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PATENT APPLICATION
Navy Case No. 78059

MOBILE X-RAY UNIT

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to X-ray machines and, more particularly, to a battery operated X-ray machine having an improved circuit arrangement so as to generate intense relatively short pulsed of X-rays. This invention allows for the overall weight of the X-ray machine to be reduced with a corresponding reduction in its physical size so that it more advantageously serves as a portable device.

2. Description of the Prior Art

X-ray machines that generate X-rays from cold field emission of electrons from the cathode of an X-ray tube are commonly employed in pulsed shadowgraph radiographs. Pulsed or flash shadowgraph radiograph was developed in 1938 as a means for observing extremely rapid motion where the subject was obscured from observation with visible light or debris. To date, flash radiography remains the principal means of observing lensed implosions and ballistic impacts over microsecond and nanosecond time scales. The majority of these X-ray systems utilize the well known Marx generator which can be viewed as a distributed

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1 transmission-storage line, consisting of n-cascaded high-voltage
2 barium titanate disc capacitors. To produce X-rays, the Marx
3 generator is coupled to a field-emission X-ray tube either
4 directly or by coaxial cables. Coaxial cables provide a low
5 impedance energy store and can be rapidly discharged into the X-
6 ray tube.

7
8 When high voltage (H.V.) pulses arrive at the anode of the
9 X-ray tube they establish a large potential gradient in the
10 anode-cathode gap. This gradient produces an intense electric
11 field at the tips of the small metal whiskers which are present
12 on the surface of the cathode mesh. The whiskers are heated by
13 the passage of the field emission electron current and vaporize,
14 creating a neutral plasma which acts as a virtual cathode capable
15 of supporting a much larger current. Electrons emitted from the
16 expanding virtual cathode are accelerated by the electric field
17 in the anode-cathode gap and eventually collide with the anode
18 creating X-rays by the usual Bremsstrahlung and line radiation
19 processes. Electrons continue to cross the anode-cathode gap
20 until the expanding cathode plasma reaches the anode at which
21 time the X-ray tube impedance drops to a few ohms and effectively
22 shorts the tube.

23 While Marx generator driven X-ray systems have worked well
24 in the past, they have employed large transformer-rectifier high

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1 voltage power supplies for charging the Marx capacitors and
2 generally use heavy coaxial cables to couple the Marx generator
3 to the X-ray tube. The heavy coaxial cables act to sharpen the
4 high voltage pulses produced by the Marx generator but, the
5 physically large bundle of cables disadvantageously adds to the
6 weight of the X-ray machine so as to hinder its portability.
7 Further more, the heavy high voltage power supply also
8 disadvantageously contributed to the weight of the X-ray machine
9 while also hindering its maneuverability. It is desired that a
10 means be provided that reduce the overall weight of the X-ray
11 machine, while also eliminating the need for the heavy coaxial
12 cables with both features contributing to an X-ray unit that is
13 truly portable. More particularly, it is desired that a compact
14 and portable design for X-ray machines be provided so that the X-
15 ray machine may advantageously be used in remote locations, as in
16 X-ray imaging devices for medical diagnostics and also for triage
17 related to medical disasters.

18
19 OBJECTS OF THE INVENTION

20
21 Accordingly, it is a primary object of the present invention
22 to provide an X-ray machine that is of a relatively light-weight,
23 about 26 pounds, occupies less than one half of a cubic foot, and
24 may serve as a compact and portable device for use in remote

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1 locations requiring ease of mobility.

2 It is the object of the present invention to provide a
3 portable X-ray machine that develops an intense pulse of X-rays,
4 but also has variable accelerating voltage so as to accommodate
5 various X-ray applications.

6 Another object of the present invention is to provide a
7 portable X-ray unit that generates a high dose X-ray pulse, which
8 has a short time duration, 10-100 nanoseconds. This short X-ray
9 pulse eliminates the need for long integration time, so that it
10 advantageously may be used for high resolution digital detector
11 arrays.

12 Detector arrays, such as charge coupled device (CCD) or a
13 amorphous silicon devices both of which are used in digital
14 processing cameras have high dark currents when integrating over
15 long time exposures unless cooled to about 0° Fahrenheit; the
16 dark current of these devices decreases their sensitivity.

17 Furthermore, it is an object of the present invention to
18 provide an X-ray unit that may be used for dental X-ray imagery
19 and controlled by a portable computer, such as a notebook
20 computer, when used in remote or confined spaces or used for X-
21 ray inspection, security detection, and medical applications
22 requiring high quality X-ray images.

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SUMMARY OF THE INVENTION

The present invention is directed to an X-ray unit which is relatively light-weight, thereby contributing to its portability, yet generating hard X-ray pulses without the need of any coaxial cables between its Marx generator and its X-ray tube. The X-ray unit comprises a high vacuum X-ray tube having a conical anode surrounded by a coaxial annulus of stainless steel mesh which serves as the cathode, control electronics, and a plurality of spark gap switches and ceramic disc capacitors which form the Marx generator 18. The battery powered control electronics comprises: the H.V. power supply, Ultraviolet (U.V.) flash-gap assembly 57, and power management circuit. The control electronics 20 can receive either a manual, an optical, or an electrical pulse and use that pulse to trigger the X-ray unit.

The control electronics also generates a sync pulse whenever the Marx generator is triggered and this pulse is brought to the front panel of the control electronics enclosure 20 so that it can be used to synchronize or command other devices to fire with the Marx generator.

The energy storage capacitors within the Marx column are surrounded with an insulating pressurized shell 12 and covered by

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1 a close fitting aluminum cylinder 32 which acts as the outer
2 conductor of a lumped coaxial transmission line. The outer
3 aluminum cylinder also functions as a very effective Faraday
4 shield preventing the escape of potentially harmful
5 electromagnetic radiation from the pulsed X-ray unit.

6 BRIEF DESCRIPTION OF THE DRAWINGS

7
8 These and other objects, features and advantages of the
9 invention, as well as the invention itself, will become better
10 understood with reference to the following detailed description
11 when considered in connection with the accompanying drawings,
12 wherein like reference numbers designate identical or
13 corresponding parts throughout the several views and wherein:
14

15 Fig. 1 illustrates a mobile X-ray unit in accordance with
16 the present invention.
17

18 Fig. 2 is a block diagram of the essential functions related
19 to the present invention.
20

21 Fig. 3 is a schematic diagram of the portion of the control
22 electronics of the present invention.

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1 Fig. 4 is a schematic diagram of the further section of the
2 control electronics of the present invention.

3
4 Fig. 5 is a blow-up of the pulsed power circuit of device 57

5
6 Fig. 6 is a schematic illustrating some of the mechanical
7 features of the Marx generator of the present invention.

8
9 Fig. 7 is an equivalent circuit of the Marx generator of the
10 present invention.

11
12 Fig. 8 illustrates the X-ray tube assembly of the present
13 invention.

14
15 Fig. 9 Details the X-ray unit in one typical application
16 thereof.

17
18 DETAILED DESCRIPTION OF THE EMBODIMENTS OF THE INVENTION

19
20 Before the drawings are discussed, it should be noted that
21 the mobile X-ray unit of the present invention is of a relatively
22 light-weight, about 26 pounds, and provides a Marx generator that
23 contributes to the production of high power X-ray pulse having a
24 predetermined duration and adjustable accelerating potential.

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1 The Marx generator comprises a plurality of capacitors that are
2 discharged in several nanoseconds thereby eliminating the need of
3 any pulse sharpening commonly performed by coaxial cables
4 discussed in the "Background" section.

