2205

INSTRUCTIONS AND APPLICATIONS

Sound Level Meter Type 2205



A small and handy meter that has A, B and C weighting networks and meets the requirements of IEC Recommendation 123 for sound level meters.

- Accelerometers
- Acoustic Standing Wave Apparatus
- Artificial Ears
- Artificial Voices
- Audio Frequency Response Tracers
- Audio Frequency Spectrometers
- Audio Frequency Vacuum-Tube Voltmeters
- Automatic A. F. Response and Spectrum Recorders
- Band-Pass Filter Sets
- Beat Frequency Oscillators
- Complex Modulus Apparatus
- Condenser Microphones
- Deviation Bridges
- Distortion Measuring Bridges
- FM-Tape Recorders
- Frequency Analyzers
- Frequency Measuring Bridges
- Hearing Aid Test Apparatus
- Heterodyne Voltmeters
- Level Recorders
- Megohmmeters
- Microphone Accessories
- Microphone Amplifiers
- Microphone Calibration Apparatus
- Mobile Laboratories
- Noise Generators
- Noise Limit Indicators
- Pistonphones
- Polar Diagram Recorders
- Preamplifiers
- Precision Sound Level Meters
- Recording Paper
- Strain Gage Apparatus and Accessories
- Stroboscopes
- Variable Frequency Rejection Filters
- Vibration Pick-ups
- Vibration Pick-up Preamplifiers
- Wide Range Vacuum Tube Voltmeters
- Vibration Programmers
- Vibration Control Signal Selectors
- Vibration Control Generators
- Vibration Meters

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The Sound Level Meter

Type 2205

November 1968

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1. General

Introduction

Sound Level Meters are a quick and efficient means of determining noise levels whether they be concerned with vehicles, unsatisfactory working conditions, or health hazards, etc. Hence they are the ideal tool for noise abatement engineers, traffic police, industrial hygienists, public health inspectors and other people whose concern it is to keep noise to a tolerable level in today's industrial society.

The portable and simply operated sound level meter can be used to advantage in the initial survey of noisy environments and then, if the survey shows it is necessary, a more detailed analysis, using more powerful instrumentation, can be made later. Effective noise control usually requires this subsequent detailed analysis and a Brüel & Kjær catalog should be consulted for information on the complete range of acoustical instrumentation available.

Basic Acoustics

Sound can be looked upon from two viewpoints. It may be considered as a transmission of energy through a solid, liquid or gaseous medium, in the form of vibrations which constitute variations in pressure or the positions of the particles in the medium, or it may be considered as the auditory sensation which results when such vibrations, normally in air, impinge on the ear.

Frequency

One characteristic of a pure tone sound is its frequency. This is the number of times the pressure variations occur in the medium per second, and is denoted Hertz (Hz) or cycles per second. A low pitched or base note has a low frequency; a high pitched note has a high frequency. Frequency and pitch (the subjective measure of frequency) are closely related.

Amplitude

The second characteristic of a pure tone is its amplitude. This is the strength of the pressure variations in the medium, and is related to the loudness or intensity of the sound. The hum of a bumble bee is of low amplitude whereas a ship's whistle is of high amplitude. The variations of pressure plotted against time for a pure tone is shown in Fig. 1.1. It can be seen from the diagram that the frequency $f = \frac{1}{T}$ where T is the time between each wave crest.

Pressure variations are usually measured in Newtons per square meter (N/m^2).

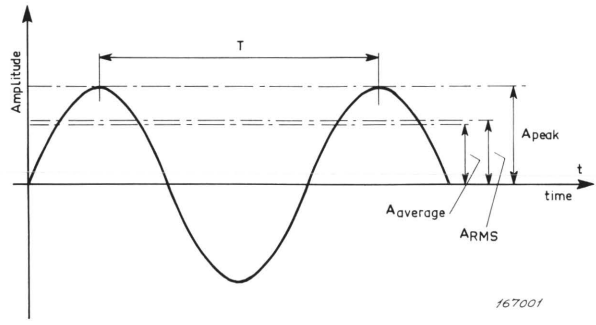


Fig. 1.1. The variation of pressure plotted against time. (A sinusoidal wave).

Noise

Noise is commonly defined as any unwanted sound. It may consist of a few or infinitely many frequencies, and can range in intensity from light conversation in a library to the roar of a jet engine at an airport.

Hearing

The human ear is a remarkably sensitive instrument. It is capable of detecting pressure variations in the frequency range 20–20,000 Hz and of handling amplitudes from 0.00002 to more than 20 N/m^2. This is a pressure ratio of more than a million to one!

The Decibel Scale

A logarithmic scale has been chosen to measure sound *partly* because the ear responds legarithmically (This means the increase in stimulus δE necessary to produce a perceptible increase in sensation δS is proportional to the total stimulus S

$$\text{i.e.} \qquad \delta S \sim \frac{\delta S}{S}$$

$$\text{or} \qquad E = c \log S)$$

and partly because the ear can handle such a wide range of pressures. Acoustical instruments for measuring pressure variations are usually calibrated in dB (decibel). A dB value is a measure of relative power, i.e. so many dB above a reference power level where

$$\text{dB} = 10 \log \frac{P}{P_o}$$

where P_o is the reference and P is the actual power measured. However, the

power transmitted by a sound wave is proportional to the square of the pressure variations, so we have

$$\text{dB} = 10 \log \frac{p^2}{p_o^2} = 20 \log \frac{p}{p_o}$$

where p_o is the reference pressure and p is the amplitude of the pressure variations. When sound pressure is measured in dB re 0.00002 N/m^2 with equal weight given to all frequencies, it is termed *sound pressure level.*

To the non technical operator the logarithmic scale just means that the range of human hearing is measured on a scale from 0 to 120 dB instead of 0.00002 to 20 N/m^2. This is very convenient.

In Table 1.2 are given some commonly encountered sound pressure levels, in order to give a better understanding of the dB scale.

The Detection of Sound

The ear may be a very sensitive instrument for the detection of sound waves but its response to a certain sound pressure depends on the frequency of the sound. The sensitivity is greatest around 1000–6000 Hz and falls off at both higher and lower frequencies.

A set of equal loudness contours is given in Fig. 1.3. The curves show the intensity levels in dB re 0.00002 N/m^2 which at various frequencies are judged by the average person to be equally loud. Other sets of equal loudness contours which deviate from these curves have been published by various investigators but the above curves have been recommended as standard by the International Organization for Standardization (ISO/R 226 –-1961 (E)).

The reference level is set up at 1000 Hz and the curves give the sound pressure level in dB necessary for a tone of different frequency to sound equally loud.

From these curves, the phon scale was derived as a measure of loudness level. In Fig. 1.3 it will be seen that the loudness level of a sound, measured in phons, is equal to the sound pressure level of a pure tone at 1000 Hz which has the same apparent loudness as the sound of interest. It will also be noticed that the lines of constant phon become straighter as the loudness level is increased.

At a level of 120 phon the ear is approximately equally sensitive to all frequencies in the audible range, while at 0 phon the variation in sound pressure level is great.

Although the response of the human ear depends on many other things besides frequency, modern sound level meters usually contain weighting networks in order to try and incorporate in the meter a frequency response similar to that of the ear. Three different curves have been internationally agreed upon and standardized. These are referred to as the A, B and C curves

Sound pressure in N/m^2	Sound level in dB		Environmental conditions
		140	
100	134 dB		Threshold of pain
		130	
			Pneumatic Chipper
		120	
10	114 dB		Loud automobile horn (dist. 1 m)
		110	
			Inside airliner (DC 6)
		100	
1	94 dB		Inside subway train (New York)
		90	
			Inside motor bus
		80	
0.1	74 dB		Average traffic on street corner
		70	
			Conversional speech
		60	
0.01	54 dB		Typical business office
		50	
			Library
		40	
0.001	34 dB		Bedroom at night
		30	
			Broadcasting studio
		20	
0.0001	14 dB		Threshold of hearing
		10	
			Living room, suburban area
0.00002		0	

Table 1.2. Some commonly encountered sound pressure levels.

and are shown in Fig. 1.4. When sound pressure is measured using one of these weighting networks and quoted in dB re 0.00002 N/m^2 it is termed *sound level.* The weighting networks used should always be stated clearly e.g. if the sound level measured using the A networks is 70 dB it should be quoted as 70 dB(A).

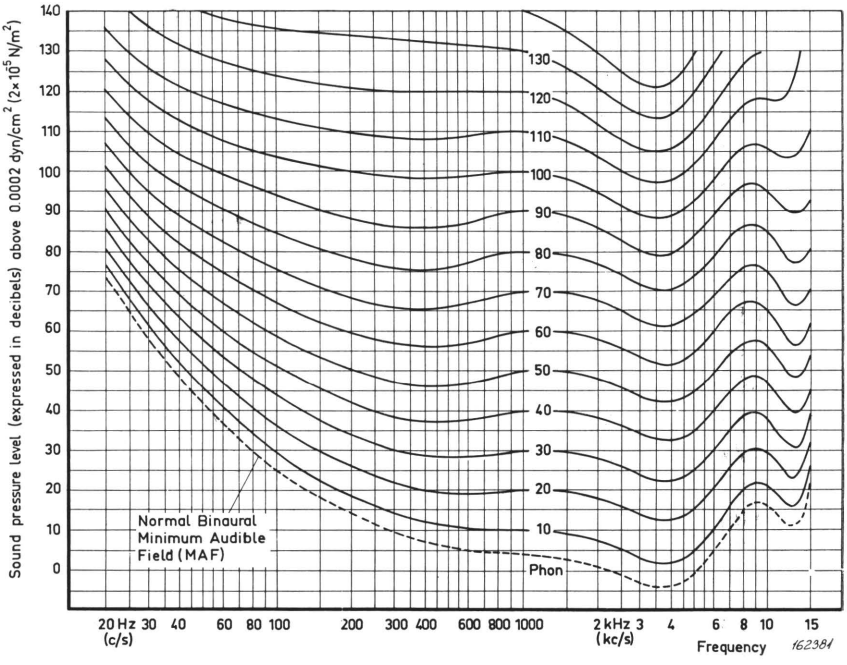


Fig. 1.3. Equal loudness contours.

