Aug. 20, 1963 G. H. HUFFERD ETAL 3,101,420

DISTORTED BEARING PIEZOELECTRIC VOLTAGE SOURCE

Filed Nov. 6, 1961

2 Sheets-Sheet 1

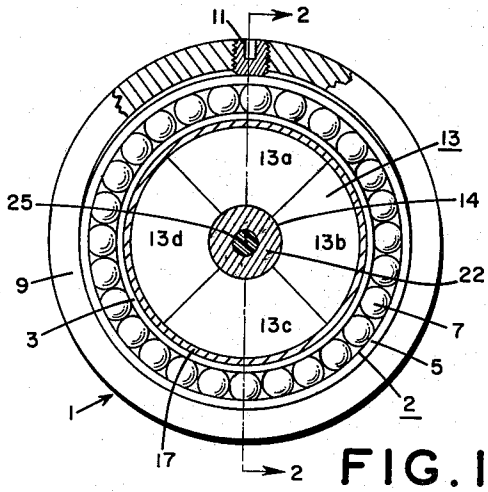


FIG. 1

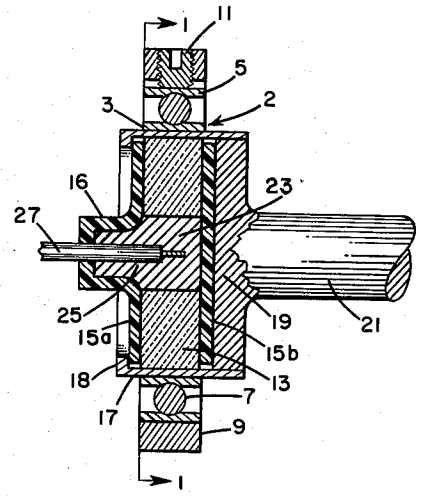


FIG. 2

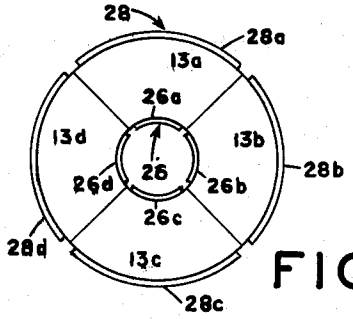


FIG. 1a

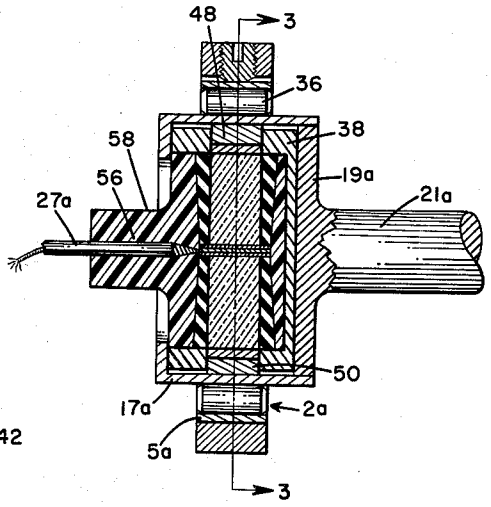


FIG. 4

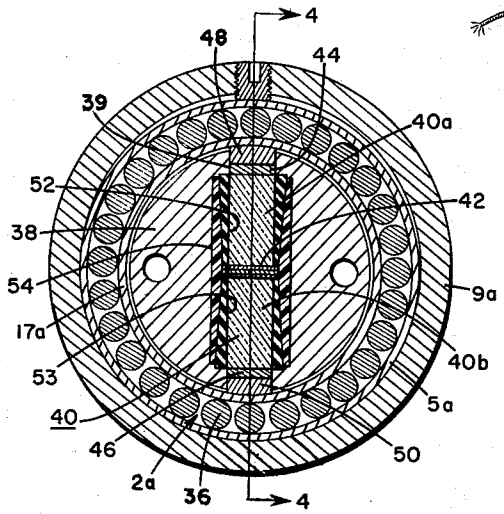


FIG. 3

INVENTORS
GEORGE H. HUFFERD
ROBERT H. JOSEPHSON
ALFRED L.W. WILLIAMS

BY

ATTORNEY

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2 Sheets-Sheet 2

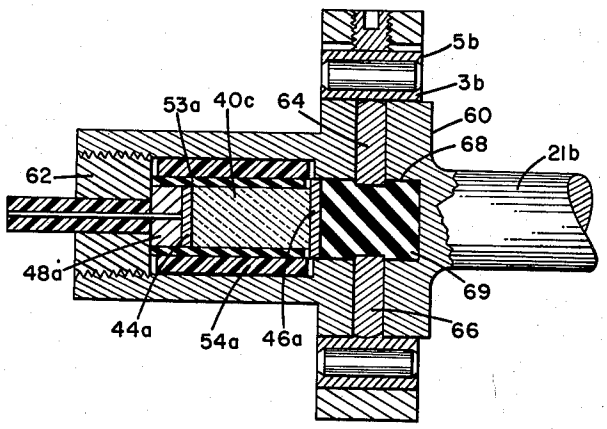


FIG. 5

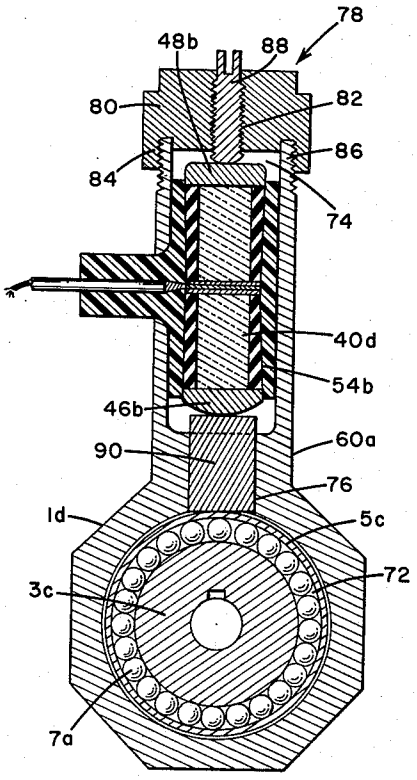


FIG. 6

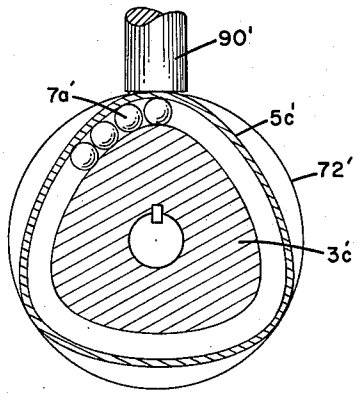


FIG. 7

INVENTORS
GEORGE H. HUFFERD
ROBERT H. JOSEPHSON
ALFRED L. W. WILLIAMS

BY

ATTORNEY

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3,101,420
DISTORTED BEARING PIEZOELECTRIC VOLTAGE SOURCE

George H. Hufferd, Lyndhurst, Robert H. Josephson, Cleveland Heights, and Alfred L. W. Williams, Cleveland, Ohio, assignors to Clevite Corporation, a corporation of Ohio

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19 Claims. (Cl. 310—8.7)

This invention relates to improvements in piezoelectric voltage source devices and, particularly, to improvements in the mechanism for squeezing a piezoelectrically responsive ceramic or crystal element used in such devices.

An object of the present invention resides in the provision of a voltage source of the character indicated which employs a low friction distorted radial bearing to alternately squeeze and release an element piezoelectrically responsive in compression to generate an electric potential.

A further object of this invention resides in the provision of a distorted bearing actuator for piezo electric devices in which the area of stress or load application is comparatively larger than in devices known in the prior art. The objective is to effect a reduction in actuator wear and, moreover, a reduction in actuation load on the stress area to reduce metallurgical qualitative requirements of the stressed or actuated member.

