MONITORING LOUDSPEAKERS FOR THE NATIONAL BROADCASTING SERVICE

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INTRODUCTION

With over 100 main studios and their associated control booths, in addition to transmitting stations and offices, the National Broadcasting Service makes heavy demands on high quality monitoring loudspeakers and, in fact, several hundred such loudspeakers are now in service. Since the loudspeaker is such a vital component in the broadcasting chain, while at the same time being probably the most imperfect, it has been the practice to review periodically the standards of monitoring facilities and improve them in the light of recent technical advances. A review of this kind was begun some two years ago when it was apparent that a substantial purchasing programme for monitoring loudspeakers lay ahead. As a result, a completely new design for a very high quality loudspeaker system was developed and some improvements were made to the small medium quality system already in service. This paper describes the characteristics of these two loudspeaker systems which are now in general use in the National Broadcasting Service. Fig. 1 shows the production versions of the two systems.

* See page 432.

CURRENT "HIGH FIDELITY" TECHNIQUES

The Meaning of "High Fidelity"

Before describing the new standard loudspeaker system, it may be useful to review the present state of the loudspeaker art and outline the current techniques and principles. The ultimate objective of realism is still generally accepted as the criterion for a loudspeaker and the introduction of technically satisfactory stereo (and pseudo stereo) has taken the art one step closer to this objective. Stereo reproduction is particularly useful in that it enables us to distinguish between faults which are inherent in the loudspeakers and faults which are a product of "hole-in-the-wall" monophonic reproduction.

In the search for realism, it is usual to measure such basic loudspeaker properties as frequency response, harmonic distortion, transient distortion and polar response. A good loudspeaker must be satisfactory in all these respects. However, superimposed upon these characteristics are the undefined properties, commonly called "colourations," which are so easily manifest to the ear but so difficult to locate by measurement. Certainly it is well known that a loudspeaker with excellent frequency and transient responses may sound quite objectionable on programme. A probable explanation is to be found from a close examination of the complex ripple pattern in the frequency response. The frequency response of a loudspeaker is strikingly reminiscent of the response of a room or enclosure, and the ear may well draw upon its wealth of experience to interpret the complex loudspeaker response in terms of similar acoustic environment. This may explain why loudspeakers are commonly said to have a "boxy" or "pipe" quality. Nevertheless, whatever interest lies in the fine detail of the frequency response, the ear is also very sensitive to the smoothed response, and a general tilt of only 2 db over the upper or lower portion of the spectrum can be detected readily by a discriminating listener.

Fig. 1.—The Type 3 and Type 2 Loudspeaker Systems.

Low Frequency Response

The smoothed frequency response of a loudspeaker system divides into three separate regions of difficulty which may be classified as the low, middle and high frequencies. In practice, most attention has been given to the two extremities at which the low frequency response becomes an enclosure problem and the high frequency response a diaphragm problem.

At the very lowest frequencies, all loudspeakers work as simple pistons and the problem is to couple the piston to the air. Electrostatic diaphragms have been produced and, like the multiple bass speaker arrangements, have achieved some success due to their abnormally large area. Horns of various shapes can be used but are never able to achieve very low bass response in enclosures of normal size. Other experimental enclosures have appeared from time to time but it can be fairly said that the reflex enclosure is still the most efficient in terms of bass response per unit of volume.

A recent development has been the appearance of "bookshelf" size enclosures of 1 or 2 cubic feet with adequate bass response down to about 50 c/s. These units represent an integrated speaker plus enclosure design in which a high flux density speaker is designed to a lower electro-acoustic efficiency in

