Group 4

Vibration Transducers and Preamplifiers

types: 4321, 4344, 4366, 4367, 4368, 4369, 4370, 4371, 8305, 8306, 8307, 8308, 8309 and 8310

Vibration Transducers

FEATURES:

- Acceleration ranges cover 0,000002 g to 100000 g
- Frequency ranges cover from near DC to 60 kHz (+ 10% limit)
- Temperature ranges cover —200°C to + 400°C
- Wide application range
- Rugged sealed construction
- Individual calibration data supplied
- Artificially aged for long term stability
- Several Uni-Gain® types

USES:

- Shock and Vibration measurement and analysis
- Accelerometer calibration
- Vibration monitoring
- Production control
- Vibration test control

The Brüel & Kjær accelerometer range incorporates transducers suitable for most application requirements both in the laboratory and under field conditions. In addition to a group of general purpose transducers a number of transducers are available for special purposes; i. e. high temperature, high shock, very low acceleration levels, fluctuating temperatures, calibration of other accelerometers, and measurements on delicate structures. The application areas of the individual transducers naturally overlap, but by reference to the summary table on the back cover the user can isolate the transducers of interest. Full specifications can be found inside the back cover of this brochure.

Construction

An accelerometer is an electromechanical transducer which produces at its output terminals an electrical output proportional to the acceleration to which it is subjected.

All Brüel & Kjær accelerometers use piezoelectric materials, which when physically stressed, produce an electrical output. Three different piezoelectric materials are used, these are designated PZ23, PZ45 and PZ100. PZ23 belongs to the well known lead zirconate titanate family. It has a high sensitivity (approx. 300 pC/N), and can be used up to 250°C. PZ45 is a specially formulated ceramic which can be used up to 400°C. It also has a particularly flat temperature response. PZ100 is a carefully selected and prepared quartz crystal. It gives a very good long term stability and has a very flat temperature response curve.

Three different mechanical designs are employed, one compression type and two shear types. The compression design consists of two or more piezoelectric discs on which rests a relatively heavy mass. The mass is preloaded by a stiff spring and the whole assembly is mounted in a metal housing with a thick base. When the accelerometer is subjected to vibration, the mass will exert a variable force on the piezoelectric discs. This force is proportional to the acceleration of the mass. Due to the piezoelectric effect a variable charge will be developed across the piezoelectric element. This charge is proportional to the force and therefore to the acceleration of the mass.

For frequencies much lower than the resonant frequency of the assembly the acceleration of the mass will be virtually the same as the acceleration of the whole transducer. Therefore, the charge produced will be proportional to the acceleration to which the transducer is subjected. This charge can be measured electronically at the output terminals of the accelerometer and used for accurate determination of vibration amplitude, frequency and waveform.

The shear type accelerometers operate in the same way but are arranged so that the piezoelectric ceramic is stressed in shear between an axial centre post and the seismic mass.

The three configurations used in the Brüel & Kjær accelerometer programme are shown schematically in Fig.1.

The Centre Mounted Compression Design, Fig.1a, is a traditional design that gives a high sensitivity to mass ratio and can withstand high levels of vibration and shock. The mass, the spring, and the piezoelectric discs are mounted on a round centre post extending from the base of the accelerometer. Despite the use of a relatively thick base the base strain sensitivity and temperature transient sensitivity are somewhat higher than for the Delta Shear® design. Types 4344, 8305, 8306, 8308, 8309 and 8310 are of this design.

The Annular Shear Type, Fig.1b. This configuration provides reasonably good isolation of the piezoelectric element from environmental conditions and aids miniaturisation. The resonant frequency is reasonably high. Subminiature Accelerometer Type 8307 is of this design.

The Delta Shear® Design, Fig.1c, is a unique Brüel & Kjær design (Patent No. 131401) in which three flat slices of piezoelectric ceramic are clamped between the triangular centre post and the seismic masses with a very high radial force applied by a preloading ring.

The mating surfaces of the centre post, the piezoelectric elements, and the seismic masses are worked to a fine degree of flatness and dimensional accuracy so that the need for an intermediate layer of adhesive, as typically found in annular shear type accelerometers is avoided. These factors result in the Delta Shear® design exhibiting very good amplitude linearity and long term stability. The Delta Shear® arrangement exhibits a very high sensitivity-to-mass ratio together with a very low sensitivity to temperature transients and base strains, and a generally low sensitivity to other external forces. Accelerometer Types 4321, 4366, 4367, 4368, 4369, 4370 and 4371 are of this design.

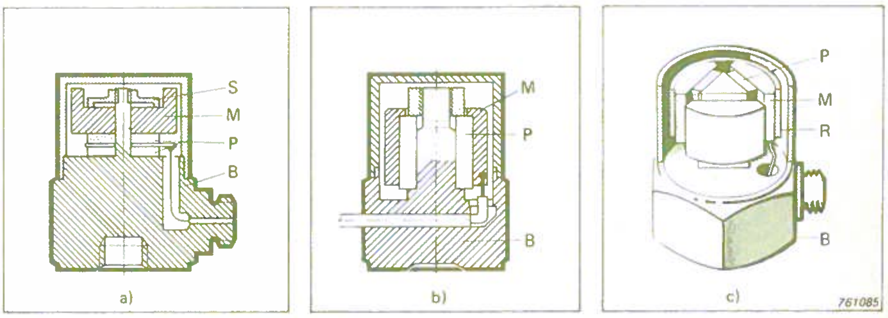

Fig.1. Schematic drawing of the three accelerometer configurations.
a) Centre mounted compression design
b) Annular shear design
c) Delta Shear design.
S = Spring. M = Mass. P = Piezoelectric element.
B = Base. R = Preloading Ring

Characteristics

Sensitivity
The sensitivity of an accelerometer is the ratio between its electrical output and the acceleration causing that output.

Because a piezoelectric accelerometer can be considered as a charge or a voltage source the sensitivity is expressed in mV/g and pC/g. Generally, with a given piezoelectric material, the sensitivity is a direct function of the weight of the loading mass; therefore increased sensitivity is accompanied by increased physical size. The application will largely determine what balance of sensitivity and size is appropriate. At the extremities of the Brüel & Kjær range we have Type 8306 with a sensitivity of 10 V/g and a weight of 500 g and Type 8307 with sensitivity and weight of 2 mV/g and 0,4 g respectively.

Uni-Gain®
B & K accelerometer Types 4321, 4370, 4371, 8306, 8308 and 8310 feature Uni-Gain® sensitivity. This means that the sensitivity has been adjusted during manufacture to be within 2% of a convenient value, for example 10 pC/ms^{-2}. The use of Uni-Gain® accelerometers with fixed gain preamplifiers makes sensitivity adjustment of the measuring system an easy matter. Setting-up time is reduced to a minimum and calculations during measurements are avoided. Furthermore, Uni-Gain® accelerometers of the same type can be interchanged without recalibration of the measuring system.

Transverse Sensitivity
Accelerometers are also slightly sensitive to acceleration in a plane normal to their main axis due to minute irregularities in the structure and alignment and polarisation of the piezoelectric discs. The majority of Brüel & Kjær accelerometers have maximum transverse sensitivities of less than 3 or 4% of the main axis sensitivity. Because the transverse sensitivity varies for different directions in the base plane the accelerometers are individually measured and marked with a red spot to indicate the direction of minimum transverse sensitivity (except types 4321, 8306, 8308 and 8310).

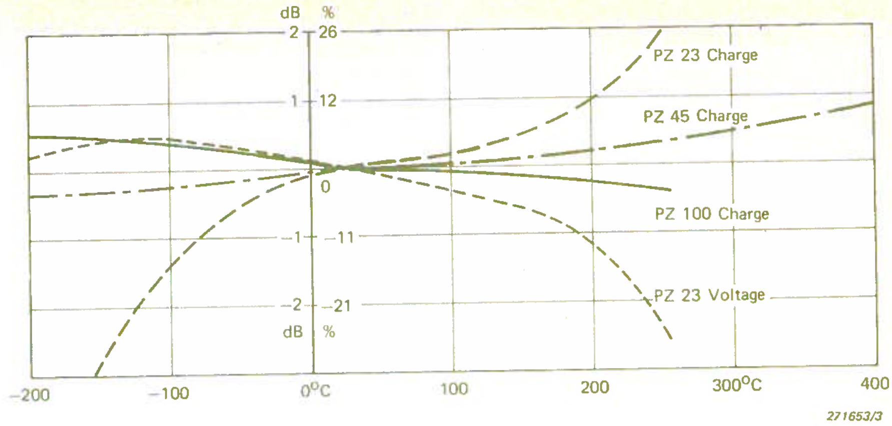

Fig.2. Typical Charge and Voltage sensitivity changes as a function of temperature for the three piezoelectric materials

Environmental Sensitivity
As discussed under **Construction** the likely environmental conditions should be considered when selecting an accelerometer for a particular application. An important environmental factor is temperature (and change of temperature), but acoustic pressure, base strains, humidity, magnetic fields and nuclear radiation may also be considered.

Temperature. Within the temperature range specified for the Brüel & Kjær accelerometers the piezoelectric materials will show temperature dependent variations in sensitivity and capacitance. The variation of voltage and charge sensitivity for the three piezoelectric materials used are shown in Fig.2.

