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ACOUSTIC DEVICE

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FIG. 1

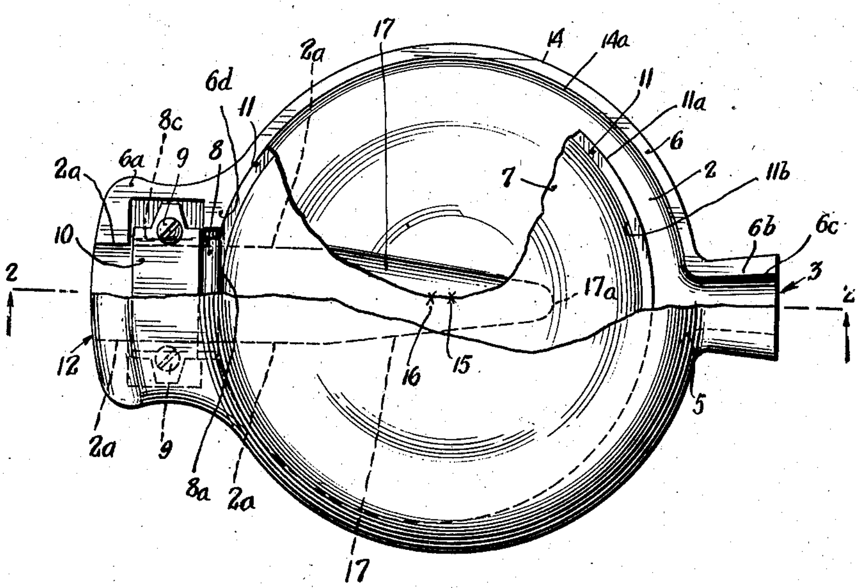
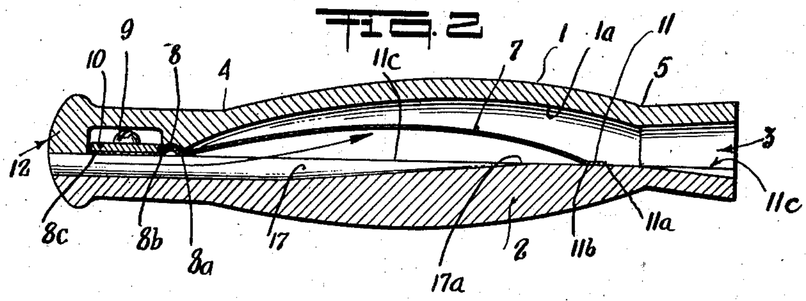


