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(54) A HIGH VOLTAGE GENERATING DEVICE

(71) We, MATSUSHITA ELECTRICAL INDUSTRIAL CO. LTD., of 1006, Oaza Kadoma, Kadoma-shi, Osaka, Japan, a body corporate organized according to the laws of Japan, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a high voltage generating device utilizing a ceramic piezoelectric element.

An object of this invention is to provide an improved mechanism for striking the piezoelectric element.

Another object of this invention is to provide the above-mentioned mechanism in a small size with a simple structure which is capable of smooth and accurate operation so that it can be used in a gas igniter, particularly as in the case of a cigarette lighter.

Still another object of this invention is to provide a piezoelectric unit which is manufactured without any special difficulty and is reliable in that it produces a spark, when required, for the ignition of gas, e.g. when it is used in a gas igniter.

Generally, the essential components of a high voltage generating device utilizing a piezoelectric element include a striker or a hammer for striking the piezoelectric element, means for causing the striker to accumulate energy required for the striking, and means for utilizing this accumulated energy in a sudden release causing the striker to strike the piezoelectric element hard. Conventional means for causing the striker to accumulate energy include a coil spring and an operating body associated with said striker. In such means, the energy is accumulated in the striker by displacing it, i.e. by displacing the operating body associated with it, in such a manner that the coil spring is either compressed or expanded by the displacement of the striker. With such an arrangement, if the operating body could move only in one way, the accumulated energy would not be readily and simply released. Accordingly, in the conventional device, the operating body is provided with a rod which projects from the operating body in a direction orthogonal to the direction of travel of the operating body and by means of which rod the operating body is engaged to the striker. Such a structure, with the rod contained in the operating body, results in a relatively complicated mechanism, a larger operating body and rather awkward operation.

Further, in the conventional device, two piezoelectric (hereinafter abbreviated to piezo) elements are generally used, being stacked to make one unit and a high voltage lead being attached to an electrode provided between the two piezo elements. Such a piezo unit is constructed in the following manner. First an electrode plate is inserted into the central portion of a cylindrical case, and then a piezo element and a buffer plate is inserted on each side of the electrode. Finally, an end plate is fitted to one end, and a metal tablet is fitted to the other end, of the case. With such an arrangement, however, the impact due to the striker is largely absorbed by the case, thus reducing the energy available to the piezo elements. Therefore, the voltage produced by such a unit is usually comparatively low.

Moreover, if such a conventional device is to be used in a cigarette lighter, it is necessary to connect a resistor of about 30 kilo-ohms between the piezo element and the spark gap, in order to prolong the sparking period and thus to ensure ignition.

According to the present invention there is provided a high voltage generating device including a piezoelectric unit; an enclosure housing said piezoelectric unit; a striker slidable within the enclosure along an axis which is aligned with the piezoelectric unit; spring means one end of which is secured to the striker for firstly imparting a rotational bias about its axis of movement in one direction and for secondly storing energy for operation; at least one stop rod attached to the striker and projecting through an aperture in the enclosure; an operating body

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for loading the spring means; and means for releasing the striker when sufficient energy has been stored in the spring means, the striker operating the piezoelectric unit on impact.

The present invention will now be described in greater detail by way of examples with reference to the accompanying drawings, wherein:—

Figure 1 is a plan view of one preferred form of high voltage generating device;

Figure 2 is an elevational view of the device shown in Figure 1;

Figure 3 is an exploded view showing the essential parts of the device shown in Figure 1;

Figure 4 is a plan view of a second preferred form of high voltage generating device;

Figure 5 is an elevational view of the device shown in Figure 4;

Figures 6 and 7 are isometric views showing, in detail, the essential parts of the device shown in Figure 4;

Figure 8 is an isometric view of a third preferred form of high voltage generating device;

Figure 9 is a plan view of the device shown in Figure 8;

Figure 10 is an elevational view of the device shown in Figure 8;

Figure 11 is a sectional view of one type of piezo unit for use with the invention;

Figure 12 is an enlarged sectional view of the piezo unit shown in Figure 11;

Figure 13 is a sectional view of a modified form of the piezo unit shown in Figure 11;

Figure 14 is a sectional view of a second modified form of the piezo unit shown in Figure 11; and

Figure 15 is a partly schematic diagram of a gas igniter being one application of the invention.

Referring to Figures 1 to 3, an enclosure 1 contains a piezo unit 2 and slidably receives an operating body 3. Hooks 4, for securing the piezo unit 2, extend from the side plates of the enclosure 1.

