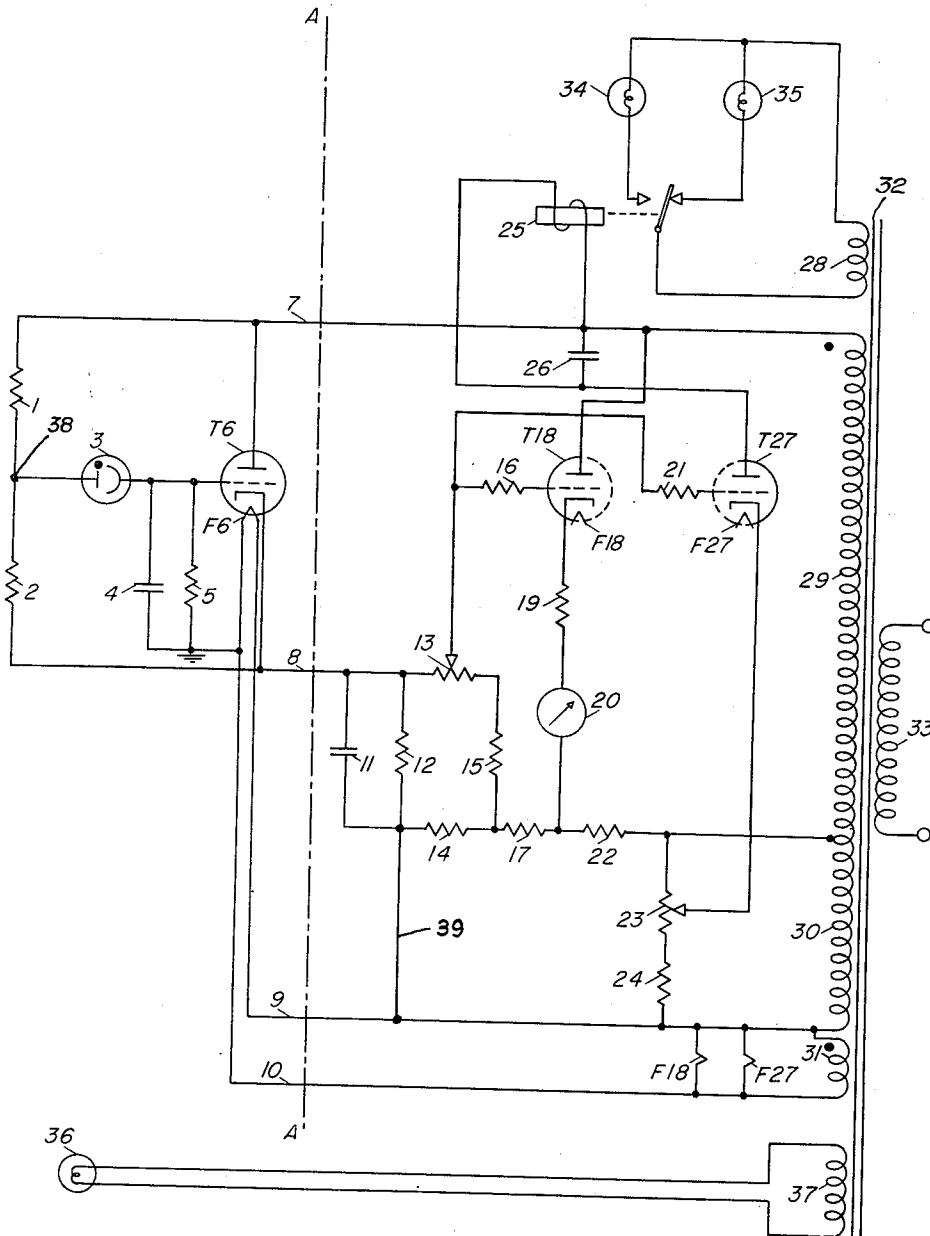


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PHOTOELECTRIC APPARATUS

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PHOTOELECTRIC APPARATUS

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This invention relates to new and improved photoelectric supervisory and control apparatus which is directly responsive to light intensity. The specific embodiment of this invention disclosed herein is particularly adapted for use in smoke indication and control systems. However, it should be understood that many of the features thereof are broadly applicable to all types of photoelectric controls.

More and more cities and metropolitan areas are recognizing the importance of smoke control in the interest of health and cleanliness. Many cities have municipal ordinances which require the installation of automatic smoke indicating and alarm systems in industrial plants. These ordinances also prescribe the legal limits for the amount of smoke which can emanate from the plant chimney stacks.

