United States Patent [19]

Wagner

[11] **3,744,467**

[45] **July 10, 1973**

[54] **STARTER MOTOR CIRCUIT WITH FAST RESET MEANS**

[75] Inventor: **Harold H. Wagner**, Peoria, Ill.

[73] Assignee: **Caterpillar Tractor Co.**, Peoria, Ill.

[22] Filed: **Oct. 13, 1971**

[21] Appl. No.: **188,969**

[52] **U.S. Cl.** ..... **123/179 BG**, 123/179 BG

[51] **Int. Cl.** **F02n 17/00**

[58] **Field of Search** ..... 123/179 B, 179 BG

[56] **References Cited**

UNITED STATES PATENTS

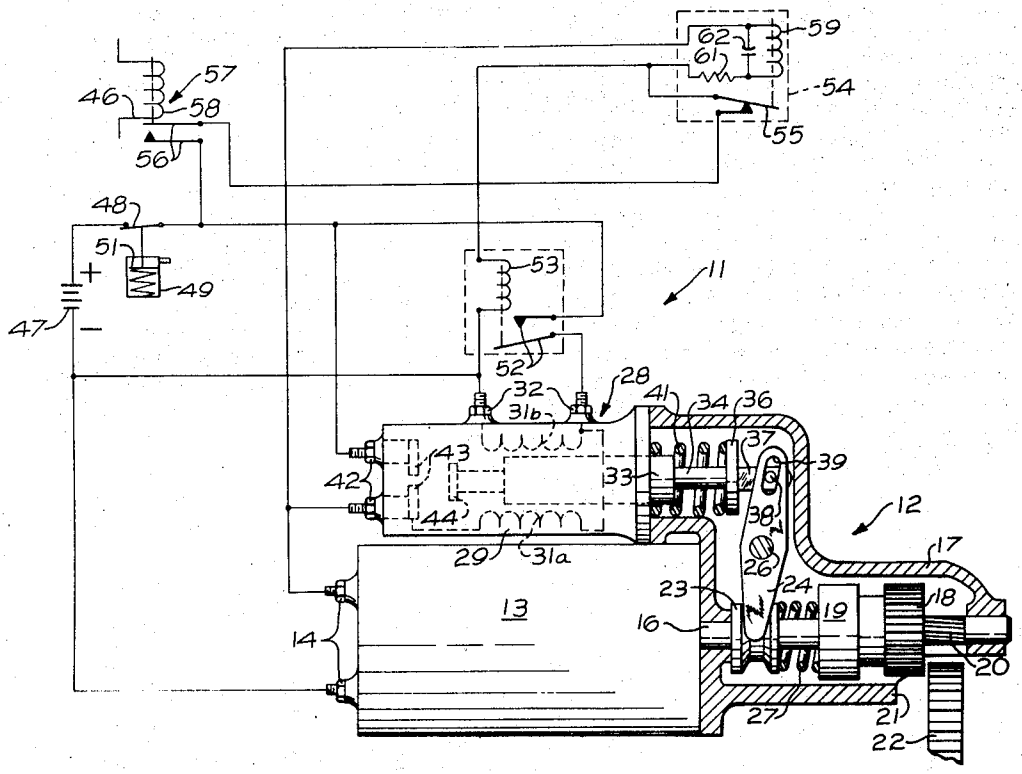
2,991,370	7/1961	Sutton	123/179 B
2,988,079	6/1961	Voigt	123/179
3,259,753	7/1966	McWhirter	290/38
3,071,125	1/1963	Leaver	123/179
3,443,557	5/1969	Herbert	123/179
3,415,999	12/1968	Noury	290/38

Primary Examiner—Laurence M. Goodridge
Assistant Examiner—Ronald B. Cox
Attorney—Donald J. McRae and Fryer, Tjensvold, Feix, Phillips & Lempio

