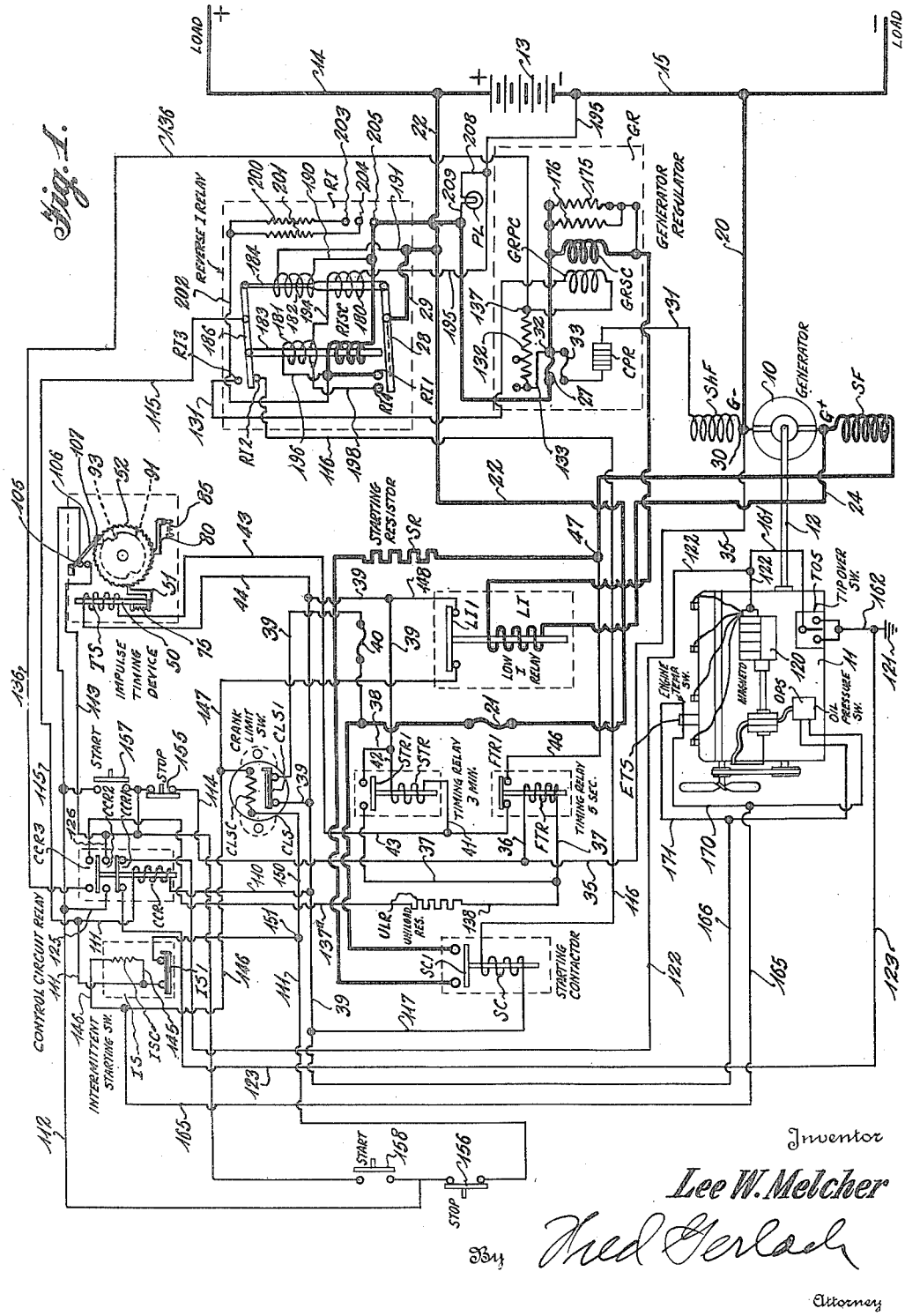
Jan. 12, 1943. L. W. MELCHER 2,307,845

ELECTRIC CONTROL SYSTEM FOR ENGINE GENERATOR UNITS

Filed June 21, 1940 4 Sheets-Sheet 1

Fig. 1.



