March 27, 1951 F. DE W. BICKEL ET AL 2,546,686

BLASTING DEVICE

Filed March 21, 1947 4 Sheets-Sheet 1

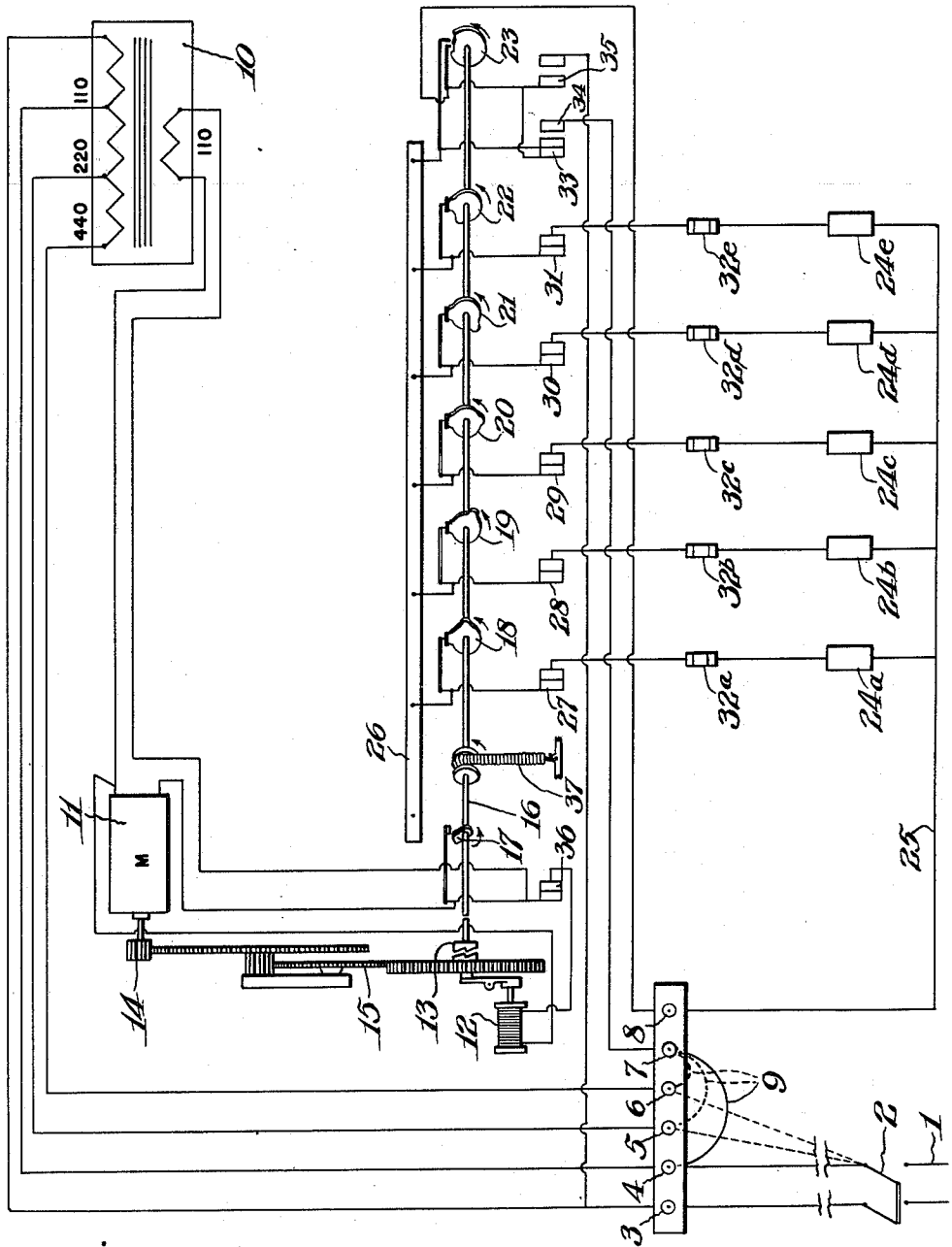


Fig. 1.

