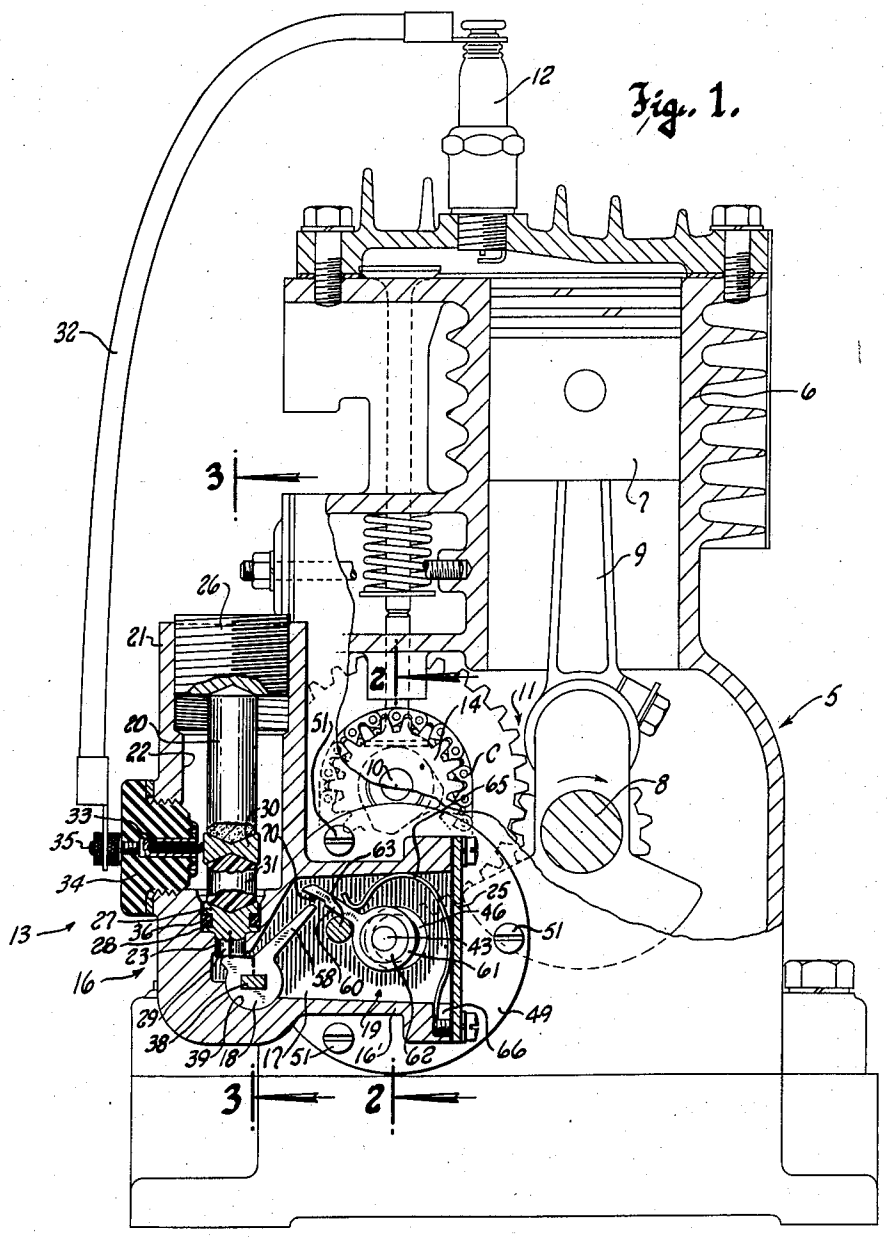
Jan. 27, 1959 J. R. HARKNESS 2,871,280

PIEZOELECTRIC IGNITER UNIT FOR INTERNAL COMBUSTION ENGINES

Filed Aug. 20, 1956 4 Sheets-Sheet 1

Fig. 1.



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PIEZOELECTRIC IGNITER UNIT FOR INTERNAL COMBUSTION ENGINES

Filed Aug. 20, 1956 4 Sheets-Sheet 2

Fig. 2.

