

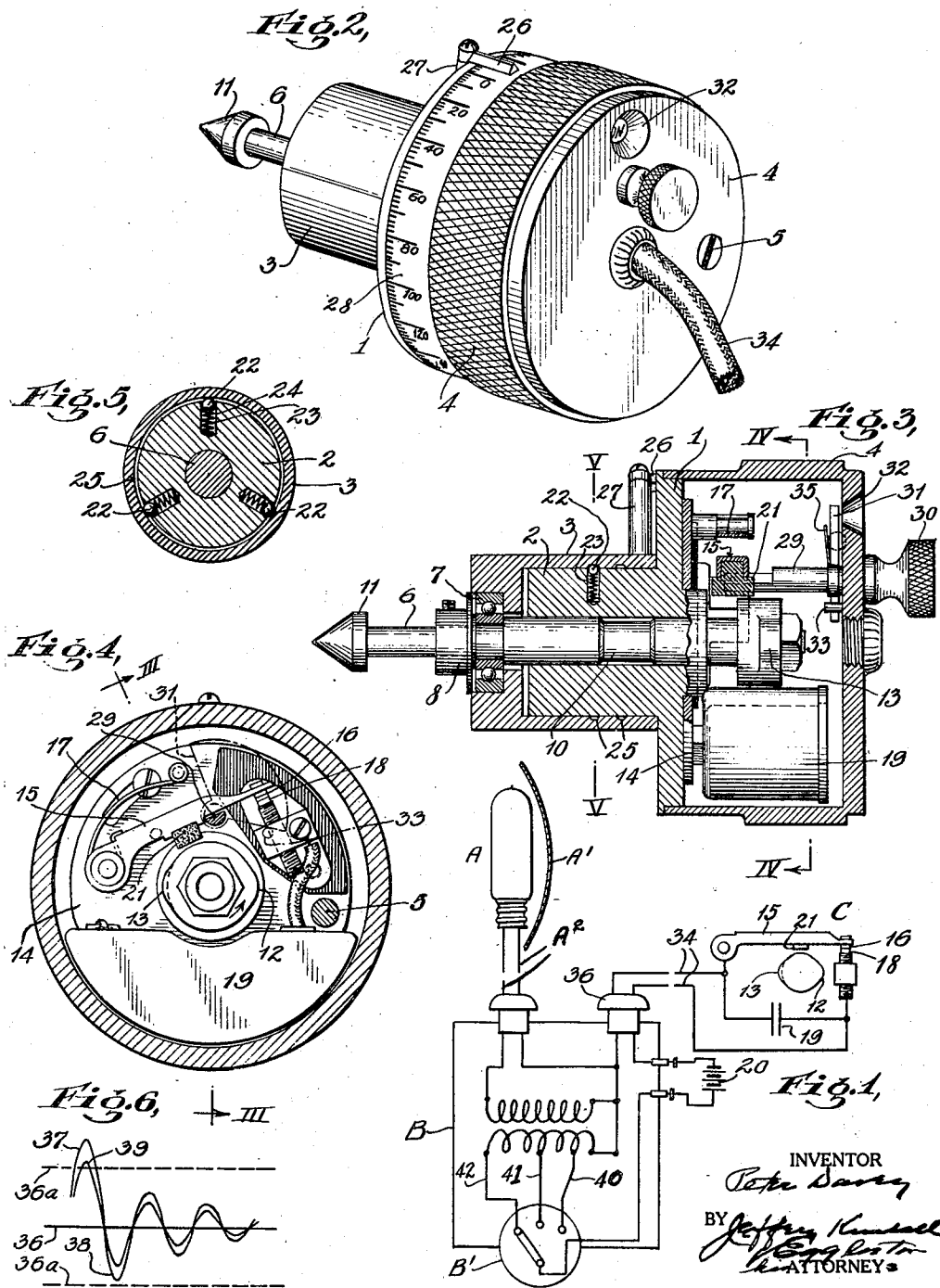
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STROBOSCOPIC APPARATUS AND METHOD

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STROBOSCOPIC APPARATUS AND METHOD

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My invention provides an improved and convenient form of apparatus for stroboscopic examinations of moving bodies, and an apparatus which is readily adjusted to show the moving body as though stationary at any stage in its cycle of operations, or moving at very greatly reduced speed. The latter phenomenon is usually referred to as a "creeping" motion.

