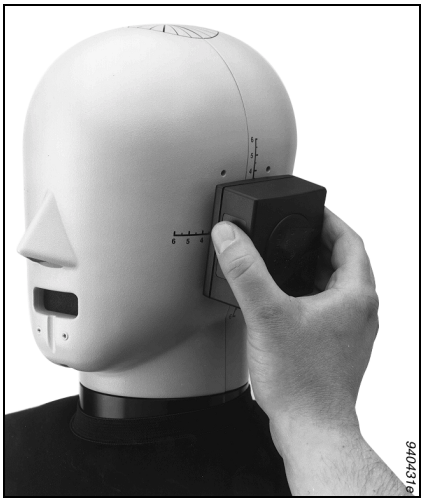



*Fig. 3.2* *Calibration using Sound Level Calibrator Type 4231*




to the actual sound recording, it will be available during the sound editing process to ensure accurate playback levels

**Note:** Calibrating ½″ microphones at the usual calibration frequency of 250 or 1000 Hz applies for the microphones' pressure response which, at these frequencies, is equal to the free-field and diffuse-field response. At higher frequencies they become different. In Type 4100 (D), the microphones are built into the head pinnae and there is a large difference between the pressure response and the diffuse-field response – see Fig. 3.3 and Table 3.1.

As an example, when using Type 4231 to calibrate the simulator, it delivers a sound pressure level of 94 dB at 1 kHz. This produces a diffuse-field level of 94 + 1.52 dB. Similarly, Type 4228 delivers 124 dB at 250 Hz to the Type 4100, giving a diffuse-field level of 124 + 0.33 dB.

A diffuse-field correction in the calibration channel equalizes the sound pressure level from the calibrator and the diffuse-field response, so that they have the same level.

## 3.2 Frequency Response Calibration

The human ear drum's frequency response to sound coming from a particular direction is influenced by:

- reflections and diffractions from torso, head and pinna
- resonances in the ear canal

In addition, human perception of sound from a given direction is based on:

- the time difference between the signals arriving at the two ear drums

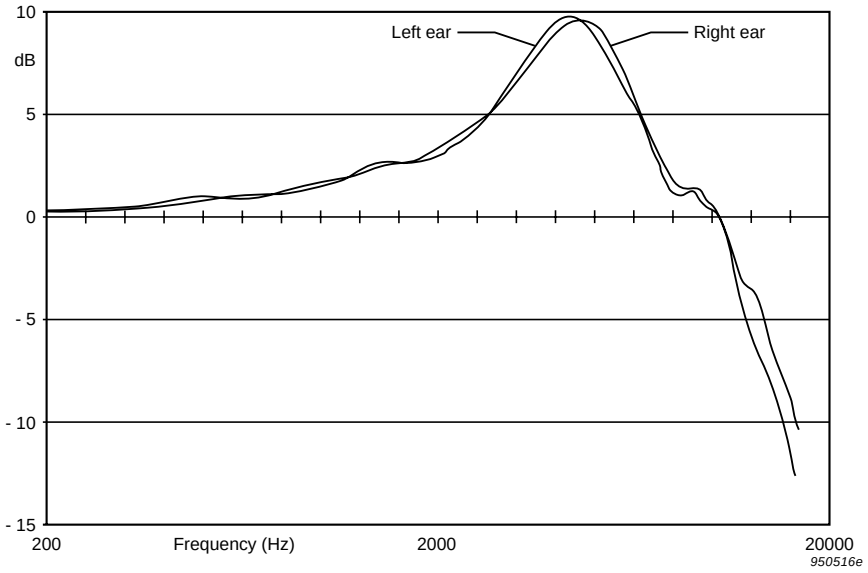
In designing a good head and torso simulator to substitute for the presence of a human being, all these factors are important.

First, the physical dimensions of the head need to match those of an average person. In Type 4100, this is satisfied by compliance with ITU –T Rec. P.58.

