Brüel & Kjær

Technical Review

Teletechnical, Acoustical and Vibrational Research

No. 2

April 1958

PREVIOUSLY ISSUED NUMBERS OF BRÜEL & KJÆR TECHNICAL REVIEW:

1-1954	Noise Measurements with the Audio Frequency Spectrometer Type 2109.
2-1954	The Automatic Analysis of Distortion in Sound Reproducing Equipment.
3-1954	Mobile Laboratories.
4-1954	Tube Measurements and Sound Insulation. Calibration of Probe-Tube Microphones.
1-1955	The Standing Wave Apparatus.
2-1955	Modern Accelerometers.
3-1955	Non Linearity of Condenser Microphones.
4-1955	A New Beat Frequency Oscillator Type 1014.
1-1956	Noise Measurements and Analyses.
2-1956	Use of Resistance Strain Gauges to determine Friction Coefficients.
3-1956	Determination of Acoustical quality of Rooms from Reverberation Curves.
4-1956	Electrical Measurements of Mechanical Vibrations.
1-1957	Strain Gauge Measurements.
2-1957	Sound Analysis in Industrial Processes and Production.
3-1957	Measurement on Tape Recorders.
4-1957	Measurements of Modules of Elasticity and Loss Factor for Solid Materials. Surface Roughness Measurements.
1-1958	Measurement of the Complex Modulus of Elasticity.

COPIES AVAILABLE ON REQUEST

TECHNICAL REVIEW

No. 2 - 1958

Reprint July 1960

Acknowledgement.

Thanks are due to Mr. Galt B. Booth, Chief Development Engineer, MB Manufacturing Company, New Haven, Connecticut, for many valuable discussions during the fall of 1957 leading to the articles contained in this issue of the B & K Technical Review.

CONTENTS:

Vibration Testing of Components.

by

Jens T. Broch
Dipl. ing. E.T.H.

Summary.
After a short introduction explaining the purpose and importance of vibration testing of mechanical and electro-mechanical components the merits of the three most important types of vibration tests are briefly described: the shock test, the random motion test, and the frequency sweep test. The frequency sweep test is discussed to some length with special regards to the B.F.O. Type 1015 and the Automatic Vibration Exciter Control Type 1016. Finally an example of the use of Type 1015 in a random motion test set-up is given and some practical units used in actual vibration test systems shown.

Résumé:
Après une courte introduction mettant en relief let buts et l'importance des essais aux vibrations de pièces mécaniques et électromécaniques, cette étude décrit brièvement les mérites des trois types les plus importants d'essais aux vibrations: l'essai aux chocs, l'essai aux mouvements désordonnés et l'essai sous fréquence glissante. On s'arrête plus longuement à ce dernier, eu spécialement égard au générateur interférentiel type 1015 et au dispositif automatique de réglage d'excitation de vibrations type 1016. Pour terminer un exemple est donné de l'emploi de l'appareil 1015 dans un ensemble d'essai sous mouvement désordonné et l'on montre quelques éléments pratiques utilisés dans des systèmes réels d'essai aux vibrations.

Zusammenfassung:
Zweck und Bedeutung der Schwingfestigkeitsprüfung werden einleitend erläutert. Anschließend werden die drei wichtigsten Erregungsmethoden kurz beschrieben: Stoß-, Rausch- und Heultonerregung. Die Heultonerregung wird unter besonderer Berücksichtigung des Schwebungssummers 1015 und des Regelgenerators für Schwingungserreger, Typ 1016, behandelt. Zum Schulß wird ein Anwendungsbeispiel über Typ 1015 innerhalb einer Rauscherregungs-Prüfanordnung aufgeführt, fernes werden einige moderne Prüfeinrichtungen gezeigt.

The Purpose of Vibration Testing.

Mechanical vibrations in a structure occur whenever a change in the forces applied to it takes place. This change in the applied forces can have a periodic or non-periodic character, depending upon its source. If the change in forces and the number of force cycles applied are great enough, the structure might be damaged. The purpose of vibration testing is to determine the damaging effects of vibrations on a test specimen and thereby enable changes to be made in the design to prevent such damage from taking place under actual operating conditions.

The importance of vibration testing is a function of the severity of the conditions under which the specimen is supposed to operate, and has been fully recognized in recent years.

As long as only simple structures are considered, it is possible to calculate the effects of vibrations. However, as the structure becomes more and more complicated and the operating conditions more and more complex and severe, the amount of calculation involved is large. In such cases, vibration testing may be the only practical solution to the problem of determining vibrational effects.

This is especially true in the aircraft and missile field, where not only the periodic changes in force caused by the engines, but also the forces due to air stream turbulances, play a rcle. Also gas turbine parts and parts of other fast running machinery are now normally subjected to vibration testing before the final design of the part is approved.

Types of Vibration Tests.

Three different types of vibration tests are especially important, namely the shock test, the random motion test and the frequency sweep test. Common for the two latter types of vibration tests is the use of a vibration exciter or shaker table.

In the following the three types of test will be briefly described:

1. The Shock Test.

If the test specimen considered is supposed to operate under conditions where a force is suddenly applied to the structure (or suddenly released), e.g. the firing of a gun, a shock-test might be the test which comes closets to normal operating conditions. The shock test is normally made by bolting the specimen to a platform which is allowed to drop a specified distance into a pit of sand or onto specially shaped lead pellets. In an alternative, newer, method, the specimen is bolted to a platform having a metering pin. The platform is

accelerated by hydraulic pressure applied to the base of the platform through a small hole around the metering pin. The acceleration is adjusted by shaping the lead pellets of the drop test, or the metering pin of the hydraulic test.
The damages caused by transients during a shock-test are normally due to the excitation of one or more of the natural frequencies of the structure under test. A determination of the natural frequencies of the specimen as well as their Q-values may be made by a preliminary frequency sweep test, to be described below, which will give the design engineer much valuable information that cannot be obtained directly from the shock test. He can then predict from the expected frequency spectrum of the transient, which of the natural vibration modes are the most dangerous ones.
If the preliminary frequency sweep test indicates potential trouble, a shock test might be applied later on to see if the corrective measures taken by the design engineer were adequate.

2. *The Random Motion Test.*

If the specimen is supposed to operate under random motion conditions, i.e. high speed aircraft parts, missiles, etc. which are subjected to aero- or hydrodynamic flow turbulances, a random motion test will be the one closest to normal operating conditions.
The random motion vibration test is normally carried out by feeding a vibration exciter with a band of "white" electrical noise and producing a certain specified acceleration density level on the shaker table. The test specimen is then vibrated for a certain period of time, or until damage is caused.
However, to obtain a "white" driving force, the response of the driving system must be truly linear with respect to frequency within the frequency band considered. It is therefore necessary, before the vibration test is carried out, to determine and correct the actual frequency response of the driving system with the test specimen mounted on the shaker table.

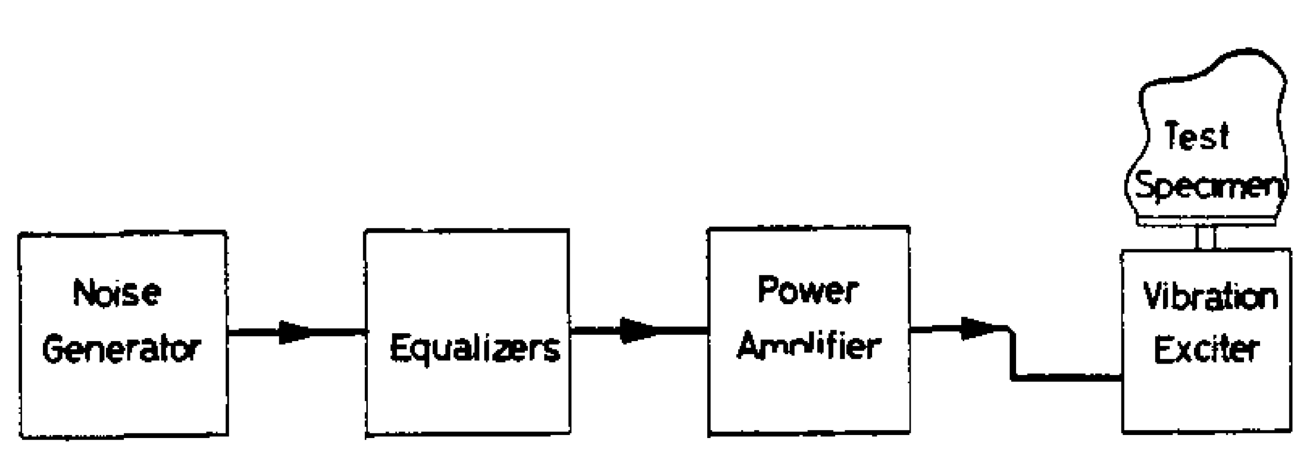

Fig. 1a. block diagram of a typical random motion test arrangement.

Fig. 1a shows a block diagram of a typical random motion test set-up. It consists of a noise generator, a number of equalizers for frequency response correction, a power amplifier, a vibration exciter and the test specimen itself. Fig. 1b illustrates the use of the equalizers to obtain a linear frequency response for the driving system. For the sake of convenience, a test specimen with only one resonance is assumed.

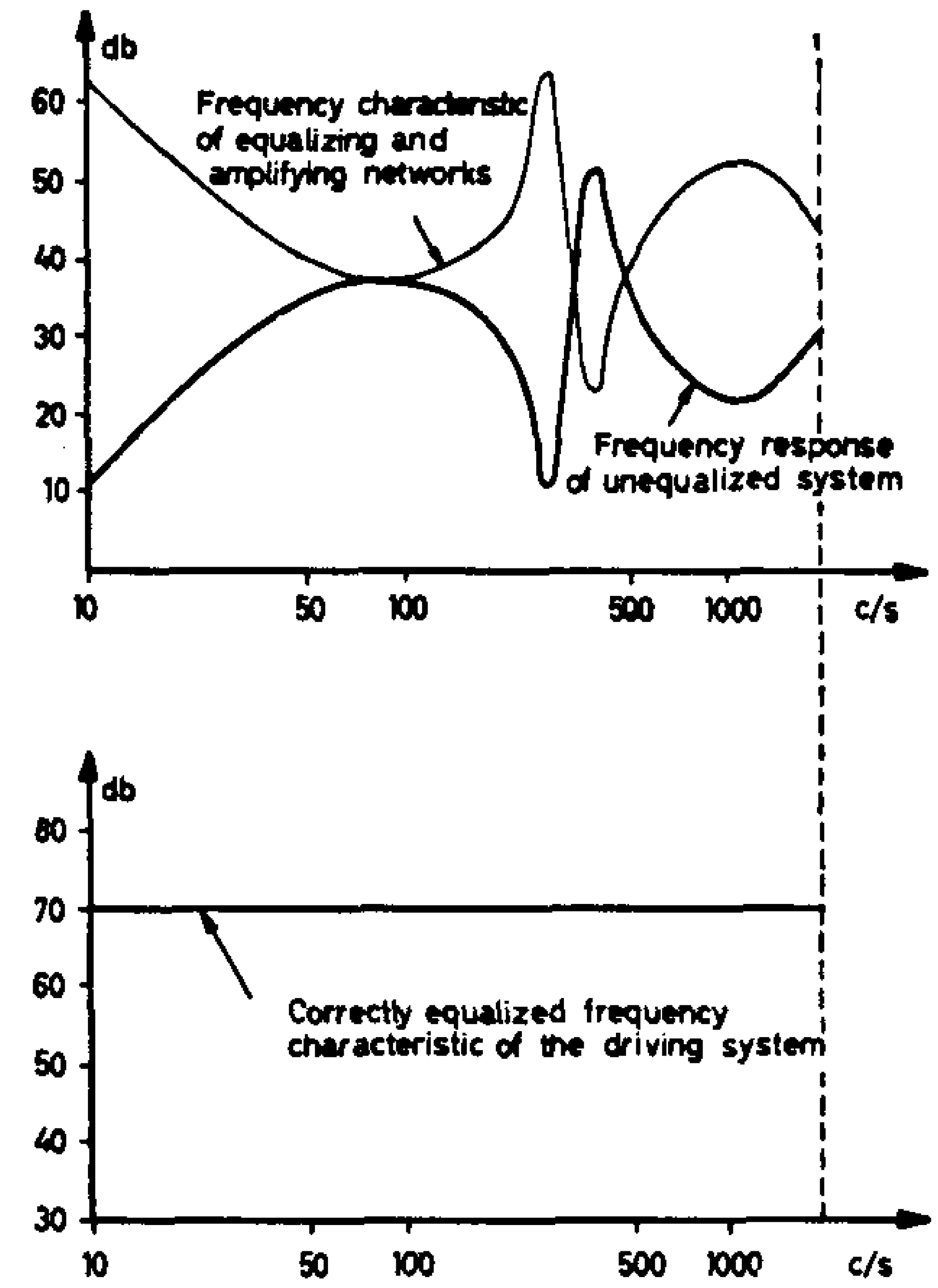

Fig. 1b. Curve showing how a linear frequency response of the driving system is obtained.

To record the frequency characteristics shown in fig. 1b, it is necessary to carry out a somewhat simplified frequency sweep test at a low vibration level.

As mentioned under item 1, vibrational damage to a test specimen is normally caused by the exitation of one or more of its natural frequencies (resonances). The random motion vibration test, moreover, enables measurement of the severity of the major structural responses in different frequency bands to be made by simply analyzing the output from vibration pick-ups placed on the test specimen.

A very important feature of the random motion type of vibration test is that all resonances of the test specimen are excited simultaneously, thereby obtaining the correct response to non-linearities, if any.

3. The Frequency Sweep Test.

If the test specimen is supposed to be subjected to a discrete vibration frequency spectrum produced by for example rotating machinery, a frequency sweep test will be the most convenient type of vibration test to apply. In this case, no equalizers are needed as the output from the driving oscillator can be controlled by a vibration pick-up, mounted on the shaker table (or the built-in signal generator coil).

Fig. 2 shows a block diagram of a typical frequency sweep test arrangement. It consists basically of an oscillator, the frequency of which is slowly changed all the time during the test, a power amplifier, a shaker table and the test specimen.

In the set-up shown the automatic control arrangement is built into the oscillator unit itself.