Inventor

Lee W. Melcher

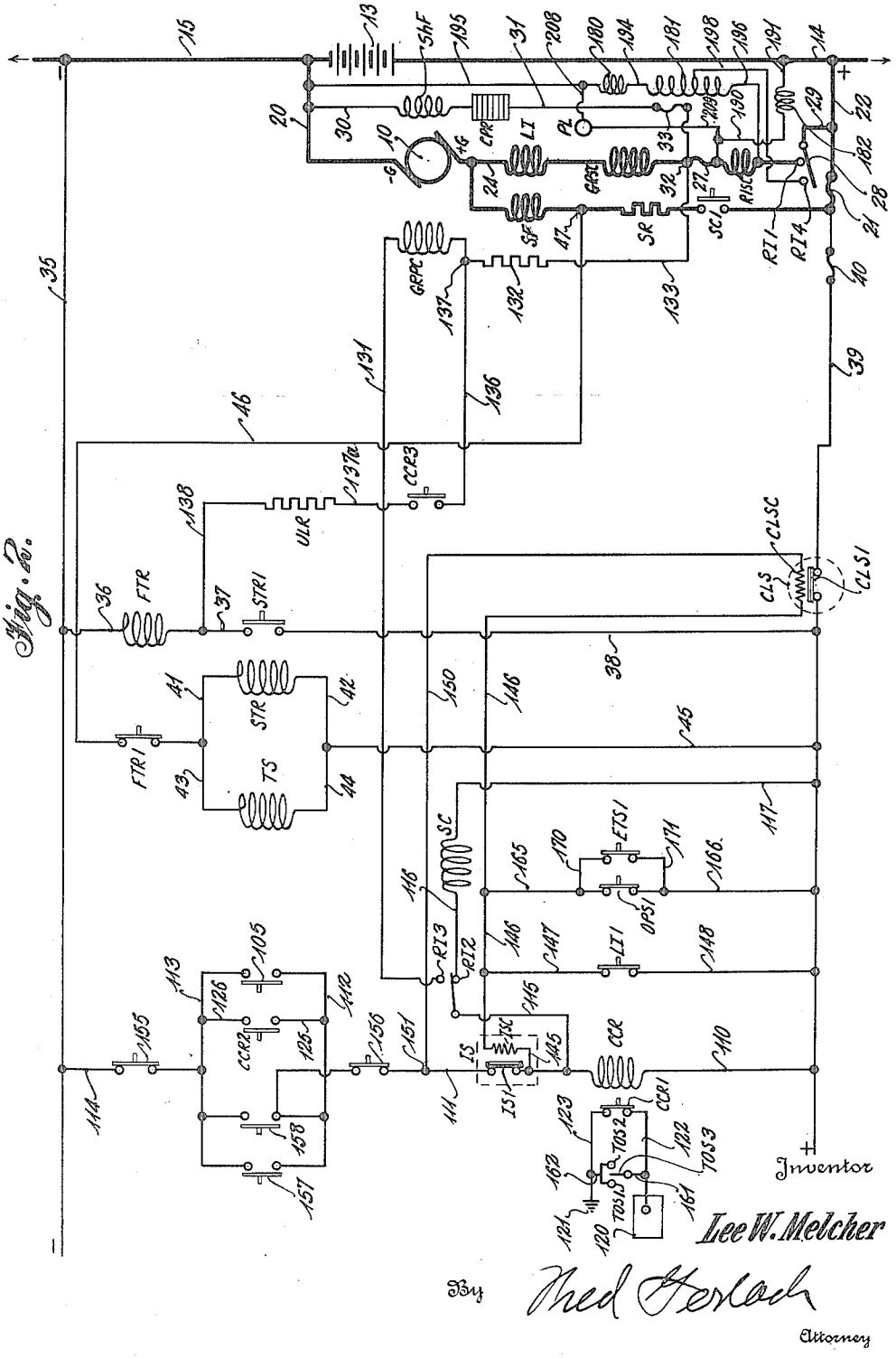
By Fred Gerlach

Attorney

Jan. 12, 1943. L. W. MELCHER 2,307,845

ELECTRIC CONTROL SYSTEM FOR ENGINE GENERATOR UNITS

Filed June 21, 1940 4 Sheets-Sheet 2

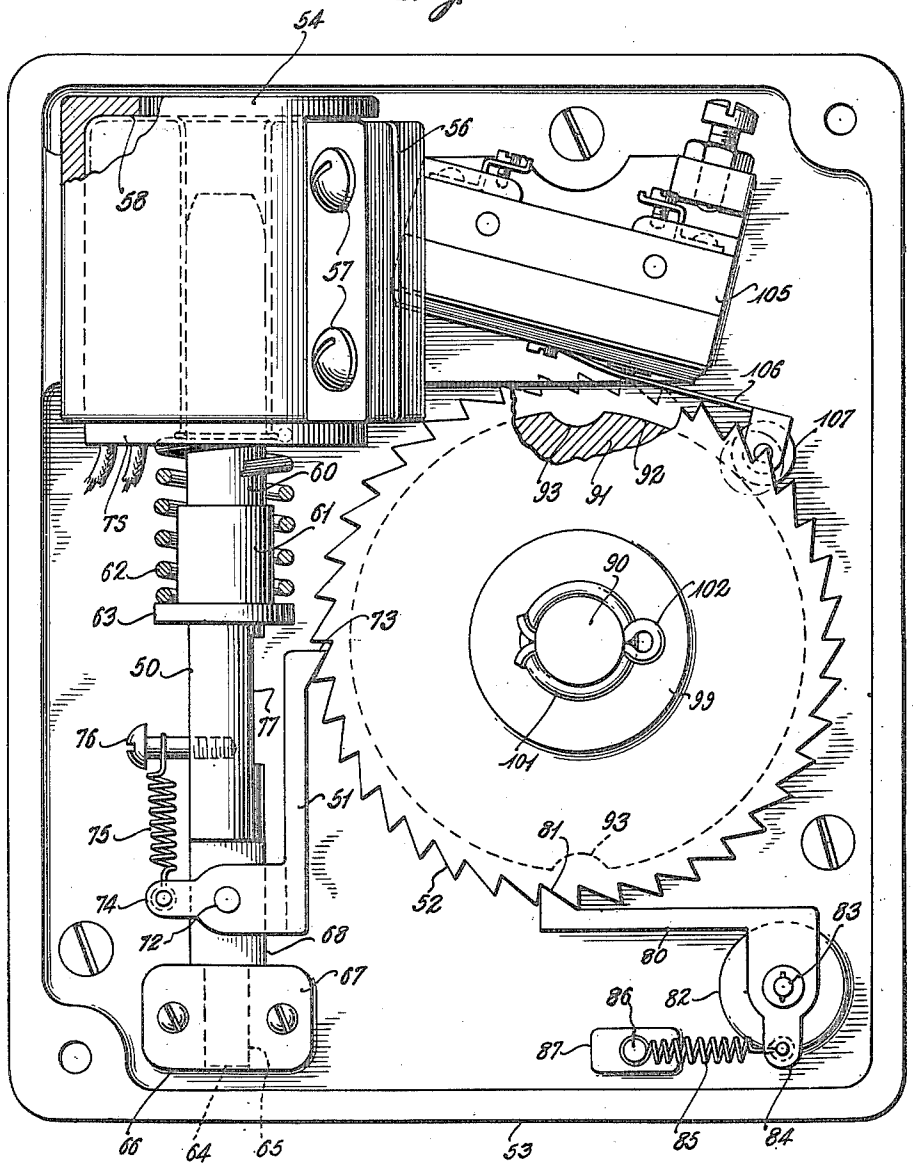


Jan. 12, 1943. L. W. MELCHER 2,307,845

ELECTRIC CONTROL SYSTEM FOR ENGINE GENERATOR UNITS

Filed June 21, 1940 4 Sheets-Sheet 3

Fig. 3.



Inventor

Lee W. Melcher

By Fred Gerlach

Attorney

Jan. 12, 1943. L. W. MELCHER 2,307,845

ELECTRIC CONTROL SYSTEM FOR ENGINE GENERATOR UNITS

Filed June 21, 1940 4 Sheets-Sheet 4

Fig. 4.

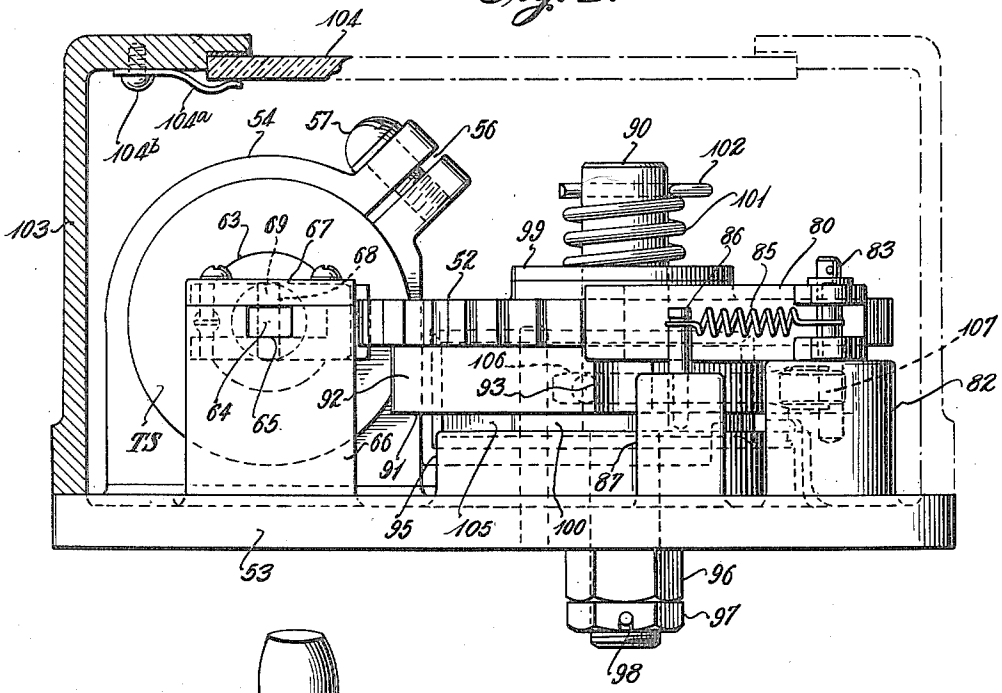


Fig. 5.

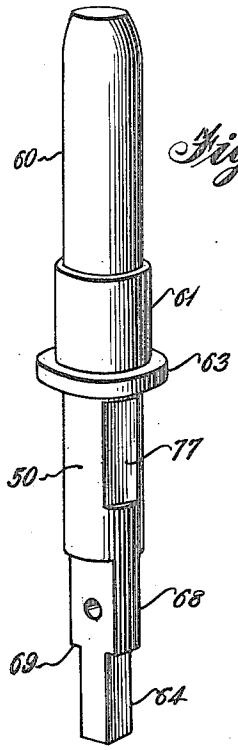
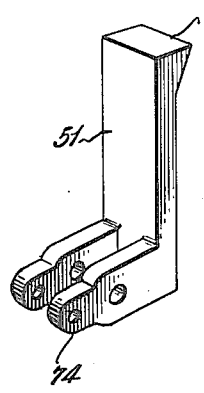


Fig. 6.



Inventor

Lee W. Melcher

By Fred Gorlach

Attorney

Patented Jan. 12, 1943 2,307,845

UNITED STATES PATENT OFFICE

2,307,845

ELECTRIC CONTROL SYSTEM FOR ENGINE GENERATOR UNITS

Lee W. Melcher, Oconomowoc, Wis., assignor to Waukesha Motor Company, Waukesha, Wis., a corporation of Wisconsin

Application June 21, 1940, Serial No. 341,747

25 Claims. (Cl. 290—30)

This invention relates to control systems and more particularly to electrical control systems for use in conjunction with engine-generator units in which a storage battery or the like normally provides a source of current for a load and a generator mechanically coupled to an internal combustion engine operates as a motor to start the internal combustion engine and is then driven by the engine to generate a current for effecting recharging of the battery.

A primary object of the present invention is to provide a control system of this character which is fully automatic in operation, which protects the battery and the engine against injury from improper operation, which may be mechanically controlled at any time if desired, and which under normal automatic operation provides for periodic recharging of the battery after a predetermined interval of time following each preceding operation of the engine-generator.

A further object is the provision of such system in which the restarting of the engine-generator is substantially independent of the voltage of the battery or the degree of use thereof.

A further object of the invention is the provision of a control system for engine-generators in which the engine-generator terminates operation upon the generated current reaching a predetermined minimum and an electric timer provides for restarting the engine-generator after a predetermined interval of time following the termination of operation thereof.

A further object is the provision of such engine-generator control system in which the electric timer automatically terminates operation upon starting of the engine-generator and automatically resumes operation upon the termination of operation of the engine-generator.

A still further object is the provision of such a control system in which the electric timer requires no additional special switches, relays or the like for effecting automatic operation thereof upon stopping and starting of the engine-generator.

Another object is the provision of such a control system in which an engine-generator is automatically limited to a subnormal load for a predetermined interval of time following starting thereof, and in which an electric timer predetermines the time during which the load is thus limited.

A further object is the provision of an engine-generator control system in which the cranking of the engine is intermittently interrupted if the engine fails to start.

A further object is to provide such engine-generator control system in which the cranking operation is entirely discontinued and the system must be manually reconditioned for further operation if the engine continues to fail to start after a predetermined period of cranking.

Another object is the provision of a control system for engine-generators providing for terminating the operation of an engine-generator when a predetermined minimum current is supplied by the generator and in which the stopping of the engine-generator is delayed for a predetermined time period following generation of such minimum current to prevent stoppage of the engine-generator upon a temporary change in load.

