Jan. 10, 1928.

1,655,675

A. CUNNINGHAM

DIAPHRAGM HORN

Filed July 21, 1926

2 Sheets-Sheet 1

Fig-1

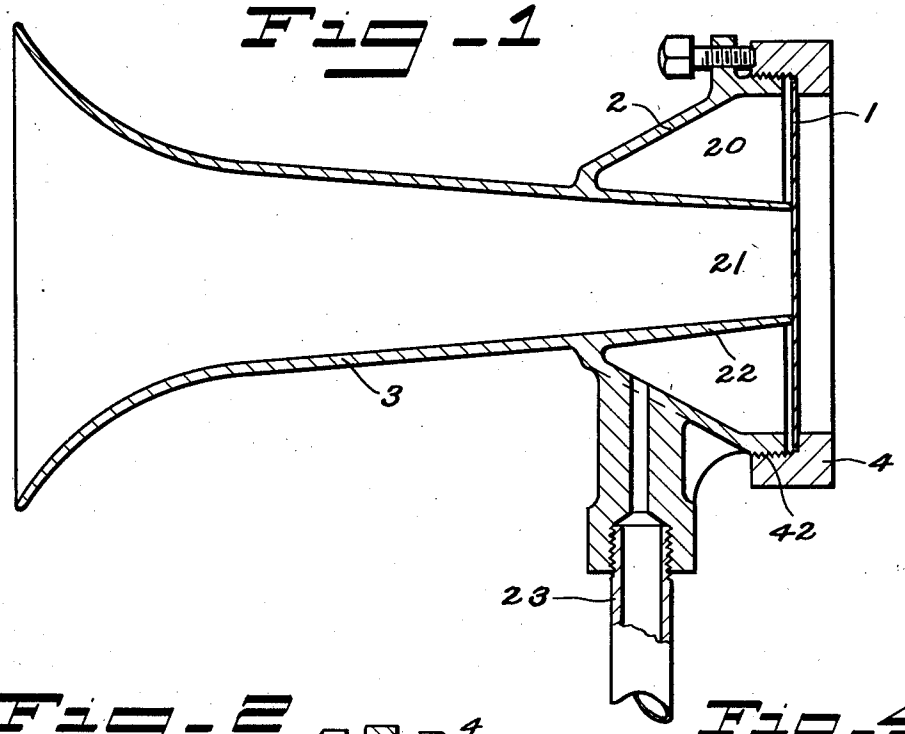


Fig-2

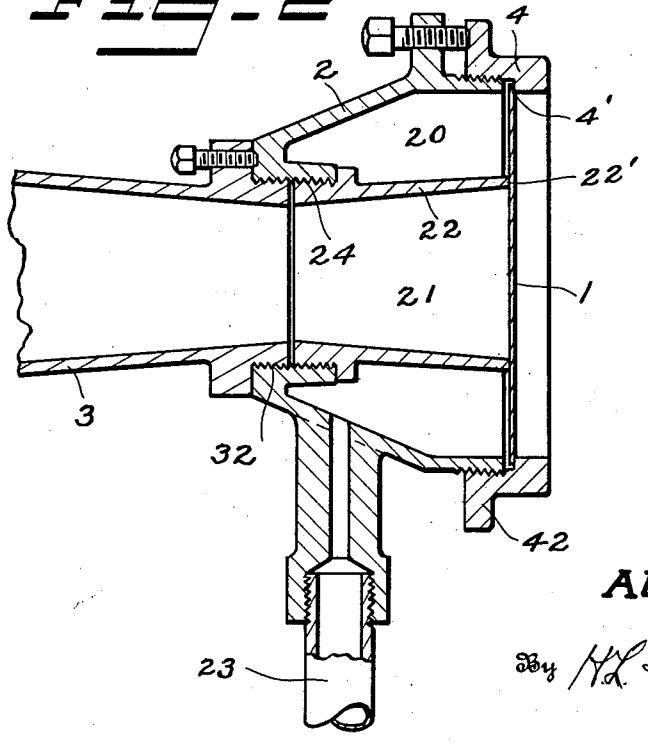
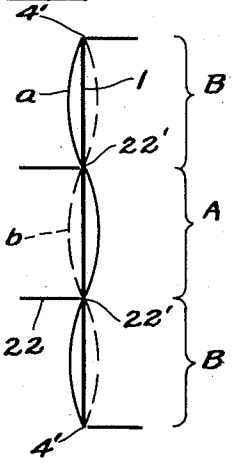


Fig-4



Inventor

Allan Cunningham

By H.L. & L. Reynolds.

