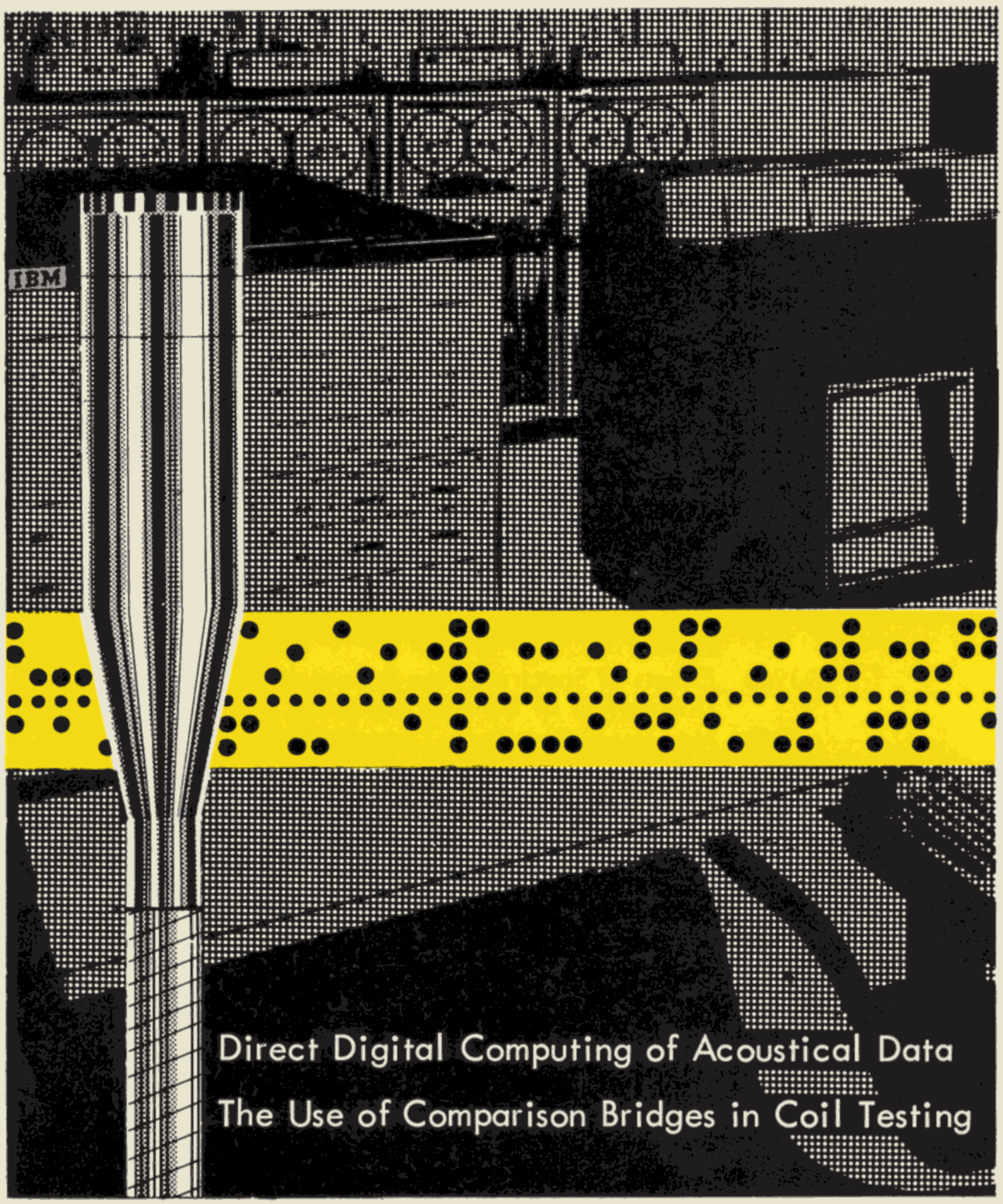
Brüel & Kjær

# Technical Review

To Advance Techniques in Acoustical, Electrical, and Mechanical Measurement




No. 2 1965

**PREVIOUSLY ISSUED NUMBERS OF BRÜEL & KJÆR TECHNICAL REVIEW**

1-1960 Pressure Equalization of Condenser Microphones and Performance at Varying Altitudes.

2-1960 Aerodynamically Induced Noise of Michophones and Windscreens.

3-1960 Vibration Exciter Characteristics.

4-1960 R.M.S. Recording of Narrow Band Noise with the Level Recorder Type 2305.

1-1961 Effective Averaging Time of the Level Recorder Type 2305.

2-1961 The Application and Generation of Audio Frequency Random Noise.

3-1961 On the Standardisation of Surface Roughness.

4-1961 Artificial Ears for the Calibration of Earphones of the External Type.

1-1962 Artificial Ears for the Calibration of Earphones of the External Type, part 2.

2-1962 Loudness Evaluation.

3-1962 Testing of Stereophonic Pick-ups by means of Gliding Frequency Records.

4-1962 On the Use of Warble Tone and Random Noise for Acoustic Measurement Purposes.
Problems in Feedback Control of Narrow Band Random Noise.

1-1963 Miniature Pressure Microphones.
Methods of Checking the RMS Properties of RMS Instruments.

2-1963 Quality Control by Noise Analysis.
A. F. Nonlinear Distortion Measurement by Wide Band Noise.

3-1963 Effects of Spectrum Non-linearities upon the Peak Distribution of Random Signals.

4-1963 Non-linear Amplitude Distortion in Vibrating Systems.

1-1964 Statistical Analysis of Sound Levels.

2-1964 Design and Use of a small Noise Test Chamber.
Sweep Random Vibration.

3-1964 Random Vibration of some Non-Linear Systems.

4-1964 The Accuracy of Condenser Michophone Calibration Methods. Part I.

1-1965 The Accuracy of Condenser Microphone Calibration Methods. Part II.

# TECHNICAL REVIEW

No. 2 – 1965

# Contents



K. LARSEN & SØN - LYNGBY

# Direct Digital Computing of Acoustical Data

by

*G. Marup Jensen*

*L. Lindén* and *R. Lundin*

ASEA, Västerås, Sweden

## ABSTRACT

A modern spectrograph makes it possible to gain detailed knowledge of noise within a very short time. However, the need for averaging the results of several measuring points, as well as the work involved with corrections for background noise and room effect, make more detailed analysis expensive when it has to be performed by manual methods. In order to reduce these costs and also to accelerate the data processing, a new system for direct computing of acoustical data has been developed. This system comprises a potentiometer connected to the level recorder, a set of potentiometers for correcting the position of the spectrometer amplifiers, a unit composed of an integrator and a digital voltmeter and, finally, a calculating machine with a tape puncher. The data computing is programmed for making background noise and room-effect corrections, as well as for calculating average pressure and power levels in third-octave as well as octave bands. The calculation time for a series of eight measuring points with a Facit EDB computer is two minutes, but this can be reduced with more rapid machines such as the GE 625 to below one second. It is believed that the reduction of costs resulting from the application of this new method can allow a more thorough investigation of acoustical problems with the important object of reducing the noise exposure for human beings.

## SOMMAIRE

Un spectrographe moderne permet d'acquérir en un temps très court une connaissance détaillée des bruits. Cependant la nécessité de faire la moyenne des résultats de mesure en différents points, de même que le travail que représente l'apport de corrections pour tenir compte de la présence du bruit de fond et de l'effet de salle, rendent coûteuse une analyse plus détaillée, si elle doit être opérée selon les méthodes manuelles. En vue de réduire ces frais et également d'accélérer le traitement des informations, un nouveau système de calcul direct des données acoustiques a été mis au point. Ce système comprend un potentiomètre connecté à l'enregistreur de niveau, un jeu de potentiomètres pour corriger la position des amplificateurs de spectromètre, un élément composé d'un intégrateur et d'un voltmètre digital et, finalement une machine à calculer avec une perforatrice de bande.

Le traitement des données est programmé pour effectuer les corrections de bruit de fond et d'effet de salle, comme pour calculer le niveau moyen de pression et de puissance tant dans des bandes d'un tiers d'octave que d'une octave.

Le temps nécessaire avec un calculateur Facit EDB pour le calcul d'une série de 8 points de mesure est de 2 minutes. Il peut être réduit par l'emploi de machines plus rapides, telle la GE 625 pour laquelle le temps demandé est inférieur à 1 seconde.

La réduction des frais résultant du recours à cette nouvelle méthode permettra, croit-on, une étude plus poussée des problèmes acoustiques en vue de réduire l'exposition aux bruits des êtres humains.

## ZUSAMMENFASSUNG

Mit modernen Tonfrequenz-Spektrographen können Geräusche schnell und zuverlässig analysiert werden. Ist jedoch eine Mittelwertbildung mehrerer Meßpunkte nötig oder soll der Einfluß des Meßraumes oder des Störpegels bei der Analyse berücksichtigt werden, so ist die Auswertung relativ zeitraubend und damit teuer. Zur schnelleren Erfassung der Meßwerte kann eine Datenverarbeitungsanlage eingesetzt werden, sofern diese mit geeigneten digitalen Informationen gespeist wird. Ein neues System zur direkten Verarbeitung akustischer Meßwerte wurde entwickelt und wird beschrieben. Das System enthält ein mit dem Pegelschreiber gekoppeltes Potentiometer, welches eine dem aufgezeichneten Pegel analoge Gleichspannung abgibt. Eine weitere Potentiometeranordnung gestattet es, Anfangs- und Endwert der Analogspannung so einzustellen, daß diese dem Meßbereich des Spektrometers entspricht. Die Analogspannung wird integriert und über ein Digitalvoltmeter dem Rechner zugeführt, der mit einem Streifenlocher verbunden ist. Die Datenverarbeitungsanlage kann für verschiedene Aufgaben programmiert werden, z. B. für die Berechnung des mittleren Druck- oder Leistungspegels in Terz- oder Oktavbändern. Die Eigenschaften des Meßraumes und der Einfluß des Störpegels auf die Messung können beim Programmieren berücksichtigt werden. Ein Facit EDB-Rechner benötigt für die Auswertung von acht Meßpunkten zwei Minuten. Schnellere Maschinen, wie z. B. die GE 625, brauchen dazu weniger als eine Sekunde. Es ist zu erwarten, daß durch dieses kostensparende Verfahren eine gründlichere Untersuchung vieler akustischer Probleme ermöglicht wird, mit dem Ziel, die für den Menschen lästigen Geräusche zu vermindern.


## Introduction.

There is a growing need for noise measurements in all fields of modern society. In most cases it is not sufficient merely to know the sound level, for instance in dB(A). This concerns both architectural acoustics, normal acoustical planning in industry and military problems in connection with, for instance, submarines. In order to obtain a sufficiently exact measure of the acoustical properties, it is normally necessary to perform measurements at several measuring points. Although an automatic spectrum recorder, such as the B & K 3315, facilitates the collecting of detailed information of the noise in third-octave bands in a short time, the calculation of average levels as well as the correction for room effect and background noise are very laborious, time-consuming and expensive. It is therefore often necessary both from an economic and a practical point of view to limit the measurements to octave bands, where the use of third-octave bands would have been most desirable.

This concerns, for instance, noise sources such as mechanical gears and electrical motors which have a tendency to emit discrete tones. In such cases it is desired to measure in relatively narrow bands, e.g., third-octave bands. In a complete manufacturing programme, however, it is only a certain proportion of the products that emit noise of this type. When manual methods are applied for the calculations, it is therefore not economic to use third-octave band analysis in general. This makes the use of octave band analysis a standard method, and when more detailed information is needed, this must be obtained from additional tests or from taped records of the noise.

