Nov. 2, 1965 J. M. FARRELL 3,215,133

ENGINE COMPRESSION OPERATED PIEZOELECTRIC IGNITION SYSTEM

Filed Nov. 22, 1963 2 Sheets-Sheet 1

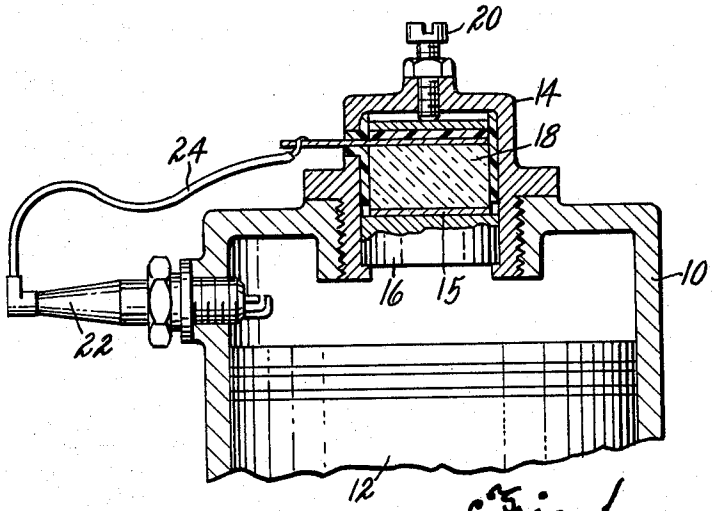


Fig. 1

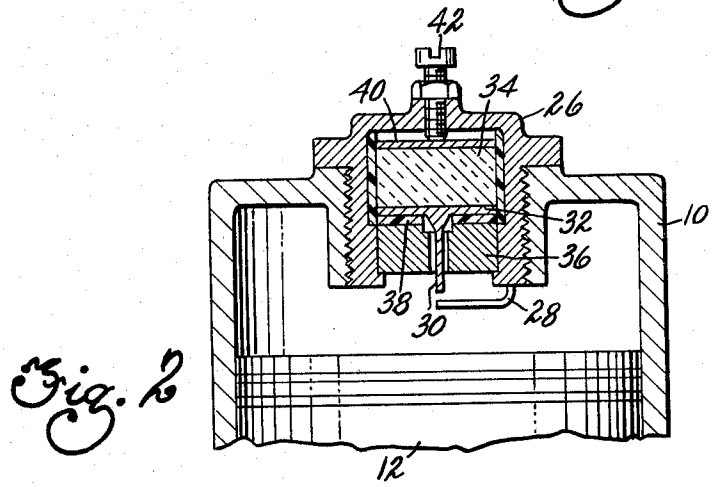


Fig. 2

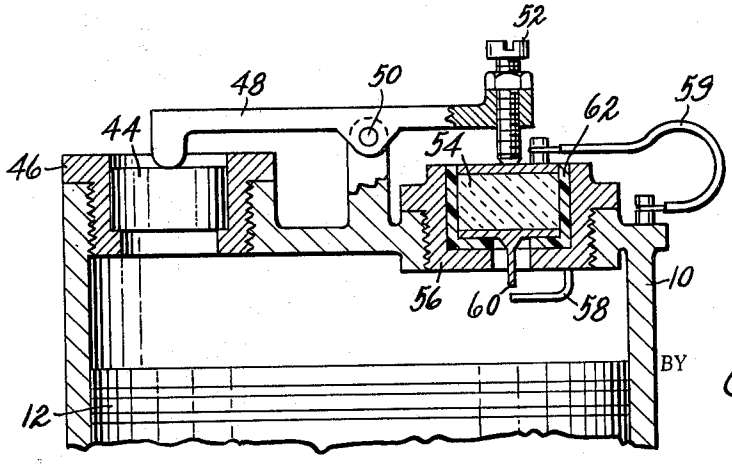


Fig. 3

INVENTOR.
JOHN M. FARRELL
BY C. R. Meland
HIS ATTORNEY

Nov. 2, 1965 J. M. FARRELL 3,215,133

ENGINE COMPRESSION OPERATED PIEZOELECTRIC IGNITION SYSTEM

Filed Nov. 22, 1963 2 Sheets-Sheet 2

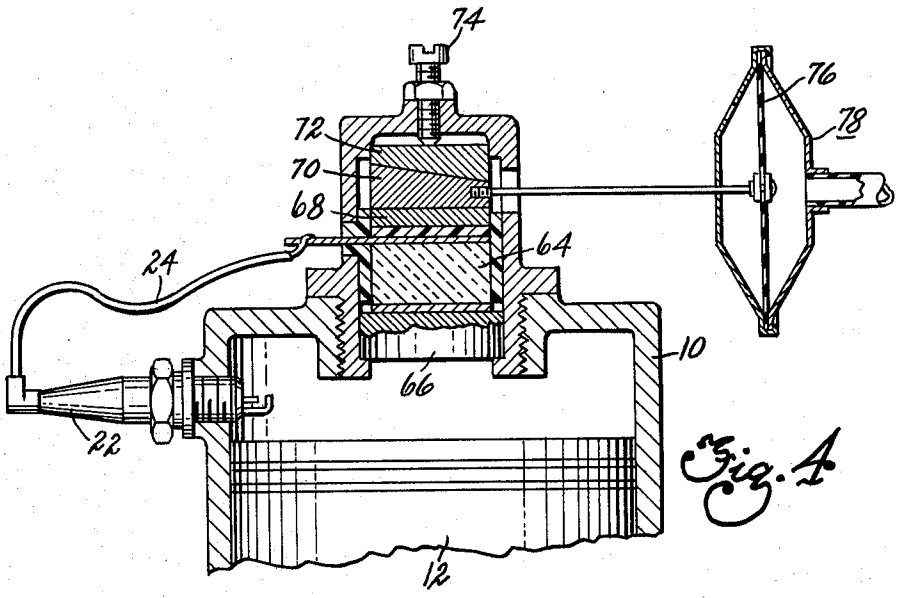


Fig. 4

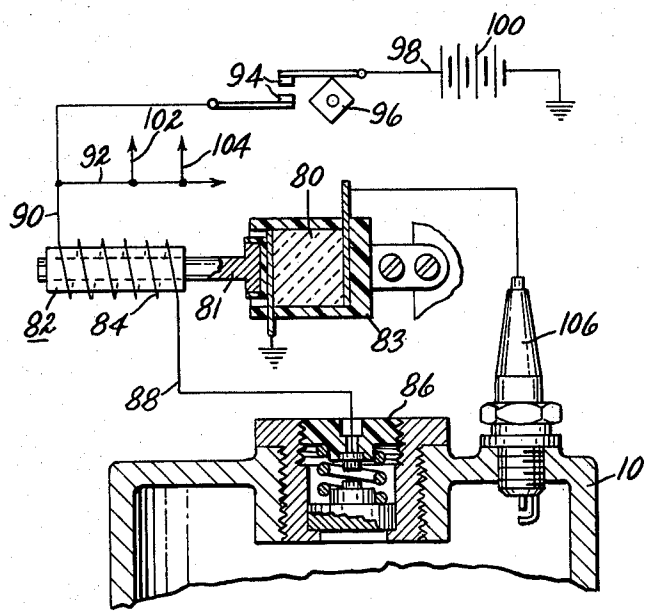


Fig. 5

INVENTOR.
JOHN M. FARRELL
BY C. R. Meland
HIS ATTORNEY

United States Patent Office

3,215,133

Patented Nov. 2, 1965

3,215,133

ENGINE COMPRESSION OPERATED PIEZOELECTRIC IGNITION SYSTEM

John M. Farrell, Detroit, Mich., assignor to General Motors Corporation, Detroit, Mich., a corporation of Delaware

Filed Nov. 22, 1963, Ser. No. 325,610

8 Claims. (Cl. 123—148)

This invention relates to ignition systems for internal combustion engines and more particularly to an ignition system wherein a piezoelectric crystal or element is used as a source of voltage to directly fire a spark plug and wherein a piezoelectric crystal is stressed by engine compression.

It is well-known to those skilled in the art that a piezoelectric crystal can be stressed and will provide a high output voltage that is capable of directly firing a spark plug without the use of ignition coils or batteries. In the past piezoelectric crystal has been stressed through a cam and follower mechanism and the cam is driven in synchronism with the engine so that the firing of the spark plug occurs at some point of rotation of the cam.

In contrast to the cam and follower arrangement for stressing a piezoelectric crystal, it is an object of this invention to provide ignition systems wherein the pressure produced during the compression stroke of an internal combustion engine is used to stress the piezoelectric crystal to cause a firing of a spark plug at a predetermined pressure within the cyclinder of the engine.

Another object of this invention is to provide a combined spark plug and pressure operated piezoelectric spark source which can be fitted into a cylinder of an internal combustion engine.

Still another object of this invention is to provide a piezoelectric ignition system wherein the crystal is stressed through a link or lever which is operated by engine compression.

