USER MANUAL

Sound Intensity Calibrator
Type 4297

BE 1653 – 14
English

Brüel & Kjær

Sound Intensity Calibrator Type 4297

User Manual

BE 1653 – 14
April 2017

Health and Safety Considerations

This apparatus has been designed and tested in accordance with IEC/EN 61010 – 1 and ANSI/UL 61010 – 1 *Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use*. This manual contains information and warnings which must be followed to ensure safe operation and to retain the apparatus in safe condition.

Safety Symbols and Signal Words Used

The apparatus will be marked with this symbol when it is important that you refer to the associated danger or warning statement given in this manual

The manual uses this symbol when a danger or warning statement is applicable

Hazardous Voltage/Electricity. Both the apparatus and manual use this symbol when there is a risk for shock or electrocution

Hot Surface. This manual will use this symbol when there is a risk for burning or scolding

Earth (Ground) Terminal. The apparatus will be marked with this symbol when applicable

Protective Conductor Terminal. The apparatus will be marked with this symbol when applicable

Alternating Current. The apparatus will be marked with this symbol when applicable

Danger Signals an imminent hazardous situation, which, if not avoided, will result in death or serious injury

Warning Signals a possibly hazardous situation, which, if not avoided, will result in death or serious injury

Caution Signals a hazardous situation, which, if not avoided, could result in minor or moderate injury or damage to the apparatus

Notice Signals a situation or practice that requires attention, but does not directly result in personal injury if ignored

Risks and Hazards

Explosion Hazards

Danger: The apparatus is not designed to be used in potentially explosive environments. It should not be operated in the presence of flammable liquids or gases

Electrical Hazards

Warning: Any adjustment, maintenance and repair of the open apparatus under voltage must be avoided as far as possible and, if unavoidable, must be carried out only by trained service

Caution: Switch off all power to equipment before connecting or disconnecting their digital interface. Failure to do so could damage the equipment

Mechanical Hazards

Caution: Whenever it is likely that the correct function or operating safety of the apparatus has been impaired, it must be made inoperative and be secured against unintended operation

Waste Handling

Brüel & Kjær complies with the EU's Waste Electrical and Electronic Equipment (WEEE) Directive, which issues the following waste handling instructions:

- Do not dispose of electronic equipment or batteries as unsorted municipal waste
- It is your responsibility to contribute to a clean and healthy environment by using the appropriate local return and collection systems
- Hazardous substances in electronic equipment or batteries may have detrimental effects on the environment and human health
- The symbol shown to the left indicates that separate collection systems must be used for any discarded equipment or batteries marked with that symbol
- Waste electrical and electronic equipment or batteries may be returned to your local Brüel & Kjær representative or to Brüel & Kjær Headquarters for disposal

Brüel & Kjær Sound & Vibration Measurement A/S
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For service and support, contact your nearest Brüel & Kjær Customer Care support team:

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Chapter 1

Introduction and Description

1.1 Introduction

Sound Intensity Calibrator Type 4297 is used for on-site sound pressure calibration and pressure-residual intensity index verification.

The most important and unique feature is that there is no need to dismantle the sound intensity probe. The calibrator is optimized for use with Type 2270-S and Type 2260 E Investigator™ sound intensity systems for phase enhancement, but it can also be used with sound intensity analysis systems such as PULSE™.

Type 4297 is a complete sound intensity calibrator in one compact, portable unit with a built-in sound source. A barometer is not required as the acoustic feedback system automatically adjusts for variations in atmospheric pressure. Type 4297 fulfils the requirements:

- IEC 61043 –1993; Electroacoustics – Instruments for the measurement of sound intensity – Measurements with pairs of pressure sensing microphones
- ANSI S1.9 – 1996; Instruments for the Measurement of Sound Intensity

Table 1.1 *Comparison of various capabilities in sound intensity calibrators*

Type Number	Pressure Level	Intensity Level	Velocity Level	P-R Int. Index	Dismantling Necessary	Sound Source Included	Supports ¼″ Microphones
4231 + DP-0888	Yes	No	No	No	Yes	Yes	No
3541-A	Yes	Yes	Yes	Yes	Yes	Yes	Yes
4297	Yes	No	No	Yes	No	Yes	No

1.2 Description

1.2.1 General

Sound Intensity Calibrator Type 4297 enables instruments that measure sound intensity to be accurately calibrated.

Type 4297 is intended for use with Brüel & Kjær Sound Intensity Probes Type 3599 or 3654 (or earlier Types 3545, 3548, 3583, 3584 or 3595) with a Sound Intensity Microphone Pair Type 4197 (or earlier Type 4181). The microphones must be used with ¼″ preamplifiers, and a 12 mm spacer. Note that Type 4297 can be used up to 6.3 kHz without a spacer to check the pressure-residual intensity index.

The Sound Intensity Calibrator can be used for calibration of sound pressure sensitivity. To do this, the microphones are both positioned in the calibration chamber. There is no need to dismantle the probe and both microphones are exposed to exactly the same sound pressure (amplitude and phase).

The broad-band pink noise sound source is provided 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 that states the levels that should be detected during calibration.

Please note: The wrist strap has a protection plug attached. This is designed to be placed inside the calibrator to prevent dust and dirt entering the acoustic chamber when the instrument is not in use. The rubber gasket can be cleaned with a clean dry cloth. To remove specks of grease or other sticky substances, use a a cloth slightly dampened with pure alcohol.

Fig. 1.1 *Sound Intensity Calibrator Type 4297*

What the Calibration Procedure Includes

Calibration of an intensity-measuring instrument includes:

- sound pressure calibration of the individual microphone channels
- measurement of the pressure-residual intensity index spectrum of the sound intensity measurement system

Pressure-Residual Intensity Index Measurement

Fig. 1.2 shows an arrangement for measuring the pressure-residual intensity index. The probe is placed in the Type 4297. The sound source produces the same sound pressure level at each microphone, so both microphones are exposed to the same sound pressure and same phase, and therefore any intensity detected is residual intensity. The microphone channels are calibrated against this known sound pressure level (nominal value 94 dB).

