4809

Instructions and Applications

Vibration Exciter Type 4809

The Vibration Exciter Type 4809 is a permanent magnet type exciter for use in accelerometer calibration, mechanical impedance measurement or testing of small structures. It has a force rating of 10 lbf. (44.5 N).

BRÜEL & KJÆR

030-0479

VIBRATION EXCITER TYPE 4809

May 1972

CONTENTS

1. INTRODUCTION

The Type 4809 Vibration Exciter is a permanent magnet type exciter with a force rating of 10 lbf (44.5 N). It has a round table with a centrally located mounting hole for connection to the test object. It can be operated in any position.

The Type 4809 can be used for accelerometer calibration, for mechanical impedance measurements, for educational demonstrations or for vibration testing of small objects or structures.

It has a maximum acceleration capacity of 75 g and a maximum displacement of 0.315 in. (8 mm) peak to peak. Low distortion operation is possible in the frequency range 20 Hz to 20 kHz.

2. DESCRIPTION AND OPERATION

2.1. PRINCIPLE OF OPERATION

The forces generated in an electrodynamic exciter are due to the interaction between an electrical current in a coil and a magnetic field. This is illustrated in Fig.2.1.

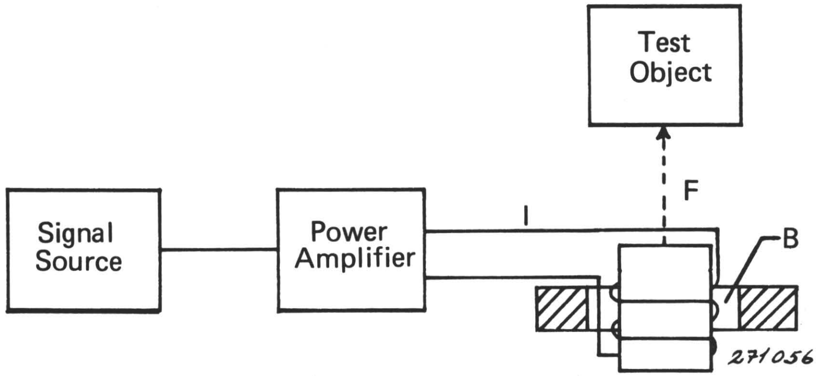


Fig.2.1. Principle of operation of a B & K Exciter

I is the current in the coil, B the flux density of the magnetic field and F the force generated by the coil. The magnitude of the force is given by

	F	=	BIL
where	F	=	Force in Newtons
	B	=	Magnetic flux, in Gauss
	I	=	Current in coil, Amperes
	L	=	Length of conductor in magnetic field, meters

The current for the exciter is provided by a power amplifier. A signal source, such as a sine-wave oscillator or random generator is connected to the input of the amplifier. As the signal is fed to the coil, a fluctuating force and hence a vibratory motion is imparted to the test object. Of course the coil itself is wound about a moving element and this has a certain mass. Hence the acceleration due to an applied force F will be:

$$a = \frac{(m + m_e)}{F}$$

where m is the mass of the test object and m_e is the moving element mass.

If the acceleration is given in gravitational units (g) and the weights of the moving element and test object are known, the maximum acceleration possible can be quickly computed. The maximum force available from the Type 4809 is 10 lbf. (44.5 Newton). The moving element weight is 0.132 lb. (60 gm.). If the test object weights 0.37 lb. (.170 kg), the maximum acceleration with this load is:

$$a = \frac{W + W_e}{F} = \frac{0.13 + 0.37}{10} = 20\ g$$

2.2. DESCRIPTION

Fig.2.2 shows a sectional drawing of the Type 4809. The magnetic field, B, mentioned in section 2.1, is here supplied by a permanent magnet which projects up into the space enclosed by the driver coil. A cast iron magnetic structure surrounds the magnet in order to confine the magnetic force to the exciter as much as possible.

