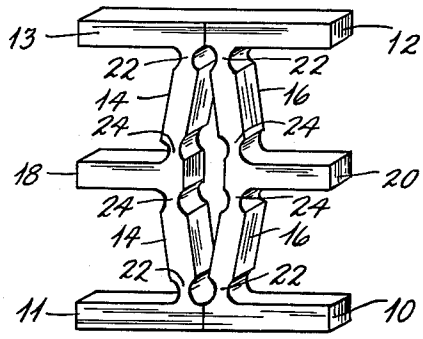
May 8, 1962 H. E. SAWYER 3,033,157

APPARATUS FOR PRODUCING SOUND WAVES

Filed Oct. 20, 1955 5 Sheets-Sheet 1

Fig. 1



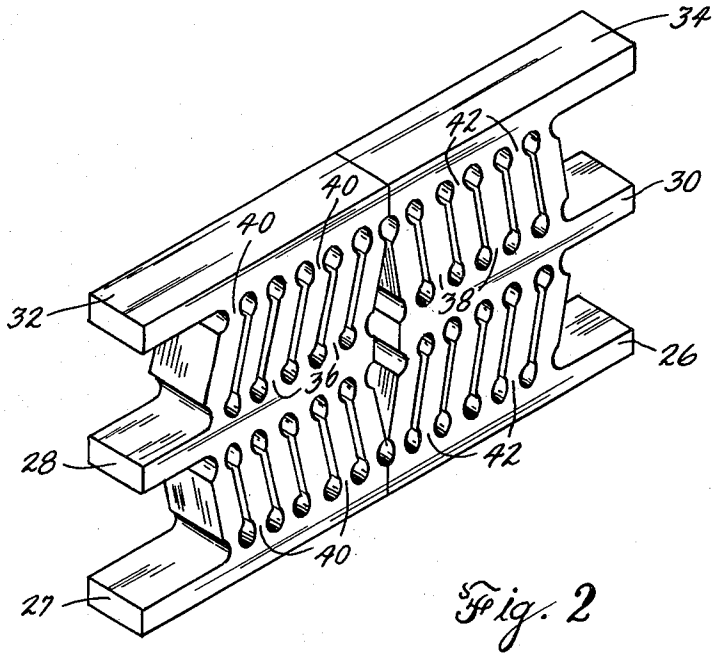


Fig. 2

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APPARATUS FOR PRODUCING SOUND WAVES