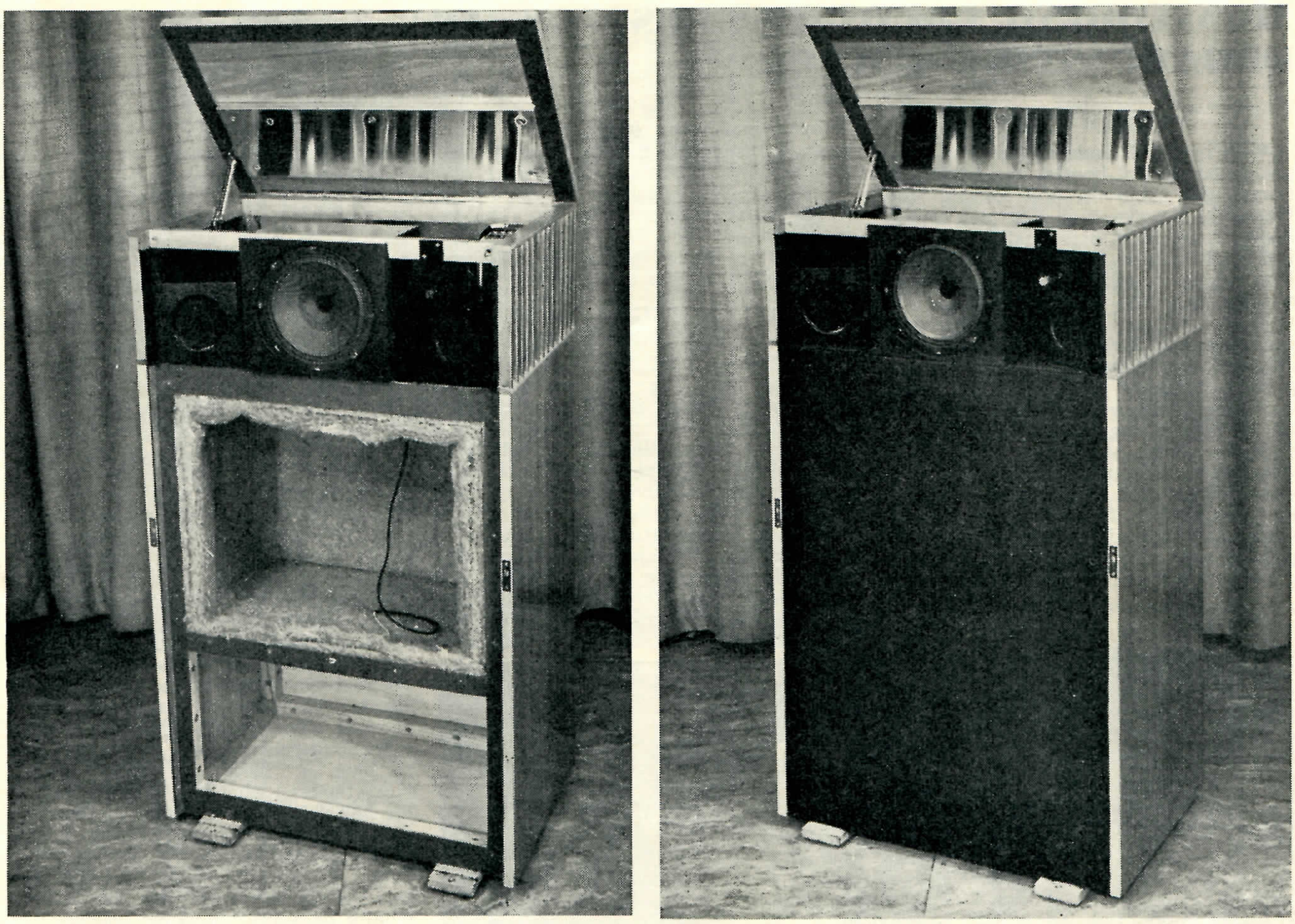


Fig. 2.—Type 3 Cabinet before and after Mounting the Loudspeakers.

the interests of obtaining bass response from the small enclosure. Given an adequate power source and moderate demands on acoustic volume, the design is most successful, particularly for domestic stereo applications. It is not possible, however, to obtain similar results from conventional driver units which have not been designed specifically for small enclosures.

Middle and High Frequency Response

Above about 300 c/s conventional loudspeaker cones break up into complex modes of vibration giving rise to the irregular frequency response referred to earlier. Various techniques are used to control this breakup, for example concentric compliance rings, variable hardening, superimposed domes and sandwich construction. Electrostatic units do not suffer from the same defect. It has recently been shown that the usual method of mounting a middle frequency unit behind a cut-out in the baffle is, in itself, a potent source of colouration. Extreme tapering of the cut-out or mounting the speaker from the front removes this effect. The middle frequency response remains, however, as the least understood part of the spectrum, and the one which contains the least well-defined defects.