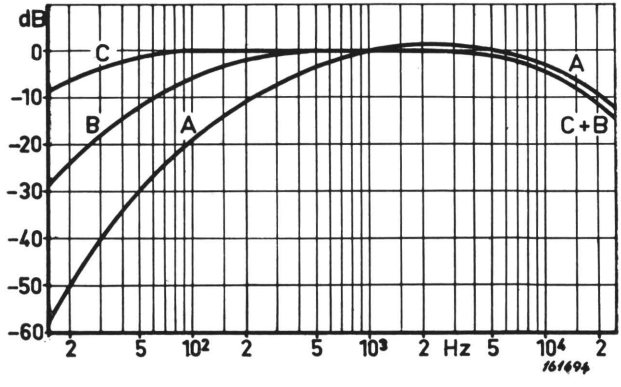


Fig. 1.4. The response of the built-in weighting networks.

2. B & K Sound Level Meter 2205

Sound Level Meters

Sound level meters are required to measure noise of different levels, spectra and waveforms under widely varying conditions of sound source distribution and reflections at the sound field boundaries. Usually the purpose of these measurements, whether they are estimating hearing damage risk, annoyance, acoustical insulation efficiency, acceptability of manufactured products or any other factor, is to collect data which will improve our understanding of the problem and also help in solving it.

Obviously an instrument giving readings that can be related to subjective impressions of loudness would be desirable. Attempts have been made in the past to design such an instrument, but in view of the difficulties involved in simulating the human hearing system for all types of noise, the International Electrotechnical Commission (IEC), has decided that the most practical solution is simply to standardize an apparatus by which sound pressure can be measured under closely defined conditions, so that results obtained by different users can be compared.

Some of the requirements of the IEC Recommendation Publication 123 are: A general purpose sound level meter shall cover the frequency range 31.5–8000 Hz and shall include at least one of the three different response curves A, B and C.

The microphone shall be omnidirectional within certain specified tolerances. The indicating meter shall be of the square law type i.e. it must be capable of correctly summing two pure tones according to the root-mean-square law.

Sound Level Meter Type 2205

The 2205 Sound Level Meter is such a general purpose instrument and is designed to make accurate sound level measurements in accordance with these IEC specifications. Its small size and high degree of stability make it ideal for use in the field and its simple operation enables the user to make valuable measurements where perhaps he has not the technical knowledge to operate a more complex instrument.

In the standard version equipped with a piezoelectric microphone, the instrument fulfils the usual standards for ordinary sound level meters (IEC Recommendation 123), but the circuitry is designed so that when a B & K 1/2" condenser microphone and adaptor are added, the instrument is brought up to full precision standards (IEC Recommendation 179). See Appendix I.

The IEC give no requirements for the dynamic range but the 2205 covers 32–140 dB SL.

All three weighting networks (A, B and C) are included in the instrument.

Technical Description of 2205
(Non-technical readers can omit the rest of this chapter).
A block diagram of the instrument is given in Fig. 2.1.

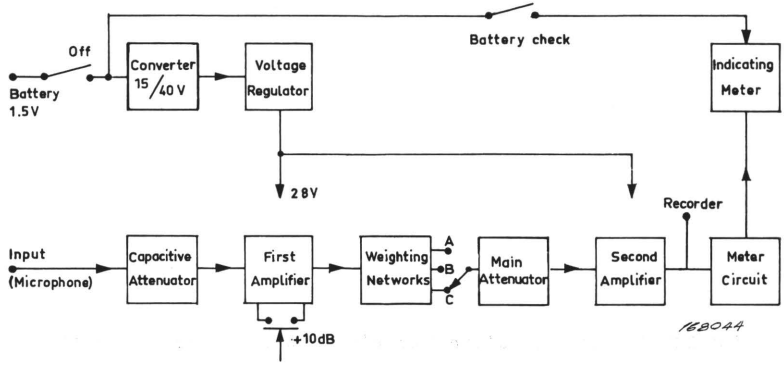


Fig. 2.1. Block diagram of the Sound Level Meter.

The instrument may be considered in the following main parts:

1) Microphone
2) Capacitive Attenuator
3) First Amplifier
4) Weighting Networks
5) Attenuator
6) Second Amplifier
7) Output socket
8) Meter circuit
9) Indicating meter
10) Power Supply

1. The Piezoelectric Microphone
The microphone supplied with the standard version is the B & K Piezoelectric Microphone Type 4117, the construction of which is shown in Fig. 2.2.
It consists essentially of a strip of piezoelectric ceramic to which a bending moment is applied by the diaphragm as it is excited by incident sound. An electrical signal across the "bender" is produced, which is led to the output terminal of the microphone. Owing to the high capacitance (4000 pF) of the microphone, it can be used with a relatively long extension cable to the meter without loss of sensitivity.

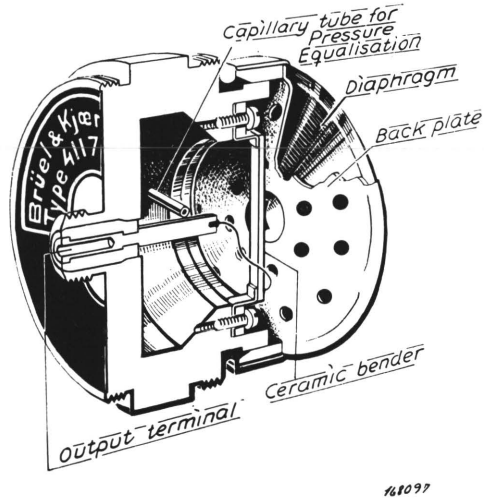


Fig. 2.2. Construction of the Piezoelectric Microphone Type 4117.

2. Capacitive Attenuator

This attenuator is operated by the single range switch of the instrument and determines the measuring range. It is coupled to the Main Attenuator and may be locked in any position to avoid mistakes due to inadvertent switching. See Chapter 3.

3. First Amplifier

The first amplifier has a gain of 45 dB. It has a field-effect transistor in the input and the noise is below 1.2 μV referred to the input. The gain can be reduced by means of the "+ 10 dB" push-button switch. When the button is depressed, the measuring range of the instrument is increased by 10 dB relative to that selected by the main range switch.

4. Weighting Networks

These are the internationally standardized A, B, C weighting networks and are made up by resistance/capacitance circuits. They are designed to give the instrument a frequency response similar to the human ear. They are very useful for scaling noises in correspondence with noise surveys, noise limit control etc., and help the noise abatement engineer to determine the existence of hearing damage risk and other criteria. The frequency characteristics of the A, B and C weighting networks are shown in Fig. 1.4.

5. Main Attenuator

This is a resistive attenuator and is the main attenuator of the instrument. It is operated by the range switch together with the capacitive attenuator mentioned above. The interconnection of the two attenuators is designed so that the 10 dB steps are obtained with the best possible signal to noise ratio. The total attenuator range is 30–120 dB sound level (re 2×10^{-5} N/m^2).

6. Second Amplifier

This amplifier has a gain of 68 dB and is used to boost the signal before feeding it to the meter circuit. It is in this amplifier that the sensitivity adjustment of the instrument is provided by means of a screwdriver operated potentiometer. This potentiometer will provide a variation of about 12 dB in meter reading.

7. Output Socket

This is a standard microsocket fitting B & K cables with microplugs e.g. AO 0037. Tape recorders or level recorders can hence be connected when measurements need to be recorded for later evaluation. The load impedance should be at least 5 kΩ. Output voltage for full scale deflection on the meter is 2.5 V RMS. Maximum peak value 10 V.

8. Meter Circuit

The meter circuit is a square law rectifier, which transforms the signal into a form suitable for the indicating meter, and provides appropriate damping. It gives the characteristic required for correct addition of sound levels at differing frequencies, being a "quasi-RMS" circuit which indicates correct RMS values within 5 % for signals with crest factors (i.e. Peak value/RMS value) up to 3 at full scale deflection. The internationally standardized "Fast" and "Slow" meter damping characteristics are provided.

9. Indicating Meter

The meter is easily readable with calibration from − 10 dB to + 10 dB over a scale length of 5.5 cm. A window at the zero mark indicates the position of the main range switch. When the "+ 10 dB" switch is depressed, 10 dB must be added to the indication at the window. The meter is a ribbon suspended, coil DC voltmeter.

10. Power Supply

Power is supplied from an ordinary 1.5 V torch battery of approximate dimensions 50 mm length and 25 mm diameter. A converter transforms this voltage to about 40 V, with the battery in new condition. This is regulated to 28 V for feeding the amplifiers. A connection from the battery to the indicating meter gives a convenient check of battery condition. The battery life is about 10 hours for continuous operation.

3. Operation of Controls

Important Note

Before attempting to dismantle any part of the instrument please read the cautionary notes after these operating instructions.

Function of Controls

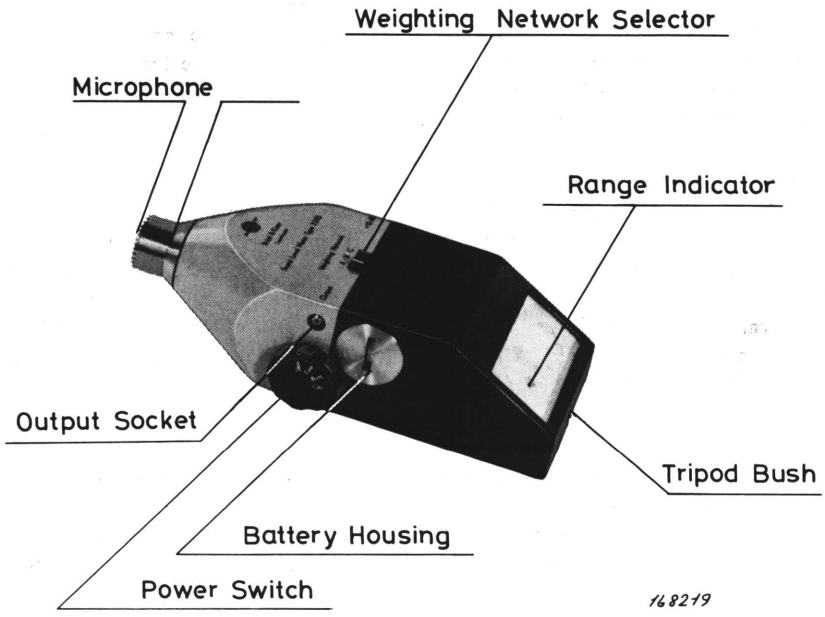


Fig. 3.1. Photograph of 2205.

BATTERY HOUSING (Fig. 3.1)

Remove the cover with the assistance of a coin, and insert a battery of the appropriate type (See Specifications, Chapter 10). Insert the battery so that its central contact (+) is to the outside. Replace the cover of the housing after first checking that the Power Switch is set to OFF.