5
6 One embodiment of the present invention is illustrated in
7 Fig. 1 for the mobile X-ray unit 10. The mobile X-ray unit 10
8 comprises two aluminum enclosures 32 and 14, with the enclosure
9 32 housing an X-ray tube assembly 16 and a Marx generator 18, and
10 with enclosure 14 housing control electronics 20 (not shown, but
11 to be described with reference to Figs. 2, 3 and 4,5).

12
13 The pressurized housing 12, encloses the Marx generator 18,
14 and forms a pressure seal at o-ring 138 at end plate 133,
15 described with reference to Figs.6

16
17 The Marx generator 18 comprises a plurality of capacitors
18 C1, C2,... and C10 that operate together with a plurality of
19 spark-gap switches G1, G2,... and G10. and Clamping diodes Cd1,
20 Cd2....Cd10 referred to later. The charge state of the marx
21 capacitors C1, C2 ... C10 is indicated by light emitting diode
22 bar graph array 42 as M1, M2,... and M10 mounted on enclosure 14.

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1 The enclosure 14 also contains provisions for accommodating
2 a digital volt meter (DVM) 38, a potentiometer 40 that adjusts
3 the voltage generated by the Marx generator 18, and a dot/bar
4 graph display 42 that shows the charged state of the Marx
5 generator 18. The enclosure 14 also provides a housing for
6 receiving a fiber optic trigger input 44, a connector 46 for the
7 receipt of a transistor transistor logic (TTL) trigger input, and
8 a connector 48 making available a TTL trigger sync output.
9 Further, the face of the enclosure 14 allows for mounting of a
10 rotary switch 50, a manual trigger push button 52, a power on-off
11 switch 54, and a battery charge input 56. The enclosure 14, in
12 particular, the control electronic 20 within the enclosure 14
13 provides signals and functions for the Marx generator 18, via a
14 cable 58 carrying, a high voltage (HV) trigger signal and a high
15 voltage cable 60.

16
17 The Marx generator consists of a plurality of high voltage
18 ceramic disc capacitors and spark gap switches. The capacitors
19 contained in the Marx column 18 are charged to a H.V. in parallel
20 via bleeder resistors RA in the resistor chain. Each spark gap
21 switch G1-G10, consists of two closely spaced spherical
22 electrodes. The spark gap switches are arranged so that each
23 charged capacitor C1-C10 in the Marx column is isolated from all
24 other capacitors via resistors RA. The spark gap switches are

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1 mounted along a common optical axis together with an ultraviolet
2 photoionization source 59, from the control electronics 20, and
3 mounted in close proximity to the first spark gap switch G1,
4 within the marx column 18.

5
6 Triggering of the Marx column begins with the control
7 electronics 20 which initiates a high voltage trigger pulse from
8 a H.V. trigger transformer 82 via path 102 into spark-gap device
9 57. Breakdown of this spark gap switch causes its impedance to
10 collapse from an open circuit to a low impedance spark channel
11 having a few tens of milliohms of resistance. This device 57, now
12 transfers the energy stored in capacitor C0 to device 59 by way
13 of path 58. The U.V. photoionization source 59 emits a large
14 flash of hard U.V. created by the discharge of capacitor C0 into
15 device 59 which is connected to the ground plane of the device
16 10.

17
18 The hard U.V. emitted from device 59 photoionizes spark gap
19 G1, the closure of this switch places the first capacitor in the
20 Marx column C1 in series with the second capacitors in the column
21 C2 doubling the voltage across the second spark gap switch G2.
22 The increased voltage stress across the second spark gap together
23 with the hard ultraviolet illumination it receives from the
24 closure of the first spark gap switch G1 causes it to break down

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1 quickly. This process continues at an accelerating rate until
2 all capacitors in the Marx column are fully erected in series and
3 have formed the center conductor of the coaxial device.
4

5 The full Marx voltage now appears across switch G10 which is
6 connected to power feedthrough device 128 which transmits the
7 H.V. output of the Marxed capacitors to the anode 28 of the X-ray
8 tube 16, via conducting tube 168. The X-ray tube assembly 16 is
9 held within the enclosure 32 by the clamping arrangement 22. The
10 X-ray tube assembly 16 has a vacuum window 24, through which X-
11 rays are emitted, and a cathode 26 and an anode 28 having one of
12 its ends connected to a screw connection 30 that is mechanically
13 engaged by a complementary arrangement, to be described with
14 reference to Fig.8 The X-ray tube assembly 16 is mechanically
15 connected to the system 10 by way of a mating contact plugged
16 into feedthrough power connector 128. The outer conducting member
17 162, of the X-ray tube 16, is clamped into the outer shell 32 by
18 means of screws 22 placed 120 degree's apart. Application of
19 the full Marx potential across the anode-cathode gap of the X-ray
20 tube 16 produces an intense electric field between the wires in
21 the mesh of the cathode and the surface of conical shaped anode.
22 This electric field extracts electrons from the cathode by the
23 process of cold field emission. The electrons accelerate towards
24 the anode where they collide and produce Bremmstrahlung and K-

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1 line radiation. This radiation continues until the plasma
2 produced at the cathode crosses the gap and shorts out the tube.
3 Plasma closure in our tube sets the X-ray pulse width at 50
4 nanoseconds.

5
6 The operation of the control electronics 20 may be further
7 described with reference to Fig. 3 illustrating a plurality of
8 circuit elements indicated by conventional symbols, such as a
9 resistance symbol, and identified by typical component values and
10 also illustrating various logic elements most identified with the
11 term Q serving as their indicated logic function and some of
12 which logic elements are of the type given in Table 1.

13
14 TABLE 1

15 NOMENCLATURE	16 FUNCTION/TYPE
17 Q1	18 HEWLETT PACKARD (HP-R-2503) OPTICAL
	19 RECEIVER
20 Q2	21 PULSE STRETCHER (LM555)
22 Q5	23 5 VOLT REGULATOR (7805)
24 Q6	ENCO 300 VOLT SUPPLY)
	DUAL TIMER (LM556)

25 The control electronics 20 have the capability of accepting
26 either of three input signals, each of which serves as a trigger
27 to start the operation of an X-ray mobile unit 10 for the
28 generation of the associated X-rays. The three input signals
29 are: (a) the optical pulse of 650 nanometers, present on signal

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1 path 68 and received by the Q1 device. (b) the input from
2 connector 46 the pulse generated by the TTL logic present on
3 signal path 66 and accepted by the Q3 device. (c) and a manual
4 pulse generated by the manually activated push-button 52. The
5 selection of either of these three input signals is accomplished
6 by the selection of the rotary switch 50 arranged as shown in
7 Fig. 3.

8
9 Either of these input signals activates the Q2 device so
10 that the control electronics 20 will not respond to another input
11 signal for a predetermined time, such as 330 milliseconds, which
12 reduces the unwanted possibility of repetitive triggering caused
13 by closely spaced input pulses. The Q2 device produces an output
14 pulse which is then shaped by edged differentiation provided by
15 the circuit components on the input stage of the Q4C nand gate
16 which inverts its received signal and transfers it to the base of
17 a common emitter formed by element Q5 and its associated circuit
18 components. The inverted output of nand gate Q4C is also routed
19 to a further nand gate Q4D which, in turn, provides a sync output
20 to connector 48 which, in turn, provides the sync pulse on to
21 signal path 78, to be described with reference to Fig. 9.

22
23 The collector of the Q5 device is connected to the primary
24 of a toroidal trigger transformer 80. The pulse signal present

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1 at the primary of transformer 80 appears across the secondary of
2 transformer 80 and triggers an SCR device, indicated as D6, which
3 discharges the 1.0 microfarad capacitor connected to the anode of
4 D6. The energy discharge of the 1 μ f capacitor is applied to
5 signal path 70 that is routed to a H.V. trigger transformer 82
6 that assists in rendering the first spark-gap device 57
7 conductive in a manner as to be described with reference to
8 Fig. 5.

