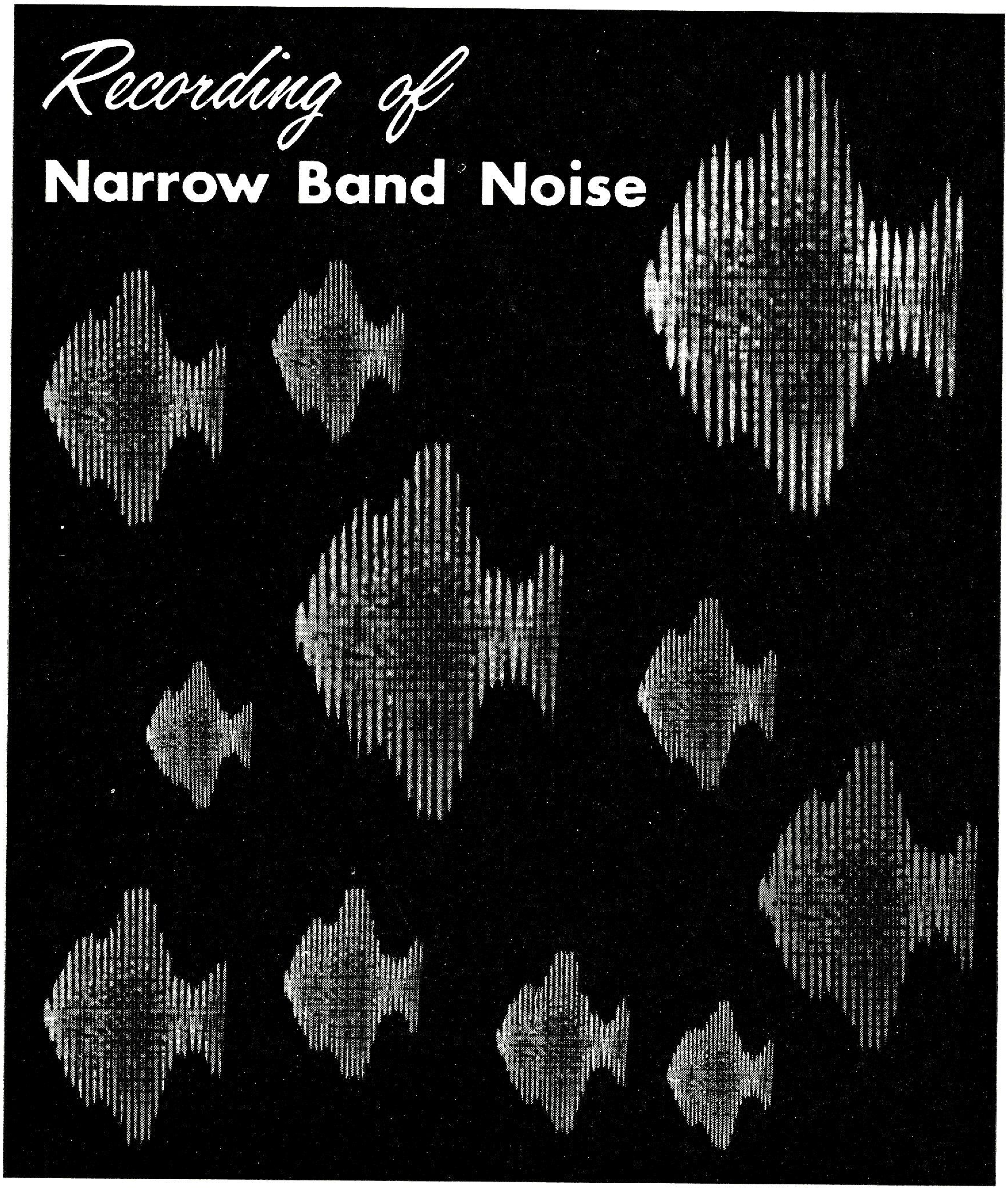
Brüel & Kjær

Technical Review

Teletechnical, Acoustical, and Vibrational Research

Recording of Narrow Band Noise



No. 4 1960

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DET BERLINGSKE BOGTRYKKERI

R. M. S. Recording of Narrow Band Noise with the Level Recorder Type 2305.

by

Jens T. Broch, Dipl-Ing. E.T.H. and *Carl G. Wahrmann,* M.Sc.

ABSTRACT

Following a brief description of the Level Recorder Type 2305, the properties of the r.m.s. detection and averaging circuit of the Recorder are discussed to some length. It will be found that the Recorder is capable of measuring the true r.m.s. value of any periodic signal with crest factors less than 5 and a fundamental frequency higher than the lower limiting frequency marked on the instrument. The true r.m.s. value of random input signals whose envelope fluctuations are of frequencies higher than approximately five times the lower limiting frequency of the Recorder are also accurately measured. However, on recording random signals with envelope fluctuation frequencies less than five times the lower limiting frequency, such as narrow band noise signals, the instrument does not indicate the true r.m.s. value of the signal. Theoretical investigations show that the maximum error in the r.m.s. indication may then be up to 1.6 db. Some practical experiments however indicate, that the greatest error will normally be in the order of 1 db only. Finally the influence of Recorder pen fluctuations upon the input signal to the rectifier circuit is investigated, and it is shown that as long as the Recorder servo remains stable, the disturbing influence is negligible.

SOMMAIRE

Après une brève description générale de l'Enregistreur de Niveau Brüel & Kjaer 2305, les caractéristiques de son circuit de détection quadratique et des différents circuits d'intégration sont discutées plus en détail. Ces circuits permettent d'obtenir sur l'enregistreur la valeur efficace vraie de signaux périodiques non-sinusoïdaux ayant des facteurs de crête pouvant aller jusqu'à 5 et situés dans la bande passante. Une étude théorique et expérimentale de la réponse de l'enregistreur au cours de l'enregistrement du niveau fluctuant de bandes étroites de bruit gaussien est présentée ensuite. Les résultats montrent qu'une mesure exacte du niveau efficace est obtenue sur l'enregistreur lorsque la fréquence la plus basse des fluctuations de niveau est supérieure à cinq fois la limite inférieure de la bande passante de l'enregistreur. Pour des fluctuations plus lentes, l'enregistreur indiquera un niveau légèrement inférieur au niveau efficace et en particulier pour des fluctuations quelconques partant de la fréquence zéro un calcul théorique montre que le niveau mesuré peut être trop faible de 1,6 dB mais des essais pratiques n'ont montré que des erreurs de 1 dB environ maximum.
Enfin une étude expérimentale montre que l'influence des mouvements désordonnés du stylet sur le signal à l'entrée du redresseur de valeur efficace est négligeable tant que la boucle servo-mécanisme de l'enregistreur fonctionne dans des conditions stables.

ZUSAMMENFASSUNG

Pegelschreiber Typ 2305 enthält einen Effektivwertgleichrichter, dessen Eigenschaften näher beschrieben werden. Es wird festgestellt, daß der Pegelschreiber den Effektivwert von Spannungen beliebiger Kurvenformen bis Scheitelfaktor 5 getreu aufzeichnet, sofern die Frequenz der Grundwelle oberhalb der eingestellten unteren Grenzfrequenz des Gerätes liegt. Bei weißem Rauschen muß die Frequenz der einhüllenden Amplitudenschwankung etwa um den Faktor 5 über der unteren Grenzfrequenz des Pegelschreibers liegen. Ist der Abstand geringer, wie es z.B. bei schmalbandigem Rauschen häufig der Fall ist, so ist die Effektivwertanzeige mit einem Fehler behaftet, der theoretisch bis zu 1,6 dB betragen kann. Experimentelle Nachprüfungen ergaben indessen, daß die Ungenauigkeit in der Regel 1 dB nicht überschreitet.
Anschliessend wird untersucht, welchen Einfluß Schwingungen des Schreibstiftes auf die Gleichrichterschaltung ausüben. Es zeigt sich, daß keine nachteiligen Störungen auftreten, solange der Pegelschreiber in einem regeltechnischen stabilen Betriebszustand arbeitet.

The Level Recorder Type 2305, which was introduced on the market by Brüel & Kjær during 1959/60, is, as was its predecessor Type 2304, a potentiometer-type recorder. The Recorder is, however, of a completely new design, although the basic principle is the same as for the Type 2304. Not only have the amplifiers been re-designed to supply a higher driving force to the writing system and to enable full-wave r.m.s. detection of the input signal, but also new mechanical and electrical features have been incorporated. These make special accessories, such as two-channel selectors, automatic reverberation switches, D.C.-A.C. inverters and polar diagram recorders superfluous, because the same functions can now be performed by self-contained devices.

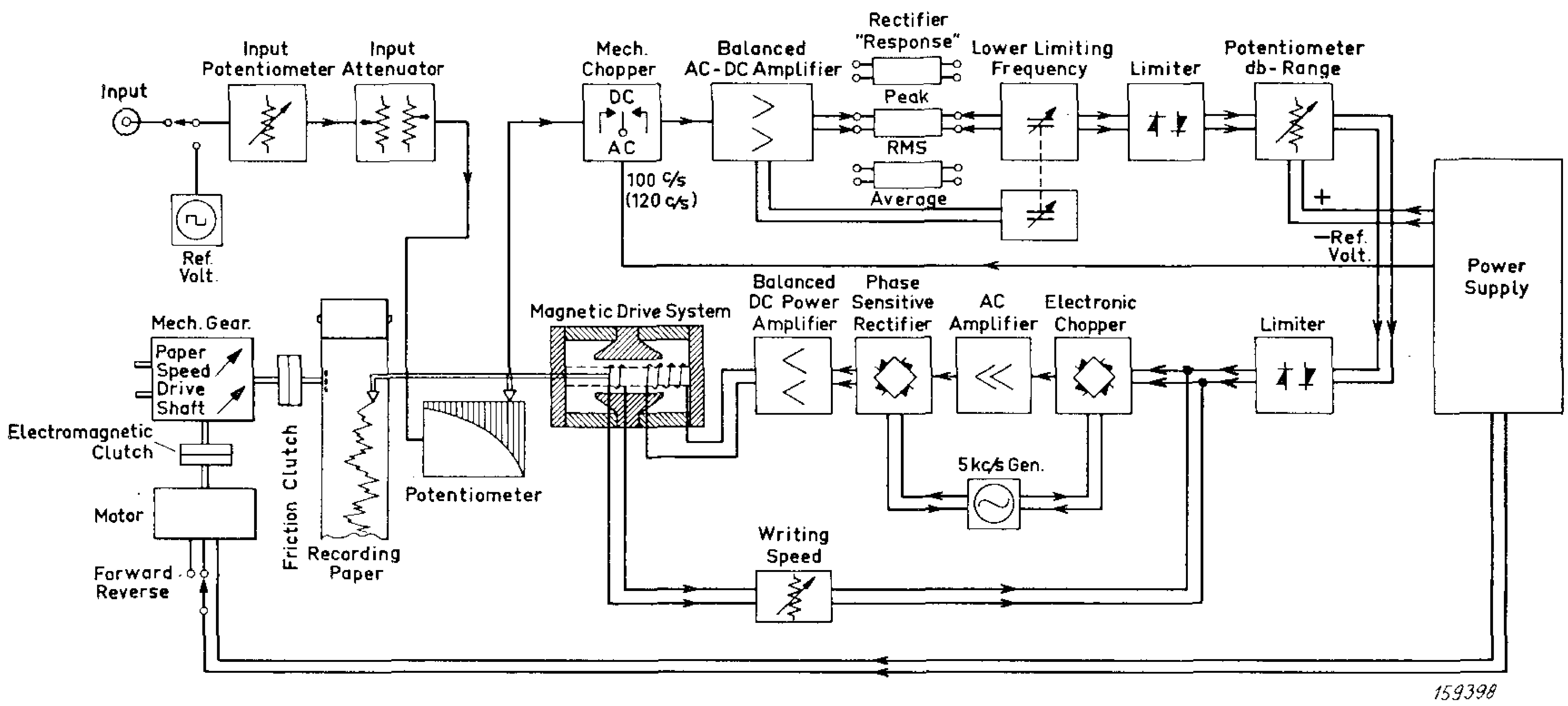

Fig. 1. Block diagram of the Level Recorder Type 2305.

Fig. 1 shows a block diagram of the Recorder, and a photograph illustrating its external appearance is shown in Fig. 2.