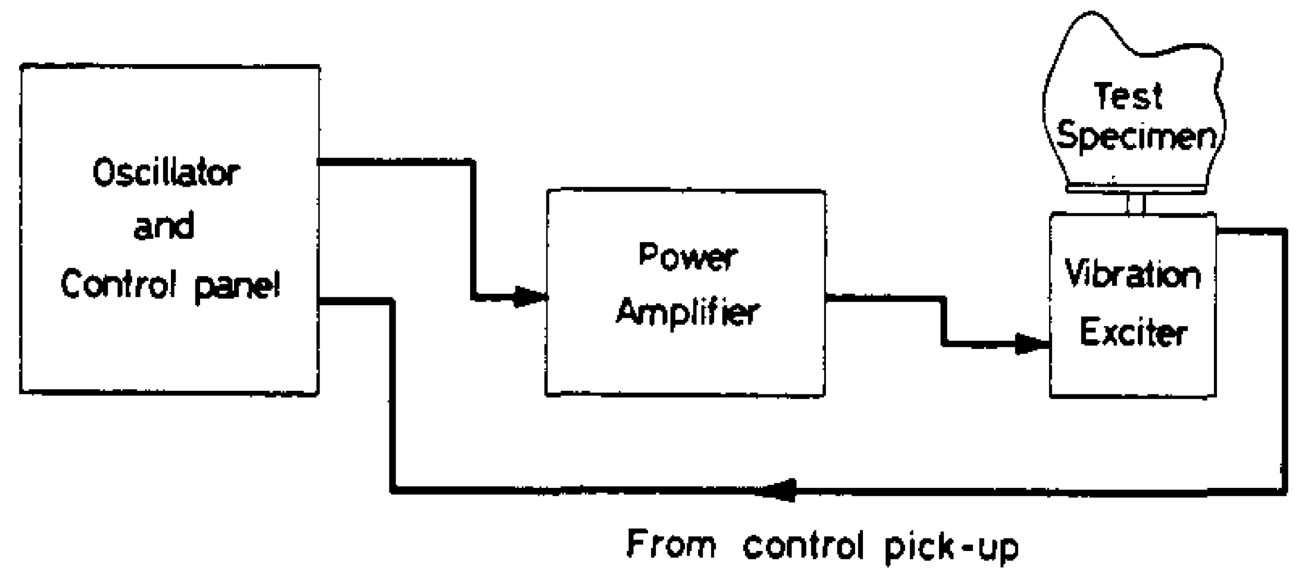

Fig. 2. Block diagram of a typical frequency sweep test set-up.

By driving the vibration exciter with a fixed amplitude, variable frequency signal, and by recording the output from a vibration pick-up, mounted on the test specimen, the frequency response is obtained, and the natural frequencies as well as their Q-values can be found directly from the recording. Alternatively, if automatic control is used, the output from the vibration pick-up will be held constant, and the inverse frequency response may be obtained by recording the input to the vibration exciter.

A comparison of the random motion test equipment with that necessary for a frequency sweep test indicates the much greater cost of the first. Not only the costs of the equalizer panels are saved, when sinusoidal tests are used instead of random motion, but smaller power amplifiers and vibration exciters can be used for the same test.
In many cases, the great cost of the random motion equipment may not be justified on the basis of the number of tests that are to be carried out. In cases where a random motion excitation would be the technically "proper" way of testing the specimen, a reasonable simulation of the test conditions may be obtained by using a frequency sweep test. Corrections should then be made, however, for the difference in response of the specimen resonances with respect to sinusoidal excitation.

The Frequency Sweep Test.

As mentioned above, the frequency sweep test consists of feeding a vibration exciter with a certain amount of power at a slowly changing frequency. Due to resonances in the test specimen and vibration exciter system, the power necessary to subject the test specimen to a certain, constant vibration level will not, however, remain constant during the test, but will be a function of the frequency of the vibrations. To keep the vibration level constant, the output from a vibration pick-up (signal gen. coil), built into the shaker, or mounted on it, is used to control the input power to the vibration exciter.
Normally, the control of the vibration level is made in such a way that when the vibration level of the table tends to increase, which would cause the output voltage from the control pick-up to increase, the input power to the vibration exciter is automatically decreased until approximately the same vibration level is regained as was present before the change in vibration level occured.

The automatic decrease in exciter input power will not follow instantaneously when an increase in vibration level is felt by the control pick-up, but it will take a certain amount of time to regain the original level. This time constant of the regulation, or in other words "the regulation speed", should be selected according to the expected Q-values of the system resonances and the sweep rate chosen for the frequency sweep, i.e. the regulation speed must be greater than the speed with which the system resonances are built up.
This means in practice that the highest regulation speed should be used, the upper limit of the regulation speed being set by interaction between the regulation speed and the actual vibration frequency (causing distortion).
To determine which of the three vibrational quantities, acceleration, velocity or displacement is the most important one, with respect to structural damages in the test specimen, environmental studies have been carried out in the United States.
These studies show that at lower frequencies the vibrations observed are most likely to have a constant displacement level while at higher frequencies the vibrations observed depend upon the acceleration level. The resulting structural damage is then due to displacements at low frequencies and accelerations at high frequencies, which is reasonable due to mechanical interferance in the first and inertia stresses in the second.
Vibration tests are therefore often carried out at constant displacement level at low frequencies, and at constant acceleration level at higher frequencies. The exact frequency of the cross-over from constant displacement operation to constant acceleration operation is stated in the different vibration test specifications, e.g. MIL-E-5272A a.o., and depends upon the conditions under which the test specimen is supposed to operate in practice.

Frequency Sweep Test Oscillators.

Brüel & Kjær have developed two oscillators to be used in frequency sweep test systems, namely the *Beat Frequency Oscillator Type 1015* and the *Automatic Vibration Exciter Control Type 1016.*
Both signal sources work according to the heterodyne principle and are supplied with an automatic output regulator.
The B.F.O. Type 1015 covers the frequency range 2 to 2000 c/s with a true logarithmic frequency scale, and is furthermore supplied with an additional range covering the frequency band 2000 to 4000 c/s.
The main frequency range of the Automatic Vibration Exciter Control Type 1016 is 5—5000 c/s (logarithmic frequency scale) and the additional range is 5000 to 10000 c/s.
Type 1016 also includes a reversible motor drive for automatic frequency scanning, an automatic cross-over arrangement, and a vibration meter for setting and monitoring the vibration level of the shaker table.
The speed of the frequency sweep is variable from 3 to 350 degrees/min. (one frequency decade = 72 degrees). When the preset frequency limits of the

sweep range are reached, the motor is automatically reversed, thus traversing the same frequency range with the same speed, but in the opposite direction. As mentioned above it is desired to test the specimen at a constant displacement level at low frequencies, and at a constant acceleration level at higher frequencies. The automatic cross-over arrangement is provided to enable this change in the vibration excitation characteristic, and the cross-over can be set to any predetermined frequency in the range 10 to 500 c/s.
The vibration meter features an electronic amplifier, the differentiating and integrating networks necessary to convert the output from a velocity type of vibration pick-up into a voltage proportional to the acceleration or displacement level of the shaker table, a VTVM, and a rectifier arrangement which supplies the control voltage for regulation of the Oscillator output.
Fig. 3 shows a complete block diagram of Type 1016, and in fig. 4 a photo of the unit is shown.

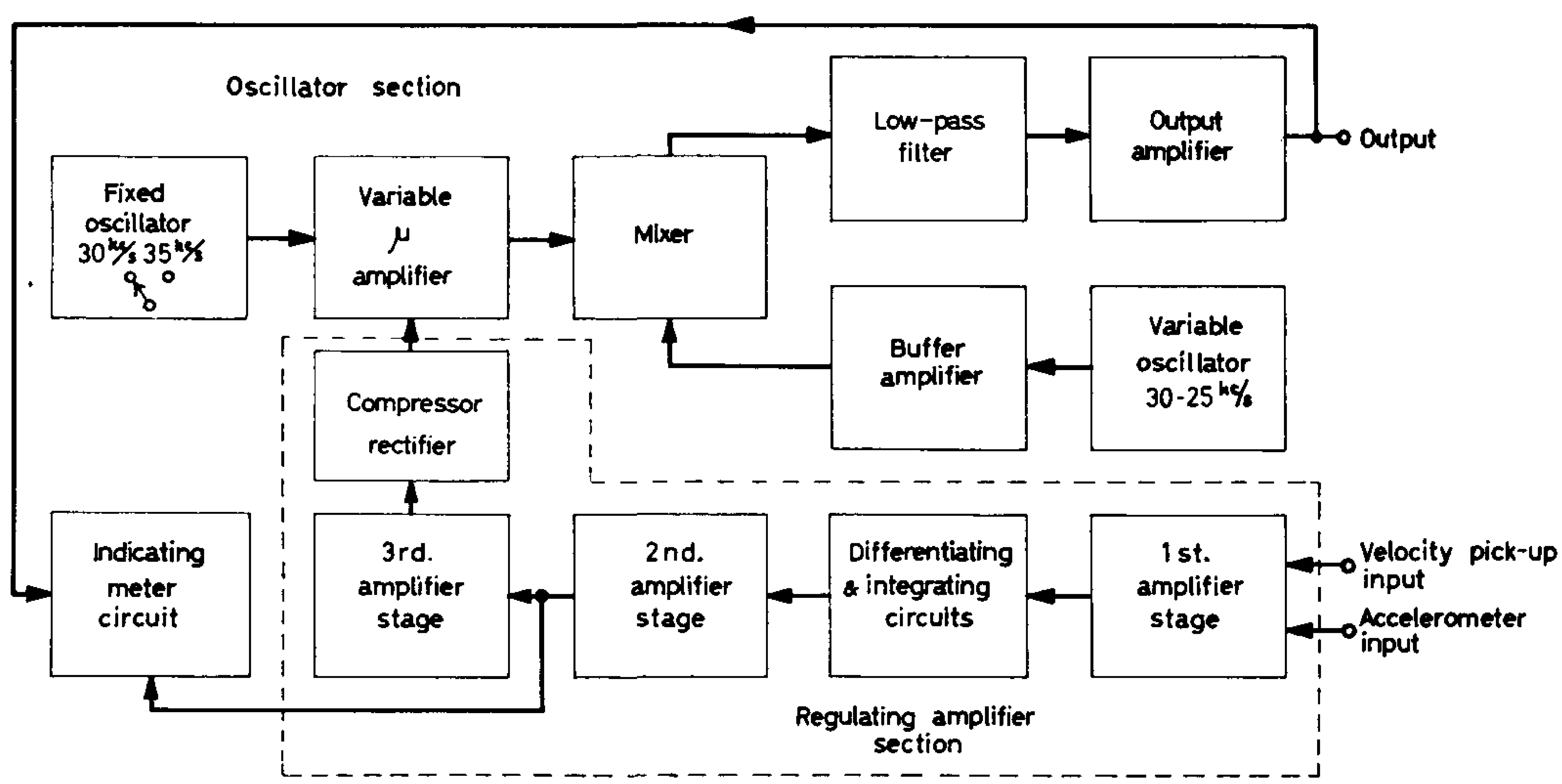

Fig. 3. Block diagram of the Automatic Vibration Exciter Control Type 1016

The vibration meter is furthermore supplied with two input terminals. One of these is used in conjunction with a velocity type pick-up (signal generator coil) and to be able to keep the displacement or acceleration level of the shaker table constant the output signal from the pick-up is integrated (or differentiated) once with respect to time. This is achieved automatically when the "Function Selector" of Type 1016 is set to position "Displacement" or "Acceleration Vel. Gen.", respectively.
The second input terminal in combination with the "Function Selector" also enables the output from the Automatic Vibration Exciter Control to be controlled from an accelerometer. However, piezo-electric accelerometers should be used in connection with a cathode follower type preamplifier, the input impedance of Type 1016 for accelerometer operation being 111 kohm.

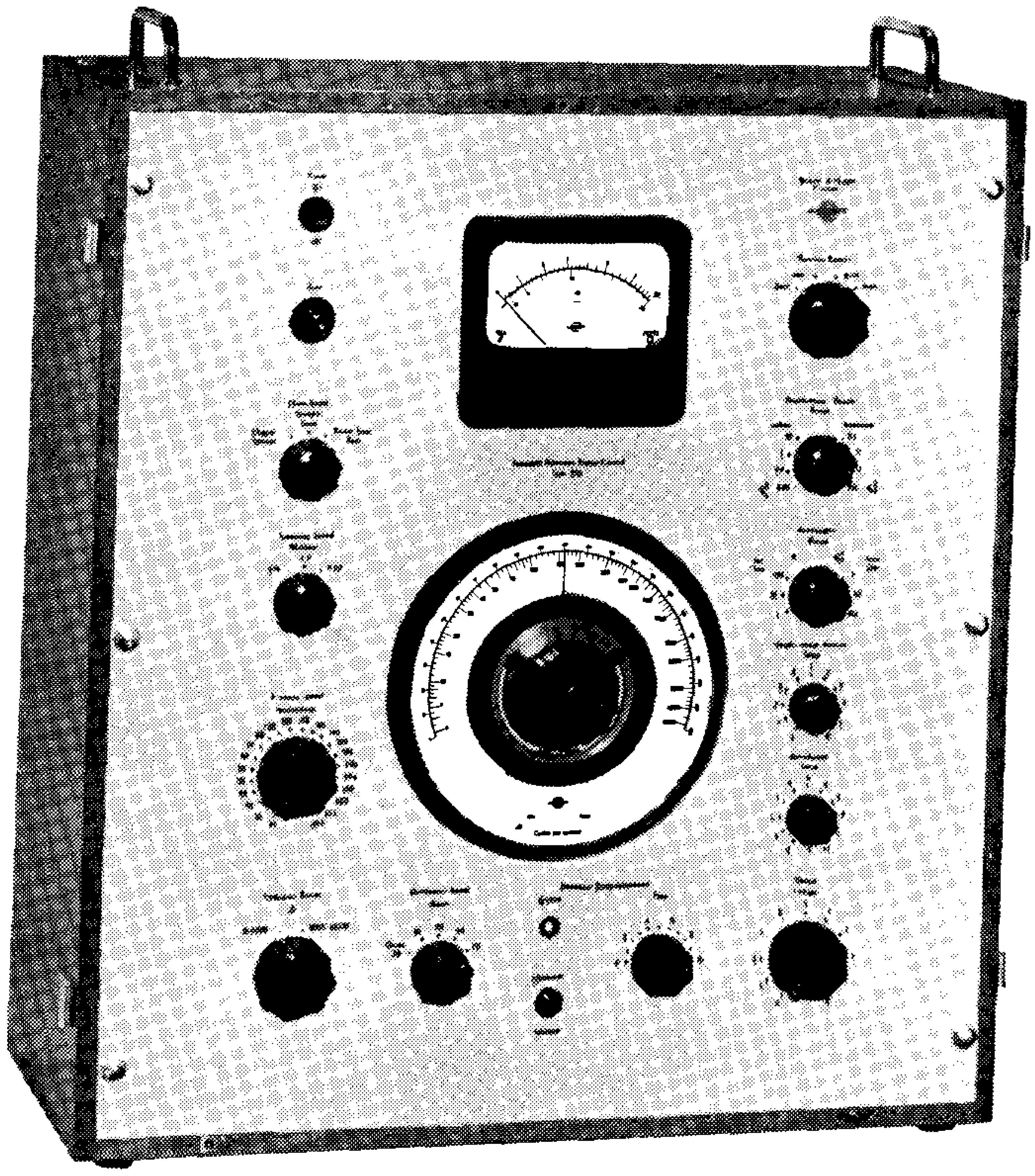

Fig. 4. Photo of Type 1016.

