United States Patent [19]

Baker

[11] **3,879,610**

[45] **Apr. 22, 1975**

[54] **IONOGRAPHIC EXPOSURE METHOD, APPARATUS**

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[73] Assignee: **Diagnostic Instruments, Inc.**, San Diego, Calif.

[22] Filed: **Aug. 27, 1973**

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[52] **U.S. Cl.** **250/315**

[51] **Int. Cl.** **B41m 5/00**

[58] **Field of Search** ..... 250/315 A

[56] **References Cited**

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3,780,288 12/1973 Dryden ..... 250/315 A

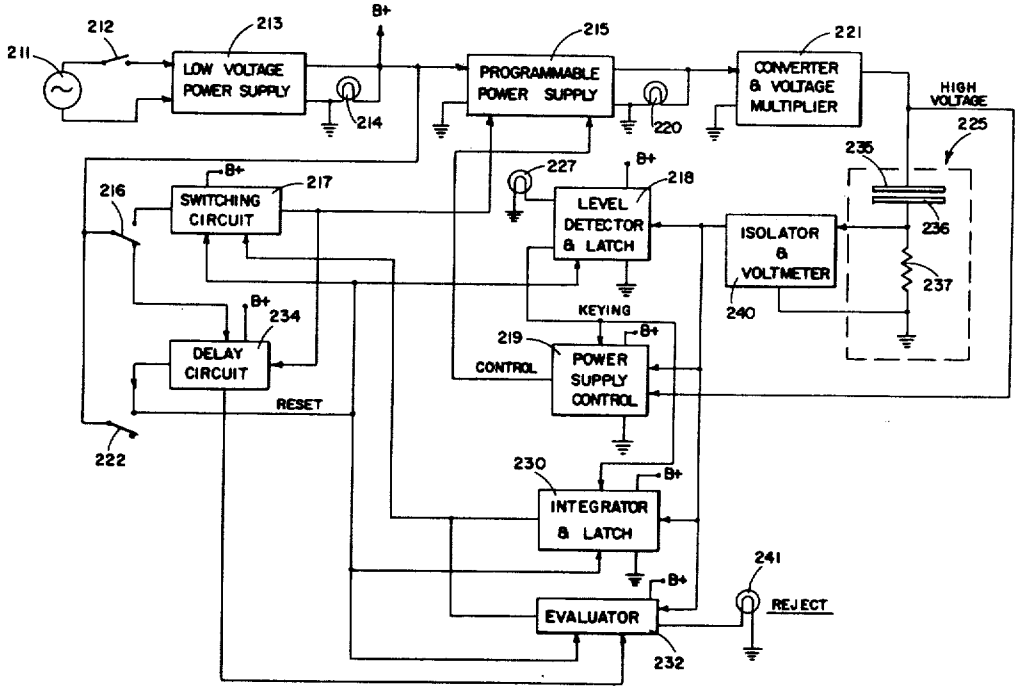
Primary Examiner—James W. Lawrence

Assistant Examiner—C. E. Church

[57] **ABSTRACT**

In a system for controlling ionographic imaging potential, an ionographic exposure technique and associated apparatus whereby an ionographic cassette means is subjected to an imaging potential according to a prescribed program involving a preparatory "test sequence" and an "imaging sequence" wherein an imaging potential is developed and applied to ionographic electrodes in a prescribed programmed manner, while monitoring the ionographic current output and providing for electrical leakage check procedures.

