Dec. 10, 1963 G. H. HUFFERD ET AL 3,114,059

PIEZOELECTRIC VOLTAGE SOURCE

Filed Aug. 31, 1961

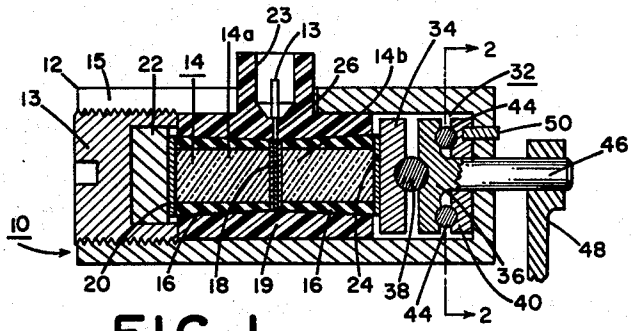


FIG. 1

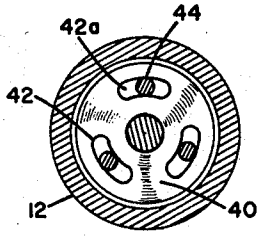


FIG. 2

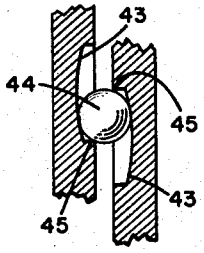


FIG. 3a

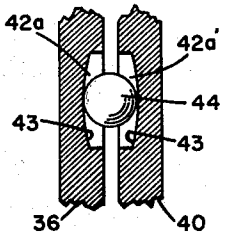


FIG. 3

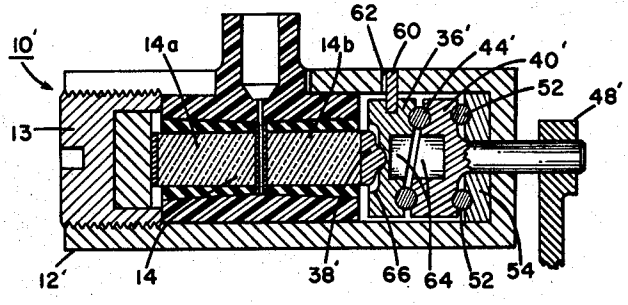


FIG. 4

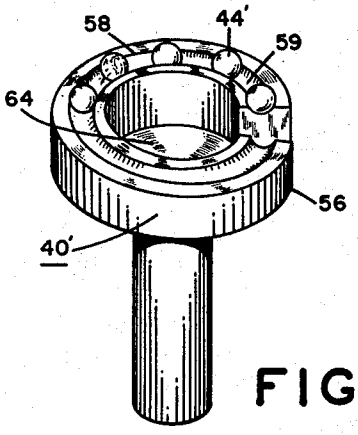


FIG. 5

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PIEZOELECTRIC VOLTAGE SOURCE

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This invention relates to improvements in piezoelectric voltage sources and has particular reference to an improved pressure actuating mechanism for squeezing a piezoelectrically responsive ceramic or single crystal element and for releasing same.

An object of the invention resides in the provision of a piezoelectric generator and a mechanical pressure actuator therefor adapted to be employed in conjunction with devices that require periodically an electric charge or spark.

A further object resides in the provision of a voltage source of the character indicated which employs an inclined plane to obtain mechanical advantage for gradually compressing the piezoelectrically responsive ceramic element.

A still further object resides in the provision of a voltage source which can provide four electric potentials per oscillating cycle, the device being particularly suited for use as a spark generator in a multicylinder engine ignition system.

For a better understanding of the present invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawings, and its scope will be pointed out in the appended claims.

In the drawings:

FIGURE 1 is a longitudinal sectional view of the piezoelectric voltage source;

FIGURE 2 is a transverse sectional view on the line 2—2 of FIGURE 1;

FIGURE 3 is an enlarged fragmentary view of the cam members in neutral position, and FIGURE 3*a* is a similar view illustrating the cam members in rotated position;

FIGURE 4 is a longitudinal sectional view through a modified piezoelectric voltage source;

FIGURE 5 is a perspective view of a cam member of the device shown in FIGURE 4.