Another object of this invention is to provide a piezoelectric ignition arrangement wherein the piezoelectric crystal is stressed by engine compression and wherein a variable pressure can be applied to the piezoelectric crystal for engine timing by means of a vacuum control or similar engine or manifold vacuum adjusted device.

Another object of this invention is to provide an ignition system wherein the piezoelectric element is stressed by an electrically energizable device such as an electromagnet and wherein the energization of the device depends upon a timing control and a pressure responsive control which operates in accordance with cylinder pressure.

Further objects and advantages of the present invention will be apparent from the following description, reference being had to the accompanying drawings wherein referred embodiments of the present invention are clearly shown.

In the drawings:

FIGURE 1 illustrates a piezoelectric ignition apparatus where the piezoelectric crystal or element is stressed by engine cylinder pressure.

FIGURE 2 illustrates a piezoelectric ignition apparatus where the device for stressing the crystal and the spark plug are combined into one unit.

FIGURE 3 illustrates an arrangement wherein the piezoelectric crystal is stressed through a lever which is moved in accordance with cylinder pressure.

FIGURE 4 illustrates an arrangement for adjusting the pressure on a piezoelectric crystal through the use of a vacuum timing control.

FIGURE 5 illustrates a piezoelectric ignition system where the piezoelectric crystal or element is stressed by an electromagnet and wherein the circuit for the electromagnet is controlled by an engine driven timing device and by engine cylinder pressure.

Referring now to FIG. 1, the reference numeral **10** designates the cylinder of a four cycle internal combustion engine. The reference numeral **12** designates a reciprocable piston of the engine which is connected with a crank shaft in the usual manner. The exhaust valves and intake valves for the engine are not illustrated but they are conventional.

The cylinder **10** has a threaded opening which receives a housing **14**. The housing **14** contains a reciprocable piston **16**, one end of which engages a part **15** that engages a piezoelectric crystal or element **18**. The piezoelectric crystal or element **18** is capable of developing an output voltage when it is stressed.

An adjusting screw **20** is provided for adjusting the initial force applied to the crystal **18** and this adjusting screw is threaded into one end of the housing **14**. One side of the crystal is connected with a terminal of a spark plug **22** by a conductor **24**. The spark plug is threaded into one wall of the cylinder **10** as is apparent from FIGURE 1. The opposite side of the piezoelectric crystal **18** is grounded either through part **15** and the piston **16** or if desired, through a conductor which engages the housing **14**. The output terminals of the piezoelectric tal **18** is grounded either through part **15** and the piston electrodes of the spark plug **22**.

As the piston **12** reciprocates in the cylinder **10**, pressure is developed within the cylinder which will force the piston **16** upwardly during the compression stroke of the engine. At some predetermined pressure, the crystal **16** is stressed sufficiently to cause a firing of the spark plug **22** since the crystal develops a high output voltage when it is mechanically stressed. The timing of the spark will depend upon the pressure in the cylinder **10** and by the preloading of the piezoelectric element **18** by the adjusting screw **20**. Thus as the preloading of the piezoelectric element **18** is increased, less pressure in the cylinder **10** is required to stress the piezoelectric element **18**. It therefore is seen that the timing of the spark can be varied by varying the preloading of the piezoelectric element **18**. The adjusting screw is insulated from the top side of the piezoelectric crystal **18** so that the top side of the crystal is not grounded.

Referring now to FIGURE 2, an ignition apparatus is illustrated which is similar to that shown in FIGURE 1 but wherein the spark plug and spark source are built into one unit. In FIGURE 2, a metal housing **26** is threaded into the cylinder **10**. The housing **26** carries a spark electrode **28**. Another spark electrode **30** is provided which is connected with a conductive plate **32** which engages one side of the piezoelectric crystal **34**.

An annular piston **36** is provided which is insulated by insulating material **38** from the plate **32**. The top end of the piezoelectric crystal engages a metal plate **40** which in turn engages an adjusting screw **42** threaded into the housing **26**. The adjusting screw is once more used to preload the piezoelectric crystal **34**.

With the arrangement of FIGURE 2, the top end of the piezoelectric crystal **34** is electrically connected with the housing **26** through the screw **42** and therefore is connected with electrode **28**. The opposite side of the piezoelectric crystal **34** is electrically connected with electrode **30**.

When the cylinder **10** has a predetermined pressure, the piston **36** is forced upwardly to stress the crystal **34** an amount sufficient to cause an arc to jump between electrodes **28** and **30**. As the pressure reduces in the cylinder **10**, the crystal **34** is no longer stressed. The timing of the arc between electrodes **28** and **30** again de-

pends upon the pressure developed in the cylinder **10** and upon the preloading of the crystal **34** by the screw **42**.

