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Cover: The different instruments used for automatic recording of frequency irregularity in rooms.

Automatic Recording of Frequency Irregularity in Rooms

SUMMARY

To save the tedious job to calculate the F.I. (expressed in db/c/s) from a room response curve, two different methods for obtaining direct recording of the F.I. as a function of frequency are developed.

The room response is recorded via a microphone, amplifier and level recorder. On the recorder is fixed a contact strip with 100 silver lamellae which via an electronic scaler registers the total "length" of the room response curve in db.

The other method uses the output voltage from the moving coil in the level recorder. This voltage is proportional to the F.I. in db/c/s and recorded on a second level recorder with extremely low recording speed.

The two sets of apparatus have been used for measuring the diffusion effect of three different types of diffusers in a small model room.

This paper was given by Dr. Per V. Brüel at the International Electro-Acoustics Congress in the Netherlands 1953.

Formerly, a room's acoustic goodness was judged by its so-called reverberation time, i. e., the time taken for the sound to die away in the room, depending on both the room's volume and the sound's frequency. Apart from that, geometric analyses of the sound paths in concert halls and radio studios have been made, so that consideration could be given to the uniform distribution of the sound throughout the auditorium when the room's shape was being decided upon. However, the last ten years have shown, that an examination of a room's reverberation time is not always sufficient; thus, for example, some radio studios with approximately the same size and reverberation time have in practice shown themselves to be widely different acoustically.

Attempts have therefore been made in recent years (see refs. 1, 2 and 3) to find a measuring unit apart from volume and reverberation time which would characterize a room's acoustics. Particular attention has been paid to the sound field's homogeneity, and to this end Bolt and Roop have defined a measuring unit, the so-called »Frequency Irregularity« (FI). To estimate a room's FI, a loudspeaker with a good frequency response, and connected to a B. F. Oscillator, is placed at one end of the room, and a pressure microphone, connected to a level recorder via an amplifier, at the other end.
The B. F. O. is mechanically coupled to the level recorder, so that the record-

1. *Bolt and Roop, J. A. S. A., vol. 22/1950, p. 280.*
2. *Sommerville & Ward, Acustica, vol. 1/1951, p. 40.*
3. *Furrer & Lauber, Acustica, vol. 2/1952, p. 251.*