A further object resides in the provision of a voltage source of the character indicated which is particularly suited for use as a spark generator in a multi-cylinder engine ignition system and can provide 2, 4, 6, 8 or more electric potentials at engine camshaft speed.

A further object resides in the provision of a voltage source which can provide a continuous electric potential in the form of steady state high voltage alternating current, whereby the need of a transformer is obviated in many applications.

A still further object of this invention resides in the provision of a device which can be used in association with an engine ignition system to manually control the point of maximum compression of the piezoelectric element relative to the position of the piston in the engine.

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 plan view partly in section of a distorted bearing voltage source taken along line 1—1 of FIGURE 2;

FIGURE 1*a* is a detailed plan view of a component shown in FIGURE 1;

FIGURE 2 is a longitudinal sectional view taken along line 2—2 of FIGURE 1;

FIGURE 3 is a plan view of a modified voltage source shown partly in section taken along line 3—3 of FIGURE 4;

FIGURE 4 is a longitudinal sectional view taken along line 4—4 of FIGURE 3;

FIGURE 5 is a longitudinal sectional view of a modified piezoelectric voltage source;

FIGURE 6 is a view similar to FIGURE 5 illustrating still another modification of the piezoelectric voltage source; and

FIGURE 7 is a diagrammatic view of the principle of operation embodied in FIGURE 6.

An aspect of the present invention resides in the provision of a piezoelectric voltage source which comprises a radial bearing including a first and a second bearing race having a common axis and adapted for relative rotation, the first race being distorted and the second

race being distortable out-of-round relative to the axis; and piezoelectric element means mounted in load transmitting engagement with the second race whereby, upon relative rotation between the races, a load established by the distortion is applied to the piezoelectric element to generate a voltage.

Referring now in greater detail to the drawings, wherein similar reference characters designate corresponding parts throughout, there is shown, in FIGURES 1 and 2, a piezoelectric voltage source 1. The voltage source 1 includes a rolling contact radial bearing 2 comprised of an annular inner race 3 and an annular outer race 5, the races being coaxially disposed relative to each other. In the preferred embodiment the inner and outer races 3, 5 are preferably formed of flexible metallic material. Each annular race provides a bearing surface radially spaced from the common axis of the races 3, 5. Rollably interposed between the annular inner and outer races are a plurality of ball bearings 7 which are suitably restrained between the races to insure a low friction engagement when relative rotation between the inner and the outer race takes place.

A distorting ring 9 circumferentially surrounds the outer race 5 for distorting the bearing races out-of-round relative to the common axis thereof. The distorting ring 9 is formed of rigid material having an inside diameter which is slightly larger than the outside diameter of the outer race 5. A set screw 11 extends radially through the ring 9 and engages the outer race 5. The above noted distortion of the outer race is established by advancing the set screw 11 against the outer race until the outer race has taken on an out-of-round configuration of predetermined proportions.

The position of the set screw 11 thus fixes the out-of-round distortion of the normally annular outer race 5. In the distorted condition the races are shaped so that the smallest diameter is in a radial plane extending through the central axis and the center portion of the set screw 11. The largest diameter across the bearing is located at an angle of about 90 degrees relative to the location of the smallest diameter. Since the inner race 3 is constructed of flexible material and the ball bearings are interposed between the inner and outer races, the inner race is distorted out-of-round to the same degree as the outer race.

Mounted coaxially within the inner race 3 is a piezoelectric element 13 in the form of a circular disc having a central aperture 14. The space defined by aperture 14 is filled by a rigid conducting member 23 constructed of electricity conducting material. A narrow circular opening 25 in member 23 is adapted to receive a terminal or cable 27. The outer faces of the disc 13 are protected by plastic top and bottom covers 15*a*, 15*b* having insulating qualities. The top cover 15*a* has an axial projection 16 which surrounds member 23, and a central opening 24 in the top cover registers with opening 25. The bottom cover 15*b* is interposed between the piezoelectric element 13 and a support flange 19. The flange 19 is integrally connected with rotatable shaft 21. An annular sleeve 17 is disposed with a press fit between the outer radial surface of element 13 and the inner race, one axial end of the sleeve is securely connected to the radial surface of support flange 19, and the other end forms a radial flange 18 which overlaps and abuts the top cover 15*a*. The sleeve 17 thus serves to maintain the covers 15*a*, 15*b* in place, and establishes a rigid connection between the shaft 21 and the element 13 so that when the shaft is rotated, the disc 13, the sleeve 17 and the inner race 3 rotate in unison with shaft 21 while the outer race 5 and the distorting ring 9 are held stationary by means not shown. The sleeve 17 is constructed of flexible material to permit radial load transmittal.

