July 31, 1928. 1,679,159

L. O. FRENCH

CIRCUIT CONTROL MECHANISM FOR INTERNAL COMBUSTION ENGINES

Filed Feb. 23, 1927 2 Sheets-Sheet 1

Fig. 1.

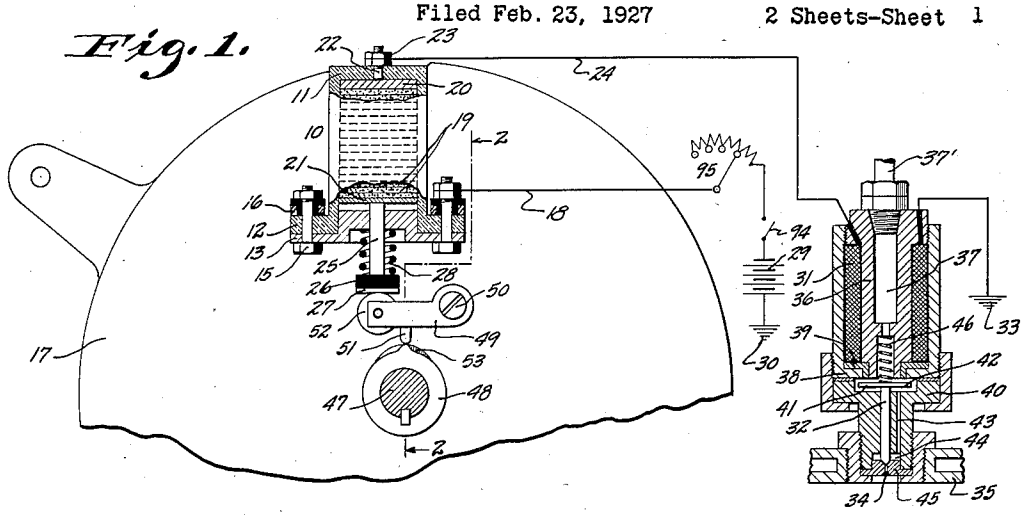


Fig. 2.

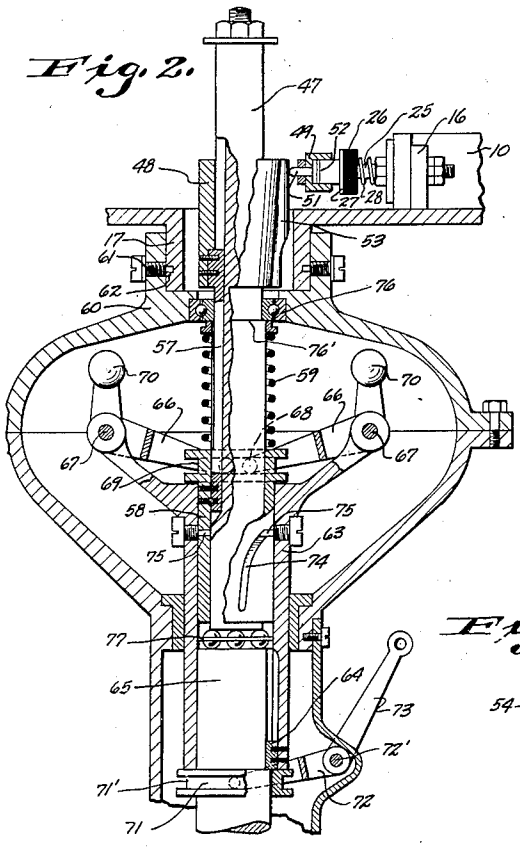


Fig. 6.

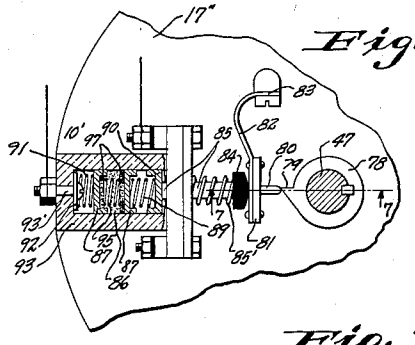


Fig. 7.

