PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H01J 40/14 — A1

(11) International Publication Number: WO 99/05695

(43) International Publication Date: 4 February 1999 (04.02.99)

(21) International Application Number: PCT/US98/15120

(22) International Filing Date: 15 July 1998 (15.07.98)

(30) Priority Data:
08/901,419 28 July 1997 (28.07.97) US

(71) Applicant: LITTON SYSTEMS, INC. [US/US]; 21240 Burbank Boulevard, Woodland Hills, CA 91367 (US).

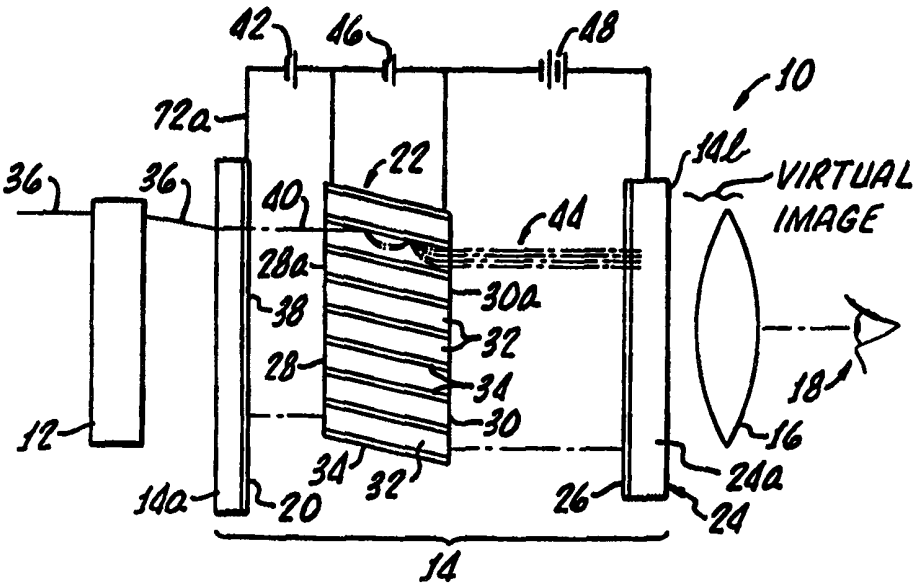
(72) Inventors: SALDANA, Michael, R.; 1690 Katy Street, New Braunfels, TX 78130 (US). FITTERER, Alric, M.; 1009 Filmore Drive, Plano, TX 75025 (US).

(74) Agent: MARSTELLER & ASSOCIATES, P.C.; P.O. Box 803302, Dallas, TX 75380–3302 (US).

(81) Designated States: CA, IL, NO, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.

(54) Title: NIGHT VISION DEVICE HAVING IMPROVED AUTOMATIC BRIGHTNESS CONTROL



(57) Abstract

A night vision device (10) includes an improved power supply (62) which operates the image intensifier tube (14) of the device (10) according to a variable duty cycle either at a design voltage level for the tube (14) or at a voltage level simulating a dark–field. This duty cycle variation is effected as a function of the current flow in the image intensifier tube (14) in order to provide automatic brightness control and bright source protection.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	**ES**	Spain	**LS**	Lesotho	**SI**	Slovenia
AM	Armenia	**FI**	Finland	**LT**	Lithuania	**SK**	Slovakia
AT	Austria	**FR**	France	**LU**	Luxembourg	**SN**	Senegal
AU	Australia	**GA**	Gabon	**LV**	Latvia	**SZ**	Swaziland
AZ	Azerbaijan	**GB**	United Kingdom	**MC**	Monaco	**TD**	Chad
BA	Bosnia and Herzegovina	**GE**	Georgia	**MD**	Republic of Moldova	**TG**	Togo
BB	Barbados	**GH**	Ghana	**MG**	Madagascar	**TJ**	Tajikistan
BE	Belgium	**GN**	Guinea	**MK**	The former Yugoslav Republic of Macedonia	**TM**	Turkmenistan
BF	Burkina Faso	**GR**	Greece			**TR**	Turkey
BG	Bulgaria	**HU**	Hungary	**ML**	Mali	**TT**	Trinidad and Tobago
BJ	Benin	**IE**	Ireland	**MN**	Mongolia	**UA**	Ukraine
BR	Brazil	**IL**	Israel	**MR**	Mauritania	**UG**	Uganda
BY	Belarus	**IS**	Iceland	**MW**	Malawi	**US**	United States of America
CA	Canada	**IT**	Italy	**MX**	Mexico	**UZ**	Uzbekistan
CF	Central African Republic	**JP**	Japan	**NE**	Niger	**VN**	Viet Nam
CG	Congo	**KE**	Kenya	**NL**	Netherlands	**YU**	Yugoslavia
CH	Switzerland	**KG**	Kyrgyzstan	**NO**	Norway	**ZW**	Zimbabwe
CI	Côte d'Ivoire	**KP**	Democratic People's Republic of Korea	**NZ**	New Zealand		
CM	Cameroon			**PL**	Poland		
CN	China	**KR**	Republic of Korea	**PT**	Portugal		
CU	Cuba	**KZ**	Kazakstan	**RO**	Romania		
CZ	Czech Republic	**LC**	Saint Lucia	**RU**	Russian Federation		
DE	Germany	**LI**	Liechtenstein	**SD**	Sudan		
DK	Denmark	**LK**	Sri Lanka	**SE**	Sweden		
EE	Estonia	**LR**	Liberia	**SG**	Singapore		

NIGHT VISION DEVICE HAVING IMPROVED AUTOMATIC BRIGHTNESS CONTROL

FIELD OF THE INVENTION

The present invention is generally in the field of night vision devices of the light amplification type. More particularly, the present invention relates to an improved night vision device having an image intensifier tube (I^2T) and an improved power supply for the I^2T which operates the tube in a unique way to achieve both improved automatic brightness control and improved bright-source protection. A method of operating the I^2T and a method of operating the improved power supply are disclosed also.

BACKGROUND OF THE INVENTION

Even on a night which is too dark for diurnal vision, invisible infrared light is richly provided by the stars. Human vision cannot utilize this infrared night time light from the stars because the so-called near-infrared portion of the spectrum is invisible for humans. A night vision device of the light amplification type can provide a visible image replicating the night time scene. Such night vision devices generally include an objective lens which focuses invisible infrared light from the night time scene onto the transparent light-

receiving face of an I^2T. At its opposite image-face, the image intensifier tube provides an image in visible yellow-green phosphorescent light, which is then presented to a user of the device via an eye piece lens.

A contemporary night vision device will generally use an I^2T with a photocathode behind the light-receiving face of the tube. The photocathode is responsive to photons of infrared light to liberate photoelectrons. These photoelectrons are moved by a prevailing electrostatic field to a microchannel plate having a great multitude of dynodes, or microchannels, with an interior surface substantially defined by a material having a high coefficient of secondary electron emissivity. The photoelectrons entering the microchannels cause a cascade of secondary emission electrons to move along the microchannels so that a spatial output pattern of electrons which replicates an input pattern, and at a considerably higher electron density than the input pattern results. This pattern of electrons is moved from the microchannel plate to a phosphorescent screen by another electrostatic field to produce a visible image.

A power supply for the I^2T provides the electrostatic field potentials referred to above, and also provides a field and current flow to the microchannel plate(s). Conventional night vision devices (i.e., since the 1970's and to the present day) provide automatic brightness control (ABC), and bright source protection (BSP). The former function maintains the brightness of the image

provided to the user substantially constant despite changes in the brightness (in infrared and the near-infrared portion of the spectrum) of the scene being viewed. BSP prevents the I^2T from being damaged by an excessively high current level in the event that a bright source, such as a flare or fire, comes into the field of view.

The ABC function is accomplished by providing a regulator circuit monitoring the output current from the phosphorescent screen (See Figure 9). When this current exceeds a certain threshold, the field voltage level across the opposite faces of the microchannel plate(s) is decreased to reduce the gain of the microchannel plate(s), as is graphically depicted in Figure 10. This reduction of microchannel plate voltage also has the effect of reducing the resolution of the I^2T. That is, the gain versus voltage function of the I^2T at lowered MCP voltages results in a matrix pattern from the microchannel plate(s) appearing in the image. This matrix pattern is sometimes referred to as fixed-pattern noise in the image. As a result, in bright-field conditions with the ABC feature of the conventional night vision device operating the conventional night vision device may drastically lose resolution so that the user of the device is no longer able to discern details of the viewed scene which would be discernible were they viewed under darker field conditions in which ABC were not applying.