A device which enables the transfer of acoustical data directly to a punched tape or punched card, however, would make it possible to perform calcula-

tions on a digital computer. This means that measurements could then always be made in third octaves, and the computer would present the result of the measurements both as octave and third-octave data. The octave-band data could thus be utilized when these suffice, while the third octaves would always be available for studies if required.
A manufacturer supplying machines and equipment for almost all purposes, ranging from small motors for household appliances to heavy machinery for industry and power plants, has to be able to furnish adequate acoustical data on the products. In addition, development work as well as the need for collecting sufficient information to give guarantees entail much work and time. This makes a system for direct recording of acoustical data very desirable. Unfortunately, such a system has not been commercially available up to now. ASEA, however, has developed a very reliable digital voltmeter*), which forms a vital part of such a system. It was therefore decided to design a system which would satisfy the need for analogue-digital conversion and for

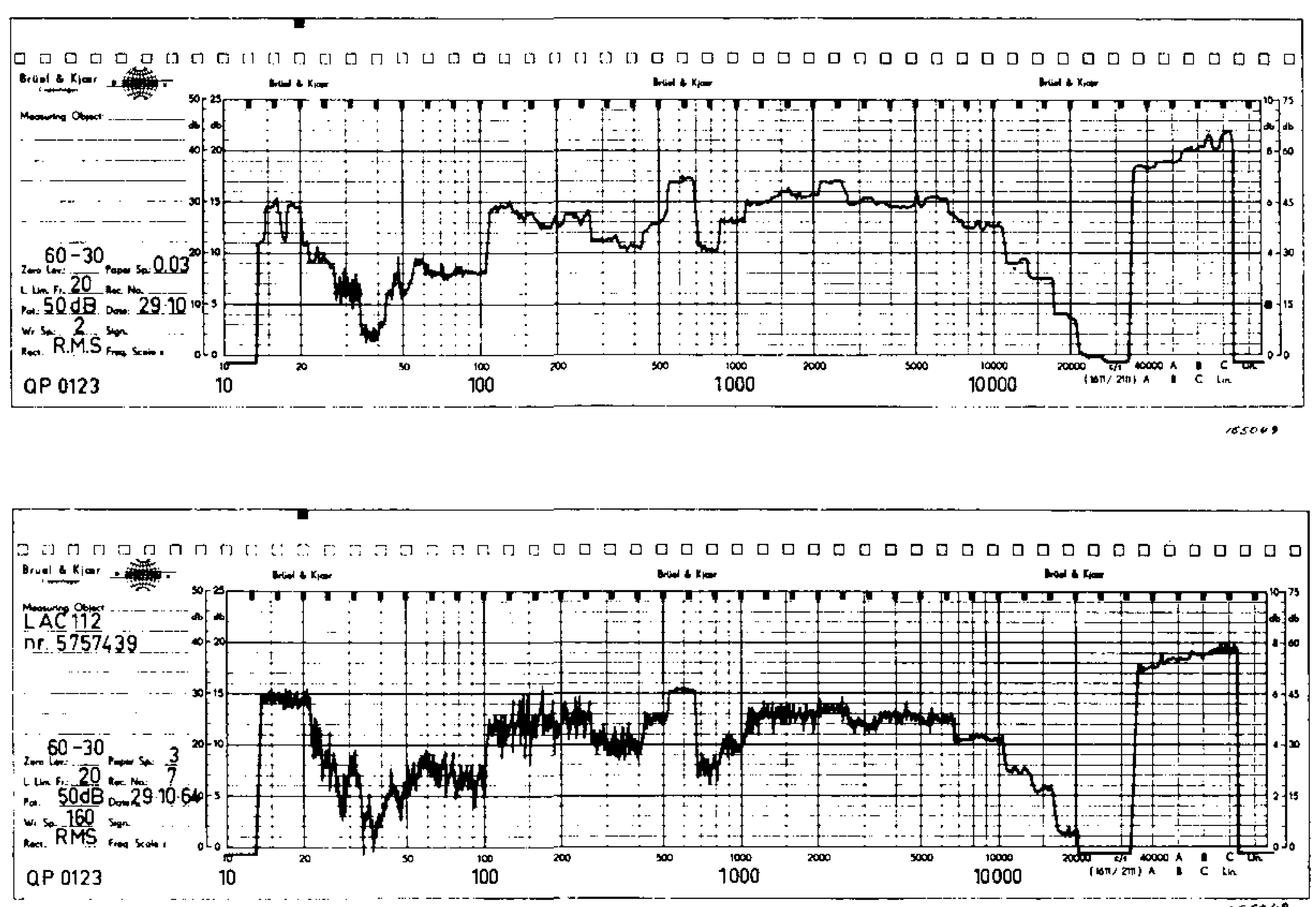



*Fig. 1. Spectrograms of the airborne noise from a small DC motor running at full load. The upper curve has been recorded with a writing speed of 2 mm/s, a paper speed of o.03 mm/s and a lower limiting frequency of 20 Hz, while the corresponding data for the lower curve are 160 mm/s, 3 mm/s and 20 Hz. In the upper curve it is very easy to determine the average level for each band. This is more difficult in the lower curve, but, on the other hand, the study of the fluctuating character can give very valuable information about the origin of the noise.*

the transfer of the information to punched tape (or cards). This system has been used for some time and has aroused great interest among people who are making large-scale acoustical measurements. The system is therefore now

*) ASEA Journal 55 (1963): 5-6, p. 83.

being marketed, and it is the purpose of this article to explain the principles underlying the choice of system and to describe the system and its applications.

Fig. 1 shows two third-octave band spectrograms for a small DC motor. The spectrograms were recorded with different writing speeds. In the upper curve, which was recorded with a very slow writing speed, the level shows comparatively small fluctuations. It is thus very easy to read off the level in most of the filter bands. In the lower curve, which was recorded with a high writing speed, the level fluctuates heavily, especially at low frequencies. A marked difference in the character of the noise can be seen in the various frequency bands. At low frequencies the noise has a greatly fluctuating and random character, which is typical of aerodynamic noise. In the 630-Hz band fluctuations are considerably smaller. This noise is a typical electromagnetic noise, which in this case consists of a discrete tone. Finally, the noise in the medium- and high-frequency bands shows fluctuations of a more random nature, a type of noise which is typical of ball bearings, and brush rattling. In some cases a marked difference in character of these two types of noise can be observed.

As is obvious from this example, a high writing speed enables a lot of valuable information to be obtained already during the measurement itself. This may form the basis for determining the origin of the noise. When a high writing speed is used it is therefore possible already at this stage to determine whether additional measurements are needed and consequently to arrange such measurements directly after the original ones. In this way, it will often be possible to dispense with the trouble of setting up the machine again. On the other hand, it is more difficult to determine the "average" band levels from records made with a high writing speed.

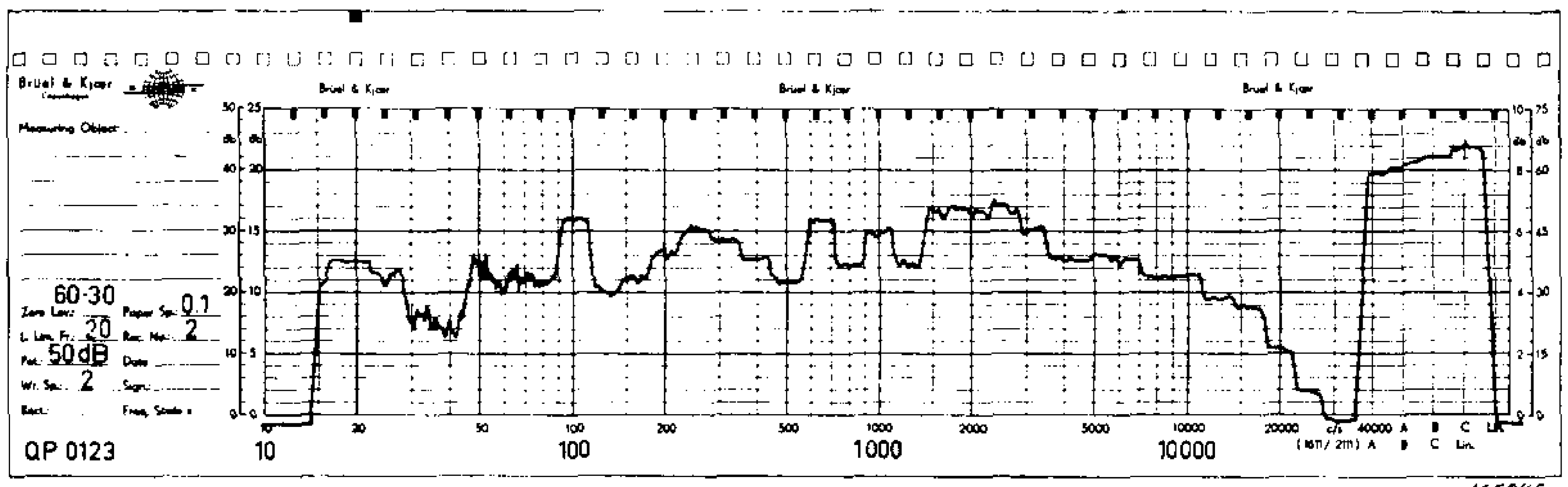
In order to determine the level it has become common practice when reading spectrograms having a fluctuating character to take the average of the dB-level as shown for the 250 Hz band in Fig. 1. This is not correct when the fluctuations are large, but will in most cases give a reasonably good approximation for practical purposes*).

From some preliminary tests it was also found that the "average" level was very little influenced by the writing speed, and this was verified by some further measurements reported later in this article.

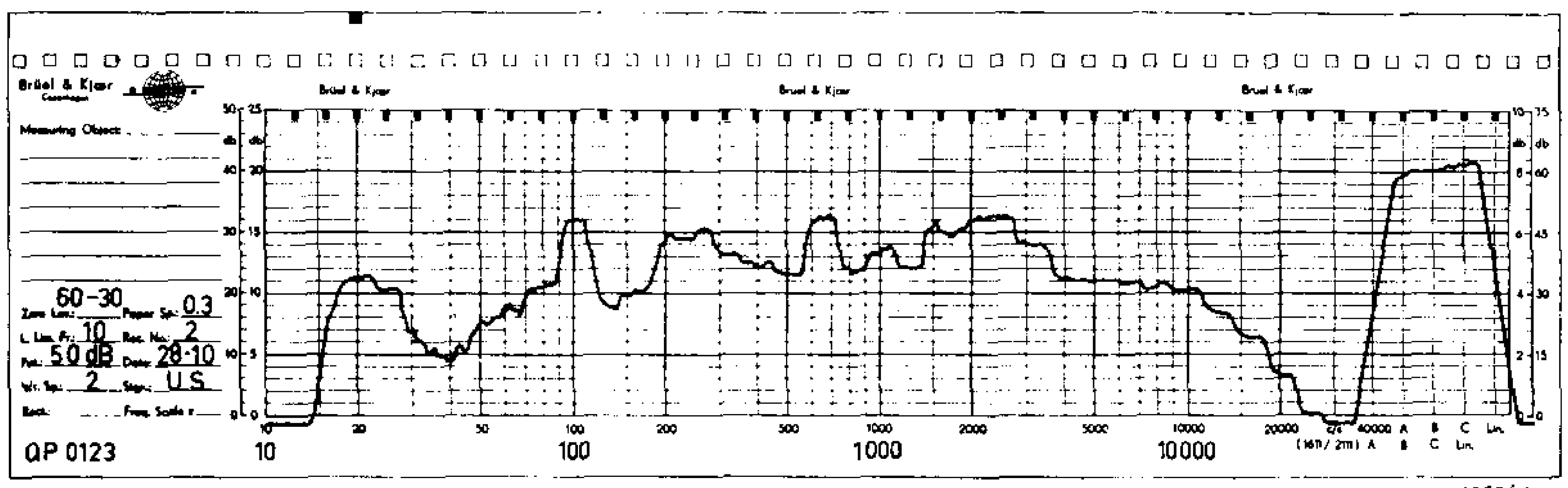
It should be borne in mind, however, that the recording time of the curves shown in Fig. 1 is approximately 8300 and 83 seconds, respectively. Naturally, the longer recording times cannot be accepted for routine measurements and it can be seen from the examples shown in Fig. 2 that with a low writing speed the recording time cannot be reduced to an acceptable value without recording erroneous levels.

