March 21, 1933. A. S. KNAPP 1,902,646

AUTOMATIC STARTING SYSTEM FOR INTERNAL COMBUSTION ENGINES

Filed July 23, 1928 2 Sheets-Sheet 1

Fig. 1.

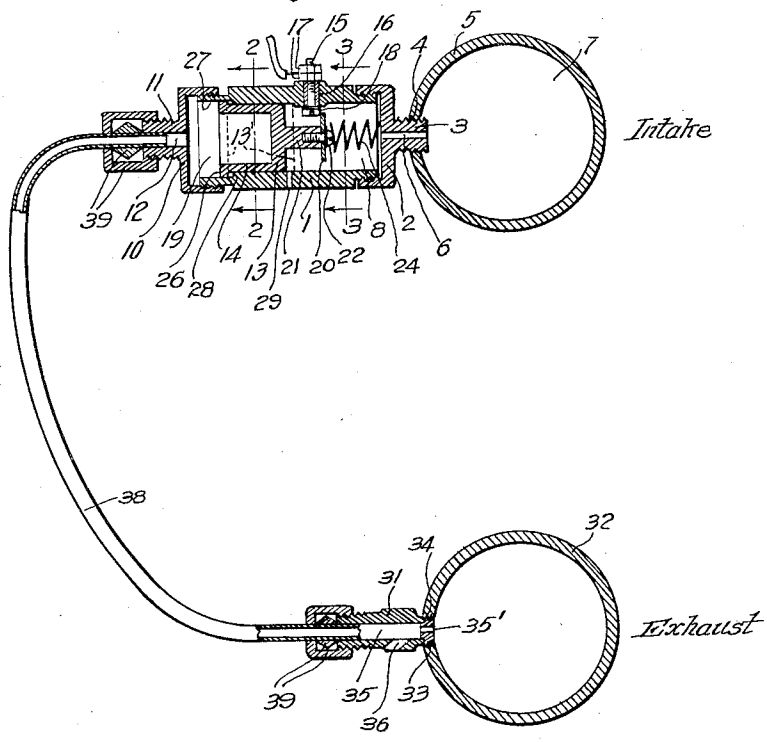


Fig. 2.

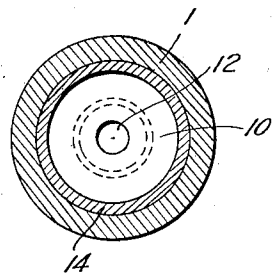
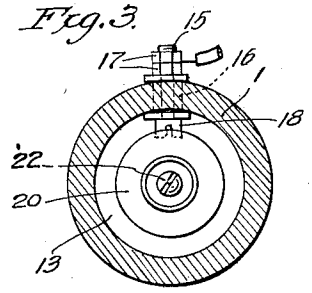


Fig. 3.



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AUTOMATIC STARTING SYSTEM FOR INTERNAL COMBUSTION ENGINES

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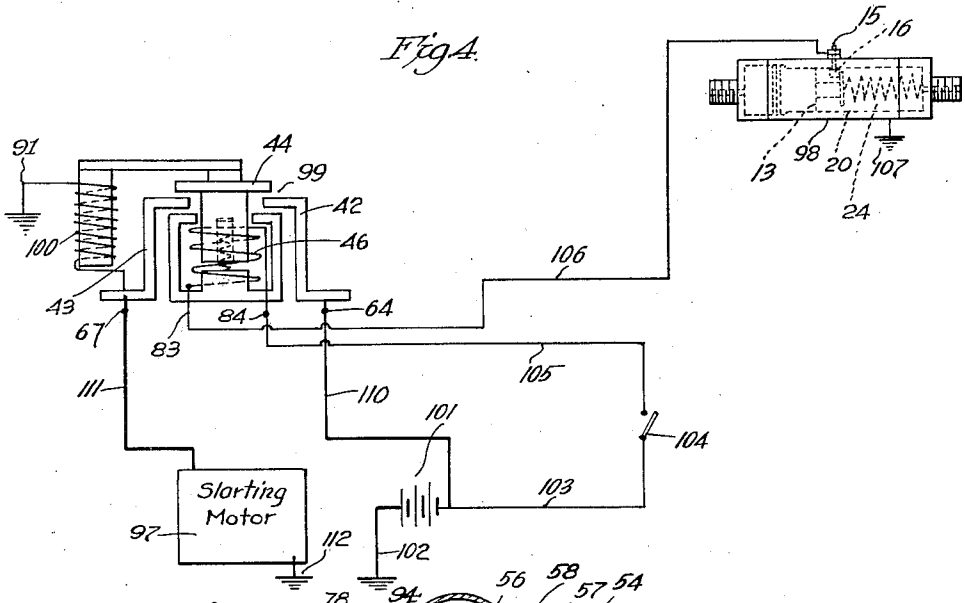
Fig.4.