An aspect of the invention resides in the provision of a piezoelectric voltage source which comprises a housing means rigid against longitudinal expansion; piezoelectric element means having first and second end faces and a longitudinal axis normal thereto, the element means being longitudinally mounted in the housing with the first end face thereof being restrained by the housing means to prevent its movement and with the second end face thereof being spaced from the housing; electrical insulating means insulating the piezoelectric element means; cam means of a given longitudinal length mounted along the axis and being in effective engagement with the piezoelectric element means and in effective bracing engagement with the housing means, the cam means having a rotatable cam portion, a cooperating cam portion and an actuating means connected to the rotatable cam portion, at least one of the cam portions having a cam surface inclined relative to the longitudinal axis of the piezoelectric element means and in effective bearing engagement with a cooperating cam surface on the other cam portion, whereby upon cyclic motion of the actuating means the rotatable portion rotates first in one direction and then in the reverse direction to increase the given longitudinal length of the cam means and to then return the cam means to its given length to squeeze and release the piezoelectric element means.

Referring now in greater detail to the single sheet of drawing wherein similar reference characters designate corresponding parts throughout, there is shown, in FIGURE 1, a piezoelectric voltage source 10 capable of use as an alternating voltage or electric spark generator. The voltage source 10 includes a housing 12 of steel or like material rigid against longitudinal expansion and having a normally open end closed by an externally threaded plug 13 held in place on the housing 12 by complementary threads on the housing.

Within the housing 12 there is secured a piezoelectric crystal element 14, preferably though not necessarily comprised of two separate cylindrical elements 14*a* and 14*b* mounted end-to-end and comprised of polycrystalline ceramic material such as barium titanate, lead titanate zirconate or the like, suitably polarized, electroded and electrically grounded so that, upon squeezing, a high voltage potential is established near the center of the two ceramic elements. The two piezoelectric elements shown, 14*a*, 14*b*, are mechanically in series and electrically in parallel. Such elements, when squeezed, generate a high voltage and have sufficient storage capacity and internal resistance to hold the charge for a considerable period of time.

To facilitate a proper electrical connection with a hot lead 13 there is disposed between the ceramic elements 14*a* and 14*b* a plurality of thin aluminum discs 18. These aluminum discs serve to distribute the pressure across the center of the elements. This ensures that the forces which are applied on the elements are uniformly distributed over the cross-sectional area. This is to avoid fractures of the ceramic elements due to shear or compressive stresses.

The outer end faces of ceramic element 14*a*, 14*b* abut thin aluminum plates 20, 24, respectively. The thin metal plates 20 and 24 establish, in combination, an electrical ground connection for the ceramic elements 14*a* and 14*b* and, in addition thereto, uniformly distribute the compressional forces acting upon the end face of the ceramic element 14*b* as hereafter described. A heavy metal end plate 22 is interposed between plug 13 and the aluminum plate 20, and in combination these members restrain the movability of ceramic element 14*a*. The plug 13 can serve to preload the ceramic elements in the housing 12 and enables periodic adjustment.

The other surfaces of the ceramic elements 14*a* and 14*b* are suitably enclosed by a protective sleeve 16 of moisture resistant insulating material. A protective plastic housing 19 having electrical insulating qualities suitably encloses the elements 14*a* and 14*b*, including the sleeve 16 surrounding the elements. The plastic housing 19 has, adjacent to the aluminum discs 18, a narrow bore 26 and a collar 23 to receive the hot lead cable 13 which is inserted through the bore 26 for electrical coupling with discs 18.

From the foregoing description those versed in the art will appreciate that a piezoelectric response in the form of an electric potential is obtainable by axially squeezing the ceramic elements 14*a*, 14*b* and, more particularly, by applying pressure against the outer end face of thin plate 24 in a direction substantially coaxial to the longitudinal axis of the ceramic elements.