An additional bright source protection is provided in conventional night vision devices by decreasing the field voltage provided to the photocathode. This happens because the high impedance of the photocathode in combination with a high resistance value circuit element creates a greater voltage drop under the high current conditions caused by a large number of photons incident on the photocathode (with a resulting high number of photoelectrons being provided by the photocathode). The photoelectrons provided by the photocathode represent a current flow increasing in magnitude with increasing light levels in the viewed field, such that the combined impedance of the photocathode and circuit element causes a decrease in the voltage level effective at the photocathode to move these electrons to the microchannel plate(s).

Recalling Figure 9, it will be noted that this circuit architecture requires the use of two transformers, which are relatively large and heavy components of the circuit. Further, is seen that a typical conventional circuit architecture for a power supply of a night vision device provides a high-value resistor (generally 1-18 G-ohm) to the output of the photocathode voltage multiplier and a clamping circuit consisting of a voltage source and a low-leakage, high-voltage diode. As photocathode current flows through the high-value resistor, the photocathode voltage will decrease linearly until it reaches a voltage equal to the voltage source (plus the high-voltage low-leakage diode

voltage drop). See Figure 11 for a graphical illustration of this BSP voltage relationship at the photocathode. This voltage is commonly referred to as a clamp voltage, and is typically between 30 and 40 volts D.C.

This conventional method of BSP also has a disadvantage of decreased resolution for the I^2T. The reduced electrostatic field between the photocathode and the microchannel plate(s) input causes a reduced resolution for the tube. That is, photoelectrons liberated from the photocathode are not moved to the microchannel plate(s) as effectively, and may not be liberated to reach the microchannel plate(s) at all. This is because photoelectrons must overcome a surface potential barrier at the photocathode in order to be liberated into free space and be moved by the prevailing electrostatic field to the input of the microchannel plate(s). As the voltage applied to the photocathode decreases, statistically, some photoelectrons will not be able to overcome this surface potential barrier and will not be liberated into free space. The image information represented by these trapped photoelectrons will be lost from the image provided by the I^2T to the user of the night vision device.

SUMMARY OF THE INVENTION

In view of the deficiencies of the conventional related technology, it would be desirable to provide a

power supply for an I^2T which does not reduce the microchannel plate(s) voltage in order to provide ABC.

Additionally, it would be desirable to provide such a power supply for an I^2T which, for purposes of BSP under extremely bright-field conditions, does reduce microchannel plate voltage, but to a much lower extent of voltage reduction than was used in conventional night vision devices for purposes of ABC.

Still another desirable feature of an improved power supply for an I^2T of a night vision device would be to provide a constant voltage for connection to the photocathode of the I^2T.

An advantage for such an improved power supply could be realized if the constant-voltage to the photocathode of the image intensifier tube were gated on and off at a constant duty cycle over part of the current range for the phosphorescent screen of the tube, and were gated at a duty cycle inversely related to current level at this phosphorescent screen of the tube over a portion of the current level range indicative of a need for an ABC function.

Accordingly it is an object for this invention to provide an improved power supply for an I^2T which avoids one or more of the deficiencies of the related conventional technology

Another object for this invention is to provide such an improved power supply for an I^2T which realizes one or more of the advantages set out above.

Yet another objective for this invention is to provide a method of operating such an improved power supply for an I^2T.

Another objective for this invention is to provide a method of operating an I^2T.

Still another objective for this invention is to provide a night vision device having such an improved power supply.

An advantage of the improved power supply for an I^2T is that a night vision device using such a power supply does not experience the loss of resolution in bright field conditions which is common with conventional night vision devices. In fact, resolution, signal-to-noise ratio, and fixed pattern noise of the image intensifier are all preserved at desirably high levels throughout the ABC and BSP operations of the tube and power supply, which is not the case with conventional I^2T power supplies. Additionally, mean time between failures for the power supply may be improved in comparison to conventional power supplies because parts counts may be reduced.

A further advantage of the present inventive power supply is that the photocathode and microchannel plate at all times enjoy operation at full design voltage level (except for extreme cases of BSP in which voltage to the MCP is reduced slightly). Effectively, gating of the photocathode voltage "simulates darkness" during that portion of the gating cycle in which voltage is off, and keeps the components of the I^2T operating under the ideal

conditions of low current densities that they were designed for.

Other objects, features, and advantages of the present invention will be apparent to those skilled in the art from a consideration of the following detailed description of a preferred exemplary embodiment thereof taken in conjunction with the associated figures which will first be described briefly.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic representation of a night vision device embodying the present invention;

Figure 2 shows an I^2T in longitudinal cross section, with an associated power supply embodying the present invention;

Figure 3 is a schematic representation of an improved power supply for an I^2T embodying the present invention;

Figures 4-8 respectively provide graphical representations of photocathode peak voltage, duty cycle, voltage wave form, microchannel plate voltage, and I^2T output brightness;

Figures 9-11 respectively provide a schematic circuit illustration, and graphical representations of microchannel plate voltage and photocathode voltage for a conventional I^2T power supply.

DETAILED DESCRIPTION OF AN EXEMPLARY PREFERRED EMBODIMENT OF THE INVENTION

While the present invention may be embodied in many different forms, disclosed herein is a specific exemplary embodiment that illustrates and explains the principles of the invention. It should be emphasized that the present invention is not limited to the specific embodiment illustrated.

Referring first to Fig. 1, there is shown schematically the basic elements of one version of a night vision device 10 of the light amplification type. Night vision device 10 generally comprises a forward objective optical lens assembly 12 (illustrated schematically as a functional block element - which may include one or more lens elements). This objective lens 12 focuses incoming light from a distant night-time scene on the front light-receiving end 14a of an I^2T 14 (as will be seen, this surface is defined by a transparent window portion of the tube - to be further described below). As was generally explained above, the I^2T provides an image at light output end 14b in phosphorescent yellow-green visible light which replicates the night-time scene. This night time scene would generally be not visible (or would be only poorly visible) to a human's diurnal vision. This visible image is presented by an eye piece lens illustrated schematically as a single lens 16 producing a virtual image of the rear light-output end of the tube 14 at the user's eye 18.

More particularly, I^2T 14 includes a photocathode 20 which is responsive to photons of infrared light to liberate photoelectrons, a microchannel plate 22 which receives the photoelectrons in a pattern replicating the night-time scene, and which provides an amplified pattern of electrons also replicating this scene, and a display electrode assembly 24. In the present embodiment the display electrode assembly 24 may be considered as having an aluminized phosphor coating or phosphor screen 26. When this phosphor coating is impacted by the electron shower from microchannel plate 22, it produces a visible image replicating the pattern of the electron shower. Because the electron shower pattern still replicates the scene viewed via lens 12, a user of the device can effectively seen in the dark, by only star light or other low-level illumination. A transparent window portion 24a of the assembly 24 conveys the image from screen 26 outwardly of the tube 14 so that it can be presented to the user 18.

Alternatively, as those ordinarily skilled in the pertinent arts will know, the output electrode assembly may include a charge coupled device (CCD). In this case, the reference numeral 26 would indicate such a CCD, with the output of the image intensifier tube being in the form of an image signal from this CCD. The user of such a device would view the image information on a display, such as a liquid crystal display, or cathode ray tube.

Still more particularly, microchannel plate 22 is located just behind photocathode 20, with the

microchannel plate 22 having an electron-receiving face 28 and an opposite electron-discharge face 30. This microchannel plate 22 further contains a plurality of angulated microchannels 32 which open on the electron-receiving face 28 and on the opposite electron-discharge face 30. Microchannels 32 are separated by passage walls 34. The display electrode assembly 24, generally has a conductive coated phosphor screen 26, is located behind microchannel plate 22 with phosphor screen 26 in electron line-of-sight communication with the electron-discharge face 30. Display electrode assembly 24 is typically formed of an aluminized phosphor screen 26 deposited on the vacuum-exposed surface of the optically transparent material of window portion 24a. The focusing eye piece lens 16 is located behind the display electrode assembly 24 and allows an observer 18 to view a correctly oriented image corresponding to the initially received low-level image.

As will be appreciated by those skilled in the art and also viewing now Figure 2, the individual components of I^2T 14 are all mounted and supported in a tube or chamber (to be further explained below) having forward and rear transparent plates cooperating to define a chamber which has been evacuated to a low pressure. This evacuation allows electrons liberated into the free space within the tube to be transferred between the various components by prevailing electrostatic fields without atmospheric interference that could possibly decrease the signal-to-noise ratio.

