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Burge, Jr. et al.

[11] **3,865,539**

[45] **Feb. 11, 1975**

[54] **PIEZOELECTRIC VOLTAGE GENERATOR**

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[73] Assignee: **TRW Inc.**, Redondo Beach, Calif.

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[52] **U.S. Cl.** **431/255**, 310/8.7

[51] **Int. Cl.** **F23q 3/00**, F02p 3/12

[58] **Field of Search** 431/255; 310/8.3, 8.6, 310/8.7; 137/81.5

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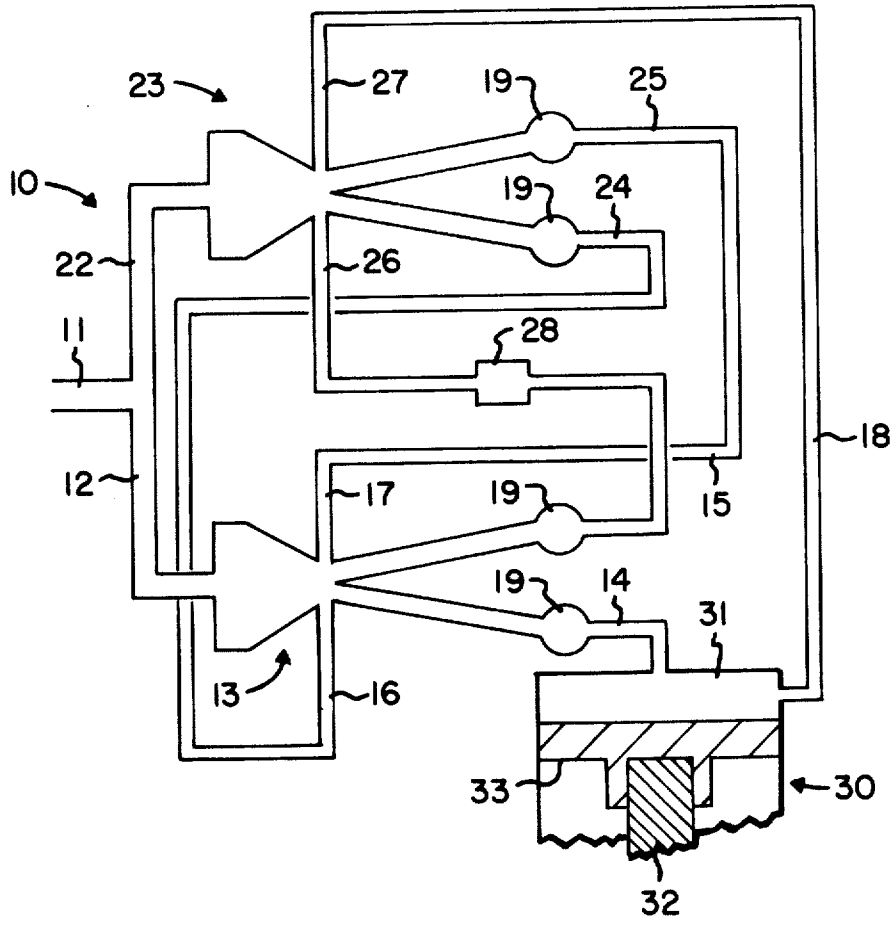
Primary Examiner—Edward G. Favors

Attorney, Agent, or Firm—William B. Leach; Harry I. Jacobs

[57] **ABSTRACT**

A piezoelectric device is fitted with a hydraulic piston for exerting a loading thereon. The piston is periodically driven by a fluidic actuator thereby to repeatedly stress the piezoelectric crystal and produce an electrical voltage which may be used in a spark ignition circuit. The piezoelectric device, in combination with an internal combustion engine provides for automatic ignition and re-ignition in the event of an interrupted combustion process.

