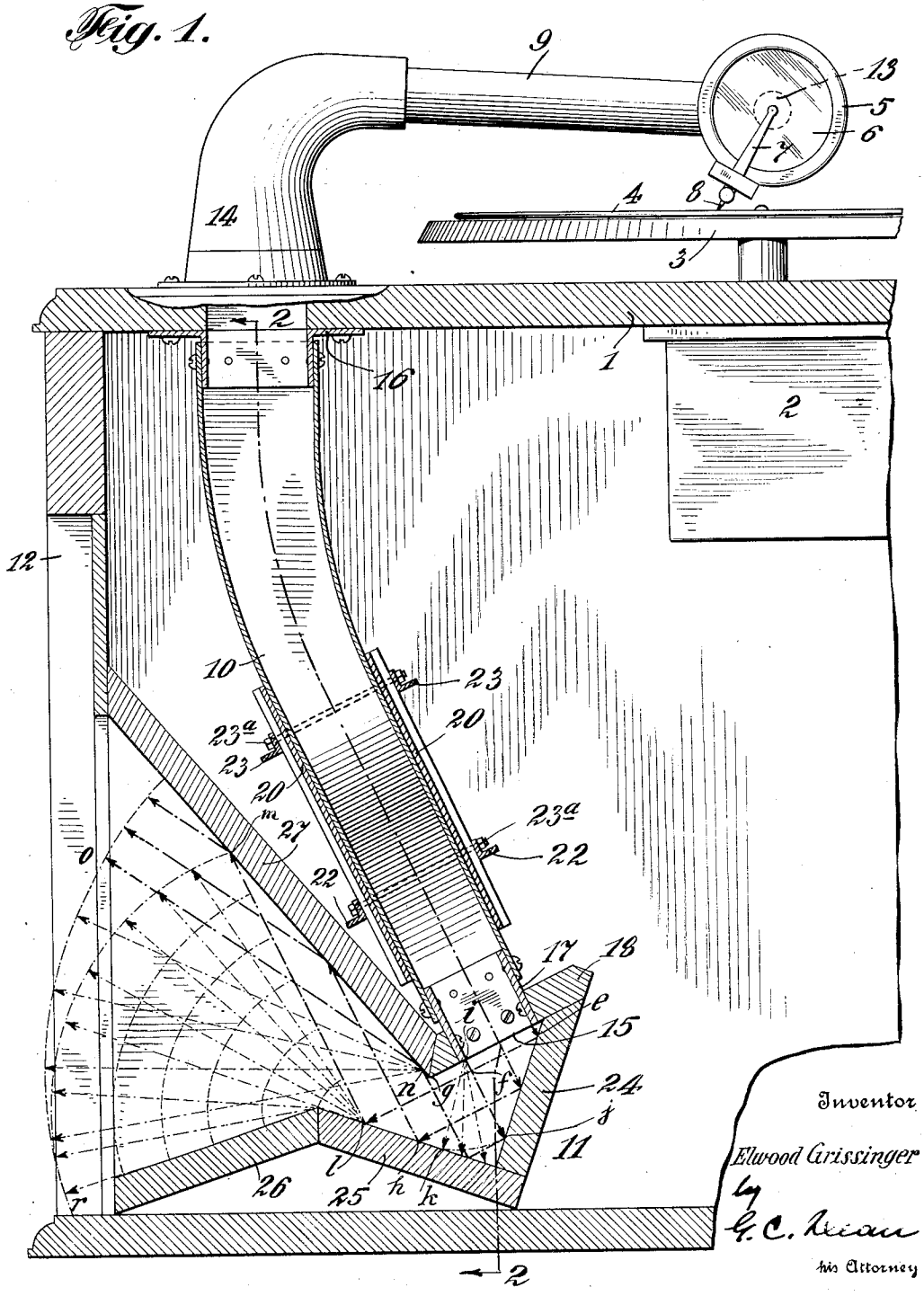
Dec. 18, 1923. 1,477,556

E. GRISSINGER

SOUND PROJECTING APPARATUS AND METHOD

Filed July 12, 1921 4 Sheets-Sheet 1

Fig. 1.



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Dec. 18, 1923. 1,477,556

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SOUND PROJECTING APPARATUS AND METHOD