The piezoelectric elements 14*a* and 14*b* are compressed by a cam mechanism 32 which is mounted in the housing 12 filling the space between the thin plate 24 and outer portions of the housing. The cam mechanism has a normal longitudinal length which is increased to compress or squeeze elements 14*a*, 14*b* as hereafter described. The mechanism 32 and the plastic housing 19 are loaded into the housing 12 from the open end of the housing, the latter having a slot 15 through which the collar 23 ex-

tends so that the size of the collar 23 presents no assembling difficulties.

Cam mechanism 32 comprises a stationary cam member 40 and a rotatable and axially displaceable cam member 36 separated by bearing balls 44 which are mounted in such a position that when members 36 and 40 are rotated in relation to each other a cam action takes place and the balls force a further separation between the two members to increase the longitudinal length of mechanism 32. This displacement of cam member 36 is transmitted axially to circular disc 34 which is in operable engagement with the ceramic elements.

Cam members 36 and 40 are coaxially disposed within housing 12 and member 40 is formed of a metal disc and secured stationary within the housing by virtue of pin 50 protruding through the housing 12 into disc 40. Cam member 36 is of similar configuration and material as member 40, and cam member 36 is disposed within the housing with a sliding fit; the member 36 is provided with a stem 46 which extends centrally and slidably through member 40 and housing 12. A handle 48 is mounted at one end to the stem 46.

Interposed between the cam members are bearing balls 44, each of which is confined in two pockets 42*a* and 42*a'*, one of which, 42*a*, see FIGURE 3, is located in one cam member and the other, 42*a'*, is located in registering and cooperating position in the other cam member. Each member 36, 40 has a plurality of pockets or depressions, see FIGURE 2, each of which is in registering position with the other cooperating pocket. The pockets are disposed equidistantly in circular array about the common axis of members 36, 40. Each pocket 42 has an inclined cam surface 43, see FIGURES 3 and 3*a*, which is in effective cooperating relationship with the cam surface of the registering pocket. This arrangement is best illustrated in FIGURE 3 in which pocket 42*a* is machined into disc 36 and the registering pocket 42*a'* is machined into stationary member 40.

The bearing balls 44 are initially in the center position as shown in FIGURE 3. In operation when handle 48 is turned to impart through stem 46 rotary movement to cam member 36 relative movement between the latter member and stationary cam member 40 takes place. Upon clockwise rotation of the handle 48 the pockets of member 36 are moved out of registering position until ball 44 abuts restraining walls 45 in the cam members as shown in FIGURE 3*a*, thereby blocking any further clockwise movement. A counter-clockwise movement is similarly limited by the confines of the pockets.

It will be noted that as the cam member 36 rotates, each ball 44 in each pocket 42 is forced to roll on the tapered cam surface 43 of each pocket, e.g., 42*a* and 42*a'*, thereby forcing the cam members apart. This in turn causes an axial displacement of cam member 36 in the direction of the ceramic element.

Interposed between the ceramic element 14 and the cam member 36 is a slidably disposed circular disc 34. The disc 34 and cam member 36 are mounted within the housing in an end-to-end relationship and interposed between them is a self-aligning load transmitting bearing member 38 slidably supported and confined in suitable depressions in disc 34 and cam member 36. Preferably, the bearing 38 is spherical and coaxially mounted with respect to the longitudinal axis of the element 14.

The disc 34 is disposed within the housing 12 with a loose fit so that, upon application of pressure, the major face of the disc 34 can tilt and align itself with the end face of the ceramic element 14*b* so that the compression that is applied upon the elements is substantially coaxial. This is to prevent fracture of the ceramic material and, moreover, to satisfy the need for symmetrical alignment of the mechanical and electrical axis for proper piezoelectric response.

The elongation of cam mechanism 32 and more directly the axial displacement of disc 34 causes the element 14 to be gradually squeezed or compressed whereby a piezoelectric response is obtained in the form of a high electric potential near the aluminum discs 18 which may be grounded or transmitted through the hot lead 13 to any desirable device or apparatus.

