

Sept. 3, 1946.

P. ORLICH ET AL
ECHO SOUNDING DEVICE

2,407,175

Filed Nov. 14, 1940

3 Sheets-Sheet 1

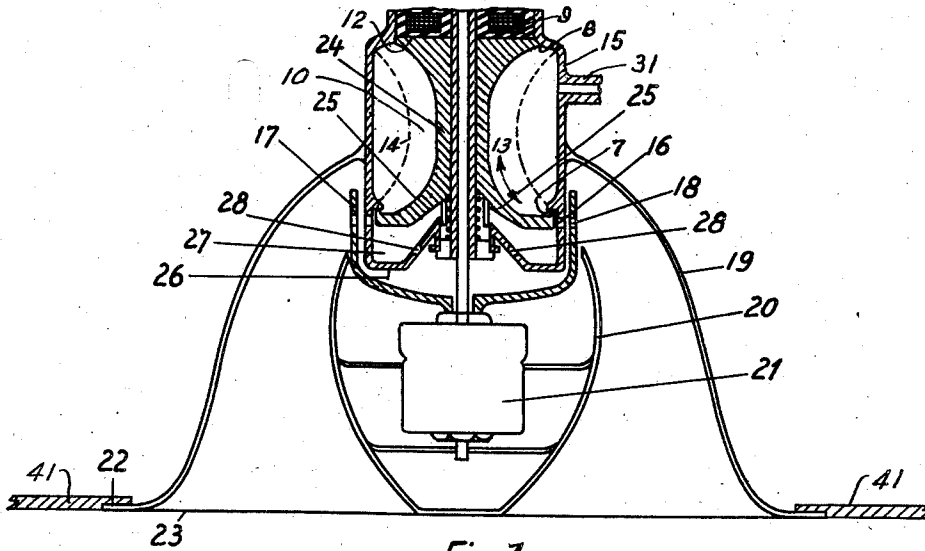


Fig. 1.

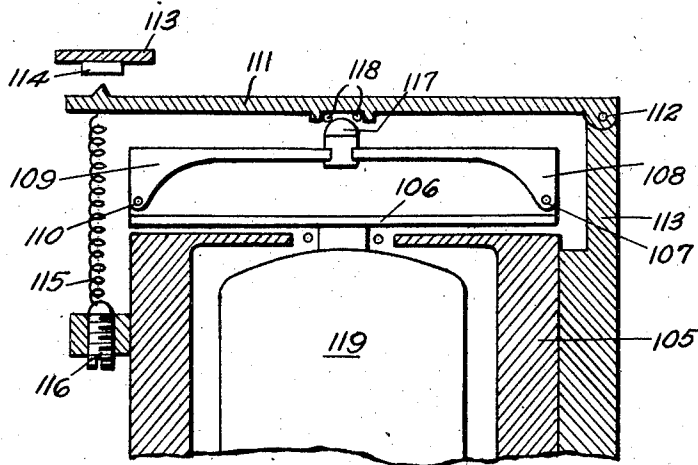


Fig. 4.