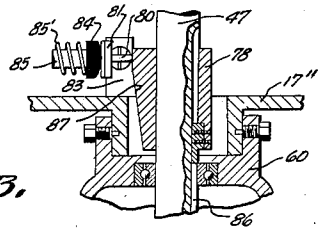


Fig. 3.

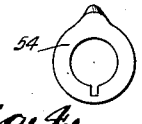


Fig. 4.

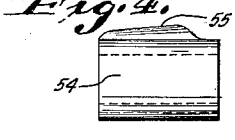
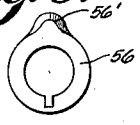


Fig. 5.



INVENTOR.

Louis O. French

EX1026
HARBOR FREIGHT TOOLS
IPR2025-01121

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CIRCUIT CONTROL MECHANISM FOR INTERNAL COMBUSTION ENGINES

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Fig. 8.

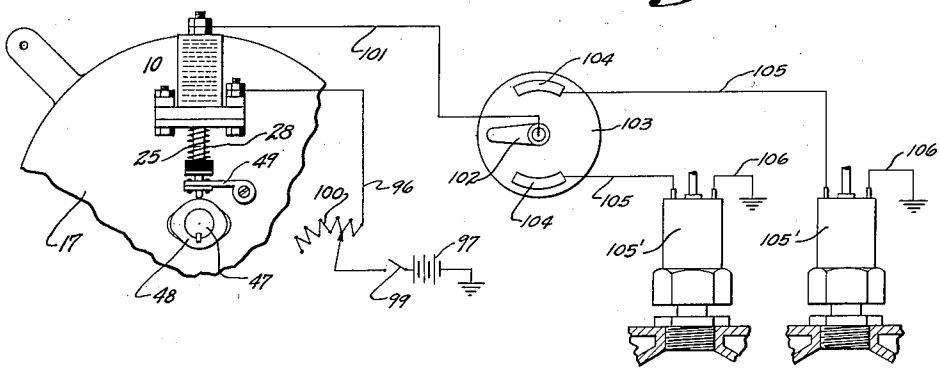
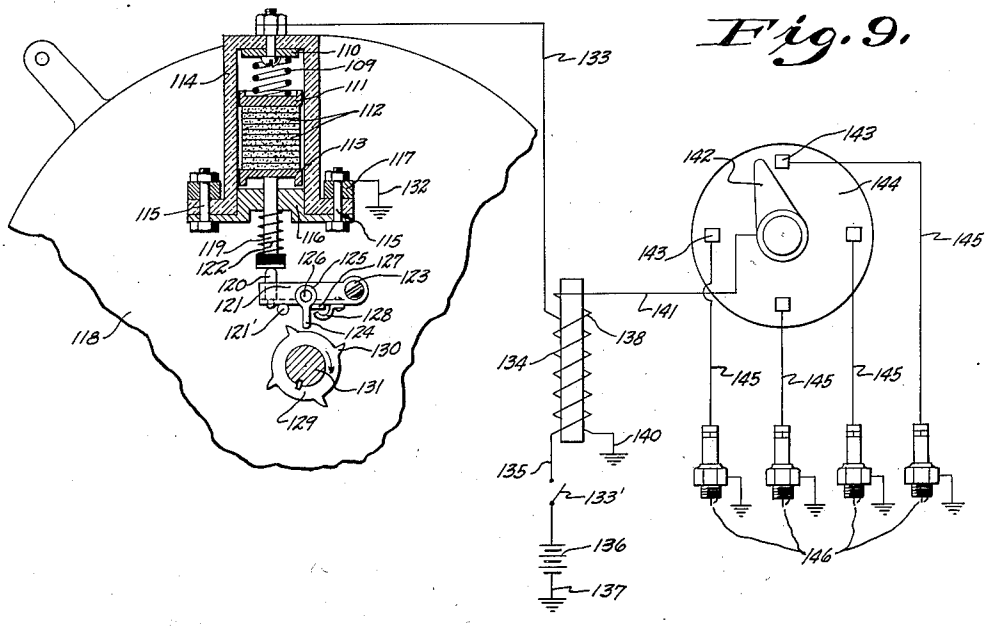


Fig. 9.



INVENTOR.

Louis O. French

Patented July 31, 1928. 1,679,159

UNITED STATES PATENT OFFICE.

LOUIS O. FRENCH, OF MILWAUKEE, WISCONSIN.