Filed July 12, 1921 4 Sheets-Sheet 2

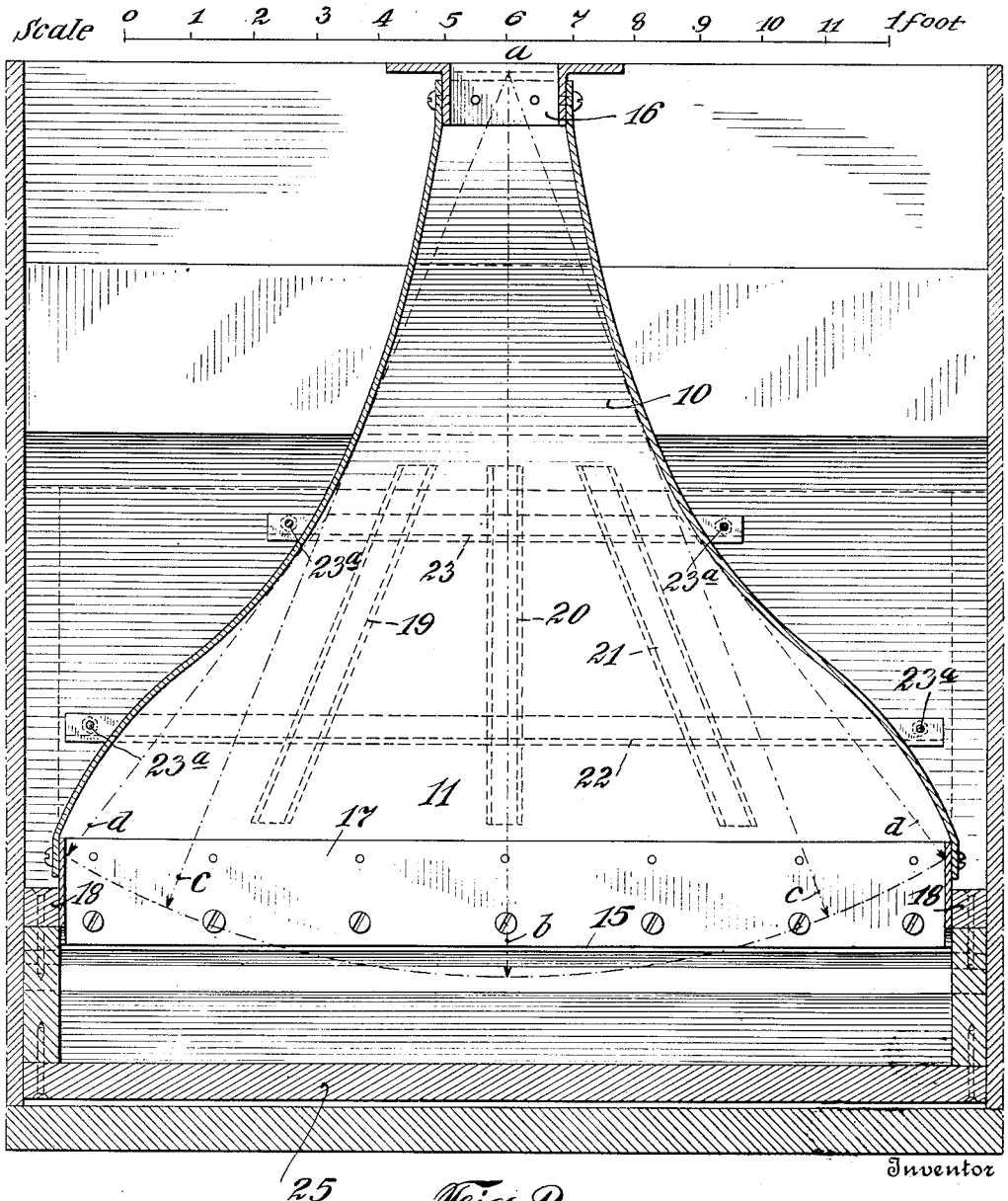


Fig. 2.

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Dec. 18, 1923. 1,477,556

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SOUND PROJECTING APPARATUS AND METHOD

Filed July 12, 1921 4 Sheets-Sheet 3

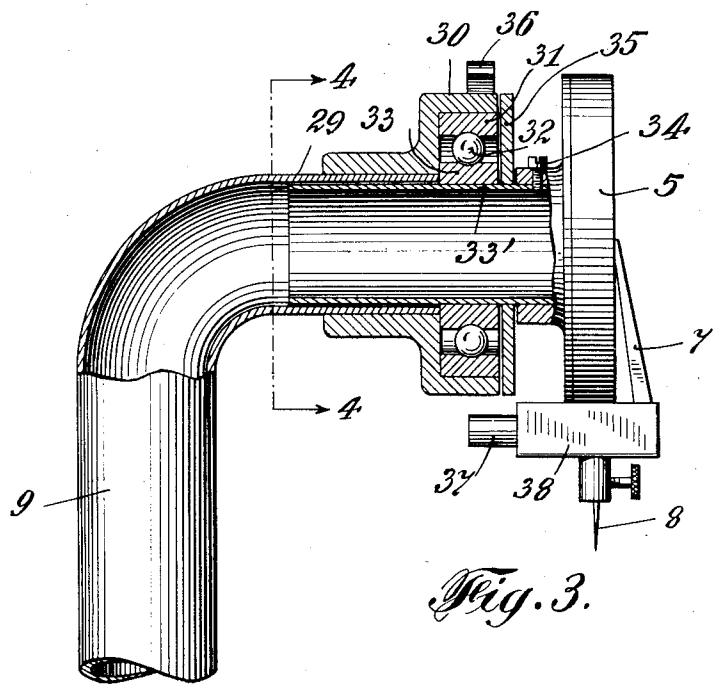


Fig. 3.

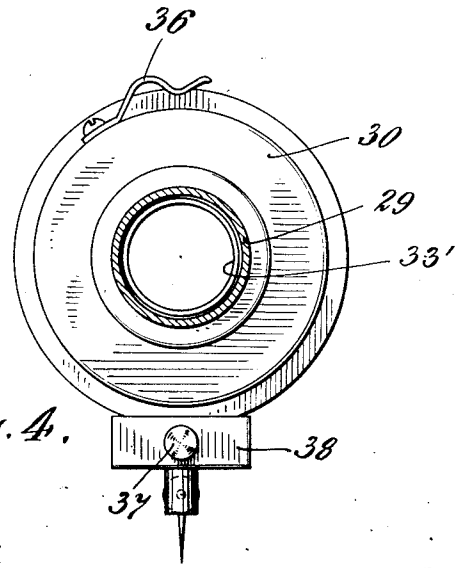


Fig. 4.

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SOUND PROJECTING APPARATUS AND METHOD

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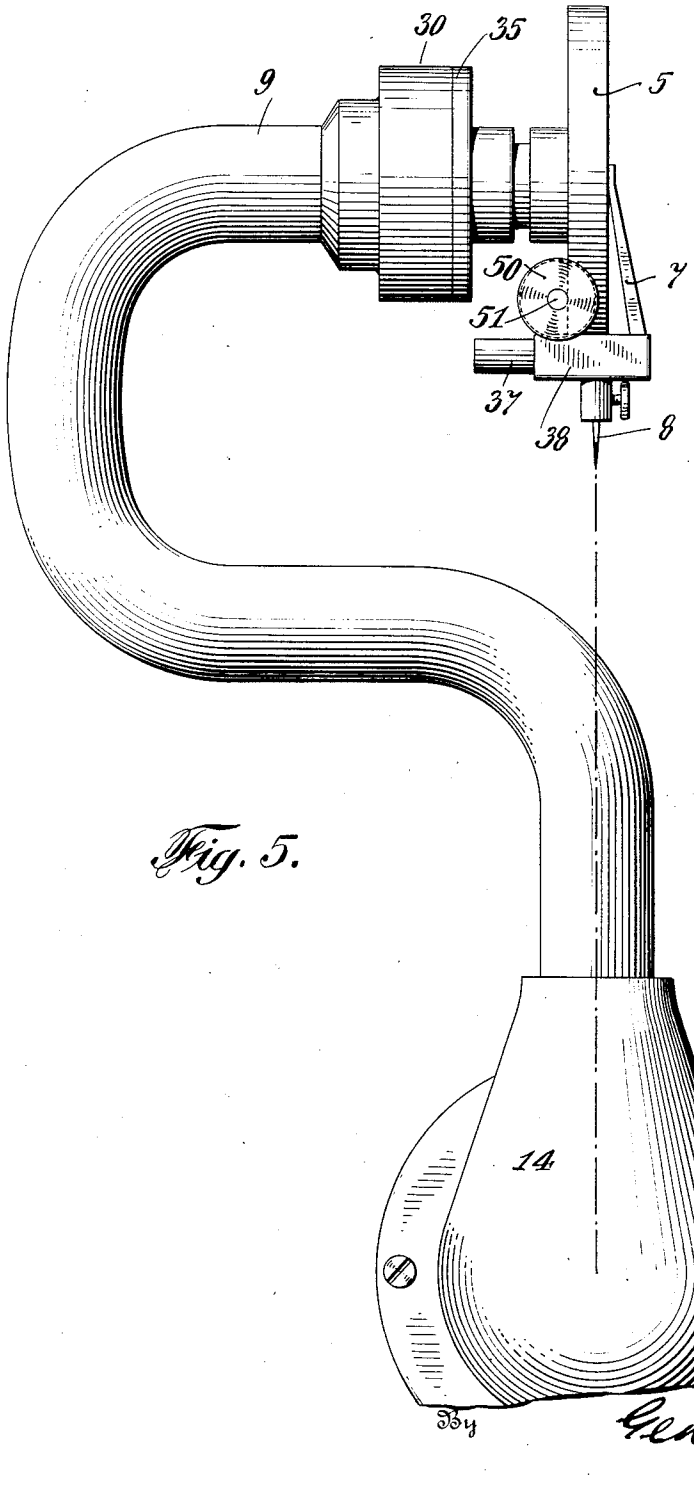


Fig. 5.

