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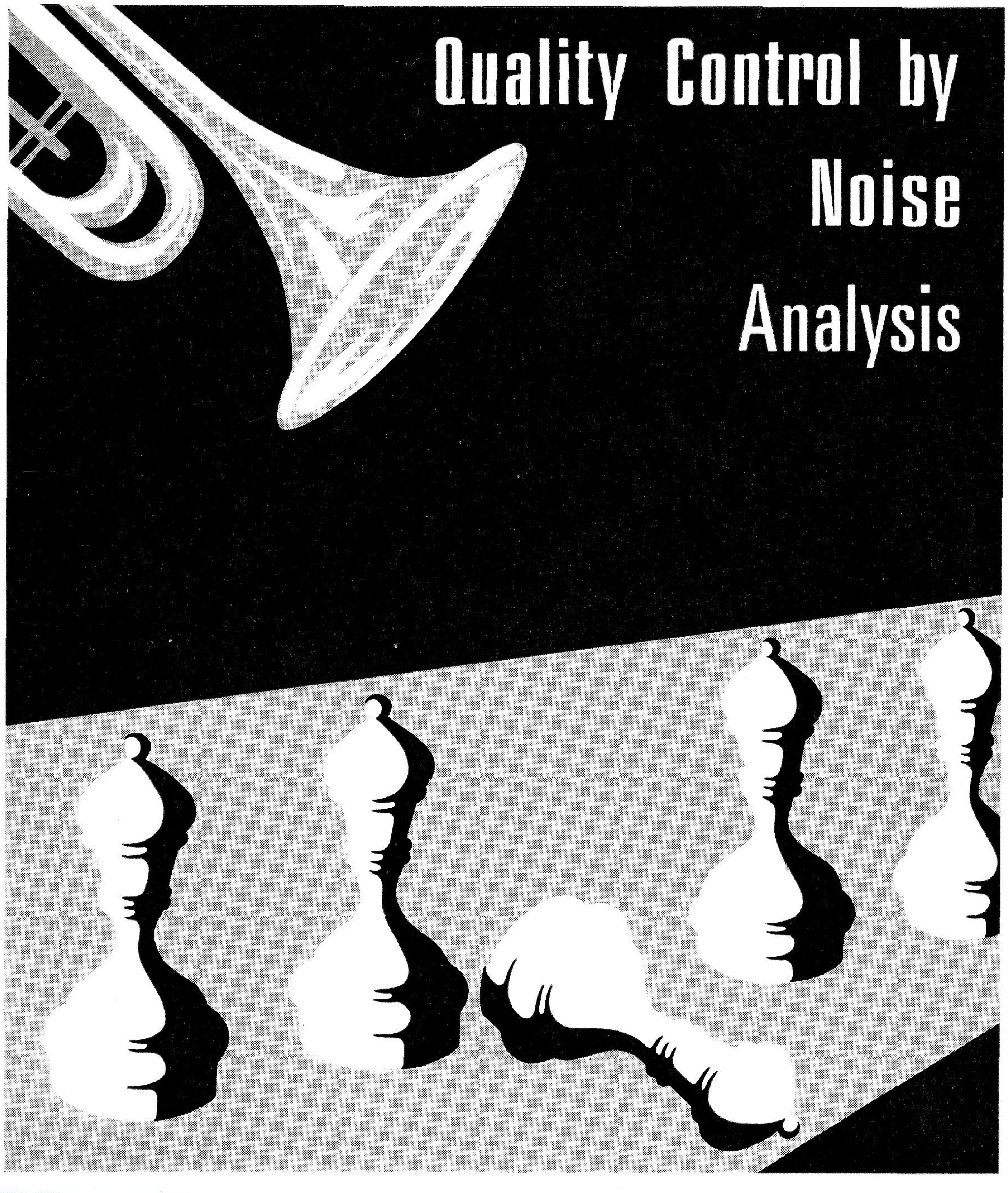

Quality Control by Noise Analysis

No. 2 1963

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K. LARSEN & SØN - LYNGBY

Quality Control by Noise Analysis

By *J. August Jensen**)

ABSTRACT

After a short introduction to quality testing of mass-produced units by means of noise- and vibration test methodes it is discussed where and when these measurements may be applied. The practical problems of isolating the test object from background noise and unwanted vibration are discussed. The requirements to a special instrument for this kind of testing are outlined and finally a brief description is given of an instrument developed for this purpose.

SOMMAIRE

Après une courte présentation des méthodes de contrôle de qualité d'appareils de grande série au moyen d'essais aux bruits et vibrations on discute où et quand ces méthodes s'appliquent. Les problèmes pratiques d'isolement de l'appareil testé contre les bruits de fond et vibrations parasites extérieures sont discutés. Les spécifications d'un instrument de mesure spécial pour ce genre d'essais sont soulignées, et en fin d'article une brève description d'un tel instrument est donnée.

ZUSAMMENFASSUNG

Wenn massengefertigte Erzeugnisse hinsichtlich Schall- oder Körperschallentwicklung zu prüfen sind, ist die Isolierung der Prüflinge vom Umgebungsgeräusch in der Regel das Hauptproblem. Daneben benötigt man ein geeignetes Prüfgerät, den B & K »Geräuschwächter«.

During the recent years noise measurements have become more and more common in the production of domestic machinery such as oil-burners, refrigerators, and other house hold equipment and also on automobiles, office machinery etc.

The reason for this has been that people in general have become more "noiseminded", as the number of mechanized aids in daily life has increased. It is in fact, so that noiselessness has become a quality in itself.

To provide more comfortable conditions for the users of this equipment and because noiselessness is a natural requirement in sales efforts, the manufacturers of such equipment have developed a routine of measuring the noise on their finished products.

These tests have again led to associated development in test technique: It is very often the case that a particular mechanical defect in, for instance, rotating machinery, will produce a noise of a certain frequency and strength. This makes it possible to adopt acoustical measuring methods when checking machinery for mechanical faults, as an analysis of the noise and/or vibration produced by a certain apparatus, will very often reveal, and locate faults, which would otherwise remain hidden until the apparatus had been in use for some time.

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*) Paper given at the 4th International Congress on Acoustics, Copenhagen 21—28 August 1962.

The advantage of noise and vibration checks compared to direct mechanical measurements is obvious, as the noise check can be carried out within a few seconds while mechanical measurements of similar phenomena consume much more time, which means that this kind of measurement my be suitable for production line testing of mass-produced units.

Tests of this kind may be applied to all sorts of machinery containing motors and gear-boxes. On gear-boxes for instance (Fig. 1), a noise or vibration test may indicate, if they contain any inaccurately cut gear wheels, unbalanced drive shafts, faulty ball bearings, etc. In for instance, small electric motors, a vibration check may indicate unbalance of rotating parts, or oil-agitation in bearings. This makes the electro-acoustic test methods suitable for a very wide range of equipment covering anything from ventilators, vacuum-cleaners, kitchen aids, and office machinery to heavy gears and motors for automobiles and trucks.

The electro-acoustical quality test should preferably take place at the time when the product leaves the assembly line. The test should be carried out on fully completed units and if possible under simulated working conditions, i.e. with power applied, motors running with load applied, etc. It may however, sometimes be advantageous to run the test at an earlier

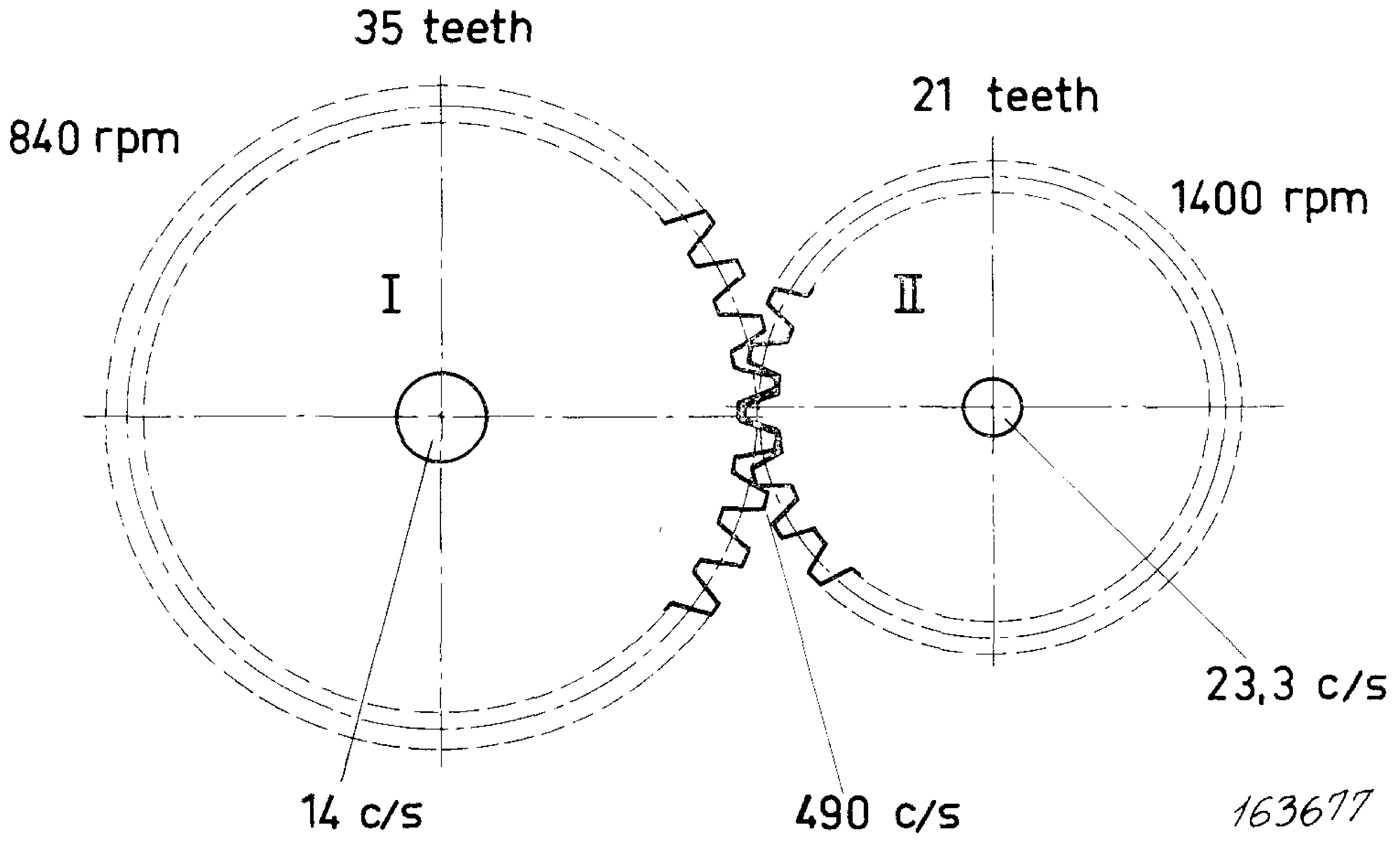

Fig. 1. In a simple gear train, three main noise frequencies may arise:

1. *Unbalance in driveshaft I gives rise to a frequency of* $\frac{840}{60} = 14$ *c/s.*
2. *Unbalance in driveshaft II gives rise to a frequency of* $\frac{1400}{60} = 23.3$ *c/s.*
3. *Inaccurately cut gear wheels give rise to a frequency of* $\frac{21 \times 1400}{60}$ $\frac{35 \times 840}{60} = 490$ *c/s.*

stage, as for example in the automobile industry where motors, gear boxes and, differential gears may be tested separately before mounting in the chassis.

One of the main problems that arises the moment it is decided to carry out noise tests derives from the fact that the background noise, which is normally present in the factory near the assembly lines, tends to destroy or at least disturb the noise and vibration measurements. It is of course a requirement that the background noise level does not exceed or even come near the noise level generated by the test object. A few cases exist where the background noise may be eliminated by means of electrical filters in the measuring system. However, this only applies to special conditions where the background noise mainly contains one predominant frequency. In by far the most cases it is necessary to apply some kind of acoustic screening to damp out background noise at the place where the noise test

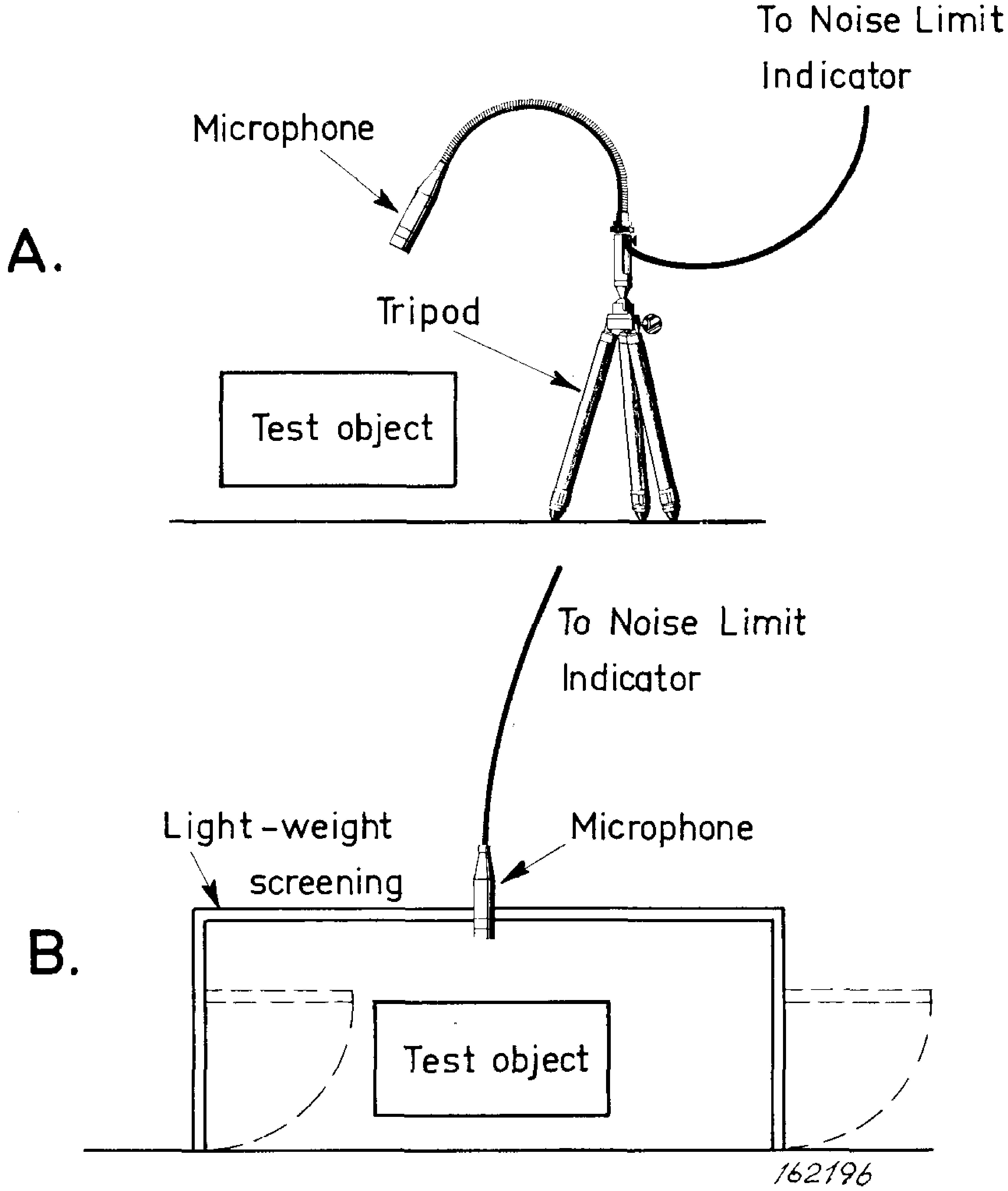

Fig. 2. Where the noise intensity generated by the test object exceeds the ambient noise to a fair degree, the microphone can be placed at a convenient distance from the object as shown in Fig. 2a. If the ambient noise level comes too close to be measured, a lightweight screen may be necessary as shown in Fig. 2b.

is carried out. Quite often, especially when manufacturing house-hold equipment, the noise level to be measured is of the order of 30—40 dB or maybe even less. This level is comparable to the level in a quiet living room, but far below that which is normally expected in a factory. Depending on the kind of industry the noise level in assembly shops normally varies between 60 and 100 dB.