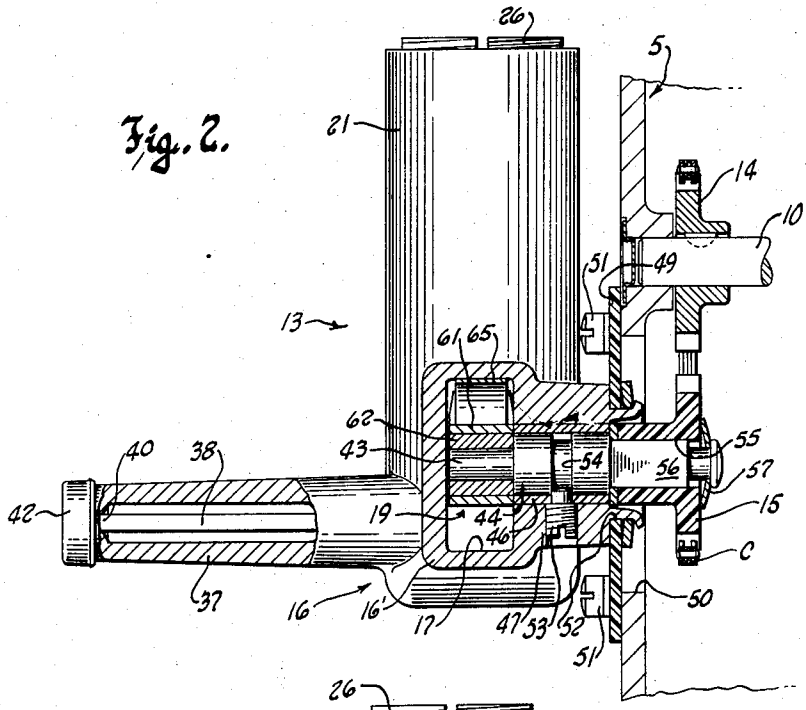
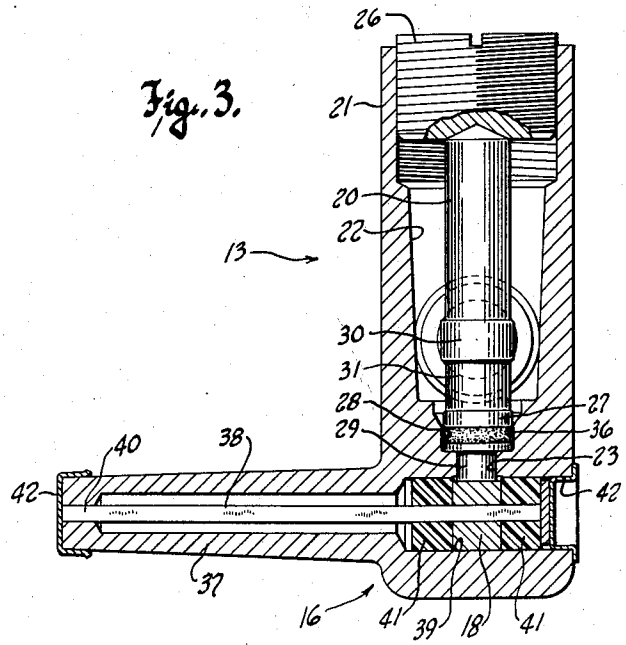


Fig. 3.



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PIEZOELECTRIC IGNITER UNIT FOR INTERNAL COMBUSTION ENGINES

Filed Aug. 20, 1956 4 Sheets-Sheet 3

Fig. 4.

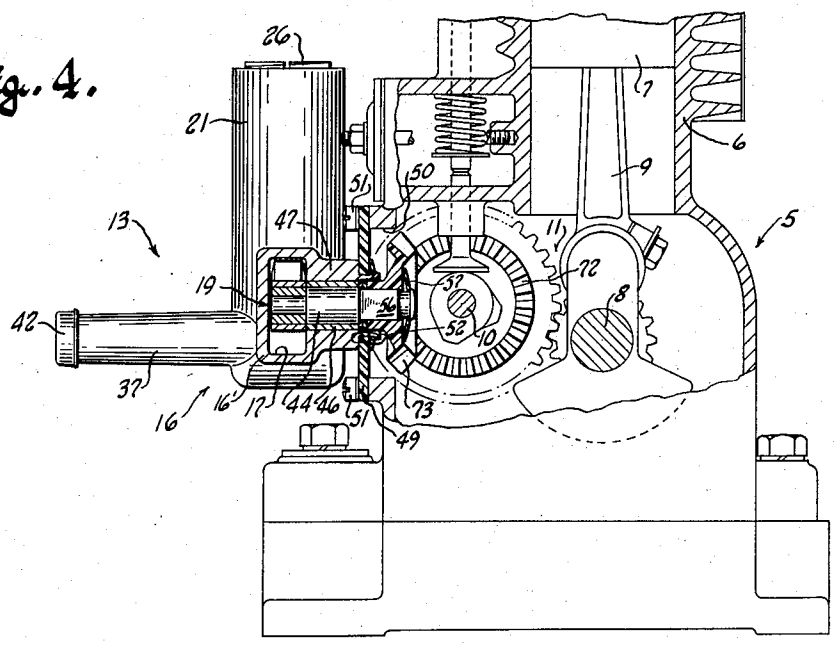
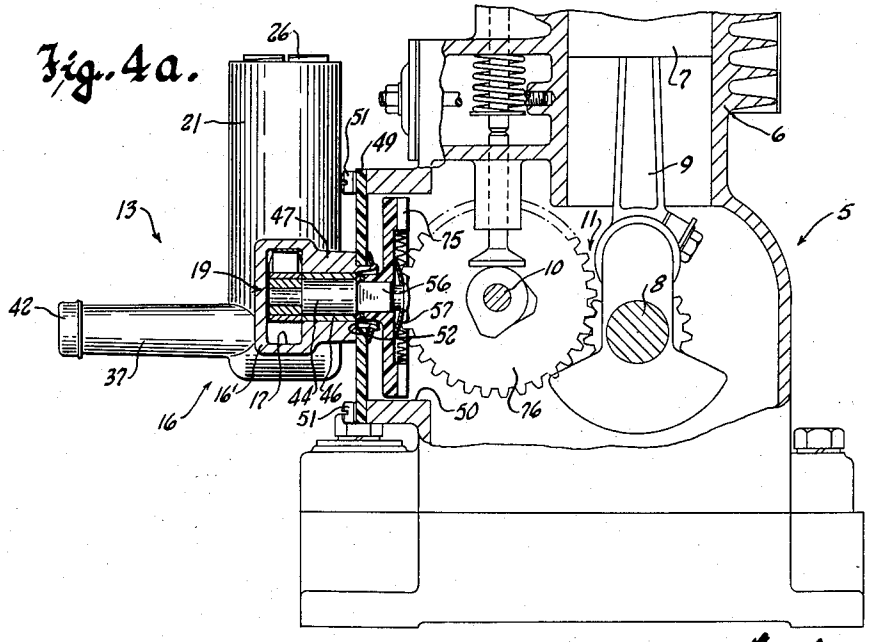


Fig. 4a.