---

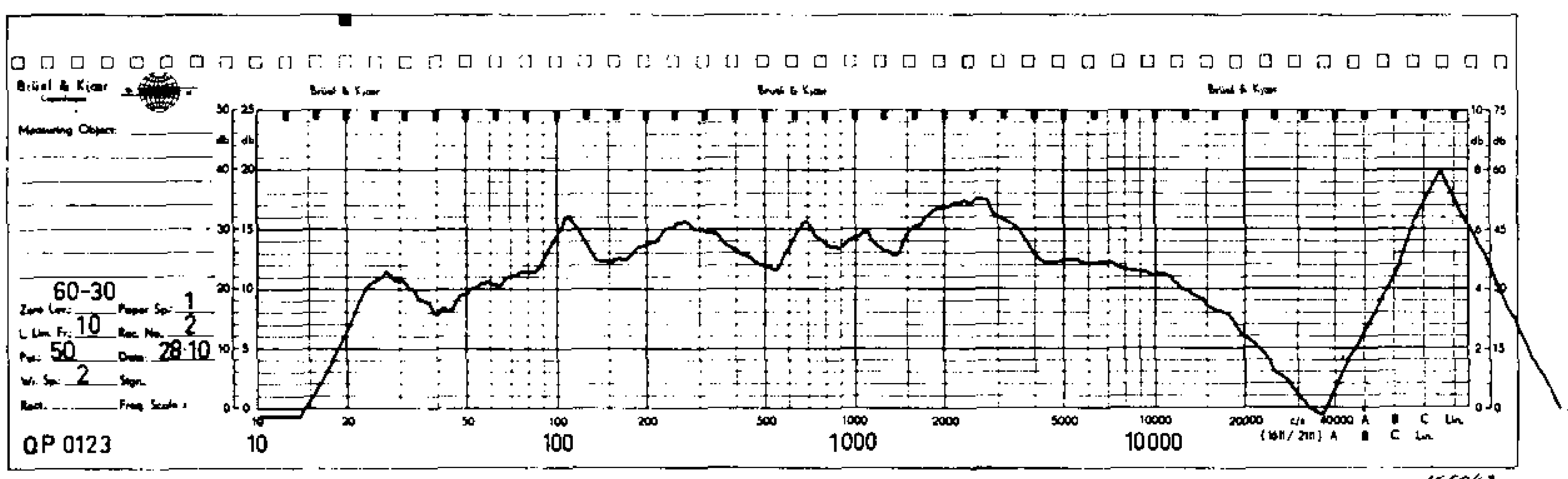
*) To obtain a true average the averaging should be made on a pressure or intensity basis. This should of course be possible but would, on the other hand, presuppose strict rules for the selection of writing speed.




a) Paper Speed: 0.1 mm/sec




b) Paper Speed: 0.3 mm/sec




c) Paper Speed: 1 mm/sec

*Fig. 2. Spectrograms for the same motor as in Fig. 1 recorded with the low writing speed and three different paper speeds, using various recording times. It can be seen from the two lower spectrograms that the correct level is not obtained for all filters during the time they are connected.*

As should be clear from the discussion above, many advantages can be gained by maintaining a high writing speed, and it was therefore decided to design the system in such a way that a high writing speed could be used.

In order to obtain an "average", a linear potentiometer is mechanically coupled to the moving system of the recorder. A direct voltage is applied to the terminals of the potentiometer, and the signal from the sliding contact is integrated. The arithmetic average can then be determined by dividing the integrated signal with the measuring time. Since the pen stylus on the present design of the recorder needs some time to reach the correct level after a filter change, this averaging system must be combined with a time delay as shown in Fig. 3. The output from the integrator will thus have the appearance shown in Fig. 4.

It has been assumed above that a whole set comprising a spectrometer and a level recorder should be used for the measurements. However, the first approach examined was to connect the analogue-digital converter directly to the output of the spectrometer. Apart from the disadvantage of not being able to obtain written information about the noise of the test object during the measurement, it was found that this led to the following difficulties:

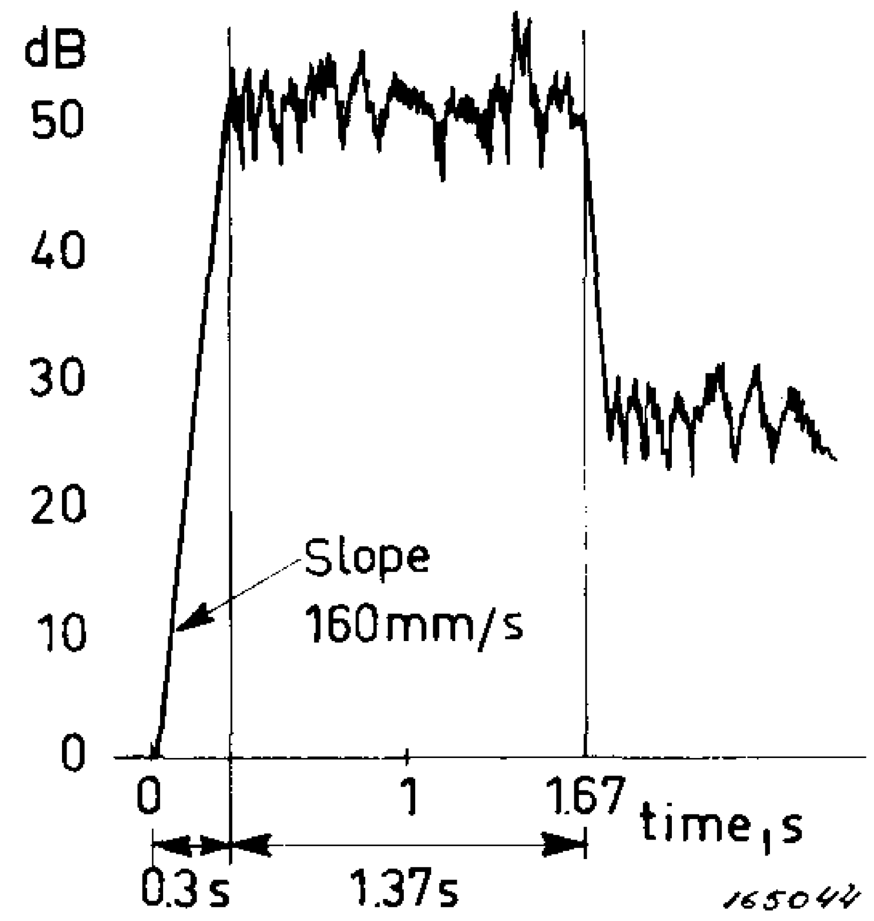



*Fig. 3. Record of the noise in a band with maximum dynamic range, a writing speed of 160 mm/s and a paper speed of 3 mm/s. It is found that the time elapsing before the actual level is reached may cause a delay of o.3 seconds.*

Using the voltage from the output of the spectrometer would mean that an r.m.s. rectifier having a dynamic range of 50 dB should have to be designed, which is a very difficult problem. (The built-in rectifier can only cover a maximum level range of 20 dB. A larger dynamic range is not necessary when the meter is utilized for reading, because the amplification can be altered in steps of tens of dB).

When the decision had to be made, no logarithmic digital voltmeter was available on the market. On the other hand, the read-out of a linear digital voltmeter would not give the sound pressure level in decibels, but in a quantity proportional to the sound pressure.

In addition to the points mentioned above, it was the intention to design the system so that the correct absolute level of both sound and vibration referred to the normal zero levels could be obtained. The system should thus include the following components in addition to the normal equipment for automatic recording of frequency spectra (B & K Type 3315):

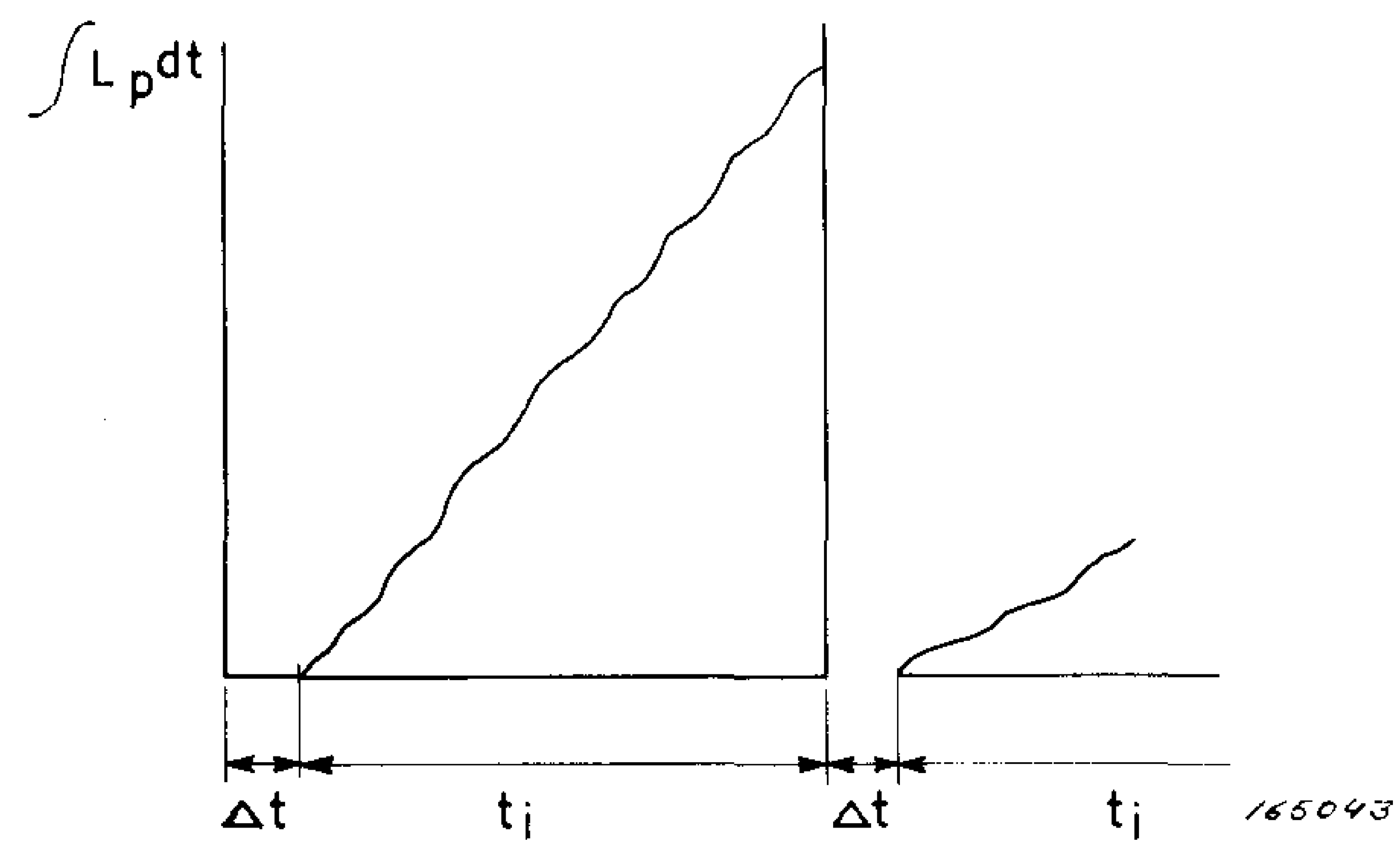



*Fig. 4. Appearance of the integrated output voltage. The integration starts after the time delay $\Delta t$ = o.3 s and the integration time thus becomes $t_i$ = 1.37 s. The average is calculated as* $\frac{1}{t_i}\int L_p\,dt$.

a) A linear potentiometer mechanically coupled to the recorder pen.
b) A set of potentiometers giving a voltage corresponding to the position of the "Meter Range" and "Range Multiplier" on the spectrometer.
c) An integrator with time delay of 0.3 seconds.
d) A linear digital voltmeter.
e) A calculating machine.
f) A tape puncher.
g) A potentiometer which can be used for adding tens of dB in the case of vibration measurements.

The reason for introducing the potentiometer g) is that the zero reference level for vibration velocity in many countries is $5 \times 10^{-8}$ m/s (r.m.s.). With this reference level the velocity level corresponding to the peak acceleration of gravity (1 g = 9.81 m/s²) at 50 Hz is

$$L_v = 20 \log \left( \frac{9.81}{\sqrt{2} \times \pi \times 2 \times 50 \times 5 \times 10^{-8}} \right) = 113 \text{ dB re } 5 \times 10^{-8} \text{ m/s}$$

When, for instance, calibrating a B & K Accelerometer Type 4328 with the preamplifier Type 1606 with the "Sensitivity Adjustment" potentiometer in position 0, the attenuation of the integrator will cause a read-out level of 63 dB at the "3 c/s" position and of 83 dB at the "30 c/s" position. In order to make possible a read-out of the desired absolute level 113 dB it is thus necessary to add 50 or 30 dB to the read-out of the meter, and this can be done with the "Additional Level" potentiometer.

**Description of the System.**

The complete diagram for the system is shown in Fig. 5. The integrator, digital voltmeter and DC supply for the potentiometer are all accommodated in a single unit. This unit supplies the potentiometer $P_1$ with a direct voltage.

