Brüel & Kjær

Technical Review

Teletechnical, Acoustical and Vibrational Research

NEW ACCELEROMETERS

No. 2 April 1955

Reprint: AUGUST 1960

MODERN ACCELEROMETERS

by

Per V. Brüel. D. Sc.)*

Piezo-electric elements are particularly well suited to the construction of vibration pick-ups, the voltages from which are proportional to the acceleration of the vibrations in question[1][2]. Such a vibration pick-up is called an accelerometer (German: Beschleunigungsgeber). Accelerometers with Rochelle salt as the sensitive element were commercially produced more than 30 years ago. Fig. 1 shows some typical examples.

Rochelle salt has a large piezo-electric effect, so that these accelerometers have as a rule high sensitivity. Another great advantage of Rochelle salt is that it is possible to construct the crystal elements with a relatively small internal impedance, so that the accelerometer can stand being loaded by the capacity from quite a long cable between the accelerometer and a subsequent amplifier, and the input impedance of the amplifier need not be extraordinarily high in order to obtain frequency linearity even at the lower frequencies.

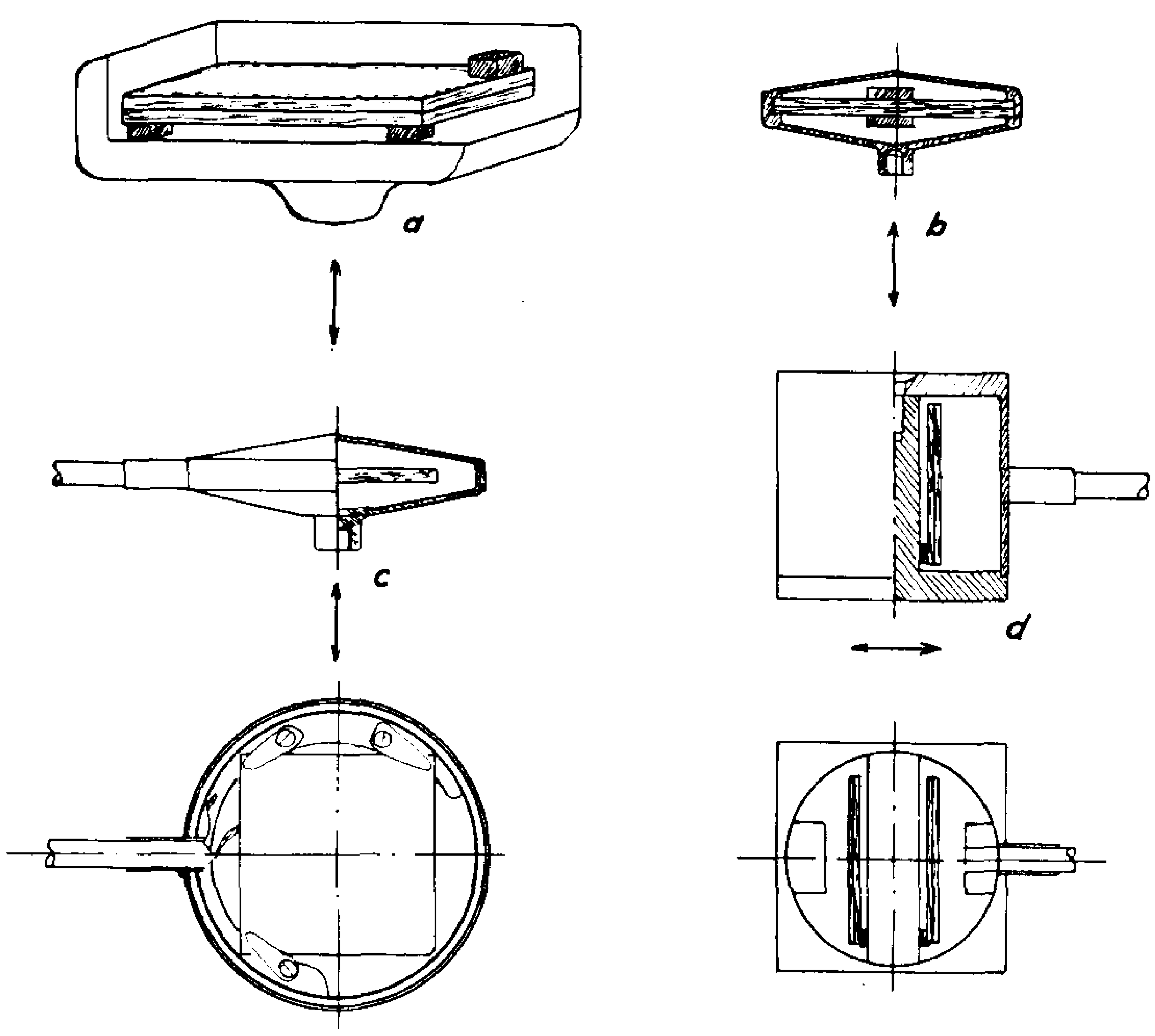

Fig. 1. Accelerometers with Rochelle salt or ADP as the sensitive element.
a) Early American type fastened at three points,
b) Rod type fixed at terminals with weight in center,
c) Modern light weight accelerometer fixed at three corners without extra mass at the fourth one,
d) The cubic form with two elements for torsion balancing is the design Dr. Oberst.

*) Lecture held in Göttingen, Germany, on the 21st April 1955 during the International Congres for "Sound and Vibration in Solids".

On the condition that the internal capacity of the accelerometer is relatively great, it is possible, within a limited frequency range, to integrate electrically the voltages produced, both once and twice, and thus obtain output voltages which are proportional respectively to the velocity and deflection amplitudes. Fig. 2 shows such a system, which can be used for velocities in the frequency range 30—2.000 c/s, and for amplitudes in the range 50—2.000 c/s. The upper frequency limit is imposed by the lowest resonant frequency of the accelerometer, and the lower limit by the time constant of the integrating network,

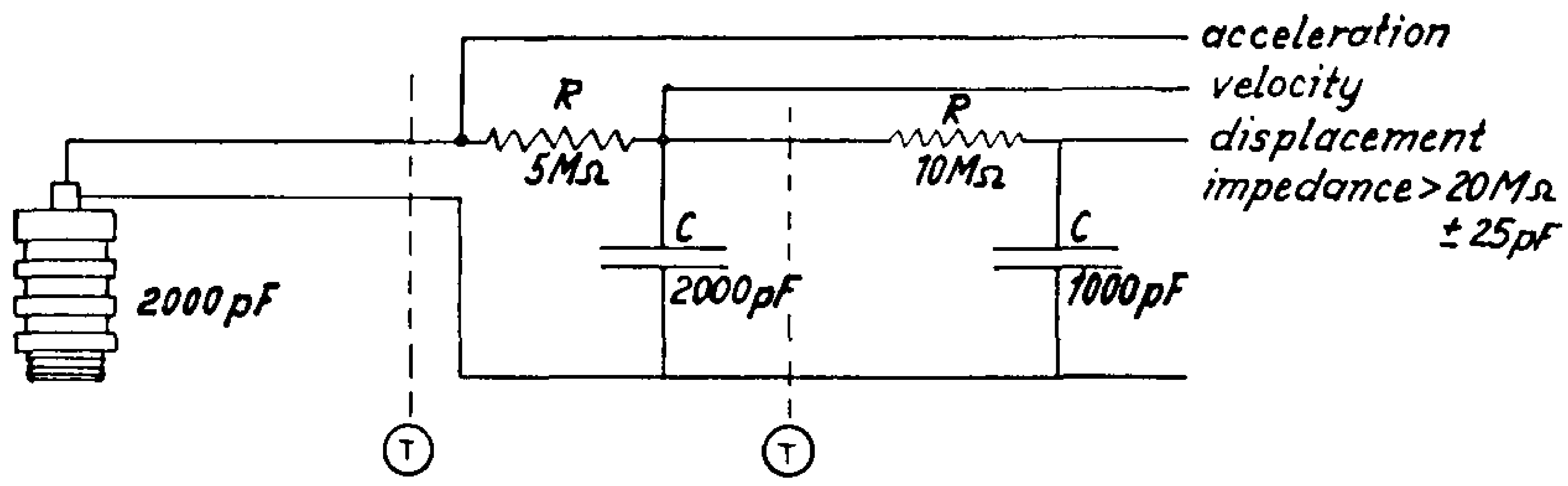

Fig. 2

Fig. 2. Integration Network for integration of voltages proportional to the vibrations' acceleration in order to derive voltages representing velocity and displacement amplitudes.

If a long time constant is chosen, the output voltages will be small, which reduces the total sensitivity of the system. Another practical difficulty with the sysem shown is to ensure that each unit subsequent upon the accelerometer shall not load the previous unit to any mentionable degree. The numerical values shown on fig. 2 are a compromise, which will do for a limited frequency range. A great improvement is obtained by inserting an amplifier tube or a cathode follower beween the individual steps at the points marked T, whereby more practical impedances can be obtained for the integration networks, while at the same time more exact measurements can be made.

The usual objections to Rochelle salt elements are, that the material becomes spoiled when it is exposed to

1) Temperatures above 50—55° C for short periods of time.
2) Damp air (over 85 % relative humidity) for other than very short periods.
3) Dry air (under 30 % relative humidity) for extended periods.
4) Tensile or compressive loads of over 150 kg/cm^2.
5) Furthermore sensitivity and in particular capacity are dependent on temperature.

