

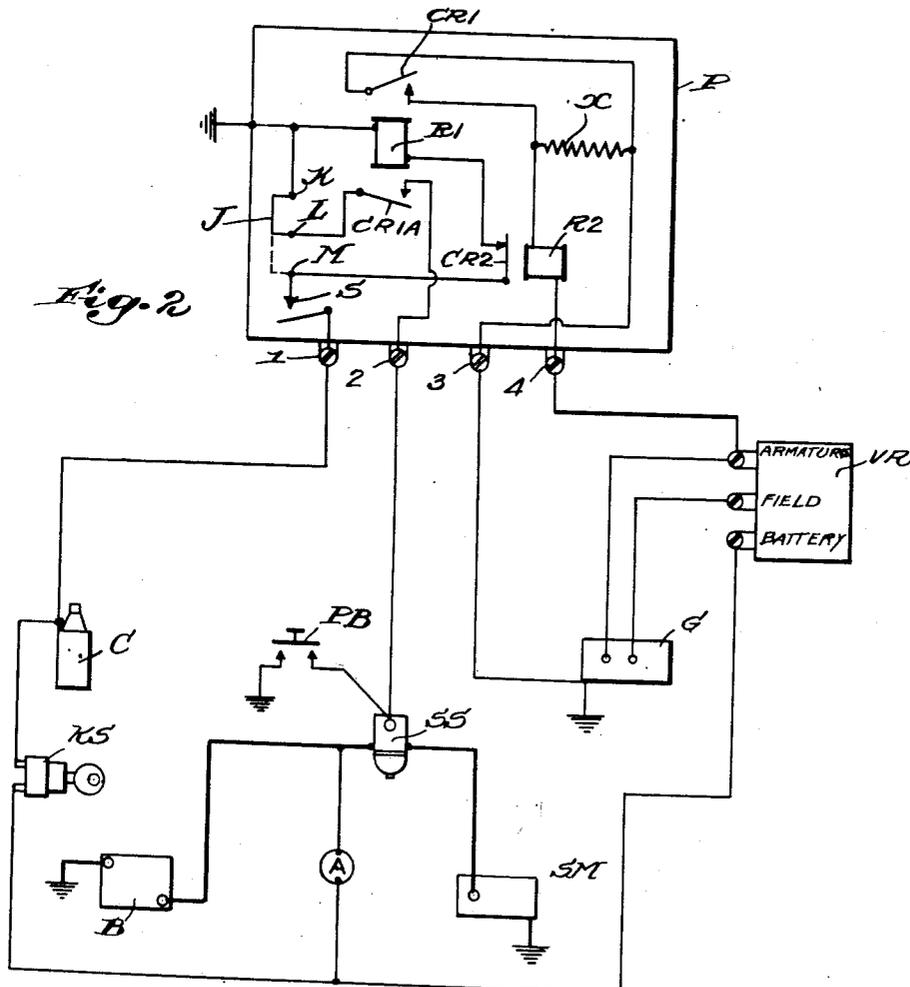
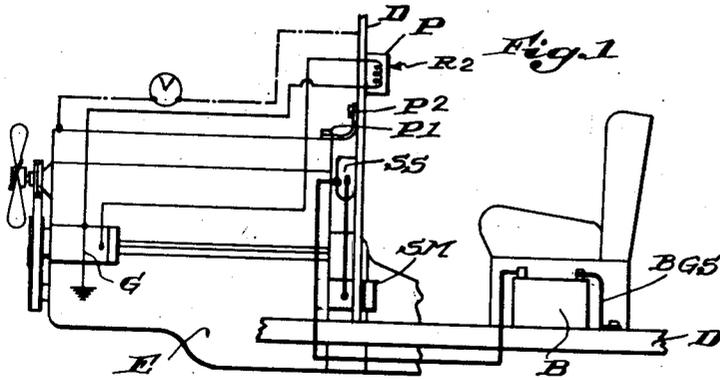
Sept. 29, 1953