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Jan. 27, 1959 J. R. HARKNESS 2,871,280

PIEZOELECTRIC IGNITER UNIT FOR INTERNAL COMBUSTION ENGINES

Filed Aug. 20, 1956 4 Sheets-Sheet 4

Fig. 5.

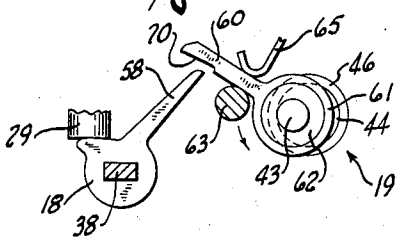


Fig. 6.

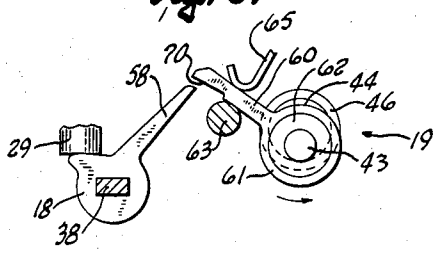


Fig. 7.

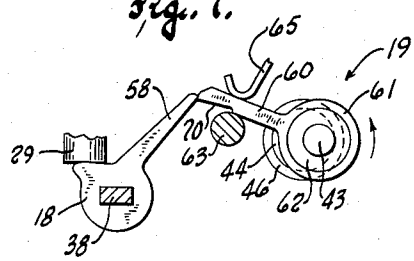


Fig. 8.

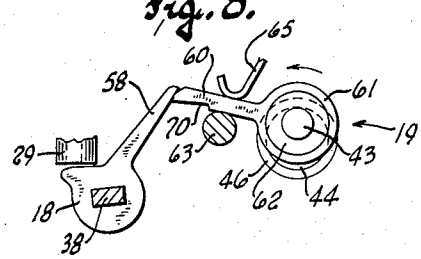
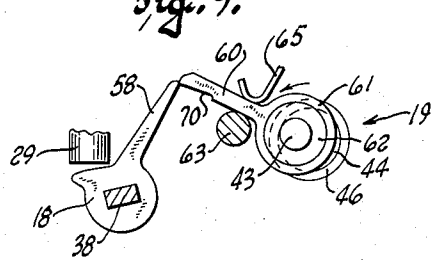


Fig. 9.



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United States Patent Office

2,871,280

Patented Jan. 27, 1959

2,871,280

PIEZOELECTRIC IGNITER UNIT FOR INTERNAL COMBUSTION ENGINES

Joseph R. Harkness, Milwaukee, Wis., assignor to Briggs & Stratton Corp., Milwaukee, Wis., a corporation of Wisconsin

Application August 20, 1956, Serial No. 604,886

5 Claims. (Cl. 123—148)

This invention relates to ignition systems for internal combustion engines and refers more particularly to an ignition system of the type disclosed in Patent No. 2,649,488, issued August 18, 1953, to J. R. Harkness, and wherein the spark plug firing voltage is derived from a polycrystalline piezoelectric element, as distinguished from a magneto or battery energized ignition coil.

In general, the aforesaid patent teaches that a polycrystalline piezoelectric element such as polycrystalline metallic titanate, mixed with a ceramic binder and vitrified into a solid ceramic body is capable of generating a sufficiently high voltage for satisfactory commercially reliable spark plug firing when abruptly mechanically stressed; and, moreover, that a piezoelectric element of such composition is capable of withstanding the high mechanical stresses imposed upon it in that service.

As disclosed in said patent, the piezoelectric element is abruptly periodically stressed in timed relation with the rotation of an engine shaft, as a consequence of the blows of a hammer upon a striker pin. The hammer, which is strongly biased toward engagement with the striker pin, is operated by a cam follower having a motion transmitting connection with the hammer. The follower, in turn, is actuated by a cam carried by a rotatable part of the engine, such as the engine camshaft. In the mechanism described and disclosed in the aforesaid patent, therefore, the cam causes the cam follower to swing the hammer away from the striker pin and then, as an abrupt step on the cam moves across the follower, the hammer is suddenly released to strike the striker pin a forceful blow in response to the strong bias acting upon the hammer.

While the operation of an internal combustion engine equipped with the piezoelectric ignition system disclosed in the aforesaid patent was generally satisfactory, several annoying problems were presented by that system. The first of these problems was that of noisy operation, which resulted from the rapidly recurring blows of the hammer upon the striker pin. These hammer blows were transmitted into all of the metal structure of the engine to the extent that sound was radiated from all the walls thereof and created a highly disagreeable and disconcerting rattling noise whenever the engine was in operation.

