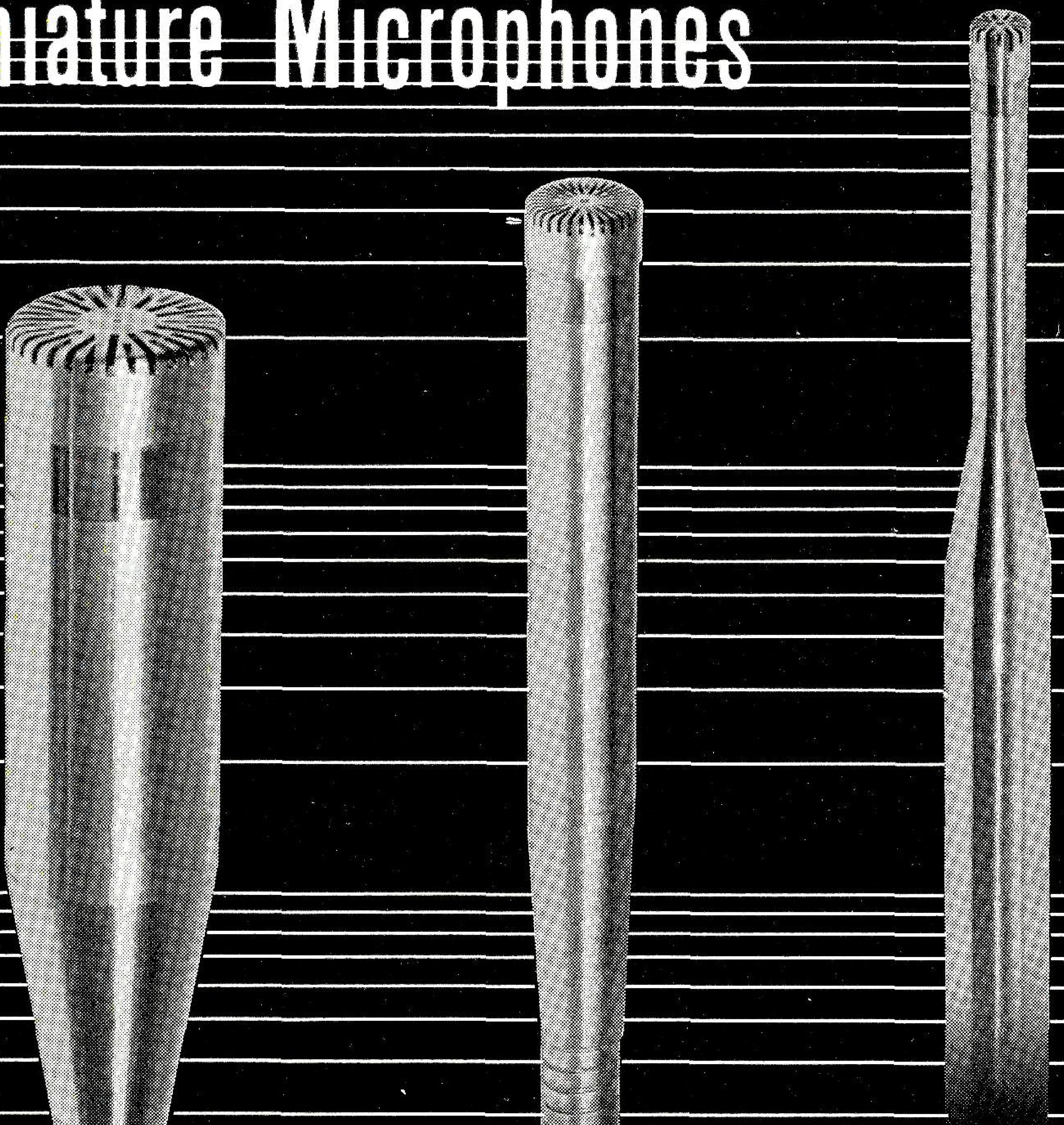
Brüel & Kjær

Technical Review

To Advance Techniques in Acoustical, Electrical, and Mechanical Measurement

Miniature Microphones



Checking of RMS Instruments

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CONTENTS

K. LARSEN & SØN - LYNGBY

Miniature Pressure Microphones

by

Gunnar Rasmussen)*

ABSTRACT

Methods of making a given microphone "look acoustically smaller" in a sound field are briefly outlined and some measurements described. Choice of optimum diaphragm thickness for ¼" microphones is discussed and various design problems facing the development of small microphones reported. Finally the influence of severe environmental conditions upon the operation of the microphone is mentioned. Some methods used during the manufacture of precision microphones to control their various characteristics are also indicated.

SOMMAIRE

Les conditions nécessaires à la réduction des «dimensions acoustiques» d'un microphone sont brièvement analysées ainsi que les principes des méthodes de mesure.

Les différents problèmes relatifs à la miniaturisation des microphones à condensateurs sont ensuite présentés, en particulier les effets de l'inertie de l'air sur le mouvement de la «membrane equivalente».

Enfin l'influence de conditions d'environnements sévères et les problèmes de contrôle des caractéristiques en cours de fabrication sont considérés.

ZUSAMMENFASSUNG

Meßmikrophone geben aufgrund ihrer endlichen Abmessungen Anlaß zu Schallfeldverzerrungen. Durch geeignete konstruktive Meßnahmen kann man die Abmessungen eines Mikrophons im akustischen Sinne verkleinern. Die grundsätzlichen Probleme, welche mit der Entwicklung eines kleinen Kondensatormikrophons zusammenhängen, werden eingehend beschrieben.

In his textbook "Electroacoustics, the analysis of transduction and its historical background" F. V. Hunt writes about Wente's "uniformly sensitive instrument" of 1917: It ushered in a new and thrilling era for the quantitative measurement of acoustical phenomena. The principal changes introduced in the condenser microphone itself during the next three decades consisted of the virtual elimination of the cavity in front of the diaphragm and a drastic reduction in the size of the instrument.

The removal of any cavity in front of the diaphragm, and also an increase in the effective sensitive area of a condenser microphone will make the transducer appear smaller in an acoustic sound field. This effect is best illustrated in Fig. 1 where the free field correction for 0° incidence are shown for two microphones. The front cavity is only 2 mm deep with an internal diameter of 18.6 mm, but it will make the microphone look more than 10 % larger in diameter and increase the free field correction by more than 1.5 db between 7 and 12 kc/s. It is possible, however, to utilize the

*) This paper was presented by the author at the 4th International Congress on Acoustics, Copenhagen 21.—28. August 1962.

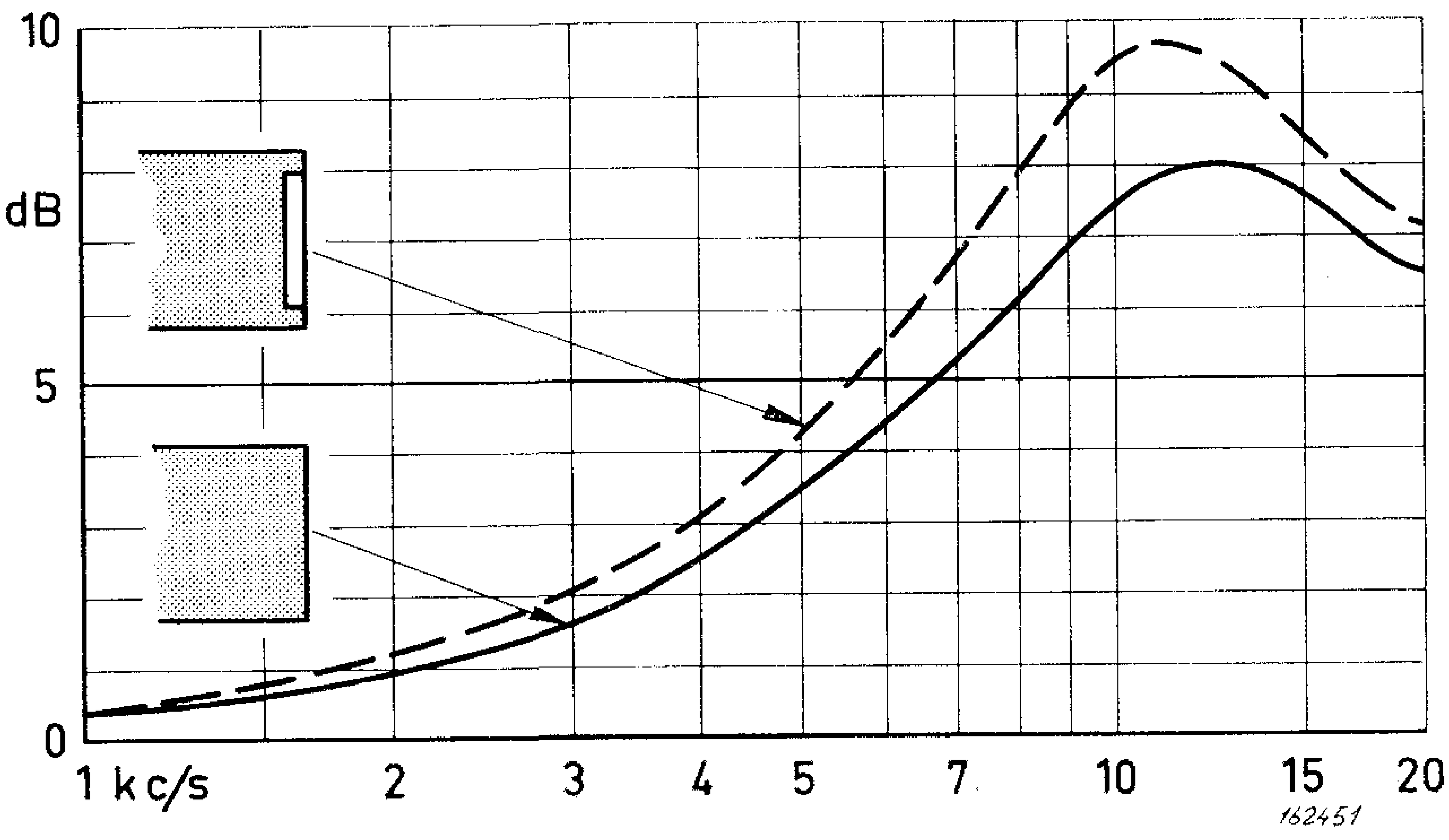

Fig. 1. Typical free-field correction curves (0° sound incidence) for a condenser microphone with and without a small cavity in the front of the diaphragm.

effect of cavities and obstacles in front of a microphone diaphragm, to increase the linear frequency range and the omnidirectional properties far beyond the frequency range given by the conventional considerations regarding diaphragm resonance, wavelength and diameters. In Fig. 2 are shown the frequency response curves obtained by optimizing the properties of a front cover in order to obtain the best possible uniformity of sensitivity for a 1″ microphone at any angle of incidence. In fact this 1″ type 4131 microphone with random incidence corrector UA 0055 is more omnidirectional up to 15 kc/s than a conventional microphone, only ½″ in diameter. Some of the experimental steps leading to this design are shown in

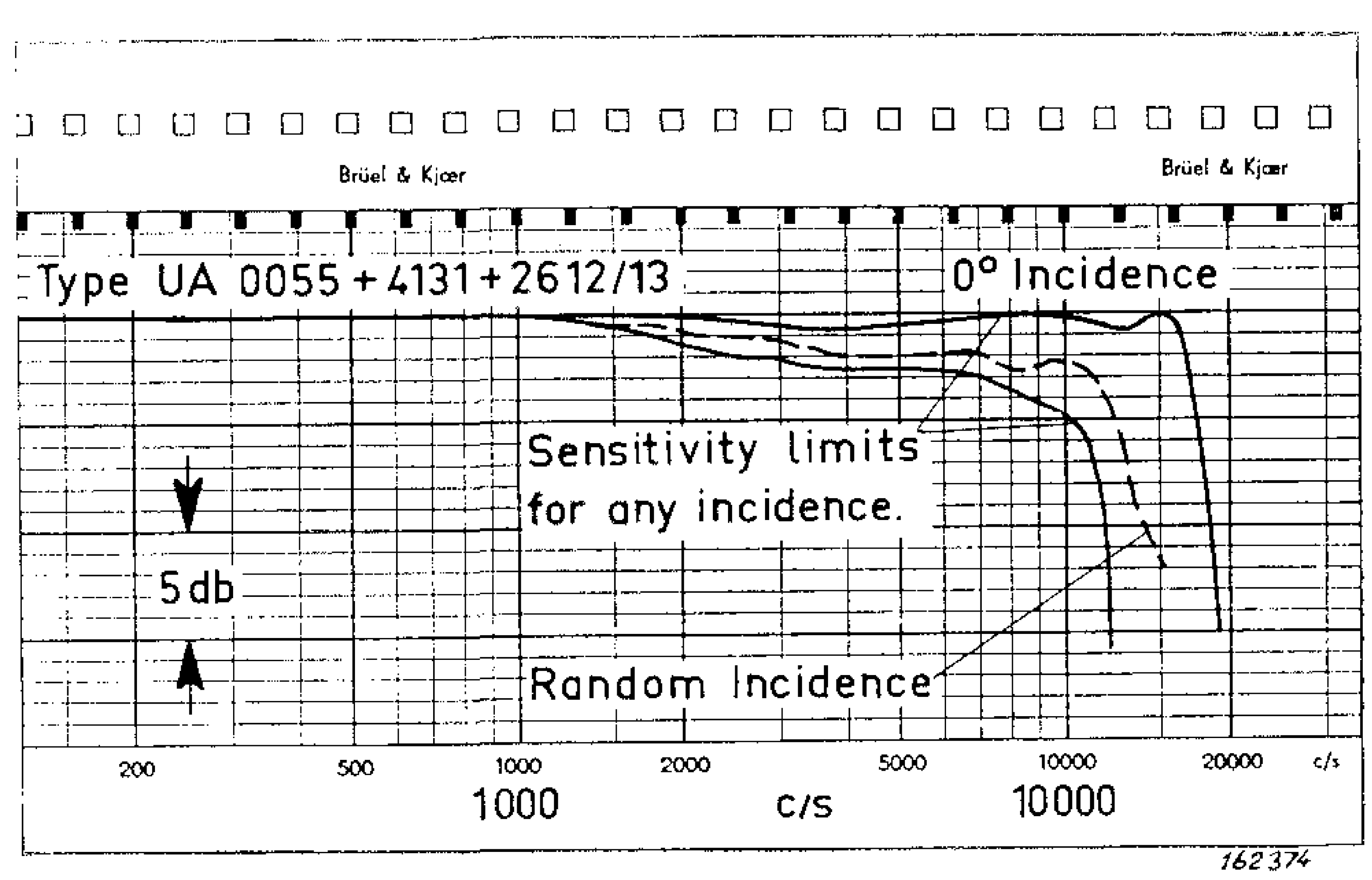

Fig. 2. Frequency Response curves obtained by "optimizing" the properties of a front cover.

