United States Patent

Gordon

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[54] POWER REGULATING MEANS FOR LIGHT AMPLIFIER TUBES

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[52] **U.S. Cl.** ..... **315/205**, 250/213 VT

[51] **Int. Cl.** **H05b 37/00**

[58] **Field of Search** ..... 250/213 VT; 307/110; 313/65; 315/151, 205

[56] **References Cited**

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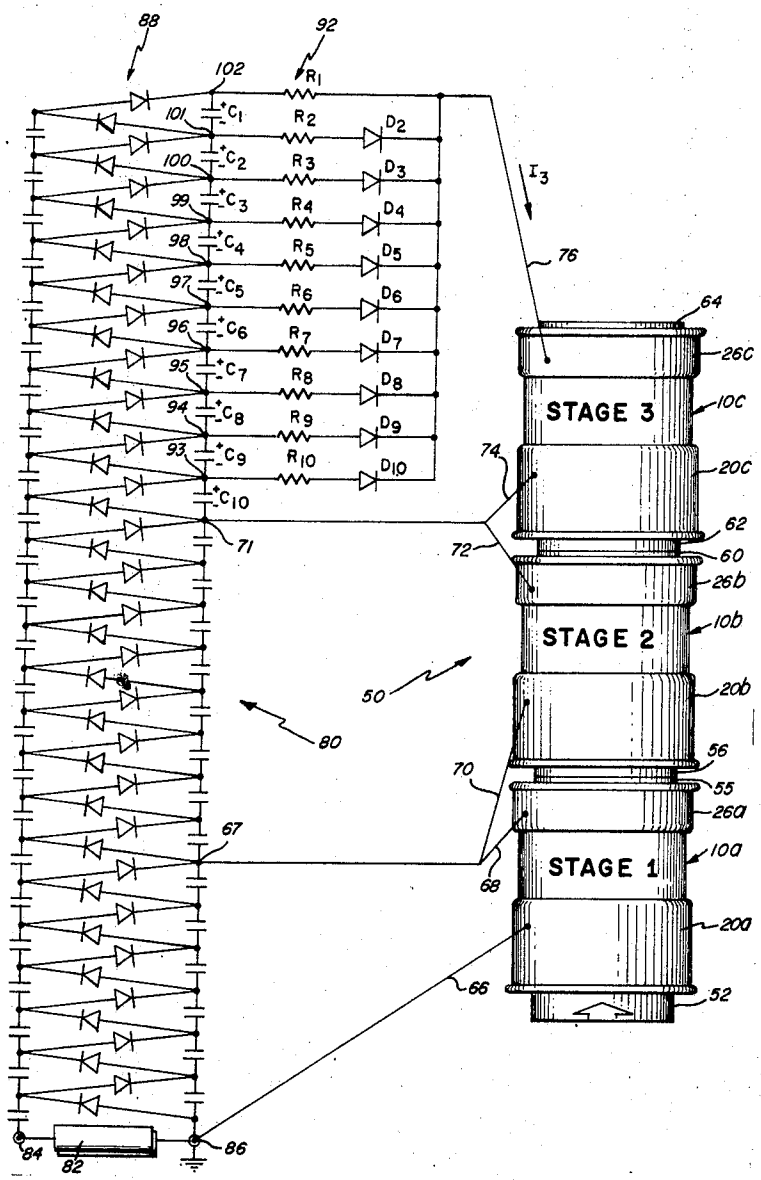
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Primary Examiner—Roy Lake
Assistant Examiner—Lawrence J. Dahl
Attorney—Harold A. Murphy and Joseph D. Pannone

[57] **ABSTRACT**

A light amplifier tube having a voltage source and circuit means connected between the cathode and the anode of the tube for regulating the power supplied to the tube and thereby controlling the output brightness of the tube.

