

May 31, 1966

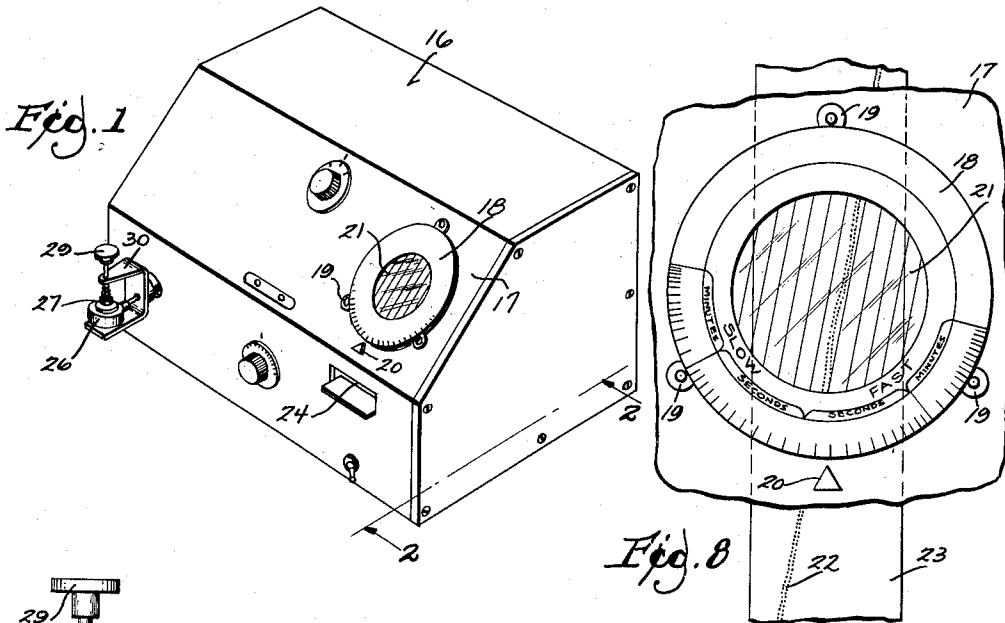
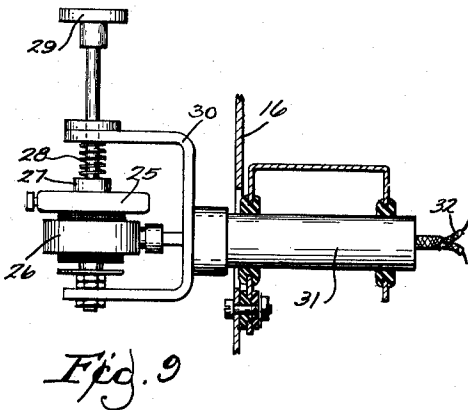
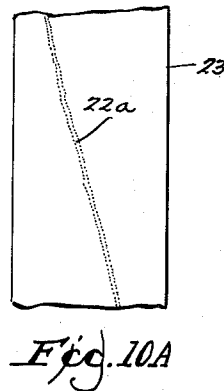
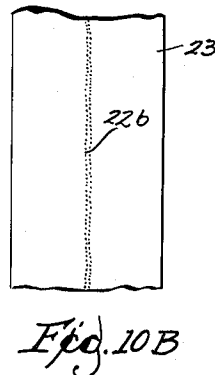
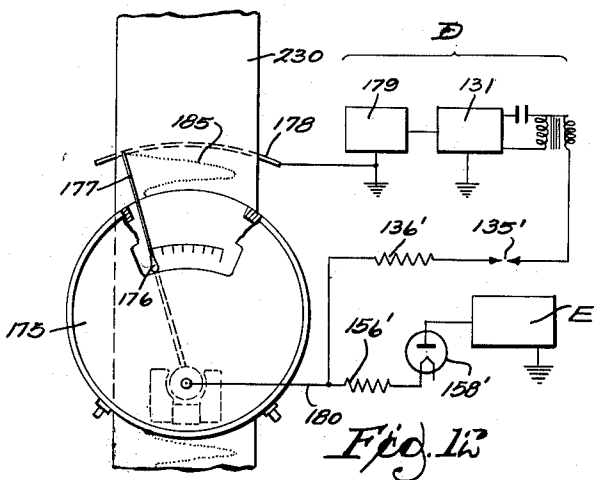
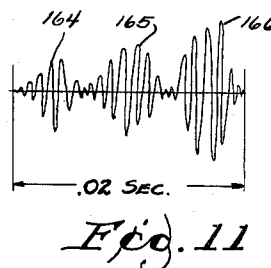
D. K. ALEXANDER