The testing of products making loud noises such as internal combustion engines of course creates no problems with regard to background noise level. However, medium-"class" noises such as those produced by vacuum-cleaners, normally require some kind of acoustic screening, of the measuring site, from the rest of the assembly hall. A lightweight screen such as shown in Fig. 2b is often sufficient for this class of measurement.

For the testing of units making relatively little noise, several methods of screening may be employed. The object may be placed in a hard-walled chamber in order to produce a diffuse sound field for the measurement (see Fig. 3), or it may be placed in a large, silent, highly absorbing room to make it possible to obtain directional noise patterns, see Fig. 4.

The common requirement for both kinds of rooms is that they must have a shell of heavy material to attenuate the disturbing sound from outside. This may be built as a brick-wall, a metal or wooden wall with sand filling; the thickness depending on the desired amount of insulation.

Besides the practical problem of opening and closing heavy doors and gates of such a chamber, this solution is a rather expensive one as regards the construction of the chamber. When it is desired to measure noise of frequencies that lie below 100—200 c/s especially, such a chamber becomes less practical and more expensive. Another fact is that a rather heavy

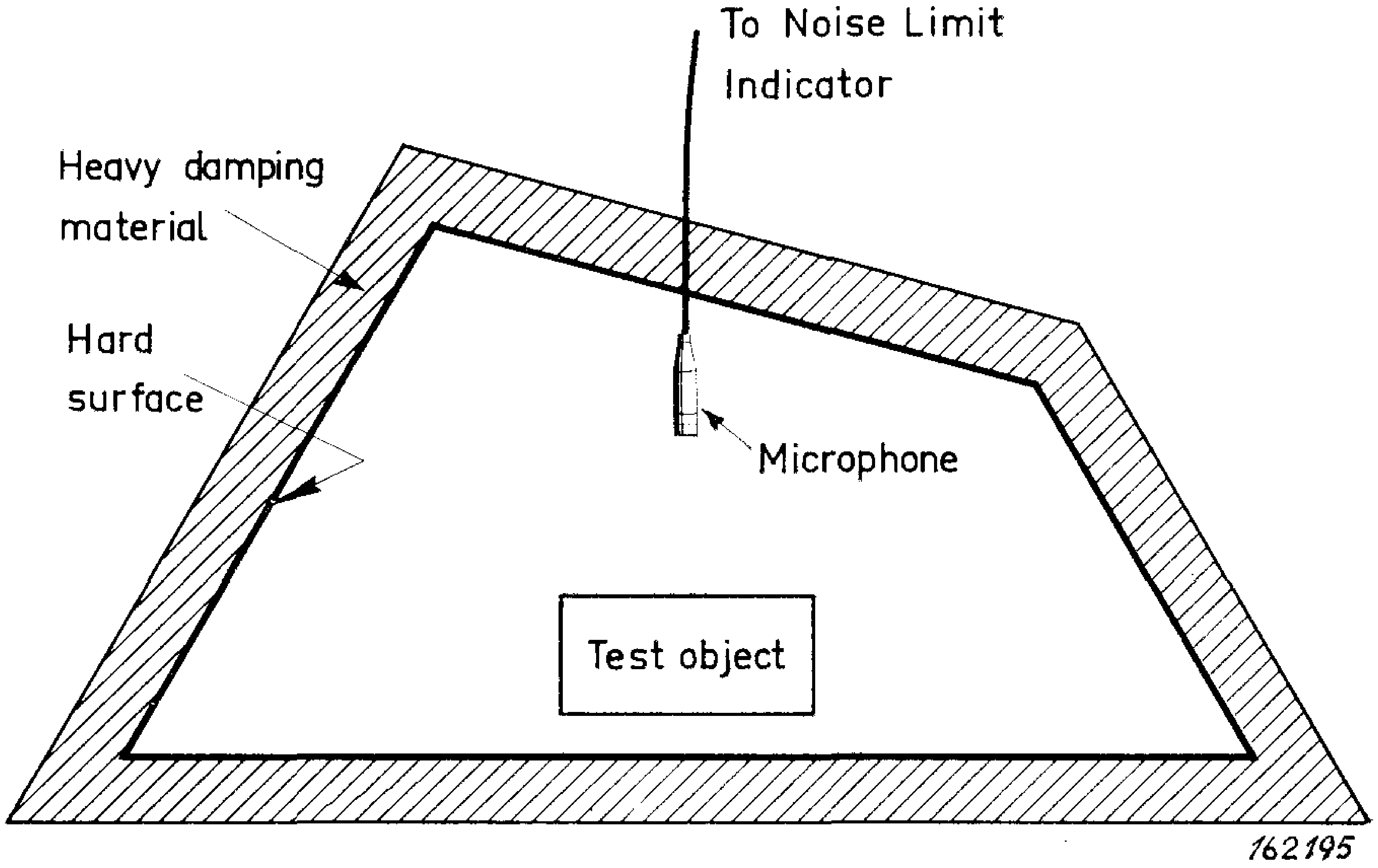

Fig. 3. Noise testing in heavy screen. The room has reasonably small outside dimensions and walls of heavy damping material. This room is not suited for directional testing, as it produces a diffuse sound field.

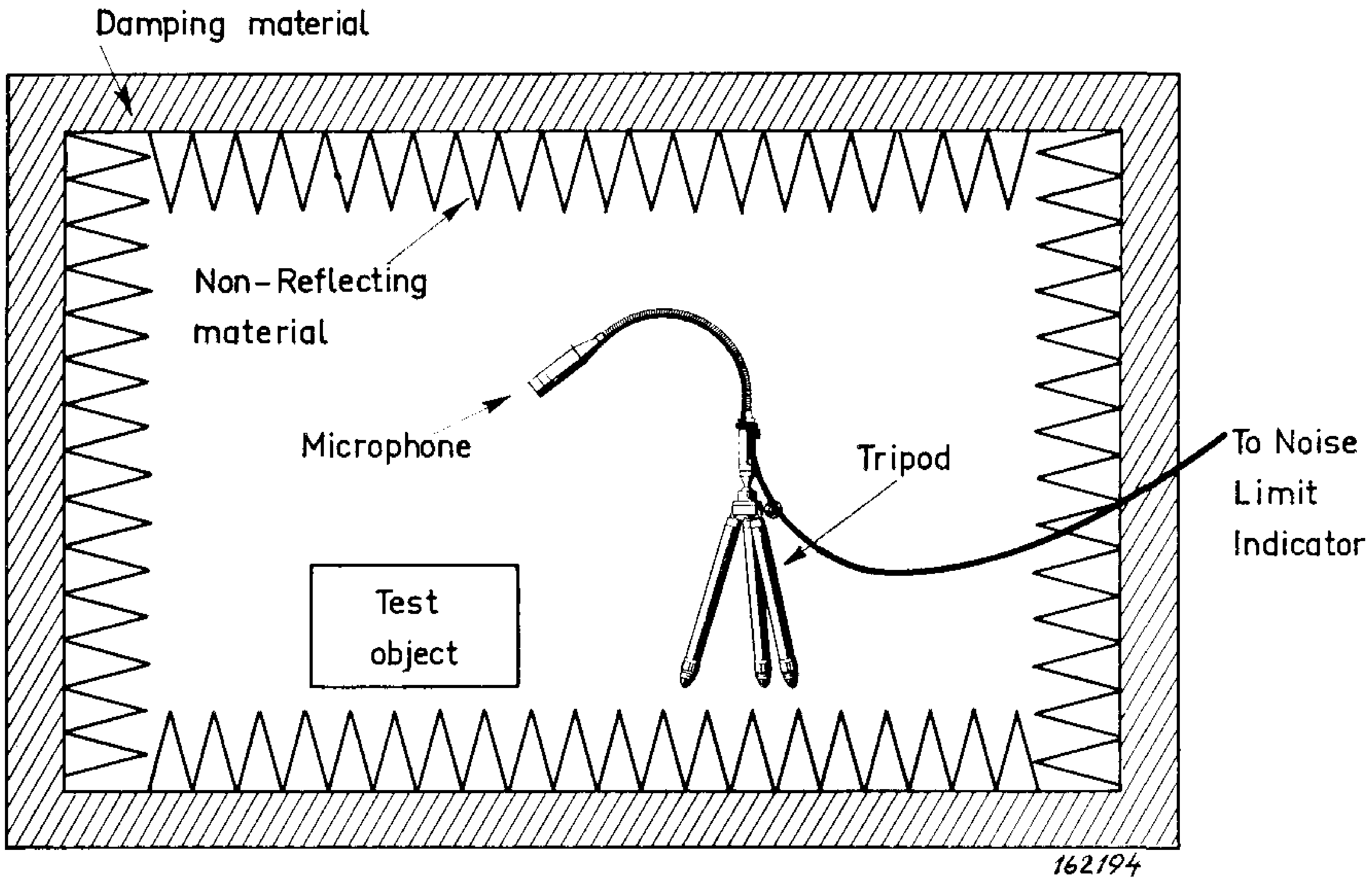

Fig. 4. Noise testing in room with absorbing walls. Directional testing is possible, but the chamber must be largely dimensioned.

vibration at this frequency may only produce a limited noise due to poor radiation which, of course, is desirable for the user but less convenient with regard to possible fault detection. It has therefore become more common in noisy areas to carry out the electro-acoustic check as a vibration test, i.e. to employ a vibration pick-up, instead of a microphone, as the sensitive element. It has proved to be much easier to isolate a test object from unwanted vibration than from background noise, in that the object may be placed on a test stand mounted on shock absorbers, foam rubber pads, springs, or other kinds of vibration isolators. This involves less practical problems for the test stand operator than acoustic screening against background noise.

A great advantage in vibration measurement compared to acoustic noise measurement is that the vibration pick-up may be placed at a position on the test object where the vibration is most pronounced for certain critical modes of operation. In this way the measurement becomes more selective. A disadvantage of the vibration measurement is that the pick-up must be fastened to the test object (see Fig. 5), and which is more serious, at higher frequencies the number of vibration nodes and antinodes in the test object increases considerably, thereby making the measurement inaccurate due to uncertainty in pick-up fastening and to retroaction of the pick-up.

One way of solving the fastening problem, which may be used at lower frequencies, is as follows:

If the unit vibrates as a whole generating only a few pronounced frequencies, it may be advantageous to place the unit under test on a leightweight test stand, which may then be brought to vibrate in phase with the unit under

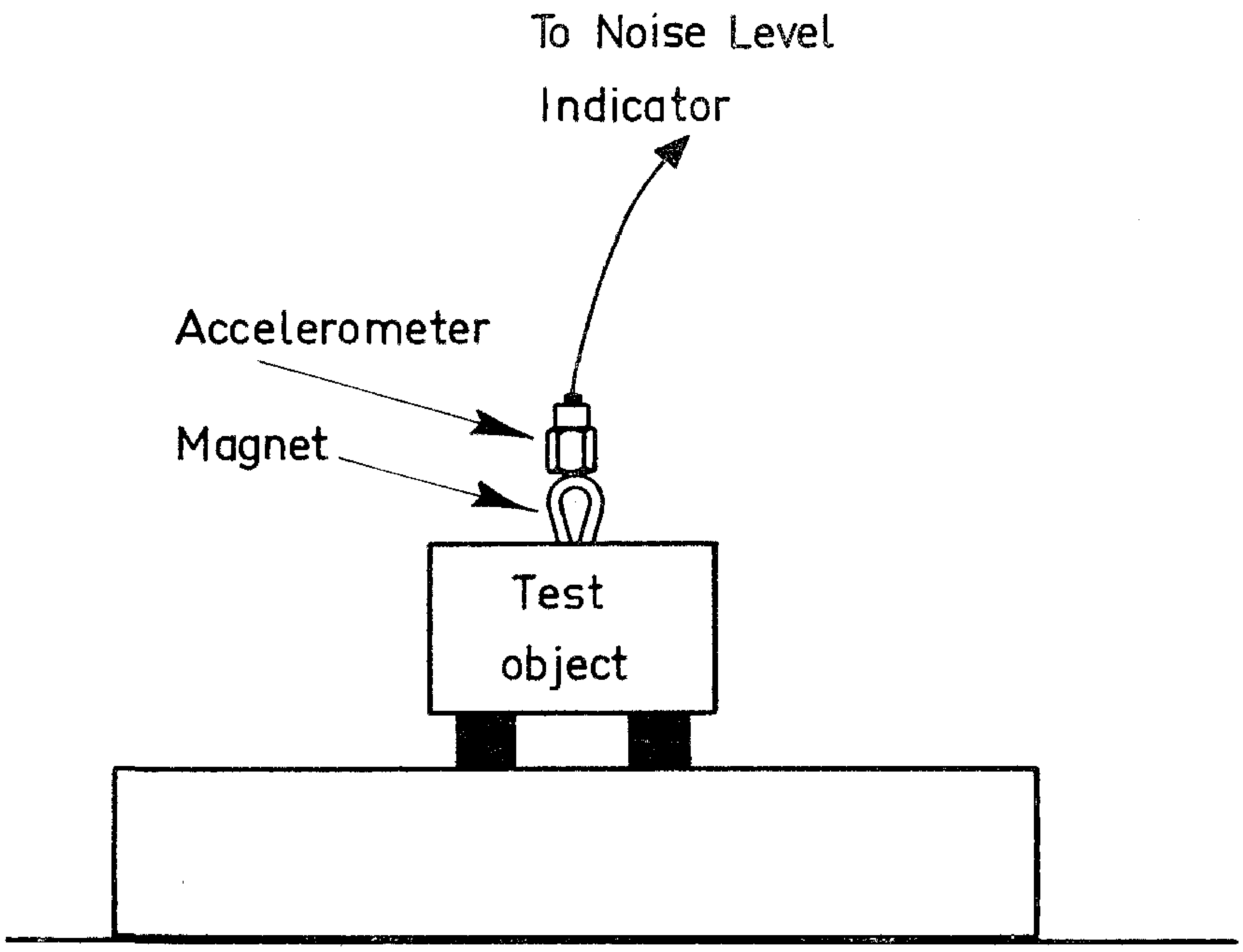

Fig. 5. The accelerometer may be fastened by means of a small magnet.

test. The vibration pick-up may thus be fixed to the test stand instead of the test unit itself (see Fig. 6).