9 Claims, 5 Drawing Figures



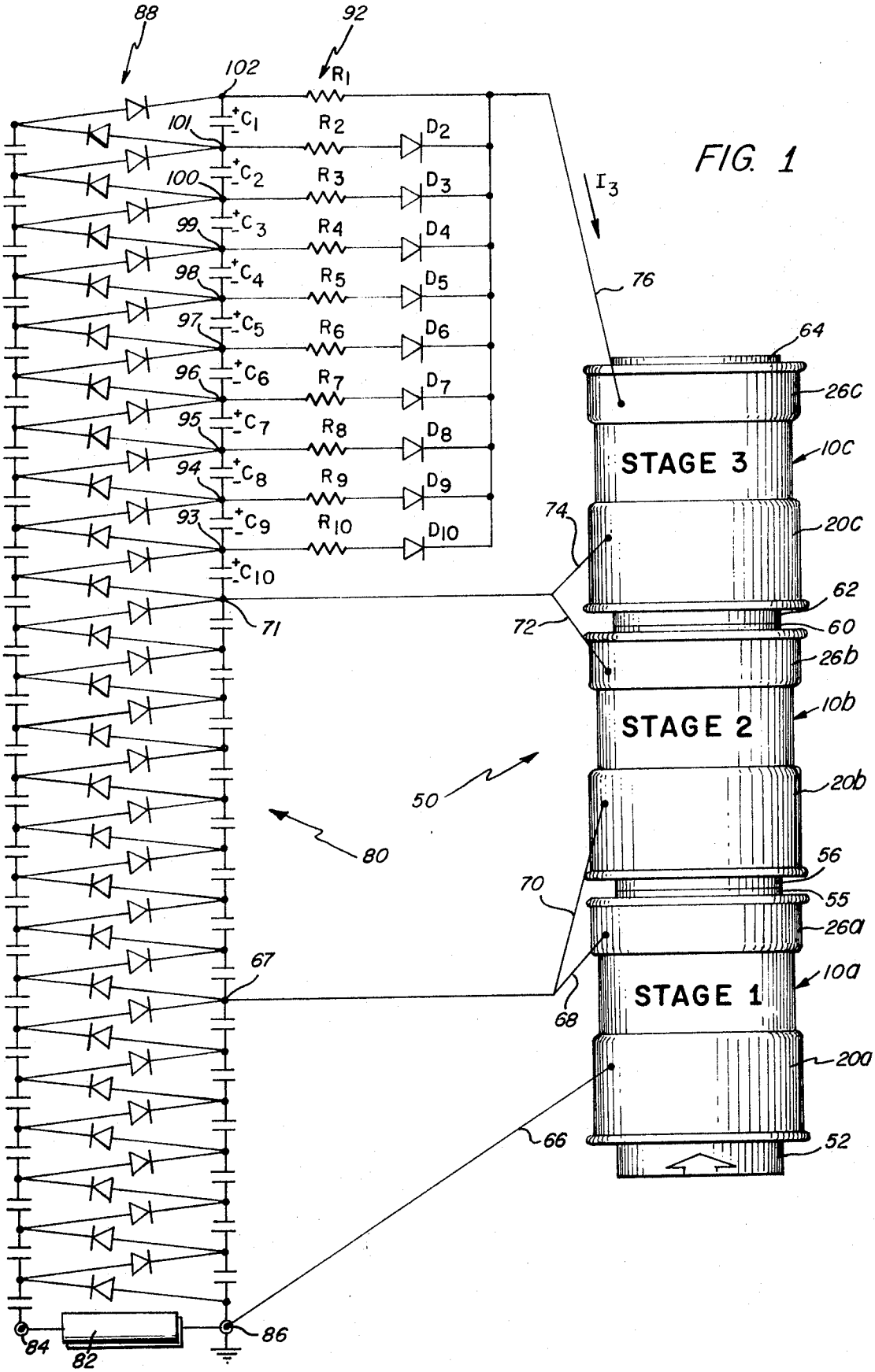

88
92
102
R1
101
C1
R2
D2
100
C2
R3
D3
99
C3
R4
D4
98
C4
R5
D5
97
C5
R6
D6
96
C6
R7
D7
95
C7
R8
D8
94
C8
R9
D9
93
C9
R10
D10
C10
71
80
67
84
82
86
I3
76
64
26c
STAGE 3
10c
74
20c
62
72
60
26b
STAGE 2
10b
50
20b
56
70
55
26a
STAGE 1
10a
68
20a
66
52