3,254,346

ELECTRONIC PRINTER AND WATCH TIMER

Filed May 21, 1962

4 Sheets-Sheet 1



INVENTOR.
DONALD K. ALEXANDER
BY
Wheeler, Wheeler & Wheeler
ATTORNEYS

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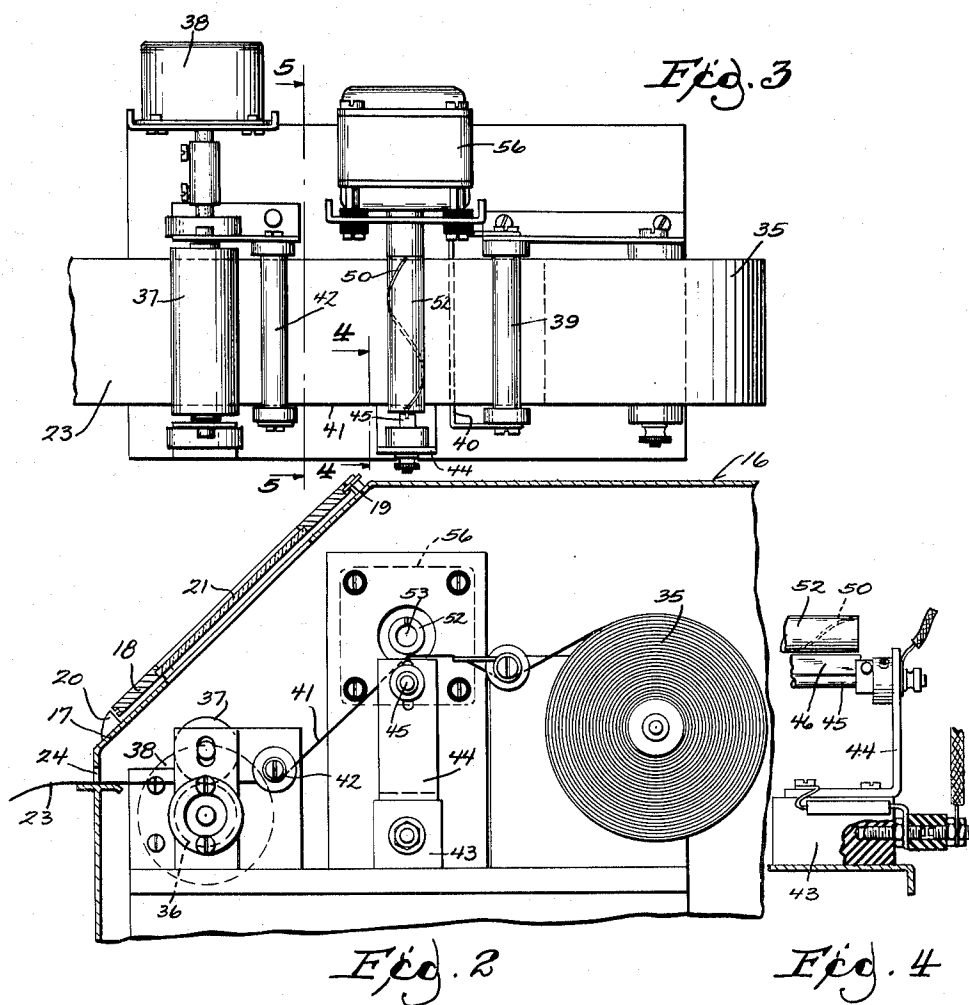
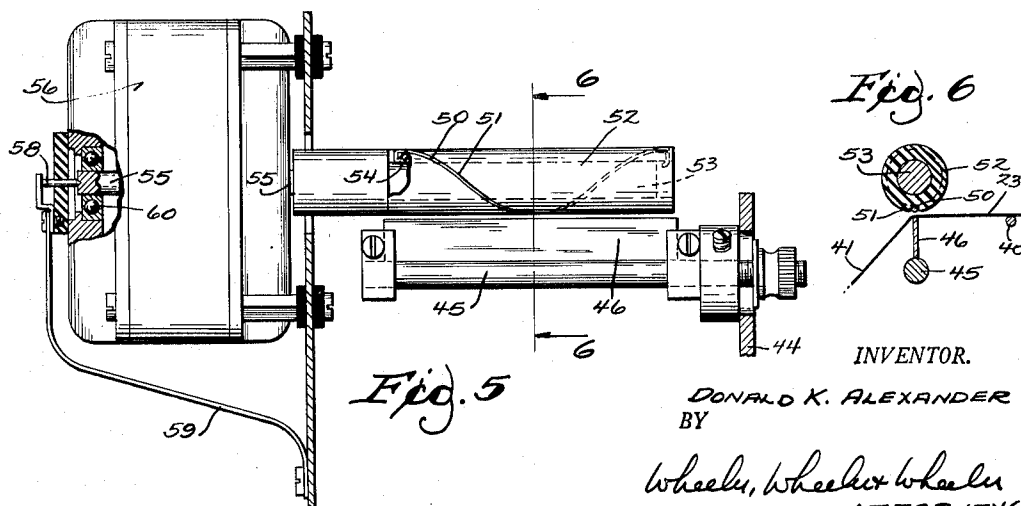
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4 Sheets-Sheet 4

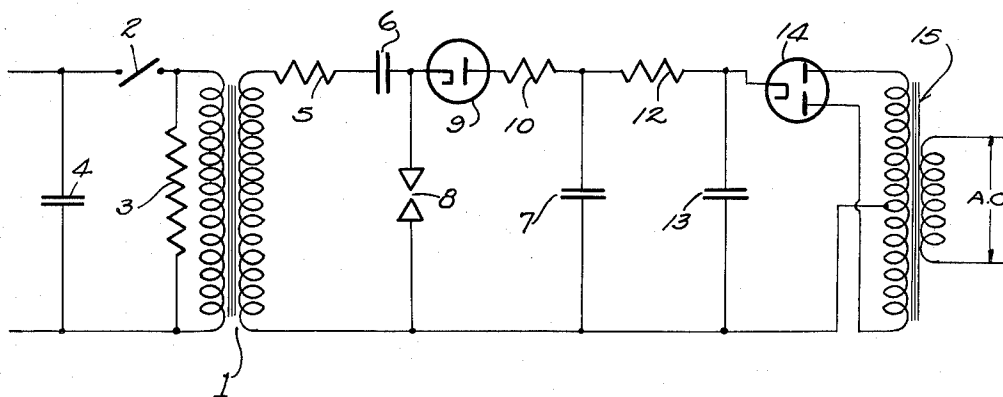


Fig. 13

INVENTOR.

DONALD K. ALEXANDER

BY

Wheeler, Wheeler & Wheeler
ATTORNEYS

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3,254,346

ELECTRONIC PRINTER AND WATCH TIMER

Donald K. Alexander, 91 Cherry St.,
Williams Bay, Wis.

Filed May 21, 1962, Ser. No. 198,405
23 Claims. (Cl. 346-74)

This invention relates to an electronic printer and watch timer. The present application is a continuation in part of my application 378,145 filed September 2, 1953, now abandoned, and of like title.

In its broader aspect, the invention can be used for various types of electronic frictionless recording. Features of the broad invention include printing on moving tape by means of an arc, preferably of relatively heavy direct current, which flows only under the control of an ionizing spark which, in and of itself, is of such low amperage as to make substantially no mark upon the recording tape but which has voltage adequate to jump a gap in which the tape is located and is of such short duration (whether A.C. or D.C.) as to minimize brush discharges and other sources of erratic movement. In consequence, I provide a sharply delineated arc burn or perforation of the tape which is accurately controlled as to position and duration by the ionizing spark but produces a much clearer mark on the tape than any which could be produced by a spark.