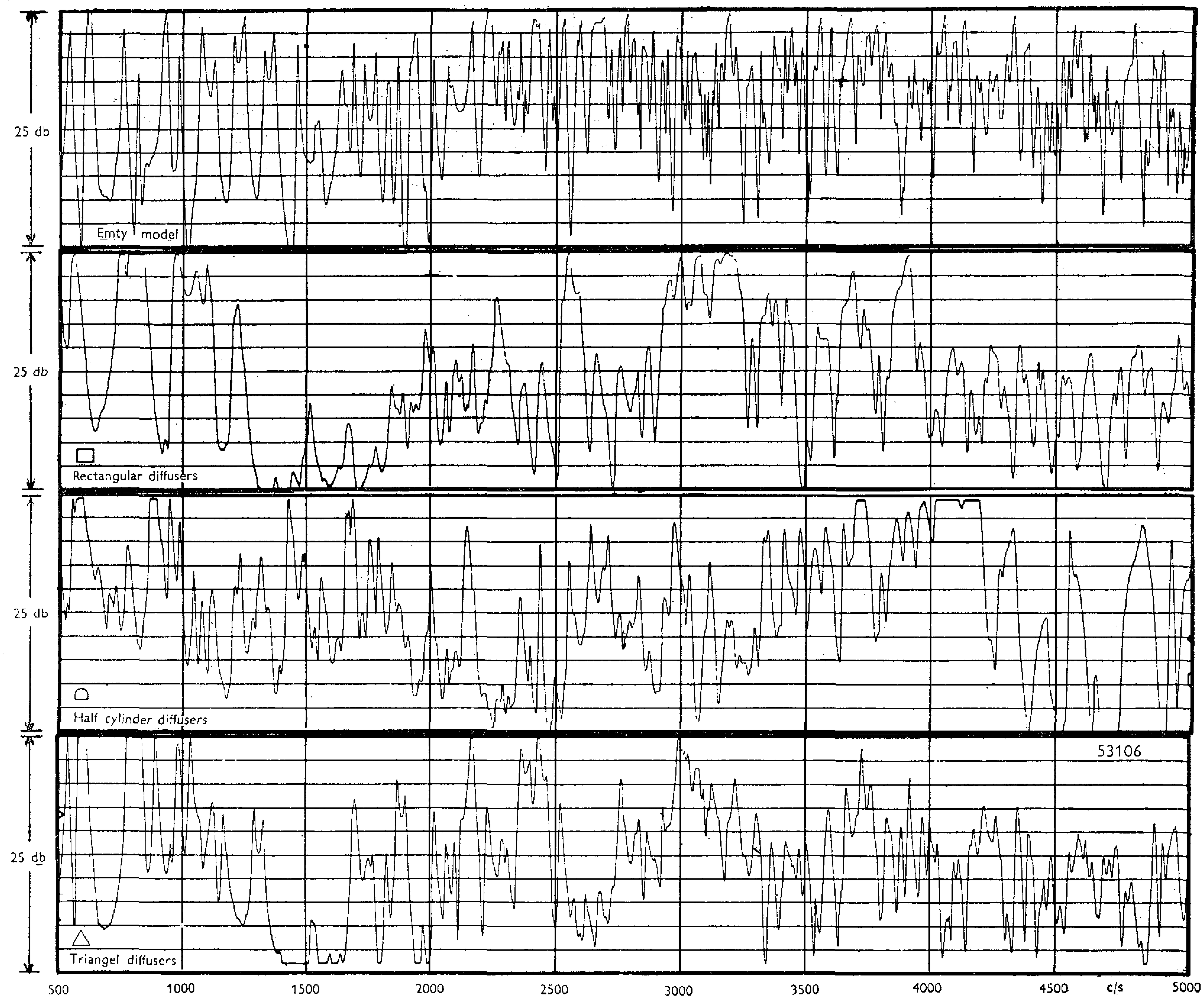

Fig. 1. Frequency Response Curve in a model room, with different diffusers. Above: empty room without diffusers. Below: with diffusers of rectangular, semi-circular and triangular cross section.

ing paper moves synchronously with the frequency variation, and the frequency scale is made linear by using a circular cut in the B. F. O.'s main condenser plates.

The room's frequency response is recorded with a very slow frequency variation of about 1—5 c/s/s. A typical set of such curves is reproduced in fig. 1. Bolt and Roop define the FI as the total of the differences in db between all the maximum and minimum points of the response curve, divided by the frequency band in question. The unit of FI is therefore db/c/s. The figure for smaller solo studios is about 1—3 db/c/s, and for studios with bad acoustics, 5—10 db/c/. The value varies with frequency, so the FI has to be given as a curve, as a function of frequency.

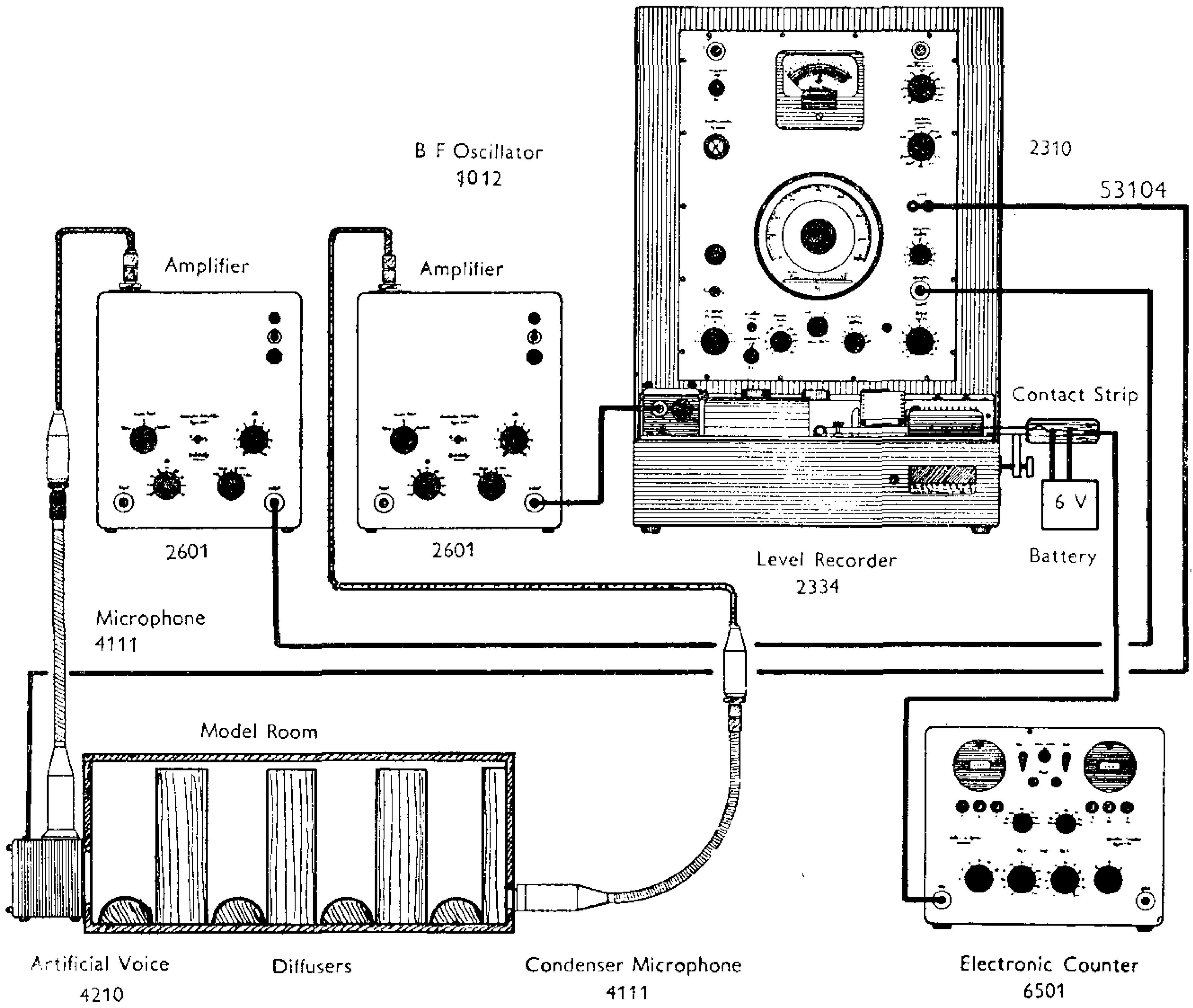

Fig. 2. Measuring set-up with electronic counter and special sound source for the semi-automatic estimation of »Frequency Irregularities«.