[57] **ABSTRACT**

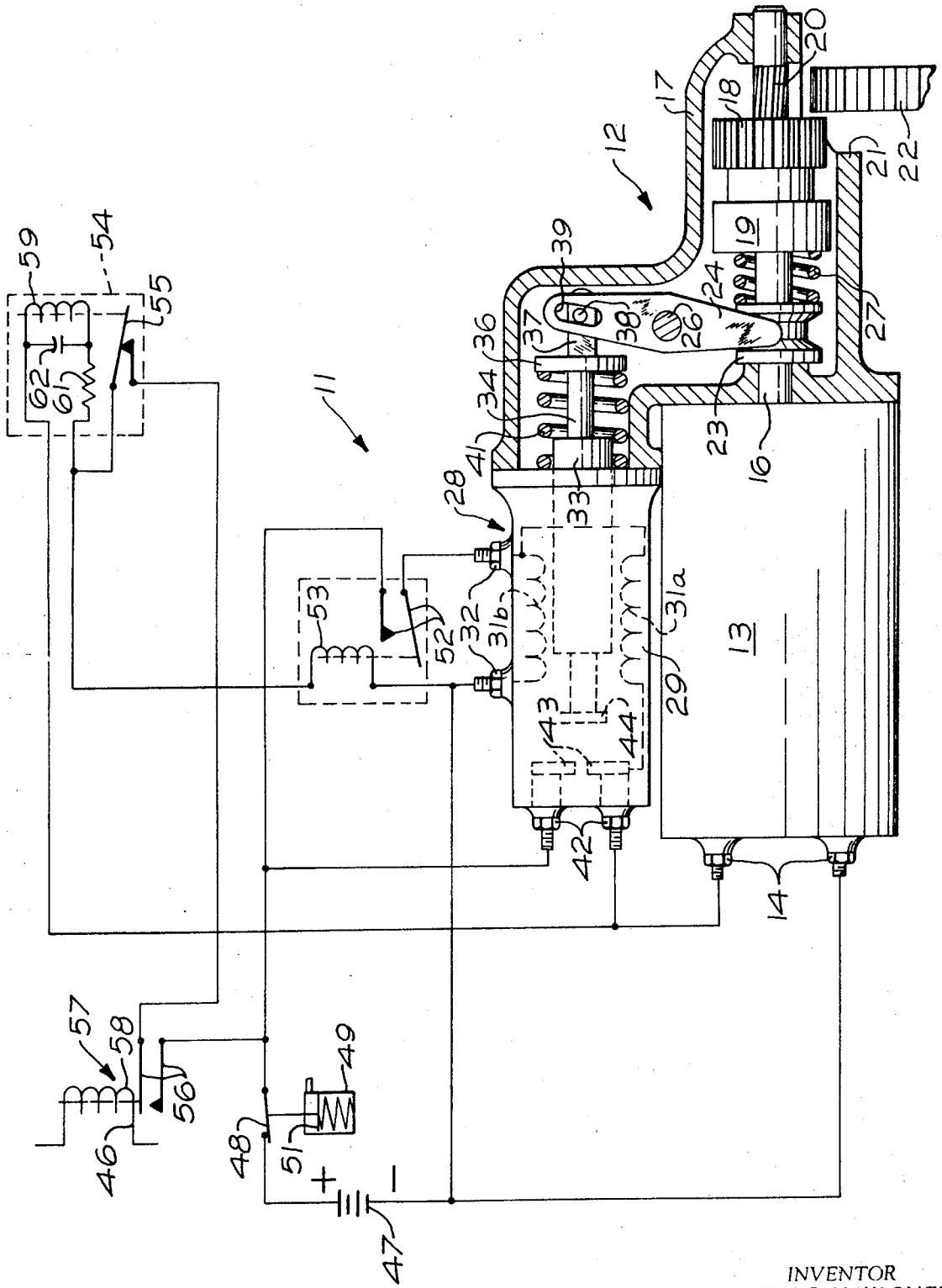
A control circuit for the starter motor of an engine has rapid acting and reliable means for automatically reattempting starting in the event that the pinion gear of the starter motor fails to engage the driven gear of the engine due to tooth abutment or other causes. A time delay relay periodically reopens the pinion gear shifting solenoid circuits until such time as the pinion gear is engaged at which point the time delay means is inactivated while the engine is being cranked. The quick precise response of the circuit is of particular value in connection with emergency motor-generator installations designed to start automatically in response to an electrical power failure and which do not have an operator in attendance to actuate a starter motor.

2 Claims, 1 Drawing Figure



PATENTED JUL 10 1973

3,744,467



INVENTOR
HAROLD H. WAGNER

BY
Fryer, Tjensvold, Feix, Phillips & Lempio
ATTORNEYS

STARTER MOTOR CIRCUIT WITH FAST RESET MEANS

BACKGROUND OF THE INVENTION

This invention relates to electrical starter motors for cranking internal combustion engines and more particularly to control circuits for energizing starter motors.