Attorneys

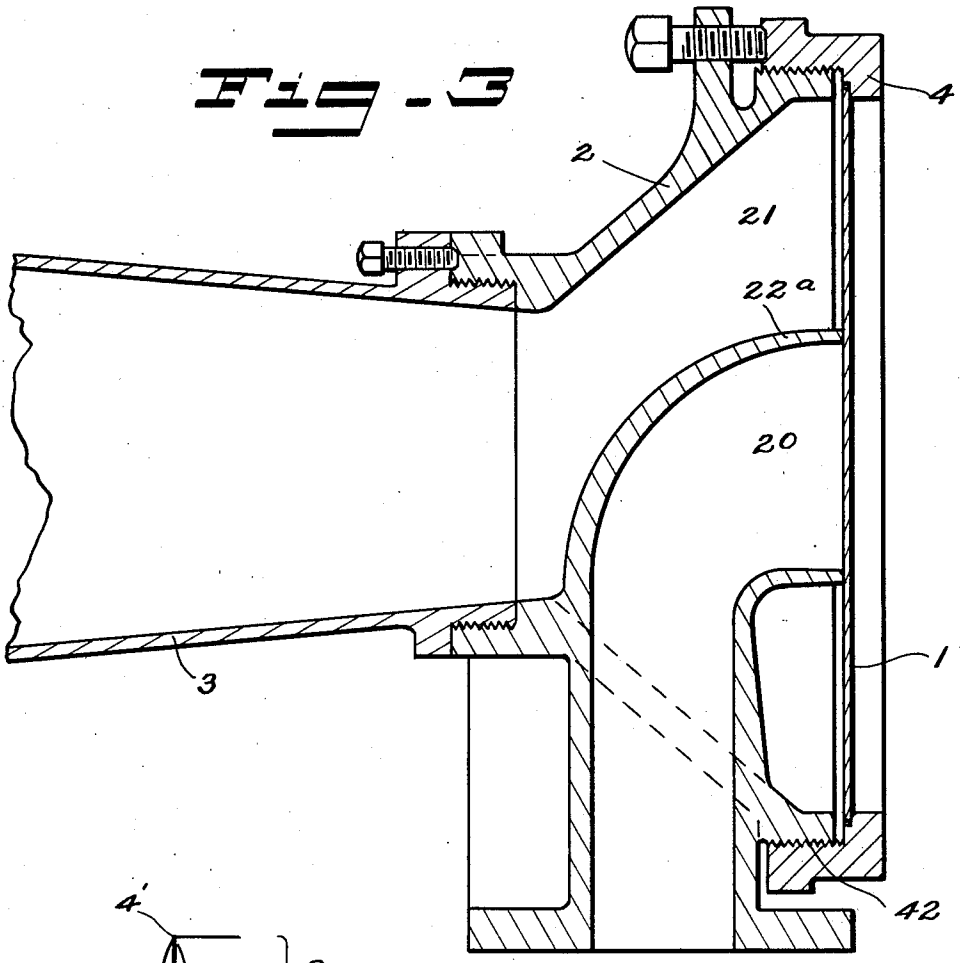
Jan. 10, 1928. 1,655,675

A. CUNNINGHAM

DIAPHRAGM HORN

Filed July 21, 1926 2 Sheets-Sheet 2

Fig. 3



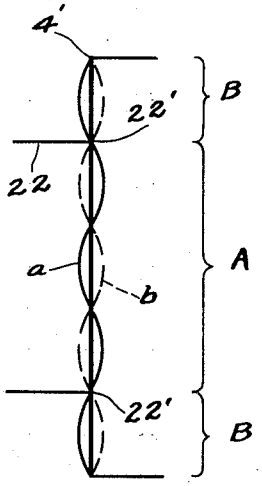


Fig. 5

Inventor

Allan Cunningham

By W. L. & C. L. Reynolds

Attorneys

Patented Jan. 10, 1928. 1,655,675

UNITED STATES PATENT OFFICE.

ALLAN CUNNINGHAM, OF SEATTLE, WASHINGTON.

DIAPHRAGM HORN.

Application filed July 21, 1926. Serial No. 123,883.

My invention relates to diaphragm horns or whistles, and most particularly to horns of the type shown in the patent to Astrom, No. 870,074.

