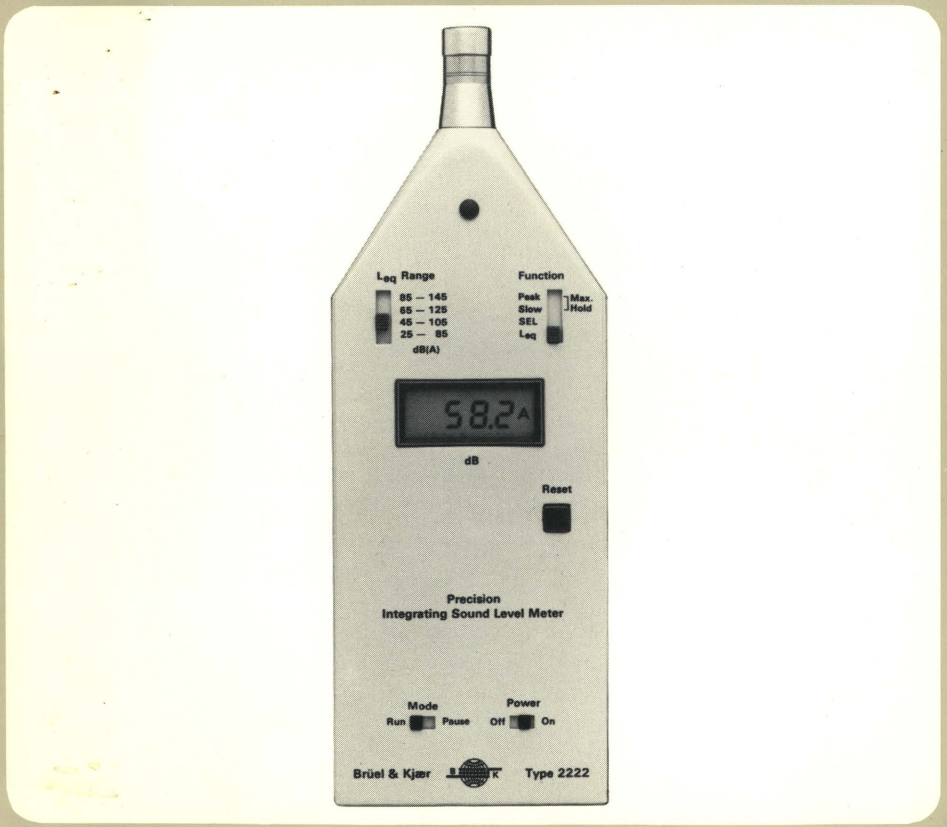
2221
2222

Instruction Manual

Precision Integrating Sound Level Meters
Types 2221 and 2222



Pocket-sized Precision Integrating Sound Level Meters complying with Proposed IEC standard for Precision Integrating Sound Level Meters Type 1P, and relevant sections of IEC 651 type 1, DIN-IEC 651 Klasse 1, ANSI S1.4.1971 type 1, and BS 5969 Type 1. It measures L_{eq} over periods up to 2,77 hours, SEL and Max. Hold "Fast/Slow" and "Peak". The measuring range from 25 to 145 dB is covered in four overlapping sub-ranges and the results are directly shown on a digital display with 0,1 dB resolution. An AC output is provided for recording purposes. It is supplied with Prepolarized Condenser Microphone Type 4176.

Types 2221 and 2222 are identical except that the Type 2221 has a "Fast" time weighting, whilst the Type 2222 has a "Slow" time weighting.

Brüel & Kjær

1-033 0601-1A
BE 0601

Precision Integrating Sound Level Meters Types 2221 and 2222

Type 2221 from serial no. 1013675

Type 2222 from serial no. 851150

May 1982

CONTENTS

types 2221 and 2222

Precision Integrating Sound Level Meters

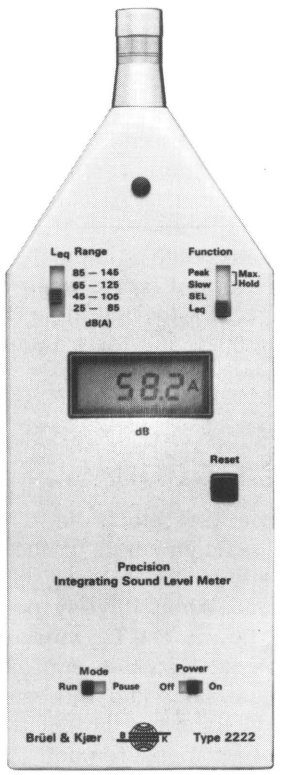
USES:

- Determination of L_{eq} for assessment of hearing loss risk or noise annoyance.
- Measurement of cyclical machine noise
- Determination of Sound Exposure Level (SEL)
- Measurement of Max. noise levels
- Spatial averaging of machine noise
- Sound power level measurements according to survey method

FEATURES:

- Direct indication of L_{eq} and SEL
- Fulfils proposed IEC standard for Precision Integrating Sound Level Meters Type 1P, and relevant sections IEC 651 Type 1, DIN-IEC 651 Klasse 1 and ANSI S1.4.1971 Type 1
- Max. Hold "Peak"
- Max. hold "Fast" (2221) or Max. hold "Slow" (2222)
- Easily read digital display
- Light and compact
- AC output for recording
- Delivered with individually calibrated Condenser Microphone
- 60 dB dynamic range
- Comprehensive display: overload, underrange, battery state, frequency weighting, overflow

In addition to offering Type 1 measurement characteristics, these Precision Integrating Sound Level Meters are truly portable. Just over 20 cm long, 2,4 cm thick and weighing 400 g, they will easily fit in your pocket.
The use of microprocessor technology results in accurate, true measurements and simplicity of use. L_{eq}, SEL, and "Peak" and "Fast/Slow" Max. Hold are indicated on a large digital display making reading errors virtually impossible. In addition to these basic functions, the Types 2221 and 2222 have a pause function which greatly extends the applications of the instruments.
The comprehensive digital display and the functional simplicity permit confident and efficient use of this Sound Level Meter.
An AC output allows recording of the weighted input signal.



Introduction

Today, noise is an important consideration in many areas of the environment and noise measurements are no longer carried out exclusively by specialists. With this in mind, B & K has developed the Precision Integrating Sound Level Meters Types 2221 and 2222. These instruments have all of the features necessary for a wide variety of noise measurements and comply with the proposed IEC recommendation for Integrating Sound Level Meters Type 1P and IEC 651 Type 1, DIN-IEC 651 Klasse 1 and ANSI S1.4.1971 Type 1 standards.

The Types 2221 and 2222 carry out basically 4 measurements: L_{eq}, SEL, Max. Hold "Fast" (Type 2221) or "Slow" (Type 2222), and Max. Hold "Peak"; all in four sensitivity ranges.

L_{eq} Measurements

L_{eq} is the A-weighted noise level averaged over the measurement period. It can be considered as the continuous steady noise level which would have the same total A-weighted acoustic energy as the real fluctuating noise over the same period of time. The measurement of L_{eq} is based on the equal energy principle:

$$L_{eq} = 10 \, \mathrm{Log}_{10} \frac{1}{T} \int_0^T \left(\frac{p(t)}{p_o} \right)^2 dt$$

where p_0 is the reference sound pressure (20 μPa), p(t) is the A-weighted time varying sound pressure and T is the time interval over which it is measured.

SEL Measurements

Sound Exposure Level (SEL) is the

constant level which if maintained for a period of 1 second would have the same A-weighted acoustic energy as the measured noise event, and is defined as:

$$SEL = 10\ Log_{10}\ \frac{1}{\tau_{ref}} \int_{-\infty}^{+\infty} \left(\frac{p(t)}{p_o}\right)^2 dt$$

$\tau_{ref} = 1s$

The SEL is used primarily to describe and compare single events (e.g. vehicle pass-by, etc.).

Max. Hold "Fast/Slow"

This is the maximum A-weighted RMS sound level measured with the standardized "Fast" (Type 2221) or "Slow" (Type 2222) time constant, over the measurement period. It is used for fluctuating noises.

Max. Hold "Peak"

The peak value of impulsive noises is an important factor when considering hazard to hearing. The rise time is 30 μs, and the frequency response linear.

Description

Principle: (see block diagram)

The basic function of the instrument is to perform the L_{eq} measurement/calculation for any period up to 2,77 hours. The L_{eq} measurement principle is described in greater detail below since the SEL and Max. Hold functions are obtained on the basis of L_{eq} measurement.

The amplified and A-weighted signal from the microphone is squared through the log and antilog converters. The integrator summates the signal, generates an impulse and is reset when a trigger level is exceeded. The impulse repetition rate is proportional to the square of the instantaneous value of the input signal, and the number of impulses is thus proportional to the noise dose received since the beginning of the measurement. The impulses are accumulated by a dose counter. A crystal oscillator generates clock pulses which are accumulated in the time counter. From the two counter outputs the L_{eq} calculation is carried out by the microprocessor and repeated every 0,5 s updating the display. Dose and time counters are only set to zero when the instrument is reset.