To record the frequency response of a room is an easy procedure, but to calculate from that curve the FI as a function of frequency is a big job. This paper describes a procedure for automatically recording the FI by either of two different methods. The first set-up is shown in fig. 2.
As test room, a small model of a radio studio is used, provided with different

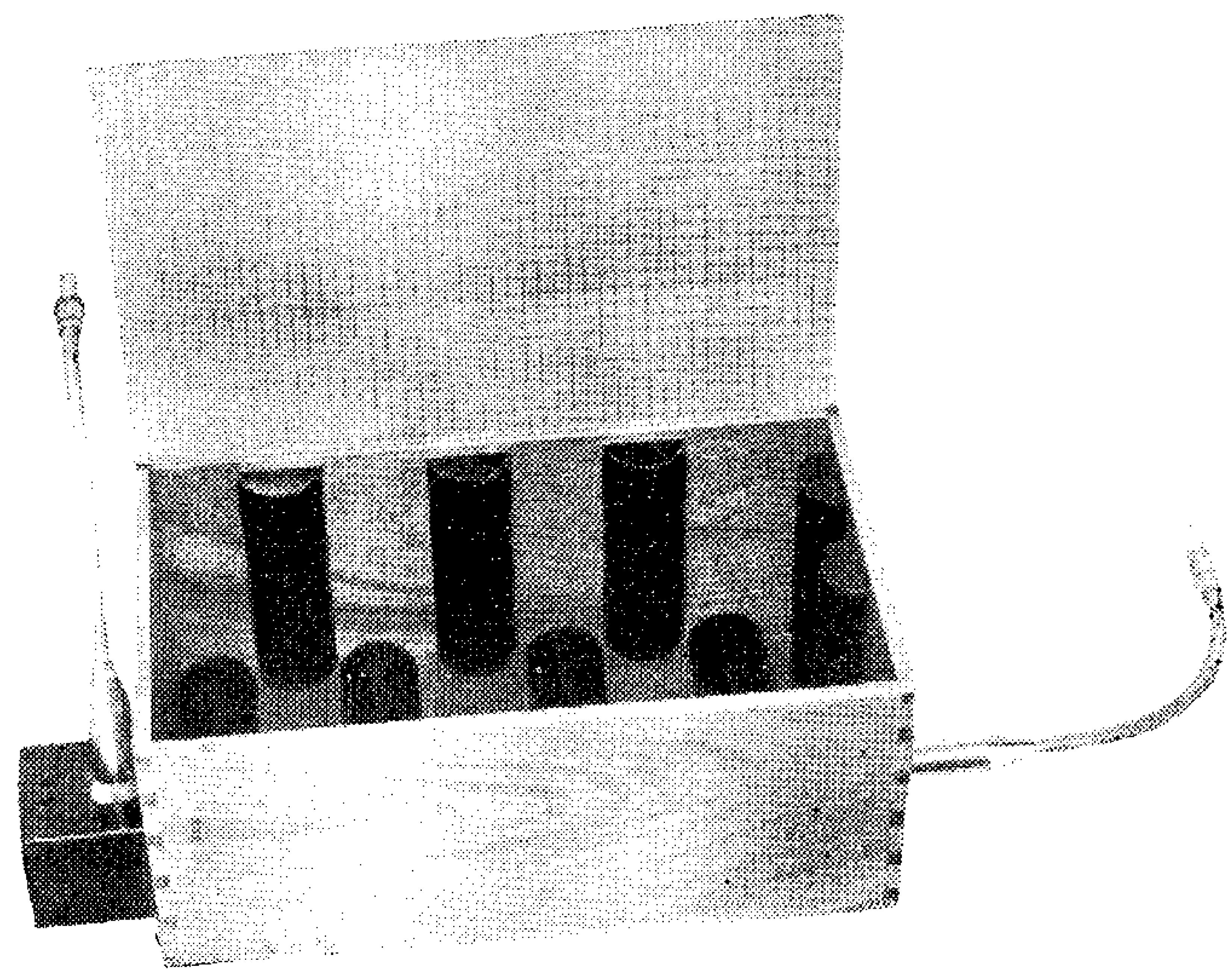

Fig. 3. Photograph of model room and the three types of diffusers used.

