

# PRODUCT DATA

## Sound Intensity Probe Kit Type 3599

including Sound Intensity Microphone Pair Type 4197 and Dual Preamplifier Type 2683

Type 3599 is a two-microphone probe kit for measuring sound intensity. Specially designed for use with Brüel & Kjær's range of sound intensity analyzers, the probe set includes Remote Control Unit ZH-0632 and ½" Sound Intensity Microphone Pair Type 4197 enabling 1/3-octave centre frequency measurements between 20 Hz and 6.3 kHz. The upper 1/3-octave centre frequency to 10 kHz can be extended using pressure correction.

Used with ½" Microphone pair Type 4197, the probe complies with IEC 1043 Class 1. These ½" microphones feature patented phase-corrector units making precision low-frequency phase matching a practical possibility, leading to increased measurement range and accuracy.



### Uses and Features

#### Uses

- Sound intensity measurements using two-microphone technique, in accordance with IEC 1043 Class 1
- Sound power measurements in accordance with ISO 9614 – 1, ISO 9614–2, ECMA-160 and ANSI S 12.12
- Sound intensity mapping

#### Features

- Microphone pair matched for phase and amplitude response
- Individual calibration data
- 1/3-octave centre frequency ranges:
  - 20 Hz to 10 kHz with corrections
  - 50 Hz to 6.3 kHz according to IEC 1043 Class I
- Minimal shadow and diffraction effects
- Well-defined acoustical microphone separation
- Remote Control Unit which works together with the complete range of Brüel & Kjær analyzers

## Introduction

The measurement of sound intensity (sound power per unit area) is increasingly being used as a routine technique in a wide range of noise investigations. The method permits the determination of sound power from direct measurement of sound intensity, even in situations where pressure-based measurements would be impossible. Since the method does not require special acoustic environments such as reverberation and anechoic chambers, significant savings can also be made.

**Fig. 1**  
Sound Intensity Probe Kit Type 3599 comprising Remote Control Unit ZH-0632, intensity probe, microphones, cables and accessories, is supplied with a carrying case. Sound Calibrator Type 4231 (not included in the kit) can also be stored in the case

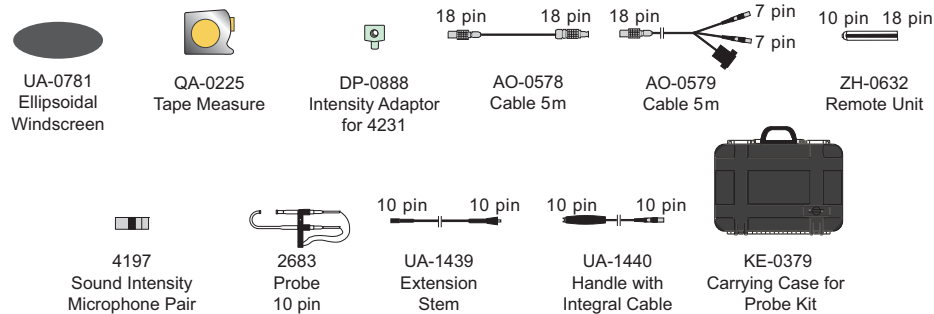


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To measure sound intensity accurately using a two-microphone technique, you need a reliable sound intensity probe set containing a matched microphone pair to obtain information on both the instantaneous pressure and pressure gradient in the sound field. The microphones are separated by a fixed distance in the sound field, and the microphone signals are fed to a sound intensity processor which calculates the sound intensity. The sound intensity is calculated from the time average of the sound pressure multiplied by the particle velocity (calculated from the measured pressure gradient). Such a system measures the component of the sound intensity along the probe axis and also indicates the direction of energy flow.