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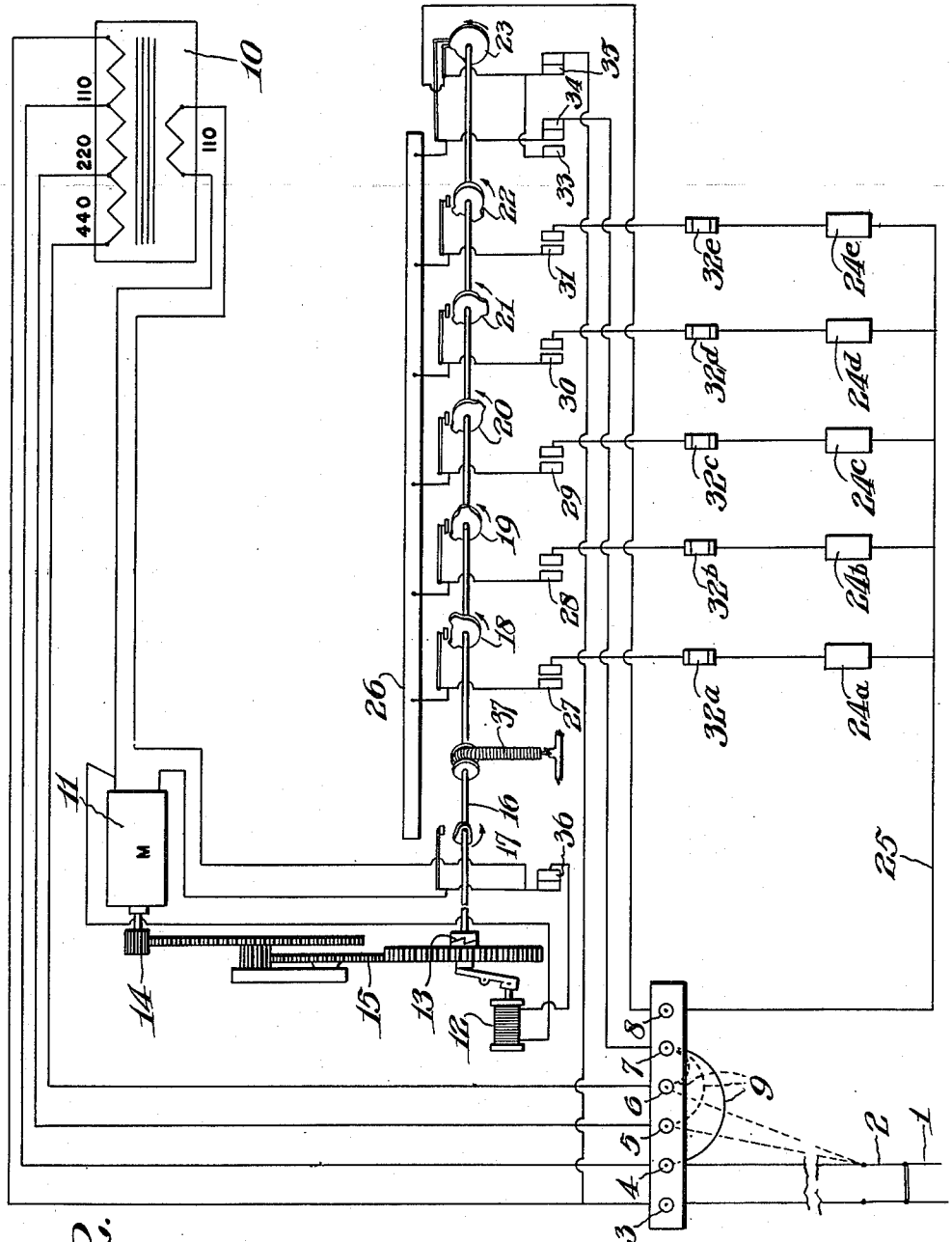


Fig. 2.

