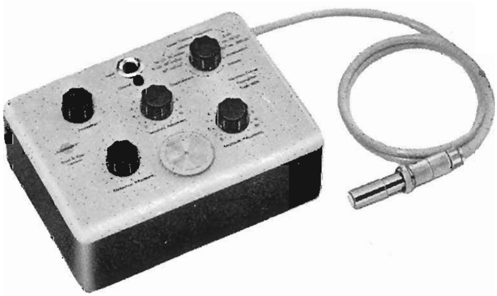
1606

INSTRUCTIONS AND APPLICATIONS

Vibration Pick-up Preamplifier Type 1606



An instrument designed for use in vibration measuring systems. It constitutes an essential link between the accelerometer and the measuring amplifier the high input impedance ensuring a low cut-off frequency of the accelerometer employed. The built-in integrating networks make the measurement of velocity and displacement possible and a "vibrating table" is provided for calibration of the measuring arrangement.

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Vibration Pick-up Preamplifier.

Type 1606

DECEMBER 1956

Contents.

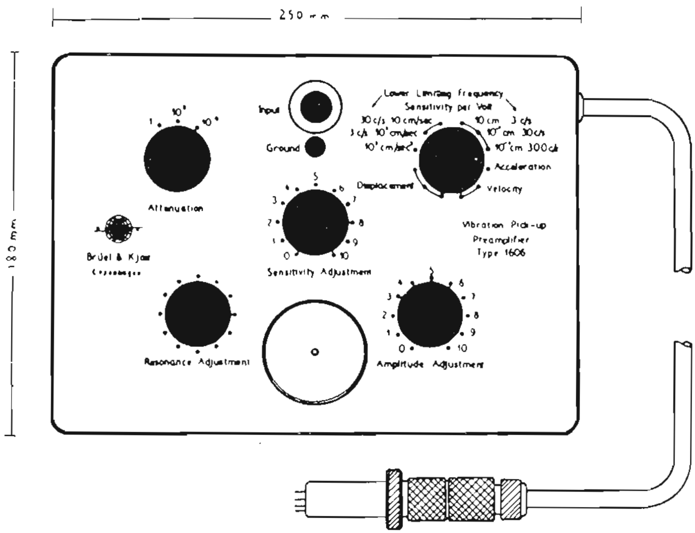
Description.

General.

The Vibration Pick-up Preamplifier Type 1606 is designed for use in vibration measuring systems, and constitutes an important link between the accelerometer e. g. Type 4328 or 4329, and the measuring amplifier, i. e. Frequency Analyzer Type 2105, Audio Frequency Spectrometer Type 2109 or Microphone Amplifier :Type 2602.

It consists of a two stage amplifier, a set of integrating networks and a "vibrating table".

The input impedance of the amplifier is high to ensure a low cut-off frequency of the accelerometer, and when the Accelerometer Type 4328 or 4329 is used for the measurement a cut-off frequency lower than 5 c/s is obtained.



Rig. 1. Drawing of the
Vibration Pick-up Preamplifier Type 1606.

Employing the integrating networks measurements of velocity and displacement are readily carried out.

Furthermore, the "vibrating table" enables the mechanical-electrical transducer and the measuring set-up to be calibrated at an acceleration peak level of 1 g* (1 g* = 981 cm sec^{-2}).

Both filament and plate voltages for the double-triode used in the circuit are supplied from the Analyzer or Amplifier employed as indicating instrument via a 7 core cable.

Fig. 1. shows a drawing of the Preamplifier.

Description of the Amplifying Circuit.

The two stage amplifying circuit contains a double triode and is supplied with a continuously variable sensitivity control. Furthermore a variable capacitive attenuator in the input circuit enables the input signal to be attenuated by 40 or 80 db in two steps.

The amplifier itself is supplied with negative feedback whereby the input impedance obtained is high.

