

# PATENT SPECIFICATION

(11) 1 517 068

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(21) Application No. 27669/76 (22) Filed 2 July 1976

(31) Convention Application No. 50/098134U

(32) Filed 14 July 1975

(31) Convention Application No. 51/013283U

(32) Filed 6 Feb. 1976

(31) Convention Application No. 51/018083U

(32) Filed 17 Feb. 1976

(31) Convention Application No. 51/018080U

(32) Filed 17 Feb. 1976 in

(33) Japan (JP)

(44) Complete Specification published 12 July 1978

(51) INT CL<sup>2</sup> F02P 3/12

(52) Index at acceptance

F1B 2D11B 2D11D

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## (54) GAS IGNITION DEVICE

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

The present invention relates to a gas ignition device in which a high voltage is generated to be applied to a discharging gap thereby to cause electric discharge across the gap for gas ignition, in particular, to a gas ignition device suitable for lighters.

In a gas ignition device of the prior art, a piezo-electric ceramic material is subjected to a mechanical external compressive force to cause a high electric voltage to be generated upon the removal of the external pressure for gas ignition. Though two methods have been known for applying the external pressure, it is not possible for either of them to make ignition by a light touch and also to eliminate a noise accompanying the ignition operation. Further, in a prior art gas ignition device of the type in which a piezo-electric ceramic material is applied with a mechanical external force to generate a high electric voltage, the high voltage discharges only once for every ignition operation thus possibly resulting in mis-operation.

According to the present invention there is provided a gas ignition device comprising a piezo-electric transformer, a rectifier circuit for rectifying the output of said

piezo-electric transformer, and a discharging gap for causing the output of said rectifier circuit to make electric discharge thereby to form a spark discharge for gas ignition.

The invention will now be described by way of example only with particular reference to the accompanying drawings wherein:—

Figure 1 shows the basic layout of a gas ignition device of the present invention,

Figure 2 shows a piezo-electric transformer used in the gas ignition device of the present invention,

Figure 3 shows an embodiment of the gas ignition device of the present invention,

Figure 4 shows an equivalent circuit of part of the circuit shown in Figure 3;

Figure 5 shows a charging curve of a capacitor of the circuit shown in Figure 3,

Figure 6 shows another embodiment of the gas ignition device of the present invention,

Figure 7 shows still another embodiment of the gas ignition device of the present invention,

Fig. 8 shows a different kind of basic layout of a gas ignition device of the present invention,

Fig. 9 shows an embodiment of the gas ignition device according to the basic layout shown in Fig. 8,

Fig. 10 shows a terminal voltage of a capacitor of the circuit of Fig. 9,

Fig. 11 shows some waveforms of the discharge current flowing through a discharge gap and

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Fig. 12 shows the circuit shown in Fig. 9 assembled in a case.

In Fig. 1, reference letter A is an oscillation circuit and reference B is a piezo-electric transformer. When the oscillation output from the oscillation circuit A is applied to the primary side (input side) electrodes of the piezo-electric transformer B, an AC high-voltage is generated on the secondary side (output side) electrode of the piezoelectric transformer B. The output from the piezoelectric transformer B is rectified through a rectifier circuit C to be stored in a capacitor D. When the voltage between the terminals of the capacitor D reaches the discharge starting voltage of a discharging gap E, spark discharge is generated across the discharging gap for gas ignition.

The piezo-electric transformer B comprises, as generally shown in Fig. 2, a rectangular piezo-electric ceramic plate 1 which is provided with a pair of electrodes 2 and 3 on respective portions of its upper and lower surfaces and an electrode 4 on the longitudinal end surface. Thus, the piezo-electric ceramic plate 1 is polarized in the direction of thickness of the plate at the portion between the electrodes while it is polarized in the direction of the length of the plate at the remaining portion. When an electric voltage which is equal in frequency to the proper resonance frequency of the piezo-electric ceramic plate 1 determined by its longitudinal size is applied between the primary side electrodes 2 and 3 of the piezoelectric transformer B, a mechanical oscillation is excited in the direction of length of the piezo-electric ceramic plate 1 because of the piezo-electric effect thus causing a high electric voltage to be generated on the secondary side electrode 4.