FIG. 2



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BY *Mock & Blum*

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FIG. 3

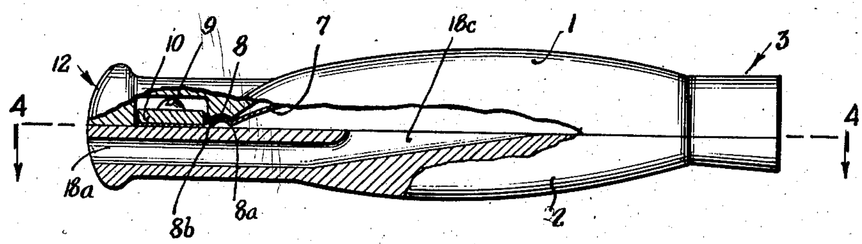

FIG. 4

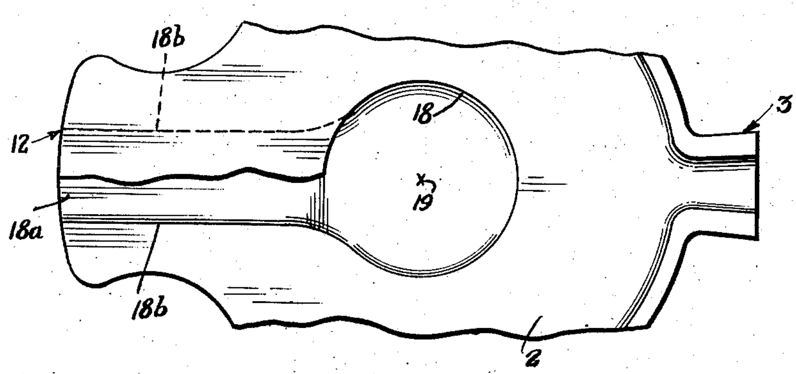

FIG. 5

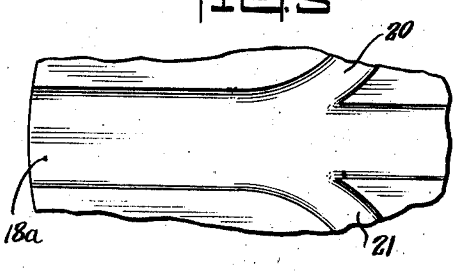

FIG. 6

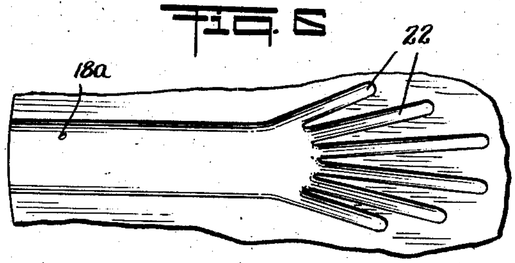

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Fig. 7

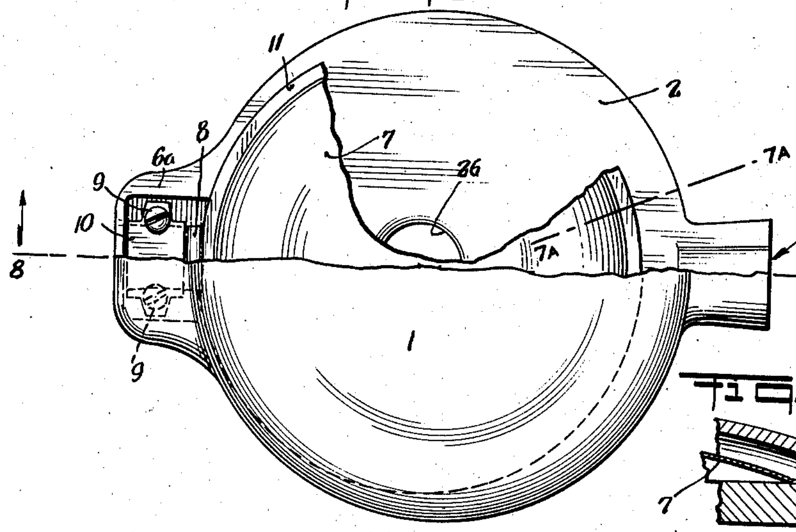

Fig. 7A

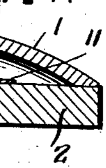

Fig. 8

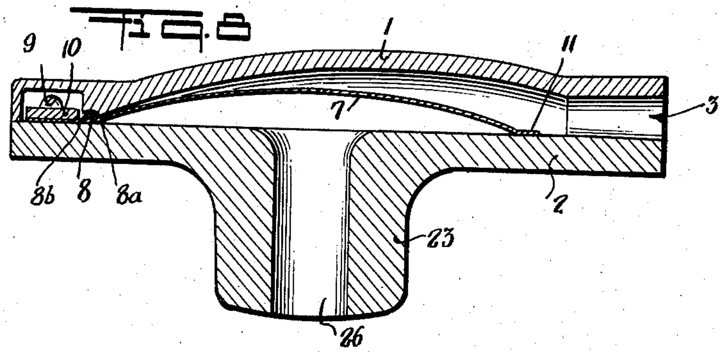

Fig. 9

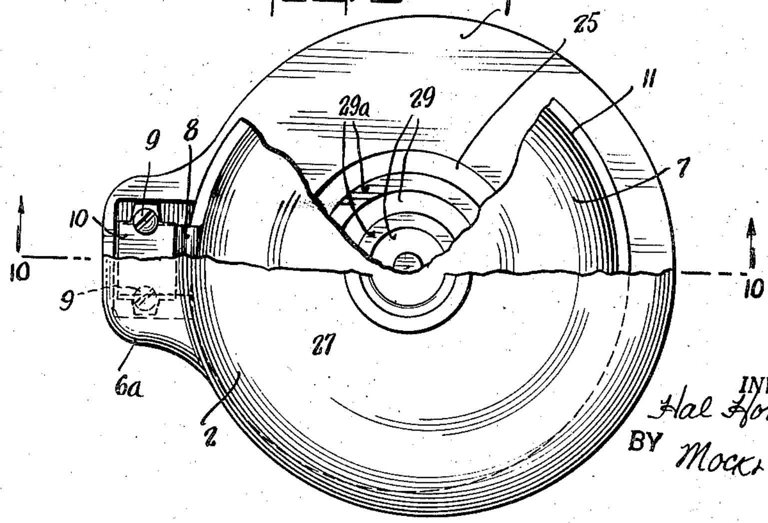

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Fig. 10

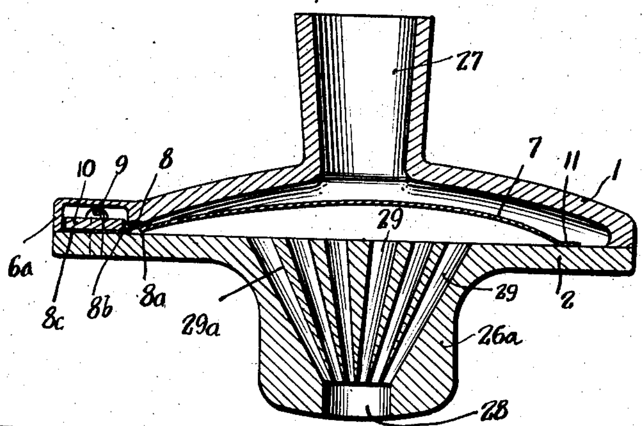

Fig. 11

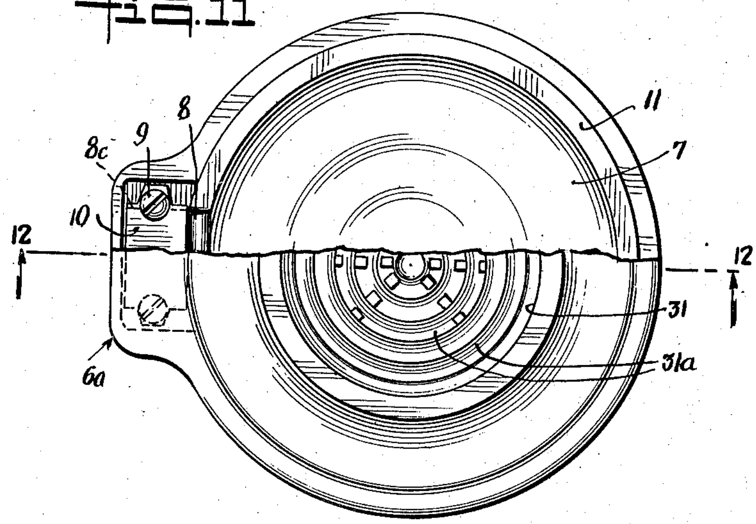

Fig. 12

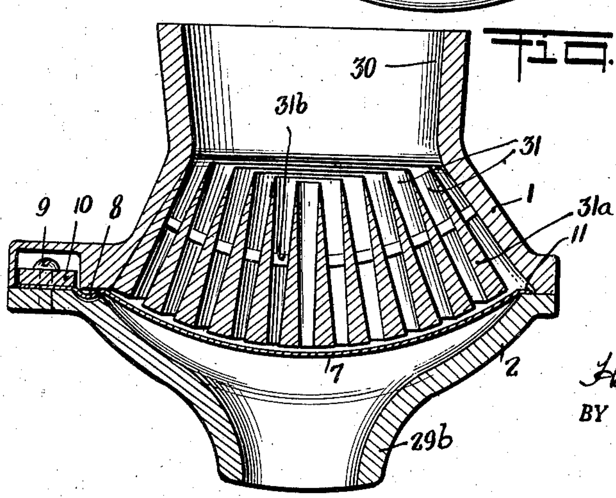

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Fig. 13

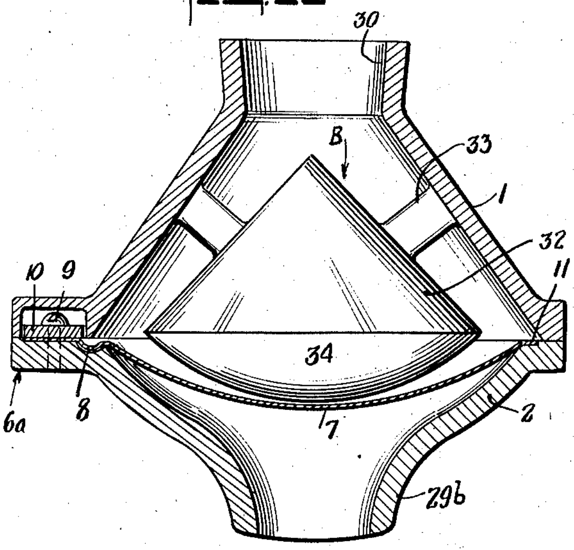

Fig. 14

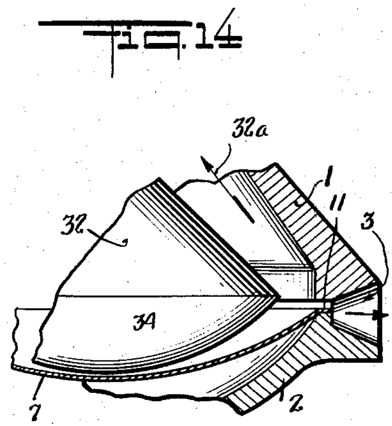

Fig. 15

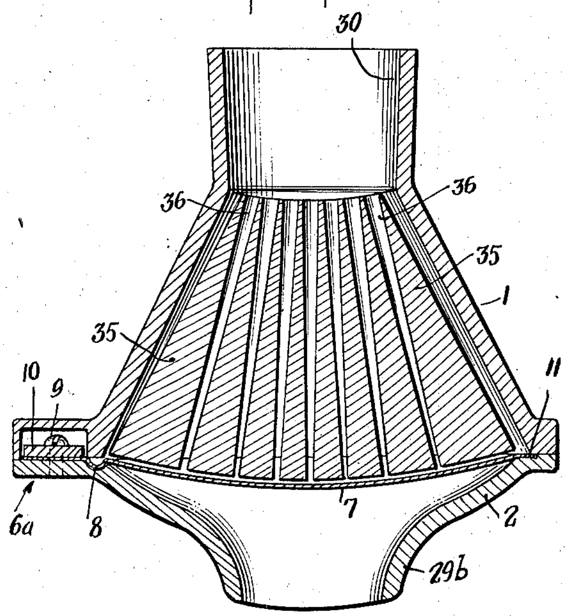

Fig. 16

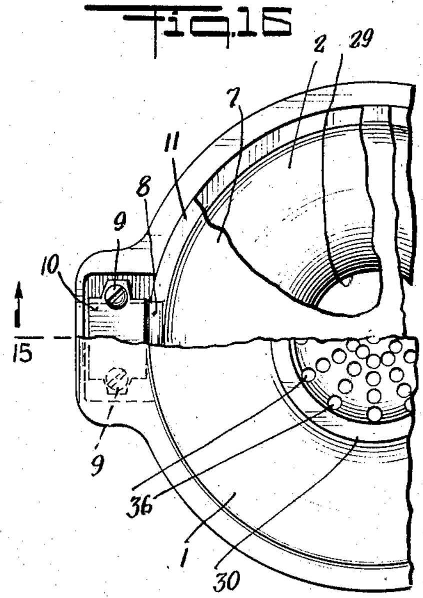

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FIG. 17

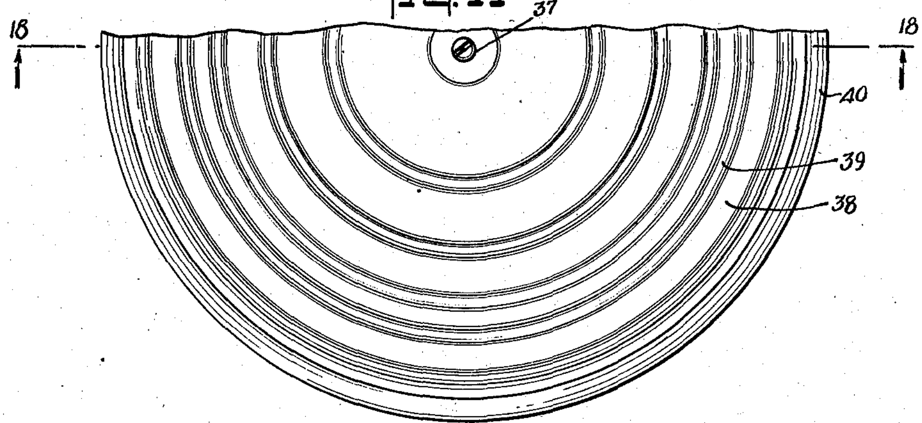

FIG. 18

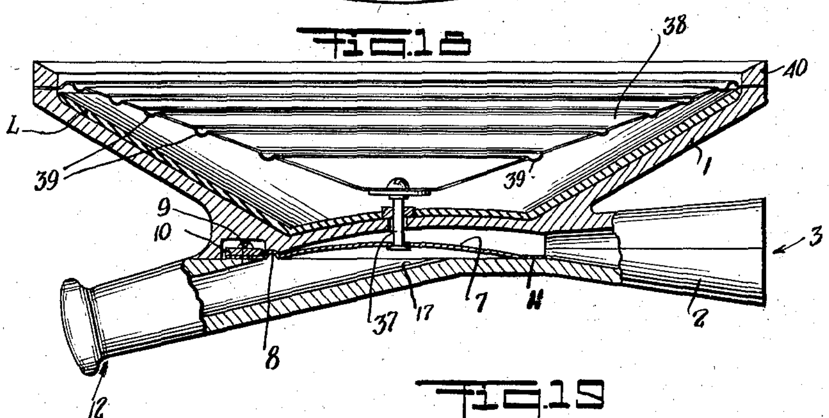

FIG. 19

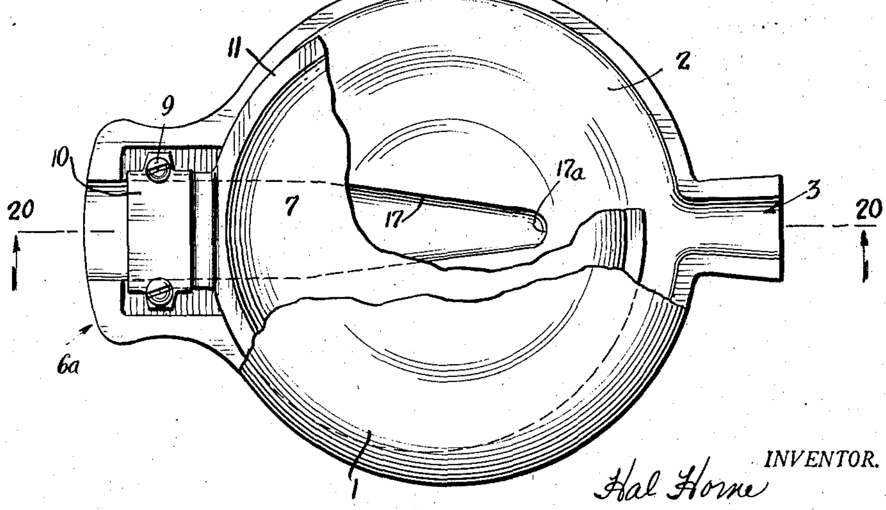

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Fig. 20

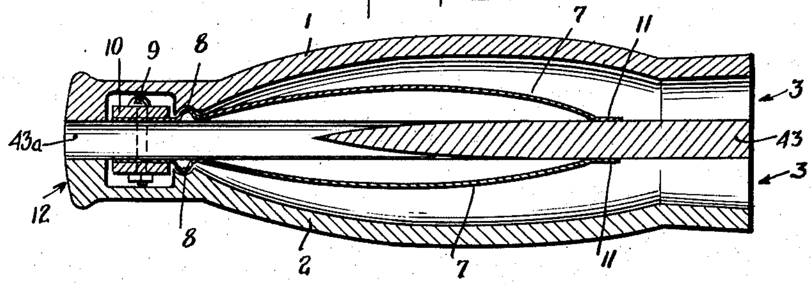

Fig. 21

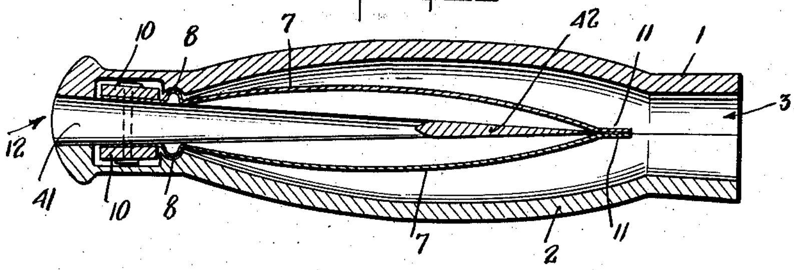

Fig. 22

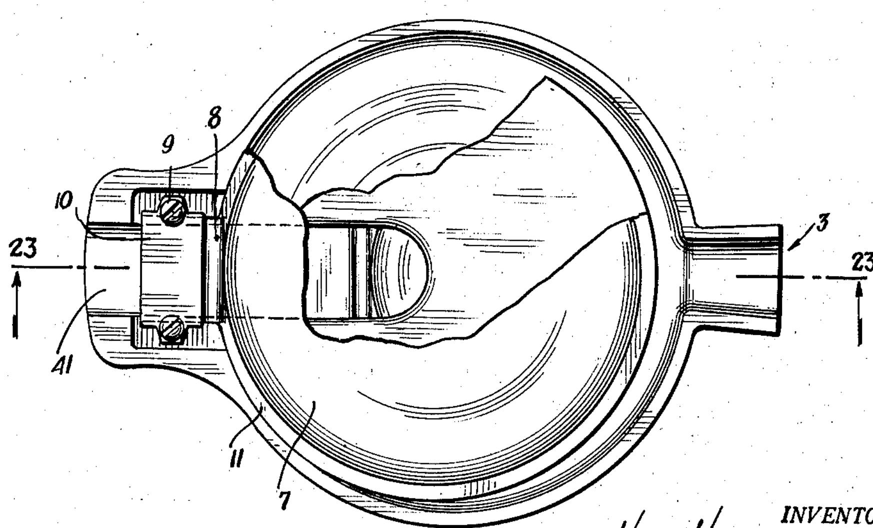

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FIG. 23

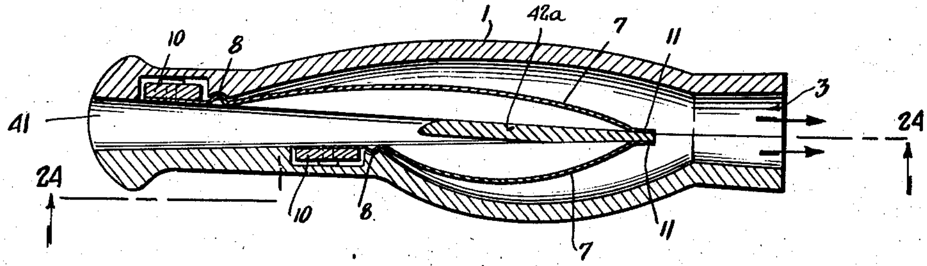

FIG. 24

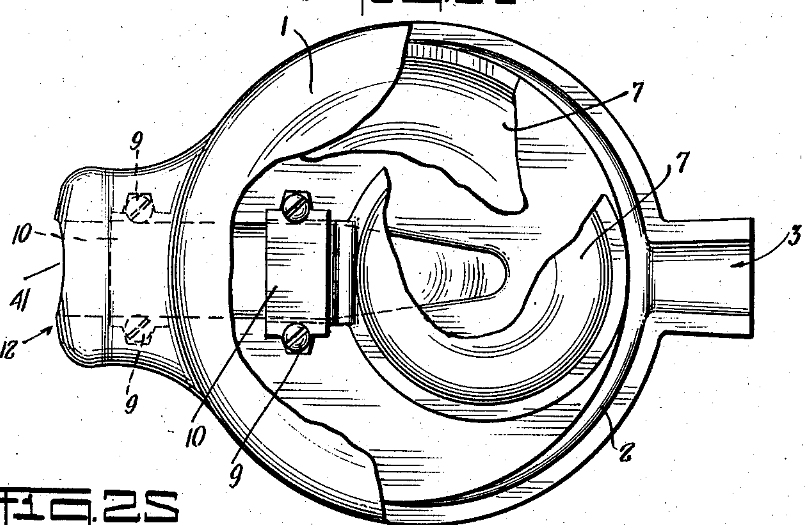

FIG. 25

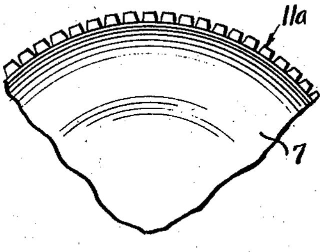

FIG. 27

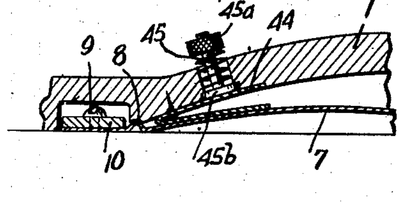

FIG. 26

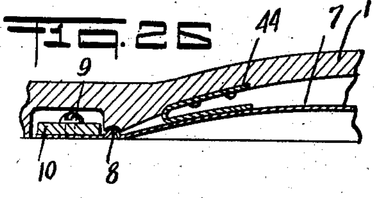

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Fig. 28

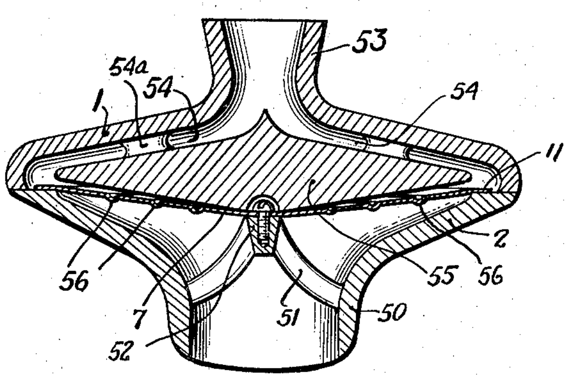
