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2,410,403

METHOD OF AND APPARATUS FOR STARTING ENGINES

Filed June 12, 1943

2 Sheets-Sheet 1

Fig. 1.

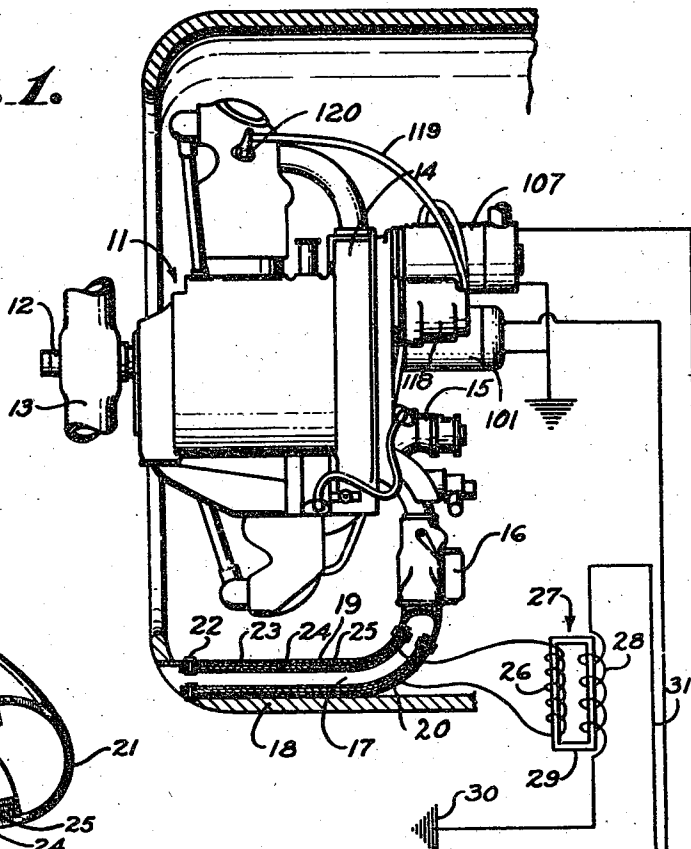
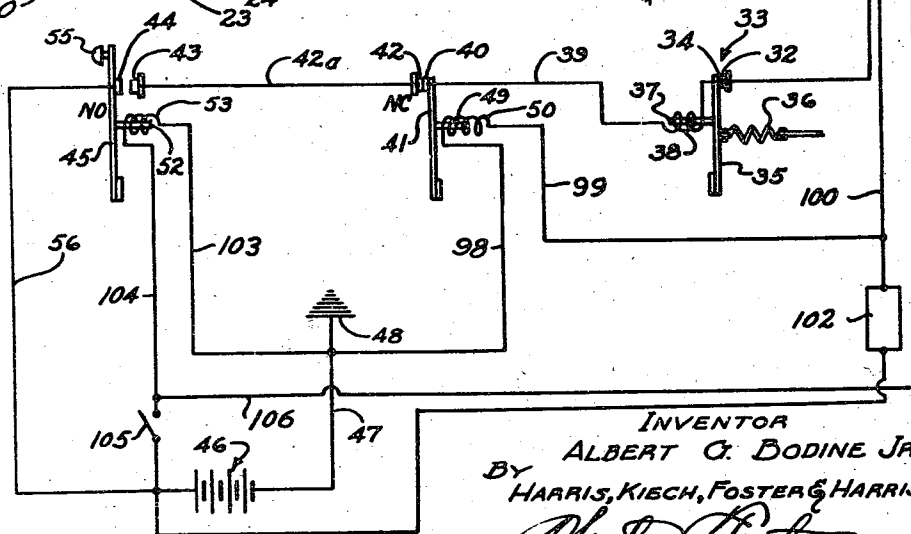
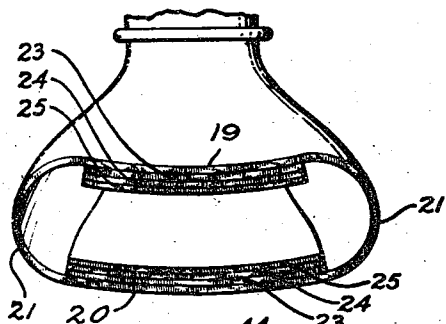


Fig. 2.