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BLASTING DEVICE

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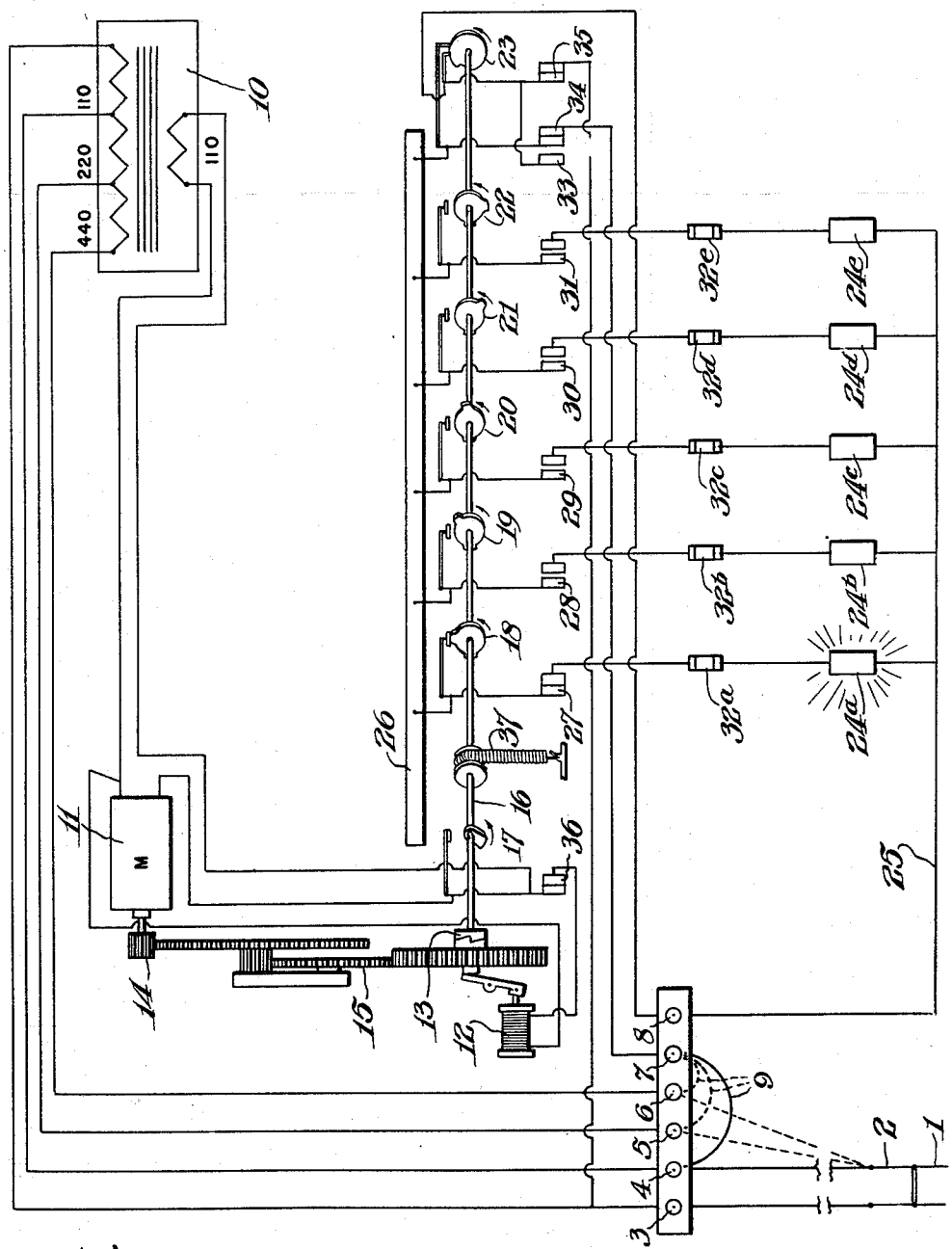


Fig. 3.

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Fig. 4.

