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FLUOROSCOPIC INTENSITY CONTROL WHEREIN THE BRIGHTNESS OF THE IMAGE IS MAINTAINED AT A PREDETERMINED LEVEL

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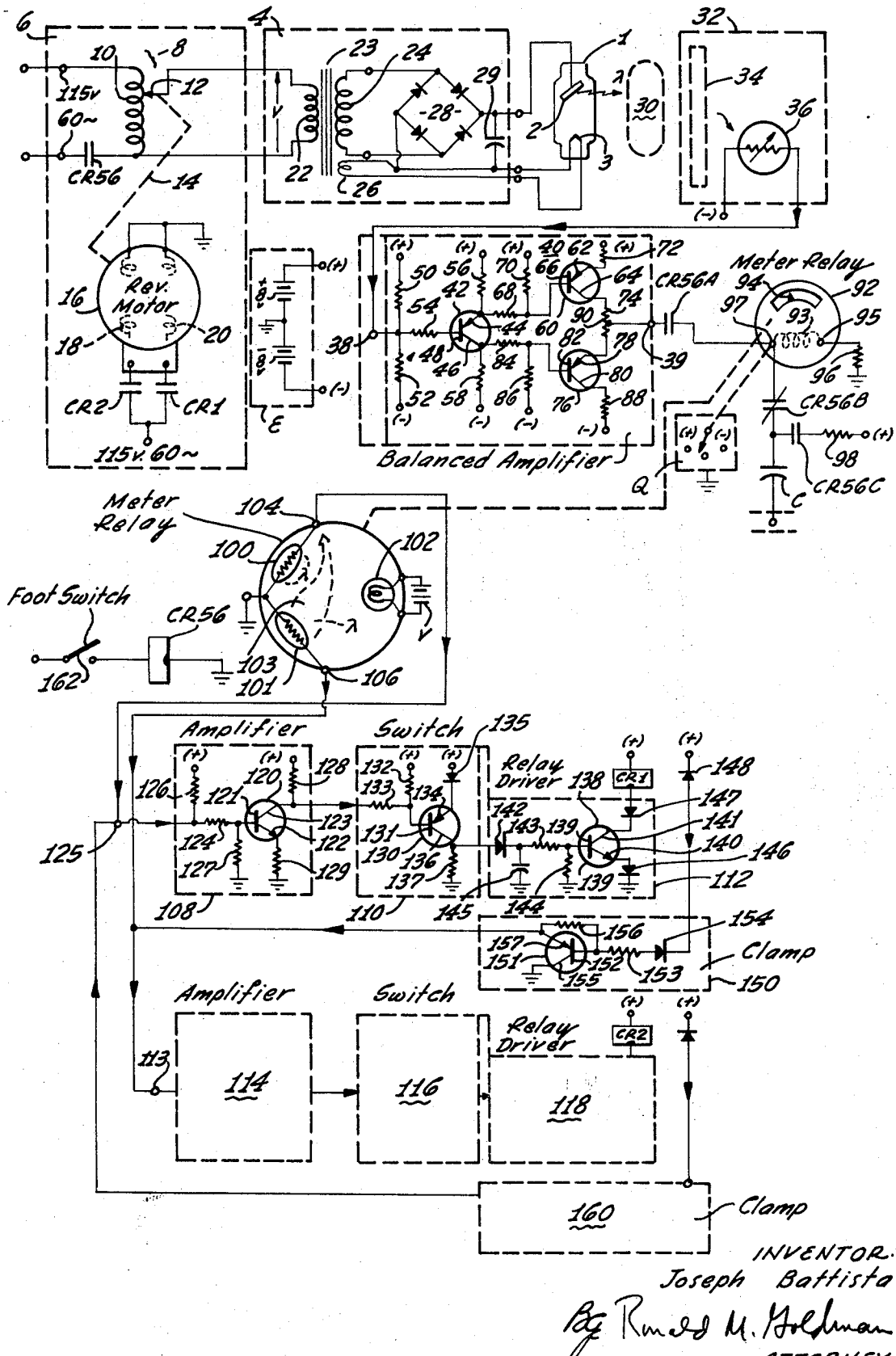


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# FLUOROSCOPIC INTENSITY CONTROL WHEREIN THE BRIGHTNESS OF THE IMAGE IS MAINTAINED AT A PREDETERMINED LEVEL

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## ABSTRACT OF THE DISCLOSURE

