2209

Instructions and Applications

B K

Impulse Precision Sound Level Meter Type 2209

A compact and portable instrument for precision sound and vibration measurements. It conforms to IEC 179 for Precision Sound Level Meters, the proposed IEC Recommendation for Impulse Precision Sound Level Meters and to DIN 45 633 parts 1 and 2.

BRÜEL & KJÆR

030-0522

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

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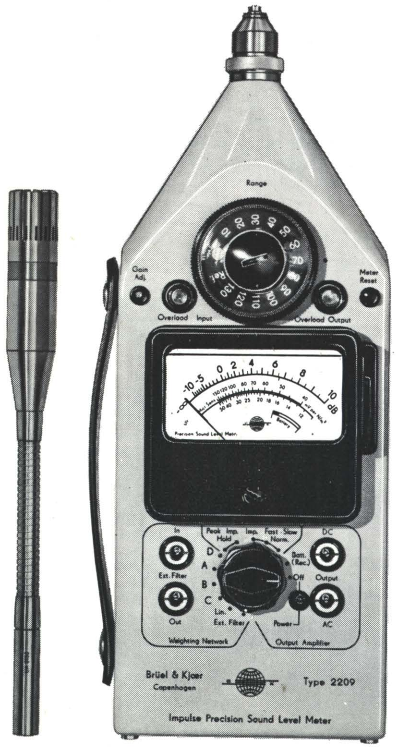

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IMPULSE PRECISION SOUND LEVEL METER TYPE 2209

From serial no. 934190

Revision June 1981

CONTENTS

type 2209

Impulse Precision Sound Level Meter

FEATURES:

- Complies with IEC standard 651 Type 1 (Imp.)* and ANSI S1.4-1971 Type 1
- RMS detector for signal crest factors up to 40
- Impulse detector with Max. RMS Hold facility
- Peak detector with 20 μs rise time and Hold facility
- "D", "A", "B" and "C" frequency weighting, plus "Lin" response
- 2 Hz or 10 Hz selectable low frequency cut-off
- Linear amplifier to 70 kHz
- Plug-in preamplifier
- System overload indicators
- AC and DC outputs
- Individually calibrated, high sensitivity, precision condenser microphone
- Interchangeable meter and attenuator scales to facilitate direct reading in sound and vibration units
- Wide selection of accessories

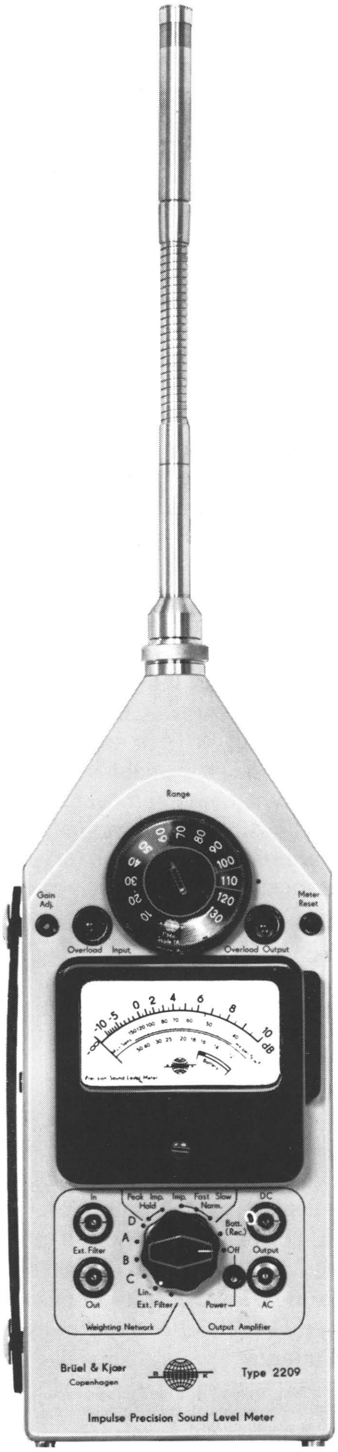
USES:

- Product noise reduction and noise emission certification
- Evaluation of hearing loss risk due to impulse noise

The Impulse Precision Sound Level Meter Type 2209 is the best available analog instrument, featuring A, B, C, D-weighting, provision for use with external filters, impulse and peak measurement capability, and interchangeable meter scales for true flexibility. The impulse and peak measuring abilities assure accurate measurement of signals such as exhaust noise and repetitive impulses which have a high peak value compared to their RMS level. The Type 2209 can measure with either "Impulse" or with peak hold to suit the various different national standards. The wide frequency range of the 2209 gives the option of being used with many different microphones over the frequency range from infrasonic to ultrasonic sound.

The Type 2209 fulfils IEC 651 Type 1 (Imp.)* and ANSI S1.4-1971 Type 1, allowing the user to perform a very wide variety of acoustic and vibration measurements.

- Performs as Octave, Third octave or narrow band analyzer with system-matching filter sets
- Performs as Vibration Meter or Analyzer with appropriate accessories
- Measurement of noise having high peak values
- Infrasonic and ultrasonic measurements
- Community, industrial and architectural measurements
- Measurement of shock, vibration and blast noise
- Audiometer Calibration



* IEC 651 supersedes the earlier IEC recommendations 123, 179 and 179 A

Noise Measurements

The Impulse Precision Sound Level Meter Type 2209 meets the requirements of IEC 651 Type 1*, DIN 45 633 part 1 and ANSI S.1.4-1971 Type 1 for precision sound level meters, as well as IEC 651 Type 1 (Imp.)* and DIN 45 633 part 2 for impulse precision sound level meters.

The 2209 is supplied with a high sensitivity, 1/2 inch Condenser Microphone Type 4165, complete with individual calibration chart and frequency response curve. The 4165 provides a measuring range from 24 to 140 dB(A), as well as a wide frequency range in both free and diffuse sound fields, because of its excellent omnidirectional characteristics.

Microphone Extension Rod Type UA 0196 is supplied to ensure conformance of the complete instrument to the omnidirectional requirements of the standards for precision sound level meters. Only with an omnidirectional sound level meter can the user be sure, when making community and industrial measurements, that all noise sources are measured accurately.

A plug-in microphone preamplifier permits use of microphone extension cables up to 100 metres without degradation of most signals. Cables are available in standard lengths of 3, 10 and 30 metres. Because the cables are inserted between the removable input preamplifier and the sound level meter, there is no influence of cable capacitance on system performance. A windscreen is provided to reduce the effects of wind noise when measuring outdoors. It also finds use in protecting against dust and oil spray when measuring in industrial environments.

The Condenser Microphone Type 4165 is stable over wide ranges of temperature and humidity. Its quartz-coated diaphragm protects against corrosive and humid environments in most cases. Back-venting permits its use with Dehumidifier Type UA 0308 in high humidity environments.

* IEC 651 Type 1 (Imp.) instruments correspond to the earlier IEC recommendations 179 and 179 A in all significant points

Features of Impulse Precision Sound Level Meters

Impulse sound level meters are designed in accordance with IEC 651 Type 1 (Imp.)* for measuring noise which has high peak values compared to RMS level (called high crest factors). This category of noise includes continuous sounds such as auto motive exhausts and stamping machines, as well as single impulses from punch presses and pile drivers. Impulse sound level meters can measure high crest factor signals more accurately than ordinary precision sound level meters.

Impulse sound level meters have an added "Impulse" meter response mode for which the meter circuit has a rise time of 35 ms compared to 125 ms on "Fast" and 1 s on "Slow" response. The 35 ms rise time approximates that of the human ear, so that "Impulse" response more closely approximates subjective human loudness evaluation of impulse sounds having a rise time shorter than 125 ms. Some national standards specify the use of impulse sound level meters to evaluate hearing loss risk due to impulse noise.

Brüel & Kjær offers a variety of microphones for special requirements. For measuring very high noise levels, use a 1/4 or 1/8 inch microphone. For sound power measurements in reverberant rooms, use a 1/2 inch Condenser Microphone Type 4134 to obtain a uniform random incidence response up to 20 kHz. And for measurements down to 19 dB(A) use the 1 inch Type 4145. Individual attenuator scales are supplied so that less sensitive microphones may be read directly in decibels. For complete specifications on individual microphones, refer to the data sheet on condenser microphones. See also Fig.4 herein for mounting adaptors that may be required.

The impulse handling capability of the 2209 provides accurate measurement of signals with crest factor up to 10 at full scale, increasing to 40 for readings 12 dB below full scale. The 2209 provides A, B and C-weighting for measuring sound level, D-weighting for measuring aircraft noise, and linear response for measuring sound pressure and vibration. Other features include "Slow", "Fast", "Impulse" and "Impulse Hold" response, "Peak Hold" response, amplifier overload indicator lamps, connections for external filters, AC and DC recorder outputs, and a built-in reference voltage for convenient calibration check.

Infrasonics

Infrasonic sounds occur in industry when walls are excited by low frequency vibrations which propagate through building structures from remote machinery and air conditioning equipment.

Infrasonic noise is not normally detected on sound level meters because signals below 10 Hz are heavily attenuated. When a 1 inch Condenser Microphone Type 4145 is used and the preamplifier is set to it's low frequency range, the 2209 has a linear acoustical response to about 2 Hz. A Low Pass Filter with 22,5 Hz upper cut-off frequency Type 5742 can be fitted to the combination with 2209 and one of the Filter Sets Type 1613 or 1616 to allow sound measurements in the Infrasonic region between 2 and 22,5 Hz to be made. The Type 5742 is available from B & K Systems Engineering Group.

Ultrasonics

Ultrasonic measurements are required to measure noise emission of ultrasonic welders and cleaners, to tune ultrasonic welders to maximum efficiency and to calibrate all types of ultrasonic transducers and hydrophones in air. Some countries have noise exposure criteria for ultrasonic sound. When used with the 1/4 inch Condenser Microphone Type 4136, the 2209 has a linear response to above 70 kHz.

True Peak Detection

When it is necessary to measure the peak value of an acoustic wave, the 2209 provides the capability. This requirement occurs in standards for hearing loss risk which set impulse noise limits based upon peak sound pressure level. Other requirements are found when measuring vibrational shock and blast noise.

In its "Peak Hold" mode the

2209 detects the peak value of the input signal, using a rise time shorter than 20 microseconds. Circuitry then captures the peak level and displays it as a steady level on the meter.

Vibration

Vibration reduction is often the key to noise control. Because of this close relationship between noise and vibration, the 2209 is designed to quickly convert to a complete vibration meter by replacing the microphone with the Integrator Type ZR 0020 and connecting an accelerometer.

A circular calculating disc permits rapid conversion from instrument readings to units of displacement, velocity or acceleration. When the 2209 is used to measure just one vibration parameter, attenuator and meter scales can be installed to read directly in either acceleration, velocity or displacement units.

Fig.1. Pistonphone Type 4220 and Sound Level Calibrator Type 4230

System Calibration

Two calibrators are available for system acoustical calibration. The Pistonphone Type 4220 provides a 250 Hz tone at a nominal sound pressure level of 124 dB (± 0,2 dB) with an accuracy of 0,15 dB. The Sound Level Calibrator Type 4230 provides a 1 kHz tone at a sound pressure level of 94 dB, with an accuracy of 0,3 dB from 20 to 26 °C. When using the 2209 as a vibration meter, the Accelerometer Calibrator Type 4291 provides a 10 ms^{-2} peak excitation signal at 79,6 Hz (ω=500). Calibrators also provide a useful calibration signal for an associated tape recorder or graphic level recorder.

Frequency Analysis

Measuring sound and vibration level is usually only a part of long-

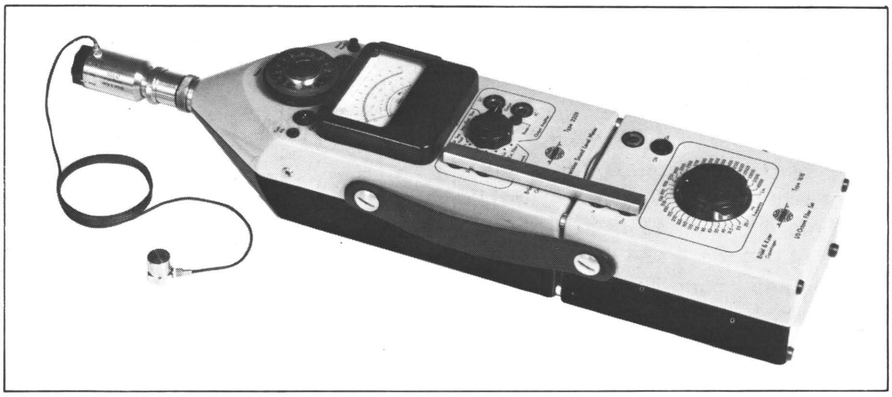


Fig.2. The sound level meter equipped with integrator and accelerometer for vibration measurements, and 1/3 octave filter for frequency analysis

term programs. Eventually, frequency analysis is required. Octave or third-octave frequency analysis is required for enclosure and barrier design and to test conformance to Noise Criteria curves. And vibration studies usually require narrow band analysis. For this reason, the 2209 has provision for adding frequency analysis filters.

Octave Filter Set Type 1613 or Third-Octave Filter Set Type 1616 attaches directly to the sound level meter and connects electrically by a convenient connecting bar. The 1613 contains 11 octave filters with center frequencies from 31,5 Hz to 31,5 kHz. It features recessed adjustable attenuation control for each filter so the user can normalize the read-out of all filters to one convenient instrument reading when calibrating audiometers or testing conformance to noise tolerance curves. The 1616 contains 34 third-octave filters from 20 Hz to 40 kHz. The 1613 and 1616 meet the most strict national and international standards for uniformity of frequency response.

Portable Tunable Filter Type 1621 or Tracking Filter Type 1623 can be used with the 2209, they have selectable bandwidth as narrow as 3% of tune frequency on the 1621 and 6% on the 1623.

Graphic Recording

The portable Level Recorders Types 2306 and 2309 eliminate the tedious task of plotting data by hand, and they produce immediate time history and frequency analysis records which can be inserted directly into measurement reports. When recording community noise over long time periods, the fiber pens may be replaced by a stylus scribing on waxcoated paper. The resulting fine recording line permits slower paper speeds while maintaining an easily interpretable chart record. Frequency analyses are plotted on frequency preprinted paper in a few seconds with octave, third-octave or narrow band filter.

During long-term recording, battery condition can be monitored continuously on the meter.

Tape Recording

Sound and vibration signals should be tape recorded when they must undergo several kinds of frequency analysis or be compared with new data or new criteria. B & K offers the Types 7005/6, which are portable four channel instrumentation tape recorders for both field and laboratory use, being small, light, and powered from internal batteries. Easily exchangeable plug-in units permit any combination of up to four IRIG Intermediate Band Direct and Wide Band FM channels to be obtained. Additionally, a Two Channel Compander Unit may be fitted for automatic level regulation to obtain an effective record-playback signal to noise ratio of over 70 dB.