Two sound intensity probe sets are available from Brüel & Kjær: Type 3599 (see Fig.1) for use with Brüel & Kjær analyzers such as, PULSE™ Type 3560; PULSE LAN-XI Type 3160-A-042, and Type 3564 for use with Hand-held Sound Intensity System Type 2270-G. Dual Preamplifier Type 2683 with Microphone Pair Type 4197, Extension Stem UA-1439 and Handle with Integral Cable UA-1440 can also be used with other intensity systems, for example, NEXUS™ Conditioning Amplifier Type 2691. The characteristics of Sound Intensity Probe Kit Type 3599 and Sound Intensity Microphone Pair 4197 are described in this Product Data.

**Fig. 2**  
The sound intensity probe kit



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For further details of the sound intensity analyzers and information on which probe set is suitable for which analyzer, see the separate Product Data for the analyzers.

## Probe Description

**Fig. 3**

The remote control unit used in conjunction with handle UA-1440



The sound intensity probe is constructed on a face-to-face design. It comprises a robust frame which holds the microphone preamplifiers and matched microphones in a face-to-face configuration. The distance between microphones is defined by solid, plastic spacers, held in place by threaded studs on the microphone grids. Sound is constrained to act on each microphone through a narrow slit between the spacer and the microphone grid. This gives well-defined acoustic separation of the microphones and minimises shadow and reflection effects.

The probe is strong but lightweight and can be connected directly to the remote control unit or a simple handle. To

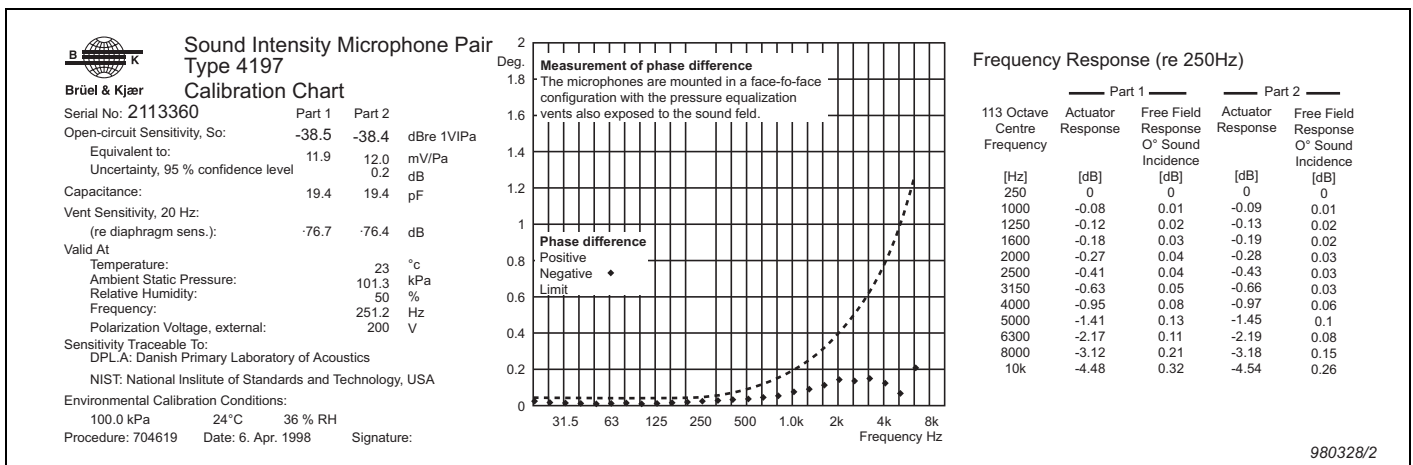
minimise the acoustical disturbance, an extension stem may be used between the handle/remote control unit and the probe. The probe kit is supplied in a carrying case containing a microphone pair, windscreen (ellipsoidal) and accessories. The case has pockets for the remote control unit handle, a Sound Calibrator Type 4231 and other small accessories.