It is a condition that the unit is placed on the stand in the same manner for every test (every unit), i.e. some means of locating the units may be necessary.

A suitable solution to the problem of measuring noise in areas with conspicuous background noise will thus be to employ vibration measurements at low frequencies and noise measurements in a fairly lightweight and inexpensive chamber at higher frequencies. The dividing point is somewhat dependent on the special arrangement but is often chosen somewhere between 400—800 c/s (a measuring chamber with a volume of approximately

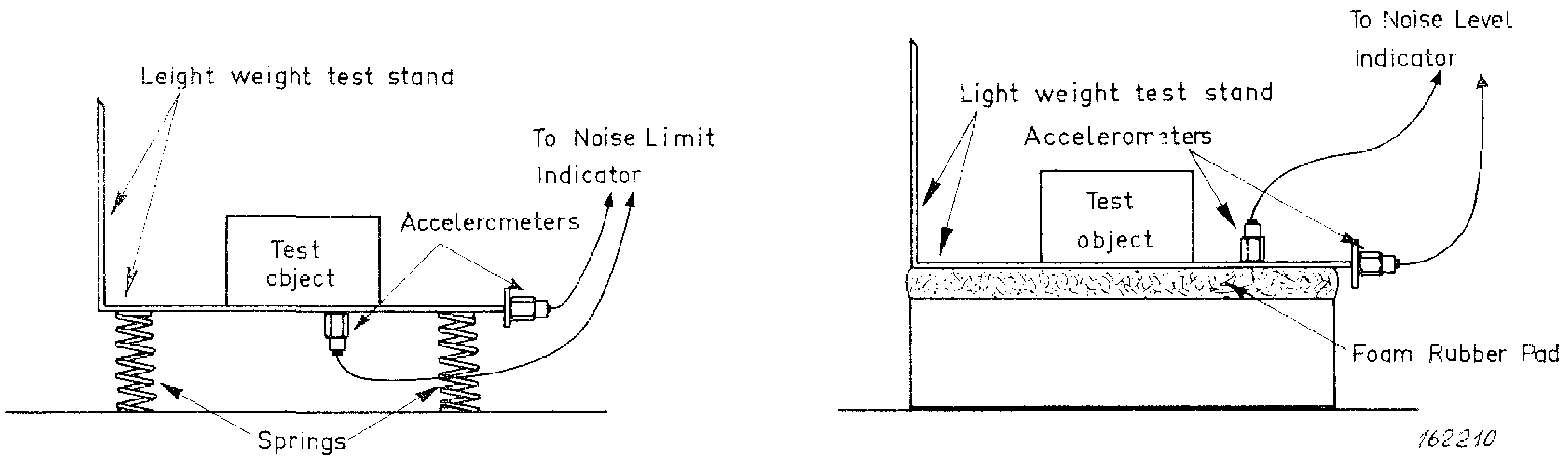

Fig. 6. Placing the object on a lightweight test stand enables vibration pick-ups to be mounted on the test stand. Vibration in two directions can be checked in one operation (using the N.L.I.).

10—20 m^3 will normally be satisfactory for noise measurement in the frequency range between 500—5000 c/s).

As far as the same kind of instruments is used for noise and vibration measurements it is fairly easy to switch from one kind of measurement to the other. The only part of the measuring arrangement that has to be changed is the transducer, i.e. the microphone should be interchanged by the vibration pick-up when it is desired to switch from noise to vibration measurements and vice versa.

Several instruments may be used for noise or vibration checks. Most commonly these instruments may be divided into four groups:

a. Instruments for wide-band measurements, i.e. instruments with a uniform response to all audible frequencies.

b. Instrumens for "weighted" measurements, i.e. instruments with a built-in correction of the frequency response; so as, to a certain degree, to follow the response of the average human ear.

c. Instruments for noise analysis, i.e. instruments that are capable of selecting and measuring specific noise bands successively.

d. Instruments for the simultaneous measurement in selected frequency bands, i.e. instruments that only respond to certain preselected frequencies.

Common to all the above types of instruments is that they basically consist of a transducer, one or more amplifier stages, some sort of filter network (except for the wide band instrument) and an indicator, for instance a meter. In Fig. 7 is shown a block schematic of such an instrument. In addition to this a recording device may be employed.

The arrangement shown is of the type normally used for laboratory investigation of noise and vibration. It contains a microphone, an analyzer,

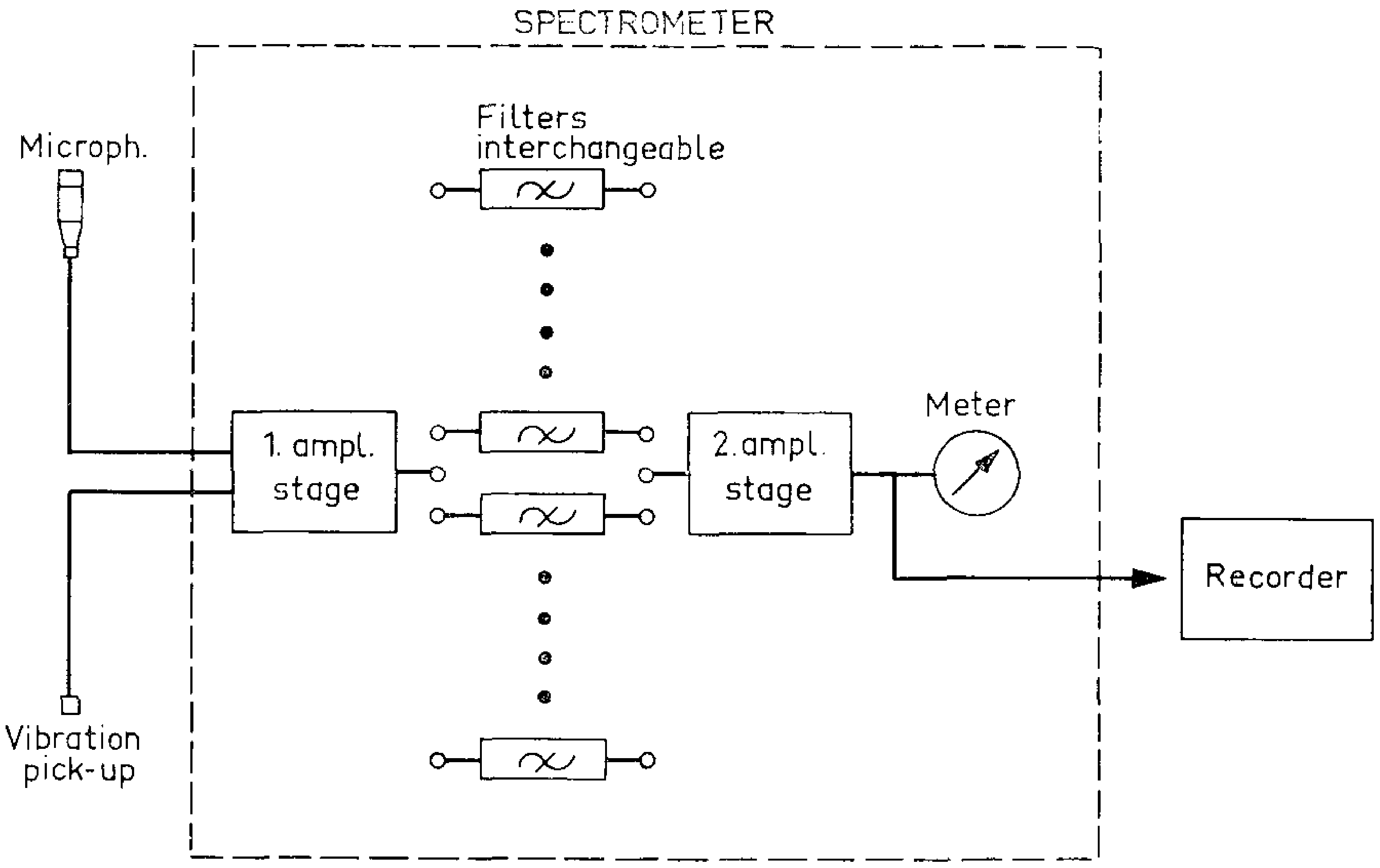

Fig. 7. Typical measuring arrangement for noise and vibration measurement (analysis).

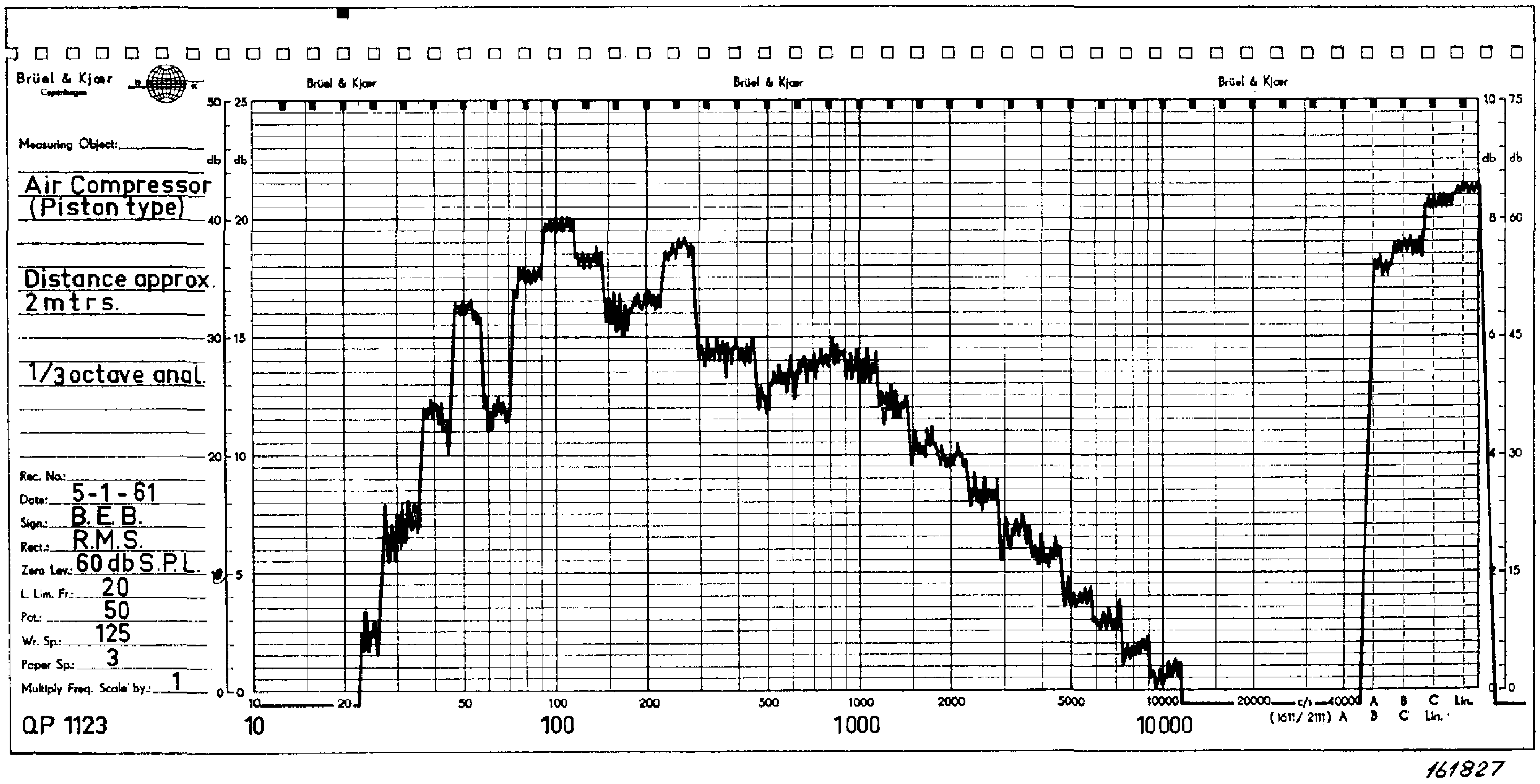

Fig. 8. Spectrogram of noise from an aircompressor such as obtained by means of the arrangement shown in Fig. 7.

and a level recorder. The analyzer contains a number of filters which may be interchanged by means of, for instance, a rotating selector. The result of the analysis is then presented in the form of a spectrogram as shown in Fig. 8. Looking at Fig. 8 it appears clearly that only three frequencies are of great importance, i.e. the three noise peaks seen at 50, 100, and 250 c/s.

After a series of such measurements has been carried out on identical units of a production batch it is normally possible to specify which noise levels can be tolerated at these frequencies.

