July 2, 1963 P. WILLEMS 3,096,080

APPARATUS FOR GENERATING OSCILLATIONS IN FLUID

Filed Oct. 26, 1960

Fig. 1

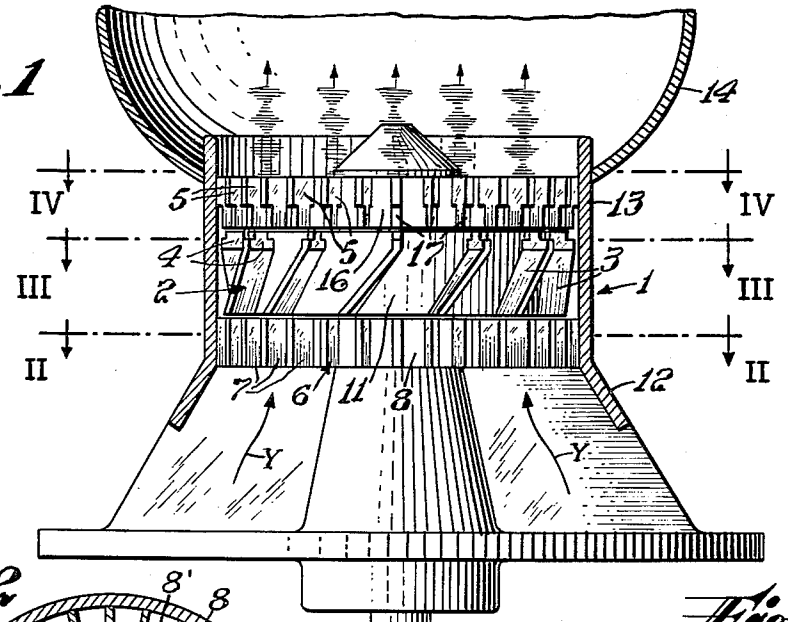


Fig. 2

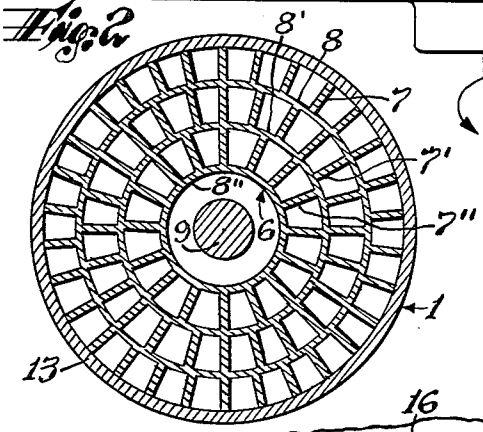
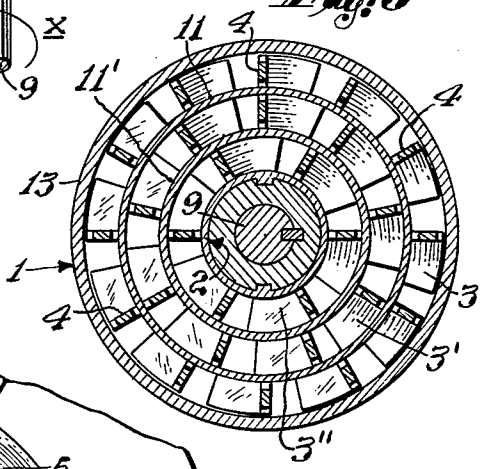


