Sept. 24, 1946. L. R. HUNTER ET AL 2,408,313

PHOTOELECTRIC COUNTER

Filed Sept. 5, 1942 2 Sheets-Sheet 1

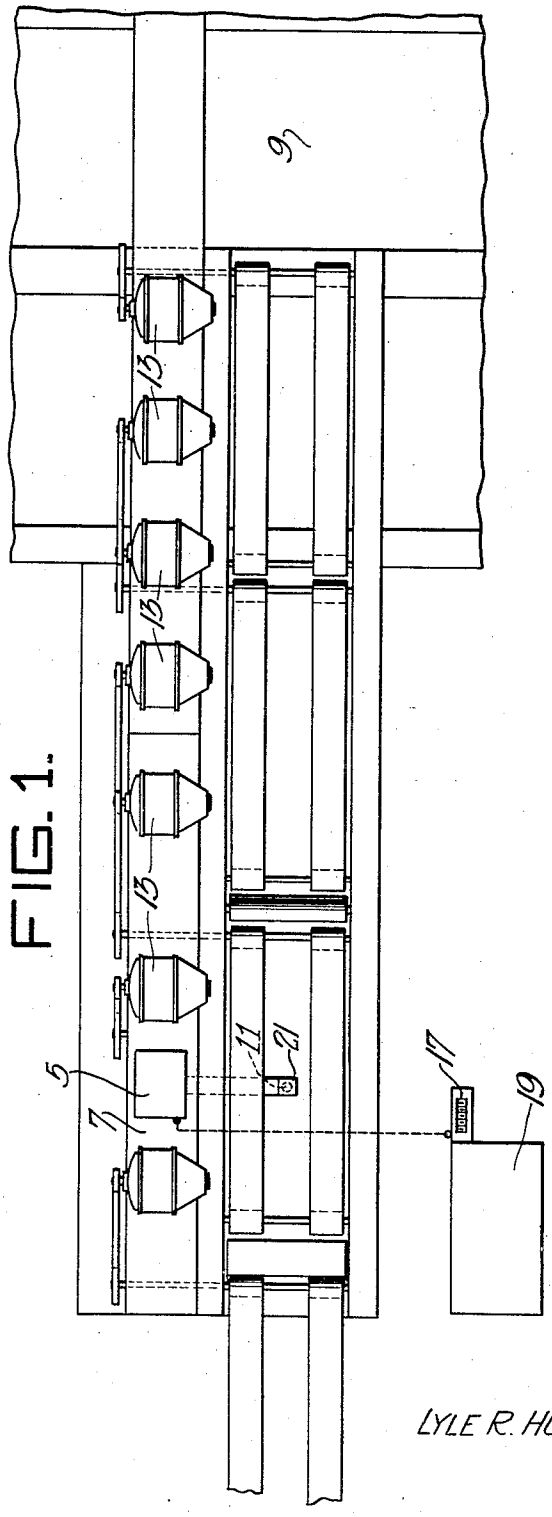


FIG. 1.

