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Testing and Adjusting Speaker Installations with the Sound-Survey Meter

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Sound-level measurements in rooms containing speaker systems provide interesting and important data not obtainable from electrical measurements or listening tests alone. This paper discusses techniques of obtaining relatively smooth and reproducible frequency-response curves under typical home room conditions, using a new ultra-miniature sound-level meter. Curves thus taken will be presented for an adjustable bass reflex unit with and without absorbent material.

THE OBJECT of this paper is to describe techniques of making acoustic frequency-response measurements on speaker systems in the rooms where they are to be used. These techniques are illustrated by results of measurements on several typical speakers, and the effects of certain variables are demonstrated.

Frequency response is, of course, only one of several factors important to good sound reproduction. Nevertheless, there is no substitute for good frequency response, and it is important in evaluating a reproduction system to have accurate frequency-response data. Listening tests by trained listeners can be very useful in evaluating the overall quality of a speaker system and can to a small extent evaluate individual factors, including frequency response, but listening tests give very rough data only, and results are subject to differences of opinion, often strong. Wholly electrical measurements, using the speaker voice-coil voltage developed by a constant current as a measure of impedance magnitude, are sometimes helpful, but they are difficult for most people to interpret and only give part of the desired information. For example, the characteristics of the typical listening room have no appreciable effect on voice-coil impedance, yet they do have an important influence on response. The only way to obtain accurate quantitative data on overall acoustic frequency response is to measure sound-pressure level directly by means of a sound-level meter or its equivalent.

Factors affecting overall response are acoustic power output, total room losses (absorption and transmission to outside), speaker system directivity, and room reflections producing standing-wave patterns. The average sound-intensity level in the room is primarily determined by the first two factors, and the sound distribution, or the manner in which sound-pressure level varies from point to point within the room, is primarily determined by the second two factors. To illustrate the foregoing statements, the listening room can be thought of as being a reservoir for acoustic energy. This reservoir is being supplied with acoustic energy by the speaker, and the rate of supply is, of course, equal to the acoustic power output of the speaker. If the room walls, floor, and ceiling did not allow any energy to be transmitted through them to the outside and if they were, in addition, lossless and did not absorb any of the acoustic energy by converting it to heat through friction, then the reservoir would have no leakage, and the energy level would build up without any limit. Such a lossless room is, of course, impossible to achieve and is also undesirable. All rooms allow some degree of transmission to the outside and some degree of absorption. The total rate of energy loss through transmission and absorption is proportional to the energy level within the room, to the total area of the room surfaces, and to the transmission and absorption coefficients, respectively, of these surfaces. It can be seen that with a given speaker power output the acoustic-energy level in the room builds up until the rate of energy loss equals the rate of energy supply, at which point the energy level is stabilized. With this picture in mind it is easy to see why a given amount of speaker power will produce a higher sound level in a "live" room (low losses) than in a "dead" room (high losses). Also, since total losses for a given type of wall material go up as total surface area increases, it is clear why a given amount of speaker power will set up a higher sound level in a small room than in a large room of the same type.

To continue the reservoir analogy, the directivity characteristics of the speaker determine the manner in which the "stream" of acoustic energy enters the reservoir, and standing-wave patterns are set up by multiple wall reflections of this energy stream, which is a pulsating stream.

The above description is clearly greatly simplified. Possible interacting effects, such as the influence of the standing-wave pattern on the acoustic impedance presented by the room to the speaker and the consequent effect on acoustic power output, are omitted. However, the simplified picture is helpful in explaining observed effects during measurements.

For example, the standing-wave pattern is a rapidly varying function of frequency, and if sound-pressure level is measured at a fixed point in the room as frequency is changed, it is well known that the response curve so obtained will be very irregular, even in regions of frequency where the system response is supposed to be flat. The irregularities are so large that they often completely obscure significant characteristics of the system response curve, such as a "notch" produced by an improperly adjusted crossover net-

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work. After experiencing this type of result, an experimenter is apt to look for permission to use a nearby anechoic chamber, thus effectively eliminating standing waves, but he will find that this approach has its difficulties. The effects of speaker directivity become important, for one example. A response curve taken with the sound-level meter at a fixed point in an anechoic chamber will generally show large irregularities, particularly at high frequencies, that are due to combinations of in-phase and out-of-phase waves from different parts of the speaker assembly, on which mechanical standing waves can exist. In the case of a bass reflex speaker, waves from the port opening can cancel waves from the speaker opening at low frequencies. These irregularities, which show up in an anechoic chamber, do not have the same significance in a normal listening room with reflecting walls, because multiple reflections from the walls help greatly in distributing the sound energy and thus partially compensate for directivity effects.[1] Therefore, in order to obtain a representative result for an overall response measurement in an anechoic chamber, it is necessary to average out these directivity effects by making measurements at a number of points, equidistant but at different angles from the speaker, and to average the results. If the speaker to be measured is of the corner-horn type, in which the walls of the listening room provide the final part of the horn, there is the problem of simulating room conditions properly in the anechoic chamber. Presumably this can be done by erecting two walls and the floor of hard, reflecting material in one corner of the chamber, but it can be seen that having an anechoic chamber available does not necessarily simplify the measurement problem. If anything, it is an invitation to spend a lot more time preparing for and making measurements, although certainly more information can be obtained in the long run.

Returning our attention to response measurements made in normal rooms, and with reference to the irregularities caused by the shifting of standing-wave patterns and speaker directivity, it is desirable to eliminate these irregularities from the measurement. Thus one can obtain results in the form of a relatively smooth curve that represents correctly the average sound level as a function of frequency and that illustrates the combined effects of speaker acoustic power output and total room losses. Such a result represents the performance of the speaker system and room as a whole. It has been found that the effects of standing waves and speaker directivity in normal rooms can largely be eliminated from response curves if at each frequency sound-level readings are taken at several points distributed within the room and the average of these readings is used for plotting the curve. The exact number of points and their exact location are not at all critical, a number of points between five and ten being satisfactory. The larger number will give somewhat smoother response curves and better reproducibility of data. In all the following measurements ten points were used, since a small adding machine was available, and the average could be obtained by moving the decimal point in the total. Another simple method of averaging if, say, five points were used would be to plot the totals on one scale and then to label the resulting curve with a scale related to the first by a factor of 5. Curves taken by this method are fairly smooth and are reproducible to a highly satisfactory, almost surprising degree.

FIG. 1. Sound-survey meter.

MEASURING EQUIPMENT

The instrument used to measure sound levels in the measurements reported below is called a *sound-survey meter* because its small size (6″ × 3⅛″ × 2½″) and light weight (1⅞ lb) are particularly welcome in sound-survey work.[2]

Figure 1 shows the instrument held as it would be held in actual use, with the thumb in position to adjust the "level" attenuator so as to obtain an on-scale meter reading for the sound being measured. The readings are in decibels referred to 0.0002 μbar, the standard reference level for sound-level meters. The only other control, on the left side, turns the instrument on and off, selects the frequency characteristic desired, and permits the condition of the plate and filament batteries to be checked by means of the panel meter. The microphone is flush-mounted in the small side of the case at the upper left corner of the photograph. The

[1] H. F. Hopkins and N. R. Stryker, A Proposed Loudness-Efficiency Rating for Loudspeakers and the Determination of System Power Requirements for Enclosures, *Proc. Inst. Radio Engrs.*, **36**, 315–335 (1938).

[2] Arnold Peterson, The Sound-Survey Meter, *General Radio Experimenter*, **XXVI**, 11, (April, 1952).

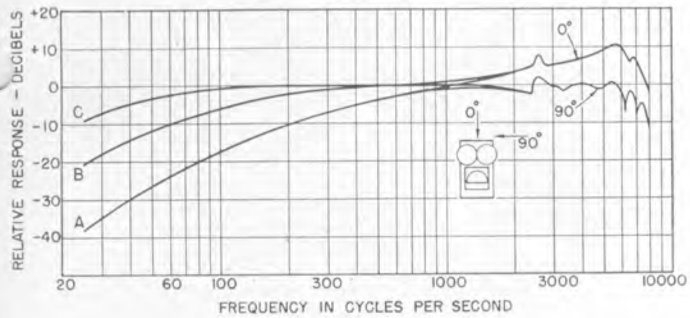

FIG. 2

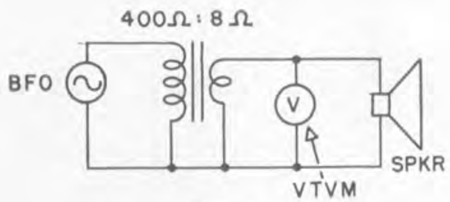

FIG. 3

sound-survey meter can be set on a table or mounted on a standard tripod for measurements at a single point; but for taking readings successively at several points in a room in order to determine average sound level, it is convenient to hand-hold the instrument.

Figure 2 is a plot of the sound-survey meter frequency response. The response curves labeled *A* and *B* approximately correspond to the response of the ear to pure tones at levels of 40 db and 70 db, respectively; the curve labeled *C* corresponds to the ear response at 100 db and is the response that was used for these measurements. All the speaker response curves to be presented have been corrected below 100 cycles in accordance with the *C* curve. As noted above, ten points were used to determine average sound level; and the lf response correction was incorporated by adding ten times the correction to the ten level readings before taking the total.

In order to check the performance of the sound-survey meter, a number of measurements were made with a standard sound-level meter,[3] which is a more accurate, stable, and versatile instrument but which costs nearly three times more than the sound-survey meter. The agreement between results of measurements was very close. In order to establish that harmonic distortion at very low frequencies was not high enough to cause errors in sound-level readings, a narrow-band sound analyzer was used.

The speaker under test was driven, as shown in Fig. 3, by an audio oscillator having less than 0.25% distortion. A toroidal output transformer provided a favorable match between the 8-ohm voice coil and the 600-ohm oscillator. The voice-coil voltage was measured directly by means of a vacuum-tube voltmeter and was held constant at 0.6 v for all measurements. This level was high enough to override most background noises without being uncomfortably high. Generally, in checking a reproducing system, the input voltage applied to the system amplifier would be held constant; but this paper is concerned primarily with the loudspeaker and the room in which it is located. Actually, a good, modern amplifier would maintain constant voltage on the speaker voice coil because of the very low output impedance obtained using feedback.