Fig. 3.—It is thus possible to optimize some of the properties of a given cartridge size, one could say make it look acoustically smaller in some respects than it really is.

Now for acoustical—and for fluctuating air pressure measurements in general—properties other than omnidirectivity may be called for, and we have investigated the possibilities of miniaturization of both the microphone cartridge itself and the succeeding preamplifier.

It should be kept in mind that the miniature microphones must still be stable with time, temperature and ambient pressure. They must have reasonable dynamic range, a high resonant frequency, and a flat frequency response. They should be unaffected by severe environments, including high vibration levels. The condenser microphone seems at the moment to be the only which is able to fulfil all these requirements. In particular it must be a stretched metal diaphragm type in order to ensure the stability.

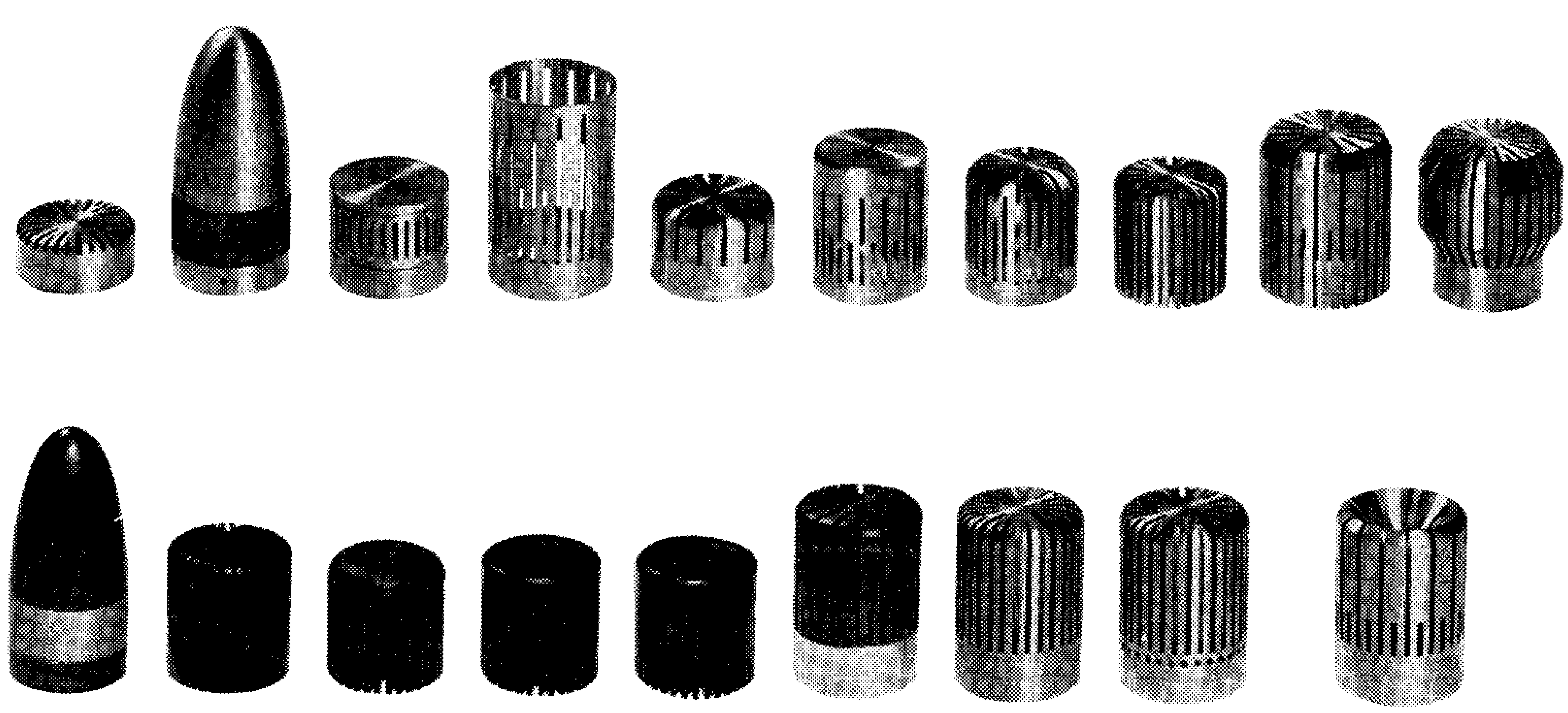

Fig. 3. Some experimental front cover designs which have been investigated at Brüel & Kjær.

The resonant frequency is given by the root of the compliance and the mass of the diaphragm. The sensitivity is controlled by the compliance below and by the mass above resonance. The effective mass is determined by the mass of the diaphragm material itself plus the mass of the moving air loading the diaphragm. The mass of the diaphragm itself should thus be less than the mass of the moving air in order to obtain the maximum sensitivity and highest resonant frequency. The mass of moving air near a diaphragm 4.5 mm in diameter is given by: $o_1 \frac{8 \times a \times \varrho}{3\pi} \pi a^2 = 0.43 \frac{8}{3} \times 1.29 \times 10^{-3} \times 0.45^3$ $= 1.7 \times 10^{-4}$ gr. o_1 is a reduction factor for the diaphragm movement below the first resonance, $\frac{8a}{3\pi}$ is the air columne as given by Lord Rayleigh,*) and ϱ the density of air and "a" the diaphragm radius.**) This mass will equal that of a 5 μ nickel diaphragm if we calculate the effective moving diaphragm mass using a reduction factor of 0.27 (see **).

Fig. 4 shows the relationship between the frequency responses and sensitivities for 1″, ½″ and ¼″ microphones. It is possible by the technique used to make microphones of similar design of still smaller diameters. A ⅛″ type has been made for laboratory use.

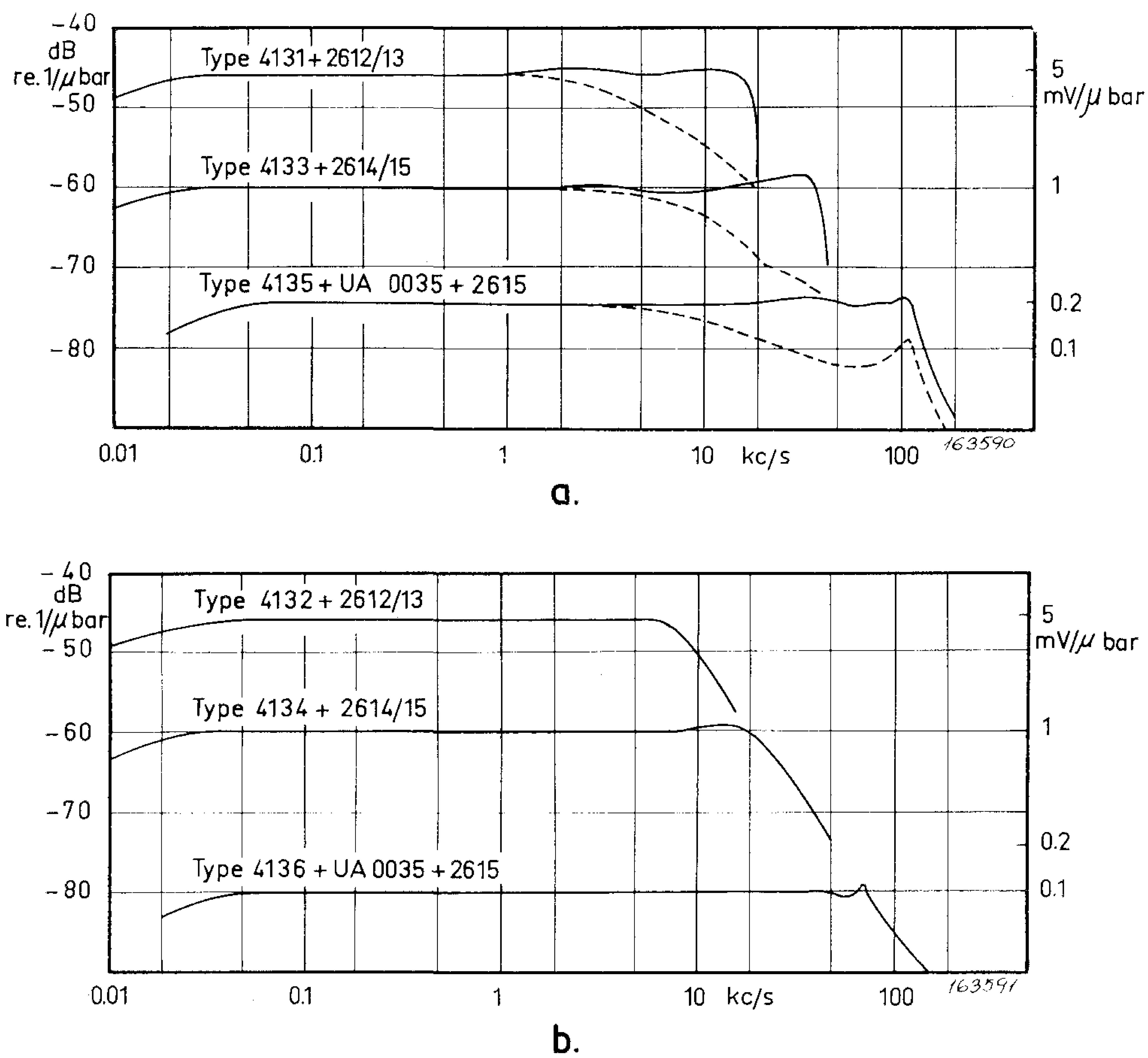

Fig. 4. Relationships between the frequency response and the sensitivity of three different "sizes" of condenser microphones (1″, ½″, and ¼″).
a) Free-field type cartridges
b) Pressure type cartridges

*) Theory of Sound, Vol. II, Chapter XVI, 2nd Ed.
**) Die Grundlagen der Akustik von E. Skudrzyk, page 430.