W. G. ROWELL
AUTOMATIC STARTING APPARATUS FOR
INTERNAL-COMBUSTION ENGINES

2,654,035

Filed May 4, 1951

3 Sheets-Sheet 1



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3 Sheets-Sheet 2

Fig. 3

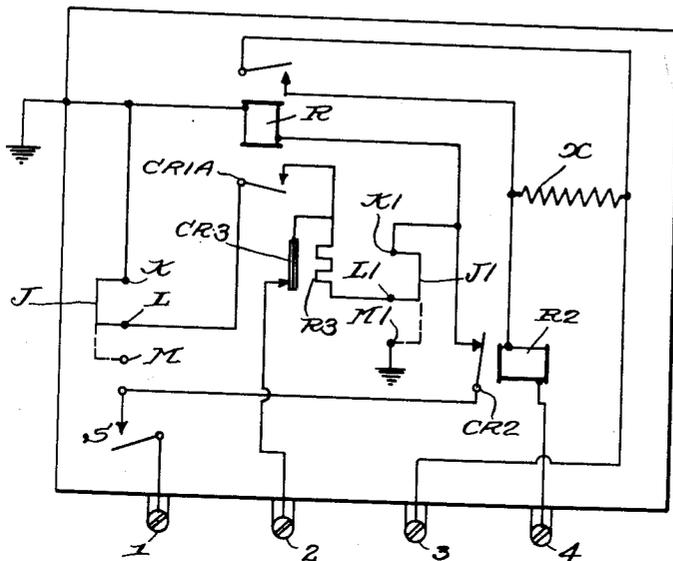
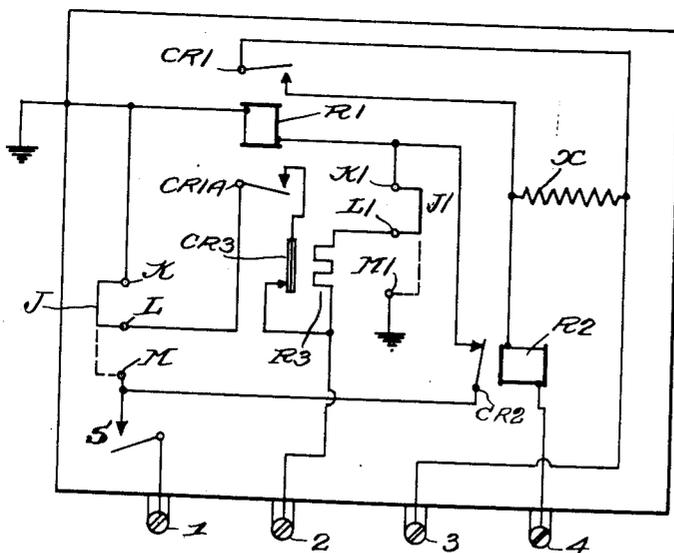


Fig. 4



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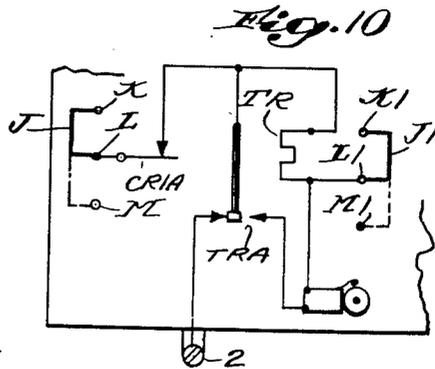
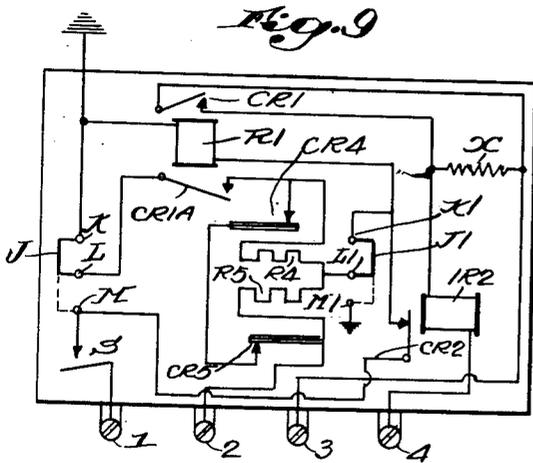
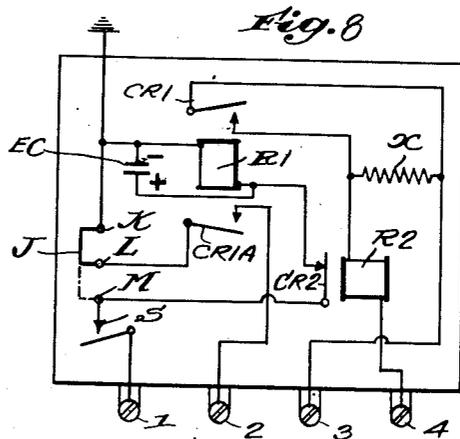
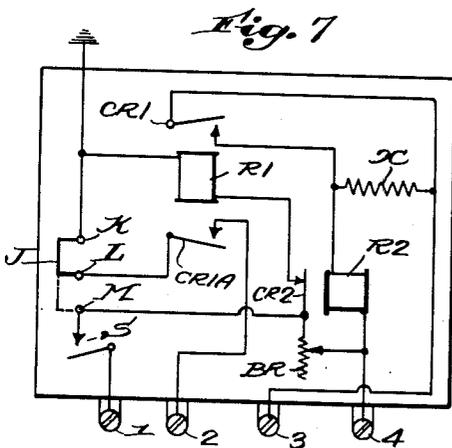
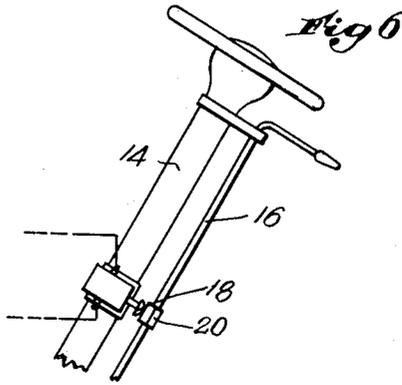
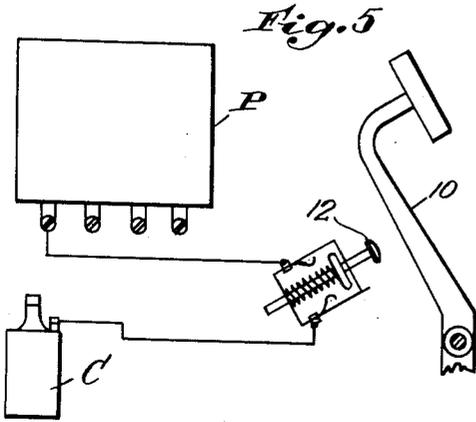
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3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