23 Claims, 8 Drawing Figures



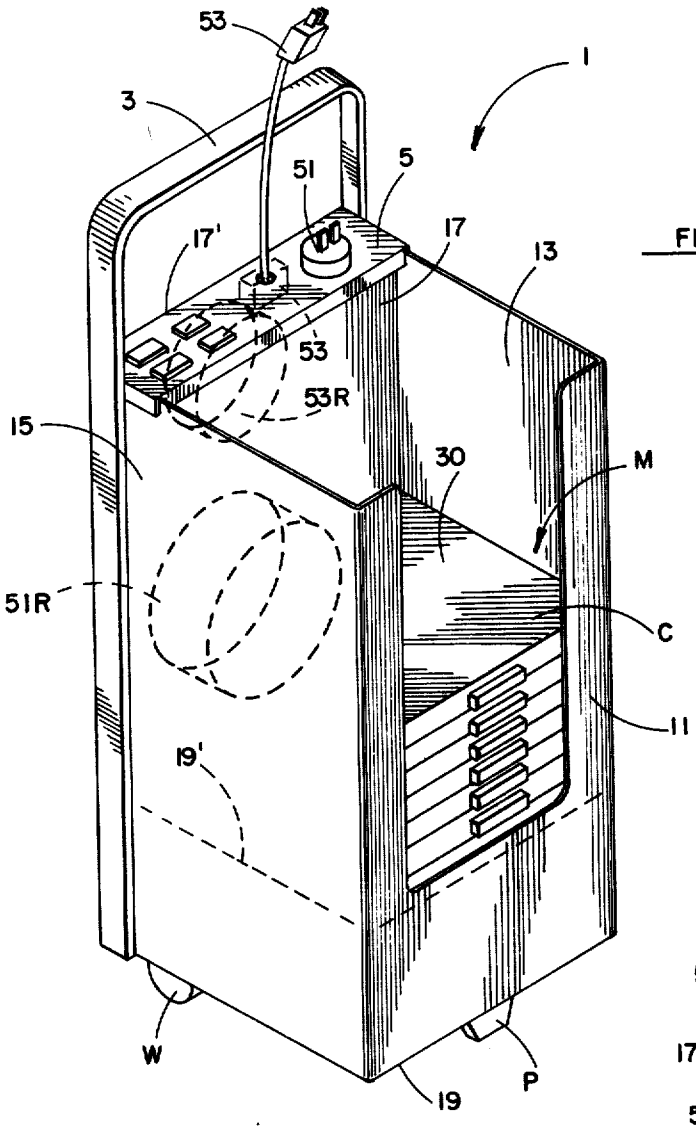


FIG. 1

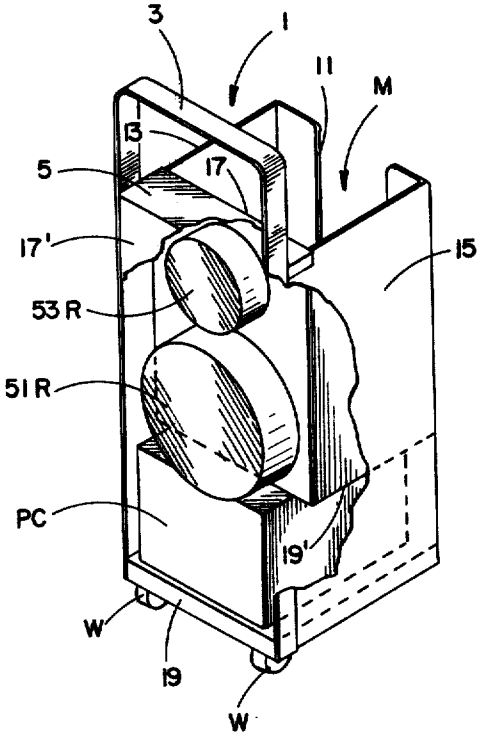


FIG. 2

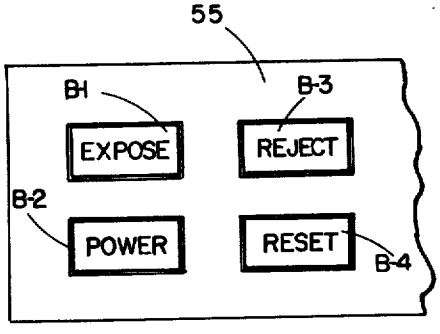


FIG. 3

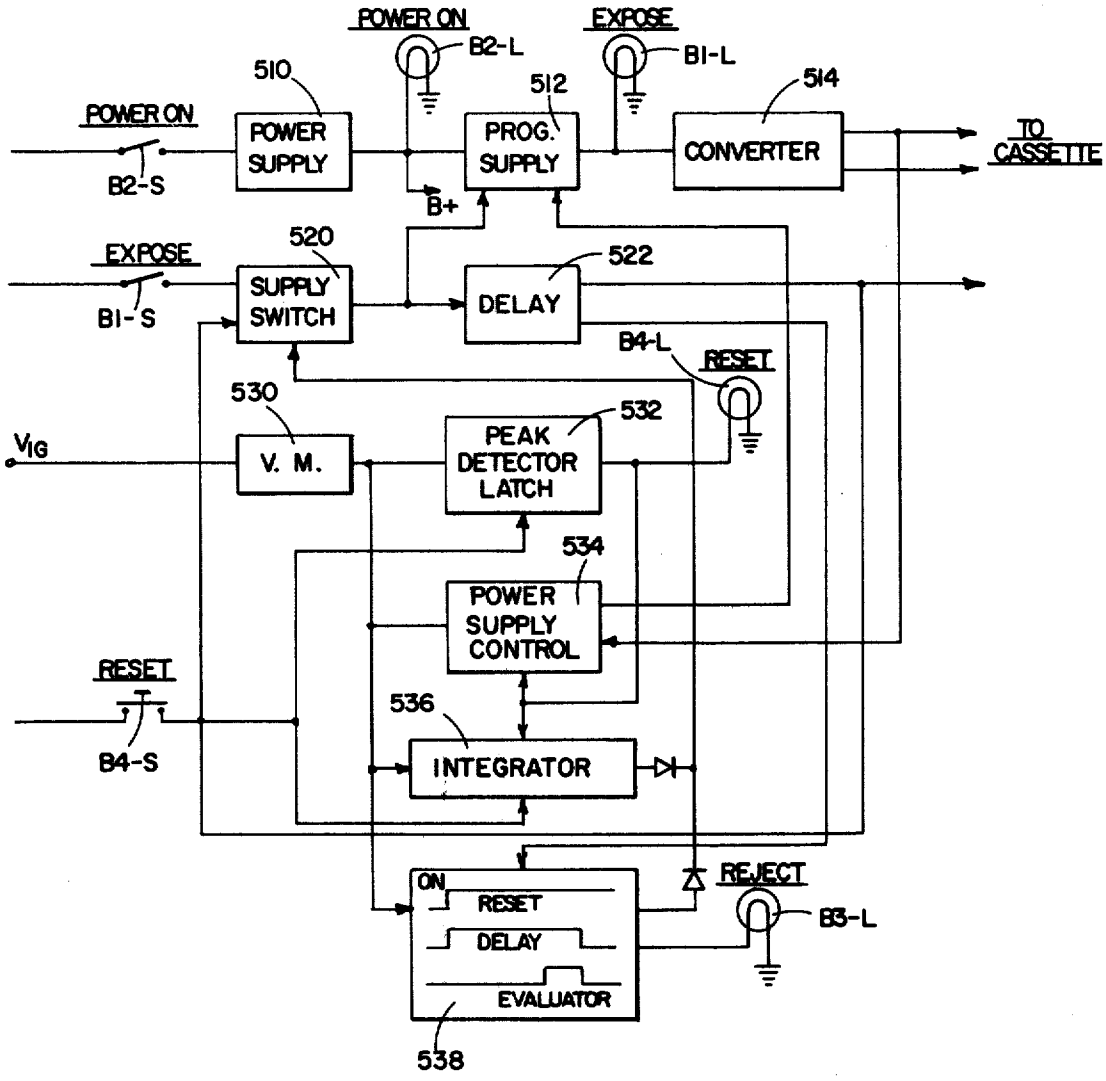

POWER ON
B2-L
EXPOSE
B1-L
510
512
514
POWER ON
POWER SUPPLY
PROG. SUPPLY
CONVERTER
TO CASSETTE
B2-S
B+
EXPOSE
520
522
SUPPLY SWITCH
DELAY
B1-S
B4-L
RESET
530
532
VIG
V. M.
PEAK DETECTOR LATCH
534
POWER SUPPLY CONTROL
RESET
536
INTEGRATOR
B4-S
ON
RESET
DELAY
EVALUATOR
REJECT
B3-L
538

FIG. 4

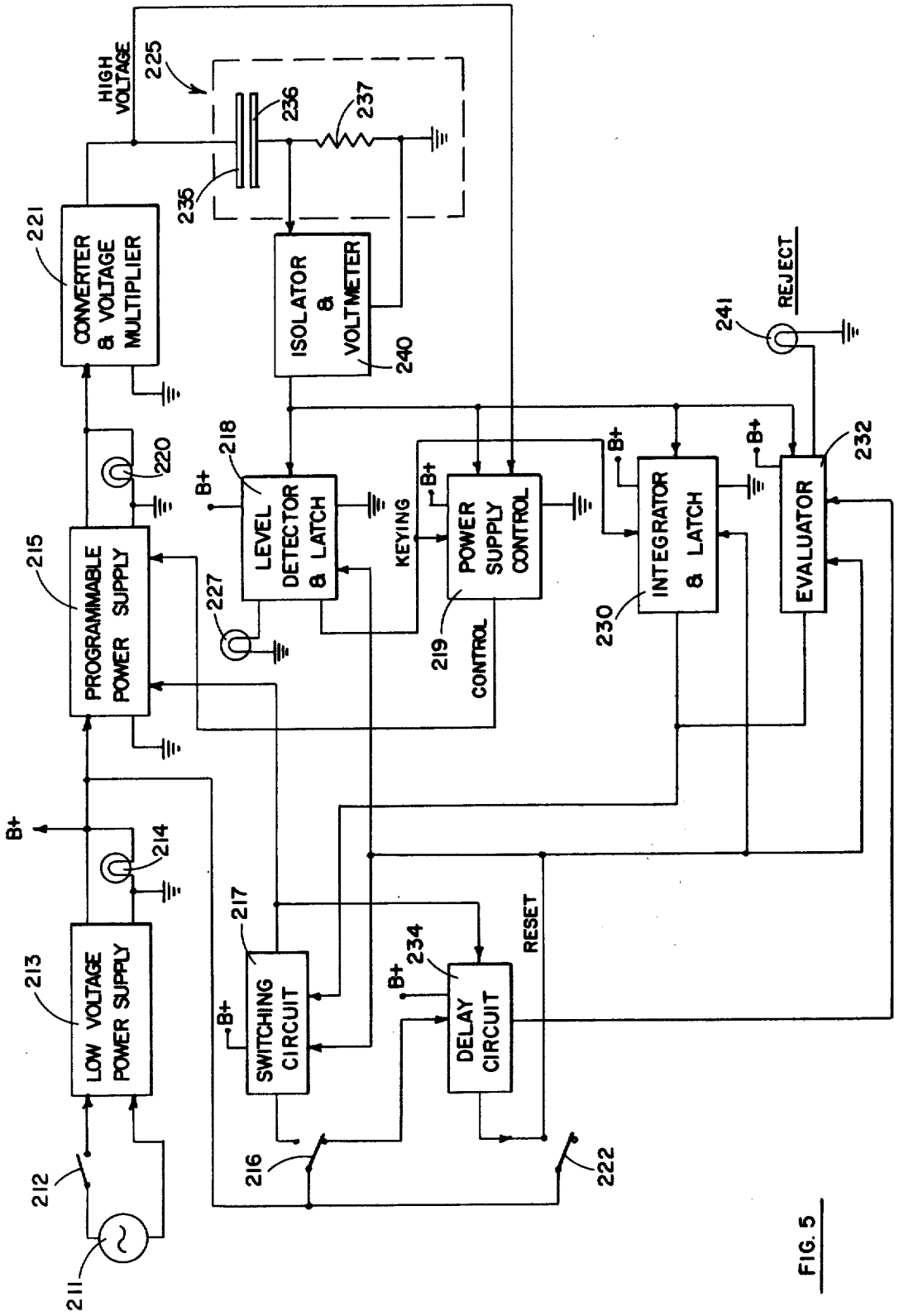

HIGH VOLTAGE
225
236
237
235
221
CONVERTER & VOLTAGE MULTIPLIER
ISOLATOR & VOLTMETER
240
241
REJECT
220
218
B+
LEVEL DETECTOR & LATCH
KEYING
POWER SUPPLY CONTROL
INTEGRATOR & LATCH
EVALUATOR
232
215
PROGRAMMABLE POWER SUPPLY
227
219
CONTROL
230
B+
214
213
LOW VOLTAGE POWER SUPPLY
217
SWITCHING CIRCUIT
234
DELAY CIRCUIT
RESET
212
216
222
211