As indicated above, photocathode 20 is mounted immediately behind objective lens 12 on the inner vacuum-exposed surface of the window portion of the tube and before microchannel plate 22. Typically, this photocathode 20 is a circular disk-like structure having a predetermined construction of semiconductor materials, and is mounted on a substrate in a well known manner. Suitable photocathode materials are generally semi-conductors such as gallium arsenide; or alkali metals, such as compounds of sodium, potassium, cesium, and antimony (commercially available as S-20), carried on a readily available transparent substrate. A variety of glass and fiber optic substrate materials are commercially available.

Considering in somewhat greater detail the operation of the I^2T 14, it is seen that in response to photons 36 entering the forward end of night vision device 10 and passing through objective lens 12, photocathode 20 has an active surface 38 from which are emitted photoelectrons in numbers proportionate to and at locations replicative of the received optical energy of the night-time scene being viewed. In general, the image received will be too dim to be viewed with human natural vision, and may be entirely or partially of infrared radiation which is invisible to the human eye. It is thus understood that the shower of photoelectrons emitted from the photocathode are representative of the image entering the forward end of I^2T 14. The path of a typical photoelectron emitted from the photon input point on the

photocathode 20 is represented in Fig. 1 by dashed line 40.

Photoelectrons 40 emitted from photocathode 20 gain energy through an electric field of predetermined intensity gradient established between photocathode 20 and electron-receiving face 28, which field gradient is provided by power source 42. Typically, power source 42 will apply an electrostatic field voltage on the order of 200 to 800 volts to create a field of the desired intensity. After accelerating over a distance between the photocathode 20 and the input surface 28 of the microchannel plate 22, these photoelectrons 40 enter microchannels 32 of microchannel plate 22. As will be discussed in greater detail below, the photoelectrons 40 are amplified by emission of secondary electrons to produce a proportionately larger number of electrons upon passage through microchannel plate 22. This amplified shower of secondary-emission electrons 44, also accelerated by a respective electrostatic field generated by power source 46, then exits microchannels 32 of microchannel plate 22 at electron-discharge face 30.

Once in free space again, the amplified shower of photoelectrons and secondary emission electrons is again accelerated in an established electrostatic field provided by power source 48. This field is established between the electron-discharge face 30 and display electrode assembly 24. Typically, the power source 48 produces a field on the order of 3,000 to 7,000 volts, and more preferably on the order of 6,000 volts in order

to impart the desired energy to the multiplied electrons 44.

The shower of photoelectrons and secondary-emission electrons 44 (those ordinarily skilled in the art will know that considered statistically, the shower 44 is almost or entirely devoid of photoelectrons and is made up entirely or almost entirely of secondary emission electrons. Statistically, the probability of a photoelectron avoiding absorption in the microchannels 32 is low). However, the shower 44 is several orders of magnitude more intense than the initial shower of photoelectrons 40, but is still in a pattern replicating the image focused on photocathode 20. This amplified shower of electrons falls on the phosphor screen 26 of display electrode assembly 24 to produce an image in visible light.

Viewing Figure 2 in greater detail, the I^2T 14 is seen to include a tubular body 50, which is closed at opposite ends by a front light-receiving window 52, and by a rear fiber-optic image output window 54. The window 54 defines the light output surface 14b for the tube 14, and carries the coating 26, as will be further described. As is illustrated in Figure 2, the rear window 54 may be an image-inverting type (i.e., with optical fibers bonded together and rotated 180° between the opposite faces of this window 54 in order to provide an erect image to the user 18. The window member 54 is not necessarily of such inverting type. Both of the windows 52 and 54 are sealingly engaged with the body 50, so that an interior

chamber 56 of the body 50 can be maintained at a vacuum relative to ambient. The tubular body 50 is made up of plural metal rings, each indicated with the general numeral 58 with an alphabetical suffix added thereto (i.e., 58a, 58b, 58c, and 58d) as is necessary to distinguish the individual rings from one another.

The tubular body sections 58 are spaced apart and are electrically insulated from one another by interposed insulator rings, each of which is indicated with the general numeral 60, again with an alphabetical suffix added thereto (i.e., 60a, 60b, and 60c). The sections 58 and insulators 60 are sealingly attached to one another. End sections 58a and 58d are likewise sealingly attached to the respective windows 52 and 54. Those ordinarily skilled in the pertinent arts will know that the body sections 58 are individually connected electrically to a power supply 62 (which provides sources 42, 46, and 48, as described above), and which is effective during operation of the I^2T 14 to maintain an electrostatic field most negative at the section 58a and most positive at the section 58d.

Further viewing Figure 2, it is seen that the front window 52 carries on its rear surface within the chamber 56 the photocathode 20. The section 58a is electrically continuous with the photocathode by use of a thin metallization (indicated with reference numeral 58a') extending between the section 58a and the photocathode 20. Thus, the photocathode by this electrical connection and because of its semi-conductive nature, has an

electrostatic charge distributed across the areas of this disk-like photocathode structure. Also, a conductive coating or layer is provided at each of the opposite faces 28 and 30 of the microchannel plate 22 (as is indicated by arrowed numerals 28a and 30a). Power supply 46 is conductive with these coatings by connection to housing sections 58b and 58c. Finally, the power supply 48 is conductive with a conductive layer or coating (possibly an aluminum metallization, as mentioned above) at the display electrode assembly 24 by use of a metallization also extending across the vacuum-exposed surfaces of the window member 54, as is indicated by arrowed numeral 54a.

It should be noted in considering the description below of the structure and operation of the power supply 62, that the term "image intensifier tube" is used in a generic sense. Those ordinarily skilled in the pertinent arts will appreciate that the tube being powered may be configured as an electron multiplier tube in which the output is an electrical signal rather than a visible image. Also, the tube being powered may be of the photodetector, phosphorescence detector, or scintillation detector type, in which the output is also an electrical signal rather than a visible image. Such tubes are generally used, for example, to detect a phosphorescent response in a chemical reagent exposed to exciting light of another color or wavelength, or in a detector for high-energy events having as a result of their occurrence

the production of a small number of photons (i.e., as few as one photon per event).

Such application of tubes having a photocathode and a dynode (either of microchannel plate configuration with many dynodes, or of another configuration with one or more dynodes) may experience some or all of the difficulties in operation which are described above in the context of night vision devices. Accordingly, it will be appreciated that a power supply embodying principles of this invention may be used in such applications.

Considering now Figure 3, it is seen that the power supply 62 includes a power source, which in this case is illustrated as a battery 64. It will be appreciated that a battery 64 is generally used as the power source for portable apparatus, such as night vision devices. However, the invention is not limited to any particular power source. For example, a regulated line-power source could be used to provide input power to a power supply implementing and embodying the principles of the present invention. Considered generally, the power supply 62 includes three voltage mulitpliers or voltage converters, respectively indicated with the numerals 66, 68, and 70. The voltage converter 66 for the photocathode 20 includes two converters of differing voltage level, and indicated with the numerals 66a and 66b (note that the converter 66b provides a voltage level which is positive with respect to the face 28 of MCP 22, while converter 66a provides a voltage level which is negative relative to

the face 28 of the MCP 22. A tri-stable switching network 72 switches controllably between alternative positions either conducting the photocathode 20 to voltage converter 66a, to an open circuit position, or to voltage converter 66b, all via the conductive connection 72a. A duty cycle control 74 controls the switching position of the switching network 72, and receives as inputs a square wave gating trigger signal from an oscillator 76, and a control signal via a conductor 78 from an ABC/BSP control circuit 80. It will be appreciated that the switching network 72 may be configured to switch (i.e., to toggle) between voltage sources 66a and 66b without having an open-circuit condition. This alternative would yield essentially a square-wave voltage on the graph of Figure 6.

Power supply to the microchannel plate 22 (that is, to the conductive layers or metallizations 28a and 30a) is effected from the voltage converter 68 via connections 68a and 68b. Interposed in connection 68a is a series element 82, which in effect is a variable resistor. A high-voltage MOSFET may be used for element 82, and the resistance of this element is controlled over a connection 82a by a regulator circuit 84. Regulator circuit 84 receives a feed back control signal from a summing junction 86, which receives an input from conductor 88 via a level-adjusting resistor 90, and also receives an input via conductor 92 from the ABC/BSP control circuit 80. Conductor 88 also provides a feed back signal of the voltage level applied to the input

face 28 (i.e., at metallization 28a) of the microchannel plate 22 into the voltage converter circuit 66. Note that this conductor 88 provides a reference voltage level of microchannel plate voltage on face 28, not a signal of photocathode voltage level.