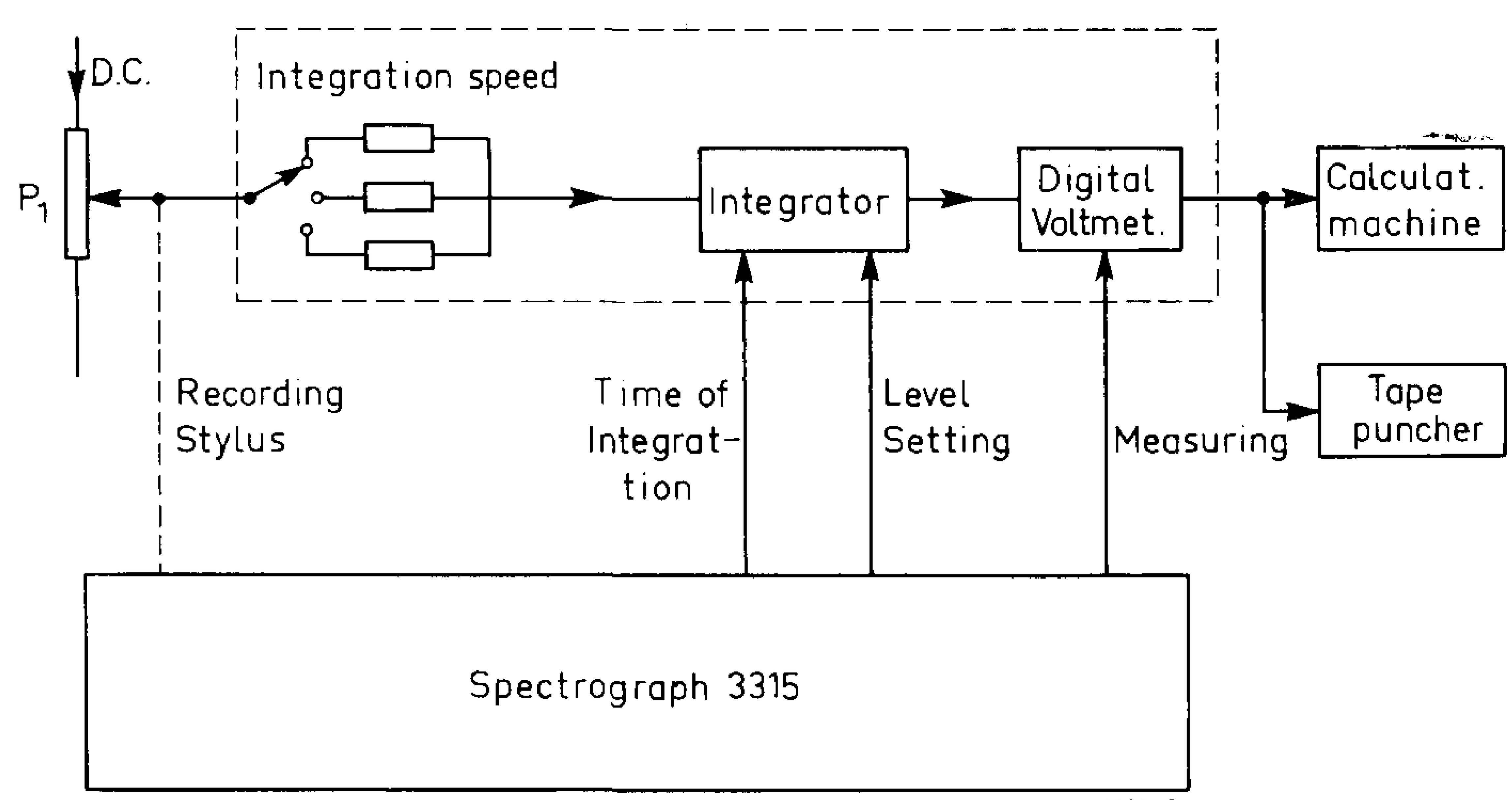
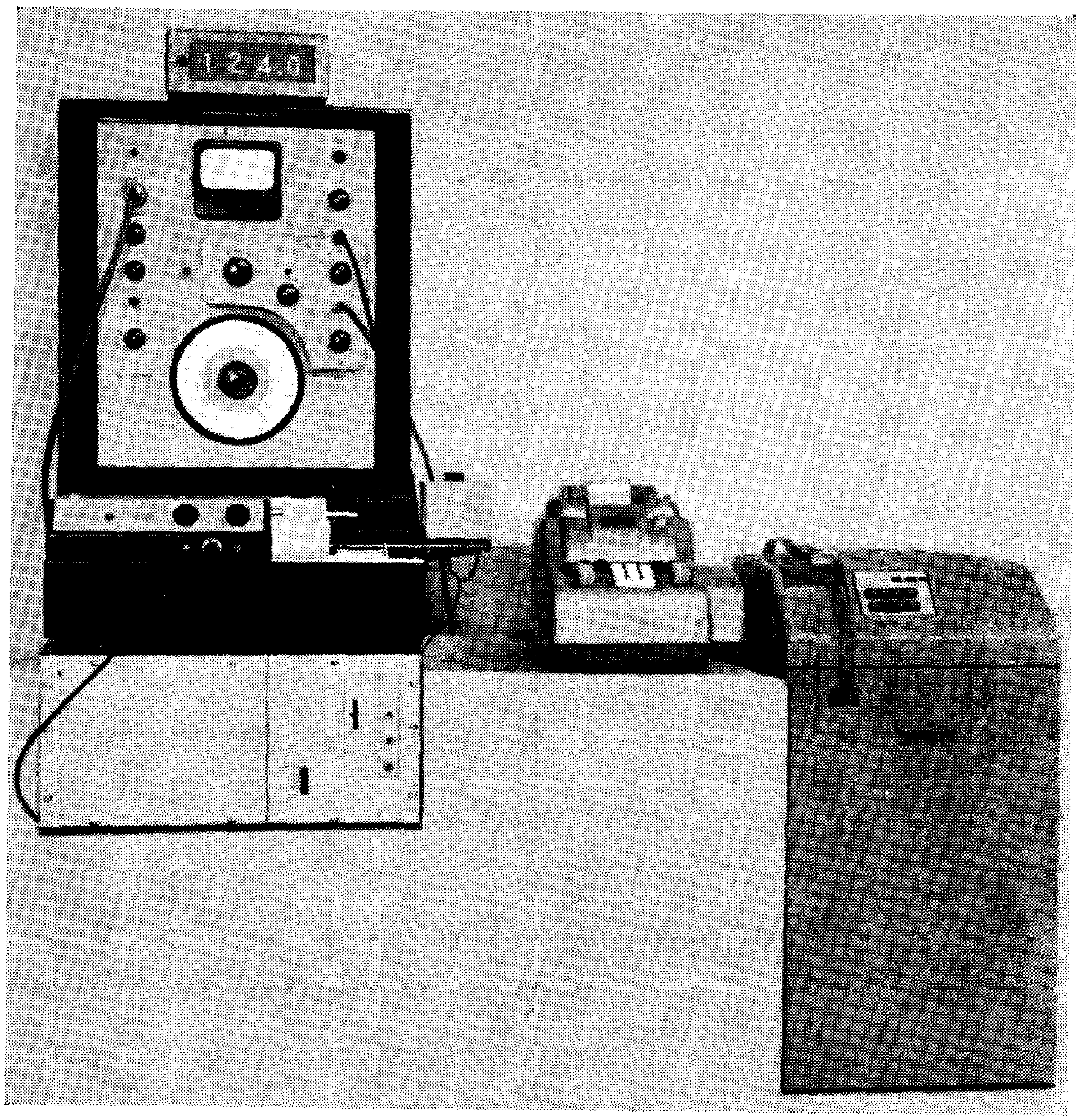



*Fig. 5. Block diagram of the complete system.*

The potentiometer is mechanically coupled to the moving coil of the level recorder. The voltage corresponding to the position of the sliding contact in this potentiometer is connected to the integrator input. The integrator is preset before each measurement to a voltage from three potentiometers, which are mechanically coupled to the "Meter Range", "Range Multiplier" and "Function Selector" of the spectrometer. A voltage from a fourth potentiometer marked "Additional Level" can be added to the preset voltage. This makes it possible to add tens of dB for vibration measurements. The total voltage is taken via the integrator to the digital voltmeter. The voltmeter is equipped with all facilities for direct connection to an Addo calculating machine and an Addo tape puncher.
A photo of the total set-up is shown in Fig. 6. The potentiometer is of the same type as that used in the level recorder*), the only difference being that




165091

*Fig. 6. Photograph of the complete set-up for acoustical data processing. To the left can be seen the spectrometer mounted on the analogue-digital converter unit, and to the right, the calculating machine and tape puncher.*

---

*) The reason for selecting this potentiometer was that a marketed potentiometer which was first tested failed after a few months of service and the B & K ZR 0021 was not yet available.

it has a linear distribution of resistance. The set of potentiometers used for giving a voltage corresponding to the position of the potentiometers of the spectrometer are, together with the potentiometer for "Additional Level", mounted on the front of the spectrometer. These potentiometers can also be incorporated in the spectrometer cabinet. The ASEA analogue-to-digital converter as well as the integrator and DC supply are placed in the unit visible below the spectrometer. All parts in this unit are mounted on standard 19″ modules, which can be inserted in a 19″ rack. This unit supplies the potentiometers with a stabilized direct voltage maintained within ± 0.2 % for ± 10 % mains variations. The integrator is a DC chopper amplifier with three different integrating times, i.e. 1.4, 4.2 and 14 seconds, corresponding to the paper speeds 3, 1 and 0.3 mm/s.

The digital voltmeter, which measures the level in tenths of a dB is fully transistorized with the most critical parts mounted in a temperature-stabilized oven. The digital voltmeter is of a very reliable design because it is made for industrial weighing equipment used in, for instance, steelworks. A reliable digital voltmeter is naturally of the utmost importance since otherwise the investment in a direct data converting system will be more or less wasted. The digital voltmeter is provided with all facilities for connection to an Addo calculating machine and an Addo programmed tape puncher. The control unit for the Addo calculating machine has, in the prototype system, a stepping motor, while the marketed system has a fully transistorized control unit.

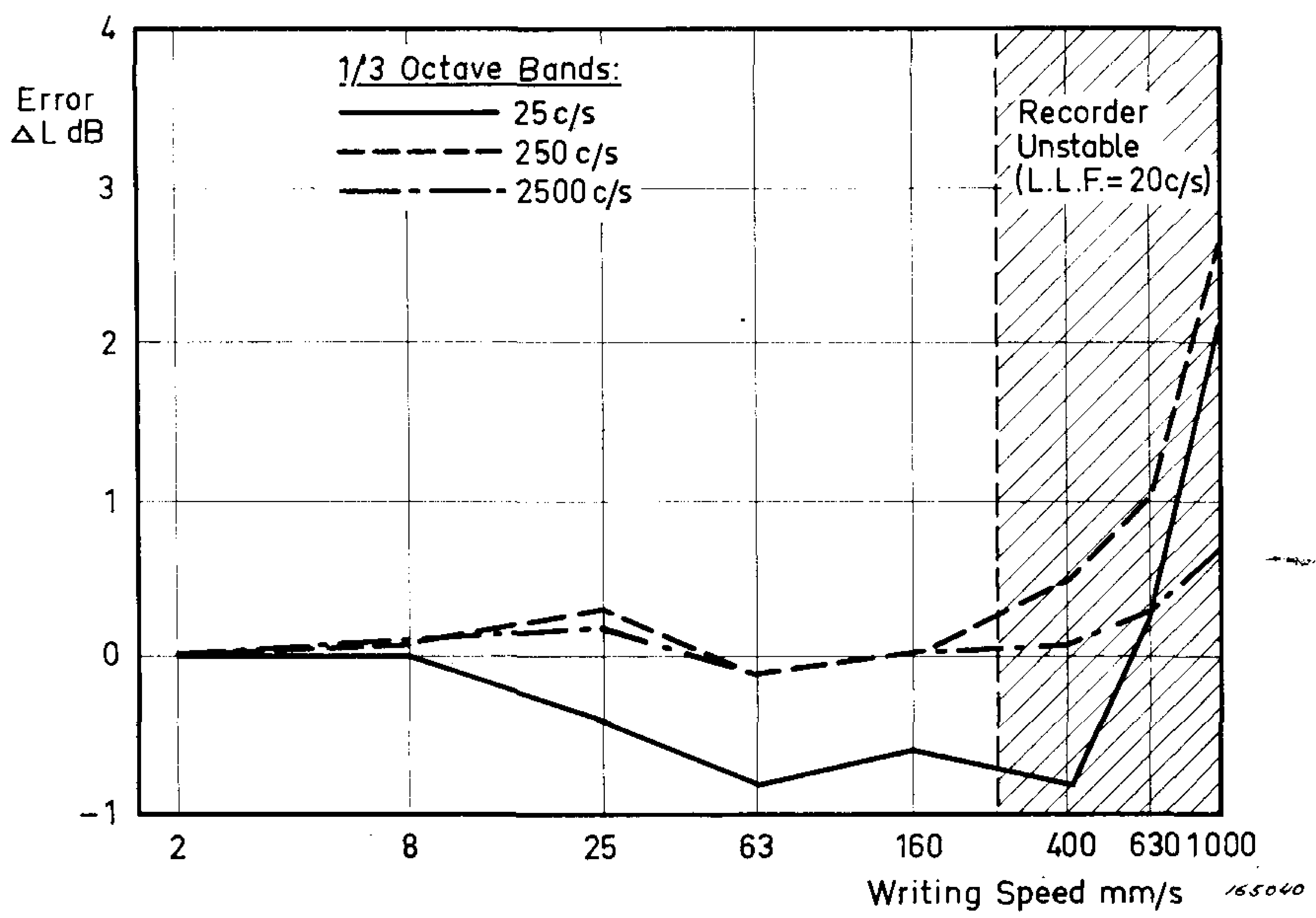



*Fig. 7. Curves showing the difference in average level estimated from measurements with different writing speeds and differently fluctuating signals (different bandwidths).*

**"Averaging" Accuracy.**

As mentioned earlier (page 6) some preliminary measurements showed that the "average" level was relatively little affected by the writing speed. This has been checked by applying a white noise signal from a B & K white noise generator to the input of the system and taking the average from twenty successive level determinations each measured with an integration time of 1.4 seconds. The measurements were performed for three different third-octave bands with midfrequencies of 25, 250 and 2500 Hz at different writing speeds, and the result is reported in Fig. 7. As may be seen from this figure the deviations are smaller than 1 dB in the stable range of operation of the recorder.