9
10 In addition, the control electronics 20 contain a battery
11 charged state indicator circuit Q8-Q11, that indicates when the
12 X-ray mobile unit 10 battery 81, preferably a 12 volt device,
13 needs to be charged. This indication is accomplished by flashing
14 the back light of the digital voltage meter 38, see Fig.1

15 The flashing of the DVM black-light is accomplished by the
16 operation of the Q9 device which uses its first timer as a
17 comparator and provides an output that is used to carry the
18 second timer's reset line high. The second timer of the Q9
19 device is now free to oscillate and strobes, via signal path 84,
20 a transistor switch comprised of transistors Q10 and Q11 which
21 sinks, via signal path 86, the current through the LED back-light
22 of the digital voltage meter DVM 38. The 12V output is applied
23 to signal path 88 which is routed to the control electronics
24 illustrated in Fig. 4. The onslaught of the flashing begins when

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the voltage of the 12 volt battery reaches about 9 volts. The remainder of the control electronics 20 may be further described with reference to Fig. 4 which illustrates a plurality of circuit elements indicated by conventional symbols, such as those of a resistor, identified by typical component values and also illustrates various logic elements most identified with the term Q, and some of which are given in Table 2.

TABLE 2

NOMENCLATURE	FUNCTION/TYPE
Q12	0-13 kV SUPPLY OF ENCO MODEL 4300
Q13	0-12 VOLT SUPPLY OF ENCO MODEL 9414
Q14	VOLTAGE REGULATOR (7805)
Q15	OPERATIONAL AMPLIFIER (OP295)
Q17	BAR/DOT DISPLAY DRIVER (LM3916)
38	DIGITAL VOLTAGE METER OF MODUTEC (0-200 mV FULL SCALE)

The control electronics 20 of Fig. 4 includes a DC to DC converter comprised of elements Q12, Q13, Q14 and associated circuit components arranged as shown in Fig. 4. Element Q13, via signal path 88, accepts a voltage signal of approximately 9 - 14 volts DC and produces, on signal path 90, a constant 24 volts DC output for current loads of preferably no more than 1 ampere. The element Q12 which is a programmable high voltage supply provides a voltage of between 0 - 13 kV that is applied to the Marx generator 18, via signal path 92. The output of the element Q12 is regulated to 0.1% no load to full load and can provide .33

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1 milliamps of current at 13kV.

2 The signal path 60 is routed to the Marx generator 18 by way
3 of a charge line 92 that comprises a ten megohm resistor 93, a
4 seven megohm resistor 95, and a 0.1 microfarad capacitor which is
5 actually capacitor C0 arranged as shown in Fig. 5. The charge
6 line 92 provides an output on signal path 94 that is routed to
7 the Q17 element which is a bar/dot display driver.

8
9 The program voltage input to element Q12 is also monitored,
10 via signal path 96, by element Q15A and its associated circuit
11 components acting as a first operational amplifier configured as
12 a voltage follower and which impresses its output voltage across
13 a low voltage divider which is passed onto element Q15B serving
14 as a second operational amplifier. Q15B provides an output signal
15 serving as the programming voltage monitor of the H.V. capacitor
16 charging supply, this voltage is routed to the element Q17. The
17 HV output of Q12 is monitored by a 5000x attenuator and is sent
18 to element Q17 via signal path 94.

19
20 The difference between the signal developed by elements Q15B
21 and the voltage attenuator is applied to element Q17, this is
22 used to drive Q18 which contains 10 LED's (M1, M2, ... M10 shown
23 in Fig. 4) that indicate the charge state of the Marx generator
24 18.

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1 The output voltage (0 - 13 kV) generated by element Q12 is
2 adjustable by potentiometers, such as potentiometer 40, that are
3 electrically connected, as shown in Fig. 4, to signal paths 96
4 and 100.

5 The charge line 92 that carries the 0 - 13 kV potential has
6 its 10 megohm resistor 93 and its 0.01 capacitor C0 connected
7 between the lower spark-gap terminal 100 or anode electrode of
8 the spark-gap switch 57. A trigger pin wire 102 extends through
9 the outer body of the spark-gap switch 57 and runs, but does not
10 touch, the cathode electrode 100. The trigger pin wire 102 is
11 biased to the fully charged potential of the 0.1 microfarad
12 capacitor (C0) by way of a 7 megohm resistor. The trigger pin
13 wire 102 is connected to a 500 picofarad decoupling capacitor
14 which, in turn, is connected to the trigger transformer 82, whose
15 primary winding is connected to signal on signal path 70
16 previously discussed with reference to Fig. 3.

17
18 When the signal present on signal path 70 is applied to the
19 primary side of the trigger transformer 82, it produces a 25
20 kilovolt pulse at the secondary of transformer 82. When the 25
21 kilovolt pulse passes through the 500 picofarad decoupling
22 capacitor, it appears as a spark in the air gap between the
23 trigger pin wire 102, the anode electrode 100. The cathode
24 electrode 103 connected to the ground potential via a 100 k

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1 resistor to be described with reference to Fig. 7. The spark
2 photoionizes the region just in front of the cathode 103 which
3 results in the formation of a breakdown channel between the
4 cathode and the anode 100 of the spark-gap switch 57. The plasma
5 produced by the breakdown channel rapidly fills the anode-cathode
6 gap of the spark gap device 57, thereby, producing a low
7 resistance path between the 0.1 microfarad capacitor C0 and the
8 U.V. photoionizer source 59 in the Marx generator 18.

9 The Marx generator 18 has mechanical features which are
10 important to the present invention and may be further described
11 with reference to Fig. 6.

12
13 Fig. 6 illustrates the enclosure 32 as being cut-away so as
14 to expose the internally housed components primarily related to
15 the Marx generator 18. Enclosure 32 has two inlets 110 and 112
16 which enter the pressurized cylinder, to be described
17 hereinafter, that is confined within the chamber 114. Chamber
18 114 is defined by its conducting aluminum walls, wherein the
19 internal walls thereof fit over an acrylic insulating cylinder
20 116 both of which cooperate in a manner to be described with
21 reference to Fig. 6 to form a return path for the lumped element
22 transmission line formed by the capacitance between the marxed
23 capacitors and the wall of enclosure 32, the connection and
24 switching inductance between each capacitor and it's neighbor.

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1 The Marx generator 18 comprises capacitors C1, C2,...and C10, and
2 spark-gap devices G1, G2,... and G10 to be further described
3 hereinafter with reference to Figs. 6 and 7 and all of which are
4 held by a polycarbonate rod 132.

5
6 The capacitors C1, C2, ... C10 and the spark-gap devices G1,
7 G2,...and G10 are affixed to the polycarbonate rod machined into
8 a spine configuration 132 by appropriate means, known in the art.
9 The polycarbonate spine 132 does not occupy the complete space
10 between the acrylic cylinder 116 but now leaves, at one of its
11 ends, a chamber 120 into which is introduced a pressurized gas,
12 via conduit 122 which may be monitored with a pressure meter 124.
13 The other end of the polycarbonate spine 132 abuts up to within 1
14 mm of the power feedthrough 128. The spine 132 carries and allows
15 for the attachment of a turning mirror 34 previously discussed
16 with Fig. 1, and to be further described with reference to
17 Fig. 6.

