4117

Instructions and Applications

Piezoelectric Microphone Type 4117

High quality piezoelectric microphone for measurement and monitoring purposes. Each microphone is individually calibrated.

BRÜEL & KJÆR

030-0075

Piezoelectric Microphone

Type 4117

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Contents

1. Introduction

1.1. PURPOSE OF THE PIEZOELECTRIC MICROPHONE

The Brüel & Kjær one inch Piezoelectric Microphone Type 4117 has been designed for the general purpose Sound Level Meter Type 2205, which fulfils the requirements of the IEC Recommendation Publication 123. Reasons for choosing a piezoelectric microphone instead of a condenser microphone are its low price, its very high capacitance, and the fact that is does not require polarization voltage. This also means that it is less affected by water condensation on the back of the diaphragm than would be the condenser microphone.

All these advantages justify the use of the piezoelectric microphone as a general purpose microphone in cases where low price and good quality are desired. The microphone does not fulfil the requirements for precision sound pressure measurements, however, so in cases where this is a demand one of the B & K condenser microphones should be preferred.

1.2. DEFINITIONS OF FREE-FIELD AND PRESSURE RESPONSE

The *Free-Field Response* of a microphone is the ratio of the RMS output voltage to the RMS sound pressure existing in a free field (plane sound waves) at the microphone location with the microphone removed.

The *Pressure Response* of a microphone is the ratio of the RMS output voltage to the RMS sound pressure, uniformly applied over the diaphragm.

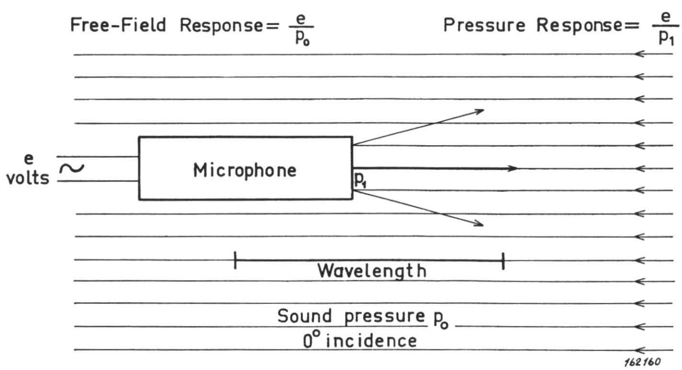

Fig. 1.1. Definitions of Free-field and Pressure Response.

The two definitions coincide for a microphone having negligible dimensions with respect to the sound wavelength. In the case of the B & K one-inch microphones this is practically fulfilled up to about 1400 Hz, where the wavelength is equal to ten times the diameter of the microphone (i.e. 240 mm). The difference in response is then a fraction of a decibel (approx. 0.6 dB).
At higher frequencies the diffractions of the sound waves on the microphone produce an appreciable change in the resulting sound pressure acting on the microphone diaphragm as illustrated in Fig. 1.1. The difference $p_1 - p_0$, called *free-field correction,* depends on the orientation of the microphone with respect to the direction of propagation of the sound and on the external dimensions of the microphone (in particular those of the front and of the fitted protective grid).
The free-field behaviour of a microphone is thus described by means of a set of free-field correction curves for various incidences, which should be added to the pressure frequency curve of the microphone in each particular case.
For microphones intended for free-field work it is possible to give the diaphragm resonance such a damping that the normal incidence free-field corrections are compensated for up to frequencies well above the resonance frequency, in order to obtain the flattest possible frequency response.

1.3. RANDOM INCIDENCE RESPONSE (DIFFUSE FIELD RESPONSE)

The random incidence response of a microphone for a given frequency is the RMS value of the free field sensitivity for all angles of incidence of the sound wave. It corresponds to the diffuse field sensitivity of the microphone, the diffuse field being a sound field in which the sound energy density is uniform and the mean acoustic power per unit area is the same in all directions. The International Electrotechnical Commission (publication no. 123, § 8.2) has given a practical rule for the calculation of the random incidence sensitivity from the free-field sensitivities at definite angles, with coefficients proportional to the relative solid angles.*)
When the spectral distribution of the sound varies with the angle of incidence, correct integration is only possible in the range where the microphone is both linear and omnidirectional. Omnidirectional microphones are also necessary in the case of rapidly moving sources (aeroplanes, motorcars, etc.).

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*) S_0, S_{30}, S_{60} ---- S_{180} being the sensitivity of the microphone at angles of incidence of 0°, 20°, 60°, ---- 180°, the random incidence (diffuse field) response S is given by the formula:

$$S^2 = 0.018\,(S_0^2 + S_{180}^2) + 0.129\,(S_{30}^2 + S_{150}^2) + 0.224\,(S_{60}^2 + S_{120}^2) + 0.258\,S_{90}^2$$

2. Description

2.1. CONSTRUCTION

The mechanical construction of the Piezoelectric Microphone Type 4117 is shown schematically in Fig. 2.1. The active element is a ceramic bender which consists of two layers of PZT (Lead Zirconium Titanate) electrically connected in parallel in order to achieve a high capacitance. The capacitance is in the order of 4 nF. The bender is supported at both ends by means of bronze ribbons to which it is soldered. The diaphragm is a thin metal foil. As the pressure from the whole diaphragm area must be transferred to a point on the bender the diaphragm is given a conical shape, which makes it very stiff and therefore act a piston. Along the edge it is corrugated, and the apex is attached to the bender by means of an epoxy resin glue.

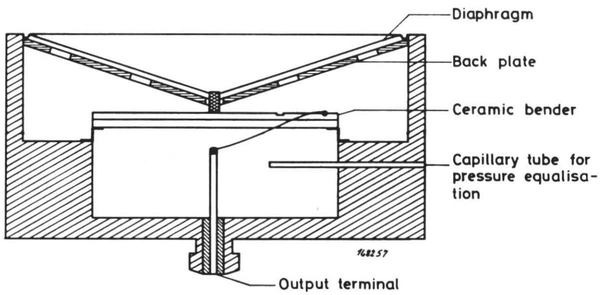

Fig. 2.1. Schematic drawing of the piezoelectric microphone.

When the microphone is exposed to a sound pressure the diaphragm vibrations are imparted to the ceramic bender as variable forces tending to bend it. Due to the piezoelectric effect a variable potential will be developed in the bender, which is proportional to the force and therefore to the sound pressure.

To dampen the natural resonances of the diaphragm and the bender, a conical back plate has been placed very close behind the diaphragm. In the back plate there are a number of holes and these together with the air in the space between the diaphragm and the back plate give the necessary damping. The spacing is adjustable and in the production calibration this is used to obtain the desired frequency response of the microphone.

At the low frequencies the response of the microphone is affected by the influence of a pressure equalization arrangement. This arrangement consists

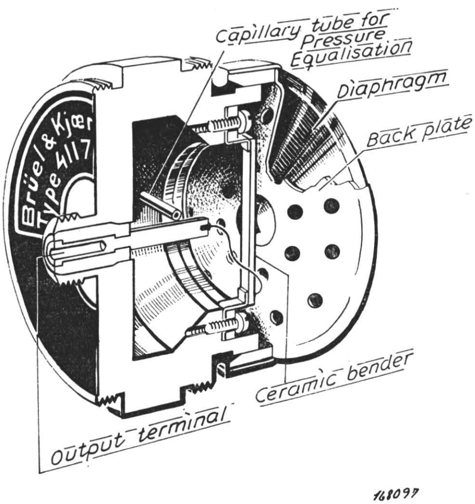

Fig. 2.2. Cut-away drawing of Type 4117.

of a capillary leakage hole through which the equalization of the static pressure on both sides of the diaphragm is obtained at a suitable rate. The hole is situated in front of the grid mounting thread. The pressure equalization is then obtained also in the case of closed cavity or flush mounting measurements. The time constant of the pressure equalization is 0.05 seconds corres-

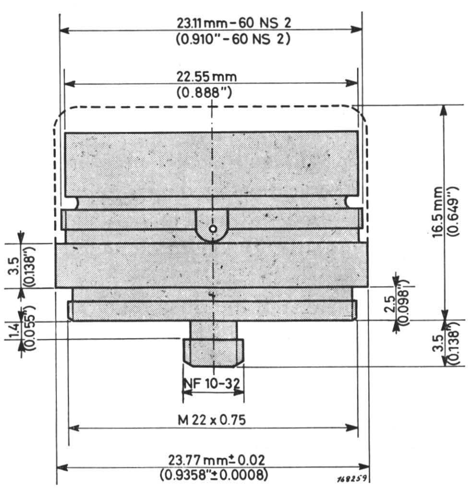

Fig. 2.3. Physical dimensions of the microphone.

ponding to a -3 dB cut-off frequency of 3 Hz approximately. The time constant may be increased, however, by inserting a thin wire in the capillary tube. The diameter of the hole is 0.25 mm (0.01 in). The physical dimensions of the microphone are shown in Fig. 2.3.