Fig. 3



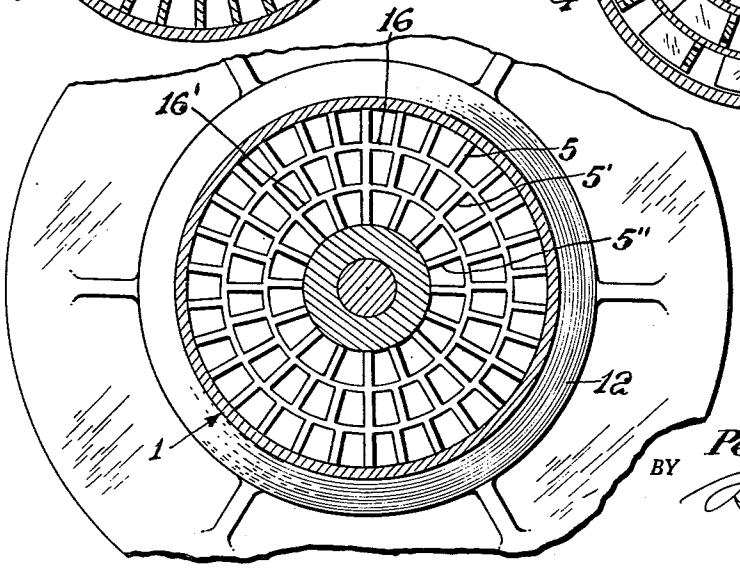


Fig. 4

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APPARATUS FOR GENERATING OSCILLATIONS IN FLUID

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13 Claims. (Cl. 259—1)

This invention relates to an apparatus for generating oscillations at high sonic and ultrasonic frequencies in gaseous and liquid fluids.

Such oscillations when produced in air are commonly employed to transmit signals. They have a velocity of propagation of substantially 330 meters per second. Oscillations of the high sonic and ultrasonic frequency range are generated in liquids for the purpose of sounding distances between the generator and immersed objects, but also for mixing, homogenizing, emulsifying and the like, as is well known. Sound waves are propagated in liquids at velocities of more than 1400 meters per second. Sound waves directed against the surface of a solid body are partly reflected, and partly propagated in the body at velocities of the order of 5000 meters per second.

Known ultrasonic generators include Galton whistles, sirens, magnetostrictive and piezoelectric oscillators. Some of these oscillator types are capable of generating ultrasonic oscillations both in gaseous and in liquid fluids, others are more limited in their applications. The known whistle type generators are actuated by air under pressure and thus require equipment for producing such air.

Acoustic oscillations in air at an elevated level of enery (up approximately 50 watts of sound energy) have been produced by the so-called Hartmann generators. They rely on discharge of air from an orifice at supersonic velocities, and are not capable of being employed with liquids because it is not possible to induce flow of a liquid at speeds greater than the speed of sound therein, that is, at speeds in excess of approximately 1,400 meters per second.

A Galton whistle is capable of operating in a liquid medium, at least at relatively low frequencies, but its efficiency is low. At high frequencies a Galton whistle cannot operate in a liquid medium. The standing wave of relatively great amplitude which is required in the Galton whistle can be generated in a fluid filled cavity only when sound waves are totally reflected from the walls of the cavity. Whereas reflection is substantially complete (about 99.99%) at air-metal interfaces, only approximately 86% of a sound wave is reflected into the liquid at a liquid-metal interface. The resonance required for the operation of a Galton whistle thus is not available in a liquid filled space.

The ultrasonic whistle of Janowsky and Pohlmann is capable of operating in a liquid medium and may be employed for ultrasonic treatment of liquids which are fed to the whistle at a suitable high pressure. The whistle consists essentially of a nozzle orifice and of a lip adjustably mounted opposite the orifice. It is limited to relatively small scale operations.

Oscillations of high frequency have been produced in air by sirens. They are equipped with a casing or stator provided with a plurality of nozzles arranged about an axis and discharging axial streams of air at high pressure and velocity. A disc rotates about the stator axis and has openings which are sequentially axially aligned with the nozzle orifices as the disc rotates. As the openings pass over the nozzle orifices they release brief axial pulses of air at a high frequency which is a function of the rotary speed of the disc.

The known air sirens thus generate axial sound or ultrasound waves. Their frequency and energy depend on the pressure and rate of air streaming through the nozzles, and on the frequency of interruption of the air streams by the imperforate portions of the rotary disc. The effects produced by the air sirens built so far are quite limited. At an upper frequency limit of 40 kilocycles per second, a few kilowatts of energy can be generated.

It is an object of this invention to provide a mechanical oscillator capable of producing oscillations under many conditions of application at high levels of frequency and intensity.