FIG. 1

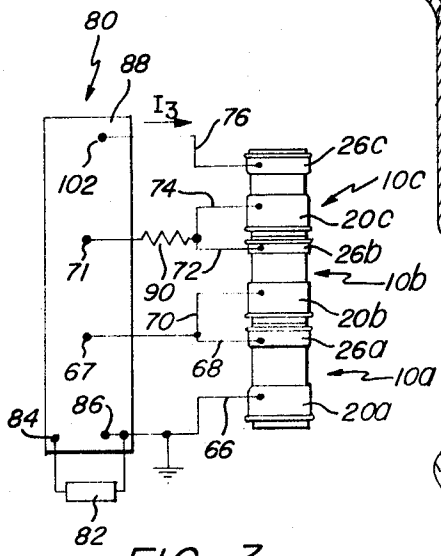


FIG. 3
PRIOR ART

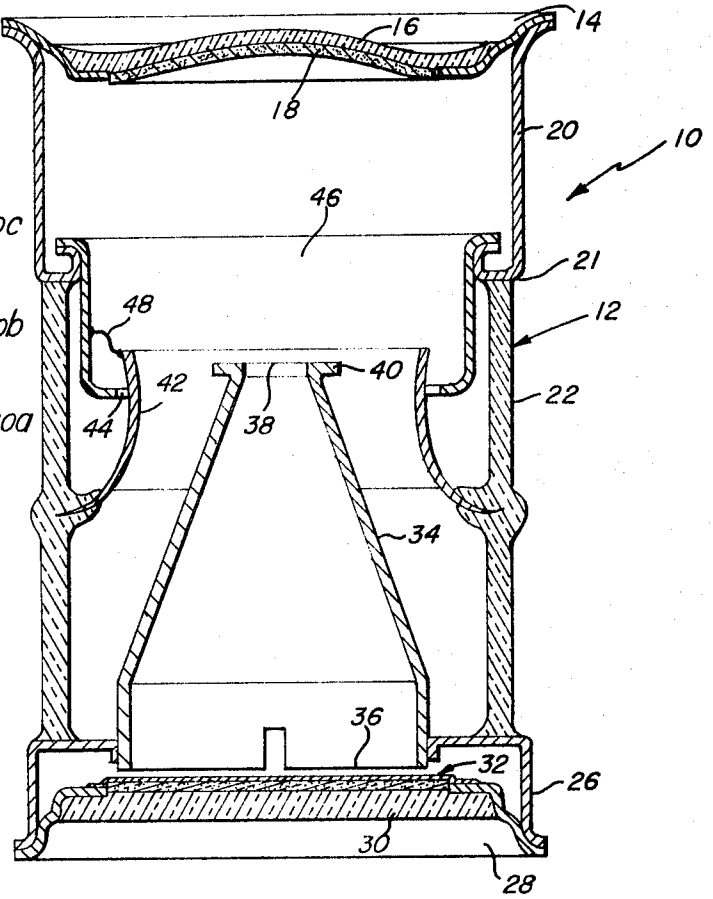


FIG. 2

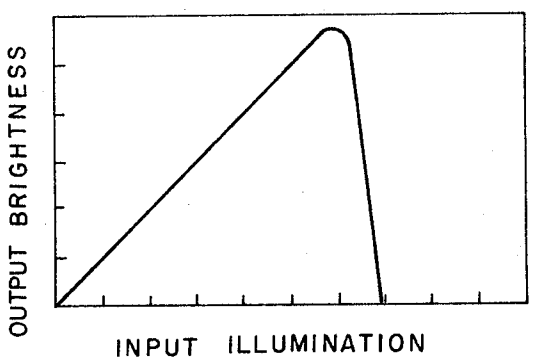


FIG. 4

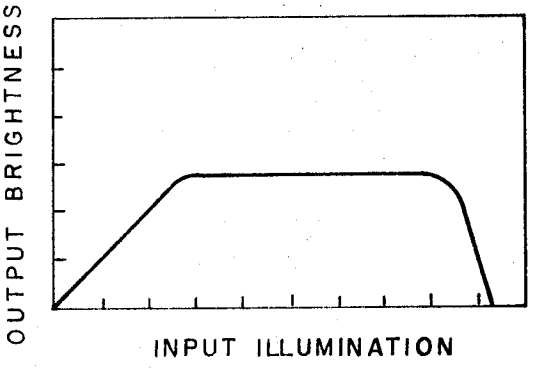


FIG. 5

POWER REGULATING MEANS FOR LIGHT AMPLIFIER TUBES

BACKGROUND OF THE INVENTION

This invention relates generally to power regulating means for light amplifier tubes and is concerned more particularly with a circuit for controlling the voltage applied to the anode of an image intensifier tube.

An image intensifier tube is a light amplifier device comprising a generally tubular envelope having therein a photocathode disposed in spaced relationship with a viewing screen anode. Usually, the photocathode comprises a layer of photoemissive material which may be deposited on the inner surface of a transparent faceplate at the input end of the tube. Generally, the viewing screen comprises a layer of phosphor material which may be deposited on the inner surface of a transparent faceplate at the output end of the tube. In operation, photons of radiant energy emanating from localized areas of an external object pass through the input faceplate and impinge on corresponding localized areas of the photocathode. The photoemissive material of the photocathode emits electrons from each discrete area thereof in proportion to the intensity of radiation incident on the respective areas. Thus, the image conveyed by radiant energy to the photocathode is converted into an electron image having incremental regions of varying electron density which correspond to the light and dark areas of the external object.

By maintaining the viewing screen anode at a much higher positive potential than the photocathode, a strong electrostatic field is established therebetween which accelerates the electron image toward the viewing screen before appreciable spreading of the image can take place. While traveling through the electrostatic field, the electrons in the image attain higher levels of kinetic energy which they expend in associated regions of the phosphor layer when the electron image strikes the viewing screen. As a result, incremental regions of the phosphor material emit photons of visible light in proportion to the energy and density of the penetrating electrons. Consequently, the electron image, thus amplified by the electrostatic field, is converted into a bright visual image which may be viewed externally through the output faceplate of the tube.

As increasingly higher positive voltages are applied to the anode viewing screen, the resulting stronger electrostatic fields accelerate the electron images to increasingly higher levels of kinetic energy and produce brighter visual images at the output end of the tube. However, when the anode potential exceeds a critical value, the visual images become blurred due to field emission electrons striking the viewing screen; and electrical breakdown may occur due to arcing between the anode and cathode structures. Consequently, in order to avoid the described adverse effects of field emission, other means have been devised for achieving still brighter visual images with image intensifier tubes. One means utilized by those skilled in the art comprises a plurality of colinear image intensifier tubes attached end to end to form a multiple stage device. Thus, the output visual image of the first stage impinges on the photocathode of the second stage wherein it is amplified a second time and converted to a brighter visual image which impinges on the photocathode of the third stage and so on. In this manner, an initial image of a faintly illuminated object may be amplified a number of times and appear as a much brighter visual image at the output end of the multiple stage, image intensifier device.