The first of the above disadvantages imposes severe limitations on the use of Rochelle salt. For example, a Rochelle salt accelerometer has only to lie in a sun-heated automobile on a summer's day, to have its sensitivity considerably reduced, or to be completely spoiled.

The second and third disadvantages have recently been overcome to some extent by adapting an encapsulating method, employing aluminium or copper foil, to these elements whereby an effective protection against damp and dryness is obtained (see fig. 3).

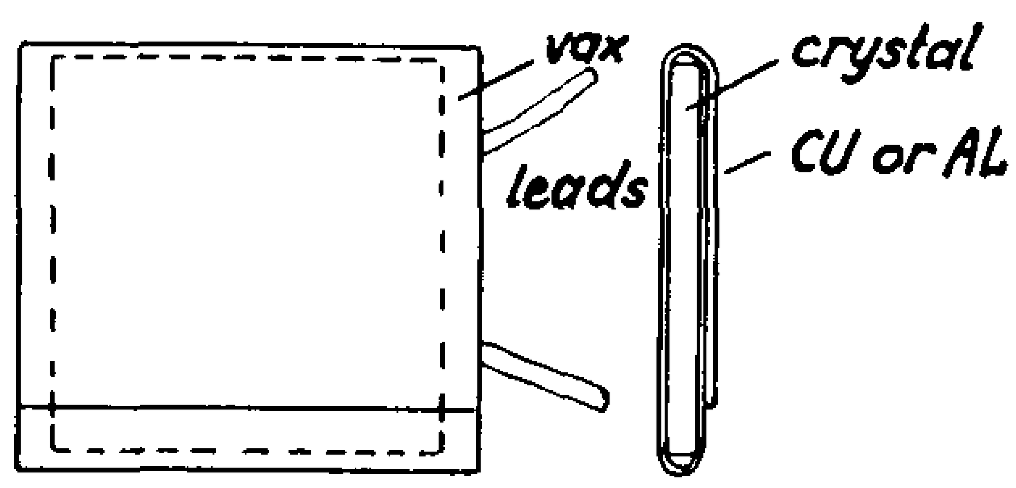

Fig. 3

Fig. 3. Modern sealed type of Rochelle salt element protected from humidity and dessication. Courtesy Brush Electronics Co.

It is very unfortunate that Rochelle salt is mechanically weak, as it is thus not possible for accelerometer applications to increase the accelerometer sensitivity by increasing the effective mass. It can be said that the suitability of a material for use in an accelerometer is the product of its mechanical strength, piezo-electric effect and dielectric constant. This product is indicated in table 1.

Another piezo-electric material, ammonium dihydrogen phosphate (ADP), has also been used in accelerometers[3]). ADP withstands temperatures up to 120° C, and the temperature-independence of its sensitivity is also better than is the case with Rochelle salt, but both the piezo-electric effect and, in

Property	Unit	Material			
		Rochelle salt	ADP	Quartz	Barium Titanate
Piezoelectric effect P	volt/cm / dyne	18×10^{-5}	17×10^{-5}	5×10^{-5}	1×10^{-5}
Density	g/cm³	1.77	1.78	2.6	5.5
Max. safe temp.	degree C	45	125	550	110
Max. safe humidity	%	85	94	100	100
Min. safe humidity	%	30	0	0	0
Dielectric constant ε		350	15	4.5	1200
Breaking stress B	dyne/cm²	1.5×10^{8}	2×10^{8}	10×10^{8}	8×10^{8}
Effectivity factor $P\times B\times\varepsilon$	volt/cm	9.5×10^{6}	0.5×10^{6}	0.23×10^{6}	9.6×10^{6}

Table 1. Material constants for different piezo-electric materials.

particular, the internal capacity, are much reduced. With ADP accelerometers, therefore, one must have preamplifiers in the immediate vicinity of the accelerometer.

More recently, an electrically polarized, ceramic material, mainly prepared from Barium Titanate, has been much used for accelerometers. Properly prepared and polarized, Barium Titanate combines a uniformly high piezo-electric effect with large capacity and electrical stability, as well as great mechanical strength. Table 1 shows the most important constants of the more commonly used piezo-electric materials for accelerometers.

Its great strength when exposed to pressure can be made use of when

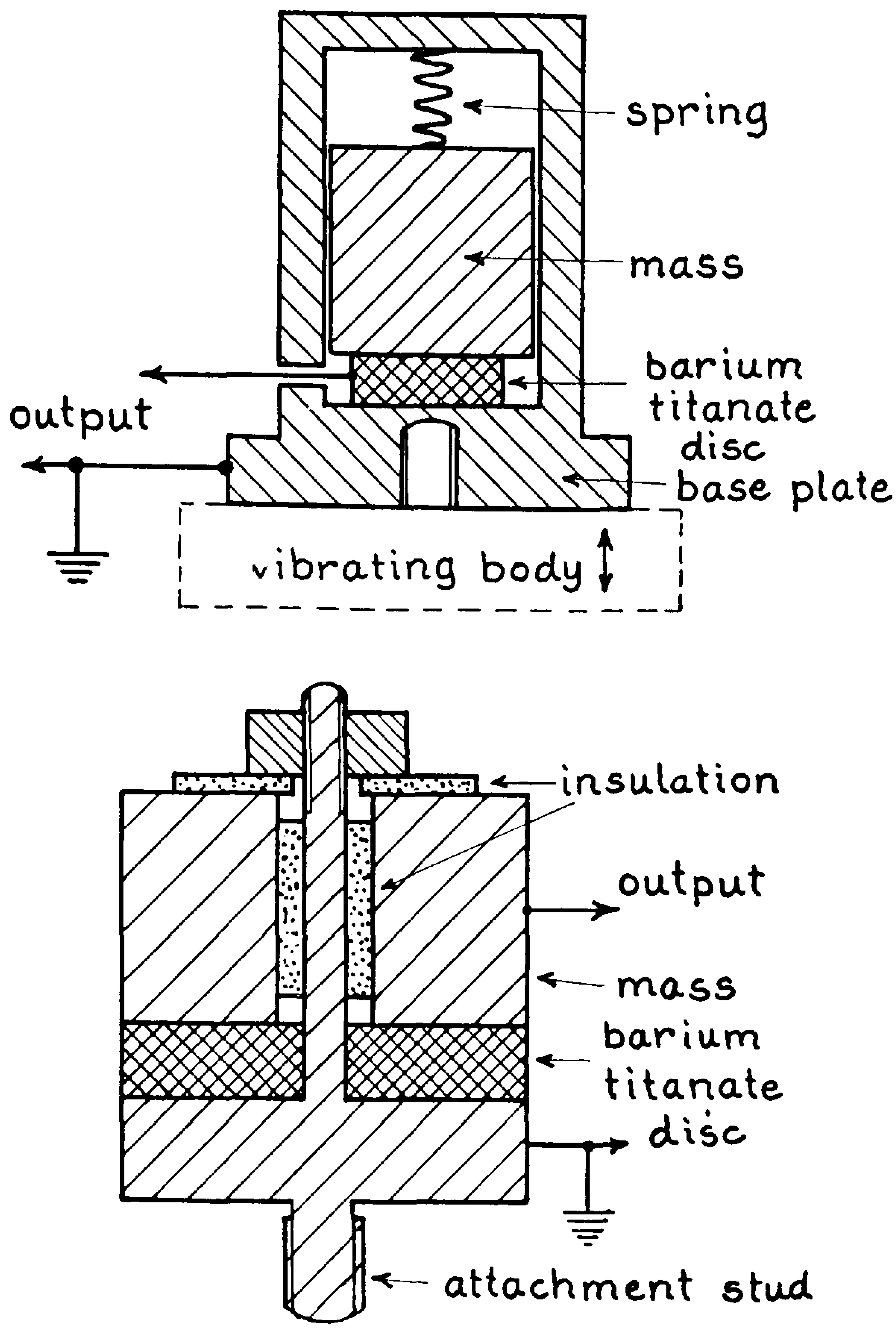

Fig. 4. Barium Titanate Accelerometer designed in the United States. Above left a commercial type, below a model designed by National Bureau of Standards.

constructing accelerometers by allowing the weight to press on a relatively small piezo-electric element, so that this element is exposed to quite considerable pressure variations when experiencing accelerations.

With suitable construction it is possible in practice to make a Barium Titanate accelerometer which is either more sensitive than a Rochelle salt unit or the useful frequency range may be extended by arranging that the resonant frequency occurs high up in the frequency spectrum.

Fig. 4 left, shows an accelerometer which is commercially produced in U. S. A. and which is widely used. Two Barium Titanate discs are used in its construction[4]).

The sensitivity increases in proportion to the thickness of the discs, and the mass of the spring-loaded weight placed above the discs. The spring-loading should always be somewhat greater than the product of the mass of the weight and the greatest acceleration required to be measured. The force of the spring is in practice 5—50 kg. If the discs chosen are too thick, the capacity will often be too small. The practical thickness values are 0.5 to 2 mm, whereby it is possible to obtain capacities from 3000 to 500 pF.