4 Claims, 5 Drawing Figures



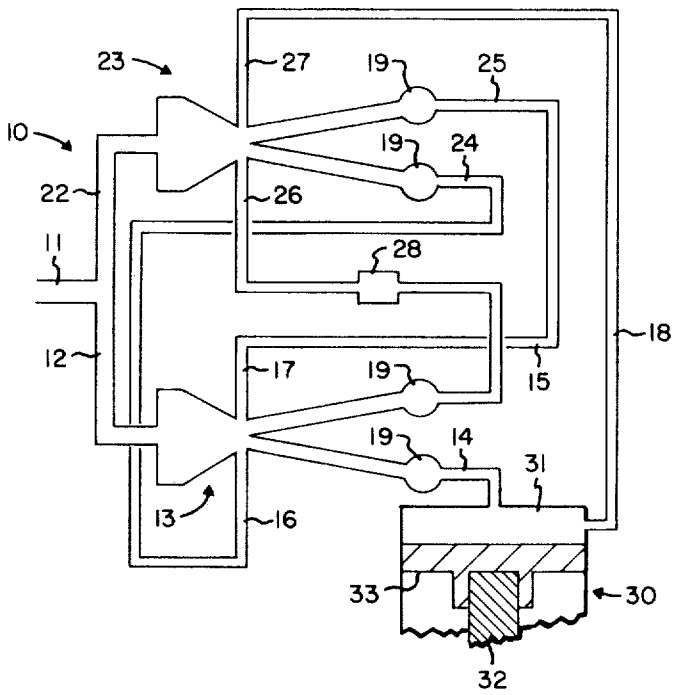

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28
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30
32

Fig. 1

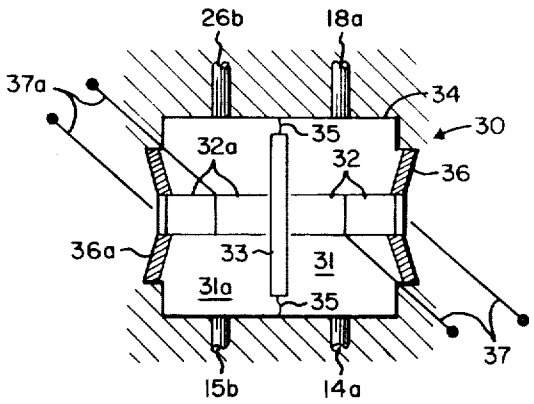

26b
18a
37a
34
30
35
32a
32
36
36a
33
31
31a
35
37
15b
14a

Fig. 2

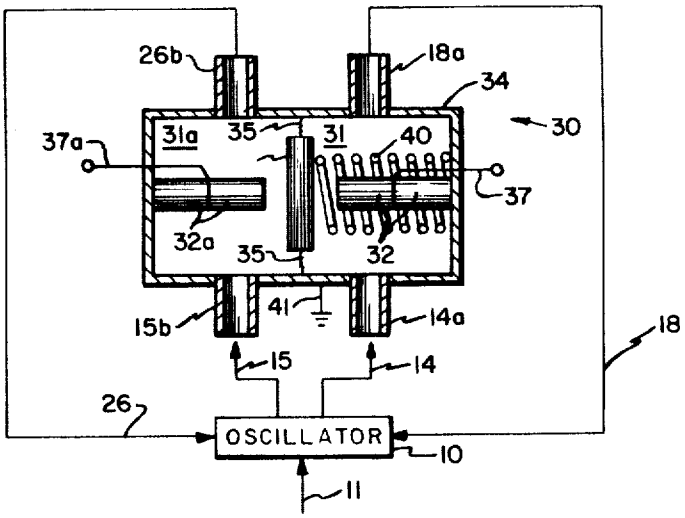

26b
18a
34
30
37a
31a
35
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32a
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32
41
15b
14a
18
15
14
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OSCILLATOR
10
11