The voltage converter 70 has connection to the screen 26 via a connection 70a, and provides a feed back of screen current level into ABC/BSP control circuit via conductor 94. Energy flow in the circuit 62 is provided by an oscillator 96 and coupled transformer 98, with output windings 98a providing energy input to voltage converters 66 and 70, and a conductor 100 providing energy to voltage converter 68. It is noted that the circuit 62 requires only the single transformer 98, which advantageously reduces cost, size, weight, and parts count for the power supply; and also improves reliability for the power supply and night vision device 10. The oscillator 96 receives a control feed back via a regulator 102 and a feed back circuit 104, having an input from a feedback winding 98b of transformer 98.

Having considered the structure of the circuit 66, attention may now be given to its operation, and the cooperation of this circuit operation with the operation of the I^2T 14. Attention now to Figures 4-8, with attention first to Figure 4, shows that the most negative voltage level produced by voltage converter 66a for application by power supply circuit 66 to the photocathode 20 of the tube 14 is always constant at a selected voltage level. Comparing this Figure 4 to the

voltage curve of Figure 11 reveals that the prior art teaches to vary the voltage applied to the photocathode in order to provide a BSP function. However, Figure 5 shows that the power supply circuit 66 provides a BSP function by keeping the voltage applied to the photocathode 20 constant (recalling Figure 4) while gating connection of the photocathode between connection to this constant voltage source (i.e., about -800V), to an open circuit (i.e., voltage off), and to a lower voltage i.e., relatively more positive relative to the face 28 of MCP 22 - about +30V) provided by voltage converter 66b (simulating darkness for the photocathode 20). When the photocathode 20 is connected to voltage source 66b (i.e., to a source of about +30 volts relative to the face 28 of MCP 22), this condition might be considered a " hard turn off" for the photocathode. Under this condition, the photocathode is not responsive to photon received from the scene being viewed. This gating function is carried on at a constant cyclic rate and cycle interval, while varying the duty cycle of the applied constant voltage preferably as a function of current level sensed at screen 26 (i.e., by feed back over conductor 94).

It should be noted, however, that this gating function can be carried out with respect to other parameters of operation of the image intensifier tube 14. For example, an alternative way of controlling the gating function would be to use the current level at face 30 i.e., at electrode 30a) as a controlling parameter.

Figure 5 shows that over a range of screen current indicated with the numeral 106, the duty cycle of the applied constant voltage to the photocathode 20 is fixed at 100%. However, at screen current levels above a selected level, the duty cycle progressively ramps down substantially linearly to a low level of essentially 10^{-4}% as a function of increasing screen current, as is indicated by numeral 108. It will be noted that Figures 5 and 7 are drawn to the same scale of screen current along the abscissa of the of the graph, and that these graphs are arranged one vertically above the other for the reader's convenience in understanding the relationship of photocathode gating duty cycle to voltage applied to the microchannel plate 22.

Returning attention to Figure 5 and with attention now to Figure 6 it is seen that for screen current levels above that at which the duty cycle for gating of the constant voltage to the photocathode 20 reaches its lowest value, an additional function of BSP is provided by decreasing the voltage applied to the microchannel plate 22. It will be noted that for all screen current levels lower than those necessary to initiate this BSP protection function, the voltage applied across the microchannel plate 20 is a constant. Thus, the microchannel plate 22 operates at its designed voltage differential across electrodes 28a and 30a. The reduction of voltage level applied across the microchannel plate 20 is effected by action of the series element 82 increasing its resistance under control of MCP

regulator 84. As noted this regulator 84 receives a summed input from the conductor 88 via the level adjusting resistor 90, and from the ABC/BSP control circuit 80, which itself is responsive to the level of current sensed at screen 26 by conductor 94.

Comparing this operation of power supply circuit 62 to the operation of the conventional power supply discussed above with reference to Figures 9-11, and viewing Figure 10, it is seen that the power supply 62 avoids the problem of loss of resolution for an I^2T caused in the conventional power supplies by operation with too low a voltage on a microchannel plate.

The voltage wave form of Figure 6 might be produced by a rapid increase of light input such that the ABC function, and then the BSP function operate in succession. For this reason, Figure 6 is also annotated with a time arrow, indicating that in this instance time proceeds from left to right on the graph. It will be noted that the constant voltage level gated to the photocathode 20 (i.e., from voltage converter 66a) is substantially -800V, while the positive voltage level from voltage converter 66b is about +30 volts relative to the face 28 (electrode 28a) of the microchannel plate 22.

The reader should not be confused by the similarity in appearance between the graph of Figure 10 and that of Figure 5, they are illustrating differing values. Figure 10 relates to conventional microchannel plate voltage, while Figure 5 is voltage gating duty cycle to the photocathode 20 as provided by the power supply 62.

In view of the above, attention now to Figure 6 provides an understanding of the microchannel plate voltage level as the duty cycle for the application of the constant peak voltage seen in Figure 4 is varied in response to changing light levels in the viewed scene, and in response to the changes in screen current level for the I^2T. Figure 6 shows that portion of the duty cycle operation corresponding to portions 108 and 110 of Figures 5 and 7. Increasing light levels and increasing screen current levels go from left to right on the graph of Figure 6. It will be noted that a portion of the graph of Figure 6 is not shown (i.e., to the left of that part shown). This portion which is not shown would correspond to section 106 of Figure 5, and in this realm of operation the duty cycle is always 100%.

At the left side of the graph of Figure 6, it is seen that the duty cycle is here slightly less than 100%, and that within the interval for each duty cycle the voltage applied to photocathode 20 is initially the high constant peak voltage indicated in figure 4 (i.e., indicated at numerals 112), and then decays over a very short time interval at a natural open-circuit, capacitor-discharge rate (indicates at segments 114 of the voltage curve). This voltage decay is actually a very small voltage because of the short time interval, and occurs because the virtual capacitor existing between the photocathode 20 and the conductive metallization on the front light-receiving face of the microchannel plate 22 (i.e., conductive coating 28a) is open-circuit when the

switching network 72 (recalling Figure 3) is not conducting the photocathode to neither voltage converter 66a or to voltage converter 66b. This virtual capacitor is diagrammatically indicated on Figure 3, and indicated with the character "C".

Next in each duty cycle, the network 72 conducts the photocathode to voltage converter 66b, which effectively replicates darkness for the photocathode 20 by dropping the voltage as is indicated at voltage cutoff's 116 of Figure 6. Effectively, this dropping (i.e., more positive) voltage level for the photocathode 20 is a hard turn off. That is, when the applied voltage at the photocathode 20 is about +30 volts relative to the face 28 of microchannel plate 22, then electrons will not flow from this photocathode to the microchannel plate in response to photon of light hitting the photocathode. This voltage cutoff 116 is provided by having voltage converter 66b provide a voltage which is about 30 volts positive with respect to the voltage provided at coating 28a on the front face of the microchannel plate 22 by voltage converter 68.

Restated, it is seen that in essence when the photocathode 20 operates, it always operates substantially at the high constant peak voltage seen in Figure 4. When the photocathode 20 is not operating, it is switched to a voltage which replicates a dark field for the photocathode (i.e., the +30 volts from voltage converter 66b). The photocathode 20 operated by the power supply 62 of the present invention is switched

between operation at its designed voltage level and dark-field condition at a duty cycle which varies dependent upon the light intensity of the scene being viewed, as indicated by current flow at the screen 26. This function is carried out in accord with the duty cycle function indicated in Figure 5 in order to provide ABC. The result of this ABC operation is illustrated in Figure 8, which indicates that over a broad range of input light levels, a substantially constant brightness for the image presented to a user of the night vision device 10 is achieved. At the left-hand side of Figure 8 is seen a linearly decreasing section of the brightness curve from the image intensifier tube 14. This occurs with very dim lighting levels, but the image intensifier tube 14 will still provide a usable image in at least a portion of this regime of its operation.

Returning to consideration of Figures 5 and 7, within section 108, the duty cycle is progressively decreased until it reaches it low level of 10^{-4}% as a function of increasing screen current. If light level of the viewed scene continues to increase (indicative of a bright source in the scene), then the duty cycle maintains its low 10^{-4}% level, while the bright source protection function explained above is effected in section 110, recalling Figure 7.

