Oct. 25, 1960 T. M. JOHNSON 2,957,957

SOUND SWITCH

Filed Jan. 13, 1956 4 Sheets-Sheet 1

Fig 1

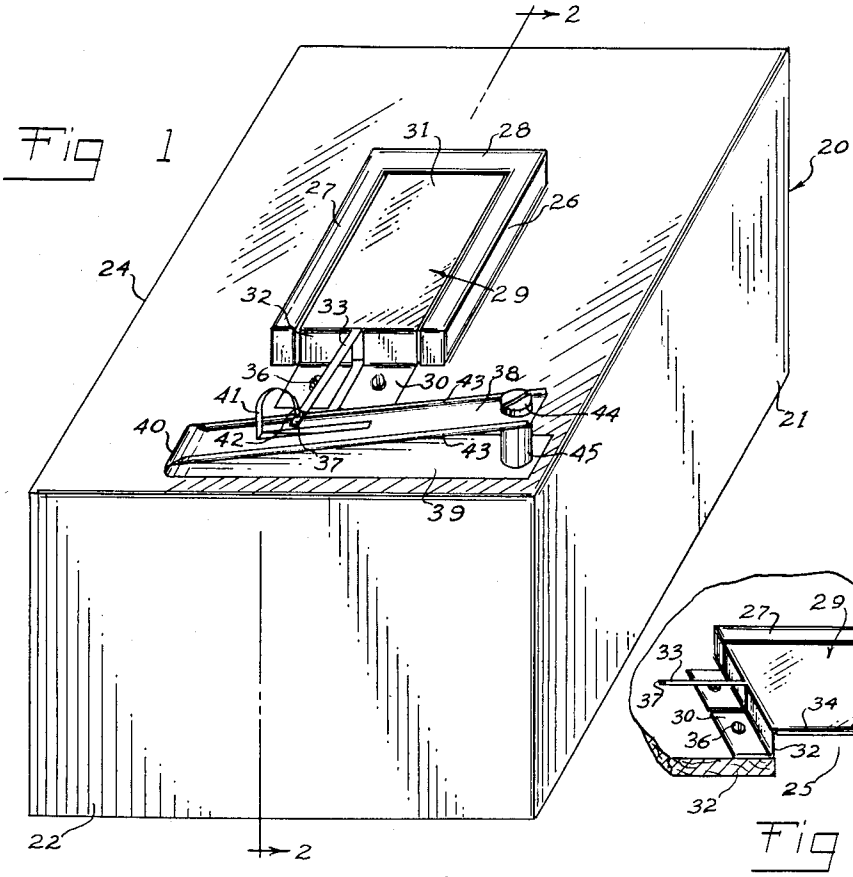


Fig 3

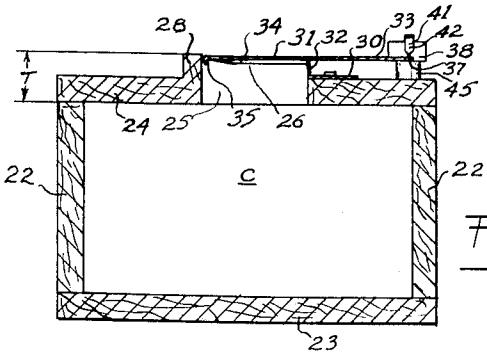
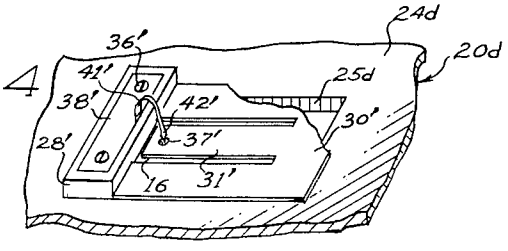


Fig 2

Fig 4



INVENTOR.
THOMAS M. JOHNSON
BY
ATTORNEY

Oct. 25, 1960 T. M. JOHNSON 2,957,957

SOUND SWITCH

Filed Jan. 13, 1956 4 Sheets-Sheet 2

Fig 5

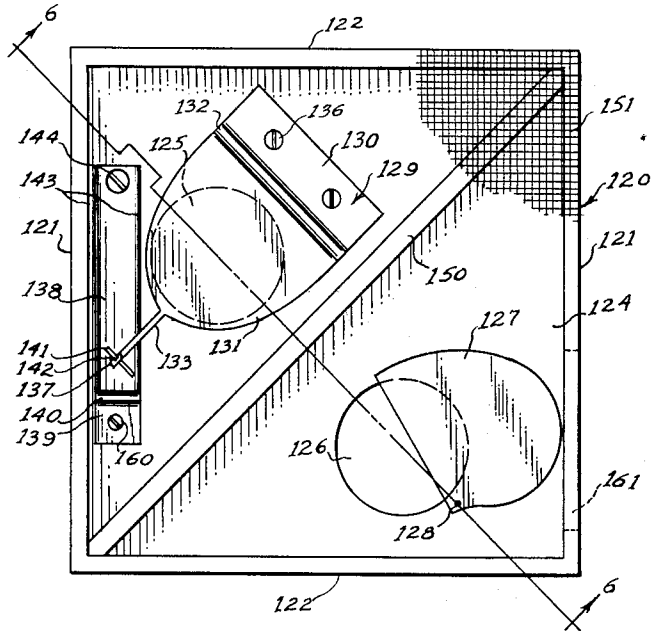
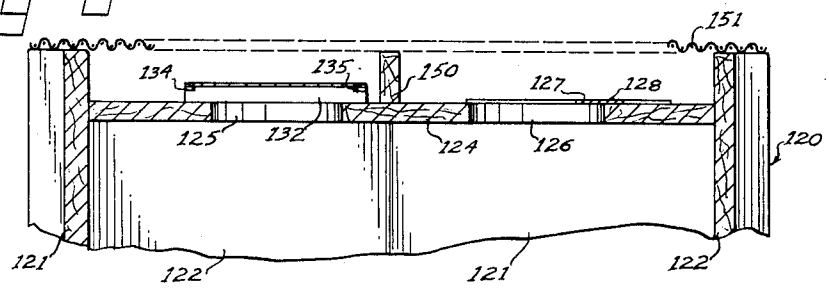