CIRCUIT-CONTROL MECHANISM FOR INTERNAL-COMBUSTION ENGINES.

Application filed February 23, 1927. Serial No. 170,328.

The invention relates to circuit control mechanism for electrical systems for internal combustion engines, such as electrically controlled fuel injection systems or ignition systems for such engines.

In electrical systems heretofore proposed the control of the current to an electromagnetically-operated fuel-metering device or the spark plug or other electrically-operated ignition device has been by a timer of the make-and-break type. Such timers are open to the objection of the pitting of the contacts through arcing and the consequent necessity for the renewal of defective contacts and accurate setting, and in some instances the renewal of the parts on which these contacts are carried because of the difficulty of replacing the contacts in said parts. One of the objects of this invention is to provide a timer which eliminates the use of contacts by providing a variable resistance and engine-controlled or engine-operated means for varying this resistance to control the operation of a fuel-metering device of a fuel injection or supply system or the ignitor of the ignition system of the engine.

This application is also a continuation in part of my prior application Serial No. 99,325, filed April 2, 1926, for means for controlling fuel supply to internal combustion engines and also contains subject-matter divided from my copending application Serial No. 103,561, filed April 21, 1926, for fuel injection systems, as to the circuit arrangement, including a variable resistance timer and a distributor in the same circuit.

Another object of this invention is to provide a control of the type described for the fuel-metering device of a fuel injection system wherein the control of the operating magnet for the metering device is effected during the available injection period by a fluctuation of current flowing through said magnet during this period, the variable resistance being varied during the available injection period by engine-controlled means to effect the operation of said device at the desired time or period in the engine's cycle to thereby control the amount of fuel delivered to the engine. Since during the available injection period some current is flowing through the operating magnet and the current is then increased during this period, the time constant of the magnetic control circuit is reduced and thus the operation of said magnet is very sensitive and suitable for high-speed engines.

A further object of the invention is to provide engine-controlled actuating mechanism for a variable resistance whereby either the time of active energization or the strength of such energization, or both of these, may be varied to control the electrically-operated device and in the case of a fuel-metering device thus cause it to control the supply of more or less fuel to the engine or to supply constant quantitv fuel changes at different engine speeds.

The invention further consists in the several features hereinafter set forth and more particularly defined by claims at the conclusion hereof.

In the drawings Fig. 1 is a view, partly in section, of a circuit control mechanism embodying the invention, parts being broken away, the mechanism being shown as associated with a fuel-metering device of a fuel injection system;

Fig. 2 is a sectional view through the control mechanism, taken on the line 2—2 of Fig. 1;

Fig. 3 is a top view of a timing cam;

Fig. 4 is a side elevation view of the timing cam shown in Fig. 3;

Fig. 5 is an end view of another timing cam;

Fig. 6 is a detail view of a modified control mechanism;

Fig. 7 is a detail sectional view taken on the line 7—7 of Fig. 6;

Fig. 8 shows the circuit control mechanism and another circuit arrangement for a fuel injection system;

Fig. 9 is a view, partly in section, of a circuit control mechanism embodying the invention, parts being broken away, the mechanism being shown in an engine ignition system.

The timer or circuit control mechanism is a variable resistance or rheostat associated with the control circuit of the system in which the resistance is periodically varied by engine-controlled means to cause the operation of the fuel-metering device or the ignition device during the desired or predetermined cyclic period and thus control the operation of said device.

The variable resistance or rheostat may be of any suitable construction though those of the compressible or pressure type, either us-

ing disks or powdered resistance material, are preferred as they require only a small movement to effect rapid changes in resistance and are not subject to appreciable wear. As illustrative of a variable resistance, I have shown in Figs. 1 and 2 a rheostat 10 of the pressure disk type wherein the numeral 11 designates a casing of insulating material provided with side flanges 12 associated with the side flanges 13 of a cover and guide plate 14, said flanges having bolts 15 passing therethrough and clamping the device to posts 16 on the supporting member 17, said bolts preferably being insulated from said posts so that one of them may be used as a terminal for a conductor 18. A plurality of resistance disks 19, of carbon or any suitable resistance material or composition resistance material, are mounted in the casing 11 between a metal terminal plate 20 and a pressure plate 21. The plate 20 has a threaded terminal stud 22 projecting through the rear end of the casing and clamped thereto by nuts 23, one of which serves to clamp a conductor 24 to said terminal. A thrust member 25, bearing against the plate 21, is slidably mounted in a guide bore in the plate 14 and has a head 26 of insulating material faced with a metal plate 27. A spring 28 is interposed between said head and plate 14 and normally acts to move said member 25 outwardly to a position where the plate 21 is exerting little if any pressure upon the disks 19, though current is flowing therethrough, so that a relatively large resistance is interposed between the terminals to impede the passage of the current from a battery 29 or other suitable source of current connected at one side to the conductor 18 and having its other side grounded at 30.

