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[54] **GAIN CONTROLLABLE IMAGE INTENSIFICATION SYSTEM**

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[52] **U.S. Cl.** **315/30,** 313/96, 315/10

[51] **Int. Cl.** **H01j 29/52**

[58] **Field of Search** .... 250/213, 213 VT; 315/10, 315/30; 313/94, 96

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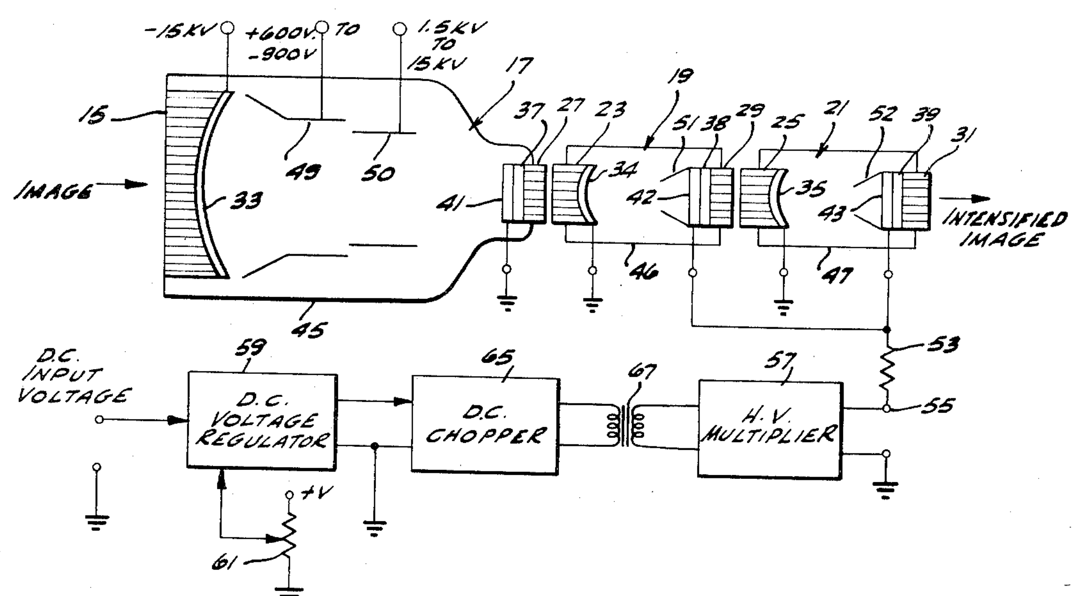
[57] **ABSTRACT**

A system which utilizes a plurality of cascaded image intensifier tubes selectively coupled to a power supply to intensify the image of a scene. The power supply is adaptable for supplying the same or different operating potentials to the tubes. The system also includes means coupled to the power supply for protecting the tubes from damage and for providing improved light gain control of the tubes by controlling the amplitude of the operating potentials as a function of the amplitude of tube photocurrent.

11 Claims, 4 Drawing Figures



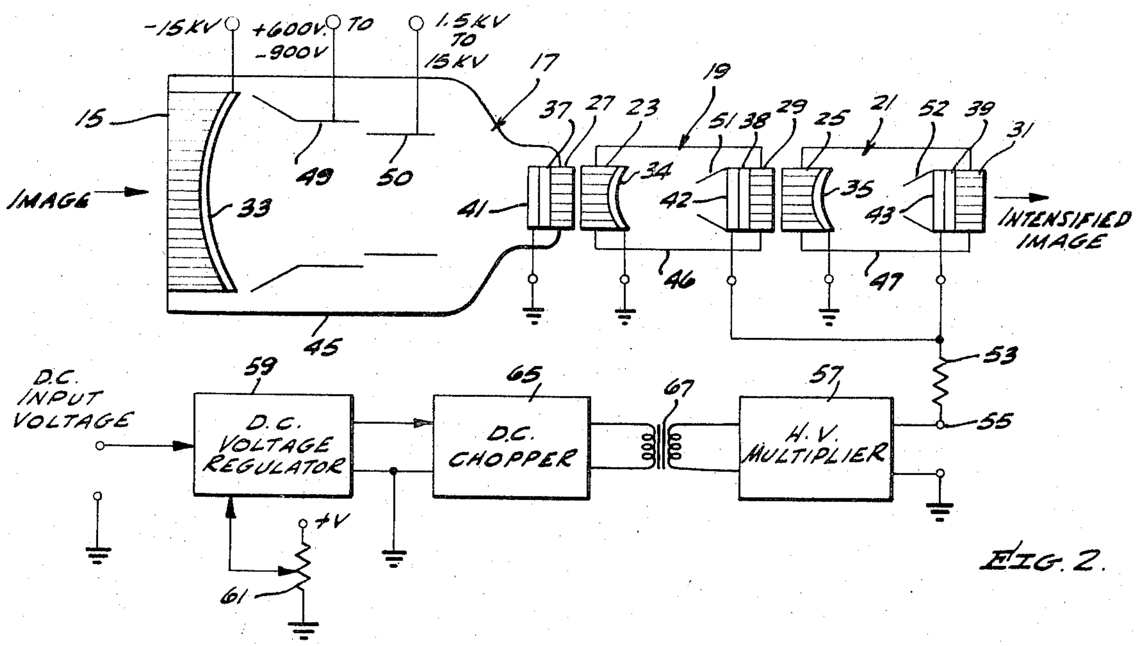


FIG. 2.