Because the described multiple stage, image intensifiers function as light amplifiers, they are particularly useful in areas where the level of illumination is extremely low. However, when using an image intensifier of the cascade type in a poorly illuminated area, a highly illuminated object may appear in the user's field of view. As a result, a relatively high current will pass through the respective stages of the image intensifier and produce an objectionably bright image on the output viewing screen of the multiple stage device. Consequently, these high gain, image intensifiers require means for automatically controlling the output brightness of the final image during periods of overloading.

One well known means for controlling the output brightness of a multiple stage image intensifier comprises a power limiting resistor connected in series between the photocathode of the final stage and the associated voltage source. Thus, when the current passing through the final stage increases, the voltage drop across the power limiting resistor increases and the voltage drop across the final stage decreases correspondingly. When the voltage applied across the final stage falls below a critical value, the resulting electrostatic field will not accelerate the electron image in the final stage to sufficiently high velocities to produce a visual image on the output viewing screen of the final stage. However, when the voltage applied across the final stage is decreasing to the critical value, the current through the final stage is increasing. Consequently, the power supplied to the final stage rises to a maximum value before decreasing; and the associated visual image reaches a sharp peak of brightness before becoming dim and disappearing from the output viewing screen. Thus, the power limiting resistor does not provide an adequate solution to the problem of controlling the output brightness of the final stage during periods of overloading.

SUMMARY OF THE INVENTION

Accordingly, this invention provides means for supplying substantially constant power to an image intensifier tube whereby the visual image on the output viewing screen of the tube is maintained at a substantially constant level of brightness. The present invention comprises a power regulating circuit which is connected between the anode viewing screen of an image intensifier tube and a voltage source having a series of graduated voltage taps. The tap having the highest value of voltage in the series is connected to a first current sensing means which may be a resistor having a predetermined ohmic value. Lower voltage taps in the aforesaid series are connected to respective current sensing means which, in turn, are connected to respective voltage detector means. Each of the respective current sensing means may also be a resistor having a predetermined ohmic value; and each of the respective voltage detector means may be a reverse biased diode. The voltage detector means are connected in common with the first current sensing means to the anode of the image intensifier tube. A tap having a voltage value lower than any of the aforesaid voltage taps is connected to the photocathode of the image intensifier tube.

BRIEF DESCRIPTION OF THE DRAWING

For a more complete understanding of the present invention, reference is made to the accompanying drawing wherein:

FIG. 1 is an elevational view of a three stage, image intensifier device shown connected to a schematic representation of the power regulating circuit of this invention and a power supply of the voltage multiplier type;

FIG. 2 is an axial sectional view of one stage of the three stage, image intensifier device shown in FIG. 1;

FIG. 3 is an elevational view of a three stage, image intensifier device connected to a power limiting means of the prior art and the power supply shown in FIG. 1;

FIG. 4 is a diagrammatic representation of the output image brightness produced by the image intensifier device shown in FIG. 3; and

FIG. 5 is a diagrammatic representation of the output image brightness produced by the image intensifier device shown in FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring more particularly to the drawing wherein like characters of reference designate like parts throughout the several views, there is shown in FIG. 2 an image intensifier tube 10 including a generally tubular envelope 12 which has a

metal ring **14** at one end. The ring **14** supports a spherically ground, glass faceplate **16** which is disposed in transverse relationship with the longitudinal axis of the tube. The faceplate **16** is sealed across the open portion of the ring **14**, and a photocathode **18** which comprises a layer of photoemissive material such as antimony cesium, for example, is deposited on the inner surface of the faceplate **16**. The ring **14** is sealed around its entire periphery to one end of a hollow metallic cylinder **20** which forms part of the envelope **12** and functions as the cathode terminal of the tube. The other end of cylinder **20** is turned inwardly and curves smoothly back on itself to form an annular rounded shoulder **21** which is sealed to one end of a dielectric cylinder **22**, such as glass, for example, which also forms part of the envelope.