[3] E. E. Gross, Type 1551-A Sound-Level Meter, *General Radio Experimenter,* XXVI, 10 (March, 1952).

RESULTS OF MEASUREMENTS

Figure 4 illustrates the nature of acoustic response curves obtained when the sound-survey meter is in a fixed location in a typical living room. The speaker was a large bass reflex speaker. Frequency was varied slowly while voice-coil voltage was held constant, and maximum and minimum readings of the sound-survey meter were noted. No attempt was made to determine the shape of the curve at intermediate points, because this is very difficult to do without a continuous recorder. As described previously, the rapid shift of room standing-wave patterns with respect to frequency caused large irregularities in the response curve. Above 300 cycles both the rapidity and the violence of the irregularities increased so fast that it was impractical to continue the curve without a recorder, even plotting only the maxima and minima. The behavior between 200 and 300 cycles is but a mild forerunner of the higher-frequency behavior.

One method for getting smoother curves is to make measurements outdoors, which is the closest approximation to an anechoic chamber that most of us can obtain. Figure 5 is an example of the result obtained in a typical suburban back yard with the large bass reflex speaker again. The curve is smooth enough so that up to 2,400 cycles it was possible to plot every little irregularity, but above 2,400 cycles the irregularities became rapidly worse, and only maxima and minima were plotted. This technique produces smooth curves at low frequencies, but not at high frequencies. However, to the extent that it is useful in eliminating effects of standing waves, it has the same disadvantages as the anechoic chamber; namely, speaker directivity characteristics have too much effect, and the characteristics of the listening room are not included in the results. In this curve, for example, there is a hump at 35 cycles that is considerably smaller than later measurements show. This may result from the fact that the sound-survey meter was placed directly in front of the speaker at a distance of only 6 in. and, therefore, was not in a position to respond properly to the lf radiation from the bass reflex port 15 in. below. Measurements taken so close to the speaker are also subject to hf proximity effects that are not representative of listening conditions. However, the background noise level outdoors,

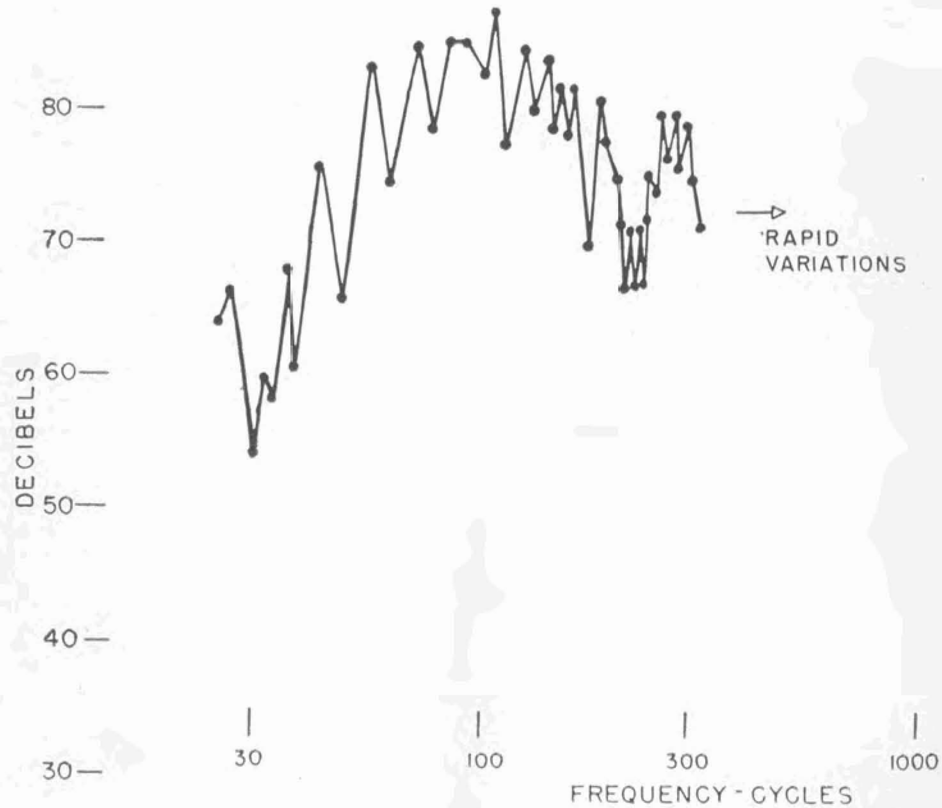

FIG. 4. One-point response, indoors.

in the New Jersey suburbs at least, is fairly high, owing to frequent airplanes, power lawnmowers, and delivery trucks; and there is a limit to how loud the test tones can be made without overloading the speaker at low frequencies and, incidentally, without annoying one's neighbors. It was for these reasons that the measurements of Fig. 5 were made with the sound-survey meter so undesirably close to the speaker, and these reasons are felt to be a major and important disadvantage of outdoor measurements. Also, there is no easy way to make outdoor measurements on a corner-horn type of speaker.

The measurements reported in this paper were of necessity made on speakers that were available on loan to the author. The large bass reflex speaker cabinet already mentioned had an adjustable partition between the main volume and the port volume, as shown in Fig. 6. The "throat" opening between the two volumes could be adjusted by removing the back of the cabinet and loosening the three wing nuts that held the sliding part of the partition in place. The interior of the cabinet was lined with about an inch of absorbing material. The speaker was a General Electric 1201D, a 12-in. speaker with a resonant frequency of about 70 cycles.

Most of the curves to be presented were taken in the author's living-room, the nature of which is shown by Fig. 7. An average amount of furniture, draperies, and rugs were present, and the speakers were located as shown. Three windows are indicated, and a few tests were made with these first open, then shut; but no significant difference was found. At each frequency sound-level readings were taken at the ten locations indicated by the crosses.

The solid response curve of Fig. 8 was obtained by the averaging method for the bass reflex speaker with the throat opening set arbitrarily at 4 in. Each point of this curve is the simple average of ten readings taken around the room, and these points have been joined by straight lines. Below 400 cycles the points are very closely spaced so that no significant features have been skipped, but the spacing is greater above 400 cycles, and irregularities have undoubtedly been missed. The primary interest in these measurements, however, was at lower frequencies. Note that this curve is relatively smooth compared to the curve previously shown

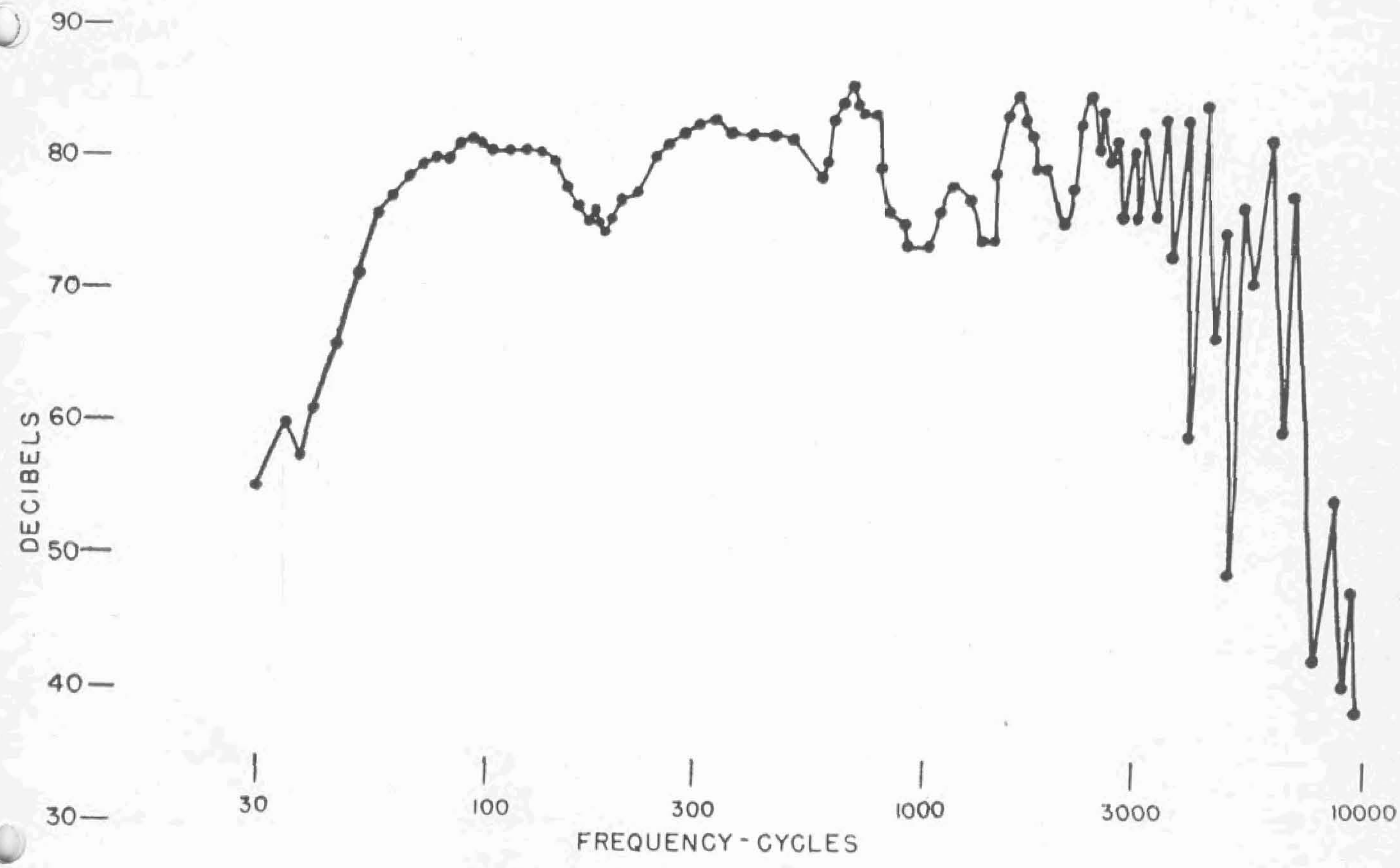

FIG. 5. One-point response, outdoors; bass reflex, 6-in. throat.

for indoor response with the sound-survey meter at a fixed location. It is evident that this procedure is effective in obtaining the average level in the room at each frequency in spite of the presence of standing waves. The result is only what one would expect, of course; but it is always reassuring to see an expected result confirmed by experiment. As previously explained, this average curve is determined primarily by speaker acoustic power output and total room-loss characteristics as functions of frequency. The various peaks and valleys that are greater than 1 or 2 db indicate characteristics either of the speaker or of the room, because reproducibility of data is that good, as is demonstrated below.

