

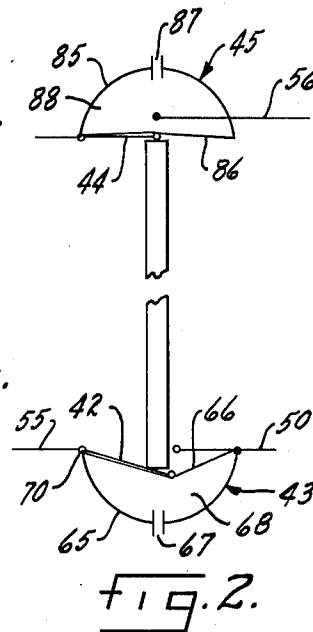
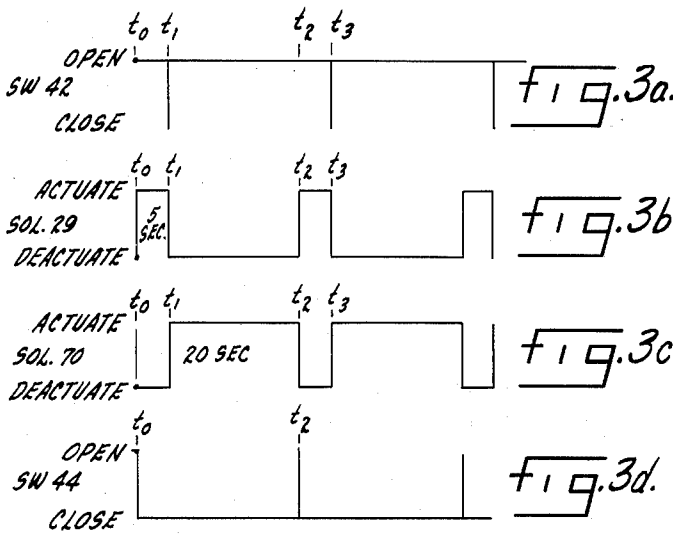
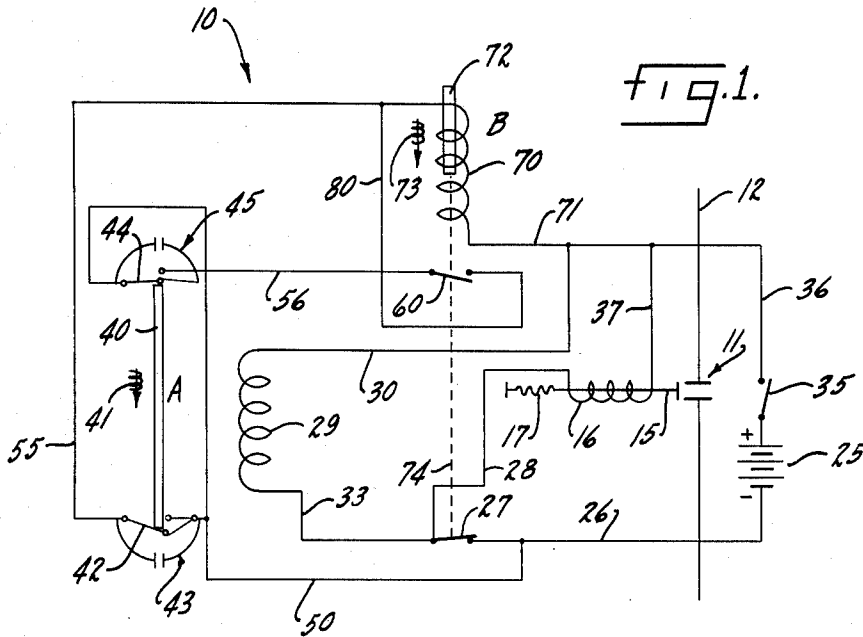
Jan. 18, 1966

W. L. STELTER
DUTY CYCLE CIRCUIT

3,230,401

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2 Sheets-Sheet 1



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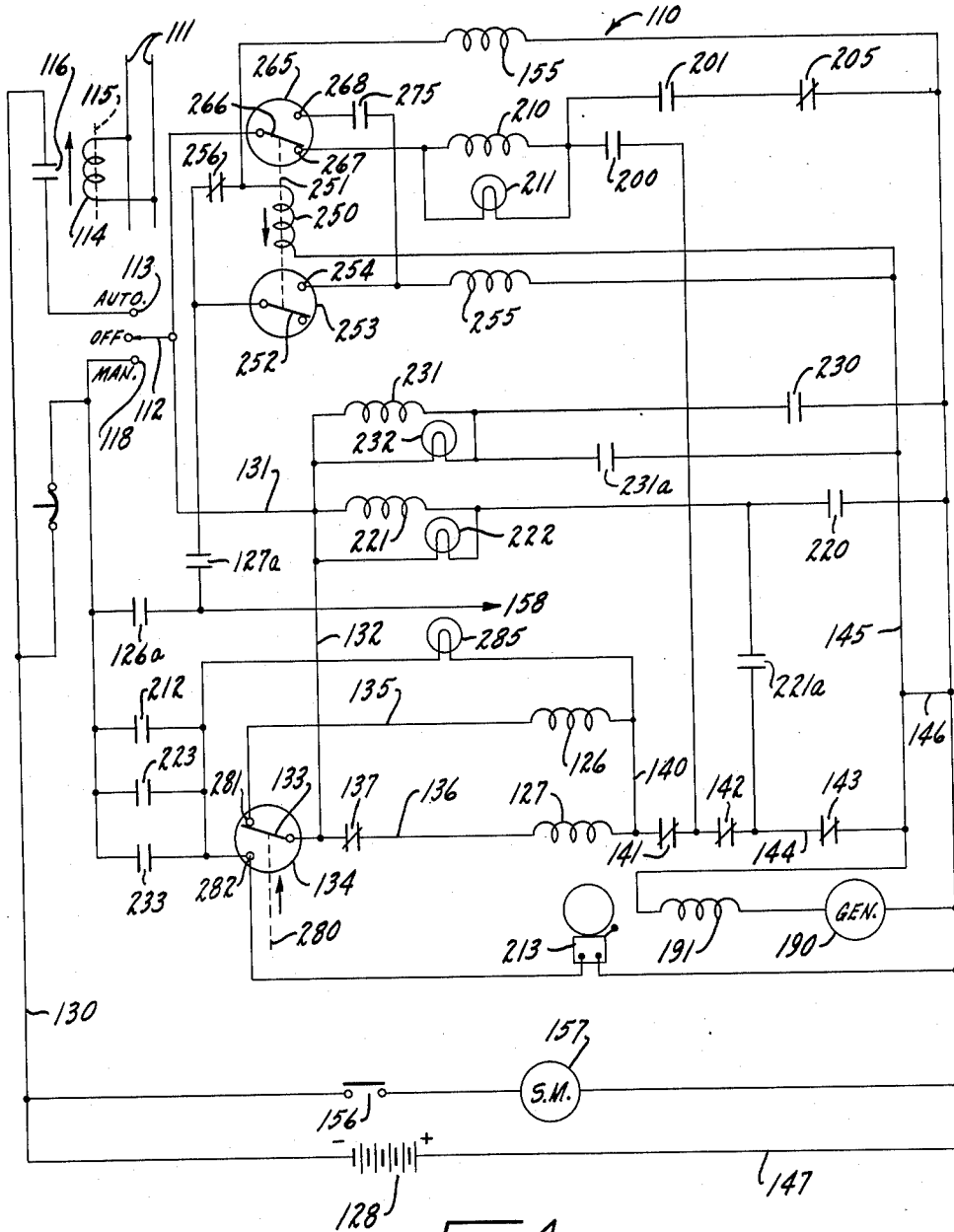