Another object is the provision of a sonic and ultrasonic oscillator which is effective in both gaseous and liquid fluids.

A further object is the provision of such oscillators which provide a directed stream of fluid in which oscillations are propagated in the single direction of fluid flow.

With these and other objects in view, the invention mainly consists in a mechanical oscillator in which a rotor produces an axial flow of fluid through a housing. A plurality of lip means are mounted in the housing and capable of oscillation transversely of the direction of fluid flow.

In its more specific aspects, the invention contemplates providing the rotor with a plurality of ducts which extend helically about the axis. The ducts are arranged in a plurality of coaxial sets, each set having a corresponding plurality of entrance and discharge orifices which are arranged in respective coaxial ring areas on a radial face of the rotor. A plurality of lip means are mounted in the housing, each set of lip means being axially adjacent the discharge orifices of one of the duct sets. When the rotor turns about its axis, fluid flows through the helical ducts and from the discharge orifices against the lip means which are thereby caused to oscillate transversely of the direction of fluid flow.

Other features and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings in which like reference numerals designate like parts throughout the figures thereof, and wherein:

FIG. 1 shows an ultrasonic mechanical oscillator of the invention in side-elevation, partly sectional view; and

FIGS. 2, 3, and 4 show the oscillator of FIG. 1 in plan section on the lines II—II, III—III, and IV—IV, respectively.

The working elements of the ultrasonic generator illustrated in the drawing are contained in a tubular casing **1** which is partly broken away in FIG. 1 in order to reveal the rotor **2** which is fixedly mounted on a shaft **9** for rotation in the direction of the arrow *x* (FIG. 1), that is, clockwise as viewed in FIGS. 2, 3 and 4.

The casing **1** has a frusto-conical lead-in portion **12** the narrow end of which is joined by a cylindrical portion **13**. A horn of parabolic cross section **14** is releasably attached to the discharge end of the cylindrical casing portion **13** and may be replaced by a differently shaped discharge nozzle.

A guide vane assembly **6** is fixedly mounted on the cylindrical casing portion **13** about the shaft **9**. It consists essentially of three short coaxial cylinders **8**, **8'**, and **8''** which are connected with each other and with the casing portion **13** by a plurality of flat plates **7**, **7'**, and **7''** the major dimensions of which extend axially and radially in the casing **1**.

Axially adjacent the fixed guide vane assembly **6** the rotor **2** carries three coaxial sets of buckets **3**, **3'**, and **3''**. The innermost set of buckets **3''** is mounted on the rotor body **2** itself and the radially outer sides of the bucket **3''** are fastened to a cylindrical partition wall **11'** which in turn carries an intermediate bucket set **3'**. A

partition wall 11 similarly divides the buckets 3' from an outer set of buckets 3 which are closely spaced from the housing 1. The main wall of each bucket is arranged in a helix about the axis of the rotor 2 and is joined by a discharge portion 4 which is axially arranged and attached to the rotor 2 or the partition walls 11, 11' over a part of its axial length only.

In the direction of liquid flow through the apparatus, as indicated by the arrows *y*, the rotary buckets 3, 3', 3'' are followed by stationary vanes 5, 5', and 5'' secured to the casing 1 in an arrangement similar to that of the guide vane assembly 6. As best seen from FIG. 1, the vanes 5, 5', and 5'' are secured to the casing 1 and to interposed partition walls 16, 16' only over a part of their axial length. Each vane has a lip portion 17 axially adjacent the buckets 3, 3', 3'' which is free to oscillate in a tangential or circumferential direction.

The afore-described apparatus operates as follows:

When the rotor 2 is rotated in the direction of the arrow *x* by a motor (not shown), fluid is drawn through the lead-in portion 12 of the casing 1 and the guide vane assembly 6. The plates 7, 7', 7'' of the latter reduce any turbulence that may have existed in the streaming fluid, and the flow of the fluid is substantially laminar as it leaves the guide vane assembly 6.