The accelerometers also exhibit sensitivity to temperature fluctuations (temperature transients). This effect is of no great importance until low frequency/low level accelerations are being measured. In such conditions the Delta Shear® accelerometers Types 4321, 4366, 4367, 4368, 4369, 4370, and 4371 which have very low temperature transient sensitivities are to be recommended.

Acoustic Pressure. Average noise levels in machinery have negligible effect on the output of the B & K accelerometers, and normally the acoustically induced vibration in the structure is greater than the signal due to the acoustic sensitivity. Only when very low level accelerations are to be measured in high intensity acoustic fields need the acoustic excitation effects be considered.

Base Strains may be induced into the accelerometer from distortion of the test object, with a resultant signal output. The accelerometers are constructed with thick rigid bases to minimise base strain outputs. The Delta Shear® designs give the best isolation from base strains.

Frequency Range
Typical frequency range characteristics for each accelerometer are shown in Fig.3. The upper frequency limit is usually taken to be one third of the mounted resonant frequency for less than 1 dB (12%) error, or one fifth of the resonant frequency for less than 0,5 dB (6%) error. This assumes that the accelerometer is properly fixed to the specimen. Poor mounting techniques have a very marked effect on the upper frequency limit so that when measurements are taken at frequencies higher than 2 to 3 kHz, care should be exercised if reliable results are to be obtained. This is covered in the section headed

Mounting Methods.
The low frequency response of an accelerometer is, in practice, dependent on the type of preamplifier used after it. With voltage preamplifiers the low frequency limit is a function of the preamplifier input-resistance and the combined accelerometer, cable, and preamplifier input capacitances. The low frequency limit (—3 dB) using a vol-

tage preamplifier can be calculated from the formulae:

$$f = \frac{1}{2\pi RC}$$

f = lower frequency limit (3 dB down)

R = input resistance of the voltage preamplifier

C = effective circuit capacitance

$$\text{which} = \frac{(CA + CL)\,CC}{CA + CL + CC}$$

CA = accelerometer capacitance

CL = cable capacitance

CC = preamplifier input series capacitance

When an accelerometer is followed by a **charge preamplifier** the low frequency response of the system is determined only by the low frequency response of the preamplifier.

Dynamic Range

The dynamic range of an accelerometer defines the range over which its electrical output is directly proportional to the acceleration of its base. The lower dynamic limit for vibration measurement is dependent on the amount of noise entering the monitoring system. Normally the major part of the noise originates from the preamplifier circuitry, but the accelerometer and its connecting cable may also be partially responsible. Possible sources of noise are variable ambient pressure (sound), temperature, and electrostatic or magnetic fields. The influence of these factors has been reduced to a minimum by careful design. The lowest measurable vibration levels are shown in Table 1.

An accelerometer's upper dynamic limit is determined by the preloading on the mass/piezoelectric element system and by the mechanical strength of the piezoelectric element. In general, the smaller the accelerometer, the higher the vibration level at which it can be used.

The highest shock level to which the accelerometers should be subjected is contained in the specification table. Dropping an accelerometer on a hard floor can result in shocks of several thousand g, so special care should be excercised in handling them. When using the ac-

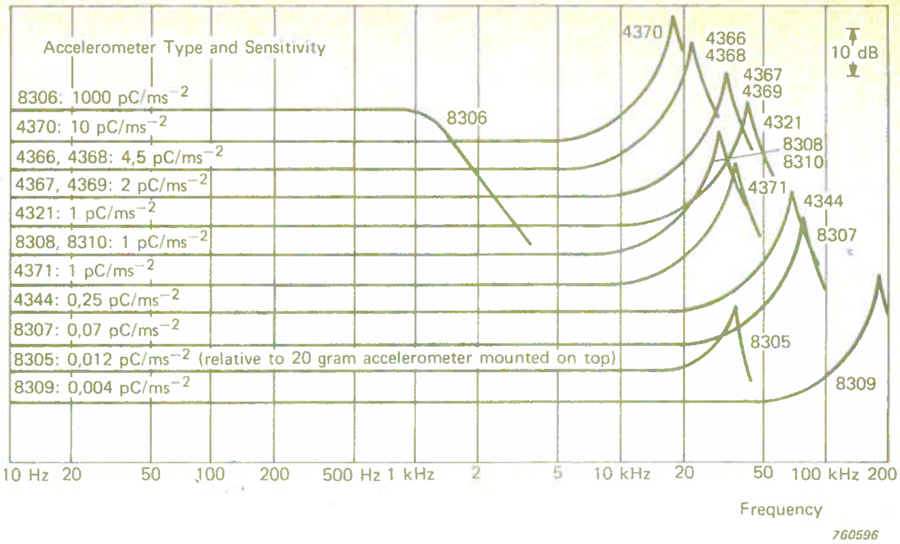

Fig.3. Typical frequency response curves for the various accelerometers

	Accelerometer Type (std. cable included)	2623 Acc'n. 0 dB gain LLF 0,16 Hz mm/s²	2626 Acc'n. 1 V/g Out LLF 0,3 Hz mm/s²	2634 Acc'n. 1 mV/pC LLF 1 Hz mm/s²	2635 Acc'n. 1 V per m/s² LLF 2 Hz mm/s²	2635 Vel. 100 V per m/s LLF 1 Hz µm/s	2635 Disp. 10 V/mm LLF 10 Hz µm	2635 Disp. 1 V/mm LLF 1 Hz µm	2651 Acc'n. 10 mV/pC LLF 1 Hz mm/s²	2651 Vel. 10 mV/pC LLF 10 Hz µm/s
With Frequency Analyzer Type 2120 3% constant percentage bandwidth filter over freq. range 2 Hz to 30 kHz*	4321	4	1,2	2	0,2	4	0,008	0,25	0,6	2,6
	4370	0,4	0,12	0,2	0,02	0,4	0,0008	0,025	0,06	0,26
	4371	4	1,2	2	0,2	4	0,008	0,25	0,6	2,6
	4344	13	2,5	7	0,7	13	0,027	0,83	2	8,6
	4366	1,2	0,3	0,5	0,05	1	0,002	0,06	0,12	0,7
	4367	3,2	0,7	1,4	0,14	3	0,006	0,17	0,4	2
	4368	1,2	0,3	0,5	0,05	1	0,002	0,06	0,12	0,7
	4369	3,2	0,7	1,4	0,14	3	0,006	0,17	0,4	2
	8305		3	12	1,2	25	0,06	2	4	14
	8306		0,0012	0,002	0,0002	0,004	0,000008	0,00025	0,0006	0,0026
	8307	22	5	19	2	45	0,1	3	7	23
	8308/10		1,2	2	0,2	4	0,008	0,25	0,6	2,6
	8309	200	80	330	35	750	1,75	50	130	400
Over Linear Frequency Range 2 Hz to 30 kHz*	4321	30	9	85	4	80	0,1	6	22	44
	4370	3	0,9	8,5	0,4	8	0,01	0,6	2,2	4,4
	4371	30	9	85	4	80	0,1	6	22	44
	4344	100	20	300	13	270	0,33	20	73	145
	4366	9	2	22	1	20	0,025	1,5	6	11
	4367	24	5	57	2,7	50	0,07	4	15	30
	4368	9	2	22	1	20	0,025	1,6	6	11
	4369	24	5	57	2,7	50	0,07	4	15	30
	8305		30	670	25	500	0,7	40	130	330
	8306		0,009	0,085	0,004	0,08	0,0001	0,006	0,022	0,044
	8307	170	52	1150	43	1000	1,15	70	230	570
	8308/10		9	85	4	80	0,1	6	22	44
	8309	1500	900	20000	750	15000	20	1250	4000	10000

* Note: Measurements are limited in practice at the high frequency end by the accelerometer resonance – see under "Characteristics"

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Table 1. Lowest measurable vibration levels (worst case) signal/noise > 6 dB

celerometers at frequencies above the quoted frequency range, the maximum allowable vibration level is reduced in proportion to the increase in sensitivity due to the accelerometers resonance.

Mounting

Mounting Methods

In order to obtain reliable results, especially at higher frequencies, it is of the utmost importance to fix the accelerometer properly to the specimen. The reliability of the high frequency performance is determined by the stiffness of the accelerometer mounting. The frequency response given on the calibration chart is for the best possible mounting of the accelerometer, which is when the accelerometer is attached to a smooth flat surface with a threaded steel stud. When other methods are used the resonant frequency will generally be lower. Fig.4 shows eight different methods of mounting an accelerometer.

Due to its small size, the Subminiature Accelerometer Type 8307 has a plane base and should be fixed by means of wax, double adhesive disc, dental cement, or a quick setting cyanoacrylate cement. Types 8308 and 8310 are attached with screws through the three attachment holes provided in the flange, while Type 8309 has an integral threaded fixing stud.

For measurements up to 2 to 3 kHz the mounting method is not critical if the accelerometer is fixed directly onto the specimen. If a fixture or bracket of any kind is inserted between accelerometer and specimen the frequency response should be examined before the actual measurements are taken.