Fig. 5 shows a photo of the Accelerometers Type 4308 and 4309, two piezo-electric accelerometers being very well suited for this purpose. Because the mechanical dimensions of the accelerometers are small, they can be readily built into a vibration test set-up.

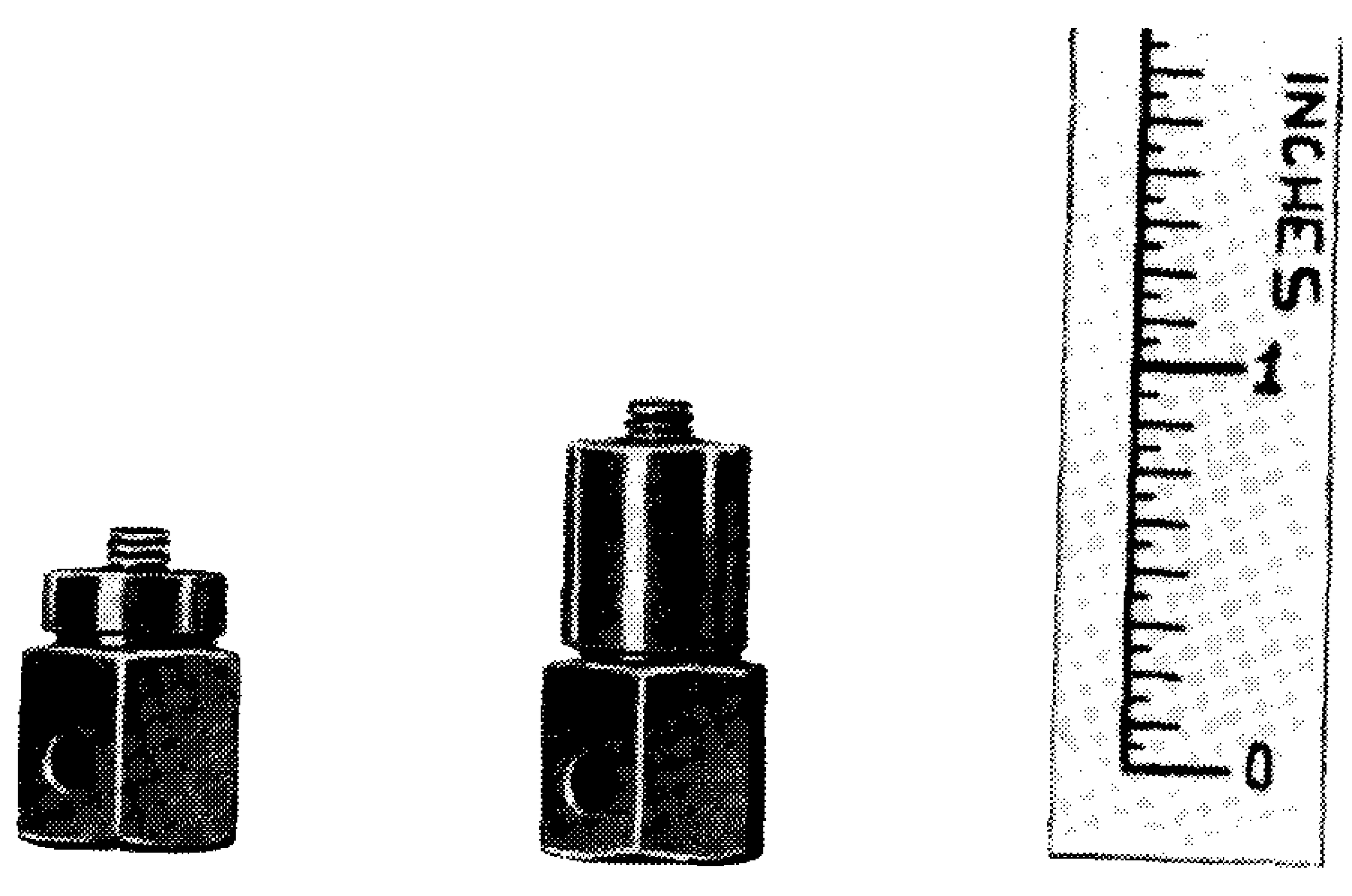

Fig. 5. Photo of the Accelerometers Type 4308 and 4309.

The B.F.O. Type 1015 is less refined than the Automatic Vibration Exciter Control, as it contains no built-in Vibration Meter, nor motor drive or automatic cross-over arrangement. The output power, however, is much higher than that available from Type 1016, which enables the instrument to be used without power amplifier for the vibration testing of small, leight weight components at not too high g-levels. It is furthermore well suited for laboratory development work. Fig. 6 shows a photo of the instrument.

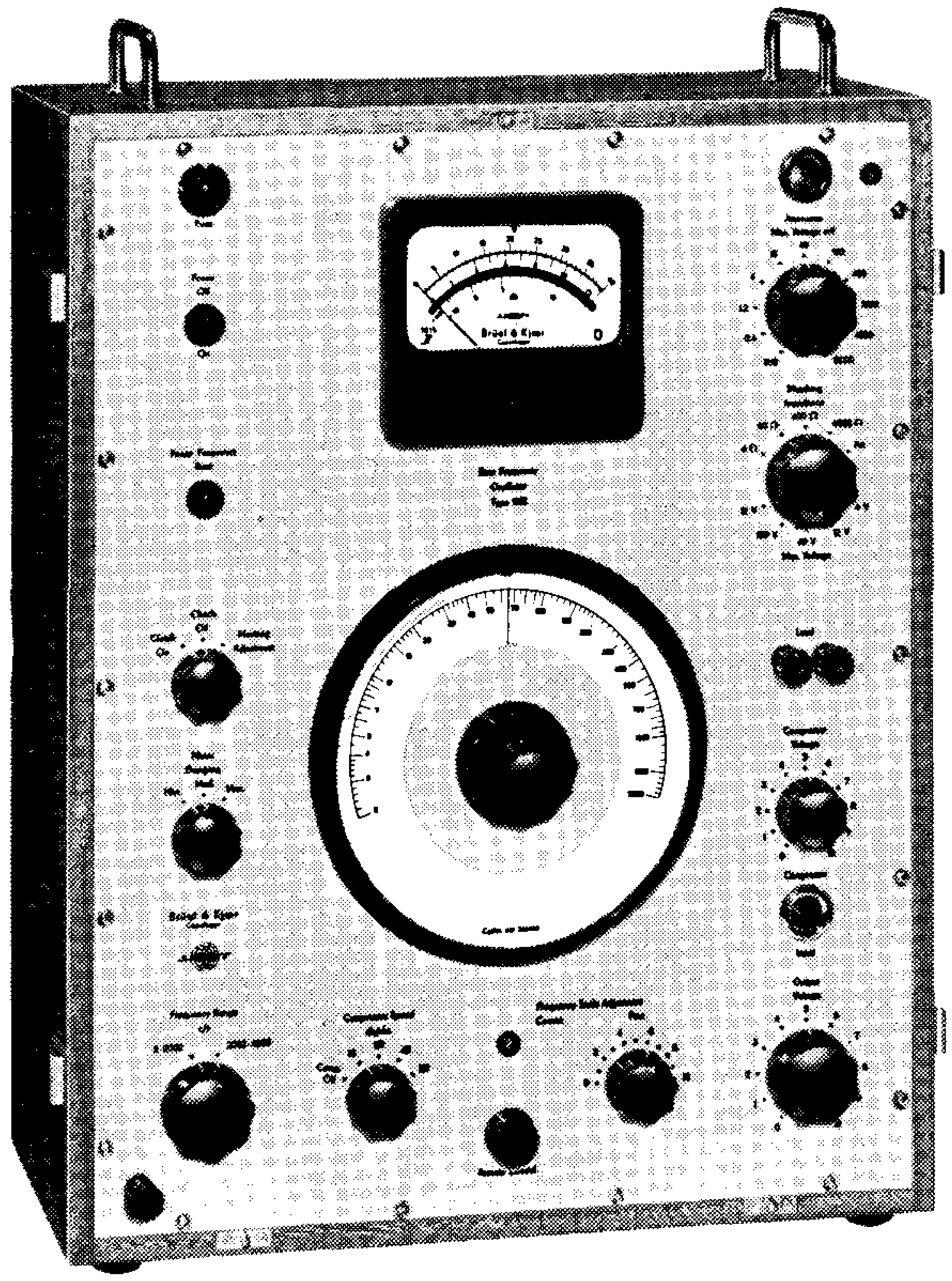

Fig. 6. Photo of the B.F.O. Type 1015.

As previously mentioned, a random motion test should be preceded by a frequency sweep test at a low vibration level, enabling the equalizers of the test arrangement to be correctly adjusted before the actual test is carried out.

A measuring set-up for the frequency sweep test preceding a random motion test is shown in fig. 7 employing the B.F.O. Type 1015 and the High Speed Level Recorder Type 2304*.

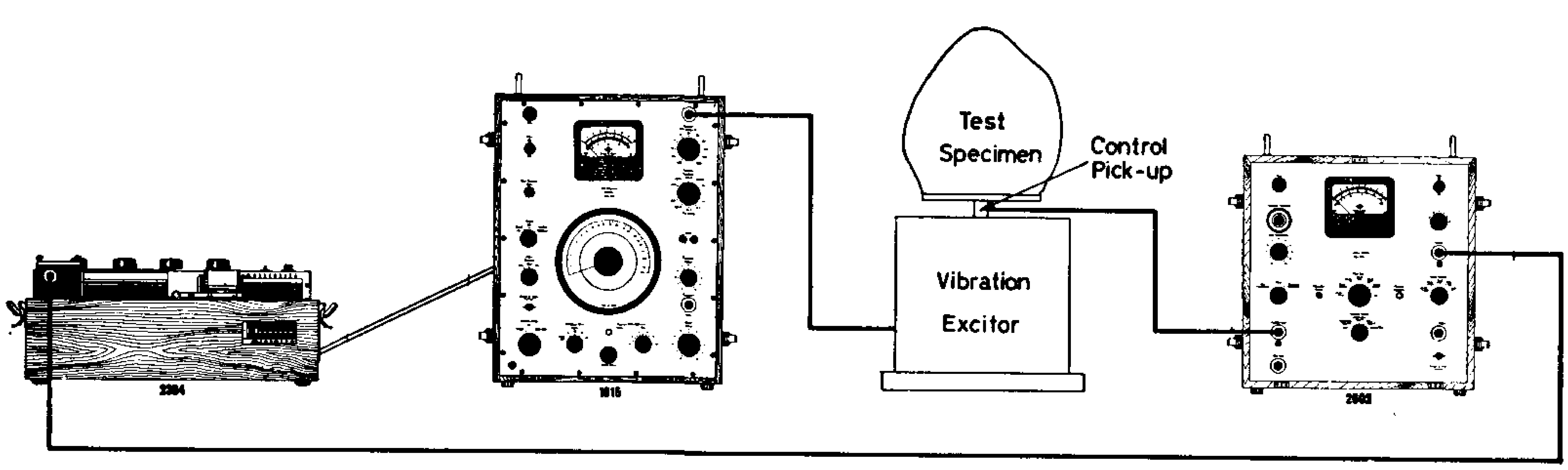

Fig. 7. Measuring arrangement suitable for the determination of system frequency characteristics.

* The frequency characteristic of Type 2304 is linear from 20 c/s to 200ooo c/s only.

The tuning capacitor of the B.F.O. is driven automatically from the motor drive in the Level Recorder, and the frequency sweep is synchronized with the drive of the preprinted, frequency calibrated recording paper.
The output from an accelerometer mounted on the shaker table is amplified by means of, for example, the Microphone Amplifier Type 2603 or the Spectrometer Type 2110 in connection with the Vibration Pick-up Pre-amplifier Type 1606, and fed to the input of the Level Recorder.
The equalizers of the random motion control panel should now be set to compensate for the peaks and notches in the frequency characteristic of the system, and a renewed frequency sweep of the B.F.O. should be made to make sure that the equalizers are properly set. The frequency characteristic of the system should then be a straight horizontal line on the recording paper.
To give the reader, who has not previously been involved in vibration testing, an idea of the variety of the test conditions. it might be mentioned that vibration tests are now carried out on structures ranging from complete air-frames to small parts, like vacuum tubes and miniature electro-mechanical relays. In case of small components, the conditions, under which a specific duration vibration test should be carried out, are normally specified according to the vibrations measured in practice at the place where the component is to be mounted.

Many, if not most, vibration tests are also carried out in environmental chambers at specified temperatures, pressures and humidities.