Fig 6



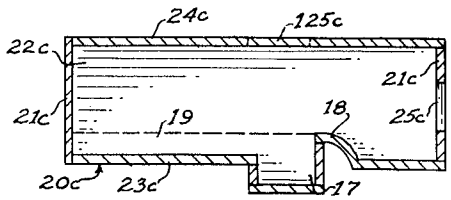


Fig 9

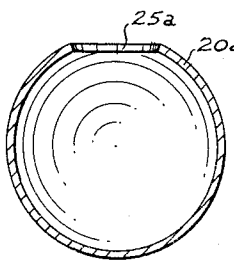


Fig 7

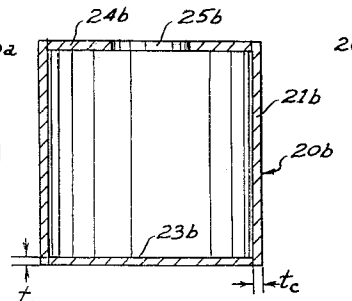


Fig 8

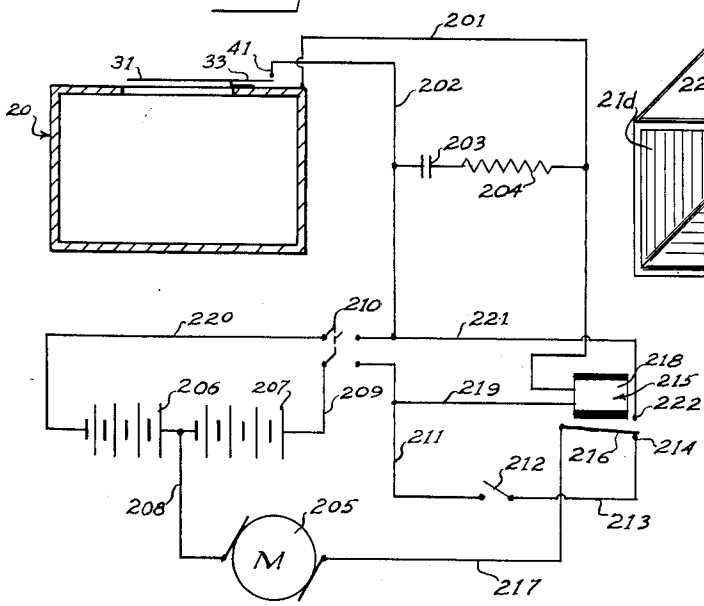
INVENTOR.
THOMAS M. JOHNSON
BY
ATTORNEY

Oct. 25, 1960 T. M. JOHNSON 2,957,957

SOUND SWITCH

Filed Jan. 13, 1956 4 Sheets-Sheet 3

Fig 11



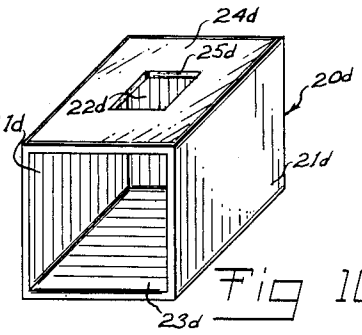


Fig 10

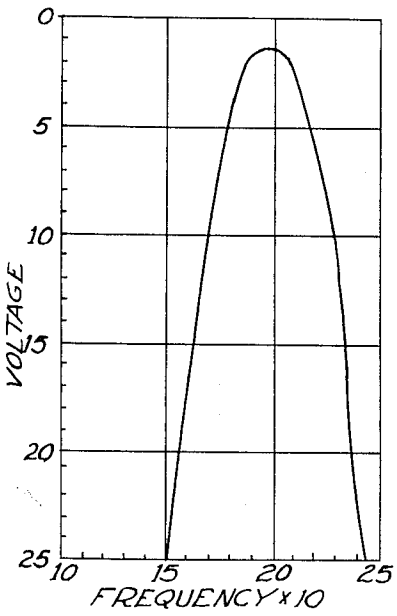


Fig 12

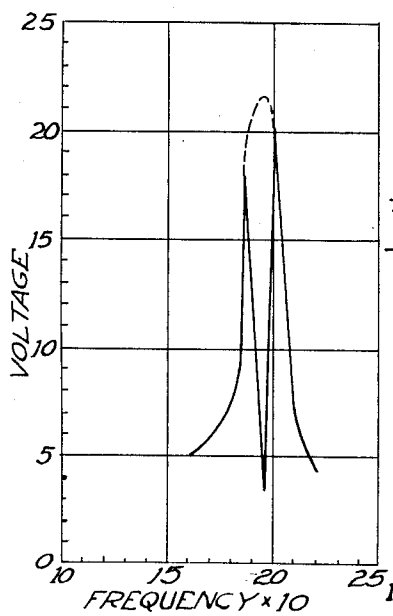


Fig 13

INVENTOR.
THOMAS M. JOHNSON
BY
ATTORNEY

Oct. 25, 1960 T. M. JOHNSON 2,957,957

SOUND SWITCH

Filed Jan. 13, 1956 4 Sheets-Sheet 4

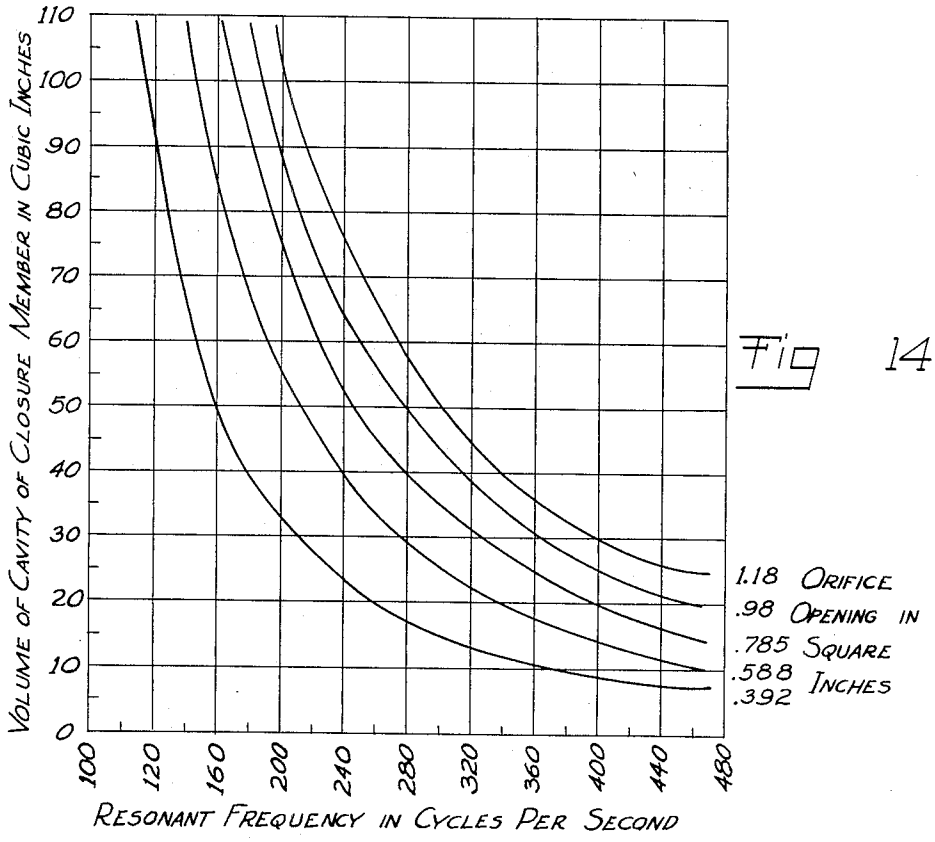


Fig 14

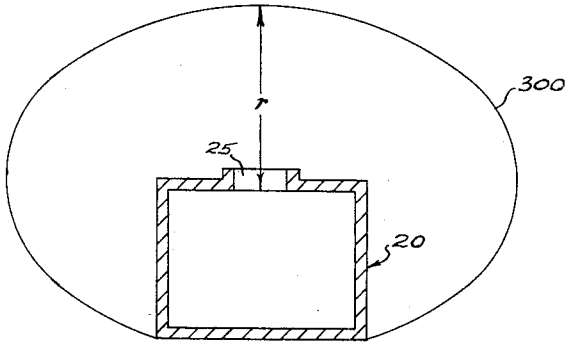


Fig 15

INVENTOR.
THOMAS M. JOHNSON
BY
ATTORNEY

United States Patent Office

2,957,957

Patented Oct. 25, 1960

2,957,957

SOUND SWITCH

Thomas M. Johnson, 428 Oakridge Road, Decatur, Ga.

Filed Jan. 13, 1956, Ser. No. 559,054

23 Claims. (Cl. 200—61.01)

This invention relates to sound switch and more particularly to sensitive, frequency selective sound switch and electric circuit therefor. This invention is a continuation-in-part of my co-pending application, Serial No. 483,511, filed January 24, 1955, entitled "Sound Actuated Toy."

In the past, switches have been operated by diaphragms which pick up noise and sound from the surrounding air but, in general, these switches have not been frequency selective and hence were operated by substantially any frequency of sound with sufficient pressure waves to cause vibration of the sound pick-up mechanism.

Also, in the prior art sound switches, the contact terminals move only a fraction of the amplitude of the sound causing actuation or a fraction of the particle movement of the vibrating air transmitting the sound to the sound switch.

These prior art sound switches have had some use in conjunction with toys of various descriptions. Because the prior art sound switches have usually only been able to pick up sound from only one or two directions, and have not, in general, been small, portable or frequency selective, their application to self-propelled relatively noisy toys such as those having electric motors has been restricted. If these prior art switches have been applied to relatively noisy toys and the like, the construction of the same has been relatively costly and complicated. Further, the prior art sound switches have usually been inoperative if removed an appreciable distance from the source of sound.

Since it is of primary importance in the toy art to provide a mechanism which is inexpensive to manufacture, and yet durable and practical, the prior art sound switches have not had wide application.

