Dec. 1, 1936. R. R. RIESZ 2,062,478

ACOUSTIC DEVICE

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FIG. 1

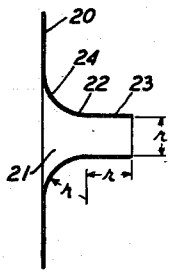


FIG. 2

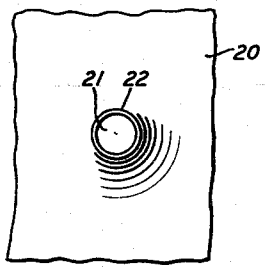


FIG. 3

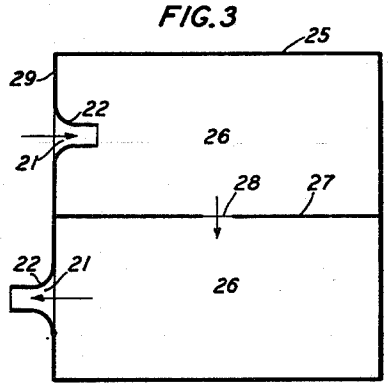


FIG. 4

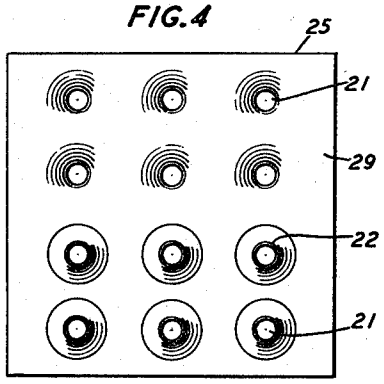


FIG. 5

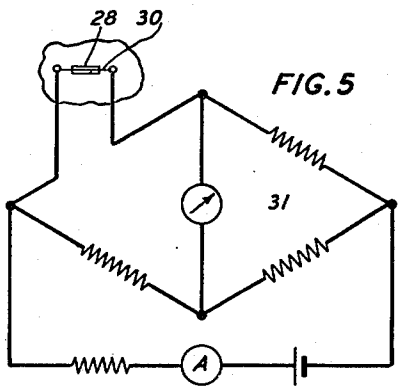


FIG. 6

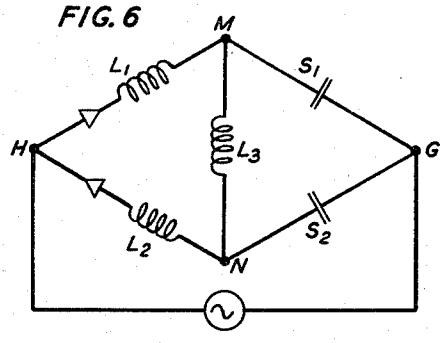
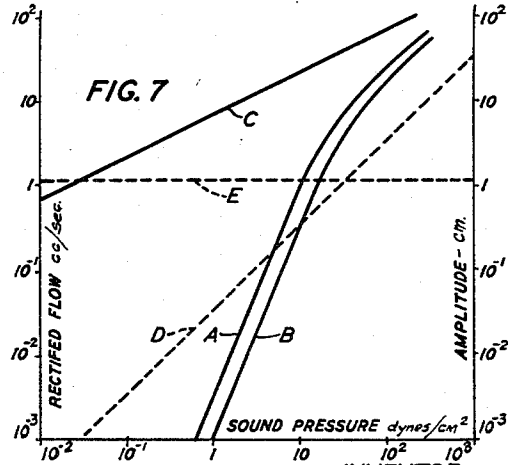