Fig. 3

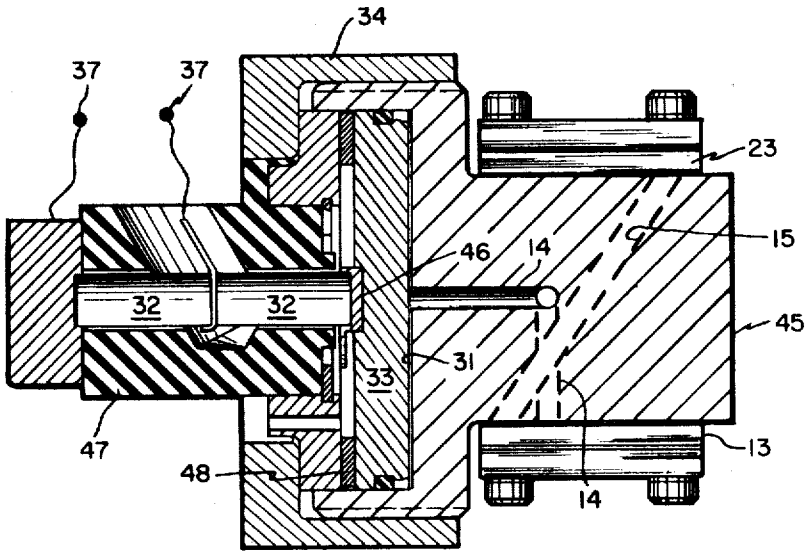

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23
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14
32
32
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48
13
14

Fig. 4

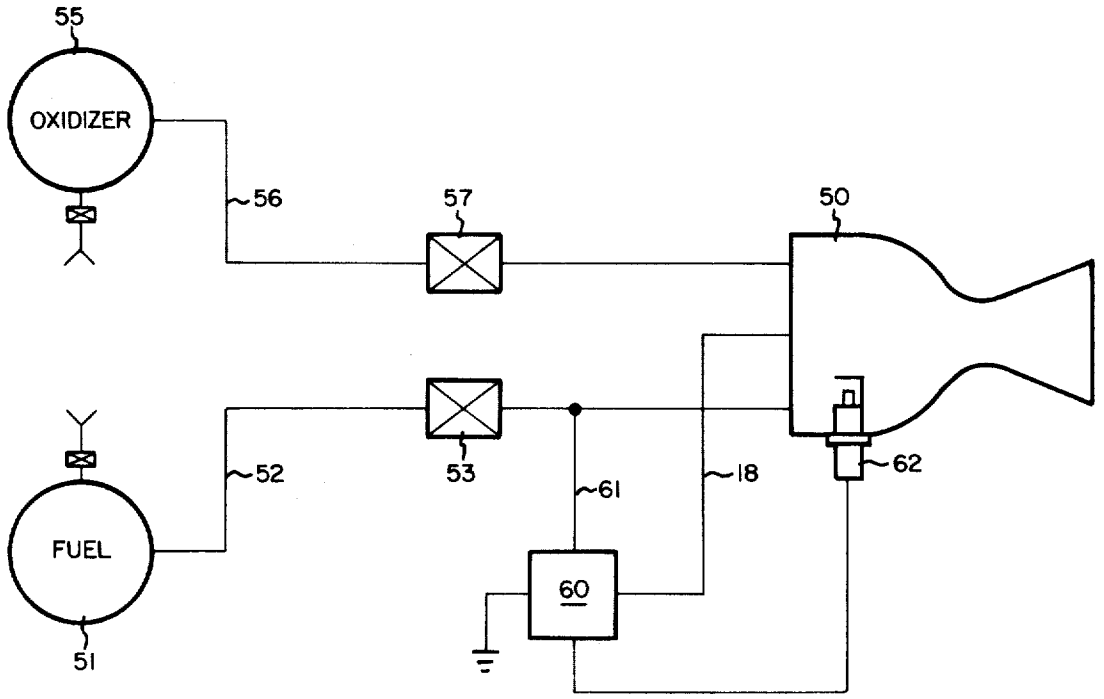


Fig. 5

PIEZOELECTRIC VOLTAGE GENERATOR

BACKGROUND OF THE INVENTION

This invention relates to piezoelectric voltage generators in general and more specifically to propellant ignition systems.