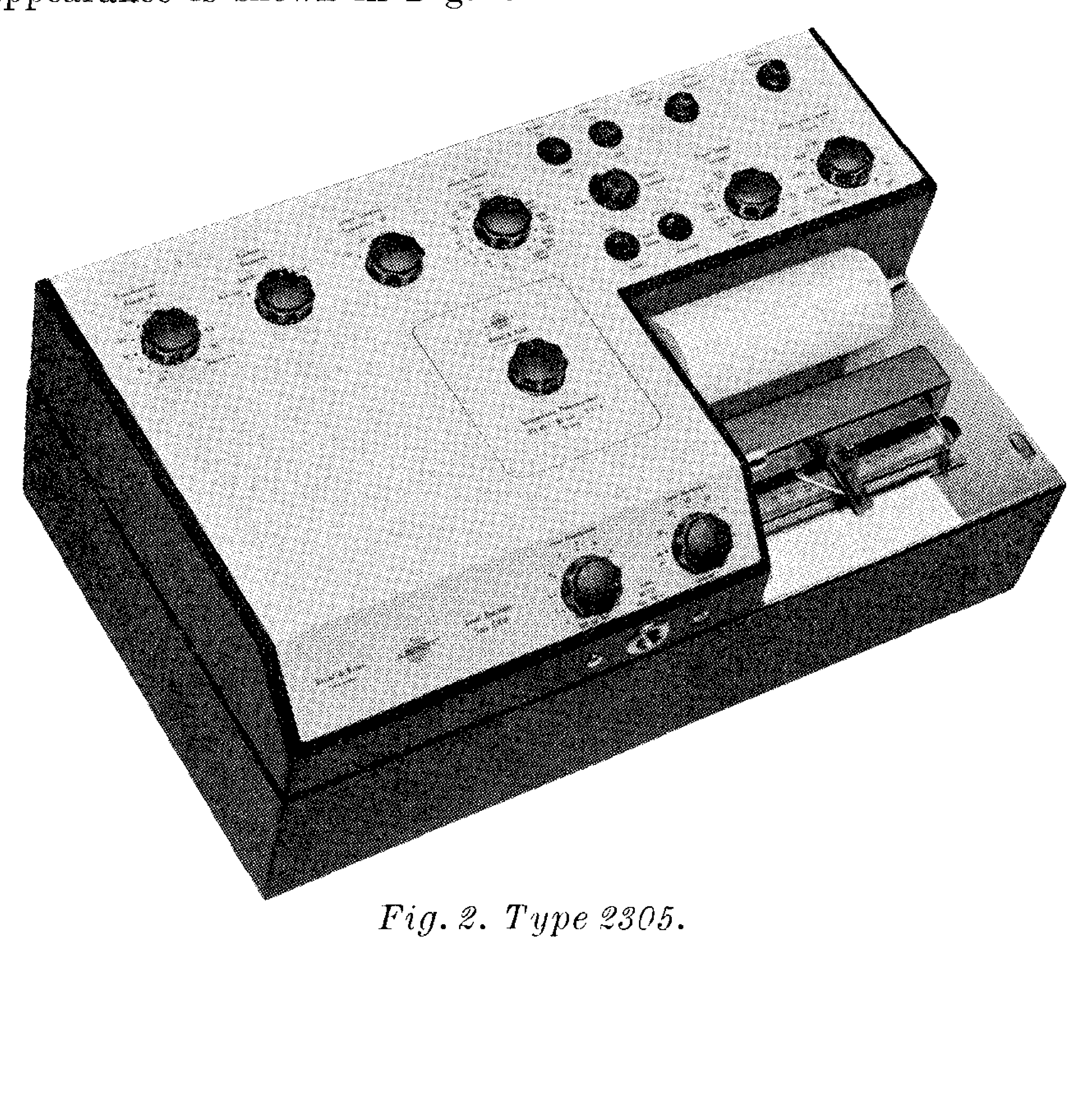

Fig. 2. Type 2305.

As can be seen from the block diagram, and as stated in the introduction, the operation of the instrument is based upon the servo principle. The input voltage is fed to an interchangeable range potentiometer via a continuously variable input potentiometer and a calibrated input attenuator. Due to the interchangeability of range potentiometer units, dynamic ranges from 10 db to 75 db may be selected by the user.

From the range potentiometer the signal is then led to a balanced direct-coupled AC-amplifier, where it is amplified and rectified in the special B & K rectifier system, which enables the DC output voltage to be proportional either to the peak, the average, or the true R.M.S. value of the AC signal. The use of a balanced direct-coupled AC input amplifier instead of a conventional AC amplifier has two distinct advantages; firstly, unwanted blocking of the amplifier (and thus overshoot in the recording) due to overdriving is eliminated, and secondly the influence of variations in the supply voltage is decreased to a minimum.

The rectified and smoothed voltage is then compared with a d.c. reference voltage and the difference in voltage amplified, first in a chopper amplifier using an electronic chopper with a frequency of approximately 5 kc/s, and then in a push-pull type DC Power Amplifier.

A velocity dependent feedback network is used to stabilize the writing system making selection of different writing speeds possible over a wide range.

The Recorder is capable of writing on two different widths of recording paper, 50 mm (2 inches) and 100 mm (4 inches). To change from 50 to 100 mm it is only necessary to release a mechanical snap-lock arrangement on the moving arm which holds the stylus. A wire-driven mechanical gear then transforms the movement of the drive coil to a stylus movement which is twice as great.

Recordings can be made by ink on various types of preprinted recording paper, or by a sapphire stylus on wax-coated paper. The inking pen is readily interchangeable, allowing multi-coloured recordings to be produced.

Level recorders such as the Type 2305 are frequently used to record complex phenomena like noise and vibration data. In such circumstances it is a great advantage, and some times a necessity, that the recorder is capable of measuring the r.m.s. value of the input signal. As long as the signal being measured is of a more or less sinusoidal type, such as is the case when frequency reponse characteristics of various types of networks are recorded according to the sweeping single-tone method, the type of rectifier circuit used is not so important. However, as soon as a recording is made of phenomena with high crest factors*) or of signals with more or less continuous frequency spectra and random amplitude distribution, the true r.m.s. detection of the signal becomes important. To design a high-quality r.m.s. rectifier circuit for this purpose which would be of a reliable and not too complex construction has therefore been the aim of designers for many years.

Brüel & Kjær have, some time ago, succeeded in designing an r.m.s. rectifier circuit which is capable of measuring the true r.m.s. value of signals with crest factors up to 5 and with an accuracy better than 0.5 db. This special circuit has

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* Crest factor $= \dfrac{\text{peak value of the signal}}{\text{r.m.s. value of the signal}}$

already been incorporated in most of the Brüel & Kjær measuring amplifiers and is also made use of in the Recorder Type 2305.

A description of the development of the rectifier as well as the theory of its operation is given in the B & K Technical Review Nr. 3-1958, therefore only some of the main properties of the circuit will be outlined in the following.

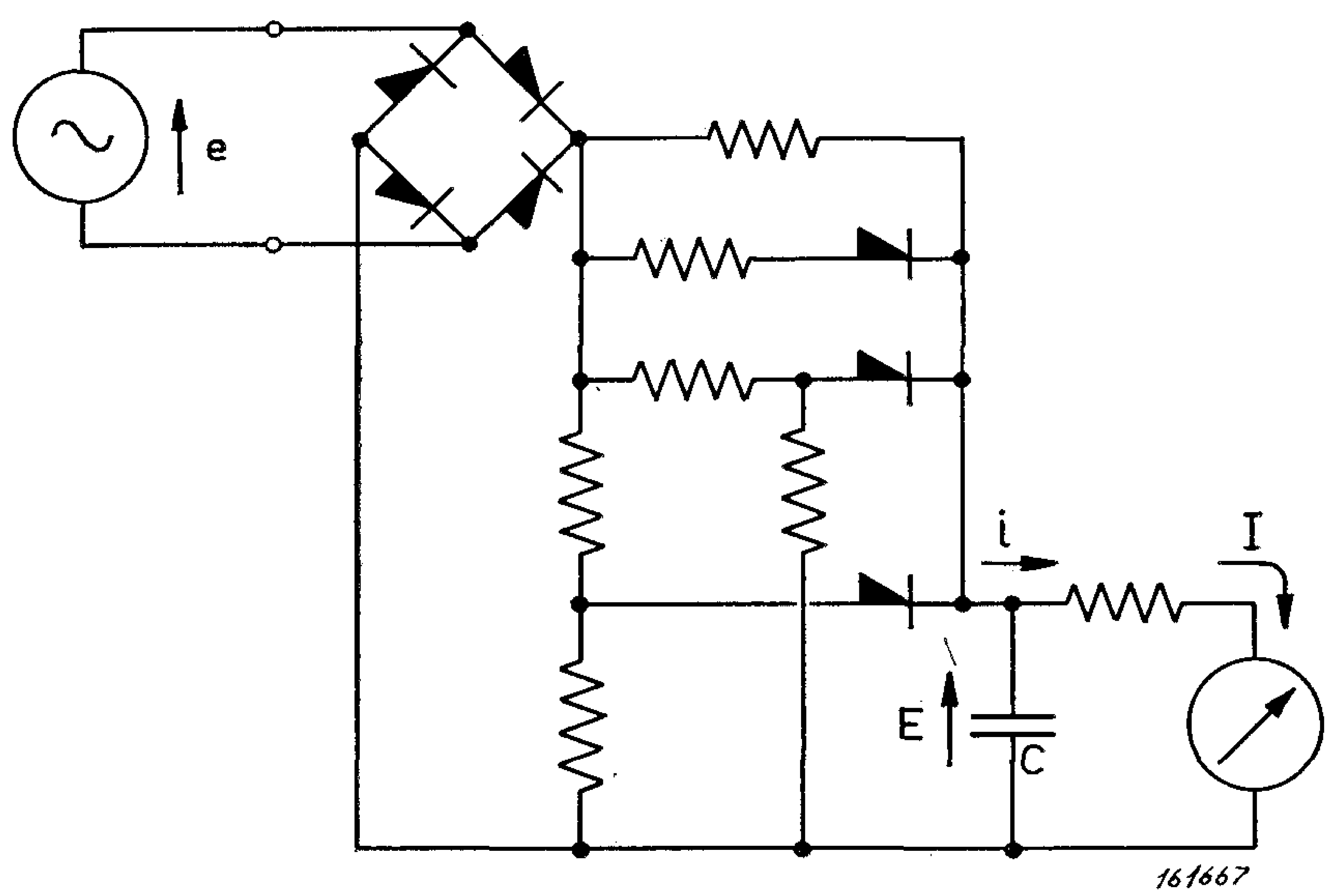

Fig. 3. Basic diagram of the B & K true r.m.s. rectifier and meter circuit.

Fig. 3 shows the basic diagram of the rectifier and meter circuit, and Fig. 4 illustrates its principle of operation. It can be seen that the d.c. voltage on the capacitor is directly proportional to the r.m.s. value of the rectifier input signal. If the magnitude of this signal changes, the d.c. voltage on the capacitor will also change, the change being proportional to the change in r.m.s. value of the input signal. *It is a requirement for the circuit that the time constant of the "averaging" network (capacitor plus meter plus the resistors) is long enough to keep the d.c. voltage on the capacitor essentially unchanged within the desired period of integration.*

Before proceeding into a more detailed description of the behaviour of the Recorder as an r.m.s. recorder for complex signals, the mathematical expression for the r.m.s. value of such signals should be recalled:—

$$A_{r.m.s.} = \sqrt{\frac{1}{T} \int_{O}^{T} a^2 (t) \, dt}$$

If the signal shows a distinct periodicity the exact r.m.s. value can be found by

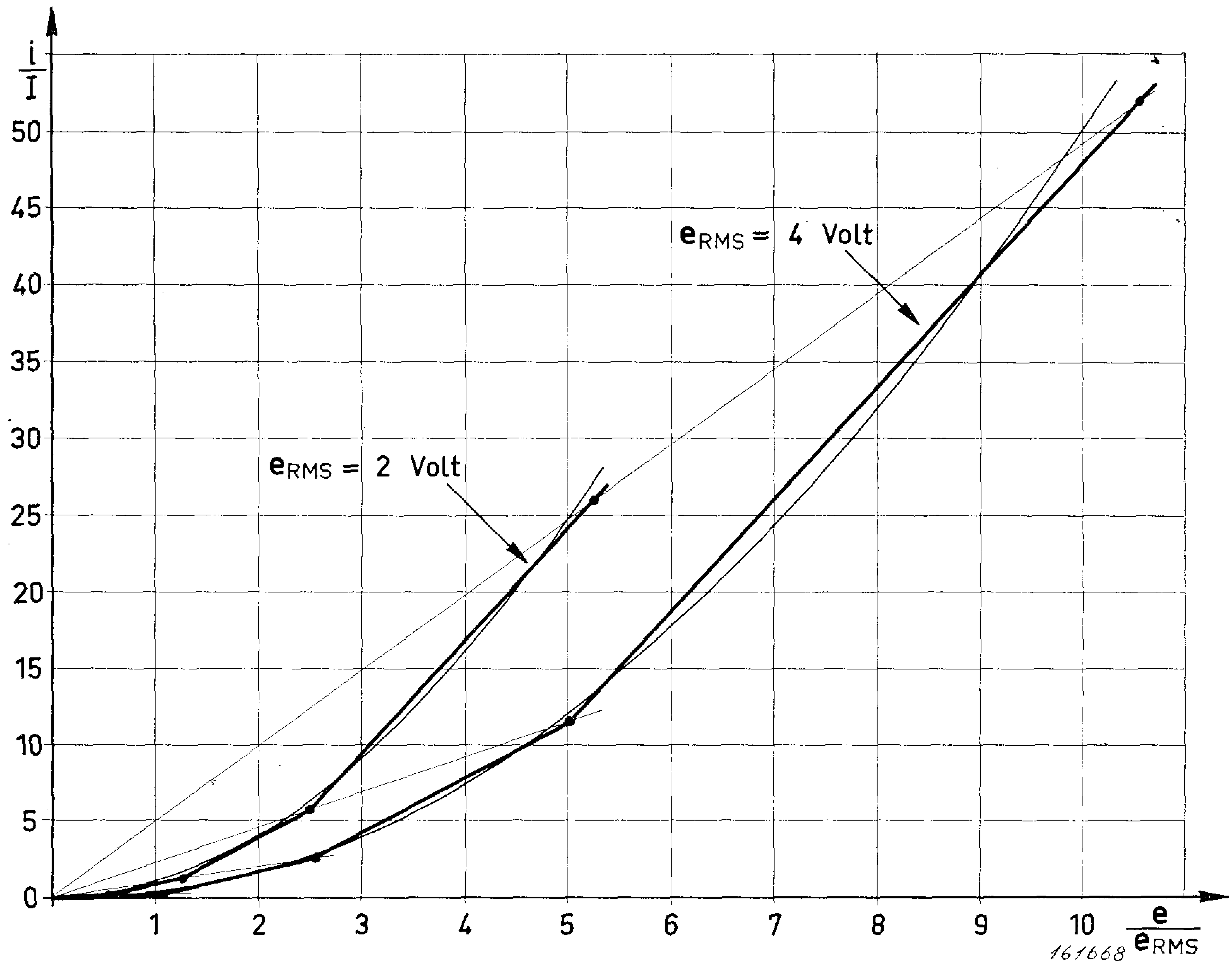

Fig. 4. Drawing illustrating the principle of operation of the true r.m.s. rectifier: The theoretically correct parabolic shape of the squaring circuit is approximated by means of a number of straight line portions. When the r.m.s. value of the rectifier input signal changes, the operating "parabola" also changes, whereby a linear meter scale is obtained.

mathematical integration over one period (1 period = T), Fig. 5. However, in the case of signals with continuous spectra the exact r.m.s. value can be found by integrating over infinite time:—

$$A_{\text{r.m.s. continuous}} = \lim_{T \to \infty} \sqrt{\frac{1}{T} \int_0^T a^2(t)\, dt}$$

This is, of course, not possible in practice, and an averaging time must then be used which defines the signal with an accuracy that is sufficient for the purpose of the particular experiment in question.

