Towards a Kirlian Device for Monitoring Physiological State

Part I: Device Considerations

by

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Introduction

After learning about the Soviet studies in Kirlian photography[1,2] (High-Voltage photography) and after two years of experience in the United States with some experiments designed to reveal a variety of phenomena associated with the process[3,4] and others designed to reveal the mechanism whereby a high-voltage impulse applied to a living system is converted to a pattern registered on a film[5,6], it seemed time to attempt the construction of a device that would enable one to evaluate the utility of Kirlian photography as a monitor of physiological state. From the studies of Sheinkin[7], it appeared that the Kirlian technique could be utilized to reveal objective information concerning the mental state of psychotic patients. From the Soviet claims[1], this was a natural and a beneficial application of the process. We thus embarked upon a program to build an effective and reliable instrument which could be utilized to determine the nature of the relationship between a patient's physiological state and Kirlian photographs of his or her fingertips. The ultimate objective was to study psychiatric day hospital and inpatients both at the time of admission and during the course of treatment. Part I of this series is exclusively devoted to the device considerations, while Part II will deal with the clinical studies.

High-voltage power supplies used in previous experimental work are of four basic types: (1) iron-core induction coils with electromechanical vibrator current interrupters; (2) iron-core automobile ignition coils, operated by transistors or silicon controlled rectifier circuits; (3) air-core Tesla coils with primary-circuit spark gap and tuned circuits and (4) air-core high voltage transformers in vacuum tube or transistor oscillator circuits. Types (1) and (3) are inherently unstable due to electrode contact impedance variations in normal operation. Types (2) and (4) are inherently stable giving uniform and reproducible high-voltage pulses when controlled by suitable timing circuits. The power supply described in this report is of type (4) and can be characterized as a Hartley oscillator circuit. We could also choose between the experimental configuration wherein the finger is in contact with the film and backed by a metal electrode, as in Fig. 1(a), or we could place the finger in contact with a transparent electrode, as in Fig. 1(b), and photograph the generated light which passes through the electrode using an external camera. The contact photography technique suffers from the possibility of artifacts being generated by physical contact between the film emulsion and the chemicals of the skin and also by the possibility of discharges occurring at the back side as well as at the emulsion side of the film. The transparent electrode technique does not suffer from these drawbacks. However, two weaknesses that it has in common with the film contact technique are (a) the lack of control of the finger orientation and of the finger to electrode spacing, and (b) the buildup of moisture during extended

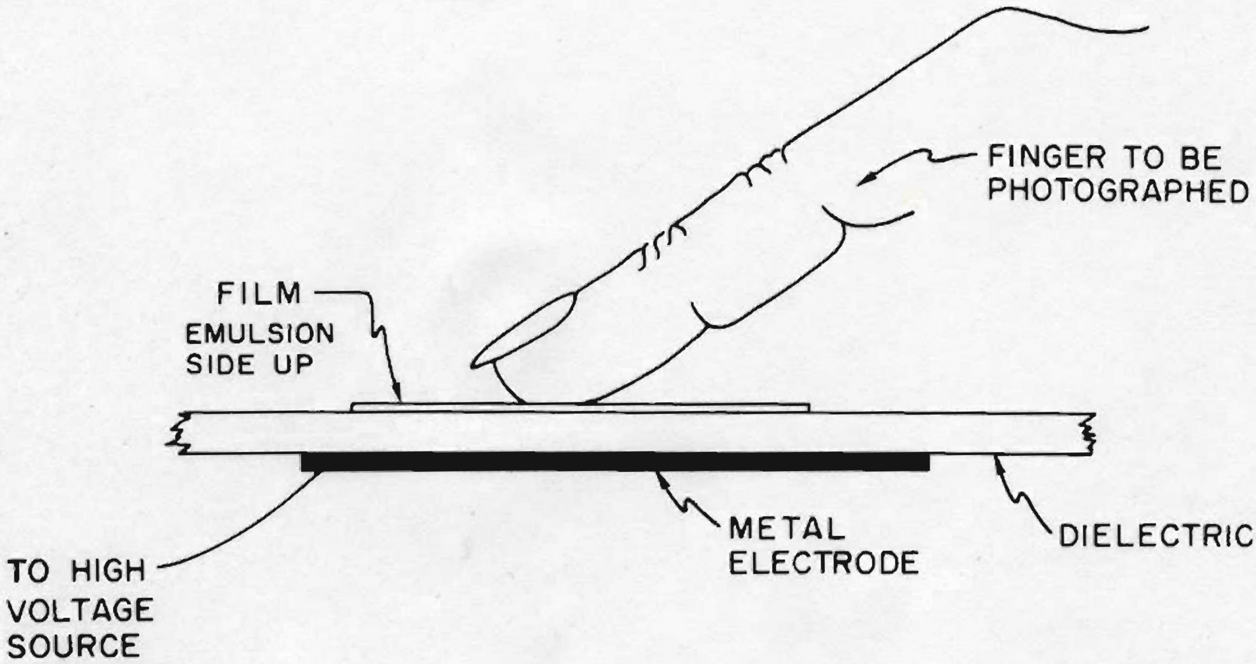


Fig. 1(a). Simple electrode-film configuration used in contact photography.

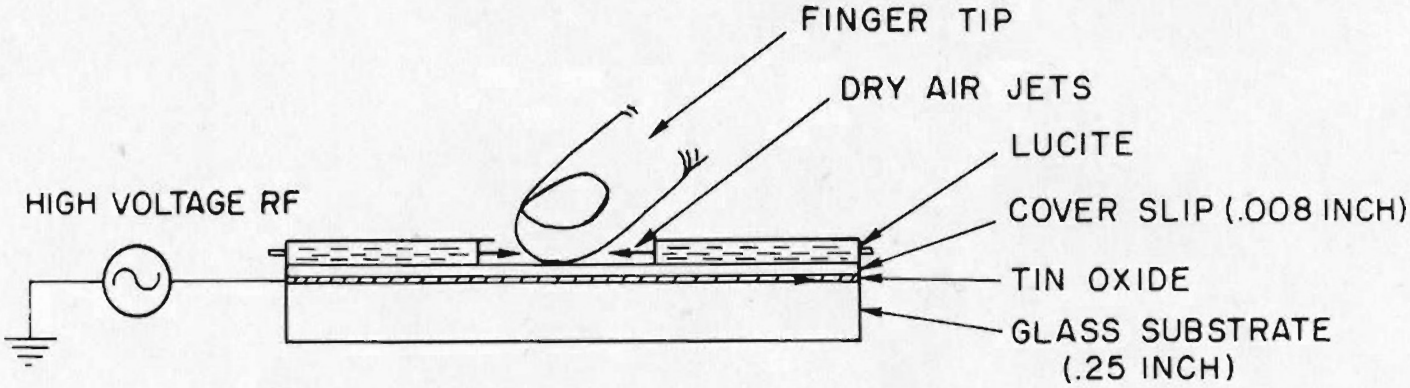


Fig. 1(b). Simple electrode-film configuration used in transparent electrode Kirlian photography.

tests. Since the Soviet work indicated that the transparent electrode technique was as effective as the film contact technique, and since our own studies showed that this technique eliminated problems associated with placing film in the discharge gap, we decided to confine our attention to the transparent electrode technique. With this decision made, the design goals for the new apparatus were as follows: (1) To provide accurate control over finger orientation and finger to electrode spacing for a single finger; (2) to provide a means of preventing moisture buildup on either the transparent electrode or the finger during extended tests; (3) to provide a capability for taking pictures under normal room illumination; (4) to provide a simple control capability for taking the photographs; (5) to provide a capability for taking both single and multiple pulse exposures; (6) to provide a rugged and reliable device that is fully consistent in its operation so that meaningful comparisons can be made between different data; (7) to provide a finger holder and armrest so that the subject will be comfortable during the tests and, finally, (8) to provide such a simple operation that unskilled operators can readily learn to use the equipment.

Device Design

A schematic drawing of the device, showing the location of the main components, is presented in Fig. 2(a). Fig. 2(b) presents a photograph of the device. Additional photographs of the actual device from a variety of angles are presented in Figs. 2(b) to 2(e). The device will be described under the component headings (a) finger holder, (b) electrode compartment, (c) photography, (d) moisture control and (e) power supply. These components are mounted on a single custom-built chassis forming a compact piece of portable equipment having