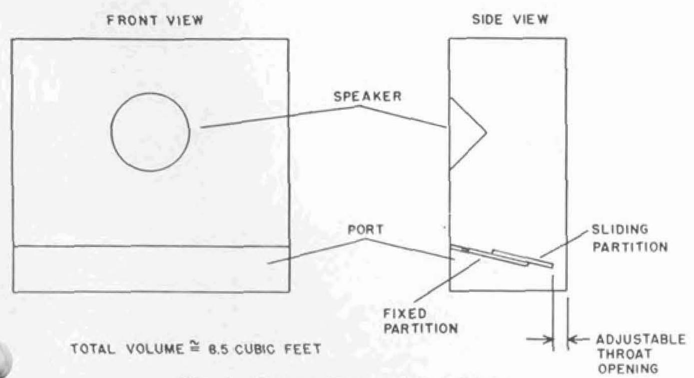

FIG. 6. Large bass reflex cabinet.

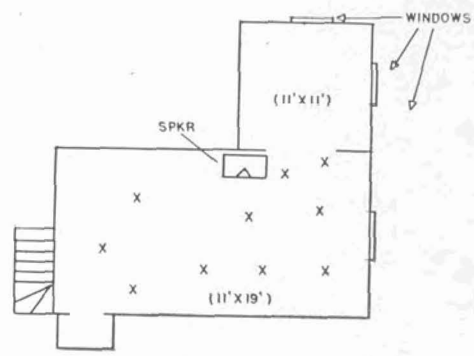

FIG. 7. Measurement room.

Several curves, to be shown below, were taken with the throat of the large bass reflex cabinet set at different openings ranging from 1 to 6 in. It was intended thus to determine experimentally the optimum setting giving the best lf response. Also, one curve was taken with the entire partition removed, including the fixed part as well as the sliding part. Since it is difficult to compare two curves of this type unless they are plotted together, the solid curve of Fig. 8, with a

4-in. opening, was selected as a reference curve; and each of these other curves is plotted in the later figures together with this reference curve. During the experimental work for this paper, and after these other curves were taken, including the one with the entire partition removed, the partition was screwed back into place, the throat opening reset to 4 in., and a second run, supposedly duplicating the solid curve of Fig. 8, was made to test reproducibility. The plotted circles in Fig. 8 show the results. Reproducibility is very close from 25 to 85 cycles, and from 160 cycles up; but between 85 and 160 cycles, the curve is undeniably different. This difference is believed to have resulted from the removal and replacement of the partition. First, the partition was fastened to the inside of the cabinet only at its two short sides, there being no screws along the long front edge. It is believed that as originally assembled the front edge was pressed tightly against the inside of the cabinet and held there by the side screws; but in replacing this partition the author, working with the absorbent material already stapled in place inside the cabinet, was not able to achieve a good fit. Therefore, after replacement, the front edge of the partition was free, whereas originally it was restrained. Second, in support of the foregoing theory, it is shown in Fig. 9 that the curve taken with the partition completely removed follows the second-run curve between 85 and 160 cycles too closely to be a coincidence. Third, there are four facts to confirm that the speaker and cabinet characteristics had actually changed.

1. The first- and second-run curves of Fig. 8 agree very well below 85 cycles and above 160 cycles.

2. All the many measurements reported in this paper strongly support a reproducibility figure of 1 or 2 db; yet the difference in this case is 7 db.

3. The impedance curve obtained by electrical measurements alone, and also shown in Fig. 8, is substantially different for the two runs, the resonant peak at 25 cycles being 25% higher in one case, and the behavior being completely different between 30 and 50 cycles.

4. It is known that the room in which the measurements were made was in the same condition for both runs, with the possible exception of one large chair. However, moving this chair around had no effect, nor did opening or closing three windows.

Continuing our consideration of Fig. 8, all subsequent measurements merely confirmed the stability of the second-run curve. For example, note the spread of the seven repeat points taken at 100 cycles. Five out of the seven are within 1 db of the average and the other two are within 2 db. At 30, 60, 100, and 400 cycles, fifty sound-level readings were taken evenly distributed throughout the room; and the very good agreement with the second-run points shows that there is little to be gained by taking more than ten readings at each frequency.

Figure 8 also shows the results of check measurements using a standard, high-accuracy sound-level meter together with a sound analyzer for isolating fundamental tones from harmonics. The close agreement between these measurements shows that harmonics are not "contributing" to the measured lf response. All the foregoing checks promote confidence both in the technique of measurement and in the sound-survey meter used.

Some speakers produce distortion with strong harmonics that can result in measured bass response that is too high. In the absence of a sound analyzer, one can generally detect this condition by ear, because of the ear's greater sensitivity to the harmonics. As an example, the first speaker used for these measurements seemed to change the character of its tone below 70 cycles, developing what might be described as a slight rattle. Measurements with the sound analyzer showed that the second and third harmonics of frequencies around 30 to 50 cycles were larger than the fundamental; so a second speaker, of the same make and type, was tried and found to be very satisfactory, with harmonics only about 6% of the fundamental below 50 cycles and becoming completely negligible rapidly for higher frequencies. The first speaker was obviously defective, and the second speaker was used for the bass reflex measurements. It is seen to be important when making response measurements at very low frequencies to keep one's ears on the alert for harmonics.

The impedance curves were derived in the usual manner by driving the voice coil through a high resistance (300 ohms in this case) from a constant voltage (9 v) and plotting against frequency the voltage measured across the voice coil by a vacuum-tube voltmeter, afterwards labeling the plot appropriately in the terms of impedance in ohms. The first- and second-run impedance curves of Fig. 8 have already been mentioned. A third curve is also plotted and is labeled "back of cabinet high." The back of the cabinet was about 3/16 in. less in height than the recess into which it fitted, and on its inside surface were mounted two blocks apparently intended to press down on the partition when in place. Therefore, it was possible to screw the back on in two ways, either resting on the bottom of the recess (the easy way) or pressed against the top of the recess. The impedance curve was taken under the latter condition during the process of determining the cause of the difference between the first- and second-run response curves, and it is seen to be somewhat similar to the first-run curve, with two added small peaks, one at 52 cycles and one at 85 cycles, but the response at 100 cycles fell on the second-run response curve.

Having established the technique and validity of measurement, we shall next describe the previously mentioned results of varying the throat opening in this particular cabinet-speaker combination. Since any differences will be at low

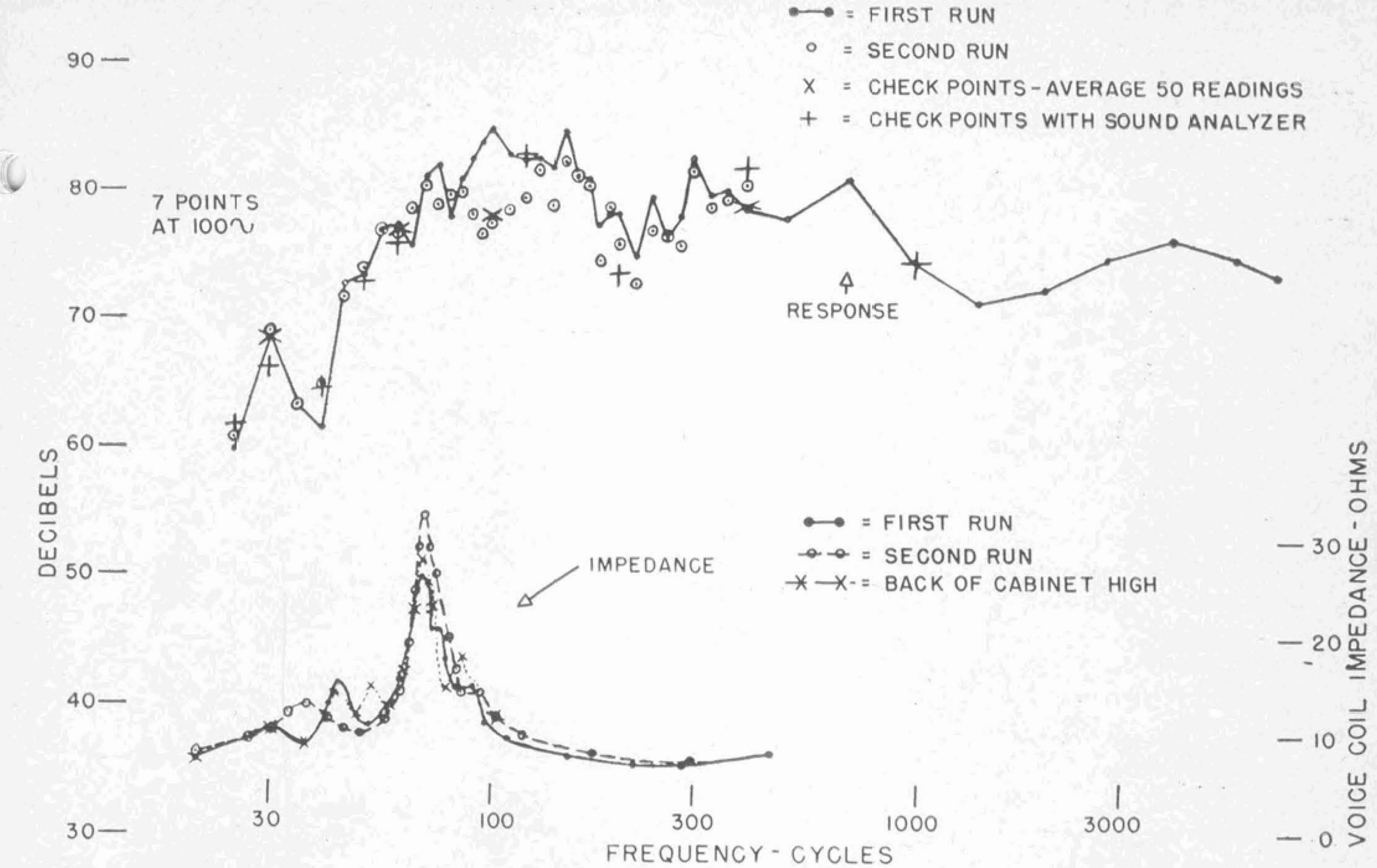

FIG. 8. Bass reflex, 4-in. throat, *vs* reference.

