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.

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-
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.

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. 3 Simplified block diagram of an intensity measuring instrument. The signals from two pressure microphones, pA and pB, are used to determine the pressure at the midpoint on the probe axis, p, and the particle velocity along the probe axis, u. Multiplying p and u gives the intensity reading I.](image)

![Fig. 4 Arrangement for sound pressure calibration](image)

![Fig. 5 Arrangement for sound intensity and particle velocity calibrations](image)

![Fig. 6 Arrangement for measuring residual intensity and pressure-residual intensity index](image)
**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 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

<table>
<thead>
<tr>
<th>Component</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Intensity Coupler UA 0914</strong></td>
<td>FIRST CHAMBER: Ports 1 and 2&lt;br&gt;SECOND CHAMBER: Port 3&lt;br&gt;CHAMBER VOLUME: 10 cm³ each&lt;br&gt;EQUIVALENT LOAD FOR EACH PORT: 250 mm³</td>
</tr>
<tr>
<td><strong>Sound Source ZI 0055</strong></td>
<td>ATTENUATION OF OUTPUT: 0 to –10 dB (variable)&lt;br&gt;BATTERY: 1.5 V Alkaline Battery (type 6LF22 (Q8 0016))&lt;br&gt;Lifetime: 25 hours continuous&lt;br&gt;ELECTRICAL OUTPUT FROM INTERNAL GENERATOR: Pink: 45 mV in each 1/3-octave&lt;br&gt;White: 45 mV in 250 Hz 1/3-octave&lt;br&gt;FREQUENCY RANGE: 10 Hz to 20 kHz&lt;br&gt;OUTPUT IMPEDANCE: 50 Ω</td>
</tr>
<tr>
<td><strong>Correction Barometer UZ 0004</strong></td>
<td>PRESSURE RANGE: 650 hPa to 1080 hPa&lt;br&gt;ACCURACY: Better than ±2.0% at 20°C</td>
</tr>
<tr>
<td><strong>Signal Levels obtained in Intensity Coupler UA 0914</strong></td>
<td>REFERENCE CONDITIONS: Pressure: 1013 hPa&lt;br&gt;Temperature: 20°C&lt;br&gt;Relative Humidity: 65%&lt;br&gt;CALIBRATION USING TYPE 4228&lt;br&gt;PORTS 1 AND 2: Sound Pressure Level: 118.0 ±0.4 dB re 20 µPa&lt;br&gt;Calibration Tolerance: ±0.2 dB&lt;br&gt;Ambient Pressure Coefficient: 8.4 x 10⁻³ dB/hPa&lt;br&gt;Temperature Coefficient: &lt;±0.002 dB/°C&lt;br&gt;Humidity Coefficient: Negligible&lt;br&gt;PORTS 1 or 2, AND 3: Simulated Sound Intensity Level: 117.85 ±0.5 dB re 1 pW m⁻²</td>
</tr>
<tr>
<td><strong>Calibration Tolerance</strong></td>
<td>±0.25 dB&lt;br&gt;Nominal Microphone Spacing: 50 mm&lt;br&gt;Ambient Pressure Coefficient: 1.25 x 10⁻⁴ dB/hPa&lt;br&gt;Temperature Coefficient: 0.024 dB/°C&lt;br&gt;Humidity Coefficient: Negligible</td>
</tr>
<tr>
<td><strong>Simulated Particle Velocity Level</strong></td>
<td>Ambient pressure coefficient: ±0.5 dB re 1 pW m⁻²&lt;br&gt;Nominal Microphone Spacing: 50 mm&lt;br&gt;Calibration Tolerance: ±0.3 dB&lt;br&gt;Ambient pressure coefficient: –8.3 x 10⁻³ dB/hPa&lt;br&gt;Humidity Coefficient: negligible</td>
</tr>
<tr>
<td><strong>Pressure-Residual Intensity Index of Sound Field in UA 0914 Measured With</strong></td>
<td>Ambient Pressure Coefficient: 0.05 dB/°C&lt;br&gt;Temperature Coefficient: 0.024 dB/°C&lt;br&gt;Humidity Coefficient: Negligible&lt;br&gt;PORTS 1 AND 2 (SPL only): 250 Hz: ±2.0 dB&lt;br&gt;20 Hz to 1 kHz: ±3.0 dB re level at 250 Hz&lt;br&gt;1.25 kHz to 5 kHz: ±6.0 dB re level at 250 Hz</td>
</tr>
</tbody>
</table>

### Compliance with Standards:

<table>
<thead>
<tr>
<th>Standard</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Safety</strong></td>
<td>EN 61010–1 and IEC 1010–1: Safety requirements for electrical equipment for measurement, control and laboratory use.</td>
</tr>
<tr>
<td><strong>Humidity</strong></td>
<td>IEC 68–2–3: Damp Heat: 90% RH (non-condensing at 40°C (104°F))</td>
</tr>
</tbody>
</table>

### Ordering Information

<table>
<thead>
<tr>
<th>Type 3541</th>
<th>Sound Intensity Calibrator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Includes the following accessories:</td>
<td></td>
</tr>
<tr>
<td><strong>UA 0914</strong></td>
<td>Intensity Coupler&lt;br&gt;Type 4228: Pistonphone&lt;br&gt;ZI 0055: Sound Source&lt;br&gt;UZ 0004: Correction Barometer&lt;br&gt;2 x UA 1314: Two 1/2&quot; Microphone Adaptors&lt;br&gt;DB 3111: Intensity Coupler Base-Plate</td>
</tr>
<tr>
<td><strong>6 x Q8 0013</strong>:</td>
<td>1.5 V Alkaline Battery IEC Type&lt;br&gt;LX 6&lt;br&gt;<strong>Q8 0016</strong>: 9 V Alkaline Battery IEC Type&lt;br&gt;<strong>2 x AO 0038</strong>: Cable with 10–32 UNF&lt;br&gt;<strong>2 x JP 0145</strong>: 10–32 UNF to BNC Plug Adapter&lt;br&gt;<strong>UC 5288</strong>: Dummy Microphone</td>
</tr>
<tr>
<td><strong>Microphone Adaptors for Pistonphone:</strong></td>
<td>DP 0776: 1/2&quot; Adaptor&lt;br&gt;DP 0775: 1/4&quot; Adaptor&lt;br&gt;DP 0774: 1/8&quot; Adaptor&lt;br&gt;Calibration Charts</td>
</tr>
</tbody>
</table>

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