I have found in using such horns as Astrom's that certain horns will produce a clear tone, of good carrying power and volume, and producing a sharp and distinct echo. These qualities are all of the greatest value to mariners, who must indicate their position and project the sound of their horn to the farthest degree for their own safety and for the safety of approaching vessels, and who must employ the echoing properties of the horn to locate unseen objects, which they may be approaching, such as docks, cliffs, and the like. Certain other horns of the same type and apparently identical with horns which possess proper carrying power, echo, and the like, have been found to possess these qualities in a very inferior degree. In other words, their carrying power is poor, the tone is weak and indistinct and the echo, likewise is indistinct, and for the purposes to which it is put, rather inconclusive, affording no means of judging the distance a vessel may be from an unseen object.

Heretofore the reason for these variations in two horns, apparently alike, has been unknown. I have discovered, however, that there is a relation between two measurements or distances of the diaphragm used in such horns which determines these qualities of the horn, and it is my object in this specification, therefore, to disclose the principles which will enable all such horns to be made clear in tone, of the utmost carrying power, and with a clear and distinct tone and echo.

My discovery relates to the diaphragm and to the relation of certain measurements and distances thereof as embodied in a horn of the type indicated; it relates also to certain improvements in the mechanical structure of the horn permitting its rapid and economical manufacture.

In the accompanying drawings I have illustrated horns and diaphragms embodying the principles of my discovery, and illustrating these principles applied to various types of horns, and in various ways.

Figure 1 is an axial section through a preferred embodiment, illustrating these principles applied in their simplest form.

Figure 2 is a like section illustrating a slight modification in the manner of application, portions of the horn being omitted.

Figure 3 is an axial section illustrating a further modification or reversal of the form of horn shown in Figure 1.

Figures 4 and 5 are diagrams illustrating the principles of my discovery.

As in the Astrom patent referred to above, a diaphragm 1 supported about its periphery, and having areas in communication with a pressure chamber 20 and with a pressure relief chamber 21, is caused to vibrate by the rapidly recurring building up of pressure in the chamber 20 and its escape to the chamber 21. As shown in Figure 1, the pressure chamber 20 is defined by a casing 2, which may be of any suitable shape but which is preferably circular in cross section, and the relief chamber 21 is defined by a tube 22 extending through the chamber 20 and communicating with a horn or resonator 3.

It will be observed that the rear end of the chamber 20 and of the chamber 21 is open and that the open end of the tube 22 bears against the inner face of the diaphragm. Thus, as the diaphragm is positioned across the open rear end of these two chambers, bearing against the end of the tube 22, pressure escaping from the chamber 20 will cause a vibration of the diaphragm 1, as it passes between the end of the tube 22 and the diaphragm, and thus into the chamber 21. Pressure is supplied to the chamber 20 by means of a pressure inlet connection and port 23. The diaphragm is engaged about its periphery and supported in place by an annular nut or ring 4, threaded at 42 upon the casing 2. Preferably the end of the tube 22 lies substantially in, or slightly above, the plane of the open rear end of the casing 24, but the diaphragm is not placed under any appreciable tension; it is merely held to its seat by the clamping ring 4 with sufficient pressure to prevent its being unseated. All of the above is common in horns of this type, and this construction or any like construction can be employed.

I have found that a definite relationship exists between the distance across the end of the tube 22 and the width of the annular chamber 20, the width of the annular chamber being taken as the inside distance be-

tween the peripheral engagement of the diaphragm by the ring 4 and the edge of the tube 22 where it contacts with the diaphragm. The relationship between these distances I have found must be such that one of the distances (which, it does not matter) is a whole multiple of the other distance. The first can be equal to the second distance, that is, one times the second distance, or it can be two, or three or four, or five times the second distance, and so on. So long as one of these distances is a whole factor or a whole multiple of the other distance, the horn will give a clear, powerful tone, which will carry for long distances, and which will give back a sharp and distinct echo, but if the relationship of the two distances is disturbed by a small amount, the character of the tone and its desirable qualities will be impaired. While horns wherein the relationship of the two distances varies by as much as ten to fifteen thousandths of an inch in a six-inch diaphragm will produce a noise, the tonal quality is so affected by a variation of this amount that it is far from satisfactory. The width or thickness of the wall of the tube 22 appears not to affect this condition, and this may vary considerably in thickness. I am now using a wall thickness at this point of approximately one-eighth of an inch. The controlling factor is the relation of the inside distances, first the inside diameter of the tube 22, and second the distance between the outside of this tube 22 and the inside of the peripheral ring 4.