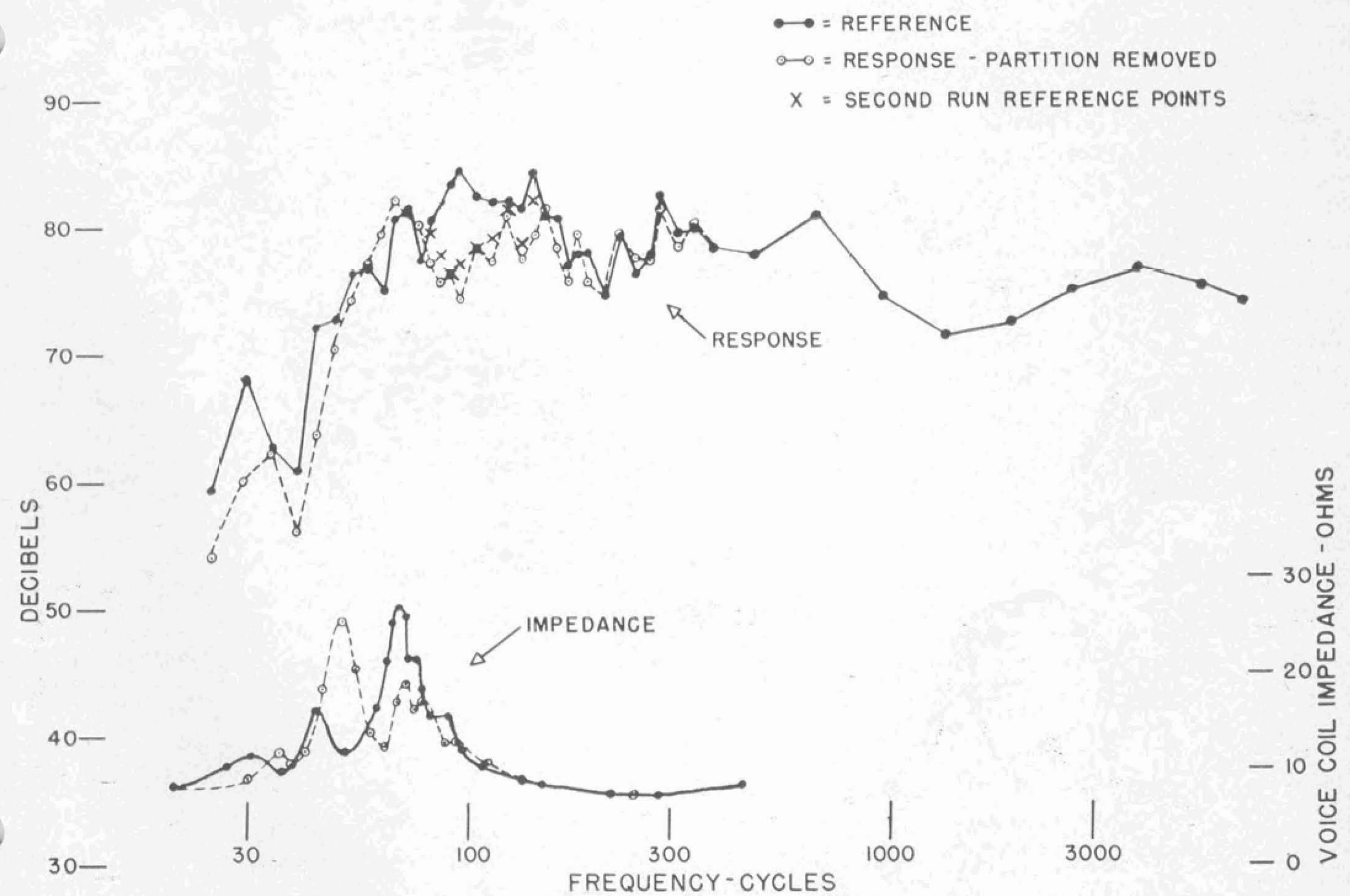

FIG. 9. Bass reflex, partition removed, *vs* reference.

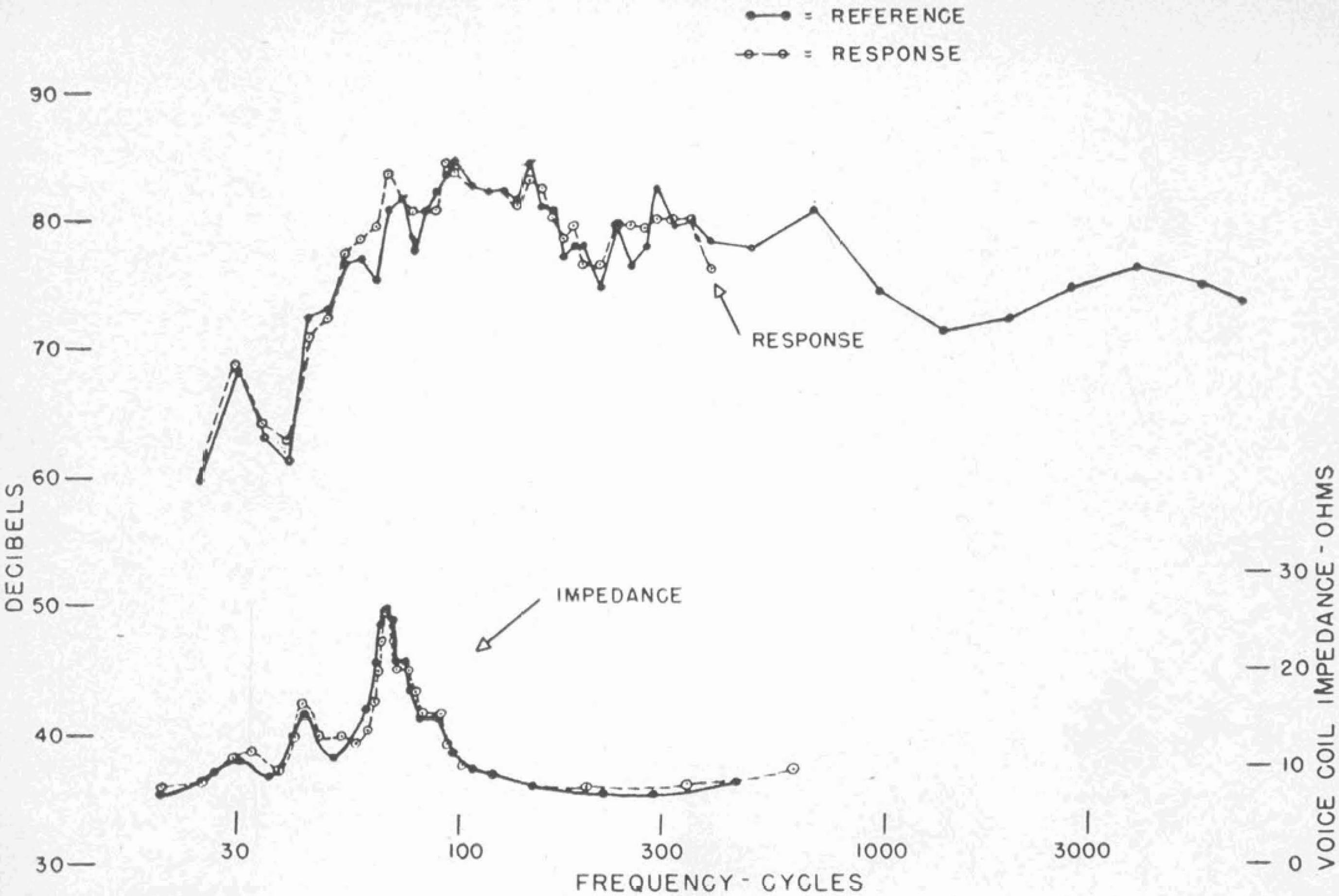

FIG. 10. Bass reflex, 6-in. throat, *vs* reference.