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Patented Dec. 18, 1923. 1,477,556

UNITED STATES PATENT OFFICE.

ELWOOD GRISSINGER, OF BUFFALO, NEW YORK.

SOUND-PROJECTING APPARATUS AND METHOD.

Application filed July 12, 1921. Serial No. 484,240.

To all whom it may concern:

Be it known that I, ELWOOD GRISSINGER, a citizen of the United States and resident of Buffalo, in the county of Erie and State of New York, have invented certain new and useful Improvements in Sound-Projecting Apparatus and Methods, of which the following is a specification.

My present invention is shown as embodied in a phonograph cabinet and it includes a special form of sound projector peculiarly adapted to serve the purpose of an amplifier for such cabinets, but certain features of the projector will be found useful in connection with telephone receivers and other vibratory diaphragm sound producers and also in connection with other sources of sound, particularly where, as in the case of human speech and music, the sounds comprise a wide range of frequencies, and particularly where it is desired to faithfully reproduce a multiplicity of sets of waves or complex waves of many frequencies, simultaneously.

A primary object of my invention is to provide an air column associated at one end with the diaphragm of the phonograph reproducer and at the other end communicating with the open air, in which the air column will be a suitable medium for development, expansion of wave front, and projecting into the open air, sound waves having a wide range of physical lengths, including sound waves of which the quarter wave length is long and requires great length of air column, and also short waves of the higher frequencies; the quarter lengths of which may be two inches or less.

In the ordinary commercial tone arm, the diameter of the air column is small as compared with the half or quarter wave lengths of the higher frequencies necessary for good phonographic reproduction and it seems to be a fact that under such conditions the waves travel around bends and past obstructions with very little detriment. We know from the actual physical lengths of the waves that in such narrow conduit the phase conditions of rarification, condensation and oscillation at any one instant must be nearly the same for regions in advance of the bend, at the bend, and beyond the bend. That is to say, the total phase difference subject to disturbance is small. Hence, such cross-flow, eddying flank diffusion or reflection as can occur around the bends are relatively innocuous. It is equally evident however, that where the diameter of the conduit is great as compared with the physical length of the wave phases, sound energy diffusing or flowing around the shorter inside of the curve may be completely out of phase with corresponding energy reflected or flowing around the longer path defined by the outer wall of the conduit.

The above will make it easier to understand some aspects of my device wherein the waves from the tone arm or other source traverse a conduit comprising a primary expansion portion in which the wave front is afforded guided and limited but rapid expansion along lines diverging in one dimension, with little or no expansion or divergence in the other dimension, thereby forming a relatively thin sound beam, with widely diverging flanks and deeply curved wave fronts. This beam discharges through a slot-like outlet which the curved wave fronts or wave phases cross at different times and at different angles. The beam then traverses a secondary expansion portion in which the wave front is afforded guided but rapid expansion in the other dimension, while the divergent flanks of the beam are deflected inward by non-divergent walls so that the inturned portions cross each other and cross the mouth of the projector at considerable angles.

The primary conduit may be curved to almost any desired extent in the thin direction without danger of serious phase displacement for the short length waves, the reasons being presumably similar to those suggested for the case of a curved tone arm. It is to be noted, however, that curvature either of a small diameter pipe or of a thin layer conduit is not a good thing acoustically. Hence, in the preferred form of my invention, the middle portion of the air col-

umn is made fairly straight (downward for the cabinet type of phonograph), and the waves are turned abruptly outward through the side of the cabinet, preferably by high angle reflection, the arrangement being so ordered that the main beam preferably crosses the plane of the vertical mouth of the projector at a sharp upward angle.

At every point in my air column where the air path of the waves is modified by sudden change of size or shape of the air column, the action on the different portions of the wave front of each individual wave is non-simultaneous and the distances, that is, the effective air column lengths are also substantially different. Consequently, reflex or backward flow of wave energy is minimized, practically all of the energy gets out, and whatever air column resonance there is, does not cause distortion so far as detectable by the human ear.

Another feature or aspect of my invention concerns the relation of the slender part of the air column with respect to the succeeding portion where there is rapid widening in one dimension. In my device the slender part of the air column is in the tone arm. This part is, by itself considered, a resonance column of very definite natural frequencies including a fundamental and the usual harmonics of said fundamental according to the well known laws of pipes, open at one end. From structural necessity the length of this pipe in my instrument is the same as usual, about 12 inches, but in my case, from this point on, the air column is continuous with and merges into a portion which progressively and rapidly widens in one dimension while not expanding at all in the other dimension, and preferably converging in said other dimension. In my device, the one-dimension widening is progressive for a length at least equal to and preferably greater than the length of the small diameter part of the air column.

By thus intimately associating the slender part of the air column which is in the tone arm, with an equal or greater length and breadth of widened air column, the otherwise sharply resonant air column in the tone arm is not so free to resonate by itself in accordance with its own dimensions and elasticity.

The composite unit comprising the slender air column in the tone arm conjoined with a widened portion having a length equal to or greater than the length of the tone arm and thickness approximately equal to or less than the outlet of the tone arm, so that the outlet slot is 12 inches or more in width by 2 inches or less in depth, constitutes in and of itself, a remarkably effective air column both for loading the diaphragm to make it do maximum work during each excursion, and also for propagating and projecting waves of all lengths. The widened portion may be curved in the direction of its thinness through an arc of 90 degrees or more, provided the radius of curvature be not too sharp, without substantial impairment of its function. Consequently it is quite possible to arrange the outlet slot horizontally in the front face of the cabinet and have the intermediate conduit curved through 90 degrees to bring its small end into registry with the vertical passage through which the tone arm discharges downward.

The slot outlet however is of special advantage in connection with the reflector outlet shown in the drawings. The thinner the slot the thinner is the beam projected on the first reflector and the less is the distance across the open mouth of the slot, adjacent which the reflected beam must travel; also the less will be the energy diffused or reflected back and upward through the slot toward the diaphragm; also the less the reflected beam adjacent the mouth of the slot will become out of phase with the flank diffusion from the front face of the beam.