FIGURE 3 illustrates a system where the piezoelectric crvstal and the spark gap are built into one unit and where the crystal is stressed by a lever that is operated by cylinder pressure. In FIGURE 3, a piston **44** can reciprocate within a housing **46** threaded into an opening in cylinder **10**. The lever **48** is pivoted at **50** and one end of this lever engages the piston **44**. The opposite end of lever **48** has an opening which receives an adjusting screw **52**. The adjusting screw can apply pressure to the piezoelectric element **54** which is located within housing **56**. The housing **56** is connected with one electrode **58** of a spark gap, the other electrode **60** being disposed within an insulator **62** fitted within the housing **56**. The top end of the piezoelectric crystal **54** is electrically connected with housing **56** and to electrode **58** by conductor **59** or through screw **52**. The lower end of the piezoelectric crystal **54** is connected with the electrode **60** so that the output voltage of the piezoelectric crystal **54** is impressed across electrodes **58** and **60**.

With the arrangement of FIGURE 3, the piston **44** is moved upwardly by engine cylinder pressure and a force is transmitted to the crystal **54** to stress it through the lever **48**. A timing adjustment can be made with the arrangement of FIGURE 3 by adjusting the screw **52** relative to the lever **48**.

FIGURE 4 illustrates an arrangement for varying the timing of the firing of a spark plug in a piezoelectric apparatus. In FIGURE 4, the piezoelectric element **64** is disposed between a piston **66** and a part **68**. A wedge **70** is located between parts **68** and **72**. The part **72** can be adjusted through a preloading adjusting screw **74**. It will be appreciated that movement of the wedge **70** will vary the preloading of the piezoelectric element **64**. By varying the preloading of the crystal, the point at which the element **64** is stressed to fire a spark plug is accordingly varied.

In FIGURE 4, the wedge **70** is moved in accordance with conditions of operation of the engine. Thus the wedge **70** can be connected with the diaphragm **76** of a vacuum unit **78** which is connected to the intake manifold of the engine. It is apparent that the wedge **70** could be adjusted in accordance with other engine conditions.

The arrangement of FIGURE 4 can be used with the other systems described above and provides a means for varying engine timing in accordance with conditions of operation of the engine.

Referring now to FIGURE 5, a piezoelectric ignition system is illustrated wherein the piezoelectric crystal **80** is stressed by an electromagnetic actuator **82**. The actuator **82** has, for example, a reciprocable armature **81** engaging one side of the crystal **80**, the opposite side of the crystal engaging a fixed support **83**. The electromagnetic actuator **82** has a coil winding **84**. One end of the coil winding **84** is connected with a pressure operated switch **86** which is capable of connecting the conductor **88** to ground whenever the pressure in cylinder **10** reaches a predetermined value.

The conductor **90** which is connected with the opposite side of coil winding **84** is connected with a conductor **92** and a pair of breaker contacts **94**. The breaker contacts **94** are opened and closed by a cam **96** which is driven by the crank shaft of the engine. The closing and opening of the contacts **94** are therefore synchronized with the position of the pistons in a multi-cylinder engine. The opposite side of the breaker contacts **94** are connected with a conductor **98** and this conductor is connected to one side of a battery **100**. The opposite side of the battery **100** is grounded.

The conductor **92** is connected with conductors **102** and **104** which are intended to illustrate conductors that can feed other electromagnetic actuators of the type designated by reference numeral **82**. Thus it is contemplated

with the system of FIGURE 5 that each cylinder of the engine will have an electromagnetic actuator and a piezoelectric crystal and that the circuit for each electromagnetic actuator will employ a pressure switch of the type designated by reference numeral **86**. The breaker points **94**, however, will be common to one side of all of the coil windings of the respective electromagnetic actuators.

It is seen from FIGURE 5 that one side of the piezoelectric crystal **80** is grounded whereas the opposite side of this crystal is connected with the electrode of a spark plug **106** which has its spark gap located in the engine cylinder **10**.

With the apparatus of FIGURE 5, the spark plug **106** will be fired whenever the piezoelectric crystal is stressed and the crystal will be stressed only when the coil winding **84** is energized. The coil winding **84** can only be energized when breaker contacts **94** and the contacts of pressure switch **86** are simultaneously closed. The arrangement is such that the pressure switch **86** closes before the timing cam **96** permits a closure of breaker contacts **94**. When both contacts **94** and the contacts of the pressure switch **86** are closed, the spark plug **106** will be fired since at this time the crystal **80** is stressed by the electromagnetic actuator **82**. The cam **96** and the breaker contacts **94** can be of the same type as is provided in a conventional distributor in which case, the closing of contact **94** can be controlled by the centrifugal advance and vacuum advance mechanisms of a distributor.

