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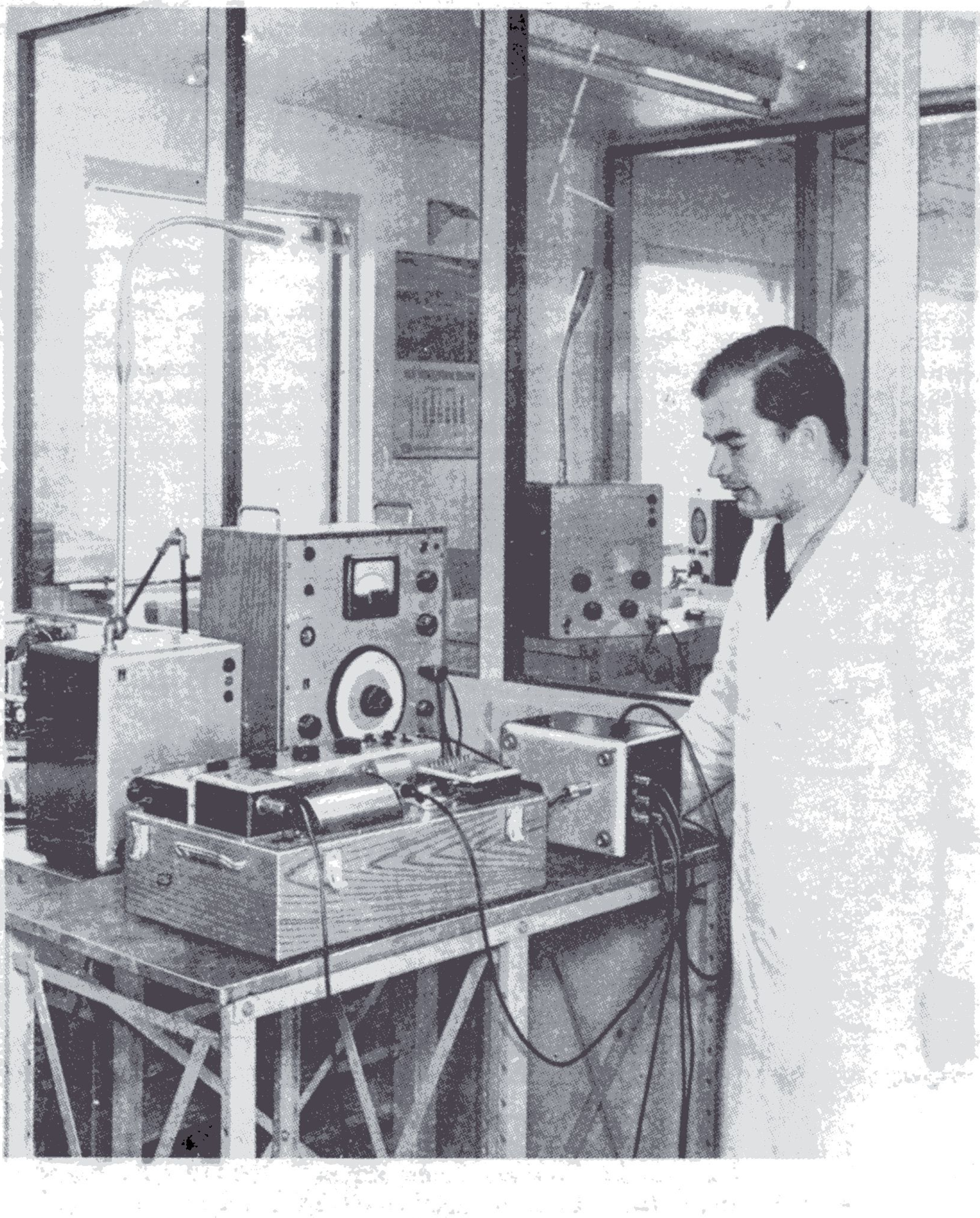
Teletechnical, Acoustical and Medical Research



No. 4 October 1952

Cover: Air borne sound insulation recording of glass wall.

Continued from No. 3

B. B. C. IMPULSE GLIDE METHOD

Of recent date a new method for the acoustic investigation of radio studios and concert halls has been developed in the British Broadcasting Corporation's Research Department, mainly by T. Sommerville and C. L. S. Gilfort.[9] This does not employ warbled tone, but the loudspeaker gives a pure tone for a period of about 200 milliseconds. By the means an almost stationary condition is obtained in the room, but, however, in such a way that a number of the room's eigentones in the region of the pure tone are struck, by which means the very irregular reverberation curves registered with ordinary reverberation measurements without warbled tone are avoided. The reverberation curves are shown on a cathode ray tube screen with horizontal time-axis and vertical level-axis with a linear db scale.

The writing speed is chosen around 100—150 db/sec. The reverberation curves are photographed on a film wich moves slowly across the cathode ray tube screen. The film's movement is coupled to the tone generator's frequency scale, so that the frequency of each reverberation curve can be established exactly. Fig. 18 shows a typical example of such a film strip taken in a studio. This technique is still in the experimental stage, but many promising results have already been reached. In order to give the impulse glide method greater usefulness, it will, however, be necessary to fix the requirements for length of tone, writing speed and several other details which have very great influence on the appearance of the final picture. Similarly, a procedure will have to be worLed out for the interpretation of the curves so as to establish a criterion for good acoustics. The B. B. C. has introduced a new conception called "colouration" in evaluating the curves, but this conception has not yet been defined in such a way as to be expressible in numbers. Up to now the greatest advantages have been 1) easy and quick estimation of the reverberation time as a function of frequency, 2) recording of reverberation curves with very small frequency intervals, 3) possible eigentones are easily observed as a result of the extended reverberation time (flutter echo, unpleasant reflection effects and so on).

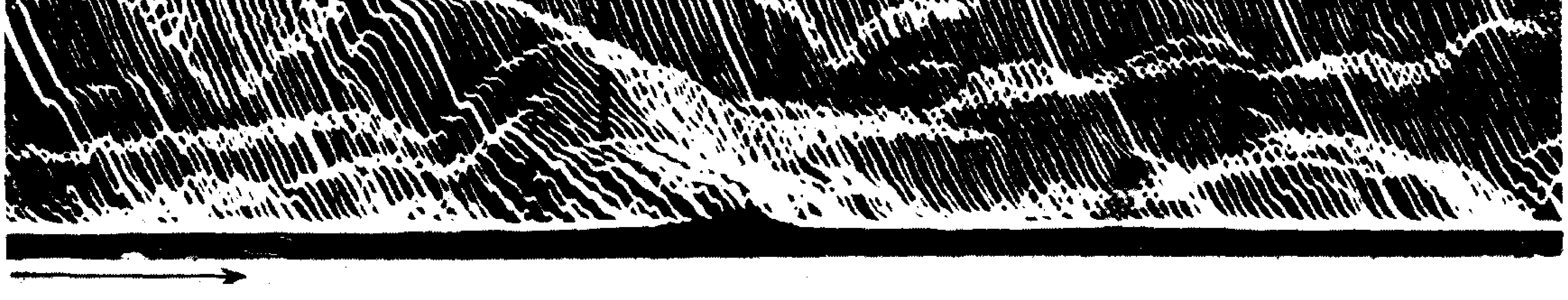


Fig. 18. A series of reverberation curves recorded with the B. B. C.'s impulse glide method, showing severe "coloutation" (100-110 c/s). Fig. 4 p. 57 in T. Sommerville, „Acoustics in Broadcasting". Loc. cit.

The B. B. C.'s impulse glide method has also however some disadvantages: A) The photographic registering of the curves is not practical, for the film must first be developed and copied before the curves can be investigated. B) The light spot diameter on the cathode ray tube can hardly be made smaller than 0.5 mm, which gives a ratio between the effective screen diameter and line thickness of 120. This relatively poor ratio makes it difficult to follow the separate curves, if these are too close to each other, or cross one another. If one could use a recorder such as type 2301, which writes with a line thickness of 0.05 mm on waxed paper with an effective width of 50 mm, the ratio would be 1000, which is considerably better than with the cathode ray tube. C) A considerable disadvantage with the use of a cathode ray tube as indicated is, paradoxical though it may sound, that the cathode ray tube is not always quicker than a mechanical level recorder, and with low frequencies often even slower. The explanation is that any level recorder is constructed with a logarithmic amplifier, a rectifier with a given time constant, and a D. C. amplifier, which controls either the cathode ray tube Y-plates or the mechanical writing system. The time constant's CR value after the rectifier must be chosen in accordance with the lowest frequency one wishes to record, but the time constant in the case of the cathode ray tube must be somewhat larger than in the case of the mechanical recorder, as only a very little superimposed A. C. voltage on the D. C. voltage to the deflection plates will pull the light spot out to a vertical stroke, which makes the registering of a proper curve impossible.

With the mechanical recorder a ripple-voltage will only give a vibration in the writing system, but on account of the inertia of the system the stylus will only shift very slightly, and distinct and attractive curves will be obtained. With high frequencies, where sufficiently great smoothing is available even with a small condenser, a cathode ray tube recorder can naturally be made to work quicker than a mechanical recorder. Furthermore, it is shown in practice that the servo-system used in the dynamic recorder can be adjusted to both integrating and differentiating feed-back, in which the different constants can be adjusted to give exactly the shortest resonance time for that writing system, so that the accuracy with transients can be surprisingly great. This advantage of a feed-back system can only with difficulty be made use of with a cathode ray tube. There is thus no advantage at all in choosing a cathode ray tube as the registering instrument.

The Universal Selector type 4406 is constructed to carry out measurements by the impulse glide method in conjuction with the High Speed Level Recorder type 2301 and the Beat Frequency Oscillator type 1012, and thus make use of the results and experience that the B. B. C. has published on this method. At the same time the limitations of the B. B. C.'s original technique previously mentioned are eliminated. The measuring set-up is just as is shown in fig.

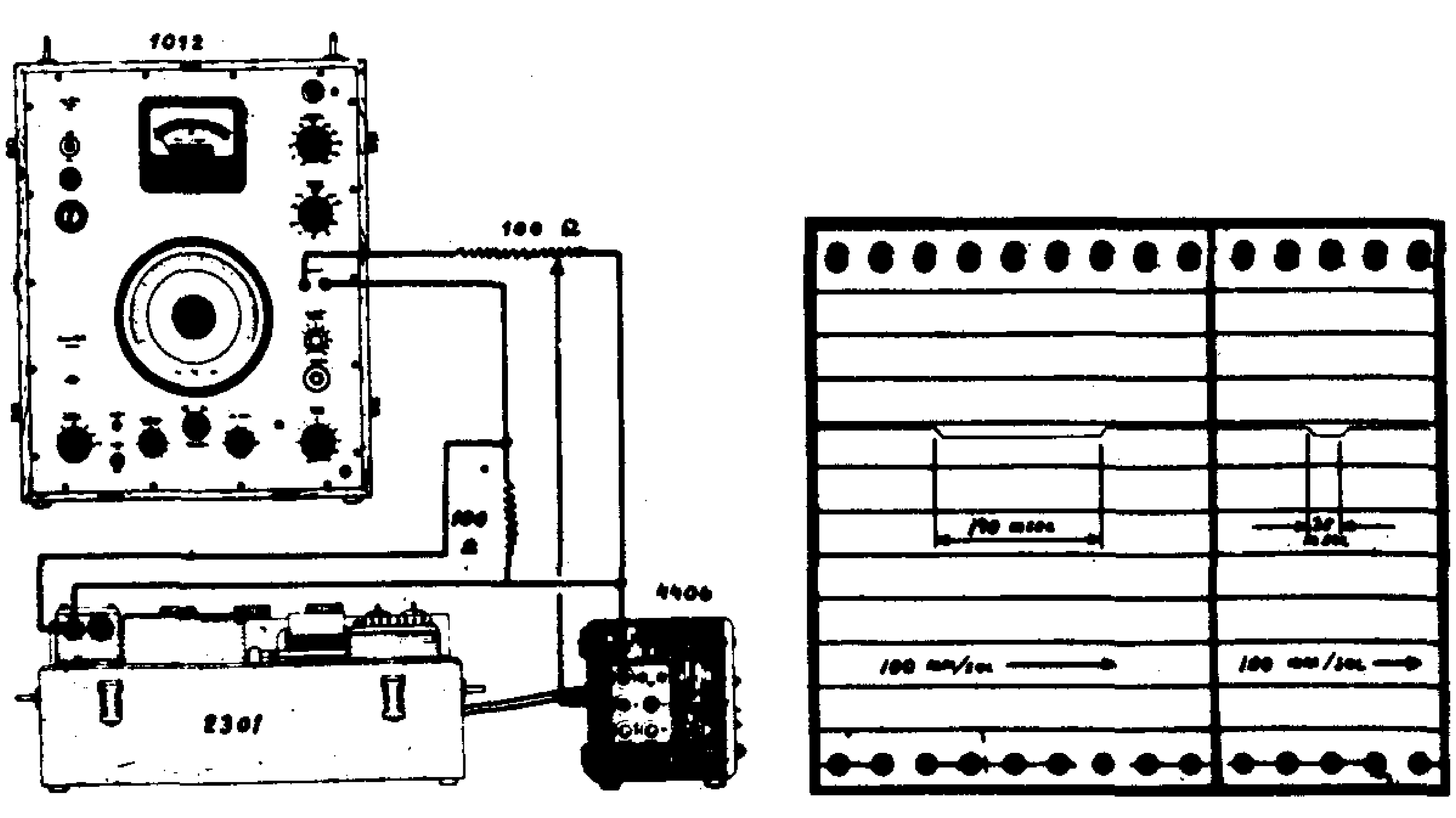


Fig. 19. Adjustment of the correct impulse length for the impulse glide method.

