

[54] **AMBIENT-LIGHT-REGULATED NIGHT CUT-OFF POWER CONTROL UNIT**

[75] Inventors: **George Duve**, Washington; **Peter E. Wicinski**, Andover, both of N.J.

[73] Assignee: **Area Lighting Research Inc.**, Hackettstown, N.J.

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[52] U.S. Cl. **250/206; 250/215; 317/124; 200/38 DC**

[51] Int. Cl.² **G09F 11/10**

[58] Field of Search **250/206, 215, 214 R; 307/117; 317/124; 200/38 DC, 38 D, 38 DA; 315/159; 219/502**

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Primary Examiner—Walter Stolwein
Attorney, Agent, or Firm—Kirschstein, Kirschstein, Ottinger & Frank

[57] **ABSTRACT**

A power control unit that, responsive to the dimming of light at dusk, energizes a lamp load as a result of a change of state of a photocell. Furthermore, the photocell, with the assistance of a timer, measures the span of time between dawn and dusk. The unit determines a fraction of such span as a function of the time between dawn and dusk for each day. The fraction varies with the day of the year in a manner such that the period of time selected for each day is longer when the daytime is shorter and the nighttime longer and is shorter when the daytime is longer and the nighttime shorter. At a time after dusk equal to said period, the unit de-energizes the lamp load. Because the unit is regulated by the length of the span of time between dawn and dusk, the unit automatically will vary the off/on ratio of the lamp load as the lengths of days and nights vary and, furthermore, automatically will re-establish correct off-and-on real times when power is resumed after a power failure.