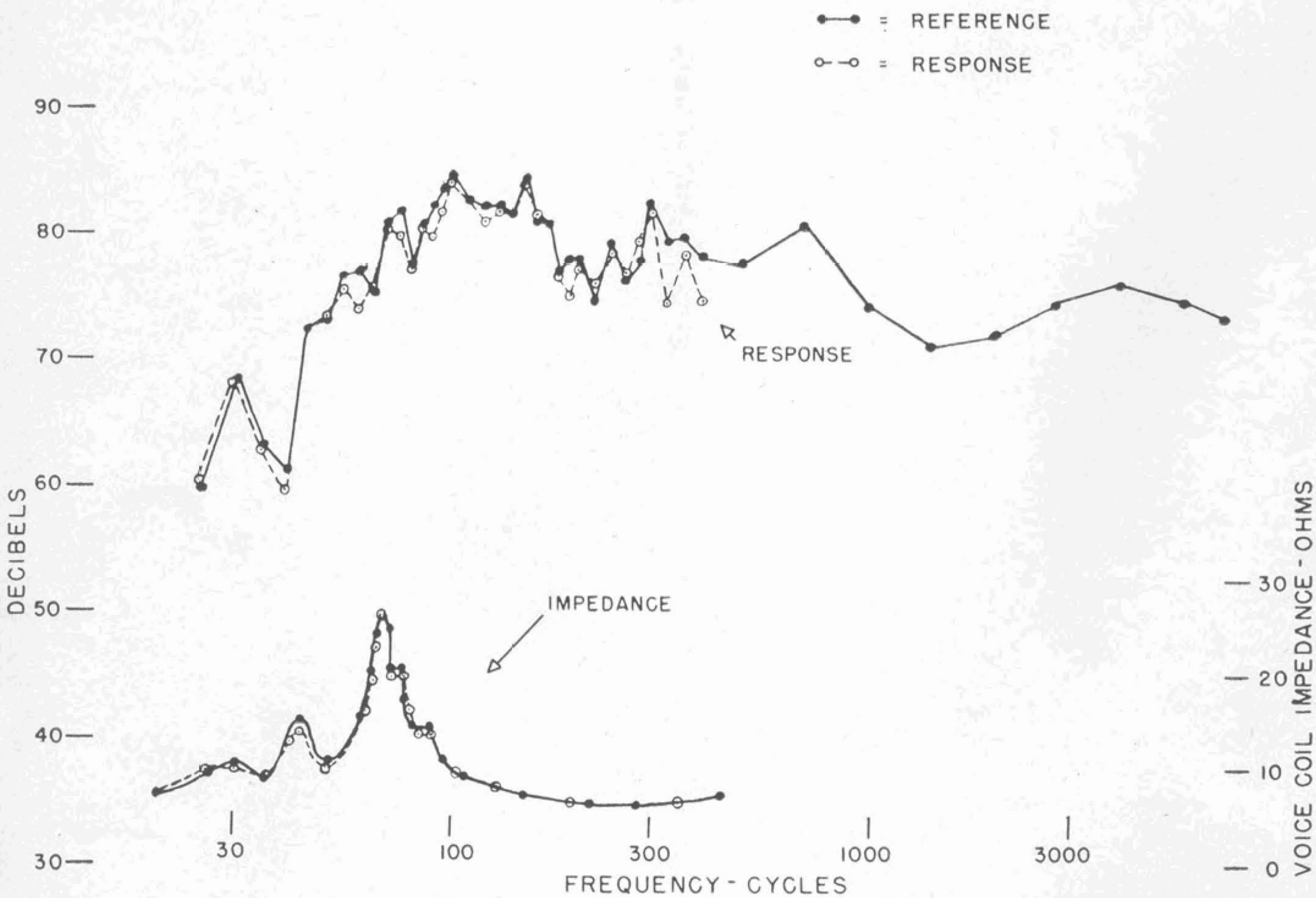

FIG. 11. Bass reflex, 3-in. throat, *vs* reference.

frequencies, measurements were taken only up to 400 cycles. In all these curves the reference condition (throat opening set at 4 in.) is represented by the solid curve.

Figure 9 was taken with the partition completely removed. Other than the valley between 85 and 160 cycles referred to previously, the major differences between this condition and the reference condition are that the reference is less smooth below 70 cycles and is about 5 db higher. The impedance curve, by contrast, shows a drastic difference. It appears difficult, if at all possible, to predict response characteristics from impedance-magnitude curves alone. In this case, with a major peak at 50 cycles instead of 70 cycles, the response below 50 cycles was poorer. The difficulty of interpreting impedance-magnitude curves is that the acoustic power output for a given voice-coil voltage depends not only on impedance magnitude but also on the resistance (real part of impedance) and on the efficiency of conversion from electric to acoustic energy. All these quantities vary with frequency. Furthermore, the resistance and efficiency are both difficult, if not impractical, to measure without more diversified equipment.

Proceeding toward smaller throat openings, we next consider a 6-in. opening, with the results shown in Fig. 10. The only deviation from the reference curve is slight and occurs between 60 and 70 cycles. The two curves follow each other very closely otherwise.

Results for a throat opening of 3 in. are shown in Fig. 11. Nearly every detail of one curve can be seen in the other.

Figure 12 corresponds to a throat opening of 2 in. The curves are still nearly identical. The impedance curve was not taken because of an oversight, but it would not be expected to show any marked difference from the reference shown.

Figure 13 was taken with a 1-in. throat opening. The curves are again very close, except for the rise above 300 cycles. The peak in the impedance curve at 45 cycles is in this case definitely lower than the reference, whereas it is progressively higher for larger throat openings.

Figure 14 is a comparison between the indoor response curve obtained with the sound-survey meter in a fixed location and the reference curve. The average of the rapid variations appears to follow the reference fairly well, except for the regions around 30 cycles and 230 cycles. One might well ask why it is necessary to go to the trouble of averaging with respect to position in the room at each frequency if one can get the same result by averaging with respect to frequency at a single position in the room. The answer is, in the first place, that the variations are so fast and large at a single point that a recorder is needed to do a reasonable job, and, in the second place, that important characteristics (peaks or valleys) of the speaker or room would be indistinguishable from the peaks and valleys caused by standing waves. Also, the variations due to standing waves are so large that it is difficult to draw a good average curve.

Figure 15 compares the outdoor response curve obtained with the sound-survey meter in a fixed location, very close to the speaker, and the reference curve. The differences can be ascribed to room absorption characteristics and directivity and proximity effects. The de-emphasis of the peak near 30 cycles has been mentioned previously.

In summary of the measurements on the large bass reflex speaker, it is apparent that the speaker and cabinet are not matched, because the adjustment provided had no significant effect on response. However, the curves do indicate the small effects that can be obtained with this combination and help to show the very satisfactory reproducibility obtainable in acoustic measurements by the averaging method described.

MEASUREMENTS ON A SMALLER BASS REFLEX CABINET

As mentioned before, the object of making measurements on an adjustable bass reflex cabinet in the first place was to show that the sound-survey meter could be used to determine the optimum adjustment, avoiding either a too-rapid cutoff or an excessively high peak at low frequencies. We have seen, instead, that the adjustment had no effect and have concluded from this that the 12-in. speaker used is not suited to the cabinet, the latter being too large (8.5 ft^3). Therefore, a smaller bass reflex cabinet (5.8 ft^3) was obtained with the idea that it might better match the characteristics of the available speaker. This cabinet also had a sliding partition, by means of which the throat opening could be varied. The results of measurements made with the throat fully open and also fully closed are shown in Fig. 16. The two curves are practically identical, except for a couple of points well below cutoff. Once again it appears that speaker and cabinet are not matched, although the cabinet is causing a peak at 70 cycles and a dip at 90 cycles. These features do not appear in the response of the large bass reflex cabinet using the same speaker. The cabinet has also shifted the main resonant peak of the impedance curve from 70 cycles (in the large cabinet) to 80 cycles.

Bass reflex cabinets are frequently described as being suitable for "any speaker up to 12 in." or "any speaker up to 15 in." The foregoing results indicate that such statements are open to question. Most bass reflex cabinets are not readily adjustable, yet the measurements on two that are adjustable, using a very common 12-in. speaker, show that even the adjustment provided cannot make the cabinet match the speaker. A bass reflex system involves the relationship of several resonances with respect to each other, and it is difficult to understand how "any speaker" up to a certain specified size can be expected to match a given cabinet, adjustable or not. The bass reflex principle has been shown

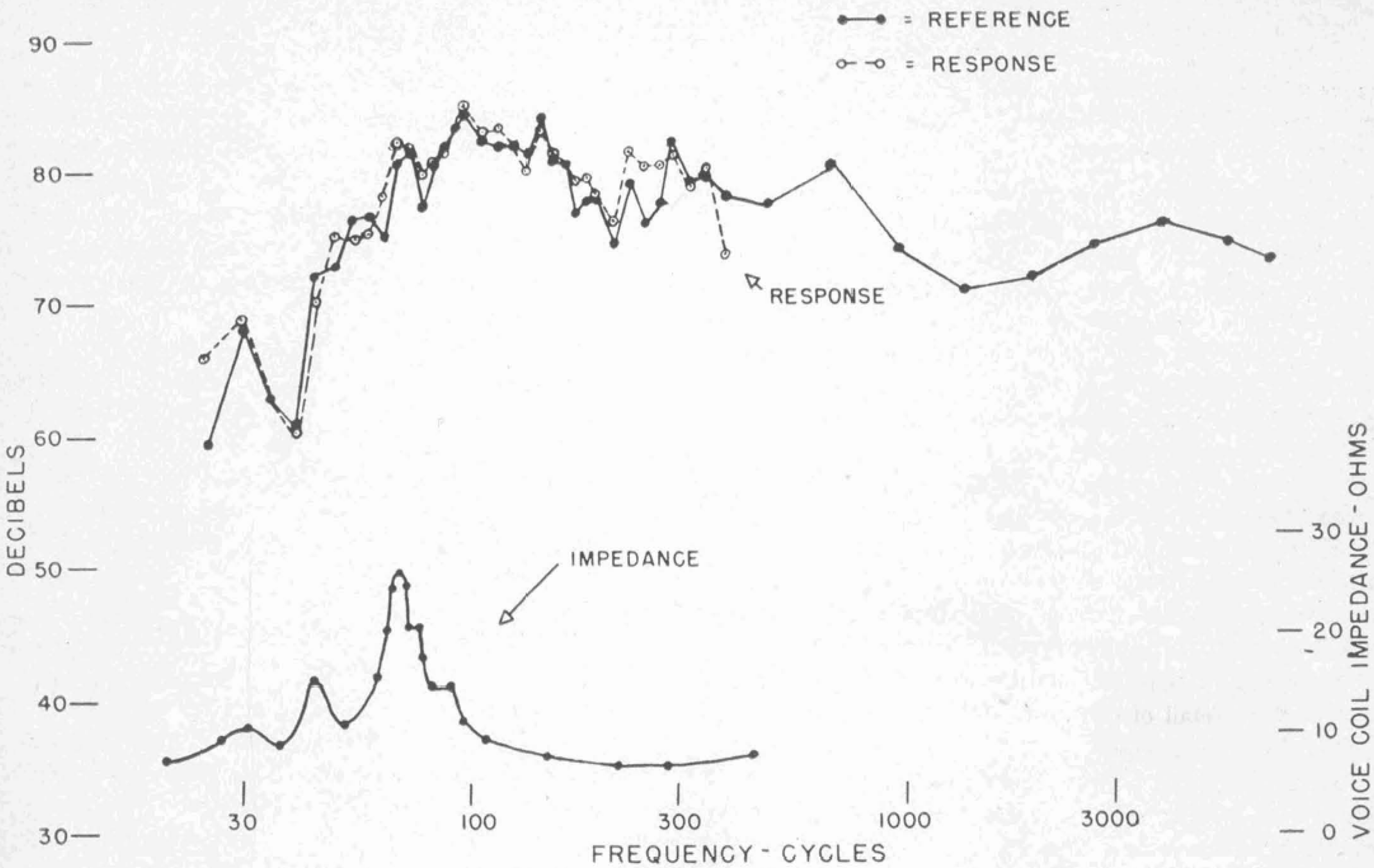

FIG. 12. Bass reflex, 2-in. throat, *vs* reference.