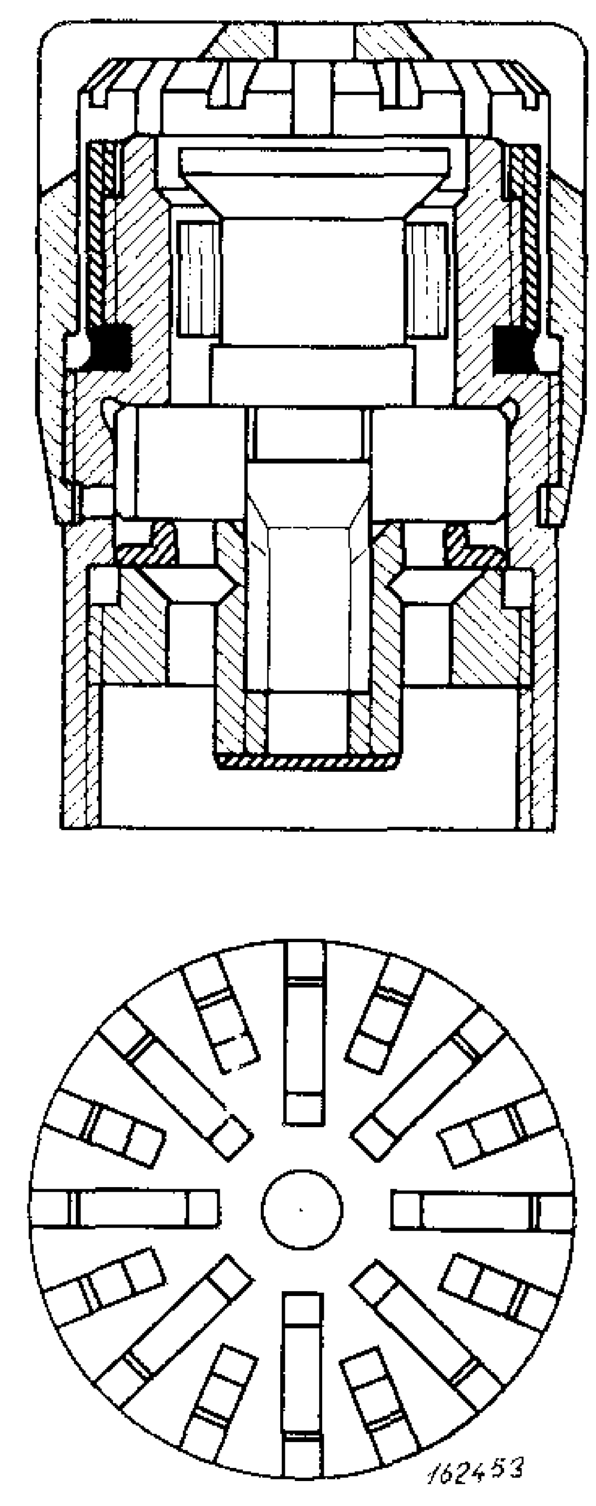

Fig. 5. Sketch of a ¼″ microphone cartridge.

In Fig. 5 is shown a ¼″ type. This microphone has only recently come on the market and I should like to mention some of the design problems faced during its development. The diaphragm is made up in a way which will give a maximum free moving area. The diaphragm tension is adjusted by tighting up the diaphragm on the housing from the front. The diaphragm thickness is 6 μ for one type and 2 μ for another. The material is nickel. The diaphragm thickness is choosen in order to give a flat and uniform pressure response for the one type and a flat free field response at 0° incidence for the other type. The frequency response for the pressure type is linear up to 70 kc/s within $\pm$ 2 db. It is interesting that the natural frequency of the diaphragm with no air loading and no air cushion between the diaphragm and the back plate is 50 kc/s. It is possible to increase the frequency range to 70 kc/s by choosing the correct size of back plate and using maximum damping of the diaphragm center around resonance, thereby virtually blocking the diaphragm center and increasing the resonance. In this way the maximum sensitivity will be located at the edge of the back plate. This will make the microphone more sensitive to wave motions in the space between the diaphragm and the insulator. A special shaped Teflon damping ring is introduced in order to overcome this. How this works is shown in Fig. 6. This standing wave effect is incidentally also present in ½″ and 1″ microphones but normally does not manifest itself within the working frequency range. In 1949 Isadore Rudnick proposed the effect as a reason for resonances in the W.E. 640 A.A. at 36 kc/s.*) The sensitivity and thus the com-

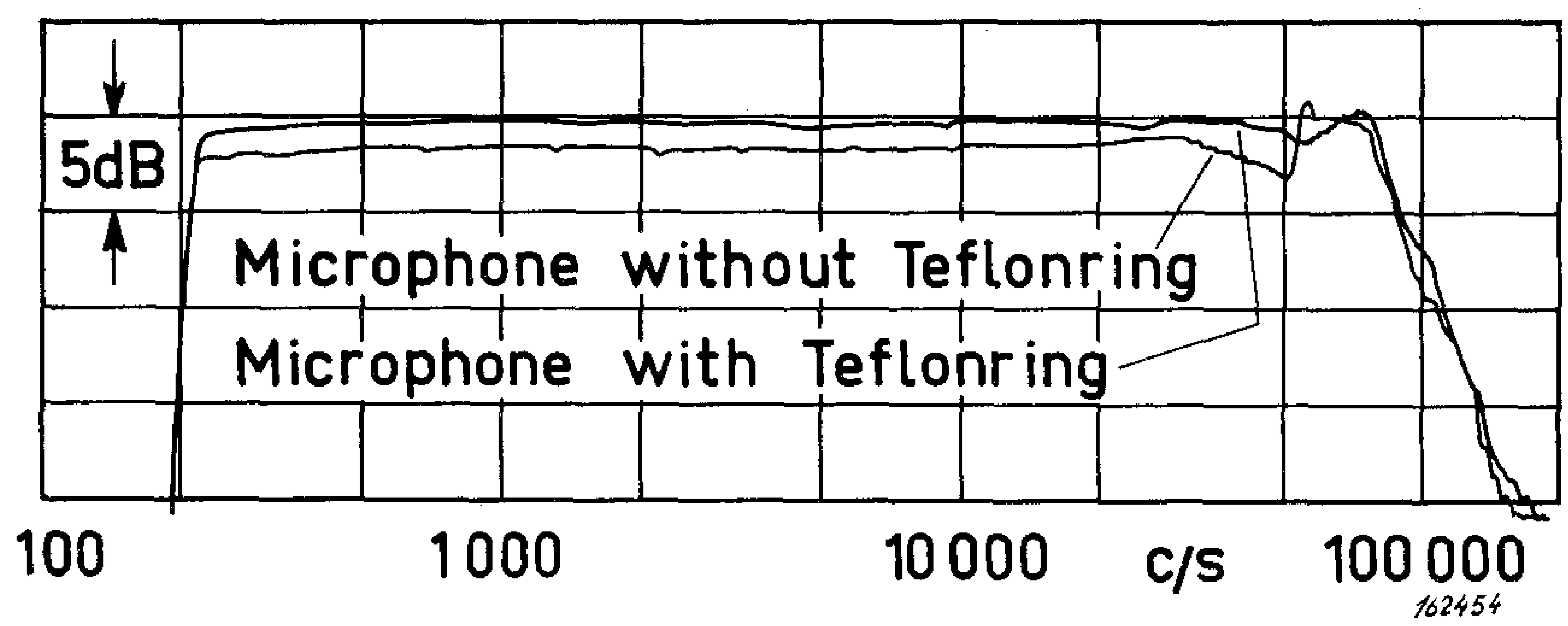

Fig. 6. Response curves illustrating the effect of using a specially shaped Teflon ring upon wave-motion in the space between the diaphragm and the insulator.

pliance of the type with 2 μ diaphragm is around 2—3 times that of the type with 6 μ. The resonance of the free moving diaphragms are the same. However, it is possible to damp the 2 μ diaphragm in order to compensate for the pressure increase in front of the diaphragm for 0° incidence and obtain a flat response above 120 kc/s still with good sensitivity.

The stiffness of the back space is kept very low in order to maintain the sensitivity stable at low ambient pressures as encountered at high altitudes. The stiffness is less than 8 % of the diaphragm stiffness as seen from the curves in Fig. 7. This again gives the equivalent volume of the microphone as less than 0.0005 cm^3. The back space volume is 0.005 cm^3. The resonance damping will of course decrease at low ambient pressure and it is interesting to see that Q values of the order of 500 are obtained for the diaphragm resonance at 14 mm of mercury. The equalization of the pressure from the back space takes place through a small slot to the front of the cartridge and it is adjusted to a lower limiting frequency of 1—5 c/s. The rate of climb allowed for less than 1 db change in sensitivity is greater than 20000 m/sec.

The microphones are aged at 150°C for several days and exposed to controlled temperature variations for at least two weeks, during which period it is checked for stability. They are tested in a humidity chamber overnight and must work properly under normal conditions within 15 min. after they have been taken out from the humidity chamber.

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*) JASA Vol. 20, No. 6, 1948, I. Rudnick et M. N. Stein.

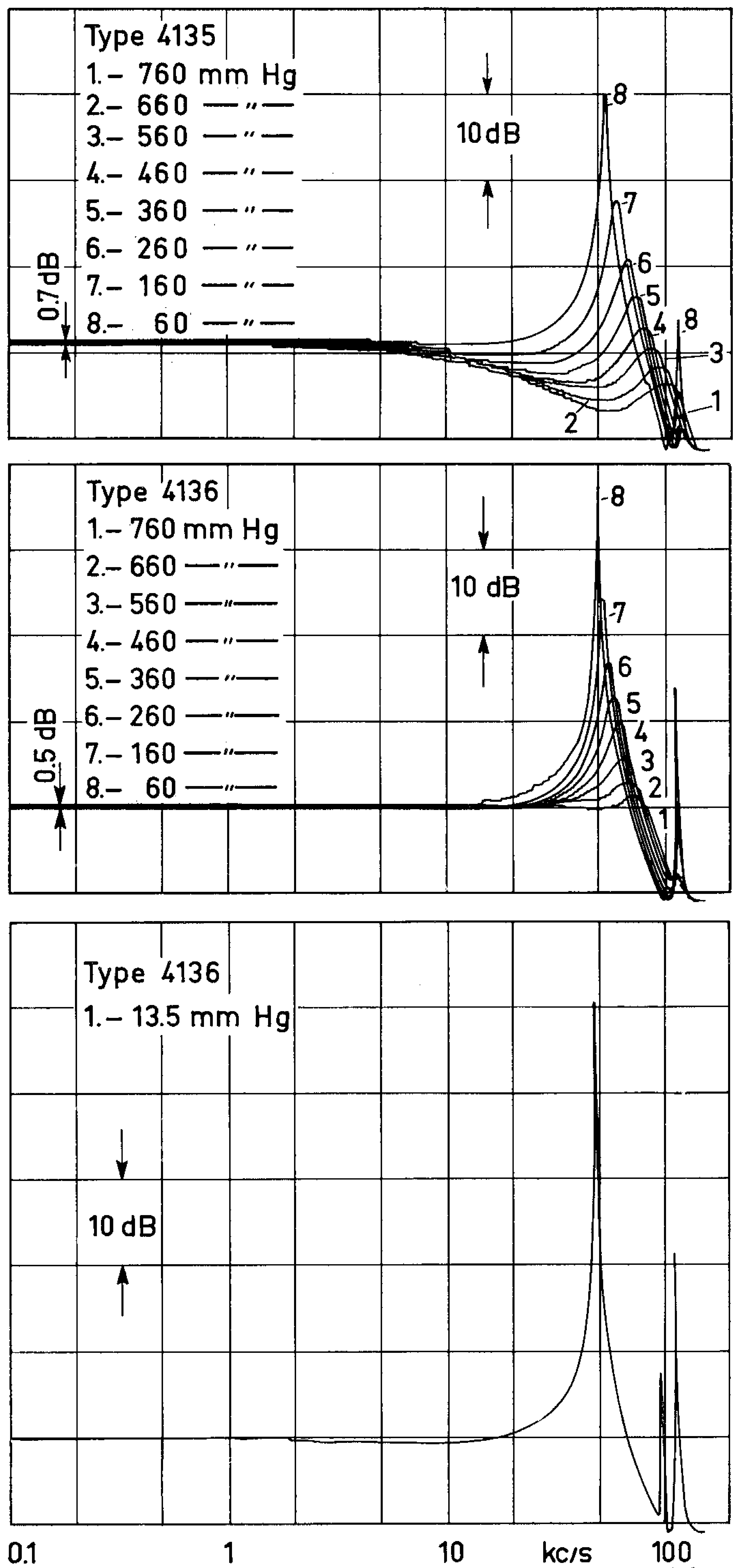

Fig. 7. Measurement of diaphragm stiffness and air damping.

Having produced condenser microphone cartridges for several years we have found it possible to avoid most of the troubles with moisture sensitivity normally believed to be an inherent failure in microphones of that type. This requires trained personnel and good working conditions, but once established it seems possible to prove that condenser microphones can be made to withstand even one of the most severe environments—the dessicator. People sometimes still store their condenser microphones in dessicators—an old practice maybe. But if there are any disturbing particles in the microphone they will dry out, maybe become loose and drop in between the diaphragm and back plate, or be attracted by the polarizing voltage when taken into use again. After 7—15 min. the microphone will sometimes get noisy when the dried-out particles absorb moisture again. Therefore we do not recommend the use of dessicators, although we try to make microphones which can stand this treatment.

By further miniaturization, employing the technique from which I have mentioned a few examples and peculiarities, it should be possible to extend acoustical measurements into fields hitherto not well investigated. Careful design may offer stability and accuracy comparable to that of the associated electronic instrumentation.

Methods of Checking the RMS Properties of RMS Instruments

by

Carl Gustav Wahrman, M.Sc.,*)

ABSTRACT

The two tone test recommended in various sound level meter standards is shown to be insufficient for instruments intended to measure signals having gaussian noise character.
A gaussian noise check is better but still imperfect. Best is the method of using rectangular pulses af varying crest factors and signs.

SOMMAIRE

L'essai de la caractéristique d'intégration des sonomètres au moyen de la méthode des deux signaux de fréquence différentes préconisée par les recommandations internationales est insuffisant lorsque l'on considère l'emploi des sonomètres à la mesure de bruits gaussiens.
L'essai à l'aide d'un signal gaussien, quoique meilleur, reste cependant imparfait en pratique. La méthode présentée employant des impulsions rectangulaires de facteur de crête variable et signes différents semble être la plus universelle.