**Computer Programming.**

The computer programme as utilized at ASEA is written in Algol for a digital computer type Facit EDB.

The programme takes into account the following possibilities:

a) Individual correction for background noise and room effect in each measuring point, and indication of whether the difference between the sound pressure level of the object and the background noise level is less than 3 dB or between 3 and 10 dB.

b) Individual correction for the room effect at each point.

c) Conversion to integer dB (e.g., 31.5 becomes 32 dB, 31.4 becomes 31 dB).

d) Determination on an intensity basis of average levels in third-octave and octave bands at the measuring surface. Indication of the influence of the background noise (see a).

e) Calculation of the sound power level in third-octave and octave bands.

f) Calculation of the sound pressure level under free-field conditions at a radius of 3 m, hemispherical radiation (this type of noise specification has been proposed by the ISO TC 43/WG9 Working Group for noise measurements on electrical machines).

g) Calculation, by means of the ISO curves, of the sound level dB(A), dB(B), dB(C) and the total linear level for all measuring points and for the average levels in third-octave and octave bands.

h) For vibration measurements corrections similar to those mentioned above can be introduced. In addition a correction for attenuation is made when the "30 c/s" position is used.

i) The average levels for vibration measurements are calculated on a velocity basis.

All calculations are made in tenths of a dB and rounded off to integer dB for printing.

**Operation.**

When operating the digital converter set, the spectrograph is first calibrated in the normal way. The level of the recorder is then set by means of a pistonphone so that a relative level of 44.0 dB on the graph corresponds to 124.0 dB. After this the instructions for the digital computer are punched by means of the calculating machine and tape puncher. The following instructions are given:

a) Serial number (nn).
b) Measuring radius.
c) Instructions for background noise (whether a correction is to be made with the same background noise in all measuring points, or the background correction is to be made different for different points).
d) Instructions for room effect (as under c, common correction or individual correction).

| | |
|---|---|
| 19 | Serial number of measurement |
| 1.00 | Radius of hypothetical hemisphere, cm |
| 2 | Instruction that background noise-corrections shall be made in each point |
| 1 | Instruction that room-effect corrections are identical in all measuring points |
| 197.01 | *Identification for background measurement at point 1* |
| 1.50 … 70 | 34 frequency band levels for midfrequencies 10 to 20000 Hz |
| 197.02 | |
| 197.08 | |
| 99.999.999.99 | End of background noise data |
| 195.01 | Identification for room-effect corrections at point 1 |
| 80− … 10− | 34 frequency band corrections |
| 99.999.999.99 | End of room-effect corrections |
| 193.01 | Identification for noise-measurement at point 1 |
| 33 … 35 | 34 frequency band levels |
| 193.02 | |
| 193.08 | |
| 99.999.999.99 | End of noise measurement |
| 20 | Serial number |

165039

*Fig. 8. Example of a set of instructions punched onto the tape for data computing.*

After these data have been punched, the background noise is measured. Since all the potentiometers of the instrument are coupled to the system potentiometers, it is only necessary to adjust the amplifiers of the spectrometer before the measurements, by setting the spectrometer to "Linear" and adjusting the level until the deflection on the meter lies between 10 and 20 dB. After having switched back to "1/3 octave", the identification for the background noise at point 1 (nn 701) is punched and the measurement is made at "Single Sweep". When all the background measurements have been completed, the identification for room-effect correction at point 1 is punched by "nn 501", followed by the correction levels at each frequency. It is also possible to use a set of

Meas. Series: --------------------

| Frequency Hz (c/s) | Sound Pressure Level in dB re $2 \times 10^{-5}$ N/m$^2$ — Measuring Points 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | SPL on Meas. surface r=1m dB re $2\times10^{-5}$ N/m$^2$ 1/3oct | octave | Power Level dB re. 1 pW 1/3oct | octave | SPL at 3m radius dB re $2\times10^{-5}$ N/m$^2$ 1/3oct | octave |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 16 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | | | | | 25 | | 33 | | 15 | |
| 20 | * 27 | * 30 | * 34 | 39 | 37 | * 36 | 39 | + 23 | | | | | + 35 | | 43 | | 25 | |
| 25 | + 28 | * 31 | * 34 | 39 | * 38 | * 36 | * 36 | + 25 | | | | | * 35 | | 43 | | 25 | |
| 31.5 | 43 | 41 | * 27 | 33 | 36 | 36 | 34 | 39 | | | | | 38 | + 40 | 46 | 48 | 28 | 30 |
| 40 | 26 | 26 | 25 | 25 | 26 | 26 | 25 | 25 | | | | | 26 | | 33 | | 15 | |
| 50 | + 29 | * 32 | * 36 | 41 | + 28 | + 29 | * 32 | * 39 | | | | | * 35 | | 43 | | 25 | |
| 63 | + 49 | + 45 | + 49 | + 48 | + 46 | + 48 | + 47 | + 47 | | | | | * 48 | * 49 | 56 | 57 | 38 | 39 |
| 80 | * 39 | * 38 | 49 | 43 | * 39 | * 38 | * 38 | * 41 | | | | | * 41 | | 49 | | 31 | |
| 100 | 39 | 44 | 39 | 38 | 42 | 42 | 38 | 44 | | | | | 41 | | 49 | | 31 | |
| 125 | 45 | 44 | 40 | 40 | 44 | 41 | 45 | 41 | | | | | 43 | 51 | 51 | 59 | 33 | 41 |
| 160 | 52 | 48 | 49 | 45 | 50 | 52 | 50 | 47 | | | | | 49 | | 57 | | 39 | |
| 200 | * 48 | * 48 | * 48 | + 47 | * 48 | + 46 | * 51 | + 47 | | | | | * 48 | | 56 | | 38 | |
| 250 | 48 | 47 | 51 | 52 | 51 | 53 | 49 | 49 | | | | | 50 | + 55 | 58 | 63 | 40 | 45 |
| 315 | 53 | 50 | 47 | 52 | 53 | 55 | 51 | 51 | | | | | 52 | | 60 | | 42 | |
| 400 | . 56 | 51 | 52 | 53 | 54 | 56 | 54 | 52 | | | | | 54 | | 62 | | 44 | |
| 500 | 51 | 51 | 52 | 51 | 53 | 51 | 53 | 51 | | | | | 52 | 58 | 60 | 66 | 42 | 48 |
| 630 | 58 | 55 | 55 | 53 | 54 | 53 | 54 | 51 | | | | | 55 | | 63 | | 45 | |
| 800 | 57 | 55 | 56 | 51 | 50 | 51 | 55 | 52 | | | | | 54 | | 62 | | 44 | |
| 1000 | 52 | 53 | 51 | 53 | 51 | 49 | 50 | 52 | | | | | 51 | 58 | 59 | 66 | 41 | 48 |
| 1250 | 50 | 53 | 54 | 55 | 54 | 52 | 51 | 52 | | | | | 53 | | 61 | | 43 | |
| 1600 | 56 | 54 | 55 | 54 | 56 | 54 | 52 | 53 | | | | | 54 | | 62 | | 44 | |
| 2000 | 59 | 63 | 63 | 57 | 56 | 57 | 55 | 52 | | | | | 59 | 61 | 67 | 69 | 49 | 51 |
| 2500 | 54 | 56 | 58 | 53 | 52 | 52 | 53 | 51 | | | | | 54 | | 62 | | 44 | |
| 3150 | 54 | 52 | 52 | 52 | 53 | 51 | 51 | 51 | | | | | 52 | | 60 | | 42 | |
| 4000 | 55 | 56 | 57 | 54 | 55 | 52 | 57 | 54 | | | | | 55 | 58 | 63 | 66 | 45 | 48 |
| 5000 | 51 | 52 | 52 | 51 | 51 | 50 | 52 | 50 | | | | | 51 | | 59 | | 41 | |
| 6300 | 48 | 49 | 49 | 49 | 48 | 49 | 50 | 48 | | | | | 49 | | 57 | | 39 | |
| 8000 | 47 | 49 | 50 | 49 | 48 | 50 | 52 | 50 | | | | | 50 | 53 | 57 | 61 | 39 | 43 |
| 10000 | 41 | 44 | 43 | 44 | 41 | 42 | 46 | 43 | | | | | 43 | | 51 | | 33 | |
| 12500 | 36 | 39 | 40 | 38 | 35 | 36 | 41 | 37 | | | | | 38 | | 46 | | 28 | |
| 16000 | 34 | 36 | 36 | 35 | 33 | 32 | 37 | 34 | | | | | 35 | 41 | 43 | 49 | 25 | 31 |
| 20000 | * 34 | 32 | 34 | 32 | 33 | 32 | 36 | 32 | | | | | 34 | | 42 | | 24 | |
| A | 66 | 68 | 68 | 65 | 65 | 64 | 65 | 63 | | | | | 66 | 66 | 74 | 74 | 56 | 56 |
| B | 66 | 67 | 67 | 65 | 65 | 64 | 65 | 63 | | | | | 65 | 65 | 73 | 73 | 55 | 55 |
| C | 67 | 67 | 67 | 65 | 65 | 65 | 65 | 64 | | | | | 66 | + 66 | 74 | 74 | 56 | 56 |
| Lin. | 67 | 67 | 68 | 65 | 65 | 65 | 65 | 64 | | | | | 66 | + 66 | 74 | 74 | 56 | 56 |

* means that the background-noise deviates ≦ 3 dB
\+ " " " " " " > 3 dB but ≦ 10 dB

165050

*Fig. 9. Example of processed data.*

corrections for the actual room, which can be stored in the memory of the computer.

Finally, after the appropriate amplification of the spectrometer has been selected, the noise measurement can be started once the identification nn301 has been punched. This procedure is carried out for all the measuring points.

An example of a set of instructions is shown in Fig. 8.

**Presentation of Results.**

The results of the calculations are printed out on a sheet of paper (A4) as shown in Fig. 9. The equivalent free-field sound pressure levels of each measuring point are given to the left in the table and the pressure and power levels in third-octaves and octaves to the right. The computing of this sheet takes approximately two minutes with the present Facit EDB computer. This time can be reduced to less than one second with more rapid computers such as Ge 625. Compared with manual methods the digital conversion system brings about a tremendous reduction in time between the execution of the measurements and the instant when the results can be studied. Naturally, this leads to a marked decrease in the costs for noise measurements. More and better information can therefore be obtained, and this is assumed to be of great value in the important task of reducing noise exposure for human beings.

# The Use of Comparison Bridges in Coil Testing

by

*J. M. Walters,* M.E.

Technico Limited, Dublin, Ireland

**ABSTRACT**

Comparison bridges are very useful in the production testing of coils and transformers as they provide rapid direct indication. By the use of simple auxiliary devices the scope of such bridges may be widened to include turns count and transformer ratio tests. The construction and application of such devices is described.

**SOMMAIRE**

Les ponts de comparaison sont très utiles pour le contrôle à la production de bobines et de transformateurs car ils fournissent une indication directe très rapide.
Par l'emploi d'éléments auxiliaires simples, le champ d'application de ces ponts peut être étendu et inclure la détermination du nombre de spires et les contrôles du rapport de transformation. On décrit la construction et l'emploi de tels dispositifs.