Ground loops may give rise to noise in the measuring circuit so that low acceleration signals may not be measurable. In such cases the accelerometer should be electrically isolated from the specimen, for example by using an isolated stud and mica washer or a cementing method. At lower frequencies the clamping magnet may also be used. The Balanced Accelerometers Types 8308 and 8310 have both poles of the sensitive element insulated from the case so further insulation is not necessary.

The accelerometers have either side-mounted or top-mounted cable connectors. Apart from the advantages one connection type may have over the other when the accelerometer is mounted in inaccessible places, side-mounting of the cable in most cases offers easier whip-free cable mounting, see Fig.5.

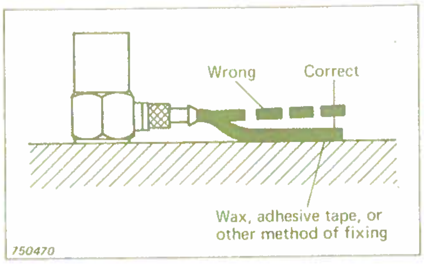


Fig.5. Clamping of the cable to avoid cable whip

Temperature and Cooling

The high temperature capacity of B & K accelerometers is usually limited by the upper temperature limit of the piezoelectric material. Additionally, Type 8306 is restricted to 85°C, 8309 to 120°C, and Types 4367 and 4369 to 180°C. The remaining accelerometers can be used in ambient temperatures up to 250°C without damage, while accelerometer Types 8308 and 8310 will operate within specifications in ambient temperatures up to 400°C.

Accelerometers can be used on test objects with surface temperatures in excess of the normal maximum allowable temperature when some form of cooling method is used. For example when a cooling plate is inserted beneath the base of the 250°C accelerometers and a mica washer is used between the measuring surface and the cooling plate, measurements can be made on surfaces with temperatures up to about 350°C. By directing a stream of air across the surface, temperatures of up to about 450°C can be tolerated. See Fig.6.

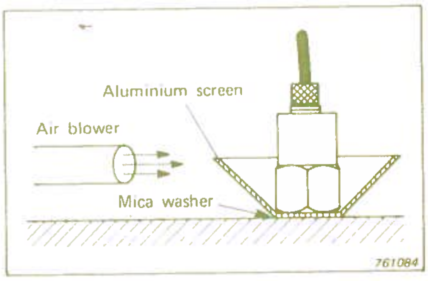


Fig.6. Forced air cooling of an accelerometer

Humidity

All the accelerometer types are of a sealed construction, the Types 8308, 8310 and 8305 being all welded and the remainder epoxy sealed. To ensure reliability in wet or very humid environments the cable entry should be sealed with a room temperature vulcanising silicon rubber such as Dow Corning Silastic 738 RTV. (Fig.7.) With the epoxy sealed types it should be noted that after several exposures to the stated maximum ambient temperature the epoxy seal may not be sufficient for subsequent use in liquids. The accelerometers have a high resistance to the majority of corrosive agents encountered in industry.

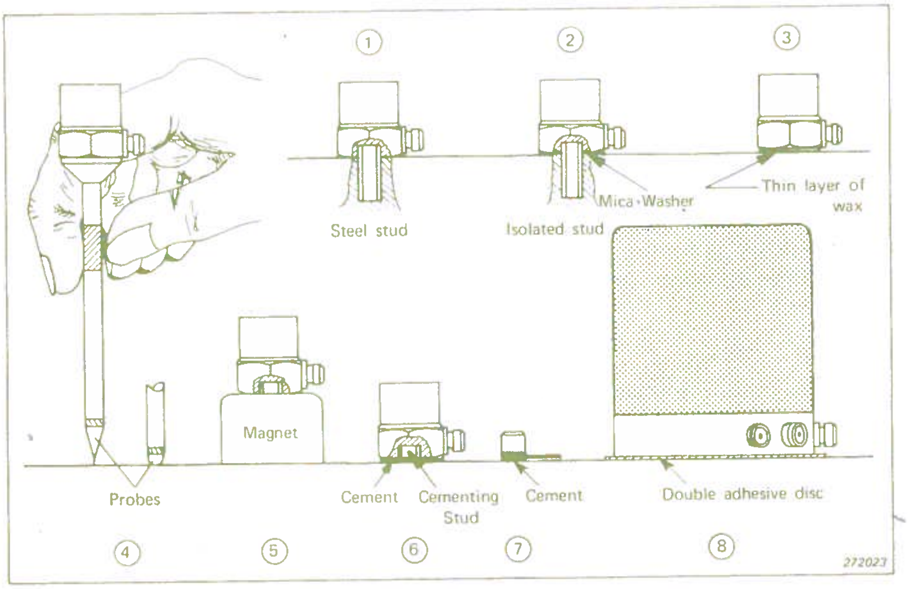


Fig.4. Different methods of mounting an accelerometer

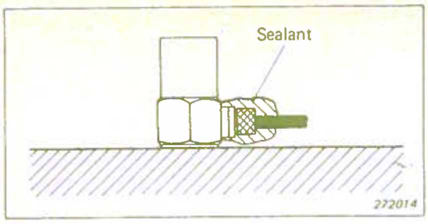


Fig.7. Sealing of the cable entry for use in liquids

Connecting Cables

Flexible coaxial cables are used for the connection between accelerometer and preamplifier. Four types are available from B & K. A PVC insulated cable is used for temperatures up to 100°C (212°F) and a Teflon insulated cable for temperatures up to 260°C (500°F).

A special reinforced cable is available for the more arduous applications (AO 0089).

For the Balanced Accelerometer Type 8308, special double shielded, armoured, and high temperature connecting cables intended for permanent industrial monitoring installations are available to individual order through the B & K systems engineering group. For typical examples see special data sheet 15—154. Accelerometer Type 8310 is equipped with a 3 m long integral hardline cable.

The cables delivered with the other accelerometers are 1,2 m (4 ft) long and terminate with the appropriate connectors. See accessories list for further details of the individual cables supplied with each accelerometer. Connecting cables may be ordered with or without termination in any length up to 180 m (600 ft). Miniature plugs and tools for fitting them to the cable may also be ordered separately; see accessories section. (Not available for the micro-miniature plugs used with accelerometer Type 4344 and for the plugs used with the reinforced cable.)

All B & K accelerometer cables are designed for minimum noise output, but it is recommended to fix the cable as firmly as possible to the specimen, for example by using wax, tape, cable clip or similar clamping methods to avoid cable whip which may introduce noise into the measuring system. See Fig.5.

Cable capacitance reduces the sensitivity of the measuring system when voltage amplifiers are employed. The B & K accelerometers are calibrated with their normal, 1,2 m (4 ft), connection cables, so that when these cables are employed the sensitivity value from the calibration chart is applicable. When longer cables are used, the correct voltage sensitivity can be found simply by dividing the charge sensitivity of the accelerometer by the total capacitance in the circuit, i. e.

$$\text{Voltage sensitivity} = \frac{\text{charge sensitivity}}{\text{total capacitance}}$$

where the charge sensitivity is found from the calibration chart and the total capacitance is found by adding the cable capacitance to the accelerometer capacitance (without cable). The input capacitance of voltage amplifiers is usually negligible.

With **charge amplifiers** the cable capacitance has nearly no influence upon the sensitivity of the measuring system, but it should be borne in mind that long cables can result in extra background noise.

Preamplifiers

A preamplifier is introduced into the measuring set-up for two reasons. 1) To convert the high output impedance of the accelerometer to a lower value, and 2) to amplify the relatively weak output signal from the accelerometer if the following instrumentation does not have a sufficiently high sensitivity. There are two basically different alternatives, the voltage amplifier and the charge amplifier.

The voltage amplifier is designed to present the highest possible resistance to the accelerometer while the input capacitance is kept low to avoid loss of sensitivity. The charge amplifier is designed to present both a very high input capacitance and resistance.

Voltage Amplifiers

The voltage amplifier is usually placed near the accelerometer with only a short interconnecting cable in order to avoid loss of sensitivity due to cable capacitance. A large degree of signal amplification is usually unnecessary. The voltage amplifier is primarily an impedance conversion device with a low output impedance which allows loading by very long cables.

Charge Amplifiers

With the charge amplifier, which works on the change in input charge, the variation in input signal due to varying capacitive loading of the accelerometer is compensated for in the preamplifier by a large degree of capacitive feedback. A great advantage of the charge amplifier therefore, is that very long cables can be used between the accelerometer and preamplifier without changing the sensitivity of the measuring system.

It is necessary to follow the accelerometer with a preamplifier, *except in the following cases:* 1) When using high sensitivity accelerometer Type 8306 which has a built-in preamplifier and 2) When feeding the signal into measuring instruments having a built-in preamplifier such as the Vibration Meters Types 2510 and 2511 and the Sound Level Meters Types 2203, 2209, 2210 and 2215.

Calibration

Factory Calibration

Each individual accelerometer undergoes a very extensive calibration and temperature stabilizing procedure in order to ensure completely predictable performance and stable operation. The individual calibration for each unit includes:

Weight
Voltage and/or charge sensitivity
Capacitance
Cable capacitance
Full frequency response curve (Not for 8307, 8308, 8309, and 8310)
Undamped natural frequency (Not for 8306, 8307, 8308, 8309, and 8310)

Maximum transverse sensitivity
Mounted resonance frequency (Not for 8307 and 8309)
Charge changes with temperature where applicable

In addition the typical values for resistance and many environmental effects are checked and stated. A complete calibration chart as delivered with each accelerometer is shown in Fig.8.