Nevertheless, there seem to be practical limits for desirable thinness at the slot. I believe I know the reasons for these limits, but it will be sufficient to say that for waves of the intensity that can be generated by a phonograph diaphragm, that for a slot as thin as $\frac{1}{2}$ inch to give an area of expanded wave front sufficient for satisfactory loudness, the slot must be longer than is convenient for phonograph cabinets of present-day commercial widths. Also, extreme thinness of slot without sufficient increase in length and width of the expansion conduit seems to result in a shriller quality for the reproduction and a tendency to too faithful reproduction of needle noises. On the other hand, a slot thicker than 2 inches sacrifices quality, apparently because of absorption or dissipation of high frequency waves upon which quality depends. Moreover, the indefinable "instrumental" quality imparted by the instrument itself, which for a $\frac{1}{2}$ inch slot may be too "sharp" or "shallow", is, with the two inch slot, too muffled and hollow. The two inch main beam projected from such a slot will have the forward diffusion from its front face at least 2 inches out of phase with the part of the reflected main beam which travels in the same direction. I have previously explained that it is bad for the high-frequency, short waves, to have the energies thereof get as much as 2 inches out of phase.

In any event, the remarkable results have been attained with a 14 inch by 14 inch expansion conduit having a slot outlet approximately $1\frac{1}{4}$ inches by 14 inches and with a 24 inch conduit having a slot outlet approximately 24 inches by 1 inch.

Where the outlet of the tone arm is standard size, say 1¾ inches by 1¾ inches, the pinching in on the flat sides to bring the sound beam down to 1¼ inches or 1 inch, or even less, seems to be a good thing, probably because it makes it easier for the waves to spread laterally at the rapid rate necessary to fill the width of the conduit, thereby developing a considerable arc of curvature for wave front, the advantages of which have been described above. It is quite possible and may be of advantage to accentuate this effect by pinching in the beam more along the axis where the wave path is shortest, than at the sides where it is longer.

Where, as in the preferred form, the wide thin sound beam projected from the slot impinges successively upon two high angle reflectors and is then permitted guided but wide angle expansion in a vertical direction, care should be taken to keep the dimensions of the throat through which the main beam is finally projected, as narrow as may be without choking the exit of said main beam. In practice I have found that this dimension, the distance from the bottom reflector to the roof at the nearest point, may be not very much greater, and preferably less than the inlet slot from which the primary beam is projected, although this seems to be partly an energy problem and the desideratum seems to be to have the beam "fill" the throat without choking it. For example, where the slot outlet for the primary beam was 14 inches by 1¼ inches, this final "throat" was 14 inches by 1⅛ inches, the results were very good, but this same reflecting projector with this same 14 inches by 1⅛ inch throat, gave very good results where the primary slot was graduated down first to 1 inch expanding conduit then a ¾ inch and then ½ inch, the 14 inch dimension of the primary slot and the throat being the same in all four cases.

The reflecting projector mouth piece seems to be of further advantage as affording a considerable further extension of the air column. By measurement in accordance with the scale on the drawings it will be seen that the reflection path of the axis of the main beam through this reflecting projector mouth is about 11 inches, which, added to say 14 inches for the lateral expansion part, plus say 12 inches for the tone arm, gives a total air column length of say 37 inches which is sufficient to physically contain a quarter inch wave length of very low frequency. Moreover, the wide mouth of said projector tends to add a certain virtual or "phantom" acoustic length to the air column so that it will be safe to say that the above physical dimensions afford a controlled virtual air column length for generation of quarter waves nearly 4 feet long, that is to say, near the next to the lowest octave on the piano and below the lowest fundamental frequency of the male human voice. Of course when the 24 inches by 24 inches lateral expansion is employed the actual physical length of the air column measured along the axis is fully 4 feet.

I find the herein described principle of one-dimension expansion of the wave front is so effective that the total length of the air column from the diaphragm to the mouth of the projector may be made short and of very low frictional resistance, thus making practicable another feature of my invention which consists in arranging the tone arm outlet at the front of the phonograph cabinet directly over the projector outlet. This makes desirable another feature of my invention which consists in arranging the sound box so that the stylus needle trails toward the vertical axis of the tone arm, on the right hand side of the center of a record. This makes it convenient for right-hand manipulation of the sound box to renew the needle or rotate the same into and out of operating relation to the record. A further feature is mounting the sound box upon ball bearings, for rotation about an axis which coincides with the axis of the sound outlet of said box.

The above and other features of my invention may be more fully understood from the following description in connection with the accompanying drawings, in which:—

Figure 1 is a vertical section along the central axis of the sound amplifier and projector showing diagrammatically the path of the main "beam" and also a part of the forward diffusion thereof near the mouth of the projector.

Fig. 2 is a section at right angles to the plane of Fig. 1 taken along the curved and broken line 2—2 on said Fig. 1, indicating diagrammatically also the lateral expansion and downward curvature of the wave front in this dimension;

Fig. 3 is a detail section showing the mounting of the reproducer on the tone arm;

Fig. 4 is an elevation partly in section on the line 4—4, Fig. 3.

Fig. 5 is a plan view of a modification.

For reasons which will be obvious from the foregoing general description of the invention, these drawings are intended to indicate approximate sizes as well as the proportions of the parts in one desirable embodiment of my invention. The scale for Figs. 1 and 2 is indicated on Fig. 2, but Figs. 3, 4 and 5 are on a scale twice as large.

In these drawings the invention is shown as applied to a cabinet type of phonograph. The top 1 carries the motor box 2 driving turn table 3 supporting record 4 in operative relation to sound box 5 having diaphragm 6 operated by a stylus lever 7 through needle

8. These parts may be of any known or desired construction, but as above indicated, the sound box preferably embodies the invention set forth in my application Serial No. 404,860.

The top 1 also carries the tone arm 9 on standard 14; also the primary expansion conduit 10 and the reflecting, secondary-expansion projector 11, which opens through the side 12 of the cabinet.

The diaphragm 6 has its inner face in operative contact through opening 13, with the upper end of the air column which extends continuously through said parts 9, 14, 10, 15 and 11 to the outer air.

The diameter of the air column may be say $\frac{5}{8}$ inch to $\frac{3}{4}$ inch for the length of the tone arm 9, but in the device shown this is enlarged to about $1\frac{3}{4}$ inches in the standard 14. Then for the next 14 inches or so through the expansion chamber, the air column has a front-to-rear contraction to say $1\frac{1}{4}$ inches, while the lateral widening in the same distance is approximately 14 inches. The next 4 inches measured along the axis of the main beam, follows the reflection path, and is contained in a portion of the projector which actually measures only about $1\frac{1}{2}$ inches from front to rear. The path of the beam from the second reflection out to the mouth of the projector is about 8 inches to 10 inches though the shortest distance to the mouth is say 4 inches to 6 inches. This is short as compared with lengths of either tone arm or primary expansion conduit. The final expansion in the vertical direction is also limited as to angle, being preferably between top and bottom walls diverging at angles less than 90°, preferably about 60° to 70°. The horizontal width of the mouth across the face of the cabinet is preferably the same or slightly greater than that of the slot outlet at 15. Usually it will be found convenient and acoustically desirable to make this dimension about the same as the practically permissible width of the cabinet.