An X-ray apparatus includes means which automatically maintains to a predetermined level the brightness of an image appearing on the image intensifier. The brilliance of the image appearing on the image intensifier is monitored by a suitable photoelectric device, and the representations therefrom are applied to the winding of a balanced meter relay via the output of a form of balanced amplifier, the latter of which provides an output current which direction of current flow depends upon whether the output of the photoelectric monitoring device is above or below a predetermined level. An output of the meter relay is obtained from either one of two output terminals: If the meter pointer is substantially deflected from the reference center position in one direction, an output is produced at one termnial, and if the meter pointer is substantially deflected from the reference center position in the opposite direction, an output is provided at the second terminal. Each of the outputs is connected to suitable switching circuits which control the raising or lowering of the voltage of an adjustable power supply which supplies power to the X-ray tube. Suitable inhibit circuitry is provided so that should the switching circuits associated with one of the outputs of the meter relay be energized, the other switching circuit associated with the other meter relay output terminal is prevented from operating until the first switching circuit has been completely deenergized. The adjustable power supply includes a reversible A.C. motor containing two windings and a shaft suitably mechanically linked to a movable output tap on an autotransformer. The energization of one of the motor windings effects the rotation of the motor shaft, and hence, the movable tap, in a first direction; whereas the energization of the other winding results in the movement of the motor shaft, and, hence, the movable tap in an opposed direction. Suitably, each motor winding is connected in a respective one of two electrical circuits with the output of a respective one of the switching circuits associated with the meter relay output, and the power supply output voltage is adjusted, automatically, to raise or lower the voltages applied between the anode and cathode of the X-ray tube which provides a corresponding adjustment of the intensity of X-radiation emanating therefrom, and a corresponding change in the brilliance of the image appearing on the image intensifier tube.

This invention relates to an X-ray apparatus, and more particularly, to an X-ray apparatus in which the brightness of the fluoroscopic image is automatically regulated.

X-ray apparatus, by definition, includes a source of X-rays for directing X-rays through a patient. And, inasmuch as the patient is inhomogeneous in its density, the more dense portions of that body absorb a greater amount of the incident X-radiation than other less dense portions thereof. Accordingly, as the generated X-rays are applied over a certain area on one side of the patient, the X-radiation which penetrates through that area forms



an image or field of high and low intensities of X-radiation. Conventionally, this image is received by an image convertor located in the apparatus on the other side of the patient which converts this X-ray image into a visual image. Conventionally, this conversion is accomplished with either a screen of X-ray sensitive phosphorescent material commonly termed "a fluoroscopic screen" or an image intensifier.

In the more sophisticated modern equipment, the image on the fluoroscopic screen or image intensifier is monitored by a television camera, such as a vidicon or orthicon which then transfers the visual image to a television receiver located at a remote position where a visual image may be monitored and observed without exposing the radiologist to stray X-radiation.

In the very best apparatus, the image intensifier is used in place of the fluoroscopic screen. Basically, such a device contains an X-ray sensitive faceplate which converts an incident X-ray image into a visual image and then electronically amplifies the visual image, presenting an intensified visible image on a second smaller sized faceplate. Conventional image intensifiers amplify the level of the received image by a factor of about 3000. The output of the image intensifier is then available at the second faceplate to permit observation of the enhanced visible image. Alternatively, the image intensifier is also used in conjunction with a television pickup system so that the image may be observed on a remotely located television set.

In giving an X-ray examination there is quite often a need for the radiologist to adjust the intensity of X-radiation generated in order to increase the brilliance of the visual image to a level which he finds desirable. Likewise, in many instances the radiologist must reduce the level of X-radiation generated to reduce the brilliance of the image either because the image is too bright or because it subjects the patient to a higher level of radiation than is necessary under the circumstances. However, with most presently available apparatus this adjustment must be performed manually. And, in order to effect such a manual adjustment, the radiologist must subject the patient to needless exposure while he is making the adjustment and determining whether the observed visual image is suitable: This procedure is obviously undesirable.

In the more sophisticated commercially available systems having television pickup cameras, such as the vidicon or orthicon, automatic controls are provided to which the manual adjustment of source intensity is an adjunct. As is well known, the output of the television camera and likewise the television receiver can be both manually and automatically adjusted to increase or decrease the brilliance of the visual image without changing the intensity of the X-ray source. Assuming that the image received by the vidicon camera is within a suitable range of brilliance, the vidicon can be adjusted to produce higher or lower brilliance images at the output of the television receiver. Conventionally, such television pickups contain automatic gain control circuits which, electronically, automatically maintains the output of the vidicon tube to a predetermined level within a small range of values, and thus provides for an image of constant brilliance. There are instances, however, where the intensity of the X-ray source should be increased so that the output of the image intensifier is within a range of brilliance within the threshold level of the vidicon tube.

While the vidicon system has proved satisfactory, it and the gain control circuitry associated therewith are relatively very expensive. For example, a recently developed television pickup tube called the "Plumecon" performs the same essential functions as the vidicon tube, but is only

one-tenth as expensive. Unfortunately, however, there appears to be no available inexpensive control circuits for use with the Plumecon that can hold the output signals therefrom to a present level. Accordingly, while a pickup tube of the Plumecon type serves to reduce the cost of remote image displays for X-ray apparatus, without an inexpensive intensity control circuit the quality or control of the available image with such tube type is reduced.