The other end of cylinder **22** is peripherally sealed to a flanged end portion of a metallic sleeve **26** which functions as the anode terminal of the tube. An opposing end portion of sleeve **26** is circumferentially sealed to the outer periphery of a metal ring **28** which supports a glass faceplate **30** in transverse relationship with the longitudinal axis of the tube. The faceplate **30** is sealed across the open portion of the ring **28** and, with ring **28** and sleeve **26**, complete the envelope **12**. An imaging screen **32**, which comprises a layer of phosphor material, such as zinc cadmium sulphide, for example, is deposited on the inner surface of the faceplate **30**. The imaging screen **32** also includes a thin coating of reflective metal, such as aluminum, for example, on the inner surface of the phosphor layer. This coating of reflective metal directs visible light emitted by the phosphor material toward the output faceplate **30** and also electrically connects the imaging screen **32** to the anode terminal sleeve **26**. The flanged end portion of sleeve **26** extends radially inward of the tube envelope **12** and is circumferentially attached to a frustoconical, metal sleeve **34** thereby electrically connecting the sleeve **34** to the anode terminal of the tube. Sleeve **34** extends axially within the tube envelope and has a large diameter, open end **36** disposed closely adjacent the imaging screen **32** and an opposing, smaller diameter, open end **38** which carries an outwardly extending radial flange **40**.

Located a predetermined radial distance from the outer perimeter of flange **40** is an upper rim of a concentrically disposed, metal sleeve **42** having a lower outwardly flared end portion which is embedded in a surrounding portion of dielectric cylinder **22**. An opposing upper end portion of sleeve **42** extends axially through a large aperture **44** which is centrally disposed in a base portion of a metallic cup **46**. The sleeve **42** is electrically connected to the cup **46**, as by means of an interconnecting wire **48**, for example. The rim of the cup **46** is curved radially outward and is circumferentially attached to the inwardly turned end portion of metallic cylinder **20** thereby electrically connecting the respective members **42** and **46** to the cathode terminal of the tube. Thus, the axially aligned, cylindrical members **20, 46** and **42**, respectively, form a cathode terminal assembly which becomes increasingly smaller in diameter as it extends away from the photocathode **18** and toward the smaller diameter, open end **38** of frustoconical, anode member **34**.

In operation, the anode assembly is maintained at a much higher positive potential than the cathode assembly, such as 16,000 volts higher, for example. Radiant energy, transmitting an image of an external object, passes through the faceplate **16** and strikes the photocathode **18**, thereby causing emission of a corresponding electron image. The radius of curvature of the photocathode **18** is such that the electron image, emitted by the photocathode, converges as it is drawn toward the highly positive anode assembly. Furthermore, the combination of the inwardly tapering cathode assembly and the outwardly tapering anode assembly establishes spherical equipotential surfaces between the photocathode **18** and the smaller diameter end **38** of the frusto-conical, anode member **34**. As a result, the electron image is brought to a focus at the opening in the smaller diameter end **38** of member **34** where the image crosses over and continues traveling toward the imaging screen **32** as an enlarging, inverted image. The metallized coating on the imaging screen **32** is transparent to electrons but reflects photons of visible light. Consequently, the electron image passes through the metallized coating of the imaging screen **32** and impinges on the underlying layer of phosphor material, thereby producing a bright visual image which may be viewed externally through the output faceplate **30**.

Alternatively, the glass faceplate **16** may be replaced by a fiber optic faceplate comprising a rigid bundle of fiber optic rods. In this instance, the fiber optic faceplate, generally, is formed by hermetically sealing a plurality of fiber optic rods in side by side relationship and peripherally sealing one end of the resulting cylindrical bundle to the metal ring **14**. Thus, the opposing end portion of the fiber optic bundle protrudes outwardly from the input end of the tube, in colinear relationship with the envelope **12**. Generally, the inner end surface of the fiber optic bundle is ground to provide it with a spherical contour similar to the faceplate **16**; and the photoemissive material of the photocathode **18**, usually, is deposited directly on the inner surface of the fiber optic faceplate. Similarly, the output faceplate **30** may be replaced by a fiber optic faceplate comprising a cylindrical bundle of fiber optic rods having one end circumferentially sealed to the metal ring **28**. In this instance, the inner end of the fiber optic bundle also is ground to a spherical contour and the phosphor material of the imaging screen **32**, generally, is deposited directly on the inner surface of the fiber optic faceplate. The outer, flat end surface of the fiber optic faceplate, which protrudes outwardly from the output end of the tube, provides a ready means for optically coupling a second image intensifier tube thereto in order to increase the amplification gain of the first image intensifier tube.

In FIG. **1**, there is shown a three stage, image intensifier device **50** comprising three colinearly disposed, image intensifier tubes **10*a***, **10*b*** and **10*c***, respectively, each similar in construction to the image intensifier tube **10** previously described. The first stage image intensifier tube **10*a*** is provided with an input fiber optic faceplate **52** and an output fiber optic faceplate **55**. The fiber optic faceplate **55** is optically coupled as by means of a transparent epoxy cement, for example, to a fiber optic faceplate **56** which extends outwardly from the input end of the second stage image intensifier tube **10*b***. Similarly, a fiber optic faceplate **60** protrudes outwardly from the opposite end of image intensifier tube **10*b*** and is optically coupled to a fiber optic faceplate **62** which extends outwardly from the input end of the third stage image intensifier tube **10*c***. The opposite end of the image intensifier tube **10*c***, which constitutes the final stage of the described device **50**, is provided with a fiber optic faceplate **64**.