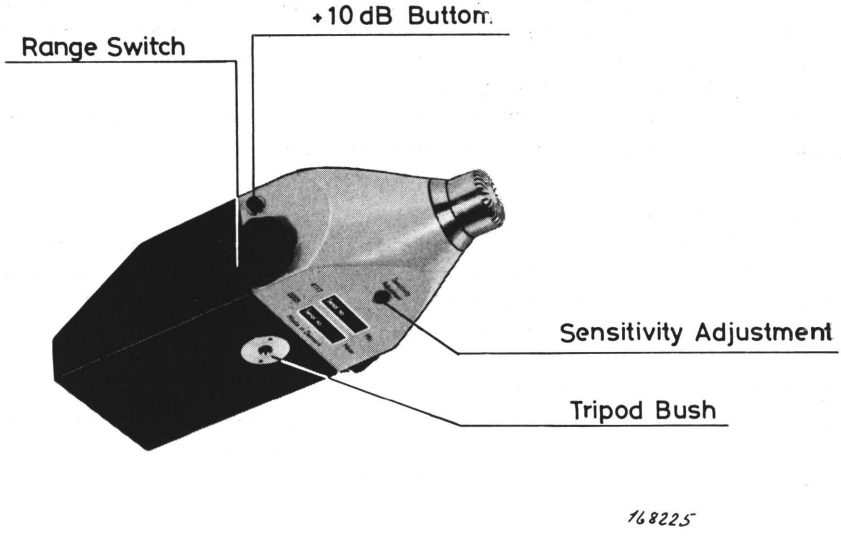


Fig. 3.2. Photograph of 2205.

RANGE SWITCH (Fig. 3.2)
This switch selects the range of sound level indicated by the meter. It has ten positions which are indicated at the small window close to the zero of the meter scale. The indication at this window gives the magnitude of the scale zero, e.g. when the meter indication is + 6 dB and the range indication at the window is 80 dB, the sound level at the microphone is 86 dB (A, B or C) provided the "+ 10 dB" Button is not depressed.

WEIGHTING NETWORK SELECTOR (Fig. 3.1)
This is a special sliding selector switch.
The choice of network to be used is left to the operator who should appreciate the particular requirements of the noise problem in hand.
The switch may, however, be locked in any position for use by non-technical people to avoid unintentional errors.

POWER SWITCH (Fig. 3.1)
Before moving this switch from the OFF position, set the Range Switch to its 120 dB position, or to some other position which is known to be above the local sound level. Marked with four positions OFF, BATT, FAST, SLOW, the Power Switch determines the signal which is displayed on the meter. Switching to position BATT gives a check on the condition of the battery. If the battery is in satisfactory condition, a meter deflection within the markings "Batt" will be obtained. This deflection will be independent of the

setting of the Range Switch, so it is possible to make a quick check of battery condition at any time. If a meter deflection is not obtained at position BATT, check that the polarity of the battery is correct.
Switching to position FAST or SLOW connects the meter to the microphone signal. The sound level in dB (A, B or C) can then be measured from the position of the Range Switch and the meter deflection.

+ 10 dB BUTTON (Fig. 3.2)
When held depressed, this button switches the range of the instrument upwards by 10 dB. This means, for example, that when the Range Switch is set to indicate 80 dB at the window of the scale, and the + 10 dB Button is depressed, the scale zero corresponds to 90 dB.

SENSITIVITY ADJUSTMENT (Fig. 3.2)
This is an adjuster operated by a small screwdriver for matching the meter indication to a calibration signal (see Chapter 5, Calibration). Once correctly set it should not be touched until the next calibration check.

TRIPOD BUSHES (Figs. 3.1 and 3.2)
Two bushes are provided which are located on the back of the instrument and below the meter scale. These can be used to mount the instrument on an ordinary photographic tripod. The thread of the bushes is 1/4" BSW.

Cautions
Always remove the protective dust cover from the microphone before measurements are made, and always replace it after use.

DO NOT REMOVE THE PROTECTION GRID FROM THE MICROPHONE. If ever the grid is removed by accident do not under any circumstances touch the microphone diaphragm. The smallest deformation of the diaphragm will affect the frequency response of the microphone.
Do not attempt to dismantle any part of the instrument unless it should prove absolutely necessary. The mechanical and electrical assemblies are designed to operate without any maintainance except the occasional calibration check. Removal of the microphone cartridge for mounting remote to the body of the instrument must be undertaken with extreme care. The contacts on the microphone mounting are gold plated for the lowest possible contact resistance. If dirt or oil has accumulated, carefully clean the contact points with alcohol, using a lightly moistened brush, or lint-free cloth. Do not allow the liquid to run. In connecting the microphone, take care that the small central contact pins on the extension cable and the meter do not sustain damage. The microphone and all adaptors should be screwed on finger tight. Do not overtighten.

Locking of Attenuators

It is possible to lock the main Range Switch of the instrument in any of its positions in order to reduce the possibility of errors in measurement. With the attenuators locked, the range of the instrument becomes approximately − 5 dB to + 20 dB relative to the number indicated at the window of the scale. The use of the + 10 dB Button is retained. The procedure for locking the attenuators, which should be followed with reference to Figs. 3.3 and 3.4, is as follows:

1. Unscrew and remove the microphone.
   (Note the cautions listed in the previous section).
2. Remove the screws which secure the front case of the instrument.

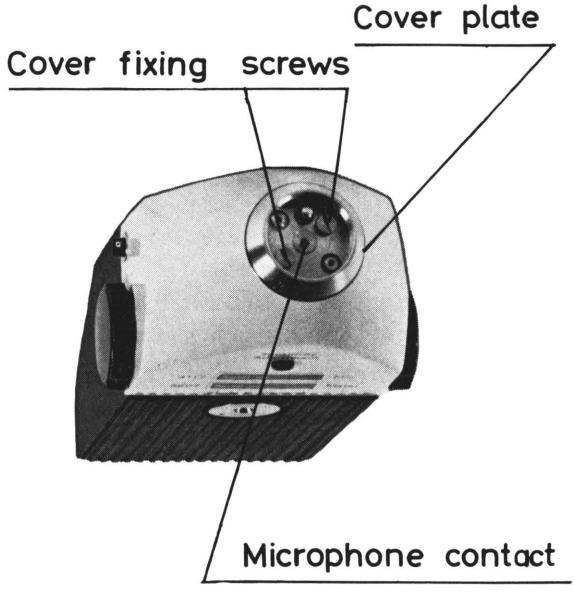


Fig. 3.3. Removal of front cover.

3. Lift off the cover plate and nylon spacing washer.
4. Remove the green front case of the instrument. Note that the + 10 dB Button fits loosely into this case and that it could be lost unless due care is taken at this stage.
6. Remove the knob of the range switch using a 1.5 mm allen key.
7. Screw the stop pin fully anticlockwise.

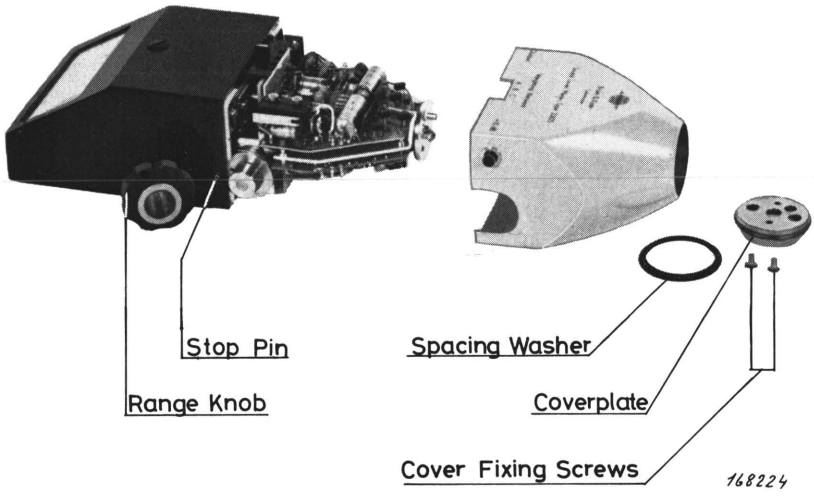


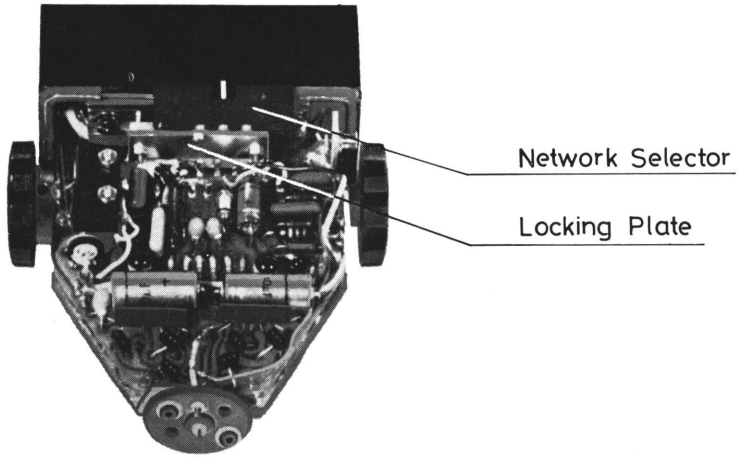
Fig. 3.4. Locking of Attenuators.

8. Set the attenuator switch to the desired position and position the knob of the range switch so that the stop pin engages the hole a the back of the knob. Lock the knob with its allen screws.
9. Replace the front cover of the instrument, taking care that the + 10 dB button is correctly positioned.
10. Replace and secure the nylon spacing washer and front cover plate.
11. Replace the microphone observing the cautions listed in the previous section of this chapter.

    NOTE: It is advisable to mark by means of a self adhesive label that the range switch of the instrument is locked. This will reduce the possibility of damage caused by forcing the switch.

Locking of Networks

First follow the above procedure for removing the outer cover. Having done this, loosen the two nuts which hold the locking plate (Fig. 3.5). Remove the locking plate, select the network required and replace the locking plate with its pin set in the respective slot. Fasten the nuts. Reassemble.
It may be advisable to put some adhesive tape over the switch to prevent it being forced while it is locked.



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Fig. 3.5. Locking of Weighting Networks.

4. Operational Procedure

General Procedure

The following general procedure should always be adopted when undertaking sound level measurements:

1. Calibrate the instrument as in chapter 5.
2. Select the weighting network to be used.
3. Point the meter at the sound source remembering to keep as far behind the meter as possible.
4. Adjust the attenuators until a meter deflection between 0 and 10 dB is obtained.
5. Read off the sound level value.