A further object is to provide such a control system for engine-generators in which the operation of an engine-generator is terminated upon the engine tipping over, or upon failure of the engine to maintain a predetermined oil pressure, or upon excessive heating of the engine; and in which the operation of the engine is immediately terminated upon tipping over while the stopping of the engine-generator is delayed for a predetermined time interval following sub-normal oil pressure in the engine or over-heating thereof to avoid stoppage upon a temporary disturbance in the engine.

A further object is the provision of an engine-generator control system as above set forth in which a common switch means energizable from the battery of the system provides for intermittently interrupting cranking of the engine upon failure of the engine to start and also provides for delaying termination of the operation of the engine-generator when a predetermined minimum current is supplied by the generator, or the engine fails to maintain a predetermined oil pressure, or the temperature of the engine becomes too high.

A still further object is the provision of an improved electric timer for controlling the operation of an electric control system.

These and other objects and advantages of the invention will be apparent from the following description, the appended claims and the accompanying drawings in which like reference characters designate like parts in the several views, and in which:

Fig. 1 is a wiring diagram of a control system arranged in accordance with the present invention;

Fig. 2 is a simplified across-the-line diagram of the system shown in Fig. 1;

Fig. 3 is an elevational view, partly broken away, of a portion of the timer mechanism;

Fig. 4 is a bottom plan view of the mechanism shown in Fig. 3 with the cover member for the mechanism indicated thereon;

Fig. 5 is a perspective detail of the plunger of the mechanism of Fig. 3; and

Fig. 6 is a perspective detail of the pawls in the mechanism of Fig. 3.

The drawings illustrate a preferred embodiment of the invention and in Figs. 1 and 2 show a control system for an engine-generator unit at a period during a cycle of operation when the engine and generator are both inoperative and the system is under the control of an electric timer which operates from the battery of the system and predetermines a time limit after which the engine-generator will become automatically operative to recharge the system battery, if required, and to supply a current to any load connected to the battery at the time. The generator is designated by the reference numeral 10, and as shown in Fig. 1, is mechanically coupled to an internal combustion engine 11 by a drive shaft 12. A storage battery 13 or the like normally supplies a source of E. M. F. for any desired load through the leads 14 and 15 and is adapted to be periodically recharged by the engine-generator. The battery 13 and the engine-generator 10—11, for example, could provide for supplying a lighting, heating, ventilating or other load for domestic, farm or industrial purposes or for a bus, trolley bus, railway car or the like.

To simplify the description of the control system for the engine-generator 10—11 the various relays and switches of the system will be designated by reference letters and the contacts operated thereby will be designated by the same reference letters with the numerals "1," "2," "3," etc., appended thereto depending upon whether the relay or switch operates one, two, three or more sets of contacts. To facilitate further an understanding of the invention the description of the system will also be separated into the several phases of operation thereof.

The Main Power Circuit

A. Upon operation of the generator as a motor

Referring to the drawings and more particularly to Fig. 2, one side of the generator 10 is connected to the negative side of the battery 13 by the lead 20. From the other side of the generator the circuit is completed through a series starting field SF, a starting resistor SR, a normally open starting contactor SC1, a starting fuse 21, and thence back to the positive side of the battery through leads 22 and 14. Upon closing of the starting contactor SC1 the battery 13 will thus operate the generator 10 as a motor to effect cranking and starting of the engine 11.

B. Upon operation of the generator as a generator

The negative side of the generator is again connected to the negative side of the battery by the lead 20. The opposite or positive side of the generator connects by lead 24 through the series coil LI of a low current relay, a series coil GRSC of a generator regulator GR, a generator fuse 27, a series coil RISC of a reverse current relay RI, a contact RI1 of the reverse current relay, the armature 28 of the reverse current relay, and thence through the leads 29, 22 and 14 to the positive side of the battery 13. Excitation for the generator 10 is obtained from a shunt field ShF which is connected to the negative side of the generator by a lead 30 connecting with the lead 20. The other side of the shunt field ShF is connected to the positive side of the generator by a lead 31 which connects to the main generator circuit at a point 32 positioned between regulator current coil GRSC and the generator fuse 27. A carbon pile resistor CPR of the generator regulator GR and a field fuse 33 are also connected in the lead 31 to be in series with the field ShF. Thus upon driving of the generator 10 by the engine 11 and closing of the contacts RI1 of the reverse current relay the generator will operate to supply a current to the battery 13 and the load leads 14 and 15.

The Automatic Electric Timer

Assuming the battery 13 to be at least partly charged and the control circuit to be in the condition indicated by Figs. 1 and 2, an automatic electric timer will be under operation of the battery as stated above to predetermine the next operation of the engine-generator. This timer comprises a relay FTR, a relay STR and an impulse timing device including a timer solenoid TS. Both the relays FTR and STR are of the quick make, slow break type, but the relay FTR has its contacts FTR1 normally closed when the relay is deenergized while the contacts STR1 of relay STR are normally open upon deenergization of the relay. Thus the contacts FTR1 will open only after a predetermined time following energization of relay FTR while the contacts STR1 reopen after a predetermined time following deenergization of relay STR. The relays FTR and STR may be of any conventional design and are so adjusted in the preferred embodiment of the invention that the normally closed relay FTR opens its contacts FTR1 approximately 5 seconds after energization thereof while the normally open relay STR reopens its contacts STR1 only after approximately 3 minutes following deenergization thereof.

Referring again to Fig. 2 in particular, the control circuit for relay FTR comprises a lead 35 which connects with the negative lead 15 of the battery 13, a lead 36, the coil FTR of the relay, a lead 37, the contacts STR1 of the relay STR, the lead 38 and a lead 39 which connects through a control circuit fuse 40, the starting fuse 21, the lead 22 and the lead 14 to the positive side of the battery. The leads 35 and 39 are thus normally connected across opposite sides of the battery 13 and across opposite sides of the generator 10 upon operation of the generator, and as best shown in Fig. 2, supply the voltage of the battery or the generator to the various elements of the engine-generator control system. The relay STR and the timer solenoid TS are connected in parallel by the leads 41 and 42 and the leads 43 and 44, respectively, and are included in a control circuit which comprises on one side a lead 45 (Fig. 2) which connects with the lead 39 and thence to the positive side of the battery 13, and on the other side the normally closed contacts FTR1 of the relay FTR and the lead 46 which connects at the point 47 to the starting circuit of the generator between the starting field SF and the starting resistor SR.

From the above description it will be evident that when the generator 10 is at a stand-still a circuit is established between the battery 13, lead 20, generator 10, series field SF, point 47, lead 46, the normally closed contacts FTR1, the coils of the relay STR and solenoid TS, the lead 45 and

the lead 39 back to the other side of the battery. This causes energization of the relay STR and rapid closing of the contacts STR1 thereof. Upon closing of the contacts STR1 the relay FTR is energized across the lines 35 and 39 and after approximately 5 seconds opens its contacts FTR1. Upon opening of the contacts FTR1 the coils of relay STR and of the solenoid TS become deenergized and after approximately 3 minutes the contacts STR1 of relay STR open to deenergize the coil of relay FTR. The contacts FTR1 then rapidly close and again energize the relay STR and the solenoid TS. The cycle of operation is thus repeated as long as both the relays FTR and STR are subjected to battery potential, and since the solenoid coil TS is connected in parallel with the relay STR, the solenoid receives an energizing impulse at approximately 3 minutes intervals.

Upon starting of the engine-generator, however, and the generation of a potential in the generator 10, the polarity of the point 47 changes from that of the negative side of the battery 13 to that of the positive side of the generator. Since the starting contactor SC1 opens upon operation of the engine-generator, as will be hereinafter described, and as the resistance of the series coils LI, GRSC and RISC of the main power circuit is practically negligible, the potential across the relay STR is insufficient to effect further energization thereof and the operation of the timer thus automatically terminates upon operation of the engine-generator. Upon termination of the operation of the engine-generator, however, the relay STR is again subjected to substantially battery potential and the timer automatically resumes operation.

As described above, the solenoid TS receives an impulse each time that the relay STR is energized and thus at approximately 3 minute intervals during the operation of the timer. As more particularly shown in Figs. 3 to 6 the solenoid TS operates a plunger 50 which in turn operates a pawl 51 associated with a ratchet wheel 52. The solenoid TS is rigidly mounted in predetermined positioning on a base member 53 by means of a clamping bracket 54 which extends around the outer surface of the solenoid coil and is attached to the base 53. To provide for removably receiving the solenoid the clamping bracket 54 is split as indicated at 56 and clamping screws 57 provide for releasably clamping the bracket around the solenoid. To further assure that the solenoid will remain in fixed positioning on the base 53 during operation of the device, the clamping bracket 54 is also provided with an inturned flange 58 which extends around the upper end of the solenoid when in place in the bracket.