By means of the continuously variable sensitivity control the amount of amplification can be varied. However, at the same time the amount of negative feed-back is also changed, which influences the input impedance to a certain extent. When the sensitivity control is in position "0" the input impedance will reach its highest value. The lowest value of the input impedance is obtained when the Preamplifier is adjusted for maximum amplification, and is then of the order of 40 MΩ.

A change in amplification i. e. a change in the setting of the sensitivity control also influences the high-frequency cut-off of the Preamplifier. (See fig. 2).

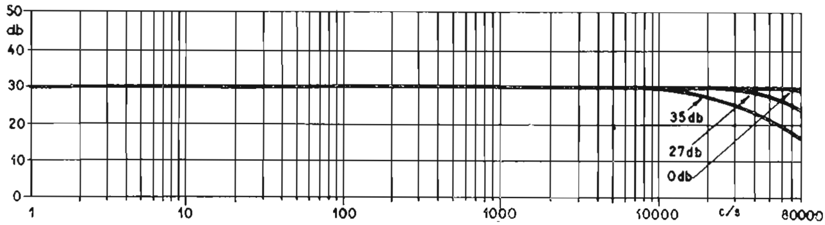


Fig. 2. Frequency response of the Preamplifier Type 1606. The dependency of the high frequency cut-off upon the setting of the sensitivity control is clearly noticed, and is indicated by the different amount of amplification obtained for various settings of the kontrol knob.

The max. amplification which can be achieved is of the order of 35—40 db, and is obtained with the capacitive attenuator in position "I", the sensitivity control in position "10" and the integration switch in position "Acceleration.".

Max. allowable output voltage is 10 volts when switched for acceleration measurements, and before the actual measurement is taken the output voltage from the Preamplifier should be checked. If the voltage exceeds the value of 10 volts the input signal to the Preamplifier should be attenuated by means of the capacitive input attenuator.

Because of the negative feedback employed in the circuit the low frequency characteristic of the Preamplifier will depend upon the capacity coupled to its input. An example of the low-frequency characteristic obtained when a low-impedance generator is connected to the input of the Preamplifier via a capacitor of approx. 700 pF is shown in fig. 3.

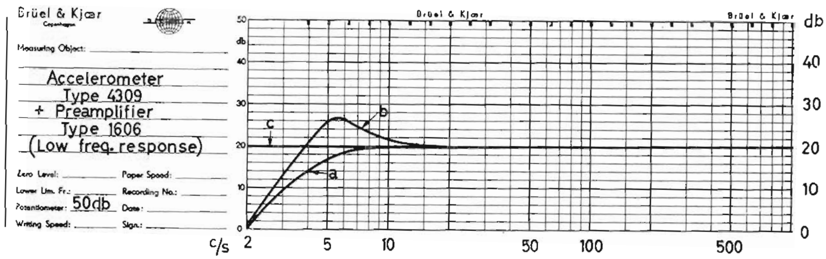


Fig. 3. Low frequency response of the Preamplifier Type 1606.

Curve a) Valid when the signal to be measured is fed to the input of the Preamplifier via a capacitor of approx. 700 pF and the sensitivity control of 1606 is in position max. (amplification approx. 40 db).

Curve b) Valid when the signal to be measured is fed to the input of the Preamplifier via a capacitor of approx. 700 pF and the sensitivity control of 1606 is in position min. (amplification 0 db).

Curce c) Valid for any setting of the sensitivity control when the signal to be measured is applied directly to the input of 1606 (700 pF capacitor omitted).

Description of the Integrating Networks.

The output from the amplifying circuit is fed to the integrating networks. Employing the different networks vibration measurements can be carried out as the measurement of velocity or displacement, when an accelerometer is connected to the input of the Preamplifier.

When the Preamplifier is switched for velocity measurements, the output from the Accelerometer is integrated once with respect to time. With the integration switch of the Preamplifier set to position "Displacement" a further integration with respect to time takes place, and the output from Type 1606 will now be proportional to the displacement of the vibrating body, at the point where the Accelerometer is mounted.