In order to determine the correct frequency response to sound from different directions, Brüel & Kjær conducted a comprehensive research program. A probe microphone was placed at the entrances to the ear canals of 40 test persons. Then the frequency response to a sound source (a loudspeaker) was sampled and measured for all directions around each test subject's head. The results were averaged and compared to similar measurements with the simulators. This gave valuable information for use in the design of the head and torso simulators.

In practice, it is normally acceptable to calibrate the head and torso simulator in a diffuse sound field, where sounds from all directions are equally represented. This diffuse-field response (see Fig.3.3) is given on the calibration chart provided with Type 4100.

*Fig.3.3 Diffuse-field characteristics of the head and torso simulator*




As can be seen from Fig.3.3, the response is far from flat, and normalisation is usually required. This can be achieved by equalization in the conditioning amplifier, before the signals are processed and recorded on a DAT recorder, and can improve the signal-to-noise ratio by as much as 10 dB. If equalization is done in conjunction with post-processing on a computer, the values are as given in Table 3.1.

Note that the microphones are positioned at the entrances to the simulator's ear canals and the human ear canal is not simulated. However, changes in the frequency response occurring in the ear canal are not associated with any directional clues or information and can be excluded.

*Table 3.1 Diffuse-field correction as a function of frequency*

| Frequency (Hz) | Correction (dB) | Frequency (Hz) | Correction (dB) | Frequency (Hz) | Correction (dB) | Frequency (Hz) | Correction (dB) |
|---|---|---|---|---|---|---|---|
| 200 | 0.27 | 630 | 0.93 | 2000 | 3.16 | 6300 | 6.31 |
| 212 | 0.28 | 670 | 0.93 | 2120 | 3.49 | 6700 | 5.35 |
| 224 | 0.29 | 710 | 0.96 | 2240 | 3.81 | 7100 | 3.93 |
| 236 | 0.31 | 750 | 1.01 | 2360 | 4.11 | 7500 | 2.89 |
| 250 | 0.33 | 800 | 1.09 | 2500 | 4.45 | 8000 | 1.81 |
| 265 | 0.35 | 850 | 1.19 | 2650 | 4.84 | 8500 | 1.32 |
| 280 | 0.38 | 900 | 1.30 | 2800 | 5.38 | 9000 | 1.31 |
| 300 | 0.41 | 950 | 1.40 | 3000 | 5.91 | 9500 | 1.20 |
| 315 | 0.44 | 1000 | 1.52 | 3150 | 6.52 | 10000 | 0.54 |
| 335 | 0.48 | 1060 | 1.64 | 3350 | 7.22 | 10600 | 0.02 |
| 355 | 0.53 | 1120 | 1.79 | 3550 | 7.96 | 11200 | – 1.45 |
| 375 | 0.58 | 1180 | 1.96 | 3750 | 8.56 | 11800 | – 3.27 |
| 400 | 0.63 | 1250 | 2.19 | 4000 | 9.10 | 12500 | – 4.32 |
| 425 | 0.68 | 1320 | 2.40 | 4250 | 9.52 | 13200 | – 5.44 |
| 450 | 0.73 | 1400 | 2.52 | 4500 | 9.60 | 14000 | – 6.83 |
| 475 | 0.79 | 1500 | 2.51 | 4750 | 9.57 | 15000 | – 8.29 |
| 500 | 0.84 | 1600 | 2.49 | 5000 | 9.19 | 16000 | – 9.67 |
| 530 | 0.89 | 1700 | 2.50 | 5300 | 8.75 | 17000 | –11.48 |
| 560 | 0.92 | 1800 | 2.63 | 5600 | 7.98 | 18000 | –12.10 |
| 600 | 0.93 | 1900 | 2.85 | 6000 | 7.22 | 19000 | –12.00 |

The result is a better signal-to-noise ratio, a simplified diffuse-field correction, and easier headphone calibration in the playback process.

