Oct. 23, 1951 B. H. SHORT ET AL 2,572,397

ENGINE STARTER CONTROL SYSTEM

Filed Oct. 30, 1946 2 SHEETS—SHEET 1

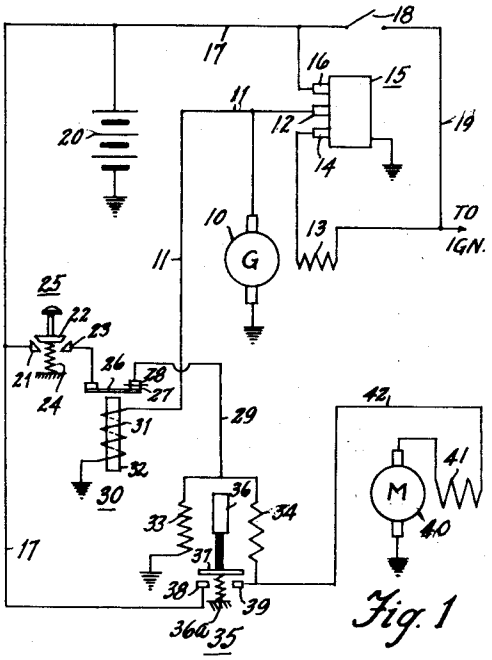


Fig. 1

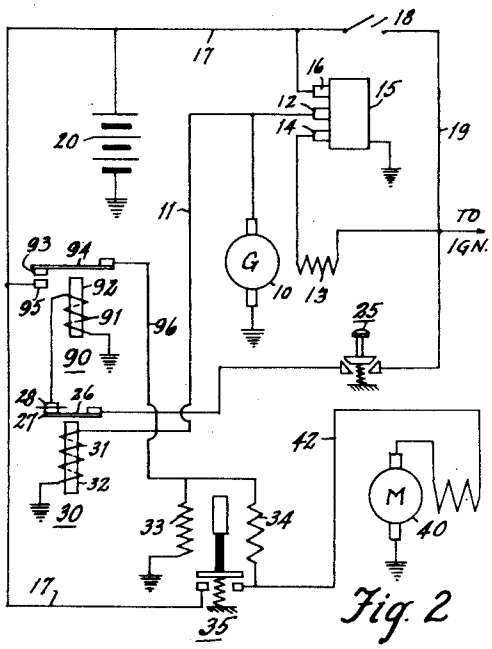


Fig. 2

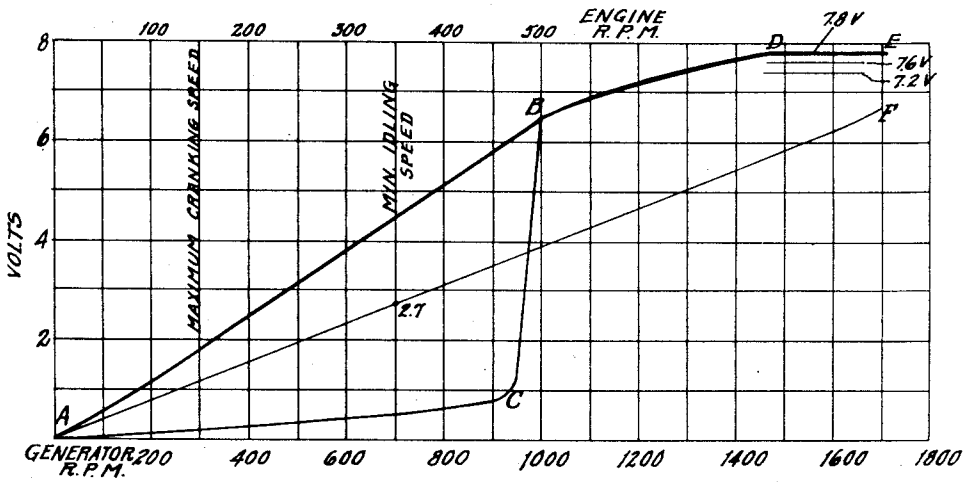


Fig. 3

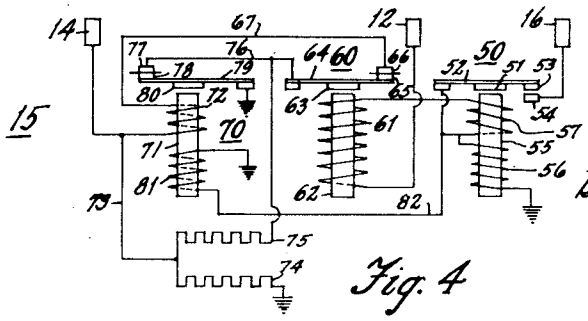


Fig. 4

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ENGINE STARTER CONTROL SYSTEM