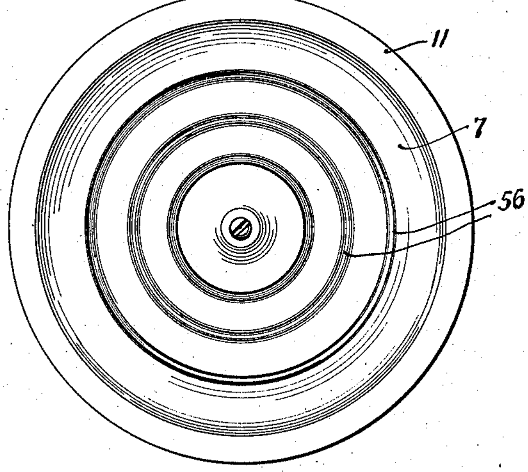


Fig. 29



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Patented Apr. 13, 1948 2,439,736

UNITED STATES PATENT OFFICE

2,439,736

ACOUSTIC DEVICE

Hal Horne, New York, N. Y.

Application February 10, 1944, Serial No. 521,816

10 Claims. (Cl. 46—178)

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This invention relates to a new and improved sound generator and sound modifier which can be used as a musical instrument, and for various other purposes.

One of the objects of this invention is to provide a precision instrument for this purpose.

Another object of this invention is to compensate for the fact that it is impossible commercially to manufacture the outer shells which constitute the casing of this instrument, with sufficient precision to produce shells which are substantially alike.

Another object of this invention is to divide the air space between the shells into a plurality of air columns.

Another object of this invention is to produce a device which has a casing which consists of a plurality of outer shells, and which also has an internal diaphragm. Said internal diaphragm may be made of resilient metal or a suitable resilient alloy.

Another object of this invention is to provide a device in which said diaphragm will have a plunger vibration or movement and plunger action, in order to secure best results.

Another object of this invention is to provide means whereby the internal diaphragm is anchored to one of the outer shells, in such manner as to avoid or minimize any leakage at the point of anchorage. Another object is to provide a musical instrument which can produce various unique tonal effects by an unskilled person.

Numerous additional important objects of the invention will be stated in the annexed description and drawings, which will illustrate several preferred embodiments of the invention.