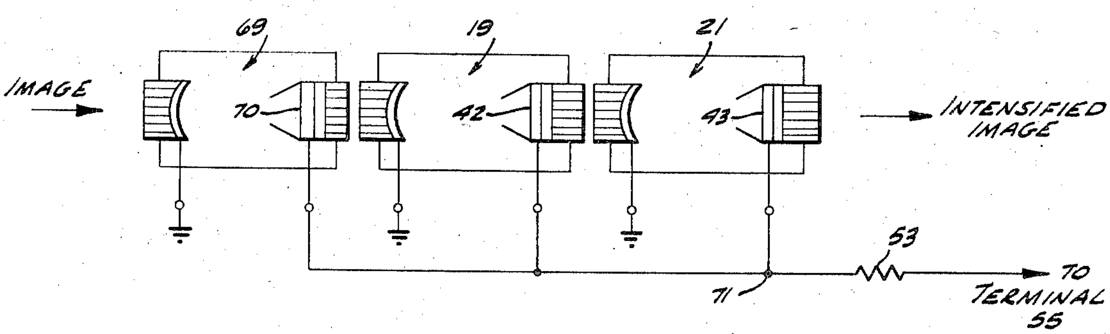


FIG. 3.

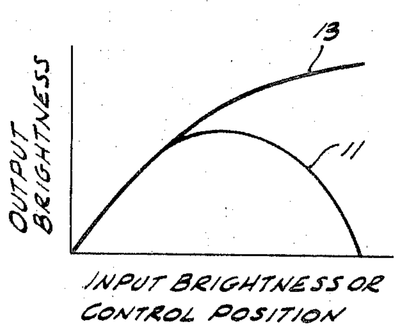


FIG. 1.

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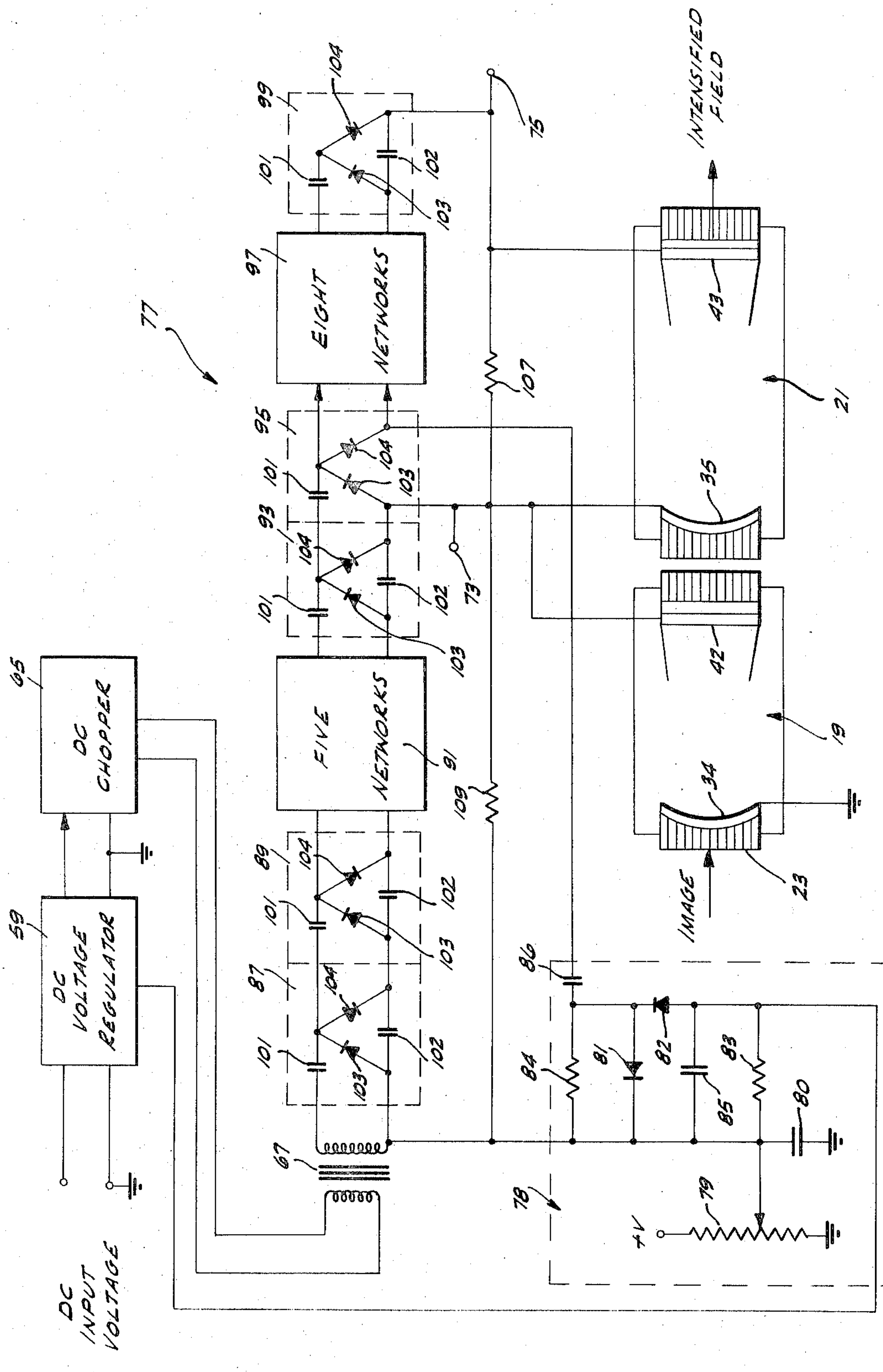
DC VOLTAGE REGULATOR
DC CHOPPER
FIVE NETWORKS
EIGHT NETWORKS
INTENSIFIED FIELD
IMAGE
DC INPUT VOLTAGE
+V

FIG. 4

GAIN CONTROLLABLE IMAGE INTENSIFICATION SYSTEM

BACKGROUND OF THE INVENTION

This invention relates to image viewing systems and particularly to an image intensification system which controls the output image brightness and which protects the tubes in the system from damage. The invention herein described was made in the course of or under the Contract No. DAAB07—68—C—0188 with the United States Army.

