PRODUCT DATA

Sound Intensity Calibrator — Type 3541-A

Type 3541-A enables calibration of sound intensity measuring instruments by using a coupler designed especially for sound intensity calibrations. Intensity-probe microphones are positioned in the coupler, which in conjunction with a pistonphone simulates a plane sound wave propagating along the axis of the probe. The instrument's sensitivity to both sound intensity and particle velocity can then be calibrated. The pistonphone can also be used for sound pressure calibrations. In addition to calibration, Type 3541-A can be used to measure the pressure-residual intensity index of instruments used for measuring sound intensity at 250 Hz.

Type 3541-A components in their case are shown on the right. The main components are the Intensity Coupler and Pistonphone. Other components are the Correction Barometer, Dummy Microphone (1/4″), Microphone Adaptors (two), Microphone Adaptors for Pistonphone (1/2″, 1/4″ and 1/8″). Calibration Charts are stored in the lid.


100086

Uses and Features

Uses

- Sound intensity and particle velocity calibrations
- Sound pressure calibration
- Measurement of pressure-residual intensity index at 250 Hz

Features

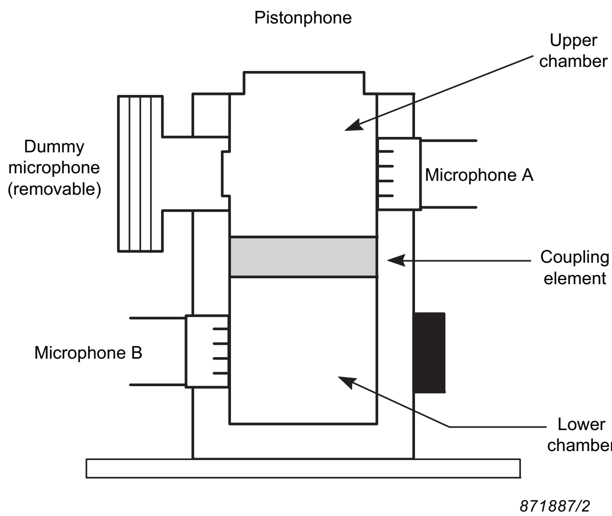
- Intensity coupler for simulating a plane sound wave in a free field (US. pat. No. 4715219)
- Pistonphone for sound intensity, particle velocity and sound pressure calibrations

Introduction

Sound Intensity Calibrator Type 3541-A enables instruments that measure sound intensity to be calibrated against simulated sound intensity and particle velocity levels. Instruments and microphones cannot be considered fully calibrated if only the sound pressure sensitivities of the individual microphone channels are calibrated. Calibration with the simulated sound intensity and particle velocity levels of Type 3541-A ensure that these parameters can be measured correctly.

Type 3541-A is intended for use with Brüel & Kjær Sound Intensity Probes with a Sound Intensity Microphone Pair. Other microphone pairs have much higher vent sensitivities and this restricts their use (see “Microphones and Vent Sensitivity”).

Fig. 1
Simplified cross-section of intensity coupler



A simplified cross-section of the intensity coupler is shown in Fig. 1. The coupler consists of two chambers connected by a coupling element. When the pistonphone is attached to the coupler there is a phase difference between the sound pressures in the upper and lower chambers. The amplitude of the sound pressure is the same in both chambers, so a plane sound wave propagating in a free field is simulated. If one microphone is positioned in the upper chamber and the other in the lower chamber, the simulated sound wave can be used for calibrating the sensitivity of the measuring instrument to sound intensity and particle velocity.

The coupler and pistonphone can also be used for sound pressure sensitivity calibration. For this, the microphones are both positioned in the upper chamber. Then they are exposed to exactly the same sound pressure (amplitude and phase).

The supplied calibration chart states the levels that should be detected during calibration. The chart also gives information about corrections to the calibration levels for use when conditions are different from the stated reference conditions. A correction barometer determines correction terms to the sound pressure and particle velocity calibration levels due to changes in atmospheric pressure. The sound intensity calibration level is independent of any change in atmospheric pressure.