### Sound Intensity Microphone Pairs

Phase matching of 1/2" Microphone Pair Type 4197 is better than 0.05° between 20 Hz and 250 Hz, and is better than  $f/5000$  degrees at higher frequencies, where  $f$  is the frequency. Such phase matching is possible as a result of the integral microphone phase-corrector units (patented) which are fitted to the Type 4197 microphones. The normalised microphone frequency responses differ by less than 0.2 dB up to 1 kHz and by less than 0.4 dB up to 7.1 kHz.

Type 4197 is supplied with 8.5 mm, 12 mm and 50 mm spacers. Calibration data provided (Fig. 4) include phase matching up to a 1/3-octave centre frequency of 6.3 kHz, microphone sensitivities at 250 Hz, actuator responses and individual free-field frequency responses valid for the microphones mounted on a 1/4" preamplifier.

**Fig. 4** Calibration chart supplied with the Type 4197 microphone pair. The measured microphone phase matching and individual microphone free-field responses are given



Brüel & Kjær can also supply a 1/4" Microphone Pair Type 4178 which consists of a pair of 1/4" microphones, phase matched to better than 0.2° from 20 Hz to 1 kHz and sensitivity matched to better than 1 dB. Type 4178 is supplied with 6 mm and 12 mm spacers, along with calibration charts giving the individually measured free-field frequency response for each microphone.

## Remote Control Unit

Remote Control Unit ZH-0632 supplied with Type 3599 has four control buttons and four LEDs. Functions for these controls and indicators are determined by the application software in the analyzer. Text for these controls and indicators are placed on removable labels. Three sets of labels are provided with the set, one for use with analyzers Type 2144 and Type 2133 (SC 2194/95), and two for use with PULSE™ Type 3560 and PULSE LAN-XI Type 3160-A-042 (SC 1375/76 or SC 2206/07). The reverse sides of two of these labels may be used to write alternative text on.

### LEDs

- **Overload:** indicates any overload conditions when measuring, after which you should autorange again, using the remote's **Input Autorange** button
- **Start/Stop:** indicates that the respective functions have been activated
- **Direction:** these LEDs indicate the direction of the active function of the active display: red is positive; green is negative. If the active display shows data with direction, the direction of the display value pointed out by the main cursor is shown by one of the two LEDs

The remote control unit is equipped with a detachable cable which carries both control and microphone signals. Two cables are delivered with the kit: one cable is for connecting to Portable PULSE Type 3560-C or PULSE LAN-XI Type 3160-A-042 using two 7-pin LEMO and one 9-pin SUB-D connectors; the other cable is used for connecting the remote unit to analyzers with 18-pin LEMO input (for example, Types 2144, 2133 and 3560). This cable can also be used as an extension cable together with the 3560C cable.

## IEC 1043 Standard

The IEC 1043 standard (Electroacoustics – Instruments for the measurement of intensity – measurement with pairs of pressure sensing microphones, 1993) distinguishes between Probe, Processor and Instrument and classifies them according to the measurement accuracy achieved. There are two degrees of accuracy, Class 1 and Class 2. Type 3599 complies with IEC 1043 Class 1 which has the most stringent tolerance requirements. Note, however, that the IEC standard only specifies the frequency range from centre frequencies of 50 Hz to 6.3 kHz in 1/3-octave bands.