Those skilled in the art will appreciate that the embodiment of the present invention depicted and described herein and above is not exhaustive of the invention. For example, the ABC and BSP aspects of the

invention may be implemented separately of one another if desired. Those skilled in the art will further appreciate that the present invention may be embodied in other specific forms without departing from the spirit or central attributes thereof. Because the foregoing description of the present invention discloses only an exemplary embodiment thereof, it is to be understood that other variations are recognized as being within the scope of the present invention. Accordingly, the present invention is not limited to the particular embodiment which has been described in detail herein. Rather, reference should be made to the appended claims to define the scope and content of the present invention.

I CLAIM:

1. A night vision device having an objective lens receiving light from a scene being viewed and directing this light to an image intensifier tube, said image intensifier tube providing a visible image of the scene being viewed, and an eyepiece lens providing this visible image to a user of the night vision device; said image intensifier tube including a photocathode receiving photons from the scene and releasing photoelectrons in a pattern replicating the scene, a microchannel plate receiving the photoelectrons and providing a shower of secondary emission electrons in a pattern replicating the scene, and a screen receiving the shower of secondary emission electrons and producing a visible image replicating the scene; said night vision device including a source of electrical power at a selected voltage level, and a power supply circuit receiving said electrical power at said selected voltage level to responsively provide electrical power at higher voltage levels to said photocathode, to opposite faces of said microchannel plate, and to said screen, said power supply providing a constant voltage level of electrical power for said photocathode.

2. The night vision device of Claim 1 wherein said power supply includes only a single transformer.

3. The night vision device of Claim 1 wherein said power supply further includes a pair of voltage converter circuits each providing a differing voltage level to said photocathode, and a switching network connection said photocathode alternatingly to one of said pair of voltage converter circuits and to the other of said pair of voltage converter circuits.

4. The night vision device of Claim 3 wherein said switching network connects said photocathode to open circuit after connection to the more negative one of said pair of voltage converter circuits.

5. The night vision device of Claim 4 further including a duty cycle controller controlling said switching network in response to a current level at said screen.

6. The night vision device of Claim 5 wherein said duty cycle controller includes a gating trigger signal generator, and a control circuit receiving a gating signal from said gating trigger signal generator and providing an output signal controlling said switching network.

7. The night vision device of Claim 1 wherein one of said pair of voltage converter circuits provides a negative voltage level to said photocathode, and the

other of said pair of voltage converter circuits provides voltage to said photocathode which is positive relative to a voltage level provided to a first face of said microchannel plate.

8. The night vision device of Claim 1 further including another voltage converter circuit providing a selected voltage level to said opposite faces of said microchannel plate, and a voltage control element in series connection between said another voltage converter circuit and a first face of said microchannel plate.

9. A night vision device having an objective lens receiving light from a scene being viewed and directing this light to an image intensifier tube, said image intensifier tube providing a visible image of the scene being viewed, and an eyepiece lens providing this visible image to a user of the night vision device; said image intensifier tube including a photocathode receiving photons from the scene and releasing photoelectrons in a pattern replicating the scene, a microchannel plate receiving the photoelectrons and providing a shower of secondary emission electrons in a pattern replicating the scene, and a screen receiving the shower of secondary emission electrons and producing a visible image replicating the scene; said night vision device including a source of electrical power at a selected voltage level, and a power supply circuit receiving said electrical power at said selected voltage level to responsively

provide higher voltage levels to said photocathode, to opposite faces of said microchannel plate, and to said screen; wherein said power supply further includes a pair of voltage converter circuits each providing a differing voltage level to said photocathode, and a switching network connection said photocathode alternatingly to one of said pair of voltage converter circuits and to the other of said pair of voltage converter circuits.

10. The night vision device of Claim 9 further including a duty cycle controller controlling said switching network in response to a current flow level at said screen; said duty cycle controller including a gating trigger signal generator circuit, and a control circuit receiving a gating trigger signal from said gating trigger signal generator and responsively providing an output signal controlling said switching network.

11. The night vision device of Claim 9 wherein one of said pair of voltage converter circuits provides a negative voltage level to said photocathode, and the other of said pair of voltage converter circuits provides a relative positive voltage to said photocathode;.

12. The night vision device of Claim 9 further including another voltage converter circuit providing a selected voltage level to said opposite faces of said microchannel plate, and a voltage control element in

series connection between said another voltage converter circuit and a first face of said microchannel plate.

13. The night vision device of Claim 9 wherein said switching network in a gating cycle further connects said photocathode alternatingly to open circuit after connection of said photocathode to said negative voltage level converter circuit.

14. A method of operating a night vision device, said night vision device having an objective lens receiving light from a scene being viewed and directing this light to an image intensifier tube, said image intensifier tube providing a visible image of the scene being viewed, and an eyepiece lens providing this visible image to a user of the night vision device; said image intensifier tube including a photocathode receiving photons from the scene and releasing photoelectrons in a pattern replicating the scene, a microchannel plate receiving the photoelectrons and providing a shower of secondary emission electrons in a pattern replicating the scene, and a screen receiving the shower of secondary emission electrons and producing the visible image replicating the scene; said method including steps of:

providing a constant negative voltage level available to be switched to said photocathode;

providing a voltage level which is positive relative to a first face of the microchannel plate;

in a variable duty cycle alternating connection of said photocathode between said constant voltage level and said relative positive voltage; and

varying said duty cycle in response to a current level from said screen.

15. The method of Claim 14 further including the steps of maintaining said variable duty cycle at substantially 100% over a first range of screen current, and progressively decreasing said duty cycle from 100% to a lower level over a second range of screen current.

16. The method of Claim 15 wherein said lower level for said duty cycle is selected to be substantially 10^{-4}%

17. The method of Claim 14 further including the steps of providing a voltage differential across said microchannel plate, and decreasing said voltage differential across said microchannel plate after said variable duty cycle has reached a selected low level.

18. The method of Claim 18 wherein said voltage differential across said microchannel plate is reduced after said duty cycle is decreased to substantially 10^{-4}%.

19. A method of operating an image intensifier tube, said image intensifier tube including a photocathode receiving photons and releasing photoelectrons, a microchannel plate receiving the

photoelectrons and providing a shower of secondary emission electrons, and a screen receiving the shower of secondary emission electrons and producing a visible image; said method including steps of:

providing a constant negative voltage level available to be switched to said photocathode;

providing a voltage level which is positive with respect to a first face of the microchannel plate;

in a variable duty cycle switching said photocathode alternatingly from said constant voltage level to said relative positive voltage; and

varying said duty cycle.

20. The method of Claim 19 further including the steps of maintaining said variable duty cycle at substantially 100% over a first range of screen current, and progressively decreasing said duty cycle from 100% to a lower level over a second range of screen current.

21. The method of Claim 20 wherein said lower level is selected to be substantially 10^{-4}%

22. The method of Claim 20 further including the steps of providing a voltage differential across said microchannel plate, and decreasing said voltage differential across said microchannel plate to a lower level after said variable duty cycle has reached a selected low level.

23. The method of Claim 22 wherein said voltage differential across said microchannel plate is reduced after said duty cycle is decreased to substantially 10^{-4}%.

24. A method of operating a power supply for an image intensifier tube, said image intensifier tube including a photocathode receiving photons and releasing photoelectrons, a microchannel plate receiving the photoelectrons and providing a shower of secondary emission electrons, and a screen receiving the shower of secondary emission electrons and producing a visible image; said power supply providing selected voltage levels to each of said photocathode, to opposite faces of said microchannel plate, and to said screen; said method including steps of:

providing a respective voltage level for each of opposite faces of said microchannel plate and for said screen;

providing a constant negative voltage level available to be switched to said photocathode;

providing a voltage level available to be switched to said photocathode which is positive relative to a voltage level provided to a first of said opposite faces of said microchannel plate;

in a variable duty cycle switching connection of said photocathode alternatingly from said constant voltage level to said relative positive voltage; and

varying said duty cycle in response to a current level from said screen.

25. The method of Claim 24 further including the steps of maintaining said variable duty cycle at substantially 100% over a first range of screen current, and progressively decreasing said duty cycle from 100% to a lower level over a second range of screen current.

26. The method of Claim 25 wherein said lower level is selected to be substantially 10^{-4}%

27. The method of Claim 24 further including the step of decreasing a voltage level difference across said opposite faces of said microchannel plate after said variable duty cycle has reached a selected low level.

28. The method of Claim 27 wherein said voltage level difference across said microchannel plate is reduced after said duty cycle is decreased to substantially 10^{-4}%.