Calibration Procedure

Fig. 2
Arrangement for sound pressure calibration. It can also be used to measure residual intensity and pressure-residual intensity index at 250 Hz

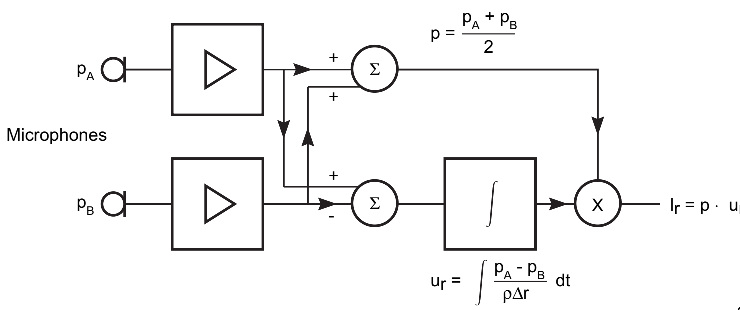
Full calibration of an intensity measuring instrument and its microphones includes:

- Sound pressure calibration of the individual microphone channels
- Sound intensity and particle velocity calibration
- Measurement of the pressure-residual intensity index spectrum of the system

Sound Pressure Calibration

Fig. 2 shows Pistonphone Type 4228 fitted to the coupler, with both microphones positioned in the upper chamber of the coupler. With this arrangement, the pistonphone produces the same sound pressure level at each microphone. The microphone channels are calibrated against this known sound pressure level.

Sound Intensity and Particle Velocity Calibrations



871673/3

Fig. 3
Simplified block diagram of an intensity measuring instrument. The signals from two pressure microphones, p_A and p_B, are used to determine the pressure at the midpoint on the probe axis, p, and the particle velocity along the probe axis, u_r. Multiplying p and u_r gives the intensity reading I_r. Δr is the microphone spacing and ρ the density of air

Fig. 3 is a simplified block diagram showing how sound intensity is measured. The particle velocity signal is obtained by integrating, with respect to time, the instantaneous difference in sound pressure between the two microphones. This signal is zero during a sound pressure calibration, so the correct functioning of the instrument is not confirmed.


960113/2

Fig. 4
Arrangement for sound intensity and particle velocity calibrations

Fig. 4 shows the pistonphone fitted to the coupler, and the microphones positioned in different chambers of the coupler. With this arrangement, the coupler causes a phase change between the sound pressures at the microphones, corresponding to a nominal spacing of 50 mm with no reflections. The phase change between the sound pressures simulates the sound intensity and particle velocity levels so that the pressure-difference signal for the integrator is not zero. Only now is the correct functioning of the instrument confirmed.

Pressure-Residual Intensity Index Measurement


100064

Fig. 5
Arrangement for measuring residual intensity and pressure-residual intensity index over a wide range of frequencies using Sound Intensity Calibrator Type 4297

Fig. 5 shows an arrangement for measuring pressure-residual intensity index over a wide range of frequencies using Sound Intensity Calibrator Type 4297. The intensity probe is fitted in the calibrator, which delivers broad-band pink noise, so the sound pressure spectrum measured in the coupler is constant (in octave bands) over a wide frequency range. Both microphones are exposed to the same sound pressure, so any intensity detected is residual intensity.