For the quality control check of similar units it would then be possible to employ an instrument which only responds to these particular frequencies and which will give a warning signal when the predetermined noise levels are exceeded. Such an instrument to be used in production control must naturally also be a fast working one in order to save time. The laboratory equipment outlined in Fig. 7 requires some operation time and also to a certain degree technically trained personnel. To overcome this problem B & K have developed an instrument for the production line testing of equipment generating noise or vibration. The main requirements set up for this instrument can briefly be stated as follows:

1. It should be an analyzing instrument.
2. It should provide for both noise and vibration measurements.
3. It should give *fast* and accurate measurements to facilitate high speed operation.
4. It should be easy to operate by untrained personnel.
5. It should be easy to readjust for different types of production

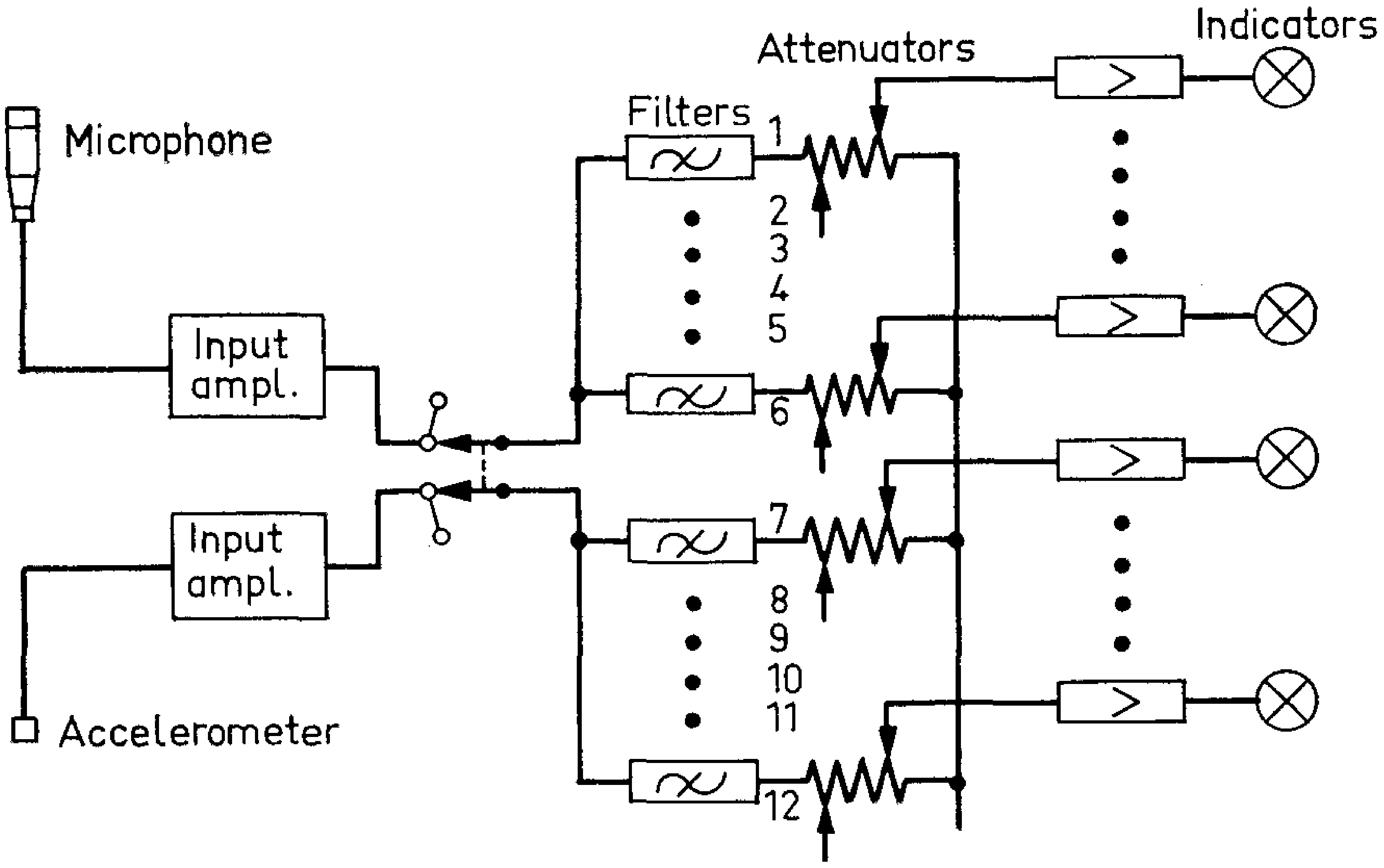

Fig. 9. Basic principle of operation of the Noise Limit Indicator.

During the development of this instrument it was found that it would be possible in addition to the above to make the instrument divide the test objects in several noise or vibration classes. Obviously this is an advantage as the test units may then be divided into groups and avaluated according to the purpose they are supposed to be used for. The instrument for production testing is called a Noise Limit Indicator and the basic design is shown in Fig. 9. Fig. 10 shows a photograph of the completed unit.

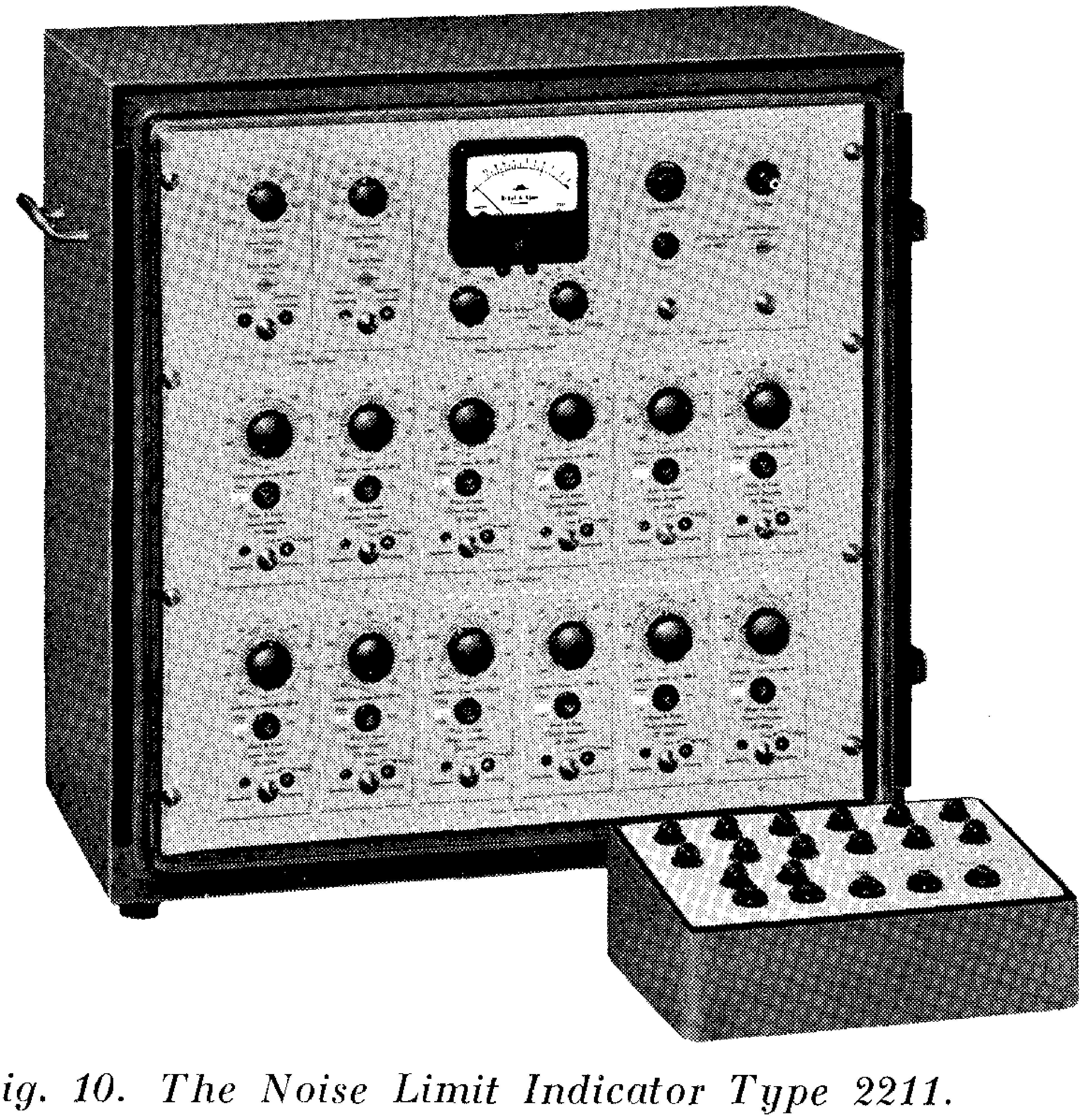

Fig. 10. The Noise Limit Indicator Type 2211.

As can be seen, it employes two input amplifiers so that noise and vibration may be tested simultaneously (two microphones or two accelerometers may also be used in parallel). 12 different noise frequencies may be checked in one operation, each of the frequency bands adjusted to its own individual "critical" level.

Doubling of the attenuators after the filters, makes it possible to check the test unit for both noise and vibration successively without changing the adjustment of the apparatus though checking noise and vibration at different levels. A special "sensitivity increase" circuit allows the above mentioned classification of the test objects besides the usual "go — no go" test. Combining the two input channels and the "sensitivity increase" circuit makes it possible to divide the test objects into five noise or vibration classes if desired. (See Figs. 11 & 12).

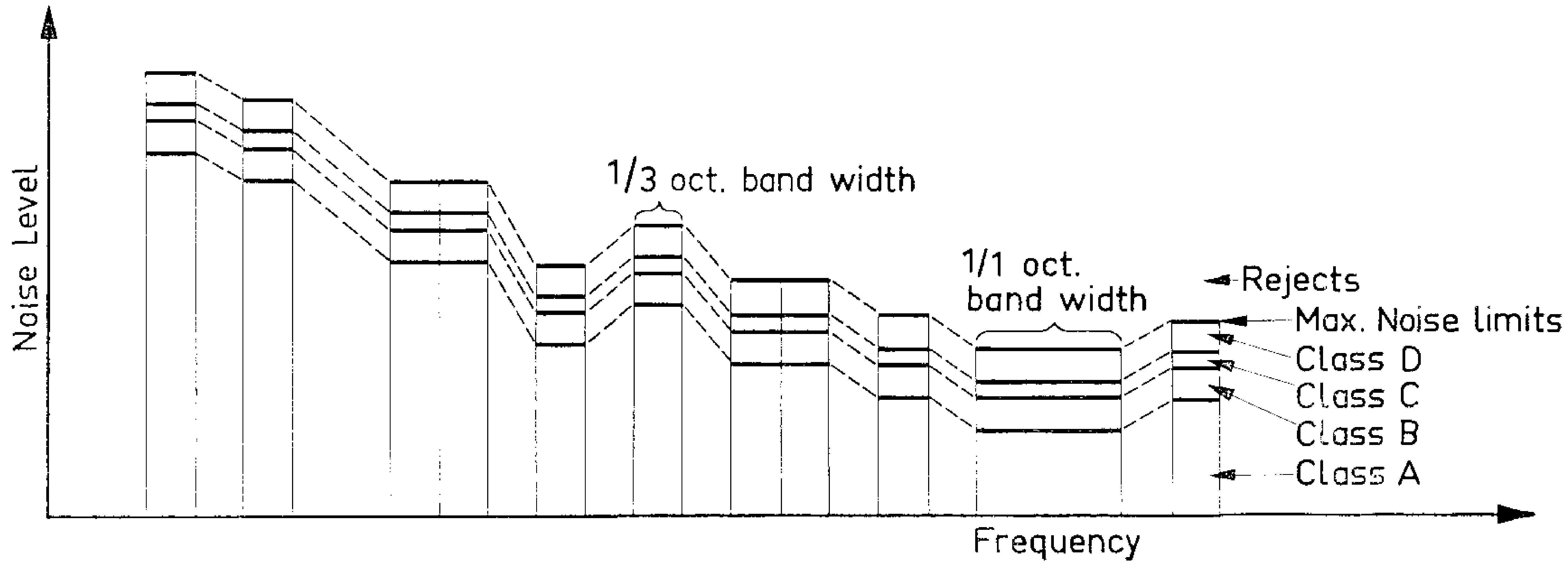

Fig. 11. Besides the normal "go — no go" tests on actual noise or vibration classification may be carried out.

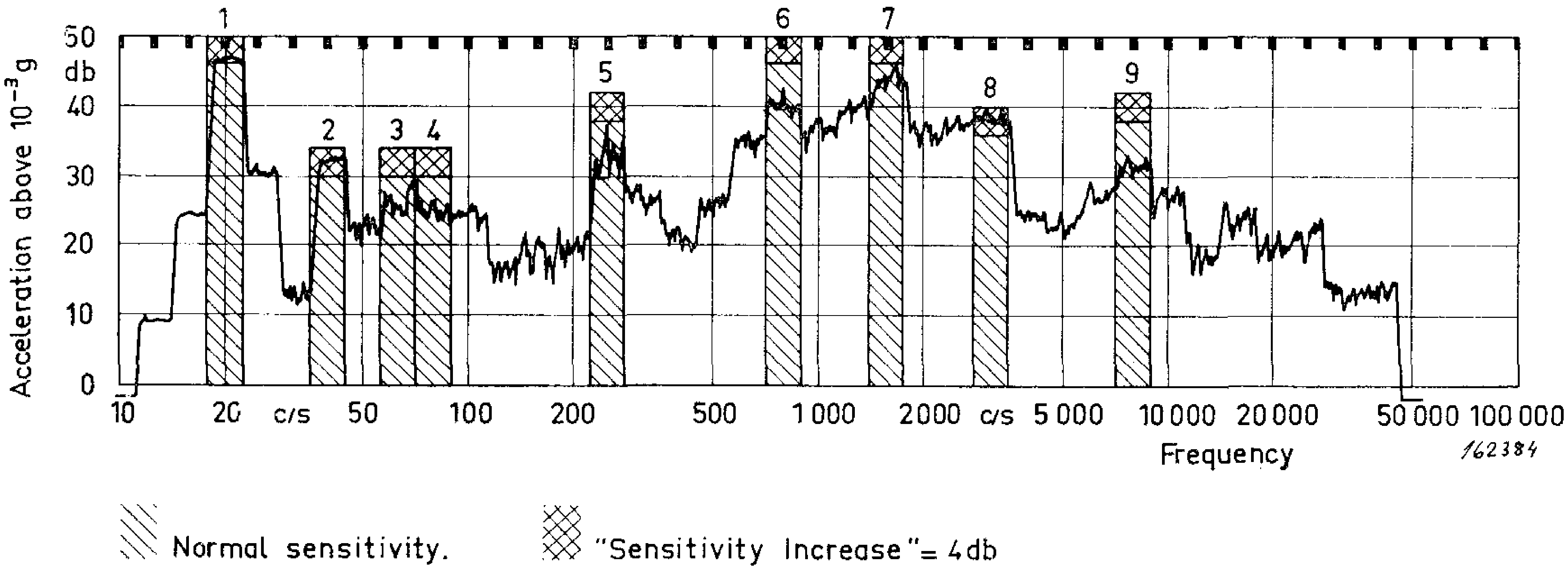

Fig. 12. 1/3 octave vibration spectrogram of a sewing machine. The figure illustrates the use of nine band-pass filters. The cross hatching gives the amount of "sensitivity increase", here chosen to 4 dB. From the illustration it can be seen, that at normal sensitivity no indicators will light-up, whereas at "sensitivity increase", indicators no. 1, 2 and 8 will light.

The operation time of the instruments permits a normal "go — no go" test to take place in one to two seconds besides the time it takes to replace the units in the test stand. In this way the test time merely becomes a question of how fast it is possible to replace the test units.