In the prior art, many different types of photoelectrically operated smoke indicating and alarm arrangements have been utilized to provide a continuous check on the over-all combustion efficiency of industrial heating systems, as well as indicating that the system is operating within the legal limits provided by the applicable ordinances. Generally speaking, all of these arrangements transmitted a light beam through a monitored smoke passage so that the intensity of the light impinging upon a photoelectric scanner was proportional to the passage smoke concentration. The electrical output of the scanner could therefore be utilized to give quantitative indications of smoke as well as produce a control function in response to excess smoke.

An object of this invention is to improve the sensitivity of photoelectric controls and particularly smoke-responsive controls whereby this apparatus may be fabricated more easily and cheaply.

Another object of this invention is to provide a reliable quantitative indication of the smoke intensity within a supervised volume, which indication is independent of the surface conditions of the focusing lenses of the light source and the photoelectric scanner.

It has been long known in the photoelectric control art that increased sensitivity of operation can be readily attained by the use of gas phototubes in lieu of vacuum type phototubes. However, the increased sensitivity obtained by gas phototubes is dependent to a great extent upon the ionizing potential applied to the electrodes of the phototube. In the usual photoelectric control circuit, an ionizing potential is applied to the gas phototube through an impedance network.

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Prior to the photoelectric conduction in the phototube, sufficient potential is applied to the phototube so that the tube is operating in the region of maximum sensitivity. However, after energy from a light source impinges upon the gas phototube, the voltage drop across the phototube load reduces the potential applied to the phototube in an amount proportional to the intensity of the incident light so that, generally, the tube is no longer operating in a highly sensitive condition. Accordingly, a novel structural feature of the apparatus of this invention comprises a feed-back arrangement whereby the potential of the power supply source applied to the gas phototube is increased in amount substantially equal to the potential drop created across the phototube load in response to incident light energy. With this arrangement, a substantially constant ionizing potential is applied to the electrodes of the phototube under varying conditions of light intensity.

In view of the fact that the phototube of this invention is operated under optimum conditions, a minimum number of amplifying components are utilized to transmit the output signal generated by the phototube to smoke indicating and alarm apparatus.

Another feature of this invention makes possible a reliable quantitative indication of the smoke within a supervised volume. This indication, generally speaking, is dependent only upon smoke intensity. An electrical bridge arrangement is provided for the input of the indicating and control apparatus which is operated by the phototube scanner whereby a meter, which is calibrated in terms of light transmission or smoke density, can be readily adjusted to compensate for most interfering conditions so that a zero deflection of the meter indicates 100% light obscurity and full deflection of the meter indicates zero light obscurity.

In order that all of the features of this invention and the mode of operation thereof may be readily understood, a detailed description is set forth hereinafter, with particular reference being made to the schematic circuit diagram of the drawing.

In a practical industrial installation of the apparatus shown in the drawing, the apparatus to the left of dividing line A—A comprises a photoelectric scanner located in the stack or flue of the combustion system which is to be monitored for smoke. Light source 36 is optically coupled to phototube 3 of the scanner so that the light from the source will impinge upon the cathode of the

phototube after having traversed the monitored volume. Inasmuch as the output current of the phototube is dependent upon the amount of incident light on the cathode, this arrangement is responsive to the presence of smoke in the space between light source 36 and phototube 3.

The photoelectric scanner is electrically coupled by means of cable conductors 7, 8, 9 and 10 to a remote indicating control unit which comprises the components to the right of dividing line A—A. In particular, conductor 7, which is connected directly to the upper terminal of secondary winding 29, supplies the anode potentials for phototube 3 and cathode follower tube 6. Conductor 8 transmits the output signal developed in the cathode circuit of tube 6 to the indicating control equipment. Conductors 9 and 10 apply the potential of winding 31 to the filament of tube 6. Conductor 10 also applies ground to the components of the photoelectric scanner.

The cathode follower comprising tube 6 and its associated components is utilized to translate the high impedance of the phototube load comprising resistor 5 and shunting capacitor 4 to a low impedance output which may be readily transmitted over a relatively long cable without appreciable signal attenuation, thus permitting positioning of the scanner apparatus at a considerable distance from the control unit without the necessity of utilizing expensive and complicated high impedance transmission means.

