Product Data

Sound Intensity Calibrator — Type 3541

USES:

- ❍ Sound intensity and particle velocity calibrations
- ❍ Sound pressure calibration
- ❍ Measurement of pressure-residual intensity index

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
- ❍ Broad-band sound source for pressure-residual intensity index measurement

Type 3541 enables calibration of 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 can be used to measure the pressure-residual intensity index spectrum of instruments used for measuring sound intensity.

Fig. 1 Type 3541 components in their case. Main components: Intensity Coupler, Pistonphone, Sound Source. Other components: Correction Barometer, Dummy Microphone, 1/4″ Microphone Adaptors (two), Microphone Adaptors for Pistonphone (1/2″, 1/4″ and 1/8″), 10–32 UNF to BNC Adaptors (two). In lid: Calibration Charts, Electrical Output Cables

Sound Intensity Calibrator Type 3541 enables instruments which 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 ensure that these parameters can be measured correctly.

Type 3541 is intended for use with Brüel & Kjær Sound Intensity Probes Types 3583 or 3584 (or earlier Types 3545 or 3548) with a Sound Intensity Microphone Pair Type 4181. Other microphone pairs have much higher vent sensitivities and this restricts their use; see "Microphones and Vent Sensitivity".

A simplified cross-section of the intensity coupler is shown in Fig. 2. It 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 simulat-

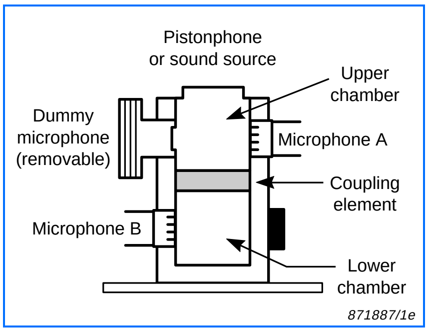


Fig. 2 Simplified cross-section of intensity coupler

ed. If one microphone is positioned in the upper chamber and the other in the lower chamber, then 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 calibration of sound pressure sensitivity. 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 broad-band sound source is supplied for measurement of the pressure-residual intensity index spectrum. This is used to assess the accuracy of sound intensity measurements.

A calibration chart is supplied which 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.

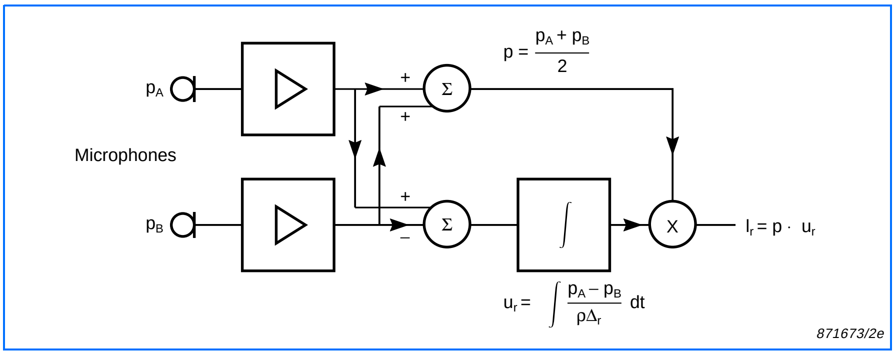


Fig. 3 Simplified block diagram of an intensity measuring instrument. The signals from two pressure microphones, p_A and p_B, are used to determine the pressure at the midpoint on the probe axis, p, and the particle velocity along the probe axis, u_r. Multiplying p and u_r gives the intensity reading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

Calibration Procedure

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. 4 shows Pistonphone Type 4228 fitted to the coupler, and 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

Fig. 3 is a 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.

Fig. 5 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.

