This invention relates to a control system for a gas burning domestic clothes dryer and more particularly to a control system incorporating a compact, light weight and comparatively simple but highly efficient and reliable electronic ignitor for igniting a combustible fuel.

Although various features of the invention have other applications in the ignition of combustible fuel, the invention is illustrated herein as applied to a gas burning domestic clothes dryer wherein minimum reliability and safety are major considerations, coupled with ease of manufacture and minimum cost. In such dryers, the automatic ignition of the gas is desirable, to avoid the unreliability and other troubles encountered with pilot flames. Automatic ignition systems are known using a glow-type igniter which is heated by an electric current flowing through a resistance-type heating element. The glow-type igniter is a small and inexpensive device but is not completely reliable and is subject to failure when repeatedly energized over a period of time.

It has also been proposed to use a high voltage arc transformer having a primary winding for connection to a power line source of alternating current and a secondary winding connected to electrodes for creating an arc therebetween. Such transformers may perform satisfactorily but are large and expensive.

According to this invention, an ignitor system is provided for a gas burner wherein a pair of electrodes adjacent the burner are connected to a secondary winding of a transformer having a primary winding connected to a capacitor discharge circuit which is energized from a power line source of alternating current. The discharge circuit operates at certain points of half cycles of the alternating current for producing a rapidly changing current in the primary winding and to thereby produce a high rate of change of flux in the transformer, with a high voltage being thereby induced in the secondary winding sufficient to create a strong arc between the electrodes for igniting the gas.

This arrangement requires components in addition to those required in the heretofore proposed arc transformer arrangement. It is found however that it is smaller in size and weight, less expensive, and also extremely reliable and efficient. Such advantages arise in part from the fact that with sudden release of the energy stored in the capacitor to produce the rapidly changing current in the primary winding, the required high voltage can be induced in the secondary winding with comparatively small numbers of turns on both the primary and secondary windings. In addition, since the arc is maintained for only a small portion of each cycle, the power requirements are minimized and a transformer having a small core and overall physical size is satisfactory. With the prior arrangement in which the power line is connected directly to the primary winding, a comparatively large number of primary turns are required to reduce exciting current to a satisfactory value, a comparatively large number of secondary turns are required to obtain the required output voltage; and a large core is required to meet the power requirements.

The capacitor of the capacitor discharge circuit cooperates with the transformer to form a resonant circuit and as a practical matter it is found that with components of the proper size, the resonant frequency is substantially higher than the power line frequency, on the order of at least five times the power line frequency. By way of example, the resonant frequency may be 2000 cycles with a power line frequency of 60 cycles.

Another feature of the invention is in the use of a solid state device in the discharge circuit preferably a silicon device arranged to conduct heavily when the voltage thereacross reaches a certain value. In one preferred embodiment, a silicon controlled rectifier is used having a gate electrode connected to the power line input in a manner such as to cause triggering of the controlled rectifier at the optimum point of each positive (relative to the controlled rectifier) half cycle of the alternating current. In another preferred arrangement, a silicon bidirectional avalanche diode or sometimes referred to as a five layer diode is used which conducts or breaks over in either direction when the voltage thereacross exceeds a certain value.

In still another arrangement a unidirectional avalanche diode or what is sometimes referred to as a four layer diode is used which conducts or breaks over in only one direction when the voltage thereacross exceeds a certain value.

A further feature of the invention relates to the incorporation of the ignition circuit in a gas dryer control system in a manner such as to obtain highly safe and reliable operation.

This invention contemplates other and more specific objects, features and advantages which will become more fully apparent from the following detailed description taken in conjunction with the accompanying drawings which illustrate preferred embodiments and in which:

FIGURE 1 is a schematic wiring diagram of an electrical control circuit used to automatically control the heat applied to a home type dryer and incorporating an electronic ignitor circuit constructed according to the principles of this invention;

FIGURE 2 is a graphical representation of a voltage waveform which appears across into the primary winding of a high voltage transformer shown in FIGURE 1;

FIGURE 3 is a circuit diagram of a modified electronic spark ignitor similar to that of FIGURE 1;

FIGURE 4 is a circuit diagram of a modified electronic spark ignitor wherein a silicon bidirectional avalanche diode is used as an electronic switch;

FIGURE 5 is a graphical representation of a voltage waveform which appears across the primary winding of a high voltage transformer shown in FIGURE 4; and

FIGURE 6 is a circuit diagram of another modified spark ignitor similar to that of FIGURE 4 wherein a unidirectional avalanche diode is used as an electronic switch.