Conventional image intensification systems employing image intensifier tubes lack either proper light gain control or adequate protection for the image intensifier tubes or both. Without proper light gain control, the output image intensity will start dropping or cut off completely whenever the input image intensity increases, and/or the light gain control position is increased, beyond a certain level of brightness. Without adequate protection for the image intensifier tubes, at least one of the tubes may be damaged whenever the input image intensity increases, or the setting of the light gain control is increased, beyond a certain level.

At the present time there are no known image intensification systems which not only control the light gain such that the output level of brightness always increases with either an increase in the input image intensity or in the setting of the light gain control but also protect the tubes from overload conditions.

SUMMARY OF THE INVENTION

Briefly, an improved image intensification system is provided which utilizes a plurality of cascaded image intensifier tubes, a power supply and means coupled to the power supply for sensing tube photocurrent in order to improve the light gain characteristics of the system while protecting the tubes from overload conditions.

It is therefore an object of this invention to provide an improved image intensification system.

Another object of this invention is to provide an image intensification system having proper light gain control and tube protection.

Another object of this invention is to provide an image intensification system in which the image intensifier tubes are cascaded for light gain and paralleled for reception of the power supply voltage.

Another object of this invention is to provide an image intensification system in which the image intensifier tubes are cascaded for light gain and are respectively coupled to a plurality of taps on the power supply for receiving different power supply voltages.

Another object of this invention is to provide an image intensification system which utilizes photocurrent of predetermined tubes to control the operating potentials applied to all of the tubes.

A further object of this invention is to provide an image intensification system which will not cut off with an increase in the input light or light gain control level.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects, features and advantages of the invention, as well as the invention itself, will become more apparent to those skilled in the art in the

light of the following detailed description taken in consideration with the accompanying drawings wherein like reference numerals indicate like or corresponding parts throughout the several views wherein:

FIG. 1 is a graph that illustrates how the output brightness of an image varies as a function of either the brightness control position or input light level in relation to the system of the invention.

FIG. 2 is a schematic circuit and block diagram in accordance with one embodiment of this invention.

FIG. 3 illustrates another configuration of the embodiment of FIG. 2 in accordance with the principles of the invention.

FIG. 4 is a schematic circuit and block diagram in accordance with a second embodiment of this invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In any image intensification system the output brightness varies as a function of either the voltage applied to the tubes or the level of the input light. FIG. 1 illustrates this functional relationship in the curves **11** and **13.** Curve **11** illustrates how, in the prior art, the output brightness decreases when either the input brightness increases or the brightness control position is increased beyond a certain level. The output brightness may even decrease until an undesirable cut-off condition exists in the system. Furthermore, systems in the prior art have been found to be very susceptible to tube damage in response to an increase in the level of either the input brightness or the applied voltage. Curve **13**, on the other hand, illustrates the output gain characteristics in accordance with this invention, wherein there is no decrease in the level of the output brightness with an increase in the level of the input brightness or brightness control position.

One mechanization of an image intensification system for achieving the gain control characteristics illustrated in the curve **13** of FIG. **1** is shown in FIG. **2,** which illustrates a schematic circuit and block diagram in accordance with one embodiment of this invention. The image of a scene may be focused by a suitable lens (not shown) onto a fiber plate **15** of a first image intensifier tube **17** in order to intensify the brightness of the image of the scene. The tube **17** is coupled to two cascaded image intensifier tubes **19** and **21** in order to further intensify the image. With the use of the three cascaded intensifier tubes **17, 19** and **21,** the light coming in one end of the system leaves the other end of the system much brighter and, therefore, the system can greatly intensify the image. The illustrated image intensifier tubes **17, 19** and **21** respectively utilize input fiber plates **15, 23** and **25** and output fiber plates **27, 29** and **31.** The output fiber plate of one tube may be clamped to the input fiber plate of the following tube in order to minimize the loss between adjacent tubes. Fiber plates, which are well known in the field of fiber optics, may be used at each end of each of the tubes rather than lenses or direct coupling in order to minimize the loss of light and obtain better image resolution as the light passes from one tube to the next. Each fiber plate is made up of a large number of glass fibers placed parallel to each other and fused together all around and along the length of each of the fibers in order to make the fiber plate vacuum tight. Each fiber consists of a core of glass of a high index of refraction surrounded by a layer of glass of a low index of refraction to enable the fiber to pick up a portion of the light from the image at one end and pass it through to the other end. In addition, each glass fiber should be as small or smaller than the least element that is to be resolved in order to avoid a loss of resolution of the image.

Each of the input fiber plates **15, 23** and **25** is used in the conversion of light energy into electrical energy. For this purpose, the front surface may be flat to receive the light from the image and the back surface may be concave. A thin layer of a photosensitive substance is placed upon the concave surface of each of the input fiber plates **15, 23** and **25** to form the photocathodes **33, 34** and **35**, respectively. Each of the photocathodes **33, 34** and **35** has the property of emitting electrons when exposed to light in a direct relationship to the intensity of the light striking it.