The width of the noise bands to be employed for such tests has been discussed. For the Noise Limit Indicator it is possible to choose between band widths of 1/3 octave and 1/1 octave. This also conforms to the band width of the analysing instruments used in most laboratories for noise analysis. Also, for the measurement of vibration it will, in most cases, be an advantage to choose 1/3 octave filters instead of a narrow band width as, this permits the vibration frequency to vary slightly during measurements (due to slight changes in motor speed etc.) without disturbing the check.

As already mentioned it is necessary to determine frequency bands and tolerable noise levels prior to production testing with the Noise Limit Indicator. Another important point, which seems to be somewhat neglected in the preparatory work in such tests, is that the test object should be tested under actual working conditions. This is not always possible: For instance, a gear box for an automobile should then be tested in the automobile and on the road. A test in a test stand may not at all give the same results. It is therefore necessary to test a series of gear boxes under working conditions, take them out of the automobile and test them again in a standard suspension in the test stand which is used for production testing. The differences in measurements should be duly noted and the noise and vibration levels recalculated accordingly before the production test takes place. Also it is necessary to take precaution for warm-up time etc.

Conclusion.

Quality tests by means of noise or vibration analysis seems to be advantageous for practically all kinds of mechanical equipment containing moving and especially rotating parts. For actually mass-produced units it is useful to investigate carefully the relationship between mechanical defects and noise or vibration generation. Also the influence of the change in ambient conditions from the test stand to the actual working conditions should be carefully determined.

Once these investigations have been finished, it proves advantageous to use the Noise Limit Indicator in mass-production, while for production in short batches, normal laboratory equipment may be sufficient, although it requires more time for the tests to be carried out.

A. F. Nonlinear Distortion Measurement by Wide Band Noise

by

*Bjarne E. Bang**)

ABSTRACT

Using wide band noise passed through a filter with a sharp band-stop characteristic, the overall distortion is measured selectively. The practical suitably of the method is investigated and some measured results presented. Difficulties in the interpretation of the results are discussed.

SOMMAIRE

L'emploi de bruit blanc à large bande dont une «raie» est arrêtée par un filtre arrête-bande à flancs raides permet la mesure sélective de distorsion totale. L'intérêt pratique de cette méthode est étudié et quelques résultats expérimentaux sont présentés. Les points délicats de l'interprétation des résultats sont discutés.

ZUSAMMENFASSUNG

Sendet man Breitbandrauschen durch ein flankensteiles Band-Sperrfilter, so kan man nichtlineare Verzerrungen selektiv messen. Es wird die praktische Eignung dieses Verfahrens untersucht, ferner werden einige Messergebnisse vorgelegt und diskutiert.

In electro-acoustic systems various forms of distortion are present. The nonlinear distortion, which will be discussed in the following, arises from nonlinear characteristics in the transmission system. If a pure sine-wave is applied to the input of the system, the nonlinearity produces harmonics and, additionally, when two or more sine-waves are applied, intermodulation between the signals will result. Usually, the nonlinear distortion is measured using pure sine-wave signals. By this method, however, the sound system is operated under very special circumstances. Therefore it may be more realistic to use a test signal which has a character similar to speech and music. A nonlinear distortion measuring method utilizing a signal of this type is described in the CCITT Livre Rouge Tome IV, page 189. In this paper it is suggested that a statistical signal (white noise) be used as test signal. A white noise signal can be considered as a signal containing an infinite number of sine-waves within its band, the magnitudes of which are statistically distributed. A white noise signal often used in measurements to simulate among other things speech and music, has a Gaussian (normal) magnitude distribution.

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*) Paper given at the 4th International Congress on Acoustics, Copenhagen 21-28 August 1962.

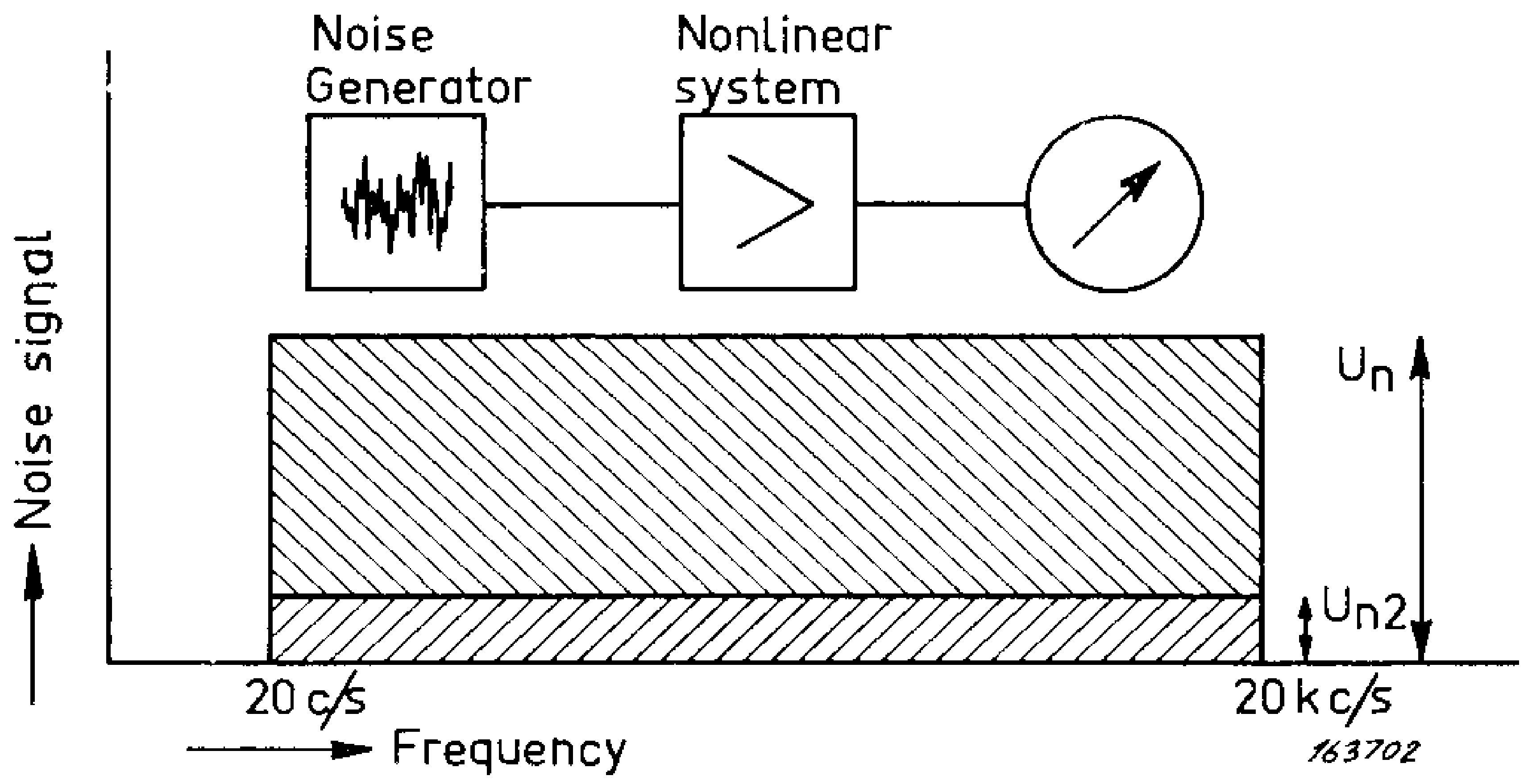

Fig. 1. The signals derived from wide band noise U_n transmitted through a system containing nonlinearities.

Applying a white noise signal U_n to a system containing nonlinearities, a new noise signal U_{n2} can arise on the output of the system in combination with the transmitted signal U'_n. Fig. 1. It is produced from the harmonics as well as from the combination signals (mixing products). The level and spectrum density will depend on the degree and character of the system nonlinearities. This effect can be utilized in nonlinear distortion measurements. To be able to measure the signal U_{n2} produced by the nonlinearities it is necessary to introduce a band-stop Δf in the input noise signal. Fig. 2. The signal level U_{n2} produced within this band-stop can then be measured at the output of the system under test by a selective indicator having a band-pass with center frequency f_o and width Δf equal to that of the band-stop.

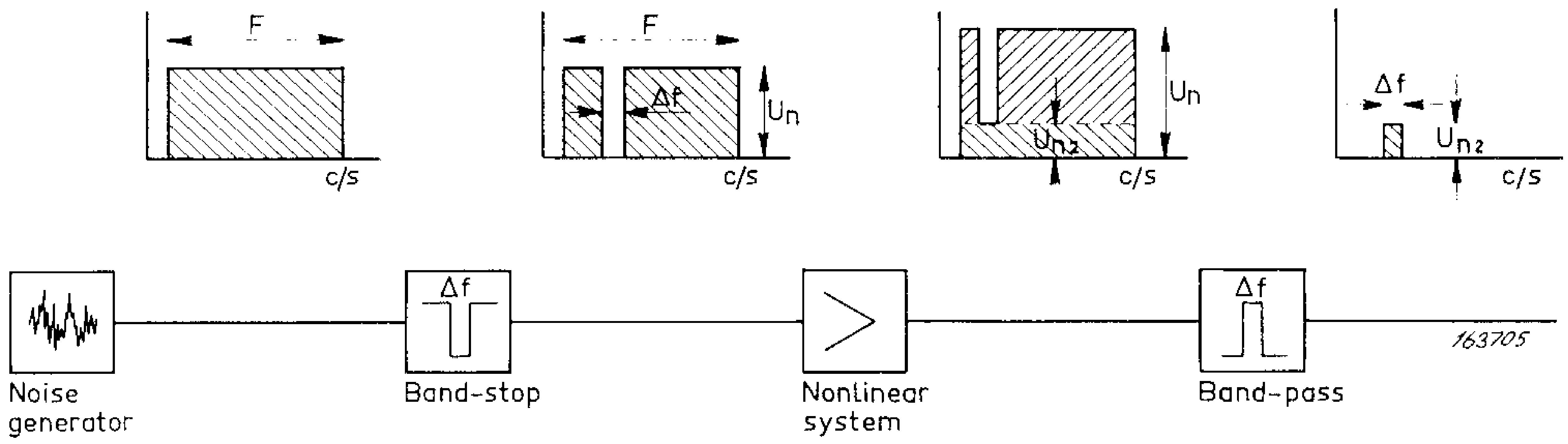

Fig. 2. Principle of measuring nonlinear distortion by wide band noise.

The principle, using ideal filters, is illustrated in Fig. 2. In practice, the band-stop and band-pass filters will have a more or less steep slope and will not show zero an infinite attenuation outside the stop band and the pass band respectively. These properties determine the limit of the noise measuring method.

The effective bandwidth Δf of the band-stop filter should be narrow compared to the effective bandwidth F of the system under investigation. The attenuation required at the "stop-bandwidth" depends on the degree of distortion which has to be measured. By "stop-bandwidth" is here meant the bandwidth Δf of the band-stop filter where it equals the effective bandwidth Δf of the following band-pass filter. In the measurements discussed later the attenuation at the stop-band limits was 13 dB approximately.

The bandwidth Δf of the band-pass filter should as mentioned be as narrow as the width of the stop-band Δf of the band-stop filter. A filter which is even narrower, i.e. only a part of Δf can also be used. The attenuation at all frequencies well away from the pass-band should be high.

It should in any case be higher than the difference in wide band noise level U'_n (F) to narrow band noise level U'_n (Δf). In practical measurements there is also a limit to how narrow the band-pass can be. For a filter only a few cycles wide the integration time of the associated indicating meter has to be inconveniently long. For a filter more than 10 c/s wide the integration time, suggested for Precision Sound Level Meters (I.E.C. Helsinki 1961), will in many cases suffice.

The measurements can be carried out using a few pairs of filters with fixed center frequency, or better, the two filters can be continuously variable. A refinement would be if the band-stop and band-pass filters could be scanned in synchronism with each other through the complete frequency range. In combination with a level recorder the measurements could in this manner be carried out automatically. Two filter types can be considered, viz. filters showing constant absolute bandwidth (heterodyne filters) or filters with constant percentage bandwidth. In both instances the signal U_{n2} produced by the system nonlinearities have to be measured in relation to the complete signal $U'_n + U_{n2}$ which has passed the system, thus containing both the original U'_n and the produced signal U_{n2}. Using a filter with constant absolute bandwidth the complete signal $U'_n + U_{n2}$ can be measured either by a wide band indicator or by a narrow band indicator. With this measuring arrangement no "frequency compensation" is necessary in either case. For filters showing constant percentage bandwidth the ratio will depend on frequency when the signal $U'_n + U_{n2}$ is measured by a wide band indicator, as the signal level of the produced signal U_{n2} will increase by 3 dB/octave increasing frequency when measured by such a filter. If, on the other hand, $U'_n + U_{n2}$ is also measured by the narrow band indicator with center-frequency f_0 equal to that of the band-stop filter, this signal level will additionally increase by 3 dB/octave, making the measured ratio independent of frequency. Utilizing the latter method, the band-stop filter has to be taken out of circuit during the selective measurement of the signal $U'_n + U_{n2}$.