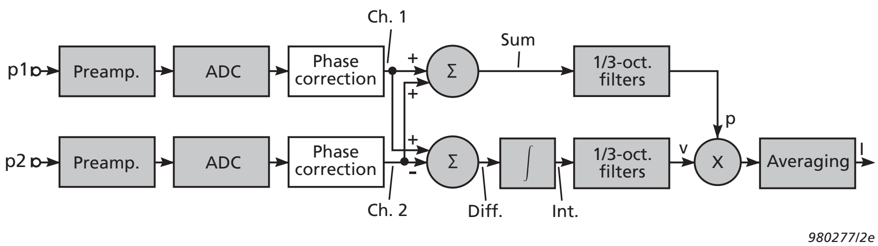
Fig. 1.4 shows how small differences in the phase responses of the microphones and input channels result in the detection of 'residual intensity'. Residual intensity is a parameter that should be taken into account when interpreting measured intensity data. The pressure residual intensity spectrum is not fixed; it is 'tied to', and 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. 1.2 by subtracting the detected intensity spectrum from the sound pressure spectrum. An example is shown in Fig. 1.4.

Fig. 1.2 *Type 4297 Sound Intensity Calibrator with a sound intensity probe in place. This configuration is used for both sound pressure calibration and pressure-residual intensity index measurement*

Fig. 1.3 *Simplified block diagram of an intensity measuring instrument. The signals from two pressure microphones, p1 and p2, are used to determine the pressure midpoint of the probe axis, p, and the particle velocity along the probe axis, v Multiplying p and v gives the intensity reading I*



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.

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 when measuring intensity level. Refer to IEC 61043 for details.

Microphones and Vent Sensitivity

Type 4297 has been designed to work with Microphone Pair Types 4197 and 4181, which have an extremely low sensitivity to sound pressure at the equalisation vents due to their patented acoustical filters. When microphones are inserted into the calibrator, their diaphragms are exposed to the sound pressure in the calibrator, but their pressure-equalization vents are not. Type 4297 cannot be used to measure the pressure-residual intensity index with pairs of conventional microphones as they have vent sensitivities several orders of magnitude higher than that of Types 4197 and 4181.

Fig. 1.4 *Typical intensity and sound pressure levels measured* ***with*** *12 mm spacer using the arrangement shown in Fig. 1.2. The pressure-residual intensity index spectrum is characteristic of the sound intensity measurement system and is obtained by subtracting the intensity spectrum from the pressure spectrum*

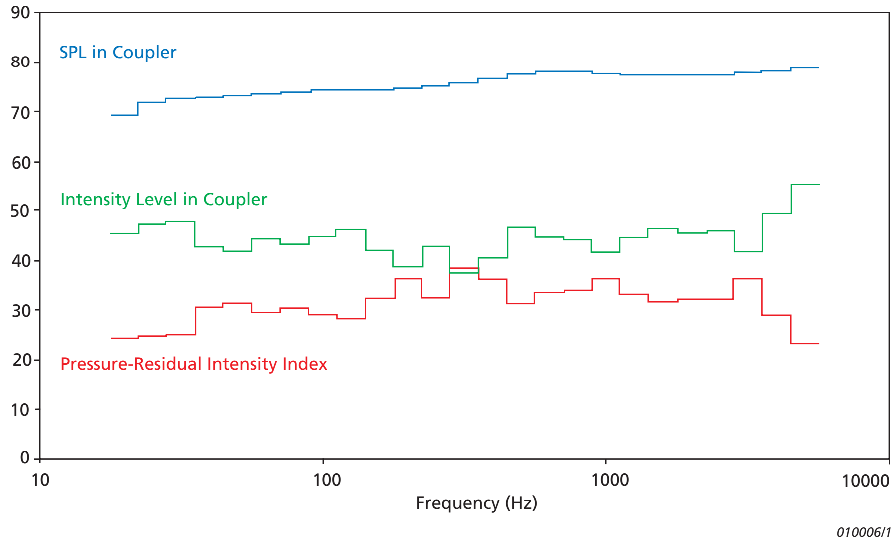
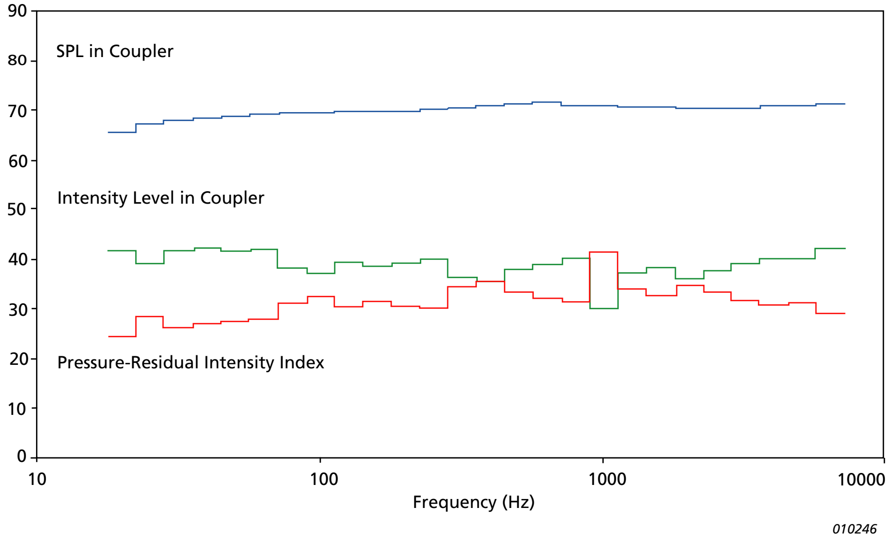


Fig. 1.5 *Typical intensity and sound pressure levels measured **without** spacer*



1.2.2 Calibration Chart

A calibration chart is supplied with each instrument in the lid of the protective case. This confirms that the specification of the calibrator is within the stated limits. The following information is provided:

- Product serial number
- Sound pressure level
- Frequency
- Reference conditions
- Pink noise sound pressure level

The date of issue of the calibration chart and the signature of the test engineer who performed the tests are shown. An example of a calibration chart is shown in Fig. 1.6.

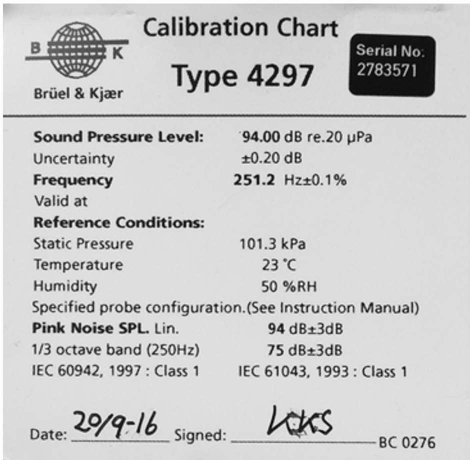


Fig. 1.6
Type 4297 Calibration Chart

1.2.3 Use of Power Supply

An external DC power supply can be used. It is not necessary to remove the internal batteries.