To achieve the results herein contemplated, the electrical circuit includes a printing spark gap across which two different potentials are impressed. One potential is that of an ionizing current and the other is that of a marking current.

The ionizing current achieves its objective by creating a spark across the gap. Despite the fact that its voltage is high enough so that it readily jumps the gap, it is controlled relatively easily because it has low amperage. If the ionizing current had sufficient amperage so that it alone would mark the paper it would be more difficult to control.

The marking current does not have sufficient voltage to jump the gap in the absence of the ionizing current. Hence, despite its high amperage, which enables it to perform its marking function to produce a sharp clear well-defined mark on a paper tape, it nevertheless is easily controllable in duration and intensity. The ionizing current precisely controls the initiation of flow of the marking current. According to the constants of the marking current circuit, the ionizing current spark sets limits to the duration of the marking current arc. The arc is extinguished whenever its voltage drops below the holding voltage of the gap. Normally, this happens at the conclusion of the ionizing spark. It may happen prior to the conclusion of the ionizing spark if the marking current circuit constants are such that the available energy will be drained off at a rate which lowers the marking current potential below the holding voltage of the gap even while the ionizing spark is effective. It may also happen immediately after extinction of the spark.

From a practical standpoint it is desirable and virtually essential that the potentials of the ionizing current and the marking current be isolated from each other, having substantially no common path except across the gap upon which both potentials are impressed. The exclusion of each current from the path provided by the other is most easily achieved if one of the two currents is D.C. and the other A.C. The preferred arrangement is one in which an A.C. source supplies the current for ionization and control, the marking current being derived from a D.C. source. In such a preferred organization a capacitance or a second gap in the A.C. circuit will exclude the D.C. potential from that circuit.

Since the capacitance excludes arcing current from the ionizing spark source, the D.C. current will be completely excluded from the A.C. circuit. If an auxiliary gap is used instead of a capacitance, this gap will be ionized along with the marking gap. However, since the resistance of the secondary of the spark transformer is quite high, such D.C. current as can flow through it, after both gaps are ionized, will be of no importance and will neither limit, nor add to, the marking of the tape.

In either case, a rectifier in the D.C. circuit will exclude from that circuit at least one-half cycle of the A.C. current, thus precluding A.C. current as such from traversing the D.C. circuit.

The exclusion of each type of current from the circuit of the other is very important from a practical standpoint because, for example, a current sufficiently heavy to do sharp and effective marking of the tape during a single A.C. impulse would be too heavy to handle in the coils of any ordinary practical A.C. spark transformer. The alternative of using a less heavy current over a longer period of time is more apt to set fire to the paper tape and it produces a less sharp mark on the tape because of the movement of the tape during the prolonged interval. The mark produced by the present invention is sharp notwithstanding tape movement because among many modes of operation it can be produced almost instantaneously by a current sufficiently heavy to achieve the result without requiring any prolonged interval. There is less danger of setting fire to the tape because the heat of the marking current is effective for so short an interval that it has terminated before it can be communicated to any portion of the tape other than that immediately subjected to the arc.

For the purposes hereof the effect of the ionizing current as it jumps the gap is described as a spark while the effect of the marking current controlled thereby is described as an arc. In practice it is preferred that the A.C. spark be limited to one-half cycle, whereby the resulting arc is limited to one pulse. The printing current of the arc, therefore, marks the tape sharply and without burning.

It is well recognized that there are material differences between a spark and an arc, even though the line of demarcation is not sharply defined. In general, a spark has relatively high voltage and low amperage. It is usually, but not necessarily, the result of a number of passages of high frequency A.C. current and it is frequently preceded or accompanied by a brush discharge. An arc, on the other hand, is of relatively much greater intensity, usually more sharply defined as to path, brush discharges usually being absent, and by reason of its greater amperage develops greater heat. I have found considerable advantages in the apparatus and method disclosed in using a spark of extraordinarily brief duration to perform solely an ionizing rather than a printing function to control the movement of the arc by which the printing is actually effected.

The broad invention as above described has particular application to a watch timer in which the gap through which the tape moves is defined in part by a bar which spans the tape transversely and in part by a rotating helix, the rate of rotation of which is carefully synchronized with a crystal controlled frequency (usually 90 c.p.s.) to the impulses electronically transmitted as a result of the ticking of a watch so that the mark inscribed on the moving tape by the arc will deviate from parallelism with the center line of the tape in a direction and to a degree accurately represented the extent to which the watch is inaccurate. For the purpose of indicating the direction and extent of deviation aforesaid, an angularly adjustable grid is mounted over the path of the tape and provided with suitable calibrations from which the deviation may be

instantly read by the operator in terms of seconds of gain or loss per day or hour.

A number of improvements specific to the watch timer are included. I eliminate or greatly reduce the effect of extraneous noise so that the instrument will respond only to the relatively sharp ticks of the watch. I eliminate all but the first of the series of metallic impacts involved and audibly indistinguishable in a single tick of a watch. This is accomplished by a circuit in which the very first sound picked up by the microphone in each watch tick triggers an electronic tube to release the energy of a condenser which requires an appreciable interval for the restoration of such energy so that no further response will follow from ensuing sounds until the first click of the next separate tick of the watch.

I have also eliminated pitting of the bearings of the synchronized driving motor by grounding the helix directly from the shaft of such motor without requiring the passage of high voltage currents, or any currents, through the bearings.

Despite the fact that I prefer to use high frequency A.C. current of low amperage for the ionizing function above referred to, I have provided damping means in the circuit which substantially completely eliminates all flow after the first half cycle so that the effect of such current is virtually reduced to a single impulse of interrupted D.C.

Better control of the printing effect of the arc and longer life for the printing portions of the device have been achieved through the use as the rotating helix of a molybdenum wire embedded substantially to its full depth in a closely fitted channel in a cylinder of fiber glass with plastic impregnation.