The buckets 3, 3', and 3'' carry the fluid in a helical path toward the discharge end of the apparatus. Each bucket constitutes a helically inclined duct which is open only at its axial entrance and discharge orifices. The fluid is driven at high speed against the lip portions 17 of the vanes 5, 5', 5''. Because of the axial orientation of the discharge portions 4 of the buckets 3, 3', 3'', the stream of fluid moves predominantly in an axial direction as it hits the edges of the lip portions 17. The lip portions 17 are made to oscillate, and these oscillations are transmitted to the flowing fluid.

The oscillations of the lip portions 17 are due to two phenomena the effects of which are superimposed. The passage of each bucket in a corresponding row on the rotor 2 imparts a pulse to the vane 5 and to its lip portion during rotation of the rotor. This pulse generates an oscillation the frequency of which depends on the effective free length of the lip 17. The initial amplitude of the oscillation is a function of the energy imparted to the lip portion by the bucket as it passes. The amplitude gradually decreases as the oscillation is damped by the surrounding fluid, until passage of a succeeding bucket transmits a new pulse to the lip. Successive excitation of the lips by the passing buckets establishes wave trains which are transmitted to the streaming fluid.

The second type of oscillations is generated in the fluid itself as it is thrown at high speed against the edge of the lips 17 by the buckets 3, 3', 3''. These oscillations are in turn transmitted from the fluid to the vanes 5, 5', and 5''. Their frequency depends on the rotary speed of the rotor, on the number of circumferentially arranged buckets and vanes, and on the axial velocity of the fluid.

Since the discharge portions 4 of the buckets are attached to the rotor 2 and to the partition walls 11, 11' only over a portion of their length, another set of lips capable of oscillations is formed opposite the lip portions 17. A third mode of oscillation is thus generated and superimposed on the oscillations generated by the afore-described mechanisms.

The relatively rigid assembly of the main portions of the vanes 5, 5', 5'' directs the sonic or ultrasonic waves generated in the fluid in the direction of the rotor axis. When a very intense directional effect is desired, the vanes 5, 5', 5'' and the partition walls 16, 16' are axially elongated in such a manner that the axial length of each of the tubular ducts formed between the vanes and partitions is several times greater than the circumferential and radial width thereof. Each of the ducts then in effect may form a resonant column of fluid, or a column approaching conditions of resonance so as to increase the specific intensity of the sound waves traveling therethrough.

Whether a horn 14 or a differently shaped nozzle is employed at the discharge end of the mechanical oscillator of the invention will depend on the effects that it is desired to achieve.

The apparatus illustrated is assembled from essentially flat metallic elements which are joined along edges in the manner illustrated and described. It will be appreciated that a structurally equivalent machine may be built from integral blocks of material in which the several ducts and passages are formed by correspondingly arranged bores. The flat plates 7, 7', 7'' may thus be integral with the cylinders 8, 8', 8'' and the ducts defined therebetween may be formed by boring and have radial cross sections of arcuate shapes. The buckets 3, 3', 3'' and partition walls 11, 11' can be formed from a single piece of material by suitable machining operations, and the same holds for the vanes 5, 5', 5''. The ducts formed between the buckets 3, 3', and 3'' are narrower at their entrance ends in a direction transverse to the direction of fluid flow than at their discharge ends between the discharge portions 4, and similar differences in flow section may be incorporated in elements of the generator of the invention when made from integral blocks of material by boring or other machining operations.

The effects of the two (or three) modes of oscillation generated by the apparatus of the invention in the fluid conveyed therethrough are superimposed. Interference and resonance phenomena are set up. Fluids passed through the apparatus show the effects associated with ultrasonic treatment of high intensity and a broad range of frequencies. Mixtures of a liquid with a solid which only slowly dissolves therein when fed to the apparatus are dischraged as homogeneous solutions. Two immiscible liquids entering the machine emerge as colloidal dispersions of one in the other. Solids are suspended in liquids, and liquids may be finely distributed in a gaseous carrier by the apparatus illustrated.

The frequency and the amplitude of the oscillations generated can be varied at will within the limits set by the materials of construction. The apparatus is capable of being adapted to a wide range of applications without basic change. It is equally suitable for ultrasonic treatment of a system having a liquid as its main constituent or carrier phase, or one having a gaseous carrier phase.