Briefly, the present invention includes a sound switch which is frequency selective and which may be made to operate on a relatively low amplitude of sound. The mechanism of this invention includes a closure member formed of relatively rigid material and provided with an orifice or hole which communicates with a resonator cavity defined by the closure member. The vibrator assembly which is preferably mounted on or within the closure member includes a diaphragm and a protruding reed which extends from the diaphragm to terminate in an electrical terminal in close proximity to another electrical terminal. The diaphragm is positioned so as to be acted on by the air within the resonator cavity and the ambient air; thus the diaphragm will be actuated by a pressure differential between the air in the cavity and the ambient air, or by a flow of air either into and out of the cavity. The diaphragm and reed are tuned as a combination to be in resonance with a pre-selected frequency

and the resonator cavity is tuned to resonance with the diaphragm and reed; thus, when that predetermined frequency of sound is generated, the mechanism of this invention will resonate to cause rapid intermittent contact of the terminals. Contrary to the prior art, my sound switch amplifies the particle movement of the air, transmitting this movement to the switch region where contact is made.

The circuit of this invention in which the sound switch may be utilized includes a source of D.C. current having a center tap leading to a motor and a relay means which is adapted to supply current from one side of the source of current or the other, to reverse the rotation of the motor. The relay is controlled by the sound switch.

Accordingly, it is an object of the present invention to provide a sensitive frequency selective sound actuated switch.

Another object of my invention is to provide a sound switch which will be operated by the generation of a predetermined frequency of sound and is substantially inoperable by other frequencies of sound.

Another object of my invention is to provide a sound switch which is easy to adjust to pick up minute generations of sound of proper frequency.

Another object of my invention is to provide a sound switch which is very sensitive and can be operated on a relatively low amplitude of sound.

Another object of my invention is to provide a sound switch which is practical in use in conjunction with moving objects and is adapted to pick up sound from a source relatively remote from the location of the switch.

Another object of my invention is to provide a sound switch which is inexpensive to manufacture, durable in structure and efficient in operation.

Another object of my invention is to provide a sound switch which is operable by sound regardless of its position with respect to the source of that sound.

Another object of my invention is to provide a sound switch which is operable at relatively low frequencies of sound and within a range which is not too objectionable to people.

Another object of my invention is to provide a sound switch which is operable within a sound frequency range such that standing sound waves in a usual size room do not appreciably affect the operation of the sound switch.

Another object of my invention is to provide an electrical circuit which incorporates the use of my sound switch.

Other and further objects and advantages of my invention will become apparent from the following description when taken in conjunction with the accompanying drawings, in which like characters of reference designate corresponding parts, and wherein:

Fig. 1 is a perspective view of a sound switch constructed in accordance with the present invention.

Fig. 2 is a cross-sectional view taken along line 2—2 in Fig. 1.

Fig. 3 is a fragmentary perspective view of a detail showing the vibrator assembly of the sound switch shown in Fig. 1.

Fig. 4 is a fragmentary perspective view showing a high frequency vibrator assembly constructed in accordance with my invention in operative association with the contact means on the high frequency closure member shown in Fig. 10.

Fig. 5 is a top plan view of a second embodiment of

my sound switch wherein the resonant frequency of the closure member may be adjusted.

Fig. 6 is a fragmentary cross-sectional view taken along line 6—6 in Fig. 5.

Fig. 7 is a cross-sectional view of a spherical shaped closure member suitable for use in my invention.

Fig. 8 is a cross-sectional view of a cylindrical shaped closure member suitable for use in my invention.

Fig. 9 is a cross-sectional view of an irregular shaped closure member suitable for use in my invention.

Fig. 10 is a perspective view of a closure member for short range and high frequency suitable for use in my invention, said closure member being directional in nature so that it best picks up sound originating from a point in front of the large opening of the closure member.

Fig. 11 is a schematic wiring diagram of my invention showing the use of my sound switch to control an electrical load.

Fig. 12 is a graph showing a plot of the power necessary to vibrate the vibrator assembly of my invention vs. the frequency of the sound across the range in which is the resonant frequency of my sound switch. The power is indicated as a function of the voltage registered across an actuated "driving speaker" placed at a fixed distance from the sound switch.

Fig. 13 is a plot of the function in terms of voltage of the root mean square of the pressure differential between the cavity of the closure member and the ambient air vs. the frequency of sound causing vibration of the cavity.

Fig. 14 is a graph showing plots of the volume of the cavity of closure members having a given size orifice vs. the resonant frequency of those closure members, the lip thickness of the orifice remaining constant at .25 inch.

Fig. 15 is a schematic cross-sectional view of a typical closure member of this invention and illustrating a theoretical sonic egg which exists around the closure member when it is in resonance.

In more detail, the sound switch of the present invention is an acoustically driven device which is very sensitive and which, when properly constructed, can be operated with as little as about one ten-millionth of a watt of sound power of the right frequency. It can be consistently and reliably operated with a mouth whistle at any distance up to about twenty feet. Over about twenty feet from a source of sound, the sound switch of the present invention is slightly less reliable; however, it is to be noted that a relatively low amplitude of sound generated by a mouth whistle has actuated my sound switch when it was in excess of 145 feet from the source of sound.

An even toned whistle (not shown) which may readily be blown by a child has been found ideal for actuating my sound switch; however, it is understood that other sources of sound may be employed. Preferably, except for the sound switch illustrated in Figs. 4 and 10, my sound switches should be tuned to a frequency of from about 200 cycles per second to about 400 cycles per second so that the whistle or other source of sound will present a pleasing note. Other advantages of the frequency range described above will be pointed out hereinafter.

As described above, my sound switch may be made very frequency selective, i.e., the sound switch will be operated only when the correct frequency or pitch of sound is made. Thus, it is possible to operate several of my sound switches in the same location, each being tuned to a frequency different from the resonant frequency of the other sound switches and each being independently respectively operated from different sources of sound.

FIRST EMBODIMENT

The first embodiment of my sound switch is shown in Figs. 1 through 3 wherein the resonator cavity which is denoted generally by numeral **20** is shaped as a cubical having sides **21**, ends **22**, bottom **23** and top **24**. Sides **21**, ends **22**, bottom **23** and top **24** each are relatively rigid members which in the present embodiment are made of wood and define a cavity denoted by C in Fig. 2. It is to be remembered that while resonator cavity **20** is manufactured of wood adhesively secured together, as thus seen in Fig. 2, other rigid materials such as metal or plastic may be substituted for the wood.

As best seen in Fig. 2, an orifice or hole **25** is cut through top **24**, and in this particular embodiment, hole **25** is a rectangular hole cut in the central portion of top **24**. Around hole **25** is arranged a lip comprising lip members **26**, **27** and **28**, the thickness or height of which is defined in Fig. 2 by T. It will be seen that the inner surfaces of lip members **26**, **27** and **28** are coplanar, respectively, with the three of the four portions of top **24** which define hole **25**, to thus extend the effective thickness, T of hole **25**, the purposes of which will be described in more detail later.

The vibrator assembly of the first embodiment of my invention as shown in Figs. 1 through 3 is denoted generally by numeral **29**. Vibrator assembly **29** is preferably manufactured of thin sheet metal which is intially formed generally as a rectangle and then is bent adjacent one end to provide a flat mounting base or flange **30**. A second bend is made parallel to the first bend and at a distance approximating the height of lip members **26**, **27**, **28** to thereby provide a diaphragm **31** suitable for extending into opening **25**. Diaphragm **31** is thus supported by a vertical spacer plate **32** which, when installed, forms a fourth lip member. It is thus seen that I have formed vibrator assembly **29** by bending a rectangular sheet of metal transversely to provide a perpendicular portion and then again along a line parallel to and spaced from the first bend to provide a diaphragm **31** parallel to base **30**, perpendicular to spacer plate **32** and extending in cantilever fashion from spacer plate **32**.

Prior to the bending operation just described, a cantilever reed **33** which is a narrow rectangular member is cut from the central portion of the base **30** and spacer plate **32**. From Figs. 1, 2 and 3, it will be seen that reed **33** extends from one edge of diaphragm **31**, generally the same plane with diaphragm **31** but in an opposite direction therefrom. Reed **33** extends generally parallel to and beyond base **30**.