2,654,035

AUTOMATIC STARTING APPARATUS FOR INTERNAL-COMBUSTION ENGINES

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Lexington, Mass.

Application May 4, 1951, Serial No. 224,488

3 Claims. (Cl. 290-37)

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This invention relates to an automatic starting apparatus and more particularly to an automatic starting apparatus for internal combustion engines of the type having an electric starting motor which is energized through a solenoid switch. In one preferred form the invention is exemplified by automotive engines, although not limited to this or any other type of internal combustion engine.

Early types of automatic starting systems on automobiles generally used a relay operating under the control of an electric circuit closed when the ignition key was turned into the "on" position. This action caused the starting motor solenoid switch to function and a resulting cranking action of the motor was obtained. At this point certain difficulties developed which have never been satisfactorily dealt with, as is evidenced by the fact that automobiles, at the present time, do not have automatic starting equipment. Assuming that the engine was started by the relay controlled circuit, there was the problem of interrupting the closed circuit to discontinue operation of the electrical starting motor. It was naturally imperative that the starting motor be prevented from running at the same time that the engine was running. Should both devices operate simultaneously serious damage to the starting motor and fly wheel of the engine could well take place.

To prevent the motor and engine from operating simultaneously, a large number of devices have been proposed, including such things as a vacuum operated switch; combinations of vacuum switches and generator relays; governor switches; transformer controls, and the like. Of these the most promising has been a relay operating from the generator voltage, produced when the engine was in operation, to interrupt the starting motor circuit and stop the cranking action. However, in using conventional relays available it was found that insufficient voltage was generated by the generator, with the engine at idling speed, to operate the relay. There were also problems involving the control of the automatic starting operation when the gears of the starting motor were not properly engaged with the engine, or when the generator was not operating properly, or for various other reasons.

The present invention deals with the problems indicated and aims to devise an improved automatic starting mechanism which will automatically initiate a cranking action when an internal combustion engine is at rest with the ignition "on," or when the engine stalls while in opera-

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tion. Another object of the invention is to automatically interrupt the cranking action as soon as the motor starts in order to avoid damage to the engine. Still another object of the invention is to so control and limit operation of the starting mechanism as to avoid any undesirable operation of the automatic starting mechanism at such times as the rest of the engine equipment is not functioning properly. Still another object is to provide a device which is relatively simple in construction and inexpensive to manufacture, easy to install, efficient and durable in use, and applicable to all types of engines using a starting motor that is solenoid actuated.

These and other objects and novel features will be more fully understood and appreciated from the following description of a preferred embodiment of the invention selected for purposes of illustration and shown in the accompanying drawings, in which

Fig. 1 is a diagrammatic view illustrating an internal combustion engine, together with electrical means for cranking the engine in combination with the control means of the invention;

Fig. 2 is a schematic wiring diagram showing parts of the apparatus illustrated in Fig. 1 and further indicating electrical connections running to the control apparatus of the invention;

Fig. 3 is a wiring diagram somewhat similar to the apparatus shown in Fig. 2 but further including an additional control element;

Fig. 4 is another wiring diagram showing the apparatus of the invention including still another control element which may be desired to be employed in one modified form of the invention;

Fig. 5 is a schematic view indicating diagrammatically a manually operated clutch pedal and an electric switch combined with the control apparatus of the invention;

Fig. 6 is a view similar to Fig. 5 but illustrating the combination with the control apparatus of an electrical switch adapted to be operated by a typical gear shift and steering wheel of an automobile;

Fig. 7 is a wiring diagram of a form of the control apparatus of the invention in which is included an adjustable biasing voltage arrangement;

Fig. 8 is another wiring diagram of the control apparatus of the invention but including means for producing a slow release relay action;

Fig. 9 is a wiring diagram of the control apparatus of the invention in which is included a plurality of thermal timing relays; and

Fig. 10 is a wiring diagram of a portion of the

control apparatus which includes special signalling means.