Therefore, it is an object of the invention to automatically regulate the intensity of fluorscopic image in an X-ray apparatus without requiring the intervention of the operator;

It is a further object of the invention to provide an X-ray apparatus in which the brightness of the visual image is automatically maintained at the preset level;

And, it is a still further object of the invention to provide an automatic brilliance control suitable for use in an X-ray apparatus having remote displays.

Briefly stated, the invention includes a photosensitive pickup for monitoring the level of illumination from the visual image appearing on a fluorscopic screen or other image converter. The output of this monitoring pickup is also monitored by electrical circuitry which signals a departure of the pickup output above or below a predetermined level. A source of X-rays which generates X-rays proportional in intensity with the voltages applied from an adjustable power supply is provided. A voltage control means is provided which is responsive to the signals generated by the monitoring means and causes the power supply voltage to increase or decrease in response to the output of the monitoring means, signaling the departure of said pickup signal above or below predetermined levels, respectively.

Further in accordance with the invention, the monitoring means comprises a meter relay and includes relay means responsively connected to first and second output terminals of the meter relay.

Moreover, the voltage control means, in accordance with another aspect of the invention, comprises a motor driven autotransformer in which the motor is reversible and suitable connections are made between the relay and the motor control windings to cause the motor to be properly driven in either the forward or reverse direction.

The foregoing and other advantages and features which are believed to be characteristic of the invention, both as to its organization and method of operation, together with further objects and advantages thereof is better understood from the following description considered in connection with the figure of the accompanying drawing which illustrates one embodiment of the invention by way of example.

The figure of the drawings shows a conventional source of X-rays, tube **1**, having an anode **2**, and a heater or filament winding **3** which also functions as the electron emitting cathode. An adjustable power supply for the X-ray tube includes two portions. One portion is the high voltage and rectifying section **4**. The second portion is a low voltage control section **6**.

The low voltage control section **6** contains an autotransformer **8** having a winding **10** which is connected to a source of A.C. currents suitably the 115 A.C. voltage. A slidable electrical contact or tap **12** is positionable along the turns of winding **10** to provide selections of a desired output voltage. As is conventional, the autotransformer steps down the line voltage in proportion to the position of the slidable tap **12** to the shaft of a reversible A.C. motor **16** which permits the conversion of the motor shaft rotation to the linear up and down movement of slidable contact **12**.

Reversible motor **16** is conventional and contains two stator windings **18** and **20**, schematically indicated in the figure, for controlling the direction of rotation of the motor shaft. One side of each winding is connected to ground potential. The other end of winding **18** is connected to a source of current, suitably 115 volt A.C. line voltage, in series with normally open relay contacts CR1. The remaining end of the other winding **20** is likewise connected to the same source of current in series with normally open relay contacts CR2. The output from the low voltage control section **4** is taken from autotransformer **10** and is connected to the input of high voltage power section **4**, by a connection to primary winding **22** of a high voltage transformer **23**. Transformer **23** includes a high voltage secondary or output winding **24** and a low voltage or filament winding **26**. The output of high voltage winding **24** is connected across one diagonal of a conventional bridge rectifier **28**. The other or output diagonal of bridge rectifier **28** is connected between the anode **2** and filament **3** of X-ray tube **1**. As is conventional, a filter capacitor **29** is connected across the output diagonal of the bridge rectifier. The filament winding **26** is connected across the filament terminals of filament **3**.

The "fluorscopic" or receiving apparatus in the X-ray equipment is located on the side of a patient **30** opposite source **1** and is schematically indicated by the dashed lines **32**. This includes image converting apparatus **34**, such as a fluorscopic screen or other conventional apparatus, which converts a received X-ray image into a visual image. Phosphorescent screens or X-ray image intensifier tubes are ordinary examples of such converters.

A photosensitive pickup, a photoresistor **36**, is located in housing **32** adjacent the fluorscopic screen so as to receive the light from any visual image appearing on the screen. Photoresistor **36** is connected in an electrical circuit between a source of voltage (—) and the input **38** of a balanced amplifier schematically represented by dashed lines **40**. Balanced amplifier **40** includes a first PNP transistor **42** in a dual output amplifier circuit. Transistor **42** has an emitter **44**, a collector **46**, and a base **48**. A source of bias voltage is represented by E. One output terminal provides a positive eight volts relative to ground potential while the other terminal provides a negative eight volts relative to ground potential, although the total voltage between the terminals is 16 volts.