Another objection to the piezoelectric ignition system of the aforesaid patent, was that its hammer did not accelerate at the desired high speed when the energy stored in the hammer biasing spring was suddenly released by the cam, thus creating substantial time delay and accompanying spark retardance during the intervals between release of the hammer biasing spring and the actual impact of the hammer upon the striker pin. While such time delay has no ill effects at slow engine speeds, such as during starting of the engine, it was objectionable when the engine was operated at normal high speed.

Still another objection to the piezoelectric ignition system of the aforesaid patent resulted from the fact that its hammer cocking mechanism comprised a cam with a long inclined surface bearing upon the hammer carried cam

follower and leading to an abrupt step in the cam to release the hammer each time the abrupt step on the cam moved across the cam follower. Obviously, the cam had to exert a large force upon the hammer carried cam follower in order to overcome the hammer biasing force while imparting cocking motion to the hammer, to carry it away from the striker pin. The friction force between the cam and its follower during such cocking of the hammer, of course, was proportional to the hammer biasing force being exerted upon the cam follower and was, moreover, greatest when the largest radius portion of the cam rode over the follower. Thus the friction torque increased very rapidly as the cam rotated toward its step, due to the combined effects of increasing frictional force and the increasing radius at which this greater frictional drag was being exerted. The result was an undesirably large consumption of power by the ignition system.

The problem outlined above was further complicated by the fact that the cam was connected to its shaft through a ratchet-like unidirectional driving connection which constrained the cam to rotate with the shaft in only one direction of shaft rotation, and disrupted the connection between the cam and its shaft in the event of reverse rotation of the shaft as frequently happens when the engine backfires during starting. In the absence of such a unidirectional driving connection between the cam and its shaft, the hammer operating mechanism including the cam and its follower, would almost certainly be damaged beyond repair in the event of engine backfiring.

This ratchet-like mechanism, which comprised several small parts making up a relatively complex device, was not only expensive to manufacture but was never completely free from the possibility of malfunction, particularly after long periods of use.

In general, the object of this invention is to provide a piezoelectric ignition system in which all of the objections discussed above are overcome.

With a view toward effecting a substantial reduction in noise, it is a further object of this invention to provide a piezoelectric igniter of the character described which is capable of being mounted on the exterior of an internal combustion engine as a unit, and wherein all of the components of the igniter are located externally of the engine crankcase, with the exception of a single driving member by which the unit may be operated from a rotatable shaft of the engine. In accordance with this invention, the components of the igniter unit are contained within a relatively small and compact housing which is adapted for mounting upon the exterior of an internal combustion engine, over an access hole in the crankcase thereof, by means of a resilient disc which not only serves as a cover for the hole in the engine crankcase, but also functions on the order of a diaphragm to minimize the transmission of shocks incidental to operation of the hammer, to the engine walls.

Further according to this invention, the igniter unit includes a drive shaft journalled in the housing of the unit and projecting through the cover or resilient disc to have a resilient driving member fixed thereon at the side of the cover remote from the igniter unit, whereby the only mechanical connections between the igniter unit and the engine are through two resilient members, namely, the closure disc and the resilient driving member, and whereby the shock incidental to operation of the hammer of the igniter unit will be confined to the unit itself and more or less isolated from the engine walls to minimize noise radiation thereby.

In this connection, it is a more specific object of this invention to provide a piezoelectric igniter unit of the character described wherein those portions of the igniter unit housing which are heavily stressed during operation of the hammer are provided with considerable cross sec-

tion so as to have a minimum of resilience, to thus effect further reduction in noise during operation of the unit.

With a view toward eliminating or minimizing frictional forces incidental to cocking of the hammer against the strong bias acting thereon, it is a further object of this invention to provide an improved hammer operating mechanism wherein cocking of the hammer is effected by means which operates with negligible friction, so that almost all of the power consumed in operation of the igniter mechanism is that which is directly required for cocking the hammer against its biasing force.

In this connection, it is a more specific object of this invention to provide a piezoelectric igniter of the character described with improved hammer cocking mechanism which is more dependable in operation by reason of the fact that the hammer cocking mechanism needs no unidirectional ratchet mechanism such as was previously required in piezoelectric ignition systems of the type hereinbefore referred to.

Still another object of this invention resides in the provision of a piezoelectric igniter of the character described in which the time delay which was inherent in past devices of this nature, is substantially reduced through the expedient of providing a hammer which is of small mass and accelerates more rapidly due to the biasing force thereon when it is released to strike the striker pin.

Other objects of this invention reside in the provision of a piezoelectric igniter unit of the character described, which comprises relatively few and simple parts contained in a compact housing, and which is inexpensive to manufacture and service and dependable in operation.

With the above and other objects in view, which will appear as the description proceeds, this invention resides in the novel construction, combination and arrangement of parts substantially as hereinafter described and more particularly defined by the appended claims, it being understood that such changes in the precise embodiment of the hereindisclosed invention may be made as come within the scope of the claims.