Other specific improvement in the circuit and mechanical arrangement of the parts will be set forth in the following disclosure of the invention.

In the drawings:

FIG. 1 is a view in perspective of a watch timer embodying my invention.

FIG. 2 is an enlarged detail view taken in section through the watch timer on the line indicated at 2—2 in FIG. 1.

FIG. 3 is a plan view of portions of the apparatus in FIG. 2, the case being omitted.

FIG. 4 is a further enlarged detail view in transverse section on the line 4—4 of FIG. 3.

FIG. 5 is a still further enlarged view in transverse section on the line 5—5 of FIG. 3.

FIG. 6 is a detail view taken in transverse section on the line 6—6 of FIG. 5.

FIG. 7 is a circuit diagram showing the electrical wiring of the device.

FIG. 8 is an enlarged fragmentary detail view in plan of the calibrated dial for reading the direction and extent of deviation of the tested watch from accuracy.

FIG. 9 is a view in side elevation of the microphone and watch holder, portions of the case being shown in section.

FIG. 10A and FIG. 10B are replicas in plan of fragmentary portions of recordings made by the apparatus.

FIG. 11 is a diagram showing the response of the audio amplifier to a single watch tick.

FIG. 12 is a view diagrammatically illustrating a more general application of the recording principle of the invention to instruments generally.

FIG. 13 is a view diagrammatically illustrating the basic features of the generic circuit.

The basic features of the generic circuit are diagrammatically illustrated in FIG. 13. The ionizing current to be impressed across the gap 8 is one or more A.C. impulses derived from the secondary of a spark coil 1 having a triggering device 2 in the connections to its primary. The current supplied to the primary may be derived either from an A.C. source or a D.C. source. If the current supply is D.C., the triggering device 2 may

be a thyratron tube. The optional resistor 3 and capacitance 4 diagrammatically represent means for controlling duration of the current impulse which produces the spark. Resistor 3 may serve to damp the input pulse, thereby sharply limiting the duration of the ionizing spark across the gap at 8. The lower the value of the resistor, the greater the damping effect. Use of the optional capacitance at 4 will tend to increase the duration if the source is D.C.

If the source of spark current is A.C., the triggering device 2 may be a mechanical or electronic switch of some character. The showing is intended to be generic, with the triggering device 2 representing any appropriate device for initiating a momentary spark, the resistor 3 and capacitance 4 being intended to represent optional means for regulating the duration of the spark.

The secondary of the spark coil 1 is connected through a resistor 5 and a capacitance 6 with the opposing electrodes of printing gap 8. The capacitance at 6 is preferred to an auxiliary gap as a means of excluding marking current potential from ionizing current source 1.

For the purposes of this diagram, a capacitance 7, rather than a battery, serves as a source of marking current potential connected to the electrodes of the printing gap 8 through a circuit which includes a rectifier 9 and resistor 10. The rectifier 9 excludes the ionizing current potential from the marking current source 7. The resistor 10 controls the maximum length of the marking current arc, functioning in this regard with due reference to the value of the capacitance 7 and the D.C. voltage impressed thereon. For the purposes of this diagram, which substitutes capacitance 7 for a battery, means is provided for charging the capacitance from a power transformer 15 through the full wave rectifier 14. Preferably, but optionally, the charging circuit includes a resistor 12 and capacitance 13 as shown, these furnishing better control of the time and intensity of flow of the marking current across the printing gap 8. The rectifier 9 will readily pass the marking current from the source 7 but constitutes a means for excluding the ionizing potential of source 1 from the marking current circuit, at least to the extent above indicated, that A.C. current as such cannot pass the rectifier. If the first half cycle of the ionizing current happens to be in phase with the rectifier and will be able to pass through it, this does not alter the principle. Thereafter, every half-cycle of the same polarity as the marking source, will ionize the gap, thereby precluding the passage of the other half-cycle through the rectifier because of the low resistance of the ionized gap. In practice, the polarity of the first half-cycle of the spark is arranged to be the same as that of the marking source. The rectifier tube 9 presents an infinite resistance to that polarity of the ionizing spark which is the polarity of the marking current source. Since the resistance of the spark gap 8 is less than the inverse resistance of the rectifier, the spark will traverse the gap, thereby ionizing it. The gap having been ionized, the marking current and the next half-cycle of the spark will traverse the gap together.

Assuming that the triggering device 2 represents a means for controlling the start and duration of the ionizing spark, the arc of heavy marking current will normally flow across the marking gap 8 only at the precise initiation time of the ionizing current.

Not only does the spark of ionizing current determine the initiation of the arc of marking current, but it also controls its approximate duration. If the energy of the source 7 (FIG. 13) is drained off prior to termination of the ionizing current spark to a level such that it will no longer mark the tape, then the arc may be of shorter duration than the spark. Of course, since the spark is very short, this will not happen in normal practice.

If the marking current is derived from a source of such characteristics as to be able to maintain a potential above the holding voltage of the gap for any appreciable period after termination of the ionizing spark, then the duration

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of the marking arc may be appreciably longer than the duration of the ionizing spark. Again, while this may happen, it normally will not do so in a device especially designed for marking tape. Given the desired characteristics, the spark will always initiate the arc and will control its length in the sense that for every spark impulse, there will appear but one arc impulse, since the arc is incapable of restarting itself. Thus, it is true in a very real sense that the spark controls the length of the arc, whether the arc is identical in duration or slightly longer or slightly shorter than the ionizing spark.

By blocking the marking current from the ionizing source at least up to the point of ionization of the gap and blocking at least one polarity of the ionizing current from the marking current source, it is possible to print with precision sharply defined burn marks on a paper tape exposed to the arc in gap 8 and to regulate or control all characteristics of each of the two types of current independently of the other. Only by so doing can a well-defined mark be burned into the tape without setting fire to the paper.

The preferred exemplification of the invention for the specific purpose of watch timing will now be described.