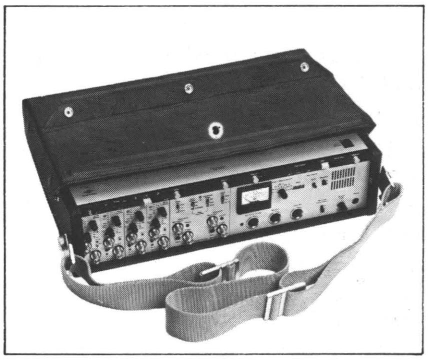


Fig.3. The Tape Recorder Type 7005

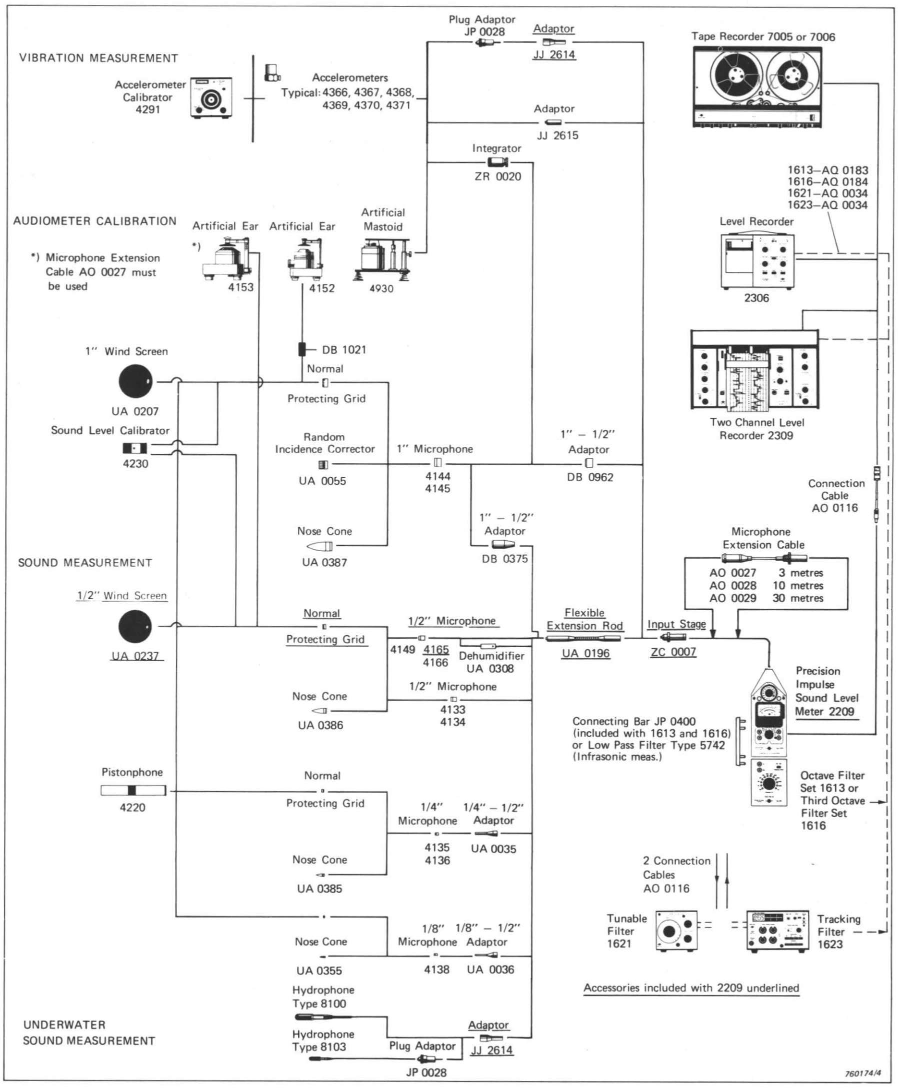


Fig.4. Survey of accessories available for sound and vibration measurements

Audiometer Calibration

Because audiometers play a vital role in measuring hearing loss and in recognizing the onset of noise-induced hearing loss, their accuracy must be checked frequenctly. The 2209 becomes an audiometer calibrator when fitted with the Artificial Ear Type 4152 or 4153 and Microphone 4144 or 4134 respectively. It calibrates bone-conduction audiometers when fitted with Artificial Mastoid Type 4930. An octave or third-octave filter is usually used to isolate ambient noise and vibration and to test for amplitude linearity and distortion. A practical carrying case KE 0055, similar to that shown in Fig.5, with provision for accessories requiered for audiometer calibration may be ordered separately.

Measuring Sets

The 2209 can be ordered with accessories according to the need. A carrying case should be included to ensure that all items are in one set, ready to be taken into the field on short notice. To simplify ordering, two sets containing the most commonly used accessories are offered. The sturdy fibreglass carrying case has a molded foam interior for safely storing the sound level meter, filter, calibrator, accessories and noise control records. It can be carried aboard aircraft to ensure safe handling and prompt arrival at the business and of your trip.

Sound and Vibration Sets Types 3507 and 3511

Sound Level Meter	2209
Octave Filter Set	1613 (3507 only)
Third Octave Filter set	1616 (3511 only)
Pistonphone	4220
Accelerometer Set	4366S
Microphone 1/2"	4166
Nose Cone 1/2"	UA 0386
Integrator	ZR 0020
Adaptor for Tripod	UA 0588
Extension Cable	AO 0027
Carrying Case	KE 0055
B & K Input Adaptor	JP 0028

Accessories

A wide selection of accessory equipment is available to expand the application possibilities of the sound level meter. A survey showing the connection possibilities of the most useful items is given in Fig.4. For more information on the individual instruments and transducers indicated, please ask for separate data sheets.

Fig.5. Sound and Vibration Set Type 3511

Technical Description

The Impulse Precision Sound Level Meter Type 2209 contains a condenser microphone, plug-in preamplifier, input attenuator amplifier, selectable frequency-weighting networks, output attenuator amplifier, and detector circuit with moving coil meter. A built-in reference oscillator provides a ready check of amplifiers and meter circuit.

Microphone

The B & K Microphone Type 4165 is a precision condenser microphone that has proven to be highly stable and reliable. It has linear response in a free field when the sound wave is at 0° incidence to the centerline axis (perpendicular to the diaphragm). Response of the complete instrument and the IEC 651 Type 1 tolerances for 0° incidence are shown in Fig.6. The 2209 also has a linear response in diffuse fields as required by ANSI S.1.4-1971 Type 1 and shown in Fig.7. The 2209 also meets the omnidirectional requirements of IEC and ANSI. Directivity response of the microphone and the complete sound level meter are shown in Figs.15 and 16.

A calibration chart and frequency response curve are supplied with each microphone. Sensitivity is typically 50 mV/Pa with standard 200 V polarization voltage. The 4165 is extremely reliable and is unaffected by wide ranges of temperature and humidity. The diaphragm is quartz-coated to protect against humid and corrosive environments.

Plug-in Preamplifier

The input preamplifier has a high input impedance to permit measurement at low amplitudes and low frequencies with high impedance microphones and accelerometers. Because the preamplifier is removable and stays with the microphone, long extension cables can be used to locate the microphone at remote measuring locations. Long cables produce little or no effect on frequency response except at very high sound levels. See Fig.8.

A switch is located in the input preamplifier socket for selecting the instrument's low cut-off frequency. See Fig.9. In its normal 10 Hz cut-off position, the switch is in its fully anti-clockwise position. Turn fully clockwise for 2 Hz cut-off when measuring infrasonic noise or low frequency acceleration.

Amplifier

The input and output amplifiers are each preceded by an attenuator, the settings being controlled by two concentric range selectors on the front panel of the instrument. A reference calibration oscillator is accompanied by a system gain-adjust potentiometer. The system's frequency response is linear within 1 dB to 70 kHz. Weighting network A, B, C or D may be selected or external filters can be inserted between the input and output amplifiers.

The second section of the output amplifier supplies 0,5 V RMS at full scale deflection to the AC output socket. Alternatively, 5 V RMS can be obtained from the third section when the meter switch is set to "Batt. (Rec)". In this position, the

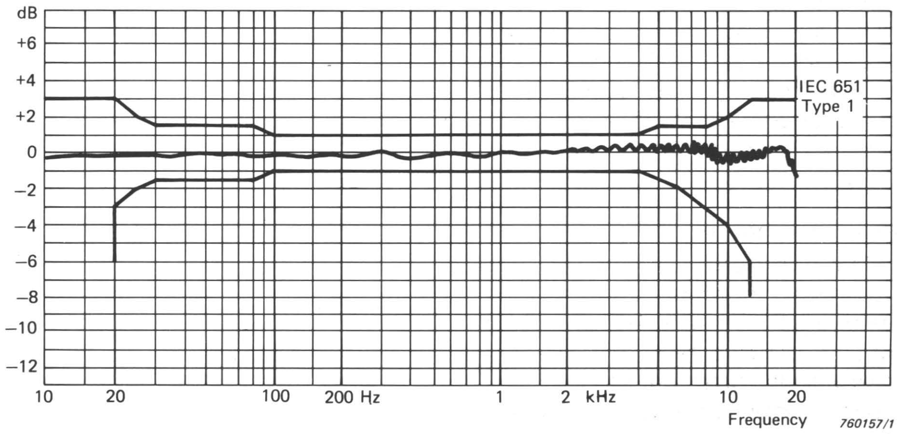


Fig.6. Free-field frequency response of complete instrument to sine waves with 0° incidence

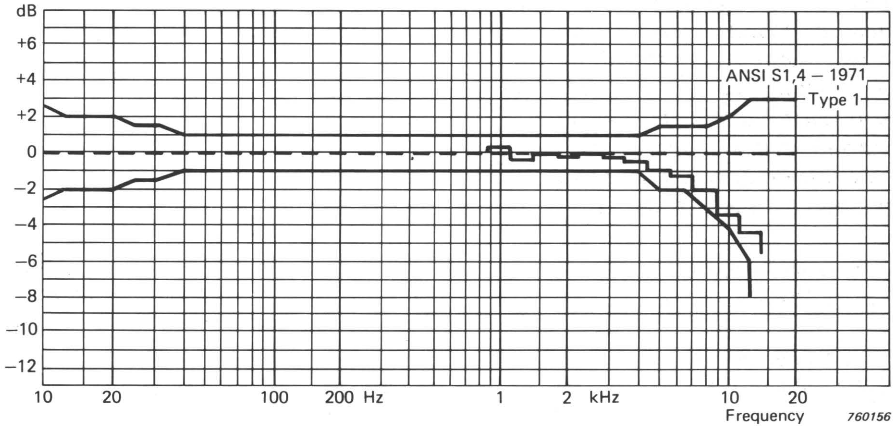


Fig.7. Diffuse field (random incidence) frequency response of complete instrument

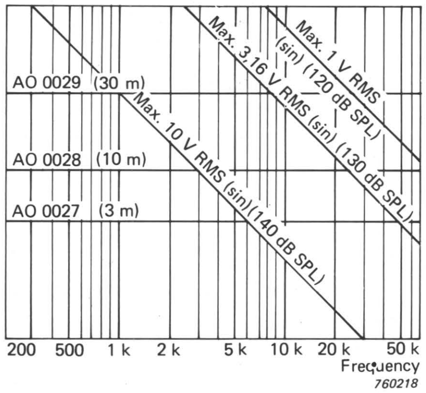


Fig.8. Maximum permissible input voltage with different lengths of extension cable as a function of frequency

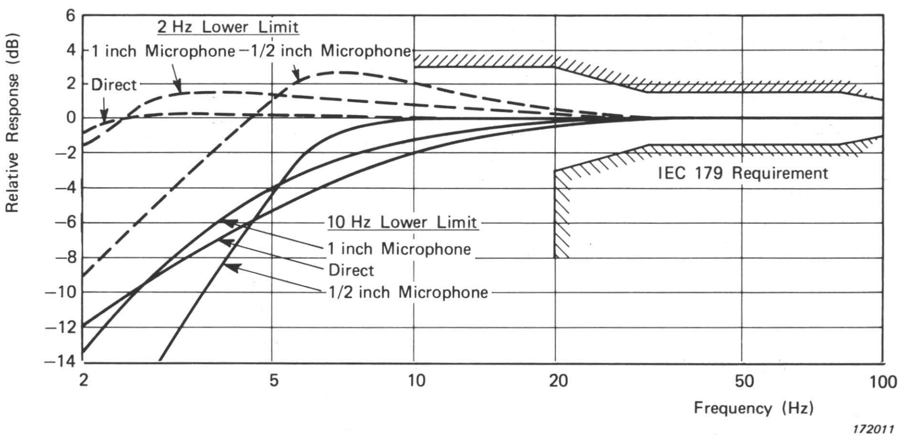


Fig.9. Adjustable low frequency responses of the 2209 with 1" and 1/2" microphones

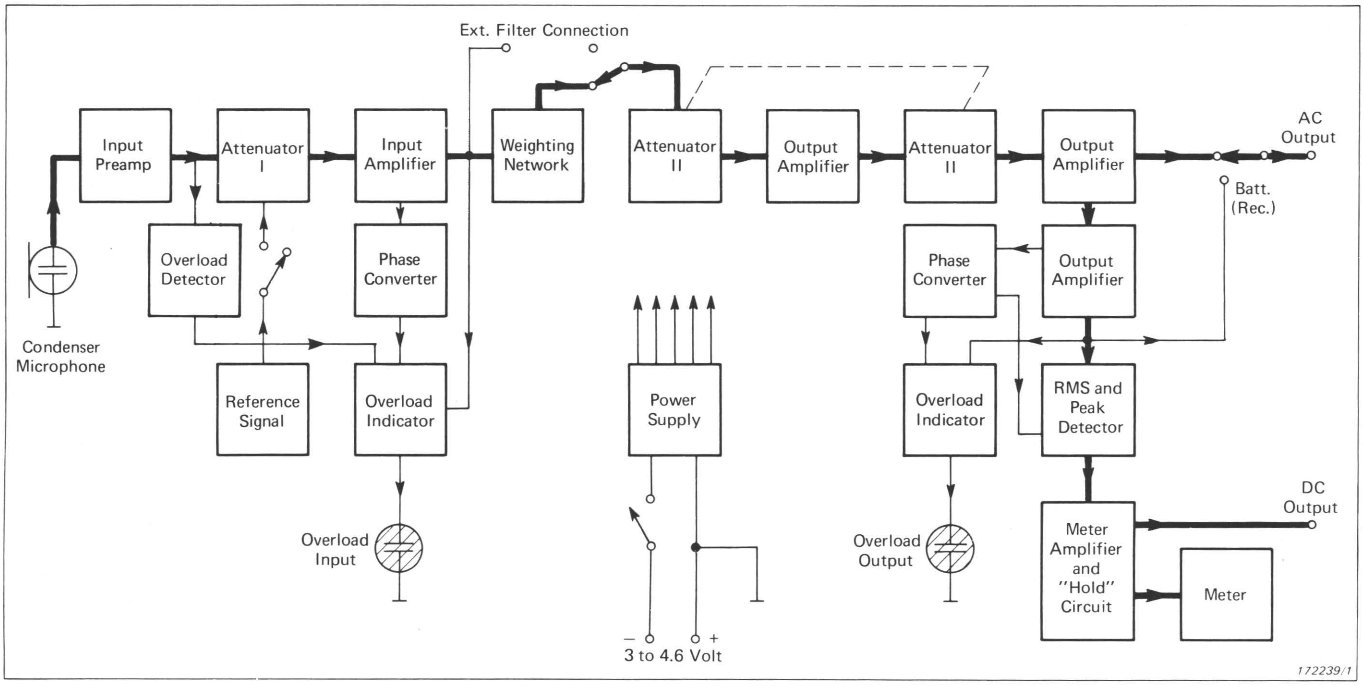


Fig.10. Block diagram of Type 2209

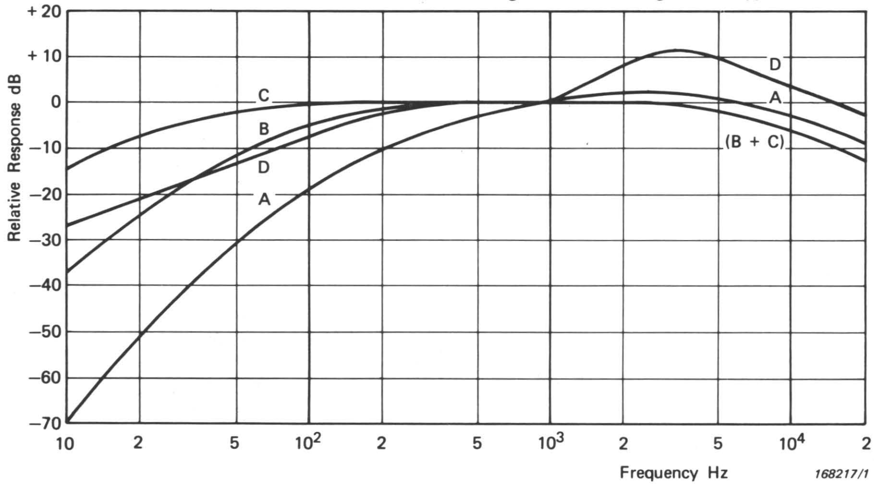


Fig.11. Frequency response curves of the A, B, C and D weighting networks

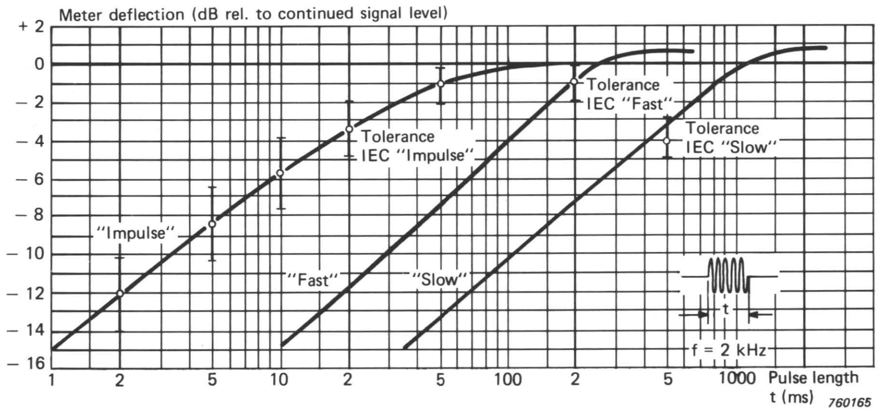


Fig.12. Response of meter rectifier and meter to tone bursts of varying duration

meter monitors battery condition during recording. The third section of the amplifier also drives the meter detectors.

Because short duration, high amplitude signals can overload the amplifiers without causing the meter to deflect above full scale, overload indicators are provided for the input and output amplifiers. The indicators respond to either positive or negative peaks having durations as short as 50 μs, and they continue to flash for about one second after overload.