The conductor 24 leads to one terminal of the operating coil 31 of the electromagnetically-controlled fuel-metering device, here shown as including a control valve 32, and the other terminal of said coil is grounded at 33.

While the metering device instanced here as a control valve 32 is shown herein for the purpose of illustration as a fuel injector valve, I desire it to be understood that the present invention is not limited to this arrangement, as fuel regulation may be obtained by having the electromagnetically-operated valve function as a suction or bypass valve of a pump, as a distributor valve in the discharge line from a single pump furnishing several cylinders with fuel, or as a valve in the discharge line associated with a fuel injector valve.

The electromagnetic valve may be of any suitable construction and as instanced here directly controls the passage of fuel through the discharge nozzle 34 into the engine cylinder 35. As the features of the valve shown here have been made the subject of other applications, a detailed description thereof is not deemed necessary. However, the valve shown includes a core 36 having a fuel passage 37 extending therethrough, supplied with fuel from the discharge pipe 37' of the pump, an outer pole 38, a sealing gasket 39 of non-magnetic material interposed and clamped between the poles, a casing 40 of non-magnetic material having a chamber 41 communicating with the passage 37 in which the armature 42 of the valve works, a passage 43 connecting said chamber with a chamber 44 adjacent the valve seat member 45, and a spring 46 tending to close said valve through the fuel pressure also tends to close said valve where the valve is mounted in a pressure chamber.

In all of the instances above cited where the control valve may be used, the rheostat normally includes so much resistance in the circuit that the current flowing through the valve-controlling magnet is insufficient to lift the valve, however, when pressure is put upon the disks 19 by the inward movement of the stem 25 of the plunger enough resistance is cut out of the circuit to permit the magnet to open the valve and thus either establish a flow of fuel to the supply side of the fuel pump in the first instances cited of the suction or bypass valve to thus control the amount of fuel supplied by the pump to the engine, and in the other instances cited control the passage of fuel in the discharge line of the pump to the engine.

As a means for periodically varying the resistance, I have shown in Figs. 1 and 2 a shaft 47, either driven by the engine or operating in cyclic synchronism therewith and having a timing cam 48 mounted thereon. While said cam may operate directly on the head 26 of the member 25, I prefer to interpose a lever 49 between said parts pivoted at 50 and having a curved projection 51 engaging said cam and a pivoted roller 52 engaging the wear plate 27.

This timing cam may have rotary motion alone so that as the speed of the engine increases the time during which resistance is cut out to permit the valve to operate decreases, but I prefer to provide a greater range of adjusting the timing period and/or the amount of resistance periodically cut out of the control circuit by providing a cam of varying contour movable relative to the projection 51.

In the timing cam shown in Figs. 1 and 2 the lift is constant and the duration of lift is varied as shown at 53, and in Figs. 3 and 4 the cam 54 has a surface providing a variable lift, or the cam may be shaped to give a combination of variable lift and variable duration of lift, as shown by the surface 56' of the cam 56 of Fig. 5. Any one of the above described cams may be mounted

on the shaft 47 and by varying the position of the cam relative to the lever 49 the operation of the member 25 is varied, either by causing said plunger to exert pressure upon the disks for varying periods of time, or to vary the pressure upon the disks. Varying the period during which the resistance is cut out causes the magnet to hold the valve open for longer or shorter periods of time; varying the amount of resistance cut out causes the magnet to vary the lift of the control valve. Hence in either instance the amount of fuel passing by the valve may be varied, though it will be understood that where the control valve is associated with the supply side of the pump the period during which the valve is held open is the prime factor and that the variable lift to the valve is more particularly of advantage where the valve is used in the discharge line from the pump.