The averaging process can be made mathematically when an oscillographic time record of the signal is available. However, normally the signal is measured, rectified and averaged by means of a level indicating electronic instrument, thus saving the experimenter the time-consuming calculations involved in the evalua-

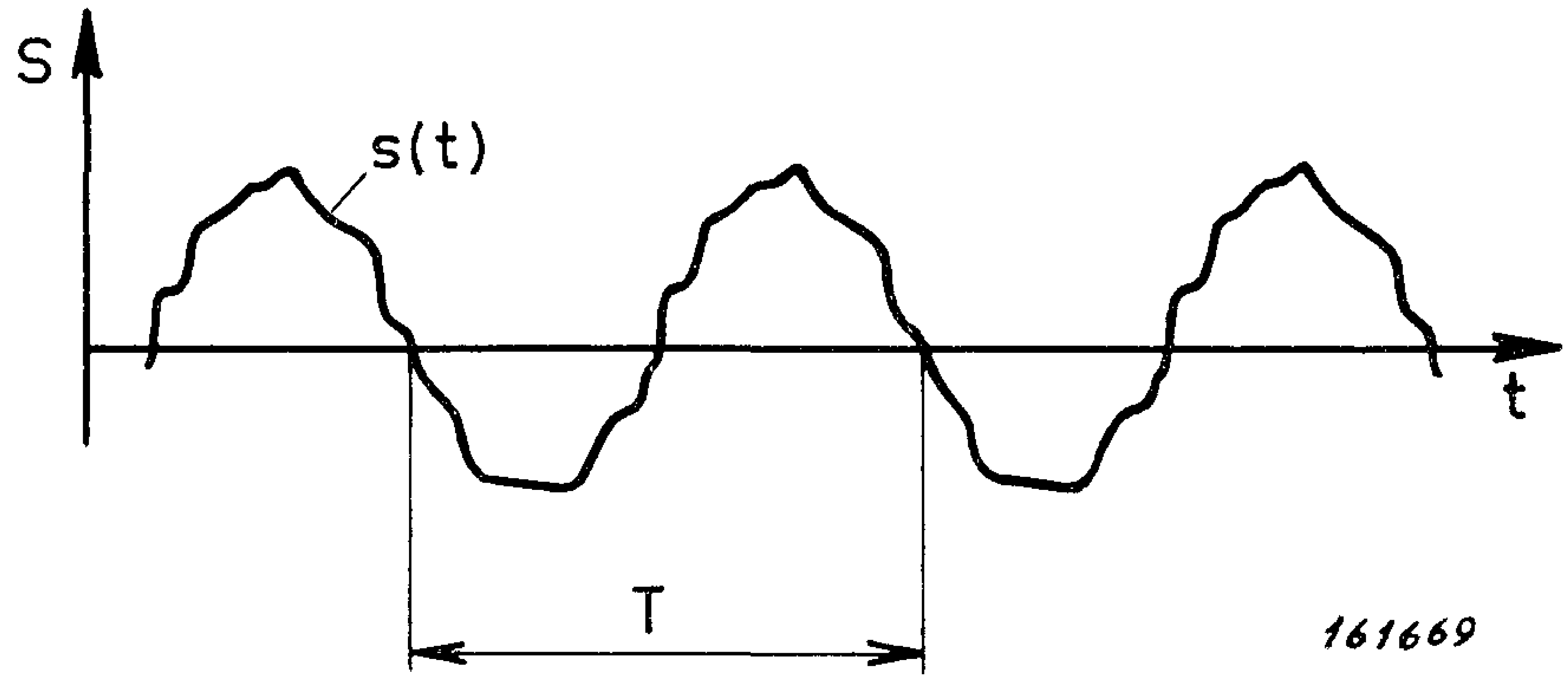

Fig. 5. Example of a complex periodic signal.

tion of oscillographic records (samples of the signal), Fig. 6. This averaging process takes place in the rectifier filtering circuit of the instruments as outlined above.

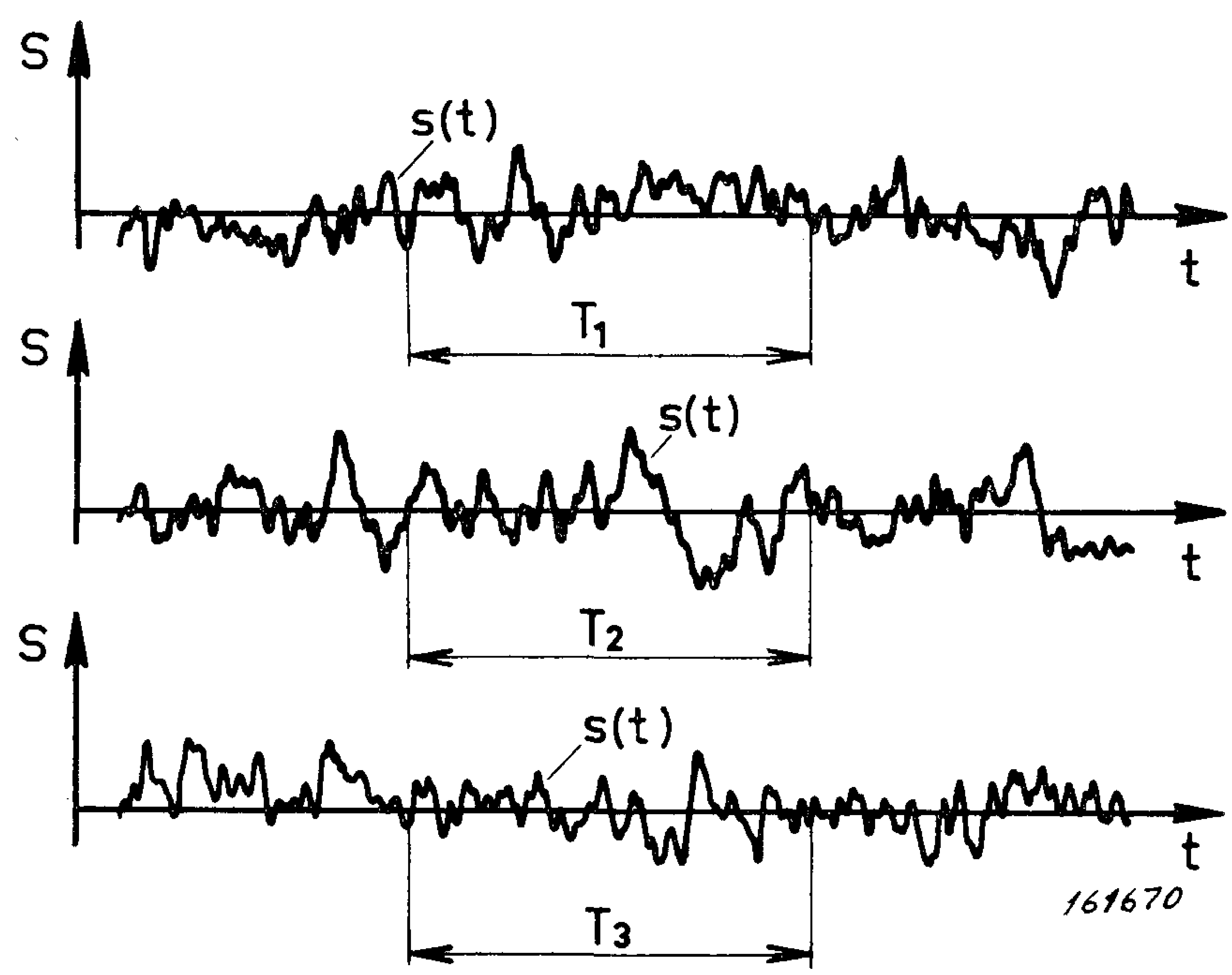

Fig. 6. Samples of a complex non-periodic signal.

As the Level Recorder operates according to the servo principle and contains a fairly complicated feedback system which works over a number of amplifying stages, a compromise between servo stability and ideal integration characteristics

of the rectified signal has been necessary. Fig. 7 shows the basic diagram of the r.m.s. rectifier circuit in the Recorder, and the similarity between this circuit and the one shown in Fig. 3 is clearly noticed.
In the Recorder, however, it has been necessary to duplicate the squaring network to ensure equal load conditions for the capacitors C_a and C_b during both half periods, thereby avoiding shift in d.c. level at the rectifier.

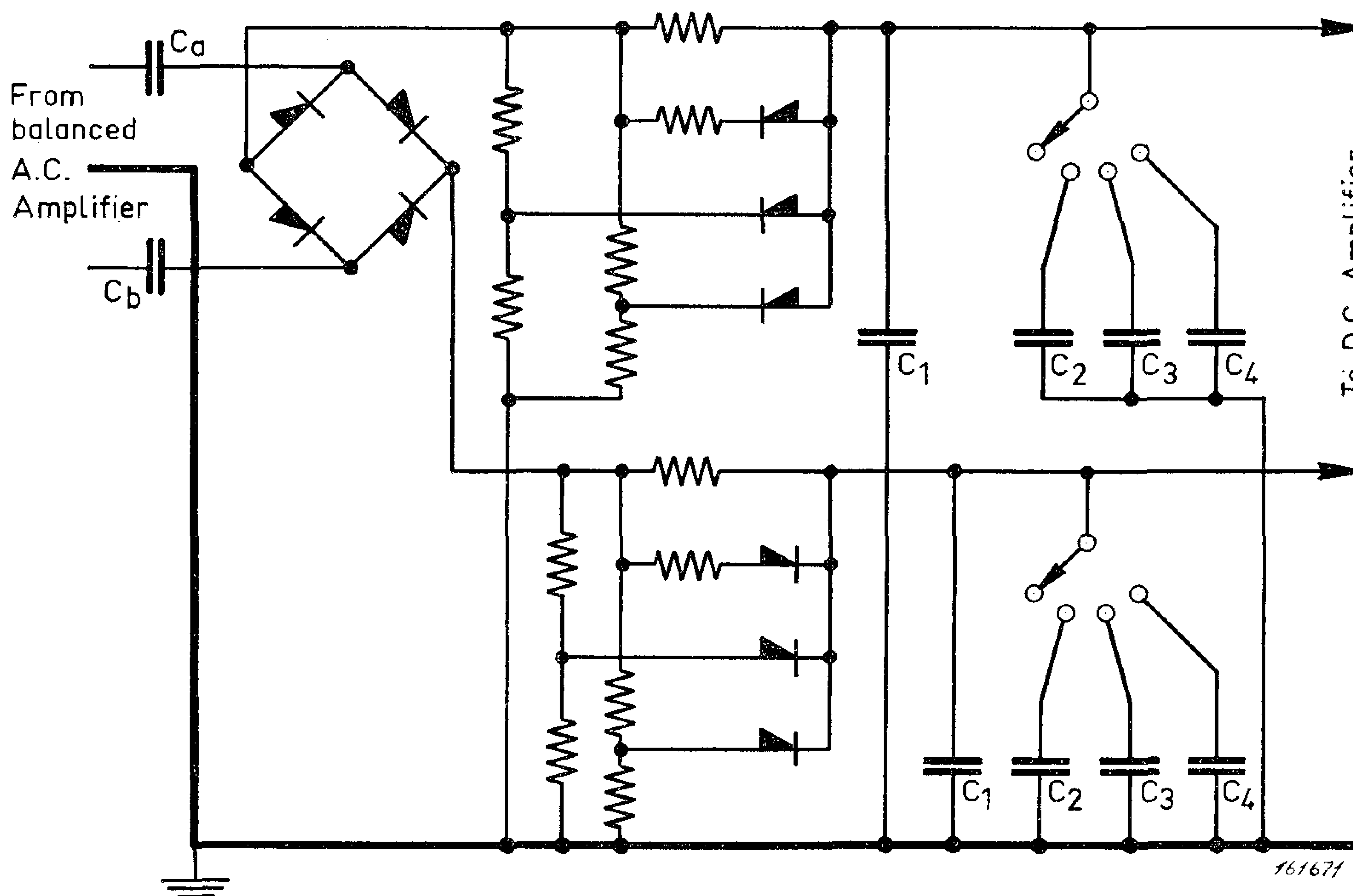

Fig. 7. Basic diagram of the r.m.s. rectifier circuit in the Level Recorder Type 2305.

The filtering capacitors in the rectifier smoothing circuit are marked C_1, C_2, C_3 and C_4, and are switched in by means of the front panel control "Lower Limiting Frequency". As previously stated in this article the true r.m.s. value of the input signal is only measured when the voltage on the capacitors remains essentially constant during the period of integration. For an input signal with a constant r.m.s. level, such as a periodic signal the true r.m.s. value is measured when the frequency of the signal is higher than that marked on the "Lower Limiting Frequency" switch of the Recorder. If the r.m.s. level of the input signal varies with time, the Recorder will, when the *signal* frequency is higher than that marked on the "Lower Limiting Frequency" switch, record the variations in level as long as the variations are of a very low frequency (this is, of course, the main purpose of a level recorder). If the *variations in level* are of high frequencies (about 5 times that marked on the "Lower Limiting Frequency" switch) the rectifier integration circuit will cause the true "overall" r.m.s. level to be measured, and the paper recording will show no variations in level. Now, if the main frequencies of the *level* variations lie between O (periodic input signal) and 5 times the "Lower Limiting Frequency" what will the Recorder then measure? (This is the case, for example, when noise signals are analysed by means of narrow band filters and recorded on the Type 2305.) It is therefore the purpose of this article to investigate the recording characteristics of Type 2305 within this range.

Following the rectifier smoothing circuit is the d.c. amplifier and power output stages which drive the Recorder writing system. The feedback in the writing system allows, as mentioned beforehand, the writing speed to be varied between 4 mm/sec. and 2000 mm/sec. (on the 100 mm paper). If a very low writing speed is chosen, a further smoothing of the recording pen fluctuations (caused by variations in the input signal level) takes place within the writing system. It is obvious that the two smoothing circuits, if improperly adjusted relative to each other, will cause the servo to become unstable. To avoid this situation the following "rule of thumb" method may be used for the setting of the two knobs "Lower Limiting Frequency" and "Writing Speed":—

1. Set the "Lower Limiting Frequency" switch according to the frequency of the signal to be measured.
2. Then set the "Writing Speed":—

   For "Lower Limiting Frequency" 10 c/s, the writing speed used should be lower than 100 mm/sec (large figures).