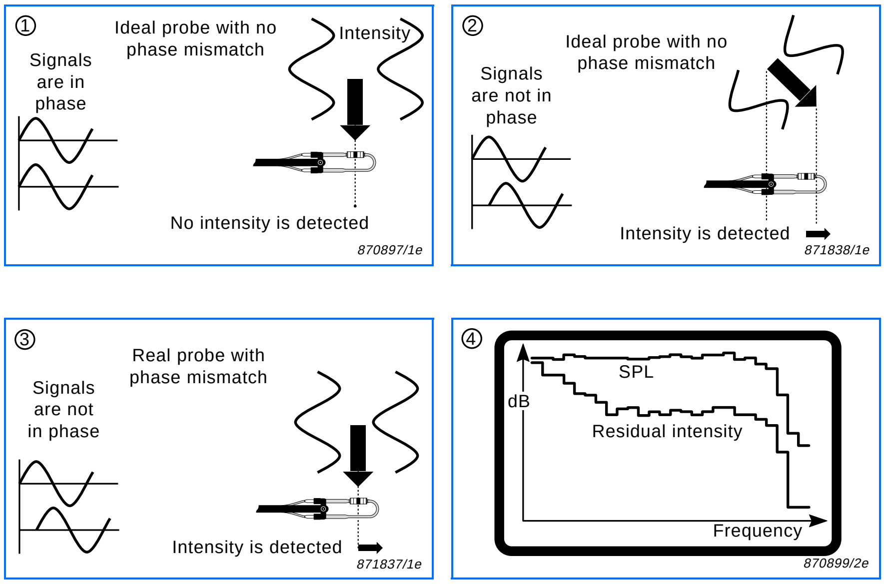
Fig. 4 Arrangement for sound pressure calibration

Fig. 5 Arrangement for sound intensity and particle velocity calibrations

Fig. 6 Arrangement for measuring residual intensity and pressure-residual intensity index

Residual Intensity

1. 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.
2. 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.
3. In practice, if a sound wave is incident at 90°, then 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.
4. 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 boxes 1 and 3). However, for practical applications this situation can easily be simulated using the set-up shown in Fig. 6.

Pressure-residual intensity index measurement

The box at the top of the page shows 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 noticing that the residual intensity spectrum is not a fixed one; it is “tied” to, and rises and falls with, the measured sound pressure level.

Fig. 6 shows an arrangement for measuring pressure-residual intensity index. The broad-band sound source is fitted to the coupler and the microphones are positioned in the upper chamber. The broad-band sound source produces 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.

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. 6 by subtracting the detected intensity spectrum from the sound pressure

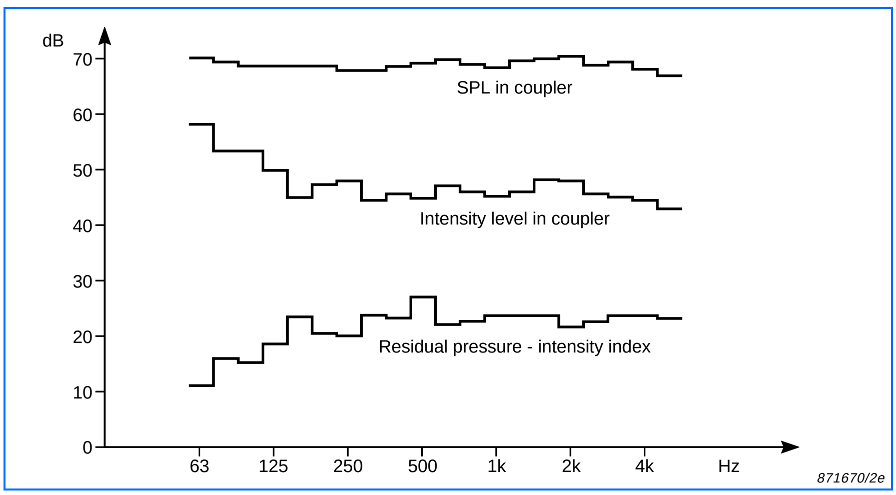


Fig. 7 Intensity and sound pressure levels measured with the arrangement shown in Fig. 6. The pressure-residual intensity index spectrum is characteristic of the measurement system and is obtained by subtracting these two spectra