The power supply is connected using the 5.5 mm diameter socket at the rear of the unit marked 12 V as shown in Fig. 1.7. A smoothed and regulated supply of 10 – 14 V with 100 mV maximum ripple is required. Ensure that the correct polarity is used – positive to the 2 mm centre pin.

The following Brüel & Kjær power supplies are recommended:

- ZG 0386 EU Power Supply
- ZG 0387 UK Power Supply
- ZG 0388 US Power Supply

Fig. 1.7
Rear view of Type 4297. The external power supply input socket marked 12 V is shown on the left. The external generator signal is applied to the LEMO socket shown on the right

Battery Replacement

Two type LR6 1.5 V alkaline batteries (part number QB-0013) are used to power the unit. The batteries must be replaced if neither of the two small red LED indictors fail to light when the start button is pressed. If the instrument is activated, there is an automatic ‘power-off’ function if the battery level falls below that needed for correct operation of the calibrator.

To replace the batteries, open the unit (see Chapter 2) and pull up the black plastic button. Lift the hinged flap to expose the battery compartment. Make sure that the new batteries are inserted with the correct polarity. Close the flap and press the black button to fasten the hinged flap in place. See Fig. 1.8.

Fig. 1.8
Type 4297 with the battery compartment access cover in the open position

Chapter 2

Calibration Procedure with Hand-held Analyzer Type 2270-S Sound Intensity System

2.1 Sound Pressure Calibration

2.1.1 General

To open the unit, lift the black handle into the vertical position and turn it anticlockwise through 90°, as shown in Fig.2.1.

Fig.2.1
To open the unit, lift the handle and turn it 90° anticlockwise

Place the calibrator on a clean, flat surface. Lift the upper half to a near vertical position and remove the protection plug, shown in Fig.2.2.

Please note: The black plastic protection plug is designed to be fitted inside the calibrator to prevent dust and dirt entering the acoustic chamber when the instrument is not in use.

Fig. 2.2
With the unit open, you can now remove the protection plug

Fig. 2.3
Insert the Sound Intensity Probe into the holder

As shown in Fig. 2.3, place the Type 3545, 3548, 3583, 3584, 3595, 3599 or 3654 sound intensity probe into the holder. This comprises the intensity probe sound source, which is surrounded by a two-part black rubber gasket. This gasket 'contains' the calibration signal within a controlled and defined area.

With the sound intensity probe correctly positioned, close the unit completely by reversing the procedure described above, as shown in Fig.2.4. The unit should close without any excessive pressure being required. This indicates that the sound intensity probe is correctly fitted in the compartment.

Fig.2.4
Type 4297 with a sound intensity probe in position

2.1.2 Calibration

You are now ready to start the sound pressure calibration of your Type 2270-S installed with Sound Intensity Software BZ-7233.

Please note: Do not disturb your work surface/equipment during calibration as this will falsely affect readings.

1) With the sound intensity probe connected to your Type 2270-S, switch on the Hand-held Analyzer and select *Sound Intensity*.

2) Ensure that the analyzer is properly set up for calibration with the calibrator to be used.
   a) Tap ☰ and select **Setup**.
   b) Expand *Input* by tapping it and ensure that the *Input* line reads *Top Socket* and that the *Spacer* line reads *12 mm*.
   c) Tap ☰ and select **Transducers**.

   If the transducers are not in the system, instructions on entering a new microphone pair can be found in the documentation that came with your Type 2270-S.

3) Tap ☰ and select **Calibration** from the list of options. The Calibration screen will appear (Fig.2.5).

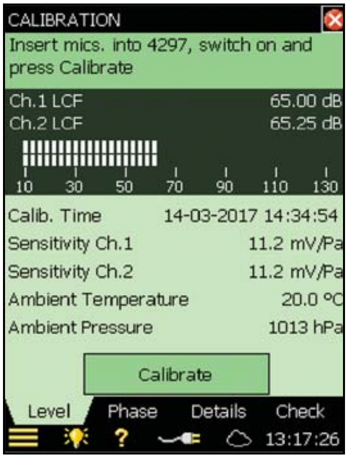


Fig. 2.5
Calibration screen

4) On the *Details* tab:
   a) Tap **Calibrator**, select *4297*.
   b) Tap **Calibration level** and enter *94 dB*.
5) On the *Level* tab:
   a) Tap **Ambient Temperature** and enter the current temperature.
   b) Tap **Ambient Pressure** and enter the current barometric pressure.
6) Press the **Start** button on the Type 4297 control panel (see Fig. 2.6). The sine wave (251.2 Hz) LED indicator should light. If it does not, the batteries need to be replaced, as described in Chapter 1.

Fig. 2.6
Type 4297 control panel showing the start, sine wave/ broadband noise selector buttons and LED indicators

Please note: If a sound intensity probe is not placed in the chamber, the unit will shut down after approximately 10 seconds.

7) Allow at least 5 seconds for the pressure to equalize and for stabilization of the feedback circuit.

8) Tap **Calibrate** and wait for it to finish.

2.2 Phase Calibration and Pressure-Residual Intensity Index Verification

Phase calibration and pressure-residual intensity index verification are part of the complete calibration process and should follow after sound pressure level calibration; however, they can also be performed individually. If calibrating and verifying phase by itself, perform steps 1) through 5) and then continue from step 9).

Please note: Minimize vibrations at your work surface/equipment during calibration as vibrations will falsely affect readings.

9) On the Type 4297 control panel (see Fig. 2.6), press the sine wave/broadband noise button again (so the broadband noise LED indicator lights) then press the **Start** button.

10) On Type 2270-S, tap on the *Phase* tab at the bottom of the screen and the Phase Calibration screen will appear (Fig. 2.7).

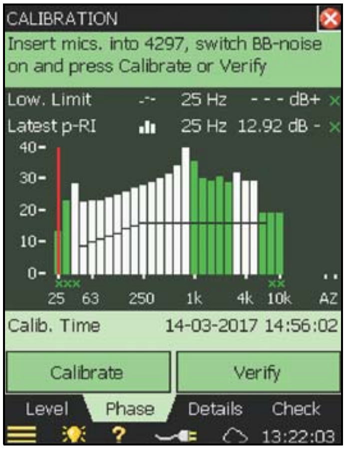


Fig. 2.7
Phase Calibration screen

11) Tap **Calibrate** and wait for it to finish.