Filed Oct. 20, 1955 5 Sheets-Sheet 2

Fig. 3

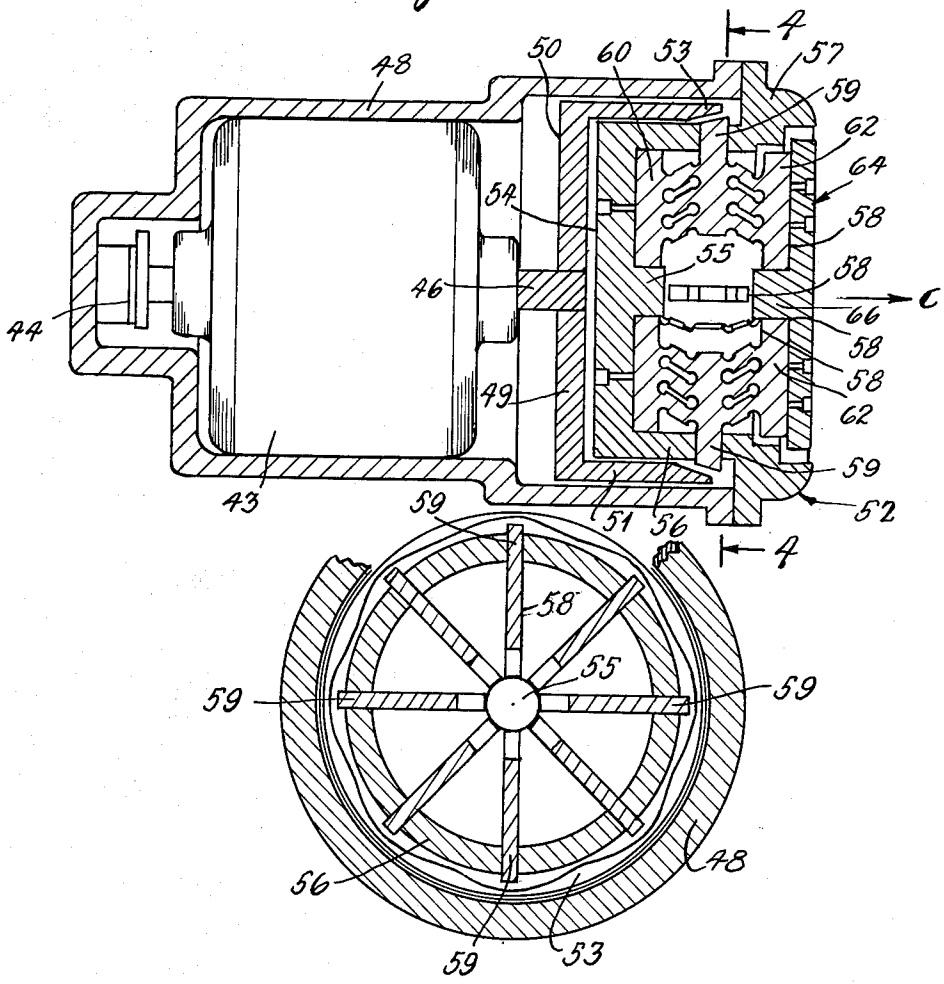


Fig. 4

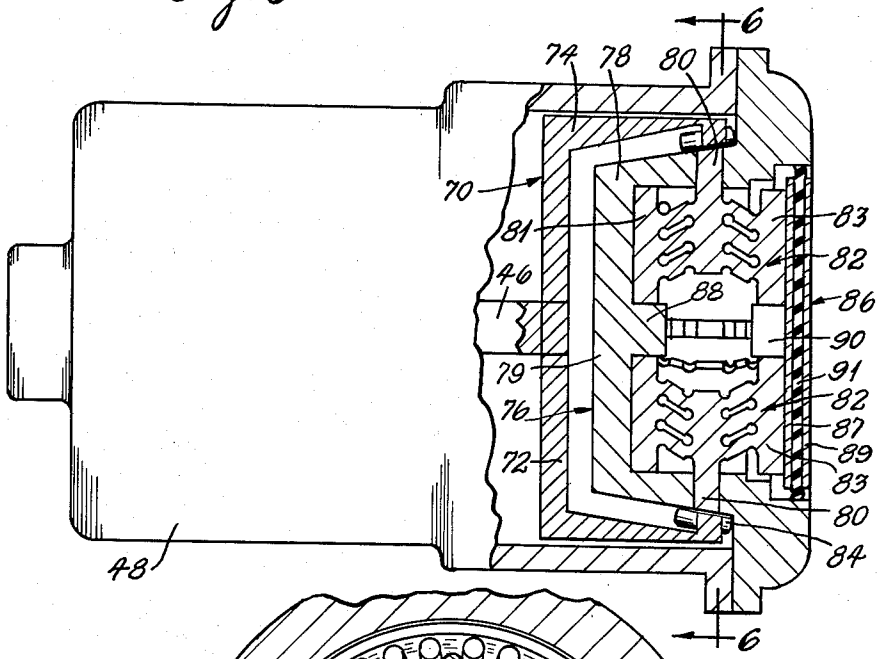
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APPARATUS FOR PRODUCING SOUND WAVES

Filed Oct. 20, 1955 5 Sheets-Sheet 3

Fig. 5



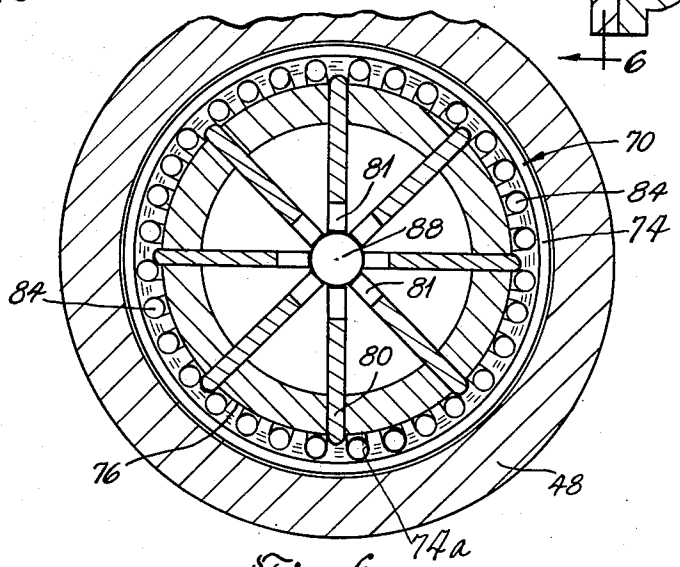


Fig. 6

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APPARATUS FOR PRODUCING SOUND WAVES

Filed Oct. 20, 1955 5 Sheets-Sheet 4

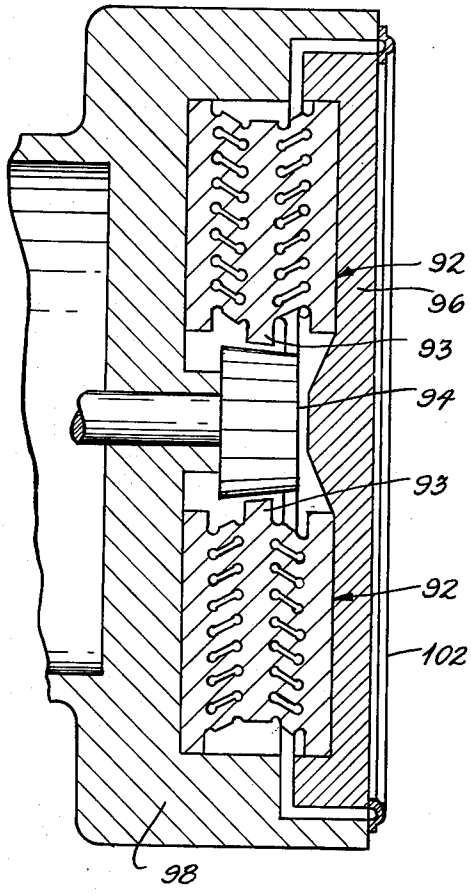


Fig. 7

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APPARATUS FOR PRODUCING SOUND WAVES

Filed Oct. 20, 1955 5 Sheets-Sheet 5

Fig. 10

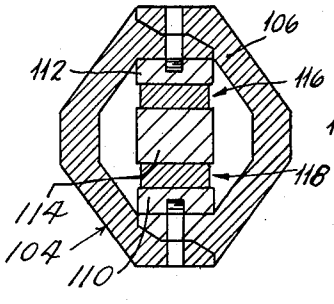
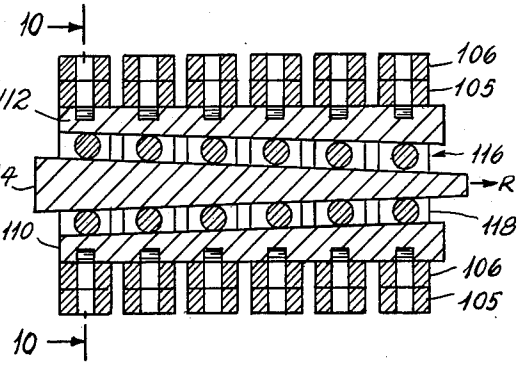


Fig. 9.