Detector

The RMS detector can measure signals with crest factors as high as 40, i.e. 32 dB peaks above RMS level. The detector provides three time constants, "Impulse", "Fast" and "Slow" in accordance with standards for precision and impulse sound level meters. Fig.12 shows the response of the 2209 to tone bursts of varying duration. Decay time of the impulse circuit is 3 s. This corresponds to the 1,5 s decay time constant of the Peak detector circuit required in IEC 651. "Impulse Hold" permits the maximum RMS level measured with the "Impulse" time constant to be stored as a steady deflection for ease in measuring impulse sounds. The meter can be reset by momentarily depressing the "METER RESET" button. The 2209 also has a "Peak Hold" detector for measuring the true peak value of noise and vibration signals. Rise time of the detector is approximately 10 μs.

A DC output of 0,8 V at full scale deflection is available from the detector circuit. The meter is a ribbon-suspended moving coil type with a removable meter scale. The scale is graduated —10 to +10 dB on its "Sound Level Meter" side and 0 to

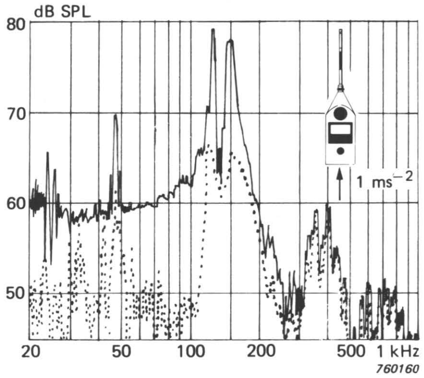


Fig.13. Equivalent sound pressure level when complete sound level meter is excited vertically at 1 m/s². The dotted line indicates sound level produced by vibration exciter

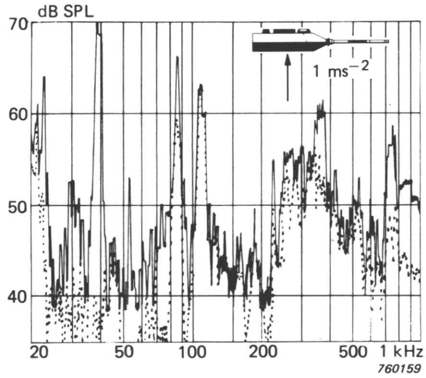


Fig.14. Equivalent sound pressure level when complete sound level meter is excited horizontally at 1 m/s². The dotted line indicates sound level produced by vibration exciter

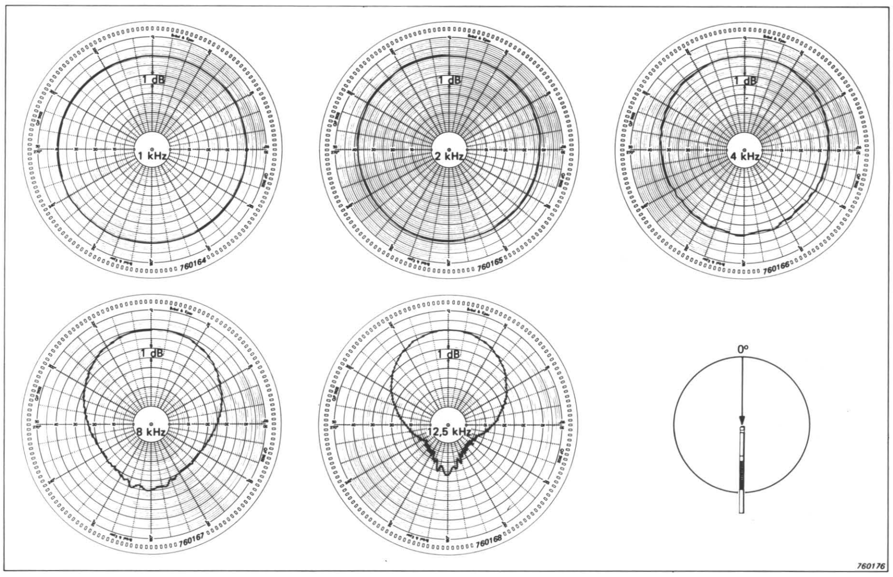


Fig.15. Directional characteristics of the microphone Type 4165 in a free-field

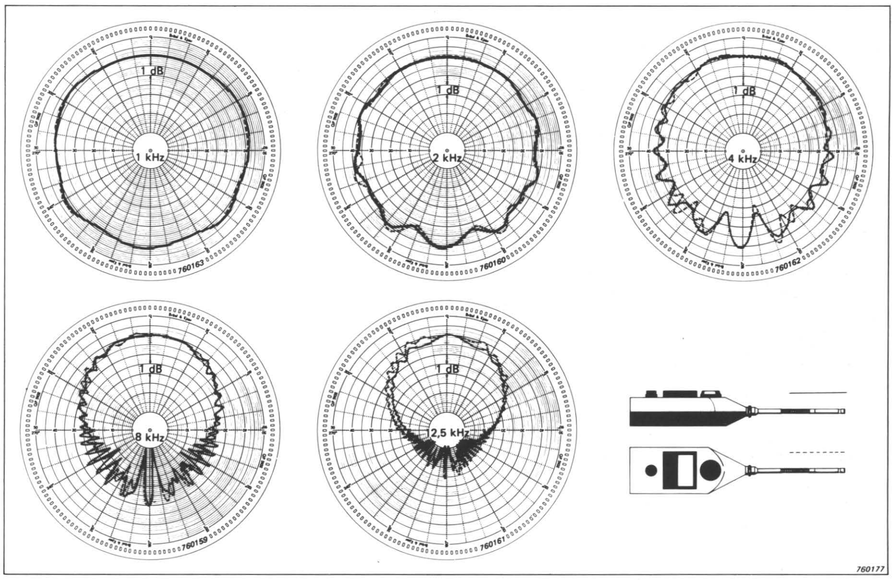


Fig.16. Directional characteristics of the complete instrument inclusive microphone and extension rod in a free-field

10 and 0 to 30 on its "Vibration Meter" side. Additional graduations on each side permit battery condition check and calibration by the internal reference voltage.

Documentation

Brüel & Kjær sound level meter specifications are supported by full documentation so users can plan interconnections with other instruments and predict system noise in vibration, acoustic and electromagnetic environments. This documentation eventually proves to be invaluable in most measurement programs.

Specifications 2209

(Specifications refer to 2209 with Extension Rod UA 0196 and Microphone 4165, unless otherwise stated)

Measuring Ranges:

	Microphone Type No.	Max. Level (dB)	Minimum dB Level (5 dB above noise floor)										
			Weighting Network					External Filter Type No.					
								1613 (Octave)			1616 (1/3 Octave)		
			D	A	B	C	Lin	31,5 — 63 Hz	125 — 250 Hz	0,5 — 16 (31,5) kHz	20 — 400 Hz	0,5 — 16 (40) kHz	Lin
1"	4144 — 4145	140	25	18	22	24	36	23	18	15	17	17	28
1/2"	4165*— 4166	140	34	24	28	34	42	33	28	22	25	19	32
1/2"	4133 — 4134	150	46	36	40	46	56	45	40	34	37	31	44

* Included in 2209

Conformance to Standards:
The 2209 conforms to the requirements of IEC 651 Type 1, DIN 45 633 part 1 and ANSI S.1.4-1971 Type 1 for precision sound level meters and IEC 651 Type 1 (Imp.) and DIN 45 633 part 2 for impulse precision sound level meters

Reference Conditions for Instrument Calibration:
Type of Sound Field: Free
Ref. Direction of Incidence: Perpendicular to microphone diaphragm

Ref. Sound Pressure Level: 84 dB re 20 μPa
Ref. Frequency: 1 kHz
Ref. Temperature: 20°C
Ref. Measuring Range: 80 dB (90 dB FSD)

Absolute Accuracy at Reference conditions: ± 0,7 dB

Microphone:

Type:
B & K Free-field response 1/2" Condenser Microphone Type 4165
Polarization Voltage:
200 V
Frequency Response: At 0° incidence; Free-field
± 1 dB from 4 Hz to 12,5 kHz
± 2 dB from 3 Hz to 20 kHz
An individual response curve is supplied with each microphone
Directional Characteristics:
See Figs. 15 and 16
Sensitivity:
Typically 50 mV/Pa, individually calibrated
Temperature Coefficient:
Approx. —0,01 dB/°C (—0,055 dB/°F)
Permitted Temperature Range:
—50°C to + 60°C (—58°F to + 140°F)
Effect of Ambient Pressure:
Approx. —0,01 dB per kPa at 101,3 kPa
Long Term Stability:
Better than 1 dB per 300 years at 27°C (81°F)
Typically 1 dB per 100 hours at 100°C (212°F)

Input:

Input Section:
Plugs in complete with Microphone capsule
Imput Impedance:
> 1 GΩ//< 0,5 pF
Maximum Input Voltage:
10 V (sine) RMS. See also Fig. 8

Output:

Output Impedance: (load does not affect meter deflection)
AC: 600 Ω (200 Ω in pos. "Batt. (Rec.)" max. load 10 kΩ//200 pF, noise at least 50 dB below FSD voltage)
DC: 25 kΩ

Output Voltage:
AC: 0,5 V RMS for FSD (5 V in "Batt. (Rec.)" mode, max. 100 V peak-to-peak)
DC: 0,8 V for FSD (dynamic range 25 dB)

Amplifier:

Attenuators:
20 to 140 dB FSD in 10 dB steps
Accuracy: 5 Hz to 50 kHz ± 0,2 dB
2 Hz to 80 kHz ± 0,5 dB

Frequency Response:
± 0,5 dB: 5 Hz (20 Hz) to 30 kHz
± 1 dB: 2 Hz (10 Hz) to 70 kHz
(Figures in parentheses obtainable by switch in input preamp)

Maximum Amplification:
114 dB

Gain Adjust:
+ 3 to —10 dB

Inherent Noise:
Linear:
2 Hz to 70 kHz:
Max. 30 μV referred to imput*
10 Hz to 70 kHz:
Max. 30 μV referred to imput**
Curve A:
Max. 2,8 μV referred to input**
*300 pF across input, **60 pF across input

Weighting Networks:
A, B, C and D weighting plus linear amplifier response

External Filter Sockets:
Output Impedance: < 5 Ω in series with 470 μF (max. load 500 Ω)
Input Impedance: 146 kΩ

Indicating Meters:

Detector:
RMS (in pos. "Imp. Hold", "Imp.", "Fast" and "Slow")
Crest Factor Capability:
10 at FSD increasing to
40 at 12 dB below FSD
Meter Accuracy: (For crest factors up to 10)
± 0,5 dB from FSD to 12 dB below FSD
± 1 dB from 12 dB to 20 dB below FSD
(These limits are increased by 0,5 dB for crest factors between 10 and 20 and by 1 dB for crest factors between 20 and 40)
PEAK: (in pos. "Peak Hold")
Rise Time: < 20 μs
Meter Accuracy: ± 0,5 dB from FSD to 12 dB below FSD
Frequency Response: ± 1 dB from 2 Hz (or 10 Hz) to 16 kHz

Damping:
"Impulse", "Fast" and "Slow"
"Impulse Hold": decay time < 0,05 dB/s
"Peak Hold": decay time < 0,05 dB/s, rise time < 20 μs

Scale Graduations:
Sound: 1 dB divisions from —10 to 0 dB.
0,5 dB divisions from 0 to + 10 dB
Vibration: 0 to 10 and 0 to 30 linear

Calibration:
Internal 2 kHz oscillator, stability better than ± 0,2 dB

Instrument Environment:

Operating Temperature Range:
—10°C to + 50°C (+ 14°F to + 122°F) give less than ± 0,5 dB change in indication
Permitted Humidity Range:
The instrument is affected less than 0,5 dB between 0 and 90% relative humidity provided no condensation occurs
Effect of Vibration:
See curves Fig. 13 and Fig. 14
Effect of Sound Field:
At least 60 dB below sensitivity of Microphone Type 4165
Effect of Electrostatic Field:
Negligible with microphone grid fitted
Effect of Electromagnetic Field:
80 A/m (1 Orsted) (50 Hz) gives:
< 28 dB(D)
< 18 dB(A)
< 28 dB(B)
< 36 dB(C)
< 36 dB(Lin)

Batteries:

Type:
3 × 1,5 V IEC Type LR 20 Alkaline Cells (e.g. Mallory Type MN 1300) B & K order No. QB 0004

Life: (Continuous operation)
20 hours with recommended Alkaline batteries
14 hours with rechargeable NiCd-cells (B & K order No. QB 0008, 3rqd.)
(Saft Volta block VR 4D)
(Varta RS 4)
Recharging from Power Supply Type 2808, Battery Box ZG 0146 and Charging Adaptor AQ 0157 + 3 Dummy cells ZR 0017
8 hours with standard dry cells

Dimensions:
Length: 325 mm (12,8 in) (545 mm (21,5 in) with Extension Rod UA 0196)
Width: 120 mm (4,8 in)
Height: 90 mm (3,5 in)

Weight:
3 kg (6,6 lb)

Accessories included:
1/2" Condenser Microphone 4165
Input Stage ZC 0007
Flexible Extension Rod UA 0196
Input Adaptor JJ 2614
Windscreen UA 0237
4 Screened Plugs JP 0006
Attenuator Scales SA 0012 to SA 0021
Screwdriver QA 0001

Accessories Available:
See survey Fig. 4

2. CONTROLS

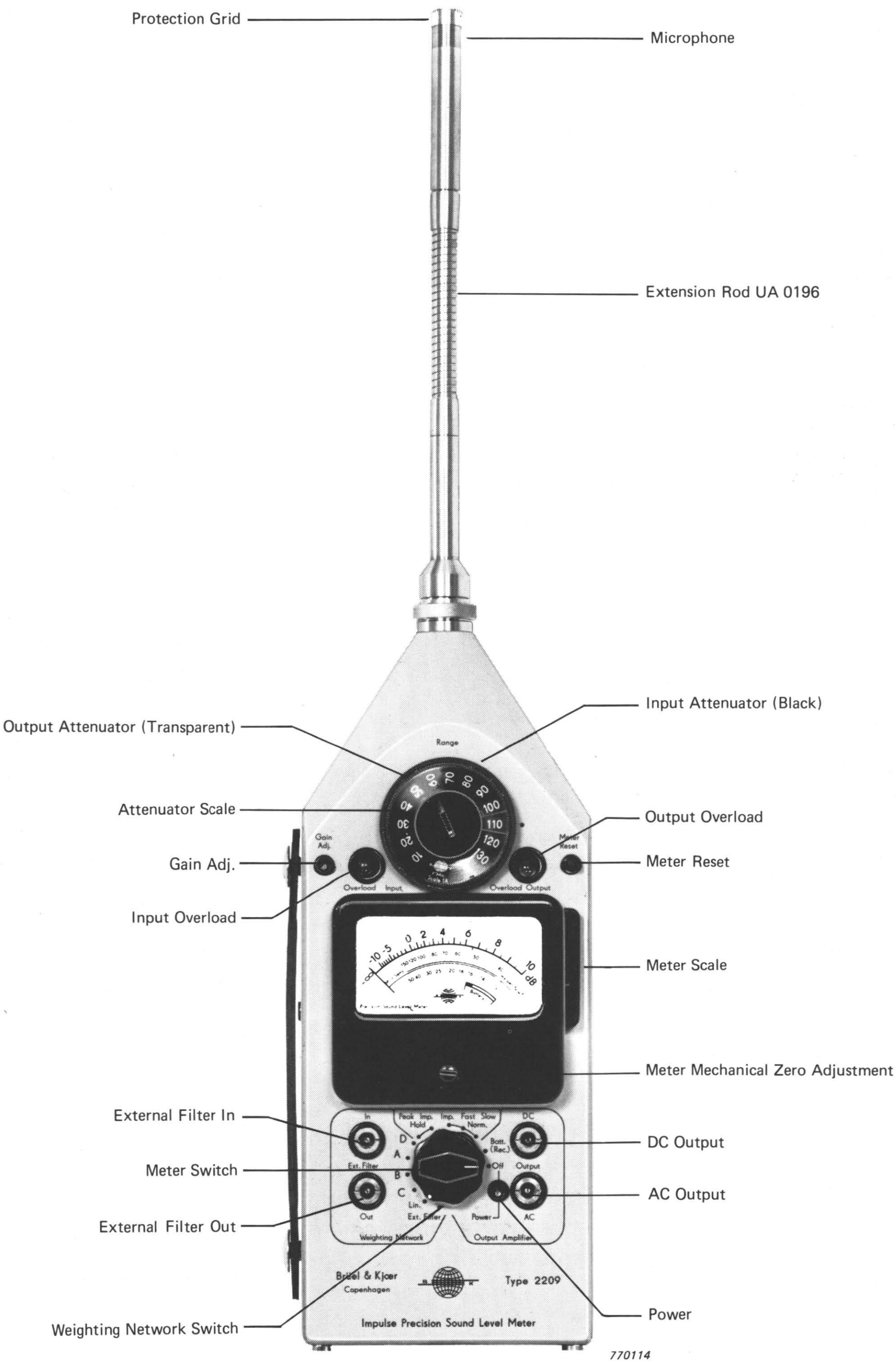


Fig. 2.1. Front view of 2209

MICROPHONE: Half-inch condenser Microphone Type 4165.