To the right in fig. 4 can be seen one of the very simple models developed by the National Bureau of Standards, with a great advantage over the model shown on the left, in that it is quite light, for it lacks the protective housing. In a manner of speaking, all the material is "active", in contrast to the one on the left, which is quite heavy in comparison for its sensitivity and capacity[5])[6])[7]). On the other hand the model shown on the left has a really solid base plate, which is easy to secure effectively to the measuring object. The connections are well fixed mechanically, and the ceramic plates are protected against damp, which would otherwise cause leakage between the electrodes, resulting in too poor a sensitivity for use at low frequencies.

Brüel & Kjær have recently developed a new accelerometer, produced in two models. Fig. 5 shows some drawings of the new instrument.*)

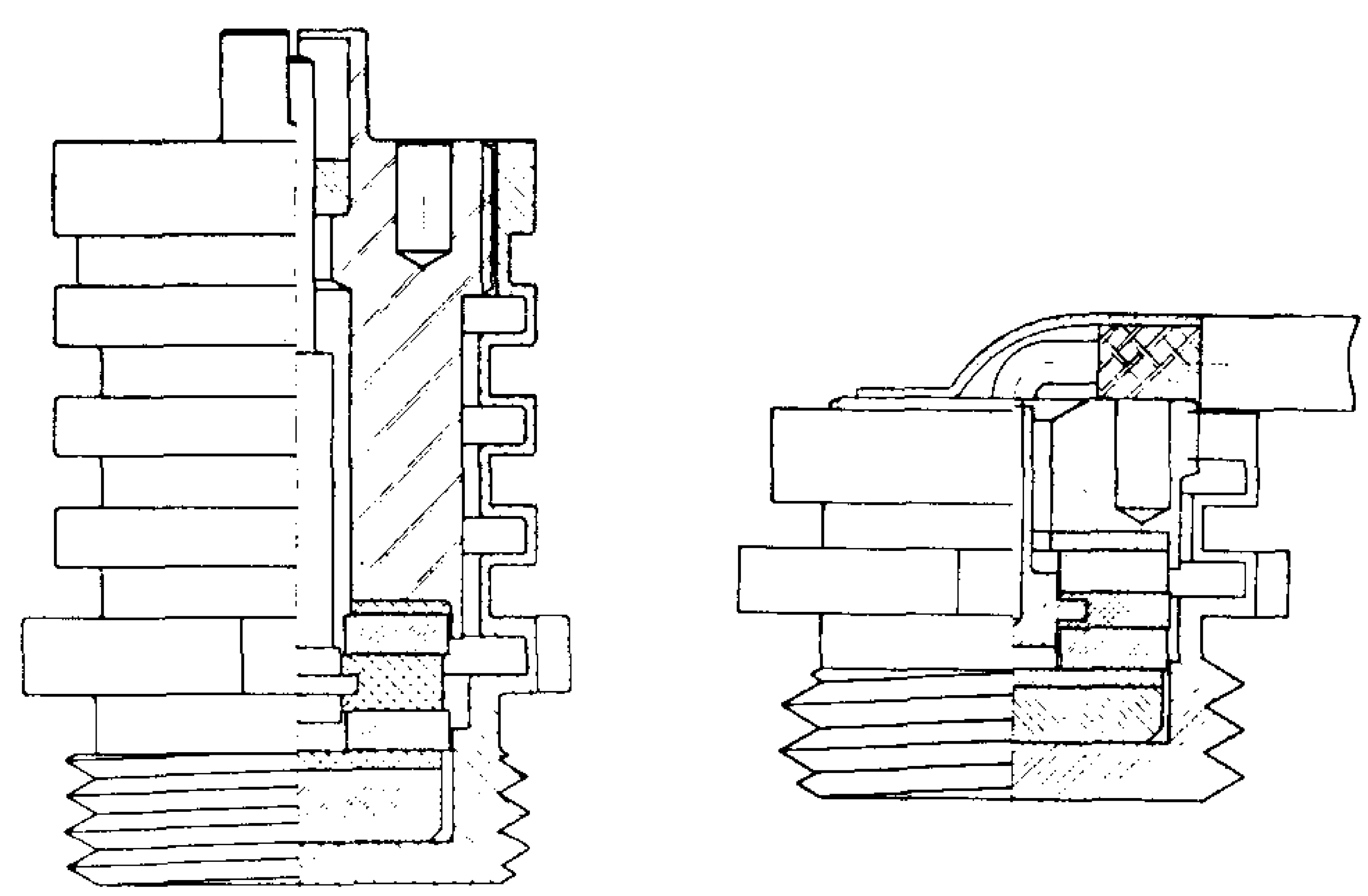

Fig. 5. The new accelerometers type 4306 and 4307.

*) Both type 4306 and 4307 are now in production.

The most characteristic feature is that the "casing" has a double function, serving both as a protection and as a spring, which gives the necessary static pressure on the ceramic discs. In the large model the connection of the cables with the accelerometer is made by means of a light miniature plug placed in the axis of symmetry of the accelerometer.

The contact between weight and spring takes place by means of a screw-thread, so that the spring pressure can be adjusted by screwing the weight

Fig. 6. Photograph of accelerometer 4306 with normal accessories in a case together with a close up photo of both models together.

nearer to or further from the Barium Titanate discs. The dimensions and other characteristics can be seen in table 2.

Table 2.

Accelerometer type	4306	4307
Sensitivity in mV/g g = acceleration of gravity	appr. 20	appr. 6
Capacity in pF	900	900
Weight in grs.	16	7
Resonance frequency in kc/s	appr. 25—30	appr. 45
Usable frequency range in c/s	2—15.000 - 20.000	2—28.000
Max. acceleration to be allowed, multiples of g (×981) cm/sec^2	2.000	5.000
Smallest leakage resistance s in ohms	10^{11}	10^{11}
Smallest acceleration to be measured with the combination Preamplifier 1606 — Spectrometer 2109 (or Analyzer 2105) cm/sec^2	0.25	1
Damping for transverse vibrations	min. 25 db	min. 30 db
Greatest diameter mm	15	15
Height mm	20	10

One of the greatest difficulties associated with Barium Titanate accelerometer manufacture is the production of suitably flat surfaces on both the ceramic disc and on the faces which are in contact with the disc, i. e. the bottom of the accelerometer, and the contact surface of the weight. Even quite small irregularities result in the resonance frequency being considerably lower than necessary. If the irregularities are great, the discs will actually crack. As the ceramic discs are very hard they cannot be expected to take up the unavoidable microscopic irregularities; it is therefore advisable to apply a thin layer of lead or similar material to those surfaces which are in immediate contact with the discs. It is impractical merely to use washers in the construction because of the thin air layers which would exist between contact surfaces. Even though the parts are tightly forced together, there will arise a little spring effect from each "air-layer", which will reduce the resonance of the system unnecessarily. The soft material should therefore be fused to the metal parts, so that the number of "air-layers" is halved.

The use of lead as a packing material has the further advantage that a considerable damping of the system is introduced, so that the resonance peaks are not pronounced, which is of significance when measurements are made of impacts and other transient phenomena.

In the small accelerometer 4307 everything has been done to make it effective at high frequencies. Thus, the height is small in relation to the diameter, in order to prevent transverse resonances at frequencies lower than those which give the first resonance in the longitudinal direction. As the effective mass of 4307 is small, the influence of the terminal plug will be relatively great, so that in the small model the wires are fastened directly to the accelerometer.