I am unable to give a scientific explanation of my discovery, but I know it to be a fact that when the relations disclosed above are maintained the tone of the horn will ring true, it will carry, it will give a proper echo, and the whistle uses but little energy and pressure. On the other hand, no reasonable amount of energy or pressure will give even approximate results if the relationship as disclosed, between the two portions of the diaphragm, does not obtain.

While I can offer no proven explanation of the action taking place in the diaphragm, the theory which appears most plausible is illustrated in the diagram Figure 4. Here the diaphragm is indicated at 1, and the edges of the tube 22 at 22′, and the inside edge of the ring 4 at 4′. For the purpose of this diaphragm, the thickness of the wall of the tube 22 has been disregarded. The diaphragm, when acted upon by the rapidly recurring escape of the pressure medium, appears to be set into vibration in a stationary wave form concentric with its center and the center of the tube 22. The vibrations do not travel outward as in the case of water waves, but appear to remain stationary, moving certain areas A and B of the diaphragm transversely of its plane. By reason of the stationary character of the wave, nodal points appear to be formed at the points of contraflexure of the wave form. The length of the wave is, of course, alike in all portions of the diaphragm. The sum of each series of nodal points forms a circle about the center of the diaphragm, and thus by locating the bearing point 22′ about some such circle, the vibration thus set up is not damped in any way.

Thus, according to this theory, and considering conditions at any given instant, the diaphragm areas A and B may vibrate to the full line position *a* of Figure 4, the nodal points 22′ remaining stationary, and at the next instant, the diaphragm will assume the position *b*, shown in dash lines, with the phase of the areas A and B reversed. In this second position as in the first, the nodal points 22′ are stationary, and it is evident that these points will not at any time move transversely of the plane of the diaphragm. It will be evident, too, that these nodal points will be located at each third of the entire diameter of the diaphragm; thus the distance A is equal to the distance B. It is also evident that if the points of support 22′ properly at the nodal circle, be moved by the slightest amount towards or away from points forming the circles 4′, interference with the wave-like vibration will result and the tone will be destroyed.

Figures 1 and 4 illustrate the rudimentary form wherein the two controlling distances are equal. In Figure 2, however, the two controlling distances have been shown as related in the proportion of two to one, that is, the diameter of the tube 22 is twice the distance between the tube and the peripheral support of the diaphragm at 4′. The only result of this change appears to be to add an overtone to the basic tone of the horn, or to deepen the resultant tone, and by following the reasoning above, it will be seen that the edge 22′ of the tube 22 still remains at a nodal point of the wave form, but that the length and amplitude of the wave has probably been changed in some manner. The outer wave may now be one-half the length of the wave across the tube, but by reflection it remains in phase therewith. The result, however, is demonstrable, the adverse result of changing the relation to, say, two and one-quarter to one, is likewise demonstrable.

Figure 2 likewise shows the tube 22 as threaded at 24 in the casing 2, which permits the tube 22 to be finished down to an exact measurement after the casing 2 has been completed, and permits the replacing of a tube where the relationship is not exact. Likewise the horn 3 has been shown as threaded at 32 into the casing.

Figure 5 illustrates diagrammatically an arrangement wherein the controlling distances bear the relationship to each other of

three to one, that is the diameter of tube 22 is three times the width of the chamber 20. The wave form in this, and in all forms where the relationship of the controlling distances is not one to one, appears somewhat complex, as the diagram will show, but this appears reasonable inasmuch as all forms of the horn which have not a relationship of one to one produce apparently a multiplicity of tones, instead of a single tone. The multiple tone, however, has all the qualities of a single tone in so far as sharpness, clearness, carrying power, and echo are concerned.

It may be remarked here that the relationship of the distance A to the distance B may be as one to two, and like results are obtained, but in this form, the restricted outlet of the pressure causes a slight muffling of the sound, which is avoided by making the pressure outlet larger in diameter than the width of the annular pressure chamber.

The principle of my discovery is equally applicable to horns of the type employing a central pressure chamber 20, as illustrated in Figure 3. In this form, the casing 2 defines an annular relief chamber 21, and a tube 22^a defines the pressure chamber 20. The discharge end of the tube is concentric with the open rear end of the casing 2, and the diaphragm 1 bears against the outlet of the tube 22^a, and is held in place by the ring 4, threaded at 42 upon the casing.