The apparatus of the invention has been illustrated in Figs. 1 and 2 in one typical operating relationship with an internal combustion engine and ignition system. Parts of a conventional automotive starting system have also been indicated diagrammatically, including a battery B and an electrical starting motor SM. Electrically connected to each of these members is a solenoid switch SS. Also connected at one side of the solenoid switch SS is the usual electrical circuit including an ammeter A, an ignition key switch KS, and a coil C. A push button switch PB normally permits manual operation of the solenoid switch SS. The electrical circuit referred to runs to a generator G and also to a voltage regulator VR for the ignition system of the internal combustion motor E.

In the typical automotive engine, of which E is intended to be representative, the starting motor SM actuated by the battery B through the solenoid switch SS cranks the motor and starts this member in operation at a normal idling speed. At this speed the generator G produces a voltage which, as noted above, is of relatively low value. For example, it has been found on measuring the voltage produced by a typical generator system, of which the generator G is illustrative, that the generator output voltage runs from as low as two-tenths of a volt up to three-tenths of a volt or higher, with the engine operating at low idling speed. Heretofore relays capable of operating on such small voltages have not been available to the automotive industry and therefore it became impractical to attempt to use such a low voltage to control a cranking relay, and it was found to be unsatisfactory to require the operator to race the motor in order to generate higher voltages.

I have found that I may satisfactorily control a relay type starting system of the class described by providing a novel combination of relays and operating circuits, which combination includes a cranking relay and a special sensitive relay. This sensitive relay has been carefully designed to operate on the available low voltages above indicated as being generated by the generator G at idling speed. I further find that I am enabled to accomplish this result by constructing the sensitive relay with novel electrical operating characteristics and by including novel protective devices for this relay.

In Fig. 2 I have illustrated one simple form of my improved relay combination and operating circuit connected into the engine starting circuit above described. As shown therein R1 denotes a cranking relay which is so positioned that it may control operation of the solenoid SS when the ignition key is turned to an "on" position. Combined with this relay is the special sensitive relay of the invention denoted by R2, and this relay is electrically connected so that it may, in response to a low idling voltage from the generator G, open the circuit to relay R1 and hold it in this open position, thus interrupting the cranking action of the starting motor SM. In other words, when the engine E begins to operate, the starting motor SM is cut off and maintained out of operation until such time as the engine fails.

The two relays R1 and R2 are connected to the several parts of the ignition system shown by means of special electrical branch circuits which will be described more in detail at a later point in the specification. Combined with these branch

circuits are a number of electrical elements including a resistor X; a switch S; terminals M, L, K; a jumper J; and contacts CR1, CR2 and CR1A.

Preferably these electrical units and portions of the electrical conductors, together with the relays R1 and R2, are mounted in a housing P of the control unit of the invention. This housing may consist of a closed rigid container which is substantially moisture-proof and which contains means for attaching it at some convenient point along the instrument panel of a vehicle, or other desired point. Located on the housing P are terminals 1, 2, 3 and 4.

Considering specifically the design of the special sensitive relay R2, it is found that regard must be had for certain limiting factors. Having in mind that for a 6 volt generator the relay will have to be responsive to a voltage output of less than two-tenths of a volt, and also bearing in mind that it is desirable to satisfy this requirement with a reasonable safety margin, I have devised a relay with a wire diameter and a number of turns capable of developing a coil resistance of 11 ohms and also responsive to a power rating of approximately 3 milliwatts. Some slight deviation from these figures may be realized without loss of efficiency, but any material departure will be found to be objectionable.

Tests have also indicated that a critical minimum resistance load point exists in a system such as that described in which lowering the resistance value of the generator load below that point produces a great disproportionate loss in the generator output when the engine is operated at its lowest idling speed. For example, with a 6 volt battery system this critical resistance point value was found to be approximately 8 ohms. A relay mechanically designed with a coil having the correct number of turns to produce a coil resistance of 11 ohms, as noted above, provides a suitable safety factor. On a 12 volt system and relay with the above combination of a coil resistance of approximately 70 ohms was found to be satisfactory and to provide a suitable safety margin.

It will be apparent, therefore, that in accordance with the invention I have provided an arrangement whereby the resistance load placed on the generator output is suitably limited so as not to appreciably reduce what voltage is available, and yet the resistance of the relay coil is low enough to produce a sufficient magnetic operating field for the relay.

In devising and installing a special sensitive relay of the characteristics indicated, there turns out to be several additional problems which originate out of the very nature of the sensitive relay. One serious limitation is found to be that a relay of the characteristics provided in relay R2 is extremely likely to be badly damaged, if not completely destroyed, should it be forced to carry the maximum voltage produced by the generator at higher operating speeds for any length of time.

I have found that I may overcome this difficulty by combining with the relay R2 a protective resistance in the form of the shunted resistor X, for example, which, as noted above, is shown in Fig. 2. This resistor is connected across the electrical conductors running to contacts CR1 so that the resistor is under the control of the contacts CR1 which, when open, remove the shunt across the resistance.