The plunger 50 is of generally circular cross-section and is provided with an upper portion 60 which is received within the interior of the solenoid coil TS and provides the movable core of the solenoid. This portion 60 is relatively closely received within the bore of the solenoid coil and thus provides a support and guide for the upper portion of the plunger 50. The connections to the solenoid are such that upon energization thereof the plunger 50 is pulled upwardly. This upward movement of the plunger in response to energization of the solenoid is limited by a portion 61 of the plunger that is of increased diameter and provides a shoulder which engages the lower end of the solenoid coil and prevents further upward movement of the plunger. Downward movement of the plunger 50 upon deenergization of the solenoid is positively assured by a spring 62 which surrounds the plunger and is compressed between the bottom of the solenoid and a collar 63 provided on the plunger below the portion 61.

The plunger 50 at its lower end is provided with an extension 64 which is of substantially rectangular cross-section as shown in Figs. 4 and 5 and which is slidably received within a correspondingly shaped groove 65 of an upstanding boss 66 provided on the base 53. The portion 64 of the plunger is normally maintained in the groove 65 by a cap member 67 which is screwed to the boss 66. The boss 66 and the cap 67 in cooperation with the extension 63 of the plunger thus provide a support and guide for the lower end of the plunger 50 and also prevent turning of the plunger about its longitudinal axis during operation of the device. Downward movement of the plunger under action of spring 62 is limited by a flattened portion 68 of the plunger which provides a shoulder 69 that engages the upper side of the boss 66 and cap 67. The arrangement of the various parts thus far described is such that upon each successive energizing impulse of the solenoid TS the pawl 51 will rotate the ratchet wheel 52 through an angle corresponding to the pitch of one of the teeth of the ratchet wheel.

The pawl 51 is pivotally mounted on the portion 68 of the plunger 50 as indicated at 72 and is provided with a nose piece 73 that is adapted to engage and operate the teeth of the ratchet wheel 52. To provide for maintaining the nose piece 73 of the pawl in positive engagement with the teeth of the ratchet wheel and thus assure a step-by-step rotation of the ratchet wheel upon each energization of the solenoid TS the pawl 51 is also provided with an extension 73 to which one end of a tension spring 75 is attached. The other end of the spring 75 is attached to a screw 76 or the like which threads into the plunger 50 and thus maintains the nose piece 73 of the pawl in constant engagement with the teeth of the ratchet wheel while permitting retraction of the pawl upon deenergization of the solenoid and dropping of the plunger. To provide for ready retraction of the pawl 51 upon deenergization of the solenoid the plunger 50 is provided with a notched or cut-away portion 77 permitting free movement of the pawl. The construction and operation of the pawl and its mounting on the plunger 50 will be readily apparent from Figs. 3, 5 and 6.

To prevent reverse movement of the ratchet wheel 52 and thus to further assure a one step advance of the ratchet wheel upon each energization of the solenoid TS a second pawl 80 similar in construction to the pawl 51 is provided and is so arranged that its nose piece 81 engages the teeth of the ratchet wheel in such manner as to permit operation of the ratchet wheel under operation of the solenoid TS while preventing backward movement of the ratchet wheel. The pawl 80 is pivotally mounted on a boss 82 provided in the base 53 as indicated at 83 and is also provided with an extension 84 to which one side of a tension spring 85 is attached. The other side of the spring 85 connects with a stud 86 or the like provided on a boss 87 mounted on the base 53, and thus the pawl 80 is maintained in constant contact with the teeth of the ratchet wheel 52 to prevent backward movement of the ratchet wheel while permitting forward advance thereof under action of the solenoid TS.

The ratchet wheel 52 is rotatably mounted on the base 53 by a shaft 90 and provides for operating a cam 91 which has a circular cam surface

92 concentric with the axis of the ratchet wheel and one or more grooves or cam operating notches 93. In the illustrated embodiment the cam 91 is formed integral with the ratchet wheel 52 and is positioned on the under side of the ratchet wheel as viewed in Figs. 1, 3 and 4. The shaft 90 extends through a boss 95 provided on the base 53 and is threaded adjacent the under side of the base to receive a nut 96 and a lock nut 97. A cotter pin 98 also extends through suitable openings provided in the lower end of the shaft 90 and positively prevents the nut 96 and lock nut 97 from working loose. The combined cam and ratchet wheel is rotatably received on the shaft 90 above the boss 95 and is preferably provided with upper and lower thrust bearing washers 99 and 100, respectively, which are also received on the shaft 90. A compression spring 101 surrounds the shaft 90 above the ratchet wheel 52 and the washer 99 and is normally maintained in a compressed condition by a cotter pin 102 which extends through a suitable opening provided in the upper end of the shaft. The cam portion 91 of the ratchet wheel is thus constantly pressed against the washer 100 and boss 95 and is caused to move in a predetermined path around the axis of shaft 90 upon operation of the ratchet wheel. At the same time the cotter pin 102 and the spring 101 provide for ready removal of the ratchet wheel and cam and their replacement by a wheel and cam of different operating characteristics.

As shown in Fig. 4 a cover member 103 having a glass front 104 removably held in place by clips 104*a* and screws 104*b* is adapted to be received on the base 53 and encloses the timing mechanism mounted on the base. Suitable openings (not shown) are also provided in the base member for receiving the electrical connections to the solenoid TS and the switch 105.

The cam portion 91 of the ratchet wheel 52 is adapted to operate a switch which in the present embodiment of the invention controls the starting of the engine-generator 10—11. For this purpose a switch 105 is suitably mounted on the upper portion of the base 53 adjacent the solenoid coil TS and is provided with an arm 106 which carries a roller 107 that extends into the path of movement of the cam 91 and operates upon the surfaces 92 and 93 thereof. The switch 105 may be of any desired or standard type which in accordance with the present invention has its contacts maintained open so long as the roller 107 engages the circular concentric surface 92 of the cam and closes its contacts when the roller drops into one of the notched groves 93 of the cam.

From the above description it will be evident that the ratchet wheel 52 and the cam 91 will be moved through a predetermined arc of rotation upon each energizing impulse of the solenoid TS and that the switch 105 which is maintained in one condition of operation (open in the present instance) by the portion 92 of the cam will be operated to its opposite condition upon the roller 107 falling into a groove 93 of the cam. In the illustrated embodiment of the invention the ratchet wheel is provided with 40 teeth and the cam portion 91 is provided with two grooves or notches 93 positioned diametrically apart. Thus if the solenoid TS is energized at approximately three minute intervals as above described it will require approximately two hours of operation of the timing device to cause the ratchet wheel 52 to make one complete revolution and the switch 105 will be closed at approximately one hour intervals following each operation of the timer. It will be understood, however, that the timing can be readily varied by changing the number of teeth on the ratchet wheel 52, the number and positioning of the grooves 93 of the cam, or both. Thus although the number of teeth on the ratchet wheel remain the same the timing of operation of the switch 105 can be decreased to one-half hour intervals by merely arranging four grooves 93 at 90 degrees apart and can be increased to two hour intervals by merely arranging one groove 93 on the surface 92 of the cam. In like manner any other desired timing arrangement can be obtained by properly regulating the number of teeth on the ratchet wheel and the number and positioning of the cam grooves 93.

Starting of the Engine-Generator

In accordance with the present invention, as described above, the automatic timer switch 105 controls the starting of the engine-generator 10—11. Referring to Figs. 1 and 2, and more particularly to Fig. 2, the control circuit for effecting starting of the engine-generator comprises the lead 39, a lead 110, the coil of a control circuit relay CCR, leads 111 and 112, the contacts of the automatic timer switch 105, and thence through leads 113, 114 and 35 to the other side of the battery 13. Also included in the control circuit thus described is a starting contactor coil SC which is connected in parallel with the control circuit relay CCR as follows: A lead 115 branches from the lead 111 and connects through the back contacts RI2 of the reverse current relay RI to a lead 116 which is connected to one side of the starting contactor coil SC. From the other side of the coil SC a lead 117 connects the lead 39 of the control circuit. The contacts RI2 of the reverse current relay are normally closed as illustrated when the generator 10 is idle or is operating as a motor to crank the engine 11. Thus when the normally open contacts of the automatic timer switch 105 are closed by operation of the timer both the control circuit relay CCR and the starting contactor SC will be energized across the battery 13.

Upon energization of the starting contactor SC the normally open starting contact SC1 operated thereby is caused to close and thus effects energization of the generator 10 as a motor through the series starting field SF to provide for cranking the engine 11. At the same time the energization of the control circuit relay CCR causes the opening of the contacts CCR1 thereof which are normally closed to complete a shorting-circuit from an engine magneto 120 to a ground 121 by way of leads 122 and 123. The magneto 120 is thus conditioned upon opening of the contacts CCR1 to supply an ignition current to the engine 11 and effect the starting thereof under the cranking operation of the generator 10 running as a motor. Under normal conditions of operation the internal combustion engine 11 will thus start and will then drive the generator 10 as a generator.

Operation of the Control System Upon Starting of the Engine-Generator

Assuming starting of the engine 11 as above described, it will be evident that in order to continue operation of the engine the control circuit relay CCR must remain energized to prevent closing of the contacts CCR1 and grounding of the magneto. This is accomplished by a set of

contacts CCR2 which are normally open and which are closed upon energization of the relay coil CCR to establish a shunt holding circuit by way of the leads 125 and 126 around the contacts of the timer switch 105. Thus the engine 11 will continue to operate although the switch 105 may be opened by the automatic timer.