Each of the output fiber plates **27, 29** and **31** is used in the conversion of electrical energy back into light energy. To achieve this result, both of the front and back surfaces of each of the output fiber plates **27, 29** and **31** may be flat. The front surfaces of the output fiber plates **27, 29** and **31**, respectively, have the thin phosphor layers **37, 38** and **39** placed thereon. Each of the phosphor layers **37, 38** and **39** has the property, when struck by electrons, of glowing or emitting light with an intensity directly proportional to the kinetic energy of the electrons upon impact therewith. The phosphor layers **37, 38** and **39** have thin aluminum anode layers **41, 42** and **43**, respectively, coated thereon to make the phosphor layers function better. The aluminum anodes **41, 42** and **43** attract the electrons being emitted from their respective photocathodes **33, 34** and **35** and provide direct current return paths for the electrons. In addition, the surface of each of the aluminum anodes that faces its respective adjacent phosphor layer has a mirror finish that reflects any light being emitted from the phosphor layer toward the aluminum anode back to the phosphor layer so that the phosphor layer is further brightened.

These coated input and output fiber plates are then selectively sealed to opposite ends of the glass envelopes **45, 46** and **47** of the tubes **17, 19** and **21**, respectively, by a suitable sealing material such as an alloy of metal conventionally used for glass to metal seals. The air is then exhausted from each of the enclosed glass envelopes **45, 46** and **47** in a conventional manner as is well known in the art.

In the embodiment of FIG. **2**, the image of the scene is projected upon the flat surface of the fiber plate **15** of the image intensifier tube **17**, which may be an 80/25 tube, manufactured by Aerojet Delft as model FFF, and also such other companies as Varian and Westinghouse, for example. Portions of the light from the image pass through corresponding fibers in the fiber plate **15** and strike corresponding portions of the photocathode **33**, causing the photocathode to emit electrons. The photocathode **33** is coupled through an output terminal to a source of a high negative potential, which may be about −15 kilovolts (KV). The electrons being emitted from the photocathode **33** are attracted to the aluminum anode **41** which, in turn, is connected through an output terminal to a reference potential such as ground. Due to the high potential existing between the photocathode **33** and the anode **41**, the electrons being emitted from the photocathode **33** attain a high energy before striking the anode **41**. The electrons striking the aluminum anode **41** pass through the anode **41** to corresponding incremental areas of the adjacent phosphor layer **37**, causing the phosphor layer **37** to glow in brilliance in proportion to the energy and intensity of the electron charge striking the corresponding incremental areas on the phosphor layer **37**. After striking the phosphor layer, the electrons drift back to the grounded aluminum anode **41** and then return to the source of the −15 KV potential. Overall, the amount of energy which is transferred to the phosphor **37** to excite the phosphor is equal to the energy given to the electrons minus the energy lost in passing through the aluminum anode **41**. The gain of the tube **17** (as well as each of the tubes **19** and **21**) is a function of the density of the electron stream from its photocathode **33**, the amount of attraction exerted on this electron stream by its anode **41** potential, the loss of energy by the electrons in passing through the aluminum anode **41**, and the characteristics of the selected phosphor **37**. Thus, electrical energy striking the anode **41** is converted into light energy by the phosphor **37**. This light energy from the phosphor layer **37** is then passed through the fiber plate **27** to the adjacent image intensifier tube **19**. In the illustrated arrangement, a focus electrode **49** and a zoom electrode **50** are also included in the structure of the image intensifier tube **17**. The focus electrode **49** is coupled through an output terminal to a source of a voltage which may be varied from a positive 600 volts to a negative 900 volts, for example. This variable voltage is used to focus the electron stream being emitted from the photocathode **33** for the best output resolution of the tube **17**. The zoom electrode **50** is coupled through an output terminal to a source of potential which may be varied from a positive 1.5 KV to a positive 15 KV in order to vary the range of brightness of the image intensifier tube **17** from approximately 100 to 1,000 times brighter than the brightness of the input image being projected upon the flat surface of the fiber plate **15**. This brightness range of from 100 to 1,000 times depends on the magnification of the tube **17**, which in turn is dependent upon the voltage on the zoom electrode **50**. The magnification, which may be defined as the size of the output image diameter divided by the size of the input image diameter, can have a range of, for example, ⅓ to 1. When the magnification is ⅓, the diameter of the photocathode **33** is effectively three times greater than the diameter of the phosphor **37** and hence the electrons are concentrated on the phosphor **37** to give the brightness gain of 1,000 times. When the magnification is 1, the respective diameters are effectively equal and the brightness gain is 100 times. When the voltage applied to the zoom electrode **50** is at its most positive potential, 15 KV, the brightness gain will be approximately 1,000 times and when the voltage on the zoom electrode **50** is at its lowest positive potential, 1.5 KV, the brightness gain will be approximately 100 times.