11 Claims, 7 Drawing Figures

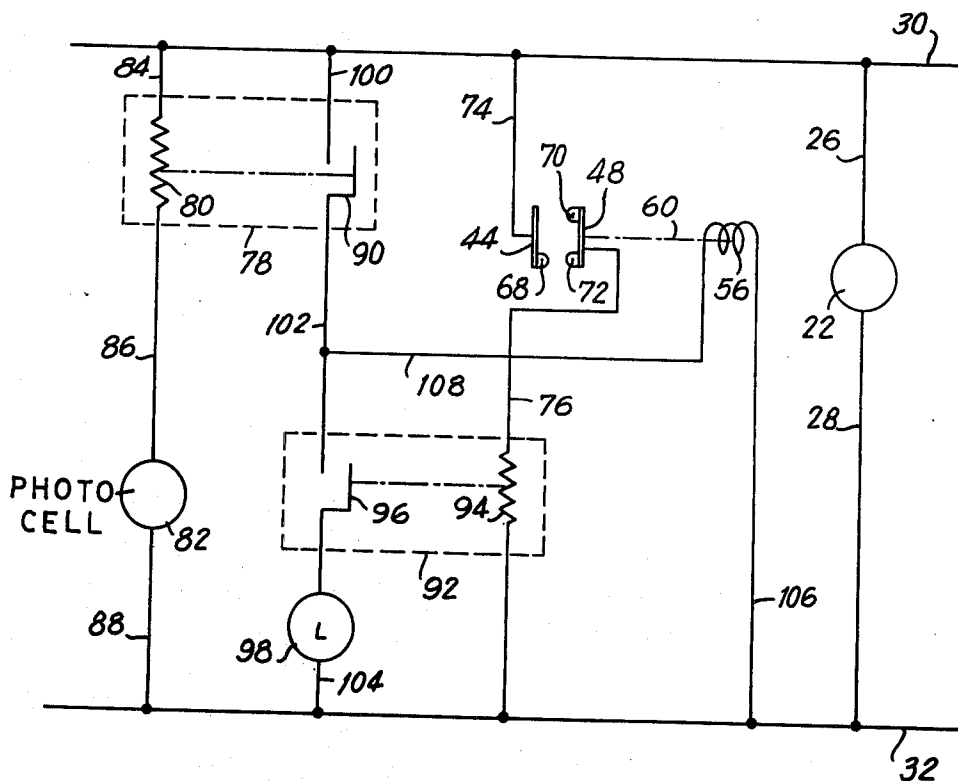


FIG. 1

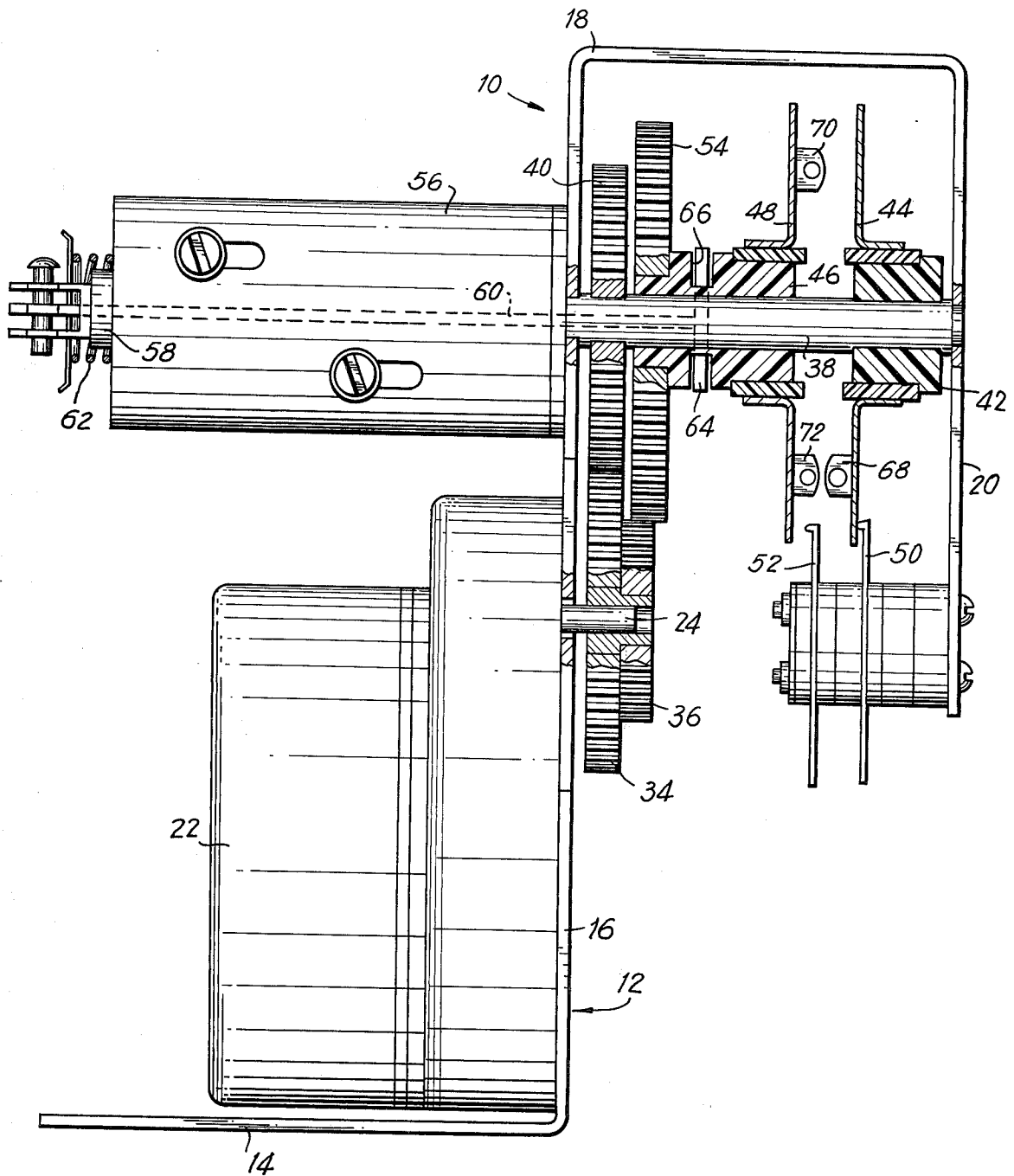


FIG. 2

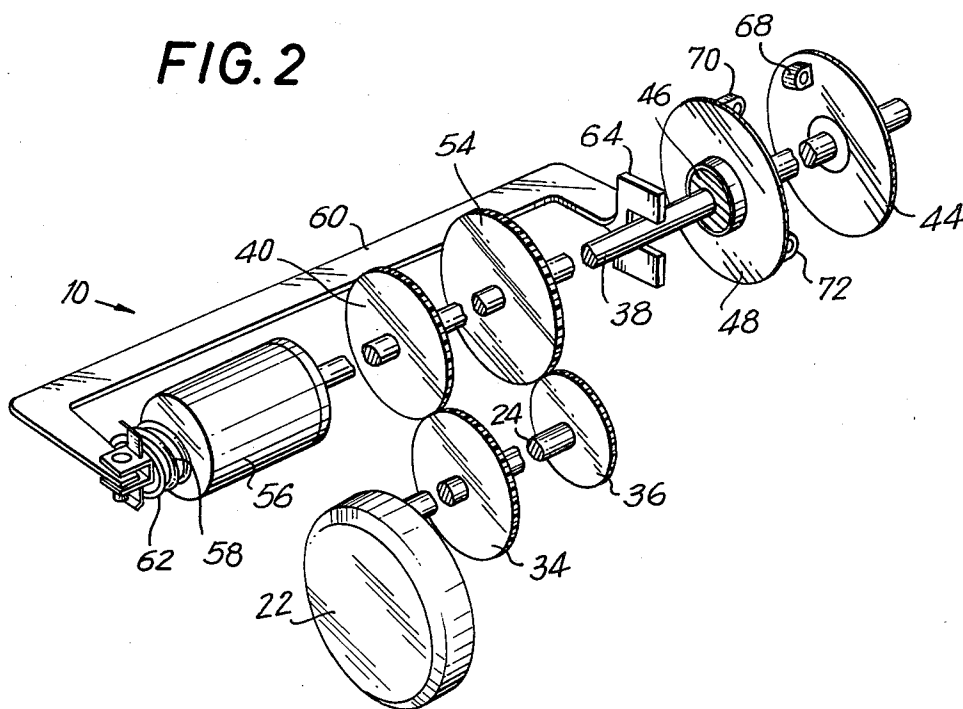
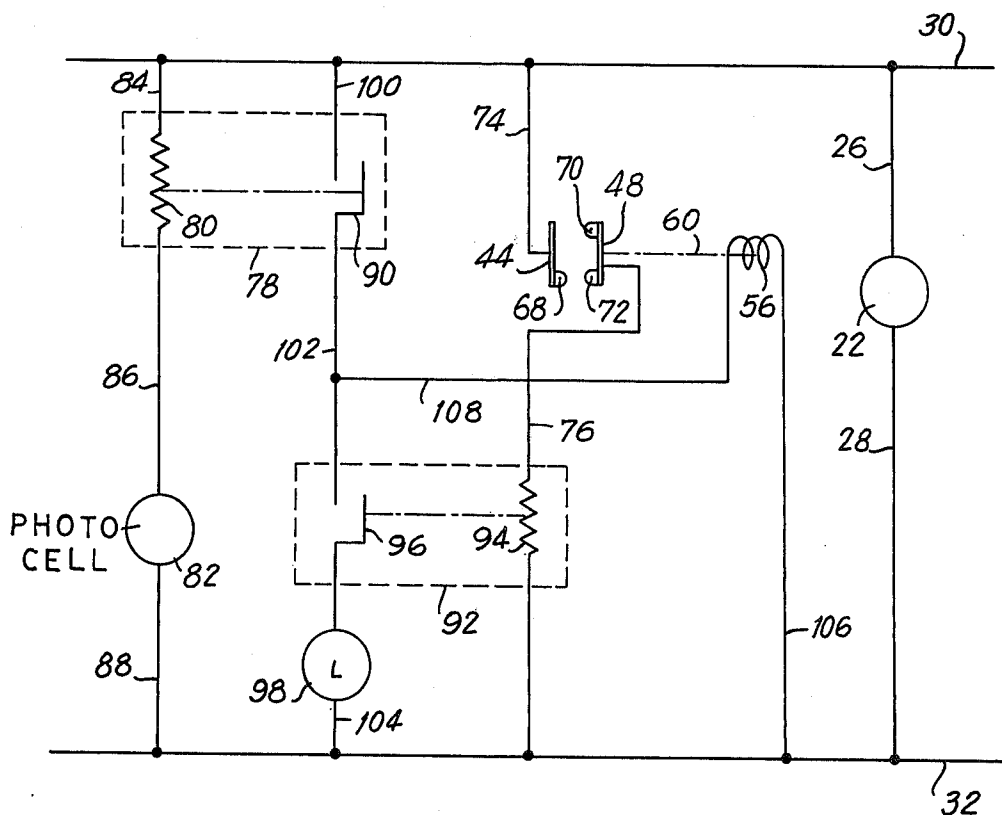
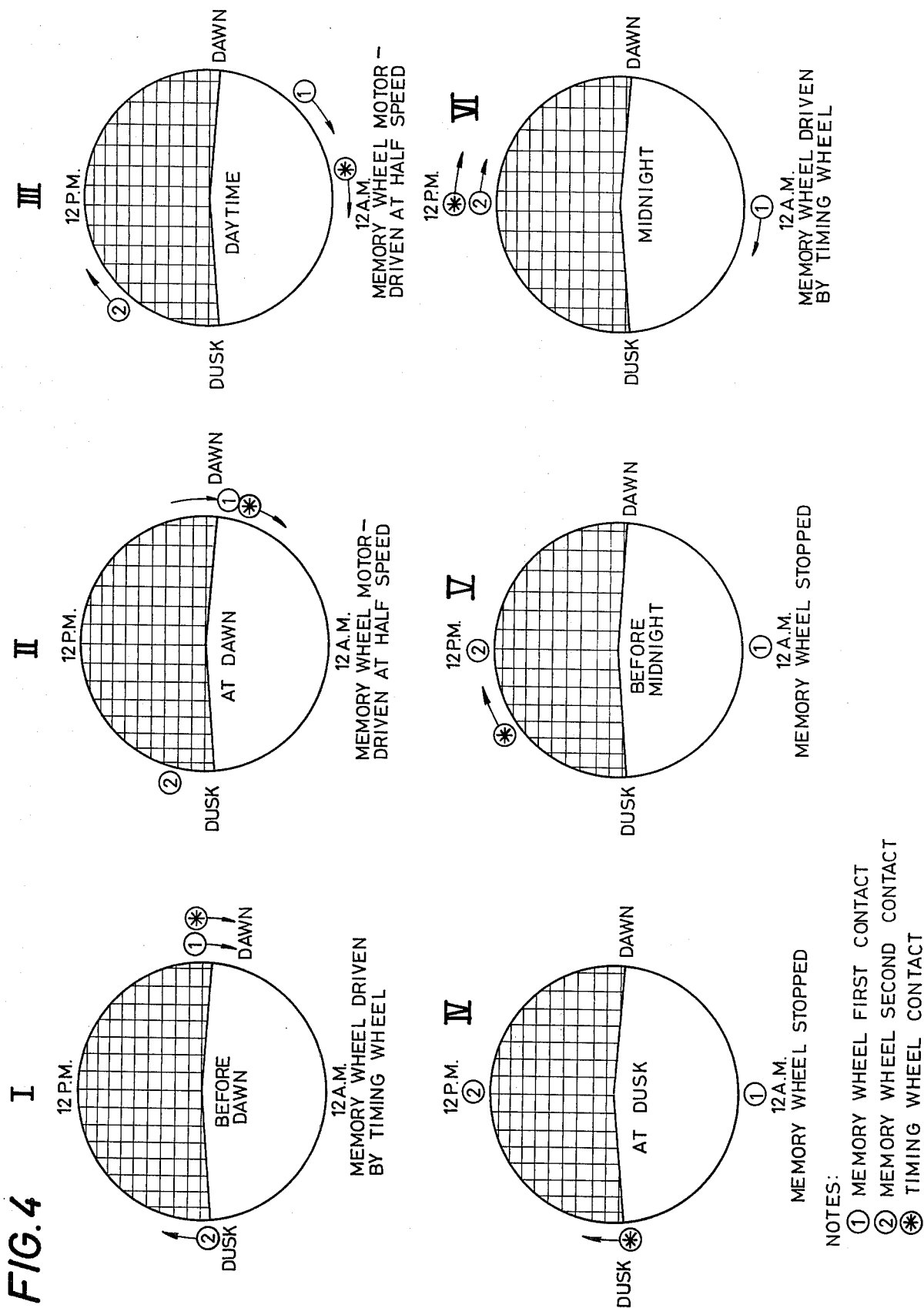