The accompanying drawings illustrate several complete examples of the physical embodiments of the invention constructed according to the best modes so far devised for the practical application of the principles thereof, and in which:

Figure 1 is a view partly in side elevation and partly in vertical section of a single cylinder internal combustion engine equipped with the piezoelectric igniter of this invention;

Figure 2 is an enlarged sectional view taken substantially on the plane of the line 2—2 in Figure 1;

Figure 3 is an enlarged sectional view taken on the plane of the line 3—3 of Figure 1;

Figure 4 is a view similar to Figure 1 but showing a modified form of the invention;

Figure 4*a* is a view similar to Figure 4 and illustrating still another embodiment of the invention; and

Figures 5 through 9 are fragmentary views showing the components of the hammer operating mechanism in the relative positions which they assume at several successive stages of one complete operating cycle.

Referring now more particularly to the accompanying drawings in which like reference characters have been applied to like parts throughout the several views, the numeral **5** generally designates the crankcase of a single cylinder internal combustion engine, having a cylinder **6** projecting upwardly therefrom to reciprocably receive a piston **7**. As is customary, the reciprocation of the piston is translated into rotation of the crankshaft **8** of the engine through a connecting rod **9**.

While it will be understood that this invention is readily adaptable to two-stroke cycle engines as well as to engines having more than one cylinder, it is shown and described by way of illustration in connection with a single cylinder four-cycle engine, wherein the crankshaft **8** drives a camshaft **10** at one-half crankshaft speed through the customary timing gears **11**, and wherein valves are actuated in timed relation to the reciprocation of the piston by means of cams on the camshaft.

At a precise instant during every second revolution of the crankshaft **8**, the spark plug **12** of the engine must be fired to ignite the combustible mixture compressed by the piston. This instant occurs when the piston is substantially at the top of its compression stroke, and the piezoelectric igniter unit of this invention generally designated **13**, provides the necessary spark plug firing voltage at the desired instant. For this reason, the unit is operated from the camshaft **10**, through a silent chain C trained about sprockets **14** and **15** on the camshaft and igniter unit, respectively. These sprockets have a one to one ratio so as to properly synchronize the operation of the igniter unit with reciprocation of the piston.

The igniter unit **13** of this invention features a housing **16** which carries all of the components of the igniter mechanism and which is adapted to be mounted on the exterior of one wall of the engine crankcase, beneath one end of the camshaft **10** of the engine. The housing, which is preferably of die cast construction, comprises a main horizontally disposed body portion **16'** defining an elongated chamber **17** containing a hammer **18** and hammer operating mechanism generally designated **19**. The hammer operating mechanism **19** is contained within one end portion of the chamber **17**, just inside a detachable cover **25** which closes said end of the chamber; while the hammer **18** is contained within the other end portion of the chamber, remote from the cover.

The piezoelectric element **20** is mounted in a cylinder **21** joined to and projecting upwardly from the body portion **16** of the housing above the hammer **18**. The cylinder **21** provides a chamber **22** in which the element is contained, and the bottom of the chamber **22** is communicated with the chamber **17** through a bore **23** which opens to the chamber **17** at a point directly adjacent to the hammer **18**, and which opens to the interior of the cylinder through a counterbore **28**.

The piezoelectric element, which is in the form of an elongated rod, is located endwise between a plug **26** screw threaded into the upper end of the cylinder and a striker pin **27** loosely fitting the counterbore **28** and seating on the bottom thereof. A reduced striker portion **29** on the pin is slidably received in the bore **23** and projects downwardly therethrough for engagement by the hammer.

The piezoelectric element **20**, however, does not extend the full distance between the striker pin and the plug, but has its lower end clamped against an electrically conductive adapter electrode **30**, and a buffer or cushioning member **31**, preferably of plastic material such as nylon is interposed between the adapter electrode and the striker pin. The opposite or upper and lower ends of both the piezoelectric element and of the buffer member are more or less convexly shaped to seat in corresponding concavities in the plug **26**, the adapter electrode **30**, and the striker pin. Not only do these concavities in the members which directly engage and endwise confine the piezoelectric element steady the same when the plug **26** is turned inwardly into the cylinder to place the element under initial endwise compression, but they serve to provide a greater area of contact between the ends of the element and the surface of the plug and adapter electrode, so as to prevent the localization of forces on the element, under the influence of abrupt mechanical stresses imparted thereto by the hammer, in a way which might damage the element.

The plug **26** at the upper end of the cylinder, of course, provides access to the piezoelectric element, and it also serves as a grounding terminal for the upper end of the element. The lower end of the piezoelectric element is electrically connected with the high tension spark plug lead **32** through a resilient electrically conductive brush **33**, in the form of a compression spring,

laterally engaged with the adapter electrode 30 and mounted in an insulative plug 34 screw threaded into the side wall of the cylinder 21. The insulative plug also supports a suitable terminal 35 which is electrically connected with the brush and which provides for connection of the spark plug lead to the igniter unit.

The insulating buffer 31 which, as stated previously, is preferably of a plastic material having good electrical insulating properties, prevents short circuiting the upper and lower ends of the piezoelectric element and, preferably, has a degree of resilience. The resiliency of the buffer member serves as protection for the piezoelectric element while, at the same time acting to transmit hammer blows on the striker pin to the adapter electrode 30 and thus to the piezoelectric element.

The striker pin, which is more or less loosely encircled by the walls of the counterbore 28 and the bore 23, is normally clamped against the bottom of counterbore by the action of the plug 26. The striker pin is also provided with an O-ring oil seal 36 confined in a circumferential groove in the larger diameter portion of the pin and having snug engagement with the wall of the counterbore to prevent lubricant in the chamber 17 containing the hammer and its operating mechanism from gaining access to the interior of the chamber 22 in which the piezoelectric element is mounted.