At the high frequency end of the spectrum a number of "tweeter" types have appeared, including moving coil units (direct radiator and horn loaded), ribbons, crystals, electrostatics and others. The main practical limitations in all cases appear to be inadequate sensitivity and the inability to handle sufficient power in the important region between about 1 and 5 kc/s where most low frequency units are showing gross defects. However, as far as the higher frequencies are concerned, there is now little difficulty in achieving adequate response as far as the upper limit of audibility. The polar response however, is not always as broad as could be desired.

NEW TYPE 3 LOUDSPEAKER

Functions

The new Type 3 monitoring loudspeaker system has been designed for the most critical locations in the National Broadcasting Service where the balance of the programme is adjusted and its quality assessed in both aesthetic and technical respects. The studio control booth is one such location. For these applications, the wide range high quality properties of the monitoring loudspeaker are called upon to serve three quite distinct functions. A good low frequency response, extended flat to at least 50 c/s, is essential to show undesirable hum or rumble on the programme. An extended high frequency response is needed to display the existence of other noises such as clicks or hiss which have a predominantly high frequency spectrum, and also to show up harmonic and intermodulation distortion. A flat middle frequency response as free as possible from colourations is necessary to permit satisfactory judgments of the balance of programme material. Deficiencies in the middle frequency reproduction lead to false accentuations of some instruments and to false balances between soloists and accompanists.

Other properties are also desirable in certain situations, particularly for control booths where space is often limited. A wide beam width at high frequencies is most necessary, and sufficient electro-acoustic efficiency is required to operate comfortably from existing standard A.P.O. Type 3 (18 watt) amplifiers. Easy service accessibility, particularly to the amplifier, with a minimum of cabinet removal is desirable. The unit should also be of minimum size while preserving a loudspeaker height at or above ear level to permit unobstructed hearing.

The new Type 3 Loudspeaker satisfies all of these requirements with the exception that a further reduction in dimensions to take it into the wall-mounting or bookshelf category would have been acceptable. This could not be done with available driver units. Nevertheless, the Type 3 unit is appreciably smaller and much more convenient than the 12 and 14 cubic foot enclosures which it replaces.

Low Frequency Design

In the Type 3 System, a 15 inch low frequency unit is mounted in a conventional reflex enclosure having a volume of 6 cubic feet. With a vent area of 15 square inches, the enclosure resonates at 39 c/s, a little above the free air cone resonance, to give the optimum bass response. The main internal standing wave, in the vertical direction, is damped by a membrane stretched across the centre of the enclosure and the upper section of the enclosure is heavily lined with felt, as shown in Fig. 2, to remove other resonances.

The low frequency unit has the usual undesirable characteristics above about 500 c/s. and the cross-over network has therefore been designed to cut off at this frequency. Additional attenuation is obtained by means of an acoustic filter placed in front of the cone. When thus operated, the response falls slowly towards the low frequency end before reaching its normal cut-off point, and recourse has been made to an equaliser to optimise the response. The equaliser lifts the output by 6 db at 40 c/s. to give an overall response for the L.F. unit, as shown in Fig. 3(a).

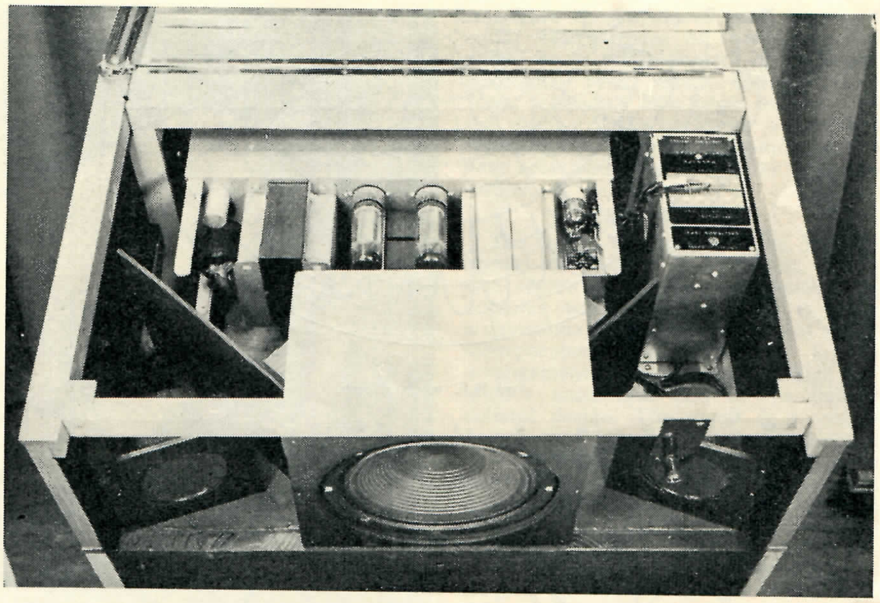


Fig. 4.—Type 3 System—Layout of Components.