   For "Lower Limiting Frequency" 20 c/s, the writing speed used should be lower than 250 mm/sec (large figures).

   For "Lower Limiting Frequency" 50 c/s, the writing speed used should be lower than 500 mm/sec (large figures).

   For "Lower Limiting Frequency" 200 c/s, all writing speeds can be used.

From the preceding description it can be concluded that two smoothing (or averaging) circuits are included in the Recorder, and that both circuits will influence the averaging of the rectified signal. It remains, however, to show how these circuits influence the measurement of the true r.m.s. value of the input signal. As long as the voltage on the capacitors (C_1, C_2, C_3 and C_4) remains constant the d.c. voltage supplied to the output amplifier is proportional to the true r.m.s. value of the rectifier input signal and, independent of the "Writing Speed" control setting, the recorded level will be a straight line as long as the servo is kept stable. If the fluctuations in the rectifier input signal are of very low frequencies the averaging time of the capacitor circuit will not be long enough to keep the "d.c." voltage constant, and the recording pen will start to fluctuate, unless a very low writing speed is used. These pen fluctuations are proportional to the fluctuations in the r.m.s. level of the rectifier input signal as measured with an integration (averaging) time T (see Fig. 6). Fig. 8 shows a typical record of this type.

Now, what happens when the writing speed is lowered until the recording shows very small (or no) fluctuation in level, even when fluctuations are present in the "d.c" voltage on the capacitors? When the fluctuations are small, the answer is

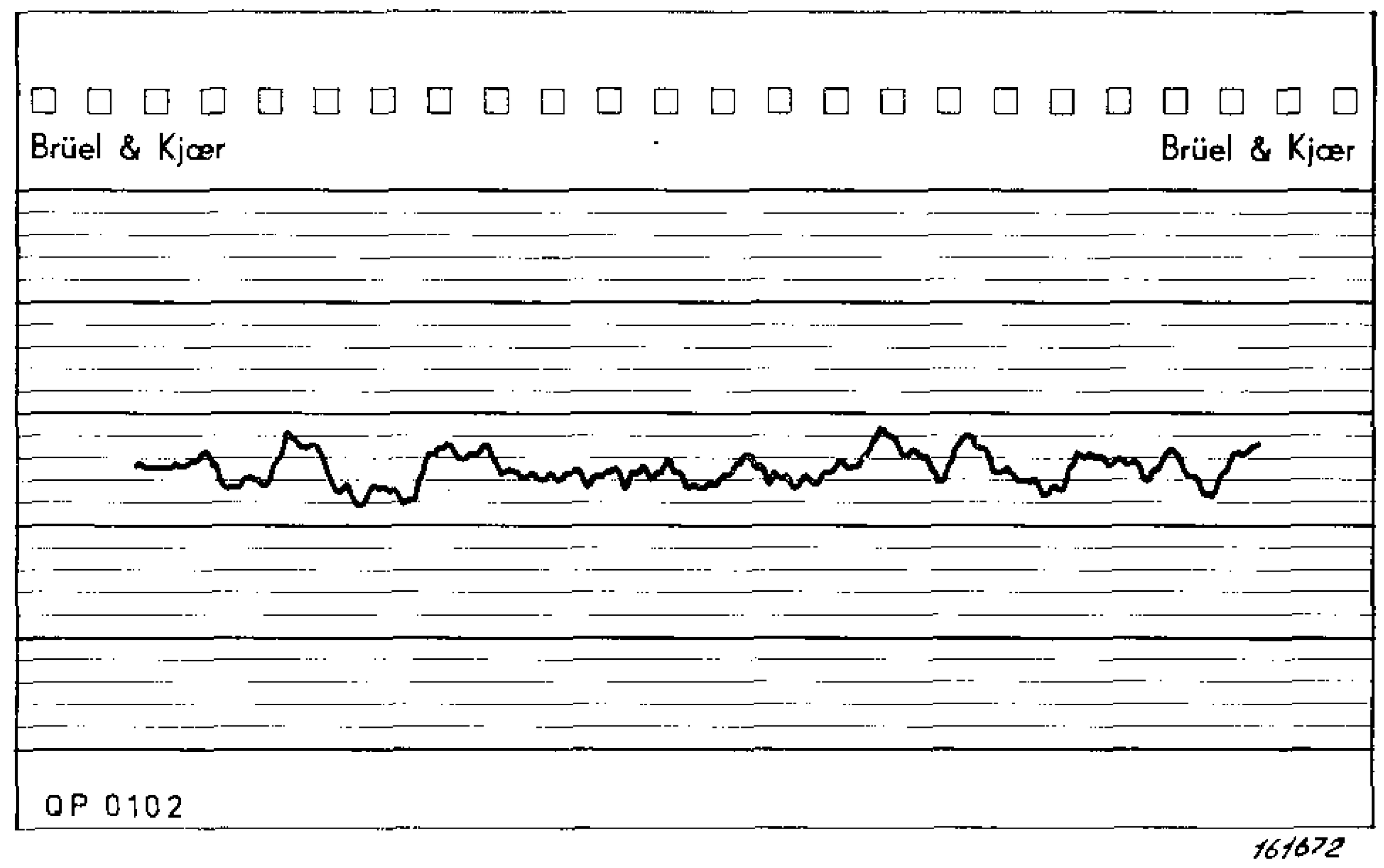

Fig. 8. Typical fluctuations in the r.m.s. values of a band of random noise recorded by means of the Level Recorder.

simple: The writing system averages the fluctuations arithmetically and the mathematical expression for the recorded level will be:—

$$A = \frac{1}{T_2} \int_0^{T_2} \sqrt{\frac{1}{T_1} \int_0^{T_1} a^2(t)\, dt_1}\; dt_2$$

where T_1 is the effective averaging time (sampling time) of the capacitor circuit and T_2 the averaging time (sampling time) of the writing system.
As long as T_1 is greater, or of the same magnitude as T_2*), or the fluctuations in the *rectifier input signal level is 0 or of frequencies* $\gg \frac{1}{T_1}$ *the true r.m.s. value of the signal is recorded to a high degree of accuracy.*
However, if T_2 is chosen to be much greater than T_1, and the frequencies of the fluctuations in the rectifier input level are of the order of $\frac{1}{T_1}$ the recorded signal level will be the "mean r.m.s." which for narrow bands of random noise corresponds to a value 1 db lower than the true r.m.s. value of the signal.
When the fluctuations of the voltage on the capacitors are relatively great the answer to this question is no longer so simple. In this case the limiters in the Recorder output amplifier (see Fig. 1) are activated, and the drive power supplied to the writing system is no longer proportional to the error signal. If T_2 is chosen much greater than T_1 and the frequencies of the fluctuations in the rectifier input level are between $\frac{1}{T_2}$ and $\frac{1}{T_1}$ the recorded signal level will be the "median"**) r.m.s. level. This level is about 1.6 db below the true r.m.s. value

* This case is normally not of great practical interest, because the Recorder then becomes unstable.

** "Median" value = 50 % probability of finding amplitudes below this value and 50 % probability of finding amplitudes above this value (in the noise r.m.s. envelope). In practice this value will not be reached, and the maximum deviation from the true r.m.s. value will be between 1 and 1.6 db.

of narrow bands of noise. (For derivation of the above "correction" figures, see Appendix I).

Fortunately most signals encountered in practice will have the properties required for true r.m.s. recording. Exceptions are modulated signals with modulation frequencies lower than 50 c/s and narrow bands of noise. Even if the center frequency of the noise band is much greater than 50 c/s the frequency of the *fluctuations in the signal level* will be in the order of the bandwidth (see Appendix II).

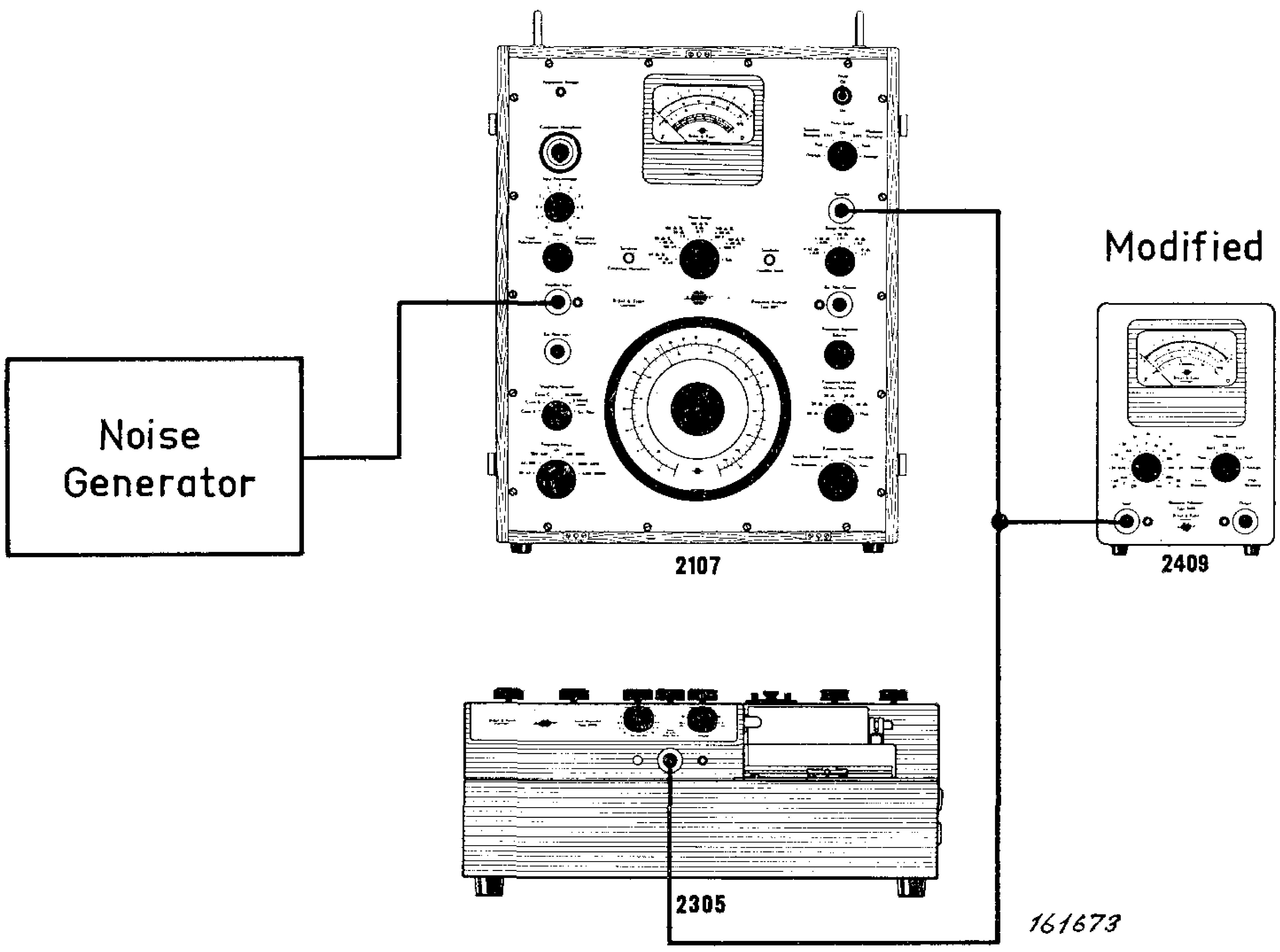

Fig. 9. Measuring arrangement used to determine the deviation in recorded signal level, from the true r.m.s. level, for a narrow band of random noise. The desired noise band is obtained by passing white random noise through the Frequency Analyzer Type 2107 adjusted for maximum selectivity.

Experiments have been made at Brüel & Kjær, where the r.m.s. level of bands of random noise were measured simultaneously with a true r.m.s.-instrument (a Voltmeter Type 2409 (B & K) modified to have an extremely large capacitor in the rectifier filtering network), and by the Level Recorder. Both the Recorder and the Voltmeter were calibrated to read the true r.m.s. value of a sinusoidal signal with a frequency of 1000 c/s. Fig. 9 shows the measuring arrangement, and in Fig. 10 the results of the measurement are plotted. The results indicate that already at a "practical" bandwidth of around 15 c/s the recorded level is the "mean" r.m.s. To record the true r.m.s. value the bandwidth of the noise should actually be higher than around 100 c/s (at 50 c/s bandwidth the accuracy is 0.5 db).