Fig. 4.

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3,230,401

DUTY CYCLE CIRCUIT

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This invention relates in general to electrical circuitry. It deals more particularly with a cyclical duty circuit.

It frequently is desirable to cyclically energize and de-energize a responsive arrangement such as a secondary electrical circuit, a mechanical device, or a chemical operation, for example. Inducing a cyclical operation by hand is a relatively simple expedient. However, if cyclical energization and de-energization must be induced automatically for a prescribed period, and the locale is a remote one, where the arrangement might be unattended during certain periods, it will be seen that the problem is more complex.

For example, it frequently is desirable to automatically initiate operation of a conventional reciprocating engine upon a predetermined signal being given. Such a signal might be promulgated by the failure of a normal power source giving rise to a need for power from an auxiliary source. An example of this situation is found where a municipal power system supplies electricity to a hospital and the hospital has engine driven auxiliary generators standing by to supply critically needed power should the municipal source fail.

The ideal situation is, of course, for an engine or engines to start immediately upon an engine starting switch being thrown in response to a predetermined signal. Unfortunately, an engine doesn't always respond as rapidly as is desirable. Indeed, as is well known, it is not unusual for an engine to refuse to start.

With this in mind, it will be seen that it would be a highly undesirable result to initiate cranking of an engine and continue cranking indefinitely, whether the engine starts or not. Continuous cranking rapidly wears down the battery and it becomes impossible to start the engine at all. The preferred mode of starting a reciprocating engine is to crank for a short period of time, rest for a short period of time, and then crank again for a short period of time. This is a procedure well known to automobile owners, for example, and is a relatively simple thing to accomplish with an automobile.

However, with a remotely located or otherwise unattended auxiliary power source for an emergency generator, for example, it is imperative that the engine or engines be started immediately, without delay. The description of the present invention is in part in the context of a cyclical duty circuit for initiating the starting of a reciprocating engine. It will be understood, however, that it might be utilized equally as well for cyclically energizing and de-energizing an infinite variety of electrical, mechanical, and chemical arrangements, as has been pointed out.

It is an object of the present invention to provide a new and improved electro-mechanical duty circuit for cyclically energizing and deenergizing a responsive arrangement of electrical, mechanical, or chemical nature, or the like.

It is another object to provide a duty circuit of the afore-described character which is effective to cyclically energize and de-energize a responsive arrangement for independently predetermined periods of time.

It is still another object to provide a duty circuit in which the cyclical time periods of energization and de-energization can readily be varied as desired.

It is a further object to provide a duty circuit including an overall timing arrangement for limiting the total time of cyclical energization and de-energization.

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It is yet another object to provide a duty cycle circuit for automatically cranking an engine according to a predetermined schedule and responsive to a predetermined signal.

The invention, both as to its organization and method of operation, taken with further objects and advantages thereof, will best be understood by reference to the following description taken in connection with the accompanying drawings, in which:

FIGURE 1 is a schematic diagram of a basic electro-mechanical duty cycle circuit embodying the features of the present invention;

FIGURE 2 is an enlarged diagrammatic representation of a portion of the circuit shown in FIGURE 1;

FIGURE 3a graphically depicts the operation of a cycle control switch in the circuit shown in FIGURE 1;

FIGURE 3b graphically depicts the operation of a cycle control solenoid coil in the circuit shown in FIGURE 1;

FIGURE 3c graphically depicts the operation of another cycle control solenoid coil in the circuit shown in FIGURE 1;

FIGURE 3d graphically depicts the operation of another cycle control switch in the circuit shown in FIGURE 1; and

FIGURE 4 is a schematic diagram of an electro-mechanical duty cycle circuit embodying the features of the present invention, adapted for cranking and monitoring an engine.

The above and other objects are realized in accordance with the present invention by providing a new and improved variable cycle electromechanical duty circuit. The invention contemplates a circuit which automatically energizes and deenergizes a responsive arrangement for predetermined periods of time. The "energization" and "de-energization" periods are independently adjustable to permit a wide range of variation in the relative length of time of each. In addition, the energization-de-energization sequence is repeated for a predetermined overall period of time.