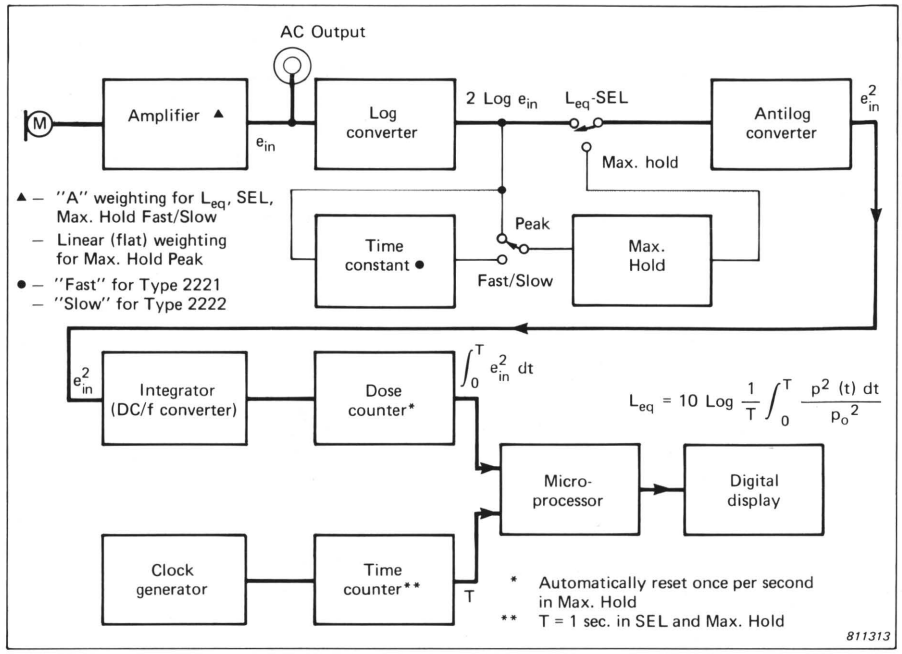


Fig.1. Simplified block diagram of the Types 2221 and 2222

The SEL measurement procedure is identical to the L_{eq} procedure, except that a time of 1 s is used for the calculation instead of the time given by the time counter. It is possible to switch between L_{eq} and SEL without interrupting the measurement.

For Max. Hold functions the logarithm of the instantaneous signal is first applied to the Max. Hold circuit, the output from which is then applied to the L_{eq} circuits for normal processing. The L_{eq} of a constant signal is equal to the instantaneous value of the signal itself. Therefore the value obtained after an L_{eq} calculation has been made on the Max. Hold output, is equal to the maximum value. For Max. Hold "Fast/Slow" the output is equal to the maximum A-weighted signal measured with the standardized "Fast/Slow" time constant; and for Max. Hold "Peak" the output is equal to the maximum instantaneous value of the signal after "Linear" (20 Hz - 20 kHz) filtering.

Microphone

Types 2221 and 2222 are equipped with a Prepolarized Condenser Microphone Type 4176. This microphone is designed to have a linear 0° incidence free field response for measurements in accordance with IEC standards, and is well suited for free field conditions, e.g. most outdoor situations. When fitted with the Random Incidence Adaptor supplied a linear random incidence response according to ANSI standards is obtained, which generally gives more accurate results for indoor measurements. The frequency responses and directional characteristics of the complete instrument are given in Figs 3 to 5. An individual calibration chart for the microphone is supplied with the instrument.

Input Stage

The removable input stage has a very high input impedance to match the high impedance of the microphone. The output impedance is low to allow extension cables to be inserted between input stage and sound level meter.

Weighting Network, Attenuator and Overload Indicator

The selection of A or Linear (flat) weighting is automatically made by the "Function" switch. The A-weighting is applied to the signal for L_{eq}, SEL and Max. Hold "Fast/Slow" measurements; linear weighting is only obtained for Max. Hold "Peak" measurements. These weightings are also applied to the AC output.

A-weighted "Peak" measurements may be obtained by modifying the instrument. The actual weighting applied is indicated on the display.

The input amplifier covers the range 25 to 145 dB in four overlapping sub-ranges. An overload indicator monitors input and output sig-

nal levels of the amplifier and if an overload occurs, the display shows "▲". It disappears only when the instrument is reset. For Max. Hold functions the lower limit of the measuring range is 15 dB higher than for the L_{eq} range.

L_{eq} Calculation

The L_{eq} is calculated over a maximum period of 2,77 hours which is the limit of the time counter. After this time, the display shows "*" to indicate that the L_{eq} value now displayed is incorrect. However, the SEL value is not affected by this time limitation as it is always calculated using a time period of 1 second. A conversion table on the reverse side of the instrument gives the L_{eq} over any period from the SEL value and the elapsed time.

Max. Hold Fast/Slow and Max. Hold Peak calculation

When Max. Hold is selected the output signal from the log converter is fed directly to the Max. Hold circuit if "Peak" is required, or via an averaging circuit for Max. Hold "Fast/Slow" measurements. The output from the Max. Hold circuit is fed via the antilog, integrator and counter circuits to the microprocessor which controls the 1 s updating and display of the Max. Hold readings.

Both instruments can be modified to obtain Max. "Slow" instead of Max. "Fast" and vice versa.

Pause

The Types 2221 and 2222 have a "Pause" function which in the "L_{eq}" and "SEL" modes, interrupts the measurement without resetting. This can be used for example when the instrument is moved from point to point for spatial averaging of the noise from a sound source.

In Max. Hold modes the "Pause" function freezes the display, but any higher signal occuring while in "Pause" will be displayed when coming back to "Run".

Reset

The instrument is reset either automatically when changing between measuring ranges and functions (except between L_{eq} and SEL) or manually by push button. The new measurement begins 1/2 second later to avoid measuring the switch noise.

Digital Display

Measurement values are shown on a 3 1/2 digit display, with a resolution of 0,1 dB. It is updated every 1/2 second for L_{eq} and SEL measurements, and every 1 second for Max. Hold measurement. The following characters may also be displayed:

"A": A-weighted frequency response
"L": Linear (flat) frequency response
"*": Maximum L_{eq} measuring time exceeded
"▲": An overload has occured during the measuring period
"▼": The sound pressure level is under the minimum range level
"BAT": Batteries must be changed.
"00.0": Initial display check
" - - - ": Underrange in Max. Hold measurements and delay after Reset

Power Supply

Power is supplied from 3 alkaline batteries (IEC R 20) which will provide approximately 10 hours of continuous operation.

Fig.2. Display of Types 2221 and 2222

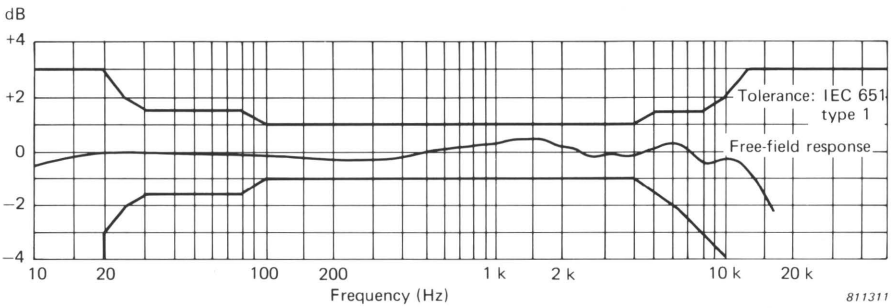


Fig.3. Typical free field frequency response of the complete instrument with 0° incidence shown as deviation from the standardized A-curve

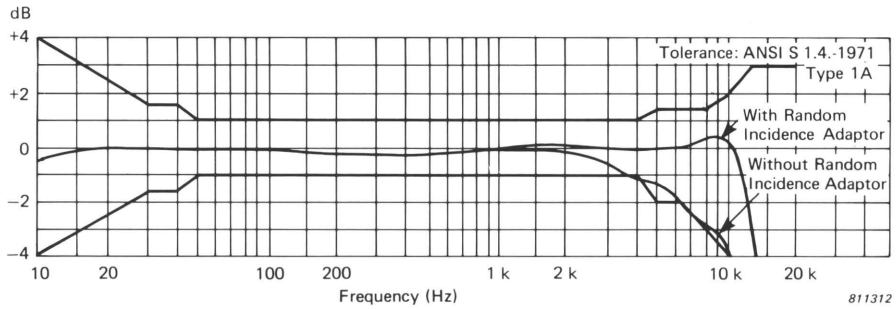


Fig.4. Typical diffuse field frequency response of the complete instrument shown as deviation from the standardized A-curve.

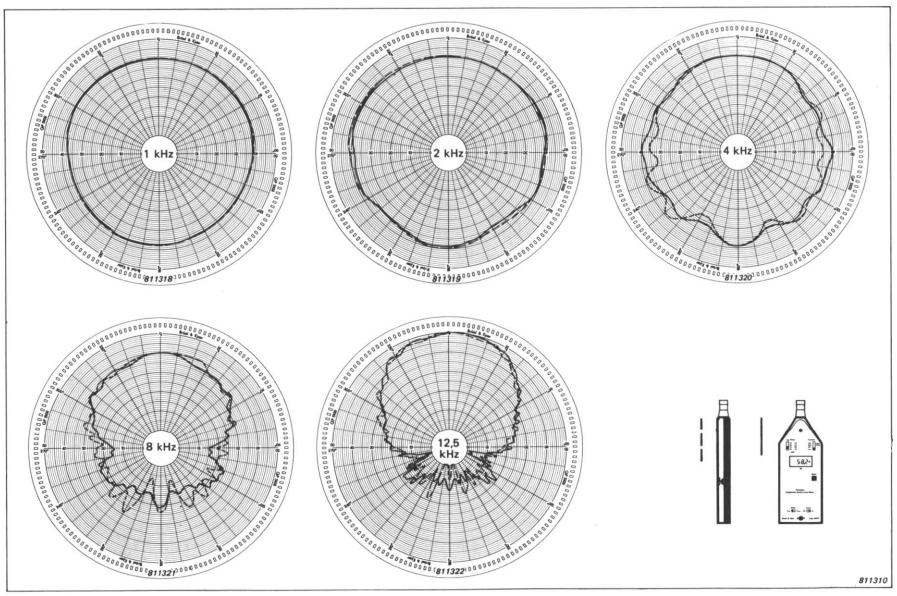


Fig.5. Directional characteristics of the complete instrument

Calibration

Calibration is easily carried out using Sound Level Calibrator Type 4230, which fits directly over the microphone and produces a nominal sound pressure level of 94 dB (±0,3 dB). Calibration with the Type 4230 permits a check of the entire instrument, including the microphone.