FIG. 5

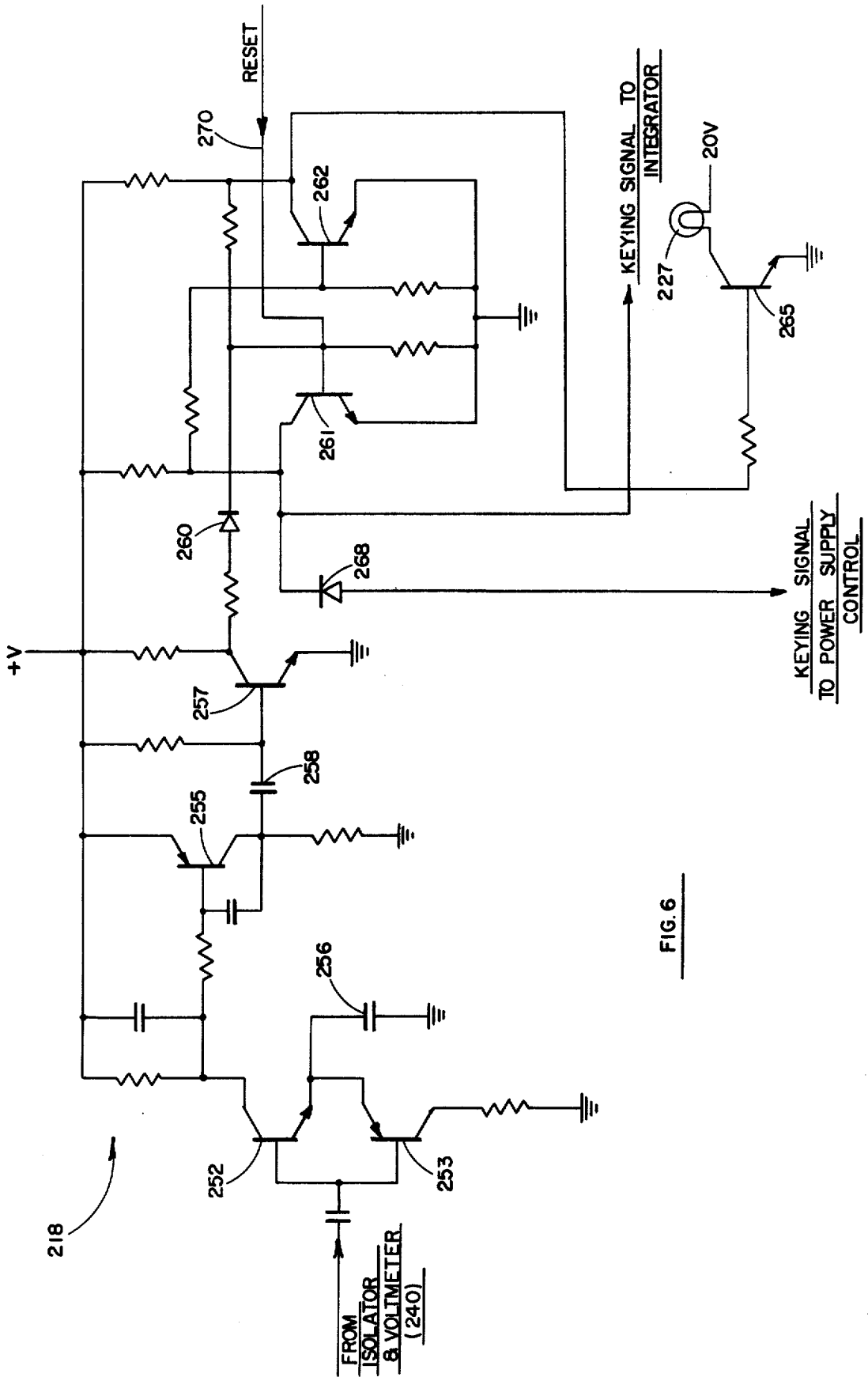

RESET
270
262
261
260
268
257
258
255
256
252
253
218
+V
20V
227
265
KEYING SIGNAL TO INTEGRATOR
KEYING SIGNAL TO POWER SUPPLY CONTROL
FROM ISOLATOR & VOLTMETER (240)

FIG. 6

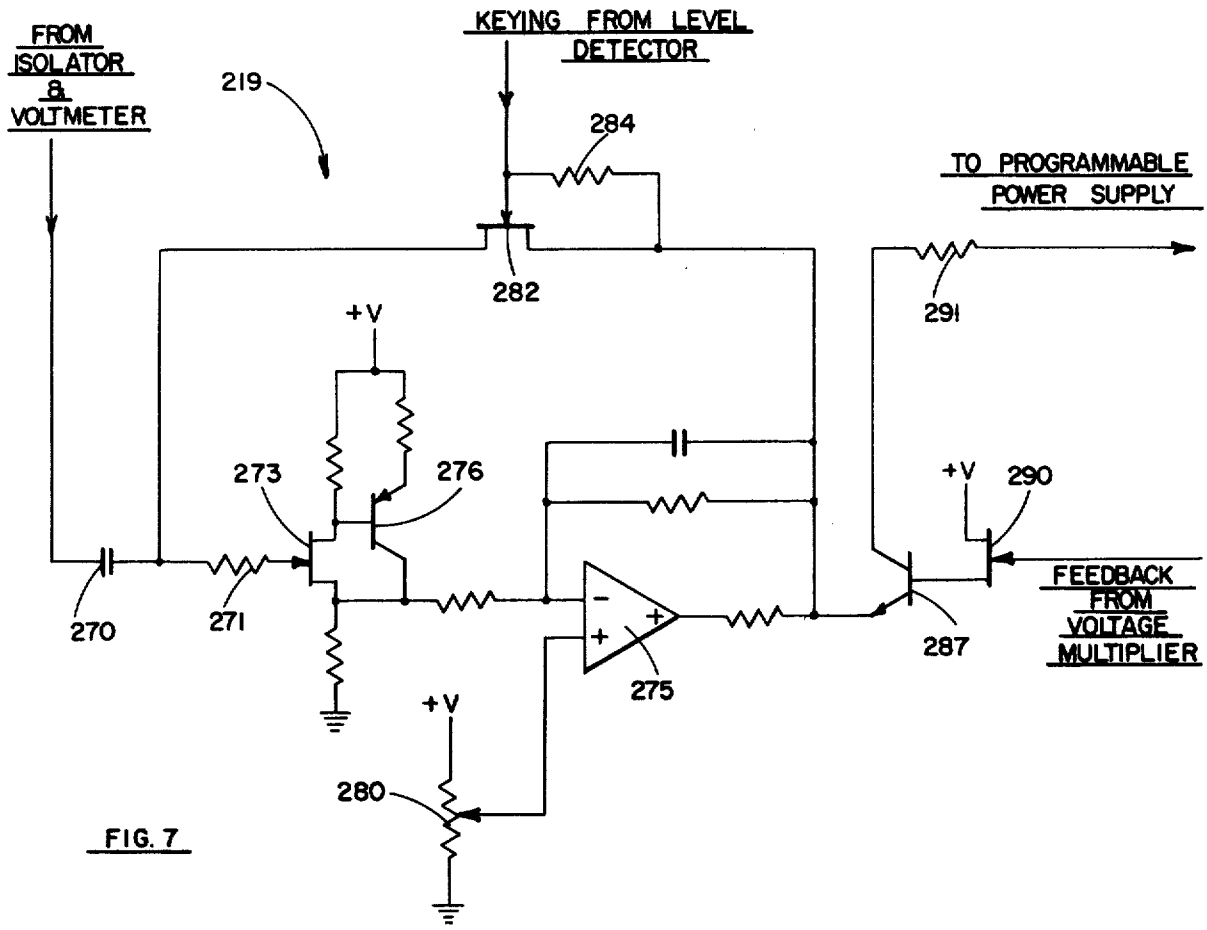

FROM ISOLATOR & VOLTMETER
219
KEYING FROM LEVEL DETECTOR
284
TO PROGRAMMABLE POWER SUPPLY
282
291
+V
273
276
+V
290
270
271
275
287
FEEDBACK FROM VOLTAGE MULTIPLIER
+V
280