The output intensified image from the output fiber plate **27** of the image intensifier tube **17** is applied to the input fiber plate **23** of the image intensifier tube **19**, which may be a 25/25 diode tube manufactured by such companies as Machlett, Varo and Westinghouse. The light passes through the fibers in the fiber plate **23** and strikes the photocathode **34** which also emits electrons in direct proportion to the intensity of the light striking the photocathode **34**. The photoelectrons are attracted to an aluminum anode layer **42**. The phosphor layer 38 sandwiched between the aluminum layer 42 and the fibre plate 29 responds to the charge and intensity of the electrons hitting the aluminum layer 42 and converts the electron energy into light energy which, in turn, is coupled through the output fiber plate 29 into the input fiber plate 25 of the image intensifier tube 21 for additional image intensification by the tube 21. The focusing electrodes 51 and 52 are respectively coupled to the anodes 42 and 43 of the tubes 19 and 21. Although the diode tubes 19 and 21 both brighten the image, neither tube changes its magnification of one (1). The tube type and operation of the image intensifier tube 21 are identical to those of the image intensifier tube 19. The photocathodes 34 and 35 of the image intensifier tubes 19 and 21, respectively, are coupled through output terminals to a reference potential such as ground. The anodes 42 and 43 of the tubes 19 and 21, respectively, are coupled together and through a resistor 53 to an output terminal 55 of a high voltage multiplier 57, which produces an output regulated direct current (DC) voltage at the terminal 55. The output fiber plate 31 of the image intensifier tube 21 may be viewed directly, may be clamped to an eye piece (not shown) for viewing the image directly at the output of the tube 21, may have a fiber bundle (not shown) clamped to it for transmitting the image to another location, or may be utilized in any desired arrangement for viewing or sensing the image. A fiber bundle is quite similar to any of the fiber plates previously mentioned and is well known in the art. The fiber bundle, however, does not have a layer or coating on either end and each fiber in the fiber bundle picks up light and displays it at the remote end. The fiber bundle may be epoxied together at both ends.

The power supply of the system includes a DC voltage regulator 59, a brightness control unit or potentiometer 61, a DC chopper circuit 65, a step-up transformer 67 and the high voltage (H.V.) multiplier 57. The output regulated DC voltage from the system power supply is produced in the following manner. A DC input voltage is applied to the DC voltage regulator 59 which has its output level controlled by the setting of the brightness control potentiometer 61 which, in turn, is coupled between a positive DC voltage and ground. The regulated DC voltage from the DC voltage regulator 59 is applied to the DC chopper 65 which converts the pure DC voltage into a bipolar square wave output voltage proportional to the DC voltage input and at a peak to peak (P/P) amplitude of, for example, 40 volts. This square wave output voltage is applied to the primary of the step-up transformer 67, which may have a 50:1 voltage step-up ratio, and the 2,000 volt P/P output from the secondary of the transformer 67 is applied to the high voltage multiplier circuit 57. The output voltage of the high voltage multiplier 57 may be applied to a filter circuit (not shown) for additional filtering before being applied through the resistor 53 to the anodes 42 and 43 of the tubes 19 and 21, respectively. The voltage regulator 59, DC chopper circuit 65 and transformer 67 are of conventional types, as are well known in the art. The high voltage multiplier circuit 57 will be explained in more detail in connection with FIG. 4.

For proper tube life, the maximum allowable anode voltage on each of the diodes 19 and 21 in relation to the corresponding photocathode should be approximately 15,000 volts. With a decrease in this anode voltage there will be little loss of image resolution but a decrease in the output gain level. It should, therefore, be obvious that by varying the brightness control potentiometer 61, the output voltage of the high voltage multiplier 57, and hence the anode voltages of the tubes 19 and 21, will be changed, thereby changing the output gain of the system.

Some of the purposes of the invention, as stated with reference to the embodiment of FIG. 2, are to properly control the light gain of the system and protect the tubes 19 and 21 from damage caused by any of such overload conditions as an excess light source, voltage or current. These basic purposes are achieved by mechanizing the system, as shown in the embodiments of FIGS. 2 and 4, so that the last tube 21 controls the voltage on both of the tubes 19 and 21, and the tube 19 is able to be cut off before the tube 21.

For proper control of the light gain of the system, it is desirable to raise or lower the voltage on tube 21 as well as on tube 19. When these voltages applied to the anodes are reduced, the gains of the tubes 19 and 21 are reduced. With the arrangement shown in FIG. 2, the gain of both tubes is controlled. As previously discussed, the tubes 19 and 21 are electrically coupled together in parallel and through the resistor 53 to the terminal 55 in order to receive the same anode potential. Because the photocurrents of both of the tubes 19 and 21 flow through the common resistor 53, which limits the power to the tubes, the voltages supplied to their respective anodes will be decreased with an increase in photocurrent, and vice versa. As a result, the gain of both of the tubes 19 and 21 is affected by the change in their anode voltages, which enables the system to have a wide range of gain. Since the tube 21 has a much larger photocurrent than that of the tube 19 and the photocurrents of both tubes flow through the common resistor 53, the amplitude of the photocurrent of tube 21 basically controls the amplitudes of the anode voltages on the tubes 19 and 21, thereby controlling the light gain of the system and protecting both of these tubes from damage. The system shown in FIG. 2 can never exhibit the output brightness characteristics as shown in the curve 11 of FIG. 1 but, on the other hand, will produce the output brightness characteristics as shown in the curve 13 of FIG. 1 since, as explained below, the tube 19 is able to be cut off before the tube 21.

The ability of the tube 19 to be cut off before the tube 21 can be achieved, in one mechanization, by selecting the tube 19 so that it has a higher threshold of cut-off than that of the tube 21. The threshold of cut-off values of these 25/25 tubes 19 and 21 is nominally between 2.5 KV and 4.5 KV. For example, the tubes might be chosen so that tube 19 cuts off when its anode potential drops below 4 KV and the tube 21 cuts off when its anode potential drops below 3 KV. In this case, since the photocurrent in the tube 21 is used to control the anode voltage on each of the tubes 19 and 21 and tube 19 is chosen to cut off before tube 21, neither would be cut off. This conclusion is based upon the fact that tube 19 has its anode voltage controlled basically by the photocurrent in tube 21 and, if there is no photocurrent in tube 21, the tube 21 cannot cut off the tube 19.