When periodical vibrations are considered, and one of the mechanical quantities acceleration, velocity or displacement is kept constant the magnitude of the remaining two quantities will depend upon the frequency of the vibrations. This is readily seen from the derivation of the respective quantity.

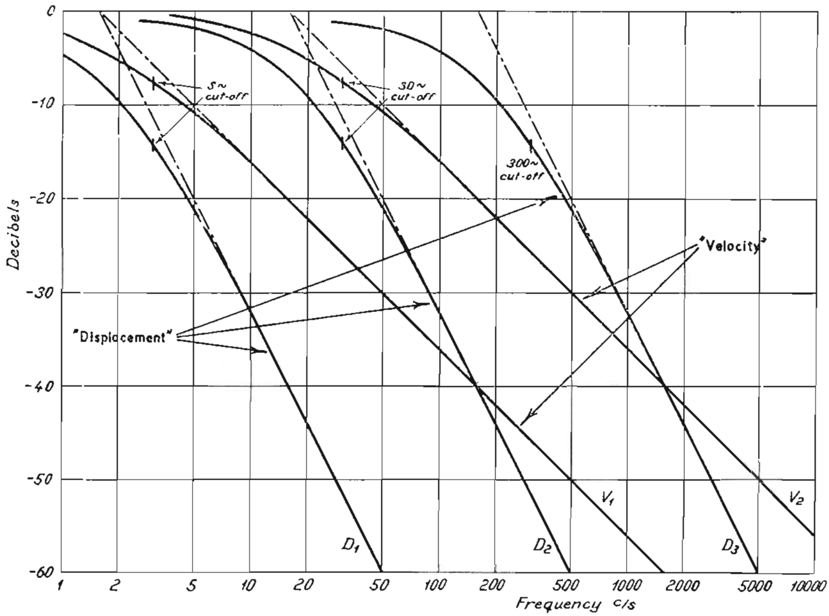


Fig. 4. Attenuation characteristics of the integrating networks.

If the acceleration is given as $a = A_0 \sin(\omega t)$ the velocity will be:

$$v = \int_0^t a dt = -\frac{A_0}{\omega} \cos(\omega t)$$

and the displacement:

$$d = \int_0^t\int_0^t a.\ dt.\ dt = \int_0^t v dt = -\frac{A_0}{\omega^2} \cdot \sin(\omega t)$$

Generally speaking, the magnitude of the electrical quantity measured on an indicating instrument will therefore be greatest if the measurement is carried out as a measurement of acceleration.

The electrical attenuation which takes place when velocity or displacement measurements are carried out employing an accelerometer in conjunction with the Preamplifier Type 1606 can be seen from the curves of fig. 4.

To better understand what actually happens the basic diagram of an integrating network should be considered, see fig. 5.

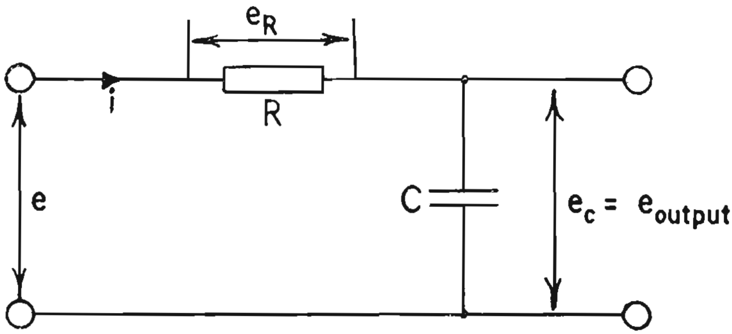


Fig. 5. Basic diagram of an integrating network.

