March 27, 1956 F. B. DANIELS 2,739,659

ACOUSTIC DEVICE

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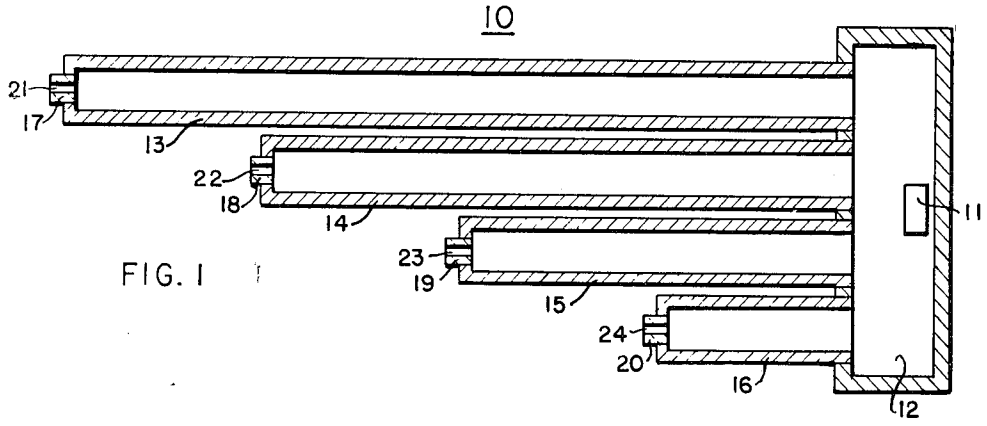