A spring 7 is provided between the piezo unit 2 and the operating body 3 received in the enclosure 1. The spring 7 normally presses the operating body 3 in the direction indicated by the arrow *a*. A guide shaft 8 is secured at one end, to one end portion of the operating body 3; a striker 9 is slidably fitted to the guide shaft 8; a spring 10 is provided between the striker 9 and the end portion of the operating body 3; a stop-rod 11 is tightly fitted in a hole 12 radially bored in the striker 9 both ends of the stop-rod 11 protruding from the periphery of the striker 9; an electric conductor 16, shown schematically, electrically connects the earthed electrode of the piezo unit 2 (often earthed to the metal enclosure 1) to a spark electrode 6 associated with a spark electrode 5 secured to the centre portion of the piezo unit 2.

Further, both ends of the stop-rod 11 protrude outward through openings 14 provided in both sides of the operating body 3 each opening 14 having an inclined side 13. Also, both ends of the stop-rod 11 protrude through L-shaped openings 15 provided in both sides of the enclosure 1. The striker 9 is normally urged by the spring 10 in the rotational direction indicated by the arrow *b*. Accordingly, the end portions of the stop-rod 11 are positioned in the recesses 15′ of the openings 15 in the non-operative state (Figure 2).

As the end portions of the stop-rod 11 engage the recesses 15′ of the openings 15 in the non-operative state, this determines the non-operative position of the striker 9. Accordingly, if the operating body 3 is pushed, against the force of the spring 7, in the direction opposite to that indicated by the arrow *a*, the spring 10 is compressed, thus accumulating energy in it. Further, pushing of the operating body 3 in the same direction causes the inclined sides 13 of the openings 14 in the operating body 3 to move the stop-rod 11 obliquely therealong until the stop-rod 11 is released from the recesses 15′ of the openings 15 in the side of the enclosure 1. Then, the striker 9 is projected with substantially the energy accumulated in the spring 10, in the direction opposite to the arrow *a* and strikes the piezo unit 2 hard.

When the piezo unit 2 is struck hard in this way it generates a high voltage producing a spark between the spark electrodes 5 and 6.

After the striker 9 strikes the piezo unit 2 and the energy in the spring 10 is spent, the operating body 3 is returned to its initial position by means of the spring 7 pushing the body 3 in the direction indicated by the arrow *a*. Accordingly, the striker 9 also returns to its initial or non-operative position and the ends of the stop-rod 11 re-engage the recesses 15′ of the openings 15 due to the rotational force imparted by the spring 10 in the sense indicated by the arrow *b*.

Thus the striker 9 is caused to move longitudinally towards and away from the piezo unit 2 and to rotate first one way and then the other by pushing and releasing the operating body 3, while striking the piezo unit 2 with a sufficiently high energy.

Referring to Figures 4 to 7, another form of high voltage generating device has an enclosure 17 for receiving a piezo unit 18, a striker 19 and a guide shaft 20 secured to one end portion of the enclosure 17. A spring 21 is provided between the end portion of the enclosure 17 and the striker 19 to impart to the striker 19 a rotational force in the direction of the arrow *c* and a longitudinal force in the direction of the arrow *d* in the non-operative state; openings 22*a* and 22*b*

are formed on the respective opposite sides 17*a* and 17*b* of the enclosure 17 these openings having oppositely inclined sides 23*a* and 23*b* respectively; stop-rods 24*a* and 24*b* are secured to the striker 19 in the radial direction and project through the openings 22*a* and 22*b*; hooks 25*a*, 25*b*, 25*c* and 25*d* extend from the side plates 17*a* and 17*b* of the enclosure 17 and secure the piezo unit 18. Further, a plate spring 26 is provided for pushing the piezo unit 18 toward the end portion of the enclosure 17; hooks 27*a* and 27*b* are formed at the centre portions of the sides 17*a* and 17*b* for stopping the plate spring 26; an operating body 28 is slidably fitted on the outside of the enclosure 17; and a spring 29 is provided between the operating body 28 and the enclosure 17 to push the operating body 28 in the direction of the arrow *e* in the non-operative state. Slots 30*a* and 30*b* are cut in opposite sides 28*a* and 28*b* of the operating body 28 in opposite directions transverse to the length of the body 28; a high voltage lead 31 is connected at one end to the piezo unit 18; a spark electrode 32 is attached to the other end of the high voltage lead 31; an electrically conductive support 33 is electrically connected at one end, to the enclosure 17; and another spark electrode 34 is secured to the other end of the support 33.