The series-aiding alternating-current potential generated by serially-connected secondary windings 29 and 30 of transformer 32 is divided by the voltage divider network comprising serially-connected resistor 1, resistor 2, and resistor 12 and its shunting components 13, 14 and 15. The portion of this potential developed across resistor 2 and resistor 12 together with the biasing potential of secondary winding 31 is applied through resistor 5 and shunting capacitor 4 to ionize gas phototube 3.

There is thus a potential divider, between the top of winding 29 and the bottom of winding 31, which comprises resistor 1, phototube 3 and resistor 5. Another potential divider between the same points comprises resistor 1, resistor 2, resistor 12 and its shunting components, conductor 39 and winding 31. When the light beam of source 36 impinges upon phototube 3 its resistance is lowered, and the potential at the grid of tube 6 becomes more positive. Since tube 6 operates as a cathode follower, the potential at its cathode also becomes more positive. This decreases the potential drop between the top of the winding 29 and the cathode of tube 6 and therefore makes the potential at the junction point 33 (which is the anode terminal of phototube 3) more positive, thus compensating for the decrease in ionizing potential which would occur due to the response of phototube 3 to incident light energy had the anode of phototube 3 remained at a constant potential. Due to the fact that this feedback arrangement maintains substantially the same ionizing potential to phototube 3 in response to both light and no-light conditions, a substantially constant gas amplification sensitivity is provided by the photoelectric scanner of this invention for all values of light intensity impinging upon phototube 3.

The control grids for tubes 18 and 27 of the indicating control unit are commonly connected through grid resistors 16 and 21, respectively, to the cathode follower tube 6 output network. Milliammeter 20 is connected in the cathode cir-

cuit for tube 18 whereby quantitative indications of the intensity of the light impinging upon phototube 3 can be made. In particular, if no light impinges upon photoelectric cell 3, milliammeter 20 is adjusted to give zero deflection by means hereinafter described in detail. If the full intensity of light source 36 impinges upon phototube 3, notwithstanding the fact that the focusing lens (not shown) for the phototube 3 and lamp 36 may be dirty, milliammeter 20 is adjusted to give a full scale reading by means hereinafter described in detail. Milliammeter 20 is also utilized to visually indicate intermediate smoke conditions exemplified by partial attenuation of the light impinging upon phototube 3.

The value of the bias applied to tube 27 may be adjusted by means of potentiometer 23 so that relay 25, connected in the anode-cathode space path for tube 27, will be operated in response to any desired reading of meter 20 between zero and full scale. The transfer contact of relay 25 is connected so that the potential from secondary winding 28 is applied to indicator lamp 34 whenever the smoke density of the monitored stack or flue is below the maximum value allowable as determined by the adjustment of potentiometer 23. If, however, the smoke density of the monitored stack or flue exceeds the maximum allowable value, relay 25 releases its contacts, causing the potential of secondary winding 28 to be applied to lamp 35 whereby a visual indication is given that the smoke density exceeds the maximum allowable value as determined by the adjustment of potentiometer 23. Capacitor 26 shunts the winding of relay 25 so that a relatively smooth operating potential is applied to the relay.

The input network to the indicator control circuit, which network is also the cathode follower load for tube 6, comprises a novel bridge arrangement whereby the operation of meter 20 may be adjusted so that with the condition of full light cut-off with respect to phototube 3, the meter gives a zero deflection reading indicative of 100% obscurity or 5 Ringelmann; and with maximum signal applied to the control grid of tube 18, this being the condition of a clear stack or flue, the meter gives a full scale deflection which is indicative of zero obscurity or zero Ringelmann.

This adjusting feature is provided in part by the voltage divider network comprising resistors 14, 17 and 22, the combination of which with conductor 39 directly shunts secondary winding 30. In particular, under no-light conditions or 100% obscurity, the values of these components are so selected that the voltage drop across resistor 14 equals the voltage drop across resistor 12. Inasmuch as the left terminal of resistor 13 and the bottom terminal of resistor 15 are at the same potential, no potential drop appears across either of these components. Consequently, the movable tap of potentiometer 13, the setting of which determines the input to tubes 18 and 27 under light conditions, may be positioned at any point on the potentiometer resistance element without disturbing the zero deflection or 100% obscurity adjustment for meter 20. The potential drop developed across resistor 22 is so proportioned that it will bias cathode follower tube 18 to substantially cut-off when no input is applied to tube 18. Therefore, meter 20 will not be deflected under 100% obscurity conditions. If full light is applied to phototube 3 from source 36, a voltage drop is created across potentiometer 13 and resistor 15. By adjusting the movable tap of potentiometer 13 full scale deflection of meter

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20 can be attained for maximum light transmission to phototube 3.