8, with the exception that the microphone amplifier is not connected to the beat frequency oscillator's automatic volume regulator. In the universal selector a camdisc is used which only gives an impulse in the loudspeaker circuit. The length of impulse can be adjusted by means of the contactors adjustment screws. To measure the length of impulse, which should be about 200 millisec, the loudspeaker current at 1ooo c/s should be registered direct on the recorder. If a paper speed of 100 mm/s is used, the current should be seen to stop after 2 cm, as indicated in fig. 19.

Fig. 20 shows a recording with the impulse glide method in the same room and with the same microphone and loudspeaker positions as in the reverberation curves of fig. 13, upper record. In the outlined area can be seen some typical forms of what the B. B. C. calls "colouration", and which are clear signs of bad acoustical conditions. The reverberation curves here have a rise after 10—30 db fall. By comparing this with the curve of fig. 13 upper record, it will be observed that also with reverberation curves taken with warble tone a marked "disturbance" in the same frequency region can clearly be seen. Fig. 21 shows the same curves, but recorded with somewhat greater recording speed, whereby a greater wealth of detail emerges, which is not exclusively an advantage, because the significant features become less intelligible with the reproduction of so many details at the same time. Fig. 22 shows the results of the impulse glide method carried out in the workshop where the curves of fig. 17 were taken. The same microphone and loudspeaker placing was used. The room's bad acoustics are clearly seen, expressing themselves in the recording by very obvious "colouration".

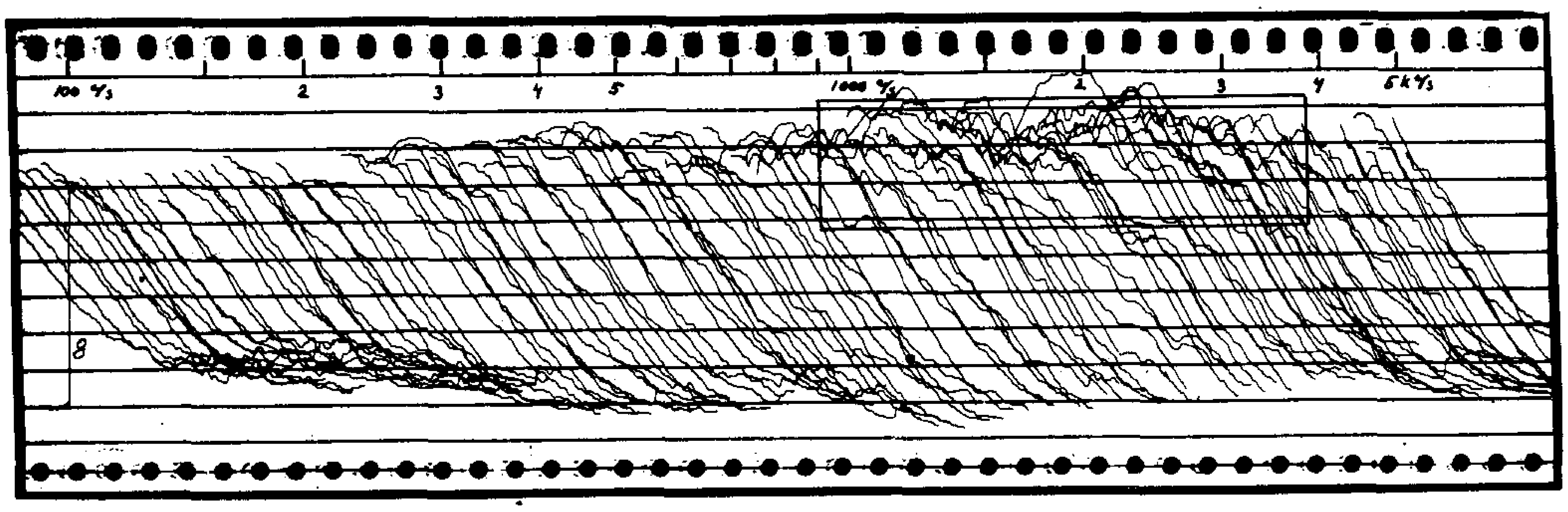


Fig. 20. Reverberation curves taken by the impulse glide method. The curves are recorded under the same conditions as in fig. 13, upper record. The framed region shows signs of "colouration". Impulse 200 millisec, W = 70 db/s, P = 30 mm/s, 50 db Pot, L = 24 cm, X3 and Y5.

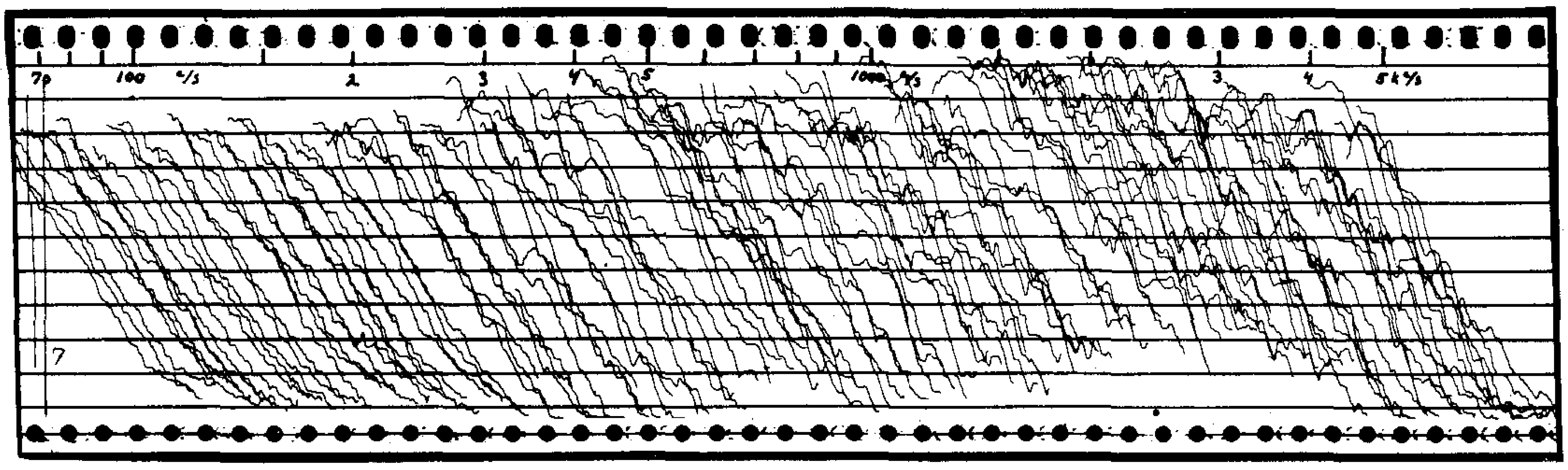


Fig. 21. Same record as in fig. 20, but taken with W = 140 db/s. Compare these curves with those of fig 13 lower record, which are warbled tone curves taken under the same conditions.

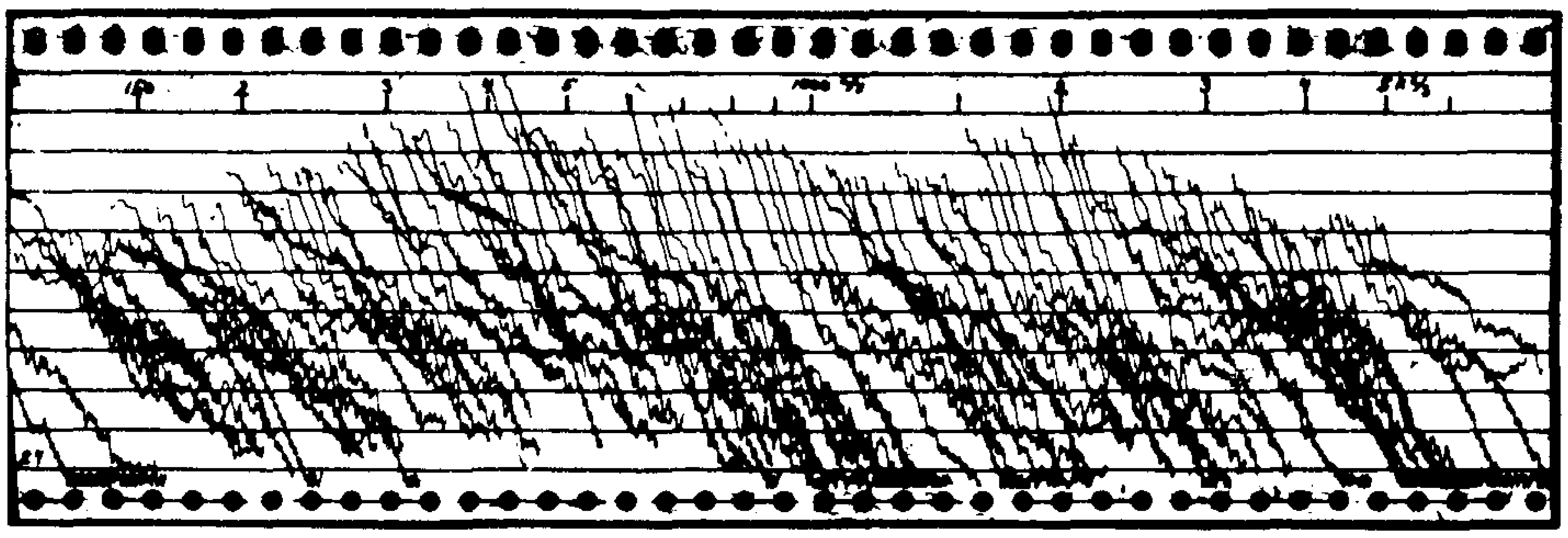


Fig. 22. Curves taken by the impulse glide method in the same work-shop as the curves in fig. 17. P = 30 mm/s. L = 24 cm. W = 140 db/s. Impulse lenght 200 millisec.

Short Impulse Method.
Reverberation measurements with warble tone and the impulse glide method are primarily investigations of a room's stationary state and as far as possible based on the room's average energy For an exact investigation of large rooms, particularly in lecture rooms and theatres, we are not only interested in the room's reverberation time, but just as much in the intelligibility of speech. It is known that the articulation will be good if the sound energy built up of direct sound together with the reflections which strike the listener within approximately 50 millisec after the direct sound, is great in relation to later arriving reflections. If the reverberation times in the rooms are large, the sound energy arriving after the first 50 millisec will be great in relation to the "useful sound", so that the intelligibility will be poor. However, the room's form and the siting of the listeners play a very important role, as it is possible by suitable shaping of the roof and walls and incorporating absorption material in the proper places to amplify the useful sound energy by concentrating the first reflection down over the auditorium and making sure that the time difference is not over 50 millisec.