Filed Oct. 30, 1946 2 SHEETS—SHEET 2

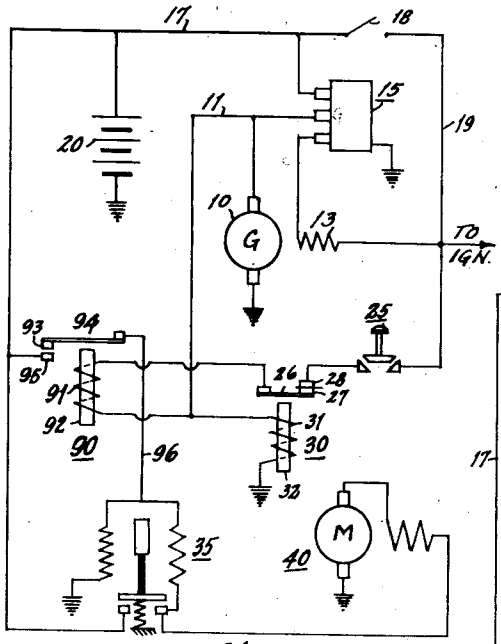


Fig. 5

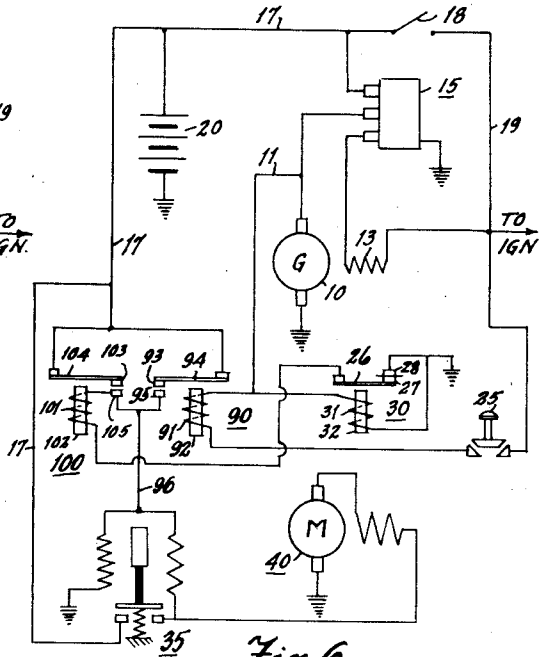


Fig. 6

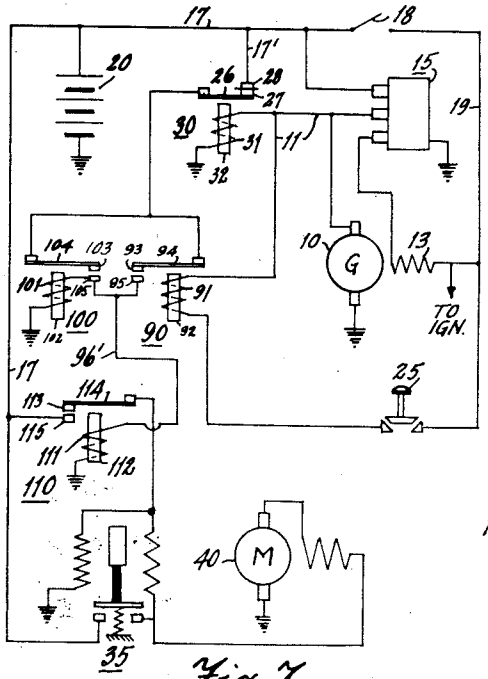


Fig. 7

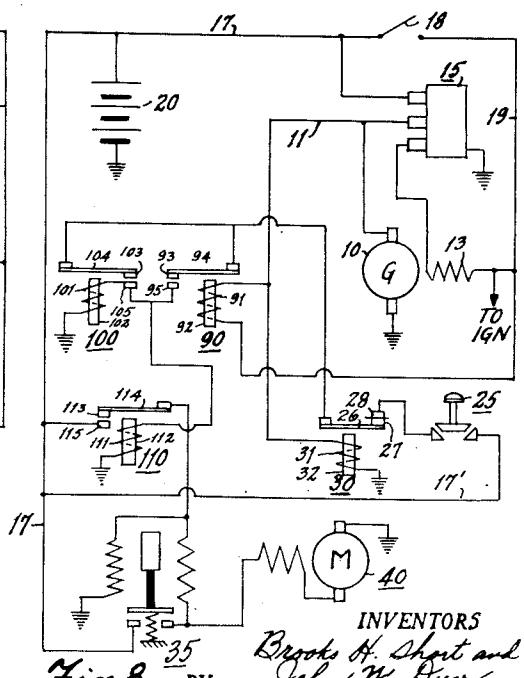


Fig. 8

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ENGINE STARTER CONTROL SYSTEM

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1 Claim. (Cl. 290—36)

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This invention relates to engine starter control systems and aims to prevent use of the starter while the engine is running.

The object of the invention is accomplished by the use of a relay switch which at the maximum cranking speed maintains its contacts closed so that the starting motor can be operated in the usual manner by a starter switch. The electromagnet of the relay is responsive to the voltage of the generator which, below the cut-in speed when the cutout relay is open, is separately excited from the battery and is self-excited when the cutout relay closes. By such arrangement, the relay switch will separate its contacts in the starter control circuit at a speed above the maximum cranking speed of the engine and well below the cut-in speed so that the cranking is discontinued automatically before engine speed increases very much above the maximum cranking speed after the engine becomes self-operative. This is of advantage to the engine starter because the starting motor pinion is automatically disengaged from the engine flywheel gear at a speed considerably lower than the minimum sustaining speed of the engine. Another advantage is that the relay switch holds its contacts open until the engine speed falls to practically zero. This result is obtained because below engine cut-in speed, the generator changes from self-exciting status to separately-exciting status whereby its voltage output below cut-in speed is very much higher than it would be if the generator were self-excited below cut-in speed. Consequently, the relay holds its contacts open until generator speed practically is zero.