Although power supplies having fixed voltage outputs may be used for applying the required voltage potentials to the anode and cathode terminal sleeves of the respective image intensifier tubes **10*a*** – **10*c***, it has been found more convenient, generally, to use one power supply, such as **80**, for example, which has a graduated series of voltage taps. Thus, the desired voltage values may be selected for connection to the respective terminal sleeves of the image intensifier device **50**. In this instance, the cathode terminal sleeve **20*a*** of the first stage image intensifier tube **10*a***, generally, is connected to ground potential, as by means of an interconnecting electrical lead **66**, for example. A relatively high positive voltage tap, such as **67**, for example, on the power supply **80**, usually, is connected to the anode terminal sleeve **26*a*** of tube **10*a***, as by means of an interconnecting electrical lead **68**, for example. Because of the dielectric properties of fiber optic faceplates **55** and **56**, the cathode terminal sleeve **20*b*** of image intensifier tube **10*b***, generally, is connected to the anode terminal sleeve **26*a*** of image intensifier tube **10*a*** by auxiliary means, as by an interconnecting electrical lead **70**, for example. Thus, the cathode of the second stage image intensifier tube **10*b*** is maintained at the same positive voltage potential as the anode of the first stage image intensifier tube **10*a***. A higher positive voltage tap, such as **71**, for example, on the power supply **80**, usually is

connected to the anode terminal sleeve **26***b* of image intensifier tube **10***b*, as by means of an interconnecting electrical lead **72**, for example. Because of the intervening fiber optic faceplates **60** and **62**, the cathode terminal sleeve **20***c* of image intensifier tube **10***c*, generally, is connected to the anode terminal sleeve **26***b* by auxiliary means, as by an interconnecting electrical lead **74**, for example. A still higher positive voltage tap, such as **102**, for example, may be connected to the anode terminal sleeve **26***c* of the final stage image intensifier tube **10***c*, as by means of an interconnecting electrical lead **76**, for example.

As shown in FIG. **1**, the power supply **80** may comprise a conventional alternating current source **82**, such as an oscillator, for example, which may be connected to the input and output terminals, **84** and **86**, respectively, of a conventional voltage multiplier network **88**. Alternatively, the power supply **80** may comprise a direct current source which may be connected to the input and output terminals of a voltage divider network, for example. However, a voltage multiplier network is preferable because of the high voltages obtainable therefrom with the use of a conventional alternating current source. One side of the alternating current source **82** is connected to the terminal **84** which, in turn, is connected to a left-hand bank of series connected capacitors in the voltage multiplier **88**. The other side of the alternating current source **82** is grounded and also connected to the terminal **86** which, in turn, is connected to a right-hand bank of series connected capacitors in the voltage multiplier **88**. The terminal **86**, also, is connected to a series array of diodes which alternately connect the terminal **86**, through respective diodes in the array, to the output sides of successive capacitors in the left-hand and right-hand banks.

It is well known by persons skilled in the art that when an alternating voltage is applied across the terminals **84** and **86**, the output side of each capacitor in the left-hand and right-hand banks will be charged up to a positive voltage value equal to the peak voltage of the alternating source times the number of diodes connected between the output side of the particular capacitor and the terminal **86**. Consequently, the output sides of successive capacitors in the left bank will be charged up to progressively higher positive voltage values which are odd number multiples of the peak voltage value applied by the alternating current source **82**. The output sides of successive capacitors in the right-hand bank will be charged up to progressively higher positive voltage values which are even number multiples of the peak voltage applied by the alternating current source **82**. Thus, if the peak voltage of the alternating current source **82** is equal to 1,000 volts, the output sides of successive capacitors in the right-hand bank will be charged up to respective voltage values of 2,000 v, 4,000 v, 6,000 v and so on. In this instance, the voltage tap **67** which is shown electrically connected to the output side of the sixth capacitor in the right-hand bank will be maintained at a positive voltage value of 12,000 volts. Similarly, the voltage tap **71** which is shown electrically connected to the output side of the 14 th capacitor in the right-hand bank will be maintained at a positive voltage value of 28,000 volts; and the voltage tap **102** which is shown electrically connected to the output side of the last capacitor in the right-hand bank will be maintained at a positive voltage value of 48,000 volts. However, it should be emphasized that the stated voltage values are applicable only when the alternating current source **82** applies a peak voltage of 1,000 volts to the respective terminals **84** and **86** and are specified herein for illustrative purposes only. Thus, the voltage multiplier **88** is provided with a graduated series of output voltage taps, each maintained at a higher voltage value than the preceding tap in the series by an intervening voltage source.