Investigations recently carried out[9] have shown that it is very important that the different reflections in the useful sound fall fairly evenly dispersed within the first 50 millisec. An example of a distribution of direct sound, the first reflection within 40—60 millisec and general reverberation, is shown in the bottom recording of fig 23.[10] Articulation diagrams such as in fig. 23 are obtained by first photographing the short impulses (approx. 10—15 millisec) recorded directly on an oscillograph. As a great writing speed is required, one cannot, for reasons already stated with cathode ray tube recorders, permit the rectification of the tone frequencies and thus directly record the articulation diagrams. Up till now one has had to be satisfied with calculating the articulation diagram via the oscillograph picture. In most cases the oscillograph is used with a linear intensity axis, which limits the investigation to a level of maximum 20 db.

With the level recorder 2301 in conjunction with the universal selector 4406 it is, however, possible to record articulation diagrams directly. A paper speed of 100 mm per sec is as a rule chosen, and a writing speed of 1ooo db/sec. The impulse is 15—30 millisec. In this measuring method frequencies below about 300 c/s have no interest, as an impulse of 20 millisec has no meaning with a frequency lower than this. One should therefore work with short time constants in the recorder, and not set the lower limiting frequency below 80 c/s. As a rule a good result is obtained by making a loop of 80 cms and recording 40—50 articulation diagrams uniformly distributed over a frequency range of 4ooo—5ooo c/s. Fig. 24 shows a section of an 80 cm loop recorded in a radio-concert studio. One notices the surprisingly

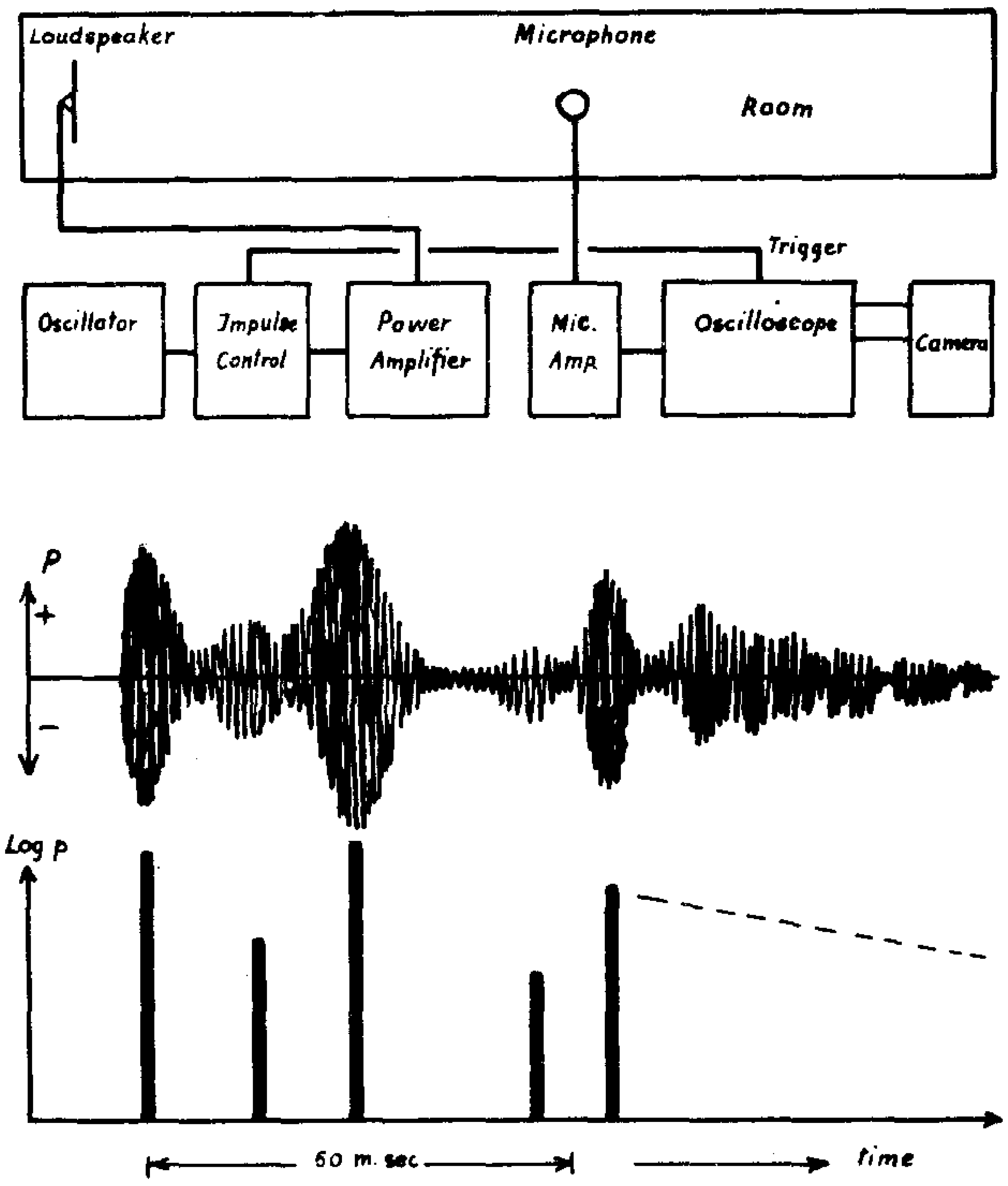


Fig. 23. Set-up for photographing oscillograms of impulses, with below an articulation diagram showing the distribution of direct sound, sound reflections during the first 50 millisec, and the general reverberation (shown as a dotted line).

slight intensity of the direct impulse in relation to the reflections arriving later, and that strong reflections arrive after 50 millisec. The curves are recorded in the audience places which are considered to be the least good.

Fig. 25 shows a range of articulation diagrams recorded in a very sound-damped room with a reverberation curve of approximately 0.2 sec. This room exhibits an outstanding intelligibility, as nearly all the sound energy strikes the listener within 50 millisec. On the other hand it will be seen from the curvature of the recordings that very powerful flutter echoes arise, which make the room's acoustics completely unsuited to music. The curves are recorded in the frequency range 500—4ooo c/s, with an impulse length of approximately 20 millisec. The section shown in the figure is taken from approximately 17oo c/s. To cover the range from 500 to 4ooo c/s a registering length of 70 cm is used. Fig. 26 shows a corresponding set of curves from a workshop. The intelligibility is quite good here, but not nearly so good, however, as in the room previous. The curves here are recorded with very great frequency intervals, so that the diagram covers frequencies from 500 til 5ooo c/s in 11 curves.

Recording of Flutter Echo.
Fig. 27 shows how it is possible with the high speed level recorder to register the characteristic flutter echoes arising between parallel surfaces, whether in a powerfully damped room or for example between two buildings. In fig. 27 the case is of two buildings at a distance of 6 metres, the loud-speaker being placed beside one building and the microphone close up against the other. Measurements were made with completely pure tones, as there is in this case no possibility of any other interference than the flutter echoes themselves, that is, the standing waves between the two buildings, as those soundwaves which have any other direction than perpendicular to the two walls will disappear. The strong fall in the level immediately after

the loudspeaker is shut off is clearly seen on the curves. Similarly it can be seen how varied and dependent on frequency is the time of commencement of the flutter echoes. With frequencies between 15oo and 35oo c/s the flutter echo begins already 10 db under the stationary level. Notice here also that the commencement level is completely constant and does not vary up and down a little as with warbled tone measurements. The damping in the flutter echo itself varies according to a reverberation time between 0.7 og 1.5 sec.

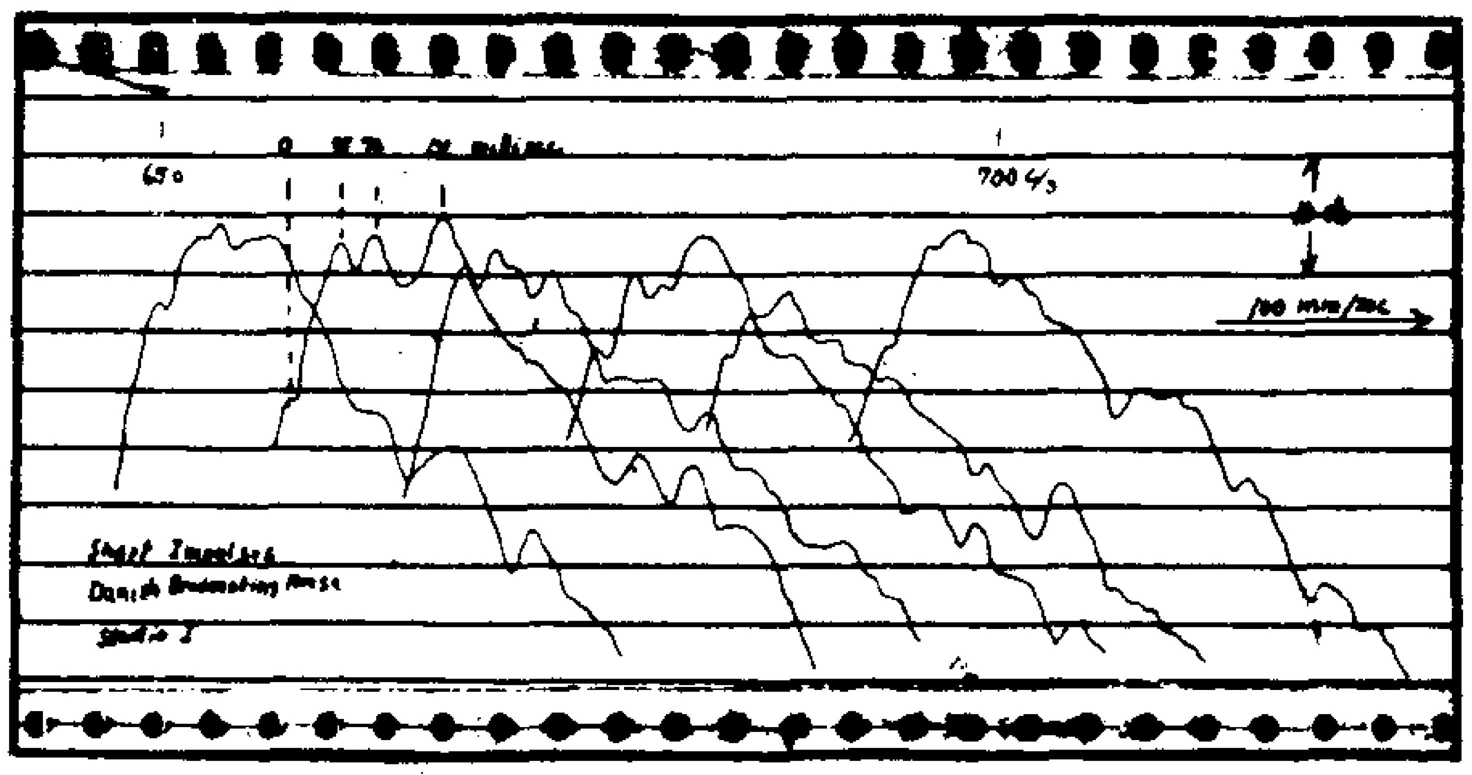


Fig. 24. Articulation diagram (short impulse recording) recorded in a large radio studio. P = 100 mm/s, W = 1000 db/s, Pot = 50 db, L = 80 cm. Impulse 25 millisec.

Measurements on Resonators.