Resistors **50** and **52** are connected in series across source E and the juncture of the series connection is connected to input **38** and one end of a base resistor **54**. Resistor **54** is connected at its other end to the base **48**, transistor **42**. A first load resistor **56** is connected between the positive bias voltage and emitter **44**. A second load resistor **58** is connected between the collector **46** and the negative bias voltage from source E. A second PNP transistor **60** is provided. Transistor **60** contains an emitter **62**, collector **64**, and base **66**. A connection is provided from the emitter **44** of transistor **42** to base **66** of transistor **60** in series with a base resistor **68**; and a base bias resistor **70** is connected between the positive source and base **66**. Emitter **62** is connected to the positive source in series with a resistor **72**. Collector **64** is connected to output terminal **39** in series with a load resistor **74**.

A third transistor **76** contains an emitter **78**, collector **80**, and a base **82**. Base **82** is connected to the collector **46** of transistor **42** in series with a base resistor **84**. A base bias resistor **86** is connected between base **82** and the negative source terminal. A resistor **88** is connected between the positive source terminal and emitter **80**. A load resistor **90** is connected between collector **78** and output terminal **39**.

Meter relay **92** is a conventional current measuring and switch device which includes a winding **93** and a pointer **94** positionable along a calibrated scale. Normally pointer **94** rests at the center of the meter scale. However, current flow in one direction through **93** effects movement of the pointer to the right and current flow through winding **93** in the opposite direction causes a current proportional pointer movement to the left.

One end of winding **93** is connected to output terminal **95** which in turn is connected to ground potential in series with a current limiting resistor **96**. The other end of

winding 93 is connected to input terminal 97 which in turn is connected to output terminal 39 of the balanced amplifier in series with normally open relay contacts CR56. Input 97 is additionally connected to a series circuit of a normally closed relay contact CR56B, and a capacitor C to the negative terminal of the voltage source.

The juncture of the series connection between contacts 56B and capacitor C is connected to the positive terminal of the source in series with normally open relay contact CR56C and resistor 98.

Meter relay 92 conventionally includes a pair of photoresistors 100 and 101 and a light source 102 that normally illuminates the photoresistors and which is energized by any suitable source, such as battery V. Pointer 94 includes a shutter portion 103. Photoresistor 100 is connected between ground potential and a first output terminal 104, and photoresistor 101 is connected between a second output terminal 106 and ground potential.

The meter relay output terminals are connected to the inputs of electrical switching circuits. The first switching circuit includes an amplifier 108, an electronic switch 110, a relay driver circuit 112, and a relay CR1. A second electrical switching circuit inculdes an amplifier 114, an electronic switch 116, a relay driver circuit 118, and a relay CR2. In substance, both switching circuits are of identical construction and include substantially identical and conventional elements and connections. Therefore, in the interest of brevity, only the first switching circuit is discussed in any great detail. However, it is understood that such conventional details apply equally to the second switching circuit.

Amplifier 108 includes a conventional NPN transistor 120 having a base 121, emitter 122, and collector 123. A base input resistor 124 is connected between an input 125 and base 121. A biasing resistor 126 is connected between the positive bias source and input 125. A second bias resistor 127 is connected between base 121 and ground. A load resistor 128 is connected between the positive bias source and collector 123, and emitter 122 is connected through a resistor 129 to ground.

Electronic switch 110 includes a PNP transistor 130 having its base 131 connected through a base bias resistor 132 to the positive bias source. Additionally, the base 131 is connected to the output of transistor 120 in series with resistor 133. Transistor 130 has its emitter 134 connected through diode 135 to the positive source. The collector 136 is connected through a load resistor 137 to ground potential.

An NPN transistor 138 in relay driver circuit 112 includes a base 139, emitter 140, and collector 141. A forward poled diode 142 in series with a resistor 143 is connected between collector 136 of transistor 130 and base 139. A base bias resistor 144 is connected between base 139 and ground. A capacitor 145 is connected between the output of diode 142 and ground. Capacitor 145 and resistors 143 and 144 form an RC time delay circuit. Emitter 140 is connected in series with a forward poled diode 146 to ground potential. Another forward poled diode 147 is connected between collector 141 and the winding of relay CR1, which in turn is connected to the positive voltage source. A diode 148 is connected across relay winding CR1 for conventional surge protection.

A clamp circuit 150 is connected to the output of the relay driver circuit. A PNP transistor 151 therein has its base 152 connected to the output of the relay driver circuit in series with a resistor 153 and diode 154. Its collector 155 is connected directly to ground potential. A bias resistor 156 is connected between base 152 and emitter 157. The output of clamp circuit 150 is taken by a connection from the emitter 157 and applied to input 113 of amplifier 114 in the second switching circuit.