FIG. 3 shows a modification of the embodiment of FIG. 2 wherein a 25/25 diode tube 69, identical with the tubes 19 and 21 of FIG. 2, replaces the 80/25 tetrode tube 17 of FIG. 1. Tubes 19 and 21 are shown cascaded to each other and to this new diode tube 69. The anodes 70, 42 and 43 of the tubes 69, 19 and 21, respectively, are connected together at a common junction point 71 and through the resistor 53 to the output high voltage terminal 55 of the high voltage multiplier 57 of FIG. 2. These three tubes 69, 19 and 21 are now chosen so that the first tube in the cascaded sequence, tube 69, has the highest threshold of cut-off and the last tube in the cascaded sequence, tube 21, has the lowest threshold of cut-off. With this arrangement the system would also produce the output brightness characteristics of the curve 13 of FIG. 1. It should be obvious that two or more diodes could be used in this cascaded sequence to attain the intensified image output. With these three tubes 69, 19 and 21 connected in a cascaded sequence, the tube 21 would basically control the anode voltages on the tubes 69, 19 and 21. The tube arrangement of FIG. 3, as well as that of FIG. 2, would provide protection for all of the tubes in the system that receive their anode voltages through the resistor 53, and, as shown in graph 13 of FIG. 1, would cause the output brightness to increase without decreasing as the input brightness increases or the brightness control 61 position is increased.

It should be noted at this time that the parallel connections of the tubes to the power supply as shown in FIGS. 2 and 3 will produce spurious lights whenever there is a difference of potential across the interface between the anode of one tube and the photocathode of the adjacent tube or between the anode of tube 21 and a fiber bundle (not shown) connected thereto. These spurious lights, which may be generated at the interfaces, may not be sufficiently bright to interfere with the operation of the system even though they may be amplified by a following tube. However, these spurious lights may be reduced and/or eliminated by utilizing a second embodiment of the invention, as shown in FIG. 4.

Referring now to FIG. 4, an arrangement is illustrated whereby the light-gain cascaded tubes 19 and 21 have their anodes 42 and 43 respectively coupled to taps 73 and 75 of a high voltage (H.V.) multiplier 77. The embodiment shown in FIG. 4 still enables the tube 21 to control the voltages on the tubes 19 and 21, affords tube protection for the tubes 19 and 21 and enables the output voltages from the taps 73 and 75 of the high voltage multiplier 77 to track each other. In the absence of input light striking the input fiber plate 23 of the tube 19, the photocurrents of the tubes 19 and 21 are at a minimum amplitude and the voltages at the taps 73 and 75 will be approximately 15 KV and 30 KV, respectively. The anode 42 of the tube 19 is connected to the photocathode 35 of the tube 21 so that there is no difference of potential across the interface between the tubes 19 and 21, and hence substantially no spurious lights will be generated at that interface. The photocathode 34 of the tube 19 is connected to ground. The type and operation of the DC voltage regulator 59, the DC chopper circuit 65, and the transformer 67 are identical to those shown in FIG. 2. The H.V. multiplier 77 is similar to the high voltage multiplier 57 of FIG. 2, but has two output voltage taps 73 and 75 rather than one shown by the output terminal 55 of FIG. 2.

As shown in FIG. 4, the control voltage which controls the output of the voltage regulator 59 is derived by a different circuit than that shown in FIG. 2 in that it is produced by a sensing circuit 78, rather than by the direct output from the movable arm of a brightness control potentiometer 79. The sensing circuit 78 is coupled between the bottom of the secondary winding of the transformer 67 and an upper portion of the H.V. multiplier 77 in order to sense the charging current therefrom. The sensing circuit 78 includes: the brightness control potentiometer 79 which is coupled between a source of positive voltage and ground; a bypass capacitor 80 coupled between the movable arm of the potentiometer 79 and ground to bypass any noise or ripple to ground; a half-wave rectifier comprised of the rectifiers 81 and 82, the sensing resistor 83, the resistor 84 and a capacitor 85; and, finally, a coupling capacitor 86 which is coupled between the junction of rectifiers 81 and 82 and an upper portion of the H.V. multiplier 77 near the 15 KV tap 73. The common junction of the movable arm of the potentiometer 79, the rectifier 81, the resistors 83 and 84, and the capacitors 80 and 85 is coupled to the bottom of the secondary winding of the transformer 67, as shown in FIG. 4. Because the coupling capacitor 86 in the sensing circuit 78 has one side very close to the 15 KV output tap 73 and the other side very close to a ground potential, the coupling capacitor must have a DC voltage rating of at least 15 KV. The operation of this sensing circuit 78 will be explained at a later time.

The 2,000 volt peak-to-peak output from the secondary of the step-up transformer 67 is applied to a plurality of serially coupled networks 87, 89, 91 and 93 which rectify and multiply this 1,000 volt peak output to produce the first output voltage of 15 KV at the tap 73. A circuit 95, which will be explained later, is serially coupled between the network 93 and a sequence of nine more serially coupled networks 97 and 99 which develop the second output voltage of 30 KV at the tap 75.

Each of the networks 87, 89, 91, 93, 97 and 99 is comprised of capacitors 101 and 102 and the rectifiers 103 and 104 to form one conventional cascade voltage doubler section in the high voltage multiplier 77. Each network is sequentially responsive to its respective input voltage to produce a higher output voltage across its respective capacitor 102 of approximately 2,000 volts which is serially additive to the output voltage from the preceding network and/or to the output voltage from the following network to obtain an effective voltage multiplication of the 1,000 volt peak output from the transformer 67. Each of the capacitors 101 and 102 may be selected to have a capacitance of approximately 1,500 micro-microfarads and a DC working voltage of 2,000 volts. Each of the rectifiers 103 and 104 is selected to have a minimum of capacitance. It should be noted at this time that the circuit 95 is identical to any of the networks 87, 89, 91, 93, 97 and 99, except for the omission of the capacitor 102. The anode of the rectifier 103 in the circuit 95 is coupled to the tap 73, while the cathode of the rectifier 104 in the circuit 95 is coupled to the coupling capacitor 86 in the sensing circuit 78. The operation of the circuit 95 will be explained in conjunction with the operation of the sensing circuit 78.