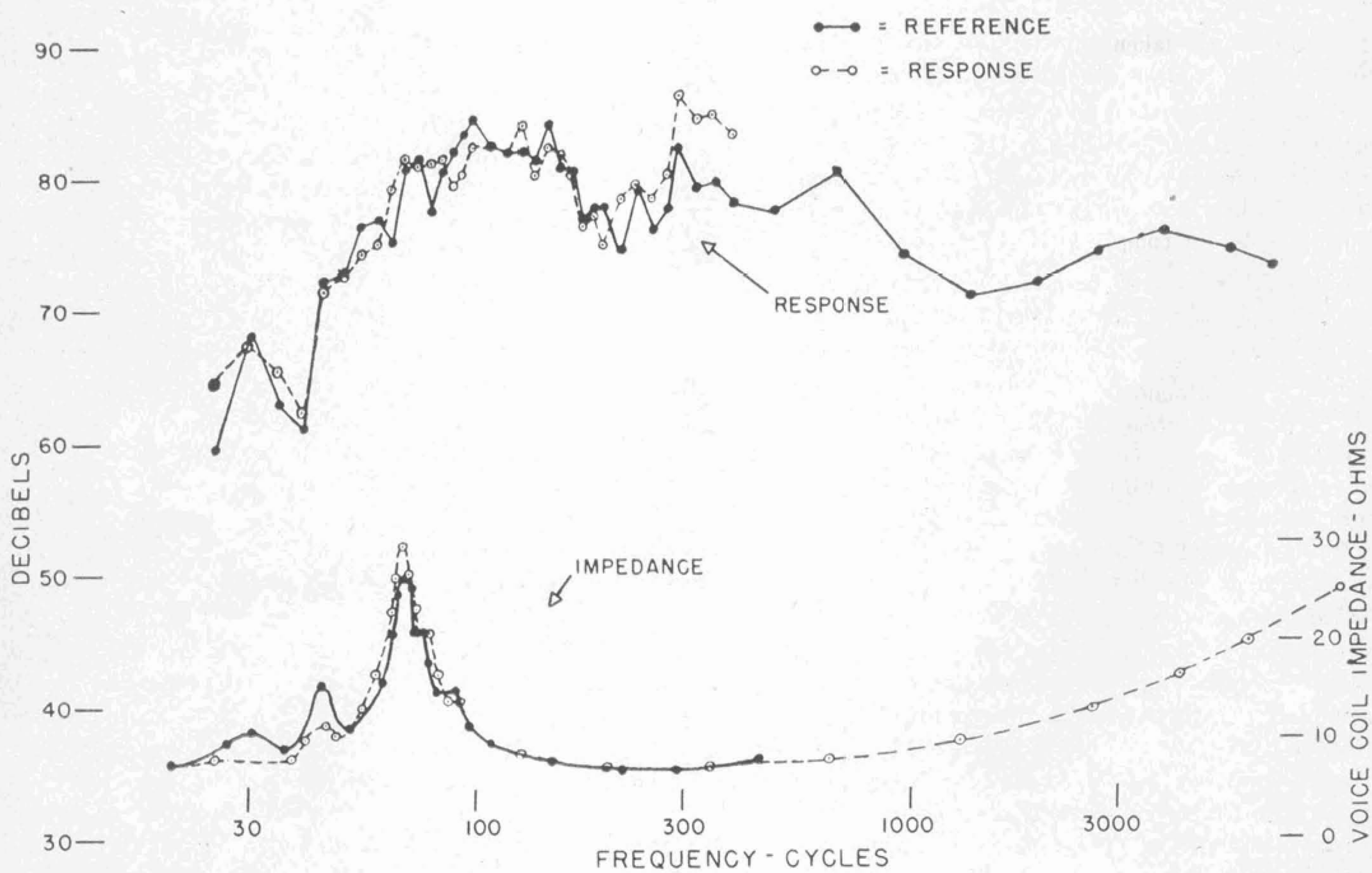

FIG. 13. Bass reflex, 1-in. throat, *vs* reference.

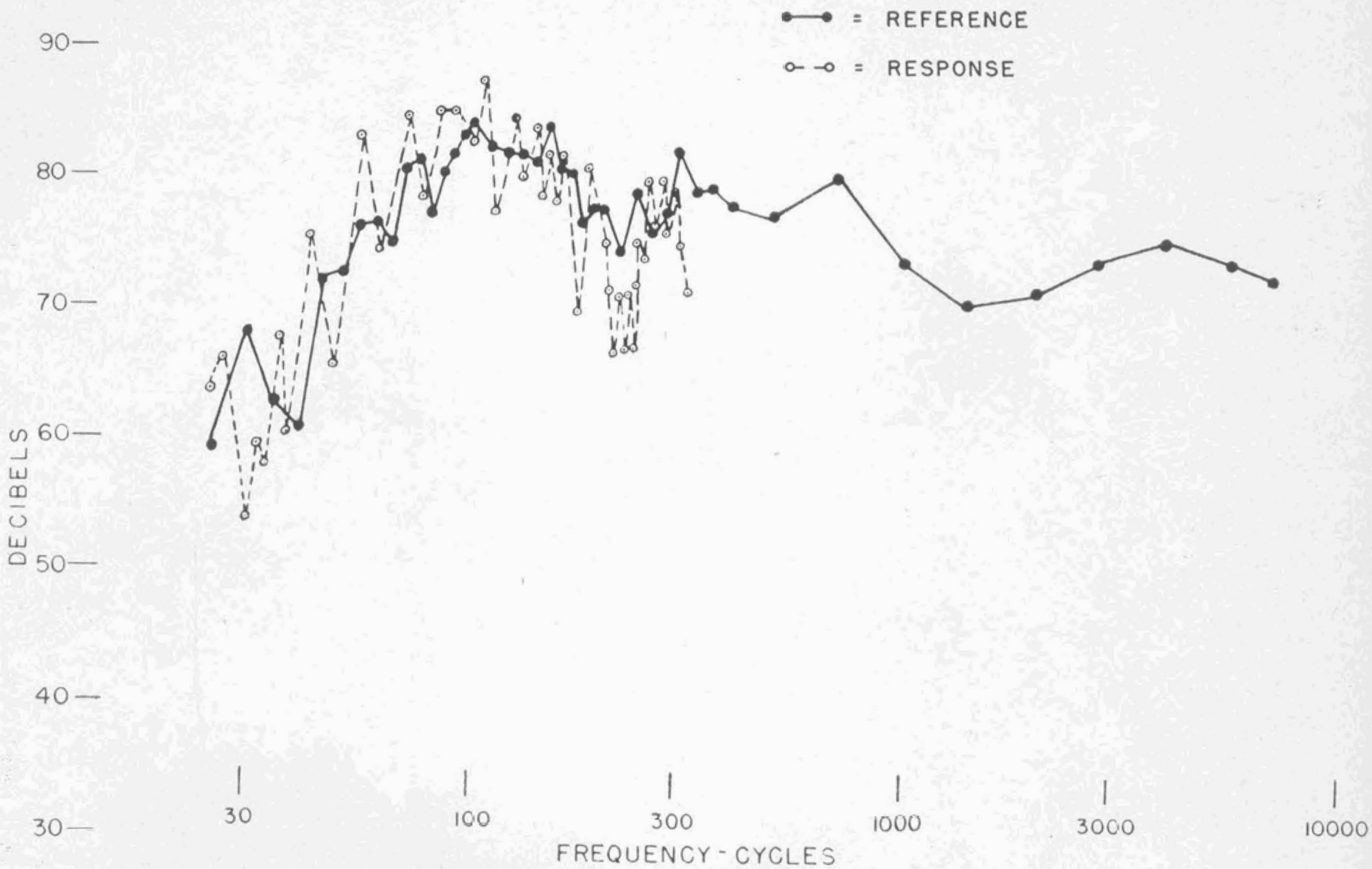

Fig. 14. One-point response, indoors, *vs* reference.