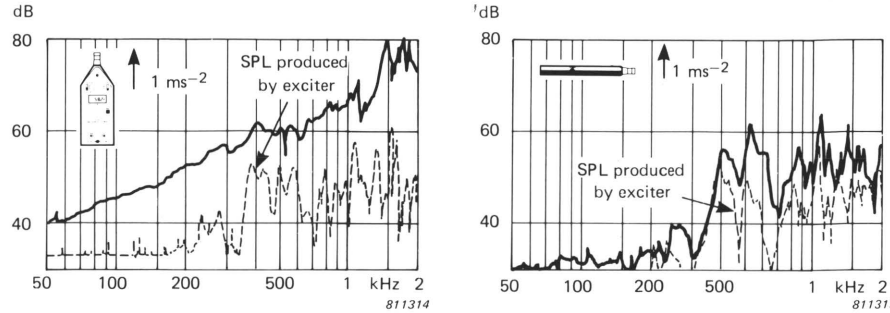


Fig.6. Equivalent Sound pressure level when complete Sound Level Meter is excited vertically and horizontally at 1 ms^{-2}

AC Output

An AC output provides the amplified and filtered signal. Upper range limit corresponds to 2 V RMS. It is well suited for level recording, particularly with the Portable Level Recorder Type 2306 which is also battery powered.

Specifications 2221 and 2222

Measuring Range:

L_{eq} dB(A)	Max. Hold "Fast/Slow" dB(A)	Max. Hold "Peak" dB(Lin.)
25-85	40-85	55-88
45-105	60-105	60-108
65-125	80-125	80-128
85-145	100-145	100-148

Signal to noise ratio >5 dB at 25 dB(A)

Frequency Response:
See Figs.3 and 4

Frequency Weighting:
In "L_{eq}", "SEL" and Max. Hold "Fast/Slow": A-weighting to IEC 651 Type 1
In Max. Hold "Peak": Linear (20 Hz - 20 kHz, +0,5 dB –3 dB) *

Detector:
Characteristics: true logarithmic RMS
Linearity range: 60 dB
Pulse range: 63 dB
Crest factor capability: 1,4 at upper limit of measuring range increasing linearly with decreasing signal to a maximum of 50 for Max. Hold "Fast/Slow". For L_{eq}, overload is the only crest factor limitation (63 dB)

Time Weighting Characteristics:
"Fast" (2221): to IEC 651 Type 1 *
"Slow" (2222): to IEC 651 Type 1 *
"Peak": rise time <30 μs
Max. Hold decay rate: <0,05 dB/s

L_{eq} Response Time for Constant Input Signal:

Display / Level	First reading	Final reading ± 0,5 dB	Final reading ± 0,1 dB
At bottom of range	4 s	32 s	174 s
10 dB above bottom of range	1 s	3,5 s	17,5 s
20 dB or more above bottom of range	1 s	1 s	4,5 s

* The modifications proposed (see p. 2 & 3) can be carried out by your local B & K representative.

Maximum Measurement Period:
L_{eq}: 2,77 hours (for periods longer than 2,77 hours L_{eq} can be determined from the SEL)
SEL: only limited by battery life

Display:
3½ digits 7 segments, liquid crystal, 7,2 mm high
L_{eq}, SEL: resolution 0,1 dB updated twice per second
Max. "Fast/Slow", Max. "Peak": resolution 0,1 dB updated once per second, display response time less than 3 seconds
Additional functions:
Overload indicated by: ▲
Underrange indicated by: ▼
Battery low indicated by: BAT
Overflow of time counter indicated by: ✱
Weighting curve indicated by: **A** or **L**

AC Output:
2 V RMS for full scale, output impedance 1 kΩ, short circuit protected

Reset Function:
Reset occurs when "Reset" is pressed or when changing "L_{eq} Range" or "Function" (except between L_{eq} and SEL)

Microphone:
Type: ½ inch B & K Prepolarized Condenser Microphone Type 4176
Sensitivity: 50 mV/Pa
Capacitance: 13 pF
Windscreen effect: <0,5 dB up to 10 kHz

Calibration:
Screwdriver operated potentiometer adjustment using Sound Level Calibrator Type 4230

Reference Conditions for Calibration Validity:
Type of Sound Field: Free
Reference Incidence Direction: Perpendicular to microphone diaphragm
Reference SPL: 94 dB (re 20 μPa)
Reference Frequency: 1 kHz
Reference Temperature: 20°C
Reference Measuring Range:
45 - 105 dB(A)

Warm-up Time:
<1 s

Effect of Humidity (at 40°C and 1000 Hz):
<0,5 dB for 30%<RH<90%

Effect of Temperature:
Microphone: –0,004 dB/°C typically
Complete instrument:
–0,004 ± 0,016 dB/°C
Storage temperature: 70°C (158°F) max. (dry air). 100 hours max. at 40°C (104°F) and 90% RH

Effect of Magnetic Field:
80 A/m (1 Ørsted) at 50 Hz gives:
<25 dB (A) or <55 dB (Lin)

Vibration Sensitivity:
See Fig.6

Batteries:
Type: Three 1,5 V Alkaline cells IEC type LR 6 (B&K order No. QB 0013)
Life: approx. 10 hours

Overall Dimensions and Weight:
205 × 72 × 24 mm (8 × 2,8 × 0,95 in)
400 g (0,86 lb) with batteries

Accessories Included:
Half inch Prepolarized Condenser Microphone ..... Type 4176
Random Incidence Adaptor ..... DZ 9566
Leather Carrying Case ..... KE 0208
2,5 mm mini-jack plug ..... JP 0213
Windscreen ..... UA 0459
Cells (×3) ..... QB 0013

Accessories Available:
Sound Level Calibrator ..... Type 4230
Level Recorder Cable ..... AO 0173
3 m Microphone Extension cable with threaded attachment (UNC 1/4" × 20) for direct connection to tripod ..... AO 0185
10 m cable as above ..... AO 0186

Ordering Information:
Types 2221 and 2222 are identical except that Type 2221 has "Fast" time weighting, whilst Type 2222 has "Slow" time weighting.

2. CONTROLS

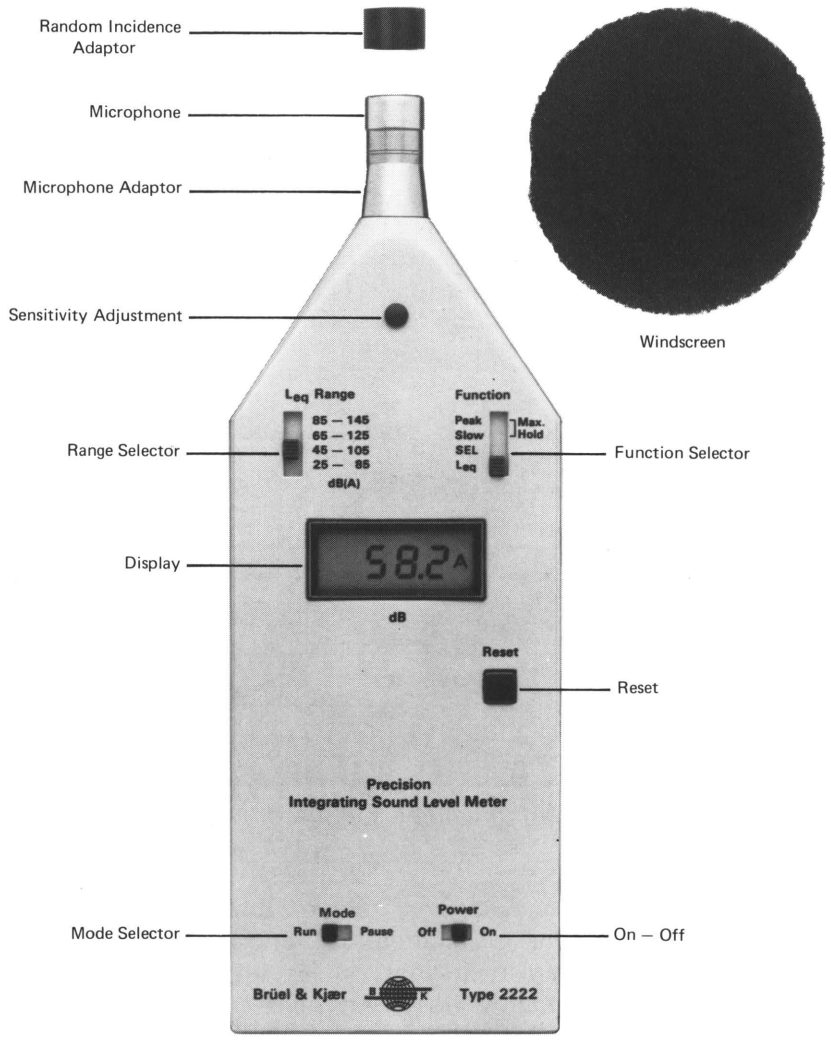


Fig. 2.1. Front view of the Sound Level Meter

FUNCTION:

Four position slide-switch for selection of the operating mode as follows:

"L_{eq}": The current L_{eq} value is displayed and updated twice per second. The maximum measurement period with direct display of the result is 2,77 hours. For measurements over periods longer than 2,77 hours, the L_{eq} can be determined from the SEL value and the elapsed time (see section 3.5.7).

"SEL": Operates the SEL calculation mode, and the measurement result is directly displayed. The measurement period is only limited by the battery life.

"Max. Hold Fast" (2221 only)**:** Holds the maximum RMS signal value measured with the standardized "Fast" time weighting until the meter is reset. (See Chapter 5).

"Max. Hold Slow" (2222 only)**:** Holds the maximum RMS signal value measured with the standardized "Slow" time weighting until the meter is reset. (See Chapter 5).

"Max. Hold Peak": Holds the maximum "Peak" value until the meter is reset. Rise time is $<30\ \mu s$.

Switching the FUNCTION selector automatically resets the instrument except between L_{eq} and SEL positions. L_{eq}, SEL and Max. Hold "Fast/Slow" measurements are A-weighted, while Max. Hold "Peak" is made with a Linear (flat) weighting. The weighting selection is made automatically by the FUNCTION selector, and "A" or "L" appears on the display as a reminder.

L_{eq} RANGE:

Four position slide-switch providing four overlapping measuring ranges. See Table 2.1.