The case 16 of the preferred watch timer embodiment is provided with a slanting face at 17 which supports the calibrated dial 18 in guides 19 for angular adjustment with respect to a fixed pointer at 20. The dial carries a plastic disk at 21 marked with a grid of parallel lines as clearly shown in FIG. 8 which may be moved into registry with the record line 22 traced on a movable tape 23 which issues, during the operation of the device, from a slot 24 in the forward wall of the cabinet 16. FIG. 8 shows the record line 22 with a definite inclination to the right as viewed toward the top of the sheet. With the guide lines of the dial adjusted into parallelism with record line 22, the calibrations on the dial show with respect to pointer 20 that the watch is running fast by about two seconds per day. FIG. 10A shows the type of record produced at 22a by a watch which is running slow. FIG. 10B shows the type of record produced at 22b by a watch which is running exactly on time.

Watch 25 to be tested is held to the face of the microphone 26 by a plunger 27 pressed lightly against the face of the watch by spring 28. A handle 29 fits the plunger to be retracted to introduce or remove the watch. The entire microphone and watch are mounted in a yoke 30 which is rotatable on sleeve 31 for which the case 16 provides bearings as shown in FIG. 9. The wiring 32 from the microphone passes into the case axially through sleeve 31 to be substantially unaffected by such manipulation of yoke 30 as is required to locate the watch in different positions for test.

Mechanically the apparatus is extremely simple. The tape 23 upon which the recording is to be made is withdrawn from supply roll 35 by feed rolls 36 and 37, one of which is driven by synchronous motor 38 (FIG. 3). Between the supply roll 35 and the feed rolls 36, 37 which deliver the tape through casing slot 24, the tape passes beneath an idler roll 39 and over a guide rod 40 to the printing gap hereinafter to be described. Thence the tape passes downwardly at 41 in general parallelism with the inclined wall portion 17 of the cabinet and the face of disk 21, through which the line printed thereon is clearly visible. The idler 42 guides the tape between the feed rolls 36 and 37.

The printing station is best illustrated in FIGS. 4, 5 and 6. A heavy insulating block 43 carries a bracket 44 upon which an adjustable rod 45 supports an electrode bar 46 over which the paper tape passes to receive the electronically printed record. Immediately over electrode 46 there is rotatably mounted a helical electrode 50 which is desirably, though not necessarily, made of .015" molybdenum wire set into a channel 51 in the surface of a rotor 52 desirably made of fiber glass with "Melamine" impregnation. The heat produced by the spark

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and arc has no effect on the fiber glass after the first layer in immediate proximity to the single turn helix at 50 has been melted into a hard glass surface. I have used tungsten for the helix, but tungsten becomes brittle in use, apparently due to crystallization as a result of the heat of the arc. The molybdenum stays soft in use.

The rotor 52 which carries the single turn helix at 50 has a metal core 53 to which the end of the wire is grounded at 54 (FIG. 5). The metal core constitutes an extension of the armature shaft 55 of the synchronous motor 56. The helical electrode 50 is grounded directly from the armature shaft 55 by means of peg or brush 58 which bears axially on the end of the shaft and is connected to ground by an electrical conductor 59. Previous attempts to operate such a motor without grounding the shaft independently of the motor frame resulted in excessive pitting of the bearings 60. The synchronous motor is operated under the control of a crystal to assure that the helix 50 will make exactly 45 turns per second (or nine turns for each tick of a correctly timed watch).

Through means hereinafter to be described, I cause an electric arc to traverse the printing gap between the electrode bar 46 and the electrode helix 50 through the intervening paper tape with sufficient intensity to mark the tape once and only once in each tick of the watch. In practice, each watch tick is actually comprised of a complex of sound caused by separate metallic impacts. I provide means whereby the arc which prints the tape always occurs in synchronism with corresponding metallic impacts in successive ticks. Assuming that the helix makes one rotation per second and assuming that the arc passes between the electrodes in exact synchronism with successive ticks then, if the watch which is supposed to tick once per second is operating on time with the synchronous motor, the perforations or burns on the tape produced by the arc will necessarily be in a straight line. Any deviation of the watch ticks from exact synchronism with the crystal-controlled motor would cause the marks printed on the tape to deviate to the right or left as above described.

The electrical parts and their connections will now be described.

The current supply is derived from a line at 65 (FIG. 7) subject to the control of a master switch at 66. I have found it unnecessary that the motor 38 which feeds the paper tape should be crystal-controlled and I have, therefore, reduced the load on the crystal and the synchronizing circuit by using at 38 a synchronous motor operated directly from a 60 cycle line 65.

The motor 56 which actuates rotor 52 and the single helix electrode 50 carried thereby receives energy from the power pack 67. In describing this and other components of the apparatus, it will be understood that particulars given are by way of example and represent the best organization known to me, but are not to be regarded as limitations on the scope of the invention.

The secondary of transformer 68 connects to the plates of a rectifying 5U4 tube at 69 and also to the plates of a 5V4 tube at 70 in the D.C. arc supply C. The cathode of the tube 69 is connected to a pair of voltage dividing resistances of 1250 ohms and 6000 ohms, respectively, at 71 and 72. Between the terminals of these resistances and ground are connected a 16 mf. condenser at 73, a 10 mf. condenser at 74 and a 50 mf. condenser at 75. The conductor 76 leads to the crystal oscillator 77 which operates at 81 kc. This in turn powers a multi-vibrator stage 78 operating at 13.5 kc. The output of stage 78 connects to another multi-vibrator stage at 79 operating at 2.2 kc. From this the vibrations are reduced in stage 80 to 450 cycles and stage 81 to 90 cycles. Across the output of stage 81, to reduce the square wave output substantially to sine wave form, is a filter network in which I connect in series a .006 mf. condenser at 82, a one meg resistor 83 and a .006 mf. condenser 84.

Across condenser 84 is a voltage dividing .5 meg potentiometer 85, the moving contact of which is connected by conductor 86 with the grid of a driver tube at 87. This potentiometer is adjusted to control voltage on motor 56.