It must not be forgotten that the dB values measured apply at one particular point of the sound field only. Usually noise is measured at the point where the listener is stationed but certain test codes for machines or vehicles may stipulate that measurements be made at a particular distance from the noise source. In the test report therefore reference should be made to the particular test code used. It is wise practice also to include general information on the environmental conditions that could affect the measurements.

These may be listed as:

1. General description of the machine under test. Dimensions, type number, operating speed (r.p.m.), power rating, conditions of installation and operation.
2. Description with sketch of the room or space where the noise source is situated e.g. nature and dimensions of walls, floors, ceilings, objects in close proximity.
3. Position of measuring points.
4. Meteorogical conditions (especially if measurements are taken out of doors): ambient temperature, relative humidity, barometric pressure, wind speed.
5. Description and serial numbers of sound level meter and accessories used.
6. Results of sound level measurements including weighting networks used, Fast or Slow damping.
7. Background noise levels.
8. Sound levels corrected for background noise, if necessary.

Use of Weighting Networks

The weighting network with which the sound level has been measured should always be quoted e.g. 60 dB (A) or 58 dB (B).

Although certain weighting networks may be recommended for specific types of measurements, it is always good practice to measure and record the sound level with all three networks. As can be seen from Fig. 1.4 very low frequencies are attenuated quite severely by the A weighting network but hardly at all by the C. Thus if the measured sound level of a noise is considerably higher with the C network than with the A then it may be assumed that much of the noise is of low frequency.

The Effect of Reflection

This is one of the main environmental factors that affect noise measurements. Any object, (the operator or the instruments), the physical dimensions of which are of the order of the wavelength of the sound or larger, will reflect the sound waves and thus cause a disturbance in the sound field. When the sound field is diffuse and/or consists of many frequencies this presents no problem and the results obtained will depend mainly on the accuracy of the instrument. However, if the sound waves are free, plane or spherical, with one or two predominant frequencies there is a possibility of considerable reflections causing errors of measurement. Investigations have shown that anomalies due to such reflections are usually most marked in the frequency range 200–4000 Hz. Errors of 2–3 dB may easily result and around 400 Hz (where the maximum reflections from the human body occur) up to 6 dB may be experienced. Whether the presence of the operator has any influence on the sound level reading or not can be determined by changing the relative position of the operator and the instrument say by holding the meter to one side and observing any difference in reading. Usually, however, sufficiently accurate readings may be obtained by simply attaching the meter to the pistol grip and holding it as far out in front of you as possible. (See Fig. 4.1). If not the microphone may be moved away from the operators presence by means of the extension cable. (See Fig. 4.2).

The Effect of Background Noise

This is the other main environmental factor that affects noise measurements. If it is required to measure the noise produced by a particular piece of machinery e.g. an electric motor, best results would be obtained if it could be measured in a quiet place. However, this is not always possible so measurements often have to be taken with background noise present. If the noise level when the machine under test is shut down (i.e. the background noise level), is more than 10 dB lower than that when the machine is operating, then no correction for background noise is necessary.

When the difference between "total" noise level and background noise level is between about 10 and 3 dB an approximate correction may be made by consulting the chart shown in Fig. 4.3.

If the difference between "total" and background noise level is less than 3 dB it is advisable to move the machine to a quieter place.

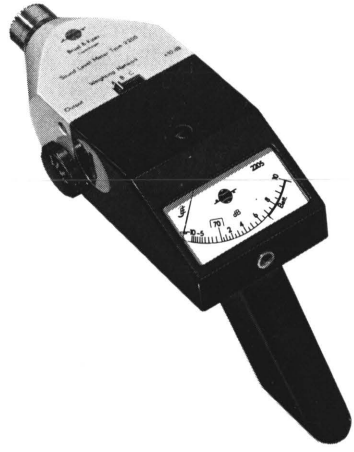


Fig. 4.1. Photograph of the Sound Level Meter and Pistol Grip Handle.

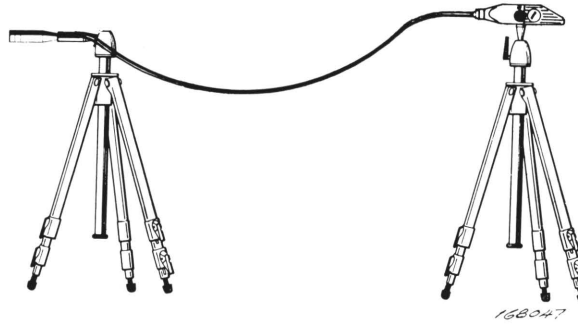


Fig. 4.2. Operation with Sound Level Meter and Microphone placed on Tripods.

Directional Characteristics

Another factor to be considered when taking measurements is the directional characteristics of the microphone. Ideally a sound level meter should have the same sensitivity for sound coming in from all directions. Unfortunately this cannot be achieved in practice except in the case of relatively low frequencies because of the size of the instrument on which the microphone is mounted or the size and shape of the microphone itself.

For higher frequencies, when the dimensions of the sound level meter are comparable to the wavelength of the sound, the sound field around the

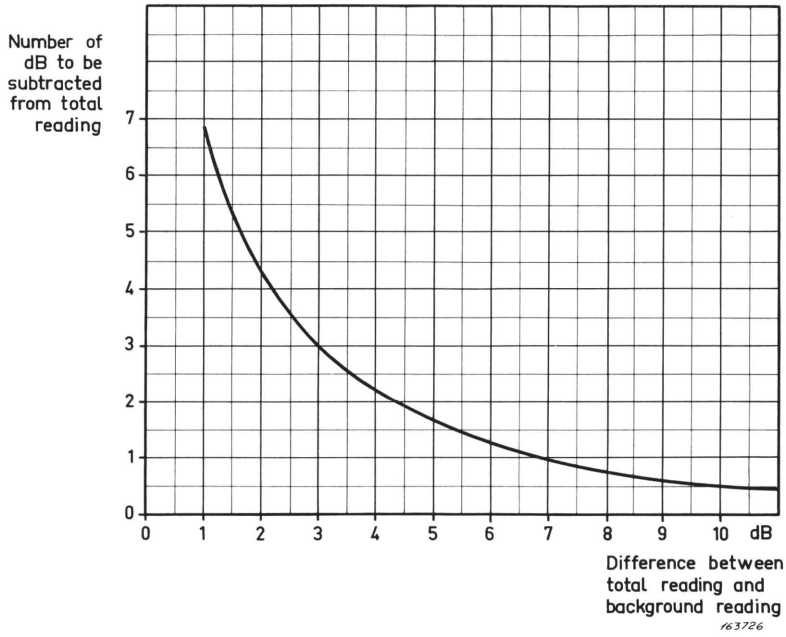


Fig. 4.3. Background Correction.

instrument will be disturbed and the pressure on the microphone diaphragm will depend on the direction from which the sound is coming.
The directional characteristics of the piezoelectric microphone Type 4117 are shown in Fig. 4.4.
As shown the variation in frequency response for varying angle of incidence is negligible for frequencies below approximately 2 kHz, while at higher frequencies the change in response is considerable. When taking sound level measurements the operator usually knows the source of the sound and automatically points the sound level meter in this direction. Consequently the directional characteristics of the instrument are not so important. Sometimes, however, it may be necessary to pay special attention to these characteristics because:–

a) Noise, even from a point source, measured in a room with hard boundaries undergoes many reflections so that the sound field is more or less diffuse.
b) The sound often originates from many sources simultaneously, take for example a machine shop.
c) Angle of incidence may vary during measurement, for example as a car passes or an aeroplane flies overhead.

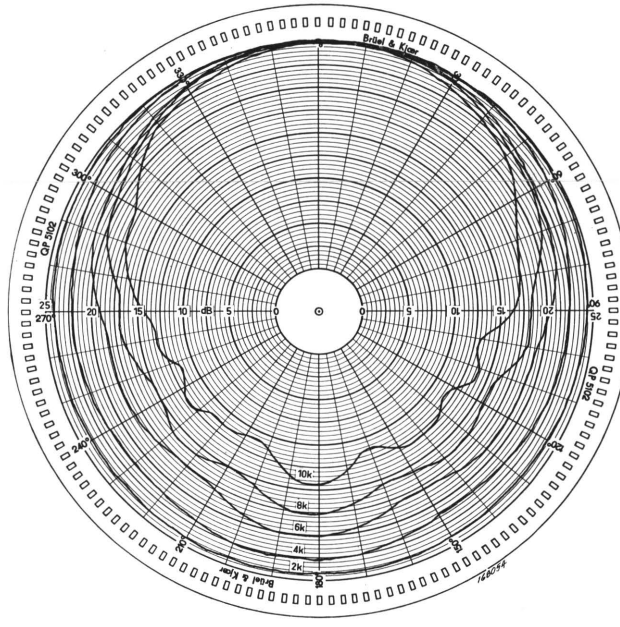


Fig. 4.4. Typical directional characteristics of the Piezoelecrtic Microphone.

In all these cases it is desirable that the sensitivity of the measuring instrument should not vary too much with the angle of incidence. Therefore when the sound contains important high frequency components it may be necessary to improve the directional characteristics of the Sound Level Meter. This may be done in various ways:–

1. The microphone extension cable can be used.
2. The omnidirectivity of a smaller microphone extends to higher frequencies than that of a larger one, consequently better high frequency characteristics are obtainable by fitting the 1/2" condenser microphone 4148. (See Appendix I).

Despite all these factors however the directional sensitivity of the piezoelectric microphone is well within the limits stated in IEC 123. (See Specifications).

5. Calibration

From time to time it may be necessary to calibrate the sound level meter. This may be done by using either the B & K Pistonphone 4220 or the B & K Sound Level Calibrator 4230. Both calibrate the whole meter including the microphone (1″ or 1/2″) and are battery driven for easy portability.

The Pistonphone Type 4220

The principle of operation is shown in Figs. 5.1 and 5.2.