Fig. 1 is a top plan view of the first embodiment, the representation of a part of the top outer shell having been omitted.

Fig. 2 is a sectional view on the line **2—2** of Fig. 1.

Fig. 3 is a sectional view, partially in elevation, of a second embodiment. This section is taken in a vertical plane.

Fig. 4 is a partial top plan view of the bottom shell of Fig. 3, taken along line **4—4** of Fig. 3.

Figs. 5 and 6 are views similar to that of Fig. 4, showing variations of the shape of the bottom shell.

Fig. 7 is a view similar to Fig. 1, of a third embodiment of the invention.

Fig. 7A is a sectional view along the line 7A—7A of Fig. 7.

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Fig. 8 is a sectional view along the line **8—8** of Fig. 7.

Fig. 9 is a view similar to Fig. 1, of a fourth embodiment of the invention.

Fig. 10 is a sectional view on the line **10—10** of Fig. 9.

Fig. 11 is a view similar to Fig. 1, of a fifth embodiment of the invention.

Fig. 12 is a sectional view on the line **12—12** of Fig. 11.

Fig. 13 is a vertical sectional view of a sixth embodiment of the invention.

Fig. 14 is a partial sectional view, which illustrates a seventh embodiment of the invention.

Fig. 15 is a sectional view on the line **15—15** of Fig. 16.

Fig. 16 is a partial top plan view, similar to Fig. 1, of an eighth embodiment of the invention.

Fig. 17 is a partial top plan view of a ninth embodiment of the invention.

Fig. 18 is a sectional view on the line **18—18** of Fig. 17.

Fig. 19 is a top plan view similar to Fig. 1, of a tenth embodiment of the invention.

Fig. 20 is a sectional view on the line **20—20** of Fig. 19.

Fig. 21 is a sectional view, similar to Fig. 20, of an eleventh embodiment of the invention.

Fig. 22 is a top plan view similar to Fig. 1, of a twelfth embodiment of the invention.