The entire widening conduit 10, together with the entire reflecting projector 11 might well be embodied in one integral gray iron casting having walls say $\frac{1}{8}$ inch or more in thickness, but as actually constructed by me and as shown in the drawings, the intermediate widened section 10 is made of 16 gauge hard rolled sheet brass the sides being cut to pattern and soldered at the corners. The transverse section is substantially rectangular throughout. At the upper end the sheet brass is firmly screwed and brazed to a square bushing 16 which is in turn screwed to the top 1. At the lower end the slot-like outlet is reinforced by a stiff brass frame member 17 which is in turn screwed to the top board 18 of the reflecting projector. As will be evident from Fig. 2, particularly, the front and rear walls of the widening section 10 are of very considerable area and the sheet brass employed being relatively thin, would be liable to vibration in response to the sound waves. Consequently I have reinforced and stiffened these flat areas by longitudinal channel bars 19, 20, 21 brazed in place and clamped by superposed cross bars 22, 23, held by tension bolts 23^a—23^a. The channel bars determine nodal lines and the unclamped areas between the bars being narrow but of widely unvarying widths and highly tensed, are rendered omni-periodic for a wide range of the high frequencies. Locating these relatively sensitive vibratory areas in advance of the reflecting projector having relatively insensitive walls, seems to result in better reproduction of the higher frequencies while avoiding all tendency to "metallic" quality. These effects may be modified or eliminated by embedding the vibratory areas or the entire conduit in a plaster of Paris or concrete jacket.

When this part of the device is an integral metallic casting, the interior surface may be continuous and smooth throughout and, if desired, the exterior may be ribbed instead of clamped.

The reflecting projector 11 constituting the secondary expansion element is made of hard elastic material smoothly finished on the inner surfaces, preferably well seasoned birch about $\frac{9}{16}$ inch to 1 inch or more in thickness. For simplicity in construction the end walls are parallel, cut to the shape shown in Fig. 1 and having secured thereto by many closely spaced screws, the boards constituting the rear reflector 24, bottom reflector 25, bottom expansion guide 26, roof guide and reflector 27, and the previously mentioned board 18 to which the outlet of the primary expansion conduit 10 is secured. The angle between reflectors 24, 25 is preferably 90 degrees but variations between 80 degrees and 105 degrees have been used.

I find that well seasoned birch of proper variety is highly desirable for this purpose, since it takes a very smooth surface and can be readily stained and polished. Acoustically considered, it is extremely stiff and hard while being elastic in the sense that an ivory billiard ball is elastic. Hence it is almost incapable of absorbing any substantial amount of the sound wave energy and, in the thicknesses and widths above described, is substantially incapable of being objectionably vibrated thereby. The same rigid construction and material may be employed for the widening conduit 10, if desired.

The surfaces, particularly the inner surfaces are stained, polished and varnished with care and the joints are all sealed, as indeed are all other cracks or joints of the entire structure.

Some of the acoustical characteristics of the primary expansion element of the air column will be evident from Fig. 2 taken in connection with Fig. 1. Fig. 1 shows how this portion of the air column is kept thin from front to rear and in this instance actually converging from 1¾ inches down to 1¼ inches. Fig. 2 shows how it expands laterally. The axial distance down the line *a*—*b*, is 14 inches, which is the distance traversed by the central part of a wave in reaching the slot outlet at 15 via the line *a*—*b*. The lines *a*—*c* and *a*—*d* show the diverging lines of travel of the waves along the edges, and the curved line *d*—*c*—*b*—*c*—*d* shows the downward curvature of a wave which necessarily results from equal-speed, equal-distance travel of the waves along said lines *a*—*b*, *a*—*c*, *a*—*d*. For a 14 inch conduit the portions of a wave crest that travel along the side lines *a*—*d*, *a*—*d* are some 2 inches or 3 inches behind the portions traveling along the axial line *a*—*b*. Thus the successive wave fronts, that is, identical phases of the same wave, cross the slot outlet at different times and at different angles, as and with the results heretofore described. For a 28 inch conduit, the distance of this lag will be 4 inches to 6 inches, thus giving for notes an octave lower, the same phase differences that the 14 inch conduit gives for the higher octave. As the wave continues its travels its impingement on different portions of the rear reflector 24 will be non-simultaneous both as regards the plane of Fig. 2 and also as regards the plane of Fig. 1; also, the angles of impingement will be different, as regards the plane of Fig. 2; similarly with respect to the second reflection from bottom reflector 25; similarly with respect to the third reflection from top reflector 27.

Fig. 1 also makes it easier to see why front to rear thinness of the slot outlet 15 is a particularly good thing, when employed in combination with a reflecting projector. The more the slot is narrowed and elongated, the less will be the distance which the reflected wave has to travel across the mouth of the slot from *e* to *f*, Fig. 1. Moreover, the thinner the main sound beam, the more we may safely decrease the height of the first reflector 24 by raising the second reflector 25 thus vertically narrowing the "throat" at *g*—*h* so that the sound can "fill" the projector at this point. If the beam is thick, the diffusion *i*—*j*, *i*—*k* impinging on the bottom reflector 25 will be strong and too much energy will be thus reflected directly back, up the air column.

In Fig. 1 also the dotted lines and arrows indicate in a suggestive though more or less inadequate manner the path of the main beam through the reflecting projector and also with less degree of completeness some of the forward diffusion from the front face *l*—*m* of the main beam and also the face *n*—*o*. The curved lines *m*—*r* and *o*—*r* represent the wave fronts of these diffusions. These various sets of lines indicate that the main beam and all of the stronger portions of the forward diffusion, cross the plane of the mouth of the projector at comparatively high angles and at different angles and at different times. Thus the curvature of the wave front and its non-simultaneous passage of points where backward reflection might occur exists not only with reference to the dimension illustrated in Fig. 2, but also with reference to the other dimension illustrated in Fig. 1.

It will be evident that the remarkable performance of the air column above described is contributed to by the characteristic sudden widening of the wave front in one dimension, to a long thin slot outlet, without expansion in the other dimension; this being followed by even more abrupt and shorter distance expansion in the other dimension (vertically) which takes place in the reflecting projector; and also so ordering the successive cross-sections of the air column, that the sound pressures can substantially "fill" the cross section; also the curving of the wave front so that the crossing of planes of possible backward reflection is non-simultaneous, for each wave and is at widely different but mostly sharp angles for different portions of the same front (or phase) of the same wave.

The long, straight-line approach of the sound beam to the first reflector, between substantially parallel walls, seems to parallel the paths of oscillation of the particles, thus giving a sharper more dependable beam for impingement on the reflector.