The longitudinal length of the cam mechanism 32 is automatically decreased to its normal length by virtue of the spring-like action inherent in a piezoelectric device of this type acting against the cam mechanism 32 and this is effective to return the low friction balls 44 to their neutral position. The release of compression in the ceramic element 14 causes a second potential to be set up near the center of the ceramic elements 14*a* and 14*b*.

Since this device operates equally well with cam member 36 rotating either clockwise or counter-clockwise, it is possible to drive the lever 48 in either direction so that four potentials can be produced during any given oscillating cycle. This is possible because the self-restoring cycle is completed when the balls 44 are again near the center of the pocket and any further advance of these balls on the inclined cam surface 43 in the other direction will, again, cause a squeezing action of the ceramic elements.

While the embodiment shown in FIGURE 1 may be constructed as aforedescribed, it is readily apparent that the increase in length of cam mechanism 32 may be established by mounting cam member 40 rotatably and cam member 36 may be mounted for axial displacement and held against rotational motion.

FIGURE 4 illustrates a modified piezoelectric voltage source. The piezoelectric elements 14*a* and 14*b* are mounted, insulated, and secured in like manner as above described.

The instant inventive concept follows the inclined plane principle, shown and described with respect to FIGURE 1, for translating rotary movement to linear or axial movement. In this embodiment cam member 40' is rotatably mounted within the housing 12', but is not axially displaceable; a plurality of ball bearings 52 are interposed between cam member 40' and a back-up plate 54 is mounted end-to-end with member 40'. The end face 58 of cam member 40' forms a surface which is inclined relative to the longitudinal axis of this member 40'. More particularly, the inclined surface constitutes a spiral-like ramp, see FIGURE 5, having an annular groove 59 to receive rollably therein a plurality of ball bearings 44' between cam member 40' and axially movable cam member 36' which forms an identical inclined surface as the one just described. The inclined surface of member 36' is in cooperating relationship with the inclined spiral-like surface of member 40'.

The cam member 36' is slidably mounted within the housing 12' and is prevented from rotating by a pin 60 which protrudes through slot 62 in the housing 12' and into the member 36'. The longitudinal width of slot 62 in the housing permits axial displacement of cam member 36'. The members 36' and 40' each have a central bore which together form the aperture 64 which is filled with a grease-like lubricant.

When the lever 48' is rotated, relative movement between cam members 36' and 40' takes place. The bearing balls 44' are forced to roll on the ramps 58 and cam member 36' is moved up on the ramp of cam member 40' whereby cam member 36' becomes axially displaced. The rotary movement of cam member 36' is of necessity limited to less than one full turn. The instant device requires rotary movement of the cam member 36' not substantially greater than 20 degrees.

In operation, the axial movement of cam member 36' continues until the rotary motion of the lever is terminated and/or a stopper (not shown) on the ramps blocks any further movement of the balls. Turning lever 48' forces the balls to roll on the ramp as aforestated, moving the cam member 36' in the direction of element 14. When the balls reach the highest level on the ramp that

has been selected to coincide with the approximate completion of the squeezing cycle, a high electric potential is developed and transmitted through disc 13 as aforedescribed and rotary motion of lever 48' is simultaneously terminated. The cam member 36' is now mechanically unbiased in the direction of element 14 with respect to member 40' and, by virtue of the natural tendency of element 14 to act as a spring, the element 14, after termination of the squeezing action, expands axially until it has reached its normal length and state. The expansion of elements 14 in the direction of the cam member 36' has the effect of forcing the cam member 36' to move downward on the ramp 58 and restoring the cam member to its original position so that the balls 44' are again at their lowest possible position on the ramp.

Upon return of the piezoelectric ceramic elements to their normal length, a second electric potential is released.

The cam plate 36' is not in direct contact with the piezoelectric element 14*b* (although this is possible) but a load and force transmitting bearing member 38' is interposed therebetween. The load bearing 38' has the additional function of aligning itself with respect to the physical symmetry of the end face of element 14*b* so that the forces transmitted through member 38' are always suitably applied to the elements. Cam member 36' has a depression 66 which registers with the dome-shaped bearing 38' and cooperates to maintain the bearing in operating position.