As a means for varying the position of the timing cam relative to the lever 49 and member 25, I have shown in Fig. 2, a key 57 slidably mounted in a keyway in the shaft 47 and secured at one end to the lower end of the cam 48 and at its other end to a sleeve 58. This sleeve may be manually operated, a spring 59 acting to move it in one direction, or it may be governor-operated.

The member 17 has a hub portion 17′ rotatably mounted, for manual adjustment to advance or retard the cutting out of resistance, in a casing 60, screws 61 being mounted in said casing and extending into an annular groove 62 in said hub portion to prevent relative longitudinal movement of these parts.

For governor operation the sleeve 58 is slidably mounted in a sleeve or hub portion 63 of the governor spider which has a keyed connection 64 with a shaft 65 driven by the engine. Levers 66 are pivoted at 67 to the governor spider, their forked arms having pin projections 68′ engaging in an annular groove 69 of the sleeve 58, their free ends carrying the governor weights 70. A collar 71 is slidably mounted on the shaft 65 and has an annular groove engaged by projections on the forked arms 72 of a lever pivoted at 72′ and having an exteriorly disposed manually-operable arm 73 whose downward movement effects an upward movement of the sleeves 63 and 58 compressing the spring 59 and thereby varying the governor's operating range and also permitting a manual shifting of the timing cam. As the speed of the engine increases the arms 68 move the sleeve 58 upwardly and hence vary the position of the timing cam and thus control the action of the resistance device, as previously pointed out.

Where an automatic advance or retard of the time of injection is desired, and particularly where such advance or retard of the time of injection has been predetermined to best suit the design of a particular engine, I have provided oppositely disposed slots 74 of varying angularity, one being shown in full, with a pin 75 carried by the sleeve 63 associated with each slot. Thus, when the sleeve 58 is moved by the governor it will also turn or be moved angularly relative to the sleeve 63 and shaft 65, and by its keyed connection with the shaft 47 cause a similar angular movement of said shaft and hence an angular forward or backward movement of the cam. The shaft 47 is journalled in a ball-bearing 76 mounted in the case 60 and has a shoulder 76′ engaging the inner race of said bearing to prevent its upward movement, and a roller thrust bearing 77 is interposed between the lower end of said shaft and the shaft 65.

Thus, by shifting the cam 48 lengthwise, either by the manual operation of the lever 73 or by the shifting of the sleeve 58 by the governor during the rotation of said cam 48, it will periodically exert pressure upon the lever 49 and hence the resistance disks for varying periods of time, and as the speed of rotation of the shaft 47 varies with the speed of the engine, such variations of timing period may, for a particular cam design within a given speed range, cause a substantially constant active period of valve magnet energization with a consequent substantially constant quantity of fuel charge, or said cam design may be such as to cause a varying period of active energization of the valve magnet with a consequent varying amount of fuel charge, generally decreasing as the speed of the engine increases, and in either case when a predetermined maximum speed has been attained the cam is moved to a position where the projection 51 rides on a part 48′ where it is no longer lifted by the cam and hence the resistance is not periodically cut out and the control valve is rendered inoperative until the speed of the engine again drops below the maximum value. Under these conditions for any given period the lift of the valve is substantially constant. With the cam shown in Figs. 3 and 4 the lift or movement of the lever 51 is varied and hence the amount of resistance cut out is varied for different speeds and hence the lift of the fuel valve is varied and hence the quantity of fuel supplied to the engine is varied. In Fig. 5, shifting of the cam varies both the duration of the cutting-out-resistance period and the amount of resistance cut out to either obtain constant quantity fuel charges at varying speeds or fuel charges varying with the speed.