Referring to FIGURE 1, reference numeral 10 generally designates an automatic control system which may be incorporated in a domestic type clothes dryer, wherein a gas burner 11 is controlled by a pair of gas control valves 12 and 13. To ignite gas from gas burner 11, a pair of spark electrodes 14 and 15 are mounted in the path of gas therefrom and are energized from a spark ignitor circuit 17 constructed according to the principles of this invention.

A drive motor 18 is provided to rotate a drying drum (not shown) during the drying operation. The gas valves 12 and 13, spark ignitor circuit 17, and drive motor 18 are all connected to an on-off switch 19 controlled by a timer control knob 20.

When wet clothes are placed in the dryer, and the switch 19 is closed, power is then applied to the gas valves 12 and 13, the spark ignitor circuit 17, and the drive motor 18, which in turn will rotate the drying drum at a sufficient speed to cause a tumbling and fluffing of the wet clothes exposing them to the drying heat. When gas valves 12 and 13 are opened, gas will flow from
3. To gain full advantage of the ignitor circuit 17, it is used in conjunction with conventional safety components as further illustrated in FIGURE 1, wherein a safety switch heater 37 has one lead connected to the power lead 38, and the other lead connected to the power line 34. The other side of the relay 38 is connected through heat detecting switch 33 and the on-off switch 19 to the other power line. The safety switch heater 37 is mounted in close association with the safety switch 35. The relay 38 has mounted on its control 39 one lead of which is connected to capacitor 40 and a solenoid valve 12, and the other lead of which is connected to switch 35 and the solenoid valve 13. A flame or heat detector 41 is mounted in close association with the gas burner 11 and is effectively connected to the flame or heat detecting switch 33. The timer knob 20 is connected to a timing motor 43 which will rotate a cam 44 to operate the on-off switch 19.

When wet clothes are placed into the dryer the timer knob 20 is manually operated to close switch 19. This action will apply power to a timing motor 45 to operate the cam 44, and the drive motor 18 to rotate the drying drum (not shown). Power is also applied to the relay 38 through heat detecting switch 33 and the safety switch heater 37 thereby closing the contact 39 of the relay 38. In addition, solenoid valves 12 and 13 are energized to allow gas to flow from the gas burner 11, and the spark ignitor 17 will operate as outlined above to produce a spark between the electrodes 14 and 15 which will ignite the gas. If the gas coming from the burner 11 fails to ignite within a time determined by the safety switch heater 37 of the safety switch 35, the safety switch 35 will open thereby removing the power for the solenoids 12 and 13 and the spark ignitor circuit 17. The farther power is applied to the ignitor circuit 17 through the heat detecting switch 33 and the timer on-off switch 19. During the positive half-cycles of the applied voltage, current will flow through the rectifier 26, resistor 30 and inductor 28 to charge capacitor 25. The value to which capacitor 25 is charged is dependent on the value of resistor 29 which controls the firing or conduction angle or the silicon controlled rectifier 26. When the voltage at the anode of the silicon controlled rectifier 26 is at the proper value, a gate current will flow through the resistor 29 causing the silicon controlled rectifier 26 to conduct in the forward direction. This heavy conduction of the silicon controlled rectifier 26 causes the capacitor 25 to discharge rapidly through the primary winding 23 of the transformer 22, effecting an oscillation of the magnetic field therein. The rapidly collapsing and re-oscillating of the primary voltage will induce a high voltage in the secondary winding 24 due to the high turn ratio between the primary winding 23 and the secondary winding 24. The voltage in the secondary winding 24 of the transformer 22 then produces a spark between the electrodes 14 and 15 to ignite the gas coming from the gas burner 11. During the remainder of the positive half-cycle the voltage in the primary winding 23 will oscillate, as shown in FIGURE 2, due to the L-C resonance of the primary winding 23 and the capacitor 25.

Due to the rapid collapse and high frequency of oscillation of the magnetic field and the high voltage thereby induced in the secondary winding 24, the transformer 22, can have a physical size which is much smaller than is the case in other circuits, and fewer numbers of turns can be used on both the primary and secondary windings. The L-C resonance is important in obtaining uniform and reliable operation, and the resonant frequency should preferably be substantially higher than the power line frequency. By way of example, the resonant frequency may be 200 cycles.