Referring now to the drawings and particularly to FIGURE 1, a variable cycle electrode-mechanical duty circuit embodying the features of the present invention is illustrated generally at 10. The circuit 10 cyclically opens and closes a switch 11 in an auxiliary electrical circuit 12 (only a portion of which is shown) associated with any conventional electrical or mechanical equipment, chemical operation or other arrangement (not shown) to energize and de-energize the arrangement. In the alternative, of course, the duty cycle circuit 10 might be utilized to mechanically energize a responsive arrangement of one type or another.

The relative periods of energization and de-energization effected by the duty cycle circuit 10 are individually adjustable without reference to each other. The circuit 10 automatically continues to energize and de-energize the responsive arrangement in question as long as a source of electrical power is operatively associated with it.

The switch 11 in the auxiliary circuit 12 is a normally open switch, adapted to be closed by the duty cycle circuit 10 according to a predetermined schedule through the medium of a switch element 15 operatively associated with a solenoid coil 16 in the circuit 10. The switch element 15 is normally maintained in the position shown in FIGURE 1, that is a retracted position, by resilient means, seen generally at 17. The solenoid coil 16 is, of course, effective to move the switch element 15 to close the switch 11 and the circuit 12 when power is supplied to the solenoid coil 16.

The solenoid coil 16 is in series with, and receives power from, a conventional source of D.C. current, seen

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generally at 25. The source 25 of D.C. current, which might be a conventional wet storage cell, has one terminal connected to the solenoid coil 16 through a conductor 26, a normally closed switch 27 and a conductor 28. The opposite terminal of the source 25 of D.C. current is preferably connected to the solenoid coil 16 through a normally open master switch 35, a conductor 36, and a conductor 37.

It will now be seen that as long as the master switch 35 remains open, the solenoid coil 16 is de-actuated and the switch 11 is maintained in open relationship. Consequently, current does not flow through the auxiliary circuit 12 to initiate action in a responsive arrangement of one type or another. However, when the master switch 35 is closed, the coil 16 is actuated and the switch 11 is closed by the switch element 15 moving against the bias of the resilient means 17. Current flows through the circuit 12 and energizes the aforescribed responsive electrical, mechanical, or chemical arrangement.

Concurrent with the actuation of the solenoid coil 16, a solenoid coil 29 is also actuated. As will be recognized, the solenoid coil 29 is connected to the source 25 of D.C. current in parallel with the solenoid 16 through conductors 30 and 33. Actuation of the solenoid coil 29 is effective to start the cyclical sequence of operation of the auxiliary circuit 12, according to a predetermined schedule. To clearly understand the operation of the duty cycle circuit 10 embodying features of the present invention, however, the status of certain portions of the circuit 10 prior to the solenoid coil 29 being actuated must be delved into.

When the solenoid coil 29 is in its unactuated state, prior to the master switch 35 being closed, a solenoid plunger 40 which is responsive to the coil 29 is biased into a position shown in FIGURE 1, by resilient means diagrammatically illustrated at 41. Consequently, a switch 42 is maintained in an open position, against the bias of a pneumatic timing assembly 43 tending to urge it toward a closed position. Similarly, prior to the solenoid coil 29 being actuated, it will be seen that a switch 44 at the opposite end of the solenoid plunger 40 is maintained in open position by a pneumatic timing assembly 45. The pneumatic timing assembly 45 is normally effective to bias the switch 44 toward its open position.

The pneumatic timing assembly 43 might be referred to as the energization cycle timer for the circuit 10. Its mechanical setting, effected manually, determines the period of time during which the circuit 10 is effective to cause current to flow through the auxiliary circuit 12 as a result of the switch 11 being closed. The pneumatic timer assembly 45, on the other hand, might be referred to as the de-energization cycle timer for the circuit 10. It is effective, by virtue of a mechanical setting, to time those alternate periods during which the auxiliary circuit 12 is de-energized by virtue of the switch 11 being retained in open relationship.

As will now be seen, with the solenoid coil 29 in de-actuated relationship, current cannot flow through the switch 42 from a conductor 50 tapped into the portion of the duty cycle circuit 10 hereinbefore described. At the same time, current cannot flow from the same conductor 50 through the normally open switch 44. In this setting, then, the duty cycle circuit 10 is prepared to initiate sequential energization and de-energization of the auxiliary circuit 12 when the master switch 35 is closed.

With the closing of the master switch 35, parallel circuits are completed through the solenoid coil 29 and the solenoid coil 16. Consequently, the auxiliary circuit 12 is closed and current flows to the responsive arrangement hereinbefore referred to as well as causing the solenoid plunger 40 to move upwardly against the bias of the resilient means 41. As a result, the normally open switch 44 is immediately closed.

Since the conductor 56 departing the now closed switch

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44 is connected to a normally open switch 60, no additional portion of the circuit 10 is completed at this time by the closing of the switch 44. However, when the solenoid plunger 40 retracts from the normally open switch 42 and the time delay assembly 43, against the bias of the resilient means 41, the time delay assembly 43 starts a predetermined period of time running during which the switch 11 will be closed, and the arrangement to which the auxiliary circuit 12 supplies current will be operative.

Referring now to FIGURE 2, the time delay assembly 43 and the switch 42 are shown diagrammatically and somewhat enlarged. It will be seen that the time delay assembly 43 includes a generally cup-shaped shell 65 having a resilient diaphragm 66 stretched across its open end and a variable aperture valve 67 providing access to the cavity 68 formed between the diaphragm 66 and the shell 65. The valve 67 might be any conventional valve arrangement which readily facilitates increasing or decreasing the size of the aperture.