The voltage across the capacitor is given by:

$$e_C = \frac{1}{C} \int i dt$$

and the total input voltage is:

$$e = e_R + e_C = Ri + \frac{1}{C} \int i dt$$

To obtain a correct integration the values of R and C must be chosen such that $e_R \gg e_C$, and consequently $i \cong \frac{e}{R}$ or

$$e_C \cong \frac{1}{RC} \int e . dt$$

at low frequencies a large value of R and C will therefore have to be employed, while at higher frequencies smaller values can be allowed. When the values of R and C in the integrating networks are shifted, the lower limiting frequency will also shift. This is clearly seen from the network characteristics shown in fig. 4, where the low-frequency cut-off is indicated on the curves.

A further integrating network, succeeding the first one and only loading this to a small extent, makes the measurement of deflection possible.

The different characteristics shown in fig. 4 are marked "Velocity" and "Displacement", and should only be employed without correction over the linear portion of the curves. Only in this range the requirement $e_R \gg e_C$ is fulfilled and the integration correct.

Application of the curves of fig. 4 to a numerical example might be illustrative:

a) Measurement of velocity:

If the deflection on the voltmeter is taken to be 100 % when the acceleration of a pure sinusoidal vibration with a frequency of 500 c/s is measured, the deflection on the meter, when the switch on the Preamplifier is set to position "Velocity—Lower Limiting Frequency 30 c/s" will be 3,16 %.

In case the switch is set to position "Velocity—Lower Limiting Frequency 3 c/s" the deflection on the indicating meter will only be 0,316 %.

b) Measurement of Displacement:

Setting the switch to position "Displacement—Lower Limiting Frequency 300 c/s", results in a meter deflection of approx. 10 %, and the indication will be slightly inaccurate due to the bending of the curve. Changing over to position "Displacement—Lower Limiting Frequency 30 c/s", a more accurate result is obtained, but the deflection on the meter will only be 0,1 % (An accurate reading can be obtained by increasing the sensitivity of the indicating instrument).

However, if the position "Displacement—Lower Limiting Frequency 3 c/s" is used the indication should be 0,001 %. and for moderate acceleration levels the noise and hum level might here cause serious errors in the measured results.

From the above discussion is seen that the vibration measurement should, also from a measuring point of view, be carried out as measurements of acceleration. This is especially true at higher frequencies.

When measurements of the velocity or deflection are required care should be taken regarding the position of the integration switch on the Preamplifier.

From the foregoing is readily seen that the highest permissable Lower Limiting Frequency-position of the switch will give the most satisfactory result.

The time constants for the different networks, RC, is chosen be 10^{-1}, 10^{-2} and 10^{-3}, which can be seen from the curves shown in fig. 4.

Description of the Vibrating Table.

A sketch of the vibrating table is shown in fig. 6, and the principle of operation is extremely simple. The moving element is suspended on a stretched metal strip, and the vibrator is exited by means of a small electromagnetic system fed from the mains power supply.

By varying the tension of the metal strip the vibrations of the table can be adjusted to resonate with the frequency of the power supply voltage. In this way almost pure sinusoidal vibrations are obtained.

The amplitude of the vibrations can be varied by varying the voltage across the coil of the electromagnetic exciter. Normally an acceleration level of 1 g* is used fo rthe calibration of the accelerometers, see page 12.

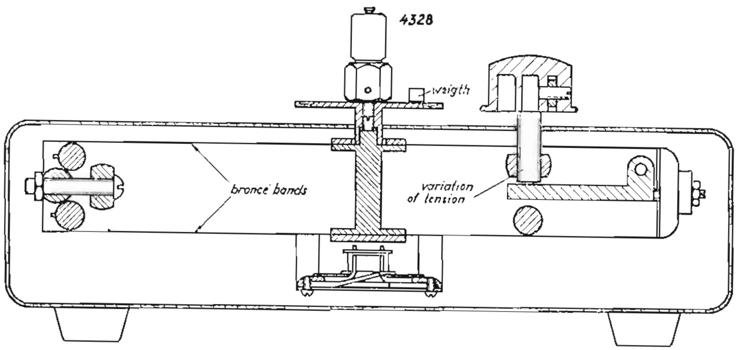


Fig. 6. Sketch of the "vibrating table" system.