Referring to Fig. 3 showing an embodiment of a gas ignition device of the present invention, reference numeral 301 is a self-oscillation transistor which operates at class C. Numeral 302 is a bias resistor for starting the oscillation of the transistor 301, numeral 303 is an oscillation transformer, numerals 304 and 305 are capacitors which adjust the phase of the feed-back loop so as to satisfy the oscillation condition, numeral 306 is a resistor which limits the base current of the transistor 301, numeral 307 is a diode which serves to lengthen the conduction time interval of the transistor 301, numeral 308 is a piezo-electric transformer which steps up the oscillating voltage generated in the capacitor 304 thereby to serve as a high voltage source, numeral 309 is a rectifier circuit which comprises two diodes 309a and 309b connected as shown in the drawings and transforms and transfers the high voltage

energy generated on the secondary side of the piezo-electric transformer 308 to an energy storing capacitor 310, numeral 311 is a discharge gap, and numeral 312 is a source switch which connects and disconnects a battery 313 to and from the circuit, respectively.

The transistor 301, the bias resistor 302, the oscillation transformer 303, the capacitors 304 and 305, the resistor 306, and the diode 307 constitute a self-oscillation circuit. When the switch 312 is closed, the self-oscillation circuit is activated and, if the capacity of the capacitor 305 is larger than the input capacity of the piezo-electric transformer 308, the oscillation circuit output voltage is stepped up by the piezo-electric transformer 308 thus causing a high AC voltage to be generated on the secondary side. When the AC voltage is negative, the diode 309b is made to be conductive for charging the output capacitor 310. When the AC voltage is positive, the diode 309a is made to be conductive, the energy storing capacitor 310 is charged and its terminal voltage is gradually increased. Thus, when the terminal voltage of the capacitor 310 reaches the break down voltage of the discharge gap 311; discharge takes place to produce a spark. In this case, even if one discharge fails to ignite the gas a further discharge follows very shortly as long as the switch 312 is closed thus ensuring reliable gas ignition. Further, since only closing and opening of the switch 312 is sufficient and it is not required to apply external force to a piezo-electric element as in the prior art, the device of the present invention can be operated by only a light touch without any noise accompanying the operation.

Next, referring to Figs. 4 and 5 illustrating the behaviour in the case of charging the capacitor 310 by means of the piezo-electric transformer 308, reference numeral 414 is the output capacitor of the piezo-electric transformer 308 having a value  $C_1$ . The energy storing capacitor 310 is set to have a capacity  $C_2$  much larger than the capacitor  $C_1$ . Numeral 415 represents the output voltage of the piezo-electric transformer 308. Assuming the voltage difference between the maximum and minimum values of the output voltage is  $E_0$ , the output capacitor 414 is charged up to  $E_0/2$  during the first negative half-cycle. At the end of the succeeding positive half-cycle, the capacitor 310 is charged up to the voltage

$$E_0 \cdot C_1 / (C_1 + C_2).$$

During the succeeding negative half-cycle, the output capacitor 414 is again charged and, at the end of the succeeding

positive half-cycle, the terminal voltage of the capacitor 310 is increased by

$$C_1/(C_1+C_2)$$

times the voltage applied to the diode 309a.

5 As a result of the repetition of the above cycles, the terminal voltage of the capacitor 310 is increased gradually up to  $E_c$ . When the terminal voltage reaches the break down voltage  $E_b$  of the discharge gap 311 as a result of  $n$  times repetition, discharge takes place and the terminal voltage of the capacitor 310 is decreased to the discharge diminishing voltage  $E_d$  at which, however, again the capacitor 310 begins to be charged. Thus, the abovementioned cycles are repeated. Consequently, even if ignition fails to be made, discharge continues until switch 312 is opened irrespective of whether ignition has occurred or not.

20 As described above, in the above-described embodiment, gas ignition can be made reliably by only lightly closing the switch without any noise accompanying the operating as in the prior art device and further the repeated operation of the prior art device, because of failure in ignition are not required. Still further, since only two diodes are used to supply energy from the piezo-electric transformer to the energy storing capacitor, the piezo-electric transformer can be made compact, that is, there is provided a gas ignition device which is compact, light and very simple to handle. When, in the self-oscillation circuit, the conduction time interval of the transistor 301 is so lengthened that the transistor 301 operates at the class B rather than the class C, the fundamental wave component of the collector current becomes large and, as a result, the output power of the oscillation transformer 303 becomes large while the collector loss is disadvantageously increased. Accordingly, the conduction time interval of the transistor 301 in the above-described embodiment is adjusted by the use of the base-emitter junction of the transistor 301, the bias resistor 302, the capacitor 305, the resistor 306 and the diode 307 so that the circuit may be kept at a maximum efficiency and the consumption of the battery may be advantageously controlled.