Further objects and advantages of the present invention will be apparent from the following description, reference being had to the accompanying drawings, wherein preferred embodiments of the present invention are clearly shown.

In the drawings:

Figs. 1, 2, 5, 6, 7 and 8 are wiring diagrams embodying the invention.

Fig. 3 is a chart for illustrating the operation of the generator when self-excited and when separately-excited.

Fig. 4 is a wiring diagram showing, in detail, one of the units of the other diagrams.

Referring to Fig. 1, a generator 10 driven by the engine has one terminal grounded and the other connected with a wire 11 connected with a terminal 12 of a regulator and cutout relay unit 15. One end of the field winding 13 of the generator is connected with terminal 14 of unit 15 and the other end is connected with a wire 19. Terminal 16 of unit 15 is connected with

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wire 17. A switch 18 connects wire 17 with wire 19 connected with the ignition apparatus as well as field coil 13.

Wire 17 is connected with battery 20 which is grounded and with a contact 21 of a starter switch 25 having a contact 22 for connecting contact 21 with a contact 23. A spring 24 urges contact 22 away from contacts 21 and 23. Contact 23 is connected with blade 26 of a relay 30. The blade 26 carries a contact 27 normally engaging a contact 28 connected with a wire 29. Relay 30 includes a core 32 surrounded by magnet coil 31 which is grounded at one end and which is connected at the other end with wire 11.

Wire 29 is connected with a fine wire magnet coil 33 and with a coarse wire magnet coil 34 of a solenoid 35 having an armature 36 insulatingly supporting a contact 37 for connecting a contact 38 connected with wire 17 with a contact 39. A spring 36a normally maintains contact 37 out of engagement with contacts 38 and 39. A starting motor 40 which is grounded has its field coil 41 connected by wire 42 with contact 39 connected with coil 34.