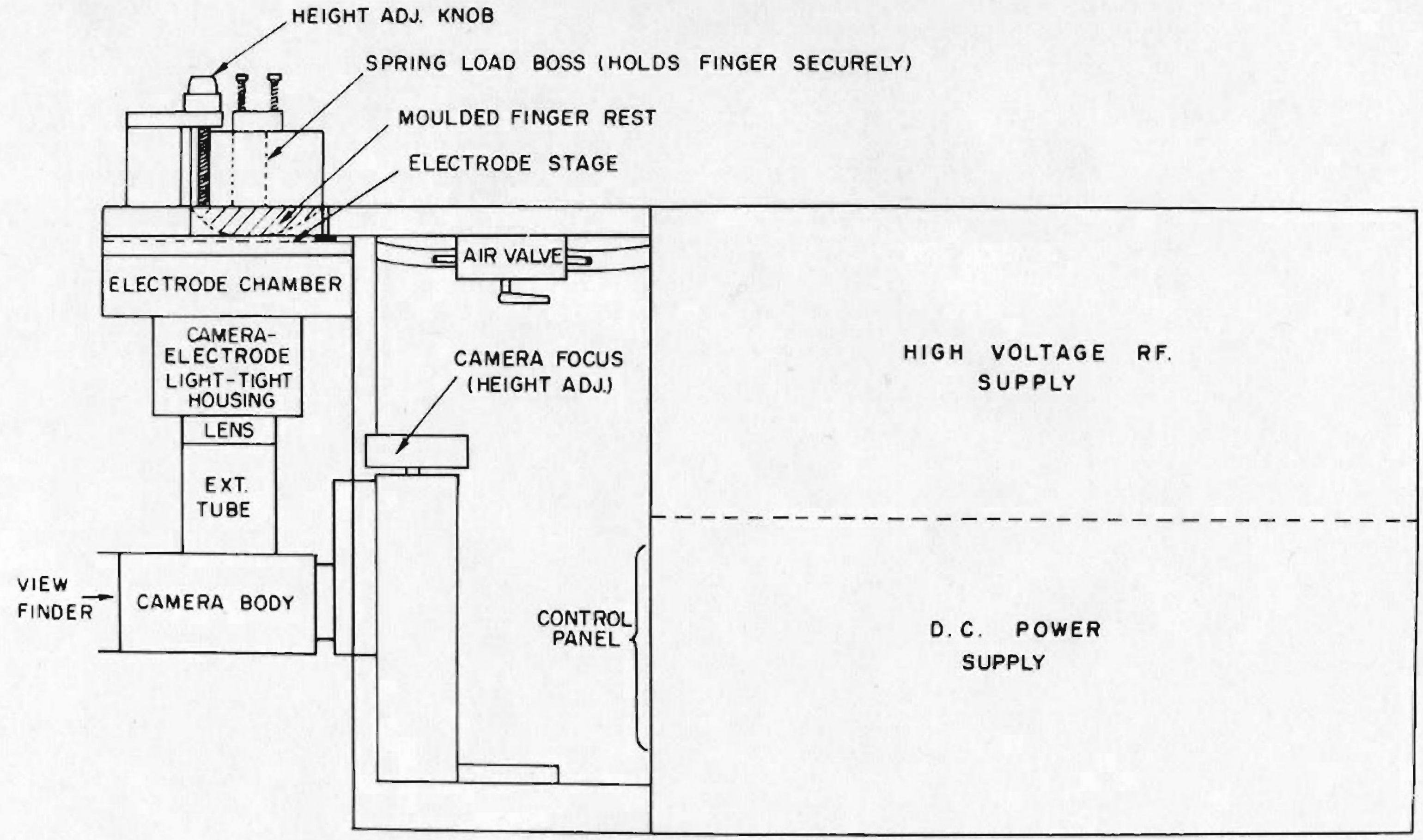


Fig. 2. (a) Functional diagram of the transparent electrode device.
(b) Photograph of the device -- overall view.
(c) - (f) Photographs of the device from different orientations.

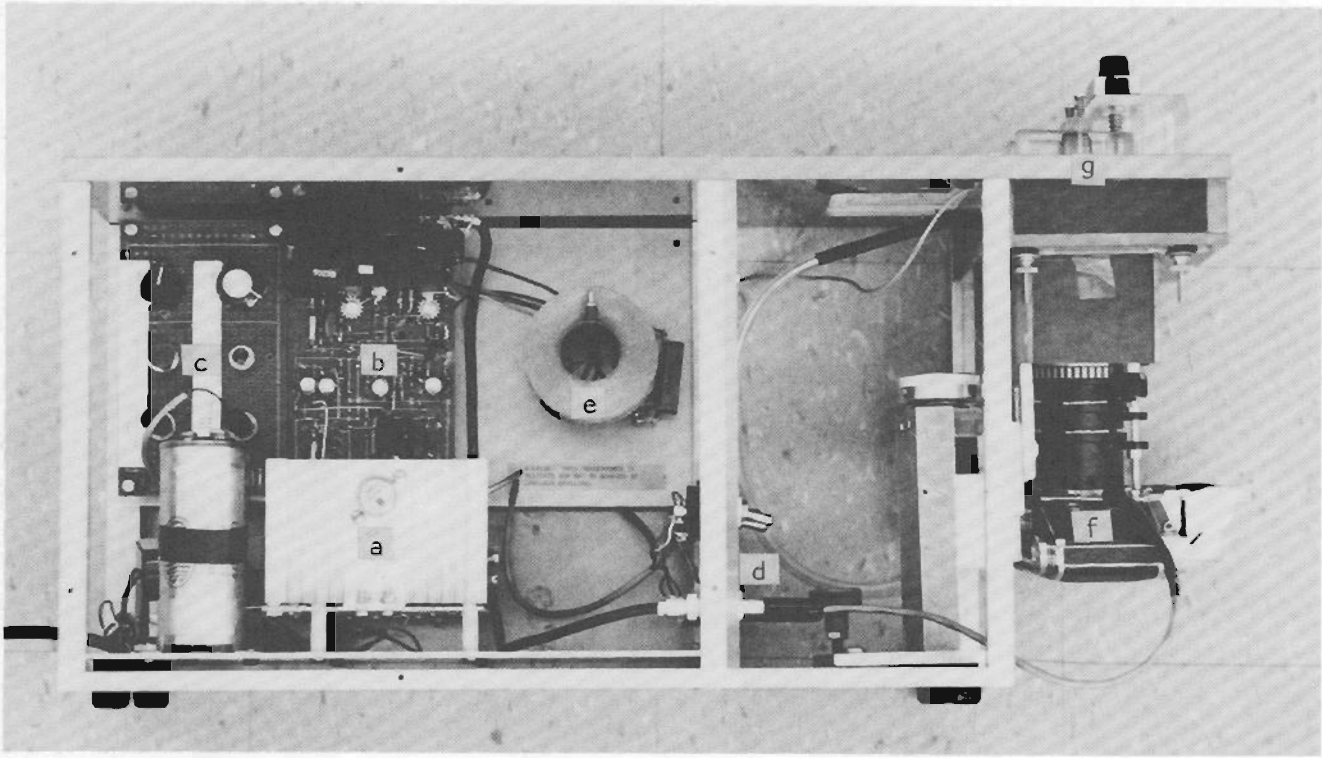
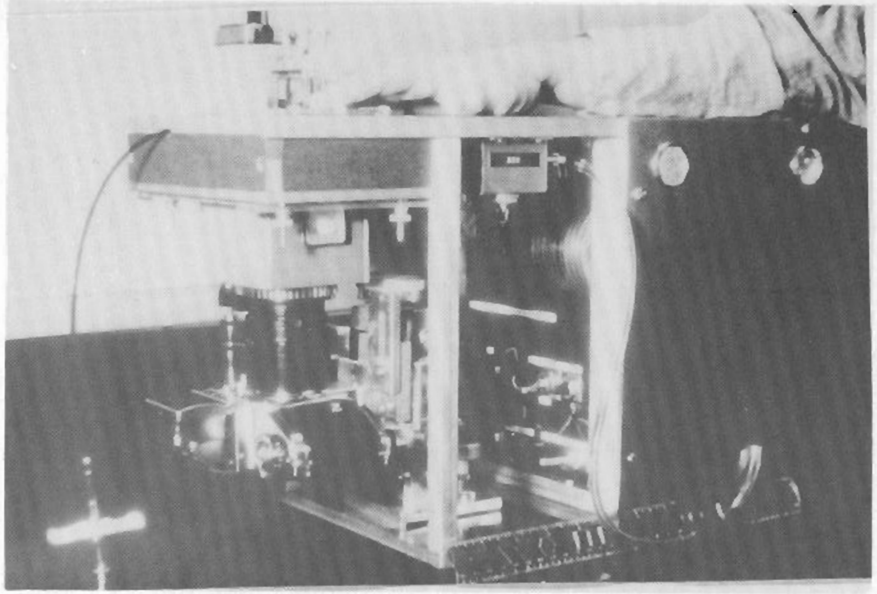
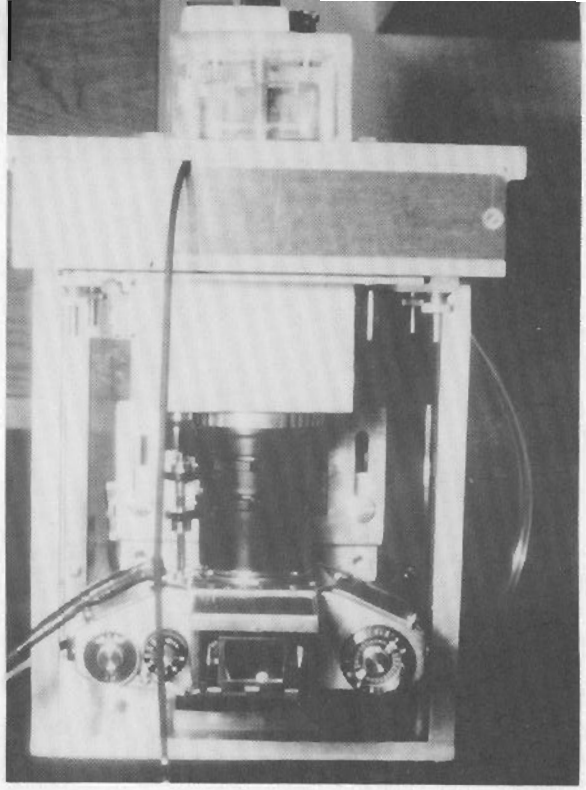


FIGURE 2b

Side view of Portable High-Voltage Photographic Apparatus, showing (a) 28-VDC, 3-A power supply; (b) 20-KVAC, 2-mA, 100 KHz power supply; (c) internal control panel; (d) external (operator's) control panel; (e) high-voltage transformer; (f) camera; (g) transparent electrode assembly and object positioning control.