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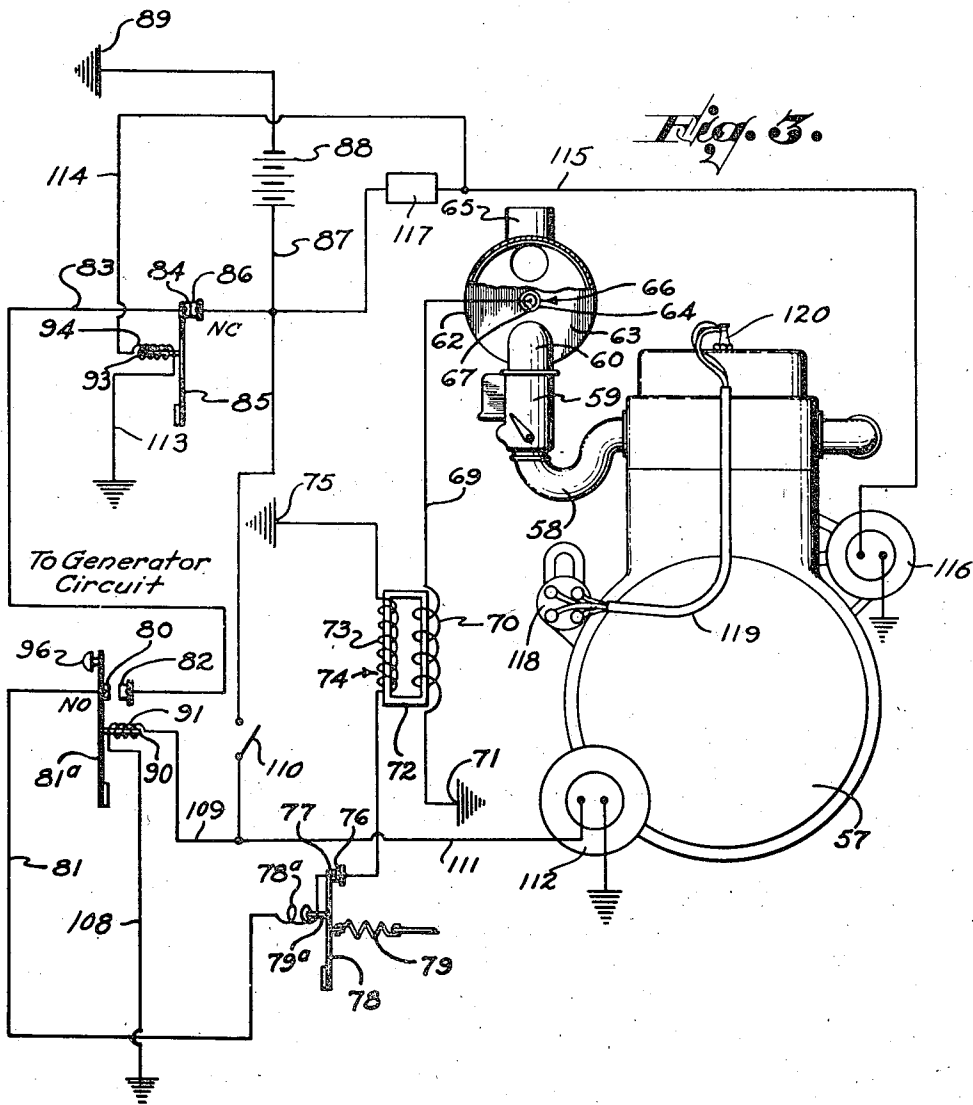
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2 Sheets-Sheet 2



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METHOD OF AND APPARATUS FOR
STARTING ENGINES

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This invention relates to a method of and apparatus for starting engines, and, since it finds particular utility in forms adapted for starting spark ignition engines of vehicles, such as aircraft and tanks, utilizing a mixture of air and gasoline vapor, the objects and advantages of my invention in such connection and forms of embodiment thereof capable of such use are described herein-after, it being understood that my invention is not restricted to such use.