In Figs. 6 and 7 I have shown a resistance actuator designed to provide a substantially constant time of diminished resistance period through a wide range of engine

speeds and thereafter a decreased time of diminished resistance above a predetermined speed and, finally, at maximum speed the cutting out of the fuel supply by the failure of the actuator to cut out resistance, particularly where the control valve is in the pressure fuel discharge line. For this purpose the shaft 47 is provided with a timing cam 78 having a toothed lobe 79 engageable with a projection 80 on a member 81 carried by a curved spring 82 anchored at 83 to the support 17', the member 81 engageable with the insulated head 84 of the thrust member or plunger 85 associated with the variable resistance device 10' so that as said cam rotates the member 85 is given a quick inward movement whose timing is substantially constant for a wide range of engine speeds and hence the resistance is periodically diminished for substantially equal periods and hence a constant quantity charge of fuel is periodically furnished the engine at these speeds and thereafter said cam may be moved upwardly by a governor, similar to the governor previously described but coming into operation only above a predetermined high speed, and through its association with a key 86, similar to key 57, and a sleeve similar to the sleeve 58 causing an upward movement of the cam 78 to bring a tapered portion 87 into play and thus gradually decrease the extent of movement of the member 81, 82 and the plunger 85, and finally fail to operate said member 81, 82 and said plunger 85 and thus cut off the supply of fuel to the engine at a predetermined maximum speed.

The resistance device 10', shown in section in Fig. 6, is also one that I have used experimentally and has a finely powdered metallic resistance material 86 interposed between flanged metal disks 87, a spring 89 being interposed between one of said disks and a metal plate 90 engaged by the inner end of the plunger 85, and a spring 91 interposed between the other disk and a washer 92, all of these parts being mounted in a casing 93 of insulating material, and the washer 92 being associated with the terminal screw 93'. A spring 96 may be mounted between annular felt washers 97 to keep said spring out of contact with the disks 87 in the powder-containing chamber so as to prevent any possibility of the packing of the powdered resistance material.

In Fig. 1 I have shown a hand-operated switch 94 in the conductor 18, and a manually-variable resistance 95 which permits the use of a certain fixed resistance in the circuit that may be advisable in some instances, and permits of varying this resistance to thereby modify the action of the engine-controlled resistance previously described.

While I have shown the apparatus in connection with a single cylinder engine, it will be understood that in a multicylinder engine a variable engine-controlled metering device control resistance may be associated with each cylinder, and that these may be connected in parallel with the source of current and the resistance 95, and arranged, as many as conveniently possible, radially relative to a common timing cam or actuator.

While the invention has been described more particularly in connection with a fuel control valve, it is not, when broadly considered, to be limited to a valve, as the control means may be associated with any other suitable fuel-metering device for the injection system of the engine.

It will be understood that, while the drawings show a system using direct current, in case alternating current is used to operate the magnet that an engine-controlled variable resistance, either ohmic or inductive, that is to say, a variable impedance, would be used to control the periodic operation of the electromagnetically-operated metering device.

In a multicylinder arrangement, instead of using a variable resistance for each device to be controlled I have shown in Fig. 8 a single variable resistance timing mechanism 10, of the first-described construction, connected by a conductor 96 to one side of a battery 97 grounded on its other side at 98, a manual cut-out switch 99 and a variable resistance 100 being associated with said conductor, the resistance 100 serving to modify the action of the control resistance 10. A conductor 101 connects the other terminal of the resistance timer 10 with a rotating brush 102, driven by the engine or rotated in cyclic synchronism therewith, of a distributor 103, said brush moving over a commutator including contact segments 104. Each of these contacts 102 is respectively connected to the coil of the control electromagnet of one of the fuel-metering devices by a conductor 105 and the other terminal of the coil is grounded at 106.

With this arrangement the cam 48 periodically acts to cut out resistance from the circuit and at such a time as it is desired to have the metering device function and while the brush 102 is in contact with one of the contacts and under these conditions current flows through the control magnet of the metering device to cause its operation. At other times, due to the inclusion of increased resistance, the current is so small that with the distributor contacts engaged the control magnet will not be energized sufficiently to cause the metering member to operate.

Furthermore, the contacts 104 are preferably of such a length or the brush 102 is of such a length that engagement takes place before the cam 48 causes a cutting out of

the increased resistance and hence, when the current increases, by the cutting out of resistance, one of the contacts 104 and the brush are already in contact so that there will be little, if any, arcing between the distributor brush and associated contacts 104. With this construction, owing to the relative proportions of the contacts and brush there is always some current flowing through the operating magnet of the metering device during the available injection period so that when the resistance is cut out by the cam 48 the current passing through the magnet will rapidly reach the desired operating strength.