The accompanying drawings illustrate a preferred form of my invention. Figure 1 is a diagrammatic illustration of the entire stroboscope. Figure 2 is a perspective of the interrupter unit thereof. Figure 3 is a longitudinal section of the interrupter unit. Figure 4 is a section of the same on line IV—IV of Fig. 3; the line III—III indicates the section of Fig. 3. Figure 5 is a section on the line V—V of Fig. 3. And Figure 6 is a conventional representation of discharges of an oscillating circuit.

The instrument illustrated comprises three separate units (Fig. 1), the illuminator A, the transformer or inductor unit B which provides the electric currents which light the illuminator, and the interrupter unit C which controls the time of lighting the illuminator. These three are united by flexible leads long enough to permit the separate units to be disposed in convenient locations, that is to say, the unit B set down in operation in any convenient place, the interrupter C applied to a suitable driving shaft even though somewhat remote from the unit B, and the illuminator approached close to the part to be examined independent of the location of B and C.

The illuminator A is an apparatus of the kind which is quickly lighted on the passage of an electric current and quickly darkened when the current ceases, such as a neon tube, in which discharges take place between two electrodes in neon gas at sub-atmospheric pressure. I customarily mount this apparatus on a handle or holder with a suitable light reflector A1 at one side of it so that the light can be conveniently approached to and directed on the particular moving part to be studied.

The transformer or induction coil which

supplies the electric currents for the illuminator A, is contained in a case or box B as diagrammatically outlined in Fig. 1. The secondary winding or circuit of the transformer is connected to the terminals of the neon tube A as illustrated, i. e. by means of the rather long flexible leads A2. The primary or inducing winding is connected to a source of energy such as the battery 20, and in series therewith to the contacts 16 and 18 of the interrupter unit C. The transformer, it will be understood, transforms energy received from the source 20 into an electric current of suitable voltage to light the illuminator whenever interrupter contacts 16 and 18 are actuated. In the present instance the core of the transformer is of iron, open magnetic circuit, and the primary circuit is of the closed circuit type, energy being stored in the core of the transformer in the form of magnetism created by the current in the primary circuit when the contacts 16 and 18 are closed, and being released to the secondary circuit and illuminator when the contacts separate. In order to adapt the instrument to various shaft speeds, I have provided the primary winding of the transfer with taps as hereinafter explained and the multi-pole switch B1 serving these taps is usually attached to the wall of the box so as to be accessible from the outside as indicated in Fig. 1. Ordinarily I use a battery 20 to supply the electric current to energize the transformer and this may be included in the transformer case, but usually I place it outside and connect it to the circuits through binding posts located in the wall of the transformer box B as also diagrammatically indicated in Figure 1.

The interrupter unit C (outlined in Fig. 1 and shown in detail in Figs. 2 to 5) contains the contacts 16 and 18 in the circuit of the primary winding of the transformer, and the interrupter shaft 6 which opens and closes them. The unit also embodies the adjustment features which permit the body under examination to be viewed in any position throughout its cycle, and mechanism whereby the number of flashes per rotation of the shaft 6 can be varied at will. The head 1 of