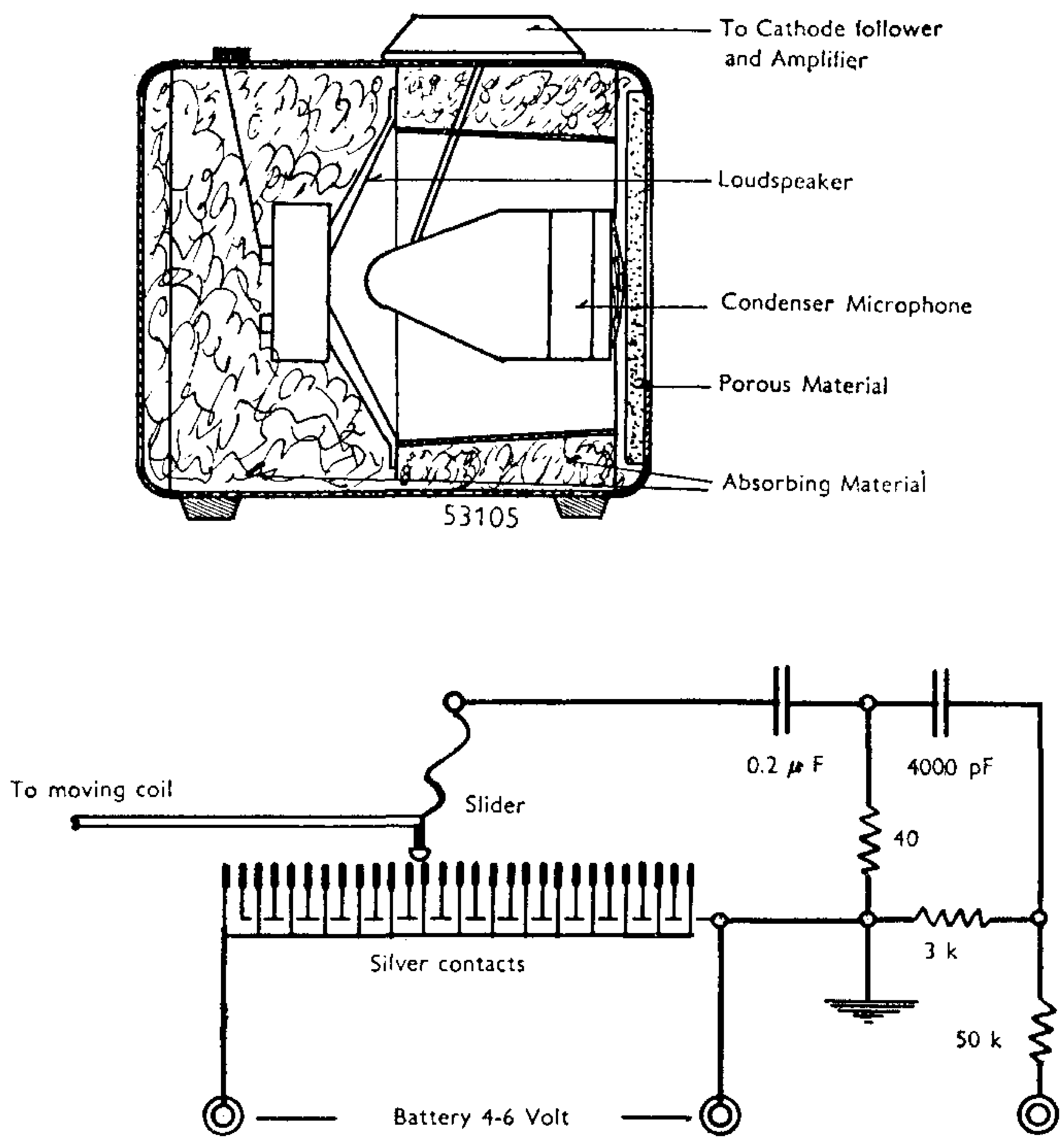

Fig. 4. Cross-section of sound source with flat frequency characteristic and high internal acoustic impedance. Below: principle of the contact arrangement for counting the total length of the frequency curve.

types of diffusers. (Fig. 3.) The normal B. F. O. type 1012 is converted to give a linear frequency scale in the range 500—5000 c/s.

As sound source we use an Artificial Voice consisting of a highly damped loudspeaker and regulating microphone which, via a microphone amplifier and the B. F. O.'s compressor, regulates the loudspeaker sound pressure to a constant value. A thick layer of porous material is placed between the Artificial Voice and the room. This material has a high and purely resistive acoustical impedance, so that, as long as the sound pressure is absolutely constant on one side of the porous layer, the sound emission on the other side will be constant. Owing to the high acoustical impedance, a variation of the sound pressure on the room side of the layer will not have any influence on the regulating microphone. In other words, the room response being recorded will be unaffected by irregularities in the sound source characteristic. Fig. 4 shows a cross section of the Artificial Voice provided with the porous material.

At the other end of the model room is placed a condenser microphone connected to a level recorder via an amplifier. The room response is thus recorded as a function of the frequency. The level recorder and B. F. O. are mechanic-