The piezoelectric disc **13** may be composed of crystal elements or piezoelectrically responsive ceramics. Preferably, the disc is comprised of polycrystalline ceramic material such as barium titanate, lead titanate-zirconate or the like, and includes a plurality of circular sectors **13***a*, **13***b*, **13***c* and **13***d* which have been polarized in alternate directions as hereafter described.

The element **13** is polarized to be piezoelectrically responsive. More particularly, see FIGURE 1*a*, sections **13***a* and **13***c* are polarized by connecting, for instance, a positive terminal of the poling supply (not shown) to electrodes **26***a*, **26***c* on the inner circumference and a negative terminal to electrodes **28***a*, **28***c* on the outer circumference of the element **13**. The adjoining circular sectors **13***b* and **13***d* are both polarized in the opposite direction, that is, with the negative terminal of the poling supply connected to electrodes **26***b*, **26***d* on the inner circumference and the positive terminal to electrodes **28***b*, **28***d* on the outer circumference.

For poling it is necessary to have all electrodes separated. It is not necessary after the poling operation to keep electrodes on the inner circumference (**26**) or the electrodes on the outer circumference (**28**) separated, as the piezoelectrically generated electric fields are parallel (not antiparallel) in all four sectors.

As aforestated, the element **13** is placed within sleeve **17** and the latter is suitably secured within the inner race **3**. The adjusting screw **11** is forced against the outer race to force an out-of-round condition of the inner and outer races, the sleeve and the piezoelectric disc. This pressure, imposed upon the piezoelectric element, is effective to place sections **13***a* and **13***c* under compression in the radial direction and sections **13***d* and **13***b* under tension in the radial direction. For this case, with poling fields as described in the preceding paragraph, the piezoelectrically generated field is uniform in a radial direction, with negative charges on the outer electrode (**28**), and positive charges on the inner electrode (**26**). The electrodes **28***a* . . . *d* on the outer circumference are connected together by contact with sleeve **17** to form one terminal which is grounded. The electrodes **26***a* . . . *d* on the inner circumference are also connected together by virtue of their contact with member **23**. With 90 degrees of rotation sectors **13***d* and **13***b* are under compression and sectors **13***a* and **13***c* are under tension, causing a reversal of the generated piezoelectric voltage. Further reversals take place with each 90 degrees of rotation, thus forming as the disc rotates a steady state alternating current, with two complete voltage cycles for each revolution of the shaft **21**.

Those versed in the art will appreciate that relative rotation between the races can be established by rotating only the inner race as aforedescribed or, alternatively, by rotating the outer race **5** and the distorting ring **9**, only, or by rotating the inner and outer races in opposite directions. Counter-rotating the races is effective to convert, theoretically, a two-lobed arrangement to a four-lobed device by driving, for example, the outer race at the same rotational speed as the inner race, but in the opposite direction.

In an engine application where the invention is used in an ignition system for spark firing and shaft **21** is driven in timed relation to the rotation of an engine camshaft, manual control of the point of maximum compression of piezoelectric element **13** relative to the position of the piston in the engine (neither are shown) can readily be established to advance or retard the spark firing by turning the normally stationary outer race in one direction or the other relative to the shaft **21**.

FIGURES 3 and 4 illustrate a modified piezoelectric voltage source which utilizes a distortable rolling contact radial bearing **2***a* to apply a compressive stress to piezoelectric element **40**.