FIG. 1

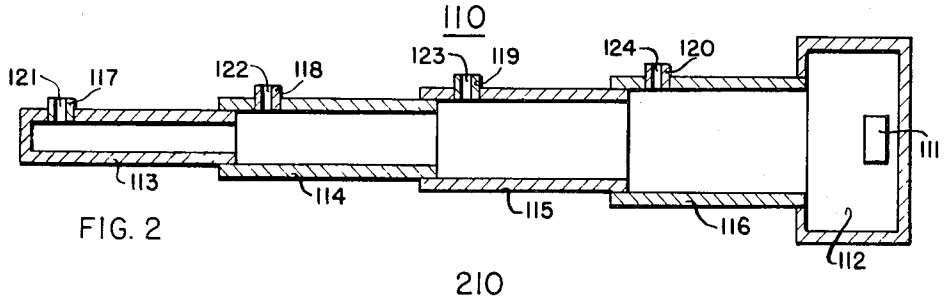


FIG. 2

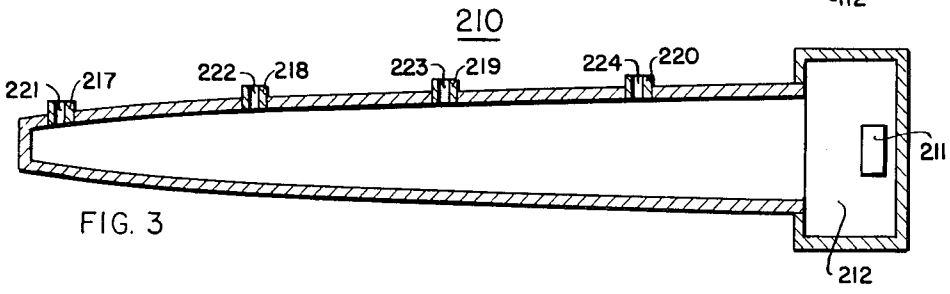


FIG. 3

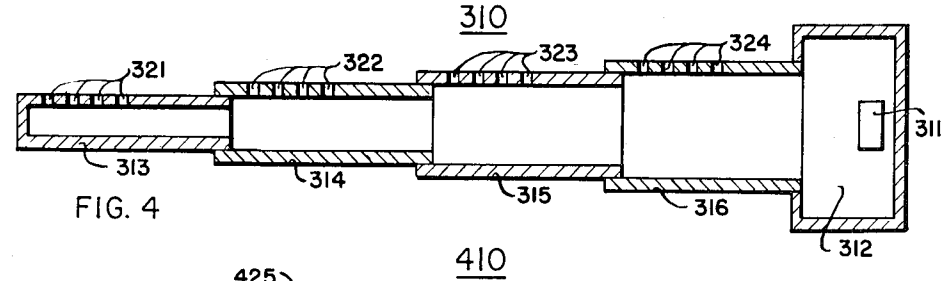


FIG. 4

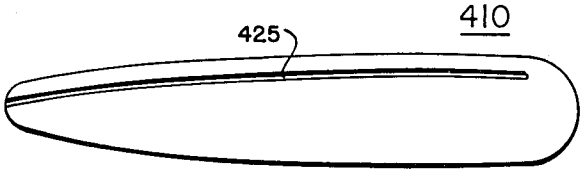


FIG. 5

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ACOUSTIC DEVICE

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8 Claims. (Cl. 181—.5)

(Granted under Title 35, U. S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government for governmental purposes without the payment of any royalty thereon.

This invention relates to an electro-acoustical apparatus and more particularly to a device for translating acoustical waves into electrical variations, and includes an acoustical transmission line of novel design. This invention relates particularly to a highly directional device that is relatively insensitive to interference from wind and other air turbulences.

There are several types of acoustical impedance elements for use in conjunction with microphones, those shown in Patent No. 2,228,886 to H. F. Olson being representative of the existing types that most nearly resemble this invention and which generally consist of a plurality of input tubes of varying length coupled to a common electro-acoustical transducer and terminating in some sort of acoustical impedance.

It is an object of this invention to provide an acoustical coupling device for an electro-acoustical transducer.

It is a further object of this invention to provide an acoustical coupling device that is highly directional.

It is a further object of this invention to provide an acoustical coupling device that does not require an additional terminating acoustical impedance, for use with an electro-acoustical transducer.

It is a further object of this invention to provide an acoustical coupling device that is relatively compact and easily constructed.

This device is particularly valuable in sound ranging systems where the eddy characteristics of the wind at the electro-acoustical transducer closely resemble the muzzle wave that it is desired to detect.

The invention and the foregoing as well as other features thereof will be understood more clearly from the following detailed description and with reference to the accompanying drawings in which:

Figs. 1 to 4 show sectional views through the axis of various species of this invention, and

Fig. 5 shows a projection of one exterior surface of another species.

Referring now to the drawings, wherein similar reference numbers designate corresponding parts throughout, Fig. 1 shows an acoustical coupling device **10** coupled to an electro-acoustical transducer **11** in a chamber **12**. The acoustical coupling device **10** which is particularly designed to have directional and other desirable features, here consists of a series of tubular pipes **13, 14, 15** and **16**, one end of each connecting to the chamber **12** and the other end of each terminating in plugs **17, 18, 19** and **20**. These plugs have vents **21, 22, 23** and **24** of the size and shape necessary to match the characteristic impedance of their respective pipes. Since each pipe is, then, terminated by its characteristic impedance at the input end, no additional terminating impedance beyond the chamber **12** is required. Without these plugs of prescribed impedance, a terminating impedance such as a damped pipe, would be necessary, and this would add considerably to

the length, weight and cost of manufacture of the device. Besides, the commonly used damping materials—that such a damped pipe would require—might absorb moisture, become displaced, or otherwise be rendered ineffectual.

A preferred form of this invention is seen in Fig. 2 where the pipes **13—16** of Fig. 1 are replaced by a single pipe **110** of successively increasing sections **113, 114, 115** and **116**. Plugs **117—120** are mounted near the junctions between the sections, and the holes **121—124** in these plugs are, again, of suitable dimensions to match each section of the pipe individually and as a whole. This impedance matching is achieved by making

$$\frac{1}{R}=\frac{1}{dc}(S_R-S_L)$$

where R is the acoustical resistance of the plug, d is the density of air, c is the velocity of sound in air, S_R the cross-sectional area of that section of pipe to the right of the junction and S_L is the cross-sectional area of that section of pipe to the left of the junction all quantities being expressed in c. g. s. units. In other words, as a result of satisfying this condition, a wave traveling from right to left in the tube would experience no reflection at the junctions. The pipe couples to chamber **112** that contains an electro-mechanical device **111**, such as a conventional pressure microphone. If physical dimensions permit, the device **111** may be mounted directly in the end of the pipe and the chamber **112** may be replaced by a flat cover.

This device is particularly suited to the pressure type microphone, which is cheaper, more rugged, and more suitable for low frequencies than the velocity type microphone.