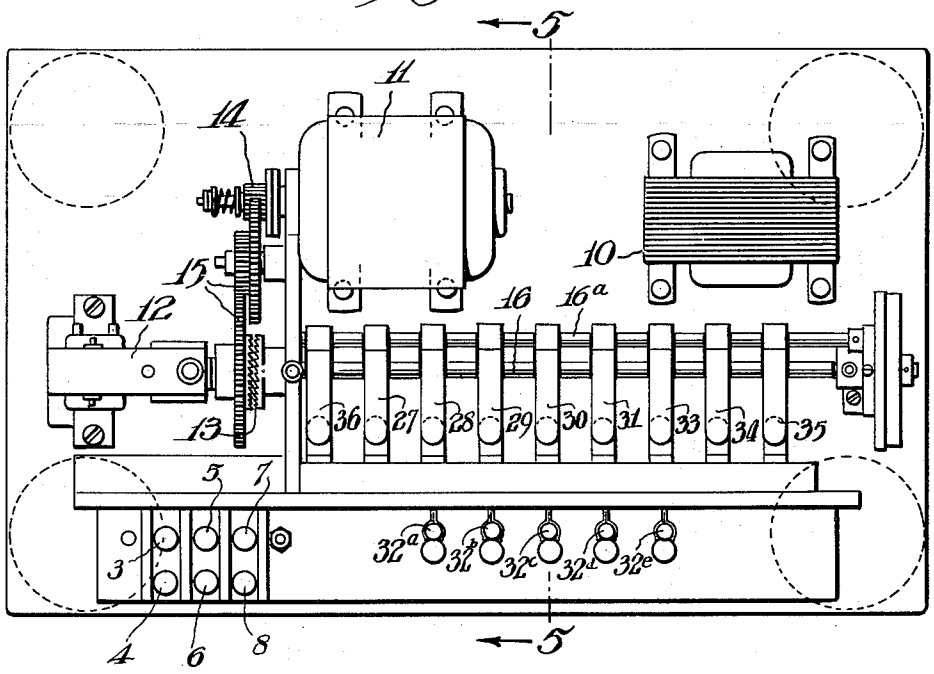
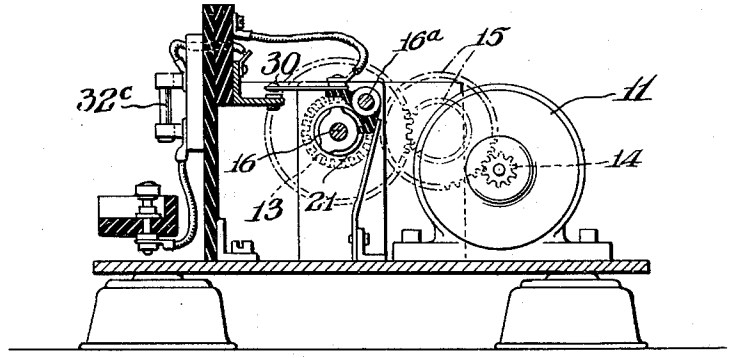


Fig. 5.



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UNITED STATES PATENT OFFICE

2,546,686

BLASTING DEVICE

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Application March 21, 1947, Serial No. 736,340

6 Claims. (Cl. 102—27)

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This invention relates to an improved method of firing a plurality of explosives charges and more particularly to a novel device whereby the charges are detonated in the most advantageous order and at predetermined and precise time intervals.

In commercial blasting operations it is customary to fire a plurality of explosives charges in bore holes in one group or "blast." These charges may be fired instantaneously, or substantially so, by the use of electric blasting caps or by a detonating fuse such as that known as Primacord. They may also be fired in rotation or in a regular sequence so that the explosion of one charge tends to decrease the required blasting effort necessitated by the explosion of charges fired subsequently. One of the most common methods of obtaining rotation firing is by the use of delay electric blasting caps. However, explosives efficiency greater than that provided by any of the foregoing methods, and also decreased vibration as compared to the instantaneous methods, can be obtained by firing the charges in a predetermined order, not necessarily in rotation, and at certain specified time intervals accurately controlled within a definite time range.

In blasting operations the movement of material after detonation of a charge of explosives, regardless of type of material involved, is usually termed "ground movement." A considerable number of measurements have been taken which show that this movement becomes appreciable within an elapsed time varying from .005 to .040 second following the explosion. Evidence indicates that this time interval depends on a number of factors consisting mainly of ratio of weight of explosives to volume of material moved, type of material, arrangement of drill holes, and type of explosives.

In blasts fired with instantaneous electric blasting caps all of the included material moves at substantially the same instant. In many cases this unified movement of the material tends to produce large blocks instead of the desired fragmentation. Furthermore, the simultaneous detonation of a large number of individual charges always produces the maxim of ground vibration.

As is well known, Primacord detonates at approximately 20,000 feet per second. When it is used to detonate successive charges of explosives, the time interval is only .0005 second if the charges are spaced 10 feet apart, and only .002 second if they are spaced 40 feet apart. These time intervals are so small that a blast of successive charges detonated by Primacord is essentially an instantaneous blast and is, therefore, subject to the same disadvantages as a blast with instantaneous caps.

