Oct. 2, 1951 F. DE W. BICKEL ET AL 2,569,511

BLASTING DEVICE

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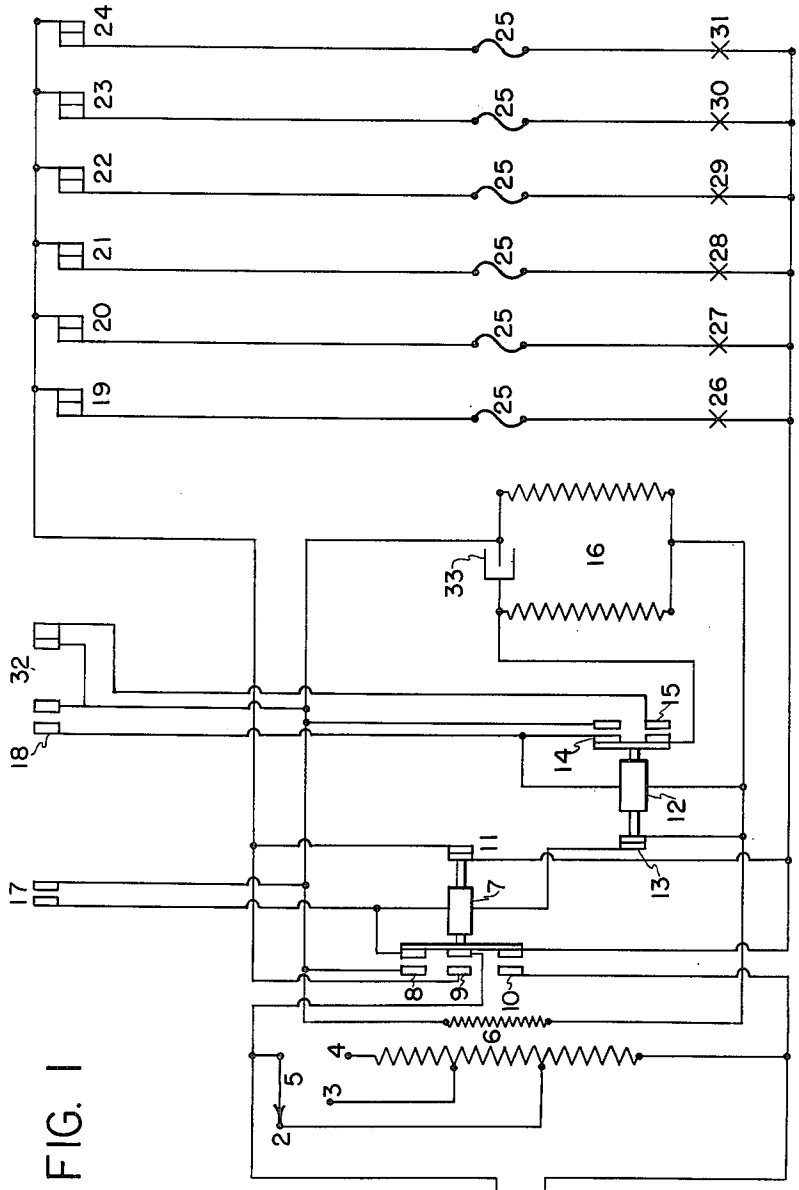


FIG. 1

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FIG. 2.