29. An improved power supply circuit for a tube device having a photocathode, dynode, and output electrode, said improved power supply comprising:

a transformer receiving electrical energy from a source;

a pair of voltage converters receiving power from said transformer and respectively supplying first and second voltage levels each of which is available to be switched to said photocathode;

a switching network connecting said photocathode alternatingly to said first voltage level and to said second voltage level; and

a duty cycle controller switching said photocathode between connection to said first voltage and said second voltage as a function of current level from said output electrode.

30. The improved power supply of Claim 29 in which said tube device is configured as an image intensifier tube wherein said dynode is included in a microchannel plate and said output electrode includes a phosphorescent screen providing a visible image, said power supply further including an additional voltage converter circuit providing a voltage differential across said microchannel plate, and a voltage control element in series connection between said another voltage converter circuit and a first face of said microchannel plate, a regulator circuit varying said voltage control element in dependent upon current level from said screen.

31. The improved power supply of Claim 29 in which said power supply circuit includes only a single transformer.

32. An imaging device having an image intensifier tube, said image intensifier tube including a photocathode, and a microchannel plate having a pair of opposite faces; said microchannel plate providing a

shower of electrons in a pattern replicating a scene, and means for providing a visible image in response to said shower of electrons and replicating the scene; said imaging device including a source of electrical power at a selected voltage level, and a power supply circuit receiving electrical power at said selected voltage level to responsively provide higher voltage levels respectively to said photocathode, and to said pair of opposite faces of said microchannel plate, and said power supply circuit providing a substantially constant voltage level for said photocathode, as well as a substantially constant voltage differential across said microchannel plate.

33. A method of operating an image intensifier tube, said image intensifier tube providing a shower of electrons replicating a scene being viewed; said image intensifier tube including a photocathode, a microchannel plate providing a shower of secondary emission electrons in a pattern replicating the scene; said method including steps of:

providing a substantially constant negative voltage level available to be switched to said photocathode;

providing a relative positive voltage level;

in a duty cycle toggling connection of said photocathode between said constant voltage level and said relative positive voltage level.

34. An improved power supply method for automatic-brightness-control operation of an image intensifier tube, said improved power supply method comprising steps of:

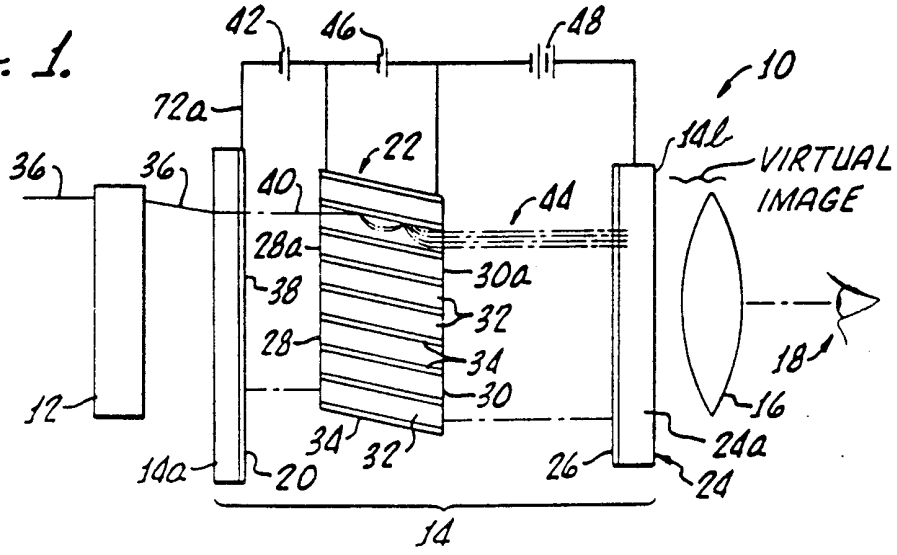
providing a substantially constant voltage level to be connected to a photocathode of the image intensifier tube;

gating connection of the substantially constant voltage level to the photocathode on and off at a variable duty cycle; and

within a selected range of the current flow within the image intensifier tube indicative of a need for automatic brightness control performing the variable duty cycle gating at a duty cycle inversely related to the current level.

35. A night vision device having an objective lens receiving light from a scene being viewed and directing this light to an image intensifier tube, said image intensifier tube providing a visible image of the scene being viewed, and an eyepiece lens providing this visible image to a user of the night vision device; said image intensifier tube including a photocathode receiving photons from the scene and releasing photoelectrons in a pattern replicating the scene, a microchannel plate receiving the photoelectrons and providing a shower of secondary emission electrons in a pattern replicating the scene, and a screen receiving the shower of secondary emission electrons and producing a visible image replicating the scene; said night vision device comprising a source of electrical power at a selected voltage level, and a power supply circuit receiving said electrical power at said selected voltage level to responsively provide respective higher voltage levels to each of said photocathode, to opposite faces of said microchannel plate, and to said screen; said power supply circuit providing a substantially constant voltage level to said photocathode.

FIG. 1.


42
46
48
10
72a
14b
VIRTUAL IMAGE
36
36
40
22
44
28a
30a
38
32
28
34
30
18
12
16
34
32
24a
14a
20
26
24
14

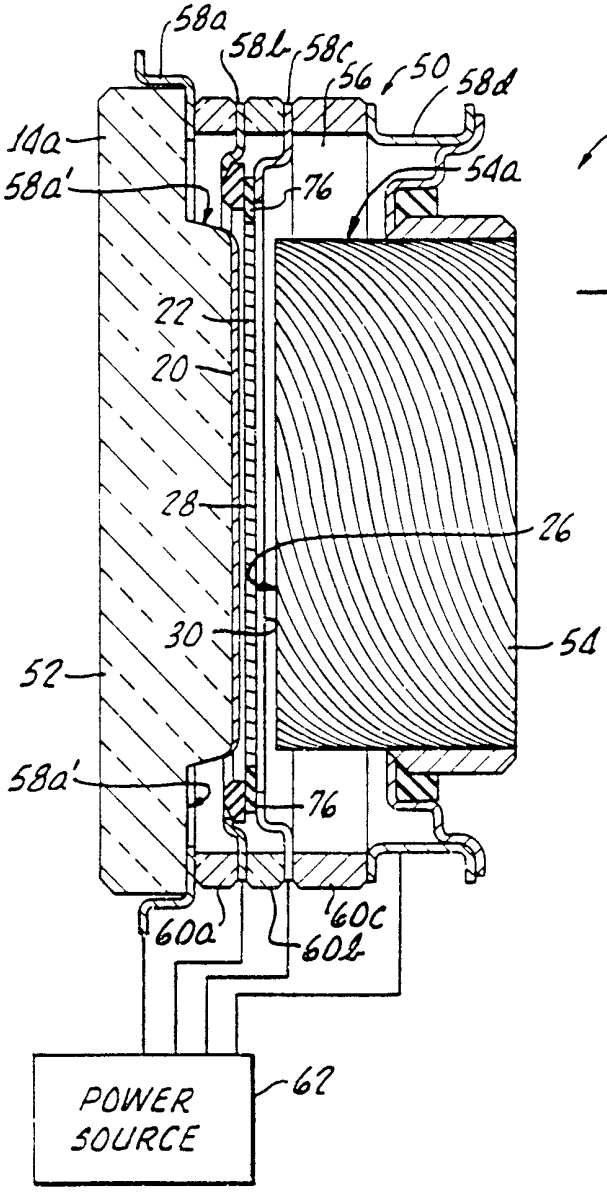

58a
58b
58c
56
50
58d
14a
14
58a'
54a
76
22
20
28
26
30
54
52
58a'
76
60c
60a
60b
POWER SOURCE
62

FIG. 2.