I have found that wide variations in pressure cause no variation in the tone or in the strength of the sound emitted from a horn constructed with my discovery, and I have found that the shape of the pressure inlet, and its size, so long as sufficient of the pressure medium is supplied, likewise has no appreciable effect upon the sound. Extremely satisfactory results have been obtained with horns of the type shown in Figure 1, employing a four inch diaphragm, and an inlet opening of $\frac{1}{8}$ inch, at pressures as low as 10 pounds to the square inch, and ranging upwards to 300 pounds to the square inch. While compressed air has proven the most satisfactory pressure medium, the horns have operated satisfactorily by steam pressure.

It will be noted in Figure 1, that the casing 2 and horn or resonator 3 are cast integral; the tube 22 likewise forms part of the same casting. This construction differs from the usual construction which employs a spun horn with an attached spun bell at its outer end. This latter construction has been found expensive because of the necessity of assembling and securing the spun resonator to the base casting, but has been considered essential because of the vibratory, resonant effect of such a horn. Inasmuch as I have discovered that it is wholly the vibration of the diaphragm which produces the proper quality of sound, and that the horn, as 3, is chiefly desirable to project the sound in the proper direction, I am enabled to use a cast horn, cast integral with the casing, as shown. Such a type of construction permits the finishing of the entire casting at once, and at a cost several times less than the cost of a like unit using a spun horn. My complete unit, therefore, consists of three pieces, the main casting with the horn, the diaphragm 1, and the retaining nut or ring 4.

What I claim as my invention is:

1. In a diaphragm whistle, in combination, a casing opening rearwardly and a tube therein opening rearwardly, said casing and tube defining pressure and relief chambers, a fluid pressure connection to the pressure chamber and a forwardly directed sound outlet from the relief chamber, a diaphragm and means for securing it in place over the open rear ends of the two chambers, whereby fluid must pass between said diaphragm and the end of the tube prior to escaping through the sound outlet, the radical distance across the pressure chamber being a whole factor of the radial distance across the relief chamber.

2. In a diaphragm whistle, a diaphragm, means for supporting said diaphragm about its periphery, means normally contacting with said diaphragm to form a nodal circle and means for applying a force to said diaphragm to vibrate it, the relation of the diameter of said nodal circle to the radial distance across the annular space between said circle and the diaphragm's peripheral support, being such that one is a whole multiple of the other.

3. In a diaphragm whistle, a diaphragm, means for supporting said diaphragm about its periphery, means normally contacting with said diaphragm to form a nodal circle and means for applying a vibratory force to said diaphragm, the diameter of the circle thus defined being a whole multiple of the radial distance across the annular ring between said circle and the peripheral support of the diaphragm.

4. In a diaphragm whistle, in combination, a casing opening rearwardly and having a forwardly directed sound outlet, a tube in said casing communicating at its forward end with said sound outlet, its rear end being disposed concentrically with the open rear end of said casing, and slightly above the plane thereof, a diaphragm positioned to close the open rear ends of said casing and tube, means engaging said diaphragm about its periphery to maintain it in position, and to press it against the rear end of said tube and a fluid pressure connection to the annular chamber between said tube and casing, the inside diameter of said tube, at its rear end, being a whole multiple of the radial

width of the rear end of said annular chamber.

5. In a sound generator, a pressure chamber having a pressure inlet, a flexible membrane in said chamber and supported therein about its periphery, a resonator tube projecting at its outer end from said chamber, its inner end bearing directly against the membrane between its peripheral support and its center, and forming a pressure relief chamber, the width of said relief chamber at the membrane being a whole multiple of the width of the annular pressure chamber.

6. In a diaphragm horn, a flexible membrane, means engaging said membrane about its periphery, means contacting with said membrane about a circle inside of its peripheral support, and means for applying a force to said membrane to induce a stationary-wave vibration therein transversely of its plane, the inner contact circle being disposed in a nodal circle of one of the wave forms.

7. In a horn employing a resonant diaphragm and means for vibrating it, means for supporting the diaphragm at opposite sides at different but concentric nodal points.

8. In a horn employing a resonant diaphragm and an elastic fluid under pressure for vibrating it, of means for supporting the diaphragm about its periphery and means forming a muting contact with one face of the diaphragm at a nodal point thereof.

Signed at Seattle, King County, Washington, this 23rd day of June, 1926.

ALLAN CUNNINGHAM.