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SOUND REPRODUCING SYSTEM

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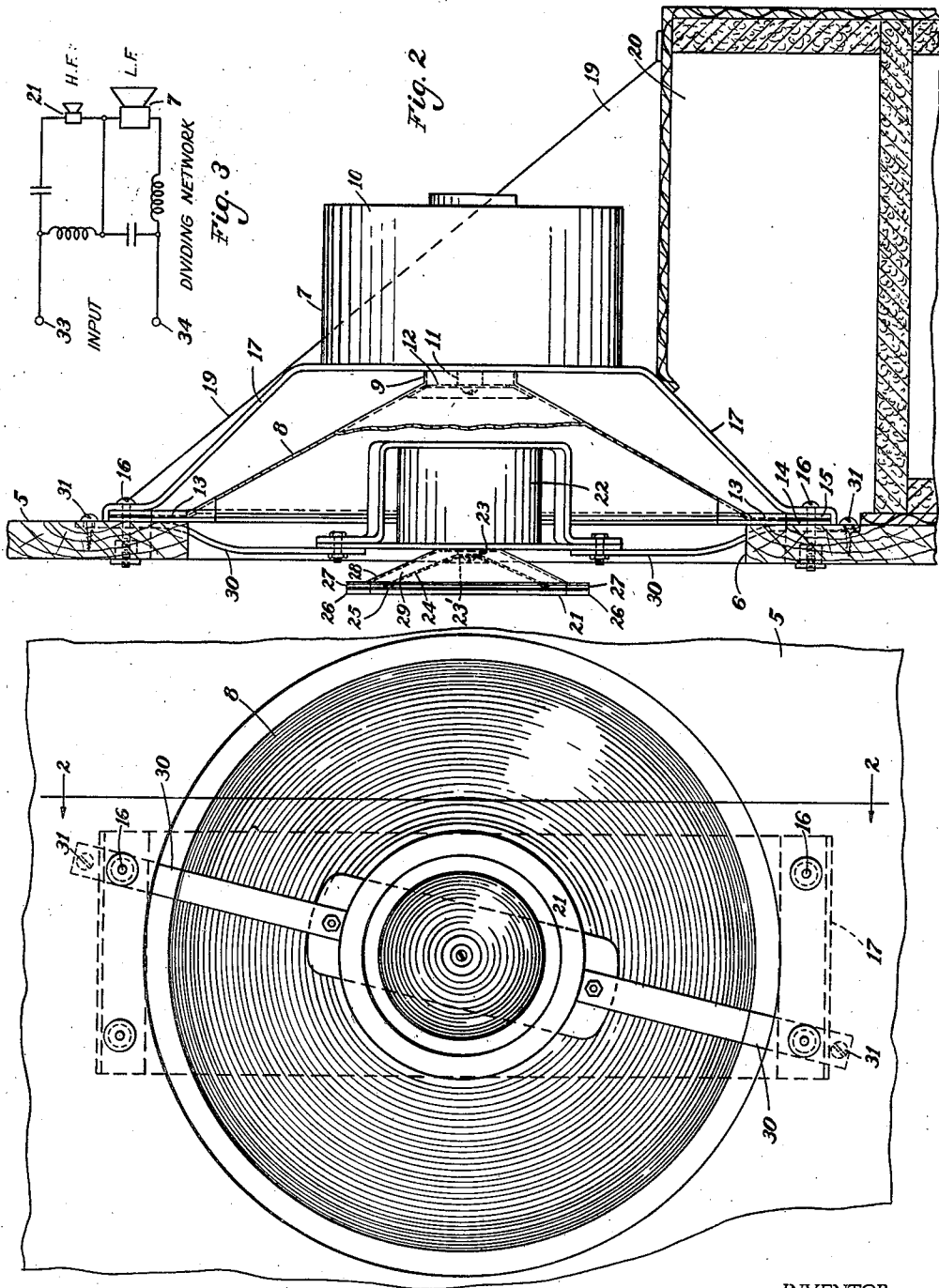


Fig. 1

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SOUND REPRODUCING SYSTEM

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This invention relates to sound reproducing systems and more particularly to sound reproducing systems of the dual loud speaker type in which one loud speaker is adapted to reproduce audio signals in the lower portion of the audio frequency range and the second loud speaker is adapted to reproduce audio signals in the remaining portion of the audio frequency range.