ZUSAMMENFASSUNG

Die Effektivwertanzeige von Schallpegelmessern wird nach der Norm mit einem Doppelton-Signal geprüft. Es zeigt sich, daß dieses Verfahren unbefrieddigend für solche Geräte ist, welche für die Messung von Breitbandrauschen beabsichtig sind. Eine Prüfung mit Breitbandrauschen ist besser, jedoch ebenfalls nicht vollkommen. Am besten eignen sich Rechteck-Impulse mit veränderlichem Scheitelfaktor und veränderlichen Vorzeichen.

For a long time the Root Mean Square has been accepted as the most practical measure determining the magnitude of an alternating variable. This is also the case within the field of acoustic although it is not evident whether the primary standard for noise measurement: the human ear, makes any root mean squaring at all.
Unfortunately, it has also for a long time been common practice to calibrate electrical instruments so as to show the RMS value of a sinusoidal input even

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*) This article is based on a paper presented by the auther at the 4th International Congress on Acoustics, Copenhagen 21.—28. August 1962.

though the instrument actually measures either the arithmetic average value or the peak value. This has been because it is simpler to make average or (approximate) peak measuring instruments, than a true RMS instrument. (Another point is that it is also difficult to make a good peak measuring instrument).

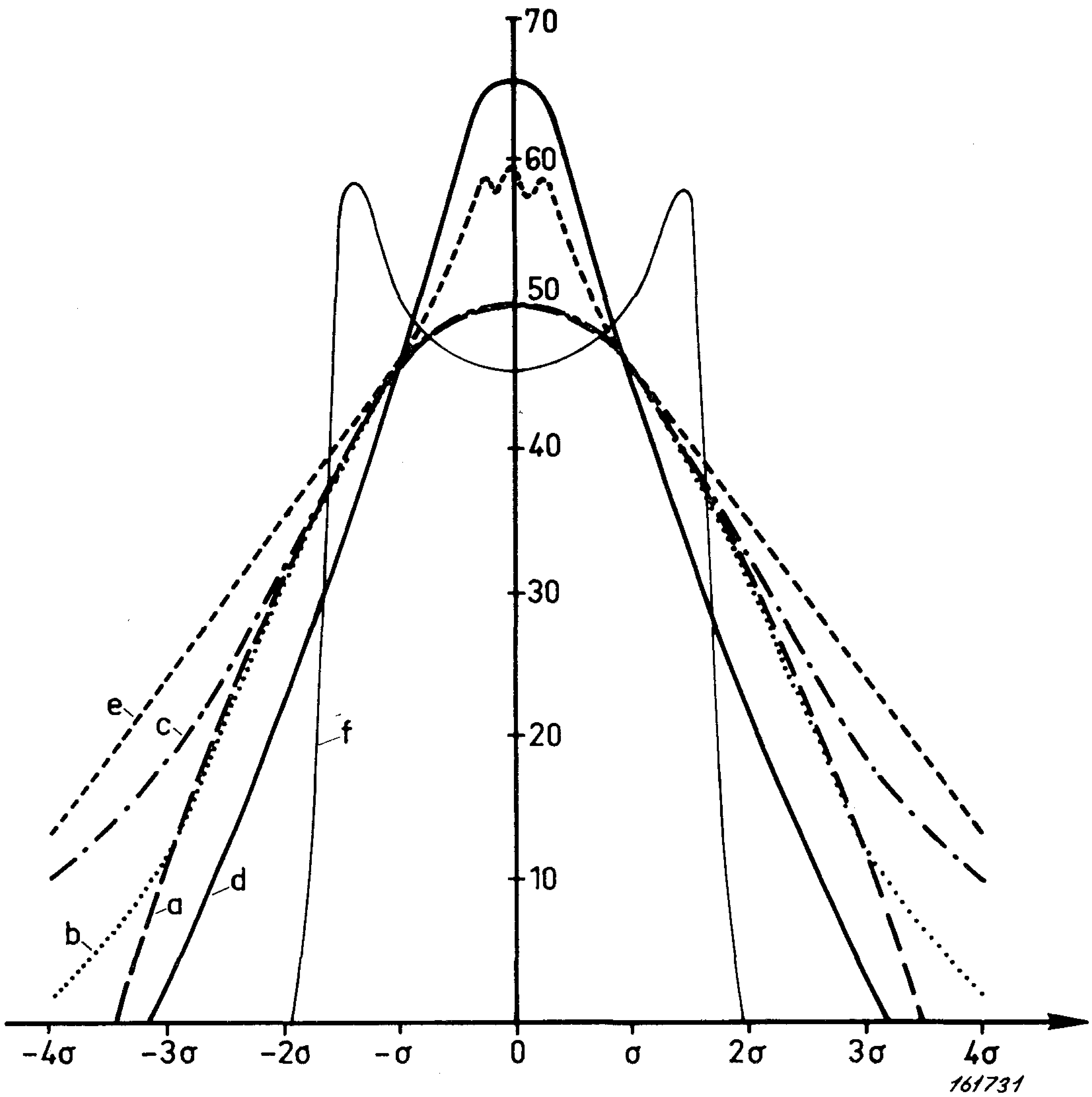


Fig. 1. Curves of probability-density-distributions.
(a) Random noise.
(b) Noise from a mechanical workshop.
(c) Office noise.
(d) Music played by an orchestra.
(e) Speech in an auditorium.
(f) Sine wave.

The user of such an instrument may risk great errors when measuring acoustical signals as they are often far from sinusoidal.
However, it is now possible to make instruments measuring an approximate RMS value. It is therefore of interest to have a good method of checking whether an instrument claimed to show the RMS value really is an RMS instrument, and how good a possible approximation is.
To this end some national and international standards for sound level meters[1]) have included a check where the reading for the combination of two non harmonically related sinusoidal voltages of the same amplitude is compared to the reading for each of the sinusoidal components. The RMS value of the combination is exactly $\sqrt{2}$ times the RMS value of the single sinusoid. If the combination is attenuated 3 dB, the three readings should be the same within suitable tolerance.
This is a necessary but unfortunately not a sufficient condition for an RMS instrument. This condition excludes the simple average or peak measuring instruments, but the circuits shown in the following can be made to satisfy the above check as accurately as desired, and some of these are very bad approximations to an RMS instrument.
The signals measured with a sound level meter are often non-sinusoidal and very seldom similar to the above two tone signals. Very often the signals have a more or less Gaussian probability distribution as shown in Fig. 1. Therefore it would be natural to use a Gaussian random noise signal as another signal for checking RMS instruments at least in sound level meters. The Gaussian noise checks has the draw-back of not being absolute as the RMS value of the signal has to be measured by another RMS instrument. A Gaussian noise check has been included in some standards for sound level meters[2]).
Let us consider first the simple average and peak measuring circuits and their current voltage characteristics shown in Fig. 2A and B. Their

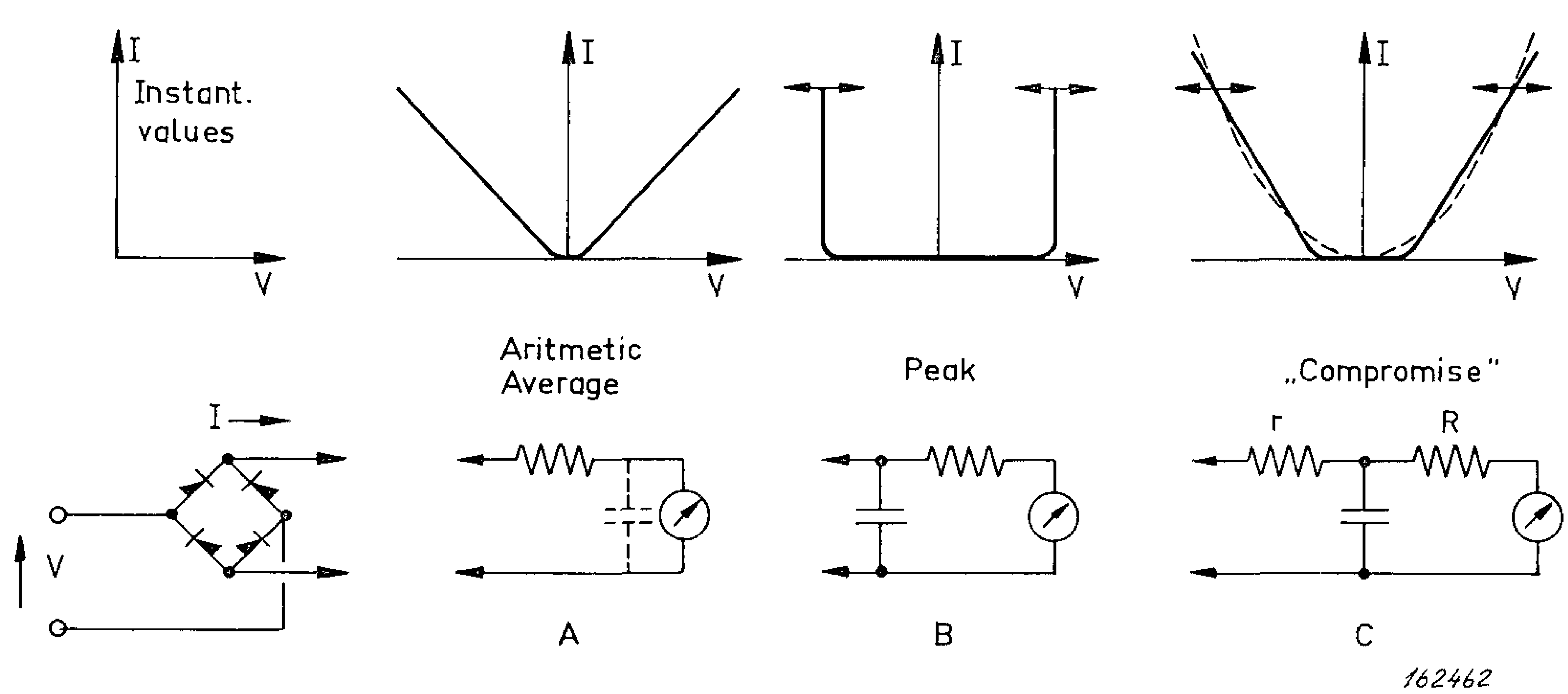


Fig. 2. Diagrams and characteristics of some simple meter circuits.

characteristics are very bad approximation to a parabola which is the curve wanted for an RMS instrument. The RMS value of a signal is always between the average and the peak values, and therefore a compromise between the average and the peak measuring circuits as shown in Fig. 2C seems to be an obvious solution to a better approximation. The horizontal arrows on the characteristic Fig. 2C indicate that the characteristic moves with the reading on the instrument. This property takes care of the "root extraction" in this RMS circuit.[3])
In Fig. 3 is shown the error obtained with this circuit for different input signals as a function of the ratio between the two resistors R and r. These curves are also valid for similar circuits using either single rectification