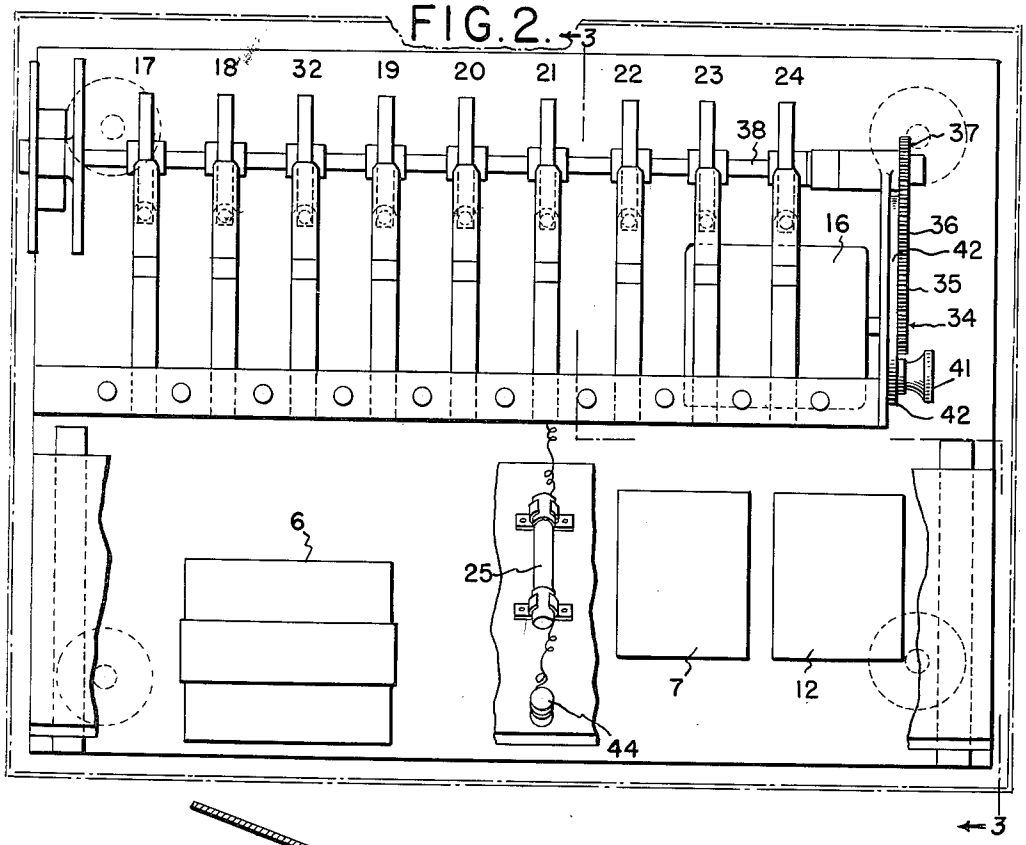


FIG. 3.

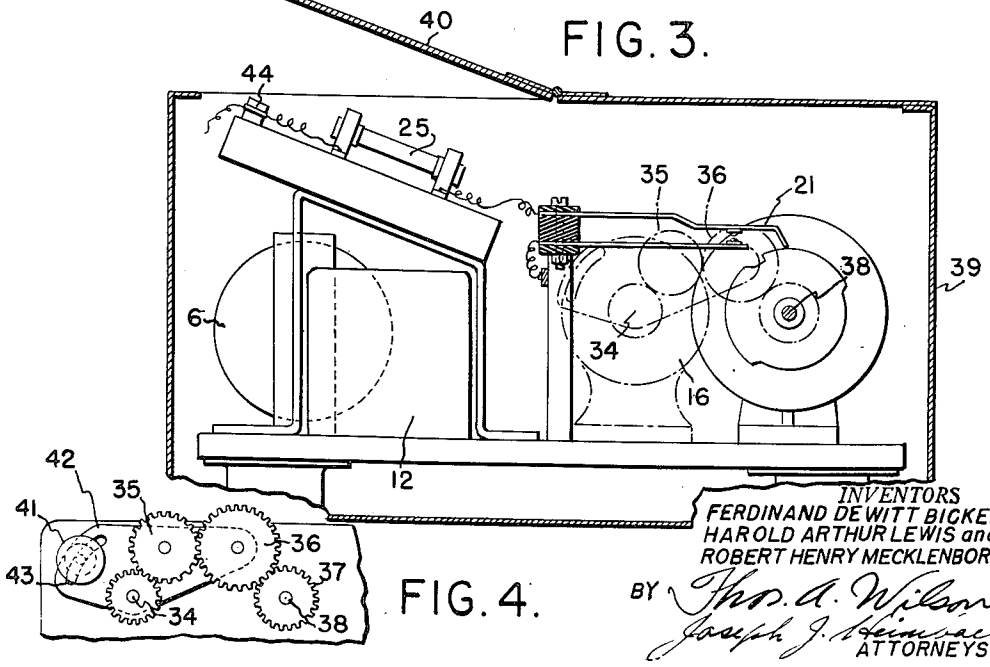


FIG. 4.