Operation.

Measuring Arrangement.

The Preamplifier should be used in connection with one of the following indicating instruments:

1) Audio Frequency Spectrometer Type 2109
2) Frequency Analyzer Type 2105
3) Microphone Amplifier Type 2602.

A block diagram of the required measuring arrangement is shown in fig. 7.

When a written record of the measurements is desired the above mentioned instruments can be connected to the Level Recorder Type 2304.

A great advantage which is gained when the Spectrometer Type 2109 is employed in conjunction with the Level Recorder Type 2304, Speed Multiplier Type 3004 and Flexible Shaft Type 3003 is that an analysis of the vibrations considered can be carried out automatically on pre-printed, frequency calibrated recording paper.

The combination Spectrometer + Level Recorder has been found so useful that a unit, the Audio Frequency Spectrum Recorder Type 2311, consisting of these two instruments mechanically coupled together, is made available. See also manual for the Type 4308 and 4309 and Technical Review no. 4-1956.

It is furthermore possible to use the Microphone Amplifier Type 2601 in conjunction with the Level Recorder Type 2304 or the A.F. Voltmeters Type 2407 or 2408 as indicating instruments. However, the Microphone Amplifier Type 2601 can not be used separately because this instrument does not contain an indicating meter.

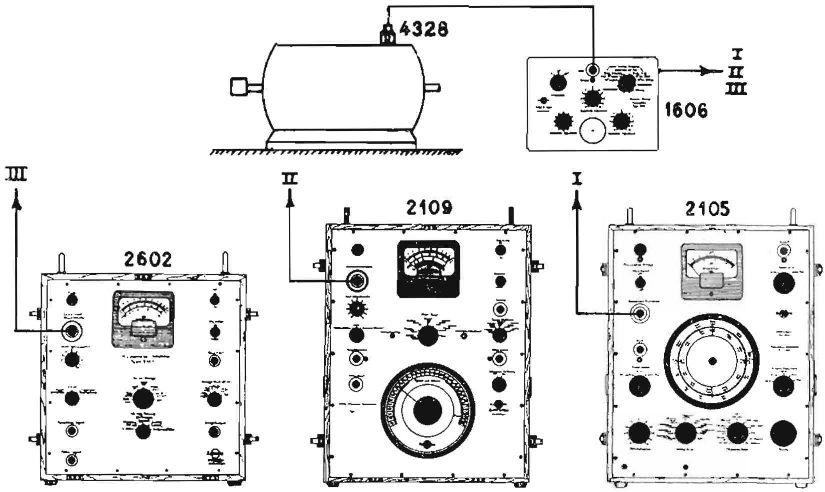


Fig. 7. Complete measuring arrangements for the measurement of mechanical vibrations.

There are two possible methods of connecting the instruments:

1) *The measuring arrangement is placed in the immediate vicinity of the measuring point.*

In this case the measuring cables supplied with the instrument when delivered from the factory will enable proper connection of the measuring set-up to be made.

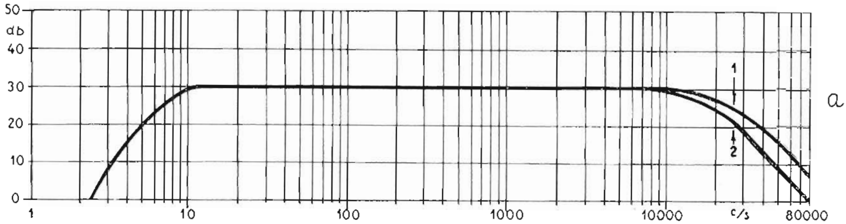
The seven-poled plug at the end of the measuring cable from the Preamplifier should be connected to the input marked "Condenser Microphone" on the front panel of Type 2105, 2109 or 2602.