To stiffen diaphragm **31**, longitudinal stiffening ribs **34** are formed by bending the edges of diaphragm **31** downwardly. As best seen in Fig. 3, the ends of stiffening ribs **34** are tapered so as not to interfere with the vibration of diaphragm **34** as will be described later. At the free end of diaphragm **31**, a transverse stiffening rib is formed by bending the end of diaphragm **31** downwardly as best seen in Figs. 2 and 3.

The vibrator assembly is installed on resonator cavity **20** so that spacer plate **32** lies generally parallel to the edge of hole **25** and diaphragm **31** projects generally over hole **25** while base **30** is mounted flat against top **24**. For mounting base **30**, appropriate screws **36** may be utilized. Of course, other means of securing base **30** to top **24** may be employed without departing from the scope of this invention.

For better operation, base **30** may be weighted by applying solder or by manufacturing the base of thicker material than the remaining vibrator assembly. To provide electrical contact, the free tip of reed **33** is provided with a coating or tip **37** formed of silver. Of course, other electrically conducting material may be substituted for silver to provide this electrical terminal.

To provide an electrical contact for tip **37**, I have mounted on top of **24** a contact assembly which is formed initially from a rectangular sheet of metal. The strip is bent at substantially its mid-section to an acute angle, thus providing a pair of arms **38** and **39** which have a common body portion **40**. Struck from arm **38** at a position adjacent body portion **40** is an upstanding finger **41**, the free end of which is curved to terminate in a

point 42 at a position immediately above tip 37. As best seen in Fig. 1, arm 39 is mounted flat against top 24 by any suitable means such as glue, bolts or the like. To prevent vibration of arm 38, a pair of stiffening ribs 43 are formed by bending the edges of arm 38 upwardly.

To provide definite adjustment of point 42 with respect to tip 37, a bolt 44 resiliently urges arms 38 and 39 together. Bolt 44 is journaled by the end of arm 38 and threadedly engages arm 39. Between arms 38 and 39 and surrounding bolt 44 is a rubber washer 45 which urges arms 38 and 39 resiliently apart. Of course, an appropriate hole (not shown) is provided in top 24 beneath screw 44 so that when screw 44 is rotated, top 24 will not interfere with its operation. It is thus seen that even though the ends of arms 38 and 39 may be moved an appreciable distance by the rotation of screw 44, point 42 is only moved a proportionately less distance. It should be noted here that it is most desirable to provide for micro adjustment of the distance between point 42 and tip 37, since through adjustment of this distance my sound switch may be made more sensitive and less selective in frequency, or less sensitive and more selective in frequency.

SECOND EMBODIMENT

For purpose of mass production, I recommend the manufacture of a sound switch constructed as shown in Figs. 5 and 6. In this embodiment, I have provided a resonator cavity or closure member 120 having a top 124 provided with an orifice or hole 125. The lower portion of resonator cavity 120 which is not shown in Figs. 5 and 6 is made in the same manner as resonator cavity 20. A tuning aperture 126 is also provided in top 124 and this aperture 126 has a restriction gate 127 which is adapted to be slideably pivoted about pivot pin 128 to adjustably close aperture 126. In the embodiment shown in Figs. 5 and 6, hole 125 and aperture 126 are both round holes having their centers generally on the diagonal of top 124, the hole 125 and aperture 126 being respectively disposed on opposite sides of the diagonal which intersects the diagonal of their centers.

To cooperate with hole 125, the vibrator assembly 129 is positioned on top 124 in much the same manner as vibrator assembly 129. Vibrator assembly 129 comprises a base 130, a diaphragm 131 and a spacer plate 132 all integrally formed of sheet metal. Base 130 is substantially a rectangular member secured to top 124 by bolts or screws 136. The spacer plate 132 extends upwardly at an obtuse angle from one edge of base 130 and terminates in the horizontally extending diaphragm 131. In this instance, the edges of diaphragm 131 are curved and are each provided with peripheral crimps or flanges 134 and 135. As best seen in Fig. 5, the peripheral crimps 134 and 135 extend down a short distance from the respective edge of diaphragm 131 to provide stiffening means therefor. Flanges or peripheral crimps 134 and 135 respectively extend from plate 132 around the curved edges of diaphragm 131 to terminate at reed 133 which in turn extends from the front of diaphragm 131. Reed 133 is integrally formed with diaphragm 131 and extends in the same plane outwardly therefrom. Tip 137 of reed 133 is provided with a coating of silver just as tip 37.

In the present embodiment, the contact means for tip 137 is formed initially of a rectangular sheet of metal which is bent at numeral 140 to form a bent common body portion for arms 138 and 139. Arms 138 and 139 extend in opposite directions from body portion 140, arm 139 being spaced downwardly from arm 138. Stiffening ribs 143 are provided along the edges of arm 138 in a manner similar to the formation of stiffening ribs 43 in the first embodiment. Finger 141 is struck diagonally from arm 138 and projects up and then downwardly to terminate in point 142.

The second embodiment is assembled by securing base 130 to top 124 by means of bolts 136 so that diaphragm 131 extends generally over hole 125 and reed 133 extends beyond hole 125 as shown in Fig. 5. The contact means is arranged diagonally with respect to the center line of the vibrator assembly so that it lies adjacent the edge of top 124 with point 142 arranged immediately above tip 137. Arm 139 may be secured to top 124 by bolts such as bolt 160 and definite adjustment of point 142 with respect to tip 137 may be had by rotation of bolt 144 which is journaled adjacent its cap by arms 138 and threadedly engages top 124.

From Figs. 5 and 6, it will be noted that the sides 121 and ends 122 extend above top 124 to form a protective perimeter about the vibrator assembly 129 and the contact means. For further protection, a diagonally extending cross member 150 may be provided on top 124 so that the top edge of cross member 150 is in the same plane with the top edges of sides 121 and ends 122. Disposed over the top edges of sides 121, ends 122 and cross member 150, and secured thereto is a wire mesh screen 151 which prevents trash from entering hole 125 or aperture 126. Of course, a suitable slit 161 indicated by broken lines in Fig. 5 may be provided in side 121 so that this side 121 does not interfere with the operation of gate 127.

RESONATOR CAVITY SHAPES

In Figs. 7, 8 and 9, I have illustrated other shapes of resonator cavities or closure members than those previously described. These shapes may be substituted for the shape of resonator cavity 20 or resonator cavity 120 in embodiments one and two, respectively. In Fig. 7, it is seen that the resonator cavity denoted by numeral 20(*a*) may be entirely spherical and have an orifice 25(*a*) over which the vibrator assembly of the previous embodiments may be mounted. In Fig. 8 is a right cylindrical closure member or resonator cavity 20(*b*) which has a cylindrical side 21(*b*), a flat bottom 23(*b*) and a flat top 24(*b*) having opening 25(*b*) therein. In this embodiment, the vibrator assembly is mounted over opening 25(*b*).

In Fig. 9, it is seen that an irregular shaped resonator cavity or closure member 20(*c*) may be utilized in accordance with my invention; however, it is recommended that the shapes of the closure members are relatively simple and define no voids or secondary cavity since accurate engineering is necessary for best operation of irregular shaped closure members or resonator cavities. In Fig. 9, it is seen that sides 21(*c*), ends such as end 22(*c*), and top 24(*c*) are all flat members; however, bottom 23(*c*) is an irregular shaped portion defining an obstruction 18, a well 17, and a shadow area defined by broken lines indicated by numeral 19. If, as is shown in Fig. 9, orifice 25(*c*) is provided in side 21(*c*), resonator cavity 20(*c*) acts as a cavity within a cavity and thus the effective volume of the cavity is reduced. If, however, hole 25(*c*) is moved to a position in top 24(*c*) above well 17, the opening being indicated by 125(*c*), the problem of obstruction 18 and well 17 is eliminated and no loss volume would be present.