Furthermore, the preliminary "slot" expansion followed by the secondary expansion in the other dimension and the reflecting projection of the waves, makes possible the following features of construction which are of acoustic as well as structural advantage. The tone arm has its vertical axis at the front of the cabinet, that is, above and near the outlet of the projector which opens through the side of the cabinet. The waves from the tone arm can be carried almost directly downward and whatever curvature is necessary, as for instance that shown in Fig. 1, is in the direction in which the air column is thin. At the same time the air column is being expanded in the other dimension, at a high rate. Frictional losses and particularly attenuation of the high frequencies is very small because the expansion is so free and the distance so short. By the time the waves reach the reflecting projector, the wave front has been expanded so that the distance and therefore

the velocity of oscillation of the air particles in propagating the wave, is greatly decreased. As friction decreases much more than in direct proportion to decrease of velocities, the frictional losses are much reduced. Moreover, the propagation of the waves in this part of the air column being by reflection from hard polished surfaces, losses for the higher frequencies are small.

In my projector the waves, without having to traverse any curves after they have been expanded more than two inches in the direction of the curve and without having to turn any corners except by high angle reflection, are enabled to traverse an air column which, as we have seen above, is 36 inches or more in length, yet the main beam emerges from the mouth of the projector not more than 8 inches or 10 inches from the base of the tone arm outlet.

The thus compactly disposed air column affords the desired quarter wave length column for the generation of the long waves of the lowest frequencies necessary for phonograph work, and at the same time, affords a low friction, phase-preserving path for the high frequencies upon which the quality of the reproduced sound depends.

The novel location of the tone arm on the same side of the cabinet through which the sound is projected into the outer air, would require a tone arm and sound box of usual construction, to trail on the left-hand side of the record which would be awkward and inconvenient in practice. Accordingly my invention includes arranging the sound box to operate on the right hand side of the record with the stylus trailing toward the vertical axis of the tone arm. The preferred construction for this purpose is illustrated in Figs. 1 and 2. The tone arm 9 is curved around through a right angle to form a horizontal terminal portion 29. On this is mounted a housing 30 in which may be fitted an ordinary, ready-assembled roller bearing comprising outer ring member 31, the intermediate balls 32 and the inner ring member 33. The latter has fitted within the same a relatively long sleeve 33′, on the outer end of which the sound box is secured by means of screw 34. A face plate 35 closes in and protects the ball race. Outside of the housing 30 is secured a spring 36 adapted to frictionally engage and retain the sound box when turned to the uppermost position for removal or insertion of the needle or for discontinuing operation of the phonograph. The weight of the projection 37 and housing 38 on the sound box may be adjusted to cause the stylus to bear upon the record with any desired degree of force. While this mounting for the sound box is of special advantage in connection with my present invention it is obvious that any known or desired sound box and any known or desired mounting thereof may be employed.

While I have described in great detail the characteristics of one illustrative form of a composite air column, and the structure whereby all of the various features are practically attainable, it will be obvious that the perfect reproduction obtainable by this invention is contributed by and is the composite result of numerous very novel features localized at various points along the air column, each of which represents careful study, invention and discovery by itself, as well as in relation to the whole. For instance, it is in the nature of a discovery that where the air column is expanded in one dimension only, the expansion may be very rapid, provided the other dimension be sufficiently thin; that preferably this other dimension is less than 2 inches; that when the thinning in of this dimension gets down toward a half inch and less, the length and width of widening conduit required to give the desired enlargement of wave front may become great, that is, say 24 inches or even 36 inches for a $\frac{1}{2}$ inch slot, and that the limitations on slot thicknesses are of particular importance with reference to the higher frequencies to be reproduced. Another instance is discovery of the desirability for the thinness of main sound "beam" in connection with a reflecting projector, and the desirability of narrowing the "throat" so that the sound may "fill" the same. Another instance is the discovery, involving more or less of the foregoing, that the best way to expand a wave is to give it primary guided expansion in one dimension, keeping the other dimension small, preferably well below 2 inches until expansion in said dimension is adequate, then affording the wave a guided and limited, but nevertheless rapid secondary expansion in planes at right angles to the primary expansion.

When I speak of expansion in one dimension followed by expansion in another dimension the word "dimension" is not to be taken in a strictly geometrical sense, that is to say, it is the spacing and proximity of the front and rear walls of conduit 10, that is of importance so far as concerns the broader aspects of the invention involved. If the spacing and proximity be preserved these walls could be given a curvature in a direction parallel with the waves. As an extreme illustration, the desired proximity of the walls could be preserved where one wall is a cone and the other wall an inner cone concentric with the first. In this particular case the benefit of a downwardly curving wave front crossing the mouth of the projector at different distances and times and angles, will be lost unless the mouth of the conduit were cut on a plane at an angle to the axis of the cones. This instance is cited

merely as an illustration of the fact that some of my discoveries are generic and applicable to geometrical forms of air column quite different from those shown in the drawings.

While the vertical end walls of the projector mouth are above described as parallel, the principal value of this is cheapness of construction. They may diverge or converge, provided the angle be not too abrupt. With respect to lateral diffusion of the sound, in the outer air, it will be noted that the 24 inch slot does not sound as loud as the 14 inch slot when in front of the respective instruments, whereas, from an adjoining (side) room, the 14 inch slot will not sound as loud as the 24 inch slot, at least this is so for many kinds of records.

With respect to the length for conduit 10, it will be noted that if a conduit 14 inches by 14 inches by 1 inch makes the edge portions of a given wave front or given wave phase 2 inches or 3 inches behind the axial portion, when passing the mouth 15, then a conduit 28 inches by 28 inches would make this distance 4 inches to 6 inches so that the 28 inch conduit would give the same phase differences for a wave front of frequencies an octave lower than would the 14 inch conduit.

For waves of average phonographic intensity the area to which the conduit 10 widens the wave front, is preferably between 12 square inches and 30 square inches, although inferior but fair results have been obtained with a 14 inch by 14 inch by $\frac{1}{2}$ inch conduit, the outlet area of which is only 7 square inches. A 24 inch by 24 inch by 1 inch having an area of 24 inches gave almost as good results as a 16 inch by 16 inch by $1\frac{1}{4}$ inch which had an area of 20 inches. The latter is perhaps the most satisfactory instrument of all the instruments I have specifically described.

The mouth portion of the projector wherein the thin beam is thickened to the desired final area is preferably shorter than the axial length of the primary conduit and shorter than the width of the beam projected therefrom.

Fig. 5 shows a tone arm which is bent horizontally in reverse curves, so as to bring the vertical plane of the trailing stylus needle into the same plane with the vertical pivotal axis of the tone arm. The frictional drag of the record on the needle is made to take effect in the plane of the vertical axis and there is less tendency for the needle to jump the groove in the record or to press more strongly on one side of the groove than on the other. In the form shown these reverse curves result in increasing the length of the tone arm severel inches, as will be evident by comparision with the form shown in Fig. 1. Fig. 5 also shows an adjustable weight 50 screw threaded on a rod 51 which projects above and beyond the stylus, whereby the distance, and resulting leverage of pressure of the stylus on the record, may be regulated as desired.