this unit has a central projecting cylindrical boss 2 on which a rotatable sleeve 3 is mounted; a cover 4 extending from the periphery of the head 1 houses the various other mechanism, and a screw or screws 5 fastens the cover to the head. The shaft 6 projects from the enclosure of this cover through the boss 2 and a ball bearing 7 mounts the shaft in the sleeve 3. This bearing not only acts as a radial bearing, but also holds the shaft against endwise movement with respect to the sleeve. The collar 8 on the shaft conceals the bearing and protects it from dirt. The shaft 6 also has a radial bearing, rather long or extended, in the boss 2; this tends to reduce vibration, and within this long bearing a circumferential groove 10 is provided for lubrication purposes. On the outer end of the shaft 6 is a centering point 11 to be pressed against the end of a shaft (say of the machine under examination) which is rotating at such a speed as to produce the proper number of interruptions of the primary circuit as will be understood. The frictional engagement of a centering point 11 with the driving shaft is quite sufficient to drive the interrupter, and because of its simplicity and convenience this is a very desirable arrangement for driving stroboscopes, or at least for driving portable stroboscopes. The shaft 6 actuates the contacts 16 and 18 by a cam 12 on its opposite end, which is arranged to strike a lever 15 carrying the contact 16; the lever is so biased by the spring 17 as to hold the contact 16 in engagement with the stationary adjustable contact 18, except when lifted by the cam. Usually I place a block 21 on the lever to receive the blows of the cam or cams. The lever 15 and contact 18 are conveniently mounted on a plate 14 attached to the head 1 as shown, and as before indicated, rather long flexible conductors 34 connect the contacts 16 and 18 to the primary winding of the transformer B and the source of energy 20 in series as shown in Fig. 1. The condenser to reduce the arcing or sparks at the contacts 16 and 18, appears at 19, and is connected in shunt to the contacts 16 and 18. I have found that it is important in flash-illuminating stroboscopes that this condenser be placed as close to the interrupter contacts as possible, and I therefore mount it in or as a part of the interrupter unit. It may be fixed to the plate 14 as shown in Fig. 3. The cam 12 lifts the contact 16 off the contact 18 once in each rotation of the shaft 6 as will be apparent. Other cams may be put on the shaft 6 to cause the contacts 16 and 18 to open more than once, at will, in each rotation of the shaft. Another such cam is shown at 13, and this cam is shown as displaced angularly 180° from the cam 12 and also displaced from the cam 12 longitudinally of the shaft so that by adjustment either the cam 12 alone or both cams 12 and 13

may be made to strike the lever 15. Cam 13 therefore, by proper adjustment, in cooperation with cam 12 provides for interrupting the primary circuit twice in each shaft rotation and at opposite points in the cycle. To bring different cams into operative relation to a lever such as 15, I have found it important that the lever be mounted immovable axially and the cams be arranged for axial adjustment, rather than that the lever be mounted for axial adjustment on its fulcrum pin and the cams fixed axially as has been proposed heretofore. My construction produces a simpler motion of the lever and more reliable operation. I have therefore mounted the lever 15 in fixed axial position on the plate 14 and arranged the shaft 6 to slide, carrying its cams 12 and 13 with it. To slide the shaft to the left or right, the sleeve 3 is slid on the boss 2, and a ball or balls 22 pressed by springs 23 in the boss coact with two grooves 25 on the inner periphery of the sleeve to define the two positions of the shaft and frictionally hold the sleeve and shaft in each of these positions until manually moved at the will of the operator. When the shaft 6 is in its right hand position as shown in Fig. 3, only the cam 12 strikes the lever 15 as before described. When the shaft is moved to the left however (with respect to Fig. 3) the cam 13 is also brought into position to strike the block 21, and the latter being wide enough to be struck by the cam 12 when the shaft is to the left as well as when it is to the right, the lever 15 is then actuated twice in each rotation of the shaft and the engagement of 16 with 18 is broken twice, bringing about two light flashes in the illuminator for each shaft rotation in the place of one when the shaft is in its right hand position.

A second function of the balls 22 is to impose sufficient frictional resistance between sleeve 3 and the boss 2 to prevent the head 1 turning with the shaft. A pin 29, the inner end of which is flattened underneath the lever 15, can be turned at will by the nurlled head 30 and when turned temporarily retains the contact 16 out of engagement with the contact 18; a sight plate 31, fixed to turn with the pin 29 is exposed through a port 32 and conveniently marked, as with "Off" and "On", to indicate whether the contact 16 is held off the contact 18 or whether the instrument is in condition for operation. The same plate 31 may cooperate with pins 33 to restrict the turning movement of the pin 29 to the desired limits, while notches in the cover cooperating with a ball pressed by a spring 35 on the plate 31 (see Fig. 3) holds the pin frictionally in its two extreme positions.