The accelerometer sensitivity calibration is carried out by back-to-back comparison with an NBS calibrated reference standard accelerometer. This reference standard is frequently confirmed by the absolute laser interferometry method. The overall accuracy of the sensitivity calibration stated on the calibration chart is better than ± 2%.

Reference Standard Accelerometer Type 8305, is calibrated by a laser interferometer giving a sensitivity calibration accuracy of better than ± 0,5%. Type 8305 is covered in greater detail under **Special Types.**

Subsequent Calibration

For the sensitivity and frequency response calibration of the accelerometers and the vibration measuring instruments a number of calibrators are available.

Calibration Exciter Type 4290 is a small shaker which is driven from an external generator. It has a built-in control accelerometer and is used for making accelerometer frequency response curves.

Accelerometer Calibrator Type 4291 is a portable battery driven exciter with a built-in 79,6 Hz (ω = 500) oscillator. The acceleration level can be adjusted to 1 g peak by means of a built-in velocity coil and meter. Provision is made for back-to-back calibration, insert voltage calibration and reciprocity calibration. Frequency response curves can be plotted with the use of an external generator. The instrument may be driven from internal batteries or an external power supply.

Preamplifier Type 4292 has a built-in shaker table and 79,6 Hz (ω = 500) oscillator. This is set to 1 g peak by adjusting the shaker drive level until a bronze ball inside the table balances on the threshold of rattling.

High g Calibration Head Type 4815 is one of the range of interchangeable heads for the B & K vibration exciter system V. It is particularly intended for back-to-back sensitivity calibration of accelerometers at actual use levels up to 100 g.

Transducer Calibration Amplifier Type 2650 is designed for use in comparison calibration set-ups. The

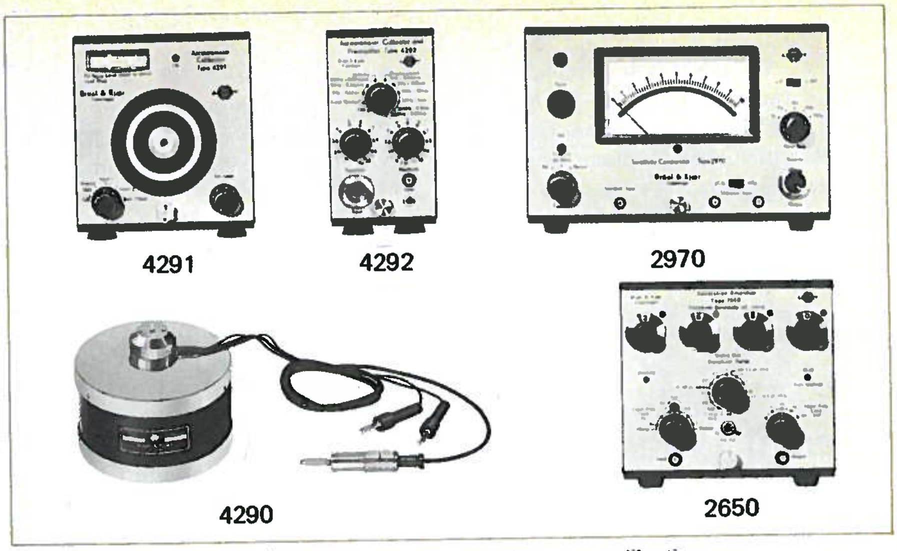


Fig.9. Instruments for accelerometer calibration

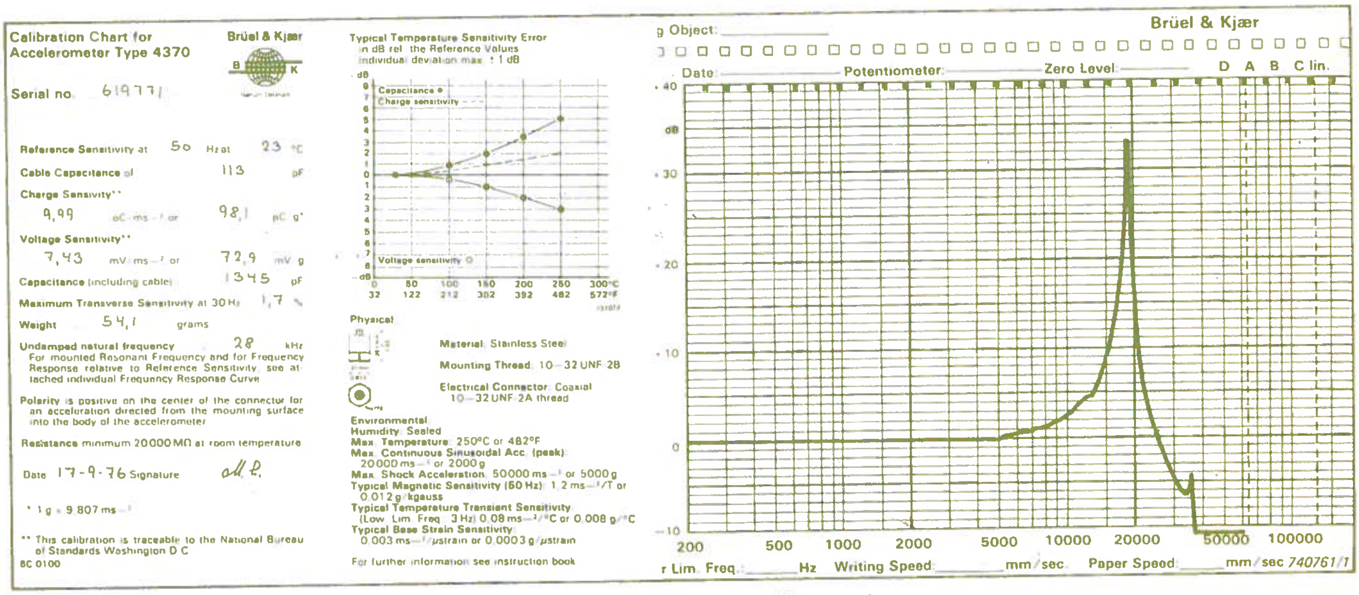


Fig.8. A typical accelerometer calibration chart

unknown transducer charge or voltage sensitivity is indicated to 4 digits. A 1000 Hz test oscillator is built-in for calibration purposes and both the high pass and low pass filter cut-off frequencies can be switch selected.

Sensitivity Comparator Type 2970 aids rapid back-to-back comparison calibration of accelerometers in conjunction with the Standard Accelerometer Type 8305, the Calibration Exciter Head Type 4815, the Conditioning Amplifier Type 2626, and the Calibration Preamplifier Type 2650. The 2970 indicates the balance condition between the known and unknown accelerometer signals. The Standard Accelerometer Type 8305 and the Conditioning Amplifier Type 2626 are available as a calibrated set under Type 3506.

Special Types

In addition to the "General Purpose" accelerometers there are a number of types that have been developed to suit certain applications; their special features will be discussed more fully.

400°C Balanced Accelerometers Types 8308 and 8310

These accelerometers are intended for operation at temperatures up to 400°C (752°F). The 8310 differs from the 8308 in that it has an Integral high temperature cable. The accelerometers have three additional features which make them specially suited for high reliability, permanent vibration monitoring in the severe environmental conditions found on steam and gas turbines, including aircraft engines, nuclear reactors, electrical generators and on industrial machinery in general.

Firstly, the robust, all welded, hermetically-sealed stainless steel body is amply dimensioned and has three fixing holes enabling the accelerometer to be solidly bolted to the measuring point. Flange dimensions are in line with the three hole fixing described in the ARINC Characteristic 544.

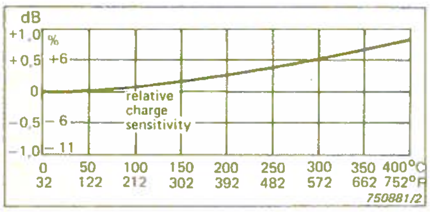


Fig.10. Typical change of charge sensitivity with temperature for Types 8308 and 8310

Secondly, the 8308 and 8310 have a balanced output which, when fed into a differential charge amplifier (such as Type 2634), largely eliminates the electromagnetic interference problems usually associated with vibration measurements on running machinery. Both poles of the piezoelectric element are insulated with the same capacitance and high resistance with respect to the case. Possible ground loops are broken because the accelerometer casing has no connection to either of the signal leads. The signal is transmitted in a twisted shielded pair (see under connecting cables) so that any noise pick-up will be essentially equal on the two wires. In a proper differential preamplifier, such as the B & K Type 2634 these two noise signals are subtracted and thus largely cancelled.

Thirdly, the 8308 and 8310 are Uni-Gain® accelerometers, which means that all 8308s and 8310s are delivered with the same sensitivity (1 pC/ms $^{-2}$) within ± 2%. This gives a very close interchangeability tolerance which allows replacement, or switching from accelerometer to accelerometer on a multipoint monitoring set-up, without altering the sensitivity of the associated measuring instrumentation.