More particularly, in this embodiment the bearing **2***a* comprises an outer race **5***a* and an inner race is constituted

by sleeve **17***a*. Roller bearings **36** are placed between sleeve **17***a* and outer race **5***a* obviating the need of a separate inner race.

A round mounting base **38** is placed coaxially within sleeve **17***a* without engaging the inner surface of the sleeve **17***a*. The base **38** is suitably supported by and connected to support member **19***a* of shaft **21***a*. The base is formed of rigid material and provides a chordally extending slot **39** (not visible as such) to receive in the slot the piezoelectric element **40** and protective enclosures **52**, **53** and **54** hereafter further described. The piezoelectric element **40** is comprised of two separate cylindrical elements **40***a* and **40***b* mounted end-to-end and manufactured of polycrystalline ceramic material of the type above described.

The piezoelectric elements **40***a* and **40***b* during manufacturing are suitably polarized to be piezoelectrically responsive in compression, and are electroded and electrically grounded so that upon application of a compressive force a high voltage potential is generated. The two elements **40***a* and **40***b* are mechanically in series and electrically in parallel by being mounted with the like poles to the center. To facilitate a proper electrical connection with terminal **27***a* there is disposed between the ceramic elements **40***a* and **40***b* a plurality of thin aluminum discs **42**. The outer end faces of ceramic elements **40***a* and **40***b* abut aluminum discs **44** and **46**, respectively, to provide electrical ground connection for the piezoelectric elements and to complete the electrical circuit.

Each element **40***a*, **40***b* is suitably enclosed by a protective cylindrical sleeve **52**, **53**, respectively, of moisture resistant insulating material. A protective plastic housing **54** having electrical insulating qualities suitably encloses the elements **40***a* and **40***b*, including sleeves **52**, **53** surrounding the elements. The plastic housing **54** has, adjacent to the aluminum discs **42**, a narrow bore **56** and a collar **58**, see FIGURE 4, to receive the terminal **27***a* which is inserted through bore **56**.

The discs **42**, **44** and **46** serve to uniformly distribute the compressional forces acting upon the elements **40***a*, **40***b* to insure symmetrical alignment of the mechanical axis with respect to the electrical axis of the piezoelectric elements.

A heavy metal end plate **48** is disposed in slot **39** between disc **44** and sleeve **17***a* (inner race) and a similar plate **50** is interposed between disc **46** and the sleeve, both plates **48** and **50** engage the sleeve **17***a* at diametrically opposed ends.

The diameter across the outer radical faces of metal plates **48** and **50** is greater than the diameter of the mounting base **38** so that the plates protrude radially outward to form shoulders positioned to transmit loads.

In operation the device functions in the same manner as the device previously described. Rotation of shaft **21***a* establishes relative rotation between the sleeve **17***a* and the outer race **5***a*. The distortion ring **9***a* maintains the outer race **5***a* in a fixed out-of-round condition. The shape of sleeve **17***a* is, by virtue of engagement with roller bearings **36**, parallel to that of the outer race. Again, the radial distance between any given point on the outer circumference of the sleeve **17***a* and the central axis varies during circumferential progression of sleeve **17***a* since the distortion of the sleeve is not fixed. This variation in the radial distance establishes a load which is applied to the plates **46** and **48** which transmit this load onto elements **40***a* and **40***b* and a high voltage electric potential is generated at the point of maximum compression. Upon rotating base **38** further relative to the outer race, the compression upon the elements is gradually released with the complete release occurring approximately 90 degrees relative to the point of maximum compression or squeezing action whereupon another electric potential is generated.

The device is thus capable of generating four electric

potentials per revolution which are releasable through terminal 27*a*.

FIGURE 5 is another modification of the principal device embodying the same basic features of above described devices. A hollow housing 60 is coaxially disposed with respect to the inner and outer races 3*b* and 5*b*, respectively, and is constructed integral with shaft 21*b*.

A single piezoelectric element 40*c* is mounted longitudinally in the housing and is suitably enclosed by a protective sleeve 53*a* and a housing 54*a* composed of insulating material.