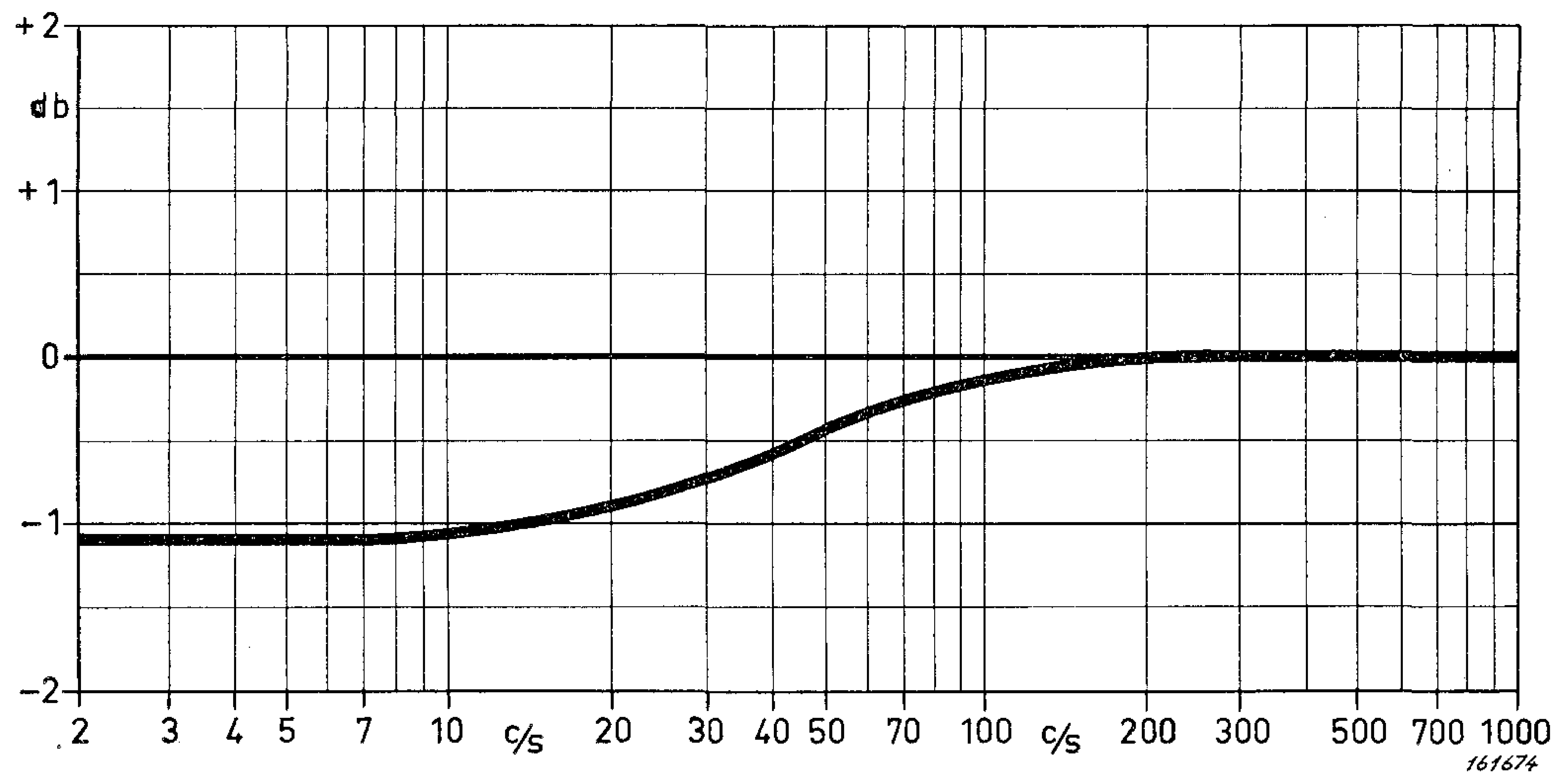

Fig. 10: Curve showing the error in r.m.s. recording of narrow band random noise as a function of bandwidth. The Recorder was adjusted for:
"Potentiometer db Range": "10" (A 10 db range potentiometer was used).
"Lower Limiting Frequency": "10" c/s
"Writing Speed": "8" mm/s

So far the r.m.s. recording characteristics of the Level Recorder have been discussed, assuming that the input to the rectifier circuit is of the same type as the Recorder input signal. This is, of course, true as long as the writing system (recording pen) of the Recorder does not move. However, there still exists the question as to what happens to randomly varying input signals when the Recorder pen (and thus the slider on the range potentiometer) fluctuate.

To obtain an answer to this a band of random (Gaussian) noise was again applied to the Recorder input. The amplitude characteristics of such a signal may be best described by means of an amplitude density (probability density) curve. This curve indicates the probability of finding instantaneous amplitude values within a differential area of width dx at a distance x from the mean, divided by the area. If the amplitude density curve of a random (Gaussian) signal is plotted to a logarithmic scale the curve becomes a parabola as shown in Fig. 11.

A measuring arrangement which is capable of recording the curve automatically on a level recorder of the Type 2305 is shown in Fig. 12 and is described in the B & K Technical Review No. 4-1959. The amplitude density curve of the Recorder input signal was now measured by means of this arrangement. The result was the curve shown in Fig. 11. Next the amplitude density characteristic of the signal between the slider of the Recorder range potentiometer and ground was recorded for various pen fluctuation amounts (i.e. various writing speeds). As can be seen from the block diagram Fig. 1, the input signal to the rectifier is the same signal as the signal between the slider of the range potentiometer and ground but amplified by a linear amplifier. The amplitude density characteristic

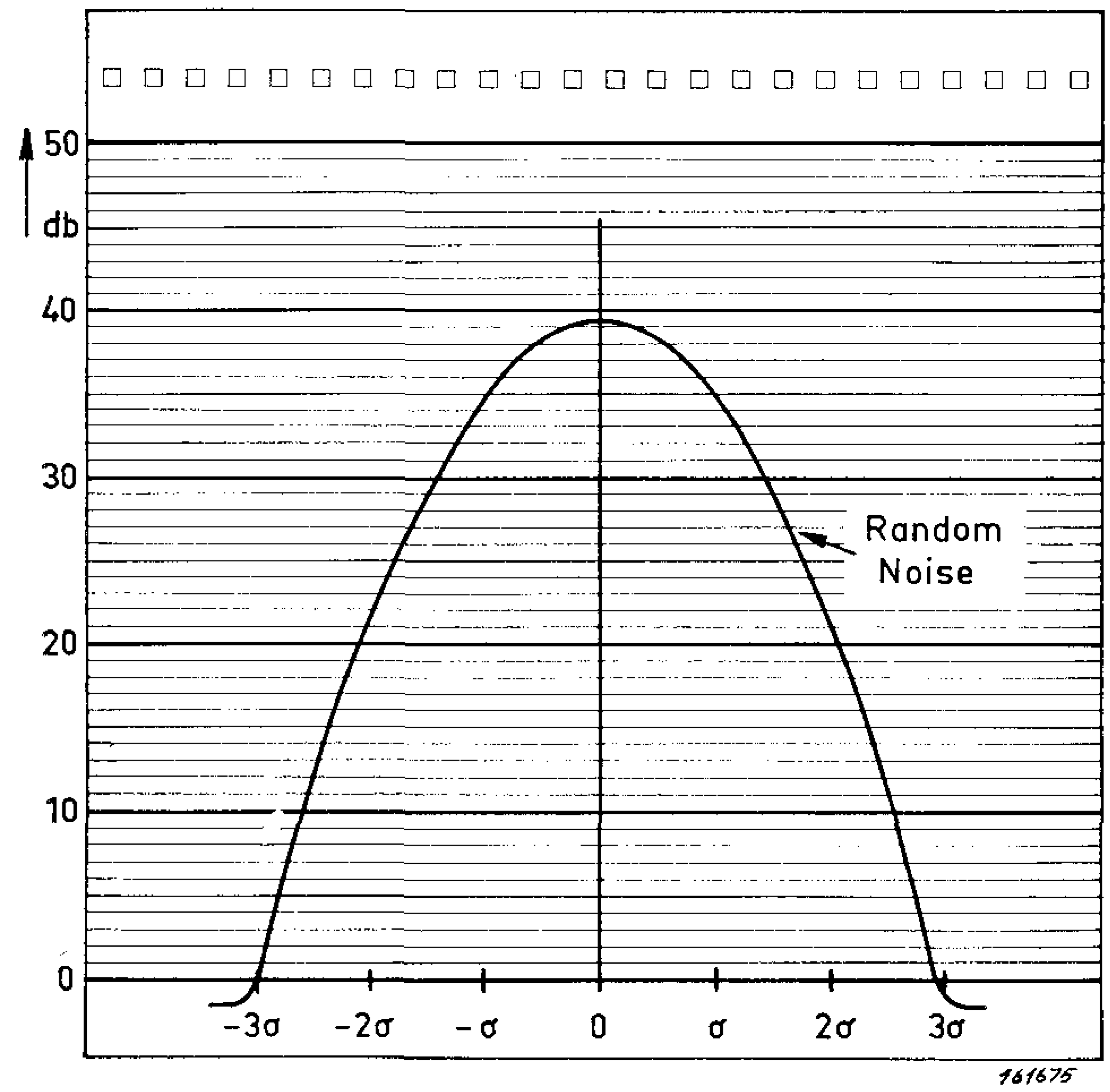

Fig. 11. Typical amplitude density curve of random noise plotted to a logarithmic scale. The curve was recorded automatically by means of the measuring arrangement shown in Fig. 12.

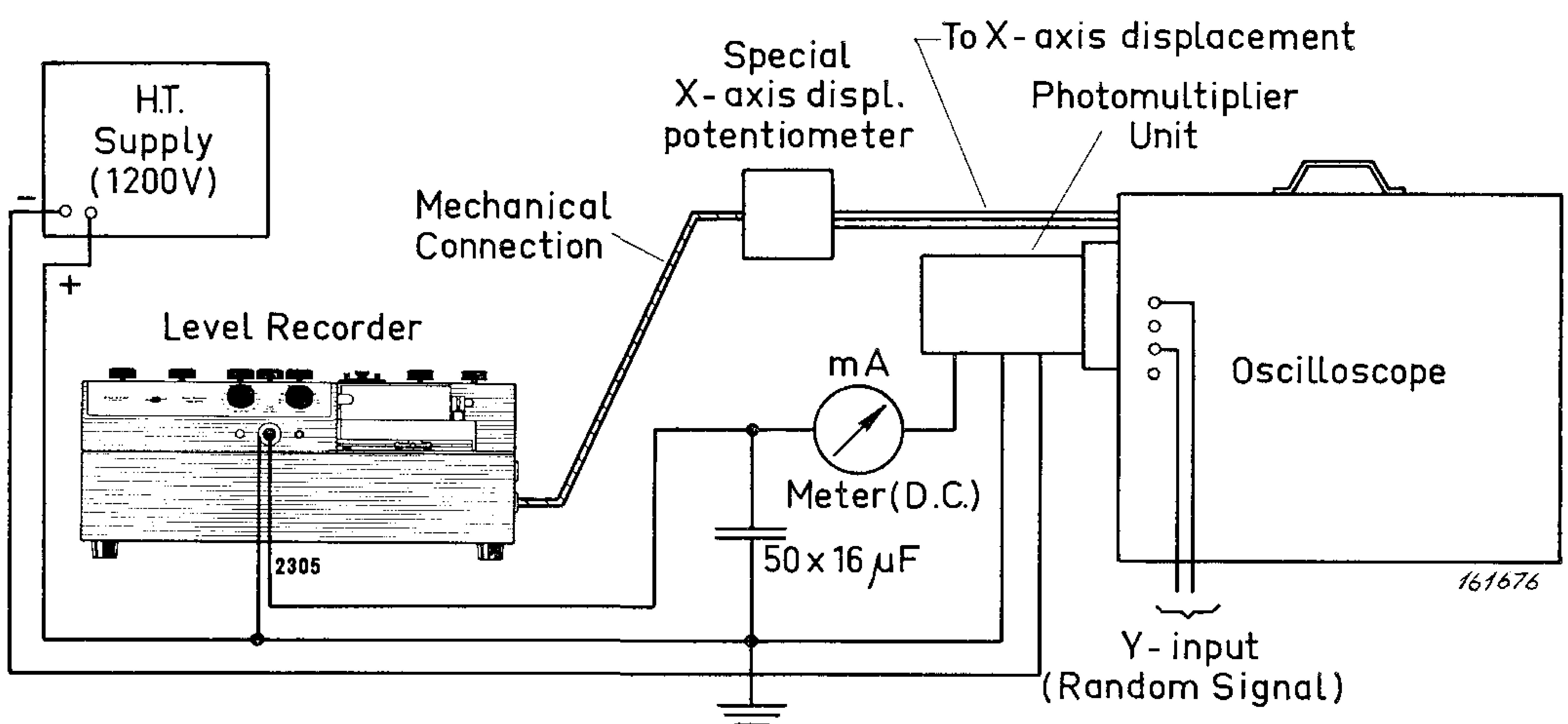

Fig. 12. Measuring arrangement for the automatic recording of amplitude density curves.

of this signal is shown in Fig. 13 for three different writing speeds. Even under conditions where the Recorder servo system is unstable the deviation between the Recorder input signal and the input signal to the rectifier circuit is very small. This is demonstrated in Fig. 14 where the amplitude density curve of the rectifier input signal for maximum pen fluctuation (the fluctuations covered almost the full writing width on the recording paper) is compared to the Recorder input signal.

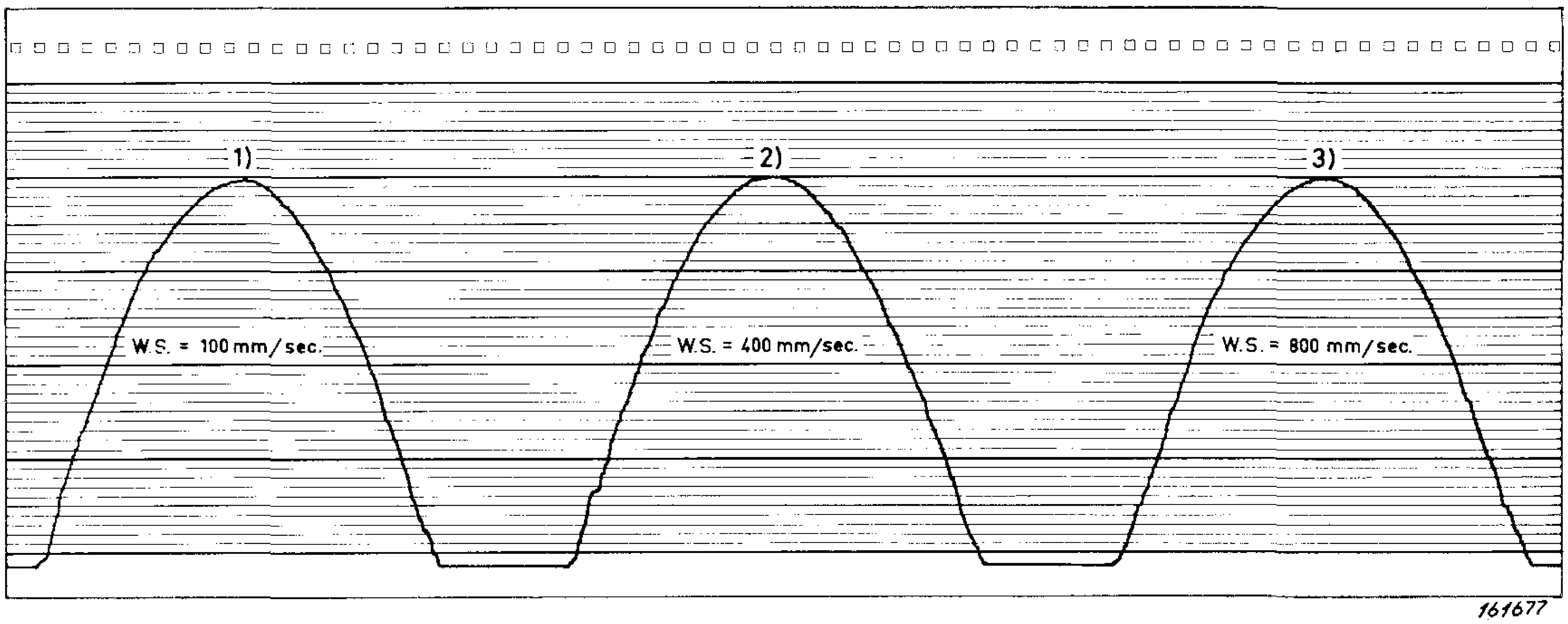

Fig. 13. Typical amplitude density curves of the input signal to the Recorder rectifier system using a 50 db range potentiometer on the Recorder. Random noise was used as the Recorder input signal.