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3 Sheets-Sheet 2

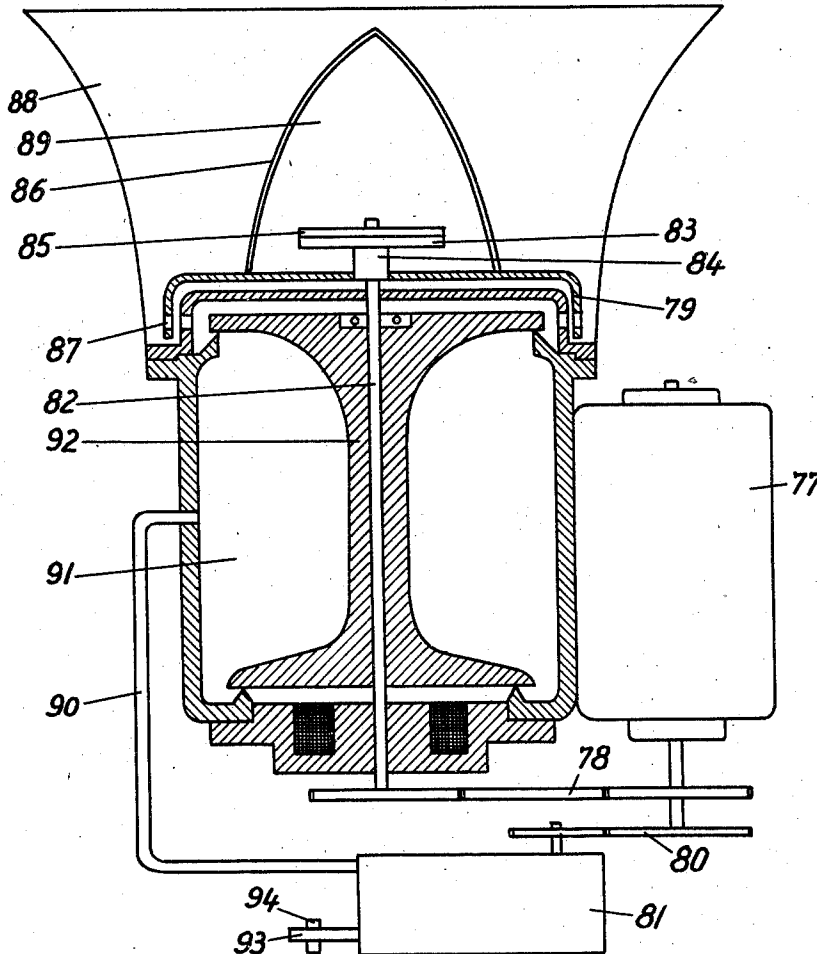


Fig. 2.

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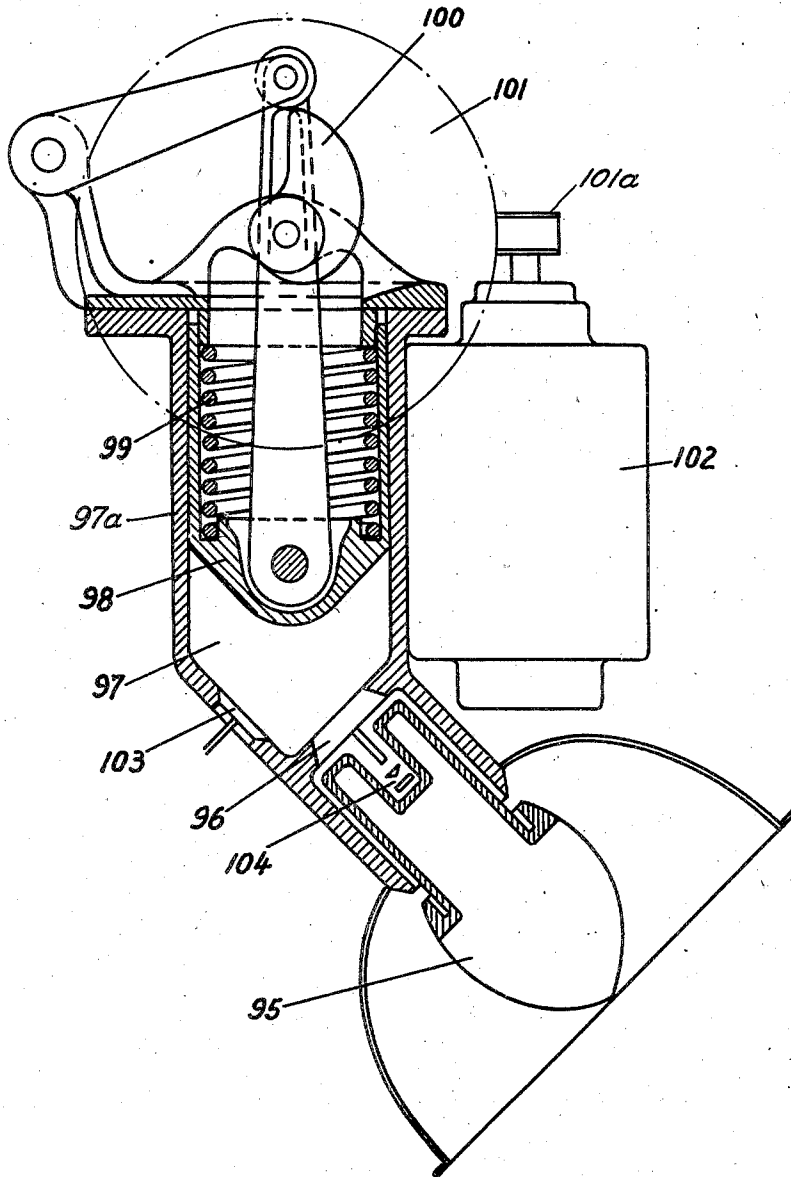


Fig. 3.