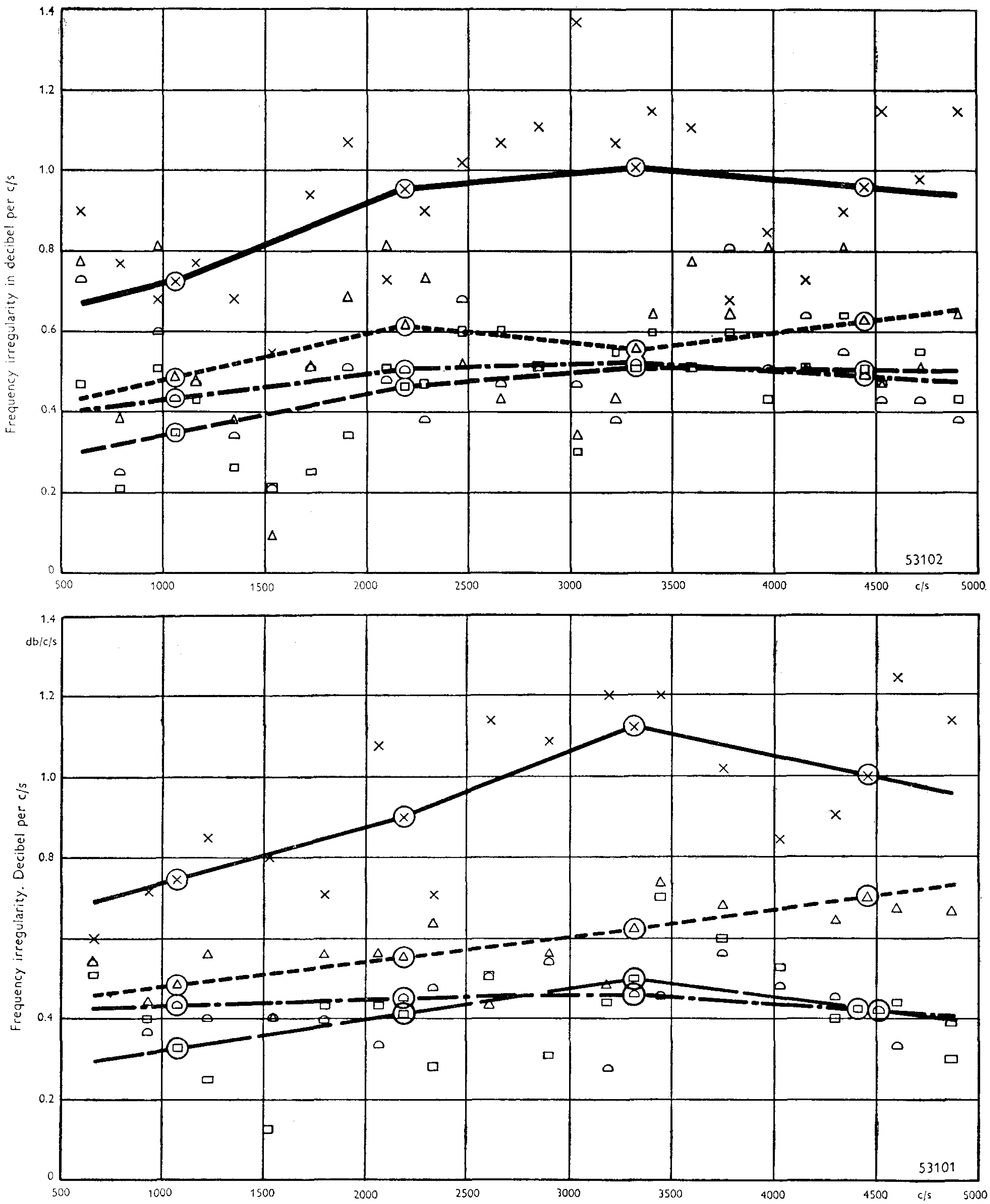

Fig. 5. Measuring results in model room with three different types of diffusers. Curves taken with two positions of the diffusers.

Continuous curve: the empty room.
Dotted curve: triangular diffusers.
Dot and dashed curve: semi-circular diffusers.
Dashed curve: rectangular diffusers.

ally connected by means of a chain drive. The curves shown in fig. 1 are recorded directly from the model with this set-up.
A small contact strip is mounted on the right-hand side of the recorder, and the recorder's slider is coupled to the slider on this contact strip. Each time the latter slider moves one contact, an electrical impulse is obtained which is registered on an electronic counter. In other words, this set-up allows the recording of the total length of movement of the recorder stylus. The B. F. O. sweep is linear in time, so that if the electronic counter is read at regular periods, say 10 secs. or ½ minute, that is, at constant known frequency intervals, the FI in db/c/s can be immediately obtained.

Fig. 5 shows the results from the model room using three different kinds of diffusers. The two sets of curves are for different positions of the diffusers. The points marked with circles are mean values over a wider frequency interval. It is seen that points calculated for small frequency intervals fluctuate very much, so that better results are obtained by calculating the FI over wider intervals. As seen from the curves, the empty room has of course the highest FI. In the low frequency range the best diffusers are rectangular in cross section, and the worst, triangular. At high frequencies, the rectangular are not as good as the semi-circular, but are still better than the triangular. It should be noted that the »Frequency Irregularities« have much lower values measured in a model room than they would have in a full sized studio. The reason is that the reverberation time in a model room is much shorter than in the studio, as the ratio of surface to volume is much greater in the model room. This means that the »goodness« of the natural oscillations will be less in the model room, the peaks and valleys will be less pronounced, and as a result a lower value of FI will be obtained.