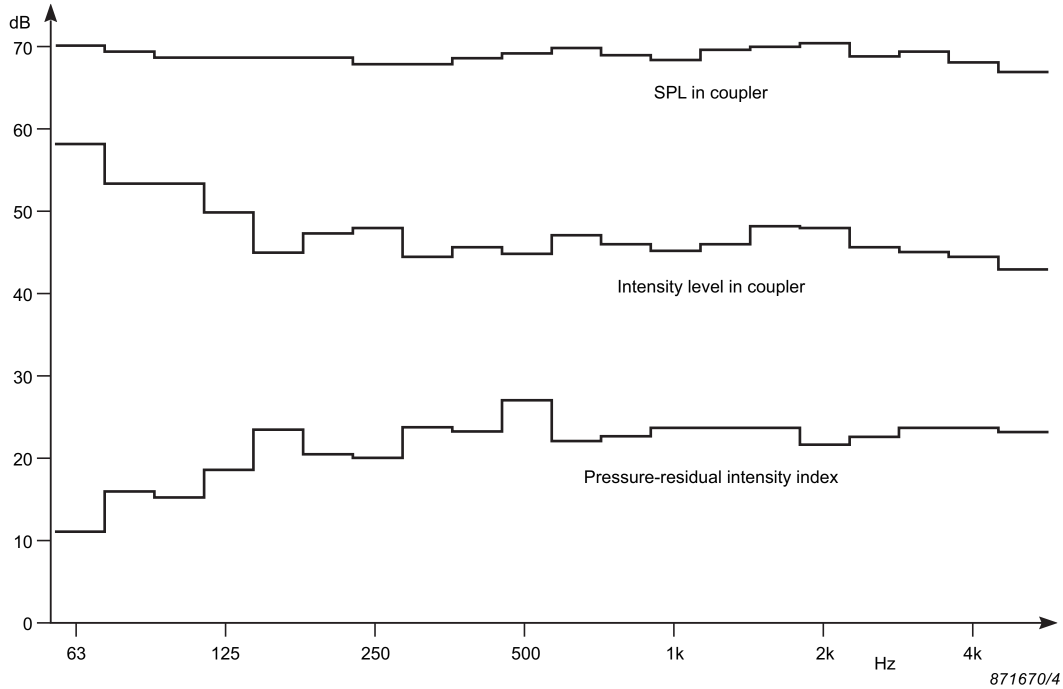
The residual energy explains how small differences in the phase responses of the microphones and input channels result in the detection of "residual intensity". Residual intensity is a parameter that should be taken into account when interpreting measured intensity data. It is worth noting that the residual intensity spectrum is not a fixed one; it is tied to (rises and falls with) the measured sound pressure level.

It can be shown that, for a given measurement system and frequency, the difference between measured sound pressure level and detected residual intensity level will be a constant. This constant difference is called the pressure-residual intensity index.

The pressure-residual intensity index spectrum can be measured with the arrangement shown in Fig. 5 by subtracting the detected intensity spectrum from the sound pressure spectrum. An example of this is shown in Fig. 6.

Type 3541-A, by means of the Pistonphone Type 4228 and Coupler UA-0914, can be used to measure the pressure-residual intensity index in the 250 Hz 1/3-octave band. For measurements of pressure-residual intensity index over a wide frequency range, it is recommended to use Sound Intensity Calibrator Type 4297.

Fig. 6
Intensity and sound pressure levels measured with the arrangement shown in Fig. 5. The pressure-residual intensity index spectrum is characteristic of the measurement system and is obtained by subtracting these two spectra