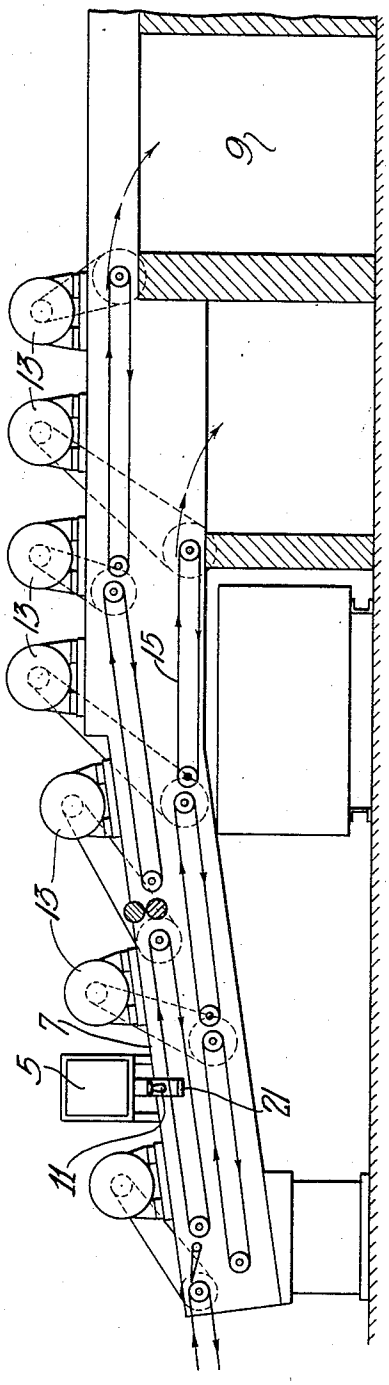


FIG. 2.

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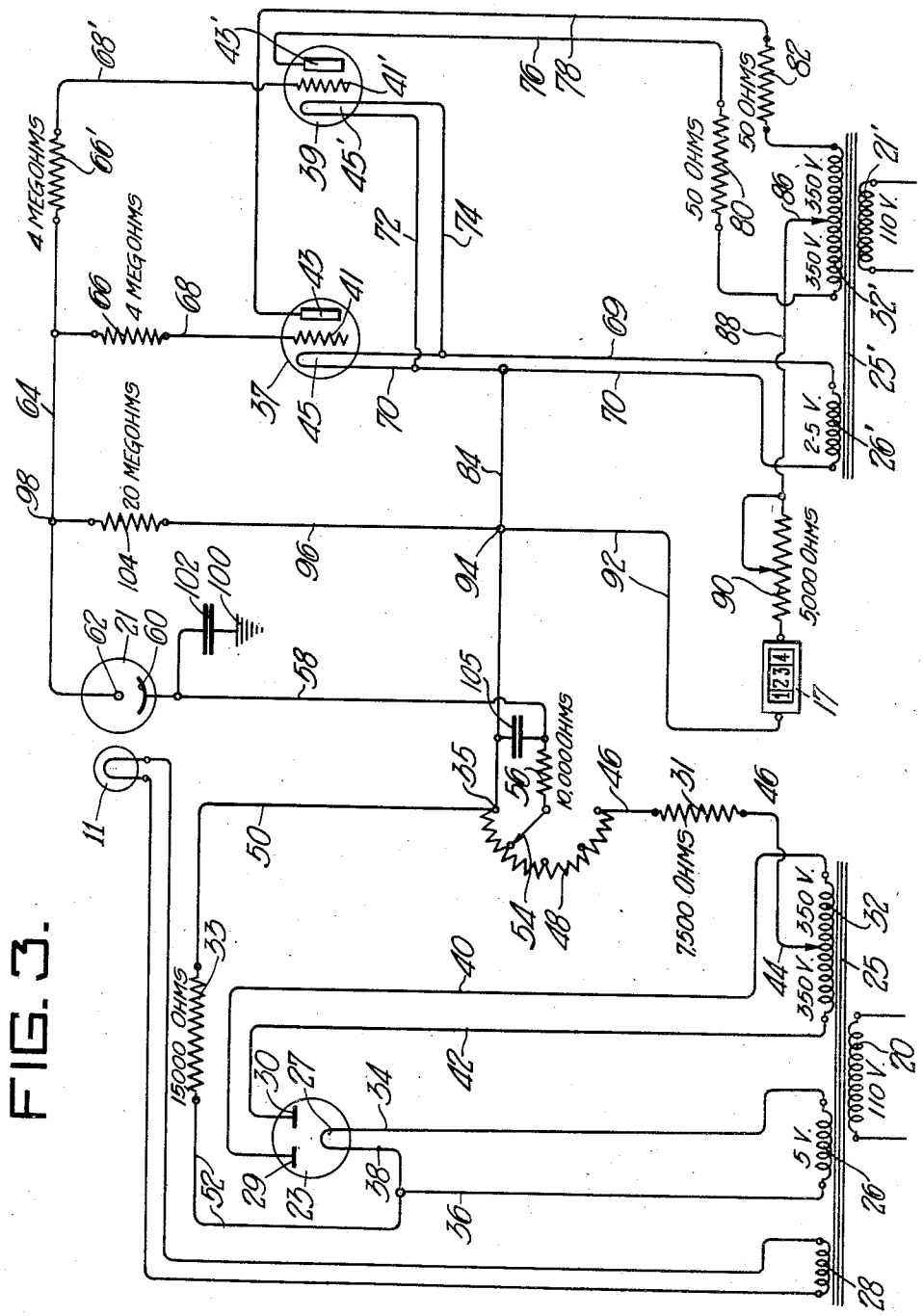