# Chapter 4

# Service

Each Head and Torso Simulator is individually calibrated for the specific microphone/preamplifier pairs it contains. Therefore, if one of the microphones or preamplifiers malfunctions or if for some other reason you wish to remove or change one or both of the microphones or preamplifiers, you will need to send the simulator for service and recalibration. Please consult your local Brüel & Kjær service representative.

Brüel & Kjær offers a range of calibration services for Types 4100 and 4100 D. Details of order numbers are given in section 5.4.

# Chapter 5

# Specifications

# 5.1 Specifications – Type 4100

**MICROPHONES AND PREAMPLIFIERS**
Two Type 4190–L–002 microphone/preamplifier assemblies with built-in TEDS, each comprising a ½″ Falcon Range Microphone Type 4190 placed in the bottom of the concha, and Falcon series Preamplifier Type 2669 L with charge injection calibration (CIC) facility and LEMO connector
**Microphone Sensitivity:** 50 mV/Pa. Individually calibrated

**Upper Limit of Dynamic Range:** 148 dB SPL at 3% distortion
**Max. Sound Pressure Level:**
159 dB peak with Preamplifier Type 2669 and mains driven power supplies
138 dB peak with Preamplifier Type 2669 and battery power supplies
**Preamp. Lower Limiting Frequency:** <2 Hz (–3 dB)

# 5.2 Specifications – Type 4100 D

**MICROPHONES AND PREAMPLIFIERS**
Two Type 4189–A–002 microphone/preamplifier assemblies with built-in TEDS, each comprising a ½″ Falcon Range Microphone Type 4189 placed in the bottom of the concha and a DeltaTron Preamplifier Type 2671 with BNC connector

**Microphone Sensitivity:** 50 mV/Pa. Individually calibrated
**Upper Limit of Dynamic Range:** 146 dB SPL at 3% distortion
**Max. Sound Pressure Level:** 138 dB peak with DeltaTron Preamplifier Type 2671
**Preamp. Lower Limiting Frequency:** <12 Hz (–3 dB)

# 5.3 Common Specifications – Types 4100, 4100 D

**PINNA SIMULATOR**
Dimensions similar to those specified in ITU–T Rec. P.58, IEC 959 and ANSI S3, 36–1985, except for the ear canal extensions

**HEAD AND TORSO SHAPES**
The main dimensions comply with the dimensional requirements of
ITU–T Rec. P.58 and the reports from IEC 959 and ANSI S3 36–1985

**SHOULDER DAMPING FABRIC**
The shoulders, chest and back are covered with a damping fabric to adjust diffraction. The fabric has a minimum of 10% absorption in the range of 100 Hz to 20 kHz

**LEFT/RIGHT EAR TRACKING**
±1 dB up to 5 kHz
±3 dB up to 8 kHz

**CALIBRATION**
Sensitivity calibration can be made using a calibrator or pistonphone with Calibration Adaptor DP 0887

**DIMENSIONS AND WEIGHT**
**Head Height:** 700 mm (27.6″)
**Torso:** 480×440×210 mm (18.9×17.3×8.3″)
**Weight:** 7.9 kg (17.4 lb.)

CE CE-mark indicates compliance with EMC Directive and Low Voltage Directive. (See also Microphone and Preamplifier Product Data)

# 5.4 Ordering Information

Types 4100 and 4100 D Sound Quality Head and Torso Simulator Include the following accessories:

| | |
|---|---|
| BC 0200: | Calibration Chart |
| DP 0887: | Calibration Adaptor |
| UA 1043: | Support Leg |
| UA 1052: | Handle |
| UC 5290: | Tripod Mounting Adaptor |

**CALIBRATION OPTIONS**

| | |
|---|---|
| CAI 4100 | Accredited Initial Calibration |
| CAI 4100 D | Accredited Initial Calibration |
| CAF 4100 | Accredited Calibration |
| CAF 4100 D | Accredited Calibration |
| TCF 4100 | Conformance Test |
| TCF 4100 D | Conformance Test |

Brüel & Kjær reserves the right to change specifications and accessories without notice

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