Such engines are designed for starting and operating with definite gasoline-air ratios; for example, airplane engines are usually designed for normal operation in flight with a ratio of about .05 pound of gasoline to 1 pound of air. At this ratio, which may be referred to as lean cruising ratio, the conventional airplane engine operates smoothly and efficiently. Engines designed for such a normal operating ratio of gasoline and air usually are easily started by the conventional starter mechanism and ignition system with a mixture of about .10 pound of gasoline to 1 pound of air at atmospheric temperatures approaching normal room temperature. This mixture may be referred to as rich take-off or starting mixture.

The range of ratios of gasoline to air at which the conventional aircraft engine can be readily started at atmospheric temperatures approximating normal room temperature is rather wide and is frequently from .05 pound of gasoline to 1 pound of air, to .10 pound of gasoline to 1 pound of air. The conventional means for supplying gasoline to the airplane engine during the time that the starting mechanism is actuated and before ignition occurs, such as a priming pump delivering the gasoline to the combustion chambers through a fixed jet, are for this reason not ordinarily of such construction as to be readily adjustable by the pilot or engineer for varying within narrow limits such gasoline-air ratio.

As the atmospheric temperature at which it is desired to start the airplane engine is lowered, the range of ratios of gasoline to air in the mixture at which the engine can be readily started by the usual starter and ignition systems diminishes greatly. This is because the ignition temperature of a mixture of a given ratio of gasoline and air is dependent upon the energy level of the air or its capacity under the excitation of an ignition spark to disassociate and oxidize the vaporized gasoline. This energy level in turn in the ordinary airplane engine is dependent entirely upon the energy of translation of the oxygen molecules through space. Consequently, as the

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temperature of the air diminishes, the energy level of the gasoline-air mixture lowers, decreasing greatly the range of ratios of gasoline and air at which ignition will occur under the conventional pressure and spark conditions provided by the usual starter and ignition system.

It is impossible for the airplane pilot or engineer to quickly determine for a given atmospheric temperature below normal room temperature or, having made such a determination, to adjust the gasoline delivery system to provide a ratio of gasoline and air within that narrow range required for such temperature at which ignition under such conditions will readily occur.

As a consequence, when airplane engines of such conventional construction which are capable of readily starting at approximately normal room temperature are attempted to be started at atmospheric temperatures substantially lower, great difficulty is encountered, and much time consumed, with disastrous results to our armed forces, in either warming the air or the engine to a temperature approaching normal room temperature or by empirically and blindly varying the ratio of gasoline and air in the mixture to that narrow range at which ignition will occur at such reduced temperatures.

It is an object of my invention to provide a method of and apparatus for delivering to a spark ignition engine a mixture of gasoline and a combustion supporting gas at such energy level as to be readily combustible at standard ratios by spark ignition under all atmospheric temperature conditions.

It is another object of my invention to provide a method of and apparatus for starting a spark ignition engine by providing a mixture of fuel, such as gasoline and air, which is combustible by spark ignition at all atmospheric temperatures and in all of the ratios of such ingredients, in which such mixture is accomplished by conventional mixture control apparatus in the operation of such a spark ignition engine.

Further objects of my invention include the provision of such a method and apparatus which is positive in operation, which requires no experience or particular skill for its operation or performance, and which does not affect the ratio of gasoline to air or the combustion characteristics of such a mixture after the engine is started.

Other objects of my invention comprise the provision of an apparatus of the class described which is automatically actuated when the starter circuit of the engine is closed, which may be

readily and inexpensively installed in a spark ignition engine, and which may be energized by the conventional current source associated with such engine.