FIG. 3





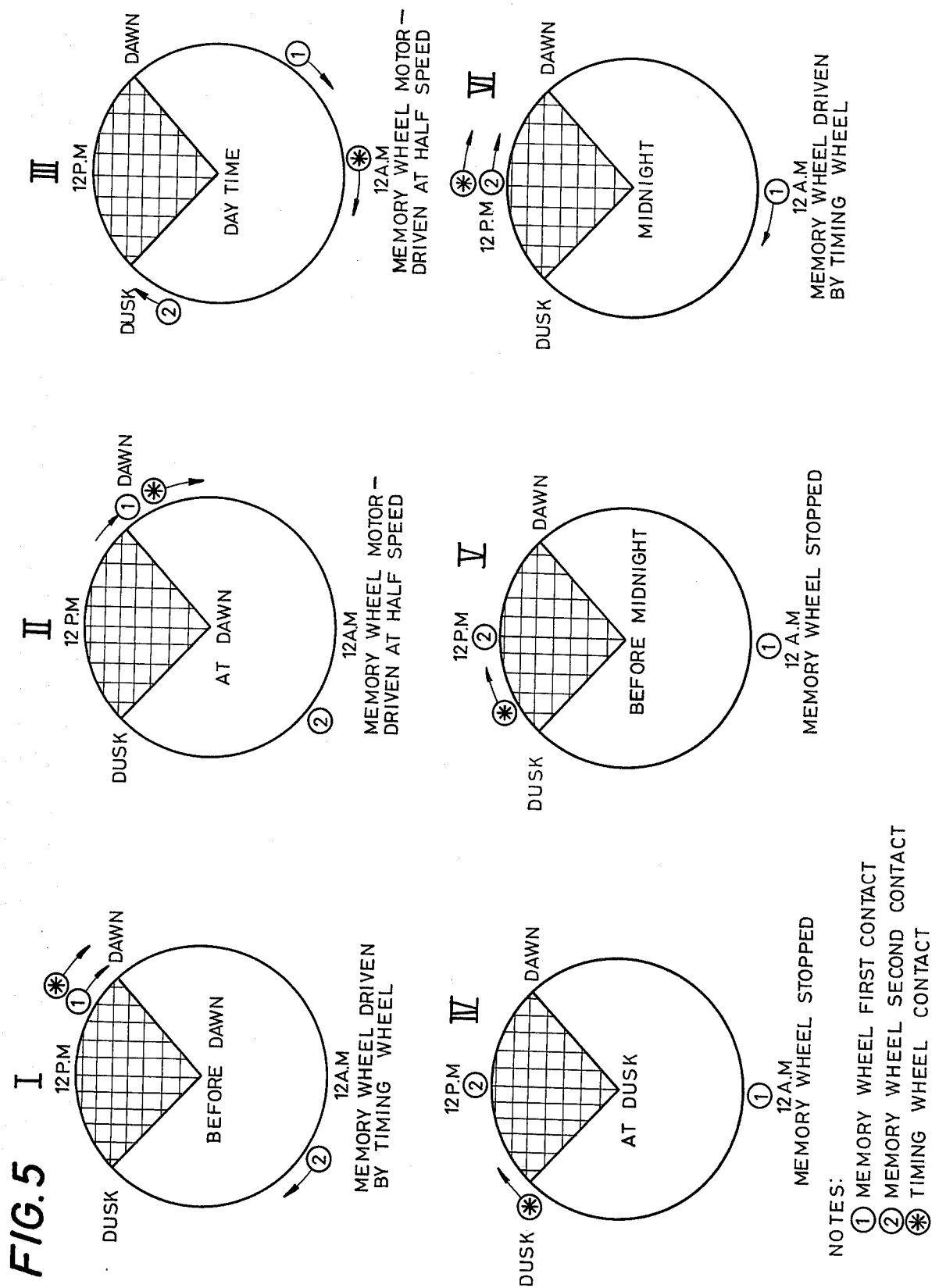


FIG. 6

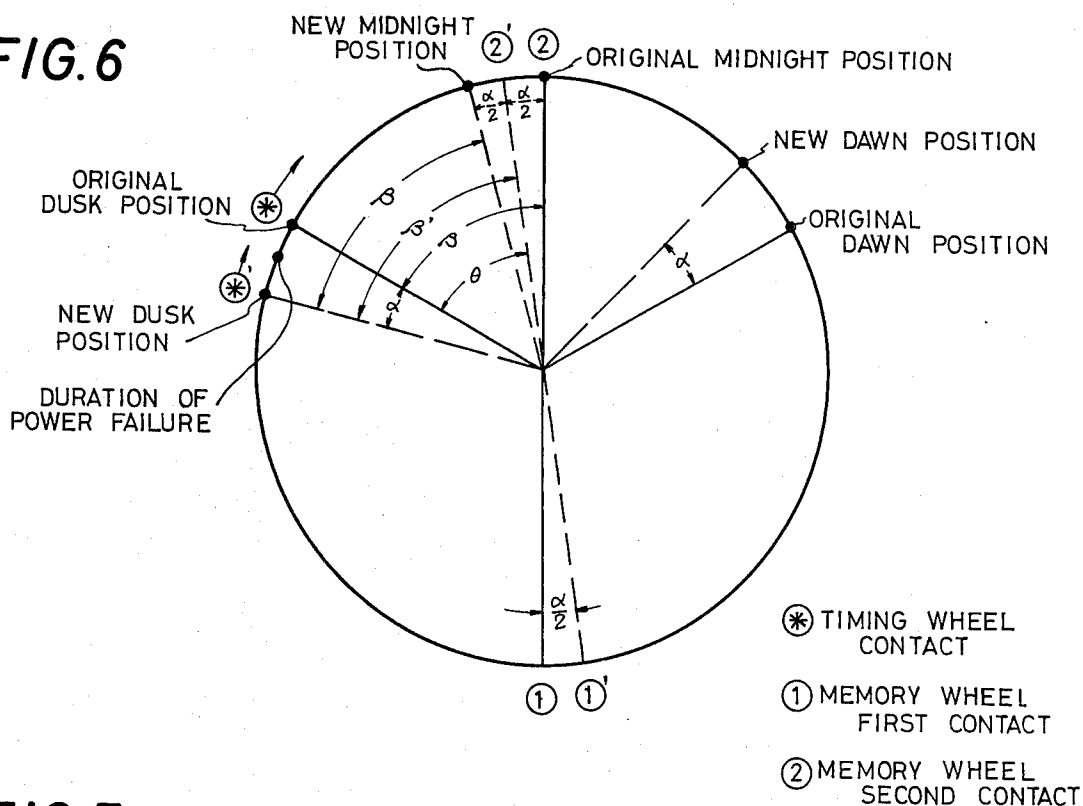
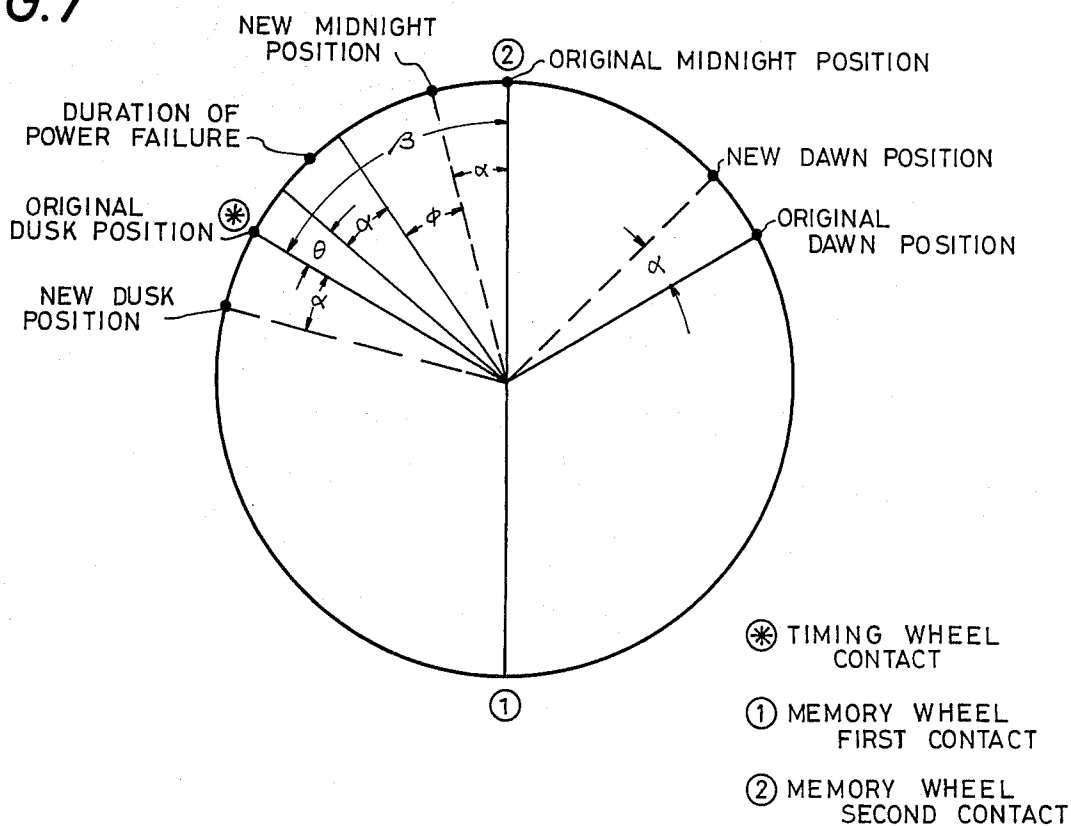