18
19 The power feedthrough 128 also provides a path for the
20 electrical connection between G10 and the X-ray tube 16. More
21 particularly, when the screw electrode 128 is screwed into the
22 insulating spine 132 it causes the Marx generator 18 to be
23 electrically connected to the anode 28. The insulating spine 132
24 shown in Fig. 6, as well as the acrylic cylinder 116, abuts up

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1 against the O-ring pressurized seal 134. The O-ring pressurized
2 seal 134, in cooperation with the aluminum housing 32, provides
3 an entrance passageway 136 into which the X-ray tube 16 of Fig. 1
4 is inserted. The aluminum enclosure 32 as well as the acrylic
5 cylinder 116 mate with a second O-ring pressurized seal 138.

6
7 The O-ring pressurized seal 138 and the enclosure 32 have
8 provisions that provide for the mating with a high voltage
9 connection 140 that is connected to a brass member 142 which, in
10 turn, is connected to the high voltage connector 140, via a
11 conductor 144. The brass member 142 has a diameter of about 1.27
12 centimeters and allows for the soldering thereto of a resistor
13 charging ladder network to be described hereinafter with
14 reference to Fig. 7.

15 In operation, the chamber 114 is pumped to a vacuum pressure
16 of approximately 10^{-3} torr and back filled with dry nitrogen gas
17 to a pressure of preferably about 25 to 30 psi.. The 2 atmosphere
18 pressure of nitrogen gas allows for the spark-gap electrodes G1,
19 G2...and G10, previously discussed with reference to Fig. 4, to
20 be separated by about 1 mm. The capacitors C1, C2,.... and C10
21 are respectively physically separated from each other by barriers
22 146, whereas the spark-gap devices G1, G2, ...and G10 are
23 separated from each other by barriers 148. The barriers 146 and
24 148 comprise and the polycarbonate spine 132. Capacitor C1, C2

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1 ...and C10 have a very high dielectric constant of about 7000,
2 and may be further described with reference to Fig. 7.

3
4 Fig. 7 illustrates the Marx generator 18 which is a
5 conventional impulse-type high-voltage circuit in which
6 capacitors C1, C2, ...and C10 are charged in parallel through a
7 high-resistive ladder network formed by resistors R1-R19 having a
8 typical value of 100 k and arranged as shown. When the capacitor
9 voltage reaches a critical value, such as 13 kV, the capacitors
10 are discharged in series through the spark-gap devices G1, G2...
11 and G10 in response to a trigger signal, produce a high-voltage
12 pulse which is applied to the anode 28 of the X-ray tube 16.

13
14 Fig. 7 shows an equivalent circuit of the Marx generator 18
15 that employs clamping diodes Cd1, Cd2, Cd3, Cd4, Cd5, Cd6, Cd7,
16 Cd8, Cd9 and Cd10 arranged as shown, that act to dampen any
17 negative ringover associated with the capacitors when the
18 capacitors are discharged into the inductance of the X-ray tube
19 16. The Marx generator 18, in particular the first stage thereof
20 having the spark-gap device G1 previously discussed with
21 reference to Fig. 4, preferably utilizes an ultraviolet initiator
22 which may be described with reference to Fig. 7.

23 Fig. 6 illustrates the turning mirror 34, which as discussed
24 directs the hard, ultraviolet light pulse. Fig. 5 further

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1 illustrates how the turning mirror is positioned within the
2 insulating spine 132. The turning mirror tilted 45° from the line
3 of sight of spark gap switches G1-G9 so that it directs the
4 ultraviolet light pulse to the region between the electrodes 130
5 and 128 of spark-gap device G10 located at the output stage of
6 the Marx generator 18. As previously discussed with reference to
7 Fig. 4, the discharge of the 1 microfarad capacitor onto signal
8 path 70 is applied to the trigger transformer 82 which develops
9 at its secondary a 25 kV pulse. When the 25 kV pulse passes
10 through the 500-picofarad decoupling capacitor, it appears as a
11 spark in the gap between the trigger pin wire 102 and anode and
12 cathode and anode electrodes 100 and 103. As previously discussed
13 with reference to Fig. 4, the spark transitions the normally high
14 resistance path between the cathode and anode electrodes of
15 device 57 to a low resistance path. One end of the low
16 resistance path is indicated with the reference number 58
17 previously discussed with reference to Fig. 5a.

18
19 The low resistance spark channel formed in device 57 causes
20 the rapid discharge of capacitor C0 through path 58. Cable 58
21 enters the Marx unit 18 and is connected to the U.V. initiator 59
22 which emits a large flash of hard U.V. and causes the sequential
23 cascaded discharge of the capacitors C1-C10 which have been
24 charged parallel through Resistor chain R1-R19 described in

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1 fig.7, are then discharged through spark gap switches G1-G10.

2 This path formed by the spark gap switches G1-G10 forms the
3 center conductor of the coaxial device 10.
4

5 The capacitors C1- C10 have a typical value of 0.01 μ f and
6 are arranged on the polycarbonate 118 spine 132 as illustrated in
7 Fig. 6, further, the separation between the capacitors provided
8 by the polycarbonate rod 132 decrease the interstage capacitance.
9 The low interstage capacitance, in cooperation with the
10 relatively low inductance of the spark gap switches G1-G10,
11 allows the capacitors C1- C10 to completely discharge into the X-
12 ray tube 16 within nanoseconds. This fast discharge eliminates
13 the need for any coaxial cables which would normally be used to
14 sharpen the high-voltage pulse emerging from the Marx generator.
15 The elimination of these coaxial cables reduces the overall
16 weight of the mobile X-ray unit 10, while increasing its
17 mobility.
18

19 The mobile unit 10 having the parameters hereinbefore
20 described provides for the generation of a high voltage pulse
21 having a duration of less than 100 nanoseconds. This high
22 voltage, high energy pulse is adjustable by means of the
23 potentiometers shown in Fig. 4, in particular, the potentiometers
24 electrically connected to signal paths 96 and 100. The high

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1 voltage pulse developed by the Marx generator 18 is applied to
2 the anode 28 of the X-ray tube 16 by means of the spark gap
3 electrode 130 shown in Fig.6

4 The x-ray tube 16, shown in Fig.8, is a field emission type
5 comprised of a geometric arrangement of anode 28 and cathode 26
6 derived from the well known "Siemens-tube" configuration. More
7 particularly, the X-ray tube 16 has a conical copper/tungsten
8 anode 28, and a stainless steel mesh punched to form an anode
9 cathode 26. The X-rays are extracting from the X-ray tube along
10 a tube axis and as a result of a conical anode 28, the emitting
11 area is about 2 mm in diameter. The X-ray tube 16 uses a
12 commercially available 30 kV DC ceramic insulator 158 bonded to
13 conflat flanges 160 and 162 each having a typical diameter of
14 2.75 inches. The conflat flanges 160 and 162 are mated to a
15 stainless steel tube 164 having a typical outer diameter of 1.5
16 inches and an inner diameter of 1.375 inches. The stainless
17 steel tube is connected to an adapter plate 166.

18
19 The anode stalk 168 is a tube having a typical outer
20 diameter of 0.24 inches and a typical inner diameter of 0.125
21 inches. The x-ray tube is evacuated through the center of the
22 anode tube by way of holes 170, 172 and 174 arranged in a spiral
23 so as not to weaken the anode tube 168.

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1 As seen in Fig. 1, the enclosure 20 encloses and confines
2 the main power producing components that generate the high
3 voltage potentials of 0 - 13 kV. The charge lines 58 and 60
4 comprise coaxial cable that carries a relatively high voltage of
5 0 - 13kV and whose outer conductor, enclosure 32 provides a
6 return path for the charge line 92.