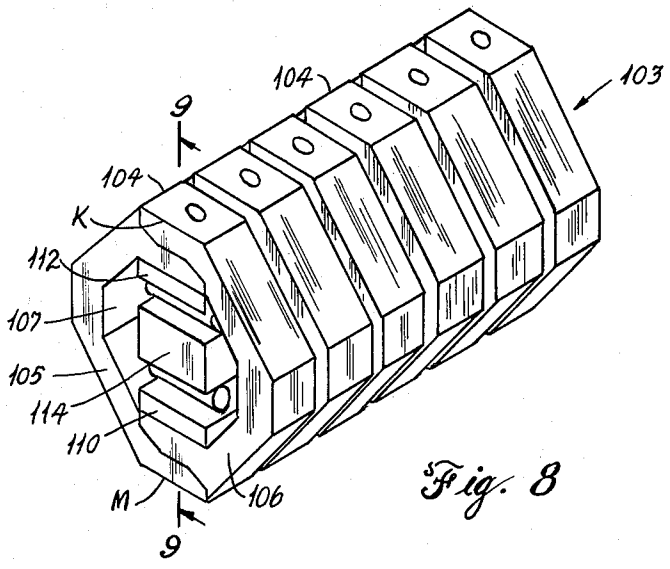


Fig. 8

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3,033,157

APPARATUS FOR PRODUCING SOUND WAVES

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Filed Oct. 20, 1955, Ser. No. 541,866
24 Claims. (Cl. 116—137)

This invention relates to mechanical vibrators and more particularly it relates to a device adaptable for use as a generator for producing sound waves.

In general, the heretofore known devices for producing sound waves have for the most part made use of piezoelectric or magnetostrictive equipment. Such devices are limited in their available power by the tendency of the vibrating elements to fracture at high sound pressure levels, and by the relatively low efficiency of conversion of electrical into acoustic power. Mechanical oscillators for producing sound waves have also been utilized. Such oscillators are so designed that the restoring force is applied to a limited area of the plate or vibrating element and the driving force is applied to one or more points on the plate which are separated by relatively large distances. The inertial or reacting forces resulting from the driving and restoring forces are meanwhile distributed more or less uniformly over the total area of the plate. The concentration of the forces which tend to move the plate coupled with the substantial uniform distribution of the reacting forces over the total plate area creates bending moments in the plate. These bending moments cause deflections of the surface of the plate thereby introducing additional degrees of freedom to the vibrating system and destroying the uniformity and velocity of all points of the vibrating surface.

It is, accordingly, the primary object of the present invention to provide a mechanical vibrator for generating sound waves wherein the vibrating element oscillates with substantially all the points of the element surface vibrating at the same velocity and in phase.

It is a further object to provide a mechanical vibrator for generating sound waves wherein there is furnished a restoring force which is applied at closely spaced points in accordance with the distribution of the forces due to inertia and radiation reaction.

It is another object to provide a mechanical vibrator for generating sound waves wherein a driving force is furnished which is applied to the same points to which the aforesaid restoring force is applied, the driving force consequently also being distributed in accordance with the distribution of the forces due to inertia and radiation reaction.

Briefly, the invention contemplates a device wherein there is a utilization of the force and amplitude transformations which are inherent in the common toggle joint but differs from the usual form of toggle construction in that the points of articulation are effectively replaced by cantilever springs. The toggle joint-cantilever spring units, whether single or multiple are considered as being used in pairs and the driving force is considered as applied equally to each end of the central knee or "drive bar" of the toggle unit. The components of acceleration and driving forces which are parallel to the vibrating element surface and drive bar are of equal value for each unit and opposite in direction for each unit of a pair. Consequently, the device is in dynamic balance in directions parallel to the piston surface.

One feature of the invention resides in the distribution of the driving force to the vibrating element over closely spaced points of application.

Another feature is the distribution of the restoring

force over the same points of application as the driving force.

Another feature resides in an amplitude and force transformation between the driven plate and the mechanical driving mechanism wherein a toggle joint in which the points of articulation are supplanted by cantilever springs is utilized as an amplitude-force transforming device between a vibrating element and a suitable drive such as a mechanical or electro-mechanical drive.

In accordance with the present invention, there is provided an apparatus for generating sound waves. It comprises a vibrating element, means for providing a periodic driving force, means for applying the driving force to closely spaced points on the surface of the element and means for applying a restoring force to the respective same closely spaced points whereby the surface of the vibrating element is forced into harmonic vibration with all points of the surface vibrating at substantially the same velocity and in phase.

Also, in accordance with the present invention, there is provided an apparatus for generating sound waves. It comprises a radial array of a plurality of pairs of multiple toggle joint-cantilever spring units in back-to-back opposing relation. Each of toggle units comprises a firmly affixed first bar, a second bar spaced from and in parallel arrangement with the first bar and a third driving bar intermediate, spaced from and substantially parallel to the first and second bars and a plurality of ribs having thinned end portions connected at an angle between the driving bar and the first and second bars respectively whereby the points of articulation of the toggle joint are effectively replaced by cantilever springs. A plate adapted to be vibrated and having one face in contact with the second bars is provided. There is also provided a motor for generating a driving force and a cam operatively associated with the motor and adapted to periodically simultaneously apply a pressure to each driving bar whereby the applied driving forces are equal and opposite in direction for each unit in a pair and parallel to the surface of the plate and whereby the application of the force to the driving bar causes the force to be applied to closely spaced points on the surface of the plate. The cantilever springs provide a driving force counteracting restoring force to be applied to the same respective points thereby forcing the surface of the vibrating element into harmonic vibration with all points of the surface vibrating at substantially the same velocity and phase. Means are included for controlling the amplitude of the applied driving force to control the displacement of the vibrating plate.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

FIG. 1 is a three dimensional representation of a pair of single toggle joint-cantilever spring units in back-to-back abutting relation.