In some types of such sound reproducing systems, it has been the practice in the past to employ a relatively large baffle having one opening therein through which lower frequency sound waves generated by the front or hollow surface of the conical diaphragm of a low frequency response dynamic loud speaker are projected, and having a second opening spaced from the first through which the higher frequency sound waves generated by the front or hollow surface of a smaller conical diaphragm of a high frequency response dynamic loud speaker are projected. While such systems have a flatter audio frequency response characteristic with higher power handling capacity than is possible by the use of a single loud speaker designed to reproduce all frequencies in the audio frequency range, nevertheless such dual loud speaker reproducing systems have failed to produce the expected fidelity and naturalness of sound reproduction, particularly in the case of speech and especially when the input energy is divided between the loud speakers at a frequency near the middle of the speech range. As it is possible by careful design to preserve piston action and flatness of response in low frequency cone loud speakers of moderate size up to about 1500 cycles per second, and as it is difficult if not impracticable to construct high frequency cone loud speakers which are suitable for frequencies below about 1500 cycles, at the same time preserving uniformity of response and desirable radiation characteristic up to a high frequency, the neighborhood of 1500 cycles becomes a logical region in which to effect the frequency division or cross-over, although it falls near the middle of the essential speech frequency range. It is believed that the unnatural reproduction afforded by such dual loud speaker systems arises from the fact that the location of the two loud speakers in side by side relation not only causes effective changes in the phase relations of the reproduced sound components reaching the ear, but also produces the confusing impression of a double source.

While it is well known that substantial shifts among the phase relations of the components of a steady complex tone of moderate intensity are undetectable by the ear, the same is not true of transient sounds, the accurate reproduction of which is essential to the natural rendition of speech, music and noise. Although it

is also well known that the phase relations of sounds at the ears of a listener may be greatly modified by reflections from walls and surrounding objects, it nevertheless is true that the ear can discriminate to a marked degree between the direct sound from a source and that reflected from the walls of a room. This is particularly true at the higher frequencies where the ears, as well as most loud speakers, possess considerable directivity, and is also true for transient sounds. As a matter of fact, the ear gathers its impression of the latter type of sound almost entirely from the components arriving directly from the source. It has furthermore been proved experimentally that even when two ordinary loud speakers of identical characteristics are mounted side by side and as closely adjacent as their construction permits, the ear has no difficulty in determining from which loud speaker the sound comes when listening under usual home conditions of distance from the sources and room reverberation.

From the above considerations, it may be seen that the side by side spaced relation of the two loud speakers of a dual system may produce the following undesirable effects. First, because of possible differences in the path length from the two loud speakers to the ear of the listener, phase shift may occur among the frequency components of a reproduced sound, resulting in audible distortion in the case of transients. Importance is lent to this by the fact that transients occur naturally at either or both the start and the finish of sounds produced by many musical instruments, that speech is very rich in transients, and that many types of impulsive sounds are entirely transient in character.

Second, one intuitively expects speech sounds to issue from a single, relatively small source and is disturbed when the source appears to be a multiple or an extended one. For example, when the speech energy is split into two frequency bands, each band being separately reproduced by loud speakers in spaced side by side relation, a confusing and unnatural effect is experienced by the listener. He may hear one group of lower frequency components as issuing from one source and a group of higher frequency components as issuing simultaneously from another source appreciably distant from the first. These subjective effects are of a subtle nature and are difficult to analyze but, nevertheless, are believed to account for the readily observable difference between dual loud speaker systems of the kind discussed above and the improved system which is the subject of this invention.