FIG. 3.

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Patented Sept. 24, 1946

2,408,313

UNITED STATES PATENT OFFICE

2,408,313

PHOTOELECTRIC COUNTER

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Application September 5, 1942, Serial No. 457,480

5 Claims. (Cl. 250—41.5)

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In the preparation of bundles of metal sheets and the like for shipment, it becomes necessary to know the number of sheets that are in each bundle. As the sheets move along the line of travel from the shears which cut the strip into the desired length of sheets, at a high rate of speed, counting mechanism must be utilized in order to give an indication of the number of sheets which pass along the line of travel.

In view of the high rate of travel of the sheets, it is found that all of the mechanical counting devices which are available up to this time are inadequate to install for the desired purpose of this invention, since the speed of actuation of all such devices is not rapid enough to keep pace with the travel of the sheets, and it has been found in practice that every type of mechanical counter that is available has been tried but has been found to be a failure for the intended purpose.

In view of the many failures resulting from the installation of the mechanical counting devices, it has been necessary to resort to other means for counting the rapidly moving sheets. In view of this necessity, there has been evolved an electrical control system for actuating a counting mechanism, the sensitiveness of the electrical control system being such that an accurate counting of the sheets is attained, quite regardless of the speed at which the sheets travel.

In general terms, the present invention provides a photoelectric cell in circuit with two thyratron rectifying tubes, current from which tubes is adapted to actuate a counting mechanism, or other electrical devices operable from the current output of the thyratron tubes. This current is a continuously flowing pulsating direct current.

The arrangement of the apparatus is such that light from a suitable source is directed upon a photoelectric cell through the spaces between successive sheets moving along an operating line which piles the sheets in suitable stacks or bundles for shipment to market. It will be understood that a flash of light which is produced between the sheets and falls upon the photoelectric cell must be sufficiently intense to activate the photoelectric cell, and consequently, the more rapid is the travel of the sheets, the greater must be the space therebetween.

The invention will be understood more readily from a consideration of the accompanying drawings, wherein:

Figure 1 represents a plan view of sheet handling equipment;

Figure 2 represents an elevation thereof; and

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Figure 3 represents a wiring diagram showing the circuits for the control of the mechanism.

From the drawings it will be seen that the reference numeral 5 indicates a cabinet for a photoelectric control, the cabinet being shown as mounted on a table 7 which comprises conveying instrumentalities for conveying the sheets to a piler 9. The photocell is activated by light from suitable light sources, such as that indicated at 11. A plurality of motors 13 drive a conveyor for moving the sheets to the piler, and also for actuating an auxiliary conveyor 15 which receives discarded sorted sheets from the stock which is being handled by the equipment.

The photoelectric counter, designated at 17, is located conveniently at an operator's station 19, and it is controlled in the following manner, reference being had to the diagram of Figure 3.

From this view, a photoelectric cell is indicated at 21, the cell 21 being in circuit with a rectifying tube 23 which is positioned in the cabinet 5, and which receives current from a transformer 25, as is shown on the drawings.

The tube 23 is a standard radio rectifying tube, known in the trade as "Type 80," which receives alternating current from the transformer 25, which current results when the transformer is energized from a suitable source of 110 volt, 60 cycle alternating current.