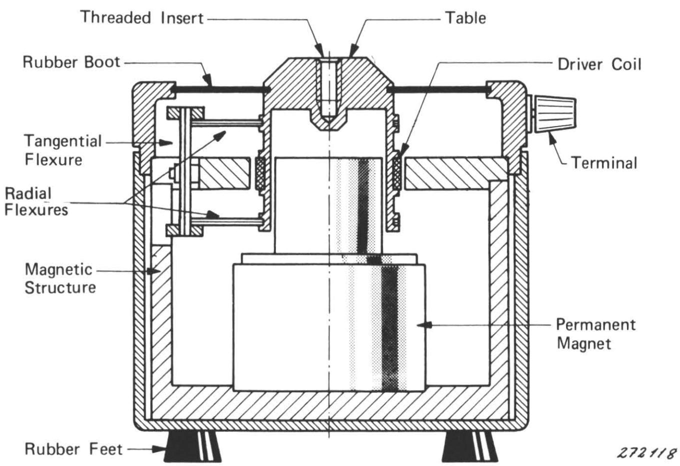


Fig.2.2. Sectional drawing of a Vibration Exciter Type 4809

The moving element is a cylinder machined out of aluminum with a table at one end and a driver coil wound around the open end. The table has a diameter of 1.16 inches (29.5 mm). In the center is a threaded hole.

This hole is NOT to be used for direct mounting to a test object or connecting rod. It is intended to receive one of the special inserts supplied with the Exciter.

The moving element is suspended by two sets of radial flexures. These are in turn mounted on tangential flexures. Each flexure is a sandwich of metal and rubber bonded together. The design is such that a high degree of damping is provided for the resonant modes of the flexure. In this way continuous operation is possible at any frequency.

The leads to the driver coil are epoxied onto the top surfaces of the flexures and led out to the two terminals. The terminals can accept either a standard B & K connector (JP 0101) or banana plugs (JB 0002/3).

Rubber overtravel stops (not shown in Fig.2.2) are provided to limit the peak-to-peak travel to 0.315 inches (8 mm). These are intended for emergency use, to protect the Exciter and the test specimen. If the moving element hits these stops, there is a clearly audible bumping sound and the signal waveform from any transducer mounted on the Exciter will be distorted. The level of acceleration should be reduced at once.

2.3. REPLACEABLE INSERTS

The Exciter is provided with 5 inserts, a bottle of thread locking cement, and an insert mounting tool. The inserts have an internal thread for a stud with 32 threads per inch and a no. 10 screw.

The inserts are made of aluminum and are intended to act as mechanical "fuses", protecting the moving element from damage. The inner threads of the inserts fail before the moving element is damaged, for most types of abusive treatment. In order to minimize insert replacement and, since mechanical fuses are not 100% safe, to avoid possible damage to the moving element, the user is warned to be careful to avoid the two most common causes of abuse:

The first is the use of screws that are too long, and which therefore hit the bottom of the insert hole before the attachment to the test object is tight. A suitable choice of length will avoid this. The internal thread on the inserts is 0.16 inches (4.0 mm) long, measured down from the table surface. The hole is 0.27 inches (6.8 mm) deep.

The second cause of abuse is the application of excessive mounting torque. A safe limit for the mounting torque of the Type 4809 is 30 lb.in. (0.35 kgm).

To install an insert, the insert is placed on the tool, with the pin of the tool inside of the insert internal thread and with the blade of the tool in the slot of the insert. Both the insert and the hole are thoroughly cleaned with a solvent to remove all traces of oil or contaminants from fingerprints. A drop of cement is placed on the insert external threads, and the insert is screwed into the hole. If properly installed, the upper surface of the insert should be about 0.1 millimeters or 0.005 inches below the table surface.

If an insert is damaged, it can be unscrewed with the same tool. It is advisable to heat the insert with a soldering iron to weaken the cement before unscrewing.