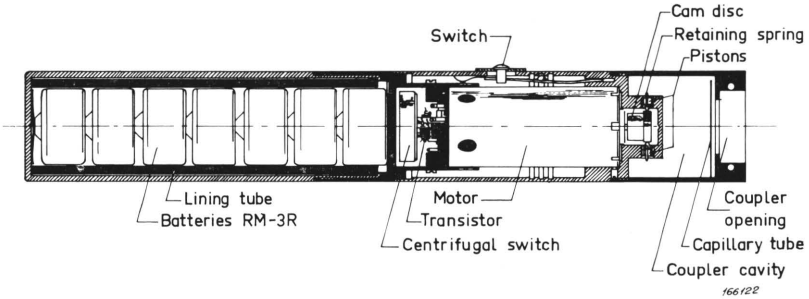


Fig. 5.1. Assembly drawing of the Pistonphone, Type 4220.

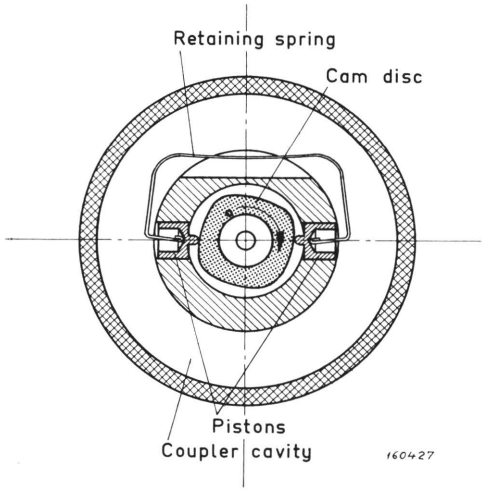


Fig. 5.2. Cross-section showing the principle of operation.

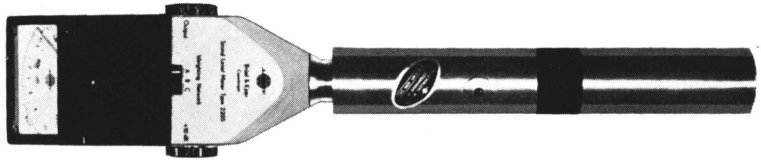
The two pistons are driven symmetrically by means of a cam disc, mounted on the shaft of a battery driven miniature electric motor. The cam, which is made of specially selected, tempered steel and machined to a high degree of accuracy, gives the pistons a sinusoidal movement at a frequency equal to four times the speed of rotation. The cavity volume is therefore varied sinusoidally and an RMS sound pressure P, produced.
The sound pressure level in dB produced at the microphone diaphragm can then be calcuted using

$$\text{S.P.L.} = 20 \log \frac{P}{P_o}$$

where P_o is the reference pressure = 0.00002 N/m^2.
The pistonphone produces a constant sound pressure level of 124 dB at 250 Hz. The only factor affecting the sound pressure level produced is the ambient atmospheric pressure. A barometer is therefore supplied with the pistonphone calibrated directly in dB to be added or subtracted from the value indicated on the pistonphone. The accuracy of calibration is ± 0.2 dB and distortion less than 3 %.
To calibrate:

NOTE: The Pistonphone (and the Calibrator) should be placed on and removed from the microphone slowly in order to avoid damage to the diaphragm.

1. Place the Pistonphone on the Sound Level Meter making sure it fits tightly. See Fig. 5.3.



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Fig. 5.3. Calibration with the Pistonphone.

2. On the sound level meter set KNOB 1 to "Fast", KNOB 2 to 120 dB and the weighting network to "C". Switch the pistonphone to "Measure". The meter should now indicate 4 dB. If it does not, adjust the sensitivity adjustment with the aid of a small screwdriver until a correct deflection is obtained. To do this it will be found best to hold the Pistonphone and meter half on and half off a bench (Fig. 5.4) so that the sensitivity adjustment hole is free for the screwdriver to be used with the other hand.
3. When adjustment has been completed, switch the Pistonphone off and slide it off the Sound Level Meter slowly in order not to suck out the delicate diaphragm.

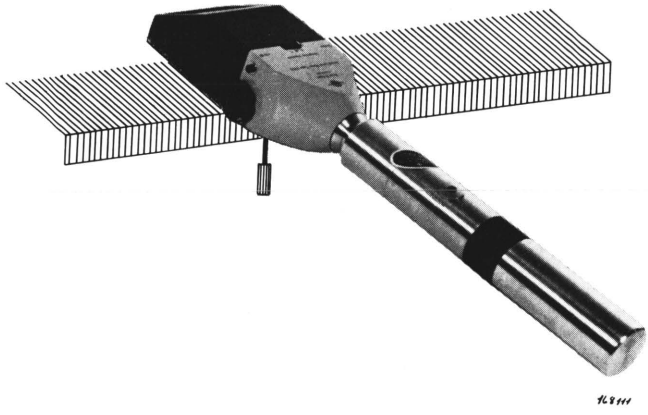


Fig. 5.4. Sensitivity Adjustment.

For important barometric or altimetric changes in the ambient pressure, a correction must be made. A barometer, graduated both in dB of correction and mm of Hg is supplied for this purpose.

The Sound Level Calibrator Type 4230

The Calibrator operates in a reverse way to the piezoelectric microphone. An alternating potential difference is applied across the piezoelectric ceramic

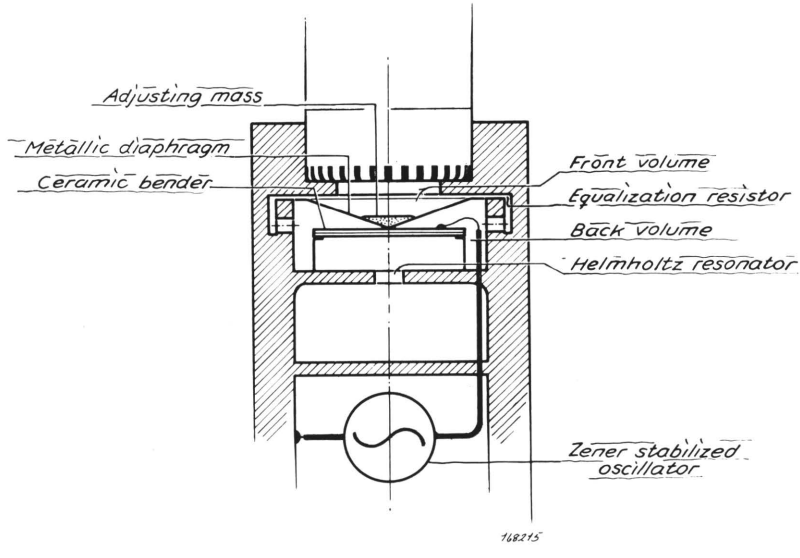


Fig. 5.5. Schematic of the Calibrator Type 4230.

which causes a bending moment to be produced in it. The "bender" then causes the diaphragm to vibrate and produce a sound pressure in the coupler volume.

The Calibrator calibrates the meter at 1000 Hz (± 2 %) and thus is independent of the weighting networks. The pressure produced is 94 ± 0.3 dB (= 10 μbar or 1 N/m^2).

To calibrate:

1. Place the Calibrator on the Sound Level Meter.
2. On the meter set KNOB 1 to "Fast" and KNOB 2 to 90 dB. Press the button on the calibrator and the meter should indicate 4 dB. If it does not a similar adjustment procedure as given above for the Pistonphone, should be followed.

The influence of static pressure is very small, thus the calibration signal is virtually independent of barometric pressure, or altitude for ordinary use.

The calibration may also be regarded as independent of temperature for most applications since the piezoelectric material used for the "bender" has a very low temperature coefficient which gives the system an overall coefficient of 0.003 dB/°C for 0 to 40°C.

6. Applications

Noise Measurements

The measurement of noise is the prime function of the instrument, hence it is designed to be easily portable so that measurements can be taken continuously without fatigue.

Most countries now have their own regulations on how to measure noise and what levels are permissible. Hence, if the results are for official use, the user is referred to these regulations for more information before starting measurements. An example of the regulations for the control of vehicle noise is given below.

Vehicle Noise Control

Social surveys in towns have shown that noise, especially that from vehicles, is one of the most undesirable by-products of modern society. In order to reduce the noise produced by individual vehicles, certain restrictions have been laid down in many countries. Such restrictions generally demand the noise produced by a vehicle to be below specified limits when measured in a prescribed manner (a typical such limit is 85 dB (A)).

Three measurement methods have been internationally accepted and have been published in the form of an I.S.O.-Recommendation (R. 362). One of these is, however, given preference because it is related to normal driving conditions, and this method is sometimes termed the *moving vehicle test.* The second method is a stationary vehicle test, and when this test is used the relationship between the result obtained and that of the moving vehicle test should be established for typical examples of the vehicle model concerned. The third method concerns measurements with the vehicle in motion under conditions which are different from the ISO reference test. In the following some details of the reference moving vehicle test will be outlined.

From a number of carefully controlled psycho-acoustic experiments it has been found that relatively good correlation exists between subjective assessment of motor vehicle noise and sound level meter readings obtained with the A-weighting network inserted. Even though deviations from this correlation in some cases (especially in the case of motorcycles) become very significant the international recommendation is based on the use of dB (A) as the measuring unit.

A suitable acoustical environment for the measurements would consist of an open space of some 50 m radius, of which the central 20 m, for example would consist of concrete, asphalt or equivalent material. Acoustical focussing

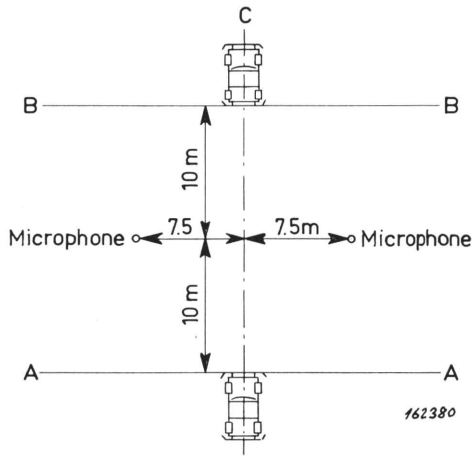


Fig. 6.1. Typical test site used for the moving vehicle test recommended by ISO.

effects and sites between parallel walls should be avoided. It is also important that wind and wind noise do not affect the measurements and the background noise level should be at least 10 dB below that produced by the test vehicle. Fig. 5.12 shows a sketch of a typical test site. The vehicle should follow the path C–C, and the microphones should be located 1.2 m above the ground level. When the front of the vehicle reaches the position indicated in the figure by the line A–A the throttle should be fully opened and held there until the rear of the vehicle reaches the line marked B–B. *At least two measurements should be made on each side of the vehicle as it passes the measuring positions.*

The vehicle should be driven in second gear (or third gear if it has more than 4 gears) at a speed corresponding to 3/4 of the maximum engine speed, or at 50 km/h, whichever is the lowest.