The striker 19 is fitted to the guide shaft 20 in such a manner that it can rotate around the shaft 20 and also slide along the shaft 20. In the non-operative state, the stop-rods 24*a* and 24*b* of the striker 19 are engaged in the slots 30*a* and 30*b* in the opposite sides of the operating body 28. Therefore, the stop-rods 24*a* and 24*b* serve also to prevent the operating body 28 from coming off the enclosure 17.

It is only required to push the operating body 28 in the direction of the arrow *f* (Figure 7) or in the opposite direction to that of the arrow *d* in order to cause the piezo unit 18 to generate a high voltage. That is, by pushing the operating body 28 in the direction indicated by the arrow *f* against the force of the spring 29, the striker 19 is moved in the direction opposite to that of the arrow *d* by means of the stop-rods 24*a* and 24*b* which are engaged in the slots 30*a* and 30*b* of the side plates 28*a* and 28*b*, and accordingly, the energy required for the striker 19 to strike the piezo unit 18 is accumulated in the spring 21. When the striker 19 reaches a certain position, the stop-rods 24*a* and 24*b* come in contact with the inclined edges 23*a* and 23*b* of the openings 22*a* and 22*b* formed in the side plates 17*a* and 17*b* of the enclosure 17, and then slide along the inclined edges 23*a* and 23*b*, thereby turning the striker 19 in the direction opposite to the arrow *c* against the force of the spring 21.

As a result, the stop-rods 24*a* and 24*b* are gradually pushed out from the slots 30*a* and 30*b*, until the rods 24*a* and 24*b* are completely released from the slots 30*a* and 30*b* at which point the striker 19 is projected in the direction of the arrow *d* with substantially the energy accumulated in the spring 21, and strikes the piezo unit 18 with an intense impact thus generating a high voltage.

When the energy in the spring 21 is thus spent, the operating body 28 returns to the initial position due to the force of the spring 29, and the stop-rods 24*a* and 24*b* are again engaged in the slots 30*a* and 30*b*.

An impact intense enough to generate a high voltage is given to the piezo unit 18 only by pushing the operating body 28 in the direction opposite to the arrow *e* against the force of the spring 29.

Referring to Figures 8 to 10, a third form of high voltage generating device has an enclosure 35, a piezo unit 36 being enclosed in one end of the enclosure 35. A plate spring 37 is fitted to a metal tablet forming the end block 38 of the piezo unit 36 for securing the piezo unit 36 in place. A striker 39 is located in the enclosure 35 facing the piezo unit 36. A recess 40 is formed in one end of the striker 39 a spring 41 being provided between the bottom of this recess 40 and one end of the enclosure 35 to impart to the striker 39, a longitudinal force in the direction of the arrow *g* and a rotational force in the direction of the arrow *h* in the non-operative state. One end of a stop-rod 42 projects radially from the striker 39 and extends through an L-shaped opening 43 formed in one side of the enclosure 35. An operating body 44 is rotatably fitted to a shaft 46 which is supported by a support 45 extending from the enclosure 35. A spring 47 is fitted to the shaft 46 to impart a rotational force in the direction of the arrow *i* on the operating body 44 in the non-operative state. An electrically conductive plate 48 is electrically connected to the enclosure 35 and supports an electrode 50 opposite an electrode 49 connected to the piezo unit 36. The operating body 44 is provided with an inclined edge 51 in the lower end thereof.

Rotating of the operating body 44 in the direction opposite to that of the arrow *i* forces the stop-rod 42 to move in the direction opposite to the arrow *g*, thereby accumulating energy in the spring 41, until the end portion of the operating body 44 is disengaged from the stop-rod 42, at which point the striker 39 is projected back with substantially the accumulated energy of the spring 41 to strike the end block 38 of the piezo unit 36, thus causing the piezo unit 36 to generate a high voltage.

After the striker 39 strikes the piezo unit 36, the operating body 44 is rotated by means

of the spring 47 in the direction of the arrow *i*. On the way back, the inclined edge 51 of the operating body 44 tends to push the stop-rod 42 downward, that is to slightly turn the striker 39 in the direction opposite to that of the arrow *h* against the force of the spring 41. Thus, the operating body 44 returns to the initial position, and the striker 39 returns to the non-operative position when the stop-rod 42 engages the recess in the L-shaped opening 43 temporarily, i.e. when the end of the inclined edge 51 passes over the rod 42.