FIG. 7



AMBIENT-LIGHT-REGULATED NIGHT CUT-OFF POWER CONTROL UNIT

BACKGROUND OF THE INVENTION

1. Field of the Invention

A power control unit that measures the span of time between dawn and dusk and in response to such measurement, which varies from day to day, regulates the period of energization of an electric load.

2. Description of the Prior Art

Certain types of electric loads, notably outdoor lighting loads, desirably are automatically controlled by ambient light conditions. Indoor lighting loads, as in homes, apartment houses, factories and offices, usually are turned off or on by hand. However, loads such as street lighting loads, highways lighting loads and area lighting loads, for various reasons such as economy, their isolated positions and to guard against forgetfulness, are turned on automatically at dusk and are turned off subsequently, e.g., at dawn for street and highway lighting loads and sometime during the night for area lighting loads. Typical areas are parking lots, parks and building perimeters.

Various control systems have been employed for this purpose. For street and road lighting loads the system in common use is photoelectrically regulated, turning on at dusk and off at dawn. Recently, with the advent of the energy crisis this system has posed a difficulty, to wit, the energization of more lights than was necessary at off-traffic hours, i.e., late at night. The current solution to this difficulty — permanently disconnecting some light, e.g., every other light — was satisfactory for late hours, but somewhat hazardous for early hours such as from dusk to midnight.

It might be thought that clocks would be suitable to overcome the problem, the same to be used to shut off some, but not all, of the lighting loads at a preselected night hour. However, simple, i.e., 24-hour, clocks do not suit the purpose because the span of time from dusk to a preselected evening hour varies from day to day and from season to season. Even this further drawback might be believed to be solvable by the use of astronomical clocks. An astronomical clock is one that alters a span of time as a function of the change in the day of a year. Such a clock includes an electric 24-hour timer and an electric 365-day timer, the 24-hour day being subdivided by the year timer into time periods that are functions of the day of the year.

Nevertheless, even the astronomical clock does not provide an acceptable answer. One objection to these clocks is their cost which is high in comparison to a simple clock; another and more serious objection is that an astronomical clock does not measure real time; it only can measure abstract time. In other words, an astronomical clock can only measure time as long as the clock is running. If the clock stops, the abstract time measured by the clock stops, while real time, the passage of which is inexorable, continues. Therefore, in the event of a power failure, astronomical clocks lose track of real time — they are out of step with real time. When power is re-established, astronomical clocks resume their measurement of abstract time as if the failure never had existed. What this means in concrete terms is that, if astronomical clocks are used for turning off certain street and road lighting loads at a preselected hour of the night, every clock must be re-set by hand after power is restored. Since there is a huge num-

ber of such loads, the re-setting of the astronomical clocks creates an economic burden.

The same considerations apply to area lighting loads. Here the problem is similar, but more serious because area lighting is not considered to be necessary in the very late hours of the night so that in many situations area lighting is almost invariably turned off at a preselected hour of the night. Astronomical clocks are used for area lighting shut-off and sometimes for turn-on as well, although the latter can be performed by a device, e.g., a photoelectric cell, responsive to ambient lighting conditions. The power failure disturbance is more easily rectified because the clock is not isolated and because only one or a few clocks are used for a given area so that it or they can be re-set by personnel affiliated with the area. Still, the twin problems of cost and forgetfulness mitigate against the utilization of astronomical clocks to control area lighting.

There are other fields in which power failures and length-of-day variations create problems in the control of electric loads. One example is an electric control unit used within a home or an apartment to regulate a lamp load. This type of unit is designed to turn a lamp on at or after dusk and to turn it off at a preselected late night hour. Here, too, variations in the length of day and power failure cause the 24-hour timer to be out of phase with ambient light conditions and real time, and to require re-setting which in this instance does not give rise to a massive effort, yet is inconvenient and, so far as variation in length of day is concerned, a nuisance since re-setting must be practiced on a weekly or bi-weekly basis.

Another example is a two-rate power consumption meter, a meter that measures power consumption over different periods of a day, customarily in order to charge a high rate in a period of greater demand, and to charge a low rate in a period of low demand. It would be convenient to use a control unit at each meter to switch from one rate to another at selected times of day were it not for the loss of step between real and abstract time resulting from a power failure. In this example, length-of-day variations are not a factor except insofar as the control unit may include an off/on ambient light reference.

SUMMARY OF THE INVENTION

1. Purposes of the Invention

It is an object of the invention to provide a power control unit which avoids the foregoing difficulties, problems and drawbacks.

It is another object of the invention to provide a unit of the character described which is capable of energizing an electric load at a time of day that either is a fixed hour of a day or an hour of a day that is a function of the length of a day that is preselected and, hence, independent of the length of the current day.

It is another object of the invention to provide a unit of the character described which measures a span of time between dawn and dusk of every day, determines a preselected fraction of such span and then, at time equal to said fraction after dusk for that day, de-energizes an electric load.

It is another object of the invention to provide a unit of the character described which utilizes a time of transition of ambient light every day, preferably dusk, as a point of reference and then, for de-energization of an electric load, measures from said reference point a span of time that is a fraction of the period between

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dawn and dusk or that day.

It is another object of the invention to provide a unit of the character described which with the use of a 24-hour electric timer, and without an astronomical clock, sets a de-energization time or an electric load which time is independent of length-of-day variation.

It is another object of the invention to provide a unit of the character described which will de-energize an electric load at approximately a preselected hour of every day and is unaffected by a power failure to the extent that, although for the day the failure occurs the de-energization time may be altered, depending upon the time of day that the failure occurs, the de-energization will be re-established automatically the succeeding full time power day.

It is another object of the invention to provide a unit of the character described in which each day at dawn a first contact starts uninterrupted constant speed movement through a closed cycle that it completes the following dawn, in which each day at dawn a second contact starts movement in a closed cycle well ahead of and at a preselected slower rate than the first contact, in which at dusk of each day the second contact is stopped and an electric load is energized, in which at approximately a preselected hour of each day the first contact catches up and couples with the stopped second contact and de-energizes the electric load, and in which from said preselected hour of each day until dawn the first and second coupled contacts travel together in their respective cycles, the second contact constituting a pair of conjointly movable such contacts mutually fixedly spaced apart in their cycle so that one second contact is always well ahead of the first contact at dawn while the other second contact is coupled to the first contact, the other second contact being uncoupled from the first contact at dawn to permit the first contact to race after the 1- second contact, the relative rates of movement of the first and second contacts being such as to obtain coupling of the first and second contacts at the preselected hour each day.