The rectifier 31 prevents current from flowing in the primary winding 23 and capacitor 25 during the negative half-cycle of the applied voltage. The resistor 30 and the inductor 28 serve to limit the current through the silicon controlled rectifier during the time it is conducting to discharge capacitor 25.
5. preferably a silicon bidirectional avalanche diode or what sometimes is referred to by those versed in the art as a five layer diode. The bidirectional switch 51 is connected to the other lead of the capacitor 25.

The characteristics of a silicon five layer diode are similar to those of two silicon controlled rectifiers which are connected in opposite directions across an A.C. source. When the applied voltage has reached the desired value, either positive or negative, the five layer diode will conduct during the remainder of the half cycle.

In operation, the positive half cycle of the applied voltage will continue to charge capacitor 25 until the positive breakover voltage of the five layer diode 51 is reached, which may be approximately 100 volts. At this point the five layer diode 51 will act as a short circuit to discharge capacitor 25 through the primary winding 23 of the transformer 22. This action will cause a high voltage to be generated in the secondary winding 24 of the transformer 22 in a similar manner as described above. During the negative half cycle of the applied voltage the capacitor 25 will charge in the opposite direction, and when the applied voltage has reached the negative breakover voltage of the five layer diode 51 it will act as a short circuit to discharge capacitor 25 through the primary winding 23 of the transformer 22. It can be seen in FIGURE 5 that a high voltage spark is generated during both the positive and negative half cycles of the applied voltage.

FIGURE 6 shows an additional modified ignitor circuit 17c which is substantially the same as the circuit 17b of FIGURE 4, except that a unidirectional avalanche diode 53 or what is commonly referred to as a four layer diode by those versed in the art, preferably a silicon device, is substituted for the bidirectional switch or silicon five layer diode 51 of the circuit 17b.

The operation of circuit 17c is the same as circuit 17b except that the four layer diode 53 will conduct or break over only during the positive half cycles (relative to the diode 53); therefore, the high voltage spark is generated only during the positive half cycles.

It will be understood that modifications and variations may be effected without departing from the spirit and scope of the novel concepts of this invention.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. In a system energized from a power line source of alternating current for igniting fuel flowing from a fuel burner, a pair of electrodes adjacent the fuel burner and located in close proximity to each other for producing a spark discharge therebetween, a transformer having a core of magnetic material and primary and secondary windings on said core, means connecting said secondary winding to said electrodes, a capacitor, a silicon controlled rectifier, means connecting said capacitor and silicon controlled rectifier in a closed series loop with said primary winding, and means for charging said capacitor from said power line source of alternating current, said silicon controlled rectifier being arranged to discharge said capacitor through said primary winding when said capacitor is charged to a certain level, to produce a high rate of change of flux relative to time in said transformer and thereby induce a high voltage in said secondary winding sufficient to create an arc between said electrodes.

2. In an appliance for operation from a power line source of alternating current, in combination, a fuel burner, a pair of electrodes supported adjacent said fuel burner and located in close proximity to each other for producing a spark discharge therebetween, a transformer having a core of magnetic material and primary and secondary windings on said core, means connecting said secondary winding to said electrodes, a capacitor connected in series with said primary winding, means for connection to said power line source of alternating current for charging said capacitor, a silicon controlled rectifier associated with said primary winding, said silicon controlled rectifier having a gate circuit dependent upon said power line source of alternating current, whereby said silicon controlled rectifier is made conductive when said capacitor is charged to a certain level for discharging said capacitor through said primary winding to produce a high rate of change of flux relative to time in said transformer and thereby induce a high voltage in said secondary winding sufficient to create an arc between said electrodes.

3. In an appliance for operation from a power line source of alternating current, a pair of electrodes for producing a spark discharge therebetween, a transformer having a core of magnetic material and primary and secondary windings on said core, means connecting said secondary winding to said electrodes, a capacitor connected in series with said primary winding, charging means for connection to said power line source of alternating current for charging said capacitor during half cycles thereof of at least one polarity, said charging means including a diode, a first impedance connected in shunt relation with said diode, and a second impedance connected in series relation with said diode and said first impedance, and a discharge device for discharging said capacitor through said primary winding at a certain point in each of said half cycles to produce a high rate of change of flux relative to time in said transformer and thereby induce a high voltage in said secondary winding sufficient to create an arc between said electrodes.