Each of the thyratron tubes employed in the system is essentially a hot cathode rectifier in which a control grid 41 has been placed between the anode plate 43 and the cathode filament 45. In conventional operation of thyratron tubes, the cathode is of special construction, being heat insulated and of large emitting area, so that even when operated at low power it is capable of furnishing thermionic current of a predetermined specified number of amperes. With the anode at a definite potential with respect to the cathode, no current will pass until the grid potential is raised above a certain critical value. When the grid potential is raised to this value, an arc suddenly starts and the full current flows, limited only by the electron emission of the cathode and the resistance in the anode circuit. Once the arc starts, however, the grid loses control and no longer has any effect on the discharge, regardless of its potential. The arc may be stopped only by removing the anode potential.

In a thyratron tube, the grid can be used to start the current while applying an alternating voltage to the anode. The arc then goes out every half cycle while the anode is negative. It

will start during the next half cycle only if the grid potential is above its critical value.

The present invention differs importantly from the foregoing, in that the discharge in the thyratron tubes is controlled by the grid, the discharge being stopped when a space between sheets passes a suitable light source for energizing the photoelectric cell, this latter, upon energizing, closing a circuit which enables a direct current negative voltage to be applied to the grid during the instant that the photocell 21 is energized, this voltage being greater than the alternating current potential between the anode and cathode.

The resulting interruption of the action of the thyratron tube causes an actuation of the counter solenoid in a suitable direction to transmit motion to the counting device.

As soon as each plate obscures the light source, the photocell 21 is deenergized and the thyratron circuit reestablished, this circuit being closed during the time interval required for the sheet to travel completely across the light source. This time is much longer than the time of flashes between the plates, and gives an opportunity for any lag in the circuit or counting device to have disappeared before the next operation.

In order to obtain full wave rectification, and to increase the sensitivity of the circuit, thereby rapidly actuating the counter mechanism by applying maximum rectified current to the counter mechanism, two of the thyratron tubes are employed, and there is sufficient inductance in the solenoid coil of the counter to maintain the operation of the tubes continuous during the relatively long time intervals that the photoelectric cell is masked by passage of a sheet or plate between the light source and photoelectric cell.

As is shown in Figure 3, the secondary of the transformer 25 is connected in sections to the elements of tube 23. Thus, one section 26 is connected to the filament 27 through leads 34, 36 and 38, the section 32 of the transformer secondary is connected to plates 29 and 30 of the tube 23 through leads 40 and 42, respectively, and transformer section 28 energizes the source of light 11.

It will be seen from Figure 3 that with the tube 23 being a "Type 80" radio rectifying tube, the cathode filament 27 receives 5 volts from the transformer section 26, and each of the anode plates 29 and 30 receives 350 volts from the transformer section 32, this being tapped at its midportion, as is indicated at 44. These specified conditions may be varied, however, depending upon the type of rectifying tube that may be employed. Also, the position of the tap 44 may be adjusted, as may be necessary to provide requisite current conditions in the remainder of the control circuit, as will be pointed out hereinafter.

The tap 44 is shown as being connected by a conductor 46 and resistance 31 to the variable resistance 48 of a potentiometer 35. The resistance 48 also is connected through conductor 50 to a suitable resistance 33, which in turn is connected to transformer section 26 through conductor 52, which is connected as shown to the lead 36.

The resistances, in the illustrated embodiment of the invention, may have a resistance of 7500 ohms in resistance 31, to a total of 10,000 ohms in resistance 48 and 15,000 ohms in resistance 33. Resistances 31 and 33 are fixed resistances and are employed for protective purposes. These values all may be modified to suit any particular installation.

Potentiometer arm 54 is connected through fixed protective resistance 55 and conductor 58 to the cathode 60 of the photocell 21. The anode 62 is connected through conductor 64 to the grids 41 and 41' of the thyratron tubes 37 and 39, conductor 64 being connected to the grid 41 through resistance 66 and conductor 68, and to the grid 41' through resistance 66' and conductor 68'. The resistances 66 and 66' are employed for protective purposes and, in the illustrated embodiment of the invention, have a value of 4 megohms.