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Conventional delay electric blasting caps are commonly designed to fire at intervals of one-half second or more, which intervals are far greater than the time necessary for ground movement to become appreciable. Under these circumstances, the ground movement caused by the explosion of one charge frequently cuts off an adjacent charge which has not yet fired, thereby causing a misfire and a potential hazard. Recently special delay electric blasting caps have been produced which are designed to fire at delay intrevals ranging from .025 to .050 second. These likewise have caused cut-offs under certain conditions. Furthermore, they have been produced in only three periods of delay which are inadequate for firing a plurality of charges to the best advantage. Still further, since in all types of commercial delay electric blasting caps the delay firing is accomplished by chemical means, the timing is subject to such wide variation as to render their use impractical in many cases. This variation from the intended interval is commonly of the magnitude of plus or minus 10% but in many instances may reach 25% or higher.

The use of either instantaneous or delay electric blasting caps for the direct priming of explosives charges in bore holes constitutes a potential hazard for several reasons. Many instances of premature detonations are on record from lightning and also from stray currents which are often present as a result of the widespread use of electrical equipment on operations where blasting is practiced. One even greater hazard stems from the disposal of a misfired charge of explosives containing an electric firing device. On the other hand, to the best of our knowledge there is no case on record of a premature detonation of a charge of explosives under any of the foregoing circumstances when the charge

was primed with detonating fuse. Furthermore, the hazard in the event of a misfired hole is greatly reduced with the use of detonating fuse; it being a well known fact that the sensitivity of detonating fuse is much less than that of the primary detonating compounds contained in electric blasting caps.

Under the conditions set forth in the foregoing it has long been recognized by those skilled in the art that the conventional methods of firing a plurality of charges which have been used heretofore have been inadequate from the standpoints of desired fragmentation, vibration, and safety.

An object of the present invention is a blasting timer whereby the respective delay intervals between the detonation of a plurality of explosives charges can be definitely assured at much shorter duration than has been possible heretofore, for example, of the order of .005 to .040 second. A further object is such a blasting timer whereby very brief delays of predetermined time intervals are obtained by mechanical rather than chemical means. A still further object is a blasting device whereby a high degree of safety in operation is assured and the possibility of accidental premature detonation of charges is minimized. A further object is a method of firing charges of explosives in predetermined order and at precise time intervals by the use of such a timer in order to enhance safety, increase fragmentation, and decrease vibration. Additional objects will be disclosed as the invention is described at greater length hereinafter.

We have found that the foregoing objects are accomplished when we utilize a mechanically operated timing device for firing explosives charges by means of power current provide a plurality of firing circuits containing blasting initiators, in detonating position with respect to the several explosives charges, or preferably with the blasting initiators in the open and in detonating position with respect to detonating fuse which in turn is in detonating position with respect to the several explosives charges, effect the firing of these charges at the desired times, and provide that all firing circuits are short-circuited initially and normally, said short-circuited arrangement being removed at an instant just prior to firing, and being reestablished immediately thereafter. The firing of the charges takes place by remote control so that, while the mechanically operated timer is relatively close to the place of blasting, the operator himself is at a safe distance.

Whereas this timing device can be constructed to incorporate many modifications, the invention will be understood more clearly by reference to the accompanying drawings of the preferred design in which:

Figure 1 is a diagrammatic representation of the timing device, showing the apparatus and wiring arrangements for accomplishing the desired objects of the invention, the firing circuits being in the initial and normal short-circuited position prior to the firing of the explosives charges;

Figure 2 is a similar representation at a time when the cam shaft has started rotation and the short-circuiting arrangement has been removed;

Figure 3 shows the same assembly at a slightly later moment in the rotation of the cam shaft, with the short circuit removed, as in Figure 2, but at the instant of energizing the first circuit.

Figure 4 shows a plan view of the timing device, showing the physical relationship of the various elements; and

Figure 5 shows in detail the mechanical arrangement of the cam and the contacts.