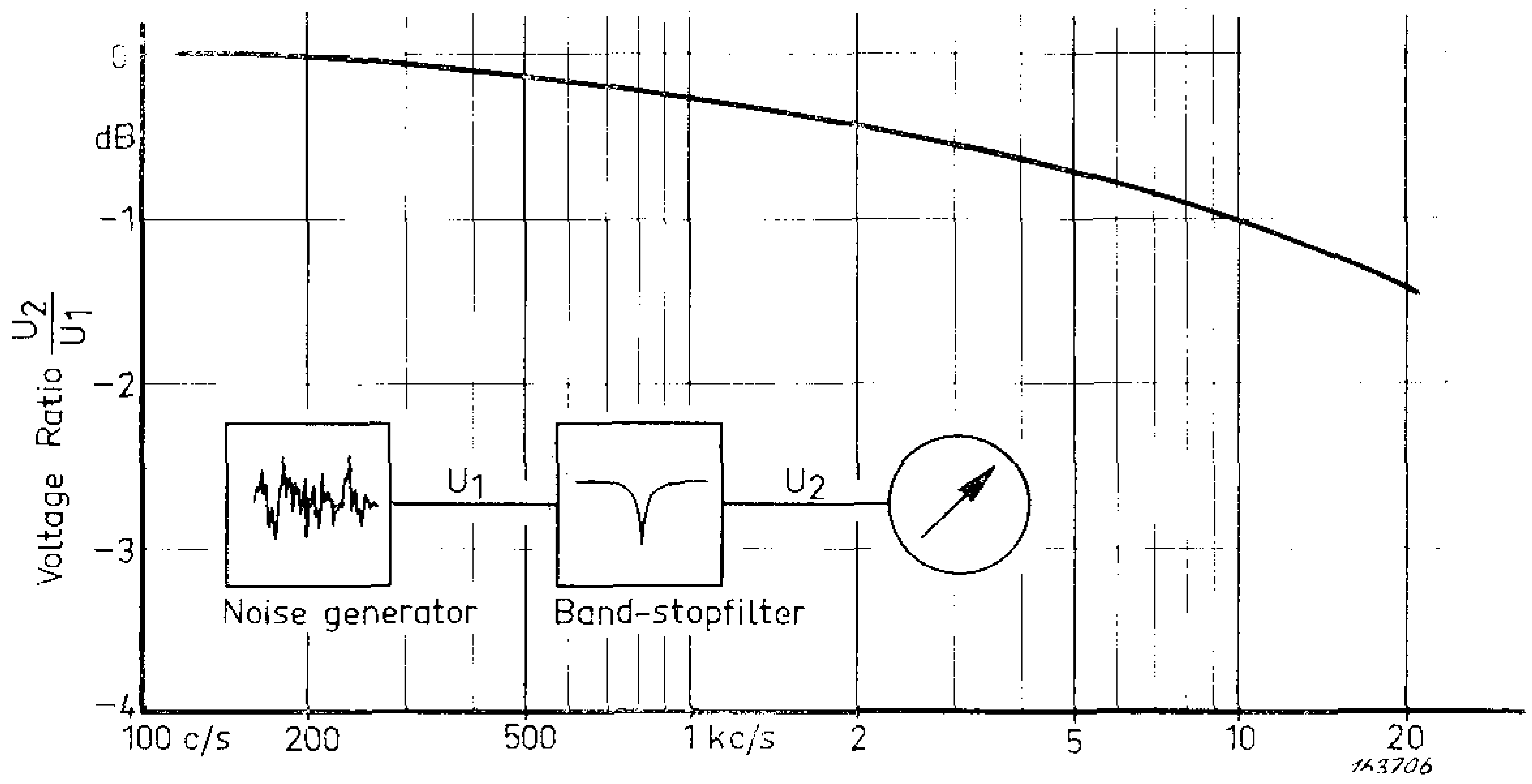

Fig. 3. Decrease in r.m.s. level of wide band noise caused by inserting a band-stop filter.

Practical Measurements.

Since, to the author's knowledge, no special equipment is available commercially an equipment was devised using standard electro-acoustic measuring instruments, i.e.

Random noise generator, giving uniform spectrum density (white noise) with Gaussian distribution in the frequency range 20 c/s — 20 kc/s.

Band-stop (rejection) filter. 20 c/s — 20 kc/s continuously variable, having constant percentage bandwidth.

Band-pass filter, 20 c/s — 20 kc/s continuously variable, having a 3 dB constant percentage bandwidth of 6 %.

Indicating meter, 2 c/s — 40 kc/s measuring r.m.s.

Firstly, the capability of the instrumentation was checked. A filter had to be chosen which would not extract too much energy from the effective white noise signal. After investigating various band-stop filters, sometimes using two units in cascade, it was decided to employ a single filter having an effect as shown in Fig. 3. The filter was later found to give a ratio $U'_n + U_{n2}$ to U_{n2} of about 13 dB. Fig. 4b. Its frequency characteristic compared with the band-stop filter was as illustrated in Fig. 4a.

Some distortion measurements were carried out on a hearing aid. The measuring arrangement used can be seen in Fig. 5. The noise generator supplies a white noise signal to the band-stop filter and further to a loudspeaker via an amplifier. Therefore, it was placed in a special hearing aid test box ensuring reflexionfree transmission from loudspeaker to hearing aid micro-

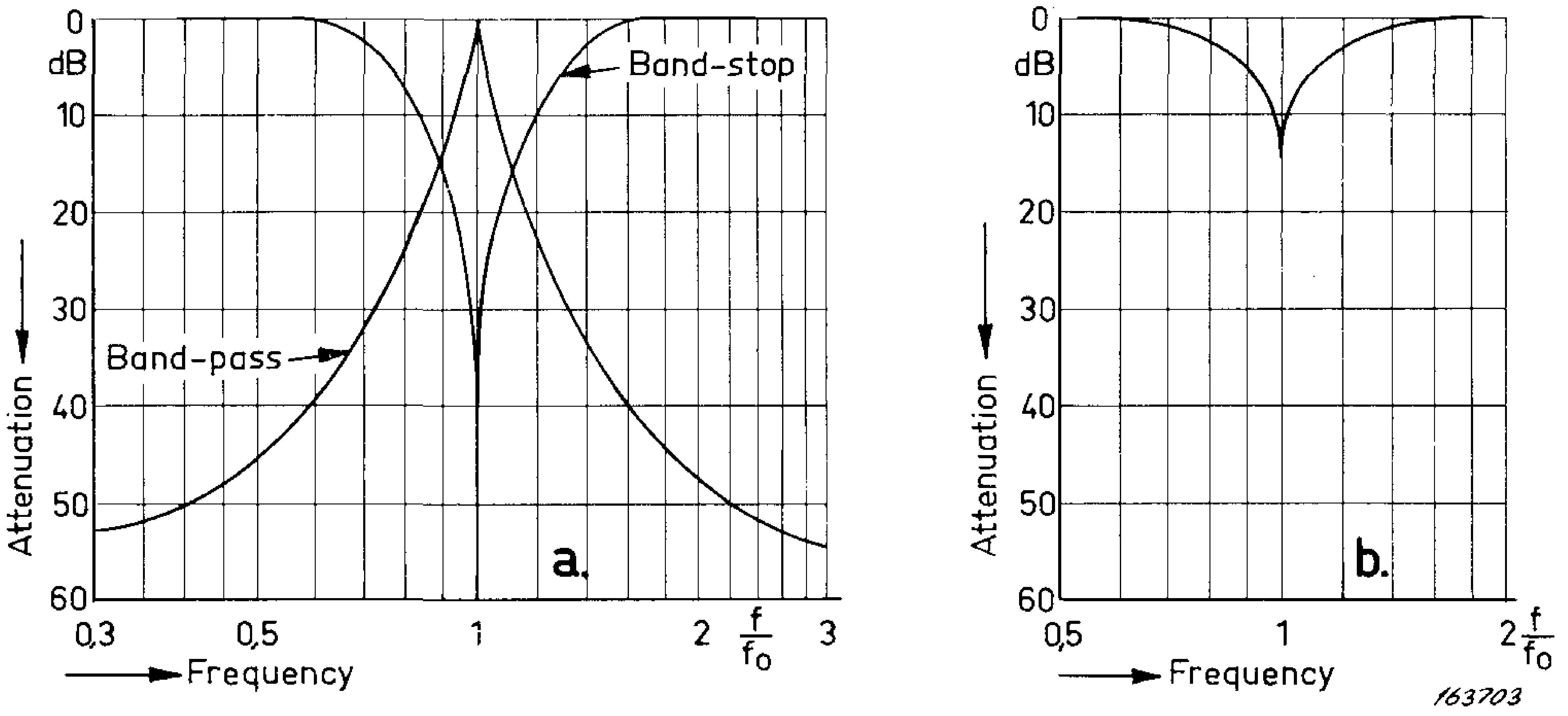

Fig. 4.

a. Amplitude versus frequency characteristic of band-stop and band-pass filters as measured by sine wave.

b. Band-stop filter's frequency characteristic measured via the band-pass filter and using a white noise signal.

phone. The ear piece was placed in an artificial ear, the output of which was fed to the band-pass filter via an amplifier. Finally, the various levels were measured by an r.m.s. indicating meter.

For the sake of comparison, the distortion as a function of frequency was measured first by sine-wave for input sound pressure levels of both 60 and 70 dB at the hearing aid microphone. Fig. 6. Note the increase in distortion at 1500 c/s. For the measurements using noise the sound pressure level was adjusted to a wide band input level U_n of 60 dB and 70 dB respectively. As constant percentage bandwidth filters are used. The complete signal $U'_n + U_{n2}$ was measured selectively by the band-pass filter and with the band-stop filter out of circuit. The ratio, complete signal $U'_n + U_{n2}$ to produce signal U_{n2} is expressed in dB, derived from the expression

$$20 \log \frac{\sqrt{U'^2_n + U_{n2}^2}}{U_{n2}} \text{ dB}$$

From the curve in Fig. 6 it can be seen that at 60 dB sound pressure level and high frequencies the ratio tends towards 13 dB, which was found earlier

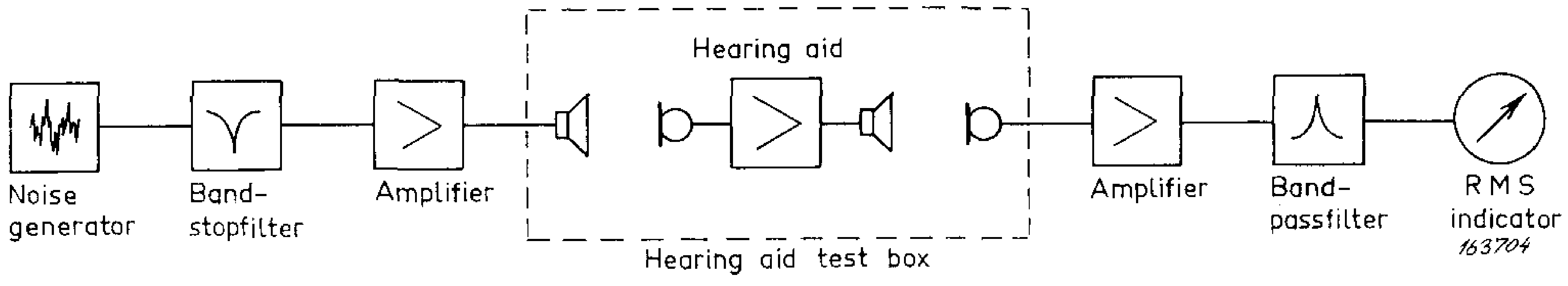

Fig. 5. Arrangement for nonlinear distortion measurement on a hearing aid by using a wide band noise signal.

to be the highest ratio measurable by the equipment used. At 70 dB level and towards the lower frequencies the ratio reaches 0 dB. As 0 dB is the lowest ratio measurable by this principle ($U'_n + U_{n2}$ measured selectively by the band-pass filter) a limit of maximum distortion measured by this equipment is attained. A great difference in the results obtained by the sine-wave measuring method and the noise method is noted at high frequencies for both sound pressure levels. The sine-wave method shows a large increase in distortion at 1500 c/s whereas the noise method tends to decrease. The reason for this difference may be that the noise peaks which are able to excite the possible resonance at 1500 c/s, have a much lower energy level than does the distinct sine-wave used during the sine-wave measurement. If the bandwidth of the noise is assumed to be in the order of say ± 100 c/s, the r.m.s. level within this narrow band compared to the r.m.s. level U'_n of the effective bandwidth F of the hearing aid, will be:

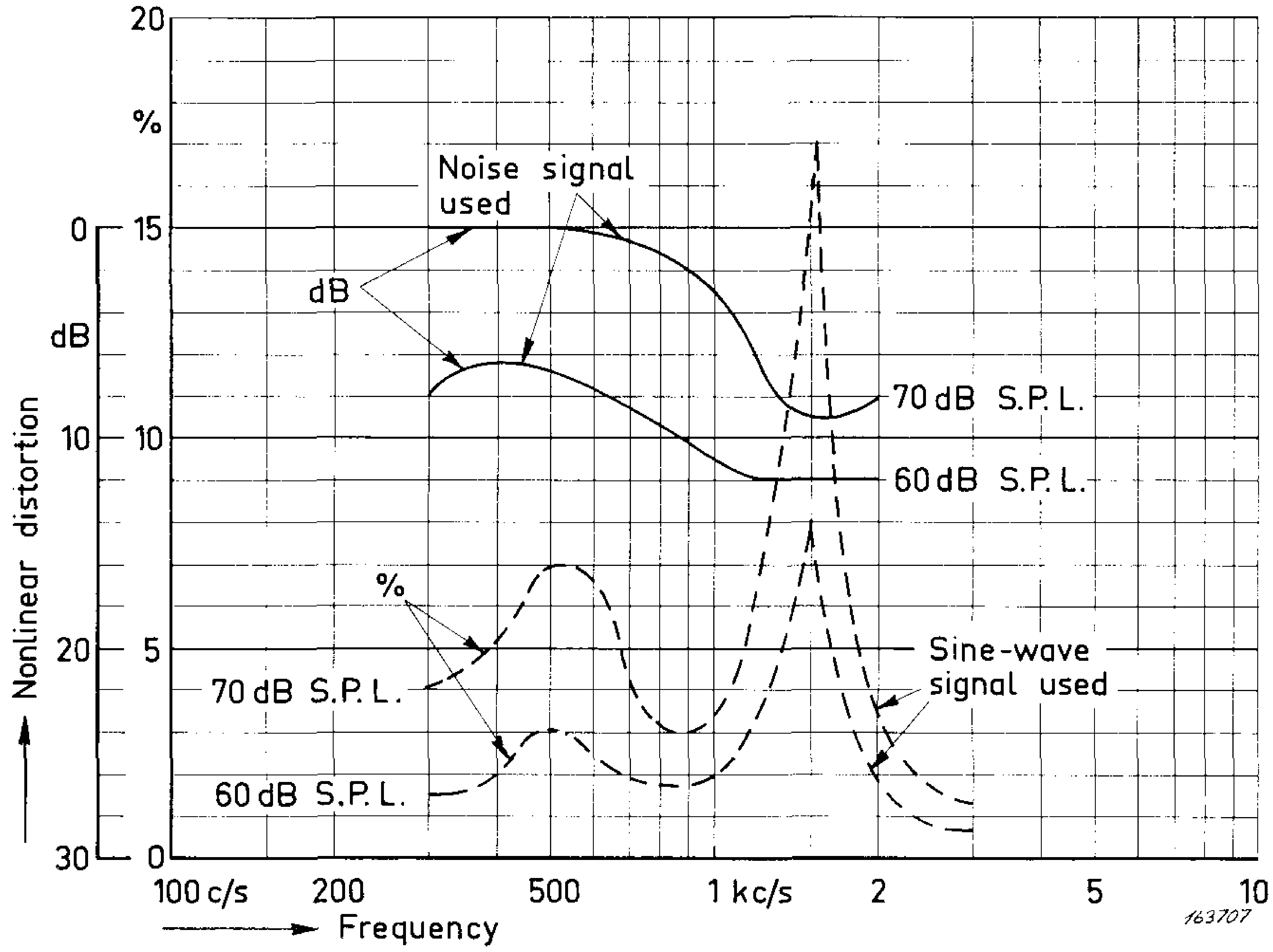

Fig. 6. Results from nonlinear distortion measurement on a hearing aid. Test signals: noise (full lines), sine wave (dashed lines).

$$\sqrt{\frac{F}{\Delta f}} = \sqrt{\frac{3000}{200}} = 4 \text{ times} \sim 12 \text{ dB lower}$$

F = 3000 c/s approx.