Fig. 23 is a sectional view on the line **23—23** of Fig. 22.

Fig. 24 is a section on the line **24—24** of Fig. 23.

Fig. 25 is a partial view which illustrates a modification of the internal diaphragm, showing that said internal diaphragm can be provided with a scalloped edge.

Figs. 26 and 27 are respective sectional views which illustrate additional embodiments of the invention.

Fig. 28 is a sectional view of another embodiment.

Fig. 29 is a partial top plan view of the diaphragm shown in Fig. 28.

The device shown in the embodiment of Figs. 1 and 2 comprises outer shells or casing members **1** and **2**. These casing members **1** and **2** can be made of resilient non-metallic material, as disclosed in U. S. Patent No. 2,274,897, issued on March 3, 1942. Said outer shells **1** and **2** can be made of any metallic or non-metallic material, which can be either resilient or non-resilient. Only one of said shells, such as the shell **1**, can be resilient or resonant, so that the shell **2** can be sufficiently rigid to be non-resonant or substantially non-resonant. Both shells 1 and 2 can be rigid and non-resonant.

The line 2—2 of Fig. 1 indicates the location of the vertical median longitudinal plane of the device. Each shell 1 and 2 is provided with respective lateral flanges 6*a*, 6 and 6*b*, at each side of said median vertical longitudinal plane. The respective flanges 6*a*, 6 and 6*b* are identical in both shells, so that the partial illustration of said flanges in Fig. 1 is sufficient.

The device has a front inlet portion or lip portion 12, to which the lips of the user are applied. It also has a rear outlet or throat 3, through which air escapes rearwardly, when air is forced into the device, in the direction of the longitudinal arrow which is shown in Fig. 2. Said throat 3 is transversely and laterally tapered, so that its rear outlet end is larger than its front inlet end. The inner wall of throat 3 is frusto-conical.

Intermediate the points 4 and 5, the body of the shell 1 is laterally and also longitudinally arched. The inner wall 1*a* of the shell 1 is substantially parallel to the respective adjacent portion of the outer wall of said shell 1. Each of said inner and outer walls of the shell 1, between said points 4 and 5, may have the shape of a part of a sphere, or any other rounded or arched or concavo-convex shape.

Each said inner wall and outer wall of shell 1, between said points 4 and 5, can have the shape of parts of several spheres of respective different radii, in order to secure or to approximate exponential spacing between the inner wall 1*a* of shell 1 and the respective inner wall of shell 2, or between the inner wall 1*a* of shell 1 and the adjacent wall of the diaphragm 7.

The internal wall of the shell 2 is provided with a recess or depression which has parallel longitudinal walls 2*a* at the lip portion 12. Rearwardly of said parallel walls 2*a*, said depression has walls 17 which are inclined longitudinally towards each other. Said recess of the shell 2 has a rounded rear end 17*a*.

The internal diaphragm 7 is made of very resilient springy material, such as Phosphor bronze or any other suitable metal or alloy or non-metallic material. The body of said diaphragm 7, rearwardly of its transverse rib 8, is both longitudinally and laterally arched, so that each wall of said body has the shape of a part of a sphere, or of a cone. Said body 7 is preferably of equal thickness and resilience throughout. If the body of the diaphragm 7 is made of Phosphor bronze, the thickness of said body may be .003–.007 inch, preferably .005 inch.

Each flange 6 has respective edges 14 and 14*a* which are concentric. Each said edge 14 and 14*a* has the shape of a part of a circle, whose center is located at the point 15.

At the lip portion 12, said flanges 6 are extended so as to form lateral ribs 6*d* which terminate at the longitudinal edges of the lateral rib 8 of the diaphragm 7. The respective ends of said ribs 6*d* are spaced laterally from the respective longitudinal walls 2*a*.

As previously stated, the internal diaphragm 7 has a body which is both longitudinally and laterally arched, so that each face of said body has the shape of a part of a sphere, or a part of a cone. This invention is not limited to this, as said faces may have any suitable curvatures and said faces may have the shapes of parts of cones. Said diaphragm 7 has a peripheral flange 11, which has respective outer and inner concentric edges 11*a* and 11*b*. The inner edge 11*b* of the flange 11 is a continuous circle, whose center is located at the point 16. The outer edge 11*a* has the shape of a part of a circle. The respective spaced ends of said partial circle of the outer edge 11*a*, terminate substantially at the rear edge 8*a* of the lateral rib 8. Said rib 8 also has a front lateral edge 8*b*. Said rib 8 is integral with the body 7, and said rib 8 is also integral with a forwardly extending planar extension 8*c*. A rigid stiffening member or rigid bar 10 is suitably fixed to the extension or projection 8*c*. The rib 8 has the shape of a part of a cylinder. As shown in Fig. 1, the width or lateral dimension of the lateral rib 8 is greater than the width of the longitudinal recess of the shell 2, between its longitudinal parallel walls 2*a*. The lateral end-portions of extension 8*c* abut the respective parts of the internal wall of the shell 2. Said internal wall of the shell 2 is of planar shape, laterally beyond each longitudinal wall 2*a*. Screws 9 fix the stiffening member 10 to the internal wall of the shell 2, at points which are offset laterally with respect to said walls 2*a*. The shanks of the screws 9 enter suitable tapped recesses which are provided in the respective parts of the respective planar parts of the internal wall of the shell 2. The screws 9 therefore do not interfere with the free passage of air through the recess which is provided between the walls 2*a* in the internal wall of the shell 2, in the direction of the arrow which is shown in Fig. 2. The front and rear edges 8*b* and 8*a* of the rib 8 abut the internal wall of the shell 2, laterally at each side of the longitudinal walls 2*a*.

For convenience, the device will be described with reference to its position shown in Fig. 2, in which the top and bottom planar faces of the flange 11 are horizontal. The bottom planar face of the flange 11 abuts the internal respective annular horizontal planar face of the shell 2, save at the recess between the walls 2*a*, so as to provide a seal which is wholly or substantially air-tight, save at the recess of shell 2 between the walls 2*a*.

The line 11*c* in Fig. 2 indicates the horizontal plane of the respective internal horizontal face of shell 2, and it is clear that the lateral edges 8*b* and 8*a* are in the same plane as the plane of the bottom or sealing face of the flange 11. The bottom face of the extension 8*c* of the diaphragm 7 is also in the horizontal plane which is indicated by the line 11*c*.

The diaphragm 7 and its flange 11 therefore normally separate the interior of the casing into two wholly separate air chambers between which access is provided, only when the diaphragm 7 oscillates. Hence the interior of the device normally has two wholly separated air columns. There is a top air column between wall 1*a* and diaphragm 7, which is open only at its rear through throat 3. There is a bottom air column between diaphragm 7 and the respective part of the internal wall of shell 2. Said bottom air column is normally open only at its front, through the recess of shell 2.

At its rear end, the shells 1 and 2 are shaped so as to provide said outlet or throat 3, which has an internal wall 6*c* of frusto-conical shape. Said wall 6*c* tapers outwardly and rearwardly, so that the rear end of said wall 6*c* is of greater diameter than its front end. Said throat 3 may be of any desired length. The shells 1 and 2 may be fixed to each other, only at the flanges 6*a* and the ribs 6*d*, so that such shells 1 and 2 are unconnected to each other along their respective flanges 6 and 6b of the shells 1 and 2 are biased normally to contact with each other, by the resilience of the shells 1 and 2. If shell 2 is rigid, the resilience of shell 1 biases its two flanges 6 and its two flanges 6b, normally to contact with the respective flanges 6 and 6b of shell 2. The respective ribs 6d of the shells 1 and 2 also normally contact with each other. However, when the air columns within the shells vibrate, said shells are free to vibrate in unison with said air columns rearwardly of ribs 6d, if both shells 1 and 2 are resilient and resonant so that the shells can temporarily separate very slightly from each other at their respective flanges 6 and 6b, rearwardly of the ribs 6d during such vibration. If desired, the ribs 6d of the respective shells can be unconnected to each other, so that the shells are connected to each other only along all or along any desired portions of their respective flanges 6a. The respective shells 1 and 2 can also be fixed to each other along their respective flanges 6 and 6b. Hence I can control the extent of temporary separation of the shell 1 and 2, at any parts of their normally abutting flanges. If the shell 2 is made rigid and non-resonant, the permanent connection between shells 1 and 2 can be made in any of the previously described ways.