Thus far the circuit control mechanism has been described in connection with the metering control device of a fuel injection system but it will be understood that instead of running the current through the magnet 31 it may be passed through the primary winding of an induction coil of the ignition system of the engine in which instance it is preferable to use a cam having a rapid drop, such as the cam 78, without a taper, so that the rapid fluctuation or change in current strength through the variation of resistance under the action of the toothed projection 79 will create a rapid change in flux in the primary winding and hence induce a current of higher voltage in the usual secondary winding associated with the spark plugs of the engine to cause said induced current to jump the spark terminals and ignite the charge in the engine.

As further illustrative of this use of the timer I have shown in Fig. 9 the variable resistance timer 108 associated with a high tension ignition system of an internal combustion engine. As shown, this timer includes a spring 109 which is interposed between a terminal plate 110 and a metal disk 111, the carbon or other resistance disks 112 being disposed between said disk and a metal disk 113, these disks being mounted within the casing 114 of insulating material which is secured by bolts 115 to the end plate 116 and the arms or lugs 117 projecting from the angularly shiftable base or mounting plate 118, similar to the arms 16 on the plate 17.

As in the first-described construction, a push-rod 119 is slidably mounted in the end plate 116 and enages the disk 113 and its headed end is held against a pin projection 120 on the outer end of a lever 121 by a spring 122, said lever being pivotally mounted on a pin 123 secured to the base plate and having a projection intermediate its ends engaged by the actuating cam. As shown, a projection 124 has spaced ears 125 (one being shown) through which a pivot-pin 126 passes, said pin also passing through the lever 121, which is preferably of channel formation, with the pin passing through the flanges thereof. This projection has an angle portion 127 forming a stop, to limit its swinging movement in one direction, engaged by a flat spring 128 normally holding it in "stop" position and secured to the web of the lever adjacent its pivot. The projection 124 is disposed in the path of the operating cam 129 which has a toothed lobe 130 for each spark plug or as many lobes as can be satisfactorily used on one cam and in the present instance I have shown four lobes for a four cylinder engine, each lobe having a tapered advancing face and a straight rear face to provide a rapid return of the lever 121. The cam 128 on the engine-driven shaft 131 is normally rotated in the direction of the arrow. If, however, the shaft 131 is reversed by a backfire or any other cause, or if the plate 118 is turned so that the straight side of the cam lobes engage said projection no damage can occur since under these conditions the projection 124 is free to swing outwardly toward the outer end of the lever 121 and said lever is limited in its outward movement by a stop-pin 121′.

The inner end of the timer is grounded through metal parts, as at 132, and the outer end has a conductor 133 secured to its terminal and connecting it with the primary coil or winding 134 of an induction coil, the other end of said winding being connected by a conductor 135 to one side of a battery 136 whose other side is grounded at 137, said conductor having a manually-controlled cut-out switch 133 therein.

The secondary winding 138 of the induction coil is grounded at one end 140 and has its other end connected by conductor 141 with the engine-driven distributor brush 142 which engages, or is spaced a short distance from, the contact segments 143 of the distributor 144. Each segment 143 is respectively connected by a conductor 145 with one terminal of a spark plug 146 whose other terminal is grounded.

With this construction the spring 109 is relatively heavier than the spring 122 and the timer with its lever 121 is so adjusted relative to the stop pin 121′ as to cause the spring 109 to exert only a slight pressure on the disks 112 so that a very small amount of current is flowing in the primary circuit until one of the lobes 130 of the cam 129 engages the projection 124 and lifts the lever 121 and hence puts pressure on the disks 112 to provide for a considerably greater flow of current for a brief interval and then a return to the smaller current flow. As the strength of the current flow in the primary winding 134 is thus changed rapidly from a full current flow to a very small amount, as for instance, a small fractional part of an

ampere, such change will set up a rapid change in flux in the magnetic field of the induction coil and thus induce a current in the high voltage secondary winging 138 at a time when the brush 142 is electrically associated with one of the contacts 132 so that the high voltage current will pass through the insulated terminal of the spark plug and jump the gap to the grounded terminal to produce the desired spark.