PROTECTION GRID: Protects the diaphragm of the microphone from physical damage. This grid should not be removed, except when the microphone is to be fitted with a Nose Cone or Rain Cover, or for inspection of the diaphragm. DO NOT TOUCH THE DIAPHRAGM WITH ANY OBJECT.

EXTENSION ROD UA 0196: This flexible extension rod connects the microphone to the sound level meter at a sufficient distance that the influence of the body of the sound level meter and operator on the sound field is minimized. This extension rod must be used in order for the instrument to conform to precision standards.

If a Dehumidifier Type UA 0308 is used, it is placed between the microphone and the extension rod.

When screwing the microphone, extension rod, and sound level meter together, only light finger torque should be used.

METER SWITCH: This 7-position rotary switch is both the power switch and meter function selector, with positions as follows:

"Off": Power off position. In all the other positions the power is on, and the POWER lamp flashes.

"Batt.(Rec.)": Battery check position. If the meter needle deflection is below the red area, the batteries must be replaced. If the meter needle deflection is on the red block, the instrument may be used for a short time before battery replacement is necessary. A higher meter needle deflection indicates sufficient battery power.

"Slow": Provides a "Slow" meter response. (See Fig.12 in Chapter 1.)

"Fast": Provides a "Fast" meter response. (See Fig.12 in Chapter 1.)

"Imp.": Provides the "Impulse" meter response for measurement of subjective level of short-duration sounds. (See Fig.12 in Chapter 1.)

"Imp. Hold": Holds the maximum RMS value of the applied signal until the METER RESET button is depressed. Rise time is the same as that for "Imp." response; decay rate is $< 0,05$ dB/s.

"Peak Hold": Holds the maximum peak value of the applied signal until the METER RESET button is depressed. Rise time is $< 20\,\mu s$.

POWER: This lamp flashes when the instrument is switched on.

WEIGHTING NETWORK SWITCH: This 6-position switch determines the frequency-response characteristics of the instrument's electronics, and the selection of an external filter, as follows:

"A", "B", "C", "D": Each of these 4 positions selects one of the standardized frequency-weighting networks for the subjective indication of loudness. (See Fig.11 in Chapter 1.)

"Lin.": Gives linear frequency response from 2 Hz (or 10 Hz; see section 3.2.2) to 70 kHz.

"Ext. Filter": Selects an external filter connected to the EXTERNAL FILTER sockets. No meter needle deflection will be obtained in this position if a filter is not connected.

METER SCALE: This is a double-sided scale which may be removed by sliding it out to the right. One side is calibrated for precision sound level measurements and the other side for vibration (or voltage) measurements.

"Precision Sound Level Meter" scale: The upper scale (black) is calibrated from "—10" dB to "+ 10" dB for the reading of sound level. "0" dB on the scale corresponds to the attenuator setting indicated inside the red lines. Thus, for example, if the meter shows "—2" dB and the attenuator setting is "70" dB, then the sound level is 68 dB. The lower scale (red) is used for calibration of the instrument using the sensitivity of the microphone which is found on its individual calibration chart. When checking the batteries (with the METER SWITCH in "Batt. (Rec.)" position), the meter needle deflection must be within the black lines labelled "Battery" on the lowest meter scale, and above the red block for long-term use.

"Vibration Meter" scale: The upper scale (black) is calibrated from "0" to "10" and "0" to "31,6" in linear units. The vibration level (or voltage) is then the meter reading referenced to the full-scale deflection shown inside the red lines, when the appropriate ATTENUATOR SCALE is fitted. The lower scale (red) is used for calibration of the instrument using the sensitivity of the accelerometer (see section 3.5.3) which is found on its individual calibration chart. The "Battery" check scale is the same as the one on the other side of the METER SCALE.

METER MECHANICAL ZERO ADJUSTMENT: The screw head just below the METER SCALE is adjusted with the instrument switched off to give a meter needle deflection on the "—∞" mark ("Precision Sound Level Meter" scale) or the "0" mark ("Vibration Meter" scale).

METER RESET: This push button resets the meter when using the "Imp. Hold" or "Peak Hold" position.

INPUT SOCKET SWITCH: This screwdriver-operated switch is located in the centre of the input-stage socket; see section 3.2.2. The lower frequency limit of the instrument is 2 Hz with this switch fully clockwise and 10 Hz with it fully anticlockwise.

Since the 2209 can measure sound levels (and vibration levels or voltages) over a wide dynamic range (from 24 dB to 140 dB for sound levels, for example) but the METER SCALE can only accurately display 20 dB of this range at a time, an attenuator system is necessary to set the range of the instrument so that the sound level (or vibration level or voltage) will be within the 20 dB indicated on the METER SCALE. In order to minimize the chances of an overload, and to give the best possible signal-to-noise ratio, a dual attenuator system consisting of INPUT and OUTPUT ATTENUATORS is used. The correct use of these switches is described in Chapter 3, Operation.

INPUT ATTENUATOR (black):

This 9-position switch controls the gain of the input amplifier in 10 dB steps, and also selects the internal reference voltage. The range of this switch is physically limited to a position from "60" dB to "Ref." being adjacent to the black spot. (If ATTENUATOR SCALES other than No. 1A are used, then different values will be noted.) Maximum input gain is obtained in the fully clockwise position; and the internal reference voltage is selected in the fully anticlockwise position (provided the transparent OUTPUT ATTENUATOR is also set to its fully clockwise position).

OUTPUT ATTENUATOR (transparent):

This 6-position switch controls the gain of the output amplifier in 10 dB steps. The range of rotation of this switch is physically limited so that the red lines on the knob may only be moved anticlockwise from the black dot. Maximum output gain is obtained in the fully anticlockwise position, while the minimum output gain (red lines by the black dot) is recommended for use whenever possible.

The total gain setting depends on both INPUT and OUTPUT ATTENUATOR positions; the measuring range corresponding to the gain setting is always directly indicated between the red lines on the knob.

ATTENUATOR SCALE:

Ten reversible ATTENUATOR SCALES are provided with the 2209 to permit direct reading of virtually any sound, vibration or voltage unit within the range of the instrument. The SCALES are changed by unscrewing the large screw in the centre of the attenuator knobs with a coin or a large screwdriver and removing the transparent knob. Ensure that the small cut-out in the SCALE by the "Ref." mark is correctly located over the pin in the black knob, and then refit the transparent knob (ensuring its correct location) and the screw.

GAIN ADJ.:

This screwdriver-operated potentiometer is used for adjusting the gain of the input amplifier over a range of 13 dB to permit calibration with various transducer sensitivities. It is adjustable from —10 dB to + 3 dB.

INPUT and OUTPUT OVERLOAD:

Separate flashing lamps indicate any overload of the input and/or output amplifiers. The INPUT and/or OUTPUT ATTENUATORS should be adjusted as necessary to remove the indicated overload which will otherwise give erroneous readings. If an overload cannot be removed, it should be noted with the measurements.

EXTERNAL FILTER IN:

Socket for connection to the input of an external filter (such as Octave Filter Set Type 1613 or 1/3 Octave Filter Set Type 1616). The minimum load impedance of the socket is 500 Ω. Accepts plug JP 0006 or cable AO 0007, etc..

EXTERNAL FILTER OUT:

Socket for connection to the output of an external filter to the 2209. Input impedance of the socket is 146 kΩ. The maximum input voltage is 0,2 V RMS, 2 V Peak. Accepts plug JP 0006 or cable AO 0007, etc..

The EXTERNAL FILTER IN and OUT sockets may be connected to a 1613 or a 1616 directly by means of the Connection Bar JP 0400 supplied with each filter.

DC OUTPUT:	This socket provides a DC voltage from the meter rectifier, giving 0,8 V (open circuit) for full-scale meter needle deflection, with an output impedance of 25 kΩ. The meter reading is not affected by loading this socket. Accepts plug JP 0006 or cable AO 0007, etc..
AC OUTPUT:	This socket provides an AC voltage from the output amplifier. With the METER SWITCH set to "Batt. (Rec.)", the output is 5 V RMS (for full-scale deflection) into a load of not less than 10 kΩ. With the METER SWITCH set to "Slow", "Fast", "Imp.", "Imp. Hold", or "Peak Hold", the output is 0,5 V RMS (for full-scale deflection) with an output impedance of 600 Ω, and any load may be applied without affecting the meter reading. These output voltages are open-circuit values, and are suitable for use with a Tape Recorder, etc.. Accepts plug JP 0006 or cable AO 0007, etc..
TRIPOD-MOUNTING THREADS:	There are two tripod-mounting threads on the rear of the 2209, the upper for mounting the 2209 alone, and the lower for mounting the 2209 when fitted with a filter set (Type 1613 or 1616). For vertical mounting, a thread is also provided on the bottom of the 2209.

3. OPERATION

3.1. INTRODUCTION

This Instruction Manual describes the specific procedures necessary to correctly use the Impulse Precision Sound Level Meter Type 2209. However, there are many aspects of sound measurement of a more general nature that are important to consider in order to get correct reproducible measurements. Many of these are discussed in the accompanying booklet, "Measuring Sound", which should be considered as part of this Instruction Manual.

3.2. PRELIMINARIES

3.2.1. Battery Considerations

The 2209 is powered by three standard torch batteries (D cells or Type R 20 in IEC Publication 86-2). Access to the batteries is gained by sliding the rear cover off the instrument. The batteries should be inserted with polarities as shown in the battery compartment. See Fig.3.1.

Fig.3.1. Battery compartment of 2209

Good-quality dry cells give an operating time of 8 hours, while alkaline cells such as Mallory Duracell MN 1300 give 20 hours of continuous operation. Rechargeable nickel-cadmium cells may also be used, giving an operating time of 14 hours. These cells may be recharged using the Power Supply Type 2808 with Battery Box ZG 0073 and Charging Adaptor AQ 0043 — see the 2808 Instruction Manual.

The 2209 may also be powered directly from the mains using Mains Power Supply WB 0073 which is inserted in the battery compartment. If operated with Hearing Aid Test Box Type 4217 it may be powered by Power Supply Adaptor UA 0364 as described in the 4217 Instruction Manual.

The batteries should be removed from the instrument if it is not used for a long time to prevent possible battery leakage.

3.2.2. Selection of Lower Limiting Frequency

A switch is incorporated into the input-stage socket of the 2209, which acts as a low-frequency cut-off adjustment. (See Fig.3.2.) Access to this screwdriver-operated switch is achieved by removing the Input Stage ZC 0007. Turning the switch fully anticlockwise gives a low-frequency cut-off of 10 Hz, and turning it fully clockwise gives a value of 2 Hz. See Fig.10 of Chapter 1. This switch should be set to give a low-frequency cut-off of 10 Hz, provided no frequencies of interest lie below that value, to reduce the influence of very-low-frequency sounds and vibrations.

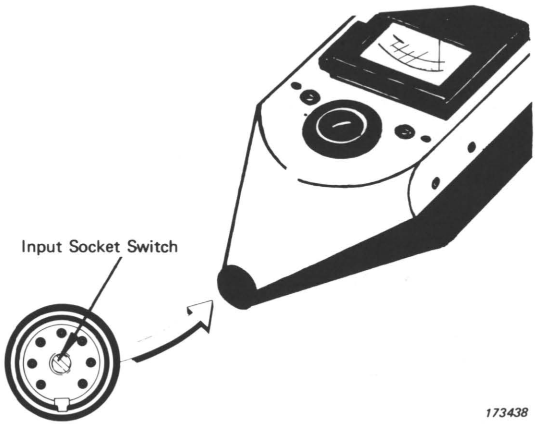


Fig.3.2. Input socket of 2209 (showing switch)

3.2.3. Mounting the Microphone

There are several methods of mounting the microphone, which will be outlined below. (See also Fig.6 of Chapter 1.) However, there are one or two general considerations which will be mentioned first. When connecting or disconnecting the microphone, ensure that the instrument power is turned off. In dry weather, it is recommended that static electricity be discharged from your body before fitting or removing microphones. Only light finger torque should be applied to the microphone, extension rod, etc.. Dust and foreign objects should be kept off the diaphragm, which must not be touched with any object. If the diaphragm must be cleaned, cotton wool should be used very carefully. Dry and preferably warm conditions are recommended for storing the instrument and its accessories.

Direct Mounting

Insert the Input Stage ZC 0007 (with 5 connection pins) into the input-stage socket, and secure it by turning the threaded retainer. If the Dehumidifier UA 0308 is required, it should be screwed on next, and finally the microphone. (The silica-gel of the Dehumidifier should be blue. If it is pink it should be dried out at a maximum temperature of

130°C.) If microphones other than the half-inch type are used, an adaptor is necessary (see Fig.6 of Chapter 1).

Mounting on Extension Rod UA 0196

Insert the Input Stage ZC 0007 as described above. Screw on the Extension Rod, then the Dehumidifier if necessary (as above) and then the microphone. Microphones of other sizes will need an adaptor (see Fig.6 of Chapter 1). The Extension Rod UA 0196 should be used straight to satisfy the various precision standards.

Use of Extension Cable and Tripod

The necessary extension cable (3 m, 10 m or 30 m long, see Fig.6 of Chapter 1) should be inserted directly into the input-stage socket of the 2209, and secured by turning the threaded retainer. The Input Stage ZC 0007 is then attached to the cable, and the microphone and other accessories are attached as previously described. The microphone or the Extension Rod may be attached directly to the tripod using Adaptor UA 0354. This arrangement allows the operator to be close to the Sound Level Meter but at a distance from the microphone.

3.3. CALIBRATION FOR SOUND MEASUREMENTS

3.3.1. General

The 2209 may be calibrated in two ways: either using an acoustic calibrator (effectively a miniature loudspeaker) placed over the microphone; or using the built-in reference voltage in the instrument. The acoustical method has the advantage that it checks the entire instrument, including the microphone, and so is the preferred method. When the instrument is first received, it is a useful check to calibrate it by both methods; these should agree to within about 0,5 dB.

3.3.2. Acoustical Calibration (External Source)

The Sound Level Calibrator Type 4230 or Pistonphone Type 4220 is recommended. The 4230 provides a 1 kHz test tone at 94 dB with an accuracy of 0,3 dB between 20 and 26 °C. The Pistonphone Type 4220 provides a 250 Hz test tone at 124 dB (±0,2 dB) with an accuracy of 0,15 dB.

Calibration with Microphone Type 4165

The calibration procedure when the 2209 is used with the microphone with which it is normally supplied (Type 4165) is as follows:

1. Turn the METER SCALE to "Precision Sound Level Meter", and adjust the METER MECHANICAL ZERO ADJUSTMENT screw with a small screwdriver (if necessary) to give a meter needle setting on the "—∞" mark of the METER SCALE while the instrument is switched off.

2. Check that the correct ATTENUATOR SCALE (Scale No. 1A, "10" to "130"dB) is inserted (see Chapter 2 for instructions) and set the lower limiting frequency as required (see section 3.2.2).

3. Attach the Input Stage and microphone with the required extension cables and adaptors as described in section 3.2.3.

4. Turn the METER SWITCH to "Batt. (Rec.)" to check the batteries; then set it to "Fast" meter response. (The instrument warm-up time is 30 s.)

5. Set the WEIGHTING NETWORK SWITCH to "C" or "Lin.".

6. Set the ATTENUATORS to "90" dB if the Sound Level Calibrator Type 4230 is used, or "120" dB if the Pistonphone Type 4220 is used, with the OUTPUT ATTENUATOR (transparent) as far clockwise as possible (red lines by the black dot).

7. Fit the half-inch adaptor on the acoustic calibrator, and place it over the microphone with its normal protection grid. Turn the acoustic calibrator on, and hold it still over the microphone. (See also the separate Instruction Manuals.)

8. Adjust the GAIN ADJ. potentiometer with a small screwdriver to give a meter reading of "+ 3,8" (= 93,8 dB) if a 4230 is used, or to give a reading of the value given on the calibration chart (corrected as necessary for barometric pressure) if a 4220 is used. (See also the separate Instruction Manuals.)

Calibration with microphones other than Type 4165

The 2209 may be used with one-inch, half-inch, quarter-inch, and eighth-inch B & K condenser microphones. When using quarter-inch or eighth-inch microphones, see also section 4.6. Using the microphone sensitivity (mV/Pa) from its calibration chart, select and insert the correct ATTENUATOR SCALE as shown in Table 3.1. Apart from the choice of adaptor for the acoustic calibrator (step 7), and the calibration value (step 8) when using the 4230, which is given below, the calibration procedure is identical to that given above for the Type 4165. With the use of quarter-inch and eighth-inch microphones, the use of the Pistonphone is recommended for calibration.