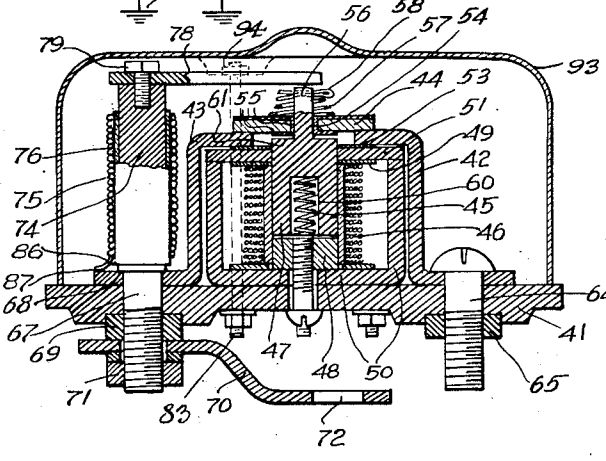
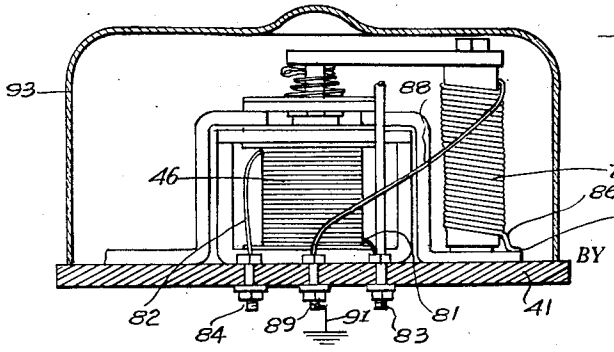


Fig.5.

Fig.6.



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1,902,646

UNITED STATES PATENT OFFICE

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AUTOMATIC STARTING SYSTEM FOR INTERNAL COMBUSTION ENGINES

Application filed July 23, 1928. Serial No. 294,834.

This invention relates to apparatus for starting internal combustion engines and particularly to an automatic control system for the electric starting motor with which many internal combustion engines, and particularly automobile engines, are usually provided.

Automobile engines as well as certain other internal combustion engines are commonly provided with an electric starting motor for turning over the engine until the same is in operation and firing regularly. Such starting motors are normally out of operative engagement with the engine shaft but are provided with suitable mechanism, such as a Bendix drive device, an over-running clutch, or other means, whereby the initial operation of the starting motor operates to place the same in operative engagement with the engine shaft and further operation thereof rotates such shaft and causes the engine to start, and whereby the increased speed of the engine shaft when the engine begins to fire automatically releases or breaks the operative connection of the starting motor to the engine.

The principal object of this invention is to provide, in conjunction with an internal combustion engine having such a self-engaging and self-releasing starting system, novel and advantageous means for automatically closing the circuit of the starting motor upon initial closing of a manually operated switch in a controlling circuit, or upon any interruption or "stalling" of the engine while such manually operated switch is closed, and for automatically opening the starting motor circuit as soon as the internal combustion engine has started or resumed its regular operation, that is, as soon as the first explosion of a charge in one of the cylinders thereof has been effected.