The arrangement of the two loud speakers in spacial side by side relation has previously been an unavoidable requirement in such systems

inasmuch as it was necessary to provide the equivalent of a baffle for each loud speaker, since otherwise there would be free circulation between the front and back surfaces of each cone diaphragm with a resultant serious reduction in the response at the lower end of the desired frequency range.

It has long been recognized that the high frequency loud speakers of all such reproducing systems are subjected to large external acoustic driving forces which arise from the sound pressures set up by the low frequency loud speakers. These pressures become especially high in systems wherein the rear of the low frequency speaker is separately enclosed, and may be of sufficient magnitude to damage the high frequency loud speaker unless protective measures are taken against such a contingency. In current systems, this protection has taken the form of increased stiffness of the center or apex suspension of the diaphragm of the high frequency loud speaker. However, sufficient stiffness for adequate protection not only results in a value which is detrimental to normal operation of the high frequency speaker, but has the added disadvantage of concentrating at the center of the cone the reaction forces due to external acoustic driving, thus exposing the cone itself to forces which may result in its deformation.

In accordance with the main feature of the present invention, there is provided a sound reproducing system in which the loud speaker or reproducer designed to reproduce sound in the higher portion of the audio frequency range is mounted in coaxial superimposed relation with the loud speaker or reproducer designed to reproduce sound in the lower portion of the audio frequency range whereby the effect of a unit sound source is obtained.

Another feature of the dual reproducing system of this invention resides in the use therein of a small diameter conical diaphragm high frequency loud speaker, the cone diameter being of the order of two and one half inches. A small diaphragm is desirable here for several reasons, among which are: (1) the extension of the high frequency range due to the smaller mass of the small diaphragm; (2) the preservation of piston motion to a higher frequency, thus contributing to flatness of response, and (3) the consequent elevation of the frequency range in which wave motion in the cone structure takes place to a region wherein the damping contributed by the cone material itself and its leather supporting edge is high and effective in suppressing the resonances concomitant with such wave motion; also, (4) sharply directional radiation is postponed to such a high frequency that the deflecting vanes, used in former systems of this type to distribute the radiation, may be dispensed with.

Such small diaphragms have not been successfully employed before as direct radiators in high frequency loud speakers of dual systems in which advantage is taken of the maximum obtainable flat response of the low frequency loud speaker as previously described, because the acoustic radiation resistance of such small diaphragms falls off rapidly at frequencies considerably higher than the optimum crossover frequency. For example, the radiation resistance of a two and one-half inch diameter diaphragm in a baffle begins to fall off at about 3400 cycles per second, whereas flat response may be desired down to 1500 cycles. This results in such a re-

duction of acoustic efficiency that the high frequency loud speaker is unable adequately to complement the response to the low frequency loud speaker over a considerable region above the crossover frequency. To offset this, another feature of this invention relates to the proportioning of the housing of the high frequency loud speaker diaphragm so that the stiffness of the entrapped air therein together with the stiffness of the cone diaphragm supports of this loud speaker resonates broadly the mass of the cone diaphragm system at a frequency in the neighborhood of the lower portion of its frequency range. By thus increasing the velocity per unit force of the diaphragm in the region wherein its acoustic efficiency falls off due to the decrease in radiation resistance, the response is restored to a level comparable with that obtainable from the system over the remainder of its frequency range.