Caution

As even a light touch may damage the diaphragm of the microphone no cleaning of the diaphragm should be attempted. The grid is an effective protection against mechanical damage and should not be removed unless special adjustment of the pressure equalization is required.

2.2. SENSITIVITY

Each microphone is individually calibrated and supplied with its own calibration chart (see Fig. 2.4). The calibration is carried out at 250 Hz with a load capacitance of 100 pF. Corrections have been made for the barometric pressure so that the sensitivity is given at 760 mm Hg. The voltage sensitivity is in the order of 0.3 mV/μbar.

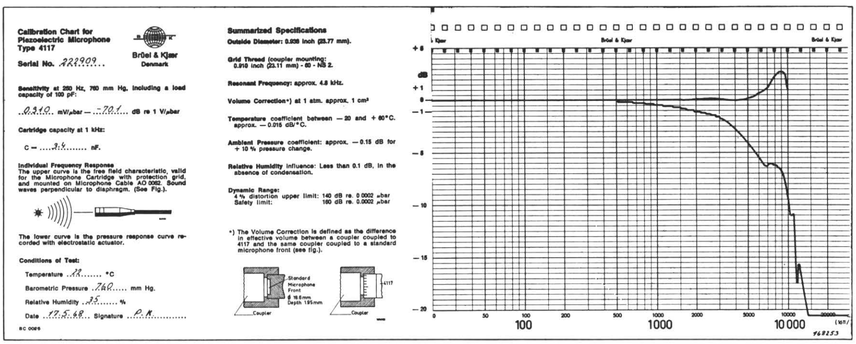

Fig. 2.4. Typical calibration chart as supplied with each microphone.

2.3. CAPACITANCE

The capacitance of the microphone cartridge is given on the calibration chart. Cartridge capacitance comes into the question when the low frequency cut-off of the measuring system is computed, as it determines the effect of loading on the microphone. The nominal capacitance is 4 nF. Because of this high capacitance of the microphone the input impedance of the amplifier need not be very large, e.g. a 2 MΩ impedance gives a low frequency cut-off at about 20 Hz.

The cartridge capacitance is measured at 1000 Hz in a capacitance bridge, comparing with a standard capacitance equal to the nominal capacitance of the microphone.

2.4. CHARGE SENSITIVITY

This sensitivity can be calculated from the voltage sensitivity and the equivalent capacitance of the microphone. Charge sensitivity of a microphone is expressed in pico-coulomb/μbar and is independent of the capacitive loading on the cartridge. It is determined by multiplying the voltage sensitivity with the microphone capacitance.

$$S_{charge} = S_{voltage} \times C_{microphone}$$

Since the voltage sensitivity is given in mV/μbar and the capacitance in nF the charge sensitivity will be in pC/μbar.

2.5. FREQUENCY RESPONSE

An individual frequency response curve is attached to the calibration chart supplied with each microphone. The free-field curve is derived from the pressure response curve recorded automatically by means of the electrostatic actuator method.

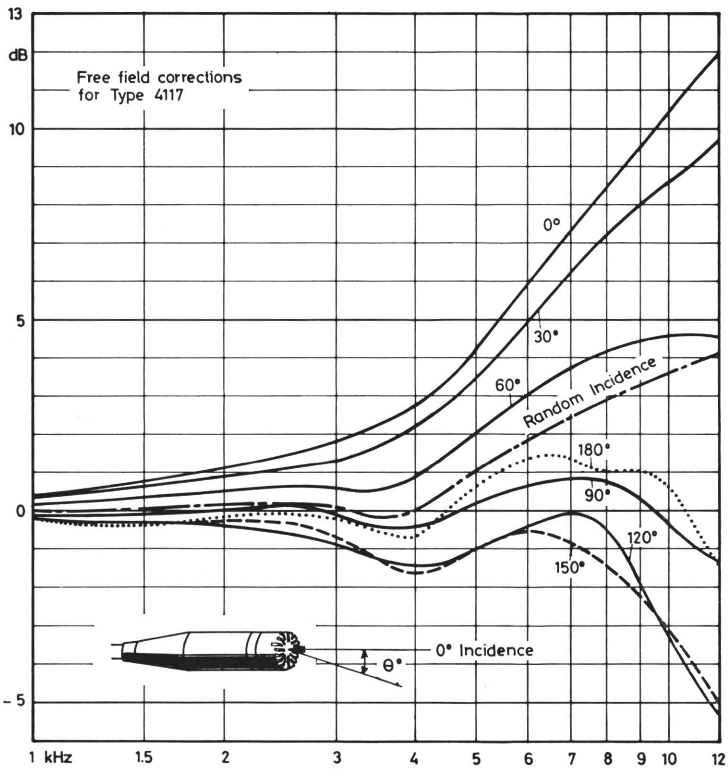

Fig. 2.5. Free-field correction curves to be added to the pressure characteristic of the microphone.

2.6. FREE-FIELD CORRECTIONS

The pressure increase, which is caused by the reflections of free-field sound waves on the microphone diaphragm, becomes appreciable above 1 kHz. The corresponding correction curves are given in Fig. 2.5. The frequency response for the various angles of incidence is obtained by adding the free-field correction to the pressure response supplied with each cartridge. The IEC Recommendation Publication 123 gives a practical rule for calculation of the sensitivity for a diffuse sound field (random incidence) from the free-field sensitivities at definite angles (see page 6 for definition and formula). This is used to calculate the random incidence correction curve given in Fig. 2.5. The random incidence response of the microphone is obtained by adding this curve to the individual pressure response.

2.7. DIRECTIONAL CHARACTERISTICS

In Fig. 2.6 are shown typical directional characteristics at various frequencies.

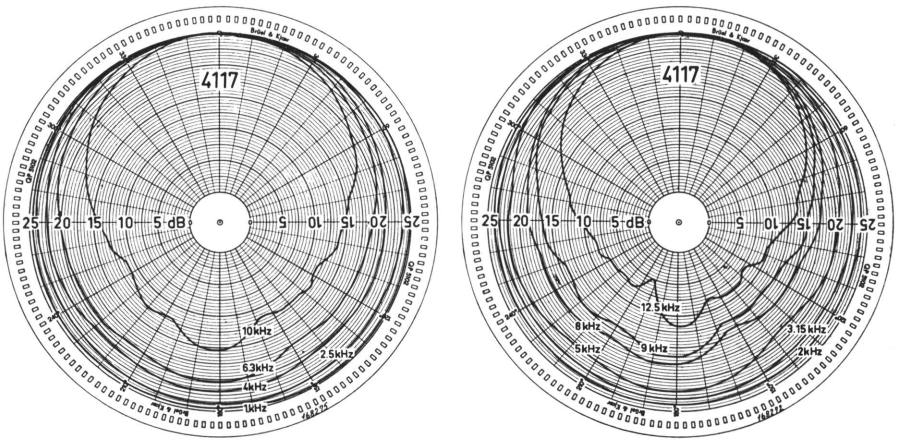

Fig. 2.6. Typical directional characteristics of the piezoelectric microphone.

2.8. DYNAMIC RANGE

The lower limit of the dynamic range is set by the inherent noise level of the amplifier used with input loaded by the microphone capacitance. Used with the B & K Sound Level Meter Type 2205 this limit is 32 dB SL for 5 dB signal to noise ratio.

The upper limit of the dynamic range is set by the harmonic distortion in the complete measuring system. The microphone itself will handle sound pressure levels of up to 140 dB with less than 4 % harmonic distortion.

2.9. PHASE SHIFT

90° phase shift occurs at the resonance frequency of the ceramic bender and diaphragm system. The resonance frequency is approximately 4.8 kHz for Type 4117.

2.10. VOLUME CORRECTION

The volume correction is defined as the difference in effective volume between a coupler coupled to the 4117 and the same coupler coupled to a standard microphone front, see Fig. 2.7. The correction is approximately **1 cm³ at 1 atm.**

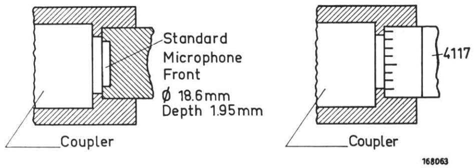

Fig. 2.7. Volume correction for Type 4117.

2.11. TEMPERATURE CHARACTERISTICS

The microphone is calibrated at room temperature but it may be used in the temperature range −10 to +70°C. Storing temperature is −10 to +90°C. A typical temperature sensitivity curve is shown in Fig. 2.8.

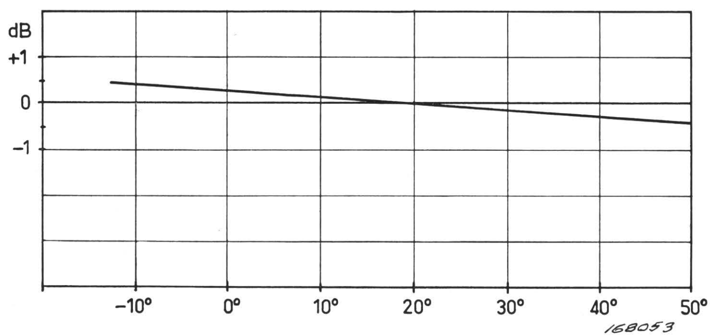

Fig. 2.8. Typical temperature sensitivity curve.

2.12. INFLUENCE OF AMBIENT PRESSURE

The microphone sensitivity will vary less than −0.15 dB for +10% variations in ambient pressure. For larger changes in ambient pressure the frequency response of the microphone will be modified, especially towards the higher frequencies because of the change in mechanical damping. The frequency response at different ambient pressures is given in Fig. 2.9.

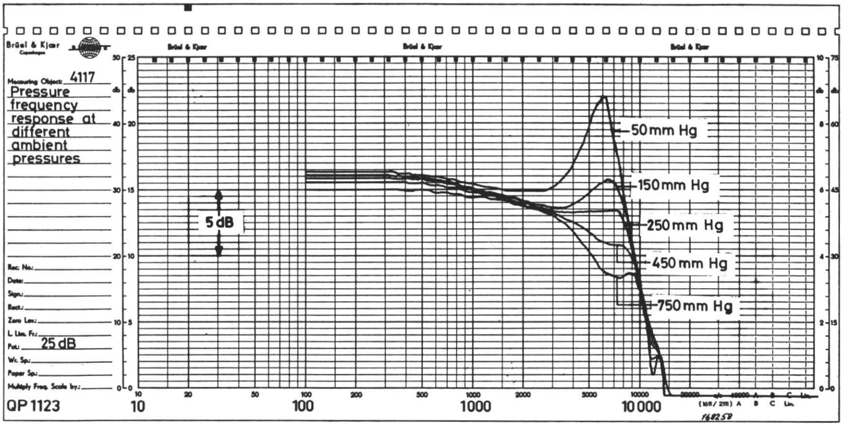

Fig. 2.9. Influence of the static ambient pressure on the frequency response of Type 4117.

2.13. INFLUENCE OF HUMIDITY

A sudden drop in ambient temperature may in some cases cause moisture condensation to take place between the diaphragm and the back plate, and on the ceramic bender. The characteristics of the microphone may thereby be changed temporarily in respect of sensitivity, frequency response and leak resistance. The influence of relative humidity in the absence of condensation is less than 0.1 dB.

Caution

The Silica Gel Cap UA 0135 should not be used with the 4117 because of the violent pressure changes introduced by mounting and removing the cap.

2.14. INFLUENCE OF VIBRATIONS

When the microphone is exposed to vibration the diaphragm and ceramic bender system will be set into motion. This will introduce an output voltage as if the microphone was exposed to a sound field. An acceleration of 1 g perpendicular to the microphone diaphragm gives approximately the same output voltage as would a 100 dB sound pressure level.

2.15. INFLUENCE OF LOAD

The signal from the piezoelectric microphone appears as an alternating voltage across a capacitive impedance. To detect this voltage the microphone is connected to an amplifier via a cable. The loading of the microphone is hence composed of the leak resistance and capacitance of the cable and the input impedance of the amplifier. The equivalent circuit of a microphone with external loading is drawn in Fig. 2.10.

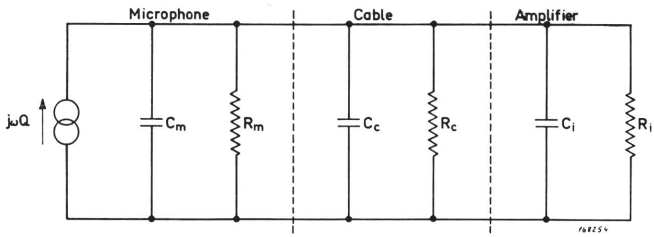

Fig. 2.10. Equivalent circuit of the microphone, cable and amplifier.

The internal resistance R_m of the microphone is essentially infinite at room temperature. Also the cable leak resistance R_c is usually extremely high, and therefore both R_m and R_c can be neglected, giving a simplified diagram as seen in Fig. 2.11.

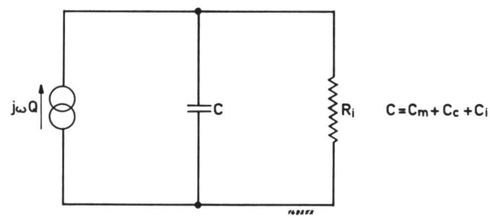

Fig. 2.11. Simplified equivalent circuit for normal operating frequency range.

The following terms will be used during the considerations:

Q = charge induced across the microphone capacitive element (Coulomb).
S_q = charge sensitivity of the microphone (Coulomb/bar).
P = sound pressure to which the microphone is subjected(bar).
S_v = voltage sensitivity of the microphone (V/bar).
C = total capacitance in the circuit, including microphone (C_m), cable (C_c) and amplifier (C_i) (Farad).
R = 1/G, where G is the total conductance in the circuit, including microphone, cable and amplifier (R in Ω).

The piezoelectric microphone is a charge generator, and the charge generated is proportional to the sound pressure to which the microphone is subjected.

$$Q(\omega) = S_q(\omega)\,P = S_v(\omega)\,C_m P \tag{1}$$

Assuming a sinusoidal sound pressure of angular frequency ω the current flowing in the circuit will be

$$I = j\omega Q \tag{2}$$

and the output voltage will be

$$E = I/(G + j\omega C) = j\omega Q/(G + j\omega C) \tag{3}$$

This shows that when $G \ll j\omega C$, i.e. when the shunt resistance in the circuit is very high or at high frequencies the voltage depends only upon the capacitive loading and the microphone sensitivity:

$$E = j\omega Q / j\omega C = Q/C \tag{4}$$

It is also seen that the output is directly proportional to 1/C. This must be taken into account when long microphone cables are employed.

From equation (3) it can also be seen that when $G \gg j\omega C$, i.e. for low frequencies or low shunt resistance the output is frequency dependent:

$$E = j\omega Q/G = j\omega RQ \tag{5}$$

This means that the output falls off at the same rate as the frequency at the low frequency end.

The corner frequency where the output is 3 dB down is where $/G/ = /j\omega C/$

i.e. $$f_c = 1/2\pi RC \tag{6}$$

where f_c is called the "cut-off frequency".