Microphone open-circuit sensitivity	B & K Microphone Type	Scale No.	Red Sensitivity Scale
40–160 mV per Pa*	4144 4145 4161 4165 4166	1 A	Upper
11–50 mV per Pa	4133 4134 4149 4163	1 B	Lower
4–16 mV per Pa	4133 4134 4149 4163	2 B	Upper
1,1–5 mV per Pa	4135 4136	2 B	Lower
0,4–1,6 mV per Pa	4138	3 A	Upper

* 1 Pa = 1 N/m^2 = 10 μbar

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Table 3.1. ATTENUATOR SCALES for sound measurement

In addition, the microphones fall into the free-field or pressure-type categories. Although this does not affect the Pistonphone calibration procedure (at 250 Hz), it does affect the value to which the 2209 should be calibrated with the Sound Level Calibrator (at 1 kHz).

These values should be set as follows:

One-inch free-field microphones:	"93,6" dB
Half-inch free-field microphones:	"93,8" dB
Pressure microphones of both sizes:	"94,0" dB
Quarter-inch and eighth-inch microphones:	"94,0" dB

3.3.3. Calibration using the Internal Reference Voltage

The stable internal voltage (± 0,2 dB at 2 kHz) in the 2209 may also be used for calibration, as follows:

1. Turn the METER SCALE to "Precision Sound Level Meter"and, using a screwdriver, adjust the METER MECHANICAL ZERO ADJUSTMENT screw (if necessary) to give a meter needle setting on the "—∞" mark of the METER SCALE while the instrument is switched off.

2. Insert the appropriate ATTENUATOR SCALE, depending on the microphone sensitivity (mV/Pa) given on its calibration chart. Selection is made with reference to Table 3.1. (See Chapter 2 for instructions.)

3. Set the lower limiting frequency as required (see section 3.2.2), and attach the Input Stage, microphone, required extension cables, and adaptors as described in section 3.2.3.

4. Turn the METER SWITCH to "Batt. (Rec.)" to check the batteries; then set it to "Fast" meter response. (The instrument warm-up time is 30 s.)

5. Set the WEIGHTING NETWORK SWITCH to "Lin.". (Weighted positions must not be used for this 2 kHz reference voltage).

6. Set the ATTENUATOR switches to "Ref." (between the red lines).

7. Adjust the GAIN ADJ. potentiometer with a small screwdriver to give a meter needle deflection on the red MICR. SENS. scale (upper scale or lower scale, as shown in Table 3.1) equal to the Open-Circuit Sensitivity of the microphone in mV/Pa obtained from its calibration chart.

3.4. SOUND MEASUREMENTS

3.4.1. General

The accompanying booklet "Measuring Sound" should be read through before proceeding with the measurements, as it contains much useful information on the subject. One or two points should perhaps be emphasized. Ensure that the microphone has the required dynamic range, frequency range and directional characteristics. Always use a Windscreen for outdoor measurements and in a dusty environment. Various Nose Cones are available for reducing wind noise (see Fig.6, Chapter 1), as well as Dehumidifiers. The microphone must be mounted on the Extension Rod UA 0196 to fulfil the requirements of the precision standards. If a one-inch microphone is used, a Random Incidence Corrector may also be necessary for certain measurements. Ensure that the measuring position is suitable and hold the Sound Level Meter at arm's length, or mount it on a tripod, to minimize reflections from the operator. Finally, make sure that the background noise level is not too high to make meaningful measurements.

3.4.2. Procedure for Sound Measurements

1. Calibrate the 2209 (including checking the batteries, etc.) as described in section 3.3.

2. Set the METER SWITCH as follows:

"Fast":	For normal measurements of sound
"Slow":	To be used when the meter needle fluctuations are too fast or great to make meaningful readings in the "Fast" position
"Imp.":	For obtaining the **subjective** level of short-duration sounds (< 0,2 s)
"Imp. Hold":	For holding the maximum RMS value of the signal
"Peak Hold":	For holding the maximum peak value of the signal.

Note: It may be found convenient to use only "Fast" or "Slow" here, and to select the required position after step 6.

3. Set the WEIGHTING NETWORK SWITCH to "Lin.".

4. Set the OUTPUT ATTENUATOR (transparent) at minimum gain, i.e. fully clockwise so that the red lines are adjacent to the black spot.

5. Turn the INPUT ATTENUATOR (black) clockwise to give the highest possible meter reading without over-deflecting and without the INPUT OVERLOAD lamp on. If necessary (when the INPUT ATTENUATOR is fully clockwise) for small signals, turn the OUTPUT ATTENUATOR (transparent) anticlockwise to give the highest possible meter reading without over-deflecting and without the OUTPUT OVERLOAD lamp on. (Remember to depress the METER RESET button if a "Hold" position is used.)

6. Select the required position of the WEIGHTING NETWORK SWITCH.

7. If the meter needle now over-deflects, reduce the gain by turning the OUTPUT ATTENUATOR (transparent) clockwise, or if this is not possible turn the INPUT ATTENUATOR (black) anticlockwise to give a meter reading in the measuring range, i.e. between "0" and "+ 10" dB. See note below. Do NOT increase the gain of this ATTENUATOR without repeating steps 2 to 5, as the input amplifier may be overloaded. (Remember to depress the METER RESET button if a "Hold" position is used.)

8. If the meter reading is too low, turn the OUTPUT ATTENUATOR (transparent) anticlockwise to give the highest possible meter reading without over-deflection and without the OUTPUT OVERLOAD lamp on. (Remember to depress the METER RESET button if a "Hold" position is used.)

9. With the microphone directed in the correct orientation for measurements, the sound (pressure) level equals the meter needle deflection plus the attenuator setting indicated inside the red lines. When writing down the readings, note also the position of the METER SWITCH and the WEIGHTING NETWORK SWITCH. (Remember to depress the METER RESET button between readings if a "Hold" position is used.)

Note: The most accurate readings will usually be obtained with meter needle deflections between "0" and "+ 10" dB, but for signals with a very high crest factor, readings may be made in the "—10" to "0" dB range to avoid errors due to output overload. If the OUTPUT OVERLOAD lamp alone flashes, the signal crest factor exceeds the instrument's capability at that ATTENUATOR setting. If the overload cannot be removed while maintaining a reading between "—10" and "+10" dB, the reading will be too low, and the overload should be noted with the results.

If the INPUT OVERLOAD lamp alone lights, turn the INPUT and OUTPUT ATTENUATORS anticlockwise together, or return to step 3 and set up the instrument again, as the sound level has increased. Any overload should be noted with the meter reading.

3.5. CALIBRATION FOR VIBRATION MEASUREMENTS

3.5.1. General

The Sound Level Meter Type 2209 may also be used to measure vibration levels by using one of the adaptors or the Integrator ZR 0020, shown in Fig.3.3. Full details of the ZR 0020 may be found on its Product Data Sheet. Using the adaptors, acceleration only can be measured; if the Integrator is used, acceleration, velocity, and displacement are all available. With the METER SCALE turned to its "Vibration Meter" side, and the correct ATTENUATOR SCALE inserted, acceleration (and velocity and displacement if the ZR 0020 is used) may be read directly from the instrument in vibration units (ms^{-2}, ms^{-1}, m, in metric units or g, in s^{-1}, in, in Imperial units). This is described in sections 3.5.2, 3.5.3, and 3.6.2.

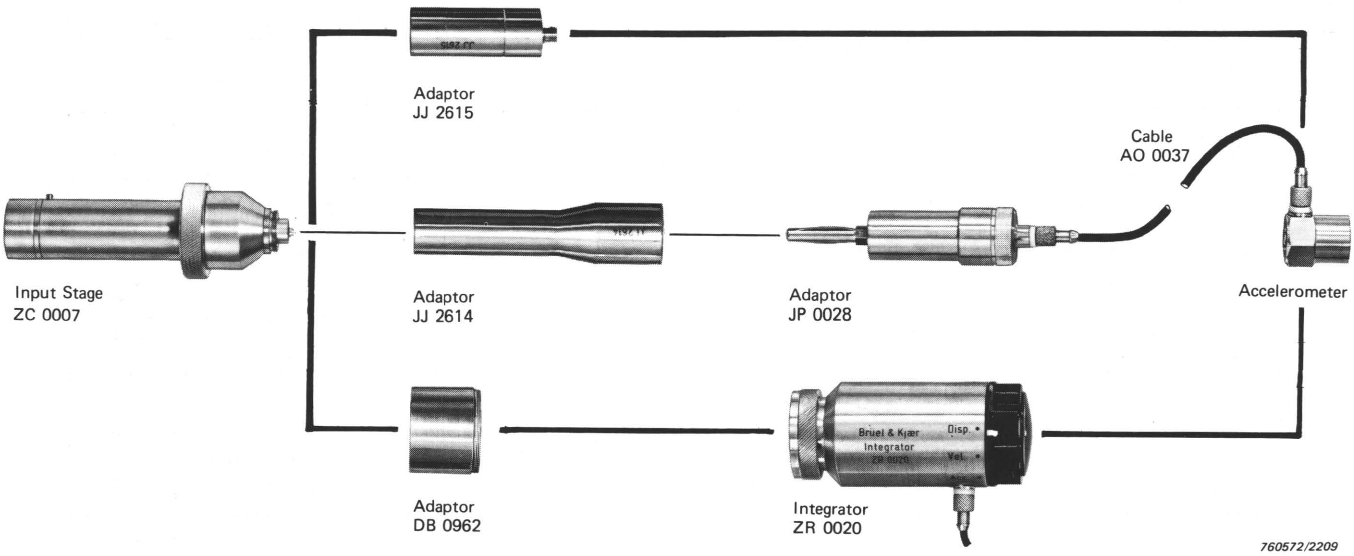

Fig.3.3. Connection of accelerometer

It is also possible to use the "Precision Sound Level Meter" side of the METER SCALE, and make vibration readings in dB. These can be simply converted to vibration units (ms^{-2}, ms^{-1}, m, in metric units or g, in s^{-1}, in, in Imperial units) using the circular Slide Rule QH 0001 provided with the Integrator. This latter method has the advantage that the ATTENUATOR SCALE does not have to be altered for each change of parameter, and is described in sections 3.5.4, 3.5.5, and 3.6.2.

As with sound measurements, the 2209 can be calibrated in two ways: either using an external calibrator (vibrating the accelerometer at a known rate); or using the built-in reference voltage in the instrument. The external method has the advantage that it checks the entire instrument, including the accelerometer.

3.5.2. Calibration using Accelerometer Calibrator Type 4291 — direct reading in vibration units

The portable battery-operated Accelerometer Calibrator Type 4291 generates a vibration level of 1 g peak (0,707 g RMS) at 500 rad s^{-1} (79,6 Hz). The calibration procedure for giving direct readings in vibration units is as follows:

1. Turn the METER SCALE to "Vibration Meter" and, using a screwdriver, adjust the METER MECHANICAL ZERO ADJUSTMENT screw (if necessary) to give a meter needle deflection on the "0" mark of the METER SCALE while the instrument is switched off.

2. Insert the appropriate ATTENUATOR SCALE for the type of measurement (acceleration, velocity, or displacement) and the accelerometer sensitivity (see its calibration chart) as indicated in Table 3.2.

3. Set the lower limiting frequency as required (see section 3.2.2).

4. Mount the accelerometer on the 4291 (see the 4291 Instruction Manual), and connect it to the 2209 using one of the methods shown in Fig.3.3. If an Integrator is used, set it to the required position ("Acc.", "Vel.", or "Disp.").

Accelerometer Sensitivity	B & K Accelerometer Type	Acc.		Vel.		Disp.	
		ms^{-2}	g	ms^{-1}	in s^{-1}	m	inch
0,89–1,12 mV/g		4 B	5 B	6 A	4 A	7 B	5 B
1,12–2,8 mV/g	4344 4367 4369 8303/4/5 8307				4 B		6 A
2,8–3,55 mV/g		5 A	6 A	6 B	4 B	8 A	6 A
3,55–8,9 mV/g	4321 4345				5 A		6 B
8,9–11,2 mV/g	4339 4343 8301 8302 8308	5 B	6 B	7 A	5 A	8 B	6 B
11,2–28 mV/g					5 B		7 A
28–35,5 mV/g		6 A	7 A	7 B	5 B	9 A	7 A
35,5–89 mV/g	4366 4368				6 A		7 B
89–112 mV/g	4338 4370	6 B	7 B	8 A	6 A	9 B	7 B
112–280 mV/g					6 B		8 A
280–355 mV/g		7 A	8 A	8 B	6 B	10 A	8 A
355–890 mV/g					7 A		8 B
890–1120 mV/g		7 B	8 B	9 A	7 A	10 B	8 B
1120–2800 mV/g					7 B		9 A

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Table 3.2. ATTENUATOR SCALES for vibration measurements

5. Turn the METER SWITCH to "Batt. (Rec.)" to check the batteries; then set it to "Fast" meter response. (The instrument warm-up time is 30 s.)

6. Set the WEIGHTING NETWORK SWITCH to "Lin.". (A weighted position should not be used for this 79,6 Hz reference signal.)

7. Set the 4291 to "Internal Gen." and adjust the ACC. LEVEL so that the lower scale of the 4291 meter indicates the mass of the accelerometer (given on its calibration chart). The accelerometer is now vibrating at exactly 1 g peak.

8. Set the ATTENUATORS of the 2209 to give the meter needle a deflection of at least 1/3 full scale with the OUTPUT ATTENUATOR (transparent) as far clockwise as possible.

9. Using a small screwdriver, turn the GAIN ADJ. potentiometer to give a meter reading of one of the following quantities, depending on the measurement parameter and units:

Acceleration:	$6{,}94\ ms^{-2}$ RMS	($7{,}07 \times 10^{-1}$ g RMS)
Velocity:	$13{,}9 \times 10^{-3}\ ms^{-1}$ RMS	($5{,}46 \times 10^{-1}$ in s^{-1} RMS)
Displacement:	$27{,}7 \times 10^{-6}$ m RMS	($1{,}09 \times 10^{-3}$ in RMS)

The 2209 is now calibrated so that direct meter readings (RMS values) may be made of the parameter required in the desired units. (Subsequent selection of, for example, "Peak Hold" will of course mean that the peak value of the vibration level will be stored and displayed.) A separate calibration and a different ATTENUATOR SCALE are necessary for each different parameter or measurement unit.

3.5.3. Calibration using the Internal Reference Voltage — direct reading in vibration units

The stable internal voltage (± 0,2 dB at 2 kHz) in the 2209 may also be used for calibration to give direct readings in vibration units, as follows:

1. Turn the METER SCALE to "Vibration Meter" and, using a screwdriver, adjust the METER MECHANICAL ZERO ADJUSTMENT screw (if necessary) to give a meter needle deflection on the "0" mark of the METER SCALE while the instrument is switched off.

2. Insert the appropriate ATTENUATOR SCALE for the type of measurement (acceleration, velocity, or displacement) and the accelerometer sensitivity (see its calibration chart) as indicated in Table 3.2.

3. Set the lower limiting frequency as required (see section 3.2.2).

4. Connect the accelerometer to the 2209 using one of the methods shown in Fig.3.3. If an Integrator is used, set it to the required position ("Acc.", "Vel.", or "Disp.").

5. Turn the METER SWITCH to "Batt. (Rec.)" to check the batteries; then set it to "Fast" meter response. (The instrument warm-up time is 30 s.)

6. Set the WEIGHTING NETWORK SWITCH to "Lin.". (A weighted position should not be used for this 2 kHz reference voltage.)

7. Set the ATTENUATOR switches to "Ref." (between the red lines).

8. Using a small screwdriver, turn the GAIN ADJ. potentiometer to give the Sensitivity Correction, which is found as follows, on the lower red METER SCALE:

From the accelerometer calibration chart, determine its sensitivity in mV/g. Using this value, and the appropriate units of vibration to be measured (ms^{-2}, g, etc.), read off the Sensitivity Correction (in dB) from Fig.3.4. (Note that the vertical scale is a double (folded) scale, and that accelerometers whose sensitivities differ by a factor of 10, 100, etc., have the same Sensitivity Correction. These factors of 10 are automatically taken account of by the ATTENUATOR SCALE.)