In operation, the coil case and battery (if any) are set down in any location convenient to the machine containing the part to be ex-

5 aminated as before indicated. The centering
 point 11 of the interrupter unit is then
 pressed against the center of the end of a
 convenient shaft rotating at a suitable speed
 10 relative to the frequency of the cyclic opera-
 tion of the part to be examined (usually a
 shaft of the machine being examined), so
 that the interrupter shaft 6 is driven, say,
 at the same speed as the shaft to which it
 15 is applied. What constitutes a suitable speed
 for the machine shaft driving the interrup-
 ter shaft will be understood by those skilled
 in this art, but for the purposes of this ex-
 20 planation will be assumed to be such a speed
 that the machine shaft makes one revolution
 while the part to be examined moves through
 one complete cycle. The interrupter may be
 held against the machine shaft by hand, or
 25 clamped in place, the sleeve affording a con-
 venient part for clamping purposes as will
 be apparent; for this purpose, i. e., holding
 by clamping or otherwise the interrupter
 unit the member 3 to which the shaft 6 is
 30 fixed and with respect to which the head is
 slidable longitudinally of the shaft, is ex-
 posed on the outside of the interrupter unit.
 In the alternative, a separate motor may be
 used to drive the interrupter, and it will also
 35 be understood that while the centering point
 method of driving the interrupter shaft is
 advantageous because of its simplicity and
 convenience as before noted, the interrupter
 shaft may be otherwise driven, and my in-
 40 vention is not limited thereto except as ap-
 pears in the claims. With the interrupter
 shaft in its innermost or righthand position
 as shown in Fig. 3, the primary circuit of the
 45 transformer is interrupted once during each
 rotation of the interrupter shaft, each in-
 terruption causing the induction of a train
 or group of voltage waves in the secondary
 circuit which gradually decrease in value
 50 during the period in which the primary cir-
 cuit is open. A train of such waves is con-
 ventionally shown by the curve 37 in Fig. 6.
 The apparatus is intended to be so designed
 that only one wave or half cycle of each
 55 train is of sufficient amplitude to produce
 illuminating current in the illuminator A.
 The line 36 being the zero line, the broken
 lines 36^a may be regarded as indicating the
 break down voltage of the gas tube illumina-
 60 tor, that is to say, the value of voltage suf-
 ficient to light the illuminator. By this
 means therefore, the illuminator A produces
 a single and almost instantaneous flash of
 light each time the contacts 16 and 18 are
 65 operated and the rotations of the shaft 6 be-
 ing synchronous with the cyclic movements
 of the part to be examined, all these flashes
 occur at the same point in the cycle of the
 part being examined. When the illumina-
 tor A therefore is approached to and directed
 toward the moving part to be examined, this
 part is illuminated when, and only when, it

is at some certain point or stage of its cycle
 and hence appears to the eye to be standing
 stationary at this point. To view the mov-
 ing part in some point of its cycle other than
 70 that in which it is first seen, the angular rela-
 tion of the lever 15 to the shaft cam must
 be changed, which can be done with the
 greatest convenience by simply turning the
 cover 4 and thereby the head 1. This makes
 75 the light flashes occur earlier or later in the
 cycle. The amount of this angular shift, or
 the difference in phase between any two cer-
 tain positions of the moving part under ex-
 80 amination, can be measured by thus turning
 the cover 4 with respect to the sleeve 3 and
 noting thereby the angular distance through
 which the lever 15 must be carried to change
 the view from one of those positions to the
 85 other. For this purpose, I usually provide
 a pointer 26 secured by a post 27 to the sleeve
 3 in juxtaposition to a scale 28 marked cir-
 cumferentially, usually in degrees, on the
 cylindrical surface of the cover 4 adjacent
 90 thereto. By pulling out the shaft 6 to its left
 hand position (or, contra, pulling the cover
 4 and head to the right away from the sleeve
 3), so as to bring cam 13 into action, the
 moving part can be viewed in two positions
 95 simultaneously, namely (because cams 12
 and 13 are separated by 180°) at opposite
 points in its cycle. The moving part may be
 made to appear as though moving slowly,
 "creeping", in its proper direction, by slight-
 100 ly releasing the pressure of the center point
 on the driving shaft so that a small degree
 of slip occurs and the interrupter shaft 6
 rotates slightly slower than the driving shaft.
 By driving the interrupter at a greater speed
 the moving part can be made to appear mov-
 105 ing slowly backwards.