Upon starting of the engine 11 and driving of the generator 10 as such the generated voltage will build up and upon this voltage reaching a predetermined value, one half to one volt above the voltage of the battery 13 for example, the reverse current relay RI operates and causes the back contact RI2 thereof to open and the main contact RI1 and the back contact RI3 to close. Upon opening of the contact RI2 the energizing circuit for the starting contactor SC is opened and the contactor SC1 is caused to open the starting circuit of the generator 10. Upon closing of the main contacts RI1 of the reverse current relay, however, the main generator circuit is closed and the generator 10 is connected to the leads 14 and 15 to supply a recharging current to the battery 13 and to provide a source of voltage to any load connected with these leads.

As described above, the back contact RI3 of the reverse current relay closes when the contact RI2 thereof opens. This contact RI3 controls the energization of a potential coil GRPC of the generator regulator GR. Again referring to Fig. 2, the circuit for this potential coil GRPC of the generator regulator comprises the negative side of the generator 10, the leads 20, 15, 35 and 114, relay contacts CCR2, leads 111 and 115, the contacts RI3 of the reverse current relay, a lead 131, the potential coil GRPC, a temperature compensating resistor 132, and a lead 133 which connects with the positive side of the generator at the point 32 of the main generator circuit. Thus upon operation of the generator and closing of the contact RI3 the coil GRPC will be energized by the potential of the generator 10.

To permit ready starting of the engine 11, however, and to permit the engine-generator to come up to speed before a full load is applied thereon an unloading resistor ULR is connected in parallel with the resistor 132 for a predetermined period of time and provides for limiting the generated voltage to a subnormal value during this period of time. The circuit for the unloading resistor ULR is controlled by the control circuit relay CCR and by the automatic timer relay STR which also predetermines the time that the unloading resistor will be connected in the control circuit of the generator. This circuit comprises a lead 136 which connects to a point 137 intermediate the coil GRPC and one side of the resistor 132, the normally open contacts CCR3 of the control circuit relay CCR, lead 137a, the unloading resistor ULR, leads 138 and 37, the contacts STR1 of relay STR, and thence through leads 38, 39, 22 and 29, contact RI1 which is closed when the generator is operating, coil RISC, fuse 27 and the point 32 which connects with the lead 133 that connects with the other side of the resistor 132. During the starting of the engine 11 both the control circuit relay CCR and the timer relay STR are energized to close their normally open contacts CCR3 and STR1, respectively, and thus the circuit is completed for connecting the unloading resistor in parallel with the resistor 132 and limiting the generator voltage. After approximately three minutes' time following the initial cranking of the engine 11, however, the contacts STR1 of relay STR open to open the circuit to unloading resistor ULR and full load is applied to the engine-generator. The normally open contacts CCR3 of the control circuit relay CCR prevent a current from flowing through the resistors 132 and ULR during the time that the generator 10 is idle and the automatic timer is operating.

Upon driving of the generator 10, furthermore, and the supplying of a current through its main generator connections the coil of the low current relay L1 becomes energized and effects opening of its normally closed contacts LI1.

Operation of Control System Upon Failure of Engine to Start

As described above, the engine 11 normally starts to drive the generator 10 upon closing of the contacts of switch 105 of the automatic timer and operation of the generator as a motor to effect cranking of the engine. A means is provided, however, to prevent excessive drain on the battery 13 in the event that the engine does not start. This means comprises an intermittent switch IS which intermittently interrupts the cranking operation of the generator 10, and a cranking limit switch CLS which automatically stops the cranking operation if the engine fails to start within a predetermined peroid of time and which must be manually reset in order to effect further operation of the system.

The intermittent switch IS is of the thermally responsive self energizing and deenergizing type and comprises a normally closed set of contacts IS1 which are connected in the lead 111 above the control circuit relay coil CCR (see Fig. 2) and a heater element ISC which is also connected to the lead 111 between the contacts IS1 and the coil CCR by the lead 145. The circuit for the heater element ISC is completed through the leads 146 and 147, the contacts LI1 of the low current relay LI which are normally closed as shown when the generator is at standstill or operating as a motor, and a lead 148 which connects with the lead 39. The thermal switch IS is so regulated in accordance with the present invention that the contacts IS1 thereof will remain closed and effect energization of the heating element ISC for approximately 15 seconds following closing of the timer switch 105 and will then open under action of the heating element and remain open for approximately 45 seconds while the heating element cools. Upon opening of the contacts IS1 the circuit for the control relay CCR and for the starting contactor SC is interrupted even though the timer switch 105 is still closed and thus the cranking operation of the generator 10 is stopped. Upon closing of the contacts IS1, however, following cooling of the switch IS the cranking of the engine 11 is again started and the cycle of operation thus described is repeated with each cycle of operation of the switch IS. Should the engine-generator start, however, the low current relay LI will be energized to open its normally closed contact LI1 and the energizing circuit for the heating coil ISC is thus interrupted to maintain its contacts IS1 closed and the control circuit relay CCR energized.

The cranking limit switch CLS prevents this cyclic operation of the control circuit from operating indefinitely if the engine 11 still continues not to start. The switch CLS is also of the thermally responsive type and comprises a heating element CLSC and normally closed contacts CLS1. The heating element CLSC of the

switch CLS is connected in parallel with the intermittent switch IS and thus upon closing of the timer switch 105 a circuit is completed through the element CLSC by way of lead 111, a lead 150 which connects with the lead 111 at a point 151 above the contacts IS1 of the intermittent switch IS, the heater element CLSC, leads 146 and 147, the normally closed contacts LI1 of the low current relay, and the lead 148 which connects with the lead 39. The contacts CLS1 of the cranking limit switch are connected in the control circuit lead 39 ahead of any of the circuits for the control circuit and thus entirely disconnect the control circuit when the heater CLSC operates to open the contacts CLS1. The cranking limit switch CLS, however, is set to operate at a much slower time than the intermittent switch IS, after approximately a three minute interval of time for example, and thus the intermittent switch will go through several cycles of operation during one operation of the switch CLS. Upon continued failure of the engine 11 to start, however, and after the period of time for which the switch CLS is set it will open its contacts and will disconnect the control circuit from the battery 13 until such time as it is manually reset as described above. It will be evident, however, that if the engine-generator starts within the time for which the switch CLS is set the energizing circuit for the heating element CLSC will be broken by opening of the contacts LI1 of the low current relay and the contacts CLS1 will remain closed to maintain the control system energized.

Termination of Operation of the Engine-Generator

Upon the battery 13 becoming fully charged and upon the load current supplied through the leads 14 and 15 decreasing to a predetermined minimum the low current relay LI will become deenergized and operate to close its contacts LI1. The heater ISC of the intermittent switch IS will thus be again energized across the lines 35 and 39 and after approximately 15 seconds will open its contacts IS1. The opening of the contacts IS1 causes the control circuit relay CCR to become deenergized and the consequent operation of its several sets of contacts. Thus the magneto circuit contacts CCR1 are closed while the holding-circuit contacts CCR2 and the contacts CCR3 of the unloading resistor circuit are opened. Upon closing of the contacts CCR1 the magneto 120 of engine 11 is grounded through ground 121 and the engine terminates its operation. The thermal switch IS, however, prevents stopping of the engine 11 because of some momentary decrease in the current of the generator 10.

When the generator 10 ceases to operate there will be a tendency for current to flow from the battery 13 through the main circuit of the generator. The reverse current relay RI operates, however, to open the main contact RI1 upon even the slightest current flowing from the battery to the generator, and thus opens the main generator circuit and prevents any further flow of current to the generator. At the same time the back contacts RI2 and RI3 of the reverse current relay close and open, respectively, to condition the starting contactor SC for the next starting operation of the automatic timer and to open the circuit of the regulator potential coil GRPC.

Manual Control and Operation of Auxiliary Control Devices

Although the system as thus far described is fully automatic in operation a means is also provided for effecting a continuous manual control over the operation of the system. This control comprises manually operable push-button type of start and stop switches mounted both on the control panel for the engine-generator and within convenient reach of the operator of the system. As most clearly shown in Fig. 2 a normally closed stop switch 155, which may be a panel switch, is connected in the lead 114 of the circuit for the control circuit relay CCR and may be opened at any time to open this circuit and stop the engine 11 by closing the grounding circuit 120—121 of the engine magneto 120. In like manner a normally closed stop switch 156, which may be under constant control of the operator, is interposed in the lead 111 above the point 151 (see Fig. 2) and provides for stopping the engine-generator at any time. Connected across the leads 112 and 113 in parallel with the contacts of the automatic timer switch 105 and the holding contacts CCR2 of the control circuit relay CCR are two normally open manual starting switches 157 and 158, one of which may be a panel switch and the other a switch under control of the operator, and which when closed will effect energization of the control circuit relay CCR and the starting contactor SC irrespective of the condition of switch 105. Thus the engine-generator 10—11 can be manually started at any time, always under the control, however, of the intermittent switch IS and the cranking limiting switch CLS.