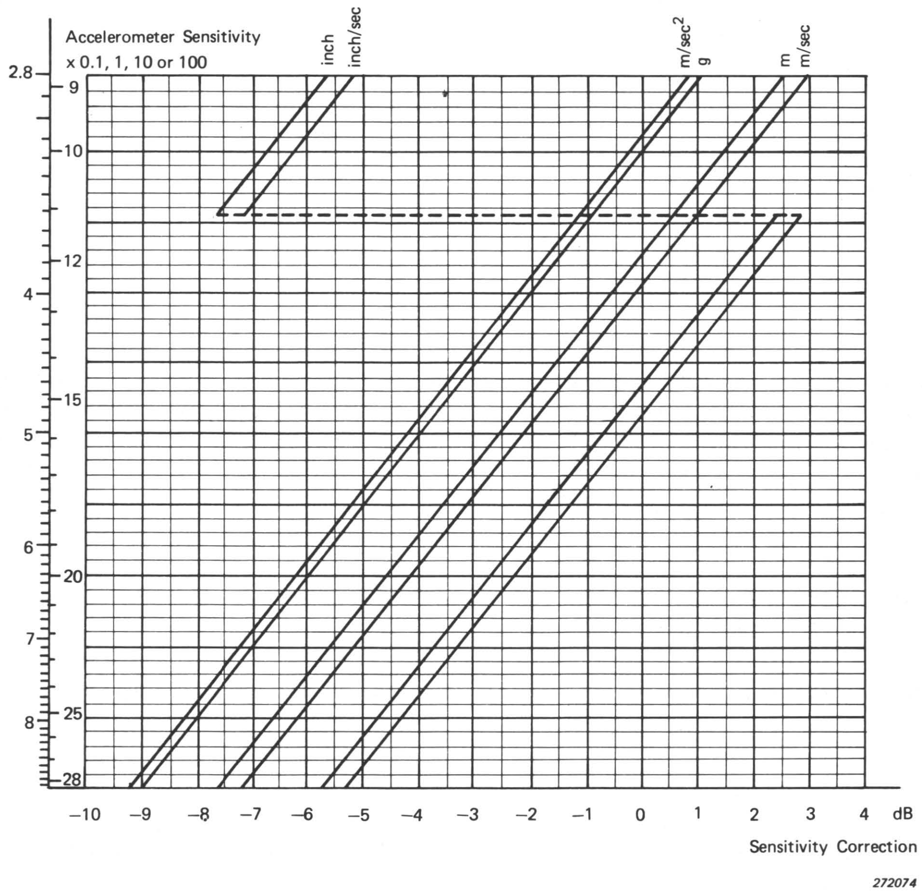

Fig.3.4. Accelerometer Sensitivity Correction Chart

The 2209 is now calibrated so that direct meter readings (RMS values) may be made of the parameter required in the desired units. (Subsequent selection of, for example, "Peak Hold" will of course mean that the peak value of the vibration level will be stored and displayed.) A separate calibration and a different ATTENUATOR SCALE are necessary for each different parameter or measurement unit.

3.5.4. Calibration using Accelerometer Calibrator Type 4291 — meter reading in dB

The portable battery-operated Accelerometer Calibrator Type 4291 generates a vibration level of 1 g peak (0,707 g RMS) at 500 rad s^{-1} (79,6 Hz). The calibration procedure for giving readings in dB (which may be converted to vibration units if required) is as follows:

1. Turn the METER SCALE to "Precision Sound Level Meter" and, using a screwdriver, adjust the METER MECHANICAL ZERO ADJUSTMENT screw (if necessary) to give a meter needle deflection on the "—∞" mark of the METER SCALE while the instrument is switched off.

2. Insert the ATTENUATOR SCALE No. 1 A ("10" to "130" dB).

3. Follow steps 3 — 8 of section 3.5.2.

4. Using a small screwdriver, turn the GAIN ADJ. potentiometer to give a meter needle deflection of "+ 7,0" dB.

5. Note the attenuator setting inside the red lines, and add 10 dB. This gives the zero reference value in dB (Z) corresponding to 1 g RMS, or any of the following vibration reference amplitudes (R) (which are equivalent to 1 g RMS at 79,6 Hz) to which the 2209 is now calibrated depending on the Integrator setting:

Acceleration:	9,81 ms^{-2} RMS	(1 g RMS ≡ 386 in s^{-2} RMS)
Velocity:	$19{,}6 \times 10^{-3}$ ms^{-1} RMS	($7{,}71 \times 10^{-1}$ in s^{-1} RMS)
Displacement:	$39{,}2 \times 10^{-6}$ m RMS	($1{,}54 \times 10^{-3}$ in RMS)

This adjustment will need to be made for each parameter to be measured. It is thus easier to calibrate for, and to make all measurements of, one parameter first, then recalibrate for another parameter and make measurements, if possible, rather than switch from one to another. The level in vibration units may be calculated as explained in section 3.7.1 or 3.7.2.

(Selection of, for example, "Peak Hold" after calibration will of course mean that the peak value of the vibration level will be stored and displayed.)

3.5.5. Calibration using the Internal Reference Voltage — meter reading in dB

The stable internal voltage (± 0,2 dB at 2 kHz) in the 2209 may also be used for calibration, to give readings in dB, as follows:

1. Turn the METER SCALE to "Precision Sound Level Meter" and, using a screwdriver, adjust the METER MECHANICAL ZERO ADJUSTMENT screw (if necessary) to give a meter needle deflection on the "—∞" mark of the METER SCALE while the instrument is switched off.

2. Insert the ATTENUATOR SCALE No. 1 A ("10" to "130" dB).

3. Follow steps 3 — 7 of section 3.5.3.

4. Using a small screwdriver, turn the GAIN ADJ. potentiometer to give a meter needle deflection on the reference mark on the underside of the upper black scale (between the "+6" and "+7" dB marks), if the Slide Rule QH 0001 is used, or 3 dB below full scale deflection otherwise.

5. The 2209 is now calibrated so that a reading of "94" dB corresponds to 1 g RMS using an accelerometer with a sensitivity of 50 mV/g. For accelerometers of different sensitivities, the results should be corrected afterwards, as explained in section 3.7.3. The level in vibration units may be calculated as explained in section 3.7.3 or 3.7.4.

(Selection of, for example, "Peak Hold" after calibration will of course mean that the peak value of the vibration level will be stored and displayed.)

3.6. VIBRATION MEASUREMENTS

3.6.1. General

When using the 2209 as a preamplifier and measuring amplifier for an accelerometer, it should be remembered that the accelerometer has a high-frequency resonance (given on its calibration chart) which probably lies within the frequency range of the meter. Measurements should therefore be made with the use of a supplementary low-pass filter, or with a band-pass filter set (see Chapter 1), to prevent measuring the results of the resonance, where it is thought possible that the signal may contain such high frequencies. The lower limiting frequency of the measuring system is set at 2 Hz or 10 Hz by the 2209.

For detailed instructions on the use of the accelerometer, see its Instruction Manual. The 2209 itself should be kept out of the vibration environment. If the accelerometer is to be used at some distance from the meter, extension cables should be used between the meter and its Input Stage, rather than between the accelerometer and the Input Stage, to prevent a decrease in overall sensitivity.

When using the "Peak Hold" circuit, the 2209 is well suited for the measurement of maximum acceleration, which is an important quantity in the investigation of materials fatigue.

3.6.2. Procedure for Vibration Measurements

1. Calibrate the 2209 by one of the methods described in section 3.5, including the battery check, selection of lower limiting frequency, etc..

2. Mount the accelerometer on the test object using one of the methods described in its Instruction Manual.

3. Select "Fast" or "Slow" METER SWITCH position, and turn the WEIGHTING NETWORK SWITCH to "Lin.".

4. Set the OUTPUT ATTENUATOR (transparent) at minimum gain, i.e. fully clockwise so that the red lines are adjacent to the black spot.

5. Turn the INPUT ATTENUATOR (black) clockwise to give the highest possible meter reading without over-deflecting and without the INPUT OVERLOAD lamp on. If necessary (when the INPUT ATTENUATOR is fully clockwise) for small input signals, turn the OUTPUT ATTENUATOR (transparent) anticlockwise to give the highest possible meter reading without over-deflecting and without the OUTPUT OVERLOAD lamp on.

6. Turn the WEIGHTING NETWORK SWITCH and the METER SWITCH to the required positions for measurements.

7. If the meter needle now over-deflects, reduce the gain by turning the OUTPUT ATTENUATOR (transparent) clockwise, or if this is not possible, turn the INPUT ATTENUATOR (black) anticlockwise to give a meter reading of at least 1/3 full scale. See note below. Do NOT increase the gain of this ATTENUATOR without repeating steps

3 to 5, as the input amplifier may be overloaded. (Remember to depress the METER RESET button if a "Hold" position is used.)

8. If the meter reading is too low, turn the OUTPUT ATTENUATOR (transparent) anticlockwise to give the highest possible meter reading without over-deflection and without the OUTPUT OVERLOAD lamp on. (Remember to depress the METER RESET button if a "Hold" position is used.) See note below.

9. If the "Vibration Meter" scale has been used (calibration as in section 3.5.2 or 3.5.3), the vibration level in the calibrated units is read directly from the METER SCALE with reference to the full-scale deflection given between the red lines on the ATTENUATOR SCALE. RMS, impulse, or peak values may be read, depending on the position of the METER SWITCH, which should be noted, as should the position of the WEIGHTING NETWORK SWITCH. (Remember to depress the METER RESET button between readings if a "Hold" position is used.)

   If the "Precision Sound Level Meter" scale has been used (calibration as in section 3.5.4 or 3.5.5), then the vibration level (M) in dB is the sum of the meter reading and the ATTENUATOR setting within the red lines. Note the position of the METER SWITCH and the WEIGHTING NETWORK SWITCH. These dB readings may be converted to vibration units (ms^{-2}, g, etc.) as decribed in section 3.7. (Remember to depress the METER RESET button between readings if a "Hold" position is used.)

   Note: The most accurate readings will usually be obtained with meter needle deflections in the upper 2/3 of the scale, but for signals with a very high crest factor, readings may be made at a smaller needle deflection to avoid errors due to output overload. If the OUTPUT OVERLOAD lamp alone flashes, the signal crest factor exceeds the instrument's capabilities at that ATTENUATOR setting. If the overload cannot be removed while maintaining a sensible meter reading, the reading will be too low, and the overload should be noted with the results.

   When operating the 2209 with the INPUT ATTENUATOR in the top two ranges for high readings, the input stage may be overloaded without either OVERLOAD lamp flashing. To ensure there is no input-stage overload, measure the peak value of the signal first; if an on-scale reading can be obtained at the highest ATTENUATOR setting, there is no overload of the input stage.

   If the INPUT OVERLOAD lamp alone lights, turn the INPUT and OUTPUT ATTENUATORS anticlockwise together, or return to step 3 and set up the instrument again, as the vibration level has increased. Any overload should be noted with the meter reading.

3.7. CONVERSION OF RESULTS IN dB TO VIBRATION UNITS

If measurements have been made in dB (either to save changing ATTENUATOR SCALES, or because they were required in dB), they may be simply converted into vibration units.

The conversion depends on the method of calibration, and whether or not the Integrator has been used. The circular Slide Rule QH 0001 (supplied with the ZR 0020) used for the conversion has two similar sides, one in metric units and the other in Imperial units.

3.7.1. With 4291 Calibration, Without Integrator

Determine the acceleration level (A) in dB referenced to 1 g RMS by:

$$A = M - Z$$

where M = measured value on 2209 (dB)
and Z = zero reference level (dB) (from section 3.5.4 step 5).

From Table 3.3, convert A from dB to a ratio (T). The vibration amplitude is then given by the product RT, where R is the vibration reference amplitude defined in section 3.5.4 step 5.

dB	0,0	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9
0	1,000	1,012	1,023	1,035	1,047	1,059	1,072	1,084	1,096	1,109
1	1,122	1,135	1,148	1,161	1,175	1,189	1,202	1,216	1,230	1,245
2	1,259	1,274	1,288	1,303	1,318	1,334	1,349	1,365	1,380	1,396
3	1,413	1,429	1,445	1,462	1,479	1,496	1,514	1,531	1,549	1,567
4	1,585	1,603	1,622	1,641	1,660	1,679	1,698	1,718	1,738	1,758
5	1,778	1,799	1,820	1,841	1,862	1,884	1,905	1,928	1,950	1,972
6	1,995	2,018	2,042	2,065	2,089	2,113	2,138	2,163	2,188	2,213
7	2,239	2,265	2,291	2,317	2,344	2,371	2,399	2,427	2,455	2,483
8	2,512	2,541	2,570	2,600	2,630	2,661	2,692	2,723	2,754	2,786
9	2,818	2,851	2,884	2,917	2,951	2,985	3,020	3,055	3,090	3,126
10	3,162	3,199	3,236	3,273	3,311	3,350	3,388	3,428	3,467	3,508
11	3,548	3,589	3,631	3,673	3,715	3,758	3,802	3,846	3,890	3,936
12	3,981	4,027	4,074	4,121	4,169	4,217	4,266	4,315	4,365	4,416
13	4,467	4,519	4,571	4,624	4,677	4,732	4,786	4,842	4,898	4,955
14	5,012	5,070	5,129	5,188	5,248	5,309	5,370	5,433	5,495	5,559
15	5,623	5,689	5,754	5,821	5,888	5,957	6,026	6,095	6,166	6,237
16	6,310	6,383	6,457	6,531	6,607	6,683	6,761	6,839	6,918	6,998
17	7,079	7,161	7,244	7,328	7,413	7,499	7,586	7,674	7,762	7,852
18	7,943	8,035	8,128	8,222	8,318	8,414	8,511	8,610	8,710	8,810
19	8,913	9,016	9,120	9,226	9,333	9,441	9,550	9,661	9,772	9,886

073010

Table 3.3. Conversion of dB to ratio. Subtract a multiple of 20 ($n \times 20$ where n is a positive or negative integer or 0) from the dB value to be converted such that the remainder is a positive number between 0 and 19,9. Look up the ratio of that remainder in the table. The desired ratio is then 10^n times the value from the table. Example: —12,6 dB must be converted to a ratio. To get a positive number between 0 and 19,9, subtract —20 (= $20 \times (-1)$) from —12,6, giving + 7,4. The ratio of 7,4 is found in the table to be 2,344. Hence the ratio of —12,6 dB = $2,344 \times 10^n$ = $2,344 \times 10^{-1}$ = 0,2344

Example: The zero reference level (Z) is 100 dB. The measured value (M) on the 2209 is 87,4 dB, and it is desired to find the acceleration in ms^{-2}.

$A = M - Z = 87,4 - 100 = -12,6$ dB

From Table 3.3, —12,6 dB becomes a ratio of T = 0,2344.
Then Acceleration = RT = 9,81 ms^{-2} $\times$ 0,2344 = 2,30 ms^{-2}.

If an RMS meter setting has been used, the acceleration is 2,30 ms^{-2} RMS. (The peak acceleration level (for sinusoidal signal) is $2,30 \times 1,414$ = 3,25 ms^{-2} peak.)

If a peak (or impulse) setting has been used, the acceleration is 2,30 ms^{-2} peak (or impulse).

This calculation may be made more simply using the circular Slide Rule QH 0001 (if available) as described in the following section.

3.7.2. With 4291 Calibration, With Integrator ZR 0020

The vibration amplitude may only be calculated in the same parameter as that set on the Integrator, and the Slide Rule must not be used to convert from one parameter to another. To determine another parameter, the Integrator must be set and the 2209 calibrated for that parameter and new measurements made. The circular Slide Rule QH 0001 (shown in Fig.3.5) provided with the Integrator should be used to make the calculations as follows:

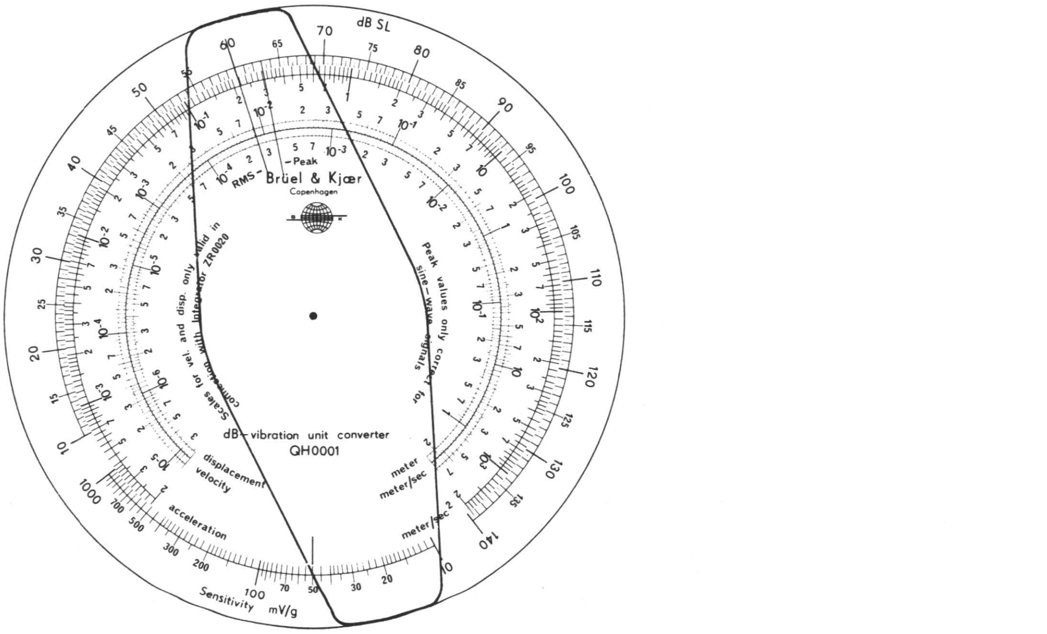

Fig.3.5. Slide Rule QH 0001 set for an accelerometer sensitivity of 50 mV/g and an SPL of 60 dB

1. Turn the cursor until its RMS line lies over the zero reference level (Z) (from section 3.5.4 step 5) on the outer dB SL scale.