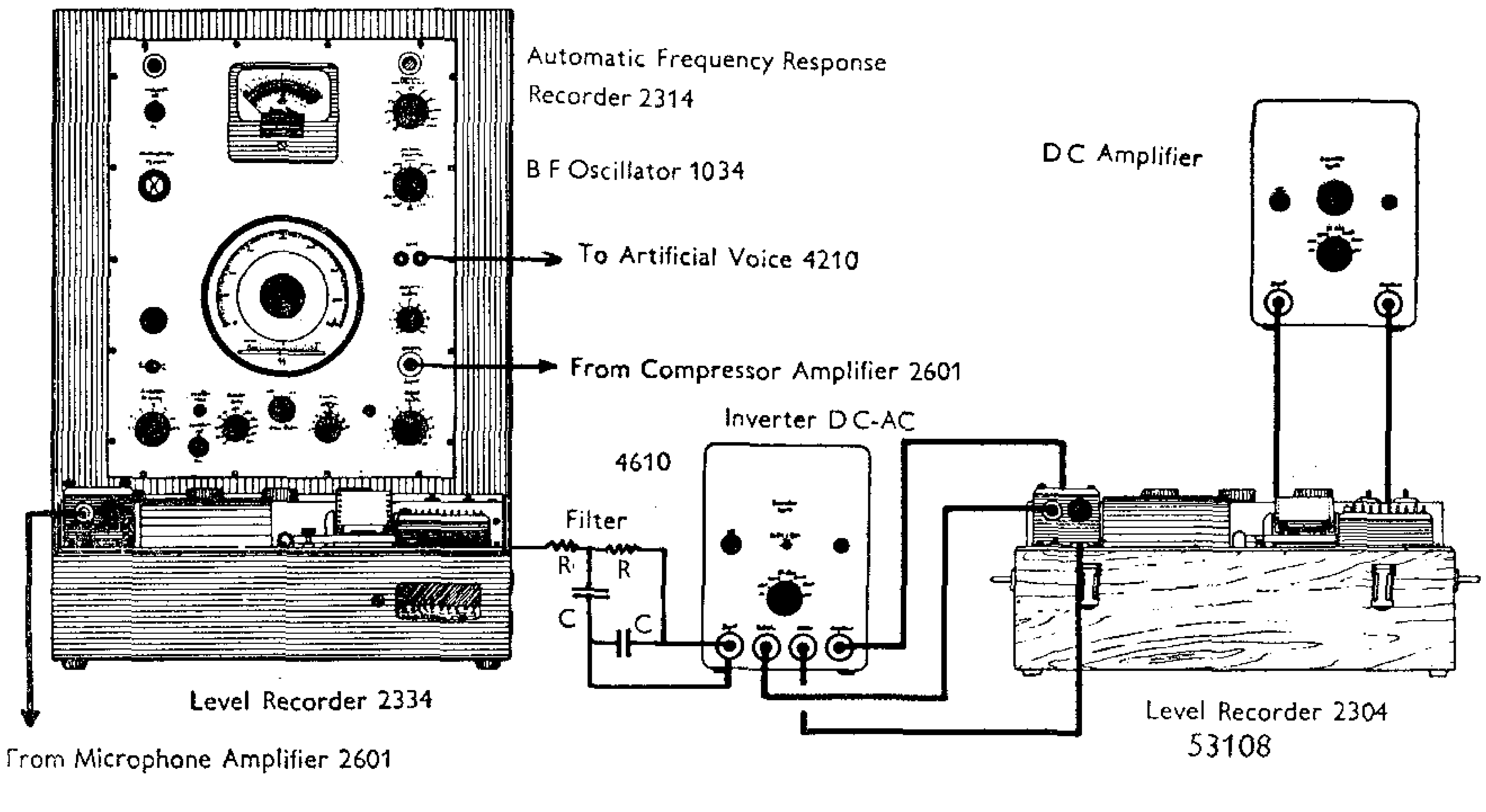

Fig. 6. Principle of the fully automatic set-up for measuring »Frequency Irregularities«.