For vibration monitoring on equipment used in conjunction with nuclear power generation the accelerometers are able to withstand nuclear radiation without any significant change in their characteristics. Radiation doses of hundreds of M Rads and in the order of 10^{18} to 10^{19} thermal neutrons/cm² flux density, (at rates of approx. 1 M Rad/hour and 10^{12} n/cm² per second) can be tolerated.

The 8308 is equipped with a two-pin connector and supplied with a mating plug for use up to 180°C. A plug for 400°C use (JP 0206) is available as an extra.

Type 8310 is equipped with a 3 m long "hard line" integral cable consisting of a pair of conductors in a shell of stainless steel (type AISI 321) filled with Magnesium Oxide insulation material. The cable can tolerate up to 800°C. A two-pin connector, which fits directly to the B & K Differential Charge Preamplifier Type 2634, terminates the cable. The connector can tolerate up to 180°C.

Where it is required to use the 8308 with a conventional single ended amplifier, a TNC to miniature plug adaptor (JJ 0207 for 180°C), which grounds one pole of the accelerometer output, can be used.

Triaxial Accelerometer Type 4321

This device consists of three individual accelerometer elements with their principal axes mounted perpendicular to each other, so that it detects vibration in three mutually perpendicular directions. Each element is a Uni-Gain® type, so that their sensitivities are all 1 pC/ms $^{-2}$ within a 2% tolerance, a feature which particularly simplifies system calibration and read-out of levels when the accelerometer is used with fixed-gain charge preamplifiers.

The three transducers contained in Type 4321 are of the new Delta

Shear® type and have therefore a particularly low sensitivity to temperature transients and other environmental influences. For ease of mounting the 4321 can either be fixed by means of a 4 mm screw passing through the body or by means of a 10 — 32 UNF stud into the base of the accelerometer.

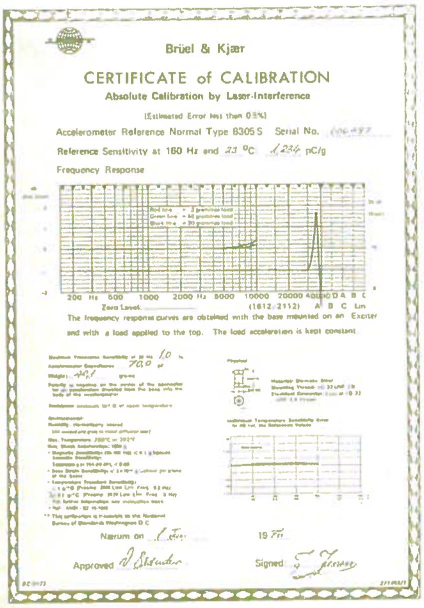
Standard Accelerometer Type 8305

This accelerometer has been designed particularly for the precise calibration of vibration transducers by the back-to-back comparison method. Careful design has resulted in very low transverse and base strain sensitivities ensuring a high degree of accuracy in comparison measurements.

High stability over time and low sensitivity to temperature changes are obtained by using a piezoelectric element of quartz.

Absolute calibration of the Type 8305 is performed at the factory by the laser interference method with an estimated error of within 0,5%. The calibration instrumentation and procedure is frequently confirmed by calibrating a reference accelerometer which has previously been calibrated at the USA National Bureau of Standards.

A factory recalibration service is available for subsequent calibration checks on the 8305. The laser interference method is used and a new calibration certificate issued.


Brüel & Kjær

CERTIFICATE of CALIBRATION

Absolute Calibration by Laser-Interference

(Estimated Error less than 0.5%)

Accelerometer Reference Normal Type 8305 S Serial No. 606497

Reference Sensitivity at 160 Hz and 23 °C 1.234 pC/g

Frequency Response

The frequency response curves are obtained with the base mounted on an Exciter and with a load applied to the top. The load acceleration is kept constant.

Nærum on 19

Approved Signed

Fig.11. Typical Calibration Certificate as supplied with Type 8305

It is recommended that when used for calibration purposes, the standard accelerometer should have its primary calibration performed together with the preamplifier with which it will subsequently be used. In this way cumulative errors are kept to a minimum.

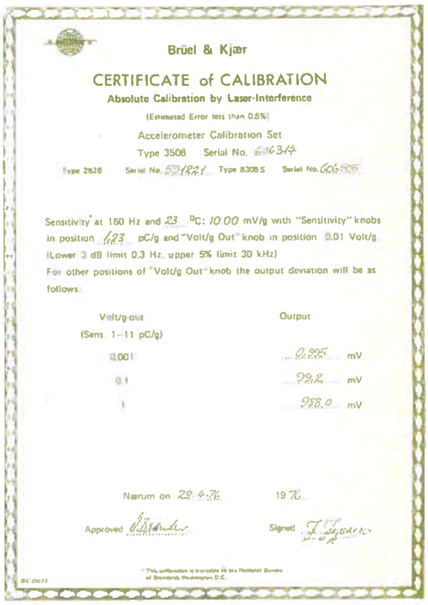
The precision Charge Conditioning Preamplifier Type 2626 is ideal for use with the Type 8305. These two instruments are available as Accelerometer Calibration Set Type 3506, and represent an integral system calibrated from vibratory input to low impedance voltage output.

Fig.12. The Accelerometer Calibration Set Type 3506

By using the Calibration Set Type 3506 together with Sensitivity Comparator Type 2970 the comparative sensitivity of an unknown accelerometer can be determined within 0,2%. Comparative frequency response curves can be made by using a sweep generator.

The Accelerometer Calibration Set Type 3506 is calibrated as an integral unit in the Brüel & Kjær calibration laboratory by the laser interference method, giving a maximum probable error of within 0,5%. As with the 8305, a factory recalibration service is offered.

The centre mounted quartz crystal accelerometer and the precision charge amplifier together with their carefully controlled calibration makes the calibration set Type 3506 an extremely accurate reference.


Brüel & Kjær

CERTIFICATE of CALIBRATION

Absolute Calibration by Laser-Interference

(Estimated Error less than 0.5%)

Accelerometer Calibration Set

Type 3506 Serial No. 616314

Type 2626 Serial No. 591821 Type 8305 S Serial No.

Sensitivity at 160 Hz and 23 °C: 10.00 mV/g with "Sensitivity" knobs in position 1.23 pC/g and "Volt/g Out" knob in position 0.01 Volt/g (Lower 3 dB limit 0.3 Hz, upper 5% limit 30 kHz)

For other positions of "Volt/g Out" knob the output deviation will be as follows:

Volt/g out (Sens. 1–11 pC/g)	Output
0.001	0.995 mV
0.1	99.2 mV
1	988.0 mV

Nærum on 28-4-76 1976

Approved Signed

Fig.13. Typical Calibration Certificate for Type 3506

Low g Accelerometer Type 8306

The 8306 has the extremely high Uni-Gain® sensitivity of 10 V/g and 10000 pC/g, allowing vibration measurements at levels as low as 2×10^{-6} g when taking suitable precautions to eliminate wide band noise, such as by using a 1/3 octave bandwidth or narrower filter. A preamplifier is built into the transducer which acts as an impedance converter and signal amplifier. It eliminates the effects of noise and losses in long connecting cables and permits the use of readout instrumentation at remote positions. The preamplifier also incorporates an active low-pass filter to give 18 dB per octave attenuation above 1000 Hz. Thus the accelerometer resonance and high frequency vibration will not influence the measured results. Power supply requirements of the preamplifier are 2 mA at 28 V which can be supplied by an external battery or battery driven power supply Type 2804. The General Purpose Vibration Meter Type 2511 is equipped with a 28 V power supply socket on the front panel specially intended for powering the 8306.

Two output terminals are provided, "Voltage" where a low impedance output voltage is proportional to the acceleration level, and "Charge" where, by the addition of a 1000 pF capacitor, the output charge is proportional to the acceleration level.

The high sensitivity of the 8306 will be welcomed in all areas where low level (up to 1 g), low frequency (up to 1000 Hz) vibration measurements have to be made. Applications are found on large structures, buildings, bridges, ships etc. and possibly for seismic investigations.

Subminiature Accelerometer Type 8307

The Subminiature Accelerometer Type 8307 satisfies the need for the very small, light-weight transducer necessary where external mass influence is particularly critical. Heavy transducers would change the mode of vibration thus invalidating the results obtained.

Fig.14. Subminiature Accelerometer Type 8307 showing integral cable and miniature connector. 1,7 × Natural Size

Typical application areas are with model testing, light printed circuit boards, thin skins such as aricraft or car shells and with complex structures where the transducer must be sited in a confined space.

The accelerometer is mounted on a base of Beryllium which is drilled to take the low noise teflon cable. The 300 mm long cable is rigidly bonded to the base to minimise accelerometer responses due to cable movement. A standard miniature connector terminates the cable.

Both Charge and Voltage sensitivities are high, relative to the size of the transducer. The resonant frequency is 75 kHz which allows operation up to 25 kHz within the + 10% sensitivity deviation level.

100 000 g Shock Accelerometer

Accelerometer Type 8309 is particularly applicable in the measurement and analysis of high level shocks. Typical applications are in the measurement of shocks due to explosions, tests on pneumatic impact tools such as rock drills, and shock measurements on the valves of the internal combustion engine. The transducer's rugged construction ensures reliable operation under the severe conditions imposed by such environments.