A firt bleeder resistor 107 is connected between the 15 KV tap 73 and the 30 KV tap 75 and a second bleeder resistor 109 is connected between the 15 KV tap 73 and the bottom side of the secondary winding of the transformer 67. These resistors 107 and 109 form a bleeder resistor network for the H.V. amplifier 77 and have relatively high resistances to minimize any loading of the multiplier 77. These bleeder resistors 107 and 109 are required to discharge the capacitors 101 and 102 in the serially coupled networks, and thereby reduce the anode voltages of the tubes 19 and 21 when the brightness gain setting of the potentiometer 79 is reduced or the system is turned off.

In the operation of the high voltage multiplier, an alternation of one polarity of the square wave input is applied to the first network 87 which causes the serially coupled capacitors 101 on the upper portion on each of the networks to charge all down the line through their respectively forward-biased rectifiers 103. On the next alternation of the opposite polarity the charge on the capacitor 101 in any network is series aiding with the input voltage to that network. This condition respectively reverse-biases the rectifier 103 and forward-biases the rectifier 104 in that network, thereby completing the path for the discharge of the capacitor 101. The discharge of the capacitor 101, in conjunction with the input voltage to the network, charges the capacitor 102 in the same network to a higher voltage than the input voltage to the network. After several cycles of the square wave input, the capacitors 102 are charged up, thereby achieving a voltage multiplication.

The sensing circuit 78 senses the charging current resulting from the photocurrent in the upper part of the high voltage multiplier 77 from the tube 21 and uses this to control the amplitude of the output voltage from the regulator 59, which in turn controls the amplitude of the voltage in the secondary of the transformer 67. Due to the intentional omission in the circuit 95 of the capacitor 102 between the anode of the rectifier 103 and the cathode of the rectifier 104, the charging current to the upper part of the high voltage multiplier 77 is forced to go into the sensing circuit 78 and passes through the coupling capacitor 86 to the junction of the rectifiers 81 and 82. Before this charging current is returned to the serially coupled networks 97 and 99 in order to complete the circuit return back to the secondary of the transformer 67, it is subjected to half wave rectification. Positive going surges in this charging current are shunted by the rectifier 81 around the resistor 84 to the bottom part of the secondary of the transformer 67. Negative going surges in this charging current are shorted by the rectifier 82 and pass through the resistor 83 to the bottom part of the secondary of the transformer 67. The capacitor 85 is coupled across the resistor 83 to filter the current fluctuations passing through the rectifier 82 and produce a relatively smooth DC voltage across the resistor 83. The resistor 84 improves the operation of the half wave rectifier by stabilizing the potential at the junction of the rectifiers 81 and 82.

The sensing circuit 78 compensates for the bleeder current in the following manner. The DC voltage drop across the sensing resistor 83 is proportional to the bleeder current through the resistor 107, as well as to the photocurrent from the tube 21. That component of the voltage drop across the sensing resistor 83 which is proportional to the bleeder current through the resistor 107 is proportional to the high voltage developed at the tap 75, which in turn is proportional to the control voltage applied from the sensing circuit 78 to the regulator 59. The control voltage is equal to the voltage selected by the setting of the brightness control potentiometer 79 minus the voltage developed across the sensing resistor 83. Thus a feedback loop is closed. The basic effect of that component of the voltage drop across the sensing resistor 83 which is caused by the flow of bleeder current through the resistor 107 is to increase the range of the control potentiometer 79 that is required to control the system. Therefore, this system effectively compensates for the bleeder current by subtracting from the voltage produced by the current sensed by the sensing circuit 78 that part which is produced as a result of bleeder current flow. The difference between the two is due to the photocurrent in the tube 21.

With an increase in the photocurrent of the tube 21 only, the amplitude of the control voltage applied to the DC voltage regulator 59 will decrease, thereby causing the output of the DC voltage regulator 59 to decrease. The effective resistance (load line) presented to the tube 21 is controlled by the value of the sensing resistor 83. The photocurrent in the tube 19 will not affect the operation of the sensing circuit 78.

Image intensification systems in the prior art basically utilize cascade voltage connections to the power supply similar to those shown in FIG. 4 in order to avoid spurious lights. However, the mechanizations of prior art systems, as mentioned before, provide very poor gain control characteristics and tube protection. Conventional arrangements using a multiplier stack cause the voltage on the upper end of the stack (last tube 21) to drop to low values, causing a characteristic similar to that of the curve 11 of FIG. 1. The use of series load resistors with cascaded voltage connections also leads to the characteristic shown by the curve 11 of FIG. 1, with the output being completely cut off, and the first tube being overloaded both in voltage and in power.

The tube protection furnished by the embodiments shown in FIGS. 2, 3 and 4 take into consideration the maximum amount of power that would be delivered to any of the tubes. More specifically, in case of a constant power supply resistance the maximum transfer of power from the source to the tube occurs when the voltage applied across the tube is equal to one-half of the supply voltage. This maximum power occurs, therefore, when the power applied to the tube equals one-fourth of the square of the voltage applied to the resistor connected between the power source voltage and the anode of the tube divided by the resistance of the resistor. In the embodiments shown in FIGS. 2, 3 and 4 the circuits are so arranged such that at this voltage the maximum power is not excessive. This affords good protection to the tubes provided the spots have sufficient size.