Means are also provided to automatically terminate operation of the engine-generator in the event that the engine 11 tips over, or in case the oil pressure of the engine gets too low or the heat of the engine becomes too high. Each of these latter two means, furthermore, operates through the intermittent switch IS so that a temporary disturbance in the engine will not cause it to stop operation.

The means for discontinuing operation of the engine in the event that it tips over, such for example as where the engine-generator is mounted on a bus, trolley coach, railway car or the like and the vehicle itself turns over, comprises a tip-over switch TOS that is connected by leads 161 and 162 across the leads 122 and 123 of the engine magneto grounding circuit and in parallel with the contacts CCR1 of the control-circuit relay. The switch TOS which is diagrammatically illustrated in the drawings comprises a pair of spaced contacts TOS1 and TOS2 and a movable contact TOS3 adapted to engage either of the contacts TOS1 and TOS2 but normally maintained by gravity or the like in an open circuit position between the spaced contacts as shown. The switch TOS is mounted on the engine 11 and thus as long as the engine remains substantially upright the switch remains open and the magneto grounding circuit is under control of the contacts CCR1. Should the engine tilt beyond a predetermined degree to either side, however, such as upon tipping over, the movable contact TOS3 will move into contacting engagement with one of the contacts TOS1 and TOS2 and will ground the magneto 120 through the ground 121, thus stopping the engine.

The means for stopping the engine 11 in case the oil pressure of the engine drops below a predetermined safe value comprises a pressure responsive switch OPS which may be of any desired

or standard type having contacts OPS1 that are normally closed when the pressure is less than the predetermined value and are opened when the pressure is above this value, and which is attached to the engine to be subjected to the oil pressure therein. As best shown in Fig. 2 the contacts OPS1 of the switch OPS are connected across the leads 146 and 39 of the control circuit and in parallel with the contacts LI1 of the low current relay by a pair of leads 165 and 166. Thus the contacts OPS1 of the oil pressure switch OPS provide for completing a circuit for both the heater element ISC of the intermittent switch IS and the heater element CLSC of the cranking limit switch CLS around the contacts LI1 of the low current relay LI. Upon starting and normal operation of the engine, however, the switch contacts OPS1 will open in response to the engine oil pressure and the circuit for the heaters ISC and CLSC through these contacts will be interrupted. Should the oil pressure of the engine drop below a predetermined value, however, the contacts OPS1 will again close, or will remain closed if the pressure does not exceed this value upon starting of the engine, and will complete an energizing circuit for the heaters ISC and CLSC, although the contacts LI1 of the low current relay may at the time be open. Thus under normal operation of the system and upon failure of the oil pressure the switch IS will open its contacts IS1 after approximately 15 seconds to effect deenergization of the control circuit relay CCR and stopping of the engine 11. If for any reason, however, the switch IS fails to operate the switch CLS will operate after a further period of time to disconnect the entire control system and thus stop the engine. It will be evident, furthermore, that although the contacts OPS1 establish a parallel circuit around the low current relay contacts LI1 during the starting of the engine-generator, both of these contacts will normally open upon starting of the engine and thus the operation of the system is not affected. Should either of these contacts close or remain closed, however, the engine 11 will be stopped under control of the switches IS and CLS.

As described above, a means is also provided for terminating operation of the engine 11 in the event that the temperature thereof rises above a predetermined safe value. This means comprises a temperature responsive switch ETS which may also be of any desired or standard type having contacts ETS1 that are normally open when the temperature is below a predetermined value and are closed when the temperature rises above this value and which is also attached to the engine to be subjected to the temperature thereof. As is again best shown in Fig. 2 the contacts ETS1 of the engine temperature switch ETS are connected across the leads 165 and 166 of the oil pressure switch OPS and in parallel with the contacts OPS1 thereof by the leads 170 and 171. Thus if the engine temperature rises above a predetermined value the switch contacts ETS1 will close and will complete an energizing circuit for the switches IS and CLS to effect stopping of the engine 11 in the manner hereinabove described for the low current relay contacts LI1 and the oil pressure switch contacts OPS1.

Operation of the Generator Regulator

The generator regulator GR is of a standard type and is only diagrammatically shown in the drawings. It comprises a current coil GRSC and a potential coil GRPC which as described above are connected in series with the generator 10 and across the generator, respectively, when the generator is operating to supply a current to the battery 13 or a load connected to the leads 14—15, and which provide for maintaining the current and voltage within predetermined limits upon change in speed of the engine 11 and change in load on the generator 10. The regulation is obtained by the carbon pile resistor CPR which controls the current flowing through the shunt field ShF of the generator. The pressure exerted on the carbon pile resistor CPR and thus the resistance thereof is varied by suitable levers, springs, plungers and the like not shown in the diagrammatic illustration, which are operated by the coils GRSC and GRPC. If either the current or the voltage tends to vary from the values for which the regulator is set the coils GRSC and GRPC will operate to increase or decrease the pressure on the carbon pile resistor and thereby control the generator to insure reliable battery and generator protection and adequate load supply.

Thus the voltage coil GRPC of the regulator which limits the voltage of the generator 10 prevents overcharging of the battery 13 since the current to the battery will taper down to a low value as the battery becomes fully charged, while the series current coil GRSC which is set to hold the current at the rated output of the generator prevents overloading of the generator either by a connected load or by charging an exhausted battery while at the same time making full output of the generator available when desired. To provide for varying the current output of the generator, however, a plurality of shunt resistors 175 and 176 (see Fig. 1) are provided on the regulator and may be connected in parallel with the series current coil GRSC if desired. Also, as described above, a temperature compensating resistor 132 is connected in series with the potential coil GRPC to compensate for any changes in resistnace caused by changes in the temperature thereof.

Operation of the Reverse Current Relay

The reverse current relay RI is also of a standard type and is only diagrammatically shown in the drawings. It is of the closed magnetic circuit kind and in addition to the series current coil RISC above described it comprises a pair of series connected potential coils 180 and 181, a third potential coil 182, a main movable core 183, an auxiliary plunger 184, and a main and auxiliary armature 28 and 186, respectively. The current coil RISC and the potential coil 181 operate on the main core or plunger 183 while the potential coils 180 and 182 operate on the auxiliary plunger 184. The main armature 28 controls the main contacts RI1 and the auxiliary armature 186 controls the back contacts RI2 and RI3. When the relay is in the normally open condition shown in the drawings the contacts RI1 and RI3 are open while the contact RI2 is closed as described above.

The potential coil 182 is connected by the leads 190 and 191 across the contacts RI1 of the relay so as to be energized by the difference between battery voltage and the voltage of the generator. Thus when the generator 10 is not operating the coil 182 is subjected to the full voltage of the battery 13, and as the generator voltage builds up upon operation of the engine-generator the energizing voltage across the coil 182 decreases. The pull of the potential coil 182 on the auxiliary plunger 184 provides for locking the reverse current relay in the open condition. At the same

time the current from the battery which normally energizes this coil also serves to partially energize the shunt field ShF of the generator so as to assure that this field will always build up in the proper direction upon starting and operation of the engine-generator.

The potential coils 180 and 181 which are connected in series by the lead 194 are connected by the leads 195 and 196 across the generator 10 and are so arranged that the coil 181 which operates on the main core 183 tends to close the relay RI while the coil 180 operating on the auxiliary plunger 184 tends to replace the coil 182 and maintain the relay open as the generator voltage builds up and approaches the voltage of the battery. The potential coils 180, 181 and 182 are so designed as to maintain a proper balance for any battery voltage encountered in use and the gap between the main core 183 and the main armature 28 is so adjusted that the relay closes when the voltage of the generator 10 exceeds the voltage of the battery 13 by a predetermined amount, one half to one volt for example. Thus upon the voltage of the generator building up to a predetermined value the reverse current relay RI closes to close the main contacts RI1 and to open the back contacts RI2 while also closing the back contacts RI3. Since the operation of the relay depends upon the balancing action of the potential coils 180, 181 and 182 the effects of temperature changes in the coils cancel each other and temperature compensating resistors in series with the coils are unnecessary.

The series current coil RISC which is energized when the main contacts RI1 are closed provides for locking the reverse current relay in its closed condition when the generator 10 is supplying a current to the battery 13 or a connected load, and also serves to open the relay and the contacts RI1 when a current tends to flow from the battery to the generator. The current coil RISC is thus so arranged as to assist the action of the potential coil 181 on the main core 183 to maintain the relay RI closed so long as a load supplying current flows from the generator and to neutralize the action of the coil 181 to effect opening of the relay and the main contacts RI1 upon a current flowing from the battery 13 to the generator 10. To assure that the relay will open upon even a slight reverse current flowing from the battery to the generator a lead 198 is tapped into the potential coil 181 and is connected to a contact RI4 of the reverse current relay which is closed upon closing of the armature 28 and contacts RI1 of the relay to short out a portion of the windings of the coil 181. Thus the strength of the relay closing coil 181 is substantially decreased upon closing of the relay and the series current coil RISC will operate upon even a slight reverse current flowing therethrough to neutralize the action of the coil 181 and effect opening of the relay RI.