By manipulating the valve 67, of course, the size of the aperture and consequently the rate of influx or efflux of air from the chamber 68 is readily controllable. Consequently, when the diaphragm 66 is abruptly released as the solenoid plunger is retracted, the diaphragm 66 moves outwardly as fast as the air from the atmosphere can enter the chamber 68 through the valve 67.

The switch 42 is connected to the diaphragm 66 in such a manner that it moves with the diaphragm about a pivotal connection with the conductor 55, as seen generally at 70. The switch 42 is in the position shown in FIGURES 1 and 2, as has been pointed out, prior to the master switch 35 being closed. When the solenoid plunger moves upwardly to close the switch 44, the switch 42 tends to close under the biasing influence of the diaphragm 66, as controlled by the rate of influx of air into the chamber 68 through the valve 67. Since the rate of influx of air through the valve 67 is readily controllable, it will be seen that the time that it takes for the switch 42 to close is readily controllable by the setting of the valve 67.

If, for example, it is desirable that the circuit 12 be energized for a period of five seconds (after which a predetermined de-energize period is effected), it is only necessary that the time delay assembly 43 be set, by setting the valve 67, so that the switch 42 will close five seconds subsequent to the retraction of the solenoid plunger 40 from contact with the diaphragm 66. At the start of this five second period, as has previously been pointed out, the solenoid plunger retracts from the switch 42 and closes the switch 44 associated with the time delay assembly 45. However, since the switch 60 is open at this time, closing the switch 44 has no immediate effect on the duty cycle circuit 10. The effect is delayed for the five second period that the switch 42 remains open.

During this period of five seconds, while the switch 42 remains open and the switch 44 closed, the solenoid coil 16 remains actuated and current flows through the auxiliary circuit 12. However, after the five second time setting of the time delay assembly 43 has elapsed, the switch 42 closes, initiating a response in the circuit 10 which de-actuates the solenoid coil 16 and de-energizes the auxiliary circuit 12 by opening the switch 11.

The de-actuation of the solenoid coil 16 is effected by actuation of a solenoid coil 70. The solenoid coil 70 is actuated when a circuit is completed through the conductor 55, the solenoid coil 70, a conductor 71, and the conductor 36, through the master switch 35 to the source 25 of D.C. current, by the switch 42 closing. Immediately upon this circuit through the solenoid coil 70 being completed, a solenoid plunger 72 associated with the solenoid coil 70 and normally biased downwardly (as seen in FIGURE 1) by conventional resilient means 73, is effective through a mechanical tie arrangement 74 to open

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the normally closed switch 27 and close the normally open switch 60.

Opening the normally closed switch 27, of course, immediately breaks the circuit through the solenoid coil 29 and the solenoid coil 16 and causes the switch element 15 to be retracted from the switch 11 and the auxiliary circuit 12 to be de-energized. Simultaneously, with the closing of the normally open switch 60, a circuit is completed through the now closed switch 44 in the time delay assembly 45, the conductor 56, and a conductor 80, through the solenoid coil 70 to provide a holding circuit for holding the solenoid coil 70 actuated and consequently the switch 27 open and the switch 60 closed.

When the switch 27 is opened, and consequently simultaneously with the de-actuation of the solenoid coil 16, it will readily be seen that the solenoid coil 29 is also de-actuated. As a result, the resilient means 41 re-assumes control of the solenoid plunger 40 and causes it to be immediately retracted from the switch 44 associated with the time delay assembly 45 and move against the switch 42 associated with the time delay assembly 43 to open the latter switch. Since a holding circuit for the solenoid coil 70 has been completed through the closed switches 44 and 60, however, the solenoid plunger 72 is retained in actuated relationship against the bias of the resilient means 73, to hold the switch 60 closed and switch 27 open.

The time during which the solenoid coil 70 remains actuated is a measure of the de-energization time of the auxiliary circuit 12, and this period of time is in turn determined by the length of time which the switch 44 associated with the time delay assembly 45 is closed. In turn, the period of time during which the switch 44 is closed is determined by the setting of the time delay assembly 45.

Referring to FIGURE 2 once more, it will be seen that the time delay assembly 45 is substantially identical in construction to the time delay assembly 43 hereinbefore described. It includes a generally cup-shaped shell 85 having a resilient diaphragm 86 closing the open end thereof and a variable aperture valve 87 providing access to the chamber 88 formed between the diaphragm and the shell. The valve 87 is again of any conventional construction and its setting determines the rate of influx or efflux of air from the chamber 88.

When the duty cycle circuit 10 is initially actuated, by closing the master switch 35, the solenoid plunger 40 is moved by the solenoid coil 29 to close the normally open switch 44, in the manner hereinbefore described. As a result, air is forced out of the chamber 88 through the aperture 87. When, in turn, the solenoid plunger 40 is retracted by the resilient means 41 as the solenoid coil 29 is de-actuated, the switch 44 is maintained in closed relationship until a predetermined period of time has passed, as determined by the setting of the valve 87.

In other words, the time setting of the valve 87 determines the de-energization time of the auxiliary circuit 12. A de-energization time of twenty seconds might arbitrarily be chosen. It will now be remembered that after the energization time of five seconds has passed, the switch 42 closes energizing the solenoid coil 70. The solenoid coil 70 in turn opens the switch 27 to de-actuate the solenoid coil 29. This in turn causes the solenoid plunger 40 to retract under the influence of the resilient means 41, as has been pointed out, and thus starts the twenty second de-energization period of the time delay assembly 45 running.