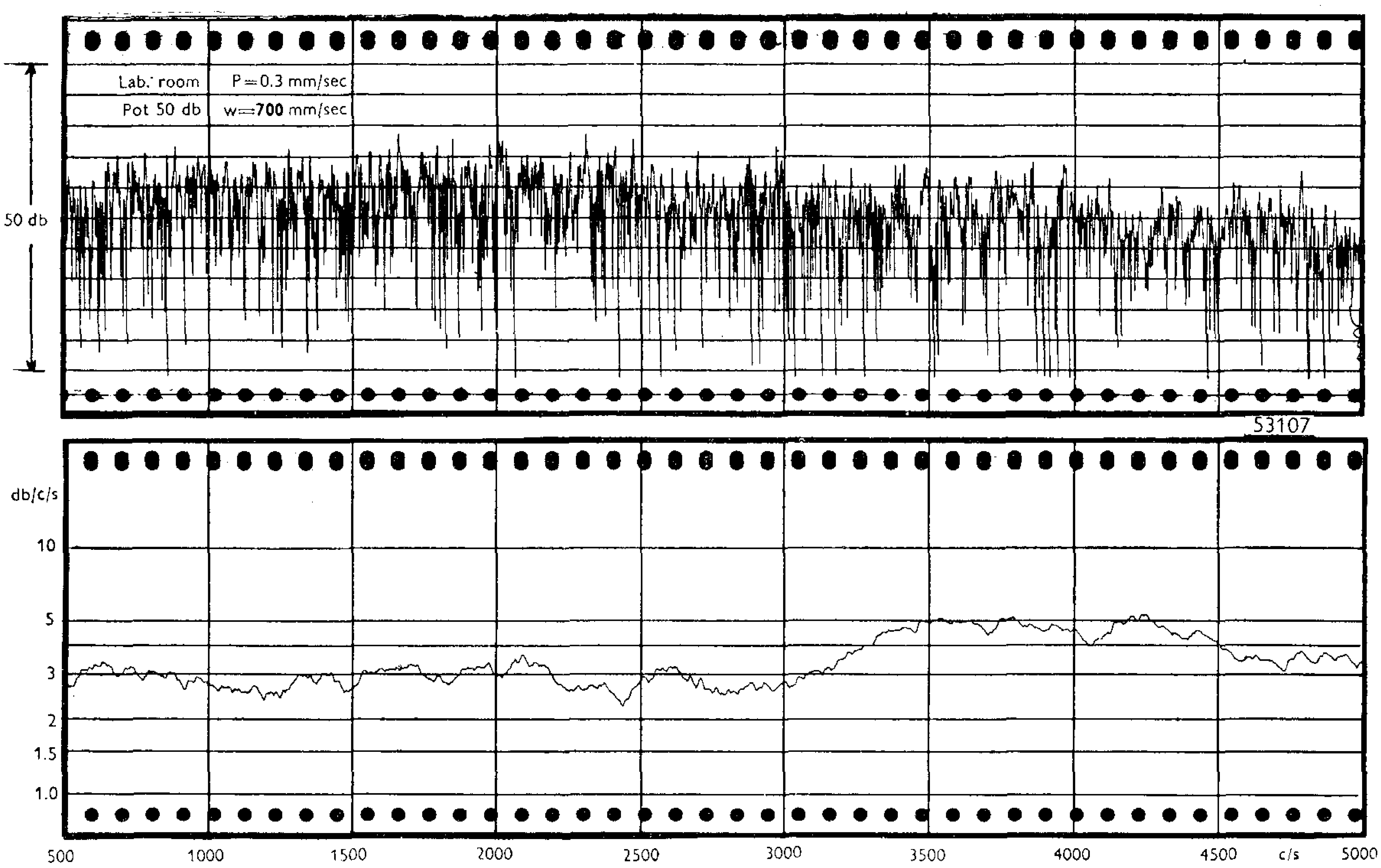

Fig. 7. Frequency Responce Curve and curve of »Frequency Irregularities« for a laboratory, recorded with the set-up of fig. 6.

The above method considerably reduces the work of calculation involved in estimating the FI, but it is actually possible to achieve a completely automatic recording of the FI as a function of frequency.

Fig. 6 shows the measuring set-up. The sound source, microphone and microphone amplifier are just as in fig. 2. With this fully automatic method, the feed-back voltage from the driving coil in the recorder is led through a filter, to eliminate possible hum, and then fed to a DC-AC inverter, which converts the slowly varying voltage from the feed-back into 400 c/s a. c., which can then be recorded on another level recorder.

The voltage produced by the feed-back winding in the level recorder's driving coil system is proportional to the speed, and therefore, with a constant rate of frequency variation, proportional to the FI expressed directly in db/c/s.

However, as is clearly indicated in the curves of fig. 5, we are not interested in the instantaneous values of the FI, but on the contrary wish to have them integrated over a relatively broad frequency band. Therefore, in the second level recorder a D. C. amplifier is inserted in its feed-back circuit, whereby the recording speed can be reduced to 1.5 mm/sec., which is quite satisfactory for most room acoustic measurements of FI.

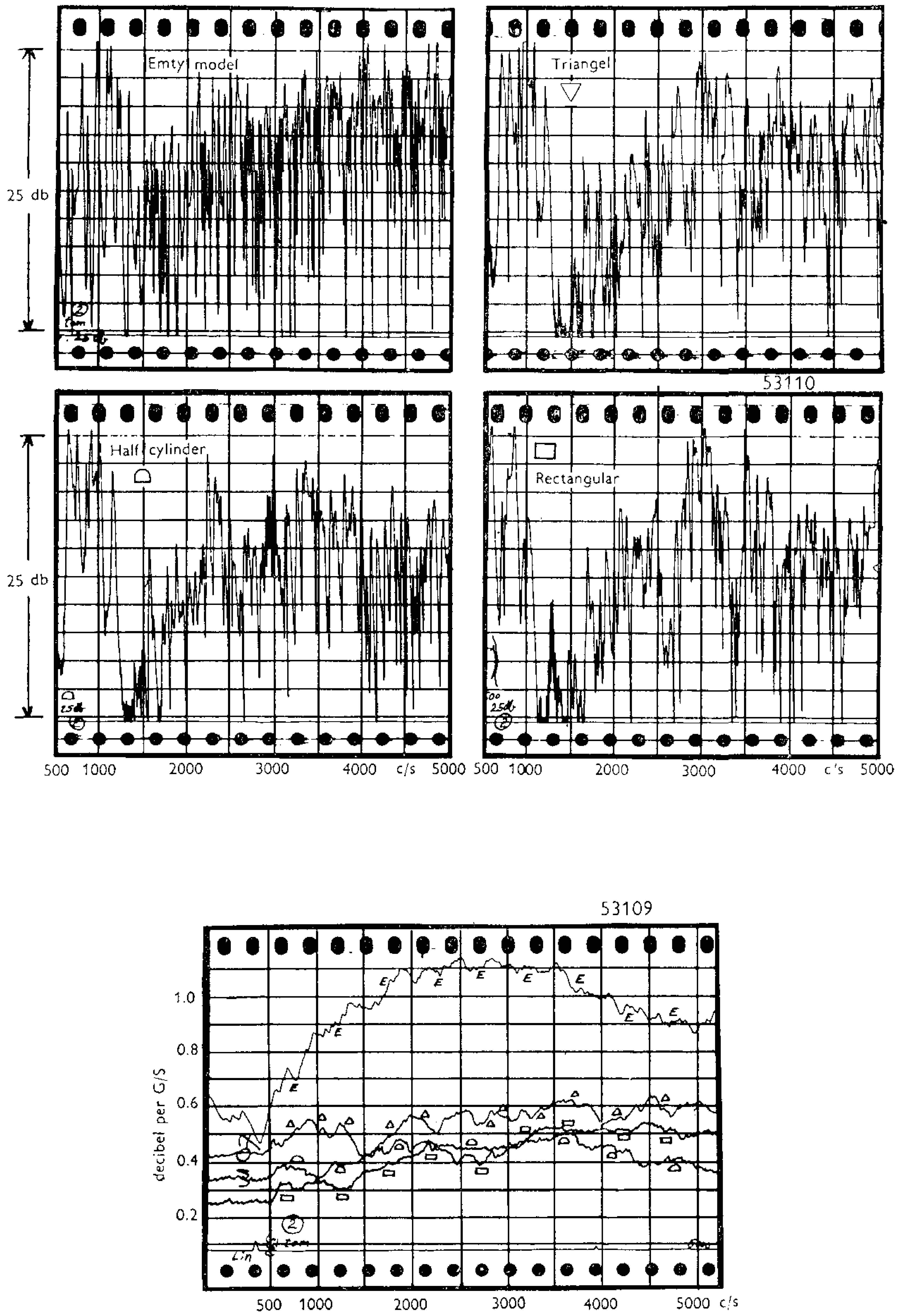

Fig. 8. Frequency Responce Curves and »Frequency Irregularities« curves taken in the model room, respectively empty and with the three different diffusers. The »Frequency Irregularities« are recorded below on the same curve paper.