The plate of the driver tube is connected through a 56K resistor at 88 to the terminals 89 and 90 of a gang switch, the moving contactor 91 of which connects through the conductors 92 and 93 to the voltage supply system between resistors 71 and 72. The plate of the driver tube 87 also connects through conductor 94 and a .05 mf. condenser 95 with the grid 96 of a 6L6 power tube 97, the anode of which is connected by conductor 98 and .5 mf. condenser 99 to the synchronous motor 56, another terminal of which is grounded. The cathode of the driver tube 87 is connected through a 2700 ohm resistor 100 to ground. It is also connected by a conductor 101 to the terminal 102 of the gang switch aforesaid.

From conductor 101 a 27K resistor at 103 is connected by conductor 104 to the gang switch contact 105. Resistor 103 is also connected through a 100K resistor at 106 and conductor 107 to the conductor 99 and to the .5 mf. condenser 108 attached to a third terminal of the synchronous motor 56. The resistors 103 and 106 supply a path of negative feed back which secures constant power output without impairing power handling capacity.

The aforesaid grid 96 of the power tube 97 is connected to ground through a 270K resistor at 110 and its cathode is also grounded through a 250 ohm resistor at 111. A conductor 112 leads from the cathode of this tube to the grounded side of the power pack at 67. The other grid 113 of the power tube 97 is connected through conductor 114 with the line 93 which leads from the power pack as above described. The mid-terminal of synchronous motor 56 and conductors 98, 99 leading thereto are connected through a choke 115 and conductor 116 with the line 76 from the power pack. In practice, this supplies about 450 volts.

For starting purposes, the switch contacts 91 and 105 of the gang switch are first moved to the starting position in which contact 91 engages contact 89 to deliver current to motor 56. In this position of the gang switch contacts, the resistor 103 is in the circuit. This limits the negative feed back and thereby allows motor 56 to reach full synchronous speed with great rapidity. After the motor is running in synchronism, the gang switch is moved to its third or running position in which contact 91 registers with contact 90 to continue to supply current and meanwhile contact 105 registers with contact 102 to short out resistor 103 and thus allow feed back to become fully effective for voltage regulation. The third contact 117 of the gang switch registers in the running positions with contact 118 to deliver line voltage 119 to conductor 120 with which the paper feed motor 38 is in series in the line. Thus the paper feed motor starts only after the motor 56 is already in synchronous operation. Desirably I feed the tape at about six inches per minute.

The crystal 125 which picks up the watch ticks in microphone 26 is connected between ground and the grid 126 of the first tube of a three stage tick amplifier A. In practice, I use dual 6SL7 tube. In the diagrams, the tubes illustrated each represent one-half of such a dual tube. The circuit of the amplifier is generally conventional and needs no detailed description, except to note that it is designed with low capacity coupling condensers 160, 161, 162 to give preferential amplification to metallic sounds such as those produced by the watch escapement. Its output connects to the grid 130 of a 2050 trigger tube at 131, the anode of which is connected through a condenser at 132 with a primary 133 of a spark coil. The secondary 134 of the spark coil 137 connects across a spark gap at 135 to the electrode bar 46 through resistor 136. In practice, the spark gap is set at .032

inch. The constants for the rest of the circuit are indicated directly in the diagram.

The 27000 ohm resistor 136 reduces the flow of the "spark" current and minimizes the possibility of radiation into other parts of the circuit. Without this suppressor, the frequency changers jump cycles occasionally and disrupt the accuracy of printing. A 56 ohm resistor 170 across the spark coil primary assists the suppressing function of resistor 136 and is important in reducing magnitude and duration of decay voltage to cut off the spark after the first ionizing impulse.

Reference has already been made to the fact that the secondary of transformer 68 is coupled to the plates of the 5V4 rectifier tube 70. This is in the power supply circuit for the D.C. arc. The cathode of the rectifier tube 70 is grounded through a 16 mf. condenser 150 and connects through a 2000 ohm resistor 151 to a safety switch 152 which is connected with the cabinet door 153 to be opened if the door is opened. The delivery side of the resistor 151 is also connected through a 40 mf. condenser 154 to ground.

Beyond the safety switch 152 the line 155 passes through a pair of 450 ohm resistors 156 and 157 to the anodes of the #83 tube 158, the cathode of which is connected by line 159 to the bar electrode 46. Tube 158 excludes the effect of the spark from the high voltage D.C. source due to its rectifying characteristic. The mechanical arrangement of the electrical connections of the A.C. spark gap 135 and the D.C. conductor 159 to the bracket 44 which carries electrode 46 are best illustrated in FIG. 4.

The amplified sound of the tick as picked up by the crystal 125 acts through the trigger tube 131 to discharge condenser 132 through the primary of the spark coil transformer 133, 134 to produce a spark which jumps the gap at 135 and the printing gap between the electrodes 46 and 50.

Because of the use of a condenser, controlled by the trigger tube 131, as a means of creating the impulse in the primary 133 of the spark coil, the spark coil will be energized solely in response to the first of the complex of sound waves which is comprised in the watch sound which, to the ear, appears to be a single tick. Electrically analyzed, the tick of a watch appears as shown in FIG. 11. It lasts for about .02 second and comprises a first sound reaching a peak at 164, a second sound reaching a peak at 165 and a third sound reaching a peak at 166. The circuit illustrated is such that the first sound wave at 164 will be amplified to fire the trigger tube 131 for the discharge of condenser 132 and, because of the time required to recharge condenser 132, there will be nothing left to create any spark as a result of the sound waves which peak at 165 and 166. The time required to re-charge condenser 132 is greater than the entire duration of the sound complex illustrated in FIG. 11. Accordingly, one single spark is all that is produced across the printing gap. This decays sharply, suppressed by resistors 170 and 136 as aforesaid.

The spark gap at 135 and the resistor at 136 further have a damping action tending to suppress immediately any oscillation in the secondary 134 of the spark coil. Thus, what might otherwise be an alternating current spark is reduced to a single interrupted D.C. spark which jumps the printing gap but once. This is important because the first spark to jump the gap will ordinarily jump in a perfectly straight line between the electrode 46 and the closest point on the helix 50. Subsequent sparks or brush discharges might ionize the gases in this gap on devious paths other than the shortest line across the gap. I find that the rotation of the rotor 52 is a further important factor assuring the movement of this spark on a rectilinear path representing the shortest distance across the gap. The rotor and the movement of the paper keep the air stirred up and homogeneous.