Fig. 8 shows a photo of typical units used in vibration test systems. The

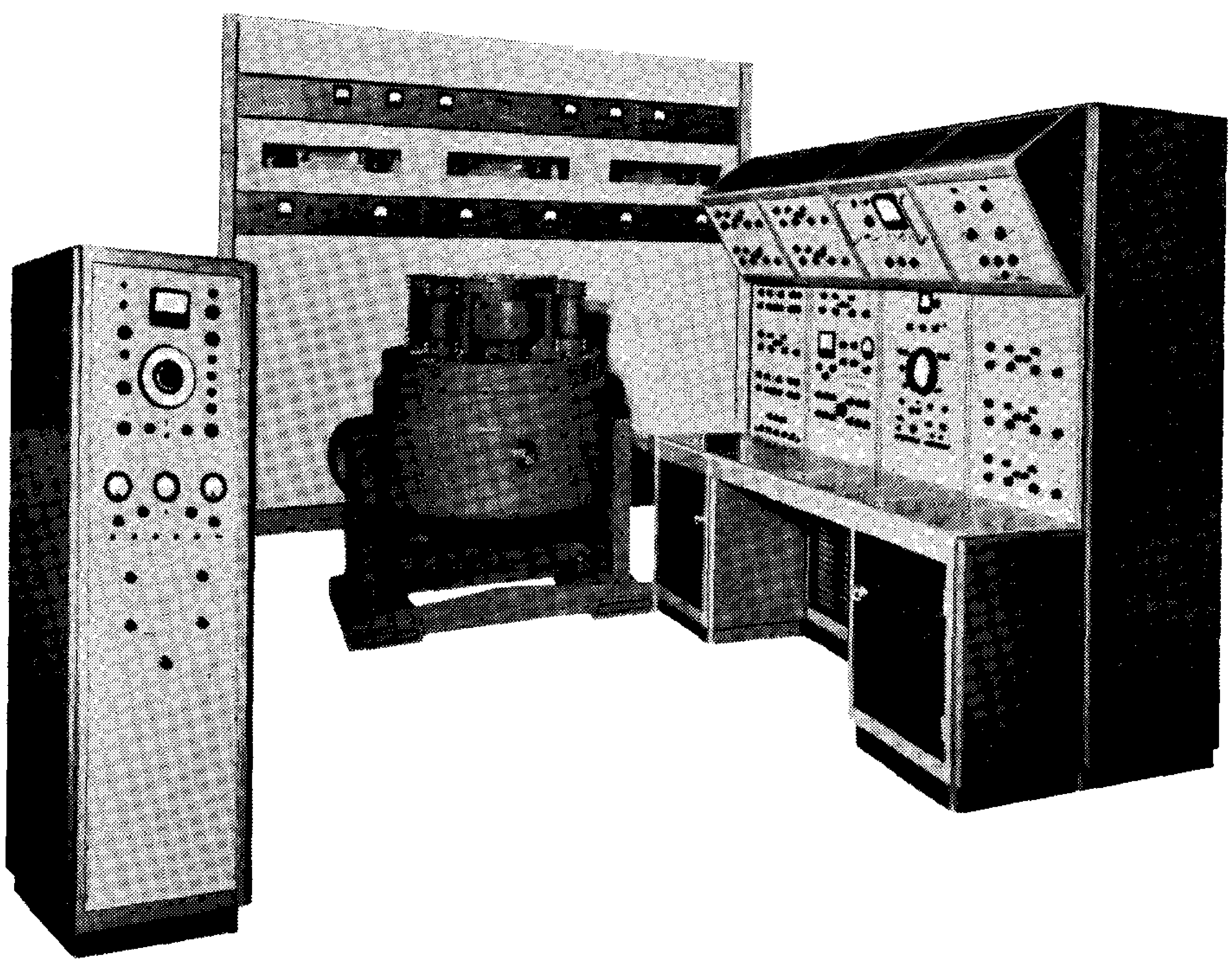

Fig. 8. Photo of some typical units in vibration test systems. (MB Mfg. Co., New Haven, Conn., U.S.A.).

units shown are made at and supplied from the MB Manufacturing Company in New Haven, Connecticut, U.S.A.

To the left on the photo, a relatively small size electronic unit designed for frequency sweep tests can be seen. In the back-ground a large power amplifier and a medium size vibration exciter are shown, and to the right the control unit for a random motion test arrangement is placed.

Automatic Level Regulation of Vibration Exciters.

by

Jens T. Broch
Dipl. ing. E.T.H.

Summary.

The basic theory of electronic level regulation is given and the differential equation governing the regulation developed with special regard to the Automatic Vibration Exciter Control Type 1016. From this equation and the regulation characteristic of Type 1016 the dependency of the regulation time constant upon the amount of "compression" used is found.

Résumé:

La théorie fondamentale de la régulation automatique de niveau est donnée de même qu'est développée l'équation différentielle régissant la régulation, spécialement axée sur le dispositif de réglage automatique d'excitation aux vibrations, type 1016. Partant de cette équation et de la caractéristique de régulation de l'appareil type 1016, on trouve la relation entre la constante de temps et le degré de «compression» utilisé.

Zusammenfassung:

Nach Einführung in die theoretischen Grundlagen der elektronischen Reglung wird eine Differentialgleichung unter besonderer Berücksichtigung des Regelgenerators 1016 abgeleitet, welche zusammen mit den Regelkennlinien des Gerätes die Beziehungen zwischen der Regelzeitkonstant und der Kompression darlegt.

When mechanical components are vibrated at a frequency in the immediate neighbourhood of resonance forces are developed in the vibrating system which are much greater than the one originally applied. This means that the loading of the vibration exciter will vary considerably with frequency, depending upon the system resonances. To keep a constant vibration level over a wide frequency range some sort of regulation must thus be employed. In frequency sweep test systems the desired regulation is normally obtained by means of electronic feed-back arrangements. A vibration pick-up built into the shaker table (signal generator coil) then supplies the reference voltage necessary for the regulation, and the vibration level of the shaker is regulated by varying the magnitude of the driving signal. The variation in signal magnitude is achieved by changing the amplification of one or more of the amplifier stages in the driver system.

One of the most important considerations in the design of such a level regulator is to determine the regulation time, i.e. the time passing from a change in vibration level is "felt" by the pick-up until the original vibration level of the shaker is regained. This time should be as small as possible to prevent undesired level changes to build up during the frequency sweep of the driving Oscillator. However, at low vibration frequencies a high regulation speed (small regulation time) result in interaction effects between the regulation and the actual wave shape of the signal to be regulated. Both the regulation speed and the frequency sweep speed of the Oscillator should therefore be variable in order to obtain the most preferable conditions for each vibration test.

Although different types of regulator design may be used in practice an analysis of the output regulator in the Automatic Vibration Exciter Control Type 1016 will give the reader a good idea of the functioning of electronic regulation systems.

Type 1016 consists of an oscillator section and a regulating amplifier section with indicating meter for monitoring the vibration level.

The oscillator section consists of two audio frequency oscillators and is working according to the heterodyne principle, see fig. 1. The regulation of the oscillator output is accomplished in the variable μ-amplifier stage, fig. 1, which is an amplifier stage working constantly at one of two fixed frequencies only. Two great advantages are gained by employing this stage for the regulation:

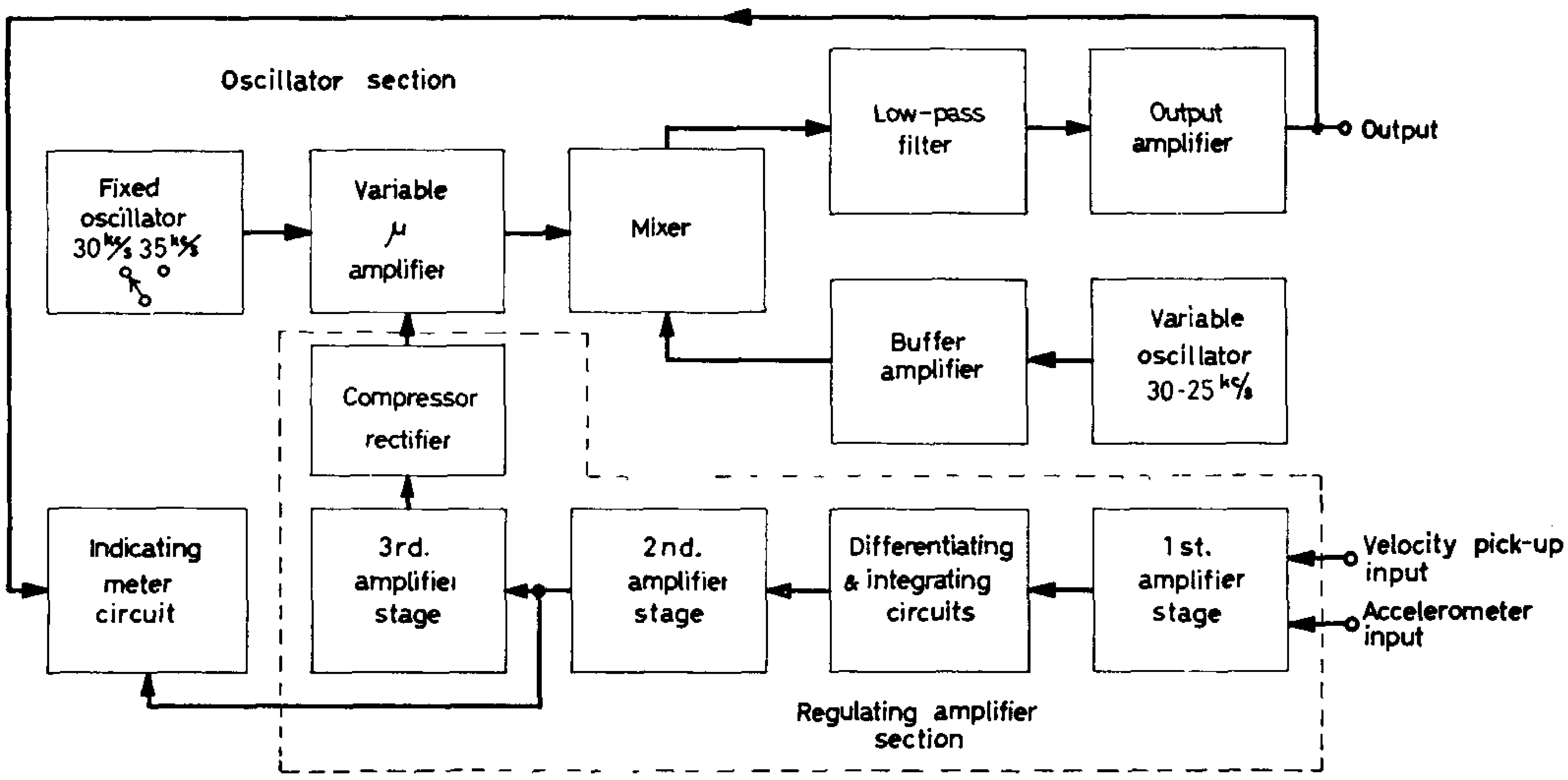

Fig. 1. Block diagram of the Automatic Vibration Exciter Control Type 1016.

1. The signal level is still so small that a wide dynamic regulation range can be obtained electronically.
2. The harmonic distortion, which necessarily will be introduced because of the non-linear amplification characteristic of the stage, can be readily "eliminated" by means of a simple band-pass filter in the output circuit.

The regulation is obtained by using the rectified voltage from the regulating amplifier section of Type 1016 (compressor) to bias a pentode type tube in the variable μ-amplifier stage.
To ensure a high degree of regulation, the working point of the pentode is chosen on the non-linear portion of the plate current-grid voltage characteristic, near cut-off.

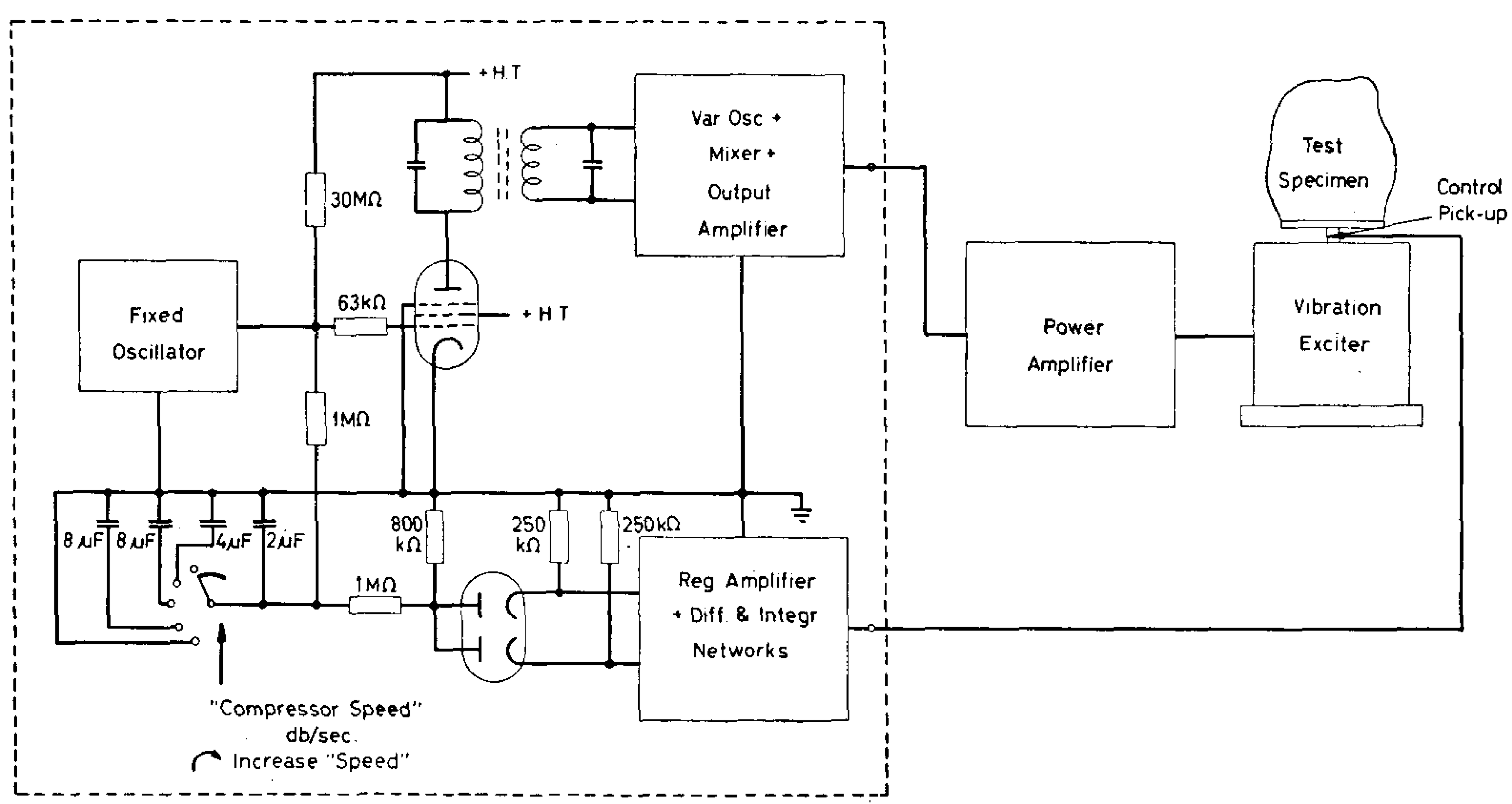

Fig. 2. Simplified diagram of the regulation arrangement.