In FIG. **3**, the image intensifier device **50** is shown connected to the power supply **80** by having the electrical lead **66** attached directly to the terminal **86**, the electrical lead **68** attached directly to the voltage tap **67** and electrical lead **76** attached directly to the voltage tap **102**. However, the electrical lead **72** is connected to a power limiting resistor **90** which, in turn, is connected to the voltage tap **71**. The currents drawn by the respective stages **10***a*, **10***b* and **10***c* from the electrically connected portions of the voltage multiplier **88** are proportional to the light energy incident on the input photocathode of the first stage **10***a*. When the image intensifier device is amplifying an image of an obscure object in a poorly illuminated area, the intensity of the light incident on the photocathode of the first stage **10***a* is low. Consequently, the current I3 passing through the final stage **10***c* also is low. Since each stage of the image intensifier requires more current than the preceding stage due to the photon gain of each stage, only a small percentage of the current I3 passes on through the second stage **10***b* while the greater part of the current I3 passes through the power limiting resistor **90**. When the current I3 is relatively low, the voltage drop across the resistor **90** is less than the voltage drop across the final stage **10***c* of the image intensifier device **50**. However, when an image of a brightly illuminated object is incident on the photocathode of the first stage **10***a*, the current I3 increases considerably and, consequently, the current through the resistor **90** also increases. As a result, the voltage drop across resistor **90** increases and the voltage drop across the final stage **10***c* decreases correspondingly. With increasing I3, the voltage drop across resistor **90** begins to exceed the voltage drop across the final stage; and, eventually, the weakening electrostatic field in the final stage does not accelerate the electron image sufficiently to produce a visual image on the output viewing screen.

In FIG. **4**, the output brightness of the visual image from the image intensifier device connected to the power limiting resistor **90**, as shown in FIG. **3**, is plotted against increasing values of input light intensity. When the intensity of the light incident on the photocathode of the first stage **10**a increases, the brightness of the output visual image from the final stage **10***c* increases to a sharp peak and then decreases to zero. The sharp peak in brightness occurs when the increasing current I3 and the decreasing voltage drop across the final stage reach optimum values for maximum power to the final stage **10***c*. Shortly after reaching the optimum value, the voltage drop across the final stage falls below the critical value for producing a visual image on the output viewing screen. Since the output brightness of the image intensifier device **50** is proportional to the power supplied to the final stage **10***c*, the output brightness of the device **50** can be lowered by increasing the ohmic value of the resistor **90**. However, it has been found that increasing the value of resistor **90** not only causes the peak of the curve shown in FIG. **4** to decrease but also to move to the left, an undesirable effect as this renders the final stage **10***c* inoperable at a lower value of input light intensity.

Experience indicates that the output brightness vs. input illumination curve shown in FIG. **5** would be more desirable. Thus, when the intensity of light incident on the photocathode of the first stage **10***a* increases excessively, the output brightness of the visual image on the viewing screen of the final stage **10***c* is maintained substantially constant until the final stage is rendered inoperable due to overloading. Since the output brightness of the final image is proportional to the power supplied to the final stage **10***c*, holding the output brightness substantially constant requires that the power supplied to the final stage **10***c* be held substantially constant, even while the current through the final stage is increasing excessively.

Referring again to FIG. **1**, the electrical lead **72** is connected directly to the voltage tap **71** of the voltage multiplier. The power regulating circuit of this invention, indicated generally as **92**, is connected between the electrical lead **76** and the portion of the voltage multiplier **88** supplying power to the final stage **10***c* of the image intensifier device **50**. The power regulating circuit **92** comprises a resistor R1 connected in series between the highest voltage tap **102** on the voltage multiplier **88** and the electrical lead **76** which is connected directly to the anode terminal sleeve **26***c* of image intensifier tube **10***c*. Progressively lower voltage taps **93–101**, respective-

ly, on the portion of the voltage multiplier **88** supplying power to the final stage **10c**, are connected to respective resistors **R2–R10** which, in turn, are connected to respective diodes **D2–D10**. The diodes **D2–D10** are connected in common with the resistor **R1** to the electrical lead **76**.

When the current **I3** passing through the final stage **10c** is relatively low in value, the voltage drop across the resistor **R1** is correspondingly low. Consequently, the diodes **D2 – D10** are maintained in a reversed-biased condition; and the lead **76** is electrically isolated from the lower voltage taps **101–93** of the graduated series. However, when the current **I3** increases to a predetermined value, due to an increase of input illumination, the voltage drop across the resistor **R1** exceeds the voltage value of the source **C1**. Consequently, the diode **D1** becomes forward biased and the electrical lead **76** is then connected electrically to the voltage tap **101** through the series resistor **R2**. As a result, the voltage source **C1** between the respective voltage taps **102** and **101** is effectively shunted; and the voltage value of the source **C1** is not applied to the anode terminal sleeve **26a**. Consequently, the voltage drop across the final stage **10c** decreases while the current **I3**, which effected the voltage change, has increased correspondingly.