The measurement report should, apart from the sound level meter readings, also include details on the state of loading of the vehicle as well as the basis of horse power rating.

Measurement of Vibration

The 2205 may be used for comparative measurements of vibration. It can be seen that by using the C weighting network over the range 50–5,000 Hz the frequency response is linear.

A 4319 Accelerometer Set which uses a 4339 Accelerometer is suitable for this purpose. See Fig. 6.2.

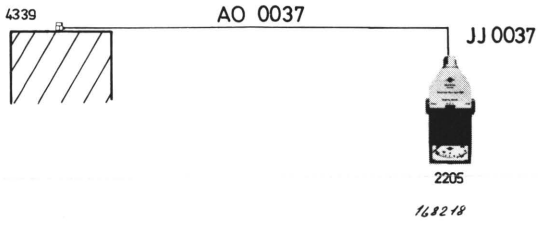


Fig. 6.2. Use with accelerometer.

Tape Recording of Sound and Vibration Data

Sound and vibration data often yield maximum information when stored on a tape recording. By forming the tape into a loop, transient phenomena, such as sound from a passing vehicle, reverberation after a gun-shot etc., can be played back continuously and analysed with B & K frequency or spectrum analysers (e.g. Types 2107 or 2112).

The 2205 is ideally suited for feeding the 7001 Tape Recorder, or a battery operated model. The Sound Level Meter OUTPUT socket should be connected to a tape recorder having an input impedance of at least 5,000 Ω.

With such a load the maximum peak output voltage is 10 V and full scale deflection on the meter corresponds to about 2.5 V RMS regardless of knob setting. 1 V RMS output is therefore indicated roughly by the 2 dB graduation on the meter scale and since many instrumentation tape recorders require a nominal recording level of 1 V RMS the Sound Level Meter is an excellent recording-level monitor. Moreover it is an ideal "calibrated source" because whatever the input signal the output from the Sound Level Meter is within a suitable known range.

Even in the case of a recorder requiring 2.5 V RMS input there is little chance of peak limiting because 10 V is acceptable and this allows a crest factor of 4.

$$(\text{crest factor} = \frac{\text{peak volts}}{\text{r.m.s. volts}})$$

In the case of a tape recorder requiring a recording level less than 2.5 V, an attenuator such as the one shown in Fig. 6.3 should be inserted between the Sound Level Meter and the recorder.

Before and after the recording, a reliable spot calibration signal can be put on the tape, from a Pistonphone Type 4220 or a Calibrator Type 4230 sound pressure level of 124 dB at 250 Hz. Since the dynamic range of a tape recorder is usually comparatively small it is best to shift the Pistonphone or Calibrator signal with the aid of the Sound Level Meter attenuators, to roughly the same range as the signals of interest, noting down the shift in dB.

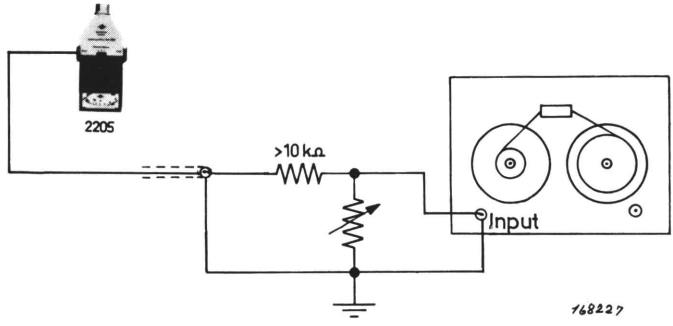


Fig. 6.3. The Sound Level Meter used with a tape recorder.

7. Accessories

The following accessories are supplied with the 2205 Sound Level Meter.

1. Pistol grip handle
2. Wrist strap.

The following are also available:–

1. Windscreen, UA 0207
2. Extension cable for piezoelectric microphone, AO 0061
3. Tripod UA 0049.
4. Miniature cable for output, AO 0037
5. Miniature to standard B & K plug adaptor, JP 0028
6. Input adaptor for accelerometer cable, JJ 0037
7. Accessories to convert the 2205 to a full precision instrument meeting all precision standards including I.E.C. 179:
   (i) 1/2" condenser microphone, 4148
   (ii) Adaptor for above, UA 0208.
   A description of these components is given in Appendix II.

Windscreen, UA 0207

When a microphone is exposed to wind, noise will be generated due to the variation of air pressure on the diaphragm. The three principal reasons for this are:

(i) the change of wind velocity
(ii) the turbulence generated around the microphone when it is placed in the wind
(III) the interference between the variations in air pressure caused by (i) and (ii).

These effects can be reduced considerably by fitting the microphone with the Windscreen Type UA 0207 (Fig. 7.1).

This is a ball of a specially prepared type of porous polyurethan sponge. It has a diameter of 9 cm (3.1/2") and should be simply pushed onto the microphone as far as it will go.

The windscreen should normally be used for all outdoor measurements and is best fitted onto the microphone when it is attached to the adaptor of the Extension Cable. The microphone can then be positioned so the diaphragm is at the centre of the windscreen. In such a position the frequency response is affected by less than 1 dB for frequencies up to 10 kHz.

The windscreen may of course be fitted onto the microphone when it is attached directly to the meter. In this case the attenuation is up to 2.5 dB at 10 kHz.

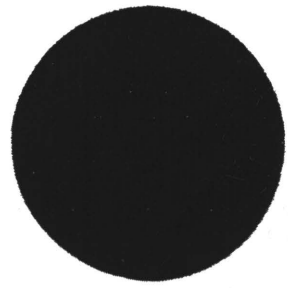


Fig. 7.1. Windscreen UA 0207.

Extension Cable AO 0061

The Extension Cable is a 6 meter (19 ft 6 in) long cable which can be used when the microphone has to be placed a greater distance away from the Sound Level Meter, or when greater flexibility is required. For precision sound level measurements it is advisable to calibrate the whole system using the Pistonphone 4220 or the Calibrator 4230.



Fig. 7.2. Extension Cable AO 0061.

Tripod UA 0049

The floor stand is a portable tripod similar to those used for photographic work. It is used for supporting the Sound Level Meter during long term measurements or when it is desirable to minimize effects of the operator on the sound field.



Fig. 7.3. Tripod UA 0049.

Miniature Cable for Output AO 0037

This is a 1.2 m (4 ft) mininoise cable fitted with miniature plugs.

Miniature/Standard B & K plug adaptor JP 0028

This is a coaxial adaptor which can be used with the output cable from the meter.

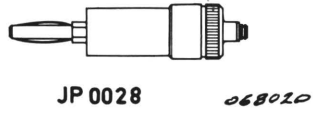
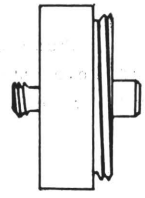


Fig. 7.4. The adaptor JP 0028.

Input Adaptor for Accelerometer Cable JJ 0037

This is simply screwed on the meter in place of the microphone so that the miniature accelerometer cable may be connected.



JJ 0037

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Fig. 7.5. The adaptor JJ 0037.

8. Appendix I

The Half-inch Condenser Microphone 4148, Input Adaptor UA 0208 and Extension Cable AO 0063

The circuitry of the 2205 is designed so that by simply adding the 1/2" condenser microphone 4148 and its adaptor UA 0208 the instrument is brought up to full precision standards (see I.E.C. 179) and is identical to the Precision Sound Level Meter 2206.

The microphone is a precision measuring condenser one designed for long term stability and high accuracy. Particular care has been taken to make it insensitive to variations in ambient conditions such as temperature, pressure and relative humidity. The construction is shown in Fig. 8.1.

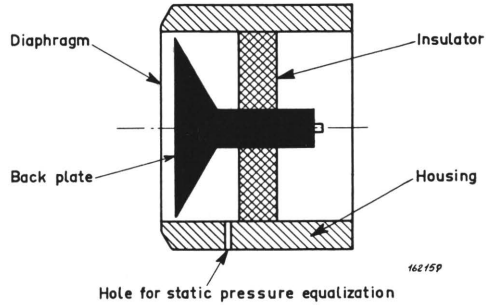


Fig. 8.1. Schematic construction of a condenser microphone cartridge.

It consists essentially of a thin metallic diaphragm mounted in close proximity to a rigid back plate. Diaphragm and back plate are electrically insulated from each other and constitute the electrodes of a capacitor (charged by a DC polarization voltage of 28 V). The charging time constant is made so high that for the frequency range of ordinary acoustical measurements the charge on the capacitor remains constant.

When the distance between the diaphragm and back plate changes due to variations in the pressure acting on the diaphragm, the capacity will also change, thus an alternating voltage is produced across the capacitor. This voltage component is proportional to the pressure fluctuations "within" the linear range of the microphone.

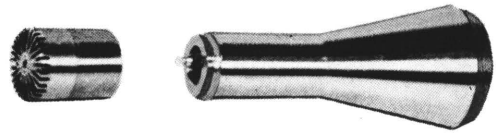


Fig. 8.2. The Condenser Microphone and adaptor UA 0208.

The condenser microphone has a low internal capacity (17 pF) and hence requires a high input impedance in the succeeding amplifier stage in order to ensure a minimum loss in sensitivity due to loading.
The adaptor is therefore a source-follower stage which contains all the circuitry necessary to adapt the 2205 to take the condenser microphone. The circuit consists of a low noise silicon field-effect transistor (FET) and one other silicon planar transistor. This stage has a very high input impedance of about 2 GΩ (2×10^9 Ω) and a low output impedance (< 50 Ω).

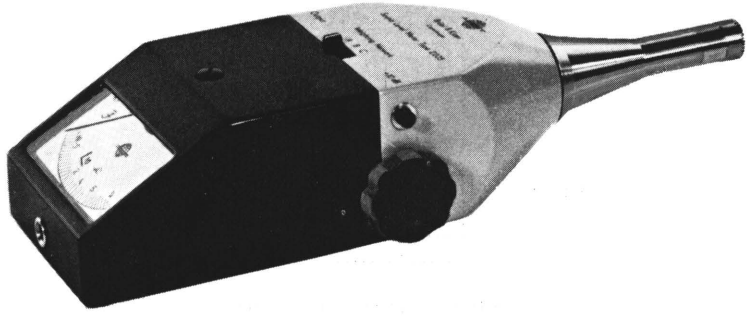


Fig. 8.3. The Condenser Microphone and adaptor fitted to the 2205.