The arched shape of the body of the diaphragm 7, due to its partial spherical shape or its partial conical shape or other arched shape gives said body considerable stiffness, so that said body retains said normal arched shape when the diaphragm 7 vibrates. The convex face of the rib 8 is located in a corresponding lateral concave recess of the internal wall of the shell 1, preferably with slight clearance between said rib 8 and said recess. Said rib 8 may fit tightly in said recess of shell 1.

When the user sings or talks into the device, at the lip portion 12, or when sound waves are otherwise produced, the diaphragm 7 resonates or oscillates while its arched body permanently retains its said normal arched shape. The flange 11 moves in unison with said permanently arched body. Said body of diaphragm 7 may vibrate or resonate as a unit, by turning relative to the lateral hinge-line which is provided by the rib 8. Said lateral hinge-line or hinge-connection is substantially at the rear lateral edge 8a of the lateral rib 8. The rib 8 and extension 8c remain in fixed position, during the vibration or oscillation of the body of diaphragm 7 and its flange 11. Said diaphragm 7 can vibrate or resonate as a unit or in sections.

The screws 9 can be applied with suitable pressure against the rigid bar 10 and the projection 8C, in order to securely anchor the diaphragm to the bottom shell 2, forwardly of the rib 8. This prevents any lateral shifting of the diaphragm 7, while permitting the arched body of said diaphragm 7 to vibrate up and down, in unison with its flange 11, so that the diaphragm 7 can operate substantially like a rigid plunger, thus producing the highest efficiency. When the body of the diaphragm 7 is thus vibrated as a single unit, the flange 11 is moved in unison with said body, relative to the internal wall of the shell 2, so that air can move between the bottom air chamber and the top air chamber, due to the temporary entire or partial raising of the flange 11 from its normal sealing position.

In addition, the air column in the top air chamber is periodically compressed and rarefied, due to the relative movement between diaphragm 7 and the shell 1.

Hence the sound waves which are produced in the bottom air column are transmitted to the top air column, by a combined action. Such transmission is produced by the vibration of diaphragm 7, which causes flange 11 to move away from its sealing position and back to its sealing position, with the consequent compressions and rarefactions of the air.

As shown in Fig. 2, the recess which is provided in the internal wall of the shell 2, is of substantially constant and maximum depth between the walls 2a. The depth of said recess is then gradually decreased to zero at the front rounded end 17a of said recess. Hence, the depth of the recess is diminished as its width is diminished along the converging walls 17. The air which is forced into said recess at its front end, is thus forced upwardly at an angle against the body of the diaphragm 7, as shown by the longitudinal arrow in Fig. 2.

The drawings are substantially to scale, so that reference can be made thereto for additional details, such as the sizes and relative proportions of the parts.

In order to secure plunger-like vibrations of the diaphragm 7, of maximum efficiency, said diaphragm 7 must be loaded by an air column. This air column is located in the air chamber which is located above the diaphragm 7. Said upper air column is closed, save at its rear end at throat 3. The curved contour of the internal wall 1a shapes this loading air column for proper distribution of the sound waves. This design, together with the plunger-like action of the diaphragm, produces very high efficiency. One of the functions of the air column which is provided above the diaphragm 7, is to provide a coupling between the movement of the diaphragm 7 and the movement of the air at the throat 3. The diaphragm 7 itself, even when it vibrates at its greatest amplitude, does not deliver any great amount of sound energy. Therefore, the loading of the diaphragm with an upper air column is an important feature. The upper air column is of small size at its front end, in order to produce an appreciable pressure load on the diaphragm 7 at its front end, adjacent the lateral edge 8a, between said diaphragm and the wall 1a, when the upper column is compressed at its front end by a sound wave. This upper loading air column is enlarged at its rear end, adjacent the throat 3, in order to radiate the sound efficiently, either into the atmosphere, or into the interior of a tapered magnifying horn which can be connected to the throat 3.

In order to secure maximum efficiency, the gradual increase in volume of this upper loading air column, from front to rear, follows an exponential formula. The increase in volume of the upper air column is gradual and continuous, in order to eliminate any reflection of sound waves in said upper loading air column.

If desired, the flange 11 can be provided with a series of grooves which are concentric with the point 16, thus providing said flange 11 with concentric ribs which normally have a sealing fit against the respective part of the respective internal planar wall of the shell 2. Said internal planar wall of shell 2 can also be provided with such ribs, which may abut such ribs of flange 11.

The points 15 and 16 are located in the vertical median longitudinal plane of the device, which is defined by the line 2—2. The vibrations may be transmitted from the lower air column to the upper air column, wholly or almost wholly through the vibrations of the body of the diaphragm 7, so that the flange 11 may remain at all times in sealing position, or substantially in sealing position, instead of being moved intermittently out of sealing position.

In the second embodiment illustrated in Figs. 3 and 4, the air enters the bottom air chamber through a longitudinal bore 18a which is provided in the bottom shell 2. This bore 18a replaces the recess of the first embodiment of Figs. 1 and 2. This bore has parallel longitudinal walls 18b at the lip portion 12, and the rear ends of said walls 18b merge with a recess 18c which has an end-wall 18, which has the shape of a part of a circle, whose center is located at 19. The point 19 is located in the vertical median longitudinal plane of the device.

In the embodiment of Fig. 5, the internal wall of shell 2 is shaped to provide recesses 20 and 21, which communicate with bore 18a.

In the embodiment of Fig. 6, said bore 18a of shell 2, communicates with diverging recesses 22 which are provided in the internal wall of shell 2.

In the third embodiment of Figs. 7, 7A and 8, the shell 2, which is preferably rigid and non-resonant, has a depending mouth-portion 23, which has a vertical cylindrical bore 26. This bore 26 may be of frusto-conical shape, so that it is enlarged towards the diaphragm 7. Such tapered shape is shown in Fig. 10.

In the fourth embodiment of Figs. 9 and 10, the rigid and non-resonant shell 2 has a vertical mouth-piece 26a, which has a cylindrical bore 28, which has a frusto-conical enlargement. A plurality of partitions 29a are located in said enlargement thus providing intermediate channels 29. Said partitions 29a are spaced from each other, to provide said channels 29. Three partitions 29a are shown in this illustration, but the number may be varied. The central partition 29a is of solid conical shape. Each additional partition 29a is hollow and it has frusto-conical walls. Each channel 29 is of greatest width adjacent the diaphragm 7. The partitions 29a are fixed in spaced relation by any suitable means, such as by the ribs 31b which are shown in Fig. 12. These ribs can be integral with partitions 29a, so that said partitions 29a can be made as an independent sub-unit, which can be located in said frusto-conical enlargement.

The outermost partition 29a can be fixed to the frusto-conical wall of said enlargement by means of such ribs, this constructional feature being shown in Fig. 12. Such ribs should be of minimum thickness, in order to provide minimum obstruction in the channels 29. Shell 1 has outlet 27.