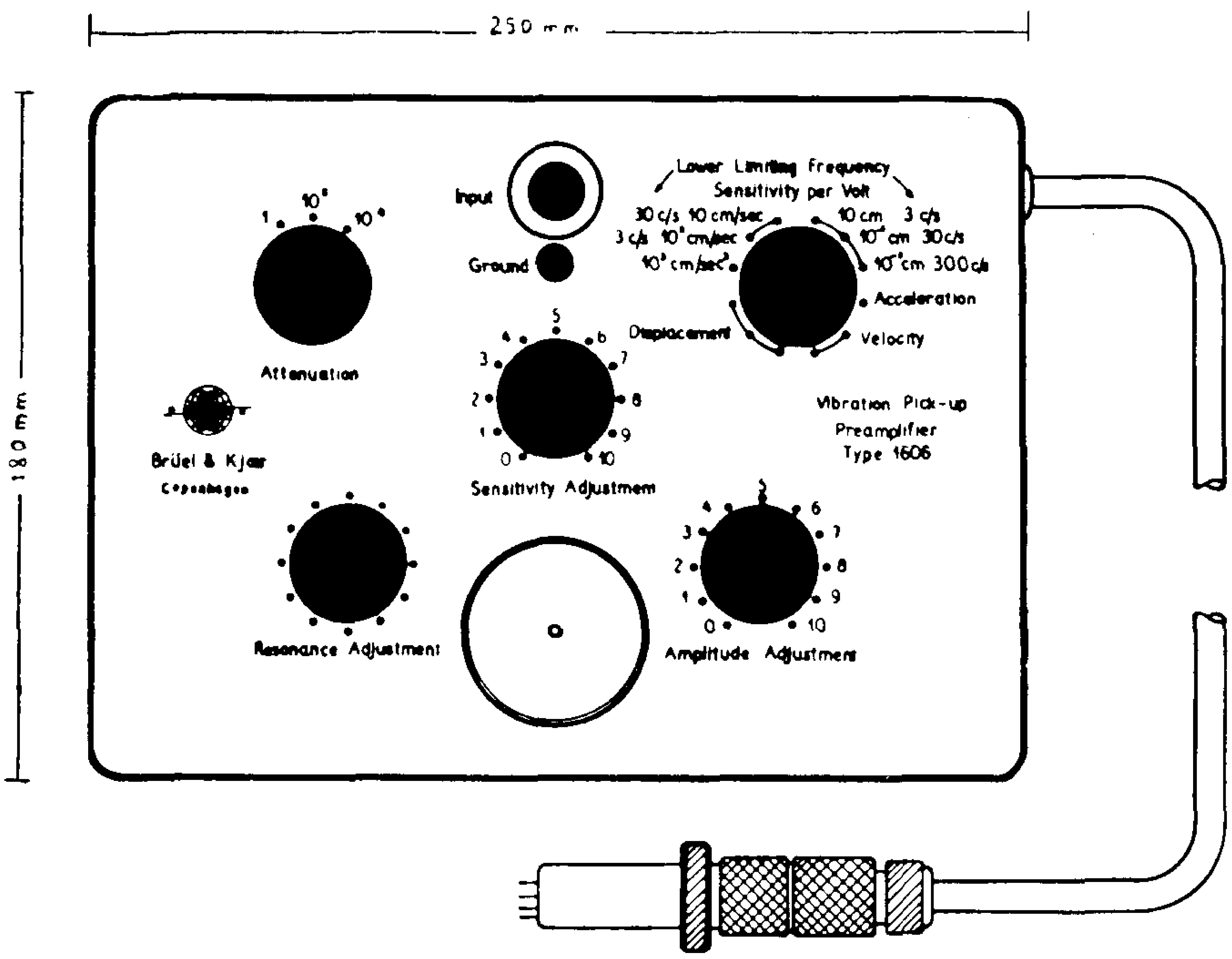

Fig. 7. Drawing of Integration- and Adjustment Apparatus 1606 for accelerometers and vibration pick-ups.

The accelerometers shown are often used together with a specially developed pre-amplifier, which is combined with the integration filters and the adjustment unit. The apparatus, which is shown in fig. 7, is intended for use together with one of the analyzers type 2105 or 2109, or microphone amplifiers 2601 or 2602. Fig. 8 shows a photograph of the pre-amplifier.

It comprises a two stage preamplifier preceded by a capacitive attenuator of 40 and 80 db and followed by a combination of integrating networks for the measurements of acceleration, velocity and displacement. Both filament and plate voltages for the double triode used in the circuit are supplied through a 7 core cable from the analyzer or amplifier employed. Furthermore, a mains-driven sinusoidally oscillating disc makes it possible to calibrate the combination of pick-up and preamplifier so as to give full deflection on the analyzer's meter scale for the values of acceleration, velocity and

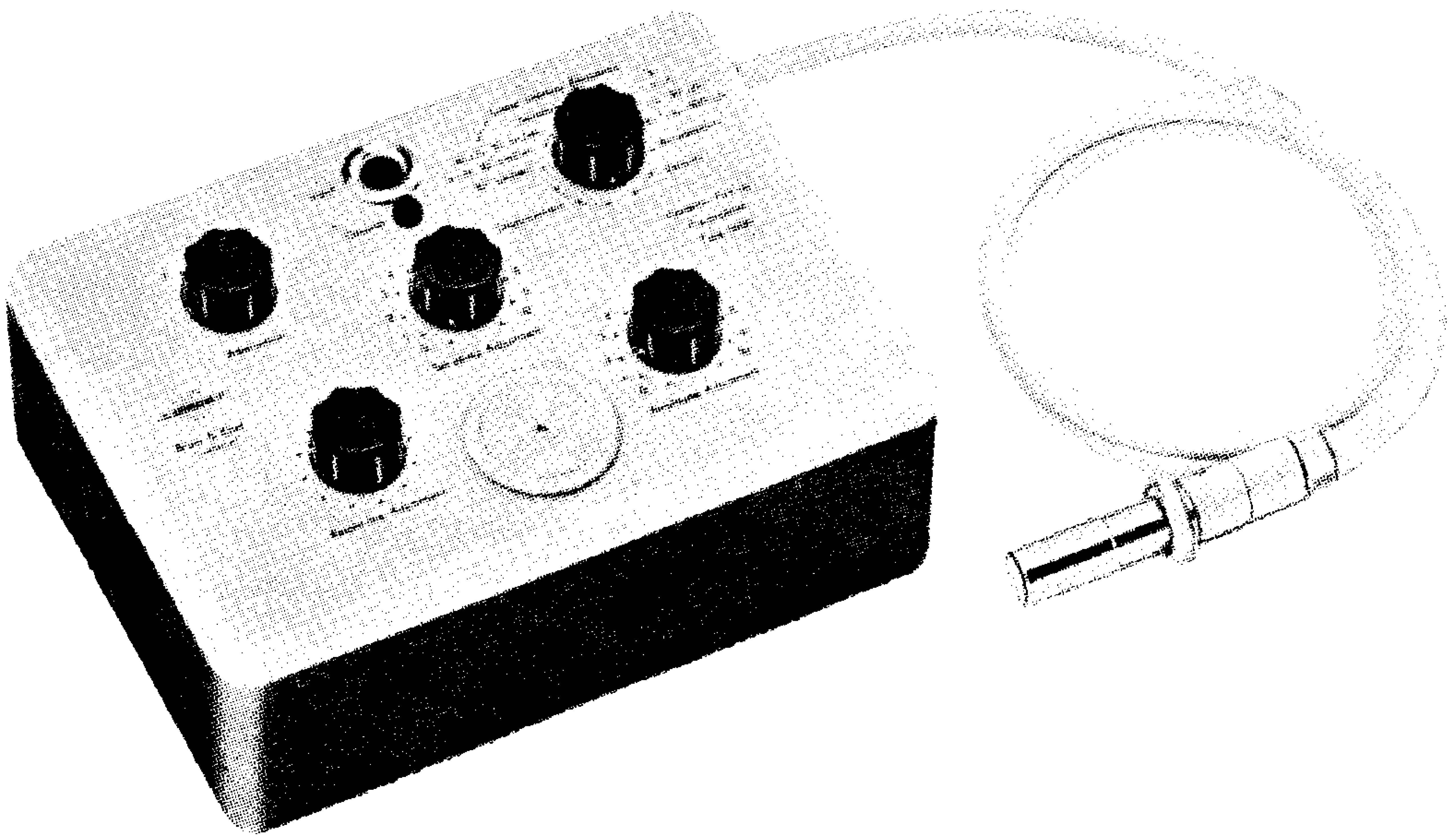

Fig. 8. Photo of Vibration Pick-up Preamplifier 1606.

displacement indicated at the selector knob of type 1606 or 10 times these values, where n is a positive or negative integer. The two positions for "velocity" and the three positions for "displacement" allow a choice to be made between different sensitivities when making these measurements. However, a higher sensitivity gives a consequent rise in the lower limiting frequency, i. e. the frequency at which the meter reading will be in error by 3 db. The input impedance of the instrument is about 30 MΩ. The lower limiting frequency for acceleration measurements, with the capacity of both type 4306 and 4307 Pick-ups, is therefore still about 1—3 c/s. The time constants of the two RC networks employed for the velocity measurements are respectively 10^{-1} and 10^{-2} sec, whereas their damping characteristics are indicated in fig. 9, curves V_1 and V_2. The damping is 20 db per decade or 6 db per octave, while the time constant determines the actual place of the parallel characteristics in the graph (e. g. for the frequencies 5 and 50 c/s the theoretical damping 20 log $\frac{1}{\omega RC}$ db is —10 db in both cases). The lower limiting frequencies 3 and 30 c/s, indicated at the selector knob, are also shown on the actual damping curves. The fault introduced with measurements at these limiting frequencies is 2 db, and can if desired be taken into account by adding this value to the meter reading.

With displacement measurements there are three possibilities. Two networks with time constant 10^{-1} in cascade yield the characteristic D_1, two networks with time constant 10^{-2} curve D_2, and two networks with time constant 10^{-3} (only employed with displacement measurements) curve D_3. The lower limiting frequencies are now respectively 3, 30 and 300 c/s, indicated again on the actual damping characteristics.