Abutting one end face of the element 40*c* is an aluminum disc 44*a* which constitutes the hot side of the piezoelectric element. Longitudinal displacement of the element is prevented by a threaded plug 62 detachably inserted in housing 60. The space between disc 44*a* and the plug 62 is filled by a heavy metal end piece 48*a*. The plug may also be used to pre-load the piezoelectric element. Abutting the other end face of the element 40*c* is a second aluminum disc 46*a* which serves as a ground connection.

The housing includes two radially extending and oppositely located cylindrical load transmitting plungers 64 and 66. The outer radial ends of the plungers engage the inner periphery of the inner race 3*b* and the opposite ends of plungers 64, 66 are illustrated extending slightly into a hollow chamber 68 which is filled with hydraulic means 69, such as rubber; the rubber is in operative load applying engagement with the ceramic element.

In the free (unstressed) condition the outer radial ends protrude beyond the cylindrical periphery of the housing 60 and, upon relative rotation between inner and outer races 3*b*, 5*b*, the plungers are displayed radially toward and into the hydraulic means 69. A hydraulic effect is established by forcing the plungers into the rubber. That is to say, the rubber is forced against the piezoelectric element compressing the latter along its longitudinal axis, whereby the piezoelectric element generates an electric potential. Upon release of the compressive force acting against the element 40*c*, a second electric potential is generated. A further description is contained in co-pending application U.S. Serial No. 183,830, assigned to the same assignee as the instant application.

The voltage source 1*d* shown in FIGURE 6 is a further modification of the basic device and FIGURE 7 illustrates diagrammatically an exaggerated three-lobed cam to facilitate better perception of this embodiment. Prime marks are affixed to the numbers to identify the corresponding components that are hereafter described.

The voltage source 1*d* includes a hollow housing 60*a* having a permanent substantially circular chamber 72 and a longitudinally extending chamber 74; the latter chamber is located radially with respect to chamber 72. A radially extending connecting bore 76 is located in the housing 60*a* between chambers 72 and 74.

In the circular chamber 72 are coaxially disposed a cylindrical outer bearing race 5*c* formed of flexible material and a cam-shaped inner race 3*c*. The inner race 3*c* is connected to a rotatable shaft (not shown) so that the inner race can be rotated to establish relative rotation between the inner and the outer races. The shape of this inner race may be two-lobed, three-lobed, four-lobed or more, depending upon the use to which it may be put. The inside diameter of the circular chamber 72 is slightly larger than a circle which would exactly circumscribe the high points of the outer race 5*c*. The high points or lobes are equidistantly distributed about the center of the cam, in actual practice the distance from the high point will be approximately .010 inch greater than the distance from the low point to the center. To avoid excessive friction, ball bearings 7*a* are interposed between the inner and the outer race.

The chamber 74 carries a longitudinally extending piezoelectric element 40*d* and a plastic housing 54*b* of the type shown in FIGURES 3 and 4 and as described in

connection therewith. Abutting one outer end of element 40*d* is a heavy metal plate 48*b* which is held in position by a pre-load and adjustment screw 78. The screw 78 comprises a cap 80 having a centrally located threaded bore 82 and providing a threaded female extension 84 which mates with end portion 86 of housing 60*a*. A threaded stem 88 is carried in bore 82 and an end portion thereof protrudes beyond the bore and engages the heavy metal plate 48*b*. The force with which stem 88 acts against the plate 48*b* can be adjusted to suit operational pre-loading requirements.

Another heavy metal plate 46*b* abuts the element 40*d* at the other end thereof. The metal plate 46*b* is partly dome-shaped to facilitate uniform load application.

An elongated load transmitting plug 90 is slidably disposed in bore 76 and fits tightly into the space between the outer race 5*c* and the heavy metal plate 46*b*.