2. Rotate the sliding scale until the vibration reference amplitude (R) (see section 3.5.4 step 5) on the appropriate vibration scale (acceleration, velocity, or displacement) also lies under the RMS line on the cursor.

3. Turn the cursor until its RMS line lies over the value of the 2209 meter reading (M) in dB on the outer dB SL scale of the Slide Rule.

4. Read the vibration level on the **same vibration scale** as that used for step 2. See the example below.

Example: The zero reference level (Z) is 80 dB. The vibration reference amplitude (R) is $7{,}71 \times 10^{-1}$ in s^{-1}, and the 2209 meter reading (M) is 51 dB. Find the equivalent velocity in in s^{-1}.

Set the RMS line on the cursor over the "80" dB line on the outer dB SL scale, and turn the sliding scale until the value of "$7,71 \times 10^{-1}$" on the VELOCITY INCHES/SEC scale also lies under the RMS line. Turn the cursor to "51" dB on the outer dB SL scale. The velocity is "$2,8 \times 10^{-2}$" in s^{-1}, read from the RMS line.

If an RMS meter setting has been used, the velocity is "$2,8 \times 10^{-2}$" in s^{-1} RMS. (The peak velocity (for a sinusoidal signal) may be read from the PEAK line as "$3,9 \times 10^{-2}$" in s^{-1} peak.)

If a peak (or impulse) setting has been used, the velocity is "$2,8 \times 10^{-2}$" in s^{-1} peak (or impulse), read from the RMS line.

3.7.3. With Internal Calibration, Without Integrator

The acceleration level (A) in dB referenced to 1 g RMS is calculated by the formula:

$$A = M - 94 + 20 \log_{10}(50/S)$$

where M is the meter reading on the 2209 (dB)
and S is the sensitivity (mV/g) of the accelerometer used (from its calibration chart).

A is now converted to vibration units as described in section 3.7.1.

The complete calculation may be made more simply using the circular Slide Rule QH 0001 provided with ZR 0020 (if available) as described in the following section.

3.7.4. With Internal Calibration, With Integrator ZR 0020

The vibration amplitude may only be calculated in the same parameter as that set on the Integrator, and the Slide Rule must not be used to convert from one parameter to another. To determine another parameter, the Integrator must be set and the 2209 calibrated for that parameter, and new measurements made. The circular Slide Rule QH 0001 should be used to make the calculations as follows:

1. After calibrating the 2209 as in Section 3.5.5., set the isolated red line on the sliding scale adjacent to the accelerometer sensitivity in mV/g on the outer scale of the Slide Rule. (It is shown adjacent to 50 mV/g in Fig.3.5.)

2. Turn the cursor so that its RMS line lies over the value of the 2209 meter reading (M) in dB on the outer dB SL scale of the Slide Rule.

3. Read the vibration level on the **scale corresponding to the Integrator setting.** If an RMS meter setting has been used, then the value read from the RMS line will be RMS, and the value from the PEAK line (for a sinusoidal signal) will be peak. If a peak (or impulse) setting has been used, the value read from the RMS line will be peak (or impulse).

3.8. VOLTAGE CALIBRATION

The 2209 may be used to make direct voltage measurements up to 10 V RMS over the frequency range of the amplifier indicated in the specifications (see Chapter 1). The calibration procedure is as follows:

1. Turn the METER SCALE to "Vibration Meter" and, using a screwdriver, adjust the METER MECHANICAL ZERO ADJUSTMENT screw (if necessary) to give a meter needle deflection on the "0" mark of the METER SCALE while the instrument is switched off.

2. Insert ATTENUATOR SCALE No. 3 B for voltage measurements.

3. Set the lower limiting frequency as required (see section 3.2.2).

4. Fit the 2209 with its Input Stage, Adaptor JJ 2614, Plug JP 0101 and/or other connectors necessary to connect the voltage to the 2209.

5. Turn the METER SWITCH to "Batt. (Rec.)" to check the batteries; then set it to "Fast" meter response. (The instrument warm-up time is 30 s.)

6. Set the WEIGHTING NETWORK SWITCH to "Lin." and the ATTENUATORS to "'Ref." (between the red lines).

7. Using a small screwdriver, turn the GAIN ADJ. potentiometer to give a Sensitivity Correction of "0" on the red scale.

The 2209 is now calibrated for direct reading of RMS voltage measurements, with reference to the full-scale deflection shown between the red lines on the ATTENUATOR SCALE. (Subsequent selection of, for example, "Peak Hold" will of course mean that the peak value of the voltage level will be stored and displayed.)

3.9. VOLTAGE MEASUREMENTS

The procedure for making voltage measurements is as follows:

1. Calibrate the 2209 as described in section 3.8, including the battery check, selection of lower limiting frequency, etc..

2. Connect the 2209 to the voltage to be measured, using the necessary adaptors and connectors.

3. With the METER SWITCH set to "Fast" and the WEIGHTING NETWORK SWITCH set to "Lin.", ensure that the OUTPUT ATTENUATOR (transparent) is set to minimum gain, i.e. fully clockwise so that the red lines are adjacent to the black spot.

4. Turn the INPUT ATTENUATOR (black) clockwise to give the highest possible meter reading without over-deflecting and without the INPUT OVERLOAD lamp on.

5. Turn the OUTPUT ATTENUATOR (transparent) anticlockwise if necessary to give the highest possible meter reading without over-deflecting and without the OUTPUT OVERLOAD lamp on.

6. The RMS voltage is the meter reading referenced to the full-scale deflection shown between the red lines on the ATTENUATOR scale. The peak voltage may be obtained (for a sinusoidal signal) by multiplying the RMS reading by 1,414, or other positions of the METER SWITCH may be selected as required.

4. SPECIAL CHARACTERISTICS

4.1. GENERAL

A brief general description of the 2209 is given in Chapter 1, including some of the more important characteristics and complete specifications. However, it is possible that the user will require a little more information on the impulse and peak characteristics of the 2209, so these are included here.

4.2. IMPULSE DETECTOR

The purpose of the impulse detector is to approximate the subjective effects of short-duration sound on the human ear. The averaging time of the human ear is in the range from 30 to 100 ms (according to various investigators). Hence for impulses shorter than the ear's averaging time, the subjective loudness will not be so great. The 2209 "Impulse" characteristic is shown in Fig.12 of Chapter 1, together with the IEC tolerances.

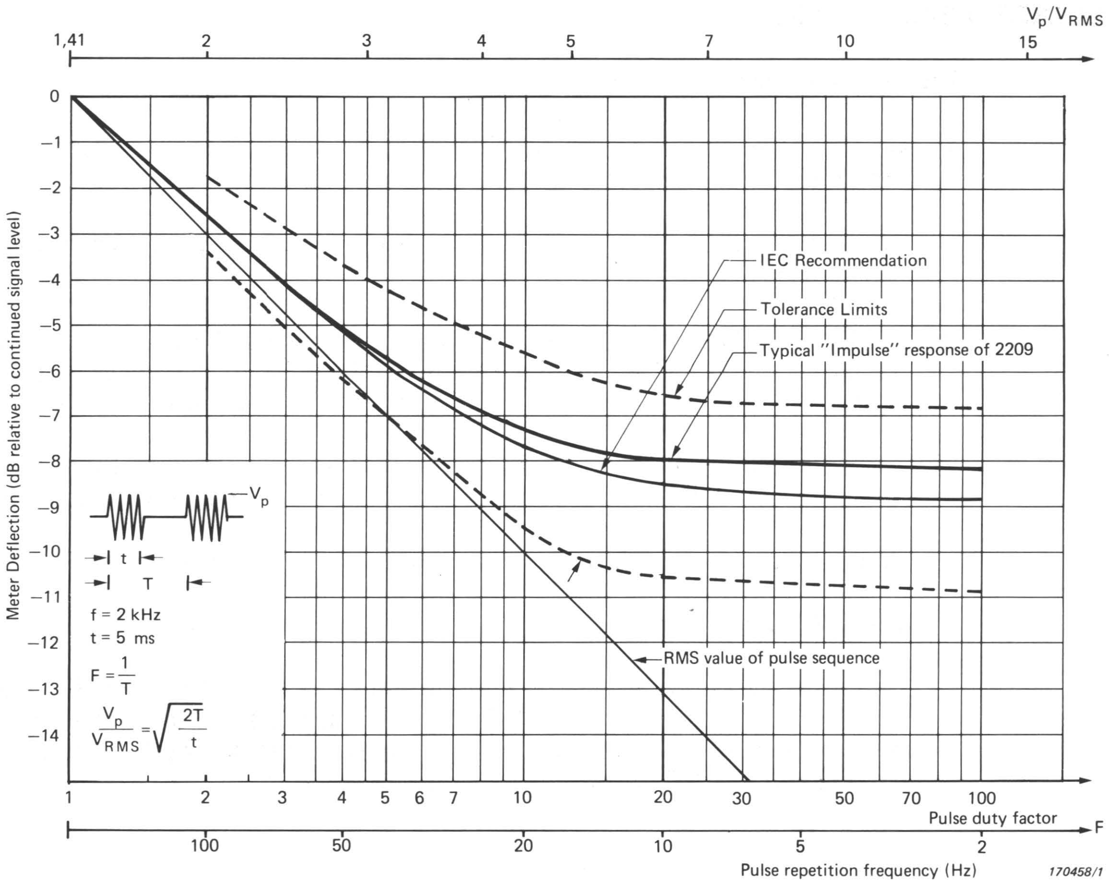

Fig. 4.1. Response of 2209 to repeated impulses

For repeated impulses, the greater the repitition rate, the greater is the subjective loudness. The characteristics of the 2209 for repeated impulses and the IEC specifications are given in Fig.4.1. The decay time of the impulse circuit is 3 s, in accordance with the IEC recommendations.

4.3. PEAK DETECTOR

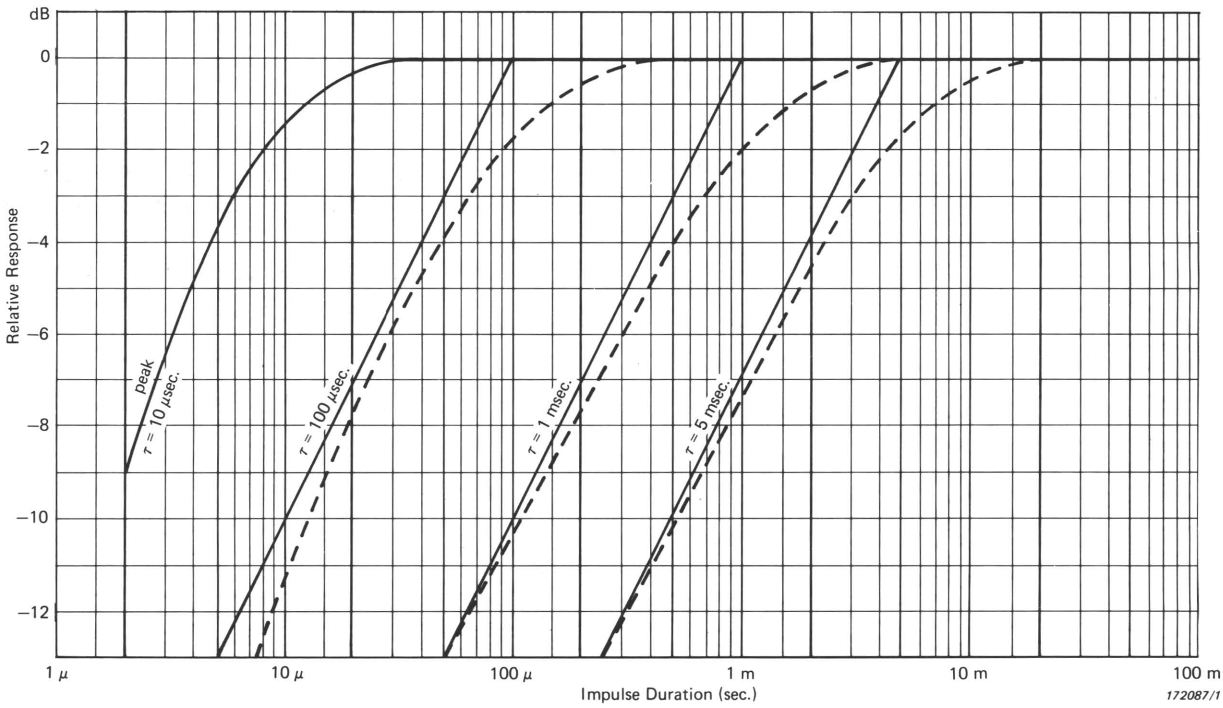

Fig.4.2. Standard and optional "Peak Hold" responses of 2209

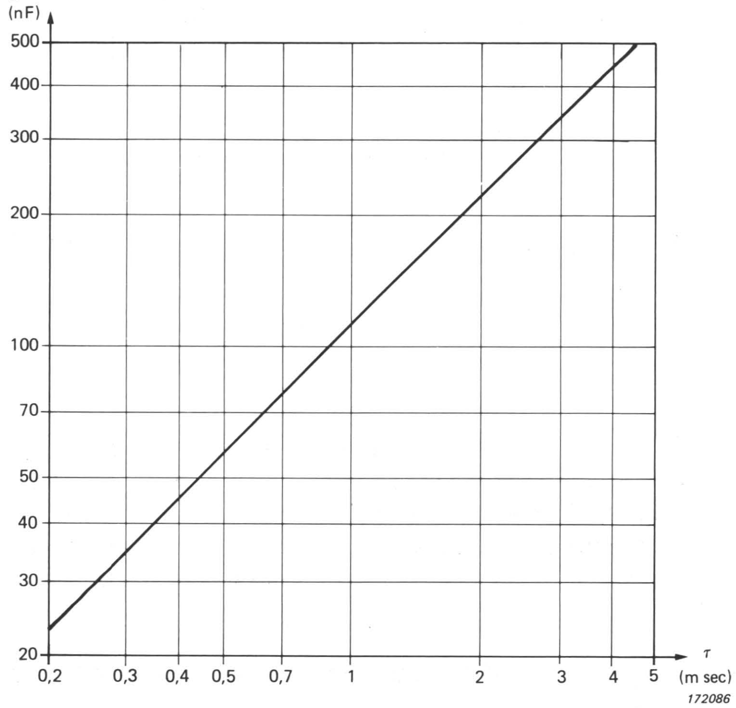

Fig.4.3. Optional charge capacitor vs. time constants for "Peak" rectifier

To detect peak levels, the time constant of the RMS detector is reduced to 10 μs. The output of the peak circuit is then stored in the hold circuit to permit display by the relatively slow meter. In general, the peak values for noise may be 10 to 20 dB or more above the RMS values.

An internal modification to the 2209 may be made to change the time constant of the peak circuit over a range from 10 μs to 5 ms by changing the value of one capacitor. See Figs.4.2 and 4.3 for response characteristics and capacitor values. Information concerning these changes may be obtained from the Service Department.

4.4. HOLD CIRCUIT

The hold circuit stores the highest level fed from the impulse or peak detectors. If the meter needle over-deflects, or if a new reading of lower-level signals is needed, the meter must be reset. Note that once the circuit is holding a signal, changing the ATTENUATORS will not decrease the meter deflection. The decay time of the hold circuit is less than 0,05 dB/s with temperature characteristics shown in Fig.4.4.