THIRD EMBODIMENT

If directional characteristics are desired, it is preferable to provide a high frequency closure member or resonator cavity such as closure member 20(*d*) of Fig. 10. In Fig. 10, the resonator cavity or closure member 20(*d*) is shown as having sides 21(*d*) and end 22(*d*), a bottom 23(*d*) and a top 24(*d*). The shape of closure member or resonator cavity 20(*d*) is generally rectangular with one end of the closure member being left open. In this instance, a rectangular hole 25(*d*) is provided in the top 24(*d*) near the open end for cooperation with the vibrator assembly.

The vibrator assembly suitable for use in this high frequency directional sound switch, is shown in Fig. 4 and includes a flat rectangular base 30′ which extends over opening 25(*d*) in top 24(*d*). The diaphragm 31′ is

integrally formed with base 30' by providing a U-shaped slit 16 in the central portion of base 30'. Thus, one end of diaphragm 31' joins base 30' while the other end of diaphragm 31' projects beneath a contact finger 41'. A coating of silver on the free end of diaphragm 31 forms an electrical contact or tip 37'. Arranged adjacent hole 25(*d*) is a rectangular block 28' mounted on top 24(*d*). On block 28' is the contact means which includes a flat base 38' secured to block 28' by means of screws 36'. The finger 41' extends from one edge of base 38' and is curved upwardly and then projects downwardly to terminate in point 42' immediately above contact tip 37'. In this instance, the contact means is adjusted by bending finger 41' so that point 42' is adjacent tip 37'.

In utilizing the third embodiment of my sound switch, the open end of resonator cavity 20(*d*) should be facing the direction of the source of sound so that the sound waves may travel into resonator cavity 20(*d*). The third embodiment of my invention is far less sensitive in picking up sound than the other embodiment and hence would have utility over the previous embodiments in special cases only.

ELECTRICAL CIRCUIT

In Fig. 11, it is seen that a conductor such as wire 201 is electrically connected to the tip 37 of reed 33 preferably by soldering or otherwise affixing wire 201 to base 30. A second wire 202 is electrically connected to finger 41, preferably by soldering wire 202 to arm 39. Similarly, wires may be affixed to the other embodiments shown herein and thus the electrical connections of only the first embodiment is shown.

Across wires 201, 202 is a condenser 203 in series with a resistor 204 which tends to smooth out any current flowing between wires 201 and 202 upon the making of contact between finger 41 and tip 37 to prevent arcing. Resistor 204 may also be arranged in series with finger 41 and tip 37 if so desired. It will be understood by those skilled in the art that wires 201 and 202 may lead to any circuit to perform a multitude of operations. In the present embodiment, however, the sound switch is used to reverse a motor 205. In Fig. 11, it is seen that a pair of batteries 206, 207 are connected in series and that one brush of motor 205 is connected through wire 208 to the series connection between the two batteries 206, 207. This center tap arrangement enables wire 208 to be connected to the positive pole of battery 206 and the negative pole of battery 207.

The positive pole of battery 207 is connected through wire 209, switch 210, wire 211, switch 212 and wire 213 to a contact terminal 214 of a relay denoted by numeral 215. This relay 215 includes a single pole double throw switch 216 which is normally in contact with terminal 214 and is connected through wire 217 to the other brush of motor 205. It is now seen that when switches 210 and 212 are closed, current from battery 207 will be supplied to rotate motor 205 in one direction.

Relay 215 is also provided with a coil 218, one lead of which is connected to wire 201 and the other lead of which is connected to wire 219 which, in turn, is connected to wire 211. To supply current to coil 218, a wire 220 leads through a second throw arm in switch 210 to wire 202. It is thus seen that upon closing of the sound switch, i.e., contact of tip 37 of reed 33 with finger 41, coil 218 is energized to throw switch 216 of relay 215, thereby breaking the circuit from battery 207 to motor 205 and making a circuit from battery 206 through wire 220, switch 210, wire 221 and terminal 222 to one brush of motor 205 through switch 216 and wire 217. By this operation, the direction of rotation of motor 205 is reversed since the direction of flow of current is reversed. Of course, when the sound switch opens, switch 216 returns to its normal position and motor 205 begins to rotate in its original direction of rotation.

If desired, a mechanical linkage may be provided from motor 205 to switch 212 so that when motor 205 is reversed to a predetermined position, switch 212 will be opened to prevent current from flowing from battery 207 to motor 205 when the sound switch is open and to permit the sound switch to reverse motor 205 past the predetermined position and thereby close switch 212 for normal operation.

For best operation of the electrical circuit, it is preferable to provide certain size condenser 203 and resistor 204 according to Table I below. This arrangement should provide a .2 second time delay between the operation of the sound switch and relay 215.

Table I

Sound Switch Circuit Load in Milliwatts	Condenser Size in Microfarads	Resistor Size in Ohms
15	16	9
30	30	6
45	40	5
60	60	4

RESONATOR CAVITY CONSTRUCTION

For practical purposes the low frequency resonator cavity or closure members 20, 20(*a*), 20(*b*), 20(*c*), 120 should have a volume of from about 15 cubic inches to about 100 cubic inches and should have a resonant frequency of from about 200 cycles per second to about 400 cycles per second. Below about 200 cycles per second, noises such as electrical motors running, persons clapping or shouting, or other similar noises will tend to actuate the sound switch. Since the number of standing wave patterns increase with an increase in frequency, above about 400 cycles per second will set up sufficient wave patterns in a room such that there will be appreciable blank sound areas (depending on the distance of the sound switch from the sound source) in which the sound switch will be unresponsive. It should be understood that the sound switches which I have disclosed above are operable both above and below the resonant frequencies which I have described; however, the relatively critical frequency range of about from 200 cycles per second to about 400 cycles per second should be observed in order to obtain best results from my sound switch.

From Fig. 13, it is seen that a closure member designed to resonate at about 194 cycles per second will resonate over a larger range of frequencies except that a larger amplitude of sound is necessary in order to cause the closure member to resonate. Thus, it is advisable to design the closure member or resonator cavity with sufficient accuracy to insure proper operation of the sound switch.

In the construction of the various closure members which I have disclosed, many things should be taken into consideration. For example, if closure member 20(*c*) is constructed having obstruction 18 between orifice 25(*c*) and the opposite side 21(*c*), the distance from orifice 25(*c*) to the corner of the opposite wall 21(*c*) should not be greater than twice the cube root of the total volume of closure member 20(*c*). Assuming the total volume of closure member 20(*c*) to be, say 12.64 cubic inches, the distance from orifice 25(*c*) to any corner of the opposite side 21(*c*) should not be over 4.66 inches. Indeed, if the distance from orifice 25(*c*) to a corner of the opposite side 21(*c*) is, say 4.72 inches, closure member 20(*c*) would have poor operating characteristics.

For best operating results, the sides, ends, top and bottom of each closure member or resonator cavity should be rigid, rattle-tight and air-tight. In the first two embodiments of my invention, I have shown the resonator cavity or closure member as being made of wood which may be adhesively secured together in such a manner as to be rigid, rattle-tight and air-tight. On the other

hand, in Figs. 7, 8 and 9, I have shown that the resonator cavity or closure member may be made of metal; however, in each instance, the requirements for rigidity, rattle-tightness and air-tightness apply. Further, according to my experiments the thickness of the material forming the sides, top and bottom of the resonator or closure member is of some importance to provide the rigid structure desirable. Referring to Fig. 8, since a closure member **20**(*b*) is illustrated which has curved sides **21**(*b*) and a flat top **24**(*b*) and bottom **23**(*b*), for the purpose of illustrating how the thickness of a closure member should be calculated, I have indicated the thickness of bottom **23**(*b*) to be t_f meaning the thickness of the flat member and have indicated the thickness of side **21**(*b*) to be t_c to mean the thickness of the curved side. The thickness of the curved or spherical wall area defining, or partially defining, the cavity should be according to the following formula:

$$t_c=\frac{.01V}{25} \tag{1}$$

where t_c is the thickness of the curved or spherical wall in inches and V is the volume of the cavity defined by the walls in cubic inches.