FIG. 2 is a three dimensional representation of a pair of multiple toggle joint-cantilever spring units in back-to-back abutting relation.

FIG. 3 is a side elevation partly in section of a preferred embodiment of the invention.

FIG. 4 is a section taken along line 4—4 of FIG. 3 looking in the direction of the arrows.

FIG. 5 is a side elevation partly in section of a second embodiment of the present invention.

FIG. 6 is a section taken along line 6—6 of FIG. 5 looking in the direction of the arrows.

FIG. 7 depicts a side elevation of a portion, partly in section, of a third embodiment of the present invention.

FIG. 8 is a three dimensional representation of a wedge

and roller drive and associated U springs which may be used in the present invention in the place of the toggle joint-cantilever spring units shown in FIGS. 1 and 2.

FIG. 9 is a section taken along line 9—9 of FIG. 8; and

FIG. 10 is a section taken along line 10—10 of FIG. 9.

Referring to FIG. 1, there is shown for the purpose of explanation, a fundamental pair of toggle-cantilever spring units utilized in the device of the present invention. Two pairs of spaced substantially parallel bars 10 and 12 and 11 and 13 are linked by relatively wide angled cross arms 14 and 16, the angles thereof opening toward an imaginary line linking parallel pairs of abutting bars 10 and 11 and 12 and 13. A bar 18 and a bar 20 preferably integral with cross arms 14 and 16 extend laterally from the angles respectively thereof and substantially parallel with bars 10 and 11 and 12 and 13. In normal toggle operation, the application of a force to bars 18 or 20 which is applied parallel to the longitudinal axes thereof tends to widen the angles of cross arms 14 and 16 so that bars 10, 11 and 12, 13 tend to move further apart. However, if it is considered that bars 10 and 11 are firmly affixed to an immovable backplate, the arcuate thinning 22 of cross arms 14 and 16 at the points of articulation and at the junctions 24 between the angles thereof and bars 18 and 20 in effect supplies a device which combines toggle and cantilever spring action. Accordingly, it is seen that with the firm affixation of bars 10, 11 to an immovable backplate and the application of a driving force to either bar 18 or 20, bars 12, 13 will be caused to move away from bars 10, 11 and the cantilever spring will supply the restoring force which will tend to bring bars 12, 13 to and past its original position so that with this arrangement and a periodic application of a driving force to bars 18 and 20, bars 12, 13 will vibrate.

FIG. 2 shows a multiple toggle-cantilever spring device consisting of two multiple units in abutting or back-to-back relation. As in the structure of FIG. 1, bars 26 and 27 which may be called exterior strips, parallel to one another, are equivalent to bars 10 and 11 of FIG. 1 and are intended for firm affixation. Bars 28 and 30 which may be called interior strips, parallel to one another, are the member to which the driving force is applied, bars 32 and 34 form the vibrating bar and cross arms generally designated as 36 and 38 respectively having narrowed portions at the points of articulation 40 and 42 provide the cantilever spring tensioning action for producing a restoring force to counteract the driving force. It is seen that application of a driving force applied to bars 28 and 30 are opposite in direction resulting in a dynamic balance in directions parallel to the surface of bars 32 and 34.

In the embodiment of the present invention in FIGS. 3 and 4, there is shown a suitable motor 43 which is preferably dynamically balanced and associated thrust screws 44 and drive shaft 46 which is suitably mounted in an outer case 48. A cam 50 is mounted on drive shaft 46 and adapted to be rotated thereby. Cam 50 may be described as a cylinder closed at one end with wall 49 and having a substantially circular side wall 51. The open end portion 53 of side wall 51 has a scalloped tapered inner perimeter substantially as shown in FIG. 4. Received within cam 50 is a massive cylinder 52 having an end wall or abutment 54 and a circular side wall 56, the side wall 56 having a flanged open end portion 57 which makes an abutting contact with case 48. Extending from the center portion of end wall 54 is a boss 55. Firmly seated within cylinder 52 between boss 55 and side wall 56 and having a bar bolted to end wall 54 is a radial array of toggle-cantilever spring units 58 similar to those shown in FIG. 2. As shown in the embodiment of FIGS. 3 and 4 a radially disposed array of 8 such units are shown with the drive bars 59 thereof extending through openings in the wall 56. The openings are substantially equispaced and arranged in one plane so that the units are each disposed along radii and radially displaced an equal distance from each other. A piston or vibrating element 64 having a boss 66 extending inwardly from the center portion thereof is firmly affixed by bolting or other suitable means to bars 62 of units 58. When vibrating element 64 is affixed in position, bosses 55 and 66 are substantially in register. The ends of driving bars 59 are tapered to make a substantially abutting contact with the end portion 53 of side wall 51 when cam 50 is moved axially toward drive bars 59. In FIG. 4, it is seen that the scalloped inner perimeter of end portion 53 of side wall 51 results from eight equal convexities. It is further seen that the high points of each of the convexities will strike a drive bar simultaneously and corresponding points on the convexities will also strike the drive bars simultaneously.