The input switch of the indicating instrument should likewise be set to position "Condenser Microphone".

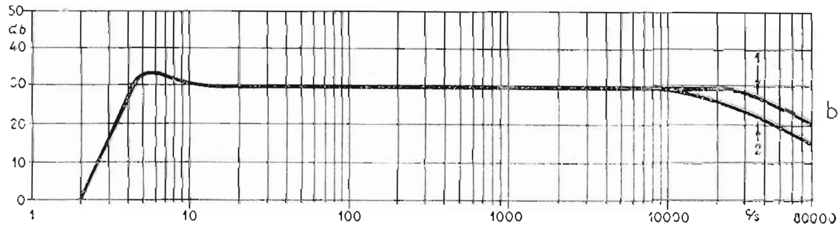
Typical frequency characteristics of the measuring arrangement when the above conditions are fulfilled are shown in fig. 8.

2) *The measuring arrangement is placed some distance away from the measuring point.*

The seven-cored measuring cable from the Preamplifier should then be extended by means of the Extension Cable Type AO 0040 (length 3 m) or Type AO 0041 (length 10 m). Several lengths of Extension Cables may be coupled together.



Typical frequency response of 1606 + 2105



Typical frequency response of 1606 + 2109 [1606+2602]

Fig. 8. Typical frequency response of the electronic measuring device:

a) The measuring equipment consists of Preamplifier 1606 + Frequency Analyzer 2105.
The curve marked 1 is taken with the sensitivity control of Type 1606 in position minimum (amplification of 1606 = 0); the curve marked 2 is valid when the sensitivity control of 1606 is in position maximum, utilizing the full amplification of the instrument.

b) The measuring equipment consists of Preamplifier 1606 + Spectrometer 2109 (or Preamplifier 1606 + Microphone Amplifier 2602). The meaning af the curves 1 and 2, respectively, is explained under a).

The measuring cable connecting the Accelerometer to the Preamplifier should if possible not be extended.

The effect upon the frequency response of measuring set-up produced by employing several lengths of the Extension Cable Type AO 0041 can be seen from fig. 9 a and b.

Calibration of the Measuring System.

To calibrate the measuring arrangement the "vibrating table" should be used. When the set-up is connected as described under "Measuring Arrangement", the Accelerometer should be screwed onto the "table" by means of a 1/8″ Whitworth screw, and the Preamplifier connected to the mains.

The knob on the Preamplifier marked "Attenuation" is set to position "1".

The knob marked "Sensitivity Adjustment" is set to position "0", and the integration switch to position "Acceleration".

The Analyzer or Microphone Amplifier employed as indicating instrument is switched to "Linear" and set to its 100 mV range.

The knob marked "Resonance Adjustment" is now turned until maximum deflection is obtained on the instrument meter.

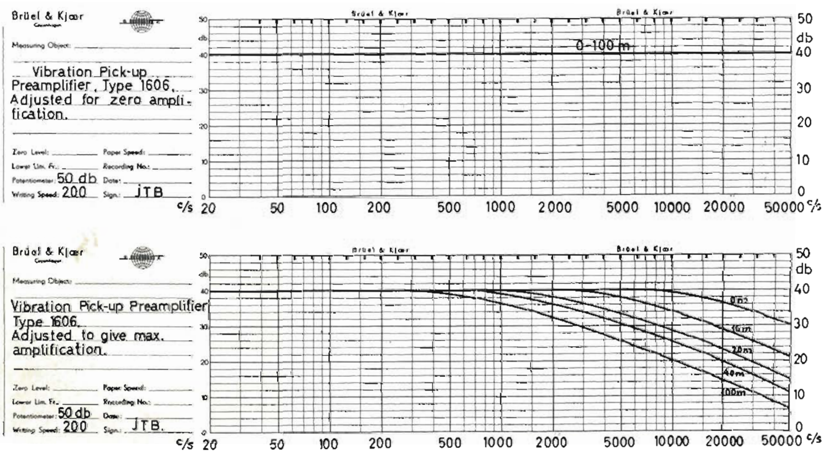


Fig. 9.