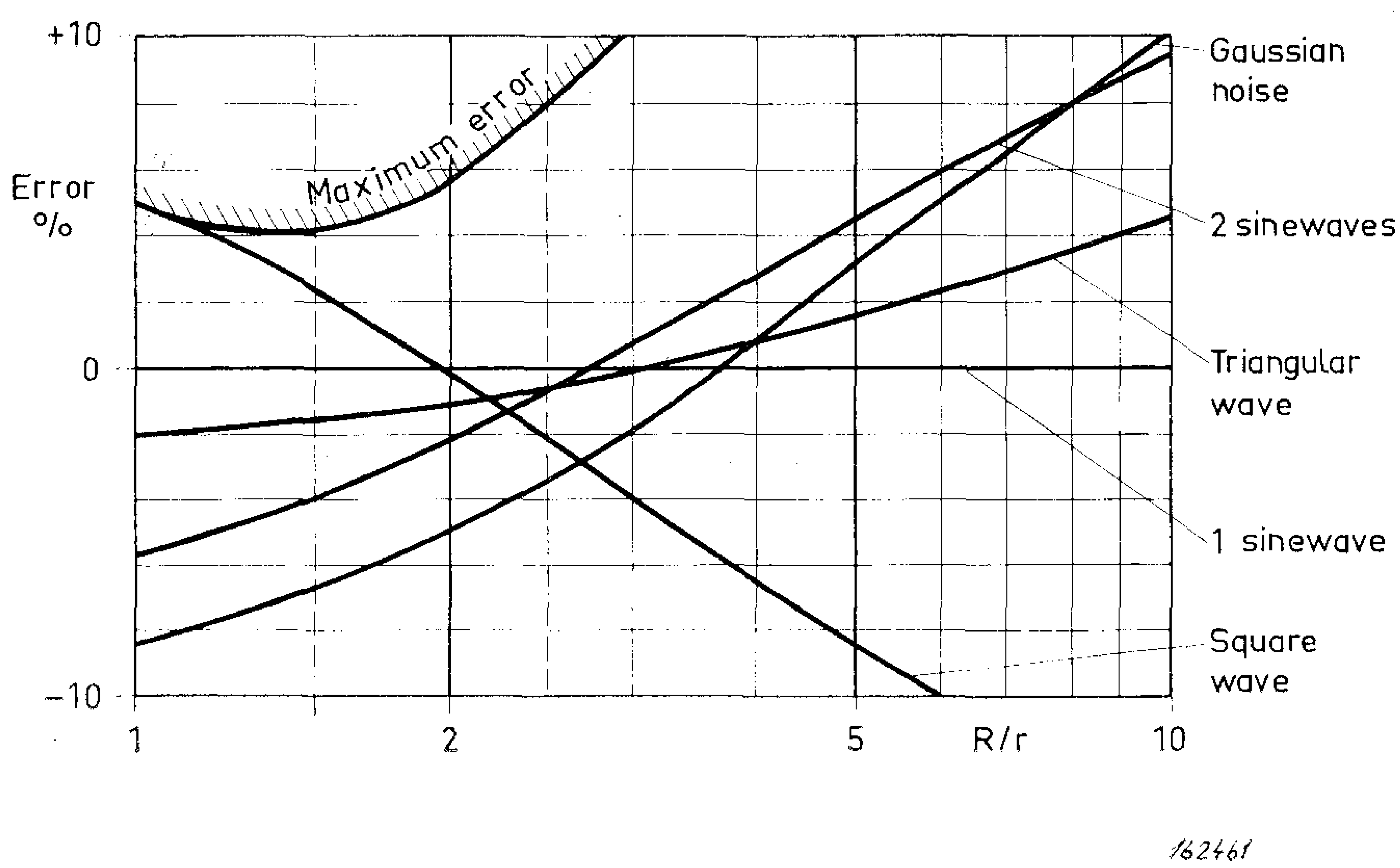
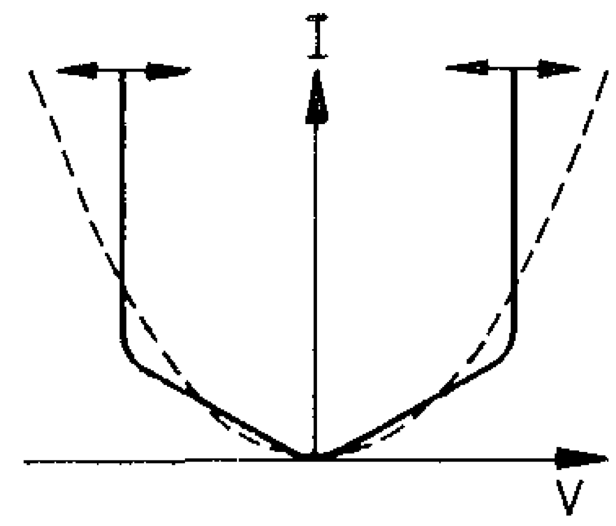
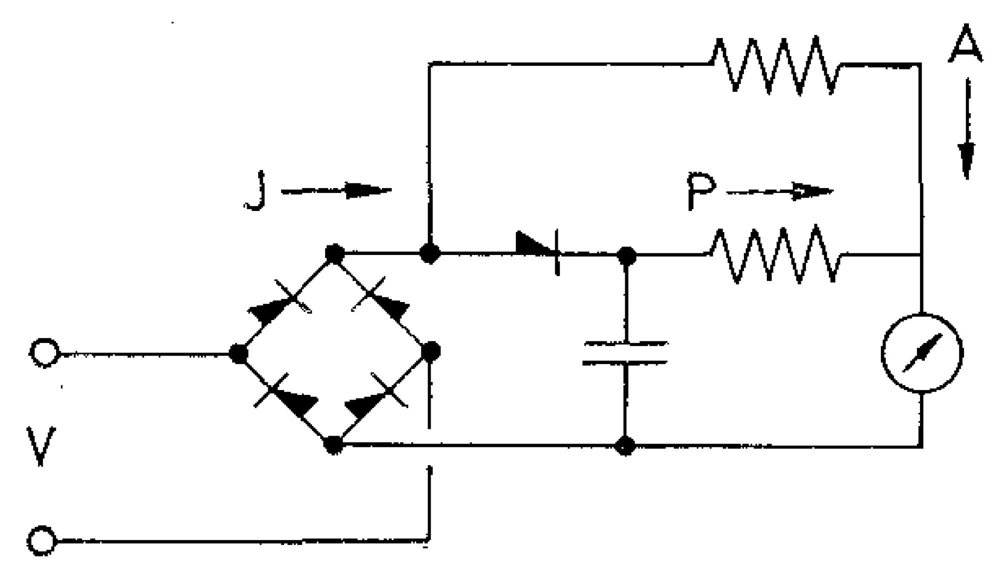


Fig. 3. Errors obtained with different waveforms on the "compromise" circuit Fig. 2C.

or voltage doubling, if the R/r scale is simply multiplied by 2 or 4 respectively.[4]) It is seen that an R/r of about 2.7 gives zero error with the two tone test, whereas the error with a Gaussian signals is about — 3 %. A value of R/r = 3.6 gives zero error for Gaussian signals and about + 2 % for the two tone signal. An error of 3 % is negligible compared to all the other errors normally appearing in sound level measurements, and therefore this circuit seems usable for such measurements.
Instead of making a compromise between the average and the peak measuring circuit, a combination of the two can be made as shown in Fig. 4A. The current in the meter consists of A parts proportional to the average value and P parts proportional to the peak value of the input



Signal	Ave.	Peak	RMS
1 tone	0,90	1,41	1
2 tones	0,81	2	1



1 tone: $0{,}90\,A + 1{,}41\,P = 1$

2 tones: $0{,}81\,A + 2\,P = 1$

$A = 0{,}90$ $\qquad P = 0{,}137$

$\underline{\underline{A/P = 6{,}57}}$

Fig. 4. Diagram, characteristic and calculation for a combined average-peak circuit satisfying the two tone test.

signal. Two equations can now be set up and a ratio A/P can be found so that this circuit satisfies the two tone test. This is shown in Fig. 4B.
How does this circuit behave when measuring Gaussian noise. Theoretically, the peak value of Gaussian noise is infinite, and the meter should thus show infinity. However, in practice it is hard to make a simple peak measuring circuit, which shows more than 3 to 4 times the RMS value of the Gaussian noise. This causes the combined circuit to measure 1 to 2 dB too much. This circuit may thus be worse than the simple average measuring circuit which shows only —1 dB error on Gaussian noise.

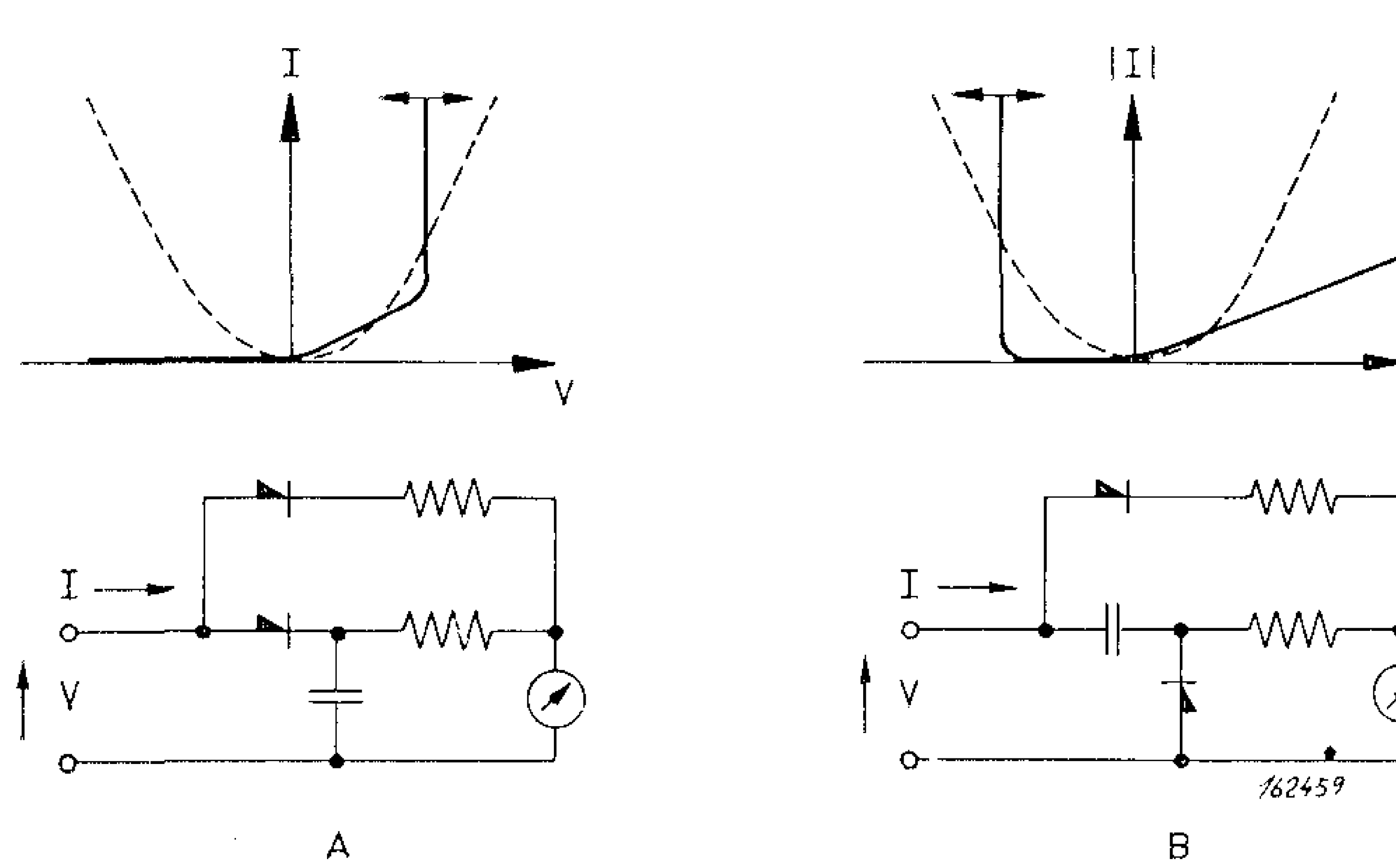


Fig. 5. Two simple combined average — peak circuits and their characteristics.

The combined circuit in Fig. 2C contains one diode less than the circuit in Fig. 4 and as the first circuit seems to be better than the last, there should be no reason for using the last circuit. Still a designer not knowing about the first circuit might "invent" the last circuit thinking he has made an improvement as the circuit satisfies the two tones test.
The circuits in Fig. 2C and 4 can be simplified as shown in Fig. 5 and 6A by using only single rectification. The circuit in Fig. 6B contains three resistors and suitable ratios between them can be found, so that this circuit satisfies both the two tone and the Gaussian noise test at the same time. The characteristics of these circuits are very unsymmetrical, but the above mentioned standards do not require a symmetrical characteristic, and neither the two tone test nor a Gaussian noise test checks this property.
It is obvious that such "unsymmetrical" circuits are not recommendable as approximate RMS circuits. Although most acoustical signals have more or less symmetrical distributions, the signal may sometimes happen to be rather unsymmetrical, and the readings on this meter will then depend on the polarity of the signal and possible 180° phase inversion in the amplifier.