More specifically my invention contemplates the raising of the energy level of a gasoline-air mixture for a spark ignition engine by imparting to the oxygen atomic vibratory energy separate from its heat or translatory energy, whereby the range of ratios of gasoline to air at which combustion by spark ignition will occur at reduced temperatures is greatly enhanced and substantially equal to the range of such ratios over which such engine may be operated at temperatures approaching normal room temperature.

These and other objects of my invention are accomplished by supplying to the air charged with the gasoline to a spark ignition engine during the starting operation a quantity of ozone developed in such air charge prior to the commencement of and during the engine starting operation. My invention contemplates the creation of such ozone without the development of any nitrous oxide, which nitrous oxide combined with the water in the air would be harmful in the engine, by avoiding a point electrical discharge and reforming the oxygen in the air by a corona or brush type electrical discharge.

Apparatus embodying my invention and capable of performing the method of my invention is described in the following specification, which may be more readily understood by reference to the accompanying drawings, in which

Fig. 1 is an elevational view partially sectioned and partially diagrammatic of such an apparatus installed in an airplane engine;

Fig. 2 is an end view of the air inlet passage of the apparatus illustrated in Fig. 1; and

Fig. 3 is an elevational view partially sectioned and partially diagrammatic of an embodiment of the apparatus of my invention installed in a spark ignition engine of a vehicle, such as a tank.

Referring to the drawings, which are for illustrative purposes only, the numeral 11 indicates an airplane engine of conventional construction having at its forward end a propeller shaft 12 adapted for driving a propeller 13 mounted thereon. The engine 11, which is of the spark ignition type, is provided with an annular inlet manifold 14 through which a mixture of gasoline vapor and air is supplied by an internal supercharger. The ratio of gasoline to air is controlled during operation by a carburetor 16 communicating with a source of liquid gasoline and communicating with an air inlet passage 17 formed in a cowl 18 surrounding the engine 11.

As well illustrated in Figs. 1 and 2, the air inlet passage 17 includes inner and outer side walls 19 and 20 arcuate in form and concentric with the cowl 18 and curved end walls 21 connecting such side walls and converging rearwardly of the cowl 18. The air inlet passage 17 communicates at its forward end with the atmosphere and supplies air to the carburetor 16 and annular inlet manifold 14, acting as an air scoop during flight.

The carburetor 16 is usually provided with means for supplying gasoline to the manifold 14 during the starting operation through a fixed jet, such means usually comprising a fuel pump 15.

Secured by insulated bushings 22 adjacent the inner and outer side walls 19 and 20 of the air inlet passage 17 and separated therefrom by an

insulating sheet 23 is an electrode plate 24. The bushings 22 may be insulated by any suitable material, such as a plastic, and the insulating sheets 23 may be formed of a similar insulating material or of glass. Preferably there is provided on the inner surface of each of the electrode plates 24 an inner insulating sheet 25 for a purpose which will be later described.

The electrode plates 24 are connected to a suitable source of high voltage, which may be the conventional buzzer coil, or a high voltage generator. In the embodiment illustrated in the drawings the source of high potential includes a high voltage secondary winding 26, the electrode plates 24 in the air inlet passage 17 being connected to opposite terminals thereof. The high voltage secondary winding 26 is part of a transformer 27 which includes a low voltage primary winding 28 linked to the high voltage secondary winding 26 by a continuous coil 29. One end of the primary winding 28 is connected to ground at 30, and the other end is connected by a conductor 31 to a stationary contact 32. The stationary contact 32 is part of a make-and-break apparatus 33, which may be of any suitable construction. The make-and-break apparatus 33 illustrated in the drawings is of a buzzer type, including a movable contact 34 carried by a switch element 35 which is urged to circuit closing position by a spring 36.