The whole apparatus is adjusted by giving the first level recorder a uniform change of level, for example by means of a B. F. O. with a logarithmic scale shifting frequency quite slowly, and with a small condenser in series with the level recorder's potentiometer. The voltage will then vary logarithmically, that is, will give a linear db scale as a function of time. On the second level recorder a horizontal line should then be recorded. By comparing the slope

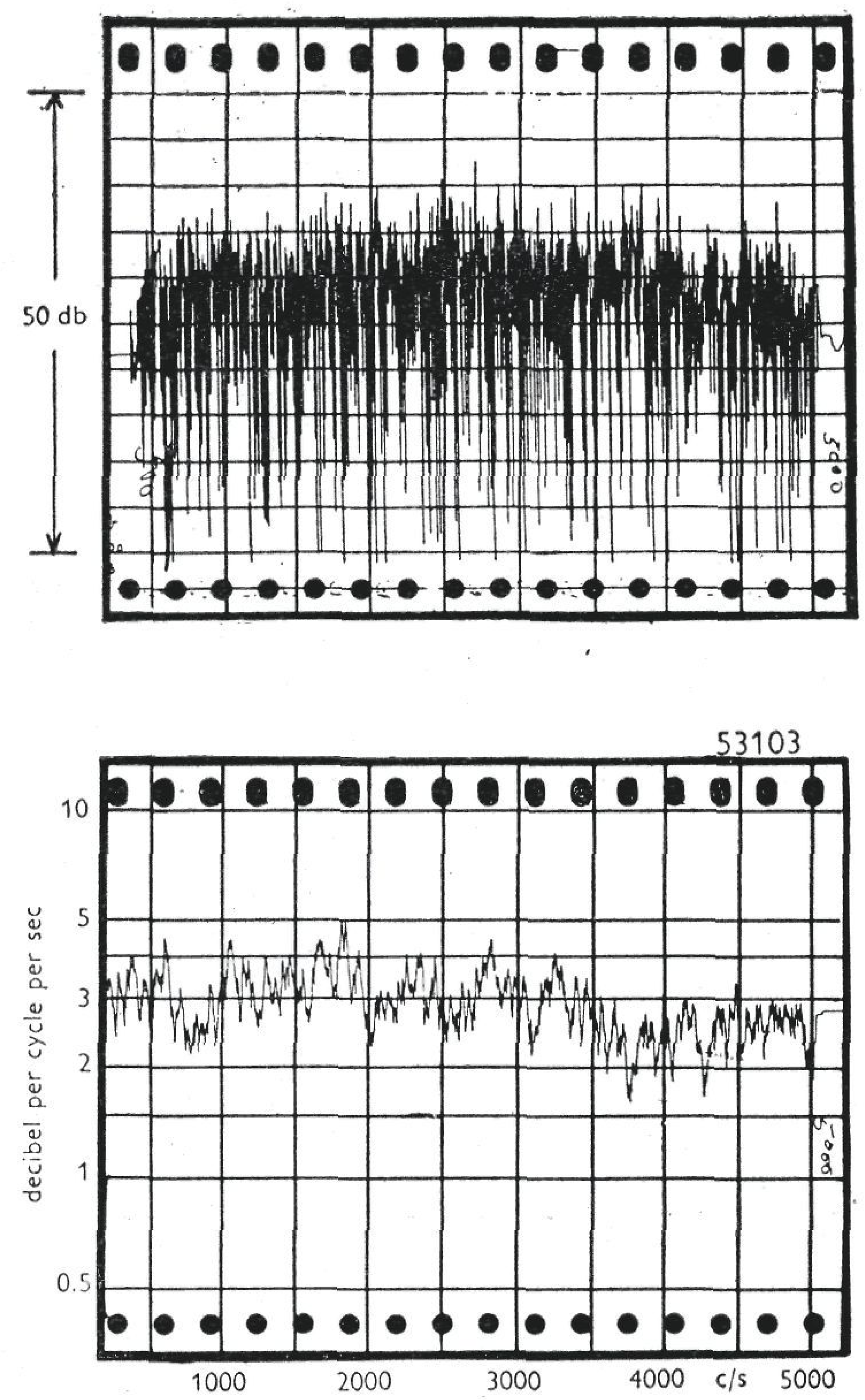

Fig. 9. Frequency Response Curve and »Frequency Irregularities« curve taken in an ordinary sitting room. The total recording period was 40 minutes.

of the line on the first recorder with the horizontal line on the second, the whole system can be adjusted.

Fig. 7 shows a typical result from an acoustically relatively good room. The frequency range from 500—5000 c/s is traversed in about 20 minutes.

Fig. 8 shows the automatic recording in the small model room with the three types of diffusers. On the whole, the results agree with those taken by means of the electronic counting method.

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