The fifth embodiment of Figs. 11 and 12 is the same in general principle as the fourth embodiment of Figs. 9 and 10. In the fifth embodiment of Figs. 11 and 12, the diaphragm 7 is downwardly arched, towards the mouthpiece 29b of shell 2. Above the diaphragm 7, the partitions 31a are provided with connecting ribs 31b. Fig. 12 shows six partitions 31a, which correspond to the partitions 29a of Fig. 10. These partitions 31a have intermediate channels 31. Shell 1 has outlet 30.

Fig. 13 shows a single solid baffle B, whose upper part 32 is conical, and whose lower part 34 has the shape of a part of a sphere. Said baffle is fixed by ribs 33 to the internal wall of shell 1. This shell 1 has an outlet 30, and shell 2 has mouthpiece 29b.

The baffle B of Fig. 13 compels the sound waves which are produced at the centre of the bottom of the diaphragm 7, to travel laterally outwardly. There is a difference of curvature between the bottom surface of the element 34 and diaphragm 7, and there is a difference in angle between the wall of the element 32 and the respective adjacent tapered wall of shell 1.

The fifth and sixth embodiments of Figs. 12 and 13 are designed to eliminate interference of the sound waves at the outlet throat 30. There may be a slight phase difference between the respective sound waves which are produced at the centre and at the edge of the arched body of the diaphragm 7. This results from a difference between the respective lengths of path of the respective sound waves. If this difference in length of path is only a few millimeters, there is a sufficient difference in phase at the outlet throat 30 to produce substantial interference at high frequencies. This objectionable interference is eliminated or minimized by the design of Figs. 12 and 13, and particularly by the design of Fig. 12. This design causes all the waves which are produced by the diaphragm 7, to move in paths of substantially equal length to the inlet of the outlet throat 30. This eliminates phase difference and interference at the inlet of said throat 30, and also in said throat 30 between its inner and outer ends.

For this purpose, an even better design is shown in the seventh embodiment of Fig. 14, which is generally similar to Fig. 13, save that in Fig. 14, I also provide the throat 3 which has been shown in previous embodiments, and which is common to shells 1 and 2 in addition to the throat 30 of shell 1. Some of the air travels in an annular channel which is indicated by arrows 32a, towards and out of the throat 30, and some of the air escapes directly through the throat 3.

When the diaphragm 7 vibrates, in the sixth embodiment of Fig. 13, there may be interference of the resultant sound waves due to a phase difference of 180° at certain frequencies at the inlet of throat 30. This is eliminated by providing the two separate outlet throats 3 and 30.

The eighth embodiment of Fig. 15 and Fig. 16 has the same purpose as the fifth embodiment of Fig. 12, and said eighth embodiment is more easy to manufacture. In the eighth embodiment of Fig. 15, the convex side of the diaphragm 7 faces the mouth-piece 29b of the shell 2. The divided air column above the diaphragm 7 gives high efficiency at a wider range, and in addition such divided air column produces better overtones.

Fig. 15 shows a single conical insert 35, which is provided with a series of bores 36. Each bore 36 is of frusto-conical shape, so that each said bore 36 is wider adjacent the throat 30 than adjacent the diaphragm 7. This insert 35 is suitably fixed to the internal wall of the shell 1. The diameter of each said bore 36 is increased exponentially towards throat 30, according to the same exponential formula. This provides efficient coupling of the respective air columns in the respective bores 36, and of the diaphragm 7 to the air column of throat 30, and to the respective air column of a magnifying exponential horn which may be connected to the throat 30. The parts are designed so as to prevent any reflection of sound from the throat 30, back towards the diaphragm 7. The internal wall of throat 30 is tapered according to an exponential formula. The throat 30 is also tapered according to said formula. In the embodiment of Fig. 15, as in the other embodiments, the diaphragm 7 is fixed only at its rib, and no part of flange 11 is fixed between said shells 1 and 2.

In the ninth embodiment of Figs. 17 and 18, the lip-portion 12 of the bottom shell 2 is provided with an upwardly inclined inlet bore which opens into a recess of shell 2. A pin 37 is fixed to the arched body of the diaphragm 7. Said pin 37 projects, with very slight clearance, through the top wall of the shell 1. At its upper end, said pin 37 is fixed to a diaphragm 38, which has horizontal annular corrugations 39. The rim of said diaphragm 38 is fixed to the rim of the shell 1 by means of a rigid clamping ring 40, which is fixed to the rim of shell 1. As previously stated, both shells 1 and 2 can be rigid and non-resonant. This applies particularly to embodiments like Figs. 13, 15, 18, etc.

As shown in Fig. 18, the top cavity of the shell 1 is provided with a fixed liner L, which is made of felt or some other sound-absorbing material.

Since the cone 38 is larger than the diaphragm 7, said cone 38 radiates the lower frequencies at high efficiency. As in the previous embodiments, the air chamber between the diaphragm 7 and the adjacent internal wall of the shell 1, is of exponential design. Fig. 18 also shows the throat 3, which is common to shells 1 and 2, and through which the high frequencies are radiated. This type of instrument has an extremely large frequency range. The high frequencies can be amplified by means of a suitable amplifying exponential horn which can be connected to the exponential throat 3.

The tenth embodiment of Figs. 19 and 20 is substantially the same in principle as the first embodiment of Figs. 1 and 2. In this tenth embodiment, the internal walls of the shells 1 and 2 are shaped to provide a common inlet bore 43a. For this purpose, said internal walls have equal recesses. Said internal walls of shells 1 and 2 are also shaped to provide a common longitudinal partition 43. The respective flanges 11 of the respective diaphragms 7 divide the interior of the device into three air chambers. The central air chamber is located between the two diaphragms 7. The top and bottom air chambers have respective outlet throats 3. The tenth embodiment delivers sound of greater volume than the first embodiment. In the tenth embodiment, the respective diaphragms 7 are identical.

Whenever I provide a single diaphragm, or a plurality of identical diaphragms, each said diaphragm may have a natural frequency which is in the normal audible limit, or such natural frequency may be above or below the audible limit.

In the eleventh embodiment of Fig. 21, the respective diaphragms 7 are identical. This eleventh embodiment has an internal partition 42 and the inlet 41 has an internal frusto-conical wall whose width decreases rearwardly. A single throat 3 is provided.

In the twelfth embodiment of Figs. 22, 23, and 24, I provide two diaphragms, each of which has a respective frequency which is within the audible limit.

The natural frequency of the bottom diaphragm of Fig. 23 is higher than the natural frequency of the top diaphragm. Hence the higher frequencies are emitted, largely or wholly by the bottom diaphragm, and the lower frequencies are emitted largely or wholly by the upper diaphragm. An acoustic dividing network can be used here to make the division between the two frequency ranges more positive. The partition 42a of Fig. 23 generally corresponds to the partition 42 of Fig. 21. The partition 43 of Fig. 20, the partition 42 of Fig. 21 and the partition of 42a of Fig. 23 can be made of flexible or resilient material also, of a thickness which permits each said partition to vibrate.

Fig. 25 shows that the continuous flange 11 can be replaced by separated flange sections 11a. This scalloping of the flange produces a softer sound.

Fig. 26 shows that the diaphragm 7 can be biased by means of a blade spring 44, whose upper end is fixed to the shell 1, so as to increase the force with which the diaphragm 7 normally or permanently divides the interior of the device into a plurality of air chambers. Such biasing spring also imposes an additional load on the diaphragm.

Fig. 27 shows that the upper leg of said blade spring 44 is fixed only at its free end to the shell 1. Therefore, the biasing pressure of said spring 44 against the diaphragm can be regulated by depressing the knob 45a, thus moving its shank through a bore of fixed plug 45b, thus increasing the load on the diaphragm. If the knob 45a is released, the pressure of its shank on the spring 44 is decreased to zero. The biasing compression spring 45 normally holds knob 45a in such position that its shank exerts no pressure on spring 44. This adjustment of pressure on spring 44 can be made at will while playing the instrument.