a) Frequency characteristic of the Accelerometer + Preamplifier + several lengths of Extension Cable Type AO 0041. Preamplifier Type 1606 adjusted to give 0 db amplification.

b) Frequency characteristic of the Accelerometer + Preamplifier + several lengths of Extension Cable Type AO 0041. Preamplifier Type 1606 adjusted to give max. amplification (approx. 40 db).

A small nut should then be placed on the "vibrating table" and the knob marked "Amplitude Adjustment" turned until the nut *just starts rattling* on the table. The acceleration peak value of the vibrations now equals that of gravity. In cases where this value of acceleration cannot be obtained, even when the knob "Amplitude Adjustment" is set to maximum, the Preamplifier Type 1606 should be placed on a soft rubber plate, whereby the amplitude of the vibrations is increased.

The Analyzer or Microphone Amplifier is then switched to its 1 volt range, and the knob marked "Sensitivity Adjustment" on the Preamplifier turned until the meter shows a deflection of 0,7 volts ($\frac{g^*}{\sqrt{2}}$).

The measuring arrangement is now calibrated to indicate the r.m.s. value of the vibrations, and a value of 1 volt measured on the indicating instrument corresponds to an acceleration of 1000 cm sec^{-2} r.m.s.

It is also possible to adjust the set-up to indicate the average or the peak value of the vibrations considered.

In these cases the knob marked "Sensitivity Adjustment" should be turned until the following deflection is obtained on the instrument meter:

1) *Average value:* Meter indication 0,63 volts ($2 \cdot \frac{g^*}{\pi}$).

2) *Peak value:* Meter indication 0.981 volt (g^*).

The Accelerometer should then be unscrewed from the "vibrating table", and the connection of the Preamplifier to the mains volltage broken, whereafter the actual measurements can start.

Measurement of Acceleration.

The Accelerometer is mounted on the object to be tested. The adjustment of the Preamplifier should not be changed from the one made during the calibration procedure.

The setting of the knob marked "Sensitivity Adjustment" must *under no circumstances* be changed. A shift in the setting of this knob will invalidate the calibration.

With the Analyzer or Microphone Amplifier set to "linear" a check should be made that the output voltage from the Preamplifier does not exceed 10 volts.

If the indicating instrument gives an indication greater than 10 volts the knob on the Preamplifier marked "Attenuation" should be set to position "10^2" or "10^4" depending upon the magnitude of the voltage measured.

The voltage measured on the Analyzer or Microphone Amplifier should never exceed 10 volts.

Measurements and analysis of the acceleration of the vibrations considered can now be carried out as the measurement of voltage, remembering that 1 volt corresponds to an acceleration value of 1000 cm sec^{-2}, when the knob on the Preamplifier marked "Attenuation" is in position "1".

Measurement of Velocity.

The integration switch is set to "Velocity". However, two different positions of the switch may be used:

1) "Velocity-Lower Limiting Frequency 3 c/s".

This position should be used when the frequency of the vibrations under consideration is lower than 30 c/s.

2) *"Velocity-Lower Frequency 30 c/s"*.

When the frequency of the vibrations considered is higher than 30 c/s the integration switch should be set to "Velocity-Lower Limiting Frequency 30 c/s".

The velocity in cm sec^{-1} corresponding to a meter indication of the measuring amplifier of 1 volt is marked on the Switch "Attenuation" knob on the Preamplifier in position "1").

Measurement of Displacement.

Set the integration switch to "Displacement". The three different positions marked "Displacement" should be used as follows:

1) *"Displacement-Lower Limiting Frequency 3 c/s"*.