FIG. 7

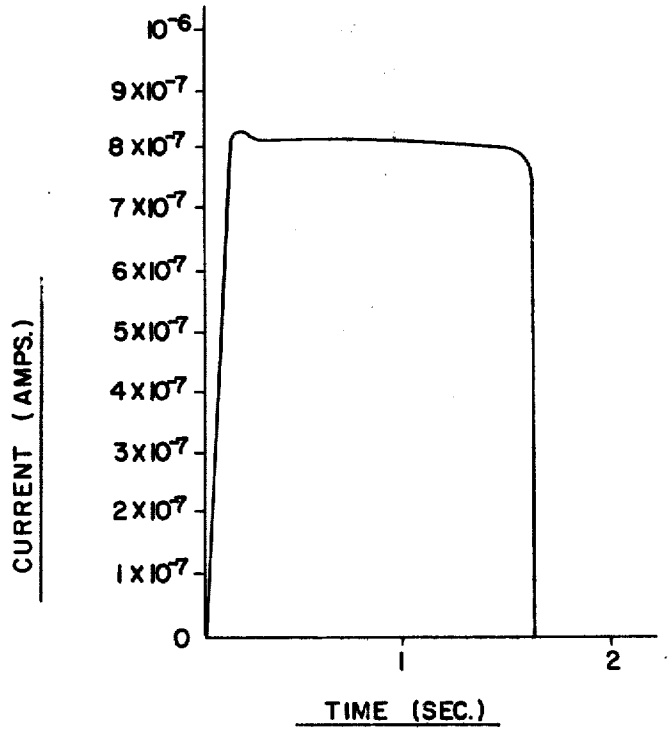

10^{-6}
9×10^{-7}
8×10^{-7}
7×10^{-7}
6×10^{-7}
5×10^{-7}
4×10^{-7}
3×10^{-7}
2×10^{-7}
1×10^{-7}
0
1
2
CURRENT (AMPS.)
TIME (SEC.)

FIG. 8

IONOGRAPHIC EXPOSURE METHOD, APPARATUS

BACKGROUND OF THE INVENTION

The subject invention relates to ionographic imaging, and more particularly to techniques and associated apparatus for radiation-exposing ionographic cassettes in a prescribed manner while monitoring cassette conditions and operation. Workers in the arts dealing with ionographic devices are aware that many difficulties are typically encountered in the course of generating an ionographic charge image, especially if one wishes to image with minimum of X-radiation exposure to the patient, yet secure reliable, repeatable results the first time.

Of course, ionography and its underlying principles have been known for some time and involve the generation and development of X-radiation images utilizing photoemissive source means and electrostatic image media as described in U.S. Pat. No. 2,221,776 to C. Carlson.

The ionographic process as understood today, generally employs two plane parallel electrodes defining an intermediate "working gap" across which a given DC potential is established so that, when the gap is subjected to an X-radiation imaging pattern an electrostatic record thereof may be generated. Typically, one (anode) electrode is made relatively radiotransparent and has affixed thereto an image-charge-receiving dielectric receptor sheet (e.g. of Mylar by duPont), whereas the other (cathode) electrode supports a photoemissive layer confronting this receptor across the gap and is adapted to generate charged particles reflecting the incident X-radiation pattern and produce the charge image on the receptor. As workers in the art understand, a subject which is flooded with a prescribed amount of imaging radiation (usually X-ray photons, although gamma photons are, at times, feasible) will differentially absorb the flux according to its distribution of mass absorption coefficient and thickness so that the flux emergent from the subject will (inversely) reflect its relative absorption in a sort of "shadow image" radiation pattern. When this pattern strikes the said photoemitter it causes ejection of electrons into the gap; this, in turn, causes particles to be generated and deposited on the receptor in a charge distribution reflecting the radiation pattern.

A typical ionographic cassette, generally along the lines aforedescribed and particularly contemplated for use with the subject invention, comprises a "prepackaged" arrangement, where the ionographic electrodes and associated elements are arranged in a multilayered sandwich, enclosed in an outer envelope and are provided with external connector means, etc., this more fully described in copending, commonly-assigned U.S. Pat. application, Ser. No. 264,247 entitled "Cassette Unit" by Sidney E. Hindell, filed on June 19, 1972 (herewith incorporated by reference). As mentioned below, such a cassette is particularly suited for use with the subject invention, being portable, requiring no particular exposure setup and also including connector terminals suited for application of exposure potential.

It has become apparent to the inventors that in the course of exposing and imaging such ionographic electrodes, certain problems are experienced which can interfere with the quick, efficient generation of an image and/or can subject the patent to unnecessary, possibly

deleterious, radiation. For instance, a patient may be subjected to a repeated X-radiation when a "good" image is not obtained—e.g. upon discovery, after the fact, that dust particles or other leakage sources in the cassette spoiled a "shot". It is no easy matter to pre-test or otherwise control the condition of such ionographic cassettes to prevent this absolutely, and, as a practical matter in the present state of the art there is almost certainly going to be some such leakage or other problem with at least some small percentage of today's cassettes.

Such problems are further compounded in the light of more sophisticated, recently developed ionographic imaging techniques such as those provided to compensate for image charge retarding potential. That is, as some workers in the art may realize, a retarding field is built up on a receptor as charges are deposited and this tends to impede the charging process. In order to alleviate this difficulty, it has been proposed to use a controllable power supply whereby the potential applied to the ionographic cassette electrodes is increased as the image charge builds up, thus maintaining the electric field and current flow in the cassette gap at a constant level. These problems and the related control voltage technique for solving them are discussed in two co-pending, commonly-assigned U.S. Patent applications, one entitled "Field Control in Imaging Systems", Ser. No. 158,172 filed 30 June 1971; the other, entitled "Electrical Power Supply Control System", Ser. No. 260,822, filed 8 June 1972 (both herewith incorporated by reference).

More particularly in Ser. No. 158,172 an ionographic imaging system is described for depositing electrical charges on an insulative surface. In the system, the ionographic imaging process is accomplished in a gap formed between two electrodes. As noted in this application, a retarding field is built up as charges are deposited on the insulative surface, thereby tending to impair the efficiency of the process. In order to overcome this difficulty, the use of a controllable power supply is described by means of which the potential applied to the electrodes is increased as the charge is built up so as to keep the electric field and the current flow in the gap constant. That is, there is provided a system for programming the supply of current from a power source to a load (ionographic gap) in response to the sensed current flowing through this load.

The system of related Ser. No. 260,822 is similarly adapted for controlling the supply of current to a load, (which may comprise elements of an ionographic imaging system). This current is sensed and when a "peak" level is reached, a level detector circuit initiates the operation of control circuits which control the supply of current to the load. The load current is maintained substantially constant by means of a power supply control which controls the output voltage of a programmable power supply during a predetermined period of time, as measured by an integrator, which integrates a signal in accordance with the load current. The integrator operates to automatically cut off the supply of current to the load when the desired flow to the load has been attained. Such a system involves a unique combination of circuitry which can automatically (or, at times, semiautomatically) provide all of the control functions necessary for supplying current in an optimum manner to such a load. Control of input power can be somewhat critical for the proper operation of ionography equipment; and this system can provide such accurate con-

trol—yet without the need for highly-experienced or highly trained operators. That is, critical functions are accomplished automatically, so that the operation is relatively foolproof; further including various operator-warning indicators to further reduce the likelihood of improper equipment operation or of operating the equipment when a malfunction conditions exists. FIGS. **5–8** illustrate details of this latter system and the referenced application U.S. Ser. No. 280,822 may be referred to for details.

The following Specification describes and illustrates related ionography imaging techniques and associated apparatus primarily geared to alleviating difficulties like those aforementioned and to, in general, make the ionographic exposure process more efficient, more controllable and less hazardous to the human subject—doing so according to cassette handling techniques involving leakage pretesting, image-current monitoring and related reject and reset procedures.

OBJECTS

It is therefore an object of the subject invention to improve ionographic imaging techniques and associated apparatus so as to alleviate at least some of the aforedescribed problems and provide the herein described features and advantages.

It is another object to provide such in terms of monitoring ionographic gap current; before, during and after exposure.

Yet another object is to so monitor this current in an automatic program.

A further object is to provide such a program whereby ionographic gap electrical leakage sources may be tested-for and detected before exposure of a human subject.

Yet a further object is to provide such monitoring for ionographic exposure systems operating according to a programmed voltage-control mode adapted to compensate for image charge retarding potential.

A still further object is to provide such techniques and associated apparatus and systems adapted to automate cassette check-out with simple, convenient operator indicators.

Another object is to provide such an automatic system which is nonetheless conveniently subject to intervention and override at the discretion of the operator.

These and other objects of the invention will become more evident through consideration of the following disclosure and illustrative drawings wherein preferred embodiments are indicated comprising, in brief, an automatic exposure console for ionographic cassettes adapted in a mobile apparatus to provide for the carriage of electronic imaging controls and related connector means as well as storing the cassettes themselves.

FIGURES

For a better understanding of the invention, as well as other objects and further features thereof, reference is invited to the following detailed description of a preferred embodiment, to be read in conjunction with the accompanying drawings, wherein like reference numerals denote like parts, these drawings comprising:

FIG. **1**, an upper perspective view of an ionographic exposure console according to the invention;

FIG. **2**, a different perspective, partly sectioned, of the console in FIG. **1**;

FIG. **3**, an enlarged plan view of the control panel portion of the control in FIGS. **1** and **2**;

FIG. **4**, a schematic diagram of an exposure control system suitable for use with the console in FIGS. **1** and **2**;

FIG. **5**, a functional block diagram of a preferred embodiment of a power supply control system of a type useful with the invention;

FIGS. **6** and **7** are schematic circuit drawings illustrating a level detector and latch circuit and a power supply control circuit, respectively, for the system of FIG. **5**; and

FIG. **8** graphically illustrating a typical current control function of this system.

DESCRIPTION OF PREFERRED EMBODIMENT

Referring now to FIGS. **1** and **2**, a preferred embodiment of the system according to the invention is illustrated comprising ionographic exposure console **1**. Console **1**, according to the invention, is adapted to store an array of ionographic cassettes C, as well as to house electrical exposure control means including exposure control assembly PC (show in phantom in FIGS. **1** and **2**) together with associated electrical connector means (including extensible power cable **51** and extensible cassette cable **53**) and an associated control panel **55**, including four control indicators (**B1** through **B4**, shown enlarged in FIG. **3**). Generally speaking, console **1** will be seen as adapted to "bring the imaging controls to the patient" and to the radiation source, no matter where located. Such a console can thereby facilitate ionographic imaging at any one of several sites, essentially carrying all that is necessary in one compact, easily-manipulated package requiring only a conventional electrical outlet and an imaging (X-ray) source.

More particularly, console **1** comprises a flat base, or platform **19** upon which are mounted the aforementioned electrical control means PC, shelf (or magazine floor) **19'**, the control panel and its supporting wall and four walls surrounding a cassette storage magazine M. The console is readily transported and manipulated, being carried on a pair of rolling casters (wheels W) rotatably mounted under platform **19** together with a supporting stanchion P for establishing a stable rest-position. Console **1** is constructed of a size and weight convenient for such hand manipulation and so as to conveniently package and position the imaging controls, as well as to carry a reasonable number of cassettes C, (which are typically 8 inches by 10 inches by ⅜ inches thick). The illustrated console embodiment will be understood as preferably about 1 foot square (12 inches by 11 inches) in crossection, by 2 feet high (with a handle **3** extending about 10 inches higher)—these dimensions having been found desirable for typical imaging routines.

For instance, it has been found that such a console, fully-loaded with all electronics and other controls and carrying a full magazine of cassettes 30 is relatively compact, reasonably light, well balanced and mobile, (weighing on the order of 50 pounds) and, yet stable and convenient to use "at rest". Such a unit is easily maneuvered by an operator, being rocked back (with stanchion P raised up; e.g. tilted) to center the weight over wheels W and easily rolled along and maneuvered, thus tilted in the manner of the well known "hand truck". Handle **3** is accordingly located above the rear of the console and, above control panel **55**; and, prefer-

ably it extends down along sidewalls **13, 15** to reinforce these and to couple securely and directly, with base platform **19.**

Furthermore, the cassette/magazine M and the imaging controls are disposed to be "operator handy", e.g. the manipulative elements on control panel **55** are located at "operator-access" height and convenient to the typical seated operator (who would normally be seated on a stool or the like, attending a patient, seated or prone, with a cassette under the member to be imaged by an adjacent X-ray source. Thus, with an operator seated upon a stool, the connectors and control buttons on panel **55** lie within easy reach and in clear view.

Console **1** has thus been designed, according to a feature of novelty, to store a number of ionographic cassettes and carry them to the imaging site along with the control elements using parts arranged in an attractive, functional package which is aesthetically pleasing and compatible for use in the typical imaging environment (such as an office, clinic, hospital or laboratory). The console is also relatively compact and easy to store, e.g. in a closet.

To described its mechanical parts more particularly, console **1** includes cassette magazine M defined by a bottom shelf **19'** and, supported thereon, a pair of opposed sidewalls **13, 15** joined by front and rear walls (**11, 17** respectively), front wall **11** being cut-out down its midsection to afford ready access to the cassettes while yet retaining them in registry. A space for locating connector reels **51-R, 53-R** (shown in phantom in FIGS. 1 and 2) is provided behind magazine rear wall **17,** (reels rotatably hung thereon) and under panel **55,** being closed by outer rear wall **17',** this space being about 11 × 23 by 3 inches deep in this embodiment. The materials may be sheet steel or any like rigid construction material, preferably relatively lightweight, yet strong. Adjacent walls are preferably made of unitary parts, folded, stamped and/or fastened together such as by welding, riveting or bolts, etc., as known in the art.

As mentioned, the cassette cable (terminal connector **53**) providing electrical connection to the cassette electrodes in a plug-in fashion as known in the art, is made extensible and connected to the electrical control stage PC through a relatively elongate intermediate cable section, wrapped about associated rotatable extension (storage) reel **53-R,** being wound thereabout to be manually extensible from panel **5** a suitable distance. Here, a reel about 6 inches in diameter, carrying up to about 12 feet of line is adapted to be connected to the working cassette, positioned under the member to be imaged. Reel **53-R** is rotatably mounted from the rear of rear magazine wall **17** and is rotationally spring-biased to automatically urge return of cable **53** when extended therefrom any appreciable amount, as known in the art. Connector **53** is also, preferably, adapted to be coupled and decoupled so as to prevent the risk of the operator being confronted with any "high voltage" surface.

Similarly, power cable **51** is provided of prescribed length, to be connected to control stage PC through an intermediate length, a portion of which is wound rotatable, spring-return extension reel **51-R** provided therefor, as with aforementioned reel **53-R.** Here, a maximum of about **10'** of cable was found suitable for reaching "house power", with a reel **51-R** about 6 inches in diameter.

The control switch-indicator panel **5** (i.e., portion on which indicators **B-1** through **B-4** are mounted) is shown in plan view in FIG. **3** and described as follows, the description being rendered in conjunction with a summary functional description of a typical mode of operating and using this console embodiment.

As indicated in FIG. **3,** and as marked on the respective bezels there shown, these indicators comprise an "EXPOSE" control **B-1,** a "POWER" control **B-2,** a "REJECT" control **B-3** and a "RESET" control **B-4.** The switch and lamp portions of controls **B-1, B-2, B-4** are denoted by the suffix -S or -L, respectively. For instance, POWER control **B-2** has a switch portion, **B2-S** and a lamp portion **B2-L,** as depicted in FIG. **4.** REJECT control **B-3** comprises merely a lamp **B3-L.** Further details regarding these controls and the associated functions and the electronic control mode are described below in conjunction with the description of FIG. **4.** EXPOSE condition may, alternatively be characterized as "READY".

More particularly, EXPOSE control **B-1** comprises an "Expose-OK" (or "Electrodes-Hot") indicator lamp **B1-L** and a bistable ("two-way") manual switch **B1-S,** successive actuations of which couple, and decouple, DC input power to the cassette electrodes, as more fully explained below. The POWER control **B-2** comprises a "Power-On" indicator lamp, **B2-L** and an associated power switch, **B2-S,** similar to EXPOSE switch **B1-S,** successive actuations thereof acting to connect and disconnect, line voltage to a DC power supply means; the active output from which is indicated by lamp **B2-L.** In a similar manner RESET control **B-4** comprises a lamp **B4-L** and a monostable switch **B4-S,** like **B2-S,** successive actuations of which couple and decouple energizing power to detections, monitoring and control means as further explained below. RESET lamp indicator **B4-L** is adapted to be energized in accordance with the energization of a peak detector stage **532** as described below.