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BLASTING DEVICE

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3 Claims. (Cl. 175—115)

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This invention relates to an improved blasting timer. More particularly, this invention relates to a mechanical blasting timer adapted to be used for the firing of explosive charges in any predetermined sequence, and at precise time intervals with a maximum degree of dependability and safety.

It has been known for some time that better fragmentation, decreased vibration, and greater blasting efficiency may be obtained in many instances by firing explosive charges in a correct order with a short period of delay between various charges or groups of charges. Numerous efforts have been made to provide equipment to accomplish the above method of firing explosive charges, but none of the equipments has been completely satisfactory.

A considerable number of measurements have been taken which show that the movement of material following an explosion becomes appreciable within from .005 to .040 second, the elapsed time depending upon the type and volume of material to be moved, the arrangement of the drill holes, and the type and amount of explosive used.

If the delay between the firing of successive charges is too slight, maximum blasting efficiency may not be achieved since the burden will probably move at substantially the same instant all along the line of the bore holes, this unified movement often resulting in the production of large blocks instead of the desired fragmentation. On the other hand, if the delay between the firing of successive charges is too great, a preceding charge may have moved the burden away from a later charge sufficiently so that the force of the later explosion is largely dissipated uselessly, or, even worse, so that the light burden is thrown a great distance, thereby creating a hazard to personnel and property. Another possibility where the delay is too great is that the later charge will be cut-off by the first blast, and will not be fired, thus creating a potential hazard.

It is because of the precise timing required that delay electric blasting caps have not been satisfactory. Recently, delay caps have been developed which are designed to fire at delay intervals ranging from .010 to .050 second, but the number of periods of delay is limited, and the accuracy is seldom over 75%.

In co-pending application Serial No. 736,340, filed March 21, 1947, now Patent No. 2,546,686, a mechanical blasting timer capable of providing delay periods of from .005 to .040 second is

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described. The timer described therein comprises an electric motor connected to a spring-returned cam shaft through a solenoid operated clutch, and a plurality of cam-operated breaker points for establishing and breaking firing circuits in predetermined order and at precise time intervals.

Under ordinary conditions of usage and handling, the above described device would be completely satisfactory. It is well known, however, that for many blasting operations, unusual conditions prevail and any apparatus used for such operations will receive rough handling. With the device of prior application, a potential hazard exists if the apparatus is improperly operated, or if the current supply is temporarily interrupted.

An object of the present invention is a blasting timer adapted to provide very brief delays in firing of explosive charges in predetermined order whereby the possibility of dangerous or inefficient detonation of charges is minimized. A further object is a blasting timer whereby a very high degree of safety in operation is assured. Additional objects will be disclosed as the invention is described in greater detail.

We have found that the foregoing objects are accomplished when we provide a mechanically operated timing device for firing explosive charges by means of a power current wherein the electrical connections to the explosive charges are short circuited at substantially all times except during that portion of the cycle wherein the actual firing of the individual charges or groups of charges occurs, and then only provided the timing device has uninterruptedly performed the entire preceding portion of the cycle. We have further found that a preferred means of achieving the above is by the use of spring-loaded relays electrically energized.

To better illustrate this invention, reference is made to the accompanying drawings which show a preferred embodiment.

In the drawings:

Figure 1 is a diagrammatic sketch of the electrical arrangement of the blasting timer.

Figure 2 is a plan view of the timing device showing the mechanical arrangement.

Figure 3 is a cross-sectional view showing the operation of the cam shaft and firing circuit breakers; and

Figure 4 is a view of the gearing arrangement between the motor and the cam-shaft.

In the figures, 1 is the switch for closing the circuit from an outside source of alternating cur-

rent to the blasting timer, 2 is the 110 volt terminal, 3 is the 220 volt terminal, 4 is the 440 volt terminal and 5 is the selector switch of the 110 volt transformer 6. 7 is a spring-loaded power relay which operates the shunt breaker points 11, the relay auxiliary contact breaker points 8, and the firing circuit breaker points 9 and 10. 12 is a spring-loaded control relay which operates the power relay breaker points 13, the relay auxiliary contact breaker points 14 and the motor control breaker points 15. 16 is a split-phase self-starting induction motor. 17 are the cam-operated power relay breaker points, 18 are the cam-operated control relay breaker points and 32 are the cam-operated motor control breaker points. 19, 20, 21, 22, 23, and 24 are cam-operated firing circuit breaker points, 25 are fuses, and 26, 27, 28, 29, 30 and 31 are electric blasting caps. 33 is the capacitor unit for the motor 16. 38 is the cam-shaft containing a plurality of discs having notches at predetermined locations. 34, 35 and 36 are gears mounted on the frame 42 through which the gear 37 of cam-shaft 38 is driven by the motor 16. The frame 42 is held in position by the set screw 41 which passes through the frame slot 43. The wiring leading to the blasting cap is connected to the machine by means of terminal posts 44, the entire unit being mounted in the case 39 having a hinged lid 40.