Referring to Figures 11 to 14, there are shown three types of piezo unit which can be used in the high voltage generating devices described with reference to Figures 1 to 10.

Referring to Figures 11 and 12, a cylindrical case 101 of synthetic resin is provided with setback gaps 102 and 102′ inside both end portions thereof. An electrode 103 is inserted at the mid portion of the cylindrical case 101 and a high voltage lead 104 is electrically connected to this electrode 103. Piezo elements 105 and 105′ are fitted in the case 101, one end of each being in contact with the electrode 103. Buffers 106 and 106′, made of metal plate such as aluminium or copper, are inserted in the gaps 102 and 102′ and are normally in contact with the piezo elements 105 and 105′ respectively. An impact member 107 and an end plate 108 are attached to the buffers 106 and 106′ respectively. Protrusions 109 and 109′ are formed at the ends of the case 101 with the aid of heat. It will be understood that the protrusions 109 and 109′ need not be formed all around the peripheries of the gaps 102 and 102′ respectively but may be made at several spots around the peripheries.

These protrusions serve to retain the buffers 106 and 106′, the impact member 107 and the end plate 108 within the case 101. The buffers 106 and 106′ are free to move within the case 101. Therefore, the impact applied to the metal tablet 107 is delivered to the piezo elements 105 and 105′ through the buffer 106 with very little absorption of the impact by the case 101. Accordingly, a high voltage can be generated with high efficiency.

Referring to Figure 13 a modified form of the piezo unit shown in Figures 11 and 12, being suitable for use in a cigarette lighter, has a lead 104 with a high resistance.

Referring to Figure 14 yet another modified form of piezo unit has electro-resistive elements 110 and 110′ provided between each of the piezo elements 105 and 105′ and the electrode plate 103 inserted in the mid portion of the case 101.

Referring to Figure 15 with either of the above modified forms of piezo unit, no separate resistor is necessary, i.e. the high voltage lead 104 is directly connected to the electrode 111 of the spark gap. A gas nozzle 112 and a striking mechanism 113 are schematically shown.

It will be appreciated that the high voltage generating devices constructed as described above provide simple and compact means for generating high voltages.

WHAT WE CLAIM IS:—

1. A high voltage generating device including a piezoelectric unit; an enclosure housing said piezoelectric unit; a striker slidable within the enclosure along an axis which is aligned with the piezoelectric unit; spring means one end of which is secured to the striker for firstly imparting a rotational bias about its axis of movement in one direction and for secondly storing energy for operation; at least one stop-rod attached to the striker and projecting through an aperture in the enclosure; an operating body for loading the spring means; and means for releasing the striker when sufficient energy has been stored in the spring means, the striker operating the piezoelectric unit on impact.

2. A high voltage generating device according to claim 1, wherein means are provided for resetting the device to the inoperative state after the piezoelectric unit has been struck.

3. A high voltage generating device according to claim 1 or 2, wherein a pair of stop-rods in diametrically opposite positions are provided on the striker, there being a correspondingly arranged pair of apertures in the enclosure.

4. A high voltage generating device according to claim 3, wherein the operating body is slidable within the enclosure and is provided with oppositely arranged openings through which the stop-rods project, each said opening having an inclined edge, the inclined edges together causing the rotation of the rod against the rotational bias of the spring means when the operating body is actuated.

5. A high voltage generating device according to claim 4, wherein each aperture in the enclosure is an L-shaped slot having its longer arm parallel to the direction of movement of the operating body and striker, each said inclined edge causing rotation of the striker by pushing its associated stop-rod of the short arm of the slot against the rotational bias of the spring means on operation of the device, whereby the energy stored in the spring means causes the striker to strike the piezoelectric unit, the stop-rods moving in the long arms of the slots.

6. A high voltage generating device according to claim 5, wherein second spring means are provided between the operating body and the piezoelectric unit for resetting the device after the striker has struck the piezoelectric unit, said second spring means

of the spring 47 in the direction of the arrow *i*. On the way back, the inclined edge 51 of the operating body 44 tends to push the stop-rod 42 downward, that is to slightly turn the striker 39 in the direction opposite to that of the arrow *h* against the force of the spring 41. Thus, the operating body 44 returns to the initial position, and the striker 39 returns to the non-operative position when the stop-rod 42 engages the recess in the L-shaped opening 43 temporarily, i.e. when the end of the inclined edge 51 passes over the rod 42.

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Referring to Figure 15 with either of the above modified forms of piezo unit, no separate resistor is necessary, i.e. the high voltage lead 104 is directly connected to the electrode 111 of the spark gap. A gas nozzle 112 and a striking mechanism 113 are schematically shown.

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WHAT WE CLAIM IS:—

1. A high voltage generating device including a piezoelectric unit; an enclosure housing said piezoelectric unit; a striker slidable within the enclosure along an axis which is aligned with the piezoelectric unit; spring means one end of which is secured to the striker for firstly imparting a rotational bias about its axis of movement in one direction and for secondly storing energy for operation; at least one stop-rod attached to the striker and projecting through an aperture in the enclosure; an operating body for loading the spring means; and means for releasing the striker when sufficient energy has been stored in the spring means, the striker operating the piezoelectric unit on impact.

2. A high voltage generating device according to claim 1, wherein means are provided for resetting the device to the inoperative state after the piezoelectric unit has been struck.

3. A high voltage generating device according to claim 1 or 2, wherein a pair of stop-rods in diametrically opposite positions are provided on the striker, there being a correspondingly arranged pair of apertures in the enclosure.

4. A high voltage generating device according to claim 3, wherein the operating body is slidable within the enclosure and is provided with oppositely arranged openings through which the stop-rods project, each said opening having an inclined edge, the inclined edges together causing the rotation of the rod against the rotational bias of the spring means when the operating body is actuated.

5. A high voltage generating device according to claim 4, wherein each aperture in the enclosure is an L-shaped slot having its longer arm parallel to the direction of movement of the operating body and striker, each said inclined edge causing rotation of the striker by pushing its associated stop-rod of the short arm of the slot against the rotational bias of the spring means on operation of the device, whereby the energy stored in the spring means causes the striker to strike the piezoelectric unit, the stop-rods moving in the long arms of the slots.

6. A high voltage generating device according to claim 5, wherein second spring means are provided between the operating body and the piezoelectric unit for resetting the device after the striker has struck the piezoelectric unit, said second spring means

forcing the operating body and the striker away from the piezoelectric unit, the stop-rods sliding within the long arms of the L-shaped slots until they reach the ends where they are forced into the short arms of the slots by the rotational bias of the first spring means.

7. A high voltage generating device according to claim 3, wherein the operating body includes two longitudinally extending side plates each having a slot cut therein into which the stop-rods engage in the inoperative state of the device.

8. A high voltage generating device according to claim 7, wherein each aperture in the enclosure is provided with an inclined edge, the inclined edges together causing rotation of the striker by moving the stop-rods out of the slots when the device is operated so that the rods are freed from the operating body to allow the striker to strike the piezoelectric unit.

9. A high voltage generating device according to claim 8, wherein second spring means are provided between the operating body and the piezoelectric unit for resetting the device, said second spring means being located on the other side of the latter unit from the first spring means, and arranged to urge the operating body away from the position at which the inclined edges can cause the release of the striker.

10. A high voltage generating device according to claim 1 or 2, wherein the operating body is in the form of a pivoted lever which engages with a single stop-rod to urge the striker to move and load the spring means, until a position is reached where further rotation of the lever allows the release of the striker which then strikes the piezoelectric unit.

11. A high voltage generating device according to claim 10, wherein said aperture is an L-shaped slot.

12. A high voltage generating device according to claim 11, wherein second spring means are provided to return said operating lever to a reset position after the striker has struck the piezoelectric unit, said operating lever having an inclined edge whereby the operating lever forces the stop-rod into the short arm of the slot against the rotational bias of the first spring means, and thereafter returns to the other side of the stop-rod which is released from the short arm after the passage of the end of the lever.

13. A high voltage generating device according to any one of the preceding claims, wherein the piezoelectric unit comprises a cylindrical case which has a setback gap in the inside at either end portion thereof, a metallic buffer plate which is movably fitted in each setback gap of the case and is in contact with the piezoelectric element, and an impact member and an end plate attached respectively to said buffer plates.

14. A high voltage generating device according to claim 13, wherein a high voltage lead which is connected to the piezoelectric unit has a high resistance.

15. A high voltage generating device according to claim 13, wherein said piezoelectric unit includes two piezoelectric elements contained in the cylindrical enclosure and electro-resistive elements provided between each of the piezoelectric elements and an electro-conductive plate provided between the two piezoelectric elements.

16. A high voltage generating device constructed substantially as herein described with reference to and as illustrated in Figures 1 to 3, or Figures 4 to 7, or Figures 8 to 10 of the accompanying drawings.

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