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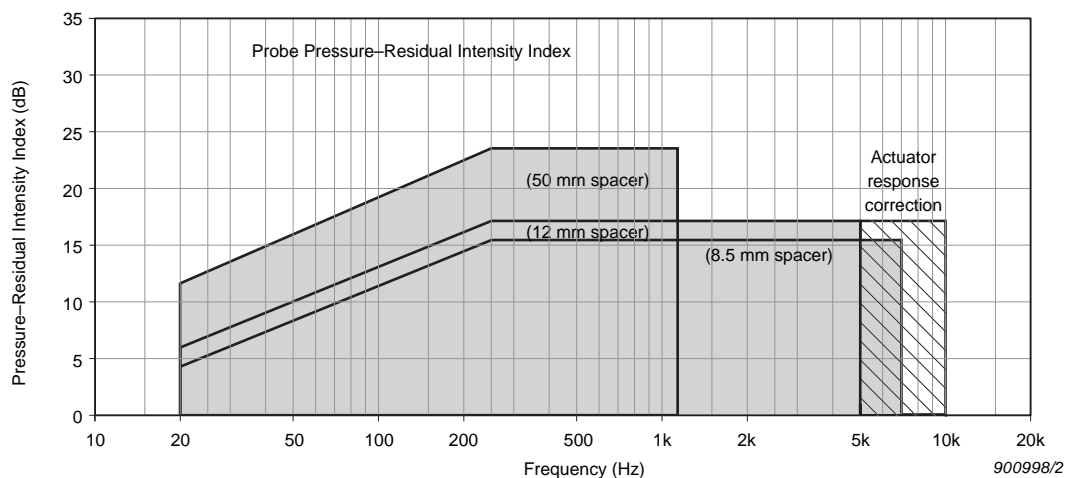
## Frequency Range

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The useful free-field frequency range according to IEC 1043 Class I for Type 3599 using the various microphone and spacer combinations, is from 1/3-octave centre frequencies of 50 Hz to 6.3 kHz. However, using the actuator response correction described in an article by Prof. F. Jacobsen in Brüel & Kjær's Technical Review No. 1, 1996 (BV 0048), the frequency response can be extended to 10 kHz using just the 12 mm spacer. The actual frequency range in practice depends on the difference between the pressure and intensity levels, that is, the Pressure-Intensity Index, which is dependent on the nature of the sound field and the phase response deviation between the probe and processor channels.

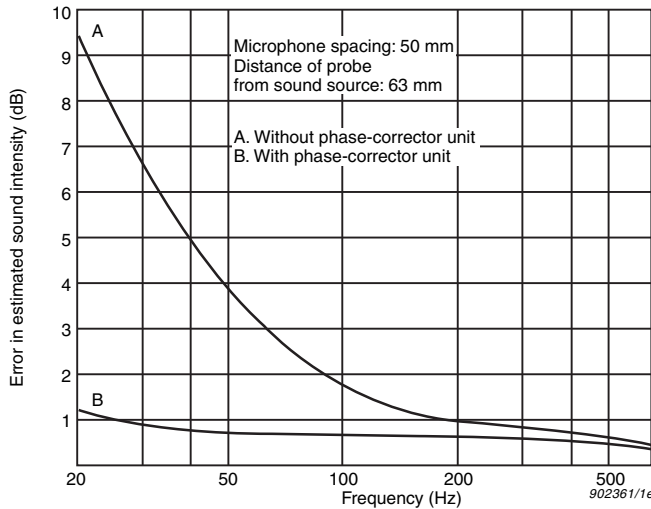
The overall frequency ranges are shown in Fig. 5 for 1/2" Microphone Pair Type 4197 with 8.5, 12 and 50 mm spacers. Note that the frequency range depends on the difference between the pressure level and the intensity level. In most field measurements, the sound intensity level is lower than the sound pressure level. The ability of a sound intensity instrument to measure intensity levels much lower than the pressure level depends on the probe and processor phase matching. The difference between pressure and intensity levels is called the *Pressure-Intensity Index* which is denoted by  $\delta_{PI}$  and is normally a positive quantity.

**Fig. 5**  
Specified frequency and Pressure-Residual Intensity Index ranges for the probe (Pressure-Residual Intensity Index = Pressure Level – Intensity Level (measured in a closed coupler)). Frequency axis is in 1/3-octave centre frequencies