It is known that certain crystals, when deformed or stressed, develop an electric field referred to as the piezoelectric effect. The deformation is usually very small, but the associated mechanical force may be very large.

A typical piezoelectric igniter system is represented by the U.S. Pat. to Riverson, No. 4,603,710 which discloses a piezoelectric igniter for a hand held cigarette lighter. The stress producing means includes a slideable piston acting under the influence of gravity or acceleration forces.

While devices of this type are very satisfactory for many applications, they nevertheless suffer from shortcomings in applications such as rocket motors.

Accordingly, it is an object of this invention to provide a piezoelectric voltage generator not subject to the shortcomings and disadvantages of the prior art.

It is another object of the present invention to provide a piezoelectric voltage generator that utilizes a pressurized gas, such as rocket propellant, in the stress producing mechanism.

It is a further object of the present invention to provide a piezoelectric voltage generator wherein the crystal is repeatedly stressed at a high rate.

SUMMARY OF THE INVENTION

In accordance with the teachings of the invention a piston is mounted in a housing and a piezoelectric device is mounted in relationship to the piston so as to stress the piezoelectric device upon a relatively small movement of the piston. The piston movement is actuated by fluid pressure supplied to the piston chamber through a fluidic oscillating circuit. Either impact and non-impact stress loading may be utilized.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram of a fluidic oscillating circuit and a portion of a piezoelectric assembly in accordance with the invention;

FIG. 2 is a schematic diagram of a non-impact piezoelectric assembly used in conjunction with the fluidic oscillating circuit of FIG. 1;

FIG. 3 is an alternative piezoelectric assembly of the impact type;

FIG. 4 is a particular embodiment of a piezoelectric voltage generator; and

FIG. 5 is a schematic diagram of a piezoelectric assembly as shown in FIGS. 1 - 4 in a rocket motor system.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1 there is shown a fluidic oscillator circuit **10** suitable for periodically actuating movement of a stress loading piston as herein further explained. A fluid, such as gaseous air, nitrogen, hydrogen or other gas, is supplied under pressure to the circuit inlet **11** whereupon the fluid may flow through either of two paths **12, 22.** One path **12** leads to one portion of the fluidic circuit herein denoted as a first fluidic device or digital amplifier **13** which has two outlets **14, 15.** One outlet **14** is coupled to the piston chamber **31** of a piezoelectric assembly **30** which includes a piezoelectric device **32** and a piston **33,** the operation of which will be explained below. The digital amplifier **13** also includes control ports **16, 17.** When pressure is supplied to control port **17,** the fluid flow is caused to exit through outlet **14.** When pressure is depleted at port **17** and supplied to control port **16,** the fluid flow is caused to flip to the other outlet **15.** Thus, if control pressure is alternately supplied to control ports **16, 17,** the fluid flow is caused to alternately flip from one outlet **14,** to another **15.**

The other inlet fluid path **22** is coupled to a second fluidic device, or flip-flop, **23** also having two outlets **24, 25** and two control ports **26, 27.** It may be seen from FIG. **1,** that when fluid flows through outlet **14** of the amplifier **13,** fluid will also be flowing through outlet **24** of the flip-flop **23** thereby supplying pressure to control port **17.** The digital amplifier is designed to be used as a power amplifier device. Thus, fluid logic devices operating at low supply pressures can provide control signals for the higher flow and higher pressure output of the digital amplifier.

Fluid in the piston chamber **31** is permitted to exit through a fluid return path **18** thereby supplying pressure to control port **27.** This then causes fluid to exit from the flip-flop **23** through outlet **24** which supplies pressure to the digital amplifier control port **16** causing fluid to exit the flip-flop through outlet **15.** The pressure in piston chamber **31** therefore decays permitting the relief of stress on the piezoelectric device **32.**

Further study of FIG. **1** shows that pressure supplied by outlet **15** to control port **26** flips the fluid flow to outlet **25,** control port **17,** and thus, fluid flow is flipped to again enter the piston chamber **31.** A fluidic circuit of the type shown in FIG. **1** has vents sized and located to allow the pressure to decay within a selected time period after the fluid source has been flipped to a different path. Vents are schematically shown and identified by numeral **19** in FIG. **1.**

It will be immediately apparent to one familiar with the fluidic art that the operation of the oscillating circuit of FIG. **1** is dependent upon the proper selection of flow path resistance and capacitance as well as supply pressure. To this end, an accumulator or capacitance cavity **28** is included to provide additional control over the circuit frequency characteristics. The circuit of FIG. **1** is merely an example of one circuit having acceptable operating characteristics and was assembled with commercially available components, thus the circuit of FIG. **1** is not purported to be an optimum circuit.