Accordingly, the produced signal U_{n2} will also be of a low value, thus making the ratio $\frac{\sqrt{U'^2_n + U^2_{n2}}}{U_{n2}}$ high. Note that both $U'_n + U_{n2}$ and U_{n2} are measured via the band-pass filter (Δf).

The measurements show that by using wide band random noise together with the discussed instrumentation it is possible to obtain data illustrating the nonlinear distortion in sound systems, though within certain limits. In the first instance the obtained data have to be interpreted from subjective investigations as the system, for which the described measuring method is intended, is used for sound transmission. With experience it can be established if a system showing a particular amount of distortion expressed in per cent. or, as in the examples, in dB, exhibits low or high subjective nonlinear distortion. The distortion measuring method discussed here is in some countries used on multi channel telecommunication equipment. The reason why the method is not widely used for more simple electro acoustic systems may be that commercial filters with adequate data have not been available.

Bibliography:

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Lennart Brandqvist: Ny metod för mätning av förvrängning vid ljudåtergivning. *Radio och Television* — nr. 8 — 1958.
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A Note on Perceived Noise Level

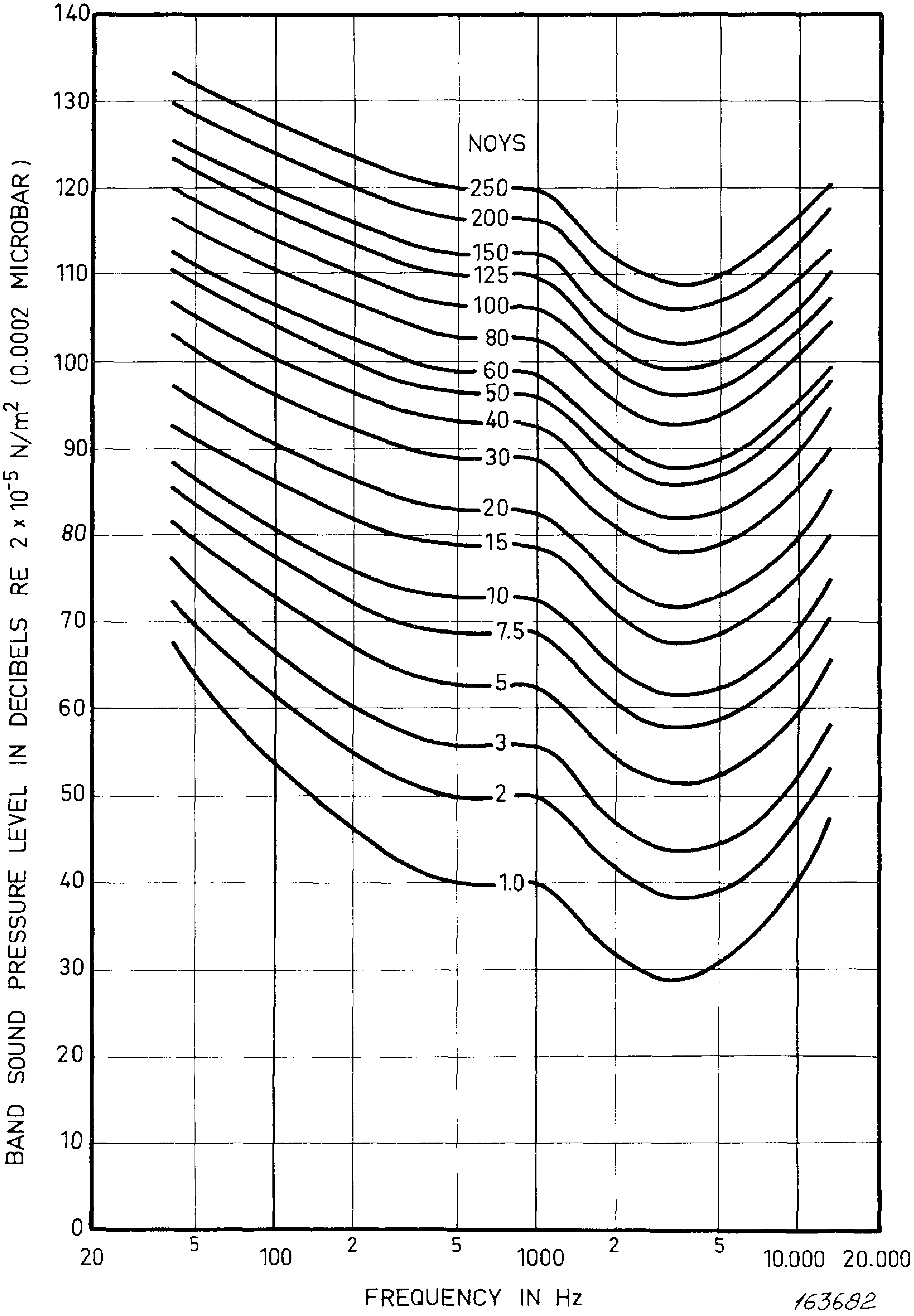
In the B & K Technical Review No. 2-1962 a review was made of current methods for loudness evaluation. The general methods of loudness calculation due to S. S. Stevens and E. Zwicker were described.

Also a method, developed by K. D. Kryter et al., for the calculation of a quantity called "perceived noise level" was discussed. This method has been introduced in an attempt to relate the subjective "noisiness" (or "unwantedness" of a sound to objective measurements. It has, since its first introduction, gained considerable importance, especially in the field of aircraft noise measurements. However, the original curves and tables published by Dr. Kryter in 1959 and shown in Fig. 18 of the B & K Technical Review No. 2-1962 left the "very" high frequency region open for dispute.

A careful study by Kryter and Pearsons lead to a revision of the original curves and some of the trends of their findings were also published in an Appendix to the above mentioned article in the B & K Technical Review. Their final results are now available in the form of a U. S. Government report NASA TN D-1873 "Some Effects of Spectral Content and Duration on Perceived Noise Level", by K. D. Kryter and K. S. Pearsons. This report (or parts of it) will also appear in the June issue of the Journal of the Acoustical Society of America. The final Noys-curves are shown in Fig. PNL 1.

The author wishes to thank Dr. Kryter for his kind submission of the curves given in this note, and for a greatly appreciated discussion earlier this year.

Jens T. Broch.


NOYS
250
200
150
125
100
80
60
50
40
30
20
15
10
7.5
5
3
2
1.0
BAND SOUND PRESSURE LEVEL IN DECIBELS RE 2 × 10^-5 N/m^2 (0.0002 MICROBAR)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
20
5
100
2
5
1000
2
5
10.000
20.000
FREQUENCY IN Hz
163682

PNL 1.

News from the factory

We introduce

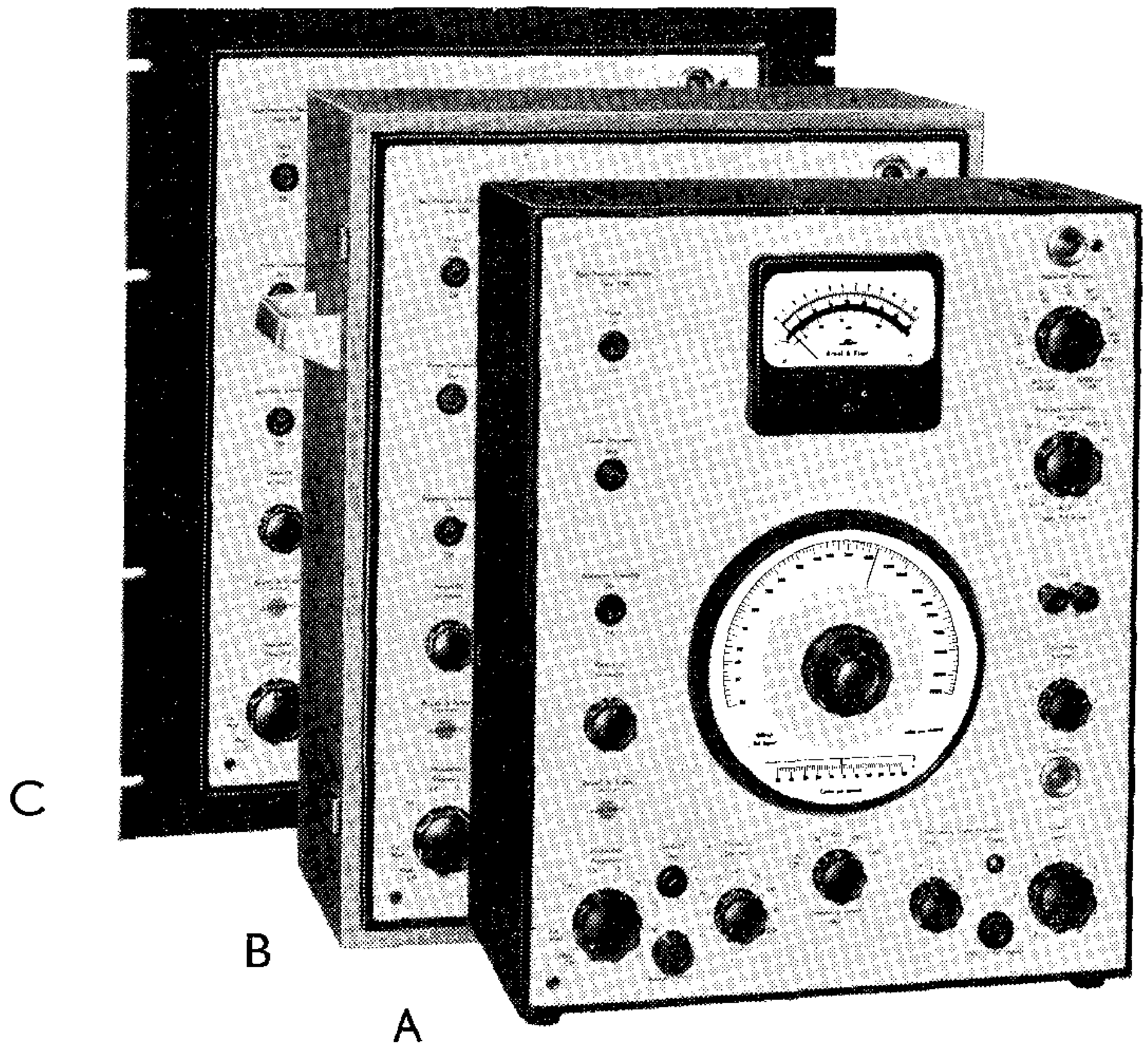
A NEW MECHANICAL DESIGN

In answer to many customer requests, Brüel & Kjær have the pleasure to announce the introduction of a new "Lightweight Metal Case", and its incorporation on all our larger instruments produced in the future.

The case has been designed with a view to provide these instruments with a greater flexibility regarding mounting possibilities. As a result, of this new functional cabinet design, we are now able to supply our instruments in any of three versions, namely: Type "A", "B" or "C". Thus offering our customers a choice, of instrument mounting, most suited to their particular requirements.

"Type A" instruments are intended for use under laboratory conditions, where the danger of damage, due to transportation, is non existent. These basic versions will be housed in the new Lightweight Metal Case, bearing the instruments type number plus the letter "A".

"Type B" instruments, consist of a basic version (Type "A") instrument, being housed, together with its metal case, in the well known, attractive B & K mahogany cabinet with removeable front cover. Intended for field and transportable use generally, these mahogany cabinets have proved to be worthy travellers, affording the instrument excellent protection from damage during transportation. When supplied in this version, instruments will bear their type number plus the letter "B".



Beat Frequency Oscillator Type 1022, an example of the new cabinet system.

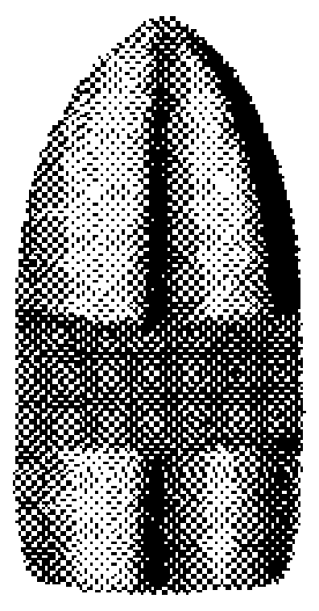
"Type C". Here again, this version of an instrument is based upon type "A", and it is intended to be used in standard 19″ rack installations. The instrument is supplied together with the necessary mechanical components which, when assembled to the instrument, forms a frame that makes it suitable for mounting in such an installation. These instruments will bear their type number plus the letter "C".

This new Lightweight Metal Case has also given rise to the design and production of a new frame capable of housing two or three B & K instruments, that would normally be interconnected externally, in a combined unit internally interconnected. This frame is known as the »B & K Combination Unit". An excellent example of the use of the "B & K Combination Unit" is the new "Octave, Third Octave and Narrow Band Spectrum Recorder Type 3333", see page 26.

Dismounting of the combination unit has been made very simple, due to the design of the new Lightweight Metal Case, thus enabling any or all of the instruments housed in the combination unit (Analyzer, Band-Pass Filter Set or Level Recorder) to be removed and used separately as "Type A" instruments.

Nose Cone UA 0053.

This Nose Cone is designed for use on the 1/4″ microphones (4135), instead of the normal protecting grid, where measurements are taken in locations where the microphone cartridge is subjected to high speed airflows.

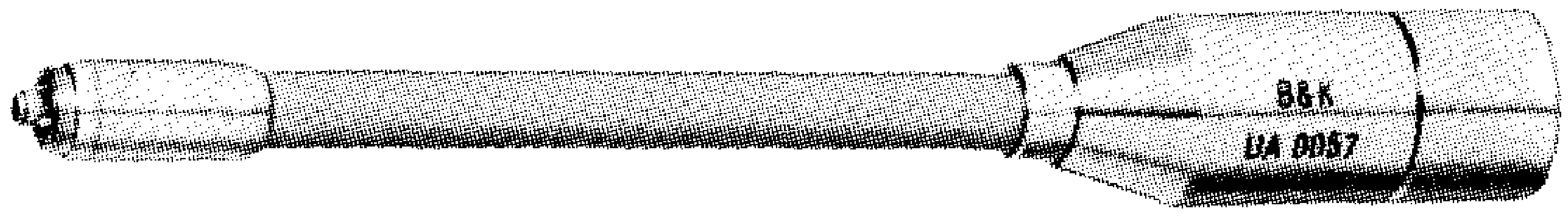


Nose Cone UA 0053.