It should be noted that the extension cable for the piezoelectric microphone may not be used. Another cable AO 0063 is available which fits between the 2205 and the adaptor UA 0208.
The revised specifications with the precision measuring fitments are those of the Precision Sound Level Meter 2206. The differences from the standard 2205 are:

Measuring Range:	37–140 dB (A)
	40–140 dB (B)
	45–140 dB (C)
Input Impedance:	$>$ 2,000 MΩ in parallel with 50 pF
Noise:	< 2 μV with 17 pF across input

Dimensions:	Length 23.5 cm (9.2 in)
	Width 8.4 cm (3.3 in)
	Height 5.1 cm (2.0 in)
Weight:	0.83 kg (29 oz) including battery

The specifications of the Microphone 4148 are:

Sensitivity:	Approximately 1.4 mV/μbar (– 57 dB re 1 V/μbar) or 14 mV per N/m^2 (– 37 dB re 1 V per N/m^2)
Capacity:	17 pF
Frequency Response:	Linear from 4 Hz to 16 kHz to within $\pm$ 2 dB at 0° incidence in a free field (see Fig. 8.4)

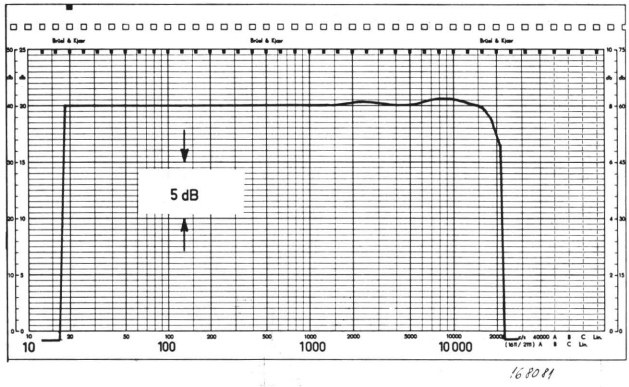


Fig. 8.4. Typical Frequency Response of the Condenser Microphone for 0° incidence.

9. Appendix II

ACCURACY OF MEASUREMENTS

The Piezoelectric Microphone 4117

The sensitivity of this microphone which is normally supplied with the 2205 is approximately 0.3 mV/μbar (– 70 dB re 1 V/μbar) or 3 mV per N/m^2 (– 50 dB re 1 V per N/m^2). It has a lienar frequency response within ± 1 dB up to 5 kHz and within ± 3 dB up to 10 kHz, at 0° incidence in a free field (see Fig. 9.1). Thus it fulfils the accuracy requirements for ordinary sound level meters (IEC 123).

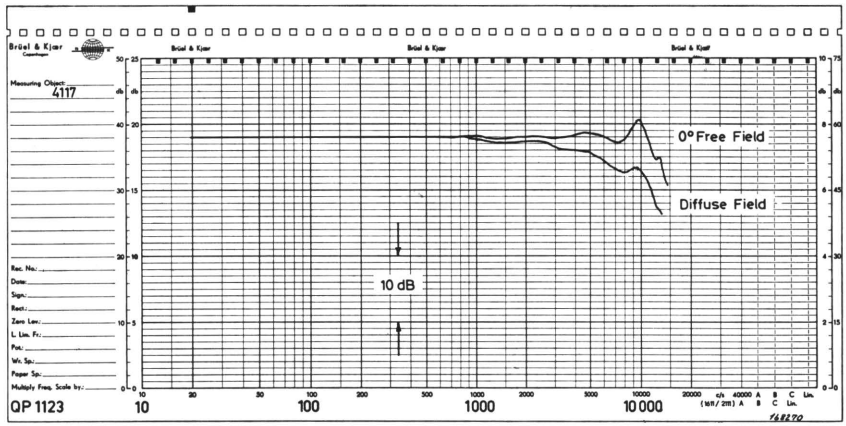


Fig. 9.1. Typical frequency response of the Piezoelectric Microphone 4117.

The microphone is supplied with a calibration chart giving complete technical specifications and an individually obtained frequency response curve as shown in Fig. 9.1. To ensure high operating stability under varying conditions of temperature and humidity the microphone diaphragm and housing are made of materials having identical temperature coefficients of expansion. The microphone as well as the amplifiers is unaffected by up to 90 % humidity as long as no condensation takes place within the instrument.

The temperature stability of the microphone is shown in Fig. 9.2. It can be seen that it is within ± 1 dB for the range – 10°C to + 50°C.

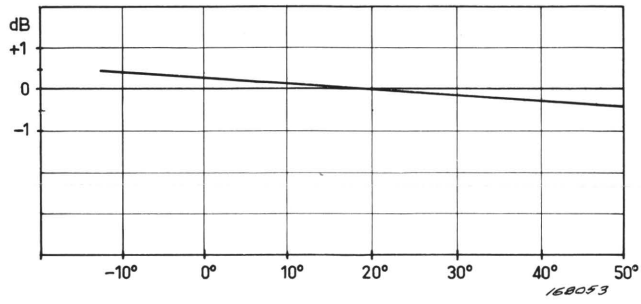


Fig. 9.2. Temperature stability curve.

The Amplifiers

The amplifiers are insensitive to variations in temperature. Within the range 15° to 45°C the amplification does not vary noticeably, and as shown in Fig. 9.3 the change is less than ± 1 dB in the range – 10° to 50°C.

The extensive use of transistors requires that the instrument should not be subjected to more than 70°C for long periods of time. Below –10° to –15°C the instrument becomes inoperative.

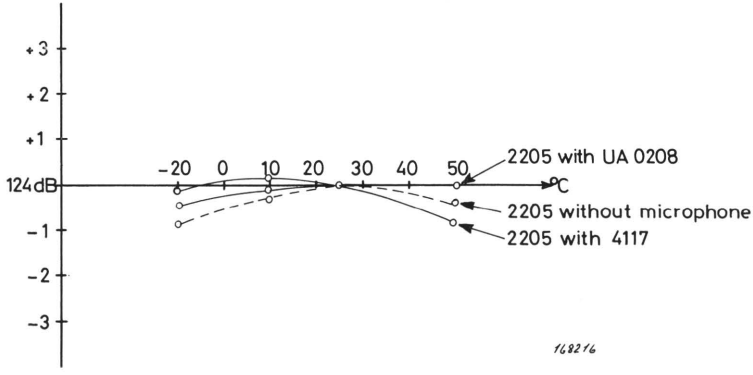


Fig. 9.3. Amplification against temperature for the 2205.

The Meter

The meter is calibrated at a temperature of about 20°C but may show a slight variation due to the temperature characteristic of the diodes in the rectifier circuit. This variation, however, is very slight in the temperature range of normal use.

The Power Supply

As long as the battery check is correct then the readings are not affected by variations of supply voltage.

The Weighting Networks

When the piezoelectric microphone is used, the 2205 complies with the network tolerances for ordinary sound level meters as recommended by IEC 123. See Figs. 9.4, 9.5, 9.6.

When the condenser microphone 4148 and its extension are used, the 2205 complies with the network tolerances for precision sound level meters as recommended by IEC 179. See Appendix I.

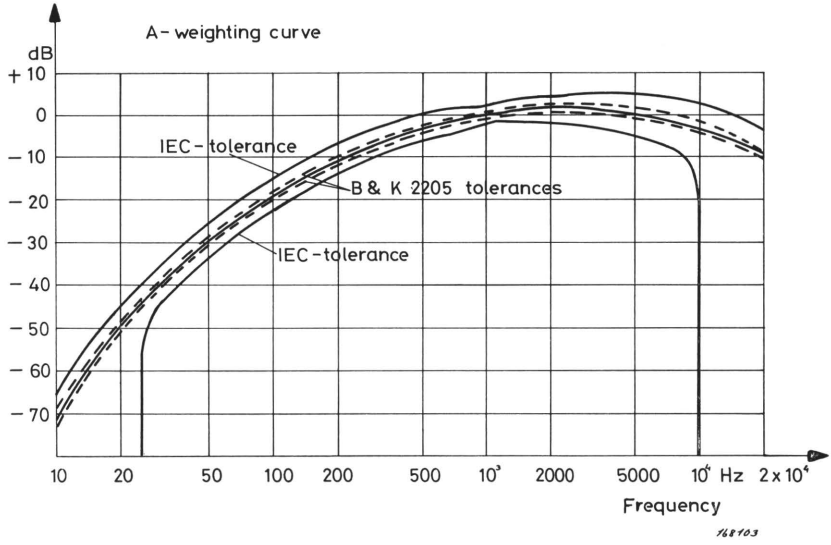


Fig. 9.4. Graph showing the tolerances of the electrical network of the 2205 about the A weighting network compared with those set by IEC 123.

Effects of Vibration

Fig. 9.7 shows the effect of vibration on the 2205 with piezoelectric microphone and Fig. 9.8 shows the effect on the meter with the microphone removed. As can be seen the sensitivity to vibrations is about 100 dB sound level for 1 g perpendicular to the microphone diaphragm.

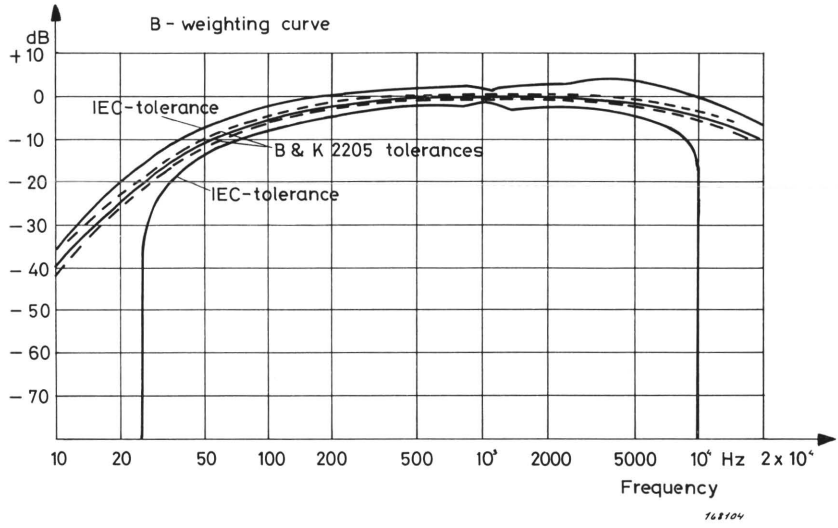


Fig. 9.5. Graph showing the tolerances of the 2205 about the B weighting network compared with those set by IEC 123.