The resistor X is chosen to afford a resistance such that at low generator voltages the relay is

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fully sensitive but at higher voltages from the generator, relatively lower actual voltages are applied to the relay. In selecting a proper value for resistor X it will be apparent that too low a resistance value will not give sufficient protection to the R2 relay coil at a high generator output. On the other hand, too high a resistance value will cause the R2 relay to release as soon as the contacts CR1 open and remove the shunt across the resistance. Having due regard for these conditions I have found that a resistance of approximately 5 ohms, for example, is satisfactory.

I also find that the timing of the opening of contacts CR2 in relation to the opening of contacts CR1 is of importance. I provide for the contacts CR2 being adjusted so as not to open until the R2 relay is almost fully operated, and the contacts CR1 are adjusted not to open until the relay is almost fully released. With this arrangement the resistance X is not cut into the operating circuit until the R2 relay is fully operated. This ensures the holding of relay R2 operated when its operating voltage is reduced by the resistor X.

A second serious limitation in the use of an extremely sensitive relay, such as relay R2, is due to the fact that because of its very sensitiveness relay R2 is responsive to and undesirably affected by secondary low voltages from sources other than that produced by the generator, and therefore relay R2 must be protected from such voltages, if they exist.

In practice I have found that one very troublesome low voltage does exist in the conventional form of ignition and starting systems of automotive vehicles at the time the engine is being cranked and prior to its actually having been started. A voltmeter connected between any given point on the engine and the body or chassis of the vehicle, for example as shown in dotted lines in Fig. 1, will show a voltage of a substantial value, sometimes running as high as five-tenths of a volt. It will readily be appreciated that this voltage is over twice as much as that required to operate the sensitive relay and, consequently, this voltage would operate the relay prematurely and repeatedly interrupt cranking before the motor started.

I have discovered that this troublesome factor may be completely eliminated by a novel circuit arrangement in which none of the common ground points on the body or chassis of the vehicle are utilized. Instead, a separate operating circuit to the generator has been devised and provided independently of the body or chassis ground connection so that the sensitive relay R2 is at all times isolated from this stray voltage. This novel circuit has been illustrated in Figs. 1 and 2.

In order that the importance of grounding the circuit in the manner shown in Fig. 1 may be fully appreciated, it is helpful to consider the manner in which objectionable voltages are produced when the electrical motor is cranking and prior to the engine actually starting. For example, in the starting circuit shown in Fig. 1, which runs from the battery B, through a cable to solenoid SS, from solenoid SS through a cable to the starting motor SM, and through the armature and coils of the starting motor to the starting motor frame, then through the engine E, through the battery ground strap BGS to the frame of the body D and back to the battery, then a voltage would be produced, at any point between D and E.

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Obviously there are many parallel ground return paths from the starting motor back to the battery through miscellaneous bolts and nuts supporting the engine mechanism. These are of little moment as the path providing the lowest resistance is the one provided by the ground strap.

If a test lead of a voltmeter is placed at any point on the body or frame and the other test lead on any point on the engine, a reading will be obtained when the starting motor is running. This is due to the resistance of the ground strap and the surface resistance of its connections on the engine and the body, in combination with the other parallel resistances between the engine and the battery.

The entire series resistance of the starting motor circuit when operating from a 6 volt battery and drawing 120 amperes is only .05 ohm. Therefore, assuming that the total resistance between the ground strap points P1 and P2 is only .004 of an ohm, a voltage measured across P1 and P2 would be .48 volts. It will readily be seen that with the sensitive relay R2 of the invention connected between points D and E, the relay will be subjected to a voltage which is more than twice that required to operate this relay. This would make the relay completely inoperative for the purposes of the invention.

I avoid this difficulty in the way shown in Fig. 2 by wiring one side of the coil of the sensitive relay R2 to the output lead of the generator G and the other side of the coil to the engine or generator frame, as noted. Wired in such a manner the relay is completely independent of all voltages except those produced by the generator.

A third major difficulty inherent in a sensitive relay combination is the problem of excessive inductive load of the starting solenoid which could damage or impair the sensitive relay contacts. I find that I can avoid this trouble by constructing the relay R1 with heavy duty contacts CR1 and by constructing the relay R2 with relatively light duty contacts CR2.

Considering more in detail the operation of the apparatus illustrated in Fig. 2, when the ignition key switch KS is turned to the "on" position, current flows to the ignition coil C and also over the electrical conductor to a terminal i on the housing P of the control unit. From terminal i current goes through switch S to terminal M of a change-over switch, through normally closed contacts CR2 through the coil of R1 relay to ground. This operates the R1 relay which, in turn, energizes the solenoid switch SS to start the cranking action. The circuit goes from ground through terminals K and L connected by jumper J through the closed contacts CR1A to terminal 2, and from terminal 2 to the solenoid switch SS. This energizes the solenoid SS which closes the circuit shown in heavy lines to the starting motor SM which, in turn, operates and cranks the engine.