Please note: Tapping **Calibrate** includes the verification process, but verification can be performed individually. To do so, tap **Verify** and let the verification continue for 2 minutes and press **Stop Verify**

12) Tap **Yes** to accept the new calibration (and verification). There should be no yellow smileys.

13) Turn off the calibrator, remove the probe, insert the protection plug and close the calibrator.

Please note: The frequency range for the calibrators does not include the 8 and 10 kHz bands. Results shown from these bands are extrapolated from the 6.3 kHz band.

Chapter 3

Calibration Procedure with Type 2260-E Investigator™

3.1 Sound Pressure Calibration

3.1.1 General

To open the unit, lift the black handle into the vertical position and turn it anticlockwise through 90°, as shown in Fig.3.1.

Fig.3.1
To open the unit, lift the handle and turn it 90° anticlockwise

Place the calibrator on a clean, flat surface. Lift the upper half to a near vertical position and remove the protection plug, shown in Fig.3.2.

Please note: The black plastic protection plug is designed to be fitted in the calibrator to prevent dust and dirt entering the acoustic chamber when the instrument is not in use.

Fig. 3.2
With the unit open, you can now remove the protection plug

Fig. 3.3
Insert the Sound Intensity Probe into the holder

As shown in Fig. 3.3, place the Type 3545, 3548, 3583, 3584, 3595, 3599 or 3654 sound intensity probe into the holder. This comprises the intensity probe sound source which is surrounded by a two-part black rubber gasket. This gasket ‘contains’ the calibration signal within a controlled and defined area.

With the sound intensity probe correctly positioned, close the unit completely by reversing the procedure described above, as shown in Fig. 3.4. The unit should close without any excessive pressure being required. This indicates that the sound intensity probe is correctly fitted in the compartment.

Fig. 3.4
Type 4297 with a sound intensity probe in position

3.1.2 Calibration

You are now ready to start the sound pressure calibration using your Type 2260-E installed with Sound Intensity Software BZ-7205.

Please note: Do not disturb your work surface/equipment during calibration as this will falsely affect readings.

1) With the sound intensity probe connected to your Type 2260-E Investigator™, switch on Type 2260. Press the **Start** button on the Type 4297 control panel (see Fig. 3.5). The sine wave (251.2 Hz) LED indicator should light. If it does not, the batteries need to be replaced, as described in Chapter 1.

Please note: If a sound intensity probe is not placed in the chamber, the unit will shut down after approximately 10 seconds.

2) Allow at least 5 seconds for the pressure to equalize and for stabilization of the feedback circuit.

3) Press the **Calibrate** button on Type 2260-E.

4) Select **Calib. Menu** followed by **External.** Using the arrow keys, select the calibrator *Type 3541* or *Unknown*, then set the *Calib. Level* manually to **94.00 dB** using the arrow keys and soft keys. Set *Correction* to **0.000**.

5) At this point, you can also change *Temperature* and *Amb. Pressure* to your chosen values.

6) Select **Calibrate** on the screen menu. The display will advise that the calibration process is in progress. When calibration has been completed following a steady-state signal, select **Save**. If you wish to repeat the external calibration, choose **Undo** to repeat the process. Typical results for channels 1 and 2 are **–38 dB** (the open circuit sensitivity as read from the calibration chart).

7) Turn off the calibrator, remove the probe, insert the protection plug and close the calibrator.

Fig. 3.5
Type 4297 control panel showing the start, sine wave/ broadband noise selector buttons and LED indicators

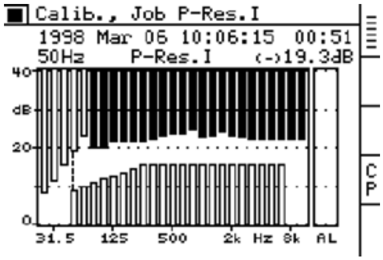
3.2 Phase Calibration and Pressure-Residual Intensity Index Verification

3.2.1 Verification up to 3 kHz

The following steps describe the procedure used for phase calibration and verification of pressure-residual intensity index with Type 2260-E using a broadband pink noise source at frequencies up to 3 kHz. Please also refer to section 2.3.1 in the technical documentation for Sound Intensity Software BZ-7205 (BB-1131).

1) With the sound intensity probe correctly placed in Sound Intensity Calibrator Type 4297, press **Start** on the Type 4297 control panel (if necessary). The sine wave LED indicator will light.
2) Press the noise type toggle on the control panel to select the pink noise source. The sine wave LED indicator should now go out while the LED indictor for broadband pink noise should now light. If it does not, then the batteries should be replaced as described in Chapter 1.
3) Allow at least 5 seconds for the pressure to equalize.
4) Press the **Calibrate** button on Type 2260 (**not** the soft key on the display).
5) Select the **Calib. Menu** soft key and then choose **p-Residual Intens. Idx**.
   The screen should now look like Fig. 3.6.

Fig. 3.6
p-Residual Intens. Idx screen



6) Select **Phase Calib. & Verify** to calibrate the phase difference between the channels to a minimum or select **Verify** followed by **OK**.

7) The phase calibration and/or the verification will now be performed. Note that the *Elapsed Time*, shown in the display, must exceed 30 seconds. (In the first 30 seconds, Type 2260-E compensates electrically for its own phase mismatch. Thereafter, the phase mismatch of the whole system, Type 2260 and probe, is measured. When satisfied that a stable situation has been reached (after about 1 – 2 minutes), press **Stop Verify** soft key.)

8) Once the **Stop Verify** soft key is pressed, press **Save**. If you wish to repeat the verification, choose **Undo** to repeat the process.

3.2.2 Verification above 3 kHz

If you wish to perform a pressure-residual intensity index verification using the broadband pink noise source at frequencies above 3 kHz, then the same procedure as described above is used. See 3.2.1"Verification up to 3 kHz" on page 18.

Please note: The maximum frequency at which verification can be made without the spacer is 6.3 kHz.

However, it is necessary to remove the spacer that separates the two microphones of the sound intensity probe while ensuring that the correct spacing is maintained to enable correct fitting in the chamber and sealing of the gasket.

1) Loosen the knurled black collar on one side of the microphone/spacer assembly, to allow the sound intensity probe to slide backwards and forwards.