2.4. ADDITIONAL COOLING

Under normal operation, up to its rated current of 5 Amperes, the 4809 can operate continuously without overheating. However, since the table is an integral part of the moving element skeleton, its temperature can increase considerably under full load conditions. If the specimen is temperature – sensitive, this could have some effect on the test. For instance, with many accelerometers, an increase in temperature of 10°C can mean a change in sensitivity of 2%.

For this reason, openings in the casing of the Exciter are provided so that additional cooling may be provided. If the two steel plugs on either side of the body are removed, compressed air fittings may be screwed in. The openings are threaded with 12 mm threads with 1.75 mm pitch.

2.5. POSITIONING THE EXCITER

For accelerometer calibration or testing of small objects up to 1 kg. the Exciter would normally be used in its upright position, standing on the rubber feet provided. For many uses, though, it is more convenient to take the Exciter to the test object and operate it in a position other than the upright one.

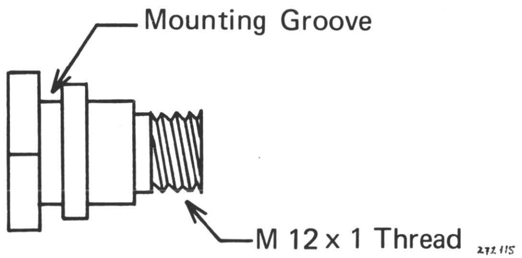


Fig.2.3. Plug for forced air openings

For this reason the threaded plugs for the forced air openings have a groove cut into them (see Fig.2.3) to facilitate the suspension of the Exciter by cables or other hangers. The plugs are located along a line passing through the center of gravity of the instrument.

272125

Fig.2.4. Stand for using Type 4809 in horizontal position

For use in a horizontal or near-horizontal position, a stand can be easily fabricated from sheet steel, as shown in Fig.2.4.

2.6. PUSHRODS

Since the Type 4809 has a central point through which all its force is directed and since it is usually more convenient to have the driving point a short distance from the Exciter, a pushrod is generally used to transfer the force. This can also be used to provide external protection for the Exciter. The dimensions and stiffness of the rod can be designed in such a way that side loads and moments result in bending of the rod rather than rubbing of the driver coil.

Fig.2.5 shows a sketch of a pushrod for use with the Type 4809 Exciter. The two halves are screwed tight to the Exciter table and the object, then locked together by means of four center screws.

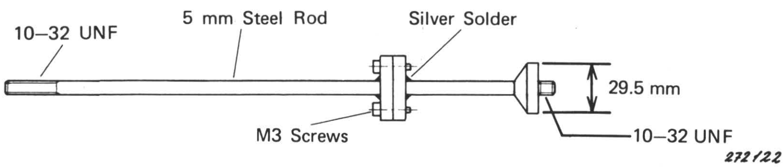
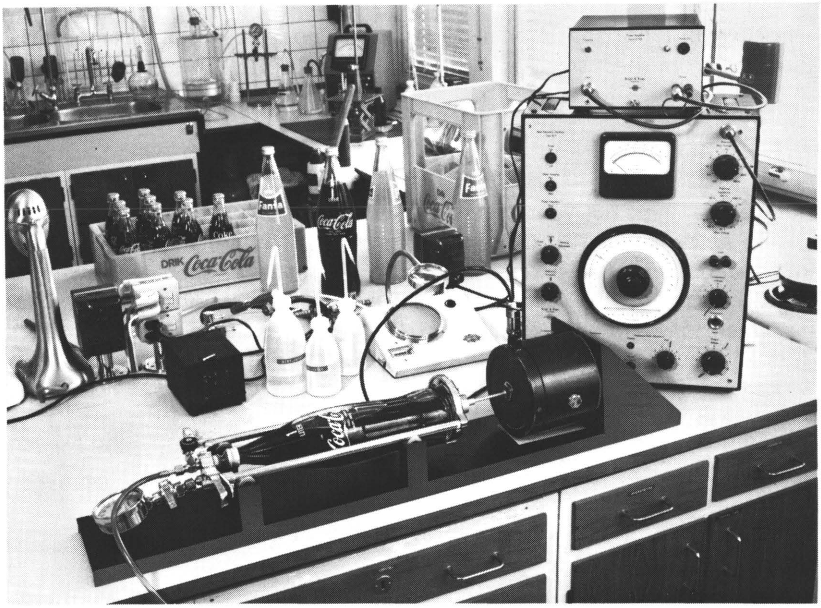


