

[54] DENTAL X-RAY MONITORING SYSTEM
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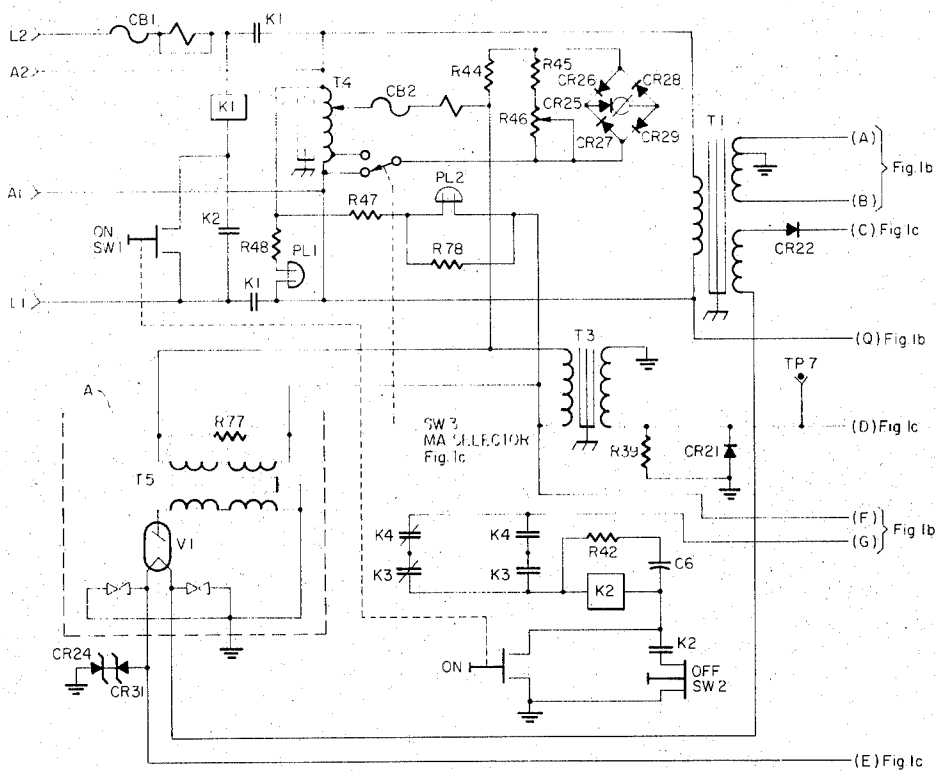
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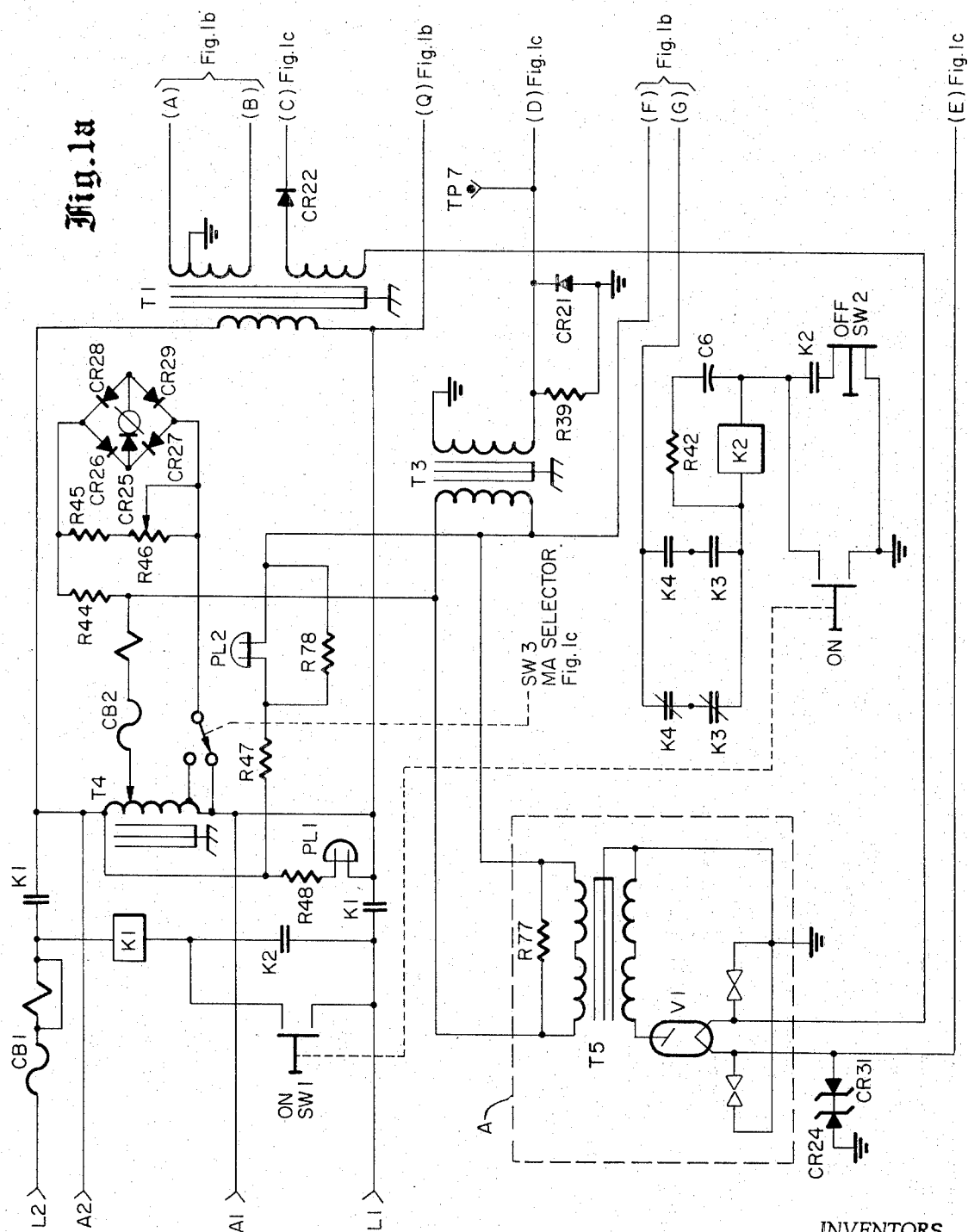
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[57] ABSTRACT
A control circuit for a dental x-ray head having a monitoring system incorporated therein for apprising the x-ray machine operator of various malfunctions that may occur within the x-ray machine.