Thus, it will be noted that current passing at all times through the primary winding is intermittently and rapidly fluctuated in value to induce the high voltage ignition current and that the broad idea of timing the passage of the energizing current through the periodic variance of the resistance is applicable to either ignition or fuel injection systems though in such latter systems the ability to change the relative difference between high and low current value is made use of for varying the action of the fuel-metering device to supply more or less fuel to the engine.

It will be noted that in the forms shown the lever associated with the cam engages the thrust or push-rod beyond the point of connection with the cam so that a greater fluctuation of resistance is thereby obtained than could be obtained by direct action of the cam on said thrust or push-rod.

I desire it to be understood that this invention is not to be limited to any particular form or arrangement of parts except in so far as such limitations are included in the claims or necessitated by the prior art.

What I claim as my invention is:

1. In a timer for internal combustion engines, the combination of a variable resistance, and engine-controlled means for periodically varying said resistance.

2. In a timer for internal combustion engines, the combination of a variable resistance of the pressure type, and engine-operated means for periodically varying said resistance.

3. In an internal combustion engine, a timing circuit comprising a closed circuit, and engine-controlled means for periodically fluctuating the flow of current in said circuit.

4. In a timer and circuit control mechanism for internal combustion engines, the combination of a variable resistance, a variable actuator controlled by the engine for periodically varying said resistance, and means for varying the action of said actuator.

5. In a timer and circuit control mechanism for internal combustion engines, the combination of a variable resistance, an engine-controlled timing cam for periodically varying said resistance, said cam having a variable contour, and means for moving said cam and said resistance relative to each other to vary the relative duration of the periodic change of resistance.

6. In a timer and circuit control mechanism for internal combustion engines, the combination of a variable resistance, an engine-controlled timing cam for periodically varying said resistance, said cam having a variable lift, and means for changing the position of said cam and said resistance relative to each other to vary the amount of resistance cut out during a periodic cutting out of resistance.

7. In a timer and circuit control mechanism for internal combustion engines, the combination of a variable resistance, an engine-controlled timing cam for periodically varying said resistance, said cam having a variable lift associated with a variable duration of lift, and means for changing the position of said cam and resistance relative to each other to vary the amount of resistance periodically cut out and the relative duration of the period during which such resistance is cut out.

8. In a timer for internal combustion engines, the combination of a variable resistance, an engine-operated timing cam for periodically varying said resistance, and a speed-responsive device associated with said cam to vary its time of cutting out resistance.

9. In a timer for internal combustion engines, the combination of a variable resistance, an engine-controlled resistance actuator to periodically vary said resistance, and automatic means for advancing or retarding said actuator.

10. In an internal combustion engine, the combination of an electrical control circuit including a variable resistance, means operating in cyclic synchronism with the engine for periodically varying said resistance, and another variable resistance in said circuit for modifying the action of said first-named variable resistance.

11. In a timer and control mechanism for internal combustion engines, the combination of a variable resistance, an engine-controlled actuator having a variable action to periodically vary said resistance, a speed-responsive device, means associated with said device for cyclicly advancing or retarding said actuator, and means associated with said device for varying the relation of said actuator to said resistance.

12. In a fuel injection system, the combination with a plurality of electromagnetically-controlled fuel-metering devices, of a current distributor for said devices, a variable resistance associated with said distributor and controlling the control electromagnets of said devices, and engine-controlled means for periodically varying said resistance to operate said devices.

13. In a timer and control mechanism for internal combustion engines, the combination

of a variable resistance, engine-driven means for periodically varying said resistance to cause a periodic cutting out of resistance for substantially constant cyclic periods through a wide range of engine speed, and a speed-responsive device for varying the action of said means above a predetermined speed and rendering said means inoperative at a predetermined maximum speed.

14. In a timer for internal combustion engines, the combination of a plurality of disks of resistance material, arranged in a column, a spring associated with one end of said column, a thrust member associated with the other end of said column, and engine-operated means for periodically reciprocating said thrust member to vary the pressure on said disks.

15. In a fuel injection system, the combination with an electromagnetically controlled fuel-metering device, of a control circuit for the magnet of said device including a variable resistance permitting the flow of current through said magnet during the available injection period, and engine-operated means for periodically varying said resistance to increase the current flow through said magnet during the available injection period sufficient to operate said device.

In testimony whereof, I affix my signature.

LOUIS O. FRENCH.