Fig.2.5. Pushrod for use with the Type 4809

Fig.2.6 shows a pushrod in use transmitting force to a gas pressure measuring device in the laboratory of a soft drink manufacturer. The gas measuring apparatus and bottle-holding jig are free to move horizontally on rollers and the pushrod is attached to the entire fixture with a locking pin which permits frequent removal of the fixture.



272124

Fig.2.6. Horizontal vibration fixture with Type 4809 built in

3. CHARACTERISTICS

3.1. FREQUENCY RESPONSE AND RESONANCE

In Fig.3.1 is shown a plot of the frequency response of a Type 4809 Exciter. The acceleration in g is plotted with respect to frequency for a constant voltage.

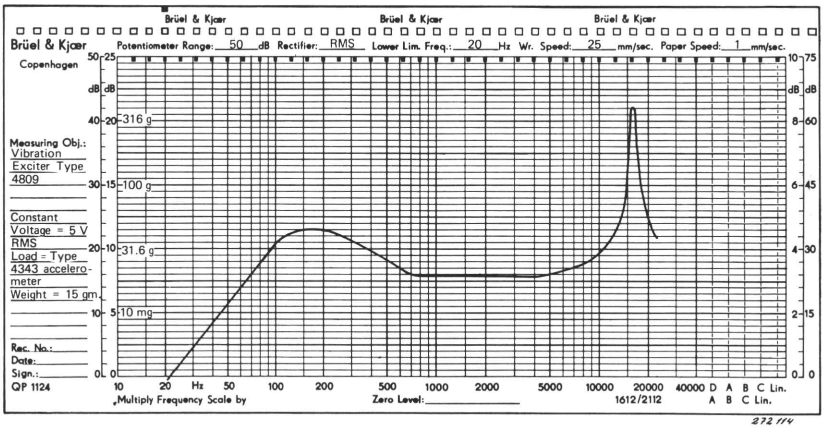
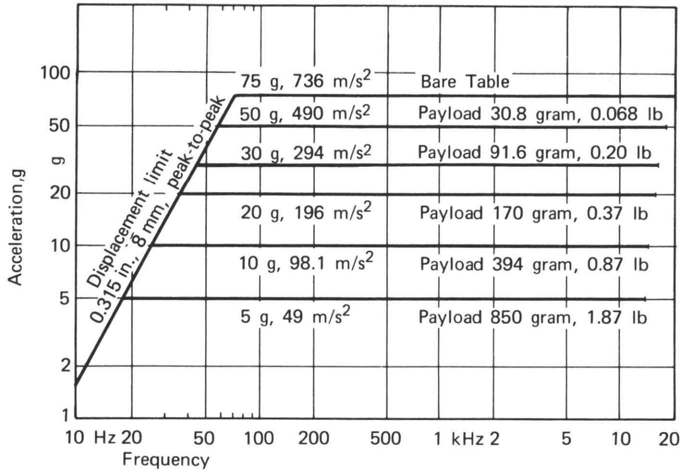


Fig.3.1. Frequency response of the Type 4809

The acceleration level increases with frequency to a damped peak at about 150 Hz. This is the suspension resonance of the Exciter. The acceleration level then remains constant from 700 to 5000 Hz, after which it climbs sharply to a peak at 16 kHz. This peak is the major axial resonance of the moving element itself. It can be seen that the Exciter could be operated in the range 700 to 5000 Hz without using a compressor loop to control the oscillator. However, the use of a compressor loop is generally recommended, since resonances from the test object also enter in.