A particular object of the invention is to provide an automatic control system which is dependent for its operation upon the combined effects of the suction in the intake passage and the expansive effect of the gases in the exhaust passage, and particularly a device which operates initially to open or break the starting motor circuit under the control of the exhaust gases alone but which, having been once operated to such circuit opening condition, is held in this position by the combined action of the intake suction and the expansive effect of the exhaust gases.

Various means have already been proposed for automatic control of the starting motor circuit, and among other things it has been proposed to utilize the intake suction alone for this purpose, the operation in that case being to open the starting motor circuit as soon as the suction in the intake passage reaches a certain value. I have found, however, that such devices are unreliable for the reason that the initial turning over of the engine by the starter causes a suction to be developed in the intake passage whether the engine has started firing or not, so that the starting motor circuit is sometimes interrupted before the first explosion has taken place, and the engine consequently fails to start. Furthermore, under certain conditions of engine operation, as when running under heavy load with a wide throttle opening, the intake suction sometimes falls so low as to be ineffective in holding open any switching device of practical design. Other control devices have operated through the current generated by the generator which is operatively connected to the engine and is provided for the purpose of charging the storage battery which furnishes the current for ignition. These devices are also open to serious objection, however, as the generator frequently fails to generate sufficient current to cause the starting motor circuit to be held open, even when the engine is in operation, so that the starting motor continues in operation and runs down the battery. This, of course, would be particularly true in case of any trouble in the generator, causing it to fail to function properly. These objections are overcome, according to my invention, by making the opening of the starting motor circuit dependent primarily upon the expansive effect or energy of the exhaust gases, as I have found that such expansive effect of the exhaust gases changes very rapidly as soon as the first explosion of the engine occurs. The expansive effect of the exhaust gases so long as the engine is be-

ing turned over only by the starting motor is very slight, while the exhausting of the first exploded charge through said exhaust passage causes a very marked and rapid increase in such effect. The term "expansive effect" is intended to include all phenomena associated with the expansion of the exhaust gases through the exhaust passage, such as velocity and pressure.

A further advantage of this arrangement is that it is dependent only upon the functioning of the engine itself, and not upon the generator or other accessory thereof, and will, therefore, operate properly so long as the engine is able to operate properly.

However, under certain conditions of operation of an engine, such as an automobile engine, the exhaust pressure, or the expansive effect of the exhaust gases, may fall so low as to be ineffective in positively holding open any switching device of practical design, by the action of such pressure or expansive effect alone. Such a condition may exist, for example, when the engine is running under very light load, or "idling". At such time, however, due to the relatively small opening of the throttle, the intake suction is relatively high, and for this reason my invention also provides means whereby the holding open of the starting motor circuit, once it has been opened by the exhaust gases, is made dependent upon the combined effect of exhaust pressure and intake suction, that is, upon the difference in pressure in the exhaust passage and the intake passage. This combined utilization of exhaust pressure and intake suction is of particular advantage, for as just stated, when the conditions of operation are such that the exhaust pressure alone is too low to be effective for the desired purpose, the intake suction is sufficiently great to keep the switching device in circuit opening position, and on the other hand, when the intake suction alone is too low to be effective, as in the above mentioned case of running under heavy load, the exhaust pressure is sufficient for this purpose. By this arrangement, therefore, the circuit of the starting motor is positively kept open as long as the engine is firing, regardless of the operating conditions thereof, but is closed practically instantaneously when the engine stalls or stops firing while the manual control switch is closed, for in that case both the exhaust pressure and intake suction fall to practically zero almost instantaneously. However, for the reasons previously stated, I prefer to make the movement of the switching device from closed to open position dependent upon the pressure or expansive effect of the exhaust gases alone. The switching device of my invention, therefore, preferably comprises means whereby, when the switch is in closed position, the intake suction is substantially ineffective thereon, so that the initial opening of the switch must be accomplished by the exhaust pressure alone, and whereby, when said switch is opened, the intake suction is also caused to act thereon to assist in holding the same in that position.