It is another object of the invention to provide a unit of the character described which constitutes relatively few and simple parts, is economical and inexpensive to manufacture and is reliable in operation.

Other objects of this invention in part will be obvious and in part will be pointed out hereinafter.

2. Brief Description of the Invention

An ambient-light-regulated night cut-off power control unit includes an electric clock that drives a first contact at a constant angular speed through a circular path once every 24 hours. The clock also drives a group of second contacts through a circular path at a slower rate, e.g., once every 48 hours. The contacts of the group of second contacts move conjointly so that their relative angular spacing remains constant. With two contacts in the group the spacing between the same is 180°. The radii of the two circular paths are equal and their centers are coincident. An electrically controlled mechanism moves one of the two paths relative to the other in a direction perpendicular to their planes of movement so that in one condition of the mechanism the planes of the two paths essentially are coincident and in a second condition of the paths are mutually displaced in the aforesaid perpendicular direction. The mechanism is under the control of a light responsive device which from dusk to dawn causes the first condition to prevail and which from dawn to dusk causes the second condition to prevail.

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The electric load has an energizing circuit with two switches series connected therein. One switch is operated by the light responsive device, being closed from dusk to dawn and open from dawn to dusk. The other switch is operated by the first contact and the group of second contacts, being closed when the first contact is not coupled to a second contact and open when the first contact is coupled to a second contact.

With the aforesaid construction, between the preselected de-energization hour and dawn the first contact is coupled to a second contact; previously the drive between the clock and the second contact had been disengaged so that the first contact moves the second contact with it, i.e., contacts move conjointly. Such disengagement of the drive took place when the light responsive device sensed the transition from daylight to dusk. At daylight the electrically controlled mechanism disengages the first contact from the aforesaid second contact so that while the first contact continues its travel in the 24-hour cycle, the second contact now is driven in a 48-hour cycle whereby the first contact leaves the said second contact behind it and starts to race forward to another second contact which, when there are two second contacts, as there are in the embodiment now being described, is, at dawn, 180° ahead of the first contact.

The first contact during the daylight hours reduces the arc between itself and the other second contact and will approach the other second contact at dusk by a fraction of the length of daylight at a given day on which the operation of the unit is operation considered.

As dusk falls the light responsive device senses the change in ambient light and upon the occurrence of dusk will actuate the electrically controlled mechanism to disengage both of the second contacts from the clock so that, at dusk, both of the second contacts become stationary.

Where there are two second contacts spaced 180° apart, the other second contact (the one being approached by the moving first contact) is in a position, with respect to the frame of the unit, corresponding to midnight because midnight (and noon) are half-way between dusk and dawn and because the aforesaid fraction is half of the dawn-to-dusk time span. As dusk passes into night, the first contact continues to approach the other second contact (the one at the midnight position) until, finally, the first contact engages said other second contact. This engagement de-energizes the lighting load which had been energized under the control of the light responsive device when dusk fell. When the first contact engages (couples to) the other second contact, the aforesaid sequence of operations repeats.

The aforesaid device, i.e., the device above described, will function as a true time-of-the-day de-energizing device for its geographical location, that is to say, where the group of second contacts revolves at one-half the speed of the first contact, the device will turn off the light at true midnight (the bisection of the time from dusk to dawn at the geographical location of the power control unit). It therefore will disregard the mean time for the particular time zone in which the unit is located and likewise will disregard any artificially controlled shifting of such time such, for instance, as daylight-saving time.

The invention consists in the features of construction, combinations of elements and arrangements of

parts which will be exemplified in the unit hereinafter described and of which the scope of application will be indicated in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings in which is shown one of the various possible embodiments of the invention:

FIG. 1 is a side view in partial vertical control section of a power control unit embodying the present invention;

FIG. 2 is a perspective exploded schematic view of the principal components of the control unit;

FIG. 3 is a diagram of the electric circuit of the control unit;

FIG. 4 is a series of six circle graphs illustrating the sequence of operations of the power unit and the locations of the sundry contacts at different times of a day in the winter;

FIG. 5 shows circle graphs similar to FIG. 4 but at different times of a day in the summer;

FIG. 6 is a circle graph showing the positions of the contacts in explanation of the operation of the unit when power fails between dawn and dusk; and

FIG. 7 is a view similar to FIG. 6 but showing the positions of the contacts when power fails between dusk and midnight.

PREFERRED EMBODIMENT OF THE INVENTION

Referring now in detail to the drawings, and, more particularly, to FIGS. 1 - 3, the reference numeral 10 denotes a power control unit constructed in accordance with the present invention. Said unit includes certain mechanical parts which are best understood by reference to FIGS. 1 and 2, and certain electrical parts which are best understood by reference to FIGS. 1 and 2 and the connections between which are shown in FIG. 3.

The unit includes a frame 12 of any convenient configuration that serves to support the sundry parts of the unit. The frame is stationary. All angular positions of the various moving parts are positions with respect to the stationary frame. As illustrated, and as best seen in FIG. 1, the frame 12 is of Z shape with a depending leg at one tip of the Z. More specifically, the frame constitutes a straight horizontal reach 14 which is adapted to be secured to a support, e.g., a horizontal support, below it. (It will be understood that the unit will operate with the reach 14 horizontal and lowermost, or vertical, or with the reach 14 horizontal and uppermost.) The reach 14 has attached to an end thereof a straight vertical reach 16 at the upper end of which is a second straight horizontal reach 18 that terminates in a second straight vertical reach 20. The horizontal reach 18 extends away from the vertical reach 16 in a direction opposite to the horizontal reach 14 so that the two horizontal reaches, in addition to being at the top and bottom of the vertical reach, are on the right and left sides thereof, respectively, as seen in FIG. 1. The vertical reach 20 extends downwardly toward the plane of the horizontal reach 14.

The vertical reach 16 has secured thereto the casing of a 24-hour timing motor 22 that includes an output shaft 24 which extends through the vertical reach 16 toward the vertical reach 20. The timing motor 22 is connected by leads 26, 28 (see FIG. 3) to power lines 30, 32.

For simplicity, the timing motor 22 is of a synchronous type adapted to be energized from an AC source

of power, for example, a 60-cycle AC source of power, and rotates at a constant speed. The motor has an internal gear train (not shown) that turns the output shaft 24 once every 24 hours. Inasmuch as the timing motor is connected directly across the power lines, it will turn constantly so long as power is supplied.

Fixed to the timing motor shaft is a large gear 34 and a small gear 36. These gears turn at the same angular speed and are effectively unitary. By way of example, the large gear has on it 54 teeth and the small gear has 36 teeth. Rotatably supported by and between the vertical reaches 16, 20 is a counter shaft 38. Said counter shaft is above and parallel to the motor output shaft 24. The shaft 38 has fixed to it a large gear 40 with the same number of teeth as the large gear 34, in the embodiment being described, therefore, 54 teeth. The gear 40 is permanently in mesh with the gear 34. Hence, the shaft 38 rotates at the same speed as the shaft 24, which is to say, one revolution per day.

Fixed to the shaft 38 remote from the vertical reach 16 and near the vertical reach 20 is an electrically non-conductive collar 42. The collar 42 rotates with the shaft 38. It may be made of a material such, for example, as plastic, e.g., a phenol-formaldehyde condensation resin. The collar 42 has secured to it a timing wheel 44. The timing wheel is flat and circular and is composed of electrically conductive material such, for instance, as brass. The timing wheel is schematically indicated in FIG. 3. It will be quite apparent that it turns at the same rate as the output shaft of the timing motor, which is to say, one revolution per day, and that it continues to turn so long as there is power in the lines 30, 32.