The operation of the timer of the present invention is as follows:

After the blasting caps 26, 27, 28, 29, 30 and 31 have been positioned with regard to the blasting explosives, the leg wires are connected to the terminal posts 44 of the blasting machine. As points 19 to 24 are closed, the completeness of the circuit may be tested with a galvanometer. The selector bar 5 is connected to the terminal 2, 3 or 4, depending on the voltage of the current supply. The operator then closes switch 1, which may be located at a remote point, thereby starting the blasting timer.

The current from switch 1 energizes the transformer 6, which in turn induces a 110 volt current in the transformer or secondary circuit. Contact 15 being open, a portion of the current flows through the capacitor 33, setting up a split-phase in the field of the induction motor 16, which therefore immediately starts. Through the drive gears 34, 35, 36 and 37, the cam-shaft 38 is rotated by the motor 16.

As the cam-shaft rotates the breaker points operated thereby are opened and closed in predetermined order, as follows:

Points 19 to 24 are open one at a time, all being open by the time the cam-shaft has rotated about 80°. Further rotation causes points 17 to close, thus completing a circuit through the power relay 7. The relay 7 upon energization opens points 11, removing the short-circuit across the firing circuit, and closes points 8, 9 and 10. Points 9 and 10 complete the firing circuit up to the cam-operated firing circuit points, and points 8 provide a by-pass circuit so the relay will remain energized after points 17 are reopened, provided there is no interruption in the supply current. The points 17 are reopened by further rotation of the shaft, and the timer is now in readiness to begin the firing operation. At this point, the cam-shaft 38 will have rotated about 110°. To be certain that the motor has reached constant speed, an interval of about 20° rotation of the cam-shaft is permitted before any of the firing circuit points are closed, the points 19 to 24 then

being closed in sequence, each holding for a short duration, and then breaking. By making the amount of rotation of the cam-shaft 38 equal between the closing of each of the points, an equal time interval between the completion of each firing circuit is assured. The amount of rotation of the cam-shaft between the closing of each point is determined by the number of circuits to be completed, and the time interval by the speed of rotation. About 90° of rotation for the closing of all circuits has been found preferable. After the last firing circuit has been broken, points 18 are closed, points 32 being simultaneously opened, thereby completing the circuit to the control relay 12. The energized relay 12 opens points 13, thereby breaking the circuit to the power-relay 7. Since the relay 7 is spring-loaded, it returns to its original position, thereby short-circuiting the firing circuit and also breaking the circuit from the power source to the firing circuit. The control relay 12 also closes points 14, thereby establishing a by-pass circuit so that the opening of points 18 will not deenergize the relay 12. Points 15 are also closed, partially completing the short circuit for the capacitor 33. Further rotation closes points 32, and opens points 18, thereby completing the short circuit. The removal of the split phase causes the motor 16 to be dynamically braked to a stop at a point where the cam-shaft 38 is approximately in its starting position. The cam shaft will be held in that position until switch 1 is opened, deenergizing the relay 12.

As previously mentioned, the firing time interval is directly determined by the amount of rotation of the cam-shaft between the closing of each of the firing circuit breaker points and by the speed of the cam-shaft. Therefore, the firing time interval may be altered by changing either the positions of the cams on the cam-shaft, or by varying the speed of rotation of the cam-shaft. We have found it preferable to do the latter, and are able to accurately adjust the speed of the cam-shaft by means of a mechanism such as shown in detail in Figure 4. The mechanism consists of a pivotal gear assembly permanently engaged with the motor 16, and pivoting about the shaft thereof. By means of the slot 43 in the frame 42, the assembly is secured in proper position by set screw 43. Gear 37 on the cam-shaft 38 is removable and so cut as to mesh with gear 36 of the gear assembly. By changing the diameter of gear 37, the ratio of gear 36 and of gear 37 is changed, and since the gear 36 has a practically constant speed under the load conditions, the speed of the cam-shaft 38 will vary inversely with the diameter of gear 37. It is, therefore, a simple matter to have a series of different sized cam-shaft gears calibrated to produce a number of varying precise firing time intervals, thereby permitting the operator to select the most desirable interval between shots. Further selectability is, of course, provided by having a large number of firing contacts so that the operator, if he is not firing that many charges, may use, for example, every second or third terminal post, thereby doubling or tripling the time interval between each shot.