FIG. 7



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FIG. 8

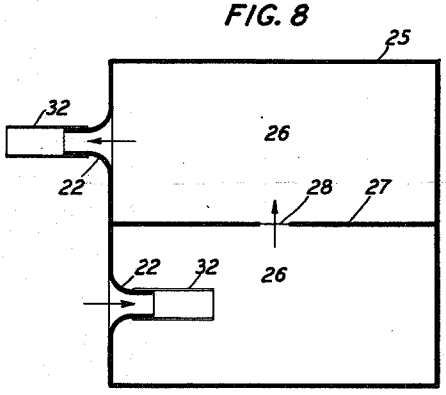


FIG. 9

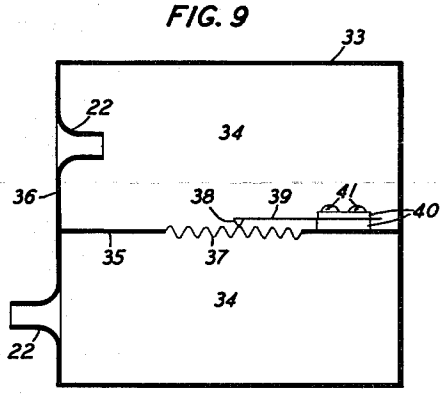


FIG. 10

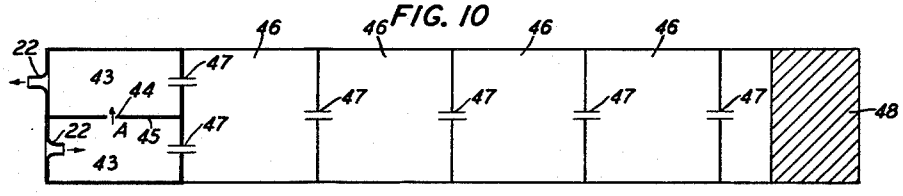


FIG. 11

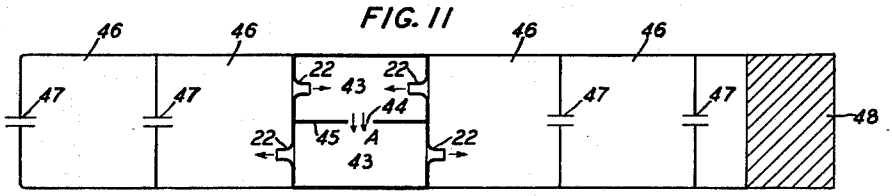
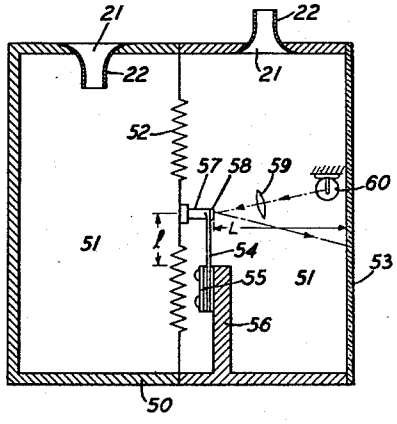


FIG. 12



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UNITED STATES PATENT OFFICE

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ACOUSTIC DEVICE

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Application September 28, 1935, Serial No. 42,569

16 Claims. (Cl. 181—0.5)

This invention relates to acoustic devices, and, more particularly, to a device for rectifying sound wave energy.

An object of this invention is to rectify sound wave energy.

A feature of this invention comprises means for rectifying sound wave energy.

Another feature of this invention comprises an acoustic rectifier capable of rectifying sound waves over a broad frequency band.

A further feature comprises sound measuring, sound analyzing or sound controlled means incorporating means for rectifying sound wave energy.

Still another feature comprises an acoustic rectifier embodying a wall member having an opening therein for the passage of sound wave energy, such opening offering a maximum impedance to the flow of sound energy therethrough in one direction and a minimum impedance to its flow in the opposite direction.

Other and further features will be evident from the description which follows hereinafter.

A more complete understanding of the invention will be obtained from the following detailed description, taken in conjunction with the attached drawings, wherein:

Fig. 1 is a cross-sectional view of a half-wave acoustic rectifier;

Fig. 2 is a front view of the device of Fig. 1;

Fig. 3 is a cross-sectional view of a full-wave acoustic rectifier;

Fig. 4 is a front elevational view of the device of Fig. 3;

Fig. 5 shows the circuit of a hot-wire anemometer for measuring unidirectional flow through the rectifier of Figs. 3 and 4;

Fig. 6 is an electrical circuit analogy of the device of Fig. 3;

Fig. 7 shows experimental and calculated characteristic curves for the rectifier of Fig. 3;

Fig. 8 is a cross-sectional view of an acoustic rectifier in which the length of the orifices is variable;

Fig. 9 is a cross-sectional view of an acoustic relay embodying the invention;

Figs. 10 and 11 are cross-sectional views of acoustic filters embodying an acoustic rectifier; and

Fig. 12 is a cross-sectional view of a sound meter.