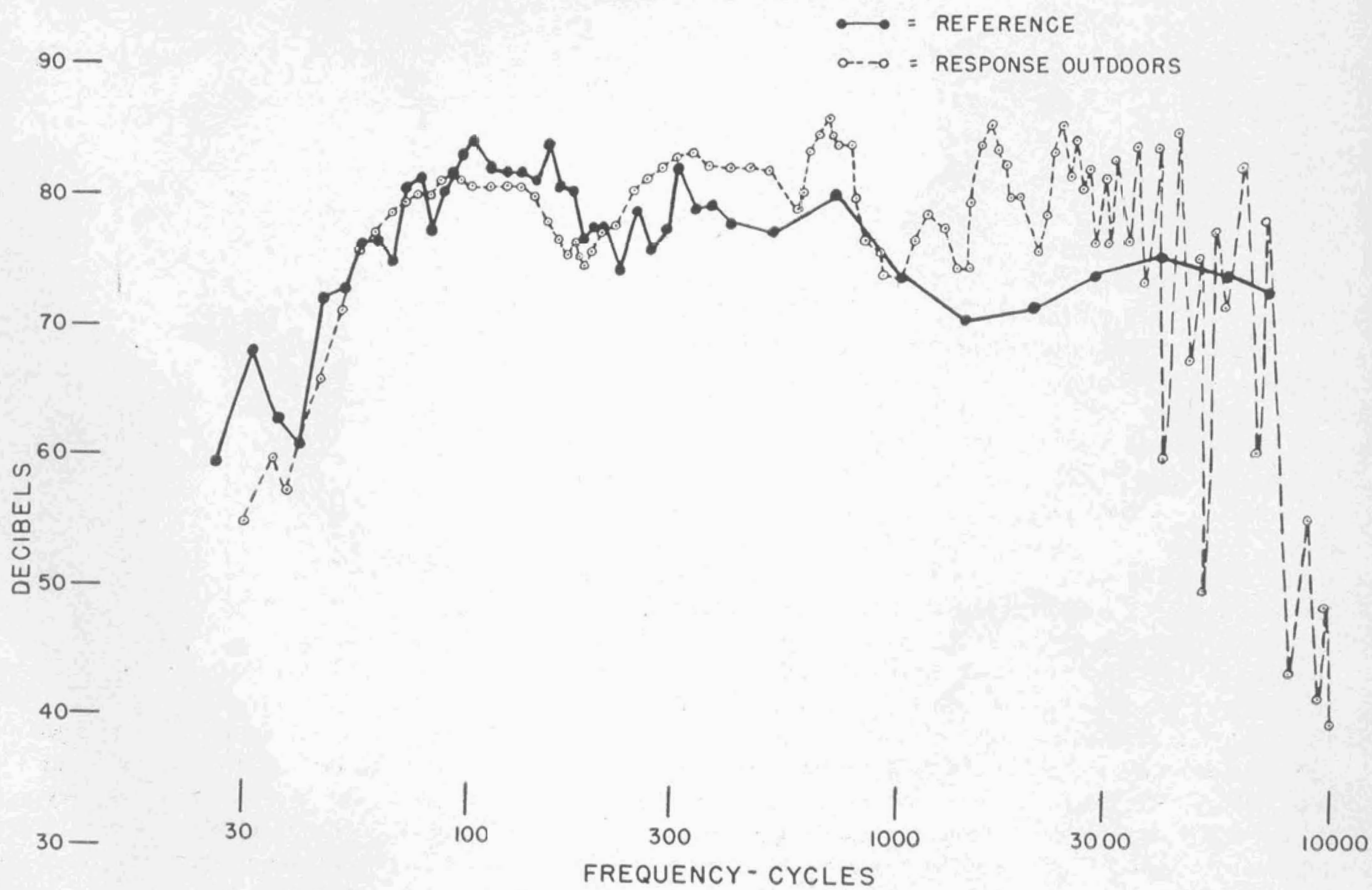

Fig. 15. One-point response, outdoors, *vs* reference.

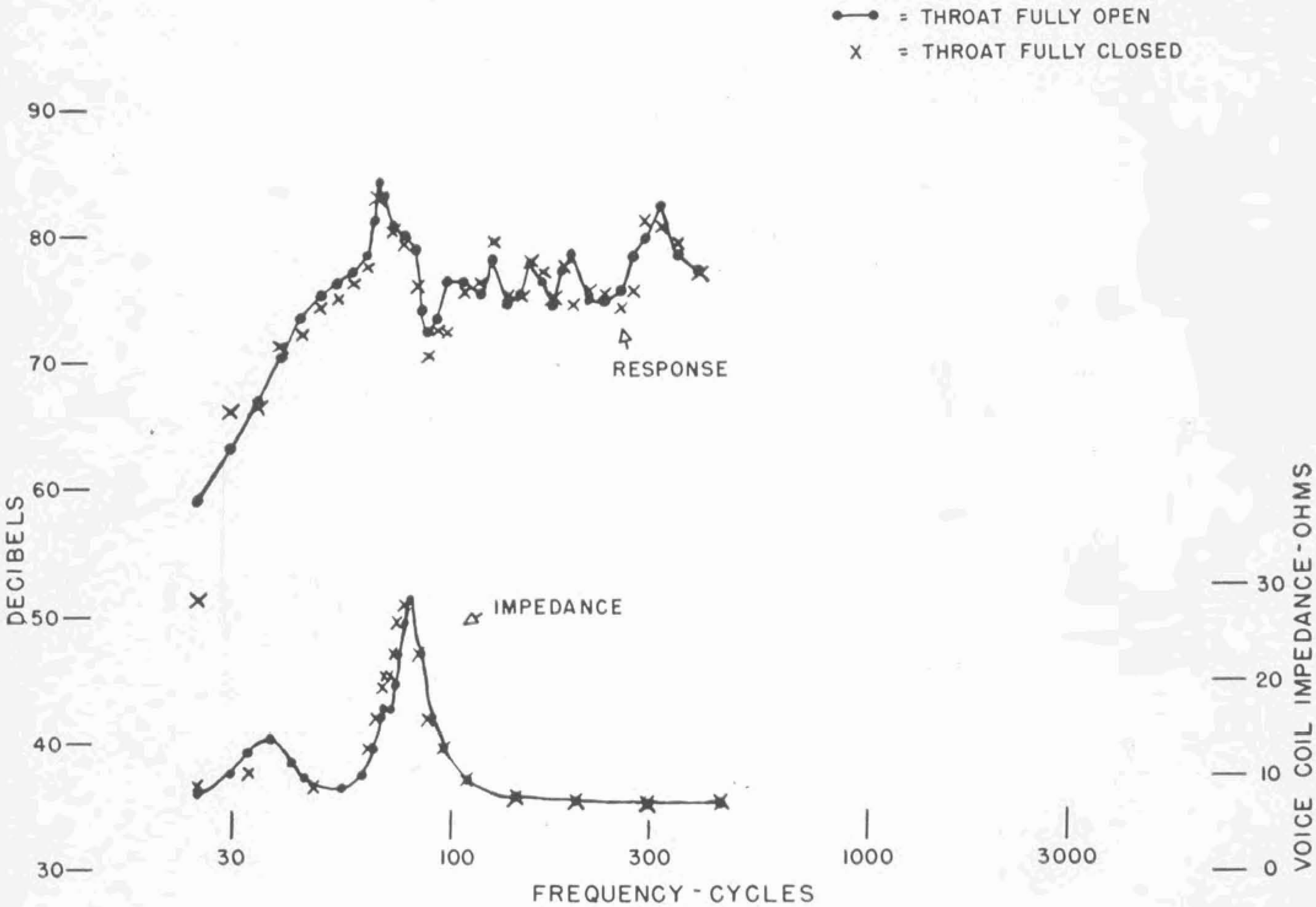

FIG. 16. Small bass reflex.

by others to be capable of extraordinary performance when carefully and properly designed, but experience in this work has since shown that the characteristics of speakers used in such systems are very critical and that "any speaker" obtained from "any manufacturer" out of "any production run" cannot be expected to give proper results automatically without individual testing.

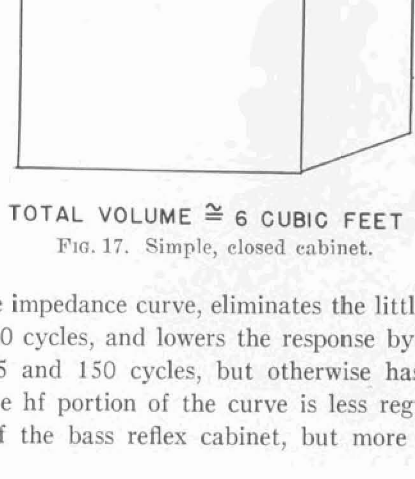

FIG. 17. Simple, closed cabinet.

MEASUREMENTS ON A SIMPLE, CLOSED CABINET

Figure 17 is a sketch of a 6-ft^3 cabinet. A 1201D speaker was used here also, but not the same one that was used in the bass reflex cabinets. Some dislike the bass reflex speaker cabinet on the grounds that it is a resonant device and therefore may have poor transient response, although it is probable that much of the blame heaped on the bass reflex principle is due to listener experience with cabinets and speakers that are not suited for each other. One alternative is the large horn type, but a simpler type is a closed box filled with absorbing material to damp interior resonances. Figure 18 shows the difference in response of the cabinet of Fig. 17 with and without the absorbing material. The material greatly broadens and reduces the resonant peak of the impedance curve, eliminates the little impedance peak at 230 cycles, and lowers the response by about 4 db between 65 and 150 cycles, but otherwise has very little effect. The hf portion of the curve is less regular than in the case of the bass reflex cabinet, but more points were