2) Pull the spacer and one microphone away for the other microphone. While holding the microphone attached to the spacer with one hand, unscrew the spacer from the microphone. Be careful that you do not loosen or unscrew the microphone protection grid.

3) Use the spacer (Fig. 3.7) to maintain the correct distance between the two microphones and tighten the knurled black collar to hold the slider in place.

4) Insert the sound intensity probe, without the microphone spacer, into Type 4297 and perform the verification exactly as described in "Verification up to 3 kHz" on page 18.

5) After the verification, replace the spacer between the two microphones.

Fig.3.7
Use the spacer to maintain the correct distance between the two microphones

Fig.3.8
Sound intensity probe showing the spacer used to maintain the correct distance between the two microphones

Chapter 4

Use of the Calibrator with Other Instruments

4.1 PULSE LabShop

4.1.1 Sound Pressure Calibration and Pressure-Residual Intensity Index Verification

PULSE LabShop does not include Type 4297 in its choice of calibrators.

Before you can calibrate a sound intensity probe, a number of conditions must be met:

- In the Configuration Organiser, there must be a signal for each of the two channels you are using for the sound intensity probe. These signals must be members of the same signal group.
- A transducer must be added to or selected from the Transducer Database for both channels for the probe. Remember that the microphone transducers must be of the same type and should be a paired set.
- In the Measurement Organiser, there must be a CPB analyzer inserted in the measurement template that you are going to calibrate from, and the signal group containing the two signals from the probe must be connected to it.
- In the Calculation tab page for the CPB analyzer, measurement of mean pressure and intensity (or measurement and storage to the multi-buffers) for the signal group containing the signals from the probe microphone channels must be selected.
- For sound pressure calibration you can then use a generic acoustical calibrator.
- For pressure-residual intensity index, you need to add a function in the Function Organiser and in the Function properties select Calculation of the *PI Index* spectrum and double-click to create a display.

4.2 Other Instruments

Refer to the user manual of your specific instrument for information on how to perform sound pressure calibration and pressure-residual intensity index verification with your equipment.

4.3 Using an External Signal

Fig.4.1
Rear view of Type 4297. An external noise source can be applied to the LEMO socket on the right

It is possible to apply an external signal to Type 4297.

Please note: Use only Brüel & Kjær cable AO-0440 (BNC to LEMO cable).

1) Connect the external generator to the LEMO socket (Fig.4.1).
2) It is necessary that Type 4297 is switched on. Press **Start** and select broadband pink noise. The LED indicator should be illuminated.
3) Ensure that the rms voltage applied to Type 4297 does not exceed 70 mV rms (94 dB approximates to 65 mV with the spacer in place, but the exact figure is dependent on the frequency applied).
4) In the frequency range 20 Hz to 10 kHz, both sine wave and broadband pink noise signals may be used. The use of a sine wave signal gives more stable results and allows for corrections of phase mismatching in the sound intensity probe.

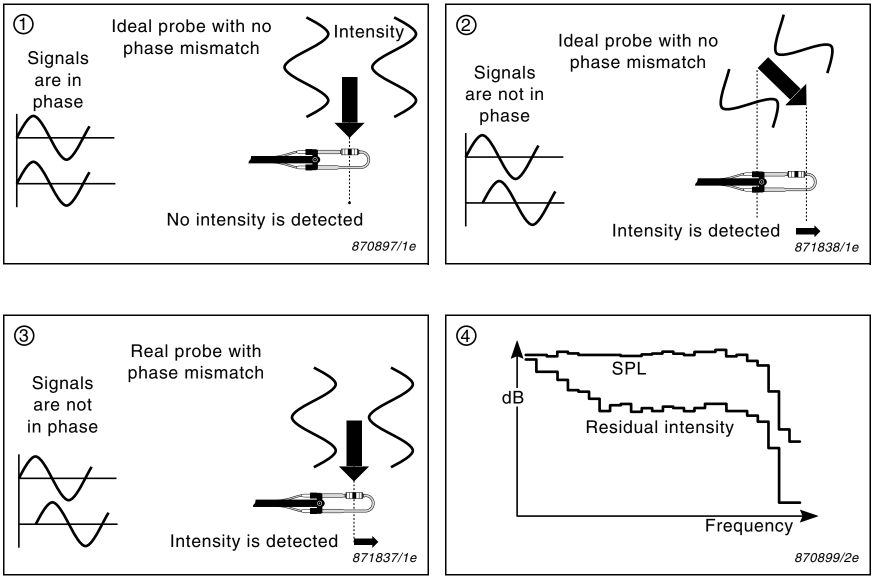
Chapter 5

Pressure-Residual Intensity Index

The information below is valid for intensity measurement systems which use probes equipped with pressure-sensing microphones and which work out the intensity in accordance with the described principle.

Please note: Even under 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°. However, for practical applications, this situation can easily be simulated using the set-up shown in Fig. 1.2.

Fig. 5.1
Setup for simulating a free-field situation where the angle between the propagation of the sound wave and the probe is exactly 90°

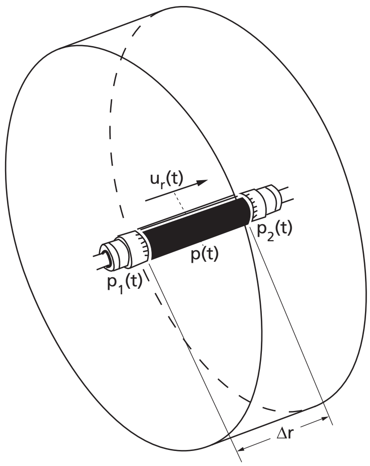


1) A sound wave is incident on a probe axis at 90°. There is no flow of acoustic energy along the probe axis. The signals from the microphones are in phase and no intensity is detected.

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'.