Turning now to FIG. **2** there is shown one embodiment of a non-impact piezoelectric assembly **30.** The assembly includes a piston **33** mounted in a housing **34** by flexural members **35** which permit small movements of the piston. One pair of piezoelectric devices **32** are mounted between the piston **33** and one endwall **36** of the housing **34** which in this embodiment is a bias member providing prestressing of the piezoelectric device. In accordance with well known piezoelectric technology, an electrical potential will occur across leads **37** when the piezoelectric devices **32** undergo stress forces caused by small movements of the piston **33.**

Also shown in FIG. **2** is an inlet **14***a* which when coupled to the outlet **14** of the fluidic oscillating circuit of FIG. **1** provides means for periodically moving the pis-

ton 33 away from the piezoelectric devices 32 to thereby relieve the prestressed condition. A vent port 18*a* may be coupled to return path 18 of the fluidic oscillator.

As further shown in FIG. 2, a second chamber 31*a* may be included as well as a second pair of piezoelectric devices 32*a* having electrode leads 37*a* and which also are prestressed by a second bias member 36*a*. The actuation of the piston 33 may be augmented by coupling the second chamber 31a into the fluidic circuit. This may be implemented by substituting the second chamber 31*a* for the accumulator cavity 28 of FIG. 1. Thus, an inlet 15*b* to the second chamber 31a is provided which is coupled to outlet 15 of FIG. 1, and an outlet 26*b* from the second chamber 31*a* is coupled to the control port 26 of FIG. 1. While a piezoelectric assembly may be constructed having a single piezoelectric crystal element, the use of at lest a pair of elements as at 32 is a convenient means of providing an increased potential for a given piston deflection.

FIG. 3 shows an embodiment of the invention in the form of an impact type of device. This embodiment, like that of FIG. 2 is a two chamber device coupled to the fluidic oscillator. The piezoelectric devices 32, 32*a* are each spaced from the piston 33. As shown the spacing is exaggerated for clarity, and in application would be in the order of 0.25 inches. In addition to the features already described in conjunction with FIG. 2, there may be included a bias member 40 in place of the fluidic pressure to the second chamber 31a. Thus, fluidic pressure drives the piston toward piezoelectric device 32*a* impacting therewith and upon venting of the pressure in the first chamber 31, the bias member 40 drives the piston into impact with the first piezoelectric devices 32. As a feature of implementation, the housing 34 is grounded at 41.

A design that was constructed for research and development purposes is shown in FIG. 4. The purchased fluidic devices 13, 14 were mounted on a fluidic logic body 45 having formed therein the various interconnecting fluid passageways of which outlets 14, 15 of the digital amplifier 13 are indicated. Outlet 14 leads to the chamber 31 for activation of the piston 33 which engages a copper terminal 46. This terminal in turn engages one end of the piezoelectric device 32. An insulation body 47 supports the piezoelectric devices 32 in housing 34. This embodiment used an O-ring seal instead of flexure elements to support the piston and further support for the piston is providedi by ring member 48.

The voltage generator of FIG. 4, shown substantially to scale, utilized a piston 1.75 inches in diameter. Both gaseous nitrogen and gaseous helium with pressure up to 400 psig were used to drive the fluidic oscillator. The fluidic circuit was permissive of piston actuation at the rate of 50–60 cycles per second and output peak voltages measured up to approximately 7,000 volts.