**ZUSAMMENFASSUNG**

Toleranzmeßbrücken sind wegen ihrer schnellen und direkten Anzeige für die Produktionskontrolle von Transformatoren und Spulen sehr nützlich. Durch Hinzufügen einfacher Hilfseinrichtungen können diese Brücken auch zur Messung der Windungszahl und des Übersetzungsverhältnisses von Transformatoren eingesetzt werden. Der Aufbau und die Anwendung solcher Einrichtungen wird beschrieben.

**General.**

Coils and transformers making use of ferrite, iron dust or laminated cores are extensively used in communication equipment. The production of such components usually necessitates testing following each operation or assembly stage in order that faulty units be rejected as soon as possible. Thus an inductor is normally tested for correct number of turns as soon as it is wound. It is then fitted with its core and checked for inductance and similarly transformers are given appropriate tests.

Many of these tests involve the use of bridges. For speed and ease of operation under production conditions comparison bridges are much more convenient than those of what may be called traditional types. Such comparison bridges are normally of the design shown in simplified form in Fig. 1. The amplifier has a high input impedance so that it does not load the bridge arms appreciably and its gain is stabilized by feed back. In conjunction with the use of a phase-sensitive detector this allows the meter to be calibrated directly in percentage difference between TEST and STANDARD impedances.

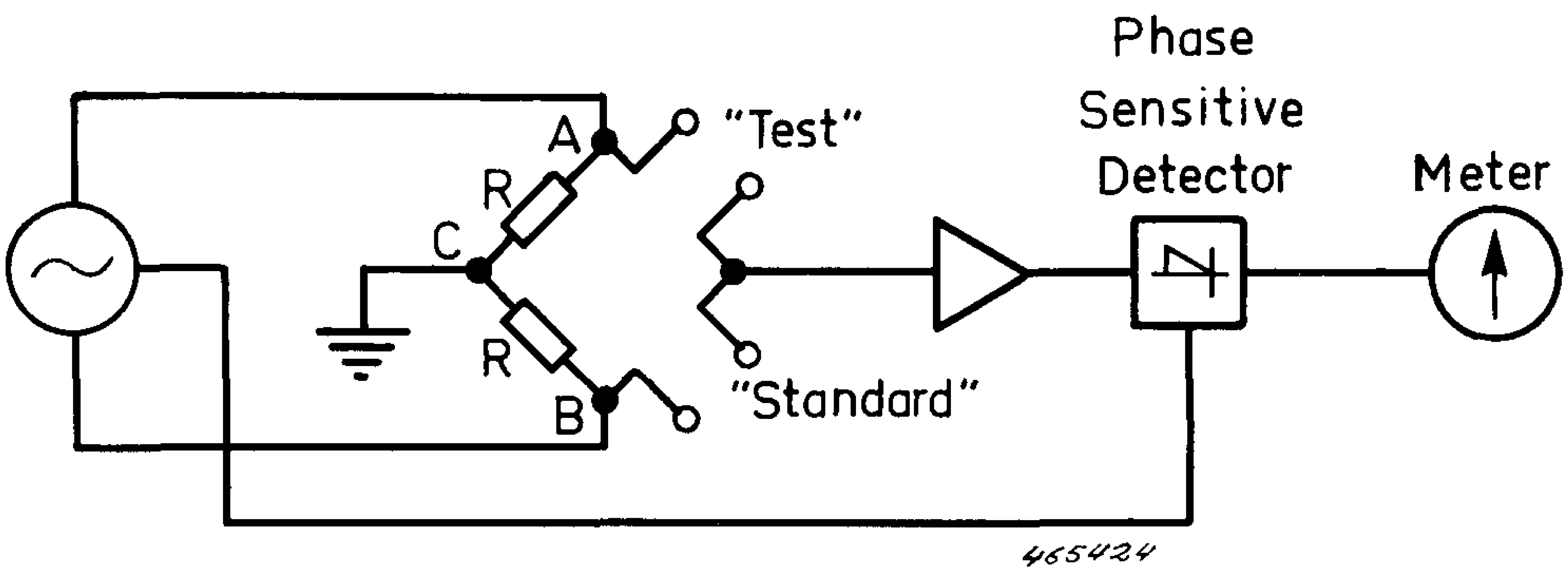



*Fig. 1.*

Variation of amplifier gain allows full scale meter deflection to be set to represent a required percentage difference, commonly from 5 % to 100 %. For the highest accuracy, impedances compared should have equal phase angles; if not an error in indicated difference is caused as is made clear in the vector diagram of Fig. 2. Here the voltage drops in TEST and STANDARD are represented by AD and DB respectively while X is a measure of the difference in phase angle. The indicated ratio is AX/XB while the true ratio is AD/DB. The resultant error is shown in Fig. 3 for phase angle differences up to 30° and ratio's not greater than 2 : 1. As can be seen the error is not great provided the phase angles are approximately equal.

*Example:*

If a measuring range — 50 to + 100 deviation is in use, and a 30° phase-angle difference is present when a reading of + 100 % (Ratio 2 : 1) is obtained, then the real deviation is 104.7 %.

At a reading of 20 % (Ratio 1.2 : 1) and still 30° phaseangle the real deviation is 21.4 %, see Fig. 3.

**Inductance Checks.**

The most direct method is to have available a standard inductor for each type in production. Alternatively where this would mean an excessive number of standards a different approach may be adopted by the use of special

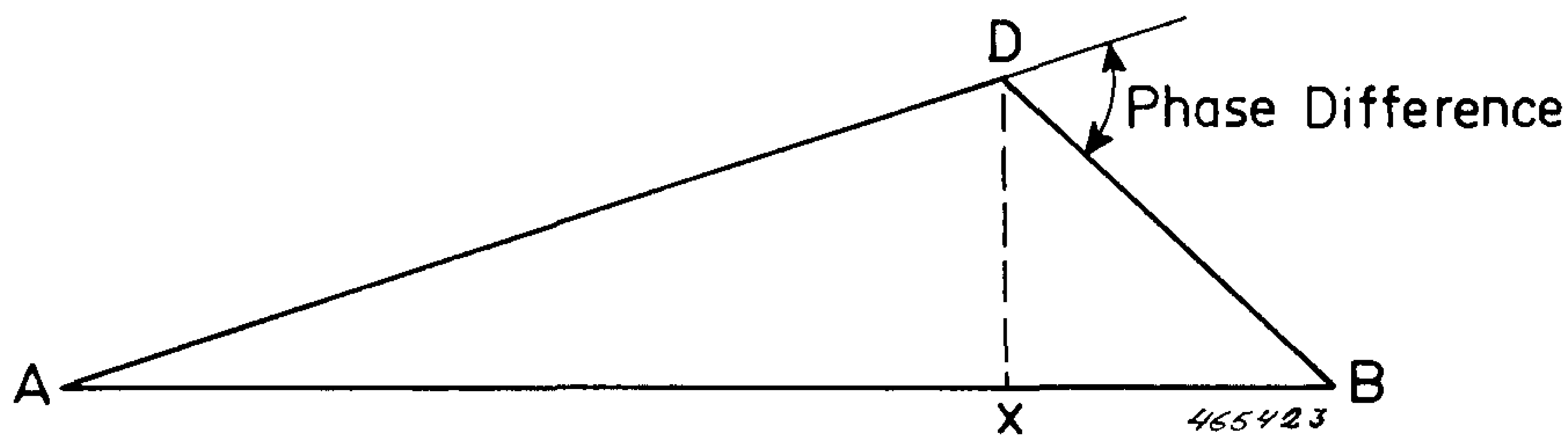



*Fig. 2.*

scales. Thus a comparison scale calibrated from — 50 % to + 100 % represents for instance o.5 to 2 henries when used with a standard of 1 henry. By the use of 2 scales as shown in Fig. 4, one covering from 1 to 4 and the other from 3 to 12, complete overlapping ranges are made available. Suitable standard values are 2, 6, 20, 60 millihenries etc. The instrument is thus made direct reading.
Particularly suitable for this application is the range of comparison bridges made by Brüel & Kjær. Not only have these instruments large meters but, even more important for this purpose, they have facilities for rapidly changing scales. Blank scales are provided with these instruments and they may readily be calibrated as in Fig. 4. Calibration may be carried out on the meter, by using resistance boxes to set up appropriate ratios. This is preferable to calibrating from calculation as it takes into account any meter or amplifier nonlinearity which may be present.

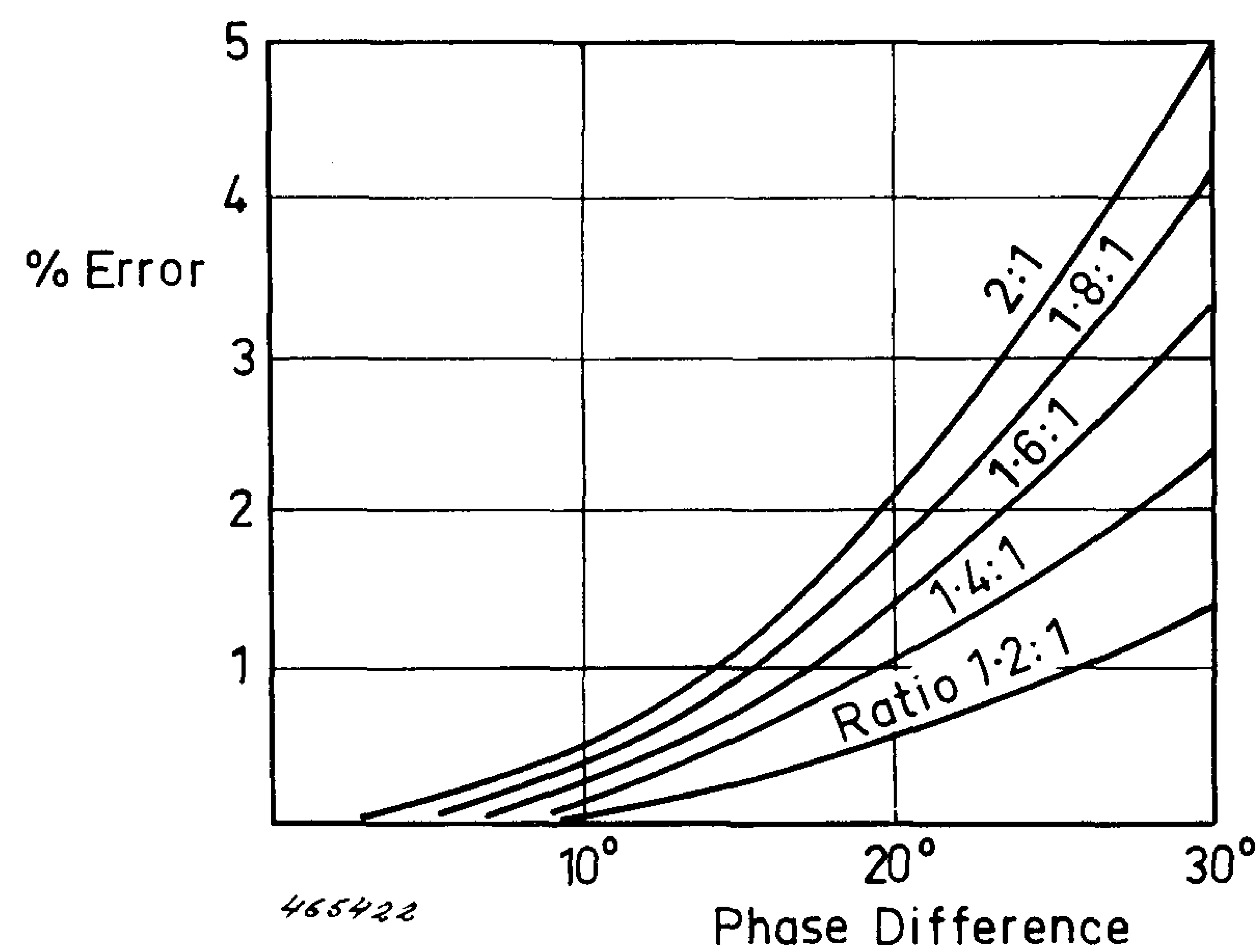



*Fig. 3.*

**Turns Count.**
A facility for checking the number of turns on wound bobbins prior to fitting of cores is of great value in coil production. Instruments for this purpose are available but are usually expensive and probably only justifiable for high volume production. A comparison bridge of suitable type in association with a fairly simple test jig will allow count checks to better than 1 % to be carried out inexpensively however, as will be described.
If a transformer of unity ratio is connected to a comparison bridge, one winding to STANDARD and the other to TEST and in the correct sense, an indication of equality will be given as each winding produces an equal back