Other features of the high frequency loud speaker are the provision of a diaphragm center support which produces relatively low damping and a diaphragm edge support which produces relatively high damping. In some former types of cone loud speakers intended solely for the reproduction of high audible frequencies, the center suspension of the cone has consisted of a spider or disc of relatively thick fibrous material having substantial internal damping by virtue of friction among its constituent fibres. The outer cone suspension in such former loud speakers has often consisted of an annular flange-like extension of the cone material itself but of substantially reduced thickness, and which afforded little damping for the edge of the cone. Such construction was not conducive to efficient and accurate sound reproduction as will be pointed out. All of the vibratory energy applied to the cone by the driving coil must necessarily flex the center support because of the rigid attachment of the periphery of the latter to the truncated apex of the cone at or near its junction to the driving coil. Therefore, any energy dissipated in the center suspension is unavailable for the production of sound. On the other hand, edge damping of the cone is desirable for the suppression or control of energy reaching the edge by virtue of flexural vibration propagated through the cone structure itself as wave motion. If little or no damping is provided at the outer margin of the cone, reflection of this wave energy takes place and the motion is propagated inwardly toward the apex, interfering with the outwardly moving waves and producing at certain frequencies undesirable resonances which manifest themselves in sharp variations of sound output with frequency. The provision of suitable edge damping results in the suppression of such resonances and the more efficient transmission of the vibratory energy through the cone; a result similar to that obtained by the termination of an electrical transmission line in its characteristic impedance.

In the present invention, the center suspension of the cone consists of a flexible disc of thin metal having low internal damping, such as one of the harder grades of duralumin, while the outer edge of the cone is suspended by means of an annulus of soft leather, such as carpincho, having high internal damping. This combination results in an efficient diaphragm system producing a very flat response-frequency characteristic throughout its intended range.

A further feature of the invention relates to

an arrangement whereby the excessive stiffening of the center suspension of and the need of a baffle for the high frequency loud speaker has been obviated and instead the rear surface of the diaphragm of this loud speaker is completely enclosed to provide a chamber of entrapped air which cushions the diaphragm of the high frequency loud speaker against the damaging action of the sound pressures developed by the low frequency loud speaker. Furthermore, the enclosure of the rear surface of the high frequency loud speaker prevents circulation between the front and back of the cone diaphragm thereof and thus the response at the lower end of its desired frequency range is not reduced.

Other features and various advantages of the invention will appear from the detailed description and claims when taken with the drawing in which

Fig. 1 is a front view of the dual sound reproducing system of the present invention with a portion thereof broken away;

Fig. 2 is a vertical section thereof taken substantially on the line 2—2 of Fig. 1 and

Fig. 3 is a diagrammatic showing of a dividing network or audio frequency input circuit suitable for actuating the dual loud speakers.

Referring especially to Figs. 1 and 2, 5 designates a baffle having an opening 6 therethru. This opening in the present instance is of a size to function with an eight inch diameter cone loud speaker, although it will be understood that the invention is not limited to this dimension. Behind this opening in the baffle, there is mounted a conventional moving coil type of loud speaker 7 provided with a well-known cone shaped diaphragm 8 of paper or like material. This diaphragm, as is well known, is in the shape of a truncated cone having a moving coil 9 secured to its truncated portion and mounted to oscillate in a radial field produced by a well known magnetic structure 10. This magnetic structure includes a cylindrical core to a boss 11 on the free end of which the truncated portion of the cone diaphragm and the moving coil are resiliently mounted by a flexible center suspension generally designated 12. The outer margin of the cone-shaped diaphragm is supported by the usual flexible suspension 13 of carpincho leather or the like which suspension is fastened between the clamping rings 14 and 15 and serves with the baffle to prevent circulation between the front and rear of the diaphragm. These clamping rings, which are fastened by bolts 16 to the rear surface of the baffle are supported on a bracket 17, secured to the front of the magnetic structure to function as a support therefor. The rear surface of the diaphragm 8 communicates with a pair of housings 19 (one only of which is illustrated), which housings in turn communicate with a circuitous sound damped passage or labyrinth 20, only a part of which is illustrated but which is more fully disclosed in the patent to Olney #2,031,500. As is fully set forth in the mentioned patent, the passage resonates at a predetermined frequency or frequencies in the lower portion of the frequency range of its related loud speaker so that the bass response of this speaker is augmented thereby.