7
8 It should now be appreciated that the practice of the
9 present invention provides for an X-ray mobile unit 10 having
10 compact electronics so as to provide complete shielding against
11 electromagnetic interference. Further, it should be appreciated
12 that the present invention utilizes electronic components that
13 are relatively small so that the overall weight of the mobile X-
14 ray unit 10 is approximately 26 pounds. Further, it should be
15 appreciated that the mobile X-ray unit 10 has the ability, via
16 the potentiometers shown and described with reference to Fig. 4,
17 to develop an excitation that is applied to the Marx generator 18
18 which develops a high voltage output signal having an amplitude
19 which is adjustable to adapt to various applications, one of
20 which may be further described with reference to Fig. 9.

21
22 Fig. 9 illustrates an arrangement that includes a notebook
23 computer 178, known in the art, which is connected to the sync
24 output 48 of enclosure 14 having thereon a trigger output signal

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1 placed on signal path 78, previously described with reference to
2 Fig. 3. The notebook computer 178 has an output cable that is
3 connected to a CCD x-ray camera 182.
4

5 Portability of the notebook computer 178, the CCD camera
6 182, and the mobile X-ray unit 10 allows for the practice of the
7 present invention to be utilized in: Dentist's offices, medical,
8 Veterinary offices and security applications. The unit can
9 provide a high quality image; produced by the mobile X-ray unit
10 of the present invention.
11

12 It should now be appreciated that the practice of the
13 present invention provides for a mobile X-ray unit 10 utilized
14 for various applications.
15

16 It should further be thoroughly understood that many
17 modifications and variations of the present invention are
18 possible within the purview of the claimed invention. It is
19 therefore to be understood

20 the invention may be practiced otherwise than as
21 specifically described.

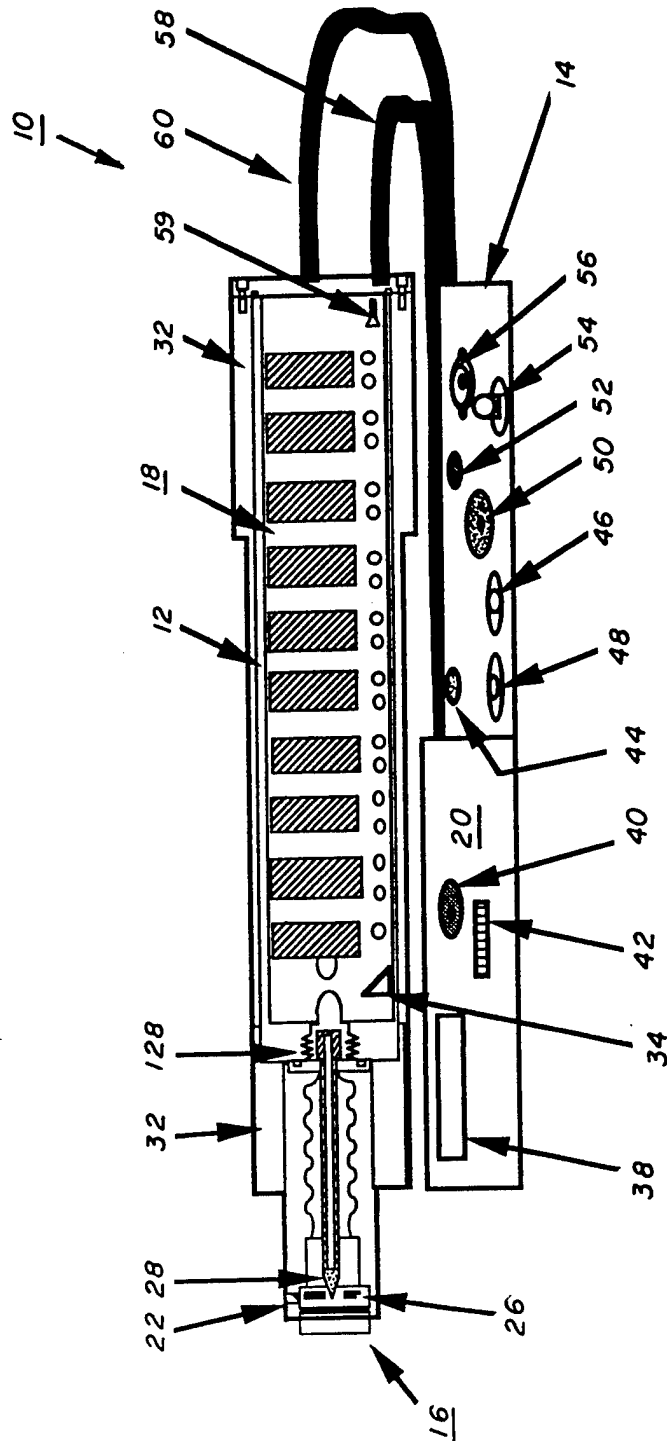
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ABSTRACT OF THE DISCLOSURE

A portable X-ray unit, of a relatively light-weight, occupying a volume of less than one-half a cubic foot containing an x-ray head assembly, a unique Marx generator, a plurality of spark-gap switches and control electronics is disclosed. The Marx generator allows for the development of a relatively high voltage in excess of 100 kV, yet allows for the discharge thereof within the nanosecond range. The Marx generator is enclosed by an acrylic insulator that cooperates with an aluminum enclosure, which functions as a return current path for the capacitors in the Marx generator and also as a shield against the escape of electromagnetic radiation from the pulsed x-ray unit. The Marx generator and spark-gap switches are confined within the pressurized chamber that may contain nitrogen gas to reduce the separation of the gap in the spark-gap switches.