In like manner, the output of amplifier 114 is connected to the input of electronic switch 116, which in turn has its output connected to the input of relay driver 118 in the second switching circuit. The output of relay driver 118 is connected to relay winding CR2 and to the input of a clamp circuit 160. The details of clamp circuit 160 are substantially identical with that of clamp circuit 150. The output of clamp circuit 160 is connected to the input 125 of amplifier 108 in the first switching circuit. Inasmuch as amplifier 114, switch 116, relay driver 118, and clamp circuit 160 are of a construction identical in detail with that heretofore described for the corresponding elements in the first switching circuit they are schematically represented only by dashed lines.

A relay CR56 is connected in series with foot switch 162 to a source of electrical potential. In the idle condition, relay contacts CR56, CR56A, and CR56C are open and relay contact CR56B is normally closed. Thus, winding 93 of meter relay 92 is disconnected from the output of balanced amplifier 40. Instead, winding 93 is connected through break contacts CR56B to a capacitor C which absorbs any transient voltages, avoiding any spurious deflection of meter pointer 94 from the center position of the scale.

The radiologist operates foot switch 162 to energize relay winding CR56. Relay CR56 closes contacts CR56D which connects the power supply of the source, CR56A which connects the output of balanced amplifier 40 to input winding 93 in meter relay 92, and opens contacts CR56B which disconnects capacitor C from winding 93. Any charge accumulation on capacitor C is discharged through resistor 98 to the positive source upon closure of relay contacts CR56B.

Relay CR56 includes the previously discussed contacts CR56, CR56B, and CR56C. In operation the 115 A.C. volt source is applied to winding 10 of autotransformer 8 in power supply section 6. Autotransformer 8 steps down the line voltage to a level proportional to the position of movable tap 12. The output voltage appearing at contact 12 is applied to primary winding 22 of transformer 23 in the high voltage section 4. The voltages applied across primary winding 22 are stepped up through transformer action to a high voltage which appears across secondary winding 24. The high voltage is applied across one diagonal of a conventional bridge rectifier circuit 28 for rectification.

Bridge rectifier 28 converts the A.C. voltage into a D.C. voltage across the other diagonal. This D.C. voltage in turn is filtered by smoothing capacitor 30 and applied between anode 2 and filament 3 of the X-ray tube. A portion of the electrical energy supplied to primary winding 22 is stepped down by transformer action to a low filament voltage appearing across secondary or filament winding 26. The heater voltage is applied across the terminals of heater 3 which causes thermal emission within X-ray tube 1.

X-ray tube 1 generates X-rays which are directed through a patient, indicated by dashed lines 30, and emanate out of the patient to form an X-ray image upon screen 34 in receiving apparatus 32. This image is converted into a visual image by the fluorescent screen. The light emanating from the visual image illuminates adjustable photoresistance 36. Since the resistance of photoresistor 36 is an inverse proportional function of the light level, a value of resistance is established which is related to the level of illumination incident thereon. Current flowing through photoresistor 36 establishes a signal or voltage at input 38 of balanced amplifier 40 which biases base 48 of transistor 42 to a predetermined value. Transistor 42 normally conducts current which flows from the positive source through load resistor 56, emitter 44, collector 46, and through load resistor 58 to the negative source.

The output voltage across each of load resistors 56 and 58 is coupled to the base of transistors 60 and 76, respectively. At a predetermined level of output voltages from transistor 42, each of transistors 60 and 76 conducts substantially the same amount of current, and hence, offer the same overall resistance considered as a voltage

divider network. This current may be considered to flow from the positive source through resistor **72**, emitter **62**, out collector **64** through resistors **74** and **90**, emitter **78**, out collector **80** through resistor **88** to the negative voltage source. Because both transistors offer the same resistance to current between the positive and negative bias source, the voltage under at the output of balanced amplifier **40** and the juncture of resistors **74** and **90** is normally zero or ground potential. Since ground potential is applied both to inputs of meter winding **93**, the meter pointer remains at its center position.

If the light level from on screen **34** is lower than a predetermined level, photoresistor **36** assumes a larger value of resistance. This causes the potential at base **48** to become more positive which in turn causes an increase in the current between the emitter and collector of PNP transistor **42**, which is reflected in a lower voltage at collector **44** and at the base **66** of transistor **60** and a higher voltage at emitter **46** and at the base **82** of transistor **76**.

Accordingly, transistor **76** conducts current more heavily while transistor **60** reduces its conduction. Accordingly, the juncture of resistors **74** and **90** is placed at a more negative potential which results in current flowing from ground potential through resistor **96**, meter winding **93**, to the output **39** of balanced amplifier **40** and causes the deflection of meter pointer **94** to the right.