The internal resistance of the microphones is extremely high, always exceeding 10,000 MΩ at room temperature (≃ 20°C). The resistance of the piezoelectric material is lower at high temperatures but usually still higher than 10,000 MΩ

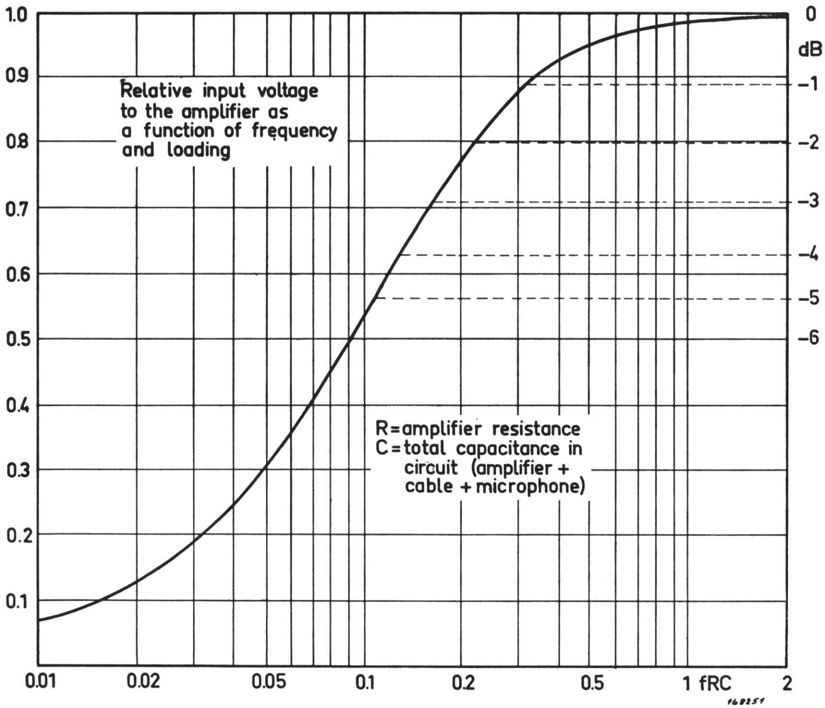

Fig. 2.12. Chart for finding required input impedance when microphone capacitance and low frequency cut-off is given.

at 70°C. This large resistance gives theoretically a low frequency cut-off value at 0.004 Hz for the microphone alone but as the time constant of the pressure equalization is 0.05 sec. the lower limiting frequency of the microphone is 3 Hz as delivered. The time constant may be increased, however, by inserting a thin wire in the capillary tube. The diameter of the hole is 0.25 mm (0.01 in). Fig. 2.12 gives a chart for finding the required input resistance for a given lower limiting frequency and a given microphone capacitance.

Example:

Find the required input impedance for a 1 dB cut-off at 10 Hz using a microphone with capacitance 4 nF.

Solution:

A 1 dB cut-off is seen to give a value of about 0.3 for fRC

$$fRC = 0.3$$

$$R = 0.3/fC = 0.3/(10 \times 4 \times 10^{-9})$$

$$R = 7.5 \text{ M}\Omega$$

The minimum acceptable input resistance of the amplifier is 7.5 MΩ.

2.16. CABLE CAPACITANCE SENSITIVITY CORRECTION

The capacitance of a long cable connecting the microphone to the amplifier will reduce the voltage sensitivity of the microphone. For example a 5 m long cable with a capacitance of 90 pF/m will give a reduction in sensitivity of approximately 10 %. The reduced sensitivity can easily be found if the total shunt capacitance in the input circuit is known, i.e. microphone capacitance, cable capacitance and amplifier input capacitance. The new sensitivity is found from the formula:

$$S_{v(c)} = \frac{S_v\,(C_m + 0.1)}{C_m + C_c + C_i}$$

where $S_{v(c)}$ = reduced voltage sensitivity.

S_v = voltage sensitivity given on the calibration chart.

$C_m + 0.1$ = microphone capacitance given on the calibration chart + 0.1 nF used during the sensitivity calibration (nF).

C_c = cable capacitance (nF).

C_i = amplifier input capacitance (nF).

Example:

A microphone has a sensitivity of 0.310 mV/μbar and a capacitance of 3.4 nF. What is its sensitivity with a connection cable of 40 m length, 90 pF/m. Amplifier input capacitance negligible.

Solution:

Cable capacitance $C_c = 40 \times 90 = 3600$ pF = 3.6 nF

$$S_{v(c)} = \frac{0.310\,(3.4 + 0.1)}{3.4 + 3.6} = \frac{0.310 \times 3.5}{7.0} = 0.155 \text{ mV}/\mu\text{bar}$$

3. Calibration

The sensitivity of the microphone is given on its calibration chart, but it may in many cases be very convenient to calibrate the whole measuring set-up right from the microphone to the indicating instrument. To do this Brüel & Kjær has developed two calibrators, the Sound Level Calibrator Type 4230 and the Pistonphone Type 4220.

3.1. SOUND LEVEL CALIBRATOR TYPE 4230

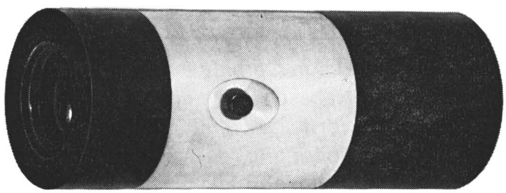

Fig. 3.1. The Sound Level Calibrator Type 4230.

The B & K Sound Level Calibrator Type 4230 creates a sound pressure level of 94 dB ± 0.3 dB at 1 kHz in the coupler volume and is a pocketsize, battery powered unit for field calibration of microphons. (See Fig. 3.1). The calibration value obtained for all weighting networks (A, B, C, D and linear) is the same, as these weighting scales have the same SPL values at 1 kHz. The influence of static pressure is very small, thus the calibration signal is independent of barometric pressure and altitude for ordinary use.

A special construction of the vibrating system makes the equivalent coupler volume more than 200 cm^3 which is greater than the total mechanical volume of the unit (125 cm^3). In practice this means the signal level is independent of the microphone type and the accuracy of the connection to the calibrator.

Caution

Apply and remove the calibrator slowly in order to avoid damage to the microphone diaphragm.

Specifications 4230

Calibration Frequency: 1000 Hz ± 2 %.

Calibration Pressure Level: 94 ± 0.3 dB re 2×10^{-5} N/m² (A, B, C, D or Linear).

Equivalent Coupler Volume: larger than 200 cm³.

Total Harmonic Distortion: less than 1 %.

Temperature Range: - 10 to + 50°C.

Power Supply: single battery.

1 × 9 V. IEC Recommendation 6 F 22, size 25.5 × 17.5 × 48.5. NEDA 1604.

Examples:

Manufacturer	Type
Union Carbide	Ever Ready No. 216 or 222
Hellesen	Type H 10
Varta Pertrix	No. 438
Tudor	No. 9 T 4
National	U-006 P

Dimensions: 40.4 mm (1.58 in) diameter, 96 mm (3.78 in) length.

Microphone Types: 1" and 1/2".

3.2. PISTONPHONE TYPE 4220

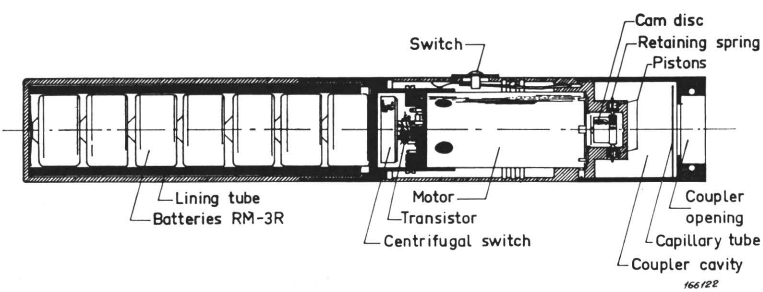

Fig. 3.2. Construction of the Pistonphone.

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Dimensions: 40.4 mm (1.58 in) diameter, 96 mm (3.78 in) length.