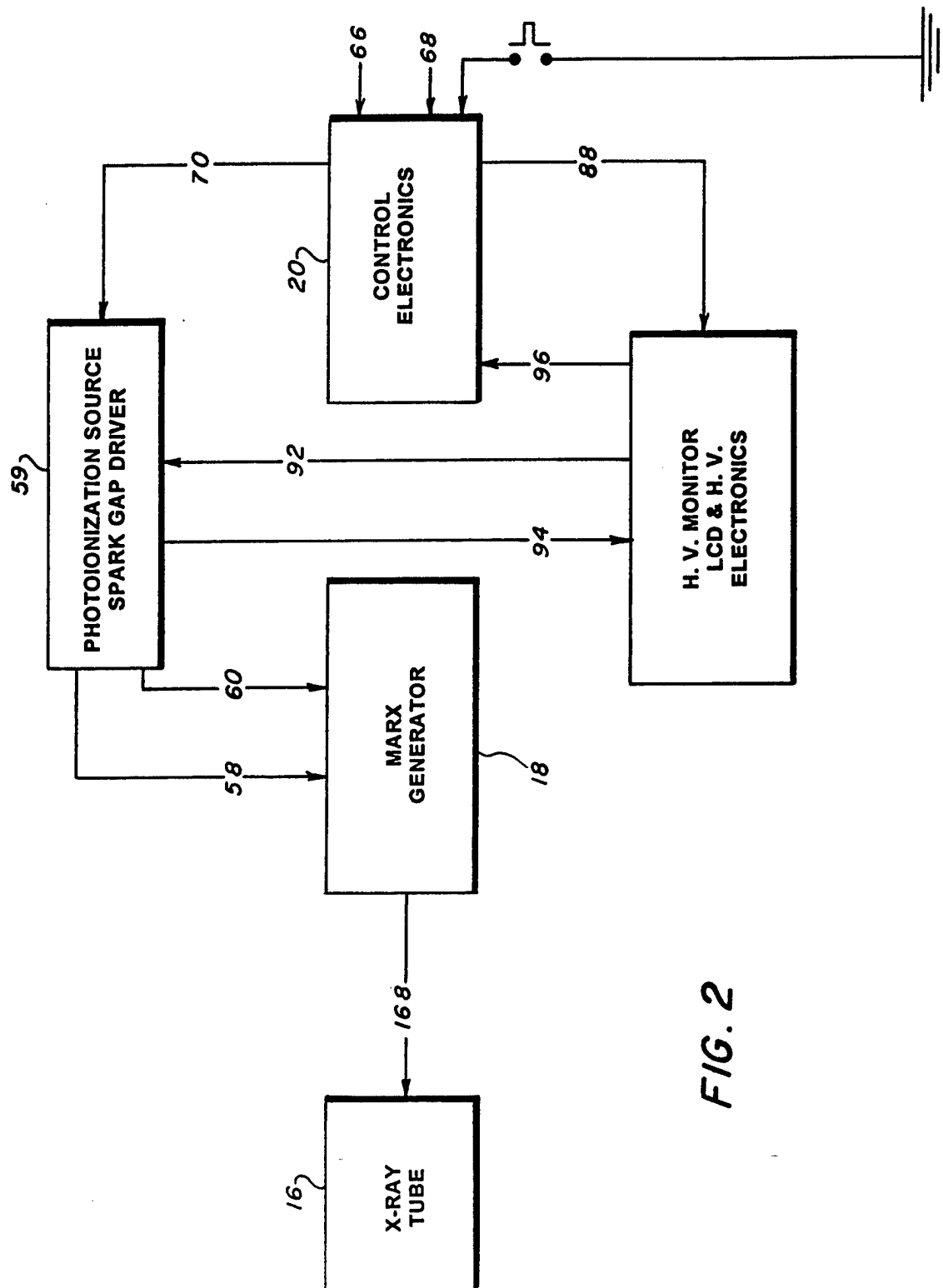
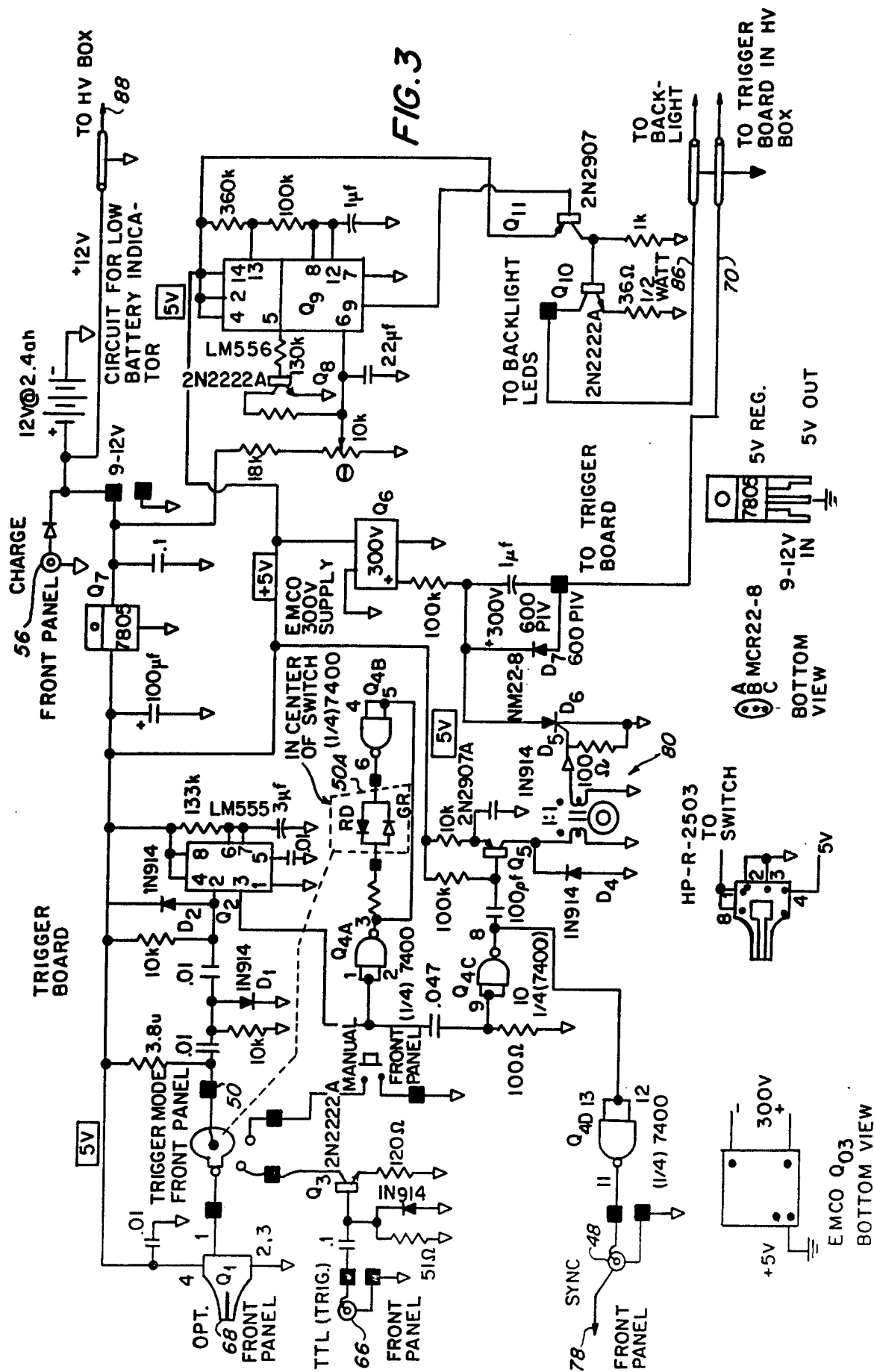