L_{eq} dB(A)	Max. Hold "Fast/Slow" dB(A)	Max. Hold "Peak" dB(Lin.)
25–85	40–85	55–88
45–105	60–105	60–108
65–125	80–125	80–128
85–145	100–145	100–148

811132

Table 2.1. Measuring ranges for the differents functions

The measurement ranges obtained are different depending on which function is selected. SEL and L_{eq} measurements use the same ranges; note however, that for SEL measurements the range values applies to the instantaneous RMS level and not to the SEL value displayed. When switching between measuring ranges, the instrument is automatically reset.

MODE:

Two position slide-switch with the following functions:

"Run": Normal operating mode. The measurement selected by the FUNCTION switch is then in progress.

"Pause": Interrupts the measurement when in L_{eq} or SEL function. Measurement will be continued when returning to "Run".

For Max. Hold functions it freezes the display. A higher level occuring while in "Pause" position is held by the max. hold circuit and displayed when returning to "Run".

POWER: Two positions slide-switch connecting power to the instrument.

RESET: Resets the time and dose counters plus max. hold detector. The measurement starts after 0,5 s delay in order to avoid switching noise.

SENSITIVITY ADJUSTMENT: Multiturn potentiometer to calibrate the instrument sensitivity. Sensitivity is increased when turning clockwise. Access to the potentiometer is protected by a removable plastic lug.

AC OUTPUT: 2,5 mm mini-jack socket accepting Plug JP 0213 and Cable AO 0173 for level recording. The maximum signal delivered is 2 V RMS and corresponds to full range. Output impedance 1 kΩ, short circuit protected.

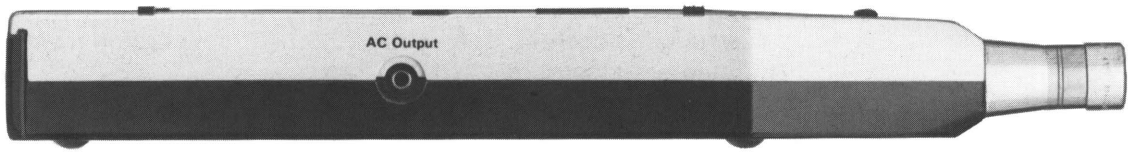


Fig. 2.2. AC Output of the Sound Level Meter

DISPLAY: 3½ digit liquid crystal display for readout of measurement results and the following indications:

"0 0.0": Displayed for one second after switching on. This display is followed by " - - - " in order to check visually all segments of the display.

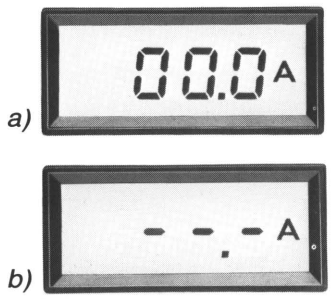


Fig. 2.3. a) Display check
b) Underrange in Max. Hold (and Reset)

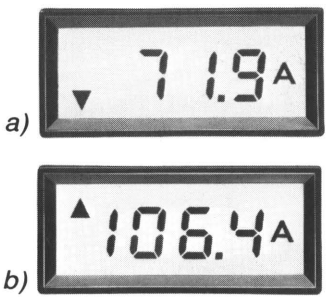


Fig. 2.4. a) Underrange
b) Overload

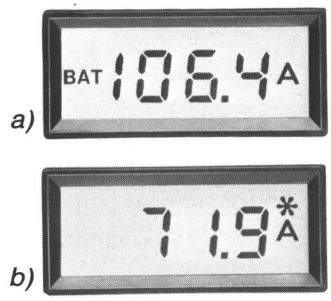


Fig. 2.5. a) Battery depleted
b) Maximum L_{eq} duration exceeded

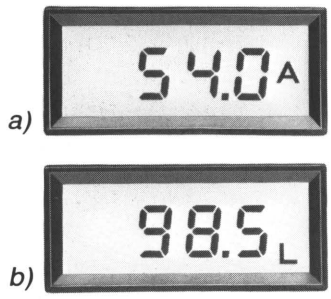


Fig. 2.6. a) A-weighting applied
b) Linear (Flat) weighting applied

" – – – " (or **" P – – "**): Displayed during the 0,5 s time delay after reset (manual or automatic), and during underrange in Max. Hold. measurements.

"▼": Indicates that the current sound level is underrange. Switch L_{eq} RANGE to a lower range. The sign disappears when the sound level exceeds the minimum range value.

"▲": Indicates that an overload has occured since the last reset and the displayed value may be incorrect. This warning only disappears with the next reset.

"✱": Indicates that the time counter capacity has been exceeded during L_{eq} measurement. The L_{eq} value displayed is incorrect, but the SEL value remains correct. See section 3.5.7 for conversion from SEL to L_{eq}. The sign will disappear with the next reset.

"BAT": Indicates that the power supply voltage is insufficient and that batteries have to be changed. See section 3.2 for battery replacement.

"A": Indicates that A-Weighting is applied. It is automatically selected by the FUNCTION switch when set for "L_{eq}", "SEL" or Max. Hold "Fast/Slow" measurements. See Chapter 5.

"L": Indicates that Linear (flat) weighting is applied. It is automatically selected by the FUNCTION switch when set for Max. Hold "Peak" measurement only.

TRIPOD MOUNTING BUSH: A 1/4″ UNC threaded bush located on the rear of the instrument for tripod mounting

RANDOM INCIDENCE ADAPTOR: Modifies the linear 0° incidence free field frequency response of the microphone to a linear random incidence response. See section 3.5.2.

WINDSCREEN: Reduces the wind noise and protects the microphone against dust, condensation and light precipitation. It is recommended for all outdoor measurements.

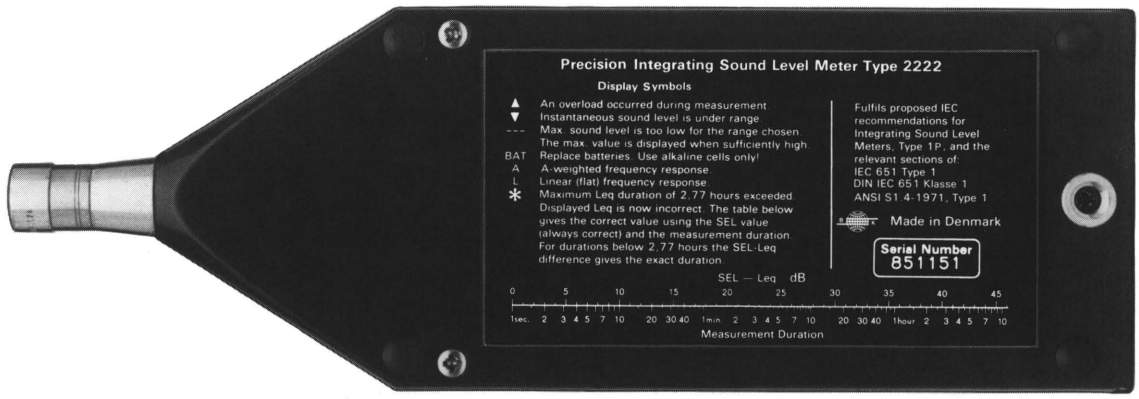


Fig. 2.7. Reverse side of the Sound Level Meter

3. OPERATION

3.1. INTRODUCTION

This Instruction Manual describes the use of the Precision Integrating Sound Level Meters Types 2221 and 2222. However, more general considerations on sound measurement techniques must be taken in account, and are given in the accompanying booklet "Measuring Sound". To obtain valid results it is also important that the measurements are carried out according to the relevant national or international standards.

3.2. BATTERY INSTALLATION

The Type 2221/22 is powered by 3 alkaline cells 1,5 V, IEC Type LR 6 (B & K no. QB 0013). These must be replaced when "BAT" symbol is indicated by the display.

To install new cells slide off the battery compartment cover. See Fig.3.1. Remove the depleted cells and insert new ones with polarities as shown inside the battery compartment. Slide on the battery cover.

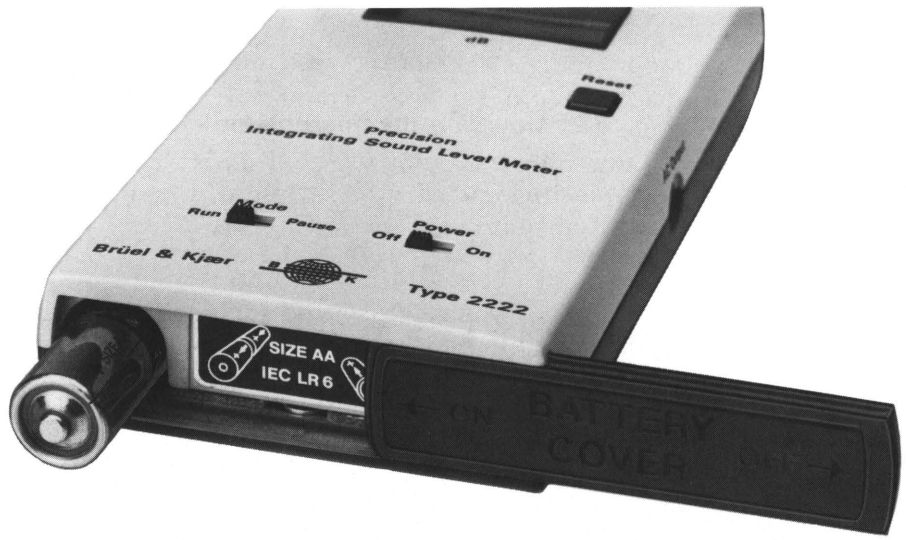


Fig. 3.1. Battery replacement

It is recommended to use only alkaline cells. Other types of dry cell will have a short life time and may leak when exhausted. New alkaline cells will provide approximately 10 hours of continuous operation.

Remove the batteries and keep the instrument in a dry place for long periods of storage.

3.3. MOUNTING THE MICROPHONE

The microphone is screwed directly onto the preamplifier, using light finger torque. Note that the protection grid is not removable on this type of microphone. A fine wire gauze filter behind the protection grid prevents dust and particle penetration to the diaphragm.