On the other hand, the thickness of the flat wall areas should follow the following formula:

$$t_f=\frac{.20A}{3\sqrt{V^2}} \tag{2}$$

where t_f is the thickness of the flat wall area in inches; A is the area of the flat wall in square inches; and V is the volume of the cavity in cubic inches.

When material other than hot rolled steel is used, these materials should be proportionately thicker or thinner than the value computed from Formulas 1 and 2 by the ratio of the rigidity of the used material to the rigidity of hot rolled steel.

Of some importance is the fact that each flat surface of the resonator cavity or closure member has a resonant frequency of its own and thus should be of such dimensions and have such characteristics as to have a resonant frequency well above the resonant frequency at which the sound switch is to operate.

For best results, according to my experiments, the lip thickness T of the orifice opening, such as orifice 25, should be computed as follows:

$$T_{max}=\tfrac{1}{3}\sqrt[3]{V} \tag{3}$$

$$T_{min}=\tfrac{1}{15}\sqrt[3]{V} \tag{4}$$

where T_{max} is the maximum height of the orifice in inches; T_{min} is the minimum height of the orifice in inches; and V is the volume of the cavity in cubic inches.

In determining the area of orifice opening, such as orifice **25**, **25**(*a*), **25**(*b*), **25**(*c*) and **25**(*d*), the following formulas may be used:

$$A_{max}=\tfrac{1}{3}\sqrt[3]{V} \tag{5}$$

$$A_{min}=\tfrac{1}{15}\sqrt[3]{V} \tag{6}$$

where A_{max} is the maximum area of an orifice in square inches; A_{min} is the minimum area of an orifice in square inches; and V is the volume of the cavity in cubic inches.

Since many factors control the resonant frequency, it may be advisable to test closure members **20**, **20**(*a*), **20**(*b*), **20**(*c*), **20**(*d*) and **120** to determine their respective resonant frequencies, once the closure member has been constructed. One easy method of testing for the resonant frequence is to arrange a conventional microphone in a closed box with a hollow tube leading from the box and in communication with the interior of the closure member so that the microphone picks up only the sound from the closure member. The microphone is then electrically connected to an audio amplifier which operates an ammeter. Next position adjacent the closure member, within one-fourth a wave length, a sound source or speaker and baffle which is connected to an audio signal generator. The signal generator should then be operated and the frequency varied until a peak signal is detected on the ammeter, then that frequency should be recorded as the resonant frequency of the closure member. Other means such as a stethoscope for determining a peak vibration within the cavity of course may be employed.

The resonant frequency of closure members **20**, **20**(*a*), **20**(*b*), **20**(*c*) and **120** may each be calculated with a reasonable degree of accuracy utilizing the following formula:

$$F_r=\frac{C_s}{2\pi}[(T+.86A^{1/2})A^{-1}]^{-1/2} \tag{7}$$

where F_r is the resonant frequency in cycles per second; C_s is the velocity of sound in inches per second (usually taken as 13,550 inches per second); V is the volume of the cavity; T is the lip thickness in inches of the orifice opening; and A is the area of the orifice opening in square inches.

Equation 7 may also be written as:

$$F_r=K(VM)^{-\frac{1}{2}} \tag{8}$$

where M is the reactance of the cavity and K is essentially the constant $C_s/2\pi$.

In case the closure member is provided with two or more orifices such as is shown in Figs. 5 and 6, the following formulas should be used to compute the resonant frequency of the cavity:

$$F_r=K(VM_t)^{-\frac{1}{2}} \tag{9}$$

$$M_t=\frac{1}{\frac{1}{M_1}+\frac{1}{M_2}+\cdots\frac{1}{M_n}} \tag{10}$$

$$M=\frac{T+.86\sqrt{A}}{A} \tag{11}$$

In the above formulas 9, 10 and 11, it will be understood that M_1, M_2 . . . M_n are respectively calculated according to Formula 11, where T is the lip thickness in inches of each respective orifice opening and A in Formula 11 is the area of each respective orifice opening in square inches. It will also be understood that M_1, M_2 . . . M_n are respectively the positive reactances of the cavity as introduced by the orifice openings. F_r and V have been previously defined. M_t represents the total reactance.

Still another situation may exist where the lip thickness T defined by, say lip members **26**, **27** and **28** of the orifice **25**, are not each the same. In this situation, the reactance M of the orifice may be calculated according to the following formula:

$$M=\frac{1}{PA}[W_1(T_1+.86\sqrt{A}) + W_2(T_2+.86\sqrt{A})\ldots W_n(T_n+.86\sqrt{A}) \tag{12}$$

where P is the perimeter of the orifice in inches; W_1, W_2 . . . W_n are the respective inside widths of the respective walls forming the orifice T_1, T_2 . . . T_n are the respective thicknesses of the respective lip members; M and A are as previously defined.

Referring to Fig. 14, it will be seen that I have provided an easy method of pre-selecting the frequency at which the resonator cavity or closure member **20** will resonate. For example, assume that I wish to provide a closure member **20** having a cavity which will resonate

at 360 cycles, then by use of Fig. 14, I may then select the cross-sectional area of orifice **25** to be .785 square inch and the volume of the cavity to be 24.4 cubic inches, provided of course that the wall height of orifice **25** is .25 inch.

Theoretically, the acoustical shape of my resonant cavity, such as resonator cavity **20** as shown in Fig. 15, is different from its physical shape, since cavity C of the closure member or resonator cavity regenerates a sound when in resonance with a sound generated from an outside source. This acoustical shape I shall term as egg **300** existing around the sound switch. Egg **300** may best be visualized as the other half of a functioning resonator cavity **20**. There is usually a volume exchange of air between the egg **300** and the resonator cavity **20** when resonator cavity **20** is resonating. Pressure and rarification alternate between the egg **300** and resonator cavity **20** at a rate equal to the frequency of the sound causing resonance. In mathematical terms, the maximum radius *r* from the center of the orifice **25** to the upper surface of the egg **300** is defined as:

$$r=\frac{C_s}{4F_r} \tag{13}$$

where C_s is the velocity of sound and F_r is the frequency of the sound causing resonance. This so-called egg **300** is of importance because it is a strong reflector of the resonant frequency sound and will set up standing waves between the source of sound and the resonator cavity. Egg **300** may be thought of as refracting sound into orifice **25** and cavity **20** and reflecting that sound back largely in the direction from which the sound came, regardless of which direction orifice **25** is pointed with respect to the source of sound.

Articles or objects placed within egg **300** will tend to de-tune resonator cavity **20**. Therefore, for proper operation, egg **300** should be in open air.

Upon the generation of a sound of proper frequency from an outside source, the vibrations continually build up until egg **300** returns approximately as much energy to the air as it is absorbing. But since there is as much energy in the volume of air in cavity C as there is in egg **300** and since the volume of air in cavity C is much smaller, it follows that there is more energy per cubic inch in cavity C. Also, since egg **300** is 180° out of phase with the volume of air in cavity C, the pressure drop across the walls of resonator cavity or closure member **20** is much greater than could be expected due to the difference in size of egg **300** and the volume of air inside cavity C. This means that substantially all the energy passes through orifice **25**.

In the present invention, the diaphragm **31** and reed **33** are placed so as to engage the volume flow of air as it goes in and out of the cavity or it may be fixed so as to be effected by the difference in pressure; in either case, the diaphragm **31** absorbs vibrational energy from the air flux. This absorption reduces the size of egg **300**, egg **300** being full size only when there are no losses. Therefore, for best efficiency, the vibrator plate and reed should not be made to absorb more than 50% of the energy passing through the orifice. Thus, the diaphragm **33** should occupy from about 50% to about 75% of the area of orifice **25**. In the second embodiment, the diaphragm **131** should be larger than the hole **125** since it is disposed above hole **125**.