Fig. 2 shows a diagram of the regulation arrangement. The switch marked "Compressor Speed" changes the time constant in the rectifier circuit and thereby the speed with which the regulation takes place. Basically, the regulation arrangement functions as a normal negative feed-back system, and the time constant of the system will depend on the amount of feed-back employed. This can be seen from the following:

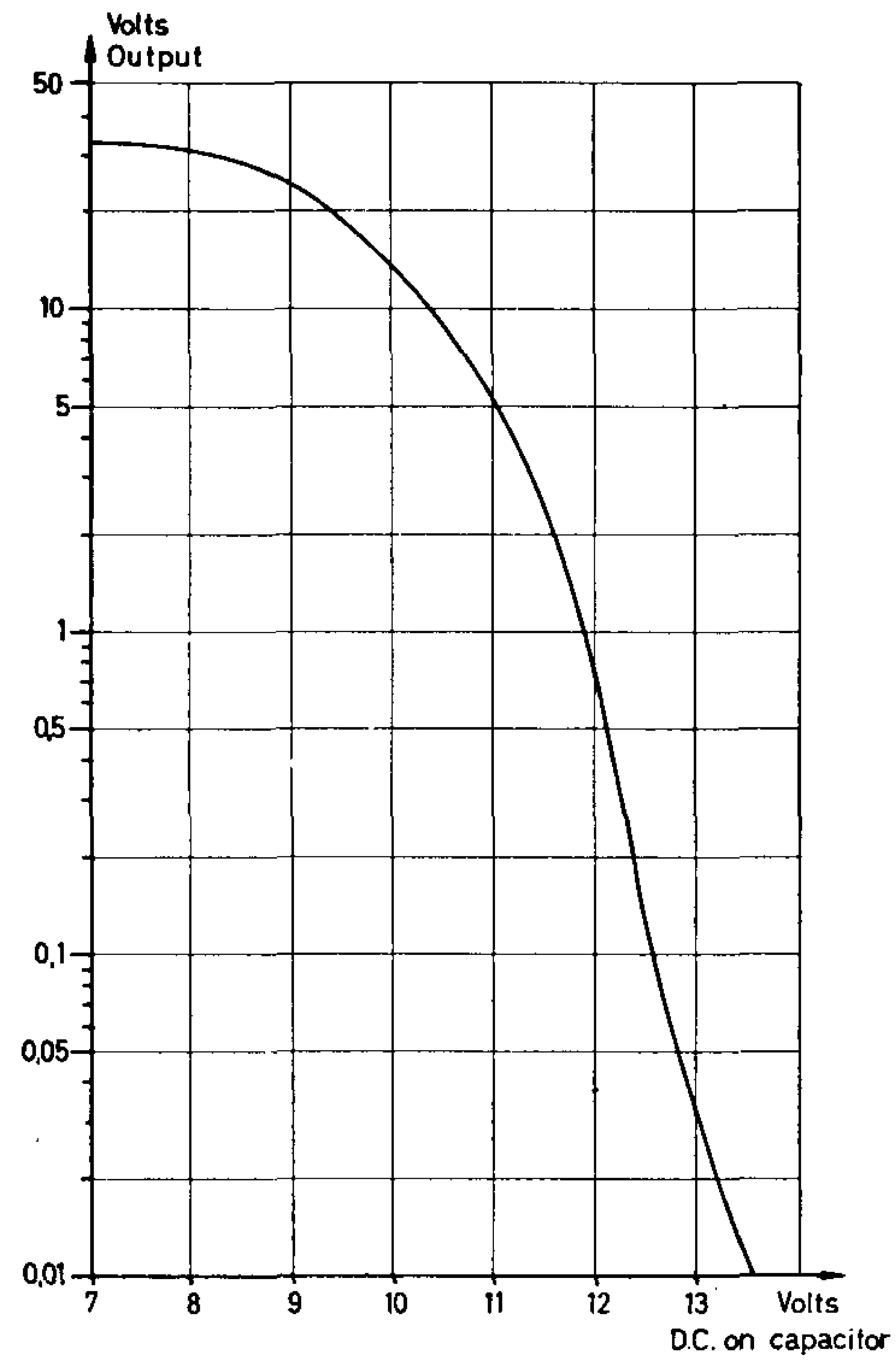

Fig 3. Typical "regulation characteristic" of Type 1016 plotted on voltage level basis.

In fig. 3 the output from the Oscillator is plotted against the voltage on the capacitor of the rectifier filtering network (fig. 2), and fig. 4 shows the same curve plotted on a relative basis (db).

Assuming the time delays in the amplifiers to be very small compared with the one in the rectifier filtering circuit itself, the time constant of the regulation will depend both upon the components of this network and the slope of the regulation characteristic, shown in figs. 3 (and 4), at the actual working point. The working point itself is chosen according to the amount of regulation desired, which again will depend upon the expected Q-values of the specimen resonances.

Now, assume the working point of the regulator to be "a", fig. 4, and a sudden increase in the vibration level of the shaker table of 10 % to take place (step function). The voltage, V_c, on the capacitors in the rectifier filtering network will then start to increase, according to the exponential curve shown in fig. 5. The time marked T_o in the figure is the R-C time constant of the filtering network.

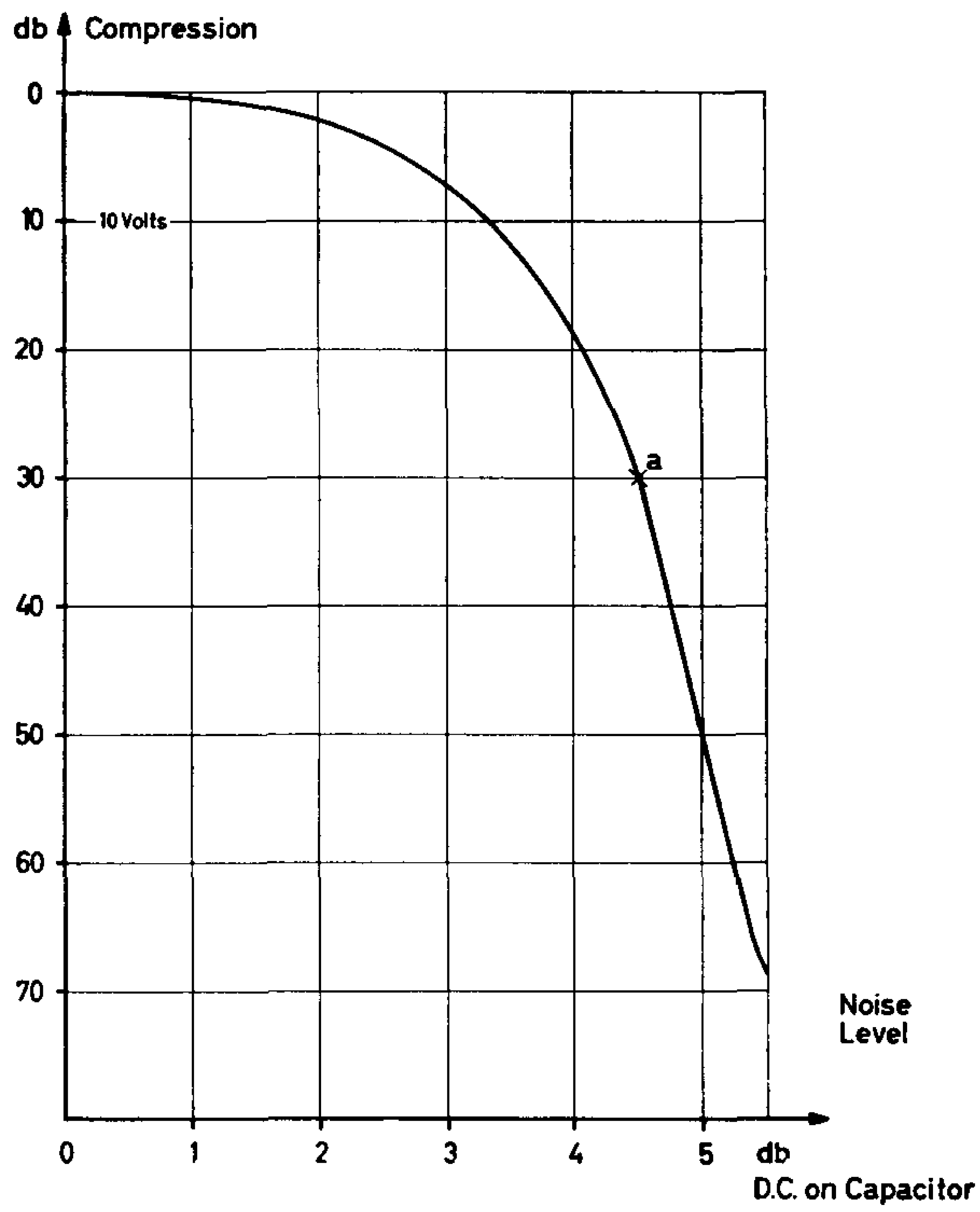

Fig. 4. The regulation characteristic of fig. 6 plotted on relative level basis (db).

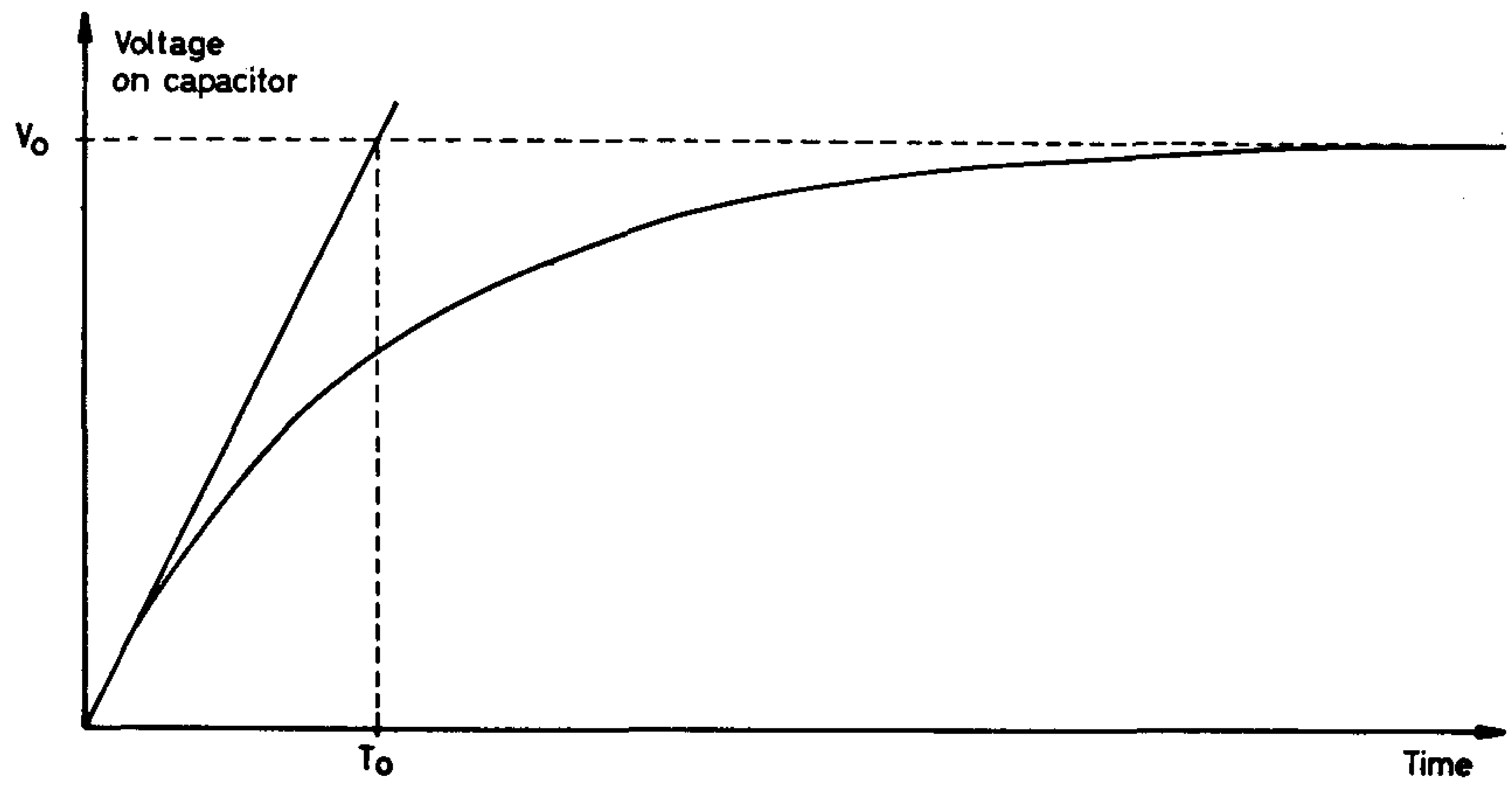

Fig. 5. Curve showing the transient d.c. voltage on the capacitor in a normal R-C filter network (step function input).

However, to reduce the output from the Oscillator, V_o, and thereby the vibration level of the table 10 %, an increase in the voltage on the capacitor of only o.3 % is necessary. This may be seen by referring to figure 4 (or fig. 3) where a 10 % (approx. 1 db) variation in the compression level is obtained by a o.3 % (approx. o.03 db) variation in the voltage on the capacitor.
The actual regulation time constant will therefore depend on the loop amplification of the system.

To investigate the dynamics of the regulation further, the factor α obtained by differentiation of the regulation characteristic fig. 4, and defined below, is shown in fig. 6.