A flash-illuminating stroboscope of the
 general type described, (omitting reference to
 the taps in the primary winding of the trans-
 former) is subject to the limitation that it
 produces sharp and well defined images only
 110 within a limited range of speed; that is to
 say, if the instrument is designed for suc-
 cessful operation at low shaft speeds, then
 it fails entirely at materially higher shaft
 speeds; or if designed for high speeds, then
 115 it produces poorly outlined images at ma-
 terially lower speeds, or even two or more
 images slightly displaced from each other
 where only one should be seen. This, I be-
 lieve I have discovered, is due to the time-
 120 constant of the transformer and the varying
 periods of energization. That is to say, the
 inductance in the primary circuit delays the
 building up of the current in this circuit, so
 that it grows or only builds up slowly fol-
 125 lowing each closing of the primary circuit
 at the contacts 16 and 18, and its ultimate
 value depends on the length of time the con-
 tacts are held closed. At slow speeds the
 contacts are permitted to remain closed for
 130

longer periods than at high speed, and accordingly the primary currents reach higher values at low speeds than at high and hence energize the magnetic field more highly, i. e.,
 5 produce a greater number of magnetic flux lines in it. Accordingly the voltage induced in the secondary winding vary inversely to the speed. Assuming, for example, that the
 10 transformer is so constructed that the short closing-periods of the contacts at high speeds are long enough to build up the magnetic field to a value capable of inducing (each time the contacts 16 and 18 are opened) a
 15 voltage wave-train in the secondary winding having one wave of sufficient amplitude to light the illuminator A (i. e., greater than 36°), then at low speed, when the contacts 16 and 18 are allowed to remain closed for longer periods of time, the magnetic circuit
 20 is so much more highly energized that (each time the contacts 16 and 18 are opened) it induces wave trains, each of which has two or more waves or half cycles of sufficient amplitude to produce flashes in the illuminator,
 25 so that the resulting images are indistinctly outlined or multiple images are produced where only one should be seen. Contra, if the transformer is so constructed that at low speeds the magnetic field builds up to a value only sufficient to induce one wave
 30 of sufficient amplitude to light the illumination, then at high speeds (the windings being neither increased nor diminished and all other things remaining unchanged) the magnetic circuit is so incompletely energized during each short charging period that the resulting wave trains have no waves of sufficient amplitude to light the illuminator,
 35 and the apparatus fails entirely. To operate throughout a wide speed range therefore it is only necessary to compensate for the variations in the length of the periods in which the contacts are held closed (or the variations in the ratio of contact-open periods to the contact-closed periods) to the end of
 40 maintaining the product of the number of effective or active turns in the secondary winding, multiplied by the number of magnetic flux lines cutting the said secondary per unit of time, within such limits that each induced voltage-train has one wave, and only one wave, of sufficient amplitude to light the illuminator.

It will be apparent upon consideration that
 55 increasing the number of interruptions of the primary circuit per rotation of the interrupter shaft (to display the part under examination in two or more positions simultaneously) acts in exactly the same manner as increasing the speed of the operating shaft, so that a stroboscope without my invention may function quite satisfactorily at a certain speed when producing one view per cycle, but fail when used to produce two or
 60 more views per cycle at the same speed. Ob-

viously the reverse is also true. My invention may be used to correct for this also, as is quite apparent.