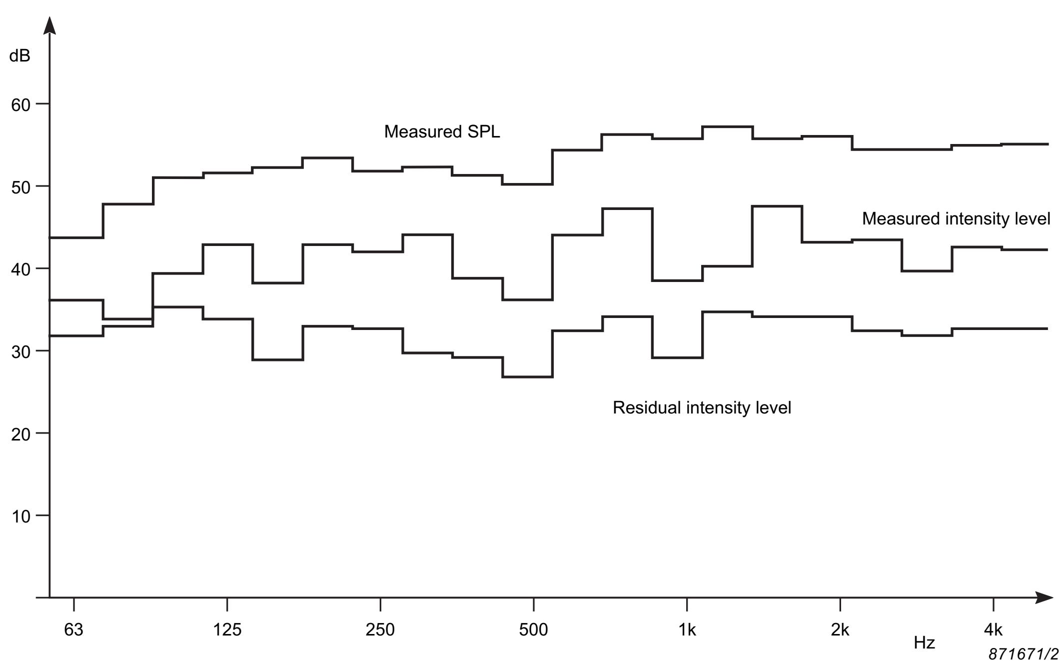
Residual Intensity Level

If a pressure-residual intensity index spectrum is to be used to assess the accuracy of sound intensity measurements, the mean sound pressure spectrum in the field must also be measured. The residual intensity level is then quickly established by subtracting the pressure-residual intensity index spectrum from the measured mean sound pressure spectrum. An example of this is shown in Fig. 7.

The residual intensity level is then compared to the measured sound intensity level. It can be shown that, for a certain frequency, the residual intensity level must be at least 7 dB lower to ensure a measurement error of less than 1 dB.

The residual intensity level shown in Fig. 7 is dependent on the sound pressure level measured in the field and should not be confused with the intensity level, which is measured with the arrangement shown in Fig. 5.

Fig. 7
Sound intensity and mean sound pressure spectra measured in the field with an instrument calibrated using Type 4297. The residual intensity spectrum is obtained by subtracting the pressure-residual intensity index spectrum in Fig. 6 from the measured SPL spectrum



Microphones and Vent Sensitivity

Coupler UA-0914 has been designed to work with Microphone Pair Types 4181 and 4197, which have an extremely low sensitivity to sound pressure at their pressure-equalization vents. When microphones are inserted into the coupler, their diaphragms are exposed to the sound pressure in the coupler but their pressure-equalization vents are not. Coupler UA-0914 cannot be used to measure the pressure-residual intensity index with conventional microphone pairs as they have vent sensitivities several orders of magnitude higher than that of Type 4181 and 4197. The coupler can, however, be used with conventional microphone pairs for calibration of sound pressure, sound intensity, and particle velocity.

Residual Intensity

Fig. 8
A sound wave is incident on a probe axis at 90°. There is no flow of acoustic energy along the probe axis. The signals from the microphones are in phase and no intensity is detected

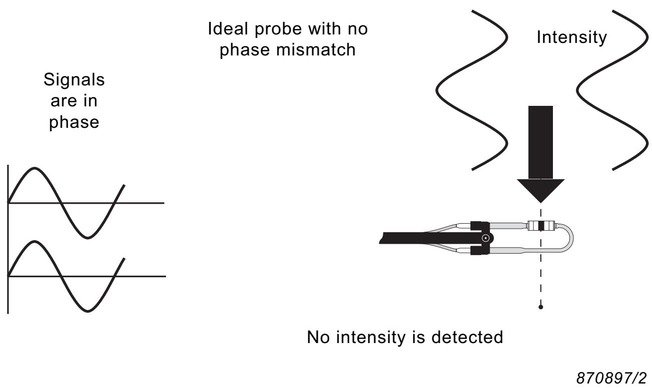


Fig. 9
If a sound wave is incident at an angle other than 90°, then acoustic energy flows along the probe axis. The microphone signals are out of phase and intensity is detected