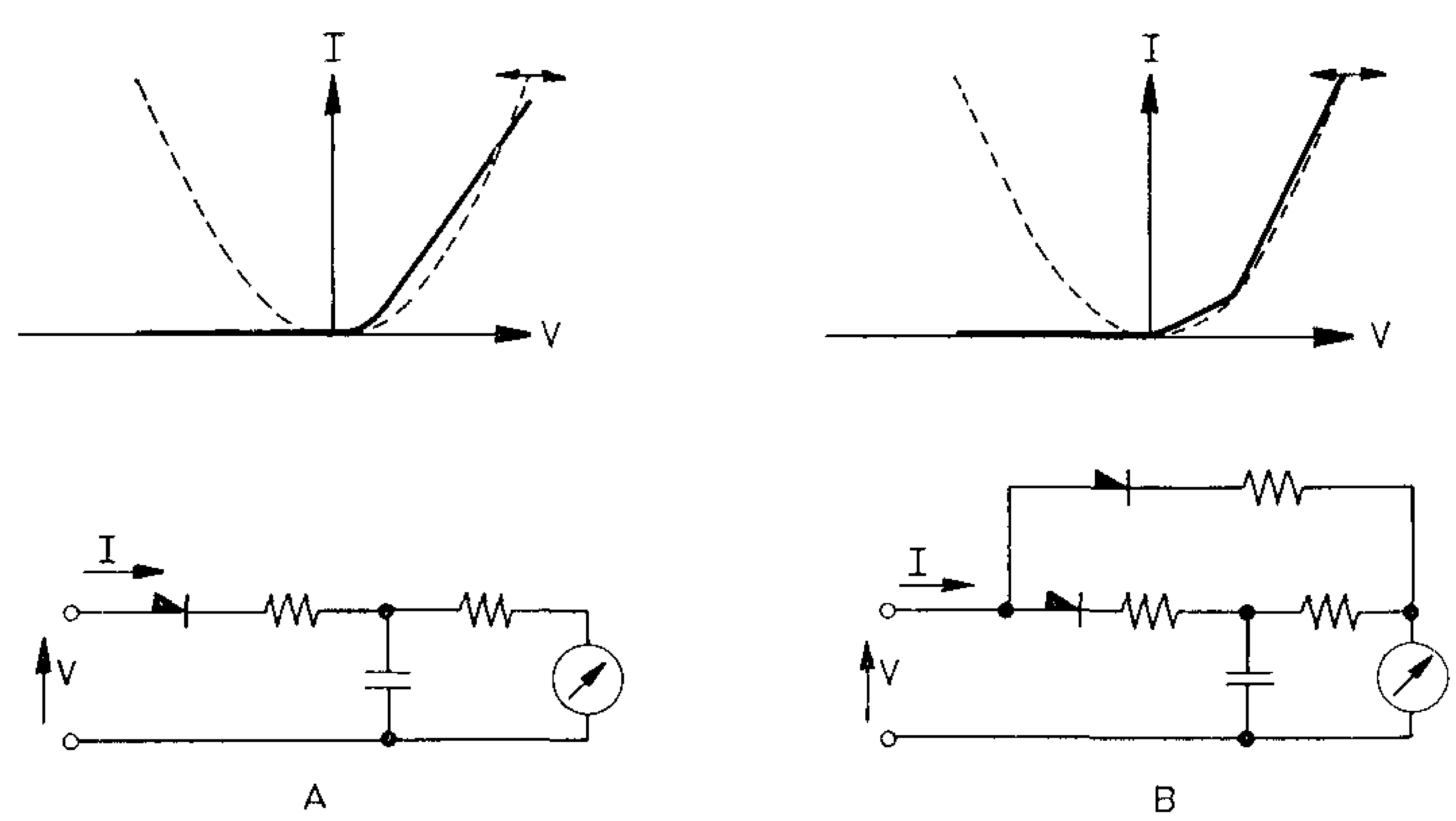


Fig. 6A. A simple average-peak compromise and
Fig. 6B. An improved circuit using the ideas of Fig. 5A and 6A together.

Thus the two tone and the Gaussian noise tests are not very satisfying for testing approximate RMS instruments, at least not when the construction is unknown. An unknown characteristic cannot be determined by only two or three measurements. The most obvious way of checking such a characteristic is to check a great number of points on the curve. Sometimes this can be done by DC measurements, if access can be made to the interior of the instrument.
However, in most cases a complete instrument containing AC amplifiers has to be checked, and therefore an AC test has to be used. A square wave

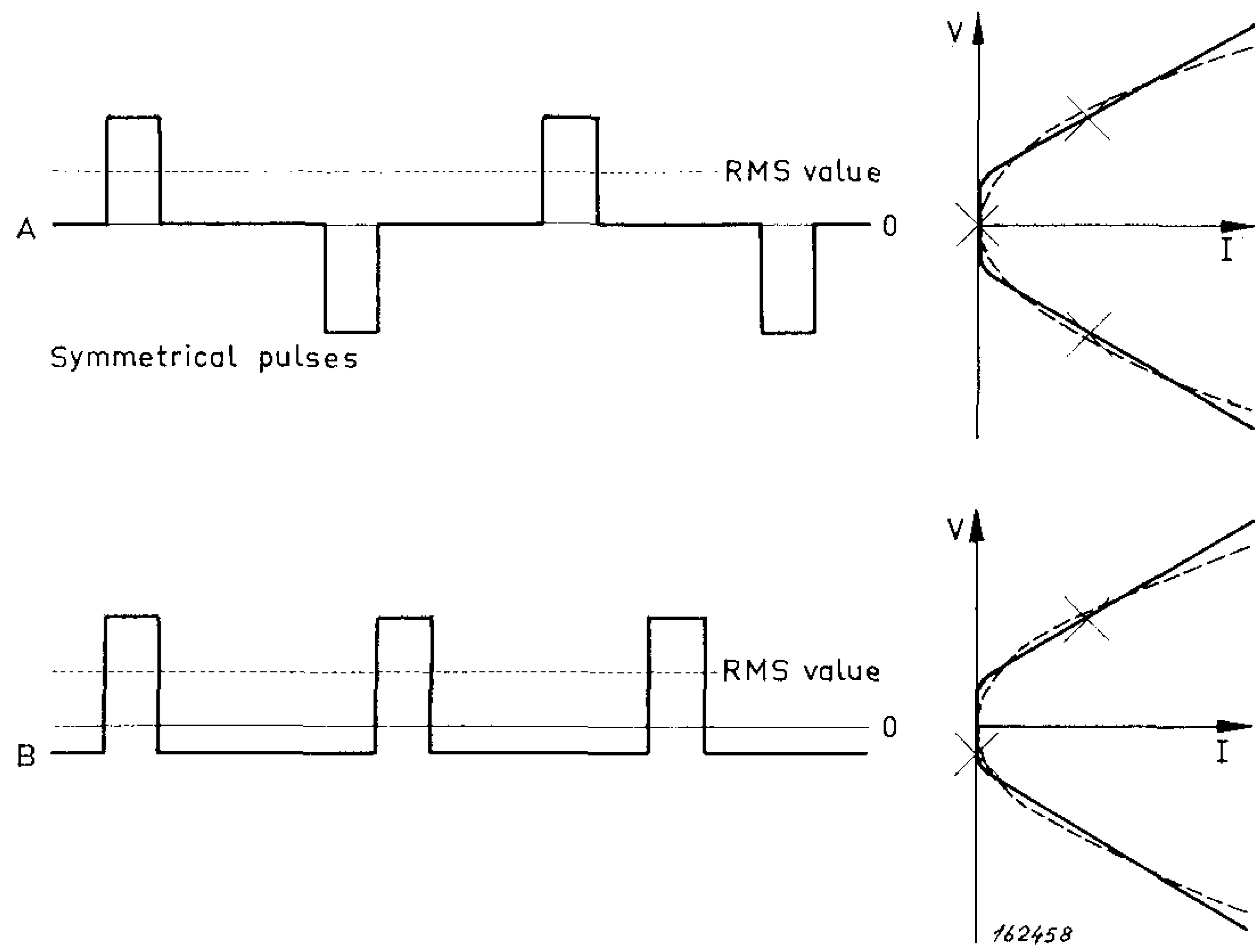


Fig. 7. Rectangular pulse signals for checking the characteristic of RMS instruments.

of varying amplitude might seem usable at first sight, but it only checks that a possible error in the squaring is compensated by an error in the root extraction. Instead a wave-form consisting of rectangular pulses can be used as the peak value here can be varied in proportion to the RMS value by varying the pulse width in proportion to the time between the pulses. In Fig. 7 is shown two such waveforms.

The symmetrical pulses check three points on the characteristic namely the zero point and two outer points. By varying the crest factor (that is the ratio peak value to RMS value), the two outer points can be moved outwards from the RMS value up to as high a crest factor as desired. Like

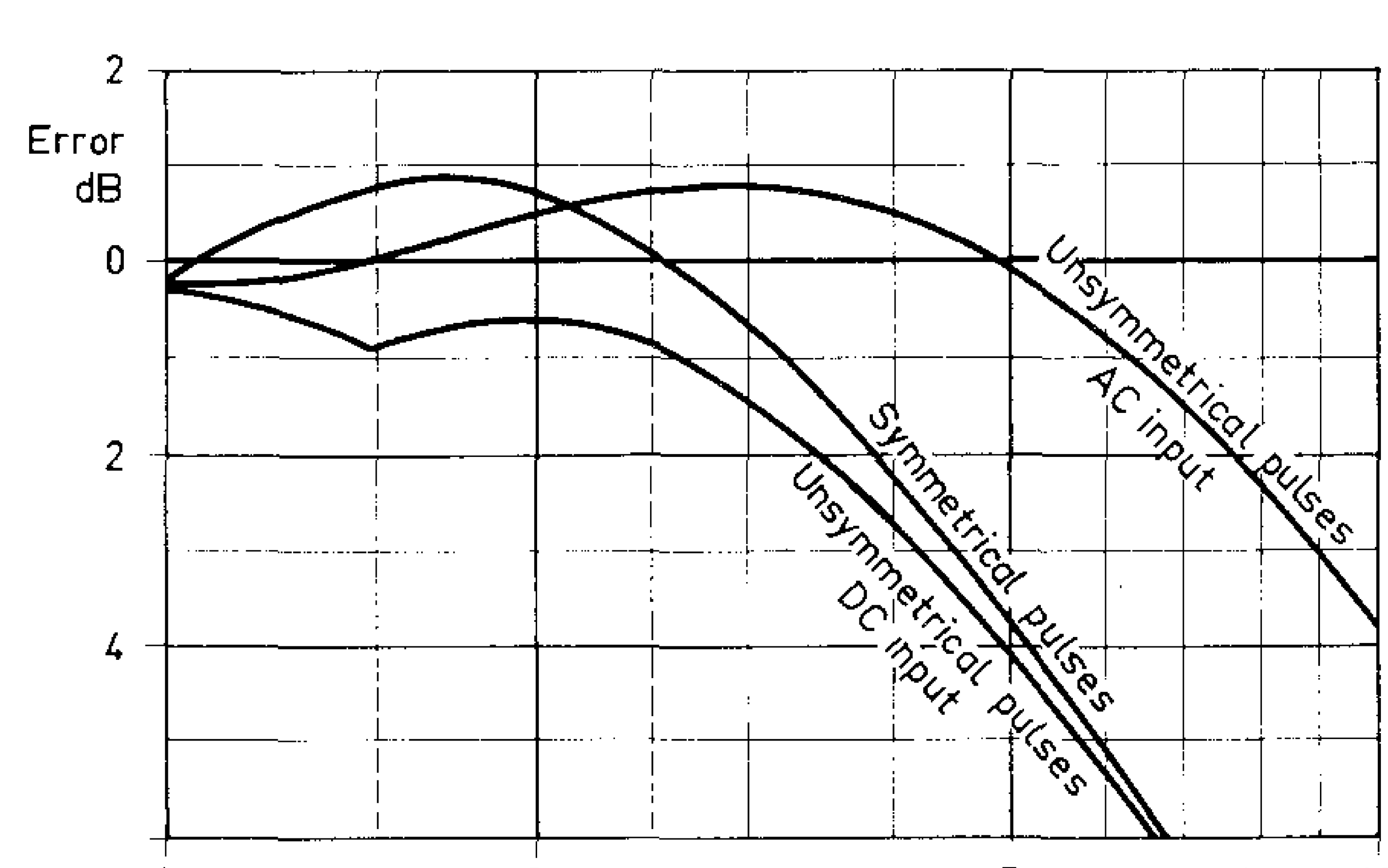


Fig. 8. Errors obtained with rectangular pulses on the circuit from Fig. 1C (R/r = 2.7).

the two tone test and the Gaussian noise test, symmetrical pulses alone do not check whether the characteristic is symmetrical. Errors on the positive side may be compensated by errors on the negative side. Besides the part within the RMS value are not checked.

To this purpose the unsymmetrical pulses as shown in Fig. 7B can be used. Here a point outside the RMS value on one side is checked together with a point inside the RMS value on the other side. By changing the polarity of the pulses and by varying the crest factor all parts of the characteristic are checked.

However, unsymmetrical pulses alone are not sufficient, because errors on the two points being checked together may counteract each other.[5] An example of this is shown in Fig. 8 which shows the error obtained with the "compromise" circuit from Fig. 2C. With a condenser in series with the input of the circuit a much smaller error is obtained for unsymmetrical pulses of high crest factors than for symmetrical pulses.

In most cases a combined test using symmetrical and unsymmetrical pulses of both signs will be sufficient. The unsymmetrical pulses check whether the characteristic is symmetrical. They also check the inner part of the characteristic together with the outer part, whereas the symmetrical pulses check the outer part of the characteristic alone.