## Patented Microphone Phase-corrector Units

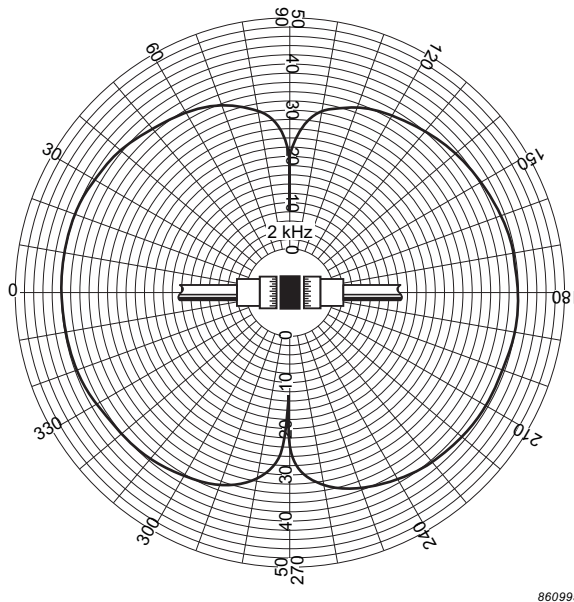
**Fig. 6**  
The phase-corrector units fitted to Type 4197 suppress vent sensitivity and result in more accurate near-field measurements



The phase matching specified for the Type 4197 microphone pair is retained even in sound fields with very high pressure-level gradients, such as those found close to point sources. This is a benefit of the patented phase-corrector units which are fitted to these microphones. Ordinary condenser microphones can have their phase responses altered if there is a difference between the pressure level at the pressure equalisation vent and that at the diaphragm. Type 4197 microphones are, however, essentially insensitive to sound at the vent and the accuracy of near-field measurements at low frequencies is consequently increased (Fig. 6).

## Directional Characteristics

**Fig. 7**  
Measured directional intensity characteristics for a probe set fitted with Type 4197 microphones and a 12 mm spacer at 2 kHz



Typical directional characteristics for a sound intensity probe are given in Fig. 7, which shows the measured intensity as a function of angle of incidence.

This figure-of-eight characteristic is due to the fact that a sound intensity system measures the component of the sound intensity along the probe axis, that is,  $I_{meas} = I \cos \theta$ .

The minimum feature of the probe's characteristics can be used to help locate sound sources.

## Calibration

**Fig. 8**  
Sound Intensity Calibrator Type 4297 with a Sound Intensity Probe in place for calibration



Phase calibration of 1/2" Microphone Pair Type 4197 is done at Brüel & Kjær by subjecting the two microphones to the same sound signal in a pressure coupler. This individual phase calibration can be used to derive the actual Pressure-Residual Intensity Index for the microphone pair.

Complete calibration of sound intensity measurement systems containing a sound intensity probe set can be conveniently made using Sound Intensity Calibrator Type 4297. This permits simultaneous sensitivity adjustment of both channels of the processor and allows determination of the Pressure-Residual Intensity Index of the probe and processor combinations which employ microphone pairs with phase-corrector units, that is, Type 4197.

The advantage of Type 4297 is that the probe need not be dismantled to perform a calibration. Further details can be found in the separate Product Data for Type 4297 (BP 1877). Another possibility is Sound Intensity Calibrator Type 3541-A (BP 2325). If only amplitude (pressure) calibration is required, the two channels can be calibrated separately using Sound Calibrator Type 4231 with Coupler DP-0888.

## Specifications – Sound Intensity Probe Kit Type 3599

### Matched Sound Intensity Microphone Pairs

**SOUND INTENSITY FREE-FIELD FREQUENCY RANGES  
(1/3-OCTAVE CENTRE FREQUENCIES) WITH ½" MICROPHONES  
TYPE 4197 CONNECTED TO DUAL PREAMPLIFIER TYPE 2683  
(IEC 1043 CLASS 1)**