A predetermined deflection of meter pointer **94** results in the shutter portion **103** thereof moving to a position shielding photoresistor **100** from the source of light **102**. Accordingly, the level or resistance of photoresistor **100** is increased, and accordingly, there is a reduction in current between resistor **126** in amplifier **108** and photoresistor **100** to ground potential. This results in a more positive voltage at input **125** and base **121** of NPN transistor **120**.

Transistor **120** decreases conduction and provides a higher output voltage from collector **128** through resistor **133** to the base **131** of transistor **130**. Transistor **130** senses the higher level of voltage and fully conducts current from the positive source, diode **135**, emitter, collector, and resistor **137** to ground. This provides a positive output across resistor **137**. This output voltage is applied to base **139** of NPN transistor **139** through diode **142** and resistor **133**. Additionally, capacitor **145** is charged. Transistor **138** conducts fully causing current to flow from the positive source through relay winding CR1, diode **147**, between collector and emitter **141** and **139**, diode **146** to ground potential and lowers the voltage at the output juncture of diode **147** and relay winding CR1.

Relay winding CR1 closes its normally open contacts CR1 connected in series with winding **20** of reversible motor **16** in power supply control section **6**. Current flows through the winding and causes motor **16** to revolve its shaft in the clockwise direction. By means of linkage **14**, slidable contact **12** is raised up the turns of the autotransformer winding **10**. Accordingly, the voltage, V, applied to primary winding **22** of transformer **23** is increased, resulting in a larger voltage across secondary winding **24** and, hence, across the anode **2** and filament **3** of tube **1**.

Since the radiation produced by X-ray tube **1** is proportional to the voltage applied between its anode and cathode, the increase in that voltage increases the intensity of the generated radiation. Since the intensity of the radiation is greater, the intensity of the visual image that appears on screen **34** is likewise more brilliant.

Photoresistor **36** monitors the increase in illumination, and, accordingly, decreases in resistance in proportion to the increase in the level of illumination. Since balanced amplifier **40** is preadjusted to provide a zero or ground potential at its output upon photoresistor **36** presenting a predetermined level of resistance at input **38**, when the level of illumination on screen **34** is raised to the predetermined level, current through winding **93** ceases and meter pointer **94** is rebalanced in its center position. Accordingly, the shutter portion **103** of meter pointer **94** uncovers photoresistor **100**, which again permits light source **102** to illuminate photoresistor **100**. Accordingly, photoresistor **100** is lowered to a substantially lower normal level of resistance, which in turn is presented to input **125** of amplifier **108** via the first output terminal **104** of meter relay **92**. Electronic switch, transistor **130** ceases conduction and removes the voltage input to relay driver circuit **112**.

Although the output of electronic switch **110** is no longer presented at the input of relay driver circuit **112**, transistor **138** continues to conduct until capacitor **145** discharges through resistors **143** and **144** over a predetermined period of time. Subsequently, transistor **138** ceases conduction, deenergizing the winding of relay CR1. After the release time of the relay, relay contacts CR1 are restored to their normally open position, which in turn interrupts current through reversible motor winding **20**. Motor **16** stops and accordingly leaves slidable contact **12** of autotransformer **8** at its last position.

During the period in which transistor **138** of relay driver circuit **112** conducts, the voltage appearing at the input of clamp circuit **150** is reduced from the normal value. Accordingly, current flows through resistor **156**, resistor **153**, and diode **154** making base **152** slightly more negative in polarity relative to emitter **157**. Accordingly, transistor **152** conducts current from emitter **157** through collector **155** to ground potential.

Since the voltage drop between the emitter and collector is slight, the output of clamp circuit **150** is effectively reduced to a zero or ground potential. Accordingly, the input **113** of amplifier **114** in the second switching circuit is grounded. This prevents any input signal from the second output terminal **106** of meter relay **92** from energizing the second switching circuit while relay CR1 in the first switching circuit is operated. This is necessary to prevent both relays CR1 and CR2 from being operated at the same time, and hence, to preclude energizing both windings of motor **16** simultaneously. This can occur if there is a rapid swing of the meter pointer from the right over to the left. Obviously if both windings of motor **16** are simultaneously energized, the motor would burn out.

Where overillumination occurs, the resistance of photoresistor **36** is reduced from the preset level and the output **39** of the balanced amplifier **40** becomes more positive relative to ground potential, because transistor **62**, therein, conducts more fully than transistor **76**. Accordingly, current flows in a direction from the output terminal **39** through meter winding **93**, resistor **96**, to ground potential. This current in the meter winding causes the meter pointer **94** to swing to the left. In the instance of sufficient deflection, the pointer shutter portion **103** covers photoresistor **101** connected between the second output terminal **106** of the meter relay and ground. The level of resistance of photoresistor **101** is raised which accordingly places input **113** of amplifier **114** in the second switching circuit at a higher potential. This increase in level of input voltage is amplified by amplifier **114** and applied to electronic switch **116**. Electronic switch **116** changes its state from a nonconducting to a conducting condition providing an output voltage in the same manner as described for switch **110**. Relay driver circuit **118** detects the output and operates in the same manner as relay driver **112**, previously described, the winding of relay CR2 and the output voltage supplied to the input of clamp circuit **160** from the illustrated side of winding CR1 is lowered, clamp circuit **160** is thus operated and reduces the potential at the input **125** of amplifier **108** in the first switching circuit to prevent inadvertent operation of the first switching circuit, while the second switching circuit operates. Relay CR2 closes its normally open contacts CR2, which in turn completes a current path between a