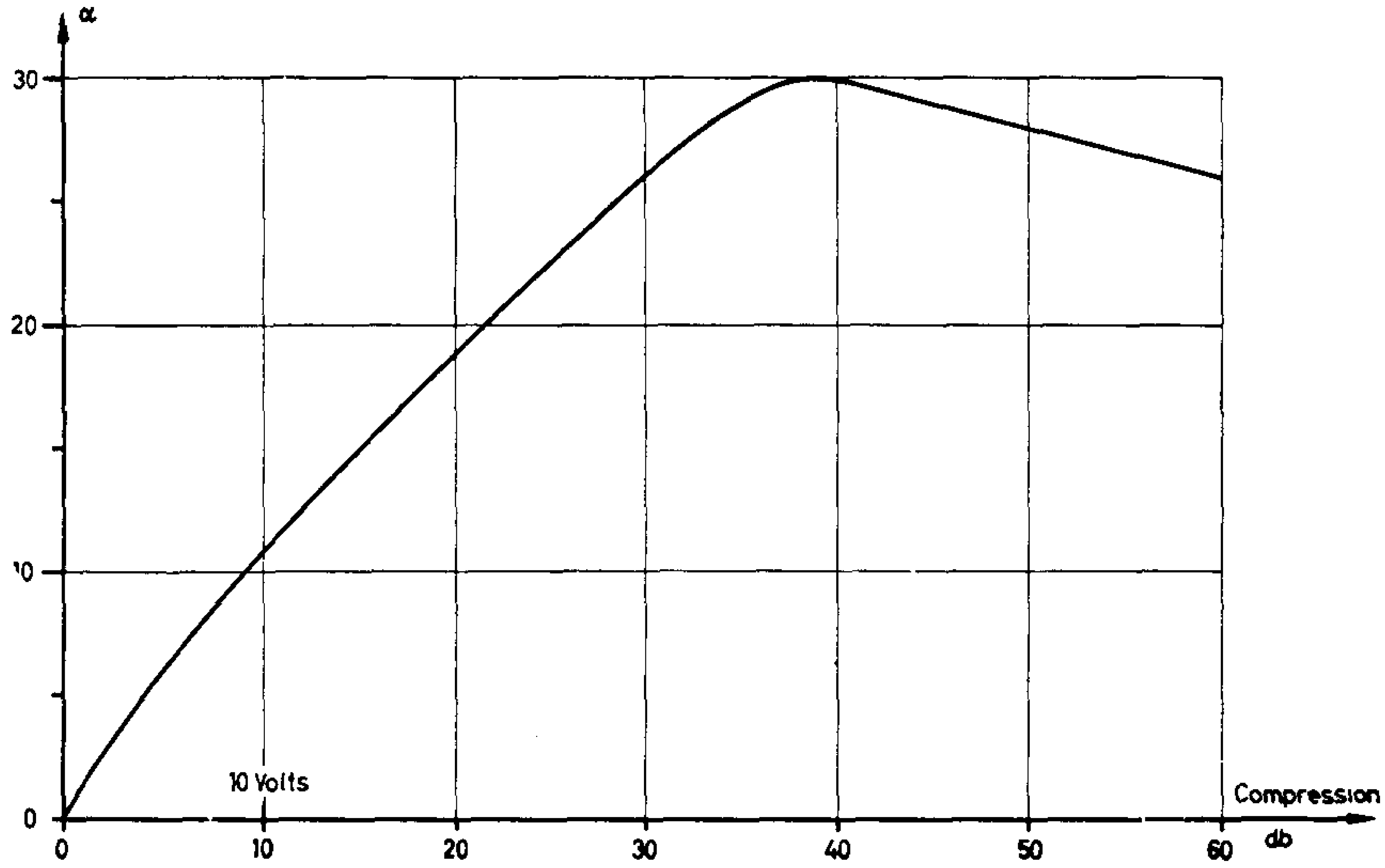

Fig. 6. Differential curve of fig. 4.

The factor α is, by definition:

$$\alpha = \lim_{\Delta V \to 0} \left(\frac{20 \log \left(\frac{\Delta V_o + V_o}{V_o} \right)}{20 \log \left(\frac{\Delta V_c + V_c}{V_c} \right)} \right) = \frac{\frac{\Delta V_o}{V_o}}{\frac{\Delta V_c}{V_c}}$$

and fig. 6 shows α as a function of the amount of compression employed (voltage ratio of the actual output from the Oscillator to the max. available output).

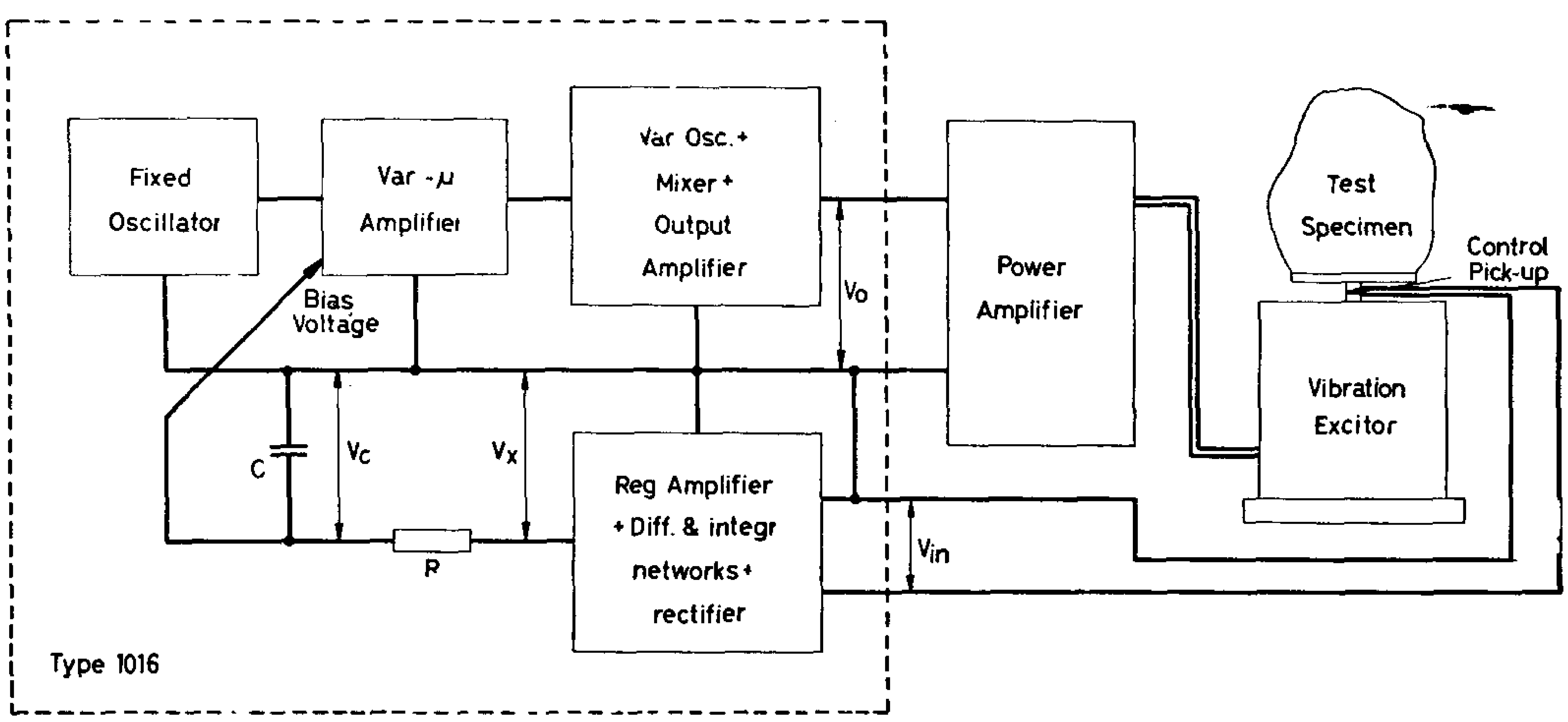

Fig. 7. Block diagram of the test set-up showing the simplified "Compressor Speed" network used to find the differential equation governing the regulation.

Reducing the R-C filtering network to a single equivalent R and C, the differential equation governing the regulation can be formulated — see also fig. 7:

$$RC \frac{dV_c}{dt} + V_c = V_x$$

The voltage V_x will, because of the closed loop, at any moment depend upon the voltage V_c on the capacitor (fig. 7).
Assuming the voltage V_{in} to suddenly increase an amount ΔV_{in} the voltage V_x will also increase an amount ΔV_x proportional to ΔV_{in}. Looking at the dynamics of the system, the above equation can be written:

$$RC \frac{d\Delta V_c}{dt} + \Delta V_c = \Delta V_x$$

Furthermore is:

$$\frac{\Delta V_o}{V_o} = -\alpha \frac{\Delta V_c}{V_c} \quad \text{ɔ:} \quad \Delta V_o = -\alpha \frac{V_o}{V_c} \Delta V_c$$

and:

$$\frac{\Delta V_x}{V_x} = \frac{\Delta V_{in}}{V_{in}} = \frac{\Delta V_o}{V_o} \quad \text{ɔ:} \quad \Delta V_x = \frac{V_x}{V_o} \Delta V_o$$

or:

$$\Delta V_x = -\alpha \frac{V_x}{V_c} \Delta V_c = -\alpha \beta \, \Delta V_c = -\gamma \, \Delta V_c$$

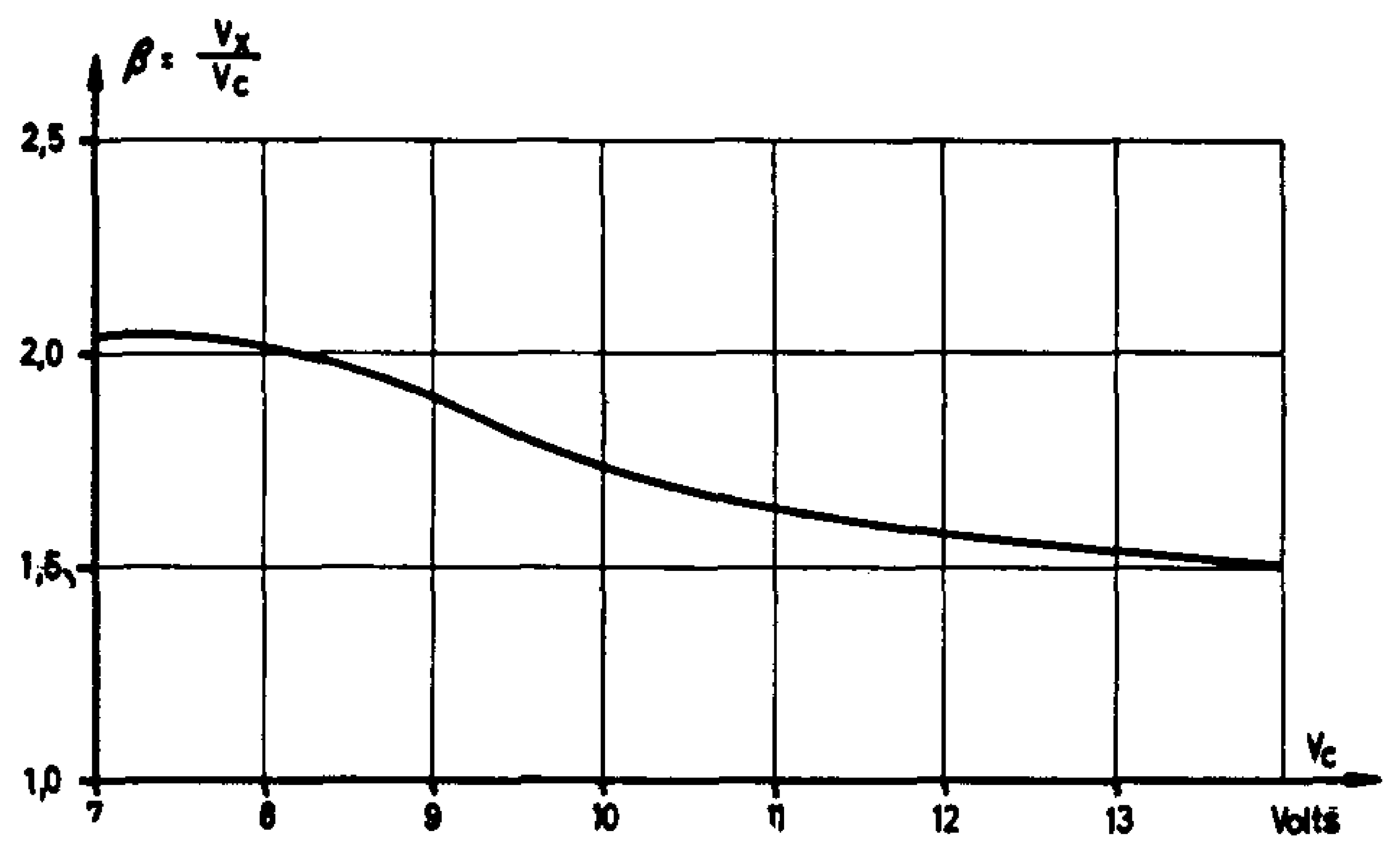

Fig. 8. Curve showing the dependency of the factor β upon the voltage V_c.

In fig. 8 β is plotted as a function of the voltage V_c on the capacitor and fig. 9 shows the factor $\gamma = \alpha \times \beta$ versus the amount of compression employed.