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UNITED STATES PATENT OFFICE

2,407,175

ECHO SOUNDING DEVICE

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Kiel, Germany; vested in the Alien Property
Custodian

Application November 14, 1940, Serial No. 365,646
In Germany May 2, 1939

3 Claims. (Cl. 116—147)

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This invention pertains to sound-emitting devices of the kind operated by a compressed gas, such as whistles and sirens. Some features of the invention are particularly concerned with the emission of signals for echo sounding devices.

One object of the invention is to improve the efficiency of sound-producing devices of this kind.

Another object, pertaining especially to sound emitters for aircraft, is to provide a more compact construction and one which enables the sound emitter to be integrated with the structure of the aircraft.

Another object is to improve the operation of the valve controlling the sound emission.

Another object is to improve the synchronization of the signal emission of an echo sounding device and the start of a measuring apparatus for determining the time interval between the signal emission and echo reception.

Another object is to reduce the liability of the sounding apparatus to be disabled by becoming iced.

Another object is to provide an improved governor mechanism suitable for, though not limited to, use on the rotor of a siren or its driving motor.

Other objects will appear from the following specification, in which several illustrative embodiments of the invention will be described, with reference to the accompanying drawings, wherein

Fig. 1 is an axial section of a siren embodying features of the invention;

Fig. 2 is an axial section of a modification of the inventive siren, together with its driving motor and compressor, in an arrangement illustrating several features of the invention;

Fig. 3 is a whistle sound emitter, with associated compressor and driving motor; and

Fig. 4 is an axial section of part of a motor showing a governor mechanism in accordance with the invention.

Sirens have an air chamber which is inserted in the compressed air supply line just in front of the outlet openings of the rotor, in order to produce a uniform flow of air. Such an air chamber is used in all kinds of sirens, including those driven pneumatically as well as those driven by a motor and likewise those whose openings lie in a cylindrical surface, as well as those whose openings are in a disk.

According to the invention the efficiency of such sirens is considerably improved by tuning the air chamber to the emitted frequency. This tuning causes stationary air waves to be set up with a loop at the openings and a node at the most remote wall areas. In accordance with the

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invention the tuning is achieved by making the greatest distance between the openings and the walls of the air chamber equal to an uneven multiple of one-quarter of the emitted wave length.

Referring first to Fig. 1 of the drawings, 15 is an air chamber of a siren having a rotor 17 and driven by a motor 21. The air chamber is supplied with compressed air by an inlet nipple 31. Inside the air chamber is a differential valve 24, known per se, the valve surfaces 7 and 8 of which have different areas and rest upon corresponding seats of the air chamber. The differential valve is held in closed position by an electromagnet 9. However, due to the differences in the respective areas of the two valve surfaces, upon opening of the magnet circuit the valve is released and is moved by the compressed air in the direction indicated by the arrow. Thereby the air in the chamber can flow out through the openings 16 and 18 of the stator and the rotor 17, respectively. This construction is particularly adapted for sirens used for echo sounding devices built into aircraft and intended to emit intermittent sound.

In accordance with the invention the air chamber 10 is adapted to the sounding frequency by making the distance between the openings 16 and the upper end 12 of the air chamber an uneven multiple of $\lambda/4$. In this connection it is important that especially in those cases in which the inner walls are constituted by the armature of a differential valve, the valve surfaces at 12 constitute as large a fraction of the end surface as possible and the curved zone 13 is kept relatively small, so that the tuning can be carried out in a clean-cut manner. In cases in which it is not necessary to produce such accurate tuning, it is preferable to give the air chamber a strictly cylindrical shape, with flat end faces. In all cases the relations are best secured if the air chamber is at any rate made in the form of a solid of revolution.

If the outer walls of the air chamber are not straight as in the example, but are to a certain degree curved, as indicated by the dash line 14, the straight line distance from the openings 16 to the end faces at 12 is not the criterion for determining the wave length, but rather the length of the shortest curved connecting line between said openings 16 and said end faces at 12.