In operation, motor 43 runs continuously, ideally at resonance speed as will be explained further herein below. Cam 50 is moved axially to make contact with the ends of drive bars 59. The end portion 53 is so tapered that the amplitude of displacement is increased as the cam moves toward bars 59. The scalloped inner perimeter of end portion 53 is so cut as to provide a harmonic motion of the drive bars 62. Considering two diametrically opposed units 58, when diametrically opposed convexities ride along the ends of driving bars 59, the driving forces are applied in opposite directions parallel to the exposed or outside surface of element 64. Due to the presence of multiple toggle units, the driving force is applied to linearly aligned equispaced points on the inner surface of element 64 causing element 64 to move in the direction of the arrow C, the distance being determined by the distance that cam 50 has been axially moved toward element 64. The cantilever spring tensioning action now supplies a restoring force at the same points where the driving force has been applied. Realizing that with a radial array of 4 pairs of diametrically disposed multiple units 58, the driving and restoring force is applied at a multiplicity of points on element 64, it is seen that there is provided a means whereby the radiating surface of element 64 is forced into harmonic vibration with all points of the surface vibrating at the same velocity and the same phase. The toggle units 58 in which the points of articulation are supplanted by cantilever springs serves as the amplitude-force transforming device between the mechanical drive and the vibrating element. Ideally, motor 43 may be run at resonance speed, i.e., the vibration frequency of element 64. For example, if it is desired that element 64 vibrate at 800 cycles per second, with the radial array of eight drive bars in FIGS. 3 and 4, cam 50 would be rotated at 100 r.p.s. or 6000 r.p.m. In the device, the toggle units may consist of hard brass and housing 48, cylinder 52, cam 50 and vibrating element 64 may consist of suitable rigid metallic materials. It is to be noted that in the present device, vibrating element deflections are reduced to a small percentage of the amplitude of motion. Also, the use of toggle leverage between the vibrating element and the rotating cam effects substantial modification of the vibrating element amplitude and forces thus permitting greater unit pressures at the vibrating element and greater mechanical tolerances of the mechanical driving mechanism than would be feasible otherwise.

The embodiment of the present invention shown in FIGS. 5 and 6 accomplishes the same result as that of FIGS. 3 and 4 and is substantially similar thereto. However cam 50 of the device of FIGS. 3 and 4 has been replaced by cylindrical member 70 consisting of end wall 72 and side wall 74. The inner periphery of the side wall is tapered so that its thickest portion is where it extends from end wall 72 and it is thinnest at the other end. The outer periphery of the side wall 78 of cylinder 76 is correspondingly tapered. The drive bars 80 of tog-

gle units 82 extend through circumferentially disposed openings through side wall 78. A roller drive is peripherally disposed around cylinder 76 in register with the ends of drive bars 80, the rollers 84 thereof being so spaced that all the driving bars are simultaneously contacted by rollers when member 70 is rotated. As in the device of FIGS. 3 and 4, bars 81 of units 82 are suitably affixed to end wall 79 and vibrating element 86 is suitably affixed to bars 83 of units 82. Bosses 88 and 90 extend from the center portions of the inner surface of wall 79 and the inner portion of element 86.

In operation, as cylinder 74 is moved to the right in FIG. 5, it presses rollers 84 against the prepihery of side wall 78. Upon rotating cylinder 74, rollers 84 move in a circular path about the periphery of cylinder 76 in the plane of the axes of driving bars 80. This causes the periodic simultaneous application of a driving force to bars 80 and consequently to a multiplicity of spaced points on element 86. The toggle joint-cantilever spring units 82 in turn apply the restoring force at the same points on element 86 as where the driving force was applied and a harmonic vibration of element 86 ensues similar to that described in the device of FIGS. 3 and 4. Plate 86 may consist of a sandwich arrangement of relatively rigid flat metal plates 87 and 89 having a sealing medium 91 therebetween, the sealing medium serving to prevent any fluid from entering into the device when it is vibrated in a liquid medium.

The embodiment of FIG. 7 is substantially the same as that of FIGS. 3 and 4 except that the toggle units 92 are not seated in back-to-back relation but are arranged so that the driving bars 93 thereof are in opposing relation. Cam 94 is a tapered polygonal cone, the number of sides thereof corresponding to the number of driving bars to be contacted during its rotation. The ends of the driving bars 93 are tapered to be substantially parallel with the sides of cam 94. As with device of FIGS. 3 and 4, the amount of displacement of vibrating element 96 is dependent on the distance that cam 94 is axially moved thereto. During rotation, the strongest contact between bars 93 and cam 94 is made when the bars contact the junction angle of the sides of cam 94. Units 92 are suitably affixed to cylinder 98 and vibrating element 96 is secured to units 92 in a like manner as that described in connection with the devices of FIGS. 3 and 4 and FIGS. 5 and 6. In the event that device is being used as a vibrator in a liquid medium, a ring seal 102 is provided to prevent any of the liquid from entering into the device.

In FIGS. 8, 9, and 10, there is shown another embodiment of a restoring force means and an amplitude and force transformation means. A linearly aligned array 103 comprising spaced parallel disposed U springs 104 consisting of members 105 and 106 respectively provides a relatively long inner bore which may be of circular or polygonal configuration and an outer perimeter which is also polygonal in its cross-sectional aspect. In the embodiment shown, an octagonal configuration is utilized. An outer polygonal configuration is preferred so that the vibrating element which is generally of plate-like structure may have a relatively flat surface with which to be in contact. In FIG. 8, the vibrating element may rest against surface K and the array 103 may be firmly affixed at surface M to a rigid anchored surface. Colinearly disposed within bore 107, is an arrangement comprising bars 110 and 112 having a length which is a bit greater than the length of bore 107 and a width which is substantially equal to the width of one side of the inner polygonal perimeter. One face of bars 110 and 112 is flat to permit abutting contacts thereof respectively with diametrically opposed sides of the inner perimeter. The other face (FIG. 9) respectively of bars 110 and 112 is inclined, the direction of inclination being the same for each bar so that a wedge-like space is provided therebetween. A wedge 114 is disposed in the wedge-like space so that its face substantially matches the inclined faces of bars 110 and 112. Interposed between the inclined faces of the bars and the faces of the wedge are two linearly aligned arrays 116 and 118 of spaced parallel disposed rollers which make contact with the inclined faces of the bars and the faces of the wedge.