Referring to Fig. 6 showing another embodiment of the present invention, reference numeral 601 is a self-oscillation transistor which operates at class C. Numeral 602 is a bias resistor for starting the oscillation of the transistor 601, numeral 603 is an oscillation transformer, numerals 604 and 605 are capacitors which adjust the phase of the feed-back loop so as to satisfy the oscillation condition, numeral 606 is a resistor which limits the base

current of the transistor 601, numeral 607 is a diode which serves to lengthen the conduction time interval of the transistor 601, numeral 608 is a piezo-electric transformer which steps up the oscillating voltage generated in the capacitor 604 thereby to serve as a high voltage source. Numeral 609 is a rectifier circuit which comprises two diodes 609a and 609b connected as shown in the drawings and transfers the high voltage energy generated on the secondary side of the piezo-electric transformer 608 to an energy storing capacitor 610, numeral 611 is a discharging gap and numeral 612 is a switch which is positioned at the terminal A' when the transistor 601 is not operated while at the terminal B' when the transistor 601 is operated. Numeral 613 is a battery and numeral 614 is a source energy storing capacitor. The transistor 601, the bias resistor 602, the oscillation transformer 603, the capacitors 604 and 605, the resistor 606, and the diode 607 constitute a self-oscillation circuit. When the switch 612 is positioned at the terminal A', energy is stored in the source energy storing capacitor 614; while, when the switch 612 is positioned at the terminal B', a discharge circuit of the capacitor 614 is constituted so as to give a bias through the oscillation starting bias resistor 602 to the base of the transistor 601 thereby to activate the self-oscillation circuit. Thus, the output voltage of the oscillation circuit which is generated across the terminals of the capacitor 604, is stepped up by the piezo-electric transformer 608 and, as a result, a high AC voltage is generated on the secondary side. When the high AC voltage is negative, the diode 609b is conductive to charge the output capacitor 610. When the high AC voltage is positive, the diode 609a is conductive to charge the energy storing capacitor 610 thereby to step up the terminal voltage. Thus, when the terminal voltage reaches the breakdown voltage of the discharge gap 611, discharge begins. Though, due to the discharge, the terminal voltage of the energy storing capacitor 610 is made to be lower than the discharge diminishing voltage, the energy storing capacitor 610 is charged again by the piezo-electric transformer 608; thus, the above-described process is repeated. These cycles of charging and discharging continue until the energy in the source energy storing capacitor 614 is decreased to be incapable of starting the self-oscillation circuit. When the source energy storing capacitor 614 has completely lost its energy, the self-oscillation does not occur even if the switch 612 is at the position B'. Since gas ignition is made with the discharge energy in these cycles of charging and discharging and

usually within a few discharges, it is possible, by setting the source energy storing capacitor 614 at such a capacity value as to cease the self-oscillation in a few cycles, that wasteful discharge in lighting a cigarette is controlled at a minimum level.

As described above, in the embodiment shown in Fig. 4, ignition can be effected by simply closing the switch without any noise accompanying the operation as in the prior art and, even in the case of failure in ignition, ignition is assured by the succeeding cycles of charging and discharging. Further, since the number of cycles is suitably limited, wasteful discharge can be kept at the minimum and, as a result, the battery can be prevented from being consumed wastefully.

As described hereinbefore, in accordance with the present invention, there is provided an excellent gas ignition device for lighters.

Fig. 7 shows another embodiment of the present invention.

In Fig. 7, reference numeral 701 is a self-oscillation transistor which operates at class C. Numeral 715 is a bias resistor for starting the oscillation of the transistor 701, numeral 703 is an oscillation transformer, numerals 704, and 716 are capacitors which adjust the phase of the feed-back loop so as to satisfy the oscillation condition, numeral 708 is a piezo-electric transformer which steps up the oscillating voltage generated in the capacitor 704 thereby to serve as a high voltage source, numeral 709 is a rectifier circuit which comprises two diodes 709a and 709b connected as shown in the drawing and transfers the high voltage energy generated on the secondary side of the piezoelectric transformer 708 to an energy storing capacitor 710, numeral 711 is a discharging gap, and numeral 718 is a resistor which serves to lengthen the duration of discharge across the discharging gap 711, numeral 717 is a switch which is connected with the C' terminal and the D' terminal when the transistor 701 is not to be operated and to be operated, respectively, numeral 713 is a battery, numeral 714 is a capacitor which stores the electric source energy.