2(c)



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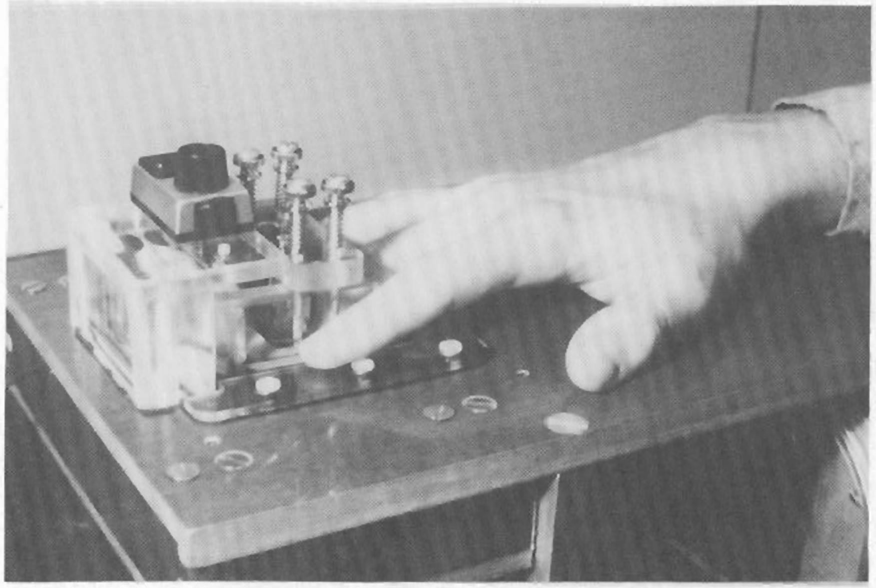
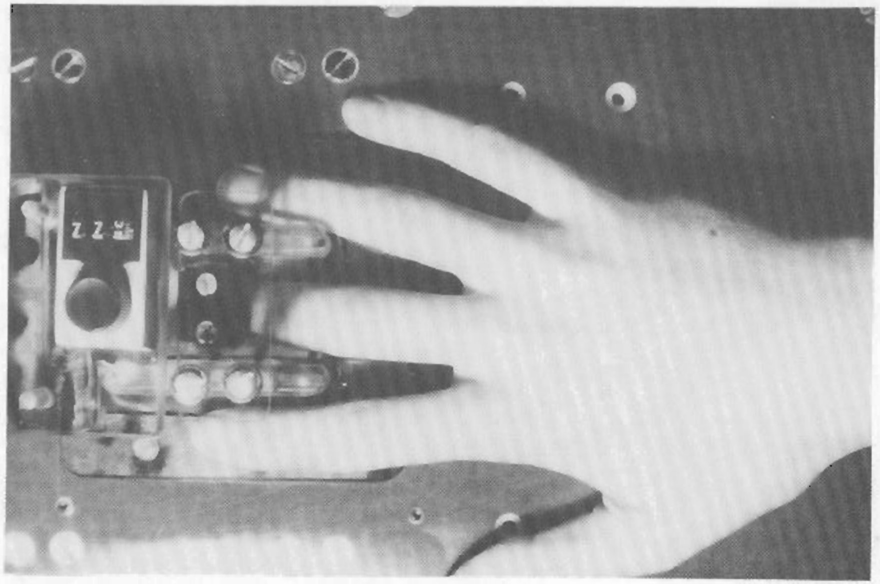


2(e)



2(f)

a built-in armrest.

(a) Finger holder: This is set on an insulated stage with a molded hole for the finger pad cut in its center. The sides of the hole are gently sloped, especially along the finger alignment direction so that the finger is well supported even though the major portion of the finger pad sticks through the hole. The finger is held in place over the molded hole by using a spring-loaded boss, padded on the contact end, that rests firmly on the top of the finger between the first and second knuckles (see Fig. 3). This stage is installed above the surface of the transparent electrode on a jig that provides a calibrated screw adjustment for raising or lowering the stage. In this way, the finger pad can be set at any spacing relative to the electrode surface just by turning the calibrated screw and observing the turns-recording gauge. The jig itself is rigidly fastened to the armrest of the device. To produce light tightness, the area around the finger holder was sealed with a flexible rubber sheet.

(b) Electrode Compartment: The electrode consists of a 2" x 2" square of 1/8"-thick glass coated with tin oxide. The tin oxide coating is both conductive and transparent. The conductive surface is covered by an 8-mil thick microscope cover slip on the finger holder side, so that the electrical discharge will not erode the tin oxide layer, and the combined unit is mounted in a Plexiglas holder. The electrical connection is made to the tin oxide surface of the electrode. The entire electrode system is contained in a light-tight box to allow operation under room illumination.

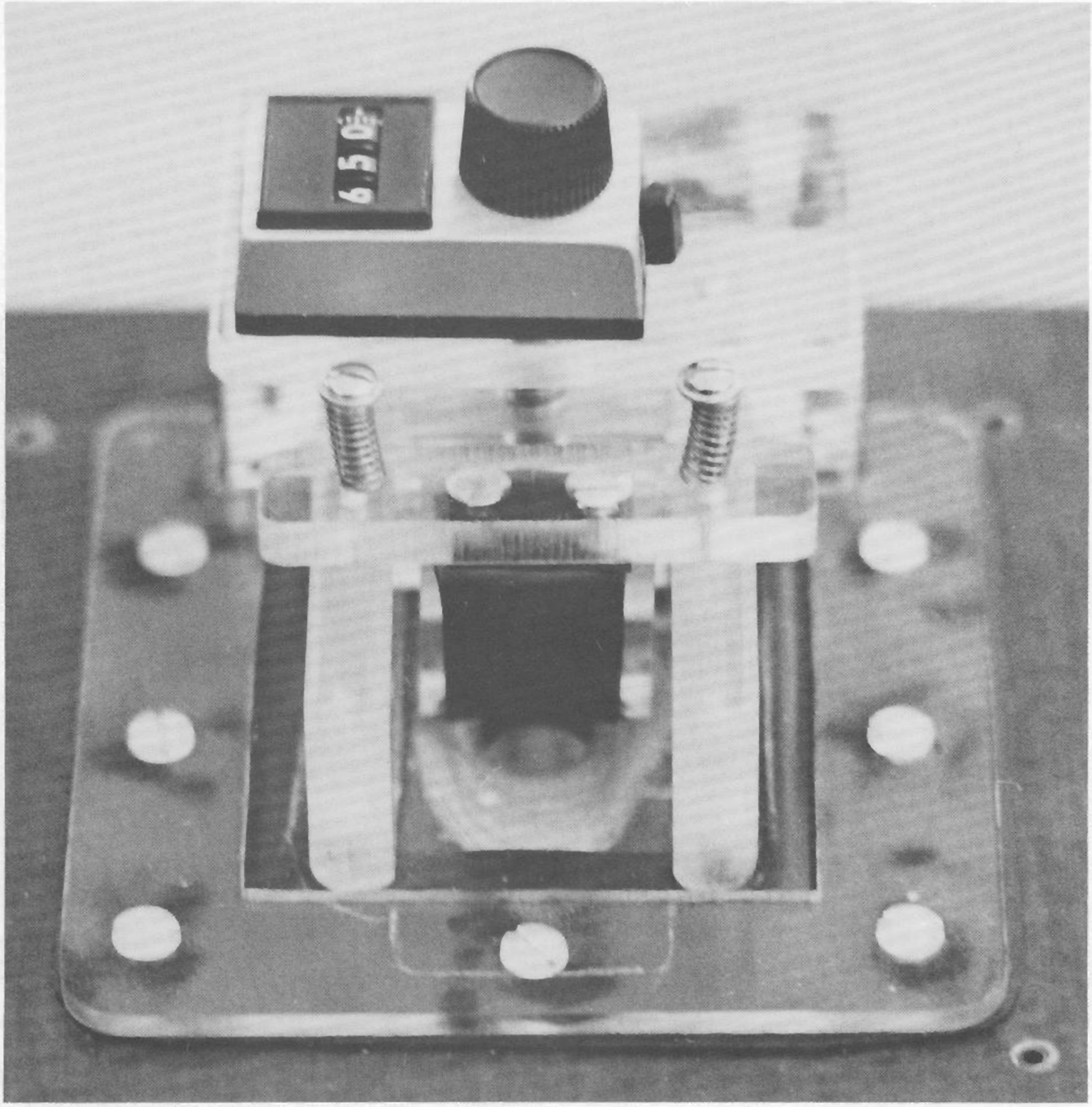


FIGURE 3

Object positioning control, viewed from top of Portable High-Voltage Photographic Apparatus, with transparent electrode assembly showing through hole in lower-center part of photograph.

(c) Photography: A 35-mm single lens reflex camera is mounted on a movable stage below the electrode compartment. This allows focusing on the center of the transparent electrode. A 50-mm/f2.0 lens was used with extension tubes to provide a 1:1 image-to-object size ratio. For light-tight operation, the lens was enclosed in the electrode chamber. The film used was typically Kodak 2475 recording film (ASA/1600). The power supply and camera operate simultaneously by using the "X"-flash contact on the 35-mm camera to also activate the power supply-"on" switch.

(d) Moisture Control: An air jet was positioned in the electrode compartment so as to force dry air into the fingerpad-electrode gap and prevent the buildup of moisture. This air supply, from a suitable dry air source, was provided with a valve to turn off the flow of air during the actual discharge exposures. Its purpose was to allow drying of the finger during the periods between exposures.