The switch element 35 is provided with an armature 37 adapted to be drawn toward a coil 38 into position opening the contacts 32 and 34 when the coil is energized. The coil 38 is connected to the movable contact 34 and by a conductor 39 to a movable contact 40 carried by a switch element 41. The switch element 41 is normally in circuit closing position in which the movable contact 40 is in engagement with a stationary contact 42, which is connected by a conductor 42a to a stationary contact 43. The stationary contact 43 is adapted for engagement with a movable contact 44 carried by a switch element 45 which is normally in circuit opening position. The movable contact 44 is connected by a conductor 45 to one terminal of a source of electrical current, such as a battery 46, usually associated with the engine 11, the other terminal of which is connected at 47 to the ground 48. The numeral 118 indicates a magneto connected by conductors 119 to each spark plug 120 associated with the engine in the usual manner.

The switch element 41 is provided with an armature 49 surrounded by a coil 50 adapted to draw the switch element 41 to circuit opening position when the coil 50 is energized. The coil 50 is connected by a conductor 98 to ground and by conductors 99 and 100 to a generator 101 associated with the engine 11, so that the coil 50 is energized when the engine 11 is operating and the generator circuit is energized. The generator 101 is connected through a conventional cut-out 102 to the battery 46.

Similarly the switch element 45 is provided with an armature 52 surrounded by a coil 53 adapted for moving the switch element 45 into circuit closing position when the coil 53 is energized. The coil 53 is connected by a conductor 103 to ground and through a conductor 104 and starter switch 105 to the battery 46, so that, when the switch 105 is closed to supply current through a conductor 106 to starter 107, the coil 53 is energized. The switch element 45 is adapted for manual actuation by the pilot or engineer of the aircraft and for such purpose is located

in a convenient place for such operation, as, for example, in the pilot's compartment, and is provided with a suitable actuating button 55.

It is not necessary that the high voltage output of the secondary winding 26 be of high frequency, inasmuch as the primary and secondary windings 28 and 26 are so designed with respect to the source of current supply 46 as to provide to the electrode plates 24 voltage sufficient to provide the desired type of discharge between them in the air inlet passage 17. This voltage is maintained insufficient to provide an arc between the electrode plates 24, inasmuch as an arc generates nitrous oxide, which, combined with water in the air, forms acid severely corrosive to the engine parts with which they come in contact.

The voltage supplied to the electrode plates 24 is sufficient to provide a moderate corona or brush discharge. The insulating sheet 25 upon the inner side of each of the electrode plates 24 is of a material which does not de-energize ozone and may be of glass or Cellophane. The electrode plates 24 extend circumferentially and longitudinally of the air inlet passage 17 a substantial distance, providing extensive surfaces so that the electrical discharge is not a point discharge, and the generation of nitrous oxide incidental to such a point discharge is prevented.

When it is desired to start the engine 11, the pilot or engineer of the airplane closes the movable switch element 45, thus connecting the battery 46 through the conductors 56 and 42a, normally closed contacts 42 and 40, and conductor 39 to the coil 38 and normally closed contacts 32 and 34. When the coil 38 is energized, the switch element 35 is moved to circuit opening position de-energizing the coil 38 and permitting the switch element 35 to return to circuit closing position. The circuit is thus rapidly and alternately opened and closed through the conductor 31 and primary winding 28 to the ground at 30.

An alternating current of the desired voltage is thus set up in the secondary winding 26 providing to the electrode plates 24 in the air inlet passage 17 a voltage of that value suitable for providing a moderate corona or brush discharge between them.

This discharge between the electrode plates 24 is continued while the pilot maintains the switch element 45 in circuit closing position. When the pilot closes the engine starter switch 105, the coil 53 is energized, thus retaining the switch element 45 in circuit closing position and permitting the pilot to release the control button 55 thereon. The corona or brush discharge between the pairs of electrode plates 24 is thus continued while the engine starter circuit is energized.

As soon as the engine 11 starts, the generator circuit associated therewith is energized, thus energizing the coil 56 and moving the switch element 41 to circuit opening position terminating the brush discharge between the electrode plates 24 simultaneously with the starting of the engine 11.

The conversion of oxygen in the air to ozone is thus positively and automatically terminated upon the commencement of engine operation, preventing the acceleration of combustion by the continuous supply of ozone during engine operation which would completely nullify the anti-knock characteristic of the gasoline or combustion decelerating compounds added thereto and subject the engine to damaging stresses.