Preferably I compensate for changes in the periods of the contact operation which
 70 accompany changes in the frequency of operation, by counteracting the tendency for the strength to which the magnetic field is built up to vary, specifically by changing the time-constant of the primary or inducing
 75 circuit inversely to the change of frequency, more specifically by changing the inductance of the primary circuit, and more specifically still by reducing the inductance of the primary circuit by cutting out transformer-prim-
 80 ary turns when the speed is increased, and increasing the same inductance by cutting in turns when the speed is reduced, thus speeding up the creation of the magnetic field with increasing speed frequency and delaying the
 85 building up of the field as the speed frequency is reduced, so that at every speed the magnetic circuit is energized sufficiently to light the illuminator but at no speed is the field energized sufficiently to produce two voltage
 90 waves in a single train exceeding the rather definite break down voltage of the tube, i. e. of sufficient amplitude to light the illuminator. It is not necessary that the strength of the field bear a close relation to the speed, and this is especially true where the discharge
 95 is highly damped, so that there is a wide difference in amplitude between the maximum wave and the next highest in the train. High damping in itself, it will be observed, broadens the range of speed (i. e., contact frequency) that can be covered without any change in the circuits or apparatus, inasmuch as it permits considerable difference between the
 100 lowest speed which produces a train of waves 37 (Fig. 6) whose second highest wave 38, for example, is less than 36° and hence is insufficient to light the illuminator, and the highest speed which produces a wave train 39 whose maximum wave is sufficient to light
 105 the illuminator. I have found three or four adjustments are sufficient to cover the entire range of speed usually encountered in practice. The taps 40 and 41 in the primary circuit of the transformer, in conjunction with
 110 the terminal connection 42 provide for three changes in the inducing circuit inductance. The tap switch B1 with its movable switch arm is a convenient means for changing the connections to any one of these leads. For
 115 the highest speeds the magnetizing current is made to travel the tap 40 and hence only the smallest part of the primary circuit. Accordingly the magnetic field is built up rapidly. For the lowest speeds the terminal connection 42 and the entire primary winding are utilized, and hence the magnetic field is built up much more slowly. At some certain intermediate speeds the tap 41 and an intermediate part of the primary winding are re-
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sorted to so that the magnetic field builds up at an intermediate rate. While the proper location of the higher speed taps in a winding satisfactory as a whole for low speed work, can be predetermined to some approximate degree as appears from the foregoing, the subject of induction coils and oscillating transformers of the type used in this work is so far from having been reduced to exact calculation, it will be understood, that the best location of the taps may require experiment and trial on each size and type of apparatus. It must also be understood that regardless of the correctness of my theories of the cause of the fault and its counteraction as above explained, the fact is that taps such as 40, 41, etc., suitable locations for which can be found readily, when utilized in the manner described, do act to adapt the instrument to produce sharp and well defined images throughout substantially the wide range of speeds usually encountered in practice.

The inductance and hence the time-constant of the primary circuit can also be varied in other ways as will be understood by those skilled in the art.

In the foregoing I have assumed that the voltage at the source remains substantially constant. The time required to build up the magnetic field to any predetermined value varies of course, inversely with the value of the voltage applied to the primary winding of the inductor at B. As an alternative therefore, the tendency for the field strength to vary with the frequency of contact operation can be compensated for and counteracted by suitably varying the voltage of the source, using higher source voltages with the higher speeds and lower source voltages with lower speeds. The same result can be obtained without varying the source voltage, by adding ohmic resistance in series with the primary winding as the speed is increased and reducing the resistance of the primary circuit as the speed is reduced.

Furthermore the capacity of the condenser 19 affects the range of operations. By suitably reducing the capacity at this point as the speed is increased and increasing the capacity for reduced speeds, the range of operation of the instrument can be increased. This is not so desirable as the use of the tapped primary however, because the tapped primary operation entails a higher resistance in the primary circuit with the lower speeds and thus is more economical in battery consumption.

The above described correction for changes in the periods of contact operation which accompanies changes in the frequency of operation, is the subject of a divisional application for patent, Serial No. 553,775, filed July 29, 1931.

While I have thus described what I believe to be the best forms of my invention, it

will be understood that my invention is not limited thereto except as hereinafter appears in the claims:

1. In a stroboscopic apparatus, the combination of a flash-illuminator for lighting the part to be examined, electrical apparatus to provide electric currents to light the illuminator, and an interrupter unit having a shaft protruding from substantially the center of the unit and provided with a centre point, contacts operated by the shaft to open and close a circuit of said electrical apparatus, and means for adjusting the time of actuating the contacts with respect to the shaft rotation, the said illuminator, electrical apparatus, and interrupter unit comprising three separate units united by flexible electric conductors so that each can be disposed in a convenient location.