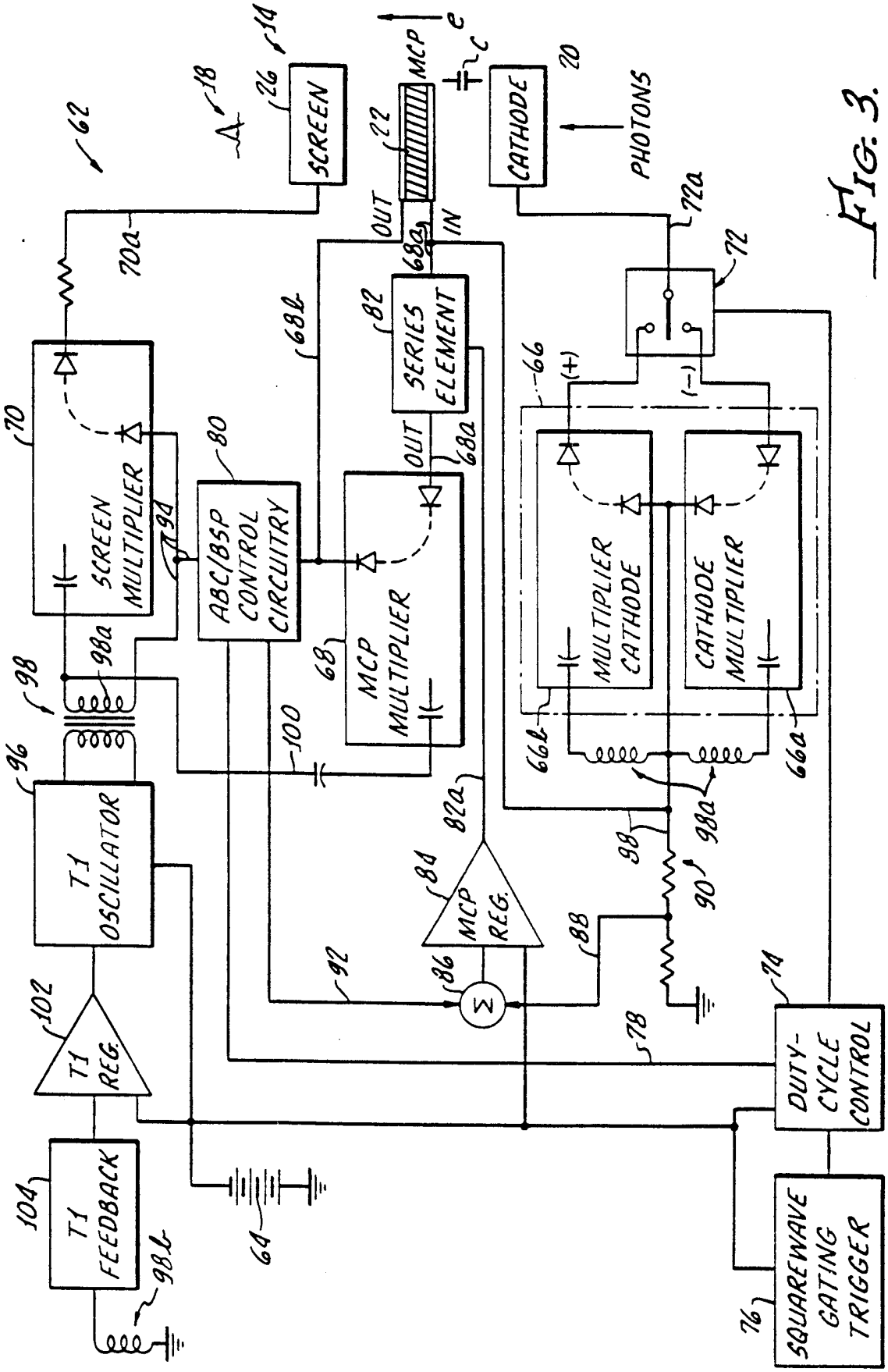

62
18
26
14
SCREEN
MCP
22
e
c
CATHODE
20
PHOTONS
72a
70a
OUT
IN
68a
68b
82
SERIES ELEMENT
72
66
(+)
(-)
70
SCREEN MULTIPLIER
94
80
ABC/BSP CONTROL CIRCUITRY
OUT
68a
MULTIPLIER CATHODE
CATHODE MULTIPLIER
98
98a
68
MCP MULTIPLIER
100
66b
66a
96
T1 OSCILLATOR
82a
84
MCP REG.
98
98a
90
88
92
86
Σ
78
74
102
T1 REG.
DUTY-CYCLE CONTROL
104
T1 FEEDBACK
64
98b
76
SQUAREWAVE GATING TRIGGER

FIG. 3.

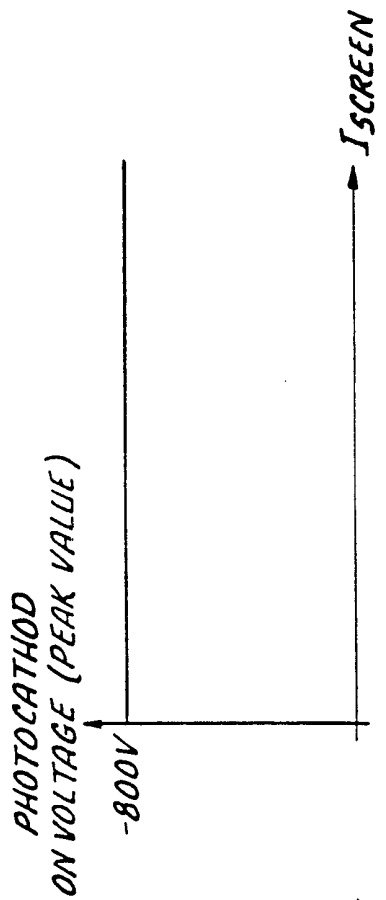


FIG. 4.

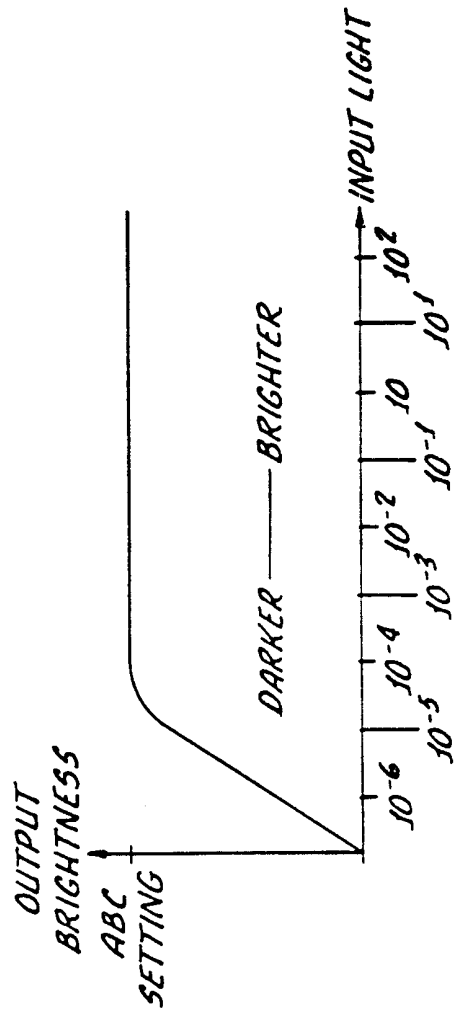


FIG. 8.

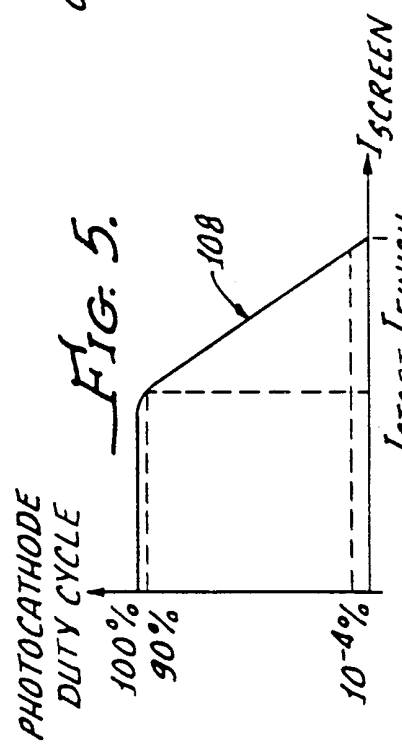


FIG. 5.

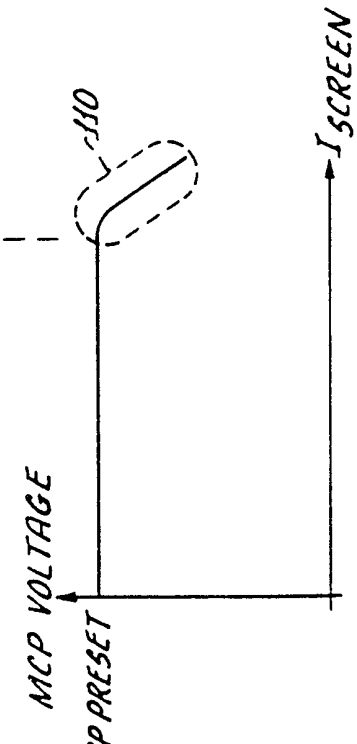


FIG. 7.