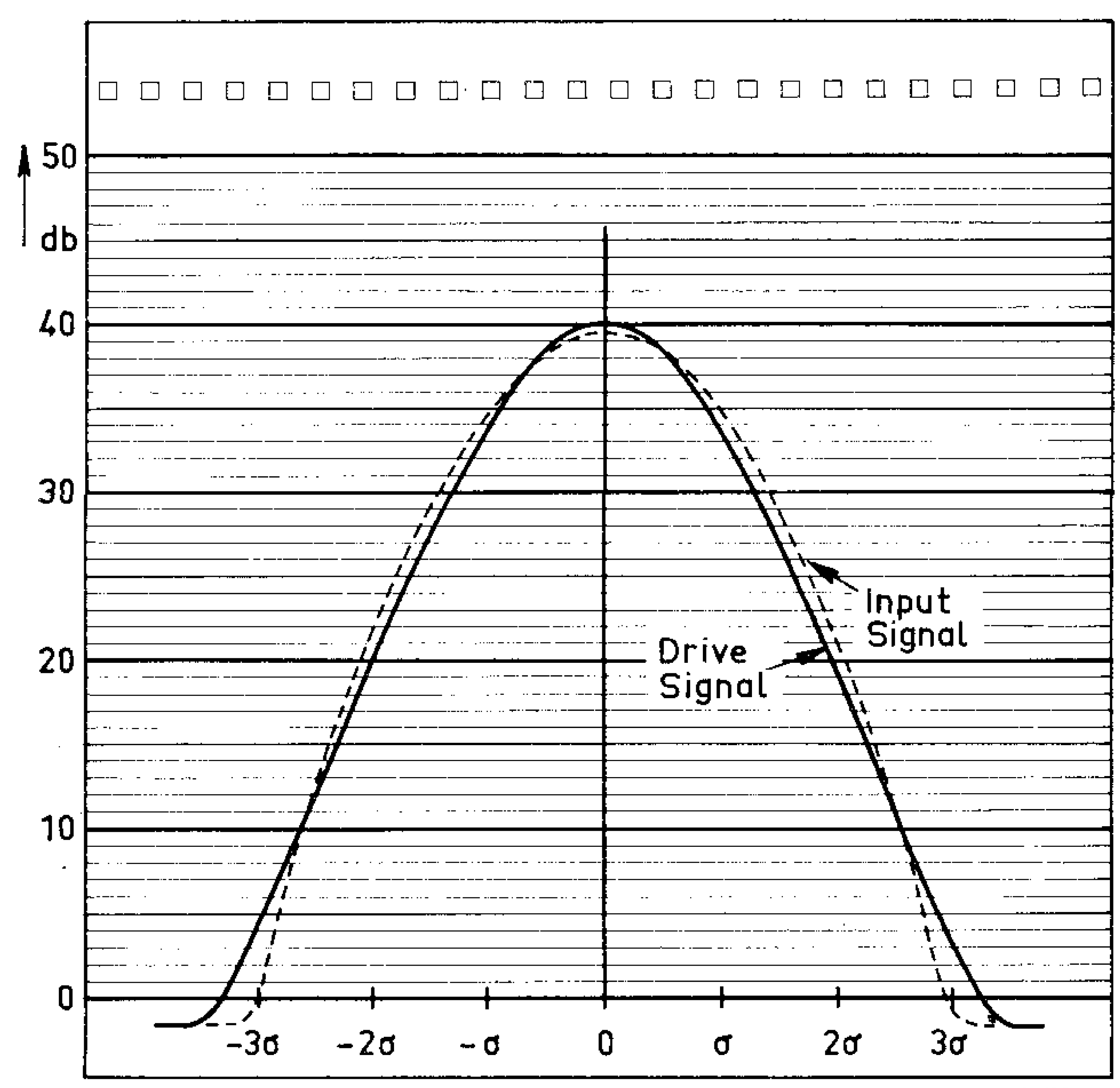

Fig. 14. Amplitude density curve of the drive signal to the Recorder rectifier system when the Recorder is switched for unstable operation (W.S. = 1000 mm/sec, L.L.F. = 10, Pot. db Range: 50). For the sake of comparison the amplitude density curve of the input signal is also shown.

The reason why the pen fluctuations do not seem to influence the amplitude characteristics of a random input signal to any great extent may be explained on the basis of the averaging effect of the writing system. It may therefore be safe to state that as long as reasonable pen fluctuation is used in the recording, little or no correlation exists between the instantaneous amplitude values of the input signal and the instantaneous pen position. However, as the frequency of the pen fluctuation is allowed to increase towards the frequency of the envelope of the input signal, the correlation between the two signals becomes greater and the pen fluctuation will then influence the input signal to a certain extent (via the slider on the range potentiometer). Normally this will not occur, as the setting of the Recorder control knobs for stable operation and clear read-out ensures the easy discrimination of the mentioned correlation.

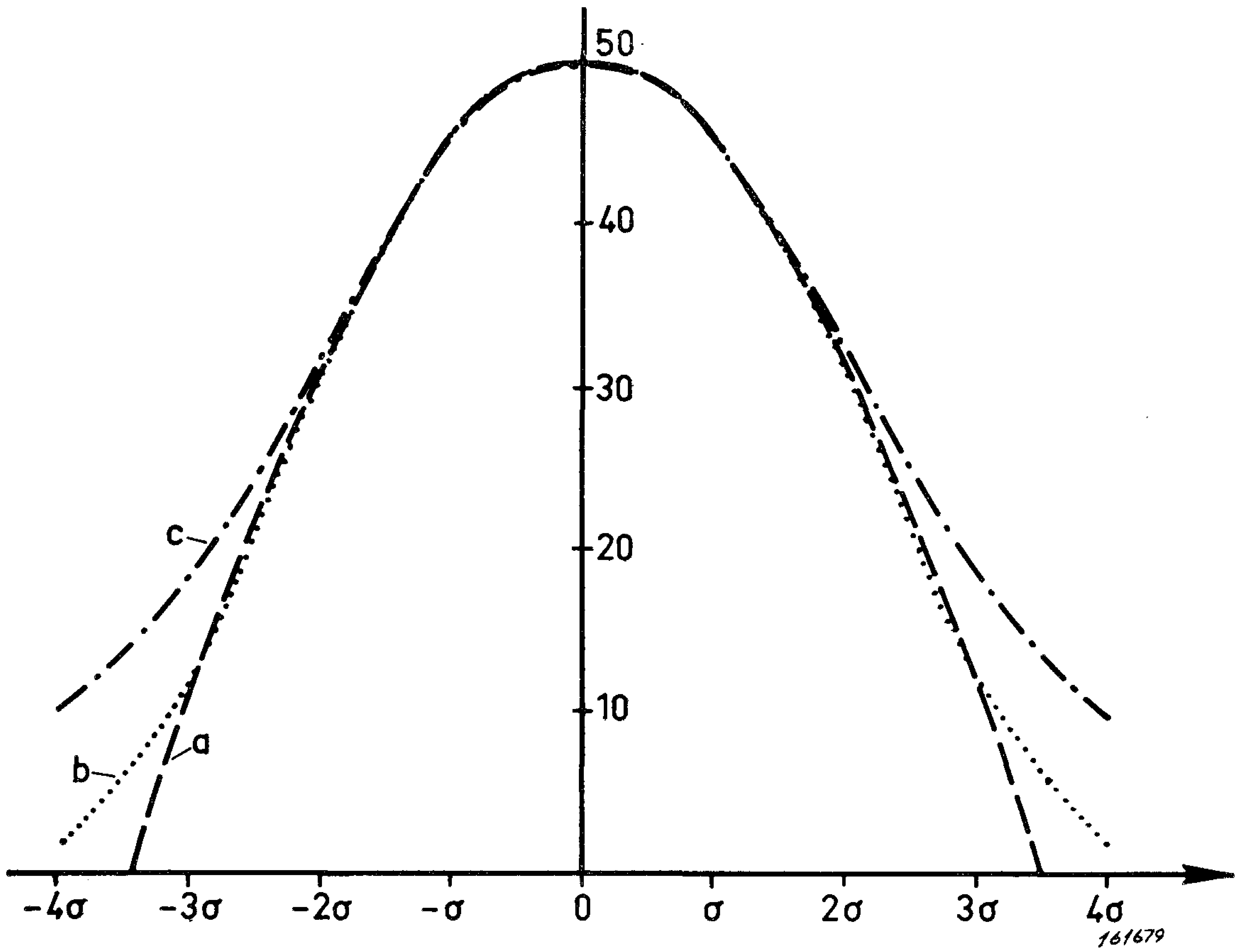

Fig. 15. Typical amplitude density curves of:
(a) Random noise.
(b) Noise in a mechanical workshop.
(c) Office noise.

The choice of a random input signal to demonstrate the effect of recording pen fluctuation upon the input signal to the rectifier system has been made on the basis of practical experience. Many complex noise and vibration signals found in practice have close to random amplitude distributions. For example, tape recorded office and factory noise have been analysed at Brüel & Kjær with regard to their amplitude density curves. The results of these analyses are shown in Fig. 15 and compared to a true random signal.

Finally it now only remains to briefly discuss the influence of the Recorder control knob marked "Potentiometer db Range" upon the recording characteristics of the instrument. *The particular setting of this knob controls the resolving* *power of the Recorder, and as a practical rule it should be set to a position corresponding to the level range of the range potentiometer used.* However, the lower this knob is set the greater is the resolution. By increasing the resolution the Recorder will, in the case of narrow band noise measurement, indicate a value closer to the "median" r.m.s. value of the noise, while a decrease in resolution causes the Recorder indication to approximate the "mean" r.m.s. value. Furthermore, if too great a resolution is applied to the system the servo will tend to become unstable, therefore it is necessary to use a low writing speed when a much higher resolution than that corresponding to the level range of the range potentiometer is desired. The influence of the resolution upon the frequency characteristic, and thus the averaging time of the writing system, will be discussed in a later article to appear in Technical Review.

APPENDIX I

Theoretical Errors in the r.m.s. Recording of Narrow Bands of Random Noise. The correction figures given on p. 11 and 13 for the r.m.s. recording of narrow bands of random noise by means of the Level Recorder Type 2305 were derived from the following:—

1. Narrow bands of random noise may be looked upon as modulated signals with carrier frequencies approximately equal to that of the center frequency of the band. The frequency spectrum of the modulation signal will then be of the type shown in Appendix II.
2. The instantaneous values of the "carrier" will be distributed according to the normal (Gaussian) distribution law and the true r.m.s. value of the noise band will consequently be equal to the standard deviation (σ) of the Gaussian distribution curve. However, the *peaks* of the noise band (and thus the peaks of the "carrier") will be distributed according to the Rayleigh probability density curve shown in Fig. A. I. 1.

If now the averaging circuits of the Recorder are adjusted so that the true r.m.s. value of each cycle of the "carrier" signal is measured, the fluctuations of the voltage on the capacitor in the r.m.s. averaging circuit will correspond to a Rayleigh curve where x in Fig. A. I. I. is substituted by $\frac{x}{\sqrt{2}}$. The "mean" r.m.s. value of the voltage on the capacitor will thus be the arithmetic average deviation of this curve which is $\frac{1.2533 \times \sigma}{\sqrt{2}} = 0.89\,\sigma$ (this is approximately 1 db below σ). Should the fluctuation of the voltage on the capacitor be great enough to actuate the limiters in the Recorder output amplifier most of the time during recording, the writing system will adjust itself to a level where the actual input signal to the limiters is below and above this level, fifty percent of the time, respectively. This is the median value of the "modified" Rayleigh curve: $x_m = \frac{1.1774 \times \sigma}{\sqrt{2}} = 0.83\,\sigma$ (i. e. approximately 1.6 db below σ).