In the antique Greek and Roman open-air theatres there were built in under the auditorium rows of large jars, the so-called resonators, which according to ancient writings should have raised the sound quality in the theatre. Vitruvius thus describes a very complicated system whereby the various jars should be tuned according to the Greek tone scale to produce the best results. These and a long list of other details from various sources suggest that the resonators worked by extending the reverberation time, which can be almost considered as nil in an open-air theatre, for those frequencies to which they were tuned. In connection with the considerable amount of investigation undertaken to clear up these problems, we shall only here indicate how, with the help of the universal selector and the level recorder, we can form a picture of the reverberation time's extension which is produced in an artificial way by these resonators. Fig. 28 shows first how the resonator's resonance frequency and damping characteristics are estimated. The resonator here being measured is a copy based on the antique description. The resonator is set up in the open air to avoid all forms of troublesome reflections. A microphone placed in front of the resonator neck holds the sound pressure around the resonator's mouth constant by means of the compressor in the tone generator. With another microphone directly connected to the input of the level recorder the sound pressure inside the resonator

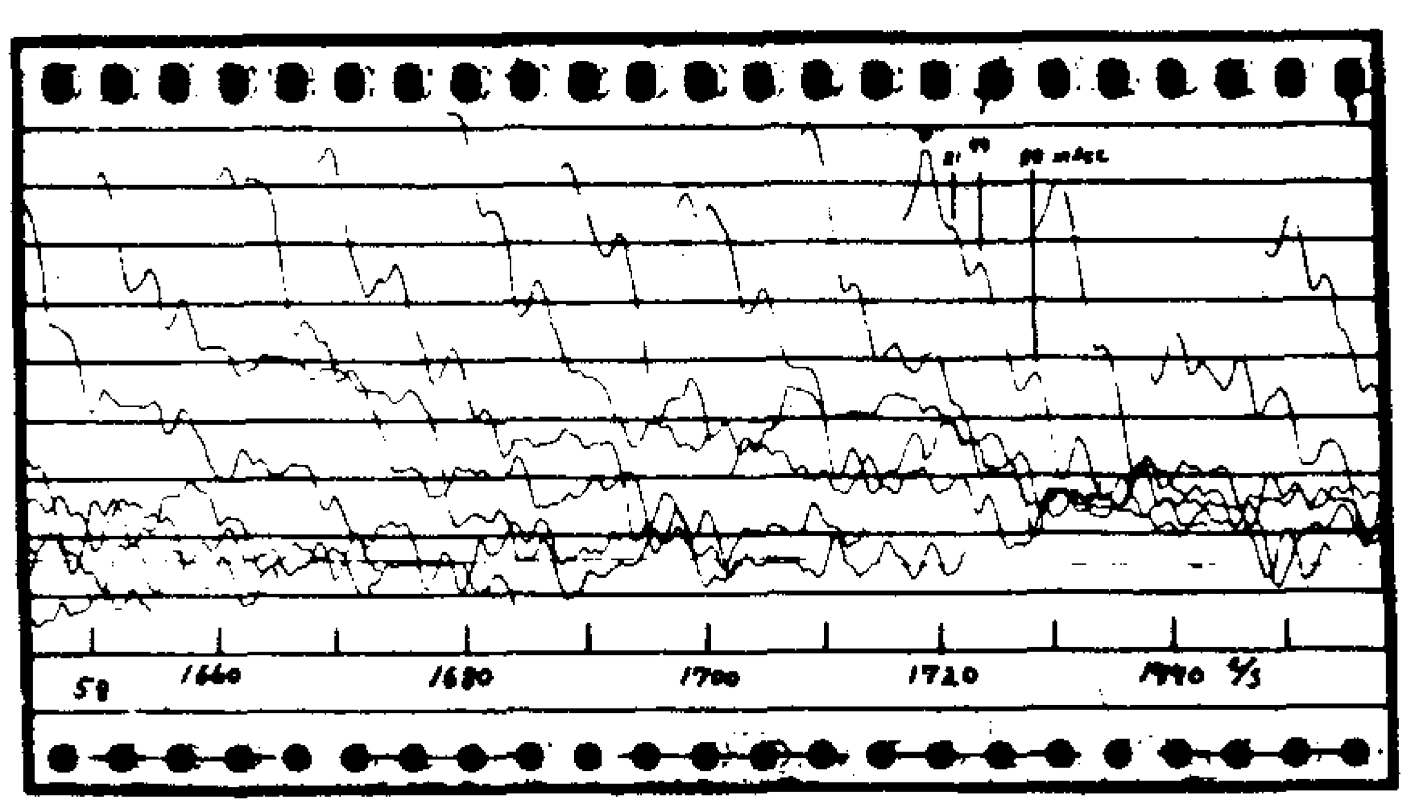


Fig. 25. Articulation diagram of a very sound-damped room with reverberation time of about 0.2 sec. P = 100 mm/s, W = 1000 db/s, L = 80 cm. Frequency around 17oo c/s. Impulse 20 millisec. Pot = 50 db.

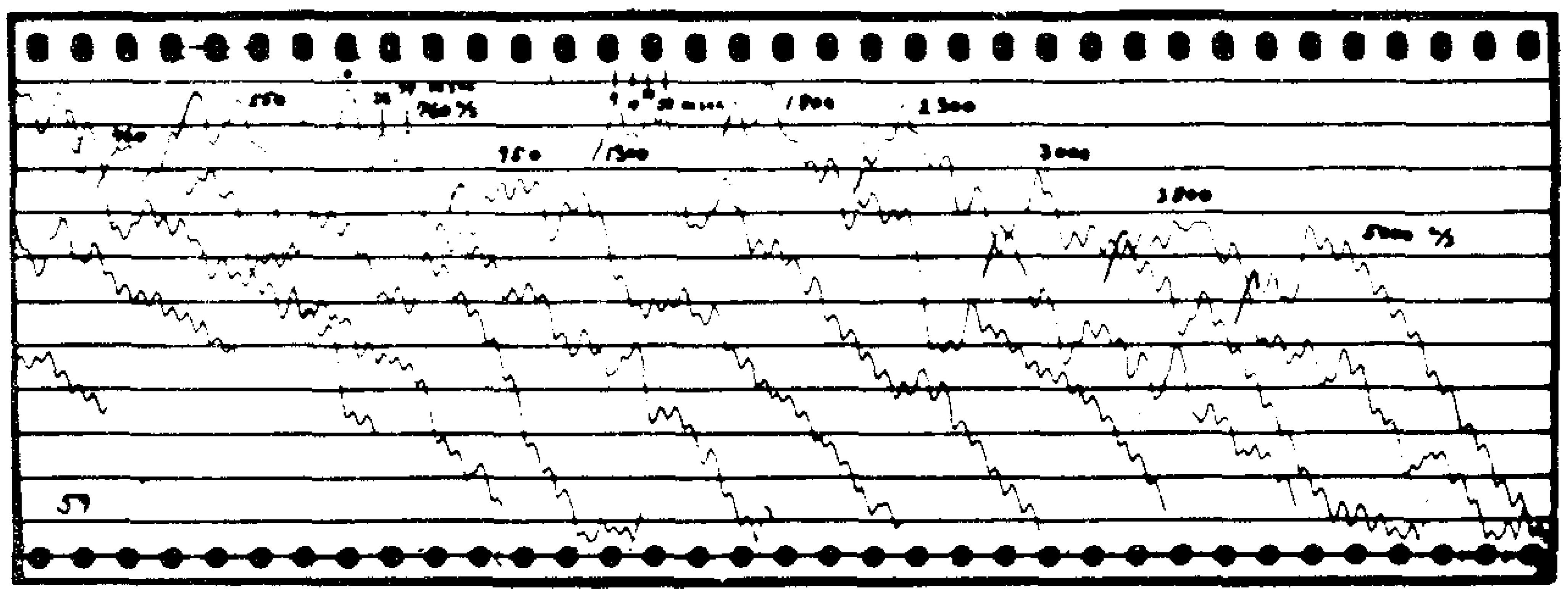


Fig. 26. Articulation diagram from a work-shop. P = 100 mm/s. W = 1000 db/s. L = 27 cm. Pot = db. Impulse 20 millisec.

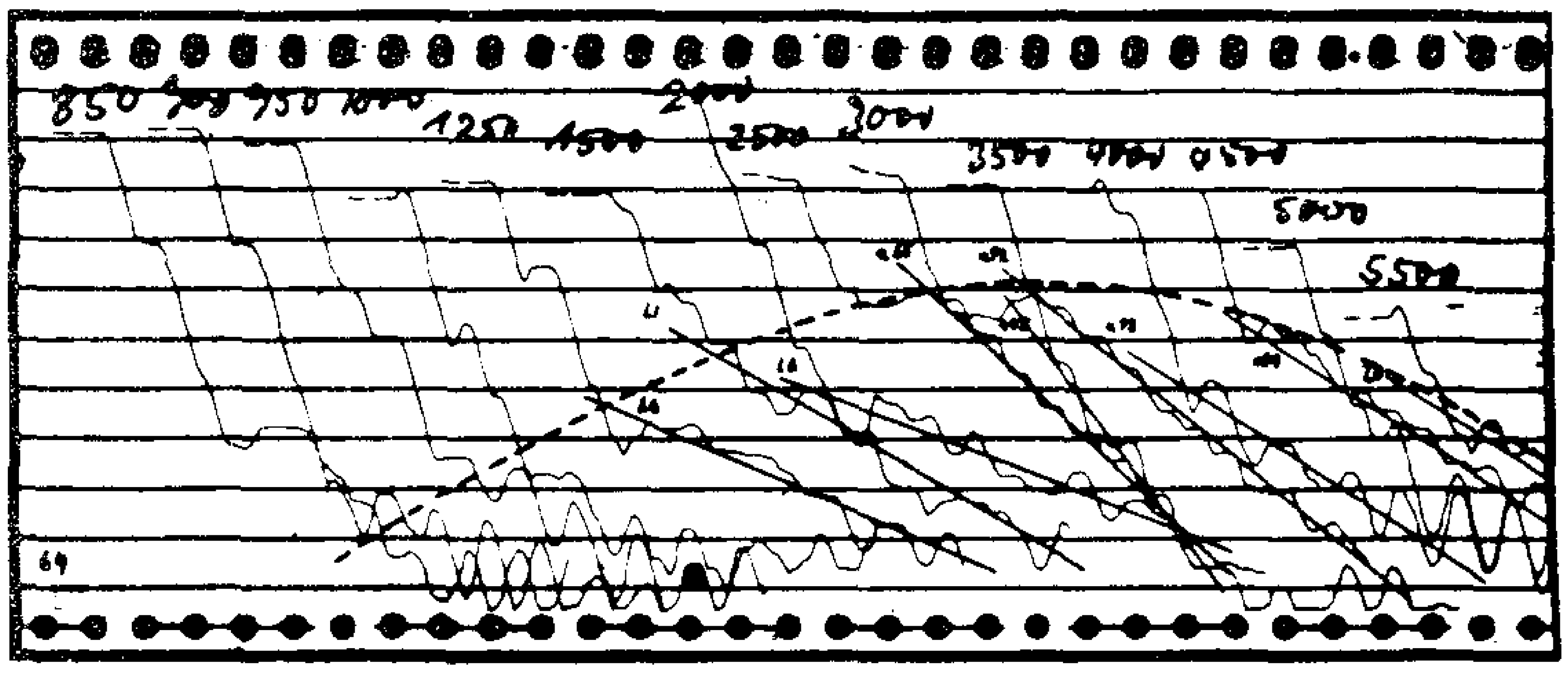


Fig. 27. Flutter echo between two buildings 6 metres apart. Measured with pure tones. P = 100 mm/s. L = 26 cm. Pot = 50 db. W = 700 db/s.

is measured as a function of frequency, and the result is as shown in fig. 28. The basic resonance frequency for the resonator lies, as is seen, around 85 c/s. The little resonance which appears around 125 c/s is due to the first "overtone", where a velocity maximum arises inside the jar itself, this phenomenon appearing because the jar is relatively extended in length. The last strong resonance around 370 c/s is due to vibrations in the body of the jar itself, that is, the jar acts as a kind of bell, which gives rise to a high sound pressure inside the jar.

For reverberation measurements the internal microphone is removed, and the "reverberations times" are measured in the open air as a function of frequency by impressing a warbled tone with a very small band width, and recording the reverberation curves.