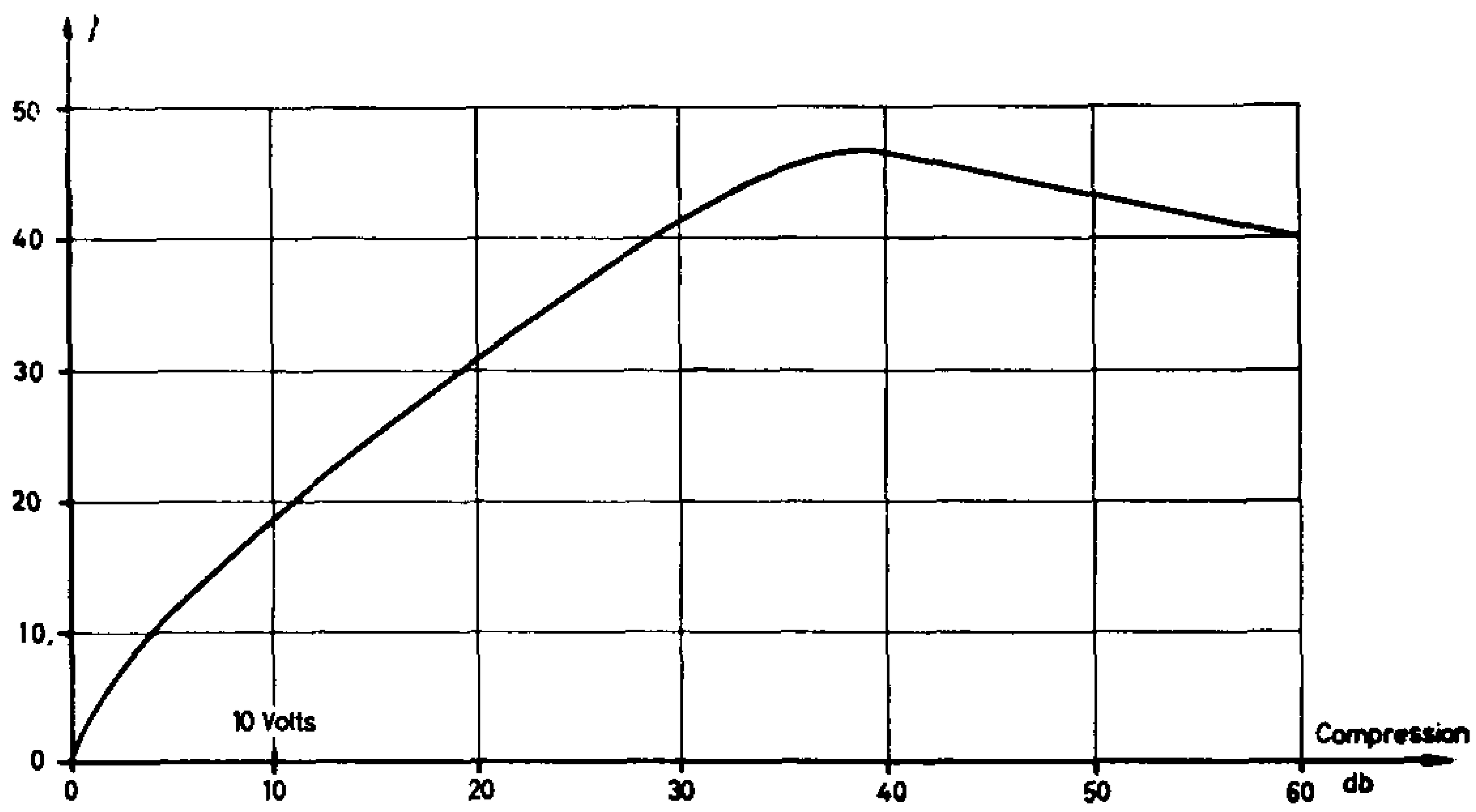

Fig. 9. The differential loop-amplification γ plotted against the amount of compression employed.

The differential equation for the system dynamics then becomes:

$$RC\frac{d\Delta V_c}{dt} + \Delta V_c = -\gamma\ \Delta V_c$$

or:

$$RC\frac{d\Delta V_c}{dt} + (1 + \gamma)\ \Delta V_c = 0$$

This is the well-known equation for the dis-charging of a capacitor through a resistor. The time constant is in this case, however:

$$T = \frac{RC}{1 + \gamma} = \frac{T_o}{1 + \gamma}$$

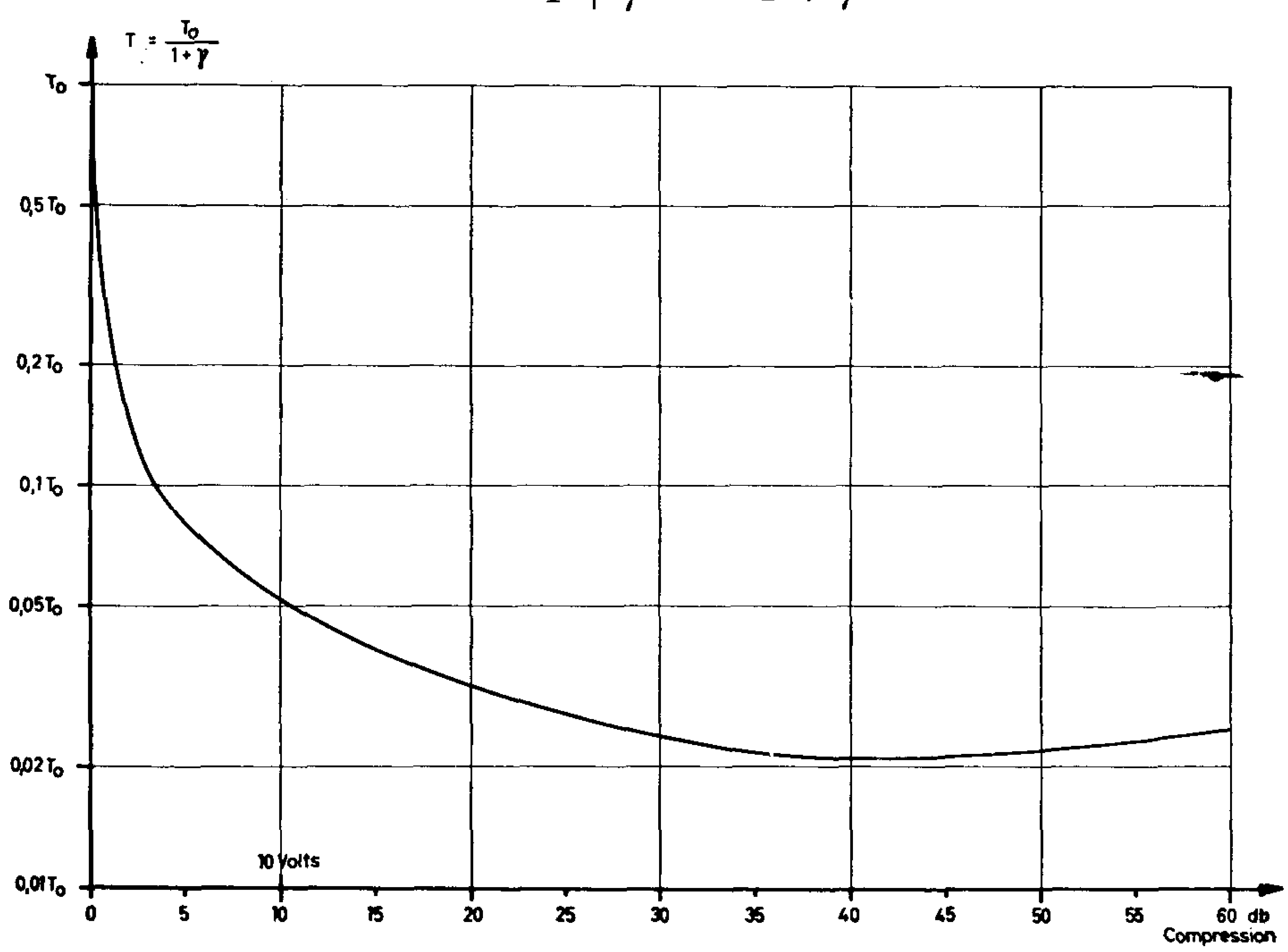

Fig. 10. Curve showing the variation of the regulation time constant T with compression.

where γ is the differential loop-amplification which is large and positive in the operating range.

The variation of the regulation time constant T with the amount of compression is shown in fig. 10.

The above analysis is based on small voltage changes in the system (differentials). When greater changes are induced, the time constant of the regulation will differ from the values given in fig. 10, due to the non-linearity of the regulation curve. It will then also depend upon whether the change in input to the vibration meter consists of a decrease or an increase in the applied voltage.

The practical use of the curve shown in fig. 10 presupposes that the equivalent RC time constant T_0 (fig. 7) is known. In the case of Type 1016 T_0 will depend upon the position of the switch marked "Compressor Speed" and is:

Compressor Speed:	T_0
10 db/sec	~ 33 sec
20 db/sec	~ 21 sec
40 db/sec	~ 9 sec
80 db/sec	~ 3 sec

An electronic regulation system, such as the one described has several advantages above other types of regulators (e.g. electro mechanical servo mechanisms). First of all it is relatively inexpensive. Furthermore, a wide dynamic regulation range is obtained with a high degree of accuracy, and regulation speeds can be achieved which are much greater than when electro-mechanical components are employed in the regulation system.

The system described in this article has been applied to all the electronic signal sources produced by Brüel & Kjær, of which Type 1016 is a typical example.

News from the Factory.

Modification of Strain Gauge Apparatus Type 1516.

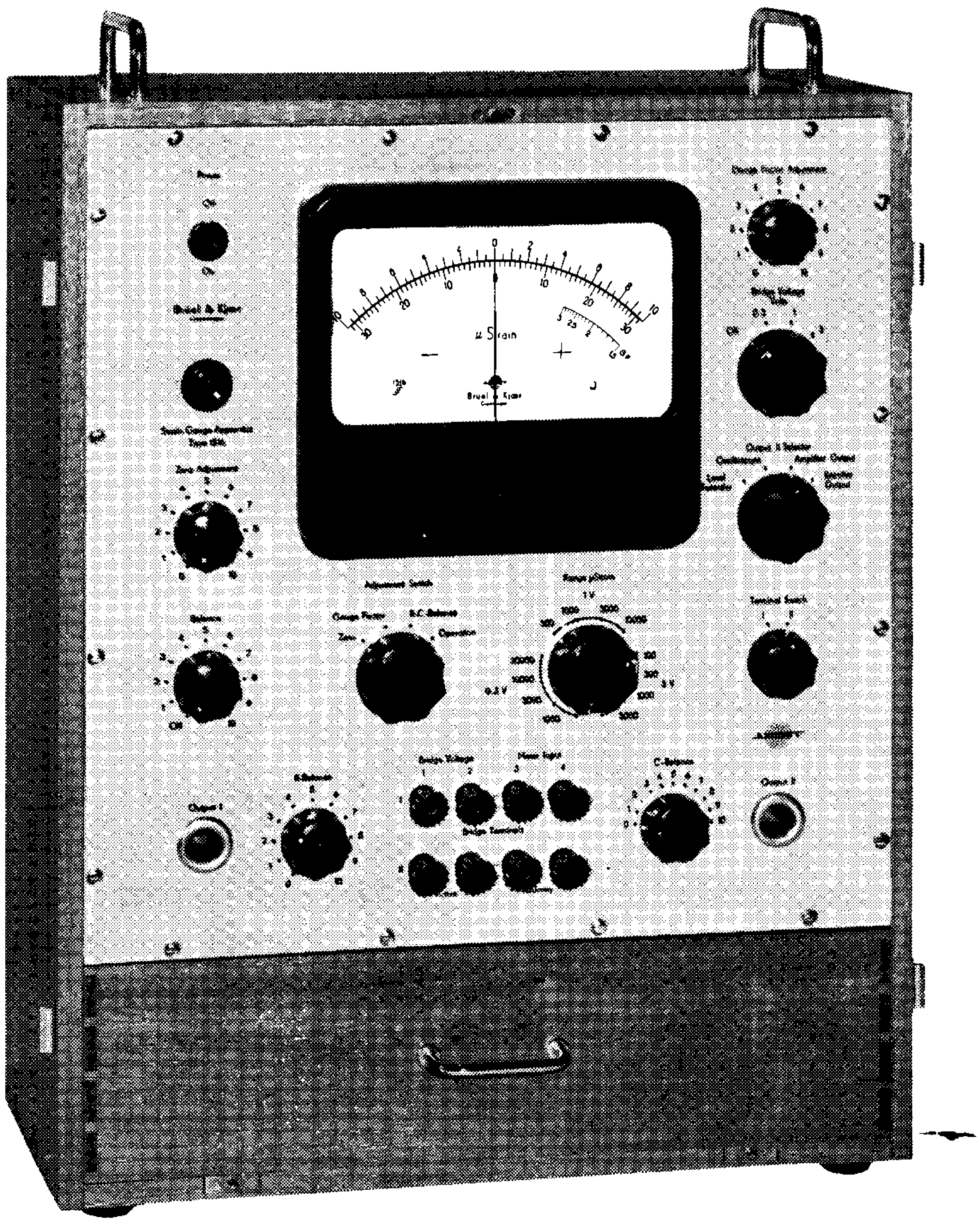

Fig. 1. Photo of Type 1516.

The main unit in the B & K strain measuring systems, the Strain Gauge Apparatus Type 1516, has been partly redesigned to make it still more convenient for some of its applications.

The instrument meter itself has been replaced by a large square type meter. Furthermore the oscillator and some of the amplifier stages have been redesigned featuring:

Influence of mains voltage variations of ± 10 % upon the measured result smaller than ± 1 %.

Harmonic distortion of bridge voltage even with a load of 10 ohms smaller than 2 %.
Amplifier noise and microphonics reduced to a minimum.
Low source impedance for all output facilities except "Output I" (the bridge diagonal).
Wide linear frequency range of the amplifier (20—100ooo c/s).
A photo of the "new" Type 1516 is shown in fig. 1.

Modification of Vibration Pick-up Preamplifier Type 1606.