The detailed operation of the circuit of this invention is as follows. After the installation of the photoelectric scanner and its light source in the stack or flue which is to be monitored, and the interconnection of the output of the scanner to the indicating control unit by means of cable conductors 7, 8, 9 and 10, the 100% obscurity adjustment of the apparatus should be checked. That is, with no light impinging upon the cathode of phototube 3, meter 20 should give a zero deflection reading indicative of 5 Ringelmann or 100% obscurity. If zero meter deflection is not indicated, in all probability the input bridge network of cathode follower tube 18 is out of adjustment. As hereinbefore explained, under proper no-light adjustment conditions, and with cathode follower tube 18 at cut-off bias, the potential drop across resistor 14 should be equal in amplitude to the potential drop across resistor 12 so that no current will flow in the anode-cathode space path of tube 18, thereby providing for a zero deflection of meter 20.

After proper zero adjustment, the full scale adjustment of the indicating control unit is made by applying the full intensity of light source 36 to phototube 3 and moving the arm of potentiometer 13 to a position whereat meter 20 displays a full scale deflection which is indicative of zero Ringelmann or zero obscurity.

If it is desired to have tube 27 operate indicating lamp 34 in response to an allowable smoke condition, and operate indicating lamp 35 in response to an excessive smoke indication, the negative bias applied to tube 27 should be adjusted by a proper positioning of the movable arm of potentiometer 23 so that sufficient current will flow in the anode-cathode space path of tube 27 to operate relay 25 during allowable smoke conditions.

The detailed operation of the circuit of this invention in response to a no-smoke condition is as follows. With the application of a suitable alternating-current potential to primary winding 33, the filaments of tubes 6, 18 and 27 are energized by secondary winding 31, light source 36 is energized by secondary winding 37, an energizing potential is applied to the anode-cathode space path of tube 6 by series-aiding secondary windings 29 and 30 in a circuit which includes the upper terminal of secondary winding 29, cable conductor 7, the anode-cathode space path of tube 6, cable conductor 8, and resistor 12 and its shunting paths back to the lower terminal of secondary winding 30, an energizing potential is applied to the anode-cathode space path of tube 18 by secondary winding 29 in a circuit which includes the upper terminal of secondary winding 29, the anode-cathode space path of tube 18, resistor 19, meter 20, and resistor 22 back to the lower terminal of secondary winding 29, and an energizing potential is applied to the anode-cathode space path of tube 27 by secondary winding 29 in a circuit which includes the upper terminal of secondary winding 29, relay winding 25 and its shunting capacitor 26, the anode-cathode space path of tube 27, and the upper tapped portion of potentiometer 23 back to the lower terminal of secondary winding 29.

The series-aiding potential of secondary windings 29 and 30 is also applied to the voltage divider network comprising serially-connected resistor 1, resistor 2, and resistor 12 and its shunting components. The portion of this voltage drop

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developed across resistor 2, and resistor 12 and its shunting components is applied to the space path of phototube 3 in a circuit which includes the lower terminal of resistor 12, secondary winding 31, the series combination comprising resistor 5 and shunting capacitor 4, the space path of phototube 3 to the upper terminal of resistor 2. This potential is sufficiently large to cause photoelectric ionization in the space path of phototube 3 in response to incident light whereby a potential drop is developed across resistor 5 which charges capacitor 4.

The potential across resistor 5 and capacitor 4 is applied to the control grid-cathode space path of tube 6 through secondary winding 31, and resistor 12 and its shunting components whereby a conventional cathode follower output signal is developed across resistor 12 which charges capacitor 11. Inasmuch as the lower terminal of resistor 2 is connected to the cathode of tube 6 and also to the upper terminals of capacitor 11 and resistor 12 by means of cable conductor 8, the anode potential of phototube 3 is increased with respect to ground in an amount substantially equal to the increase in potential of the cathode of phototube 3 due to the charging of capacitor 4. This feed-back arrangement, which is provided by the cathode follower circuit of tube 6, makes possible the application of a substantially constant energizing potential to the space path of phototube 3 in response to both light and no-light conditions whereby the sensitivity of the phototube is maintained at a relatively high constant value notwithstanding current flow in the phototube.