In Fig. 7, the transistor 701, the oscillation transformer 703, capacitors 704 and 716, and a resistor 715 constitute the self-oscillation circuit A. When the switch 717 is connected with the C' terminal, the electric source energy storing capacitor 714 stores electric charge, while, when the switch 717 is connected with the D' terminal, the discharging circuit of the capacitor 714 is constituted whereby the self-oscillation circuit A begins to oscillate. The oscillation output voltage generated across both the terminals of the capacitor

704 is stepped up through the piezo-electric transformer 708 so that an AC high voltage is generated on the secondary side of the piezo-electric transformer 708. This AC high voltage is rectified through the rectifier circuit 709 whose output is stored in a capacitor 710.

When the terminal voltage of the capacitor 710 reaches the breakdown voltage of the discharging gap 711, spark discharge takes place to produce a spark. The resistor 718 is provided so that the duration of discharge may be lengthened and thus the ignition efficiency may be improved. Although the above-described spark discharge causes the terminal voltage of the capacitor 710 to be reduced, the capacitor 710 can repeat charging and discharging until the energy of the electric energy storing capacitor 714 is not enough to drive the self-oscillation circuit A and, as a result, several repetitions of the spark discharge can take place.

Fig. 8 shows another embodiment of the present invention which is different from the circuit of Fig. 1 in that an induction element F as well as a discharging gap E are connected between the terminals of a capacitor D.

In Fig. 9 illustrating an electric circuit of the type shown in Fig. 8, reference numeral 801 is a battery, numeral 802 is a switch, numeral 803 is a transistor, numeral 804 is a diode connected between the base of the transistor 803 and the ground, numerals 805 and 806 are capacitors, numeral 807 is a resistor connected in parallel with the capacitor 806, numeral 808 is an oscillation coil, numerals 809 and 810 are capacitors, and the above-described elements 803 to 810 constitute the oscillation circuit A. Reference numeral 811 is a piezo-electric transformer to which is applied the oscillation output from the oscillation circuit A and at the output electrode of which is generated a high voltage. Numerals 812, 813, 814 and 815 are diodes, numerals 816 and 817 are capacitors, and these diodes 812 to 815 and capacitors 816 and 817 constitute a fourfold voltage rectifier circuit. Numeral 818 is a capacitor which stores the rectified output from the fourfold rectifier circuit. Numeral 819 is a coil, and numeral 820 is a discharging gap. When the terminal voltage of the capacitor 818 reaches the breakdown voltage of the discharging gap 820, the electric charge stored in the capacitor 818 is discharged through the coil 819 thus causing spark discharge to take place across the discharging gap for gas ignition. The coil 819 is provided so that the duration of discharge may be lengthened without considerably reducing

the duration of discharge may be ignition efficiency may be improved.

Fig. 10 shows the terminal voltage of the capacitor 818 in Fig. 9. As shown in Fig. 10, the capacitor 818 repeats charging and discharging.

Fig. 11 shows the behaviour of the discharge current flowing through the discharging gap, in which the curve A" corresponds to the case where the discharging gap 311 and 611 alone is connected in parallel with the capacitors 310 and 610 as shown in Figs. 3 and 6, the curve B" corresponds to the case where the resistor 718 is also provided as shown in Fig. 7; and the curve C" corresponds to the case where the induction element 819 is also provided as shown in Fig. 9. In the case A", the peak value is high but the duration is short; while, in the case B", the peak value of the discharge current is reduced but the duration is lengthened. In the case C", the duration can be lengthened without considerably reducing the peak value. Further, according to the experiments by the inventors, the ignition efficiency is much improved when the induction element 819 in Fig. 9 has an inductance of 100  $\mu$ H to 500 mH.