(e) Power Supply: This is a pulsed radio-frequency source producing high-voltage (20 kV) pulses of 100 kHz RF, with the capability of varying both the pulse width and the pulse repetition rate. A schematic diagram of the specially designed circuit is given in Fig. 4(a) with that for the input DC supply given in Fig. 4(b), while Fig. 5 presents a block diagram of this supply. The ouput of the high-voltage transformer develops 20 kV AC at 2 ma when supplied from a 28 V DC source. As the input voltage is varied upward from zero, the output will rise proportionately so that a simple variable high-voltage

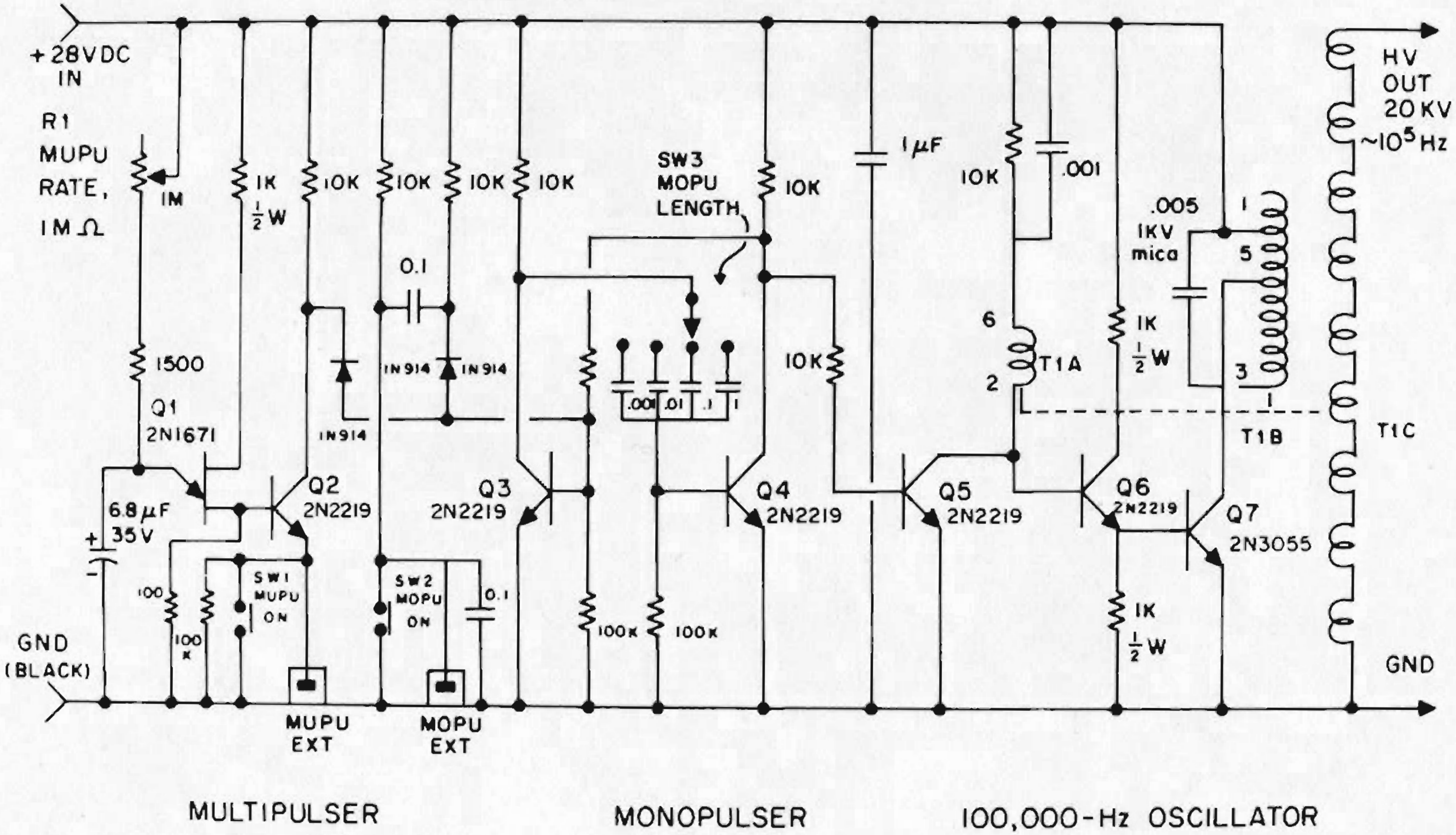


Fig. 4. (a) Circuit diagram of the 20 kV AC - 2 ma, 100 kHz power supply for high-voltage photographic apparatus.

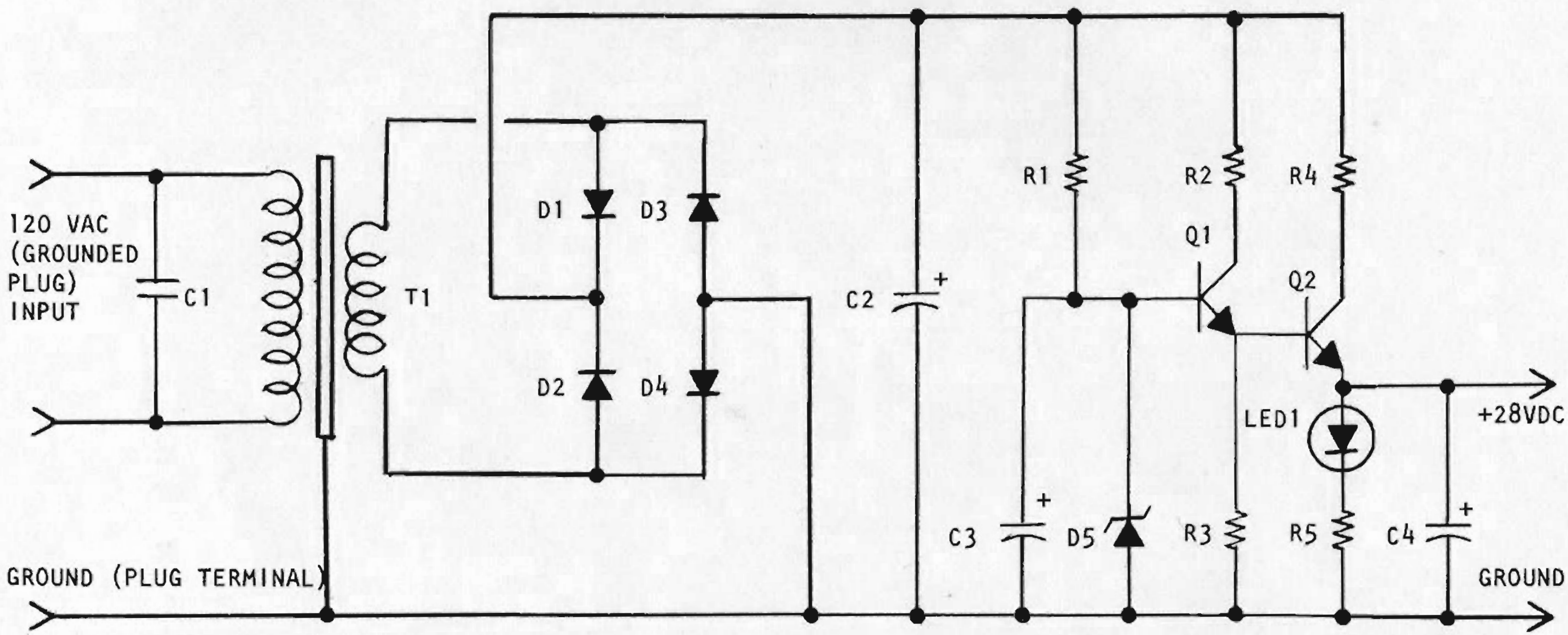


FIGURE 4b

28-VDC Power Supply, supplies power to the 20-KVAC Power Supply of the High-Voltage Photographic Apparatus. Parts list:

C1	0.01 uF, 1 KV, ceramic capacitor
C2, C4	4000 uF, 50 V, electrolytic capacitor
C3	50 uF, 50 V, electrolytic capacitor
D1-D4	15 A, 200 PIV silicon rectifiers
D5	1N972, 30-V, 400 mW zener diode
LED1	250-mW, red light-emitting diode
Q1	2N2219, NPN TO-5 silicon transistor
Q2	2N3055, NPN TO-3 silicon transistor
R1	1000 ohm, 0.5 W, carbon resistor
R2	100 ohm, 0.5 W, carbon resistor
R3, R5	10,000 ohm, 0.5 W, carbon resistor
R4	1 ohm, 10 W wire-wound resistor
T1	117 to 25 VAC (RMS), 3 A