As above indicated, the spark itself has no printing effect due to the fact that it is of low amperage. What the spark does is to ionize an arc path and thereby to trigger the relatively heavy amperage D.C. arc discharge from the tube 158 across the gap to the printing operation. The voltage of the D.C. current is sufficiently low so that the arc which does the printing is not self-maintaining but will exist only during the interval in which the low amperage spark ionizes the air on the desired rectilinear path of flow across the gap.

The operation is as follows: the main line switch 66 being closed, the watch 25 to be tested is mounted directly on the crystal microphone 26 by withdrawing plunger 27, positioning the watch, and then releasing plunger 27 to hold the watch against the microphone under bias of spring 28. The entire microphone may be turned with yoke 30 to any desired position in order that the watch may be variously tested.

The sharp metallic sound of the watch tick is conducted through the metal of the watch case and through the microphone and picked up by the crystal 125 and preferentially amplified in the three stage tick amplifier A. In response to the first amplified sound of the complex of sounds comprising the tick, the condenser 132 is discharged by trigger tube 131 through the spark coil primary 133, thus precluding any response to subsequent sounds of that tick.

Meantime the synchronous motor 56 has been brought up to speed in the starting position of the gang switch and is in synchronized operation, supplied with power through the crystal-controlled driver tube 87 and the power tube 97 in the synchronizing driver circuit B to rotate rotor 52 and electrode helix 50 of the printing gap at exactly 45 rotations per second. A relatively high amperage current from the arc power supply C is impressed across that gap but is ineffective to form an arc pending ionization of the gases in the printing gap.

When, in response to the first sound impulse of the watch tick, condenser 132 is discharged through the primary 133 of the spark coil, a momentary spark across the printing gap is established at a level just adequate to traverse the gap on the straightest possible line between the bar 46 and the helix 50. This ionizes the gas in the printing gap to permit the flow of the heavier D.C. current from the printing power supply C to burn a mark on the paper tape traversing the gap at a constant speed determined by the synchronous motor 38.

The printing operation will be repeated once and only once at each tick of the watch and because of the helical form of the electrode 50 and the synchronous movement of the parts, the line of printing dots burned in the tape by the arc in its successive discharges across the printing gap will either be parallel to the path of the tape or will deviate therefrom to the left or the right according as the watch tick is in fact synchronized with the crystal-controlled rotation of the helix 50 or is accelerating or decelerating with respect to helix rotation.

When the grid 21 of dial 18 is moved to parallelism with the path of the arc burns printed on the tape moving therebeneath, the calibrations of the dial in relation to the cabinet will give an immediate and direct reading of the performance of the watch under test. The overall accuracy of the instrument is so high that lateral displacement of certain dots from the general line will disclose minor irregularities other than the mere gain or loss of the watch so that an experienced analyst using the instrument is guided to watch defects responsible for any deviation from strict accuracy.

It is the purpose of FIG. 12 merely to suggest diagrammatically the application of my printing system and method to general instrument use. The instrument 175 will be understood to represent any instrument having a pointer 176, the movement of which it may be desired to record. For the purposes of the present invention, the pointer is extended at 177 and beneath the path of movement of its tip there is provided the electrode bar 178. Through

the printing gap between the tip 177 and the bar 178, is advanced the tape 230 upon which the movement of the pointer is to be recorded. The bar 178 is grounded with the oscillator 179 which triggers the thyatron whereby a spark is produced at intervals to jump the gap at 135' connected through resistor 136' to the needle or pointer 176 and extension 177. E represents a source of heavier current to provide a printing arc connected through rectifier 158' and current limiting resistor 156' to conductor 180 and thence to the pointer. The operation is exactly as above described except that the spark does not depend upon a microphone pick up of sound but is produced at pre-determined regular intervals to ionize gases in the printing gap and to control the flow of the printing gap from the source E which, according to the position of the pointer extension 177, produces a printed mark 185 on the moving tape 230. Since the tape has regular advance, given intervals of its length represent time intervals and the printed pattern will indicate where the pointer was at any given time. Yet this result is achieved virtually without any friction which could affect even the most sensitive instrument.

I claim:

1. A method of producing sharply delineated arc burns on a tape, which method comprises passing a tape through a spark gap, separately impressing an ionizing current potential and a marking current potential across said gap, and the marking current having voltage too low to allow it to traverse the gap by itself, excluding marking current from the ionizing current source at least up to the point of ionization of the gap, excluding ionizing current as such from the marking current source, and controlling the time and duration of flow of the ionizing current across said gap, thereby controlling the initiation time of the flow of marking current across said gap, and setting limits to the flow of marking current.

2. A method according to claim 1 in which the ionizing current source is an A.C. source and the marking current source is a D.C. source, the step of excluding ionizing current as such from the marking current source, including the exclusion by rectification of at least one half cycle of the A.C. ionizing current from the D.C. marking current source.

3. A method according to claim 2 in which the marking-current potential is impressed substantially continuously across the gap.

4. A method according to claim 2 including the further step of damping the flow of current from the ionizing source immediately upon ionization of said gap, whereby to limit the duration of the flow of marking current across said gap to one pulse.

5. A method of producing sharply delineated arc burns on tape, which method comprises passing a tape between electrodes, impressing across said electrodes a potential of marking current of sufficiently heavy amperage to produce a burn mark on the tape, said current potential being insufficient to break down the gap between said electrodes and sufficient to jump the gap when an ionizing current is passed between the electrodes, separately impressing briefly across said electrodes an ionizing current with voltage sufficient to jump the gap and limiting the duration of said ionizing current to a precise interval of time, the flow of the ionizing current constituting the sole determinant of the initiation of flow of said marking current, and setting limits to flow of marking current.