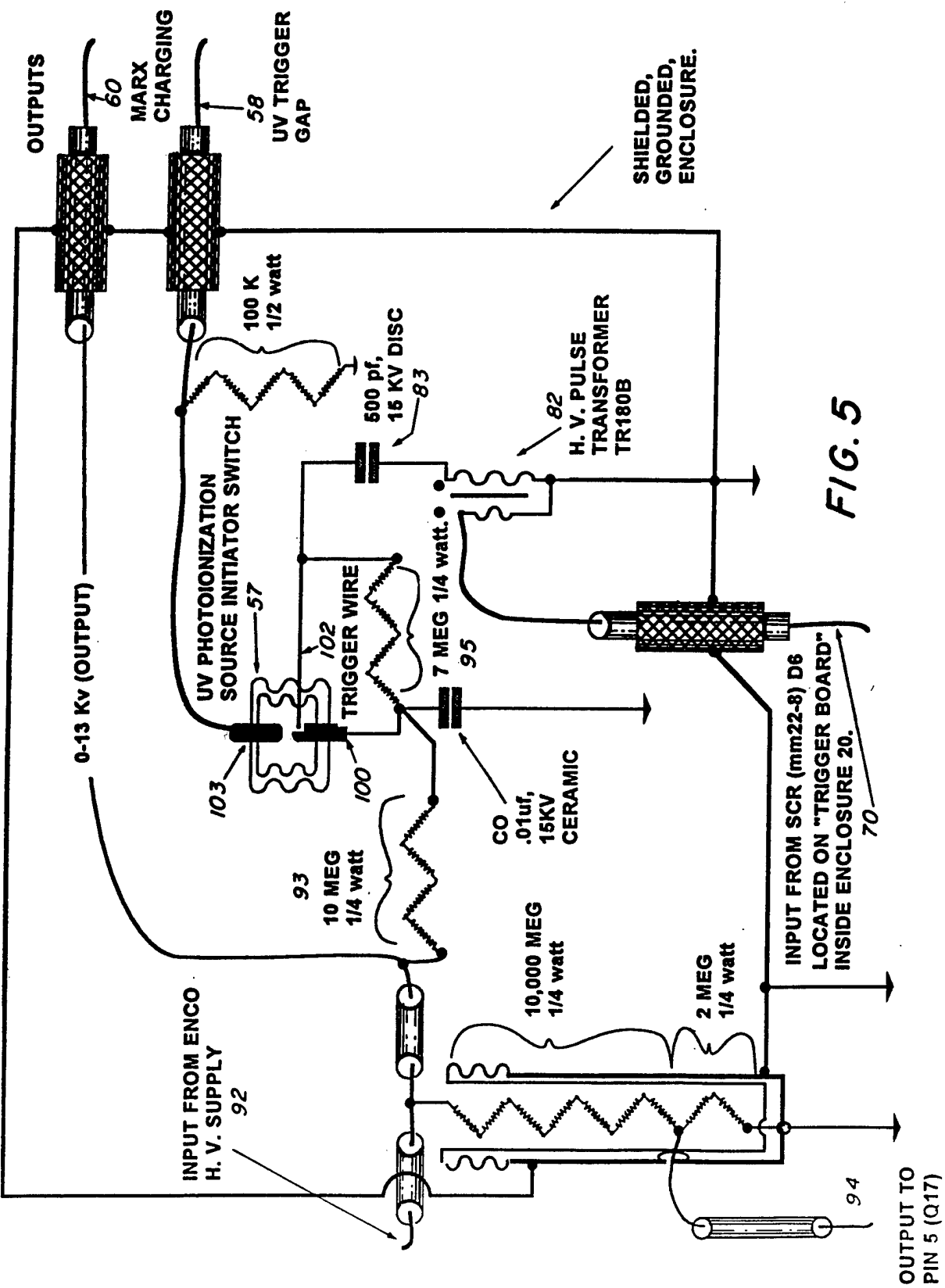
FIG. 2



HIGH VOLTAGE ENCLOSURE



FIG. 4



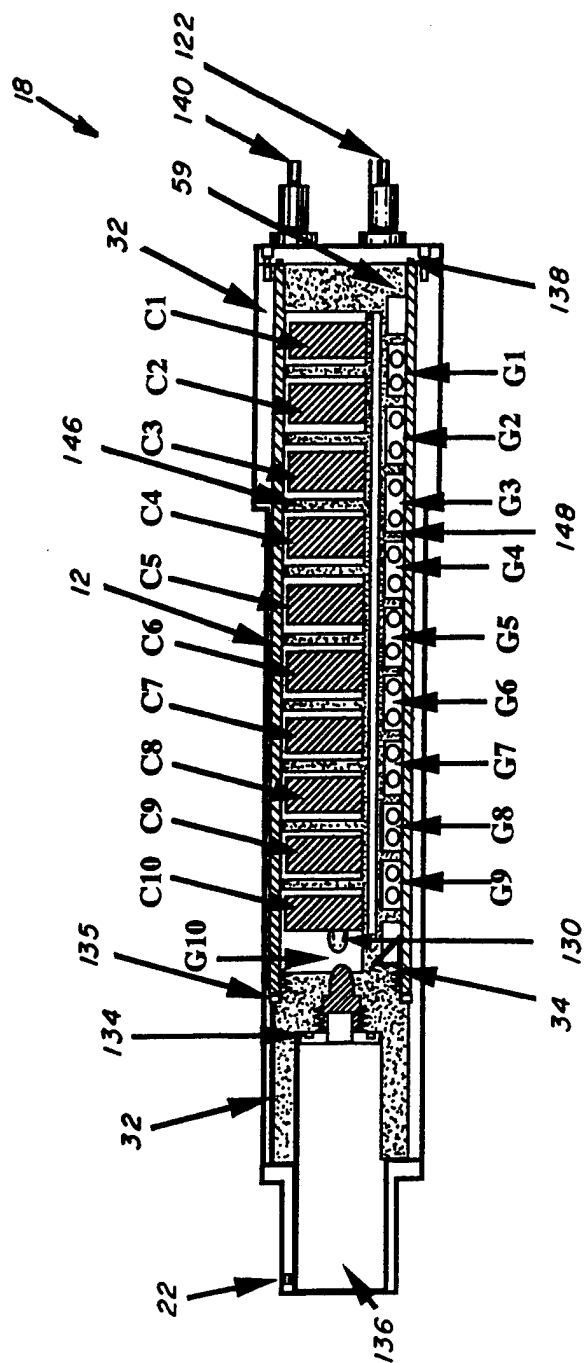
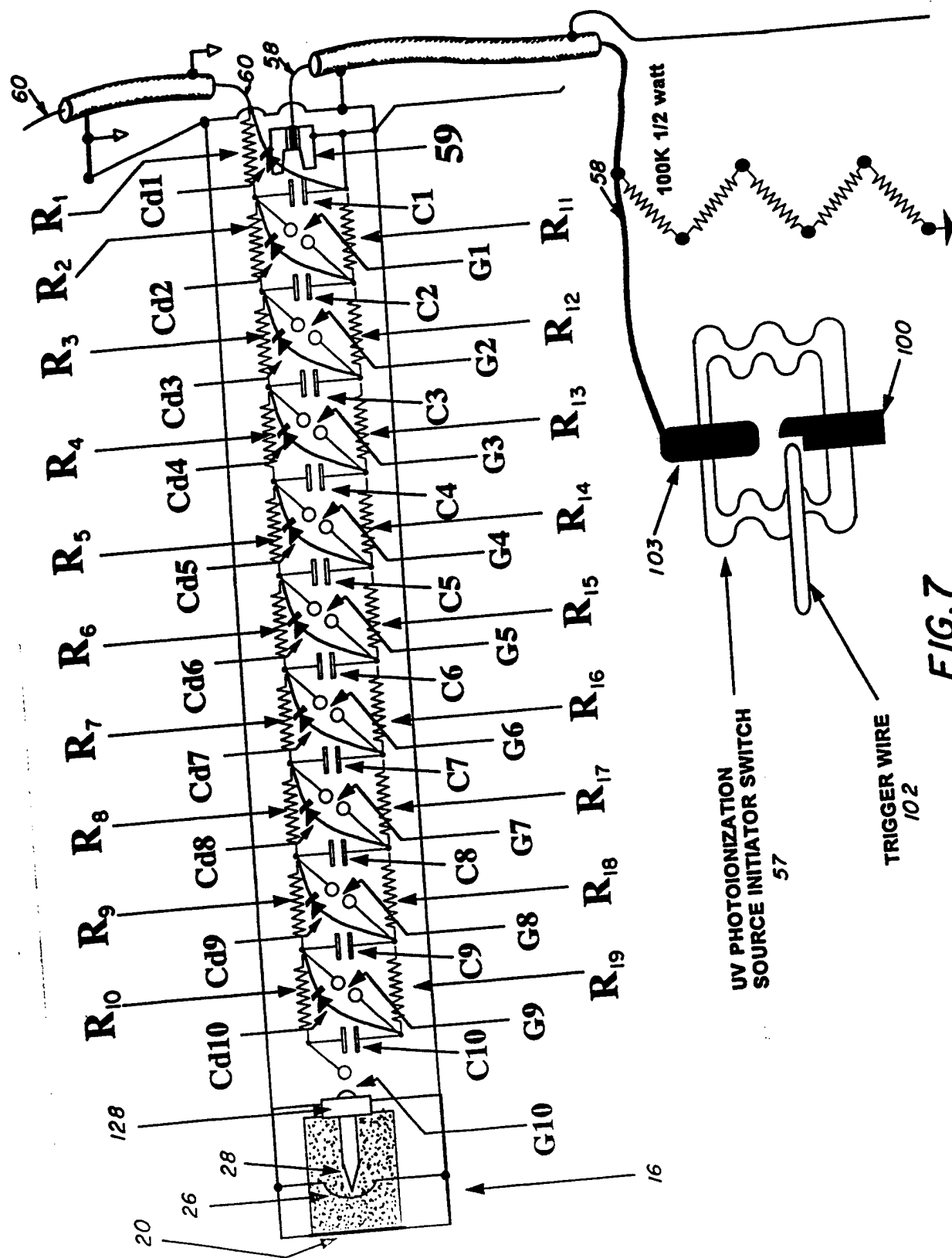