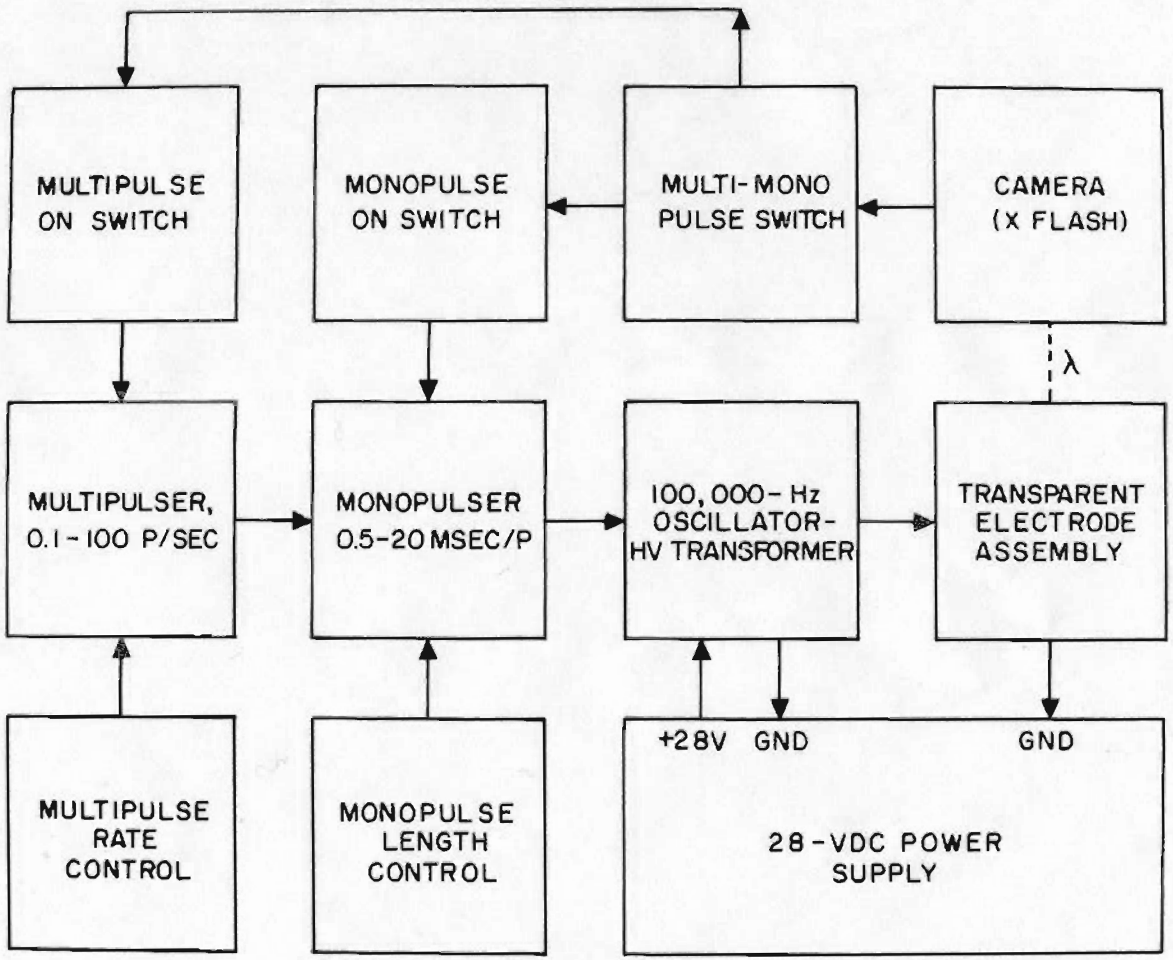


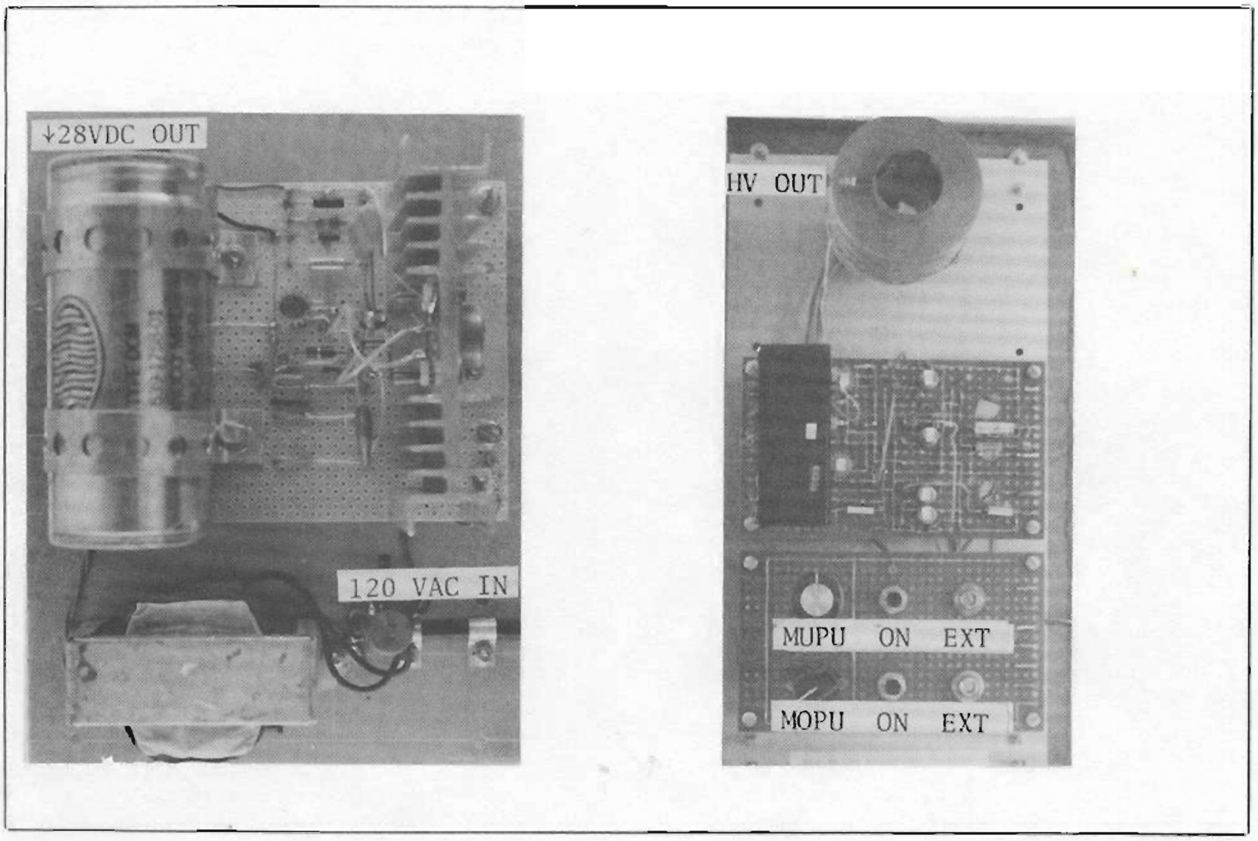
Fig. 5. BLOCK DIAGRAM OF PORTABLE HIGH-VOLTAGE PHOTOGRAPHIC APPARATUS

source is readily available. Photographs of the electronic circuitry for both the DC power supply and the 100 kHz power supply are given in Fig. 6. A listing of safety hazards and precautions associated with the use of this type of device are given in Appendix I.

As part of the device chassis, the power supply is provided with a control panel in the immediate proximity of the camera controls. This panel includes power switch, pilot light, single/multiple pulse mode switch, momentary "on" and continuous "on" switches in parallel with the "X-contact" flash jack of the camera. A scope output connection is also provided for monitoring the pulse width and pulse repetition rate. In addition, the side panel was modified to provide a set of control switches for setting the pulse repetition rate (3 pulses/sec to 30 pulses/sec in steps of 3 from left switch of series to right switch).

Device Operation Procedure

The camera is loaded with Kodak 2475 recording film (ASA/1600). The power supply is turned on and the moisture control connected to a dry air supply by a suitable length of tygon tubing. The pulse width, pulse rate and pulse mode controls are set according to the design of the experiment. The X-contact of the camera is connected by a suitable cable to the power supply. The subject's finger is then placed carefully in the finger holder and the calibrated adjusting screw is turned until the desired spacing is achieved between the finger and the transparent electrode. The procedure for this is to observe a test discharge through the view-finder of the camera and turn the



(a) (b)

FIGURE 6

Electronic circuitry of (a) 28-VDC, 3-A power supply, and (b) 20-KVAC, 2-mA, 100-KHz power supply. Abbreviations on control panel (refer to text and block diagram):

MUPU multipulse rate control	ON multipulse on switch	EXT multipulse external switch
MOPU monopulse length control	ON monopulse on switch	EXT monopulse external switch

spacing adjustment knob until the fingerpad just contacts the glass coverslip surface. When this occurs, the discharge is absent from the small contact region and the reading on the turn's indicator thus registers the zero spacing setting which is then used as a reference for all other spacing readings. By backing off or advancing the adjustment knob a given number of turns, a given spacing may be set.

After the spacing has been set, the camera is adjusted to the desired f-stop and shutter speed. The air is turned off momentarily and the shutter is tripped with the cable release. The X-contact triggers the high-voltage source which provides either a single pulse or a series of pulses depending on the setting of the pulse mode switch. The film is advanced and the parameters of spacing, f-stop, shutter speed, pulse width, pulse rate and pulse mode are set according to the design of the next experiment. Finally, having completed a series of exposures, typically 36, the film is removed from the camera for processing and replaced with a fresh roll.

Device Testing

To test the performance and the usefulness of the apparatus, five experiments were conducted:

(1) The purpose of the first experiment was to determine the effect of changing the pulse width and the number of pulses on the appearance of the photographic patterns. The effect of increasing the pulse width is simply to increase the exposure level. Then, typically, the pulse width is set as short as possible

to adequately expose the film (to avoid excessive heating of the skin). The result of changing the number of pulses in a multiple exposure sequence is also to increase the exposure as illustrated in Figs. 7(a) and 7(b), where 7(b) was exposed by four times as many pulses as used in 7(a).

(2) The purpose of the second experiment was to determine the degree to which the discharge pattern was repeatable with all parameters held constant from one exposure at a particular spacing to the next. At each spacing (6 in all), 9 exposures were taken with about a 15-second period between each. In Fig. 8, results from 5 alternate exposures are given for 2 of the spacings. For this study, the pulse width was 9 m sec and single pulses were used. As we can see from Fig. 8, the pattern is quite accurately repeatable from exposure to exposure. This held true for all the intermediate exposures not presented.