Fig. 5.2
Intensity measurement principle



$I_r(t) = p(t) \times u_r(t)$

where

$I_r(t)$	: Instantaneous intensity in the direction of the probe axis
$p(t)$	: Instantaneous pressure at the centre of the probe spacer
$u_r(t)$	: Instantaneous particle velocity in the direction of the probe axis

The pressure at the centre is represented by the average of two measured pressures. The particle velocity is obtained by integration of the air disc's acceleration, which is a function of the difference between the measured pressures:

$$I(t) = \frac{p_1(t) + p_2(t)}{2} \int \frac{p_1(t) - p_2(t)}{\rho_0 \Delta r_0} dt$$

where

$p_1(t)$, $p_2(t)$	: Measured instantaneous pressures
Δr_0	: System parameter representing the microphone separation, Δr (See Fig. 4.2)
ρ_0	: System parameter representing the air density

Measured Pressure Level

$$L_p = 20\log \frac{(p_1^2 + 2p_1p_2\cos\phi + p_2^2)^{1/2}}{2p_{ref}} dB$$

Measured Intensity Level

$$L_1 = 10\log \frac{p_1p_2\sin\phi}{I_{ref}\,\omega\,\rho_0\Delta r_0} dB$$

where $\phi = \phi_f + \phi_e$

ϕ_f	: phase difference between measured pressures
ϕ_e	: phase error of measurement system
p_1, p_2	: measured pressures (RMS values)
ω	: angular frequency
p_{ref}	: reference pressure (2×10^{-5} Pa)
I_{ref}	: reference intensity (10^{-12} W/m^2)

The **pressure-residual intensity index** of a measurement system is defined as the difference between the indicated pressure and intensity levels for equal pressure applied to the microphones ($\phi_f = 0$).

For a small phase difference between the channels of a measurement system, the pressure-residual intensity becomes:

$$L_{K,0} = 10\log \frac{I_{ref}\,\omega\,\rho_0\Delta r_0}{p_{ref}^2\sin\phi_e} dB$$

Please note: The pressure-residual intensity index is a function of the selected system variables for gas density and microphone separation. Thus, the index should be determined for those values of the variables that are to be used for the measurements.

The curves in Fig.5.3 indicate that a measured pressure-intensity index should be at least 7 dB higher than the residual pressure intensity index of the measurement system to ensure an error due to phase mismatch of less than 1 dB.

Thus, we could define the dynamic capability of an intensity measurement system by subtracting 7 dB from the residual pressure-intensity index.

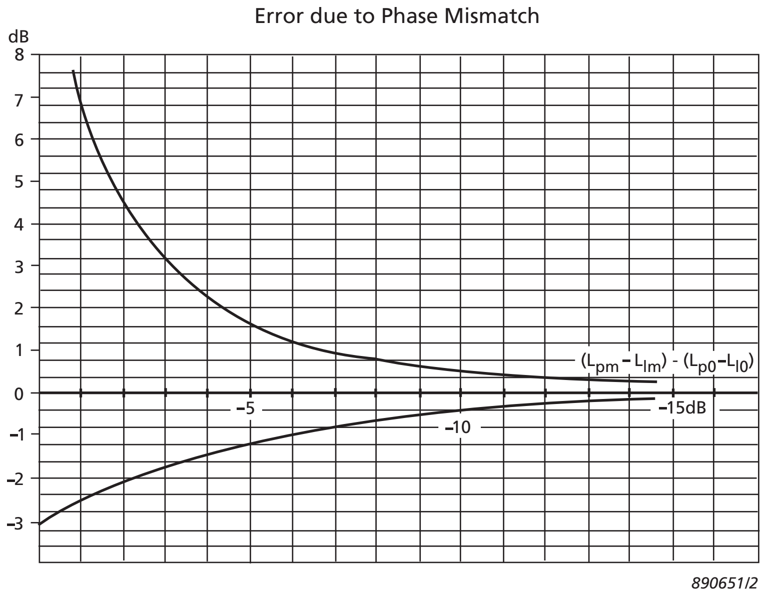


Fig. 5.3
Error due to phase mismatch for intensity measurements

Phase corrected intensity can be calculated by certain measurement systems in accordance with the following formulae:

$$I_{cor} = I_m - \frac{p_m^2 I_0}{p_0^2}$$

or

$$I_{cor} = I_m \frac{p_m^2 \sin\phi_e}{\omega\rho_0 \Delta r_0}$$

where:

I_{cor} : phase corrected intensity

I_m : measured intensity

p_m : measured pressure

I_0, p_0 : measured intensity and pressure for equal pressure applied to the microphones.

Please note: The correction factor [sin $\phi_e / (\omega \rho_0 \Delta r_0)$] is a function of the selected system variables for gas density and microphone separation. Thus, the factor should be determined for those values of the variables that are to be used for the measurements.

Chapter 6

Specifications

Please note:

- All specifications are for a probe with a 12 mm spacer unless otherwise stated
- All values are typical at 23°C, unless measurement uncertainty or tolerance field is specified. All uncertainty values are specified at 2σ (that is, expanded uncertainty using a coverage factor of 2)

POWER SUPPLY
2 × 1.5 V alkaline battery, type LR6 (QB-0013)
Lifetime: 8 hours continuous
External DC Power Supply Voltage: Regulated or smoothed 10 – 14 V, max. 100 mV ripple
Power: 3.5 W
Current: 300 mA
Inrush Current: 1000 mA
Socket: 5.5 mm diameter, 2 mm pin (positive)

SIGNAL LEVELS OBTAINED IN INTENSITY CALIBRATOR
Reference conditions according to IEC 60942
Ambient Static Pressure: 101.3 kPa
Ambient Temperature: 23 °C
Relative Humidity: 50%

INDIVIDUAL CALIBRATION ACCURACY
Sound pressure level for sine output 251.2 Hz ± 0.1% at reference conditions: 94 ± 0.08 dB re 20 µPa
Nominal Sound Pressure Level: 94 ± 0.2 dB re 20 µPa
Stabilisation Time: 5 s
Temperature Coefficient: < ± 0.002 dB/°C
Humidity Coefficient: Negligible
Total Harmonic Distortion: <2%

SOUND PRESSURE LEVELS MEASURED WITH SPACER
Pink Noise: all levels measured in 1/3-octaves:
251.2 Hz: 75 dB ±3.0 dB SPL
20 Hz to 3.15 kHz: ± 3.0 dB re level at 251.2 Hz
Linear: 94 dB ± 3.0 dB SPL
Fulfils IEC 60942, 1997 Class 1

SOUND PRESSURE LEVEL MEASURED WITHOUT SPACER
20 Hz to 6.3 kHz: ± 3.0 dB re level at 251.2 Hz

PRESSURE-RESIDUAL INTENSITY INDEX OF SOUND FIELD
Pink Noise: all levels measured in 1/3-octaves:
Fulfils IEC 61043, 1993 Class 1
Measured with 12 mm Spacer: >24 dB from 40 Hz to 3 kHz
Measured without Spacer: >24 dB from 40 Hz to 6.3 kHz