Projecting outwardly from the lower portion of the cylinder 21, substantially at right angles to the cylinder and to the main body portion 16 of the housing, is a tubular extension 37 formed as part of the housing and containing an elongated torsion bar spring 38 of rectangular cross section. At its inner end, the hollow interior of the extension opens to a counterbore 39 which crosswise intersects the chamber 17 and freely rotatably receives the cylindrical body portion of the hammer 18.

The inner end of the torsion bar projects into the counterbore to have the hammer 18 mounted thereon, and its outer end is non-rotatably received in a rectangular hole in the outer extremity of the extension, at 40. A pair of bushings 41, which may be of nylon if desired, are mounted on the torsion bar at each side of the hammer and are freely rotatable in the counterbore 39. These bushings cooperate with the hammer to constrain the bar to twisting movement about its longitudinal axis. Caps 42, one pressed over the outer end of the extension and the other into the mouth of the counterbore 39, retain the torsion bar biasing spring against displacement, but can readily be removed to provide for inspection and/or replacement of worn parts.

The purpose of the torsion bar, of course, is to propel the hammer into engagement with the downwardly projecting striker portion of the striker pin with substantial force whenever the hammer operating mechanism cocks the hammer and then suddenly releases it. When this occurs, the sudden forceful hammer blow upon the striker pin is transmitted thereby through the buffer member and the adapter electrode 30 onto the piezoelectric element, to cause such abrupt mechanical stressing of the element as will generate the desirable high sparking voltage therein. The manner in which the hammer operating mechanism effects cocking and then sudden releasing of the hammer, will be described at greater length hereinafter.

The hammer operating mechanism is mounted on a crank pin or eccentric 43 which projects into the chamber 17 in the main body portion of the housing from the enlarged medial portion 44 of a drive shaft carried by the igniter housing. The medial portion of the drive shaft is rotatably journalled in a bearing 46 carried by a boss 47 which extends rearwardly from the main body portion of the housing and has an adaptor plate 49 fixed on its outer end. This adaptor plate is of a size to cover an access hole 50 in the crankcase 5 of the engine, below one end of the camshaft 10, and it serves to support the igniter housing on the engine as by means of cap screws 51 passing through holes in the plate and threaded into suitable apertures in the crankcase wall.

The outer end of the drive shaft projects into the crankcase from the boss 47 on the main body portion of the igniter housing, through a central hole 52 in the adaptor plate and has the igniter drive sprocket 15 mounted on its extremity and drivingly connected thereto. As will be seen best from Figure 2, the silent chain C drivingly connects the igniter sprocket 15 with the camshaft sprocket 14 for rotation in the same direction therewith.

The drive shaft of the unit is held against axial displacement by means of a set screw 53 threaded into the boss 47 on the housing, and having its extremity projecting through a hole in the bushing 46 and into a circumferential groove 54 in the enlarged medial portion 44 of the drive shaft. The sprocket 15 may be provided with a square hole 55 in its hub to receive a reduced square end portion 56 on the drive shaft; and the sprocket may be held against axial displacement from a position engaging the shoulder at the junction of the portions 44 and 56 of the drive shaft by means of a spring clip 57 interengaged between a headed portion on the adjacent extremity of the drive shaft and the face of the sprocket 15 which is remote from the igniter unit.

One of the most important features of this invention resides in the fact that both the igniter sprocket 15 and the adaptor plate 49 are made of a material such as nylon or the like, which though having adequate rigidity, nevertheless embodies a degree of resilience. By this construction, coupled with the fact that the hammer and its operating mechanism are mounted externally of and spaced from the engine crankcase, the sound waves created by the blows incidental to forceful impingement of the hammer upon the striker pin during operation of the unit are attenuated before reaching the walls of the engine. Without such attenuation, these sound waves would result in the highly objectional and annoying rattling noise characteristic of past piezoelectric igniter systems of the type hereinbefore referred to. The only two points at which the igniter unit of this invention is mechanically connected to the internal combustion engine are at the area of the adaptor plate 49 and at the driving member or sprocket 15, and both of the igniter unit elements which are involved in this connection are made of a plastic material having some resiliency so as to attenuate sound waves incidental to the blows of the hammer upon the striker pin and thus quiet the operation of the unit.

While the connection of the igniter unit of this invention to the engine in the manner described serves to minimize the noise incidental to operation of the igniter unit, still further reduction in noise is achieved in accordance with this invention, through the expedient of constructing those portions of the igniter unit housing which receive maximum stress due to the recurrent hammer blows with the greatest possible stiffness.

The plug 26, for instance, which bears upon the upper end of the piezoelectric element, is solid metal and has a relatively large diameter and substantial axial length, so as to have a long screw engagement in the upper end portion of the cylinder in which piezoelectric element is mounted. At the opposite end of the piezoelectric element, namely, at the bottom portion of the cylinder 21, the housing of the unit is also provided with extra thick walls surrounding the counterbore 39 in which the hammer 18 is snugly but rotatably mounted.