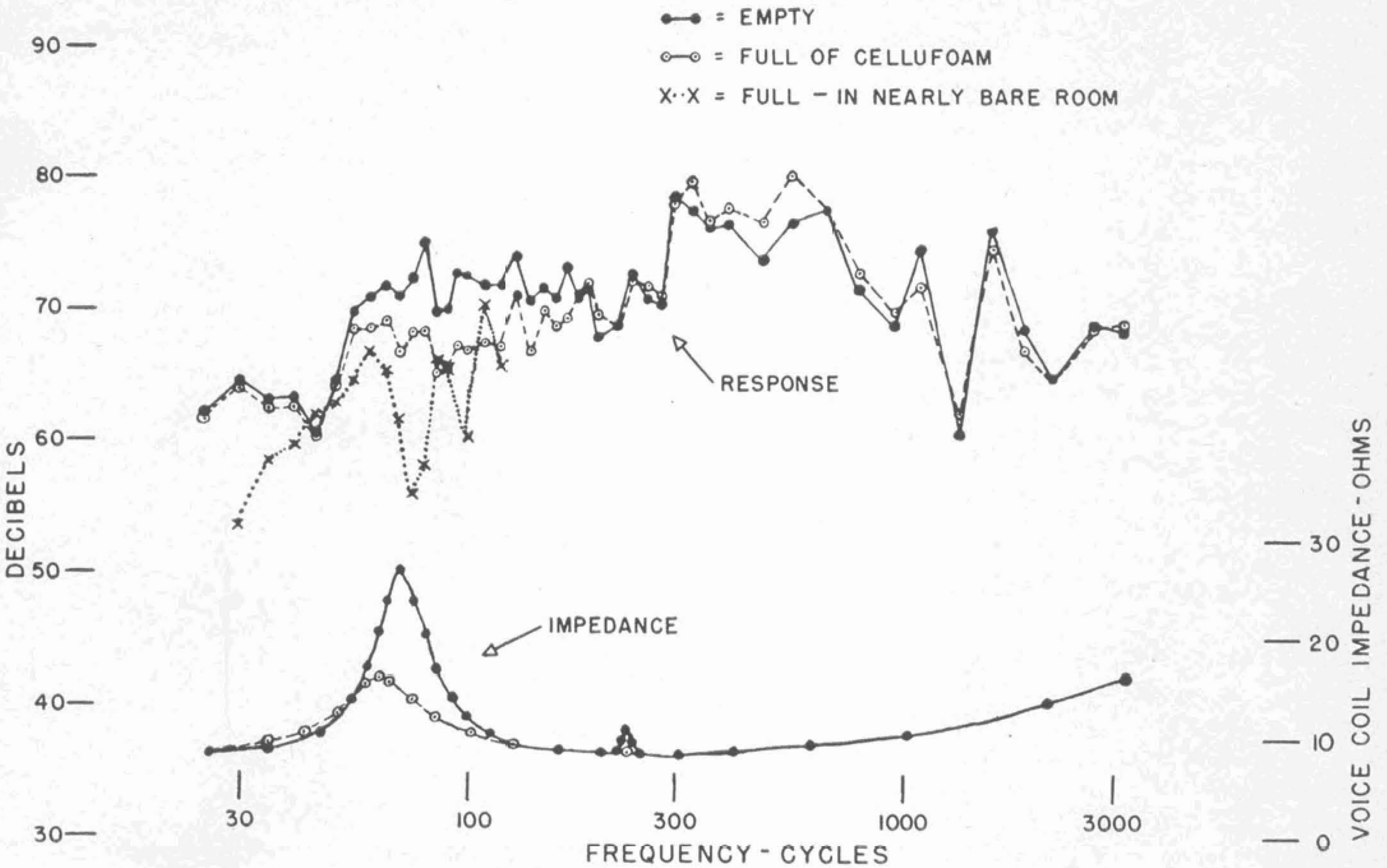

FIG. 18. Simple, closed cabinet.

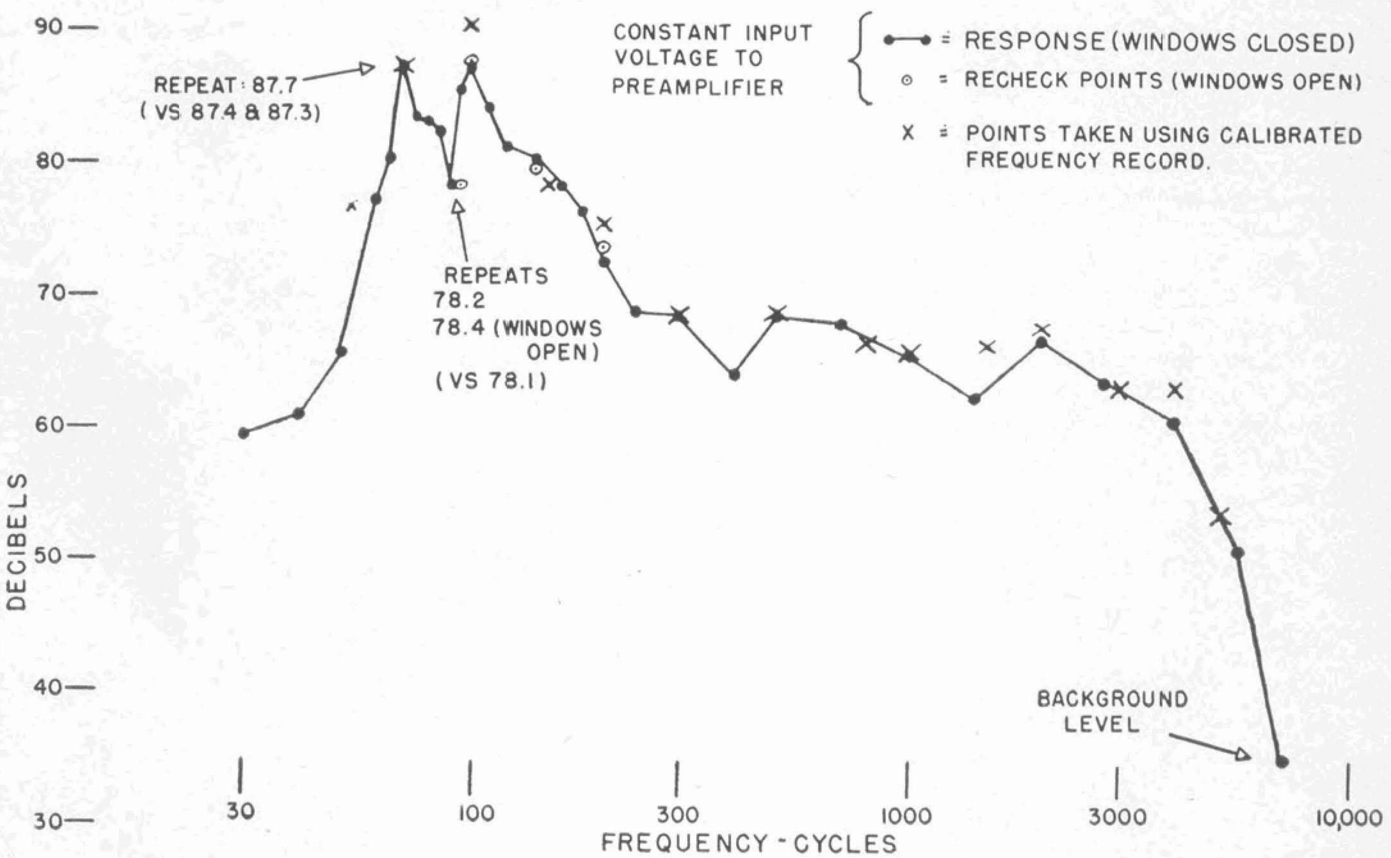

FIG. 19. Typical home radio-player console.

taken for the closed cabinet, and it is quite possible that more points taken for the bass reflex cabinet would show similar irregularities. Except for the portions of the curves differing because of the absorbing material, the agreement is excellent.

The third curve illustrates the characteristic obtained in a different room, one with very little furnishings, no draperies or rug, and all doors and windows closed. A large variation of room characteristic with respect to frequency is evident. In this extreme case, in which room absorption is very low, it is conceivable that the driving-point impedance of the room, as seen by the speaker, could vary appreciably with frequency as the standing-wave pattern changed. This effect might help to explain the large variations noted.

MEASUREMENTS ON A TYPICAL HOME RADIO-PLAYER CONSOLE

As a matter of interest, measurements were made on the radio-player console ("family radio") in the author's living-room. The speaker is an 8-in. type, and the cabinet is open at the rear and bottom. The player uses a General Electric "variable-reluctance" pickup and a home-built preamplifier and equalizing network. Measurements were made with a constant voltage applied to the preamplifier input terminals in place of the pickup. Figure 19 shows the results. It is clear why record scratch has never been objectionable on this player. The rise below 300 cycles is caused by the equalizing network and is intended to compensate for the recording characteristic of records.

The dip at 90 cycles was checked by repeating points at 90, 100, 140, and 200 cycles with three windows open, but the results duplicated the original readings very closely indeed, thus proving that the dip is a speaker-and-cabinet characteristic.

Since it was easy to do, an additional check was then made using a constant-tone frequency test record, previously calibrated independently, with the results shown by the crosses. Agreement is excellent, except for the 50-cycle point. At 50 cycles, however, the tone sounded very rough, and a check with the sound analyzer showed harmonics much higher than the fundamental, which would explain the high reading at 50 cycles. The agreement otherwise indicates that the frequency response of the pickup is flat up to at least 5 kc.

MEASUREMENTS ON LARGE CORNER-HORN SPEAKER SYSTEM

Response measurements on this system showed up two facts that had been suspected by the owner as a result of many hours of listening. First, the efficiency of the lf horn was about 5 db greater than that of the hf speaker, with the obvious result that there was a "step" downward in the response curve at the crossover frequency. Second, the crossover network was too high in frequency, and the output from the lf horn started to drop before the crossover point, resulting in a dip in the response curve just below the crossover frequency. Both of these defects, their nature and magnitude precisely defined by the sound-survey meter, can be corrected. The curve itself is not shown, because the data were unavailable.

CONCLUSION

The method of measuring acoustic response using the average of several sound-level readings made at different points within a room has been found to give satisfactorily smooth and highly reproducible response curves. The sound-survey meter is useful for making these response measurements. Bass reflex systems can be adjusted for best overall results, and the suitability of a particular speaker for use in a particular cabinet can be determined. The optimum amount of absorbing material required, within the speaker housing, can be determined. Defects in room absorption characteristics can be detected and the effects of corrective measures checked. Other uses include setting correct relative levels in multiple-speaker systems, including stereophonic systems and the checking of crossover networks, determination of speaker placement for best coverage, and setting the initial reference level in systems using a tone-compensated volume control.