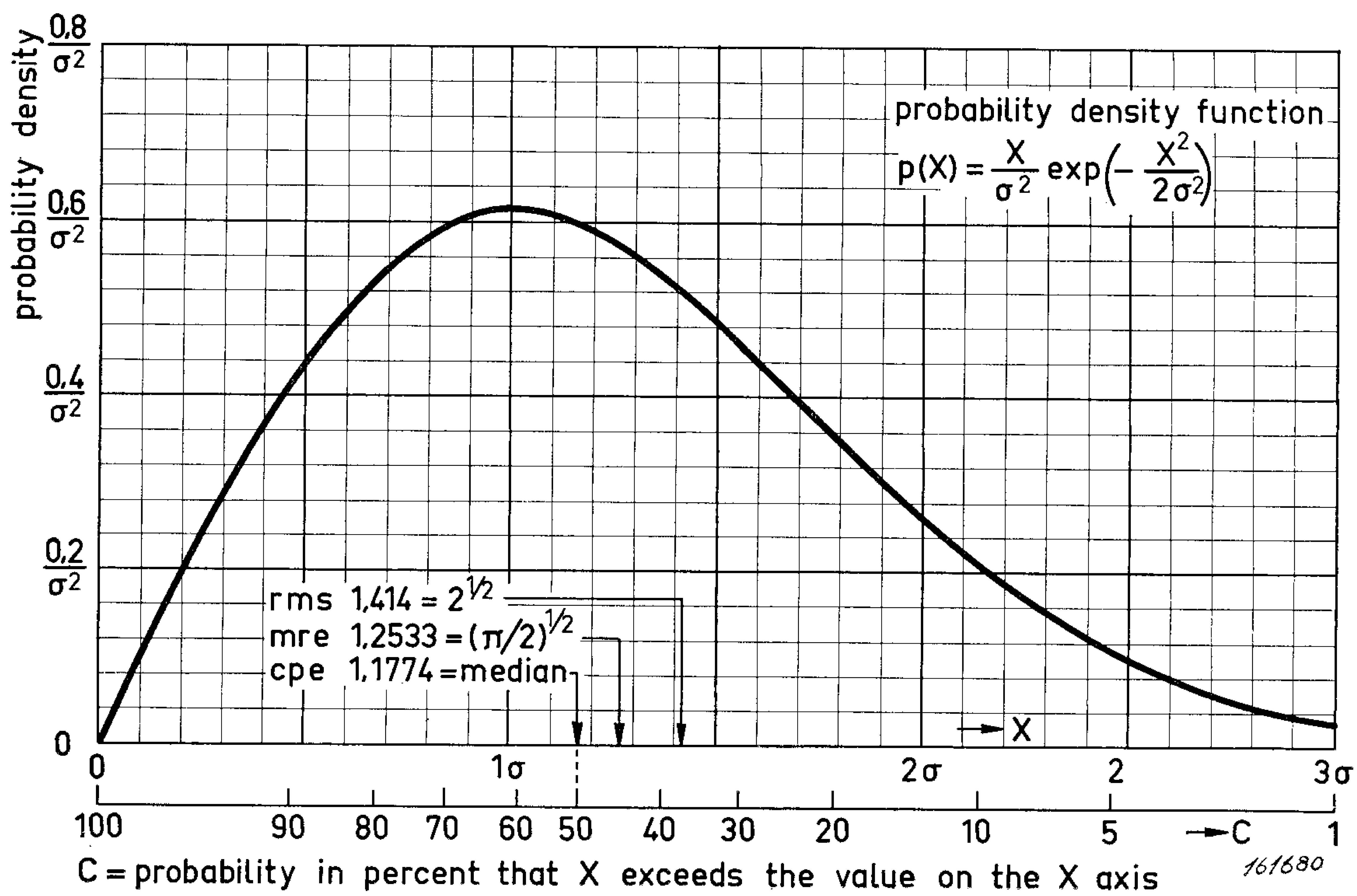

Fig. A. I. 1. The Rayleigh probability density curve (5).

APPENDIX II

Measurement of the Frequency Spectrum of the Envelope of Narrow Band Random Noise.

Fig. A. II. 1 shows a photograph of narrow band random noise as displayed on the screen of a cathode-ray oscilloscope. Here the bandwidth is approximately

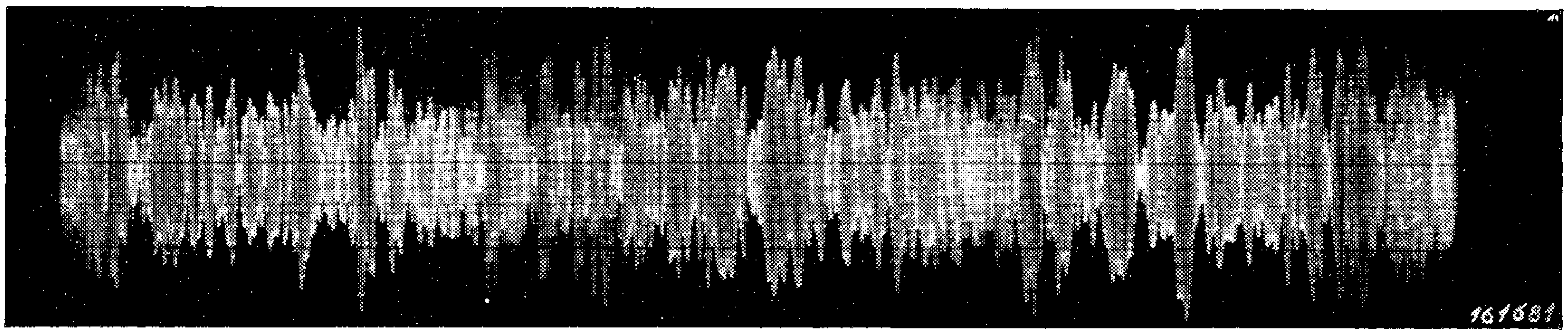

Fig. A. II. 1. Photographic record of narrow band random noise as a function of time.

2 % of the center frequency of the band, the band-pass filter having the shape shown in Fig. A. II. 2. (This shape was obtained by passing random noise firstly through a Frequency Analyzer Type 2105 and then through an Analyzer of the Type 2111 adjusted for ⅓ octave analysis, see also Fig. A. II. 3). It can be seen from the photograph that the noise band has the character of a modulated signal, the carrier frequency of which equals the center frequency of the band.

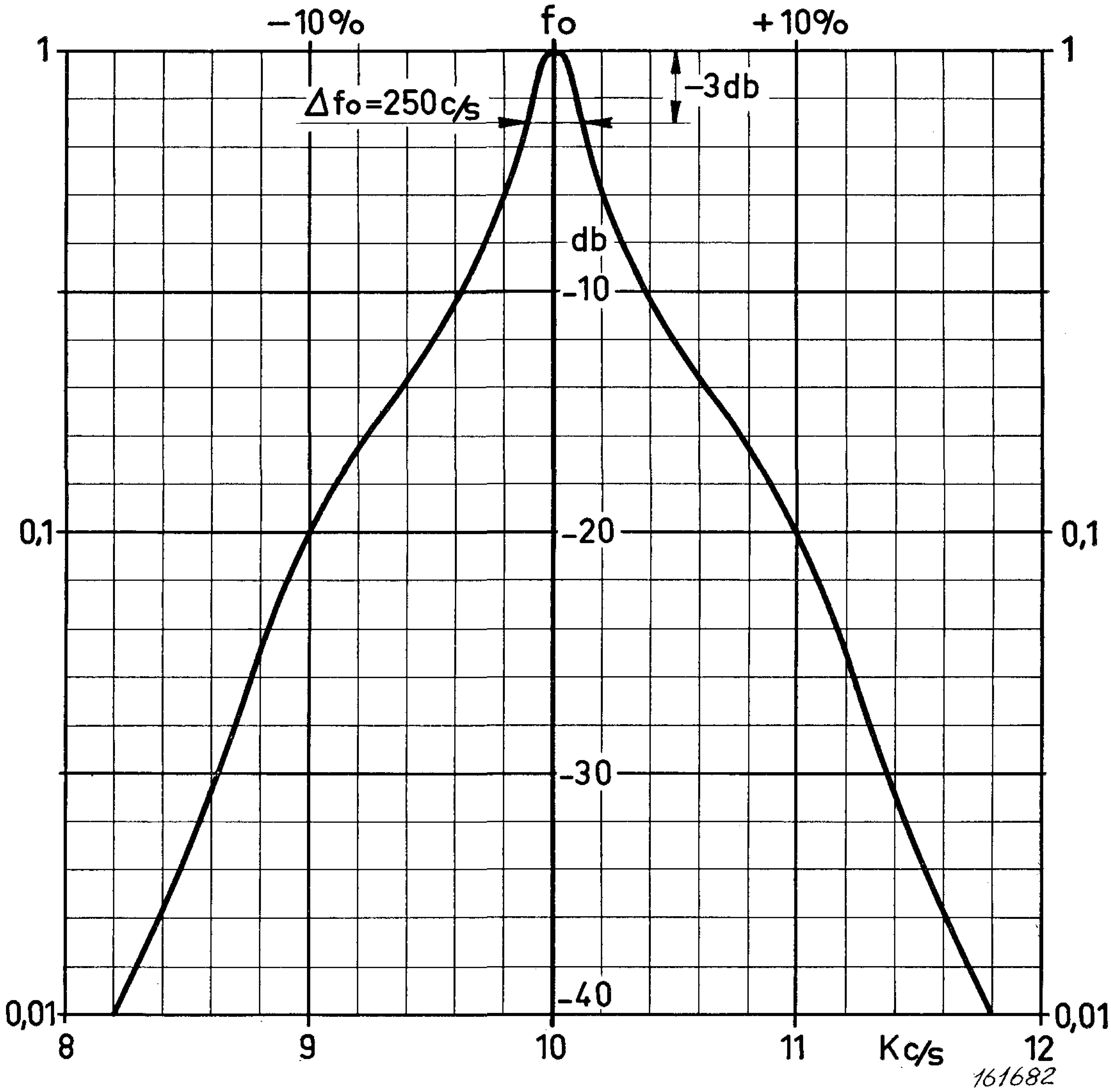

Fig. A. II. 2. Frequency Spectrum of the noise band.

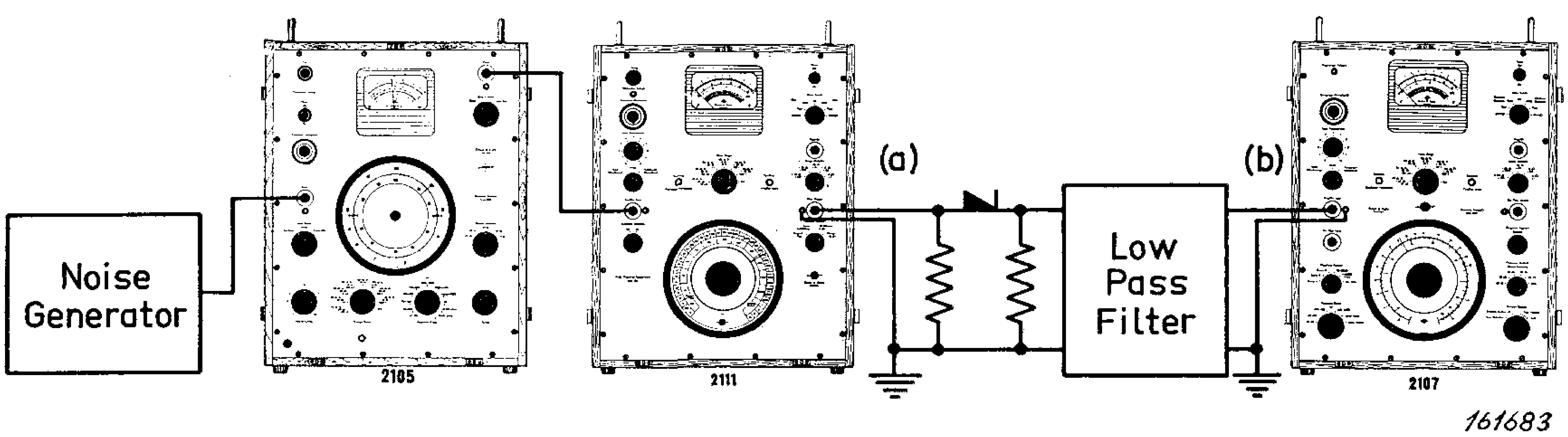

Fig. A. II. 3. Measuring arrangement used to determine the frequency spectrum of the noise envelope (envelope of the noise peaks).

The oscilloscope was connected between point (a) on Fig. A. II. 3. and ground. To determine the frequency spectrum of the modulating signal the band of noise was fed to a half-wave rectifier, after which the carrier frequency was attenuated by means of a sharp low-pass filter. The shape of the signal was measured between point (b), Fig. A. II. 3. and ground, and again displayed on the screen of an oscilloscope (see Fig. A. II. 4.). From the figure it can be seen that the

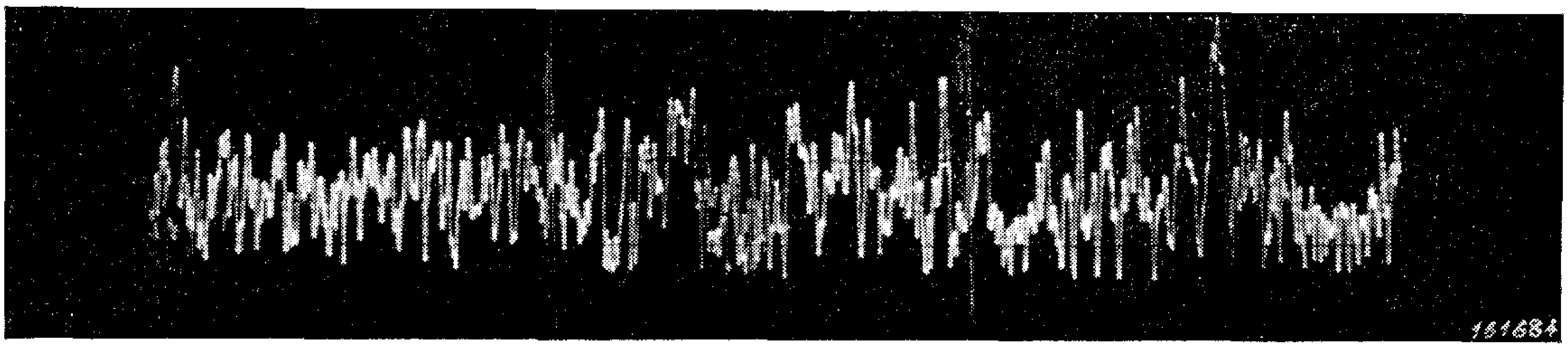

Fig. A. II. 4. Photographic record of the noise envelope as a function of time.

modulating signal has a rather "random" appearance, and it may therefore be expected that its frequency spectrum will be of the continuous type. This is demonstrated in Fig. A. II. 5 where the result of a frequency analysis on the basis of spectrum level (constant bandwidth) of the signal is plotted. (Actually the frequency analysis was carried out on a constant percentage bandwidth basis, Fig. A. II. 3. The result, however, has been "corrected" for the 3 db/octave