Slidable longitudinally on the counter shaft 38 is a sleeve 46 of electrically non-conductive material such, for example, as a phenol-formaldehyde condensation resin. This sleeve has fixed to it a memory wheel 48 of electrically conductive material such as brass. The memory wheel 48 is parallel to and faces the timing wheel 44. The two wheels are spaced apart so as to be out of contact with each other. The two wheels have associated therewith brushes that enable them to be connected in the circuit shown in FIG. 3. Specifically, there is associated with the timing wheel 44 a timing brush 50 and with the memory wheel 48 a memory brush 52. The timing brush constantly bears against the timing wheel. The memory brush, however, need not bear constantly against the memory wheel; it will suffice if it bears against the memory wheel in a certain condition (position) of the memory wheel which hereinafter will be referred to as the first condition and also, on occasion, as the actuated condition.

The memory wheel is adjacent one end of the sleeve 46, this being the end closer to the collar 42. The opposite end of the memory wheel has fixed thereon a large gear 54 which, by way of example, has 72 teeth, this being exactly twice the number of teeth as on the small gear 36.

Means is included to longitudinally shift the sleeve 46 between the first, i.e., actuated, condition and a second, i.e., deactuated, condition. In FIG. 1 the sleeve 46 is shown in its second, to wit, deactuated, condition. The aforesaid shifting means includes a solenoid 56, the bobbin of which is secured to the vertical reach 16. The solenoid has an armature 58 to the outer end of which a yoke 60 is attached. A return spring 62 biases the armature 58 to the left (deactuated condition), as viewed in FIG. 1. The yoke 60 extends behind the sole-

noid bobbin toward the shaft 38 and terminates in a pair of arms 64 that engage an annular slot 66 in the sleeve 46. Thus, when the solenoid is de-energized the return spring will urge the armature 58 to the left, as shown in FIG. 1, and will shift the sleeve 46 and the parts carried thereby toward the left into the position illustrated in FIG. 1. When the solenoid is energized it will shift the sleeve to the right, as viewed in FIG. 1.

When the sleeve 46 is in its second condition, i.e., its deactuated condition, the gears 36 and 54 are in mesh. In this condition the sleeve 46 and the memory wheel 48 will be driven by the timing motor at half the speed of the timing wheel 44, to wit, one revolution every two days. When the solenoid is energized the sleeve 46 will be shifted to the right to disengage the gears 36, 54 which will permit either one of two events to transpire, namely, (1) the memory wheel will remain stationary, there being sufficient friction between the arm 64 and the slot 66 to hold the sleeve and memory wheel stationary despite the rotation of the counter shaft 38 within the bore of the sleeve, or (2) the memory wheel will be turned by the timing wheel.

The timing wheel has a single contact 68, hereinafter sometimes referred to as the first contact, which extends away from the plane of the timing wheel toward the plane of the memory wheel. The memory wheel has a pair of contacts 70, 72, hereinafter sometimes referred to as the second contacts. These contacts in the control unit being described are 180° apart. The second contacts extend from the memory wheel toward the plane of the timing wheel. The first contact and the second contacts are at the same radial spacing from the center of the counter shaft 38 so that if the two wheels are close enough to each other, one or the other of the second contacts is in the path of the first contact and will be struck thereby (coupled thereto), it being recalled that the first contact turns twice as fast about the counter shaft as the second contacts when both wheels are being driven by the timing motor.

In order to enable the gears 36, 54 to mesh with each other when the sleeve 46 is shifted by the return spring to its second (deactuated) condition, the mutually facing sides of the teeth on these two gears are tapered, thereby enabling them to conveniently cam into mesh.

To recapitulate, in the first (actuated) condition of the sleeve 46 the second contacts of the memory wheel lie in the path of travel of the first contact of the timing wheel, but the gears 36, 54 are out of mesh so that the memory wheel will either be stationary or will be driven by the timing wheel through coupled contacts. In the second (deactuated) condition of the sleeve 46 the gears 36, 54 are in mesh so that the memory wheel will be driven at half the speed of the timing wheel while at the same time the second contacts of the memory wheel are out of the path of travel of the first contact of the timing wheel.

The timing brush 50 is connected by a lead 74 to a power line, e.g., the power line 30. The memory brush 52 is connected as by a lead 76 to the other power line, e.g., the power line 32 through an electric component hereinafter described. Hence, when the first contact engages (is coupled to) a second contact a circuit will be completed between the power lines and any other electrical component that may be in that circuit, but the circuit is opened when the first contact is not coupled to either second contact.

Two relays are employed in the operation of the power unit. Conveniently, these relays constitute and

are illustrated as thermal relays, although it will be understood that any other type of relay is acceptable, e.g., an electromechanical relay or an electronic relay, both of which are well known to the art. The first of the relays is a photocontrol relay 78 (see FIG. 3). It includes a resistance 80 in series with a photocell 82. The relay and photocell are connected in series between the power lines 30 and 32 by leads 84, 86, 88. The photocell has a high impedance at night and a low impedance in the daylight. Therefore, in the daylight the resistance 80 is warm and at night the resistance 80 is cool. Associated with the resistance 80 is a pair of normally closed contacts 90. When the resistance 80 is warm, the contacts 90 are open. When the resistance 80 is cool, the contacts 90 are closed. The contacts 90 will be sometimes referred to hereinafter as the photocontrol contacts. Most conveniently, the resistance 80 operates the contacts 90 through a bimetallic strip, the strip flexing in one direction to open the contacts when the resistance 80 is warm and straightening out to close the contacts when the resistance 80 is cool.

The second of the relays is a turn-off relay 92. It includes a resistance 94. Associated with the resistance 94 is a pair of normally closed contacts 96, hereinafter sometimes referred to as the turn-off contacts. When the resistance 94 is warm, the contacts 96 are open. When the resistance 94 is cool, the contacts 96 are closed. A similar bimetallic strip can be used for the turn-off relay 92.

The circuit also includes a load 98 which in the presently preferred use of the control unit constitutes a lamp load, for example, a street or road light or an area light.

Referring again to FIG. 3, a lead 100 runs from the power line 30 to the contacts 90. From the contacts 90 a lead 102 runs through the contacts 96 to the load 98. A lead 104 extends from the load 98 to the power line 32. The resistance 94 is interposed in the lead 76. A lead 106 connects the power line 32 to one end of the solenoid 56. Another lead 108 connects the other end of the solenoid to the lead 102.

Turning now to the operation of the control unit and considering the same for a normal (non-power failure) cycle, such cycle first will be described with respect to a typical day in the wintertime for which the circular graphs are illustrated in FIG. 4. Inasmuch as the operating cycle of the control unit is repetitive on a 24-hour basis, except for a certain variation that soon will become apparent and which depends upon the change in length of day as the days progress, it is convenient to consider some starting point to which the cycle substantially will return after 24 hours, the difference between the points of return constituting the mode by which the present invention includes an astronomical feature.

The starting point will be taken as shortly before dawn, for which the positions of the various contacts are shown in the first graph (graph I) of FIG. 4. At this time, for reasons which soon will be apparent, the timing wheel contact 68, also referred to as the first contact and which is denoted by an asterisk in a circle, is at a certain angular position with respect to the frame of the control unit; the first contact[⊙] is coupled to and driving at a one-per-24-hour revolution rate one of the second contacts 70, 72 of the memory wheel. The second contact shown being driven as aforesaid is the contact 70 and is denoted by the reference numeral 1 in a circle. The other second contact, to wit, the

contact 72, which is 180° away from the contact ①, is denoted by the reference numeral 2 in a circle. The directions of rotation of all three contacts ③, ① and ② are indicated by arrows. At this time all of the contacts are turning at the same speed.

When the sun rises at dawn, the contacts ① and ③ still are moving together. Just before the sun rises, the photocell 82 has a high impedance so that very little current is flowing through the resistance 80 of the photo-control relay. Therefore, the contacts 90 are closed. This causes current to flow from the power line 30 through the lead 100, then through the contacts 90 and the lead 108 to the solenoid 56 and, finally, through the lead 106 to the power line 32. Of course, this condition had existed for some time previously, actually, since the setting of the sun at dusk. However, it is mentioned here in order to appreciate the conditions that prevail in the circuit and in the control unit immediately prior to dawn. Since the solenoid is energized, the timing wheel is in its first condition and, furthermore, because the contact ③ has caught up with (is coupled to) the contact ① and is driving the same, current is flowing from the power line 30 through the lead 74, the contacts ③, and ① and the lead 76 to the power line 32, passing through the resistance 94. Because the resistance 94 is energized, it opens the contacts 96. Hence, the circuit to the load 98 is broken. Accordingly, the load is off, i.e., deactuated, before dawn. Also, due to the fact that the sleeve 46 is in its first condition, the gears 36 and 54 are disengaged, thus allowing the timing wheel to drive the memory wheel through their coupled contacts.