(3) The purpose of this experiment was to determine the degree to which the same finger spacing could be achieved after removing the finger from the finger holder and a few minutes later placing it back in the finger holder. The zero reference method described earlier was used to return to the same finger spacing. We see from Fig. 9 that, although the ability to re-establish a prior spacing is not perfect, it is fairly good. The top sequence are repeated exposures prior to the first finger removal step. The middle and bottom exposures are analogous exposures after the first replacement and second replacement steps, respectively. These results are fully

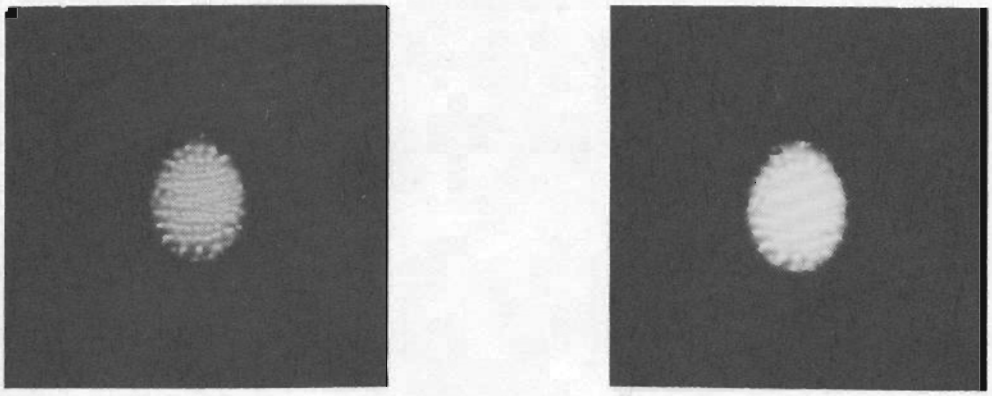


Fig. 7. Fingerpad images resulting from a change in the number of pulses in a multiple pulse exposure: Left, 20 pulses of 3 m sec width; Right, 80 pulses of 3 m sec width.

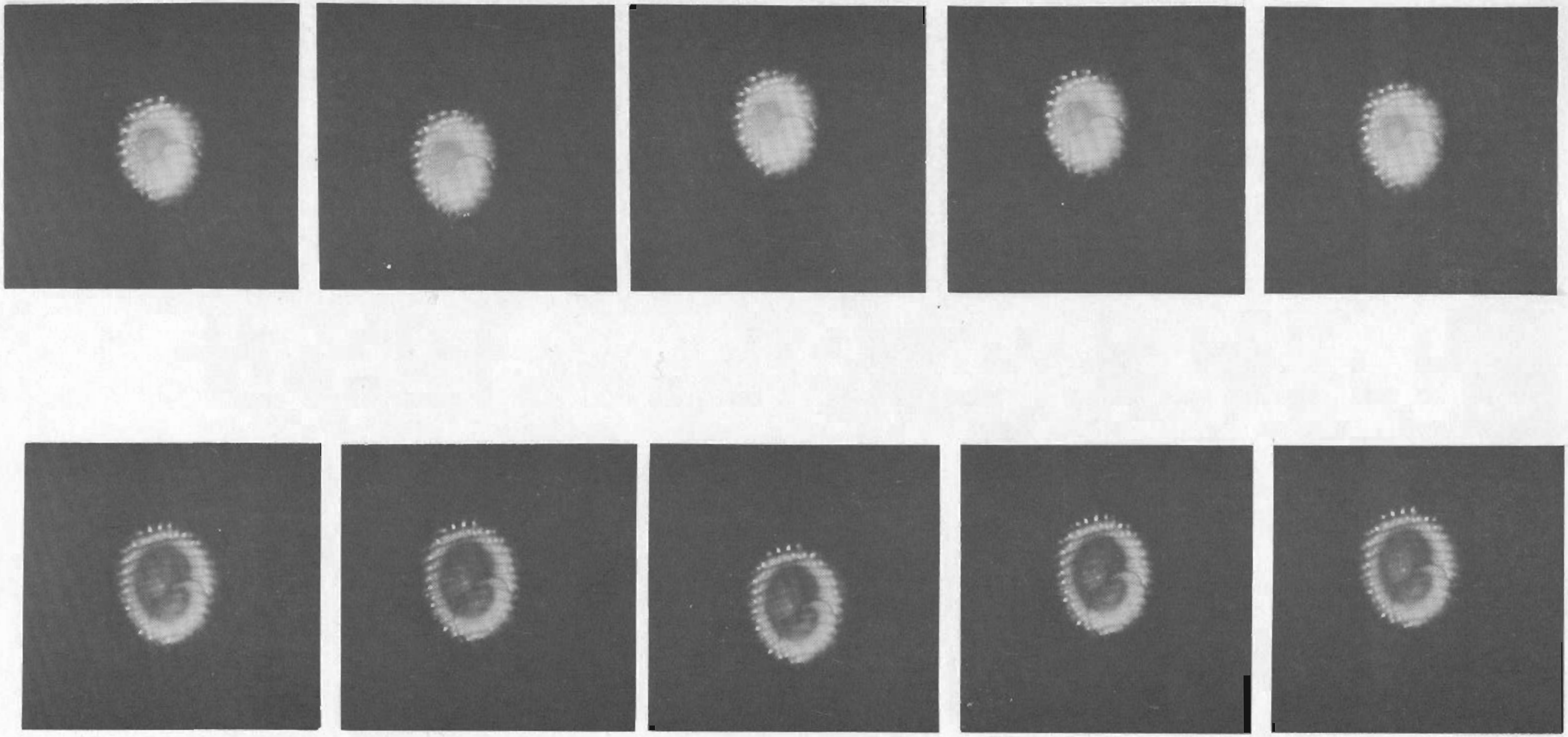


Fig. 8. Fingerpad images for case where all parameters held constant at two different spacings. Single pulse exposure; 9 m sec pulse width.
Top: Exposures 1, 3, 5, 7 and 9 for zero set spacing
Bottom: Exposures 19, 21, 23, 25 and 27 for -20 set spacing (250μ less than top).

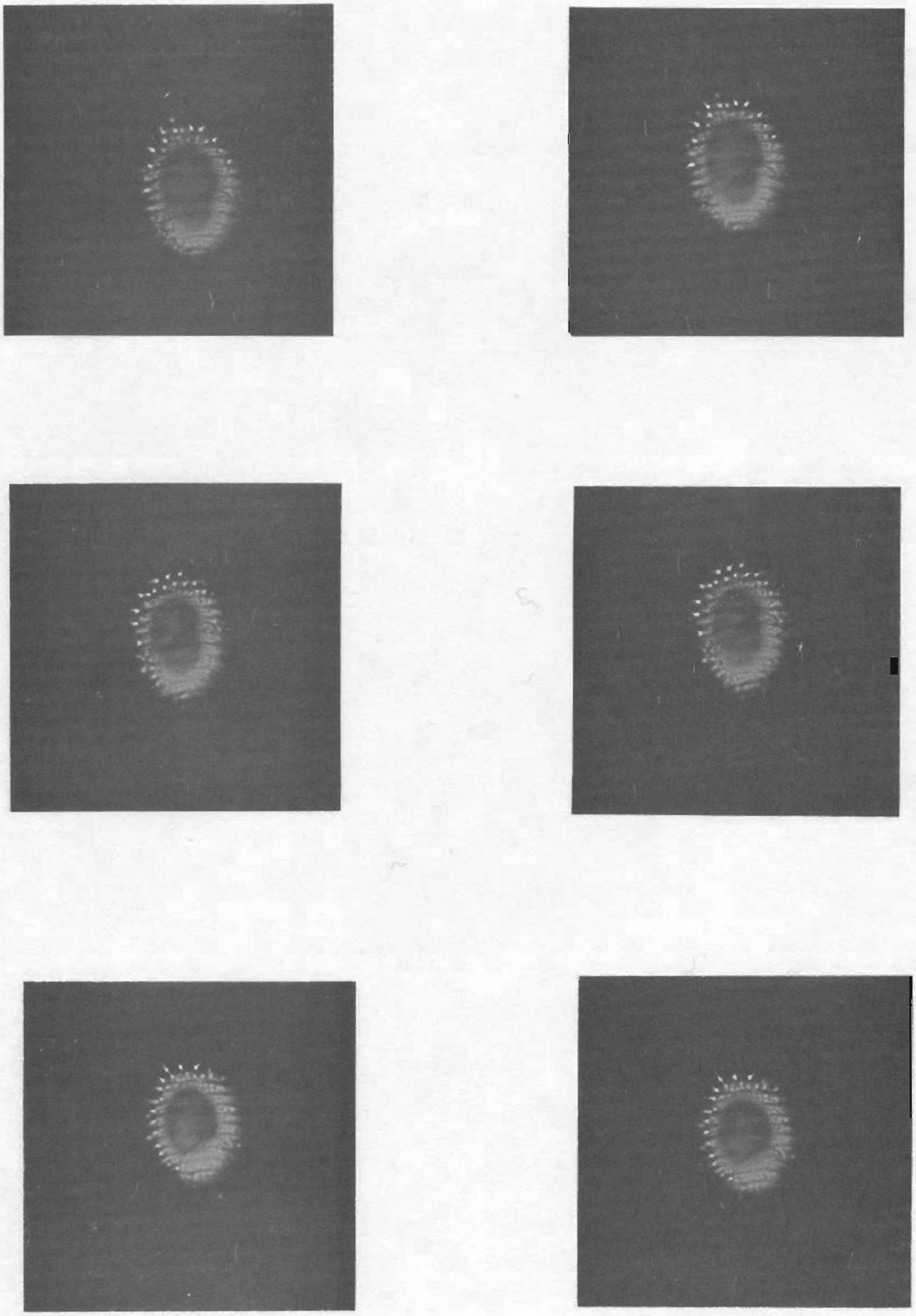


Fig. 9. Fingerpad images associated with repeated replacement of finger in finger holder. Single pulse exposure; 9 m sec pulse width.
Top: Exposures 1, 3 for first setting at -10 set spacing
Middle: Exposures 6, 8 for first replacement at -10 set spacing
Bottom: Exposures 11, 13 after second replacement at -10 set setting.