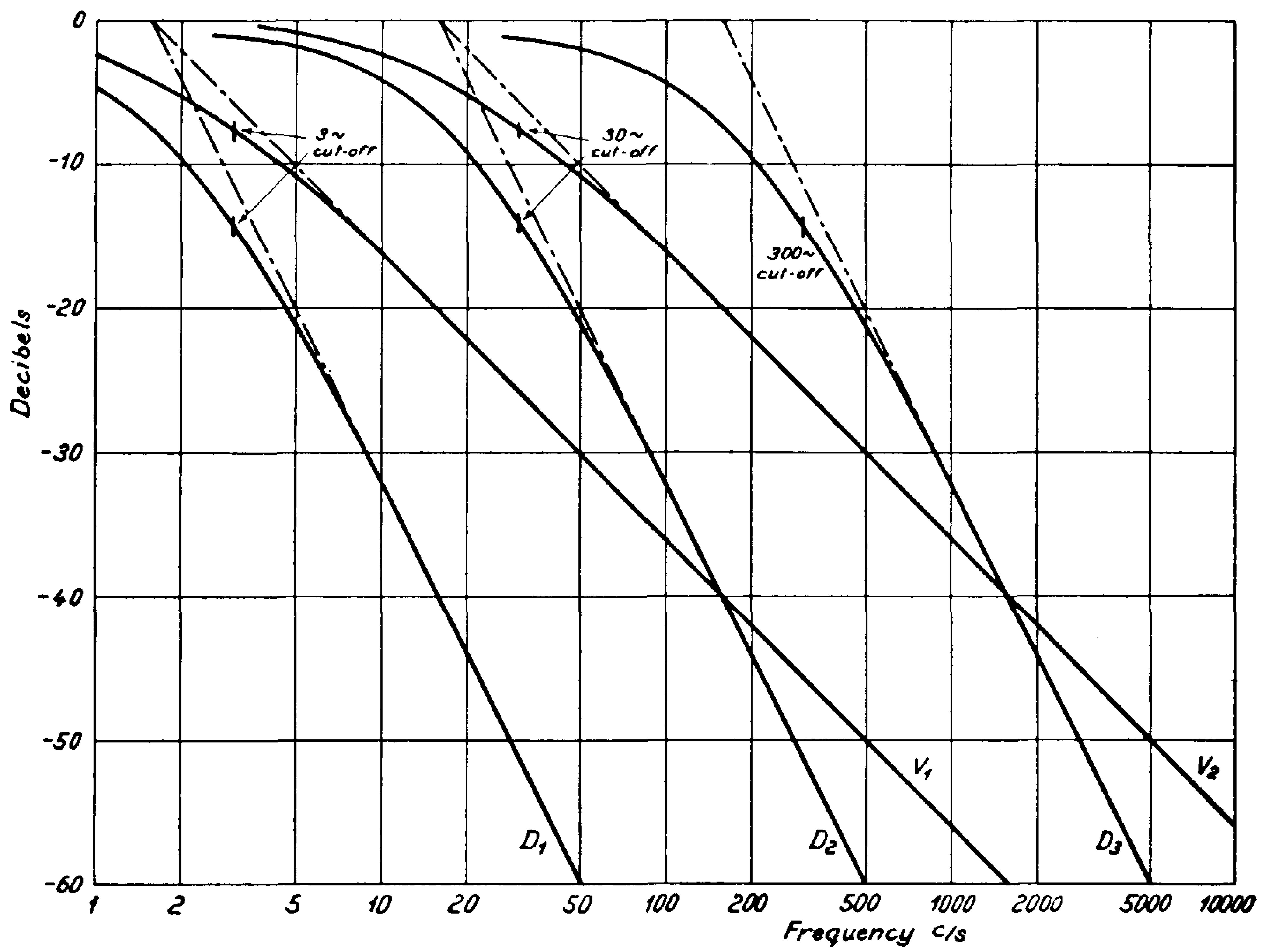

Fig. 9. Damping characteristics of the integration networks in 1606.

With the sensitivity adjustment so adjusted that the analyzer shows full scale deflection on its 1 volt range for an acceleration of 1000 cm/sec^2 (the calibration is done on "Acceleration" see p. 13), switching to the next position, "Velocity", will give a full scale deflection on the analyzer's indicating meter, with unchanged setting of "Voltage Range", for a velocity of 100 cm/sec. For the velocity associated with an acceleration of "a" cm/sec^2 at the angular frequency ω is $\frac{a}{\omega}$ cm/sec, and the analyzer's input after the integration network will be $\frac{a}{100\omega}$ volt (i. e., $\frac{a}{1000} \times \frac{10}{\omega}$ volt; $\frac{a}{1000}$ volt being the output for the acceleration "a", and $\frac{10}{\omega}$ the network damping). A full scale deflection on the meter, i. e. 1 volt analyzer input, therefore corresponds to a velocity of 100 cm/sec, independent of the frequency. The second integrating network damps less at the same frequency (curve V_2 versus V_1 in fig. 9), and gives as output $\frac{100}{\omega}$ volt $\times \frac{a}{1000} = \frac{10\omega}{a}$ volt: consequently a velocity of 10 cm/sec will give full scale deflection on the analyzer's meter. For displacements, the same reasoning explains the full scale deflection values as indicated at the selector knob. The displacement associated with a vibration of angular frequency ω and acceleration "a" cm/sec^2 is $\frac{a}{\omega^2}$ cm. The output after two integrating networks in cascade is $(\frac{10}{\omega})^2 \times \frac{a}{1000}$, $(\frac{100}{\omega})^2 \times \frac{a}{1000}$ and $(\frac{1000}{\omega})^2 \times \frac{a}{1000}$ volts respectively, resulting in full scale deflections corresponding to displacements of 10, 0.1 and 0.01 cm. The indicated values are thus valid with the analyzer on its 1 V range, and the preamplifier attenuator setting on 1.

Increasing the analyzer's sensitivity with the voltage range selector or making use of the preamplifier's attenuator extends the measuring range both upwards and downwards.

The attenuator is provided to avoid overloading the preamplifier, 10 volts being allowed for the total signal after the preamplifier. Before each measurement this upper limit for the total signal should first be controlled with the analyzer on "Linear", the preamplifier on "Acceleration" and the attenuator of the preamplifier set hereafter accordingly. The sensitivity can then be increased with the "Voltage Range" knob of Analyzer 2105 in 20 db steps or with "Meter Range" and "Range Multiplier" in 20 and 10 db steps on Analyzer 2109. Selective measurements for analysis of vibrations are carried out with the above described control as a first step, after which the different harmonics are found by traversing the total frequency range with the aid

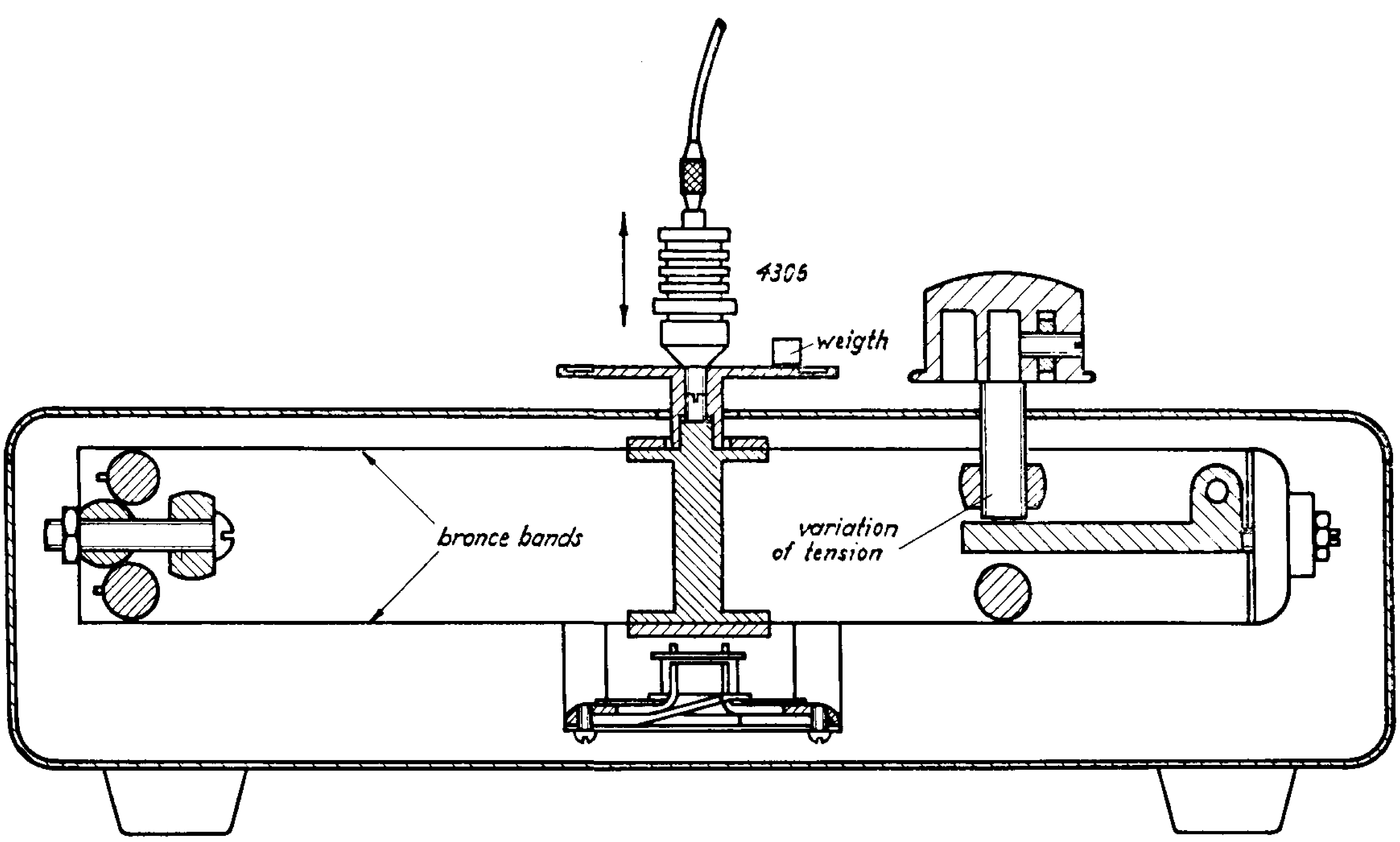

Fig. 10. Sketch of the suspended adjustment table with knob for resonance tuning together with a fixed accelerometer.

of the tuning knob of Analyzer 2105, switching the frequency range after each octave, or with Analyzer 2109, switching the filter switch either manually or mechanically from the first to the 27th fixed filter, covering the frequency range 40—16000 in 27 steps. The Analyzer 2109 has one amplifier before and one amplifier after the 27 fixed 1/3 octave filters. Care should be taken not to overload the first amplifier. The total signal is controlled with the "Range Multiplier" on "x1" ~~and~~ appropriate "Meter Range" setting to get a sufficient deflection on the meter, after which the different components can be increased with the "Range Multiplier" switch in 10 db steps.