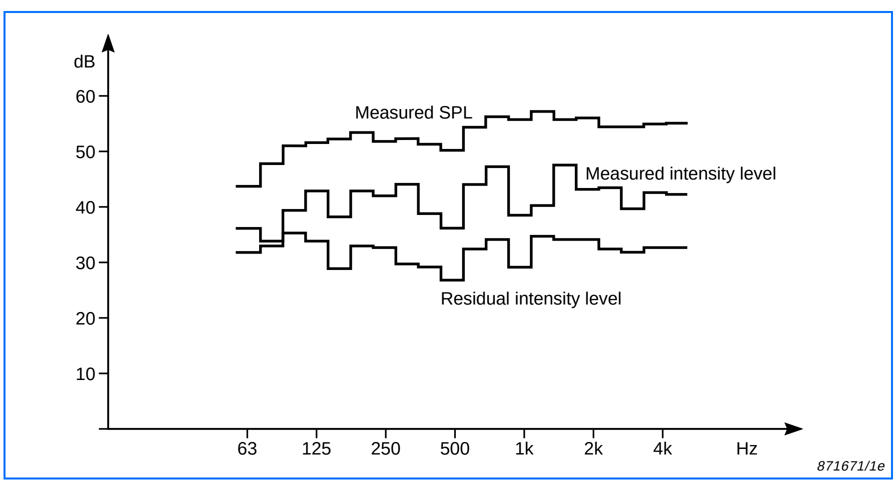


Fig. 8 Sound intensity and mean sound pressure spectra measured in the field with an instrument calibrated with Type 3541. The residual intensity spectrum is obtained by subtracting the pressure-residual intensity index spectrum in Fig. 7 from the measured SPL spectrum

spectrum. An example of this is shown in Fig. 7.

Residual Intensity Level

If a pressure-residual intensity index spectrum is to be used to assess the accuracy of sound intensity measurements, then 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. 8.

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. 8 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. 6.

Microphones and Vent Sensitivity

The coupler, UA 0914, has been designed to work with Microphone Pair Type 4181 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. It can, however, be used with conventional microphone pairs for calibration of sound pressure, sound intensity, and particle velocity.

Specifications Type 3541

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

Sound Source ZI 0055

ATTENUATION OF OUTPUT:
0 to –10 dB (variable)
BATTERY:
1 × 9 V Alkaline Battery, type 6 LF 22 (QB 0016)
Lifetime: 25 hours continuous
ELECTRICAL OUTPUT FROM INTERNAL GENERATOR:
Pink: 45 mV in each $^1/_3$-octave
White: 45 mV in 250 Hz $^1/_3$-octave
FREQUENCY RANGE: 10 Hz to 20 kHz
OUTPUT IMPEDANCE: 50 Ω

When the Sound Source, ZI 0055, is fitted to the Intensity Coupler, UA 0914, and driven from an external source the following specifications apply:
SENSITIVITY:
15.4 Pa/V (10 Hz to 1 kHz)
MAXIMUM INPUT VOLTAGE: 70 mV RMS
INPUT IMPEDANCE: >18 kΩ (f <5 kHz)

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^{-1}
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 MEASUREMENT USING ZI 0055 (Pink noise with 0 dB attenuation**.** All levels measured in $^1/_3$-octaves):
PORTS 1 AND 2 (SPL only):
250 Hz: 74 ±2.0 dB
20 Hz to 1 kHz: ±3.0 dB re level at 250 Hz
1.25 kHz to 5 kHz: ±6.0 dB re level at 250 Hz

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 2σ (i.e. expanded uncertainty using a coverage factor of 2)

COMPLIANCE WITH STANDARDS:

CE	CE-mark indicates compliance with: EMC Directive.
Safety	EN 61010–1 and IEC 1010–1: Safety requirements for electrical equipment for measurement, control and laboratory use.
EMC Emission	EN 50081–1: Generic emission standard. Part 1: Residential, commercial and light industry. EN 50081–2: Generic emission standard. Part 2: Industrial environment. 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.
EMC Immunity	EN 50082–1: Generic immunity standard. Part 1: Residential, commercial and light industry. EN 50082–2: Generic immunity standard. Part 2: Industrial environment.
Temperature	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) IEC 68–2–14: Change of Temperature: –10 to +50 °C (2 cycles, 1 °C/min.)
Humidity	IEC 68–2–3: Damp Heat: 90% RH (non-condensing at 40 °C (104 °F))

Ordering Information

Type 3541 Sound Intensity Calibrator
Includes the following accessories:
UA 0914: Intensity Coupler
Type 4228: Pistonphone
ZI 0055: Sound Source
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
2 × AO 0038: Cable with 10–32 UNF connectors
2 × JP 0145: 10–32 UNF to BNC Plug Adaptor
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

Brüel & Kjær

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