It is important in some cases to design the siren for two or more operating frequencies, as in the case of the air protective sirens. In such cases there may be used either a plurality of passages for the air stream within the air chamber, one

example of which would be a smooth cylinder and the other a curved conduit, for example, a spiral channel; or the air chamber can be tuned to a common multiple, for instance, the least common multiple of the two signal frequencies. So, for example, a siren with frequencies of 1800 and 3000 cycles per second can be used if its air chamber is tuned to three-fourths of 1800 cycles or with five-fourths of 3000 cycles.

In order to utilize the good properties of the compressed air-operated sound emitter in accordance with the invention to the full extent, it is advisable to connect the sound emitter with a ring-shaped horn; for it has been shown that other horn shapes allow sub-maxima of the directional characteristic of the sound emitter to occur, which are perpendicular to the main direction. In the use of such devices an erroneous indication was given because at small heights the path of the direct sound beam between the sender and receiver and the path of the reflected sound beam are almost the same; that is, in the use of the sound emitter with a tuned air chamber, the advantage achieved is nullified by the use of an unsuitable sound horn. It is particularly advantageous for benefit of the sound characteristics to construct the ring horn of the sound emitter as a so-called exponential horn, that is a horn whose cross-sectional area increases exponentially along its length. The construction of the sound horn as an exponentially expanding ring horn has an additional advantage; the motor used to drive the rotor of the siren can be built into the inner space of the inner horn. Thereby the whole sound emitting unit is reduced to a small height. Furthermore, it is thereby possible to build the sound emitter into a part of the body of the aircraft, for example, into its deck. Since for aerodynamic reasons the outer surface of the aircraft must be smooth, the sound emitter is brought into the inside of the part of the body of the aircraft on which it is mounted, such as the fuselage. This, however, requires a break in the static frame of the fuselage. It is therefore important to build in the sound emitter in such a way that the outer horn constitutes a stress-sustaining unit of the aircraft fuselage. This manner of building in the unit is, furthermore, suitable for all kinds of shapes of horns, so that it constitutes a distinct feature of the invention in itself.

Fig. 1 exemplifies the latter construction of the inventive siren. The air currents flowing out of the ports 16 and 18 flow into a sound horn, which consists of an outer horn wall 19 and an inner horn wall 20. These two horn walls are of exponential form. In the hollow of the inner horn 20 is lodged a motor 21 which drives the rotor. The outer horn 19 is constructed as a stress-sustaining part of the aircraft fuselage and merges with the outer wall of the fuselage 41. In front of the opening of the horn there is preferably stretched a screen or diaphragm 23. Fig. 1 also shows an additional improvement of the sound emitter of an echo sounding device in accordance with the invention. Since the axial forces and accelerations occurring during the movement of the differential valve 24 provided in the air chamber to produce very short sound impulses may become too large and lead to injury of the device, there is enclosed between the valve plate 25 next to the outlet ports and the enclosing wall 26 of the air chamber, an air cushion 27. This device, known per se, has the disadvantage that the valve has imparted to it axial vibrations

caused by the spring action of the air compressed in the air cushion. These axial vibrations cause a repeated closing and opening of the differential valve so that the true sound signal is misleadingly interfered with by these vibrations, whereby the desired signal is furthermore unnecessarily extended. If such devices are used as a sound emitter for air-sounding devices or devices for measuring elevation above ground, the danger exists that the echo coming in may go into the outlets of the sound signal emitted. This disadvantage is eliminated by providing in the part of the enclosing wall 26 of the stator which is parallel to the valve plate 25, bleed ports 28 in suitable number and size to weaken the cushioning effect to such an extent that the air cushion does not act as a spring upon the valve, so that the valve is not set in vibration.