source of power and the second winding **18** in reversible motor **16**. In this instance, motor **16** rotates its shaft counterclockwise. Through conventional mechanical linkages **14**, motor **16** shaft lowers slidable tap **12** to reduce the voltage V applied across primary winding **22** of transformer **23**. Since the output of the high voltage section is proportional to the level of voltage applied to primary winding **22**, the high voltage applied between anode **2** and cathode **3** of X-ray tube **1** is reduced as the position of tap **12** is lowered.

Accordingly, the intensity of radiation emitted from X-ray tube **1** is lowered and the level of illumination of the visual image appearing on screen **34** is reduced. This change is monitored by photoresistor **36** which accordingly increases in resistance as the level of incident light decreases.

Upon the attainment of a predetermined lower level of illumination and larger level of resistance of photoresistor **36**, the output voltage of balanced amplifier **40** is again reduced sufficiently near zero volts and accordingly the meter relay pointer is again rebalanced at or near its center position. Accordingly, the shutter portion **103** of meter pointer **94** again uncovers photoresistor **101** and the second output terminal **106** of meter relay **92** appears again as a high resistance. Electronic switch **116** restores to its nonconducting state and removes the input to relay driver circuit **118**. At the completion of a predetermined period of time, relay driver circuit **118** deenergizes relay winding CR2 and removes the input signal from input of clamp circuit **160**. Clamp circuit **160** removes the inhibiting or ground potential from input **125** of amplifier **108** in the first switching circuit. At the completion of a relay release interval, relay CR2 restores and opens its normally open contacts CR2. This interrupts the flow of current into the winding **18** of motor **16**. Accordingly, motor **16** halts, leaving the slidable contact **12** at its last position.

It is apparent that in this manner the level of illumination appearing on screen **34** is maintained automatically at a predetermined level while the radiologist conducts a fluoroscopic examination of his patient. This is accomplished automatically without the intervention of the radiologist, and thus, frees the radiologist for his examination and precludes any unnecessary exposure of the patient inherent in those prior art circuits which permit the patient to be exposed while the radiologist manually adjusts the radiation intensity to a desired level. Additionally, the invention permits the use of a relatively inexpensive television pickup camera, such as the Plumecon, without the expensive and complicated brightness control circuits formerly used in the orthicon or vidicon systems.

It is further noted that in addition to control of the power supply voltage, indirectly, by photodetector **36**, the voltage control circuits can, instead, be placed under the control of other (not illustrated) ancillary equipment. Thus, for example, assuming foot switch **162** is not operating, and hence, contact CR56A, which connects amplifier **40** to winding **93** of meter relay **92**, remains open, and that the ancillary apparatus, symbolically illustrated as Q, is connected to terminal **97** and includes sources of positive and negative voltages that may be selectively applied to terminal **97**. Thus, a current of the selected polarity may flow between ground, resistor **96**, coil **93**, and the source in Q. The meter relay will then be actuated in the same manner as previously discussed for photoelectric control.

Thus, if a source of positive voltage in Q is selected and is applied to terminal **97**, the meter pointer **94** swings in one direction and exposes one of the photocells in the meter relay to meter light **102**, causing the associated switching circuit to actuate reversible motor **16** which in turn commences movement of movable tap **12** in the corresponding direction. Likewise, by selectively connecting the negative voltage source included within such ancillary equipment to terminal **97**, current flows to meter winding **93** in the direction opposite to that in the preceding case. Accordingly, the other photoelectric cell in meter relay **92** is exposed to the source **102** causing operation of the associated switching circuit and energization of the other winding of reversible motor **16**, which in turn drives movable tap **12** in the opposite direction; hence, changing the voltage applied between the anode and cathode of X-ray tube **1**.

While the illustrated embodiment shows certain specific amplifier switches, transistors, and relays, and uses a meter relay in order to enable visual indication of the departure from normal or any visual image, it is apparent that other equivalent circuits exist which accomplish the same function without a meter relay and with details different than those used to illustrate the invention.

Thus, while these specific details have been used to illustrate the invention, it is not the intention to limit the invention to those details.