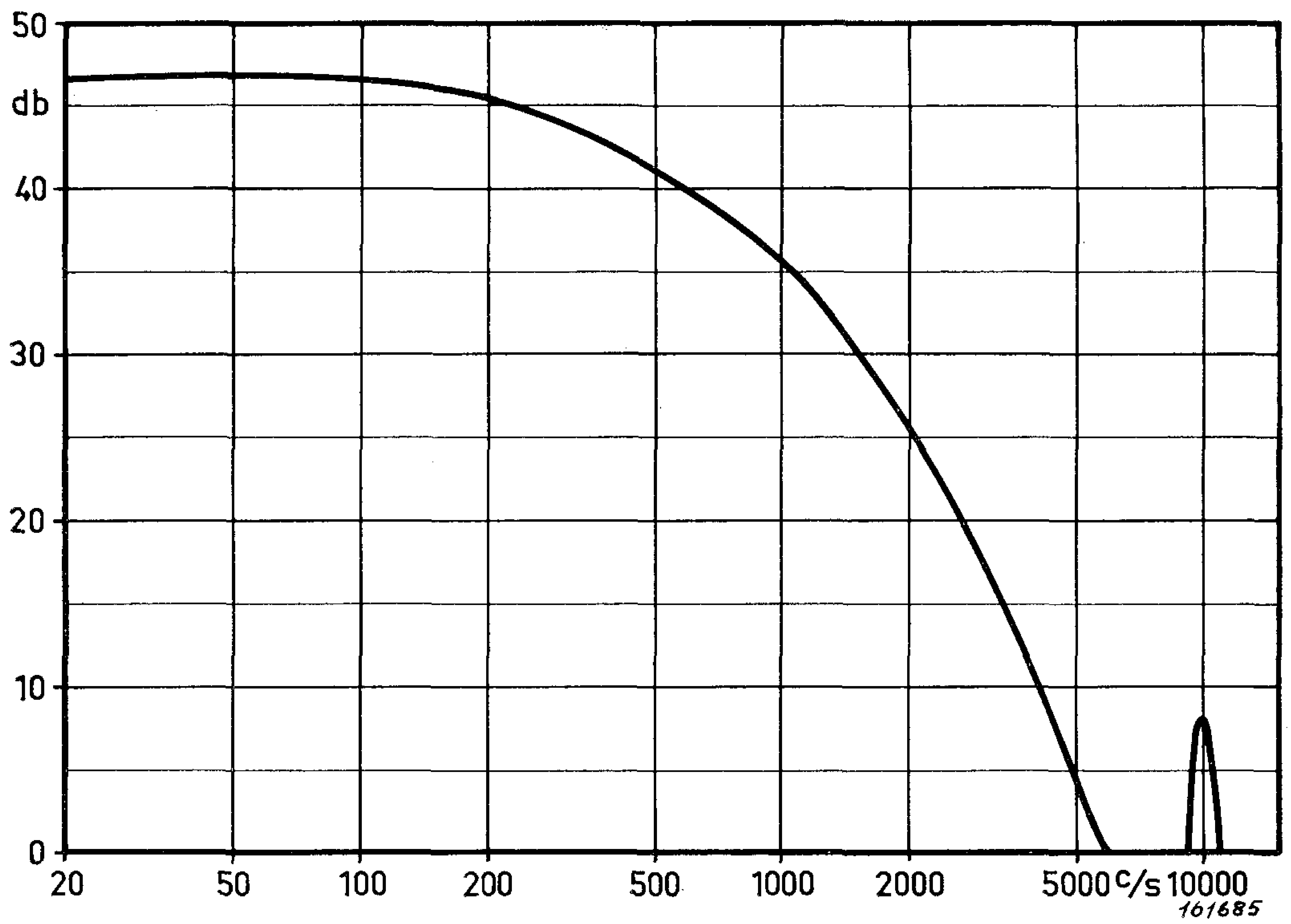

Fig. A. II. 5. Frequency spectrum of the noise envelope plotted on a spectrum level basis.

increase in energy level obtained from this type of analysis, in order to give the reader a clearer picture of the frequency spectrum).

The spectrum shown in Fig. A. II. 5. has a 3 db "cut-off" frequency in the order of magnitude of the bandwidth of the noise band, but does also contain higher frequencies. This is to be expected because of the non-ideal shape of the narrow band filter (see Fig. A. II. 2). However, the main portion of the "energy" in the signal is contained within limits given by the noise bandwidth.

Selected References:

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2. J. S. Bendat: "Principles and Applications of Random Noise Theory", John Wiley & Sons, Inc., 1958.
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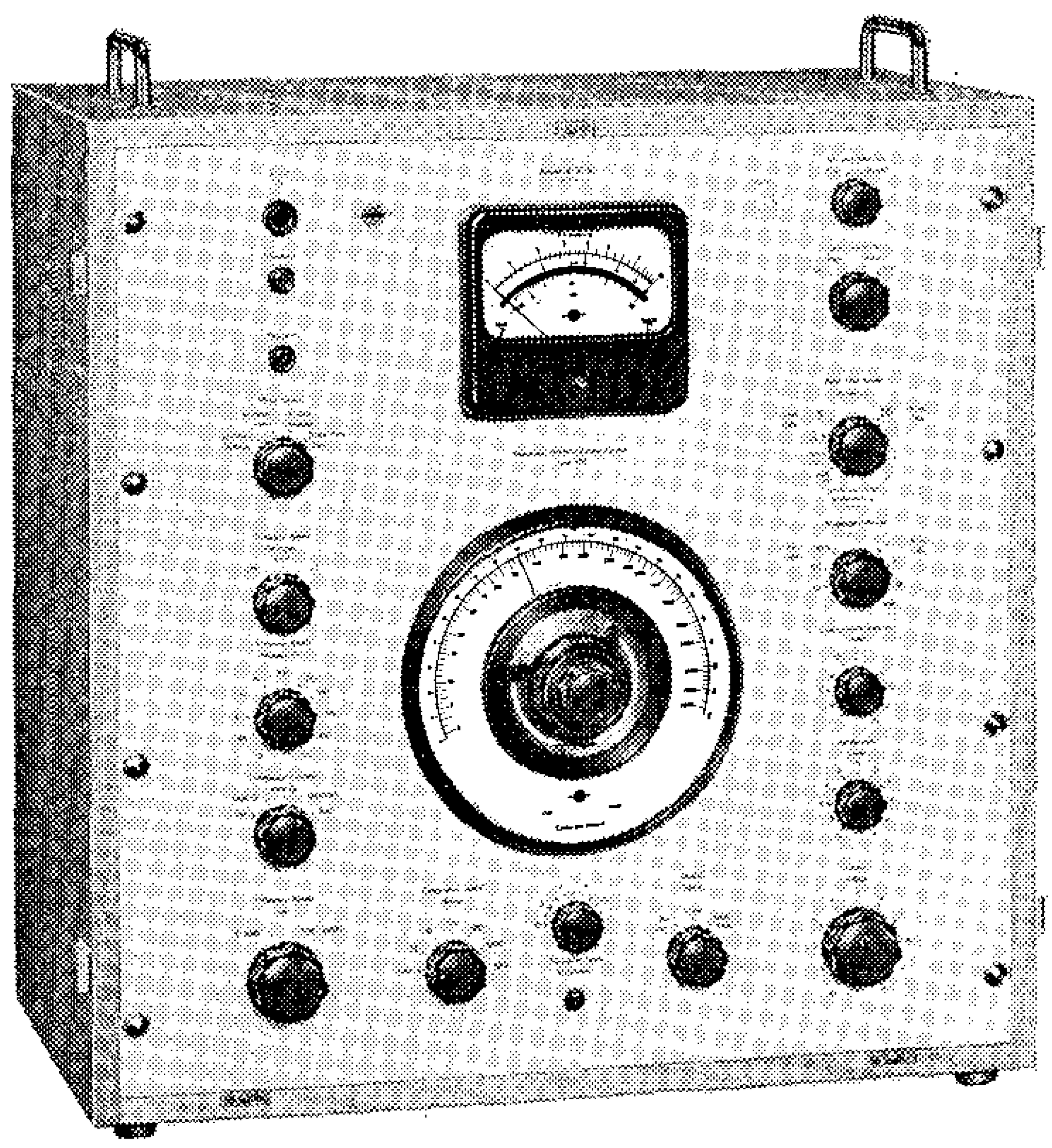
5. "Reference Data for Radio Engineers", fourth edition. Published by the International Telephone and Telegraph Corporation, Publication Department, New York 1957.

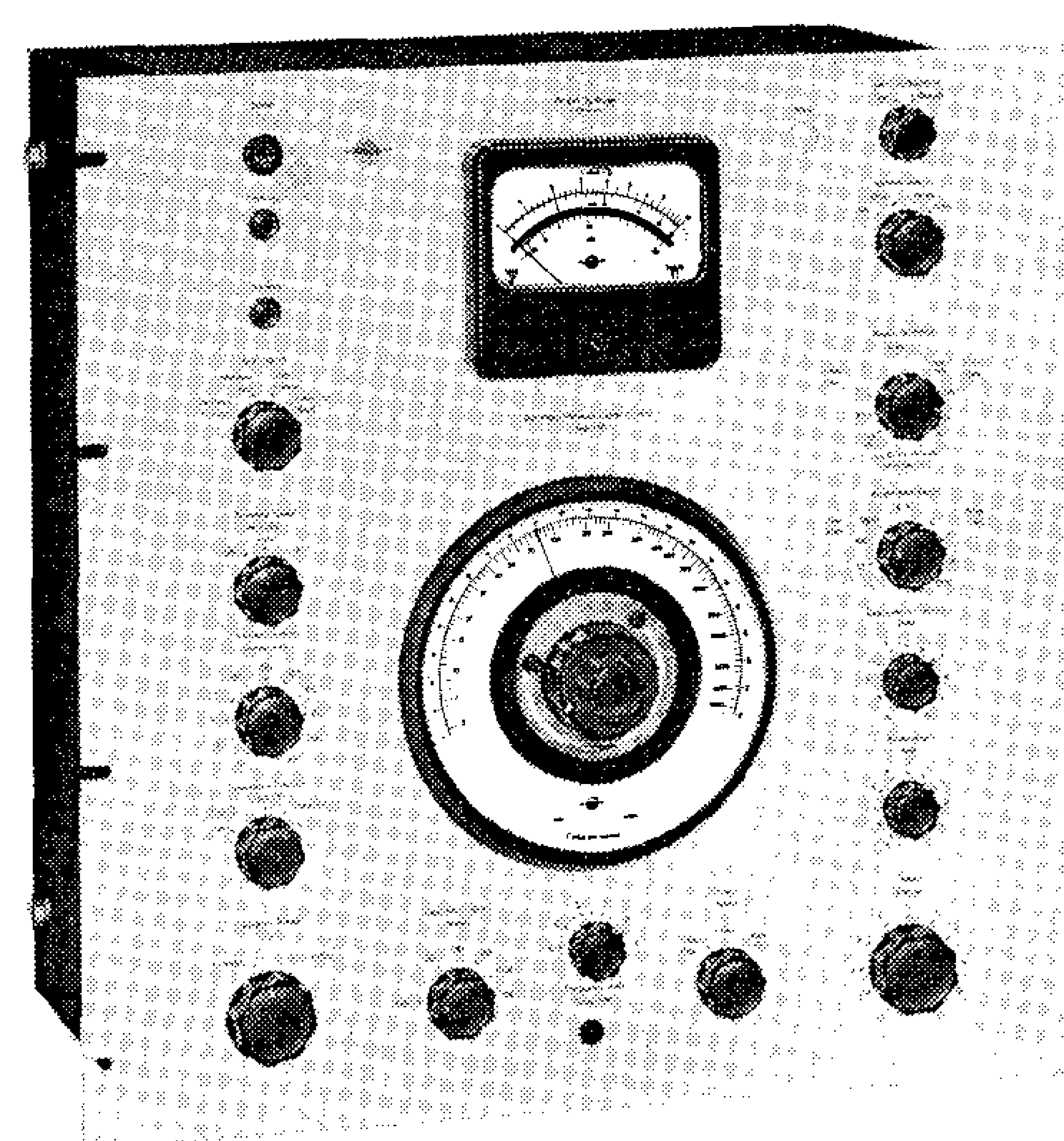
News from the Factory.

New Automatic Vibration Exciter Control Type 1018/1038.

Due to the increase in activity in the vibration test field in recent years Brüel & Kjær have developed a new Control Oscillator for frequency sweep tests, which supersedes the already well-known Automatic Vibration Exciter Control Type 1016. It includes all the good features of the Type 1016, but a number of new *very important* advantages have been added.



Type 1018



Type 1038

A general introduction to the improvements is given in the following:—

1. To facilitate complete automatic sweep over any predetermined frequency range, with maximum regulation speed (small time constants) and minimum distortion, an automatic regulation speed arrangement has been included. The arrangement is controlled from the oscillator tuning capacitor spindle and ensures that the regulation speed is automatically increased with an increase in frequency. The most suitable regulation speeds for various specimen Q's (resonance amplification factors) can be pre-selected.
2. An extra acceleration control range of 1000 g has been added.
3. It is now possible to control shaker displacement levels by means of an accelerometer (additional integration circuit in the vibration meter section).
4. A cathode-follower stage has been added in the oscillator output section facilitating the use of long cables between the Automatic Vibration Exciter Control and the power amplifier.
5. An extra output terminal for control of a stroboscope, or connection of special

external oscillators. The output terminal is mounted on the front panel of the instrument.

6. An extra output terminal from the vibration meter section for vibration level and wave-shape monitoring. The output terminal is mounted on the front panel of the instrument.

7. Vibration meter calibration in metric (and inches) system.

8. Mirror scale on the instrument meter granting more accurate reading of the vibration levels (as well as oscillator output).

9. Built-in compensation network for frequency response compensation of velocity type vibration pick-ups.

10. Change in oscillator output circuit, whereby no input "volume control" is required on the power amplifier.

11. Inclusion of various circuits to reduce the influence of disturbing "noise" signals at low frequencies and low vibration levels.

12. Means of frequency scale adjustment during operation.

13. The height of the front panel, which is designed to fit in 19″ racks, has been changed to $19^{7}/_{32}$″.

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