Middle Frequency Design

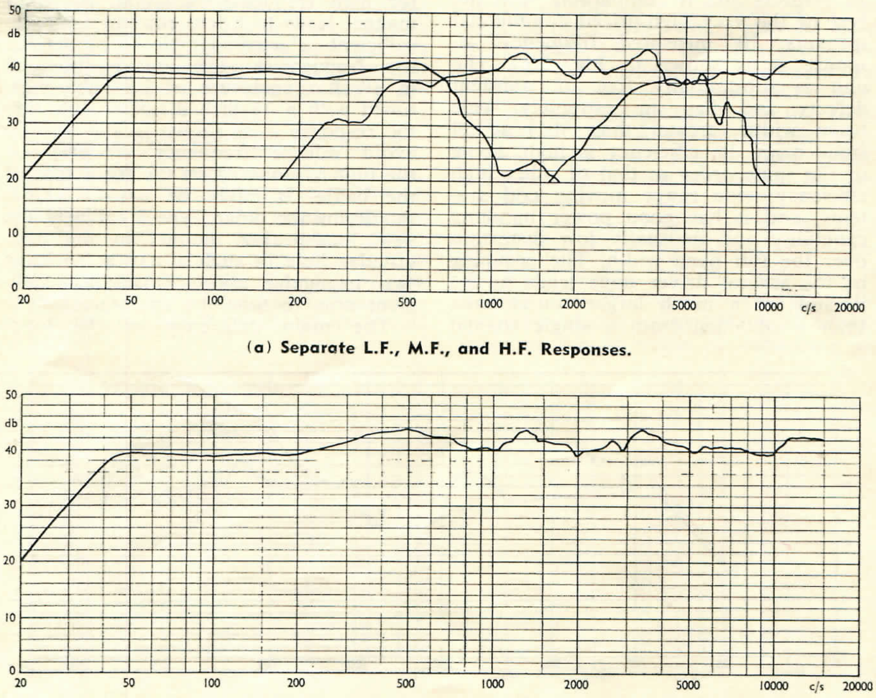
The middle frequency range, between 500 and 5,000 c/s., is handled by an inexpensive 8 inch loudspeaker mounted in a small fully enclosed, heavily padded box. In this frequency range, the mounting of a speaker behind a cut-out in a baffle has been found to be one of the prime causes of colourations, due to the cavity formed by the thickness of the baffle. The M.F. unit is therefore mounted on the front face of its enclosure and this also provides for very easy access from the front. The attenuation that must be provided in the cross-over network to reduce the level of the 8 inch unit to optimum balance provides an opportunity to equalise a depression in its response at 2,000 c/s.

High Frequency Design

The arrangement of the high frequency speakers is an innovation whose purpose is to provide a very wide beam width and to avoid dissociating the source of the high frequency components from the source of the remainder. Two 3 inch "tweeter" units are driven in parallel through a high pass network with a cut-off frequency of 5,000 c/s. The interference pattern from two identical spaced sources would normally be troublesome and this has been overcome by separating the tweeters by the full width of the cabinet as can be seen in Fig. 4. With this spacing, the interference pattern (see Fig. 5) shows a large number of very closely spaced maxima, the separation between successive nulls being so small that the listener's two ears bridge the gap at normal listening distances. The phasing of the M.F. and H.F. units has been further chosen to provide a substantial degree of null fill-in in the 5,000 c/s. region where the effect is most troublesome. The tweeters are inclined inwards by 20 degrees to give a uniform polar response. The inwards rather than outwards inclination superimposes the high frequency image on to the M.F. unit and ensures that the image remains fixed when the listener moves around the cabinet.