As dawn occurs (see graph II), the impedance of the photocell 82 drops to a low value allowing sufficient current to flow through the resistance 80 to open the contacts 90. Opening of said contacts 90 de-energizes the solenoid 56 and permits the return spring 58 to shift the sleeve 46 to its second (deactuated) condition in which, firstly, the contacts ① and ③ disengage, and secondly, the gears 36 and 54 mesh. Separation of the contacts ③ and ① opens the current path through the resistance 94 so that the contacts 96 close. However, the contacts 90 have opened so that the load does not energize. Because the memory wheel 48 is now driven by the engaged gears 36 and 54, said wheel is rotating but at a speed which is half of the speed of the timing wheel with the gear ratios given. Therefore, the contact ③ starts to move ahead of the contact ① and to catch up with the contact ② which is rotating at the same speed as the contact ① but 180° ahead of the same. Eventually, as will be understood, the contact ③ of the timing wheel will catch up with the contact ② of the memory wheel.

During the day (see graph III), the contact ① of the memory wheel will be moving at only half the speed of the contact ③ of the timing wheel, so that at any given time of the day the contact ① of the memory wheel will have moved through only half the angular distance that has been traversed by the contact ③ of the timing wheel. Obviously, if a different gear ratio had been used than the two-to-one ratio described, the ratio between the distances would have been different.

As the day progresses, the contact ③ of the timing wheel moves further and further away from the contact ① of the memory wheel but approaches the contact ② of the memory wheel. However, during the daytime the contact ③ will not catch up with the contact ② because daylight is not long enough. It will be seen that at dawn

the contact ③ of the timing wheel is 180° and, therefore, 12 hours behind the contact ② of the memory wheel. It might be thought that the timing wheel contact would catch up with the memory wheel contact ② since many days have a daylight time of more than 12 hours. However, it should be realized that as the timing wheel contact is moving through the aforesaid 12-hour arc, the memory wheel contact ② is moving through an arc of 6 hours; so at the end of the movement of the timing wheel contact through 12 hours the memory wheel contact ② still is 6 hours ahead of it, assuming both of these contacts to be moving continuously.

At dusk, for which the positions of the contacts are shown in graph IV, the timing wheel contact ③ is still behind the memory wheel contact ②. When dusk falls the impedance of the photocell is restored to a high level reducing the current through the resistance 80 to a point that enables the contacts 90 to close. It will be recalled that the contacts 96 previously were closed and still are closed. Therefore, the closing of the contacts 90 energizes the electric load 98 which, if it is a lamp load, will turn on the lamp. Concurrently, closing of the contacts 90 actuates the solenoid 56 through the circuit previously described. This shifts the sleeve 46 to its first (actuated) position placing the memory wheel contact ② in the path of travel of the timing wheel contact ③ although, because the memory wheel contact ② is still ahead of the timing wheel contact ③, the circuit to the resistance 94 still remains open.

It should be pointed out here that the memory wheel contact ② at dawn started out 12 hours ahead of the timing wheel contact ③. But during the period of daylight the timing wheel contact has reduced the distance between it and the memory wheel contact by a fraction of the distance traveled by the timing wheel contact. The fraction in the illustrated example is one-half. At dusk, therefore, the timing wheel contact still is behind the memory wheel contact ② by half of the distance traveled by the timing wheel contact during the daytime. At dusk, of course, the memory wheel 48 has stopped rotation and, similarly, the two memory contacts ① and ② have come to rest, so that from this point on, the distance between the advancing timing wheel contact and the stationary memory wheel contact closes at the rate of movement of the timing wheel contact; in other words, more rapidly than it had during the daylight hours. The movement of the timing wheel contact ③, as it approaches the stationary memory wheel contact ②, is illustrated in graph V. The memory wheel contact ② has stopped at a point corresponding to midnight, actually half the distance from dusk to dawn, or, phrased differently, 180° away from the hourly span from dawn to dusk.

Therefore, when, as shown in graph VI, the timing wheel contact ③ catches up to and couples with the memory wheel contact ②, the time will be midnight. When these two contacts touch, a circuit is completed through the resistance 94 which causes the normally closed contacts 96 to open, thereby de-energizing the electric load 98.

Thereafter, i.e., beyond midnight, the timing wheel contact ③ and the memory wheel contact ② will move together, the memory wheel contact being driven by the timing wheel contact. This is possible because the sleeve 46 is in its first (actuated) position with the gears 36, 54 out of engagement, permitting the memory wheel to be driven by the timing wheel when their contacts are physically in abutment with (coupled to)

one another. The driving of the memory wheel contact ② by the timing wheel contact* continues to the position shown in graph I immediately before dawn except, of course, that the contacts ① and ② have reversed their positions. Thereafter, the cycle repeats, starting at dawn.

The foregoing explanation has been illustrated in FIG. 4 for a mid-winter day. As daytime becomes longer, dawn will occur earlier each day, and dusk later. Therefore, the starting point of the cycle at dawn becomes earlier and the daylight arc of movement becomes longer. However, with the gear ratio shown, the daylight hours, or, conversely, the evening hours, are being split in half for location of the memory wheel contact in its idle position so that this contact always comes to rest at midnight. This position is assumed regardless of the length of daytime due to the foregoing structure and circuitry.

The above will be appreciated by reference to FIG. 5 wherein a similar series of circle graphs is illustrated for a summer day. It will be seen by observation of the positions of the various contacts that the same events are taking place, with one memory wheel contact always stopping at midnight, despite the change in the length of daytime, and waiting for the timing wheel contact to catch up with it and engage the same.

Thus, the control unit has the ability to respond to ambient light conditions or turning on the electric load and to the occurrence of a preselected time for turning off the electric load, the turn-on time always being solely a function of the falling of night and the turn-off time always being a function of the occurrence of a selected hour regardless of a change in the length of daytime, this having been accomplished without the use of an astronomical clock.

If it is desired to de-energize the electric load at a time other than true midnight, the ratio of the gears 36, 54 should be changed to a less than or greater than 2 to 1 ratio, a lower ratio being employed for a later-than-midnight turn-off and a higher ratio being employed for an earlier-than-midnight turn-off. It should be mentioned that because with a ratio different from 2 to 1 the de-energizing engagement is not symmetrical with respect to the median between dusk and dawn, the turn-off time will vary slightly and therefore only be approximate as the length of day varies.

The control unit 10, due to its unique operation, i.e., the utilization of the falling of dusk to energize an electric load and the occurrence of a preselected hour to turn off the electric load, the latter by means of the selection of a period of time which is a fraction of the hours between dawn and dusk (either from dawn to dusk or from dusk to dawn), the said additional time being added on at the occurrence of dusk for turn-off, has the ability to re-set itself any time after a power failure has been cured. Heretofore, the problem has been that upon the occurrence of a power failure a clock which was used, not recognizing the power failure, became de-phased from real time; it only measured the passage of time when electric power was present, failing to recognize the stoppage of electric power. The re-setting ability of the present control unit resides in the fact that it employs a transition between the presence and absence of ambient light, i.e., the rising or setting of the sun as a reference point. It measures a period of time between dawn and dusk (from either to the other), adds a fraction of this period to the time of dusk and, at the end of this fraction following dusk, turns off

the load that was turned on at dusk. It is simply because the unit is by virtue of the foregoing not a slave to the presence of power that it is able to re-set itself after a power failure.

The operation of the unit upon the failure of power obviously is not precise the day after the failure occurs because the unit must re-set itself after the resumption of power following failure. Moreover, the variation in the operation of the unit will depend upon when the power failure took place; there is a difference in the operation of the unit for the day when the failure takes place between dawn and dusk, when the failure takes place between dusk and midnight, and when the failure takes place between midnight and dawn.