After the twenty second de-energization period has elapsed, sufficient air has entered the chamber 88 in the time delay assembly 45 to permit the switch 44 to spring open and open the circuit through the conductor 26, the conductor 50, the switch 44, the conductor 56, the switch 60, the conductor 80, the solenoid coil 70, the conductor 71, the conductor 36, and the master switch 35, to the source 25 of D.C. current. As a re-

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sult, the spring biasing means 73 moves the solenoid plunger 72 downwardly, as seen in FIGURE 1, and the tie arrangement 74 once more closes the switch 27 and opens the switch 60. At this point, of course, the circuit through the solenoid coil 29 is again closed and the coil 29 actuated, as is the solenoid coil 16 which closes the auxiliary circuit 12. The solenoid plunger 40 immediately retracts from the switch 42, permitting the five second energization period to begin running once more. At this point one energization-de-energization cycle is completed and another cycle begins.

The sequence of operation of the duty cycle circuit 10 described above is illustrated graphically in FIGURE 3. It should be kept in mind, of course, as has also been described above, that the energization period of the auxiliary circuit 12 might be measured in terms of the time during which the solenoid coil 29 is actuated. This is true because the solenoid coil 16 must be actuated during the same period that the solenoid coil 29 is actuated and, of course, the switch 11 closes to complete the auxiliary circuit 12 during the period that the solenoid coil 16 is actuated.

Referring to FIGURES 3a-3d, imagine for a moment that time moves from left to right across the graphs shown. Additionally imagine that the time t_0 connotes that moment in time when the master switch 35 closes.

Now referring specifically to FIGURE 3b, it will be seen that just prior to the time t_0 that the master switch 35 closes, the solenoid coil 29 is in de-actuated relationship. Upon the switch 35 closing, the solenoid coil 29 immediately is actuated. Simultaneously, of course, as has been pointed out, the solenoid coil 16 is actuated and the auxiliary circuit 12 closed by the closing of the switch 11.

At the time that the solenoid coil 29 is actuated, the switch 44 is moved (by the solenoid plunger 40) from an open to a closed relationship, as seen in FIGURE 3d. At this time the switch 42 remains open (under the influence of the time delay assembly 43) and the solenoid coil 70 remains de-actuated.

Since a five second time delay has been set into the time delay assembly 43, the switch 42 springs closed at time t_1 , after a delay of five seconds, as seen in FIGURE 3a. Immediately upon the switch 42 closing, the solenoid coil 70 is actuated, as seen in FIGURE 3c. Actuation of the solenoid coil 70 opens the switch 27 and closes the switch 60. Opening the switch 27, of course, immediately de-actuates the solenoid coil 29 and the solenoid plunger 40 once more opens the switch 42. The closing and opening of the switch 42 thus happens almost instantaneously, as can be seen in the graph in FIGURE 3a.

Because the switch 60 is closed at the time the switch 42 initially closes, however, and a circuit is immediately completed through the switches 44 and 60 to the solenoid coil 70, the holding circuit through the solenoid coil 70 remains closed even though the switch 42 immediately re-opens. Consequently, the switch 27 remains open and the auxiliary circuit 12 is de-actuated.

This relationship is maintained for the de-energization period set into the time delay assembly 45; in this instance twenty seconds. After the twenty second period, at time t_2 , referring to FIGURE 3d, the switch 44 automatically springs open. This breaks the afordescribed holding circuit through the solenoid coil 70 and the switch 27 closes once more under the influence of the biasing means 73 urging the solenoid plunger 72 downwardly, as seen in FIGURE 1. As a result, the circuit through the solenoid coil 29 and the solenoid coil 16 is closed, at time t_2 , again and the auxiliary circuit 12 energized through the closing of the switch 11 therein.

Actuation of the solenoid coil 29 once more causes the solenoid plunger 40 to retract from the switch 42 and the energization period pre-set into the time delay assembly 43 again begins to run. After the energization time delay of five seconds, and at time t_3 , the switch 42 springs

closed. Thus, another energization cycle has been completed and in a manner identical to that hereinbefore described another de-energization cycle begins. The sequence is continued in precisely the manner described until the master switch 35 is opened.

As has previously been pointed out, a particularly advantageous practical application of the duty cycle circuit 10 hereinbefore described is found in regulating the starting of an engine, for example. As such, the duty cycle circuit is preferably embodied in circuitry of substantially more sophisticated form, however. Such a sophisticated circuit is shown generally at 110 in FIGURE 4.

The circuit 110 preferably sets up a duty cycle of cranking and rest periods for starting a conventional reciprocating engine (not shown) when power in a main power line 111 fails as a result of the failure of a local power supply, for example. The engine might then drive auxiliary generators to produce electricity which would normally be provided by the local power supply.

Circuit 110 further establishes an overall starting period for the engine. In other words, it permits the engine to be cyclically cranked for only a predetermined period of time before completely de-activating the starting mechanism if the engine does not start, to prevent permanent damage to the engine, the starting motor, or the battery, for example.

The circuit 110 further serves to shut the engine down should it overspeed during normal operation once it has been started. In addition, if the temperature of the cooling water in the engine exceeds a predetermined value, the circuit 110 shuts the engine down. Also, if the oil pressure in the engine drops below a predetermined level, the engine is shut down.

Initiation of operation of the circuit 110 might be "primed" by moving the selector switch 112 to the "auto" position, seen generally at 113. Once this has been accomplished, if the current in the circuit 111 fails, the solenoid coil 114 associated therewith is de-actuated and a solenoid plunger 115 closes the switch 116 under the influence of conventional resilient means (not shown). In contrast, if it is considered desirable to manually initiate cranking of the engine (not shown), the selector switch 112 might be moved to the "manual" position, seen generally at 118.

If the selector switch 112 is in the "auto" position and the switch 116 closes, the relay coils 126 and 127 are actuated by current from the conventional source 128 of D.C. current. This source 128 might be a wet cell battery of well known construction. The relay coils 126 and 127 are actuated through a circuit which includes a conductor 130, the closed switch 116, the closed selector switch 112, a conductor 131, a conductor 132, a switch 133 incorporated in an overall time delay assembly 134, a conductor 135 to the coil relay 126, and a conductor 136 through a normally closed switch 137 to the relay coil 127. Additional circuitry associated with the actuation of the relay coils 126 and 127 includes a conductor 140, normally closed switches 141, 142, and 143 in a conductor 144, a conductor 145, a conductor 146 and a conductor 147.