To be used when the frequency of the vibrations being measured is lower than 30 c/s.

2) *"Displacement-Lower Limiting Frequency 30 c/s"*.

To be used when measurements are carried out on vibrations the frequency of which lays between 3 c/s and 30 c/s.

3) *"Displacement-Lower Limiting Frequency 300 c/s"*.

To be used when frequency of the vibrations under consideration is greater than 300 c/s.

The displacement values marked on the switch correspond to a meter indication on the measuring amplifier of 1 volt, when the knob marked "Attenuation" on the Preamplifier is in position "1".

When the measuring set-up has been calibrated in the way described under "Calibration of the Measuring System" the measurements actually consists of measuring a voltage by means of one of the instruments Type 2109, 2105 or 2602. For further details the manuals on these instruments should thus be considered.

Furthermore reference should be made to the manual on the Accelerometer Sets Type 4308 and 4309, as well as Technical Review no. 4-1956.

Specification.

Amplification: Max. voltage amplification when switched for the measurement of acceleration is approx. 40 db.

Input Impedance: Greater than 40 $M\Omega$ for any position of the sensitivity control.

Input Attenuator: An input attenuation in 2 steps of 40 db is provided to avoid overloading of the Preamplifier. With the Integration Switch in position "Acceleration" a maximum output voltage of 10 volts is allowed.

Frequency Range: Somewhat dependent on the position of the sensitivity control: When adjusted for 0 db amplification the frequency range is from 1 c/s to 100 000 c/s; with max. amplification from 1 c/s to approx. 20 000 c/s.

Hum and Noise Level: About 5 μV.

Integration Switch: Allows selection of Acceleration, Velocity or Displacement measurements. The values indicated around the switch correspond to full scale deflection on the meter of the Analyzers Type 2105 or 2109 when the measuring arrangement is calibrated as stated in the instruction manual. By changing the position of the input attenuator of the Preamplifier or Analyzer the sensitivity range of the set-up can be varied.

Measuring Ranges: Depending on the sensitivity and frequency response of the Vibration Pick-up employed. Typical measuring ranges are:

Accelerometer Type		4303	4305	4328	4329	
Acceleration	cm/sec^2	$0.2—10^5$	$0.2—10^5$	$0.25—10^6$	$1—2\times10^6$	
	Lower Limiting Freq.	2 c/s	2 c/s	5 c/s	5 c/s	Position of Integration Switch: "Lower Limiting Freq."
Velocity (Max. Sensitivity)	cm/sec^2	0.001	0.001	0.0025	0.01	3 c/s
	cm/sec.	0.0005	0.0005	0.0013	0.005	30 c/s
Displacement (Max. Sensitivity)	μ	0.5	0.05	0.13	0.5	3 c/s
	μ	0.01	0.01	0.025	0.1	30 c/s
	μ	0.002	0.002	0.005	0.02	300 c/s
High Frequency Limit of Measuring Range		Approx. 1.500 c/s	Approx. 3 000 c/s	Approx. 20 000 c/s	Approx. 30 000 c/s	

1 $\mu = 40$ μ inches $= 40 \times 10^{-6}$ inches.

Calibration Disc: This is a mains-driven resonance system suspended on a metal strip, the tension of which can be mechanically regulated by the knob marked "Resonance Adjustment". By employing the control knob marked "Amplitude Adjustment" the acceleration of the vibrating disc can be adjusted to equal the acceleration of gravity (981 cm/sec^2).

This acceleration value is then used for calibration of the measuring arrangement.

Power Supply: 115—127—150—220 Volts a. c. 50 or 60 cycles.

DIMENSION excl. dials and knobs	HEIGHT	WIDTH	DEPTH
Centimetres	10.5	25	18
Inches	4	10	7
WEIGHT	3.9 kg	9 lbs.	

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