Cabinet

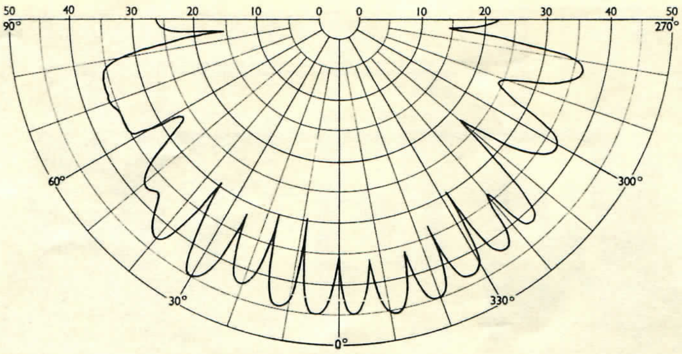
The design of the cabinet involves a substantial departure from normal practice in the interests of better serviceability. With the exception of removing



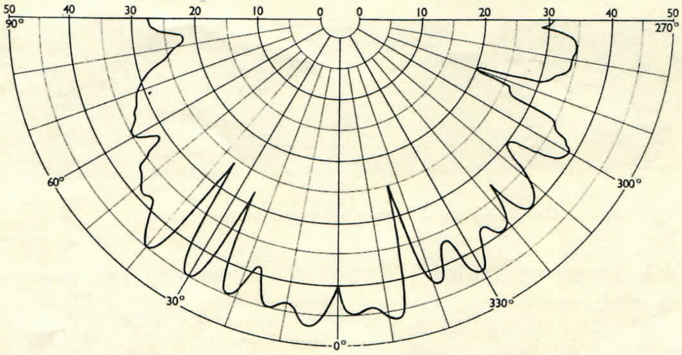
(a) Separate L.F., M.F., and H.F. Responses.

(b) Combined Response.

Fig. 3.—Overall Frequency Response of Type 3 System.



(a) H.F. units alone.



(b) M.F. and H.F. units.

Fig. 5.—Polar Diagrams at 5 kc/s of Type 3 System.

the amplifier complete, all servicing can be done from the front. The lid hinges up for valve changing and testing and the grille frame slips off to expose all four loudspeaker units. The L.F. unit is mounted behind a baffle board which screws on from the front and which includes the vent. Other L.F. units may therefore be substituted with the provision of a new baffle. A pilot light is visible through the grille fabric and the power switch is within finger reach at the back. The veneered surface of the cabinet is finished in a clear polyester plastic which is extremely hard and scratch resistant.

Use of the Equaliser

The equaliser improves the bass response of the system by applying a correction which rises below 150 c/s. to a value of 6 db at 40 c/s. The mid-frequency loss of the equaliser is 16 db and this leaves a standard Type 3 amplifier with sufficient gain to be fully driven from a + 8 VU line. In small studios and control booths, it is always difficult to generate enough very low frequency energy owing to acoustic properties of the small space. For these applications, the equaliser should always be used. A switch is provided however to enable the equaliser to be removed from circuit if it becomes necessary to do so. This situation would normally occur only where the maximum possible power output is required in a large room or where the unit is driven from a line level of less than + 8 VU.

Performance

The complete Type 3 Loudspeaker system gives a pleasing performance in all respects and is comparable with the best of the very high-priced commercial speakers. Its measured frequency response is as shown in Fig. 3(b). The unit is substantially free of transient defects and has an extremely wide beam width (greater than 90°) at all frequencies. Its efficiency is high, being of the same order as that of other high efficiency wide range moving coil systems, and it has good power handling capability and unusually low distortion over the full band width. The grouping of the several driver units leads to the illusion of a much larger source area than is obtained from a single coaxial speaker and it is this, as much as its other characteristics, that gives the Type 3 system abnormally good definition in the reproduction of complex orchestral music.

MODIFIED TYPE 2 LOUDSPEAKER

Purpose and Application

The initial design for the small Type 2 monitoring loudspeaker system was produced some years ago with the object of satisfying the need for large numbers of cheap units of adequate quality to meet the less critical applications. Many of these units have been used in offices and other places where space or cost rules against the use of a very high quality system. Following the development of the main Type 3 system, the opportunity was taken to bring the design of the earlier Type 2 system up to date. As a result, major changes have been made, although the original external cabinet design has been retained. The earlier Type 2 cabinets may be modified readily to incorporate most of the benefits of the newer design. The revised Type 2 system cannot be compared with the Type 3 system in terms of quality, but it does provide a reasonably wide range system with a satisfactory balance and at a very low price. Its bass response falls rapidly below 80 c/s. and it should not therefore be used as an arbiter when monitoring for hum on a programme.