A further object of the invention is to provide an automatic control device which may be quickly and conveniently applied to any internal combustion engine having a starting system of the type above described.

A further object of the invention is to provide means for preventing closure of the starting motor circuit in case the starting motor is still "spinning", as may occasionally result in case the engine fires only once or a few times and then stops firing, after having caused the starting motor to be released from operative engagement with the engine shaft in the usual manner of such devices. In this event, with this or any other form of automatic device for closing the starting motor circuit, said circuit would be automatically opened as soon as the engine started to fire, but the device would immediately tend to reestablish such circuit when the engine stopped firing. This might be disadvantageous in the event the starting motor were still spinning as above described as the drive mechanism might fail to function under such conditions to reestablish operative engagement with the engine shaft. This particular disadvantage is overcome according to my invention by providing means dependent upon the back electromotive force generated by the starting motor while so spinning, to hold open the starting motor circuit until the starting motor has stopped or has been reduced to a velocity low enough to permit proper functioning of the drive mechanism.

The accompanying drawings illustrate my invention and referring thereto:

Fig. 1 is a vertical section of the controlling switch device applied to the intake and exhaust manifolds of an internal combustion engine.

Figs. 2 and 3 are transverse sections on lines 2—2 and 3—3 respectively in Fig. 1.

Fig. 4 is a wiring diagram showing the manner in which the automatic circuit opening switch and the relay switch are connected in relation to the controlling circuit and the starting motor circuit.

Fig. 5 is a vertical section through a preferred form of relay switch device.

Fig. 6 is a side elevation of the relay switch taken in the opposite direction to Fig. 5, with the casing of said switch shown in section.

The primary controlling or circuit opening switch of my invention comprises, as shown in Figs. 1 to 3 inclusive, a cylindrical casing 1, upon one end of which is threadedly mounted suitable means, such as fitting 2, for mounting upon the intake manifold. For this purpose said fitting may be provided

with a threaded stem portion 3 adapted to screw into a threaded opening 4 in the intake manifold pipe 5 and provided with a duct or passage 6 extending therethrough so as to establish communication between the intake passage 7 and the suction chamber 8 inside the casing 1. A fitting 10 may also be threadedly mounted upon the other side of casing 1, said fitting being provided with a threaded stem 11 having a duct or passage 12 therethrough.

A piston or plunger 13 is mounted in the cylindrical casing 1, the cylindrical portion 14 of said plunger fitting the interior of said casing so as to slide freely therein while maintaining a reasonably gas tight fit. Said plunger divides the interior of casing 1 into the suction chamber 8 aforesaid and a pressure chamber 19. A contact member such as threaded pin 15 may be mounted upon the side wall of casing 1 between the plunger 13 and the suction duct 6, said pin being insulated from the casing by suitable insulation indicated at 16 and being provided outside the casing with means such as nuts 17 for connection of an electric wire or conductor thereto. The head 18 of said pin projects inside the casing and constitutes one contact element of the switch. The other contact element may comprise a disc or plate 20 secured to a projecting stem portion 21 of the plunger as by means of screw 22, said stem portion being of sufficiently small diameter to avoid contact thereof with contact element 18. A coiled compression spring 24 is provided between plunger 13 or contact member 20 and the inner face of fitting 2, so as to tend to force the contact element 20 into engagement with contact element 18 as shown in Fig. 1. Spring 24 may be held in proper position by engagement beneath the head of screw 22.

Plunger 13 is provided with a projecting flange or shoulder 26 sliding in a portion of the casing of enlarged internal diameter as indicated at 37 and adapted to engage a shoulder 28 on said casing to limit the movement of plunger 13 to the right in Fig. 1 by the combined influence of the pressure in chamber 19 and the suction in chamber 8, as hereinafter described. A small bleeder opening 29 extends through the side wall of casing 1 in position to be uncovered by plunger 13 when the contact elements are in circuit closing position so as to establish communication between chamber 8 and the atmosphere, but to be covered or closed by said plunger upon movement thereof into position of engagement of shoulder 26 with shoulder 28.