It should be noted that, with the arrangement shown in FIG. 4, it is not necessary to select the tubes 19 and 21 according to their threshold but the power supply could be arranged such that tube 19 would cut off before tube 21. For example, the voltages at the taps 73 and 75 could be 13 KV and 28 KV, respectively, so that the tube 19 would operate at a lower anode-to-cathode potential than the tube 21. It should be further noted that instead of the anode of tube 19 being at the same potential as the photocathode of tube 21, the system could be arranged so that there is an overlapping of potentials. For example, the 15 KV terminal could have been connected only to the anode of tube 19 while the photocathode and the anode of tube **21** could have been respectively connected to, for example, 10 and 25 KV taps on the power supply. This would produce an overlapping voltage arrangement such that the potential at any innerface may be so small that spurious lights are not substantial. It should also be understood that in the embodiments shown in FIGS. **2, 3** and **4** other combinations of tubes and tube types could be used in conformance with the teachings of the invention.

The invention thus provides an image intensifier system which protects the tubes from damage, and provides good gain control or output brightness characteristics such that the tube anode voltages from the power supply track each other.

While the salient features have been illustrated and described with respect to two particular embodiments, it should be readily apparent that modifications can be made within the spirit and scope of the invention as set forth in the appended claims.

What is claimed is:

1. A system for intensifying an image comprising:

a plurality of intensifier means cascade coupled to one another in sequence for respectively increasing the brightness of an image of a scene, each of said plurality of intensifier means operating to develop an output image of the scene at a more intensified brightness level than that presented thereto, each of said intensifier means having the ability to be cut off before the next succeeding intensifier means in said sequence;

power supply means coupled to each of said plurality of intensifier means for simultaneously applying variable operating potentials at other than zero potential to said plurality of intensifier means; and

sensing means, coupled to said power supply means, being substantially responsive to the amplitude of the photocurrent in the last intensifier means in said sequence for causing the operating potentials to be varied as a function thereof in order to control the gain of said plurality of intensifier means and the brightness of the output image of the scene as a function of the amplitude of the photocurrent being sensed.

2. The system of claim **1** wherein:

each of said plurality of intensifier means is an image intensifier tube, each of said image intensifier tubes being selected to have a higher threshold of cut-off characteristic than the following image intensifier tube connected in cascade therewith.

3. The system of claim **1** further including:

an amplifying tube coupled to said plurality of intensifier means, said amplifying tube being responsive to the reception of the image of the scene for brightening the image of the scene and applying the brightened image of the scene to said plurality of intensifier means; and

second means coupled to said amplifying tube for supplying operating voltages thereto.

4. The system of claim **3** wherein:

said amplifying tube is a tetrode intensifier tube.

5. The system of claim **1** wherein:

said power supply means includes output means coupled to each of said plurality of intensifier means for simultaneously providing the same operating potentials thereto; and

said sensing means includes a resistor coupled between said output means and each of said plurality of intensifier means and being responsive to a change in the total amplitude of the photocurrents from said plurality of intensifier means for inversely changing the amplitude of the operating potentials simultaneously being applied to said plurality of intensifier means.

6. The system of claim **5** wherein:

said plurality of intensifier means includes first and second intensifier tubes.

7. The system of claim **1** wherein:

said power supply means includes a tapped high voltage output circuit for respectively providing a different operating potential to each of said plurality of intensifier means.

8. A system for intensifying an image comprising:

a plurality of intensifier means cascade coupled to one another in sequence for respectively increasing the brightness of an image of a scene, each of said intensifier means having the ability to be cut off before the next succeeding intensifier means in said sequence;

power supply means selectively coupled to each of said plurality of intensifier means for applying operating potentials to said plurality of intensifier means, said power supply means including a tapped high voltage output circuit for respectively providing a different operating potential to each of said plurality of intensifier means; and

sensing means coupled to said power supply means for selectively sensing the photocurrent of said plurality of intensifier means, said sensing means being responsive to the amplitude of the photocurrent in the last intensifier means in said sequence to vary the operating potentials to control the gain of said plurality of intensifier means and the brightness of the output image of the scene as a function of the photocurrent being sensed, said sensing means including a first circuit coupled to a tap in the tapped high voltage output circuit for regulating the amplitude of the voltage applied to said tapped high voltage output circuit as a function of the amplitude of the photocurrent being sensed by said sensing means.

9. The system of claim **8** wherein said power supply means includes:

a voltage regulator being responsive to the reception of an input direct current voltage and a control signal from said first circuit in said sensing means for producing an output direct current voltage having an amplitude which varies as a function of the amplitude of the photocurrent sensed by said sensing means;

a chopper circuit coupled to said regulator and being responsive to the output voltage therefrom for producing a direct current square wave output voltage having an amplitude proportional to the amplitude of the output voltage of said regulator;

a transformer coupled between said chopper circuit and said tapped high voltage output circuit for transferring the direct current square wave output voltage to said tapped high voltage output circuit, said tapped high voltage output circuit being responsive to the square wave output voltage for developing the different operating potentials; and

control means coupled to said tapped high voltage output circuit for varying the operating potentials to each of said plurality of intensifier means in order to control the brightness of the output intensified image of the scene.

10. The system of claim **9** wherein:

said tapped high voltage output circuit is a high voltage multiplier having a plurality of networks connected in sequence with one another for developing different potentials along the sequence.

11. The system of claim **10** wherein:

said plurality of intensifier means includes first and second image intensifier tubes.

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