The assembly may be plugged directly into the Instrument via its 5 pin DIN plug (see Fig.3.2) or connected via a 3 m or 10 m extension cable available under order numbers AO 0185 and AO 0186 respectively. The microphone end of the extension cable has a threaded attachment to enable it to be connected directly to a standard tripod screw. This arrangement allows the operator to remain close to the Sound Level Meter for reading purposes, while at the same time enabling him to be well away from the microphone, and therefore not influence the sound field.

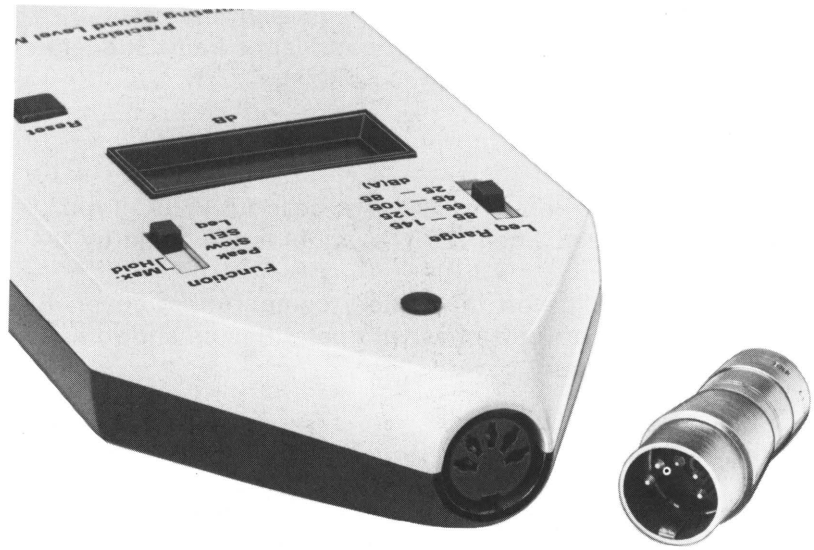


Fig. 3.2. Mounting the microphone

3.4. CALIBRATION

The Sound Level Calibrator Type 4230 is used for acoustical calibration of the whole Sound Level Meter, including the microphone.

Due to the quality of the instrument, calibration should only be necessary from time to time and should require very little adjustment. If a large adjustment is needed, the instrument is most probably defective and has to be checked for faults (Consult your B & K representative).

The Type 4230 gives a nominal sound pressure level of 94 dB $\pm$0,3 dB (re. 20 $\times$ 10^{-6} Pa). The calibration procedure is as follows:

1. Remove the Random Incidence Adaptor or the Windscreen if fitted.

2. Set the controls on the Sound Level Meter as follows:

FUNCTION:	"L_{eq}"
RANGE:	"45 - 105"
MODE:	"Run"
POWER:	"On"

3. Fit the Sound Level Calibrator with a 1/2″ adaptor (B & K no. DB 0311) over the microphone

4. Start the Sound Level Calibrator and press RESET on the Sound Level Meter

5. Wait for the displayed value to stabilize and read the display which should be 93,8 dB ±0,1 dB.

6. If an adjustment is necessary, remove the plastic plug on the top of the instrument and with a small screw driver turn the potentiometer a few degrees:
   - clockwise if the displayed value is less than 93,8 dB
   - anticlockwise if the displayed value is greater than 93,8 dB.

7. Repeat steps 4 to 6 until the correct value is obtained. Remove the Sound Level Calibrator and replace the plastic plug.

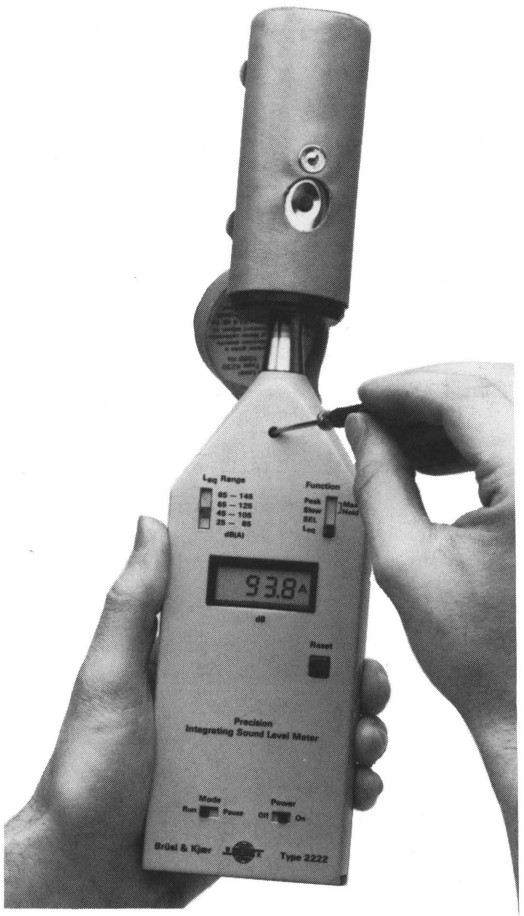


Fig. 3.3. Calibration with Sound Level Calibrator Type 4230

3.5. SOUND LEVEL MEASUREMENT

3.5.1. General

Before proceeding with a measurement, the accompanying booklet ″Measuring Sound″ which contains useful information should be read by users who are not familiar with sound measurements.

It is good practice before starting measurements to check the proper functioning of the sound level meter and its calibration. Always use the windscreen supplied when measurements are made outdoors or in very dusty environments. Keep the instrument at arms length (or mounted on a tripod) to minimize body reflections which can produce reading errors of up to a few dB in the range 300 to 500 Hz.

3.5.2 Considerations Regarding the Type of Sound Field

The condenser microphone fitted to the Type 2221/22 is designed to have a linear free field response for 0° incidence. Use of the supplied Random Incidence Adaptor DZ 9566 results in a linear response under diffuse field conditions. The use of the Random Incidence Adaptor is described in the Fig.3.4 and in the following text. When performing measurements to national and international recommendations, the sound level meter should be used as prescribed in the relevant standard.

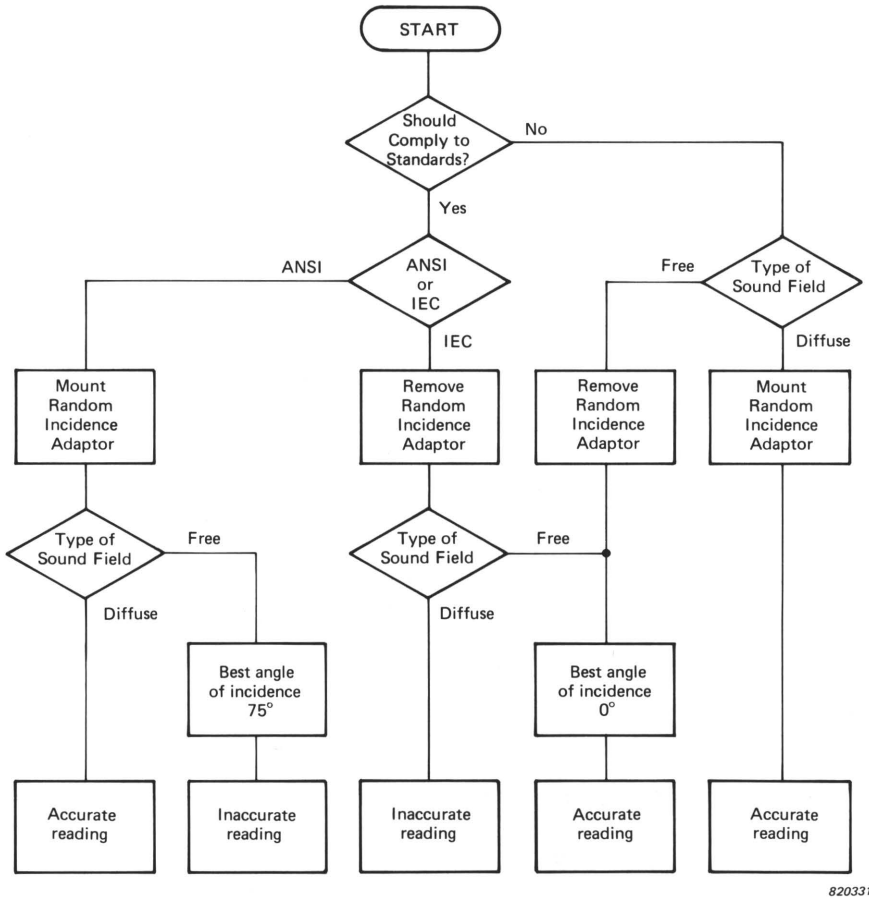


Fig. 3.4. Flow chart for use of the Random Incidence Adaptor regarding standards and type of sound field

IEC Standards:
When performing measurements requiring the use of a sound level meter to IEC standards the Random Incidence Adaptor DZ 9566 should NOT be mounted on the microphone.

The sound level meter should be pointed directly at the source if a free field condition is assumed to exist (Fig.3.5). In a diffuse field the sound level meter may be orientated in any direction.

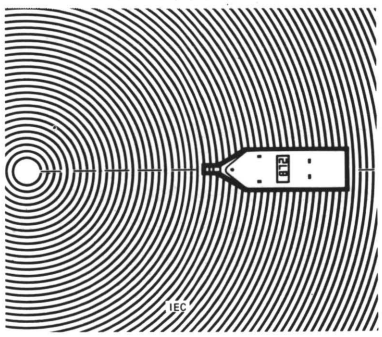


Fig. 3.5. Measurements to IEC Standards in a free sound field

ANSI Standards:
When performing measurements requiring the use of a sound level meter to ANSI standards, the "free field" microphone's characteristics should be adapted to a linear random incidence response by mounting the Random Incidence Adaptor DZ 9566. This applies for measurements in all types of sound field.

In a truly diffuse field, the sound level meter can be oriented in any direction. Under ideal free field conditions optimum response is obtained by orientating the sound level meter as shown in Fig.3.6.