In the preceding description relating to FIGURES 1 to 5 the inner race was distorted by loading the outer race. In the present embodiment the outer race 5*c* is deformed upon relative rotation between the outer race and the cam-shaped inner race by virtue of the out-of-round condition of the inner race. In operation the outer race remains stationary and as the inner race rotates it produces as many squeezing and releaseing cycles as there are lobes on the inner race by forcing the load transmitting plug 90 against the element 40*d* compressing the latter longitudinally. A two-lobed cam can provide four sparks per revolution which can fire a four cylinder engine at camshaft speed; a three-lobed cam can provide six sparks per revolution which can fire a six cylinder engine at camshaft speed; a four-lobed cam can provide eight sparks per revolution which can fire an eight cylinder engine at camshaft speed, bearing in mind that at lobe position the element 40*b* is under compression and at mid-point between the lobes the element is completely released, thereby establishing as aforementioned two sparks per cycle, one at high spot of lobe and the other at low spot which is about half distance between lobes.

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, in combination: a radial bearing including a first and a second bearing race having a common axis and adapted for relative rotation, said first race being distorted out-of-round and said second race being distortable out-of-round relative to said axis; and piezoelectric element means mounted in load transmitting engagement with said distortable second race whereby upon relative rotation between said races a load, established by distorting said second race, is applied to said piezoelectric element means to generate a voltage.

2. A piezoelectric voltage source according to claim 1, wherein said races are concentrically mounted and said first race constitutes the outer race thereof.

3. A piezoelectric voltage source according to claim 1, wherein said races are concentrically mounted and said second race constitutes the inner race thereof.

4. A piezoelectric voltage source according to claim 2, wherein said outer race has a permanent out-of-round configuration and said second race is formed of flexible material.

5. A piezoelectric voltage source comprising, in combination: a radial bearing including an inner and an outer bearing race concentrically mounted and adapted for relative rotation, said inner race having a permanent out-of-round configuration, and said outer race being formed of flexible material and distortable relative to the com-

mon axis of said races; and piezoelectric element means mounted in load transmitting engagement with said outer race, whereby upon relative rotation between said races a load, established by distorting said outer race, is applied to said piezoelectric element means to generate a voltage.

6. A piezoelectric voltage source comprising, in combination: a radial bearing including a first and a second bearing race having a common axis and adapted for relative rotation, said races being formed of flexible material and distortable out-of-round relative to said axis; and piezoelectric element means mounted in load transmitting engagement with one of said races, whereby upon relative rotation between said races a load, established by distorting one of said races, is applied to said piezoelectric element means to generate a voltage.

7. A piezoelectric voltage source according to claim 6, and distorting means engaging one of said races to distort the race out-of-round relative to said common axis.

8. A piezoelectric voltage source according to claim 7, and adjusting means operably associated with said distorting means to vary the degree of distortion of the last named race relative to said axis.

9. A piezoelectric voltage source comprising, in combination: a radial bearing including a first and a second bearing race having a common axis and adapted for relative rotation, said first race being distorted and said second race being distortable relative to said common axis; and means piezoelectrically responsive in compression and coaxially mounted with respect to said axis and in load transmitting engagement with said distortable second race, said means being polarized in a direction extending radially relative to said axis, whereby upon relative rotation between said races a load, established by distorting said second race, is applied to said piezoelectric element to generate a voltage.

10. A piezoelectric voltage source comprising, in combination: a radial bearing including a first and a second bearing race having a common axis and adapted for relative rotation, said first race being distorted and said second race being distortable relative to said common axis; and means piezoelectrically responsive in compression and radially mounted with respect to said axis and in load transmitting engagement with said distortable second race, said means being polarized in a direction extending radially relative to said axis, whereby upon relative rotation between said races a load, established by distorting said second race, is applied to said piezoelectric element to generate a voltage.

11. A piezoelectric voltage source comprising, in combination: a radial bearing including a first and a second bearing race having a common axis and adapted for relative rotation, said first race being distorted and said second race being distortable relative to said common axis; and means piezoelectrically responsive in compression and coaxially mounted with respect to said axis and in load transmitting engagement with said distortable second race, said means being polarized in a direction coaxial relative to said axis, whereby upon relative rotation between said races a load, established by distorting said second race, is applied to said piezoelectric element to generate a voltage.