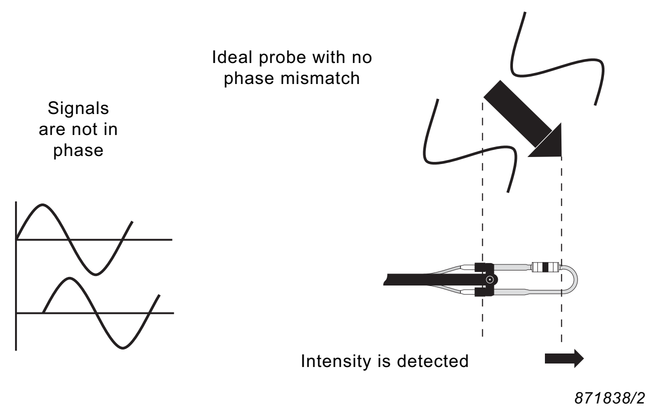


Fig. 10
In practice, if a sound wave is incident at 90°, small differences between the phase responses of the microphones cause a small phase difference between the microphone signals. There now appears to be a flow of acoustic energy along the probe axis

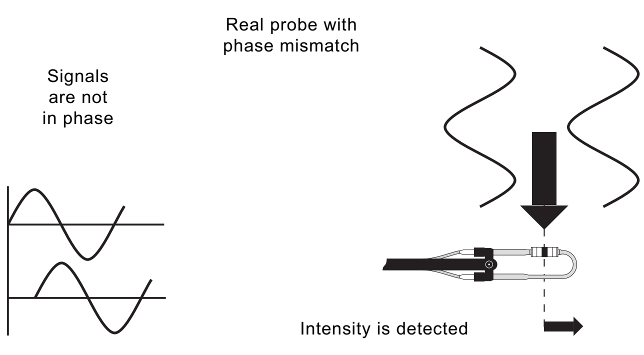
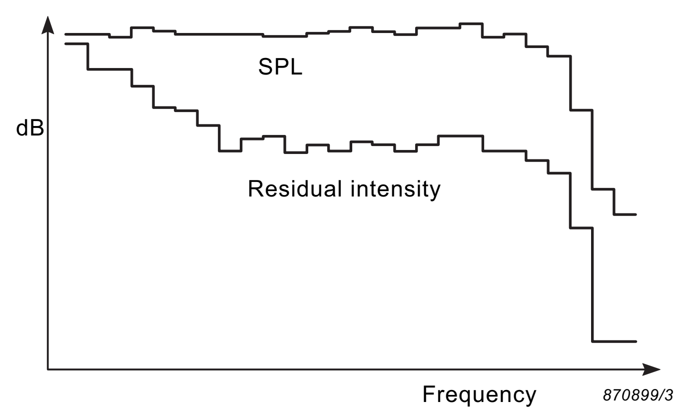


Fig. 11
It is this apparent flow of acoustic energy that is detected and called "residual intensity"



Even under controlled laboratory conditions, it is very difficult to create a free-field situation where the angle between the propagation of the sound wave and the probe axis is exactly 90 degrees (as shown in Fig. 8 and Fig. 10). However, for practical applications this situation can easily be simulated using the setup shown in Fig. 5.

Compliance with Standards

CE, C-Tick	CE-mark indicates compliance with: EMC Directive and Low Voltage Directive. C-Tick mark indicates compliance with the EMC requirements of Australia and New Zealand.
Safety	EN/IEC 61010–1: Safety requirements for electrical equipment for measurement, control and laboratory use. ANSI/UL 61010–1: Safety requirements for electrical equipment for measurement, control and laboratory use.
EMC Emission	EN/IEC 61000–6–3: Generic emission standard for residential, commercial and light industrial environments. EN/IEC 61000–6–4: Generic emission standard for industrial environments. CISPR 22: Radio disturbance characteristics of information technology equipment. Class B Limits. FCC Rules, Part 15: Complies with the limits for a Class B digital device. This ISM device complies with Canadian ICES–001 (interference causing equipment standard)
EMC Immunity	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. **Note:** The above is only guaranteed using accessories listed in this Product Data sheet.