The thyratron tubes 37 and 39 are similar, and are provided with cathode filaments 45, 45', respectively, and anode plates 43, 43', respectively.

These elements are energized from sections of a secondary coil of a transformer 25', which is similar to transformer 25, the primary coils 20 and 21' of the transformers 25, 25' being energized from a 60-cycle, 110-volt alternating current supply.

Thus the cathode filaments 45 and 45' are energized by section 26', which gives from about 2 to about 5 volts, as shown in the diagram, and section 32' energizes the plates 43 and 43' with 350 volts each. Leads 69, 70 connect the transformer section 26' with the cathode filament 45, the filament 45' being connected across through leads 72, 74, while the ends of the transformer section 32' are connected to the anode plates 43, 43', respectively, by conductors 76, 78, in which are interposed respectively the resistances 80, 82.

The lead 70 of the cathode filament 45 is connected through conductor 84 to conductor 52 at the potentiometer resistance 48, this wire 84 serving as the return line for the photocell 21 and also completing the electronic circuit through the cathode filament of the thyratron tubes.

The transformer section 32' is tapped at the middle third as is indicated at 86. Conductor 88 connects the tap 86 to a variable resistance 90 which in turn is connected to a solenoid for actuating the counter 17. Conductor 92 connects the solenoid to conductor 84.

It will be apparent from the drawings (Figure 3) that two thyratron tubes are employed in order to utilize both of the two alternations of the current source thereby producing full wave rectification and increasing the sensitivity of the system and render the system fully responsive to the high-speed installations to which the system is applied. There is sufficient inductance in the solenoid coil of the counter to maintain the operation of the tubes continuous during the relatively long time intervals that the photoelectric cell is masked by passage of a sheet or plate between the light source and photoelectric cell. The thyratron tubes being in parallel, deliver a total current to the counter, which current is the sum of the current outputs of the tubes, thereby producing extremely rapid actuation of the counter. In Figure 3 the filaments 45, 45' are rendered incandescent by alternating current from the transformer coil 26'. The two terminals of the transformer 25' are connected to the two anode plates 43, 43' and the cathodes are connected to each other, as shown, and to wire 84 of the external circuit. Therefore it will be seen that the thyratron tubes pass unamplified pulsating rectified current to the counter circuit. The rectified current in the counter circuit exhibits variations which depend on those of the supply voltage but

there is no interruption. In order to reduce these variations and obtain a more uniform rectified current through the counter solenoid, advantage is taken of the inductance of the solenoid coil which assists in such action by smoothing out the pulsations of the rectified current, and prevents stopping of the tubes as the current never reaches the zero point.

It is thought to be unnecessary in view of the foregoing explanation to discuss the circuits in detail. One of the characteristics of the thyratron tubes is that they operate on a difference in voltage between the independent cathode and anode circuits of from 3 to 7 volts, which voltage may be considered negative since the arc in the tubes passes from the plate to the cathode filament. The voltages of the current supply and the value of the resistances 80, 82, 90, 43, 66 and 66' must be adjusted so as to give this voltage difference between the independent anode and cathode circuits.

Upon the attainment of this condition, the thyratron tubes operate, and a pulsating direct current passes continuously through the counting device 17. But it is desired not to have a continuous current flow through the counter, as the latter will fail to operate under this condition, but it is necessary to interrupt this current periodically responsively to the spaces between the sheets in order for the counting device 17 to reset to count the sheets accurately.

The interruption of the tubes is effected by impressing on the control grids 41, 41', a negative direct current voltage by a value greater than the positive 3 to 7 volt difference between the anode plates and filaments.

This is accomplished in the following manner.