Electrical starter motors for internal combustion engines or the like customarily have a pinion gear which is shifted into engagement with a gear of the engine for cranking purposes and which is disengaged after the engine has started. Shifting of the pinion gear into engagement is accomplished by electrically energizing a pinion solenoid which is itself energized through a starting relay. In the absence of corrective measures, an attempt to engage the pinion gear in this manner may fail because of a condition termed a butt engagement. This is a condition where the teeth of the pinion gear and of the engine gear do not have the right relative angular positions to engage. Instead, one end of the teeth of one gear abut the ends of the teeth of the other.

Various means have been employed to reduce the occurrence of butt engagements which, aside from failing to start the engine, can have various undesired effects such as accelerated gear wear and overheating of solenoids or other circuit components. One such technique consists of beveling the adjacent ends of the teeth on the two gears and others involve imparting a slight rotation to the pinion gear as it is advanced towards the engine gear. None of these means are fully effective to prevent butt engagements. Tests of one commonly used starter motor system produced a butt engagement for approximately every thirty attempted starts.

Although it is an annoyance, such an occurrence does not cause an overly severe problem in instances where an operator is controlling the starter such as in an automotive vehicle. Starter systems generally have means for indexing the pinion gear each time the system is actuated and if a butt engagement occurs it is evident to the operator who then releases the starter button or the like momentarily and reattempts starting of the engine. In certain systems, a butt engagement can be a more serious situation in that an operator is not present to momentarily deactivate the starter circuit. Starter motors are often employed, for example, in standby power systems designed to start up automatically in response to failure of electrical utility power. In certain situations, such as in hospitals for example, starting up of the standby power system must be both extremely reliable and extremely rapid. Accordingly such systems require means for detecting a butt engagement and for momentarily deenergizing the pinion solenoid to initiate repeated attempts at pinion gear engagement until the engine is being cranked. The circuits heretofore used for this purpose have been undesirably slow and irregular with respect to response time. One commonly used system, for example employs a thermostatic switch through which the pinion shifting solenoid current passes. The switch is heated by the heavy current until a bi-metalic element distorts to open the switch. This process usually takes several seconds and another several seconds are required for the switch to cool and reclose to initiate a second attempt at engagement of the pinion gear. This is not only an undesirably long time but the time interval varies considerably in response to different external conditions such as the initial temperature of the switch, degree of enclosure of the switch and other variables. The switch remains in the circuit and draws current while the starter motor is in the process of cranking the engine.

SUMMARY OF THE INVENTION

The present invention is a starter motor control circuit which very rapidly and consistently resets to reattempt pinion gear engagement until such time as the starter motor is cranking the engine. For this purpose a precision time delay relay having low current requirements momentarily interrupts the starting solenoid circuit a predetermined time after each energization, to reset the entire circuit, until such time as the pinion gear is engaged. At that point the time delay relay is in effect isolated from the circuit and does not receive current while the starter motor is cranking the engine.

Accordingly it is an object of this invention to decrease the average time required to start an engine with an electrical starter motor in response to start signals.

It is another object of this invention to provide means for resetting a starter motor circuit at periodic intervals until engagement of the starter motor pinion gear with an engine gear is completed which means is consistent with respect to timing of the resetting operation and which is inactivated when the starter motor is in the process of cranking the engine.

The invention, together with further objects and advantages thereof, will best be understood by reference to the following description of a preferred embodiment taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWING

The accompanying drawing is a partially broken out view of a typical starter motor and pinion solenoid therefor together with a control circuit according to the invention shown in diagramatic form.