VIBRATOR ASSEMBLY CONSTRUCTION

Vibrator assemblies **29**, **129**, **29'** of the various embodiments are preferably made from sheet metal material such as hot rolled tin-plated steel having a thickness of about .001 inch to about .030 inch. I have found that best results are obtained if the vibrator assembly is formed of hot rolled tin-plated sheet steel having a thickness of about .010 to about .020 inch. Improved operations will also result if base **30**, **130** and **30'** are weighted by either building up a solder layer on the base or by making a double layer of metal along the base. Each of the vibrator assemblies **29**, **129**, **29'** and their respective resonator cavities **20**, **120**, **20**(*d*) are respectively tuned to the same resonant frequency. Of course, if resonator cavities **20**(*a*), **20**(*b*), **20**(*c*) are used, the same rule applies. Thus, each vibrator assembly is tuned to be in resonance with the frequency of the sound which causes actuation of the sound switch. Further, each resonator cavity or closure member is tuned to resonate at the frequency of the sound causing actuation of the sound switch.

Considering the first embodiment of my invention, it is preferable that vibrator assembly **29** be tuned such that its second harmonic is the same frequency as the frequency to be utilized in actuating the sound switch. Further, for best results, diaphragm **31** itself should have a resonant frequency of not more than 90% nor less than 10% of the fundamental or resonant frequency of the sound switch itself. It should be noted here that since the vibrator assembly is a complex device, the second harmonic of this vibrator assembly **29** is not necessarily twice or two times the fundamental frequency (first harmonic) at which it is in resonance. Thus, it is best to test vibrator assembly **29** to determine the frequency of its second harmonic.

In the second embodiment, the reed **133** and diaphragm **131** are on the same side of the supporting member, spacer plate **132**, and hence this vibrator assembly **129** is tuned to have a fundamental frequency (first harmonic) equal to the resonant frequency of the closure member of resonator cavity **120**. Thus, if resonator cavity **120** is tuned to resonate at say 200 cycles per second, vibrator assembly **129** should have a fundamental resonant frequency of 200 cycles per second. The vibrator assembly **29'** of the third embodiment should also be tuned to resonate with its resonator cavity **20**(*d*) when its fundamental frequency is the same as the resonant frequency of resonator cavity **20**(*d*).

In the second embodiment, a good rule of thumb is to make the diaphragm **131** as small as possible to still cover hole **125** and make reed **133** as long as possible to provide a reed which may be shortened to tune the vibrator assembly **129**.

In tuning the vibrator assemblies, generally, the stiffer the diaphragm, the higher is the resonant frequency, and the longer the reed, the lower is the resonant frequency. Thus, in tuning the diaphragm, more crimping or stronger flanges or peripheral crimps will raise the resonant frequency of the diaphagm. Further, shortening of the reed will raise the resonant frequency of the vibrator assembly while adding weight to the tip of the reed will lower the resonant frequency.

Therefore, the one method of constructing the vibrator assemblies is to make the diaphragm to fit the particular opening such as openings **25**, **125**, **25**(*a*), **25**(*b*), **25**(*c*), **25**(*d*) and leave the reed as long as possible. Then through a process of shortening the reed, bring the vibrator assembly into tune utilizing the testing equipment to be described hereinafter. If the reed has been cut too short, add silver to the tip of the reed.

It should be understood here that vibrator assembly **29** is operable when it is tuned to have a resonate fundamental frequency which is the same as the resonant frequency of resonator cavity or closure member **20**. It should also be understood that if the vibrator assemblies are tuned to harmonics of the fundamental frequency other than the fundamental frequency (first harmonic) or the second harmonic, they are operable but far less efficient.

In determining the resonant frequency and harmonic frequencies of the vibrator assemblies **29**, **129**, **29'**, I

have found that a capacitance pick-up or inductance pick-up such as an electrical coil or magnetic pick-up (none shown) to be useful in ascertaining when a peak vibration occurs. The coil may be appropriately connected to an audio-amplifier which, in turn, operates an ammeter to form the test equipment. For ascertaining the resonant frequency of the vibrator assembly, the coil should be positioned or held close to the reed **33**, **133** or the diaphragm **31'**. A signal generator having a speaker located close to reed **33**, **133** or diaphragm **31'** should then be actuated and the frequencies swept by changing the frequency of the sound generated until the lowest frequency peak is determined by deflection of the ammeter. This frequency is the fundamental or first harmonic of the vibrator assembly; the next lowest frequency peak determined for the vibrator assembly I consider the second harmonic.

The approximate resonant frequency for either the reed alone may be calculated utilizing the following formula:

$$(14) \qquad F_r = \frac{.5596K}{L^2}\sqrt{Q/P}$$

where F_r is the resonant frequency in cycles per second of the reed; L is the length of the reed in centimeters; Q is Young's modulus in dynes per square centimeters; P is the density of the material in grams per cubic centimeter used in manufacturing the reed and K is the thickness of the reed in centimeters divided by the square root of 12.

The reed stands up better as a contact member if it is provided with a plating or coating of silver or some other corrosive resistant electrically conductive metal on its tip. Thus, in the specifications, I have shown reeds **33**, **133**, and diaphragm **31'** with silver tips **37**, **137**, **37'**, respectively.

It should be pointed out that it is immaterial whether the vibrator assembly and contact means are located on the outside or inside of the various resonator cavities or closure members. My sound switch will operate as well if the vibrator assembly and contact means are located within the closure members, provided of course that the diaphragm is positioned adjacent the holes or apertures **25**, **125**, **25'**, respectively.

Referring now to Fig. 12, it will be seen that a given vibrator assembly **29** will vibrate over a range of frequencies at its second harmonic resonant frequency; however, it will be noted that substantially less power is necessary to cause deflection of the vibrator assembly when it is tuned to 200 cycles per second than at other frequencies on either side of 200 cycles per second. Thus, it is apparent that for best results, the vibrator assembly should be tuned accurately to resonate with the resonator cavity.

In Fig. 13, it is seen that if a sound generator is positioned to provide sound to my sound switch, which is tuned to approximately 190 cycles per second, the power generated by the resonator cavity or closure member increases as the frequency of the sound approaches the frequency at which the resonator cavity or closure member is tuned. If the vibrator assembly were arrested, the power generated by the closure member would increase as shown by broken lines in Fig. 13 to a peak at the resonant frequency of the closure member. In this instance, the vibrator assembly is tuned to resonance with the closure member and therefore absorbs a large amount of the power generated by the closure member when the vibrator assembly becomes resonant. In the plot of Fig. 13, the power generated by the resonator cavity or closure member builds up to the point where the vibrator assembly begins to vibrate and then drops drastically until the resonant frequency of my sound switch is reached, at which time the vibrator assembly is vibrating at a maximum. If the frequency is increased beyond this point, the power generated by the closure member or resonator cavity begins to increase as the vibrator assembly vibrates less and less until it shuts off at the second peak of about 200 cycles.

With the vibration of the vibrator assembly, the tip **37** of reed **33** or the tip **137** of reed **133** or tip **37'** of diaphragm **31'** vibrates rapidly and intermittently contacting points **42**, **142**, **42'**, respectively, to thus effectively close the sound switches. While I have disclosed one use of my sound switch in operating a relay, it will be understood that my sound switch may be utilized in many other ways, for either the detection of a certain frequency of sound or for the operation of an electrical device or for both.

It is to be remembered that when in operation the reeds **33**, **133** move at a much higher amplitude than diaphragms **31**, **131**, respectively. Thus, adjustment of the distance between tips **37**, **137** and contact points **42**, **142** are relatively easy and relatively minute energies of sound causing vibration of the vibrator assemblies **29**, **129** will cause marked vibration of reeds **33**, **133**. Further, frequencies of sound other than the frequency to which the sound switch is tuned will generally not actuate the sound switch.

It will be obvious to those skilled in the art that many variations may be made in the embodiments disclosed for purpose of illustration, without departing from the scope of my invention as defined by the appended claims.

I claim:

1. A frequency selective sound switch comprising a pair of acoustically driven vibrator means in close proximity to each other, each of said vibrator means being constructed and arranged for resonant vibration at substantially the same selected resonant frequency, a first electrical contact means connected to at least one of said vibrator means, and a second electrical contact means positioned in close proximity to said first electrical contact means so as to be actuated when said pair of vibrator means vibrate at said selective frequency.

2. The structure defined in claim 1 wherein said resonant frequency is from about 400 cycles per second to about 200 cycles per second.