The switch element 45 is retained in circuit closing position for that length of time before the engine starter circuit is closed which is necessary to convert oxygen in the air inlet passage 17 to ozone in the desired degree of concentration. This period of time of course varies with the characteristics of the apparatus, such as the quantity of air in the air inlet passage 17, the distance between the electrode plates 24, and the area of such electrode plates. Likewise the degree of concentration of the ozone desired within the air in the air inlet passage 17 and consequently in the mixture of air and gasoline in the cylinders of the engine 11, which may be desired, varies with the extent to which atmospheric temperature, and hence the temperature of the air within the air inlet passage 17, is below normal room temperature, and the delay which is permissible between the energizing of the engine starter circuit and the starting of the engine 11. While the rate of increase of the concentration of ozone within the air in the air inlet passage 17 decreases as the concentration increases, as the temperature of the air in the inlet passage decreases, the equilibrium concentration of ozone therein for any given energy input is increased. Therefore, as the need for ozone in the air charge increases because of lowered atmospheric temperature, the concentration of ozone increases for a specific time of energization of the electrode plates 24.

I have found that by maintaining for about 30 seconds to 3 minutes a suitable voltage between the electrode plates 24 in the air inlet passage 17 of a spark ignition engine, such as employed in a heavy type of bomber plane currently being manufactured and used, there is created a concentration of ozone of the order of about 4 per cent to 7 per cent in the mixture of air and gasoline in the cylinders of the engine, and that this is effective to cause the engine to start immediately at very low atmospheric temperatures, such as -100 F., when the engine starter circuit is energized. Concentrations of ozone of the order of 5 per cent to about 10 per cent in the mixture of air and gasoline in the cylinders of such an engine having normal operating characteristics of .05 pound of gasoline per pound of air at lean cruising speed and .10 pound of gasoline per pound of air at rich take-off speed permit the immediate starting of the engine when the engine starter circuit is closed, utilizing ratios of gasoline to air in the range from .03 to 1, to 1.2 to 1 by weight, whereas at such a reduced temperature without the introduction of ozone the ratio of gasoline to air at which the engine can be quickly started is limited to the range of about .07 to 1, to about .08 to 1 by weight. Ozone in the gasoline-air charge to any concentration, however small, raises the energy level and hence facilitates combustion and the initiation of engine operation.

Illustrated in Fig. 3 is another embodiment of the apparatus of my invention capable of performing my method and adapted for use with spark ignition engines of vehicles such as tanks or the like. The numeral 57 indicates such an engine of conventional construction having an inlet manifold 58 connected through a carburetor 59 with a source of gasoline and an air inlet pipe 60. Since the air inlet pipe 60 of conventional construction is usually not of sufficient volume for the purpose of my invention, I have indicated by the numeral 62 a reservoir or container, to one end 63 of which the air inlet

pipe 60 is connected. To the opposite end 64 of the container 62 an air intake pipe 65 is connected, the air intake and inlet pipes 65 and 60 being positioned against opposite sides of the container 62, so that the air in its passage there-through is directed transversely across the container 62.

Supported by suitable insulated brackets centrally of the container 62, which is illustrated as cylindrical in form, is a tubular electrode 66 covered with a layer 67 of suitable insulating material, such as Cellophane or glass, to insulate the metal electrode 66 from the ozone within the container 62. The inner surface of the walls of the container 62 may be provided with a layer 68 of similar insulating material for the same purpose.

The electrode 66 is connected by a conductor 69 to one end of a high voltage secondary winding 70, the other end of which is connected to ground at 71. The secondary winding 70 is linked by a continuous coil 72 to a low voltage primary winding 73 forming a transformer 74. One end of the primary winding 73 is connected to ground at 75, and the other end is connected to a stationary contact 76 adapted for engagement with a movable contact 77 carried by a movable switch element 78. The movable switch element 78 is urged to a normally circuit closing position by a spring 79.