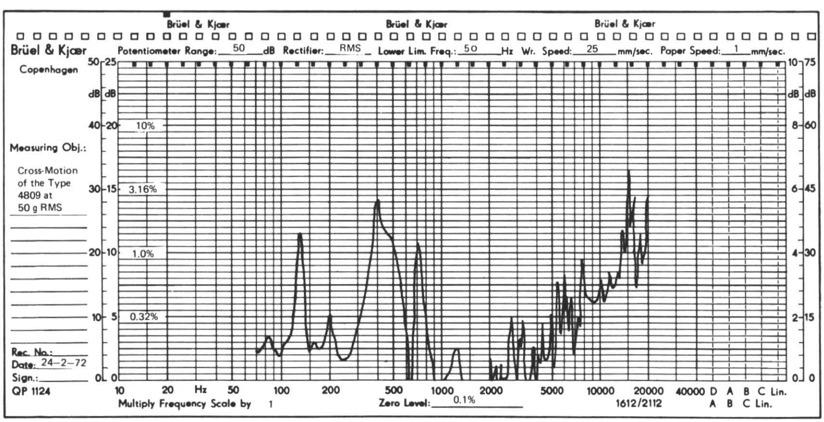
3.2. RATED FORCE AND LIMITS

Fig.3.2 shows a diagram of loading limits with respect to frequency for the Type 4809 Vibration Exciter powered by a Type 2706 Power Amplifier. Above 70 Hz, it can be seen that the limits are based solely on the amount of force available, as mentioned in section 2.1. However, for a given acceleration level, displacement increases as frequency decreases. Therefore, at the lower frequencies the Exciter must be held to the 0.315 inch (8 mm) limit in order to avoid hitting the end stops.



271067

Fig. 3.2. Load rating curves for the Type 4809



272090

Fig. 3.3. Cross-motion of the Type 4809

3.3. CROSS-MOTION

If an Exciter is to be used for accelerometer calibration, it is important that its motion be as rectilinear as possible, to avoid adding any error to the calibration. The cross-motion of the Type 4809 is very low, as can be seen in Fig.3.3, where cross-motion, expressed as a percentage of the axial motion, is plotted against frequency for an acceleration level of 50 g RMS. Except for a few isolated peaks, the cross-motion is well below 1% throughout the frequency range of the Type 4809.

4. APPLICATIONS

4.1. ACCELEROMETER CALIBRATION

By attaching a Type 8305 Standard Accelerometer to the table of the Type 4809 and then mounting the accelerometer to be tested on top of the Type 8305, back-to-back comparison calibration may be performed. Fig.4.1 shows a typical calibration setup using the Type 2970 Sensitivity Comparator.