FIG. 6



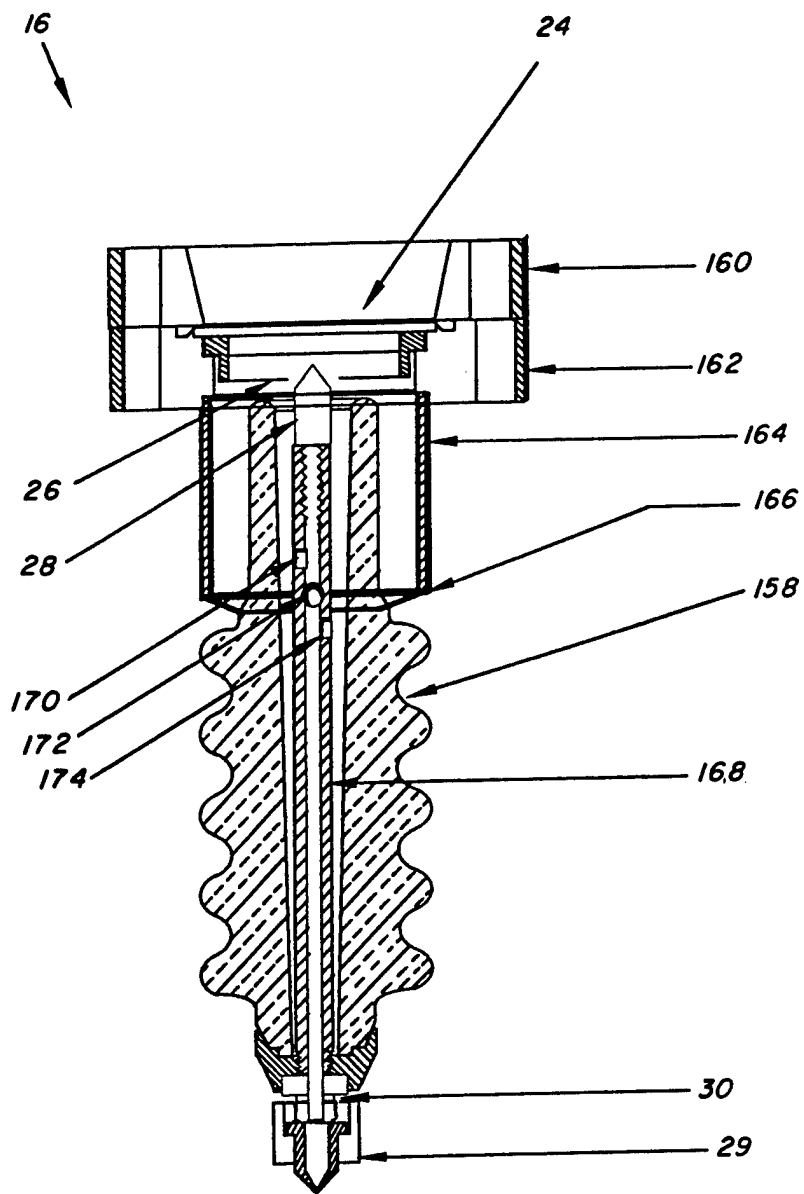


FIG. 8

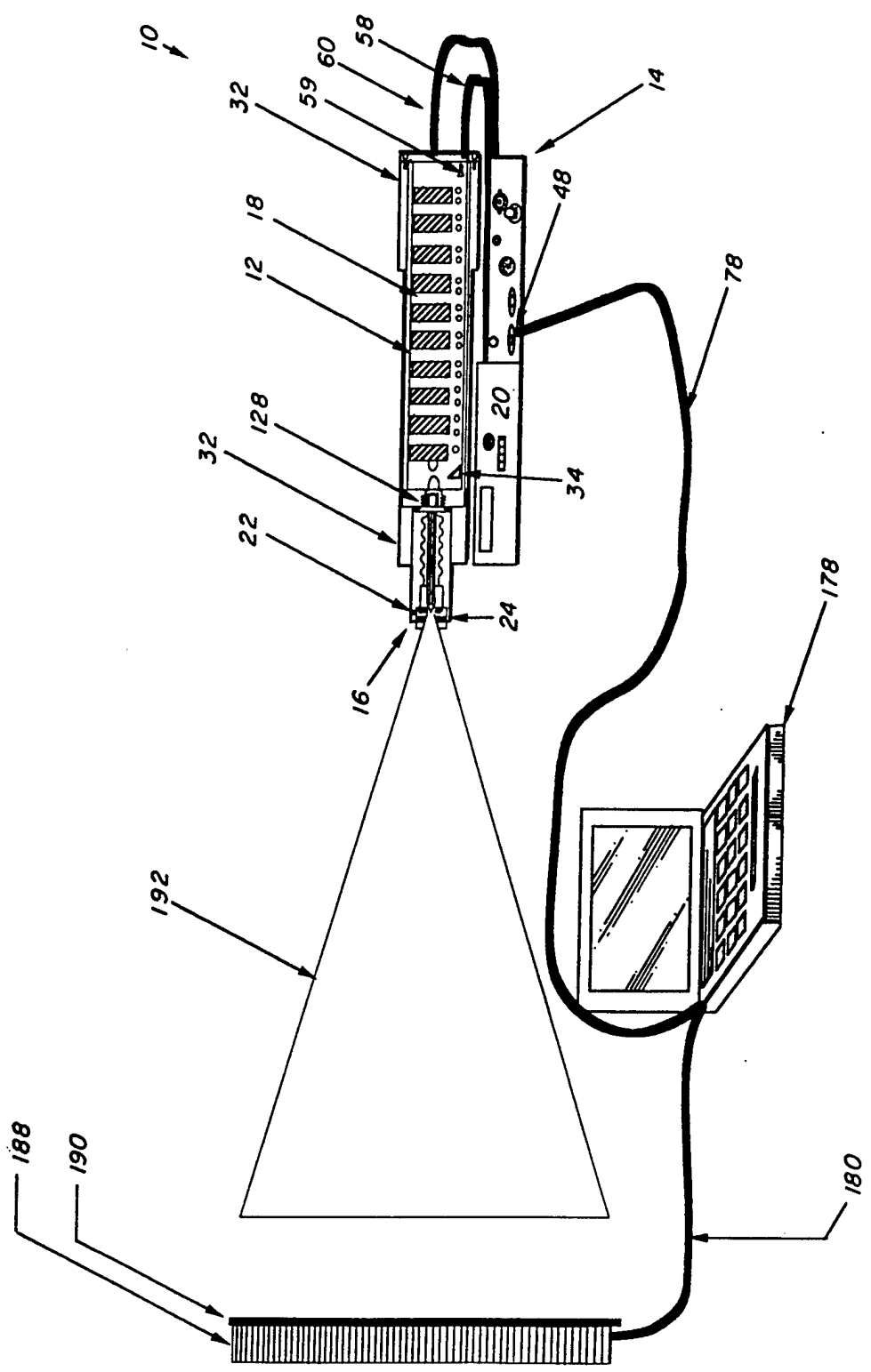


FIG. 9