To adjust ,the pick-up employed its output is fed in the jack marked "Input" and attached to the vibrating disc. For accelerometer 4306 a special connecting piece, which can be screwed in both the test pin hole and in the vibrating disc, is supplied for this purpose. With the a. c. mains cable connected to the side of the preamplifier the resonance of the vibrating table can be adjusted with the corresponding knob, tuning in on a maximum meter deflection of the analyzer. The table is suspended on a stretched metal strip, the tension of which can be varied mechanically with the aid of the knob "Resonance Adjustment". (See fig. 10). After this the "Amplitude Adjustment" knob is screwed up until a small nut placed on the disc obtains an acceleration equal to that of gravity, which is indicated by the rattling of the nut on the disc. In those cases where this acceleration "g" cannot be obtained even with "Amplitude Adjustment" screwed full up, the whole instrument should be placed on a soft rubber plate to increase the vibration amplitude.

With the analyzer on its 1 volt range the sensitivity of the combination pick-up and preamplifier is calibrated by means of the knob "Sensitivity Adjustment" in one of the following ways: At resonance the movement of the vibrating disc may be regarded as purely sinusoidal. The peak value of the acceleration, i. e. the acceleration at the turning points of this sinusoidal movement, equals that of gravity. Taking this acceleration as reference one can adjust the analyzer's meter deflection on this value g (i. e. on 98 scale parts out of 100), with the result that full scale deflection will correspond to an acceleration with a peak value of 1000 cm/sec^2. Also the values of velocity or displacement as indicated at the selector knob of Preamplifier 1606 will then indicate the peak values of these quantites.

It is also possible to adjust the sensitivity during the calibration to give a scale reading on the analyzer's meter of $\frac{g}{1.4}$ or alternatively $\frac{g}{\pi/2}$ (i. e. 70 or 64 scale parts out of 100), in order to read the measuring results off in r.m.s. or in average values. In these cases the meter readings on Analyzer 2105 or 2109, or VT Voltmeter 2407 following the Microphone Amplifier 2601, will indicate r.m.s. or average values for velocity and displacement measurements as well as for accelerations. After the calibration the measurements can begin. First with the analyzer still on "linear" and 10 volt range it should be controlled that with the preamplifier selector on "acceleration" the total signal does not exceed 10 volts. If it does, the attenuator is set on 10^2 or 10^4

to obtain an appropriate input signal. If the analyzer is set on a more sensitive range than 1 volt full scale deflection, the value indicated on Preamplifier 1606 should be multiplied by factors of 10 or 3.16 (in case the "Range Multiplier" switch of Analyzer 2109 is used). After this, both velocity and displacement measurements can take place as well as analysis of the vibration under consideration. When making velocity and displacement measurements the most sensitive position should be chosen on the selector permitted by the frequency of the fundamental of the vibration, which therefore should be determined first by traversing the frequency range with the analyzer in its selective position.

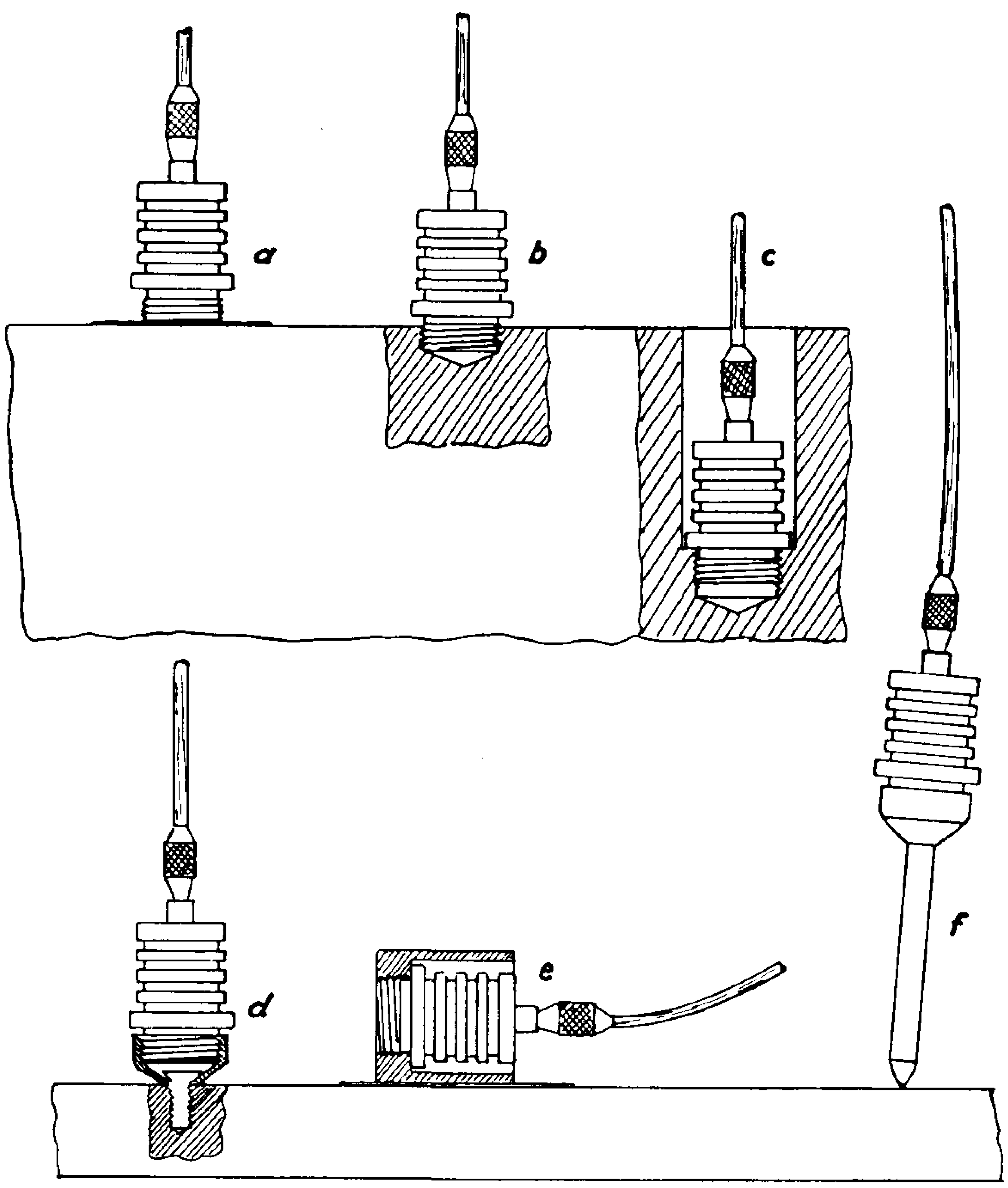

Fig. 11. Typical examples of mounting for accelerometer type 4306.
a) with double adhesive tape.
b) American fine thread type NF ½"×20.
c) counter sunk in hole of min. 15 mm diameter with thread NF ½"×20.
d) ⅛" WG or 3 M screw with conus.
e) aluminium cube mounted with double adhesive tape for lateral vibrations.
f) testing pin.

When an accelerometer is to be used for measurements on vibrating parts, it is very important that it be carefully attached if vibrations containing high frequencies are to be correctly measured. If an elastic intermediate layer, e. g. a thin screw or a thick layer of adhesive material exists between the accelerometer and the surface of the measuring object, a resonance will be obtained which can completely invalidate the results. If interest is limited to low frequency vibrations, it is possible to make do with simple means, e. g. the accelerometer can be held by hand against the vibrating surface, or, if necessary, one of the supplied test probes can be used. Fig. 11 shows a number of examples of ways of fastening the accelerometer 4306.