4. In an appliance for operation from a power line source of alternating current, a pair of electrodes for producing a spark discharge therebetween, a transformer having a core of magnetic material and primary and secondary windings on said core, means connecting said secondary winding to said electrodes, capacitor means in circuit with at least one of said windings to define a resonant circuit having a resonant frequency on the order of at least five times the frequency of said source, and circuit means connected to said primary winding and to said source of alternating current for producing a rapid change in the current through said primary winding at a certain point in half cycles of at least one polarity of said alternating current, said rapid change in current being effective to cause oscillation of said resonant circuit and to produce a high voltage in said secondary winding sufficient to create an arc between said electrodes.

5. In an appliance for operation from a power line source of alternating current, a pair of electrodes for producing a spark discharge therebetween, a transformer having a core of magnetic material and primary and secondary windings on said core, means connecting said secondary winding to said electrodes, a capacitor connected in circuit with said primary winding, means for connection to said power line source of alternating current for charging said capacitor during half cycles thereof of at least one polarity, and a solid state conduction device for discharging said capacitor through said primary winding at a certain point in each of said half cycles to produce a high rate of change of flux relative to time in said transformer and thereby induce a high voltage in said secondary winding sufficient to create an arc between said electrodes.

6. In an appliance for operation from a power line source of alternating current, a pair of electrodes for producing a spark discharge therebetween, a transformer having a core of magnetic material and primary and secondary windings on said core, means connecting said secondary winding to said electrodes, a capacitor connected in circuit with said primary winding, means for connection to said power line source of alternating current for charging said capacitor during half cycles thereof of at least one polarity, a silicon controlled rectifier having a gate electrode, means connecting said silicon controlled rectifier in circuit with said primary winding and said
capacitor, and means connecting said gate electrode to said power line source of alternating current for triggering said rectifier and discharging said capacitor through said primary winding at a certain point in each of said half cycles to produce a high rate of change of flux relative to time in said transformer and to thereby induce a high voltage in said secondary winding sufficient to create an arc between said electrodes.

7. In an appliance for operation from a power line source of alternating current, a pair of electrodes for producing a spark discharge therebetween, a transformer having a core of magnetic material and primary and secondary windings on said core, means connecting said secondary winding to said electrodes, a capacitor connected in circuit with said primary winding, a bidirectional switching device connected in circuit with said capacitor and said primary winding and arranged to discharge when the voltage thereacross in either direction reaches a certain value, and means coupling said capacitor to said power line source of alternating current for charging said capacitor during each half cycle thereof to a value such as to cause a discharge of said capacitor through said device and said primary winding.

8. In an appliance for operation from a power line source of alternating current, a pair of electrodes for producing a spark discharge therebetween, a transformer having a core of magnetic material and primary and secondary windings on said core, means connecting said secondary winding to said electrodes, a capacitor connected in circuit with said primary winding, a unidirectional switching device connected in circuit with said capacitor and said primary winding and having a certain breakdown voltage, and means coupling said capacitor to said power line source of alternating current for charging said capacitor during half cycles thereof of one polarity to a value such as to cause discharge thereof through said device and said primary winding.

9. In an appliance for operation from a power line source of alternating current and including a gas burner, means for supplying gas to said burner, a pair of electrodes adjacent said burner for producing a spark discharge therebetween to ignite gas flowing from said burner, a transformer having a core of magnetic material and primary and secondary windings on said core, means connecting said secondary winding to said electrodes, a capacitor connected in circuit with said primary winding, means including flame detector switch means and series current limiting impedance means for connecting said capacitor to said power line source of alternating current for charging said capacitor during half cycles thereof of one polarity, and a discharge device for discharging said capacitor through said primary winding at a certain point in each of said half cycles to produce a high rate of change of flux relative to time in said transformer and to thereby induce a high voltage in said secondary winding sufficient to create an arc between said electrodes, said flame detector switch means being arranged to be opened by the heat from a flame at said burner with current flow through said switch means being limited to the charging current of said capacitor.
UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION


Douglas J. Walker

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 8, after line 27, insert -- 3,045,148 7/1962
McNulty et al----123-148(E)X --; same column 8, after line 33, insert -- 3,303,385 2/1967 Staiger----315-206 --.

Signed and sealed this 1st day of October 1968.

(SEAL)
Attest:
Edward M. Fletcher, Jr. EDWARD J. BRENNER
Attesting Officer Commissioner of Patents