2. In stroboscopic apparatus, a flash-illuminator, a shaft, a center point on the end of said shaft through which the shaft can be driven, and means mounted directly on the said shaft to open and close a circuit and thereby controlling the lighting of said illuminator.

3. In stroboscopic apparatus, a flash-illuminator, a contact to open and close a circuit and thereby controlling the lighting of said illuminator, a shaft having a cam thereon to actuate said contact, and a center point on the end of said shaft through which the shaft can be driven.

4. In flash-illuminating stroboscopic apparatus, a flash-controlling contact, a shaft having a cam thereon for moving said contact, means for changing the position of the contact around the axis of the shaft to change its time of operation by said cam, and a center point on an end of said shaft through which the shaft can be driven.

5. An electrical flash-illuminating stroboscope having contacts to interrupt a circuit and a condenser in shunt to said contacts, characterized by the fact that the condenser is located close to the contacts.

6. In an electrical stroboscope, an induction apparatus to furnish electric currents to the illuminator, a power-driven interrupter unit having contacts to make and break the primary circuit of the induction apparatus, and a condenser, connected in shunt to said contacts, placed in said interrupter unit.

7. In a stroboscope, the combination of an illuminator, a controlling electrical circuit therefore contacts in said electric circuit to control the lighting of the illuminator, a plurality of cams to actuate one of said contacts, and means supporting said cams and contacts, characterized by the fact that said movable contact is mounted to move in a fixed place on said means and said cams are adjustable on said means, and thereby adjustable with respect to said movable contact to

bring various of the cams into position to operate said movable contact.

8. In a stroboscope, the combination of an illuminator, contacts in an electric circuit to control the lighting of the illuminator, a lever carrying one of said contacts, a shaft, a plurality of cams on said shaft to actuate said lever, said cams being spaced apart longitudinally on the shaft, and means carrying said shaft, characterized by the fact that said shaft is slidable in said means to change the relation of the cams to the lever.

9. In a stroboscope, the combination of a flash-illuminator, contacts in an electrical circuit to control the lighting of the flash illuminator, a revolving cam for actuating said contacts, and means for adjusting said contacts angularly about the axis of revolution of the cam.

10. In a stroboscope, a flash-illuminator, contacts in an electrical circuit to control the lighting of said illuminator, a lever carrying one of said contacts, a shaft having a cam to actuate the lever, means on said shaft for detachably connecting said shaft to a mechanism for driving it, and means for moving the lever around the shaft.

11. In a stroboscope, a flash-illuminator, a shaft having a plurality of cams longitudinally spaced thereon, a member to which the shaft is fixed against longitudinal movement, contacts in an electrical circuit to control the lighting of said illuminator, a lever carrying one of said contacts and arranged to be actuated by said cams, and a second member carrying said lever and a contact cooperating with the contact on the lever, said two members being movable relatively to each other lengthwise of the shaft to bring to and remove from said lever one of said cams, and said second member being adjustable around the axis of the shaft to change the angular position of the lever with respect to said shaft.

12. In a stroboscope, a flash-illuminator, contacts in an electrical circuit to control the lighting of the illuminator, a lever carrying one of said contacts, a member carrying said lever and a cooperating contact, a sleeve member exposed for holding purposes and slidable and rotatable with respect to the first mentioned member, and a shaft having a plurality of cams and mounted to rotate in but longitudinally fixed to said sleeve member, said cams being arranged to actuate said lever, and being spaced axially from each other so that by sliding one of said members with respect to the other one of said cams is brought to and removed from a position in which it can actuate the lever.

13. The combination of claim 12 characterized by the fact that a scale is provided circumferentially on one of said members and the other has a cooperating index member.

14. In stroboscopic apparatus, means af-

fording separate views of an object at spaced intervals, and cooperating mechanism including a shaft to be driven, a first member in which said shaft is mounted, a second member rotatable with respect to said first member, a contact controlling the spacing of the intervals at which said means affords the separate views and means whereby said shaft operates said contact, said contact and said means being mounted one on the shaft and the other on said second member so that turning the second member with respect to the first causes the part to be examined to be seen in different positions.

In testimony whereof, I have signed this specification.

PETER DAVEY.