Heretofore the compressed air for driving a siren, or whistle, of an air sounding unit has been either taken from a compressed air container, such as a steel flask, or it has also been suggested to use the exhaust gases of the aircraft. The use of exhaust gases, however, has the disadvantage that the superatmospheric pressure which is available is much too small, to produce the loud sound impulse required in practice. The use of a steel flask has seemed up to now the best means of supplying the compressed air, although it always had the disadvantage that it had to be exchanged from time to time and a relatively long compressed air conduit was required. An important improvement of the whole signal emitting apparatus of an air sounding unit is now provided, by producing the compressed air by a compressor which is arranged in the immediate vicinity of the sound emitting apparatus. By this means not only is there an important saving of space and weight, as against the known units operating with a steel flask, and the exchange of the steel flasks done away with, but in addition to that the following advantage is achieved: It has been found in the operation of echo sounding units on aircraft that a difficulty occurred in unfavorable weather conditions, caused by the icing of the transmitting device, as a result of which in whistles the whistle openings were closed and in sirens the rotor was frozen fast. This danger occurs above all in echo sounding devices used for landing purposes and therefore usually having a measuring range of only one hundred or a few hundred meters, because these devices are not operated constantly, but are set in operation only shortly before the landing. By producing the compressed air by the use of a compressor near the sound emitter, the compressed air is supplied at a temperature much above the atmospheric temperature. The compressed air supplied by the compressor necessarily has a temperature of about 100° C. or more. Now if care is taken to avoid any substantial loss of heat on the way from the compressor to the sound emitter itself, the whistle or siren is pre-warmed. The pilot can therefore switch in the sounding apparatus a few minutes before the landing, if he knows or fears that the transmitter may have become iced, and thereby can thaw it out.

In the arrangements known heretofore, which used the exhaust gases of the motors as an operating medium for the siren or the whistle, it is true that gases of elevated temperature were used; however, as previously indicated, such devices have not proven to be useful in practice.

An additional advantageous arrangement of the echo sounding apparatus in accordance with

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the invention consists in driving the compressor as well as the rotor of the siren by one and the same motor; that is, a motor is used for driving the compressor, which is required for other functions on the aircraft. In this way the arrangement of a special motor and thereby an increase in the weight and space requirements are avoided. This advantage is naturally also achieved if the compressor is operated directly by the aircraft motor. Such a device is desirable for the use of a whistle as the sound emitter.

In Fig. 2 there is shown an illustrative embodiment of such a device. 77 is a driving motor which drives the rotor 79 of a siren through a step-up transmission gear 78 and a compressor 81 through a reduction gear 80. The transmission gear 78 is connected by a shaft 82 to rotor 79 not rigidly, but through an elastic coupling 83. Also there is mounted on the hollow shaft 84 which connects the elastic coupling 83 with the rotor 79, a centrifugal governor 85 providing for a constant rotary speed of the rotor 79. 86 is the inner wall of a ring horn set in front of the outlet ports 87 of the rotor, the outer wall of the horn being indicated at 88 and being also of the exponential form. The elastic coupling 83 and the centrifugal governor 85, which is advantageously constructed as a centrifugal braking governor, are arranged within the hollow space 89 enclosed by the wall 86.

From the compressor 81 the compressed air is conducted through a conduit 90 into the tuned air chamber 91 of the siren. It is particularly advantageous to construct the air chamber 91 in such a way, as shown in the example, that the whole, or at least the greatest part of the shaft of the rotor, is surrounded by it. Hereby the uniform heating of the moving parts of the siren, as well as all parts of the rotor, is accomplished. Also upon replacement of the siren by a whistle such a construction of the air chamber is desirable. The inner wall of the air chamber 91 is formed, in known manner, by an electromagnet armature 92 serving as a valve for controlling the supply of air to the ports 87, and the air induction ports 93 of the compressor 81 are provided, in known manner, with a pressure regulating valve 94. The electromagnet armature 92 is shown again as a differential valve.

The length of the compressed air conduit 90 and the heat insulation of the same are made to conform to the conditions prevailing in the compressor 81. Under certain conditions it is necessary to provide the conduit 90 with heat insulation, if this conduit is not altogether eliminated, and to arrange on the compressor 81 itself cooling fins, so that on the one hand the temperature necessarily arising from the compression of the gases does not become too high and create a fire hazard, while on the other hand a further cooling of the air conducted to the tuned air chamber 91 is prevented. At very high temperatures of the air, to be sure, and with the simultaneous use of good insulation of the compressor 81 against the surrounding conditions, it may be indicated to cool the compressed air first on the outer wall of the air chamber 91, whereby it is prevented that the whole siren is subjected to excessive and damaging heating after being thawed and the rotor set in operation.