Microphone Types: 1" and 1/2".

2. Pistonphone Type 4220

The accuracy of this calibrator is ± 0.2 dB which is in the same order as the precision usually obtained by the reciprocity method. The principle of operation of the Pistonphone is shown in Fig. 3.3 and Fig. 3.4.

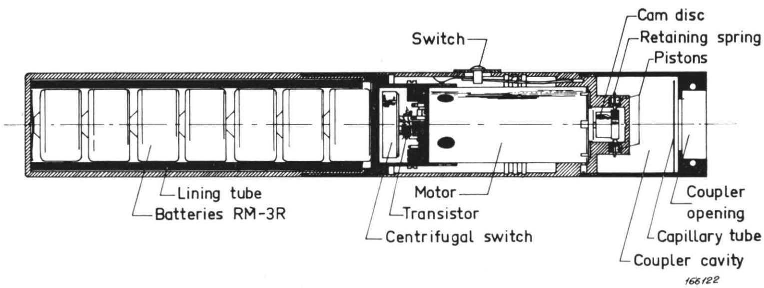

Fig. 3.3. Construction of the Pistonphone.

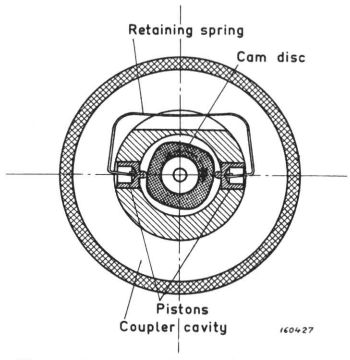

Fig. 3.4. Principle of operation.

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 pistonphone produces a sound pressure level of 124 dB ± 0.2 dB at 250 Hz. As the ambient atmospheric pressure affects the sound pressure produced, a barometer is supplied with the pistonphone calibrated directly in dB to be added to or subtracted from the value given on the Pistonphone calibration chart.

SPECIFICATIONS 4220

Accuracy:	± 0.2 dB.
Sound Pressure Level:	124 dB re 2×10^{-5} N/m^2 (individually calibrated).
Frequency:	Position "Measure": 250 Hz ± 1 %. Position "Check": 350 to 400 Hz with new batteries.
Distortion:	Less than 3 % at 250 Hz.
Batteries:	7 Mallory RM – 3 (R) mercury cells supplied. (B & K part No. QB 0002). Diameter 25.1 mm (0.98 in). The battery compartment will also accept RM – 4 (R) cells (diameter 30.2 mm, 1.19 in), giving 50 % longer service life.
Temperature Range:	Batteries: 0–60° C (32–140° F). Pistonphone alone: – 40 to +60° C (– 40 to +140° F).
Humidity:	Relative Humidities of up to 100 % will not influence the calibration.
Dimensions:	Length: 230 mm (9 in). Diameter: 36 mm (1.4 in).
Weight:	Pistonphone with batteries: 0.7 kg (1.5 lb). Total weight of the case containing pistonphone, adaptors and barometer 1.6 kg (3.5 lb).

4. Accessories

Microphone Extension Cable AO 0062

This cable is used to connect the microphone to any of the B & K amplifiers or analyzing instruments provided with a standard B & K 14 mm socket. It is 3 m (9.85 ft) long and has a capacitance of approximately 80 pF/m.

Fig. 4.1. Microphone Extension Cable AO 0062.

Microphone Extension Cable AO 0061

This cable is designed as an extension cable for the Sound Level Meter

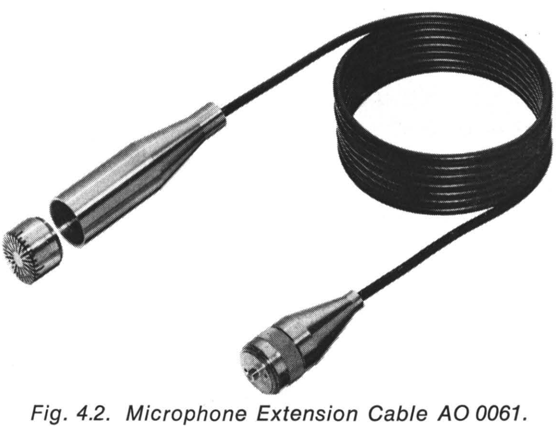

Fig. 4.2. Microphone Extension Cable AO 0061.

Type 2205 and the Vehicle Noise Meter Type 2207 which meets the requirements of British Standard BS 3539 Part I. The cable is 6 m (19.7 ft) long and has a capacitance of approximately 80 pF/m.

Windscreens UA 0082 and UA 0207

When a microphone is exposed to wind, a noise will be generated in consequence of variation of the air pressure on the diaphragm. The three principal reasons for this noise are, firstly, the change of wind velocity; secondly, the turbulence generated around the microphone when it is placed in the wind; and thirdly the interference between the variations in air pressure caused by wind velocity changes and turbulence.

Fig. 4.3. Windscreen UA 0082.

These effects can be reduced considerably by fitting the microphone with one of the windscreens UA 0082 or UA 0207 (Figs. 4.3 and 4.4). The windscreen should normally be used for all outdoor measurements.

The Windscreen UA 0082 was originally designed for use with the B & K condenser microphones but may equally well be fitted onto the Piezoelectric Microphone. It is made of a spherical grid covered with a double layer of nylon cloth, and it has the advantage with the condenser microphones that there is enough space inside for some of the accessories fitted onto the microphone. The UA 0082 should be mounted around the microphone on the microphone adaptor of one of the extension cables AO 0061 – AO 0062, or on one of the B & K Sound Level Meters. When using one of the extension cables the microphone should be positioned in the windscreen so that the

The accuracy of this calibrator is ± 0.2 dB which is in the same order as the precision usually obtained by the reciprocity method. The principle of operation of the Pistonphone is shown in Fig. 3.2 and Fig. 3.3.

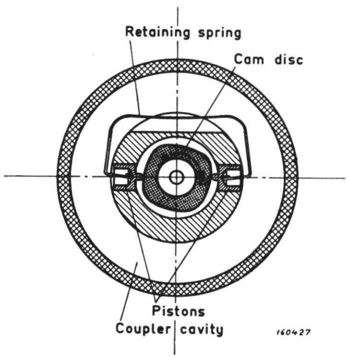

Fig. 3.3. Principle of operation.

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 Pistonphone produces a sound pressure level of 124 dB ± 0.2 dB at 250 Hz. As the ambient atmospheric pressure affects the sound pressure produced, a barometer is supplied with the Pistonphone calibrated directly in dB to be added to or subtracted from the value given on the Pistonphone calibration chart.

Specifications 4220

Accuracy:	± 0.2 dB.
Sound Pressure Level:	124 dB re 2×10^{-5} N/m^2 (individually calibrated).
Frequency:	Position "Measure": 250 Hz ± 1 %. Position "Check": 350 to 400 Hz with new batteries.
Distortion:	Less than 3 % at 250 Hz.
Batteries:	7 Mallory RM – 3 (R) mercury cells supplied. (B & K part No. QB 0002). Diameter 25.1 mm (0.98 in). The battery compartment will also accept RM – 4 (R) cells (diameter 30.2 mm, 1.19 in), giving 50 % longer service life.

Temperature Range:	Batteries: 0–60° C (32–140° F). Pistonphone alone: – 40 to +60° C (– 40 to +140° F).
Humidity:	Relative Humidities of up to 100 % will not influence the calibration.
Dimensions:	Length: 230 mm (9 in). Diameter: 36 mm (1.4 in).
Weight:	Pistonphone with batteries: 0.7 kg (1.5 lb). Total weigrt of the case containing Pistonphone, adaptors and barometer 1.6 kg (3.5 lb).

4. Accessories

4.1. MICROPHONE EXTENSION CABLE AO 0062

This cable is used to connect the microphone to any of the B & K amplifiers or analyzing instruments provided with a standard B & K 14 mm socket. It is 3 m (9.85 ft) long and has a capacitance of approximately 80 pF/m.

Fig. 4.1. Microphone Extension Cable AO 0062.