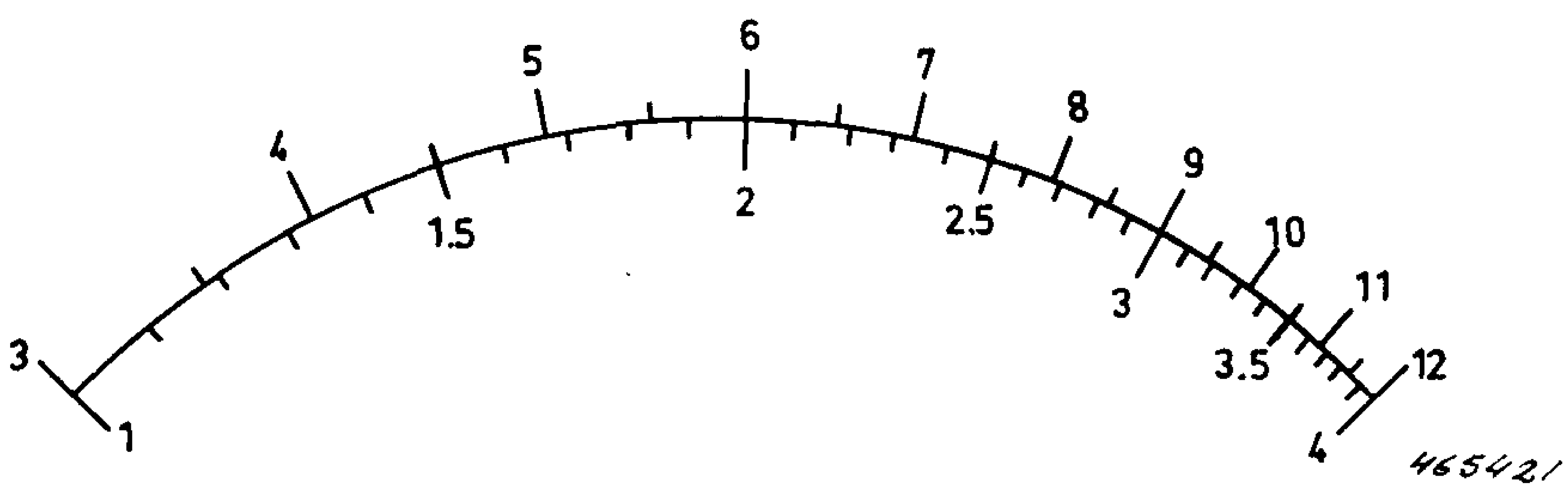



*Fig. 4.*

E.M.F. Thus if a coil under test can be made one winding of a transformer the secondary turns of which can be varied, the bridge can be used to indicate the setting at which unity ratio is achieved. The turns count will then equal the number of turns on the secondary.

An efficient (magnetically speaking) core which may be opened to insert the test coil and a "secondary" coil the turns of which may be selected by switches are therefore necessary. The unavoidable air gap of such an arrangement must be consistently maintained at a very small value as otherwise variations in flux leakage ratio will lead to errors in indication. A suitable and easily constructed jig is shown in Fig. 5. The test core is constructed of mumetal laminations; the fixed part using those of "U" form and the moving pieces of "I" form. The laminations are built up to stacks of suitable thickness using Araldite as an adhesive and keeping the "U" and "I" stacks separate, of course. The mating faces are then ground smooth to ensure the minimum air gap on assembly. The U stack is then mounted rigidly in the jig while the I stack forms an armature which is held in the swinging arm shown. This arm is of channel section with internal width slightly greater than the armature stack thickness. The armature is retained in position in the channel by a single screw passing through a slightly oversize hole. Thus it is free to move to a certain extent in its holder and is self-aligning when the jig is closed, spring S ensuring that the air-gap is kept to a minimum. The jig is constructed of sheet brass.

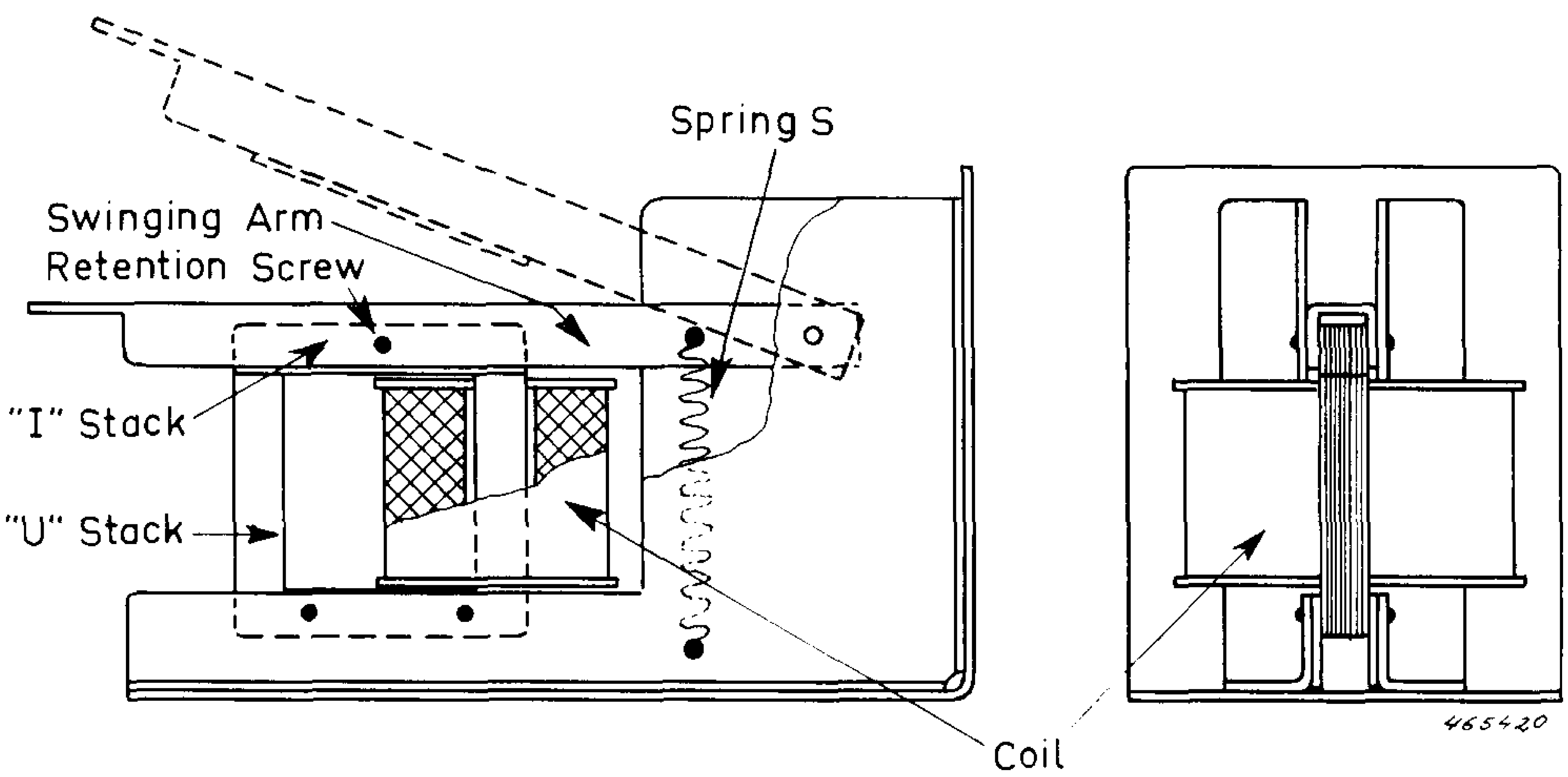



*Fig. 5.*

The core dimensions shown cater for small bobbins up to 3/4″ long by about 1″ diameter with central hole not less than 3/16″ diameter or diagonal. The

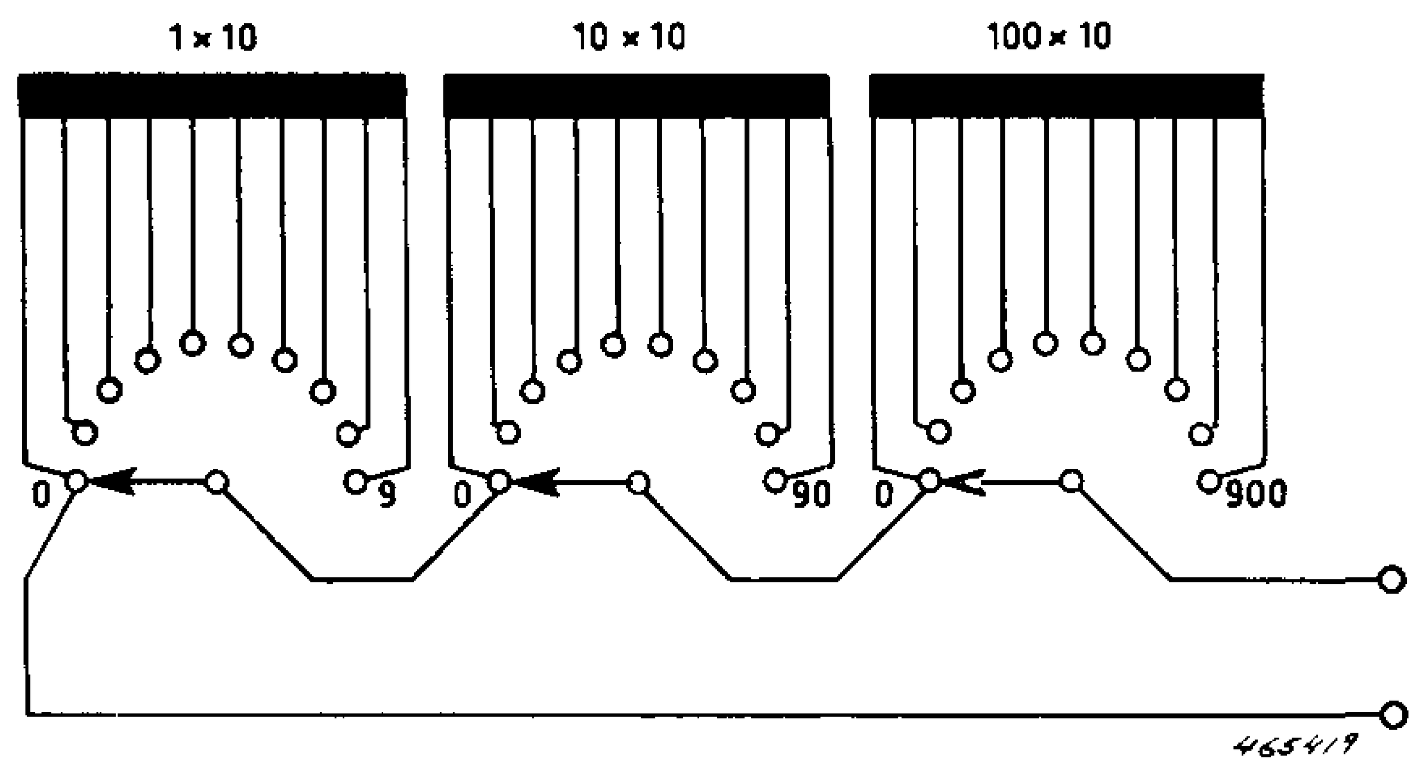



Fig. 6.

dimensions may of course be varied to cater for other coil sizes. It is tempting to make the core large in size but of small cross-section to allow the testing of both large and small bobbins. This is not advisable, however, as it is difficult to make such an arrangement of sufficient rigidity and accuracy suffers due to a poor magnetic circuit. It is better to make two or more core sizes to cover the range.

The variable "secondary" coil is constructed on a decade arrangement as shown in Fig. 6, using suitable decade switches for selection. That shown caters for a maximum of 599 turns and was wound of 40 S.W.G. enamel wire. Used with a Brüel & Kjær bridge Type 1505, which operates at a frequency of 10 kc/s, readings are not accurate for bobbins with less than 20 turns. This is due to the low inductance of such bobbins when on the core as the corresponding low impedance overloads the bridge. For such small number of turns a bridge with a higher operating frequency, such as the Type 1506 (100 kc/s) is more suitable.