The arrangement of the compressor, as well as the coupling of the sound emitter, is not limited to the form shown. Instead of the elastic coupling 83, for example, any other non-rigid coupling can be used, for example, a friction coupling. It is even possible to use a rigid coupling

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between the motor 77 and the rotor 79. In this case, to be sure, it is necessary to provide a speed regulator for the compressor motor.

A special form of the inventive conception consists in the use of a pump and impact mechanism as a compressor, which commends itself particularly for use in air sounding units on account of its compact construction and small space requirements.

In Fig. 3 is shown a sound emitter of an air sounding unit in accordance with the invention, using such an impact mechanism compressor. 95 is a whistle, which is separated by a check valve 96 from a compression chamber 97 enclosed by a cylinder 97a. Within the compression chamber reciprocates a piston 98 against a spring 99, the reciprocation being caused by means of a cam 100, which is driven by a worm wheel 101 operated by the worm 101a of a motor 102. An additional check valve 103 serves for suction of the atmospheric air into the compression chamber 97. A switch 104 arranged in the compression space is adapted to control the time measuring mechanism of an echo sounding device, not shown.

Said switch 104 being pressure responsive can be connected, for example, with the measuring mechanisms of the kind shown in the copending applications of Peter Orlich and Hans Hartz, Serial No. 285,310, filed July 19, 1939, and of Peter Orlich, Günther Negel, and Hans Hartz, Serial No. 365,647, filed November 14, 1940, or Patent No. 2,032,893 to Bernhard Settegast and Wilhelm Rudolph. Measuring apparatus of this type operate upon the principle of measuring the interval between the instant of emission of the sound signal and the instant of reception of the echo. Accordingly, the measuring mechanism which measures this time interval must be set in operation at the same instant as the signal is emitted. The emission of the signal is generally repeated periodically and usually the signal transmitter is set in operation by some kind of an electric device. Heretofore, the transmitter and the measuring mechanism have been simultaneously controlled by a control member, for example, a shaft rotating at constant speed. In practice, disadvantages of this system have occurred which are due to the fact that electrical control effected by means of relays or switches, particularly mechanical switches or similar transmitting members, is not absolutely exact and consequently no correct synchronism between the signal emission and the setting in operation of the measuring device is afforded. This disadvantage is satisfactorily avoided by using said pressure responsive switch 104 automatically actuated by the inventive sound emitter of Fig. 3 to set in operation the mechanism for measuring the length of time for the transmission of the sound.

It is obvious that the motors for driving the rotor of the siren and the time-measuring apparatus are to be kept at a constant speed. For this purpose centrifugal governors are frequently used, in which a switch contact is closed under the influence of centrifugal force, this switch controlling any part of the motor, either the field or the armature. In the known governors it is usual to provide a lever that also operates the switch contact, eccentric to the axis of rotation, so that centrifugal force acts directly upon the switch lever. This has the disadvantage, however, that the switch lever, on account of its eccentric position, forms only a chord within the

available circle, which defines the limits of the rotary part of the governor. Consequently, the length of the switch lever in comparison with the dimensions of the whole centrifugal governor is relatively small, resulting also in a relatively small extent of movement, which is furthermore the cause of a relatively large irregularity. Now it is particularly desirable in air sounding apparatus according to the invention to provide a switching movement as large as possible for the given total dimensions of the centrifugal governor and thereby to achieve the greatest possible accuracy of the governor, by constructing the centrifugal governor arm as a bell crank lever, the end point of one leg of which is arranged on a rocking axis at the periphery of the rotating housing or other carrier, and the free leg of which extends to the axis of rotation, where it acts upon a non-rotating switch lever. In contrast to the usual centrifugal governors the switch is therefore stationary, in a centrifugal governor according to the invention. For this reason the governor is particularly suited for regulating the field of a motor, because all collectors are eliminated.