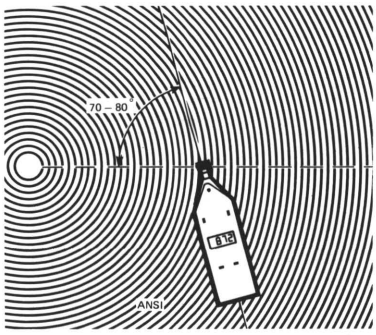


Fig. 3.6. Measurement to ANSI Standards in a free sound field

Measurements not requiring the use of an IEC or ANSI sound level meter:

Measuring with a free field microphone in a diffuse field, or measuring with a linear random incidence response microphone in a free field results in small innaccuracies in the values obtained. More accurate results will be obtained by selecting the appropriate microphone frequency response to suit the type of sound field.

Consequently, when adherence to IEC or ANSI Sound Level Meter Standards is not required, the Random Incidence Adaptor DZ 9566 should not be mounted on the microphone under free field conditions, and the meter should be pointed directly at the sound source during measurements. A free field condition can generally be assumed for outdoor measurements or in absorbent rooms.

For measurements in a diffuse field, the Random Incidence Adaptor DZ 9566 should be mounted on the microphone, and the meter may be oriented in any direction in the diffuse field. A diffuse field can generally be assumed for indoor measurements or in reverberation rooms.

3.5.3. L_{eq} and SEL Measurements

1. Carry out the calibration check before commencing with a measurement:

2. Set the controls on the Sound Level Meter as follows:

FUNCTION:	L_{eq} or SEL
L_{eq} RANGE:	in order to include the expected value
MODE:	"Run"
POWER:	"On"

3. To begin measurement, press RESET.

The L_{eq} or SEL value measured can be read directly from the display which is updated twice per second while the measurement is running. Alternatively the measurement can be interrupted by setting the MODE switch to "Pause". The "A" displayed indicates that A-weighting is applied.

If an input overload occurs, the sign "▲" appears (held continuously) and the reading may be incorrect. Switch L_{eq} RANGE to a higher range. If the input signal is underrange the sign "▼" appears. If it is displayed too often, switch L_{eq} RANGE to a lower position. Switching between measuring ranges automatically resets the instrument.

The L_{eq} measurement duration for periods shorter than 2,77 hours can be obtained by substracting the measured L_{eq} from the SEL value and using the conversion table at the back of the instrument. SEL is obtained by setting FUNCTION to "SEL". See Fig.3.7.

The L_{eq} value displayed for measurements over a period of more than 2,77 hours will be incorrect and a "✻" will appear on the display. However, knowing the measurement duration, the correct L_{eq} value can be obtained from the SEL indication using the conversion table at the back of the instrument.

The measurement period for an SEL measurement is only limited by the battery life.

Note: It is possible to switch between "L_{eq}" and "SEL" during a measurement without loosing the results. When measuring low levels it is recommended to set the MODE switch to "Pause" before switching between "L_{eq}" and "SEL", as the clicking noise from the switch may introduce an error. This is irrelevant when measuring higher levels.

3.5.4. Max Hold "Fast" or "Slow" Measurements

1. Carry out the calibration check before commencing with a measurement.

2. Set the controls on the Sound Level Meter as follows:

FUNCTION:	Max Hold "Fast" or "Slow"
L_{eq} RANGE:	to include the expected value
MODE:	"Run"
POWER:	"On"

3. To begin measurement press RESET.

The display will indicate the maximum "Fast" or "Slow" RMS value occuring after the instrument has been last reset automatically or manually. See note section 3.5.6.

Note that the measuring ranges in Max. Hold "Fast" or "Slow" modes are as follows:

40-85 dB(A)
60-105 dB(A)
80-125 dB(A)
100-145 dB(A)

Note:
If the captured level is close to the bottom of the chosen range the display may alternate between two values (e.g. between 61,4 dB and 61,8 dB in the range 60–105 dB). This is caused by the quantitative nature of the dose counter. The correct value is between the two readings shown.
This phenomenon only occurs when measuring levels close to the low end of the range. For an easier reading change to a lower range.

The decay rate $<$0,05 dB/sec of the Max. Hold function allows time to write down the displayed value.

Setting MODE to "Pause" freezes the display, but the Max. Hold circuit is still active. A higher value which occurs while in "Pause" will be displayed when the instrument is set again to "Run".

3.5.6. Max. Hold "Peak" Measurements

The procedure is identical to that for Max. Hold "Fast" or "Slow" measurements except that the FUNCTION selector has to be set to "Peak".

The measuring ranges are as follows (See note above):

55-88 dB(Lin.)
60-108 dB(Lin.)
80-128 dB(Lin.)
100-148 dB(Lin.)

Note:
The Types 2221 and 2222 have been especially constructed to allow simple modification of Max. Hold "Fast" to Max. Hold "Slow" or vice-versa, and Max. Hold "Peak" with A weighting to Max. Hold "Peak" with Linear (flat) weighting. For further details contact your local B & K representative.

3.5.7. Use of the L_{eq}/SEL Conversion Table

This is printed on the reverse side of the Sound Level Meter and may be employed as follows:

Determination of the elapsed time (max. L_{eq} period not exceeded):

1. Read L_{eq} and SEL displayed values
2. Work out SEL – L_{eq}
3. Locate this last result on the top part of the scale, and read the measurement duration indicated directly below it on the bottom part of the scale.

Example (See Fig.3.7):

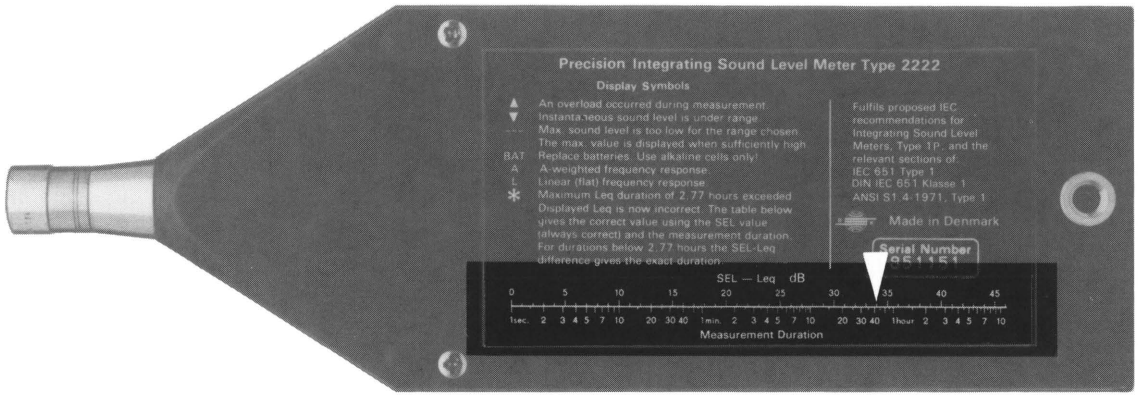


Fig. 3.7. Determination of elapsed time

With a displayed L_{eq} and SEL of 60 dB(A) and 94 dB(A) respectively, the difference SEL – L_{eq} = 34 dB. This corresponds to an elapsed time of approximately 42 min.

Determination of the correct L_{eq} for measurement period longer than 2,77 hours:

1. Locate time duration of the measurement on the bottom part of the scale, and read the SEL – L_{eq} difference directly above.
2. Substract this value from the displayed SEL value (no time limit) to obtain the L_{eq}.

Example (See Fig.3.8):

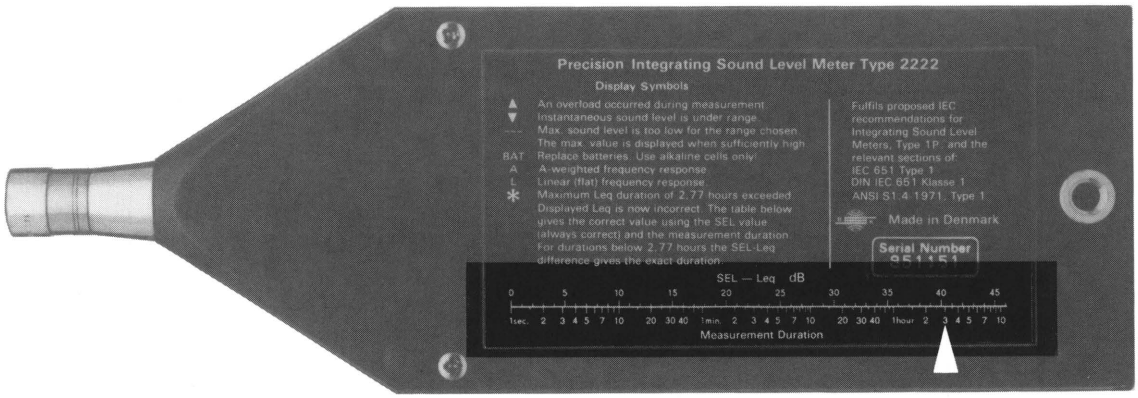


Fig. 3.8. Determination of L_{eq} of a period greater > 2,77 hours

After a measurement period of 3 hours the displayed SEL is 98 dB(A). For a measurement period of 3 h, the conversion table gives a SEL – L_{eq} = 40,3 dB. The L_{eq} for 3 hours is then 98 – 40,3 = 57,7 dB(A)

3.5.8. Noise Dose Evaluation

The percentage of the noise dose for a range of "Allowed 8 hours L_{eq}" values is easily obtained from the SEL using the nomogram given in Fig.3.9. The SEL value is read directly by the 2221/22.