There is shown in Figs. 1 and 2 means for rectifying or rendering unidirectional, alternating acoustic energy or sound waves. It comprises a planar plate, disc or member **20** having an orifice **21** defined by a tubular portion or member **22**. While the portion or member **22** is shown as formed integrally with the member **20**, it may be a separate member suitably secured to the member **20**, for instance, by welding, soldering or riveting. The portion **22** comprises, preferably, a cylindrical portion **23** and a flaring or frusto-conoidal portion **24**, the diameter of the large base of the portion **24** being twice that of the portion **23**, or being equal to the diameter of the portion **23**. The shape of the orifice is similar to that of the boundary of a stream issuing from a circular aperture in a plate.

The characteristics of air flow through an aperture have been studied heretofore. It has been discovered, however, that a rectified current of air may be produced when an alternating current of air is incident upon an aperture or, preferably, upon an orifice such as is shown by Figs. 1 and 2.

The rectifying action should be a maximum when the orifice is constructed so that the impedance flow in opposite directions through the orifice has the maximum asymmetry. For steady flow, the asymmetry will be a maximum for the orifice shown in Figs. 1 and 2. For flow from left to right of Fig. 1, the shape of the orifice is that of the boundary of a stream issuing from a circular aperture in a plate so that the area of the stream of fluid issuing from the orifice is equal to the area of the cylindrical portion **23**. Calling this area S, the acoustic impedance of the orifice for flow in this direction is:

$$R_+=\frac{1}{S}\sqrt{\frac{\rho(p-p_0)}{2}}$$

where $(p-p_0)$ is the drop in pressure across the orifice. For flow from right to left, the orifice is a Borda mouthpiece and the area of the emerging column of fluid is one-half that of the portion **23**. This represents the maximum amount by which the area of the fluid column can be contracted by shaping the orifice. The acoustic impedance for flow in this direction is given by:

$$R_-=\frac{2}{S}\sqrt{\frac{\rho(p-p_0)}{2}}$$

Therefore;

$$\frac{R_-}{R_+}=2$$

It is apparent that half-wave rectification, only, may be accomplished with the device of Figs. 1 and 2. A full-wave rectifier is shown in Figs. 3

id 4. It comprises a hollow, cubical case **25** vided into two compartments or chambers **26** equal volume by a partition or wall **27** conining a slit or slot **28** providing a connecting ssage between the chambers. The front wall of the case contains a plurality of orifices such shown by Figs. 1 and 2, one group rectifying r current flow from left to right and the other, ght to left, the arrows indicating the direction the rectified flow. When the cube is placed in sound field, a steady stream of air is sent into ie upper compartment and another steady ream of air is emitted from the lower compartent. The result is that there is a unilateral rculation of air through the rectifying orifices id the slot in the wall between the compartients. If the heated element **30** of a hot-wire iemometer **31**, such as that of Fig. 5, is secured the wall **27** across the slot **28**, the steady flow in be readily indicated.

A more complete understanding of the invenon will be obtained from the theory developed ereinafter. A rectifier such as is shown by Figs. and 4 was constructed, a hollow brass cube 4 iches on a side and divided into two compartients of equal volume being used, r being approximately .25 inch. The electrical analog is iown in Fig. 6, wherein L_1 represents the mass f the air in the orifices for the upper compartient; L_2, the mass of the air in the orifices for ie lower compartment; L_3, the mass of the air i the slot; and S_1 and S_2, the stiffness of the pper and lower compartments, respectively. 'his is a system of two degrees of freedom, but $L_1=L_2$ and $S_1=S_2$, the system will have a single esonant frequency. Let a plane wave whose requency is equal to the resonant frequency of he system, i. e., $p=P\sin\omega t$, where p is the pressure drop across the orifice (assuming only one rifice), act upon the system. The wave shape i the upper branch HMG is described by

$$\dot{\Phi}=S\sqrt{\frac{2}{\rho}P\sin\omega t}\qquad 0<t<\frac{\Pi}{\omega}$$

$$\dot{\Phi}=-\frac{S}{2}\sqrt{\frac{2}{\rho}P\sin(-\omega t)}\qquad -\frac{\Pi}{\omega}<t<0$$