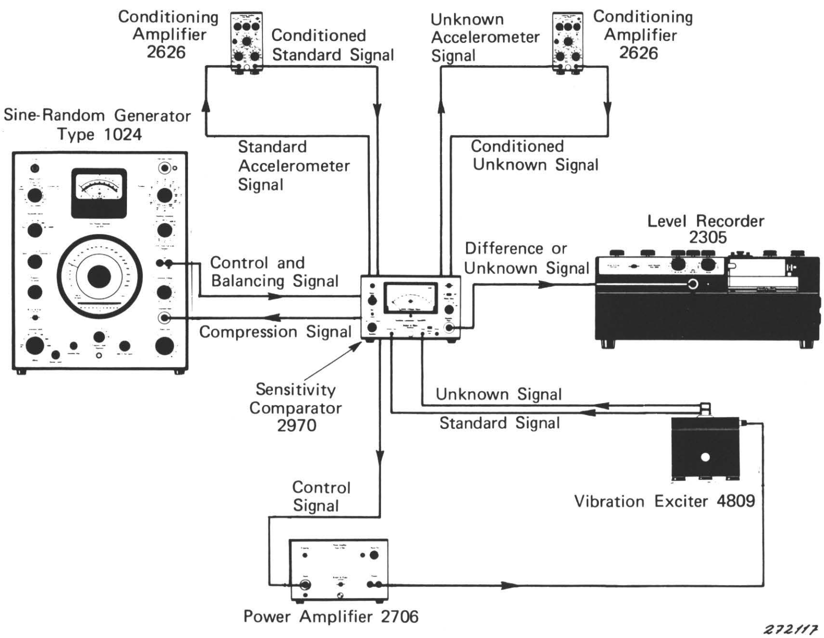


Fig.4.1. Accelerometer Calibration

The signal from the Standard Accelerometer is used to control the compressor loop in the Generator, which means that it determines the vibration level of the Exciter itself. The output from both accelerometers goes through the Sensitivity Comparator, which compares the two outputs and indicates the difference on a meter scale. The gain of the Conditioning Amplifier on the unknown line is adjusted until this meter reading falls to a minimum. A careful balancing and adjusting procedure is necessary to ensure the highest possible accuracy. This procedure is thoroughly covered in the Type 2970 manual and will not be gone into here.

4.2. MECHANICAL IMPEDANCE

Mechanical impedance can be defined as the resistance of an object to being set in motion. A dynamic force applied to an object will result in a certain velocity, in accordance with the equation:

$$Z = \frac{F}{V}$$

where F is the force, V the velocity and Z the mechanical impedance vectors.

In the equation, the quantities are stated as vectors, as in the majority of cases there will be a phase difference between the applied force and the resulting velocity. On the other hand, it is not always necessary to consider this phase difference when making measurements. The numerical value of mechanical impedance is often all that is required, and, since Z is proportional to $\frac{F}{V}$, a plot of mechanical impedance can be obtained by holding the velocity constant and varying the frequency.

Fig.4.2 shows the basic setup for measuring the numerical value of mechanical impedance. The signal from the Beat Frequency Oscillator Type 1022 is amplified in the Power Amplifier Type 2706 and fed to the Vibration Exciter. Between the Exciter and the measuring point on the test structure is a Type 8001 Impedance Head which has a force gauge and an accelerometer built in. The acceleration output is integrated in the Type 2625 and the resulting velocity signal is passed on to the Type 2608 Measuring Amplifier. Here the velocity level can be monitored as the signal is amplified and fed back to the Generator. The compressor loop thus formed holds the vibration level at a constant velocity.

With the velocity held constant in this way, the force signal can then be amplified and fed into the Type 2307 Level Recorder. A plot of the mechanical impedance versus frequency can thus be obtained.

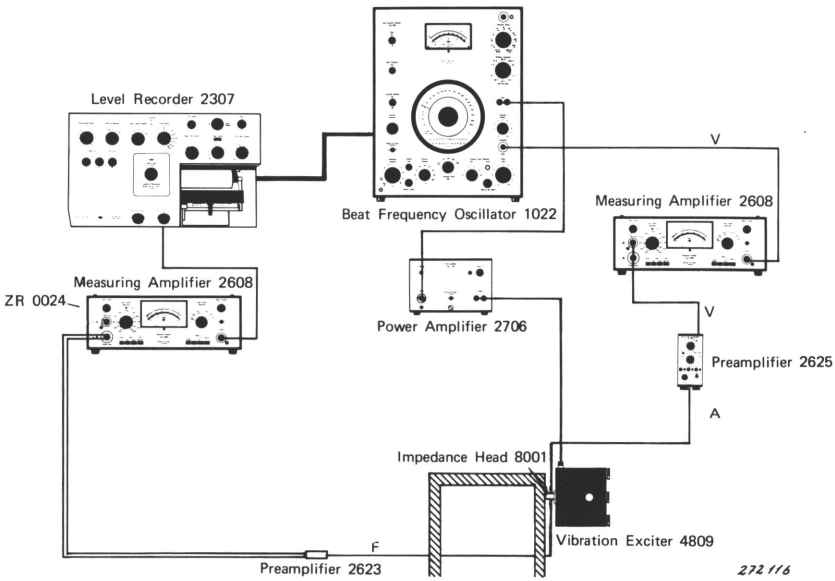


Fig.4.2. Mechanical Impedance measurement

4.3. FORCE CONTROLLED TESTING

For structural testing it is the general rule to control the Exciter with a force-controlled compressor loop such as that shown in Fig.4.3.