Fig.15. 100000 g Shock Accelerometer Type 8309. Natural Size

The 8309 is of small size and low weight, an essential requirement where extra mass can change the dynamic characteristics of smaller test objects. The 300 mm long integral cable gives the advantage of a reduced size and weight over transducers with plug and socket type connectors. Additionally, plug and socket connectors are of doubtful reliability at shock levels as high as 100000 g.

The rather high transverse resonance frequency of 28 kHz exhibited by the 8309 is a particularly acceptable feature in high shock measurement where the cross motion of a test object is sometimes difficult to define.

All of the B & K charge and voltage preamplifiers are suitable for use with the 8309 but care should be taken when measuring very high shock levels that the maximum input charge or voltage rating of the preamplifier is not exceeded. With voltage preamplifiers this can be avoided by adding extra cable between the transducer and the preamplifier.

It is normally accepted that for pulse shapes similar to a half sine, the minimum pulse length for less than 10% amplitude error is 5/fr (fr = accelerometer resonant frequency), the amplitude error being a result of the "ringing" effect. For the 8309 this gives a minimum pulse length of 30 μs.

However, with certain preamplifier cut-off characteristics i. e. upper cut-off frequency should be approximately 0,5 × accelerometer resonant frequency and have 12 dB/octave roll off, the ringing can be effectively damped. With this condition fulfilled, pulse lengths down to 1/fr (6 μs for 8309) can then be handled with an amplitude truth within 10%. Well suited to this purpose is Charge Amplifier Type 2626 switched to "linear" where the upper cut-off frequency is 100 kHz.

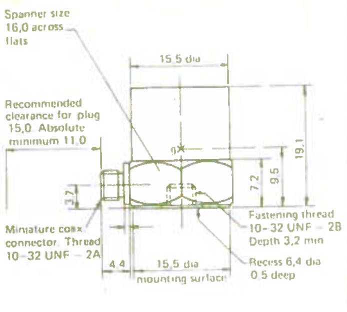
Zero shift is a phenomenon peculiar to piezoelectric accelerometers subjected to very high dynamic stresses. It manifests itself as a small voltage output from the accelerometer after the shock pulse has passed. Zero shift has been reduced to negligible proportions in the 8309 by careful treatment and handling of the piezoelectric disc.

Rigid mounting is particularly important when using the 8309 at high shock levels. The integral, threaded fixing stud is adequately dimensioned to transmit the motion of the test point to the piezoelectric element without distortion.

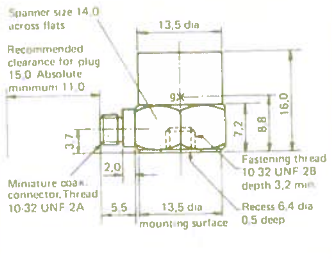
Accelerometer Dimensions

Shown 85% natural size (except 8306)