A high frequency cone-type loud speaker 21 of small size but of essentially the same structure as that of the low frequency loud speaker, is mounted coaxially with the diaphragm of the first loud speaker so that it nests in the hollow of said diaphragm. This high frequency loud speaker

also includes a magnetic structure 22 for establishing a radial magnetic field through a moving coil 23 attached to the truncated apex of a cone-shaped diaphragm 24 made of paper or like material. It will be understood that the truncated apex of the cone is supported by a flexible metallic disc suspension 23' of low internal damping fastened to a boss on the end of the cylindrical core (not shown) of the magnetic structure 22. The harder grades of duralumin are suitable for the disc suspension. The outer edge of this cone diaphragm is supported by a flexible suspension or annulus 25 of carpincho leather or the like, having relatively high damping, this suspension in turn being secured between clamping rings 26 and 27. These clamping rings are secured to the periphery of a cone-shaped metal housing 28 completely enclosing the back surface of the diaphragm and being attached to the front of the magnetic structure 22. It will be understood that this housing is spaced from the diaphragm a distance sufficient to enable the diaphragm 24 to have its maximum movement without striking the housing. This housing together with the rear surface of the diaphragm provides a chamber 29 in which air is trapped, the stiffness of which functions as a cushion to prevent the sound pressures developed by the low frequency loud speaker from moving the diaphragm system sufficiently to damage it. As this stiffness is distributed uniformly over the diaphragm surface, there is no tendency toward deformation of this diaphragm such as might result were sufficient mechanical stiffness for protective purposes concentrated, for example, in the center suspension of the diaphragm. The stiffness of the system, of course, becomes ineffective above resonance and offers no impediment to the operation of the speaker within its intended frequency range. This entrapped air also provides the stiffness element which cooperates resonantly with the mass of the moving system, as previously described, to offset the falling off of acoustic radiation resistance.

The high frequency loud speaker unit is supported by means of the arms 30 in nested coaxial relation with the cone diaphragm of the low frequency loud speaker. The ends of these arms are respectively bolted to the magnetic structure 22 and to the rear surface of the baffle 5, the main fastening to the baffle being accomplished by the same bolts 16 that mount the low frequency loud speaker. The baffle is preferably recessed at its rear surface to receive the outer ends of the arms 30 thereby enabling these arms to lie flush so that no obstruction is offered to the sealing of the low frequency cone rim to the baffle. It will be noted that the outer ends of the arms 30 are secured to the rear surface of the baffle independently of the low frequency loud speaker by the screws 31 so that support for the high frequency loud speaker is not lost during installation or removal of the low frequency loud speaker. Because both loud speakers are supported from the back of the baffle, the usual grille in the front of the cabinet which houses the sound reproducing system can be made non-removable and yet ready access is permitted to the loud speaker units.

It will be understood that the moving or voice coils of the loud speaker units 7 and 21 will be connected into an audio frequency dividing network, as shown in Fig. 3, the terminals 33 and 34 being connected to a suitable source of audio frequency currents such as the output of a radio

receiver. The magnetic structures of these loud speakers are arranged to develop suitable radial magnetic fields through the driving coils of these devices either by including permanent magnets therein or by electromagnets energized from a suitable direct current source in accordance with the well-known manner.