To adapt the relay for various currents the series current coil RISC is provided with a plurality of shunt resistors 200 and 201 (see Fig. 1) which may be connected in parallel with the coil, if desired, by a lead 202 and suitable contact terminals 203, 204 and 205. A pilot light PL is also connected across the generator 10 in parallel with the series connected coils 180 and 181 of the reverse current relay by the leads 208 and 209 and provides for indicating to the operator when the generator is operating to supply a voltage to the connected load.

Summary of Operation of the Engine-Generator Control System

From the above description it will be evident that with the control system of the engine-generator 10—11 in the condition shown in the drawings in which the engine-generator is inoperative the contacts FTR1 of the timer relay FTR are closed to complete an energizing circuit for the timer relay STR and the timer solenoid TS. The timer relay STR is thus energized and closes its normally open contacts STR1 which completes a circuit from the battery 13 through the relay FTR. After a predetermined time, approximately 5 seconds, in accordance with the present invention, the relatively slow opening relay FTR opens its contacts FTR1 and thus deenergizes both the relay STR and the timer solenoid coil TS. After a longer period of time, approximately three minutes in the present example, the deenergized and slower opening relay STR reopens its contacts to deenergize the relay FTR to cause its contacts FTR1 to again close and effect energization of the relay STR and the timer solenoid TS. Thus the relays FTR and STR will be alternately energized and deenergized in a predetermined time cycle and the timer solenoid TS will also be energized in a predetermined time cycle upon energization of the relay STR.

Upon each energization of the timer solenoid TS, however, the ratchet wheel 52 and the cam 91 is advanced through one step of operation and thus after a predetermined number of impulses of the timer corresponding to a predetermined time period the contacts of switch 105 will be closed to initiate starting of the engine-generator. Upon closing of the timer switch contacts 105 both the control circuit relay CCR and the starting contactor SC will close to condition the magneto 120 for starting of the engine 11 and to connect the generator 10 to the battery for operation as a motor to effect cranking of the engine 11. If the engine fails to start after a predetermined cranking thereof the self energizing and deenergizing intermittent switch IS operates to intermittently interrupt the cranking operation. If the engine still fails to start after a further predetermined time and predetermined operations of the intermittent switch IS the cranking limit switch CLS operates to entirely stop the operation of the engine-generator and the control circuit therefor, and must be manually reset to effect further operation of the system. During operation of the intermittent switch IS, however, and before operation of the cranking limit switch CLS the contacts of the timer switch 105 remain closed to continue cranking of the engine under operation of the intermittent switch IS.

The energization of the starting contactor SC effects the closing of the starting contactor SC1 and the operation of the generator 10 as a motor to effect cranking and starting of the engine 11. Upon normal conditions the engine starts and upon the generator voltage reaching one half to one volt above the voltage of the battery the reverse current relay operates to open the circuit to the starting contactor and to connect the generator to its load circuit. During starting of the engine-generator, however, the unloading resistor ULR is connected in the circuit of the generator regulator GR to limit the load on the generator to a sub-normal value to assist the engine-generator in coming up to speed and is then

disconnected after a predetermined time by the contacts STR1 of the timer relay STR.

Since the voltage of the generator 10 is limited by the generator regulator GR the charging current of the battery 13 automatically decreases as the battery becomes fully charged, and when the total connected load current including that required to recharge the battery 13 is less than a predetermined minimum value the low current relay LI operates to terminate operation of the engine-generator 10—11. The contacts LI1 of the low current relay LI, however, operate through the energizing circuit of the intermittent switch IS and thus delay termination of the operation of the engine-generator for a predetermined time to avoid stopping of the engine-generator upon a temporary change in load.

As will be evident from the above description one side of the relay STR of the timer means is normally connected to one side of the battery 13 while the other side of this relay connects to a point 47 which is connected to the other side of the battery through the generator 10. Thus so long as the generator 10 is inoperative the relay STR will be energized across the battery 13. Upon operation of the engine-generator, however, the polarity of the point 47 will change to thus effect deenergization of the timer relay STR and stopping of the operation of the timing means. When the engine-generator terminates operation, however, the polarity of the point 47 will again change and thus the timer means will again be connected across the battery 13 to resume operation and to predetermine the next operation of the engine-generator.

It will thus be apparent that upon each closing of the timer switch 105 an energizing circuit for starting the engine-generator 10—11 will be established and under normal conditions of operation the engine-generator will start and operate to supply a recharging current to the battery 13 and a load current to any load connected to the leads 14 and 15. When the load current supplied by the generator 10 is less than a predetermined minimum value, however, the engine-generator will automatically stop operation. After a predetermined period of time following termination of operation of the engine-generator the timer switch will again close its contacts 105 and the engine-generator 10—11 will again become operative irrespective of the voltage of the battery or the degree of use thereof.

If during operation of the engine-generator 10—11, however, the engine tips over, or the engine fails to maintain a predetermined minimum oil pressure, or the temperature of the engine becomes too high the operation of the engine-generator will automatically terminate. Such termination of the operation of the engine-generator will be immediate upon the engine tipping over but will be delayed through operation of the intermittent switch IS upon failure of the engine oil pressure or high engine temperature to prevent stoppage of the engine upon temporary disturbances therein. The self energizing and deenergizing intermittent switch IS thus not only provides for interrupting the cranking of the engine 11 but also provides for delaying termination of operation of the engine when the generator 10 supplies a predetermined minimum load current, or the oil pressure of the engine gets too low or the engine temperature becomes too high.

While the form of apparatus herein described constitutes a preferred form of the invention, the invention is not limited to this precise form of apparatus and contemplates such changes and modifications as fall within the scope of the appended claims.

I claim:

1. In a control system of the character described for an engine-generator, an internal combustion engine, a generator mechanically coupled with said internal combustion engine and adapted to supply a curernt during operation of the engine-generator, means for effecting starting of said internal combustion engine, means for terminating operation of said engine-generator when a predetermined minimum current is supplied by said generator, and means for effecting operation of said starting means upon the passage of a predetermined time interval following each termination of operation of the engine-generator.

2. In a control system of the character described for an engine-generator, an internal combustion engine, a generator mechanically coupled with said internal combustion engine and adapted to supply a current during operation of the engine-generator, a battery connected to be recharged by said generator, means for starting and terminating operation of said engine-generator, and means including timer means energized by said battery for effecting starting of said engine-generator upon the passage of a predetermined time interval following each termination of operation thereof.

3. In a control system of the character described for an engine-generator, an internal combustion engine, a generator mechanically coupled with said internal combustion engine and adapted to supply a current during operation of the engine-generator, a battery connected to be recharged by said generator, means for starting and terminating operation of said engine-generator, an impulse timer energized by said battery, and means for effecting starting of said engine-generator after a predetermined number of timer impulses following each termination of operation of the engine-generator.

4. In a control system of the character described for an engine-generator, an internal combustion engine, a generator mechanically coupled with said internal combustion engine and adapted to supply a current during operation of the engine-generator, means for starting and terminating operation of said engine-generator, means including a timer means for effecting starting of said engine-generator after a predetermined time interval following each termination of operation thereof, and means for terminating operation of said timer means upon starting of said engine-generator.

5. In a control system of the character described for an engine-generator, an internal combustion engine, a generator mechanically coupled with said internal combustion engine and adapted to supply a current during operation of the engine-generator, means including a timer means for starting said engine-generator, and means for initiating operation of said timer means upon stopping of said engine-generator.

6. In a control system of the character described for an engine-generator, an internal combustion engine, a generator mechanically coupled with said internal combustion engine and adapted to supply a current during operation of the engine-generator, means including a timer means for starting said engine-generator, means for terminating operation of the engine-generator, and means for effecting operation of said timer

means when said engine-generator is stopped and for stopping operation of the timer means when the engine-generator is operating.

7. In a control system of the character described for an engine-generator, an internal combustion engine, a generator mechanically coupled with said internal combustion engine and adapted to supply a current during operation of the engine-generator, a battery connected to be recharged by said generator, circuit means normally connected to said battery for controlling operation of said engine-generator, electric timer means for initiating starting of the engine-generator, means connected in said circuit means for terminating operation of said engine-generator, and means for connecting said electric timer means to said circuit means to effect energization and operation of the timer means from said battery when said engine-generator is stopped and to stop operation of the timer means when the engine-generator is operating.

8. In a control system of the character described for an engine-generator, an internal combustion engine, a generator mechanically coupled with said internal combustion engine and adapted to supply a current during operation of the engine-generator, a battery connected to be recharged by said generator, circuit means normally connected to said potential source for controlling operation of said engine-generator, electric timer means for initiating starting of the engine-generator, means connected in said circuit means for terminating operation of said engine-generator, and means including a connection to a portion of said circuit means which changes polarity upon operation of said engine-generator for connecting said electric timer means to said battery to effect energization and operation of the timer means when the engine-generator is stopped and to stop operation of the timer means when the engine-generator is operating.