In every embodiment described herein, the outer shells 1 and 2 may remain in permanent air-tight contact with each other, during the operation of the device, or selected portions of the edges of the flanges of said shells may intermittently separate from each other very slightly, during such operation, to permit air waves to pass between the temporarily separated selected portions of said edges or flanges. Likewise, in every embodiment, the inner diaphragm or diaphragms may permanently divide the interior of the device into separate air columns which do not communicate with each other at any time, or said diaphragm may flex, in order to permit temporary and intermittent communication between said air columns.

Preferably, selected portions of the edges of the shells do separate temporarily and intermittently, while the sound waves are produced and the diaphragm or diaphragms do temporarily and intermittently permit communication with respective air columns, while the sound waves are produced.

In the embodiment of Figs. 28 and 29, the design follows the principle of Fig. 8. The mouthpiece 50 of shell 2 has three ribs 51 which are fixed to the inner wall of said mouthpiece 50. The respective angles between said ribs are equal, so that in a horizontal plane, their bottom ends are spaced by angles of 120°. Said ribs are of streamline shape, so as to offer minimum resistance to air which flows upwardly through mouthpiece 50. Said ribs 51 have a common center member 52, to which the flat disc-shaped central part of the metal diaphragm 7 is fixed. Said diaphragm 7 has a plurality of circular corrugations 56.

The baffle 55 is fixed to the shell 1 by ribs 54a, providing a channel 54.

This channel 54 is of tapered shape so that its volume increases exponentially towards outlet throat 53 of shell 1.

The corrugations 56 of the thin conical diaphragm 7, break up its surface into a plurality of nodal rings. Since the diaphragm 7 is rigidly fixed at its central part, said central part cannot vibrate. The vibrations of diaphragm 7 increase in amplitude, in proportion to the radial distance from the fixed central part of said diaphragm 7.

In each of the embodiments described herein, the intermediate diaphragm 7 can operate merely like a piston or plunger without any self-resonance of said diaphragm. It is also within the scope of the invention to have said diaphragm resonant so that it will respond to sound waves of various pitches within the audible limit, by vibrations of the arched body of said diaphragm.

When I specify a diaphragm in a claim or claims, I include the use of a plurality of diaphragms in such claim or claims.

The body of the diaphragm preferably has a permanent concavo-convex shape. The convex face of the diaphragm may face either the inlet opening or the outlet opening.

The edge portion of the diaphragm is a continuous annulus in some of the embodiments, and said edge-portion is partially annular and partially straight, in other embodiments.

In every embodiment, at least a major part of the edge of the diaphragm is of circular or annular contour.

Each embodiment herein discloses an acoustic instrument which has a hollow body, which has an inlet opening and an outlet opening. Said hollow body has internal diaphragm means, which comprise a single diaphragm or a plurality of diaphragms. Said diaphragm means are biased, either by the inherent resilience of said diaphragm means or otherwise, to separate the interior of said hollow body into an inlet chamber and an outlet chamber. In the normal biased position of said diaphragm means, said inlet chamber is wholly or substantially separated from the outlet chamber, so that the diaphragm means must be moved out of normal biased position, in order to permit the desired transmission of compressional waves between the inlet chamber and the outlet chamber. The inlet and outlet openings respectively communicate with the inlet chamber and the outlet chamber.

I claim:

1. An acoustic device comprising a hollow body which has an inlet opening, said body having an internal partition, said body having a pair of internal diaphragms each said diaphragm being connected to said body and being movable relative to said body, each said diaphragm being biased to a normal position in which an edge-portion of each said diaphragm abuts said partition, said partition being located intermediate said diaphragms, said diaphragms and said partition defining an inlet chamber of the hollow space of said body with which said inlet opening communicates, said inlet chamber being wholly enclosed save for said inlet opening when said diaphragms are in their respective normal positions, each said diaphragm being spaced from the inner wall of said hollow body to provide a respective outlet air chamber, said body having outlet means for said outlet air chambers, all said chambers being separated from each other when said diaphragms are in their respective normal positions.

2. An acoustic device according to claim 1, in which said diaphragms have respective different natural frequencies.

3. An acoustic device which comprises a hollow body which has an inlet opening and an outlet opening, said body comprising a pair of shells which are shaped to provide said openings and which have respective abutting edge-portions between said openings, a resilient diaphragm located in said hollow body, a fixed part of said diaphragm being fixed to one of said shells at said inlet opening, said fixed part of said diaphragm being located to leave said inlet opening substantially unobstructed, said diaphragm having a body which has an edge-flange which is spaced from said fixed part and which is biased by the resilience of said diaphragm to a normal position in which said edge-flange abuts the internal wall of one of said shells normally to separate the interior space of said hollow body into an inlet chamber which normally communicates only with said inlet opening and an outlet chamber which normally communicates only with said outlet opening, said chambers having respective air-columns therein, said edge-flange being displaceable from said normal position to establish communication between said chambers when the pressure in said inlet chamber exceeds the pressure in said outlet chamber.

4. An acoustic device according to claim 3 in which said diaphragm is arched both longitudinally and laterally, with the exception of said fixed part thereof.

5. An acoustic device according to claim 3 in which said diaphragm has a concavo-convex rib between said edge-flange and said fixed part.

6. An acoustic device according to claim 3 in which said body of said diaphragm has sufficient rigidity to maintain said body in its predetermined normal shape, and to limit the flexing of said diaphragm substantially to the junction between said fixed part and said body.

7. An acoustic device according to claim 3 in which said body of said diaphragm has sufficient rigidity to maintain said body in its predetermined normal shape and to limit the flexing of said diaphragm substantially to the junction between said fixed part and said body, said outlet chamber having an air column which follows an exponential formula and which has its greatest cross-section at said outlet opening.

8. An acoustic device which comprises a hollow body, said body having an inlet opening and an outlet opening, an arched diaphragm located in said body, one part of said diaphragm being fixed to said hollow body, another part of said diaphragm being movable relative to said body, said movable part having an edge-portion, said movable part being biased to a normal position in which its said edge-portion normally abuts an interior wall of said hollow body to normally separate the interior space of said body into an inlet chamber which communicates only with said inlet opening and an outlet chamber which communicates only with said outlet opening, each said chamber having a respective air column, said movable part being movable out of said normal position under the force of compression in said air column of said inlet chamber to establish communication between said chambers, said edge-portion having at least a major part of annular shape.

9. An acoustic device which comprises a hollow body, said body having an inlet opening and an outlet opening, an arched diaphragm located in said body, one part of said diaphragm being fixed to said hollow body, another part of said diaphragm being movable relative to said body, said movable part having an edge-portion, said movable part being biased to a normal position in which its said edge-portion normally abuts an

interior wall of said hollow body to normally separate the interior space of said body into an inlet chamber which communicates only with said inlet opening and an outlet chamber which communicates only with said outlet opening, each said chamber having a respective air column, said movable part being movable out of said normal position under the force of compression in said air column of said inlet chamber to establish communication between said chambers, said hollow body having a longitudinal axis, said inlet opening and said outlet opening being located at the respective ends of said axis.

10. An acoustic device which comprises a hollow body, said body having an inlet opening and an outlet opening, an arched diaphragm located in said body, one part of said diaphragm being fixed to said hollow body, another part of said diaphragm being movable relative to said body, said movable part having an edge-portion, said movable part being biased to a normal position in which its said edge-portion normally abuts an interior wall of said hollow body to normally separate the interior space of said body into an inlet chamber which communicates only with said inlet opening and an outlet chamber which communicates only with said outlet opening, each said chamber having a respective air column, said movable part being movable out of said normal position under the force of compression in said air column of said inlet chamber to establish communication between said chambers, said movable part having a permanent concavo-convex shape, at least a major part of said edge-portion being continuously curved.

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