The anode plates 29 and 30 produce a pulsating direct current from the tube 23, some of this current being conducted through the potentiometer 35 and conductor 53 to the photocell 21, the potentiometer arm 54 being suitably adjusted to supply sufficient voltage for the photocell and also supply a voltage to the grids 41, 41' of at least 3 to 7 negative volts greater than whatever voltage is between the plate and filament of each tube, when the photocell is operating responsively to light hitting the photocell through the spaces between the traveling sheets. Thus, for example, if the voltage between the plate and filament of each tube is 150 and the voltage drop across the photocell, for example, is 90 volts, the potentiometer must be adjusted to take care of the 90 volts and to impress at least from, say 153 volts to 157 volts between the grid and cathode filament in each tube. It will be seen, therefore, that under these conditions, the rectifying circuit would be required to supply at least 243 volts through the potentiometer 35. This voltage is a positive direct current voltage and must be sufficient to, in effect, change the voltage differential between the plates and cathode filaments 45, 45' to negative in order to interrupt the action of the thyratron tubes and obtain a resetting of the counter mechanism during the infinitesimally short period of interruption of the thyratron tubes, the counter mechanism operating to count upon closing the thyratron circuit.

It will be understood, of course, that the potential on the thyratron anodes and cathodes is an alternating current potential, the action of the tubes being controlled by a direct current potential of suitable value and direction applied to the grids of the thyratron tubes; and this direct current potential is applied only when the photoelectric cell is energized by the flash of light passing between the moving plates.

The photoelectric cell therefore acts as a very rapid circuit maker and breaker, which is required because of the high speed of travel of the sheets; and each time the photocell is energized, that instant of energization interrupting the thyratron circuit to make the latter operative again to actuate the counter the instant that each of the successive moving plates interrupts the light source; so that the thyratron circuit is closed during the length of time that each sheet passes over the light source, which is relatively long compared to the length of time that the photocell is active.

Usually the sheets move on the conveyor at a speed of about 800 feet per minute with a space of ¼ inch between the sheets. This means, therefore, that each quarter-inch space between the sheets passes over the light source in $\frac{1}{384,000}$ of a minute, or $\frac{1}{6400}$ second. That means, therefore, that in $\frac{1}{6400}$ second the photocell must energize and enable the grids of the thyratron tubes to interrupt the thyratron circuit, due to potential drop across resistance 66*a*. Then at the expiration of $\frac{1}{6400}$ second, the thyratron circuit closes and actuates the counter to count one unit, the thyratron circuit remaining closed and the tubes arcing during the time interval that it takes the length of the sheet to pass over the light source. Then as the plate moves out from the light source, during the next $\frac{1}{6400}$ second that the photocell is energized, the cycle of operation is repeated.

It will be seen in view of the high speeds involved that instrumentalities must be employed which operate instantaneously without lag. The photoelectric cell is free from lag, as are also the rectifying tube 23 and the thyratron tubes 37 and 39, and the time interval during which the sheets pass over the light source and with attendant de-energization of the photocell enables lag in the solenoid coil of the counter to be taken up and reset ready for the next counting.

It will be seen from the drawings that the conductor 82 is joined to the conductor 84 at the point 94, at which point there is shown connected a conductor 96, which connects with the conductor 64 at the point 98. The conductor 53 is shown as being grounded at 100 through condenser 102, this condenser being an optional provision, in certain installations it being found to be needed to smooth out the operation of the system. The conductor line 94—98 with its resistor 104 serves to balance the photocell and thyratron tube circuits. There is also provided a condenser 105, which is connected across the photoelectric cell 21, this condenser rendering smooth the rectified current from tube 23, which otherwise would be subject to peak variations.

The values of the respective units indicated on the drawings are illustrative only, they being determined for each change of the load operated by the circuit, it being understood that the invention is not limited necessarily to the particular embodiment herein specifically illustrated and described.