Fig. 29 shows such a set of curves covering the range from 50 c/s to a little over 100 c/s. The output level is kept constant by using the automatic volume regulator. The extended reverberation can be clearly seen, starting right up with the commencement level around the resonance frequency of the resonator itself. The artificial resonance has thus about the same charateristics as reverberation in a room, and does not begin as a sort of flutter echo as shown in fig. 27, with a strong fall in sound level and then the reverberation effect. As can be seen from the curves, the artificial reverberation is only apparent over a very small frequency range, so that many resonators must be employed to obtain any appreciable result. Without access to the universal selector, which allows the quick recording of reverberation curves one after the other with very small frequency steps, it would be impossible to bring out the phenomena demonstrated here within any reasonable length of time.

Loudspeaker Measurements.
It is well known that a loudspeaker's quality with regard to sound reproduction is not exclusively a question of producing a straight frequency characteristic, and in the course of time a long series of investigations has been carried out to find methods of judging and demonstrating these other characteristics: For example, square waves have been impressed on the loudspeaker, and observed for deformation in an oscillograph. The phase relationships can be investigated, and in connection with the frequency characteristics one can to some extent work out those distortions which arise when impulses of various types are impressed on the loudspeaker.

The reason why a loudspeaker which can have a good frequency characteristic might incorrectly reproduce impulses and tones composed of many different frequencies is often because the speech coil or diaphragm has not enough damping in certain frequency ranges, so that individual oscillations continue to persist after the electrical influence on the speech coil has ceased. It should therefore be logical to consider investigating these oscillation phenomena by directly recording the "reverberation curves" of the sound from the loudspeaker when it has been impressed a short impulse or a suddenly interrupted pure tone. However, the reverberation times here being considered will be very short, and the measurements must of course be carried out in a room with absolutely no reverberation time, to avoid any influence from that source. Also, the measurements must be carried out with very small frequency intervals, as many of the resonance phenomena found in the diaphragm or speech coil can be very selective.

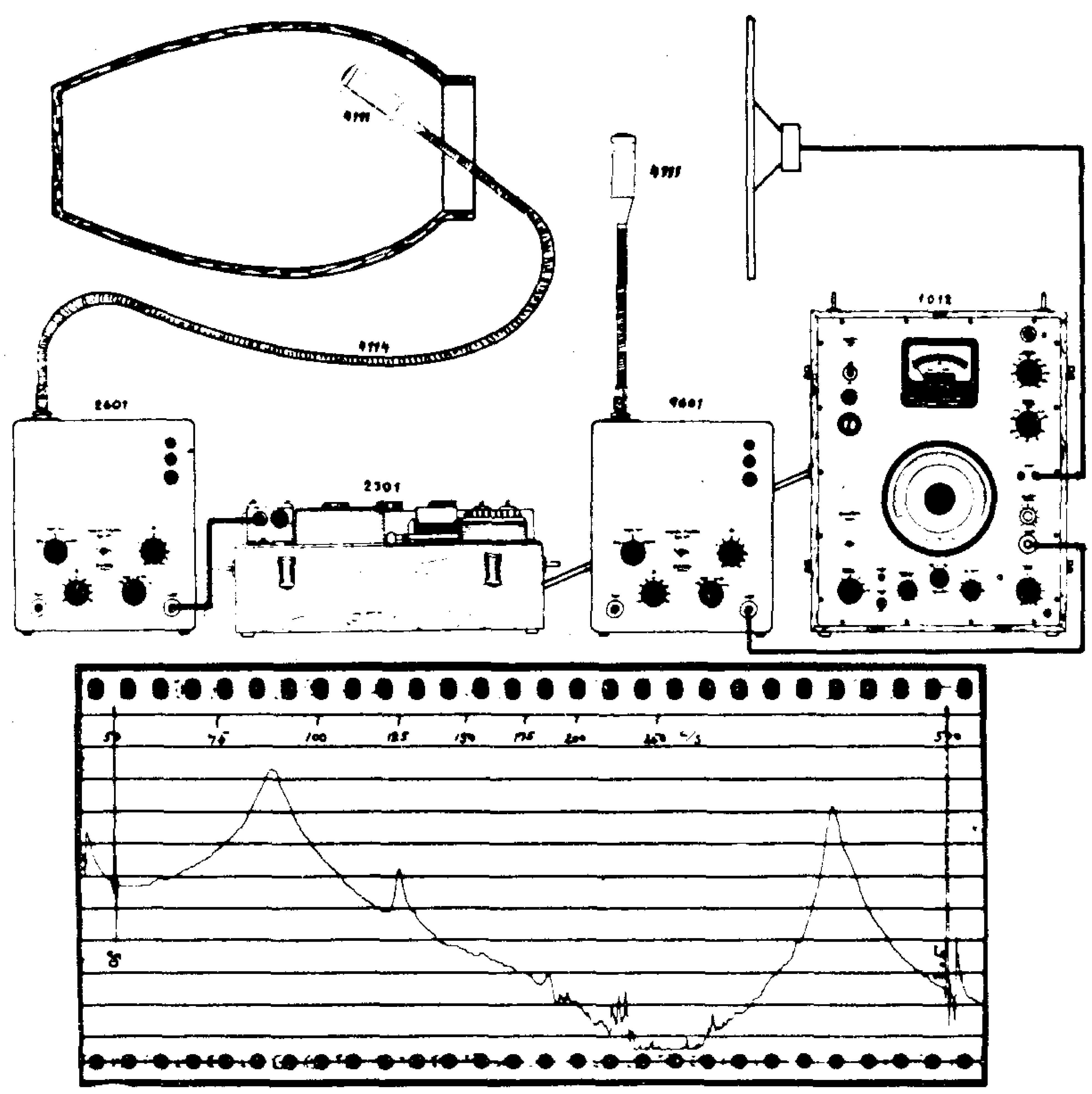


Fig. 28. Measuring set-up for recording of resonance curve of resonator, as expressed by variations of pressure within resonator. Constant sound-pressure in front of resonator. Pot = 50 db. Resonance around 85 c/s.

Fig. 30 shows a measuring set-up for loudspeaker investigations which gives many interesting details. The measurements themselves are carried out in the open, in order to obtain a sound damped space in every way. The loudspeaker's reverberation curves are recorded with a microphone placed some distance in front of the loudspeaker. For these investigations pure tones are used, impressed on the loudspeaker for some seconds and then suddenly interrupted. Fig. 31 shows thus a range of reverberation curves taken with a small loudspeaker, which however has excellent sound quality as far as subjective judgement is concerned. It will be seen that with the interruption of the loudspeaker current the sound level drops as quickly as the level recorder can follow, through a level of 20 db. Small irregularities then show up as far as a number of the curves are concerned, but as they lie so far under the maximum level, they have only slight significance. Around the loudspeaker's resonance frequency it will be seen that the tendency towards irregularities rises, so that the fall from the output level to the point where the curves begin to bend becomes rather less, but the curves show clearly that a loudspeaker of this kind is of excellent quality. The figure shows only the range from 70 to 300 c/s. Above 300 c/s the curve for the loudspeaker is even better.

Fig. 32 shows the reverberation curves from a loudspeaker of the same type as in fig. 31, but here, as the curve shows, there is a fault in the voice coil spider, so that it continues oscillating a long time after the current to the voice coil is cut off. Apart from that, the curves show that the loudspeaker has excellent characteristics on all frequencies other than the voice coil

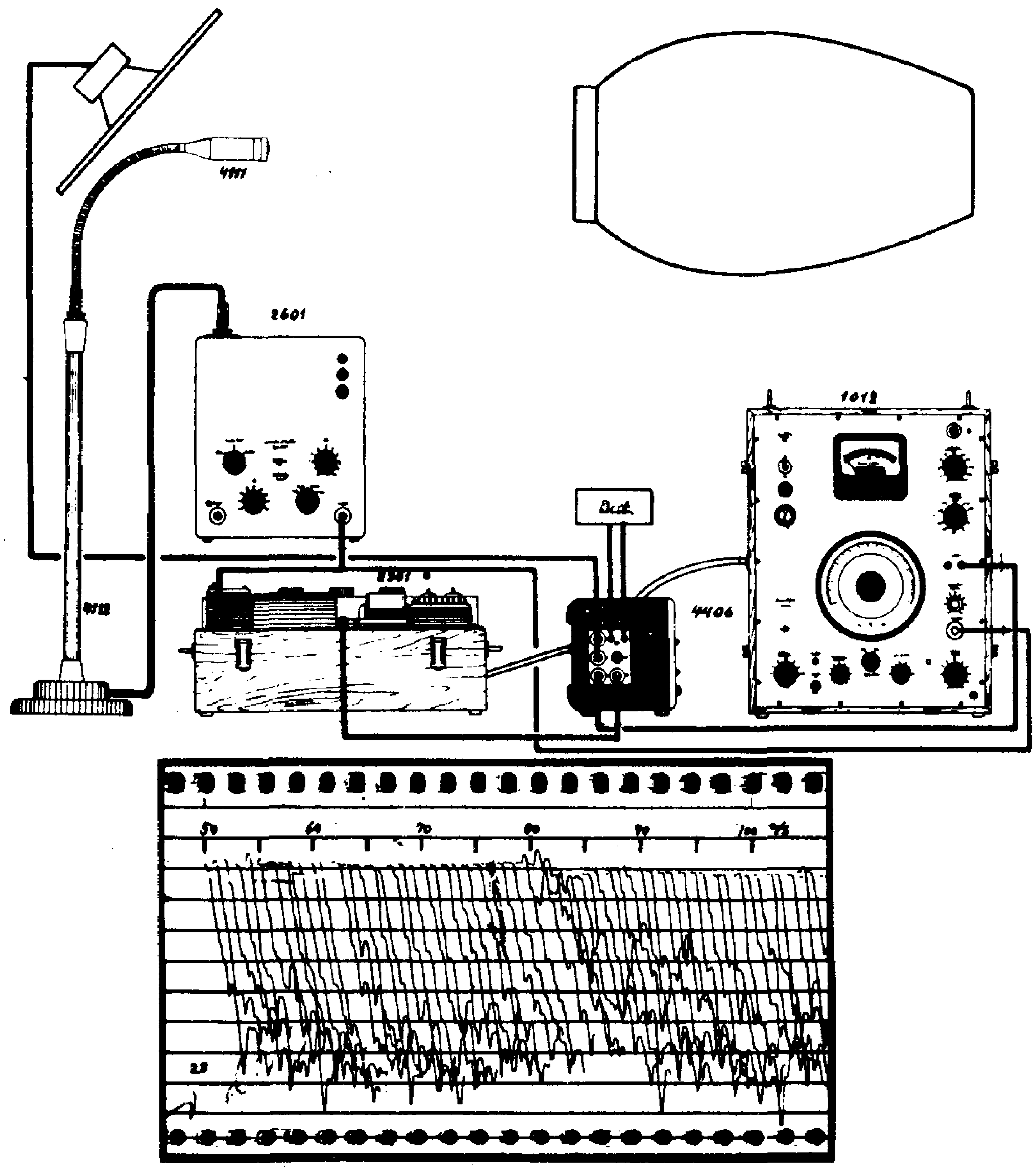


Fig. 29. Measuring set-up for recording artificial reverberations in the open air in front of a resonator. The resonator's influence begins to appear around 85 c/s. P = 30 mm/s. Pot = 50 db. L = 24 cms. W = 700 db/s. Frequency 50—110 c/s.