Specifications – Sound Intensity Calibrator Type 3541-A

Intensity Coupler UA-0914

First Chamber: Ports 1 and 2
Second Chamber: Port 3
Chamber Volume: 10 cm^3 each
Equivalent Load for Each Port: 250 mm^3

Correction Barometer UZ-0004

Pressure Range: 650 hPa to 1080 hPa
Accuracy: Better than ±2.0% at 20°C

Signal Levels obtained in Intensity Coupler UA-0914

REFERENCE CONDITIONS:
Pressure: 1013 hPa
Temperature: 20°C
Relative Humidity: 65%

CALIBRATION USING TYPE 4228

PORTS 1 AND 2:
Sound Pressure Level: 118.0 ±0.4 dB re 20 μPa
Calibration Tolerance: ±0.2 dB
Ambient Pressure Coefficient: 8.4×10^{-3} dB/hPa
Temperature Coefficient: <±0.002 dB/°C
Humidity Coefficient: Negligible

PORTS 1 OR 2, AND 3:
Simulated Sound Intensity Level: 117.85 ±0.5 dB re 1 pW/m^2
Calibration Tolerance: ±0.25 dB
Nominal Microphone Spacing: 50 mm
Ambient Pressure Coefficient: 1.25×10^{-4} dB/hPa
Temperature Coefficient: 0.024 dB/°C
Humidity coefficient: Negligible

SIMULATED PARTICLE VELOCITY LEVEL:
117.7 ±0.6 dB re 50 nm/s
Calibration Tolerance: ±0.3 dB
Nominal Microphone Spacing: 50 mm
Temperature Coefficient: 0.05 dB/°C
Ambient pressure coefficient: -8.3×10^{-3} dB/hPa
Humidity Coefficient: Negligible

PRESSURE-RESIDUAL INTENSITY INDEX OF SOUND FIELD IN UA-0914 MEASURED WITH:
50 mm Nominal Microphone Spacing: >30 dB
12 mm Nominal Microphone Spacing: >24 dB

Dimension and Weight (Case)

Height: 280 mm (11″)
Width: 230 mm (9″)
Depth: 63 mm (2.5″)
Weight: 2.3 kg (5.1 lb)

Note: All values are typical at 20°C (77°F), unless measurement uncertainty or tolerance field is specified. All uncertainty values are specified at 2 σ (i.e., expanded uncertainty using a coverage factor of 2)

Ordering Information

Type 3541-A Sound Intensity Calibrator
Includes the following accessories:
- UA-0914: Intensity Coupler
- Type 4228: Pistonphone
- UZ-0004: Correction Barometer
- 2×UA-1314: Two 1/4″ Microphone Adaptors
- DB-3111: Intensity Coupler Base-Plate
- 6×QB-0013: 1.5 V Alkaline Battery IEC Type LR 6
- QB-0016: 9 V Alkaline Battery IEC Type 6 LF 22
- UC-5298: Dummy Microphone
- Microphone Adaptors for Pistonphone:
  – DP-0776: 1/2″ Adaptor
  – DP-0775: 1/4″ Adaptor
  – DP-0774: 1/8″ Adaptor
- Calibration Charts

OPTIONAL ACCESSORIES
Type 4297 Sound Intensity Calibrator

BP 2325 – 13 2012-01

HEADQUARTERS: Brüel & Kjær Sound & Vibration Measurement A/S · DK-2850 Nærum · Denmark
Telephone: +45 7741 2000 · Fax: +45 4580 1405 · www.bksv.com · info@bksv.com

Local representatives and service organisations worldwide

Brüel & Kjær