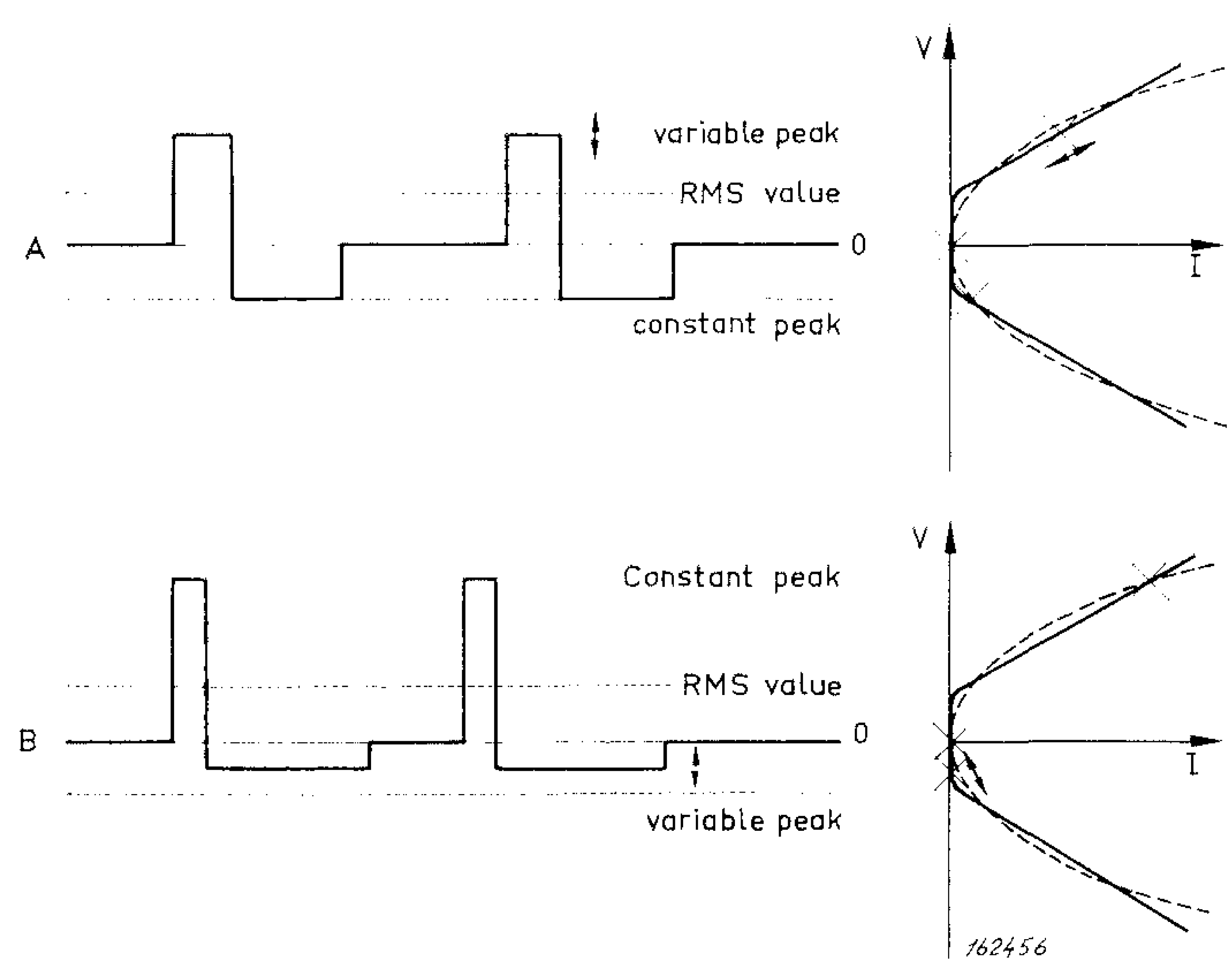


Fig. 9. Two waveforms for testing RMS characteristics where only one check point is varied at a time.

These tests always check two or three points on the characteristic at a time, and these points cannot be varied independently. Although it is not very probable, it might therefore happen that errors on the positive and the negative side were compensating each other, so that the test would erroneously indicate a correct RMS instrument. To avoid this, the more complicated waveforms shown in Fig. 9 can be used.

The waveform shown in Fig. 9A has a variable maximum peak (here positive) whereas the other two check points, the zero and the minor peak are fixed. The minor peak is fixed at the RMS value.

Four sets of measurements are now made:

One using this waveform, another using the same waveform with opposite sign, a third using symmetrical pulses as in Fig. 7A having the same crest factor and finally the fourth using a square wave. All waveforms should have the same RMS value. For each crest factor four points on the characteristic are being checked by four measurements whereby the error due to each point can be found. Actually, the zero point is involved also, but an error from this point can always be eliminated by displacing the characteristic parallel to the I-axis on the figures. Such a displacement has no influence on the squaring properties.

In this way the two parts of the characteristic from the RMS value outward, can be checked. The inner part of the characteristic can now be checked by the waveform shown in Fig 9B. This time the maximum peak value is constant at a suitable large value within the range, which was checked by the waveform Fig. 9A, whilst the minor peak value is varied.

In those cases where the characteristic varies with the waveform as in Figs. 4 and 5, these pulse tests do not give the true characteristics. The true characteristic can only be measured by breaking into the circuit. However, it is a problem whether the true characteristic is of greater interest than the apparent characteristic as determined by the pulses.

It should be noted that the pulse tests do not necessarily give the maximum possible error with a given crest factor. A more complicated waveform, which seeks out the points on the characteristic having the greatest deviation from the ideal curve may show greater error.

Finally a practical hint when making the pulse tests: The RMS value or rather the meter reading should be held constant whilst the crest factor is varied. If for example the peak value is held constant instead, the meter reading will vary, and possible scale errors may falsify the test. The non-linearity of the diodes may also cause the circuit to look better than it is.

References:

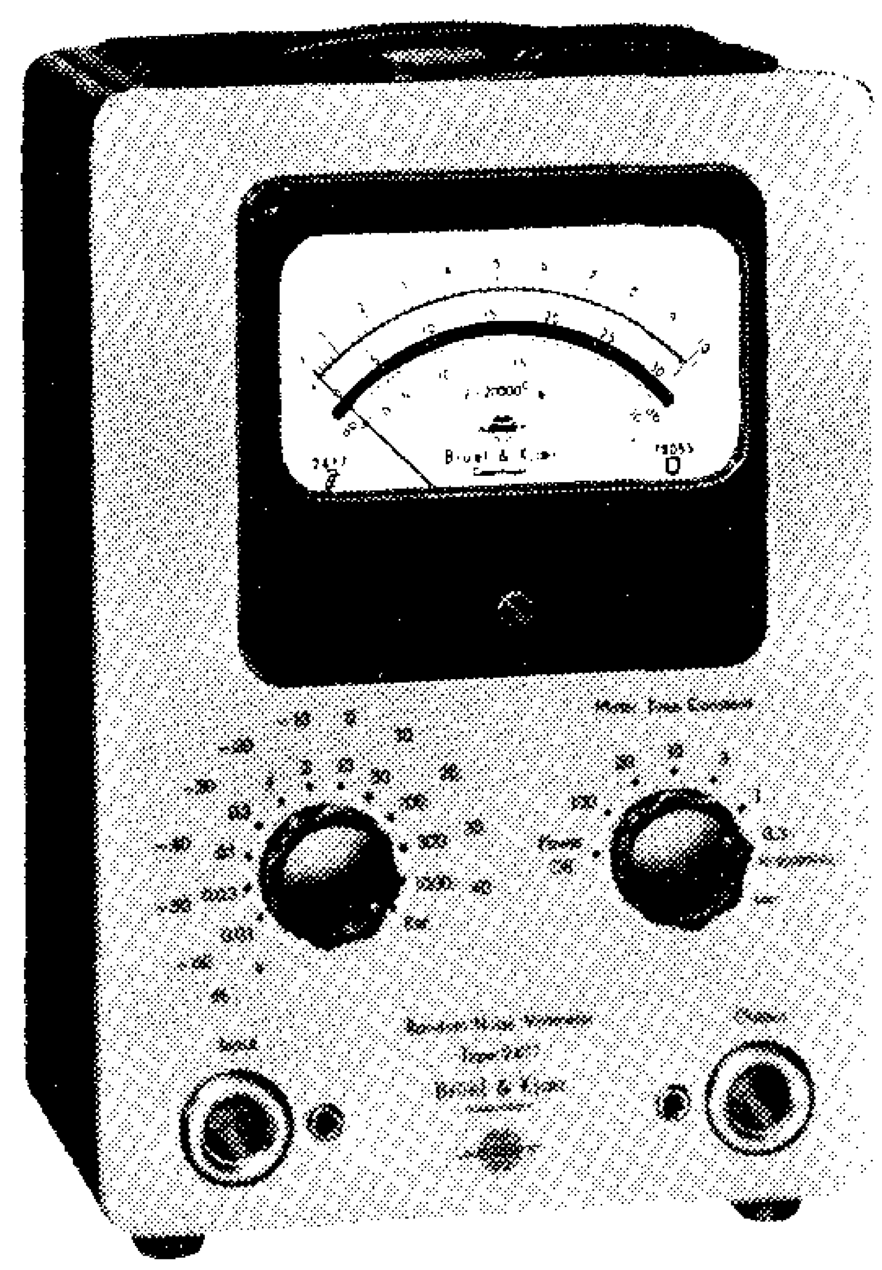
1. For instance: I.E.C. Rec. 123, ASA Z. 24.3-1944, BS. 3489:1962, DIN 5045.
2. For instance: ASA S. 14-1961.
3. C. G. Wahrmann. "A true RMS instrument". B & K Technical Review no. 3-1958.
4. H. Gommlich. "Das Verhalten einer einfachen Gleichrichterschaltung beim Messen nichtsinusförmiger Spannungen". Elektronische Rundschau Bd. 15 (1961) no. 4.
5. The German standard DIN 45502 recommends a pulse test, but unfortunately is the symmetrical pulse test not included.

News from the Factory

Random Noise Voltmeter Type 2417.

This voltmeter has been developed mainly for the measurement of narrow band random noise signals. Variable time constants from 0.3 sec. to 100 sec. allow measurements on noise bands as narrow as 3 c/s band-width to be made to within 0.5 dB accuracy. The frequency range of the instrument is 2 c/s — 20 kc/s.

For detection of the noise signal a quasi-R.M.S. rectifier circuit is used. The resulting D.C. signal is indicated by the instrument meter and is



Type 2417.

furthermore available at a set of output terminals. It is thus possible to record the variations in incompletely averaged signals on the Level Recorder Type 2305.

The input impedance is 1.5 MΩ paralleled by 15 — 20 pF. Full scale meter deflections are obtained for input voltages from 10 mV to 1000 V (in 10 dB steps).

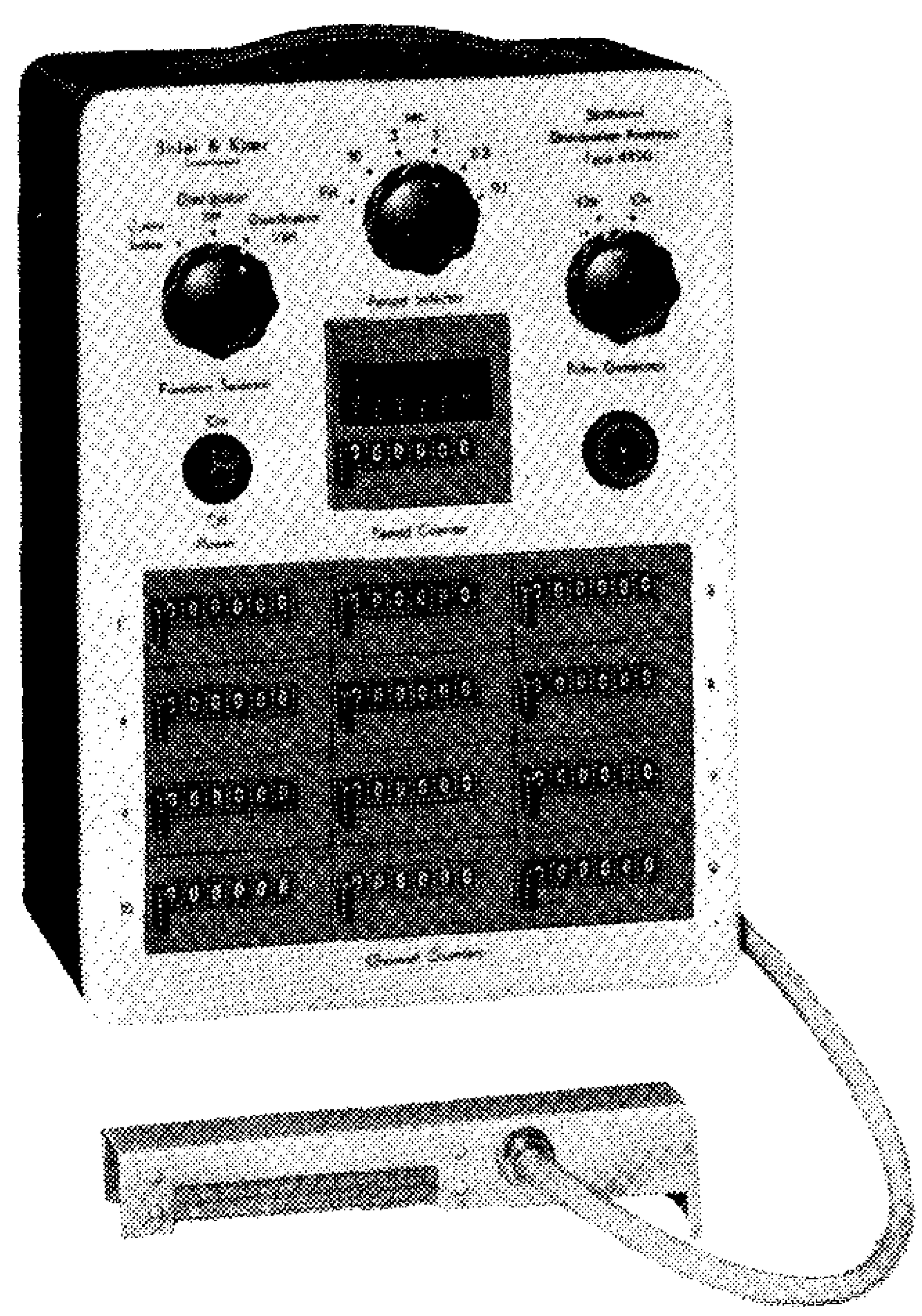
Statistical Distribution Analyzer Type 4420.