With the construction described, it will be noted that the reaction forces resulting from the hammer striking the striker pin are carried directly into the massive and most rigid areas of the housing as represented by the plug 26 and lower end portion of the cylinder surrounding the hammer and striker pin. These sections, of course, are connected by the rigid thick walled tubular structure or cylinder 21. Direct radiation of sound waves from the outside of the igniter unit can be reduced if desired,

by a bag-like covering enclosing the unit and filled with material having low sound conductivity.

Attention is also directed to the fact that the hammer **18**, which has a cylindrical body portion, has relatively small polar inertia so that it will quickly respond to the biasing torque of the torsion bar spring whenever it is released from its cocked position by the hammer operating mechanism **19**. By holding the polar inertia of the hammer to a minimum, objectionable time delay and consequent spark retardance which was found objectionable in piezoelectric igniter systems of the type hereinbefore referred to is largely eliminated.

Connected with the hammer and preferably integral therewith, is an actuating arm **58** by which the hammer may be rocked away from the striker pin and then abruptly released to strike the striker pin in response to the biasing torque built up in the torsion bar spring in consequence of such cocking of the hammer. The hammer operating mechanism **19** effects such actuation of the hammer in timed relation to the reciprocation of the piston of the engine and, for this purpose, it comprises a cocking lever **60** freely rotatably journalled on the crank pin **43** by means of a bushing **62**. The cocking lever **60** projects toward the outer end of the actuating arm **58** and is disposed approximately at right angles thereto.

The underside of the medial portion of the cocking lever is cooperable with a stationary fulcrum **63** provided by a pin in the chamber **17** supported by the walls thereof and parallel to the drive shaft of the igniter unit. The cocking lever is normally biased downwardly, in a counterclockwise direction as seen in Figures 1 and 5 through 9, to be yieldingly maintained engaged with the stationary fulcrum by means of a curved leaf spring **65**. The spring is confined in the chamber **17** with its medial portion substantially encircling the eccentric and its free end bearing upon the upper side of the cocking lever. The lower end portion of the spring is anchored in a well **66** in the bottom wall of the main body portion of the igniter housing just inwardly of the cover **25**. Inasmuch as the leaf spring bears against the inside of the cover and against the upper wall of the chamber **17**, it exerts a substantial downward force on the cocking lever but is free to yield in a manner described later, to allow the cocking lever to be lifted off its stationary fulcrum **63**.

Consequently, as the drive shaft rotates, the medial portion of the cocking lever is caused to move on the fulcrum **63** with a combined rocking and endwise sliding action, causing the outer extremity of the lever to describe an arc which is substantially the reciprocal of that described by the eccentrically mounted inner portion of the lever and which arc or orbit, moreover, is intersected by the free end portion of the actuating arm **58** on the hammer.

It is important to note that the fulcrum **63** is spaced from and intermediate the axes of the eccentric and the rocking axis of the hammer carried actuating arm, and that the arm and cocking lever are disposed substantially at right angles to one another. By reason of this arrangement and the relative lengths of the arms, the extremity of the cocking lever is caused to recurrently engage behind the free end portion of the actuating arm and swing it against the bias of the torsion bar spring in the direction to cock the hammer, so as to carry it away from the striker pin, and then abruptly release the actuating arm to permit the hammer to descend upon the striker pin at the proper instant in the cycle of engine operation.

Successive relative positions of the cocking lever and actuating arm during the course of a complete engine cycle are illustrated in Figures 5 to 9, inclusive, wherein the normal direction of drive shaft and eccentric rotation is counterclockwise, and wherein Figure 5 shows the relative positions of the arm and lever immediately after release of the arm to produce a hammer blow upon the striker pin. In this condition of the parts, the actuating arm lies closest to the fulcrum **63**, and the cocking lever is substantially fully endwise projected by the eccentric, with its outer end portion overlying and extending beyond the adjacent end of the arm.

As the eccentric is rotated through the next 90° toward its position shown in Figure 6, it slides the cocking lever endwise along the fulcrum **63**, in a direction away from the actuating arm. After rotating nearly 180° from its position seen in Figure 5, the eccentric retracts the outer end of the cocking lever beyond the plane of the underside of the actuating arm, and the lever begins to swing in a counterclockwise direction on its fulcrum **63** to carry the outer end of the lever downwardly beneath the arm as seen in Figure 7, where the cocking lever is shown fully retracted. The next 90° of rotation of the eccentric, from its Figure 7 position to its Figure 8 position, causes the lever to be projected outwardly, endwise along its fulcrum to thus rock the actuating arm in the hammer cocking direction, away from the striker pin, and load the torsion spring. At the same time, the outer end of the lever slides downwardly along the rear of the arm a slight distance away from the outer end thereof, with the lever tilting counterclockwise on its fulcrum **63** through this portion of its cycle. As motion of the free end of the lever continues, due to further rotation of the eccentric, the lever continues to be projected endwise outwardly and to swing the arm in the direction to complete cocking of the hammer and loading of the torsion spring, but its free end begins to slide toward the end of the arm as it rocks clockwise on its fulcrum. Figure 9 shows the positions of the parts when the lever is fully projected by the eccentric and the hammer is fully cocked, and just before the free end of the lever is carried off of the end of the actuating arm. As the eccentric continues to turn past this point, which is about 350° beyond the position of the eccentric shown in Figure 5, the lever is rocked or tilted clockwise on its fulcrum **63**, and its outer end slides easily from engagement with the actuating arm, permitting the hammer to strike the striker pin a hard sudden blow in response to the action of the torsion spring (Figure 5). The underside of the lever is undercut, as at **70**, to assure clearance for the actuating arm **58** when the latter snaps off of the free end of the lever.