4.2. MICROPHONE EXTENSION CABLE AO 0061

This cable is designed as an extension cable for the Sound Level Meter

Fig. 4.2. Microphone Extension Cable AO 0061.

Type 2205 and the Noise Event Meter Type 2208. The cable is 6 m (19.7 ft) long and has a capacitance of approximately 80 pF/m.

4.3. WINDSCREENS UA 0082 and UA 0207

When a microphone is exposed to wind, a noise will be generated in consequence of variation of the air pressure on the diaphragm. The three principal reasons for this noise are, firstly, the change of wind velocity; secondly, the turbulence generated around the microphone when it is placed in the wind; and thirdly the interference between the variations in air pressure caused by wind velocity changes and turbulence.

Fig. 4.3. Windscreen UA 0082.

These effects can be reduced considerably by fitting the microphone with one of the windscreens UA 0082 or UA 0207 (Figs. 4.3 and 4.4). The windscreen should normally be used for all outdoor measurements.

The Windscreen UA 0082 was originally designed for use with the B & K condenser microphones but may equally well be fitted onto the Piezoelectric Microphone. It is made of a spherical grid covered with a double layer of nylon cloth, and it has the advantage with the condenser microphones that there is enough space inside for some of the accessories fitted onto the microphone. The UA 0082 should be mounted around the microphone on the microphone adaptor of one of the extension cables AO 0061 – AO 0062, or on one of the B & K Sound Level Meters. When using one of the extension cables the microphone should be positioned in the windscreen so that the diaphragm is approximately at the centre of the spherical windscreen. In this position the locking ring of the windscreen is tightened around the microphone adaptor of the cable. When using a Sound Level Meter the locking ring is tightened around the microphone itself. The influence of the windscreen on the frequency response of the microphone is less than 2 dB for frequencies up to 8 kHz.

Fig. 4.4. Windscreen UA 0207.

The Windscreen UA 0207 is a ball of a specially prepared type of porous polyurethane sponge which has a diameter of 9 cm (3.5 in). It is best fitted onto the microphone when it is attached to the adaptor of one of the extension cables AO 0061 – AO 0062, but also the combination 4117 – 2623 as described in Chapter 5 is suitable. The windscreen is simply pushed onto the microphone as far as it will go. The microphone is then positioned so the diaphragm is at the centre of the windscreen. In this position the frequency response of the microphone is affected by less than 1 dB for frequencies up to 10 kHz. When using a Sound Level Meter such as Type 2205 or 2208, the diapragm can not reach the centre of the windscreen and in this case the attenuation is up to 2.5 dB at 10 kHz.

4.4. MINIATURE CABLE AO 0037

This cable is fitted with miniature plugs JP 0012 (10–32 NF thread) at both ends. It is 1.2 m (4 ft) long, and the capacitance of each cable is calibrated at the production stage (approx. 105 pF). One cable AO 0037 is supplied with each Piezoelectric Microphone Type 4117.

4.5. MININOISE CABLE AC 0010

1.2 m (4 ft) of this cable is used for the AO 0037. The AC 0010 can be delivered in lengths of up to 183 m (600 ft). The capacitance is 90 pF/m (30 pF/ft) and the cable can stand operation temperatures up to 100 °C (212 °F).

Fig. 4.5. Miniature Cable AO 0037.

4.6. ADAPTOR JP 0028

This adaptor converts a miniature plug JP 0012 (10–32 NF thread) into a standard B & K 14 mm plug.

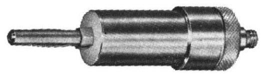

Fig. 4.6. Adaptor JP 0028.

4.7. MICROPHONE STAND UA 0049

This stand fitting all types of B & K microphones will be of invaluable assist-

Fig. 4.7. Microphone Stand UA 0049.

ance in field measurements, where the microphone should always be placed in an undisturbed region of the sound field, i.e. in most cases apart from the instrument.

When it is required to support the 4117 microphone on the UA 0049 it is necessary to use one of the extension cables AO 0061 – AO 0062. The UA 0049 is a lightweight portable tripod with telescopic legs, similar to those used in photographic work, as shown in Fig. 4.7. The height of the Stand can be adjusted from approximately 50 cm to 140 cm. The Tripod Adaptor UA 0028 (seen on top of UA 0049) may be used separately for adapting the microphones on standard camera tripods with thread 3/8" W.

4.8. RANDOM INCIDENCE CORRECTOR UA 0055

Noise level measurements are often carried out in sound fields where the waves impinge upon the microphone diaphragm with variable or undefined incidence. This is for example the case with noise from aircraft in flight and noise in workshops. Furthermore the spectral composition often varies with incidence.

A realistic analysis of the sound pressure is in such cases only possible if the microphone is omnidirectional and linear in the frequency range used for the measurement. It has been noticed (Figs. 2.5 and 2.6) that the sensitivity of the piezoelectric microphone varies appreciably as a function of the incidence above 2–3 kHz. The normal incidence sensitivity is at all frequencies higher than the random incidence sensitivity, e.g. approximately 7 dB above at 10 kHz.

The noise generated by a machine tool in a workshop, for instance, will be reflected by the surroundings, and since the reflected sound is attenuated at the higher frequencies with respect to the direct sound an error is introduced in the measurement. The piezoelectric microphone, however, can be made practically omnidirectional up to 10 kHz by interchanging the microphone grid with the Random Incidence Corrector UA 0055, see Fig. 4.8.

This specially shaped device does not significantly affect the normal incidence response of the microphone but renders the free-field corrections of the micro-

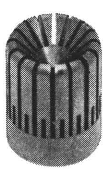

Fig. 4.8. The Random Incidence Corrector UA 0055.

phone at incidences other than 0° practically identical to the normal incidence corrections up to 10 kHz. The directional characteristics of the piezoelectric microphone fitted with UA 0055 are shown in Fig. 4.9.

If better omnidirectional properties are desired at high frequencies the B & K half-inch (Type 4133/34) or quarter-inch (Type 4135/36) condenser microphone cartridges can be used.

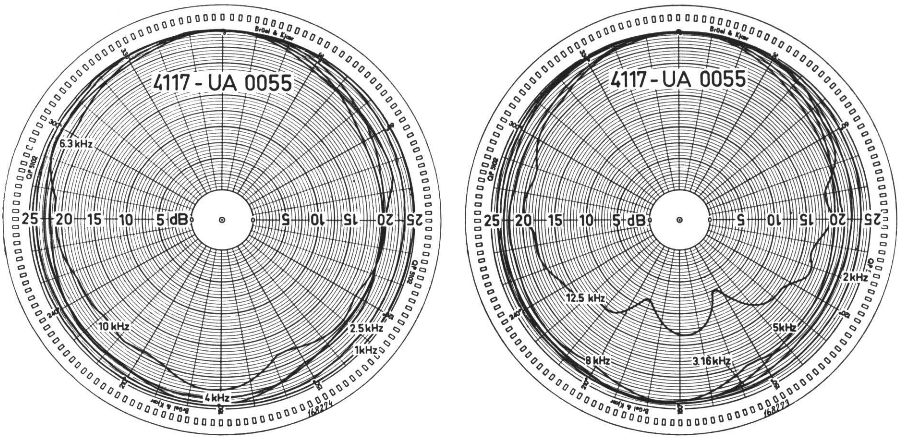

Fig. 4.9. Typical directional characteristics of the piezoelectric microphone fitted with the random incidence corrector.

5. Preamplifiers

5.1. GENERAL

The amplifier requirements of the Piezoelectric Microphone Type 4117 are very similar to those of the B & K Piezoelectric Accelerometers. Most of the accelerometer preamplifiers produced by Brüel & Kjær may therefore also be used as microphone preamplifiers for the piezoelectric microphone. Condenser microphone preamplifiers require special attention.

5.2. CONDENSER MICROPHONE PREAMPLIFIERS

Brüel & Kjær produce several cathode followers and FET microphone preamplifiers for use with the wide range of B & K condenser microphone cartridges. They all supply a DC polarization voltage to the cartridges. As a DC voltage should not be applied to the ceramic bender, these amplifiers can not be used with the Type 4117. If a capacitor is connected in series with the microphone to block the polarization voltage even the slightest leakage of the capacitor will cause a DC charge to be generated on the microphone. The following Type numbers must therefore not be used with Type 4117:

2612 – 2613 – 2614 – 2615 – 2617 – 2619 – 2627.