**8.5 mm spacer:** 250 Hz to 6.3 kHz ( $\delta_{pI0} > 15.3$  dB)\*

**12 mm spacer:** 250 Hz to 5.0 kHz ( $\delta_{pI0} > 16.8$  dB)

**50 mm spacer:** 20 Hz to 1.25 kHz ( $\delta_{pI0} > 23$  dB above 250 Hz)

\*Pressure-Residual Intensity Index

**SOUND INTENSITY FREE-FIELD FREQUENCY RANGES WITH ¼" MICROPHONES TYPE 4178**

**6 mm spacer:** max. 10.0 kHz

**12 mm spacer:** max. 5.0 kHz

#### DIMENSIONS

**Length of Extension Stem:** 42 cm (16.5 in)

**Width:** 43 mm (1.7 in)

#### WEIGHT

**Incl. handle:** 0.35 kg (0.77 lb)

**In case:** 6.50 kg (14.3 lb)

## Specifications – Sound Intensity Microphone Pair Type 4197

Diameter		½"
Polarization voltage (V)		200
Open-circuit sensitivity	mV/Pa	11.2*
	dB re 1 V/Pa	-39
Free-field frequency response 0° incidence	±1 dB	5 Hz to 12.5 kHz*
	±2 dB	0.3 Hz to 20 kHz
Resonance frequency		34 kHz
Lower limiting frequency	-3 dB	0.14 Hz
Vent sensitivity re diaphragm sensitivity	at 20 Hz	<-64 dB* (-18 dB/octave)
Polarized cartridge capacitance	at 250 Hz	19.5 pF*
Cartridge thermal noise		20.0 dB(A)
Upper limit of dynamic range	Distribution <3%, 100 Hz	162 dB SPL
Temperature coefficient	-10°C to +50°C, 250 Hz	-0.002 dB/°C
Ambient pressure coefficient	at 250 Hz	-0.007 dB/kPa
Humidity coefficient	100% RH	<0.1 dB
Vibration sensitivity	at 1 m/s <sup>2</sup>	65.5 dB SPL
Magnetic field sensitivity	50 Hz, 80 A/m	6 to 34 dB SPL
Thread for preamplifier mounting		5.7 – 60 UNS
Accessories included		8.5 mm spacer UC-5349 12 mm spacer UC-5269 50 mm spacer UC-5270

\*Individually calibrated

### Microphone Matching Specifications

Phase response difference (absolute value) (1/3-octave centre frequencies)		<0.05°: 20 Hz to 250 Hz*
		< $\frac{f[\text{Hz}]^\circ}{5000}$ : 250 Hz to 6.3 kHz*
Amplitude response difference	normalized at 200 Hz	<0.2 dB: 20 Hz to 1 kHz
		<0.4 dB: 20 Hz to 7.1 kHz
Sensitivity difference	at 250 Hz	<1 dB
Polarized capacity difference		<1.0 pF

\*Individually calibrated





## Specifications – Dual Preamplifier Type 2683

Phase matching		<0.015° at 50 Hz (20 pF mic. capacitance) $f$ [kHz] $\times 0.06^\circ$ : 250 Hz to 10 kHz
Electrical noise re microphone sensitivity <sup>‡</sup>	¼" 6.4 pF dummy	39.2 dB SPL (A)
	½" 19.5 pF dummy	19.4 dB SPL (A)
Input impedance		>15 GΩ  xx pF where xx is typically Ch. A = 1.1 pF; Ch. B = 0.4 pF
Attenuation	For ½" microphones	Ch. A = 0.6 dB; Ch. B = 0.3 dB
	For ¼" microphones	Ch. A = 1.7 dB; Ch. B = 0.7 dB
Other specifications		Refer to Product Data (BP 1584) for Type 2670

<sup>‡</sup> This corresponds to a total (Microphone + Preamplifier) noise floor of 39.3 dB SPL (A) and 22.7 dB SPL (A) respectively.