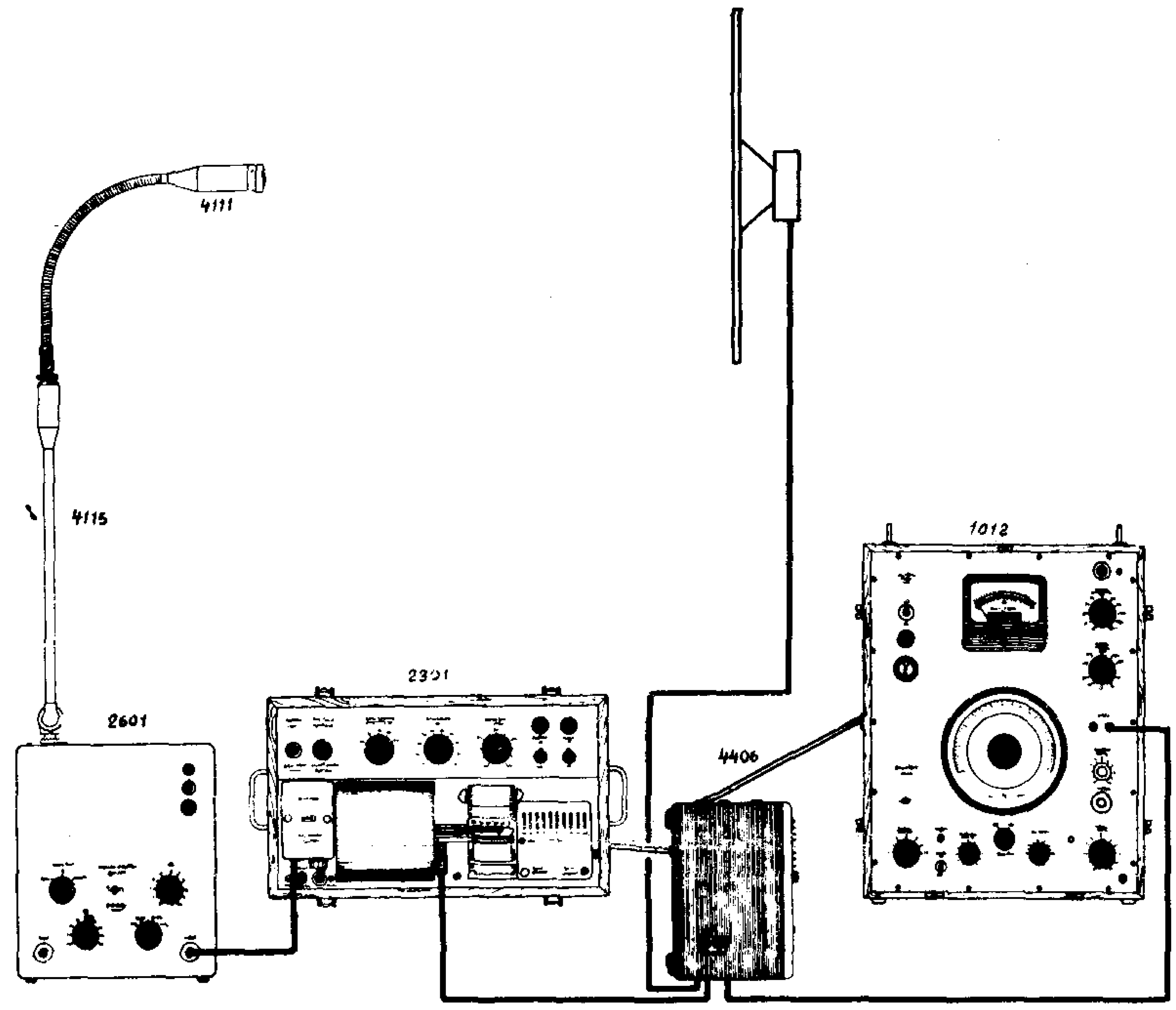


Fig. 30. Measuring set-up for investigating loudspeakers by recording their reverberation curves.

spider's resonance frequency. Another point to notice with these curves is that the upper level gives the loudspeaker's frequency characteristics, so that with this measuring method one has the frequency characteristics and the dynamic qualities shown on one and the same figure.

Fig. 33 shows the reverberation curves for a very dear and large loudspeaker, which according to the factory's report should have an excellent quality. The frequency characteristic is certainly fairly good, but a subjective judgement shows that the speaker actually sounds horrid. An investigation by means of the new measuring method shows in fact that the diaphragm and voice coil oscillate very powerfully and with a long reverberation time, over nearly the whole frequency range. With low frequencies in particular it is seen that the vertical drop in level is very short. It is easy to see from the figure that this is a bad loudspeaker, even though tests with respect to the frequency characteristics show good results. To investigate the details with this same loudspeaker in the lower frequency range, fig. 34 shows the range 50 to 300 c/s, but recorded with rather more curves. One notes that around the loudspeaker's resonance frequency, which lies at approximately 60 to 70 c/s, the curves are completely distorted, so that the ability to reproduce a pulse or discontinuity at this frequency is completely illusory.

Fig. 35 shows a loudspeaker mounted in a cabinet. The loudspeaker has a splendid frequency characteristic, and reproduction in the treble is after subjective judgement extremely good, but on the other hand it can be rather woolly in the lower frequencies. These conditions can also be seen clearly from the curves, which show good quality for frequencies above a couple of hundred cycles. To investigate the woolly section a little closer, fig. 36 shows a number of curves taken around the resonance frequency, with lesser frequency intervals, and one can see that this loudspeaker's bad qualities lie exclusively in a very small frequency range around the loudspeaker's resonance frequency. The results obtained with the help of this method are completely in accordance with the subjective interpretation of loudspeakers, so that one can say that a means had hereby been provided for the quick and precise demonstration of the whole of a loudspeaker's behavour.

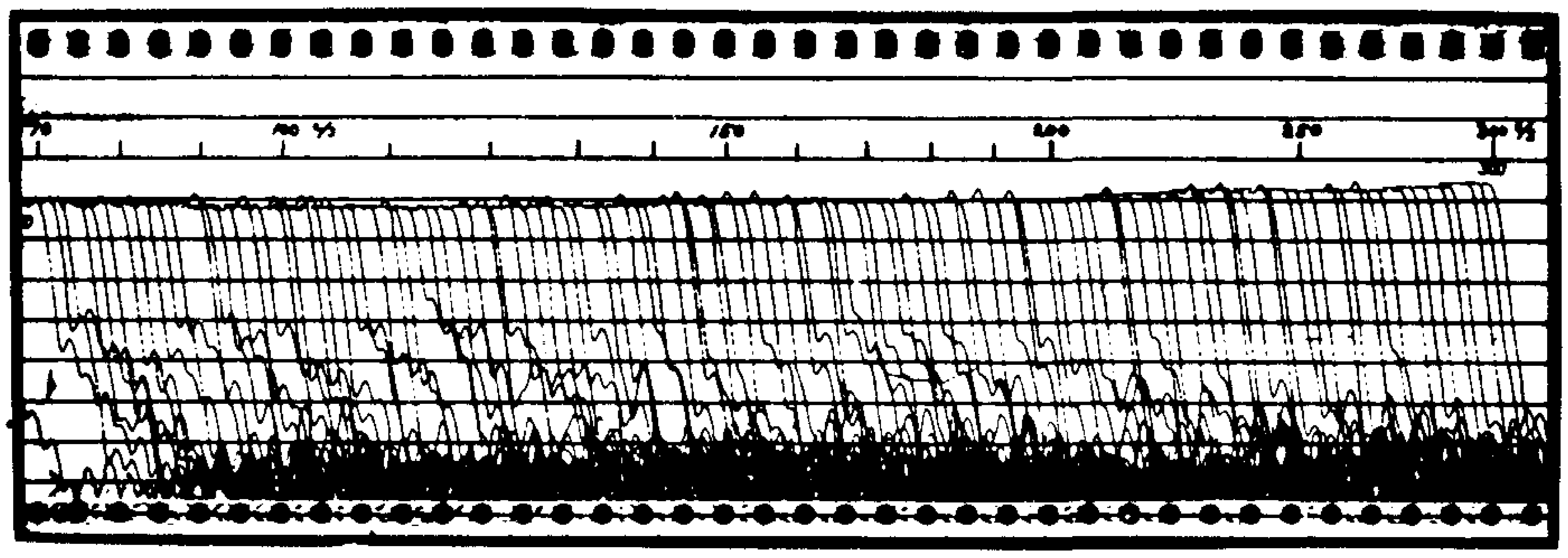


Fig. 31. ***Reverberation curves of a little loudspeaker with excellent sound quality. P = 100 mm/s. W = 1ooo db/s. Pot = 75 db. X2 and Y5 Frequency 70—300 c/s.***

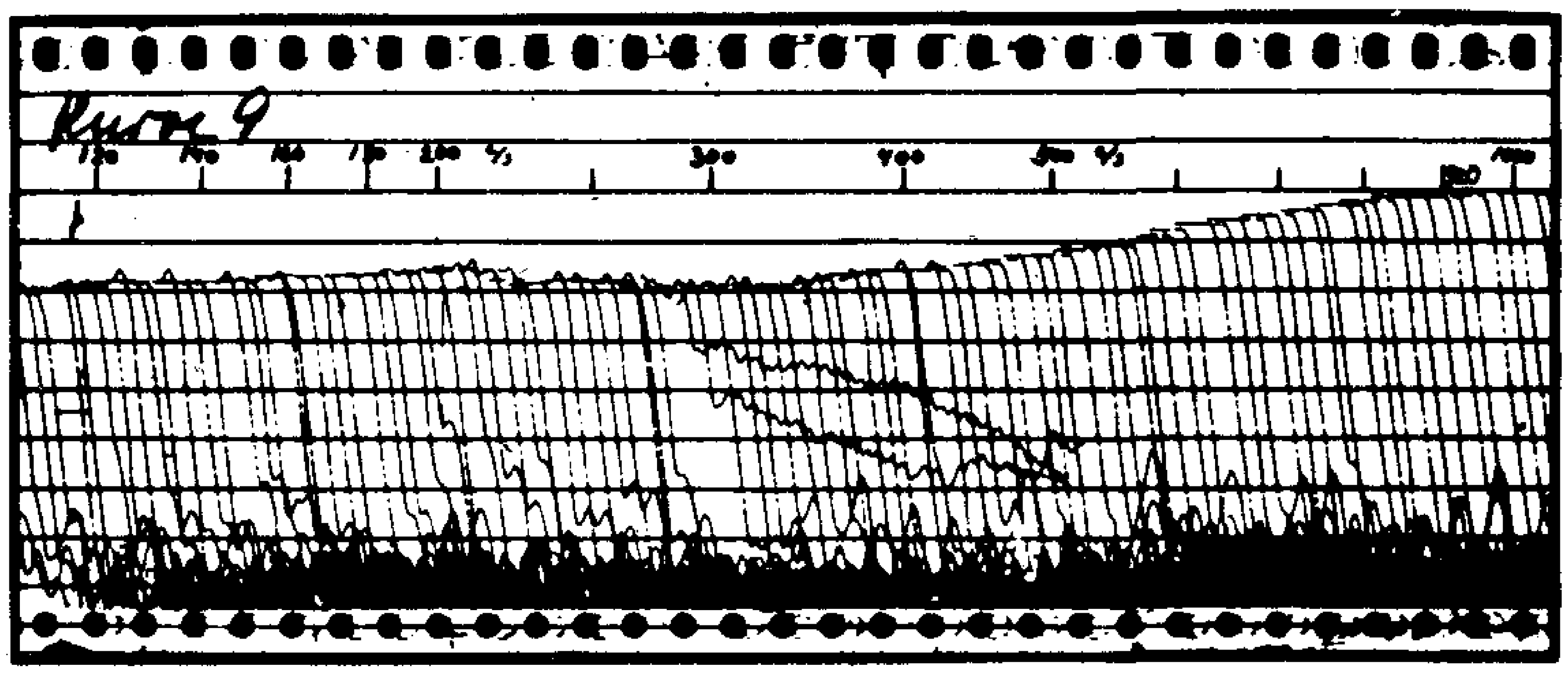


Fig. 32. ***Reverberation curves of loudspeaker of same type as in fig. 31, but with a fault in the voice coil spider about 280 c/s. P = 100 mm/s. W = 1000 db/s. Pot = 75 db. Frequency 100—920 c/s.***

Insulation Measurements.