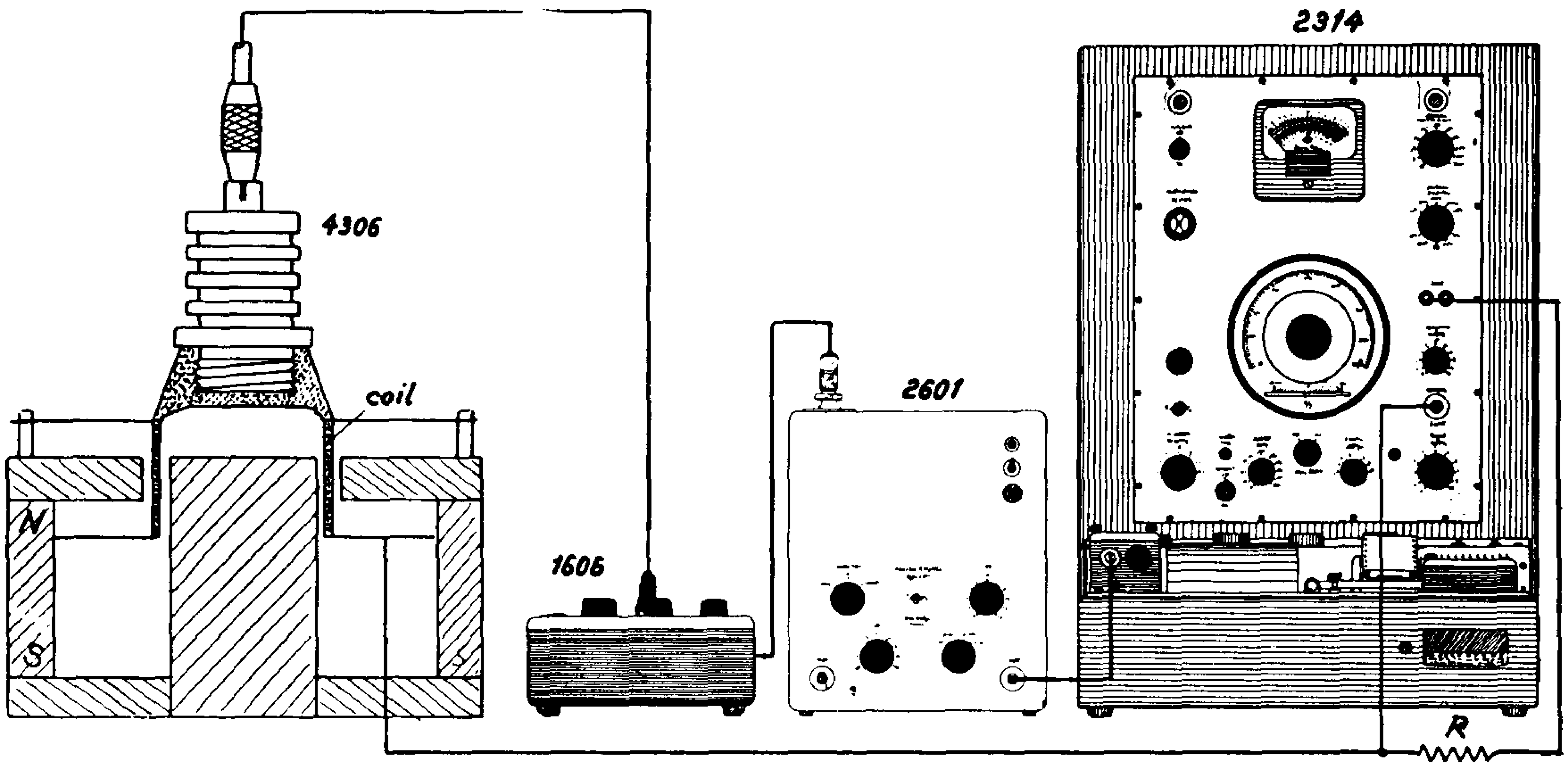

Fig. 12. Test set-up for the determination of the accelerometer's frequency characteristic at low frequencies.

Adjustment of accelerometers presents many difficulties. The absolute sensitivity is estimated as previously described by placing the accelerometer on the adjusting table of 1606 together with a little screw or such like. For a single frequency, normally 50 or 60 c/s, the output voltage of the accelerometer is read off when the peak value of the acceleration is just exactly equal to that gravity. The frequency characteristic for low frequencies is recorded as shown in fig. 12, where the accelerometer is placed on a small vibrator system with low resonance point, but otherwise with a compact coil system. If a constant current is sent through the coil the whole system will have a constant acceleration. In the frequency range 20—2000 c/s the set-up shown enables the frequency curve of fig. 14 to be easily recorded.

For frequencies above 2000 c/s the task is considerably more difficult. Two or more accelerometers are employed, and it must be assumed that these have approximately the same frequency curve. This is, as a rule, the case, if they have the same mechanical construction and sensitivity. Two accelerometers are put together, as shown in fig. 13, and coupled to a B. F. O.,

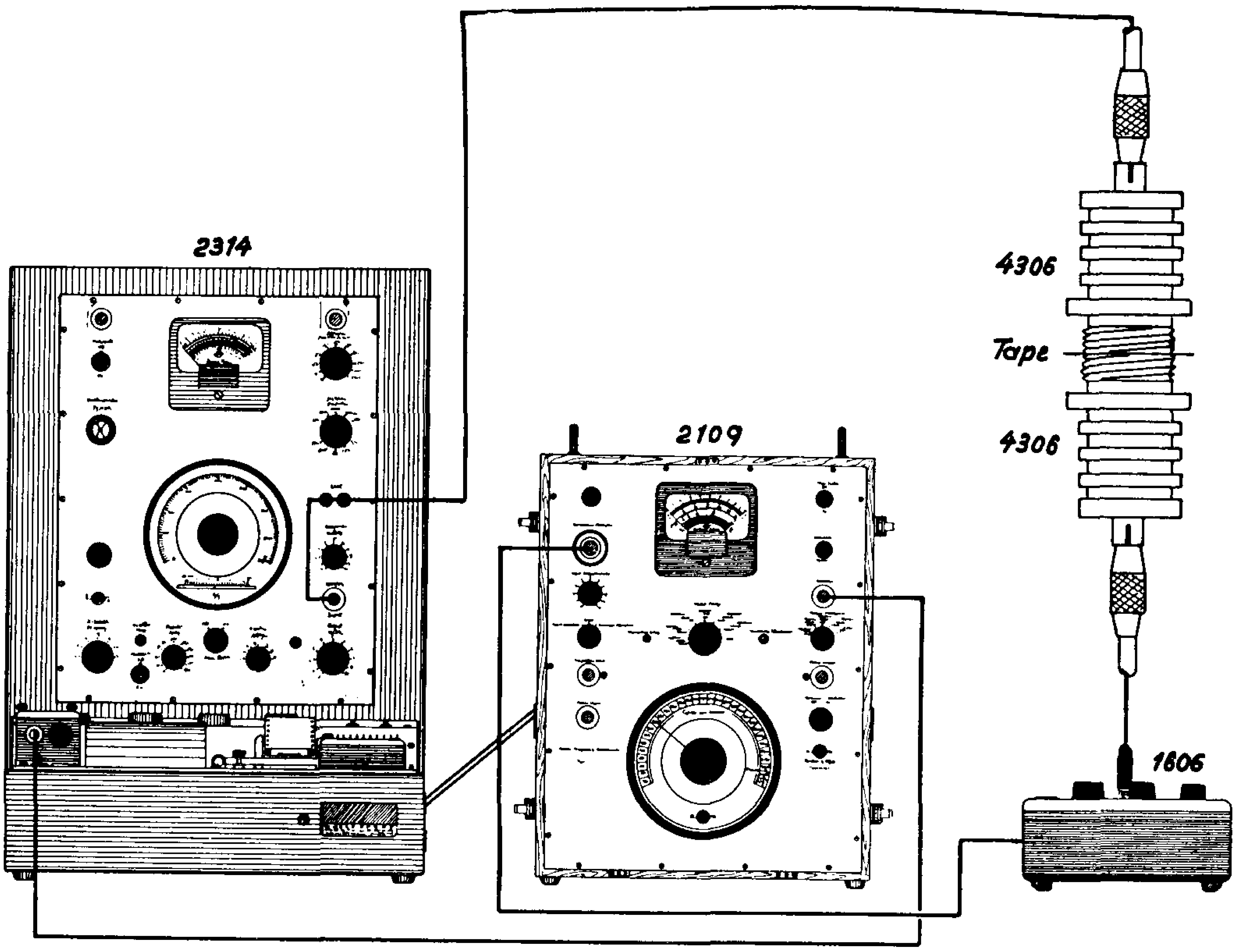

Fig. 13. Test set-up for determination of frequency characteristic at high frequencies.

amplifier and level recorder. The one accelerometer is used as transmitter and the other as receiver. If the frequency characteristics of both accelerometers are flat and a constant voltage is applied to the transmitter an output voltage will be obtained from the receiver which is proportional to the square of the frequency. Shown logarithmically, as in fig. 14, the recorded