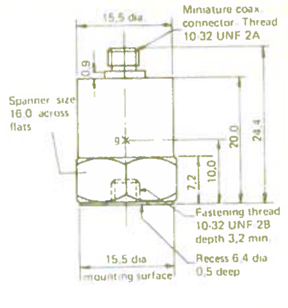
Type 4366



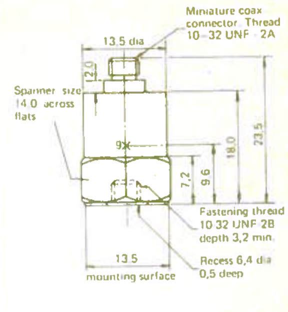
Type 4367



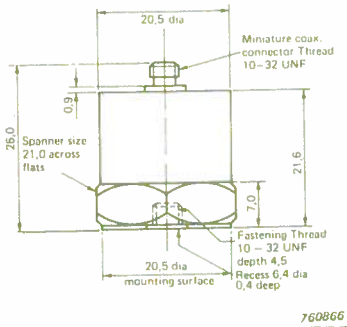
Type 4368



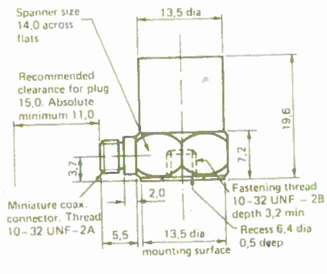
Type 4369



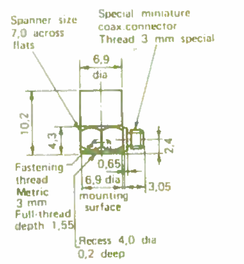
Type 4370



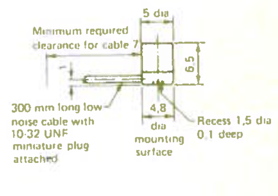
Type 4371



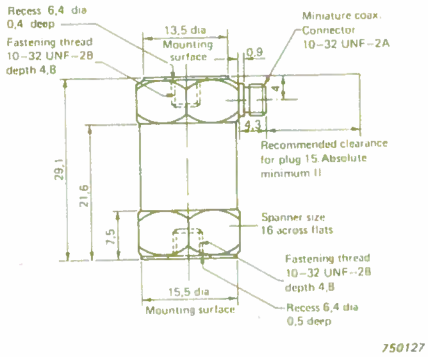
Type 4344



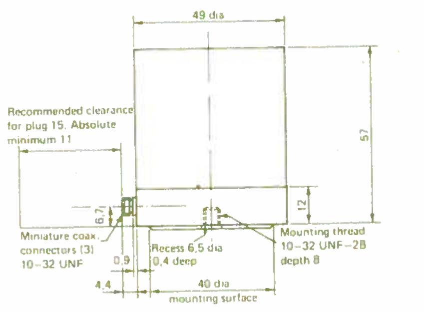
Type 8307



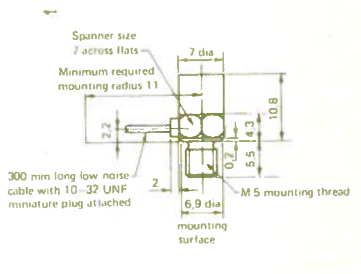
Type 8305



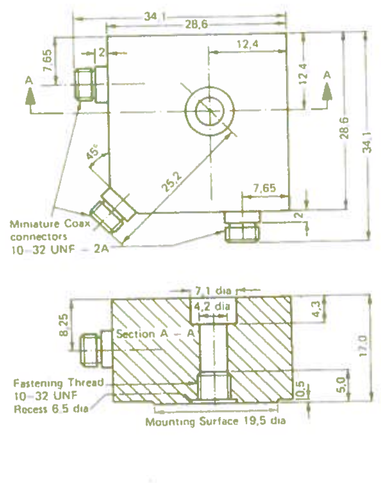
Type 8306



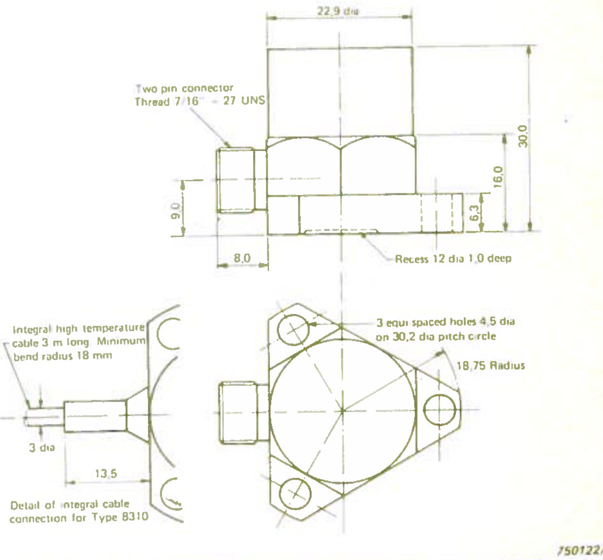
Type 8309



Type 4321



Types 8308 & 8310



All dimensions in mm

Standard Accessories

Part No.	Standard Accessories	4366 4368	4367 4369	4370 4371		4321	4344		8305	8306	8307		8308 8310	8309	
		S	P	S	P	S	S	P	S	S	S	P	S	S	P
AO 0037	100°C PVC mininoise cable AC 0010 fitted with miniature plugs JP 0012 Length 1,2 m (4 ft)	1	5								1	5		1	5
AO 0038	260° Teflon mininoise cable AC 0005 fitted with miniature plugs JP 0012 Length 1,2 m (4 ft)			1	5	3			1						
AO 0051	As AO 0037 but with micro-miniature plug on one end														
AO 0052	As AO 0038 but with micro-miniature plug on one end						1	5							
AO 0089	100°C Reinforced PVC cable AC 0032 fitted with reinforced miniature plugs. Length 3 m (10 ft)									2					
YS 9419	8–32 NF steel screw Length 0,5 in.												3		
YQ 0093	4 mm steel screw Length 16 mm												3		
JJ 0032	Extension connector for above B & K cables										3	5		2	5
JP 0028	Microplug to B & K plug adaptor	1		1		3	1			1	1			1	
JP 0209	2 pin plug for balanced accelerometers Max. temperature 180° C												1 (Not 8310)		
YQ 2962	10–32 NF threaded steel stud. 0,312 in long								2						
YQ 2960	10–32 NF threaded steel stud. 0,5 in long	5	5	5	5	5			2	5					
YM 0414	10–32 Nut	1		1		1			1						
YP 0150	10–32 NF insulated stud. 0,5 in long	1		1		1			1						
YO 0534	Insulated mica washer	1		1		1			1						
YQ 2007	M3 threaded steel stud. 0,25 in long						6	5							
YM 0334	M3 nut						1								
YQ 0093	M4 steel screw. 0,625 in long					1									
QA 0029	Tap for 10–32 NF thread	1		1		1			1						
QA 0041	Tap for M3 thread						1				1				
QA 0068	Tap for M5 thread													1	
DB 0756	Cement stud 10–32 NF	1		1											
DB 0757	Cement stud M3						1				2				
QA 0013	Hexagonal key for 10–32 NF studs	1		1		1			1						
QA 0042	Hexagonal key for M3 studs						1								
QA 0038	Hexagonal key for M4 studs					1									
YJ 0216	Beeswax for mounting	1		1		1	1			1	1			1	
YP 0080 DB 0544	Probe with sharp tip. 10–32 NF Round tip	1		1											
UA 0070 DL 3014	Electrically isolated mounting magnet Cable clip for magnet	1		1											
UA 0322 AO 0047 DA 0064	Insert voltage adaptor with cable and tommy bar								1 1 1						
DB 1440	Adaptor. 4–40 UNC to 10–32 NF thread								1						
DB 1441	Adaptor. 6–32 UNC to 10–32 NF thread								1						
DB 1442	Adaptor 8–32 UNC to 10–32 NF thread								1						
DB 1443	Adaptor 1/4–28 UNF to 10–32 NF thread								1						
DU 0079	Adhesive mounting disc. Dia 40 mm (1,6 in)									5					
YO 0073	Adhesive mounting disc. Dia 5,5 mm (0,2 in)										25				
QS 0007	Tube of cyanoacrylate adhesive										1				
	Individual calibration chart	1	5	1	5	1	1	5	1	1	1	5	1	1	5

760876

What to Order

The accelerometers are supplied in two forms designated by the suffices S and P which follow the type number.

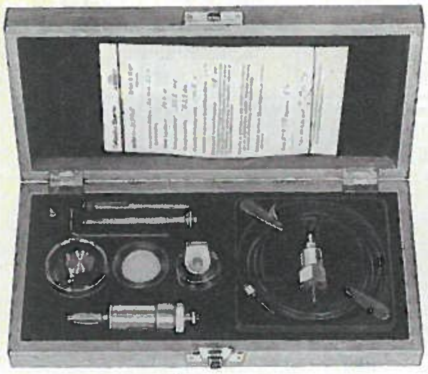


Fig.16. A typical accelerometer set

The accelerometers can be delivered as **accelerometer sets** (suffix S) where a single accelerometer is supplied in a mahogany case complete with a wide range of accessories typically as shown in Fig.16.

The **accelerometer packages** (suffix P) contain five individually packed accelerometers complete with fixing studs and cable as shown in Fig.17.

Accelerometers Types 4321, 8305, and 8306 are only supplied in accelerometer sets. Types 8308 and 8310 are supplied singly packed.

A complete list of small accessories as supplied with each accelerometer set or package is shown under **Standard Accessories.** Additional accessories are available on order.

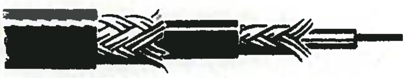
Fig.17. Accelerometer package

Additional Available Accessories

AC 0005
Teflon/PFA insulated low noise cable. Capacitance 90 pF/metre (30 pF/ft). For use up to 260°C (500°F). Available in standard lengths of:

100 m (300 ft)
50 m (165 ft)
25 m (82 ft)

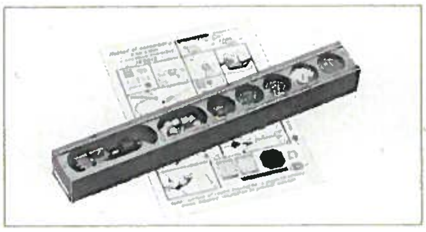
AC 0010
PVC insulated low noise cable. Capacitance 90 pF/metre (30 pF/ft). For use up to 100°C (212°F). Available in lengths up to 180 metres. (600 ft).



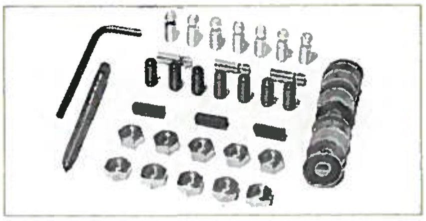
AC 0032
PVC insulated reinforced low noise cable. Capacitance 90 pF/metre (30 pf/ft). For use up to 100°C (212°F). Available in lengths up to 180 metres. (600 ft).

AC 0200
As AC 0032 but with Teflon/PFA insulation and max. temperature 260°C (500°F).

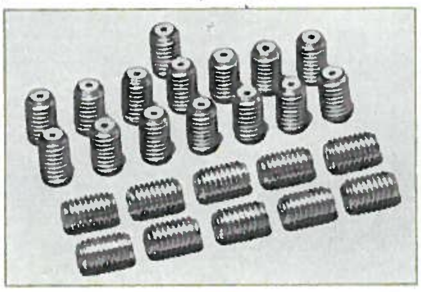
DB 1425
Thread Adaptor M 3 Female to 10 — 32 NF Male.



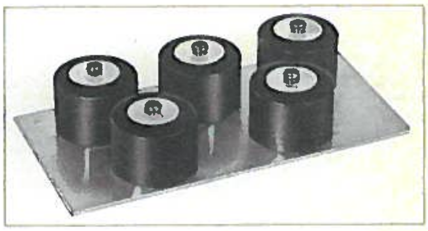
UA 0129
This set contains 20 miniature plugs JP 0012 for accelerometer cables AC 0005 and AC 0010. Assembly tool included.



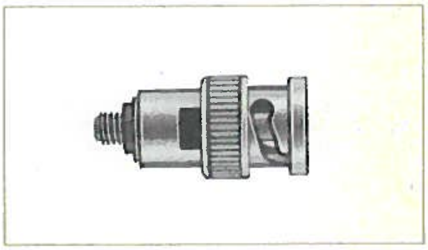
UA 0125
Fixing stud set containing 10 isolated studs YS 0420, 10 steel studs YQ 2960, 10 nuts YM 0414, 10 mica washers YO 0534, and 1 thread tap 10 — 32 NF.



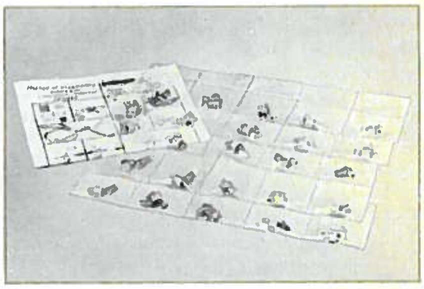
UA 0186
Set of 25 extension connectors, Type JJ 0032, for miniature plugs JP 0012.



UA 0142
Clamping magnet set containing 5 permanent magnets UA 0070 with electrically isolated mounting.



JP 0145
Adaptor allows miniature plugs (JP 0012) to be fitted to BNC sockets.



UA 0130
Set of 25 Miniature plugs JP 0012.

Specifications

Accelerometer B & K Type		4366	4368	4367	4369	4371	4370	4344
								
*Weight (grams)		28	30	13	14	11	54	2
*Voltage Sensitivity	mV/ms^{-2}	~4,0	~4,0	~1,5	~1,5	~1	~10	~0,25
	mV/g	~40	~40	~15	~15	~10	~100	~2,5
*Charge Sensitivity	pC/ms^{-2}	~4,5	~4,5	~2	~2	1 ± 2%	10 ± 2%	~0,25
	pC/g	~45	~45	~20	~20	~10	~100	~2,5
*Typical Mounted Resonance	kHz	22	22	32	32	35	18	70
*Frequency Range†	5%	0,2 – 4800	0,2 – 4800	0,2 – 6600	0,2 – 6600	0,2 – 7000	0,2 – 3500	1–14000
	10%	0,2 – 7000	0,2 – 7000	0,2 – 9700	0,2 – 9700	0,2 – 12000	0,2 – 6000	1–21000
*Capacitance Incl. Cable	pF**	1200	1200	1200	1200	1200	1200	1000
*Max. Transverse Sensitivity	%***	< 4	< 4	< 4	< 4	< 4	< 4	< 4
Piezoelectric Material		PZ23	PZ23	PZ23	PZ23	PZ23	PZ23	PZ23
Construction		Delta Shear	Delta Shear	Delta Shear	Delta Shear	Delta Shear	Delta Shear	Centre Mounted Compression
Typical Base Strain Sensitivity **** (in base plane at 250 $\mu\epsilon$)	ms^{-2}/μstrain	0,006	0,006	0,008	0,008	0,02	0,003	0,3
	g/μstrain	0,0006	0,0006	0,0008	0,0008	0,002	0,0003	0,03
Typical Temp Transient Sensitivity ****(3 Hz LLF)	ms^{-2}/°C	0,1	0,1	0,4	0,4	0,8	0,08	50
	g/°C	0,01	0,01	0,04	0,04	0,08	0,008	5
Typical Magnetic Sensitivity (50 Hz–0,03 T)	ms^{-2}/T	3	3	6	6	7	1,2	5
	g/k Gauss	0,03	0,03	0,06	0,06	0,07	0,012	0,05
Typical Acoustic Sens. Equiv. Acc. at 154 dB SPL (2–100 Hz)	ms^{-2}	0,002	0,002	0,005	0,005	0,01	0,001	0,1
	g	0,0002	0,0002	0,0005	0,0005	0,001	0,0001	0,01
Min. Leakage Resistance at 20°C	GΩ	20	20	20	20	20	20	20
Max. Ambient Temperature	°C	250	250	180	180	250	250	250
Max. Shock (± Peak) Along main axis	kms^{-2}	50	50	100	100	200	50	140
	g	5000	5000	10000	10000	20000	5000	14000
Max. Cont Sinusoidal Acceleraion (Peak)	kms^{-2}	20	20	30	30	60	20	30
	g	2000	2000	3000	3000	6000	2000	3000
Max. Acceleration (Peak) with Mounting Magnet	kms^{-2}	1	1	2	2	2	0,5	–
	g	100	100	200	200	200	50	–
Base Material		Stainless Steel AISI 316	Stainless Steel AISI 316	Titanium	Titanium	Titanium	Stainless Steel AISI 316	Titanium