12. A piezoelectric voltage source comprising, in combination: a radial bearing including a first and a second bearing race having a common axis and adapted for relative rotation, said first race being distorted and said second race being distortable relative to said common axis; and means piezoelectrically responsive in compression and chordally mounted with respect to said axis and in load transmitting engagement with said distortable second race, said means being polarized in a direction extending chordally relative to said axis, whereby upon relative rotation between said races a load established by distorting said second race is applied to said piezoelectric element to generate a voltage.

13. A piezoelectric voltage source comprising, in combination: a rolling contact radial bearing including an inner and an outer race having a common axis and adapted for relative rotation, said inner and outer races being formed of flexible material and distortable relative to said axis; a distorting ring circumferentially surrounding said outer race for distorting said races relative to said axis; and piezoelectric element means in the form of a circular disc having a central aperture and comprising a plurality of circular sectors, said sectors being polarized in a direction alternately from the outer circumference of said disc radially toward the inner circumference thereof and the adjacent sector being polarized radially from the inner circumference toward the outer circumference thereof, said disc being coaxially mounted with respect to said inner and outer races for load transmitting engagement with one of said races, whereby upon relative rotation of the races a load, established by distorting said races relative to said axis, is applied to said piezoelectric disc to generate a voltage.

14. A piezoelectric voltage source according to claim 13, wherein said element means is comprised of at least four circular sectors, at least two of said circular sectors being polarized in a direction extending from the outer circumference of said circular disc radially toward said inner circumference thereof, and the remaining two circular sectors being polarized in a direction extending from the inner circumference of said circular disc radially toward said outer circumference thereof.

15. A piezoelectric voltage source according to claim 13, wherein said element means is comprised of an even number of circular sectors, half of the number of said sections being polarized in a direction extending from the outer circumference of said circular disc radially toward said inner circumference thereof, and the remaining sectors being polarized in a direction extending from the inner circumference of said disc radially toward said outer circumference thereof.

16. A piezoelectric voltage source comprising, in combination: a rolling contact radial bearing means including an inner and an outer race having a common axis and adapted for relative rotation, said inner and outer races being formed of flexible material and distortable relative to said axis; a distorting ring circumferentially surrounding said outer race for distorting said races relative to said axis; and an elongated piezoelectric element means having first and second end faces, said element means being chordally mounted relative to said inner race and said first and second end face thereof being restrained by said inner race to prevent its movement, whereby upon said relative rotation of said races a load, established by distorting said races relative to said axis, is applied to said piezoelectric element means to generate a voltage.

17. A piezoelectric voltage source comprising, in combination: a rolling contact radial bearing means including an inner and an outer race disposed about a common axis and adapted for relative rotation, said inner and outer races being formed of flexible material and distortable relative to said axis; a distorting ring circumferentially surrounding said outer race for distorting said races relative to said axis; hollow housing means coaxially disposed with respect to said races and 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; hydraulic means operably confined within said housing and abutting the second end face of said element means; and load transmitting means disposed in said housing means and one end thereof in engagement with one of said races and the other end being in engagement with said hydraulic means, said transmitting means being effective, upon relative rotation of said races, to displace the hydraulic means to apply a load, established by distorting said races relative

to said axis, to said piezoelectric element to generate a voltage.

18. A piezoelectric voltage source according to claim 16, wherein said inner race surrounds portions of said housing means and said load transmitting means is in engagement with said inner race.

19. A piezoelectric voltage source comprising, in combination: a rolling contact radial bearing including an inner and an outer race disposed about a common axis and adapted for relative rotation, said inner race having a permanent out-of-round configuration and said outer race being formed of flexible material, said outer race being distortable relative to said axis; hollow housing means at least partly radially disposed with respect to said races and

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 load transmitting means disposed in said housing means and in engagement with said outer race and the second end face of said element means, said load transmitting means being effective upon relative rotation of said races to apply a load, established by distorting said outer race relative to said axis, to said piezoelectric element means to generate a voltage.

No references cited.