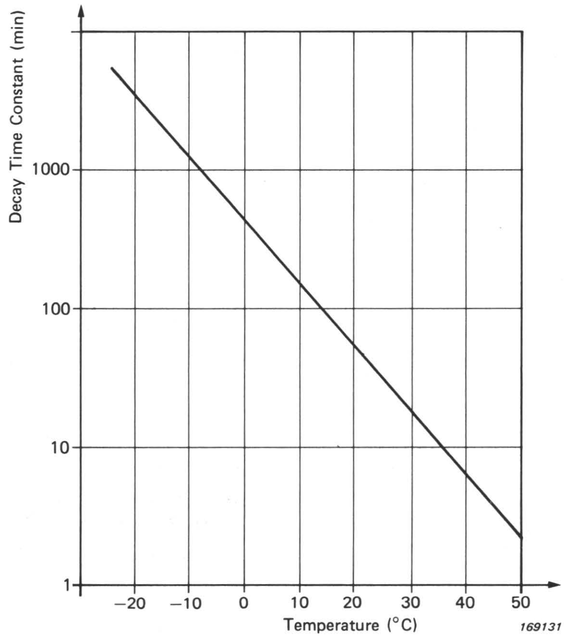

Fig.4.4. Decay time vs. temperature for "Hold" circuit

4.5. CREST-FACTOR CAPABILITIES

The crest factor of a signal is defined as the ratio of the peak to the RMS value. The 2209 is capable of measuring the RMS values of signals with crest factors up to 40 for less than full-scale meter needle deflections. This feature, in combination with the output overload detector, ensures there is no undetected overload in the detector circuit. Crest-factor capabilities for less than full-scale meter needle deflection are shown in Fig.4.5.

The accuracy of the RMS measurements as related to the crest factor of the signal is shown in Table 4.1.

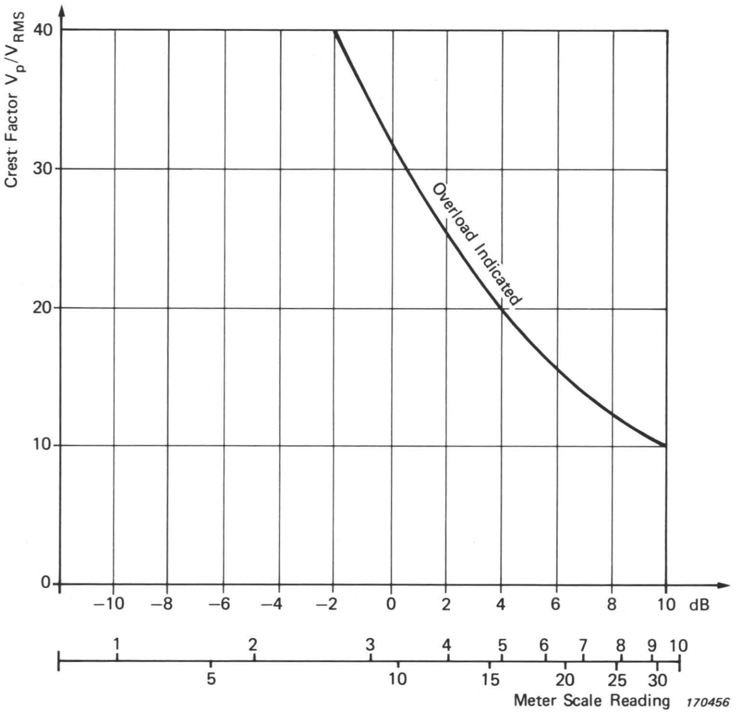

Fig. 4.5. Maximum Crest Factor at a given meter needle deflection

Meter Deflection (dB scale)	Crest Factor		
	less than 10	10 to 20	20 to 40
−10 to − 2 − 2 to +10	± 1 dB ± 0,5 dB	± 1,5 dB ± 1 dB	± 2 dB ± 1,5 dB

760065

Table 4.1. Accuracy of METER SCALE readings for various Crest Factors within limitations given in Fig. 4.5

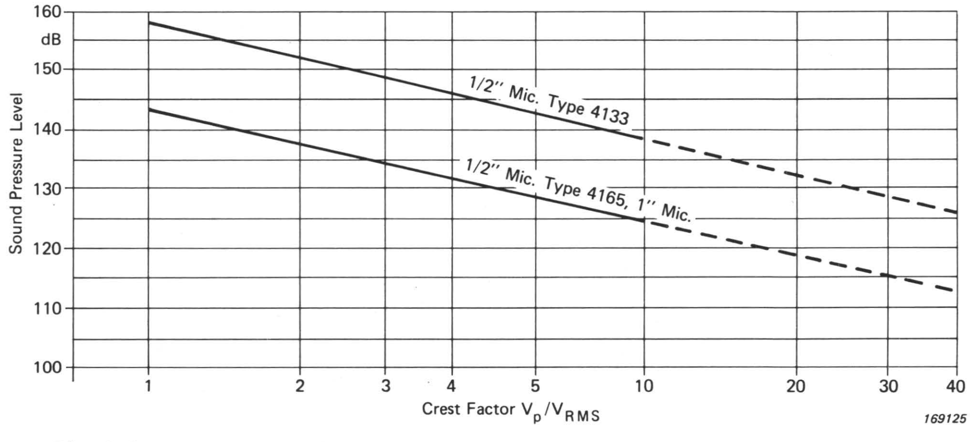

Fig. 4.6. Maximum SPLs that can be accurately measured with one-inch and half-inch microphones with respect to signal crest factor

The 2209's crest-factor capabilities are also related to the maximum sound pressure levels that can be measured accurately. Fig.4.6 shows these relationships for one-inch and half-inch B & K microphones.

4.6. INPUT CAPACITANCE

Due to the low capacitance of condenser microphones, their sensitivity is affected by capacitive loads, as shown in Fig.4.7. For one-inch and half-inch microphones, their capacitance is between about 18 and 65 pF (the actual values are given on the calibration charts), and hence the input capacitance has relatively little effect. With the quarter-inch and eighth-inch microphones, however, whose capacitance is about 6,5 and 3,5 pF respectively, the loading effect is more pronounced, and system calibration using a Pistonphone Type 4220 is recommended.

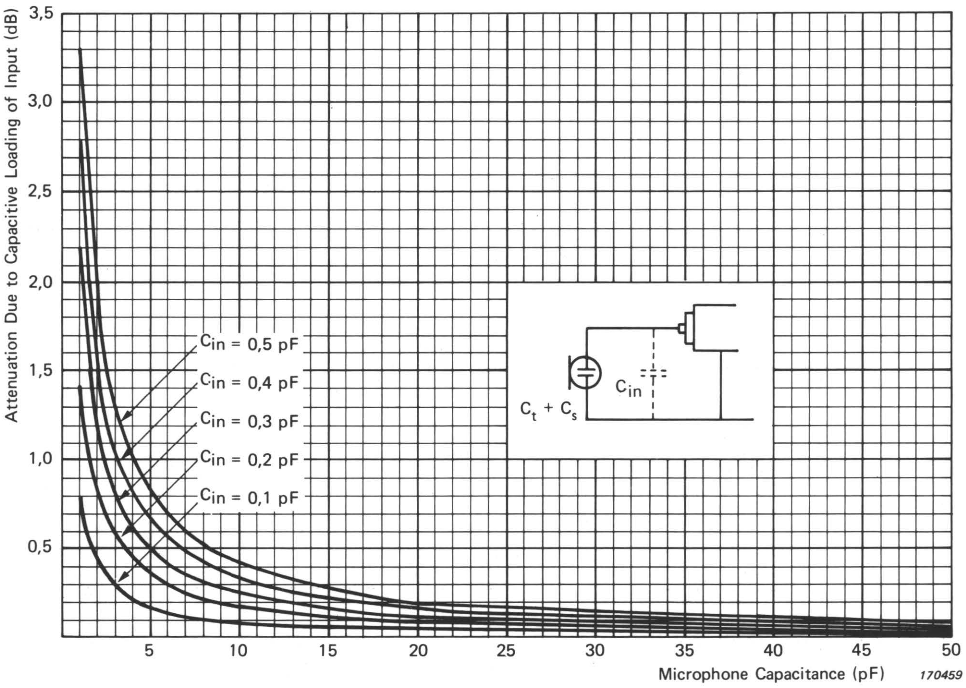

Fig.4.7. Attenuation caused by preamplifier input capacitance

4.7. INPUT-STAGE CONNECTIONS

For completeness, the pin connections of the input stage are given in Fig.4.8.

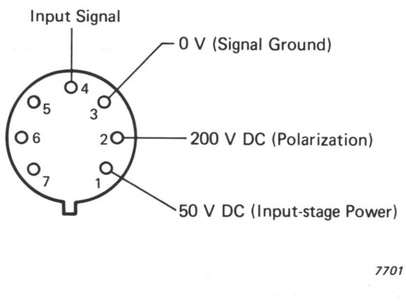

Fig.4.8. Pin connections of the input-stage socket. External view of socket shown

5. ACCESSORIES

The accessories available for and included with the 2209 are summarized in Chapter 1. The following Table 5.1 lists the ten double-sided interchangeable ATTENUATOR SCALES supplied for use with various transducers.

Scale No.		Function	B & K Type No.
1	A B	10 – 130 dB 20 – 140 dB	SA 0012
2	A B	30 – 140 dB 40 – 160 dB	SA 0013
3	A B	50 – 160 dB 10 μV – 10 V	SA 0014
4	A B	$3 \cdot 10^{-1} - 3 \cdot 10^{5}$ $10^{-1} - 10^{5}$	SA 0015
5	A B	$3 \cdot 10^{-2} - 3 \cdot 10^{4}$ $10^{-2} - 10^{4}$	SA 0016
6	A B	$3 \cdot 10^{-3} - 3 \cdot 10^{3}$ $10^{-3} - 10^{3}$	SA 0017
7	A B	$3 \cdot 10^{-4} - 3 \cdot 10^{2}$ $10^{-4} - 10^{2}$	SA 0018
8	A B	$3 \cdot 10^{-5} - 30$ $10^{-5} - 10$	SA 0019
9	A B	$3 \cdot 10^{-6} - 3$ $10^{-6} - 1$	SA 0020
10	A B	$3 \cdot 10^{-7} - 3 \cdot 10^{-1}$ $10^{-7} - 10^{-1}$	SA 0021

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Table 5.1. ATTENUATOR SCALES and Type Numbers

6. USE WITH OTHER INSTRUMENTS

6.1. GENERAL

The 2209 can be used with a variety of other instruments, such as filters and recorders; a selection of these is shown in Fig.6 of Chapter 1. Details of all these instruments may be found on their Product Data Sheets, or in the B & K Catalogues, and full operational instructions are given in the appropriate Instruction Manuals. However, since the 2209 may be used for measuring signals with high crest factors, some more general information is contained below on the recording of these signals from one of the 2209's OUTPUT sockets.

6.2. LEVEL RECORDERS

B & K produces two mains-operated Level Recorders (Types 2305 and 2307) suitable for laboratory use, etc., and a portable battery-operated Level Recorder (Type 2306) which is very suitable for field recordings. Each type may be connected directly to the 2209 via one of its OUTPUT sockets for recording signals (analyzed or time histories) on a paper trace, as follows.

6.2.1. AC Recording

For the recording of continuous non-impulsive sounds, the AC OUTPUT of the 2209 gives the greater dynamic range (> 50 dB) and linearity. The output voltages are given in the specifications (Chapter 1) and the signals are independent of the METER SWITCH position (except in the "Batt. (Rec.)" position). The operating procedures for the Level Recorders are given in the appropriate Instruction Manuals.

6.2.2. DC Recording

For the recording of discontinuous noise, such as that from typewriters, punch presses, etc., the DC OUTPUT is recommended to ensure stable operation of the Level Recorder in its DC mode. The DC OUTPUT comes directly from the meter rectifier circuits, and thus its characteristics will be selected by the METER SWITCH. For the recording of impulsive sounds, the "Impulse" position should be used.

The DC OUTPUT of the 2209 has a dynamic range of approximately 25 dB. Using 50 mm Level Recorder Paper and a 25 dB Range Potentiometer, the dynamic range is optimized by adjusting the Level Recorder for an indication of "+ 20" dB above the bottom line on the paper corresponding to a full-scale meter needle deflection of the 2209. (For example, if the 2209 indicates "+ 4" dB during calibration, the Level Recorder should be set to indicate "+ 14" dB above the bottom line on the paper. See the Level Recorder Instruction Manual.) Thus a signal 5 dB above the full-scale meter needle deflection can be accurately recorded, provided no overloads occur.

For DC recordings, the Level Recorder controls may be set as follows:

POTENTIOMETER RANGE:	"25 dB" (2305 or 2307)
RECTIFIER RESPONSE:	"DC" (2305 or 2307)
RECORDING MODE:	"DC Log." (2306)
LOWER LIMITING FREQUENCY:	"50 Hz" (2305 or 2307)
WRITING SPEED:	"250 mm/s" (2305 or 2307)
WRITING SPEED/LF LIMIT:	"250 mm/s"/"25 Hz" (2306)
PAPER SPEED:	"0,3 mm/s"

Fig.6.1 shows some recordings of punch-press noise from the 2209 DC OUTPUT using various meter responses.

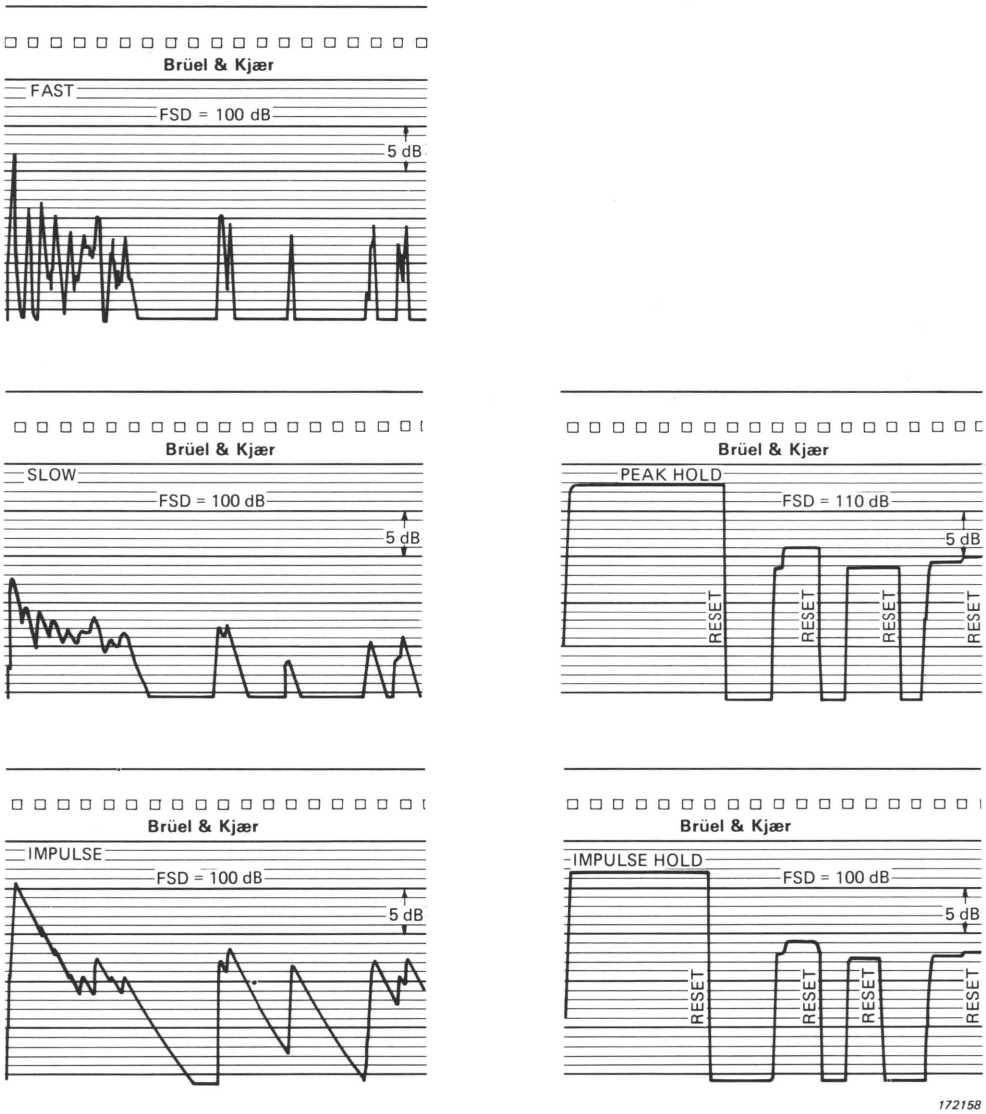

Fig. 6.1. Recordings of punch-press noise from DC OUTPUT with various meter responses

6.3. TAPE RECORDERS

When signals are to be recorded from the Type 2209 for storage and later analysis, the portable battery-operated B & K Tape Recorders Types 7005 and 7006 are available. Always adjust the Tape Recorder gain for the best dynamic range without overload, and record a reference level to which all changes of 2209 ATTENUATOR setting may be referred. For the recording of impulsive or single events, the Tape Loop Cassette UD 0035 may be used with the Tape Recorder to ease analysis. For full details, consult the appropriate Instruction Manuals.

6.4. DIGITAL RECORDERS

The ideal and most flexible approach to impulse recording is the B & K Digital Event Recorder Type 7502, which provides an extremely wide range of frequency transformation, and also permits the recording of information before the triggering. For full details, see its Instruction Manual.

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

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