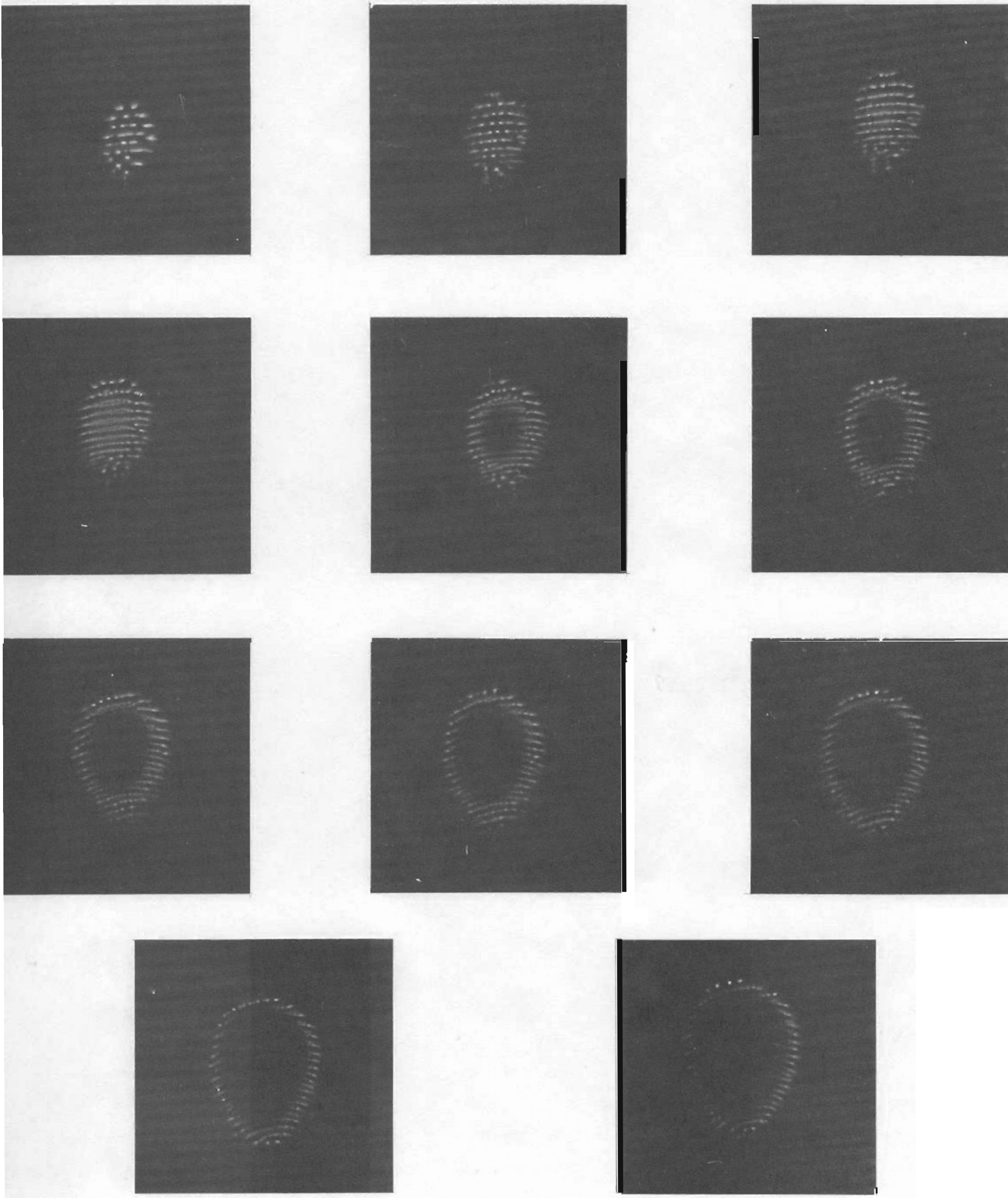
representative of the 6 different series of 5 exposures each that were tested (5 replacement trials).

(4) The purpose of this experiment was to determine the effect of changing the fingerpad to electrode spacing on the recorded discharge pattern. Figures 10(a), (b), (c), ... are a series of exposures wherein the spacing was decreased in steps of 125 microns between each exposure. We can see that, as the spacing is reduced, the pattern becomes larger in diameter due to the finger flattening on the electrode. The authors believe that this is the cause of many of the reported changes in the size of the patterns observed in contact Kirlian photography that have been attributed to changes in the subject's physiological state.

(5) The purpose of this final experiment was to determine if this apparatus, constructed to eliminate many of the common artifacts operative in previous experimental arrangements, is able to detect any significant changes of physiological state of a subject in various stages of meditation. The actual experiment was to take 6 exposures about one minute apart for each of 6 different meditative states (or points of concentration). The results presented in Fig. 11 are fully representative of the entire series, top, middle and bottom are exposures 1, 3 and 5 of State 1, State 3, and State 5, respectively. In this case, one of the authors (WAT) was the subject and the type of meditative state was to visualize an internal organ, a beautiful landscape, etc. As we can see, negligible differences were manifested by this procedure.

Discussion

From the results of the previous section, the device can be considered as



ig. 10. Fingerpad images illustrating the electrode spacing effect -- spacing decreased 125μ between each exposure. Single pulse exposure; 9 m sec pulse width.

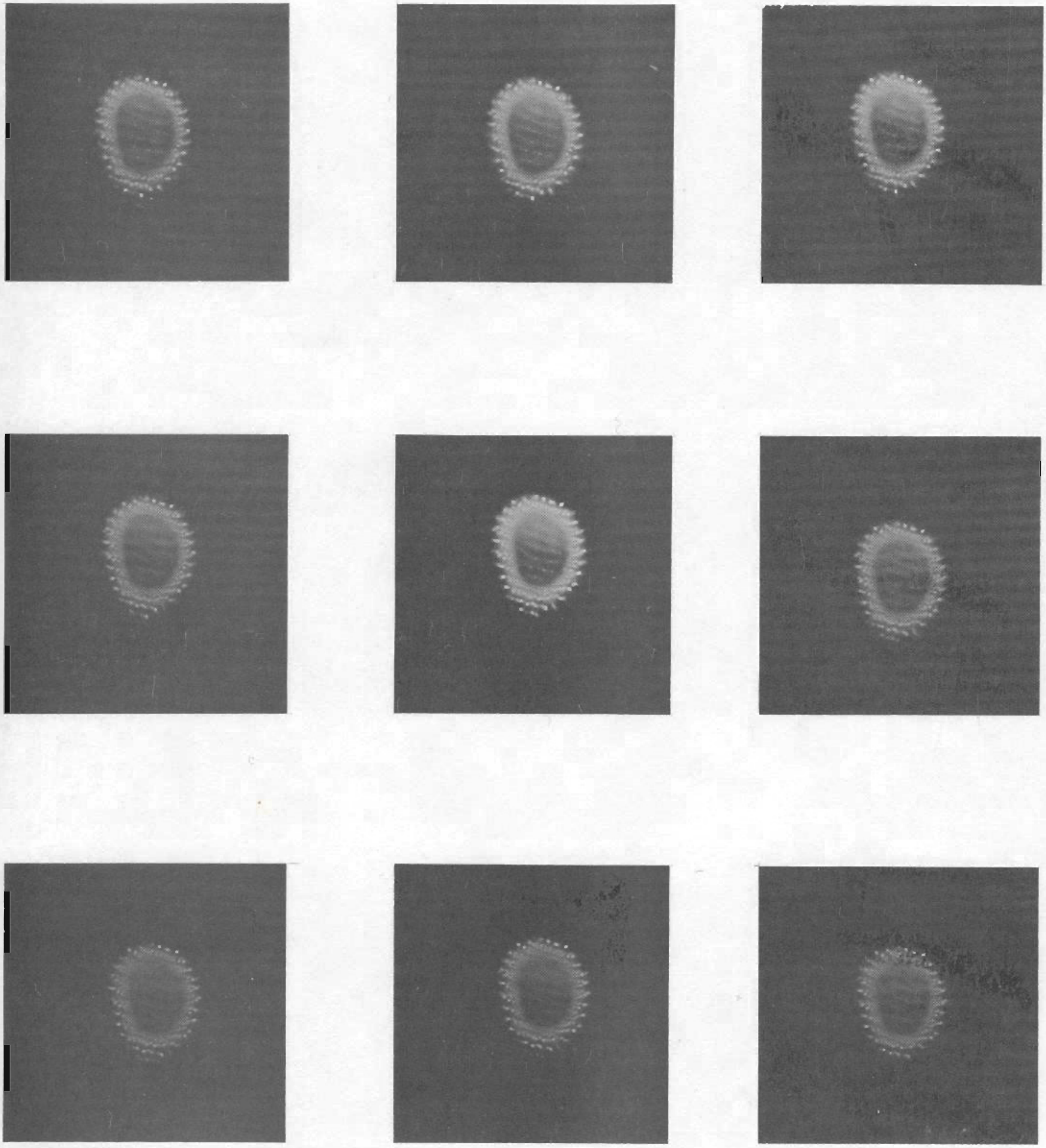


Fig. 11. Fingerpad images associated with different meditative states:
Top, State 1; Middle, State 2; Bottom, State 3.

a technical success relative to the design considerations. The power supply was found to be reliable in all ways, and the total system effectively eliminates most of the weaknesses inherent in other devices; i.e.,

(1) It provides a well controlled finger spacing and finger orientation. However, although the finger holder was quite satisfactory for the present studies, it may not be adequate when used with psychotic patients.