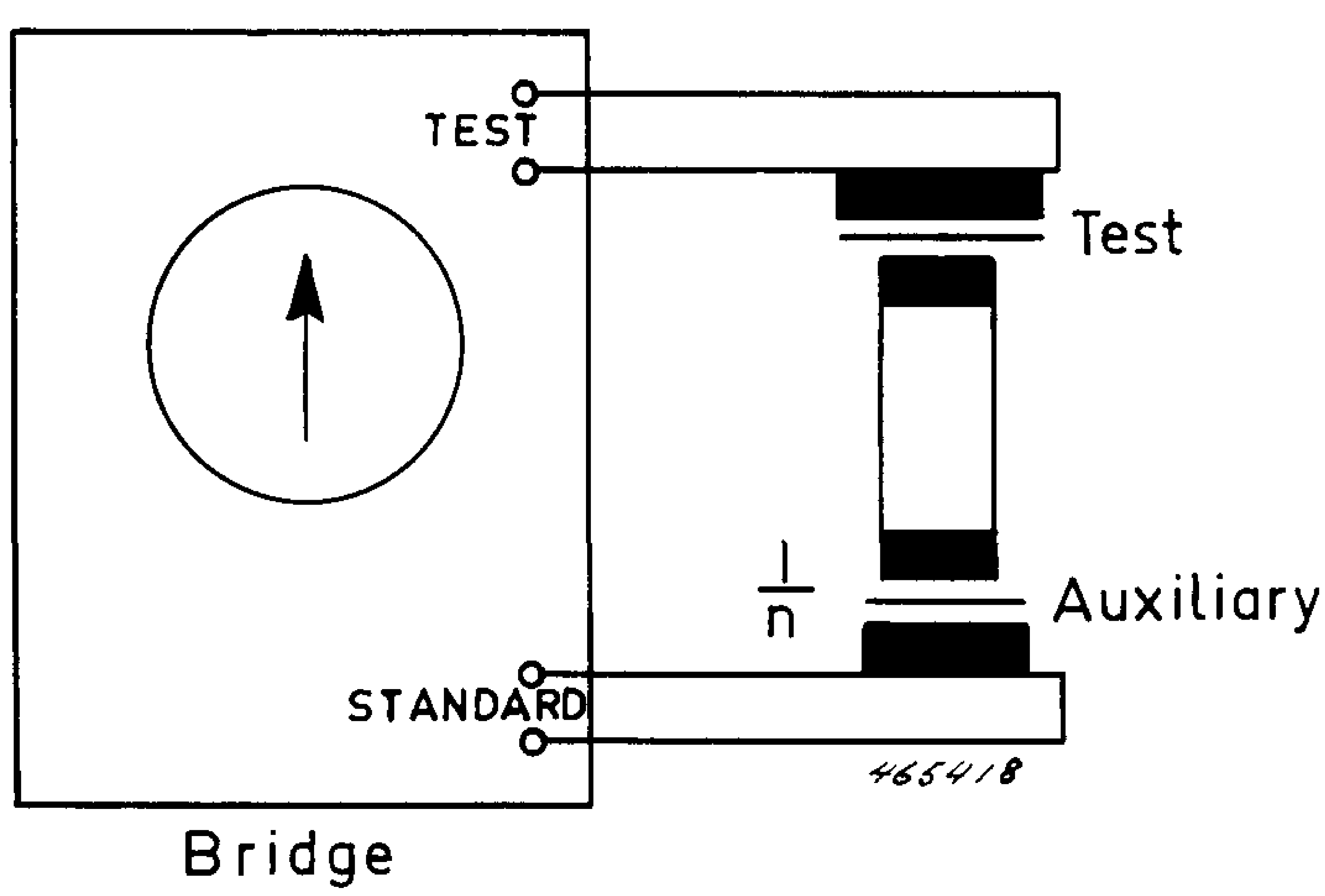



Fig. 7.

If bobbins with larger numbers of turns are to be tested the self capacitance difference between "primary" and "secondary" may lead to inaccuracy. If so, a bridge with lower operating frequency may be necessary, such as the Type 1504.

**Turns Ratio.**

In transformer testing, turns ratio is often of more importance than exact number of turns. A comparison bridge may be used to check the turns ratio of two windings by making use of a standard transformer of equal ratio and connecting both back to back between the TEST and STANDARD bridge terminals. The correct relative sense must be maintained otherwise cancellation of the induced voltages will overload the oscillator.

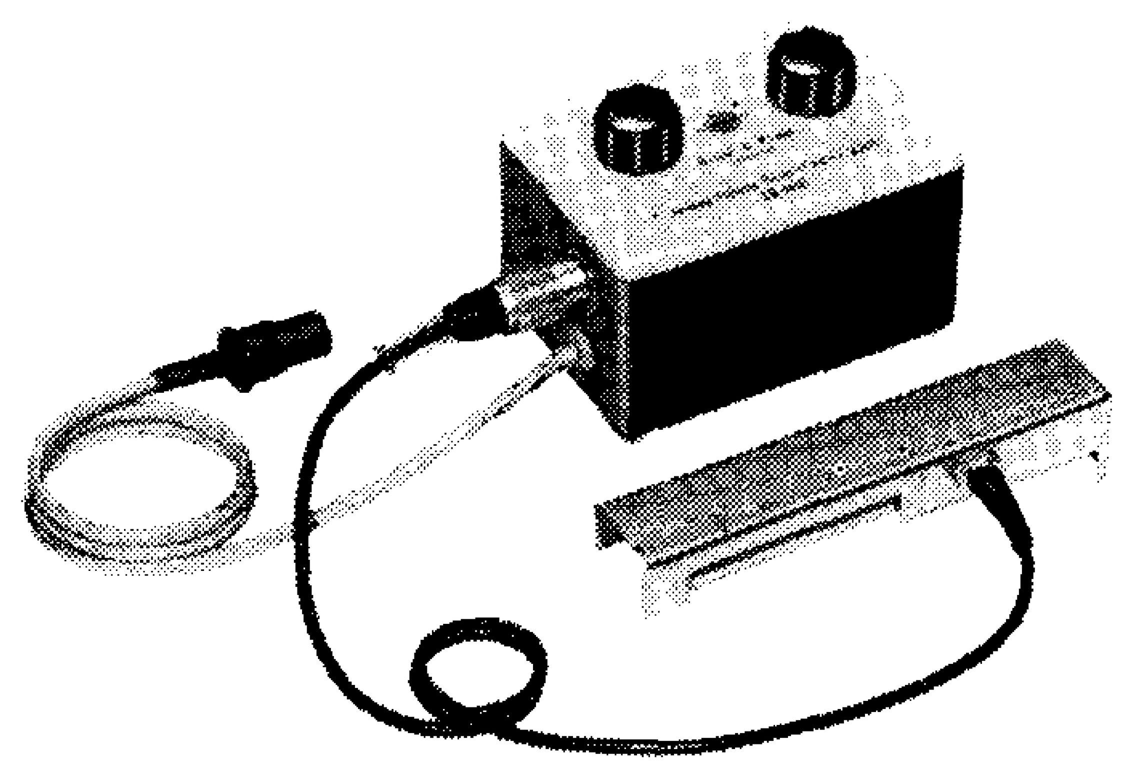
To avoid the necessity of having standard transformers available for every type in production the bridge may be used to indicate ratio directly. Thus if one winding is connected to TEST and the other to STANDARD the turns ratio will be indicated as a percentage unbalance (again assuming the correct sense). An unbalance of $-50\,\%$ to $+100\,\%$ will then represent turns ratios from 0.5 to 2 and a specially calibrated scale may be constructed to give direct indication of ratio. To handle larger ratios a suitable auxiliary transformer may be interposed between the bridge and one of the windings of the transformer under test. With the arrangement as shown in Fig. 7 the ratio of the latter is then "n" times that indicated, where "n" is the ratio of the auxiliary transformer.

# News from the Factory

**New Analog Voltage Read-out for 2305.**

The purpose of the Analog Voltage Read-Out ZR 0021 is to obtain a DC voltage output from the Brüel & Kjær Level Recorder Type 2305, which is proportional to the input level (in dB). This is accomplished by utilizing the electromechanical servo system of the Level Recorder to drive an accessory slide wire.

The DC voltage output can be fed into a digital voltmeter or other type of analog-to digital converter and the digital output so obtained may be stored on magnetic tape, punched paper tape or IBM punched cards in a standard digital code, for use in computer programs.



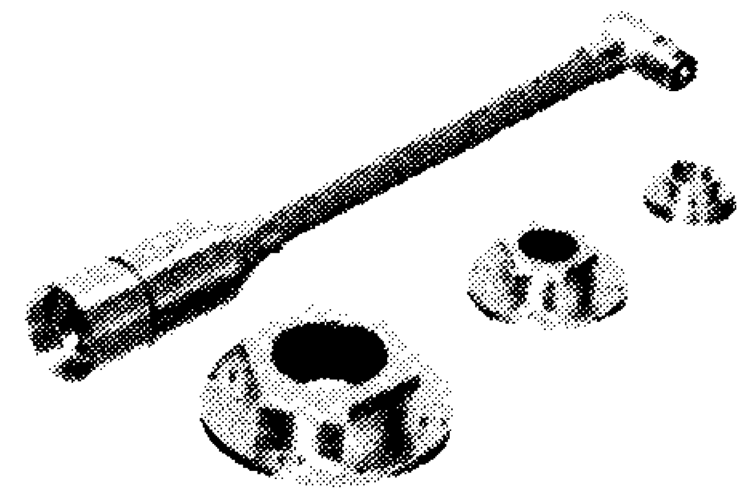
*Analog Voltage Read-out ZR 0021.*

This system, using the B & K Level Recorder and Analog Voltage Read-Out unit, provides an output which is proportional to the log of the **true RMS, peak, or absolute average value** of the signal. Operating thus, as a log converter, it is capable of slewing rates in excess of 200 dB/sec. Also its dynamic range can be as great as 75 dB.

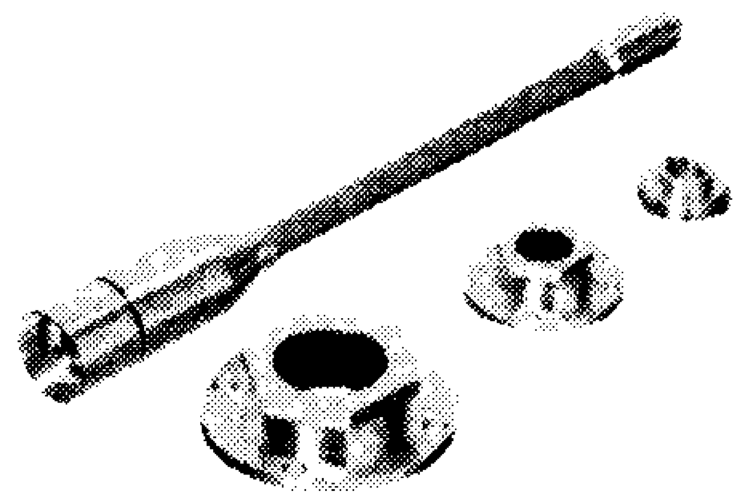
It is also possible to obtain an analog voltage output and use the Level Recorder for writing curves at the same time.

**New Flexible Adaptors UA 0122 and UA 0123.**

The flexible Adaptors UA 0122 and UA 0123 have been designed for use with the B & K 1/2″ Microphones (4133—4134) as well as the 1/4″ Microphones (4135—4136). They consist basically of a flexible rod and three mechanical mounting pieces, see Figs. 56 and 57. At one end of the rod is placed a mounting arrangement for attachement to a Cathode Follower Type 2615 (or 2614) and at the other end the Microphone cartridge itself can be mounted. UA 0122 allows side mounting of the cartridge while UA 0123 is designed for end mounting. Both Adaptors make use of the well known



*The Flexible Adaptor UA 0122.*



*The Flexible Adaptor UA 0123.*

B & K double screening system which reduces the input capacity, and thus its influence on the microphone characteristics, to a minimum. The increase in input capacitance caused by the Flexible Adaptor is of the order of 2 pF. Teflon and silicone treated rubber are used as insulation materials and the inner one of the two screens is of a special mini-noise type.
The 1/4″ Microphones can be mounted directly on the Adaptors while the 1/2″ Microphones require the use of a mechanical coonversion arrangement, which is supplied with the Adaptor. Also supplied with Adaptor are two flush mounting pieces one for the 1/4″ Microphone and one for 1/2″ Microphone. The flush mountings are designed with the smallest possible heights. It is recommended when the Microphone and Flexible Adaptor are mounted on the Cathode Follower to calibrate the complete arrangement by means of a Pistonphone Type 4220 if accurate measurements are to be made.

**Brüel & Kjær**

ADR.: BRÜEL & KJÆR
NÆRUM - DENMARK

TELEPHONE: 800500
BRUKJA, Copenhagen

TELEX 5316


PRINT: K LARSEN & SØN, DENMARK