Finally, we shall only demonstrate how the Universal Selector type 4406 can also be used for the automatic recording of sound insulation of walls, windows, doors and so on. Fig. 37 shows the measuring set-up used. A microphone is placed in both the transmitting and receiving room, separated by the wall to be measured. The microphones should preferably be of good quality, so that they have a linear frequency characteristic over the whole frequency range in which we wish to carry out measurements. Before beginning the measurements the two microphones are placed close together and subjected to an idential sound signal. The amplifiers' gain is then adjusted so that they are uniform to ± 1 db. The frequency charracteristics are then checked to see that they are uniform over the whole frequency range. The one microphone is then placed in the receiver room and the other in the transmitter room, together with the loudspeaker.

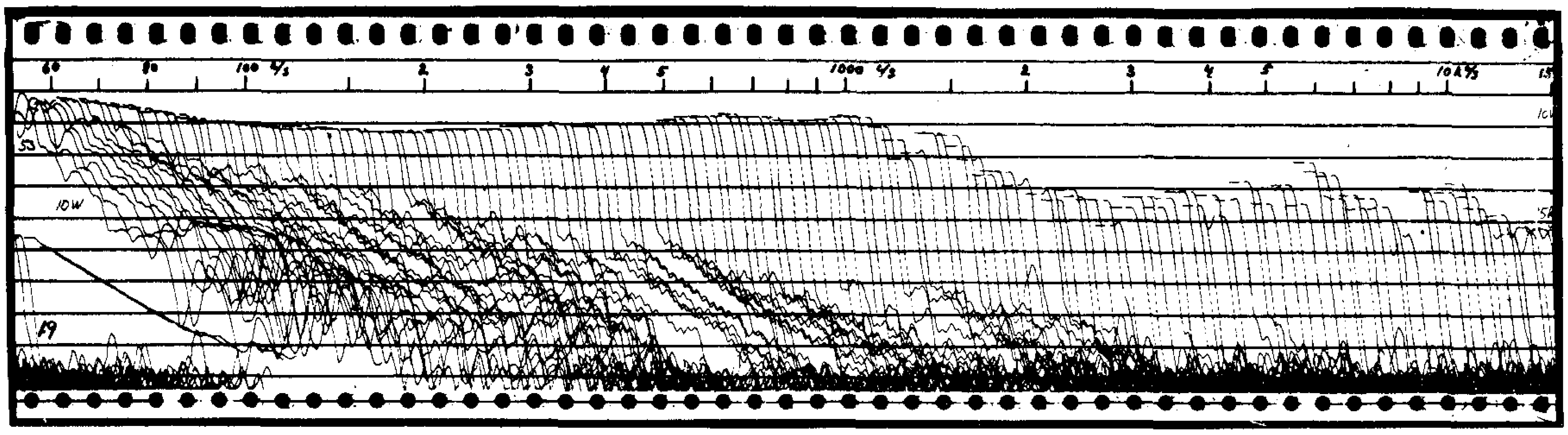


Fig. 33. Big and expensive 10 watt loudspeaker which sounds horrid. P = 100 mm/s, Pot = 75 db. W = 1ooo db/s. Frequency 53—15ooo c/s.

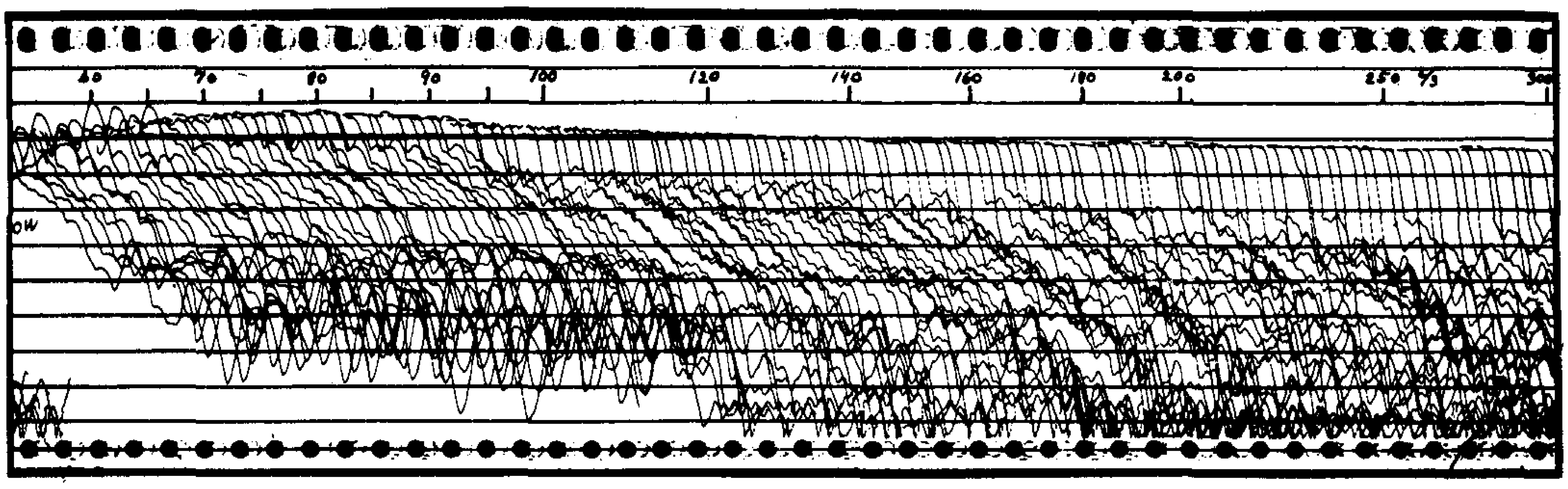


Fig. 34. Same loudspeaker as in fig. 33, but only the low frequency range from 50—300 c/s.

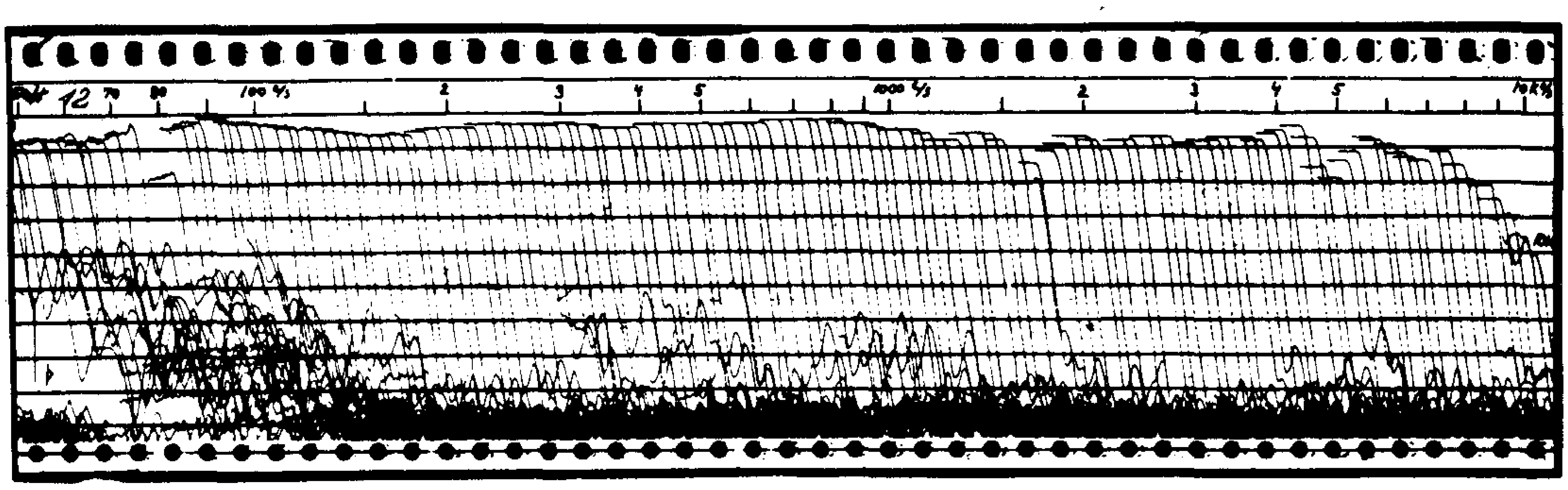


Fig. 35. Curves from a loudspeaker of fine quality in the treble, but a little "woolly" in the base. P = 100 mm/s, Pot 75 db, W = 1ooo db/s. Frequency 50—10ooo c/s.

The universal selector is then set so that it switches over from the one microphone to the other a couple of times a second, and controls the lifting magnet so that the shifting itself is not seen on the recording paper. The sound difference between the two rooms will then be recorded, as shown in fig. 38. However, it can perhaps be rather difficult to observe the difference between these two curves, which swing up and down in sound level, so one can arrange matters as is shown schematically in fig 37, where the tone generator's automatic volume regulator is used to keep the sound pressure constant in the receiver room. The sound intensity in the transmitter room will then regulate itself up and down in accordance with the test-wall's insulation properties over the frequency range. The result will be that one can read off the sound intensity difference in db direct from the upper curve.

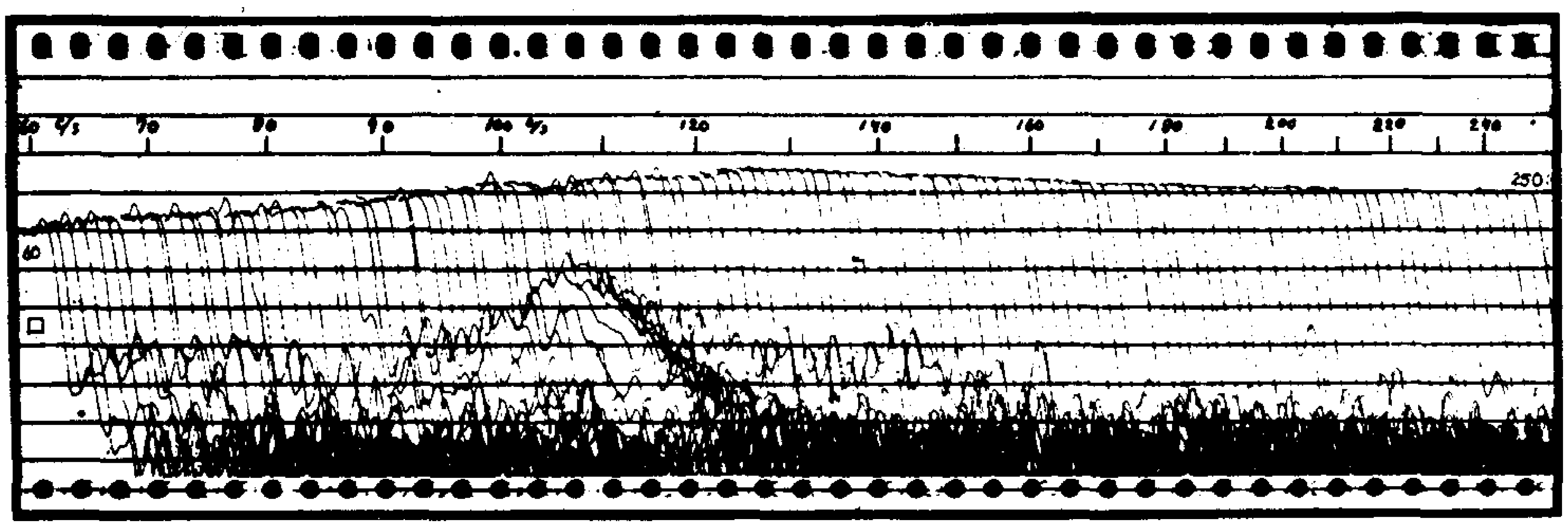


Fig. 36. The same loudspeaker as in fig. 35, but the lower frequencies are shown in more details over the range 60—250 c/s. The "woolliness" lies within a narrow range.