(2) It prevents the buildup of moisture between the finger and electrode.

(3) It prevents contact between the film emulsion and the skin.

(4) It uses a well controlled voltage source to provide pulses of high voltage of a well defined and repeatable magnitude and duration resulting thereby in a consistent exposure level.

(5) It prevents the effects associated with light entering the back side of the film. This is the source of colors other than blue when color film is used in the discharge gap[5]. During this study, it was noticed that, so long as the electrode coverslip was clear, the light pattern was always blue and that the presence of any non-blue color heralded the buildup of an organic deposit on the glass surface.

From these test results, it appears that the apparatus does not discriminate between different physiological states, which is at variance with the claims of others[1-4]. From this study, it would seem that many of the physiological coupling effects suggested by one of the authors[6] are not working to a sufficient degree to be a dominant factor. It also seems that either we did not receive correct information from the Soviets on the utility of the transparent electrode or their own transparent electrode studies were carried out with inadequate experimental controls.

The remaining question for us is whether or not our controls have resulted in the discarding of useful information that would reflect changes in physiological state. We appear to have arrived at a fork in the road and find three paths available to us:

(1) We can assume that our controls have eliminated important information pertaining to physiological state changes and can retrace our steps modifying those factors and device aspects that seem pertinent. In the present study, it is possible that the use of quartz instead of glass for the transparent electrode system would have produced some difference in the registered light pattern. Certainly, the very short wavelength ultraviolet radiation generated in the discharge does not penetrate the glass. To proceed further in the search for a more effective Kirlian device, the next step would be to incorporate the film contact technique into the present system. This could be done by incorporating a film cassette into the electrode compartment such that the back of the film would be in contact with the electrode surface.

(2) We can explore the possibility of other important correlative variables in the Kirlian process - for example, total discharge current. It is also possible that electron energy distribution information, as distinct from light patterns, may reveal important information. This could be revealed by using different phosphors deposited on the side of the glass coverslip facing the fingerpad. However, we might expect that, if the voltage is high enough to produce the streamer phenomenon[5] and light generation, then the electron energy distribution

information would be inherent in the light pattern. The phosphor technique would have advantages for the range of smaller applied voltages. On the other hand, U.V. phosphors would be advantageous to enhance light intensity if one wishes to develop a microscope device.

(3) We can begin investigating alternatives to Kirlian photography with an eye towards extending existing physiological monitoring techniques.

Acknowledgements

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Appendix I

SAFETY HAZARDS AND PRECAUTIONS

The Portable High-Voltage Photographic Apparatus uses a line-operated power supply with a maximum peak-to-peak output voltage of 20 kV, a maximum current output of 1 to 2 mA, and operates at a frequency of 100 kHz. When used as directed, it presents no significant helath hazards to healthy persons.

The maximum current output of 1 to 2 mA is far below the threshold of perception current, which is 100 to 300 mA at the 100-kHZ output frequency, as shown in Fig. 12 summarizing measurements by C. F. Dalziel in 1956[8,9].

At this 100-kHz frequency, currents tend to travel along the outer surface of a conductor and show very little interaction with subsurface biological tissue. However, it is possible for a spark to jump from an electrode to a finger, producing a small (1 mm) burn if the apparatus is not set up properly.

The health hazards that must be considered in the operation of the High-Voltage Photographic Apparatus are of five types:

(1) Electric shock to subject or operator from improper or faulty power line and ground connection.

(2) Electric shock to internal organs of persons or animals with surgically-implanted electrodes and leads extending out through the skin. A current of only 0.020 mA, although far below the threshold of perception, can cause heart fibrillation if applied directly to the heart through an implanted electrode.

(3) Exposure of dark-adapted eyes to ultraviolet light emission from a corona discharge. (The glass at the electrode and the camera lens removes most

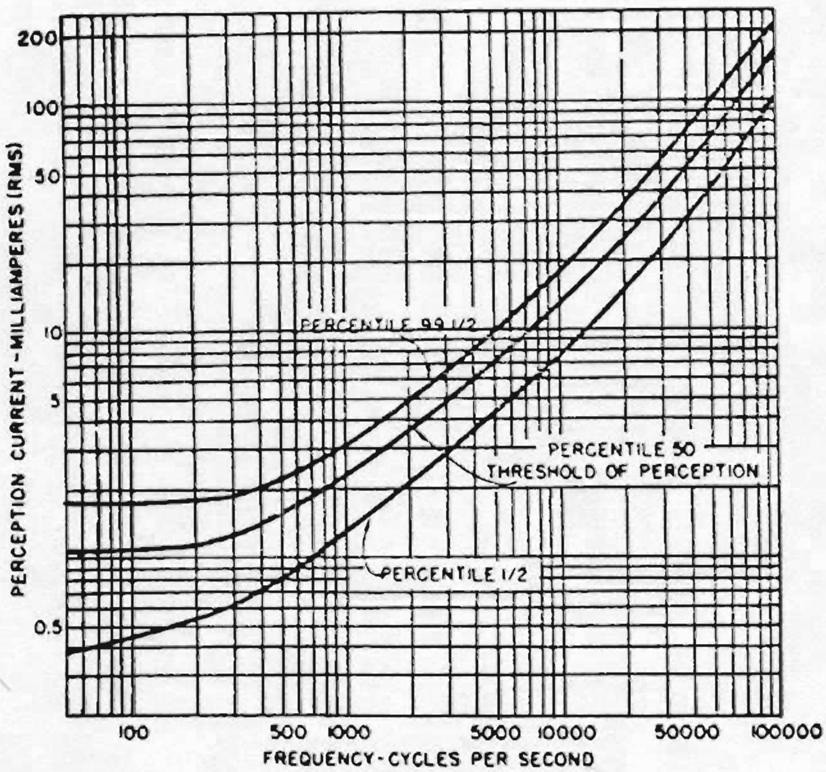

Fig. 12. Effect of frequency on the perception threhold of current by human subjects using hand-held electrodes.

ultraviolet light in the < 300 nm range.)

(4) Exposure of skin and surrounding body tissue to ultraviolet light and X-ray emission from a corona discharge.

(5) Increased concentration of ozone produced by the corona discharge.

The precautions necessary to minimize these hazards are (in the same order):

(1) Do not let this or any associated apparatus be operated by persons unfamiliar with standard procedures for safe use of grounded line-operated laboratory equipment. Always use a grounded power outlet or adapter and check for ground faults. To minimize ground fault currents and high-voltage currents near the heart when making high-voltage fingerprint exposures, ground the hand being photographed to the apparatus frame and avoid body contact with other grounded or line-powered metal objects (plumbing, lamps, etc.).

(2) Do not operate the apparatus in the presence of persons or animals with implanted electrodes or implanted inductive pickup devices, unless otherwise directed by a physician.

(3) Require use of glasses made of standard optical glass by all persons making frequent and close observation of corona discharges.

(4) Limit exposure of skin areas to about one minute per day, unless otherwise directed by a physician. Short wavelength ultraviolet and soft X-rays are theoretically possible but are not found in measurable or biologically significant quantities.

(5) The exposure time limits noted above, and normal room ventilation, are sufficient to keep the ozone concentration to a safe level, well below the 0.5 to 1.0 part per million concentrations which produce throat irritation and other more toxic effects.

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Figure Captions

1. Simple electrode-film configuration used in (a) contact Kirlian photography, (b) transparent electrode Kirlian photography.

2. (a) Functional diagram of the transparent electrode device.

   (b) Photograph of the device -- overall view.

   (c) - (f) Photographs of the device from different orientations.

3. Schematic diagram of the finger holder and its support jig.

4. (a) Circuit diagram of the 20 kV AC - 2 ma, 100 kHz power supply for high voltage photographic apparatus.

   (b) Circuit diagram of the 28 V DC power supply.

5. Block diagram for the high-voltage photographic apparatus.

6. Electronic circuity of (a) 28 V DC, 3-A power supply and (b) 20 kV AC - 2 MA, 100 kHz power supply. Abbreviations on control panel are: MUPU (multipulse rate control); ON (multipulse on switch); EXT (multipulse external switch); MOPU (monopulse rate control) ON (monopulse on switch); EXT (monopulse external switch).

7. Fingerpad images resulting from a change in the number of pulses in a multiple pulse exposure: Left, 20 pulses of 3 m sec width; Right, 80 pulses of 3 m sec width.

8. Fingerpad images for case where all parameters held constant at two different spacings. Single pulse exposure; 9 m sec pulse width.

   Top: Exposures 1, 3, 5, 7 and 9 for zero set spacing

   Bottom: Exposures 19, 21, 23, 25 and 27 for -20 set spacing (250μ less than top).

9. Fingerpad images associated with repeated replacement of finger in finger holder. Single pulse exposure; 9 m sec pulse width.

   Top: Exposures 1, 3 for first setting at -10 set spacing

   Middle: Exposures 6, 8 for first replacement at -10 set spacing

   Bottom: Exposures 11, 13 after second replacement at -10 set setting.

10. Fingerpad images illustrating the electrode spacing effect -- spacing decreased 125μ between each exposure. Single pulse exposure; 9 m sec pulse width.

11. Fingerpad images associated with different meditative states: Top, State 1; Middle, State 2; Bottom, State 3.

12. Effect of frequency on the perception threshold of current by human subjects using hand-held electrodes.