I claim:

**1.** An X-ray apparatus comprising: a controllable intensity source of X-rays; converter means for converting an X-ray image into a visible image to permit observation thereof; light monitoring means for sensing the light level of said visible image on said converter means and producing an output representative thereof; and control means responsive to the change in output of said light monitoring means above or below a predetermined output level for lowering or raising, respectively, the intensity of said source of X-rays; said control means comprising: means for amplifying the output of said light monitoring means; control signal means connected to the output of said amplifier for producing a first control signal in response to a decrease in the output level of said amplifier below a predetermined level and for producing a second control signal in response to an increase in the output level of said amplifier above a predetermined level; said control signal means including a meter relay having a meter pointer normally at a reference position for producing a first output at a first terminal in response to the deflection of said meter pointer to a first predetermined position in one direction from said reference position and for producing a second output signal at a second terminal in response to the deflection of said meter pointer to a second predetermined position in an opposed direction from said reference position, said meter relay having a current carrying meter coil for positioning said meter pointer; first switch means responsive to an output from said first meter relay output for closing a first electrical circuit to provide said first control signal; second switch means responsive to said second meter relay output for closing a second electrical circuit to provide said second control signal; first inhibit means for inhibiting operation of said second switch means during operation of said first switch means; and second inhibit means for inhibiting operation of said first switch means during operation of said second switch means.

**2.** The invention as defined in claim **1** wherein said controllable intensity source comprises: an X-ray tube having an anode and cathode; and wherein said control means further comprises adjustable power supply means for applying an output voltage between said anode and cathode; and means responsive to operation of said first switch means for increasing the output voltage of said power supply and responsive to operation of said second switch means for decreasing the output voltage of said power supply.

**3.** The invention as defined in claim **2** wherein said adjustable power supply means includes: a motor having a shaft; an autotransformer having a movable output tap; linkage means coupling motion of said shaft to said movable output tap; said motor including a first winding responsive to current flow therethrough for effecting rotation of said shaft in a first direction and a second winding responsive to current flow therethrough for effecting rotation of said shaft in a first direction and a second winding re-

ing said first winding in circuit with said first electrical circuit and means connecting said second winding in circuit with said second electrical circuit.

4. The invention as defined in claim 2 wherein, said control signal means further includes: a balanced amplifier means connected to said amplifier means for producing an output voltage of one polarity in response to an output from said light monitoring means being above a first predetermined level and for producing an output of opposite polarity in response to an output from said light monitoring means being a predetermined amount below said level.

5. An X-ray apparatus comprising: a controllable intensity source of X-rays; converter means for converting an X-ray image into a visual image to permit observation thereof; control means for changing the intensity of said source of X-rays; said control means including: first means for producing a voltage of one polarity in response to a first selection to increase the intensity of said X-ray source and for producing a voltage of opposite polarity voltage in response to a second selection to decrease the intensity of said X-ray source; a meter relay having a meter pointer normally at a reference position for producing an output at a first terminal in response to the deflection of said meter pointer to a first predetermined position in one direction from said reference position and for producing a second output signal in response to said meter pointer attaining a second predetermined position from said reference position in an opposed direction; said meter relay having a current carrying meter coil for positioning said meter pointer; means connecting said first means in circuit with said meter coil; first switching means connected to said first terminal and responsive to a first meter relay output for closing a first electrical circuit; second switching means responsive to said second meter relay output



for closing a second electrical circuit; first inhibit means for inhibiting operation of said second switching means in response to operation of said first switching means; second inhibit means for inhibiting operation of said first switching means in response to operation of said second switching means; and wherein, said controllable intensity source includes an X-ray tube having an anode and cathode; adjustable power supply means for supplying an output voltage between said anode and cathode; and means responsive to operation of said first switching means for increasing the output voltage of said power supply, and responsive to operation of said second switching means for decreasing the output voltage of said power supply; said adjustable power supply means including a motor having a shaft; an autotransformer having a movable output tap; linkage means coupling motion of said shaft to said movable output tap; said motor including a first winding responsive to current flow therethrough for effecting rotation of said shaft in a first direction; and a second winding responsive to current flow therethrough for effecting rotation of said shaft in an opposed direction; means connecting said winding in circuit with said first electrical circuit; and means connecting said second winding in circuit with said second electrical circuit.

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# UNITED STATES PATENT OFFICE
# CERTIFICATE OF CORRECTION

Patent No. 3,548,208 Dated December 15, 1970

Inventor(s) Joseph Battista

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Col. 7, line 1, "diveder" should be --divider--

CLAIM 3, Col. 10, line 75 through Col. 11, line 3 should read as follows:

of said shaft in an opposed direction; and means connecting said first winding in circuit with said first electrical circuit and means connecting said second winding in circuit with said second electrical circuit.

Signed and sealed this 31st day of August 1971.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents