Sept. 28, 1965 M. HURWITZ 3,208,443

IGNITION SYSTEM

Filed March 16, 1964 2 Sheets-Sheet 1

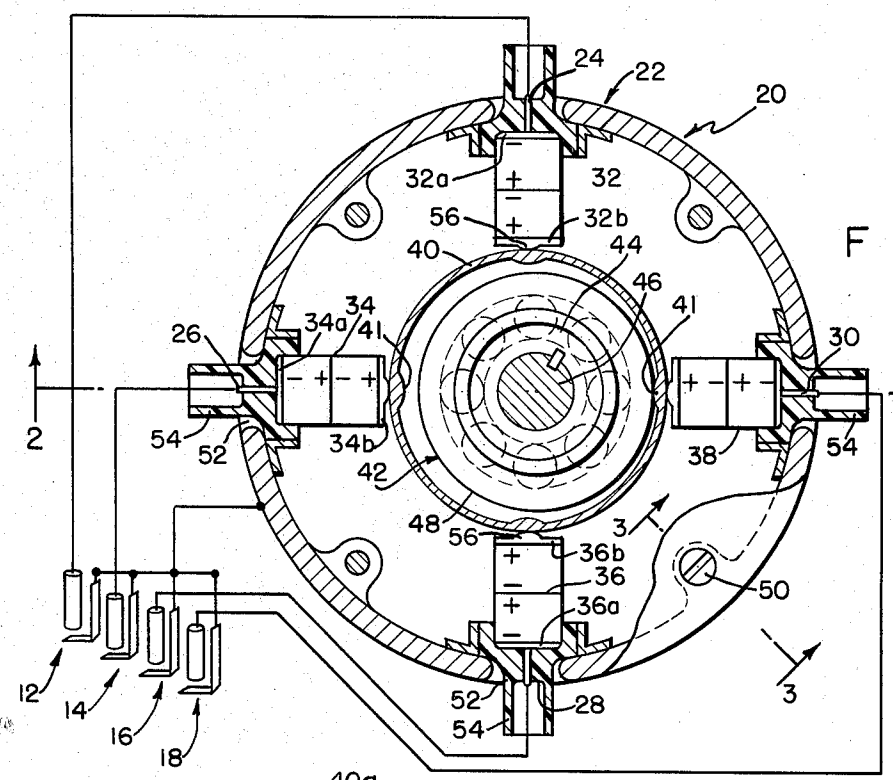

FIG. 1

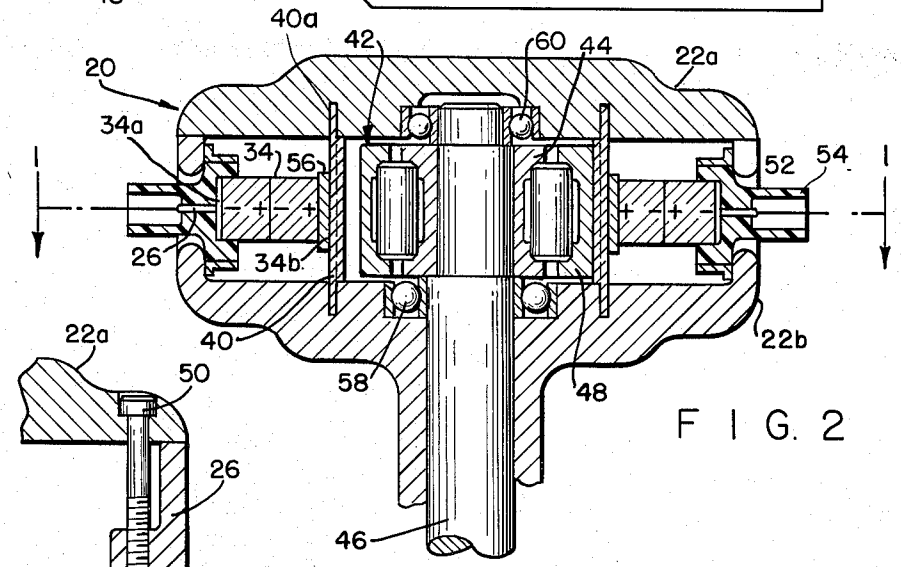

FIG. 2

FIG. 3

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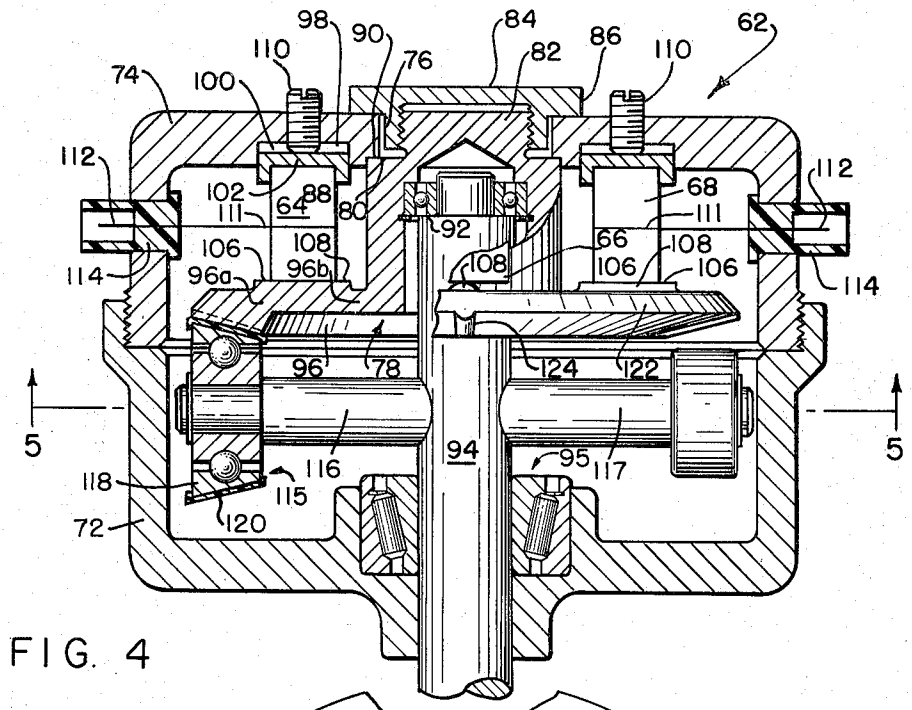

FIG. 4

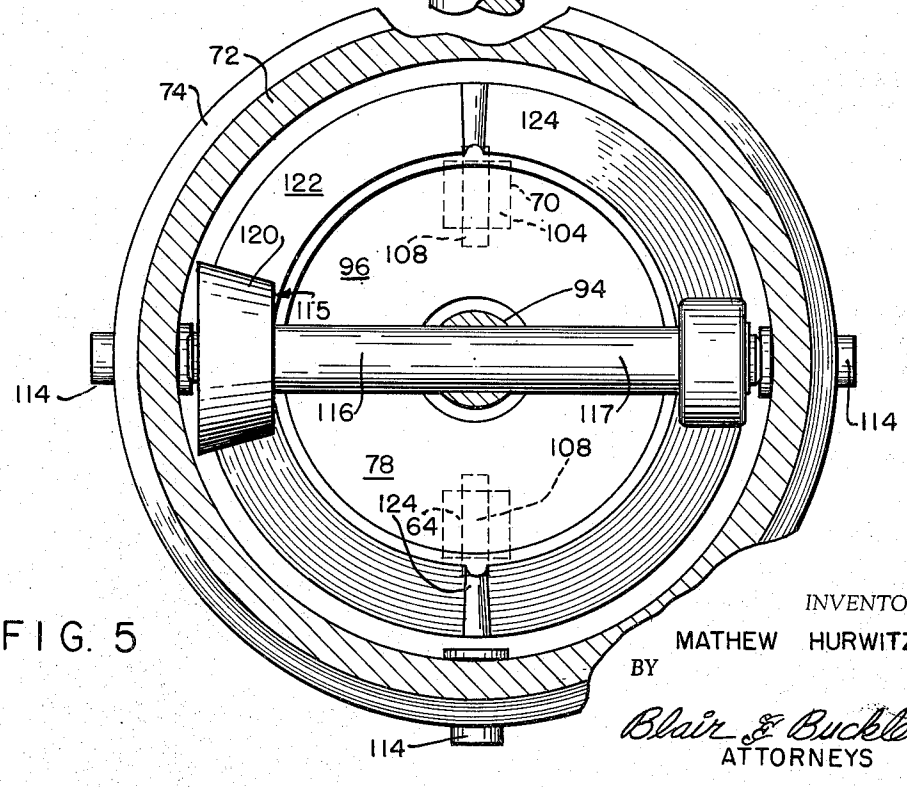

FIG. 5

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United States Patent Office 3,208,443 Patented Sept. 28, 1965

3,208,443

IGNITION SYSTEM

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Filed Mar. 16, 1964, Ser. No. 352,036
13 Claims. (Cl. 123—148)

This invention relates to a distributing voltage source particularly suited for firing the spark plugs of a multiple cylinder internal combustion engine and to an ignition system incorporating the source. In an illustrative embodiment, the source has a separate piezoelectric element arranged for direct connection to each spark plug, and an actuating member that stresses the elements one at a time. As each element is stressed, it develops a large voltage that fires its associated spark plug.

The source is characterized by simplicity and high reliability, and it makes possible a simplified improved ignition system for internal combustion engines.

Piezoelectric voltage sources of the present type are disclosed, for example, in United States Patents Nos. 3,009,975; 3,082,333; and 3,101420. During their operating cycles, the devices disclosed in these patents produce a succession of voltages on a single conductor. Hence their use in a multiple cylinder internal combustion engine requires a distributor, thus retaining the problems attendant with moving electrical contacts. Moreover, a prior piezoelectric source having a single piezoelectric element connected to the spark plugs by a distributor must fire once for each cylinder during every two engine revolutions. The actuating mechanism that stresses the element thus operates at a rapid rate to several times the engine speed. This high speed operation requires costly, careful machining and reliable lubrication for the components of the actuating mechanism.

Accordingly, the present invention is directed to providing an improved ignition system for multiple cylinder internal combustion engines. More specifically, an object of the invention is to provide an ignition system having no distributor.

A further object of the invention is to provide such an ignition system characterized by small size, simplicity and reliability. A corollary object is that the ignition system have a minimum of sliding electrical contacts, sliding mechanical members, and moving parts.

Another object of the invention is to provide a voltage source for use in an ignition system of the above type.

Another object is to provide a voltage source employing electromechanical transducers and highly suited for firing the spark plugs of a multiple-cylinder internal combustion engine without a distributor.

A further object of the invention is to provide a reliable voltage source of the above character that is small and capable of low cost construction.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

The invention accordingly comprises the features of construction, combinations of elements, and arrangements of parts which will be exemplified in the constructions hereinafter set forth, and the scope of the invention will be indicated in the claims.

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description taken in connection with the accompanying drawings, in which:

FIG. 1 is a plan view, partly broken away, of a distributing voltage source embodying the invention and shown connected in an automotive ignition system;

FIG. 2 is a sectional view of the source of FIG. 1, taken along line 2—2 thereof;

FIG. 3 is a fragmentary sectional view of the source of FIG. 1, taken along line 3—3 thereof;

FIG. 4 is a side view, partly broken away, of another voltage source embodying the invention; and

FIG. 5 is a sectional view of the source of FIG. 4, taken along line 5—5 thereof.

An ignition system illustrating the invention has a plurality of conventional spark plugs, each of which is connected to a separate electromechanical transducer, appropriately a piezoelectric element, arranged in a distributing voltage source. An actuator in the source moves in synchronism with the engine and stresses the transducers in turn, causing them to develop voltages that fire the spark plugs.

The source is constructed, as described below, with fixed contacts engaging each transducer, and it requires only a single operating motion, the movement of the transducer-stressing actuator. As a result, the source is free of sliding contacts and has high reliability.

Moreover, each transducer in a voltage source embodying the invention is stressed only once in each full cycle of the associated internal combustion engine, i.e., only once during every second rotation in the operation of a four-cycle engine.

A further feature of the invention, as described in detail below, is the simple construction for the actuating mechanism that applies a controlled, abrupt squeeze to operate each transducer at the proper time. Moreover, the actuating mechanism is suited for low cost construction, an important feature in the highly competitive automotive industry.

More specifically, FIGS. 1 and 2 show an ignition system for a four-cylinder internal combustion engine having spark plugs indicated schematically at **12**, **14**, **16** and **18**. The ignition system includes a distributing voltage source indicated generally at **20** and constructed with an electrically conductive housing **22** fitted with insulated output terminals **24**, **26**, **28** and **30**. Each spark plug has one electrode connected to an output terminal, with the other electrodes connected to the support housing, as shown. In many instances, the housing is mounted on the engine, which provides the latter connection.

Electromechanical transducers, in the form of piezoelectric elements **32**, **34**, **36** and **38**, mounted in the housing **22**, are connected between the output terminals and, through a conducting hub **40**, the housing **22**.

The source **20** also has an actuating cam, indicated generally at **42**, constructed as a roller bearing with an inner race **44** keyed to an eccentric portion **46***a* of a rotatable shaft **46**. With this construction, rotation of the shaft and the eccentric portion **46***a* thereon moves the cam bearing **42** in a circular path within the hub **40**. This carries the outer race **48** of the bearing along the inner surface of the hub, stressing the piezoelectric elements **32–38** in succession. In response, the elements develop, between the output terminals **24–30** and the source housing **22**, voltage pulses that are applied to the spark plugs.

Considering the illustrated voltage source in greater detail, the piezoelectric elements **32–38** have outer electrodes **32***a*–**38***a* and inner electrodes **32***b*–**38***b*. In the depicted embodiment, the electrodes **32***b*–**38***b* are constructed as shoes, each of which has a raised central ridge **56**.

As shown in FIGS. 2 and 3, the housing **22** is constructed with a top portion **22***a* and a bottom portion **22***b* suitably connected together with bolts **50**. The bottom portion **22***b* is fitted with flanged insulators **52** (FIGS. 1 and 2) having terminal shields **54** protruding through holes in the housing wall.

The insulators suport the piezoelectric elements on a circular path, with the electrodes **32***a*–**38***a* embedded in the insulators and connected to the output terminals **24–30**, which extend through and are also embedded in the in-

sulators 52. The remainder of each piezoelectric element is unsupported, so that it can be longitudinally stressed, i.e., in the radial direction of the source 22, to produce a voltage between its electrodes.

The shaft 46 and hub 40 are concentric with each other and with the circular path of the electrodes 32*b*–38*b*. However, as noted above, and as seen in FIG. 2, the shaft portion 46*a* is eccentric, having its rotation axis offset from its center. As also seen in FIG. 2, support bearings 58 and 60 in the housing's top and bottom portions 22*a* and 22*b*, respectively, support the shaft 46.

The hub 40 is secured to the housing 22 by means of axial extensions 40*a* (FIG. 2). Thus the hub is fixed with respect to the housing and does not rotate with the shaft 46. The hub is radially deformable as indicated more specifically below. The outer surface of the hub preferably abuts the ridges 56 on the electrodes 32*b*–38*b*, thereby providing a fixed electrical connection between these electrodes and the housing 22. Further, the hub 40 is radially thickened to form follower projections 41 extending radially from its inner surface. Each projection is aligned with the center of a piezoelectric element and its associated ridge 56, as seen in FIG. 1.

The outer race 48 of the cam bearing 42 is slightly spaced from the hub 40 and thus engages only the follower projections 41. The dimensions of the projections are exaggerated in FIGS. 1 and 2 for illustrative purposes. Thus, when the shaft 46 rotates, the race 48 successively rolls over the projections 41 one at a time and bears against them to radially deflect the hub 40 at the places where it abuts the piezoelectric elements. As a result, the actuating mechanism comprising the shaft 46, eccentric portion 46*a*, cam bearing 42 and hub 40 radially compresses the piezoelectric elements in succession, thereby producing large voltages between the output terminals 24–30 and the housing. The rolling engagement of the outer race with the follower projections minimizes wear.

The follower projections preferably cause the piezoelectric elements to be stressed with an abrupt squeeze and without producing a significant shock wave. Under such abrupt and independent stressing, the piezoelectric elements produce short voltage pulses that attain a value sufficient to fire spark plugs at essentially the same point during each rotation of the actuator shaft 46. The source 20 thus produces a series of voltages with controlled timing, so that the elements can be connnected directly to spark plugs without an intervening distributor or other timing switch.

Accordingly, when the shaft 46 is mechanically coupled with an internal combustion engine to rotate in synchronism with it, the output voltages from the source 20 fire the engine's spark plugs at the proper times in the engine's operating cycle.

When the cam bearing passes beyond a follower projection 41, the just-compressed piezoelectric element relaxes, producing another voltage pulse sufficient to fire a spark plug. However, this second spark occurs before fresh fuel is drawn into the associated cylinder, and hence does not interfere with the engine's operation. In fact, it may occur soon enough to provide timely firing in the cylinders if the first pulse fails, for some reason, to cause ignition. Still referring to FIGS. 1 and 2, the ridged shoes forming the element terminals 32*b*–38*b* distribute the actuating stressing relatively uniformly over the cross-sections of the piezoelectric elements. This enables each element to develop the maximum electrical energy for the applied stress.

Each of the piezoelectric elements 32–38 is preferably polarized in the axial direction thereof, i.e. radially relative to the source. The voltage obtained from each element therefore increases with its length. These lengths should be great enough to provide the desired output voltage without requiring a stress sufficient to depolarize the elements.

By way of illustration, the voltage source 20 of FIGS. 1–3 may be constructed with piezoelectric elements ⅜ inch long and with a cam bearing whose outer race has an outer diameter of 1¾ inches. The shaft portion 46*a* has an eccentricity of 0.060 inch. With this construction, the source typically stresses the piezoelectric elements so that each produces a potential of 16,000 volts.

As also seen in FIGS. 1 and 2, the hub 40 may preload the elements 32–38 somewhat by maintaining an initial radial compression bias thereon.

Turning now to FIGS. 4 and 5, another voltage source, indicated generally at 62, has axially oriented piezoelectric elements 64, 66, 68 and 70 arranged in a circular path and developing output voltages when they are axially stressed.

More specifically, the source 62 has a housing bottom 72 threadedly fitted with a removable housing top 74 having a central opening 76.

An actuating member, indicated generally at 78, has a hollow cylindrical sleeve 80 from which a threaded stud 82 extends. A nut 84 having a flange 86 is threaded onto the stud 82, securing the member 78 to the housing top 74, with the housing top sandwiched between the nut flange 86 and a shoulder 88 on the end of the sleeve 80. The sleeve 80 is preferably keyed (not shown) to the housing top 74 to prevent relative rotation between them.

The housing top 74 has an alignment recess 90 that receives the shoulder 88 and radially aligns the member 78 with respect to the housing top and bottom. With the member 80 thus aligned, it can accurately retain a thrust bearing 92 for the upper end of an actuating shaft 94. A roller bearing 95 mounted in the housing bottom 72 also supports the shaft 94 for rotation with respect to the housing and the member 78.

The member 78 also includes a plate 96 radially extending from the sleeve 80. The piezoelectric elements 64–70 are supported between the plate 96 and the housing top 74. More specifically, as shown in FIG. 4, the housing top 74 is recessed with sockets 98, each of which receives a metallic shoe 100 fitted over an end electrode 102 of one piezoelectric element. To distribute compressive stresses, the other end electrode 104 of each element has a shoe 106 that abuts a rib 108 extending from the top surface of plate 96.

Where desired, the piezoelectric elements 64–70 can be individually preloaded with compressive stresses. For this purpose, screws 110 are threaded through the housing top 74 into the sockets 98 to bear against the shoes 100, thereby compressing the piezoelectric elements against the plate 96.

As also illustrated, each piezoelectric element preferably comprises two sections compressed in series but electrically connected in parallel. For this purpose, the two sections are polarized in opposite directions. Thus, the end electrodes 102 and 104, on different piezoelectric sections and of the same polarity, are connected together through the housing top 74 and the member 78. The other electrodes 111 of the two sections constituting each element abut and are connected to a output lead 112 of the source. Insulators 114 feed the leads 112 through the housing top 74.

The actuating mechanism for the piezoelectric elements of the source 62 comprises a roller bearing cam 115, on one end of an arm 116 radially extending from the shaft 94. A counterweight 117 on the opposite end of the arm 116 dynamically balances the shaft.

The outer race 118 of the cam 116 has a beveled peripheral surface, preferably fitted with a pliant tread 120, that rolls along a mating beveled surface 122 on the plate 96. The angle of the bevel is such that there is no slippage between the outer race 118 and the surface 122.

For the purpose of compressing the piezoelectric elements for a brief interval as the cam 115 revolves, follower projections 124, shown oversize for clarity, depends from the bottom surface of the plate 96, opposite the ribs 108.

With this construction, when the shaft **94** rotates, the outer race **118** rolls along the beveled surface **122** with little pressure against the plate **96**. However, when the race **118** rolls over a projection **124**, it upwardly deflects the outer portion **96***a* of the plate, compressing a piezoelectric element mechanically coupled to the corresponding rib **108** and thereby producing a voltage pulse. The sleeve **80** holds the inner portion **96***b* of the plate fixed and it does not deflect upward.

Although the roller cam **115** may pass axially directly underneath the piezoelectric elements to compress them, it preferably revolves about a larger diameter as shown in FIGS. 4 and 5. With the latter arrangement, when the cam **115** deflects the outer periphery of the plate **96** upward, at a point radially outside the piezoelectric elements, the plate functions as a lever and bears against the piezoelectric elements with greater force than would be obtained by positioning the cam directly beneath the elements.

With the piezoelectric elements extending in the axial direction, the source **62** can accommodate long elements and yet be compactly packaged with a relatively small radial dimension. The long piezoelectric elements provide large voltages with minimal stress. The combination of the reduced stress required by such piezoelectric elements, and the lever action discussed above, reduces the forces that the source is required to exert on its moving and actuating elements. This makes it possible to manufacture the source at relatively low cost and, by diminishing wear, substantially enhances its operating life and reliability.

The ignition system and distributing voltage sources described above thus provide highly reliable operation and are free of sliding and other moving electric contacts. The transducers are independently stressed by a cycling actuating mechanism that produces the voltages with controlled timing. Moreover, the roller cam engages the follower projections, to stress the transducers, with a rolling motion to minimize wear.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description are efficiently attained and, since certain changes may be made in the above construction without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

Having described the invention, what is claimed as new and secured by Letters Patent is:

1. A multiple-output voltage source for use in an ignition system for a multiple cylinder internal combustion engine, said source comprising, in combination,

A. a plurality of electromechanical transducers, each of which has first and second terminals and develops between said terminals a voltage sufficient to fire a spark plug in said engine when the transducer is stressed,

B. a housing supporting said transducers with said first terminals thereof electrically insulated from each other,

C. conductor means in fixed contact with and connecting together said second transducer terminals, and

D. actuator means movable

(1) with respect to said housing and

(2) through a cyclic path to stress said transducers one at a time and in a fixed sequence,

(3) so that each transducer in turn develops a voltage between its first terminal and said conductor means.

2. The source defined in claim **1** wherein

A. said conductor means comprises a common conductor fixedly disposed in said housing abutting said second terminals and has a projecting follower means associated with each transducer, and

B. said actuator means engages said follower means one at a time to stress said transducers.

3. The source defined in claim **2** wherein engagement of said actuator means with said follower means deflects said common conductor.

4. An ignition source for firing the ignition devices of an internal combustion engine having *n* cylinders, said source comprising, in combination,

A. *n* electromechanical transducers, each of which has first and second opposed terminals and upon being stressed develops a voltage sufficient to fire one of said ignition devices between its terminals,

B. a housing supporting said transducers, with said first terminals being electrically insulated from each other,

C. *n* output terminals mounted on said housing, each output terminal being connected to a different first terminal, and

D. actuator means

(1) mounted with the housing for movement with respect thereto,

(2) for coupling with said engine to move in synchronism therewith, and

(3) abruptly stressing said transducers one at a time in a fixed sequence as it moves.

5. The source defined in claim **4** in which

A. said housing

(1) supports said transducers with said second terminals thereof disposed in a circular path and

(2) comprises an actuating member disposed to compress said transducers against said housing,

(a) said actuating member having a different follower projection associated with each transducer, each projection extending away from its associated transducer, and

B. said actuator means comprises a rotatable shaft carrying cam means around a circular path and into engagement with said follower projections to deflect said member and thereby compress said transducers in turn.

6. An ignition source for firing the ignition devices of an internal combustion engine having *n* cylinders, said source comprising, in combination,

A. *n* electromechanical transducers, each of which has first and second opposed terminals and develops a voltage between said terminals when it is compressed between its terminals,

B. a conductive housing

(1) supporting said transducers with said first terminals electrically insulated from each other and from said housing, and

(2) with said second terminals disposed along a circular path,

C. a conducting member having a first substantially circular surface,

(1) said conducting member being fixedly disposed in said housing and including

(a) a deflectable portion having a second surface opposed to said first surface, said second surface abutting and in fixed contact with said second terminals, and

(b) follower projections on said first surface and associated with each transducer, each projection being in line with and extending away from the second terminals of its associated transducer,

D. a cam bearing having an inner race and an outer race, and

E. a shaft rotatably mounted in said housing within said circular path, said shaft
(1) carrying said inner race for movement therewith,
(2) moving said outer race around said second surface of said conducting member, and
(3) compressively engaging said outer race against said conductive member at said follower projections.

7. The source defined in claim 6 in which
A. said housing supports said transducers with said first and second terminals thereof radially spaced apart with respect to said circular path,
B. said conductive member comprises an annular hub contacting said second terminals along said circular path, and
C. said shaft is concentric with said cylindrical hub and has an eccentric portion carrying said bearing.

8. The source defined in claim 6 in which
A. said housing supports said transducers with said first and second terminals axially spaced apart with respect to said shaft,
B. said conductive member includes a peripherally-supported plate contacting said second terminals along said circular path, and
C. said shaft
(1) is concentric with said circular path, and
(2) has a radial arm axially spaced from said plate and carrying said cam bearing.

9. The source defined in claim 8 in which said outer race of said cam bearing has a tread substantially continuously engaging said conductive member and maintaining rotation of said outer race when said shaft turns.

10. A distributor-free ignition system for an internal combustion engine having *n* cylinders, said ignition system including *n* fuel-igniting ignition devices and further comprising
A. *n* electromechanical transducers, each of which has first and second terminals and develops a voltage between said terminals in response to mechanical stress,
B. conductors means connecting said first and second terminals to said ignition devices so that the voltage each transducer develops is applied to a different ignition device,
C. a housing supporting said transducers with at least said first terminals thereof electrically insulated from each other, and
D. an actuator
(1) movably mounted with said housing,

(2) coupled with said engine for operation in synchronism therewith, and
(3) coupled with said transducers and stressing them one at a time in a fixed sequence.

11. The apparatus defined in claim 10 further comprising means restricting to a brief interval the time that said actuator stresses each transducer.

12. A distributor-free ignition system for an internal combustion engine having *n* cyclinders and a two-electrode ignition device for each cylinder, said engine forming a common conductor connecting together one electrode of each ignition device, said ignition system further comprising
A. *n* electromechanical transducers each of which has first and second opposed terminals and upon being stressed develops between said terminals an ignition device-firing voltage,
B. conductor means connecting said first terminals of said transducers with the other electrodes of different ignition devices,
C. a conductive housing connected with said engine and
(1) mounting said transducers with said first terminals thereof electrically insulated from each other, and
(2) supporting each transducer so that it can be stressed independently of the other transducers,
D. a conductive member in said housing
(1) abutting said second terminals of said transducers and connecting them together for connection through said housing to said common conductor of said engine, and
E. an actuator
(1) mounted with said housing for cyclic movement relative to said housing and said member and in synchronism with said engine,
(2) said actuator engaging said member and, during said movement, deflecting said member to compress said transducers one at a time in a fixed sequence.

13. The ignition system defined in claim 12 in which
A. said conductive member has follower projections on a surface thereof, opposed to said second terminals, and
B. said actuator engages said surface of said conductive member and effectively deflects said member only during engagement with said follower projections.

No references cited.

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