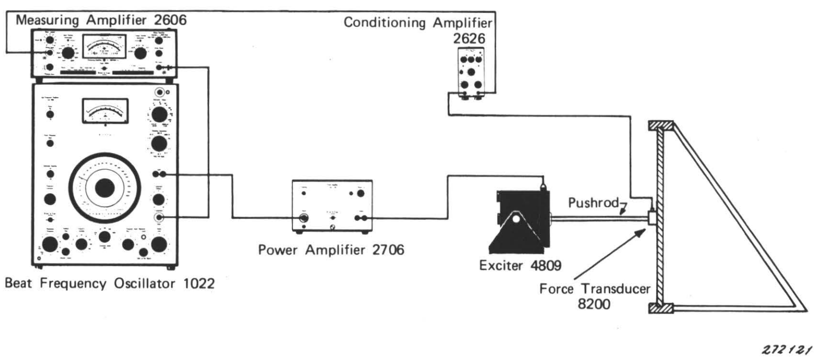


Fig.4.3. Force-controlled structural test

The Power Amplifier Type 2706 amplifies the signal from the Beat Frequency Oscillator Type 1022 and feeds it to the Exciter. The signal from the Force Transducer is boosted in the Conditioning Amplifier Type 2626 and fed to the compressor circuit of the Oscillator. In this way, the force level of the shaker system can be held constant throughout a frequency sweep regardless of table and specimen resonances, provided suitable compressor speeds and sweep speeds are selected.

The Force Transducer Type 8200 has a nominal charge sensitivity of 17.8 pC/lbf. (4 pC/N). While there are no direct reading force scales for the Measuring Amplifier, a proper choice of acceleration scales will accomplish the same purpose. The SA 0071 scale is for accelerometers with a sensitivity of 6-17 mV/g. Since the output of the Type 2626 is 10 mV/g once the sensitivity of the transducer is dialed in, the SA 0071 could be used to read Newtons or pounds instead of g.

5. SPECIFICATIONS

The following specifications apply when the Exciter Type 4809 is powered with the Power Amplifier Type 2706.

RATED FORCE:

Dynamic:	10 lb. (44.5 N), except as limited by displacement limits, as shown on Fig.3.2.
Acceleration Limit:	75 g (736 m/s^2)
Current Limit:	5 Amp. RMS
Displacement Limit:	0.315 in. (8 mm), peak-to-peak
Velocity Limit:	65 in/s (1.65 m/s), peak
Moving Element Dynamic Weight:	0.132 lb. (60 gm.)
Resonance Frequency Unloaded Table:	20 kHz
Stray Magnetic Field:	20×10^{-3} Weber/m^2 at table surface
Mechanical Fuse Inserts:	10–32 UNF center insert in 1.16 in. (29.5 mm) diameter table
Cross Motion:	less than 3% of the axial motion to 15 kHz
Dynamic Flexure Stiffness:	112.4 lb/in. (20 N/mm)
Dimensions:	Diameter 5.87 in. (149 mm) Height 5.63 in. (143 mm)

Weight:	18.3 lb. (8.3 kg)

ACCESSORIES SUPPLIED:

5 x YS 0811	10–32 UNF inserts
1 x QA 0029	Screw tap for 10–32 UNF thread
1 x QA 0061	Insert mounting tool
1 bottle QS 0003	Thread locking cement, LOCTITE screw lock

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

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

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

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

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

STRAIN MEASUREMENTS
Strain Gauge Apparatus
Multi-point Panels
Automatic Selectors

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

RECORDING
Level Recorders
Frequency Response Tracers
Tape Recorders

DIGITAL EQUIPMENT
Digital Encoder
Digital Clock
Computers
Tape Punchers
Tape Readers

BRÜEL & KJÆR

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

Orboe Print · Copenhagen · Denmark