The ohmic values of the respective resistors **R1 – R9** are preselected to sense definite incremental changes in the current **I3**. Consequently, if the current **I3**. continues to increase to progressively higher predetermined values, the voltage drops across the successive resistors **R1 – R9** in the circuit **92** will exceed, in sequence, the voltages impressed across the associated capacitors **C1 – C9**, respectively. These discrete changes in voltage across the respective resistors **R1 – R9** will be detected, in turn, by the associated diodes **D2 – D10**, respectively; and, as a result, the respective diodes **D2 – D10** will become forward biased sequentially. Due to this sequential switching action of the diodes **D2 – D10**, the lead **76** will be electrically connected to progressively lower voltage taps **102 – 93**, respectively. Therefore, the voltage applied to the anode terminal sleeve **26c** will decrease steadily in accordance with corresponding increases in the current **I3** through the final stage **10c**. As a result, the power supplied to the final stage **10c** and, consequently, the brightness of the output visual image will be maintained substantially constant during periods of high illumination prior to overloading.

As shown in FIG. **5**, when the image intensifier device **50** is connected to the power regulating circuit **92** of this invention, the objectionably sharp peak of brightness shown in FIG. **4** is avoided. As the incident light energy increases in intensity, the brightness of the output visual image is maintained substantially constant and then decreases gradually to zero. As shown in FIG. **1**, when the lead **76** is electrically connected to the voltage tap **93**, the voltage sources **C1 – C9**, respectively, are effectively shunted and only the voltage impressed across the capacitor **C10** is applied across the final stage **10c**. Consequently, the electrostatic field in the final stage becomes too weak to produce a visual image on the output viewing screen; and the final stage **10c** is rendered inoperable until the incident light energy returns to a normal operating level.

Thus, there has been disclosed herein a power supply and novel regulating circuit for supplying substantially constant power to an image intensifier device and thereby maintaining a substantially constant image brightness during periods of high illumination prior to overloading. As previously noted, the alternating current source **82** and voltage multiplier network **88** may be replaced by a direct current source and a voltage divider network. In this instance, an output voltage from the direct current source would be distributed proportionately along equal segments of an elongated resistive element and voltage taps would be attached to connecting ends of adjacent resistive segments. Thus, the resistive segments would function as individual voltage sources and the voltage taps would provide a graduated series of output voltage values. Consequently, the power regulating circuit **92** of this invention would work equally as well if the capacitors **C1 – C9** shown in FIG. **1** were replaced by the resistive segments **L1 – L9**, respectively of a voltage divider network.

From the foregoing, it will be apparent that all of the objectives of this invention have been achieved by the structures shown and described. It will be also apparent, however, that various changes may be made by those skilled in the art without departing from the spirit of the invention as expressed in the appended claims. It is to be understood, therefore, that all matter shown and described herein is to be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. The combination comprising:
- a light amplifier tube having a pair of spaced anode and cathode terminals;
- a direct current power supply having a graduated series of output voltage taps;
- a low voltage tap of said series connected to the cathode terminal of the tube;
- a first means connected between a high voltage tap of said series and the anode of the tube for sensing the value of current flowing through the tube; and
- second means responsive to changes in current values sensed by said first means for automatically switching the anode from the high voltage tap to said intermediate voltage tap when the current reaches a predetermined value.

2. The combination as set forth in claim **1** wherein said first means is a resistive element.

3. The combination as set forth in claim **1** wherein said second means is a reverse-biased diode.

4. The combination comprising:
- a light amplifier tube having a pair of spaced anode and cathode terminals;
- a direct current power supply having a graduated series of output voltage taps and intervening voltage sources;
- a low voltage tap of said series connected to the cathode terminal of the tube;
- resistive means connected between a high voltage tap of said series and the anode of the tube for developing a voltage drop in accordance with the value of current flow through the tube; and
- switching means connected between an intermediate voltage tap of said series and the anode of the tube for electrically connecting the anode to said intermediate voltage tap when a definite value of voltage drop is developed across the resistive means.

5. The combination as set forth in claim **4** wherein said switching means is a diode normally maintained in a reverse-biased condition by said intervening voltage source between the high and intermediate voltage taps and is responsive to a definite incremental change in voltage drop developed across said resistive means.

6. The combination as set forth in claim **5** wherein said reverse-biased diode is forward-biased when said voltage drop developed across the resistive means exceeds the value of said intervening voltage source.

7. The combination comprising:
- a light amplifier tube having a pair of spaced anode and cathode terminals;
- a direct current power supply having a plurality of voltage sources connected in electrical series and a graduated series of output voltage taps, each of said sources connected between respective pairs of adjacent taps in said graduated series;
- a low voltage tap of said graduated series connected to the cathode of the tube;
- a high voltage tap of said graduated series connected to a first resistive element;
- a plurality of intermediate voltage taps of said graduated series connected to respective resistive elements and series connected switching means,
- each of said switching means connected in parallel with said first resistive element to the anode terminal of the tube.

8. The combination as set forth in claim **7** wherein each of said switching means is a respective diode maintained in a normally reverse-biased state by the respective voltage source connected between the associated voltage tap and the preceding higher voltage tap in the graduated series.

9. The combination as set forth in claim 8 wherein each of said diodes is forward-biased, in sequence, by a voltage developed across the respective resistive element connected to the preceding higher voltage tap in the graduated series.

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