While there have been described what are at present considered to be the preferred embodiments of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

We claim:

1. A piezoelectric voltage source comprising: housing means rigid against longitudinal expansion; piezoelectric element means having first and second end faces and a longitudinal axis normal thereto, said element means being longitudinally mounted in said housing with said first end face thereof restrained by said housing means to prevent its movement and with said second end face thereof spaced from said housing; electrical insulating means insulating said piezoelectric element means; cam means of a given longitudinal length mounted along said axis and being in effective engagement with said piezoelectric element means and in effective bracing engagement with said housing means, said cam means having a rotatable cam portion, a cooperating cam portion and an actuating means connected to said rotatable cam portion, at least one of said cam portions having a cam surface inclined relative to the longitudinal axis of said piezoelectric element means and in effective bearing engagement with a cooperating cam surface on the other cam portion, whereby upon cyclic motion of said actuating means said rotatable portion rotates first in one direction and then in the reverse direction to increase the given longitudinal length of said cam means and to then return said cam means to its given length to squeeze and release said piezoelectric element means.

2. A piezoelectric voltage source according to claim 1, and bearing means rollably interposed between said rotatable cam portion and said cooperating cam portion.

3. A piezoelectric voltage source comprising, in combination: housing means rigid against longitudinal expansion; piezoelectric element means having first and second end faces and a longitudinal axis normal thereto, said element means being mounted in said housing with said first end face thereof restrained by said housing means and with said second end face thereof spaced from said housing means; electrical insulating means surrounding portions of said piezoelectric element means; cam means of a given normal longitudinal length mounted along said axis in said space between said second end face of said element means and said housing means, portions of said cam means being axially movable therebetween; said cam means having first and second relatively rotatable cam portions, each of said cam portions having a cam surface inclined relative to said longitudinal axis and being in effective cooperating relationship with each other; bearing means rollably interposed between said inclined cam surfaces; actuating means connected to said cam means and extending outside of said housing means to impart relative rotation to said cam portions to increase the given longitudinal length of said cam means and squeeze said element means to generate an electric potential.

4. A piezoelectric voltage source according to claim 3, and automatic means for decreasing the longitudinal length of said cam means to its normal length after said element means is squeezed to generate a second electric potential.

5. A device according to claim 3, including a self-aligning load transmitting member operably associated with said cam means to automatically align the physical symmetry of one of said cam portions with respect to said element means.

6. A device according to claim 3, wherein each of said inclined cam surfaces is comprised of a spiral-like ramp formed substantially at right angle to said longitudinal axis.

7. A piezoelectric voltage source comprising, in combination: housing means rigid against longitudinal expansion; piezoelectric element means having first and second end faces and a longitudinal axis normal thereto, said element means being mounted in said housing with said first end face thereof restrained by said housing means and with said second end face thereof spaced from said housing means; electrical insulating means surrounding portions of said piezoelectric element means; cam means of a given normal longitudinal length mounted along said axis in said space between said second end face of said element means and said housing means, portions of said cam means being axially movable therebetween; said cam means having first and second relatively rotatable cam portions, each of said cam portions having a plurality of pockets disposed in circular array about said longitudinal axis, each pocket of one cam portion having a cam surface arranged in effective cooperating relationship with a similar cam surface in a pocket of the other cam portion, and each of said surfaces being inclined relative to said axis; bearing means rollably interposed between said inclined cam surfaces; actuating means connected to said cam means and extending outside of said housing means to impart relative rotation to said cam portions to increase the given longitudinal length of said cam means and squeeze said element means to generate an electric potential.

8. A device according to claim 7, wherein the inclined cam surface of each pocket comprises a spiral-like ramp formed substantially at right angle to said longitudinal axis.

9. A device according to claim 7, including a self-aligning load transmitting member operably associated with said cam means to automatically align the physical symmetry of one of said cam portions with respect to the second end face of said element means.

10. A device according to claim 7, and automatic means for decreasing the longitudinal length of said cam means to its normal length after said element means is squeezed to generate a second potential.

No references cited.