The movable contact 77 is connected through a coil 78a surrounding an armature 79a mounted on the movable switch element 78 to a movable contact 80 by a conductor 81. The movable contact 80 is carried by a movable switch element 81a and is adapted for engagement with a stationary contact 82 connected by a conductor 83 to a movable contact 84. The movable contact 84 is carried by a movable switch element 85 and is adapted for engagement with a stationary contact 86. The stationary contact 86 is connected through a conductor 87 to one terminal of a source of electrical energy, such as a battery 88 commonly associated with the engine 57, the other terminal of which is connected to ground at 89.

The movable switch element 81a is provided with an armature 90 surrounded by a coil 91 which is connected by a conductor 106 to ground and through a conductor 109 and starter switch 110 to the battery 88. When the starter switch 110 is closed, current from the battery 88 is supplied through a conductor 111 to starter 112. In a similar manner the movable switch element 85 is provided with an armature 93 surrounded by a coil 94 connected by a conductor 113 to ground and by conductors 114 and 115 to a generator 116 associated with the engine 57. The generator 116 is connected through a conventional cutout 117 to the battery 88. The movable switch element 81a is provided with an actuating knob 96 located conveniently for actuation by the driver of the vehicle, as, for example, upon the dashboard in the driver's compartment.

The coil 90 operates to retain the movable switch element 81a in circuit closing position when the driver has released the pressure upon the actuating knob 96 so long as the starter switch 110 is closed and until the generator circuit is energized by operation of the engine 57. When the engine 57 commences operation, the generator circuit is energized, thus energizing the coil 93 and moving the switch element 85 from its normal circuit closing position to circuit opening position, thus terminating the generation of ozone

within the container 62 in a manner previously described.

This embodiment of my invention operates in the same manner as that embodiment previously described, oxygen in the air being converted into ozone as the air passes transversely across and longitudinally of the container 62 between the electrode 66 and the side wall of the container 62 which acts as a ground.

In both embodiments of my invention oxygen in a quiescent body of confined air, prior to the time that such air is mixed with gasoline and delivered to the combustion chamber of a spark ignition engine, is converted into ozone in such concentration that, when the air containing it is mixed with gasoline in such spark ignition engine within that range of ratios at which the engine is designed for operating at temperatures approximating normal room temperature, the energy level of the mixture is raised sufficiently that combustion in response to spark ignition occurs as quickly and as readily at any atmospheric temperature as it does in the absence of such ozone at temperatures approximating room temperature.

While those embodiments of my invention hereinbefore illustrated and described are fully capable of providing the advantages and accomplishing the objects and performing the method of my invention, it will be obvious to those skilled in the art that such objects may be attained, such advantages secured, and such method performed by other apparatus including many alterations and modifications of the illustrated and described apparatus, and my invention is therefore to be understood as not restricted to the specific forms selected for its illustration but as including all those modifications and variations coming within the scope of the claims which follow.

I claim as my invention:

1. In an apparatus for starting operation at any atmospheric temperature of a spark ignition engine utilizing an air-gasoline mixture in proportions employed during engine operation, which engine has an air inlet, a spark ignition system for generating a spark in a combustion chamber, and starter means for energizing such system, the combination of: a source of high potential electric current; electrode means connected to said source and positioned in and adapted for generating ozone in the air inlet; switch means adapted for opening and closing the connection between said source and said electrode means independently of the actuation of the starter means; and means adapted for automatically opening said switch means upon commencement of engine operation.

2. In an apparatus for starting operation at any atmospheric temperature of a spark ignition engine utilizing an air-gasoline mixture in proportions employed during engine operation, which engine has an air inlet, a spark ignition system for generating a spark in a combustion chamber, and starter means for energizing such system, the combination of: a source of high potential electric current; electrode means connected to said source and positioned in and adapted for generating ozone in the air inlet; manually operable switch means adapted for opening and closing the connection between said source and said electrode means; and means associated with the starter means and adapted for automatically retaining said switch means in circuit closing position while the starter means is actuated.