It might be expected that the high frequency loud speaker, since it is mounted directly in front of the cone diaphragm of the low frequency loud speaker, would constitute an undesirable obstruction to the radiation of the cone diaphragm of the low frequency loud speaker. In the present invention any existing effect of this nature is turned to an advantage by properly proportioning the size of the two loud speakers with respect to each other and to the point in the audio frequency range where the low frequency loud speaker ceases to radiate sound and the high frequency loud speaker starts its response. This crossover frequency in the present system is in the neighborhood of 1500 cycles. It may be shown from the work of Stenzel (*Elektrische Nachrichten-Technik*, June, 1927) that a cone diaphragm functioning as a piston radiator becomes effectively directive when its diameter approaches a half wave length. In the preferred form of the present invention the low frequency cone diaphragm is eight inches in diameter so that it increasingly tends to produce beam radiation from about 850 cycles upward. Furthermore, it may be deduced from the analysis given by Lord Rayleigh (*Theory of Sound*, vol. 2, page 272) and others, that a spherical obstacle in the path of a sound wave becomes effectively diffractive as its diameter approaches one-quarter of a wave length. The present high frequency loud speaker structure with its clamping rings and driving unit effectively constitutes an obstacle roughly equivalent to a sphere four inches in diameter, and therefore becomes an effective diffractor at about 850 cycles. This is the frequency at which the low frequency speaker begins to manifest directional effects. Above 850 cycles and up to the cutoff point of the low frequency speaker, the high frequency speaker structure acts as a deflector or spreader for the radiation of the low frequency loud speaker and thereby functions usefully in causing the latter to maintain a more uniform sound field. In order to satisfy the above conditions it will be noted that the diameter of the effective sphere corresponding to the high frequency loud speaker as an obstacle should be one half that of the diaphragm of the low frequency loud speaker.

The onset of directional radiation in the present system at frequencies within the range of the high frequency loud speaker is postponed to a frequency in the neighborhood of 3000 cycles by making the diaphragm of the high frequency loud speaker of small diameter, only two and one-half inches in the preferred embodiment of this invention. Thus the frequency range over which wide angle sound radiation takes place, is much greater than can be had with a single loud speaker of sufficiently great diameter to radiate low frequencies effectively. This feature constitutes another advantage of the present dual system.

What I claim is:

1. In a sound reproducing system, a loud speaker of the cone diaphragm type designed to

reproduce sound in the lower portion of the audio frequency range, a second loud speaker of the cone diaphragm type designed to reproduce sound in the higher portion of the audio frequency range, said last-mentioned diaphragm being flexibly supported at its edge and at its apex, said second loud speaker being nested in the hollow of the diaphragm of said first loud speaker and means for resonating said second loud speaker in the lower part of the audio frequency range reproduced by it, said resonating means comprising the mass of the flexibly supported portion of said second loud speaker together with the stiffness of the confined air adjacent the back surface of the diaphragm of said second loud speaker.

2. In a dual sound reproducing system comprising a low frequency loud speaker of the cone diaphragm type and a high frequency loud speaker of the cone diaphragm type, said loud speakers being mounted in nested coaxial relation, the cone diaphragm of said high frequency loud speaker having a center suspension and a peripheral annular suspension, said center suspension having negligible damping and said peripheral suspension having relatively high damping, and means for substantially enclosing the back surface of the cone diaphragm of said high frequency loud speaker to afford therewith a chamber having a cushion of entrapped air therein.

3. In a sound reproducing system, a loud speaker of the cone diaphragm type designed to reproduce sound in the lower portion of the audio frequency range up to a cross-over frequency, a second loud speaker including a cone diaphragm designed to reproduce sound in the higher portion of the audio frequency range down to said cross-over frequency, the diameter of said last-mentioned diaphragm being such that the radiation resistance thereof is seriously deficient in the lower portion of its audio frequency range, said second loud speaker being nested in the hollow of the diaphragm of said first loud speaker and resonating means for augmenting the response in the lower part of each of the audio frequency ranges reproduced by said loud speakers, said means including means for increasing the velocity per unit force of said second diaphragm in the range where its radiation is seriously deficient, each loud speaker being provided with a field magnet separate from the field magnet of the other loud speaker.

4. In a dual sound reproducing system comprising a low frequency loud speaker of the cone diaphragm type designed to reproduce sound in the lower portion of the audio frequency range up to a cross-over frequency, and a high frequency loud speaker of the cone diaphragm type designed to reproduce sound in the higher portion of the audio frequency range down to said cross-over frequency, said high frequency loud speaker being mounted in nested coaxial relation with said low frequency speaker, said high frequency loud speaker having an overall diameter approximately equal to one-half of the diameter of the low frequency cone diaphragm, whereby said high frequency speaker will noticeably spread the radiation of the low frequency speaker in the region of said cross-over frequency.

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