3. A frequency selective sound switch comprising a closure member constructed and arranged for vibration at a selected resonant frequency, an electrical switch associated with said closure member, and a vibrator assembly for closing and opening said switch, said vibrator assembly being in sufficiently close proximity to said closure member as to be effected by vibration of said closure member and being constructed and arranged for vibration at substantially one predominant resonant frequency in resonance with said closure member.

4. A frequency selective sound switch comprising a resonator having a platform, said resonator being constructed and arranged to vibrate at a selected frequency, a switch in close proximity to said platform, and a vibrator assembly constructed and arranged for vibration at a predominant resonant frequency corresponding to the resonant frequency of said resonator on said platform, said vibrator assembly being adapted to be vibrated by sound of said selected frequency to actuate said switch.

5. A frequency selective sound switch comprising a closure member defining a tuned cavity, a hole in said closure member which communicates with said cavity, a vibrator assembly disposed in alignment with and partially closing said hole and in close proximity thereto so as to be contacted by air passing through said hole upon resonation of said closure member, and an electrical switch means which is actuated by vibration of said closure member and said vibrator assembly upon the generation of a sound of a frequency with which said closure member is tuned.

6. A sound switch comprising a closure member hav-

ing a cavity of predetermined resonant frequency and a hole in communication with said cavity, a diaphragm disposed in close proximity to said hole so as to be contacted by air passing through said hole upon resonation of said closure member, means supporting said diaphragm, said means contacting said diaphragm outwardly of said hole, and electrical switch means connected to said diaphragm for actuation upon the generation of a sound which will cause said closure member to resonate.

7. A sound switch comprising a closure member having a cavity and a hole in communication with said cavity, a vibrator assembly mounted on said closure member, said vibrator assembly having a diaphragm extending diametrically across said hole so as to be contacted by air passing through said hole upon resonation of said closure member, means extending from said diaphragm, said means including an electrical contact, and a second electrical contact in close proximity to said electrical contact of said reed.

8. The structure defined in claim 7 wherein said vibrator assembly and said cavity are tuned to approximately the same resonant frequency.

9. An electrical sound switch which is actuated by a sound of a predetermined frequency comprising a closure member having an open cavity and a hole, a diaphragm extending over said hole, said diaphragm partially but not completely closing said cavity, means for securing said diaphragm to said closure member, a reed extending from said diaphragm, said reed and said plate and said means being tuned to a resonant frequency, said closure member being tuned to substantially the same resonant frequency, said reed being provided with an electrical contact, a second electrical contact mounted on said closure member and being in close proximity with said electrical contact on said reed.

10. A sound switch comprising a closure member having a cavity and a hole in communication with said cavity, a base on said closure, a spacer plate mounted on said base adjacent said hole, a diaphragm projecting from said base across said hole, a narrow movable reed projecting from one edge of said diaphragm, a contact finger adjacent the free end of said reed in a position to be contacted upon movement of said reed, said reed and said contact finger respectively including electrical terminals which close when said reed contacts said finger, a rigid arm carrying said finger, and means for adjustably fixing said arm to said closure member.

11. The structure claimed in claim 10 wherein said means for adjustably fixing said arm to said closure member includes a second arm forming a base mounted on said closure member, a common body portion connecting the ends of said arms, said finger being fixed to said first mentioned arm at a position adjacent said common body portion, and means for moving the other end of said first mentioned arm to vary the position of said finger with respect to said reed.

12. In a sound switch having a diaphragm for receiving sound generations, a narrow flexible vibrateable cantilever reed projecting from said diaphragm for vibration with said diaphragm, said reed being provided with an electrical contact adjacent its free end and a second electrical contact positioned adjacent said first mentioned electrical contact.

13. The structure defined in claim 12 wherein said diaphragm and reed are tuned to vibrate at a predetermined predominant resonate frequency, and said diaphragm is a substantially rigid member.

14. In a sound switch, a base, a flat substantially rigid diaphragm affixed by one edge to said base, said diaphragm projecting from said base in cantilever fashion and being adapted to resonate, an electrical contact means affixed to said diaphragm, and a second electrical contact means adjacent said first mentioned electrical contact means.

15. In a sound switch, a base, a diaphragm having a flat surface and affixed by one edge to said base, said diaphragm extending in cantilever fashion from said base, a vibrateable reed affixed by one end to one edge of said diaphragm, said reed projecting in substantially the same plane with the flat surface of said diaphragm, said reed being provided with an electrical contact adjacent the other end thereof, electrical contact means adjacent said electrical contact, and means for adjusting said electrical contact means to move the same toward and away from said electrical contact.

16. A method of actuation of an electrical switch comprising generating a sound of a predetermined frequency, arranging a pair of resonators in tune at one predominant frequency with said predetermined frequency and in close proximity to each other, imparting a portion of the energy of the resonation of one of said resonators to the other thereof so as to increase the normal amplitude of vibration of the other of said resonators, and translating a portion of the energy from said other resonator into mechanical movement to actuate said switch.

17. The method defined in claim 16 wherein said resonators are physically connected to each other.

18. A sound switch comprising a resonator having an opening therein, said resonator being tuned to a predetermined frequency, said opening having an axis extending into said resonator, a diaphragm disposed substantially normal to the axis of said opening and in sufficiently close proximity to said opening to be contacted by air passing through said opening upon resonation of said resonator, said diaphragm being sufficiently light in weight to be affected by said air, means providing support for said diaphragm exteriorly of said opening, an electrical switch positioned on said resonator, said diaphragm carrying a portion of said electrical switch, said electrical switch being movable to open and closed positions, said diaphragm being adapted upon actuation by said air to cause the position of said electrical switch to be changed.

19. A sound switch comprising a resonator defining a cavity, said resonator having an opening thereinto communicating with said cavity and through which air passes upon resonation of said resonator, a movable diaphragm partially but not completely closing said opening and disposed in a plane substantially parallel thereto and in the path of travel of said air, and switch means actuatable by said diaphragm.

20. The structure defined in claim 19 wherein said resonator cavity resonates between 200 and 400 cycles per second.

21. In a frequency selective sound switch a resonator cavity having an opening, a diaphragm disposed in alignment with said opening so as to be contacted by air passing through said opening upon resonation of said cavity, means secured to said resonator cavity for supporting said diaphragm, said resonator cavity and said diaphragm each being tuned to essentially the same one predominant frequency, and means actuatable by said diaphragm upon resonation of said cavity and said diaphragm.

22. In a frequency selective sound switch a resonator cavity having an opening, a diaphragm disposed in alignment with said opening so as to be contacted by air passing through said opening upon resonation of said cavity, means projecting from said resonator cavity and adjacent said opening for supporting said diaphragm in spaced relationship to said opening, said resonator cavity and said diaphragm each being tuned essentially to the same predominant resonant frequency, and means actuatable by said diaphragm upon resonation of said resonator cavity and said diaphragm.

23. A method actuation of a switch comprising generating a sound having one predominant frequency, receiving said sound at a distance from its source by a resonator cavity tuned to resonate at said one predominant frequency to oscillate air in a passageway in communication with said resonator cavity and translating the move-

ment of the oscillated air into mechanical movement by means arranged to be oscillated by said oscillating air, said means partially but not completely closing said passageway.

References Cited in the file of this patent

UNITED STATES PATENTS

1,279,831	Berger	Sept. 24, 1918
1,390,768	Dorsey	Sept. 13, 1921
1,405,708	Berger	Feb. 7, 1922
1,628,723	Hall	May 17, 1927
1,672,351	Thomas	June 5, 1928

1,861,222	Minton	May 31, 1932
1,934,859	Joaquin et al.	Nov. 14, 1933
2,015,962	Praetorius et al.	Oct. 1, 1935
2,085,198	Lindsay	June 29, 1937
2,221,963	Case et al.	Nov. 19, 1940
2,509,345	Howell et al.	May 30, 1950
2,834,423	Bradford	May 13, 1958

OTHER REFERENCES

"A Textbook of Sound," by A. B. Wood, 2nd edition, published in 1941 by the MacMillan Company of New York, pages 197–201 and 472–477.