The Statistical Distribution Analyzer Type 4420 has been developed to allow a direct statistical evalution of the data measured by a Level Recorder Type 2305 or by a Noise Limit Indicator Type 2211.

It includes a set of twelve contacts which are scanned by means of the writing arm of the Level Recorder, thus enabling the recorded information to be resolved in twelve bands and a numerical display of the data presented. Should a time-chart be required from the recorder, this can be run off simultaneously.

The Distribution Analyzer can be set to perform various functions.

1) When used with a Level Recorder, as described above, it can *either* measure the fraction of the total measurement time spent *in* each level range, ("Distribution — 2305"),
or the fraction of the total measurement time during which the signal was below the various (12) level intervals ("Cumulative").
The maximum resolution is 0.1 sec.



Type 4420.

2) If used with a Noise Limit Indicator Type 2211 the counters will register the total time that the noise (or vibration) input to Type 2211 exceeded a particular, predetermined level in a certain frequency band ("Distribution 2211").

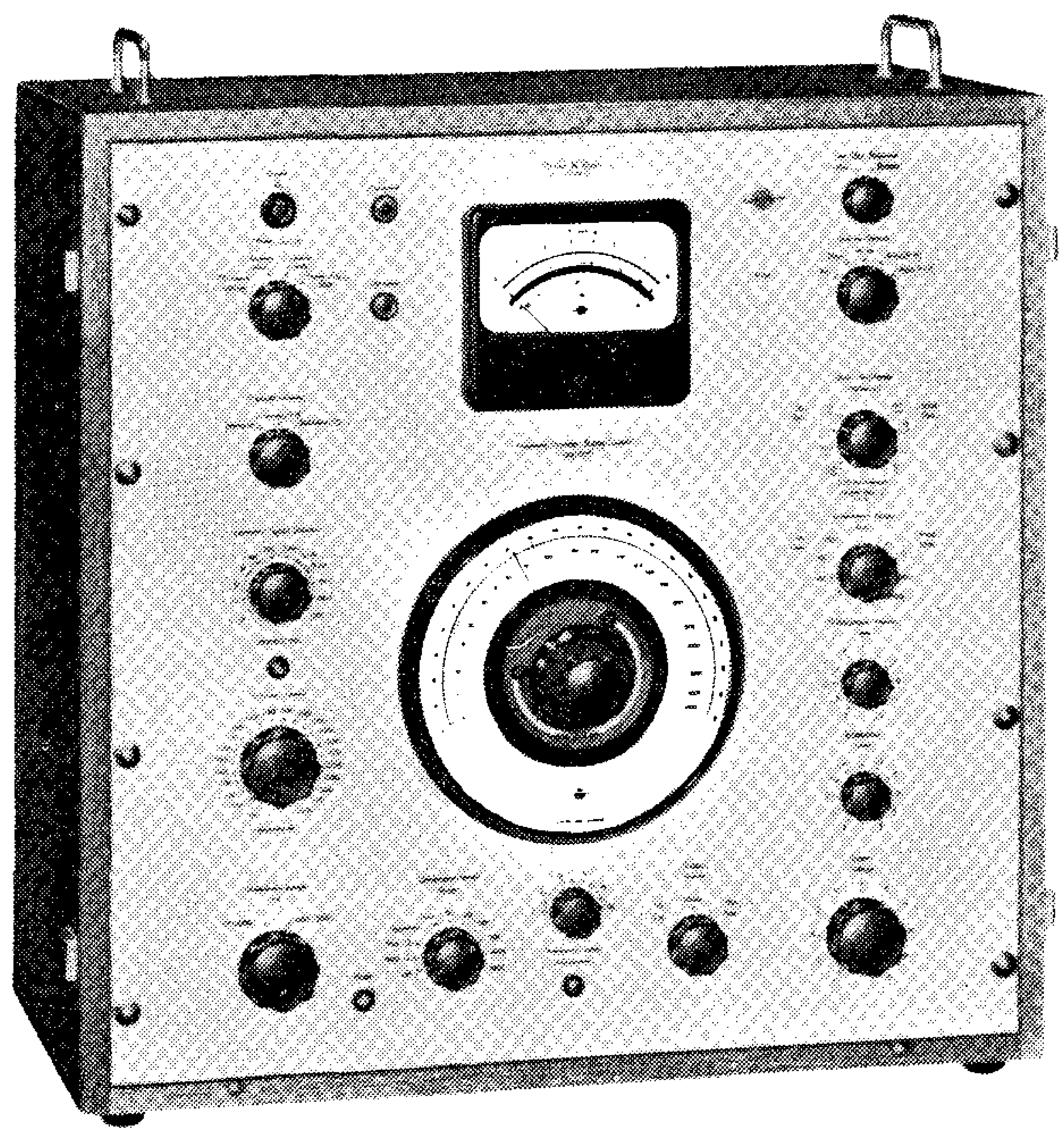
Among the measurement problems for which the Statistical Distribution Analyzer can be of great assistance are:

Traffic Noise,
Airport Noise,
Office Noise,
Engine Vibrations, and
Physiological damage studies.

Automatic Vibration Exciter Control Type 1019.

The Type 1019 supersedes Type 1018, and contains all the good features of this widely used exciter control. However, the following *new* features have been included in the Type 1019:

1) A built-in transsistor oscillator supplies the power for the tuning capacitor drive unit so that a more versatile and accurate scanning speed adjustment has been made possible. Furthermore, the scanning speed selector now includes six positions for synchronous drive with the B & K Level Recorder Type 2305 using preprinted frequency calibrated paper.



Type 1019.

2) The tuning capacitor can be arranged to rotate over a full 360° angle (or more) and cam-discs mounted on the capacitor spindle allow partial blocking of the frequency range (upper and lower part). In this way a test can be performed within the predetermined frequency range only, — even if the tuning capacitor rotates over a full 360° angle.
3) A special switch position allows the Exciter Control to be in "Stand-by" condition. This position is intended to be used when the test scepimen is replaced, or other manipulations are to be made on the shaker table. It has the advantage that no readjustments are necessary on the Exciter Control, i.e. a test can be stopped by switching the Exciter Control to "Stand-by", and started again immediately at the preset vibration level

by turning the switch away from this position. In the "Stand-by" condition a relatively high voltage is supplied to the compressor control of the generator.

4) An automatic cross-over arrangement from constant velocity to constant acceleration has been included. The cross-over frequency can be pre-adjusted within the same frequency range as the constant displacement to constant acceleration transfer, i.e. 8 — 1000 c/s.
5) All vibration ranges available on Type 1019 can be controlled from an accelerometer output signal.
6) Possibilities for "Master-Slave" arrangement where one "Master" Exciter Control can control up to 3 "Slaves". In such an arrangement the "Master" controls its own Vibration Exciter as well as the frequency of the output signal from the "Slaves". Each "Slave", however, can control the vibration level of a connected exciter (separate compressor controls). It is thus possible to synchronize the movement of a number of (up to 4) vibration exciters for the testing of large specimens. Furthermore, the phase relationship between the "Master" and "Slave" output signal can be adjusted over a full 360° angle.
7) The Exciter Control Type 1019 can be powered from mains power lines of any frequency between 50 c/s and 400 c/s.

The Automatic Vibration Exciter Control Type 1019 can also be supplied in steel cabinet for standard 19″ rack mounting as Type 1039.

The Automatic Frequency Response Recorder Type 3327.

The A.F. Response Recorder Type 3327 has been developed to allow continuous recording of the frequency response of electrical, electro-acoustic or electro-mechanical networks in the range 10 c/s to 200000 c/s*).
It consists of a rack-mounted combination of the two Beat Frequency Oscillators Type 1013 and 1017 and the Level Recorder Type 2305.
To allow automatic operation over the full 5 frequency decades mentioned above (2 — 200000 c/s), two built-in relays ensure proper cross-over from the use of the one oscillator to the use of the other.
The cross-over frequency is adjusted at the factory to 2000 c/s.
Three push-buttons on the front of the rack allow proper selection of operation, and two lamps placed beside the push-buttons marked "1013" and "1017" respectively, indicate which instrument is actually in operation.
One of the great advantages of Type 3327 is that means have been provided to utilize the compressor circuits of the oscillators over the full frequency range. It is thus possible not only to record automatically the frequency

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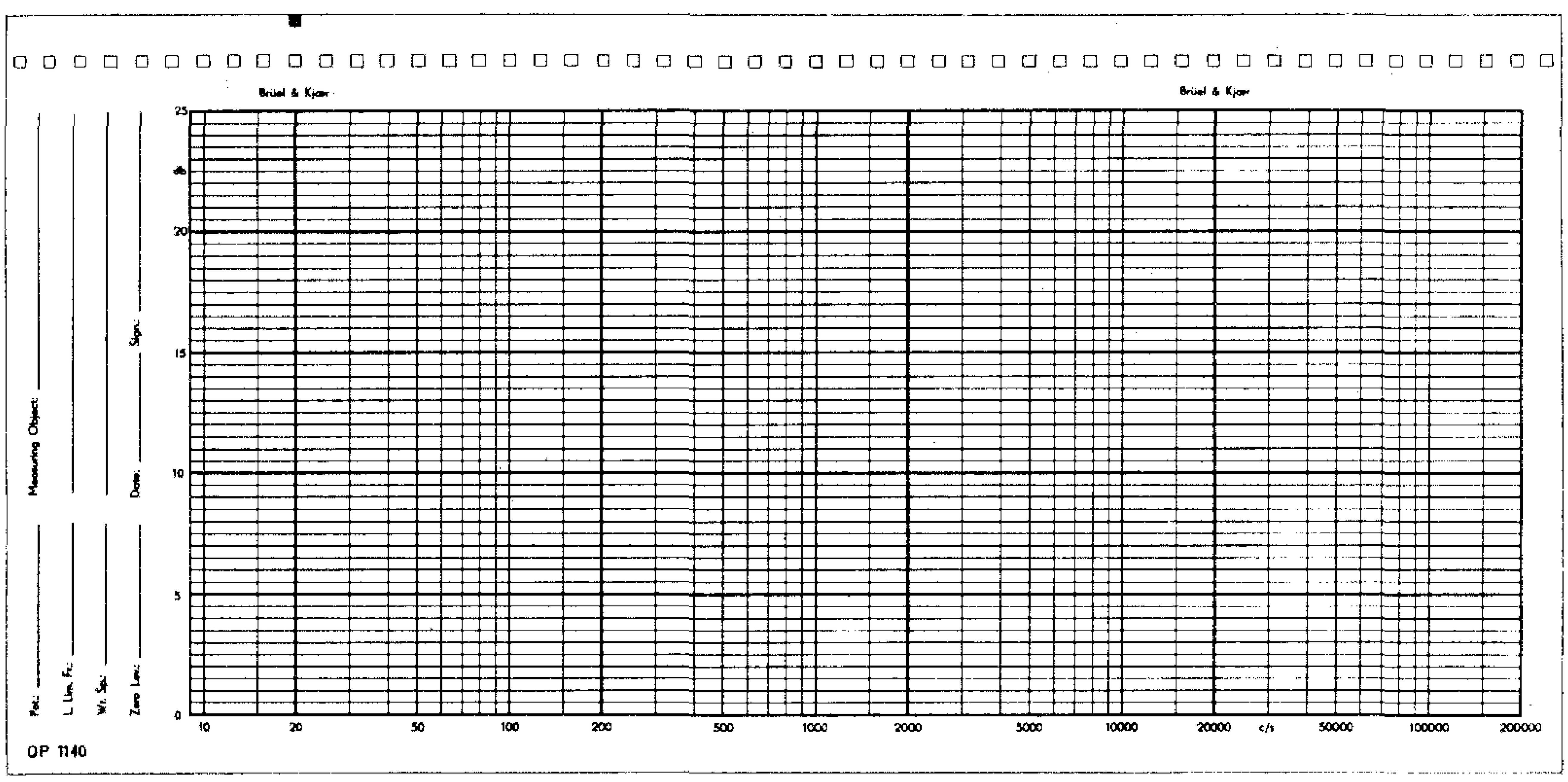
*) The total oscillator frequency range is 2 c/s — 200000 c/s. However, due to the lower limiting frequency of 10 c/s of the Level Recorder it is only possible to record response curves from 10 c/s to 200000 c/s.

response of the test specimen, but also to keep the signal level (voltage, current, sound pressure etc.) at a predetermined "point" in the measuring arrangement constant during the test.

Preprinted Paper.

Aspecial preprinted recording paper, QP 1140, has been produced for use in conjunction with the Type 3327 A.F. Response Recorder. The paper width (recording width) is 100 mm and the paper is intended for inkwriting.



QP 1140.

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