As soon as the engine starts to run, even at its lowest idling speed, the generator G produces a small voltage. The voltage is transmitted over an electrical conductor from a connection either at the generator G or at the voltage regulator VR to terminal 4. From terminal 4 the circuit is completed through the coil of the sensitive relay R2, through the closed contacts CR1 to terminal 3. From terminal 3 current passes through an electrical conductor to a ground point on the generator or engine, the former having been indicated in Fig. 2 of the drawings. This circuit energizes relay R2 which operates,

When this relay is almost fully operated the contacts CR2 open. This releases the R1 relay, the operating path of which previously described was through these contacts.

The relay R1 now performs two functions. It opens the contacts CR1A through which the solenoid switch SS was energized and this stops the starting motor SM from operating. Relay R1 transfers the energizing path of the R2 relay from the contacts CR1 through the resistor X. However, the insertion of this resistor X into the operating path of relay R2 does not cause this relay to release. As is well known to those skilled in the art, it takes considerably more current to operate a relay than it takes to hold it operated. The resistor, by virtue of the shunt across it through the contacts CR1 now being removed is in series with the coil of the R2 relay which effectively reduces the current flowing through the coil when the generator is operating at higher engine speeds, thus affording protection from higher generator voltages which, when sustained, would damage or destroy the R2 relay coil.

If the engine stalls with the engine key switch KS in the "on" position, the generator produces no voltage and relay R2 immediately releases. R2 relay in releasing closes its contacts CR2 which then closes the operating path for the R1 relay, as described above, and the entire cranking cycle is again caused to take place.

Another desirable feature of the circuit arrangement shown in Fig. 2 is the jumper arrangement consisting of the single jumper J. This arrangement permits either a ground or battery potential to be supplied, depending upon whichever is required to operate the solenoid switch SS. As the starting circuits of internal combustion engines are normally equipped and wired before installation of the control device of the invention, it is only necessary to change the jumper J in order to correctly match the existing circuit.

Assuming that the solenoid switch SS, Fig. 2, required a battery potential instead of a ground potential, as previously described to operate it, transferring the jumper J from terminal K to terminal M will produce the necessary conversion. The path to operate the solenoid switch SS then becomes battery from terminal I; through switch S to terminal M of the change-over switch; through jumper J to terminal L of the change-over switch; through contacts CR1A to terminal 2, and to the solenoid switch.

In all other respects the control functions as previously described. The switch S in the control box P is not limited to this location but may well be on the instrument panel or other points, if so desired. The current supplying primary operation of the control is through this switch. It will be apparent, therefore, that one useful purpose of this switch is to electrically cut out the operating circuit of the control when the control is not desired and normal manual starting is to be carried out.

With the control apparatus in the form described and illustrated in Fig. 2, a continuous cranking of the engine will be carried out by the electrical starting motor SM until either the engine starts, or the ignition is turned off, or until the battery is exhausted. This condition would not be desirable in the case of an unattended engine, such as a stationary engine. To take care of this repetitive cranking at predetermined intervals is, in accordance with the in-

vention, carried out by providing thermal time delay relay means which have been illustrated in Fig. 4 of the drawings and designated specifically by the numeral R3. In its simplest form the thermal relay R3 may be so connected as to permit a single predetermined timed cranking period which will, if the engine fails to start within the period, prevent further cranking action until the ignition switch is turned off and then turned on again. The circuit diagram for the single cranking period has been illustrated in Fig. 3 of the drawings.

Referring specifically to the arrangement shown in Fig. 3, the thermal timing relay R3 is employed with a jumper J1 with its terminals K1, L1 and M1 having been added. With the jumpers J and J1 in the position shown, the solenoid energizing path is as follows: Ground from terminal K; through jumper J; through terminal L; through contacts CR1A to a junction of contacts CR3 and heat coil of R3. Here the circuit divides. One part continues the ground circuit through the contacts CR3 to terminal 2 which is wired to the solenoid switch. The other part of the circuit from the aforementioned junction goes through the heat coil of R3; to terminal L; to jumper J1; to terminal K1; to battery under control of the CR2 contacts, as described in Fig. 1.

If, after a predetermined time, the engine fails to run, the solenoid switch remains energized, and due to the heat generated by the heat coil R3, the movable bimetallic element CR3 becomes warped toward the heat coil of R3. The separation of contacts CR3 opens the circuit which deenergizes the solenoid switch, thus interrupting the cranking action. The heat coil of R3, however, remains energized until the ignition key switch or switch S is turned off. This prevents further cranking.

It will be seen, therefore, that the circuit described provides a single timed period of cranking action which will automatically stop the cranking action if the engine fails to run before the timed period has elapsed. If the solenoid switch requires a battery potential instead of a ground potential, the jumpers J and J1 are connected to terminals L and M and L1 and M1, respectively. This effects the correct change in the circuit for both the solenoid switch and the R3 relay. The balance of the circuit, not described here, functions as set forth in connection with the explanation of Fig. 1.