6. Apparatus of the character described comprising spaced electrodes constituting a gap and means for feeding a tape therebetween, a source of ionizing current with a potential sufficiently high to jump the gap for the ionization thereof; means for connecting said ionizing source with the electrodes at opposite sides of the gap, the said connecting means including means for the control of current flow from the source across the gap and means for excluding marking current from said ionizing current source, at least up to the point of ionization of

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the gap, a source of marking current of amperage adequate to produce a burn mark on the tape in said gap and a potential inadequate to enable the marking current to jump the gap except as the gap is ionized by said ionizing current, and means for connecting the source of marking current with the electrodes at opposite sides of the gap, said last connecting means including means for excluding the ionizing current as such from said source of marking current.

7. A combination according to claim 6 in which the source of ionizing current is an A.C. source and the means for excluding ionizing current as such from the marking current source comprises a rectifier.

8. A combination according to claim 7 in which the marking current source comprises a D.C. source, and the means for excluding marking current from the ionizing current source comprises a conductor having portions which are conductively discontinuous.

9. A combination according to claim 8 in which the conductor portions which are conductively discontinuous comprise a capacitance.

10. An apparatus of the character described comprising the combination with spaced electrodes constituting a gap, and means for feeding a tape therebetween, of means for intermittently and momentarily impressing a spark-forming current across said gap of high voltage to ionize path between said electrodes, means for damping said spark-forming current immediately after said path is ionized and before brush discharges occur and means for impressing across said gap an arc of printing current of high amperage to perforate said tape but of potential inadequate to span the gap except upon said ionized path and for a duration approximating that of said spark.

11. In a device for electrical printing upon a tape, the combination with spaced electrodes providing a gap and means for feeding a tape between the electrodes, of a source of relatively high potential and low amperage spark current and means for the triggered delivery of a current from said source to said electrodes for effecting an ionizing spark therebetween of inadequate amperage to mark the tape, a separate source of electric arc current of potential inadequate to span the gap except upon the path ionized by the spark and inadequate to maintain flow across the gap for any appreciable period after termination of the spark but of sufficiently heavy amperage to mark the tape, said separate source having means connecting it across the electrodes, and means for excluding said arc current from the first mentioned source.

12. A device according to claim 11 in further combination with means for limiting the duration of the spark current to a single momentary impulse, means for confining said ionized path to the shortest distance between said electrodes and means to minimize brush discharges whereby the mark on the tape is sharply delineated.

13. The device of claim 11 in which the source and means for triggered delivery of spark current comprises a transformer, a capacitance arranged to discharge through the transformer and means for intermittently triggering said capacitance to effect said discharge, whereby to create a spark across said gap, said separate source comprising a D.C. source.

14. The device of claim 11 in which said gap comprises one fixed electrode and a rotatable electrode comprising a helix and means for rotating the helix at a pre-determined rate.

15. The device of claim 11 in which said gap comprises one electrode movable with respect to the other and disposed across the path of movement of the tape.

16. The device of claim 11 in which said gap comprises one electrode movable with respect to the other and disposed across the path of movement of the tape, said movable electrode comprising the pointer of an instrument, the other electrode extending along the path of movement of the movable electrode.

17. In a device of the character described, the com-

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bination with a trigger tube having a storage condenser in its output, of a spark coil having a winding connected through said condenser with said trigger tube whereby the discharge of the condenser through said winding is controlled by said tube, a spark gap comprising a relatively fixed electrode and a rotatably mounted helical electrode, means for rotating the helical electrode at a pre-determined rate, connections for impressing the output voltage of the spark coil across said electrodes for effecting an ionizing spark therebetween upon the discharge of said condenser, means for passing a record tape between said electrodes in the path of said spark, means for impressing across said electrodes an arc-forming current heavy enough to mark said tape but having insufficient potential to span the gap between said electrodes except upon the path ionized by said spark, said spark determining the path, and initiation of the tape marking arc.

18. The device of claim 17 in which the helical electrode comprises a wire having a cylindrical support provided with a channel in which said wire is embedded substantially to its full depth.

19. The device of claim 17 in which the helical electrode comprises a wire having a cylindrical support provided with a channel in which said wire is embedded substantially to its full depth, the wire being molybdenum and the cylinder comprising fiber glass with plastic bonding.

20. The device of claim 17 in which the means for rotating the helical electrode comprises a synchronous motor having crystal controlled oscillator means for supplying current thereto and including a succession of frequency changers and means for filtering the output of said frequency changers to substantially a sine wave and delivering said wave to said motor.

21. The device of claim 17 in which the means for driving the helical electrode comprises a motor having an armature shaft and bearing therefor and an electrical connection directly to said shaft independently of said bearing.

22. An apparatus of the character described comprising the combination with spaced electrodes constituting a gap, and means for feeding a combustible record sheet therebetween, of means for intermittently and momentarily impressing a spark-forming current across said gap to ionize a path between said electrodes, and means for impressing across said gap an arc of printing current of potential inadequate to span the gap except upon said ionized path for the duration of said spark, the means for intermittently and momentarily impressing a spark-forming current across said gap comprising a transformer having resistor means connected across its primary for the immediate damping of said spark.

23. The combination set forth in claim 22 in further combination with means including a resistor in series with said gap for controlling the strength of the spark-forming current discharged across the gap.

References Cited by the Examiner

UNITED STATES PATENTS

2,067,140	1/1937	Dinzl	73—99
2,235,385	3/1941	Rava	315—173 X
2,282,924	5/1942	Artzt	73—6 X
2,421,781	6/1947	Gibbs	346—101
2,425,613	8/1947	Gibbs	73—6
2,551,466	5/1951	Salmon-Legagneur	346—74
2,560,247	7/1951	Rich	346—101
2,565,008	8/1951	Wallace	346—74 X

FOREIGN PATENTS

624,738	6/1949	Great Britain.
654,310	6/1951	Great Britain.

(Other references on following page)

OTHER REFERENCES

Pages 270-271, 1954, publication entitled "Electronics" by Thomas B. Brown, published by John Wiley and Sons, N.Y.

Pages 243-315, 1st Edition, 1921, 2nd Edition, 1927, 5

Chapter III, Principles of Radio Communication, J. H. Morecraft, published by John Wiley and Sons, New York.

IRVING L. SRAGOW, *Primary Examiner*.

R. J. McCLOSKEY, A. I. NEUSTADT,

Assistant Examiners.