DESCRIPTION OF A PREFERRED EMBODIMENT

Referring now to the drawing, the control circuit **11** of the present invention is adaptable to a starter motor assembly **12** which may be of conventional construction and which will therefore be herein described only to the extent necessary to understand the coaction of the control circuit therewith. Such a starter motor assembly **12** may include an electrical motor **13** having DC power terminals **14** and having an armature shaft **16** which rotates when power is applied to the terminals. Shaft **16** extends into a housing **17** containing an axially movable pinion gear **18** disposed coaxially with respect to the shaft and coupled thereto through an overrunning clutch **19** which is movable axially along the shaft with the pinion gear and through helical splines **20** which act to index the pinion gear during each axial movement. An opening **21** is provided in housing **17** to receive a portion of an engine gear **22** of the associated engine and which is cranked in order to start the engine. The gears **18** and **22** are positioned so that when pinion gear **18** together with overrunning clutch **19** are moved axially along shaft **16** toward motor **13** the two gears are disengaged while when the Pinion gear **18** and clutch are shifted away from motor **13** the two gears are brought into engagement. To provide for this axial motion of the pinion gear **18** and clutch **19**, a shifting clutch collar **23** is disposed on shaft **16** and is engaged by a shift lever **24** which is pivoted to housing **17** by a pin **26** whereby the lever may be pivoted to move the collar in the direction of engine

gear 22. A compression spring 27 is disposed coaxially with respect to shaft 16 between collar 23 and clutch 19 whereby such motion of the clutch collar acts to urge the pinion gear 18 into engagement with engine gear 22.

To operate shift lever 24, a pinion solenoid assembly 28 is disposed adjacent motor 13 and has a housing 29 containing pull-in solenoid coil 31a and hold-in solenoid coil 31b and has solenoid terminals 32 at the exterior surface of the housing. Although shown schematically in the drawing, both coils 31a and 31b encircle an axially movable core 33 which tends to be drawn into the coils by the magnetic field thereof when the coils are energized. A rod 34 extends axially from core 33 towards lever 24 and has a flange 36 and an extension 37 carrying a transverse pin 38 which is received in a slot 39 in lever 24 whereby axial movement of the core 33 pivots lever 24. A compression spring 41 is disposed coaxially around rod 34 between flange 36 and the adjacent end of solenoid housing 29 to hold the core 33 partially withdrawn from coils 31 when the coils are unenergized. At this position of core 33, collar 23 is adjacent motor 13 and thus pinion gear 18 is withdrawn from engagement with engine gear 22. Upon energization of coils 31 core 33 is drawn into the coils against the force of spring 41 and thus lever 24 is pivoted to urge collar 23 away from motor 13. Spring 27 transmits this motion of the collar 23 to overrunning clutch 19 and thus to pinion gear 18 which then attempts engagement with engine gear 22.

Two terminals 42 at one end of housing 29 each connect with a separate one of a pair of spaced apart contacts 43 within the housing. A movable contact 44 on the end of core 33 serves to bridge the contacts 43 and establish an electrical connection therebetween when core 33 has been fully drawn into coils 31. Through electrical connections to be hereinafter described, such closing of the circuit between contacts 43 de-energizes pull-in coil 31*a*, while energization of hold-in coil 31*b* continues, and energizes the motor 13 in order to crank engine gear 22. When the engine has been started, gear 22 begins to turn faster than pinion 18. The overrunning clutch 19 enables gear 22 to turn in this manner while the pinion 18 is still engaged without turning motor 13. After this occurs, hold-in coil 31*b* is deenergized by means to be hereinafter described enabling spring 41 to pivot lever 24 and draw the pinion 18 out of engagement with engine gear 22.

If a butt engagement occurs in an operator controlled system, the condition is quickly recognized and the operator then momentarily opens the starter circuit and then reattempts operation. As previously pointed out, in most starter motor assemblies 12, the overrunning clutch 19 and pinion gear 18 mechanism is arranged to index slightly about shaft 16 with each movement of collar 23 so that the pinion gear is turned a small amount and a butt engagement is less likely to reoccur upon the subsequent attempt.

Many systems which are controlled by an operator rely wholly on the operator to take the necessary steps to correct a butt engagement. It is more desirable that this not be left to the operator's judgment as operators may exhibit undesirable delay in recognizing the condition and undesirable delay in response time. In the case of systems where actuation of the starting system is performed automatically without the presence of an operator it is imperative that the control circuit itself be capable of promptly deenergizing the solenoid coils 31 momentarily to reinitiate an attempt at engagement in the event of a butt engagement.

Considering now the means by which the starter motor assembly 12 is controlled to achieve these purposes, the control circuit 11 of the embodiment depicted in the drawings is of a form adapted to respond automatically to an electrical power failure in electrical utility power conductor 46 by cranking an engine gear 22 which may, for example, be part of an engine driving a generator in a standby emergency electrical power system. It will be appreciated that the system is applicable to the starting of engines in other situations and to the starting of operator control systems as well although the speed and reliability of the circuit is less critical in connection with operator controlled engines.