As mentioned, the REJECT indicator simply comprises a lamp **B3-L** adapted to be energized concurrent with evaluation stage **538** (see FIG. **4** description for details) upon detection of leakage current above a prescribed minimum. These indicator lamp means are, preferably, arranged to glow in different, distinguishing colors so as to be readily indentifiable by an operator; thus, Power-On lamp **B2-L** is rendered in a "cautionary yellow" shade, Expose lamp **B1-L** is a "permissive green", Reject lamp **B3-L** is an "attention-getting" red, and Reset lamp **B4-L** is a neutral white.

OPERATION

In a typical operational sequence, an operator, having brought the (portable) exposure console **1,** with its supply of cassettes, to the X-ray source control and placed one of the portable cassettes under the member to be imaged (in operative relation with the X-ray source, as known in the art), proceeds to arrange the console so he may conveniently interact with its imaging controls (i.e., manipulate and observe them during the image sequence). The operator will usually seat himself on a stool with the X-ray source controls conveniently at hand. Console **1** may be set up quite simply by withdrawing the extensible power cable **51** to plug into the nearest line voltage receptacle and thus energize the console, coupling AC line power to the electronic control unit PC and, similarly, withdrawing the

cassette connector cables **53**, coupling them with the cathode/anode terminal of the cassette and thus connecting it electrically to control unit PC.

The operator is now ready to begin an "Imaging Sequence" proper and accordingly actuates the "Power-On" switch **B2-S**, thus energizing control unit PC, including all power supply terminals, with yellow lamp **B2-L** becoming energized (and remaining so throughout the sequence, unless for some reason the entire machine must be shut down, and power disconnected).

The operator next hits the EXPOSE control **B1**, depressing switch **B1-S**, to couple the power supply stage to a programmed supply sub-stage (details below) and, thence, to energize the cassette electrodes. With this (green) indicator lamp **B1-L** comes "ON" to indicate that the cassette electrodes are "hot" and ready to receive X-ray flux and conduct current across the gap to generate the ionograph charge image.

According to a novel feature hereof, the energization of this EXPOSE indicator serves to automatically invoke a "leakage test" sub-program, whereby, before subjecting the patient and the now-energized cassette electrodes to radiation, the gap between the energized electrodes is tested for leakage current abnormalities. Workers in the art will appreciate that such abnormalities (e.g., excess leakage, over and above the normal, very minor leakage current, on the order of 0.3 microamp) can occur as a result of dust particles or other surface anomalies causing photoemitter "spikes", or from vibration or flexing of one or both of the now hot electrodes, or virtually any factor tending to reduce gap impedance.

It is important for this leakage test step to persist for at least a few seconds, enough to assure that the entire mechanical environment, including the cassette and its electrodes, the patient, etc., and the rest of the imaging environs have equilibrated and come to rest. Thus, a test leakage current reading is, according to a preferred feature, undertaken only after such a prescribed "settling period" and if leakage current is still flowing, thereafter, it is noted only then and not before. Workers in the art will recognize that such a leakage test sequence facilitates the better, more precise operation of the entire imaging sequence and the associated monitoring steps by checking out the system to be sure no leakage factors will impair imaging and thus subject the patient to additional radiation. By also introducing an associated Settling period, this sub-sequence allows transient leakage factors to subside and be ignored, so that when genuine imaging takes place, the leakage current spikes that are detected may be assumed as attributable to relatively persisting factors. The transient factors will be understood as no longer present to interface with optimum image charging. According to this feature of the invention, we have found that, for the system described, a settling period of about four seconds is quite satisfactory, since after this time the leakage current detected is not "transient"; and if it exceeds a prescribed minimum value, the imaging sequence is thereupon aborted and either a further verification is run or else the cassette is put aside as a "leaker".

Furthermore, according to an improved phase of this feature of the invention, this leakage test subsequence has been automated and (as more fully described below) the actuation of expose switch **B1-S** serves to automatically invoke a time settling period (here, 4 seconds) during which RESET indicator lamp **B4-L** is energized, and may be extended and controlled with a manual override control, being automatically de-energized at the termination of this test period unless a reject (excess current) has been detected. Moreover, after this (four second) settling time, a second "Read/-Compare" step is invoked. This involves a "Leakage Current Read/Compare" sequence, here implemented automatically, whereby the magnitude of ionographic gap current is detected and compared to a standard minimum current at the evaluator unit (details below). Upon detection of excess (leakage) current, a latch is "set" with the read REJECT lamp **B3-L** being energized and electrode power being automatically (though temporarily) disconnected.

This Reject test subsequence is, as stated, invoked when the red reject lamp **B3-L** comes on — at which time the power to the cassette and the associated supply circuit is shut down as a precaution (either automatically, as in the system described below relative to FIG. **4**, or manually if preferred) with the green expose lamp **B1-L** also extinguished; but the power lamp **B2-L** remaining on, of course. The system is accordingly in condition for resumption of the expose sequence described above and accordingly and to verify this Reject condition, the Reset button (**B4-S**) is hit again and power reapplied to the cassettes' electrodes (and the balance of the electronic system, where the automatic mode is being implemented), whereupon the reset condition is again invoked (e.g., white reset lamp **B4-L** energized) this condition to be maintained for a prescribed settling period as before either automatically or manually as described. Preferably during this test sequence or a following one, the operator is given the option and opportunity to automatically control the settling period so that he may decide how long it takes for the system to mechanically equilibrate; for instance, as described below, this is enabled by providing a manual override control whereby the operator can bypass and supersede the automatic reset delay circuit. Workers in the art will readily perceive other means for accomplishing this as well. If no excess leakage current is detected at the conclusion of this settling period then, as suggested above, the reset phase is concluded (in the automatic mode white reset lamp **B3-L** will be extinguished and only the yellow and green, power-expose, lamps remain on) and the operator is now able to begin the active exposure of the cassette to X-ray photons: the exposure step.

According to another feature of the subject invention, the reset control and the reject controls described above are also adapted to monitor the duration and approximate level of ionographic gap current during this exposure step. That is, when the operator subjects the subject member and the cassette so the contemplated X-radiation and the charge-image ionograph begins to be formed, it will be apparent that a prescribed ionographic gap current will thus be generated. As with the aforementioned "pretest" for gap current, the reset and reject controls are now operated to test for "proper" and "excess" gap current, respectively. Thus it will be apparent that during the application of this radiation flux the operation may, by monitoring the energization of the white reset lamp **B4-L**, verify that the appropriate intensity of radiation flux is arriving at the cassette electrodes, thus checking for gross misadjustments, such as misalignment of the radiation source or

interposition of some "blocking", radio-opaque material (such as a cassette cover) as well as verifying the calculated radiotransparency of the subject member, etc. The imaging set-up and radiation conditions may thus be easily checked and verified automatically, quickly and more simply; also appropriate corrective steps may be taken with a minimum of radiation flux applied to the patient and a minimum of time lost in proceeding further. Similarly, and as an optional check, an operator may monitor the ionographic gap current for abnormally high levels (indicated for instance, by energization of red reject lamp B3-L), and so very quickly detect this condition and shut the system down, doing so before any appreciable amount of excess current has been generated.

Workers in the art will appreciate that the aforeindicated monitoring during exposure capabilities, according to the invention, are of great value especially since they require no added equipment beyond that described above for the preexposure testing sequence.

With the exposure step concluded, presumably without error or incident, the white reset lamp B4-L will be illuminated indicating correct exposure. Except for corrective steps, then, the imaging sequence is concluded and the operator may now switch-off the imaging potential by hitting the Expose switch B1-S to decouple power from the cassette electrodes, whereupon green Expose lamp B1-L will be extinguished. Then, according to a feature of the automatic system implemented in FIG. 4 and described below, the Reset function will be invoked and all electronic systems will be automatically Reset preparatory to the next imaging sequence. The cassette terminals may now be safely disconnected from the connector cable 53 and the now-imaged cassette developed or used as desired. Of course, if there is no following imaging sequence to take place the power to the system may be shut down by hitting power switch B2-S.