The Fourier series representing this wave is written:

$$\dot{\Phi}=\sum_{m=1}^{\infty}(A_m\sin m\omega t+B_m\cos m\omega t)+B_0$$

The direct current component and fundamental component are:

$$B_0=\dot{\Phi}_0=.48S\sqrt{\frac{P}{\rho}}$$

$$B_1=0$$

$$A_1=\dot{\Phi}=1.07S\sqrt{\frac{P}{\rho}}$$

and

$$\dot{\Phi}_0=.45\dot{\Phi}$$

With n identical orifices, each of area S, and with R the acoustic impedance to direct current flow of each set of orifices measured in the direction of flow, the direct current pressure drop produced by each set of orifices is:

$$\Delta P=R\dot{\Phi}_0=\frac{\rho}{2(nS)^2}\dot{\Phi}_0^2$$

If it is assumed that this pressure drop remains constant as impedance is added to the path HMN by the slit connecting the compartments and of area S_x, the direct current flow will be:

$$\dot{\Phi}_x=\frac{2\Delta P}{2R+R_x}=\frac{\frac{\rho}{(nS)^2}}{\left[\frac{\rho}{(nS)^2}+\frac{\rho}{2S_x^2}\right]}\dot{\Phi}_0^2$$

And the linear velocity through the slit is:

$$I_x^2=\frac{2}{2S_x^2+(nS)^2}\dot{\Phi}_0^2=\frac{.404}{2S_x^2+(nS)^2}\dot{\Phi}^2$$

I_x approaching a maximum when S_x approaches zero.

On the basis of hydraulic theory, the amplitude of the fundamental component is:

$$\dot{\Phi}=1.07nS\sqrt{\frac{P}{\rho}}$$

so that

$$\dot{\Phi}_x=S_xI_x=1.07nS\sqrt{\frac{.404}{\rho[2S_x^2+(nS)^2]}P}$$

The above theory, of course, is approximate; but to ascertain if it gave results of the right order of magnitude $\dot{\Phi}_x$ was measured as a function of P, the amplitude of the pressure, in an approximately plane sound wave incident on the front of the acoustic rectifier. The particular rectifier was found to have two large response peaks at 362 cycles per second and 432 cycles per second, and curves A and B of Fig. 7 show the results for these respective frequencies. Curve C shows the relation to be expected from the hydraulic theory. It is evident that the experimental and the theoretical results tend to approach at high pressures. An interesting comparison is arrived at if calculation is made of the amplitude of vibration in the orifice to be expected if radiation and viscous resistances control the vibration, and this is compared with the dimensions of the orifice measured in the direction of vibration. Curve D shows the calculated amplitude and curve E shows the orifice dimension. It is evident, therefore, that the experimental results approach the calculated results when the amplitude exceeds the dimension of the orifice in the direction of vibration.

Being a tuned device, the rectifier of Figs. 3 and 4 will be sensitive over narrow frequency bands only, but by associating the rectifying orifices with a tube or resonator of variable tuning, it can be used as a sound analyzer. Fig. 8 shows tubular members **32** fitting over the members **22** and slidably adjustable thereon to vary the length of the air column, whereby the resonant and, therefore, frequency band responsive characteristics of the device may be varied.

An acoustic relay embodying this invention is shown by Fig. 9. A hollow case or shell **33** divided into two chambers or compartments **34** by a wall or partition **35** is provided in one wall **36** with orifices **21** defined by tubular members **22** connecting the chambers **34** with the atmosphere outside of the case. The partition **35** is provided with a flexible, corrugated, metallic portion **37** engaged by the contact end or point **38** of a contact spring **39** secured on the partition between insulating strips **40** and by screws **41**. When placed in a sound field, a difference in pressure on opposite sides of the flexible portion **37** will be created and the latter will be deflected to separate from the contact point **38**. By connecting the portion **37** and spring **39** by suitable conductors to an electric circuit, it is apparent that the operation of the latter may be controlled

through the relay described, by acoustic pressures in the frequency range to which the particular relay was made responsive.

The rectifier can be made to cover a broad band of frequencies by constructing it as part of an acoustic filter as shown in Figs. 10 and 11. Each figure shows a low pass filter; in Fig. 10 the rectifier precedes the filter sections, and in Fig. 11 is intermediate the filter sections. The orifice defining members **22** lead to or from chambers **43** connected through a slit or slot **44** in a partition member **45**. The chambers **46** define acoustic stiffness elements, the tubular portions **47** define acoustic mass elements. The filters may be terminated by suitable sound wave absorbing material **48**, such as felt.