* Individual values given on the calibration chart.
** With cable supplied as standard accessory.
*** Axis of minimum transverse sensitivity indicated by red dot on the accelerometer except 4321, 4345, 8306, 8307, 8308, 8309.
**** Re. ANSI S2. 11-1969 (American National Standard).
† The low frequency cut-off is determined by the preamplifier and environmental conditions.
†† Transverse resonance frequency at 11 kHz (typical) may limit the useful frequency range further

Specifications

■ Uni-Gain® sensitivity to ±2%

Accelerometer B & K Type	 4321■	 8305	 8306■	 8307	 8308■	 8309	 8310■
*Weight (grams)	55	40	500	0,4 excl. cable	100	3 excl. cable	100 excl. cable
*Voltage Sensitivity mV/ms⁻²	~0,8	–	~1000	~0,22	~1	~0,03	~1
*Voltage Sensitivity mV/g	~8	–	10000 ± 2%	~2,2	~10	~0,3	~10
*Charge Sensitivity pC/ms⁻²	1 ± 2%	~0,12	~1000	~0,07	1 ± 2%	~0,004	1 ± 2%
*Charge Sensitivity pC/g	~10	~1,2	10000 ± 2%	~0,7	~10	~0,04	~10
*Typical Mounted Resonance kHz	40††	30 with 20 gm load	4,5	75	30	180	30
*Frequency Range† 5%	1–8700††	1% 0,2 – 3100	10% 0,2–1000	1–15000	1–6000	1–36000	1–6000
*Frequency Range† 10%	1–12000††	2% 0,2 – 4400	3 dB 0,06–1250	1–25000	1–10000	1–60000	1–10000
*Capacitance Incl. Cable pF**	1200	180	1000▲	300	1100●	90	1900●●
*Max. Transverse Sensitivity %***	< 4	< 2	< 5	< 5	< 3	< 5	< 3
Piezoelectric Material	PZ23	PZ100	PZ23	PZ23	PZ45	PZ45	PZ45
Construction	Delta Shear	Centre Mounted Compression	Centre Mounted Compression	Annular Shear	Centre Mounted Compression	Centre Mounted Compression	Centre Mounted Compression
Typical Base Strain Sensitivity **** (in base plane at 250 $\mu\epsilon$) ms⁻²/µstrain	0,02	Top 0,01 Base 0,003	0,0005	0,03	0,08	5	0,08
Typical Base Strain Sensitivity g/µstrain	0,002	Top 0,001 Base 0,0003	0,00005	0,003	0,008	0,5	0,008
Typical Temp Transient Sensitivity ****(3 HzLLF) ms⁻²/°C	0,8	0,5	0,005	20	20	400	20
Typical Temp Transient Sensitivity g/°C	0,08	0,05	0,0005	2	2	40	2
Typical Magnetic Sensitivity (50 Hz–0,03 T) ms⁻²/T	7	1	2	3	25	20	25
Typical Magnetic Sensitivity g/k Gauss	0,07	0,01	0,02	0,03	0,25	0,2	0,25
Typical Acoustic Sens. Equiv. Acc. at 154 dB SPL (2–100 Hz) ms⁻²	0,01	0,008	0,0003	0,3	0,003	4	0,003
Typical Acoustic Sens. g	0,001	0,0008	0,00003	0,03	0,0003	0,4	0,0003
Min. Leakage Resistance at 20°C GΩ	20	1000GΩ at 20°C 10 GΩ at 200°C	–	20	20 GΩ at 20°C 2 MΩ at 400°C	20	20 GΩ at 20°C 2 MΩ at 400°C
Max. Ambient Temperature °C	250	200	85	200	400	120	400
Max. Shock (± Peak) Along main axis kms⁻²	100	10	1 ▲▲	100	20	1000	20
Max. Shock g	10000	1000	100▲▲	10000	2000	100000	2000
Max. Cont Sinusoidal Acceleraion (Peak) kms⁻²	30	10	0,3▲▲	30	20	300	20
Max. Cont Sinusoidal Acceleraion g	3000	1000	30 ▲▲	3000	2000	30000	2000
Max. Acceleration (Peak) with Mounting Magnet kms⁻²	0,75	1	0,05	–	–	–	–
Max. Acceleration with Mounting Magnet g	75	100	5	–	–	–	–
Base Material	Titanium	Stainless Steel AISI 316	Stainless Steel AISI 303	Beryllium	Stainless Steel AISI 316	Stainless Steel AISI 316	Stainless Steel AISI 316

▲ Capacitance of charge output of built-in Preamplifier of 8306. Voltage output impedance < 500 Ω. Voltage output load 50 kΩ minimum.

▲▲ Handling limits. Measurement limit 9,81 ms⁻² peak (1g peak)

● 2 pin balanced differential output with 40 pF to ground

●● 2 pin balanced differential output

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Summary of Accelerometer Types

* Uni-Gain® sensitivity to ± 2%

Type	Weight (grammes)	Sensitivity: Voltage mV/ms−2 (mV/g)	Sensitivity: Charge pC/ms−2 (pC/g)	Suitable Preamp.	Notable Characteristics	Application Areas
4366	28	~ 4 (~ 40)	~ 4,5 (~ 45)	Charge or Voltage	Side Connectors — Delta Shear® Types having good all-round characteristics with particularly low sensitivity to temperature transients and base strains	General shock and vibration measurements. Vibration testing and control
4367	13	~ 1,5 (~ 15)	~ 2 (~ 20)	Charge or Voltage		
4368	30	~4 (~ 40)	~ 4,5 (~ 45)	Charge or Voltage	Top Connectors	
4369	14	~ 1,5 (~ 15)	~ 2 (~ 20)	Charge or Voltage		
4371	11	~ 1 (~ 10)	1 ± 2%* (~ 10)	Charge	Side Connector — Delta Shear® Types with features as above. Also have Uni-Gain® sensitivity calibration giving simple system calibration and interchangeability	
4370	54	~ 10 (~ 100)	10 ± 2%* (~ 100)	Charge	Top Connector	General vibration measurements. Higher sensitivity for low level measurements
4344	2	~ 0,25 (~ 2,5)	~ 0,25 (~ 2,5)	Charge or Voltage	Miniature size and low weight. High resonant frequency	High level and high frequency vibration measurements. Shock measurements. Vibration measurements on delicate structures and in confined spaces
8307	0,4	~ 0,22 (~ 2,2)	~ 0,07 (~ 0,7)	Charge or Voltage	Subminiature accelerometer, extremely low weight. High resonant frequency. Integral cable	
8309	3	~ 0,03 (~ 0,3)	~ 0,004 (~ 0,04)	Charge or Voltage	Small size. 5 mm integral fixing stud. Integral cable	Shock measurements up to 1 million ms−2. High frequency vibration measurements
4321	55	~ 0,8 (~ 8)	1 ± 2%* (~ 10)	Charge	Three Delta Shear® accelerometers of the same Uni-Gain® sensitivity combined into single unit	Vibration measurements in three mutually perpendicular directions
8305	40	—	~ 0,12 (~ 1,2)	Charge	Quartz element. High stability over long time and wide temperature range. Laser calibrated to ± 0,5% accuracy	Reference Standard Accelerometer for back-to-back calibration of accelerometers
8306	500	~ 1000 (10000 ± 2%)*	~ 1000 (10000 ± 2%)*	Voltage or Charge	Very high Uni-Gain® Voltage and Charge sensitivity. Built-in preamplifier and low pass filter. Separate "Charge" and "Voltage" output. Power required 2 mA, 28 V	Ultra low level (down to 0,000002 g) and low frequency measurements on large structures, i.e., buildings, ships
8308	100	~ 1 (~ 10)	1 ± 2%* (~ 10)	Differential Charge	Robust construction. Balanced Uni-Gain® output. Tolerates temperatures up to 400°C	Permanent vibration monitoring. High temperature vib. measurements. Aeronautical, industrial and nuclear use
8310	100	~ 1 (~ 10)	1 ± 2%* (~ 10)	Differential Charge	As Type 8308 but with integral high temperature (800°C) cable	