DIMENSIONS AND WEIGHT (CASE)
Height: 6 cm (2.4″)
Width: 5.5 cm (2.17″)
Depth: 17 cm (6.7″)
Weight: 730 g (1 lb 10 oz)

ELECTRICAL SPECIFICATIONS
AC Input Sensitivity: 15.4 Pa/V with spacer
Max Input Voltage: 70 mV RMS
Input Impedance: >18 kΩ (f <10 kHz)

COMPLIANCE WITH STANDARDS

	The CE marking is the manufacturer's declaration that the product meets the requirements of the applicable EU directives RCM mark indicates compliance with applicable ACMA technical standards – that is, for telecommunications, radio communications, EMC and EME 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 WEEE mark indicates compliance with the EU WEEE Directive
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 (standard for interference-causing equipment)
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 EN/IEC 60942: Sound Calibrators – Amendment 1
Temperature	IEC 60068–2–1 & IEC 60068–2–2: 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 60068–2–14: Change of Temperature: – 10 to + 50 °C (2 cycles, 1 ° C/min.)
Humidity	IEC 60068–2–3: Damp Heat: 90% RH (non-condensing at 40 °C (104 °F))
Mechanical	Non-operating: IEC 60068–2–6: Vibration: 0.3 mm, 20 m/s^2, 10 – 500 Hz IEC 60068–2–27: Shock: 1000 m/s^2 IEC 60068–2–29: Bump: 1000 bumps at 250 m/s^2

Chapter 7

Service and Repair

Sound Intensity Calibrator Type 4297 is designed and constructed to provide many years of reliable operation. For repair, consult your local Brüel & Kjær service representative. Under no circumstances should repair be attempted by persons not qualified in the service of electronic measuring instrumentation.

Your local Brüel & Kjær service representative is able to replace the two-part black rubber gasket that surrounds the intensity probe sound source. Following replacement of the gasket, your local service centre will perform a test to ensure that the sound intensity probe can be correctly positioned and that the calibration signal is properly applied.

If any other repair is necessary, the calibrator must be returned to the Brüel & Kjær Service Centre at Nærum, Denmark.

Accredited Initial Calibration

When supplied new from the factory, your Sound Intensity Calibrator Type 4297 fully conforms to the ISO 9000 Standard.

It is also possible to supply the unit with **Accredited Initial Calibration**, Pressure-Residual Intensity Index Verification (part number 4297 CAI). The actual measured and documented values will then be immediately available.

Accredited Calibration

It is recommended that you return your Sound Intensity Calibrator Type 4297 to the Brüel & Kjær Service Centre at Nærum, Denmark, for **Accredited Calibration** (part number 4297 CAF) every 12 months. Your local service representative can arrange this for you.

Conformance Test

If documentary evidence of full conformance to the published specification is required, this can be provided with new instruments (part number 4297 TCF).

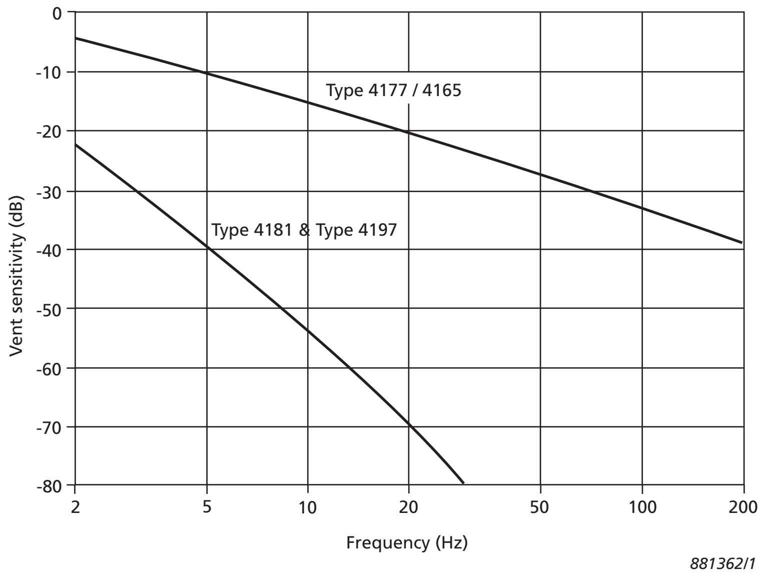
Appendix A

Sensitivity to Sound Pressure at the Equalization Vent

Ideally, the pressure-sensing microphones used with an intensity probe should only detect the sound pressure at their diaphragms. In other words, the sensitivity to sound pressure at their static-pressure equalization vents should be zero.

Microphone Pairs Types 4181 and 4197 are designed to have a very low vent sensitivity. Fig. A.1 shows the difference in vent sensitivity between these microphones which were developed especially for intensity measurements and conventional measurement microphones that were previously used for intensity probes. The vent sensitivity is expressed in dB with respect to the diaphragm sensitivity.

Fig. A.1 *Comparison of vent sensitivities of microphones from a Type 4181 pair and a Type 4197 pair. These microphone pairs have the extra pressure equalization vents (phase correctors). The curve is compared with the result from a Type 4177, the original intensity microphone pair based on two microphones, Type 4165, which had no phase correctors. Note that Types 4181 and 4177 are no longer in production.*



The low vent sensitivity leads to more accurate intensity measurements in the field. It has also made it possible to develop Sound Intensity Calibrator Types 3541 and 4297 for measurement of pressure-residual intensity index over a wide frequency range. Types 4297 and 3541 apply sound pressure to the microphone diaphragms only, and therefore, can only be used with microphone pairs such as Types 4181 and 4197.

A.1 Measurement Errors

Pressure-Residual Intensity at Low Frequencies and High Indices

Even though Type 4181 and 4197 microphones have very low vent sensitivities, an error may occur if the pressure-residual intensity index is measured for a system having a high index at low frequencies. This error can be evaluated when Type 4181 or 4197 is used because their vent sensitivities are stated on their calibration charts. In practice, high field indices at low frequencies cannot be measured accurately in the field as pressure gradients may cause errors.

Use of Nomogram

Fig. A.2 is a nomogram for determining the error in a pressure-residual intensity index measurement due to the vent sensitivity of Microphone Types 4181 and 4197.