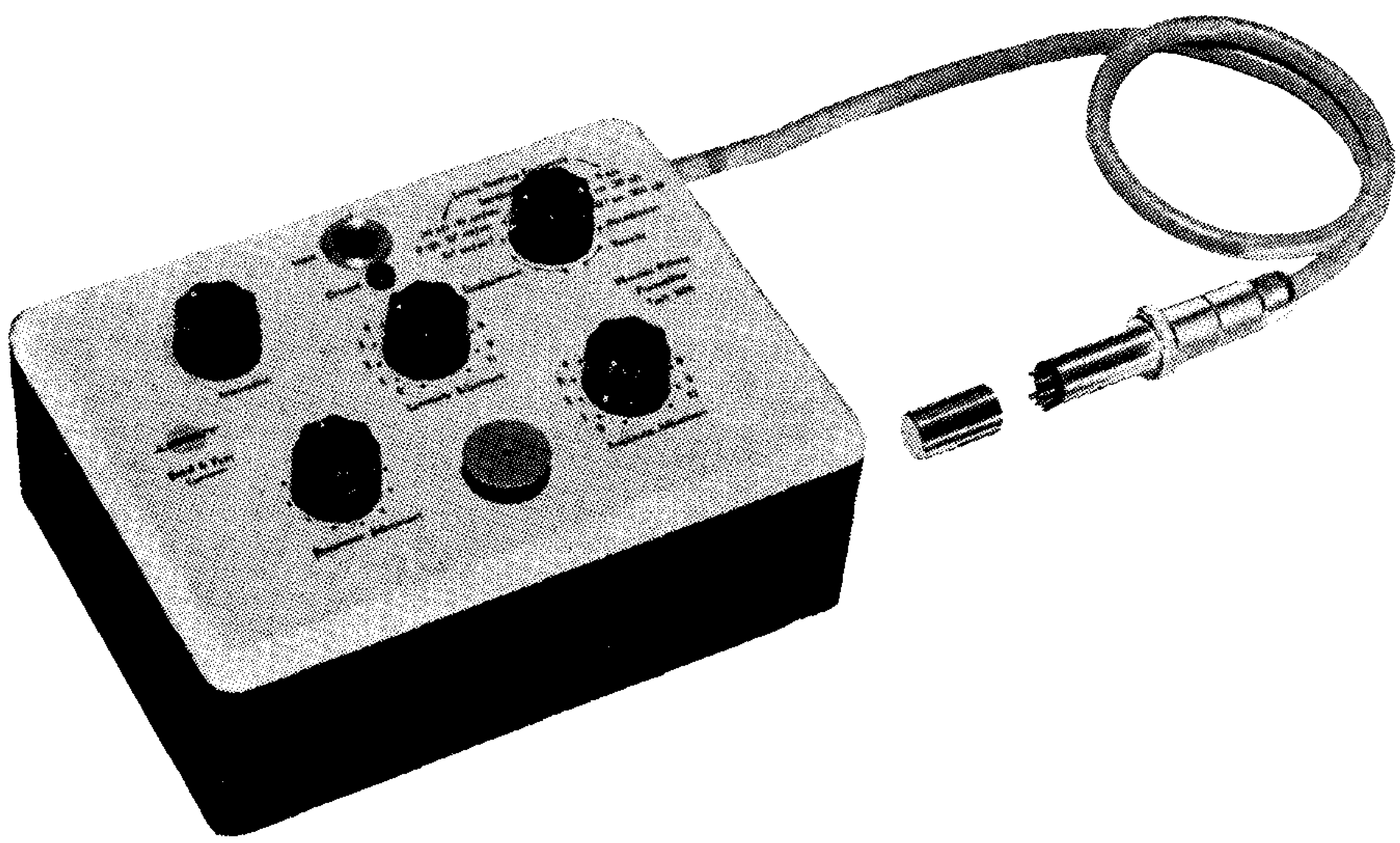

Fig. 2. Photo of the "new" Vibration Pick-up Preamplifier Type 1606.

The small shaker table for accelerometer calibration built into the Preamplifier Type 1606 has been modified to enable more accurate determination of the vibration level.
Previously the acceleration level of the shaker table was determined by means of the rattling of a small nut which could be placed on the table itself. When the nut just started to rattle the peak acceleration was 1 G. However, the nut had a tendency to move outwards toward the edge of the table, and a slight error could therefore easily be introduced because of the difference in motion between the centre and the edge of the table.
In the new and modified Type 1606 the determination of the vibration level is based on the motion of a small sphere, supported on three points, and built into the hollow axis of the shaker table.
It is now very easy to determine the "point of rattling" of the sphere, either by listening, or by the meter deflection on one of the B & K Microphone Amplifiers or Analyzers. If the meter deflection is used for indication of the rattling the instrument filter switch should be set to position "Weighting Networks — DIN 3" or "DIN 2".
The peak acceleration level of the "point of rattling" is 1 G.

Motor Drive Type 3910.

Fig. 3. Photo of the Motor Drive Type 3910.

The Motor Drive Type 3910 is designed to guide the pick-up when surface roughness measurements are carried out by means of the Roughness Meter Type 6100. The simplicity in using the Motor Drive makes in a few seconds untrained persons able to measure surface roughness perfectly. Consisting of a small motor, an electromagnetic coupling device, and a mechanical connection to the pick-up the Motor Drive Type 3910 features:

Two absolutely constant traversing speeds.
Easily adjustable traversing lengths.
Adjustable height of the pick-up holder over the measuring surface.
Very short reversing time.

A photo of Type 3910 is shown in fig. 3.

Microphone Amplifier Type 2603.

Type 2603 is a complete redesign of the Microphone Amplifier Type 2602 and has a linear frequency range from 2 c/s to 35000 c/s.
It is equipped with the internationally standardized weighting networks for sound level measurements and contains furthermore a switch by means of which the meter can be switched to indicate either the peak, the arithmetic average or the true R.M.S. value of the input signal. A true R.M.S. indication is obtained for signals with crest factors up to 5.
To obtain an accurate meter reading at the very low frequencies two different meter dampings can be selected:

Meter damping in accordance with the standards for sound level measurements.

Heavy damping for the measurement of very low frequency signals.

Some of the main features of Type 2603 and the new Audio Frequency Spectrometer Type 2110 will be described in Technical Review no. 3-1958. Fig. 4 shows a photo of the Microphone Amplifier 2603.

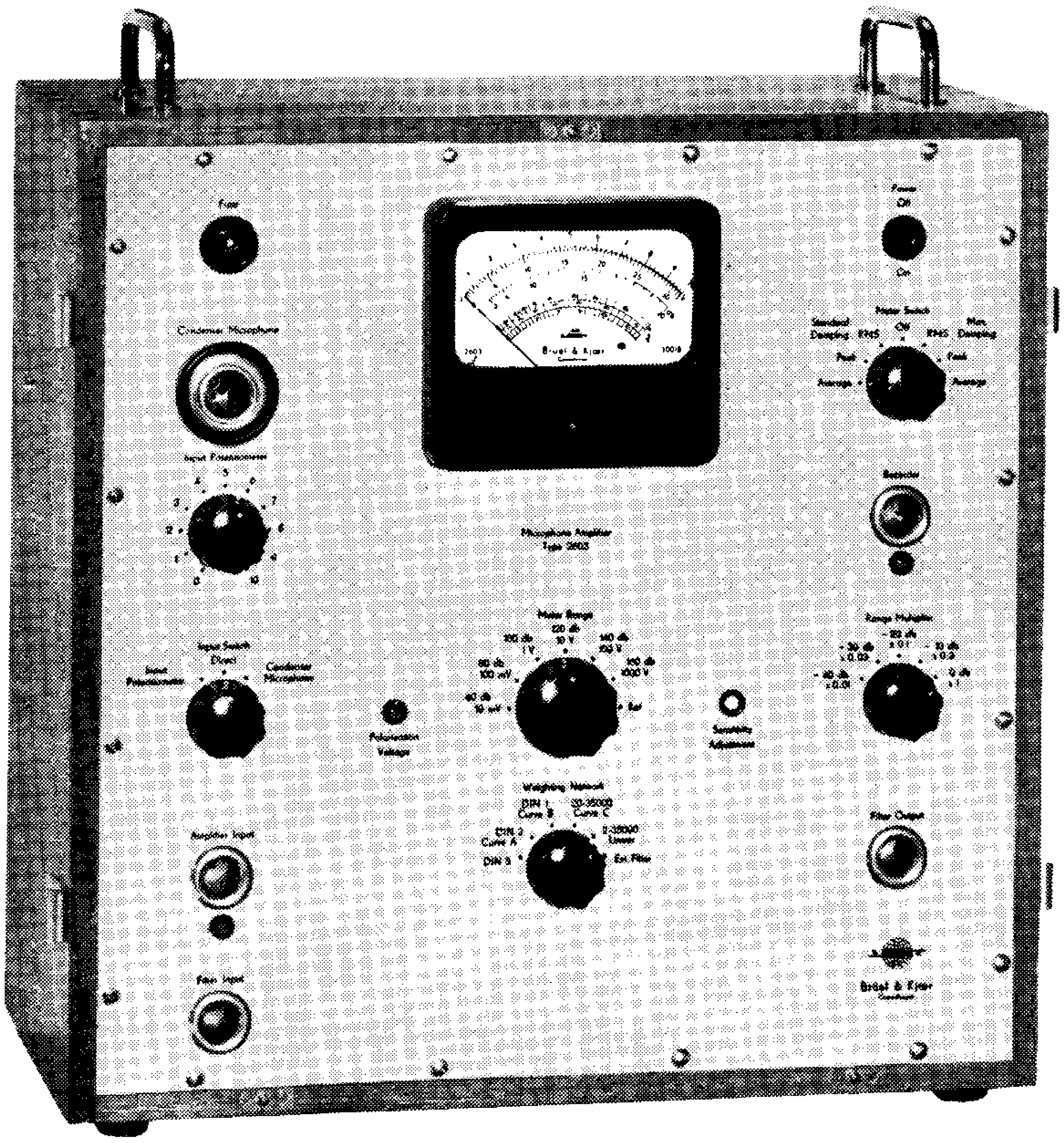

Fig. 4. Photo of Type 2603.

Noise Source Type 4240.

Fig. 5. Photo of the Noise Source Type 4240.

The Noise Source Type 4240 fig. 5 is designed to enable *quick and reliable field calibration of sound measuring equipment.*
It consists basically of two equal chambers one of which contains approx. 14000 1 mm precision steel balls of the type normally used in ball bearings. During operation the balls are falling from the upper chamber and hit a metal diaphragm, thereby producing the desired sound. After having hit the diaphragm they are falling further down into the lower chamber. This procedure will last for approx. 14 seconds and by turning the nylon housing of the Source 180° the process is started once again.
The R.M.S. sound pressure level at the microphone diaphragm is approx. 108 db; *each Noise Source, however, is separately calibrated.*

Deviation Bridge Type 1505.

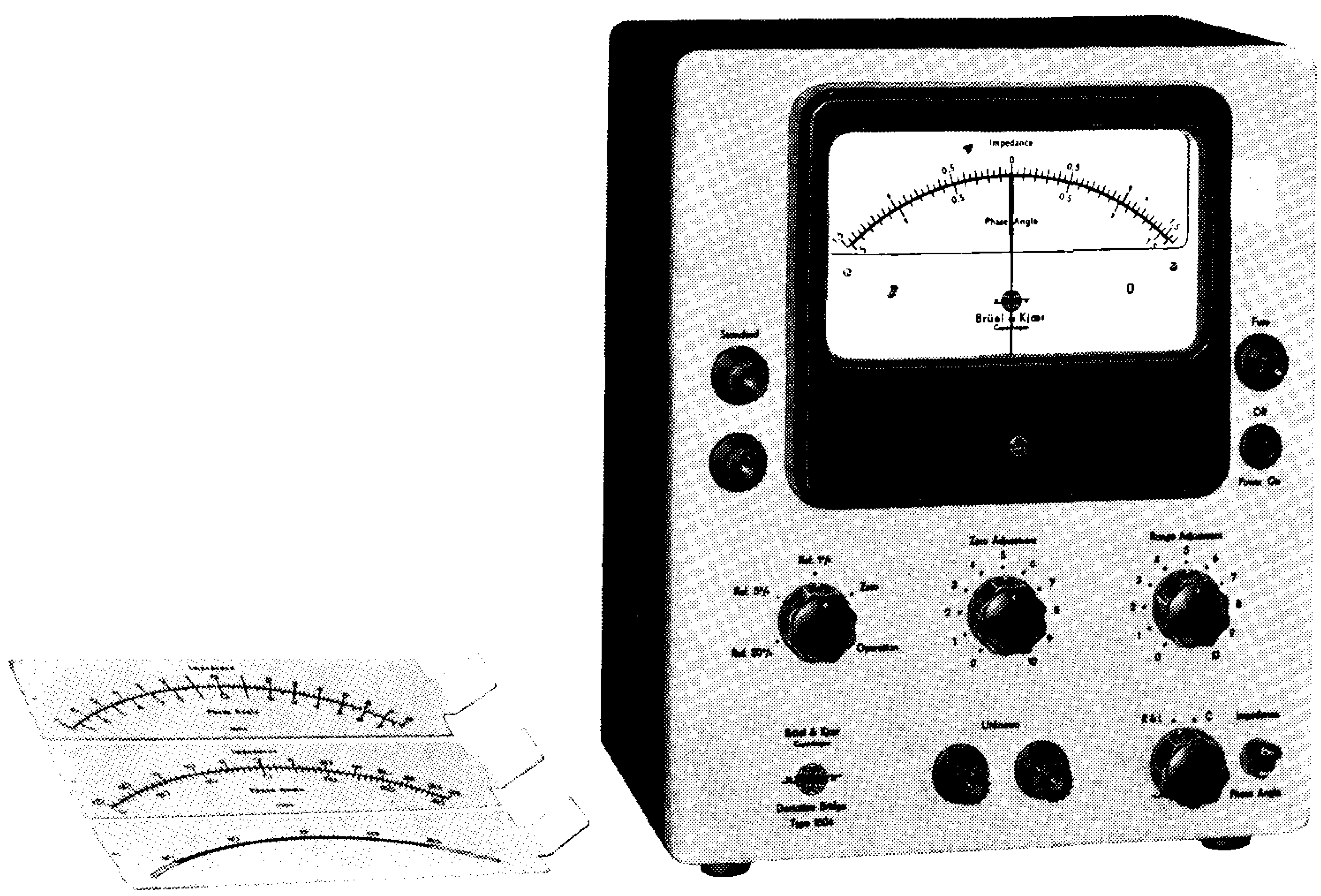

Fig. 6. Photo of the Deviation Bridge Type 1505.

The new Deviation Bridge 1505 operates at a frequency of 10 kc/s, thus satisfying the need for a test bridge overlapping the "gap" between the Bridges Type 1504 (1 kc/s) and Type 1506 (100 kc/s). It has been specially designed for the production control of magnetic heads and audio frequency transformers but has, similar to Type 1504 and 1506, several fields of application.
The following range of components can be tested:

Inductances	from o.2 mH to 10 H.
Capacitors	from 30 $\mu\mu$F to 1 μFd.
Resistors	from 10 Ω to 1 MΩ.

Three calibrated, interchangeable scales are supplied with the instrument:

Impedance deviations:	*Phase angle deviations:*
— 1.5 % to + 1.5 %	— 1.5×10^{-2} to + 1.5×10^{-2} radians.
— 7 % to + 8 %	— 7×10^{-2} to + 7×10^{-2} radians.
— 25 % to + 35 %	— 25×10^{-2} to + 25×10^{-2} radians.

Furthermore, three blank scales, which the user might calibrate for his specific application of the instrument are also included.

Brüel & Kjær

ADR.: BRÜEL & KJÆR
NÆRUM - DENMARK

TELEPHONE: 80 05 00
BRUKJA, Copenhagen

Printed in Copenhagen, Denmark