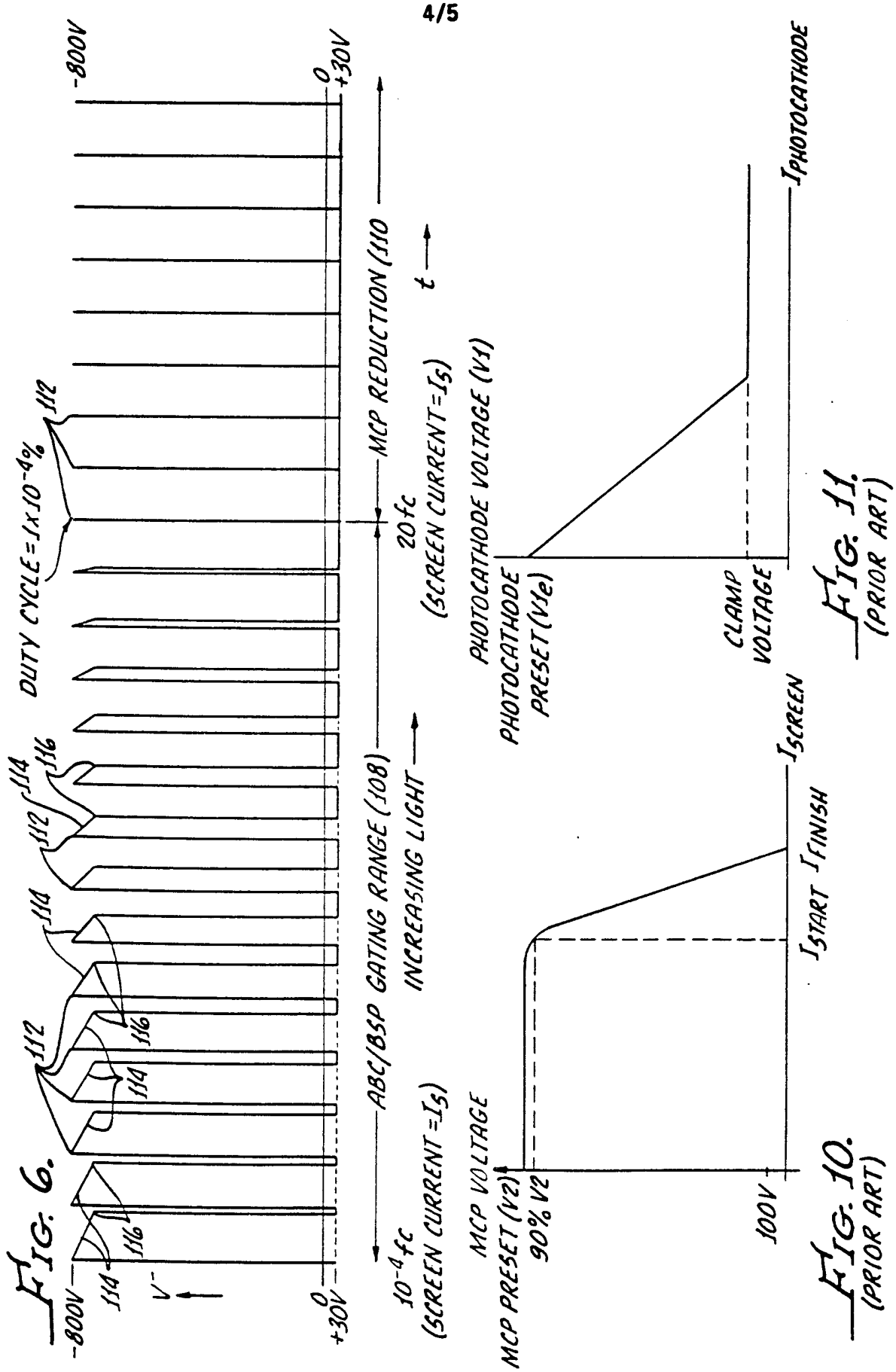


FIG. 6.

FIG. 10.
(PRIOR ART)

FIG. 11.
(PRIOR ART)

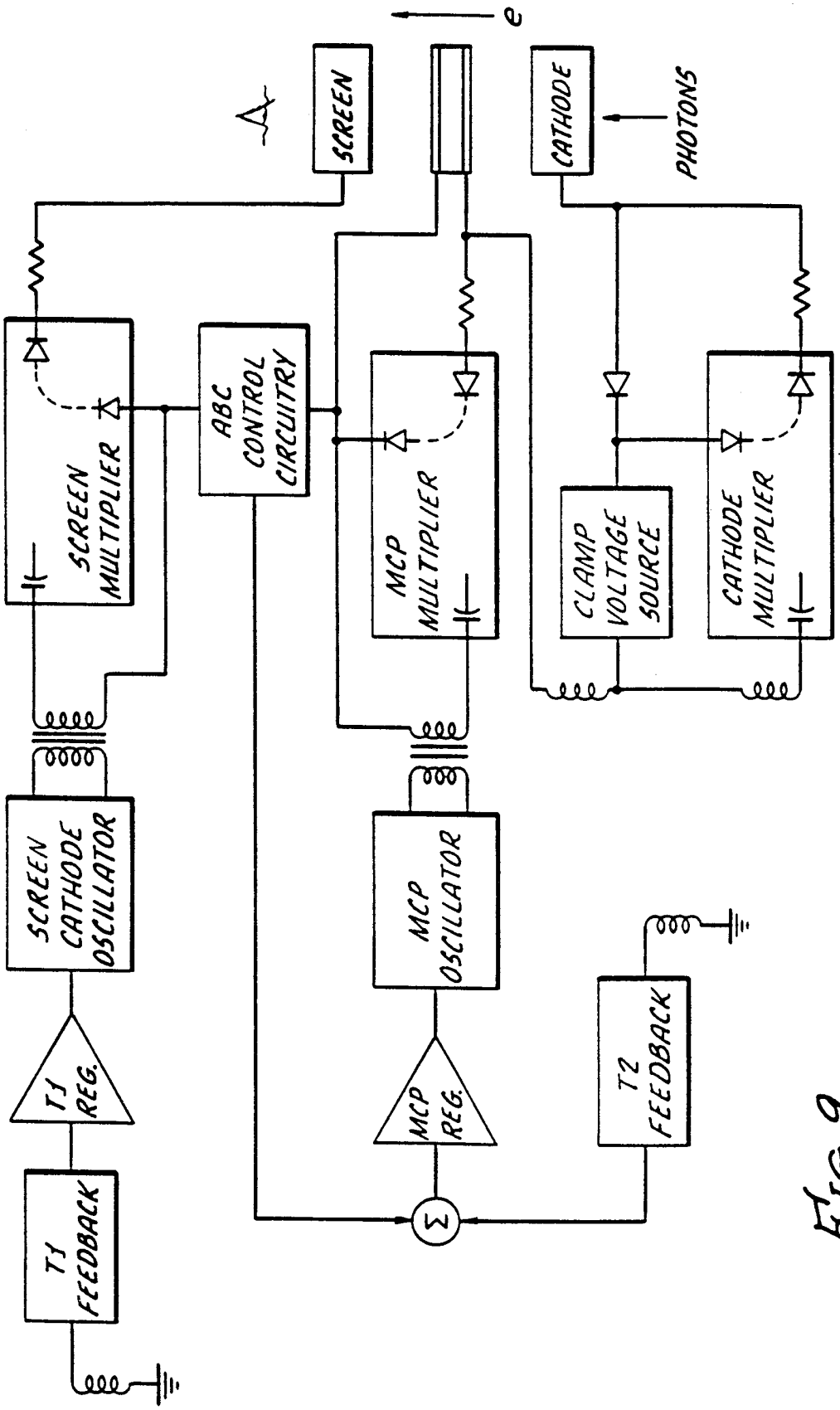


FIG. 9.
(PRIOR ART)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US98/15120

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H01J 40/14
US CL :250/214VT

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 250/214VT, 214R, 214RC, 214C; 313/103R, 105CM, 528, 537, 542, 543, 544

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

NONE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X/Y	US 5,146,077 A (CASERTA et al.) 08 September 1992 (08/9/1992), see entire document.	1,32,33,35 /2-31,34
Y	US 4,037,132 A (HOOVER) 19 July 1977 (19/7/77), see entire document.	2-31,34

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E"	earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search 04 SEPTEMBER 1998	Date of mailing of the international search report 28 SEP 1998
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer Que T. Le Telephone No. (703) 308-4830

Form PCT/ISA/210 (second sheet)(July 1992)★