A piezoelectric voltage generator as herein described may be made without any moving parts if the piston is flexure mounted. As a means for spark ignition in propulsion devices having propellant delivered to the combustion chamber under pressure, the propellant may be used to operate the fluidic oscillator. Thus, a rocket motor ignition system may be provided which is entirely automatic in operation and which would reinstate operation in the event of combustion failure or flame-out. Similar ignition systems may be devised for commercial and home furnaces and similar systems subject to flame-out. While the voltage generator as described has been discussed in terms of a gaseous fluid, liquid operating systems may also be designed in accordance with these teachings and in accordance with fluidic hardware technology.

As shown in FIG. 5, a rocket motor 50 is supplied with a fuel reactant from a fuel source 51 through a fuel line 52 and a fuel engine start valve 53. Similarly, an oxidizer reactant is supplied from an oxidizer source 55 through an oxidizer line 56 and an oxidizer engine start valve 57. The reactants may be in a gaseous state under pressure or may be pressurized by a separate pressurizing tank in a conventional manner. The reactants are thereby supplied to the rocket motor under pressure and are introduced through the usual injector device.

A fluidic oscillator-piezoelectric assembly 60 of the type herein described may be supplied with a high pressure fluid by coupling one of the reactant supply lines, such as the fuel line 52, to the fluidic oscillator inlet as by line 61. The electrode terminal 32 of the assembly is coupled to a spark-ignition device 62. The fluidic oscillator output 18 may be directed to any convenient disposal but, in particular, it may be coupled into the combustion chamber of the rocket motor. In most cases, it is necessary to use parallel reactant circuits, one directed to the rocket motor and one to the fluid-oscillator inlet, but in some applications it may be feasible due to flow requirements to direct the entire reactant flow through the fluidic circuit and then into the rocket motor. The utilization of the fluidic circuit in combination with the piezoelectric device as a voltage generator enables the use of one of the reactants as the voltage generator driving force. In this manner, the ignition system is both simple and reliable providing for automatic ignition upon opening of the engine start valves and providing automatically for reignition in the case of a flame-out. Furthermore, the system is particularly safe because the ignition source is not a separately initiating system subject to its own initiation failure.

What is claimed is:

1. A combustion system of the type having a reactant injector, a source of a reactant at a high pressure, means for supplying the reactant to the injector and a spark ignition device in communication with the combustion zone, and comprising:

a housing;

a piston moveably mounted within said housing, said housing, and one end surface of said piston defining a first chamber therebetween;

a piezoelectric device mounted within said housing and positioned in engageable relationship with the other end surface of said piston for producing an electrical potential when subjected to mechanical stresses induced therein upon movement of said piston toward said device, said device including electrode terminals coupled to the combustion system ignition device; and

a fluidic oscillator coupled to said chamber and to the reactant source, the one surface area off said piston being greater than the area of engagement of the other surface with said piezoelectric device by a factor of at least ten whereby reactant, when supplied under pressure to said oscillator, is periodically introduced into and relieved from said chamber for actuating periodic movement of said piston

and producing an alternating voltage across said terminals and to the ignition device.

2. A piezoelectric voltage generator comprising:

a housing;

a piston moveably mounted within said housing, said housing and said piston defining first and second chambers therebetween;

a first piezoelectric device mounted within said first chamber and having electrode terminals for outputing a voltage therefrom;

a second piezoelectric device mounted within said second chamber and having electrode terminals for outputing a voltage therefrom, each of said piezoelectric devices positioned to have stresses induced therein upon movement of said piston;

a fluidic oscillator coupled to said first chamber

whereby fluid, when supplied under pressure to said oscillator, is periodically introduced into said first chamber for actuating movement of said piston and producing a voltage across said terminals.

3. The piezoelectric voltage generator of claim 2 further comprising:

a flexure member interconnecting said piston and said housing for permitting movement of said piston.

4. The piezoelectric voltage generator of claim 2 further comprising:

means coupling said second chamber and said fluidic oscillator circuit and alternatingly pressuring said chambers when fluid is supplied under pressure to said fluidic oscillator.

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