In Fig. 4 is shown an illustrative embodiment of such a governor. 119 is the armature of a motor, which rotates within a field frame 105. Upon the armature is a support 106, which revolves with it and carries upon its periphery a pivot 107, about which a bell crank 108 is rockable. The leg of this bell crank 108 which is parallel to the axis of rotation is shorter than the other and is also loaded with a greater mass than the other. Hereby it is achieved that both the greatest possible centrifugal force and the greatest possible switching movement of the free end of the bell crank lever 108 occurs. Opposite the bell crank lever 108 is symmetrically arranged a second bell crank lever 109, which is likewise rockable upon a pivot 110 at the periphery of the carrier 106. By the arrangement of two symmetrical centrifugal governor lever arms there is simultaneously provided a balance of the whole system. This is, however, not absolutely essential to the device. One lever arm would be enough. On the other hand obviously three or more lever arms could be used, with an increase of the centrifugal force, and thereby a more exact operation of the governor would be provided. The free ends of the bell crank levers 108 and 109 act upon a switch arm 111, which is made as large as possible, that is, the rocking axis 112 of the switch lever is likewise placed at the periphery of the governor and secured to the housing 113 of the governor. The housing 113 forms a unit with the frame 105 of the motor. At the free end of the switch arm 111 is a contact 114, the contact surface of which is fixed to any stationary part, preferably upon the housing 113, and is perpendicular to the axis of rotation. The switch arm 111 is held by a spring 115 at a definite normal distance from the contact face 114. The tension of the spring 115 is adjustable, in known manner, by a setscrew 116, which is screwed into the housing 113.

A particular feature of the construction of this device is to be seen in the fact that the contact between the free ends of the centrifugal governor lever arms 108 and 109 and the switch lever 111 is constructed as a ball bearing. Upon the free ends of the bell crank levers 108 and 109 sits a half ball 117, which can be moved laterally within narrow limits in slots in the lever arms 108 and 109. The counter bearing of the half ball 117 is constructed as a ball bearing 118, which

is mounted upon the switch lever 111. The ability of the half ball 117 to shift enables this element always to conform uniformly to the bearing points of the balls 118. It is of course necessary to take care that the axis of symmetry of the ball bearing 118 and the half ball 117 is as nearly as possible on the axis of rotation.

The above-described conception whereby the disadvantages of the previously known centrifugal governors are removed is not limited to the illustrative form shown in Fig. 4.

The elements of the invention can obviously be used either individually or in any combination.

We claim:

1. In a siren, a casing enclosing an air chamber, means for delivering compressed air to said chamber, said casing having ports for emitting compressed air from said air chamber, a rotor mounted adjacent said ports, and means for driving said rotor at a predetermined speed, said rotor having ports coacting with said casing ports to control the emission of compressed air from said air chamber to produce a sound of definite frequency, a valve seat and a differential valve in said air chamber coacting to control the flow of compressed air from said chamber to said ports, the armature of said valve constituting an inner wall of the air chamber and designed to reciprocate in the direction of its longitudinal axis, the configuration of the armature being such as to form an outer curved surface defining a relatively small curved zone within the air chamber, whereby said air chamber is tuned to said frequency so that standing sound waves are set up with a loop at said ports and a node at the end of said air chamber most remote from said ports, the distance from said ports through said air chamber to the most remote part of the inner wall of said casing being equal to an uneven multiple of one fourth of the wave length of the emitted sound waves.

2. In a siren, a casing enclosing an air chamber, means for delivering compressed air to said chamber, said casing having ports for emitting compressed air from said air chamber, a rotor mounted adjacent said ports, and means for driving said rotor at a predetermined speed, said rotor having ports coacting with said casing ports to control the emission of compressed air from said air chamber to produce a sound of definite frequency, a valve seat and a differential valve in said air chamber coacting to control the flow of compressed air from said chamber to said ports, the armature of said valve constituting an inner wall of the air chamber and designed to reciprocate in the direction of its longitudinal axis, the configuration of the armature being such as to form an outer curved surface defining a relatively small curved zone within the air chamber, whereby said air chamber is tuned to said frequency so that standing sound waves are set up with a loop at said ports and a node at the end of said air chamber most remote from said ports, said air chamber having the form of a solid of revolution with plane end surfaces and a height equal to an uneven multiple of one-fourth of the wave length of said definite frequency.

3. In a siren for producing a sound of predetermined wave length, wall means forming an axially extending annular chamber having an outlet at one end thereof, vibration producing means including a circular row of ports surround-

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ing said outlet and being positioned a fixed distance from the opposite end of said annular chamber which distance is equal to an uneven multiple of one-fourth of the wave length of the emitted sound waves, said chamber having as its inner peripheral wall a surface of revolution, 5
said wall means having as part thereof a recip-

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rocating differential valve axially movable to open and close said outlet, and means to supply to said chamber a compressed gas of controlled temperature.

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