My present invention includes some of the features disclosed in my prior applications, Serial No. 298,846, filed May 22, 1919, Serial No. 305,601, filed June 20, 1919, Serial No. 380,492, filed May 11, 1920, and Serial No. 404,859, filed August 20, 1920, but I have elected to limit the claims of said prior applications to features not disclosed herein and to present herein all generic claims intended to cover broadly the features disclosed in said prior applications whether employed in the sensitive sonorous plate combinations to which said prior disclosures are more specifically directed, or in the non-vibratory wall combinations to which my present application is more specifically directed. It will therefore be understood that where the claims do not specify the nature of the walls they may be considered as including cases where the walls are sensitive or some of them as sensitive and others solid but preferably all the walls are solid. While I have shown and described with considerable precision and precise dimensions as well as the shape of one desirable embodiment of my invention, it is to be understood that certain of these dimensions may be varied to advantage, as I have here illustrated.

It will be noted that some of the novel features of organization and arrangement of the parts of the phonograph as shown herein resemble those disclosed in my prior application Serial No. 380,492, filed May 11, 1920, and are substantially identical with those shown in my application Serial No. 658,007, filed Aug. 18, 1923, which is a division of this case. I have elected to present the cabinet structure claims in said divisional application, the claims of this application being directed to the novel features of amplifier and projector.

I have illustrated herein and have elected to claim specifically herein an embodiment of my invention in which the widening conduit has spring metal walls adapted to add a brilliant quality to the reproduced sounds. I have also described heavy stiff walls for said widening conduit but specific claims for the latter modification are necessarily reserved for another application copending herewith.

My invention is of course independent of my theories with reference to it and in so far as I have stated theories, it has been for the purpose of indicating or accounting for the novel results. Whether correct or not they will be found useful as hypotheses to assist those skilled in the art when seeking to apply one or more of my novel principles to new conditions or purposes.

I claim:—

1. The method of amplifying and projecting complex waves having high frequency components which method consists in first expanding the wave front from an area less than 2 square inches, to a wave front at least 14 inches in one dimension by less than 2 inches in the other dimension, while the waves are being propagated a distance not less than 12 inches, then permitting limited guided but rapid expansion of the sheet-like sound wave thus produced, in planes at right angles to said first expansion.

2. The method of expanding the wave front of complex sound waves to a given area, which method consists in rapidly expanding the beam in one dimension to the required width while maintaining its thickness below two inches and then affording similar rapid expansion in the other dimension.

3. The method of deflecting sound waves while simultaneously expanding the wave front to any desired area, which method includes confining expansion in the plane of the desired deflections to less than two inches while expanding to any desired extent in the other dimension; then deflecting the expanded wave front in the direction of its thinness by impingement upon an approximately plane reflector.

4. In apparatus of the class described, means enclosing an air column to be traversed by low and high frequency waves, said means defining a slender portion of the air column, said slender portion having a cross section which is less than 1 inch square at the inlet end and which continues to be substantially less than 2 inches square for a distance of more than twelve inches; said means also defining a laterally expanding portion for said air column, said portion continuing for a further length approximately equal to or greater than the length of said slender portion and widening to a slot-like outlet having one dimension substantially less than 2 inches and the other dimension substantially greater than the length of said slender portion of the air column.

5. A sound amplifying conduit for expanding the wave fronts of complex sound waves to a desired area, said conduit comprising a primary expansion portion having walls arranged to permit guided and limited but rapid expansion of the wave front in one dimension along widely diverging lines substantially to the width of the desired area, and other walls arranged to guide and confine the waves without substantial expansion in the other dimension, thereby forming a thin sound beam with widely divergent flanks and a deeply curved wave front; and a secondary expansion portion or projector having walls arranged to confine and deflect inward the divergent flanks of said beam without further substantial expansion in said first dimension and other walls diverging at an angle permitting guided and limited but rapid expansion of said beam to the desired area in said second dimension.

6. In the combination specified by claim 5, the further feature of a plane reflector in the projector for directing the laterally expanded sound beam to said diverging walls for expansion in the other dimension.

7. In the combination specified by claim 5, the further feature of arranging the parts so that the sound beam is projected along one of the diverging walls of the mouth of the projector.

8. In the combination specified by claim 5, the further feature of having the projector directed upward so that the emerging sound waves are protected upward and at considerable angles to the plane of the mouth of the projector for the purpose described.

9. In the combination specified by claim 5, the further feature of arranging the parts so that different portions of the front of an emerging wave cross the mouth of the projector at different times, and at sharp angles.

10. In the combination specified by claim 4, the further feature of arranging the slot-like outlet with different portions of its longer dimension at substantially different distances from the inlet so that different portions of the same wave front must travel substantially different distances to reach the plane of the outlet, so that substantially different phases of the same wave will cross the plane of the outlet at the same time.

11. Means for expanding and projecting waves of all periodicities including a conduit to be traversed by the wave having two opposite sides less than 2 inches apart for a distance not less than 12 inches measured along the axis and two other opposite sides diverging to a distance approximately equal to said length as measured along the axis.

12. A sound amplifying conduit having an inlet less than 2 inches square and an outlet not less than 12 inches widthwise and less than 2 inches crosswise, the length of the conduit intermediate the inlet and outlet, measured along the axis, being approximately equal to the widthwise dimension of said outlet and the walls between the inlet and outlet comprising two opposite walls less than 2 inches apart and two other walls diverging at progressively increasing angles to a maximum divergence of approximately 90°.

13. A sound projector comprising a thin flat expansion conduit, rapidly diverging to

great width as compared with its thickness, its thickness being less than 2 inches, the conduit being curved in the direction of its thinner dimension and discharging into a shorter conduit having a wide expansion angle in the direction of said thinner dimension.

14. In the combination specified by claim 13, the further feature of having two walls substantially straight and parallel for a considerable distance of its length where it approaches the outlet.

15. A projector having two high angle reflecting surfaces on the same side of the projector, the second reflector being in receiving relation for reflection from the first reflector, and means for impinging a thin, wide sound beam, less than 2 inches thick and very wide as compared with its thickness, at a high angle upon the first of said reflectors.

16. In a sound amplifier, a sound reflecting surface, and a flat walled expansion conduit leading thereto, having two opposite approximately parallel walls for a considerable distance backward from the reflector, said sound reflecting surface being rigidly secured in fixed angular relation with the outlet of said expansion conduit.

17. A sound amplifier comprising a primary expansion conduit leading downward from the tone arm adapted to expand the sound waves rapidly in one dimension without substantial expansion in the other dimension to project a relatively wide thin sound beam, in combination with a plane reflector arranged to deflect said sound beam in the direction of its thinness, and a second plane reflector in receiving relation to the first reflector and arranged to reflect said sound beam through a further angle in the same direction.

18. In the combination specified by claim 17, the further feature of a projector comprising diverging walls for spreading the reflected beam in the direction of its thinness.