AUTOMATIC IMPLEMENTATION

Although other implementations may be employed to automate and practice the foregoing technique according to the invention, one illustrative and rather practical system is indicated in FIG. 4 and will now be described. This description will, however, follow a rather general format in view of the foregoing description and the familiarity of those skilled in the art with such details. Line power as aforementioned, is coupled to the subject exposure console 1 (via power cable 51, FIGS. 1 and 2) and applied to the subject system by depression of manual, bistable switch B2-S (the Power-On switch) to energize low voltage DC power supply 510. DC supply 510 functions to convert the AC input to a prescribed DC input-voltage level (e.g. here about 20 volts). Supply 510 includes conventional rectification and filtering means and provides a DC output to programmed supply stage 512 causing illumination of Power-On lamp B2-L (also supplying power to other control circuits not here shown, but understood as conventional). When, as indicated above, the cassette electrodes are to be energized by the appropriate exposure voltage, the operator as indicated above, will next depress the Expose switch B1-S to energize Supply Switching Stage 520 which, in turn, activates Delay Stage 522 and Programmed supply stage 512 and gates a modified version of the DC power input from Supply 510 to be applied, through converter stage 514, to the cassette electrodes. Switching stage 520 may be understood as comprising conventional switching means (solid stage devices or relays).

The output from delay station 522 in turn is adapted to enable both the peak detector/latch stage 532 and the excess current Evaluator stage 538, as indicated below. The reset function mentioned above, is invoked by the operator depressing reset switch B4-S (or automatically by delay stage 522, as discussed above) which provides the appropriate reset signal to detector 532. This also energizes the reset lamp B4-L, indicating that the cassette is being energized as well as energizing supply switch stage 520 (and intergrator stage 536). As understood in the art, this reset signal will serve to reset the circuits of these stages so as to be in condition for initiating and properly performing their respective functions at the start of the "Imaging Cycle". In the event the operator should fail to actuate reset switch B4-S, and according to an automatic feature hereof, the prior energization of delay stage 522 will cause the reset signal to automatically issue therefrom. Delay stage 522 may, preferably, comprise a conventional RC charge/discharge circuit adapted to provide the delay reset pulse indicated. Delay stage 522 is also adapted to provide a control signal to Evaluator stage 538, inhibiting the latter for a prescribed adjustable settling period during which transient inputs (e.g. generated upon closure of switch B1-S and associated circuit elements) avoid being detected by the evaluator and thus are ignored in favor of persistent current peaks.

As indicated above, the enablement of programmed supply stage 512 by switching stage 520 will initiate a prescribed DC output voltage therefrom and, illuminating lamp B1-L, be applied to the cassette electrodes through converter stage 514. The voltage from 514 is isolated and multiplied (e.g. on the order of several hundred times) before application to the cassette electrodes. With the application of the high DC voltage from converter stage 514 to the cassette electrodes, normal radiation-induced operation during the imaging period will cause ionographic current to flow through a prescribed cassette load impedance (not shown but understood in the art). This current characteristically increases exponentially to a peak value and is detected, according to another feature, by generation of a proportional voltage across this load impedance and monitoring to determine peaking time. This ionographic output voltage, Vig is applied, as indicated, to voltmeter stage 530 (e.g. comprising an isolating high impedance amplifier stage) to be detected and processed; the output signal from 530 being applied to the input of the four detection stages, namely: peak detector 532, power supply control 534, integrator 576 and evaluator 538. Supply Stage 512 comprises a conventional power supply including voltage regulation circuits capable of varying output voltage over a prescribed range in response to an input signal from power supply control 534. Note: further details on the programmed supply stage 512 and related sections will be found by reference to the aforementioned copending commonly-assigned applications.

As indicated above the excess current evaluator stage 538 essentially comprises (leakage) current detector means adapted to detect output voltage representing gap current in excess of a predetermined value and thereupon issue a Reject Signal, illuminating Reject lamp B3-L and, as appliled (e.g., preferably via a latch)

to switch stage **520,** to shut down the Supply stage **512** and thus remove the energizing voltage from the cassette electrodes, at least temporarily. Stage **538** may comprise a conventional level detector (e.g. transistorized switching circuit) such that the input is coupled through the stage upon rising above a given safe level, to activate a latch circuit which, in turn, provides the aforementioned Reject Signal.

Peak detector stage **532** is adapted, upon receipt of a normal, rising output from voltmeter **530** (indicating the onset of rising ionographic current), to follow the voltage increase and actuate a latching circuit upon detection of a prescribed minimum output (reflecting peak ionographic current). The peak latching circuit is, in turn, adapted to issue a keying signal applied to activate the power supply control stage **534** and Integrator stage **536.** Preferably, the initial starting voltage will be determined by a first potentiometer setting, with a second potentiometer setting provided to fix the maximum voltage level; the difference between these voltages (e.g. about 1 to 2 volts in an embodiment like that shown) thus determining the control range of program supplying voltage output from stage **512.**

Power supply control stage **534** in general, functions to provide feedback control to vary the output from programmable power supply **512** as a function (inversely) of the ionographic current. That is, as suggested above, the output from supply stage **512** will be decreased proportionately with any increase in cassette gap current above a prescribed reference level — and conversely will be increased proportionately as gap current drops — so that a constant ionographic current (current plateau) will tend to be maintained for the prescribed exposure period (duration of which is controlled by integrator stage **536,** as indicated below).

Integrator stage **536,** as suggested above, essentially functions to sum the total ionographic current output (integrate with respect to time) and, when a prescribed total is detected, activate an associated latch circuit which, in turn, applies a disabling signal to Switching Stage **520,** shutting down Supply Stage **512** and removing potential from the cassette. This terminates gap current output and "charge-imaging" — thus effectively performing as an ionographic exposure control, metering a prescribed amount of charge (current) to the cassette, and in turn, metering the total image charge developed therein. The integrator circuits may comprise any conventional R-C integration circuit and associated amplification circuit (e.g., a Miller integrator) adapted upon activation by a keying signal from detector stage **532** (when a predetermined current level is detected) to begin the integration of the ionographic cassette current with respect to time (e.g., charge a storage capacitor to a reference potential, whereupon the associated latch is activated to, in turn, provide an output signal which is coupled to shut-down Supply Switch Stage **520** and thus cut off the current supplied to the cassette). Additionally, the integrator stage may be adapted to simultaneously terminate incident radiation to the subject (shut-down X-Ray source).

Thus, as workers in the art can well appreciate, the foregoing provides a suitable and practical implementation of the techniques according to the subject invention whereby evaluation and exposure of an ionographic cassette is automatically controlled, the cassette being monitored and controlled for optimum use of the exposure equipment, and particularly, minimal radiation to the subject. Control indicators are provided so that the operator can determine which portions of the system are operative, and in what sense; a Reset function, both automatic and manual, is provided to ready the system for successive ionographic shots, with an evaluator stage to monitor against excess current and thus avoid system malfunctioning and/or patient overexposure.

Thus, as workers in the art will recognize, the foregoing monitoring and control system for ionographic imaging is adapted to provide to provide a convenient, automatic, accurate and reliable implementation of the operational sequences previously mentioned; doing so in a manner that is surprisingly effective and unexpectedly useful and advantageous. Of course, workers in the art will also be able to visualize other analogous systems similarly automating and implementing these operational sequences within the spirit of the subject invention.

Moreover, certain features may be added and/or other features deleted from such a system without necessarily departing from the scope of this invention. For instance, in cases where the absolute value of integrated current (total charge supplied to the cassette) is not particularly important, an operator may readily decide to dispense with the integrator stage **536,** instead, relying upon the timed voltage detection-control operation of peak detector stage **532.** To do this, one might couple a signal from the output of the integrator to automatically remove potential to the cassette upon detection that sufficient ionographic charge has been delivered — in a manner known in the art. Integrator stage **536** could also be arranged to shut down the X-ray source, as an emergency back-up, in the event more flux than usual was applied (and consequently more charge than anticipated built-up on the casssette) during any portion of the exposure interval.