9. In a control system of the character described for an engine-generator, an internal combustion engine, a generator mechanically coupled with said internal combustion engine and adapted to supply a current during operation of the engine-generator, a battery connected to be recharged by said generator, electric timer means providing for initiating starting of said engine-generator, a closed connection between one side of said generator and one side of said battery, the other side of said generator and the other side of said battery being normally disconnected when the engine-generator is stopped, a connection from said other side of the generator to said electric timer means, and a normally closed connection between said timer means and said other side of the potential source to thereby provide for energizing the timer means from said potential source when the engine-generator is stopped and to effect deenergization of the timer means upon operation of the engine-generator.

10. In a control system of the character described for an engine-generator, an internal combustion engine, a generator mechanically coupled with said internal combustion engine and adapted to supply a current during operation of the engine-generator, means for starting and terminating operation of said engine-generator, means for effecting starting of said engine-generator after a predetermined time interval following each termination of operation thereof, and means for limiting the load on said generator to a sub-normal value for a predetermined period of time during starting of said engine-generator.

11. In a control system of the character described for an engine-generator, an internal combustion engine, a generator mechanically coupled with said internal combustion engine and adapted to supply a current during operation of the engine-generator, means for starting and terminating operation of said engine-generator, timer means for effecting starting of said engine-generator after a predetermined time interval following each termination of operation thereof, and means controlled by said timer means for limiting the load on said generator to a sub-normal value for a predetermined period of time during starting of said engine-generator.

12. In a control system of the character described for an engine-generator, an internal combustion engine, a generator mechanically coupled with said internal combustion engine and adapted to supply a current during operation of the engine-generator, regulator means for regulating the load and voltage of said generator, means for effecting starting of said engine-generator, and means including a resistance connected in parallel with a portion of said regulator means for limiting the load on said generator to a sub-normal value for a predetermined period of time during starting of said engine-generator.

13. In a control system of the character described for an engine-generator, an internal combusition engine, a generator mechanically coupled with said internal combustion engine and adapted to supply a current during operation of the engine-generator, a battery connected to be recharged by said generator, means including a control circuit for effecting operation of said generator as a motor under action of said potential source to effect starting of said engine, means connected in said control circuit for discontinuing operation of said generator as a motor and for connecting said generator to said battery upon starting of said engine, means for terminating operation of said engine-generator when a predetermined minimum current is supplied by said generator, and means included in said control circuit for effecting operation of said generator as a motor and starting of said engine after a predetermined period of time following termination of each preceding operation of said engine-generator.

14. In a control system of the character described for an engine-generator, an internal combustion engine, a generator mechanically coupled with said internal combustion engine and adapted to supply a current during operation of the engine-generator, a battery connected to be recharged by said generator, a slow opening relay having its contacts normally closed and adapted to open said contacts upon energization of said relay, a slow opening relay having its contacts normally open and adapted to reopen said contacts upon deenergization of said relay, an energizing circuit for said second relay including said battery and the normally closed contacts of said first relay, an energizing circuit for said first relay including said battery and the normally open contacts of said second relay whereby each relay will be intermittently energized and deenergized in a predetermined time cycle, impulse operated means adapted to be actuated upon each energization of one of said relays, switch means adapted to be operated after a predetermined number of impulses of said impulse operated means, and means including said

switch means for effecting starting of said engine-generator.

15. In a control system of the character described for an engine-generator, an internal combustion engine, a generator mechanically coupled with said internal combustion engine and adapted to supply a current during operation of the engine-generator, a battery connected to be recharged by said generator, a control circuit for said engine-generator normally connected to said battery, a slow opening relay having its contacts normally closed and adapted to open said contacts upon energization of said relay, a slow opening relay having its contacts normally open and adapted to reopen said contacts upon deenergization of said relay, an energizing circuit for said second relay including the normally closed contacts of said first relay and a portion of said control circuit that is subjected to a change in polarity upon starting of said engine-generator, an energizing circuit for said first relay including the normally open contacts of said second relay and said battery, said energizing circuits providing for intermittently energizing and deenergizing each of said relays in a predetermined time cycle when said engine-generator is stopped and for deenergizing both of said relays when the engine-generator is operating, impulse operated means adapted to be actuated upon each energization of one of said relays, switch means adapted to be operated after a predetermined number of impulses of said impulse operated means, and means including said switch means for effecting starting of said engine-generator.

16. In a control system of the character described for an engine-generator, an internal combustion engine, a generator mechanically coupled with said internal combustion engine and adapted to supply a current during operation of the engine-generator, a battery connected to be recharged by said generator, a slow opening relay having its contacts normally closed and adapted to open said contacts upon energization of said relay, a slow opening relay having its contacts normally open and adapted to reopen said contacts upon deenergization of said relay, an energizing circuit for said second relay including said battery and the normally closed contacts of said first relay, an energizing circuit for said first relay including said battery and the normally open contacts of said second relay whereby each relay will be intermittently energized and deenergized in a predetermined time cycle, impulse operated means adapted to be actuated upon each energization of one of said relays, switch means adapted to be operated after a predetermined number of impulses of said impulse operated means, a control circuit including said switch means for initiating starting of said engine-generator, and means controlled by one of said relays for limiting the load on said generator to a sub-normal value for a predetermined time period during starting of said engine-generator.

17. In a control system of the character described, an internal combustion engine, means including a control circuit and a source of electric potential for cranking said internal combustion engine to effect starting thereof, timing means connected in said control circuit for initiating said cranking operation of the engine, and means connected in said control circuit for intermittently interrupting said cranking operation.

18. In a control system of the character described, an internal combustion engine, means including a control circuit and a source of electric potential for cranking said internal combustion engine to effect starting thereof, timing means connected in said control circuit and operable from said source of potential for initiating said cranking operation of the engine, and time delay means connected in said control circuit for energization by said source of potential for intermittently interrupting said cranking operation.

19. In a control system of the character described for an engine-generator, a battery, an internal combustion engine, a generator mechanically coupled with said internal combustion engine for supplying a recharging current to said battery, means including a control circuit and said battery for operating said generator as a motor to effect cranking of said internal combustion engine, electric timer means operable from said battery for initiating said cranking operation, and means operable from said battery for intermittently interrupting the cranking of said internal combustion engine.

20. In a control system of the character described for an engine-generator, an internal combustion engine, a generator mechanically coupled with said engine and adapted to supply a current during operation of the engine-generator, a circuit for controlling the operation of said engine-generator, means connected in said control circuit for terminating operation of the engine-generator when a predetermined minimum current is supplied by said generator, and means for delaying termination of the operation of said engine-generator for a predetermined time period following generation of said predetermined minimum current to prevent stopping of the engine-generator upon a temporary change in the load.

21. In a control system of the character described for an engine-generator, an internal combustion engine, a generator mechanically coupled with said engine and adapted to supply a current during operation of the engine-generator, a circuit for controlling the operation of said engine-generator, means connected in said control circuit for terminating operation of the engine-generator when a predetermined minimum current is supplied by said generator, means for delaying termination of the operation of said engine-generator for a predetermined time period following generation of said predetermined minimum current to prevent stopping of the engine-generator upon a temporary change in load, and means connected in said control circuit for effecting immediate stopping of said engine-generator upon tipping over of said internal combustion engine.

22. In a control system of the character described for an engine-generator, an internal combustion engine, a generator mechanically coupled with said engine and adapted to supply a current during operation of the engine-generator, a circuit for controlling the operation of said engine-generator, means connected in said control circuit for terminating operation of the engine-generator when a predetermined minimum current is supplied by said generator, means for delaying termination of the operation of said engine-generator for a predetermined time period following generation of said predetermined minimum current to prevent stopping of the engine-generator upon a temporary change in load, and manually controlled means connected in said control circuit for effecting immediate stopping of said engine-generator.

23. In a control circuit of the character described, an internal combustion engine, means including a control circuit and a source of electrical potential for cranking said internal combustion engine to effect starting thereof, timing means connected in said control circuit for initiating said cranking operation of the engine, means connected in said control circuit for interrupting said cranking operation upon failure of said engine to start, and manually controlled means in said control circuit for effecting cranking of said engine through said interrupting means.

24. In a control circuit of the character described, an internal combustion engine, means including a control circuit and a source of electrical potential for cranking said internal combustion engine to effect starting thereof, time delay means connected in said control circuit for interrupting said cranking operation upon failure of said engine to start, and means including said time delay means for automatically terminating operation of said engine.

25. In a control circuit of the character described for an engine-generator, an internal combustion engine, a generator mechanically coupled with said internal combustion engine and adapted to supply a current during operation of the engine-generator, means including a control circuit and a source of electrical potential for cranking said internal combustion engine to effect starting thereof, time delay means connected in said control circuit for interrupting said cranking operation upon failure of said engine to start, means including said time delay means for terminating operation of said engine-generator when a predetermined minimum current is supplied by said generator, means including said time delay means for terminating operation of said engine-generator upon failure of said engine to maintain a predetermined minimum oil pressure therein, and means including said time delay means for terminating operation of said engine-generator upon the temperature of said engine rising above a predetermined value.

LEE W. MELCHER.