It should be understood, of course, that the foregoing disclosure relates to only a preferred embodiment of the invention, and that it is intended to cover all changes and modifications of the example of the invention herein chosen for the purpose of the disclosure which do not constitute departures from the spirit and scope of the invention set forth in the appended claims.

What I claim is:

1. In a mechanical oscillator, in combination, a tubular housing having an axis; rotor means rotatable in said housing for actuating axial flow of a fluid through said housing; and a plurality of lip means mounted in said housing for oscillation transversely of the direction of fluid flow in contact with said flowing fluid, said lip means being angularly spaced about said axis and mounted for oscillation in respective paths tangential relative to a circle about said axis.

2. In an oscillator as set forth in claim 1, said rotor means defining a plurality of ducts axially extending in said housing, said fluid flowing through said ducts when said rotor means rotates about said axis.

3. In an oscillator as set forth in claim 2, said ducts being helically arranged about said axis.

4. In an oscillator as set forth in claim 2, said ducts having respective portions helically arranged about said axis and respective portions substantially parallel to said axis following said helically arranged portions in the direction of fluid flow.

5. In an oscillator as set forth in claim 2, said ducts each having an entrance end and a discharge end, the polar moment of inertia of the cross section of said duct at the entrance end relative to said axis being smaller than the polar moment of the cross section of said duct at said discharge end.

6. In an oscillator as set forth in claim 2, said ducts each having a discharge end, said lip means defining a plurality of conduits therebetween, said conduits being alignable with said ducts for flow of said fluid from said discharge ends into said conduits.

7. In an oscillator as set forth in claim 6, the main direction of fluid flow in said discharge end and in said conduits being substantially the same.

8. In an oscillator as set forth in claim 2, guide vane means on said housing for directing flow of said fluid into said ducts.

9. In an oscillator as set forth in claim 2, said ducts being of arcuately shaped cross section.

10. In a mechanical oscillator, in combination, a tubular housing having an axis; a rotor in said housing and defining therein a plurality of ducts helically extending about said axis in a plurality of coaxial sets, each set having a plurality of entrance and discharge orifices in a respective annular area of a radial face on said rotor, said annular areas being coaxial; a plurality of lip means mounted in said housing in a plurality of coaxial annular sets, each set of lip means being axially adjacent the discharge orifices of one of said sets of ducts; and drive means for rotating said rotor about said axis for actuating flow of a fluid through said ducts in a direction from said entrance to said discharge orifices thereof and against said lip means as said rotor rotates, the lip means of each annular set being free to oscillate transversely of the direction of flow of said fluid and tangentially relative to the respective set.

11. In an oscillator as set forth in claim 10, guide vane means for directing axial flow of said fluid into said entrance orifices of said ducts.

12. In a mechanical oscillator, in combination, a tubular housing having an axis; rotor means rotatable in said housing for actuating axial flow of a fluid through said housing, said rotor means defining a plurality of ducts axially extending in said housing, said fluid flowing through said ducts when said rotor means rotates about said axis, said ducts each having an entrance and a discharge end, a portion of said rotor at said discharge end being shaped to form a lip capable of oscillations transversely of the flow of fluid through said discharge end, and a plurality of lip means mounted on said housing for oscillation transversely of the direction of fluid flow in contact with said flowing fluid.

13. In a mechanical oscillator, in combination, a tubular housing having an axis; rotor means rotatable in said housing about said axis for actuating flow of a fluid through said housing, said rotor means including a plurality of ducts each having an entrance portion and a discharge portion, said fluid flowing through said ducts from the respective entrance portions to the respective discharge portions thereof when said rotor means rotates about said axis; and a plurality of lip means mounted on said housing, said lip means being angularly spaced about said axis and closely adjacent said rotor means for sequential alignment with said discharge portions when said rotor means rotates, said lip means being free to oscillate in the fluid flowing from said discharge portions in a direction transverse of fluid flow and substantially parallel to the movement of the aligned discharge portions.

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