As pointed out above, the conductor **92** and conductors **102** and **104** are for feeding electromagnetic actuators of the type designated by reference numeral **82**. Thus in a multi-cylinder system, there will be as many electromagnetic actuators and crystals and pressure operated switches as there are cylinders for the engine, but the electromagnetic actuators are commonly controlled by one set of breaker contacts **94**.

While the embodiments of the present invention as herein disclosed, constitute preferred forms, it is to be understood that other forms might be adopted.

What is claimed is as follows:

1. In combination, an internal combustion engine having a cylinder and a piston which reciprocates therein, an element separate from said piston shiftable by engine cylinder pressure, a spark discharge device having electrodes located in said cylinder, a piezoelectric crystal electrically connected with said spark discharge device for applying spark firing energy directly to said spark discharge device, and a lever interposed between said shiftable element and said piezoelectric crystal for stressing said crystal when engine cylinder pressure reaches a predetermined value.

2. An ignition system for an internal combustion engine having a cylinder and a reciprocable piston comprising, a spark discharge device having electrodes located within said cylinder, a piezoelectric crystal, an actuating means for stressing said piezoelectric crystal, means directly electrically connecting said piezoelectric crystal and said spark discharge device whereby voltage pulses developed by said crystal are used to directly fire said spark discharge device, a pressure responsive control means responding to pressure conditions in said cylinder, a timing control means operating in synchronism with said engine, and means connecting said timing control means, said pressure responsive means and said actuating means whereby the actuation of said actuating means is controlled by said timing control means and said pressure responsive means.

3. The ignition system according to claim **2** where the actuating means is an electromagnet and where said timing control means and pressure responsive means are switches for controlling the energization of the electromagnet.

4. An ignition system for an internal combustion en-

gine comprising, a spark plug for firing the combustible mixture of the engine, a piezoelectric crystal, an electromagnetic actuator having a coil winding for stressing said piezoelectric crystal, means directly electrically connecting said crystal and said spark plug whereby voltage pulses developed by said crystal are used to directly fire said spark plug, a pressure responsive switch operated in accordance with engine cylinder pressure, a timing switch operated in synchronism with said engine, a source of voltage, and means electrically connecting said timing switch, said pressure responsive switch and said coil winding in a series circuit across said source of voltage.

5. In combination, an internal combustion engine having a cylinder and a piston that reciprocates therein, a shiftable element separate from said piston having at least one face subjected to cylinder pressure whereby said element is shifted by engine cylinder pressure, a spark discharge device having electrodes located in said cylinder, a piezoelectric crystal electrically connected with said spark discharge device for applying spark firing energy to said spark discharge device, and a lever interposed between said shiftable element and said piezoelectric crystal for stressing said crystal when engine cylinder pressure reaches a predetermined value.

6. In combination, an internal combustion engine having a cylinder and a reciprocable piston, a spark discharge device for firing the combustible mixture in said cylinder, a piezoelectric crystal connected with said spark discharge device for directly firing said spark discharge device from the voltage developed by said crystal when it is stressed, an element separate from said piston shiftable by engine cylinder pressure and operable to stress said piezoelectric crystal, and means for varying the preloading of said piezoelectric crystal in accordance with a condition of operation of said engine.

7. The combination according to claim 6 wherein the means for varying the preloading of the crystal includes a wedge means that is adjustable in accordance with a condition of operation of said engine.

8. In combination, an internal combustion engine having a cylinder and a piston that reciprocates therein, an element separate from said piston shiftable by engine cylinder pressure, a spark discharge device having electrodes located in said cylinder, a piezoelectric crystal electrically connected with said spark discharge device for applying spark firing energy directly to said spark discharge device, and force transmitting means interposed between said shiftable element and said piezoelectric crystal for transmitting the force developed by cylinder pressure to said crystal when engine cylinder pressure reaches a predetermined value, and means for varying the effective length of said force transmitting means.

References Cited by the Examiner

UNITED STATES PATENTS

2,068,744	1/37	Gutzke	123—148
2,248,574	7/41	Knight	123—148
2,717,916	9/55	Harkness	123—148
2,852,590	9/58	Fremon	123—148

RICHARD B. WILKINSON, *Primary Examiner.*