In summary, however, it should be appreciated that, as with the prior manually implemented sequence, such automatic systems provide for a pre-testing of the operating environment (leakage current from either the cassette or other portions of the control system) — doing so in a relatively careful, delayed manner, and also allowing for settling out of spurious transients. Upon detection of such unacceptable leakage current and automatic indication thereof, the system disables the applied potential. The system also facilitates a second look (or indeed any number of subsequent looks) to repeatedly check for such error transients and even facilitates manual intervention for a repeated number of looks, as well as a manual override to extend the settling time as long as may be desired.

similarly, controls and indicators are provided during the radiation-imaging period whereby to monitor gap current and employ the detector output both to control and possibly to program the applied voltage (e.g. to compensate for retarding voltage), as well as to provide an operator indicator, assuring the operator that the gap current expected is in fact being provided during exposure. As an option, the described arrangement can readily be adapted to provide an associated overcurrent detector with automatic shut down for excess current conditions.

While the system of the invention has been described and illustrated in detail it is to be clearly understood that this is intended by way of illustration and example

only and is not to be taken by way of limitation, but that the spirit and scope of this invention is to be limited only by the terms of the following claims.

What is claimed is:

1. In a method for arranging for, and conducting, an ionographic imaging sequence for imaging a subject by directing a prescribed radiation flux upon the subject for a prescribed irradiation period and generating an electrostatic image of the differential flux transmission therethrough, across a prescribed ionographic arrangement including electrodes defining an imaging gap, the improvement therewith comprising:

providing detection means adapted to detect and monitor current across this gap;

with this detection means, monitoring the level of gap current before, and during, said irradiation period to derive values reflecting such;

comparing these values to a prescribed standard and determining any variance therefrom;

and providing for imaging controls for adjusting and limiting the imaging sequence according to variances so found.

2. The method as recited in claim 1 as adapted to check-out gap current before imaging to determine excess gap current and, accordingly, indicate the stability of the arrangement for prescribed proper imaging.

3. The method as recited in claim 2 as provided in conjunction with a programmed voltage control arrangement adapted to compensate for retarding voltage across the gap and wherein detected gap current is employed to control this voltage control arrangement, adjusting it to produce and maintain a prescribed programmed gap current level.

4. The method as recited in claim 2 wherein the ionographic imaging device, including said electrodes, is arranged to settle for a prescribed settling period, after which the test for excess gap current is repeated to verify that it is persistent and not merely transient.

5. The method as recited in claim 1 as applied to evaluate imaging with an ionographic cassette and to optimize and evaluate imaging current and thus control the imaging sequence within prescribed limits.

6. The combination as recited in claim 5 including specifically the steps of:

energizing a power stage portion of the ionographic imaging arrangement and to thereby apply energizing voltage across the gap electrodes in the cassette;

then, testing for leakagae current across the gap before imaging and responsively passing or rejecting the subject cassette as being suitable or unsuitable for imaging; and then carrying out the prescribed imaging sequence accordingly.

7. The method as recited in claim 6, wherein, during the course of testing for gap current, the cassette and associated elements are allowed to equilibrate, mechanically and otherwise, for a prescsribed settling period, lasting at least several seconds, after which gap current is rechecked to assure that the detected level is not merely transient.

8. The combination as recited in claim 7, wherein said settling period duration is adjustable and manually selected in accordance with the influential conditions then prevailing; and

thereafter comparing gap current to a standard value and interrupting the imaging sequence if this value is exceeded.

9. The combination as recited in claim 8 wherein said current detecting and related responsive steps are performed automatically, rather than manually by an operator.

10. The combination as recited in claim 6 wherein said gap current is monitored during the imaging sequence as well as before, so as to evaluate whether the arrangement is suitable for proper imaging under the circumstances; and, where improper conditions are detected, appropriate corrective action is thereupon invoked.

11. The combination as recited in claim 6 including the final step of resetting the control and detection means to be placed in condition to start the next imaging and pre-imaging sequence.

12. The method as recited in claim 11 wherein said steps are provided automatically without need for manual intervention.

13. The method as recited in claim 1 wherein said gap current detected is compared with reference current to thereby evaluate imaging conditions as compared with a standard, and interrupt imaging when conditions vary from that standard.

14. The combination as recited in claim 13 wherein said gap current is monitored during the imaging sequence, and upon detection of a current level which varies from a prescribed reference level, corrective action is taken to restore the level to reference or to interrupt imaging.

15. The combination as recited in claim 14 also including the step of providing charge integrating means adapted to generate an output keying signal, which is, in turn, adapted to automatically interrupt and disable the imaging sequence.

16. The method, as recited in claim 15 is conducted in the course of imaging with an ionographic cassette, and wherein gap current is tested for abnormal conditions, before the imaging sequence begins, and upon detection thereof, the sequence interrupted; and wherein the system is also tested for such abnormal conditions during the imaging sequence, and is likewise responsively interrupted upon detection thereof; both said testing operation being conducted so as to include a settling period during which the system equilibrates to eliminate brief transient readings; and wherein, after the imaging sequence, the system is reset to be ready to begin the next imaging sequence.

17. The method as recited in claim 15 wherein said steps are provided automatically without the need for manual intervention.

18. A control system in an ionographic imaging arrangement for monitoring and controlling an imaging sequence, such as by controlling the flow of imaging current, this system comprising in combination:

ionographic gap current detection means adapted to generate a prescribed detect signal reflecting the level of current detected;

ionographic gap current evaluation means adapted to receive this detect signal; compare it with a standard reference, and, responsively, generate a pass or no pass signal according to whether the detected gap current is within prescribed limits or not; and

system interrupt means adapted and arrangaed to receive the signal output from said evaluation means, and to responsively interrupt the imaging system upon receipt of a no pass signal.

19. The system as recited in claim 18 wherein said evaluation means is adapted to provide ionographic gap current evaluation before, as well as during, an imaging sequence, and provide evaluation output signals indicating when prescribed current variation indicate a deviation from prescribed standard conditions.

20. The system as recited in claim 18 wherein are also included current stabilizing means adapted to maintain gap current at a prescribed working level and comprising:

a programmable power supply;

means for generating a feedback signal which varies in accordance with the current across said gap;

level detector means for detecting a predetermined level of said current and generating a keying signal when said level has been detected; and

control means for controlling the voltage output of said programmable power supply, the control action of said control means being initiated in response to said keying signal, said control means receiving said feedback signal and generating a control signal for controlling said programmable power supply as a function of said feedback signal to thereby control the output voltage of the power supply and thus maintain the gap current at the prescribed level.

21. The combinataion as recited in claim 18 wherein is also included current stabilizing means operated in combination therewith, and adapted to maintain gap current at about a prescribed level, said stabilizing means comprising in combination:

a programmable power supply adapted to be energized for supplying current to said gap load;

means for generating a feedback signal which varies in accordance with the current across said gap;

means for detecting the predetermined level of said feedback signal following energization of said power supply and providing a keying signal when said feedback signal is substantially at said predetermined level;

control means for controlling the voltage output of said programmable power supply, the control action of said control means being initiated in response to said keying signal, said control means receiving said feedback signal and generating a control signal for said programmable power supply as a function of said feedback signal thereby to control the output voltage of said programmable power supply so as to maintain the gap current at the said prescribed level;

integrator means for integrating the current supplied to said gap as a function of time and for generating a control signal in accordance with a predetermined integration of the current supplied at said prescribed level to said gap, the integration action of said integrator means being initiated by said keying signal; and

switching circuit means responsive to said control signal from said integrator means for cutting off the output of said programmable power supply and thus the current to said gap when said predetermined integration has occurred.

22. The system as recited in claim 18 wherein are also included:

"exposure control" means adapted to accept input power, and condition it, for application as DC energizing voltage, to the gap electrodes of said imaging arrangement;

"exposure indicator" means associated with said exposure control means to indicate energization thereof;

"power control" means adapted to control the application of line power to said exposure control means;

"power indicator" means associated with said power control means to indicate the enrgization thereof;

"reset" means adapted to energize and initialize the state of said detection and other system means, selectively;

"reset indicator" means adapted to indicate the bistable state of said reset means; and

"excess gap current indicator" means adapted to indicate the presence of excess gap current at said detection means.

23. The combination as recited in claim 18 also including the step of providing charge integrating means adapted to generate an output keying signal, which is in turn, adapted to automatically interrupt and disable the imaging sequence.

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