Unit 15, shown in detail in Fig. 4, is a combined voltage regulator, current regulator and cutout relay. The cutout relay 50 comprises an armature 51 attached to a spring blade 52 carrying a contact 53 adapted to engage a contact 54 connected with the terminal 16. The relay includes a core 55 carrying a fine winding 56 which is grounded and carrying a coarse winding 57 connected at one end to blade 52.

Current regulator 60 has a coil 61 connected at one end with winding 57 of relay 50 and at the other end with the terminal 12. Coil 61 surrounds a core 62 facing an armature 63 carried by a spring blade 64 carrying a contact 65 normally engaging a contact 66 connected with a wire 67.

The voltage regulator 70 comprises a core 71 surrounded by a coil 72 connected at one end with wire 67 and at the other end with terminal 14 and with a wire 73 connected with a resistance 74 which is grounded and with a resistance 75 which is connected with wire 76 which connects blade 64 of regulator 60 with a contact 77 normally engaged by a contact 78 carried by a spring blade 79 which is grounded and which carries an armature 80 facing the core 71. Core 71 is surrounded also by a coil 81 which is grounded at one end and which is connected at the other end with wire 82 connected with the cutout relay windings 59 and 56 and with the spring blade 52.

The operation of the system, shown in Fig. 1, is as follows:

To start the engine the ignition is turned on by closing switch 18. Current then flows from the battery 20 to the ignition apparatus through wire 17, switch 18, and wire 19 and also to the generator field 13 and out through the terminal 14 and thence to ground through coil 72 of regulator 70, wire 67, contacts 66, 65 of the regulator 60, blade 64, wire 76, contacts 77, 78 of regulator 70 and armature 79 which is grounded. The starter switch 25 is closed, thereby connecting solenoid coil 33 with the battery through wire 29, contacts 27, 28 of relay 30, blade 26, starter switch contacts 23, 22, 21. The solenoid coil 34 is connected with the battery through this same circuit and also through the starting motor 40. The excitation of coils 33 and 34 causes solenoid armature 36 to be attracted in order to cause contact 37 to engage contacts 38 and 39 whereupon the coil 34 is short-circuited and the solenoid remains in circuit closing status solely by the energization of the coil 33. The starting motor 40 is directly connected with the battery through wire 42, contacts 39, 37, 38 and wire 17. During the cranking of the engine, the generator operates as a separately-excited generator and produces an output represented by the line A—B (Fig. 3). The battery supplies current to the field at 5.5 volts, for example, if the battery is fairly well charged. Below maximum cranking speed, about 300 R. P. M. generator speed or 150 R. P. M. engine speed, the maximum voltage output of the generator is below two volts which is insufficient to cause relay 30 to separate its contacts 27 and 28. Relay 30 is constructed so as to separate its contacts at 2.25 volts and to close its contacts when the voltage impressed on its coil is 1.2 volts. Therefore, when the engine becomes self-operative, the generator output when self-excited, will reach 2.25 volts at about 360 R. P. M. generator speed or 180 R. P. M. engine speed. Therefore, long before the speed of the engine can rise to cut-in speed or even minimum idling speed which is about 700 generator speed and 350 engine speed, the circuit of the solenoid 35 and of the motor 40 will have been interrupted.

If the generator were not separately-excited below the generator cut-in speed, 1000 R. P. M., for example, the voltage generated would be that represented by the curve A—C—B which drops off rapidly to a low value as generator speed decreases. Therefore, it is necessary to provide for separate excitation of the generator, otherwise the relay 30 would close its contacts while the engine is idling, thereby making it possible to operate the starter by closing the starter switch 25 while the engine is in operation. Even with a relatively weak battery supplying the separately-excited field at 3 volts for example, the relay 30 would remain open at idling speed because the voltage then would be about 2.7 volts.

Coil 56 of cutout relay 50 is in circuit with coil 57 of the relay and coil 61 of the current regulator 60 and terminal 12. When the generator attains speed of about 1000 R. P. M., the excitation of the coil 56 is sufficient to cause the attraction of armature 51 of the cutout relay to close its contacts 53 and 54, thereby causing current to flow from the generator to terminal 12, coil 61 of current regulator 60 and coil 57 of relay 50. Relay 50 remains closed until generator voltage falls sufficiently below battery voltage to cause reversal current in coil 57 to buck the magnetism produced by coil 56 whereupon the relay 50 opens to prevent discharge of the battery.