1 Claim, 6 Drawing Figures

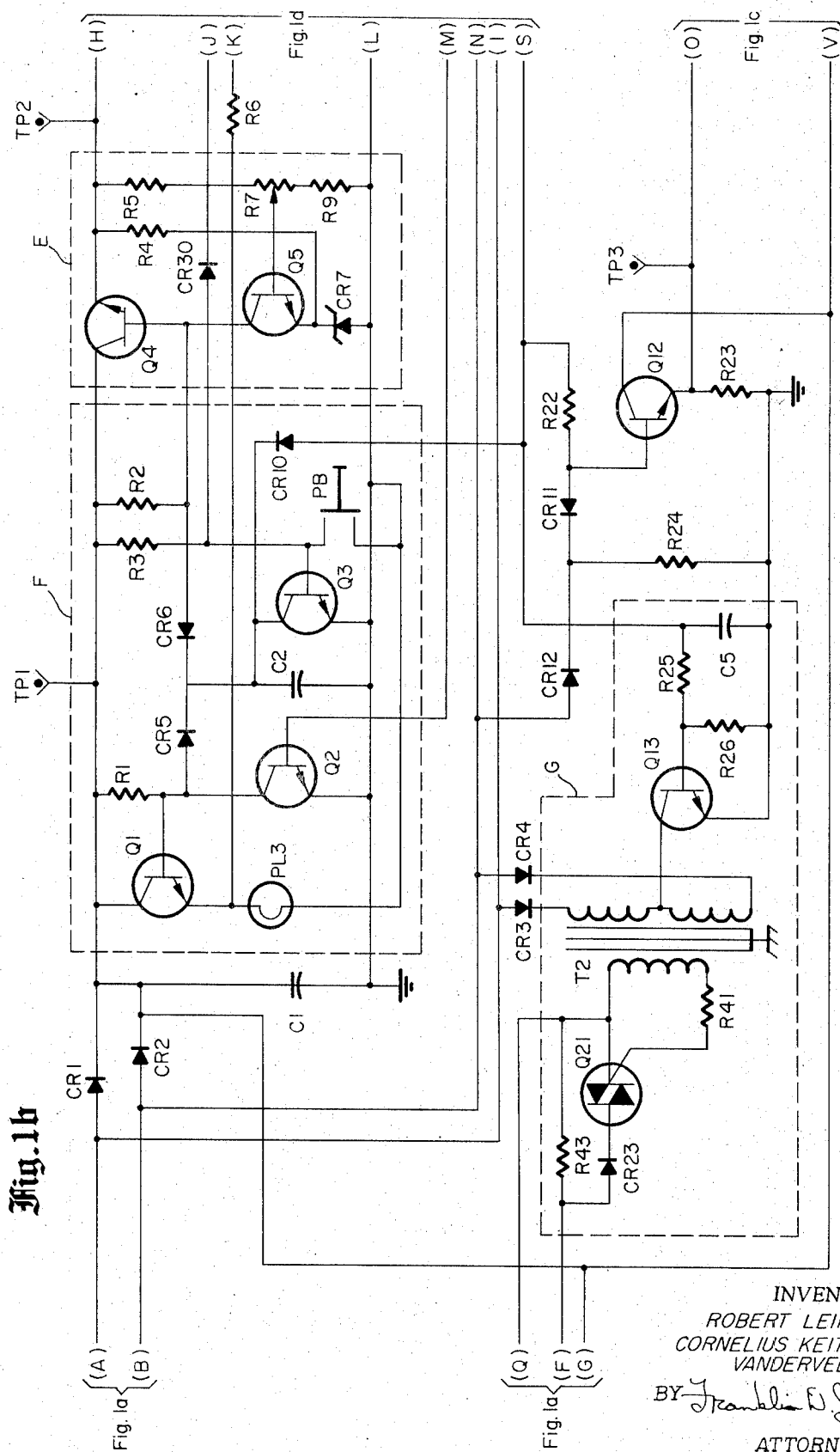




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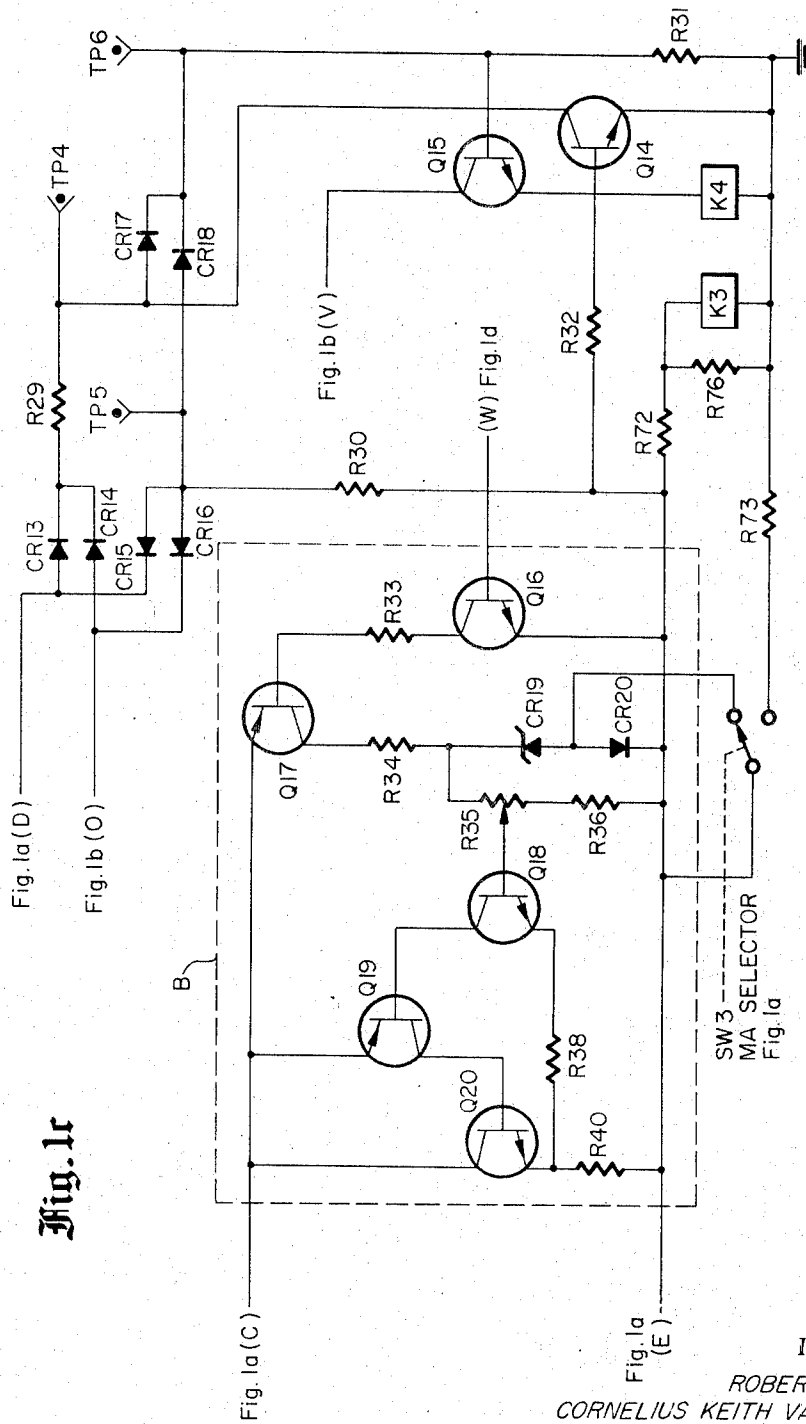
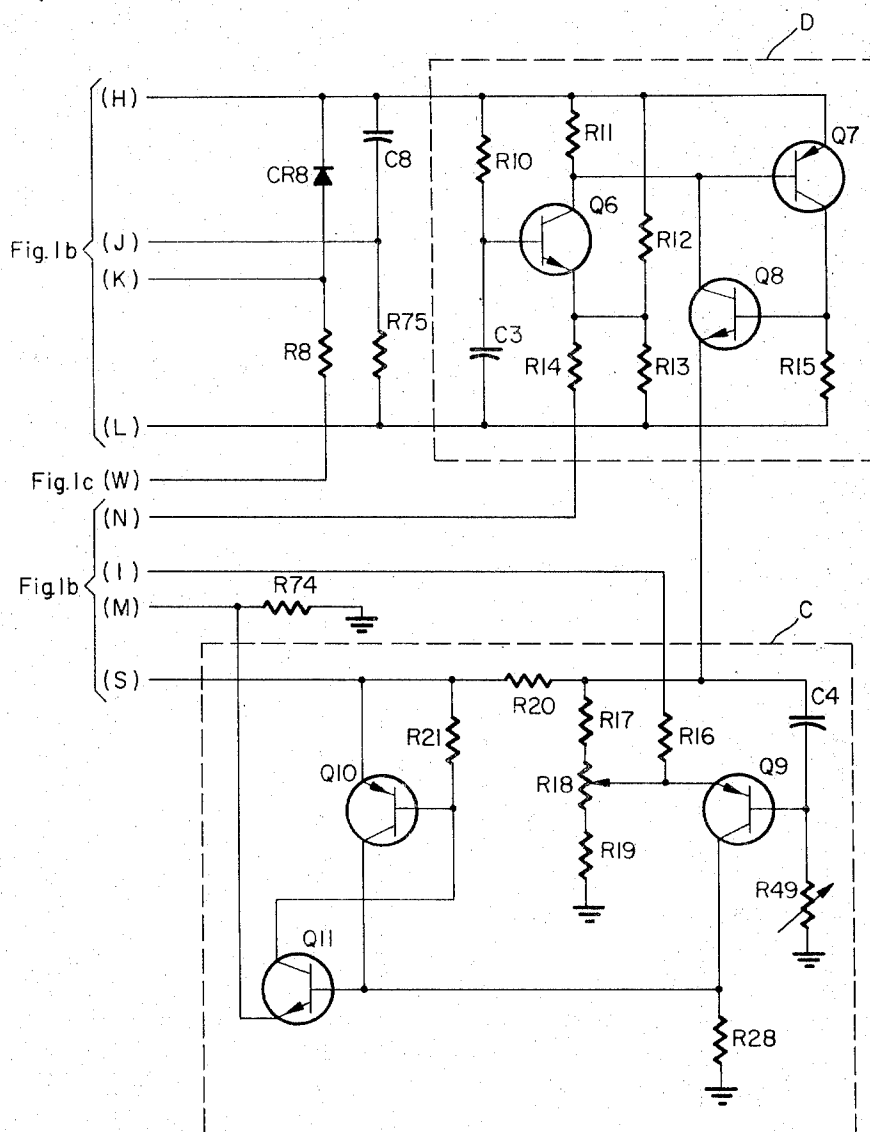


Fig. 1c

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Fig. 1d



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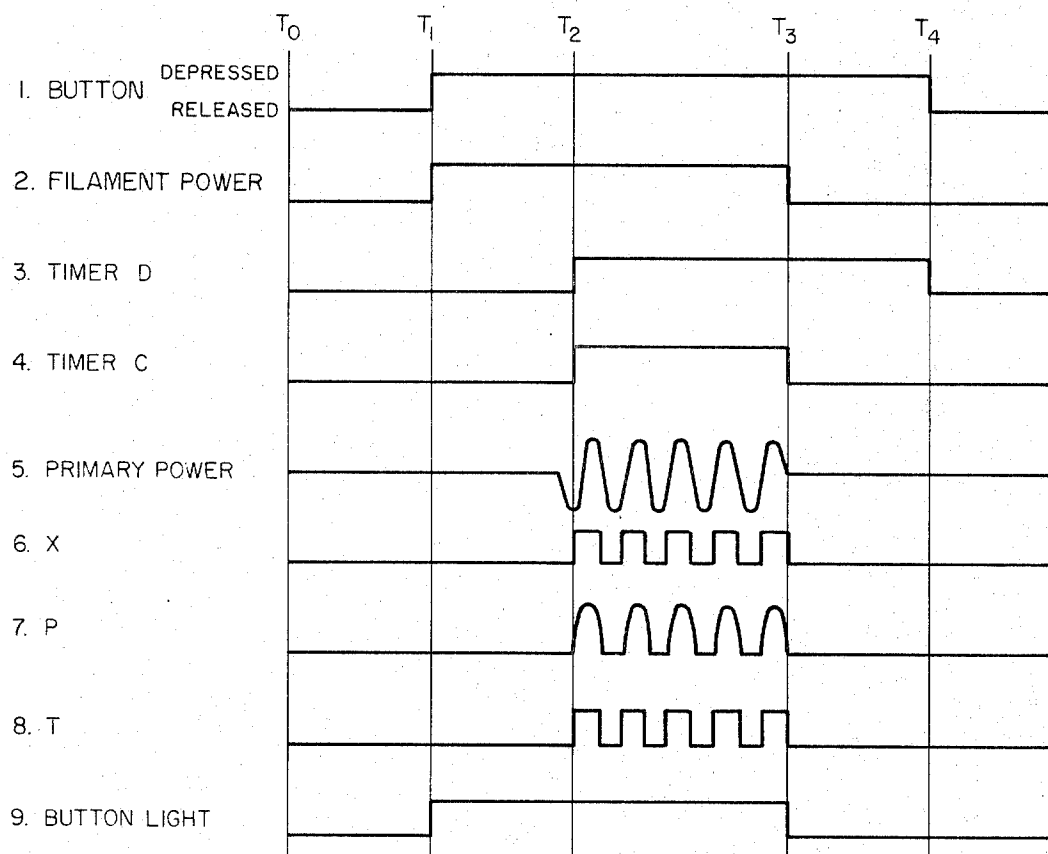
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Fig. 2

TRUTH TABLE

CONDITION	X	T	P	MONITORING
(NORMAL EXPOSURE) 1	1	1	1	1
2	0	1	1	1
3	1	0	1	0
4	0	0	1	1
5	1	1	0	0
6	0	1	0	1
7	1	0	0	0
(STANDBY) 8	0	0	0	0

Fig. 3



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DENTAL X-RAY MONITORING SYSTEM

This is a continuation of application Ser. No. 889,505, filed Dec. 31, 1969 now abandoned.

FIELD OF INVENTION

This invention relates to x-ray control circuits and more particularly to dental x-ray control circuits having a monitoring system incorporated therein.

DESCRIPTION OF THE PRIOR ART

Prior art x-ray machines incorporate control circuits which control the various factors which affect the quality of an exposure. Usually the operator is given an indication as to whether or not an exposure has taken place. This indication may be in a form of a light, a meter movement, or an audible signal. In the case of the light or the audible signal, the indication can be erroneous because although the light or the sound may be generated, no actual exposure may have taken place. In the case of a meter movement, the actual event of an exposure may be monitored by the operator but to constantly observe the meter is usually not convenient because the operator usually wants to watch the patient to ascertain whether or not the patient has moved during the exposure. The above mentioned seemingly positive indications of exposures have confused many operators and in some cases dentists have thought that they have taken exposures throughout the day only to find out upon attempting to develop the film that none of the film was exposed.

Accordingly, it is an object of the present invention to provide a novel control circuit which includes a monitoring system for monitoring certain indicia of the control x-ray machine.

It is a further object of the present invention to provide a novel control circuit which includes a monitoring system which shuts off the control circuit if an improper exposure has occurred.

SUMMARY OF THE INVENTION

A control circuit having a monitoring system incorporated therein for dental x-ray heads. The monitoring system comprises the x-ray machine operator of various malfunctions that may occur within the x-ray machine. Any malfunction that is monitored will immediately shut down the control circuit so that no more improper exposures will occur.

BRIEF DESCRIPTION OF THE DRAWINGS

Additional objects, advantages and characteristic features of the present invention will become readily apparent from the following detailed description of the preferred embodiments of the invention when considered in conjunction with the accompanying drawings in which:

FIGS. 1a, 1b, 1c, and 1d represent an electrical schematic of a control circuit for an x-ray head in accordance with the present invention;

FIG. 2 is a truth table for the control circuit of FIG. 1 in accordance with the present invention; and

FIG. 3 is a time sequence chart for the control circuit of FIG. 1 in accordance with the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIGS. 1a, 1b, 1c, and 1d, there is

shown an electrical schematic of a control circuit for an x-ray head in accordance with the present invention. Since various components, and their respective arrangements thereof, within the control circuit are well known in the electronics art, for the purpose of simplification of explanation of the present invention, not every component illustrated will be referred to specifically in this specification. Furthermore, in order that one may more readily understand the overall operation of the control circuit, the electrical schematic has been separated into seven major blocks which perform certain functions. The seven major blocks designated by capital letters are as follows:

Block A defines a schematic diagram head of an x-ray head, including an x-ray tube V1 and a high voltage transformer T5;

Block B defines that portion of the control circuit which stabilizes the emitted current of the x-ray tube and therefore stabilizes the intensity of the x-ray beam;

Block C defines a timing circuit which controls the duration of the x-ray burst;

Block D defines a fixed timing circuit which introduces a delay between the initiation of the x-ray exposure command and the initiation of the actual x-ray exposure. Such a delay is necessary in order to allow the filament of the x-ray tube V1 to reach emission temperature;

Block E defines a stabilized power supply;

Block F defines a current for controlling the initiation of an x-ray exposure; and

Block G defines that part of the control circuit which includes a solid-state power contactor.

The remaining areas or parts of the control circuit either do not perform major functions to justify separation from the other components of the control circuit, or do not lend themselves to being defined by blocks because they are illustrated in more than one figure of the drawings. However, generally speaking, the upper portion of FIG. 1a and the upper left portion of FIG. 1b includes the components for placing the control circuit in operation and for providing various voltages to the rest of the control circuit, and the lower right portion of FIG. 1a and the right portion of FIG. 1c includes the monitoring system of the control circuit.

Referring now specifically to monitoring system of this control circuit, the monitoring element of the monitoring system is a relay K2 which operates as follows: When the "on" button SW1 is depressed, power is applied to a relay K1, via lines L1 and L2. Power is then applied to a Transformer T1. The rectifying circuit, comprised of CR1, CR2 and C1, generates a DC voltage which is applied to relay K2 through the normally closed contacts of relays K3 and K4. The rectified current is allowed to flow through the coil of relay K2 by virtue of the fact that the coil is connected to ground through a parallel set of contacts of the "on" button SW1. The "on" button SW1 has to be kept depressed a fraction of a second to allow the rectified voltage to build up and energize the relay K2. Thus, the relay K2 will stay energized because one of its contacts is connected to the "on" button SW1 through the "off" button SW2. If it is desired to turn the control off, the "off" button SW2 is depressed and the relay K2 will be released which in turn releases the power relay K1.

The rest of the monitoring system is connected to the monitoring element, relay K2, through the contacts of relays K3 and K4, which are "true form C" contacts.

It can be readily seen that if relays K3 and K4 are not energized, that K2 is allowed to remain energized. If both relays K3 and K4 are energized simultaneously, the conduction path to K2 will switch from the normally closed contacts of the relays K3 and K4 to the normally open contacts of relays K3 and K4. Since relays K3 and K4 are of the dry-reed type which have very short operating and release times, small differences in the operator release times may be evened out by means of circuit consisting of R42 and C6, which is in parallel to K2. Thus, it is quite clear that as long as the relays K3 and K4 are energized or de-energized simultaneously, the relay K2 will remain energized. However, if the synchronization of the signals that are applied to the coils of the relays K3 and K4 is disturbed, then no path will be present for applying power to K2. If this condition exists, the relay K2 will release and the control circuit will be turned off.

Such synchronization will not occur if there is an error in the x-ray exposure and the monitoring system will sense such error in the x-ray exposure so as to turn off the control circuit. The turning off of the control circuit apprises the operator of a malfunction within the x-ray machine in that he will not be able to obtain any more x-ray exposure. The operator is normally apprized of the fact that an x-ray exposure has been successfully obtained through a light PL2 which would be mounted on the control panel. In addition a light PL3 is provided on a remotely located exposure button. If either one of these lights do not come on when the exposure button is depressed, the operator is apprized of the fact that a successful x-ray exposure has not occurred. An additional indication of malfunctioning of the control circuit is provided through a light PL1 located on the control panel.

To ensure proper synchronization of the control circuit, the coils of relays K3 and K4 are connected to the filament circuit of the x-ray tube V1 and to the output of the logic portion of the monitoring circuit. The current which flows through K3 is the current emitted by the filament of the x-ray tube V1 and therefore the presence of this current is directly related to the presence of an x-ray burst. The object of the logic portion of the monitoring system is to apply to the coil of the relay K4 a signal which is identical to the signal routed to the coil of the relay K3 in order to ensure that K2 remains energized. The emitted current will consist of approximate trapezoidal pulses because the x-ray tube V1 is of the self-rectifying type. The flat top of this wave shape is a direct result of the constant current characteristic of the x-ray tube V1 which is operated as a saturated diode. The duration of the pulse is approximately one-half cycle of the line voltage and each pulse is repeated a total number of times corresponding to the setting of a variable resistor 49 in the exposure timer circuit of block C. The fast acting contacts of the relay K3 will transfer during the presence of the trapezoidal current pulse and will fall back to the rest position in between two current pulses. Since the contacts of the release K3 and K4 are connected as illustrated, it can be seen that the monitoring signal which is applied to the coil of the relay K4 should be identical in duration and amplitude to the current signal sensed by the relay K3 to obtain synchronization.

From this observation, a truth table can be readily constructed which specifies the logic portion of the monitoring circuit. In accordance with the objectives of

the present invention, only certain conditions are monitored, as follows: (1) the presence of x-rays as evidenced by the emission of electron current in the x-ray tube V1, such electron current signal will hereafter be referred to as X; (2) the presence of a command from the timer circuit to produce x-rays, such command signal will be hereafter referred to as T; and (3) the presence of power being applied to the primary of the high voltage transformer T5, such power will hereafter be referred to as P.

Referring now to FIG. 2, there is shown a truth table in accordance with the present invention. The truth table identifies eight different conditions. In this truth table, the numeral one denotes the presence of a signal and a zero denotes the absence of a signal. Only conditions 1 and 8 represent normal conditions, namely, normal exposure and standby, respectively. Condition 1 identifies the normal exposure condition wherein the emission of x-rays is requested and takes place for the duration determined by the timer circuit. The condition 8 is the standby condition wherein the control circuit is turned on, but the emission of x-rays is neither generated nor requested. Conditions 2 through 7 indicate error conditions. The last column of the truth table illustrates the required output of the monitoring logic circuit as specified by the arrangement of the relays K3 and K4. It can be seen from the truth table that the signal applied to the coil of the relay K4 should be identical to the signal applied to the coil of the relay K3. Using the usual algebraic techniques, the following formula can be extracted from the truth table: $P \cdot T \cdot X + (P + T) \cdot \bar{X} = M$.

The signal represented by X is obtained from the filament circuit of the x-ray tube V1 and is applied to the coil of the relay K3 by means of correcting resistors R72 and R76. The inverse of the signal is called $\bar{X}$ and is obtained through an inverting amplifier consisting of Q14 and R32. The signal which represents the application of power to the primary of the high voltage transformer T5 and which is called P, is obtained as follows: An isolation transformer T3 is connected across the primary of the high-voltage transformer T5. The secondary of T3 has one side connected to ground and the other side to a circuit consisting of R39 and CR21. The purpose of the latter circuit is to remove negative going voltages so that at test point TP7 only positive going pulses will be present and then only during the time that power is applied to the primary of the high-voltage transformer T5. The turns ratio of the transformer T3 is selected to obtain a signal of adequate amplitude across the secondary even when the x-ray machine is operated at its lowest permissible kilovoltage.

A third signal designated as T is obtained and consists of a positive going clipped halves of a sine wave. It is derived as follows: The output of the timer, which is a positive going square wave of 15 volts that starts at the instant that the timer in Block D has run out and which terminates when the timer in Block C runs out, is present at a junction of R20 and R21. This signal is fed into an "and" gate consisting of R22 and CR11. The other input to the "and" gate applied to CR11 is a continuous train of half sine waves which are in phase with the emitted x-ray beam. Q12 is an amplifier and at test point TP3 the signal T can be observed. The "or" gate consisting of CR13 and CR14 receives the signals called P and T and therefore its output can be represented by the expression $P + T$. The same signals P and

T are combined with the signal X in an "and" gate which is made up of components CR15, CR16 and R30. The output of this "and" gate can be observed at test point TP5 and is called $P \cdot T \cdot X$. The output of the "or" gate is connected through R29 to Q14 which acts as an inhibitor. The signal present at TP4 can therefore be represented by the expression $(P+T) \bar{X}$. This signal is then combined with the output of the "and" gate which is observed on test point TP5 in an "or" gate consisting of elements CR17 and CR18. This manipulation yields the final signal represented by expression $P \cdot T \cdot X + (P+T) \bar{X}$. This signal can be observed on test point TP6, and it is routed to amplifier Q15 and then to the coil of K4.

Referring now to FIG. 3 there is shown a time sequence chart of various events previously referred to that take place within the control circuit illustrated. The time T_0 represents the control circuit being in the standby condition. The time T_1 represents the time when the operator depresses the exposure button PB. The time T_2 represents the initiation of the exposure of the x-ray burst. The period between time T_1 and the time T_2 represents the filament warm up time of approximately one second. The time T_3 represents termination of the x-ray exposure. The time T_4 represents the time when the operator releases the exposure button PB.

The top line represents the condition of the exposure button PB. Two conditions identified are the released condition and the depressed condition, as shown. The second line represents the presence or absence of power to the filament of the x-ray tube. It can be readily seen that as soon as the exposure button PB is depressed, power is applied to the filament of the x-ray tube V1. The third line represents the output of the timer in Block D, which can be observed at the emitter of Q8. The fourth line represents the output of the timer of Block C, which can be observed at the junction of R20 and R21. The start of this signal is the start of the output of the timer of Block D. The termination of this signal occurs when the timer in the Block C has timed out the requested exposure interval, or in other words, this signal represents the firing of the circuit Q10 and Q11 which then shorts the output of the Timer D. The output of the Timer C is applied to the "or" gate of the monitoring circuit consisting of R22, CR11, and driver transistor Q13, which through transformer T2 operates the power contactor Q21. The power contactor Q21 will allow current to flow to the primary of the high-voltage transformer T5 for as long as Q13 is

driven by the output of the Timer C. The fifth line represents the application of power to the primary of the high-voltage transformer T5. In the example shown in this time sequence chart, an exposure time of five cycles has been chosen. The sixth, seventh and eighth lines represent the signals X, P and T, respectively. The ninth line represents the length of time that the button light PL3 of the exposure button PB is on. It is seen that this signal is identical to the duration of the application of filament power to the x-ray tube V1.

Thus, although the present invention has been shown and described with reference to particular embodiments, for example, an x-ray tube within a dental x-ray head, nevertheless, various changes and modifications obvious to a person skilled in the art to which the invention pertains, for example, a solid state x-ray emitting device within a dental x-ray head, are deemed to lie within the spirit, scope and contemplation of the invention as set forth in the appended claims.

What is claimed is:

1. An x-ray system comprising

- a. an x-ray tube exhibiting a characteristic emission current upon application of filament and plate voltages thereto for generating x-rays,
- b. means connected to said tube for supplying said plate voltage thereto,
- c. means connected to said tube for supplying said filament voltage thereto,
- d. means for stabilizing said emission current,
- e. emission current monitoring means for generating a signal X indicative of said emission current,
- f. inverting means receiving said signal X and generating a signal $\bar{X}$ equal to the inverse of X,
- g. plate voltage monitoring means for generating a signal P indicative of plate voltage at said X-ray tube,
- h. timer means for generating a signal T indicative of elapsed time within a preselectable exposure time period,
- i. logic means for combining said signals X, $\bar{X}$, P and T so as to generate a signal M indicative of a signal equivalent to the expression $P \cdot T \cdot X + (P+T) \bar{X}$, and
- j. control means for initiating and terminating the generation of x-rays upon command from a human operator and for prohibiting the generation of x-rays in the absence of said signals M and X which are supplied to said control means only during proper operation of said system.

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