It will be apparent from the above description that the present device fully protects the operation if the current should be interrupted at any critical point in the cycle, since such interruption would deenergize relay 7, thereby not only short-circuiting the firing circuit, but also disconnecting the firing circuit. If, due to improper han-

dling, or for some other cause, the cam-shaft is not at the correct starting position, it will run to the correct position harmlessly without firing the charges, and the operator may then fire the charges without danger of improper sequence or timing.

An essential feature of the invention lies in the fact that the firing circuit is short-circuited at all times except during the actual firing of the detonators. This reduces to the absolute minimum the risk of accidental firing by stray currents. The short-circuit is removed only immediately before firing and is established again directly after the firing cycle has been completed, both removal and restoration taking place automatically. This arrangement has the additional advantage of permitting a test of each circuit to be made just prior to the actual blasting by means of a galvanometer, thus assuring that all connections are proper and intact.

While the removal of the short circuits, the firing of the shots, and the cycle of operations take place at accurately controlled and predetermined times, it will be seen that the human operator of the timing assembly may be at a considerable and safe distance from the place of blasting, the timer being placed relatively close to the blast holes, while the control switch is at a relatively remote and protected place.

Desirably we introduce into each separate firing circuit a circuit breaker such as an electric fuse, designed to blow when currents of excess amperage are applied, for example, a 10-ampere fuse in each circuit. The presence of such fuses serves to protect the timing assembly and its attachments. At the time of the blast, the force of the explosion is highly disruptive and, after the circuits have been broken by the detonation of the blasting caps, the leg wires may be thrown into contact with one another so that the circuit is remade. Such circuits might result in damage to the apparatus, as the firing current comes from the supply power lines. If desired, protecting fuses may be introduced into the lines between the motor and the source of current supply.

In the previous discussion, stress has been placed on the desirability of firing a plurality of explosive charges successively and at predetermined exact time intervals. The individual charge may consist of the load in a single hole which is one of a row of holes constituting a blast; it may be considered as one of several groups of holes in a row; or it may be considered as the charge in an entire row of holes where several parallel rows constitute a blast. Other arrangements of charges could be described in connection with the use of the timer, but the three mentioned above will serve as the most common examples, particularly as to their application to blasting in quarries.

In the quarry industry, the method of blasting in most general use is the loading and firing of a single row of vertical holes which has been drilled parallel to a vertical wall or face. Considerable advantage has been found by the employment of a short, accurately controlled interval between the firing of adjacent holes, for example, on the order of .005 to .040 second. The choice of the exact interval most suitable in a particular operation depends on a number of factors, such as type of stone formation, size and spacing of the blast holes, grade of fragmentation desired, etc. Also in order to provide maximum possible safety in blasting, particularly where large charges of explosives are used, it is desirable that no electric detonator be placed in direct firing position with the charge in the bore hole but that detonating fuse be used for this purpose. The detonating fuse branch line in the hole extends out the top and is then detonated on the surface by a detonating fuse trunk line or an electric blasting cap placed in detonating position just prior to firing the blast.

The principal advantages of short period delay blasting over instantaneous blasting under the circumstances described in the foregoing are improved fragmentation and reduced vibration. The use of the optimum delay period between the firing of adjacent holes results in increased twisting and breaking action on the material between the holes. This effect is substantially minimized if the delay period is less or greater than the optimum determined for the particular conditions. For example, if this interval were proved by experience to be .020 second, then a less interval, say .005 or .010 second would be approaching an instantaneous shot and insufficient for the desired effect. If it were .040 second it might be of such great duration that the loss of explosive gases due to overbreak from a prior firing hole might actually result in breakage much inferior to that from an instantaneous blast.