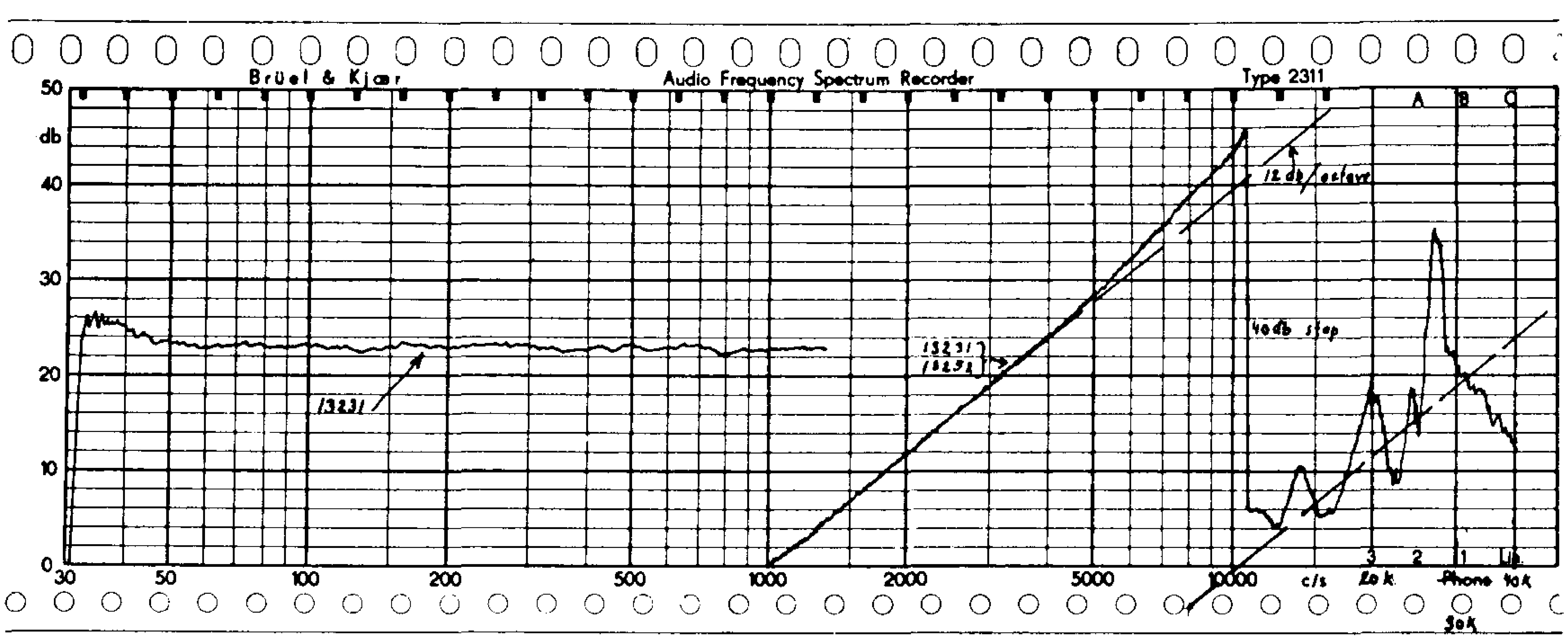

Fig. 14. Recorded curve of frequency characteristic with the test set-ups as shown in fig. 12 and 13.

voltage should rise 12 db per octave. Deviations from this are due to deviations from the flat frequency characteristic. By sharing the deviations between both accelerometers the frequency characteristic for the single one can be found. Fig. 15 shows the final result carried up ti 40 kc/s.

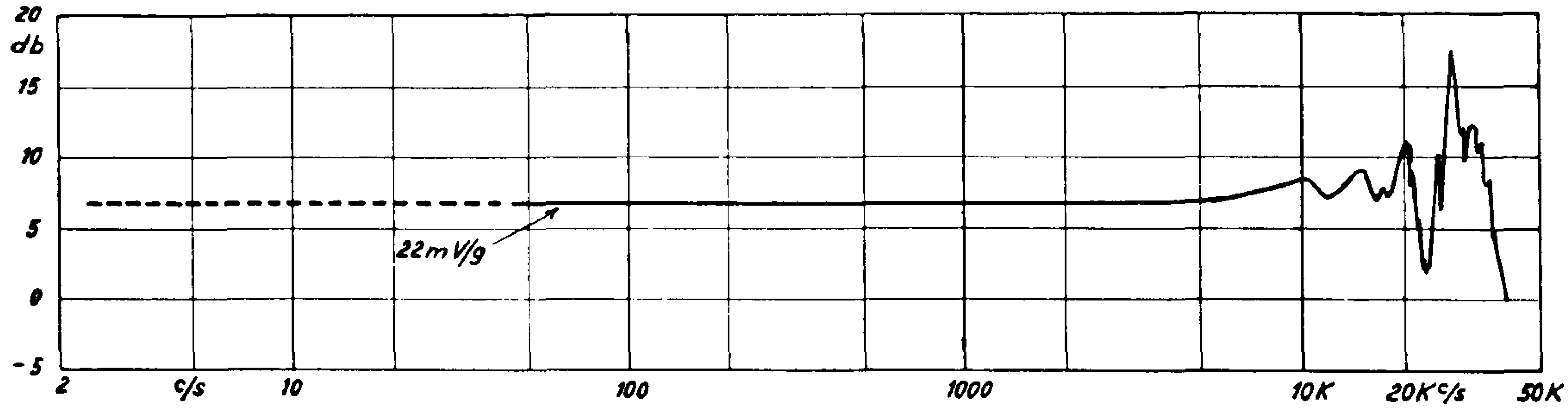

Fig. 15. Frequency characteristic and absolute sensitivity drawn from the data given in fig. 14 valid for accelerometer type 4306, serial nr. 13.

1) *Cady, W. G.:* "Piezoelectricity", McGraw-Hill Book Co., Inc., New York, 1946.
2) *Mason, W. P.:* "Piezoelectric Crystals and Their Application to Ultrasonics", D. Van Nostrand Co., Inc., New York, 1950.
3) *Massa, Frank:* A new Method of Vibration Measurement for the Frequency Range 20—20ooo c/s, Instruments, vol. 21, pp. 1013—1014, November 1948.
4) *Guttwein, G. K.,* and *A. I. Dranetz:* Self-Generating Accelerometers, Electronics, vol. 24, pp, 120—123, October 1951.
5) *Perls, Thomas A.,* and *Charles W. Kissinger:* A Barium Titanate Accelerometer with Wide Frequency and Acceleration Ranges, Nat' 1. BuStds. Rept. 2390, April 1953.
6) *Peters, R. J.:* NRL Type C-4 Barium Titanate Accelerometer, Nat' 1. BuStds. Rept. 2654, pp. 57, August 1953.
7) *Dranetz, A. I.:* Construction of Barium Titanate Accelerometers, Nat' 1. *BuStds. Rept. 2654, pp. 69, August 1953.*

Specification

ACCELEROMETER PRE-AMPLIFIER

Type 1606

Input Attenuator: An input attenuator in 2 steps of 40 db is provided to avoid overload distortion of the preamplifier. With the selector knob in position "Acceleration" a maximum output of 10 volt is allowed.

Selector Knob: Allows selection of Acceleration, Velocity or Displacement measurements. The indicated values of these quantities at the knob positions correspond to full scale deflection on the meter of analyzer 2105 or 2109. The full scale deflection values can be extended in both directions, changing the attenuator setting on the preamplifier or the voltage range. Two positions for velocity measurements and three for displacement measurements are included, so as to increase the sensitivity for these measurements. However, this increase in sensitivity also results in a rise in the lower limiting frequency, as indicated at the selector knob.

Hum and Noise of Preamplifier: About 5 μV.

Sensitivity Ranges: Depending on the exact sensitivity of Accelerometer Type 4306 and 4307 approx.:

	type 4306	**type 4307**	
Acceleration from	0,3 cm/sec^2	1 cm/sec^2	
Velocity from	0,003 cm/sec	0,01 cm/sec	for 3 c/s cut off
and	0,001 cm/sec	0,003 cm/sec	for 30 c/s cut-off
Displacement	0,1 μ	0,3 μ	with 3 c/s cut-off
	0,03 μ	0,1 μ	with 30 c/s cut-off
	0,01 μ	0,03 μ	with 300 c/s cut-off

Frequency Range: With Accelerometer Type 4306:
Acceleration measurements from 1.5 to 15.000 c/s.
Velocity measurements from 3 or 30 to 15.000 c/s.
Displacement measurements from 3, 30 or 300 to 15.000 c/s.
With Accelerometer Type 4307:
Acceleration measurements from 1.5 to 25.000 c/s.
Velocity measurements from 3 or 30 to 25.000 c/s.
Displacement measurements from 3, 30 or 300 to 25.000 c/s.

Input Impedance: With the knob "Sensitivity Adjustment" screwed fully up (i.e., with the least feed-back), the input impedance is still about 50 MΩ.

Calibration Disc: This is a mains driven resonance system suspended on a metal strip, the tension of which can be mechanically regulated by "Resonance

Adjustment". The control "Amplitude Adjustment" is for adjusting the acceleration to exactly that of gravity (981 cm/sec^2), which value is used as reference.

Calibration Principle: The acceleration "g" is used as reference to adjust the combination preamplifier-analyzer so as to obtain full scale deflection on the meter for the values of acceleration, velocity and displacement indicated at the selector knob, or 10^n × these.

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

Dimensions: 25 (length) × 18 (width) × 10,5 (height excl. knobs) cms.
10 (length) × 7 (width) × 4 (height excl. knobs) ins.

Weight: 3.9 kg.

Case: 305 × 235 × 140 mm.
12 × 9 × 5$^1/_2$ ins.

Brüel & Kjær

ADR.: BRÜEL & KJÆR
NÆRUM - DENMARK

TELEPHONE: 800500
BRUKJA, Copenhagen

Printed in Copenhagen, Denmark