5.3. B & K PREAMPLIFIERS

5.3.1. Preamplifier Type 2623

The Preamplifier Type 2623 is an impedance conversion device of an extremely small and rugged construction. An extremely high input impedance has been achieved through the use of a "field effect" transistor (FET) in the input circuit. The preamplifier is designed to withstand severe environmental conditions, and its sensitivity to vibration and acoustic noise is negligible.

The miniature cable AO 0037 supplied with the 4117 can be used to connect the microphone to the preamplifier. The microphone may also be connected directly to the preamplifier by means of the adaptor UA 0144 supplied with the preamplifier. This combination forms a very compact system of microphone and preamplifier, which can be mounted on a tripod if required. For the clamping purpose the clamp DH 0120 (also supplied with the preamplifier) is recommended, because excess pressure can damage the housing of the 2623. To fix the DH 0120 onto a tripod an adaptor is necessary which converts the 10–32 NF thread in the clamp into the tripod thread.

The power for the Preamplifier is taken from an external 28 V DC supply, a battery or the Power Supply ZR 0024 which is plugged into the preamp. input socket of the B & K amplifiers. The current consumption is about 2 mA.

Fig. 5.1. Preamplifier Type 2623.

Specifications 2623

Input Resistance:	Min. 2000 MΩ at 25°C Min. 200 MΩ at 100°C
Input Capacitance:	3.5 pF parallel 1000 pF series
Output Resistance:	40 Ω (typical)
Max. Output Current:	1 mA
Max. Output Voltage:	7 V RMS
Voltage Gain:	0 dB ± 0.05 dB
Frequency Range:	0.12 Hz – 500 kHz with 1000 pF across input
Noise:	15 μV, 2–40,000 Hz with 1000 pF across input
Power Supply:	External, 28 V DC
Diameter:	14 mm (0.55 in)
Length:	45 mm (1.77 in) 52 mm (2.05 in) with accelerometer adaptor
Weight:	20.6 g (0.73 oz)
Accessories Included:	1 Adaptor for accelerometer, UA 0144 1 Clamp DH 0120 2 Cables AO 0037 Screws (NF 10–32)

5.3.2. Preamplifier Type 2616

Fig. 5.2. Preamplifier Type 2616.

The Preamplifier Type 2616 is a battery driven three-stage transistorized unit with a field effect transistor in the input stage. It is designed for high impedance transducers and its low output impedance ensures that noise and loss in the cable do not interfere with the measurements even when a very long cable connection is used between the preamplifier and the indicating instrument. A built-in peak indicating overload indicator reacts on signals with crest factors up to 10 and for frequencies higher than 20 Hz.

A potentiometer makes it possible to adjust the voltage gain from + 1.5 dB to − 20 dB. Furthermore there is a screwdriver operated 40 dB attenuator which may be used to attenuate the input signal and thereby increase the useful dynamic range of the preamplifier.

Power is taken from six mercury cells (1.35 V each) contained in a battery compartment attached to the preamplifier. This compartment is removable and the preamplifier may be connected to an external power supply of any voltage from 6–35 V DC. A built-in network stabilizes the voltage and reduces ripple from an external power supply by about 40 dB.

Specifications 2616

Input Resistance:	> 1200 MΩ
Input Capacitance:	10 pF (typical)
Output Resistance:	< 100 Ω
Max. Output Current:	1 mA
Frequency Range:	0.13 Hz – 500 kHz with 1000 pF across input
Noise:	Max. 20 μV, 2 Hz – 40 kHz with 1000 pF across input
Dynamic Range:	30 μV – 1 V RMS with attenuator on 0 dB. 40 mV – 100 V RMS with attenuator on – 40 dB
Rise Time:	1 μsec
Signal Adjustment:	+ 1.5 to – 20 dB with attenuator on 0 dB
Power:	Internal battery. Six mercury cells of 1.35 V. External supply 6–35 V DC
Current Consumption:	4–10 mA
Dimensions:	Diameter 52 mm (2 in). Total height including battery compartment 66 mm (2.6 in)
Weight:	290 g (10.3 oz) 162 g (5.7 oz) excl. battery compartment.

5.3.3. Vibration Pick-up Preamplifier Type 2625

The Vibration Pick-up Preamplifier Type 2625 contains integration networks to be used for accelerometer applications only, but in the "acceleration" mode it is an excellent preamplifier for the Piezoelectric Microphone. It has three input sockets connected to a selector switch with individual sensitivity adjustment of each input. The two inputs not in use are connected to ground. The function selector controls four different gain ranges for the three inputs:

1) variable from – 40 dB to – 20 dB
2) variable from 0 dB to + 20 dB
3) fixed at 0 dB
4) fixed at – 40 dB

The output signal can be taken from a standard microsocket 10–32 NF or a B & K 14 mm coaxial socket at the front panel. Additionally there is a micro-socket output at the back of the preamplifier. The maximum output voltage is ± 7 Volts with a maximum current of ± 1 mA peak.

The preamplifier has a built-in battery compartment for battery operation and it can also be powered by an external supply, 28 V DC.

Specifications 2625

Input Resistance:	Varies from 3 GΩ at 0 dB gain to 450 MΩ at 20 dB gain				
Input Capacitance:	14 pF				
Frequency Range:	Acc.			1 Hz –	35 kHz
	Vel.	3.16	m/sec	1 Hz –	4 kHz
	Vel.	0.316	m/sec	10 Hz –	10 kHz

Fig. 5.3. Vibration Pick-up Preamplifier Type 2625.

Vel.	0.0316	m/sec	100 Hz –	30 kHz
Displ.	1000	mm	1 Hz –	30 Hz
Displ.	100	mm	3 Hz –	100 Hz
Displ.	10	mm	10 Hz –	300 Hz
Displ.	1	mm	30 Hz –	1,000 Hz
Displ.	0.1	mm	100 Hz –	3,000 Hz
Displ.	0.01	mm	300 Hz –	10,000 Hz

Max. Input Signal:
± 0.7 V at 20 dB gain
± 7 V at 0 dB gain
± 70 V at – 20 dB gain
± 700 V at – 40 dB gain

Gain: Fixed 0 dB and – 40 dB. Variable 0 dB to 20 dB and – 40 dB to – 20 dB

Inherent Noise: Max. 20 μV from 2 Hz to 40 kHz with 1 nF across input (referred to input)

Load Impedance: Min. 1 MΩ//max. 100 pF

Harmonic Distortion: Less than 1 % with 5 V RMS output

Power Supply: External 28 V DC source (for example ZR 0024) or internal 3 × 9 V batteries(not included)

3 × 9 V. IEC Recommendation 6 F 22, size

Batteries: 25.5 × 17.5 × 48.5 mm

Current Consumption: Approximately 2 mA.

Dimensions (excluding knobs and feet):
Height: 132.6 mm (5.22 in)
Width: 61 mm (2.40 in)
Depth: 200 mm (7.87 in)

Weight: 820 g (1.8 lb.)

Accessories Included: Two cables AO 0037, 1.2 m (4 ft.) long. One coaxial plug JP 0018.

5.3.4. Charge Amplifier Type 2624

Charge amplifiers are gaining widespread acceptance mainly because of their simplicity of operation. They eliminate the effect of shunt capacitance in the input circuit, so that the operator can work without attention to variable transducer cable lengths. The only information required is the charge sensitivity of the transducer. The charge sensitivity of the Piezoelectric Microphone can be found from the voltage sensitivity and the capacitance given on the calibration chart.

$$S_{\text{charge}} = S_{\text{voltage}} \times C_{\text{microphone}}.$$

Fig. 5.4. The Charge Amplifier Type 2624.