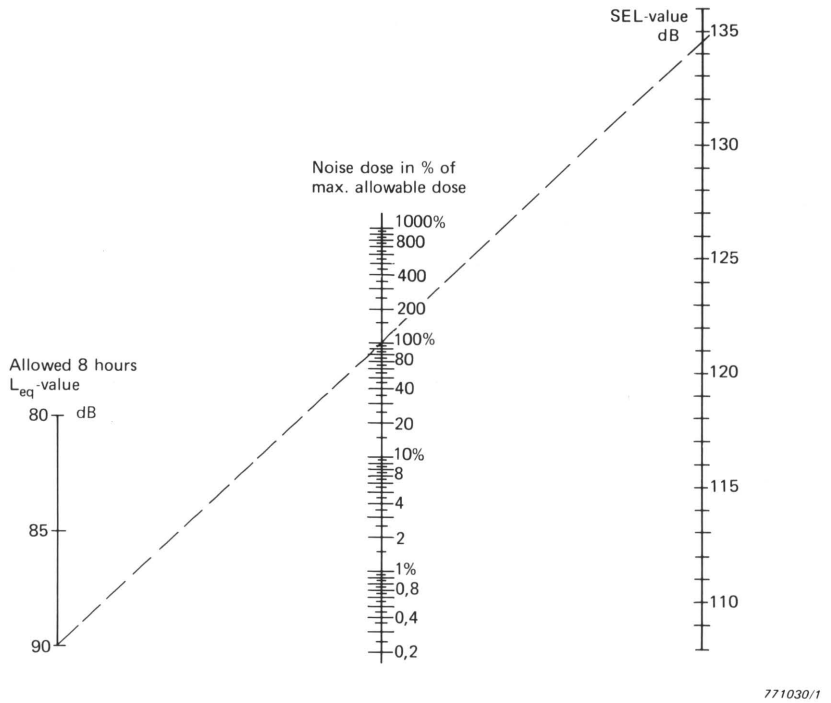


Fig. 3.9. Noise dose determination

3.5.9. Example of Measurement

This example is intended to illustrate pratically the differences between the four different functions available on the 2221/22. The measurements were carried out on noise produced by an electrical typewriter using the Type 2222. Similar results would be obtained if Type 2221 was used.

Trial		L_{eq} dB(A)	SEL dB(A)	Max. "Slow" dB(A)	Max. "Peak" dB(Lin.)
1 (Slow Typing)	1 min.	62,8	80,6	75,2	93,6
	3 min.	62,8	85,3	75,2	93,7
2 (Rapid Typing)	1 min.	68,1	85,9	82,0	93,6
	3 min.	63,4	86,0	82,0	93,6

811147

Table 3.1. Measurement results from the example

The sample of text was typed twice; the first time slowly (taking 3 min), and the second time quickly (taking 1 min), i.e. the same key strokes were used in both cases resulting in the same noise but over different time periods. Readings were taken during both trials after 1 and 3 min. In the second trial (fast typing) the 1 min of typing was followed by 2 min of silence. Background noise levels were minimized and assumed negligible. The results are shown in Table 3.1.

L_{eq}
The L_{eq} values obtained from the trials were notably different after one minute, reaching almost the same value after 3 minutes.

The noise doses referred to the measurement periods of 1 min. are different. In the first trial the noise dose corresponds to part of the total text, whilst in the second trial it corresponds to the complete text. Both noise doses referred to a measurement period of 3 min. correspond to the complete text.

SEL
The SEL values measured at 3 min. for the first trial and at 1 and 3 min. for the second trial, are almost identical

Assuming no background noise, the noise doses for the three SEL calculations (after 3 min. in the slow trial and after 1 and 3 min. in the fast trial) are identical. The time period to which they are referred is by definition 1 s, therefore the three SEL values should be identical.

Considering the two trials as two independant noise events of different durations and measuring the SEL from the begining of the event until its end, i.e. during 3 and 1 min., the values obtained in both cases are identical. This is because both noise events contain the same noise dose. This shows how the SEL can be used to directly estimate the noise dose produced by events of any duration.

Max Hold "Slow"
The two Max. Hold "Slow" values obtained are different.

The Max. "Slow" value is the maximum RMS value measured with a 1 s time constant. In the second trial the strokes from the typewriter are closer than in the first one and therefore the Max. value is higher.

Max. Hold "Peak"
The two Max. "Peak" values are identical for both trials

The "Peak" value is the maximum level of the signal (rise time $<30\mu s$), and for a typewriter it is determined by a single stroke. The strokes are identical in both cases (electricaly determined), only the repetition rate changes.

4. USE WITH OTHER INSTRUMENTS

Different instruments can be connected to the AC OUTPUT of the Sound Level Meter, for example a level or tape recorder, earphones, etc. Use with B & K Level Recorder Type 2306 and Tape Recorder Type 7005/06 is described in the following sections.

4.1. USE WITH LEVEL RECORDER TYPE 2306

Fig. 4.1. Portable Level Recorder Type 2306

1. Carry out preliminary checks and fit a 50 dB Log potentiometer on the Level Recorder (see 2306 Instruction Manual).

2. Set the controls on the Level Recorder as follows:

RECORDING MODE:	"AC Log."
SENSITIVITY:	To be adjusted later
DC LIN. POSITION:	Irrelevant
PAPER SPEED:	"3 mm/s" (for example)
WRITING SPEED/LF Limit:	"250 mm/s"
PAPER DRIVE:	"Off"
POWER:	"Off"
PEN DRIVE:	"Off"
GROUND + – :	Irrelevant

3. On the Sound Level Meter, set:

FUNCTION:	"L_{eq}"
RANGE:	"65 - 125"
MODE:	"Run"
POWER:	"Off"

4. Connect the AC OUTPUT of the Sound Level Meter to the SIGNAL INPUT socket of the Level Recorder using the cable AO 0173

5. Place the Sound Level Calibrator Type 4230 onto the microphone and check the calibration (93,8 ± 0,1 dB on display; see section 3.4).

   The difference between the reference level and the maximum range value is 125 – 93,8 = 31,2 dB.

6. Set the PEN DRIVE, PAPER DRIVE and POWER switches to "On".

7. Start the Sound Level Calibrator and adjust the SENSITIVITY knob of the Level Recorder to obtain a pen deflection of 31,2 dB below full scale line of the recording paper (see Fig.4.2).

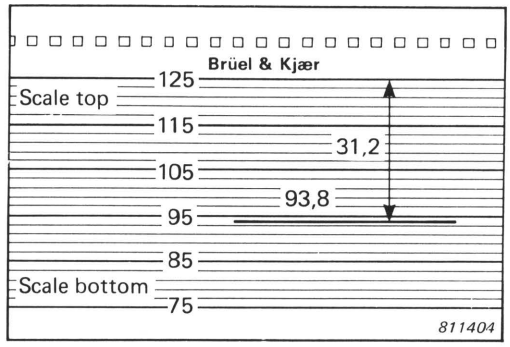


Fig. 4.2. Calibration of the Level Recorder Type 2306

The pen deflection of the Level Recorder is now calibrated and full scale on paper corresponds to the maximum of the measurement range selected on the Sound Level Meter. Do not readjust SENSITIVITY. The recording amplitude on the paper is determined by the range potentiometer fitted to the Level Recorder (50 dB).

Note: The three positions L_{eq}, SEL and Max. Hold "Fast/Slow" will give the same A-weighted signal at the AC OUTPUT. The Max. hold "Peak" position will give the L-weighted (Linear) signal. See Fig.4.3.

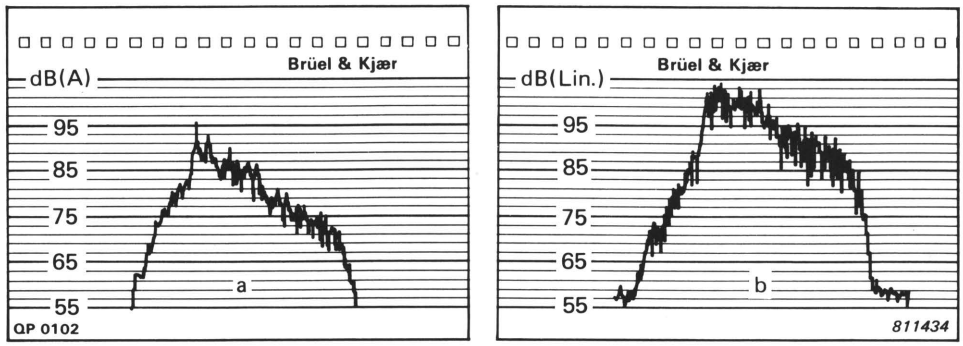


Fig. 4.3. a) Examples of recording with A-weighting (L_{eq}, SEL, Fast/Slow)
b) Examples of recording with Linear weighting

4.2. USE WITH TAPE RECORDER 7005/06

In this section only the specific settings for recording with the 2221/22 are given. For further explanation and characteristics of the recording, please consult the 7005/06 Instruction Manual.

Check calibration of the 2221/22 (see section 3.4) and carry out the preliminary checks on the Tape Recorder as described in the 7005/06 Instruction Manual. Connect the 2221/22 to INPUT socket of the Recorder Unit chosen for recording (use cable AO 0173).

4.2.1. Recording with Direct or FM Units

1. Set the controls of the Sound Level Meter as follows:
   FUNCTION: "L_{eq}"
   L_{eq} RANGE: "65-125"
   MODE: "Run"
   POWER: "On"

2. Set the controls of the recording channel of the Tape Recorder as follows:
   MODE SWITCH: "AC" or "DC"
   INPUT ATTENUATOR: "0 dB"
   METER-MONITOR SWITCH: to the corresponding channel

Make sure the INPUT SWITCH on the Compander Unit is set to "Off" position.

Fit the Sound Level Source over the microphone and start the Source. Using the small screw-driver supplied adjust the VAR. GAIN potentiometer of the FM or Direct Unit until a record level of approximately "0 dB" is indicated, and record this level as reference.

The record range obtained depends on the L_{eq} RANGE setting on the Sound Level Meter and the INPUT ATT. setting on the Recording Unit. See Table 4.1.