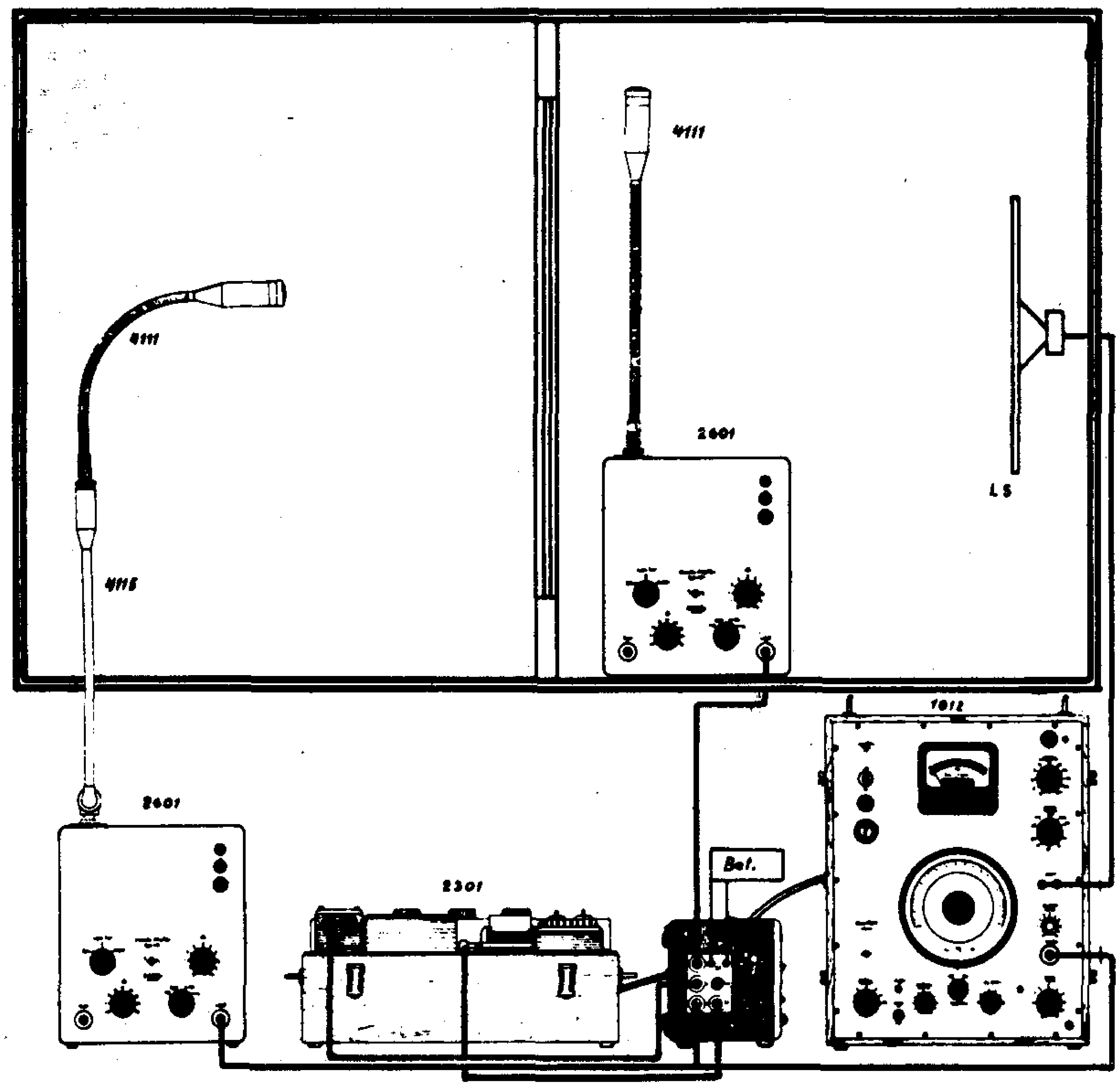


Fig. 37. Measuring set-up for the automatic recording of airborne sound insulation by means of two Condenser Microphones type 4111 plus two Microphone Amplifiers type 2601 plus the High Speed Level Recorder type 2301 plus the Universal Selector type 4406 plus Beat Frequency Oscillator type 1012 plus loudspeaker.

To obtain sufficiently uniform sound fields in both the transmitting and receiving rooms, it is necessary to use warbled tone. This is the reason why all the recorded points appear as small vertical strokes. Strictly speaking it should be unnecessary to record also the sound pressure in the receiver room, when one used the automatic volume regulator, as one would expect that the sound pressure there would be quite constant. One does not then require the universal selector at all, but as can be seen from the regulating curve, there can be such strong anti-resonant-points either in the room or the loudspeaker that the regulator cannot manage to lift the level up to the height it requires. Irregularities of this kind will immediately show themselves as a change in the sound pressure in the receiver room.

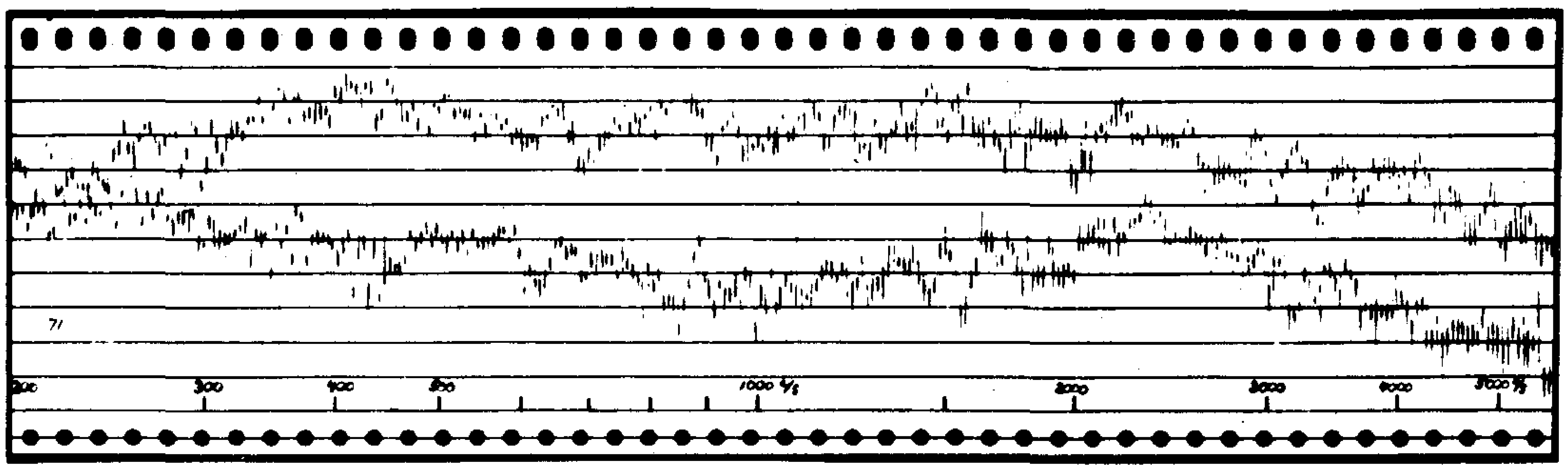


Fig. 38. Insulation measurements of a single glass wall without using the automatic volume regulator. Warble tone. P = 0.3 mm/s. W = 500 db/s. Pot = 50 db. Frequency range 200—6000 c/s.

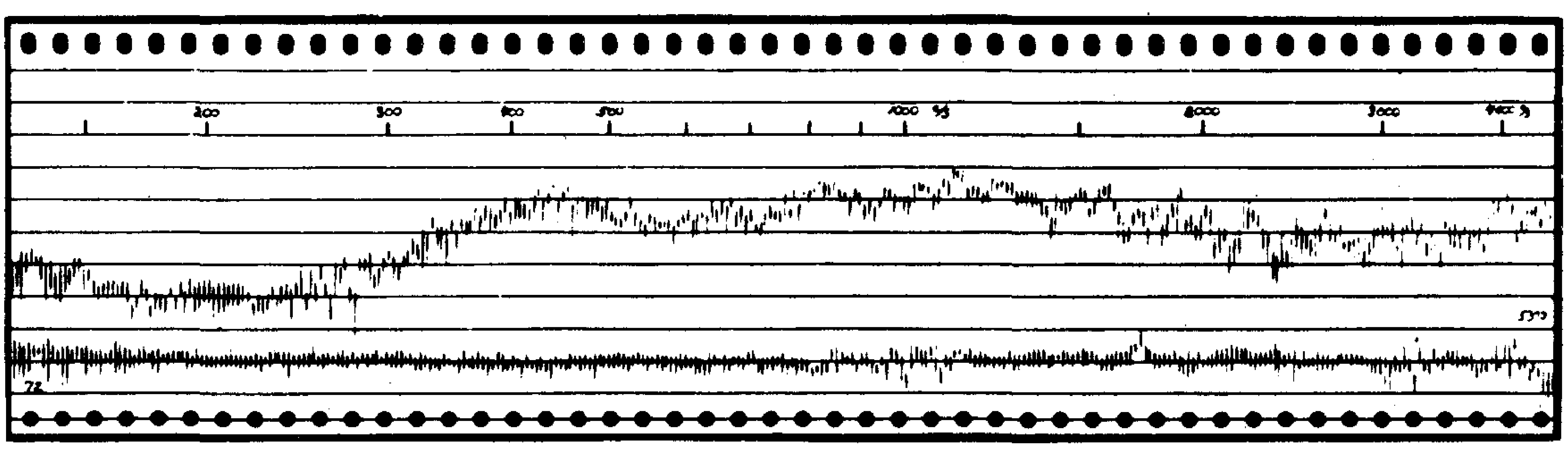


Fig. 39. The same as in fig. 38, but with the automatic volume regulator coupled in. Frequency range 120—4600 c/s.

This is also seen in fig. 39, particularly with the high frequencies, mainly as inconsiderable fluctuations in the regulation, which must wholly be ascribed to the fact that the loudspeaker has not a sufficiently uniform frequency characteristic at these high frequencies. It is therefore a great advantage to be able to record the sound level also in the receiver room, and so correct for possible faults which may arise. Notice that particularly with the high frequencies the sound transmission through the glass wall is of a very complex nature. Oscillations can be observed which are clearly caused by various transverse and longitudinal resonances in the wall, expressed as rapid changes in the insulation characteristics. The curves measured in this case are taken on a glass wall with 3 mm thick panes.

Footnotes.

1. Per V. Brüel: *"Sound Insulation and Room Acoustics"*. p. 179, Chapman & Hall, London 1951.

2. P. M. Morse & R. H. Bolt: *"Sound Waves in Rooms"*. Rev. Mod. Phys. Vol. 16, p. 114 (1944).

3. Brüel & Kjær: *"Condenser Microphone, type 4111"*, B & K., Nærum (1950). This publication describes the construction, use and adjustment of this laboratory measuring microphone.
4. Brüel & Kjær: *"Microphone Amplifier, type 2601"*, B. & K., Nærum (1949).

5. Brüel & Kjær: *"Beat Frequency Oscillator, type 1012"*, B. & K., Nærum (1952).

6. First publication was in the Danish Journal "Ingeniøren", Vol. 50, p. E. 153—160, København 1946.
   Per V. Brüel & M. Ingård: *"Hurtige Niveauskrivere (High Speed Level Recorders)"*.
   Abbreviated article in the Journal of the Acoustic Society of America, Vol. 21, p. 91—93 (1949).
   See also L. L. Beranek: *"Acoustic Measurements"*, John Wiley & Sons, New York 1949.
   A detailed description will be found in B. & K., *"Technical Review, Jan. 1949", New Instruments in Acoustic Research.* In this publication a certain amount of information is also given on the special tone generator.
   The most detailed description with different applications will be found in Brüel & Kjaer, *"Level Recorder, type 2301"*, Brüel & Kjaer, Nærum, (1951), also distributed by The Brush Development Company, Cleveland, Ohio (1951).

7. See further the theoretical basis for these rules p. 189 of *"Sound Insulation and Room Acoustics", loc. cit.*

8. T. Sommerville: *"Acoustics in Broadcasting"*, Building Research Congress 1951. Division 3, Part I, p. 53.

9. H. Haas: *"Über den Einfluss eines Einfachechos auf die Hörsamkeit von Sprache"*, B. R. S. L. C. 363 (1949) and Acustica Vol. 1, Nr. 2, p. 49 (1951).