Reduction in vibration is noticeable when using delay intervals of .005 second and above. Furthermore, the greater the number of intervals, the greater the reduction in vibration as compared to that of an instantaneous blast. For example, in a blast consisting of a plurality of holes, the greatest possible reduction is obtained when each adjacent hole starting from one end of the row is fired with one additional period of delay.

It can then be seen from the foregoing that when short period delay blasting is applied under the circumstances described, a considerable number of different intervals should be available for use under a variety of conditions and also that means should be available for supplying a moderate number of periods of the same interval. Furthermore, it is very essential that the intervals be controlled with the utmost accuracy, not only for the reasons already described above, but also to prevent the failure of one or more charges, by what are known as "cut-offs." Such action may consist of actual interruption or offsetting of the holes or breakage of the detonating fuse line or cap wires in the hole by ground movement from the prior firing of an adjacent hole. This condition can and does take place when and if the delay interval between the firing of adjacent holes is too great for the conditions obtaining in that particular instance. For example, if it had been determined previously that .020 second was the optimum delay period and could be used successfully, a delay of .040 second or .050 second could easily cause such disastrous results.

The same principles described above also apply equally to the firing of several groups of holes in a single row by the introduction of a short delay interval between each group.

It is often advantageous to make quarry blasts consisting of several rows of holes. The short delay interval with surface initiation can be successfully applied in such cases also by firing the front row nearest the open face instantaneously and the remaining rows in rotation progressively toward the rear of the blast. The advantages with this method are similar to those described above for a single row, both breakage and vibration being greatly benefited by the progressive

relief of the several explosive charges. An additional improvement to be obtained in this instance is less back break into the solid material behind the last row of holes resulting from decreased lateral shock as compared with an instantaneous blast involving all the rows of holes.

A timer, such as the one described herein, is the only known means for supplying all of the requirements for short interval delay blasting as described in the foregoing, with a high degree of safety and efficiency, these requirements being beyond the possibilities of any delay caps now designed or in production. Such firing devices cannot possibly by any method of manufacture now known provide the requisite dependability of delay interval, and furthermore there are not now available either the desired choice of intervals or the desired number of periods of the same interval. Also it is apparent that the timer is applicable to the use of all types of detonating explosives and agents suitable for blasting, such as gelatins, ammonia dynamites, "Nitramon," and the like.

We intend to be limited only by the following claims.

We claim:

1. A mechanically operated timing device for firing charges of explosives in predetermined order and at precise time intervals comprising in combination terminals for connecting said device to a power source; an electric motor; a circuit from said terminals to said motor; a rotatable cam-shaft operatively connected to said motor; at least two electrically energizable relays; circuits from said terminals to said relays; cam-operated circuit-breaking elements connected in series therein with each of said relays and relay-operated circuit-breaking elements connected in parallel therein with said cam-operated circuit-breaking elements, at least one of said relay circuits also having connected in series therein a circuit-breaking element operated by a different relay; a plurality of firing circuits, each having connected in series therewith a cam-operated circuit-closing element; a blasting circuit connecting said firing circuits to said terminals, said blasting circuit having connected in series therewith at least one relay-operated circuit-closing element; a short circuit containing

connected in series a relay-operated circuit-breaking element interposed between said relay operated circuit-closing element in the blasting circuit and said firing circuits; and means for stopping said motor when the said cam-shaft has substantially completed one revolution; the cams on said shaft being so positioned as to, (1), operate the circuit-closing elements completing the circuit to the relays which, when energized, close the main circuit and open the short circuit, (2), after the said shaft has attained constant speed, operate the circuit-closing elements in the firing circuit in predetermined order and at equal intervals, (3), operate the circuit-closing elements in the circuit of the relay regulating the circuit of the blasting circuit and short circuit control relays, and, (4), operate the motor stopping means.

2. A device as claimed in claim 1, wherein means for imparting rotary motion of the motor to said cam-shaft consists of a gear-train adapted to provide variable speeds by the use of various sized gears.

3. A device as claimed in claim 1, wherein the electric motor is a split-phase capacitor-start, capacitor-run induction motor, and the means for automatically positioning the cam-shaft consists of a cam-operated means for short-circuiting the capacitor element of the split-phase motor, thereby dynamically braking the motor to a stop at the desired position.

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