In operation, assuming that the vibrating element is affixed to surface K and array 103 is firmly secured at surface M, it is seen that when wedge 114 is moved in direction R, the vibrating element will be displaced. The tensioning action of the U springs provides the restoring force which is applied at the same points as the driving force. A motor and associated rotating cam which is cut to produce a harmonic motion may be utilized to cause a vibratory movement in the vibrating element.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

I claim:

1. An apparatus for generating sound waves comprising a vibrating element; a toggle unit having two rigid extremities, one of said extremities being anchored, the other of said extremities being in intimate contact with a surface of said vibrating element, a driving bar intermediate said extremities, and a plurality of spaced cantilever springs arranged in a row and connected between said driving bar and each of said extremities; means for generating a driving force; means for applying said driving force directly to said bar in a direction endwise of the bar; and means for controlling and varying the amplitude of said driving force whereby the application of the driving force to said driving bar causes said force to be applied to closely spaced points on the surface of said vibrating element and whereby said cantilever springs provide a driving force counteracting restoring force to be applied to said same respective closely spaced points thereby forcing the surface of said vibrating element into harmonic vibration with all points of said surface vibrating at substantially the same velocity and in phase.

2. An apparatus for generating sound waves comprising a plurality of pairs of multiple toggle joint-cantilever spring units in back-to-back relation, each of said units comprising a firmly affixed first bar; a second bar spaced from and in parallel arrangement with said first bar, a third driving bar intermediate, spaced from and substantially parallel to said first and second bars and a plurality of ribs having thinned end portions connected at an angle between said third driving bar and said first and second bars respectively whereby the points of articulation of the toggle joint are effectively replaced by cantilever springs; a plate adapted to be vibrated and having one face in contact with said second bars; a motor for generating a driving force; means for periodically applying said driving force to said third driving bars comprising a cam operatively associated with said motor and adapted to periodically simultaneously apply a pressure to each driving bar respectively of said multiple toggle joint-cantilever spring unit pair whereby the applied driving forces are equal for each unit in a pair and parallel to the surface of said plate and whereby the application of said force to said driving bar causes said force to be applied to closely spaced points on the surface of said plate, said cantilever springs causing a restoring force to be applied to said same respective points thereby forcing the surface of said vibrating element into harmonic vibration with all points of said surface vibrating at substantially the same velocity and in phase; and means for controlling the amplitude of said applied driving force.

3. An apparatus for generating harmonic mechanical vibrations in a rigid member in phase across its entire exposed face, comprising a rigid vibrating element of plate-like shape having a planar exposed face; means including a motor for providing a periodic driving force; means for transforming and transmitting said driving

force to closely spaced points on the surface of said element of equal pressure and amplitude of movement in unison and phase across it and for applying said driving force and a counteracting restoring force to said same closely spaced points and of equal pressure and amplitude of movement in unison across it; means for periodically applying said driving force to said force transforming means in a direction substantially parallel to the surface of said element; and means for varying the amplitude of said driving force, wherein said transforming means comprises a radial array of pairs of multiple toggle joint-cantilever spring units in back-to-back opposing relation and arranged in pairs, with the units of each pair in diametrically aligned radial relation, each of said units comprising, a firmly affixed first bar, a second bar spaced from and in parallel arrangement with said first bar, a driving bar intermediate, and spaced from and substantially parallel to said first and second bars and a plurality of ribs having thinned end portions connected at an obtuse angle between said driving bar and said first and second bars respectively.

4. An apparatus as defined in claim 3 wherein said means for applying said driving force to said transforming means comprises a cam operatively associated with said motor and adapted to periodically apply a pressure concomitantly to all of said driving bars whereby the applied driving forces to the units of each pair are equal, opposite in direction and substantially parallel to the surface of said vibrating element.

5. An apparatus as defined in claim 3 wherein said means for applying said driving force to said transforming means comprises a radial array of rollers disposed in substantially the same plane as said driving bars and means operatively associated with said motor and said rollers for causing said rollers to periodically simultaneously make contact with all of said driving bars whereby the applied driving forces to the driving bars of the unit of each pair are equal, opposite in direction and substantially parallel to the surface of said vibrating element.

6. An apparatus as defined in claim 3 wherein said transforming means comprises a linear array of spaced U springs having at least two diametrically opposed parallel sides along the longitudinal aspect of said array both in its inner and outer periphery, said inner and outer sides being in substantially parallel relation, two members each having an inclined face and a flat face, each of said flat faces being in contact with said inner sides, said inclined faces being disposed to provide a wedge-like opening therebetween; a wedge member disposed within said opening, the faces of the wedge being inclined in directions opposite to that of the corresponding opposing faces of said members and linear arrays of spaced parallel disposed rollers between each of the wedge faces and the faces of said members respectively.