With particular reference to Figure 1, the lines 1 lead from a source of alternating current, with switch 2 remotely located for closing the circuit to the blasting timer. As shown by the diagram the timer is adapted to use with 110, 220, or 440 volt current. By means of binding posts 3, 4, 5, 6, and 7 with their respective connecting wiring and the flexible jumper 9 shown as a solid line extending from binding post 4 to binding post 7 and as a dotted line extending from binding posts 5 and 6 to binding post 7, the current goes to transformer 10 and thence at 110 volts to the electric motor 11 and at the same time to solenoid 12 which is to throw in the clutch 13 so that by means of suitable gearing, as shown at 14 and 15, the cam shaft 16 bearing the cams 17, 18, 19, 20, 21, 22, and 23 is caused to revolve. The five electric blasting caps 24*a*, 24*b*, 24*c*, 24*d*, and 24*e*, each in detonating relationship with its line of detonating fuse or its respective explosives charges (detonating fuse or explosives charge not shown) are arranged to be in parallel circuits by means of a common line 25 connected to binding post 8 and by means of cam-operated contacts to bus bar 26. In the individual circuits between bus bar 26 and the individual electric blasting caps 24*a*, 24*b*, 24*c*, 24*d*, and 24*e*, are contacts 27, 28, 29, 30, and 31 arranged to close the circuit and fire their respective caps at the predetermined time intervals, and also included in these respective circuits are fuses 32*a*, 32*b*, 32*c*, 32*d*, and 32*e* inserted for protection of their respective wirings.

As stated previously, Figure 1 represents the timer in short-circuited position with respect to all of the electric blasting caps. In such a position a blasting galvanometer may be inserted in the individual cap circuit in order to test its continuity just prior to making the final closing connection.

Figure 2 represents the various elements by the same designations at an early period in the course of the cam shaft revolution, after the short circuit has been removed from the cap circuits. When the timer circuit is energized by the closing of switch 2, the starting of the motor and the engaging of clutch 13 cause the cam shaft to revolve. After a very brief period during which the motor and cam shaft attain uniform velocity of rotation, the individual cap circuits are opened simultaneously by their respective cams. Cam 23 then applies current to bus bar 26 and common line 25 by opening contact 33 and closing contacts 34 and 35.

Figure 3 likewise shows the same assembly with like parts designated in the same manner, this figure representing the connections at the time of firing the first electric cap. The rotation of cam 18 has closed the circuit at 27 thus causing the firing of cap 24*a*.

Subsequent to the positions shown in Figure 3, the successive contacts made by cams 19, 20, 21, and 22 fire caps 24*b*, 24*c*, 24*d*, and 24*e* at very briefly elapsed time intervals. Further rotation of the cam shaft 16 causes cam 17 to open the circuit at 36, which shuts off the motor 11; deenergizes the solenoid 12, which in turn disengages the clutch 13; and stops the cam shaft 16 from further rotation. When firing switch 2 is then opened, the spring 37 causes the return of the cam shaft 16 to its initial position.

In Figures 4 and 5, the numerals have the same significance as in the diagrammatic repre-

sentation of Figure 1, the only additional element being the pivot bar 16a which supports the movable contact.

In Figures 1, 2, and 3 only five firing circuits have been shown for the sake of simplicity, but it will be understood that the limit is not five and that rather any number within reason may be included. For example, in the following table the timing of each circuit in each of two timers having fifteen firing circuit cams is shown:

Electric Blasting Cap Number	Circuit Number	Time of Firing in Seconds A	B
24a	1	.000	.000
24b	2	.010	.005
24c	3	.020	.010
24d	4	.030	.015
24e	5	.040	.020
24f	6	.050	.025
24g	7	.060	.030
24h	8	.070	.040
24i	9	.080	.045
24j	10	.090	.050
24k	11	.100	.060
24l	12	.110	.075
24m	13	.120	.080
24n	14	.130	.100
24o	15	.140	.125

In timer A fifteen circuits are provided with an interval of .010 second between each of the circuits. Similar timers could, of course, be made with intervals of .005 second, 0.15 second, etc.

In timer B the interval between circuits has been purposely varied. By the use of circuits 1, 2, 3, 4, 5, 6, and 7, the interval is .005 second. By using circuits 1, 3, 5, 7, 8, 10, and 11, the interval is .010 second. Similarly, using circuits 1, 5, 10, 12, 14, and 15, the interval is .025 second. In all, the fifteen firing circuits provided by such a timer would give the following combinations: Seven circuits at intervals of .005 and .010 second respectively; six circuits at .015, .020, and .025 second respectively; and three circuits at .030 and .040 second respectively. Obviously innumerable combinations of firing circuits and firing time intervals are possible. This is of the utmost importance since it permits use of the timer, under the widest possible variation in conditions.