Referring to the embodiment shown in Fig. 4, the thermal timing relay R3 has been connected to provide for repetitive cranking action. Otherwise the same components are employed and are wired to function, as has been described in connection with Fig. 3. It will be noted in Fig. 4 that ground is from the change-over switch through contacts CR1A, then through contacts CR3, and then connects to terminal 2 (the solenoid switch connection) and the heat coil of R3.

With this arrangement, after a predetermined interval if the engine E fails to start, the bimetallic element CR3 warps and opens the circuit to both the heat coil of R3 and the solenoid. This deenergizes the solenoid and the heat coil of R3 which, when sufficiently cooled, will again close the contacts CR3 and a repetition of cranking will take place. As before, reversing the connections of jumpers J and J1 will supply a battery potential to the solenoid switch which connects the terminal 2 and effects the necessary changes required by relay R3.

The circuit described may be utilized in various modifications of the invention. For example, in Fig. 5 I have shown a fragmentary section of a foot operated clutch pedal 10. It will be noted that a switch 12 is connected in series with a control wire which connects my control apparatus into a typical internal combustion engine ignition system of the type already described. The switch 12 is arranged to close the operating circuit of my control when the clutch pedal is depressed. This arranged may be employed in those situations where it is desired to have the control operative only when the transmission and the engine is disengaged.

In Fig. 6 a fragmentary section of a steering column 14 and a gear shift lever 16 is shown. The electrical connections include a switch 18 and the functioning is substantially the same as that already described in connection with Fig. 5, with the difference, however, that the gear shift switch 18 is operated only when the gear shift lever 16 is in a neutral position with respect to the engine and drive shaft. In case the engine stalls with the control arranged as shown in the figure, merely moving the gear shift lever 16 into a neutral position will automatically provide for cranking the engine. A number of arrangements are possible to accomplish this and one simple device consists in a gear shift switch adaptor 20 fixed to the gear shift rod 16. The adaptor is so placed with respect to the gear shift switch that the contacts close only when the vehicle driving means are in a neutral position.

Referring now to the embodiment as shown in Fig. 7, it will be noted that, with the exception of the adjustable resistance BR and the connections thereto, the balance of the components and their functions are as shown in Fig. 1. The bleeder resistance BR is arranged in the circuit to supply a biasing voltage to the R2 relay. In this manner, a relay of less critical value and sensitivity may be chosen. The BR resistance is normally adjusted to supply a saturation current to the R2 relay but not of a sufficient intensity to cause its operation. As each vehicle will require a slightly different value of resistance to accomplish this, the resistor BR is adjustable to meet all conditions.

When current is received at the control on terminal 1, caused by turning the ignition means "on," this current is transmitted to the CR2 contacts and performs its usual function, as outlined in Fig. 1. However, a parallel circuit for this current is established through the BR resistance, through the coil of R2 relay, through the contacts CR1, through terminal 3 to ground on the engine or generator frame. This current passing through the coil of the R2 relay does not operate it during the period that the engine is cranking, but just as soon as the engine starts the slight current produced from the generator, added to this biasing current, promptly operates the R2 relay, thus causing the cranking action to stop. In all other respects the components function as in Fig. 1.

Referring to the embodiment shown in Fig. 8, it is again noted that the elements and circuits employed are the same as in Fig. 1, except that a new component, an electrolytic condenser EC, has been added. This condenser is connected as shown across the coil of the R1 relay and is energized simultaneously with the R1 coil. However, when the current is removed from the R1 coil, the energy or current stored in the con-

denser EC then discharges through the R1 coil. This action causes a momentary slow release of the R1 relay. This slow release action insures that the operating path of the R2 relay, through the contacts CR1 of R1 relay, will not be opened by the release of the R1 relay until the R2 relay is fully operated. Thus the R2 relay will be fully operated before the resistance X is placed in series with the coil of R2 relay. Of course it is understood that a slow release type of R1 relay could be used, or that other ways may be employed to slow the release of the R1 relay when its coil is deenergized.