INPUT ATT. Type 7005/06	**L_{eq} RANGE Type 2221/22**			
	25 – 85	**45 – 105**	**65 – 125**	**85 – 145**
0	25 – 55 (53,8)	45 – 75 (73,8)	65 – 95 (93,8)	85 – 115 (113,8)
10	30 – 65 (63,8)	50 – 85 (83,8)	70 – 105 (103,8)	90 – 125 (123,8)
20	40 – 75 (73,8)	60 – 95 (93,8)	80 – 115 (113,8)	100 – 135 (133,8)
30	50 – 85 (83,8)	70 – 105 (103,8)	90 – 125 (123,8)	110 – 145 (143,8)

Table 4.1. Recording range with Direct or FM Units. The equivalent sound pressure level of the recorded reference on play back is indicated in parentheses ()

With L_{eq} RANGE on "65-125 dB" and INPUT ATT. on "0 dB", the recording range is approximately 65-95 dB. The recording range is shifted down when setting the L_{eq} RANGE to a lower value, and up when setting to a higher value. The range will be shifted up by 10 dB when increasing the INPUT ATT. (provided the measuring range of the meter is not exceeded).

Example: L_{eq} RANGE "65-125 dB" and INPUT ATT. "30 dB" gives a recording range of 90-125 dB (125 dB being the higher limit of the measuring range).

4.2.2. Recording with the Compander Unit

Connect the cable AO 0173 to DIRECT INPUT of the relevant channel of the Compander Unit.

1. Set the controls of the 2221/22 as follows:
   FUNCTION: "L_{eq}"
   L_{eq} RANGE: "65-125"
   MODE: "Run"
   POWER: "On"

2. Set the controls of the recording channel of the Tape Recorder as follows:
   INPUT SWITCH: "Lin."
   COMPANDER MODE: see 7005/06 Instruction Manual
   INPUT ATTENUATOR: "0,1 V"
   METER-MONITOR SWITCH: to the corresponding channel

3. Fit the Sound Level Source over the microphone and start the Source. Record this signal for reference.

The record range obtained depends on the L_{eq} RANGE setting on the Sound Level Meter and of the INPUT ATT. setting on the Compander Unit. See Table 4.2.

INPUT ATT. Type 7005/06	**L_{eq} RANGE Type 2221/22**			
	25 – 85	**45 – 105**	**65 – 125**	**85 – 145**
0,1V	25 – 60 (53,8)	45 – 80 (73,8)	65 – 100 (93,8)	85 – 120 (113,8)
1 V	25 – 80 (73,8)	45 – 100 (93,8)	65 – 120 (113,8)	85 – 140 (133,8)

Table 4.2. Recording range with Compander Unit. The equivalent sound pressure level of the recorded reference on play back is indicated in parentheses ()

5. APPENDIX

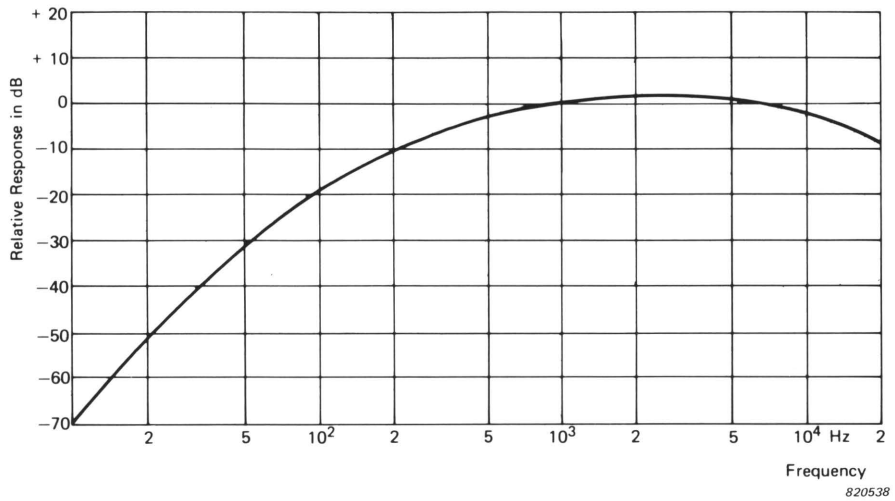


Fig. 5.1. Nominal A-weighting frequency characteristics

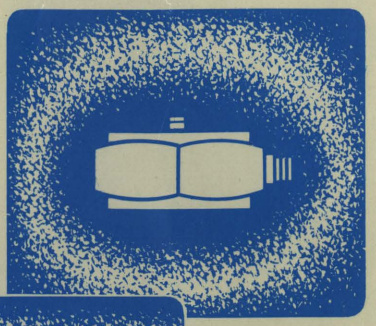
Time weighting	Duration of test tone burst (ms)	Maximum response to test tone burst referred to response to continuous signal (dB)	Tolerance (dB)
	Continuous	0	
F (Type 2221)	200	− 1,0	± 1
	50	− 4,8	± 2
	20	− 8,3	± 2
	5	− 14,1	± 2
S (Type 2222)	2000	− 0,6	+ 0,5 − 1
	500	− 4,1	± 1
	200	− 7,4	± 2
	50	− 13,1	± 2

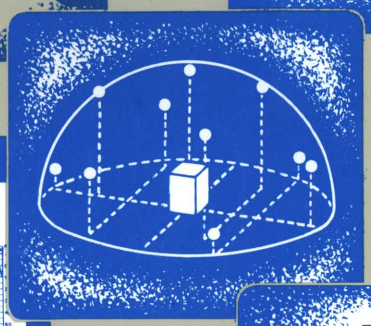
820536

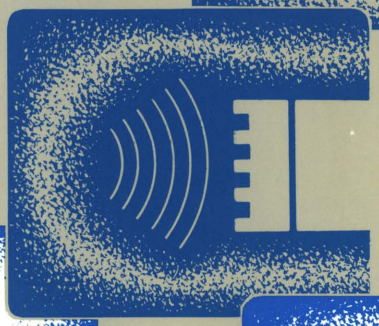
Fig. 5.2. Fast and Slow Detector Response to tone bursts

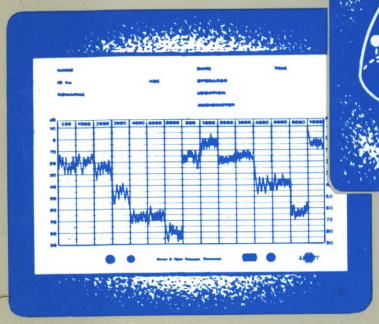
6. SERVICE AND REPAIR

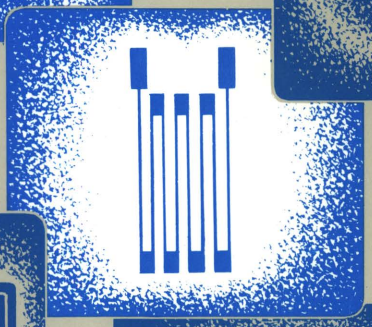
Types 2221 and 2222 are designed and constructed to provide the user with many years of reliable operation. However, should a fault occur which impairs their correct function, then their internal batteries should be removed to prevent risk of further damage. For repair consult the separate Service Instruction Manual available for the Types 2221 and 2222 or contact your local B & K service representative. Under no circumstances should repair be attempted by persons not qualified in the service of electronic instrumentation.

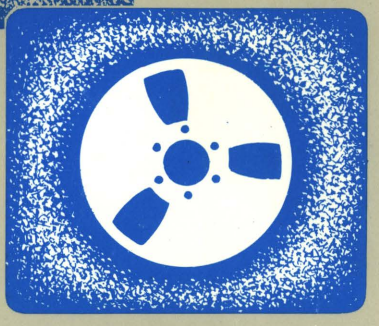


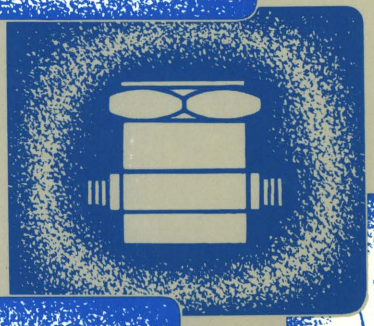


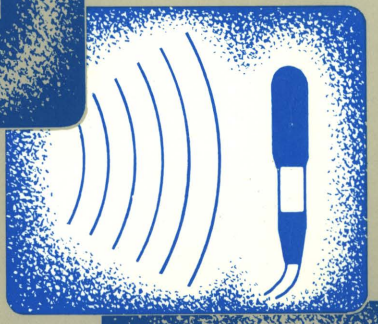


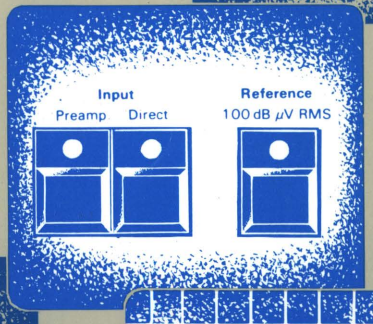


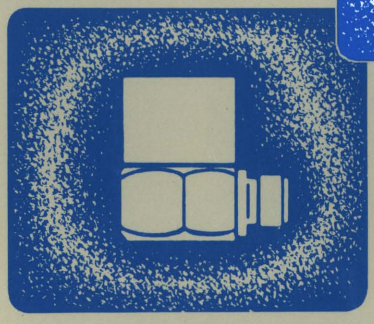


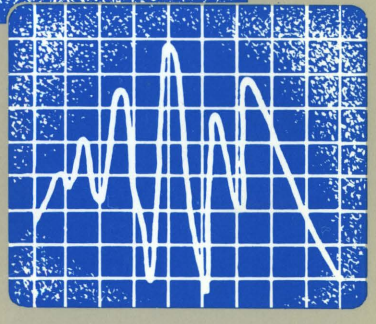


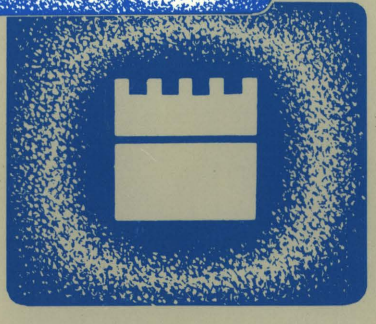












Brüel & Kjær DK-2850 NÆRUM, DENMARK · Telephone: + 452800500 · Telex: 37316 bruka dk

Printed in Denmark by Nærum Offset