As described in the foregoing in connection with the attached drawings, the invention provides for the firing of a plurality of explosives charges from a remote point by means of a blasting timer placed relatively close to the location of the blast. In order to fire a blast, a switch, connected to a source of power and located at a remote point, is closed causing the operation of an electric motor through the medium of a transformer provided to apply the correct voltage to said motor. By the application of this same current a solenoid actuates an attached clutch which engages a timer cam shaft, causing said shaft to rotate at a predetermined uniform speed. Such rotation results in (1) removal of short circuits simultaneously from all electric cap circuits; (2) closing the contacts for the various electric cap circuits and firing the respective blasts at predetermined proper intervals, each contact being maintained for a period of about .015 second which is ample to assure firing of electric blasting caps; (3) breaking the circuit to the clutch solenoid and motor, thus stopping the rotation of the cam shaft which is then returned to its initial position by a spring, and automatically re-establishing the short-circuiting of all blasting circuits.

An essential feature of the invention lies in the fact that initially and normally the firing circuits are all in short-circuited position and that the short-circuiting is removed immediately before firing and established again directly after

firing when the firing switch is opened, both removal and restoration taking place automatically in a time interval comprising a small fraction of a second. This is an important safety consideration as, with this arrangement, there is no possibility of accidental firing at inopportune moments, or when blasting personnel are in the vicinity of the shots. Furthermore, as previously indicated, the short-circuiting arrangement permits the testing of each complete circuit with a blasting galvanometer just prior to closing, thus assuring that all connections are intact and ready for firing. The device is so designed that if the automatic means for re-establishment of short circuits in the blasting circuits fails to work, this re-establishment can be accomplished manually.

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 is 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 since, at the time of the blasts, the force of the explosion is highly disruptive and, after the circuits have been broken by the detonation of the blasting caps, the leading wires may be thrown into contact with one another so that the circuit is remade. Such circuits may result in damage to the apparatus, as the firing current comes from power lines. If desired, also, 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 explosives charges successively and at predetermined exact time intervals. The individual charge may consist of the load in a single blast 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 introlled 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, 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 .015 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 seven 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 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 explosives 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.

The timer, which is the object of this invention, is the only known means for supplying all of the requirements for short interval delay blasting as described in the foregoing, 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 by power circuits in predetermined order and at precise time intervals, said device comprising a plurality of firing circuits, said circuits being initially and normally in short-circuited status; a shaft adapted to revolve and carrying a plurality of attachments adapted to cause successive closing of all of said circuits in predetermined order; an electric motor for driving said shaft; means for engaging said motor on application of the electric current; means for effecting automatic removal of short circuits from all circuits prior to the application of firing current; means whereby, after actuation and firing, a return is made in the assembly to a position in which all firing circuits are again short-circuited; and means for disengaging the motor after firing of the last explosives charge, while the electric current is still being applied, all of said operations taking place during less than the course of one complete revolution of the revolving shaft.

2. A mechanically operated timing device for firing charges of explosives by power circuits in predetermined order and at precise time intervals, said device comprising a plurality of firing circuits, said circuits being initially and normally in short-circuited status; a shaft adapted to revolve and carrying a plurality of cams adapted to cause successive closing of all of said circuits in predetermined order; an electric motor for driving said shaft; a clutch positioned to engage said motor; a solenoid arranged to cause the clutch to engage said motor on application of the electric current; means connected with the shaft for effecting automatic removal of short circuits from all circuits prior to the application of the electric current; means whereby, after actuation and firing, a return is made in the assembly to a position in which all firing circuits are again short-circuited; means for disengaging the clutch from the motor after firing of the last explosives charge and while the electric current is still being applied all of said operations taking place during less than the course of one revolution of the cam shaft; and means for effecting return of the cam shaft to its initial position when application of current is discontinued.

3. The timing device of claim 2, in which a transformer is introduced between the current source and the electric motor, whereby the volt-

age from the high voltage circuit is transformable to that required to operate the motor.

4. The timing device of claim 2, in which an electric fuse is present in each of the blasting circuits, adapted to open the respective circuits on application of excess current thereto.

5. The timing device of claim 2 in which the firing circuits are so arranged as to detonate the explosives charges at any selected interval between .005 and .040 second.

6. The timing device of claim 2 in which the firing circuits are so arranged as to detonate a plurality of explosives charges at intervals of .005 .010, .015, .020, .025, .030, or .040 second, as desired.

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