In operation, the sound waves entering the openings **121—124** are reinforced in the direction of the axis of the pipe, since, for example, a sound pulse traveling through the air along the outside of the pipe will enter through each successive opening, **121—124**, exactly in phase with pulse traveling through the pipe, while the sound waves approaching from other angles will be more or less neutralized by the phase difference between a pulse traveling through the inside of the pipe and the successive pulses from the openings produced by the same wave on the outside of the pipe, thus making the device directional.

The apparatus of Fig. 2 can be easily and economically constructed since it can be made of ordinary water pipe of successively increasing sizes. This device can be made of considerable size. For example, one device was made 1980 feet long with 99 openings. Also, it may be paralleled with similar devices.

The wind disturbances in the form of eddy currents and other localized pressure variations are minimized to a large degree by this device since the wind interference is local and comparatively static while a sound wave exists only in motion. The effect of the wind is local and random while a sound wave arrives at the various openings with a definite phase relationship. A local pressure variation effecting only a few openings would have a cumulative effect negligible compared to that of a sound wave coming from the right direction and acting on all of the openings. This noise reducing effect is very valuable in sound ranging where the effect of a local pressure change due to wind currents on a microphone closely resembles the pressure change due to a muzzle wave.

Another variation of this device, shown in Fig. 4 would have holes **321—324** drilled in the papes **313—316** and the pipe lengths or hole sizes and numbers chosen to meet the basic requirement of this invention, that the openings and pipes form a balanced acoustical unit not requiring additional termination.

Another species of this invention is seen in Fig. 3

where the coupled sections of pipe of increasing diameter are replaced by a parabolic horn **210** of equivalent length and volume. This would be easily accomplished for relatively short structures. In this species, the plugs **217—220** and end openings **221—224** could be replaced by drilled holes of similar impedance as in Fig. 4, or a continuous slot **425**, shown in Fig. 5, whose impedance per unit length balances the volumetric change so that the pipe **410** can be coupled to the electro-acoustical member without additional acoustical termination. In this case the reciprocal of the acoustical resistance of the slot per unit length must be equal to the change per unit length of the reciprocal of the characteristic impedance of the horn.

What is claimed is:

1. An acoustical pipe comprising; a plurality of pipe sections having open ends and solid walls of discrete internal diameters, axially coupled in order of increasing diameter, each of said pipe sections having orifices of acoustical resistance which matches the change in acoustical impedance of the pipe sections adjacent to said orifices, the terminating ends of said acoustical pipe being acoustically sealed; and an electro-acoustical transducer mounted in the larger of said pipe sections.

2. An acoustical transducer comprising; an enclosure of increasing cross-sectional area having a series of perforations in said enclosure substantially in the direction of the increase in said cross-sectional area, the reciprocal of the acoustical resistance of each perforation equal to

$$\frac{1}{dc}$$

times the increase in cross-sectional area of said enclosure between said perforation and the last adjacent perforation, where d is the density of air and c is the velocity of sound expressed in c. g. s. units.

3. An acoustical transducer comprising a first enclosure of decreasing cross-sectional area having a plurality of openings in said enclosure spaced in the direction of decreasing area, each of said openings having the reciprocal of its acoustical resistance equal to

$$\frac{1}{dc}$$

times the decrease in area between the cross-sectional area of said enclosure at said opening and the cross-sectional area of said enclosure at the adjacent opening where d is the density of air and c is the velocity of sound expressed in c. g. s. units, and a second enclosure containing an electromechanical transducer terminating the larger end of said first enclosure.

4. An acoustical transducer as in claim 3, wherein said first enclosure comprises a series of pipe segments of decreasing cross section coupled axially, and said openings are situated at each successive coupling.

5. An acoustical transducer as in claim 3, wherein said first enclosure consists of a tubular member of continuously decreasing cross section.

6. An acoustical transducer as in claim 3, wherein said first enclosure consists of a parabolically tapered pipe.

7. An acoustical transducer as in claim 3, wherein each of said openings consist of a plurality of cylindrical apertures in the casing of said first enclosure.

8. An acoustical transducer as in claim 3, wherein said openings are formed in plugs having centrally located tubular openings extending through said plugs and said plugs extend through the casing of said first enclosure.

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