**Note:** All values are typical at 25°C (77°F), unless measurement uncertainty is specified. All uncertainty values are specified at 2 $\sigma$  (i.e., expanded uncertainty using a coverage factor of 2)

## Compliance with Standards

   	<p>The CE marking is the manufacturer's declaration that the product meets the requirements of the applicable EU directives</p> <p>RCM mark indicates compliance with applicable ACMA technical standards – that is, for telecommunications, radio communications, EMC and EME</p> <p>China RoHS mark indicates compliance with administrative measures on the control of pollution caused by electronic information products according to the Ministry of Information Industries of the People's Republic of China</p> <p>WEEE mark indicates compliance with the EU WEEE Directive</p>
<b>Safety</b>	EN/IEC 61010–1 and ANSI/UL 61010–1: Safety requirements for electrical equipment for measurement, control and laboratory use
<b>EMC Emission</b>	EN/IEC 61000–6–3: Generic emission standard for residential, commercial and light industrial environments EN/IEC 61326: Electrical equipment for measurement, control and laboratory use – EMC requirements CISPR 22: Radio disturbance characteristics of information technology equipment. Class B Limits
<b>EMC Immunity</b>	EN/IEC 61000–6–1: Generic standards – Immunity for residential, commercial and light industrial environments EN/IEC 61000–6–2: Generic standards – Immunity for industrial environments EN/IEC 61326: Electrical equipment for measurement, control and laboratory use – EMC requirements <b>Note:</b> The above is guaranteed using accessories listed in this Product Data only
<b>Temperature</b>	IEC 68–2–1 & IEC 68–2–2: Environmental Testing. Cold and Dry Heat Operating Temperature: –10 to +50°C (+14 to +122°F) Storage Temperature: –25 to +70°C (–13 to +158°F)
<b>Humidity</b>	IEC 68–2–3: Damp Heat: 90% RH (non-condensing at 40°C, 104°F)

## Ordering Information

Type 3599 Sound Intensity Probe Kit

Includes the following accessories:

- Type 4197: Microphone Pair including spacers:
  - UC-5349: 8.5 mm spacer
  - UC-5269: 12 mm spacer
  - UC-5270: 50 mm spacer
- Type 2683: Dual Preamplifier
- ZH-0632 : Remote Control Unit
- UA-1439: Extension Stem
- UA-1440: Handle with Integral Cable
- UA-0781: Ellipsoidal Windscreen
- DP-0888: Coupler
- QA-0224: Chalk
- QA-0225: Tape Measure
- KE-0379: Carrying Case
- AO-0578-D-050: Cable with 18 – 18-pin LEMO, 5 m (16.4 ft)
- AO-0579-D-050: Cable with 2  $\times$  7-pin LEMO and Sub-D, 5 m (16.4 ft)
- SC-2206/07: Text Label Set for Remote Handle Unit
- SC-2194/95: Text Label Set for Remote Handle Unit
- WA-0307: 6.4 pF Dummy Microphone

## Optional Accessories

### CALIBRATION EQUIPMENT

- |             |   |
|-------------|---|
| Type 4228   | Pistonphone                                     |
| Type 4231   | Sound Calibrator                                |
| Type 3541-A | Sound Intensity Calibrator (includes Type 4228) |
| Type 4297   | Sound Intensity Calibrator                      |

### FRONT-ENDS

- |             |  |
|-------------|--|
| UA-2104-031 | Sound Intensity Front Panel for use with Type 3050-A-040/060 |
|             | Type 3052-A-020  |
|             | Type 3160-A-042  |

### MICROPHONES

- |           |   |
|-----------|---|
| Type 4178 | ¼" Sound Intensity Microphone Pair (with 6 and 12 mm spacers) |
|-----------|---|

### SPACERS

- |                              |              |
|------------------------------|--------------|
| For ¼" Microphones Type 4178 |              |
| UC-0196                      | 6 mm spacer  |
| UC-0195                      | 12 mm spacer |

### EXTENSION CABLES

- |         |   |
|---------|---|
| AO-324  | 5 m Single Cable Extension (18-pin LEMO)                    |
| AO-325  | 30 m Single Cable Extension (18-pin LEMO)                   |
| JP-1040 | Branched cable 0.2 m (10-pin LEMO to 2 $\times$ 7-pin LEMO) |



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