Actuation of the relay coil 126 closes the contacts 126a. Simultaneously, actuation of the relay coil 127 closes the normally open snap switch 127a which completes a circuit to the starting motor solenoid 155. Actuation of the starting motor solenoid 155 closes the contacts 156 to energize a starting motor 157 and crank the engine (not shown).

Simultaneously with the initial cranking of the engine by the starting motor 157, battery is provided to a throttle solenoid, ignition coil, and auxiliary circuits through a terminal 158, through the now closed contacts 126a. Any predetermined schedule of fuel feed might be set into the throttle solenoid operation, for example. It forms no part of the present invention and consequently is not discussed in detail.

The engine (not shown) is cranked until it starts or until a predetermined cranking cycle period set into the circuit 110 has passed, whichever period is the shorter. The initial cranking cycle or energization period might be five seconds, for example, as it was described in relation to the duty cycle circuit 10 hereinbefore discussed.

If the engine starts on the first five second cranking cycle, the generator 190 begins to generate current. The current from the generator 190 is effective to actuate the relay coil 191. The relay 191 is in turn effective in a conventional manner to open the normally closed switch 137 and de-actuate the relay coil 127. De-actuating the relay coil 127 opens the snap switch 127a, which in turn breaks the battery 128 to starting coil 155 connection. The starting motor contact 156 is thus broken and the starting motor 157 is shut off.

Actuation of the relay coil 191 by the starting of the engine (not shown) is also effective to close the normally open switch 201, in a well known manner, and preset an oil pressure sensing system for operation. The oil pressure sensing system is normally effective to shut down the engine if a certain minimum oil pressure is not maintained while the engine is running. Obviously, it is not desirable to activate the sensing system until after the engine is running, to prevent the engine from being shut down because of zero oil pressure while cranking. Consequently, until the engine starts running, the switch 201 is maintained in open position, only to be closed by the relay coil 191 after the engine starts running.

After the engine is running, if the oil pressure drops below the predetermined setting of the oil pressure switch 205 (of conventional construction), the switch 205 opens, and de-actuates the relay coil 210 which is then effective to open the normally closed switch 141 and drop out the relay coil 126. Dropping out the relay coil 126 opens the contacts 126a and shuts off current to the ignition system through the terminal 158, for example. At the same time, the relay coil 210 closes the normally open switch 200 to lock in a circuit through the oil signal light 211 and give warning to maintenance personnel. Simultaneously, the normally open switch 212 closes to sound the alarm 213.

If the water in the cooling system of the engine exceeds the setting of a normally open water temperature switch 220 (of conventional construction), the switch 220 closes and grounds the relay coil 221. Simultaneously, a water overheat signal light 222 lights up, while the coil 221 locks a normally open switch 221a closed to hold the circuit through the light 222 closed and assure that the light remains on if the switch 220 opens before the operator has a chance to investigate. In addition, the relay coil 221 is effective to open the normally closed switch 142 to drop out the relay coil 126 and shut down the engine. The coil 221 is further effective to close a normally open switch 223 and sound the alarm 213.

When the engine is running at high speeds, if it should overspeed the normally open overspeed switch 230 (of conventional construction) closes. Closing of the overspeed switch 230 grounds a relay coil 231 and simultaneously lights an overspeed signal light 232. The relay coil 231 locks a normally open switch 231a closed to hold the circuit through the light 232 closed and assure that the light remains even if engine speed is reduced. Concurrently, the actuated relay coil 231 opens the normally closed switch 143 to drop out the relay coil 126 and shut down the engine. The coil 231 further closes a normally open switch 233 to sound the alarm 213.

The aforedescribed events might occur if the engine starts and continues to run to operate an auxiliary generator, for example. However, if the engine does not start, the relay coil 191 is not actuated by the current from the generator 190. Consequently, the relay switch 201 remains open to prevent operation of the oil pressure sensing system. In addition, since the engine cannot overspeed, nor the water temperature exceed a pre-

determined maximum temperature during a starting cycle, the overspeed switch 230 and the water temperature switch 220 remain open.

If the engine does not start during a predetermined initial cranking cycle, the circuit 110 is effective to de-energize the starting motor 157 for a predetermined period of time and then re-energize it to crank once more. In this manner, a sequence of cranking and rest periods are set up for the starting motor 157 and damage to the starting motor 157, the engine itself, or the battery, for example, is obviated. After a predetermined overall period of time, the overall time delay assembly 134, previously referred to, is effective to stop the cyclical cranking operation entirely.

As has been pointed out, the initial cranking cycle of the starting motor 157 is here arbitrarily set at five seconds. Remembering now that the initial actuation of the circuit 110 causes the contacts 126a and the snap switch 127a to close and energize the starting coil 155, it will also be seen that a circuit is completed through the solenoid coil 250 and the coil 250 is actuated. Actuation of the solenoid coil 250 moves the solenoid plunger 251 upwardly against the effect of resilient means (not shown) and releases the switch 252. Releasing the switch 252 sets the pneumatic timing assembly 253 (which incorporates the switch 252) in operation to time the first cranking period of the starting motor 157.

The pneumatic timing assembly 253 is identical in construction and operation to the pneumatic timing assembly 43 previously discussed in relation to the duty cycle circuit 10. After an arbitrarily set period of five seconds, for example, it causes the switch 252 to move upwardly (in FIGURE 4) and make contact with the terminal 254 to complete a circuit through the solenoid coil 255.

Actuation of the solenoid coil 255 is then effective to open the normally closed switch 256 and consequently the circuit through the starting solenoid 155. This halts cranking action of the starting motor 157 and the rest period begins.

The rest period is timed by pneumatic timing assembly 265 which incorporates a two-way switch 266 adapted to make contact at a terminal 267, as shown in FIGURE 4, and at a terminal 268. The assembly 265 is identical in construction to that shown generally at 45 in FIGURE 2 and discussed in detail in relation to the duty cycle circuit 10, hereinbefore described.

Recall now that upon initial actuation of the circuit 110, the solenoid coil 250 is actuated and causes the solenoid plunger 251 to move upwardly, releasing the switch 252 biased by the time delay assembly 253 toward the terminal 254. Upward movement of the plunger 251 also moves the switch 266 into engagement with the terminal 268. This in turn is against the bias built into the pneumatic timing assembly 265.

When the predetermined cranking cycle period of five seconds has elapsed and the pneumatic timing assembly 253 causes the switch 252 to spring upwardly into contact with the terminal 254, the circuit is completed through the solenoid coil 255, as has also been pointed out. This in turn opens the normally closed switch 256 and de-actuates the solenoid coil 250, causing the plunger 251 to move downwardly once more under the influence of resilient means (not shown) of conventional construction. Releasing the switch 266 then starts the rest period cycle running under the influence of the pneumatic timing assembly 265.

Here it might be appropriate to interject another unique feature of this circuitry. Referring back to the oil pressure sensing system, hereinbefore described, it is often the case that engine oil pressure does not reach a sufficient value to open oil pressure switch 205 until the engine has been running for a moment. In order to prevent a false shut down of the engine if such is the case, it will be seen that the coil 210 cannot pick up

until the delay set into the switch 266 by the timing assembly 265 permits it to contact the terminal 267.

Turning back to the cyclical cranking operation if the engine does not start at once, simultaneously with the opening of the normally closed switch 256 the solenoid coil 255 closes the normally open switch 275. Consequently, although retraction of the solenoid plunger 251, as effected when the solenoid coil 250 is deactuated, would normally be expected to break the circuit through the solenoid coil 255; because the normally open switch 275 is now closed and the switch 266 remains in engagement with the terminal 268 through the predetermined rest period, the circuit is maintained through the solenoid coil 255 to "hold" the solenoid coil 255 in actuated relationship. During this holding period, of course, the solenoid coil 255 maintains the switch 256 in open relationship and consequently maintains the starting solenoid 155 as well as the solenoid coil 250 de-actuated.

However, after a predetermined rest period has elapsed twenty seconds, for example, the time delay assembly 265 causes the switch 266 to spring downwardly into contact with the terminal 267 and break the circuit through the solenoid coil 255, which in turn causes the presently open switch 256 to close. Closing the switch 256 closes the circuit through the starting solenoid 155 to once more initiate a cranking cycle by actuating the starting motor 157 through the starting contacts 156. Actuation of the solenoid coil 250 moves the solenoid plunger 251 upwardly once more and the switch 252 falls under the control, the pneumatic timing assembly 253, which begins timing another cranking period.

In the aforedescribed manner, a sequence of cranking and rest cycles is continued until the overall pneumatic timing assembly 134 is effective to shut off the cranking-rest sequence entirely. This is true because when the relay coil 127 initially closes the snap switch 127a to actuate the starting coil solenoid 155 and initiate operation of the starting motor 157, it also retracts the solenoid plunger 280 against the effect of resilient means (not shown). The overall pneumatic timing assembly 134 then assumes control of the switch 133 and after a predetermined period of time, generally in the neighborhood of two minutes or less, moves the switch 133 from contact with the terminal 281 to contact with the terminal 282. The operation of the time delay assembly 134 in this manner is identical to the operation of either of the previously described pneumatic timing assemblies 43 and 45. Obviously, it is identical in construction also.

When the two minute (for example) overall cranking period has elapsed, and the time delay assembly 134 moves the switch 133 into contact with the terminal 282, it will be seen that the circuit to the relay coil 126 is broken. Dropping the relay coil 126 out opens the contacts 126a and shuts off current to the ignition as well as to the starting solenoid 155. The solenoid plunger 280 does not move the switch 133 back into operative relationship with the terminal 281 to start the cyclical starting and rest period once more because the coil 127 is still actuated.

When the switch 133 contacts the terminal 282 a circuit is completed through the alarm light 285. The light 285 comes on at this time to advise any maintenance personnel in the area that the engine (not shown) has gone through an overall cranking and rest cycle without starting. The maintenance personnel might then reset the circuit 110 for another starting cycle by momentarily opening the switch 112. This permits the solenoid plunger to be biased upwardly once more to move the switch 133 into contact with the terminal 281.

It will readily be seen that an electromechanical (pneumatic) duty cycle circuit which provides automatic energization and de-energization of any selected responsive arrangement has been shown and described. The energization and de-energization periods are arbitrarily and readily varied without regard to each other. This per-

mits virtually any combination of energization and de-energization period lengths, of course.

The total time during which the circuit might cyclically energize and de-energize a responsive arrangement might also be readily varied. As a result, a circuit embodying features of the present invention finds adaptability in virtually any type of responsive arrangement, regardless of its sensitivity.

While several embodiments described herein are at present considered to be preferred, it is understood that various modifications and improvements may be made therein, and it is intended to cover in the appended claims all such modifications and improvements as fall within the true spirit and scope of the invention.

What is desired to be claimed and secured by Letters Patent of the United States is:

1. An electro-mechanical arrangement for cyclically energizing and de-energizing responsive means comprising; electrical circuitry having a source of power and including operator circuit means and control circuit means, energization means in said operator circuit means for energizing and de-energizing said responsive means as a function of the closing and opening of said operator circuit means, actuator means in said control circuit means for opening and closing said operator circuit means, and timer means associated with said control circuit means for controlling the operation of said actuator means to sequentially open and close said operator circuit means according to a predetermined schedule, said timer means including an operator circuit open period timer and an operator circuit closed period timer, said timers being alternatively operable to control the lengths of the responsive means de-energizing period and a responsive means energizing period, respectively.

2. An electromechanical arrangement for cyclically energizing and de-energizing responsive means comprising; electrical circuitry having a source of power and including operator circuit means and control circuit means, energization means in said operator circuit means for energizing and de-energizing said responsive means as a function of the closing and opening of said operator circuit means, actuator means in said control circuit means for opening and closing said operator circuit means, and timer means associated with said control circuit means for controlling the operation of said actuator means to sequentially open and close said operator circuit means according to a predetermined schedule, said timer means including an operator circuit open period timer and an operator circuit closed period timer, said timers being independently adjustable as to the length to their respective time periods.

3. The arrangement of claim 2 further characterized in that said operator circuit closed period timer includes a first switch which is normally open before said operator circuit means is initially closed, initial closing of said operator circuit means causing said operator circuit closed period timer to start the time period running during which said operator circuit means remains closed, said operator circuit closed period timer automatically closing said first switch to close said control circuit means when said time period has run, closing of said control circuit means effecting an opening of said operator circuit means to de-energize said responsive means.

4. The arrangement of claim 3 further characterized in that said operator circuit open period timer includes a second switch which is normally open before said operator circuit means is initially closed, initial closing of said operator circuit means causing said second switch to close, a third switch in said control circuit means being automatically closed and said operator circuit means being opened by the closing of said control circuit means when said first switch closes, closing of said second switch then serving to hold said control circuit means closed and said operator circuit means open for the predetermined

time period set in said operator circuit means open period timer.

5. An electro-mechanical arrangement for cyclically energizing and de-energizing responsive means comprising; electrical circuitry having a source of power and including an operator circuit and a control circuit, energization means in said operator circuit for energizing and de-energizing said responsive means as a function of the closing and opening of said operator circuit, actuator means in said control circuit for opening and closing said operator circuit, said control circuit including a primary circuit and a holding circuit, an operator circuit closed period timer associated with said primary circuit, and operator circuit open period timer associated with said holding circuit, said primary and holding circuits being connected in parallel with each other and in series with said actuator means to control the operation of said actuator means according to a predetermined time relationship for opening and closing of said primary and holding circuits, said predetermined time relationship being a function of the time periods preset into the respective timers of said primary and holding circuits.

6. The arrangement of claim 5 further characterized in that said operator circuit closed period timer includes a first switch which is normally open before said operator circuit is initially closed, initial closing of said operator circuit causing said operator circuit closed period timer to start a time period running during which said operator circuit remains closed, said operator circuit closed period timer automatically closing said first switch to close said primary circuit when said time period has run, closing of said primary circuit being effective to energize said actuator means and open said operator circuit to de-energize said responsive means.

7. The arrangement of claim 6 further characterized in that said operator circuit open period timer includes a second switch which is normally open before said operator circuit is initially closed, initial closing of said operator circuit causing said second switch to close, a third switch in said holding circuit closing simultaneously with the opening of said operator circuit by said actuator means when said first switch closes, closing of said second switch then serving to close said holding circuit and continue energization of said actuator means so as to hold said operator circuit open for the predetermined time period set in said operator circuit open period timer.

8. An electro-mechanical arrangement for cyclically energizing and de-energizing responsive means comprising; electrical circuitry having a source of power and including an operator circuit and a control circuit, energization means in said operator circuit for energizing and de-energizing responsive means as a function of the closing and opening of said operator circuit, actuator means in said control circuit for opening and closing said operator circuit, said control circuit including a primary circuit and a holding circuit, an operator circuit closed period timer associated with said primary circuit, an operator circuit open period timer associated with said holding circuit, said primary and holding circuits being connected in parallel with each other and in series with said actuator means to alternatively control the operation of said actuator means according to a predetermined time sequence for opening and closing of said primary and holding circuits, said predetermined time sequence being a function of the time periods preset into the respective timers of said primary and holding circuits.

9. The arrangement of claim 8 further characterized in that said timers are independently adjustable as to the length of their respective time periods.

10. The arrangement of claim 9 further characterized in that each of said timers includes a switch means, and pneumatic means biasing said switch means.

11. The arrangement of claim 10 further characterized in that said pneumatic means associated with said closed period timer tends to bias its corresponding switch means

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toward a closed switch position, and said pneumatic means associated with said open period timer tends to bias its corresponding switch means toward an open switch position.

12. An electro-mechanical arrangement for cyclically energizing and de-energizing responsive means comprising; electrical circuitry having a source of power and including an operator circuit and a control circuit, energization means in said operator circuit for energizing and de-energizing said responsive means as a function of the closing and opening of said operator circuit, actuator means in said control circuit for opening and closing said operator circuit, said control circuit including a primary circuit and a holding circuit, first switch means in said primary circuit, second and third switch means in said holding circuit, said primary and holding circuits being connected in parallel with each other and in series with said actuator means to alternatively control the operation of said actuator means, first timer means biasing said first switch means toward a closed position, second timer means biasing said second switch means toward an open position, resilient means associated with said operator circuit tending to hold said first switch means open against the bias of said first timer means prior to said operator circuit being closed initially, initial closing of said operator circuit being effective to de-activate said resilient means and release said first switch means to the influence of said first timer means and closing said second switch means against the bias of said second timer means, said

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first timer means closing said first switch means after a first predetermined period of time to close said primary circuit, closing said primary circuit being effective to energize said actuator means, energization of said actuator means opening said operator circuit to de-energize said responsive means and closing said third switch means to close said holding circuit and maintain said actuator means energized, opening of said operator circuit being effective to activate said resilient means so as to bias said first switch means toward an open position and release said second switch means to the influence of said second timer means, said second switch means opening after a second predetermined period of time to open said holding circuit and de-energize said actuator means, de-energization of said actuator means causing said operator circuit to close and begin the cycle once more.

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