In Fig. 12 showing an assembly of the circuit of Fig. 9 constituted in a case, reference numeral 901 is a box-like case which is formed of an insulating material such as resin or the like and has therein three chambers A", B" and C" formed by means of partition plates 902 and 903, a battery housing chamber D" being formed on the end portions of the chambers A" and C". The chamber A" is long and is arranged along the side portions of the chambers B" and C". Numeral 904 is a piezo-electric transformer which is formed in the shape of a flat plate and is housed in the chamber A" and dampers 905 and 905' are provided between the piezoelectric transformer 904 and the case 901 and between the transformer 904 and the partition plate 902. Numeral 906 is an oscillation transformer housed in the chamber C", and numeral 907 is a piezo-electric transformer driving circuit which has integrated parts and constitutes together with the oscillation transformer 906 the oscillation circuit.

Numerals 908 and 909 are capacitors, numeral 910 is a diode block having a plurality of diodes molded. The capacitors 908 and 909 and the diode block 910 constitute a multiple voltage rectifier circuit. Numeral 911 is a capacitor for storing the output from the multiple voltage rectifier circuit, numeral 912 is a coil to one end of which is connected a high voltage lead wire 913 connected with the discharging electrode. Further, the

chamber B" which houses the capacitors 908 and 909, the diode block 910, the capacitor 911 and the coil 912 is filled with an insulating material.

When the 1.5 V oxidation battery housed in the battery housing chamber D" is connected with the oscillation circuit, the oscillation circuit begins to oscillate and the oscillation output is applied to the driving portion of the piezo-electric transformer 904 thus causing a high voltage output to be generated at its output terminal. The high voltage output is rectified through the multiple voltage rectifier circuit consisting of the capacitors 908 and 909 and the diode block 910 and the rectified output is stored in the capacitor 911. When the terminal voltage of the capacitor 911 reaches the discharge starting voltage, the electric charge stored in the capacitor 911 is discharged through the coil 912 thus causing a spark discharge to be generated for gas ignition. Further, the coil 912 is provided for lengthening the duration of discharging without reducing the discharging voltage and thus improving the ignition efficiency.

#### WHAT WE CLAIM IS:—

1. A gas ignition device comprising a piezoelectric transformer, a rectifier circuit for rectifying the output of said piezo-electric transformer, and a discharging gap for causing the output of said rectifier circuit to make electric discharge thereby to form a spark discharge for gas ignition.

2. A gas ignition device as defined in Claim 1, further comprising an oscillation circuit which includes a battery as an electric source and whose AC output voltage is stepped up by said piezo-electric transformer.

3. A gas ignition device comprising an oscillation circuit including a battery as an electric source, a piezo-electric transformer for stepping up the AC output voltage of said oscillation circuit, a rectifier circuit for rectifying the output of said piezo-electric transformer, a capacitor for storing the output of said rectifier circuit, and a discharging gap connected in parallel with said capacitor.

4. A gas ignition device as claimed in Claim 3, in which a resistor is connected in the discharging circuit of said capacitor.

5. A gas ignition device as defined in Claim 3, in which an indication element is connected in the discharging circuit of said capacitor.

6. A gas ignition device as defined in Claim 5, in which said induction element has an inductance of 100  $\mu$ H to 500 mH.

7. A gas ignition device as claimed in Claim 3, in which said rectifier circuit is a multiple voltage rectifier circuit comprising



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the duration of discharge may be ignition efficiency may be improved.

Fig. 10 shows the terminal voltage of the capacitor 818 in Fig. 9. As shown in Fig. 10, the capacitor 818 repeats charging and discharging.

Fig. 11 shows the behaviour of the discharge current flowing through the discharging gap, in which the curve A" corresponds to the case where the discharging gap 311 and 611 alone is connected in parallel with the capacitors 310 and 610 as shown in Figs. 3 and 6, the curve B" corresponds to the case where the resistor 718 is also provided as shown in Fig. 7, and the curve C" corresponds to the case where the induction element 819 is also provided as shown in Fig. 9. In the case A", the peak value is high but the duration is short; while, in the case B", the peak value of the discharge current is reduced but the duration is lengthened. In the case C", the duration can be lengthened without considerably reducing the peak value. Further, according to the experiments by the inventors, the ignition efficiency is much improved when the induction element 819 in Fig. 9 has an inductance of 100  $\mu$ H to 500 mH.