Power failure between dawn and dusk will first be considered. The sequence of events for such power failure is best understood by reference to FIG. 6.

During the daytime the timing wheel moves twice as fast as the memory wheel 48. Thus, for any particular time interval which occurs during daylight hours, the memory wheel 48 rotates through only half the angle compared to the timing wheel 44. A power failure resulting in a retardation of the timing wheel 44 by an angle α will retard the memory wheel 48 by an angle $\alpha/2$. FIG. 6 shows the normal positions, at dusk, of the timing and memory wheel contacts with unprimed symbols *, ① and ②. The retarded positions are indicated with primed symbols *, ①' and ②'. At dusk the memory wheel stops and the energization time of the electric load is determined by the angle between the timing wheel contact* and the contact ② of the memory wheel. This angle is shown in FIG. 6 as β for a normal cycle and β' for an abnormal cycle. β is equal to $\ominus$ plus $\alpha/2$ and β' is equal to $\ominus$ plus α , therefore, β' is larger than β by an angle $\alpha/2$.

The power failure has caused the timing wheel to be retarded by an angle α ; therefore, the position of the timing wheel contact* at dusk is also retarded by an angle α . Thus, the new position of dusk has been rotated in a counterclockwise direction from the normal position at dusk by an angle α . The power failure, in effect, has rotated all the real time positions relative to the frame of the unit by an angle α in a counter-clockwise direction.

The angle between dusk and midnight is still β after the rotation, but the energization time is $62 \text{ } \alpha/2$. Since both β' and β were measured from dusk, the load will be energized after midnight for a time which is equal to half the power failure duration for the day the failure occurred between dawn and dusk.

After the timing wheel and memory wheel contacts mate, and the load is turned off, the control is back to normal operation condition. After the next dawn the only change caused by the power failure is that the timing wheel has a different position relative to the frame of the unit. Since the operation of the unit is independent of any position relative to the frame, the unit will continue to operate normally.

Power failure between dusk and midnight now will be considered.

A power failure during the evening will, of course, de-energize the load for the duration of the interruption. At dusk the unit is still operating normally and the timing wheel and memory wheel contacts are in the positions shown in FIG. 7. The memory wheel 48 stops rotating at dusk and the contact ② remains in this position. The time interval between dusk and the start of the power failure is indicated by $\ominus$ in FIG. 7. The dura-

tion of the power failure is represented by the angle α . Due to the power failure the new midnight position relative to the frame of the unit has been rotated by an angle α , in a counter-clockwise direction, from the original midnight position. The time between the end of the power failure and the new midnight position is angle ϕ in FIG. 7.

The normal burning time is represented by β which is the angle between the timing wheel contact $\textcircled{*}$ at dusk and the stationary memory contact $\textcircled{2}$. This angle is fixed because these positions were determined at dusk and the power failure came after dusk. As can be seen from FIG. 7, the load will turn off at the original midnight position. Since the new midnight position has advanced by an angle α , the load will continue to be energized beyond midnight for a period which is the same as the power failure. After the load has been turned off at night, the control is back in normal operating condition. The only noticeable change after the power failure is that all the time positions relative to the frame of the unit have changed. Since the operation of the unit is independent of any position relative to the frame, the unit will continue to operate normally.

The last situation to be considered is the effect of a power failure between midnight and dawn.

Between midnight and dawn the timing wheel and memory wheel contacts are in contact (coupled). The mechanical part of the unit 10 performs no timing operation during this part of the cycle; its only function during this period is to keep the timing wheel and memory wheel contacts together. Therefore, a power failure will have no effect upon the operation at this time. Upon the resumption of power, the load will be energized for a period of about one minute. This is due to the time delay in the turn-off relay 92. As with power failure in the other situations, the time positions relative to the frame of the unit have changed, but this has no effect on the operation of the unit.

It thus will be seen that there is provided a control unit which achieves the various objects of the invention and which is well adapted to meet the conditions of practical use.

As various possible embodiments might be made of the above invention, and as various changes might be made in the embodiment above set forth, it is to be understood that all matter herein described or shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

Having thus described the invention there is claimed as new and desired to be secured by Letters Patent:

1. An ambient-light-regulated night cut-off power system comprising: a continually operating clock, a light-responsive device the condition of which changes at dawn and at dusk, an electric load, a source of electric power, a control unit regulating the energy of said electric load from said source of electric power, means controlled by the light-responsive device to energize said load at dusk, means controlled by the condition of the light-responsive device for daily determining the span of time measured by the clock between dawn and dusk, means for determining a fraction of said span as a function of the time between dawn and dusk for each day, the fraction varying with the day of the year in such manner that a period of time is selected for each day which period is longer when the daytime is shorter and the nighttime longer and is shorter when the daytime is longer and the nighttime shorter, and means for de-energizing the electric load at a time beyond dusk

equal to said period of time so that de-energizing of the load takes place at approximately the same time each day for the geographical location of the unit regardless of the length of day and so that the time of de-energizing is re-established on the day following a de-energization when a power failure occurs.

2. A system as set forth in claim 1 wherein the means controlled by the condition of the light-responsive device for daily determining the span of time measured by the clock between dawn and dusk determines the span of time measured by the clock from dawn to dusk.

3. A system as set forth in claim 1 wherein the time beyond dusk is true midnight for the geographical location of the unit.

4. A system as set forth in claim 1 wherein circuit means is included to actuate the energizing means under the regulation of the light-responsive device.

5. A system as set forth in claim 1 wherein the means for determining the fraction of said span of time constitutes a pair of rotary elements driven by the clock at different rates of speed between dawn and dusk, said rotary elements experiencing a relative angular change due to their different rates of speed of travel, said fraction being a function of such relative angular change.

6. A system as set forth in claim 1 wherein the clock is a 24-hour clock.

7. A system as set forth in claim 1 wherein the control means, the determining means and the de-energizing means constitute two shafts, means continually driving one of said shafts from the clock at one revolution per day, means driving the other shaft from the clock at a fraction of one revolution per day, said last-named driving means including means for rendering the same ineffective, said one shaft driving a first contact, the other of said shafts driving at least two angularly spaced second contacts, one or another of the second contacts being in the path of travel of the first contact when the de-energizing means is effective to prevent the other shaft from being driven by the clock, the second contacts being out of the path of travel of the first contact when the de-energizing means permits driving of the other shaft by the clock.

8. A system as set forth in claim 7 wherein circuit means is included for actuation and de-actuation of the energizing means under the control of the light-responsive device, the circuit means being effective to prevent turning of the second shaft by the clock from dusk to dawn.

9. A system as set forth in claim 8 wherein the means energizing the electric load from the source of electric power includes switches, of which one is under the control of the light-responsive device and the other is under the control of said contacts, the load being de-energized when the first contact engages a second contact and the time of day is the period from dusk to dawn.

10. A system as set forth in claim 1 wherein the control means, the determining means and the de-energizing means constitute a first shaft, means for constantly driving the first shaft from the motor at one revolution per day, a sleeve on the shaft, said sleeve being rotatable and axially shiftable with respect to the shaft, said sleeve having a gear thereon, said output shaft having a gear thereon engageable with the gear on the sleeve, the ratio of said gears being such that the sleeve turns slower than the shaft, a solenoid having an armature, means connecting the armature to the sleeve in such manner that when the solenoid is de-energized the

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gears are in mesh, means for shifting the sleeve and disengaging the gears when the solenoid is energized, the sleeve being stationary, unless driven, when the gears are disengaged, a first contact carried by the shaft, at least two second contacts carried by the sleeve, said first contact and said second contacts having common paths of travel when the solenoid is energized and having paths of travel which are mutually spaced in a direction longitudinally of the shaft when the solenoid is de-energized, and circuit means energizing the solenoid under the control of the light-responsive device during the night, said circuit means energizing said electric

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load from said source of electric power, said circuit means including a switch which is closed when the solenoid is energized and open in the daytime, and a second switch which is open when the contact on the first shaft engages a contact on the sleeve and is closed when the contact on the first shaft is spaced from the contacts on the sleeve.

11. A system as set forth in claim 10 wherein there are two contacts carried by the sleeve which contacts are spaced 180° apart.

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