Since the voltage sensitivity is given in mV/μbar and the capacitance in nF the charge sensitivity will be in pC/μbar.
The sensitivity of the Charge Amplifier Type 2624 may be set to 0.1, 1 or 10 mV/pC with different low frequency limits (see 2624 specifications). A microphone having for example a voltage sensitivity of 0.3 mV/μbar and a capacitance of 4 nF has a charge sensitivity of 1.2 pC/μbar. When this microphone is connected to Type 2624 the output of the Charge Amplifier will be scaled to 0.12, 1.2 or 12 mV/μbar.
The Charge Amplifier is provided with an overload indicator which lights up when the dynamic range is exceeded and when the amplifier is blocked due to saturation. A reset button is used for quick recovery of normal working conditions after overload.
There is a DC potential of 12.5 V at the output terminal and therefore the resistance connected across the output should not be less than 50 kΩ. The capacitive load permitted depends on the upper limiting frequency desired and on the signal level.
Type 2624 is completely protected against overload and short circuits. It is also protected against interchanging the supply and signal cables and there is a possibility of separating electrical and mechanical ground by removing only one connection in the instrument.

Specifications 2624

Sensitivity: 0.1 – 1 – 10 mV/pC, tolerance at 100 Hz: ± 1 %.

Input Load: Maximum permissible capacitive load for the three ranges is 1 μF, 0.1 μF and 10 nF respectively. This load will cause less than 1 % reduction of sensitivity.

Frequency Range: Lower 3 dB limits (half-power points): 0.003, 0.03 and 0.3 Hz or alternatively 0.3, 3 and 30 Hz. Lower limiting frequency tolerance: ± 20 %.
With negligible capacitive load at the input the frequency ranges in the six positions are:

	Sensitivity mV/pC	– 3 dB point Hz	Frequency range Hz
a	0.1	0.003	0.3–30,000 ± 1 %
b	1	0.03	0.03–30,000 ± 1 %
c	10	0.3	5–10,000 ± 5 %
d	0.1	0.3	3–30,000 ± 1 %
e	1	3	30–30,000 ± 1 %
f	10	30	150–10,000 ± 5 %

Capacitive input load causes a high frequency boost with a maximum peak at frequencies higher than

	20 kHz. Under full capacitive load conditions (see "Input Load") the increase of sensitivity at 20 kHz is less than 10 %.
Input DC Shunt Resistance:	Greater than 10 GΩ. While resetting 25 kΩ ± 10 %.
Output Voltage and Current:	Max. 20 V peak-to-peak (DC voltage typically 12.5 V), ± 10 mA. The output is short circuit protected.
Output Impedance:	Less than 1 Ω when input load is less than 1/4 full load. 3–5 Ω at full input load.
Harmonic Distortion:	Less than 0.5 % at full output and no capacitive load, frequency lower than 20 kHz. Less than 5 % at full output and full cable capacity, frequency lower than 20 kHz.
Noise Level:	Referred to the output terminal the maximum self-generated noise in the three ranges is: 0.1 mV/pC: 10 μV + max. 0.05 μV per 100 pF source capacitance. 1 mV/pC: 10 μV + max. 0.5 μV per 100 pF source capacitance. 10 mV/pC: 20 μV + max. 5 μV per 100 pF source capacitance. (Source capacitance = cable capacitance + transducer capacitance). Noise bandwidth 2 Hz – 40 kHz. Typically 8 μV in the 0.1 mV/pC range at short cable lengths.
Pulse Response:	Measured without cable capacitance, rise time is proportional to pulse height featuring a slope of typically 1.8 V/μsec. Decay-time is constant and typically 2 μsec.
Overload Recovery Time:	The input is overload protected. Overload recovery time constant is equal to $1/2\pi f_n$ in pos. d, e and f (see "Frequency Range") i.e. min. 5 msec. The amplifier has been provided with overload indicator and manual reset facilities.
Power Supply:	External 28 V DC ± 10 %. Current consumption: Normal working conditions 17 mA (typical). With overload indicator lit max. 40 mA. With output terminals shorted max. 150 mA.
Dimensions: (excl. knobs and feet)	Height: 132.6 mm (5.22 in) Width: 30.3 mm (1.19 in) Depth: 200 mm (7.87 in)
Weight:	585 g (1.29 lb).
Accessories Included:	Two cables AO 0037, 1.2 m (4 ft.) long.

6. Specifications

Sensitivity:*)	0.3 mV/μbar (– 70 dB re 1 V/μbar)
Frequency Response:*)	Linear from 3 Hz to 10 kHz within ± 3 dB.
Lower Limiting Frequency:	Approximately 3 Hz. May be lowered by inserting a thin wire in the pressure equalization tube (hole dia 0.25 mm, 0.01 in).
Capacitance:*)	4000 pF.
Dynamic Range:	Up to 140 dB re 0.0002 μbar SPL. Safety limit 160 dB re 0.0002 μbar SPL.
Distortion:	Less than 4 % for 140 dB SPL.
Phase Shift:	90° phase shift at approx. 4.8 kHz.
Temperature Coefficient:	– 0.015 dB per °C.
Ambient Pressure Coefficient:	Approx. – 0.15 dB for + 10 % pressure change.
Relative Humidity Influence:	Less than 0.1 dB in the absence of condensation.
Humidity Range:	0–90 %.
Vibration Sensitivity:	Approx. 100 dB for 1 g applied perpendicular to microphone diaphragm.
Directional Characteristic:	See Fig. 2.6.
Operating Temperature:	– 10°C to + 70°C.
Storing Temperature:	– 10°C to + 90°C.
Grid Thread:	60 – NS 2 (23.11 mm, 0.910 in).
Connection Type:	Micro socket 10–32 NF.
Dimensions:	Length: 20 mm (0.788 in). Diameter: 23.77 mm (0.936 in).

*) Individual values given on the calibration chart.

Weight: 27 g (0.95 oz).

Accessories: The microphone is delivered in a box (KE 0054) with 1.2 m (4 ft) miniature cable (AO 0037), dust cap (DZ 9025) and calibration chart.

Fig. 6.1. The Piezoelectric Microphone Type 4117 and accessories as delivered in display box. The calibration chart is normally placed in the lid.

BRÜEL & KJÆR instruments cover the whole field of sound and vibration measurements. The main groups are:

ACOUSTICAL MEASUREMENTS
Condenser Microphones
Piezoelectric Microphones
Microphone Preamplifiers
Sound Level Meters
Precision Sound Level Meters
Impulse Sound Level Meters
Standing Wave Apparatus
Noise Limit Indicators
Microphone Calibrators

ACOUSTICAL RESPONSE TESTING
Beat Frequency Oscillators
Random Noise Generators
Sine-Random Generators
Artificial Voices
Artificial Ears
Artificial Mastoids
Hearing Aid Test Boxes
Audiometer Calibrators
Telephone Measuring Equipment
Audio Reproduction Test Equipment
Tapping Machines
Turntables

VIBRATION MEASUREMENTS
Accelerometers
Force Transducers
Impedance Heads
Accelerometer Preamplifiers
Vibration Meters
Accelerometer Calibrators
Magnetic Transducers
Capacitive Transducers
Complex Modulus Apparatus

VIBRATION TESTING
Exciter Controls — Sine
Exciter Controls — Sine — Random
Exciter Equalizers, Random or Shock
Exciters
Power Amplifiers
Programmer Units
Stroboscopes

STRAIN MEASUREMENTS
Strain Gauge Apparatus
Multi-point Panels
Automatic Selectors

MEASUREMENT AND ANALYSIS
Voltmeters and Ohmmeters
Deviation Bridges
Measuring Amplifiers
Band-Pass Filter Sets
Frequency Analyzers
Real Time Analyzers
Heterodyne Filters and Analyzers
Psophometer Filters
Statistical Distribution Analyzers

RECORDING
Level Recorders
Frequency Response Tracers
Tape Recorders

DIGITAL EQUIPMENT
Digital Encoder
Digital Clock
Computers
Tape Punchers
Tape Readers

BRÜEL & KJÆR

DK-2850 Nærum, Denmark. Teleph.: (01) 80 05 00. Cable: BRUKJA, Copenhagen. Telex: 15316

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