Design

In the new version of the Type 2 system, advantage is taken of a low priced loudspeaker unit whose response is unusually good for its class. The 12 inch unit has a free air cone resonance of about 41 c/s. and a free edge cone for high frequency radiation. Its small magnet leads to a low efficiency and insufficient electromagnetic damping at low frequencies. The unit is mounted in a reflex enclosure of 2.8 cubic feet, tuned with a 3½ inch diameter hole and the response is as shown in Fig. 6. To avoid middle frequency colourations, the unit is mounted on the front face of the baffle. It might be noted that, in modifying the older Type 2 cabinets, the new loudspeaker mounts in the non-circular hole in such a way as to leave two triangular apertures of just sufficient area to tune the enclosure.

The main deficiency of the loud-

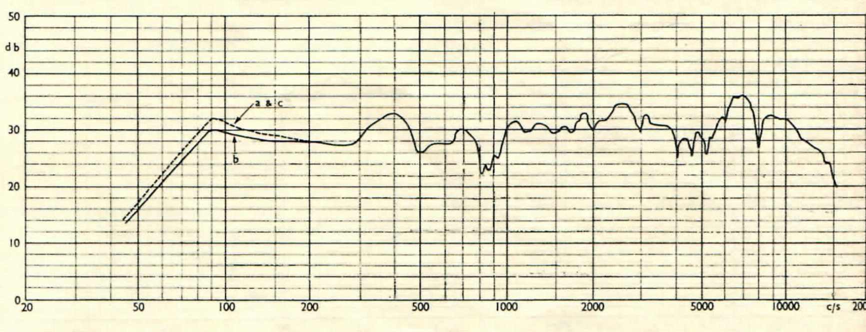


Fig. 6.—Frequency Response of Type 2 System.
(a) New design (3½" diam. vent without acoustic resistance).
(b) New design (3½" diam. vent with acoustic resistance).
(c) Modified existing cabinet (Triangular vents without acoustic resistance).

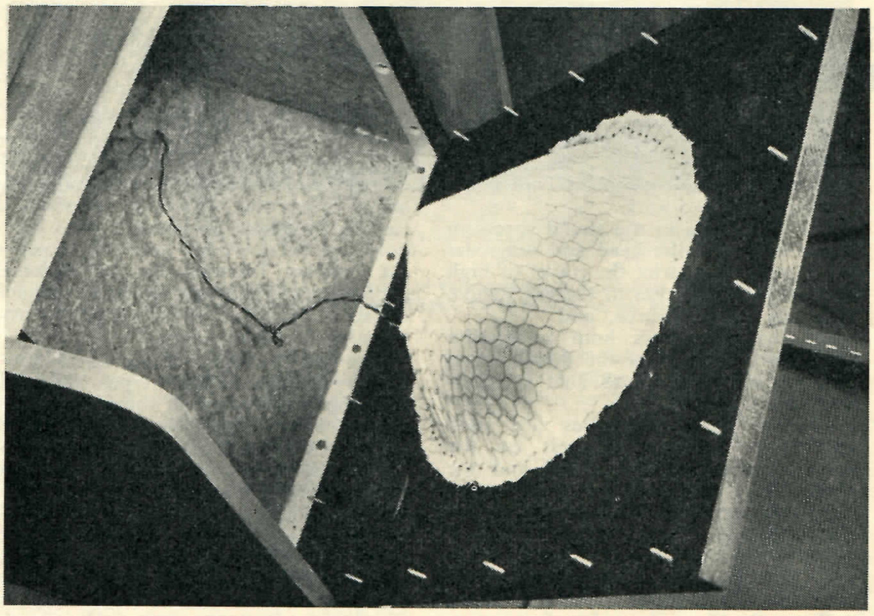


Fig. 7.—Interior of Type 2 System Showing Acoustic Resistance Element.

speaker is its lack of damping but this has been overcome by enclosing the rear of the cone with an acoustic resistance element as can be seen in Fig. 7. A layer of fabric, held rigid between layers of wire mesh, provides a resistive component for the air moved by the diaphragm. As can be seen from Fig. 8, this resistance unit removes the bass resonance peak and its associated transient to give a response equivalent to a loudspeaker with much better damping. The cabinet, as before, houses the power amplifier in the lower section. The loudspeaker mounting arrangement allows the adoption of the same approach as was used for the Type 3 system, in that both the loudspeaker and its baffle are attached from the front.