7. A device for producing harmonic mechanical, sound creating vibrations in a fluid medium, which comprises a vibratory element exposed on a planar face thereof to said fluid medium in which said vibrations are to be created, an abutment, toggle means interposed between said abutment and element and operable against said abutment to vibrate said element forcibly in a direction normal to its exposed face and of uniform amplitude of movement across its entire face, said means including a bar extending lengthwise along and secured to the face of said element opposite from said exposed face, another bar extending lengthwise along and engaging said abutment, a driver bar interposed between and parallel to said other bars and connected to each of said other bars by a plurality of links arranged in pairs along said driver bar, with one link of each pair extending between, and having cantilever spring connections at its ends to, said driver bar and the bar engaging said abutment, said bars and links being integral with one another, and the other link of each pair extending generally in the opposite direction to said one link of that pair between, and articulately connected at its ends to, the driver bar and the bar secured to said element, the links of each pair normally making with each other an obtuse angle, whereby when one applies to said driver bar, in a direction lengthwise of it, a periodic force tending to increase the obtuse angle between said links toward a straight angle said element will be advanced in a direction normal to its face, and means preventing endwise movement of said first two mentioned bars, said links of each pair having a yielding, resilient bias resisting their approach toward a straight angle, whereby in the periods between applications of said periodic force, said links of each pair will automatically return to their said normal positions.

8. The device as set forth in claim 7, and means for selectively applying said periodic force that may be adjusted to control the amplitude of movement of said driver bar at each application of a periodic force and thereby control the amplitude of vibration of said element.

9. A device for producing harmonic mechanical sound creating vibrations in a part, with all points of an exposed planar face of said part vibrating at the same velocity and amplitude, and in phase, which comprises said pact as a rigid element exposed on a face thereof to the medium through which said vibratiaons are to be transmitted, a relatively fixed bar, a movable bar approximately parallel to said fixed bar and extending along in abutting contact with and secured to said element, a driver bar interposed between, spaced from, and parallel to said other bars, a group of links arranged in side by side, but spaced apart, parallel relation to one another and in a row in the space between said driver bar and the relatively fixed bar and flexibly non-pivotally connected at their ends to those bars, another group of links arranged in side by side but spaced apart, parallel relation to one another and in a row in the space between said driver bar and the movable bar, and flexibly connected at their ends to those bars, the links on one side of the driver bar making the same obtuse angles with those on the opposite side of the bar, the links of both groups all progressing in the same general direction along the driver bar to form toggles with the bars, whereby periodic endwise movement of said driver bar relatively to the other bars, will cause vibrations of said element in directions normal to its said exposed face and in phase across it.

10. The device as set forth in claim 9, and means for applying said periodic force to said driver bar.

11. The device as set forth in claim 10 wherein said means for applying said periodic force is selectively adjustable to vary the amplitude of vibration of said element under said periodic forces.

12. The device as set forth in claim 9, wherein two similar sets of said bars and connecting links are provided, but with direction of progression of the links of one set directly opposite to the direction of progression of those of the other set and said sets being disposed in end to end alignment, whereby when said periodic forces are simultaneously applied in opposite directions to the driver bars of the two sets, the forces tending to move each set in the direction of said forces applied thereto will balance those of the other set.

13. A device for producing harmonic mechanical sound creating vibrations in a part in a third medium in which such part may be exposed, with all points of an exposed face of the part vibrating at the same velocity and amplitude and in phase, comprising a rigid element to be vibrated having a face thereof exposed to the fluid medium in which sound waves are to be transmitted, a relatively fixed abutment spaced from and generally parallel to said element to be vibrated, means including a row of individual members interposed between said abutment and said element arranged side by side at similar angles, different than right angles and straight angles, to said element face, with corresponding ends connected to one another and operable when moved into positions in which their longitudinal axes more closely approach

directions normal to said exposed face to force said element in a direction away from said abutment, said members having a continuing bias resisting said approach to said positions in which they would be normal to said exposed face, and means for applying to said members periodic forces urging them solely against said bias toward positions in which they would be normal to said exposed face.

14. The device as set forth in claim 13, wherein there are two of said first means each including a row of members arranged in opposition alignment to those in the other row, with the members of one row progressing in the opposite direction from those of the other row, and said means for applying forces to the members operable for applying the periodic forces to the members of one row in a direction opposite to that to which the periodic forces are applied to the members of the other row.

15. A device for producing sound creating vibrations of a part having an exposed face, with all points of said exposed face vibrating at the same velocity and amplitude and in phase, comprising a pair of parallel but spaced apart elements in aligned side by side relation, one of said elements having a rigid face exposed to a fluid medium in which vibrations are to be produced, means interposed between said elements for spacing them and connected to said element with said exposed face but opposite from that rigid face, said means including a plurality of arms some of which are arranged at the same angle other than a straight angle to those of the other part and other than normal to said exposed face, means applied to said arms separately from said elements for moving said arms in directions approaching normals to said exposed face, and thus separate said elements, said arms having a bias away from said normals and cause retraction of said element with said exposed face toward the other of said elements, and means for applying periodic forces to said interposed means solely in directions opposed to said bias and separately from said elements for causing approach of said arms toward positions in which they are normal to said exposed face.

16. A device for producing sound creating vibrations of a part having an exposed face, with all points of said exposed face vibrating at the same velocity and amplitude and in phase, comprising a flexible, elastic member highly resistant to endwise compression and having the property when released of always returning to its original size and shape, said member being plate-like with slots therein between an interior strip and parallel side strips, said slots on one side of said interior strip being approximately parallel to one another and making acute angles to the length of said interior strip, the said slots on the other side of said interior strip being also approximately parallel to one another and make similar acute angles of the same degree to the length of said interior strip, said slots all progressing outwardly and in the same direction along the interior strip, but with those on opposite sides of the interior strip making obtuse angles other than straight angles with each other, whereby when said interior strip is forced in a direction lengthwise of itself while one of its side strips is held against movement in a direction lengthwise of itself, said member will be distorted and said slots will approach positions normal to the interior strip, which distortion pushes the side strips apart, the inherent resiliency of said member resisting said distortion and restoring the member to its original position when the distorting force is removed, a rigid element to be vibrated attached to one side strip for movement therewith, and means for anchoring the other side strip against movement in a direction toward and from said element to be vibrated, whereby when periodic distorting forces are applied to said interior strips to compress them endwise at a selected frequency said element to be vibrated will be caused to vibrate at such frequency.