19. In the combination specified by claim 17, the further feature of a second high angle reflector in position to give the beam a second reflection in the same direction as the first.

20. In the combination specified by claim 18, the further feature of having the sound outlet to the diverging walls of substantially the same length and as thin or thinner than the inlet from which the sound beam is first projected on the reflector.

21. In the combination specified by claim 19, the further feature of having the sound outlet to the diverging walls of substantially the same width and as thin or thinner than the inlet from which the sound beam is first projected on the reflector.

22. A primary expansion conduit having opposite walls diverging in one dimension much more than in the other dimension to project a relatively thin sound beam, in combination with a projector having two adjacent approximately plane reflectors at a high angle to one another on the same side of the projector.

23. An amplifier comprising a primary expansion conduit having opposite walls diverging in one dimension more than in the other dimension to project a relatively thin sound beam and a secondary conduit having a reflecting wall at a high angle to the waves projected through said conduit and arranged to reflect them in the direction of their thinness; and a second reflecting wall on the same side of the projector adjacent and at a high angle to said first mentioned reflecting wall, to reflect a second time in the same direction the waves reflected from said first mentioned wall.

24. An amplifier comprising a primary expansion conduit having opposite walls diverging in one dimension more than in the other dimension to project a relatively thin sound beam, in combination with a secondary conduit having at least three successive reflecting walls, each arranged to reflect said projected sound beam in the direction of its thinness, the first of said reflecting walls being at an angle of 45° to the axis of said projected sound beam, the second being adjacent the first on the same side of the conduit and approximately at a right angle thereto and the third being in receiving relation to the second but on the opposite side of the conduit.

25. The method of expanding to the desired area the wave fronts of waves having slight divergence, as a preliminary to projecting them into the outer air, which method consists in affording guided, limited expansive divergence to an angle of 60 degrees or more in one dimension, substantially without expansive divergence in the other dimension, and then affording guided, limited expansive divergence to an angle of approximately 60 degrees or more in said other dimension.

26. The method of expanding the wave front of complex sound waves to a given area, which method consists in expanding and diverging the beam in one dimension to an angle approximately 60 degrees or more and to the required width without substantial divergence in the other dimensions, and affording limited guided rapid expansion in the other dimension to an angle approximating 60 degrees or more.

27. The method of deflecting sound waves while simultaneously expanding and diverging the wave front to any desired area, which method includes preventing expansion in the plane of the desired deflections while expanding to an angle of approxi-

mately 60 degrees or more in the other dimension.

28. In apparatus of the class described, means embodying an air column to be traversed by low and high frequency waves, said means defining a slender portion for the air column, said slender portion having a cross section which is less than 1 inch square at the inlet end and which is substantially less than 2 inches square at the outlet, said means also defining a laterally expanding portion for said air column, said portion continuing for a further length approximately equal to or greater than the length of said slender portion and widening to a slot-like outlet having one dimension substantially less than 2 inches and the other dimension substantially greater than the length of said slender portion of the air column; and a projector affording a further extension of the laterally expanded air column continuing for a further length which is less than the length of said widened portion, said projector embodying walls diverging in directions permitting guided and limited but rapid expansion in planes at right angles to the direction of said lateral expansion.

29. In apparatus of the class described, means enclosing an air column to be traversed by high and low frequency waves said means including a tone arm defining a slender portion for the air column, in combination with a conduit communicating directly with the outlet of the tone arm, and shaped so as to expand the waves in one dimension only to a wide thin beam in a length at least as great as the length of said tone arm.

30. In apparatus of the class described, means enclosing an air column to be traversed by high and low frequency waves said means including a tone arm defining a slender portion for the air column, in combination with a conduit communicating directly with the outlet of the tone arm, said conduit having its walls shaped so as to expand the waves to a wide thin cross section, the width of which is several times the thickness.

31. In combination with the parts specified by claim 30, two high angle reflectors arranged to deflect said beam twice in the direction of its thinner dimensions.

32. In the combination specified by claim 31, the further feature of having the wider walls of said conduit approximately parallel for a considerable distance back from the outlet thereof.

33. In apparatus of the class described, a conduit enclosing an air column to be traversed by high and low frequency waves, said conduit having walls which are characteristically different for three successive portions of the length of said conduit, namely, a tubular portion having relatively rigid insensitive walls defining a slender air column, an intermediate expansion portion having two opposite approximately parallel walls and two other opposite widely divergent walls and a projector portion having relatively rigid insensitive walls including two opposite walls which are widely divergent to afford rapid expansion of the waves in a direction at right angles to the divergent walls of said intermediate portion.

34. In the combination specified by claim 33, the further feature of arranging the walls of the intermediate portion to afford wide flat areas capable of slight sympathetic vibration for a wide range of high frequencies.

35. In the combination specified by claim 34, the further feature of having the approximately parallel walls of said intermediate portion consisting of spring metal in combination with means for determining diverging nodal lines for said flat areas.

36. In the combination specified by claim 35, the further feature of means for applying a transverse pressure along said nodal lines to tension the adjacent portions of the spring metal walls.

37. A projecting amplifier comprising a conduit having an outlet of rectangular cross section and said amplifier having at least two adjacent successive portions of its walls substantially plane, the first plane portion being at an angle of approximately 45° to the sound waves projected from said conduit and the second at approximately right angles to said first plane portion and in position to intercept at angles of approximately 45° the waves reflected therefrom.

38. A sound amplifier comprising three successive sections, including a primary expansion section having opposite walls arranged to afford guided but rapid expansion of the wave front in one demension without substantial expansion in the other dimension, to project a relatively wide thin sound beam; an intermediate section comprising a reflector arranged in immediate receiving relation to intercept said beam at a high angle and reflect the same in the direction of its thinness; and a second reflector arranged in immediate receiving relation to intercept the reflected beam at a high angle and re-reflect it in the direction of its thinness; in combination with a secondary expansion section arranged to receive the beam from said intermediate section and to afford guided but rapid expansion of its wave front in the direction of its thinness without substantial expansion in the other dimension, the throat where the beam enters the secondary expansion section being of height not greater than the outlet where it leaves the primary expansion section.

39. A sound amplifier comprising three successive sections, including a primary expansion section having opposite walls arranged to afford guided but rapid expansion of the wave front in one dimension without substantial expansion in the other dimension, to project a relatively wide thin sound beam; an intermediate section having walls arranged to intercept and deflect said beam in the direction of its thinness through an angle of approximately 180°; in combination with a secondary expansion section arranged to receive the beam from said intermediate section and to afford guided but rapid expansion in the direction of its thinness without substantial expansion in the other dimension, the throat where the beam enters the secondary expansion section being of height not greater than the outlet from the primary expansion section.

Signed at Chicago, in the county of Cook, and State of Illinois, this 7th day of July A. D. 1921.

ELWOOD GRISSINGER.