We claim:

1. An electrical control system which comprises, in combination, a source of light, first and second rectifying instrumentalities for rectifying alternating current, a load device operated by unamplified rectified current from the second rectifying instrumentalities, and means electrically connecting the first and second rectifying instrumentalities including light responsive circuit making

and breaking means for transmitting at intervals of infinitesimal duration unamplified rectified current from the first rectifying instrumentalities to the second rectifying instrumentalities, the said light-responsive circuit making and breaking means being adapted to be completely masked from the source of light over relatively long periods of time, but being exposed to light from the light source during infinitesimally short time intervals between the relatively long periods of masking, the resulting transmitted current being of a potential and polarity suitable to predeterminately interrupt action of the second rectifying instrumentalities for actuating the said load device.

2. An electrical control system, which comprises the combination with a source of light, of a photoelectric cell adapted to be completely masked from the source of light over relatively long periods of time, but being exposed to light from the light source during infinitesimally short time intervals between the long periods of masking, the said photoelectric cell being thereby rendered conductive by infinitesimally short light flashes resulting from the light passing to the cell between the masking periods, first and second rectifying instrumentalities for rectifying alternating current, the first rectifying instrumentalities producing a pulsating unamplified unidirectional current, a load operated by current from the second rectifying instrumentalities, the said second rectifying instrumentalities including rectifying tube means including an anode, a cathode, and a control grid, the said anode and cathode being connected to suitable supplies of alternating current, the rectifying tube means being adapted to deliver an unamplified pulsating direct current to the said load, means connecting the first rectifying instrumentalities in circuit with the control grid, the connecting means including the said photoelectric cell which is instantaneously operable responsively to infinitesimally short exposure to light from the light source, the photoelectric cell being adapted to close the circuit through the grid during the infinitesimally short exposures to the light, and to open the circuit when rendered non-conductive during the relatively long periods during which the cell is masked from the light source, the cell thereby transmitting to the control grid during successive infinitesimally short periods of conductivity of the cell, a direct current of a potential and polarity suitable to neutralize alternating current potentials between the anode and cathode of the rectifying tube means to interrupt action of the rectifying tube means for actuating the load device incident to restarting the rectifying tube means.

3. An electrical control system which comprises the combination with a source of light, of a photoelectric cell adapted to be completely masked from the source of light during relatively long periods of time while being exposed to light from the light source during infinitesimally short time intervals between the long periods of masking, the said photoelectric cell being thereby rendered conductive by infinitesimally short light flashes resulting from the light passing to the cell during infinitesimally short intervals between the masking periods, a rectifying circuit adapted to deliver an unamplified pulsating unidirectional current from an alternating current supply, a thyratron-type rectifying circuit comprising a pair of thyratron-type tubes, the said tubes being adapted to utilize both half waves of each alternating current cycle, the thyratron-type tubes including an

anode, a cathode, and a control grid, the anode and cathode of each tube being connected to a suitable source of alternating current and the cathodes being connected together, whereby the tubes are adapted to deliver an unamplified pulsating unidirectional current, a load device adapted to receive the said unamplified pulsating unidirectional current, means including the said photoelectric cell for connecting the grid of each of the said thyratron-type tubes with the said rectifying circuit, the photoelectric cell being rendered instantaneously responsive to an infinitesimally short flash of light passing from the light source to the photoelectric cell, the said photoelectric cell being adapted to close a circuit from the rectifying circuit through the grid of each thyratron-type tube during the infinitesimally short moments of conductivity of the photoelectric cell and to open the circuit during relatively long intervals during which the cell is completely masked, the said cell during successive moments of conductivity transmitting to the grids of the thyratron-type tubes a succession of momentary unamplified unidirectional currents, control means for the said unidirectional current so that current of a potential and polarity will be impressed on the grids suitable to neutralize alternating current potentials between the anode and cathode of each of the thyratron-type tubes for interrupting action of the tubes, thereby momentarily actuating the load device to condition the same for further actuation through a succeeding relatively long period of masking of the photoelectric cell, the load device being thus conditioned each time a momentary flash of light reaches the photoelectric cell from the light source.