In Fig. 12 showing an assembly of the circuit of Fig. 9 constituted in a case, reference numeral 901 is a box-like case which is formed of an insulating material such as resin or the like and has therein three chambers A", B" and C" formed by means of partition plates 902 and 903, a battery housing chamber D" being formed on the end portions of the chambers A" and C". The chamber A" is long and is arranged along the side portions of the chambers B" and C". Numeral 904 is a piezo-electric transformer which is formed in the shape of a flat plate and is housed in the chamber A" and dampers 905 and 905' are provided between the piezoelectric transformer 904 and the case 901 and between the transformer 904 and the partition plate 902. Numeral 906 is an oscillation transformer housed in the chamber C", and numeral 907 is a piezo-electric transformer driving circuit which has integrated parts and constitutes together with the oscillation transformer 906 the oscillation circuit.

Numerals 908 and 909 are capacitors, numeral 910 is a diode block having a plurality of diodes molded. The capacitors 908 and 909 and the diode block 910 constitute a multiple voltage rectifier circuit. Numeral 911 is a capacitor for storing the output from the multiple voltage rectifier circuit, numeral 912 is a coil to one end of which is connected a high voltage lead wire 913 connected with the discharging electrode. Further, the

chamber B" which houses the capacitors 908 and 909, the diode block 910, the capacitor 911 and the coil 912 is filled with an insulating material.

When the 1.5 V oxidation battery housed in the battery housing chamber D" is connected with the oscillation circuit, the oscillation circuit begins to oscillate and the oscillation output is applied to the driving portion of the piezo-electric transformer 904 thus causing a high voltage output to be generated at its output terminal. The high voltage output is rectified through the multiple voltage rectifier circuit consisting of the capacitors 908 and 909 and the diode block 910 and the rectified output is stored in the capacitor 911. When the terminal voltage of the capacitor 911 reaches the discharge starting voltage, the electric charge stored in the capacitor 911 is discharged through the coil 912 thus causing a spark discharge to be generated for gas ignition. Further, the coil 912 is provided for lengthening the duration of discharging without reducing the discharging voltage and thus improving the ignition efficiency.

#### WHAT WE CLAIM IS:—

1. A gas ignition device comprising a piezoelectric transformer, a rectifier circuit for rectifying the output of said piezo-electric transformer, and a discharging gap for causing the output of said rectifier circuit to make electric discharge thereby to form a spark discharge for gas ignition.

2. A gas ignition device as defined in Claim 1, further comprising an oscillation circuit which includes a battery as an electric source and whose AC output voltage is stepped up by said piezo-electric transformer.

3. A gas ignition device comprising an oscillation circuit including a battery as an electric source, a piezo-electric transformer for stepping up the AC output voltage of said oscillation circuit, a rectifier circuit for rectifying the output of said piezo-electric transformer, a capacitor for storing the output of said rectifier circuit, and a discharging gap connected in parallel with said capacitor.

4. A gas ignition device as claimed in Claim 3, in which a resistor is connected in the discharging circuit of said capacitor.

5. A gas ignition device as defined in Claim 3, in which an indication element is connected in the discharging circuit of said capacitor.

6. A gas ignition device as defined in Claim 5, in which said induction element has an inductance of 100  $\mu$ H to 500 mH.

7. A gas ignition device as claimed in Claim 3, in which said rectifier circuit is a multiple voltage rectifier circuit comprising

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a plurality of diodes and a plurality of capacitors.

5 8. A gas ignition device as defined in Claim 3, in which a switch and a capacitor are connected between said battery and said oscillation circuit in such a way that, when said switch is connected with said battery, said capacitor is charged, while, when said switch is connected with said oscillation circuit, said oscillation circuit is oscillated with said capacitor serving as an electric source.

15 9. A gas ignition device as claimed in Claim 3, in which said piezo-electric transformer is a flat piezo-electric transformer which is held by a buffer member to be housed in a case.

10. A gas ignition device as defined in Claim 7, in which said plurality of diodes included in said multiple voltage rectifier circuit are molded with an insulating material to form a single body. 20

11. A gas ignition device substantially as hereinbefore described and as shown in Figures 1 to 5, or Figure 6 or Figure 7 of Figures 8 to 12 of the accompanying drawings. 25

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Printed for Her Majesty's Stationery Office, by the Courier Press, Leamington Spa, 1978  
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.