Power for operating the starter motor assembly 12 is obtained from a battery 47 which in this example has a negative side connected to a negative one of the pinion solenoid terminals 32 and a negative one of the starter motor terminals 14. The positive terminal 14 of motor 13 is connected to one of the terminals 42 of solenoid assembly 28 while the other terminal 42 connects with the positive side of battery 47 through a normally closed switch 48. Thus when contacts 43 are bridged by contact 44 following energization of the solenoid 28, battery 47 is thereby connected across the starting motor terminals 14 and the starting motor cranks engine gear 22 through pinion gear 18. As the example of the invention being described is adapted for automatic operation, the normally closed switch 48 is provided to open the starter motor circuit once the associated engine is operating. For this purpose the switch 48 may be controlled by a fluid cylinder 49 having a piston 51 which operates the switch 48 and which is normally spring biased to a position at which the switch 48 is held closed. Cylinder 49 is coupled to a fluid system of the engine which becomes pressurized when the engine is operating such as the oil pump outlet. Thus when the engine is operating and oil pressure rises piston 51 is retracted to open switch 48 and thereby open the starter motor circuit. In an operator controlled system, switch 48 is not essential since the operator normally opens the circuit after the engine has started by releasing the starter switch.

To energize the pinion solenoid 28, the positive one of the terminals 32 is connected to the positive side of battery 47 through a normally open set of start relay contacts 52 and through the previously described normally closed switch 48. Contacts 52 are closed by energizing of a coil 53 which has one end connected to the negative side of battery 47 and has another end connected to the positive side of the battery through a set of normally closed relay contacts 55 of a time delay relay 54 and through an additional set of normally open relay contacts 56 of a power sensing relay 57 and then through previously described normally closed switch 48. Within housing 29, one end of both coils 31*a* and 31*b* connect with the positive one of terminals 32. The oposite end of pull-in coil 31*a* connects to the terminal 42 which is connected to motor terminal 14 while the opposite end of hold-in coil 31*b* connects to the negative one of terminals 32. Coil 31*a* has sufficiently high resistance that motor 13 is not operated by the current transmitted through the coil.

Accordingly, the solenoid assembly 28 is energized to commence operation of the starter motor assembly 12

upon closing of the power failure sensing relay contacts **56.** This energizes start relay coil **53** through time delay relay contacts **55** and thereby closes contacts **52** to apply battery power across terminals **32** and thereby energizes coils **31.** In the automatic system presently being described, the relay contacts **56,** which are closed to initiate starting of the engine are normally held open by a driver coil **58** of power failure sensing relay **57** which is series connected with conductor **46.** Thus as long as electrical power is being transmitted through conductor **46,** relay contacts **56** are held open. Upon a power failure in conductor **46** contacts **56** close to actuate the starter assembly **12** as described above. An operator controlled system for a vehicle or the like may be essentially similar except that conductor **46** and coil **58** are absent and contacts **56** are a normally open starter switch which is closed by the operator to initiate starting of the engine.

After closing of relay contacts **56** and the consequent energization of solenoid coils **31** as described above, pinion gear **18** is shifted axially towards engine gear **22.** Provided that gears **18** and **22** engage properly, contact **44** connects contacts **43** and the starter motor **13** is energized to turn the engine gear. This also de-energizes pull-in coil **31***a* as both ends of the coil are then connected to the positive side of battery **47.** Pull-in coil **31***a* is not needed to hold contact **44** against contacts **43** as the force of hold-in coil **31***b* is sufficient for this purpose.

Once the engine is started, cylinder **49** opens switch **48** to deenergize all elements of the starter assembly **12** and control circuit **11.** However, if a butt engagement occurs and pinion gear **18** fails to engage with engine gear **22** the elements of the circuit **11** as described to this point would not necessarily provide any corrective action and starting of the engine might be delayed indefinitely. To deenergize solenoid coil **31***b* and thereby initiate a repeated attempt at gear engagement, time delay relay contacts **55** are operated by a driver coil **59** of time delay relay **54.** One side of coil **59** connects with the positive terminal **42** of solenoid assembly **28** while the other side of the driver coil connects with battery positive through a resistor **61,** relay contacts **55,** relay contacts **56** and switch **48.** A capacitor **62** is connected across the ends of driver coil **59** to form an RC network in conjunction with resistor **61** whereby a time delay is introduced with respect to energization of the driver coil **59** upon the application of positive power thereto.