4. An electrical control system which comprises the combination with a source of light, of a photoelectric cell adapted to be completely masked from the source of light over relatively long periods of time, but being exposed to light from the light source during infinitesimally short time intervals between the long periods of masking, the said photoelectric cell being thereby rendered conductive by infinitesimally short light flashes resulting from the light passing to the cell between the masking periods, a rectifying circuit including a transformer and a triode rectifying tube having diode characteristics at any given instant for obtaining full wave rectification, the said circuit being adapted to deliver an unamplified unidirectional current, second rectifying instrumentalities including a second triode rectifying circuit including a second transformer and a pair of triode thyratron-type tubes connected to sections of the said transformer and adapted to produce full wave rectification, a load device operated by unamplified rectified current from the thyratron-type tubes, the said rectifying circuit being connected through the photoelectric cell to a control grid of each of the triode thyratron-type tubes for impressing momentary unidirectional current to the said grid of each of the triode thyratron-type tubes for interrupting alternating current discharge between the remaining elements of the tubes responsively to momentary conductivity of the photoelectric cell during infinitesimally short intervals of time, the photoelectric cell thereby momentarily closing the rectifying circuit through the said control grid in the thyratron-type tubes for infinitesimally short periods of time as light flashes to the photoelectric cell, thereby momentarily rendering the said cell conductive and deenergizing the load device responsively to the infinitesimally short

interruptions to actuation of the thyratron-type tubes, the said tubes supplying unamplified unidirectional current to the load device during relatively long periods of time during which the photoelectric cell is completely masked from the light source, the thyratron-type tubes being connected in the circuit to be self-starting, the load device being conditioned for further operation during the infinitesimally short moments of actuation of the photoelectric cell.

5. Mechanism for counting rapidly moving, closely spaced-apart metal sheet, which comprises the combination with a conveyor having the sheets to be counted traveling thereon, of a source of light positioned on one side of the conveyor and adapted to illuminate the sheets and spaces therebetween, a photoelectric cell mounted relative to the conveyor for receiving infinitesimally short flashes of light from the light source, the said infinitesimally short light flashes being the light passing through successive spaces between the rapidly moving sheets, the photoelectric cell being completely masked from the light source by passage of the sheets, first and second rectifying instrumentalities for rectifying alternating current, the first and second rectifying instrumentalities being free from mechanical and electrical inertia effects, the first rectifying instrumentalities being a rectifying circuit including a transformer and a triode rectifying tube having diode characteristics at any given instant for obtaining full wave rectification, the said circuit being adapted to deliver an unamplified unidirectional current, the second rectifying instrumentalities including a second triode rectifying circuit including a second transformer and a pair of triode thyratron-type tubes connected to sections of the said transformer and adapted to produce full wave rectification, a load adapted to be operated through

a predetermined cycle by unamplified unidirectional current from the thyratron-type tubes, a potentiometer, the said first rectifying circuit being connected through the potentiometer and the photoelectric cell to a control grid of each of the thyratron-type tubes for impressing momentary unamplified unidirectional current to the said grid of each of the triode thyratron-type tubes for interrupting alternating current discharge between the remaining elements of the tubes responsively to momentary conductivity of the photoelectric cell during infinitesimally short intervals of time as light flashes between the sheets being counted to render conductive the photoelectric cell, thereby energizing the load during each flash responsively to the infinitesimally short interruptions to actuation of the thyratron-type tubes, the said tubes supplying unamplified rectified current to the counting means during relatively long periods of time during which the photoelectric cell is completely masked during passage of the sheets between the light source and the photoelectric cell, the said load performing a resetting operating during the periods of actuation of the thyratron-type tubes, and being actuated to perform the said predetermined cycle during the infinitesimally short interruptions of the thyratron-type tubes as the photoelectric cell becomes conductive responsive to light flashes between the sheets being counted, the thyratron-type tubes being connected in the circuit to be self-starting after each interruption and, being in parallel, the said thyratron-type tubes deliver a total current to the load which is the sum of the current outputs of the tubes, thereby producing extremely rapid actuation of the counting means.

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