A range of frequencies is shown on the x-axis. A range of pressure-residual intensity index values is shown on the y-axis. The diagonal lines correspond to values of vent sensitivity. The vent sensitivity values are in dB with respect to diaphragm sensitivity at 20 Hz. To determine the measurement error using the nomogram:

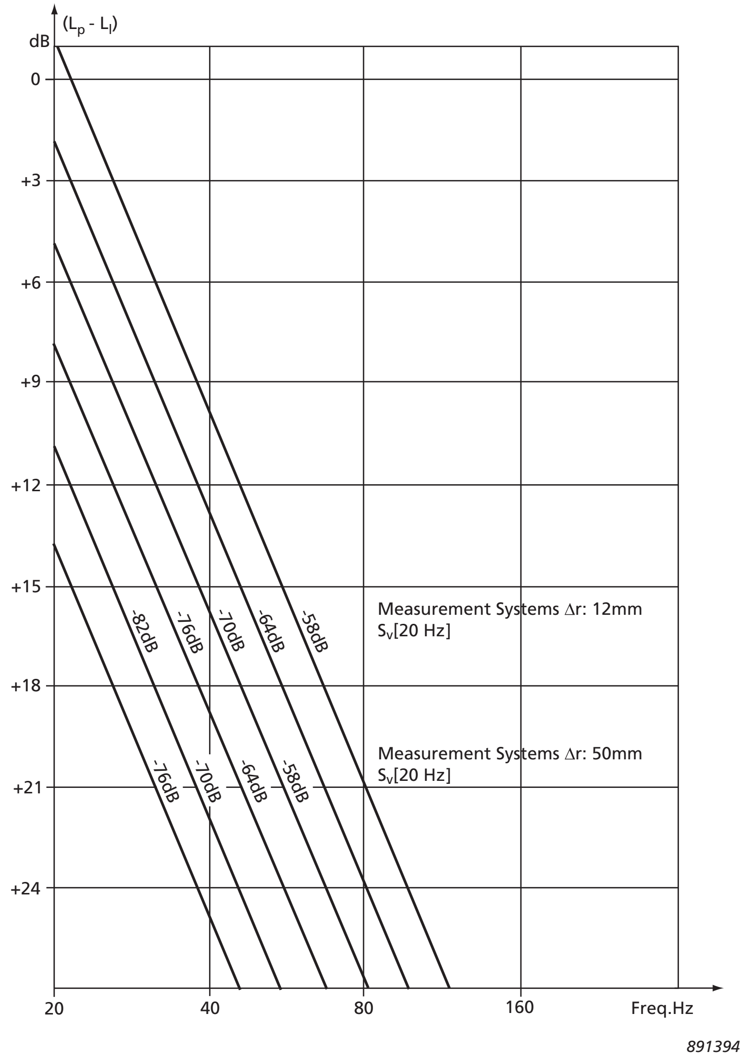
1) Read the vent sensitivity values of the two microphones used from the calibration chart. Select the higher value
2) Place a line on the nomogram so that it corresponds to the selected value of vent sensitivity and microphone separation. It must be parallel to the preprinted lines
3) Locate the point representing the measured pressure-residual intensity index at the frequency at which the measurement was taken

If the point of the intersection is to the right of the line for the vent-sensitivity value, then the measurement error is less than 1 dB.

If the point of intersection is on the line for the vent-sensitivity value, then the measurement error is 1 dB.

If the point of intersection is to the left of the line for the vent-sensitivity value, then the measurement error is greater than 1 dB.

Fig. A.2
Nomogram for determining the error in a pressure-residual intensity index measurement due to vent sensitivity



A.2 Effect of Ambient Conditions

Temperature and Atmospheric Pressure Changes

To determine the sound intensity level correctly, the air (gas) density should be entered into the measurement system. The density varies with ambient temperature and pressure. For some sound intensity analyzing systems the value of density is fixed to 1.205 kg/m^3 and cannot be changed, so the displayed level has to be corrected depending on the actual calibration or measurement conditions. The correction is 0 dB at the reference conditions 1013 hPa and 20 °C.

The correction to the indicated sound intensity level is:

$$L_I(\text{real}) - L_I(\text{measured}) = 10\log\frac{(T_a + 273) \times 1013}{293 \times P_a}\,dB$$

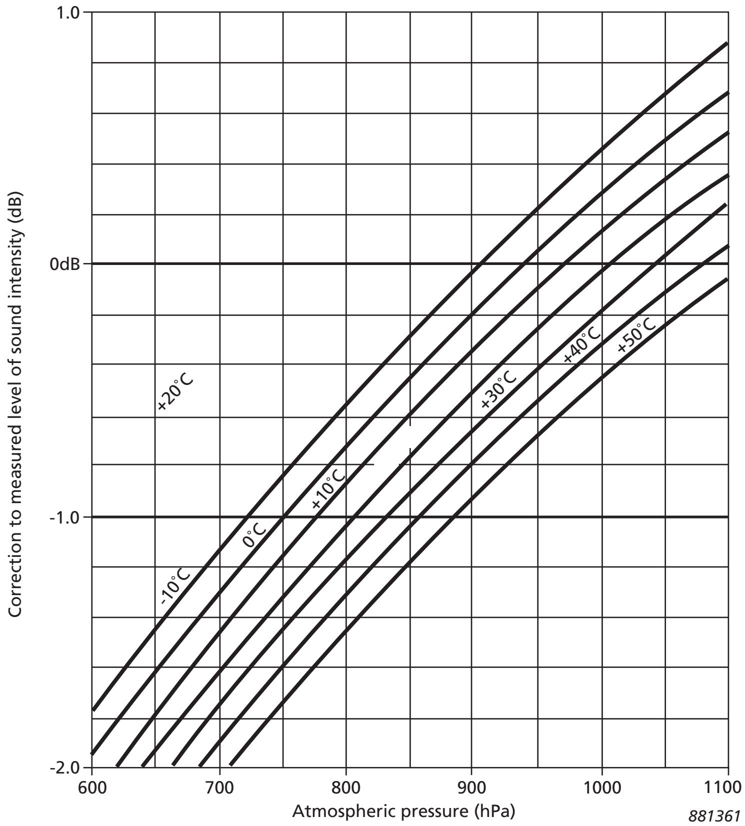
where:

T_a: ambient temperature, °C

P_a: ambient pressure, hPa

For air, the deviation from the correct reading due to deviating temperatures and pressure is given in Fig. A.3.

Fig. A.3
Deviation from correct intensity reading, due to a present gas density value of 1.205 kg/m^3 corresponding to the correct density of air at 1013 hPa and 20 °C



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