While relay 50 is closed, the generator voltage for various speeds above 1000 R. P. M. is indicated by the line B—D—E. The maximum voltage, represented by line D—E, is limited by the voltage regulator 70 which operates in the usual manner to separate contact 78 from contact 77, thereby causing the reducion of field excitation by resistances 75 and 74. The regulator will maintain the voltage between 7.2 and 7.8, for example, when cold and between 7.2 and 7.6 when hot. Current output is limited by current regulator 60 which on exceeding a predetermined current flow through its winding 61, causes contact 65 to separate from contact 66 whereby resistance 74 becomes effective to reduce field excitation.

In the circuit shown in Fig. 2, the starter switch 25 and the relay 30 do not control the starting motor solenoid 35 directly but indirectly through the relay 90 having a magnet coil 91 surrounding a core 92 and grounded at one end and connected at the other end with contact 28 of relay 30. When coil 91 is energized by the closing of switch 25 while the contacts of relay 30 are closed, a contact 93 on a spring blade 94 is caused to engage a contact 95, thereby connecting the battery through wire 17, contacts 95, 93, blade 94 and a wire 96 with the windings 33 and 34 of the solenoid 35. By this arrangement the contacts of the switch 25 and the contacts of the relay 30 do not carry the current which is required to operate the solenoid switch 35.

In the circuit diagram shown in Fig. 5, the closing of the starter switch 25 to crank the engine places the coil 91 of the relay 90 and the coil 31 of the relay 30 in series with the battery 20 after the ignition switch 18 is closed. At a generator speed slightly above maximum cranking speed, the excitation of coil 31 of relay 30 increases sufficiently to cause the opening of contacts 27 and 28, which results in deenergization of coil 91 of relay 90 and cranking by the motor 40 ceases. In case relay 30 fails to open, relay 90 will open when the generator cuts in because coil 91 of relay 90 is then short-circuited. The relays 30 and 90 of Fig. 5 provide double protection.

In the form shown in Fig. 6, the circuit between the battery wire 17 and the wire 96 includes parallel circuits, one being the contacts 93 and 95 of relay 90, the other being the contacts 103 and 105 of a relay 100 having a core 102 surrounded by a coil 101 which is connected with contact 105 and with blade 26 of relay 30. The closing of ignition switch 18 and starter switch 25 causes current to flow from the battery to the coil 91 of relay 90 and coil 31 of relay 30; but, during cranking, the contacts 27 and 28 of relay 30 remain closed while contacts 93 and 95 of relay 90 are closed.

In addition to causing the solenoid 35 to complete the starting motor circuit, the closing of contacts 93 and 95 energizes coil 101 of relay 100, causing contacts 103 and 105 to close. The starting motor load on the battery and the rising generator output reduces voltage sufficiently to release the contacts of relay 90 almost immediately, the circut being maintained through contacts 103 and 105 which will remain closed until the contacts 27 and 28 are opened. Once released, relay 100 cannot be energized until the contacts of relay 90 are closed. Relay 90 will not close until engine rotation has practically stopped. Therefore, if the engine makes a false start due to misfire or other causes, the relay 30 is thereby opened, the solenoid cannot be reenergized un-

til the engine approaches standstill and the voltage between battery and the generator armature becomes sufficient to operate relay **90**. When a normal start is made, relay **30** opens, deenergizing coil **101**, and relay **100** opens, causing cranking to cease. At generator cut-in, the generator armature is connected to the battery in the regulator **15** and the closing of the starting switch **25** short-circuits the coil **91** of relay **90** preventing contacts **93** and **95** from closing. In case the engine has been running and coasts down, the engine starter cannot be operated by pressing the button **25** because battery excitation of coil **31**, acting cumulatively with generator excitation, would cause relay **30** to open its contacts so that coil **101** of relay **100** would not be excited. Coil **91** of relay **90** would not be excited because excitation of coil **91** by the battery would be bucked by excitation produced by the generator when separately excited.

Relay **30** is known as a "high" relay because it operates at relatively high voltage differential between the generator armature terminal and ground. It opens its contacts when the voltage of the generator (self-excited) is slightly above that attained at maximum cranking speed. It closes its contacts at a much lower voltage attained at a very low generator speed at which the corresponding engine speed is below that which will sustain engine operation.