The direct-current potential developed across the combination comprising resistor 12 and its shunting capacitor 11 is applied to resistors 13, 15 and 14 so that a current flow is produced in resistors 13 and 15 whereby the cut-off bias of cathode follower tube 18 is overcome and the anode-cathode current flow thereof produces a full scale deflection in meter 20 which is indicative of a no-smoke condition in the monitored stack or flue.

This same potential is applied to the control grid of tube 27 through grid resistor 21 so that the bias of tube 27 is overcome and relay 25 is operated. The closure of the contact transfer applies the potential of secondary winding 28 to the filament of lamp 34 so that a visual indication is given which indicates that the smoke conditions within the monitored stack or flue are within the allowed limits.

The detailed operation of the circuit of this invention in response to a full smoke condition or 100% obscurity is as follows. When no light impinges upon the cathode of phototube 3, capacitor 4 discharges across its shunting resistor 5 and the only input signal applied to tube 6 is the biasing potential of filament winding 31. As a consequence, capacitor 11 discharges across resistor 12 and no signal is applied to the inputs of tubes 18 and 27. Meter 20 therefore gives a zero deflection which is indicative of a smoke condition of 5 Ringelmann, or 100% obscurity. The operating current flowing in the anode-cathode space path of tube 27 is reduced to a value wherein relay 25 releases its contact and the potential of secondary winding 28 is applied to lamp 35, thereby indicating an excessive smoke condition. Partial smoke conditions are indicated quantitatively by the readings of meter 20; and either lamp 34 or lamp 35 is illuminated, depending upon whether this smoke condition

is less or greater than the allowable limit prescribed by the particular setting of potentiometer 23.

It is to be understood that the above-described arrangements are illustrative of the application of the principles of this invention. Numerous other arrangements may be devised by those skilled in the art without departing from the scope of this invention.

What is claimed is:

1. Light responsive apparatus comprising a gas photoelectric cell, a load network connected to said photoelectric cell, a power supply source connected to said photoelectric cell through said load network, and a cathode follower amplifier including a cathode load, said load network being connected to the input of said cathode follower amplifier whereby a signal is developed across said cathode load which is proportional to the voltage drop across said load network, said cathode load being connected to said power supply source whereby the potential applied to the combination comprising said photoelectric cell and said load network varies proportionally to the potential developed across said load network in response to light energy impinging upon said photoelectric cell.

2. Light responsive apparatus comprising a gas photoelectric cell, a load network for said photoelectric cell, a cathode follower amplifier including a cathode load, and a power supply source including a voltage divider network having first and second serially-connected impedance elements connected across the output of said power supply source through said cathode load, the potential across one of said impedance elements and said cathode load being applied to said photoelectric cell through said load network, said load network being connected to the input of said cathode follower amplifier whereby a signal is developed across said cathode load which is proportional to the voltage drop across said load network, and the junction point of said first and second impedance elements being connected to one of the electrodes of said photoelectric cell whereby the potential applied to the combination comprising said photoelectric cell and said load network is increased a substantial portion of the potential developed across said load network in response to light energy impinging upon said photoelectric cell.

3. Light responsive apparatus comprising a

photoelectric cell, a light source optically coupled to said photoelectric cell through a smoke-monitored volume, a resistor-capacitor load network for said photoelectric cell, a cathode follower amplifier including a cathode load, a power supply source including a voltage divider network having first and second serially-connected impedance elements connected across the output of said power supply source through said cathode load, the potential across one of said impedance elements and said cathode load being applied to said photoelectric cell through said load network, said load network being connected to the input of said cathode follower amplifier whereby a signal is developed across said cathode load which is proportional to the voltage drop across said load network, the junction point of said first and second impedance elements being connected to one of the electrodes of said photoelectric cell whereby the potential applied to the combination comprising said photoelectric cell and said load network is increased an amount equal to a substantial portion of the potential developed across said load network in response to light energy impinging upon said photoelectric cell, smoke indication apparatus including a meter, the input of said smoke indication apparatus including a meter adjusting network shunting said cathode load, said adjusting network developing an equal and opposing potential with respect to the potential developed across said cathode load under no-smoke conditions whereby zero meter deflection occurs, and said meter adjusting network including a variable impedance element for causing exact full scale current to flow through said meter when no smoke is within said smoke-monitored volume.

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