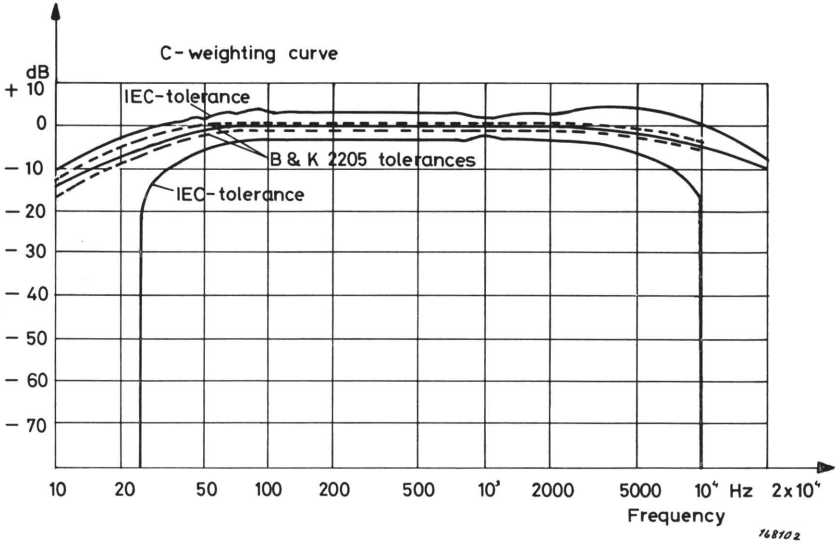


Fig. 9.6. Graph showing the tolerances of the 2205 about the C weighting network compared with those set by IEC 123.

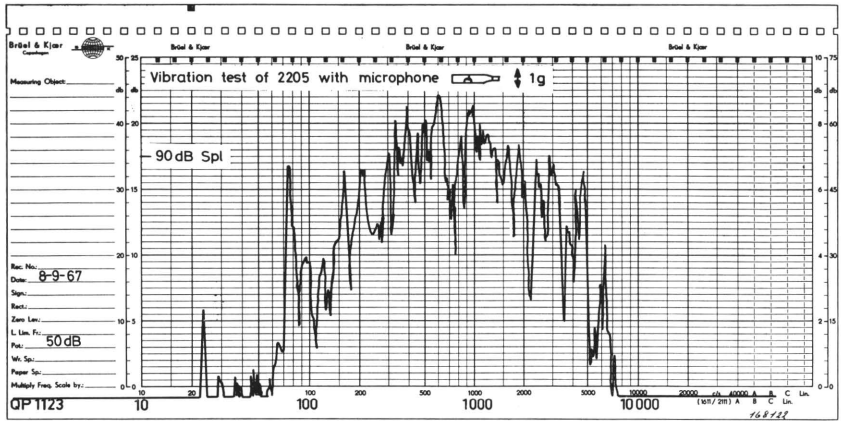


Fig. 9.7. The effect of vibration on the 2205 with piezoelectric microphone fitted.

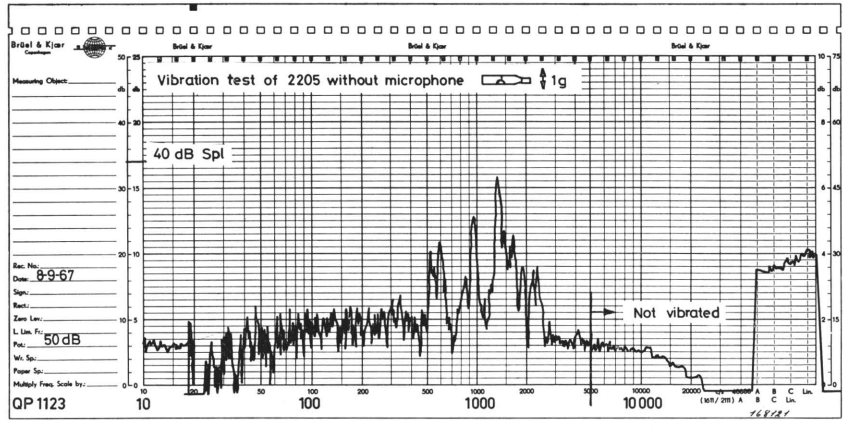


Fig. 9.8. The effect of vibration with microphone removed.

Inherent Noise Levels

The lower limit of measurement is governed by the inherent noise level of the meter itself. This of course is dependent to some extent on which weighting network is used. Fig. 9.9 gives the inherent noise for the meter without the microphone.

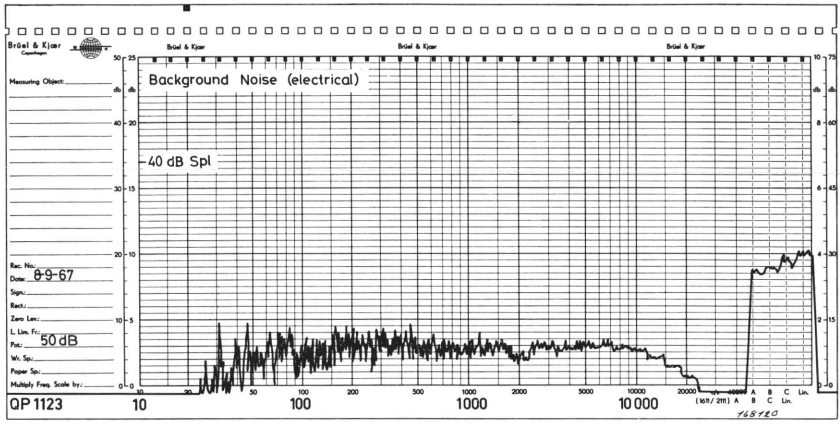


Fig. 9.9. The inherent noise of the meter with microphone replaced by 4 nF dummy.

Effects of Electric and Magnetic Fields

The sensitivity to electrostatic fields is extremely low. The sensitivity to magnetic fields is approximately 44 dB sound level for 1 Oersted.

Conclusion

As can be seen from the above paragraphs no corrections for temperature need to be made throughout the operating range –10° to 50°C. No correction is necessary either for the microphone extension cable. Care should be taken, however, not to subject the meter to undue vibration.

10. Specifications

Microphone

B & K Type 4117 Piezoelectric Microphone. Serial number located on the back of the microphone, visible with the microphone removed from the body of the meter. This number is repeated on the back of the meter with which the microphone is supplied.

Sensitivity: Approximately 0.3 mV/μB (−70 dB re 1 V/μB) or 3 mV per N/m^2 (−50 dB re 1 V per N/m^2), at 20°C.

Frequency Response: Linear within ± 1 dB up to 5 kHz and within ± 3 dB up to 10 kHz (see also Fig. 9.1). An individual calibration chart is provided with each microphone.

Capacitance: Approximately 4,000 pF.

Dynamic Range: Up to 140 dB re 2 × 10^{-4} μbar SPL (2 × 10^{-5} N/m^2).

Directional Characteristics: See also Fig. 4.3.

Frequency Hz	Directional Sensitivity ± 90° re 0° direction dB	Directional Sensitivity 90° to 180° re 0° direction dB	IEC tolerance for ± 90° *) dB
31.5 to 500	0 to − 0.5	0 to − 1	± 1
1000	0 to − 0.5	0 to − 1	± 1.5
2000	0 to − 1.0	−0.5 to − 1.5	± 4
4000	0 to − 3.0	−2.0 to − 4.0	± 8
6000	0 to − 6.0	−4.0 to − 8.0	
8000	0 to − 8.0	−6.5 to −10.0	± 15
10000	0 to −10.5	−8.5 to −14.5	

*) This tolerance is for the microphone mounted on the meter.

Vibration Sensitivity: A vibration of 1 g perpendicular to the diaphragm corresponds to an SPL of 100 dB.

Operating Temperature: −10°C to 50°C.

Temperature Coefficient: −0.015 dB per °C.

Dimensions:

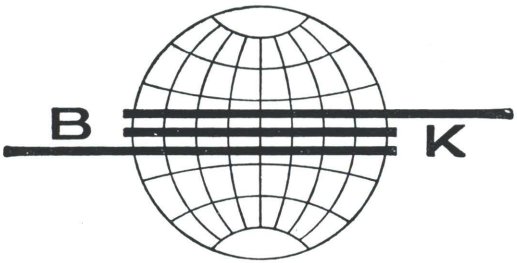
Length	20	mm (0.788 ins)
Diameter	23.77	mm (0.935 ins)
Weight	27	gm (0.95 oz)

Meter with Microphone Removed

Input Impedance:	10 MΩ in parallel with 140 pF.
Output Impedance:	$<$ 50 Ω.
Maximum Output Volts:	20 V peak to peak.
Minimum Load Impedance:	5000 Ω.
Frequency Range:	10 Hz to 20 kHz.
Warm-up Time:	4 sec.
Weighting Networks:	A, B and C.
Range Switch Error:	Main attenuator $<$ ± 0.2 dB. + 10 dB button $<$ ± 0.1 dB.
Meter Indication:	RMS. Full scale deflection for approximately 2.5 V RMS. Accuracy better than 2.5 % for pure tones. Accuracy better than 5 % for signals with crest factor less than 3.
Noise:	$<$ 1.2 μV with 4,000 pF across input..
Distortion:	$<$ 1 % at full meter deflection.
Meter Scale Calibration:	Deflection − 5 dB to − 1 dB, tolerance ± 0.5 dB Deflection 0 dB to 4 dB, tolerance ± 0.2 dB Deflection 5 dB to 10 dB, tolerance ± 0.1 dB
Battery:	1 × 1.5 Volt to IEC Type R 14. Length 50 mm (1.97 in), diameter 25 mm (1 inch). Examples: Ever Ready Type LP U11, Mallory Duracell 5 C.
Battery Life:	10 hours continuous operation.

Overall Characteristics

Dynamic Range:	32–140 dB SL.
Signal to Noise Ratio:	Better than 5 dB for the lower limit.
Operating Temperature:	− 10°C to 50°C.
Storage Temperature:	− 20°C to 70°C with battery removed.
Humidity:	0 to 90 % relative humidity.
Sensitivity to Magnetic Fields:	44 dB SL for 1 Oersted.
Sensitivity to Vibration:	100 dB SL for 1 g perpendicular to microphone diaphragm.
Dimensions:	Length 18.6 cm (7.3 in) Width 8.4 cm (3.3 in) Height 5.1 cm (2.0 in)
Weight:	800 gm (28 oz) including battery.
Accessories Supplied:	Pistolgrip Handle. Wrist-strap.



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