Relay **90** of Fig. 6 is known as a "low" relay because it operates at a relatively low voltage differential between the generator armature terminal and ground. It is adjusted to close at no-load battery voltage or slightly less and to release when battery voltage falls, due to loading of the battery when the starting motor **40** receives current from the battery.

Relay **100** of Fig. 6 is known as the "hold-in" relay. The closing of relay **90** causes coil **101** of relay **100** to be energized. The closing of contacts **103**, **105** of relay **100** causes coil **101** to remain energized although the contacts **93**, **95** of relay **90** may open. However, once the hold-in relay **100** opens, it cannot be reenergized until battery voltage exceeds generator voltage by an amount sufficient to cause the "low" relay **90** to close its contacts.

The circuit shown in Fig. 7 is like that of Fig. 6 with the exception that the wire **96** is replaced by **96'** which leads to the coil **111** of a relay **110** surrounding a core **112** to effect downward movement of spring blade **114** carrying a contact **113** engageable with a contact **115**. When these contacts are closed, the circuit is completed from wire **17** to the windings of the solenoid **35**.

The circuit shown in Fig. 8 is similar to the circuit shown in Fig. 7. The contacts of relay switches **90** and **100** are in parallel and both together in series with the electromagnet of relay switch **110** and with the contacts of relay **30** and with switch **25**. The closing of switch **18** connects the magnet coil **91** of relay **90** with the battery through the magnet coil **31** of relay **30**. Relay **90** closes its contacts. The closing of switch **25** causes current to flow from the battery through the closed contacts of relays **30** and **90** to the magnet coils of relays **100** and **110**. Relay **100** closes and maintains energization of its magnet coil while relay **90** opens during cranking. The separation of the contacts of relay **30** causes the opening of relays **100** and **110** and the solenoid switch **35**. The relay **30** will not close again until the speed of the engine, having once started, falls far below minimum idling

speed. In case of a false start, relay **30** will not close again until flywheel rotation has practically ceased.

The control circuits shown in Figs. 6, 7 and 8 prevent, on false starts, the starting motor pinion from crashing into mesh with the engine flywheel gear when the engine falters. In a false start, the engine usually fires once or more, opening the high relay **30**, then stops, due to misfire or something else. It is possible that the high relay **30** might close at this time and a cycle started where the pinion was forced to engage and disengage rapidly until the engine became self-operative. However, experience shows that, when the high relay **30** has once opened, it will remain open until cessation of rotation of the engine flywheel.

While the embodiments of the present invention as herein disclosed, constitute preferred forms, it is to be understood that other forms might be adopted, all coming within the scope of the claim which follows.

What is claimed is as follows:

An engine starter control system comprising a generator having a field winding, a storage battery charged by the generator, a device for cranking the engine, a switch for connecting the generator field winding with the battery in order that the generator will be initially separately excited, a cutout relay for connecting the generator with the battery when generator voltage attains a certain value whereby the generator becomes self-exciting at cut-in speed, said relay disconnecting the generator from the battery when generator voltage falls below battery voltage in consequence of which the generator returns to separately excited status, means for causing operation of the engine cranking device, and apparatus for controlling said means and including a normally open relay switch, the closing of which causes the cranking device to operate, said relay switch having an electromagnet for closing it, and including means for connecting said electromagnet with the battery comprising a normally open, manually closed switch and a normally closed relay switch having an electromagnet sensitive to generator voltage for opening it, said second relay switch being so constructed as to remain closed at a generator speed corresponding to maximum cranking speed and to open above maximum cranking speed and below cut-in speed and to reclose at a speed substantially below engine minimum idling speed, and including a short-circuit of the first mentioned electromagnet provided by the closing of the cutout relay whereby cranking ceases at least when the cutout relay closes regardless of failure of the second relay switch to open.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,565,854	Hasselbring	Dec. 15, 1925
1,606,532	Hasselbring	Nov. 9, 1926
1,631,747	Maby	June 7, 1927
1,828,514	Spivey	Oct. 20, 1931
1,941,433	Doman	Dec. 26, 1933
2,131,026	Doman	Sept. 27, 1938
2,131,403	Doehr et al.	Sept. 27, 1938