Referring now to the embodiment of the invention as shown in Fig. 9, it will be noted that a combination of thermal time delay relays are used. In effect, the combination of Figs. 3 and 4 are achieved. After a predetermined number of repetitive cranking cycles, controlled by the R5 thermal relay, the R4 thermal relay will function and stop further cranking action until the control is reset by turning off the power source. In all other respects the control functions as outlined in Fig. 1. The cranking circuit is energized by ground from terminal K of the transfer switch, through the jumper J, through contacts CR1A to contacts CR4 of the thermal relay. From here three circuits are energized. One; from CR4 to heating coil of R4, through transfer switch terminal L1 and K1 to battery to terminal 1, thus energizing R4. Two; from CR4 through contacts CR5 of thermal relay R5 to terminal 2 to the solenoid switch, thus energizing the solenoid. Three; from bimetallic element of CR5 through the heating coil of R5 relay to the same battery circuit as described for CR4, thus energizing the R5 relay. If now the solenoid switch controlling the cranking action remains energized for any length of time, the faster acting thermal relay R5 will be repetitively opening and closing the solenoid operating circuit. However, after a predetermined number of such cycles takes place the slower acting thermal relay R4 will operate and open the contacts CR4 which will stop further cranking cycles. The heating coil of R4 will stay energized until reset by turning off the power source. The thermal relays are mechanically and electrically identical. The difference in their operating speed is obtained by an adjusting screw which governs the permissible warping of the bimetallic element before the contacts break. It is to be noted that if a battery potential instead of a ground potential should be supplied to the solenoid switch, which is externally connected to terminal 2, all that is necessary is to connect L and M terminals by jumper J and connect L1 and M1 terminals by jumper J1. This makes the necessary change to both the solenoid switch and the thermal relays R4 and R5. It is understood that a timing means other than thermal means may be employed to produce the same results.

Fig. 10 illustrates a part of the structure shown in the control device of Figs. 3, 4 and 9. Included therein is a signal device which may comprise a bell, for example. The bell is connected, as shown, to contact TRA of the thermal relay TR and to the jumper terminal L1. If, after a predetermined interval the engine fails to start, the bimetallic element of the thermal relay warps and engages with the contact TRA. This closes the path to energize the alarm circuit. In all other respects the circuit functions in the man-

ner described with respect to the devices shown in Figs. 3, 4 and 9.

It will be observed that if the engine fails to start, the addition of contact TRA to CR3, or to CR4, or to CR5 of Figs. 3, 4 and 9, respectively, will provide a signal when the thermal relay operates. The signal denotes that a failure of engine starting has occurred and the solenoid switch is no longer energized. The signal will function during the period or periods that the solenoid is deenergized after failure to start has occurred. If the device is used with a repetitive thermal relay, it will give a signal during each repetitive "off" cranking cycle. If used on a single acting thermal the device will give a signal after the thermal relay has stopped further cranking. If the device is used as in Fig. 3 it will give a signal when the thermal relay stops cranking.

It will be apparent that I have provided a positive and efficient control for automatically starting an internal combustion engine in which a wide range of flexibility is present so that many different situations arising in the course of operation of the engine may be dealt with. In particular, the use and protection of a sensitive relay is made practical.

Many advantages are present in connection with the use of the device of the invention. It serves as an aid when the engine stalls, and less operations are required to restart the stalled motor. This is, in effect, a safety factor under some circumstances. There is believed to be a reduction in excessive battery drain and damage to the starter and fly wheel gears by more rapid disengagement of the starting motor from the engine than takes place in manual operation of the starting motor. The device is particularly advantageous for use in marine engines where the operator has both hands free to operate other engine parts and where stalling of the engine presents a problem. In the case of stationary engines the automatic control makes it practical to automatically start and stop the engine from a remote point by the use of auxiliary controls. The device also is useful in connection with the operation of under-water equipment, such as military vehicles designed to be driven completely submerged in water.

While I have herein shown and described a preferred embodiment of my invention, it will be understood that various changes and modifications may be carried out within the scope of the appended claims.

I claim:

1. An apparatus of the class described comprising an internal combustion engine, an electrical starting motor for cranking said internal combustion engine, electrical means for energizing the starting motor, a generator adapted to be driven by the engine to produce an electrical voltage, said electrical means including a solenoid switch, a cranking relay for actuating the starting motor by means of the solenoid switch, and a sensitive holding relay for controlling the cranking relay, said holding relay being responsive to the low range operating voltage of the generator developed when the engine is at idling

speed, said apparatus being mounted in a vehicle body and the said electrical means being constructed and arranged in the vehicle body to provide an electrical operating circuit for the sensitive relay, said circuit being isolated from the common engine and body ground connections.

2. In an apparatus of the class described, an internal combustion engine, electric ignition means for said engine, an electrical generator driven by said engine to produce electric power, a starting motor adapted to crank the engine, said starting motor including a battery and a ground circuit between the starting motor and the said battery, a solenoid switch for controlling operation of the starting motor, auxiliary control means responsive to said electric ignition means to energize said solenoid switch when the engine is not self-actuated, said auxiliary control means including a sensitive relay having an electromagnet sensitive to voltages produced by the generator thereby to actuate the sensitive relay, said sensitive relay being adapted to deenergize the solenoid switch when the engine is self-operated, said electromagnet having an electrical operating path including a separate ground circuit to said generator, said electrical operating path being independent of voltages in the said ground circuit between the battery and the said starting motor to prevent energizing said electromagnet when said starting motor is energized.

3. An apparatus as described in claim 2, including electrical resistance means associated with the auxiliary control for protecting the electromagnet coil of the sensitive relay from an electrical overload condition when the generator is operating at a speed in excess of engine idling speed.

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