17. The device as set forth in claim 16 wherein ends of said slots are widened to cause the distortion to occur in flexing of the ends of the portions between said slots.

18. A device for producing sound creating vibrations of a part having an exposed face, with all points of said exposed face vibrating at the same velocity and amplitude and in phase, comprising a cup-shaped shell having a circumferential row of equally spaced apart radial passages and a central cylindrical abutment in its interior, a plurality of flat, elastic, flexible plate-like members, which will resume its original shape and size when free to do so, disposed in said shell in positions radial to said abutment and each having an interior longitudinal strip thereof extending at its outer end outwardly through one of said passages and its inner end spaced from said abutment, a rigid element to be vibrated extending in a direction across the open end of said cup but having its periphery spaced from the periphery of the shell, the planes of the faces of said members being parallel to the longitudinal axis of said shell, one side strip of each member abutting the interior bottom wall of said shell and confined against endwise movement between said abutment and the interior periphery of said shell, the other side strip of each member being secured to and supporting said element floatingly in the open face of said shell, each member having one row of parallel slots therethrough from face to face between said interior strip and one side and another similar row between the interior strip and the other side strip, the slots all making similar acute angles to the length of the interior strip and progressing in the same direction along the length of the interior strip, whereby when the outer ends of the interior strips are forced in a direction inwardly of the shell the members will be equally distorted to separate the side strips of each member as the slots approach positions perpendicular to the lengths of the members, and thus carry said element in a direction out of the shell, and means for applying to all of the outer ends of said interior strips and at the same times, periodic forces inwardly radial of said shell to cause simultaneous similar endwise compressions on all of said members and outward movement of said element equally and in phase across its entire face area, said force applying means causing endwise compressions of said members at selected frequencies.

19. The device as set forth in claim 18 wherein said slots are wider at their ends to cause distortion to occur largely adjacent the ends of the slots.

20. A device for producing sound creating vibrations of a part having an exposed face with all points of said exposed face vibrating at the same velocity and amplitude and in phase, comprising a pair of elements, a member interposed between and abutting said elements spacing them and having side strips connected to an interior strip by rows of resiliently flexible arms that have substantial rigidity against endwise compression, said arms of each row being parallel to one another and making similar acute angles to the length of said rows, with the arms of one row making similar angles with those of the other row, means for compressing the interior strip of said member in an endwise direction separately from said side strips at the apexes of said angles endwise of itself relatively tosaidside strips at the outer ends of the arms to increase the obtuse angles between the arms towards straight angles and thus separate said side strips, one of said elements being secured to one of said side strips, the other of said side strips being fixed to the other of said elements, whereby when periodic compressive forces are applied endwise to said interior strip of said member, said one of said elements will be given vibrations of equal velocity and amplitude and in phase uniformly across its entire face.

21. The device as set forth in claim 20, and means for applying said periodic forces.

22. A device for producing sound creating vibrations of a part having an exposed face, with all points of said ex-

posed face vibrating at the same velocity and amplitude and in phase, comprising a pair of elements, one of which is relatively fixed and the other of which is relatively movable, a rigid part fixed at one face to said movable element and having its other face exposed in the medium in which mechanical vibrations are to be produced, a plurality of angular members interposed between, arranged in a row along and connecting said elements and operable upon movements tending to straighten said members to separate said elements, said angular members being formed of a material which is laterally flexible and elastic and substantially resistant to endwise compression, and means for applying directly to said members periodic forces of suitable frequencies in directions tending to straighten the members and cause movement of said part in one direction of equal velocity and amplitude and in phase across its exposed face, the inherent resiliency of said members retracting said movable element and through it said part, between said periods of applied force.

23. A device for producing sound creating vibrations of a part having an exposed face and an opposite face, and causing all points of said exposed face to vibrate at the same velocity and amplitude and in phase, which comprises said part, a relatively fixed abutment adjacent to and aligned with but spaced from said opposite face of said part, plate-like elements interposed edgewise between and engaging and spacing apart said part and said abutment and abutting flat against and connected to said opposite face of said part so as to have contact with said opposite face near a margin of that face and also at a plurality of intermediate portions of that opposite face, said element having a plurality of parallel interior slots providing therein a plurality of angular struts in a row along it that are flexible laterally at their ends but rigid against endwise forces and extend generally in directions between said part and said abutment, means for applying driving vibratory forces to said elements that tend to straighten said struts and move said part away from said abutment, said struts having inherent resiliency that causes them to return to normal angular conditions when said forces are decreased.

24. A sound creating device comprising a stationary element having an abutment face, a flat vibratory element having an exposed face disposed parallel to said abutment face, a plate-like member of stiff, flexible material disposed between and spacing said elements with its edges abutting and fixed to the adjacent faces of said elements, said plate-like member having in its interior area two rows of slots arranged side by side but spaced apart, with the rows extending parallel to each other and to said faces of said elements, the slots in each row being parallel to one another and all making acute angles to the planes of such faces, the slots in each row extending generally in opposite directions away from the part of said member between the rows, and means for applying to the said part of said member between the rows periodic impulses, corresponding to the frequency of sounds to be created, in directions parallel to the lengths of the rows, whereby the arms formed by the spaces between the slots in each row will act like a plurality of toggle arms that tend to straighten under such impulses, and cause vibratory movements of said vibratory element in directions normal to its exposed face at a frequency corresponding to that of the impulses applied to said member.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

May 8, 1962

Patent No. 3,033,157

Harold E. Sawyer

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 8, line 23, for "pact" read -- part --; same column, line 62, for "third" read -- fluid --.

Signed and sealed this 11th day of September 1962.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
Commissioner of Patents