A fitting 31 is also provided for connection to the exhaust manifold 32, said fitting having a threaded stem 33 engaging a threaded opening 34 in said exhaust manifold. The connection to the exhaust passage is preferably made near the engine, that is, near the point where the exhaust goes into such passage, so as to secure the maximum expansive effect of the gases for causing operation of the circuit opening switch. Said fitting is provided with a duct or passage 35, of which the portion 35′ at the inner end of said fitting and nearest the exhaust passage is preferably of restricted diameter as shown. An escape opening or passage 36 is also provided in fitting 31, said passage being preferably of a diameter considerably greater than that of the reduced passage 35′ and being inclined outwardly in the direction of passage of the exhaust gases into the duct 35. The fitting 31 is connected to the threaded stem 11 of fitting 10 by suitable passage means such as copper or brass tubing 38, the ends of which extend into the ducts 12 and 35 respectively and are held in position by suitable means such as compression coupling devices 39.

The relay switch may comprise a base 41 of fiber, bakelite or other suitable insulating materials, two contact members 42 and 43 mounted thereon, a circuit closing member 44 movable into or out of position of contact with said contact members, a spring 45 tending to move said circuit closing member out of such contact making position, and an electromagnet comprising winding 46 and movable core or armature 47 adapted to move said circuit closing member to contact making position upon energization of said winding. The winding 46 may be wound upon a spool 49 of insulating material and the magnetic circuit of core 47 may be completed by means of a fixed core section 48 and iron straps or bars indicated at 50 and 51. A washer or layer of insulating material 53 may be placed over the bars 51 and the two contact members 42 and 43 are so formed as to bear down thereon and tightly clamp the electromagnet in position. Yielding means are preferably provided between the core 47 and circuit closing member 44 for causing said circuit closing member to move downwardly with said core until it engages contact members 42 and 43, while permitting said core to thereafter complete its movement accompanied by a slight compression of said yielding means. For this purpose said core may have an upwardly projecting stem 56 extending freely through an opening 54 in said circuit closing member and a small compression spring 57 may be provided between the top of said circuit closing member and suitable means such as cotter pin 58 secured to said stem. Core 47 and stem 56 are preferably insulated from circuit closing member 44 by means of insulating material 55. The spring 45 may be mounted in a central recess 60 in movable core 47, said spring being compressed between the upper end of said recess and the fixed core section 48 so as to tend to force core 47 upwardly. Core 47 is

provided with a shoulder 61 adapted to engage circuit closing member 44 upon upward movement of said core and move the same out of engagement with contact members 42 and 43. Upward movement of core 47 may be limited by engagement of stem 56 aforesaid with suitable stop means, such as hereinafter described.

The contact member 42 may be secured to base 41 by means of binding post or screw 64 and nut 65, said binding post serving to permit connection thereto of an electric wire, cable or other conductor. The other contact member 43 may be secured to base 41 by means of a post 67 having a shoulder 68 engaging the upper face of said contact member and a nut 69 on the threaded projecting end of said post. A connecting and supporting clip or bracket 70 is also preferably mounted on post 67 and secured thereto by nut 71, said bracket having an opening 72 at its end adapted for connection to the usual binding post or terminal on the starting motor.

The post 67 is preferably formed of soft iron and extends upwardly to form a core 74 around which is placed a winding 75, a layer of suitable insulating material indicated at 76 being interposed between said winding and said core. A core extension arm 78 is secured to the upper end of core 74 as by means of screw 79 and extends over in position above the upper end of a stem 56 of core 47 to form the stop means above mentioned for limiting upward movement of said core. Core 74, extension member 78 and coil 75 constitute a holding magnet for the purpose of holding core 47 in raised position under certain conditions as hereinafter described.