If the eccentric should be rotated in the opposite (clockwise) direction, as sometimes happens during starting, or a backfire, the underside of the cocking lever is merely carried against the end of the actuating arm and slides thereon, the lever being thereby raised off the fulcrum **63** against the yielding bias of its spring. The hammer, of course, will remain in its position of engagement with the striker pin so that no sparking voltage can be generated.

With the construction described, the igniter unit is mounted on one end wall of the engine crankcase with the drive shaft of the unit projecting into the crankcase and parallel to but a distance below the engine camshaft **10**. As shown in Figures 4 and 4*a*, however, the igniter unit may also be mounted on that side wall of the engine which is adjacent to the camshaft, with its drive shaft projecting into the crankcase of the engine and disposed with its axis at right angles to the camshaft, but in the same horizontal plane as the axis of the camshaft.

When the igniter unit is mounted in this manner, its drive shaft may be drivingly connected with the engine in a somewhat simpler manner. In Figure 4, for instance, a bevel gear **72** is fixed on the camshaft and meshes with a companion bevel gear **73** on the square cross section end portion **56** of the drive shaft of the igniter unit. These bevel gears have the same number of teeth so as to assure rotation of the drive shaft of the igniter unit at one-half crankshaft speed.

In the embodiment of the invention illustrated in Figure 4*a*, the driving connection between the drive shaft of the igniter unit and the engine camshaft is still further simplified through the use of a crown gear **75** on the drive shaft meshing with a gear **76**, on the camshaft, and having the same number of teeth. In this case, however, the camshaft gear **76** is provided by one of the timing gears **11**, thus making it possible to transmit rotation from the crankshaft to the drive shaft of the igniter unit, through the camshaft, with one less gear than was necessary in the previously described embodiments of the invention.

In both of these modified embodiments, it is important to note that the drive shaft of the igniter unit may be held against axial displacement from the igniter housing solely by the meshing engagement of the gear on its drive shaft with the camshaft carried gear, thus eliminating the need for the set screw **53** used in the embodiment of the invention shown in Figures 1 to 3, inclusive.

From the foregoing description taken together with the accompanying drawings, it will be apparent that this invention provides an improved but simple, compact and dependable mechanism for recurrently imparting abrupt mechanical stresses to a polycrystalline piezoelectric element in timed relation to the angular position of a rotatable part, which mechanism is quieter in operation, has reduced friction and inertia in its moving parts, and has provision for preventing damage to the operating mechanism when the rotatable part turns in the opposite direction from that in which it is intended to go.

What is claimed as my invention is:

1. A piezoelectric igniter unit for an internal combustion engine having a crankcase and a crankshaft driven member therein, comprising: a housing; a piezoelectric element in the housing; a drive shaft rotatably journaled in the housing and having an end portion projecting a distance outwardly from one side of the housing; mechanism in the housing actuated by the drive shaft and operatively connected with the piezoelectric element for effecting sudden change in mechanical stress in the element, said mechanism including a spring which is cyclically alternately loaded and suddenly released in timed relation to rotation of the drive shaft, sudden release of the spring tending to subject the housing to abrupt, noise producing reaction forces; a driving member on said projecting end portion of the drive shaft projectable through an aperture in the crankcase of an engine, to be driven from a crankshaft driven member of the engine; and an adaptor plate fixed on said side of the igniter housing to provide for attachment of the igniter unit to the crankcase of an engine, said plate having a central aperture therein through which the drive shaft projects and being located on the housing between said driving member and the main portion of the housing, and said adaptor plate being formed of resilient material so as to minimize the transmission of shocks, produced by suddent release of said spring, into the walls of an engine upon which the igniter is mounted.

2. The piezoelectric igniter unit set forth in claim 1, further characterized by the fact that said driving member is also formed of a resilient material to further minimize the transmission of said shocks to an internal combustion engine upon which the igniter unit is mounted.

3. The piezoelectric igniter unit set forth in claim 1, further characterized by the fact that those wall portions of the igniter unit housing which receive the reaction forces incidental to sudden release of said spring have substantial cross section and rigidity.

4. The piezoelectric igniter unit set forth in claim 3 further characterized by the fact that the piezoelectric element is recurrently subjected to hammer blows by said mechanism upon sudden release of the spring, and wherein the piezoelectric element is mounted in a tubular portion of the igniter housing which is remote from the adaptor plate and has a high diameter to wall thickness ratio, the ends of said tubular portion being joined to housing parts having substantially greater thickness than that of the wall of the tubular portion.

5. The piezoelectric igniter unit set forth in claim 1, further characterized by: the fact that said housing provides a pair of chambers communicating with one another through a bore; the fact that the piezoelectric element is mounted in one of said chambers between an abutment and a striker pin opposing but spaced from the abutment and having a striker portion thereon projecting through said bore to the interior of the other of said chambers; and by the fact that said mechanism for effecting sudden change in mechanical stress on the piezoelectric element includes a hammer cooperable with said striker portion of the striker pin to impose a forceful hammer blow thereon as a consequence of sudden release of said spring, said mechanism and the hammer being contained in the other of said chambers.

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