Owing to the time delay required for energization of driver coil **59,** time delay relay **54** does not initially affect operation of the starter circuit as described above except insofar as voltage for the start relay coil **53** is transmitted through contacts **55.** After a predetermined period of time determined by the constants of capacitor **62** and resistor **61,** coil **59** is energized sufficiently to open contacts **55** and thereby deenergize coil **53** of the start relay which in turn causes contacts **52** to open to deenergize the solenoid coils **31.** Spring **41** then restores the pinion gear **18** to the initial position in readiness for another attempt to engage with gear **22.** Since power for energizing coil **59** of time delay relay **54** is supplied through the contacts **55** of the same relay, the contacts **55** automatically reclose after being opened to initiate a second cycle of operation. Should a butt engagement reoccur, time delay relay **54** will again open to reset the circuit after the predetermined time delay period and this process will be repeated as long as is necessary.

In the above described circuit configuration, both sides of the driver coil **59** of time delay relay **54** are in effect coupled to a single circuit point at contacts **43** and **44** once the contact **44** has abutted contacts **43** to energize the starter motor **13.** Thus as soon as the starter motor is energized, which occurs only if the pinion gear **18** is engaged with engine gear **22,** time delay relay **54** is in effect inactivated and does not draw current nor interrupt operation of the starter system.

While the invention has been described with respect to a single preferred embodiment, it will be apparent that many variations are possible and it is not intended to limit the invention except as defined in the following claims.

What is claimed is:

1. In a starter system for cranking a gear of an engine to start said engine, the combination comprising:
- a source of electrical current,
- an electrical starter motor,
- a pinion gear coupled to said starter motor for rotation thereby, said pinion gear being shiftable into and out of driving engagement with said engine gear,
- electrically actuated means for shifting said pinion gear toward engagement with said engine gear,
- means for connecting said motor to said source of electrical current upon engagement of said pinion gear and engine gear,
- a set of electrical contacts which are normally closed,
- circuit means for connecting said source of electrical current to said means for shifting said pinion gear through said normally closed contacts to initiate operation of said starter system, and
- time delay means for momentarily opening said set of contacts a predetermined time after said means for shifting said pinion gear is connected to said source of electrical current, said time delay means having a first terminal connected to said source of electrical current through said set of normally closed contacts and having a second terminal connected to said source through said means for connecting said source to said motor in response to engagement of said pinion gears whereby said time delay means ceases to conduct electrical current when said starter motor is energized, wherein said set of normally closed contacts and said time delay means jointly constitute a time delay relay wherein said time delay means comprises an electrical coil disposed to open said normally closed contacts upon being energized and having a first end connected to said source of electrical current through a resistor and said normally closed contacts and having a second end connected to said source of electrical current through said means for connecting said source to said motor in response to engagement of said pinion gear and having a capacitance connected across said ends of said coil to define an RC network in conjunction with said resistor.

2. In a starter system for cranking a gear of an engine to start said engine, the combination comprising:
- a source of electrical current,
- an electrical starter motor,
- a pinion gear coupled to said starter motor for rotation thereby, said pinion gear being shiftable into

and out of driving engagement with said engine gear,

electrically actuated means for shifting said pinion gear toward engagement with said engine gear,

means for connecting said motor to said source of electrical current upon engagement of said pinion gear and engine gear,

a set of electrical contacts which are normally closed,

circuit means for connecting said source of electrical current to said means for shifting said pinion gear through said normally closed contacts to initiate operation of said starter system, and

time delay means for momentarily opening said set of contacts a predetermined time after said means for shifting said pinion gear is connected to said source of electrical current, said time delay means having a first terminal connected to said source of electrical current through said set of normally closed contacts and having a second terminal connected to said source through said means for connecting said source to said motor in response to engagement of said pinion gears whereby said time delay means ceases to conduct electrical current when said starter motor is energized, further comprising means for disconnecting said source of electrical current from said starter motor and from said electrically actuated means for shifting said pinion gear and from said time delay means in response to an operating condition of said motor.

* * * * *