The respective ends of electromagnet winding 46 may be connected by wires 81 and 82 respectively to binding posts or screws 83 and 84 projecting through base 41 and serving as terminals for connection of electric wires or conductors thereto. One end of electromagnet winding 75 may be connected by wire 86 to contact member 43 or post 67, as by soldering or otherwise, as indicated at 87, while the other end of said winding may be connected by wire 88 to binding post or screw 89 projecting through the base 41 and serving as a terminal for connection of a ground wire, indicated at 91, thereto. A suitable casing or cover 93 may be provided for the relay switch mechanism above described, one of the binding posts such as 83 being, if desired, extended upwardly through said cover so as to receive a nut 94 for holding the cover in position upon the base 41.

In the wiring diagram, Fig. 4, the electric starting motor is indicated at 97, it being understood that such starting motor is provided with the usual form of drive mechanism as above described for operative connection thereof to the engine shaft when said motor is set in operation and for automatic release thereof when the engine starts. The automatic controlling or circuit opening switch above described is indicated at 98, the relay switch at 99, and the holding magnet at 100. The usual storage battery is indicated at 101, one terminal thereof being grounded in the usual manner by means of wire 102. The other terminal of said battery is connected by wire 103 to a manually operated circuit closing switch 104 which is shown in open position. From said manually operated switch, wire 105 leads to one of the binding posts such as 84 connected to relay winding 46, while the other binding post 83 is connected by wire 106 to contact member 15. The other contact element, consisting of the disc 20, is electrically grounded as indicated at 107, it being understood that such ground connection may in practice be provided solely through the casing 1 and fitting 2 to the grounded intake pipe 5. A wire or cable 110 also leads from battery 101 to binding post 64 connected to contact member 42, while the other binding post 67, connected to contact member 43 is connected by wire 111 to one terminal of the starting motor 97, the other terminal of which is grounded in the usual manner as indicated at 112.

The operation of the above described device is as follows: When the engine is not in operation and the manually operated switch 104 is open, the parts are in the position shown in Fig. 4, the circuit closing member 44 of the relay switch being held out of engagement with contact members 42 and 43 by spring 45 so that the starting motor circuit is open at this point. Contact element 20, however, is held in engagement with contact element 18 by means of spring 24 so that the break in the controlling circuit is closed at this point. Closing of switch 104, therefore, completes the controlling circuit as follows: From battery 101, through wire 103, switch 104, wire 105, electromagnetic winding 46, wire 106, contact elements 18 and 20, and thence through ground back to the battery. The resulting energization of electromagnet winding 46 draws core 47 downwardly and brings the circuit closing member 44 into engagement with contact members 42 and 43 as shown in Fig. 5.

The circuit of the starting motor is thus completed as follows: From battery 101 through wire 110, contact member 42, closure member 44, contact member 43, and wire 111 to motor 97 and thence through the ground return back to the battery. The starting motor, therefore, operates to turn over the engine until the same begins to fire, it being understood that the ignition circuit has also been closed and that the supply of fuel or of combustible mixture is controlled in the usual manner. Up until the time of the first explosion of the engine, there is a partial suction created in the intake manifold due to

the drawing of air or combustible mixture therefrom into the cylinder, but such partial suction has no effect upon plunger 13, as the bleeder opening 29 is uncovered at this time and is of such size as to permit air to be drawn therethrough at substantially the same rate at which it is drawn through duct 6 without creating any appreciable reduction in pressure in chamber 7. Furthermore, the spring 24 may have sufficient strength to counteract any slight suction which might be developed in said chamber under these conditions. During this starting period, and up until the time of the first explosion, the gases are exhausted from the cylinders at substantially atmospheric pressure, and, therefore, have practically no expansive effect, and no appreciable pressure will be developed in pressure chamber 19 of the controlling switch. Any gases which pass through duct 35′ will have relatively low velocity and will be diverted principally through escape opening 36 to the atmosphere without causing any appreciable pressure at the entrance to tube 38. As soon as the first explosion occurs, the increased speed of rotation of the engine shaft will disengage the starting mechanism so as to free the engine from operative connection with the starting motor. At the same time, the ignited gases, being discharged at high temperature and at a pressure somewhat above atmospheric, will have a great expansive effect, increasing both the pressure and velocity of the gases in exhaust passage 32. A portion of such gases will be caused to pass at high velocity through duct 35′, causing a certain pressure to be developed at the entrance of tube 38. Such increased pressure will be transmitted through said tube to the pressure chamber 19 and cause the plunger 13 to move to the right in Fig. 1, sufficiently to break connection between contact elements 20 and 18. The controlling circuit is thus broken, de-energizing electromagnet 46 and permitting spring 45 to raise core 47 and move circuit closing member 44 out of engagement with contact members 42 and 43. This in turn breaks the circuit of the starting motor, which will thereupon come to rest.