A sound meter embodying the invention is shown by Fig. 12. It comprises a hollow case **50** divided into two chambers or compartments **51** of equal volume by a flexible diaphragm, wall or partition **52**, orifices **21** connecting the chambers with the atmosphere. When the meter is placed in a sound field, the rectified pressure produces a steady deflection of the diaphragm to the right. This deflection will be of small magnitude and to make it visible on the scale **53** an optical lever may be employed. A thin reed **54** is clamped at **55** to the extension **56** from the case **50**, and its angular extension **57** rests against the center of the diaphragm. A small mirror **58** is fastened to the free end of the reed and with the lens **59** projects an image of the straight filament of the lamp **60** onto the translucent scale **53**. If the center of the diaphragm moves a distance x, the mirror will rotate through an angle

$$\alpha=\frac{3x}{2l}$$

where l is the length of the reed. The deflection of the image of the filament on the scale is

$$d=2\alpha L=\frac{3L}{l}x,$$

where L is the distance from the mirror to the screen. Thus the displacement of the diaphragm has been amplified

$$\frac{3L}{l}$$

times, and this amplification can be made as large as desired by making L large compared with l.

While this invention has been disclosed with reference to various specific embodiments thereof, it will be understood that it is to be considered as limited in scope by the appended claims only.

What is claimed is:

1. An acoustic device comprising a wall member having an opening therein for the passage of sound wave energy, said opening offering a maximum impedance to the flow of sound energy therethrough in one direction and a minimum impedance to its flow in the opposite direction.

2. An acoustic device comprising a wall member having an opening therein for the passage of sound wave energy, said opening having a shape similar to that of the boundary of a stream issuing from a circular aperture in a plate.

3. An acoustic rectifier comprising a wall member to be placed in a sound field, said member having an aperture therein, and a tubular member defining a passage in alignment with said aperture, said tubular member having a portion of constant cross-section and another portion of gradually increasing cross-section.

4. An acoustic rectifier as claimed in claim 3 in which said tubular member projects from the side of the wall member facing the source of sound waves.

5. An acoustic rectifier as claimed in claim 3 in which said tubular member projects from the side of the wall member opposite that facing the source of sound waves.

6. An acoustic device comprising a wall member having an opening therein for the passage of sound wave energy, said opening offering an impedance to the flow of sound energy therethrough whose value is dependent on the direction of flow.

7. An acoustic rectifier comprising a wall member to be placed in a sound field, said member having an aperture therein, and a tubular member defining a passage in alignment with said aperture, said tubular member having a cylindrical portion and another portion of gradually increasing cross-section, the radius of curvature thereof being equal to the diameter of the cylindrical portion.

8. An acoustic rectifier comprising a hollow case having a plurality of walls, and a partition in said case dividing the interior into two chambers and having a passage therein connecting the chambers, one of said walls containing a pair of orifices one of which connects one chamber with the atmosphere outside of the case and the other of which connects the other chamber with the atmosphere outside of the case, air flow through each orifice taking place with greater ease for one direction of flow therethrough then for the reverse direction, the orifices being arranged reversely with respect to one another.

9. An acoustic filter embodying an acoustic rectifier.

10. An acoustic device comprising an acoustic rectifier capable per se of rectifying a narrow band only of sound energy frequencies, and means acoustically coupled to said rectifier for broadening the band of sound energy frequencies rectifiable.

11. An acoustic device comprising an acoustic rectifier capable per se of rectifying a narrow band only of sound energy frequencies, and acoustic filtering means coupled with said rectifier for broadening the frequency band to which the rectifier is responsive.

12. An acoustic device comprising a hollow case, means dividing the case interior into two chambers, and means for producing a pressure difference between said chambers when the device is placed in a sound field, the higher pressure always being present in the same chamber, said dividing means containing a passage connecting the two chambers whereby a unidirectional air flow between the chambers may occur.

13. An acoustic device comprising a hollow case, and a partition dividing said case into two chambers, said case containing an orifice connecting each chamber with the atmosphere outside the case, each orifice being of greater area at one end than the other, one orifice having its small end opening into its respective chamber and the other having its large end opening into its respective chamber.

14. A full wave acoustic rectifier comprising a wall member having a pair of spaced projecting, centrally apertured portions, one portion extending rearwardly of the wall member and the other portion forwardly thereof.

15. A full wave acoustic rectifier comprising a wall member having a pair of spaced orifices

each having a shape similar to that of the boundary of a stream issuing from a circular aperture in a plate, the smaller ends of said orifices opening on opposite sides of said wall member.

16. An acoustic device comprising a hollow case, a partition member in said case dividing it into two chambers, said member containing an aperture through which said chambers are connected, said case including a wall member having a pair of openings, one connecting with each chamber, one opening confining air flow therethrough substantially inwardly only to its associated chamber, and the other opening confining air flow therethrough substantially outwardly only from its associated chamber.

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