The microphone diaphragm will then be fully protected against har particles in the air stream and a reduction of the turbulence noise may be obtained in most cases. The presence of the Nose Cone will only alter the free-field response above 20 kc/s. The Microphone Nose Cone combination will be omnidirectional up to 40 kc/s, but not useable above this frequency.

Flexible Adaptor UA 0057.

This adaptor is intended to be used in place of the UA 0035 between the quarter-inch Cartridges 4135/36 and the half-inch Cathode Followers 2614/15. It consists essentially of a 2 3/4 inches long double-screened cable with



Flexible Adaptor UA 0057.

appropriate connectors at the ends. The acoustical and electrical characteristics of the microphone equipped with a UA 0057 gives the quarter-inch microphone versatile mounting capabilities and reduces the sensitivity to vibrations of the cathode follower as compared to the UA 0035 + 2615 cathode follower combination.

Pick-up Test Recordings Type QR 2008.

These new calibrated disc recordings are intended to cover the need for testing and adjustments of monophonic and stereophonic pick-ups in addition to the already existing gliding Frequency Records Types QR 2007 and QR 2009. They are pressed on vinylite and have a playing speed of 33 1/3 r.p.m. QR 2008 consists of a set of five records (10 identical faces) with the following program:

Section 1.
Spot Frequencies: 20—16—12, 5—10 kc/s.
Velocity level: o.6 cm/sec. r.m.s. in 45° modulation.
Band 1: 45° left modulation (A).
Band 2: 45° right modulation (B).

Section 2.
Reference Tones, 1 kc/s, 4 × 60 sec.
Velocity level: 2.24 cm/sec. r.m.s. (45°) (3.16 cm/s lateral or vertical).
Band 1: 45° left (A).
Band 2: 45° right (B).
Band 3: lateral (A + B).
Band 4: vertical (A — B).

Section 3.
Lateral Tracking Test,
100 c/s (A + B), 5 × 15 sec.
Band 1: o.001 cm peak amplitude.
Band 2: o.002 cm peak amplitude.
Band 3: o.003 cm peak amplitude.
Band 4: o.004 cm peak amplitude.
Band 5: o.005 cm peak amplitude.

Section 4.
Vertical Tracking Test, as section 3 but with vertical (A — B) modulation.
Section 5.
Logarithmic Frequency Sweeps 10 c/s — 100 c/s in 16 2/3 sec.
Start Marking (10 c/s point): cessation of the 1 kc/s signal preceding each band.

Recorded level: constant amplitude o.00113 cm peak.
Band 1: 45° left (A).
Band 2: 45° right (B).
Band 3: lateral (A + B).
Band 4: vertical (A — B).

Section 6.

as section 1, but with small groove speed.

Beat Frequency Oscillator Type 1022.

This oscillator supersedes the well known B.F.O. Type 1014, and apart from a completely new mechanical design some slight modifications of the electrical circuit have been made:

1. The *automatic output regulation circuit* (compressor circuit) has been modified so that the compressor speed can now be changed during operation without influencing the already set-up test level (no voltage surges occur during switching of the COMPRESSOR SPEED switch).
2. The internal frequency modulation circuit (warbling circuit) has been changed. The frequency deviation is now variable in steps:
   0 ± 10, ± 16, ± 25, ± 40, ± 63, ± 100, ± 160 and ± 250 c/s,
   and the available modulation frequencies are:
   1 — 1.6 — 2.5 — 4 — 6.3 — 10 — 16 and 25 c/s.
   It is thus possible in room acoustic measurements to use the warbling frequency 6.3 c/s which is recommended in various standards. The type of modulation (sawtooth) has not been changed.
3. The signals from both the fixed and the variable oscillators are available, for special purposes, on terminals at the rear of the instrument.
4. The axis of the main tuning capacitor has been lengthened so that it is possible to mount a potentiometer for the control of other equipment via a servo system.
5. The cam disc arrangement at the rear of the main tuning capacitor has also been modified to incorporate a third cam. This modification now allows an output signal to be generated within any chosen frequency range, even a very narrow one.

Octave, Third Octave and Narrow Band Spectrum Recorder Type 3333.

This is a new Brüel & Kjær combination unit consisting of a Frequency Analyzer Type 2107 A*), a Band Pass Filter Set Type 1612 A*) and a Level Recorder Type 2305 A*).

This unit allows spectrograms to be automatically recorded on preprinted, frequency calibrated paper either in the form of Octave or 1/3-Octave contiguous band analysis or in the form of narrow band continuously sweeping analysis. The Band-Pass Filter Set is connected to the Frequency Analyzer

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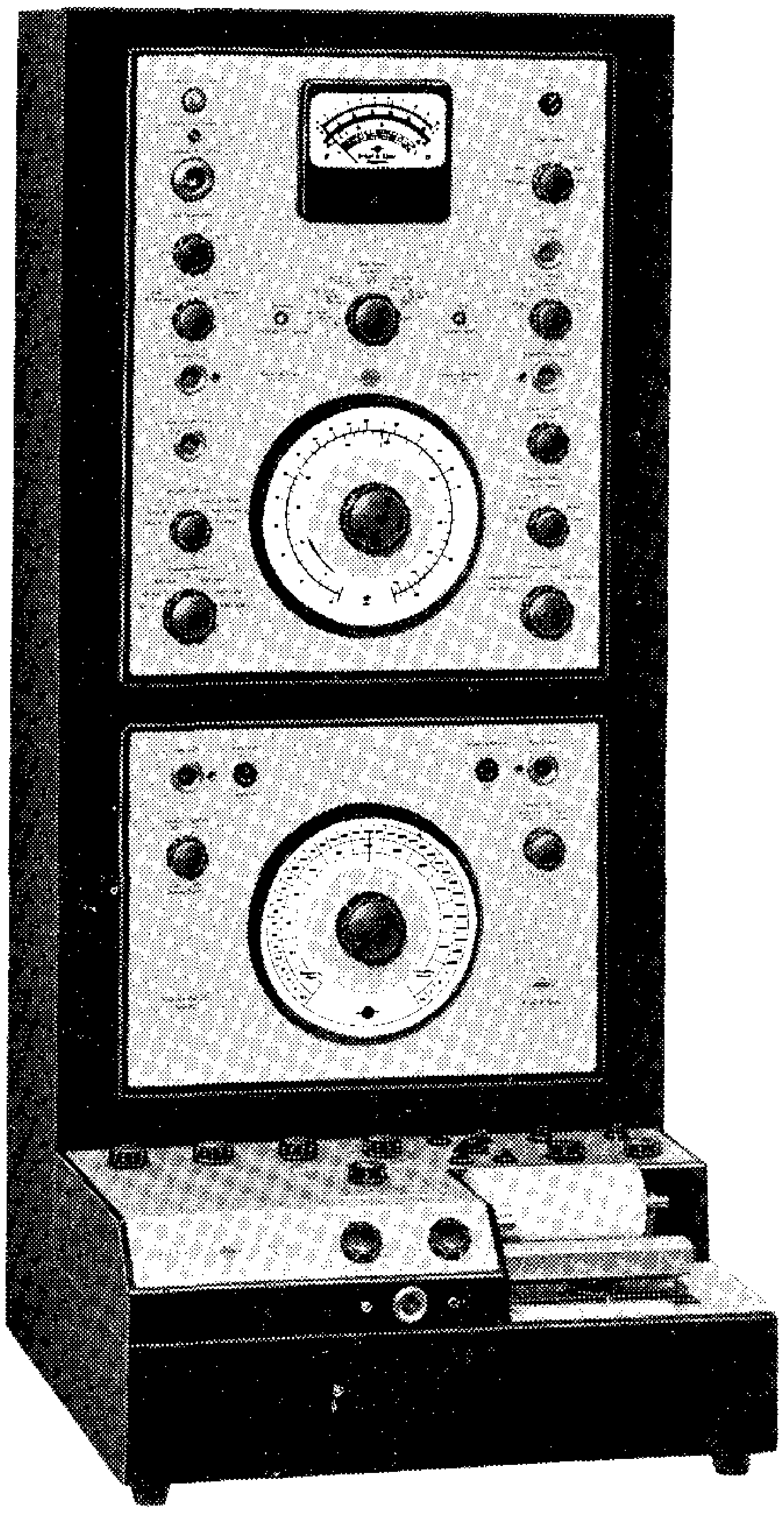
*) For explanation of the letter "A" following the "usual" B & K type number see page 23.



Octave, Third Octave and Narrow Band Spectrum Recorder Type 3333.

as "external filter" and the type of analysis obtained is determined by the position of the FUNCTION SELECTOR switch of the Analyzer.

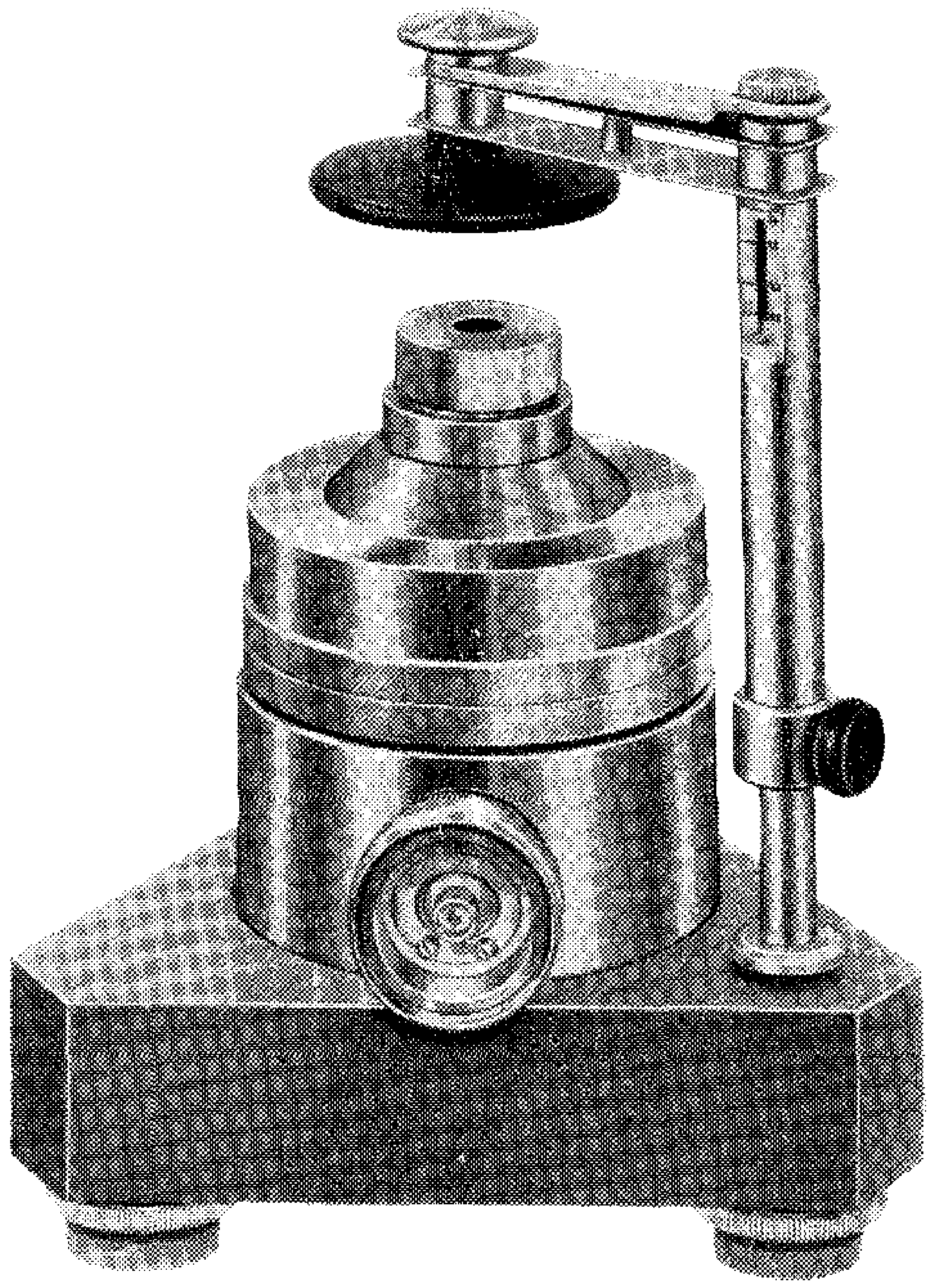
It is also possible to first select, for example, one octave of special interest and then perform a narrow band analysis inside this octave only. However, this kind of analysis cannot be made automatically but must be carried out manually (or semi-automatic if a recorded chart is desired).

It should be mentioned that the new mechanical mounting system makes it easy to dismount the combination and use any of the instruments (Analyzer, Band-Pass Filter Set or Level Recorder) separately as version "A" instruments.

Artificial Ear Type 4152.

Type 4152 is a complete redesign of the Ear Type 4151, the production of which has ceased. It is intended for measurements on earphones under controlled acoustical conditions and contains basically two interchangeable acoustical couplers as well as a clamping arrangement for the earphone being tested and sockets for the mounting of the measuring microphone.

The couplers supplied with the instrument consist of the internationally standardized 2 cm^3 coupler (I.E.C. Recommendation Publication 126) for measurements on hearing aid earphones, and a 6 cm^3 coupler which fulfills



Artificial Ear Type 4152.

the requirements to the American N.B.S. 9 A coupler for measurements on headphones (A.S.A. Z 24.5./1951).

The clamping arrangement is spring loaded and provided to retain the earphone under test in position. It can be adjusted to apply a force of 200 grammes or 500 grammes as recommended by A.S.A. Standards, the actual force value being set on a scale ingraved on the clamp holder.

The sockets, for the mounting of the measuring microphone, allow the use of a Brüel & Kjær 1″ Condenser Microphone Cartridge with associated Cathode Follower and measuring Amplifier or Analyzer, or the Precision Sound Level Meter Type 2203 directly. In all cases the Artificial Ear Type 4152 is vibration isolated by means of rubber feet. When used with the Precision Sound Level Meter Type 2203, the Artificial Ear will make a very convenient portable set up for the testing of audiometers, telephone receivers, head set ear caps etc.

By using a Brüel & Kjær Oscillator and Level Recorder together with the Artificial Ear and one of the previously mentioned amplifiers the electro-acoustic frequency response of the earphone under test can be recorded automatically on frequency calibrated recording paper. Also if an Audio Frequency Spectrometer Type 2112 is added (or a Band-Pass Filter Set Type 1612 with associated amplifiers) automatic recording of harmonic distortion is possible.

Finally, when it is desired to use the 2 cm^3 coupler separately in conjunction with a Brüel & Kjær 1″ Condenser Microphone this is readily possible without the use of extra arrangements.

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