Plunger 13 is moved by the pressure of the exhaust gases to the position indicated in dotted lines at 13′ in Fig. 1, when the shoulder 26 thereon engages shoulder 28, and remains in this position as long as the engine is in operation. It is to be noted that in the movement of said plunger to this position, it will cover the bleeder opening 29 so that the reduced pressure or suction in the intake passage will be communicated through duct 6 and cause a reduced pressure to be created in chamber 7 at the right of the plunger. Therefore, while the initial breaking of the connection between contact elements 18 and 20 is dependent substantially wholly upon the expansive effect of the exhaust gases, the holding open of said connection after it is once broken is dependent upon the combined effect of the exhaust gases and the intake suction. This is of advantage because under certain running conditions of the engine, such as when running under heavy load, the intake suction may be relatively low, but the exhaust pressure is at that time relatively great, while at other times, such as when running under light load, the converse is true, with the result that at either of these times there is a sufficient pressure difference at the two sides of plunger 13 to overcome the force of spring 7 and hold the plunger in circuit opening position.

If, however, the engine should stop or "stall" for any reason, while the manually controlled switch 104 is still closed, both the intake suction and the expansive effect of the exhaust gases will be decreased, and spring 24 will thereupon return the plunger 13 to its original position, again completing the connection between contact elements 18 and 20 and causing the starting motor to again start up the engine in the same manner as before.

When it is desired to stop the engine, the switch 104 is opened, in addition to opening of the ignition circuit, and the system is then again in its original condition.

I claim:

1. An apparatus for starting internal combustion engines comprising, in combination with an internal combustion engine and with a starting motor therefor and means for automatically effecting operative connection of said motor to said engine to start the same and automatically releasing such connection upon starting the engine, an electric circuit including said starting motor, a swtch included in said circuit, means for causing said switch to be opened upon starting of the engine, solely by the expansive effect of the exhaust gases of said engine, and means for causing said switch to be closed upon stopping of the engine, by the combined action of the decrease in intake suction and the decrease in expansive effect of the exhaust gases.

2. An apparatus for starting internal combustion engines comprising, in combination with an internal combustion engine provided with intake and exhaust passages and with a starting motor therefor and means for automatically effecting operative connection of said motor to said engine to start the same and automatically releasing said connection upon starting of the engine, an electric circuit including said starting motor, manually controlled means for causing closing of said circuit, and means connected to the intake passage and to the exhaust passage of said engine and operable to cause breaking of said circuit solely by the expansive effect of the exhaust gases upon starting of the engine and to cause said circuit to be there-

after kept open by the combined action of the intake suction and the expansive effect of the exhaust gases.

3. An apparatus for starting internal combustion engines comprising, in combination with an internal combustion engine having intake and exhaust passages, and with a starting motor therefor, and means for automatically effecting operative connection of said motor to said engine to start the same and automatically releasing such connection upon starting of the engine, an electric circuit for controlling the operation of said starting motor, a circuit opening switch included in said controlling circuit, means tending to close said switch, means connecting said switch to the exhaust passage of the engine, said switch being operable to open position solely by the pressure communicated thereto through said connecting means due to the expansive effect of the exhaust gases upon starting of the engine, additional means connecting said switch to the intake passage of the engine and means whereby said switch after being moved to open position is held in such position as long as the engine is running by the combined action of pressure communicated through said first named connecting means and suction communicated through said additional connecting means.

In testimony whereof I have hereunto subscribed my name this 14th day of July 1928.

ARTHUR S. KNAPP.