VARIATION TO THE DESIGNS

The Type 3 system is a closely integrated design involving the sensitivities, frequency responses and polar responses of its several driver units whose placement in the cabinet is also critical. It is recommended therefore that this system be not changed in any way unless comprehensive measuring facilities are available.

The Type 2 system on the other hand is very flexible and its geometry may be extensively rearranged to suit specific purposes. The response will be essentially unchanged for any configuration of the enclosure provided that the internal volume of 2.8 cubic feet is retained and that the ratio of maximum to minimum dimensions of the enclosure does not exceed about 3. The position of the vent hole is not critical as long as it has a clear path to the open air. The vent should not therefore be placed in the bottom of the cabinet near the floor or in the back of the cabinet which may be close to the wall. Ideally the vent should be close to the loudspeaker. Lining of the cabinet is of course essential, and mounting of the loudspeaker from the front of the cut-out has the advantages mentioned previously. The acoustic resistance element is equally suitable for any configuration.

The bass response may be extended by an increase in the volume of the enclosure provided that the vent area is increased in the same proportion. The resistance element may then need adjustment in the direction of increasing its resistance by the use of more layers of cloth. The purpose of this adjustment would be to retain control of the upper resonance peak which appears at a lower frequency in a larger enclosure. If the volume of the enclosure is increased substantially, experimental tuning of the vent area would be needed for optimum results.

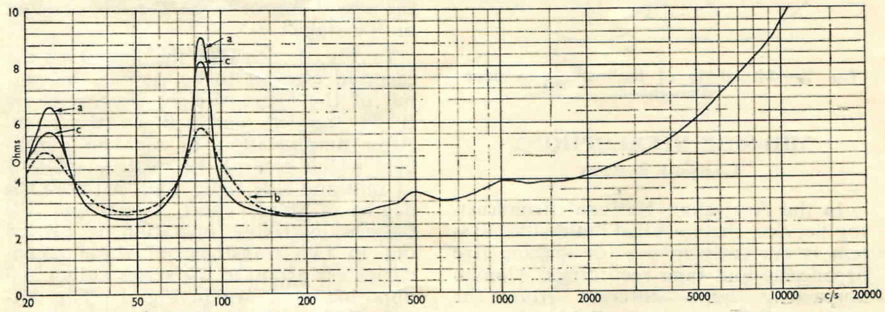


Fig. 8.—Impedance Response of Type 2 System.
(a) New design ($3\frac{1}{2}$" diam. vent without acoustic resistance).
(b) New design ($3\frac{1}{2}$" diam. vent with acoustic resistance).
(c) Modified existing cabinet (Triangular vents without acoustic resistance).

CONCLUSION

The design of the new Type 3 monitoring loudspeaker followed an extensive review of current techniques. The outcome was a system which is fairly conventional in the bass region but which incorporates some innovations in the arrangement of the middle and high frequency units and also in the overall cabinet design. The result is a system having excellent objective and subjective characteristics, in a cabinet of moderate size and good accessibility. Attention has also been given to the aesthetic design in which the polished timber is relieved by the discreet use of metallic gold trim. The unit is being used extensively in studios, control booths and transmitters where high quality mounting is essential.

The design of the earlier Type 2 small monitoring system has also been revised to give a substantially improved performance at a considerably reduced cost. This unit will continue to find widespread application in the less critical monitoring locations.

ACKNOWLEDGMENTS

The development of the Type 3 system involved some hundreds of measurements, many of which had to be taken under free-field conditions in the open air. The work of the Headquarters Radio Section laboratory and particularly that of Mr. C. N. F. Jenkins, Mr. W. M. McNaught (who appears in Fig. 1) and Mr. K. J. Drew in making these measurements in the face of frequently unsympathetic weather, is acknowledged with appreciation. The members of the Headquarters Drafting Section must also be thanked for their assistance in the mechanical design of the two systems.

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