3. In an apparatus for starting operation at any atmospheric temperature of a spark ignition engine utilizing an air-gasoline mixture in any proportion employed during engine operation, which engine has an air inlet passage, a generator for generating electrical energy during engine operation, a spark ignition system for generating a spark in a combustion chamber, and starter means for delivering such mixture to such combustion chamber and energizing such system prior to combustion, the combination of: a source of high potential electric current; electrode means connected to said source and adapted for generating ozone in the air inlet passage; switch means adapted for opening and closing the connection between said source and said electrode means; and means adapted for automatically opening such connection upon commencement of operation of the generator.

4. In an apparatus for starting operation at any atmospheric temperature of a spark ignition engine utilizing an air-gasoline mixture in any proportion employed during engine operation, which engine has an air inlet scoop, a generator for generating electrical energy during engine operation, a spark ignition system for generating a spark in a combustion chamber, and starter means for delivering such mixture to such combustion chamber and energizing such system prior to combustion, the combination of: a source of high potential electric current; electrode means connected to said source and positioned in and adapted for generating ozone in the air inlet scoop; manually operable switch means adapted for opening and closing the connection between said source and said electrode means; means associated with the generator and adapted for automatically opening such connection upon commencement of operation of the generator; and means associated with the starter means and adapted for automatically retaining said switch means closed during actuation of the starter means.

5. In an apparatus for starting operation at any atmospheric temperature of a spark ignition engine utilizing an air-gasoline mixture in any proportion employed during engine operation, which engine has an air inlet scoop, a generator for generating electrical energy during engine operation, a spark ignition system for generating a spark in a combustion chamber, and starter means for delivering such mixture to such combustion chamber and energizing such system prior to combustion, the combination of: a source of high potential electric current; electrode means connected to said source and positioned in and adapted for generating ozone in the air inlet scoop; switch means adapted for opening and closing the connection between said source and said electrode means; a relay connected to the generator and adapted for automatically opening such connection upon commencement of op-

eration of the generator; and a relay associated with the starter means and adapted for automatically retaining said switch means closed during actuation of the starter means.

6. In an apparatus for starting operation at any atmospheric temperature of a spark ignition engine utilizing an air-gasoline mixture in any proportion employed during engine operation, which engine has an air inlet scoop, a generator for generating electrical energy during engine operation, a source of electric current, a spark ignition system for generating a spark in a combustion chamber, and starter means for delivering such mixture to such combustion chamber and connecting such system to the current source prior to combustion, the combination of: means connected to the current source and adapted for supplying high potential electric current; electrode means adapted for generating ozone in the air inlet scoop; an electric circuit connecting said electrode means and said high potential supplying means; switch means adapted for opening and closing said circuit; a relay associated with the generator and adapted for automatically opening said circuit upon commencement of operation of such generator; and a relay associated with the starter means and adapted for automatically retaining said switch means closed during actuation of the starter means.

7. In an apparatus for starting operation at any atmospheric temperature of a spark ignition engine utilizing an air-gasoline mixture in proportions employed during engine operation, which engine has an air inlet, a spark ignition system for generating a spark in a combustion chamber, and starter means for energizing such system, the combination of: a source of high potential electric current; electrode means connected to said source and positioned in and adapted for generating ozone in the air inlet; and manually operable switch means adapted for opening and closing the connection between said source and said electrode means independently of the operation of the starter means.

8. In an apparatus for starting operation at any atmospheric temperature of a spark ignition engine utilizing an air-gasoline mixture in proportions employed during engine operation, which engine has an air inlet, a spark ignition system for generating a spark in a combustion chamber, and starter means for energizing such system, the combination of: a source of high potential electric current; a pair of electrode means spaced from each other and connected to said source and positioned in the air inlet and adapted for generating ozone in the air passing between said electrode means; switch means adapted for opening and closing the connection between said source and said electrode means; and means for automatically opening said switch means upon commencement of engine operation.

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